Reducing Uncertainty for Subsea Dispersant Injection

A Summary of API-IPIECA Research Collaboration

March 12, 2019

energy API

Background

SSDI Used for First Time During Macondo – Considerable Uncertainty

- Unprecedented volume of dispersants injected over extended time frame
- Untested injection methods and monitoring protocols
- Limited understanding of deep water ecosystem and dispersant impacts

Considerable Stakeholder and Industry Concerns of SSDI

- Ecosystem impacts and recovery times
- Effects of high pressures/depth on SSDI efficacy and fate of dispersed oil
- Does SSDI really reduce VOCs at the surface?

SINTEF tower tank facility (6 m x 3 m Φ, no pressure).

Negative Public Perceptions – Research and Media (fake news)

- Many news articles exaggerating dispersant impacts
- Rico-Martinez et al, 2013 *Reported as "Dispersant makes oil 52 times more toxic"*
- Kleindeinst et al, 2015 concludes *"Dispersant use inhibits oil degrading microbes"*
- Paris et al, 2018 concludes *"Subsea dispersant injection ineffectual for the Macondo Blowout"*

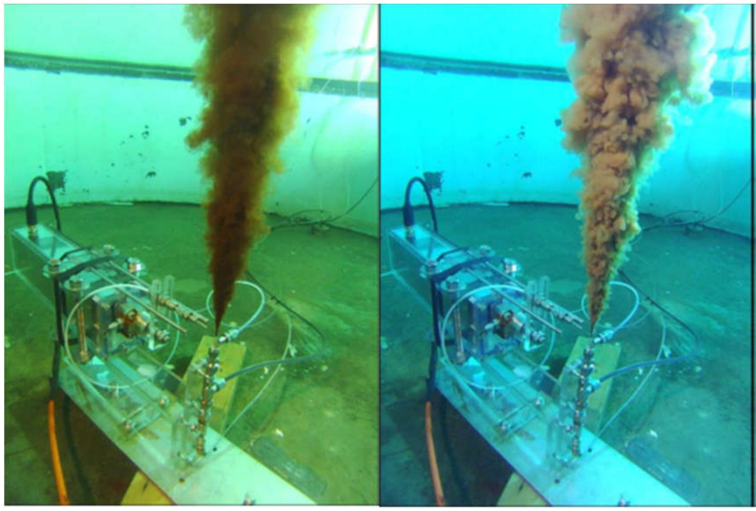
Industry Response – API (US) and IPIECA (ROW) Collaborated on SSDI Research

- Conduct research to address concerns and reduce uncertainty

API and IPIECA Research Objectives

Demonstrate Benefits of SSDI

- Oil treated at source – higher efficiency (1:100 DOR subsea vs.1:25 surface)
- Oil droplet sizes are reduced
  - Enhances biodegradation – increased surface area = more microbial attachment points
  - Reduces or eliminates buoyancy - remains in water column longer
- Less oil surfaces, forms thinner slicks and contains fewer VOCs



Address Stakeholder and Industry Concerns

- Evaluate and optimize SSDI efficacy in deep water conditions
  - What are effects of high pressure?
  - What are optimal dispersant dosage/injection methods?
  - Will discharge velocity naturally disperse the oil?
- Assess effects of oil/dispersants in deep water
  - What are the effects on deep water biota?
- Assess reduction of VOCs at the surface
- Validate new theories/models to guide future SSDI planning and potential applications

Dispersant Injection Methods

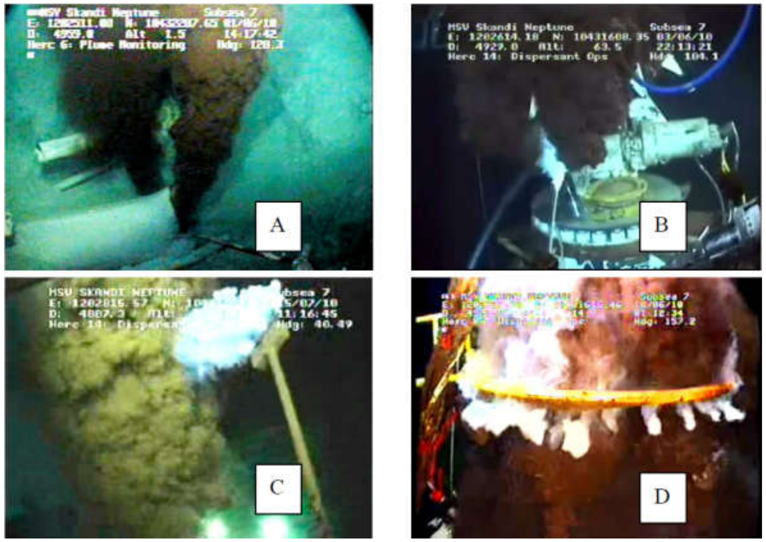
SINTEF Testing:

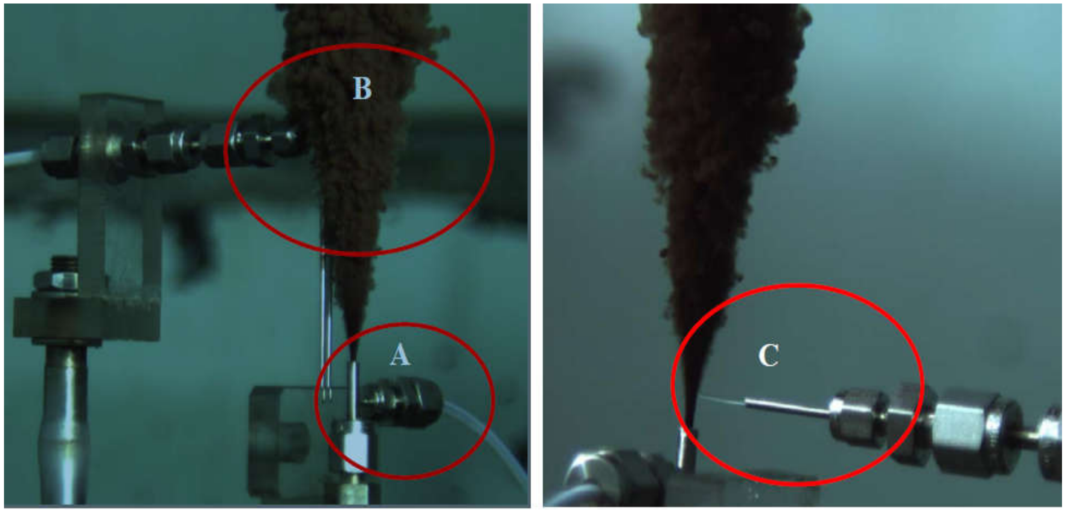
A – Upstream into pipe
B – Downstream vertical
C – Downstream horizontal

- Varied flow rates and pipe diameters

Deepwater Horizon:

A – Insertion tool into broken riser
B – Small wand
C – Larger wand
D – Application ring





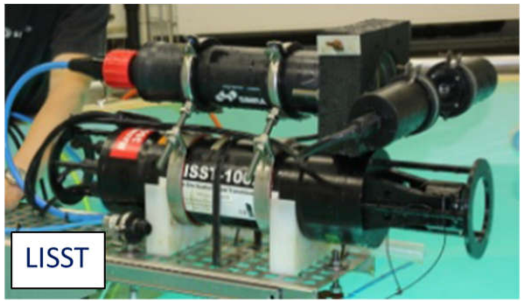
SINTEF Test Results

- Similar for all three methods
- Similar for different pipe diameters and flow rates
- Optimal if within 6 pipe diameters of discharge point

Efficacy Testing – What is the Optimal Dosage (DOR) for Different Oils & Dispersants?

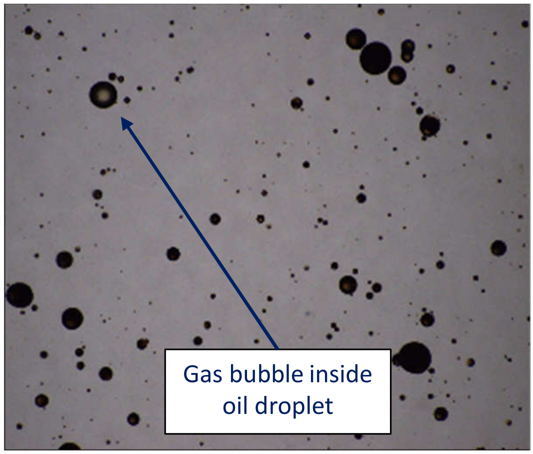
Dispersant Dosage Tests - SINTEF

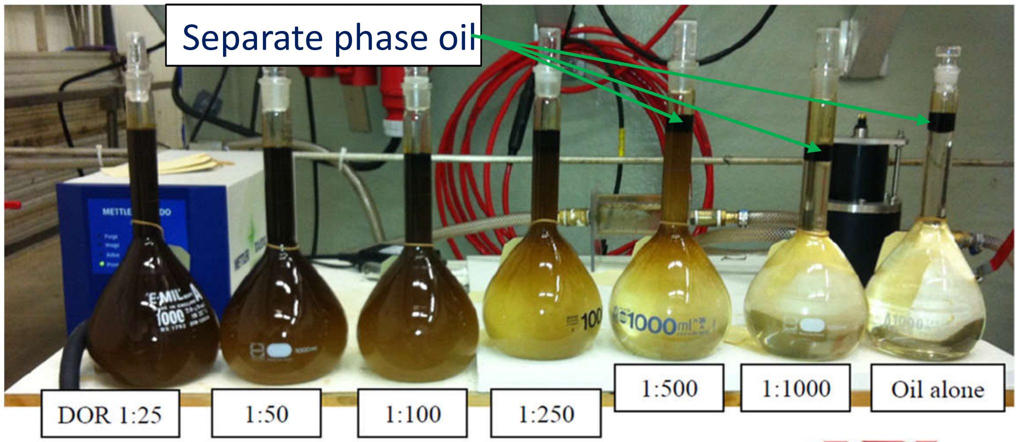
- Five Oils:
  - Oseberg – paraffinic crude (medium)
  - Norne Blend – waxy crude (medium)
  - Troll B – napthenic/biodegraded crude (heavy)
  - Grane – asphaltenic crude (very heavy)
  - Kobbe - condensate (very light)
- Three Dispersants:
  - Corexit 9500
  - Finasol 52
  - Dasic Slickgone NS
- Multiple DORs (1:25 - 1:1000 & no dispersant)
- Effectiveness based on oil droplet size reduction
  - LISST (light scattering sensor) – limited range (<450µm)
  - Developed SilCam (silhouette camera)
    - Greater droplet size measurement range
    - Differentiate gas bubbles from oil droplets



Silhouette Camera

SilCam Output





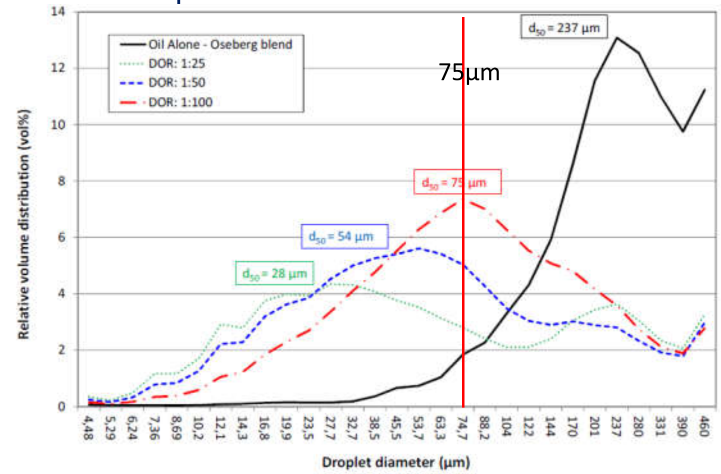
Efficacy Testing – What is the Optimal Dosage/DOR?

Dispersant Dosage Test Results

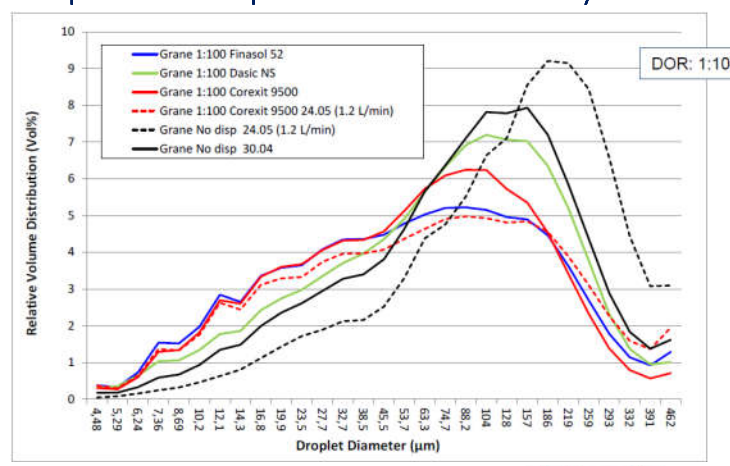
- Effectiveness varied somewhat between oils and dispersants
  - All dispersants were deemed very effective
- Median (d_{50}) droplet size by dispersant (1:100 DOR) across all oils:
  - Corexit 9500 – 86µm
  - Finasol 52 - 120µm
  - Dasic Slickgone NS - 164µm
- DOR of 1:100 reduced d_{50} droplet size to ~75µm (neutrally buoyant)
- Led to development of modified Weber number that increased accuracy of droplet size modeling

Note: Droplet sizes produced by these small scale tests are not representative of a much larger well control incident

Droplet Size Distributions for DORs



Dispersant Comparison for Grane Heavy Crude



Efficacy Testing – Do Pressure and Live Oil Matter?

Ambient and High Pressure Dispersant Efficacy Tests - SwRI

- Ambient and 2500 psi water pressure (HP) = Depth of 1750m (5760ft)
- Dispersants injected just upstream of discharge point (same as SINTEF)
- Used Oseberg oil and Corexit 9500 dispersant – 1:100 and 1:50 DORs

Test Results

- No significant difference between ambient and HP

Live Oil and Live Oil w/Natural Gas Tests

- Tests similar to above including w/ and w/o dispersant
- Used "Live" Oseberg oil (gas saturated)
- Added natural gas (20, 50 and 80%) in some tests
- Varied pressure to simulate depths between 5, 580, 1160 and 1750m

Test Results

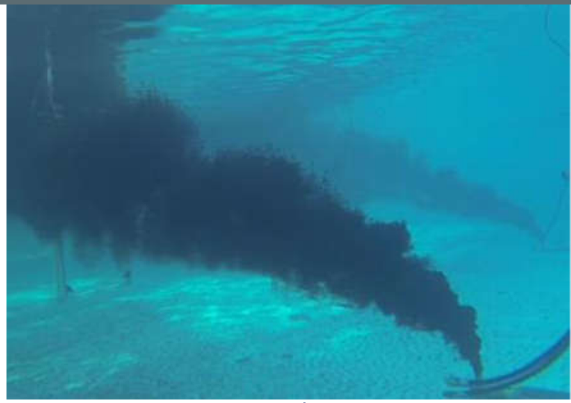
- No significant difference between dead, live or live oil w/ gas
- No difference between tests at different pressures (depths)
- Gas bubbles did not reduce dispersant efficacy

SwRI Deep Ocean Simulator
(2.3 m x 5.8 m Φ, 9,000' press.)

Efficacy Testing – Will Larger Pipes/Flows Change Results?

Upscale Pipe Dia./Flow Rate Tests – Ohmsett & SINTEF

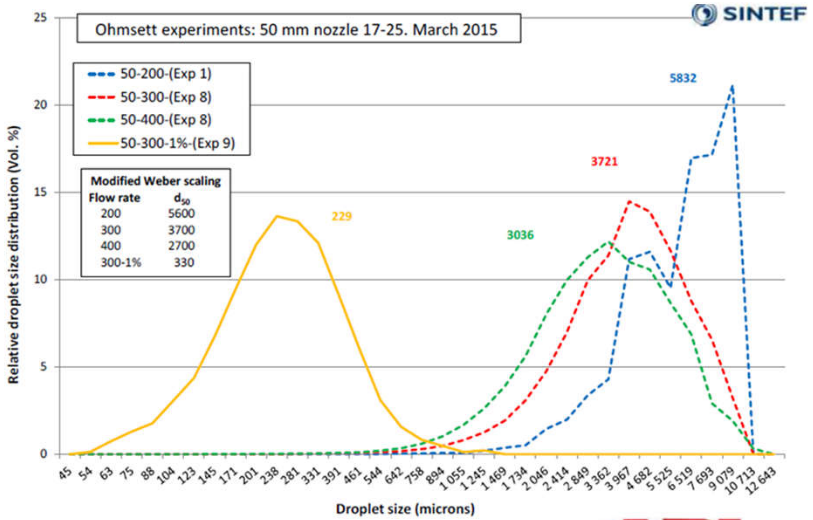
- Pipe diameter – 25, 32 and 50 mm vs. 0.5–3 mm in previous tests
- Flow Rates – 50–400 L/min vs. 0.1–10 L/min in previous tests
- Oseberg oil and Corexit 9500 dispersant (DOR 1:100)
- Towed discharge apparatus at Ohmsett to elongate the plume
- Applied dispersants using a wand adjacent to discharge point



Ohmsett tests w/ releases from two different nozzle configs

Test Results

- Demonstrated validity of modified Weber number – still accurate at a larger scale
- Produced significantly larger droplet sizes than small scale tests - still a substantial reduction w/dispersants
- Very effective delivery of dispersants with wand – validated DWH methods
- Suggests generation of 100µm droplet sizes w/o dispersants is unlikely even at higher flow rates



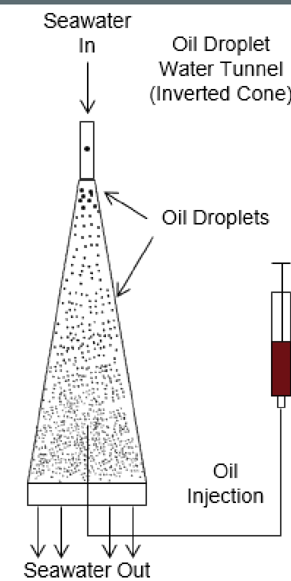
Efficacy Testing – How Do Rising Droplets Behave?

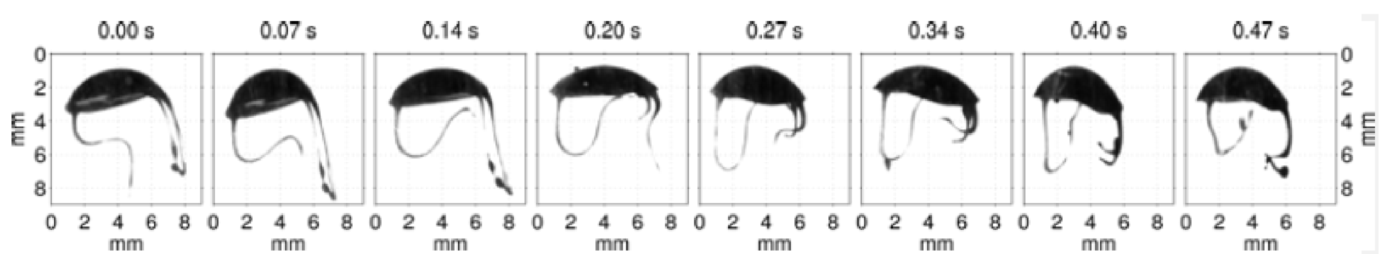
Inverted Cone Tests to Assess Tip-Streaming – Univ. of Hawaii

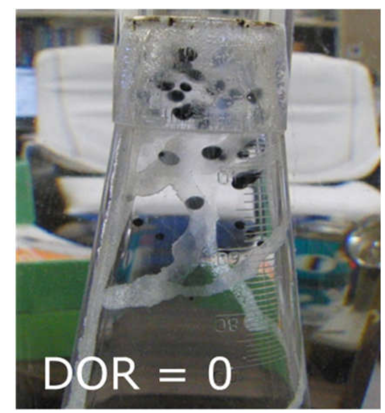
- Downward flow of seawater counteracted droplet buoyancy – became stationary
- Simulated droplets rising through water column
- Enabled observation of tip-streaming – latent breakup

Inverted Cone – Tip-Streaming Tests Results

- Tip-streaming only occurred in the first few minutes after droplet formation
- Caused by droplets shedding excess surfactant – takes bits of oil with it
- Droplets become round after shed excess surfactant
- Reduction in droplet size is relatively low







Fate and Effects – Does SSDI mitigate impacts better than surface options?

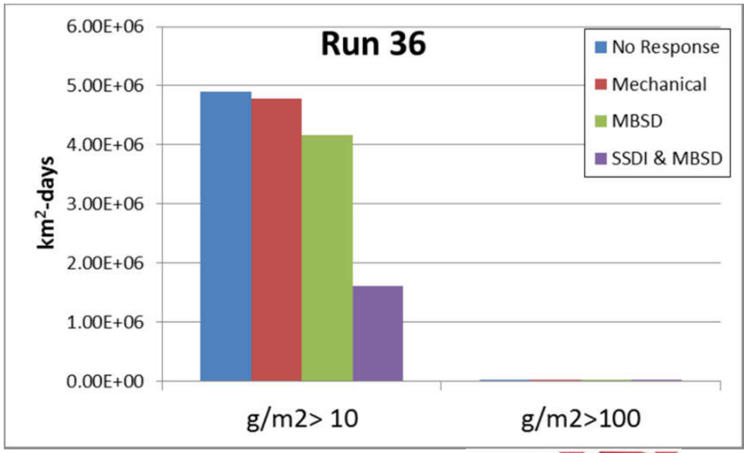
Comparative Risk Assessment (CRA)

- Excel tool that quantitatively compares response options for deep-water GOM spills
  - No Intervention, Mechanical Recovery, ISB, Surface Dispersants, SSDI
- Utilized outputs from 3D fate and effects modeling
- Tool quantified exposure to, and recovery of, valued ecosystem components (VECs) w/in various environmental compartments (ECs)
- Stakeholders provided input to tool development (toxicity thresholds, VECs, etc.)

CRA Results

- SSDI reduced risks to most VECs, some dramatically, vs. other options
  - Did increase risk to some water column VECs
- Surface options (MBSD) marginally reduced risk vs. No Intervention
- Surface VECs w/long recoveries (turtles, marine mammals) were main drivers vs. water column VECs w/low density and fast recovery
- Demonstrated value of dispersing oil in water column
  - Rapidly dilutes in 3D and efficiently biodegrades vs
  - Concentrating and persisting in 2D on the surface and shorelines

Surface Oil Thickness Model Results



Fate and Effects Testing – Is Toxicity Different at Depth?

Deepwater Species Toxicity Tests

- Collected barotolerant species that:
  - Migrate between shallow and deepwater (Sable Fish and Shrimp)
  - Reside deepwater but tolerant to low pressures (coral)
- Ran a series of dispersed oil toxicity tests at various concentrations

Toxicity Test Results

- Toxicity thresholds are similar to common near surface aquatic organisms
- Narcosis is primary effect of HC exposure – results from swelling of cell tissue
- High pressure is thought to inhibit cell tissue swelling
- Dispersed oil toxicity is same or less at depth than near the surface

Anoplopoma fimbria – Sable Fish

Lophelia pertusa – coral

Pandalus borealis – shrimp

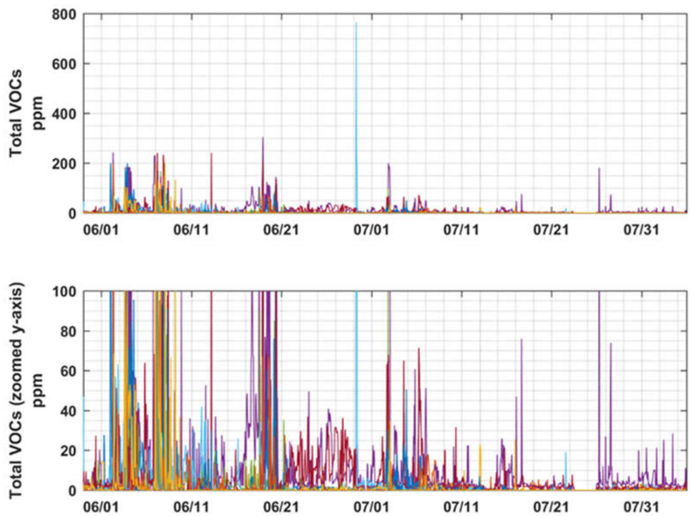
VOC Modeling – Does SSDI really reduce surface VOCs?

Modeling of Surface VOCs With and W/O SSDI

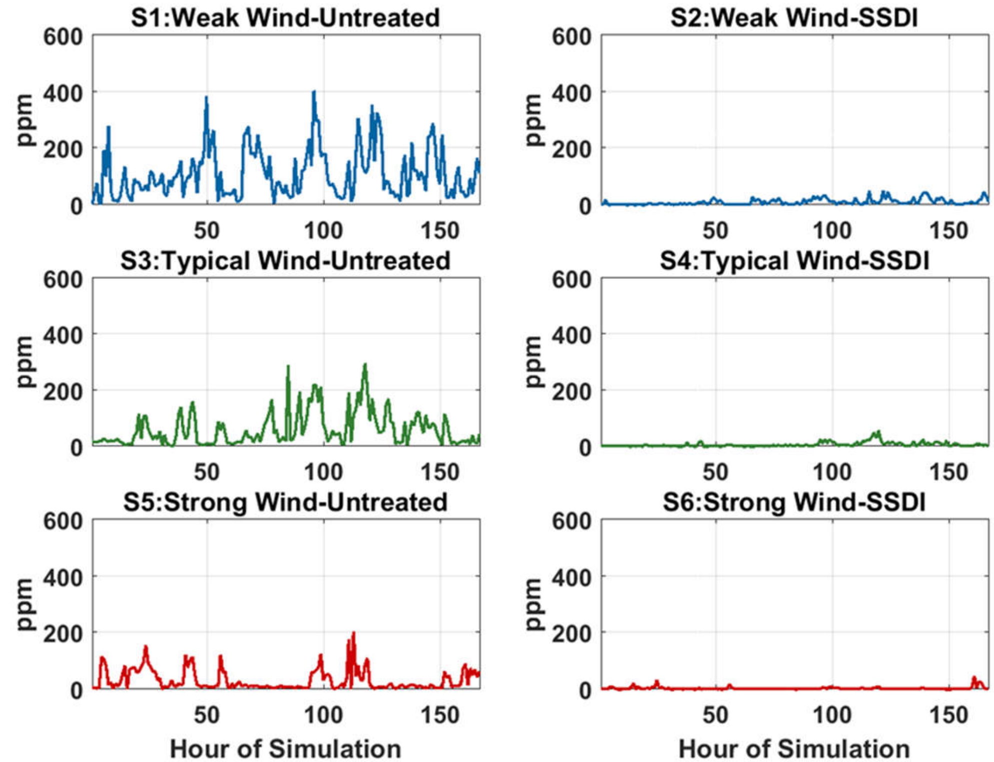
- Weak, typical and strong GOM wind scenarios
- 10m above water surface

Total VOC Data Macondo Response Vessels

- Peaks of ~300 ppm - often in 20-60 ppm range
- Total HC Exposure Limits
  - OSHA 12 hr TWA = 333 ppm
  - ACGIH 12 hr TWA =33 ppm
  - BP IH Threshold = 50 ppm



VOC Modeling Results



Summary of Results

Efficacy

- **Injection Location** – Optimal if w/in 6 pipe diameters
- **Dispersant and Oil Type** – Some variability but still effective on all oil types
- **Dosage (DOR)** – 1:100 produced good results
- **High Pressure** – No significant difference from ambient
- **Live Oils With and w/o Gas** – No significant difference from dead oil
- **Upscale Tests -** Produced larger droplet sizes but dispersants still reduced by an order of magnitude
- **Tip Streaming** – Short term and largely limited to more viscous oils

Fate and Effects

- **CRA –** SSDI reduced risks to most VECs over other options
- **High Pressure vs Dispersed Oil Toxicity** – Same or lower than ambient pressures

Research Reports

- **API** - http://www.oilspillprevention.org/
- **IPIECA** - http://www.oilspillresponseproject.org

THANK YOU FOR LISTENING