Master thesis

For submission at (2) University of Copenhagen
Copenhagen, Denmark

Jonas Karlsson

OIL MOVEMENT IN SEA ICE

A laboratory study of fixation, release rates and small scale movement of oil in artificial sea ice

External advisors
Chris Petrich (1)
Hajo Eicken (1)

Internal advisor
Niels K. Højerslev (2)

Conducted at (1) Geophysical Institute
University of Alaska Fairbanks,
Alaska, USA

Copenhagen
July 8, 2009

Acknowledgement

This work could not have been done without help from many people. As a former visiting exchange student at UAF I am especially grateful to Hajo Eicken who initially adopted me in the sea ice group and later gave me the opportunity to conduct experiments for my thesis; furthermore as both crude and synthetic oil were utilized in the sea ice laboratory, I also want to thank for access to instruments and laboratory facilities. (which was not originally aimed for that purpose.)
I want to thank Chris Petrich for the great enthusiasm, interest (and when needed, optimism) he showed my experiments. The many discussions about the experimental setup (and a lot of other stuff) were very helpful and inspiring; moreover this greatly contributed to do the experimental work more fun and exciting. During the writing process in Copenhagen, both my external advisors provided feedback and guidance; am very grateful for that.
Also the other members of the sea ice group: Jeremy Harbeck, Daniel Pringle, Heike Merkel, Matthew Druckenmiller and Mette Kaufman were very nice colleges and a great support; thanks for guiding me in Fairbanks, the Alaskan wilderness and on the GI offices.
From my home institution KU I want to thank Niels Kristian Højerslev who on a short notice offered to take over the advising of my thesis. I very appreciated the meetings with feedback and discussions, over coffee.
Besides all the people who helped me I also want to thank the Oil Spill Recovery Institute (OSRI) who supported the experimental work by a grant.

Abstract

Sea ice plays a major role in the context of potential Arctic oil spills, both as a hazard and through it's interaction with oil and water soluble contaminants. The temperature dependent pore structure of sea ice allows oil to be entrained during growth and slowly released during warming. Artificial sea ice was grown from an aqueous solution of the synthetic sea salt mixture *Instant Ocean*® in two different laboratory settings. This allowed oil entrainment and surface release to be studied under different boundary conditions.

In growing sea ice oil movement is confined to the bottommost centimeters of an ice layer with oil concentrations ranging from 1.1 wt% to 10.2 wt%; both the ocean heat flux and oil lens thickness (below the ice) are identified as potentially important for oil entrainment during growth.

Melting sea ice allows two different modes of upward transport: oil permeation through the fine scale pore network (pores and necks less than 0.1 mm) and Poiseuille flow through brine channels (diameters 1-2 mm). The latter accounts for volume fluxes of 10^{-9}m/s whereas the first transport mode is comparatively slower and probably accounts for less.

Sea ice is permeable for porosities of more than 5%. However it appears that oil movement is constrained to porosities of above 15 %.

Contents

1 Acronyms and Symbols

Sampling definitions

EXP# Experiment ID (number #)

Ice:

OR Oil release (ice just before OR)

OI Oil-Infiltrated (after OR)

OI+ just above OI

NOI Not Oil-Infiltrated (after OR)

NOI+ NOI in same depth as OI+

Coring:

C# Core ID (chronological enumerated for each experiment)

Main constituents of seawater

Na^+ Sodium

K^+ Potassium

Ca^{2+} Calcium

Mg^{2+} Magnesium

Cl^- Chloride

SO_4^{2-} Sulfate

CO_3^{2-} Carbonate

Subscripts

b brine

w water

o oil

i ice

s salt

si bulk

a air

Salinity

S absolute salinity: $1000 \cdot m_s/(m_s + m_w)$

S_{si} bulk salinity: $1000 \cdot m_s/(m_i + m_w + m_s + m_o)$

$S_{si}^{\dagger}$ common definition of bulk salinity : $1000 \cdot m_s/(m_i + m_w + m_s)$

S_b brine salinity: $1000 \cdot m_s/m_b$

If the ice is completely melted S_{si} and S_b both reduces to the (absolute) salinity $1000 \cdot m_s/(m_s + m_w)$ for saltwater used in oceanography.

Mass

m_s mass of salts

m_{ss} mass of solid salts (taken as $m_{ss} = 0$)

m_i mass of ice

m_w mass of water

m_o mass of oil

m_b mass of brine $m_b = m_s + m_w$

m_{si} bulk mass $m_{si} = m_b + m_i + m_o$

$m_{si}^{\dagger}$ (old) bulk mass $m_{si} = m_b + m_i$

Density

ρ_{si} bulk density $\sum_k \rho_k \cdot V_k/V_{si}$, for $k = i, b, o, a$

ρ_b brine density

ρ_i ice density

ρ_o oil density

Volume

V_i ice volume

V_a air volume (or gas volume)

V_b brine volume

V_o oil volume

V_s volume of solid salts (is ignored)

V_{si} bulk volume
$V_{si} = V_i + V_b + V_a + V_o$

$V_{si}^{\dagger}$ (old) bulk volume
$V_{si} = V_i + V_b + V_a$

It is assumed that $V_a = 0$ for the artificial sea ice.

Volume fraction

V_b/V_{si} brine volume fraction (BVF)

$V_b/V_{si}^{\dagger}$ (old) brine volume fraction (BVF†)

V_i/V_{si} ice volume fraction

V_a/V_{si} air volume fraction(or gas)

V_o/V_{si} oil volume fraction (OVF)

Temperature

T temperature (general)

T_f freezing-point

T_s surface temperature

α rate of change $\frac{\partial T_s}{\partial t}$

Heat flux

F_w ocean heat flux

F_c conductive heat flux (through ice)

Thermal properties

λ thermal conductivity

λ_{si} bulk thermal conductivity

λ_i ice thermal conductivity

L latent heat (general)

L_{si} bulk latent heat

Q heat

Percolation

ϕ porosity

k fluid permeability

p pressure

θ contact angle (general)

θ_o contact angle for oil in water

θ_w contact angle for water in oil

γ interfacial tension (general)

γ_{io} ice oil interfacial tension

γ_{io} ice brine interfacial tension

γ_{io} brine oil interfacial tension

Phase relations

F_1

F_2 (see table 6)

Time

t time

D degree days : $\int_0^t d\tau [T_f - T_s(\tau)]$

OR oil release (time of)

FU freeze-up (ice formation)

$\dot{}$ time derivative $\frac{\partial}{\partial t}$

Coordinates and derivatives

Euclidean coordinates:

$x,\ y,\ z$ (pointing upwards)

H ice thickness $H(z)$

v_x (x-velocity component)

v_y (y-velocity component)

τ_{yx} shear rate (component)

Principal radii of curvature:

R_1

R_2

Electrical circuits

R resistance

R_T thermistor resistance

ρ_e resistivity

U voltage

U_{ex} excitation voltage

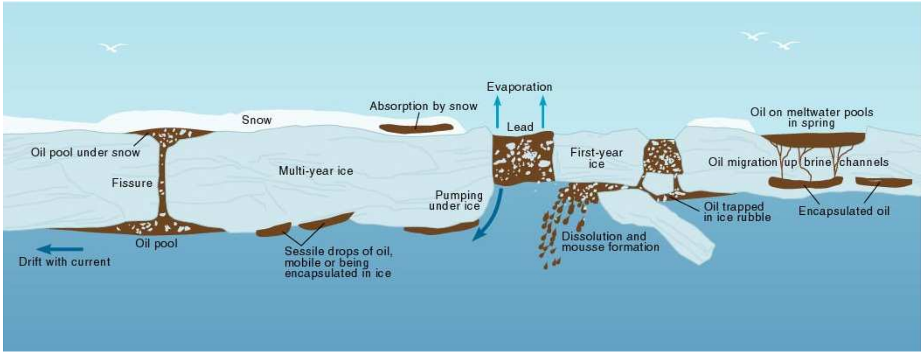


Figure 1: Possible configurations of oil and sea ice. Source: AMAP (1997)

2 Background

A substantial portion of the world's remaining oil and gas reserves are found in the Arctic (IUCN and E&P forum, 1993, Wilkinson et al., 2007) where oil and gas development has expanded dramatically over the past few decades (AMAP, 2005). Furthermore, initial plans for trans-Arctic shipping lanes are under development due to expected decreases in sea-ice cover (AMAP, 2007). This all leads to an increased risk for Arctic marine oil spills in the future.
The major potential oil fields are located near the Siberian coast (the Pechora Basin and in the Lower Ob Basin), but also the Norwegian sector of the Barents Sea faces an intensified oil exploration and transport (Sawhill and Østreng, 2006).
In Canada and Alaska oil production has been developed through many years with the Prudhoe Bay oil field (at the coast of the Arctic Ocean) being the larges in North America (AMAP, 1997).
In the Danish sector of the Arctic exploration activities and licensing has also begun (currently of the West Greenland waters)(NERI, 2007); moreover with new estimates of petroleum resources (U.S. Geological Survey, 2007) for the East Greenland Rift Basins Province this area might have even higher potential for oil and gas development.
Although the Arctic perennial sea ice cover has already been significantly reduced during the last decade (Nghiem et al., 2007) model simulations predict a further thinning and retreat (with total disappearance in 2040) (Holland et al., 2006). As oil reserves diminish in more accessible regions, this might lead to increased oil production and transport in Arctic waters.
Together with increased traffic this could involve oil spills or blowouts under various kinds of sea ice; conditions under which the fate of oil is still poorly understood (Wilkinson et al., 2007).

3 Introduction

Both with regards to the spreading and fate of oil, several conditions will be different for potential Arctic marine oil spills. Among those are lower temperatures, different light conditions and particularly the presence of sea ice.
Most important is the physics of ice movement and formation which are relevant on scales down to meters; even in the absence of oil this is still poorly represented by models (Reed et al., 1999). However oil and sea ice not only interact through drift and movement; oil is also entrained in sea ice, and able to move within it. Only the latter is considered in this thesis. Figure 1 illustrates all the possible configurations of oil spilled in ice infested waters.
Field and laboratory studies (Karlsson et al., 2009, Martin, 1979) suggest that oil is encapsulated at the base of growing sea ice and migrates into both brine channels and pores in the surrounding sea ice. During spring warming oil is slowly released to the ice surface or overlaying melt ponds. The timing and rate of the release, effect the potential biological impact of oil spills in seaice covered waters (Petrich et al., 2009).
While entrained in the sea ice, water soluble compounds of the oil are dissolved in the brine phase (Faksness and Brandvik, 2008). Together with the brine, those compounds are potentially released into the ocean both during winter and spring. The biological impact of the release depends on the toxicity of the dissolved compounds as well as the the timing with respect to under ice algal bloom.
Within the ice, dissolution rates for toxic compounds are linked to the interface area of oil and brine; as a consequence of oil movement, this area depends on the small-scale configuration[1] of oil and brine within the sea ice.

This thesis investigates the micro-structural controls of oil entrainment and transport in sea ice. This is achieved through a series of laboratory experiments which examines the entrainment and release of oil under different boundary conditions. The experimental part of my thesis work was carried out at the Geophysical Institute (GI), University of Alaska Fairbanks, USA and advised by Chris Petrich and Hajo Eicken. However my thesis is submitted for a degree at University of Copenhagen (KU) and only reviewed here.

[1]Hence what is the size distribution of oil and brine inclusions and how are they intersecting with each other.

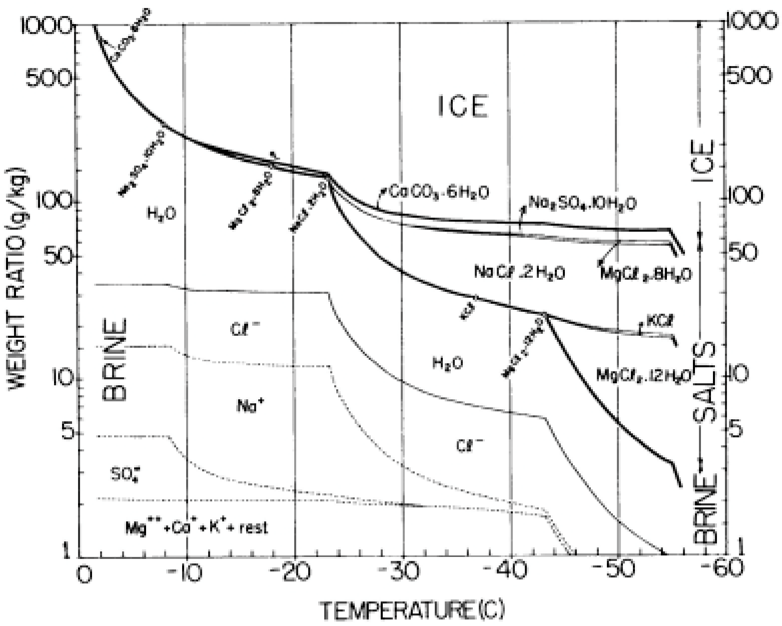


Figure 2: Phase diagram of freezing sea water. The mass fraction of ice (top), solid salts (middle) and brine (bottom) are delineated by solid lines as indicated to the right. At -8.2°C the solution is saturated with respect to sodium sulfate (Na_2SO_4) and mirabilite ($Na_2SO_4 \times 10H_2O$) start to precipitate out. However for temperatures above -22.9°C (when hydrohalite ($NaCl \times 2H_2O$) precipitation starts) the fraction of solid salts is negligible from a physical perspective. Source: Assur (1960)

4 Theory

Sea ice differs fundamentally from ordinary ice by the presence of both a liquid and a solid phase even at temperatures far below the freezing point of sea water. In nature materials with such properties are rare and can be found only in a few other environments. Among those are solidifying magma chambers and metallic castings (Wettlaufer et al., 1997, Worster, 1997). Such two-phase medias are commonly designated mushy layers.

4.1 Volume fractions for brine and ice

Sea water is an aqueous solution of various dissolved salts of which Na^+,K^+, Ca^{2+},Mg^{2+},Cl^-, SO_4^{2-},CO_3^{2-} constitute the major ions (Eicken, 2003). The salt concentration of the solution can be characterized by the absolute salinity defined as the ratio $S \equiv 1000 \cdot m_s/(m_s + m_w)$ (Cox and Weeks, 1983) where m_s is the mass of salts and m_w is the mass of pure water. During solidification none of the above ions can be incorporated into the ice crystal lattice. Hence as part of the growth process liquid inclusions of concentrated sea water are rejected from the ice crystals resulting in a matrix of pure solid ice and interstitial brine. As illustrated in figure 2 the concentration of dissolved ionic salts in the brine will steadily increase with decreasing temperature until they one by one (Melnikov,

absolute salinity

precipitation

1997) start to precipitate [2].
As the precipitation of salts can be ignored for temperatures above $-23°$C the chemical system now consist of saltwater plus ice as an additional phase[3]. Hence it is convenient to use two different salinities to describe this. Brine salinity is defined as:

$$S_b \equiv 1000 \cdot m_s/(m_w + m_s) \tag{4.1.1}$$

and bulk salinity is defined as:

$$S_{si} \equiv 1000 \cdot m_s/(m_i + m_w + m_s) \tag{4.1.2}$$

where m_i is the (additional) mass of ice. Note that in contrast to brine salinity, bulk salinity is temperature independent and hence can be measured after melting the ice.
For salt solutions of the same initial[4] composition (and salinity) intensive properties of the brine such as brine salinity and brine density (ρ_b) are functions only of temperature (T) (here approximated as in Eicken (2003)): [5]

Appendix C.1.2 & C.1.7

$$\left.\begin{aligned} S_b &= 1000 \cdot \left(1 - \tfrac{54.11}{T}\right)^{-1} \\ \rho_b &= 1 + 8 \cdot 10^{-4} S_b \end{aligned}\right\} \text{for } T > -23°C \tag{4.1.3}$$

where T is in units of °C and ρ_b is in units of g/cm^3. In his study of the phase relations for a standard composition of sea water Assur (1960) provides a much more rigorous treatment of this topic. Cox and Weeks (1983) further generalize his work to sea ice with gas inclusions and a bulk salinity (from melted sample) different from that of standard sea water:

Appendix C.1.9

$$\frac{V_b}{V_{si}} = \left(1 - \frac{V_a}{V_{si}}\right) \frac{\rho_i S_{si}}{F_1(T) - \rho_{si} S_{si} F_2(T)} \tag{4.1.4}$$

where V_a, V_b, V_i are the air, brine, ice volumes and $V_{si} \equiv V_b + V_i + V_a$ is the total volume or bulk volume. ρ_i is the ice density in g/cm^3 approximated as

Appendix C.1.3

$$\rho_i = 0.917 - 1.403 \cdot 10^{-4} T \tag{4.1.5}$$

and F_1 and F_2 are empirical polynomial functions $F_i(T) = a_i + b_i T + c_i T^2 + d_i T^3$ based on phase relations. (The coefficients are listed in table 6). Note that the volume of solid salts (V_s) is ignored.
As emphasized by Eicken (2003) temperatures and bulk salinity serve as state variables from which scalar quantities such as heat capacity, porosity and density can be derived[6] based on equation (4.1.3) through (4.1.5). These properties are linked through the constitutive phase relationship. (See figure 2).

[2] A liquid phase is maintained down to -55°C.
[3] The mass of solid salts m_{ss} can be ignored.
[4] Composition before ice formation.
[5] This is actually the well known relation for the freezing point and salinity of sea water. (The mirabilite precipitation (figure 2) is negligible).
[6] As long as the gas inclusions are negligible, else the bulk density also needs to be measured.

4.2 Volume fractions for oil, brine and ice

With oil as an additional composite some quantities such as bulk mass (m_{si}), bulk volume (V_{si}) and bulk salinity (S_{si}) have to be slightly redefined:

$$m_{si} \equiv m_s + m_w + m_i + m_o = m_b + m_i + m_o \tag{4.2.1a}$$
$$V_{si} \equiv V_b + V_i + V_o + V_a \tag{4.2.1b}$$
$$S_{si} \equiv 1000 \cdot \frac{m_s}{m_{si}} \tag{4.2.1c}$$

Here m_o is the oil mass and V_o is the oil volume. Meanwhile it is still convenient to use the old bulk salinity:

$$S_{si}{}^{\dagger} \equiv \frac{m_s}{m_s + m_w + m_i} \tag{4.2.2}$$

which will be indicated by a dagger (†). Likewise the mass of brine plus solid ice must be distinguishable from that of the bulk mass:

$$m_{si}^{\dagger} \equiv m_s + m_w + m_i = m_b + m_i = \rho_b V_b + \rho_i V_i \tag{4.2.3}$$

Note that $m_{si}^{\dagger}$ can be measured as the mass of saltwater in a melted sea ice sample. As the air volume fraction in equation (4.1.4) can be taken as zero for first year ice (Cox and Weeks, 1983), this will also be assumed for the laboratory grown ice.
In contrast to salts, which give rise to the phase relations for sea ice, the bulk part of crude oil is insoluble in water (oil and water are immiscible fluids). Hence the phase relationship for brine and solid ice should be unaffected by oil as a third (nonreactive) composite[7] - hence with the new definitions for S_{si} and V_{si} (and $V_a/V_{si} = 0$) equation (4.1.4) can be rewritten as:

$$\mathrm{BVF}^{\dagger} \equiv \frac{V_b}{V_i + V_b} = \frac{\rho_i S_{si}{}^{\dagger}}{F_1(T) - \rho_{si} S_{si}{}^{\dagger} F_2(T)} \tag{4.2.4}$$ Appendix C.1.9

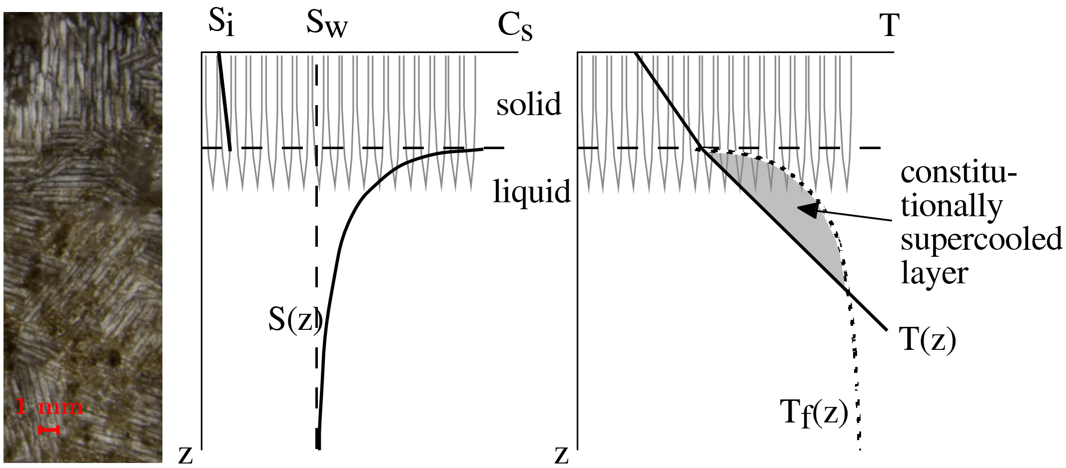
here $\mathrm{BVF}^{\dagger}$ denotes the (old) brine volume fraction where the oil volume is not included.
It is possible to separate oil and saltwater from a melted sample of oil-infiltrated ice. In addition to the ice temperature T, this allow tree quantities to be measured. Those are $S_{si}{}^{\dagger}$, $m_{si}^{\dagger}$ and m_o. As both ρ_i and ρ_b are given by T (equation (4.1.3) and (4.1.5)) m_b and m_i can be determined from equation (4.2.2) through (4.1.5) as:

$$\begin{aligned} m_b &= \frac{\rho_b}{\frac{\rho_i}{\mathrm{BVF}^{\dagger}} - \rho_i + \rho_b} \cdot m_{si}^{\dagger} \\ m_i &= m_{si}^{\dagger} - m_b \end{aligned} \tag{4.2.5}$$

Hence all volume fractions can then be calculated as:

$$\frac{V_j}{V_{si}} = \frac{m_j \rho_j^{-1}}{\sum\limits_{k=i,b,o} m_k \rho_k^{-1}} \text{ where } j \in \{\, i, b, o\} \tag{4.2.6}$$ Appendix C.1.8

[7] The total concentration of oil associated compounds that can be dissolved in the brine phase (at most) is of the order 1 milligram per liter (Faksness and Brandvik, 2008). Compared to the salt concentrations this should not impact the phase relationship.



(a) (b)

-5 Figure 3: The skeletal layer constituting the ice water interface: (a) shows the interface (ice bottom) of oil-infiltrated ice from EXP18. Here the interstitial oil between the ice platelets serves as a dye revealing the lamellar structure of the interface. (b) illustrates the constitutional[9] supercooling forming the skeletal layer. Source: Eicken (2003). Being the initial contact surface of oil and ice, the properties of this layer most likely have a strong influence on the fixation of an oil lens during growth.

if the oil density (ρ_o) is known.
In the absence of air/gas inclusions, the brine and oil volume make up the void space of sea ice. The relative fraction of this space is denoted the porosity ϕ and can be calculated as:

$$\phi = \frac{V_o}{V_{si}} + \frac{V_b}{V_{si}} \tag{4.2.7}$$

4.3 The micro-structural configuration of brine in sea ice

As a result (or record) of different meteorological and hydrographic boundary conditions (Eicken, 2003) some properties of sea ice[8]are closely linked to the specific growth- and cooling/heating history of the ice (Nakawo et al., 1984). These properties (mostly tensors such as fluid permeability, resistivity or thermal conductivity) cannot be derived from the state variables as they depend on the micro-structural configuration of the brine phase. This additional complexity impacts the requirements (and limitations) of a laboratory grown proxy for sea ice: it is not enough to reproduce the desired bulk salinity and temperature - also the boundary conditions (during growth and melt) should ultimately reflect the natural interactions with ocean and atmosphere.
This subsection attempts to give a qualitative description of the processes which impact the configuration of brine inclusions within a sea ice layer.
The (initial) pore structure and bulk salinity of sea ice can be understood qualitatively as an interface phenomenon caused by constitutional[9] supercooling.

[8]For instance properties dependent on ice crystal size and brine layer spacing.
[9]Meaning: supercooling caused by changes in (local) freezing point (rather than temperature) .

During growth rejected salt ions build up in front of the advancing ice layer where the gradient $\frac{\partial S}{\partial z}$ leads to molecular diffusion of salt ions away from the ice interface. However, the upward heat conduction is so predominant that a thin layer is established in front of the interface that is constitutionally supercooled with respect to the local (salinity dependent) freezing-point T_f. The layer below the interface has a thickness of a few millimeters to a few centimeters and is illustrated in figure 3(b). More formally the following inequality is the criterion for supercooling just below the interface:

$$\frac{\partial T_f}{\partial S}\frac{\partial S}{\partial z} > \frac{\partial T}{\partial z} \tag{4.3.1}$$

where $\frac{\partial T_f}{\partial S_b}$ is the gradient of the phase diagram (figure 2) which can be approximated by inverting and differentiating equation (4.1.3) with the notation $S \rightarrow S_b$ and $T_f \rightarrow T$. Any small platelet of ice that protrudes into the supercooled layer has a growth advantage since heat can be conducted away in all directions (Eicken, 2003). This helps to explain the lamellar structure of the interface. This bottommost ice is known as the skeletal layer. skeletal layer

The crystal lattice of ice (Ih[10]) shows a hexagonal symmetry, where the principal axis (perpendicular to the basal plan) is denoted the c-axis. The surface free energy has been measured to have a ratio of 1 to 100 between the basal plane and the edge planes (Koo et al., 1991). Hence ice is much more likely to grow sideways from the c-axis than along the c-axis.

As seen in figure 3(a) the lamellae have a thickness of 0.1-0.3 mm and are grouped parallel within areas of approximately 1 cm diameter; i.e. this can be interpreted as geometrical selection favoring the growth of ice crystals with horizontal c-axis which are perpendicular to the lamellae.

Both ice crystals and brine inclusions can be studied in thin-sections produced by a microtome. When viewed through crossed polarizers the brine inclusions show up as dark impurities whereas the ice crystals show up in distinct colors according to their c-axis orientation. The spacing between brine layers in figure 26 correspond to the lamellar spacing shown in figure 3(a). As explained by Eicken (2003), this is because the spacing and arrangement of pores remain essentially unchanged from what is laid down as the ice lamellae join up and consolidate into lower porosity sea ice. Moreover the ice crystals in figure 26 are of the same size as the groups of parallel ice lamellar shown in figure 26. Hence also the growth pattern embedded within the present skeletal layer consolidate to single crystals as the ice layer progresses. thin-sections

Being the initial contact surface of oil and ice the properties of the skeletal layer most likely have a strong influence on the fixation of an oil lens during growth. According to the illustration in figure 3 (b) the ocean heat flux is very likely to influence the constitutional supercooling and hence the depth of the skeletal layer (though of cause the transition between skeletal layer and overlaying ice is hard to define). However as discussed in section 6.1 ocean heat flux is unfortunately difficult to measure in tank experiments. oil fixation ocean heat flux

Nakawo et al. (1984) investigated the relationship between brine layer spacing and growth velocity for sea ice in the Canadian section of the Arctic ocean. It appeared that the dependence was exponential with a change in growth velocity from $1 \cdot 10^{-7}$m/s to $2 \cdot 10^{-7}$m/s corresponding to a decrease in lamellar spacing brine layer spacing

[10]The only phase of ice stable under natural conditions at the Earth's surface.

from 0.5 mm to 1 mm (roughly). However where the lamellar spacing is shown to depend on growth velocity less attention has apparently been directed to the lamellar depth which is potentially coupled to the ocean heat flux (F_w).
As supposed to larger drainage features within the ice layer (see section 4.5), the void space consisting of brine inclusions is commonly designated the pore space or fine scale pore network of the ice. Whereas the arrangement of brine inclusions is determined by the growth of the skeletal layer, their volume is given by the bulk salinity and temperature.

pore space

4.4 Permeability of sea ice

The material property which allows fluids to flow through a porous medium is the (fluid) permeability (k) defined by Darcy's flow law:

$$q = \frac{kA}{\mu}\frac{\Delta P}{L} \tag{4.4.1}$$

Darcy's law applies to a laminar, one-dimensional, steady flow of Newtonian fluids (Crowe, 2005) where ΔP denotes the pressure difference, q the volumetric flow rate, L the length, μ the viscosity and A the cross sectional area.
Based on percolation theory and X-ray computed tomography for the brine phase and its connectivity[11] (Golden et al., 2007) presents a theory for $k(\phi)$, which closely captures both laboratory and field data. It is hypothesized that sea ice displays universal transport properties remarkably similar to crustal rocks (though within a much narrower temperature range) such that the permeability is satisfying a power law:

$$k(\phi) \sim 3(\phi - \phi_c) \cdot 10^{-8}\mathrm{m}^2, \quad \phi \longrightarrow \phi_c^+ \tag{4.4.2}$$

where ϕ_c is the critical porosity for percolation of around 5% for columnar sea ice. (In temperature and salinity this would correspond to −5°C and 5‰ respectively). It has been argued that columnar sea ice is impermeable for porosities below 5 %. This transition is illustrated in figure 4 where the brine phase is examined through a stepwise warming circle; as seen, the brine inclusions undergo significant changes for temperatures around −5°C. Hence this suggests that oil movement in sea ice might be constrained to temperatures above the percolation threshold.

4.5 Brine drainage features and desalination of sea ice

Several processes are responsible for desalination of sea ice which takes place both in growing and melting ice. In contrast to the initial salt segregation at the sea ice interface processes know as gravity drainage and brine expulsion are those of highest qualitative importance for growing ice (Eicken, 2003). Due to the pressure build up resulting from volume expansion of freezing water, brine from isolated pores can be ejected through micro-cracks and microscopic pore networks to the underlying ice. Hence the process of brine expulsion is of most importance for relatively cold ice.
Gravity drainage on the other hand applies to connected pores, where cold saline brine is replaced by warmer and less saline sea water (or brine) as a result of

gravity drainage
brine expulsion

[11] See figure 4.

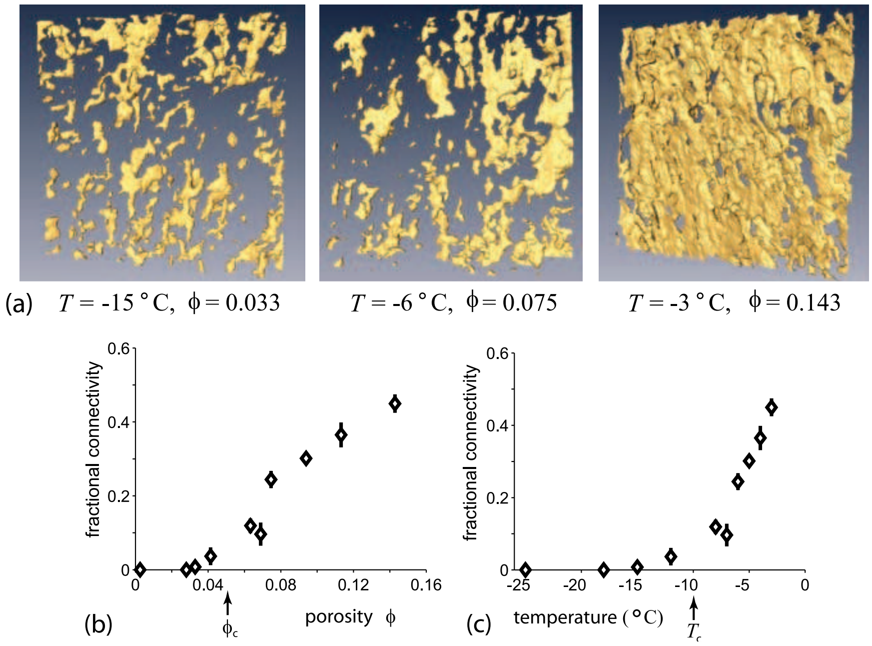


Figure 4: Thermal evolution of the brine connectivity (a) X-ray computed tomography for $2 \times 8 \times 8$ mm sub volume of a sea ice single crystal (salinity 9.3 ‰) during a stepwise warming circle. Micro-scale morphology and connectivity seems to change dramatically from $T = -6°C$ to $T = -3$°C (b) and (c) fractional (vertical) connectivity calculated as the proportion of brine inclusions intersecting both the upper and lower surface of a cylinder of height 8 mm and diameter 21 mm. T_c and ϕ_c mark the percolation threshold predicted by a lattice model. Source: Golden et al. (2007).

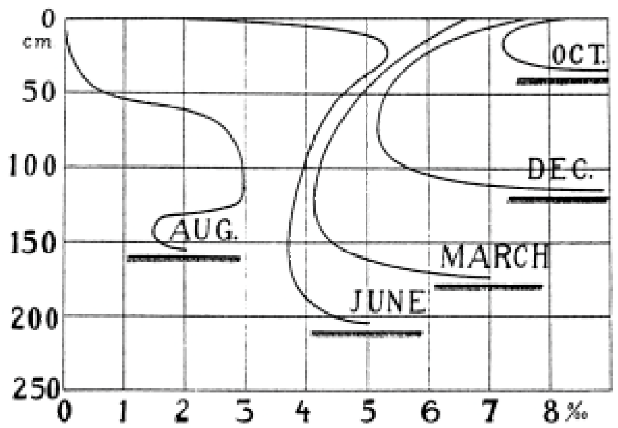


Figure 5: The evolution of salinity profiles as illustrated by Malmgren (1927) (Source Eicken (2003)). The growing ice has a characteristic C-shape whereas the melting ice has lower salinity in top and bottom.

convective overturning; this require a negative temperature gradient of a growing ice layer. Typically this convection is established through drainage features such as networks of brine inclusions connected to elongated (and possible enlarged) brine channels. When considering sea ice as a model system for an alloy these channels of zero solid fraction are analogous to what is known as chimneys in the metallurgical community (Wettlaufer et al., 1997). With a diameter of 1-2 mm even in growing ice it is very likely that the size and spatial density of such channels have a considerable impact on the transport and fixation of oil. Though whereas the above illustration (figure 3 (b)) nicely explains the origin of the pore arrangement it is less intuitive how such features are established. This is because the formation of brine channels is closely linked to convection within the ice layer (Worster, 1997) rather than the ice growth at the interface. In the downward streams of the convection, brine is replaced by colder and denser brine from above. This brine has a higher salinity and hence will dissolve the surrounding ice to form brine channels. Wettlaufer et al. (1997) emphasize that their positions and circular cross-sections are unaffected by the platelet structure at the ice water interface.

drainage features

brine channels

oil transport

brine channel formation

For warm sea ice the low-salinity melt water from melting ice at the top and bottom of an ice layer are capable of displacing brine with higher salinity from the interior of the ice[12]. Hence based on the above processes it is possible to explain the characteristic shapes of growing and melting sea ice (See figure 5).

4.6 A simple model for growth of thin sea ice

Due to simplified boundary conditions of the laboratory experiments a suitable model for the ice growth can be based on a modification of the classical Stefan problem. Stefan (1890) considered ice growth as a one dimensional heat transfer problem assuming no sinks or sources of heat Q in the ice (i.e. $\nabla^2 T = 0$)[13] and no heat flux from the water ($F_w = 0$). Hence the vertical conductive heat flux through the ice $F_c(z)|_{z>H}$ (where H is ice thickness and z is depth) is balanced by the release of latent heat L due to freezing:

$$\rho_i L \left(\frac{dH}{dt}\right) = \lambda_{si} \left(\frac{\partial T}{\partial z}\right)_{z>H} \approx \lambda_{si} \left(\frac{T_s(t) - T_f}{H}\right) \tag{4.6.1}$$

where λ_{si} is the (bulk) thermal conductivity taken as constant and T_s and T_f are surface temperature and freezing-point. By defining a degree-day variable D as:

$$D = \int_0^t d\tau [T_f - T_s(\tau)] \tag{4.6.2}$$

equation (4.6.1) can be integrated up to give

$$H^2 = H_0^2 + \sqrt{\frac{2\lambda_{si}}{\rho_i L}} D \tag{4.6.3}$$

where H_0 is the thickness at $t = t_0$. Stefan is looking at thick ice for which surface temperature is coupled to that of the air (and independent of ice thickness) (Leppäranta, 1993). For laboratory ice however the difference in surface

[12] A process know as melt water flushing.
[13] And thermal conductivity taken as constant.

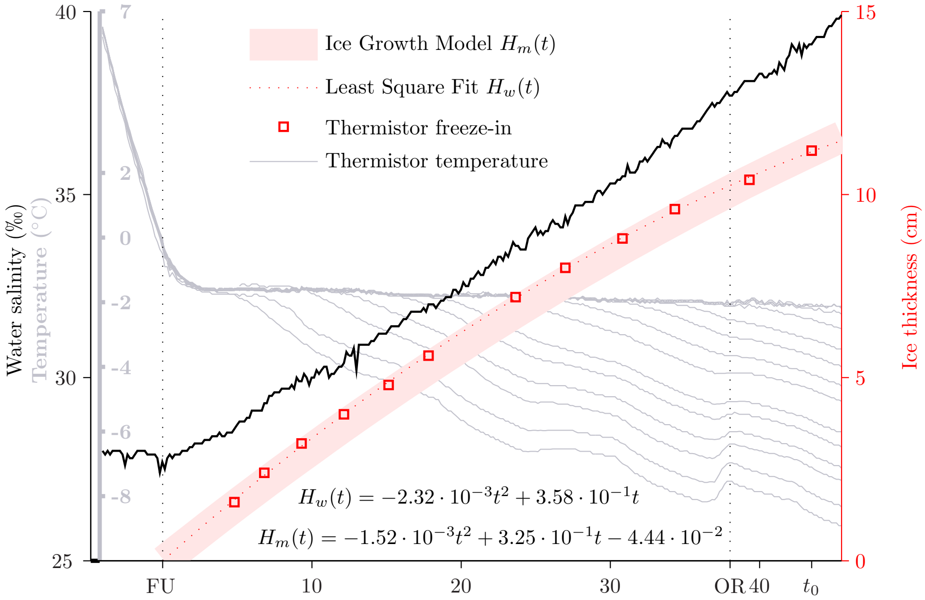


Figure 6: Ice thickness, water salinity and thermistor temperatures for EXP13 as a function of time (in days) from freeze-up (FU). The (periodic) temperature variations propagating down through the ice corresponds to defrost circles of the refrigerator. A higher resolution of the temperature data is needed to detect the actual freeze-in of thermistors.

Appendix C.2.3 EXP13

temperatures and freezing point is increasing almost linearly at a rate α of $-5.8 \cdot 10^{-5}$ $°C/s$ (see figure 6). Moreover there is a nearly constant, but unknown, ocean heat flux (F_w) between 0-30 W/m^2. Hence this parameter will have to be adjusted. Equation (4.6.1) can now be expressed as an ordinary first order differential equation:

ocean heat flux

$$\rho_i L \left(\frac{dH}{dt}\right) + F_w = \lambda_{si}\left(\frac{\alpha t + T_f(t_0) - T_0(t_0)}{H}\right) \tag{4.6.4}$$

which has a complicated analytical solution. Though Taylor expansion of the above expression suggest that H can be approximated as a second order polynomial[14] $H(t) \approx H_0(t_0) + \dot{H}_0(t_0)\cdot(t-t_0) + \ddot{H}_0(\,t_0)/2\cdot(t-t_0)^2$ (see for instance Riley et al. (2002)). Taking $H(t_0)$ as the freeze-in of the last thermistor and defining $t_0 = 0$ (see figure 6) $\dot{H}(t_0)$ is given directly by equation (4.6.4) and $\ddot{H}(\,t_0)$ can be found by differentiation. Maykut (1986) provide and empirical expression for the bulk conductivity:

Appendix C.2.4

$$\lambda_{si} = \lambda_i + 0.13\frac{S_{si}}{T} \tag{4.6.5}$$

Appendix C.1.5

here the bulk salinity is around 10 ‰ for the laboratory ice and the "effective" ice temperature is taken as $(T_s(t_0) - T_f(t_0))/2$ where $T_s(t_0)$ $=-9.0$ $°C$ and $T_f(t_0)$ $=-2.3$ $°C$. Latent heat and ice conductivity can be approximated using

[14]Where "˙" denotes the derivative with respect to time.

the equations given by Yen, Y. C. et al. (1967):

Appendix C.1.6

$$\lambda_i = 1.16 \cdot (1.91 - 8.66 \cdot 10^{-3}T + 2.97 \cdot 10^{-5}T^2) \tag{4.6.6}$$

Appendix C.1.10

$$\begin{aligned} L_{si} &= 4.187(79.68 - 0.505\ T - 0.0273S_{si} \\ &+4.3115S_{si}T^{-1} + 8 \cdot 10^{-4}S_{si}T - 0.009T^2) \end{aligned} \tag{4.6.7}$$

where the latent heat is evaluated at $T = T_f(t_0)$. The bulk density can be calculated from the density of ice equation (4.1.5) and brine equation (4.1.3) and their volume fractions equation (4.1.4). This results in a second order polynomial $H_m(t, F_w)$ which describes the ice thickness. Meanwhile the coefficients for H_m (and hence F_w) can also be estimated from a least square fit H_w of the thickness data (empirically): $H_w = -2.32 \cdot 10^{-3}t^2 + 3.58 \cdot 10^{-1}t$, where H_m is in cm and t is in hours. It appear, that an ocean heat flux of 10 watt/m^2 results in the best fit for the ice growth model; then $H_m(t) = -1.52 \cdot 10^{-3}t^2 + 3.25 \cdot 10^{-1}t - 4.44 \cdot 10^{-2}$ where H_m is in cm and t is in hours. However everything below 20-30 watt/m^2 seems to give a reasonable fit.

ocean heat flux

Figure 6 shows the ice growth model and the empirical fit to the ice thickness data. Despite all the simplifications, the growth model is still in good agreement with the thickness measurements. With this as a motivation second degree polynomials are used to fit the thickness of the laboratory grown ice.

4.7 Oil lens formation prior to entrainment

Below an level ice layer (and at low current) oil spreads under the combined actions of viscous, buoyancy and interfacial (tension) forces (Fingas and Hollebone, 2003) until the oil lens reach an equilibrium thickness of around 1 cm (Konno and Izumiyama, 2002, Wilkinson et al., 2007). However natural occurring sea ice often has a rough ice bottom which results in a different oil spreading and hence distribution.

equilibrium thickness

Wilkinson et al. (2007) modeled the spreading of oil under landfast sea ice from sonar data of ice bottom topography. A probability density function of pooling capacity[15] and fractional oil coverage[16] was calculated from 400 individual survey sites near North East Greenland. For those sites, the draft[17] had a standard deviation of 0.1 m. The examined ice was most likely to hold around 3000 m^3/km^2 of oil[18] which was expected to cover less than 10-20% of the ice bottom (for the oil covered fraction of ice, this correspond to an average oil lens thickness of 1.5-3 cm). Based on those sparse results, it appears that natural undulations of the ice bottom does not lead to significantly thicker oil lenses.

The oil in ice movement has probably no or little impact on the oil spreading below the sea ice. (In the laboratory experiments only 1255 m^3/km^2 to 350 m^3/km^2 oil migrated into the pore space above the oil lenses.)

[15] A measure of how much oil sea ice at a certain roughness can hold.
[16] The fraction of the ice bottom that ice covered by oil.
[17] The distance from ice bottom to sea level.
[18] Meanwhile this parameter not only depends on the ice topography; it also depends on the amount of spilled oil.

Table 1: Comparison of density and viscosity for oil used in the laboratory experiments and listed in Faksness (2007).

	Oil	**Type/area**	**Viscosity** (cP) at 2°C	**Density** (g/ml)
Faksness PhD project	Snøhvit condensate oil	Barents Sea	1.7	0.76
			NM[19]	0.862
	Marine Diesel		5.0	0.840
	Oseberg C	North Sea	33.6	0.835
	Libya Crude	(Libya)	67.8	0.894
	Goliat	Barents Sea	274	0.875
	Heidrun Åre	North Sea	386	0.926
	Grane	North Sea	1747	0.942
	Marlim	Brasil	2394	0.933
	IFO180	Bunker oil, Shell	28940	0.973
	Pampo	Brasil	91492	0.979
Laboratory Experiments	North Slope Crude	Prudhoe Bay, Alaska	12	0.834
	Thread Cutting Oil	Rigid Tool Company	300	0.870

5 Some characterization of the oils and their physical properties

Two different oils were used for the experiments, a low viscosity crude oil from Prudhoe Bay, Alaska (North Slope Crude) and a synthetic oil with higher viscosity used as a proxy for crude oil. The synthetic oil was manufactured by the *Rigid Tool Company* under the name "Dark Thread Cutting Oil" and had the part number 70830. In the following sections these oils will be referred to as respectively synthetic oil and crude oil. def. synthetic, crude

When spilled at sea, several weathering processes will change the physical and chemical properties of the oil. Usually the most important processes are evaporation, emulsification and oil in water dispersion. However laboratory and field studies Payne et al. (1991) suggest that once entrained in the ice, the oil is not subject to further weathering before the release in spring. As a result of damped wave action, low temperatures and limited spreading (due to sea ice), most weathering processes are significantly slowed down in ice infested waters (Faksness, 2007). weathering

5.1 Selection of oils

With Prudhoe Bay being North Americas largest oil field (AMAP, 2007) located on the coast of the Arctic Ocean (and with the potential for permanent or seasonal off shore expansion[20] (Skolnik and Holleyman, 2002, Weeks and Weller, 1984) oil from this area is highly relevant for studies of oil movement in sea ice. However according to the viscosities listed in table 1 the tested oil from Prudhoe Bay might be less representative for oil spilled in other sections of the

[20] By utilizing platforms such as man-made ice islands, steel drilling caissons or landfast sea ice.

Arctic. In Europe the potential oil fields Snøhvit and Goliat located north of Norway are closest to the marginal ice zone[21]. According to field observation of Faksness (2007) Heidrun Åre and Goliat are able to migrate through the ice to the surface whereas IFO180 stay relatively fixed during the melt. Based on that one additional (synthetic) oil with comparable viscosity was chosen for the laboratory experiments. The use of a dark thread cutting oil turned out to be convenient since no dye had to be added in order to enhance the contrast between oil and ice.

5.2 Viscosity measurements

For both oils viscosity measurements were done using a PC operated *Brookfield* DV-II+ viscometer (Brookfield, 1997) containing a cylindrical fluid chamber with a rotating cylinder in the middle. The viscometer measures the torque of the rotating cylinder at a certain angular velocity and hence sheer rate. Whereas the viscometer featured a build in temperature sensor (inside the chamber) temperature was externally controlled using a *Julabo* FP50-HL refrigerated/heating circulation (Julabo, 2006).
Viscosity measurements were conducted at temperatures in the range from $-20°$C to $2°$C (and $20°$C for comparability) all at a shear rate of 8.4 s^{-1}. Figure 7 show the measured viscosities for the crude and synthetic oil. After adjusting the set point of the external temperature some time was required for the oil chamber to equilibrate and give a constant temperature/viscosity reading. The arrows in figure 7(b) show how the temperatures have been changed from one measurement to the next. The markers indicate two different samples of the same oil. It seems like the viscosity of the crude oil is not only depended of the temperature but also the cooling/heating history of the oil. The synthetic oil is crafted specifically for applications where constant viscous properties are important. In contrast the (naturally occurring) crude oil is a complex mixture of thousands of different hydrocarbons. From an overall perspective this can maybe help explaining the different behaviors of the synthetic oil and the crude oil. Also it should be mentioned that the fluid chamber is partly exposed to the air during measurements. In addition the crude oil is very liquid so it probably contains a lot of short carbon chains. Hence this suggest that volatile components of the oil might evaporate and increase the viscosity during the course of the measurements.
In contrast to ideal Newtonian fluids (where viscosity is independent of shear rate (Bear, 1988)) many real fluids (such as most polymer solutions) belong to the category of (potentially time dependent) non-Newtonian fluids. Hence it is also of (some) importance at what shear rate $\dot{\lambda}$ viscosity is measured. To get a rough idea about the magnitude of shear rates involved in oil transport through sea ice one can examine the width Δx of pores to which the transport is confined and the upward speed v_y of the oil.
According to figure 24 and 25 the width of oil-infiltrated pores is probably of the order 1 mm to 0.1 mm. In the melt-season experiments it took 1 to 10 days for the oil to move through 15 cm of ice suggesting a upward speed between $1.7 \cdot 10^{-2}$m/s and $1.7 \cdot 10^{-3}$m/s. In euclidean coordinates shear rate is defined

[21] Though the risk of oil spill in ice covered water is of cause not only related to oil exploration, but also transportation and increased human activity in general.

as:

$$\tau_{yx} = \frac{\partial v_y}{\partial x,} + \frac{\partial v_x}{\partial y} \tag{5.2.1}$$

and can be approximated as $v_y/\Delta x$ since the speed is zero at the liquid/ice interface. Hence ideally measurements should be conducted at shear raters of the order 10^{-5}s^{-1} to 10^{-7}s^{-1}. However maybe as a result of technical difficulties (or the lack of fluid applications) shear rates in this range are apparently unsupported by standard viscometers.

5.3 Interfacial tension

On the scale of capillaries[22] (see the Bond number (Bush, 2004)) and pores the interfacial tension (γ) is essential for the behavior of (immersible) fluids. Interfacial tension is a property of two adjacent materials originating from the intermolecular (cohesive) forces acting on the boundary molecules. With γ having units of energy per surface area or force per unit length of surface (across the unit length) the interface corresponding to a minimal surface energy satisfies the Young-Laplace equation (Crowe, 2005):

$$\Delta p = \gamma\Big(\frac{1}{R_1} + \frac{1}{R_2}\Big) \tag{5.3.1}$$

where R_1 and R_2 are the principal radii of curvature describing the zero thickness surface and Δp is the pressure difference (the capillary pressure) sustained across the (static) interface. The contact angle (θ)[23] characterizing the intersection of two immersible fluids and a solid material (such as oil, brine and ice) enters the Young Laplace equation through the boundary conditions and is only dependent on the interfacial forces on a unit length of the intersection. An illustration of this configuration is show in figure 8(a).

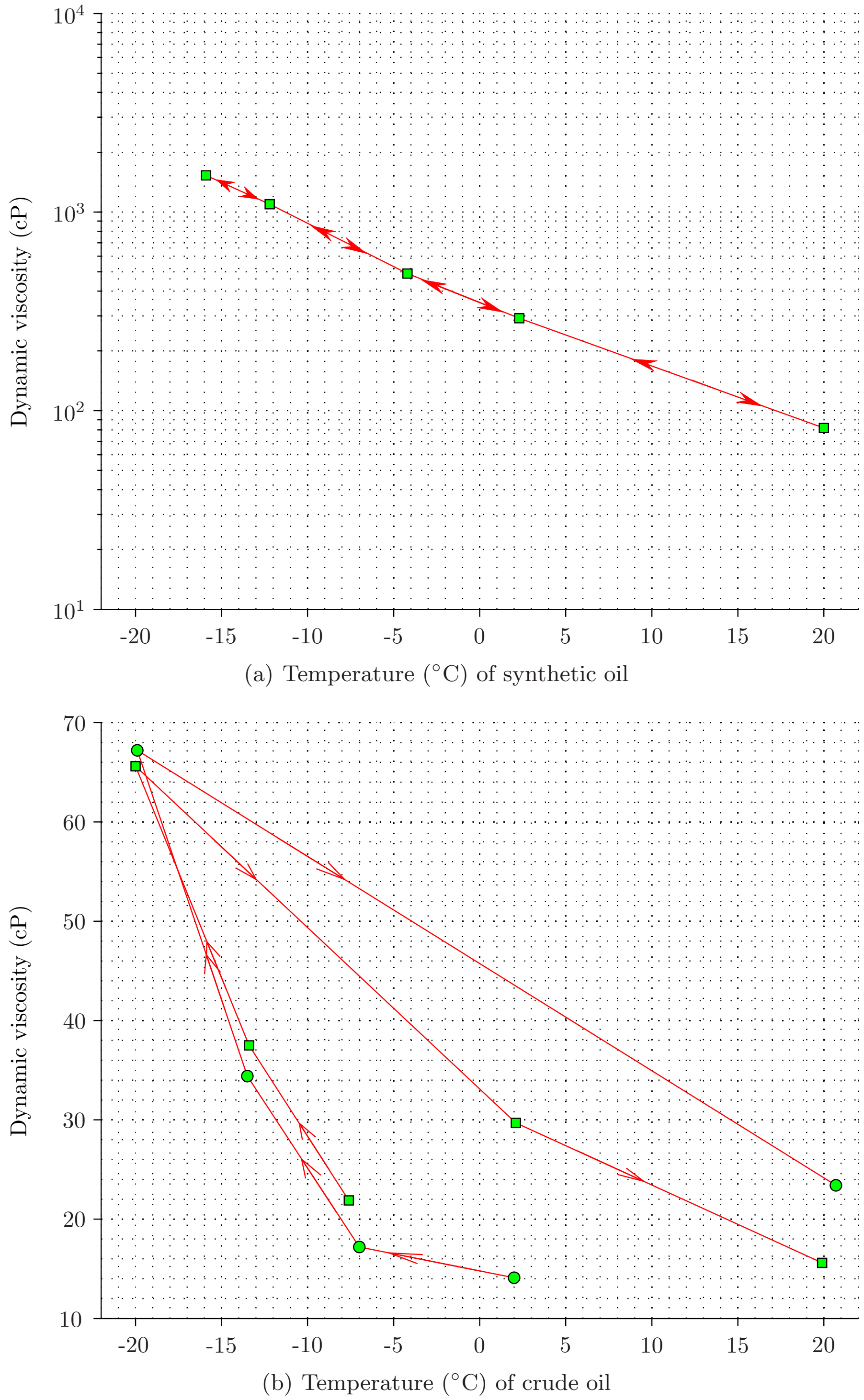
Commonly the measurements of interfacial tension and contact angle uses image processing to delineate points on the surface of an (assumed axis-symmetrical) sessile or pendant drop. These points are subsequently fitted by the Young-Laplace equation (something that could be done for instance using the GPL software provided by Stalder et al. (2006). To examine oil spreading under (smooth and) level ice Konno and Izumiyama (2002) did some measurements on sessile oil drops under an ice plate using a "mechanical # 10 oil". Contact angle and average oil water interfacial tension is reported to be nearly 180° and 0.0262 J/m^2.

As seen in figure 8(b) some attempt was made to measure interfacial tension and contact angle for ice, water and crude oil. Though as a result of the very simplistic setup a major issue became the delineation of the ice bottom something that was also a concern for Konno and Izumiyama (2002). However according to figure 8(b) it seems to be very likely that the contact angle is 130° or more.

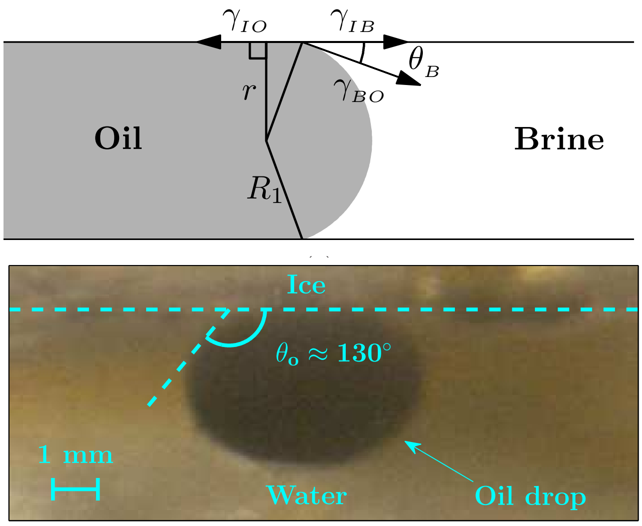
Assume that an oil lens of thickness Δz is introduced below an ice layer with vertical brine channels of radius R. For the equilibrium situation the capillary oil lens thickness

[22] In anatomy, capillaries are the smallest blood vessels, measuring 5-10 μm in diameter.

[23] According to the definition of Crowe (2005) it is unclear what of the two possible angles this would be for a solid liquid liquid (as supposed to a solid liquid gas) intersection. As a result θ has just been denoted with o (oil) or b (brine) to distinguish the two angles.



Appendix C.2.5 Figure 7: Dynamic viscosity measured at a shear rate of 8.4 s^{-1} for (a) synthetic oil and (b) two samples of crude oil (indicated by different makers). The arrows show how the temperature was changed from one measurement to the next (b)



(b)

Figure 8: (b) Attempt to measure contact angle[23] for saltwater(/brine), ice and crude oil. The sessile oil droplet is caught below an ice plate and photographed through the side of a small glass container. The scale is only approximate. (a) illustration of (contact angle[23] and) the interfacial forces acting on a unit length of the oil ice brine intersection in a vertical brine channel (where brine is upward). (Here the mutual length of the vectors is only illustrative). Appendix C.2.6

pressure balances the pressure due to buoyancy:

$$\gamma\Big(\frac{1}{R_1}+\frac{1}{R_2}\Big) = (\rho_b - \rho_o)g\Delta z \tag{5.3.2}$$

where g is the gravity constant (9.8 m/s^2). If ϕ_o is taken as 180°, $R = R_1 = R_2$ and the oil lens thickness can be expressed as:

$$\Delta z = \frac{2\gamma}{(\rho_b - \rho_o)gR} \approx \frac{2.7\cdot 10^{-5}}{R} \tag{5.3.3}$$

where Δz and R are in meters. Equation 5.3.3 uses the oil water interfacial tension measured by Konno and Izumiyama (2002), the crude oil density listed in table 1 and a brine density at −2°C. Hence to exceed the capillary pressure for a brine channel radius of 1 mm, the oil lens thickness need to be almost 3 cm[24]. However, whereas the capillary pressure remains constant, the pressure due to buoyancy increases with the oil height in a vertical brine channel (of constant radius). Hence based on the above simplification, oil can move easily into the brine channels, when first the oil lens has has exceeded a certain thickness.

[24]However for the brine pores between two ice lamellae $R_1 >> R_2$ so $1/R_1 + 1/R_2 \approx 1/R_1$ and only half the oil lens thickness would be required for the same value of R_1.

Table 2: Comparison of important salt ions (Eicken, 2003) for sea water and the synthetic sea salt *Instant Ocean*® in mmol/kg used for the laboratory experiments. (TCO_2 is all forms of CO_2 and ions.) Data source: Atkinson and Bingman (1998).

	Na^+	K^+	Mg^{+2}	Ca^{+2}	Cl^-	SO_4^{-2}	TCO_2
***Instant Ocean*®**	460	9.4	52	9.4	521	23	1.9
Seawater	470	10.2	53	10.3	550	28	1.9

6 Experimental Setup

This section outlines the developed and implementation of the setups and approaches utilized during the course of the experimental study. A total of 21 attempts were made to solidify and contaminate ice from artificial sea water (referred to as EXP1,...EXP21). Those considered to be most relevant will be presented in the following sections.
All experiments were carried out in a cold room where an aqueous solution of the synthetic sea salt mixture *Instant Ocean*® was solidified from above at a nearly constant air temperature of −20°C. Subsequently an oil lens was introduced below the ice and eventually the cold room temperature was gradually increased to induce melt. Comparative analysis of the elemental composition for various sea salts (Atkinson and Bingman, 1998) suggest that *Instant Ocean*® is suitable as a proxy for real sea salts. (see table 2).

sea salts

6.1 Tank design

As illustrated in figure 9, growth and melt season experiments were implemented in two different types of vessels. For the melt season study an insulated PVC barrel (tank 2) with a height of 95 cm and diameter of 51 cm was used. A *Rubbermaid* container with approximate dimensions 42 × 28 × 26 cm (tank 1) was utilized specifically for the growth season experiments.

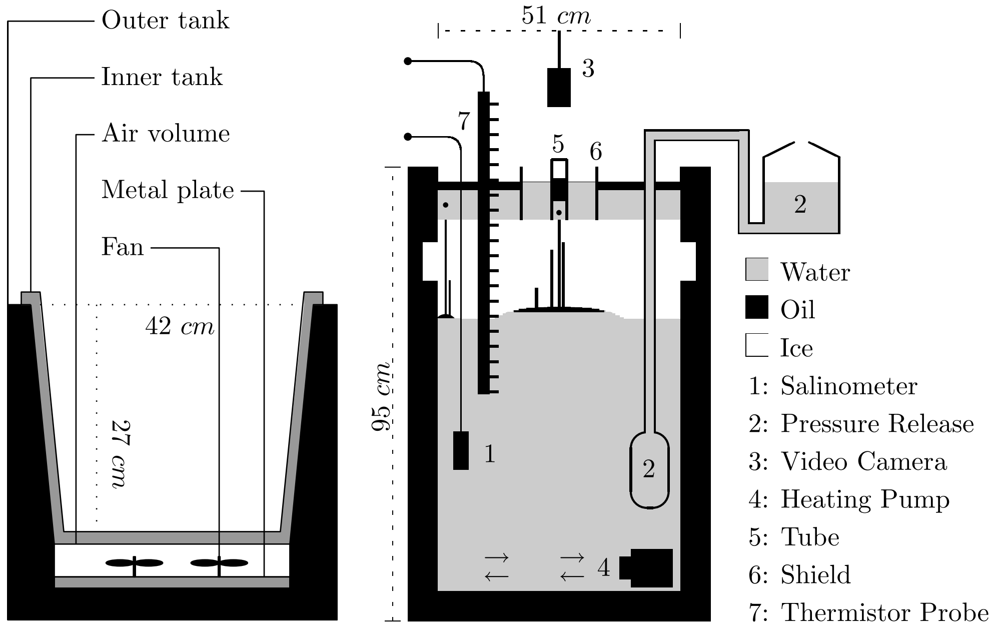
def. tank 2, tank 1

Tank 2 had previously been coated with a 10 cm thick layer of insulating spray foam on the outside. This prevented ice from growing on the sides of the tank, but also made it impossible to examine the ice growth or oil distribution during an experiment. Furthermore due to the size of the water body this tank was unsuitable for first time testing. Hence it was decided to carry out the growth season experiments in a smaller container because these experiments used thinner ice and had to be adjusted more frequently.
As a result tank 1 was built from 5 cm thick plates of blue insulation foam and subsequently shaped with spray foam to precisely fit a transparent *Rubbermaid* container. With this setup it was possible to remove the inner container during the experiment.

6.2 Bottom heating

Boundary conditions for most tank experiments are such that inevitably heat conduction through the insulated walls will result in supercooling of the whole water column unless an internal heating source is employed. When cooled below the freezing point nucleation of ice crystals furthermore lead to platelets of ice

supercooling



(a) (b)

Appendix C.2.7 & C.2.8

Figure 9: Illustration of the two different tanks used in then laboratory experiments (a) tank 1 was built specifically for the growth season experiments and had a removable outer tank. (b) for melt season experiments only tank 2 was utilized and is here shown with all instruments employed. (The dark spots in the ice and on top of melt pond are supposed to be disposed oil).

growing freely in the water column rather than being confined to the ice bottom. A major challenge adding bottom heating is the ice underside as it requires a very homogeneous heating in order to remain level.
The first attempt to achieve this in tank 1 was a metal heating plate with a considerable heat capacity installed in the bottom of the outer tank (below the plastic container). Unfortunately ice grown using this setup became slightly thinner along the container sides, this turned out to be crucial when the oil was introduced. Hence it was necessary to find a new way to add heat from below.
The second attempt was to install 6 small electrical fans in an air cell below the plastic tank. The fans were of the type used to cool computer components. However, the pipes around the propellers were removed such that the fans were just stirring the air. (See figure 9(a)). For ease of adjustment an external voltage divider was used to control the fans. The idea was that the propellers would keep the air well mixed and all the energy dissipated by the fans would end up as heat. Most likely this also ensured that the fans maintained a temperature close to that of the air (and water). The ice bottom became very level which may be attributable to the elimination of convective heating. The only issue with the second solution was the electrical motors which behaved less reliably as a result of the both humid and salty environment.
tank 2 was heated by a small fountain pump which was fixed to the side wall in the bottom of the container. See figure 9(b). The orientation of the pump resulted in a horizontal flow of seawater along the wall and bottom of the tank. Without further adjustments this setup proved to be suitable for tank 2.
The power of the propellers in tank 1 was adjusted to 3.3 W whereas the power

of the pump in tank 2 remained fixed at around 8 W. (It is assumed that all the power ended up as heating). If no heat is lost through the walls and bottom of the tanks this will correspond to ocean heat fluxes of respectively 30 W/m^2 and 40 W/m^2. However without an estimate of heat loss through walls and bottom, also the ocean heat flux remains unknown. While confirming the likely magnitude of the ocean heat flux, the ice growth model in section 4.6 does not provide a more certain estimate. It appears, that an ocean heat flux of 10 W/m^2 results in the best fit.

ocean heat flux

6.3 Adjustment of the seawater salinity

As described in section 4.5, desalination takes place both in growing and melting sea ice. This leads to a steady increase of the seawater salinity throughout the course of an experiment. Figure 6 shows the typical increase during experiments carried out in tank 1. It is clear that the inertial seawater salinity must be very low to obtain a reasonable seawater salinity when the oil is released. On the other hand for water salinities lower than 24.7 ‰ (Knauss, 2000) the temperature of maximum density $T(S)_\rho$ is less then the freezing point $T(S)_f$; something that could possible impact the desalination and crystal growth of the artificial sea ice. As a result all experiments in tank 1 were implemented using a (compromising) initial seawater salinity of around 28 ‰.
This was less of an issue for tank 2 where the increase was slower (see table 5). For experiments in this tank the inertial seawater salinity varied between 30.0 ‰ and 32.2 ‰.

6.4 Pressure relief

Laboratory sea ice grows attached to the container sides; hence during the growth process volume expansion will tend to increase the pressure in the water. Unless the pressure can be relieved this might influence the ice properties (and potentially oil movement) in at least two ways. A suddenly pressure drop could result in an instantaneous supercooling of the water column. This might change the ice crystal structure if the supercooling is enough to cause ice formation in the water. A pressure drop would likely occur if the ice cracks or loosen from the sides of the container.
If the ice is permeable[25] on the other hand an increased pressure gradient could flush brine (or oil) up through the ice. The would of cause be especially critical for the oil movement. However due to the fractional volume of brine, this might also cause a significant change in the bulk salinity and hence porosity during the ice growth.

6.4.1 Solutions for different tanks

As seen in figure 9(a) the diameter of tank 1 is increasing with height. Furthermore the sides and bottom are smooth and a bit flexible. This allows the ice to (easily) loosen from the sides during the ice growth, something that has been

[25] According to Golden et al. (2007). this should only be of concern for warmer ice since the percolation threshold for sea ice occur at a porosity of around 5 %.

confirmed by newly frozen ice along the edge of the tank 1.[26] Based on this observation one could argue that the pressure drops would be few and relatively small [27]. Hence pressure release might be of less concern for the growth season experiments.
Unfortunately this provided no satisfactory solution for experiments with oil release. The topography of the ice water interface was usually such that the minimum draft was located somewhere along the container side. Apparently, the oil is very mobile after the oil release [28] so in the experiment (EXP10) with this setup all the oil escaped along the sides of the tank. To overcome this problem an insulated pipe was connected to a compressible sack with anti-freeze liquid (1.5-2 liter) at the bottom of the tank. The upper end of the pipe was connected to the bottom of an external container in the same height as the water level. With this setup it was possible to maintain a nearly hydrostatic pressure throughout the entire experiment.
However, due to the limited size of tank 1 another problem occurred. As described earlier the heat flux from the bottom needs to be very homogeneous to ensure a relatively level ice bottom. Apparently the presence of the pressure release system was enough to disturb the carefully adjusted bottom heating. In addition sawing or drilling through the ice became almost impossible without cutting the sack (this was tested in EXP11). As a result this system for pressure release was only used in tank 2.
Before each experiment tank 1 was (instead) sprayed with freshwater to form a very thin coating of ice. This prevented the oil from escaping along the container sides since the ice was now unable to loosen from the tank. After the oil was released a 5 mm thick metal pole was used to keep a small hole open until the experiments were stopped. Hence concerns about pressure should only apply to the period before the oil release. However unlike the experiments where the ice could easily slip the sides the ice surface always stayed dry. So probably the ice has been impermeable (without cracks).

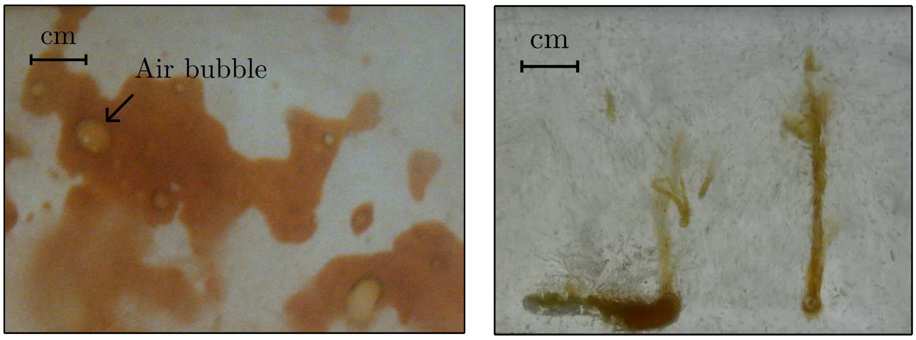
6.5 Oil release

To get a first idea about the oil behavior, ice was grown to a thickness of 5 cm and removed from tank 1. Subsequently 100 ml of synthetic oil was spilled on the water surface and the ice was put back on top. This way of getting the oil beneath the ice introduced an important issue related to the oil release. As seen in figure 10(a) also air pockets were caught under the ice. This resulted in an oil movement very different from what was observed in experiments where no air bubbles were present. Instead of infiltrating all of the bottom most ice the oil only moved up through channels with a thickness of several millimeters (See figure 10(b)). air bubbles
As a first attempt to overcome this issue the oil was injected using a cannula connected to a 4 mm plastic pipe. The pipe was kept away from the oil-infiltrated ice by gluing it to the corner and bottom of the container. However with this

[26] After an experiment it was always easy to push the ice out without using much force. The newly frozen ice had a brighter color then rest of the surface.

[27] Due to the flexible sides some volume expansion is possible and the pressure will increase slowly.

[28] It was observed that oil droplets slide along the ice bottom until the find a local minimum draft. Apparently the droplets do not migrate into the skeletal layer immediately.



(a) (b)

Figure 10: Problems with air bubbles in the first experiments (here EXP1). (a) The water ice interface seen through the bottom of the plastic container right after the oil injection. The brighter areas of the oil layer are air bubbles trapped below the ice.(b) 1 cm thick vertical section of the ice 8 hours after the oil release. The fingers of oil are most likely a result of the air bubbles.

Appendix C.2.9

setup it was almost impossible to control the oil temperature before the release. On the other hand when disconnecting the cannula small amounts of air was caught in the pipe. Another problem turned out to be oil droplets leaving the pipe while the ice was growing.

oil leakage

These problems were solved by mounting a little bottle outside the end of the pipe. Both air bubbles and oil droplets were caught in the top of the bottle. First when around 20 ml of oil/air had been released from the pipe oil started to flow out of the bottle.

freezing of injection pipe

A more critical problem became apparent when this method was used to release crude oil. For some reason saltwater was actually able to move up through the oil and freeze inside the pipe. Without an obvious solution for that problem it was necessary to find a new way to release the oil. This was achieved by using a J-shaped pipe attached to a funnel. A hole of approximately 5 cm diameter was drilled through the ice and the downward part of the pipe inserted under the ice (through the hole). By slowly filling the funnel, oil was released beneath the ice due to the hydrostatic pressure. It turned out to be really convenient to use a pipe with a diameter around 4 cm. With such a wide pipe the flowing oil was not filling up the whole cross area of the pipe. This prevented air bubbles from getting caught. Furthermore the very viscous oil could be released much faster and hence the change in temperature was minimized.

The easiest way to adjust the temperature of the oil was by having two containers with oil at different temperatures. To obtain the desired temperature the oil was mixed and stirred in a thermos can.[29]

[29] To minimize the temperature change around a liter of oil was usually prepared and stored in the thermos.

6.6 Suppression of ice growth in melt season experiments

Due to the warm (and hence high porosity) sea ice present in the melt season experiments oil leakage along the container sides could potentially be a major issue; in particular if the ice melts along the container sides. (see section 6.4.1, page 27). In an attempt to prevent this the following approach was adapted from Otsuka et al. (2004). In their experimental study of an oil-in-ice sandwich Otsuka et al. use insulation on the ice surface to suppress the ice growth in the central part of the tank. This leads to a convex ice-water interface that constrains oil pooling and hence prevent artifacts related to heat exchange with the tank sides[30]. In the current experiments the tank sides are a concern for the upward movement of oil. 5 cm thick plates of blue insulation foam were used to suppress the ice growth before the oil release. An illustration of the foam plates and their position is seen in figure 21. Unfortunately this change of surface boundary conditions might have influenced the desalination and hence salinity profiles.

6.7 Temperature measurements

Two different probe designs were used for temperature measurements inside and above the cooled water body. Whereas the first experiments used a rigid temperature probe it turned out that vertical thermistor chains had less impact on the heat flow and oil transport through the ice. Besides the temperature probes the salinometer also featured a build-in temperature sensor which was used to monitor the water temperature approximately 30 cm above the bottom of tank 2 and approximately 0.5 cm above the bottom of tank 1. salinometer

6.7.1 Thermistors

Thermistors are temperature dependent resistors suitable for high precision measurement of temperature. All thermistors used for the laboratory experiments were (negative temperature coefficient) NTC thermistors manufactured by *AVX* (part number NI24). Here the temperature conversion was based on an included table listing resistances for various temperatures in the interval from -50 °C to +50 °C. However, to obtain a better fit in the relevant temperature range only the data points shown in figure 3 were used.
[Steinhart and Hart 1968] suggested a suitable empirical model for the temperature dependence of a thermistor resistance:

$$\frac{1}{T} = a + b \cdot ln(R) + c \cdot ln(R)^3 \tag{6.7.1}$$

where T is temperature, R is the resistance and a,b,c are constants specific to the thermistor. By making the substitutions $1/T_n \mapsto x_n$, $y_n \mapsto ln(R_n)$ and $ln(R_n)^3 \mapsto z_n$ (for data points $\{R, T\}_{n=1,\cdots,N}$) equation (6.7.1) can be expressed

[30] This was the motivation for Otsuka et al. as they are looking at heat conduction through an oil lens during growth.

as an overdetermined inverse problem:

$$\underset{\begin{pmatrix} x_1 \\ \vdots \\ x_n \\ \vdots \\ x_N \end{pmatrix}}{\overset{\mathbf{X}}{\shortparallel}} = \underset{\begin{pmatrix} 1 & y_1 & z_1 \\ \vdots & \vdots & \vdots \\ 1 & y_n & z_n \\ \vdots & \vdots & \vdots \\ 1 & y_N & z_N \end{pmatrix}}{\overset{\mathbf{G}}{\shortparallel}} \underset{\begin{pmatrix} a \\ b \\ c \end{pmatrix}}{\overset{\mathbf{A}}{\shortparallel}} \tag{6.7.2}$$

Appendix C.4.1

According to Menke (1989) the best estimate of $\mathbf{A}$ (in a least squares sense) can be found as $\mathbf{A_{est}} = (\mathbf{G^T G})^{-1}\mathbf{G^T X}$. This results in the coefficients $a_{est} = 1.55719 \cdot 10^{-3}$, $b_{est} = 2.17370 \cdot 10^{-4}$ and $c_{est} = 1.49641 \cdot 10^{-7}$. The error in the fit can be seen in figure 3.
Before use, all thermistors were calibrated in an ice bath made from deionized water.

6.7.2 Temperature probes

rigid probe

Temperature measurements in the melt season experiments were conducted using the first (rigid) temperature probe consisting of 30 thermistors. The probe had a total length of 51 cm and a horizontal cross section of 0.4×2 cm^2. The 37 upper cm of the probe contained 6 thermistors measuring air temperature above the ice. To obtain a high spatial temperature resolution of the ice thermistors were positioned with a spacing of 0.8 cm from the surface and down to 15.2 cm. From here the remaining thermistors had a spacing of 2 cm.

heat conduction

Heat conduction through the thermistor probe can be a major issue for the probe design (Müller-Stoffels, 2006). To overcome this the probe was made in "Plexiglas" for which Eide and Martin (1975) have shown that the transient thermal properties are similar to that of sea ice. Furthermore the thermistors were protruding about 1 cm from the probe on horizontal wires to avoid vertical heat conduction. Nevertheless depending on the bottom heating the ice close to the thermistor probe was sometimes observed to be slightly thicker (2-5 mm). For most applications this is probably unimportant. However as discussed later in the section even such modest disturbances can be somehow problematic.

electrical insulation

A major concern is electrical insulation of the thermistors which both need be water resistant and in good thermal contact with the surrounding environment. As a compromise the wires and thermistors were sealed with a very thin layer of waterproof silicon coating. The only drawback of this less sturdy solution was that a couple of thermistors stopped functioning over the course of the experiments. However due to the close spacing of thermistors this was not a big problem.

oil seeping

During some experiments oil seeping turned out to be an issue for the probe design. In the melt season experiments (EXP14) oil started to flow up along the thermistor probe and hence could potentially change the temperature reading[31]. In the experiments with growing ice however this was not an issue since the probe (usually) did not penetrate the oil pool[32]. A probe will always con-

[31] A weak light was turned on during periods of the melt season experiments so it is likely that dark oil around the thermistor probe increased the temperature.

[32] This was of course not ideal either.

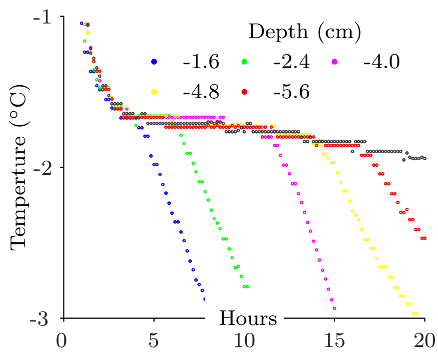


Figure 11: Example of thermistor freeze-in. Thermistors are marked according to their depth.

Temp.	Resistance	Error in fit
°C	Ω	10^{-3} °C
-30	52684	4.5
-25	38688	-6.2
-20	28677	-11.1
-15	21488	22.3
-10	16176	-8.0
-5	12300	-2.0
0	9423	0.6

Table 3: Data points used to fit the temperature curve. The errors in the fit are shown to the right.

Appendix C.3.1 & C.2.1

stitute some disturbance of the heat transport. For most applications this will be of less concern. However if the ice around the probe is just a few millimeters thicker no oil will enter the area and the difference in thickness and temperature will be further amplified. So instead of using a rigid probe for the growth season experiments thermistors and wires were installed directly in the water (tank 1). Now the positions of the individual thermistors were no longer known precisely and had to be measured after the experiment. This was done by cutting the ice around the thermistors into a thin vertical section.

thermistor chain

To prevent oil from seeping up along the wires the chain of thermistors was sprayed with freshwater to form a coating of ice. It is unclear whether the ice stayed on or melted due to the bottom heating. However it was not possible to observe any disturbance of the oil entrainment or advance in ice growth using this simplistic probe.

freshwater coating

6.7.3 Data logger

Most temperature measurements were automated using a *Campbell CR10X* data-logger (Campbell Scientific, 1988) with external storage module. A simple data logger program was written to log the raw data in 10 minute intervals (see appendix).

Appendix C.6

Thermistor resistance was measured using a voltage divider with a 10 kΩ precision resistor (R). An excitation voltage U_{ex} of 2.5 V was applied and the voltage across the precision resistor was measured. Hence the thermistor resistance R_T could be found from $R_T = R \cdot U/(U_{ex} - U)$. To accomplish measurements over several thermistors a *Campbell AM16/32* (Campbell Scientific, 2006) multiplexer was used to switch (multiplex) the circuit between the individual thermistors.

6.7.4 Processing of temperature data

Thermistors seem to be sensitive to changes in their surrounding while they freeze into the ice. Here thermistors were observed to stop (and sometimes start!) functioning. Usually some thermistors were off already from the first contact with the saltwater. As a result some cleaning of the temperature data was done manually by excluding readings for which the temperature signal was (clearly) distorted. Jumps in resistance (usually corresponding to many °C) were so pronounced that such readings could be easily distinguished from the clean temperature signal.

surface temperature

For further processing (such as input to equation (4.6.4)) it was necessary to extrapolate temperature to the ice surface. Typically the air temperature measured only a few millimeters above the ice surface was several degrees lower then the ice temperature. Hence it would be unphysical to interpolate the temperature between thermistors inside and above the ice layer. Though as seen in figure 22 the temperature gradient at a given time is almost constants so it is possible to obtain a reasonable estimate of the surface temperature by fitting a first order polynomial to the ice temperatures (see eventually C.4.2).

ice thickness

hot wire

depth gauge

Ice thickness was manually derived from the thermistor freeze-in as seen in figure 11. In addition to that some thickness measurements were done using a metal wire that penetrated the ice and had a weight attached below the ice. When connected to a battery the wire got hot and the weight could be lifted up to the water/ice interface and the wire length measured. Thickness was also measured in core holes using a simple depth gauge.

6.8 Salinity measurements

Salinity of sea water is usually measured as electrical conductivity and stated in practical salinity units as defined by UNESCO (1978). This scale assumes a constant sea water composition and is based on conductivity ratios in the interval from 1 to 42. However, typical brine salinities inside cold ice can be much higher and the composition is also varying (Assur, 1960). Hence salinities are customarily based on the electrolytic measurements of melted samples (Eicken, 2003) and will be quoted in ‰.

salinometer

automated measurements

Salinity measurements were conducted using a handheld *YSI "Model 30"* (YSI, 1998) salinometer which works as a coupled temperature and conductivity sensor. The salinometer is factory calibrated and unfortunately designed for manual measurements. Hence to measure water temperature and salinity throughout the experiment the salinity probe was installed near the bottom of the tank. A web-cam was then scheduled to take snapshots of the display in 10 minutes intervals.

Salinity measurements of melted ice samples were conducted in a small tube which was slightly bigger then the salinity probe. However after the separation of synthetic oil and water, a very thin oil film was sometimes still visible on the water surface. When using the crude oil on the other hand, the water appeared slightly more turbid which most likely is due to oil dispersion (i.e. oil water emulsification). This suggest that the presence of oil could influence the salinity reading, for instance by sticking to the sensor. To test this hypothesis salinity was measured before and after mixing and separating oil and saltwater. This was done for several test samples and all of them gave the same salinity reading

Figure 12: An almost fully encapsulated oil lens. Note the layer of oil-infiltrated ice above the lens.

Appendix C.2.10

before and after. Hence, salinity measurements appear to be unaffected by the low oil concentrations encountered in the present experiments.

issues with oil

After each salinity measurement the salinometer probe and the containers were carefully cleaned before processing the next sample. However the sensor is protected inside the probe and this makes it difficult to determine the effectiveness of the cleaning on the sensor itself. Hence one could suspect that the performance of the salinometer would be influenced over a longer period of use. To deal with that the reading was often compared to that of a similar salinometer which had never been in contact with oil contaminated salt water. It was not possible to detect any change so this is probably not of concern.

6.9 Extraction of samples for oil and salinity measurements

Due to the porous nature of sea ice, brine loss can be a major concern when extracting cores. However in most situations all attention is obviously directed to loss of brine from the core itself. Though in case of fixed sea ice with a limited extent coring can be destructive also for the remaining ice. As the tank ice has almost no free board removing a core will initially drop the water level by the thickness of the ice. Freely movable brine makes up a modest fraction of the total ice volume so most likely a considerable brine drainage will take place. This was observed in EXP8 and EXP9 where the water level increased by a couple of centimeters during a period of 10-15 minutes after the coring. By immediately filling the hole with a second core this was prevented in later experiments. As a further attempt to keep oil away from the area the second core was cooled to -20 °C and the thin gap between core and surrounding ice was filled by freshwater at the freezing point.

6.9.1 Growth season experiments

Unfortunately sampling of the ice is very difficult right after an oil release. This is because the oil is contained in the bottom-most centimeters of the ice which is also very porous. Hence most likely a considerable amount of the oil will drain out of the ice when extracting a core. Postponing the sampling seemed to be the only simple way to minimize impact. Once the ice had encapsulated the oil lens tank 1 was turned on the side and the insulation removed. By draining out the remaining water the oil-infiltrated ice was cooled in a position which

Appendix C.2.11

Figure 13: Sample definitions for measurements of oil and bulk salinity. Here illustrated for a 1 cm thick vertical section of the ice. The saw cuts mark the various subsections used for oil and salinity measurements. The layer above the oil horizon is denoted with a ”plus” sign.

ensured a minimal loss of brine and oil. However, the true ”initial” bulk salinity of the oil-infiltrated ice cannot be measured with this approach.
After leaving the ice to cool at room temperature of -20 °C it was removed from the container and cut into vertical sections with a thickness of approximately 1.5 cm. The oil-infiltrated ice to be sampled was chosen first, from the middle of the oil-infiltrated area second, from level ice with a well defined oil horizon. Figure 13 illustrates how the ice was subdivided into sections.
As mentioned in section 6.5 it was possible to extract a core right before the oil release (denoted OR).

6.9.2 Melt season experiments

In the melt season experiments cores had to be taken from warm and ”rotten” ice. With a brine volume fraction of 20-30 % this ice is almost impossible to remove without losing oil and brine. So instead of extracting cores in the usual way the following procedure was used. A plastic container with a diameter of 12 cm was inserted below the ice through a hole made with a hand saw. Now a sample with the same width as the container was sawed out and pushed horizontally above the container. While the container was slowly raised to encircle the core a small hole in the bottom allowed water to escape. By blocking the hole with a finger the container could be removed without draining away all the brine. Subsequently the container was sealed with a plastic bag and frozen down to -40 °C in upside position. Before processing the core for oil and salinity measurements the sides were cut off such that only the central part of the sample was used.
In EXP16 and EXP17 another method was tested. Here the warm ice was cooled at an air temperature of -30 °C to form ”multi-year ice” before the cores were extracted. This was originally to get more reliable picture of the oil distribution. While some desalination most likely occurs during the refreezing this may still be a good way to obtain a bulk salinity profile.

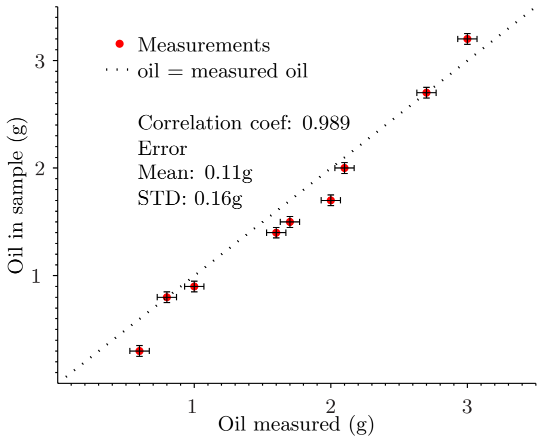


Figure 14: Validation of the oil content measurements. Values for "measured oil" are obtained by mixing oil and saltwater (in a ratio typical for that of the ice samples) and subsequently separating the oil again. The error bars show the uncertainty in the weighted oil.

Appendix C.2.12

6.10 Oil measurements

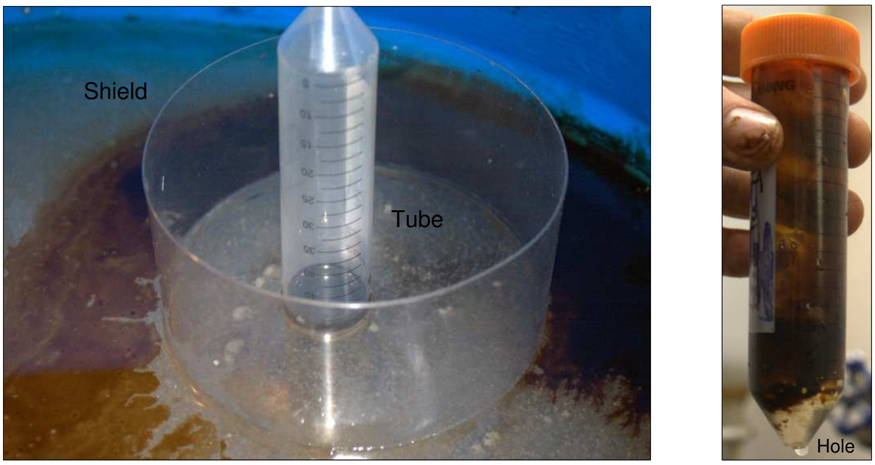
Measurements of flow rate and oil content were both based on a primitive method where oil and saltwater were separated in a tube. With more sophisticated techniques the oil content could probably be measured with much higher precision. However for the present purpose these measurements fully covered the needs so no attempts were made for further improvements.
Below follow a descriptions of the method and a short discussion of the errors related to the measurement.

6.10.1 Content

After cutting the ice into horizontal sections each sample was weighed and melted in a small container (with lid on). Then the oil water mixture was poured in a tube with a small hole in the bottom, see figure 15(b). This allowed the water to be carefully drained out through the bottom and stored for salinity measurements. However during the melting some oil would always stick to the sides and stay in the container. Hence, to minimize the uncertainty the electronic scale was first zeroed with empty tube and container. Then the total weight of the oil left in the tube and container was measured. The method was tested with known amounts of saltwater and oil typical for that of the samples. Before separating oil and water, the mixture was shaken to imitate the pouring of the melted samples. The results of the test are presented in figure 14. The mean systematic error (or offset) was 0.11 g (approximately 5%) and the standard deviation in the error was 0.16 g. Hence the amount of oil is generally slightly overestimated. This suggest that water might stick to the walls of the tube or stay as an emulsion in the oil. The offset in the oil weight has been corrected and the standard deviation was used as a (rough) guide for the error propagation (see error bars in figure 23(a) and 23(b)).

6.10.2 Flow rate

The tube for oil water separation turned out to be suitable also for accumulating the oil flow from individual brine channels (this was done in EXP14 and EXP17, see figure 15(a)). The ponds in the melt season experiments were kept at a constant depth of around 1 cm. This allowed the oil to be caught inside the



(a) (b)

Figure 15: Tools for accumulating (and later separating) oil disposed from the ice layer. (a) Measurement of flow rate over melt pond from a single brine channel. A shield with diameter of 12 cm prevents oil from entering the area from the sides (b) Subsequently the water is carefully drained out through a hole in the bottom of the tube.

Appendix C.2.13

tube when it was turned upside down and rested on the ice. A glass plate with the approximate dimensions $6 \times 6 \times 0.2$ cm^3 was then used to remove the tube without loosing oil. This was done by horizontally displacing the glass plate along the ice surface until it covered the opening of the tube. The water level in the pond ensured that the oil was not in direct contact with the glass plate. However even though the glass plate was blocking the opening, oil would seep out when turning the glass plate and tube (upside up) together. To prevent this most of the air inside the tube was sucked out through the small hole in the bottom (see figure 15(b)) As a result the oil layer was displaced to the top of the tube and it could now be turned upside up together with the glass plate.
Usually some oil was seeping up along the sides of the container or along the cord for the pump. A shield of clear plastic was used to keep that oil away from the area around the tube. With this setup it was easy to make sure that no oil from the brine channel was flowing outside the tube, and no oil was lost in the pond when the tube was removed.
During the course of EXP17 oil started to emerge from several brine channels inside the shield. Due to the limited space available it was at some point necessary to measure the flow rate from the total area instead of the individual brine channels. This was done by first cleaning the outside of the shield from oil, and subsequently taking a plastic back beneath the whole shield from the side. Finally the plastic back could be removed with the shield and the oil.
Oil weight was measured using the same procedure as described in section 6.10. However a couple of times oil droplets were lost when draining away the water. It turned out that the weight of 2-3 oil drops corresponded to around 0.1 g which is around 5 % of the measured oil weight. As seen in Figure 23(a) the lost droplets account for a rather modest contribution to the flow rate.

7 Results

7.1 Growth season experiments

Several experiments were undertaken to study fixation (and hence small scale movement) of oil in the bottom of a growing sea ice layer. However due to various experimental difficulties (described in section 6) only some of the experiments were completed successfully (EXP2, EXP13, EXP18, EXP19, EXP20, EXP21) and will be presented here.
In all experiments (using tank 1) lenses of crude or synthetic oil at slightly different temperatures were introduced below a growing sea ice layer which was solidifying at a nearly constant air temperature of $-20°C$. Subsequently as the oil lenses had been encapsulated each experiment was terminated to measure depth and oil content of the OI layer formed above the lenses. A typical evolution of ice temperature, water salinity and thickness is seen in figure 6. The thickness of oil lenses is estimated to be less than 2 cm.

7.1.1 Comparison of measurable parameters

Table 4 compares all the measured parameters for the various growth season experiments. Note that the oil temperature is not the actual (initial) oil lens temperature but the measured oil temperature before the release. In contrast to the melt season experiments ice thickness could here be measured (directly) and hence represents the sampled ice rather than the ice thickness around the thermistor probe (which might deviate slightly). However the interface temperature at OR had to be extrapolated from the location of the thermistor probe. This was done by linear interpolation of the two freeze-in temperatures closest to the OR.
In EXP2 platelets (PL) of ice were formed within the water column so although no temperature measurements are available the water has presumably been more supercooled than in other experiments (where the ice was only growing from the ice water interface).

7.1.2 Profiles of temperature and salinity

Figure 16 shows bulk salinity (a) and temperature (b) for the growth season experiments. In figure 16(a) the thickness of the oil-infiltrated (OI) layer (and hence also total ice thickness) is indicated by solid (horizontal) lines and the salinity difference between NOI and OI layers is indicated by dotted (horizontal) lines. As suggested by the illustration, the salinity of the OI layer is always higher than the corresponding NOI layer at the same depth. Oil content is here displayed as marker face color although this parameter also is listed in table 4 together with the oil type and amount.
The temperature profiles in figure 16(b) show all available temperature measurements within the water body at the time of oil release; here 0 cm is the ice surface and -27 cm is the bottom of the tank. The theoretical freezing point derived from the water salinity is indicated by round markers whereas temperature measurements from the salinity probe and thermistor probe are indicated by respectively square and triangle markers.

Appendix C.3.3

Table 4: An overview of comparable parameters for selected growth season experiments.

		EXP2	EXP13	EXP18	EXP19	EXP20	EXP21	
Oil	Type	Synt	Synt	Crude	Synt	Synt	Crude	
	Amount	50	50	400	380	340	310	(ml)
	Temperture	20	0.0	-1.5	4.6	2.2	2.7	(°C)
	OMF	21.5	10.2	1.2	1.1	3.6	4.6	(wt%)
Water	Salinity	NM	37.7	43.5	45.6	44.2	38.3	(‰)
	Temperature	PL*	-1.9	-1.0	-0.8	-1.2	-2.4	(°C)
	Freezingpoint		-2.1	-2.5	-2.6	-2.5	-2.2	(°C)
Ice	Interface temp.	NM	NM	NM	NM	-2.6	-1.9	(°C)
	Thickness	5.9	8.0	11.0	13.3	10.9	12.2	(cm)
	- of OI layer	3.4	2.3	2.1	1.5	1.4	2.9	
	Salinity OR	NM	NM	NM	NM	15.9	14.8	(‰)
	- OR+	NM	NM	NM	NM	10.6	9.8	
	- NOI	9.7	9.6	NM	NM	9.5	11.7	
	- OI	6.6	6.0	14.5	11.2	7.8	7.4	
	- OI+	9.9	8.4	9.7	10.0	9.7	8.0	
	BVF OI		5.1			12.7	16.5	(%)
	- OI+		6.7			12.4	13.6	
	- NOI		9.2			16.2	27.2	
	- OR					29.4	26.0	
	- OR +					15.9	14.6	
	OVF		10.8			3.8	5.0	(%)
	Oil Capacity		1255			350	718	($\frac{m^3}{km^2}$)
Duration	Before OR	NM	43.9	39.9	42.0	39.9	NM	(hrs)
	After OR	NM	7.5	11.9	6.7	13.0	9.2	

NM are parameters which has not been measured and blank fields are parameters which (as a result) cannot be calculated. For the oil content however there is only a small difference between the mass fraction (OMF) and the volume fraction (OVF). The definitions of the sections OR, NO, OI (and +) are shown in figure 13. In EXP2 $^{(*)}$ platelets of ice (PL) were growing within the water column so although no temperature measurements are available the supercooling it probably more pronounced here than in the rest of the experiments (where the ice was only observed to grow from the ice bottom). The duration before OR is measured from the beginning of the experiment (which is not always similar to freeze-up) and after OR is measured until the termination of the experiment. Oil capacity is the total oil volume per area which is entrained in the ice. According to the OMF it is striking that the synthetic oil generally seems to occupy most of the pore space although this oil has the highest viscosity.

Table 5: Comparison of parameters in the melt season experiments

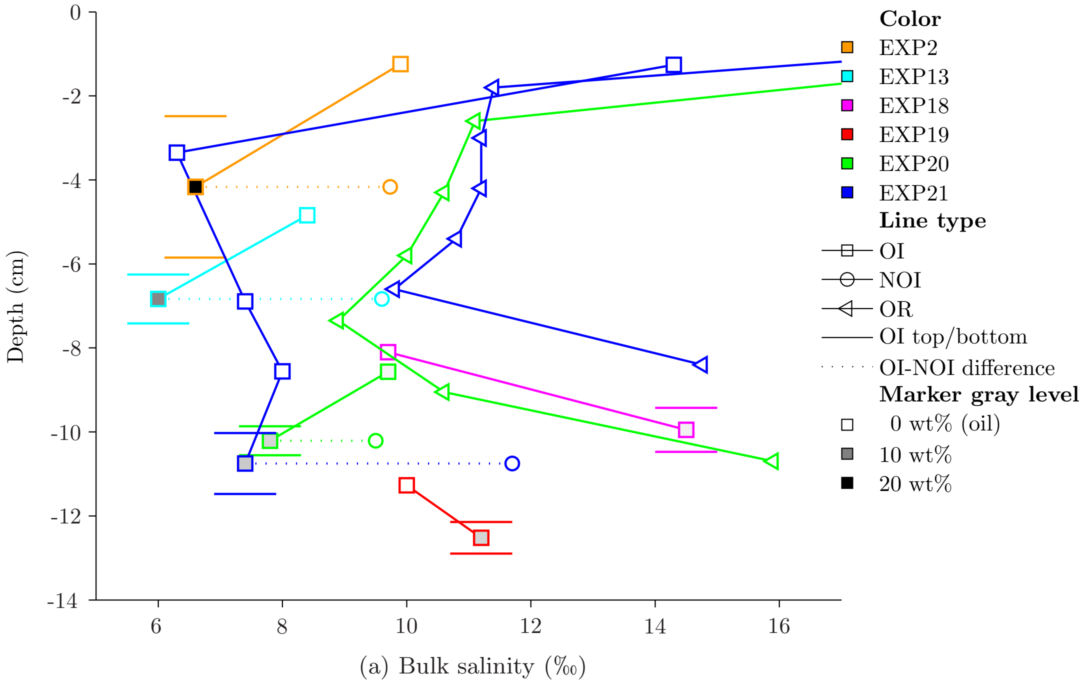
		EXP14	**EXP16**	**EXP17**	
Oil	Type	crude	synt	crude	
	Amount	600	450	500	(ml)
	Temperature	-1.4	-1.6	-1.6	(°C)
Ice	Thickness at OR	14.2	17.5	17.4	(cm)
Water	Salinity FU	32.1	30.0	30.2	(‰)
	- OR	34.8	37.2	37.6	
Duration	Freezing	2.5	3.6	3.6	(days)
	Warming	7.5	14.8	14.8	
	Oil penetration	4.6		7.7	
Setup	Pressure Release	×	×	(manual)	
	Thermistor probe	×	×		
	Weak light on		×	×	

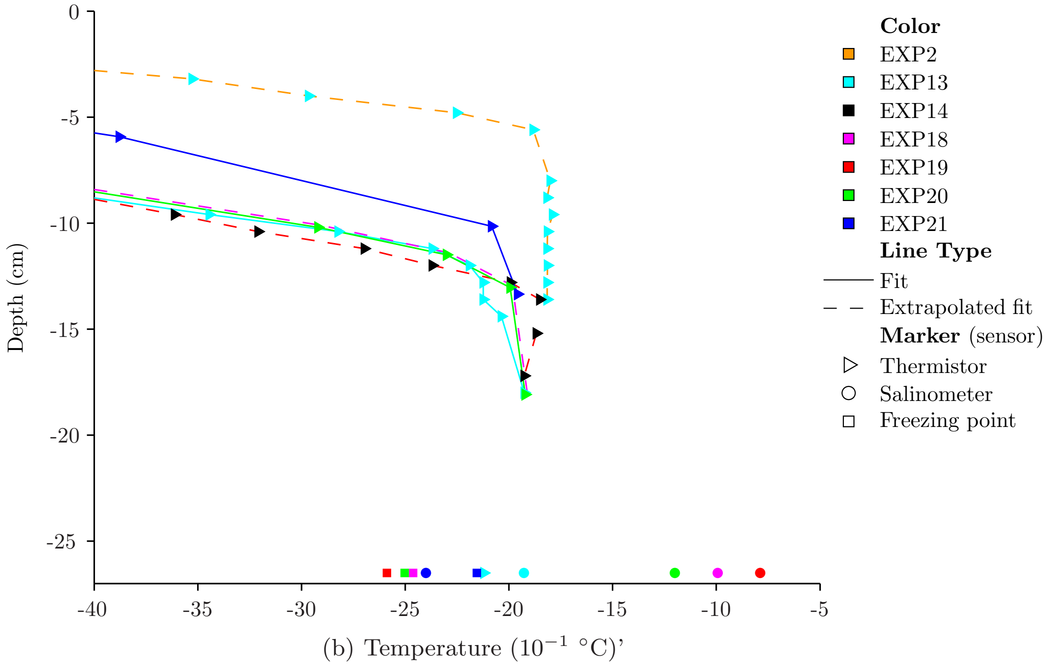
Appendix C.3.2

The color code indicates in what experiment the temperatures were measured (for markers) and eventually to what experiment the temperatures have been extrapolated (line color and style). For instance no temperature data were available for EXP2; as a result temperatures have been extrapolated from EXP13 using a similar ice thickness. Hence those data might of course deviate considerable from the actual temperatures.
Besides EXP21 the light was turned off during the course of all experiments. This suggests that the higher temperatures measured in EXP21 might be due to radiative heating of the (dark, brown) thermistors.
Figure 17 shows the porosity and oil volume fraction for EXP13, EXP20 and EXP21. Between 1/4 and 2/3 of the pore space is occupied by oil. The porosity of the bottommost ice generally decreases from the oil release (OR ice) to the termination of the experiment (OI and NOI ice). Also the porosity of the NOI and OI sections seems to be relatively equal (although there might be local inhomogeneity in the porosity as well as different desalination for the infiltrated and clean ice). However the amount of measured oil seems to agree with a decrease in salinity.

7.2 Melt season experiments

3 laboratory experiments (EXP14, EXP16 and EXP17) in tank 2 (see section 6.1) were undertaken for the study of oil movement in melting sea ice. After solidification at a nearly constant cold room temperature (−20 °C) oil lenses were introduced below the ice layer (see section 6.5) and air temperature was gradually increased to around −1 °C. During a period of 4 days (EXP14) to 8 days (EXP17) crude oil had percolated the depth of the ice layer and was continually discharged from one (EXP14) or a few point sources (EXP17) at the ice surface. However during the course (15 days from OR) of EXP16 the





Appendix C.2.18

Figure 16: Profiles for growth season experiments. (a) bulk salinity of the ice; here the position of the OI layer is indicated by solid (horizontal) lines and the salinity difference between NOI and OI layers is indicated by dotted lines.(b) vertical temperature profiles for the whole water body. Note that the higher temperatures of EXP21 most likely is due to light shining on the thermistors. The thermistor data for EXP2, EXP18 and EXP19 are extrapolated from EXP13, EXP20, EXP14.

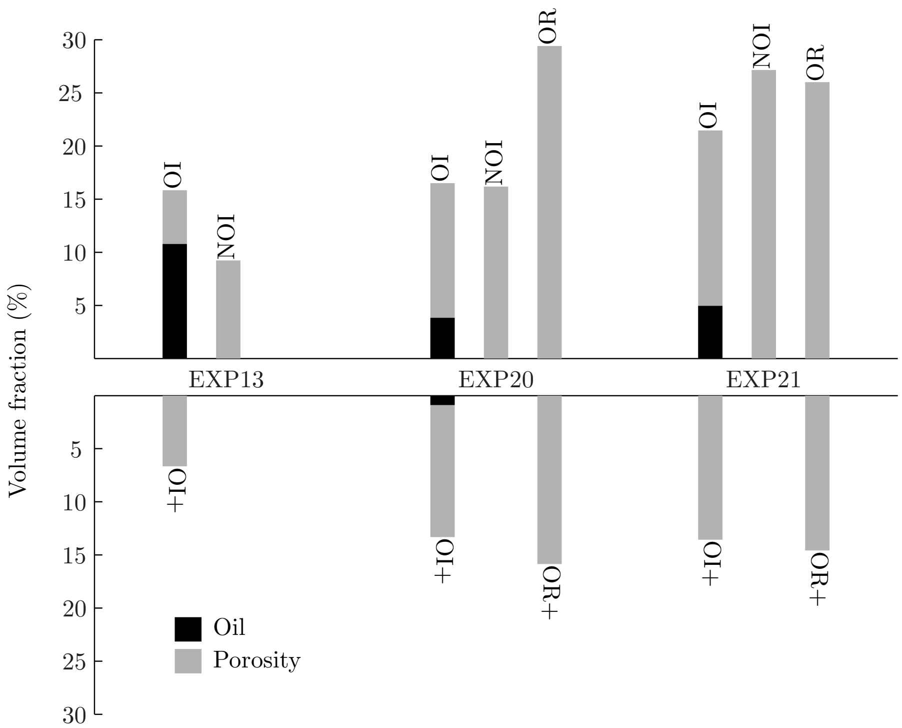


Figure 17: Comparison of oil volume and porosity for the growth season experiments. The OI layer and layers in the same depth (OR and NOI) are shown on the top side, and the layers above (denoted with +) are shown on the bottom side. The oil present in EXP20 OI+ indicate that the delineation of the layers in EXP20 might be slightly off.

Appendix C.2.18

synthetic oil never surfaced.
To examine the behavior of the two test oils under nearly identical boundary conditions EXP16 and EXP17 were implemented co-instantaneously using two copies of tank 2. Since temperature data should be comparable for the two tanks this also allowed EXP17 (with the most mobile oil) to be implemented without a thermistor probe to disturb the ice. As a result all temperature data from EXP16 have been applied to EXP17 as well.

7.2.1 Events and comparable parameters

An overview of comparable parameters and boundary conditions for the melt season experiments is shown in table 5. Here the listed oil temperatures were measured and adjusted in a thermos right before the release (section 6.5). As a result the values stated in table 5 might differ slightly from the actual oil lens temperatures [33].

oil temperature

The listed ice thicknesses are derived from thermistor freeze-in and hence only apply for the position of the thermistor probe. Nevertheless, depth gauge and hot wire measurements (see section 6.7.4) suggest that the overall variation of ice thickness is within 2-3 cm.

ice thickness

The duration from first ice formation (FU) to oil release (OR) is stated as freezing whereas the period from OR to re-cooling (EXP16 and EXP17) or termination (EXP14) is stated as warming. The time for oil penetration is counted from

duration

[33] Here the precision would obvious be less.

OR to the first oil being released naturally at the ice surface (as supposed to oil seeping up along the tank sides, thermistor probe etc.) However due to leakage of oil from such undesirable locations also the exact detection of oil penetration (using a scheduled webcame) failed. Though manual inspection suggests that oil penetration might have occurred at the earliest 8 hours before in EXP14 and at earliest 3-4 hours before in EXP17.
Figure 20 and figure 19 illustrate the timing and duration of some key events overlaid with the evolution of ice temperatures. As indicated by the markers on top of the ice, temperature peaks (during the growth) co-evolve with the light level which had to be abruptly increased during work and inspection of the experiments. The white areas of the illustration should be interpreted as missing temperature data or temperatures outside the ice layer. To account for inadequate or missing temperature data for the air ice interface surface temperatures were extrapolated as described on in section 6.7.4.

surface temperature

For EXP17 no pressure release system was installed. Instead a small hole close to the tank side was kept open after the oil release (see section 6.4.1).

7.2.2 Extraction and labeling of cores

To allow easy reference all extracted cores were enumerated chronologically as 1C, 2C, ..., NC for each experiment. Whereas the configuration of extracted cores (with regards to the overall setup) is depicted in figure 21, figure 20 and 19 attempt to illustrate the timing with regards to temperature evolution. Although each core was labeled, not all cores were utilized for further processing and analysis.

7.2.3 Measurements of oil discharge

The discharge of oil to the surface pond was confined to one or a few source points delimited by the shielded areas depicted in figure 21. By following the procedure outlined in section 6.10.2 flow rates from the individual source points were measured as a function of time. The measurements for EXP14 and EXP16 are presented in figure 23(a) and figure 23(b). Here the measured oil leakage is assumed to originate from a channel-like flow through individual brine channels connected to the surface. The vertical lines are error bars of one standard deviation estimated as (Taylor, 1997):

$$\delta q = \sqrt{\Big(\frac{\partial q}{\partial t_1}\delta t_1\Big)^2 + \Big(\frac{\partial q}{\partial t_2}\delta t_2\Big)^2 + \Big(\frac{\partial q}{\partial m_o}\delta m_o\Big)^2} \tag{7.2.1}$$

where the flow rate q is determined as the fraction of oil mass (m_o) and the course of the measurement ($t_2 - t_1$). The uncertainties δt_1 and δt_2 are estimated to respectively 2 and 4 minutes and δm_o is taken as 0.16 g from the test of oil measurements in figure 14. The estimated flow rate (green line) is also corrected for the offset (mean error) of 0.11g. However as seen in figure 23(a) this has no significant impact on the actual flow rate. For the whole ice surface, oil tansport through brine channels accounts for volume fluxes of the order 10^{-9}m/s.

As seen in figure 23(b) the oil leakage in EXP17 occurs later and the total discharge is lower (although the oil is leaking from more points in this experiment). Some measurements were made of the accumulated oil discharge of the whole area delimited by the shield. Here it was not practically possible to detect and measure the flow from individual channels. Also the arrangement of tubes sometimes failed to cover all the leaking channels. For those periods the total flow rate has been estimated as the average flow rate for the measured channels times the total number of channels (indicated by square markers without error bars).

7.2.4 Profiles of temperature, salinity and oil content

To allow easy comparison with bulk salinity and oil profiles (see figure 22(a)) ice temperatures are displayed for the ice in 4 different periods: GROWING ICE marks the temperatures at the oil release; MELTING ICE marks the temperatures just before the experiment were terminated or re-cooled; COOLED ICE marks the temperature of the re-cooled ice before the experiment were terminated and OIL ON SURFACE marks the temperatures when the first oil was disposed through the ice to the surface. For EXP16 (and EXP17) the temperature for OIL ON SURFACE is similar to the temperature for MELTED ICE (and hence is not displayed).

def.
Growing ice
Melting ice
Cooled ice
Oil on surface

The time at which salinity (and oil) profiles were extracted has been indicated correspondingly by the line type style. (However this information is also provided in figure 20 and 19).

Some attempts were made to core the MELTING ICE (1C) from which oil was leaking in EXP14 (see section 6.9.2). Unfortunately the ice was so dissolved that the core collapsed as it was sawed out. It is striking however, that the peak in bulk salinity for EXP14 C2 (around −8 cm) seems to agree with the depth at which 2C apparently was completely disconnected (or broke into two pieces during coring).

7.2.5 Modes of transport and entrainment

To document the oil configuration (and hence possible transport modes) a couple of photos have been selected to illustrate the most noticeable observations. After extracting the cores from EXP17 it was possible to image the (remaining) ice layer of COOLED ICE. As seen in figure 24 the overall oil concentration is highest in top and bottom. Furthermore macro photos of the vertical ice surface suggest that the dark plumes correspond to areas where oil is entrained in the pore space. The width of oil contaminated pores is of the order 1 mm whereas the interconnecting channels or necks seems to be less than 0.1 mm.

However there is also evidence of another entrainment and possible mode of transport. In figure 25(a) (showing a vertical section of 2C EXP14) all the oil is contained in a single[34] (non-leaking) brine channel of diameter 1- 2 mm. The horizontal intersection of this channel is also seen in figure 26(a) which compares the ice crystal structure for the growths and melt season experiments (tank 1 and tank 2).

[34] At least in the middle and upper part of the ice layer.

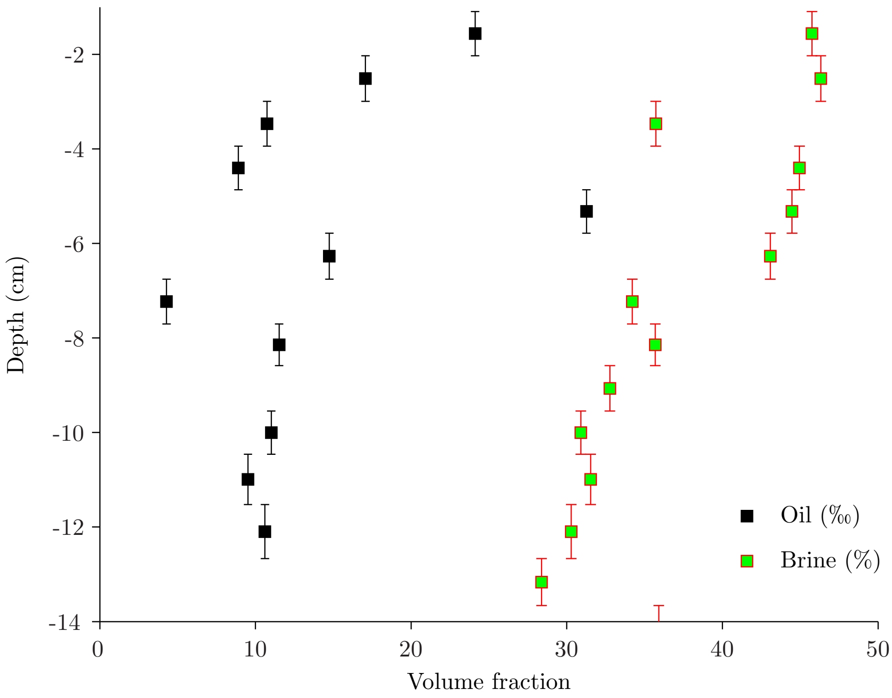


Figure 18: Volume fractions for C2 EXP14 (Melting ice). All the oil in this core is contained in a single vertical (and non leaking) brine channel of diameter around 2 mm (seen in 25(a)) without entrainment of oil in the surrounding pore space.

Appendix C.2.14

Figure 26 (b) (from Cooled ice EXP17) also shows a channel like entrainment of oil. However since this ice has been warmed after removal it is unclear to what extend (re-)warming influences the small-scale oil configuration; hence as the pore volume increases (and interconnects) interfacial forces could possible lead to a retreat of oil from smaller pores.

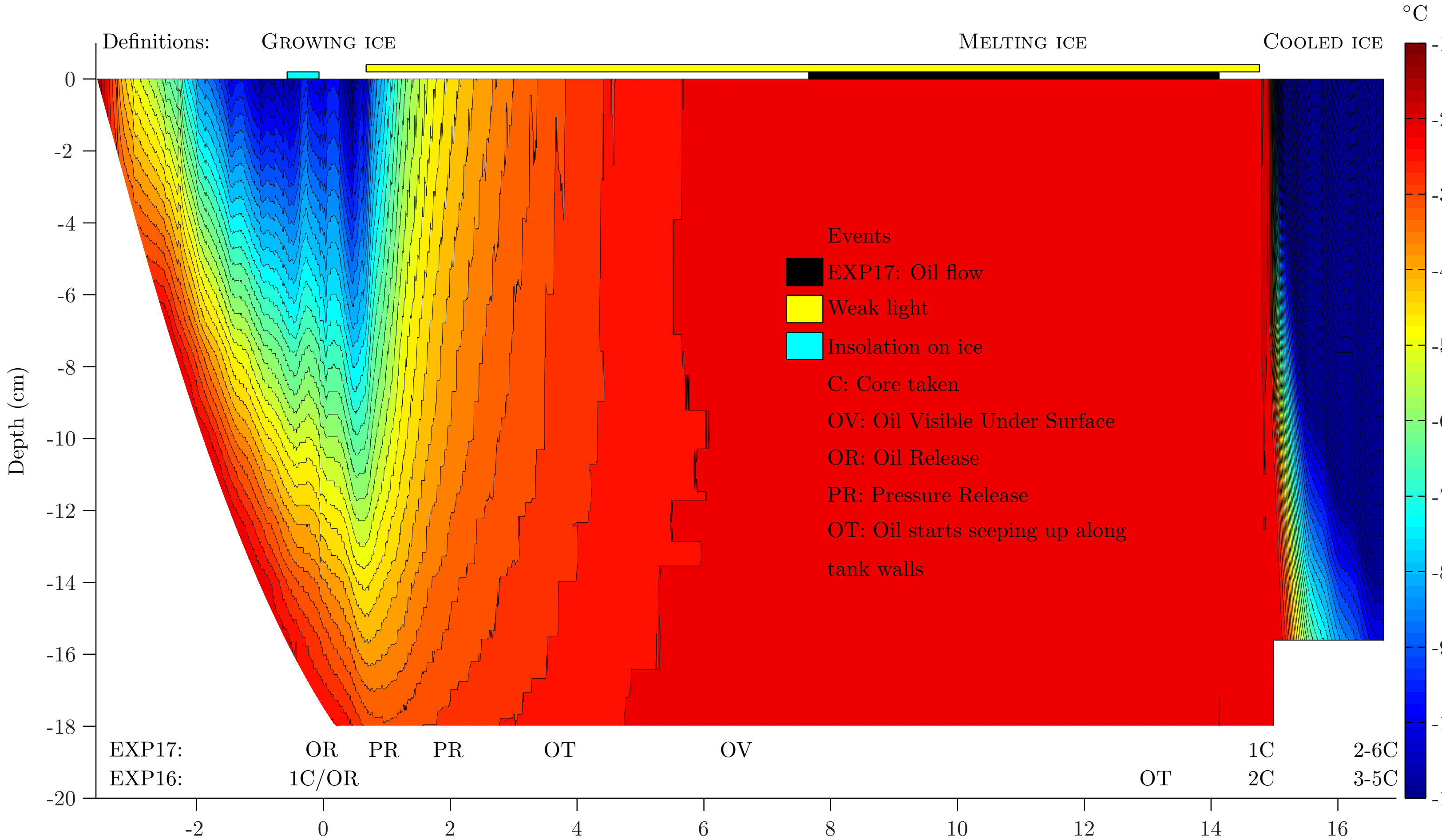


Figure 19: Events and ice temperature for EXP16 and EXP17 as a function of time (in days) from the oil release (OR). Note that white areas corresponds to missing temperature data or temperatures outside the ice layer. Around day 15 the ice layer was cooled at an air temperature of $-30°C$ to enable coring without loss of oil.

Appendix C.2.14

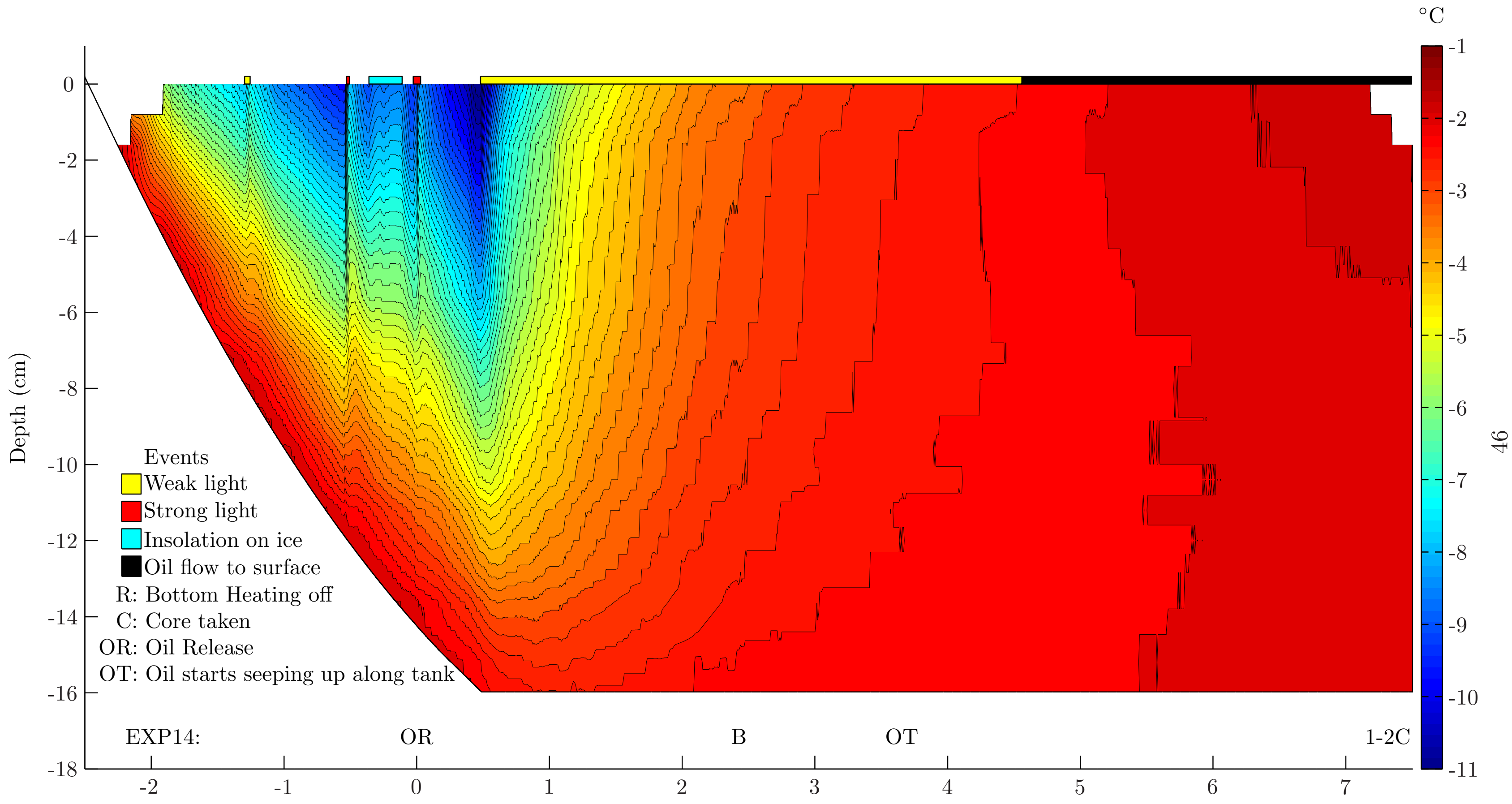


Figure 20: Events and ice temperature for EXP14 as a function of time (in days) from the oil release (OR). Note that white areas corresponds to missing temperature data or temperatures outside the ice layer.

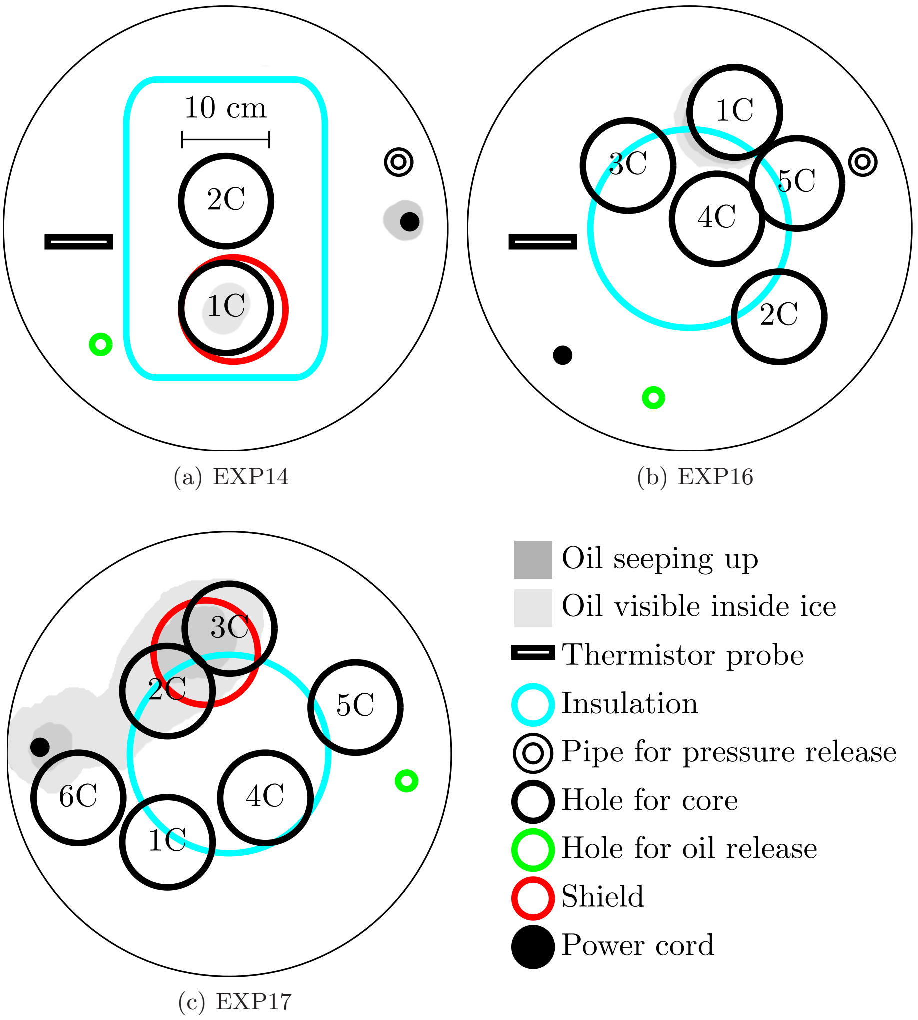
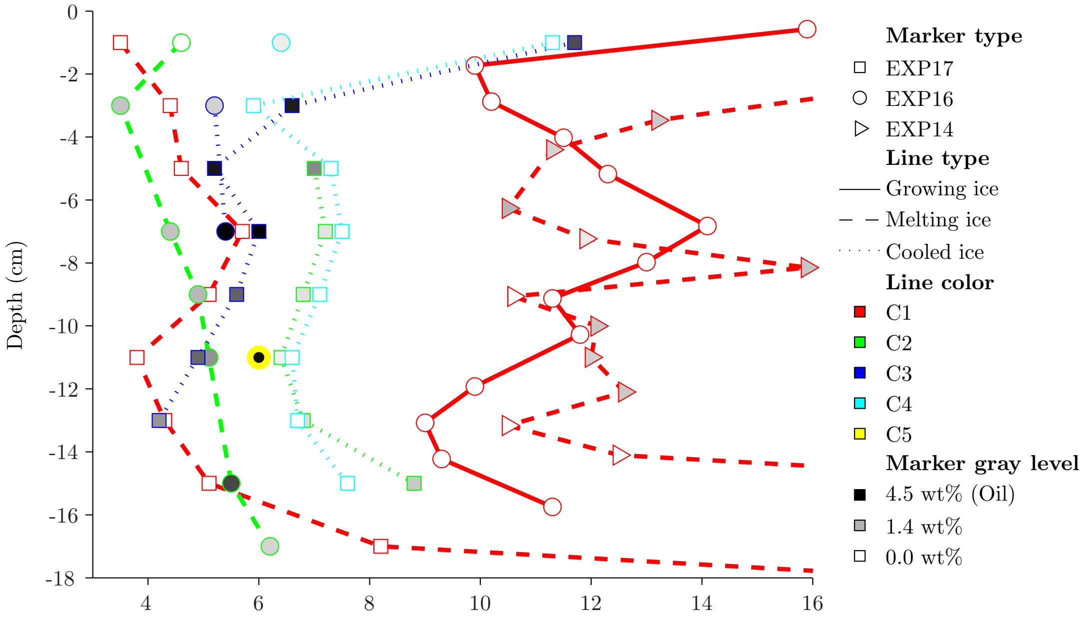
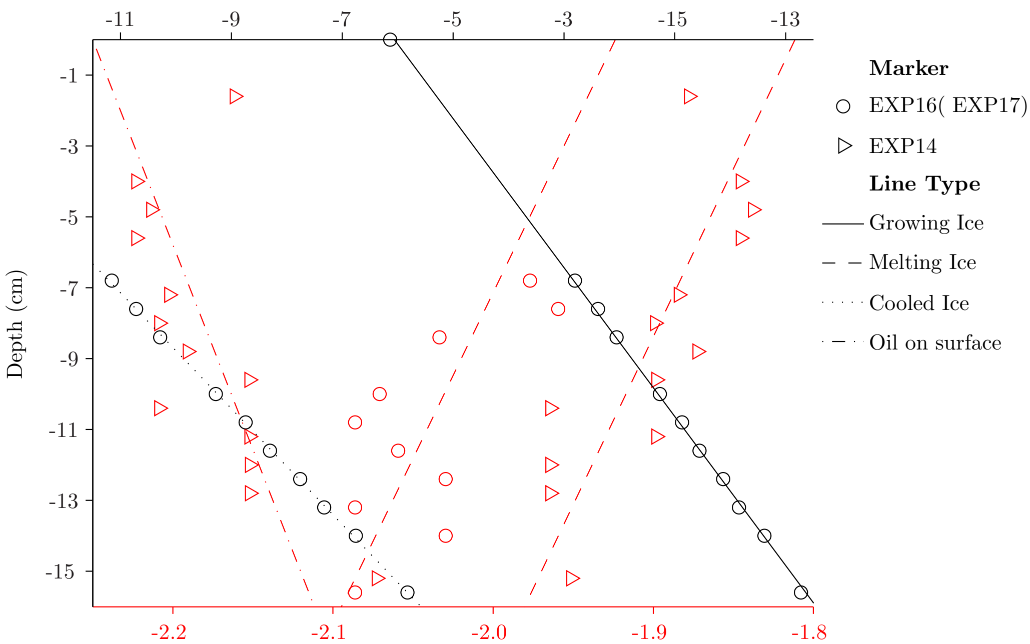


Figure 21: Overview of cores extracted in the melt season experiments. The visual oil entrainment is estimated from various photos and only indicated approximately on the illustrations. Note that the odd looking oil distribution in figure (b) is due to the impermeable freshwater core (replacing 1C) which only allow the oil to penetrate up along the sides. In figure (b) no oil is marked to be on the surface (inside the shield) since oil is only discharged from a single brine channel in this area

Appendix C.2.16



(a) Bulk salinity (‰)



(b) Temperature (°C)

Appendix C.2.15 & C.2.14

Figure 22: Profiles for melt season experiments

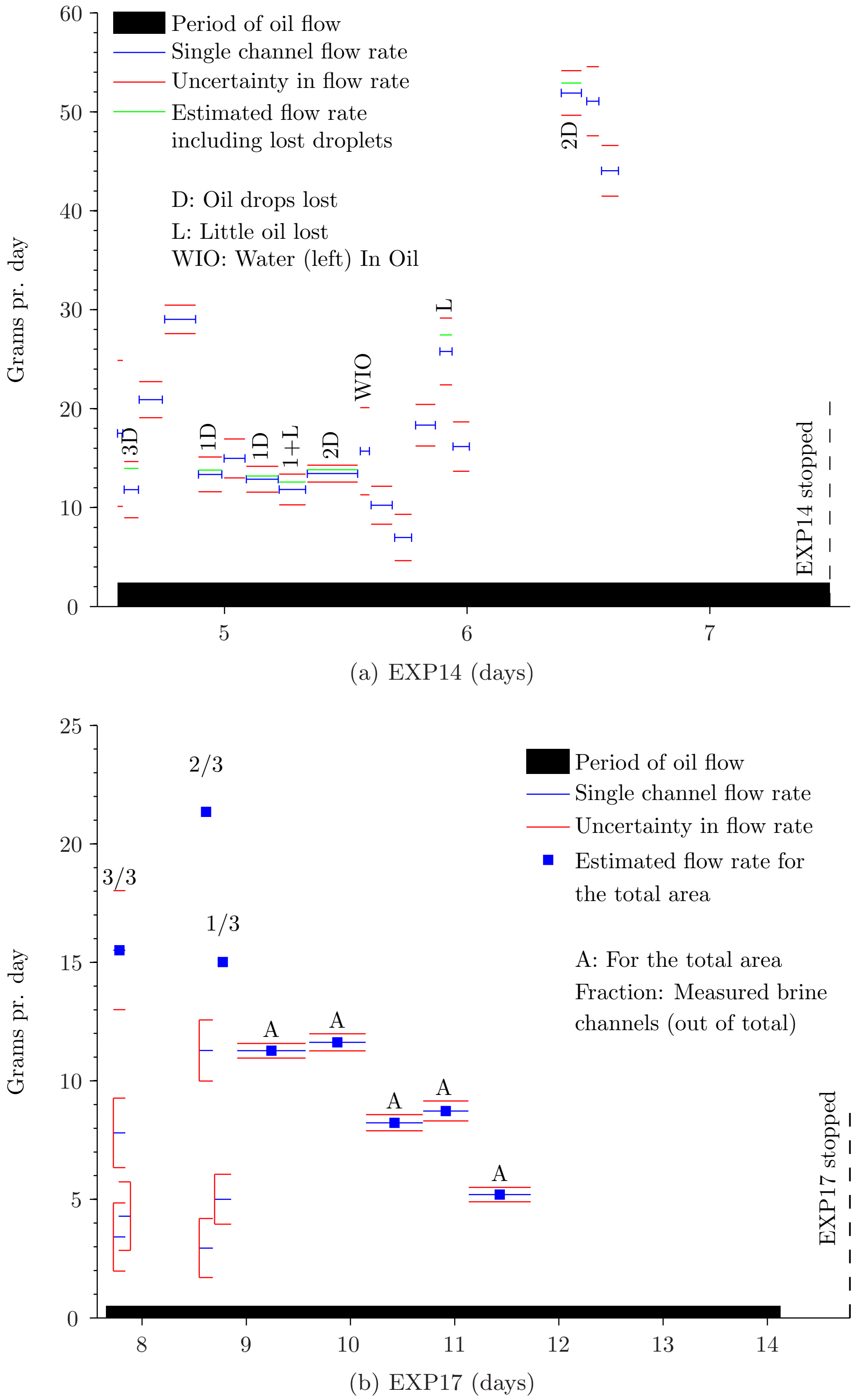


Figure 23: Oil discharge from single brine channels measured in days from the oil release. Only one brine channel was leaking oil in EXP14.

Appendix C.2.14 & C.2.15

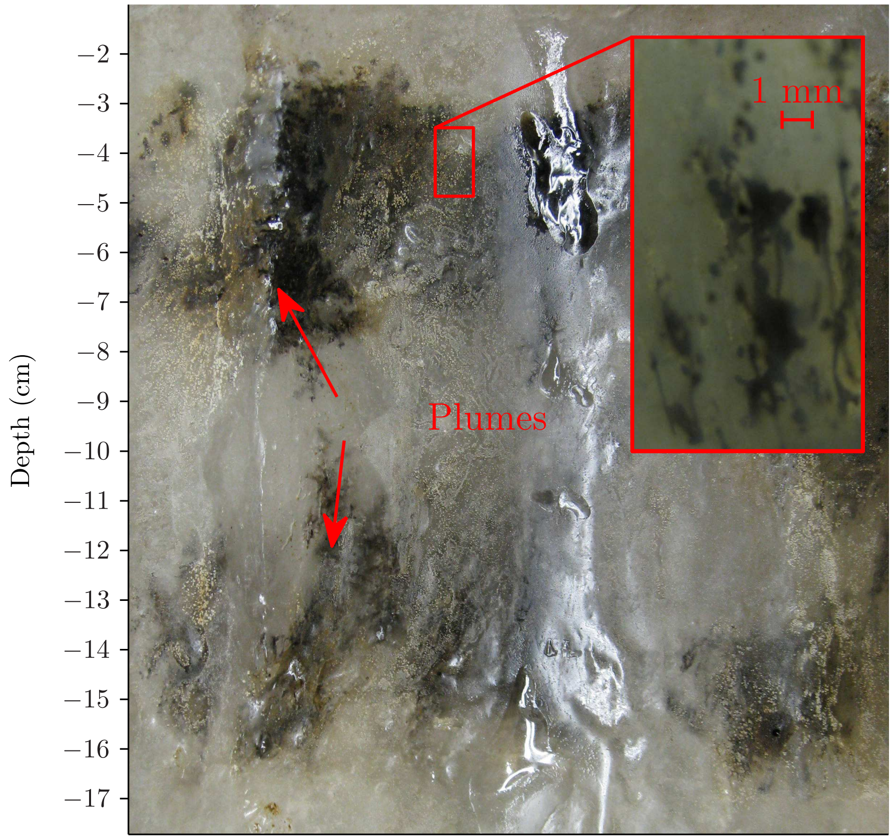


Figure 24: Photo of remaining Cooled ice for EXP17 (after all cores were extracted). As the layer from 0 to −1 cm correspond to refrozen melt water, the dark plumes of oil suggest that the overall oil concentration is highest at the top and bottom of the ice layer. This agrees with the limited observations that could be made from the ice surface before the re-cooling. In that moment the contaminated ice appeared to be only a few millimeters below the ice surface (as seen from above). The small scale configuration of oil within the plumes is illustrated by a macro photo of the same vertical surface. (Although the scale is very precise for both photos, the position of this enlargement should only be taken as approximate.) According to the macro photo this could possibly be the evidence of a secondary flow through pore space as opposed to the channel flow through individual brine channels (for which oil discharge was measured). The width of oil contaminated pores is of the order 1 mm whereas the interconnecting channels or necks seems to be less than 0.1 mm. It should also be noted however that this ice was originally melting ice which has later been re-cooled to allow sampling.

Appendix C.2.14

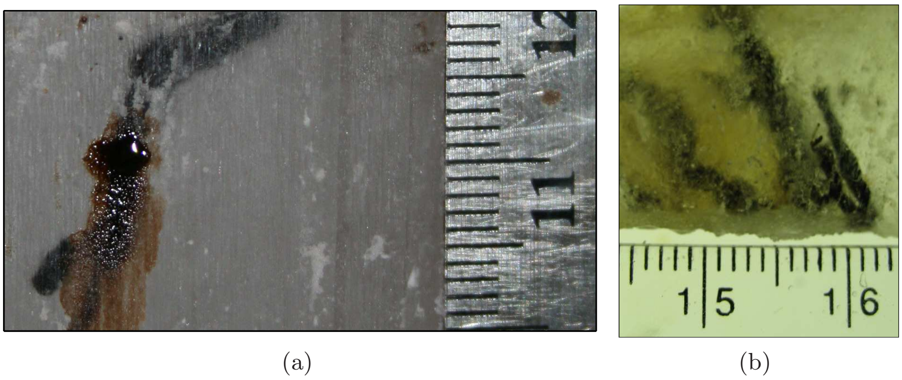


Figure 25: Macro photos of oil entrainment in brine channels. (a) shows a vertical channel of core 2C from EXP14 (depth -6 cm) stored at a temperature of $-40°C$. This core only contained a single (major) non-leaking brine channel with oil and there was no oil within the surrounding pore space. (b) shows a macro photo of COOLED ICE from EXP17. The photos are taken after the ice had been warmed to a temperature of approximately $-2°C$. However it is unclear to what extent (re-)warming influences the small-scale oil configuration; hence as the pore volume increases (and interconnects) interfacial forces could possible lead to a retreat of oil from smaller pores. Appendix C.2.17

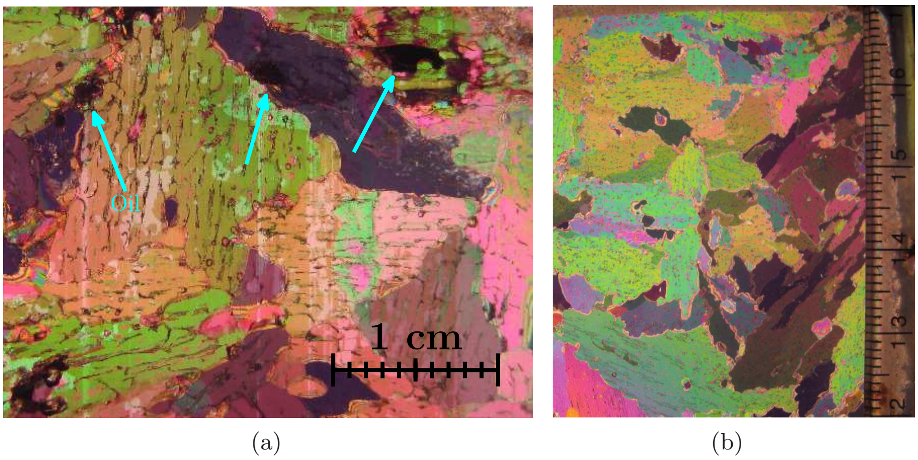


Figure 26: Horizontal thin sections viewed through crossed polarizers under a diffuse light source at a temperature of $-20°C$. The crystal size is ranging from a few mm up to around 3 cm. The small parallel impurities of spacing around 1 mm are brine inclusions. As seen the configuration is essentially unchanged from what was laid down in the skeletal layer. (a) is core 2C from EXP14 in a depth of 11 cm (tank 2). The dark areas are a result of brine channels contaminated by oil. (Here the right channel is the major channel going almost through the whole ice layer.) (b) shows a similar thin section for EXP18 (tank 1) which was taken at a depth of -6 cm. According to the above (and similar) thin sections it seems there is no significant difference in crystal size of ice grown in tank 1 and tank 2. Appendix C.2.17

8 Discussion

8.1 Growth season experiments

oil lens thickness

A rough estimate of capillary pressure in brine channels (section 5.3) suggests that an oil lens needs to exceed a certain thickness before upward oil movement occurs. For a relatively large brine channel of 2 mm diameter, this threshold corresponds to an oil lens thickness of approximately 3 cm.

For the laboratory experiments however, oil lens thickness probably remained less than 1.5 cm. Nevertheless upward oil movement was observed in all experiments.

As discussed in section 4.5 freezing of sea ice is not only a thermodynamic process; also a lot of fluid dynamics is involved in the solidification (Worster, 1997). The dense brine that leaves the ice through brine convection is to a large extent replaced by brine flowing back into the ice. Hence if the convective overturning is strong enough to break through the oil lens, dense brine will be replaced by oil instead of seawater. This mechanism might be able to explain why oil moves up through brine channels and pores thinner than 2 mm diameter.

oil concentration

It is striking that the oil mass fraction for the different growth season experiments varies with more than one order of magnitude. This could indicate that entrainment of oil is very sensible to some of the boundary conditions for the experiments. The relevance of different parameters is discussed in section 8.1.2 and section 8.1.3.

Both EXP2 and EXP13 had much higher oil concentrations than rest of the experiments. As discussed in section 6.2, EXP2 must have been significantly supercooled; here ice platelets from the water coloumn attached to the ice bottom during growth. Also the bottommost temperature for EXP13 (see figure 16(b)) is below the predicted freezing point; this is not the case for rest of the experiments. Hence supercooling of the water coloumn might explain the high oil concentrations; EXP2 showed that this can result in a different structure of the skeletal layer. However, there is also strong arguments against this.

supercooling

For the conductivity measurements to work, the sensor must be free of ice crystals. If the water is supercooled, this is an unlikely condition. Salinity measurements did work throughout EXP13.

A couple of times during the melt season experiments the automated salinity measurements suddenly failed[35]. However after warming and re-installing the probe, it returned to normal for a while. As the probe was hanging next to the tank wall and bottom, those steps in the salinity reading were intrepreted as ice nucleation on the sensor. Meanwhile both water temperatures and ice crystal structure (see figure 26) do not indicate supercooling of the water coloumn. Hence if the water is slightly below the freezing point, this should be apparent from the salinity readings.

Unfortunately bottom temperature in EXP13 was not measured by the salinity probe itself (as the only experiment). This was measured by the bottommost thermistor. Hence one could suspect that the derived freezing point might be slightly off. However it appears that the ocean heat flux in EXP13 must have been less than in rest of the experiments; even if the water coloumn was not supercooled.

[35]Here the reading increased by several salinity units

8.1.1 Volume replacement of oil and brine

According to figure 16(a) all experiments reproduced the characteristic salinity profiles described by Malmgren (1927)(see figure 5). Comparison of the bulk salinity for the OI and NOI sections suggest that the oil infiltrated ice generally contains less brine; this is expected as the entrained oil must have replaced a similar volume of brine[36]. However as seen in figure 17 such a replacement is not enough to fully explain the difference in brine volume fractions. Hence a couple of other considerations might be important as well. The brine volume fraction of the NOI and OI sections can be slightly different even before the oil release; and maybe more important, it is likely that the succeeding desalination of NOI and OI sections is very different when the oil has first infiltrated the ice. According to the profiles in figure 16(a) there is a rapid decrease of bulk salinity only a few centimeters above the ice water interface. With a growth rate of around 1/4 cm pr. hour this also corresponds to a rapid change with time. salinity profiles

As seen in table 4 the highest oil volume fractions were obtained for the synthetic oil. This is surprising because this oil had the highest viscosity; i.e. there might be another property of the oil which is more important for the oil movement. As discussed in section 5.3 this is likely to be the interfacial tension.

8.1.2 Parametrization of the oil concentration

Potentially the concentration of oil in a sample is sensitive to all of the parameters which were measured and varied during the course of the experiments. However if the oil concentration could be parametrized only by the properties of the sample (prior to the oil release), this would simplify the situation considerable.

As temperature and bulk salinity are the two state variables for sea ice, it is tempting to assume that the oil volume fraction (OVF) for a sample, only depends on these parameters. Among the oil properties temperature dependence was only measured for the viscosity (v). Meanwhile the two oils with different viscosities (around 10 cP and 300 cP) both remained within a 1-3 °C temperature range ($T_f \geq T >> T_p$) of the ice layer (figure 16(b)). As seen in figure 7 the expected variations in viscosity for oil at those temperatures would be significantly less[37]. Based on that, the oil volume fraction should only depend on temperature through the ice properties. bulk salinity temperature viscosity

With this simplification it might be possible to parametrize the oil volume fraction as OVF($\phi(T, S_{si})$), since porosity (ϕ) and fluid permeability ($k(\phi)$) are the material properties which are linked to the fluid flow through sea ice. porosity

According to equation (4.1.4) the derivatives of the porosity (at OR) satisfy $\frac{\partial\phi}{\partial \mathrm{T}} \leq \frac{\partial\phi}{\partial \mathrm{S_{si}}}$ in units of $°\mathrm{C}^{-1}$ and ‰$^{-1}$. Furthermore due to the characteristic c-shaped salinity profile of (the laboratory grown) sea ice (see figure 5) $\frac{\partial S_{si}}{\partial z}$ is numerically 3-4 times larger than $\frac{\partial T}{\partial z}$ near the ice water interface. For an experimental viewpoint, this suggest that the porosity near the OI layer must be varied through the bulk salinity rather than the temperature[38].

[36]Unless it has melted up through the solid ice.

[37]According to table 4 the OVF are even found to be higher for experiments with the most viscous oil.

[38]Furthermore, as the temperature gradient is almost linear through the ice layer, the surface temperature has to be varied 30 °C to obtain 3 °C temperature change of the OI layer (the

Few data points exist as the oil was confined to only one sample for each growth season experiment; so the relationship between ϕ and OVF can hardly be tested. Both the oil volume fraction and porosity (prior to oil release) are available for EXP21 and EXP20 (see figure 17); unfortunately those experiments used different oils. However oil was not entrained in ice of lower porosities than 15 % in any of the growth season experiments (see the + sections). Hence oil movement might be constrained to porosities above this threshold.

8.1.3 Adjustable boundary conditions

In addition to the oil properties four boundary conditions or external parameters can be adjusted in the growth season experiments. Those are air temperature, bottom heating, release time and oil lens thickness.

release time

As the salinity profile changes with ice thickness, different release times might give slightly different bulk salinities (and porosities) of the bottommost ice. However with the current setup the possible thickness variations are rather limited.

air temperature

Nakawo et al. (1984) report of a growth velocity dependence of the lamellar spacing (see section 4.3) - something that could be varied directly through the air temperature. As suggested by the field study a measurable increase of the lamellar spacing would probably require a significant increase of air temperature. This is unfortunately prevented by the bottom heating which has to be even more homogeneous for lower growth velocities (and hence lower heat fluxes)[39].

ocean heat flux

Likewise also the ocean heat flux (adjusted through bottom heating) is likely to impact the structure of the skeletal layer. This boundary condition is not only hard to adjust, it is also hard to quantify.

oil lens thickness

As suggested in section 5.3 also the oil lens thickness and hence buoyancy is likely to impact the upward oil movement. This boundary condition or parameter will be easy to vary in future oil spill experiments.

8.2 Melt season experiments

salinity profiles

The salinity profiles EXP16 C1 and EXP14 C1 (figure 22) do not have the characteristic c-shape of growing sea ice. However as suggested by figure 26 the crystal size (and brine layer spacing) are similar to ice from the growth season experiments. Hence the unexpected salinity profiles most likely relate to the short period of ice growth suppression described in section 6.6. This is less important as the sea ice micro-structure still should be representative for natural sea ice.

oil plumes

According to the salinity profiles shown in figure 22 the ice layer from -11 cm to -8 cm (roughly), is more porous than the surrounding ice. Figure 24 shows that the oil plumes are located either above or below this layer. This can be explained by faster oil transport through the porous ice in the middle.

For nearly all cores the oil concentration (for OI ice) is around 1.5 wt% (figure 22). This is low compared to the growth season experiments where the oil concentration varied between 1.1 wt % and 10.2 %. Moreover the oil is no longer

thickness of the OI layer is typically 10-20% of the total ice thickness).

[39] At a test where ice was grown at an air temperature of $-10°C$ in tank 1 the local variations of ice thickness was significantly amplified (as compared to ice growth at an air temperature of $-20°C$).

fixed in the bottom of the ice layer. This suggests that the porosity is above the threshold of 15 % discussed in section 8.1.2.

When the first oil was discharged to the surface in EXP14, also the first oil plume became visible below the ice surface. According to figure 22 this was at an ice temperature of around −2.1 °C and a salinity of around 6-8 ‰ (extrapolated from EXP17). Hence the porosity has most likely been 14-19 % at that time. In comparison, the porosity was between 30 % and 45 % when the experiment was terminated (see figure 18). porosity

In EXP16 the synthetic oil never surfaced. Meanwhile the measured oil concentration is nearly the same as in EXP14 and EXP17. The most obvious reason appears to be the higher viscosity.

8.2.1 Oil transport through pore space

Release of oil to the ice surface appears to be governed by both comparatively fast transport through brine channels and comparatively slow percolation in the fine-scale pore network. This hypothesis seems to agree with the few existing field observation of oil movement in sea ice.

Martin (1979) studied the fate of an experimental oil spill under landfast sea ice (of 1.5-2 m thickness) at the Cape Parry peninsula, Canada; here oil was released below the ice in February and April 1975. By mid May, an inspection of the spill sites showed that oil was both entrained in the ice and present at the ice surface (below the snow). In end of May a new inspection showed that melt ponds had formed below the oil slicks on the ice surface. Moreover it is described that the thickness of oil slicks increases from the continuing upward migration of oil through the ice. Allthough the flow rates were not quantified, it appears that oil must have been released to the surface over a period of at least two weeks. This might be explained by a delayed surfacing of oil transported through the fine-scale pore space.

8.2.2 Oil transport through brine channels

Laminar flow in a pipe (of constant circular cross-section) is given by the Poiseuille equation:

$$\Delta P = \frac{128\mu L Q}{\pi d^4} \tag{8.2.1}$$

where μ is the viscosity, L is the pipe length, d is the pipe diameter, ΔP is the pressure drop and Q is the volumetric flow rate. For a vertical brine channel, L correspond to the distance between oil lens and ice surface, and the pressure drop is given by $\Delta P = (\rho_w - \rho_o)gL$ where ρ_w is the density of seawater. Hence the brine channel diameter can now be estimated as:

$$d = \sqrt[4]{\frac{128\mu Q}{\pi(\rho_w - \rho_o)g}} \tag{8.2.2}$$

using the crude oil viscosity and density from table 1 and a volumetric flow rate corresponding to 20 g/day (see figure 23), d becomes 1.6 mm. This value agrees with the observed brine channel diameters (see figure 25) for EXP14. However as Q is proportional to the fourth power of d, the estimated brine channel diameter remains nearly constant allthough the flow rate is changing significantly.

Field studies by Lake and Lewis (1970) showed that the brine channel density in sea ice is of the order 10^2 m^{-2}. Hence for an oil lens of equilibrium thickness around 1 cm it would take roughly 4 days for all oil to surface. However several factors make this estimate uncertain. Among those are the brine channel diameter which may vary significantly and the effect of solar radiation (on entrained oil) which is still unknown.
Also if the brine channels drain oil from the pore space rather than an oil lens this would change the rate and duration of released oil.

9 Issues and future work

Several conditions complicate the sampling of oil in growing sea ice. When released beneath an ice layer, oil spreads unevenly unless the amount of oil is significantly increased. Combined with local inhomogenity in ice properties this causes spatial variations in the upward oil movement. Although the sampled ice was chosen consistently (see section 6.9.1) local variations within an experiment cannot be eliminated completely.

local inhomogenity

vertical resolution

The vertical resolution of sampled ice is too low to resolve the layer of oil infiltrated ice - this layer is confined to only one sample. As a result, also the measured oil concentration is sensible to the delineation of the oil-infiltrated layer.
Temperature and salinity profiles have similar shapes, also for thicker layers of growing ice; suggesting both $\frac{\partial T}{\partial z}$ and $\frac{\partial S_{si}}{\partial z}$ to be numerically less. As a result, the thickness of oil-infiltrated ice could possible increase with ice thickness.

porosity

With regards to porosity, the growth and melt season experiments suffer from two different issues. In the growth season experiments the expected porosity threshold is located very close to the bottom of the ice layer. In the melt season experiments, the whole ice layer was above this threshold. If air temperature was increased to -5 °C rather than -1 °C, it would be possible to narrow down the range of critical porosities.

destructive measurements

Most measurements are destructive as they require the ice to be melted or removed from the experiment. In addition to that, several parameters are of potential importance for the oil movement. This makes it very time consuming to obtain sufficient data. However by ultilizing several copies of the same setup more experiments could be run simultaniously. For melt-season experiments time series of the upward oil transport could be obtained by terminating each experiment at different times. For growth season experiments, one boundary condition could be varied while keeping the other constant.

solar radiation

The melt season experiments do not reflect the natural light conditions during Arctic spring. Solar radiation absorbed by the entrained oil could possible lead to upward melting of oil through the solid ice. This would be one additional transport mode.

10 Summary and conclusion

Sea ice differs fundamentally from ordinary ice as two phases, liquid brine and solid ice, are present even far below the freezing point of sea water. The brine phase is contained in a fine-scale network of pores connected to larger drainage features consisting of brine channels. Both the pores and brine channels provide space for entrainment of oil. To account for oil as a third component of sea ice, new equations have been developed for the volume fraction of each component; those suggest that all volume fractions can be determined from measurements of temperature, salinity and oil mass.
The growth and melt of natural occuring sea ice were simulated in two laboratory settings. This allowed studies of oil entrainment and transport under different boundary conditions. Conclusions on the experimental approach are summarized in the end of the section.
The growth of sea ice leads to entrainment of oil lenses within the ice. As long as the ice is growing, those lenses remain relatively fixed near the ice bottom. Experiments showed that oil could move 1.4 to 3.4 cm up through the porous ice above an oil lens. For this ice 1/4 to 2/3 of the pore space was occupied by oil. Small changes in boundary conditions for the ice resulted in oil concentrations between 1.1 wt% to 10.2 wt%. Hence oil entrainment in the bottom ice (the so-called skeletal layer) must be very sensitive to at least one boundary condition. Two boundary conditions (or external parameters) are identified as potentially important. Those are the ocean heat flux (adjusted through the bottom heating) and the oil lens buoyancy (adjusted through the oil lens thickness). The oil lens buoyancy can be easily adjusted in future oil spill experiments. The ocean heat flux is both hard to adjust and quantify.
During the spring warming increased temperatures allow oil to be transported up through the sea ice. Release of oil to the ice surface appears to be governed by both comparatively fast transport through brine channels and comparatively slow percolation in the fine-scale pore network.
The predominant path for transport to the surface was brine channels of diameters 1-2 mm; this accounted for volume fluxes of the order 10^{-9}m/s (for the whole ice surface). Oil permeation through pore space could not be quantified, however the surfacing of this oil was significantly delayed; oil appeared to move upwards through channels and necks of less than 0.1 mm connected to pores of 1 mm width.
It was hypothesized that porosity is the most important parameter for oil movement in sea ice. Sea ice is effectively impermeable for porosities below 5 %. However oil movement in sea ice appears to be constrained to porosities above 15 %. In the melt season experiments the sea ice reached porosities of up to 45 %.

Experimental setup

To reproduce natural occurring sea ice, ice growth must be confined to the ice bottom rather than the water column. This was achieved by carefully heating the tank bottom by approximately 30-40 watt/m^2 from beneath. To obtain the desired oil lens formation, the bottom heating furthermore had to be very homogeneous.
In a laboratory setting, volume expansion of freezing seawater might lead to

unnatural ice crystal growth and possibly flush oil and brine up through the sea ice. To prevent this, systems for pressure relief were installed in the melt season experiments.
Oil leakage, air bubbles, and freezing of injection pipes were the major issues related to the oil release. The best way to release oil proved to be a 4 cm u-shaped pipe inserted through a hole in the ice layer.
Both oil seeping, and heat conduction through the thermistor probe made temperature measurements difficult. The best solution turned out to be chains of silicon coated thermistors encapsulated in a thin layer of freshwater ice.
As laboratory ice grows attached to the tank walls, oil and brine loss can be a major issue when a core is extracted. Loss from the ice layer was prevented by replacing the extracted core by one of similar shape. In melt season experiments loss from melting cores was prevented either by re-freezing the ice or sealing the core in a container prior to the removal. In growth season experiments loss from extracted ice was prevented by growing ice beneath the oil lenses and subsequently cooling the whole ice layer prior to removal.

References

AMAP. *Arctic Oil and Gas.* Arctic Monitoring and Assessment Programme (AMAP), P.O. Box 8100 Dep., N-0032 Oslo, Norway, 2007. ISBN 978-82-7971-048-6.

AMAP. *Impacts of a Warmin Arctic -Arctic Climate Impact Assessment.* Cambridge Univ. Pcress, New York. (Available at http://www. acia. uaf. edu), 2005.

AMAP. Arctic pollution issues: a state of the Arctic environment report, 1997.

A. Assur. Composition of sea ice and it's tensile strength. *SIPRE Res. Rep*, 44, 1960.

M. Atkinson and C. Bingman. Elemental composition of commercial seasalts. *J Aquariculture Aquat Sci*, 8:39–43, 1998.

J. Bear. *Dynamics of Fluids in Porous Media.* Courier Dover Publications, 1988.

Brookfield. *Brookfield Programmable Viscometer, Operating Instructions.* 11 Commerce Boulevard, Middleboro, MA 02346-1031 USA, 1997. URL `www.brookfieldengineering.com`.

J. W. M. Bush. *Surface Tension.* Department of Mathematics, Massachusetts Institute of Technology, Cambridge, MA, USA, 2004. URL `http://web.mit.edu/1.63/www/Lec-notes/Surfacetension/`.

Campbell Scientific. *CR10 Measurement and Control Module Operator's Manual.*, 1988.

Campbell Scientific. *AM16/32A Relay Multiplexer*, 2006.

G. F. N. Cox and W. F. Weeks. Equations for determining the gas and brine volumes in sea-ice samples. *Journal of Glaciology*, 29:306–316, 1983.

C. T. Crowe. *Multiphase flow handbook.* CRC Press, 2005.

H. Eicken. From the microscopic to the macroscopic to the regional scale: Growth, microstructure and properties of sea ice. In D. N. Thomas and G. S. Dieckmann, editors, *Sea Ice – An Introduction to its Physics, Biology, Chemsitry and Geology*, pages 22–81, London, 2003. Blackwells Scientific Ltd.

L. I. Eide and S. Martin. The formation of brine drainage features in young sea ice. *Journal of Glaciology*, 14(70):137–154, 1975.

L. Faksness and P. Brandvik. Distribution of water soluble compounds from Arctic marine oil spills A combined laboratory and field study. *Cold Regions Science and Technology*, 54(2):97–105, 2008.

L.-G. Faksness. *Weathering of oil under Arctic conditions.* PhD thesis, University of Bergen,The University in Svalbard, 2007.

M. Fingas and B. Hollebone. Review of behaviour of oil in freezing environments. *Marine Pollution Bulletin*, 47(9-12):333–340, 2003.

K. Golden, H. Eicken, A. Heaton, J. Miner, D. Pringle, and J. Zhu. Thermal evolution of permeability and microstructure in sea ice. *Geophysical Research Letters*, 34(16):16501, 2007.

M. Holland, C. Bitz, and B. Tremblay. Future abrupt reductions in the summer Arctic sea ice. *Geophysical Research Letters*, 33:L23503, 2006.

IUCN and E&P forum. *Oil and Gas Exploration and Production in Arctic and Subarctic Onshore Regions: Guidelines For Environmental Protection*. World Conservation Union, 1993. ISBN 2831701880.

Julabo. *Operating Manual, Refrigerated and Heating Circulators*. Labortechnik GmbH, 77960 Seelbach / Germany, 2006. URL `www.julabo.de`.

J. Karlsson, C. Petrich, and H. Eicken. Poster contribution: Laboratory experiments of entrapment and small-scale movement of oil in sea ice. INRA IPY Symposium "Lessons from Continuity and Change", the Fourth International Polar Year, Fairbanks, AK, March 2009.

J. Knauss. *Introduction to physical oceanography*. Waveland Press, 2 edition, 2000. ISBN 0-13-23-8155-9.

A. Konno and K. Izumiyama. Theory and modelling of the interfacial tension force on the oil spreading under ice covers. In *Proceedings of the 16th IAHR International Symposium on Ice, Dunedin, New Zealand*, pages 185–192, 2002.

K. Koo, R. Ananth, and W. Gill. Tip splitting in dendritic growth of ice crystals. *Physical review. A*, 44(6):3782–3790, 1991.

R. Lake and E. Lewis. Salt Rejection by Sea Ice during Growth. *Journal of Geophysical Research*, 75(3):583–597, 1970.

M. Leppäranta. A Review of Analytical Models of Sea-Ice Growth. *Atmosphere-Ocean*, 31(1), 1993.

F. Malmgren. On the properties of sea-ice: Norwegian North Polar Expedition with the MAUD, 1918-1925, Sci, 1927.

S. Martin. A field study of brine drainage and oil entrainment in first-year sea ice. *J. Glaciol*, 22(88):473–502, 1979.

G. Maykut. The surface heat and mass balance. *The Geophysics of Sea Ice*, 146:395–463, 1986.

I. Melnikov. *The Arctic Sea Ice Ecosystem*. CRC Press, 1997.

W. Menke. *Geophysical Data Analysis: Discrete Inverse Theory*. Academic Press, 1989.

M. Müller-Stoffels. Preferred Crystal Orientations in Freshwater Ice: A Thesis Submitted for the Degree of Master of Science at the University of Otago, Dunedin, New Zealand. Master's thesis, University of Otago, 2006.

M. Nakawo, N. Sinha, N. R. C. Canada, and D. of Building Research. *A Note on Brine Layer Spacing of First-year Sea Ice*. National Research Council Canada, Division of Building Research, 1984.

NERI. *Strategic Environmental Impact Assessment of hydrocarbon activities in the Disko West area*, 2007.

S. Nghiem, I. Rigor, D. Perovich, P. Clemente-Colon, J. Weatherly, and G. Neumann. Rapid reduction of Arctic perennial sea ice. *Geophysical Research Letters*, 34(19), 2007. doi: 10.1029/2007GL031138.

N. Otsuka, H. Kondo, and H. Saeki. Experimental study on the characteristics of oil ice sandwich. *OCEANS'04. MTS/IEEE TECHNO-OCEAN'04*, 3, 2004.

J. Payne, G. McNABB, and J. Clayton. Oil-weathering behavior in Arctic environments. *Polar Research*, 10(2):631–662, 1991.

C. Petrich, H. Eicken, J. Karlsson, and W. Blanchard. Oil, microstructure and brine flux: Entrainment and migration of contaminants in sea ice. INRA IPY Symposium "Lessons from Continuity and Change", the Fourth International Polar Year, Fairbanks, AK,, March 2009.

M. Reed, Ø. Johansen, P. Brandvik, P. Daling, A. Lewis, R. Fiocco, D. Mackay, and R. Prentki. Oil spill modeling towards the close of the 20th century: overview of the state of the art. *Spill Science and Technology Bulletin*, 5(1): 3–16, 1999.

K. Riley, M. Hobson, S. Bence, and D. Spector. *Mathematical Methods for Physics and Engineering*. Chambridge University Press, 2 edition, 2002.

S. Sawhill and W. Østreng. 5th Report for the Norwegian Atlantic Committee: Oil and Gas. *Focus North*, 2006.

J. Skolnik and C. Holleyman. Modeling the economic impacts of offshore activities in the Alaska Arctic. *IAEE Newsletter*, pages 16–23, 2002.

A. Stalder, G. Kulik, D. Sage, L. Barbieri, and P. Hoffmann. A snake-based approach to accurate determination of both contact points and contact angles. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, 286(1-3): 92–103, 2006. URL `http://bigwww.epfl.ch/demo/dropanalysis/`.

J. Stefan. Ueber die Theorie der Eisbildung, insbesondere über die Eisbildung im Polarmeere. *Annalen der Physik*, 278(2):269–286, 1890.

J. Steinhart and S. Hart. Calibration curves for thermistors. *Deep-Sea Res*, 15: 479–503, 1968.

J. Taylor. *An introduction to error analysis*. University Science Books Mill Valley, Calif, 1997.

UNESCO. Eighth report of the joint panel on oceanographic tables and standards. *Unesco technical papers in marine science*, 28, 1978.

U.S. Geological Survey. *Assessment of Undiscovered Oil and Gas Resources of the East Greenland Rift Basins Province*, 2007. URL `http://pubs.usgs.gov/fs/2007/3077/pdf/FS07-3077_508.pdf`.

W. Weeks and G. Weller. Offshore Oil in the Alaskan Arctic. *Science*, 225 (4660):371–378, 1984.

J. Wettlaufer, M. Worster, and H. Huppert. Natural convection during solidification of an alloy from above with application to the evolution of sea ice. *Journal of Fluid Mechanics*, 344:291–316, 1997.

J. Wilkinson, P. Wadhams, and N. Hughes. Modelling the spread of oil under fast sea ice using three-dimensional multibeam sonar data. *Geophysical Research Letters*, 34, 2007.

M. Worster. Convection in mushy layers. *Annual Review of Fluid Mechanics*, 29(1):91–122, 1997.

Yen, Y. C., Cheng, K. C., and Fukusako, S. Review of intrinsic thermophysical properties of snow, ice, sea ice, and frost. In J. P. Z. . S. L. Faussett, editor, *3rd International Symposium on Cold Regions Heat Transfer*, pages 187–218, Fairbanks, AK, 1967. University of Alaska, Fairbanks.

YSI. *YSI Model 30,YSI Model 30M Operations Manual*, 1998.

Appendices

A Tables

Table 6: Coefficients for functions F1(T) and F2(T) for different temperature intervals. Source: Eicken (2003)

T ($°C$)	$\mathbf{a_1}$	$\mathbf{b_1}$	$\mathbf{c_1}$	$\mathbf{d_1}$
$0 \geq T > -2$	-0.041221	-18.407	0.58402	0.21454
$-2 \geq T \geq -22.9$	-4.732	-22.45	-0.6397	-0.01074
$-22.9 > T \geq -30$	9899.1309	.55	27.0	7160.
	$\mathbf{a_2}$	$\mathbf{b_2}$	$\mathbf{c_2}$	$\mathbf{d_2}$
$0 \geq T > -2$	0.090312	-0.016111	$1.2291 \cdot 10^{-4}$	$1.3603 \cdot 10^{-4}$
$-2 \geq T \geq -22.9$	0.08903	-0.01763	$-5.330 \cdot 10^{-4}$	$-8.801 \cdot 10^{-6}$
$-22.9 > T \geq -30$	8.547	1.089	0.04518	$5.819 \cdot 10^{-4}$

B Poster contribution

Poster contribution for the symposium: "Lessons from Continuity and Change in the 4th IPY," University of Alaska Fairbanks, 4-7 March 2009; under the thematic session: Oil and Gas Development: Balancing Interests with Sustainability. URL: http://northernresearchnetwork.electrified.ca/?q=node/370

Laboratory experiments of entrapment and small-scale movement of oil in sea ice

Jonas Karlsson (1,2), Chris Petrich (1), Hajo Eicken (1)
(1) Geophysical Institute; University of Alaska Fairbanks; Fairbanks, AK
(2) University of Copenhagen, Copenhagen, Denmark

UNIVERSITY OF ALASKA FAIRBANKS

Motivation

Sea ice plays a major role in the context of potential Arctic oil spills, both as a hazard and through its interaction with oil and water-soluble contaminants. The temperature-dependent pore structure of sea ice allows oil both to be entrained during growth and slowly released during warming. We present preliminary results from laboratory experiments aimed to quantify the fixation process and upward oil migration in both growing and melting sea ice.

Method

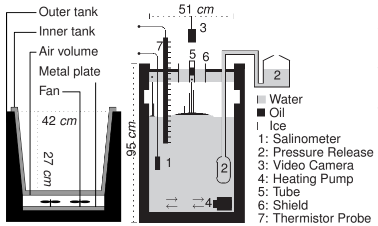


Figure: The tank used for growth season (left) and melt season (right) experiments.

Thread Cutting Oil) at slightly different temperatures were introduced below the sea ice layer which was solidifying (from above) in a coldroom of air temperature $-20^\circ C$. Subsequently as the oil lenses had been encapsulated by ice the growth season experiments were terminated to measure depth and oil content of the porous, oil infiltrated (OI) ice layer present above the lenses. For melt studies (denoted melt season experiments), air temperature was now increased gradually to around $-1^\circ C$. As the ice was fixed to the tank sides this also resulted in pond formation on top of the ice surface.

Artificial sea ice was grown from an aqueous solution of the synthetic sea salt *Instant Ocean*® using two different types of insulated vessels (seen above). At an ice thickness of 6-16 cm lenses of crude (North Slope Crude) or synthetic oil (Dark

Melt season experiments - Cooling history

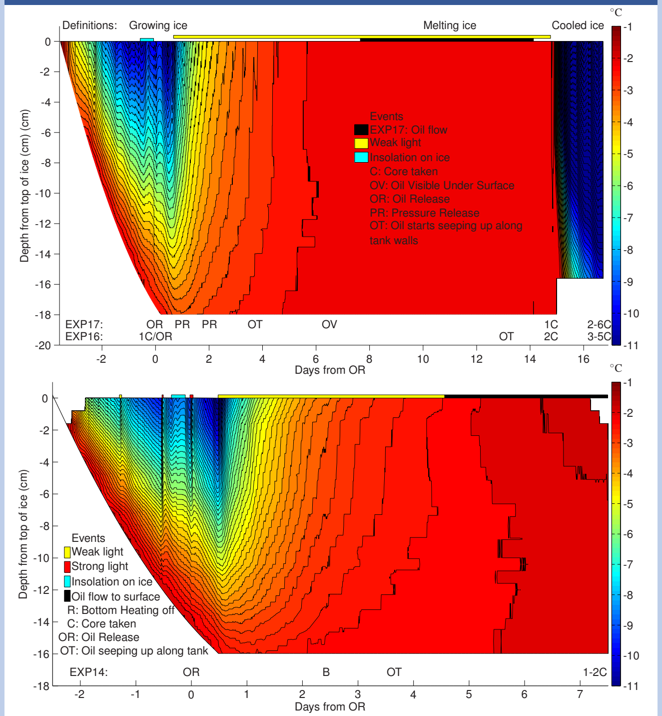


Figure: Events and ice temperature for melt season experiments as a function of time (in days) from the oil release (OR). Note that white areas correspond to missing temperature data or temperatures outside the ice layer.

Melt season experiments - Sampling

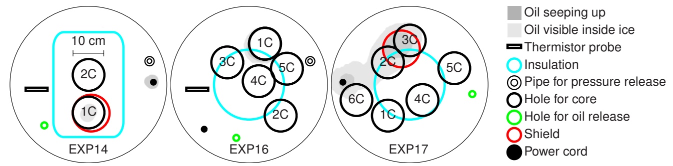


Figure: Overview of extracted cores (1C..NC) for each experiment. Oil was only released to the meltpond within the areas delineated by the shield. To prevent oil leakage along the tank sides, plates of insulating material were utilized to suppress the central ice growth in a period before the melt simulation.

Melt season experiments - Release rates of oil from individual brine channels

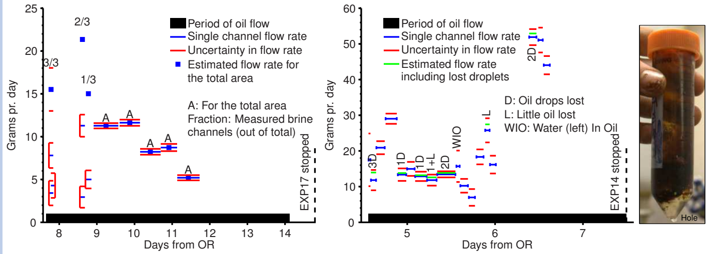


Figure: Oil discharge as a function of time (in days) from the oil release (OR). Tubes (seen to the right) in upside down position were placed (in the melt pond) on top of the oil leaking brine channels. By subsequently turning a tube upside up (with the opening blocked) water and accumulated ice oil could be seperated using a small hole in the bottom.

Melt season experiments - Profiles of temperature, bulk salinity and oil content

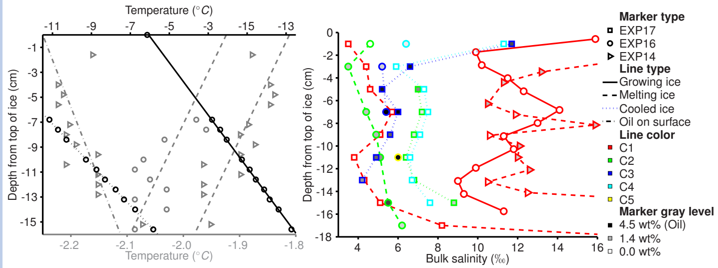
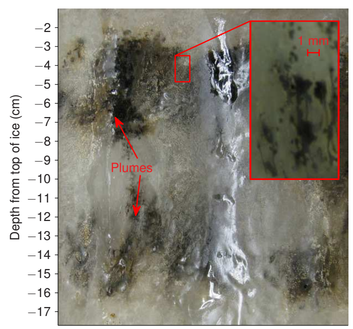


Figure: Temperature (°C) LEFT and bulk salinity (‰)/oil content (wt%) RIGHT. EXP16 and EXP17 were implemented instantaneously so temperatures sholud be nearly similar allthough no thermistor probe was installed in EXP16

Melt season experiments - Mode of transport



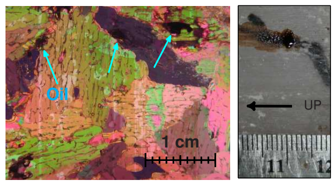


Figure: LEFT, cooled ice from EXP17; the dark plumes result from oil movement within (and hence transport through) pore space. RIGHT, examination of oil through brine channels (here core 2C from EXP14 in a depth of 11-12 cm): shown for (1) horizontal thin section viewed through crossed polarisers (2) vertical section along brine channel. Presumably the measured release rates result from oil transport through similar channels.

Growth season experiments - Cooling history and sampling

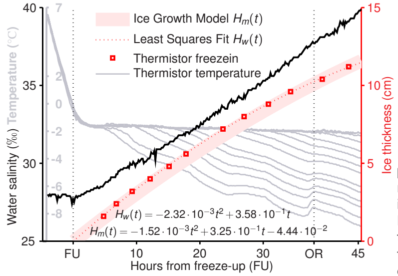


Figure: LEFT, typical progress of water salinity, ice temperatures and ice thickness for the growth season experiments. As a result of the shallow tank (27 cm) water salinity was increasing significantly with ice thickness. RIGHT, Bulk salinity (and oil content) was measured for ice sections delineated by as above. NOI is not oil infiltrated ice used for comparison. OR ice (not shown here) refers to samples extracted just before oil was released.

Growth season experiments - Profiles of temperature, bulk salinity and oil content

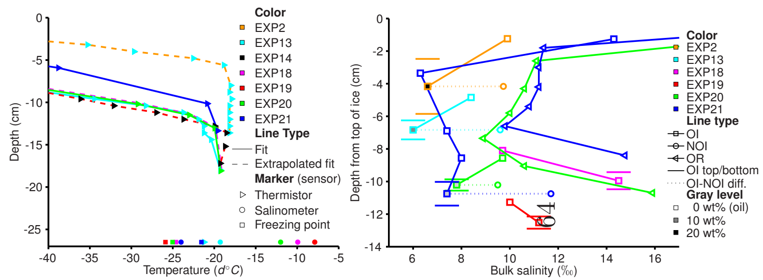


Figure: LEFT temperature (10^{-1}°C) profiles (for ice + water) and RIGHT bulk salinity (‰) profiles (for ice). Measured water temperature is compared to (salinity dependent) freezingpoint; here the differences most likely relates to the applied bottom heating which was varied between each experiment. The depth of the OI layers are indicated by solid horizontal lines. It seems that the salinity (and hence brine volume) reduction for OI sections (as compared to NOI) agrees with a volume replacement comparable to that of the measured oil amount

Summary of results and boundary conditions

	Growth season	EXP2	EXP13	EXP18	EXP19	EXP20	EXP21	
Oil	Type	Synth	Synth	Crude	Synth	Synth	Crude	
	Amount	50	50	400	380	340	310	(ml)
	Temperture	20	0.0	-1.5	4.6	2.2	2.7	(°C)
Water	Salinity		37.7	43.5	45.6	44.2	38.3	(‰)
	Temperature	PL	-1.9	-1.0	-0.8	-1.2	-2.4	(°C)
Ice	Thickness at OR	5.9	8.0	11.0	13.3	10.9	12.2	(cm)
	Salinity (NOI)	9.7	9.6	NM	NM	9.5	11.7	(‰)
OI layer	Depth	3.4	2.3	2.1	1.5	1.4	2.9	(cm)
	Salinity (OI)	6.6	6.0	14.5	11.2	7.8	7.4	
	OMF	21.5	10.2	1.2	1.1	3.6	4.6	(wt%)
	OVF		10.8			3.8	5.0	(vol%)

PL: platelet growth in the water; OMF: oil mass fraction; OVF: oil volume fraction

	Melt season	EXP14	EXP16	EXP17	
Oil	Type	crude	synt	crude	
	Amount	600	450	500	(ml)
	Temperture	-1.4	-1.6	-1.6	(°C)
Ice	Thickness at OR	14.2	17.5	17.4	(cm)
Water	Salinity FU	32.1	30.0	30.2	(‰)
	- OR	34.8	37.2	37.6	
Duration	Freezing	2.5	3.6	3.6	(days)
	Warming	7.5	14.8	14.8	
	Oil penetration	4.6	never	7.7	
Setup	Pressure Release	×	×	(manual)	
	Thermistor probe	×	×		
	Weak light on		×	×	

Conclusions

We observed $1.4-3.4\,\mathrm{cm}$ of upward oil migration in the pore space of growing ice layers. Comparison of ice porosity and oil concentration for experiments of various boundary conditions suggest that 1/3 to 2/3 of the pore space above an oil lens can be occupied by oil.

In melt studies we examined the mode and rate at which oil is transported through sea ice. The predominant path for oil percolating to the surface seemed to be discrete brine channels of diameters 1-2 mm; this accounts for volume fluxes of the order $10^{-6}\,\mathrm{kg\,m^{-2}\,s^{-1}}$ (for the whole ice surface). As oil was no longer released from the ice, 20% of the total ice volume remained contaminated with $1-4\,\mathrm{wt\%}$ of oil entrained in the pore space; here oil had invaded pores and necks down to a size of $10^{-4}\,\mathrm{m}$ (and possibly smaller).

Acknowledgements

This work was supported by a grant of the Oil Spill Recovery Institute (OSRI), Alaska.

Contact: Jonas Karlsson at e-mail minipost@gmail.com

C Code implementation

C.1 Physical calculations

C.1.1 Bulk density

```
function[rho_is]=bulkdensity(S,T);
%bulk density=bulkdensity(S,T)
rho_b=brinedensity(T);
rho_i=icedensity(T);

BIF=bif(S,T);

rho_is=BIF*rho_b+(1-BIF)*rho_i;
```

C.1.2 Brine density eq. (4.1.3)

```
function[rho_b]=brinedensity(t)
%brinedensity=brinedensity(temperature)
[I J]=size(t);
for j=1:J;
    for i=1:I
        rho_b(i,j)=1+(8*10^(-4))*brinesalinity(t(i,j));
    end;
end;
```

C.1.3 Ice density eq. (4.1.5)

```
function[icedensity]=icedensity(t)
[I J]=size(t);
for j=1:J
    for i=1:I
        icedensity(i,j)=0.917-(1.403*10^(-4))*t(i,j);
    end;
end;
```

C.1.4 Brine thermal conductivity

```
function[lambda_b]=brineconductivity(T);
[I J]=size(T);
for i=1:I
    for j=1:J
        lambda_b(i,j)=0.4184*(1.25+0.030*T + 0.00014*T^2);
    end;
end;
```

C.1.5 Bulk thermal conductivity eq. (4.6.5)

```
function[lambda_is]=bulkconductivity(S,T);
%bulk conductivity=bulkconductivity(S,T)
%[Maykut, 1986]
lambda_is=iceconductivity(T)+0.13*(S/T);
              T
```

C.1.6 Ice thermal conductivity eq. (4.6.6)

```
function[lambda_i]=iceconductivity(T);
[I J]=size(T);
for i=1:I
    for j=1:J
        lambda_i(i,j)=1.16*(1.91-8.66*10^(-3)*T(i,j)...
        +2.97*10^(-5)*T(i,j)^(2));
    end;
end;
```

C.1.7 Brine salinity eq. (4.1.3)

```
function[sb]=brinesalinity(t)
%brinesalinity=brinesalinity(temperature)

[I J]=size(t);
for i=1:I;
    for j=1:J;
        sb(i,j)=1000*(1-(54.11/t(i,j)))^-1;
    end;
end;
```

C.1.8 Volume fractions eq. (4.2.6)

```
function[vf]=ovf(m_ib,m_o,rho_i,rho_b,rho_o,BIF,ofwhat)

[I J]=size(m_ib);
    for i=1:I
        for j=1:J;

        m_b(i,j)=((rho_b(i,j)/rho_i(i,j))*m_ib(i,j))/...
            ((1/BIF(i,j))-1+(rho_b(i,j)/rho_i(i,j)));

        m_i(i,j)=m_ib(i,j)-m_b(i,j);

            if ofwhat=='o'

                vf(i,j)=(m_o(i,j)/rho_o)/((m_o(i,j)/rho_o)+...
```

```
                (m_i(i,j)/rho_i(i,j))+(m_b(i,j)/rho_b(i,j)));

            elseif ofwhat=='b'

                vf(i,j)=(m_b(i,j)/rho_b(i,j))/((m_o(i,j)/rho_o)...
                +(m_i(i,j)/rho_i(i,j))+(m_b(i,j)/rho_b(i,j)));

            elseif ofwhat=='i'

                vf(i,j)=(m_i(i,j)/rho_i(i,j))/((m_o(i,j)/rho_o)+...
                    (m_i(i,j)/rho_i(i,j))+(m_b(i,j)/rho_b(i,j)));
            end;
        end;
    end;
```

C.1.9 Brine ice volume fraction eq. (4.1.4)

```
function[p]=bif(s,t)

%BrineVolume/(IceVolume+brine volume)=bif(salinity,temperature)
        for i=1:length(s);

            if 0>=t(i) & t(i)>-2;

                a=[-0.041221 0.090312];
                b=[-18.407 -0.016111];
                c=[0.58402 1.2291*10^(-4)];
                d=[0.21454 1.3603*10^(-4)];

            elseif -2>=t(i) & t(i)>=-22.9;

                a=[-4.732 0.08903];
                b=[-22.45 -0.01763];
                c=[-0.6397 -5.330*10^(-4)];
                d=[-0.01074 -8.801*10^(-6)];

            elseif -22.9>t(i) & t(i)>=-30;

                a=[9899 8.547];
                b=[1309 1.089];
                c=[55.27 0.04518];
                d=[0.7160 5.819*10^(-4)];

            else

                a=[NaN NaN];
                b=[NaN NaN];
                c=[NaN NaN];
                d=[NaN NaN];
```

```

            end;

            P1=[d(1,1) c(1,1) b(1,1) a(1,1)];
            P2=[d(1,2) c(1,2) b(1,2) a(1,2)];

            F1=polyval(P1,t(i));
            F2=polyval(P2,t(i));
            %densit(i)y koeff
            di=[-1.403*10^(-4) 0.917];
            rho_ice=polyval(di,t(i));

            p(i,1)=(rho_ice*s(i))/(F1-rho_ice*s(i)*F2); %porosity
            if p(i,1)<0
               p(i,1)=NaN;
            end;
        end;
```

C.1.10 Latent heat (4.6.7)

```
function[L_si]=latentheat(S,T)
%latentheat(Salinity,Temperature) Calculates bulk Latent heat
  from temperature and salinity;
[I J]=size(T);

for i=1:I;
    for j=1:J;

        L_si(i,j)=4.187*(79.68-0.505*T(i,j)-0.0273*S(i,j)+...
        4.3115*(S(i,j)/T(i,j))+0.0008*S(i,j)*T(i,j)...
        -0.009*T(i,j)^2);

    end
end;
```

C.1.11 Freezing point

```
function[t0]=freezingpoint(sw)
%"freezingpoint"=freezingpoint(salinity)
%sw=[66;34;56]
[I J]=size(sw);
echo off

for i=1:I;
    for j=1:J;
        if ~isnan(sw(i,j))
            x(1,1)=-1;f(1,1)=brinesalinity(x(1,1))-sw(i,j);
            x(2,1)=-2;f(2,1)=brinesalinity(x(2,1))-sw(i,j);
```

```
            x_fit=fit(f,x,'linearinterp');
            x(3,1)=x_fit(0);f(3,1)=brinesalinity(x(3,1))-sw(i,j);

            while norm(f(3,1))>0.001
                [fnorm k]=max(norm(f));
                f(k,1)==[];
                x(k,1)==[];
                x_fit=fit(f,x,'linearinterp');
                x(3,1)=x_fit(0);
                f(3,1)=brinesalinity(x(3,1))-sw(i,j);
            end;

            t0(i,j)=x(3,1);
        else;
            t0(i,j)=NaN
        end;
    end;
end;
```

C.2 Preparation of illustrations

C.2.1 Figure 11: thermistor freeze-in

```
clear all;clear all;load EXP;
i=10;

j=10;
start=0;
p1=plot(24*(EXP(j).tp(:,1)-EXP(j).tp(1,1))-...
    start,EXP(j).tp(:,i:i+6));hold on;
t=text(15,-2,'');hold on;

col{1}='b';
col{2}='g';
col{3}='c';
col{4}='m';
col{5}='y';
col{6}='r';

for i=1:6;
set(p1(i),'MarkerEdgeColor',char(col(i)))
end;

y=-1.3;
dy=-0.2;
x='footnotesize';

text(5*2,-1.1,['\begin{' x '}\hspace{1dd}' 'Depth␣(cm)' '\end{' x
   '}'],...
```

```
    'HorizontalAlignment','left');hold on;

I=0;
for i=[1:2 4:6];
    I=I+1;
    if i<5
        l(i,1:2)=[5*I y];
    else
        l(i,1:2)=[5*(I-3) y+dy];
    end;

    m(I)=plot(l(i,1),l(i,2));hold on;
    set(m(I),'Marker',get(p1(i),'Marker'),'MarkerEdgeColor',...
        get(p1(i),'MarkerEdgeColor'),...
        'MarkerFaceColor',get(p1(i),'MarkerEdgeColor'));
    t(I)=text(l(i,1),l(i,2),['\begin{' x '}\hspace{10dd}'
      sprintf('%0.1f',EXP(j).pos(9+i)) '\end{' x '}']);hold on;
end;

set(t,'HorizontalAlignment','left','VerticalAlignment','middle');
set([p1' m],'Marker','o','MarkerSize',1,'LineStyle','none',...
    'MarkerSize',1)
set(m,'MarkerSize',2);

set(0,'defaulttextinterpreter','none')
set(gca,'Xlim',[start 20],'Ylim',[-3 -1]);


xtick=[0:5:20];
for i=1:5;
    xtickl{i}=['\begin{' x '}' num2str(xtick(i)) '\end{' x '}'];
end

ytick=[-3:0];
for i=1:4;
    ytickl{i}=['\begin{' x '}' num2str(ytick(i)) '\end{' x '}'];
end


set(gca,'Ytick',ytick,'YtickLabel',ytickl,'Xtick',xtick,...
    'XtickLabel',xtickl);
set(gca,'YMinorTick','off','XMinorTick','off');
set(gca,'Box','off');
set(gca,'TickDir','out');
%xlabel('Hours')

ylab=text(-2.5,-2,char(['\begin{' x '}Temperture␣($\mathrm{^\circ
  ␣C}$)\end{' x '}']),'Rotation',90,...
    'HorizontalAlignment','center');

```

```
xlab=text(10,-3,char(['\begin{' x '} Hours \end{' x '}']),'Rotation',0,...
    'VerticalAlignment','middle','HorizontalAlignment',...
    'center','BackgroundColor','w');hold on;

daspect([1,0.12,1]);

hold off;
laprint(1,'/home/jonas/Documents/Latex/thermistorfreezein',...
    'Width',6,'ScaleFonts','off');
```

C.2.2 Figure 3(a): skeletal layer

```
clear all;close all;PLOT=1;

if PLOT==1
magfic=2827.2/7;%from scale.jpg
k=1;
img=getimg('/home/jonas/Pictures/2008-07-08/skeletal.jpg',k);
mf=magfic/k;

x=0;X=1;y=0.1;Y=1;
ymin=round(1+y*size(img,1));
ymax=round(Y*size(img,1));
xmin=round(1+x*size(img,2));
xmax=round(X*size(img,2));

im=img(ymin:ymax,xmin:xmax,:);
g=size(im,1)/size(im,2);
f1=figure('PaperUnits','inch','PaperPosition',[0 0 5/2.54 5*g/2.54]);
h=image(im);hold on;
axis image;hold on;

set(gca,'XTick',[ ],'YTick',[ ]);

x1=0.2*mf;x2=x1+mf/10;y=2.3*mf;
set(0,'defaulttextinterpreter','none');
lw=2;dy=0.025;
h4=text(mean([x1 x2]),y-mf/30,'\begin{Large}\textbf{1 mm}\end{Large}','FontSize',12,...
    'HorizontalAlignment','center',...
    'VerticalAlignment','bottom','Color','r');
h1=line([x1 x2],[y y],'Color','r','LineWidth',lw);hold on;
h2=line([x1 x1],[y-dy*mf y+dy*mf],'Color','r','LineWidth',lw);hold on;
h3=line([x2 x2],[y-dy*mf y+dy*mf],'Color','r','LineWidth',lw);hold on;
set(gca,'Visible','off');
```

```
laprint(1,'/home/jonas/Documents/Latex/skeletal_layer',...
    'ScaleFonts','on');

elseif PLOT==2
lw=2;
magfic=2064/15;%IMG_0239a.JPG
k=1;mf1=2064/15;mf2=1921/1.5;
img=getimg('/home/jonas/Pictures/2008-07-11/IMG_0239.JPG',k);
mf=magfic/k;
%
x=.0;X=1;y=0.1;Y=1;
im=img;%(ymin:ymax,xmin:xmax,:);
g=size(im,1)/size(im,2);
f1=figure('PaperUnits','inch','PaperPosition',[0 0 5/2.54 5*g/2.54]);
h=image(im);hold on;
axis image;hold on;
ytick=[0:2064/15:(2064+3*2064/15)];
ytickl=-1*[0:1:17];
set(gca,'YTick',ytick,'YTickLabel',ytickl,'XTick',[],...
    'TickDir','out','XColor','k','YColor','k','Box','off');
ylabel('Depth (cm)');

ax1=gca;hold on;
ax2=axes('Position',get(ax1,'Position'),'Box','on');hold on;
magfic=1921/1.5;%IMG_0245.JPG
k=1;
img=getimg('/home/jonas/Pictures/2008-07-11/IMG_0241.JPG',k);
mf=magfic/k;

im=img;
g=size(im,1)/size(im,2);
h=image(im,'Parent',ax2);hold on;
axis image;hold on;
set(ax2,'Position',[0.4500 0.48500 0.4875 0.4095],'Layer','top')
g=0.03;
x1=0.5*mf;x2=x1+mf/10;y=1.1*mf;
h4=text(mean([x1 x2]),y,'\begin{Large}1 mm\end{Large}','FontSize',12,'HorizontalAlignment','center',...
    'VerticalAlignment','bottom','Parent',ax2,'Color','r');
h1=line([x1 x2],[y y],'Color','r','LineWidth',lw/2,'Parent',ax2);hold on;
h2=line([x1 x1],[y-g*mf y+g*mf],'Color','r','LineWidth',lw/2,'Parent',ax2);hold on;
h3=line([x2 x2],[y-g*mf y+g*mf],'Color','r','LineWidth',lw/2,'Parent',ax2);hold on;
%h3=line([(x2+x1)/2 (x2+x1)/2],[y-(2*g/3)*mf y+-(2*g/3)*mf],'Color','r','LineWidth',lw,'Parent',ax2);hold on;
line([1 988],[1 1],'Color','r','Parent',ax2,'Linewidth',lw)
```

```
line([1 988],[1765 1765],'Color','r','Parent',ax2,'Linewidth',lw)
line([1 1],[1 1765],'Color','r','Parent',ax2,'Linewidth',lw)
line([988 988],[1 1765],'Color','r','Parent',ax2,'Linewidth',lw)

a=annotation(gcf,'textarrow',[0.3911 0.3482],[0.5395 0.6452],...
    'TextEdgeColor','none',...
    'String',{'\begin{Large}\hspace{-3cm}Plumes\end{Large}'});
set(a,'Color',[1 0 0],'LineWidth',lw/2,'HorizontalAlignment','right');
a=annotation(gcf,'arrow',[0.3964 0.3875],[0.4966 0.3929]);
set(a,'Color',[1 0 0],'LineWidth',lw/2);


dx=mf1*size(img,2)/mf2;dy=mf1*size(img,1)/mf2;x=851;y=342;
X=1395;Y=91;
line([x x+dx x+dx x x X],[y y y+dy y+dy y Y],'Color','r','Parent',ax1,'Linewidth',lw/2)

set(ax2,'YTick',[],'XTick',[],'Box','off');
set(ax2,'Visible','off')
set(0,'defaulttextinterpreter','none');

laprint(1,'/home/jonas/Documents/Latex/section_oil1',...
    'ScaleFonts','off');

elseif PLOT==3
img=getimg('/home/jonas/Pictures/2008-06-22/IMG_8393.JPG',1);
h=image(img);hold on;
set(gca,'XTick',[],'YTick',[])
axis image;hold on;
laprint(1,'/home/jonas/Documents/Latex/section_oil2',...
    'Width',8,'ScaleFonts','off');
hold off
print('-depsc2','/home/jonas/Documents/Latex/section_oil2.eps');

elseif PLOT==4

magfic=1921/1.5;%IMG_0245.JPG
k=1;
img=getimg('/home/jonas/Pictures/2008-07-11/IMG_0241.JPG',k);
mf=magfic/k;

im=img;
g=size(im,1)/size(im,2);
f1=figure('PaperUnits','inch','PaperPosition',[0 0 5/2.54 5*g/2.54]);
h=image(im);hold on;
axis image;hold on;

set(gca,'YTick',[],'XTick',[],'XColor','r','YColor','r',...
```

```
    'LineWidth',1);
g=0.03;
lt=0.6;
x1=0.5*mf;x2=x1+mf/10;y=0.2*mf;
h4=text(mean([x1 x2]),y,'\begin{Large}1 mm\end{Large}','FontSize',12,'HorizontalAlignment',...
    'center','VerticalAlignment','bottom');
h1=line([x1 x2],[y y],'Color','k','LineWidth',lt);hold on;
h2=line([x1 x1],[y-g*mf y+g*mf],'Color','k','LineWidth',lt);hold on;
h3=line([x2 x2],[y-g*mf y+g*mf],'Color','k','LineWidth',lt);hold on;

set(gca,'Visible','off')
set(gcf,'BoundingBox','teight')
set(0,'defaulttextinterpreter','none');
laprint(1,'/home/jonas/Documents/Latex/section_oil3','Width',4,...
    'ScaleFonts','off');

elseif PLOT==5
img=getimg('/home/jonas/Pictures/2008-07-09/EXP16_b -000009.JPG',1);
h=image(img);hold on;
set(gca,'XTick',[],'YTick',[])
axis image;hold on;

laprint(1,'/home/jonas/Documents/Latex/section_oil4','Width',4,...
    'ScaleFonts','off');
hold off
print('-depsc2','/home/jonas/Documents/Latex/section_oil4.eps');

elseif PLOT==6

magfic=3454/9;%IMG_0245.JPG
k=1;
img=getimg('/home/jonas/Pictures/2008-05-01/_MG_7329a.jpg',k);
mf=magfic/k;

im=img;
g=size(im,1)/size(im,2);
f1=figure('PaperUnits','inch','PaperPosition',[0 0 5/2.54 5*g/2.54]);
h=image(im);hold on;
axis image;hold on;

set(gca,'YTick',[],'XTick',[]);
g=0.1;
lt=0.6;
x1=0.7*mf;x2=x1+mf;y=0.7*mf;
```

```
h4=text(mean([x1 x2]),y,'\begin{Large}1␣cm\end{Large}','FontSize',12,'HorizontalAlignment','center',...
    'VerticalAlignment','bottom');
h1=line([x1 x2],[y y],'Color','k','LineWidth',lt);hold on;
h2=line([x1 x1],[y-g*mf y+g*mf],'Color','k','LineWidth',lt);hold on;
h3=line([x2 x2],[y-g*mf y+g*mf],'Color','k','LineWidth',lt);hold on;

set(0,'defaulttextinterpreter','none');

laprint(1,'/home/jonas/Documents/Latex/section_oil5','Width',6,...
    'ScaleFonts','off');

elseif PLOT==7

img=getimg('/home/jonas/Pictures/2008-07-09/EXP17_18.JPG',1);
h=image(img);hold on;
set(gca,'XTick',[],'YTick',[])
axis image;hold on;
set(gca,'Visible','off');
laprint(1,'/home/jonas/Documents/Latex/section_oil8',...
    'ScaleFonts','off');
print('-depsc2','/home/jonas/Documents/Latex/section_oil8.eps');

hold off

end
```

C.2.3 Figure 6: ice growth and water salinity

```
clear all; load EXP; close all
poster=0;

    li='LineWidth';
    poster=0;
    if poster==1
        load('/home/jonas/Documents/Latex/poster/lw.mat')
        lw=lw-0.5;
        st='\begin{footnotesize}';
        ss='\end{footnotesize}';
    elseif poster==0
        lw=0.5;
        st='␣';
    end;

mw=0.5;
sw=EXP(13).sw;
freezeup=sw(1,1)+4.021/24;
```

```
sw(:,1)=24*(sw(:,1)-freezeup);
tp=EXP(13).tp;
tp(:,1)=24*(tp(:,1)-freezeup);
th=EXP(13).th;
th(:,1)=24*(th(:,1)-freezeup);
tp=EXP(13).tp;
tp(:,1)=24*(tp(:,1)-freezeup);

Gray=[0.76 0.76 0.8];
texGray='\definecolor{texGray}{rgb}{0.76,␣0.76,␣0.8}';

or=EXP(13).tx(find(EXP(13).tx(:,2)==3),1);
or=24*(or-freezeup);
I=find(th(:,4)==-3);
th=th(I,:);

Th1=polyfit(th(:,1),-1*th(:,2),2);

Th=sortrows([th(:,1:2);0 0]);
figure(1);
    close all;
ax4=axes('Position',[0.0700 0.100 0.01 0.8150],'XTick',[],'XColor','white',...
'YColor',Gray-0.01*[1 1 1],'YAxisLocation','right','Box','off','TickDir','out',li,lw);
ax3=axes('Position',[0.0700 0.100 0.8350 0.8150],'XTick',[],'YTick',[],li,lw);
I=1;
 for i=10:24;
 h(I)=plot(tp(:,1),tp(:,i),'Parent',ax3,'Color',Gray,...
     li,lw,'LineStyle','-');hold on;
 I=I+1;
 end;

ax1=axes('Position',[0.0700 0.100 0.8350 0.8150],'YColor',[1 0 0],'XTick',[],'YTick',[],li,lw);
load('/home/jonas/Documents/Latex/figures/modelfit.mat');
modelf=plot([0:50],polyval(modelfit,[0:50]),...
'Parent',ax1,'Color',[1 0.90 0.90],'LineWidth',15);hold on;

h1=plot(th(:,1),-1*th(:,2),'r-','Parent',ax1,li,lw);hold on;

model=plot([0:50],polyval(Th1,[0:50]),'r:',li,lw,...
    'Parent',ax1);hold on;
set(h1,'Marker','s','LineStyle','none','MarkerEdgeColor','r',...
    'MarkerSize',5); hold on;
ax2=axes('Position',get(ax1,'Position'),...
          'XAxisLocation','top',...
          'YAxisLocation','left',...
          'Color','none',...
```

```
         'XColor','k','YColor','r','XTick',[],'YTick',[],li,lw);
h2=plot(sw(:,1),sw(:,2),'k-','Parent',ax2,'LineWidth',0.5+lw);hold on;

set(h1,'LineWidth',0.5+lw,'Color',[0 0 0]);
set(h2,'MarkerEdgeColor',[1 0 0],'MarkerFaceColor',[1 1 1]);
plot([0 0],[0 15],'k:','Parent',ax1,li,lw);hold on;
plot([or or],[0 15],'k:','Parent',ax1,li,lw);hold on;
FU=plot([0],[0],'ro','MarkerFaceColor','r','Parent',ax2);hold on;
%xlab=xlabel('Hours from freezeup (FU)','Parent',ax2);

if poster==0;
ylab=ylabel(ax2,strvcat('Water␣salinity␣($\mathrm{\permil}$)','␣\textcolor{texGray}{\textbf{Temperature␣($\mathrm{^\circ␣C}$)}}'));
set(ylab,'Position',[-7 32.4446 1.0001])
elseif poster==1;
    ylab=ylabel(ax2,['Water␣salinity␣($\mathrm{\permil}$)' '␣\textcolor{texGray}{\textbf{Temperature␣($\mathrm{^\circ␣C}$)}}']);
set(ylab,'Position',[-8 32.4446 1.0001])
end
ylab=ylabel(ax1,'Ice␣thickness␣(cm)');
OR=text(10,10,'␣','Parent',ax4);

 set(ax2,'Ylim',[25 40]);
 set(ax1,'Ylim',[0 15]);
 set(ax1,'YAxisLocation','right');
 set(ax2,'Color','none');
 set(ax1,'YColor','r');

set([ax1 ax2 ax3 ax4],'Xlim', [-4.0210-0.8 45.4790],...
    'Box','off','XTick',[],'XTickLabel',[],'TickDir','out',li,lw);

yt=[-8:2:2 7];

for k=1:length(yt);
    if yt(k)<0
    ytl{1,k}=['\textcolor{texGray}{\textbf{' num2str(yt(1,k)) '}}'];
    else
    ytl{1,k}=[...
    '\textcolor{white}{\textbf{-}}\textcolor{texGray}{\textbf{'...
    num2str(yt(1,k)) '}}'];
    end;
end;

set(ax3,'YLim',[-10 7]);

set(ax4,'YLim',get(ax3,'YLim'),'LineWidth',2,'YTick',yt,...
```

```
    'YTickLabel',ytl,'Xlim', [-4.0210 45.4790]);
set(ax3,'YLim',get(ax4,'YLim'));
set([ax2 ax1 ax3],'Color','none');


yt=[0:5:15];
for k=1:length(yt);
    ytl{1,k}=['\textcolor{red}{' num2str(yt(1,k)) '}'];
end;

set(ax1,'Ytick',yt,'YTickLabel',ytl);

if poster==0;
t=[0:10:30 or 40 th(end,1)];

for k=1:length(t);
    tl{1,k}=num2str(t(1,k));
end;

Text=text(100,100,'␣');

tl{1,1}='FU';
tl{1,5}='OR';
tl{1,7}='$t_0$';
elseif poster==1

t=[0:10:30 or 45];



for k=1:length(t);
    tl{1,k}=num2str(t(1,k));
end;

Text=text(100,100,'␣');

tl{1,1}='FU';
tl{1,5}='OR';
%tl{1,7}='$t_0$';
end
 set(ax2,'XTick',t,'XTickLabel',tl);
 %xlab=xlabel('Hours from freezeup (FU)','Parent',ax2);
 Th2=modelfit;
 l=legend([modelf model h1 h(1)],...
 'Ice␣Growth␣Model␣$H_m(t)$','Least␣Square␣Fit␣$H_w(t)$',...
 'Thermistor␣freezein','Thermistor␣temperature');
set(l,'Position',[0.2415 0.7 0.3831 0.1642],'Box','off')
set(ax3,'YTick',[])
set(ax4,'XColor','white')

```

```
    set(ax4,'XColor','white')

    for r=1:length(Th1);

        if Th1(r)<0
            sign1{r}='␣';
        else
            sign1{r}='+';
        end;

        if Th2(r)<0
            sign2{r}='␣';
        else
            sign2{r}='+';
        end;
    end

    P1=['$H_w(t)=' char(sign1(1)) exp2text(Th1(1),3) 't^2'
      char(sign1(2)) exp2text(Th1(2),3) 't' '$'];
    P2=['$H_m(t)=' char(sign2(1)) exp2text(Th2(1),3) 't^2'
      char(sign2(2)) exp2text(Th2(2),3) 't' char(sign2(3))
      exp2text(Th2(3),3) '$'];
if poster==0
    text(9,1.7,P1,...
    'Parent',ax1);
    text(6.3,0.6,P2,...
    'Parent',ax1);
elseif poster==1;
    text(6.5,1.7,['\scalefont{0.9}' P1],...
    'Parent',ax1);
    text(2.5,0.6,['\scalefont{0.9}' P2],...
    'Parent',ax1);
xlabel('Hours␣from␣freeze-up␣(FU)')
end


if poster==0;
    laprint(1,...
        '/home/jonas/Documents/Latex/watersalinity2',...
        'ScaleFonts','on','figcopy','off');

    watersal2=importdata(...
    '/home/jonas/Documents/Latex/watersalinity2.tex');
    wat=texGray;

    for i=1:length(watersal2(:,1));
    wat=strvcat(wat,char(watersal2(i,:)));
    end;
    dlmwrite(...
        '/home/jonas/Documents/Latex/watersalinity2.tex',...
```

```
    wat,'delimiter', '');
    dlmwrite(...
        '/home/jonas/Documents/Latex/constants/model.tex',...
    P2,'delimiter', '');
elseif poster==1;
    set(ylab,'Position',[48.5 7.44465 1.00011])
    laprint(1,'/home/jonas/Documents/Latex/poster/watersalinity2',...
    'ScaleFonts','on','figcopy','off');

    watersal2=importdata(...
    '/home/jonas/Documents/Latex/poster/watersalinity2.tex');
    wat=texGray;

    for i=1:length(watersal2(:,1));
    wat=strvcat(wat,char(watersal2(i,:)));
    end;

    dlmwrite(...
        '/home/jonas/Documents/Latex/poster/watersalinity2.tex',...
        wat,'delimiter', '');
    dlmwrite(...
        '/home/jonas/Documents/Latex/poster/constants/model.tex',...
    P2,'delimiter', '');
end
```

C.2.4 Figure 6: taylor expansion of eq. (4.6.4)

Taylor expansion was done using the code below:

```
clear all; load EXP;
sw=EXP(13).sw;
freezeup=sw(1,1)+4.021/24;
sw(:,1)=24*(sw(:,1)-freezeup);
tp=EXP(13).tp;
tp(:,1)=24*(tp(:,1)-freezeup);
th=EXP(13).th;
th(:,1)=24*(th(:,1)-freezeup);

or=EXP(13).tx(find(EXP(13).tx(:,2)==3),1);
or=24*(or-freezeup);
I=find(th(:,4)==-3);
th=th(I,:);

Th1=polyfit(th(:,1),-1*th(:,2),2);

Th=sortrows([th(:,1:2);0 0]);

S=EXP(8).sp(1,4);
EXP(13).tp=addsurfacetemp2(13);
Ts=EXP(13).tp(find(EXP(13).tp(:,1)>freezeup),:);
```

```
temp=polyfit(24*60*60*(Ts(:,1)-Ts(261,1)),Ts(:,8),1);
a=temp(1)+(freezingpoint(28)-freezingpoint(38))/...
(24*60^2*(Ts(1,1)-Ts(261,1)));
b=temp(2)-freezingpoint(38);
T_m=mean([freezingpoint(40) Ts(261,8)]);
T=freezingpoint(40);%-2.4;
S=10;
lam=bulkconduc(S,T_m);%W/(m*K)
rho=bulkdensity(S,T)*1000;%kg/m^3
L=latentheat(S,T)*1000;%J/kg
%a=-(6/(2*24*60*60));%C/s
%b=-7;%C
F=-10;%-140;%W/m^2
x=4;
k=(lam)/(rho*L);
c=-F/(rho*L);
H0=-polyval(Th1,24*(Ts(262,1)-freezeup))/100;


H(1)=H0;
H(2)=(k*b)/H0;
    %H(2)=(lam*b)/(rho*L)-(F/(rho*L));
H(3)=(((k*a)-(k*b*H0^(-1))+c)*(k*b*H0^(-2)))/2;

%**************************************************


%close all
t=[0:50];
figure(x)
s=plot(th(:,1),-1*th(:,2));
set(s,'Marker','s','LineStyle','none','Color','r'); hold on;
model=plot(gca,t,polyval(Th1,t),'r:');hold on;

g=th(end,1);
k=60^2;
H(1)=100*H(1);
H(2)=100*k*H(2);
H(3)=100*k*k*H(3);

h(1)=H(3)*g*g+H(2)*g+H(1);
h(2)=2*H(3)*g+H(2);
h(3)=H(3);
modelfit=[-h(3) h(2) -h(1)];

dh=polyval([modelfit],t);
[Th1;modelfit];
%polyval([modelfit],0)
plot(t,dh,'b'); hold off;

```

```
for i=1:3;
p{i}=['$' exp2text(modelfit(i),3) '$'];
dlmwrite(['/home/jonas/Documents/Latex/constants/p' num2str(i)
  '.tex'],char(p(i)),'delimiter', '');
end;
dlmwrite(...
    ['/home/jonas/Documents/Latex/constants/lambda.tex'],...
    [sprintf('%0.2f',lam) '␣$W/m^{-1}K^{-1}$'],'delimiter', '');
dlmwrite(...
    ['/home/jonas/Documents/Latex/constants/rho.tex'],...
    [sprintf('%0.2f',rho/1000) '␣$g/cm^{3}$'],'delimiter', '');
dlmwrite(...
    ['/home/jonas/Documents/Latex/constants/latent.tex'],...
    [sprintf('%g',L/1000) '␣$J/g$'],'delimiter', '');
dlmwrite(...
    ['/home/jonas/Documents/Latex/constants/temprate.tex'],...
    ['$' exp2text(a,2) '$␣$^\circ␣C/s$'],'delimiter', '');
dlmwrite(...
    ['/home/jonas/Documents/Latex/constants/icesalinity.tex'],...
    ['$' sprintf('%0.0f',S) '$␣$\permil$'],'delimiter', '');
dlmwrite(...
    ['/home/jonas/Documents/Latex/constants/Ts.tex'],...
    ['$' sprintf('%0.1f',Ts(261,8)) '$␣$^\circ␣C$'],'delimiter',
      '');
dlmwrite(...
    ['/home/jonas/Documents/Latex/constants/Tf.tex'],...
    ['$' sprintf('%0.1f',freezingpoint(40)) '$␣$^\circ␣
      C$'],'delimiter', '');
dlmwrite(...
    ['/home/jonas/Documents/Latex/constants/middletemp.tex'],...
    ['$' sprintf('%0.1f',T_m) '$␣$^\circ␣C$'],'delimiter', '');
dlmwrite(...
    ['/home/jonas/Documents/Latex/constants/F_w.tex'],...
    ['$' sprintf('%0.0f',-F) '$␣$W/m^2$'],'delimiter', '');

save /home/jonas/Documents/Latex/figures/modelfit modelfit;
```

C.2.5 Figure 7: viscosity

```
synt1=xlsread('viscosity/viscosity_matlab.xls','1');
crude{1}=xlsread('viscosity/viscosity_matlab.xls','2');
synt2=xlsread('viscosity/viscosity_matlab.xls','4');
crude{2}=xlsread('viscosity/viscosity_matlab.xls','3');
lw=0.5;
for h=1:2;
    for i=2:length(crude{1}(:,1));
        for j=1:2;
            p{h}(i-1,j)=((crude{h}(i,j)-crude{h}(i-1,j))/5)+...
                crude{h}(i-1,j);
```

```
            v{h}(i-1,j)=(crude{h}(i,j)-crude{h}(i-1,j))/...
                (sqrt((crude{h}(i,2)-crude{h}(i-1,2))^2+...
                (crude{h}(i,1)-crude{h}(i-1,1))^2));
        end;
    end;
end;

clear figure(1)
figure(1)
hold off;
h1=plot(crude{1}(:,2),crude{1}(:,1),'-rx'); hold on;
q1=quiver(p{1}(:,2),p{1}(:,1),v{1}(:,2),v{1}(:,1),'Color','r');
hold on;
h2=plot(crude{2}(:,2),crude{2}(:,1),'-rx'); hold on;
q2=quiver(p{2}(:,2),p{2}(:,1),v{2}(:,2),v{2}(:,1),'Color','r');
hold on;
set(gca,'XLim',[-22 22],'Box','off','TickDir','out');
set([q1 q2],'LineWidth',lw)
set([q1 q2],'AutoScaleFactor',0.25)
set(h1,'LineWidth',lw,'Marker','s','MarkerEdgeColor','k',...
    'MarkerFaceColor','g','MarkerSize',5);hold on;
set(h2,'LineWidth',lw,'Marker','o','MarkerEdgeColor','k',...
    'MarkerFaceColor','g','MarkerSize',5);hold on;
ylabel('Dynamic␣viscosity␣(cP)'); hold on;

grid on
grid minor
set(0,'defaulttextinterpreter','none')
laprint(1,'/home/jonas/Documents/Latex/crude_viscosity');
hold off;

figure(2)
h2=semilogy(synt2(:,2),synt2(:,1),'-rx');
set(h2,'LineWidth',lw,'Marker','s','MarkerEdgeColor','k',...
    'MarkerFaceColor','g','MarkerSize',5);hold on;

ylabel('Dynamic␣viscosity␣(cP)'); hold on;
a=annotation(gcf,'arrow',[0.7345 0.8065],[0.4239
  0.388],'Color',[1 0 0],'LineWidth',0.01,'HeadLength',14,...
    'HeadWidth',8);hold on;


annotation(gcf,'arrow',[0.6869 0.6726],[0.4467 0.4522],'Color',[1
   0 0],'LineWidth',0.01,'HeadLength',14,...
    'HeadWidth',8);hold on;



annotation(gcf,'arrow',[0.3619 0.3446],[0.6239 0.6348],'Color',[1
   0 0],'LineWidth',0.01,'HeadLength',14,...
```

```
    'HeadWidth',8);hold on;

annotation(gcf,'arrow',[0.3845 0.4018],[0.6077 0.5967],'Color',[1
   0 0],'LineWidth',0.01,'HeadLength',14,...
    'HeadWidth',8);hold on;
annotation(gcf,'arrow',[0.5411 0.4577],[0.5164 0.5609],'Color',[1
   0 0],'LineWidth',0.01,'HeadLength',14,...
    'HeadWidth',8);hold on;
annotation(gcf,'arrow',[0.4577 0.5411],[0.5609 0.5164],'Color',[1
   0 0],'LineWidth',0.01,'HeadLength',14,...
    'HeadWidth',8);hold on;
annotation(gcf,'doublearrow',[0.2911 0.2476],[0.6707
  0.6978],'Color',[1 0 0],'LineWidth',0.01,'HeadLength',10,...
    'HeadWidth',8);hold on;
%annotation(gcf,'arrow',,'Color',[1 0 0],'LineWidth',0.01);hold
  on;
%annotation(gcf,'arrow',,'Color',[1 0 0],'LineWidth',0.01);hold
  on;

set(0,'defaulttextinterpreter','none')
grid minor
set(gca,'XGrid','on','YGrid','on','Box','off','TickDir','out',...
    'Xlim',[-22 22])
laprint(2,'/home/jonas/Documents/Latex/synt_viscosity');
hold off
```

C.2.6 Figure 8: interfacial tension 8(b)

```
clear all;close all;PLOT=2;

magfic=100/0.4;%from scale.jpg
k=1;
img=getimg(...
    '/home/jonas/Pictures/2008-07-02/surface_tension.jpg',k);
mf=magfic/k;

x=0;X=1;y=0.1;Y=0.7;
ymin=round(1+y*size(img,1));
ymax=round(Y*size(img,1));
xmin=round(1+x*size(img,2));
xmax=round(X*size(img,2));

im=img(ymin:ymax,xmin:xmax,:);
g=size(im,1)/size(im,2);
f1=figure('PaperUnits','inch','PaperPosition',[0 0 5/2.54
  5*g/2.54]);
h=image(im);hold on;
axis image;hold on;

```

```
set(gca,’XTick’,[ ],’YTick’,[ ]);
d=50;
p1=[123 25];
y2=80;

x1=0.1*mf;x2=x1+mf/10;y=0.5*mf;
set(0,’defaulttextinterpreter’,’none’);
lw=2;dy=0.025;
h4=text(mean([x1 x2]),y-mf/30,’\begin{Large}\textbf{1␣mm}\end{Large}’,’FontSize’,12,...
    ’HorizontalAlignment’,’center’,’VerticalAlignment’,...
    ’bottom’,’Color’,’c’);
h1=line([x1 x2],[y y],’Color’,’c’,’LineWidth’,lw);hold on;
h2=line([x1 x1],[y-dy*mf y+dy*mf],’Color’,’c’,’LineWidth’,lw);hold on;
h3=line([x2 x2],[y-dy*mf y+dy*mf],’Color’,’c’,’LineWidth’,lw);hold on;

a=-sind(d)/cosd(d);
b=p1(1,2)-a*p1(1,1);
plot([p1(1,1) (y2-b)/a],[p1(1,2) y2],’--c’,’LineWidth’,lw);

Y1=30;
x1=[0 400]; y1=[1 1]*p1(1,2);
plot(x1,y1,’c--’,’LineWidth’,lw);

r=20;
k=0;

for i=d+180:360;
    k=k+1;
    p(k,1:2)=[r*cosd(i) r*sind(-i)]+p1;
end;

plot(p(:,1),p(:,2),’c-’,’LineWidth’,lw);hold on;
text(3*r*cosd((180-d)/2)+p1(1,1),-3*r*sind(360-d/2)+p1(1,2),...
[’\begin{Large}$\mathbf{\theta_o␣\approx’ num2str(180-d) ’^\circ}$\end{Large}’],’Color’,’c’)
text(115+(217-115)/2,p1(1,2)/2,...
    ’\begin{Large}\textbf{Ice}\end{Large}’,’Color’,’c’,...
    ’HorizontalAlignment’,’center’);

text(115+(217-115)/2,130,...
    ’\begin{Large}\textbf{Water}\end{Large}’,’Color’,’c’,...
    ’HorizontalAlignment’,’center’);

annotation(gcf,’textarrow’,[0.7018 0.6179],[0.3714 0.4381],...
    ’TextEdgeColor’,’none’,...
    ’String’,{’\begin{Large}\textbf{Oil␣drop}\end{Large}’},...
    ’Color’,’c’,’HorizontalAlignment’,’left’)%,’LineWidth’,lw);
```

```

laprint(1,'/home/jonas/Documents/Latex/surface_tension',...
    'ScaleFonts','on');
```

```
clear all; close all;

fig=figure(1);
daspect([1,1,1]);
r=1;
xlim=[-2.5 2.5+r];
P=get(gca,'Position');

aw=0.7;
lw=aw;
fs=20;
set(gca,'Visible','off')
i=0;
v=70;
ylim=[-1.05 1.05]*r*sind(v);
%xlim*((P(1,3)-P(1,1))/(P(1,4)-P(1,2)));
x1=xlim(1,1);
x2=xlim(1,2);
y1=ylim(1,1);
y2=ylim(1,2);
oilc=[1 1 1]*0.7;


%Oil
for k=-v:v;
    i=i+1;
    c(i,1:2)=[r*cosd(k) r*sind(k)];
end;
c=[xlim(1,1) -r*sind(v);c;xlim(1,1) r*sind(v)];
oil=area(c(:,1),c(:,2));hold on;
set(oil,'EdgeColor',oilc,...
    'FaceColor',oilc);

text(mean([x1 x1 0]),mean(ylim),...
    '\textbf{Oil}','FontSize',fs);

%Tube
for i=-1:2:1;
    tube=plot(xlim,[1 1]*sind(v)*r*i,...
        '-k','LineWidth',0.5);hold on;
end;

%Angle
a=[sind(90-v) cosd(90-v)];
a1=[cosd(90-v) -sind(90-v)];
```

```
p=[a;a+6*r*a1/5];

%Lin=plot(p(:,1),p(:,2),'-r');hold on


i=0;
for k=v-90:0%180:180+v+90;
    i=i+1;
    ang(i,1:2)=a+[r*cosd(k) r*sind(k)]/1.7;
end;
tp=a+[r*cosd(((v-90)/2)) ...
    r*sind(((v-90)/2))];
text(tp(1,1),tp(1,2),...
    '$\theta_{_B}␣$','FontSize',...
    fs,'VerticalAlignment','middle')

Ang=plot(ang(:,1),ang(:,2),'-r');hold on;
set([Ang],'LineWidth',aw,'Color','k');
set(gca,'Xlim',xlim,'Ylim',ylim);



%Curvature
R=[r*cosd(v) r*sind(v);
    0 0;
    r*cosd(-v) r*sind(-v)];
plot(R(:,1),R(:,2),'k-',...
    'LineWidth',lw);
hold on;
text(mean(R(:,1)+R(3,2)/4),...
    mean(R(2:3,2)),'$R_1$','FontSize',fs,...
'HorizontalAlignment','center');hold on;

%radius
radius=[0 0;0 r*sind(v);
        0 r*sind(v)*(1-(1/6));
    -r*sind(v)*(1/6) r*sind(v)*(1-1/6);
    -r*sind(v)*(1/6) r*sind(v)];
plot(radius(:,1),radius(:,2),'k-',...
    'LineWidth',lw);hold on;
text(-radius(2,2)/6,...
    radius(2,2)/2,'$r$','FontSize',fs,...
'HorizontalAlignment','center');


daspect([1,1,1]);
set(gca,'XTick',[],'YTick',...
    [],'Box','off','Visible','off');
set(0,'defaulttextinterpreter','none')

```

```
%Water
text(mean([x2 x2 0]),mean([y1 y2]),...
    '\textbf{Brine}','FontSize',fs);

%Forces
f1=p;
F1=arrow(f1(1,:),f1(2,:),'FaceColor',...
    'k','EdgeColor','k');hold on;
text(mean(f1(:,1)),f1(2,2),...
    '$\gamma␣_{_{BO}}$','FontSize',fs,...
    'HorizontalAlignment','center',...
    'VerticalAlignment','middle');hold on;

f2=[p(1,:);p(1,:)-[r 0]];
arrow(f2(1,:),f2(2,:));hold on;
text(mean(f2(:,1)),f2(2,2),...
    '$\gamma␣_{_{IO}}$','FontSize',fs/2,...
    'HorizontalAlignment','center',...
    'VerticalAlignment','bottom');hold on;
f3=[p(1,:);p(1,:)+[r 0]];
arrow(f3(1,:),f3(2,:));hold on;
text(mean(f3(:,1)),f3(2,2),'$\gamma␣_{_{IB}}$','FontSize',fs/2,...
    'HorizontalAlignment','center',...
    'VerticalAlignment','bottom');hold on;

laprint(1,['/home/jonas/Documents/'...
    'Latex/interface_theory','Width'],7);
```

C.2.7 Figure 9(a): tank 1

```
close all;
poster=1;
h=5;
w1=6;
w2=7;
wd=0.5;
hd1=1.2;
hd2=0.5;
wt=0.2;
textdisp=0.1;
td=0.2%0.15;
fontsi=30;
textx=1.2*w1/4;
if poster==0;
lw=0.5;
elseif poster==1;
    lw=1;
end;
```

```matlab

txh=0.9;
ms=2,5;
figure('Position',[500 500 400 800])


inso=area([0 wd w2-w1 w2-w1 w1 w1 w2-wd w2],[h h hd1 hd2 hd2 hd1
  h h],0);
set(inso,'FaceColor',[0 0 0],'LineStyle','none');hold on;
insoedge=line([0 0 wd w2-w1 w2-w1 w1 w1 w2-wd w2 w2 0],...
    [0 h h hd1 hd2 hd2 hd1 h h 0 0]);
set(insoedge,'Color','k','LineWidth',0.5)

set(gca,'Ylim',[0 11])
t1x=[wd w2-w1 w1 w2-wd];t1y=[h hd1 hd1 h];
tank1=area(t1x,t1y,h);
set(tank1,'FaceColor',[0.6 0.6 0.6],'LineStyle','none');hold on;
t2x=[wd-td wd+td wd+td w2-wd-td w2-wd-td w2-wd+td];
t2y=[h+td h+td h h h+td h+td];
tank2=area(t2x,t2y,h-0.01);
set(tank2,'FaceColor',get(tank1,'FaceColor'),...
    'LineStyle',get(tank1,'LineStyle'));

px=[w2-w1 w1];py=[hd2 hd2];
plate=area(px,py,(hd1+hd2)/2.5);
set(plate,'FaceColor',[0.6 0.6 0.6]);hold on;
pline=line([px w1 w2-w1 w2-w1],[py (hd1+hd2)/2.5 (hd1+hd2)/2.5
  py(1,1)]);

water=area([wd+td w2-w1+td w1-td w2-wd-td],[h hd1+td hd1+td
  h],h+0.01);
set(water,'FaceColor',[1 1 1],'LineStyle','none');hold on;

tankedge=line(...
    [t1x w2-wd+td w2-wd+td w2-wd-td w1-td w2-w1+td wd+td wd-td
      wd-td wd],...
    [t1y h h+td h+td hd1+td hd1+td h+td h+td h h]);hold on;

set(tankedge,'Color','k','LineWidth',0.5)
set(pline,'Color','k','LineWidth',0.5)

b=[.35*w1 .65*w1];

for l=1:2;
k=0.1;

r1=rectangle('Position',[b(1,l),(hd1+hd2)/2,6*k,1*k],...
    'Curvature',[1,1],...
          'FaceColor','k');
p1=get(r1,'Position');p2=p1;p2(1,1)=p2(1,1)+0.1*w1; hold on;
```

```

r1=rectangle('Position',p2,'Curvature',[1,1],...
         'FaceColor','k');

px3=p1(1)+p1(3);
r3=area([px3-0.2*k px3+0.2*k],[(hd1+hd2)/1.7 (hd1+hd2)/1.7],(hd1+hd2)/2.5);hold on;
set(r3,'FaceColor','k');
end;
B=b(1,2)+1.4;



ih=h-wd;%(hd1+td)*2.15;
iw=0;wd/2;
i1=plot([iw w1/2],[h+txh*5 h+txh*5],'k-','LineWidth',lw);
i2=plot([iw iw],[ih h+txh*5],'k-','LineWidth',2*lw);

th=4*txh+h; iw=wd;%wd*1.7;
t1=plot([iw iw w1/2],[h+td th th],'k-','LineWidth',lw);

ax=w2/4.8; ay1=((hd1+hd2)/2)/2;ay2=h+3*txh;
a1=plot([ax ax w1/2],[t1y(2) ay2 ay2],'k-','LineWidth',lw);
px=w1/1.1;py=h+2*txh;
p1=plot([px px w1/2],[(hd1+hd2)/2.5 py py],'k-','LineWidth',lw);

f1=plot([px3 px3 textx+0.2],[0.05+(hd1+hd2)/2 h+1*txh h+1*txh],'k-','LineWidth',lw);
i3=text(textx,h+txh*5,'Outer␣tank','FontSize',fontsi,...
'HorizontalAlignment','left','VerticalAlignment','middle',...
'BackgroundColor',[1 1 1]);

t3=text(textx,h+txh*4,'Inner␣tank','FontSize',fontsi,...
'HorizontalAlignment','left','VerticalAlignment','middle',...
'BackgroundColor',[1 1 1]);
p3=text(textx,h+txh*2,'Metal␣plate','FontSize',fontsi,...
    'BackgroundColor',[1 1 1]);

a3=text(textx,h+txh*3,'Air␣volume','FontSize',fontsi,...
'HorizontalAlignment','left','VerticalAlignment','middle',...
'BackgroundColor',[1 1 1]);

f3=text(textx,h+txh*1,'Fan','FontSize',fontsi,...
'HorizontalAlignment','left','VerticalAlignment','middle',...
'BackgroundColor',[1 1 1]);


plot([wd+td w1+td],[h h],'k:');
if poster==0
```

```
text(-0.1+w1/2,h,'42␣
  $cm$','FontSize',12,'HorizontalAlignment',...
    'left','VerticalAlignment','top')
elseif poster==1
text(-0.1+w1/2,h,'\hspace{-6mm}␣42␣
  $cm$','FontSize',12,'HorizontalAlignment',...
    'left','VerticalAlignment','top')
end
plot([wd+7*td wd+7*td],[h 1.4],'k:');
text(wd+7*td,(h+1.4)/2,'27␣
  $cm$','FontSize',12,'HorizontalAlignment',...
    'left','VerticalAlignment','bottom','Rotation',[-90])

set(gca,'Visible','off')
set(gcf,'PaperPosition',[0 0 100 200])

set(0,'defaulttextinterpreter','none')

if poster==0;
laprint(1,'/home/jonas/Documents/Latex/smallbarrel','Width',...
    4.5,'scalefonts','on');
hold off;
elseif poster==1;
laprint(1,'/home/jonas/Documents/Latex/poster/smallbarrel',...
    'Width',4.5,'scalefonts','on');
hold off;
end;
```

C.2.8 Figure 9(b): tank 2

```
\hspace{2.2cm}
\definecolor{gray}{rgb}{0.8,0.8,0.8}
\definecolor{black}{rgb}{0, 0,0}
\definecolor{dgray}{rgb}{0.3,0.3,0.3}
\definecolor{white}{rgb}{1,1,1}
\setlength{\unitlength}{1cm}
\begin{picture}(8,8)
       \color{black}
       \linethickness{4cm}
       \put(2,0){\line(0,1){5.8}}
       \linethickness{0.4cm}
       \put(0.2,5.8){\line(0,1){0.2}}
       \put(3.8,5.8){\line(0,1){0.2}}
       \color{gray}
       \linethickness{3.2cm}
       \put(2,0.4){\line(0,1){5.4}}
       \color{white}
       \linethickness{3.2cm}
       \put(2,4){\line(0,1){1.3}}
```

```
        \linethickness{3.6cm}
        \put(2,4.5){\line(0,1){0.5}}
        \color{gray}
        \linethickness{0.2cm}
        %\put(1.25,4.095){\line(1,0){1}}
        \qbezier(2,4.05)(3,4.05)(3,3.5)
        \qbezier(1,3.5)(1,4.05)(2,4.05)

%oil in ice

\color{black}
\linethickness{0.05mm}
%\put(-1,0){\line(0,1){7}}
\multiput(-0.2,0)(0,0.201){30}{\line(0,5){0.05}}
\put(-0.3,0){\line(1,0){0.2}}
\put(-0.3,6){\line(1,0){0.2}}
\put(-0.47,2.5){\rotatebox{90}{95 $cm$}}

\multiput(0.5,7.8)(0.201,0){15}{\line(5,0){0.05}}
\put(0.4,7.7){\line(0,1){0.2}}
\put(3.6,7.7){\line(0,1){0.2}}
\put(1.5,7.9){{51 $cm$}}

        \linethickness{0.3cm}
        %\put(2,4){\oval(1.5,0.2)[2]}
        \qbezier(2,4)(2.5,4)(2.5,3.9)
        \qbezier(1.5,3,9)(1.5,4)(2,4)
        \put(2,5.4){\circle*{0.07}}
        \linethickness{0.03cm}
        \put(2,5.3){\line(0,-1){1.3}}
        \put(2.05,5){\line(0,-1){1}}
        \put(1.9,4.9){\line(0,-1){0.9}}
        \put(1.7,4.4){\line(0,-1){0.4}}

%oil to the side
\put(0.5,3.9){\circle*{0.3}}
\linethickness{0.02cm}
\put(0.5,5.3){\line(0,-1){1.3}}
\put(0.55,4.5){\line(0,-1){0.6}}
\put(0.5,5.5){\circle*{0.07}}
\color{gray}
\linethickness{0.3cm}
\put(0.55,4){\line(0,-1){0.4}}
\color{gray}
\linethickness{0.35cm}
\put(1.3,3.9){\line(1,0){1.4}}

%Pump
        \color{black}
        \linethickness{0.5cm}
```

```
       \put(2.95,0.7){\line(1,0){0.55}}
       \linethickness{0.3cm}
       \put(2.8,0.7){\line(1,0){0.7}}
       \linethickness{0.2mm}
       \put(1,0.75){\text{$\rightarrow$}}
       \put(2,0.5){\text{$\leftarrow$}}
       \put(1,0.5){\text{$\leftarrow$}}
       \put(2,0.75){\text{$\rightarrow$}}
       \thinlines
       %\put(3.5,0.7){\line(1,0){2.5}}
       %\put(6,0.7){\circle*{0.1}}

%Thermistor
\linethickness{0.15cm}
\put(1,3){\line(0,1){4}}
\linethickness{0.3mm}
\multiput(1,3.03)(0, 0.2){20}{\line(1, 0){0.2}}
\thinlines
\put(1,7){\line(0,1){0.2}}
\qbezier(1,7.2)(1,7.4)(0.8,7.4)
\put(0,7.4){\line(1,0){0.8}}
\put(0,7.4){\circle*{0.1}}
%Salinometer
\thinlines
\put(0.7,2){\line(0,1){4.2}}
\qbezier(0.7,6.2)(0.7,6.4)(0.5,6.4)
\put(0.5,6.4){\line(-1,0){0.5}}
\put(0,6.4){\circle*{0.1}}
\linethickness{2mm}
\put(0.7,2){\line(0,1){0.5}}

%Webcam
\linethickness{0.3mm}
\put(2,7.3){\line(0,1){0.5}}
\linethickness{0.3cm}
\put(2,7.3){\line(0,-1){0.5}}
\thinlines
\multiput(0.3,5.3)(0.2,0.2){5}{\line(1,1){0.1}}
\put(0.5,4){\line(1,1){0.1}}

%Shield
\thicklines
\put(1.5,5.3){\line(0,1){0.7}}
\put(2.5,5.3){\line(0,1){0.7}}
%Tube
\put(1.9,5.3){\line(0,1){0.8}}
\put(2.1,5.3){\line(0,1){0.8}}
\put(1.9,6.1){\line(1,0){0.2}}
%\put(2.1,6.1){\line(-1,1){0.3}}
%Oil in tube
```

```
\linethickness{0.2cm}
\put(2,5.55){\line(0,1){0.3}}
%Oilfilm
\linethickness{1mm}
\put(1.5,5.75){\line(-1,0){1.2}}
\put(2.5,5.75){\line(1,0){1.2}}

%Pressuretank
\thicklines
\put(3.2,2){\oval(0.5,1)[0.1]}
\color{black}
\linethickness{1.5mm}
\put(3.2,2.5){\line(0,1){4}}
\put(3.2,6.42){\line(1,0){1.3}}
\put(4.44,6.49){\line(0,-1){1.3}}
\put(4.365,5.19){\line(1,0){0.4}}
\color{gray}
\linethickness{1mm}
\put(3.2,2.4){\line(0,1){4}}
\put(3.15,6.42){\line(1,0){1.3}}
\put(4.44,6.47){\line(0,-1){1.3}}
\put(4.39,5.19){\line(1,0){0.4}}

%Pressuretank
\linethickness{0.656cm}
\put(4.7,5.47){\line(1,0){1}}
\thicklines
\color{black}
\put(4.37,5.13){\line(1,0){1.35}}
\put(5.705,5.13){\line(0,1){1}}
\put(4.705,5.13){\line(0,1){1}}
\put(4.705,6.13){\line(2,1){0.4}}
\put(5.705,6.13){\line(-2,1){0.4}}
\color{gray}
\linethickness{1mm}
\put(4.39,5.19){\line(1,0){1.295}}

%marks
\color{black}
%salinometer
\put(1,2.1){\text{1}}
\put(4.5,3){\text{1: Salinometer}}
%Pressure sack
\put(3.1,1.9){\text{2}}
\put(5.1,5.4){\text{2}}
\put(4.5,2.5){\text{2: Pressure Release}}

%webcam
\put(2.3,7.2){\text{3}}
\put(4.5,2){\text{3: Video Camera}}
```

```

%Pump
\put(2.5,0.6){\text{4}}
\put(4.5,1.5){\text{4: Heating Pump}}

%Tube
\put(1.9,6.2){\text{5}}
\put(4.5,1){\text{5: Tube}}

%Shild
\put(2.4,6.1){\text{6}}
\put(4.5,0.5){\text{6: Shield}}

%oilfilm
%\put(2.8,5.8){\text{7}}
%Thermistor
\put(0.65,6.5){\text{7}}
\put(4.5,0){\text{7: Thermistor Probe}}


%text
\linethickness{0.3cm}
\color{black}
\put(4.5,4){\line(0,1){0.3}}
\put(4.5,3.5){\line(0,1){0.3}}
\put(4.5,4.5){\line(0,1){0.3}}

\color{gray}
\linethickness{0.28cm}
\put(4.5,4.51){\line(0,1){0.28}}
\color{white}
\put(4.5,3.51){\line(0,1){0.28}}

\color{black}
\put(4.8,4.5){\text{Water}}
\put(4.8,4){\text{Oil}}
\put(4.8,3.5){\text{Ice}}

\end{picture}
```

C.2.9 Figure 10: air in oil

```
clear all;close all;magfic=2304/7.5;
k=4;
img=getimg(...
    '/home/jonas/Pictures/2008_02_29_SEAICE/SEAICE_0303.JPG',k);
mf=magfic/k;


```

```
x=.0;X=1;y=0.1;Y=0.58;
ymin=round(1+y*size(img,1));
ymax=round(Y*size(img,1));
xmin=round(1+x*size(img,2));
xmax=round(X*size(img,2));

im=img(ymin:ymax,xmin:xmax,:);
g=size(im,1)/size(im,2);
f1=figure('PaperUnits','inch','PaperPosition',[0 0 5/2.54
  5*g/2.54]);
h=image(im);hold on;
%axis image;hold on;

set(gca,'XTick',[ ],'YTick',[ ]);

x1=0.5*mf;x2=x1+mf;y=mf;
h4=text(mean([x1 x2]),y,...
    '\begin{scriptsize}1␣cm\end{scriptsize}','FontSize',12,...
    'HorizontalAlignment','center','VerticalAlignment','bottom');

h1=line([x1 x2],[y y],'Color','k','LineWidth',1);hold on;
h2=line([x1 x1],[y-.1*mf y+.1*mf],'Color','k','LineWidth',1);hold
   on;
h3=line([x2 x2],[y-.1*mf y+.1*mf],'Color','k','LineWidth',1);hold
   on;

set(0,'defaulttextinterpreter','none');
laprint(1,'/home/jonas/Documents/Latex/airbobble1','Width',5,...
    'ScaleFonts','off');
hold off;

%%%%%%%%%%%%%%%%%%%%%%%%
clear im img;
magfic=754/6;
k=1;
img=getimg(...
    '/home/jonas/Pictures/2008_02_27/_MG_6453.JPG',k);
mf=magfic/k;


x=.0;X=1;y=0;Y=1;
ymin=round(1+y*size(img,1));
ymax=round(Y*size(img,1));
xmin=round(1+x*size(img,2));
xmax=round(X*size(img,2));

im=img(ymin:ymax,xmin:xmax,:);

for i=1:3
    im(:,:,i)=medfilt2(im(:,:,i));
```

```
end;


g=size(im,1)/size(im,2);
h=figure('PaperUnits','inch','PaperPosition',[0 0 5/2.54
  5*g/2.54]);
h=image(im);hold on;
%axis image;hold on;
a=get(h,'Parent');
set(a,'XTick',[ ],'YTick',[ ]);

x1=0.5*mf;x2=x1+mf;y=mf;
h4=text(mean([x1 x2]),y,'\begin{scriptsize}1␣
  cm\end{scriptsize}','FontSize',10,'HorizontalAlignment',...
    'center','VerticalAlignment','bottom');



set(0,'defaulttextinterpreter','none');

h1=line([x1 x2],[y y],'Color','k','LineWidth',1);hold on;
h2=line([x1 x1],[y-.1*mf y+.1*mf],'Color','k','LineWidth',1);hold
   on;
h3=line([x2 x2],[y-.1*mf y+.1*mf],'Color','k','LineWidth',1);hold
   on;
%arrow
x=237;y=266;d=60;D=30
a1=line([x x+d],[y y-d],'Color','k','LineWidth',1);hold on;
a2=line([x+D x x],[y y y-D],'Color','k','LineWidth',1);hold on;
air=text(x+d,y-d,'Air␣
  bubble','FontSize',12,'HorizontalAlignment','left',...
    'VerticalAlignment','bottom');


laprint(2,'/home/jonas/Documents/Latex/airbobble2','Width',5,...
    'ScaleFonts','off');
hold off;
```

C.2.10 Figure 12: encapsulation of oil lens

```
clear all;close
  all;magfic=(sqrt((333-366)^2+(752-244)^2)*2)/(24-13);
k=4;
img=getimg('/home/jonas/Pictures/2008-06-23/IMG_8418.JPG',k);
mf=magfic/k;


x=.13;X=0.8;y=.4;Y=.65;
ymin=round(1+y*size(img,1));
```

```
ymax=round(Y*size(img,1));
xmin=round(1+x*size(img,2));
xmax=round(X*size(img,2));

im=img(ymin:ymax,xmin:xmax,:);
g=size(im,1)/size(im,2);
h=figure('PaperUnits','inch','PaperPosition',[0 0 12/2.54 12*g/2.54]);
h=image(im);hold on;
axis image;hold on;
a=get(h,'Parent');
set(a,'XTick',[ ],'YTick',[ ]);

set(0,'defaulttextinterpreter','none');
x1=10;x2=x1+mf;y=25;
h1=line([x1 x2],[y y],'Color','k','LineWidth',1);hold on;
h2=line([x1 x1],[y-.1*mf y+.1*mf],'Color','k','LineWidth',1);hold on;
h3=line([x2 x2],[y-.1*mf y+.1*mf],'Color','k','LineWidth',1);hold on;
h4=text(250,95,'Oil lens','FontSize',12,'Color',[1 1 1],'HorizontalAlignment','center','VerticalAlignment','middle');
x1=10;x2=x1+mf;y=25;
h4=text(mean([x1 x2]),y,'\begin{footnotesize}1 cm\end{footnotesize}','FontSize',12,'HorizontalAlignment',...
    'center','VerticalAlignment','bottom');

laprint(1,'/home/jonas/Documents/Latex/oillens','Width',12,...
    'ScaleFonts','on');
hold off;
```

C.2.11 Figure 13: sample definitions

```
clear all
poster=1;
figure(1);
colds=imread(...
    '/home/jonas/Documents/Latex/2008-07-12/_MG_8894.jpg');
magfic=size(colds,1)/16.3;
l=size(colds,1);
colds=colds(round(0.55*l):round(0.9*l),...
    round(0.2*l):round(1.2*l),:);

nrx=1:1:size(colds,2)/magfic;
for i=1:length(nrx)
xtickl{1,i}=' ';
end
xtick=nrx*magfic;

```

```
nry=1:1:size(colds,1)/magfic;
for i=1:length(nry)
       ytickl{1,i}=' ';
end
ytick=nry*magfic;

set(gcf,'Position',[600 1000 size(colds,2) size(colds,1)])
set(gcf,'PaperUnits','points','PaperPosition',[1 1 size(colds,2) size(colds,1)])
h=image(colds);
a=get(h,'Parent');
set(a,'XTick',[ ],'YTick',[ ])

set(0,'defaulttextinterpreter','Tex')
NOI=text(magfic*3.2,magfic*2,'NOI','Fontsize',22);
set(NOI,'Position',[magfic*.5 magfic*3.4]); hold on;

NOIp=text(magfic*2,magfic*2,'NOI+','Fontsize',22);
set(NOIp,'Position',[magfic*.5 magfic*1.6])

OI=text(magfic*3.2,magfic*2,'OI','Fontsize',22,'Color',[1 1 1]);
set(OI,'Position',[magfic*11 magfic*3.9]); hold on;

OIp=text(magfic*3.2,magfic*2,'OI+','Fontsize',22,'Color',[0 0 0]);
set(OIp,'Position',[magfic*11 magfic*2.1]); hold on;

x1=0.5*magfic;x2=x1+magfic;y=5.2*magfic;
h1=line([x1 x2],[y y],'Color','k','LineWidth',2);
h2=line([x1 x1],[y-.1*magfic y+.1*magfic],'Color','k','LineWidth',2);
h3=line([x2 x2],[y-.1*magfic y+.1*magfic],'Color','k','LineWidth',2);
h4=text(mean([x1 x2]),y-5,'1 cm','FontSize',18,'HorizontalAlignment','center',...
    'VerticalAlignment','bottom');

    if poster==0;

laprint(1,'/home/jonas/Documents/Latex/colds','Width',12,...
    'ScaleFonts','off')
print('-depsc2','/home/jonas/Documents/Latex/colds.eps')
hold off;

    elseif poster==1

laprint(1,'/home/jonas/Documents/Latex/poster/colds','Width',...
    18,'ScaleFonts','off')
print('-depsc2','/home/jonas/Documents/Latex/poster/colds.eps')
hold off;
```

```

    end;
    hold off;
```

C.2.12 Figure 14: test of oil content measurements

```
close all;
test=xlsread(['/home/jonas/Documents/oilexp/'...
    'Oilcapturetest/oilcapturetest.xls']);
test=test(2:end,:);
oil=test(:,1);
oil_m=test(:,4)-test(:,3);
x=[0 3.5];
err=ones(size(oil))*0.05;%error oil
Err=sqrt(2*err.^2);%error oilmeasurement
hold off;

%Text*************************************
s=std(oil_m-oil);
m=mean(oil_m-oil);
c=corrcoef(oil_m,oil);
x1='\begin{small}';
x2='\end{small}';
Cor=[x1 'Correlation␣coef:␣' sprintf('%0.3g',c(1,2)) x2];
Mean=[x1 'Mean:␣' sprintf('%0.2g',m) '$\mathrm{g}$' x2];
Error=[x1 'Error' x2];
Std=[x1 'STD:␣' sprintf('%0.2g',s) '$\mathrm{g}$' x2];
Tx=strvcat(Cor,'␣',Error,Mean,Std);

%***************************************

figure(1)

e1=errorbarxy(oil_m,oil,Err,err,Err,err);hold on
set(e1,'MarkerSize',3,'Marker','o')

h2=plot(x,x,'k:','LineWidth',1);hold on;

tx=text(2,2,'␣');

L=legend([e1 h2 tx tx tx tx tx],[x1 'Measurements' x2],[x1 'oil␣
  $=$␣measured␣oil' x2],[x1 x2],Cor,Error,Mean,Std);
set(L,'Location','Best','Box','off','FontSize',20);

set(gca,'Xlim',x,'Ylim',x,'TickDir','out','XTick',[1:3],...
'YTick',[1:3],'XMinorTick','on','YMinorTick','on','Box','off');
lim=[1 2 3];
liml{1}=char([x1 '1' x2]);liml{2}=[x1 '2' x2];liml{3}=[x1 '3'
  x2];
```

```
set(gca,'XTick',lim,'YTick',lim,...
    'XTickLabel',liml,'YTickLabel',liml);


P=get(gca,'Position');
P=(P(3)-P(1))/(P(4)-P(2));
dlab=-0.3;
y=get(gca,'Ylim');
y=mean(y);
ylab=text(dlab,y,[x1 'Oil␣in␣sample␣($\mathrm{g}$)'
  x2],'Rotation',90,'HorizontalAlignment','center');

x=get(gca,'Xlim');
x=mean(x);
xlab=text(x,dlab*1.3,[x1 'Oil␣measured␣($\mathrm{g}$)'
  x2],'Rotation',0,'HorizontalAlignment','center');
daspect(0.6,1)
set(L,'position',[0.1 0.4288 0.8030 0.4840])
set(0,'defaulttextinterpreter'...
    ,'none')
laprint(1,...
    '/home/jonas/Documents/Latex/oiltest','Width',7.5)
```

C.2.13 Figure 15: tools for accumulating oil

```
poster=1;
figure(1);
oilcap=imread('/home/jonas/Documents/Latex/oilcapture.jpg');
set(gcf,'Position',[1 1 size(oilcap,2) size(oilcap,1)])
set(gcf,'PaperUnits','points','PaperPosition',[1 1
  size(oilcap,2) size(oilcap,1)])
h=image(oilcap);
a=get(h,'Parent');
set(a,'XTick',[ ],'YTick',[ ],'TickDir','out')

t1=text(100,100,'Shield','Fontsize',22);
t2=text(480,250,'Tube','Fontsize',22);

if poster==0;
    laprint(1,'/home/jonas/Documents/Latex/oilcapture','Width',6)
    print('-depsc2','/home/jonas/Documents/Latex/oilcapture.eps')
    hold off;
elseif poster==1;
    laprint(1,...
    '/home/jonas/Documents/Latex/poster/oilcapture','Width',6)
    print('-depsc2',...
    '/home/jonas/Documents/Latex/poster/oilcapture.eps')
    hold off;
end
```

```
figure(2)
tube=imread('/home/jonas/Documents/Latex/tube.jpg');
set(gcf,'Position',[1 1 size(tube,2) size(tube,1)])
set(gcf,'PaperUnits','points','PaperPosition',[1 1 size(tube,2)
  size(tube,1)])
h=image(tube);
a=get(h,'Parent');
set(a,'XTick',[ ],'YTick',[ ]);

t2=text(145,640,'Hole','Fontsize',22);

if poster==0;

    laprint(2,'/home/jonas/Documents/Latex/tube','Width',6)
    print('-depsc2','/home/jonas/Documents/Latex/tube.eps')
    hold off;

elseif poster==1;

    laprint(2,'/home/jonas/Documents/Latex/poster/tube','Width',6)
    print('-depsc2','/home/jonas/Documents/Latex/poster/tube.eps')
    hold off;

end
```

C.2.14 Figure 20, 23(a) and 18: EXP14

```
close all; load EXP;
poster=0;
PLOT=3;
screen=[1 1 2480 1050];
ThicknessFit=EXP(14).th_fit;

fit14

p=EXP(14).profiles;
EXP(14).tp=addsurfacetemp(14);
FU=EXP(14).tx(find(EXP(14).tx(:,2)==4),1);
start=EXP(14).tx(find(EXP(14).tx(:,2)==3),1);
if PLOT==1;
    li='LineWidth';
    poster=0;
    if poster==1
        lw=2;
        st='\begin{footnotesize}';
        ss='\end{footnotesize}';
    elseif poster==0
```

```
        lw=0.5;
        st=' ';
    end;
    of=EXP(14).of;
    of_text=EXP(14).of_text;
    of(:,1:2)=of(:,1:2)-start;
    tx=EXP(14).tx;tx(:,1)=tx(:,1)-start;

    YMIN=0;
    YMAX=max(of(:,3)+of(:,4)+0.5);
    o_start=tx(find(tx(:,2)==7),1);%oil on surface
    EXP_end=tx(find(tx(:,2)==2),1);%EXP stopped
    XMIN=o_start-1/12;
    XMAX=EXP_end+1/12;
    m=mean(of(:,3))/50;

    for i=1:length(of(:,1));
        f=plot([of(i,1) of(i,2)],[of(i,3) of(i,3)],li,lw);hold
          on;%Estimate
           plot([of(i,1) of(i,1)],[of(i,3)-m
             of(i,3)+m],li,lw);hold on;
           plot([of(i,2) of(i,2)],[of(i,3)-m
             of(i,3)+m],li,lw);hold on;

           if of(i,5)>0
           est=plot([of(i,1) of(i,2)],[of(i,3)+of(i,5)
             of(i,3)+of(i,5)],'g',li,lw);hold on;%Estimate
             including lost droplets
           end;

            e=plot([of(i,1) of(i,2)],[of(i,3)+of(i,4)
              of(i,3)+of(i,4)],'r',li,lw);hold on;%Upper error
           plot([of(i,1) of(i,2)],[of(i,3)-of(i,4)
             of(i,3)-of(i,4)],'r',li,lw);hold on;%Lower error
        if of(i,3)<30
            try
            TEXT=text(mean([of(i,1)
              of(i,2)]),of(i,3)+of(i,4)+0.5,of_text(i,:),...
                'rotation',90,'HorizontalAlignment','Left',...
                'VerticalAlignment','middle');hold on;
            end
        else
            try
            TEXT=text(mean([of(i,1)
              of(i,2)]),of(i,3)-of(i,4)-0.5,of_text(i,:),...
                'rotation',90,'HorizontalAlignment','Right',...
                'VerticalAlignment','middle');hold on;
            end;
        end;
    end;
```

```

pstop=plot([EXP_end EXP_end],[0
  max(get(gca,'Ylim'))*0.35],'--k',li,lw);
stop=text(EXP_end-0.02,max(get(gca,'Ylim'))*0.05,'EXP14␣
  stopped','rotation',90,'HorizontalAlignment','left',...
    'VerticalAlignment','bottom');
o=area([o_start EXP_end],max(get(gca,'Ylim'))*[1 1]/25,0);
set(o,'FaceColor','black','LineStyle','none');

set(gca,'Ylim',[0 60],'Xlim',[XMIN XMAX],li,lw);

%Statistical
%parameters*************************
DT=of(:,2)-of(:,1);
T=sum(DT);%Length of measuring period
W=DT/T;%Weighting factor
OF=sum(W.*of(:,3));

set(gca,'TickDir','out','XMinorTick','on','YMinorTick',...
    'on','Box','off');
set(gca,'XTick',[0:1:100],'XTickLabel',[0:1:100])
if poster==0;
l=legend([o f e est TEXT TEXT TEXT TEXT TEXT TEXT],'Period␣of␣
  oil␣flow','Single␣channel␣flow␣rate','Uncertainty␣in␣flow␣
  rate␣␣',...
    'Estimated␣flow␣rate', 'including␣lost␣droplets','␣','D:␣
      Oil␣drops␣lost','L:␣Little␣oil␣lost','WIO:␣Water␣(left)␣
      In␣Oil');
elseif poster==1;
l=legend([o f e est TEXT TEXT],'Period␣of␣oil␣flow','Single␣
  channel␣flow␣rate','Uncertainty␣in␣flow␣rate␣␣',...
    'Estimated␣flow␣rate', 'including␣lost␣droplets');

    TT=text(6.1,30,strvcat('D:␣Oil␣drops␣lost','L:␣Little␣oil␣
      lost','WIO:␣Water␣(left)␣In␣Oil'));
end
set(l,'Location','NorthWest','Box','off');
set(l,'Position',[0.1288 0.5154 0.2763 0.455])
   ylabel('Grams␣pr.␣day');
%xlabel('Days');

if poster==0;
laprint(1,'/home/jonas/Documents/Latex/EXP14flowrate')
elseif poster==1
    xlabel('Days␣from␣OR');
    set(l,'Position',[0.131 0.5154 0.2763 0.455])
set([l TT],'FontSize',15)
set(l,'Location','NorthWest')
      laprint(1,...
      '/home/jonas/Documents/Latex/poster/EXP14flowrate',...
```

```
        'ScaleFonts','on')
    end;
    hold off;
    elseif PLOT==2;fs=9;

    i=7;j=30;

    z=EXP(14).tp(1:end,i:j)';
    x=EXP(14).tp(1:end,1)'-start;
    y=EXP(14).pos(:,i:j)';


    [XI YI]=meshgrid(x,y);
        z=reshape(z,size(z,1)*size(z,2),1);
        x=reshape(XI,size(z,1)*size(z,2),1);
        y=reshape(YI,size(z,1)*size(z,2),1);
        i=find(~isnan(z));
        z=z(i,1);
        x=x(i,1);
        y=y(i,1);


    ZI=griddata(x,y,z,XI,YI);%


    [i j]=find(ZI==NaN);

    for h=1:length(i)
        try;
            ZI(i(k),j(k))=ZI(i(k),j(k)-1);
        end;
    end;

    scrsz =[1 1 2480 1050];
    figure(2)
    set(gcf,'Units','points')
    w=580;h=300;
    width=w*0.0376;
    set(gcf,'Position',[0 0 w h])
    set(gcf,'PaperUnits','points','PaperPosition',[0 0 w h]);

    [c h1]=contourf(XI,YI,ZI,70);
    set(h1,'LineWidth',0.1);
    ax=gca;
    set(gca,'Xlim',[0 max(x)+1/6]);
    set(gca,'Ylim',[-18 1]);
    set(h1,'LineWidth',0.5);
    c1=colorbar;
    cbar=c1;
    set(c1,'Ylim',[-11,-1]);hold on;
```

```
    T=FU:1/(24*60):EXP(14).tp(end,1)+1;
    h2=area(T-start,EXP(14).th_fit(T),-18);
    %h2=area([FU T]-start,[0 ;EXP(16).th_fit(T)],-19.5);
    set(h2,'FaceColor','white','LineWidth',0.5);

        o_min=EXP(14).tx(find(EXP(14).tx(:,2)==7),1)-start;

    o_max=EXP(14).tx(find(EXP(14).tx(:,2)==10),1)-start;
    if isempty(o_max);
        o_max=EXP(14).tx(find(EXP(14).tx(:,2)==2),1)-start;
    end;
    oil=area([o_min o_max],[0 0],0.2);
    set(oil,'FaceColor','k','LineWidth',0.5);

    w_min=EXP(14).tx(find(EXP(14).tx(:,2)==16),1)-start;
    w_max=EXP(14).tx(find(EXP(14).tx(:,2)==17),1)-start;

    for i=1:length(w_min);
        wlight(i)=area([w_min(i) w_max(i)],[0 0],0.2);
        set(wlight(i),'FaceColor','yellow','LineWidth',0.5);
    end;

    slight_min=EXP(14).tx(find(EXP(14).tx(:,2)==18),1)-start;
    slight_max=EXP(14).tx(find(EXP(14).tx(:,2)==19),1)-start;

    for i=1:length(slight_min);
        slight(i)=area([slight_min(i) slight_max(i)],[0.0
          0.0],0.2);
        set(slight(i),'FaceColor','red','LineWidth',0.5);
    end;

    i_min=EXP(14).tx(find(EXP(14).tx(:,2)==9),1)-start;
    i_max=EXP(14).tx(find(EXP(14).tx(:,2)==6),1)-start;
    ins=area([i_min i_max],[0 0],0.2);
    set(ins,'FaceColor','cyan','LineWidth',0.5);
    set(gca,'Box','off')
    set(gca,'FontSize',fs-2)


    ylabel('Depth␣(cm)')
    title(c1,'$^\circ␣\mathrm{C}$','FontSize',fs);

    hold on;


tx=EXP(14).tx;
tx(:,1)=tx(:,1)-start;
g=-17.2;

```

```
OR=find(tx(:,2)==3);
for i=1:length(OR);
    or=text(tx(OR(i),1),g,'OR','FontSize',fs);
    set(or,'HorizontalAlignment','center')
end;

OT=find(tx(:,2)==15);
for i=1:length(OT);
    ot=text(tx(OT(i),1),g,'OT','FontSize',fs);
    set(ot,'HorizontalAlignment','center')
end;

try;
    OV=find(tx(:,2)==12);
    for i=1:length(OV);
        ov=text(tx(OV(i),1),g,'OV','FontSize',fs);
        set(ov,'HorizontalAlignment','center')
    end;
end;

B=find(tx(:,2)==14);
for i=1:length(B);
    b=text(tx(B(i),1),g,'B','FontSize',fs);
    set(b,'HorizontalAlignment','center')
end;
C=find(tx(:,2)==8);
for i=1:length(C);
    c=text(tx(C(i),1),g,'1-2C','FontSize',fs);
    set(c,'HorizontalAlignment','right');
end;

    B=text(0,0,'␣');
    C=text(0,0,'␣');
    OT=text(0,0,'␣');
    OR=text(0,0,'␣');
    E=text(0,0,'␣');
    if poster==0;
    TEXT='\vspace{-2cm}␣\hspace{-4.3mm}\begin{tabular}{r@{:␣}l}R&Bottom␣Heating␣off\\C&Core␣taken\\OR&Oil␣Release\\␣OT␣&␣Oil␣starts␣seeping␣up␣along␣tank␣\end{tabular}';
    elseif poster==1;
    TEXT='\vspace{-2cm}␣\hspace{-4.3mm}\begin{tabular}{r@{:␣}l}R&Bottom␣Heating␣off\\C&Core␣taken\\OR&Oil␣Release\\␣OT␣&␣Oil␣seeping␣up␣along␣tank\end{tabular}';
    end;
    ttt=text(-2.2000,-13,TEXT);hold on;
    text(-2.2,g,'EXP14:');
    l=legend([E wlight(1) slight(1) ins oil],'Events',...
        'Weak␣light','Strong␣light','Insolation␣on␣ice','Oil␣flow␣to␣surface');
```

```

    set(l,'Position',[0.22 0.32 0.02 0.08],'Box',...
        'off','FontSize',fs);

    set(0,'defaulttextinterpreter','none');
    set(gca,'FontSize',fs);
    set(gca,'Clim',[-11 -1],'Xlim',[FU-start EXP(14).tp(end,1)-start]);
    set(cbar,'OuterPosition', [0.905 00 0.04 1]);
    set(l,'CameraViewAngle',15);
    set(l,'DataAspectRatio',[2 1 2])
    set(l,'Position',[0.015 0.19 0.3000 0.4000]);
    set(ttt,'Position',[-2.2000 -13 0]);
    set(h1,'LineWidth',0.15);

    if poster==0;

    laprint(2,'/home/jonas/Documents/Latex/EXP14overview',...
        'Width',width,'asonscreen','on')
    elseif poster==1;
         set([l ttt],'FontSize',17);
      set(l,'Position',[0.015 0.22 0.3000 0.4000]);
     xlabel('Days from OR');
     text(2.5,1.7,'Days from OR','HorizontalAlignment','center');
     laprint(2,...
        '/home/jonas/Documents/Latex/poster/EXP14overview',...
        'Width',width,'asonscreen','on')
    end
elseif PLOT==3;

figure(5);


        xlabels{1} = 'Temperature [C]';
        xlabels{2} = 'Bulk salinity [ppt]';
        ylabels{1} = 'Depth(cm)';
        ylabels{2} = 'Depth(cm)';

    [ax temp NOI]=plotxx(p(1).t(:,2),...
        p(1).t(:,1),p(1).s(:,2),p(1).s(:,1),...
        xlabels,ylabels);hold on;
        set(NOI,'LineStyle','none');
        set(ax(1),'YLim',[-11.4 0]);
        set(ax(2),'YLim',[-11.4 0]);
        title(sprintf('EXP14: TS-profiles at T=%0.2g days',...
            datenum(p(1).d)-start));
        OI=errorbar(p(1).s(:,2),p(1).s(:,1),p(1).s(:,3),...
            'Parent',ax(2),'Color','r','LineStyle','none');

    set(temp,'Marker','square')
```

```
    set(NOI,'Marker','square','MarkerFaceColor','blue')
    set(OI,'Marker','square','MarkerFaceColor','green')

    grid minor

    time=24*(datenum(p(1).d)-datenum(p(1).d));
    Legend([temp OI],'Temp␣After␣OR','After␣OR␣(OI␣profile)');


%*************************************************
figure(6)
       set(gcf,'defaulttextinterpreter','none')
       depth=min(p(1).s(:,1)-p(1).s(:,3))*ones(1,2);
       width=[0 110];
       water1=area(width,depth,-20); hold on
       bx=gca;hold on;
       gray=[.8 .8 .8];
       set(water1,'FaceColor','gray');

       surface=-1*ones(1,2);
       width=[0 110];
       water2=area(width,depth,-20); hold on;
       bx=gca;hold on;

       p.bvf(find(p.bvf(:,2)>1),:)=[];
       ovf=errorbar(p(1).ovf(:,2)*1000,p(1).ovf(:,1),...
           p(1).ovf(:,3),'LineStyle','none','Color','k');hold on;
       bvfOI=errorbar(p(1).bvf(:,2)*100,p(1).bvf(:,1),...
           p(1).bvf(:,3),'LineStyle','none','Color',...
           'r','Parent',bx);


       set(ovf,'Marker','square','MarkerFaceColor','k');
       set(bvfOI,'Marker','square','MarkerFaceColor','green');
       t=text(-5,-5,'␣');
       L2=legend([ovf t bvfOI],'Oil␣($\mathrm{\permil}$)','␣','Brine␣($\mathrm{\%}$)');
       set(L2,'Location','SouthEast','Box','off');
              set(L2,'Position',[0.7 0.1315 0.3295 0.1577]);
       xl=xlabel(bx,'Volume␣fraction','Interpreter','none');
       ylabel(bx,'Depth␣(cm)');
       set(gca,'Ylim',[-14 -1],'Xlim',[0 50],'TickDir','out','Box','off');

       laprint(6,'/home/jonas/Documents/Latex/EXP14vf',...
           'options','factory','createview','on',...
           'viewfilename',...
           '/home/jonas/Documents/Latex/EXP14vf_view');
       hold off;
```

```
end;
```

C.2.15 Figure 19, 23(b) and 22: EXP16 and EXP17

```
clear all;close all; load EXP;PLOT=2;
IND=find(~isnan(EXP(16).tp(20,:)'));
EXP(16).tp=addsurfacetemp2(16);
EXP(16).tp=EXP(16).tp(:,IND);
EXP(16).pos=EXP(16).pos(:,IND);
FU=EXP(16).tx(find(EXP(16).tx(:,2)==4),1);
start=EXP(16).tp(1,1)+0.1389;
start=EXP(16).tx(find(EXP(16).tx(:,2)==3),1);
tx=EXP(17).tx;tx(:,1)=tx(:,1)-start;
poster=0;

if PLOT==1; figure(1) %Plot of flow rates

    li='LineWidth';

    if poster==1
        load('/home/jonas/Documents/Latex/poster/lw.mat')
        st='\begin{footnotesize}';
        ss='\end{footnotesize}';
    elseif poster==0
        lw=0.5;
        st=' ';
    end;

    of=EXP(17).of;
    of_text=EXP(17).of_text;
    of(:,1:2)=of(:,1:2)-start;
    tx=EXP(17).tx;tx(:,1)=tx(:,1)-start;

    YMIN=0;
    YMAX=max(of(:,3)+of(:,4)+0.5);
    o_start=tx(find(tx(:,2)==7),1);%oil on surface
    EXP_end=tx(find(tx(:,2)==2),1);%EXP stopped
    o_stop=tx(find(tx(:,2)==10),1);
    XMIN=o_start-1/12;
    XMAX=EXP_end;
    m=mean(of(:,3))/50;

    OF(1,:)=of(1,:)+of(2,:)+of(3,:);
    OF(1,4)=sqrt(of(1,4)^2+of(2,4)^2+of(3,4)^2);
    OF(1,1:2)=of(2,1:2);

    OF(2,:)=of(2,:);
    OF(2,3)=of(4,3)+of(5,3)+(of(4,3)+of(5,3))/2;
    OF(2,1:2)=of(5,1:2);
```

```

OF(3,:)=of(6,:);
OF(3,3)=3*of(6,3);
OF(3,1:2)=of(6,1:2);


OF=[OF;of(7:end,:)];

of=[OF(1,:);of];
clear text;
test{1,1}='3/3';
test{2,1}='2/3';
test{3,1}='1/3';
test{4,1}='A';
test{5,1}='A';
test{6,1}='A';
test{7,1}='A';
test{8,1}='A';



for i=1:length(of(:,1));
if i==2
    k=2;
    dx=0.05;
else
    k=1;
    dx=0;
end;

    f1=plot([dx+of(i,1) dx+of(i,2)],[of(i,3) of(i,3)],li,lw);hold on;%Estimate
    if i>1&i<8
    f2=plot([dx+of(i,k) dx+of(i,k)],[of(i,3)+of(i,4) of(i,3)-of(i,4)],'r',li,lw);hold on;
    end
    e=plot([dx+of(i,1) dx+of(i,2)],[of(i,3)+of(i,4) of(i,3)+of(i,4)],'r',li,lw);hold on;%Upper error
       plot([dx+of(i,1) dx+of(i,2)],[of(i,3)-of(i,4) of(i,3)-of(i,4)],'r',li,lw);hold on;%Lower error
        try
        TEXT=text(mean([OF(i,1) OF(i,2)]),OF(i,3)+OF(i,4)+0.5,test(i,1),...
            'HorizontalAlignment','center',...
            'VerticalAlignment','middle');hold on;
        end

    try
       total=plot(mean([OF(i,1) OF(i,2)]),OF(i,3),'bs','MarkerFaceColor',[0 0
```

```
          1],'MarkerSize',5,li,lw);hold on;

      end;

   end;

    E=plot([EXP_end EXP_end],[0
      max(get(gca,'Ylim'))*0.35],'--k');hold on;
   set(E,li,lw);
   stop=text(EXP_end-0.02,max(get(gca,'Ylim'))*0.05,'EXP17␣
     stopped','rotation',90,'HorizontalAlignment','left',...
       'VerticalAlignment','bottom');
   o=area([o_start o_stop],max(get(gca,'Ylim'))*[1 1]/25,0);
   set(o,'FaceColor','black','LineStyle','none');

   %set(l,'Position',[0.2 0.8 0.07 0.06])
   set(gca,'Xlim',[XMIN XMAX+2/100],li,lw);

   %Statistical
   %parameters*******************************************
   DT=of(:,2)-of(:,1);
   T=sum(DT);%Length of measuring period
   W=DT/T;%Weighting factor
   OF=sum(W.*of(:,3));

   set(gca,'TickDir','out','XTick',[7:14],'XMinorTick','off',...
       'YMinorTick','on','Box','off');

   l=legend([o f1 e total TEXT TEXT TEXT TEXT TEXT],'Period␣of␣
     oil␣flow','Single␣channel␣flow␣rate','Uncertainty␣in␣flow␣
     rate','Estimated␣flow␣rate␣for','the␣total␣area','␣','A:␣For
     ␣the␣total␣area','Fraction:␣Measured␣brine␣','channels␣(out␣
     of␣total)');
   set(l,'Location','NorthEast','Box','off');
   set(l,'Position',[0.500 0.4354 0.2852 0.5055])

   ylabel('Grams␣pr.␣day');
   %xlabel('Days');
   set(gca,'XTick',[0:1:100],'XTickLabel',[0:1:100])
   set(0,'defaulttextinterpreter','none')

   if poster==0;
   laprint(1,'/home/jonas/Documents/Latex/EXP16flowrate')
   elseif poster==1
        xlabel('Days␣from␣OR');
   set(l,'FontSize',15)
   set(l,'Position',[ 0.44 0.49 0.3888 0.3244])
         set(E,li,lw);
         laprint(1,...
         '/home/jonas/Documents/Latex/poster/EXP16flowrate',...
```

```
        'ScaleFonts','on')
    end;
    hold off;


elseif PLOT==2; %Plot of temperature development/events
    fs=9;
    fit16;
    scrsz=[1 1 2480 1050];
    figure(2)
    set(gcf,'Units','points')
    w=580;h=320;
    width=w*0.0376;
    set(gcf,'Position',[0 0 w h])
    set(gcf,'PaperUnits','points','PaperPosition',[0 0 w h])
    z=EXP(16).tp(1:end,6:end)';
    x=EXP(16).tp(1:end,1)'-start;
    y=EXP(16).pos(:,6:end)';

    [c1 h1]=contourf(x,y,z,70);hold on;
    if poster==0;
        set(h1,'LineWidth',0.2)
    elseif poster==1;
        set(h1,'LineWidth',0.5)
    end


    T=FU:1/(24*60):EXP(16).tp(end,1);
    %h2=area([start-2 T]-start,[0 ;EXP(16).th_fit(T)],-19.5);
    h2=area(T-start,EXP(16).th_fit(T),-19.5);
    set(h2,'FaceColor','white','EdgeColor',[1 1 1]);
    c1=colorbar;
    cbar=c1;
    set(c1,'Ylim',[-11,-1]);hold on;

    %xlabel('\caption{Fuel Metabolism}','FontSize',fs);
    ylabel('Depth␣(cm)','FontSize',fs);
    title(c1,'$^\circ␣\mathrm{C}$','FontSize',fs);

%*****************************************************************
%EVENTS
    t(2).x=EXP(17).tx;
    t(2).x(:,1)=t(2).x(:,1)-start;
    t(1).x=EXP(16).tx;
    t(1).x(:,1)=t(1).x(:,1)-start;
    t(1).d=-19.5;
    t(2).d=-18.7;
    t(1).e='EXP16:';
    t(2).e='EXP17:';

```

```
for g=1:2
    try
    if g==2
        PR=find(t(g).x(:,2)==13);
        for i=1:length(PR);
            pr=text(t(g).x(PR(i),1),t(g).d,'PR','FontSize',fs);
        end;
    end;
end;

try
    C=find(t(g).x(:,2)==8);
    for i=1:length(C);
        if g==1
            if i==2
                c=text(t(g).x(C(i),1),t(g).d,'2C',...
                    'FontSize',fs);
                set(c,'HorizontalAlignment','center')
                elseif i==3
                cc=text(t(g).x(C(i),1),t(g).d,...
                    '3-5C','FontSize',fs);
                set(cc,'HorizontalAlignment','center')
            end;
        elseif g==2
            if i==1
               c=text(t(g).x(C(i),1),t(g).d,'1C','FontSize',fs);
            else;
               c=text(t(g).x(C(i),1),t(g).d,'2-6C',...
                   'FontSize',fs);
            end;
            set(c,'HorizontalAlignment','center')
            else
        end
    end;
end;


try
    OR=find(t(g).x(:,2)==3);
    if g==1
    or=text(t(g).x(OR,1),t(g).d,'1C/OR','FontSize',fs,...
        'BackgroundColor','none');
    elseif g==2
    or=text(t(g).x(OR,1),t(g).d,'OR','FontSize',fs,...
        'BackgroundColor','none');
    end;
    set(or,'HorizontalAlignment','center');
end;
```

```
    try
        OT=find(t(g).x(:,2)==15);
        for i=1:length(OT);
            ot=text(t(g).x(OT(i),1),t(g).d,'OT','FontSize',fs);
            set(ot,'HorizontalAlignment','center')
        end;
    end;

    try
        OV=find(t(g).x(:,2)==12);
        for i=1:length(OV);
            ov=text(t(g).x(OV(i),1),t(g).d,'OV','FontSize',fs);
            set(ov,'HorizontalAlignment','center')
        end;
    end;


        text(FU-start+0.2,t(g).d,t(g).e,'FontSize',fs);
        clear OV OT OR PR
    end;

    g=2;

    o_min=t(g).x(find(t(g).x(:,2)==7),1);
    o_max=t(g).x(find(t(g).x(:,2)==10),1);

    oil=area([o_min o_max],[0 0],0.2);
    set(oil,'FaceColor','k','LineWidth',0.5);


    i_min=t(g).x(find(t(g).x(:,2)==9),1);
    i_max=t(g).x(find(t(g).x(:,2)==6),1);

    ins=area([i_min i_max],[0 0],0.2);
    set(ins,'FaceColor','cyan','LineWidth',0.5);

    l_min=datenum('24-Jun-2008␣12:40:03')-start;
    l_max=datenum('08-Jul-2008␣14:49:56')-start;

    light=area([l_min l_max],[0.2 0.2],0.4);
    set(light,'FaceColor','yellow','LineWidth',0.5);

    l=legend([c oil light ins c ov or pr ot ot],'Events','EXP17:␣
      Oil␣flow','Weak␣light',...
        'Insolation␣on␣ice','C:␣Core␣taken','OV:␣Oil␣Visible␣Under
          ␣Surface',...
        'OR:␣Oil␣Release','PR:␣Pressure␣Release','OT:␣Oil␣starts␣
          seeping␣up␣along','tank␣walls');
   set(l,'Position',[0.455 0.3 0.2662 0.4575])
    set(l,'Box','off','FontSize',fs);
```

```
    set(gca,'Box','off','FontSize',fs,'TickDir','out');
    set(0,'defaulttextinterpreter','none')
    set(gca,'Xlim',[FU-start
      EXP(16).tp(end,1)-start+0.2],'Ylim',[-20 1]);

    set([gca l],'FontSize',fs);
    set(gca,'Clim',[-11 -1]);

set(cbar,'OuterPosition', [0.905 00 0.04 1])
set(l,'Box','off','FontSize',fs);
set(h1,'LineWidth',0.15);
set(l,'CameraViewAngle',8);
set(l,'DataAspectRatio',[2 1 2])


if poster==0;
    text(-3.5,1,'Definitions:');hold on;
    text(10,1,'Melting␣ice');hold on
    text(-1,1,'Growing␣ice');hold on;
    text(14.8,1,'Cooled␣ice');
        laprint(2,...
        '/home/jonas/Documents/Latex/EXP16overview',...
        'Width',width,'asonscreen','on');
elseif poster==1;
    xlabel('Days␣from␣OR');
    text(-3.5,1,'Definitions:');hold on;
    text(10,1,'Melting␣ice');hold on
    text(-1,1,'Growing␣ice');hold on;
    text(14.8,1,'Cooled␣ice');
    laprint(2,'/home/jonas/Documents/Latex/poster/EXP16overview',...
        'Width',width,'asonscreen','on');
end

elseif PLOT==3
     li='LineWidth';
    if poster==1
        load('/home/jonas/Documents/Latex/poster/lw.mat')
        st='\begin{footnotesize}';
        ss='\end{footnotesize}';
    elseif poster==0
        lw=0.5;
        st='␣';
    end;

    p=EXP(17).profiles;
    P=EXP(16).profiles;
    pp=EXP(14).profiles;

    for i=1:length(p)
        m(i)=max(p(i).s(:,4)./p(i).s(:,5));
```

```
    end;
    for i=1:length(P)
        M(i)=max(P(i).s(:,4)./P(i).s(:,5));
    end;

    for i=1:length(pp)
        mm(i)=max(pp(i).s(:,4)./pp(i).s(:,5));
    end;

    sclf=max([m M mm]);


    clear h

figure(7);

        dx=0.1;
        color={'r','g','b','c','y'};
        for i=1:5;
            Ip=length(p);
            if i>Ip
                [h(17,i).l h(17,i).m]=plotydy(p(Ip).s(:,1),...
                    p(Ip).s(:,3),p(Ip).s(:,2),dx);hold on;
                set([h(17,i).l h(17,i).m],'Visible','off');
            else
                [h(17,i).l h(17,i).m]=plotydy(p(i).s(:,1),...
                    p(i).s(:,3),p(i).s(:,2),dx);hold on;%NOIw

                H=length(h(17,i).m);
                for j=1:H;
                    markc=1-(p(i).s(j,4)/p(i).s(j,5)/sclf);
                    try
                    set(h(17,i).m(j),'MarkerFaceColor',[markc markc
                       markc])
                    end
                end;
            end;

            Ipp=length(pp);

            if i>Ipp
                [h(14,i).l h(14,i).m]=plotydy(pp(Ipp).s(:,1),...
                    pp(Ipp).s(:,3),pp(Ipp).s(:,2),dx);hold on;
                set([h(14,i).l h(14,i).m],'Visible','off');
            else
                [h(14,i).l
                  h(14,i).m]=plotydy(pp(i).s(:,1),pp(i).s(:,3),...
                    pp(i).s(:,2),dx);hold on;

                H=length(h(14,i).m);
```

```
                for j=1:H;
                    markc=1-(pp(i).s(j,4)/pp(i).s(j,5)/sclf);
                    try
                    set(h(14,i).m(j),'MarkerFaceColor',[markc markc
                       markc])
                    end
                end;
            end

            IP=length(P);

            if i>IP
                [h(16,i).l h(16,i).m]=plotydy(P(IP).s(:,1),...
                    P(IP).s(:,3),P(IP).s(:,2),dx);hold on;
                set([h(14,i).l h(14,i).m],'Visible','off');
            else
                [h(16,i).l h(16,i).m]=plotydy(P(i).s(:,1),...
                    P(i).s(:,3),P(i).s(:,2),dx);hold on;

                H=length(h(16,i).m);
                for j=1:H;
                    markc=1-(P(i).s(j,4)/P(i).s(j,5)/sclf);
                    try
                    set(h(16,i).m(j),'MarkerFaceColor',[markc markc
                       markc])
                    end
                end;
            end

            set([h(17,i).l],'Color',char(color(i)));
            set([h(17,i).m],'Marker','s','Color',char(color(i)),...
                'MarkerEdgeColor',char(color(i)),li,lw)

            set([h(16,i).l],'Color',char(color(i)),li,lw)
            set([h(16,i).m],'Marker','o','Color',...
                char(color(i)),'MarkerEdgeColor',...
                char(color(i)),li,lw)

            set([h(14,i).l],'Color',char(color(i)),li,lw);
            set([h(14,i).m],'Marker','>',...
                'Color',char(color(i)),'MarkerEdgeColor',...
                char(color(i)),li,lw)


            set([h(17,i).m h(16,i).m
              h(14,i).m],'MarkerSize',8,li,lw);
            set([h(17,i).l h(16,i).l
              h(14,i).l],li,lw,'LineStyle',':',li,lw);
            col(1,i)=plot(2,2,'LineStyle','none','Marker','s',...
                'MarkerEdgeColor','white','MarkerFaceColor',...
```

```
                char(color(i)),'Visible','off');

        end;
        mark(1,1)=plot(2,2,'LineStyle','none','Marker','s',...
            'MarkerEdgeColor','k','Visible','off',li,lw);
        mark(1,2)=plot(2,2,'LineStyle','none','Marker','o',...
            'MarkerEdgeColor','k','Visible','off',li,lw);
        mark(1,3)=plot(2,2,'LineStyle','none','Marker','>',...
            'MarkerEdgeColor','k','Visible','off',li,lw);
        ltype(1,1)=plot(2,2,'k-','Visible','off',li,lw);
        ltype(1,2)=plot(2,2,'k--','Visible','off',li,lw);
        ltype(1,3)=plot(2,2,':','Visible','off',li,lw);
        if poster==1;
        ltype(1,4)=plot(2,2,'k-.','Visible','off',li,lw);
        end
        oil(1,1)=plot(2,2,'LineStyle','none','Marker','s',...
            'MarkerEdgeColor','k','MarkerFaceColor',[0 0
              0],'Visible','off');
        oil(1,2)=plot(2,2,'LineStyle','none','Marker','s',...
            'MarkerEdgeColor','k','MarkerFaceColor',[0.7 0.7
              0.7],'Visible','off');
        oil(1,3)=plot(2,2,'LineStyle','none','Marker','s',...
            'MarkerEdgeColor','k','MarkerFaceColor',[1 1
              1],'Visible','off');
        cap=plot(2,2,'LineStyle','none','Marker','none',...
            'MarkerEdgeColor','k','MarkerFaceColor',[1 1
              1],'Visible','off',li,lw);
        set([h(16,1).l],'LineStyle','-',li,lw);
        set([h(16,2).l h(17,1).l
          h(14,1).l],'LineStyle','--',li,lw);
        set(h(16,5).m,li,lw)
        %xlabel('Bulk salinity ($\permil$)');
        ylabel('Depth␣(cm)');
if poster==0;
              l=legend([cap mark cap ltype cap col cap
                oil],'\textbf{Marker␣
                type}','EXP17','EXP16','EXP14','\textbf{Line␣
                type}',...
            'Growing␣ice','Melting␣ice','Cooled␣ice',...
            '\textbf{Line␣
              color}','C1','C2','C3','C4','C5','\textbf{Marker␣gray
              ␣level}',...
            [num2str(sclf*100,2) '␣wt\%␣
              (Oil)'],[num2str(sclf*(100-70),2) '␣wt\%'],['0.0␣
              wt\%'],...
                  'Box','off','Location','bestoutside');
elseif poster==1

        l=legend([cap mark cap ltype cap col cap
          oil],'\textbf{Marker␣
```

```
        type}','EXP17','EXP16','EXP14','\textbf{Line␣type}',...
          'Growing␣ice','Melting␣ice','Cooled␣ice','Oil␣on␣
            surface',...
          '\textbf{Line␣
            color}','C1','C2','C3','C4','C5','\textbf{Marker␣gray
            ␣level}',...
          [num2str(sclf*100,2) '␣wt\%␣
            (Oil)'],[num2str(sclf*(100-70),2) '␣wt\%'],['0.0␣
            wt\%'],...
                'Box','off','Location','bestoutside');
end;
      set(l,'Box','off','FontSize',14);
      set(l,'Position',[1 0.1 0.1298 0.8]);
      set(gca,'TickDir','out','Box','off')
      set(gca,'Xlim',[3 16],li,lw);
      set(0,'defaulttextinterpreter','none')

       if poster==0;
    laprint(7,'/home/jonas/Documents/Latex/salinityprofiles',...
          'createview','on','viewfilename',...
          '/home/jonas/Documents/Latex/salinityprofiles_view',...
            'asonscreen','on');
       elseif poster==1
           xlabel('Bulk␣salinity␣($\permil$)');
           set(l,'FontSize',15)
       laprint(7,...
           '/home/jonas/Documents/Latex/poster/salinityprofiles',...
          'createview','on','viewfilename',...
          ['/home/jonas/Documents/Latex/'...
          'poster/salinityprofiles_view'],...
            'asonscreen','on');
    end;
    hold off;

elseif PLOT==4
%*************************************************************
figure(6)
         ovf1=errorbar(p(3).ovf(:,2)*100,p(3).ovf(:,1),...
             p(3).ovf(:,3),'LineStyle','none','Color','k');hold on;
         bx=gca;
         set(bx,'Ylim',[-16 -2],'Xlim',[0 20]);

         ovf2=errorbar(p(2).ovf(:,2)*100,p(2).ovf(:,1),...
             p(2).ovf(:,3),'LineStyle','none','Color','k');hold on;
         bvf2=errorbar(p(2).bvf(:,2)*100,p(2).bvf(:,1),...
             p(2).bvf(:,3),'LineStyle','none','Color','r');hold on;
         bvf1=errorbar(p(3).bvf(:,2)*100,p(3).bvf(:,1),...
             p(3).bvf(:,3),'LineStyle','none','Color','r');hold on;
         bvfNOIw=errorbar(p(1).bvf(:,2)*100,p(1).bvf(:,1),...
             p(1).bvf(:,3),'LineStyle','none','Color','r');hold on;
```

```
        l=legend([ovf1 ovf2 bvf1 bvf2 bvfNOIw],...
            'Oil␣core␣#1','Oil␣core␣#2','Brine␣core␣#1','Brine␣
              core␣#2','Brine␣NOI␣warm␣ice');

       set(bvfNOIw,'Marker','o','MarkerFaceColor','blue')
       set(ovf1,'Marker','square','MarkerFaceColor','green')
       set(ovf2,'Marker','d','MarkerFaceColor','green')
       set(bvf1,'Marker','square','MarkerFaceColor','green')
       set(bvf2,'Marker','d','MarkerFaceColor','green')

       xlabel='Volume␣fraction␣[%]';
       ylabel='Depth(cm)';
       title('EXP17␣Volumefractions');

p=EXP(16).profiles;

figure(5);
       xlabels{1} = 'Temperature␣[C]';
       xlabels{2} = 'Bulk␣salinity␣[ppt]';
       ylabels{1} = 'Depth(cm)';
       ylabels{2} = 'Depth(cm)';

    [ax temp NOI]=plotxx(p(1).t(:,2),...
       p(1).t(:,1),p(1).s(:,2),...
       p(1).s(:,1),xlabels,ylabels);hold on;
       set(NOI,'Visible','off')
       set(ax(1),'YLim',[-16 0]);
       set(ax(2),'YLim',[-16 0]);
       %plot(ax(1),p(4).t(:,1),p(4).t(:,2));hold on;
       title('EXP16:␣Temperature␣and␣Salinity␣profile␣before␣OR')
       NOIc=errorbar(p(4).s(:,2),p(4).s(:,1),p(4).s(:,3),...
           'Parent',ax(2),'Color','r','LineStyle','none');hold on;
       NOIw=errorbar(p(1).s(:,2),p(1).s(:,1),p(1).s(:,3),...
           'Parent',ax(2),'Color','r','LineStyle','none');hold on;
       OI1c=errorbar(p(3).s(:,2),p(3).s(:,1),p(3).s(:,3),...
           'Parent',ax(2),'Color','r','LineStyle','none');hold on;
       OI2c=errorbar(p(2).s(:,2),p(2).s(:,1),p(2).s(:,3),...
           'Parent',ax(2),'Color','r','LineStyle','none');hold on;

elseif PLOT==5

    clear all; load EXP;Gr=[0.5 0.5 0.5];
    close all;figure(1)
    poster=1;
    li='LineWidth';
     if poster==1
       load('/home/jonas/Documents/Latex/poster/lw.mat')
       st='\begin{footnotesize}';
       ss='\end{footnotesize}';
    elseif poster==0
```

```
        lw=0.5;
        st=' ';
    end;


    set(gcf,'Position',[2000 500 500 500])
    p14=EXP(14).profiles;
    p16=EXP(16).profiles;
    p17=EXP(17).profiles;

    p14.ti=p14.t(find(p14.t(:,1)>-14&p14.t(:,1)<0.1),:);
    p14.ti_fit=polyfit(p14.ti(:,1),p14.ti(:,2),1);
    for i=1:length(p16)
    p16(i).ti=p16(i).t(find(p16(i).t(:,1)>-16),:);
    p16(i).ti_fit=polyfit(p16(i).ti(:,1),p16(i).ti(:,2),1);
    end;

    for i=1:length(p17)
    p17(i).ti=p17(i).t(find(p17(i).t(:,1)>-16),:);
    p17(i).ti_fit=polyfit(p17(i).ti(:,1),p17(i).ti(:,2),1);
    end;


    close all;
    hl11=plot(1*p14.t(:,2),p14.t(:,1),'r>',li,lw);hold on;
    hl11f=plot(1*polyval(p14.ti_fit,[0 -30]),[0 -30],'r--',li,lw);
    ax1=gca;
    set(ax1,'XColor','r','YColor','k',li,lw);

    h12=plot(1*p16(2).ti(:,2),p16(2).ti(:,1),'ro',...
        'Parent',ax1,li,lw);
    hold on;
    h12f=plot(1*polyval(p16(2).ti_fit,[0 -30]),[0
      -30],'r--','Parent',ax1,li,lw);hold on;
    if poster==1
        set([h12f h12 hl11 hl11f],'Color',Gr);hold on;
        set(ax1,'XColor',Gr);
    end;

    [to14 to14_fit]=oilonsurftempprof(14);
    g1=plot(1*to14(:,2),to14(:,1),'r>','Parent',ax1,li,lw);
    if poster==1
        set(g1,'Color',Gr);hold on;
    end;


    hold on;
    g1f=plot(1*polyval(to14_fit,[0 -30]),[0
      -30],'r-.','Parent',ax1,li,lw);hold on;
    ax2=axes('Position',get(ax1,'Position'),...
```

```
        'XAxisLocation','top',...
        'YAxisLocation','left',...
        'Color','none',...
        'XColor','k','YColor','k');
    h21=plot(p16(1).ti(:,2),p16(1).ti(:,1),'ko',...
        'Parent',ax2,li,lw);
    if poster==1
        set(g1f,'Color',Gr);hold on;
    end;

    hold on;
    h21f=plot(polyval(p16(1).ti_fit,[0 -30]),[0 -30],'k-','Parent',ax2,li,lw);
    h22=plot(p16(3).t(:,2),p16(3).t(:,1),'ko','Parent',ax2,li,lw);
    h22f=plot(polyval(p16(3).ti_fit,[0 -30]),[0 -30],'k:','Parent',ax2,li,lw);

    xt1=[-2.9:0.1:-1.5];

    for gg=1:length(xt1)
        if poster==0
        xt1l{1,gg}=['\' sprintf('textcolor{red}{ %0.1f }',xt1(1,gg))];
        elseif poster==1;
        xt1l{1,gg}=['\' sprintf('textcolor{gray}{ %0.1f }',xt1(1,gg))];
        end;
    end;

    set(ax2,'Color','none','XAxisLocation','top',...
        'YAxisLocation','left');
    set([ax1 ax2],'Box','off','TickDir','out');

    set([ax1],'YTick',[-15:2:-1],'XTick',...
        xt1,'XTickLabel',xt1l,li,lw);
    set([ax2],'YTick',[],'XTick',[-19:2:-3],...
        'XLim',[-15.5 -2.5],li,lw);
    set([ax2 ax1],'Ylim',[-16 0],li,lw);

    set(ax1,'XLim',[-2.25 -1.8],li,lw);

    hold off;

    ylabel(ax1,'Depth (cm)');

    set(0,'defaulttextinterpreter','none')
    tx=text(2,2,' ','Visible','off');hold on;
    exp16=plot(1,1,'k>','Visible','off',li,lw);hold on;
    exp14=plot(1,1,'ko','Visible','off',li,lw);hold on;
    warm=plot(1,1,'k--','Visible','off',li,lw);hold on;
```

```
    cold=plot(1,1,'k-','Visible','off',li,lw);hold on;
    cooled=plot(1,1,'k:','Visible','off',li,lw);hold on;
    oilon=plot(1,1,'k-.','Visible','off',li,lw);hold on;

    L=legend(ax1,[tx exp14 exp16 tx cold warm cooled
      oilon],'\textbf{Marker}','EXP16␣(\&␣EXP17)','EXP14',...
    '\textbf{Line␣Type}','Growing␣Ice','Melting␣Ice','Cooled␣
      Ice','Oil␣on␣surface');hold on;
    set(L,'Location','NorthWest','Box','off');hold on;
    set(L,'Position',[0.9 0.4 0.2 0.5614])

    if poster==0;
    laprint(1,...
        ['/home/jonas/Documents/Latex/'...
        'meltseason_tempprofs'],...
        'ScaleFonts','on','asonscreen','on');
   elseif poster==1
       xlabel('Temperature␣($^\circ␣C$)','Parent',ax1);
       xlabel('Temperature␣($^\circ␣C$)','Parent',ax2);
       set(L,'Visible','off');
       set(get(L,'Children'),'Visible','off');
       laprint(1,...
        '/home/jonas/Documents/Latex/poster/meltseason_tempprofs',...
        'ScaleFonts','on','asonscreen','on');
    end;
    hold off;

     end
```

C.2.16 Figure 21: core overview (EXP14, EXP16, EXP18)

Label:

```
figure(1); close all;
poster=1;
fs=12;
lw=2;
ins=0.5;
D=5;
d=(200/2304)*D;
w=(68/2304)*D;
set(gcf,'Position',[2000 500 500 500]);
bar=rectangle('Position',[0,0,D,D],...
          'Curvature',[1,1],...
         'LineWidth',5,'LineStyle','none');
set(bar,'EdgeColor','red',...
    'Visible','on')
 daspect([1,1,1])

p1=[2 3.4];
```

```
   pw=[0.3 2.5];
x=0.5; y=[0:8];
y=(5*(y+d/2)/length(y));
dt=1.2*d +x;

wire=rectangle('Position',[x y(1) d d],...
         'Curvature',[1,1],...
        'LineWidth',lw,'LineStyle','-','FaceColor','k');
st=text(dt,y(1)+d/2,'Power␣
  cord','FontSize',fs,'HorizontalAlignment','left',...
    'VerticalAlignment','middle');


shield=rectangle('Position',[x y(2) d d],...
         'Curvature',[1,1],...
        'LineWidth',lw,'LineStyle','-','Edgecolor','red');
st=text(dt,y(2)+d/2,'Shield','FontSize',fs,...
    'HorizontalAlignment','left','VerticalAlignment','middle');

or=rectangle('Position',[x y(3) d d],...
         'Curvature',[1,1],...
       'LineWidth',lw,'LineStyle','-','EdgeColor','green');
ort=text(dt,y(3)+d/2,'Hole␣for␣oil␣
  release','FontSize',fs,'HorizontalAlignment','left',...
    'VerticalAlignment','middle');

c=rectangle('Position',[x y(4) d d],...
         'Curvature',[1,1],...
        'LineWidth',lw,'LineStyle','-');
ct=text(dt,y(4)+d/2,'Hole␣for␣
  core','FontSize',fs,'HorizontalAlignment','left',...
    'VerticalAlignment','middle');

pr=[x y(5)]; dpr=[d d];
pres1=rectangle('Position',[pr dpr],...
         'Curvature',[1,1],...
        'LineWidth',prw,'LineStyle','-','FaceColor','white');
pres1=rectangle('Position',[pr+0.25*dpr 0.5*dpr],...
         'Curvature',[1,1],...
        'LineWidth',prw,'LineStyle','-','FaceColor','white');
p1=text(dt,y(5)+d/2,'Pipe␣for␣pressure␣
  release','FontSize',fs,'HorizontalAlignment','left',...
    'VerticalAlignment','middle');


ins=rectangle('Position',[x y(6) d d],...
         'Curvature',[1,1],...
        'LineWidth',lw,'LineStyle','-','EdgeColor','cyan');
p1=text(dt,y(6)+d/2,'Insulation','FontSize',fs,...
    'HorizontalAlignment','left','VerticalAlignment','middle');
```

```

th=rectangle('Position',[x y(7)+d/2 d 0.1],...
          'Curvature',[0,0],...
         'LineWidth',lw,'LineStyle','-','FaceColor','white');
tht=text(dt,y(7)+d/2,'Thermistor probe','FontSize',fs,...
    'HorizontalAlignment','left','VerticalAlignment','middle');

oilv=rectangle('Position',[x y(8) d d],...
          'Curvature',[0,0],...
         'LineWidth',lw,'LineStyle','none','FaceColor',[0.9 0.9 0.9]);

oilvt=text(dt,y(8)+d/2,'Oil visible inside ice','FontSize',fs,...
    'HorizontalAlignment','left','VerticalAlignment','middle');

oilf=rectangle('Position',[x y(9) d d],...
          'Curvature',[0,0],...
         'LineWidth',lw,'LineStyle','none','FaceColor',[0.7 0.7 0.7]);
oilft=text(dt,y(9)+d/2,'Oil seeping up','FontSize',fs,...
    'HorizontalAlignment','left','VerticalAlignment','middle');

     set(gca,'Xlim',[0 5],'Ylim',[0 5]);



set(0,'defaulttextinterpreter','none')
set(gca,'Visible','off')
 if poster==0;
laprint(1,'/home/jonas/Documents/Latex/corelabel','Width',5,...
    'scalefonts','on');
elseif poster==1
    bar
laprint(1,'/home/jonas/Documents/Latex/poster/corelabel','Width',5,...
    'scalefonts','on');
end;
set(gca,'Visible','on')
hold off
```

Figure 21(a)

```
figure(1); close all;
poster=1;
prw=1;
fs=16;
lw=2;
D=5;
d=(468/2304)*D;
d_shield=D*12/51;
w=(68/2304)*D;
```

```
d_ins=(540*D)/1208;
set(gcf,'Position',[2000 500 500 500]);


oilv=imread(...
    '/home/jonas/Documents/oilexp/EXP14/visibleoil14.tiff');
imagesc(0:0.1:5,-1*(0:0.1:5)+5,oilv);hold on;
colormap gray
set(gca,'Clim',[50 250]); hold on;
set(gca,'Ydir','normal')


rectangle('Position',[0,0,D,D],...
          'Curvature',[1,1],...
         'LineWidth',5,'LineStyle','-');
daspect([1,1,1])

p1=[2 3.4];
   pw=[0.3 2.5];
wire=rectangle('Position',[4.5 2.5 w w],...
          'Curvature',[1,1],...
         'LineWidth',lw,'LineStyle','-','FaceColor','k');


 pr=[4.3 3.1]; dpr=[w*2 w*2];
pres1=rectangle('Position',[pr dpr],...
          'Curvature',[1,1],...
         'LineWidth',prw,'LineStyle','-','FaceColor','white');
pres1=rectangle('Position',[pr+0.25*dpr 0.5*dpr],...
          'Curvature',[1,1],...
         'LineWidth',prw,'LineStyle','-','FaceColor','white');

or=rectangle('Position',[1 1.1 w*1.3 w*1.3],...
          'Curvature',[1,1],...
         'LineWidth',lw,'LineStyle','-','EdgeColor','green');

ins=rectangle('Position',[(D-d_ins)/2 (D-d_ins*1.5)/2 d_ins
  d_ins*1.5],...
          'Curvature',[0.3,0.3],...
         'LineWidth',lw,'LineStyle','-','EdgeColor','cyan');

shield=rectangle('Position',[2 1 d_shield d_shield],...
          'Curvature',[1,1],...
         'LineWidth',lw,'LineStyle','-','Edgecolor','red');


th=rectangle('Position',[0.5 2.3 0.7 0.1],...
          'Curvature',[0,0],...
         'LineWidth',lw,'LineStyle','-','FaceColor','white');

```

```

c2x=2; c2y=2.3;
c2=rectangle('Position',[c2x c2y d d],...
         'Curvature',[1,1],...
        'LineWidth',lw,'LineStyle','-');
c2t=text(c2x+d/2,c2y+d/2,'2C','FontSize',fs,...
    'HorizontalAlignment','center','VerticalAlignment','middle');

c1x=2; c1y=1.1;
c1=rectangle('Position',[c1x c1y d d],...
         'Curvature',[1,1],...
        'LineWidth',lw,'LineStyle','-');
c1t=text(c1x+d/2,c1y+d/2,'1C','FontSize',fs,...
    'HorizontalAlignment','center','VerticalAlignment','middle');

ruler=10*D/51;
rx=2.5-0.5*ruler; ry=3.5;dy=ruler/10;

r1=plot([rx rx+ruler],[ry ry],'Color','k');
r2=plot([rx rx],[ry-dy ry+dy],'Color','k');
r3=plot([rx+ruler rx+ruler],[ry-dy ry+dy],'Color','k');
rt=text(rx+0.5*ruler,ry,'10 cm','FontSize',fs,...
    'HorizontalAlignment','center','VerticalAlignment','bottom');

set(gca,'Xlim',[0 5],'Ylim',[0 5]);

     %wire

set(0,'defaulttextinterpreter','none')
set(gca,'Visible','off')



 if poster==0;
laprint(1,'/home/jonas/Documents/Latex/exp14core','Width',5,...
    'scalefonts','on');
 else

    text(2.5,0.4,'EXP14','HorizontalAlignment','center')
laprint(1,'/home/jonas/Documents/Latex/poster/exp14core','Width',5,...
    'scalefonts','on');
end;
set(gca,'Visible','on')
hold off
```

Figure 21(b)

```
figure(1); close all;
poster=1;
prw=1;
```

```
fs=16;
lw=2;
D=5;
d=(468/2304)*D;
d_ins=(540*D)/1208;
w=(68/2304)*D;

oilv=imread(...
    '/home/jonas/Documents/oilexp/EXP16/visibleoil16.tiff');
imagesc(0:0.1:5,-1*(0:0.1:5)+5,oilv);hold on;
colormap gray
set(gca,'Clim',[50 250]); hold on;
set(gca,'Ydir','normal')

set(gcf,'Position',[2000 500 500 500]);
rectangle('Position',[0,0,D,D],...
          'Curvature',[1,1],...
         'LineWidth',5,'LineStyle','-');
daspect([1,1,1])

p1=[2 3.4];
   pw=[1 1];
wire=rectangle('Position',[pw w w],...
          'Curvature',[1,1],...
         'LineWidth',lw,'LineStyle','-','FaceColor','k');

th=rectangle('Position',[0.5 2.3 0.7 0.1],...
          'Curvature',[0,0],...
         'LineWidth',lw,'LineStyle','-','FaceColor','white');
c1x=2.5; c1y=3.3;

c1=rectangle('Position',[c1x c1y d d],...
          'Curvature',[1,1],...
         'LineWidth',lw,'LineStyle','-','FaceColor','white');


ins=rectangle('Position',[(D-d_ins)/2 (D-d_ins)/2 d_ins
  d_ins],...
          'Curvature',[1,1],...
         'LineWidth',lw,'LineStyle','-','EdgeColor','cyan');



pr=[4.3 3.1]; dpr=[w*2 w*2];
pres1=rectangle('Position',[pr dpr],...
          'Curvature',[1,1],...
         'LineWidth',prw,'LineStyle','-','FaceColor','white');
pres1=rectangle('Position',[pr+0.25*dpr 0.5*dpr],...
          'Curvature',[1,1],...
         'LineWidth',prw,'LineStyle','-','FaceColor','white');
```

```
if poster==0;
or=rectangle('Position',[2 0.5 w*1.3 w*1.3],...
          'Curvature',[1,1],...
         'LineWidth',lw,'LineStyle','-','EdgeColor','green');
elseif poster==1;
or=rectangle('Position',[2 0.7 w*1.3 w*1.3],...
          'Curvature',[1,1],...
         'LineWidth',lw,'LineStyle','-','EdgeColor','green');
end;

c1x=2.5; c1y=3.3;
c1=rectangle('Position',[c1x c1y d d],...
          'Curvature',[1,1],...
         'LineWidth',lw,'LineStyle','-');
c1t=text(c1x+d/2,c1y+d/2,'1C','FontSize',fs,...
    'HorizontalAlignment','center','VerticalAlignment','middle');

c2x=3; c2y=1;
c2=rectangle('Position',[c2x c2y d d],...
          'Curvature',[1,1],...
         'LineWidth',lw,'LineStyle','-');
c2t=text(c2x+d/2,c2y+d/2,'2C','FontSize',fs,...
    'HorizontalAlignment','center','VerticalAlignment','middle');


c3x=1.3; c3y=2.7;
c3=rectangle('Position',[c3x c3y d d],...
          'Curvature',[1,1],...
         'LineWidth',lw,'LineStyle','-');
c3t=text(c3x+d/2,c3y+d/2,'3C','FontSize',fs,...
    'HorizontalAlignment','center','VerticalAlignment','middle');


c4x=2.3; c4y=2.1;
c4=rectangle('Position',[c4x c4y d d],...
          'Curvature',[1,1],...
         'LineWidth',lw,'LineStyle','-');
c4t=text(c4x+d/2,c4y+d/2,'4C','FontSize',fs,...
    'HorizontalAlignment','center','VerticalAlignment','middle');

c5x=3.2; c5y=2.5;
c5=rectangle('Position',[c5x c5y d d],...
          'Curvature',[1,1],...
         'LineWidth',lw,'LineStyle','-');
c5t=text(c5x+d/2,c5y+d/2,'5C','FontSize',fs,...
    'HorizontalAlignment','center','VerticalAlignment','middle');
```

```
p3=[pw(1)+2.1 pw(2)-1.0 d d];
set(gca,'Xlim',[0 5],'Ylim',[0 5]);

    %wire
wlx1=pw(1)+w;wlx2=pw(1)+w+0.01;wly1=pw(2)+w ; wly2=pw(2)+w+0.1;

set(0,'defaulttextinterpreter','none')
set(gca,'Visible','off')

 if poster==0;
laprint(1,'/home/jonas/Documents/Latex/exp16core','Width',5,...
    'scalefonts','on');
elseif poster==1
    load('/home/jonas/Documents/Latex/poster/lw.mat');
     li='LineWidth';
     %set(bar,li,lw);
      text(2.5,0.4,'EXP16','HorizontalAlignment','center')
laprint(1,'/home/jonas/Documents/Latex/poster/exp16core','Width',5,...
    'scalefonts','on');
end;
set(gca,'Visible','on')
hold off
```

Figure 21(c)

```
figure(1); close all;
poster=1;
fs=16;
d_shield=D*12/51;
lw=2;
if poster==1
    load('/home/jonas/Documents/Latex/poster/lw.mat');
end;
D=5;
d=(468/2304)*D;
w=(68/2304)*D;
d_ins=(540*D)/1208;
set(gcf,'Position',[1000 500 500 500]);
oilv=imread(...
    '/home/jonas/Documents/oilexp/EXP17/visibleoil17.tiff');
imagesc(0:0.1:5,-1*(0:0.1:5)+5,oilv);hold on;
colormap gray
set(gca,'Clim',[50 250]); hold on;
set(gca,'Ydir','normal')
rectangle('Position',[0,0,D,D],...
          'Curvature',[1,1],...
         'LineWidth',5,'LineStyle','-');
daspect([1,1,1]);
```

```
p1=[2 3.4];
   pw=[0.3 2.5];
wire=rectangle('Position',[pw w w],...
          'Curvature',[1,1],...
         'LineWidth',lw,'LineStyle','-','FaceColor','k');

or=rectangle('Position',[4.4 2.1 w*1.3 w*1.3],...
          'Curvature',[1,1],...
         'LineWidth',lw,'LineStyle','-','EdgeColor','green');


ins=rectangle('Position',[(D-d_ins)/2 (D-d_ins)/2 d_ins
  d_ins],...
          'Curvature',[1,1],...
         'LineWidth',lw,'LineStyle','-','EdgeColor','cyan');

 shield=rectangle('Position',[p1-0.7/2 d_shield d_shield],...
          'Curvature',[1,1],...
         'LineWidth',lw,'LineStyle','-','Edgecolor','red');
c1=rectangle('Position',[1.3 1 d d],...
          'Curvature',[1,1],...
         'LineWidth',lw,'LineStyle','-');
c1t=text(1.3+d/2,1+d/2,'1C','FontSize',fs,...
    'HorizontalAlignment','center','VerticalAlignment',...
    'middle','BackgroundColor','none');


c2=rectangle('Position',[p1-0.7 d d],...
          'Curvature',[1,1],...
         'LineWidth',lw,'LineStyle','-');
c2t=text(p1(1)-0.7+d/2,p1(2)-0.7+d/2,'2C','FontSize',fs,...
    'HorizontalAlignment','center','VerticalAlignment',...
    'middle','BackgroundColor','none');


c3=rectangle('Position',[p1 d d],...
          'Curvature',[1,1],...
          'LineWidth',lw,'LineStyle','-');
c3t=text(p1(1)+d/2,p1(2)+d/2,'3C','FontSize',fs,...
    'HorizontalAlignment','center','VerticalAlignment','middle');


p3=[pw(1)+2.1 pw(2)-1.0 d d];
c4=rectangle('Position',p3,...
          'Curvature',[1,1],...
         'LineWidth',lw,'LineStyle','-');
c4t=text(p3(1)+d/2,p3(2)+d/2,'4C','FontSize',fs,...
    'HorizontalAlignment','center','VerticalAlignment','middle');

p4=[p3(1)+1*d p3(2)+1*d d d];
```

```
c5=rectangle('Position',p4,...
         'Curvature',[1,1],...
        'LineWidth',lw,'LineStyle','-');
c5t=text(p4(1)+d/2,p4(2)+d/2,'5C','FontSize',fs,...
    'HorizontalAlignment','center','VerticalAlignment','middle');


c6=rectangle('Position',[pw(1) pw(2)-1.0 d d],...
         'Curvature',[1,1],...
        'LineWidth',lw,'LineStyle','-');
c6t=text(pw(1)+d/2,pw(2)-1.0+d/2,'6C','FontSize',fs,...
    'HorizontalAlignment','center','VerticalAlignment','middle');

set(gca,'Xlim',[0 5],'Ylim',[0 5]);


set(0,'defaulttextinterpreter','none')
set(gca,'Visible','off')
 if poster==0;
laprint(1,'/home/jonas/Documents/Latex/exp17core','Width',5,...
    'scalefonts','on');
elseif poster==1
         text(2.5,0.4,'EXP17','HorizontalAlignment','center')
laprint(1,'/home/jonas/Documents/Latex/poster/exp17core','Width',5,...
    'scalefonts','on');
end;
set(gca,'Visible','on')
hold off
```

C.2.17 Figure 24, 25 and 26: mode of transport

```
clear all;close all;PLOT=2;
poster=0;
if PLOT==1
magfic=1960.1/3;%from EXP16_sample-000039.jpg
k=1;
img=getimg(['/home/jonas/Pictures/2008-07-09/'...
    'EXP16b_sample6-000043.JPG'],k);
mf=magfic/k;

x=0;X=1;y=0.1;Y=1;
ymin=round(1+y*size(img,1));
ymax=round(Y*size(img,1));
xmin=round(1+x*size(img,2));
xmax=round(X*size(img,2));

im=img(ymin:ymax,xmin:xmax,:);
g=size(im,1)/size(im,2);
```

```
f1=figure('PaperUnits','inch','PaperPosition',[0 0 5/2.54 5*g/2.54]);
h=image(im);hold on;
axis image;hold on;

set(gca,'XTick',[ ],'YTick',[ ]);

x1=2*mf;x2=x1+mf;y=mf*2.2;
set(0,'defaulttextinterpreter','none');
lw=2.5;

h1=line([x1 x2],[y y],'Color','k','LineWidth',lw);hold on;
h2=line([x1 x1],[y-.1*mf y+.1*mf],'Color','k','LineWidth',lw);hold on;
h3=line([x2 x2],[y-.1*mf y+.1*mf],'Color','k','LineWidth',lw);hold on;
h3=line([(x2+x1)/2 (x2+x1)/2],[y-.07*mf y+.07*mf],'Color','k','LineWidth',lw);hold on;
for i =1:10;
h4=line([x1+i*(x2-x1)/10 x1+i*(x2-x1)/10],[y-.05*mf y+.05*mf],'Color','k','LineWidth',lw);hold on;
end;
a=annotation(gcf,'arrow',[0.6429 0.7],[0.6347 0.781]);
set(a,'Color','c','LineWidth',lw);
a=annotation(gcf,'arrow',[0.4857 0.5143],[0.6109 0.7452]);
set(a,'Color','c','LineWidth',lw);

if poster==0;
h4=text(mean([x1 x2]),y-mf/15,'\begin{Large}\textbf{1␣cm}\end{Large}',...
    'FontSize',12,'HorizontalAlignment',...
    'center','VerticalAlignment','bottom');

a=annotation(gcf,'textarrow',[0.3089 0.2625],[0.5585 0.7119],...
    'TextEdgeColor','none',...
    'String',{'\begin{Large}Oil\end{Large}'});
set(a,'Color','c','LineWidth',lw,'HorizontalAlignment','center');
set(gca,'Visible','off');

elseif poster==1;
h4=text(mean([x1 x2]),y-mf/15,'\textbf{1␣cm}',...
    'FontSize',12,'HorizontalAlignment',...
    'center','VerticalAlignment','bottom');

a=annotation(gcf,'textarrow',[0.3089 0.2625],[0.5585 0.7119],...
    'TextEdgeColor','none',...
    'String',{'\textbf{Oil}'});
set(a,'Color','c','LineWidth',lw,'HorizontalAlignment','center');
set(gca,'Visible','off');

```

```
end;



if poster==0;
laprint(1,'/home/jonas/Documents/Latex/thinsc_oil',...
    'ScaleFonts','on');
elseif poster==1;
    laprint(1,'/home/jonas/Documents/Latex/poster/thinsc_oil',...
    'ScaleFonts','on');
end;

elseif PLOT==2
lw=2;
magfic=2064/15;%IMG_0239a.JPG
k=1;mf1=2064/15;mf2=1921/1.5;
img=getimg('/home/jonas/Pictures/2008-07-11/IMG_0239.JPG',k);
mf=magfic/k;
%
x=.0;X=1;y=0.1;Y=1;
im=img;%(ymin:ymax,xmin:xmax,:);
g=size(im,1)/size(im,2);
f1=figure('PaperUnits','inch','PaperPosition',[0 0 5/2.54
  5*g/2.54]);
h=image(im);hold on;
axis image;hold on;
ytick=[0:2064/15:(2064+3*2064/15)];
for i=1:17;
    if i==7;
    ytickl{i}=['$' num2str(-1*i) '$\hspace{-2pt}'];
    elseif i==17
    ytickl{i}=['$' num2str(-1*i) '$\hspace{-2pt}'];
    else
    ytickl{i}=['$' num2str(-1*i) '$'];
end

end;
set(gca,'YTick',ytick,'YTickLabel',ytickl,'XTick',[],...
    'TickDir','out','XColor','k','YColor','k','Box','off');
ylabel('Depth (cm)');

ax1=gca;hold on;
ax2=axes('Position',get(ax1,'Position'),'Box','on');hold on;
magfic=1921/1.5;%IMG_0245.JPG
k=1;
img=getimg('/home/jonas/Pictures/2008-07-11/IMG_0241.JPG',k);
mf=magfic/k;

im=img;
g=size(im,1)/size(im,2);
```

```
h=image(im,'Parent',ax2);hold on;
axis image;hold on;
set(ax2,'Position',[0.4500 0.48500 0.4875 0.4095],'Layer','top')
g=0.03;
x1=0.5*mf;x2=x1+mf/10;y=1.1*mf;
if poster==0
h4=text(mean([x1 x2]),y,'\begin{Large}1 mm\end{Large}','FontSize',12,'HorizontalAlignment','center',...
    'VerticalAlignment','bottom','Parent',ax2,'Color','r');
elseif poster==1
h4=text(mean([x1 x2]),y,'1 mm','FontSize',12,'HorizontalAlignment','center',...
    'VerticalAlignment','bottom','Parent',ax2,'Color','r');
end;
h1=line([x1 x2],[y y],'Color','r','LineWidth',lw/2,'Parent',ax2);hold on;
h2=line([x1 x1],[y-g*mf y+g*mf],'Color','r','LineWidth',lw/2,'Parent',ax2);hold on;
h3=line([x2 x2],[y-g*mf y+g*mf],'Color','r','LineWidth',lw/2,'Parent',ax2);hold on;

line([1 988],[1 1],'Color','r','Parent',ax2,'Linewidth',lw)
line([1 988],[1765 1765],'Color','r','Parent',ax2,'Linewidth',lw)
line([1 1],[1 1765],'Color','r','Parent',ax2,'Linewidth',lw)
line([988 988],[1 1765],'Color','r','Parent',ax2,'Linewidth',lw)

if poster==0
a=annotation(gcf,'textarrow',[0.3911 0.3482],[0.5395 0.6452],...
    'TextEdgeColor','none',...
    'String',{'\begin{Large}\hspace{-3cm}Plumes\end{Large}'});
set(a,'Color',[1 0 0],'LineWidth',lw/2,'HorizontalAlignment','right');
a=annotation(gcf,'arrow',[0.3964 0.3875],[0.4966 0.3929]);
set(a,'Color',[1 0 0],'LineWidth',lw/2);
elseif poster==1
a=annotation(gcf,'textarrow',[0.3911 0.3482],[0.5395 0.6452],...
    'TextEdgeColor','none',...
    'String',{'Plumes'});
set(a,'Color',[1 0 0],'LineWidth',lw/2,'HorizontalAlignment','right');
a=annotation(gcf,'arrow',[0.3964 0.3875],[0.4966 0.3929]);
set(a,'Color',[1 0 0],'LineWidth',lw/2);
end

dx=mf1*size(img,2)/mf2;dy=mf1*size(img,1)/mf2;x=851;y=342;
X=1395;Y=91;
line([x x+dx x+dx x x X],[y y y+dy y+dy y Y],'Color','r','Parent',ax1,'Linewidth',lw/2)

set(ax2,'YTick',[],'XTick',[],'Box','off');
```

```
set(ax2,'Visible','off')
set(0,'defaulttextinterpreter','none');

if poster==0;
laprint(1,'/home/jonas/Documents/Latex/section_oil1',...
    'ScaleFonts','off');
elseif poster==1;
laprint(1,'/home/jonas/Documents/Latex/poster/section_oil1',...
    'ScaleFonts','off');
end;

elseif PLOT==3
axes
if poster==0
img=getimg('/home/jonas/Pictures/2008-06-22/IMG_8393.JPG',1);
elseif poster==1;
img=getimg('/home/jonas/Pictures/2008-06-22/IMG_8393B.JPG',1);
end;
h=image(img);hold on;
set(gca,'XTick',[],'YTick',[])

axis image;hold on;

if poster==0;
laprint(1,'/home/jonas/Documents/Latex/section_oil2','Width',8,...
    'ScaleFonts','off');
hold off
print('-depsc2','/home/jonas/Documents/Latex/section_oil2.eps');
elseif poster==1;
annotation(gcf,'textarrow',[0.5446 0.3893],[0.449 0.45],...
    'TextEdgeColor','none',...
    'TextLineWidth',4,...
    'String',{'\hspace{2mm}UP'},...
    'HeadLength',15,...
    'HeadWidth',15,...
    'HeadStyle','deltoid',...
    'LineWidth',4);

    laprint(1,'/home/jonas/Documents/Latex/poster/section_oil2','Width',12,...
'ScaleFonts','off');
hold off
%print('-depsc2','/home/jonas/Documents/Latex/poster/section_oil2.eps');
end

elseif PLOT==4

magfic=1921/1.5;%IMG_0245.JPG
k=1;
img=getimg('/home/jonas/Pictures/2008-07-11/IMG_0241.JPG',k);
mf=magfic/k;
```

```

im=img;
g=size(im,1)/size(im,2);
f1=figure('PaperUnits','inch','PaperPosition',[0 0 5/2.54 5*g/2.54]);
h=image(im);hold on;
axis image;hold on;

set(gca,'YTick',[],'XTick',[],'XColor','r','YColor',...
    'r','LineWidth',1);
g=0.03;
lt=0.6;
x1=0.5*mf;x2=x1+mf/10;y=0.2*mf;
h4=text(mean([x1 x2]),y,'\begin{Large}1 mm\end{Large}','FontSize',12,...
    'HorizontalAlignment','center','VerticalAlignment','bottom');
h1=line([x1 x2],[y y],'Color','k','LineWidth',lt);hold on;
h2=line([x1 x1],[y-g*mf y+g*mf],'Color','k','LineWidth',lt);hold on;
h3=line([x2 x2],[y-g*mf y+g*mf],'Color','k','LineWidth',lt);hold on;

set(gca,'Visible','off')
set(gcf,'BoundingBox','teight')
set(0,'defaulttextinterpreter','none');
laprint(1,'/home/jonas/Documents/Latex/section_oil3','Width',4,...
    'ScaleFonts','off');

elseif PLOT==5
img=getimg('/home/jonas/Pictures/2008-07-09/EXP16_b -000009.JPG',1);
h=image(img);hold on;
set(gca,'XTick',[],'YTick',[])
axis image;hold on;

laprint(1,'/home/jonas/Documents/Latex/section_oil4',...
    'Width',4,'ScaleFonts','off');
hold off
print('-depsc2','/home/jonas/Documents/Latex/section_oil4.eps');

elseif PLOT==6

magfic=3454/9;%IMG_0245.JPG
k=1;
img=getimg('/home/jonas/Pictures/2008-05-01/_MG_7329a.jpg',k);
mf=magfic/k;

im=img;
g=size(im,1)/size(im,2);
```

```
f1=figure('PaperUnits','inch','PaperPosition',[0 0 5/2.54
  5*g/2.54]);
h=image(im);hold on;
axis image;hold on;

set(gca,'YTick',[],'XTick',[]);
g=0.1;
lt=0.6;
x1=0.7*mf;x2=x1+mf;y=0.7*mf;
h4=text(mean([x1 x2]),y,'\begin{Large}1␣cm\end{Large}',...
    'FontSize',12,'HorizontalAlignment','center',...
    'VerticalAlignment','bottom');
h1=line([x1 x2],[y y],'Color','k','LineWidth',lt);hold on;
h2=line([x1 x1],[y-g*mf y+g*mf],'Color','k','LineWidth',lt);hold
  on;
h3=line([x2 x2],[y-g*mf y+g*mf],'Color','k','LineWidth',lt);hold
  on;

set(0,'defaulttextinterpreter','none');

laprint(1,'/home/jonas/Documents/Latex/section_oil5',...
    'Width',6,'ScaleFonts','off');

elseif PLOT==7

img=getimg('/home/jonas/Pictures/2008-07-09/EXP17_18.JPG',1);
h=image(img);hold on;
set(gca,'XTick',[],'YTick',[])
axis image;hold on;
set(gca,'Visible','off');
laprint(1,'/home/jonas/Documents/Latex/section_oil8',...
    'ScaleFonts','off');

hold off

end
```

C.2.18 Figure 16 and 17: growth season profiles

```
clear all; close all;load EXP;PLOT=3;
poster=0;

lw=1;
i=[2 13 18 19 20 21];
%X={OI NOI OR color};

if PLOT==1;
li='LineWidth';

```

```
    if poster==1
        load('/home/jonas/Documents/Latex/poster/lw.mat')
        st='\begin{footnotesize}';
        ss='\end{footnotesize}';
        Lw=lw;
    elseif poster==0
        Lw=0.5;
        st=' ';
    end;

    Markf=[1.0 1.0 1.0;
    0.5 0.5 0.5;
    0 0 0];

X{2,1}=[EXP(2).profiles(1).s EXP(2).profiles(1).o(:,2)];
M=X{2,1}(1,4);
X{2,2}=[EXP(2).profiles(2).s];
X{2,3}=[];
X{2,4}=[1 0.6 0];

X{13,1}=[EXP(13).profiles(2).s(:,1:3)
  EXP(13).profiles(2).o(:,2)./...
    (EXP(13).profiles(2).o(:,2)+EXP(13).profiles(2).o(:,3))];
X{13,2}=[EXP(13).profiles(1).s(:,1:3)];
X{13,3}=[];
X{13,4}='c';

X{18,1}=[EXP(18).profiles(1).s(:,1:3)
  EXP(18).profiles(1).o(:,2)./...
    (EXP(18).profiles(1).o(:,2)+EXP(18).profiles(1).o(:,3))];
X{18,2}=[];
X{18,3}=[];
X{18,4}='m';

X{19,1}=[EXP(19).profiles(1).s(:,1:3)
  EXP(19).profiles(1).o(:,2)./...
    (EXP(19).profiles(1).o(:,2)+EXP(19).profiles(1).o(:,3))];
X{19,1}=sortrows(X{19,1},1);
X{19,2}=[];
X{19,3}=[];
X{19,4}='r';

X{20,1}=[EXP(20).profiles(3).s(:,1:3)
  EXP(20).profiles(3).o(:,2)./...
    (EXP(20).profiles(3).o(:,2)+EXP(20).profiles(3).o(:,3))];
X{20,1}=sortrows(X{20,1},1);
X{20,2}=[EXP(20).profiles(2).s(:,1:3)];
X{20,3}=[EXP(20).profiles(1).s(:,1:3)];
X{20,4}='g';
```

```
X{21,1}=[EXP(21).profiles(3).s(:,1:3)
  EXP(21).profiles(3).o(:,2)./...
    (EXP(21).profiles(3).o(:,2)+EXP(21).profiles(3).o(:,3))];
X{21,1}=sortrows(X{21,1},1);
X{21,2}=[EXP(21).profiles(2).s(:,1:3)];
X{21,3}=[EXP(21).profiles(1).s(:,1:3)];
X{21,4}='b';

marker='so<';
lstyle{1}='-';
lstyle{2}='-';
lstyle{3}='-';
%col=X{2,1}(1,4)


%color={'orange' 'c' 'm' 'r' 'g' 'b'};
%I=0;

ms=8;
ii=0;


for i=[2 13 18 19 20 21];
try
    plot([X{i,1}(1,2) X{i,2}(1,2)],[X{i,1}(1,1)
      X{i,2}(1,1)],'LineStyle',':',...
        'Color',X{i,4},'LineWidth',lw);hold on;
end
end


for i=[2 13 18 19 20 21];
X{i,1}(:,4)=(M-X{i,1}(:,4))/M;
ii=ii+1;

    for j=1:3;
        try;
        plot(X{i,j}(:,2),X{i,j}(:,1),'LineStyle',...
            char(lstyle{j}),'Color',X{i,4},'LineWidth',lw);hold
              on;i
        end;

        for k=1:size(X{i,j},1)
            p=plot(X{i,j}(k,2),X{i,j}(k,1),'Marker',marker(j),...
            'MarkerEdgeColor',X{i,4},'LineWidth',lw);hold on;

            if j==1;
            set(p,'MarkerFaceColor',[1 1 1]*X{i,j}(k,4),...
                'MarkerSize',ms,'LineWidth',lw)
            else;
```

```
            set(p,'MarkerFaceColor','white',...
                'LineWidth',lw);hold on;
            end
        end;
        ls(j)=plot(10,-8,[char(lstyle{j}) marker(j) 'k'],...
            'Visible','off','LineWidth',lw/2);
        markf(j)=plot(10,-8,'LineStyle','none','Marker',...
            's','MarkerFaceColor',[Markf(j,:)],...
            'MarkerEdgeColor','k','Visible','off');hold on
    end;

        %Icethickness/oillens
        x=[X{i,1}(1,2)-0.5 X{i,1}(1,2)+0.5]';
        y1=[1 1]'*(X{i,1}(1,1)-(X{i,1}(1,3)/2));
        y2=[1 1]'*(X{i,1}(1,1)+(X{i,1}(1,3)/2));
        l=line(x,y1,'Color',X{i,4},'LineWidth',lw,'LineStyle','-');
        hold on;
        l=line(x,y2,'Color',X{i,4},'LineWidth',lw,'LineStyle','-');
        hold on

        %Color
        lab(ii)=plot(10,-8,'LineStyle','none','Marker','s',...
            'MarkerFaceColor',X{i,4},...
            'MarkerEdgeColor','k','Visible','off');hold on

        I{ii+1}=['EXP' num2str(i)];
end;


ls(4)=plot(10,-8,'-k','Visible','off','LineWidth',lw/2);hold on
ls(5)=plot(10,-8,':k','Visible','off','LineWidth',lw/2);hold on
if poster==0
I{ii+2}='\textbf{Line␣type}';
I{ii+3}='OI';
I{ii+4}='NOI';
I{ii+5}='OR';
I{ii+6}='OI␣top/bottom';
I{ii+7}='OI-NOI␣difference';
I{ii+8}='\textbf{Marker␣gray␣level}';
I{ii+9}='\textcolor{white}{1}0␣wt\%␣(oil)';
I{ii+10}='10␣wt\%';
I{ii+11}='20␣wt\%';
elseif poster==1;
I{ii+2}='\textbf{Line␣type}';
I{ii+3}='OI';
I{ii+4}='NOI';
I{ii+5}='OR';
I{ii+6}='OI␣top/bottom';
I{ii+7}='OI-NOI␣diff.';
I{ii+8}='\textbf{Gray␣level}';
```

```
I{ii+9}='\textcolor{white}{1}0 wt\% (oil)';
I{ii+10}='10 wt\%';
I{ii+11}='20 wt\%';
end
tx=text(10,-8,' ','Visible','off');hold on
i=[2 13 18 19 20 21];

I{1}='\textbf{Color}';
l=legend([tx lab tx ls tx markf],I);
p=plot(X{2,1}(1,2),X{2,1}(1,1),'Marker',marker(1),...
            'MarkerEdgeColor',X{2,4});hold on;
 set(p,'MarkerFaceColor',[1 1
   1]*X{2,1}(1,4),'MarkerSize',ms,'LineWidth',lw)
set(l,'Box','off','Location','NorthEastOutside')
 set(gca,'Position',[0.08 0.1100 0.7750 0.8150]);
set(l,'Position',[0.82 0.4 0.31 0.3637]);
ylabel('Depth (cm)');
set(gca,'Box','off','TickDir','out','Xlim',[5
  17],'Xtick',[6:2:20],li,Lw)
set(0,'defaulttextinterpreter','none')

    if poster==0;
laprint(1,'/home/jonas/Documents/Latex/Salinityprofiles_grow',...
    'asonscreen','on');

    elseif poster==1
        xlabel('Bulk salinity ($\permil$)')
    set(l,'Position',[0.7387 0.0 0.4727 1])
    %set(l,'Location','NorthEastOutside');
    set(l,'FontSize',14);
laprint(1,'/home/jonas/Documents/Latex/poster/Salinityprofiles_grow',...
    'asonscreen','on');

    end;
    hold off;

elseif PLOT==2
    clear all; load EXP;
    close all;figure(1)
    %X={OI NOI OR color};

    li='LineWidth';
    poster=0;
    if poster==1
        load('/home/jonas/Documents/Latex/poster/lw.mat')
        st='\begin{footnotesize}';
        ss='\end{footnotesize}';
    elseif poster==0
        lw=0.7;
        st=' ';
```

```
    end;
    ms=4;

    polyval(EXP(13).th_fit1,EXP(13).tx(1,1)+1.027);
    I=max(find(EXP(13).tp(:,1)<EXP(13).tx(1,1)+1.027));
    P=find(EXP(13).pos<0.1);
    x{2,1}=[EXP(13).pos(1,P)' EXP(13).tp(I,P)'];


    x{2,1}=x{2,1}(find(~isnan(x{2,1}(:,2))),:);
    x{2,1}(17,:)=[];
    x{2,1}([15:18],:)=[];
    x{2,2}=[1 0.6 0];
    x{2,6}='c';
    x{2,7}='>';
    x{2,4}='--';

    x{14,1}=x{2,1};
    x{14,2}='k';
    x{14,6}='k';
    x{14,7}='none';
    x{14,4}='none';

    polyval(EXP(14).th_fit2,EXP(14).tx(1,1)+2.275);
    I=max(find(EXP(14).tp(:,1)<EXP(14).tx(1,1)+2.275));
    P=find(EXP(14).pos<0.1);
    x{19,1}=[EXP(14).pos(1,P)' EXP(14).tp(I,P)'];
    x{19,2}='r';
    x{19,6}='k';
    x{19,7}='>';
    x{19,4}='--';

    x{13,1}=EXP(13).profiles(2).t;
    x{13,1}(17,:)=[];
    x{13,1}(end,:)=[];

    x{13,2}='c';
    x{13,6}='c';
    x{13,7}='>';
    x{13,4}='-';

    x{20,1}=EXP(20).profiles(3).t;
    x{20,1}(1,:)=[];
    x{20,2}='g';
    x{20,6}='g';
    x{20,7}='>';
    x{20,4}='-';

    x{18,1}=x{20,1};
    x{18,1}(:,1)=0.1+x{20,1}(:,1);
```

```
    x{18,1}(:,2)=0.01+x{20,1}(:,2);
    x{18,2}='m';
    x{18,6}='g';
    x{18,7}='none';
    x{18,4}='--';


    x{21,1}=EXP(21).profiles(3).t;
    x{21,2}='b';
    x{21,6}='b';
    x{21,7}='>';
    x{21,4}='-';

    for i=[2 13 17 18 19 20 21];
        or(i)=EXP(i).tx(find(EXP(i).tx(:,2)==3),1);
     try
        x{i,3}=EXP(i).tw_fit(or(i));
     catch
        x{i,3}=NaN;
     end
        try
            x{i,5}=freezingpoint(EXP(i).sw_fit(or(i)));
        end
    end;

    I=0;

    markf(1)=text(-5,-5,'␣','Visible','off');hold on
    lab{1}='\textbf{Color}';
    exp=[2 13 14 18:21];
    for i=exp;
        I=I+1;
        p(I)=plot(x{i,1}(:,2),x{i,1}(:,1),...
            'LineStyle',x{i,4},...
            'LineWidth',lw,...
            'Color',x{i,2},...
            'Marker',x{i,7},...
            'MarkerFaceColor',x{i,6},...
            'MarkerEdgeColor',x{i,6},...
            'MarkerSize',ms);hold on;
        lab{I+1}=['EXP' num2str(i)];

        try
            plot([1]*x{i,3},[-26.5],'Color',x{i,2},...
                'MarkerFaceColor',x{i,2},'LineStyle','none',...
                'LineWidth',lw,'Marker','o','MarkerSize',ms);
            hold on;
        end;
        try
            a=plot([1]*x{i,5},[-26.5],'Color',x{i,2},...
```

```
                'MarkerFaceColor',x{i,2},'LineStyle','none',...
                'LineWidth',lw,'Marker','s','MarkerSize',ms);
        hold on;
        if i==13;
            set(a,'Marker','>');
        end
        end;


        markf(I+1)=plot(-5,-8,'LineStyle','none','Marker','s',...
            'MarkerFaceColor',x{i,2},'MarkerEdgeColor','k',...
            'Visible','off');hold on
    end;

    I=0;
    for i=exp;
        I=I+1;
        p(I)=plot(x{i,1}(:,2),x{i,1}(:,1),...
            'LineStyle','none',...
            'LineWidth',lw,...
            'Color',x{i,2},...
            'Marker',x{i,7},...
            'MarkerFaceColor',x{i,6},...
            'MarkerEdgeColor',x{i,6},...
            'MarkerSize',ms);hold on;
    end;


    lab{I+1}=['EXP' num2str(i)];
    lab{I+2}='\textbf{Line␣Type}';
    lab{I+3}='Fit';
    lab{I+4}='Extrapolated␣fit';

    lab{I+5}='\textbf{Marker}␣(sensor)';
    lab{I+6}='Thermistor';
    lab{I+7}='Salinometer';
    lab{I+8}='Freezing␣point';


    markf(I+2)=markf(1);
    k{1}='-k';
    k{2}='--k';
    for ii=1:2;
        markf(I+2+ii)=plot(-5,-5,k{ii},'Visible','off');
    end;
    markf(I+3+ii)=markf(1);
    k{1}='>k';
    k{2}='ok';
    k{3}='sk';
    for II=1:3;
```

```
        markf(I+3+ii+II)=plot(-5,-5,k{II},'Visible','off');
    end;

   l=legend(markf,lab,'Location','SouthWest');
   set(l,'Box','off','Location','SouthWest','YColor',[1 1 1],'XColor',[1 1 1]);
   set(gca,'Position',[0.08 0.1100 0.7750 0.8150]);

   if poster==0
    set(l,'Position',[0.82 0.43 0.31 0.3637]);
   elseif poster==1;
    set(l,'Position',[0.55 0 0.31 1],'FontSize',14);
   end;
    ylabel('Depth (cm)');
   xtick=[-4:0.5:-0.5];%get(gca,'Xtick')*10;
   for i=1:length(xtick);
       xtickl{i}=num2str(xtick(i)*10);
   end;
   set(gca,'XTick',xtick,'XTickLabel',xtickl,li,lw);

   set(gca,'Box','off','TickDir','out','Xlim',[-4 -0.5],'Ylim',[-27 0]);hold off;
   set(0,'defaulttextinterpreter','none')
   laprint(1,...
       '/home/jonas/Documents/Latex/Temperatureprofiles_grow',...
       'asonscreen','on');


    if poster==0;
    %xlabel('Temperature ($\mathrm{10^{-1}}$ $\mathrm{^ \circ C}$)')
laprint(1,...
       '/home/jonas/Documents/Latex/Temperatureprofiles_grow',...
       'asonscreen','on');

    elseif poster==1
        xlabel('Temperature ($d^\circ C$)')
       set(l,'Location','NorthEast');
      set(l,'Position',[0.56 0.05 0.31 1])
laprint(1,...
       '/home/jonas/Documents/Latex/poster/Temperatureprofiles_grow',...
       'asonscreen','on');

    end;
    hold off;

elseif PLOT==3;
%x=[ovf OIbvf NOIbvf ORbvf]
T1=strvcat(' ','OI','NOI','OR');
T2=strvcat(' ','OI+','NOI+','OR+');
```

```
g=0.7;
c=[0 0 0;g g g;g g g;g g g];
%strvcat('k','gray','gray','gray');
D=[10 10; 20 20;30 30];
d=[-2 -2;-2 -2;0 0;2 2];
lw=10;

x{13,1}=EXP(13).profiles(2).ovf*100;%ovf
x{13,1}=sortrows(x{13,1},1);
x{13,2}=EXP(13).profiles(2).bvf*100;%OIbvf
x{13,2}=sortrows(x{13,2},1);
for i=1:length(x{13,2}(:,1));
    try
        x{13,2}(i,2)=x{13,2}(i,2)+x{13,1}(i,2);
    end;
end
x{13,3}=EXP(13).profiles(1).bvf*100;%NOIbvf
x{13,3}=sortrows(x{13,3},1);
x{13,4}=[NaN NaN]*100;%OR

x{20,1}=EXP(20).profiles(3).ovf*100;%ovf
x{20,1}=sortrows(x{20,1},1);
x{20,2}=EXP(20).profiles(3).bvf*100;%OIbvf
x{20,2}=sortrows(x{20,2},1);
for i=1:length(x{13,2}(:,1));
    try
        x{20,2}(i,2)=x{20,2}(i,2)+x{20,1}(i,2);
    end;
end

x{20,3}=EXP(20).profiles(2).bvf*100;%NOIbvf
x{20,3}=sortrows(x{20,3},1);
x{20,4}=EXP(20).profiles(1).bvf*100;%OR
x{20,4}=sortrows(x{20,4},1);

x{21,1}=EXP(21).profiles(3).ovf*100;%ovf
x{21,1}=sortrows(x{21,1},1);
x{21,2}=EXP(21).profiles(3).bvf*100;%OIbvf
x{21,2}=sortrows(x{21,2},1);
for i=1:length(x{13,2}(:,1));
    try
        x{21,2}(i,2)=x{21,2}(i,2)+x{21,1}(i,2);
    end;
end

x{21,3}=EXP(21).profiles(2).bvf*100;%NOIbvf
x{21,3}=sortrows(x{21,3},1);
x{21,4}=EXP(21).profiles(1).bvf*100;%OR
x{21,4}=sortrows(x{21,4},1);
```

```
figure(1)
a=0.43;
da=0.05;
ax1=axes('Position',[0.1300 a+2*da 0.7750 a]);
ax2=axes('Position',[0.1300 da 0.7750 a],...
    'YDir','rev','XAxisLocation','top');
I=0;
for i=[13 20:21];
    I=I+1;

    for j=[2 1 3 4]
        X=D(I,:)+d(j,:);
        Y=[0 1]*x{i,j}(1,2);

        line(X,Y,...
        'LineWidth',lw,...
        'Color',c(j,:),...
        'Parent',ax1);hold on;

        text(X(1,2),Y(1,2)+0.01,T1(j,:),...
            'Rotation',90,...
            'Parent',ax1);hold on;

        try
        X=D(I,:)+d(j,:);
        Y=[0 1]*x{i,j}(2,2);

        lin(I)=line(X,Y,...
        'LineWidth',lw,...
        'Color',c(j,:),...
        'Parent',ax2);hold on;

        text(X(1,2),Y(1,2)+0.01,T2(j,:),...
            'Rotation',-90,...
            'Parent',ax2,...
            'VerticalAlignment','middle',...
            'HorizontalAlignment','left');hold on;

        end

    end

    xtickl{I}=['EXP' num2str(i)];


end
%ylab=ylabel('Volume fraction (\%)');
text(2.2,-0.5,'Volume␣fraction␣(\%)',...
            'Rotation',90,...
            'Parent',ax2,...
```

```
            'VerticalAlignment','middle',...
            'HorizontalAlignment','center');hold on;
set(ax1 ,'XTick',D(:,1)','XTickLabel',xtickl,'YTick',[5:5:35],...
    'TickDir','in');
set(ax2 ,'XTick',[],'XTickLabel',[],'YLim',get(ax1,'Ylim'),...
    'YTick',[5:5:35],'TickDir','in');
x1=8;x2=9;h=22;
line([x1 x2],[22
  22],'LineWidth',lw,'Color',c(1,:),'Parent',ax2);hold on;
line([x1 x2],[25
  25],'LineWidth',lw,'Color',c(2,:),'Parent',ax2);hold on;
text(x2+0.4,25,'Porosity');hold on
text(x2+0.4,22,'Oil');hold on
set(gcf,'Position',[960 530 560 400]);

    if poster==0;


laprint(1,'/home/jonas/Documents/Latex/Volumefractions_grow',...
    'asonscreen','on');

    elseif poster==1

laprint(1,'/home/jonas/Documents/Latex/posterVolumefractions_grow',...
    'asonscreen','on');

    end;
    hold off;

end
```

C.3 Compilation of tables

C.3.1 Table 3: temperature conversion

```
t=xlsread(...
    '/home/jonas/Documents/oilexp/TempertureFit/RTdata.xls');
clear table;
[I J]=size(t);

err=(t(:,1)-R2T(t(:,2)))*1000;

for i=1:I;
    table{i,1}=num2str(t(i,1));
    table{i,2}='&';
    table{i,3}=sprintf('%0.0f &',t(i,2));
    table{i,4}=sprintf('%0.01f',err(i,1));
    table{i,5}='\\';
end;
```

```
for i=1:size(table,2)
    if i==1
    Table=[strvcat(char(table(:,i)))];
    else
    Table=[Table strvcat(char(table(:,i)))];
    end;
end;

a1='\begin{tabular}{r r r}';
a2='Temp.    &Resistance &Error in fit\\ \cmidrule[1pt](l){1-3}';
a3='$\mathrm{^\circ C}$   &$\mathrm{\Omega}$        
  &$\mathrm{m^\circ C}$\\ \midrule';
a4='\cmidrule[1pt](l){1-3}';
a5='\end{tabular}';

Tempfittable=strvcat(a1,a2,a3,Table,a4,a5);

dlmwrite('/home/jonas/Documents/Latex/tempfittable.tex',...
    Tempfittable,'delimiter', '');
```

C.3.2 Table 5: overview of melt season experiments

```
clear all; load EXP;
I=2;
sign{2}=' & ';
sign{3}=' & ';
sign{4}=' & ';

for i=[14 16 17];
    exp{1,I}=['\textbf{EXP' num2str(i) '}' char(sign(I))];

    if i==17
        pressure{1,I}=['(manual)' char(sign(I))];
    else
        pressure{1,I}=['$\mathrm{\times}$' char(sign(I))];
    end;

    if i==14
        light{1,I}=[' ' char(sign(I))];
    else
        light{1,I}=['$\mathrm{\times}$' char(sign(I))];
    end;


    if i==17
        temp{1,I}=[char(sign(I))];
    else
        temp{1,I}=['$\mathrm{\times}$' char(sign(I))];
```

```
    end;

    if EXP(i).oiltype(:,1)==1;

    oiltype{1,I}=['synt' char(sign(I))];
    else
    oiltype{1,I}=['crude' char(sign(I))];
    end;

    oiltemp{1,I}=[num2str(EXP(i).oiltype(:,2)) char(sign(I))];
    oilweight{1,I}=[num2str(EXP(i).oiltype(:,3)) char(sign(I))];

    or(I,:)=[i find(EXP(i).tx(:,2)==3)];


    %Duration
    try
        End(I)=EXP(i).tx(find(EXP(i).tx(:,2)==2),1);
    catch
        End(I)=NaN;
    end;

    try
        Start(I)=EXP(i).tx(find(EXP(i).tx(:,2)==4),1);
    catch
        Start(I)=NaN;
    end


    OR(I)=EXP(i).tx(find(EXP(i).tx(:,2)==3),1);

    thick{1,I}=[sprintf('%0.1f',-1*polyval(EXP(i).th_fit2,OR(I))) char(sign(I))];

    oil_on_surf{1,I}=[sprintf('%0.1f',...
        EXP(i).tx(find(EXP(i).tx(:,2)==7),1)-OR(I)) char(sign(I))];

    before{1,I}=[sprintf('%0.1f',(OR(I)-Start(I))) char(sign(I))];
    after{1,I}=[sprintf('%0.1f',(End(I)-OR(I))) char(sign(I))];

    %Water Salinity

    sw_or{1,I}=[sprintf('%0.3g',(EXP(i).sw_fit(OR(I)))) char(sign(I))];

    sw_init{1,I}=[sprintf('%0.1f',(EXP(i).sw(1,2))) char(sign(I))];

    I=I+1;
```

```

end;

exp{1,1}='&␣&';exp{1,5}='\\';
oiltype{1,1}='Oil␣&␣Type␣&';oiltype{1,5}='\\';
oilweight{1,1}='&Amount&';oilweight{1,5}='($\mathrm{ml}$)\\';
oiltemp{1,1}='&Temperture&';oiltemp{1,5}='($\mathrm{^\circ␣C}$)\\';
sw_init{1,1}='\\Water&Salinity␣FU&';sw_init{1,5}='($\mathrm{\permil}$)\\';
sw_or{1,1}='&␣-␣OR␣&';sw_or{1,5}='\\';
before{1,1}='\\␣Duration&Freezing&';before{1,5}='($\mathrm{days}$)\\';
after{1,1}='&Warming&';after{1,5}='\\';
oil_on_surf{1,1}='&Oil␣penetration&';oil_on_surf{1,5}='\\';
thick{1,1}='\\␣Ice&Thickness␣at␣OR&';thick{1,5}='($\mathrm{cm}$)\\';
pressure{1,1}='\\Setup&Pressure␣Release&';pressure{1,5}='\\';
temp{1,1}='&Thermistor␣probe&';temp{1,5}='\\';
light{1,1}='&Weak␣light␣on&';light{1,5}='\\';




table=[exp;oiltype;
    oilweight;
    oiltemp;
    thick;sw_init;
    sw_or;
    before;
    after;
    oil_on_surf;
    pressure;
    temp;
    light];

T=strvcat(table(:,1));

for i=2:length(table(1,:));
    T=[T strvcat(table(:,i))];
end;
%oiltype
%oilweight
%oiltemp

%salinity_init
%salinity_OR

%Before OR
%After OR
```

```
%Oilonsurface
Table=strvcat('\begin{tabular}{rlcccl} \cmidrule[1pt](l){2-5}',...
    T(1,:),'\cmidrule[1pt](l){2-5}',T(2:end,:),...
    '\cmidrule[1pt](l){2-5}','\end{tabular}');

dlmwrite('/home/jonas/Documents/Latex/meltseasontable.tex',...
    Table,'delimiter', '')
```

C.3.3 Table 4: overview of grow season experiments

```
clear all; load EXP;
I=1;

for i=[2 13 18 19 20 21];
    exp(I)=i;
    oiltype(I)=EXP(i).oiltype(:,1);
    oiltemp(I)=EXP(i).oiltype(:,2);
    oilweight(I)=EXP(i).oiltype(:,3);

    or(I,:)=[i find(EXP(i).tx(:,2)==3)];
    I=I+1;

end
for i=1:length(or(:,1))
   %Oilcapacity
   oilc(i)=oilcapacity(or(i,1));
    %Duration
    try
        End(i)=EXP(or(i,1)).tx(find(EXP(or(i,1)).tx(:,2)==2),1);
    catch
        End(i)=NaN;
    end;

    try
        Start(i)=EXP(or(i,1)).tx(find(EXP(or(i,1)).tx(:,2)==1),1);
    catch
        Start(i)=NaN;
    end

    OR(i)=EXP(or(i,1)).tx(find(EXP(or(i,1)).tx(:,2)==3),1);



    before(i)=(OR(i)-Start(i))*24;
    after(i)=(End(i)-OR(i))*24;
    %Water Salinity
    try
    sw(i)=EXP(or(i,1)).sw_fit(EXP(or(i,1)).tx(or(i,2),1));
```

```
    catch
    sw(i)=NaN;
    end

    %freezingpoint
    try
    tw0(i)=EXP(or(i,1)).tw0_fit(EXP(or(i,1)).tx(or(i,2),1));
    catch
    tw0(i)=NaN;
    end

    %water temperature
     try
        tw(i)=EXP(or(i,1)).tw_fit(EXP(or(i,1)).tx(or(i,2),1));
     catch
        tw(i)=NaN;
     end

     %Ice thickness thermistor
     try
     th1(i)=EXP(or(i,1)).th_fit1(EXP(or(i,1)).tx(or(i,2),1));
     catch
     th1(i)=NaN;
     end

     %Ice thickness thermistor other
     try
     th2(i)=EXP(or(i,1)).th_fit2(EXP(or(i,1)).tx(or(i,2),1));
     catch
     th2(i)=NaN;
     end

     %Ice thickness OI ice
     try
         thOI(i)=-1*min(EXP(or(i,1)).op(:,3));
     catch
         thOI(i)=NaN;
     end

     %Depth of OI layer
     try
         depthOI(i)=min(EXP(or(i,1)).op(:,2))...
             -min(EXP(or(i,1)).op(:,3));
     catch
         depthOI(i)=NaN;
     end


     %Oil Volume Fraction

```

```
    try
        ovf(i)=100*max(EXP(or(i,1)).profiles(end).ovf(:,2));
    catch
        ovf(i)=NaN;
    end

    %Oil (mass) Fraction
    try
        of(i)=100*max(EXP(or(i,1)).op(:,4));
    catch
        of(i)=NaN;
    end

    %Brine Volume Fractions

    if or(i,1)==13;

        bvfOI(i)=100*EXP(or(i,1)).profiles(2).bvf(1,2);
        bvfOItop(i)=100*EXP(or(i,1)).profiles(2).bvf(2,2);
        bvfNOI(i)=100*EXP(or(i,1)).profiles(1).bvf(1,2);
        bvfOR(i)=NaN;
        bvfORtop(i)=NaN;

        sOI(i)=EXP(or(i,1)).profiles(2).s(1,2);
        sNOI(i)=EXP(or(i,1)).profiles(1).s(1,2);
        sOR(i)=NaN;
        sOItop(i)=EXP(or(i,1)).profiles(2).s(2,2);
        sORtop(i)=NaN;

    elseif or(i,1)==20;

        bvfOI(i)=100*EXP(or(i,1)).profiles(3).bvf(2,2);
        bvfOItop(i)=100*EXP(or(i,1)).profiles(3).bvf(1,2);
        bvfNOI(i)=100*EXP(or(i,1)).profiles(2).bvf(1,2);
        bvfOR(i)=100*EXP(or(i,1)).profiles(1).bvf(7,2);
        bvfORtop(i)=100*EXP(or(i,1)).profiles(1).bvf(6,2);

        sOI(i)=EXP(or(i,1)).profiles(3).s(2,2);
        sNOI(i)=EXP(or(i,1)).profiles(2).s(1,2);
        sOR(i)=EXP(or(i,1)).profiles(1).s(7,2);
        sOItop(i)=EXP(or(i,1)).profiles(3).s(1,2);
        sORtop(i)=EXP(or(i,1)).profiles(1).s(6,2);



    elseif or(i,1)==21;

        bvfOI(i)=100*EXP(or(i,1)).profiles(3).bvf(1,2);
        bvfOItop(i)=100*EXP(or(i,1)).profiles(3).bvf(2,2);
        bvfNOI(i)=100*EXP(or(i,1)).profiles(2).bvf(1,2);
```

```
        bvfOR(i)=100*EXP(or(i,1)).profiles(1).bvf(7,2);
        bvfORtop(i)=100*EXP(or(i,1)).profiles(1).bvf(6,2);

        sOI(i)=EXP(or(i,1)).profiles(3).s(1,2);
        sOItop(i)=EXP(or(i,1)).profiles(3).s(2,2);
        sNOI(i)=EXP(or(i,1)).profiles(2).s(1,2);
        sOR(i)=EXP(or(i,1)).profiles(1).s(7,2);
        sORtop(i)=EXP(or(i,1)).profiles(1).s(6,2);

    elseif or(i,1)==19;
        bvfOI(i)=NaN;
        bvfOItop(i)=NaN;
        bvfNOI(i)=NaN;
        bvfOR(i)=NaN;
        bvfORtop(i)=NaN;

        sOI(i)=EXP(or(i,1)).profiles(1).s(2,2);
        sOItop(i)=EXP(or(i,1)).profiles(1).s(1,2);
        sOR(i)=NaN;
        sORtop(i)=NaN;
        sNOI(i)=NaN;

    elseif or(i,1)==18;

        bvfOI(i)=NaN;
        bvfOItop(i)=NaN;
        bvfNOI(i)=NaN;
        bvfOR(i)=NaN;
        bvfORtop(i)=NaN;

        sOI(i)=EXP(or(i,1)).profiles(1).s(1,2);
        sOItop(i)=EXP(or(i,1)).profiles(1).s(2,2);
        sOR(i)=NaN;
        sORtop(i)=NaN;
        sNOI(i)=NaN;

    elseif or(i,1)==2;

        bvfOI(i)=NaN;
        bvfOItop(i)=NaN;
        bvfNOI(i)=NaN;
        bvfOR(i)=NaN;
        bvfORtop(i)=NaN;

        sOI(i)=EXP(or(i,1)).op(2,5);
        sNOI(i)=EXP(or(i,1)).op(1,5);
        sOItop(i)=EXP(or(i,1)).op(3,5);
        sOR(i)=NaN;
        sORtop(i)=NaN;

```

```
    end;

    % Temperature Interface.
    try
        t_interface(i)=EXP(or(i,1)).profiles(1).t_fit(th1(i));
    catch
        t_interface(i)=NaN;
    end;

    if isnan(t_interface(i));

       try
           t_interface(i)=EXP(or(i,1)).profiles(1).t_fit(th2(i));
       catch
           t_interface(i)=NaN;
       end
    end

end;

a=[of;
   tw-tw0;
   tw
   sOI;
   sOR];

i=length(or(:,1))+2;
OILC{1,1}='&Oil␣Capacity&';
  OILC{1,i}='($\mathrm{\frac{m^3}{km^2}})$\\';
Exp{1,1}='&␣&';Exp{1,i}='\\';

Oil{1,1}='Oil␣&Type␣&'; Oil{1,i}='\\';
Oil{2,1}='&Amount␣&'; Oil{2,i}='(ml)\\';
Oil{3,1}='&Temperture␣␣&'; Oil{3,i}='($\mathrm{^\circ␣C}$)\\';

OilDev{1,1}='&OMF&'; OilDev{1,i}='($\mathrm{wt\%}$)\\';

Water{1,1}='Water&Salinity␣&';
  Water{1,i}='($\mathrm{\permil}$)\\';
Water{2,1}='&Temperature␣&'; Water{2,i}='($\mathrm{^\circ␣
  C}$)\\';

WaterDev{1,1}='&Freezingpoint&';WaterDev{1,i}='($\mathrm{^\circ␣
  C}$)\\';


Ice{1,1}='Ice&Interface␣temp.&'; Ice{1,i}='($\mathrm{^\circ␣
  C}$)\\';
Ice{2,1}='&Thickness␣&'; Ice{2,i}='($\mathrm{cm}$)\\';
```

```
Ice{3,1}='&-␣of␣OI␣layer&'; Ice{3,i}='\\';
Ice{4,1}='&Salinity␣OR␣&'; Ice{4,i}='($\permil$)\\';
Ice{5,1}='&-␣OR$+$&'; Ice{5,i}='\\';
Ice{6,1}='&-␣NOI&'; Ice{6,i}='\\';
Ice{7,1}='&-␣OI&'; Ice{7,i}='\\';
Ice{8,1}='&-␣OI$+$&'; Ice{8,i}='\\';

IceDev{1,1}='&BVF␣OI␣&'; IceDev{1,i}='($\mathrm{\%}$)\\';
IceDev{2,1}='&-␣OI$+$␣&';IceDev{2,i}='\\';
IceDev{3,1}='&-␣NOI␣&'; IceDev{3,i}='\\';
IceDev{4,1}='&-␣OR␣&'; IceDev{4,i}='\\';
IceDev{5,1}='&-␣OR␣$+$&';IceDev{5,i}='\\';

IceDev{6,1}='\\&OVF&';IceDev{6,i}='($\mathrm{\%}$)\\';

Duration{1,1}='Duration&Before␣OR␣&';
  Duration{1,i}='($\mathrm{hrs}$)\\';
Duration{2,1}='&After␣OR&';Duration{2,i}='\\';

for i=1:length(or(:,1));

    if i<length(or(:,1));
        S='␣&␣';
    else
        S='␣&␣';
    end

    %Oilcapacity
    if ~isnan(oilc(i))
        OILC{1,i+1}=[sprintf('%0.0f',oilc(i)) S];
    else
        OILC{1,i+1}=S;
    end

    %Experiment id

    Exp{1,i+1}=['\textbf{EXP' sprintf('%0.0f',exp(i)) '}' S];

    if oiltype(i)==1;
       Oil{1,i+1}=['Synt' S];
    elseif oiltype(i)==2;
        Oil{1,i+1}=['Crude' S];
    else
        Oil{1,i+1}=['NM' S];
    end;

    if ~isnan(oilweight(i))
       Oil{2,i+1}=[sprintf('%0.0f',10*round(oilweight(i)/10)) S];
    else
       Oil{2,i+1}=['NM' S];
```

```
    end;

    if ~isnan(oiltemp(i))
       if norm(oiltemp(i))<10
          Oil{3,i+1}=[sprintf('%0.1f',oiltemp(i)) S];
       else
          Oil{3,i+1}=[sprintf('%0.0f',oiltemp(i)) S];
       end
    else
       Oil{3,i+1}=['NM' S];
    end;

    if ~isnan(of(i))
       OilDev{1,i+1}=[sprintf('%0.1f',of(i)) S];
    else;
       OilDev{1,i+1}=['NM' S];
    end;

    if ~isnan(sw(i))
       Water{1,i+1}=[sprintf('%0.1f',sw(i)) S];
    else
       Water{1,i+1}=['NM' S];
    end;

    if ~isnan(tw(i))
       Water{2,i+1}=[sprintf('%0.1f',tw(i)) S];
    else
       Water{2,i+1}=['NM' S];
       if exp(i)==2;
       Water{2,i+1}=['PL*' S];
       end
    end;

    if ~isnan(tw(i))
       WaterDev{1,i+1}=[sprintf('%0.1f',tw0(i)) S];
    else
       WaterDev{1,i+1}=[' ' S];
    end;

    if ~isnan( t_interface(i))
       Ice{1,i+1}=[sprintf('%0.1f', t_interface(i)) S];
    else;
       Ice{1,i+1}=['NM' S];
    end;

    if ~isnan(thOI(i));
       Ice{2,i+1}=[sprintf('%0.1f',thOI(i)) S];
    else;
       Ice{2,i+1}=['NM' S];
    end;
```

```matlab

    if ~isnan(depthOI(i));
       Ice{3,i+1}=[sprintf('%0.1f',depthOI(i)) S];
    else;
       Ice{3,i+1}=['NM' S];
    end;

    if ~isnan(sOR(i));
       Ice{4,i+1}=[sprintf('%0.1f',sOR(i)) S];
    else;
       Ice{4,i+1}=['NM' S];
    end;

    if ~isnan(sORtop(i));
       Ice{5,i+1}=[sprintf('%0.1f',sORtop(i)) S];
    else;
       Ice{5,i+1}=['NM' S];
    end;

    if ~isnan(sNOI(i));
       Ice{6,i+1}=[sprintf('%0.1f',sNOI(i)) S];
    else;
       Ice{6,i+1}=['NM' S];
    end;

    if ~isnan(sOI(i));
       Ice{7,i+1}=[sprintf('%0.1f',sOI(i)) S];
    else;
       Ice{7,i+1}=['NM' S];
    end;

    if ~isnan(sOItop(i));
       Ice{8,i+1}=[sprintf('%0.1f',sOItop(i)) S];
    else;
       Ice{8,i+1}=['NM' S];
    end;


    if ~isnan(bvfOI(i))
       IceDev{1,i+1}=[sprintf('%0.1f',bvfOI(i)) S];
    else;
       IceDev{1,i+1}=['␣␣' S];
    end;

    if ~isnan(bvfOItop(i))
       IceDev{2,i+1}=[sprintf('%0.1f',bvfOItop(i)) S];
    else;
       IceDev{2,i+1}=['␣␣' S];
    end;

```

```
    if ~isnan(bvfNOI(i))
       IceDev{3,i+1}=[sprintf('%0.1f',bvfNOI(i)) S];
    else;
       IceDev{3,i+1}=['␣␣' S];
    end;

    if ~isnan(bvfOR(i))
       IceDev{4,i+1}=[sprintf('%0.1f',bvfOR(i)) S];
    else;
       IceDev{4,i+1}=['␣␣' S];
    end;

    if ~isnan(bvfORtop(i))
       IceDev{5,i+1}=[sprintf('%0.1f',bvfORtop(i)) S];
    else;
       IceDev{5,i+1}=['␣␣' S];
    end;

    if ~isnan(ovf(i))
       IceDev{6,i+1}=[sprintf('%0.1f',ovf(i)) S];
    else;
       IceDev{6,i+1}=['␣␣' S];
    end;

    %Duration

    if ~isnan(before(i))
       Duration{1,i+1}=[sprintf('%0.1f',before(i)) S];
    else;
       Duration{1,i+1}=['NM' S];
    end;

    if ~isnan(after(i))
       Duration{2,i+1}=[sprintf('%0.1f',after(i)) S];
    else;
       Duration{2,i+1}=['NM' S];
    end;



end;

for i=1:size(Oil,2);

    if i==1;
        oiltable=[strvcat(char(Oil(:,i)))];
        oildevtable=[strvcat(char(OilDev(:,i)))];
        watertable=[strvcat(char(Water(:,i)))];
        waterdevtable=[strvcat(char(WaterDev(:,i)))];
        icetable=[strvcat(char(Ice(:,i)))];
```

```
        icedevtable=[strvcat(char(IceDev(:,i)))];
        exptable=[strvcat(char(Exp(:,i)))];
        durationtable=[strvcat(char(Duration(:,i)))];
        oilcapacity=[strvcat(char(OILC(:,i)))];
    else;
        oiltable=[oiltable strvcat(char(Oil(:,i)))];
        oildevtable=[oildevtable strvcat(char(OilDev(:,i)))];
        watertable=[watertable strvcat(char(Water(:,i)))];
        waterdevtable=[waterdevtable
          strvcat(char(WaterDev(:,i)))];
        icetable=[icetable strvcat(char(Ice(:,i)))];
        icedevtable=[icedevtable strvcat(char(IceDev(:,i)))];
        exptable=[exptable strvcat(char(Exp(:,i)))];
        durationtable=[durationtable
          strvcat(char(Duration(:,i)))];
        oilcapacity=[oilcapacity strvcat(char(OILC(:,i)))];
    end;

end;

c1='\begin{tabular}{r␣l␣r␣r␣r␣r␣r␣r␣l}␣\cmidrule[1pt](l){2-8}';
c2='\cmidrule(l){2-8}';
c3='\textbf{Water}\\';
c4='\textbf{Ice}\\';
c5='\textbf{Ice}\\';
c6='\cmidrule[1pt](l){2-8}␣\end{tabular}';
overviewtable=strvcat(c1,exptable,c2,oiltable,...
    '\\',oildevtable,'\\',watertable,...
    '\\',waterdevtable,'\\',icetable,'\\',...
    icedevtable,oilcapacity,'\\',durationtable,c6,'%%%␣Local␣
      Variables:',...
'%%%␣mode:␣latex','%%%␣TeX-master:␣"thesis"','%%%␣End:' );
dlmwrite('/home/jonas/Documents/Latex/overviewtable.tex',...
    overviewtable,'delimiter', '')
```

C.4 Data processing

C.4.1 Voltage temperature conversion equation ((6.7.2))

```
function[t]=R2T(V)

addpath('/home/jonas/Documents/oilexp/TempertureFit');
load A;
time=V(:,2:4);
V=V(:,8:8+28);
[ny nx]=size(V);
m=mFRAv(V);
load T0
Rt=(m*1000)./(2500*ones(size(m))-m);
```

```
I=length(m);

for i=1:I
     logR(i)=log(Rt(i));
     logR3(i)=logR(i)^3;
end;

logR=logR';
logR3=logR3';

G=[ones(size(m)) logR logR3];
T=1./(G*A)-273.15;
T=vFRAm(T,ny,nx);

for i=1:length(T(:,1));

    t0(i,:)=T0;
end;
time=datenum(time(:,1),0,time(:,2),floor(time(:,3)/100),...
((time(:,3)/100)-floor(time(:,3)/100))*100,0);
t=real(T-t0);
t=[time t];
%T=V2T(EXP8(146:end,:))
```

C.4.2 Extrapolation of surface temperature

See eventually subsection 6.7.4:

```
function[tp]=addsurfacetemp(i)
%function[tp]=addsurfacetemp(tp,pos,th). Fits the ice temperatue
  with a 1. degree polynomial and evaluate the missing surface
  temperature
load EXP
%Fits the ice thickness from thermistor freezing
surface_thermistor=find(EXP(i).pos(1,:)'==0);

for j=1:size(EXP(i).tp,1);

        %find thermistors frozen into the ice without NaN values;
        I=find(EXP(i).pos<=0&EXP(i).pos>polyval(EXP(i).th_fit,...
        EXP(i).tp(j,1))&~isnan(EXP(i).tp(j,:)));

        if length(I)>1
        P=polyfit(EXP(i).pos(I)',EXP(i).tp(j,I)',1);
        EXP(i).tp(j,surface_thermistor)=polyval(P,0);
        end;
end
tp=EXP(i).tp;
```

C.4.3 Extraction of profiles

```
function[p]=profiles(i)
%clear all;
load EXP
%i=18;
%load EXP;
echo off;

oiltype=EXP(i).oiltype(1,1);

    if oiltype==1;%(synthetic oil
        oildensity=85.3/98.0;
    elseif oiltype==2;
        oildensity=83.0/99.5;
    end;

S=(isempty(EXP(i).sp)==0)*size(EXP(i).sp,3);
O=(isempty(EXP(i).op)==0)*size(EXP(i).op,3);%number of salinity
  profiles in sp og op.

if S+O==0;

    p(1).s=[];

else;

    for j=1:S;

        p(j).s=[(EXP(i).sp(:,2,j)+EXP(i).sp(:,3,j))/2
          EXP(i).sp(:,4,j)
          0.5*sqrt((EXP(i).sp(:,2,j)-EXP(i).sp(:,3,j)).^2)];
        p(j).s=p(j).s(find(~isnan(p(j).s(:,2))),:);
        p(j).d=datestr(EXP(i).sp(1,1,j));


    end;

    for j=1:O
        [EXP(i).op(:,2,j) EXP(i).op(:,3,j)];
        dist=0.5*sqrt((EXP(i).op(:,2,j)-EXP(i).op(:,3,j)).^2);
        p(S+j).s=[(EXP(i).op(:,2,j)+EXP(i).op(:,3,j))/2
          EXP(i).op(:,6,j) dist];
        p(S+j).s=p(S+j).s(find(~isnan(p(S+j).s(:,2))),:);
        p(S+j).d=datestr(EXP(i).op(1,1,j));
        p(S+j).o=[(EXP(i).op(:,2,j)+EXP(i).op(:,3,j))/2
          EXP(i).op(:,8,j) EXP(i).op(:,9,j) dist];
        p(S+j).o=p(S+j).o(find(~isnan(p(S+j).o(:,2))),:);
        %p(S+j).o=p(S+j).o(find(p(S+j).o(:,2)),:);
    end;
```

```

end;


if isempty(EXP(i).tp)==0;

    for j=1:S+O;
        [MIN ind]=min((EXP(i).tp(:,1)-datenum(p(j).d)).^2);
        p(j).t=[EXP(i).pos(:,2:end)' EXP(i).tp(ind,2:end)'];
        p(j).t=p(j).t(find(~isnan(p(j).t(:,2))),:);
        p(j).t(find(p(j).t(:,1)>0),:)=[];
        p(j).th=min(EXP(i).th(:,1)-datenum(p(j).d));
        p(j).t_ice=p(j).t(find(p(j).t(:,1)>p(j).th),:);
    end;

else

    p(1).t=[];

end

%FIT*********************************************************

for j=1:length(p);
    if length(p(j).s(:,2))>1;

        p(j).s_fit=fit(p(j).s(:,1),p(j).s(:,2),'smoothingspline');

    elseif length(p(j).s(:,2))==1;%Only one salinity measurement interpolation impossible

        p(j).s_fit=fit([p(j).s(:,1);p(j).s(:,2)],...
            [p(j).s(:,2);p(j).s(:,2)],'nearestinterp');

    end;

    if isempty(p(j).t)==0;
       if length(p(j).t(:,1))>1;

        p(j).t_fit=fit(p(j).t(:,1),p(j).t(:,2),...
            'smoothingspline');

        elseif length(p(i).t(:,2))==1;%Only one temp. measurement interpolation impossible

        %p(j).t_fit=fit([p(j).t(:,1),p(j).t(:,2),'nearestinterp');

        end;
    end;

```

```
end;

%BrineIceFraction
%bif*********************************************************

   for i=1:length(p);
        disp(length(p(i).s)*length(p(i).t)>0);
        if length(p(i).s)*length(p(i).t)>0;
            S=[(p(i).s(:,1)+p(i).s(:,3))
              (p(i).s(:,1)-p(i).s(:,3))];
            depth=[max(S(:,1)):-0.001:min(S(:,2))]';

            K(i).p=[depth
              bif(p(i).s_fit(depth),p(i).t_fit(depth))];
            K(i).p=K(i).p(find(~isnan(K(i).p(:,2))),:);
            p(i).bif_fit=fit(K(i).p(:,1),K(i).p(:,2),...
                'linearinterp');


            for j=1:length(S(:,1));
                p(i).bif(j,:)=[p(i).s(j,1) min(...
                    [integrate(p(i).bif_fit,...
                    S(j,2),S(j,1))/(S(j,2)-S(j,1)) p(i).s(j,3)
                      1])];
            end;
        end;
    end;

if 1==0;
else;
%BrineDensity**************************************************
try;
    for i=1:length(p);
        if length(p(i).s)*length(p(i).t)>0;

            S=[(p(i).s(:,1)+p(i).s(:,3))
              (p(i).s(:,1)-p(i).s(:,3))];
            depth=[max(S(:,1)):-0.001:min(S(:,2))]';

            Bd=[depth brinedensity(p(i).t_fit(depth))];
            Id=[depth icedensity(p(i).t_fit(depth))];

            p(i).bd_fit=fit(Bd(:,1),Bd(:,2),'smoothingspline');
            p(i).id_fit=fit(Id(:,1),Id(:,2),'smoothingspline');
            for j=1:length(S(:,1));
                p(i).bd(j,:)=[p(i).s(j,1)
                  integrate(p(i).bd_fit,S(j,2),...
                    S(j,1))/(S(j,2)-S(j,1)) p(i).s(j,3)];
                p(i).id(j,:)=[p(i).s(j,1) integrate(p(i).id_fit,...
                    S(j,2),S(j,1))/(S(j,2)-S(j,1)) p(i).s(j,3)];
```

```
            end;
        end;
    end;
end;


%OilVolumeFraction
%ovf*****************************************************

for i=1:length(p);
  try;
     if length(p(i).o)>=length(p(i).s);
        k=[];
        for j=1:length(p(i).s(:,1));
            ind=find(p(i).o(:,1)==p(i).s(j,1));
            k=[k ind];
        end;
     else
         k=1:length(p(i).o(:,1));
     end;
       p(i).ovf=[p(i).s(:,1) vf(p(i).o(k,3),p(i).o(:,2),...
           p(i).id(:,2),p(i).bd(:,2),oildensity,....
           p(i).bif(:,2),'o') p(i).s(:,3)];
       p(i).ovf=p(i).ovf(find(p(i).ovf(:,2)),:);
  end;
%Brine Volume Fraction*******************************************
  isempty(p(i).o)

  if isempty(p(i).o)
            %display('yes');
  p(i).bvf=[p(i).bif p(i).s(:,3)];
  else;
  try
  p(i).bvf=[p(i).s(:,1)
    vf(p(i).o(k,3),p(i).o(:,2),p(i).id(:,2),...
      p(i).bd(:,2),oildensity,p(i).bif(:,2),'b') p(i).s(:,3)];
  end;
  end;

  end;

end;
try
p=profilesstuff(p);
end;
```

C.5 Data structuring and (manual) cleaning

C.5.1 Compilation of data from individual experiments

```
function[EXP]=getdata(n,m)
if exist('m')==0
    m=n;
end;

try
load /home/jonas/Documents/oilexp/EXP.mat;
end;

da(1,:)='/home/jonas/Documents/oilexp/EXP01/raw/da01';%1
da(2,:)='/home/jonas/Documents/oilexp/EXP02/raw/da02';%2
da(6,:)='/home/jonas/Documents/oilexp/EXP06/raw/da06';%3
da(7,:)='/home/jonas/Documents/oilexp/EXP07/raw/da07';%4
da(8,:)='/home/jonas/Documents/oilexp/EXP08/raw/da08';%5
da(9,:)='/home/jonas/Documents/oilexp/EXP09/raw/da09';%6
da(10,:)='/home/jonas/Documents/oilexp/EXP10/raw/da10';%7
da(11,:)='/home/jonas/Documents/oilexp/EXP11/raw/da11';%8
da(12,:)='/home/jonas/Documents/oilexp/EXP12/raw/da12';%9
da(13,:)='/home/jonas/Documents/oilexp/EXP13/raw/da13';%10
da(14,:)='/home/jonas/Documents/oilexp/EXP14/raw/da14';%11
da(15,:)='/home/jonas/Documents/oilexp/EXP15/raw/da15';%12
da(16,:)='/home/jonas/Documents/oilexp/EXP16/raw/da16';%13
da(18,:)='/home/jonas/Documents/oilexp/EXP17/raw/da18';%14
da(19,:)='/home/jonas/Documents/oilexp/EXP18/raw/da19';%15
da(21,:)='/home/jonas/Documents/oilexp/EXP19/raw/da21';%16

if exist('EXP')==1;
save /home/jonas/Documents/oilexp/EXP.mat EXP da;
else;
save /home/jonas/Documents/oilexp/EXP.mat da;
end;

load /home/jonas/Documents/oilexp/EXP.mat;

da(min([m n]):max([m n]),:)

for I=min([m n]):max([m n]);I

    load /home/jonas/Documents/oilexp/EXP.mat;
    run(da(I,:));
    save /home/jonas/Documents/oilexp/EXP.mat EXP da;

end;
```

C.5.2 EXP1

```
clear oiltype

EXP(1).oiltype=[1 NaN NaN];
```

C.5.3 EXP2

```
%Images thickness 7cm in EXP2_000005.cr2
%sampels 1236px=7cm
EXP(2).oiltype=[1 20 50];

EXP(2).op=sortrows([datenum(2008,3,2) -7+798*7/1236 -7+203*7/1236
   (15.0-13.6+14.9-(16.9-3.8))/14.9 (28.5-3.8)/(16.9-3.8)*3.5
  NaN;%sample 2
          datenum(2008,3,2) -7+798*7/1236 -7+203*7/1236 0
            6.4*(14.4+7.5)/14.4 NaN;%sample1
          datenum(2008,3,2) 0 -7+798*7/1236 0 9.9 NaN]);

EXP(2).tx=[NaN 3];%oil release
try
EXP(2).profiles(1).o=[mean([EXP(2).op(2:3,3) EXP(2).op(2:3,2)]')'
   EXP(2).op(2:3,4) EXP(2).op(2:3,2)-EXP(2).op(2:3,3)];
EXP(2).profiles(2).o=EXP(2).profiles(1).o(1,:);
EXP(2).profiles(2).o(1,2)=EXP(2).op(1,4);

EXP(2).profiles(1).s=[mean([EXP(2).op(2:3,3) EXP(2).op(2:3,2)]')'
   EXP(2).op(2:3,5) EXP(2).op(2:3,2)-EXP(2).op(2:3,3)];
EXP(2).profiles(2).s=EXP(2).profiles(1).s(1,:);
EXP(2).profiles(2).s(1,2)=EXP(2).op(1,5);
end
```

C.5.4 EXP6

```
%EXP6
EXP(6).oiltype=[0 NaN NaN];
EXP(6).sw=[datenum(2008,3,14,20,20,00) 28.3];
EXP(6).tw=[datenum(2008,3,14,20,20,00) -0.6];
```

C.5.5 EXP7

```
%EXP7
EXP(7).oiltype=[1 NaN NaN];

EXP(7).sw=[datenum(2008,3,15,21,7,0) 28.1;
          datenum(2008,3,16,13,9,0) 29.9];

EXP(7).tw=[datenum(2008,3,15,21,7,0) 17.4;
```

```
          datenum(2008,3,16,13,9,0) -1.5;
          datenum(2008,3,17,11,20,0) -1.8];

% thickness might be wong see notes.
EXP(7).th=[datenum(2008,3,16,13,9,0) 3 NaN -4 .2;
          datenum(2008,3,16,15,30,0) 3.5 NaN -4 .2;
          datenum(2008,3,17,11,20,0) 8.6 NaN -4 .2];
```

C.5.6 EXP8

```
%EXP8
time=datenum(2008,4,23,9,00,00);

EXP(8).oiltype=[0 NaN NaN];

EXP(8).sp=[time -0 -1 15.9 0.05;
          time -1 -2 13.6 0.05;
          time -2 -3 11.8 0.05;
          time -3 -4 10.8 0.05;
          time -4 -5 10.1 0.05;
          time -5 -6 9.9 0.05;
          time -6 -7 9.4 0.05;
          time -7 -8 9.3 0.05;
          time -8 -9 9.2 0.05;
          time -9 -10 9.1 0.05;
          time -10 -11 9.4 0.05;
          time -11 -12 10.7 0.05];

EXP(8).sw=[ datenum(2008,4,21,16,30,00) 28.2;
           datenum(2008,4,21,17,20,00) 28.4;
           datenum(2008,4,21,18,24,00) 28.8;
           datenum(2008,4,22,08,50,00) 34.1;
           datenum(2008,4,22,12,32,00) 35.7;
           datenum(2008,4,22,13,03,00) 36.0;
           datenum(2008,4,22,18,48,00) 38.7;
           datenum(2008,4,23,09,00,00) 47.0];


EXP(8).tw=[datenum(2008,4,21,16,30,00) -0.9;
           datenum(2008,4,21,17,20,00) -1.2;
           datenum(2008,4,21,18,24,00) -1.6;
           datenum(2008,4,22,08,50,00) -1.6;
           datenum(2008,4,22,12,32,00) -2.0;
           datenum(2008,4,22,13,03,00) -2.0;
           datenum(2008,4,22,18,48,00) -2.4;
           datenum(2008,4,23,09,00,00) -2.8];

    th1=[
    datenum(2008,4,23,09,00,00) -13 NaN -5 0;
```

```
    datenum(2008,4,23,09,00,00) -12.5 NaN -5 0;
    datenum(2008,4,23,09,00,00) -13 NaN -5 0;
    datenum(2008,4,23,09,00,00) -13 NaN -5 0;
    datenum(2008,4,23,09,00,00) -13 NaN -5 0;
    datenum(2008,4,23,09,00,00) -13.5 NaN -5 0;
    datenum(2008,4,23,09,00,00) -12 NaN -5 0;
    datenum(2008,4,23,09,00,00) -12.5 NaN -5 0;
    datenum(2008,4,23,09,00,00) -11.5 NaN -5 0;
    datenum(2008,4,23,09,00,00) -11.5 NaN -5 0;
    datenum(2008,4,23,09,00,00) -12 NaN -5 0;
    datenum(2008,4,23,09,00,00) -12.5 NaN -5 0;
    datenum(2008,4,23,09,00,00) -12.5 NaN -5 0];

addpath('/home/jonas/documents/oilexp/EXP8/raw');
T_raw=V2T(load('EXP8.dat'));
        save T_raw T_raw
        load T_raw;

        T=T_raw;

        T(:,4)=NaN;
        T(:,19:20)=NaN;
        T(143:end,24)=NaN;
        T(1:85,25)=NaN;
        T(121:165,25)=NaN;

        save T T


EXP(8).tp=T;


EXP(8).pos=positions(1); P1=[EXP(8).pos(:,:)];

        addpath('/home/jonas/Documents/oilexp/EXP8/raw');
        ind=xlsread('thermistorfreezein8.xls');

        th2=[T(ind(:,2),1) P1(1,ind(:,1))'
          ones(size(T(ind(:,2),1)))*NaN
          ones(size(T(ind(:,2),1)))*-3
          ones(size(T(ind(:,2),1)))*0.1];
EXP(8).th=[th1;th2];
```

C.5.7 EXP9

```
EXP(9).oiltype=[0 NaN NaN];

EXP(9).sw=[datenum(2008,4,25,18,0,0) 27.8;
            datenum(2008,4,28,10,01,0) 41.2;
```

```
            datenum(2008,0,120,11,20,0) 43.2;];

EXP(9).tw=[datenum(2008,4,25,18,0,0) 3;
            datenum(2008,4,28,10,01,0) -1.7];

        th1=[datenum(2008,4,28,10,01,0) 10.75 NaN -2
          0.25];%variation in hole 10.5-11cm

        T_raw=V2T(load('EXP9.dat'));
        save T_raw T_raw
        load T_raw;

        T=T_raw;

       T(:,4)=NaN;
       T(1:85,12)=NaN;
       T(472:end,12)=NaN;
       T(25:125,25)=NaN;
        %T(143:end,24)=NaN;
        %T(1:85,25)=NaN;
        %T(121:165,25)=NaN;


EXP(9).pos=positions(1); P1=[EXP(9).pos(:,:)];

EXP(9).tp=T;

        addpath('/home/jonas/Documents/oilexp/EXP8/raw');
        ind=xlsread('thermistorfreezein9.xls');

        th2=[T(ind(:,2),1) -P1(1,ind(:,1))'
          ones(size(T(ind(:,2),1)))*NaN
          ones(size(T(ind(:,2),1)))*-3
          ones(size(T(ind(:,2),1)))*0.1];
EXP(9).th=sort([th1;th2]);
```

C.5.8 EXP10

```
%EXP10

load('EXP');

EXP(10).oiltype=[0 NaN NaN];
EXP(10).sw=[datenum(2008,4,30,14,22,0) 27.7];
EXP(10).tw=[datenum(2008,4,30,14,22,0) 3];


        T_raw=V2T(load('EXP10.dat'));
        save T_raw T_raw
```

```
        load T_raw;

        T=T_raw;

       T(:,4)=NaN;
       T(:,12)=NaN;
       %T(1:85,12)=NaN;
       %T(472:end,12)=NaN;
       T(1:100,25)=NaN;
        %T(143:end,24)=NaN;
        %T(1:85,25)=NaN;
        %T(121:165,25)=NaN;


EXP(10).tp=T;

EXP(10).pos=positions(1); P1=[EXP(10).pos(:,:)];
EXP(10).pos(1,16:end)=EXP(10).pos(1,16:end)-0.8;

%Thickness of ice in low/thin corner
        th1=[datenum(2008,5,1,19,23,0) 7.5 NaN -2 0.2];

        addpath('/home/jonas/Documents/oilexp/EXP8/raw');
        ind=xlsread('thermistorfreezein10.xls');

        th2=[T(ind(:,2),1) -P1(1,ind(:,1))'
          ones(size(T(ind(:,2),1)))*NaN
          ones(size(T(ind(:,2),1)))*-3
          ones(size(T(ind(:,2),1)))*0.1];

EXP(10).th=sort([th1;th2]);

        clear T T_raw P1 P2 ind p tabel th1 th2;

EXP(10).tx=[datenum(2008,5,1,19,23,0) 3];
```

C.5.9 EXP11

```
%EXP11

EXP(11).oiltype=[0 NaN NaN];

EXP(11).sw=[datenum(2008,5,7,15,28,00) 28.0;
           datenum(2008,5,7,17,21,00) 27.9;
           datenum(2008,5,8,10,00,00) 30.7;
           datenum(2008,5,8,13,28,00) 31.6;
           datenum(2008,5,8,14,50,00) 31.9;
           datenum(2008,5,8,18,01,00) 33.0;
           datenum(2008,5,9,09,56,00) 40.0];
```

```

EXP(11).tw=[datenum(2008,5,7,15,28,00) 10.3;
           datenum(2008,5,7,17,21,00) 6.5;
           datenum(2008,5,8,10,00,00) -0.7;
           datenum(2008,5,8,13,28,00) -0.7;
           datenum(2008,5,8,14,50,00) -0.6;
           datenum(2008,5,8,18,01,00) -0.9;
           datenum(2008,5,9,09,56,00) -2.1];


EXP(11).tx=[datenum(2008,5,7,15,28,00) 1;
           datenum(2008,5,8,18,01,00) 5];


      T_raw=V2T(load('EXP11.dat'));

      T=T_raw;

      T(:,4)=NaN;
      T(:,12)=NaN;
      T(1:100,25)=NaN;
      T(:,29)=NaN;
      T(143:end,24)=NaN;
      T(1:85,25)=NaN;
      T(121:165,25)=NaN;


EXP(11).tp=T;



EXP(11).pos=positions(1); P1=[EXP(11).pos(:,:)];
       th1=[NaN NaN NaN NaN NaN];

       addpath('/home/jonas/Documents/oilexp/EXP11/raw');
       ind=xlsread('thermistorfreezein11.xls');

       th2=[T(ind(:,2),1) P1(1,ind(:,1))'
         ones(size(T(ind(:,2),1)))*NaN
         ones(size(T(ind(:,2),1)))*-3
         ones(size(T(ind(:,2),1)))*0.1];

EXP(11).th=sortrows([th1;th2]);
```

C.5.10 EXP12

```
%EXP12

%no manual data
```

C.5.11 EXP13

```
%EXP13
EXP(13).sp_fit=[];
EXP(13).oiltype=[1 0 50];

a=xlsread(...
    '/home/jonas/Documents/oilexp/EXP13/webcam/sw_webcam13.xls');
EXP(13).sw=[datenum(a(:,1:6)) a(:,7:8)];


        th1=[datenum(2008,0,156,17,20,0) -8.5 NaN -5 0.2;
        datenum(2008,0,156,17,20,0) -10.0 NaN -5 0.2];


        T_raw=V2T(load(...
            '/home/jonas/Documents/oilexp/EXP13/raw/EXP13.dat'));

        T=T_raw;
        T(:,4)=NaN;
        T(:,7:8)=NaN;
        T(:,9)=NaN;
        T(1:26,11)=NaN;
        T(20:55,12)=NaN;
        T(1:143,16)=NaN;
        T(20:96,25)=NaN;
        T(239:end,26)=NaN;
        T(:,29)=NaN;

EXP(13).tp=T;
EXP(13).sw(:,1)=EXP(13).sw(:,1)-EXP(13).sw(end,1)+...
    EXP(13).tp(end,1);

EXP(13).tx=sortrows([
            datenum(2008,6,2,14,00,0) 1;
            datenum(2008,6,4,9,52,0) 3;
            datenum('02-Jun-2008 18:00:00') 4;%freezeup estimated
              from salinitywater
            EXP(13).tp(end,1) 2],1);

EXP(13).pos=positions(1);

EXP(13).pos(1,16:end)=EXP(13).pos(1,16:end)-0.8;

P1=[EXP(13).pos(:,:)];
```

```
ind=xlsread(['/home/jonas/Documents/oilexp/'...
    'EXP13/raw/thermistorfreezein13.xls']);
        th2=[T(ind(:,2),1) P1(1,ind(:,1))'
          ones(size(T(ind(:,2),1)))*NaN
          ones(size(T(ind(:,2),1)))*-3
          ones(size(T(ind(:,2),1)))*0.1];

EXP(13).th=sortrows([th1;th2]);

%_MG_EXP13_000007.cr2 thickness 8 cm.
%_MG_EXP13_000011.cr2 2100px=sin(85.64)*7inch
f=2100/(sind(85.64)*7*2.54);d=-8;

EXP(13).op=[EXP(13).tp(end,1) d+276/f d
  ((16.6-13.5)+(67.8-66.5))/(109.7-66.5) ...
    NaN 6.0 0.05 ((16.6-13.5)+(67.8-66.5))
      109.7-66.5-((16.6-13.5)+(67.8-66.5)) ;%Sample 2 oil/ice
      bottom
    EXP(13).tp(end,1) d+472/f d+276/f 0 NaN 8.4 0.05 0 40];%sample
       3 above oilinfiltrated layer

EXP(13).sp=[EXP(13).tp(end,1) d+276/f d 9.6 0.05];
EXP(13).profiles=profiles(13);
EXP(13).sw_fit=fit(EXP(13).sw(:,1),...
    EXP(13).sw(:,2),'linearinterp');
EXP(13).tw_fit=fit(EXP(13).tp(:,1),...
    EXP(13).tp(:,28),'linearinterp');
try
Thicknessfit
end
I1=find(EXP(13).th(:,4)==-3);
I2=find(EXP(13).th(:,4)~=-3);
try
EXP(13).th_fit1=polyfit(EXP(13).th(I1,1),EXP(13).th(I1,2),2);
end;
EXP(13).th_fit2=[];
EXP(13).tw0=[EXP(13).sw(:,1) freezingpoint(EXP(13).sw(:,2))];
EXP(13).tw0_fit=fit(EXP(13).tw0(:,1),...
    EXP(13).tw0(:,2),'linearinterp');
```

C.5.12 EXP14

```
%EXP14
EXP(14).sp=[];
EXP(14).sp_fit=[];
EXP(14).th_fit=[];


EXP(14).oiltype=[2 -1.4 600];
```

```
% time thickness freeboard
th1=[datenum(2008,6,09,15,55,0) -8.5 NaN -6 .2;%5 cm from
  thermistor
           datenum(2008,6,09,17,00,0) -11 4.5 -7 .2;%close to edge
           datenum(2008,6,10,10,13,0) -13 1 -6 .2;%5 cm from
             thermistor
           datenum(2008,6,10,16,31,0) -16.0 2.3 NaN .2;
           datenum(2008,6,10,22,17,0) -14 NaN -8 .2;%Under
             insolation plate
           datenum(2008,6,10,22,17,0) -16 NaN -9 .2;%14 cm from
             drill hole
           %datenum(2008,6,12,11,13,0) NaN -0.5 -10 .1;
           %datenum(2008,6,12,12,28,0) NaN -0.7 -10 .1;%pond depth
           %datenum(2008,6,13,09,13,0) NaN -0.7 -10 .1;%pond depth
           %datenum(2008,6,17,10,42,0) NaN -0.6 -10 .1;
           datenum(2008,6,18,10,48,0) -21 NaN -11 .2;%Thickness
             allong barrel
           datenum(2008,6,18,10,48,0) -18 NaN -9 .2];%12 cm from
             barrel edge

    % Salinity of meltpond water
EXP(14).ss=[datenum(2008,6,13,09,13,0) 54.1;
           datenum(2008,6,14,14,40,0) 43.4;
           datenum(2008,6,15,11,34,0) 40.8;
           datenum(2008,6,16,12,09,0) 34.2;
           datenum(2008,6,16,21,37,0) 28.8;
           datenum(2008,6,18,10,12,0) 31.3];
           %surface temperatures

EXP(14).ts=[datenum(2008,6,10,16,47,0) -5.4;%Below insolation
           datenum(2008,6,10,16,47,0) -11;%free of insolation
           datenum(2008,6,11,12,57,0) -8.2;
           datenum(2008,6,11,15,30,0) -7.8;
           datenum(2008,6,11,18,15,0) -6.6;
           datenum(2008,6,11,22,39,0) -5.4;
           datenum(2008,6,12,7,30,0) -4.9;
           datenum(2008,6,12,11,13,0) -2.8;
           datenum(2008,6,12,13,31,0) -3.4;
           datenum(2008,6,12,15,08,0) -3.8;
           datenum(2008,6,12,20,45,0) -2.7;
           datenum(2008,6,16,21,37,0) -1.0;
           datenum(2008,6,17,11,24,0) -1.7];

EXP(14).sw=[datenum(2008,6,9,15,55,0) 32.1;
           datenum(2008,6,10,10,13,0) 34.6;
           datenum(2008,6,10,22,17,0) 34.8];

EXP(14).tw=[datenum(2008,6,10,10,13,0) -1.3;
           datenum(2008,6,10,22,17,0) -1.7];

```

```
       T_raw=V2T(load('EXP14.dat'));
       %load T_raw;
       T=T_raw;
       T(:,4)=NaN;
       T(:,7)=NaN;
       T(:,9)=NaN;
       T(:,8)=NaN;
       T(:,12)=NaN;
       T(:,16)=NaN;
       T(:,11)=NaN;
       T(500:end,16)=NaN;
       T(:,29)=NaN;
       T(:,30)=NaN;
       T(:,26)=NaN;
       T(533:end,25)=NaN;
       T(:,27)=medfilt1(T(:,27),14);
       T(205:250,27)=NaN;

EXP(14).tp=T;

EXP(14).tx=sortrows([datenum(2008,6,9,15,55,0) 13;
           EXP(14).tp(1,1)-1/10 4;%Freezeup
           datenum(2008,6,10,10,13,0) 13;
           datenum('10-Jun-2008␣14:20:02') 9;%insolation on
           datenum(2008,6,10,22,58,0) 3;
           datenum('10-Jun-2008␣20:20:02') 6;%insolation off
           datenum(2008,6,14,14,40,0) 15;
           datenum(2008,6,15,12,24,00) 7;
           datenum('10-Jun-2008␣10:14:23') 18;%strong light turned on
           datenum('10-Jun-2008␣22:20:00') 18;%strong light turned on
           datenum('10-Jun-2008␣10:49:57') 19;%strong light turned off
           datenum('10-Jun-2008␣23:40:03') 19;%strong light turned off
           datenum(2008,6,13,09,13,0) 14;%pump turned off
           datenum('11-Jun-2008␣10:29:56') 16;%light turned on
           datenum('09-Jun-2008␣15:50:02') 16;%light turned on
           datenum(2008,6,15,12,24,00) 17;%light turned off
           datenum('09-Jun-2008␣16:49:57') 17;%light turned off
           datenum('18-Jun-2008␣10:50:00') 2;%End
           datenum(2008,6,18,10,48,0) 8],1);

EXP(14).pos=positions(1); P1=[EXP(14).pos(:,:)];
       %th1=[NaN NaN NaN NaN NaN];

ind=xlsread(['/home/jonas/Documents/oilexp/' ...
    'EXP14/raw/thermistorfreezein14.xls']);
```

```

      th2=[T(ind(:,2),1) P1(1,ind(:,1))'
        ones(size(T(ind(:,2),1)))*NaN
        ones(size(T(ind(:,2),1)))*-3
        ones(size(T(ind(:,2),1)))*0.1];

EXP(14).th=sortrows([th1;th2]);

%OILFLUX*************************************
        [flux fluxtext]=xlsread(...
        '/home/jonas/Documents/oilexp/EXP14/raw/oilflux14.xls');
        flux=flux(4:end,:);
        fluxtext=fluxtext(4:end,10);
        EXP(14).of_text=char(fluxtext);

        T1=datenum(2008,6,flux(:,1),flux(:,2),flux(:,3),0);
        T2=datenum(2008,6,flux(:,4),flux(:,5),flux(:,6),0);
        o_m=flux(:,7)-flux(:,8);%mass of measured oil

%UNCERTAINTY in oil weight
    test=xlsread(['/home/jonas/Documents/oilexp/'...
    'Oilcapturetest/oilcapturetest.xls']);
    test=test(2:end,:);
    oil=test(:,1);
    oil_m=test(:,4)-test(:,3);
    do=std(oil-oil_m);%Uncertainty in oil mass
    o_offset=mean(oil_m-oil);
    o=o_m-o_offset;
    dT1=(2/(24*60))*ones(size(T1));%uncertainty in time
      measuremnent
    dT2=(4/(24*60))*ones(size(T1));
    DT=T2-T1;
    dDT=sqrt(dT1.^2+dT1.^2);
    dof=sqrt((o.*dDT./DT.^2)+(do./DT).^2);
    odrops=flux(:,9)*0.1*mean([1/2 1/3]);%weight of oildrops

 EXP(14).of=[T1 T2 o./DT dof odrops./DT];

 s=xlsread(...
 '/home/jonas/Documents/oilexp/EXP14/raw/salinitysample14.xls');


       date=ones(size(s(:,1)))*datenum(2008,6,18,10,48,0);
       % date pos salinity uncaertenty oilcontett ppt
EXP(14).op=[date s(:,2:9)];

fit14

EXP(14).profiles=profiles(14);

```

```
EXP(14).sw_fit=fit(EXP(14).sw(:,1),...
    EXP(14).sw(:,2),'linearinterp');
EXP(14).tw_fit=fit(EXP(14).tw(:,1),...
    EXP(14).tw(:,2),'linearinterp');

%thicknessfit
I1=find(EXP(14).th(:,4)==-3);
I2=find(EXP(14).th(:,4)~=-3);
try
%EXP(14).th_fit1=fit(EXP(14).th(I1,1)...
%,EXP(14).th(I1,2),'linearinterp');
EXP(14).th_fit=polyfit(EXP(14).th(I1,1),EXP(14).th(I1,2),2);
end;
th=EXP(14).th(find(~isnan(EXP(14).th(:,1))&...
    EXP(14).th(:,4)==-3),:);
EXP(14).th_fit2=polyfit(th(:,1),th(:,2),2);
EXP(14).tw0=[EXP(14).sw(:,1) freezingpoint(EXP(14).sw(:,2))];
EXP(14).tw0_fit=fit(EXP(14).tw0(:,1),...
    EXP(14).tw0(:,2),'linearinterp');
```

C.5.13 EXP15

```
%EXP15



EXP(15).oiltype=[0 NaN NaN];
EXP(15).tx=[datenum(2008,6,16,16,15,00) 1;
           datenum(2008,6,18,11,28,00) 2];


EXP(15).tw=[datenum(2008,6,16,16,15,00) -0.1;
    datenum(2008,6,16,20,23,00) -1.2;
    datenum(2008,6,16,21,37,00) -1.0;
    datenum(2008,6,16,23,20,00) -1.4;
    datenum(2008,6,17,08,20,00) -1.6;
    datenum(2008,6,17,10,23,00) -1.4;
    datenum(2008,6,17,12,15,00) -1.6;
    datenum(2008,6,17,14,35,00) -1.5;
    datenum(2008,6,18,00,19,00) -1.6;
    datenum(2008,6,18,09,53,00) -1.7;];

EXP(15).sw=[datenum(2008,6,16,16,15,00) 28.1;
    datenum(2008,6,16,20,23,00) 28.7;
    datenum(2008,6,16,21,37,00) 28.8;
    datenum(2008,6,16,23,20,00) 29.5;
    datenum(2008,6,17,08,20,00) 32.9;
    datenum(2008,6,17,10,23,00) 33.2;
    datenum(2008,6,17,12,15,00) 33.8;
```

```
    datenum(2008,6,17,14,35,00) 34.2;
    datenum(2008,6,18,00,19,00) 38.3;
    datenum(2008,6,18,09,53,00) 42.4];

i=32.2;

EXP(15).th=[datenum(2008,6,16,20,23,00) i-30.2 NaN -1 .2;%29.8+0.4?
           datenum(2008,6,16,21,37,00) i-29.8 NaN -1 .2;%29,4+0.4?
           datenum(2008,6,16,23,20,00) i-29.6 NaN -1 .2;%29.2+0.4?
           datenum(2008,6,17,08,20,00) i-27.0 NaN -1 .2;%26.6+0.4?
           datenum(2008,6,17,10,23,00) i-25.0 NaN -1 .2;%24.6+0.4?
           datenum(2008,6,17,12,15,00) i-24.5 NaN -1 .2;%24.1+0.4?
           datenum(2008,6,17,14,35,00) i-24.1 NaN -1 .2;%23.7+0.4?
           datenum(2008,6,18,00,19,00) i-21.6 NaN -1 .2;%21.2+0.4?
           datenum(2008,6,18,11,28,00) 12 NaN -5 .2;%min
           datenum(2008,6,18,11,28,00) 13 NaN -5 .2;%max
           datenum(2008,6,18,11,28,00) 11.5 NaN -5 .2];%middle of container

clear i;
time=EXP(15).tx(end,1);

 EXP(15).sp=[
           time -00.0 -01.1 15.8;
           time -01.1 -02.2 09.6;
           time -02.2 -03.3 08.6;
           time -03.3 -04.4 09.4;
           time -04.4 -05.5 09.5;
           time -05.5 -06.6 09.9;
           time -07.7 -08.8 10.0;
           time -08.8 -09.9 10.3;
           time -09.9 -11.0 12.2;
           time -11.0 -12.5 17.4];
```

C.5.14 EXP16 & EXP17

```
% EXP16 (EXP16a)

EXP(16).op=[];EXP(17).op=[];EXP(16).th_fit=[];
EXP(16).oiltype=[1 -1.6 450];
EXP(16).tx=sortrows([datenum(2008,6,20,02,13,0) 1;%start
               datenum(2008,6,20,06,20,0) 4;
               datenum(2008,6,23,06,55,0) 9;
               datenum('23-Jun-2008␣18:49:00') 8;
               datenum('08-Jul-2008␣15:34:00') 8;
               datenum('08-Jul-2008␣15:34:00') 2;
               datenum('10-Jul-2008␣10:46:00') 8;%cores taken
               datenum(2008,6,23,18,49,0) 6;%insulation off
```

```
                datenum(2008,6,23,20,30,0) 3;%oil release
                datenum(2008,7,06,23,30,0) 15],1);%'EXP16a oil seeping up where core were taken'

EXP(16).ss=sortrows([datenum(2008,7,08,14,30,00) 34.4 0.05;
                datenum(2008,6,24,17,30,00) 46.6*48.1/23.9 .2;
                datenum(2008,6,28,15,12,00) 40.1 .05],1);%EXP16a

a=xlsread(...
['/home/jonas/Documents/oilexp/'...
'EXP16/EXP16webcam/salinity_webcam/sw_web16.xls']);
             sw_auto=[datenum(a(:,1:6)) a(:,end)];
             sw_auto=sw_auto(1:90,:);%Here salinometer is freezing
             sw=[datenum(2008,6,20,8,59,0) 30.3;
             datenum(2008,6,21,13,33,0) 32.8;
             datenum(2008,6,23,18,49,0) 37.1;];
               %datenum(2008,6,23,19,36,0) NaN];

EXP(16).sw=sortrows([sw;sw_auto],1);


EXP(16).ts=sortrows([datenum(2008,6,23,06,25,00) -13.5 .05;
               datenum(2008,6,23,06,42,00) -7.6 .05;
               datenum(2008,6,24,17,30,00) -7.5 .05;
               datenum(2008,6,25,16,20,00) -4.2 .05],1);

th1=sortrows([
    datenum(2008,6,20,08,59,0) 0 NaN -1 NaN;%depth gauge 29-29 a
    datenum(2008,6,21,07,12,0) 3 NaN -1 NaN;%depth gauge 26 a
    datenum(2008,6,21,23,37,0) 9.1 NaN -1 NaN;% 19.9? a
    datenum(2008,6,21,13,19,0) 8 0 -2 NaN;%salinometer hole a
    datenum(2008,6,22,06,46,0) 10.2 NaN -1 NaN;%Depth gauge 18.8 a
    datenum(2008,6,22,10,16,0) 29-(2.54*7.25) NaN -1 NaN;%depth gauge inch a
    datenum(2008,6,22,19,15,0) 12.5 NaN -1 NaN;%depth gauge 16.6; a
    datenum(2008,6,23,06,55,0) 14 NaN -1 NaN;%depth gauge 15 a
    datenum(2008,6,23,18,49,0) 17 NaN -2 NaN;%hole a
    datenum(2008,6,23,19,08,0) 14.5 NaN -8 NaN;%center a
    datenum(2008,6,23,20,30,0) 17.2 NaN -2 NaN;%EXP16a oilrelease hole a
    datenum(2008,6,23,20,30,0) 16.8 NaN -2 NaN],1);%EXP16a same oilrelease hole a

%T_raw=V2T(load('EXP16.dat'));
%save T_raw16 T_raw;
load T_raw16
        T=T_raw;
        T(find(T(:,4)<-30),4)=NaN;
        T(find(T(1:601,4)<-23),4)=NaN;
```

```
        T(785:end,4)=NaN;
        T(627:end,6)=NaN;
        T(:,7)=NaN;
        T(:,8)=NaN;
        T(:,9)=NaN;
        T(:,7)=NaN;
        T(:,10)=NaN;
        T(:,16)=NaN;
        T(:,26)=NaN;
        T(:,28:30)=NaN;
        T(2686:end,27)=NaN;
        T(:,11)=NaN;
        T(655:2668,11)=NaN;
        T(:,25)=NaN;
        T(:,23)=NaN;
        T(:,12)=NaN;
        EXP(16).pos=positions(3); P1=[EXP(16).pos(:,:)];
        EXP(16).tp=T;




ind=xlsread(['/home/jonas/Documents/'...
    'oilexp/EXP16/raw/thermistorfreezein16.xls']);

        th2=[T(ind(:,2),1) -P1(1,ind(:,1))'
          ones(size(T(ind(:,2),1)))*NaN
          ones(size(T(ind(:,2),1)))*-3
          ones(size(T(ind(:,2),1)))*0.1];

EXP(16).th=sortrows([th1;th2],1);
EXP(16).th(:,2)=-EXP(16).th(:,2);


a=xlsread('salinitycore16.xls');
a(1:2,:)=[];
time=datenum(2008,6,23,18,49,0)*ones(size(a(:,1)));
EXP(16).sp=[time -1*a(:,4:5) a(:,2) 0.05*ones(size(a(:,1)))];


a=xlsread(...
['/home/jonas/Documents/oilexp/'...
'EXP16/raw/oil_profile16ab.xls'],'core16a0');
                a=a(1:end,:);

                time=datenum('08-Jul-2008 15:34:00')*ones(size(a(:,1)));
                [dim1 dim2]=size([time a]);

            EXP(16).op(1:dim1,1:dim2,1)=[time a];
```

```

            sheet{1}='core16a1';
            sheet{2}='core16a2';
            sheet{3}='core16a3';

            for i=1:3;

a=xlsread(...
'/home/jonas/Documents/oilexp/EXP16/raw/oil_profile16ab.xls',...
sheet{i});
a(1:end,:);

                time=datenum('10-Jul-2008 10:46:00')*ones(size(a(:,1)));
                [dim1 dim2]=size([time a]);

            EXP(16).op(1:dim1,1:dim2,i+1)=[time a];

            end;

            for i=1:length(EXP(16).op(1,1,:));
               a=find(EXP(16).op(:,1,i)==0);
               EXP(16).op(a,:,i)=NaN*ones(size(EXP(16).op(a,:,i)));
            end;
try
EXP(16).profiles=profiles(16);
end;

EXP(16).sw_fit=fit(EXP(16).sw(:,1),EXP(16).sw(:,2),...
    'linearinterp');

%Thickness fit
I1=find(EXP(16).th(:,4)==-3);
I2=find(EXP(16).th(:,4)~=-3);

EXP(16).th_fit1=fit(EXP(16).th(I1,1),EXP(16).th(I1,2),...
    'linearinterp');

th=EXP(16).th(find(~isnan(EXP(16).th(:,1))&...
    EXP(16).th(:,4)==-3),:);
EXP(16).th_fit2=polyfit(th(:,1),th(:,2),2);


EXP(16).tw0=[EXP(16).sw(:,1) freezingpoint(EXP(16).sw(:,2))];
EXP(16).tw0_fit=fit(EXP(16).tw0(:,1),EXP(16).tw0(:,2),...
    'linearinterp');

            %****************************************
%EXP17 (EXP16b)
EXP(17).tp=EXP(16).tp;
```

```
EXP(17).pos=EXP(16).pos;
EXP(17).oiltype=[2 -1.6 500];%crude


EXP(17).tx=sortrows([
           datenum(2008,6,20,06,20,0) 4;%'ice formation'
           datenum(2008,6,23,06,45,0) 9;%'Insulation on top'
           datenum(2008,6,23,19,47,0) 3;% EXP16(4).text='oil released b'
           datenum(2008,6,27,14,00,0) 15;%'Oil seeping up EXP16b along barrel'
           datenum(2008,7,01,12,12,0) 7;%'Oil seeping up AOI EXP16b'
           datenum(2008,7,07,23,30,0) 10;%'No more oil seeping up EXP16b'
           datenum(2008,6,24,13,20,0) 13;%'EXP16b pressure release'
           datenum(2008,6,25,13,41,0) 13;%'EXP16b pressure release - no pressure'
           datenum('08-Jul-2008␣15:34:00') 8;
           datenum('08-Jul-2008␣15:34:00') 2;
           datenum('10-Jul-2008␣10:46:00') 8;%Coring
           datenum('23-Jun-2008␣18:49') 6;%Insulation off
           datenum(2008,6,30,08,40,0) 12],1);% EXP16(8).text='EXP16b dark spots visible under surface'

EXP(17).ss=sortrows([
       datenum(2008,7,08,14,30,00) 29.7 .05;
       datenum(2008,6,24,17,30,00) 52.6*62.6/29.9 .2;
       datenum(2008,6,28,15,12,00) 42 .05],1);%29.9 gr brine + freshwater = 62.6 gr mixture has salinity 52.6 ppt

%s=p*s1+(1-p)*s2=p*s1;s1=s/p p=29.9/62.6

EXP(17).ts=sortrows([
               datenum(2008,6,23,06,25,00) -13.5 .05;
               datenum(2008,6,23,06,42,00) -7.6 .05;
               datenum(2008,6,24,17,30,00) -7.2 .05;
               datenum(2008,6,25,16,20,00) -4.2 .05],1);

EXP(17).tw=sortrows([
       datenum(2008,6,20,08,59,0) -1.5 .05;
       datenum(2008,6,21,13,33,0) -1.7 .05;
       datenum(2008,6,23,19,36,0) -1.9 .05],1);

EXP(17).sw=sortrows([
        datenum(2008,6,20,8,59,0) 30.25 .05;
        %datenum(2008,6,21,13,33,0) NaN .05;
        datenum(2008,6,23,19,36,0) 37.6 .05],1);
```

```

EXP(17).th=sortrows([
           datenum(2008,6,23,19,36,0) 18 NaN -2;% EXP16b hole b
           datenum(2008,6,23,19,36,0) 28-13 NaN -8],1);%Center of barrel b




% flux=xlsread('oilflux17.xls');
% flux=flux(2:end,:);
%
% start=datenum(2008,7,flux(:,1),flux(:,2),flux(:,3),0);
% stopped=datenum(2008,7,flux(:,4),flux(:,5),flux(:,6),0);
%
%EXP(17).of=[start stopped ((flux(:,8)-flux(:,9))./(stopped-start))];



%OILFLUX************************************
[flux fluxtext]=xlsread(...
'/home/jonas/Documents/oilexp/EXP17/raw/oilflux17.xls');
        flux=flux(2:end,:);
        fluxtext=fluxtext(2:end,10);
        EXP(17).of_text=char(fluxtext);

        T1=datenum(2008,7,flux(:,1),flux(:,2),flux(:,3),0);
        T2=datenum(2008,7,flux(:,4),flux(:,5),flux(:,6),0);
        o_m=flux(:,7)-flux(:,8);%mass of measured oil

%UNCERTAINTY in oil weight
test=xlsread(['/home/jonas/Documents/'...
    'oilexp/Oilcapturetest/oilcapturetest.xls']);
    test=test(2:end,:);
    oil=test(:,1);
    oil_m=test(:,4)-test(:,3);
    do=std(oil-oil_m);%Uncertainty in oil mass
    o_offset=mean(oil_m-oil);
    o=o_m-o_offset;
    dT1=(2/(24*60))*ones(size(T1));%uncertainty in time measuremnent
    dT2=(4/(24*60))*ones(size(T1));
    DT=T2-T1;
    dDT=sqrt(dT1.^2+dT1.^2);
    dof=sqrt((o.*dDT./DT.^2)+(do./DT).^2);
    odrops=flux(:,9)*0.1*mean([1/2 1/3]);%weight of oildrops

 EXP(17).of=[T1 T2 o./DT dof odrops./DT];

```

```
        time=EXP(16).tp(end,1);

      EXP(17).op=[];
            sheet{4}='core16b1';
            sheet{5}='core16b2';
            sheet{6}='core16b3';
            sheet{7}='core16b4';

            for i=4:7;

                a=xlsread(...
                    ['/home/jonas/Documents/oilexp/'...
                    'EXP16/raw/oil_profile16ab.xls'],sheet{i});
                a=a(1:end,:);

                time=datenum('08-Jul-2008 15:34:00')*ones(size(a(:,1)));
                [dim1 dim2]=size([time a]);
                 dim2;
            EXP(17).op(1:dim1,1:dim2,i-3)=[time a];

            end;

            for i=1:length(EXP(17).op(1,1,:));
                a=find(EXP(17).op(:,1,i)==0);
                EXP(17).op(a,:,i)=NaN*ones(...
                size(EXP(17).op(a,:,i)));
            end;
try
EXP(17).profiles=profiles(17);
end
EXP(17).profiles(1).comment='NOI-profile taken from warm ice';
EXP(17).profiles(2).comment='OI-profile taken from cooled ice';
EXP(17).profiles(3).comment='OI-profile taken from cooled ice';
EXP(17).profiles(3).comment='NOI-profile taken from cooled ice';


EXP(17).sw_fit=fit(EXP(17).sw(:,1),EXP(17).sw(:,2),...
    'linearinterp');
EXP(17).tw_fit=fit(EXP(17).tw(:,1),EXP(17).tw(:,2),...
    'linearinterp');
EXP(16).tw_fit=fit(EXP(17).tw(:,1),EXP(17).tw(:,2),...
    'linearinterp');


I2=find(EXP(17).th(:,4)~=-3);


try
EXP(17).th_fit1=EXP(16).th_fit1;
```

```
end;

EXP(17).th_fit2=EXP(16).th_fit2;

try
EXP(17).th_fit2=fit(EXP(17).th(I2,1),EXP(17).th(I2,2),...
    'linearinterp');
end;

EXP(17).tw0=[EXP(17).sw(:,1) freezingpoint(EXP(17).sw(:,2))];
EXP(17).tw0_fit=fit(EXP(17).tw0(:,1),EXP(17).tw0(:,2),...
    'linearinterp');
```

C.5.15 EXP18

```
%EXP18 (EXP17)
EXP(18).oiltype=[2 -1.5 400];%crude oil

EXP(18).tx=sortrows([
    datenum(2008,6,20,14,44,0) 1;%'EXP17 started'
    datenum(2008,6,22,06,40,0) 3;%'EXP17 Oil Release'
    datenum(2008,6,22,18,35,0) 2],1)%'EXP17 stopped'

EXP(18).sw=sortrows([
    datenum(2008,6,20,14,44,0) 26.9;
    datenum(2008,6,21,23,36,0) 39.0;
    datenum(2008,6,22,06,13,0) 43.3;
    datenum(2008,6,22,18,35,0) 49.2],1);

EXP(18).tw=sortrows([datenum(2008,6,20,14,44,0) -0.5;
                datenum(2008,6,21,23,36,0) -1.1;
                datenum(2008,6,22,06,13,0) -1.0],1);

EXP(18).th=sortrows([
    datenum(2008,6,20,15,18,0) -0 NaN -1 .1;%29.3-29.3
    datenum(2008,6,20,19,12,0) -29.3-26 NaN -1 .1;%usikker
    datenum(2008,6,22,06,13,0) -13 NaN -2 NaN;
    datenum(2008,6,22,13,11,0) -(29.3-20.5) NaN -1 .1;
    datenum(2008,6,22,17,22,0) -(29.3-19.2) NaN -1 .1],1);

EXP(18).op=[datenum(2008,6,22,18,35,00) (-11+2.1) (-11)
  (1.1/92.6) NaN 14.5 0.05 1.1 92.6;
           datenum(2008,6,22,18,35,00) (-11+2.1) (-11+3.7) 0 NaN
             9.7 0.05 0.0 84.5];

try
EXP(18).profiles=profiles(18);
end

```

```
EXP(18).sw_fit=fit(EXP(18).sw(:,1),EXP(18).sw(:,2),...
    'linearinterp');
EXP(18).tw_fit=fit(EXP(18).tw(:,1),EXP(18).tw(:,2),...
    'linearinterp');

%Thickness fit
I1=find(EXP(18).th(:,4)==-3);
I2=find(EXP(18).th(:,4)~=-3);
try
EXP(18).th_fit1=fit(EXP(18).th(I1,1),EXP(18).th(I1,2),...
    'linearinterp');
end
EXP(18).th_fit2=[];
try
EXP(18).th_fit2=fit(EXP(18).th(I2,1),EXP(18).th(I2,2),...
    'linearinterp');
end;
EXP(18).tw0=[EXP(18).sw(:,1) freezingpoint(EXP(18).sw(:,2))];
EXP(18).tw0_fit=fit(EXP(18).tw0(:,1),EXP(18).tw0(:,2),...
    'linearinterp');
```

C.5.16 EXP19 & EXP20

```
% EXP19 (EXP18a)
EXP(19).oiltype=[1 4.6 468-90]%Synthetic oil;

EXP(19).sw=sortrows([
    datenum(2008,6,28,15,40,0) 27.7 0.05;
    datenum(2008,6,29,22,33,0) 39.9 0.05;
    datenum(2008,6,30,08,40,0) 44.9 0.05;
    datenum(2008,6,30,12,49,0) 48.1 0.05],1);

%Interpolate freezeup
P=polyfit(EXP(19).sw(2:end,2),EXP(19).sw(2:end,1),1);...
    freezeuptime=polyval(P,EXP(19).sw(1,2));

EXP(19).tx=sortrows([
    datenum(2008,6,28,15,40,0) 1;%'EXP18a started'
    datenum(2008,6,28,16,00,0) 4;%'iceformation'
    datenum(2008,6,30,09,38,0) 3;%'oilrelease'
    datenum(2008,6,30,16,21,0) 2],1);%'EXP18a stopped'



EXP(19).th=sortrows([
    datenum(2008,6,28,15,40,0) 0 -2 0;%31.2-31.2
   % datenum(2008,6,29,22,33,0) NaN -1 .1;
    datenum(2008,6,30,08,40,0) -12 -2 0.1],1);%-0.7 - -0.8

```

```
EXP(19).ts=sortrows([
    datenum(2008,6,30,10,15,0) -9.1 0.05;%alufoil on top
    datenum(2008,6,30,10,15,0) -10 0.05],1);%no alufoil on top


EXP(19).tw=sortrows([
    datenum(2008,6,28,15,40,0) -1.3 0.05;
    datenum(2008,6,29,22,33,0) -0.5 0.05;
    datenum(2008,6,30,08,40,0) -0.8 0.05;
    datenum(2008,6,30,12,49,0) -0.75 0.1],1);

%Thickness from picture
%From picture_MG_8613.jpg
%cosd(4.54)*732.3=6cm
d=-(1614.5*6)/(cosd(4.54)*732.3)


EXP(19).op=[datenum(2008,6,30,16,21,0) d+2.5 d+1.5 0 NaN 10.0
  0.05 0 187.8;
            datenum(2008,6,30,16,21,0) d+1.5 d+0.0 NaN NaN 11.2
              0.05 ((15.8-13.5)+(71.4-69.4))
              188.3-69.4-((15.8-13.5)+(71.4-69.4))];
EXP(19).op(2,4)=EXP(19).op(2,7)/(EXP(19).op(2,7)+EXP(19).op(2,8));


try
EXP(19).profiles=profiles(19);
end
EXP(19).sw_fit=fit(EXP(19).sw(:,1),EXP(19).sw(:,2),...
    'linearinterp');
EXP(19).tw_fit=fit(EXP(19).tw(:,1),EXP(19).tw(:,2),...
    'linearinterp');

I1=find(EXP(19).th(:,4)==-3);
I2=find(EXP(19).th(:,4)~=-3);
try
EXP(19).th_fit1=fit(EXP(19).th(I1,1),EXP(19).th(I1,2),...
    'linearinterp');
end
EXP(19).th_fit2=[];
try
EXP(19).th_fit2=fit(EXP(19).th(I2,1),EXP(19).th(I2,2),...
    'linearinterp');
end;

EXP(19).tw0=[EXP(19).sw(:,1) freezingpoint(EXP(19).sw(:,2))];
EXP(19).tw0_fit=fit(EXP(19).tw0(:,1),EXP(19).tw0(:,2),...
    'linearinterp');

%************************************************************
```

```
%EXP20 (EXP18b)

EXP(20).oiltype=[1 2.2 432.1-89.5];


EXP(20).tx=sortrows([
    datenum(2008,7,02,18,50,00) 1;%'EXP18b started+freezeup'
    datenum(2008,7,02,18,50,00) 4;
    datenum(2008,7,04,10,42,00) 3;%'EXP18b oilrelease'
    datenum(2008,7,4,23,40,00) 2],1);%'EXP18b stopped'

a=xlsread(...
'/home/jonas/Documents/oilexp/EXP18/webcam/sw_tw_webcam.xls');
sw_auto=[datenum(a(:,1:6)) a(:,7)];
tw_auto=[datenum(a(:,1:6)) a(:,8)];

EXP(20).tw=sortrows(tw_auto,1);
EXP(20).sw=sortrows(sw_auto,1);


%Temperatureprofile at datenum(2008,7,4,10,42,00)+surfacetemp
  below
%4cm=385px
aa=pwd;
cd('/home/jonas/Documents/oilexp/TempertureFit')
load('A.mat');
cd(aa);

EXP(20).tp=[]
EXP(20).tp=[
   datenum(2008,7,4,10,42,00)
   -11.7
   1/(A(1)+A(2)*log(12.49*10^3)+A(3)*log(12.49*10^3)^3)-273.15
   1/(A(1)+A(2)*log(11.00*10^3)+A(3)*log(11.00*10^3)^3)-273.15
   -2.3%in dril hole
   1/(A(1)+A(2)*log(10.47*10^3)+A(3)*log(10.47*10^3)^3)-273.15
   1/(A(1)+A(2)*log(10.43*10^3)+A(3)*log(10.43*10^3)^3)-273.15]';
%kohm

%_MG_8719.jpg 6cm=573px position of lowest thermistor:
%-1260px:
d=-6*1260/574;

%1029px=6cm _MG_8724.jpg

EXP(20).pos=[NaN 0 -(6/574)*626 -(6/574)*976 -11.5 -(6/574)*1248
  -(6/576.2)*1737];

EXP(20).th=[datenum(2008,7,04,10,42,00) -10.9 NaN -2 NaN;
```

```
            datenum(2008,7,4,10,50,00) -12 NaN -2 0.2]; %Thickness measured from picture IMG_8710.jpg Uncrtainty +-2 mm

clear A

%_MG_8719.jpg 6cm=573px position of lowest thermistor:
%-1260px:
d=-6*1260/573;

%1029px=6cm _MG_8724.jpg

% [
%Sample 1: weight total=95.7 ,container + little oil 69.6gr, , container=68.8gr, salinity =9.7ppt,
%Sample 2: weight total=103.5gr ,container + oil= 72.0 gr, , container= 69.1gr, salinity =7.8 ppt, tube +oil=14.3, tube=13.5gr
%Sample 3: Salinity 9.5 ppt]


EXP(20).op=[datenum(2008,7,4,23,40,00) d+957*6/1029 d+630*6/1029 (69.6-68.8)/(95.7) NaN 9.7 0.05 69.6-68.8 95.7-(69.6-68.8);
            datenum(2008,7,4,23,40,00) d+630*6/1029 d+393*6/1029 (72.0-69.1 +14.3-13.5)/(103.5) NaN 7.8 0.05 (72.0-69.1 +14.3-13.5) 103.5-(72.0-69.1 +14.3-13.5)];

EXP(20).sp(:,:,1)=[
            datenum(2008,7,4,10,42,00) -0.0 -01.7 22.7 0.05;
            datenum(2008,7,4,10,42,00) -1.7 -03.5 11.1 0.05;
            datenum(2008,7,4,10,42,00) -3.5 -05.1 10.6 0.05;
            datenum(2008,7,4,10,42,00) -5.1 -06.5 10.0 0.05;
            datenum(2008,7,4,10,42,00) -6.5 -08.2 08.9 0.05;
            datenum(2008,7,4,10,42,00) -8.2 -09.9 10.6 0.05;
            datenum(2008,7,4,10,42,00) -9.9 -11.5 15.9 0.05];

EXP(20).sp(1,:,2)=[datenum(2008,7,4,23,40,00) d+630*6/1029 d+393*6/1029 9.5 0.05];
EXP(20).sp(find(EXP(20).sp(:,1,2)==0),:)=...
    NaN*EXP(20).sp(find(EXP(20).sp(:,1,2)==0),:);
try
EXP(20).profiles=profiles(20);
end
EXP(20).sw_fit=fit(EXP(20).sw(:,1),EXP(20).sw(:,2),...
    'linearinterp');
EXP(20).tw_fit=fit(EXP(20).tw(:,1),EXP(20).tw(:,2),...
    'linearinterp');

I1=find(EXP(20).th(:,4)==-3);
I2=find(EXP(20).th(:,4)~=-3);
try
```

```
EXP(20).th_fit1=fit(EXP(20).th(I1,1),EXP(20).th(I1,2),...
    'linearinterp');
end
EXP(20).th_fit2=[];
try
EXP(20).th_fit2=fit(EXP(20).th(I2,1),EXP(20).th(I2,2),...
    'linearinterp');
end;

EXP(20).tw0=[EXP(20).sw(:,1) freezingpoint(EXP(20).sw(:,2))];
EXP(20).tw0_fit=fit(EXP(20).tw0(:,1),EXP(20).tw0(:,2),...
    'linearinterp');
```

C.5.17 EXP21

```
% EXP21 (EXP19)

a=xlsread(...
'/home/jonas/Documents/oilexp/EXP19/webcam/sw_tw_webcam19.xls');

EXP(21).oiltype=[2 2.7 306.2];

EXP(21).sw=[datenum(a(:,1:6)) a(:,7)];
EXP(21).tw=[datenum(a(:,1:6)) a(:,end)];

%datenum(2008,7,8,13,40,00) temperature profile
%(6cm=652.4px picture IMG_8891.jpg) and (5cm=557px picture
  IMG_8893.jpg)

EXP(21).tx=sortrows([datenum(2008,7,8,13,00,00) 3;
           datenum(2008,7,8,22,13,00) 2],1);

load('/home/jonas/Documents/oilexp/TempertureFit/A.mat');

EXP(21).tp=[datenum(2008,7,8,13,40,00)
           1/(A(1)+A(2)*log(13.74*10^3)+A(3)*...
           log(13.74*10^3)^3)-273.15
           1/(A(1)+A(2)*log(11.58*10^3)+A(3)*...
           log(11.58*10^3)^3)-273.15
           1/(A(1)+A(2)*log(10.52*10^3)+A(3)*...
           log(10.52*10^3)^3)-273.15
           1/(A(1)+A(2)*log(10.45*10^3)+A(3)*...
           log(10.45*10^3)^3)-273.15]';

EXP(21).pos=positions(5);


           time=datenum(2008,7,8,13,00,00);d=-9.6/8;

```

```
EXP(21).sp=[];

EXP(21).sp=[time 0 d 22.3 0.05;
           time d 2*d 11.4 0.05;
           time 2*d 3*d 11.2 0.05;
           time 3*d 4*d 11.2 0.05;
           time 4*d 5*d 10.8 0.05;
           time 5*d 6*d 9.8 0.05;
           time 6*d 8*d ((21.5-3.9+4.6)/(21.5-3.9))*11.7 NaN];

EXP(21).sp(1,:,2)=[EXP(21).tx(end,1) -9.3 -12.2 11.7 0.05];
IND=find(EXP(21).sp(:,1,2)==0);

EXP(21).sp(IND,:,2)=NaN*EXP(21).sp(IND,:,2);

a=xlsread('/home/jonas/Documents/oilexp/EXP19/raw/oilprof19.xls');
a=a(:,1:9);
EXP(21).op=a;
EXP(21).op(:,1)=EXP(21).tx(end,1)*ones(size(EXP(21).op(:,1)));
EXP(21).op(1:3,:)=[];
EXP(21).op(4,:)=[];

EXP(21).th=[datenum(2008,7,8,13,00,00) -12.2 NaN -2 NaN;
           datenum(2008,7,8,22,13,00) -13.4 NaN -2 NaN]; %



try
EXP(21).profiles=profiles(21);
end
EXP(21).sw_fit=fit(EXP(21).sw(:,1),EXP(21).sw(:,2),...
    'linearinterp');
EXP(21).tw_fit=fit(EXP(21).tw(:,1),EXP(21).tw(:,2),...
    'linearinterp');

I1=find(EXP(21).th(:,4)==-3);
I2=find(EXP(21).th(:,4)~=-3);
try
EXP(21).th_fit1=fit(EXP(21).th(I1,1),EXP(21).th(I1,2),...
    'linearinterp');
end
EXP(21).th_fit2=[];
try
EXP(21).th_fit2=fit(EXP(21).th(I2,1),EXP(21).th(I2,2),...
    'linearinterp');
end;

EXP(21).tw0=[EXP(21).sw(:,1) freezingpoint(EXP(21).sw(:,2))];
EXP(21).tw0_fit=fit(EXP(21).tw0(:,1),EXP(21).tw0(:,2),...
    'linearinterp');
```

C.5.18 EXP21

C.6 Data acquisition

```
;{CR10X}
;
*Table 1 Program
  01: 600 Execution Interval (seconds)

1: Batt Voltage (P10)
 1: 3 Loc [ BatVolt ]

2: Internal Temperature (P17)
 1: 2 Loc [ DLogTemp ]

     3: Z=F (P30)
      1: 1 F
      2: 0 Exponent of 10
      3: 1 Z Loc [ pulse ]



     4: Do (P86)
      1: 43 Set Port 3 High


5: Beginning of Loop (P87)
 1: 0 Delay
 2: 16 Loop Count


     6: Pulse Port w/Duration (P21)
      1: 2 Port
      2: 1 Pulse Length Loc [ pulse ]


7: Excite-Delay (SE) (P4)
 1: 1 Reps
 2: 25 2500 mV 60 Hz Rejection Range (Delay must be zero)
 3: 12 SE Channel
 4: 1 Excite all reps w/Exchan 1
 5: 0000 Delay (units 0.01 sec)
 6: 2500 mV Excitation
 7: 4 -- Loc [ V1 ]
 8: 1.0 Mult
 9: 0.0 Offset

```

```
8: End (P95)

    9: Do (P86)
     1: 43 Set Port 3 High


10: Beginning of Loop (P87)
 1: 0 Delay
 2: 16 Loop Count


    11: Pulse Port w/Duration (P21)
     1: 2 Port
     2: 1 Pulse Length Loc [ pulse ]


12: Excite-Delay (SE) (P4)
 1: 1 Reps
 2: 25 2500 mV 60 Hz Rejection Range (Delay must be zero)
 3: 6 SE Channel
 4: 1 Excite all reps w/Exchan 1
 5: 0000 Delay (units 0.01 sec)
 6: 2500 mV Excitation
 7: 20 -- Loc [ V17 ]
 8: 1.0 Mult
 9: 0.0 Offset

13: End (P95)

14: Do (P86)
 1: 53 Set Port 3 Low

15: Do (P86)
 1: 10 Set Output Flag High (Flag 0)


16: Set Active Storage Area (P80)
 1: 1 Final Storage Area 1
 2: 122 Array ID

17: Real Time (P77)
 1: 1110 Year,Day,Hour/Minute (midnight = 0000)

18: Resolution (P78)
 1: 1 High Resolution


19: Sample (P70)
 1: 36 Reps
 2: 1 Loc [ pulse ]
```

```

*Table 2 Program
  02: 0.0000 Execution Interval (seconds)

*Table 3 Subroutines

End Program

-Input Locations-
1 pulse 1 3 1
2 DLogTemp 1 1 1
3 BatVolt 1 1 1
4 V1 1 1 1
5 V2 1 1 0
6 V3 1 1 0
7 V4 1 1 0
8 V5 1 1 0
9 V6 1 1 0
10 V7 1 1 0
11 V8 1 1 0
12 V9 1 1 0
13 V10 1 1 0
14 V11 1 1 0
15 V12 1 1 1
16 V13 1 1 2
17 V14 17 1 2
18 V15 17 1 1
19 V16 1 1 0
20 V17 1 1 1
21 V18 1 1 0
22 V19 1 1 0
23 V20 1 1 0
24 V21 1 1 0
25 V22 1 1 0
26 V23 1 1 0
27 V24 1 1 0
28 V25 1 1 0
29 V26 1 1 0
30 V27 1 1 0
31 V28 1 1 0
32 V29 1 1 0
33 V30 1 1 0
34 _________ 1 1 0
-Program Security-
0000
0000
0000
-Mode 4-
-Final Storage Area 2-
0
```