Dispersant Effectiveness as a Function of Energy Dissipation Rate

A collaboration of
U.S. Environmental Protection Agency
Fisheries and Oceans Canada
Temple University
Louisiana State University
Coastal Response Research Center
(National Oceanic and Atmospheric Administration)

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Goals and Objectives

- Measure energy dissipation rates of a range of wave energies
  - Regular wave
  - Spilling breaker
  - Plunging breaker

- Quantify natural rates of dispersion of crude oils under these wave conditions

- Quantify effectiveness of 2 dispersants in enhancing dispersion of 2 reference crude oils at the 3 different energy dissipation rates

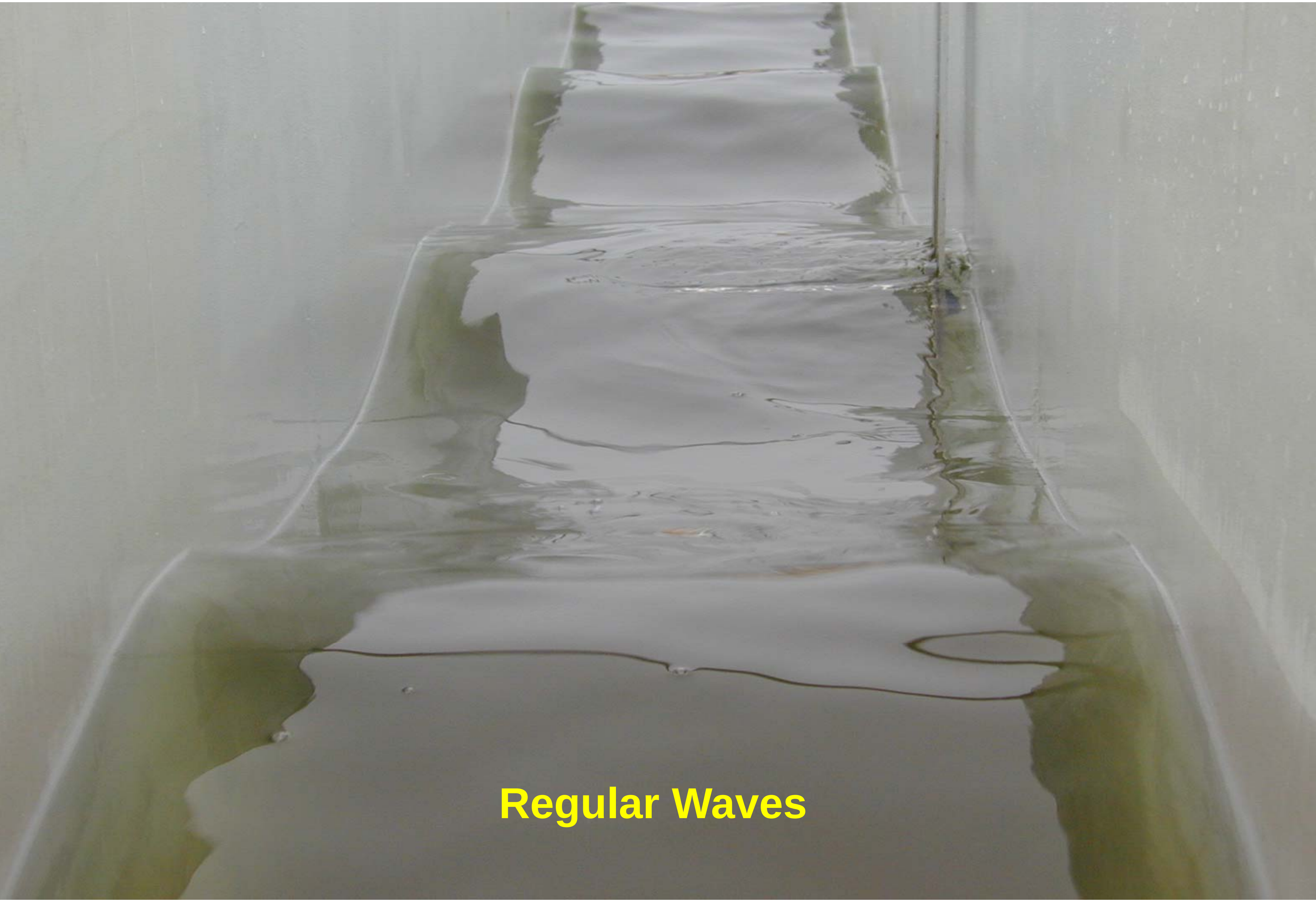
- Develop analytical tools for monitoring dispersion in the field

Background

- NRC recently concluded that 2 important factors needing to be addressed are:
  - Energy dissipation rate (energy is needed for effective dispersion to occur)
  - Particle size distribution of oil droplets (the smaller the droplet size, the more effective the dispersion)
- Energy Dissipation Rate
  - Breaking waves are important for effective dispersion
  - Breaking waves are generated by superimposing a long wavelength wave atop a shorter one

EPA/DFO Wave Tank

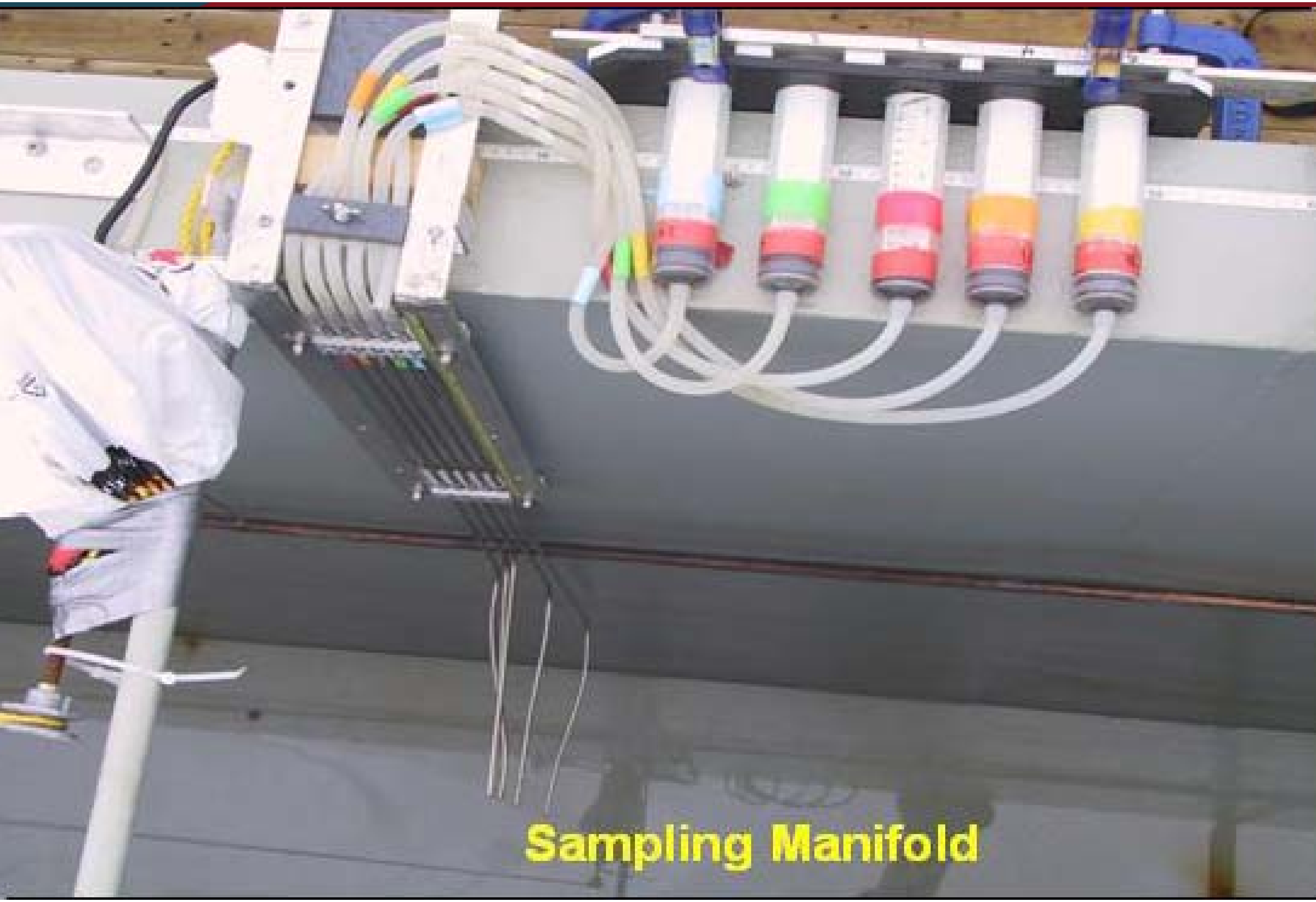
- Wave tank originally fabricated 2 years ago (16 m x 2 m x 0.6 m)
- Wave tank doubled in length to 32 m to accommodate more wave types and bigger breakers
- Wave tank is able to generate reproducible breaking waves at precise locations
  - Methods have been developed that define the energy dissipation rate at various breaking wave energies
- Can be operated in either batch mode or continuous flow to simulate dilution by ocean currents


Regular Waves


Spilling Breaker


Plunging Breaker


Wave Absorbers


Sampling Manifold

Testing Dispersion Effectiveness

- Hypothesis: energy dissipation rate, ε, is sufficient to accurately evaluate dispersant effectiveness (DE)
- Approach: DE measured at 3 different wave periods using 2 dispersants and 2 oils under batch conditions
  - Dispersants on NCP Product Schedule
    - C9500
    - SPC1000
  - Crude oils
    - Weathered Mesa Light
    - Unweathered ANS
  - 3 different ε's:
    - Regular wave
    - Spilling breaker
    - Plunging breaker

Summary of Factorial Experimental Design

Treatment	Dispersants	Oils	Waves
1	Water	MESA	Regular
2	Corexit	MESA	Regular
3	SPC1000	MESA	Regular
4	Water	ANS	Regular
5	Corexit	ANS	Regular
6	SPC1000	ANS	Regular
7	Water	MESA	Spiller
8	Corexit	MESA	Spiller
9	SPC1000	MESA	Spiller
10	Water	ANS	Spiller
11	Corexit	ANS	Spiller
12	SPC1000	ANS	Spiller
13	Water	MESA	Plunger
14	Corexit	MESA	Plunger
15	SPC1000	MESA	Plunger
16	Water	ANS	Plunger
17	Corexit	ANS	Plunger
18	SPC1000	ANS	Plunger

General Approach

- Create oil slick on water surface
- Start wave maker
- DOR = 1:25 in all experiments
- No-dispersant controls are also done, using water as the sprayed “dispersant”
- All experiments done in triplicate
- Dispersed oil measured at 3 depths and 4 locations long the length of the wave tank
  - Measurements conducted at 5, 30, 60, and 120 min
  - One rep done at 240 min (re-coalescence experiment) under quiescent conditions

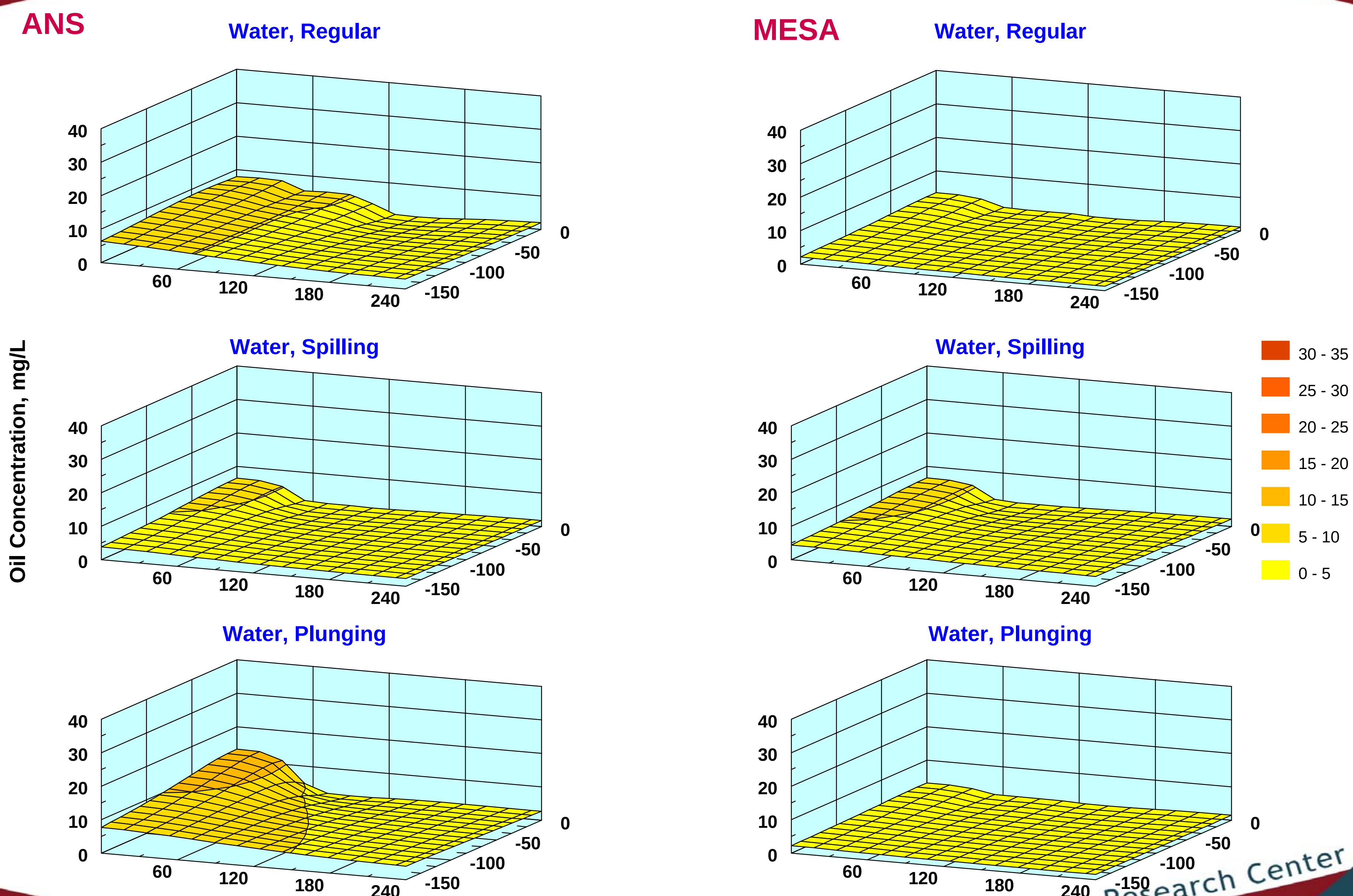
Analytical and Wave Settings

- Oil distribution measurements in tank (3 methods):
  - Fluorometry
  - Laser particle analyzer (LSST-100X)
  - Spectrophotometric analysis of grab samples at 4 different locations upstream and downstream from mixing zone

- Total analyses: 3 dispersants x 2 oils x 3 wave types x 3 replicates x 4 sampling locations x 3 depths = 864 total analyses

- Wave maker settings
  - Regular waves: 0.85 Hz, 10 cm stroke
  - Spilling breakers: 0.85/0.45 Hz, 7 cm stroke (20 s high freq, 5 s low freq)
  - Plunging Breakers: 0.85/0.50 Hz, 10 cm stroke (20 s high freq, 5 s low freq)

2006 RESULTS



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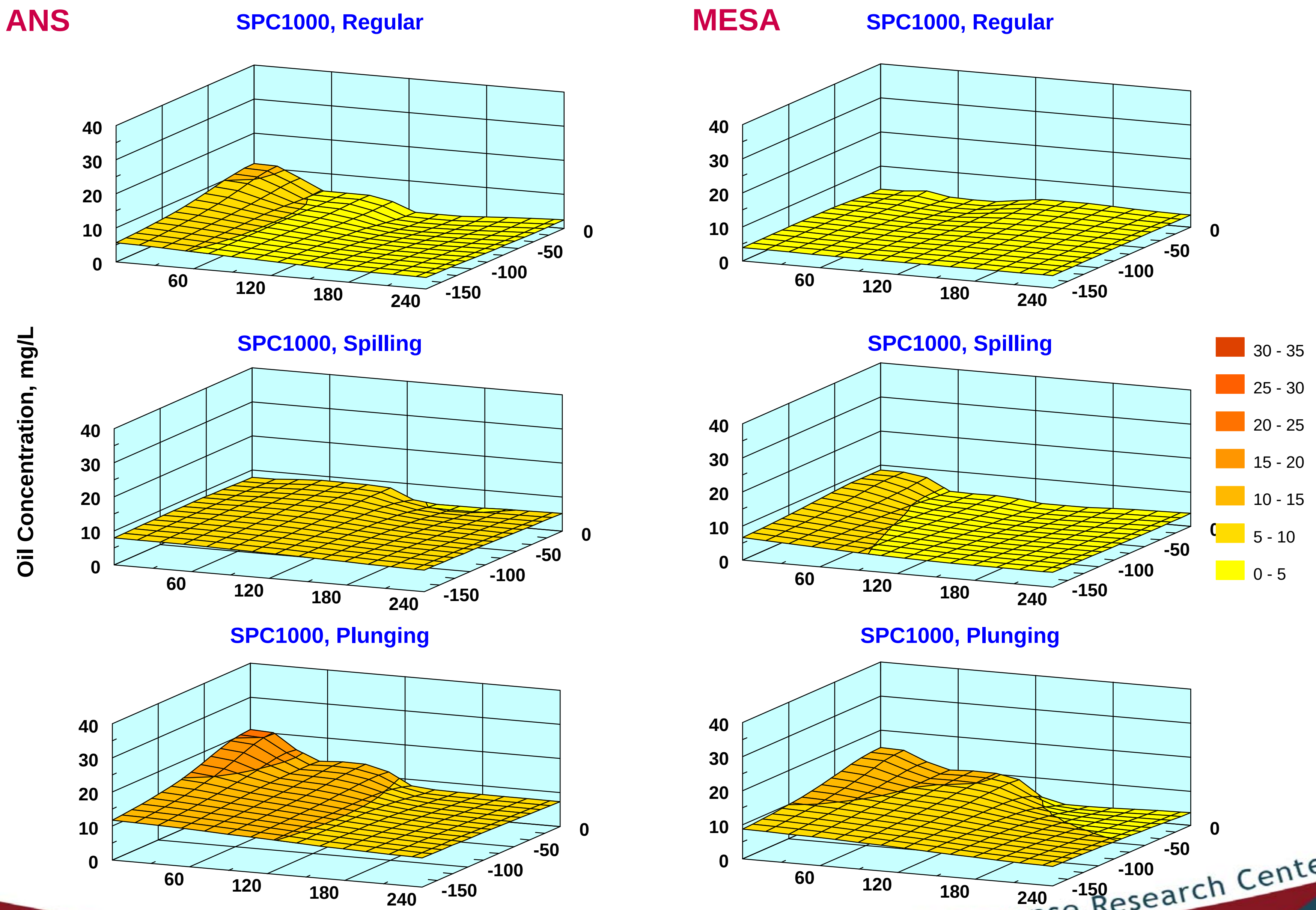
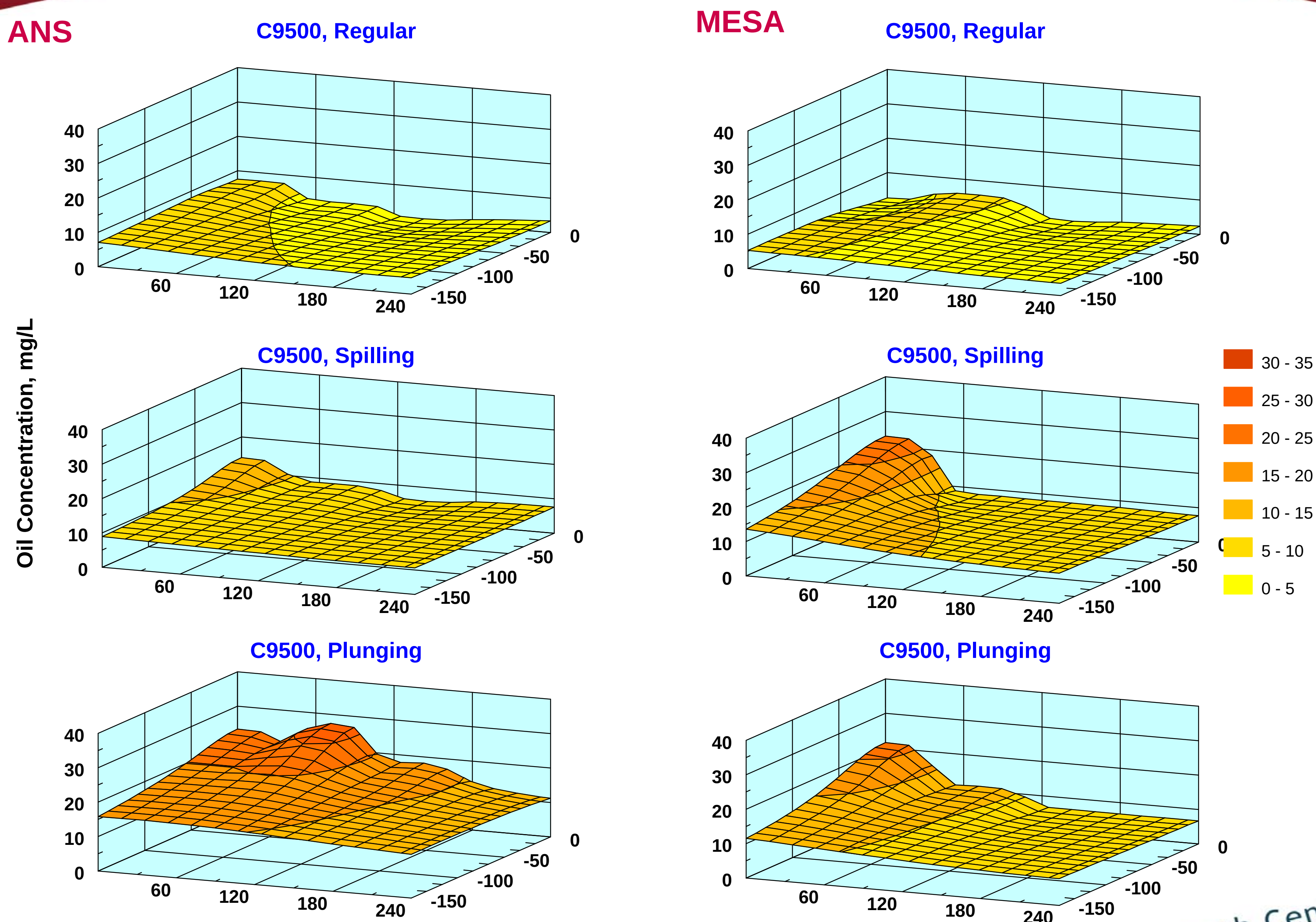
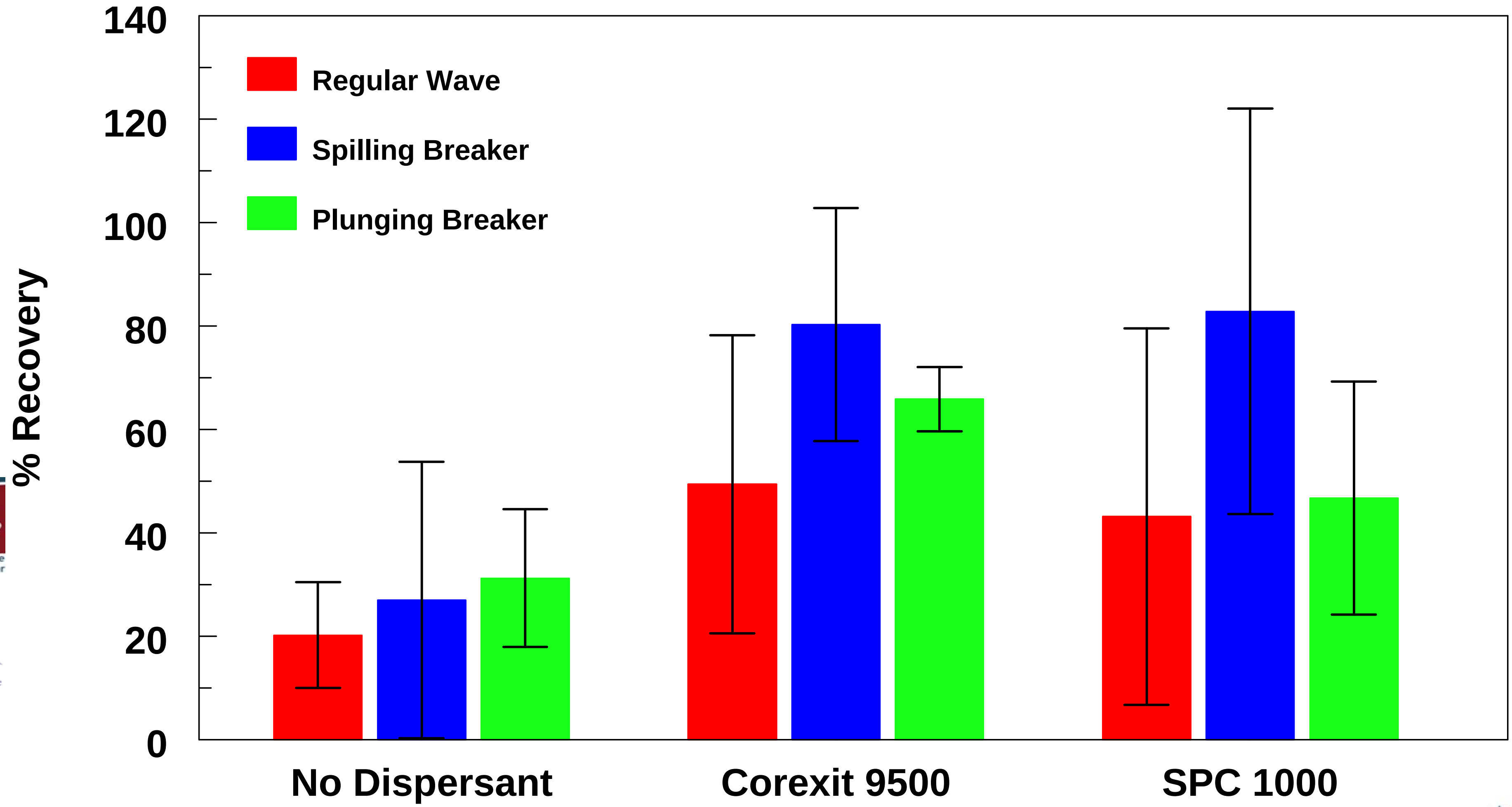
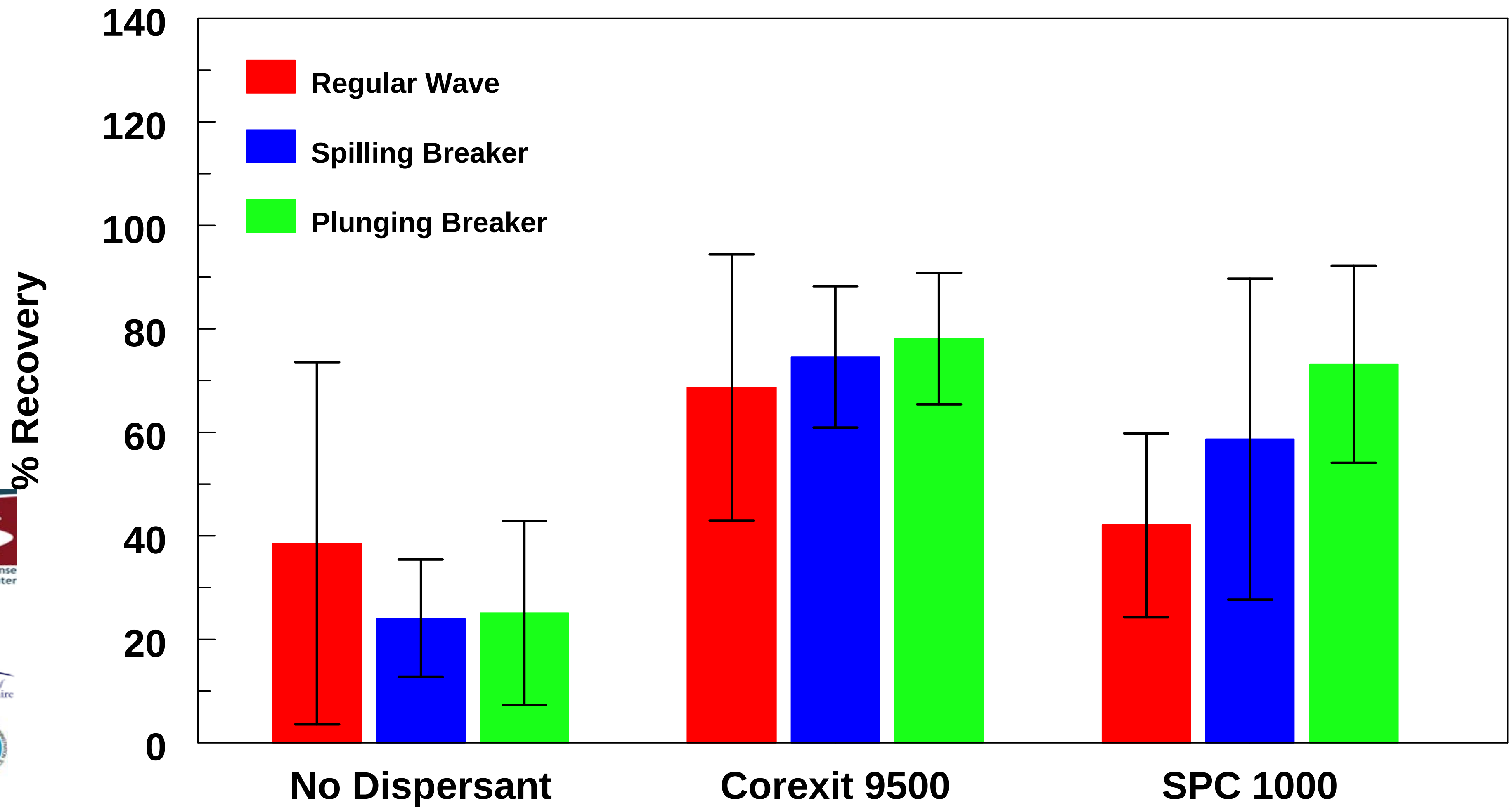

ANS
MESA
SPC1000, Regular
SPC1000, Spilling
SPC1000, Plunging
Oil Concentration, mg/L
40
30
20
10
0
60
120
180
240
0
-50
-100
-150
30 - 35
25 - 30
20 - 25
15 - 20
10 - 15
5 - 10
0 - 5


ANS
MESA
C9500, Regular
C9500, Spilling
C9500, Plunging
Oil Concentration, mg/L
0
10
20
30
40
60
120
180
240
0
-50
-100
-150
30 - 35
25 - 30
20 - 25
15 - 20
10 - 15
5 - 10
0 - 5

Average % Recovery of Dispersed MESA Oil in Tank



Average % Recovery of Dispersed ANS Oil in Tank



SUMMARY AND PRELIMINARY CONCLUSIONS

SUMMARY AND CONCLUSIONS (preliminary)

- Breaking waves are important for effective and lasting dispersion
  - Breaking waves shear oil slick into tiny droplets that don't easily recoalesce
  - Breakers push oil downwards into water column where currents may carry the dispersed oil away (to be verified next)
- Regular waves disperse oil somewhat but do not impart sufficient energy to break up the oil into small droplets or push the droplets down deeply into the water column
  - They do provide sufficient energy to maintain dispersed state caused by dispersant application

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SUMMARY AND CONCLUSIONS (preliminary)

- Aqueous recovery of oil in the EPA/DFO wave tank was moderate but variable
  - Final conclusions await analysis of remaining replicate
  - Particle size distribution analysis will aid in this determination
  - Unrecovered oil subjectively explainable by adsorption to the wave absorbers at end of tank
- Correlations between DE and ε will enable more meaningful explanations of the data presented

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Fisheries and Oceans Canada Pêches et Océans Canada

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QUESTIONS??