Dispersion of Oil released from the Deepwater Horizon MC 252 Oil Spill following Subsurface Injection of Corexit 9500

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DFO Oil Spill Countermeasure Research

By the conduct of laboratory, mesocosm and "controlled oil spill" experiments in the field, DFO developed oil spill countermeasure technologies (bioremediation, phyto-remediation and surf-washing) and methodologies to quantify habitat recovery

Why Chemical Dispersants?

- **There is no single response technique that is suitable for all circumstances**
- **Oil spill responses:**
  - **Booming and skimming**
  - ***In-situ* burning**
  - **Bioremediation**
  - **Chemical dispersion**

- **At open sea, dispersant use attracts most attention due to restrictions to other methods**

Enhanced Dispersion for Oil Spill Response

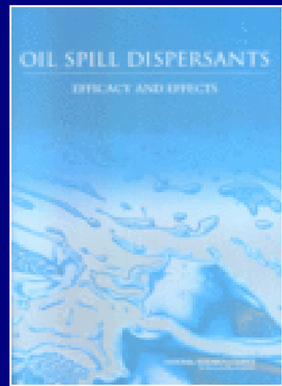
- **Based on the concept of transferring oil from the sea surface into the water column, as small oil droplets**
- **These are diluted by natural processes to concentrations below toxicity threshold limits**
- **Dispersed oil droplets are degraded more rapidly by natural bacteria**
- **Achieved with chemical oil dispersants and/or facilitation of oil mineral aggregate formation**

DFO Research Priorities

Uncertainties remain high regarding dispersant use at sea

- **Dispersant efficacy at different sea states is not clear**
- **Biological effects of dispersed oils are poorly understood**

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:

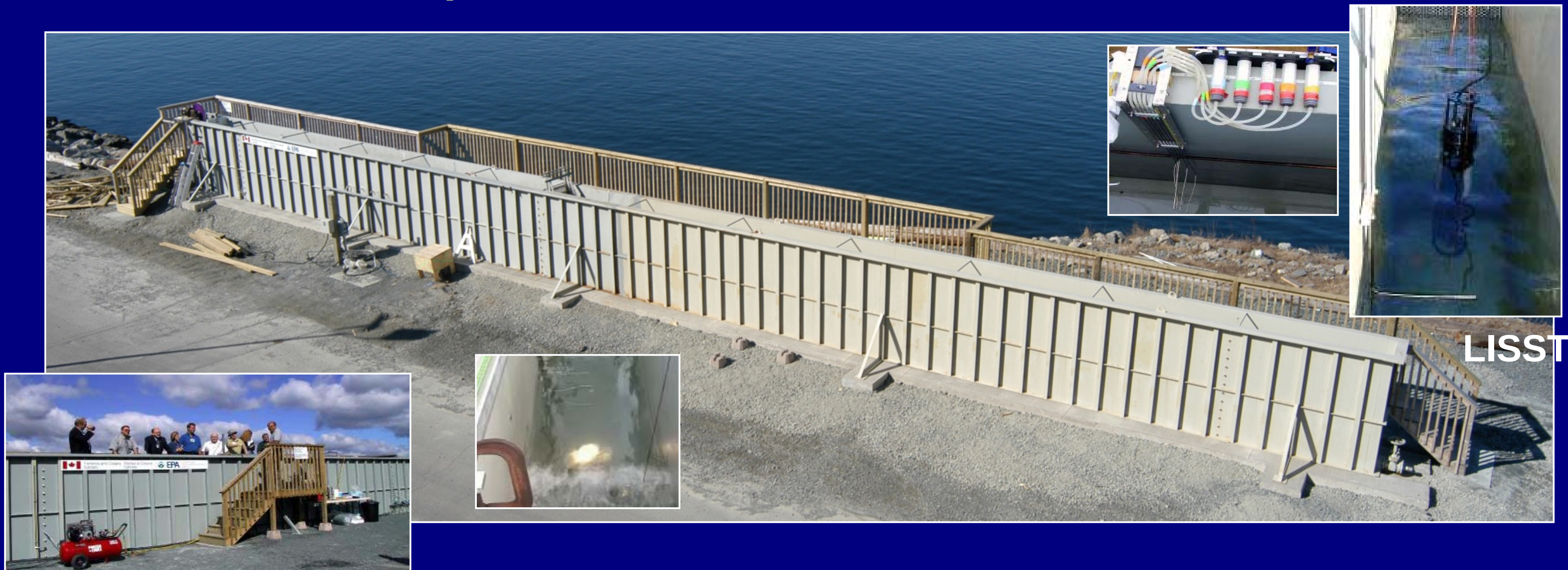


- **Energy dissipation rate (turbulence/sea state conditions)**
- **Particle size distribution and mass balance**

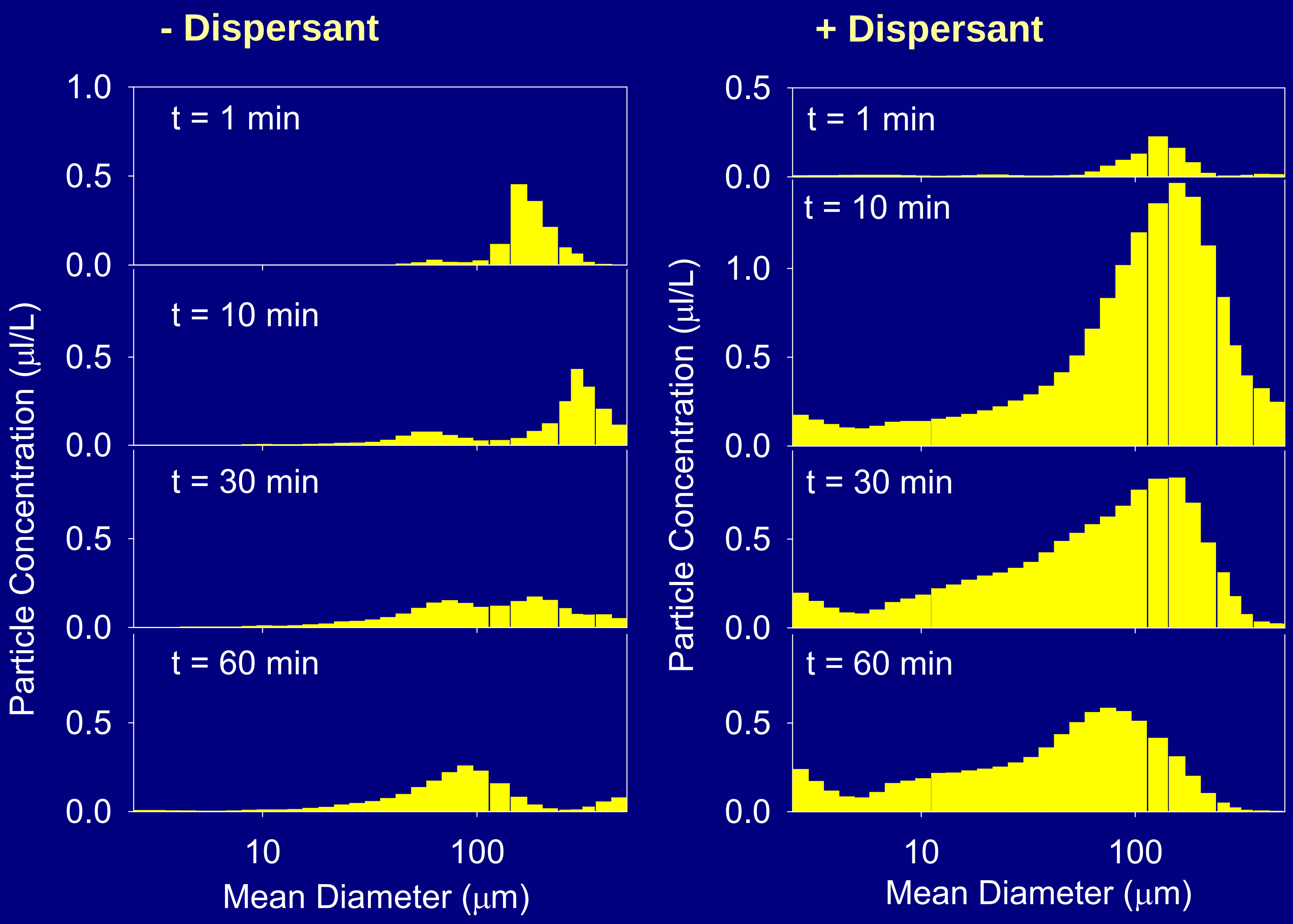
To address this issue, a wave tank facility was constructed by Fisheries and Oceans Canada (DFO) and the U.S. Environmental Protection Agency (EPA)

BIO Wave Tank

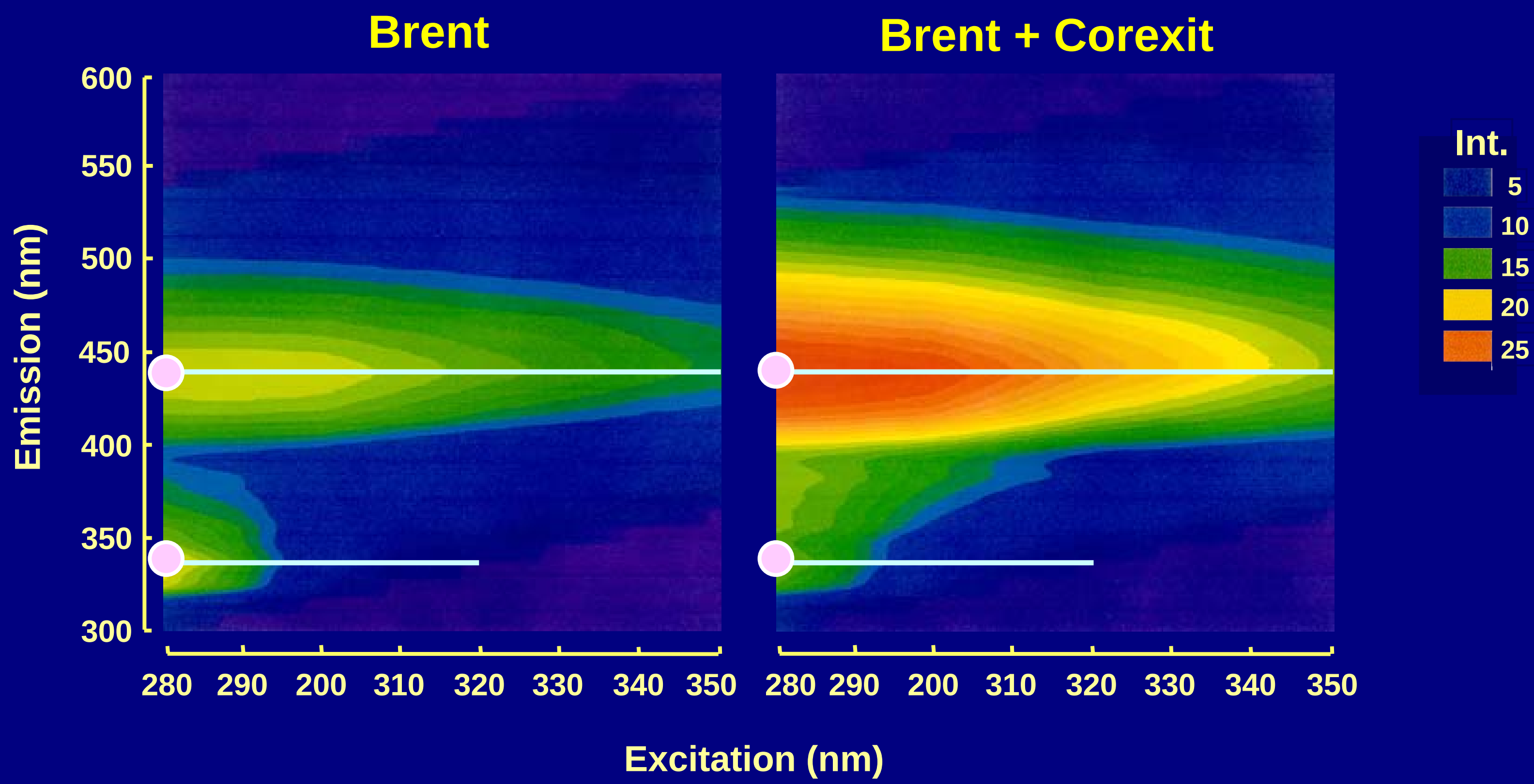
- **Constructed with co funding from DFO A-Base, PERD, NOAA, US MMS, PWSRCAC.**
- **Tidal current simulation by vertical manifolds along the sides of the tank**
- **Reproducible breaking waves produced (of known energy dissipation rate) at precise locations along length of tank**
- **Development of experimental protocols and instrumentation to monitor dispersed oil in the water column**



Oil Droplet Size Distribution



Oil Fluorescence – 3D Spectra



The 3D spectra can be summarized as the ratio of Slope or Em intensity at 340 nm divided by intensity at 445 nm. (FIR)

Gulf of Mexico Oil Spill

The Deepwater Horizon oil spill is the largest accidental marine oil spill in the history of the petroleum industry.

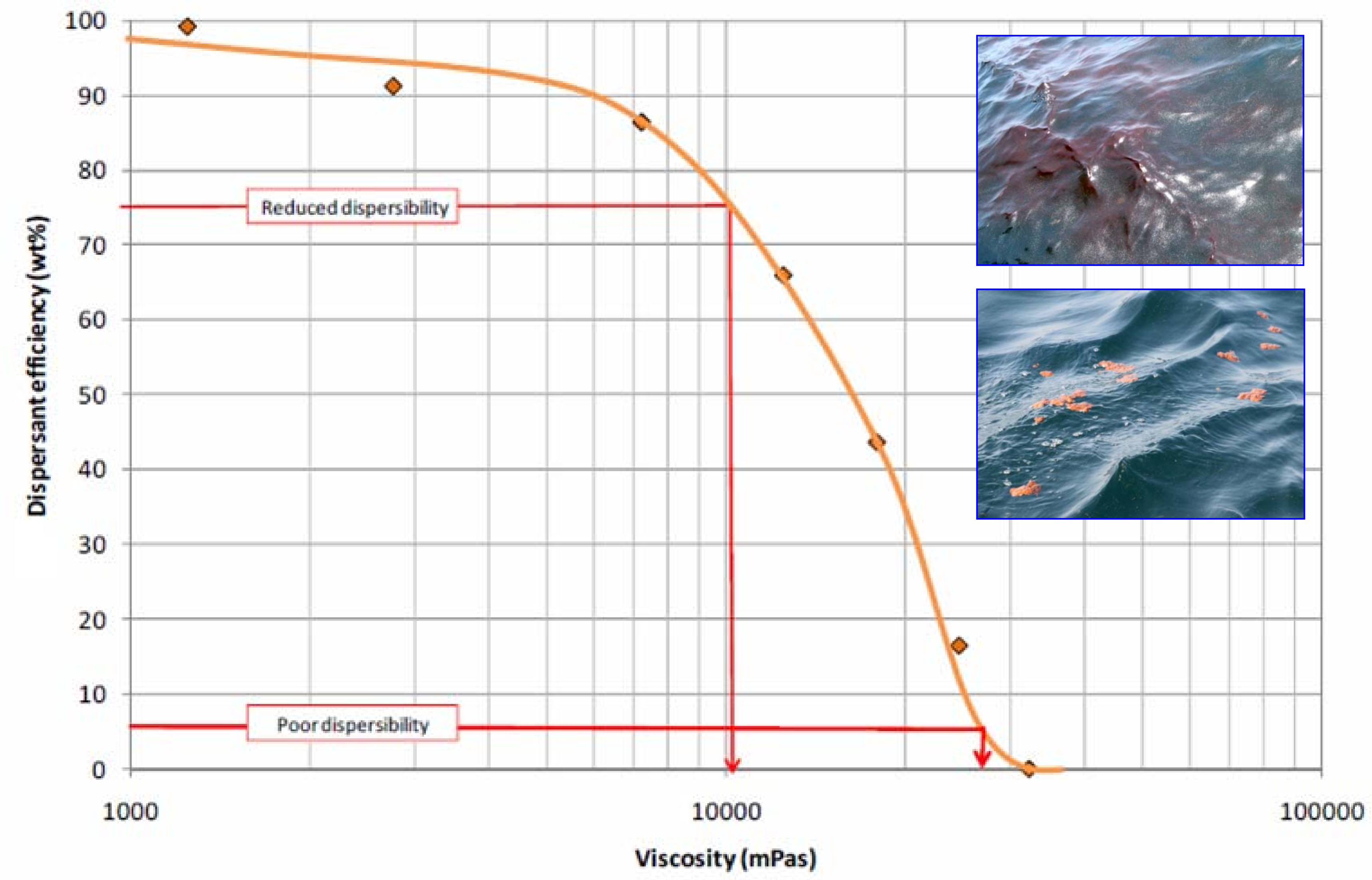
- **Occurred as a result of an explosion on the Deepwater Horizon drilling rig, April 20, 2010. The explosion killed 11 platform workers and injured 17 others.**
- **On July 15, the leak was stopped by capping the wellhead which had released 4.9 million barrels (780×103 m3) of crude oil.**
- **On September 19, the relief well process was successfully completed and the federal government declared the well "effectively dead".**

Gulf of Mexico – May 24, 2010

Application of Oil Dispersants - GoM

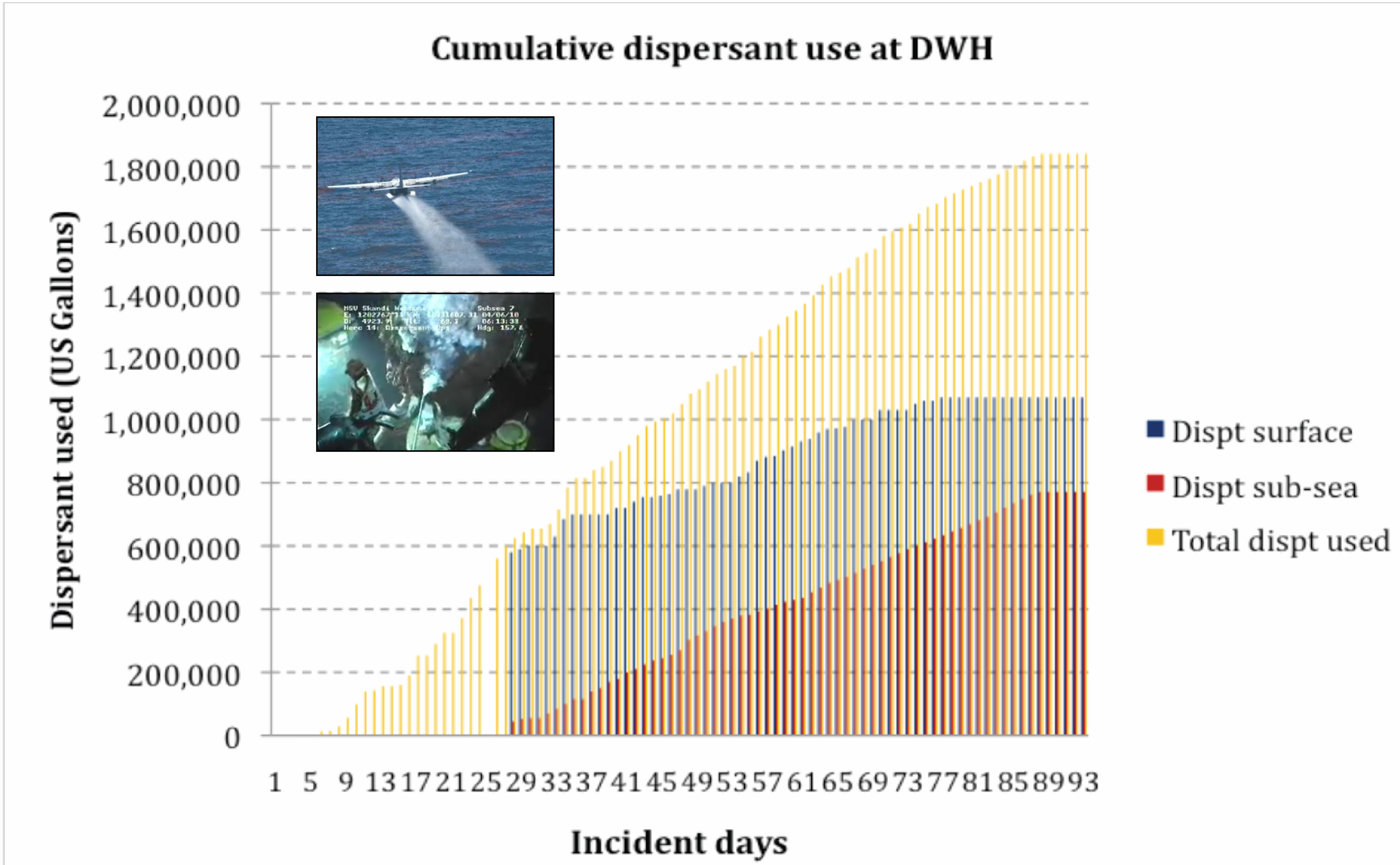
- **Based on discharge rates - final estimate of 53,000 barrels per day (8,400 m^3/d) - each day the Gulf of Mexico Oil Spill would be considered a major incident**
- **In addition to mechanical recovery techniques (skimming and booming) and in situ burning, oil dispersants were used to prevent landfall of the oil in the Deepwater Horizon Spill**
- **Beginning in early May responders began injecting dispersants at the source of the release (~1500m depth) to reduce oil from reaching the surface**
  - **Advantages of subsurface injection:**
    - **Reduced VOCs (volatile organic compounds)**
    - **Reduced Oil Emulsification**
    - **Volume of dispersant needed**

Dispersant Effectiveness vs. Viscosity



Source: SINTEF

Cumulative Dispersant Use



* 4,200,000 L of dispersant added by subsurface injection

Plume Monitoring and Assessment for Subsurface Dispersant Application (US EPA Directive – May 10, 2010)

***PART 1*:** **"Proof of Concept"** to determine if subsurface dispersant operation is chemically dispersing the oil plume.

Following review by the RRT….

***PART 2*:** Robust sampling to **detect and delineate the dispersed plume** based on the results of PART 1 and input from hydrodynamic modeling

DFO COOGER was requested by US EPA to provide scientific expertise to implement the directive

All data provided to the United States Coast Guard (USCG)Federal On-Scene Coordinator, and the Environmental Protection Agency (EPA) Regional Response Team (RRT)

DFO Sampling Effort

	Person Days	*Stations*	*Samples*
May	91	68	1020
June	136	107	1674
July	136	65	1060
August	143	92	1439
Total	**506**	**320**	**5193**

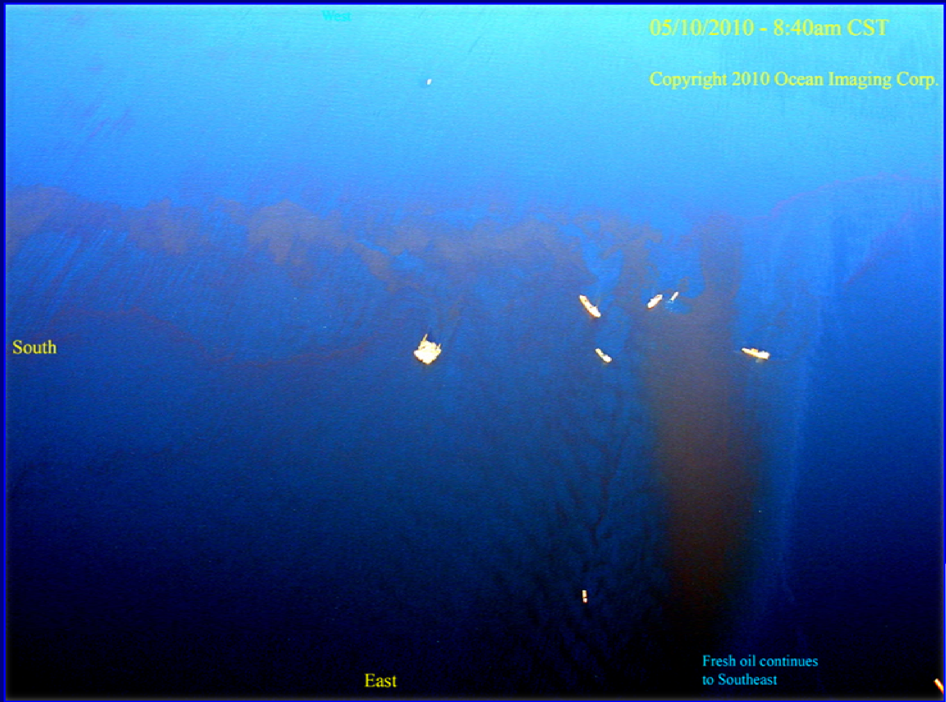
* Cost recovery from the U.S. Government with BP as the responsible party accountable for all cleanup costs

R/V Ocean Veritas


R/V Brooks McCall

Dispersant Monitoring and Assessment for Subsurface Dispersant Application

- Directives issued by US EPA and USCG required BP to implement a monitoring and assessment plan for subsurface and surface use of dispersants
  - Shutdown Criteria
    - Significant reduction in dissolved oxygen (< 2 mg/L)
    - Rotifer acute toxicity tests
- Later addenda to implement SMART Tier 3 Monitoring Program
  - Droplet size distribution (LISST)
  - CTD instrument equipped with CDOM fluorometer
  - Discreet sample collection to measure fluorometry (FIR)
  - Eliminate surface application altogether
  - Subsea limited to < 15,000 gpd

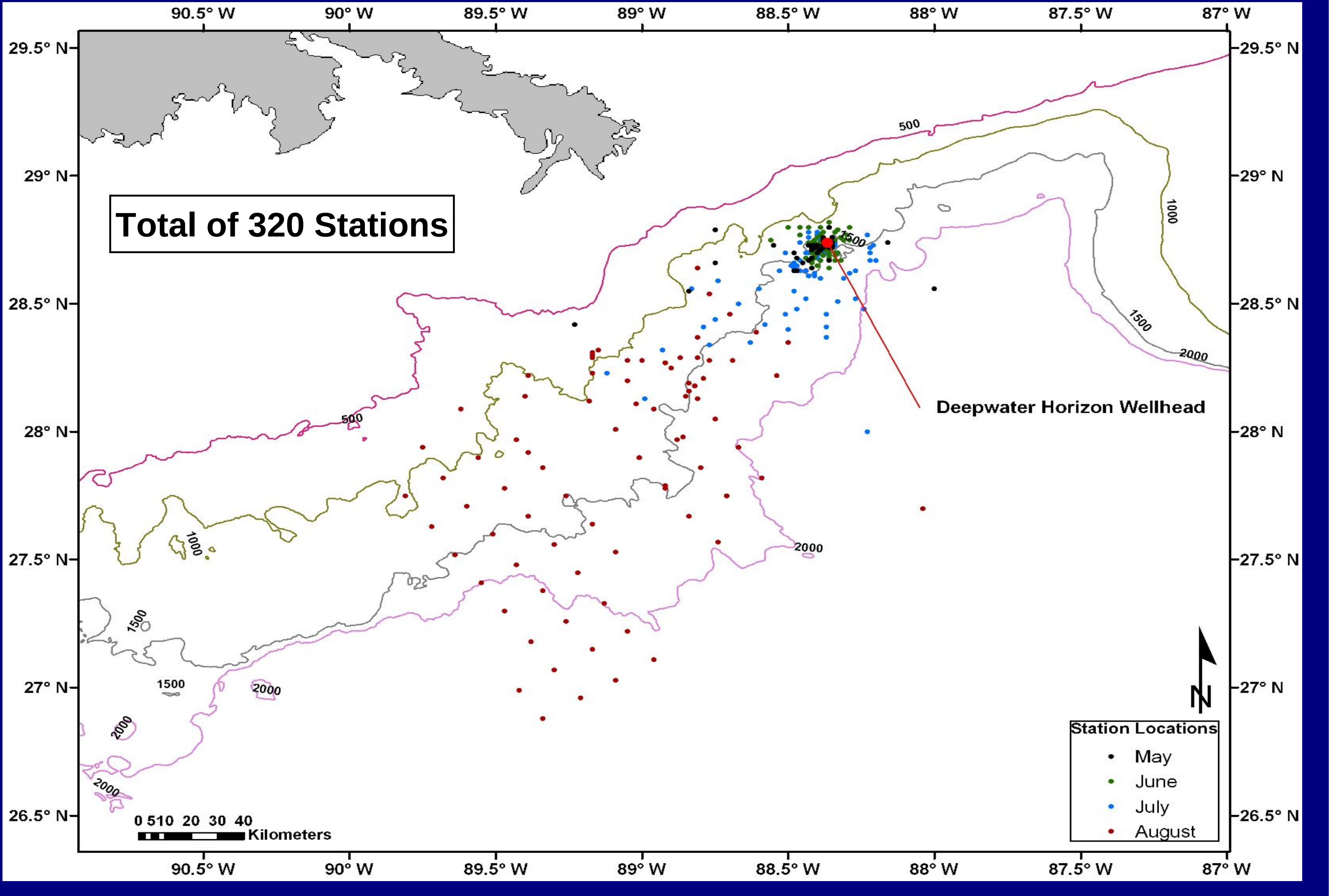

West
05/10/2010 - 8:40am CST
Copyright 2010 Ocean Imaging Corp.
South
East
Fresh oil continues
to Southeast

Joint Analysis Group (JAG)

Surface and Subsurface Oceanographic, Oil, and Dispersant Data

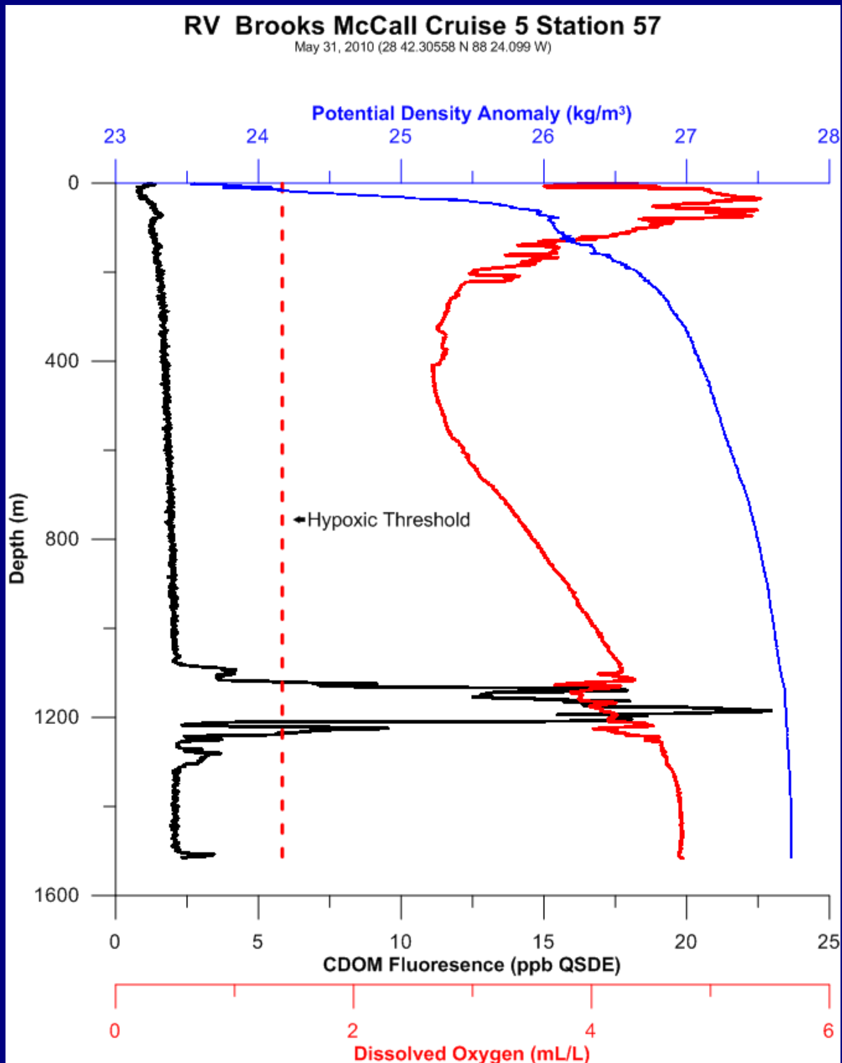
- **Working group of scientists from EPA, NOAA, OSTP, BP and DFO**
- **Analyze an evolving database of sub-surface oceanographic data by BP, NOAA, and academic scientists**
- **Near term actions:**
  - **Integrate the data**
  - **Analyze the data to describe the distribution of oil and the oceanographic processes affecting its transport**
  - **Issue periodic reports**

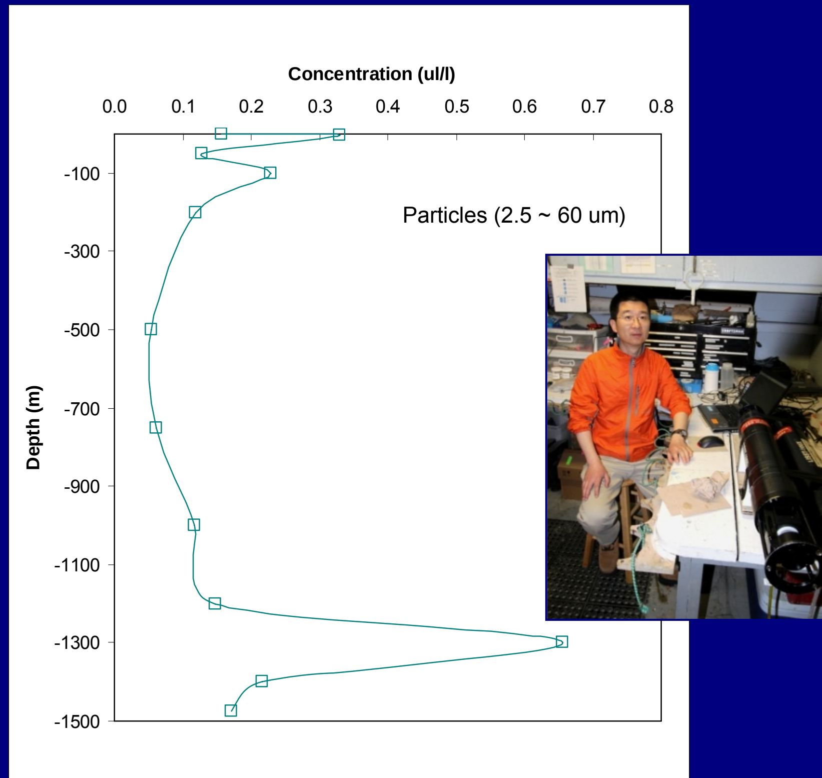
DFO Station Locations



Vertical Profile - DO_2 Depression

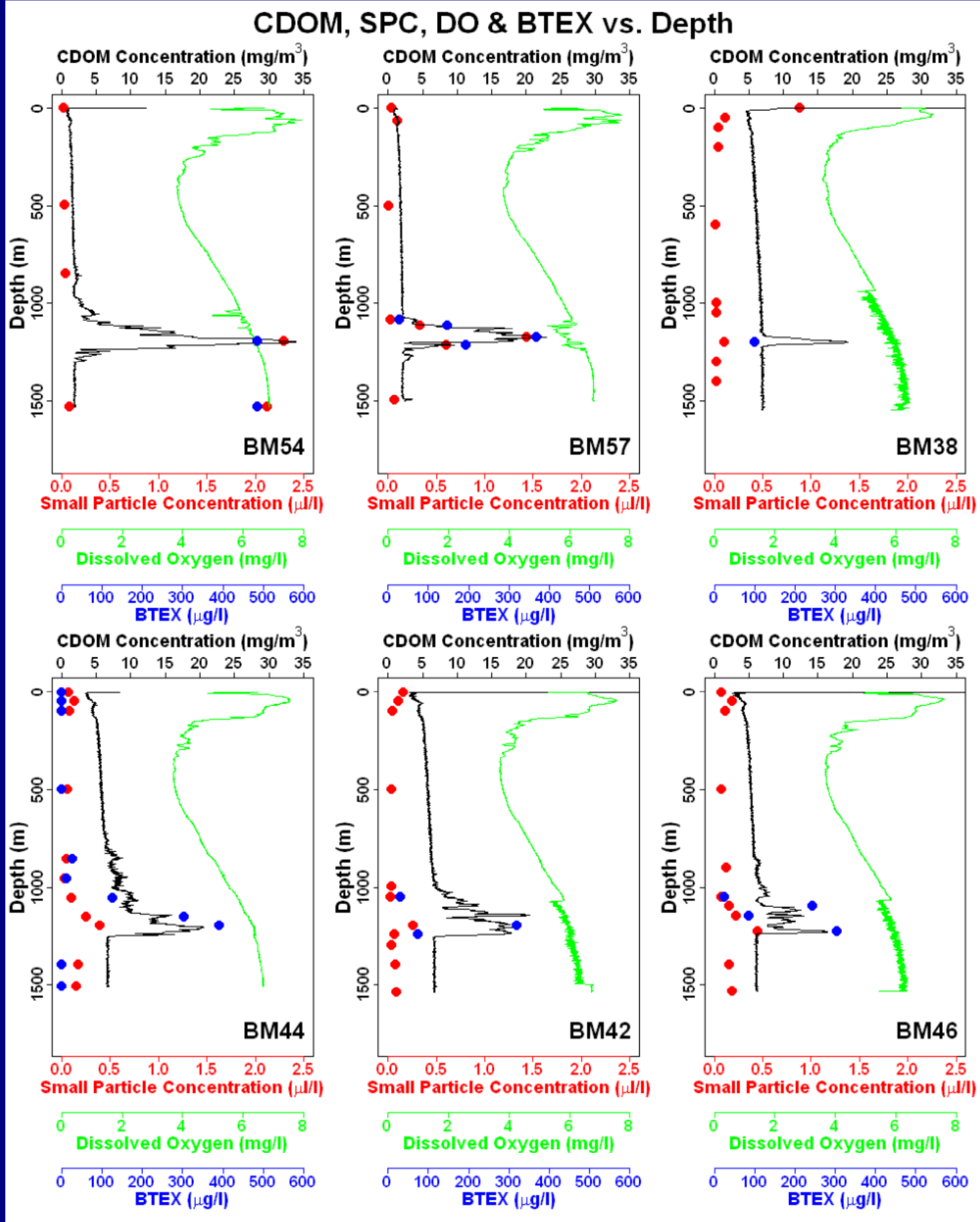
(coincident with fluorescence and <60µm LISST particle count peaks between 1100 and 1200 m)





Small particles (2.5 - 60µm) were indicative of oil droplets in the subsurface plume

Sub-surface Oil Profiles



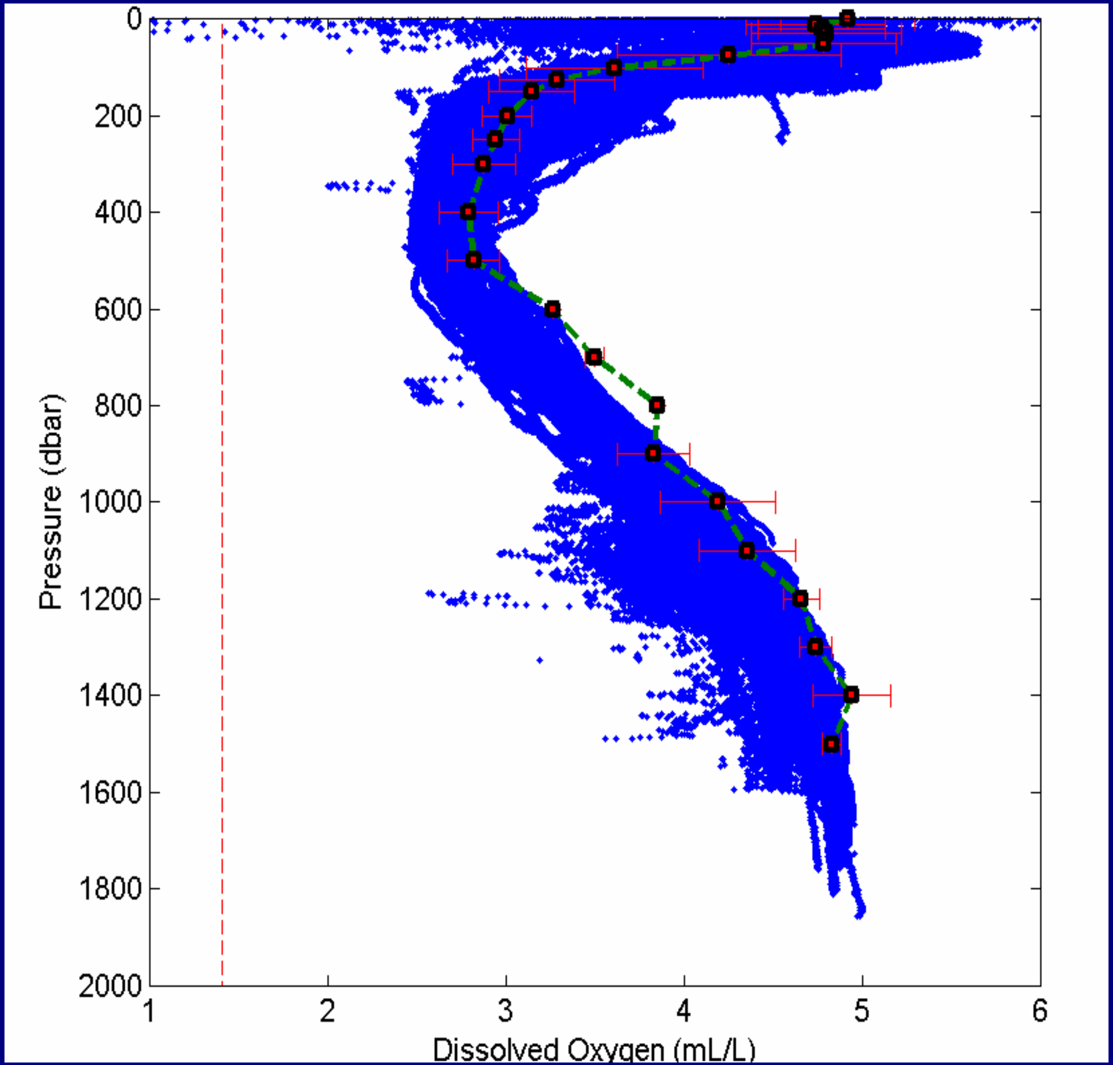
Oil Chemistry

Results as number in concentration range for subsurface plume samples (1000 – 1300 m Depth)

Concentration (ppb)	Total VOA	TPH
<10	1484	1836
10 - 100	104	33
100 – 1,000	129	0
> 1,000	16	0

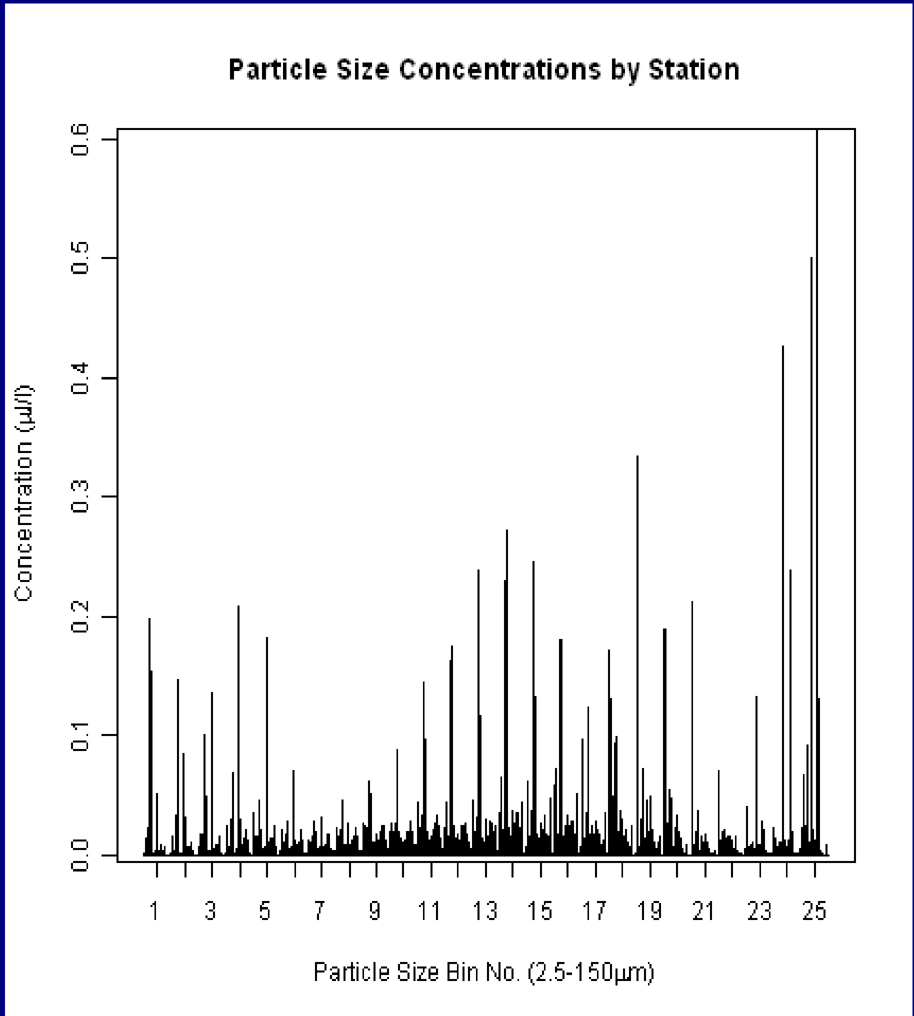
These results represent the chemistry results for 2779 individual samples from May 8 – July 22, 2010.

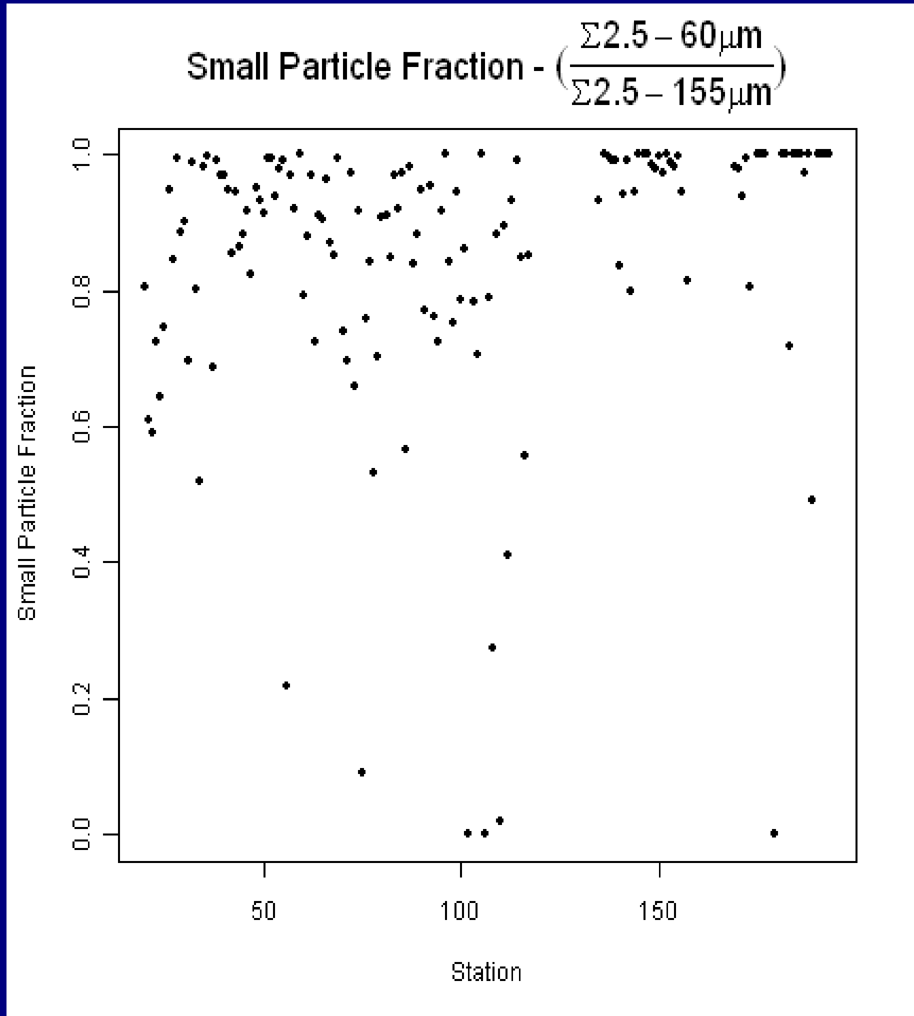
Level and Trend in DO_2 Depressions



Total of 419 DO_2 profiles compared to annual mean climatology

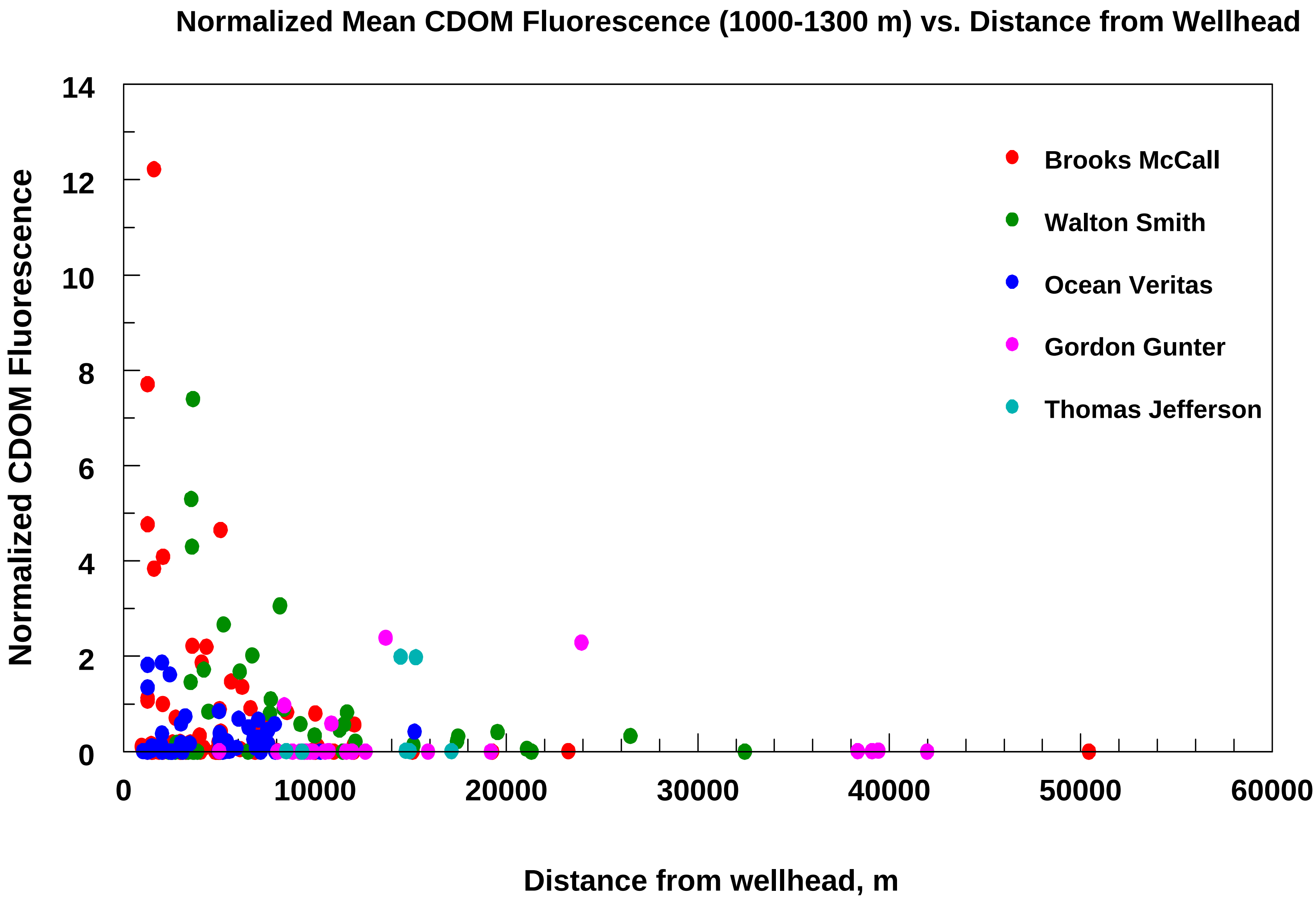
Particle Size Data
R/V Brooks McCall - Plume



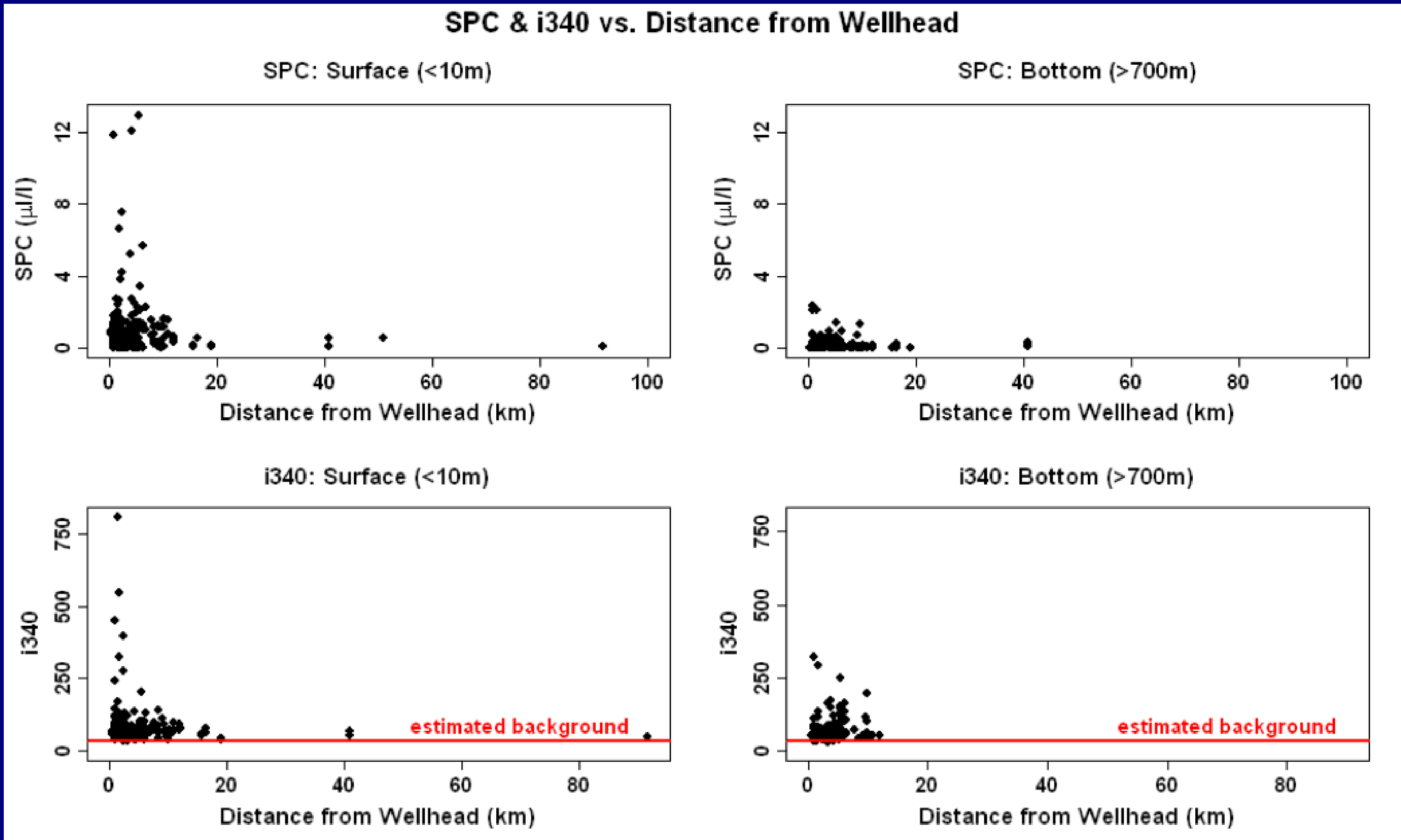


Plume = maximum small particle concentration below 800m

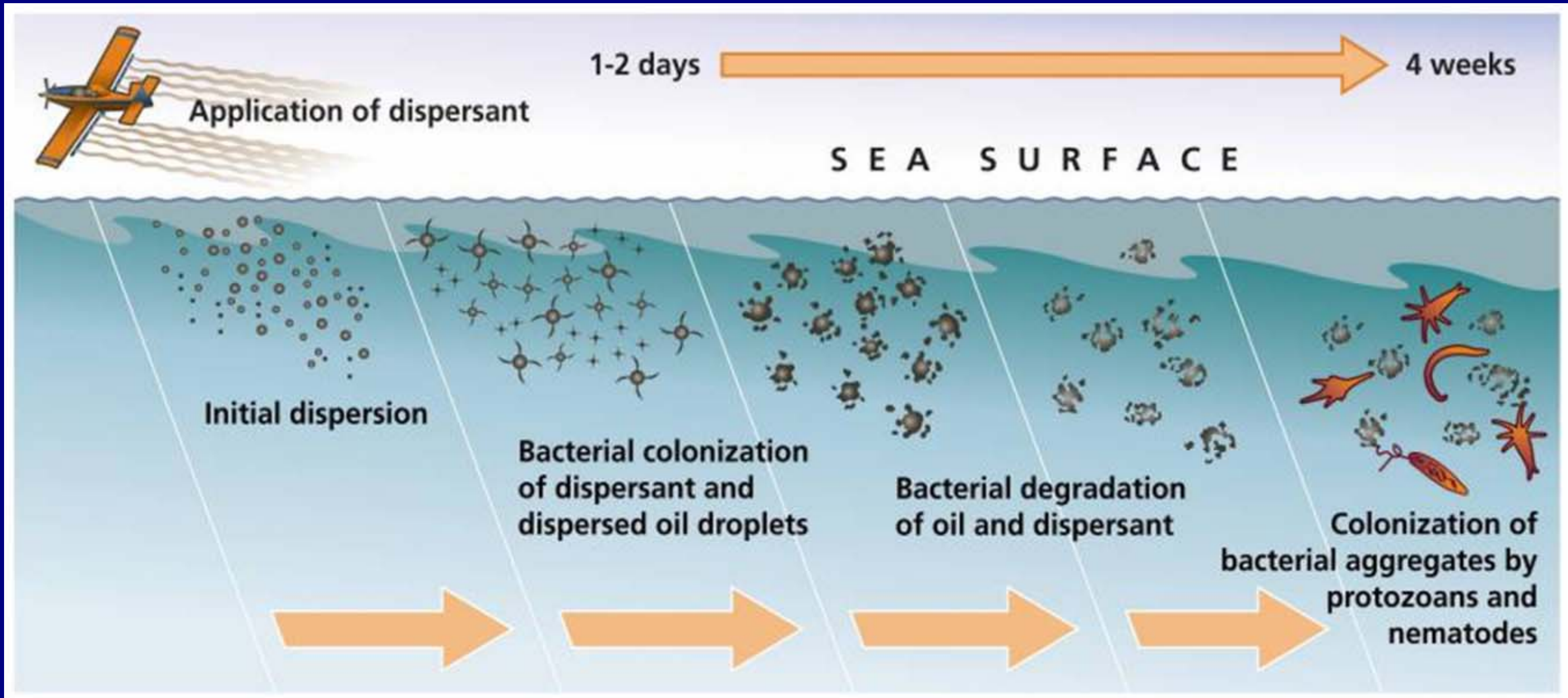
CDOM (Colored Dissolved Organic Matter Fluorescence)



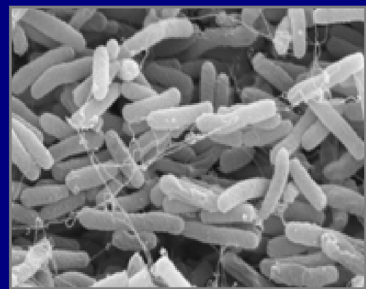
UV-Fluorescence



Fate of Dispersed Oil Droplets



Source: *http://www.response.restoration.noaa.gov*



Analysis of Near-field Oil Droplet Data

(JAG Analysis DFO Data: Dr. J.A. Galt, NOAA, HAZMAT)

- **Within 15 km of the well and below 1000 m oil droplet concentrations (< 65 microns) were fully consistent with an essentially neutrally buoyant plume.**

- **The plume was filamentous, a significant fraction of the bottle casts missed it and thus exhibited little or no oil in droplet form. Significant non-zero sample results, assumed to be within the filaments, showed total droplet volumes in the 10 ppm range with a max observed value of 16 ppm.**

- **Observed values appeared to drop off by an order of magnitude within 10 km. If we use this as a rough scaling distance for the mixing and dilution of the oil droplet filaments or plume then we would expect to have total droplet concentrations reduced to the ppb level within about 40 km.**

- **Although this is a rough estimate it is consistent with the bulk of the available observations and by the time the droplets get 40 kilometers away numerous other physical and biological processes will start to alter the state and composition of the plume.**

Fate of the Oil: GOM spill

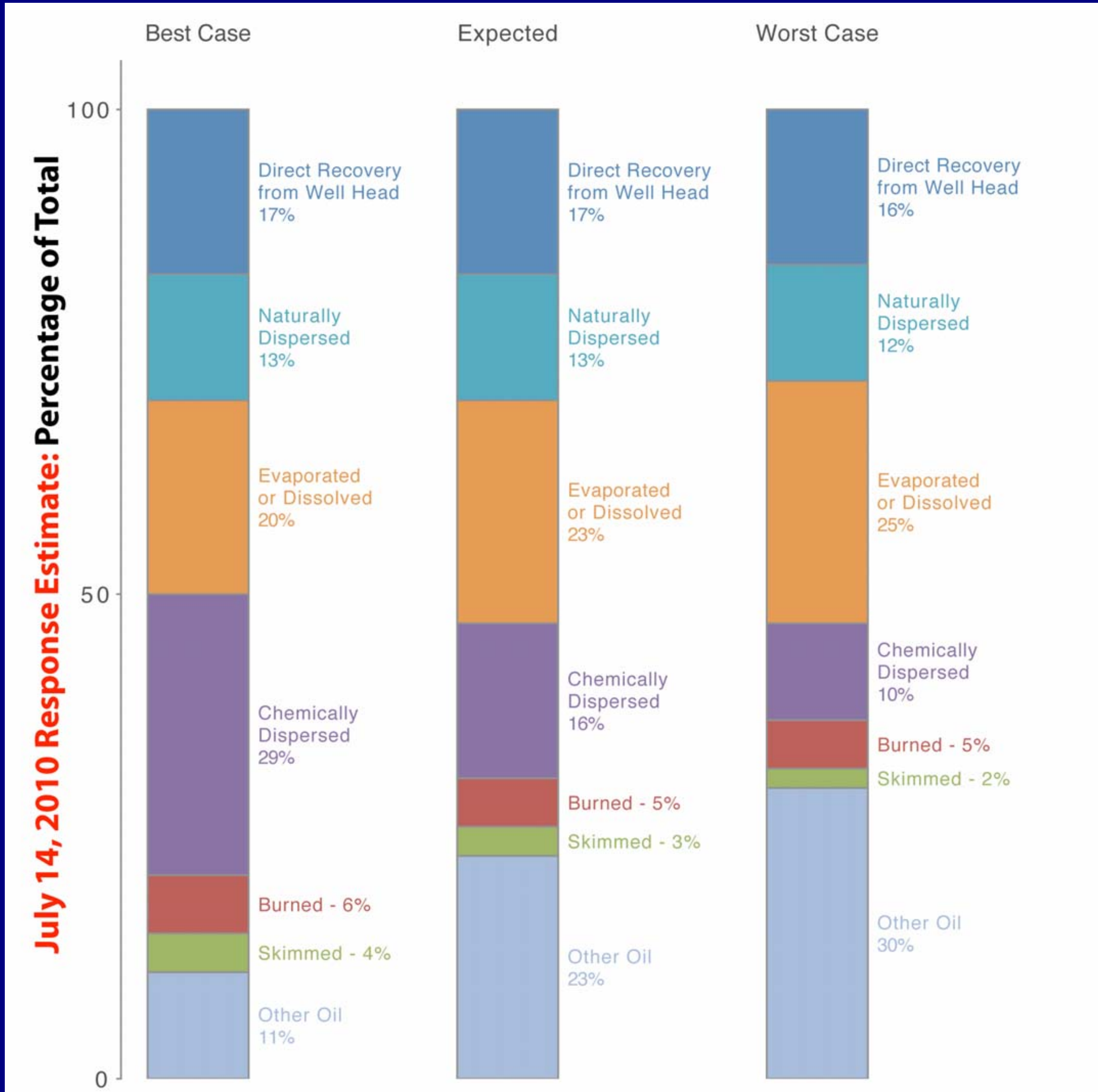
Response estimates expressed as % cumulative volume of oil discharged in the best, expected, and worst cases

Oil Budget Calculator

October 2010

NOAA (National Oceanic and Atmospheric Administration)

Other: Remaining oil is at the surface as light sheen or weathered tar balls, biodegraded, or already came ashore



Future of Dispersant Use

- The ability to effectively deploy and monitor an unprecedented dispersant response in the GoM was based on the past decades' improvements

- Misperceptions and knowledge gaps over their use remain. Areas for improvement include:

    - Need to be a common understanding of the risks and benefits of dispersant use, as well as the safety and effectiveness of dispersant products.

    - Additional research is needed on the behavior and long term fate of dispersed oil in the water column when dispersants are applied at the sea floor.