NFO Trajectory Analysis: Tools and Data Gaps

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Outline

- What is Modeling
  - What Questions do you need to Answer
  - What Processes does the Model Capture
  - What inputs do we need
  - What is the Uncertainty?
  - Processes to Model

- Challenges of Non Floating Oils
  - More Sensitive to some physical properties: density, viscosity
  - Physical Properties less understood -- “slurry oil”
  - Mobilization -- not well understood
  - You can’t see it! -- calibration is hard

Why do we need fate and trajectory analysis?

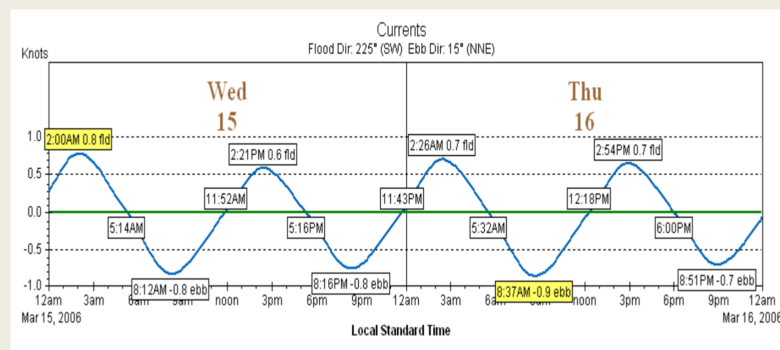
- Not just about a model result
- We want a forecast that can be used to inform decision-makers in a timely manner with all the relevant information
- Not just where the oil is going to go, but how bad is it going to be…and how certain are we about that result.

What is a model?

A *simplified* representation of a system or phenomenon, with *any hypotheses required* to describe the system or explain the phenomenon, often mathematically

A simple model:
Assume only tidal currents
Approximate tidal currents by sine function
Integrate a sinusoidal tidal velocity over a half of tidal cycle to get:

Tidal Excursion =
$2/\pi * u_{max} * \text{Tidal period} / 2$



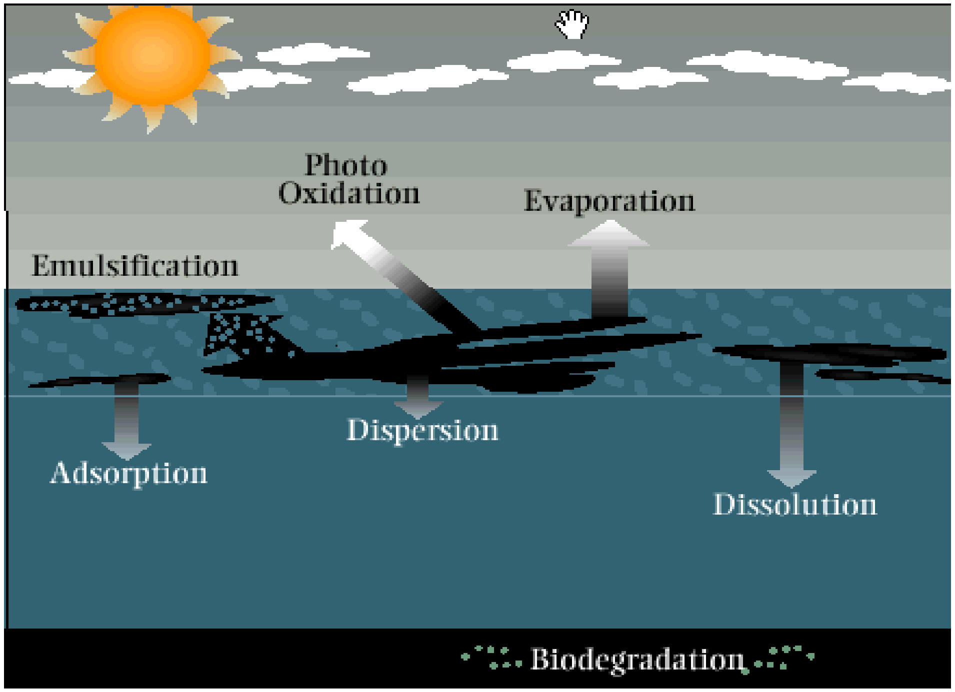
Tidal Excursion (miles) =
Max Flood(Ebb) velocity (mph) × 4

Consumers guide to oil spill models

- Important to consider both **fate** and **transport**

Weathering (Fate):

- Evaporation (outgassing) -- what does it give off, does that effect density, properties (it sure can smell...) – not much for heavy oils, but …
- Dissolution -- any toxic compound likely to dissolve into water column? Also not much – but the big concern for biota
- What if it is cut with something – Dilbit / Synbit
- Dispersion – not likely – usually high viscosity



Biggest Issue:

- How does weathering effect the properties that effect transport
  - Density!

Transport:

- Key Factor: Does it Float?
- Initial Specific Gravity
- Changes after release
  - Density changes as oils weather
    - Lose their light ends
  - Density changes as oil cools (if it's shipped heated)

While it floats:

- Similar to a traditional oil spill:
  - At least for well weathered tarballs…
- Major Factors:
  - Wind -- windage will be small for dense, viscous oil <1%
  - Currents
  - Turbulent dispersion
- Traditional Oil spill models work fine

Sedimentation:

Another factor that greatly effect density

- How sticky is it?
- What is the source of sediment?
  - River bottom
  - Beach: “Tootsie rolls”
  - Suspended sediments

OSA models are designed for “ordinary” oils:

lower viscosity, smaller droplets.

Once it doesn't float:

Lessons from sediment transport:

Near Neutrally Buoyant:

Moves like suspended load

– with the currents – we can do that.

Denser than water: Moves like bed load:

- Well established literature for traditional sediments: Beaches and Rivers
- But only if we know the parameters: Particle size and density

“Droplet” size?

Notice that a lot depends on how large the “droplets” or globules, or particles are.

Droplet size is key to a lot of oil spill fate and transport issues: lots of research (particularly with dispersants)

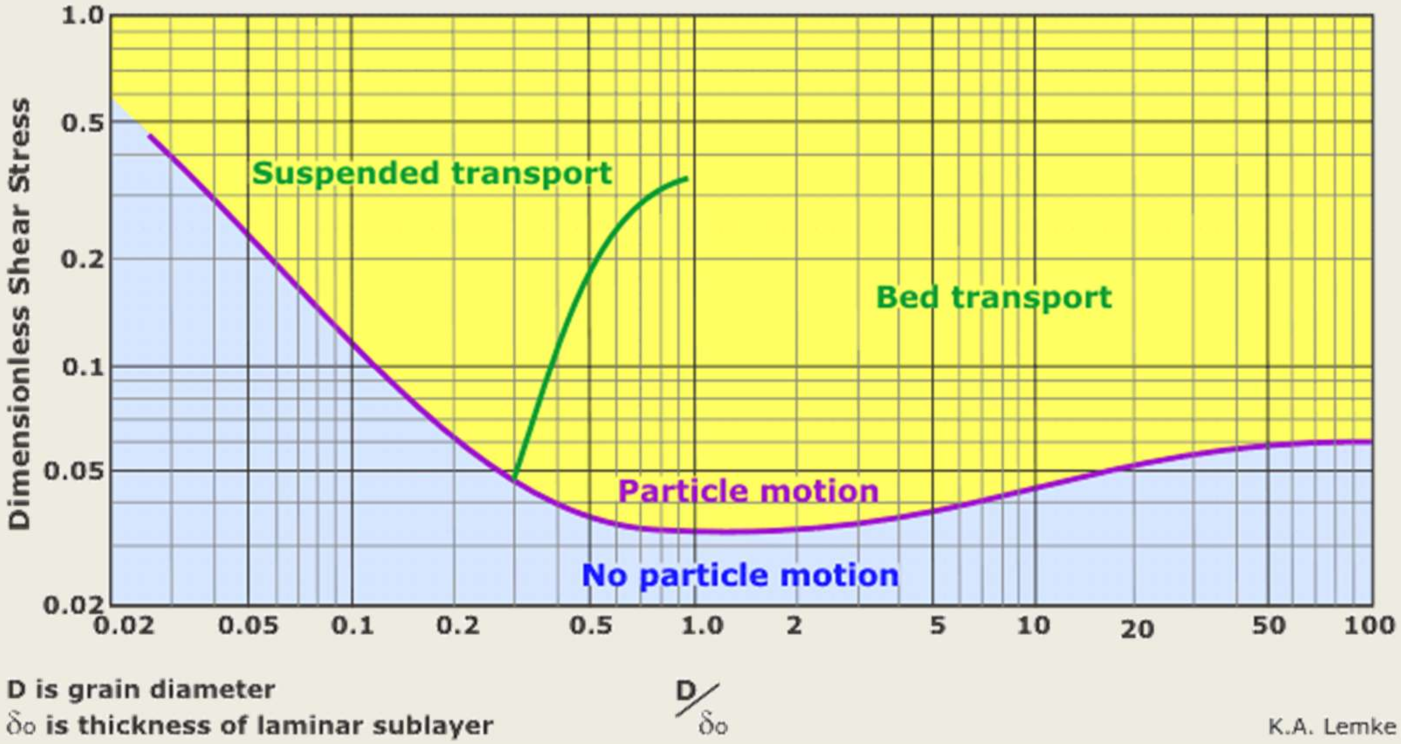
Droplet size depends on:

- Turbulence regime
- Viscosity
- Interfacial Tension

But: NFOs tend to be highly viscous – so form much larger droplets or globules – and no one is modeling that.

Shield's Number: $\theta = \dfrac{\tau_0}{(S_s - 1)\rho g d}$

- Ratio of Bed Shear Stress to buoyancy
- Need to know: particle size and specific gravity.



"Shield's Number" for oil on the bottom?

Function of:

- Bed Shear Stress
- Buoyancy

(so far so good – like sediment)

- Viscosity
- Stickiness?
- Thickness of layer?
- Size of layer?

It's a very complicated problem – we can't model it from first principles.

Example: DBL 152

Slurry Oil – went to bottom in Gulf of Mexico.

Oil didn’t move much for a while.

15m depth: Not very strong currents – not strong enough to mobilize the oil.

Would major wave energy mobilize it?

In 15m depth – need substantial energy at periods greater than 5 seconds.

But how much?

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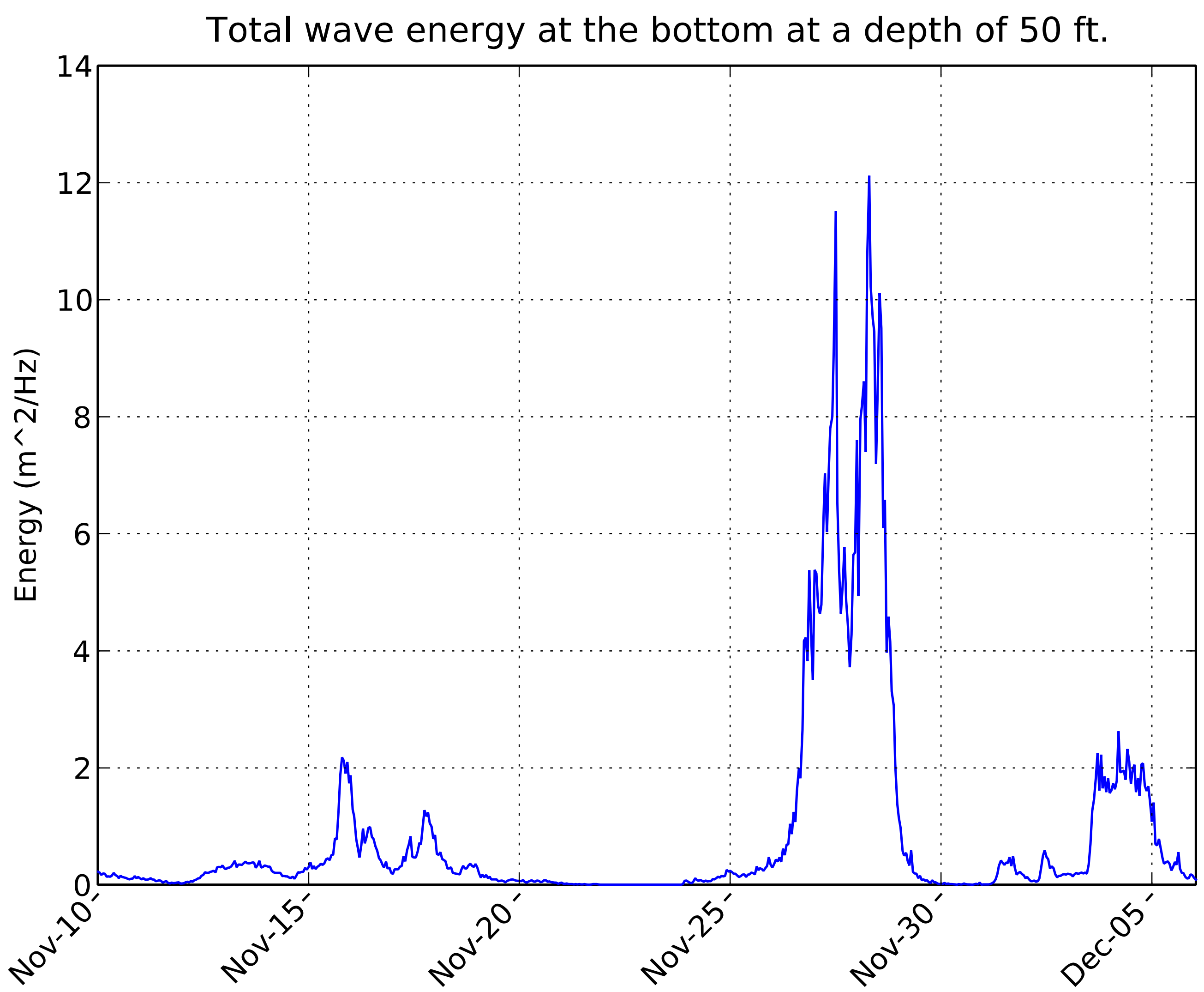
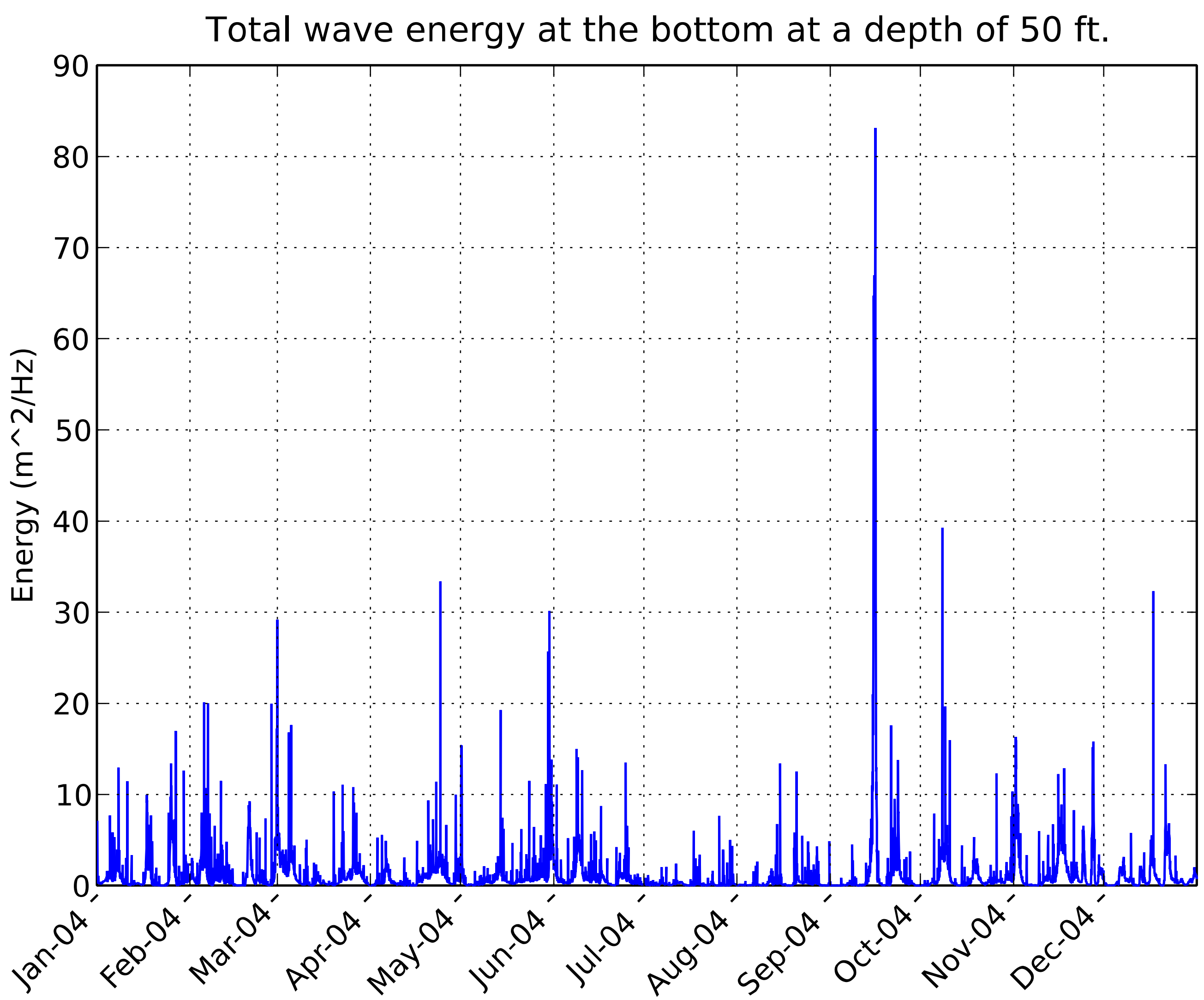
Example: DBL 152



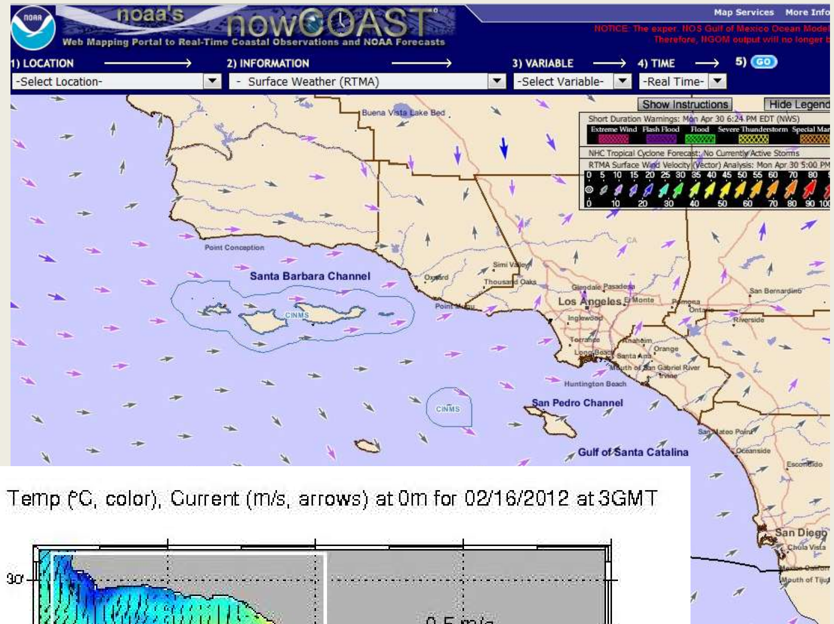
Example: DBL 152



Consumers guide to oil spill models

- Important to consider both **fate** and **transport**
- Depends on **availability** and **quality** of inputs

GNOME Inputs



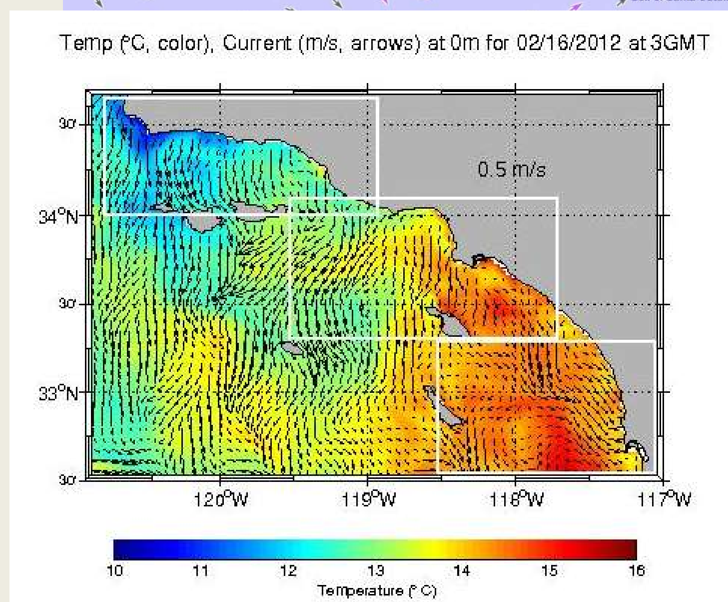
Initial position of oil

Wind forecasts:

Not important for NFOs

Ocean/River current forecasts

- Response models
- Operational models
  - Navy, NOAA
- Academic models



Highly variable what's available by region

NFOs: Same limitations as floating oil – except we always know less what's going on at the bottom.

Consumers guide to oil spill models

- Important to consider both **fate** and **transport**
- Depends on availability and quality of inputs
- Approach determined by **questions and when answers are needed**

Response modeling vs. Damage Assessment modeling

- Where is the bulk of the oil going to go?
- When will it get there?

→ What can we **do** to mitigate damage?

- What concentrations are organisms exposed to and for how long?

→ What harm **did** it cause?

Considerations of Consumer

- As a consumer of model data, its also important to consider what questions the model was designed to answer and whether its appropriate for your application
- Consider:
  - Assumptions
  - Resolution (spatial and temporal)
  - Accuracy/validation

NFOs: Same Considerations

Consumers guide to oil spill models

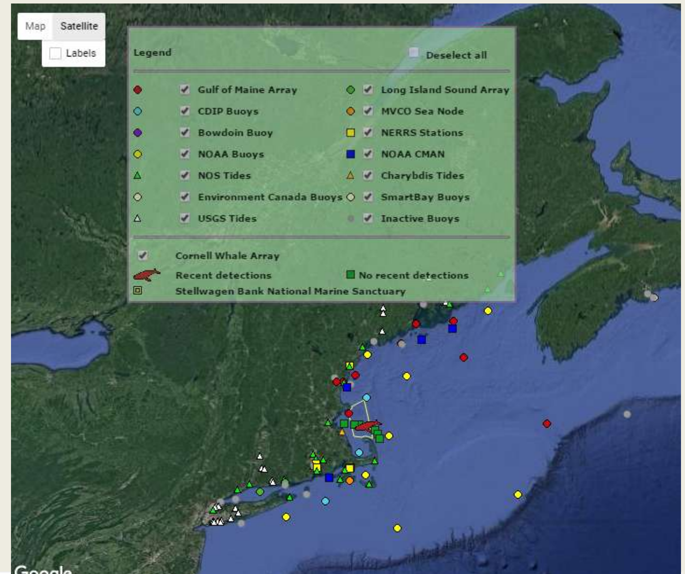
- Important to consider both fate and transport
- Depends on availability and quality of inputs
- Approach determined by questions and when answers are needed
- Forecasts must consider **uncertainty**

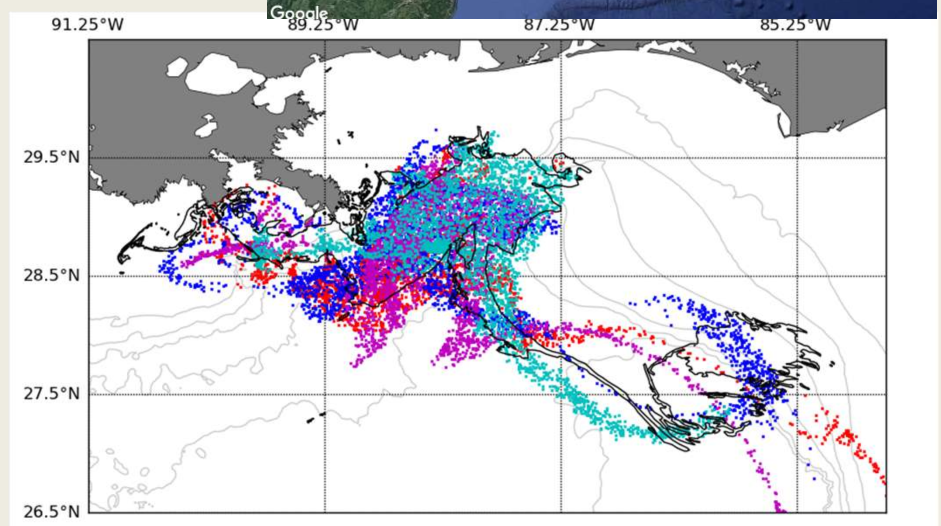
Reducing and constraining uncertainty

- On-scene observations are critical for reducing uncertainty

- Ensemble approach: output from multiple scenarios used to constrain uncertainty

But we don't often have multiple models!





Observations

- Observations are critical to modeling:
- Initial forecast is always highly uncertain
- Uncertainly goes down as observations come it – we can calibrate the model.
- Floating oil – we can see it from the air (and increasing with remote sensing – satellites and air born.
- We can’t easily get a synoptic view of oil under the surface – much harder to calibrate the models!

Consumers guide to oil spill models

- Important to consider both **fate** and **transport**
- Depends on availability and quality of inputs
- Approach determined by questions and when answers are needed
- Forecasts must consider uncertainty
- Craft the **output** to the audience

"I've never been to the same spill twice"

- Jacqui Michel

Every Spill is Unique.

However…

What NOAA, OSPR, the Entire Response Community Bring to each spill is a wealth of experience.

This experience guides our expectations, provide reality checks on model results, etc.

But NFO spills have been pretty rare – we simply do not have the same experience base.

Example: T/B Apex 3508

Initial Trajectory:

…

The Slurry Oil is specified to have a specific gravity of 1.1, which would sink in the fresh water of the Mississippi.

…

Slurry oils can be quite variable, and MSDS is often generic, and not specific to the particular product released. Without a precise specification of the physical properties, we can only provide a preliminary assessment.

…

With the low viscosity, we expect the oil to break up into droplets fairly easily, perhaps 1-5mm in size, rather than stay together in a large mass.

…

Example: T/B Apex 3508

Initial Trajectory (cont)

However, **the turbulence in the river will likely keep much of the oil suspended in the water column, in droplet form, allowing some of it to move downstream, at close to the river flow velocity.**

…

We expect that the leading edge of oil will move downstream at the flow velocity, currently about 2 miles per hour.

…

Any substantial deposits on the bottom could be re-mobilized at high flows.

Example: T/B Apex 3508

What Happened:

Most of the oil went down near the spill, ended up thick on the bottom, and did not significantly re-mobilize.

Aside from sheen, not much seem downstream

Why?

Oil was more viscous than reported on the MSDS – did not break up into smaller globules.

Perhaps more dense as well?

Turns out past experience didn't help much in this case.

Sensitivity to Properties

Oil’s behavior in the environment is always effected by physical properties:

- Density
- Viscosity
- Chemistry

But floating oil still has similar behavior:

- It floats
- It’s moved by the currents
- It’s moved by the winds
  - windage is effected by properties – but not all that much…

Sensitivity to Properties

With Non-floating oils:

Density – tends to be close to 1

- It may sink, it may float, it may remain suspended in the water column.
- VERY sensitive to Exactly the density

Viscosity:

Often large – forms very large droplets or globules

Example: M/T Athos I

Density – API 13.6

> 10 – should float, yes?

- Some "stuck" to the bottom
- Tarballs (globules) in the water column
  - Transported way downstream
  - Couldn't be seen
  - Nuclear Power Plan Cooling water intakes threatened
- Transport VERY sensitive to density!
- We really had no idea what the source was – couldn't model when the intakes would be safe.

Example: TB MM-55

Heated Asphalt:

- Density – while hot < 1.0
- After cooling > 1.0
- Starting floating – then sunk
- Transport VERY sensitive to density!

- Makes any model results VERY uncertain:
  - The oil will be anywhere from:
    - right below the barge

    To
    - Moving downstream with the currents…

Take Home Thoughts

- Pick the right tool for the right job (“All models are wrong, but some are useful”)
  - What are the questions you need answered?
  - How good do the answers need to be?
  - When do you need the answers?
- Know what questions the model was designed to answer
- You want a forecast not just model run (includes expert analysis and interpretation)
- Forecast not perfect … plan for uncertainty

  Higher for NFOs !!