Air quality, oily aerosols

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Director of the DROPPS Consortium

DROPPS* Consortium: Overarching Research Goals

- Distribution, dispersion and dilution of petroleum under the action of physical and chemical processes
- Chemical evolution and biological degradation of petroleum caused by interaction with marine bacteria and plankton; effects of oil and dispersant on planktonic ood web
- Production of oily aerosols and effects on human health
- Focus on small scale processes; link these to mesoscale with mesocosms and modeling efforts

*DROPPS: Dispersion Research on Oil: Physics and Plankton Studies

Presenting results from Johns Hopkins University

- Not my research or area of expertise!
- Early results of ongoing research
- Focus on physical processes that cause oil to splash into air
- Addition of dispersants create smaller aerosol droplets (sub-micron)
- Future studies on how far these aerosols travel
- Human health effects

On Phenomena Affecting Oil Droplets Generation and Aerosolization:

People who did all the work

David W. Murphy, Cheng Li, Xinzhi Xue, Nima N. A-Mohajer, Kaushik Sampath, Vincent d’Albignac, David Morra ……...

Presentation by

Joseph Katz

Department of Mechanical Engineering

Johns Hopkins University

Supported by

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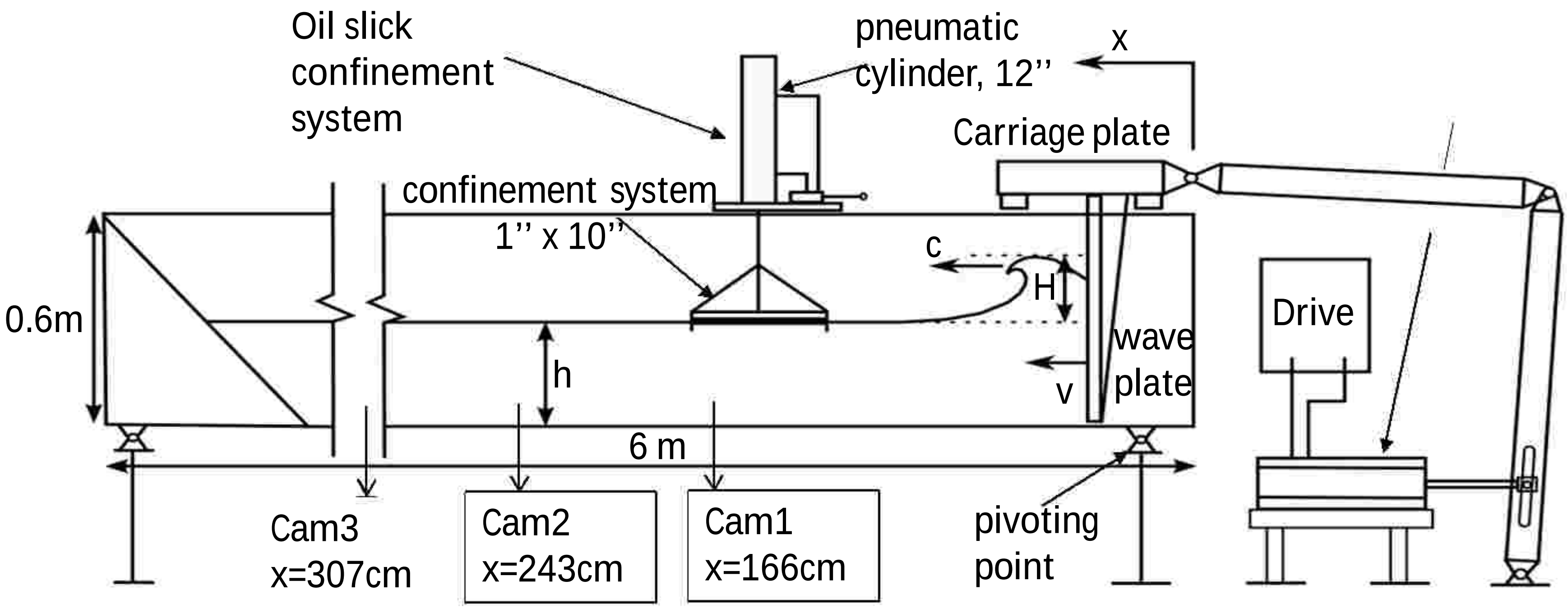
Droplet Generation by Wave Breaking
Tilting (Small) Wave Flume Facility



Wave Tank

- Dimensions: 6 x 0.6 x 0.3 m
- Removable top (safety)

Wave maker

- maximum stroke: 1.3 m
- rms error: <0.9 cm
- wave height: 18.2 cm- 34.5cm)
- water depth: 20 - 30 cm
- wave celerity: 1.78-2.41 m/s

Stroke (cm)	Height (m)	V_{max} (m/s)	Wave Speed (m/s)	Frequency (Hz)	Intrusion Depth (m)	Energy dissipation (m^2s^{-3})
53.34	0.29	1.26	2.88	0.75	0.17	~ 0.01
45.72	0.25	1.08	2.27	0.75	0.13	~ 0.007
45.72	0.22	0.90	1.94	0.625	0.07	~ 0.004

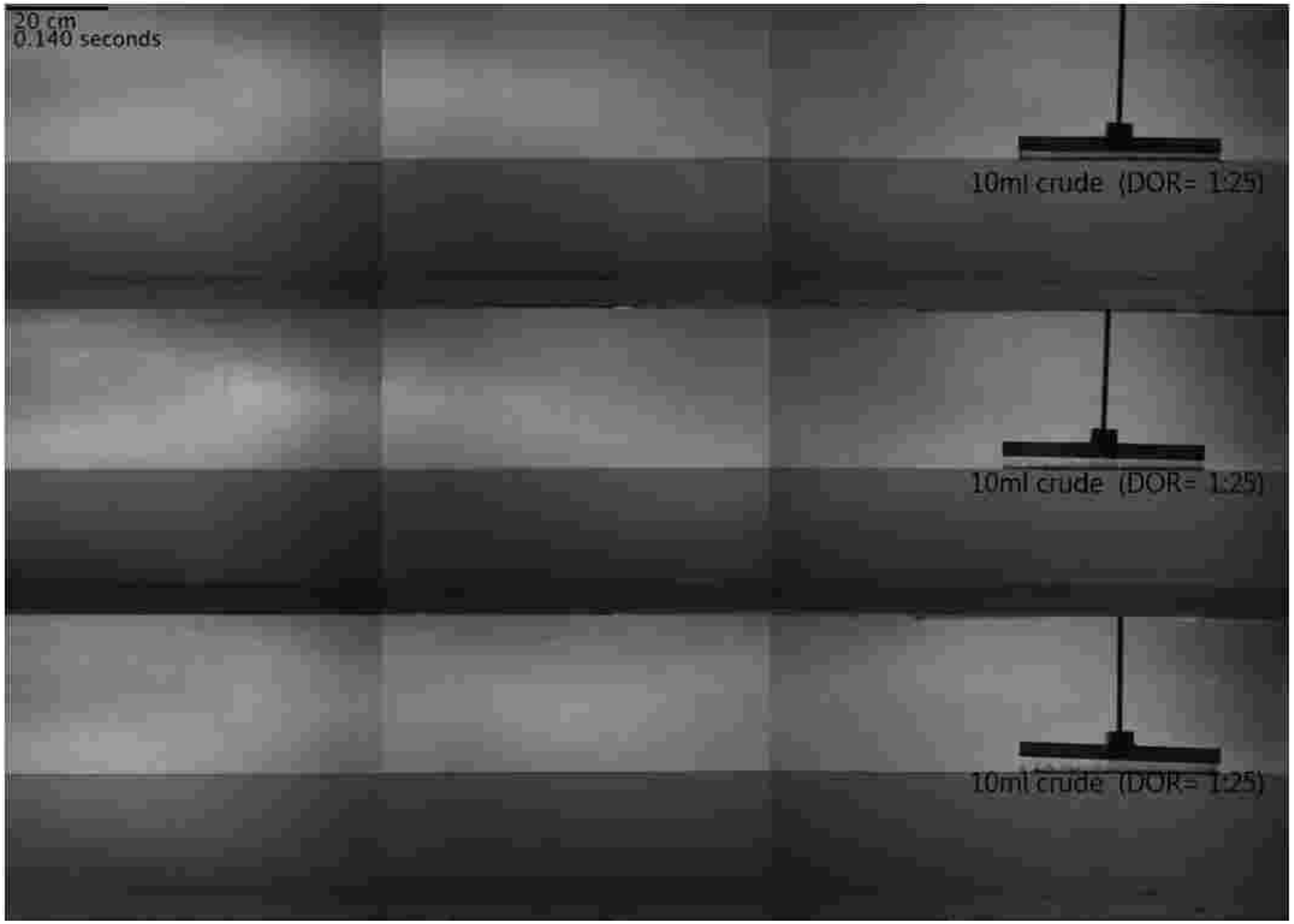
High Speed Video Showing 3 Breaking Waves

- 10ml crude oil confined in 2.54x25.4 cm^2 area introduced at x=150cm
- Oil premixed with Corexit 9500, DOR: 1:25 for 3 case

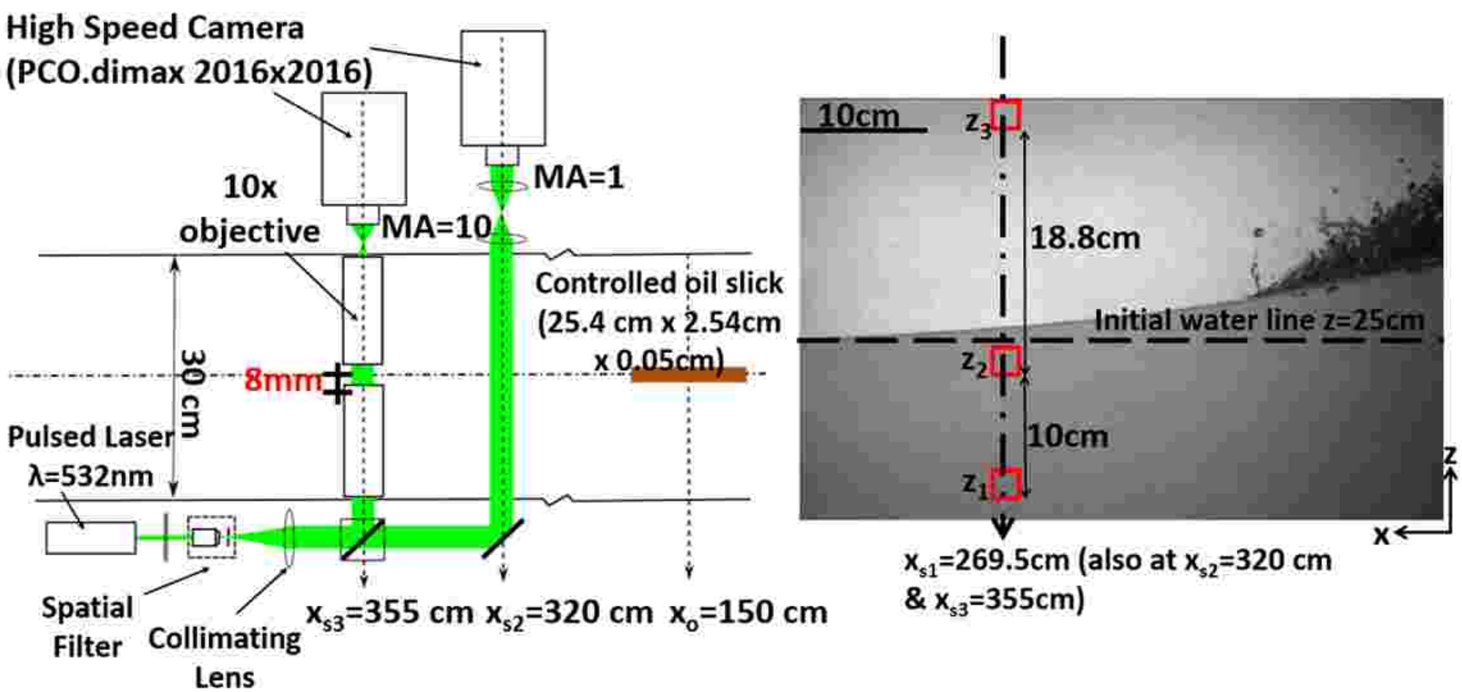
Stroke: 53.34 cm;
Frequency = 0.75 Hz;
h=28.8 cm

Stroke = 45.72 cm;
Frequency = 0.75 Hz:
H=24.9 cm

Stroke = 45.72 cm
Frequency = 0.625 Hz;
H=22.1 cm



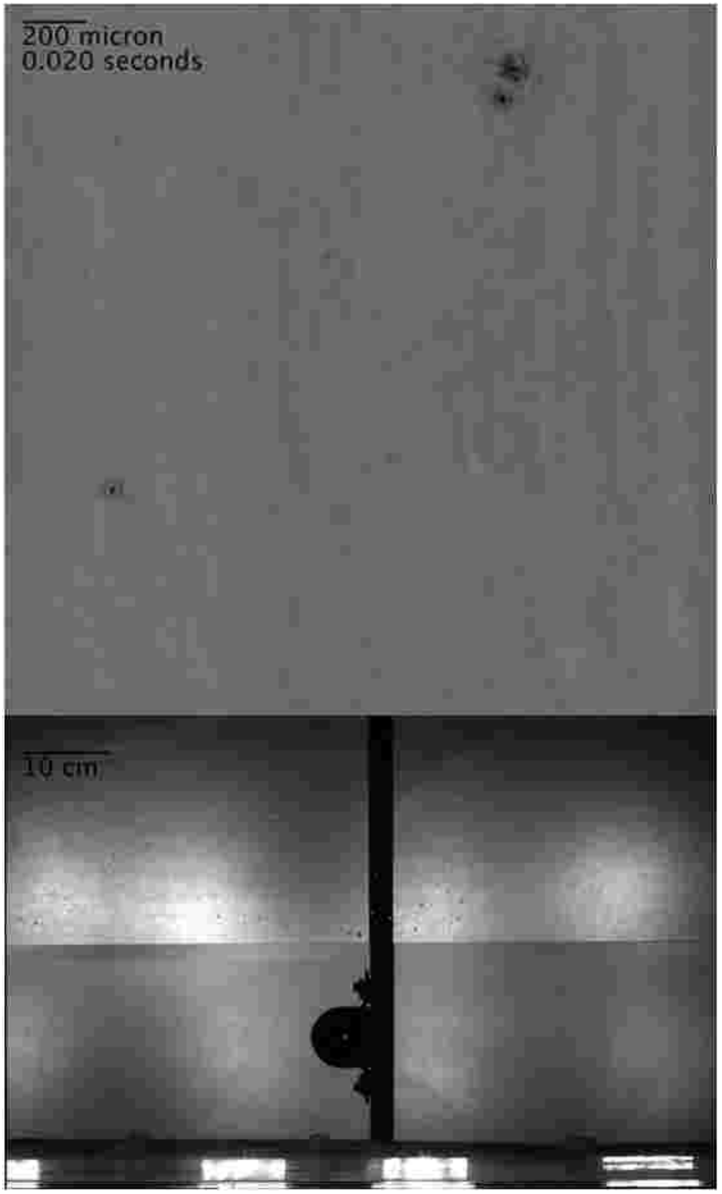
Measuring Droplet Size Distributions



Fluid	Oil Property				Dimensionless Number			# of runs	Multiresolution Sizing		
	Density (kg/m^3)	Viscosity (cSt)	Interfacial Tension (mN/m)	Surface Tension (mN/m)	Oh(50µm-500µm)	We (500µm)	Re		MA=1	MA=10	Fluorence Microscopy
Crude Oil	877	9.4	19	28	0.3-0.1	106.7	114.4	5	√	√	√
Crude Oil DOR 1:500	877	10.1	2.35	22.5	0.9-0.3	862.5	106.4	4	√	√	√
Crude Oil DOR 1:100	877	10.6	1.2	24.7	1.3-0.4	1689.1	101.4	6	√	√	√
Crude Oil DOR 1:25	877	12	0.28	28	3.0-0.9	7239.2	89.6	4	√	√	√
Fish Oil	924.4	63.1	14.9	22.5	2.2-0.7	143.4	17.0	3	√	×	×
Motor Oil	877.6	306.5	19	24.7	9.3-2.9	106.8	3.5	3	√	×	×

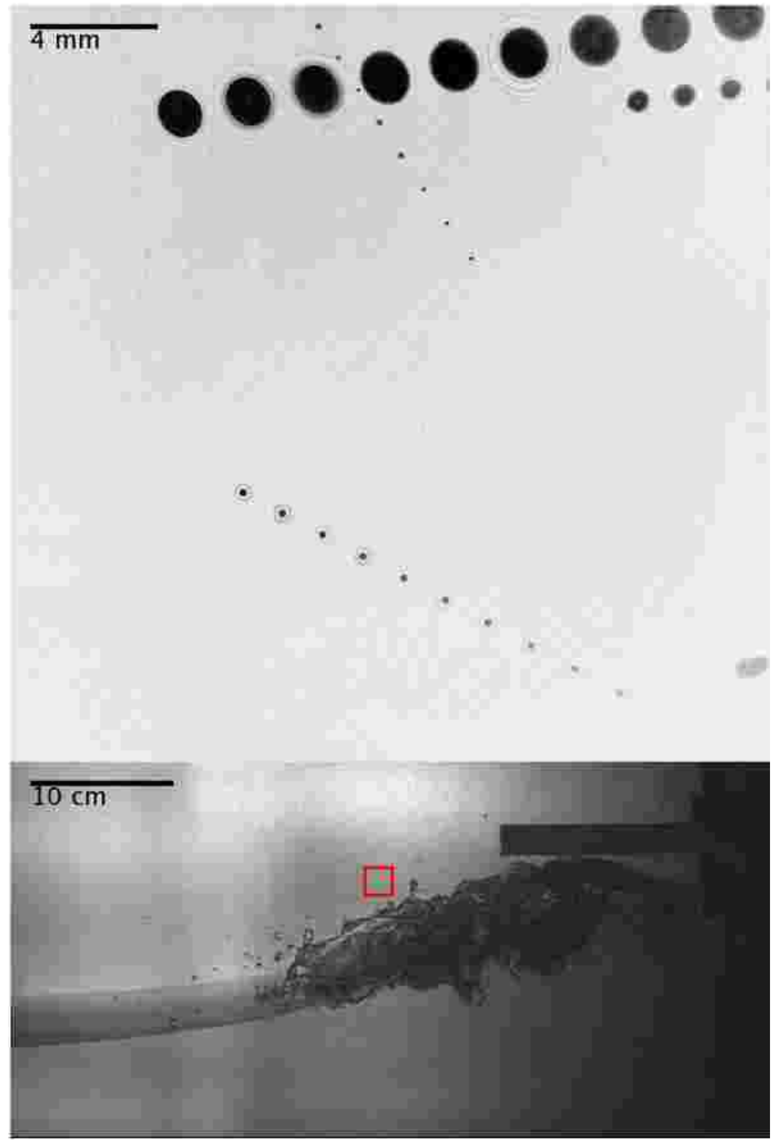
Subsurface Droplets (DOR1:25)

FOV=2.23 mm x 2.23 mm



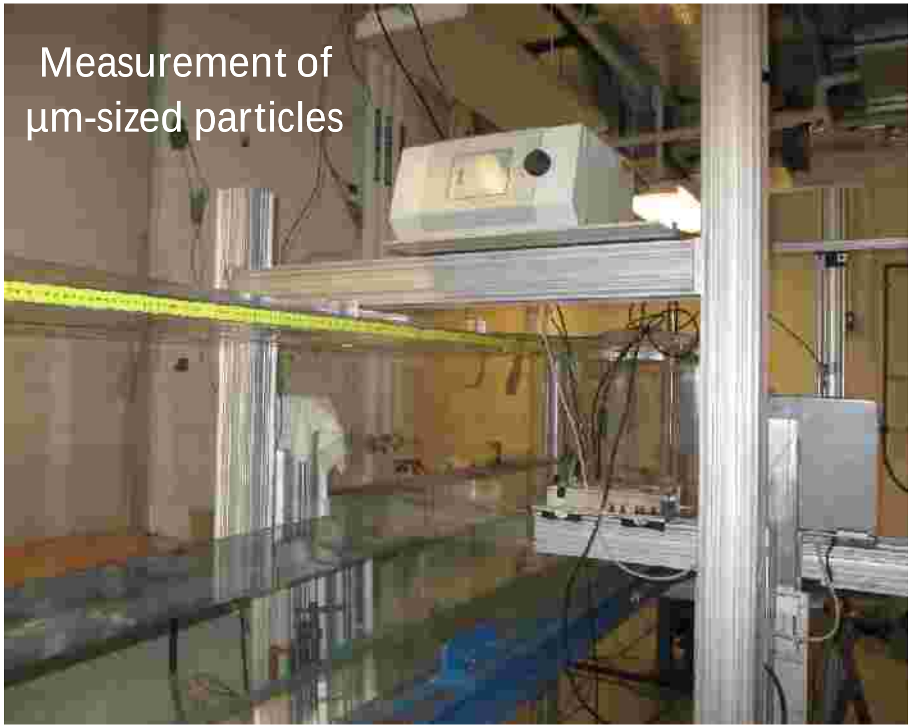
Aerosol droplets (DOR1:25)

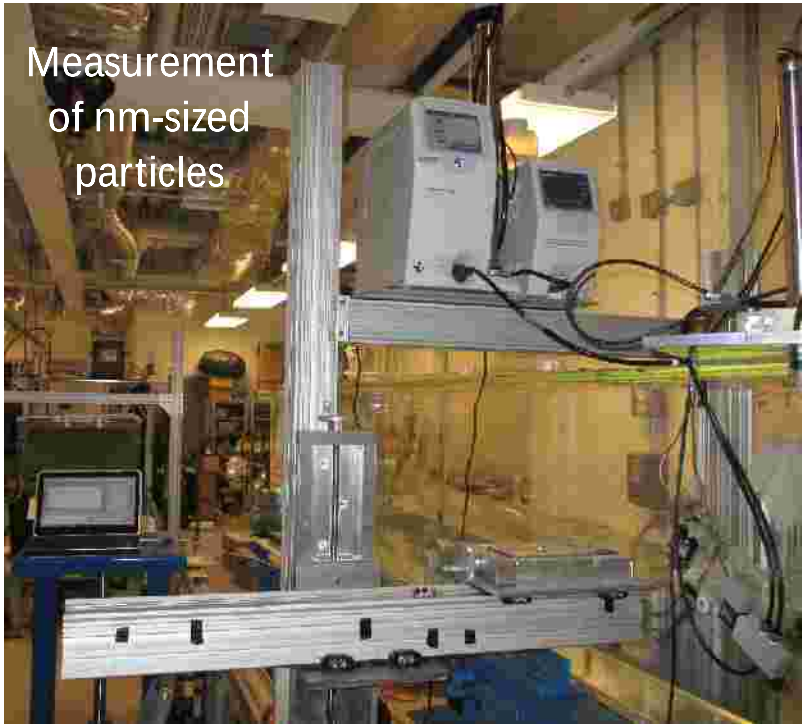
FOV=2.2 cm x 2.2 cm



Wave Tank System

Experimental set-up:



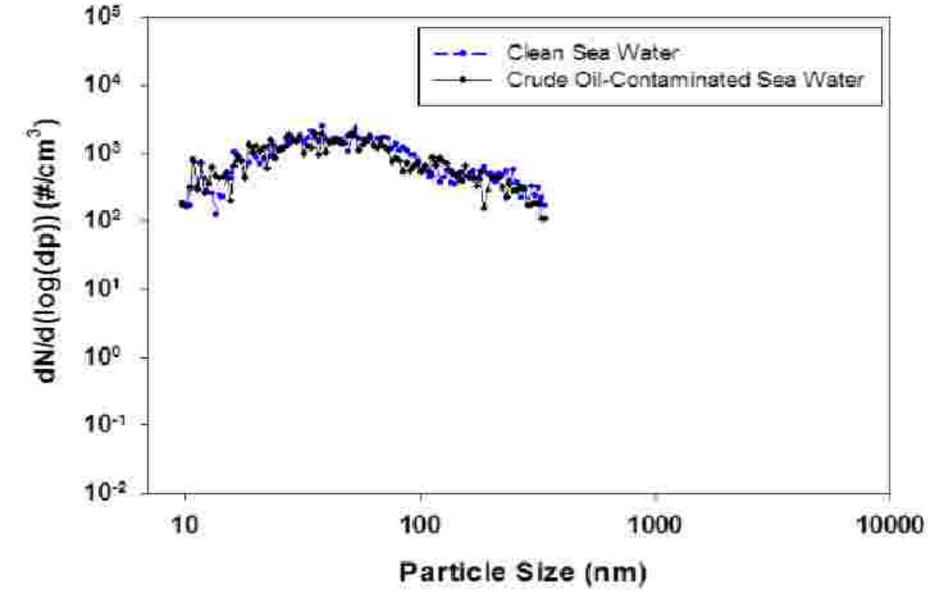


- Micron-sized and nano-sized aerosolized particles
  - Detection of nano-sized particles in 2 modes: dry and at RH = 80%
- Total polycyclic aromatic hydrocarbons (PAH)
- Total volatile organic compounds (VOC)

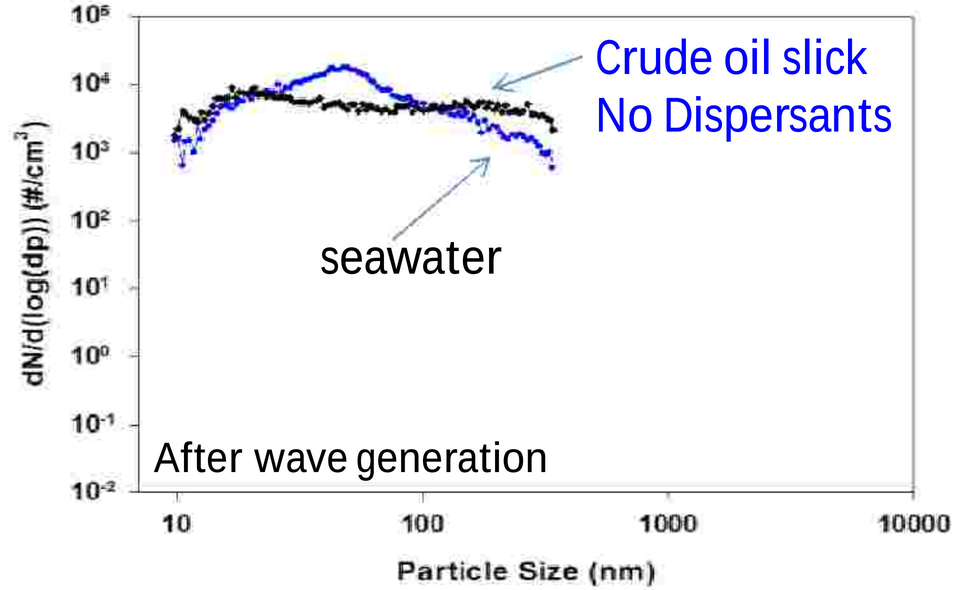
Effect of Dispersants on Nano-scale Aerosol Concentration

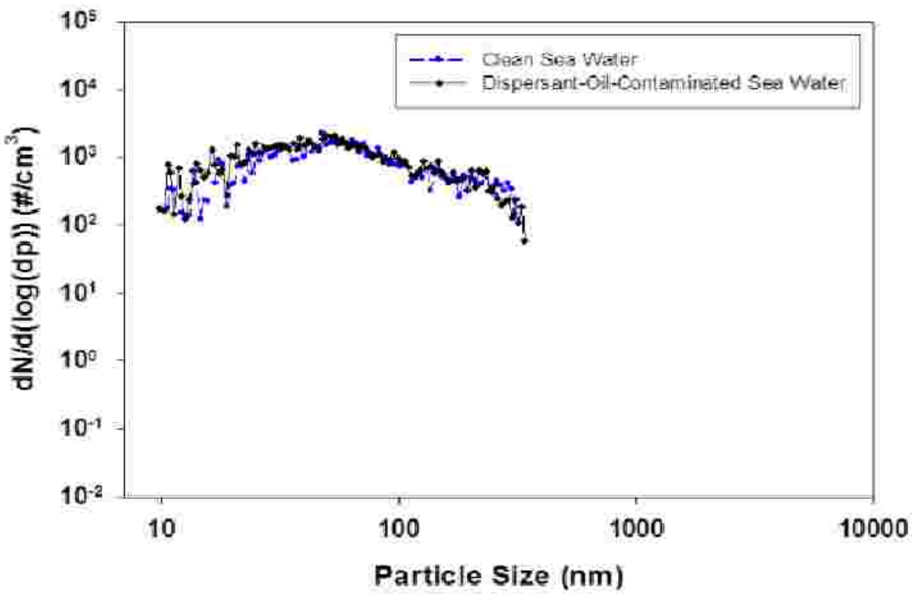
H=45.7 cm (intermediate) Wave

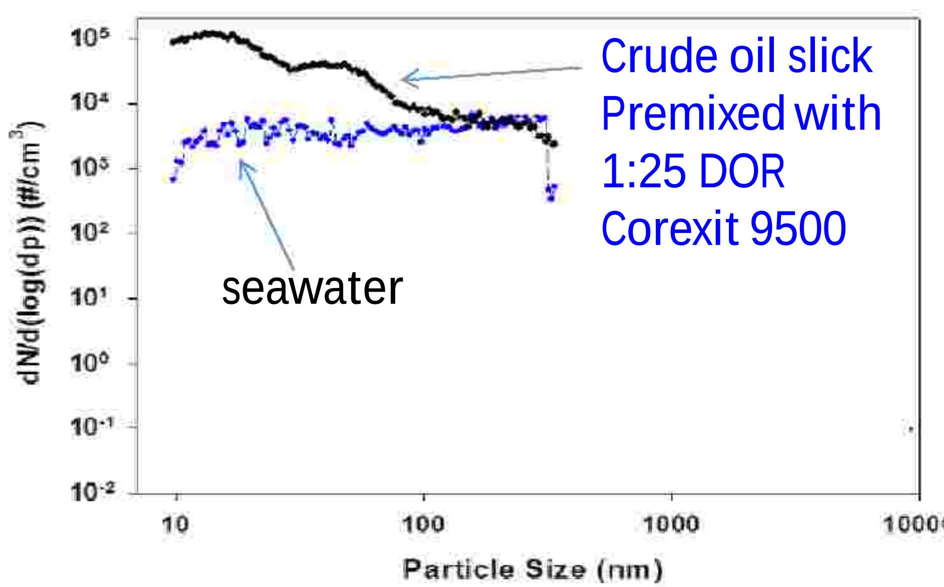
Before wave generation



After wave generation

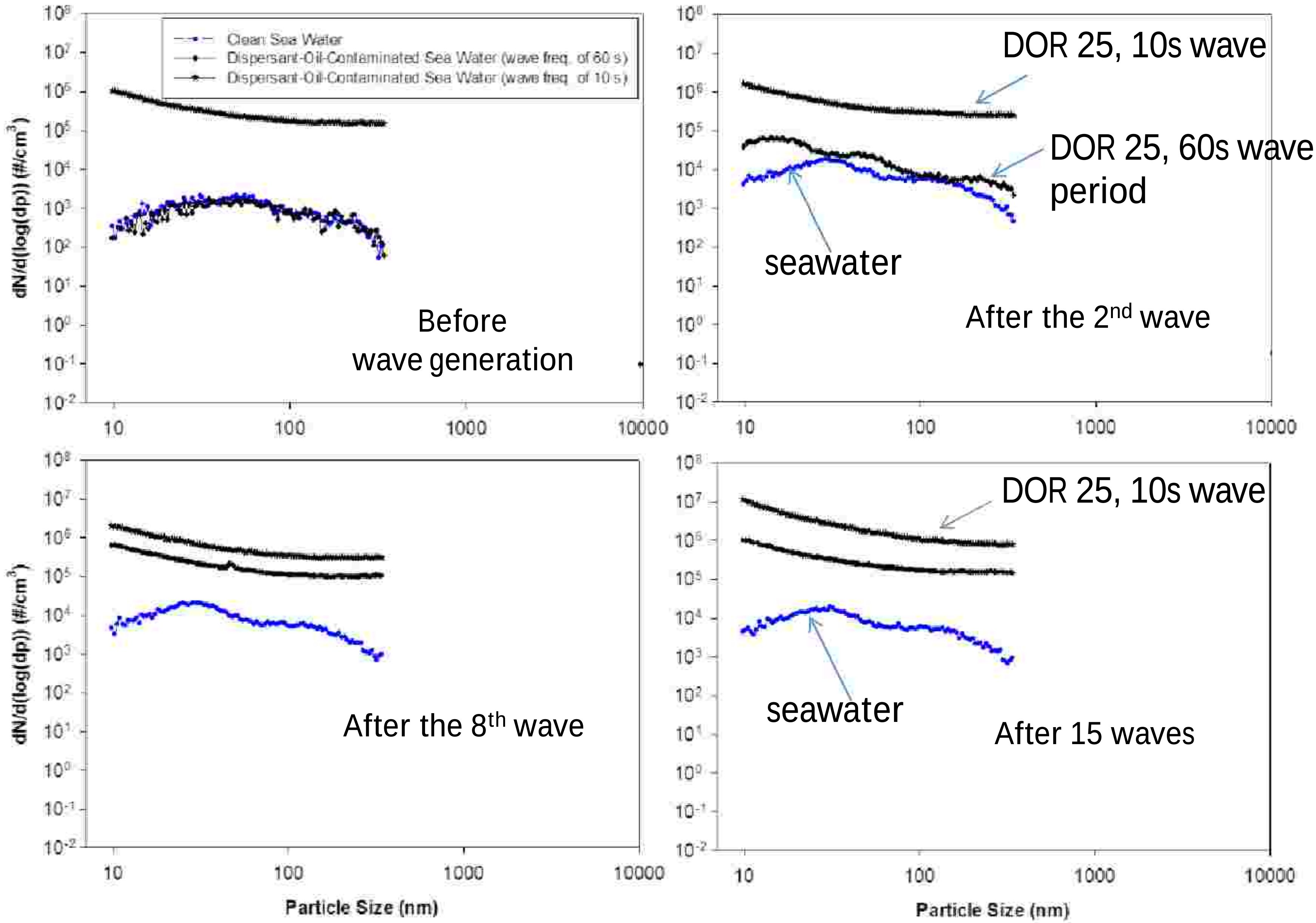




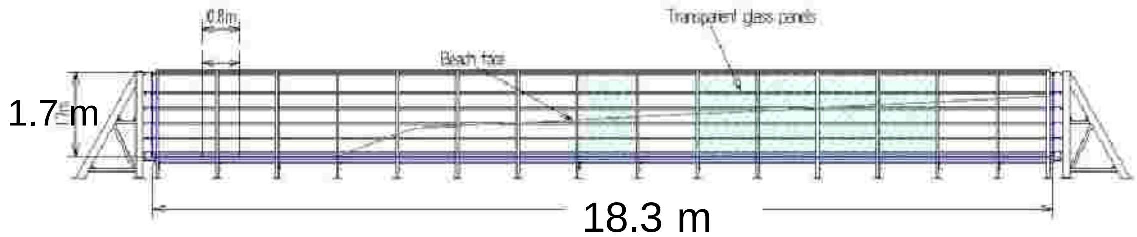


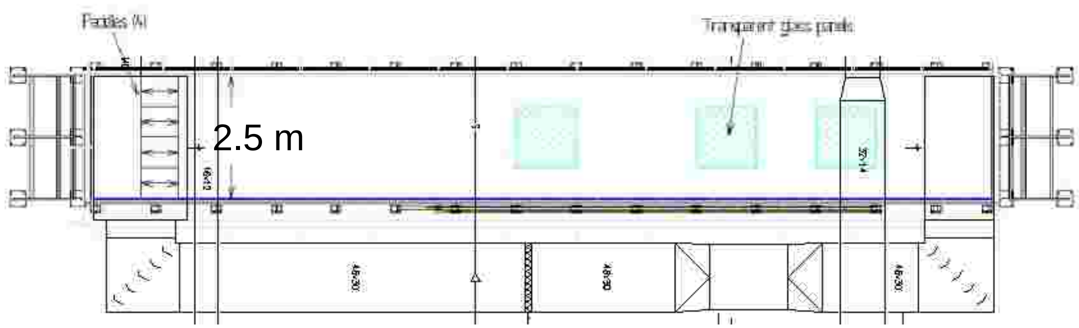
Effect of Dispersants on Nano-scale Aerosol Concentration

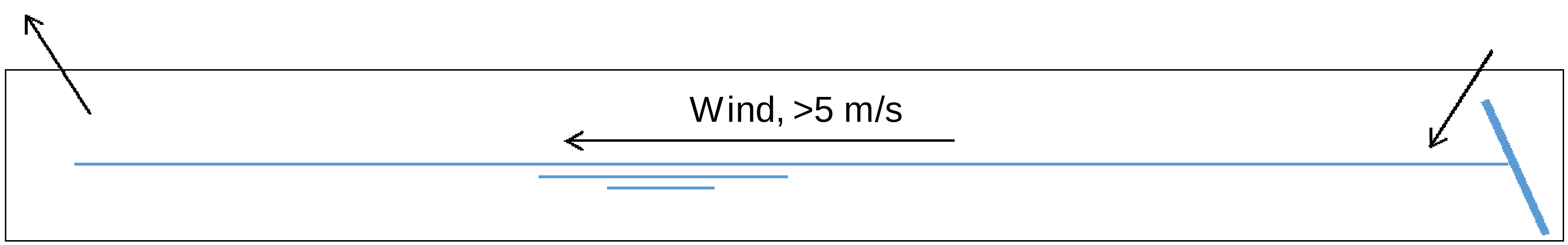
H=53.3 cm (large) Wave



Large Wave Tank – Conversion to a Wind-Wave Facility



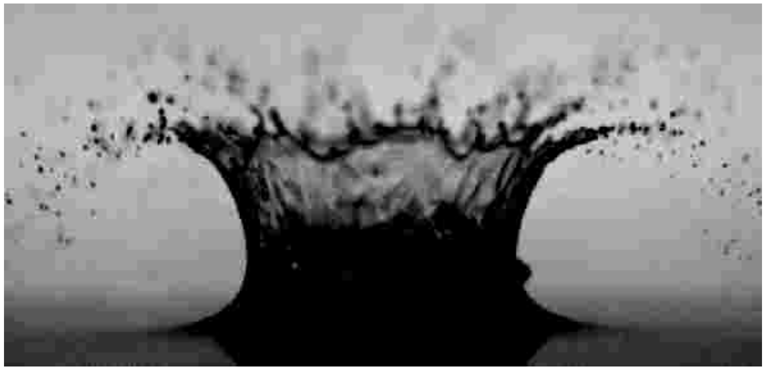




(Rain)drop Impact on a Floating Immiscible Oil Layer: Splash Behavior and Droplet SizeS

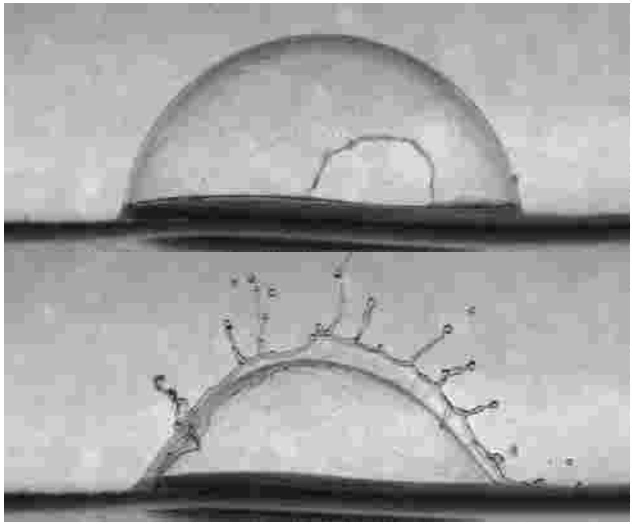
Summary of Results presented in Murphy et al., 2015. *J. Fluid Mech.* 780, 536-577

- Marine Aerosol
  - Raindrop impact causes generation of marine aerosols
  - Marine aerosol production by rainfall has not not previously investigated
  - Might contribute to aerosolization of crude oil slicks



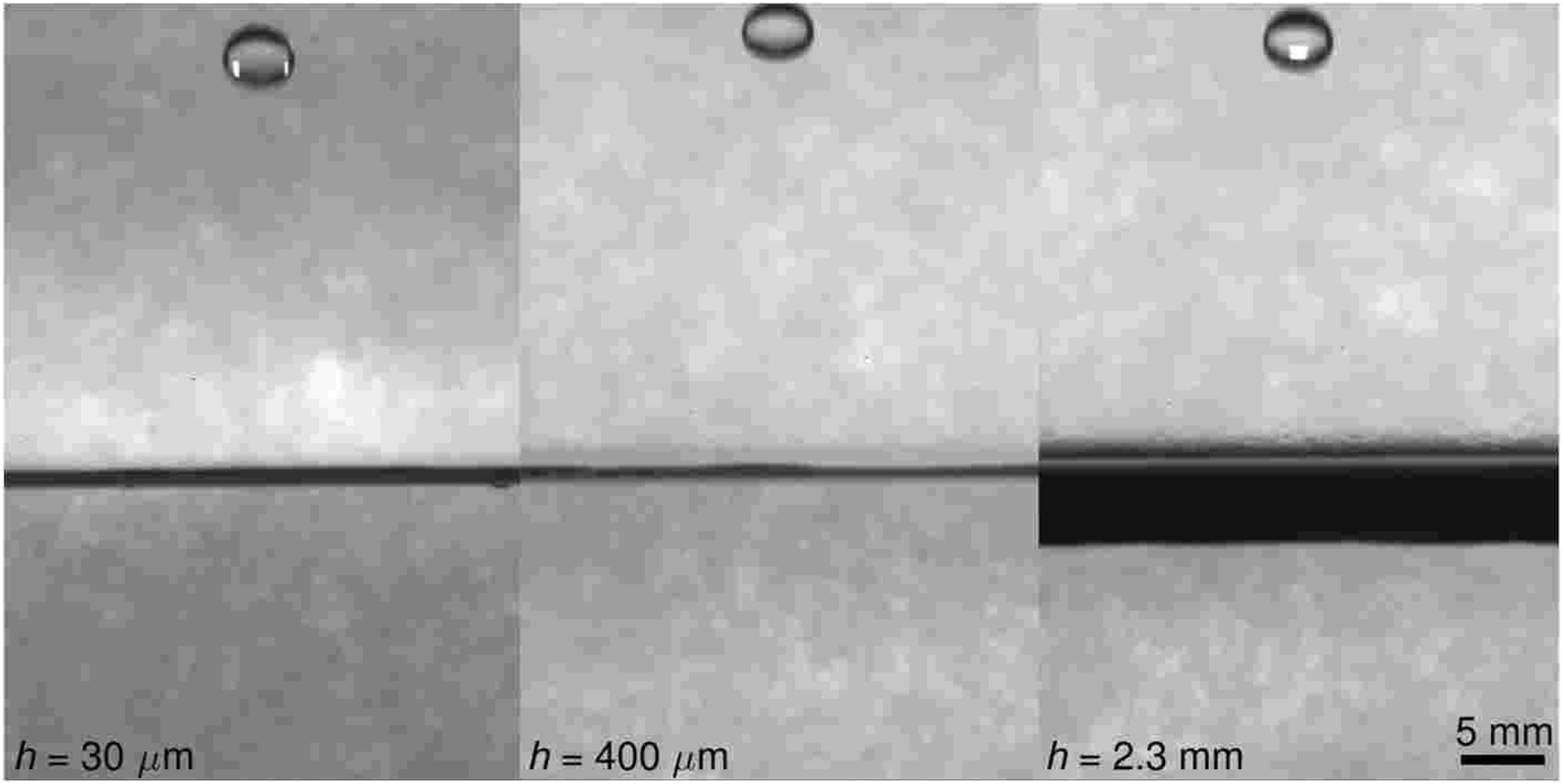
Raindrop Splash (no oil)

- Objective:
  - Investigate the effect of raindrop impact on an oil slick on generation of oily aerosols
  - Determine the effect of oil layer properties (thickness, oil properties) and raindrop scales (size and speed) on the splash behavior and size distributions of aerosolized droplets



Bubble Bursting (no oil)

Classification of Oil Layer Rupture
And Resulting Changes to Crown Behavior



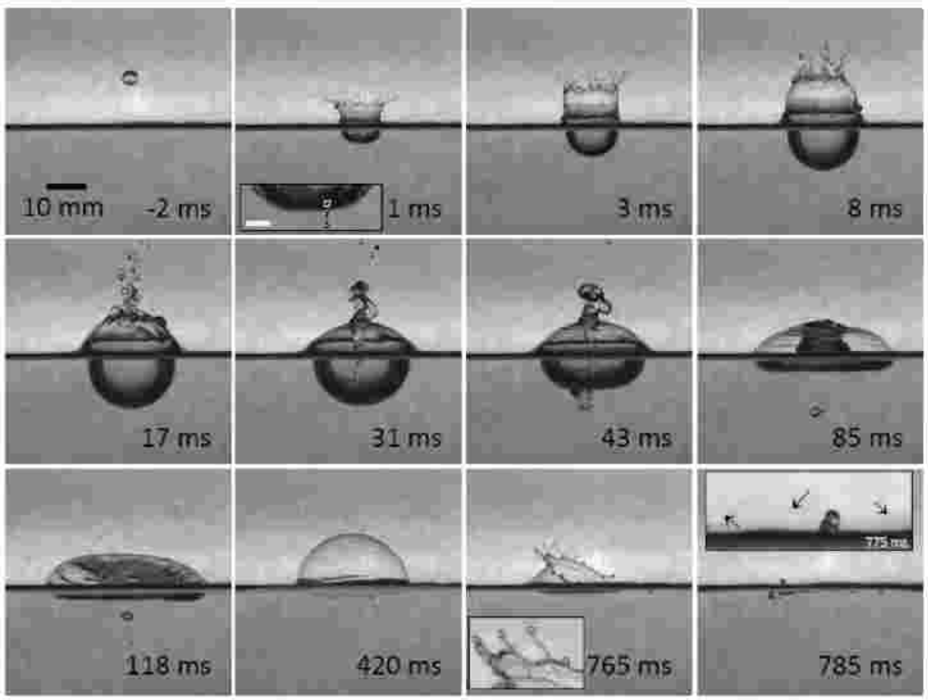
<u>Crude oil layers</u>

u = 7.2 m/s We_d = 2964

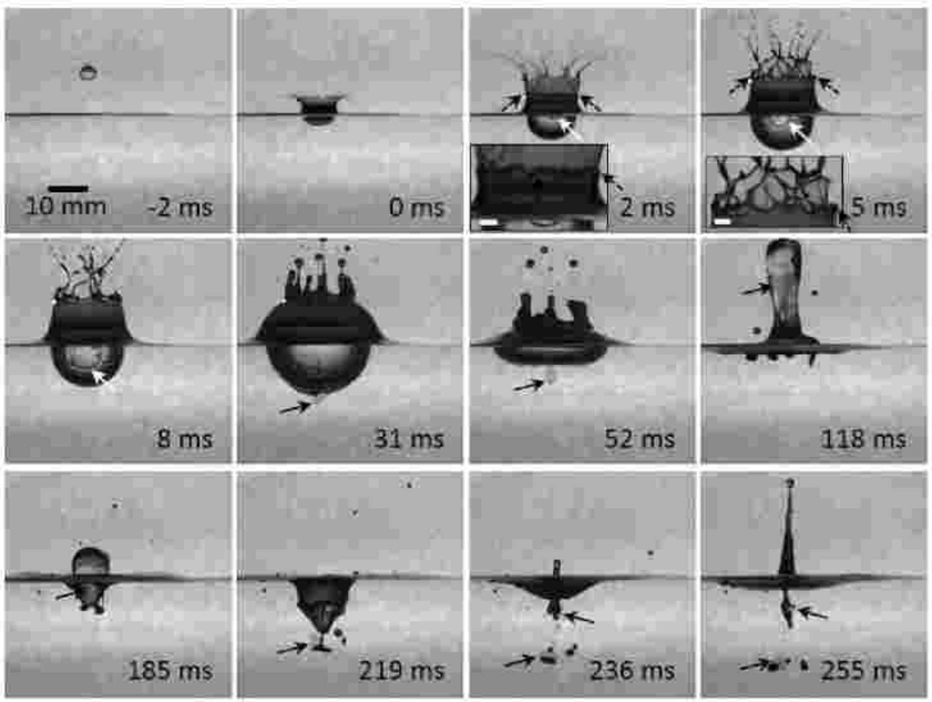
d = 4.1 mm Fr_d = 1288

Classification of Oil Layer Rupture
And Resulting Changes to Crown Behavior

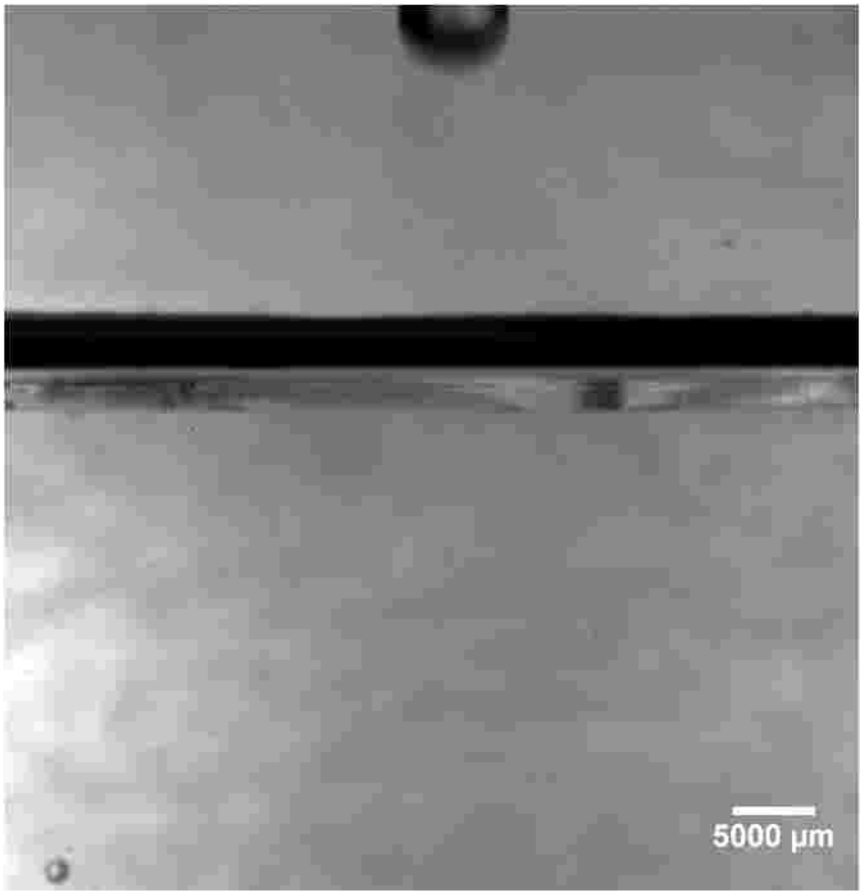
No Oil



500 µm Oil Layer



No Crown Formation for High Viscosity Gear Oil

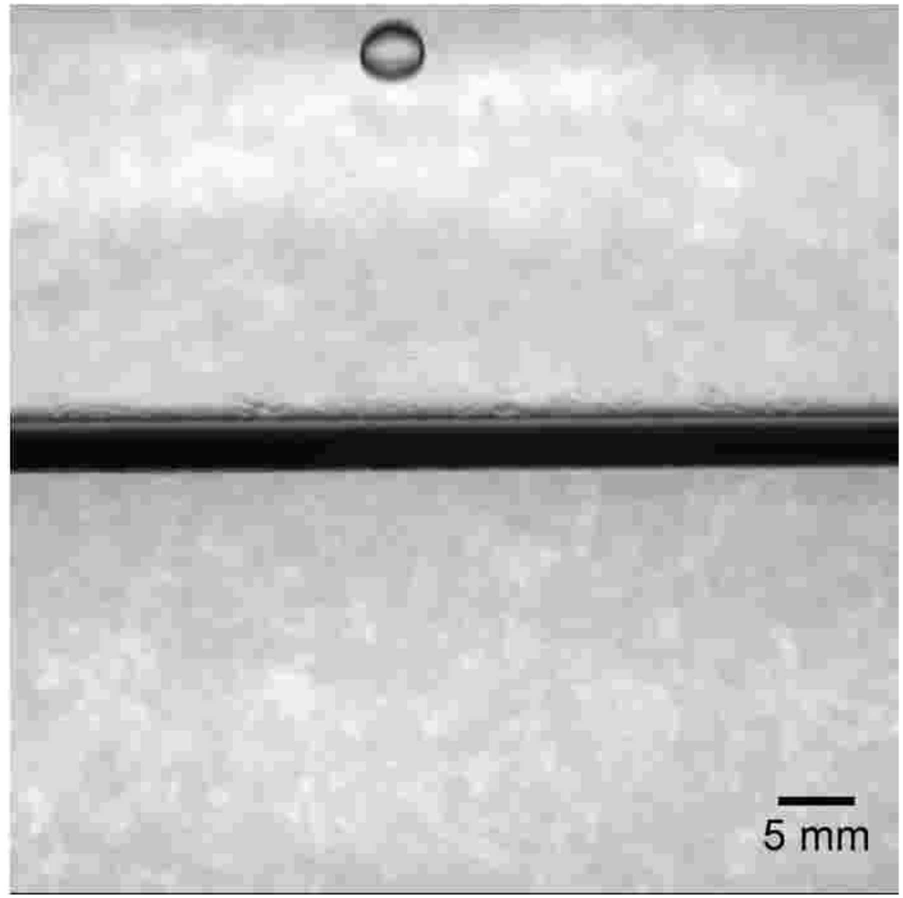


Gear oil layer

h = 600 μm
u = 5.2 m/s
d = 3.8 mm

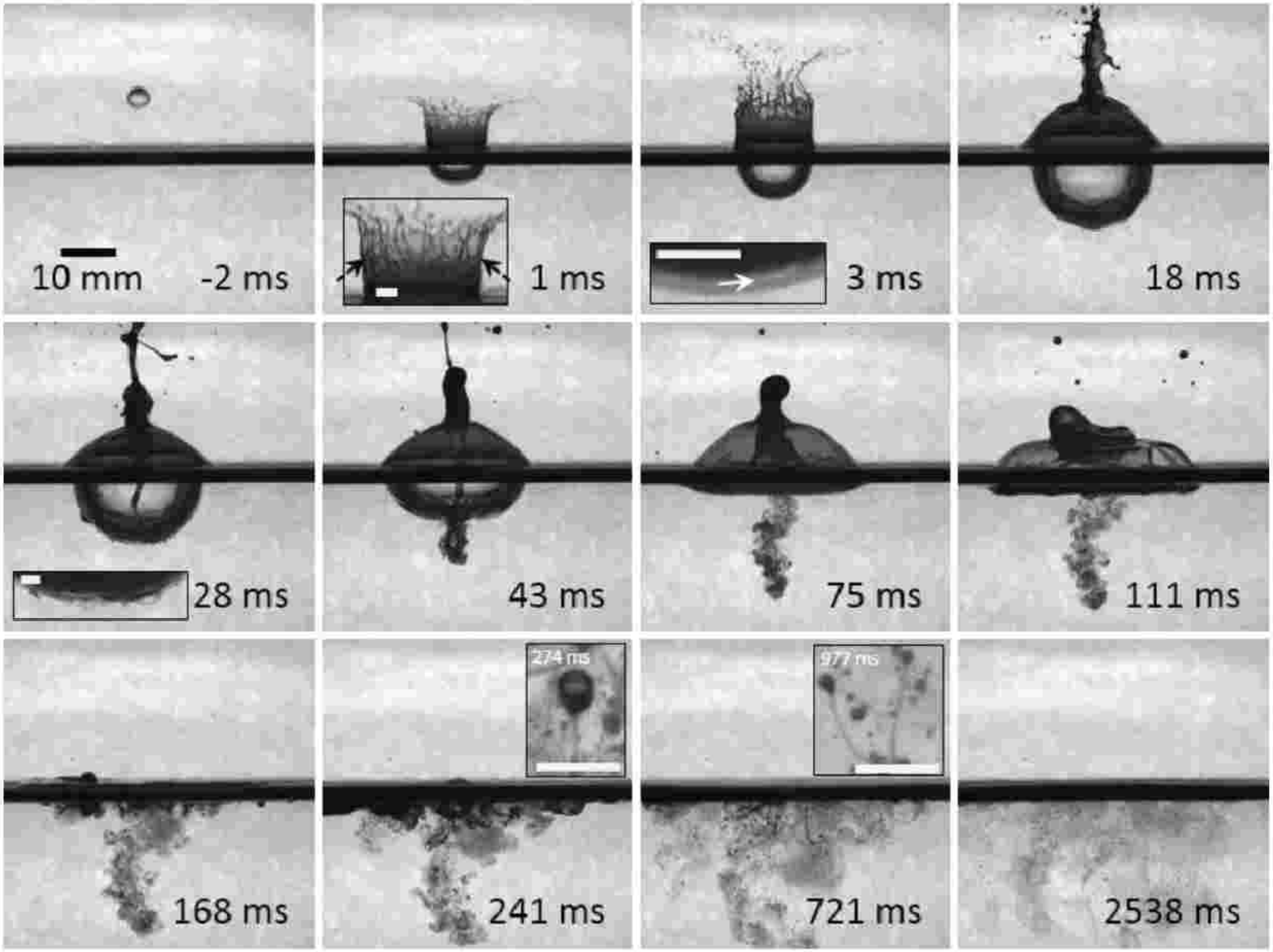
We_d = 1450
Fr_d = 1689

Effect of Dispersants



500 μm crude oil slick premixed with Corexit 9500A dispersant (DOR 1:25)

Effect of Dispersants



Lung epithelial toxicity assessment

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Airway Epithelium

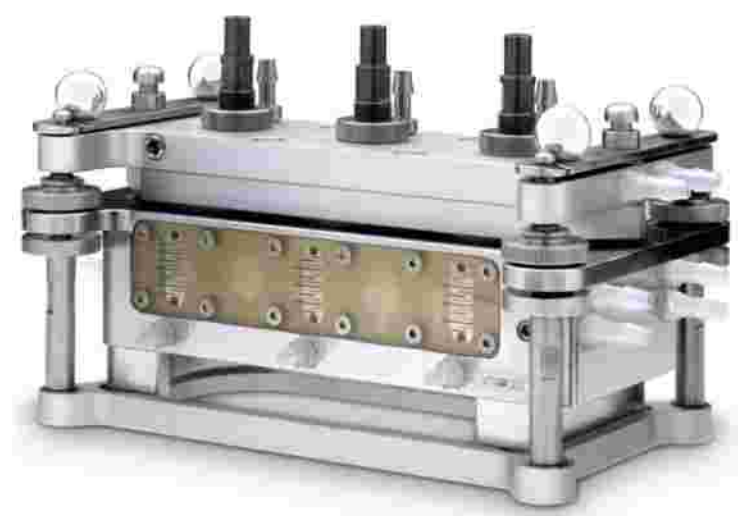
- In addition to the air, we breath in all the various other components in the air
- The airway epithelium is the first line of defense against the respirable environment

Cellular Toxicity

Simple Method:

Pollutants

Exposure Chamber:



Need to make measurements during an actual oil spill

- Members of DROPPS have been meeting with and attending South Texas Coastal Zone Area Committee meetings
- We are trying to be prepared to either go out with oil spill responders, or have them make measurements for us
- Most interested in measuring aerosol droplets of oil downwind of oil slick
- Also interested in measurements of subsurface oil droplet size with submersible holographic system

Any questions?
(remember this isn't my research!)