Subsea oil spill

ADVANCED MODELLING & SIMULATION – AMS –

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Subsea oil spill

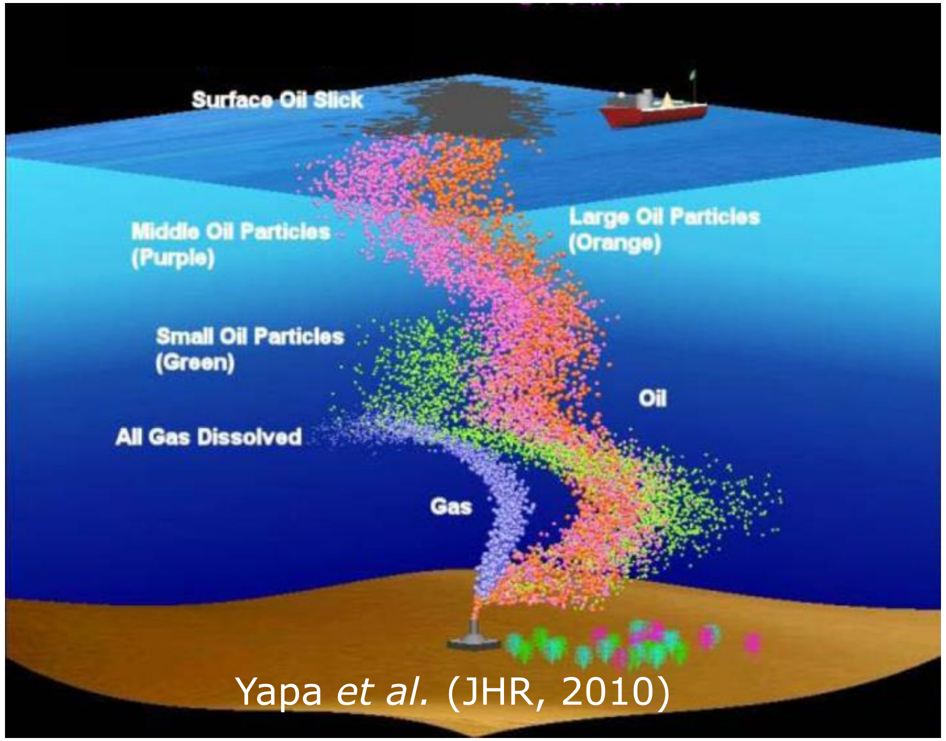
Transat – spill

The subsea oil spill context:

The event of the Gulf of Mexico revealed a lack of understanding of flows subsequent to subsea hydrocarbon spills. Improving the realism and accuracy of predictions of these flows help define efficient mitigation operations to minimize environmental impact and costs.

Our solution:

The flows include multiphase flow jets, hydrate formation and dissolution, and transient interaction of plume constituents with the surrounding. 3D CFD is expensive, which appeals for the use of cost-effective, fast-response subsea plume models.



Yapa *et al.* (JHR, 2010)

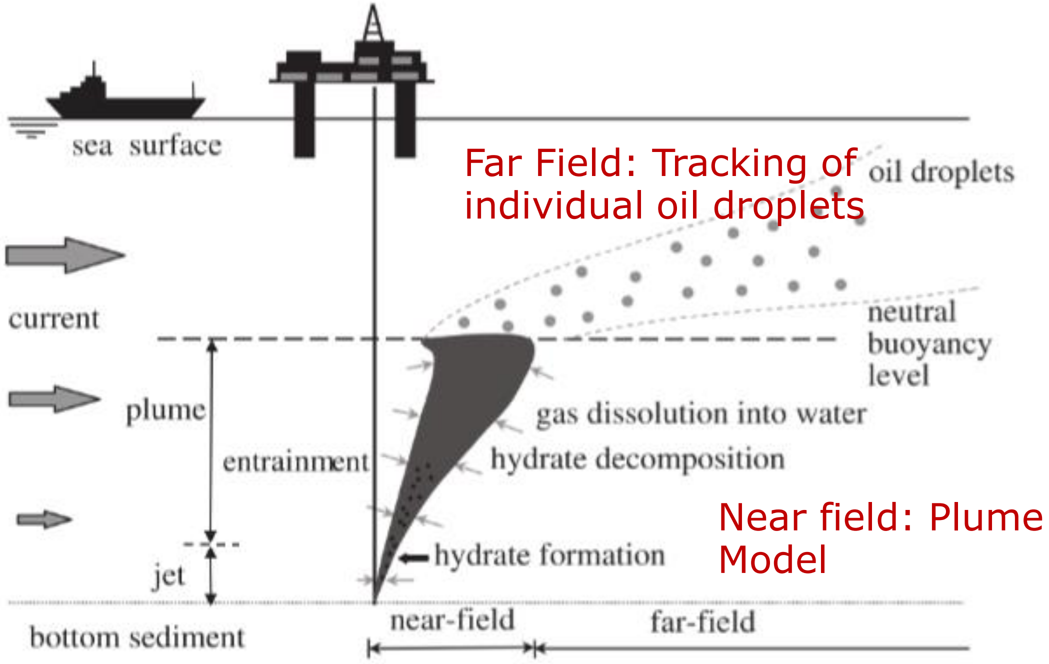
Transat – spill

Description:

a Plume model based on Yapa's approach to track oil and gas from a subsea spill, BUT linked to TransAT-3D above the neutrally buoyant layer to track gas bubbles and/or oil droplet trajectories in 3D, using sea-current data. Dispersion of the droplets by small-scale turbulence is subgrid-scale modelled using a deconvolution approach.

Credits:

TransAT-SPILL has been used for consultancy projects, including for BP, Shell, OMV Norge AS.



Transat – spill

- **TransAT-Spill** is designed for use in environmental risk assessment and oil spill contingency planning in conjunction with production in deep waters, and includes: An Integral Plume Model (near spill), combined with a far field droplet & gas bubble tracking.
- **Integral Plume Model:** based on the mixture concept, incl.: water, oil droplets and free gas bubbles. The model is used in to model the spill in the near field region where a mixture model is appropriate. At some depth the plume gets trapped due to ocean stratification, where the mixture assumption is not valid.
- **Far field oil droplet, gas bubble spill tracking:** The plume at depth of trapping is the initial condition for the far field model, where oil droplets are tracked using a Lagrangian approach. The model takes into account turbulent dispersion of the oil (Langevin model and approximate deconvolution model to generate smaller length scales). In this stage transport of the oil is mainly determined by the ambient currents. If the oil reaches the surface, the slick is tracked. A wind component is added to the surface velocity of the water.

Transat – spill

- **Mass balance of oil, gas, hydrates, water**
- **Momentum balance of oil, gas and water mixture**
  - Slip between gas and mixture
  - Entrainment of water (shear, crossflow)
  - Buoyancy
- **Energy balance of mixture**
- **Salinity transport**

- **Gas dissolution**
- **Hydrate formation, dissolution**
- **Gas separation from plume**
- **Ambient sea characterization**
  - Water density EOS(T, p, salinity)
  - Temperature variation with depth
  - Salinity variation with depth
  - Gas density EOS
  - Sea currents data

Transat – spill

Required input data:

Discharge conditions:	Environmental conditions:
• Outlet depth • Oil flow rate • Outlet diameter • Gas to oil ratio at standard conditions (GOR) • Outlet temperature	• Vertical sea temperature profile • Vertical Salinity profiles • Wind data (unsteady, spatial) • Ocean current data (unsteady, spatial)

Resulting output data:

Plume Stage output	Far Field output

• Plume Trajectory
• Depth of trapping
• Rise time to depth of trapping
• Mixture properties along the plume trajectory
  ○ Temperature, density
  ○ Salinity
  ○ Velocities
  ○ Oil & gas concentration
	• 3D transient output in the ocean
	  ○ Oil concentration
	  ○ Gas concentration
	  ○ Density
	• 2D transient output at the ocean surface
	  ○ Gas flux on the surface
	  ○ Oil surface concentration

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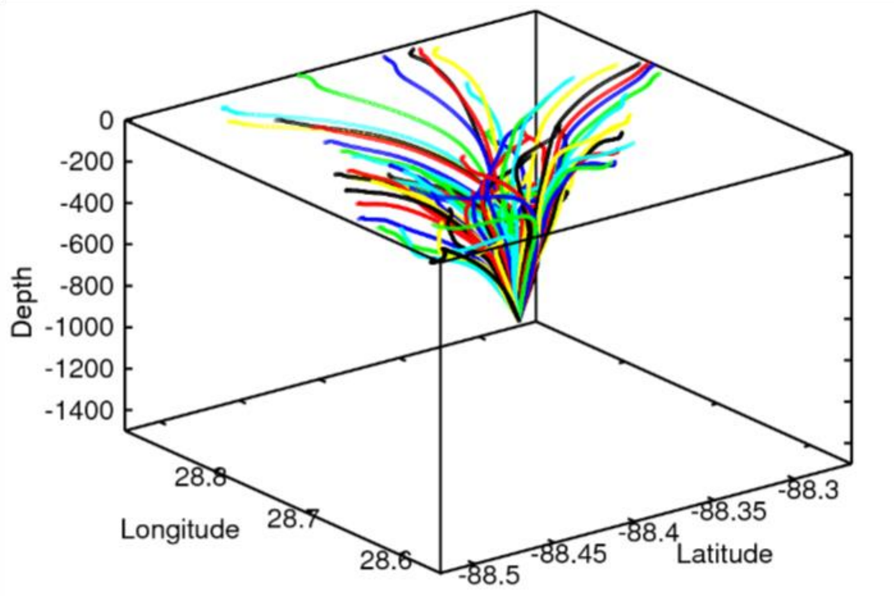
Testing

- One trajectory simulation per day
- 70 days after the spill simulated
- Rise time (and trajectories) depend on droplet size
- Typical rise time (300μ droplets): **40 hours**
- 1 deg = 144km



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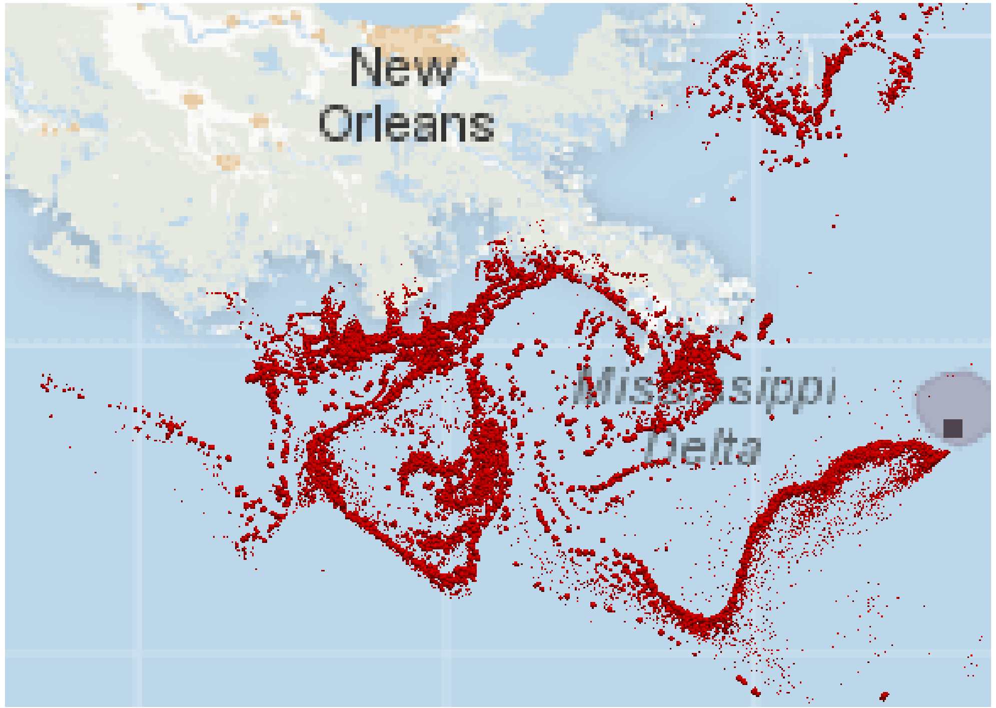
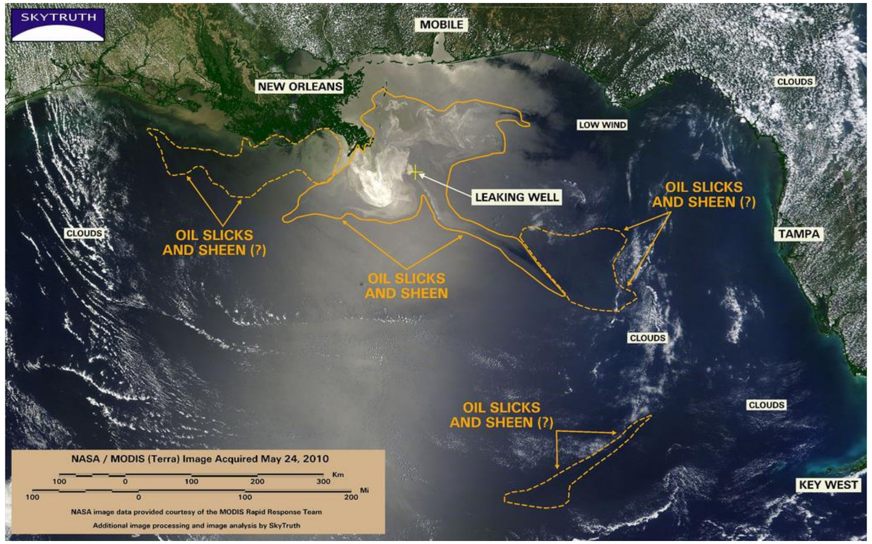
Example 1 (Company yyy):
The Macondo Well

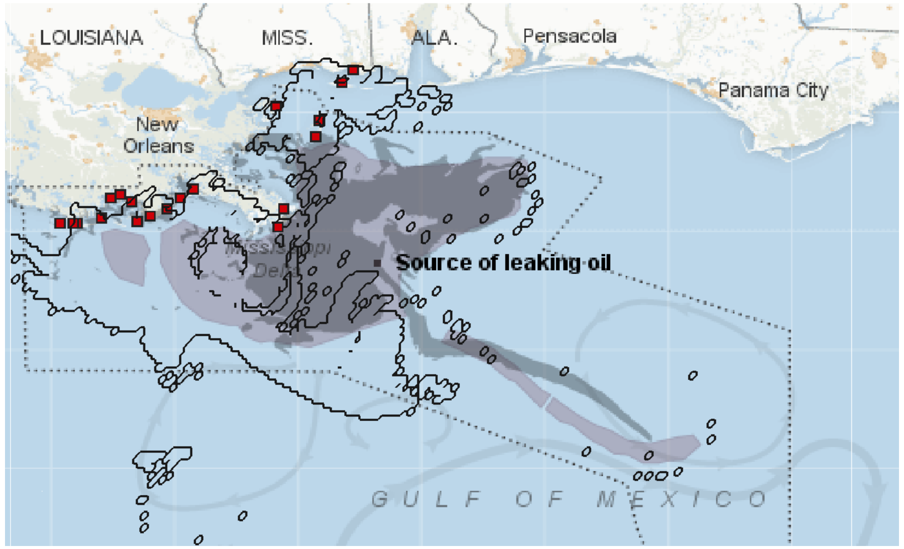
Production results

- Droplets initialized at NBL (end of the plume regime). Plume displacement and diameter are insignificant compared to dispersion on the surface => set plume as point source
- Far field calculation not sensitive to elevation of NBL
- Size range is obtained from available experiments
- Droplets:
  - rise in the water due to buoyancy
  - convected by sea currents
  - effect of wind is considered
- Turbulent dispersion is modelled
- No weathering of the oil



Satelite images





Source: skytruth.org

Satellite images were difficult to interpret: what was observed was not necessarily at the surface skin, but probably underneath it, as was proven by our simulations.

Particle Envelope/ Surface Slick boundary (this work)

Oil observed on the beach

Slick observations from satellite

Forecasts during spill by NOAA (re-initialized from satellite images)

Source: nytimes.com

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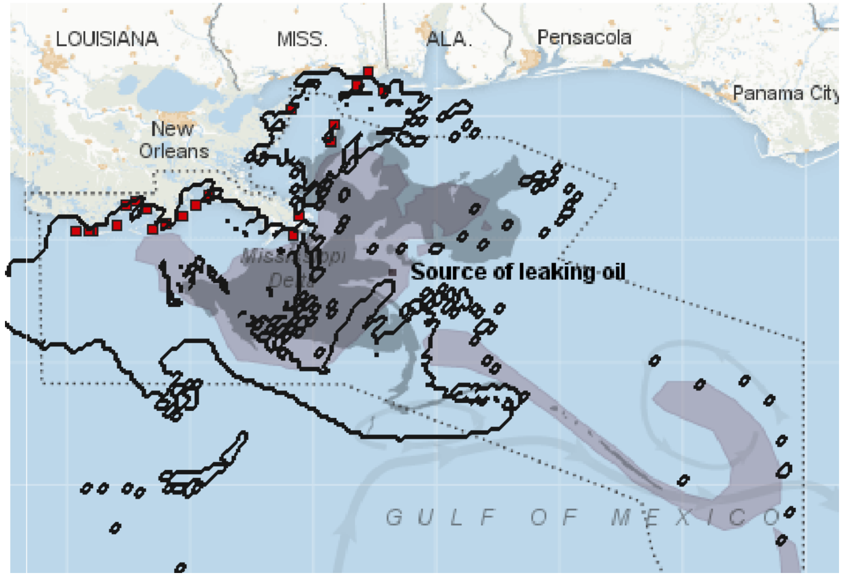
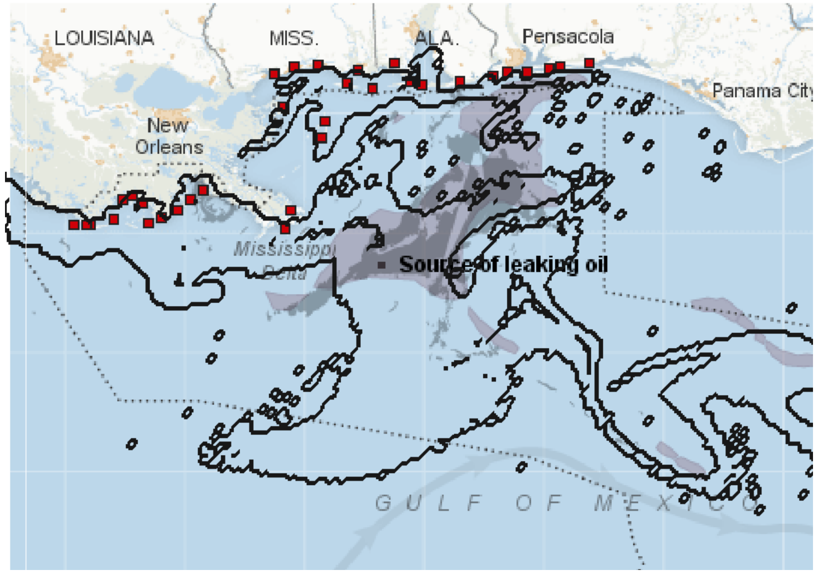
Beaching of oil

The dates for beaching were found to coincide with predictions



5-27-2010



6-6-2010

■ Oil observed on the beach

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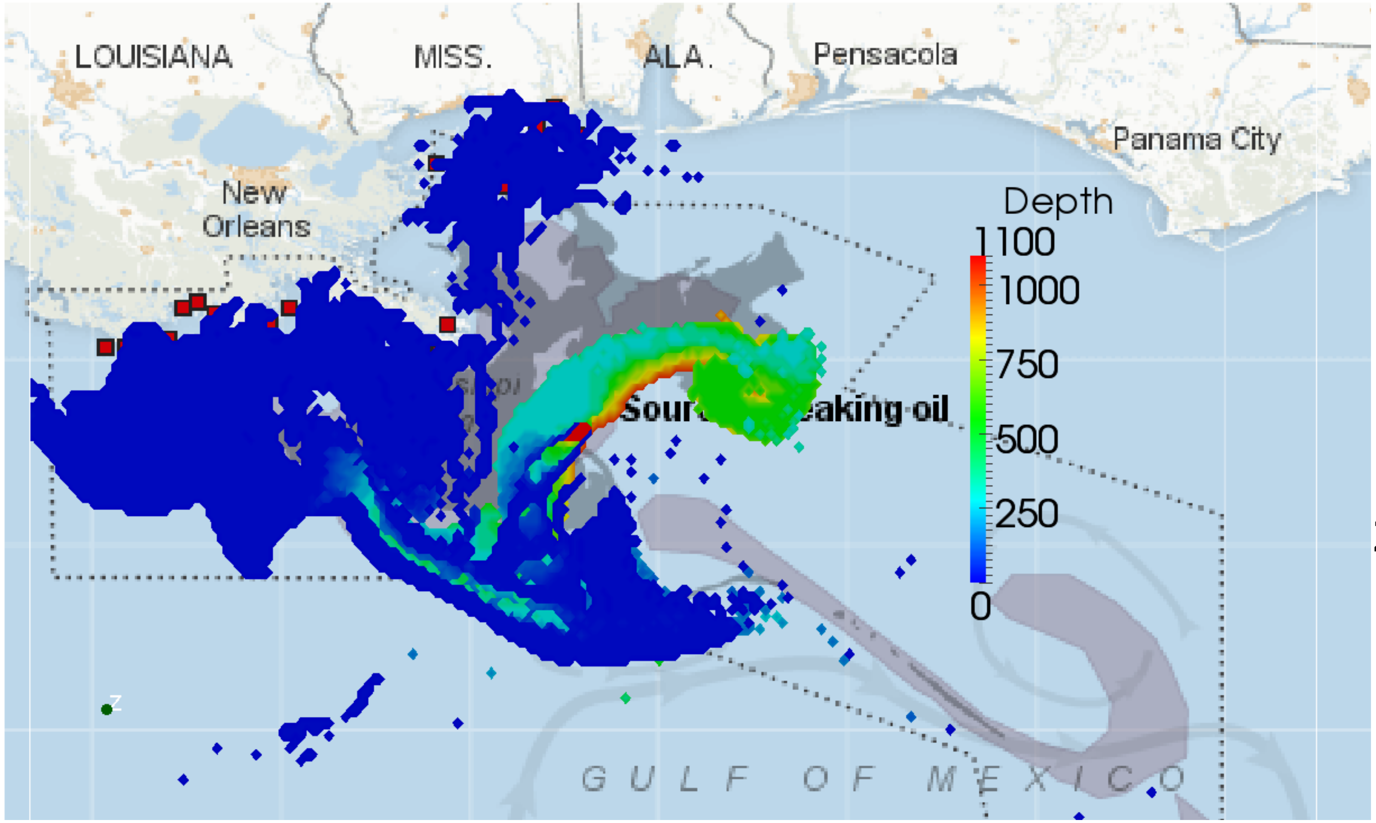
Subsurface oil

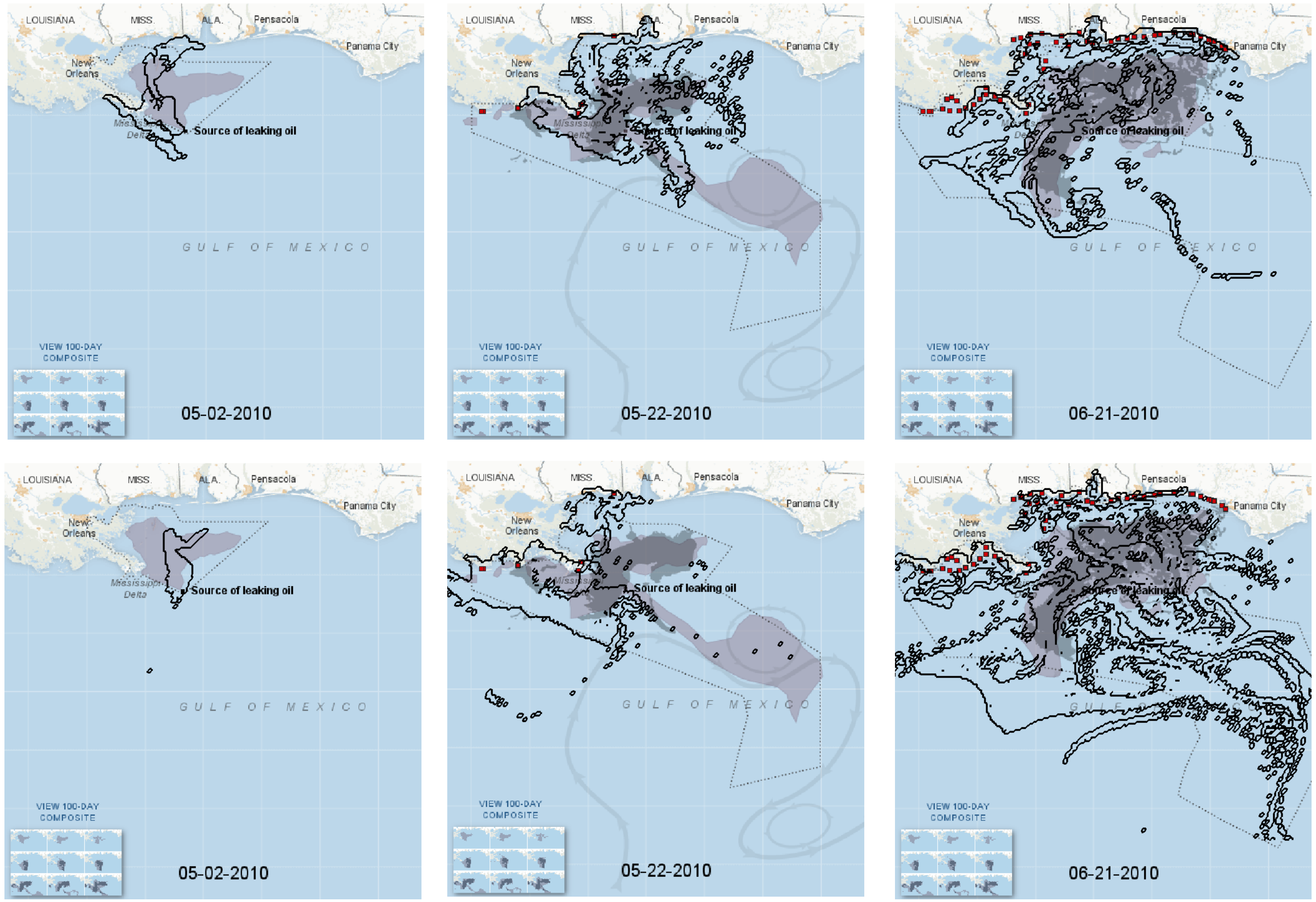


27th May

Currents models

HYCOM

IASNFS

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