Wave Tank Studies on Dispersant Effectiveness: Influence of Energy Dissipation Rate on Oil Droplet Size and Concentration

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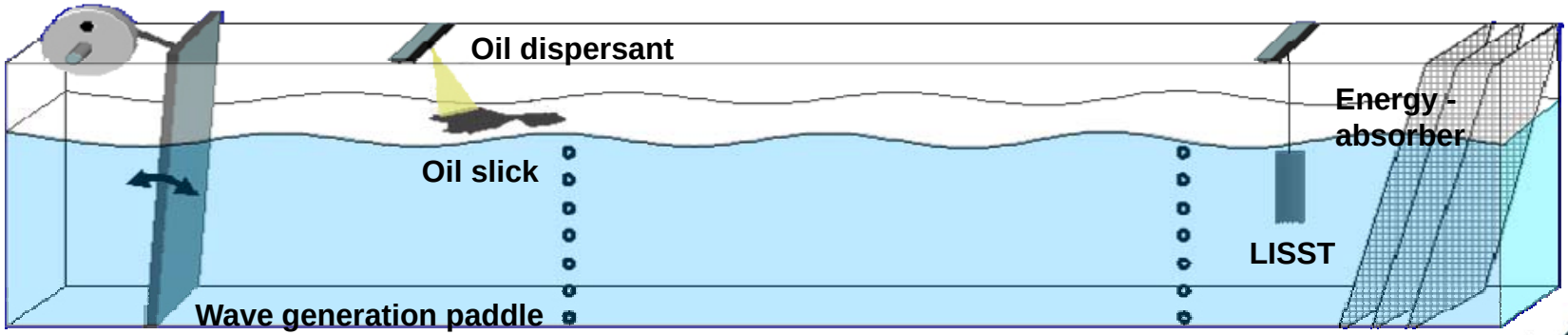
Rationale

- National Research Council (NRC) Committee on Understanding Oil Spill Dispersants: Efficacy and Effects (2005) identified two factors to be addressed in oil dispersant efficacy studies:
  - Energy Dissipation Rate
  - Particle Size Distribution
- A wave tank has been constructed in BIO to address these issues:
  - Hydrodynamic Characterization (M.C. Boufadel)
  - Dispersant Effectiveness including Particle Size Distribution (K. Lee / Z. Li / A.D. Venosa)
  - In-situ Fluorometry (S. Miles / P. Kepkay)

Wave Tank Facility

Bedford Institute of Oceanography - Nova Scotia Canada



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Factorial Experimental Design

- Factors:
  - Dispersants: Water (control), Corexit, SPC
  - Waves: regular non-breaking wave, spilling breaker, plunging breaker
  - Oil types: MESA, ANS
- Effectiveness indicators:
  - Oil concentration
  - Droplet size distribution
- Analytical methods
  - U.V. Spetrophotometry (UVS)
  - U.V. Fluorometry (UVF)
  - Laser In-Situ Scattering and Transmissometry (LISST)
  - U.V. Epi-fluorescent microscopy (UVFM)

Factorial Experimental Design Matrix

#g	Dispersant	Oil	Wave
1	W	MESA	Regular
2	C	MESA	Regular
3	S	MESA	Regular
4	W	ANS	Regular
5	C	ANS	Regular
6	S	ANS	Regular
7	W	MESA	Spilling
8	C	MESA	Spilling
9	S	MESA	Spilling
10	W	ANS	Spilling
11	C	ANS	Spilling
12	S	ANS	Spilling
13	W	MESA	Plunging
14	C	MESA	Plunging
15	S	MESA	Plunging
16	W	ANS	Plunging
17	C	ANS	Plunging
18	S	ANS	Plunging

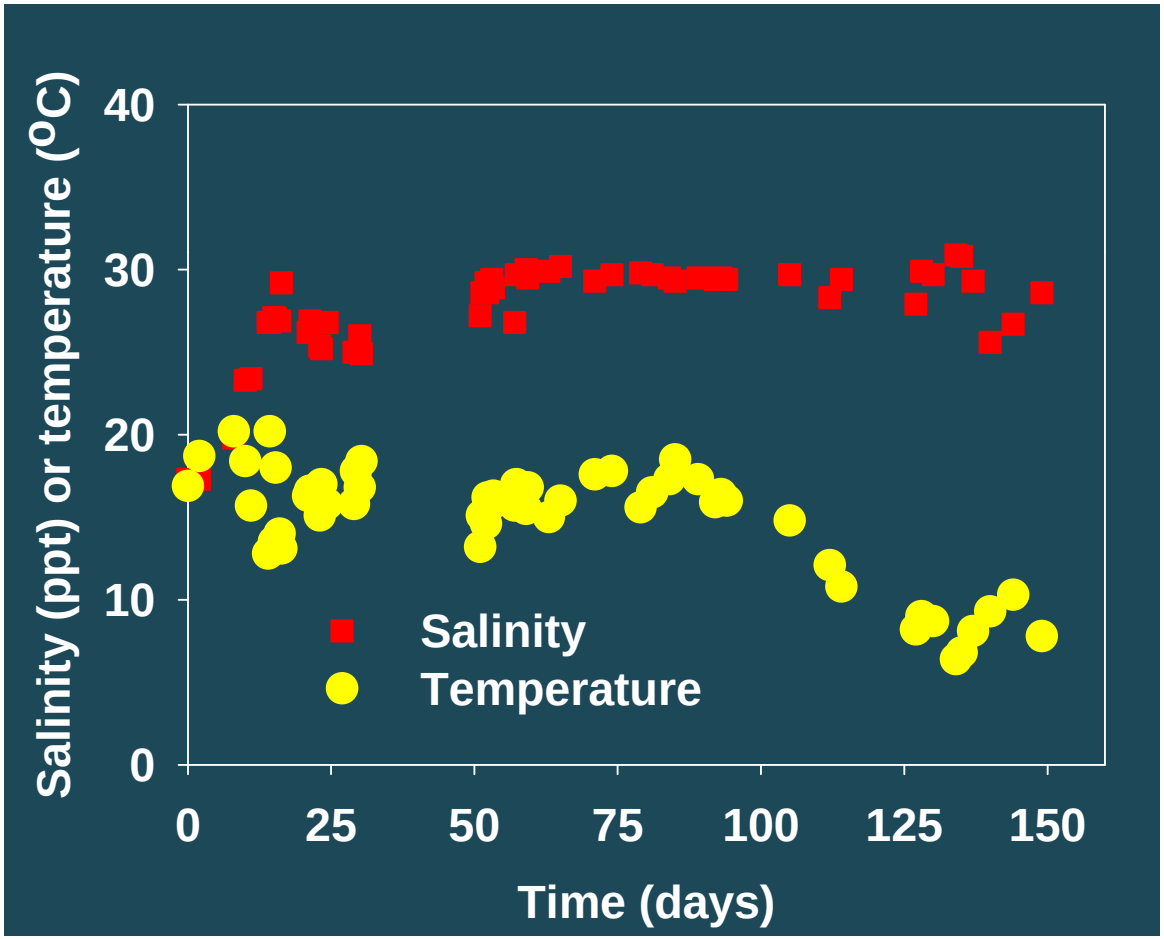
Wave Conditions

(a) Regular Non-breaking

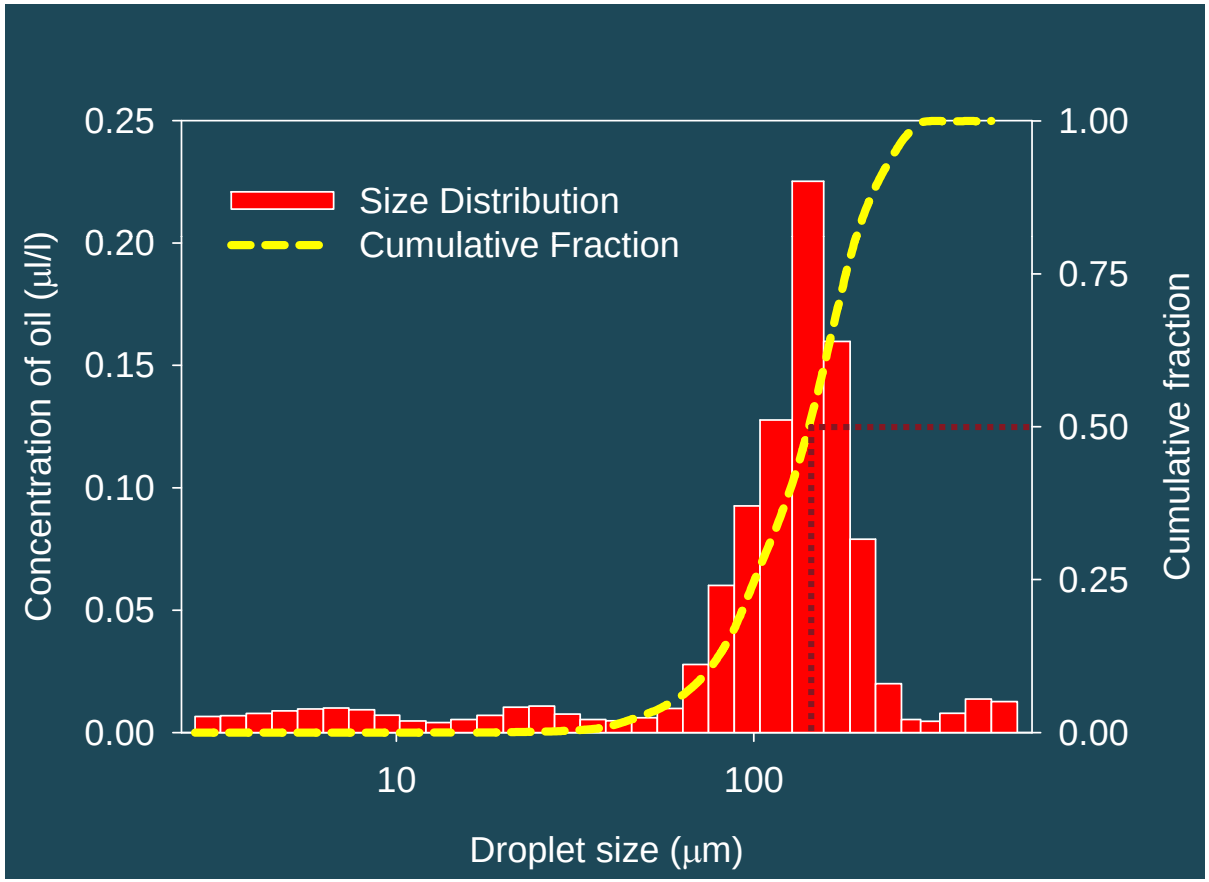
(b) Spilling Breaking

(c) Plunging Breaking

Experimental Conditions: Temperature and Salinity



Particle Size Distribution (No Dispersant)



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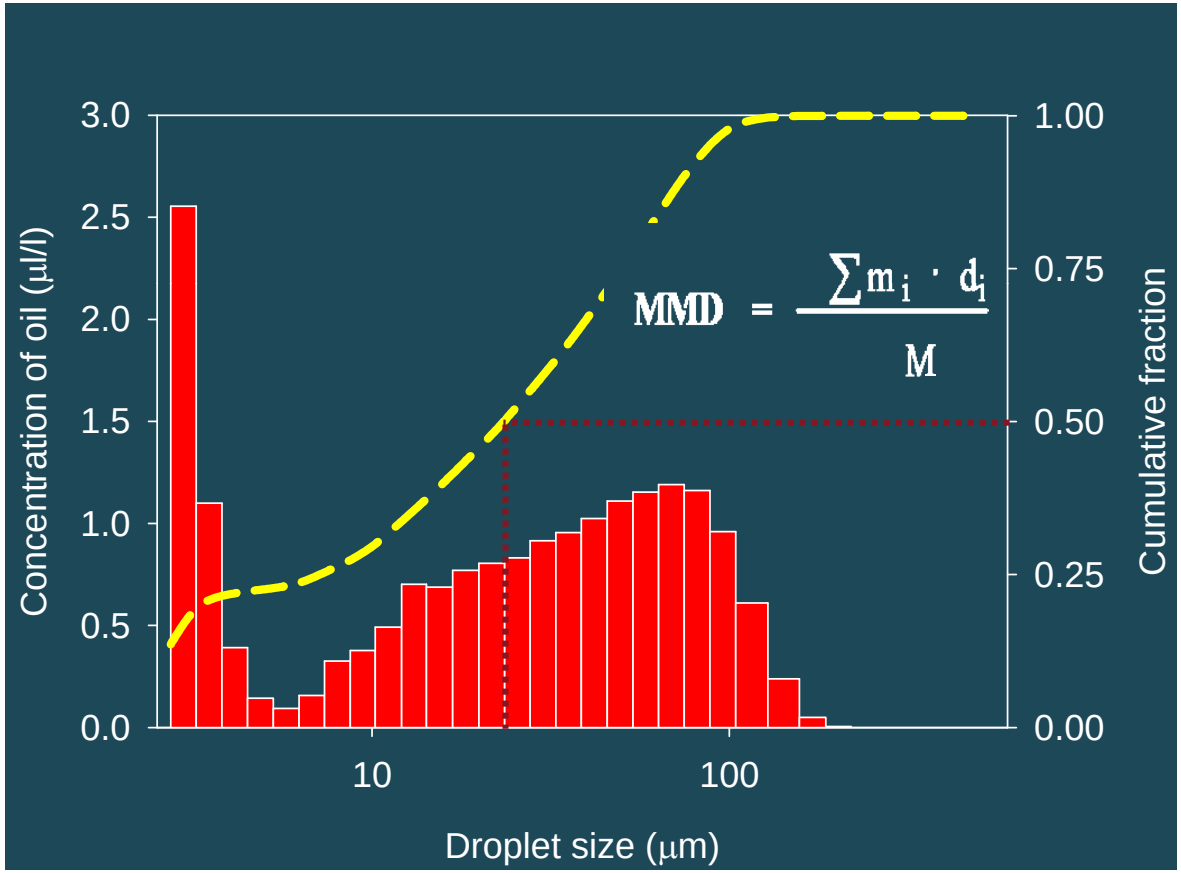
Particle Size Distribution (With Dispersant)



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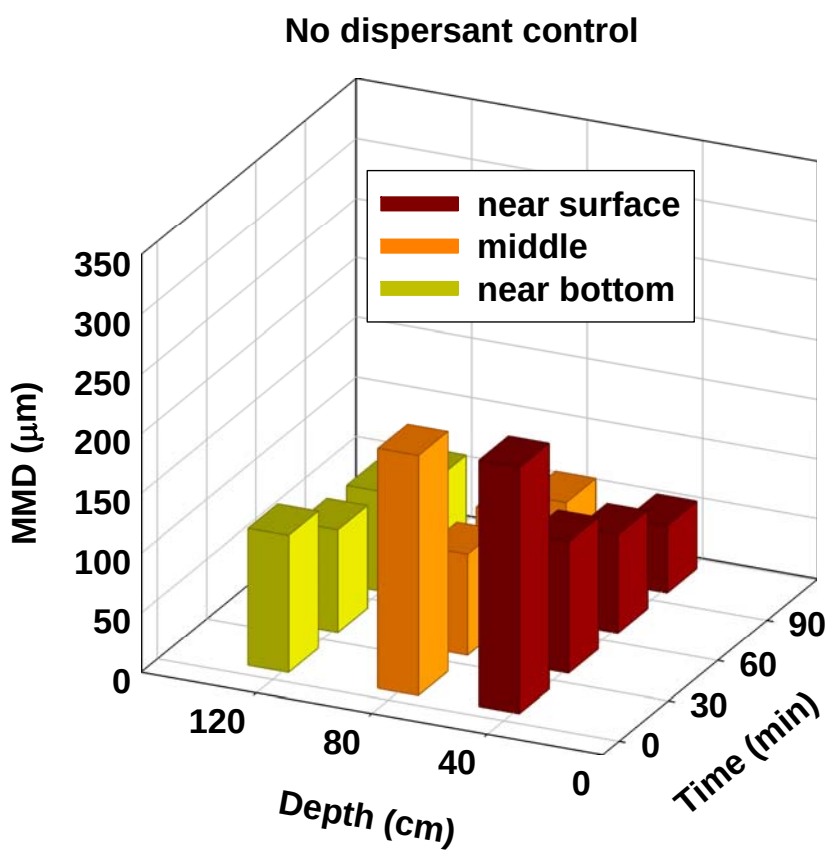
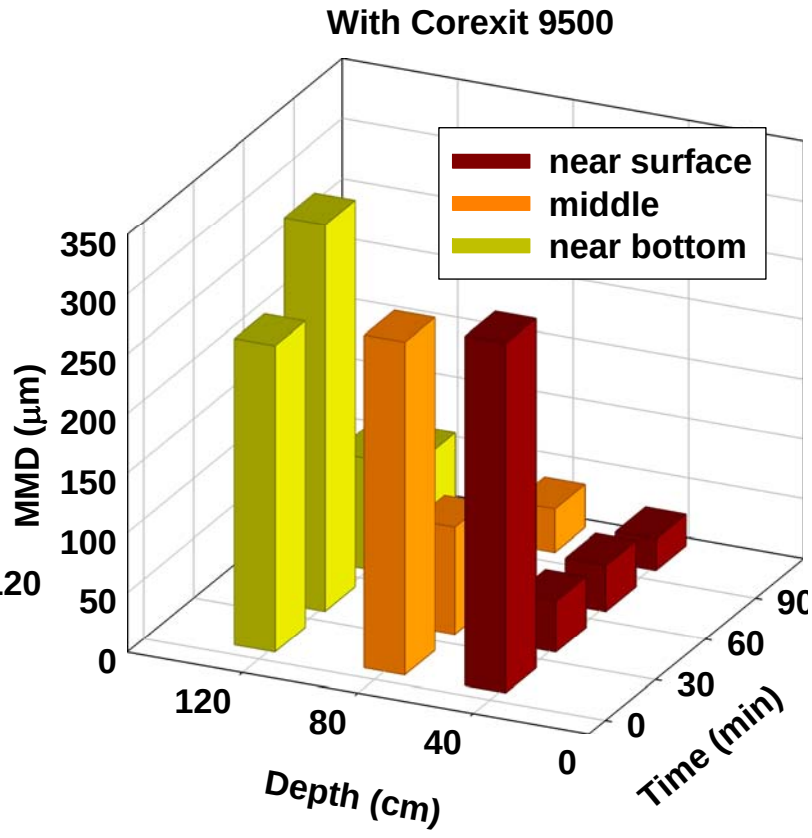
Mass Mean Diameter:
Regular Non-Breaking Waves (8m downstream)





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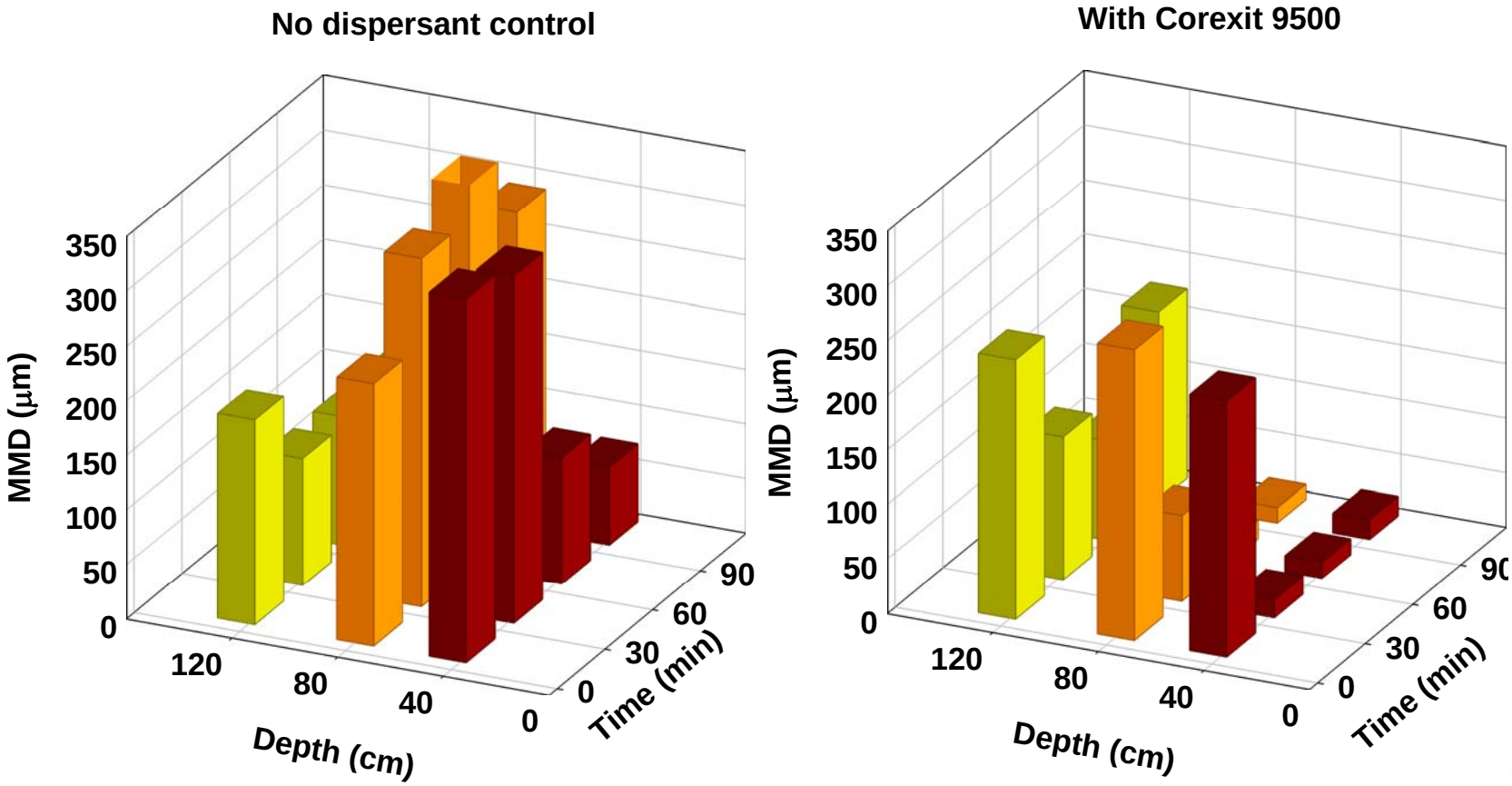
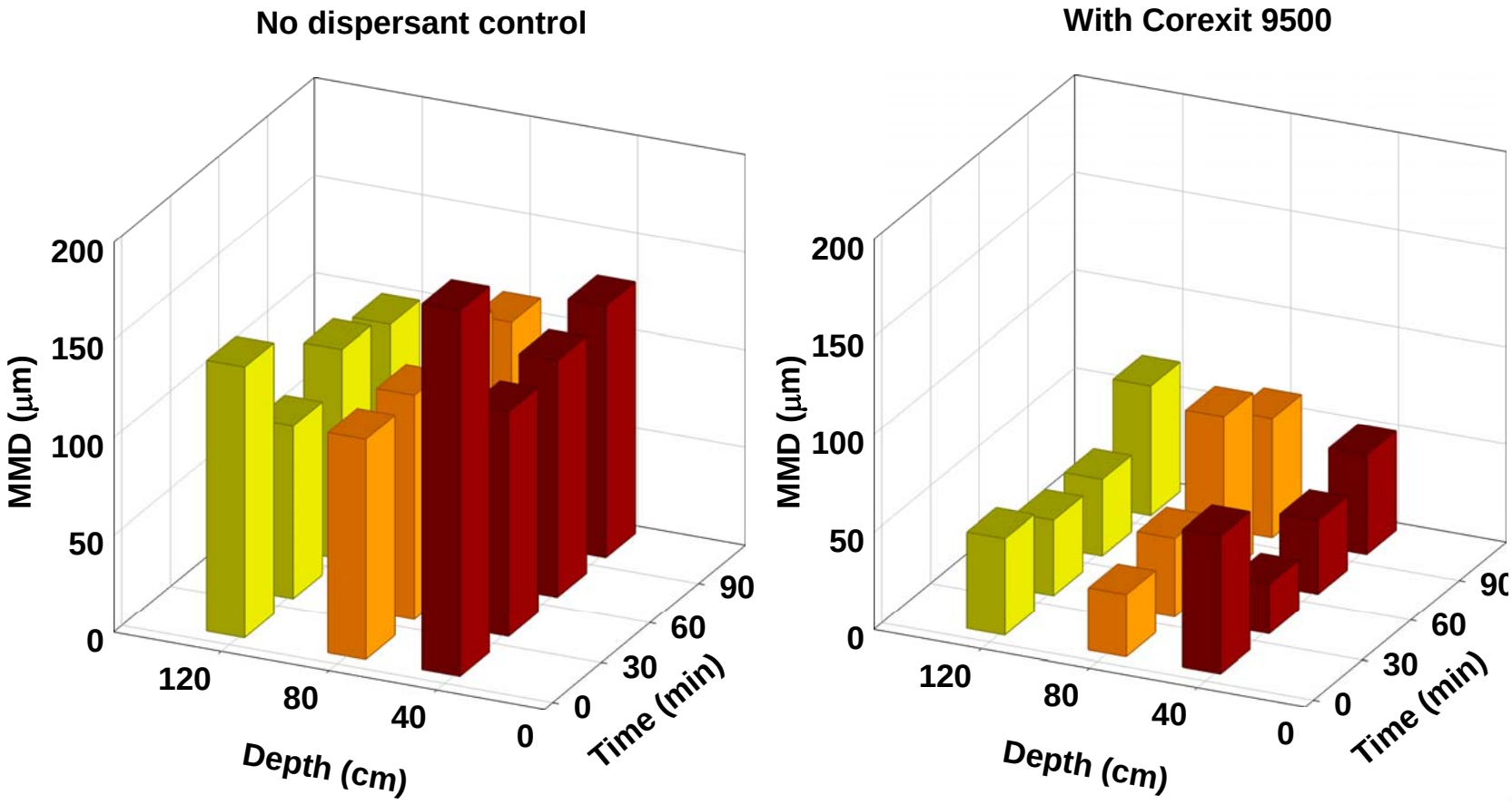
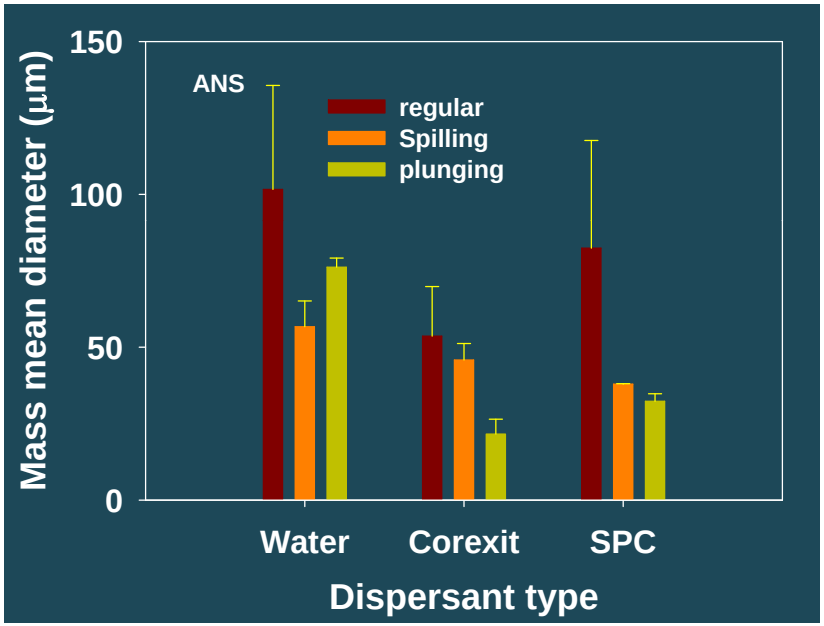
Mass Mean Diameter:
Spilling Breaking Waves (8m downstream)

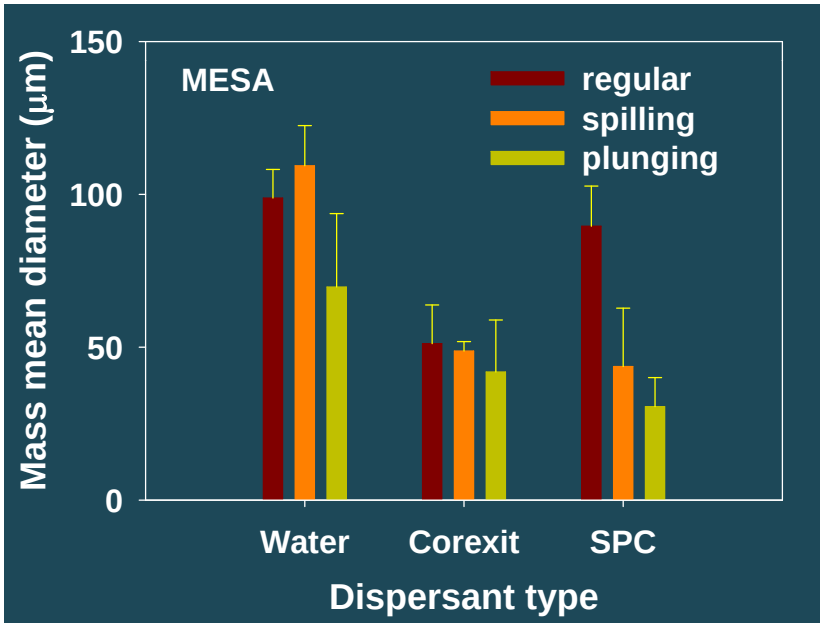


Mass Mean Diameter:
Plunging Breaking Waves (8m downstream)



Effects of Wave, Dispersant, and Oil on MMD (Near Bottom for 2 hr)





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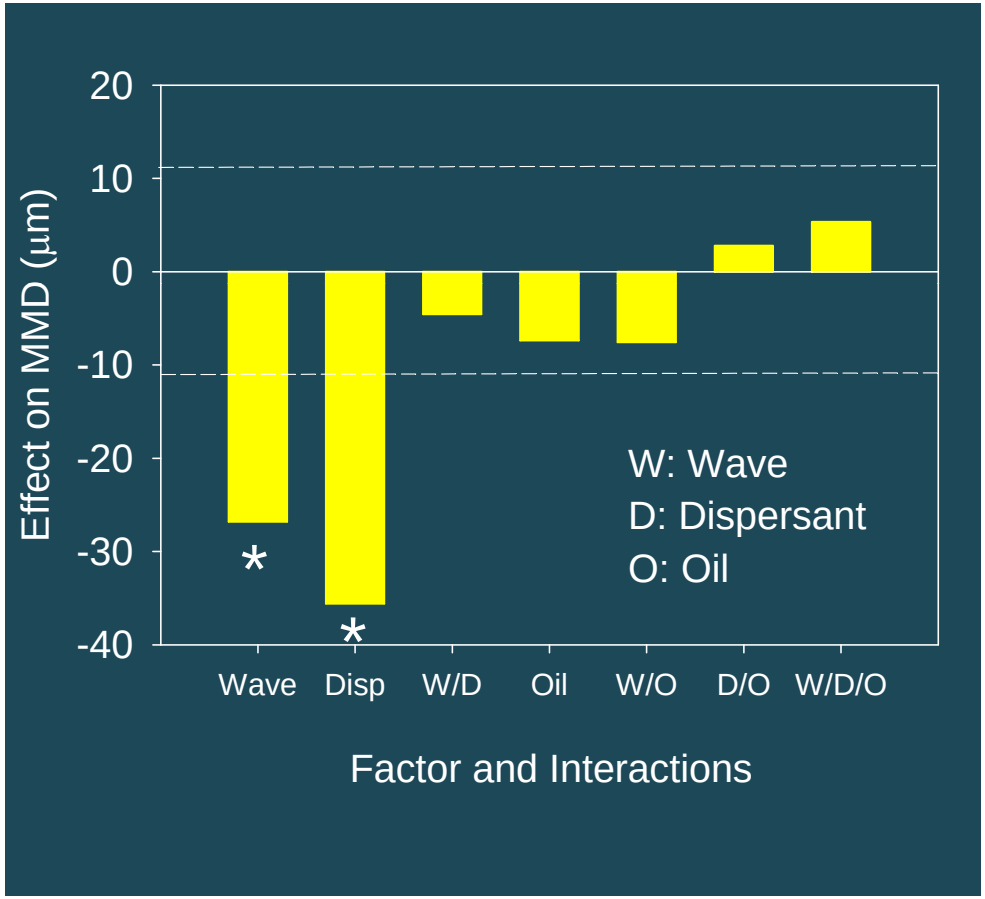
Data Analysis of Factorial Effects: MMD (Near Bottom for 2 hr)

- **Breaking waves significantly decreased oil droplet size**
- **Dispersant additions significantly decreased oil droplet size**



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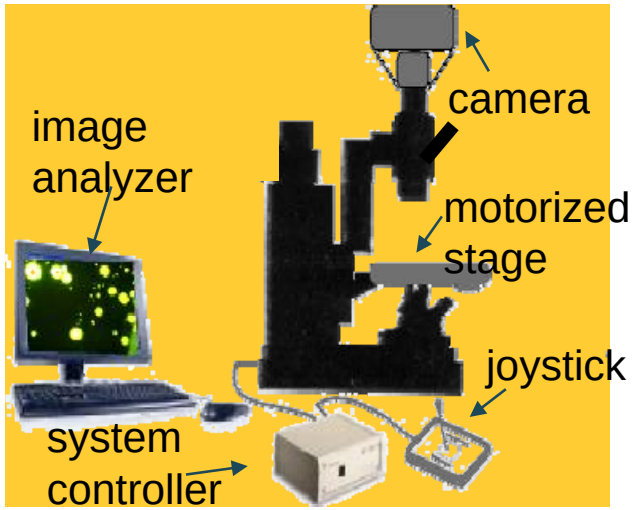
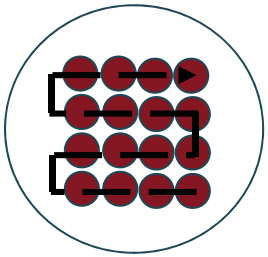
U.V. Epi-fluorescent Microscopy

- **Automated particle size analysis of dispersed oil droplets**





Automated Sequential Acquiring

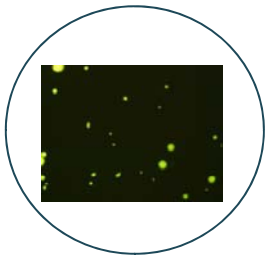
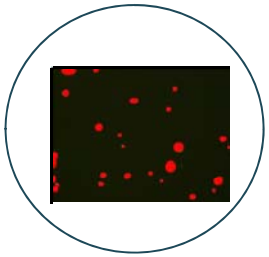
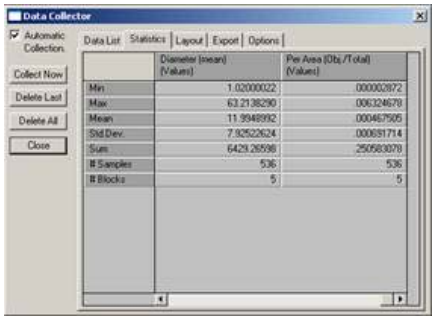


Image Capture



Count/Size

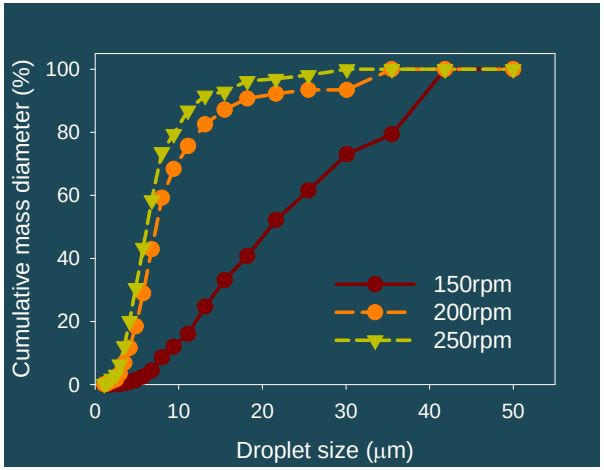


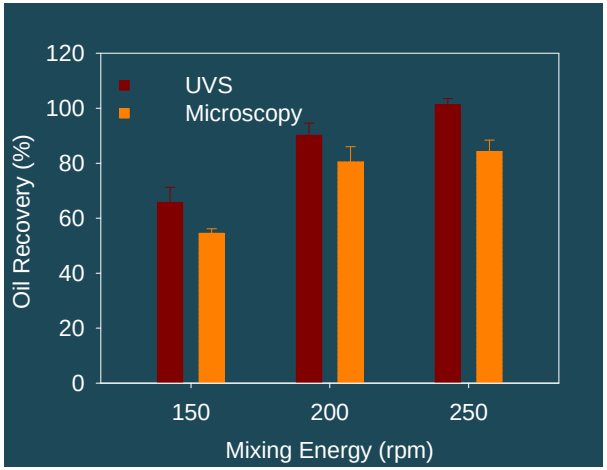
Data Report

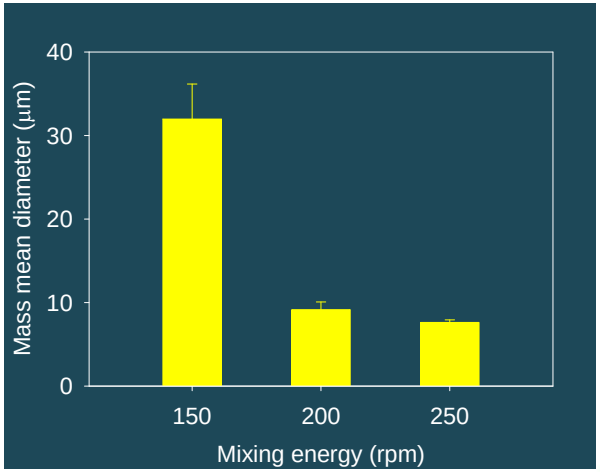
Effect of Energy Dissipation Rate On Oil Droplet Size: Laboratory Validation

rpm	m^2/s^3
150	0.01
200	0.15
250	1.5

* Boufadel, 2006







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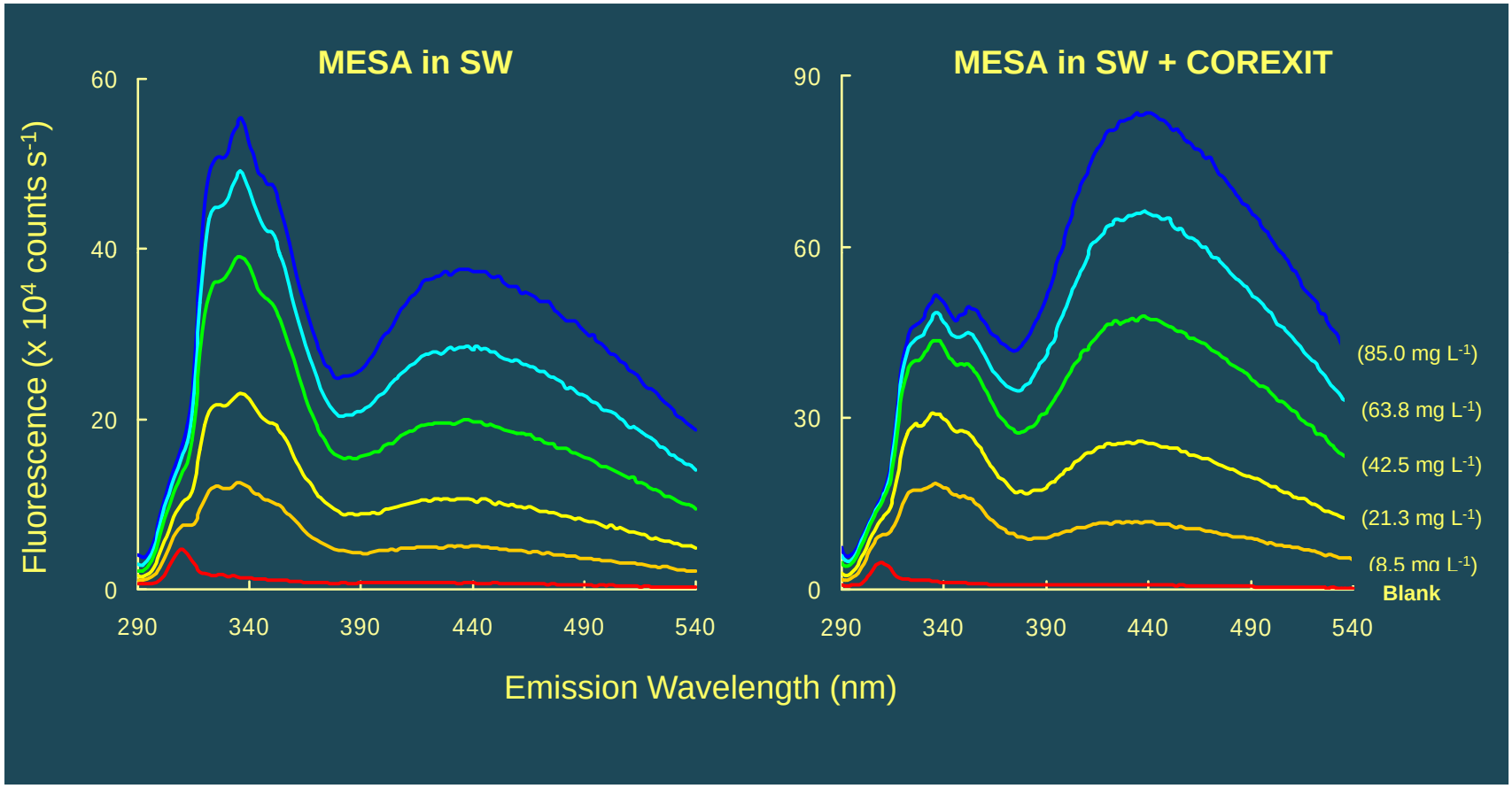
UVF Spectra of MESA and MESA/Dispersant in Seawater



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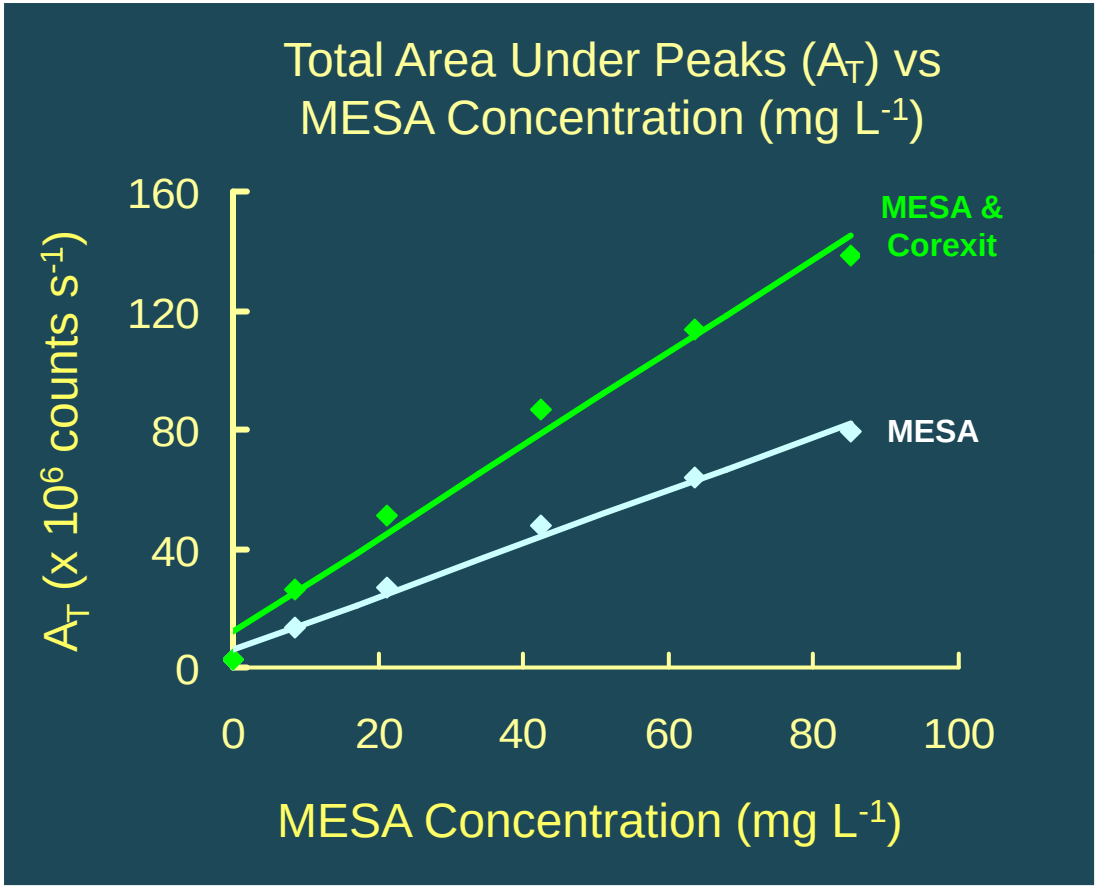
Dispersed Oil Concentration: UVF Calibration Curve



- Standard curves generated with Total Area under UV fluorescence spectra (290nm - 540nm)

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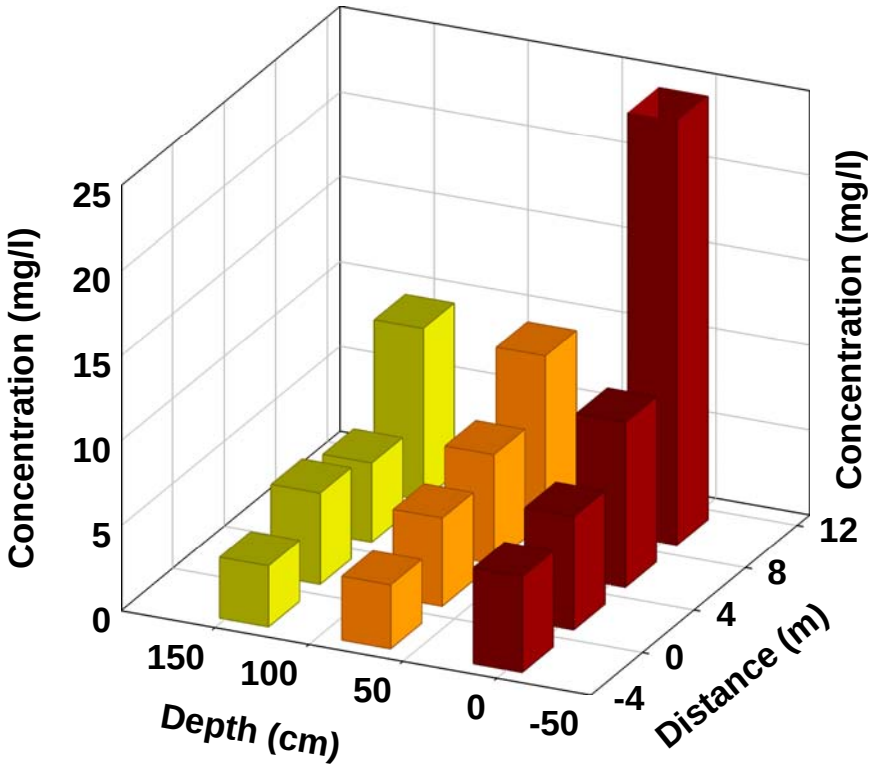
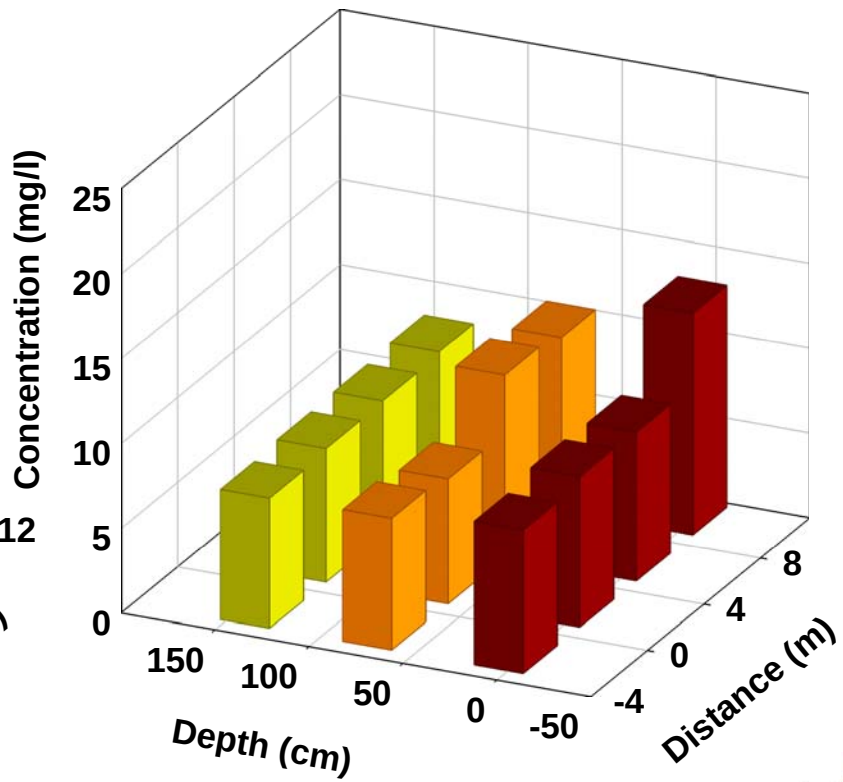
Oil Distribution: Regular Waves (2hr)

No dispersant control



With Corexit 9500



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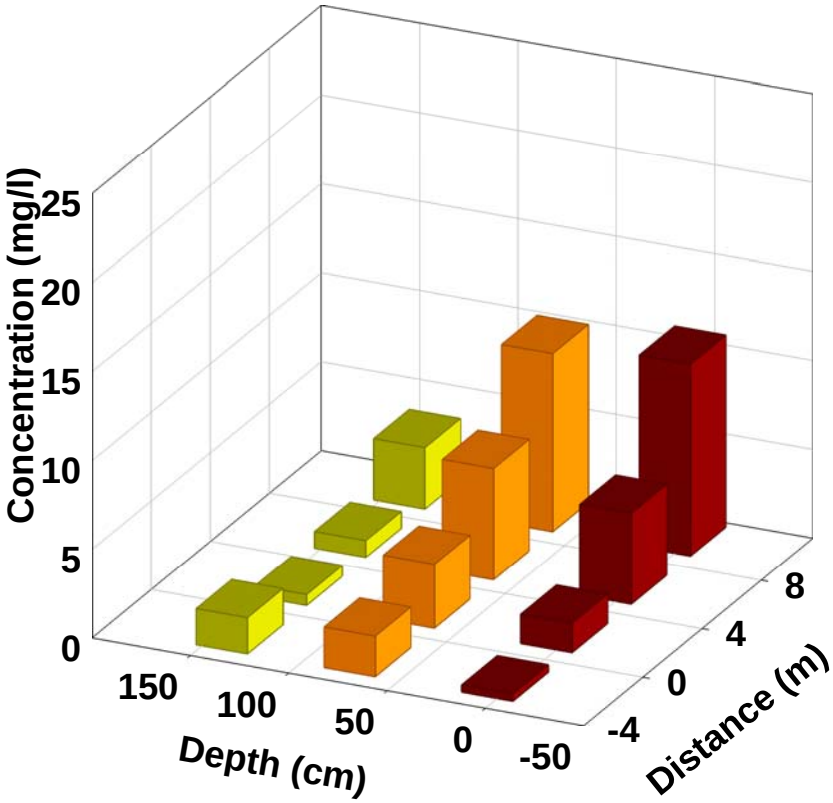
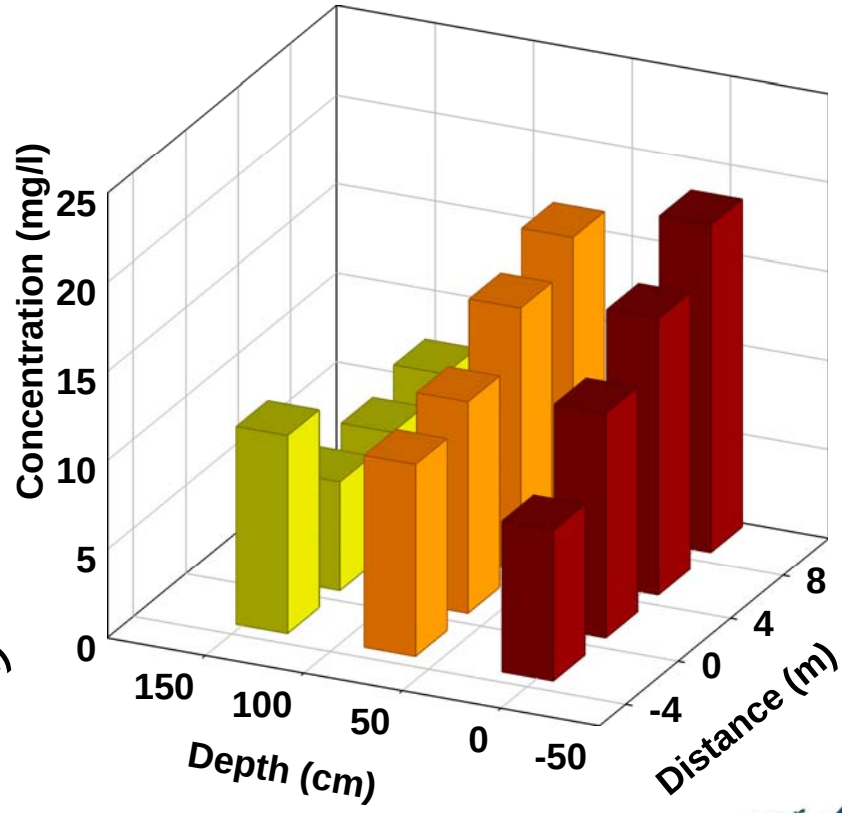
Oil Distribution: Spilling Breakers (2hr)

No dispersant control



With Corexit 9500



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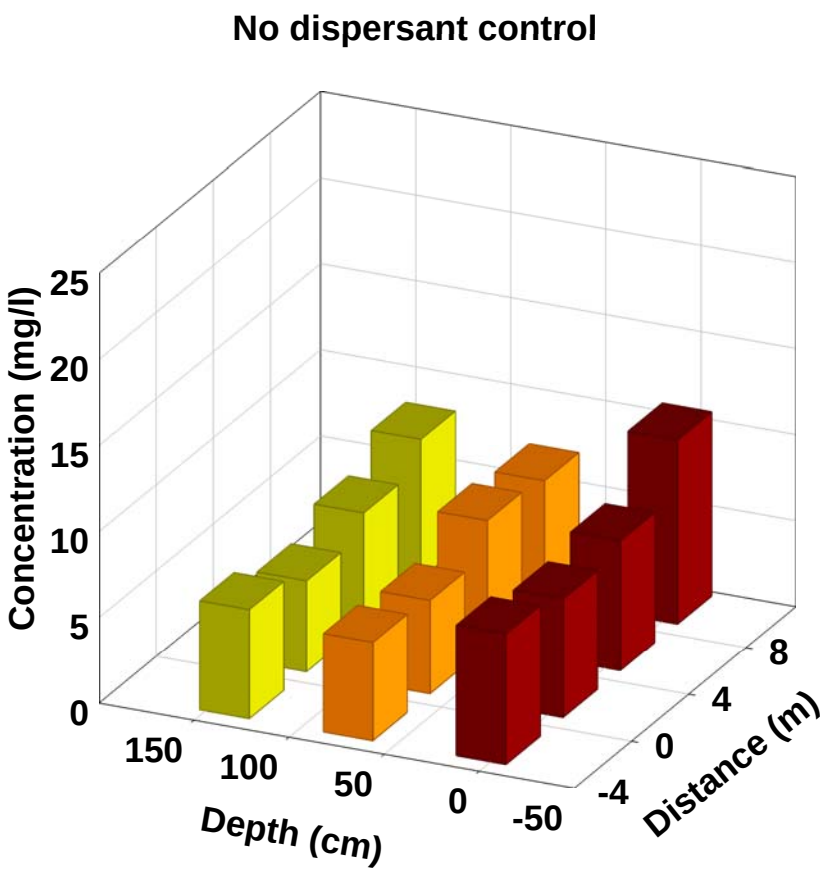
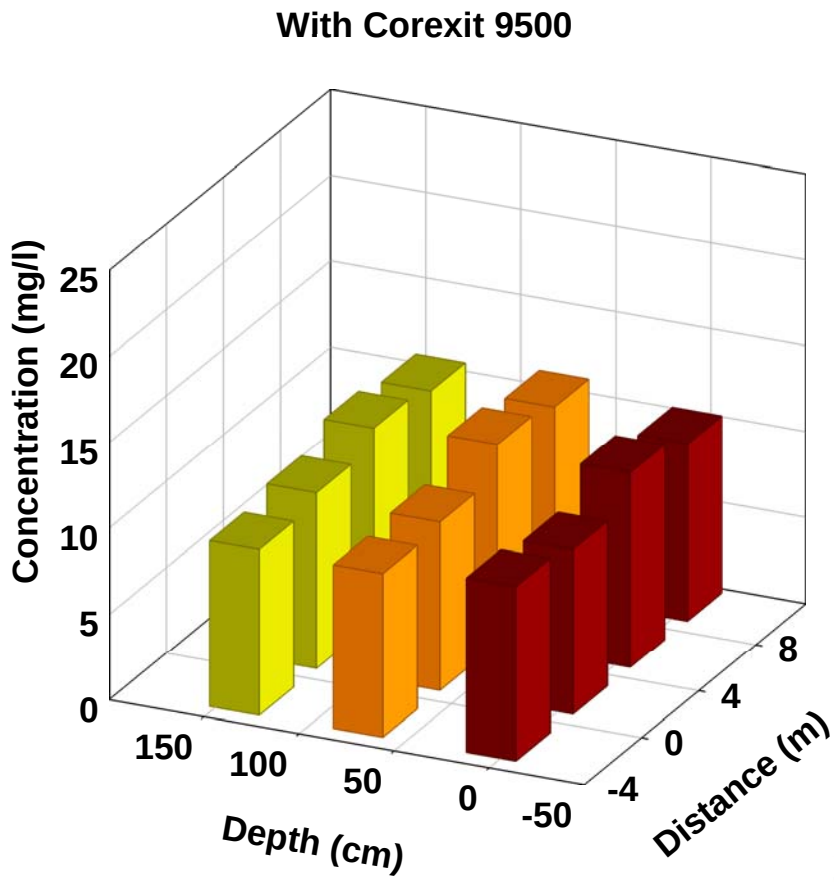
Oil Distribution: Plunging Breakers (2hr)





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Conclusions

- Dispersant reduced oil droplet size and increased dispersed oil concentrations
- Breaking waves decreased oil droplet size
    - Verified in laboratory-scale baffled flask experiments
- In comparison to non-breaking waves - plunging and spilling breaking waves enhanced oil concentrations in the water column
- No significant difference in oil droplet size observed between the two reference test oils
- In-situ dispersed oil concentrations can be effectively monitored by Laser In-Situ Scattering and Transmissometry (LISST) and Ultra-violet Fluorometry (UVF)

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Pêches et Océans Canada