Dispersant Effectiveness as a Function of Energy Dissipation Rate

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

Investigators

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Background

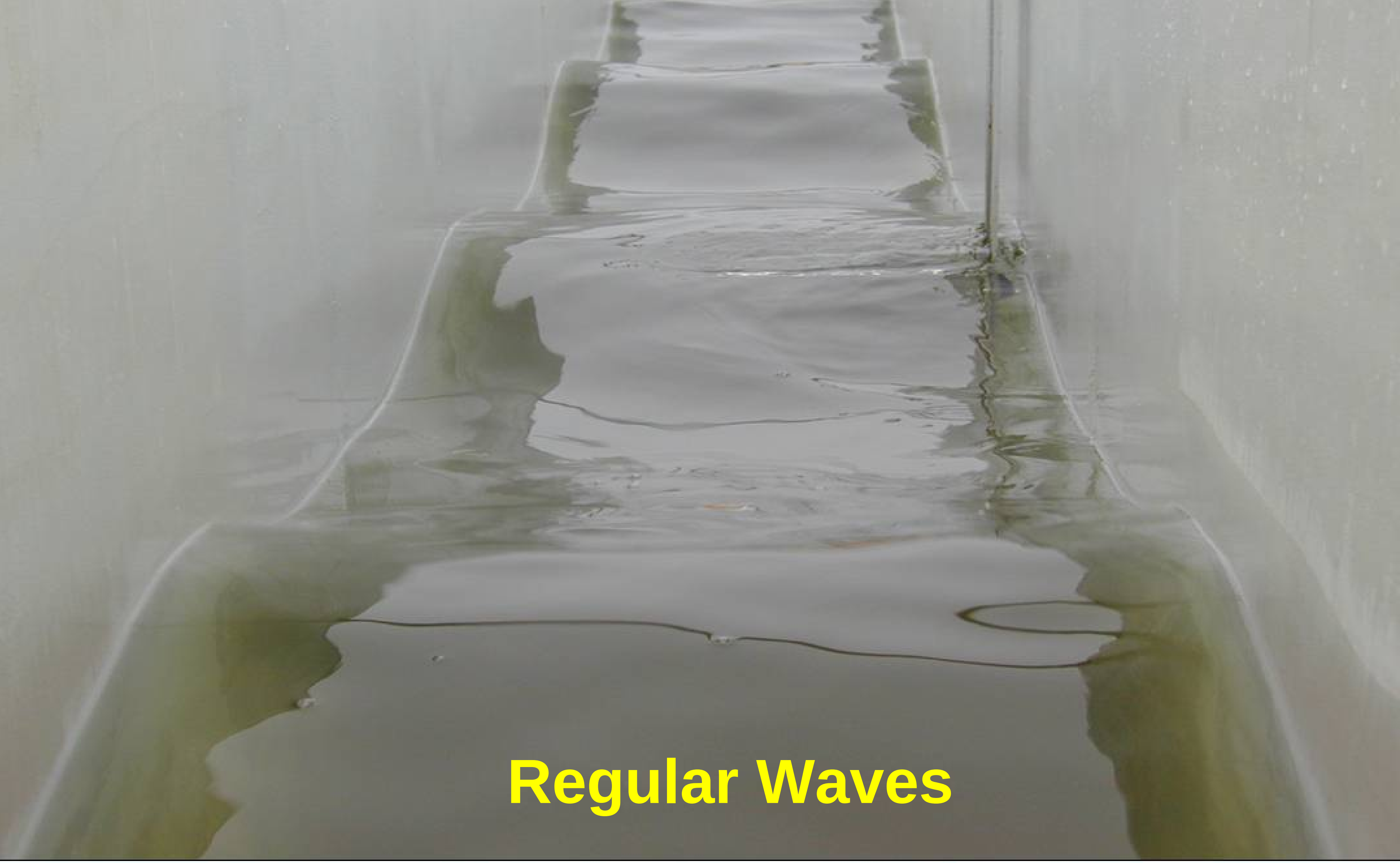
- **NRC recently concluded that the two most important factors that need to be addressed in terms of dispersant effectiveness (DE) are:**
  - **Energy dissipation rate: energy is needed for effective dispersion to take place**
  - **Particle size distribution of oil droplets: the smaller the droplet size, the more effective the dispersion**
- **Energy Dissipation Rate**
  - **Breaking waves are essential for effective dispersion**
  - **Breaking waves are generated by superimposing a long wavelength wave atop a shorter one**

Goals and Objectives

- **Measure energy dissipation rates for 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**

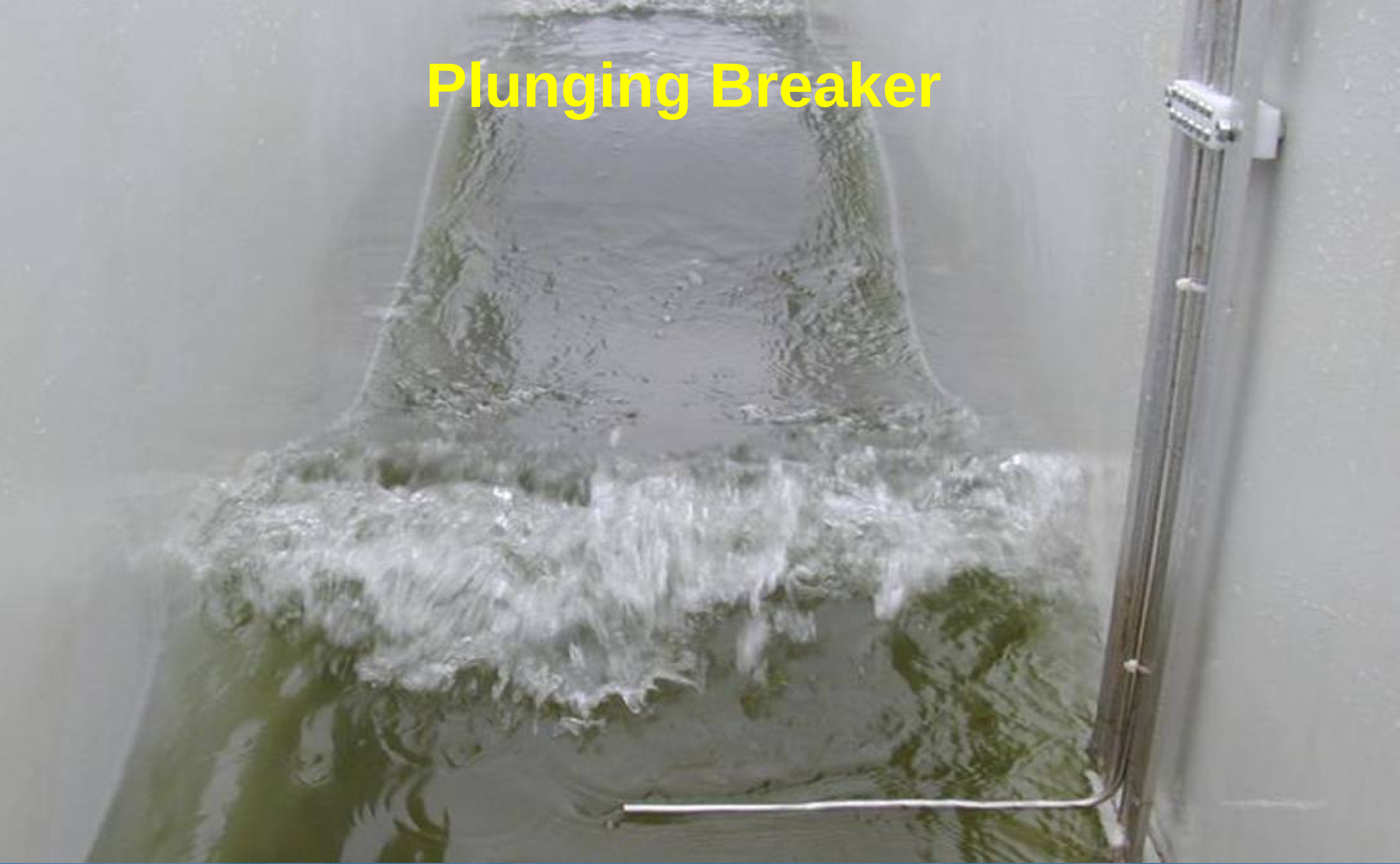
EPA/DFO Wave Tank

- **Wave tank originally fabricated 2 years ago, measuring 16 m x 2 m x 0.6 m**
- **Last year, wave tank modified by doubling the length to 32 m to accommodate more wave types and bigger breakers and to mitigate interference**
- **Wave tank is able to produce 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 or continuous flow mode to simulate dilution by ocean currents**

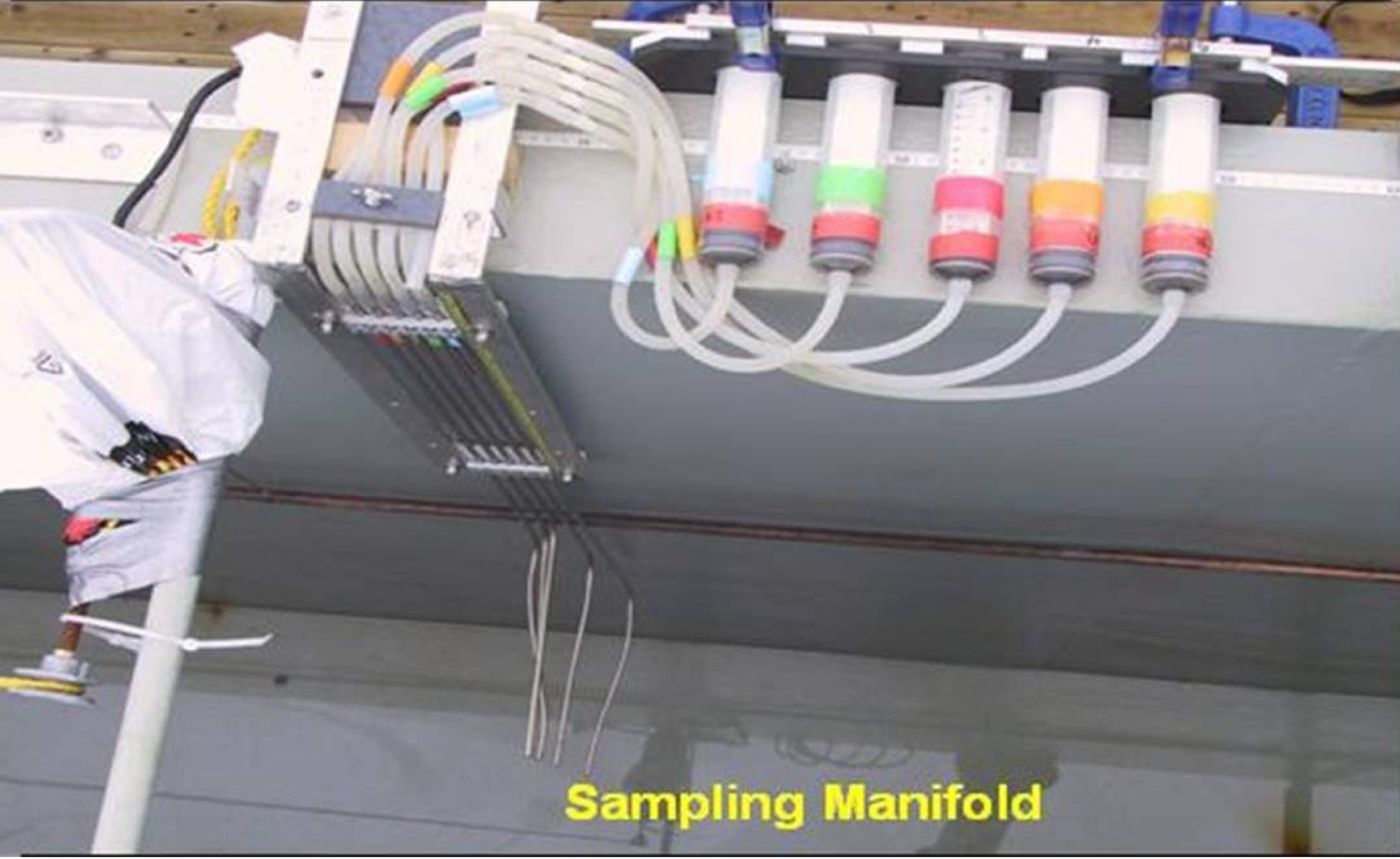

Regular Waves


Spilling Breaker

Plunging Breaker




Wave Absorbers


Sampling Manifold

Testing Dispersion Effectiveness

- **Hypothesis: energy dissipation rate, ε, is sufficient to accurately evaluate DE**
- **Approach: DE measured at 3 different wave periods using 2 dispersants and 2 oils under batch conditions**
  - **Dispersants on NCP Product Schedule (C9500 and SPC1000)**
  - **Crude oils: Mesa and Alaska North Slope Crude (ANS)**
  - **3 different ε's:**
    - **Regular wave**
    - **Spilling breaker**
    - **Plunging breaker**
  - **Factorial experiment with 3 independent replicates**

Summary of 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 breaking or regular waves**
- **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 with one rep done at 240 min (re-coalescence experiment) under quiescent conditions**

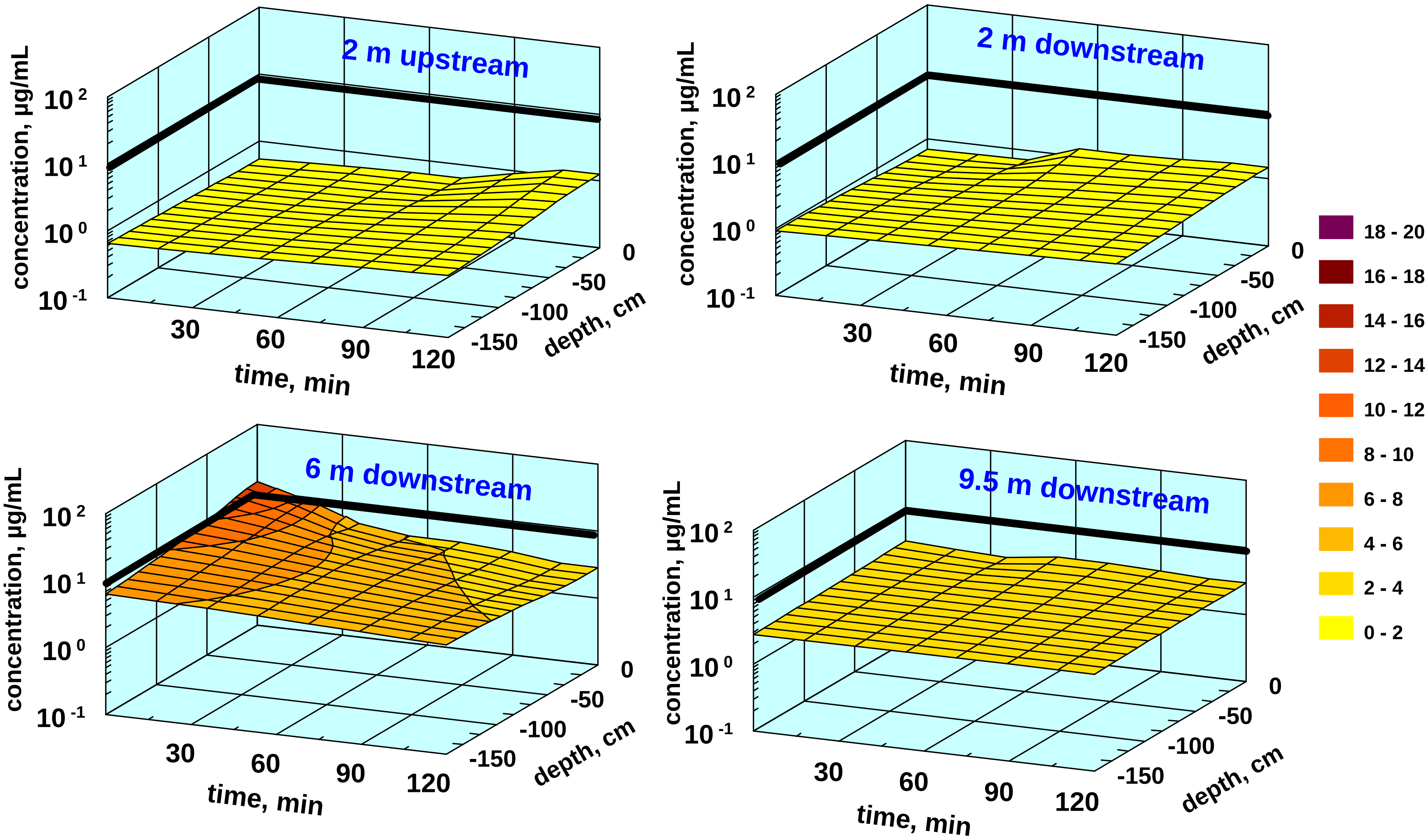
Analytical and Wave Settings

- **3 methods of oil distribution measurements used in tank:**
  - **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 and plunging breakers: 10 cm stroke**
  - **Spilling breakers: 7 cm stroke**
  - **Wave Frequency:**
    - **0.80 Hz for regular waves**
    - **0.85/0.48 Hz for spilling breakers (20 s high frequency followed by 5 s low frequency)**
    - **0.85/0.50 Hz for plunging breakers (20 s high frequency followed by 5 s low frequency)**

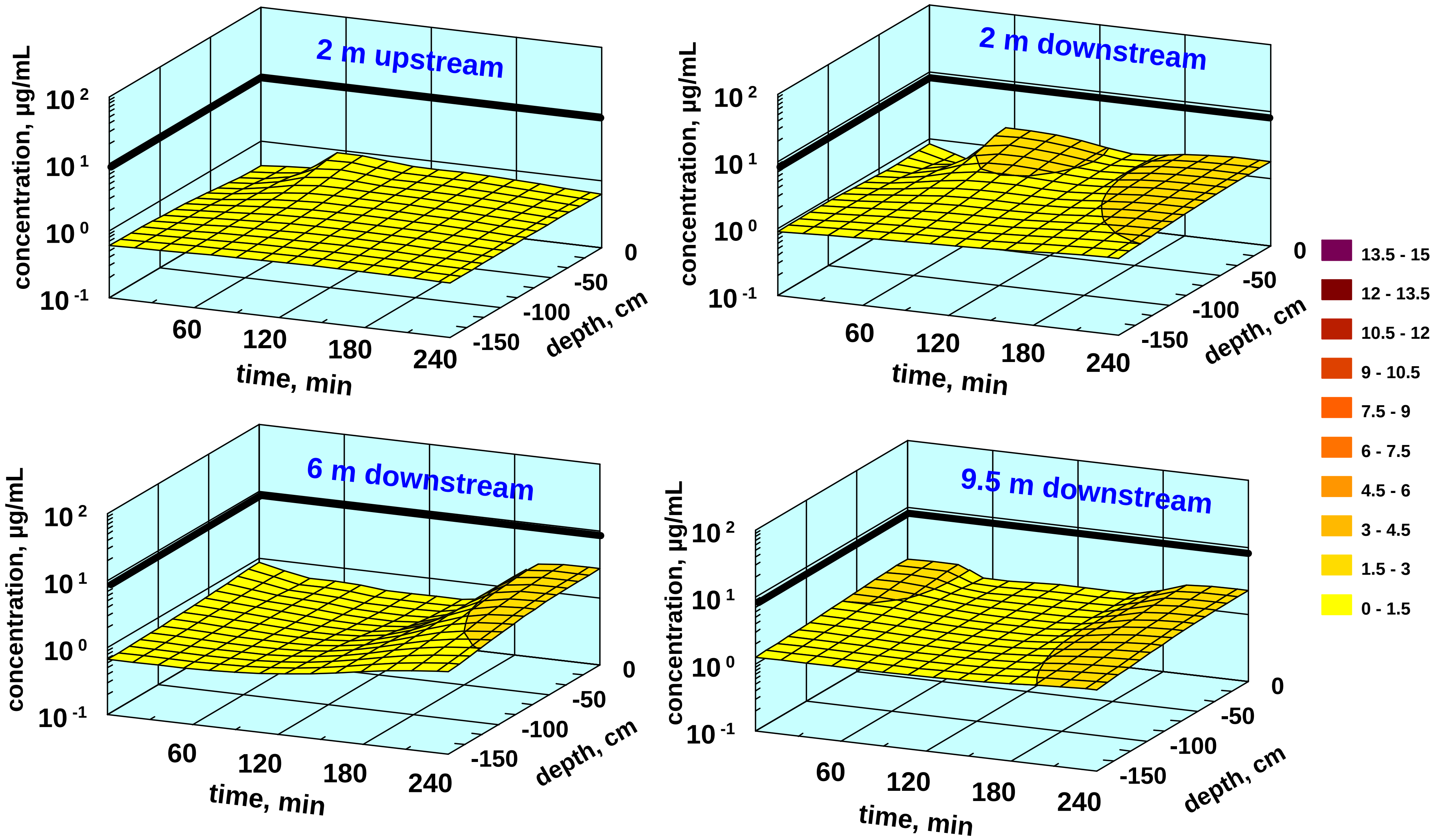
PRELIMINARY RESULTS

- Experiments still on-going
  - Only Mesa crude oil experiments will be shown
  - Only one replicate of all conditions will be shown
    - First, the 3 regular wave runs
    - Second, the 3 spilling breaker runs
    - Third, the 3 plunging breaker runs
- For reference purposes, if all 300 mL oil (~245 g) were completely dispersed in the 28 m^3 of water, the concentration would be ~8.75 mg/L

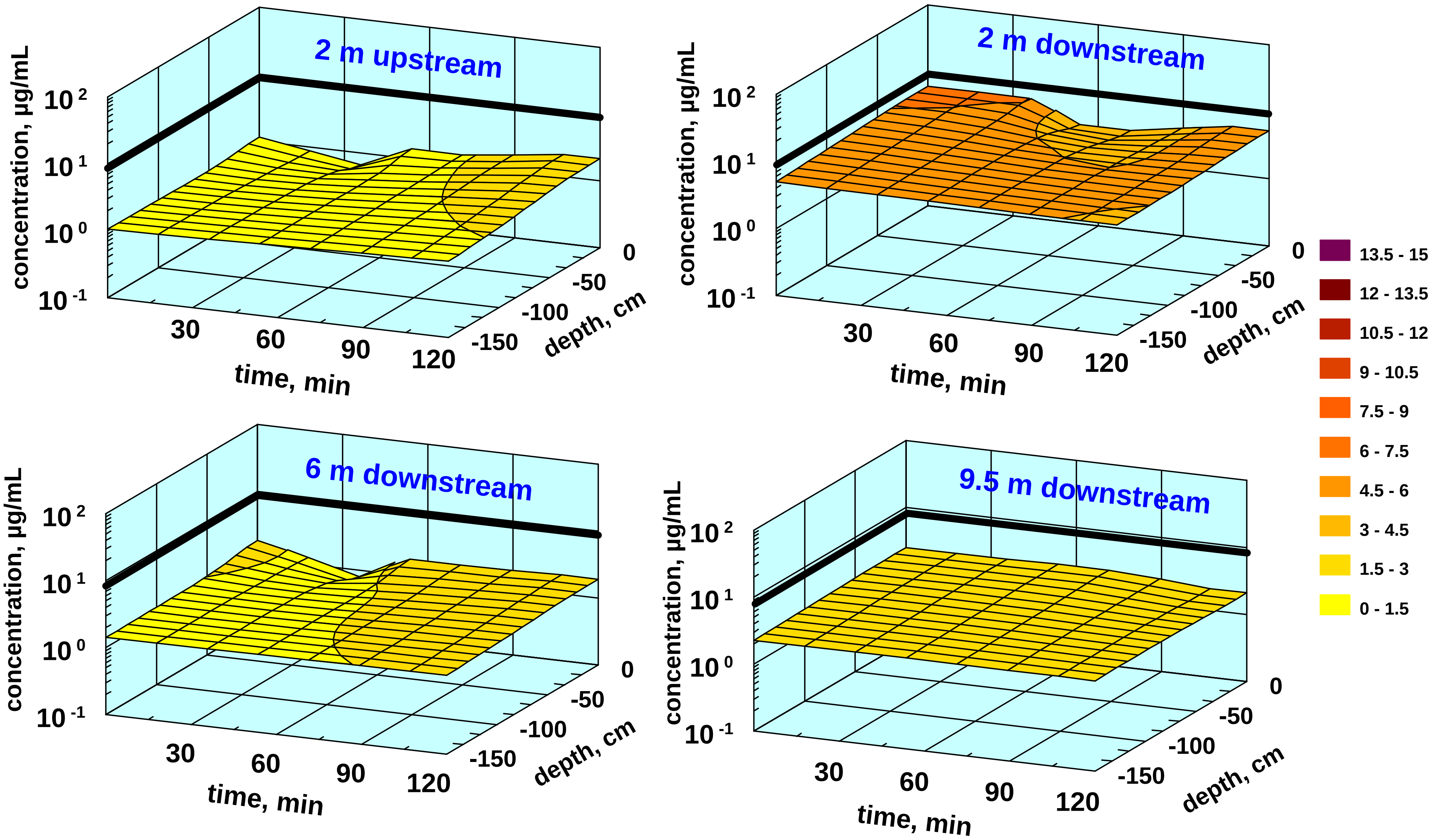
No Dispersant, Regular Wave, Mesa



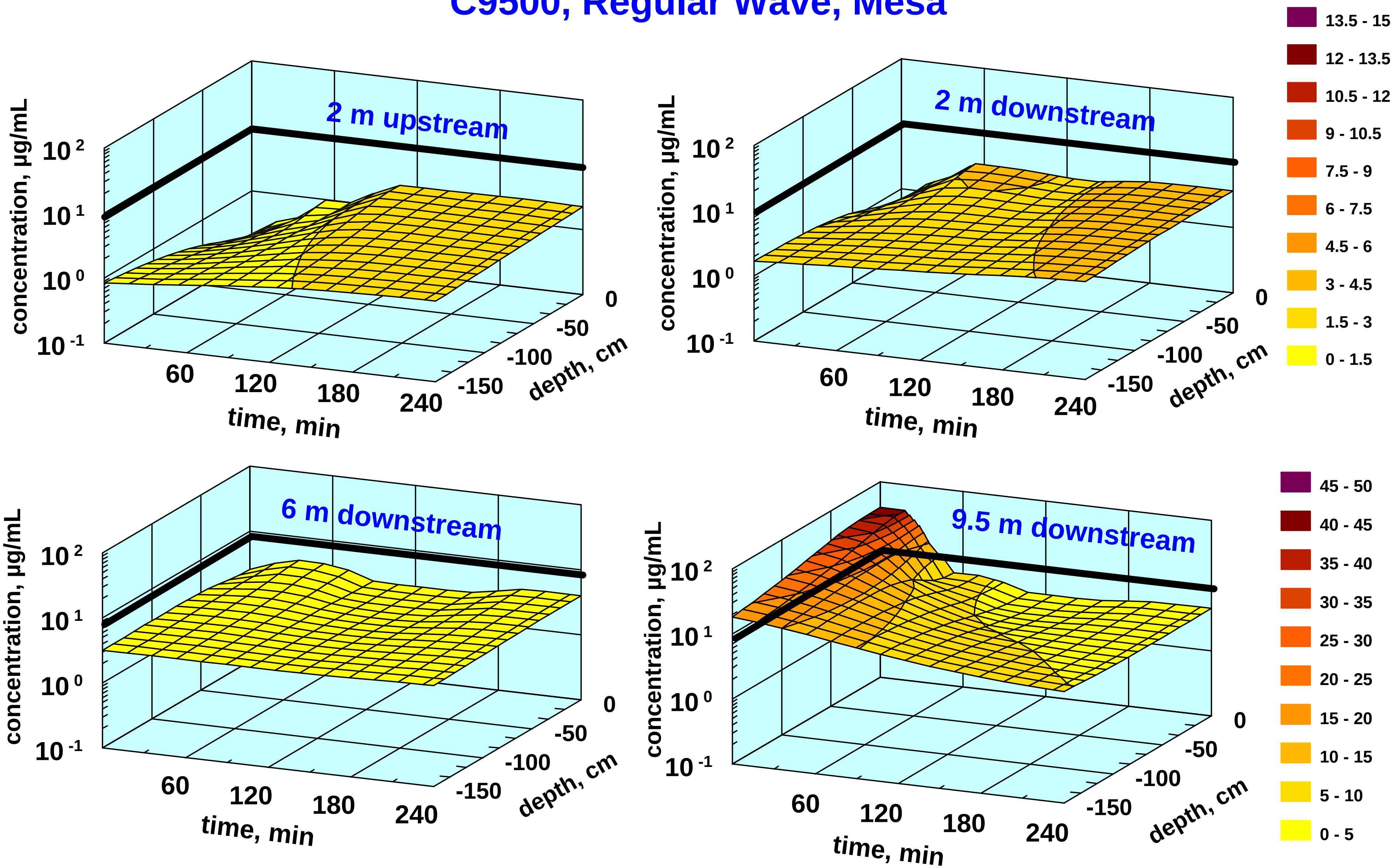
No Dispersant, Spilling Breaker, Mesa



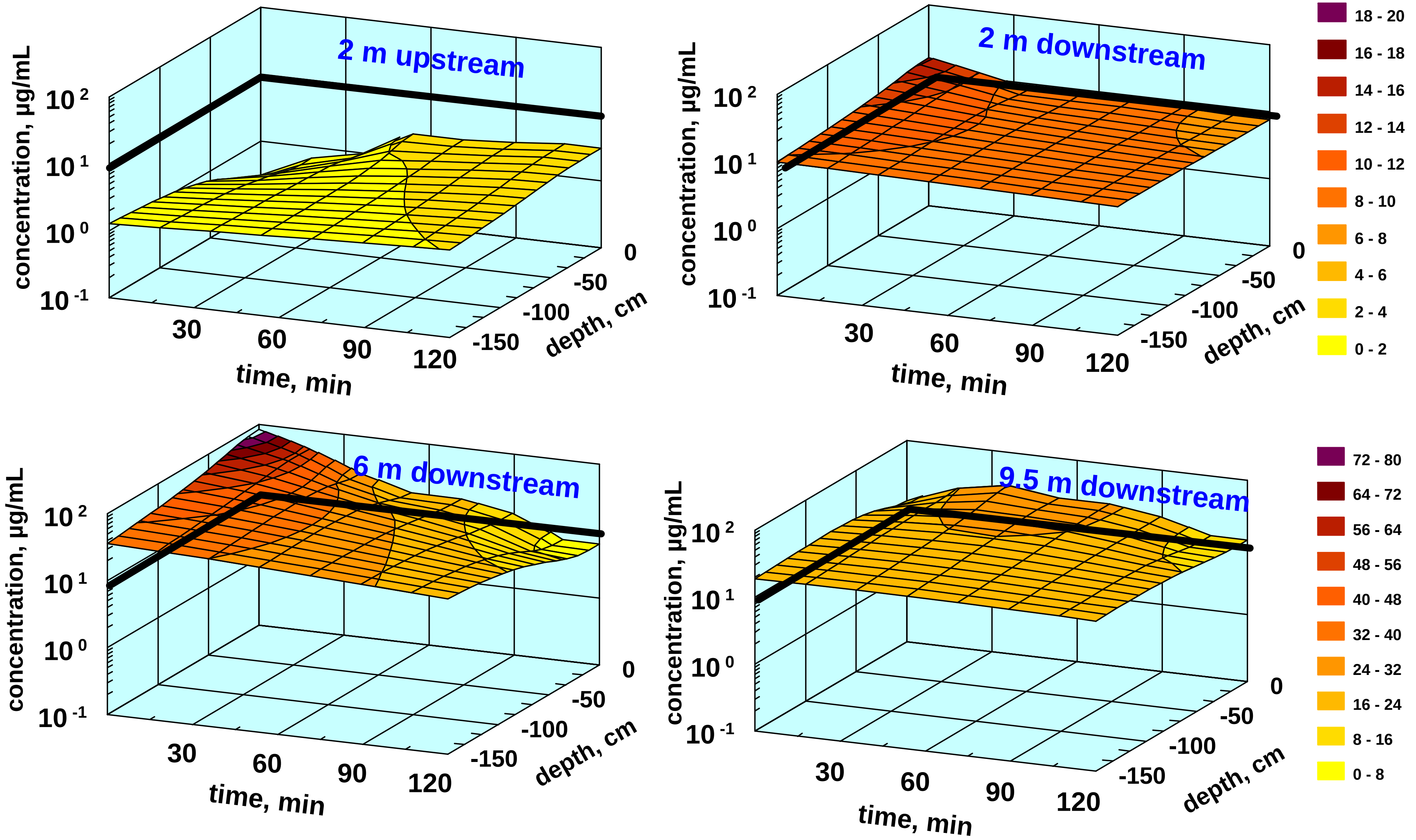
No Dispersant, Plunging Breaker, Mesa



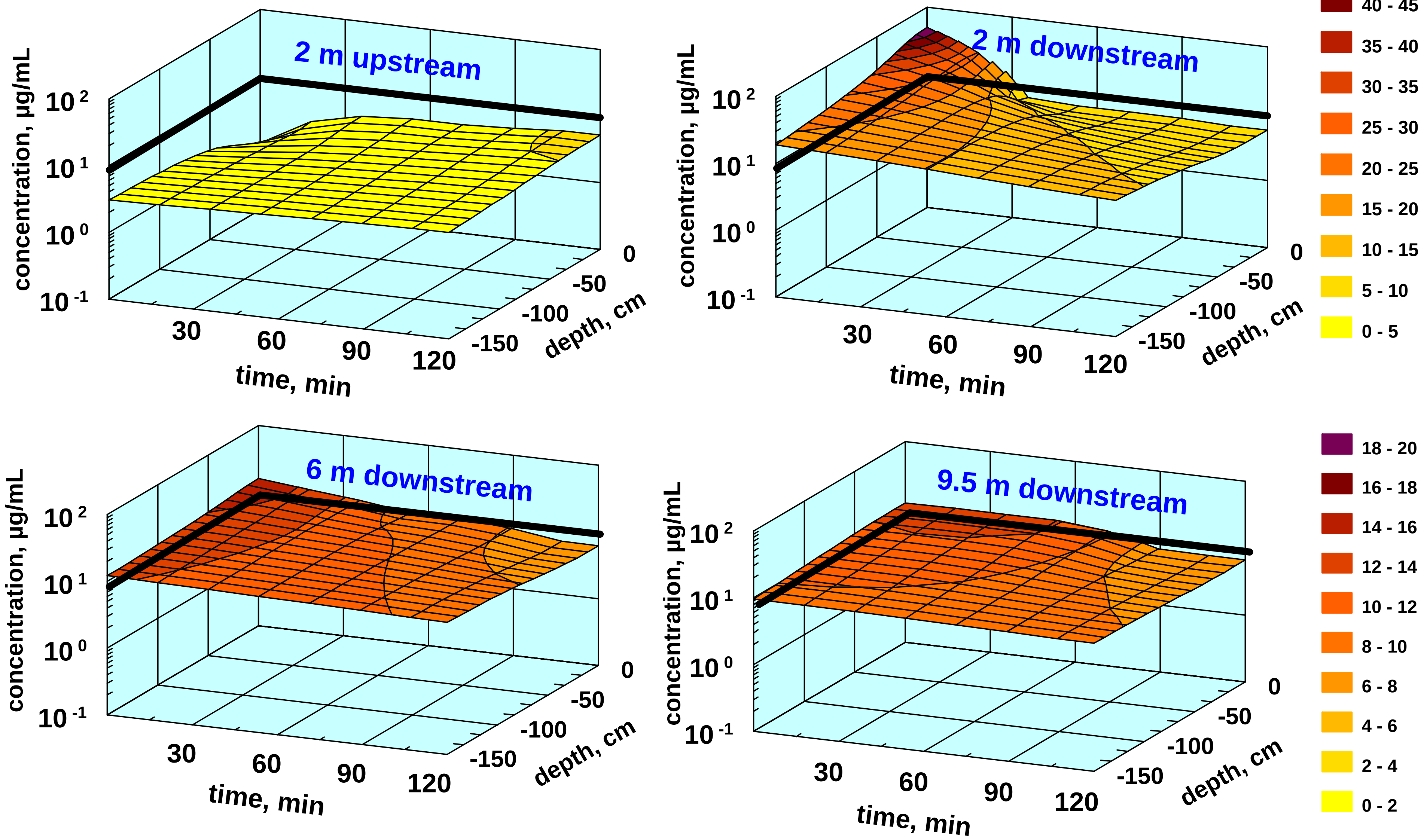
C9500, Regular Wave, Mesa



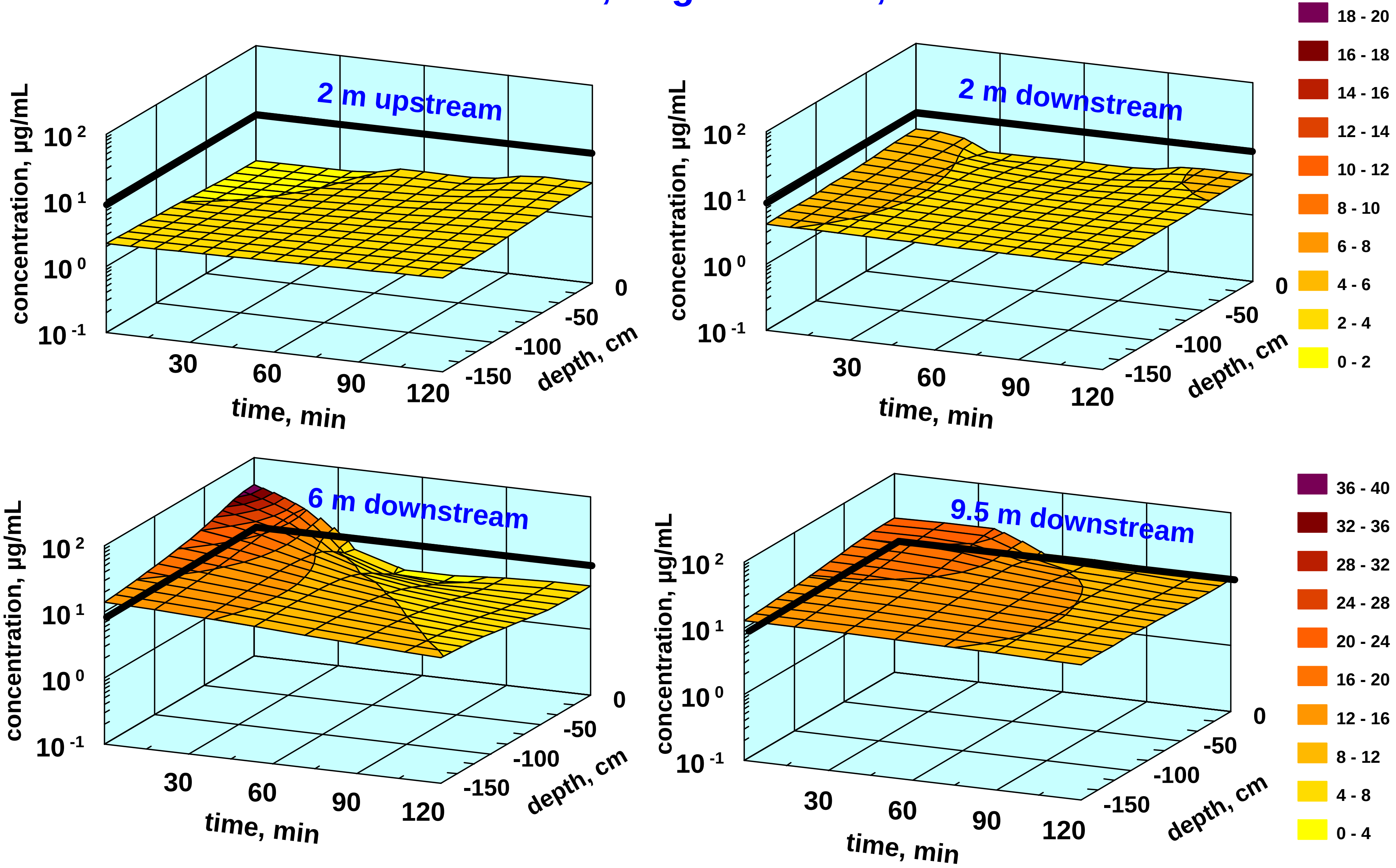
C9500, Spilling Breaker, Mesa



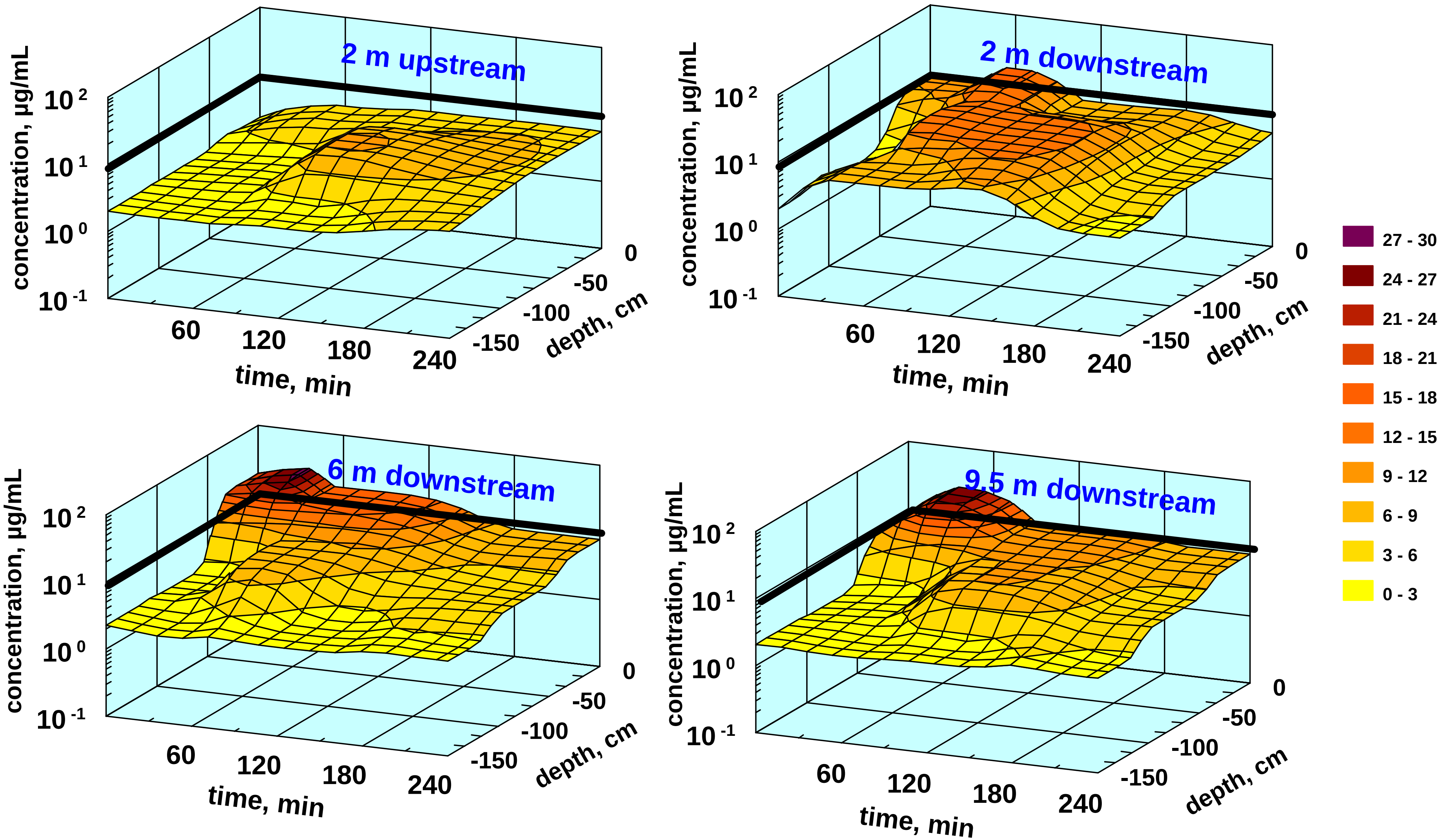
C9500, Plunging Breaker, Mesa



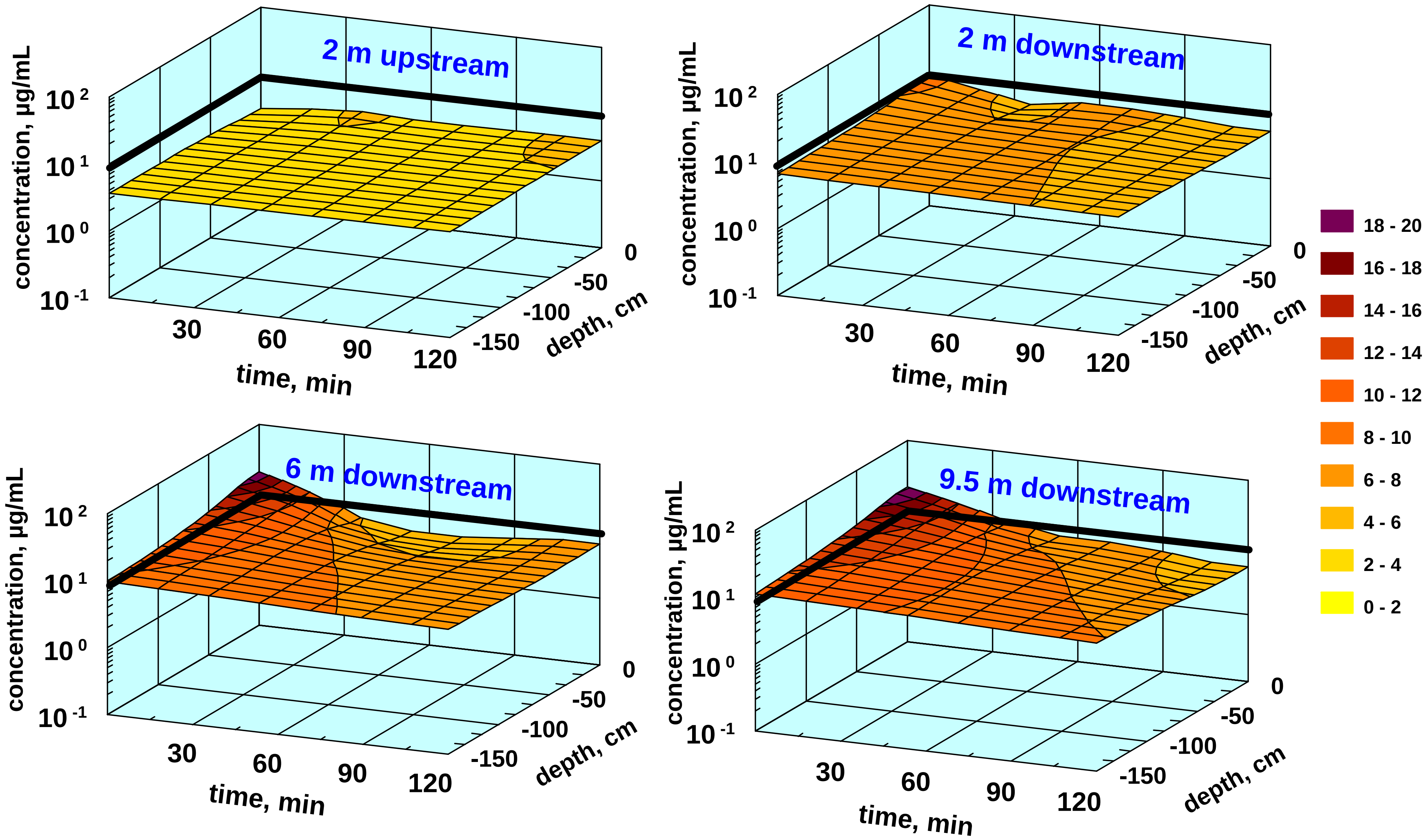
SPC 1000, Regular Wave, Mesa



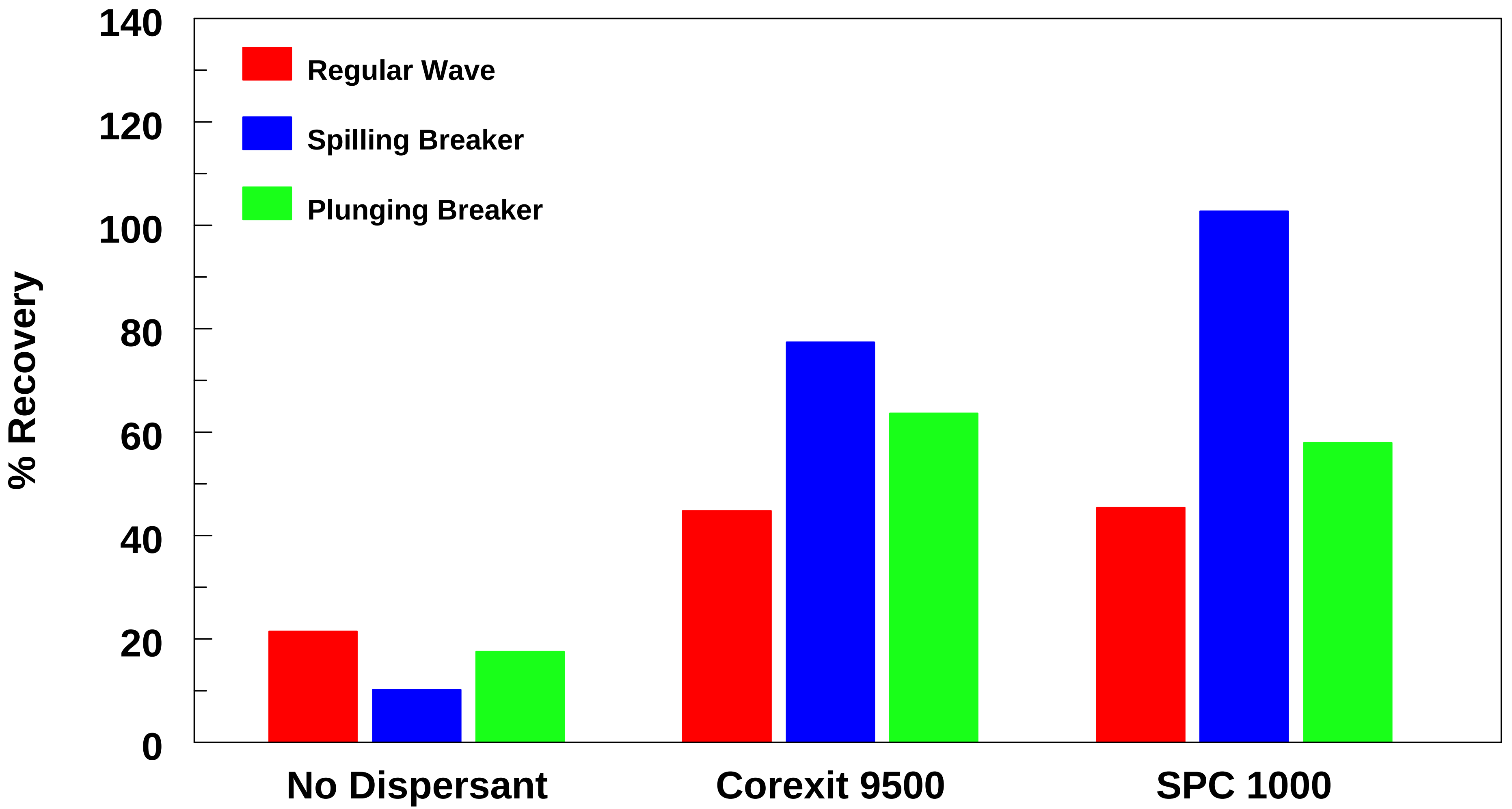
SPC 1000, Spilling Breaker, Mesa



SPC 1000, Plunging Breaker, Mesa



Average % Recovery of Dispersed Oil in the Water After 120 min



SUMMARY AND PRELIMINARY CONCLUSIONS

SUMMARY AND CONCLUSIONS (preliminary)

- **Breaking waves are critical for effective and lasting dispersion**
  - **Breaking waves shear the oil slick into tiny droplets that do not easily recoalesce**
  - **Breakers push the oil downwards into the water column where currents may carry the dispersed oil away (to be verified next year)**
- **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**

SUMMARY AND CONCLUSIONS (preliminary)

- **Aqueous recovery of oil in the EPA/DFO wave tank was moderate but variable**
  - **Final conclusions await analysis of remaining replicates**
  - **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**

WHAT YOU WILL SEE IN THE MORNING

- **Defining energy profile (M.C. Boufadel and field crew)**
  - **Tank filled with freshwater (wave gauges need freshwater)**
  - **7 wave gauges in place (1 near wave maker, one at end of tank, 5 in mixing zone)**
  - **Acoustic Doppler Velocimeter (ADV) installed in line**
  - **Wave maker turned on**
    - **View the computer outputs of the wave gauges and ADV**
    - **Together, the ADV and wave gauges are used to compute energy dissipation rate (ε)**
  - **Wave maker will be operated at all 3 wave energies to enable viewing differences**

WHAT YOU WILL SEE IN THE AFTERNOON

- **Real Dispersant Effectiveness (DE) experiment**
  - **Under quiescent conditions, a removable ring placed in tank where a 300 mL MESA oil slick is created in the vicinity of the expected mixing zone**
  - **Dispersant (C9500) sprayed manually onto slick (12 mL)**
  - **Wave maker turned on (plunging breaker)**
  - **Ring lifted to release slick**
  - **First few waves are regular, then a plunging breaker to disperse the oil**
    - **You will see about 5 plunging breakers every 25 sec**
  - **Wave maker operated for 120 min, then experiment ends**
  - **Samples collected using syringe manifolds at 4 locations simultaneously at 5, 30, 60, and 120 min**
  - **LSST droplet analyzer will be positioned at 3 different depths at 5 min intervals to integrate droplet size distribution over the time period**

QUESTIONS?