Surface Trajectories of Oil Transport in the Gulf of Mexico

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JC Dietrich, et al. (2012). "Surface Trajectories of Oil Transport along the Northern Coastline of the Gulf of Mexico." *Continental Shelf Research*, in press, DOI:10.1016/j.csr.2012.03.015.

Who Are We?

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Deepwater Horizon Oil Spill (2010)

Deepwater Horizon was a 9-year-old, mobile offshore drilling unit

Located 66km from the Louisiana coastline, in 1500m of water

Platform was engulfed on 20 April by an explosion of methane gas; structure burned for more than 24hr before sinking on 22 April

Explosion killed 11 workers and injured 17

Oil spill flow rates:

- Estimated to have begun at a rate of 9900 $m^3\ d^{-1}$
- Diminished over time to a final rate of 8400 $m^3\ d^{-1}$ on 15 July 2010

Emergency responders relied on satellite and aerial imagery

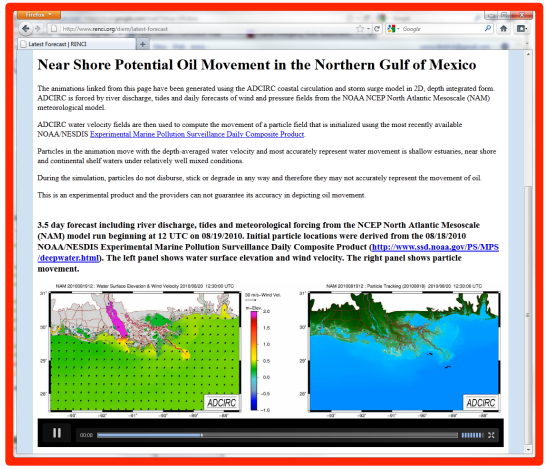
Nearshore Oil Transport : Motivation

Satellite imagery can only show current location of the slick

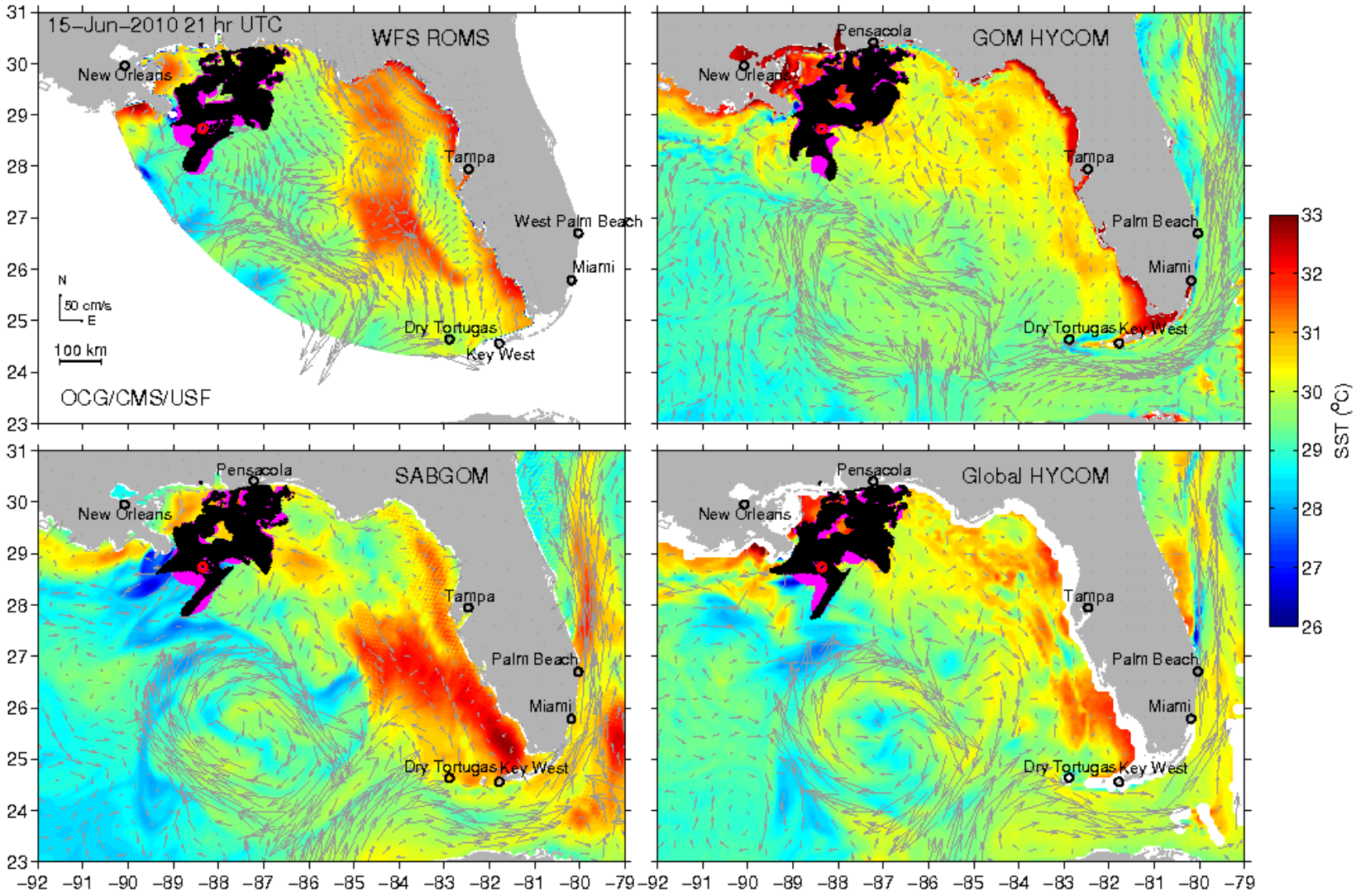
- Where will the oil move?
- What happens if a hurricane approaches?

Forecasts need to be accurate and fast

- Share computed circulation with NOAA,
  other spill modelers
- Share oil transport with emergency managers
  in real time (http://adcirc.org/oilspill)

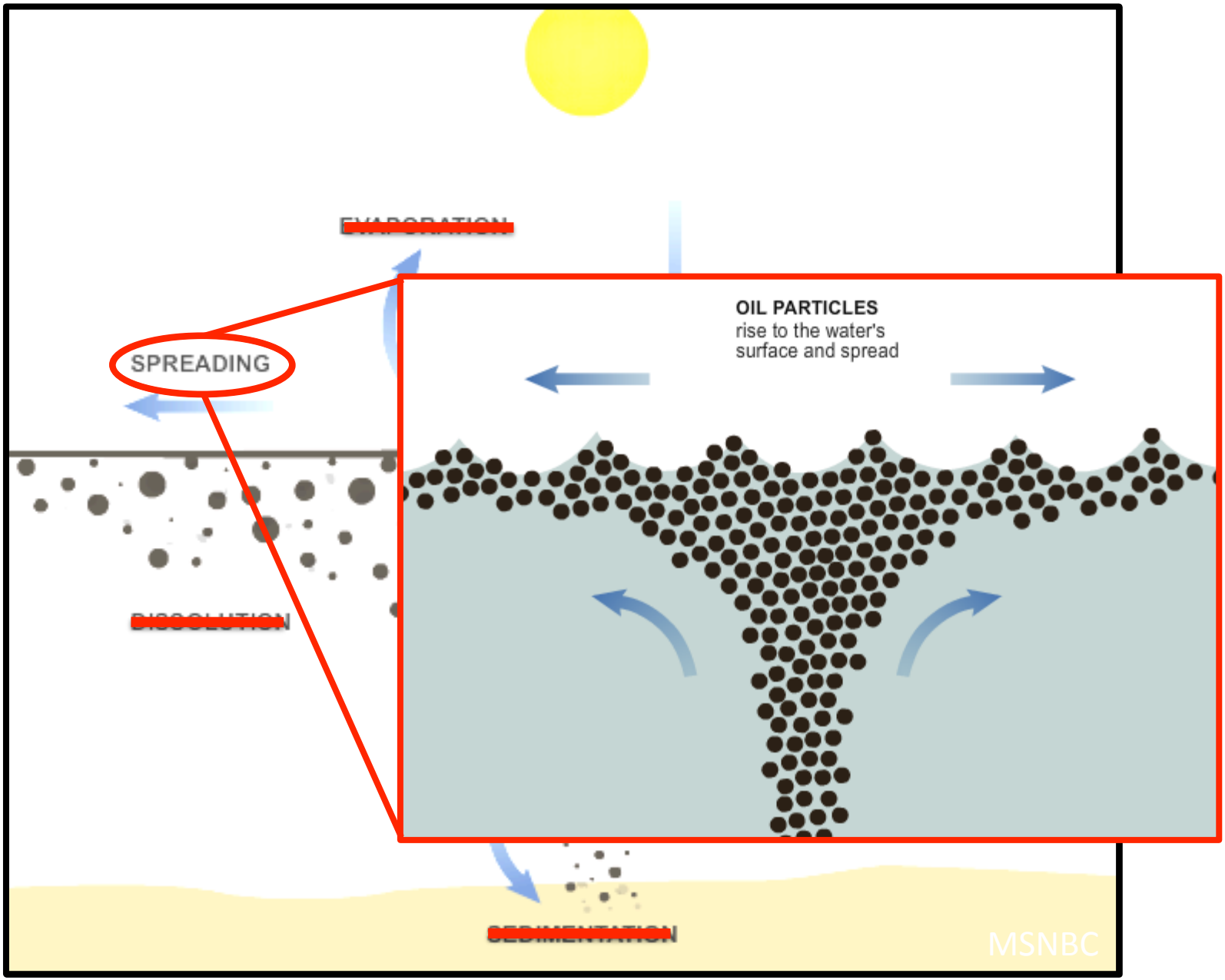


Nearshore Oil Transport : Motivation

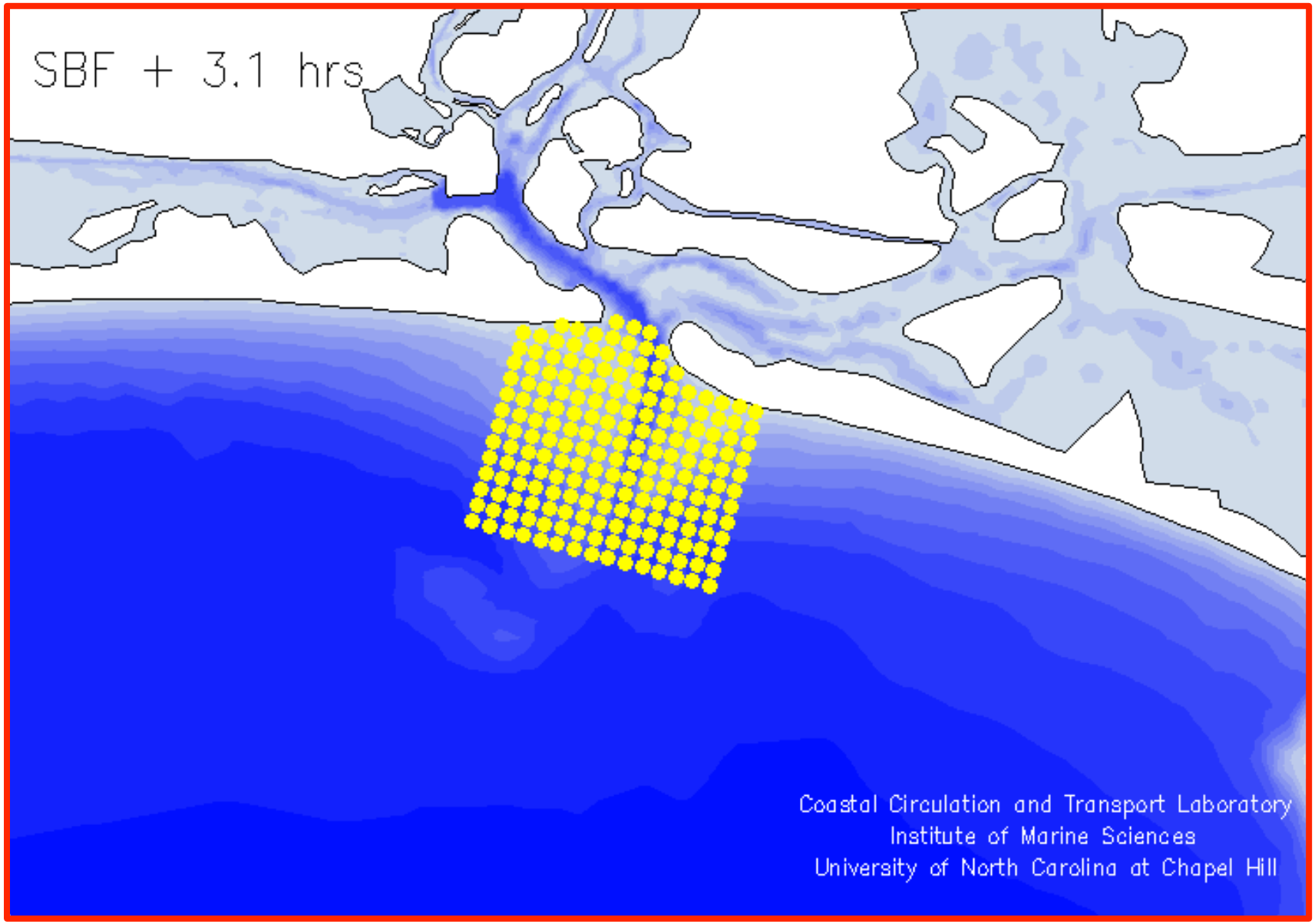


Ensemble forecasts via the Ocean Circulation Group at the University of South Florida:
http://ocgweb.marine.usf.edu/~liu/oil.html

Nearshore Oil Transport : Challenges



Nearshore Oil Transport : Lagrangian Particles



Nearshore Oil Transport : Lagrangian Particles

Particle positions are tracked through the unstructured mesh:

$$\vec{x}_p(t+\Delta t) = \vec{x}_p(t) + \vec{u}\left(\vec{x}_p, t\right)\Delta t + \vec{D}$$

- where the dispersion uses a stochastic perturbation (Proctor et al., 1994):

$$\vec{D} = (2R-1)\sqrt{\vec{c}\vec{E}_v \Delta t}$$

- with: $0 < R < 1$ is a random number,

$\vec{E}_v = 10$ m²/s are turbulent coefficients, and

$\vec{c} = 12$ are scaling coefficients;

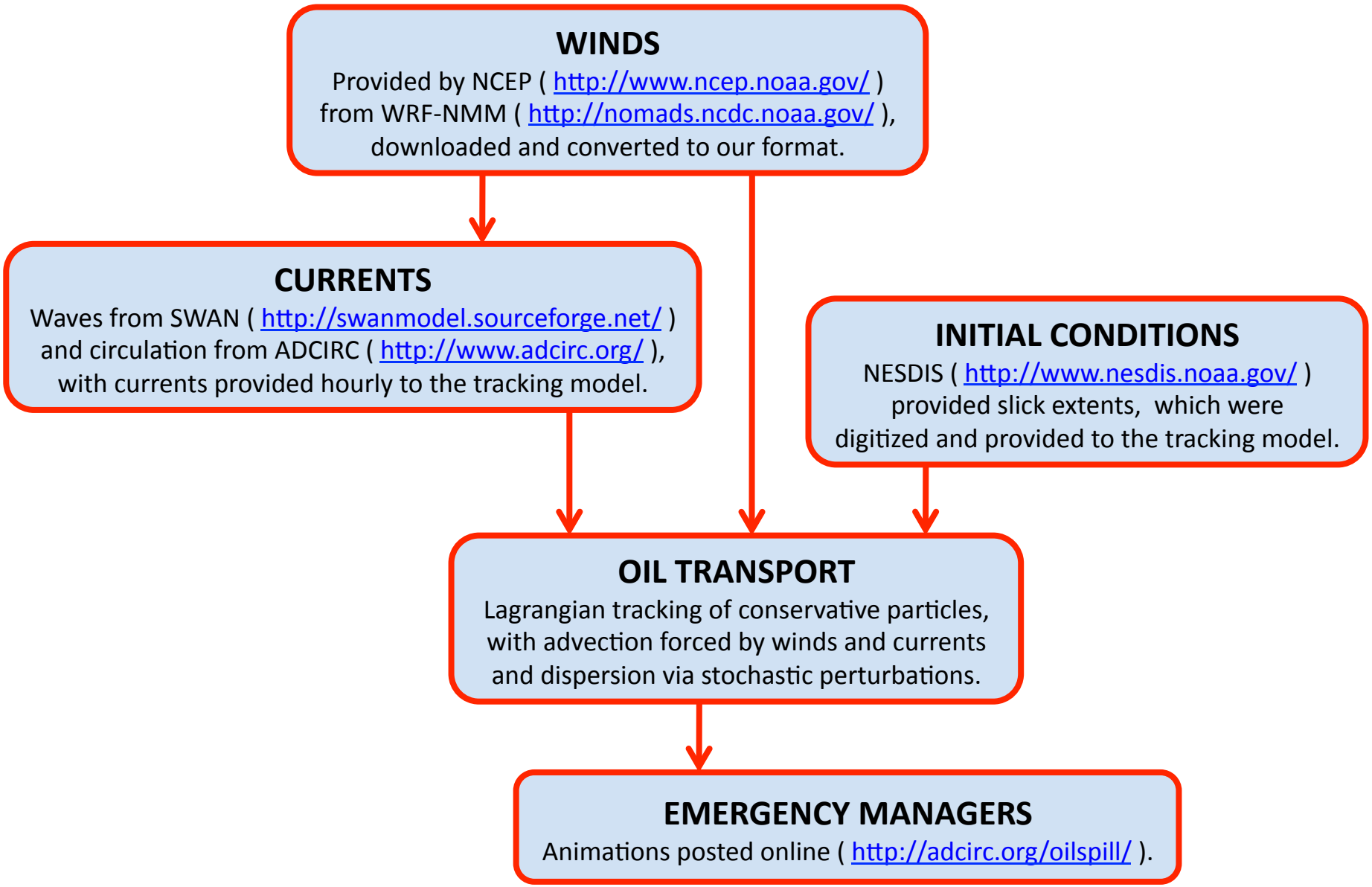
- and where the velocities are a linear combination of currents and winds:

$$\vec{u}\left(\vec{x}_p, t\right) = F_c \vec{u}_c\left(\vec{x}_p, t\right) + F_w \vec{u}_w\left(\vec{x}_p, t\right)$$

- with: $F_c = 1$ and $F_w = 0$.

Using hybrid OpenMP/MPI, 11M particles can be tracked on a 10M-element mesh in about **5.5 min/day** using 256 cores on TACC Ranger.

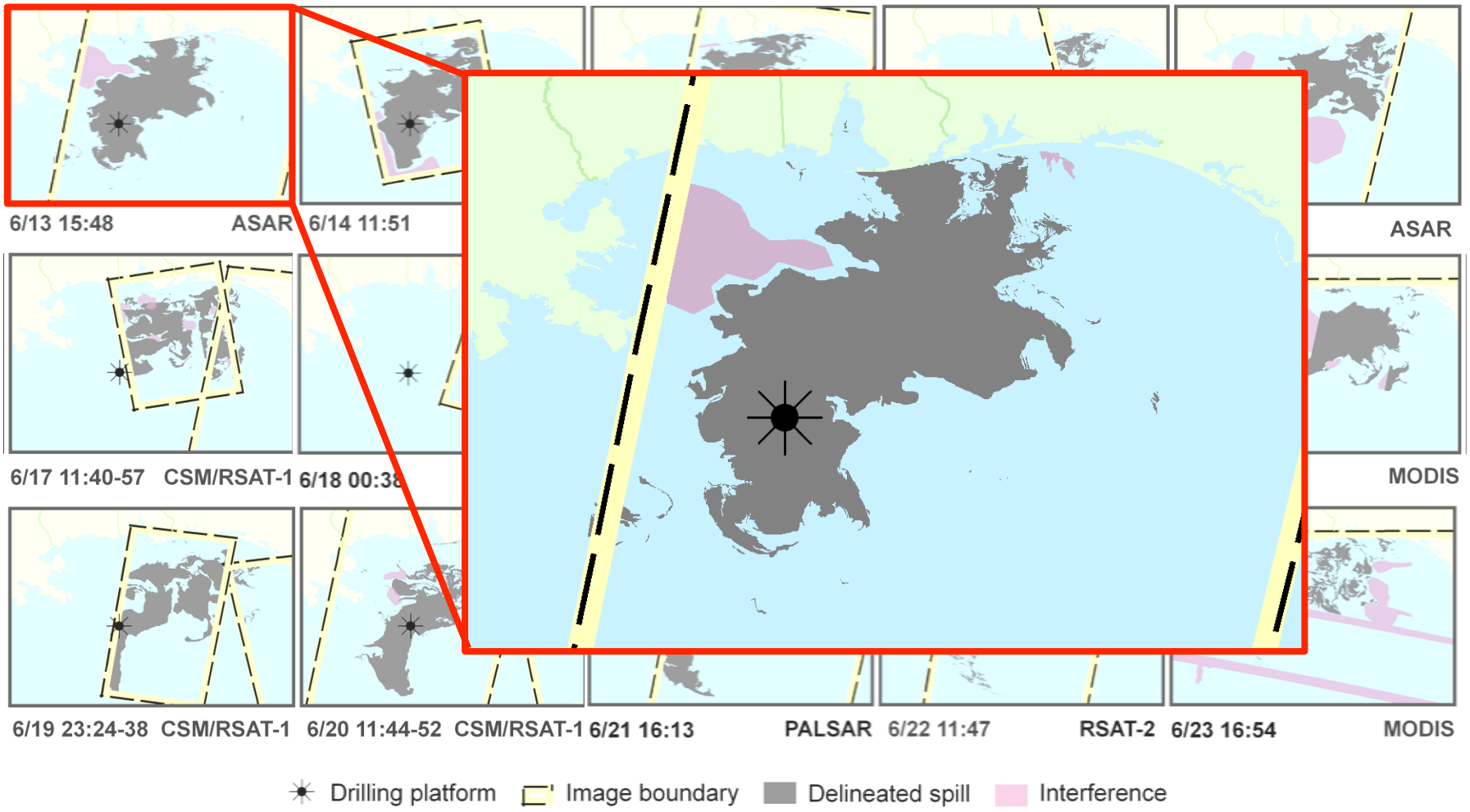
Nearshore Oil Transport : Flow Chart



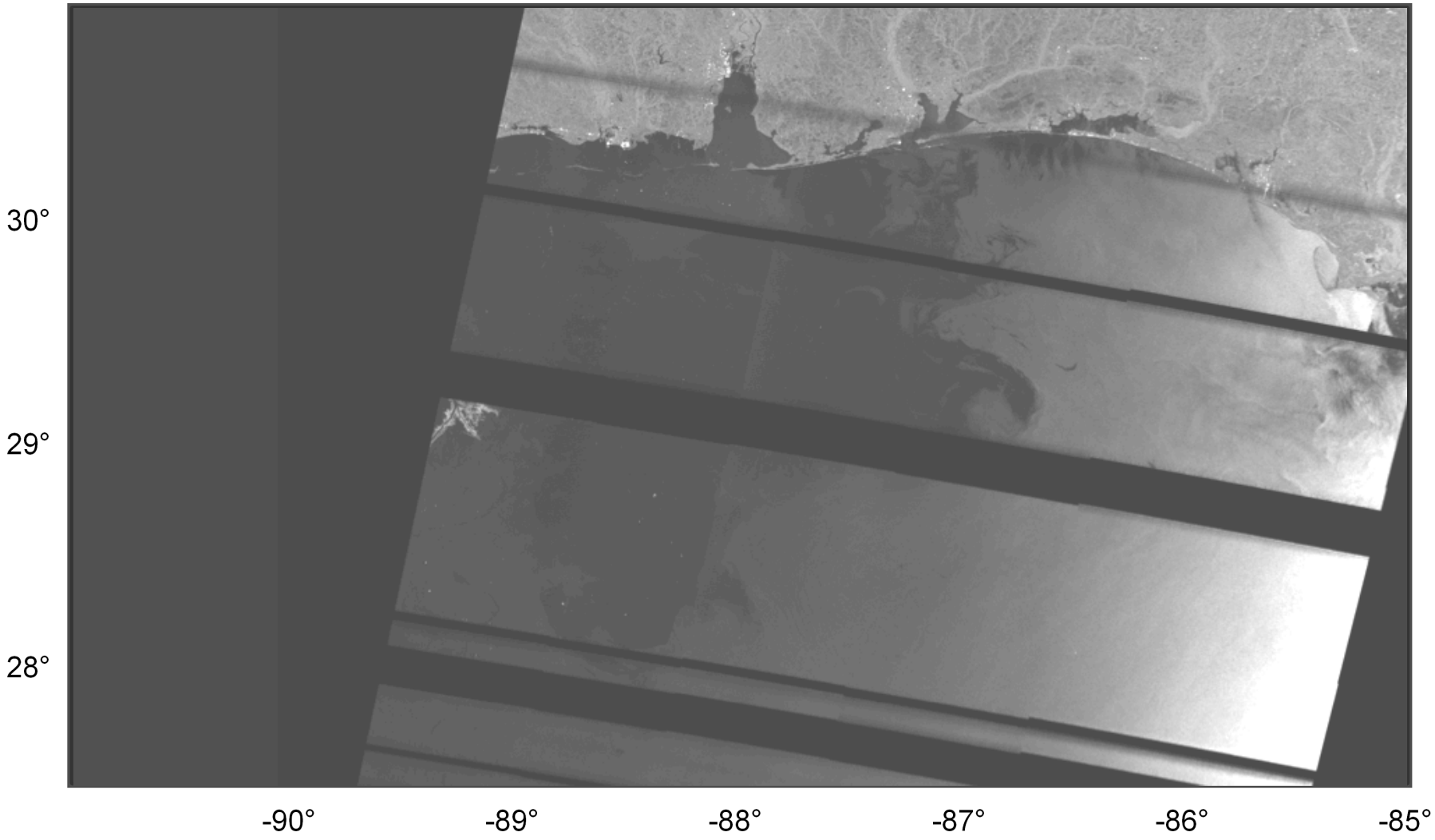
Validation : Satellite Imagery

Examples of available imagery during 13-23 June 2010:

- NESDIS consolidated observations from a suite of satellite sensors



Validation : Mid-June



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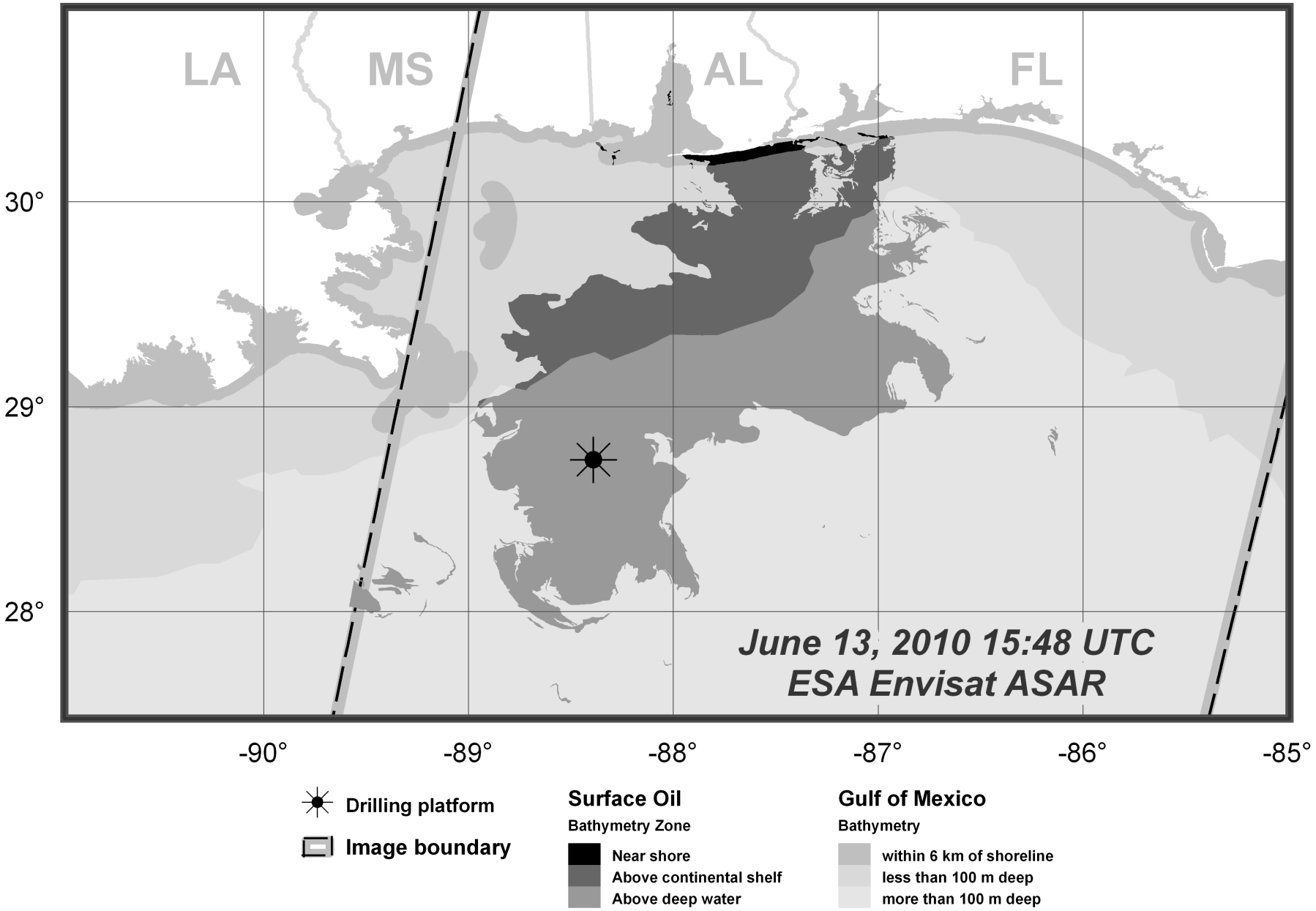

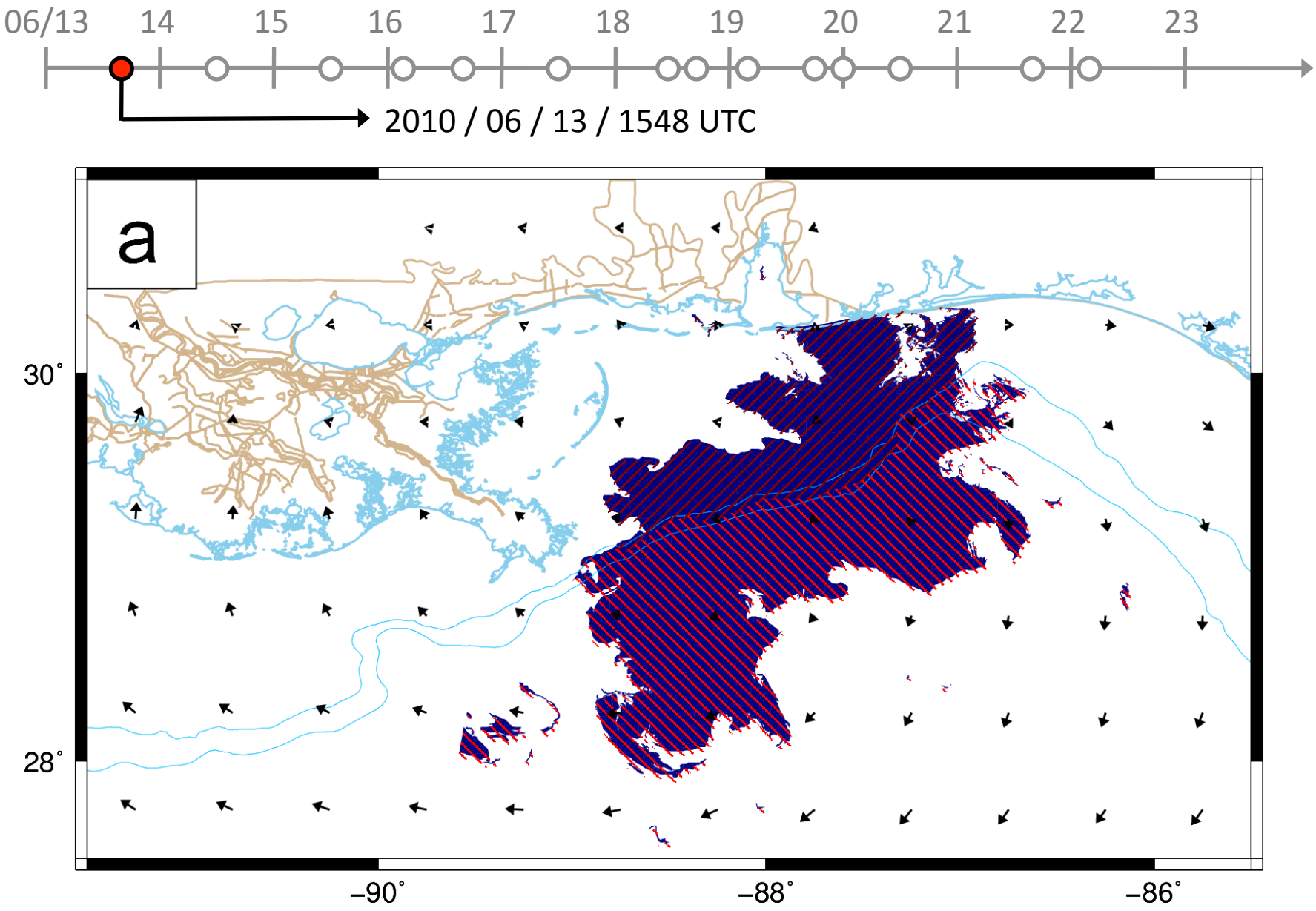
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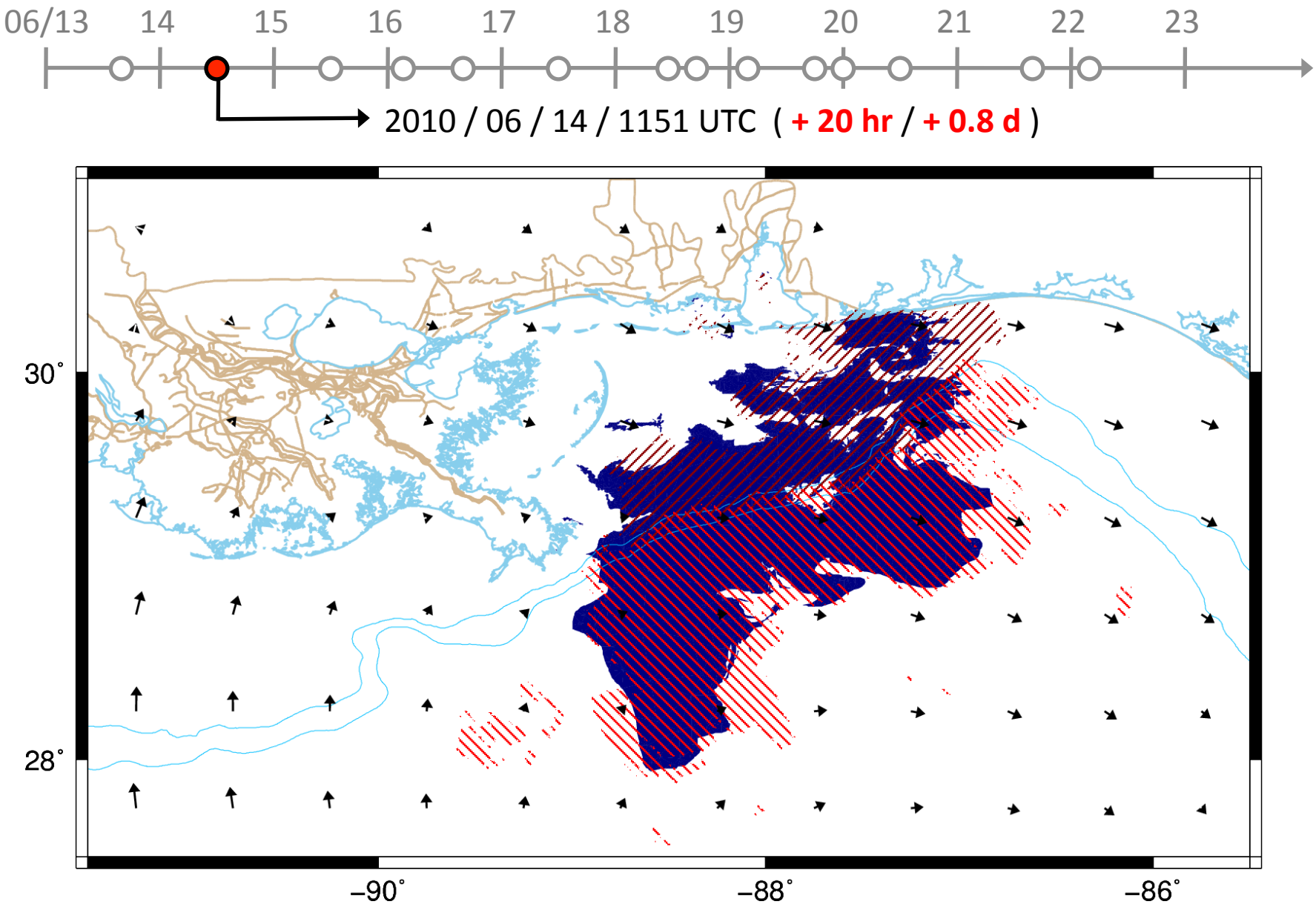
Satellite Imagery
Predicted Particle Locations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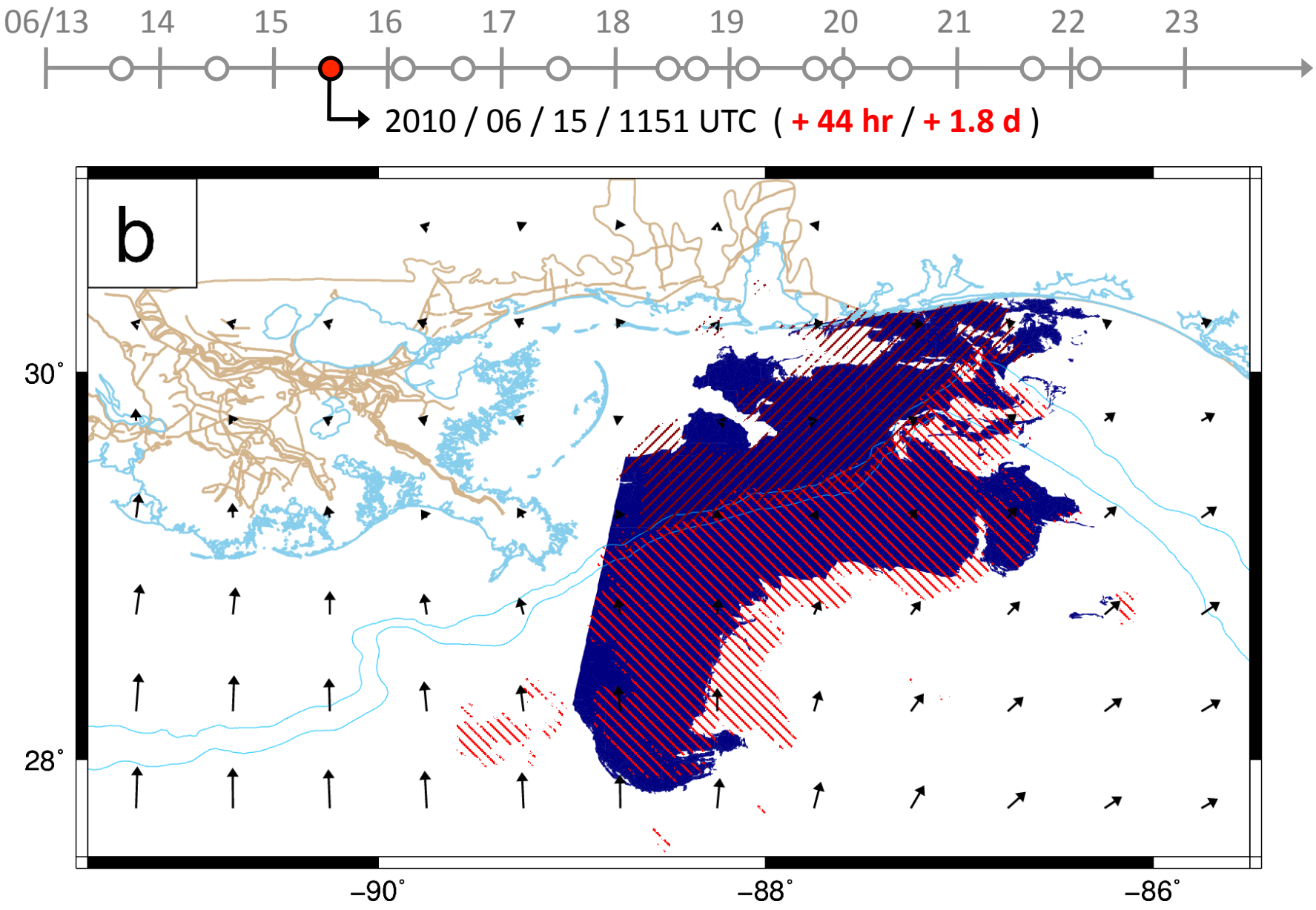
Satellite Imagery
Predicted Particle Locations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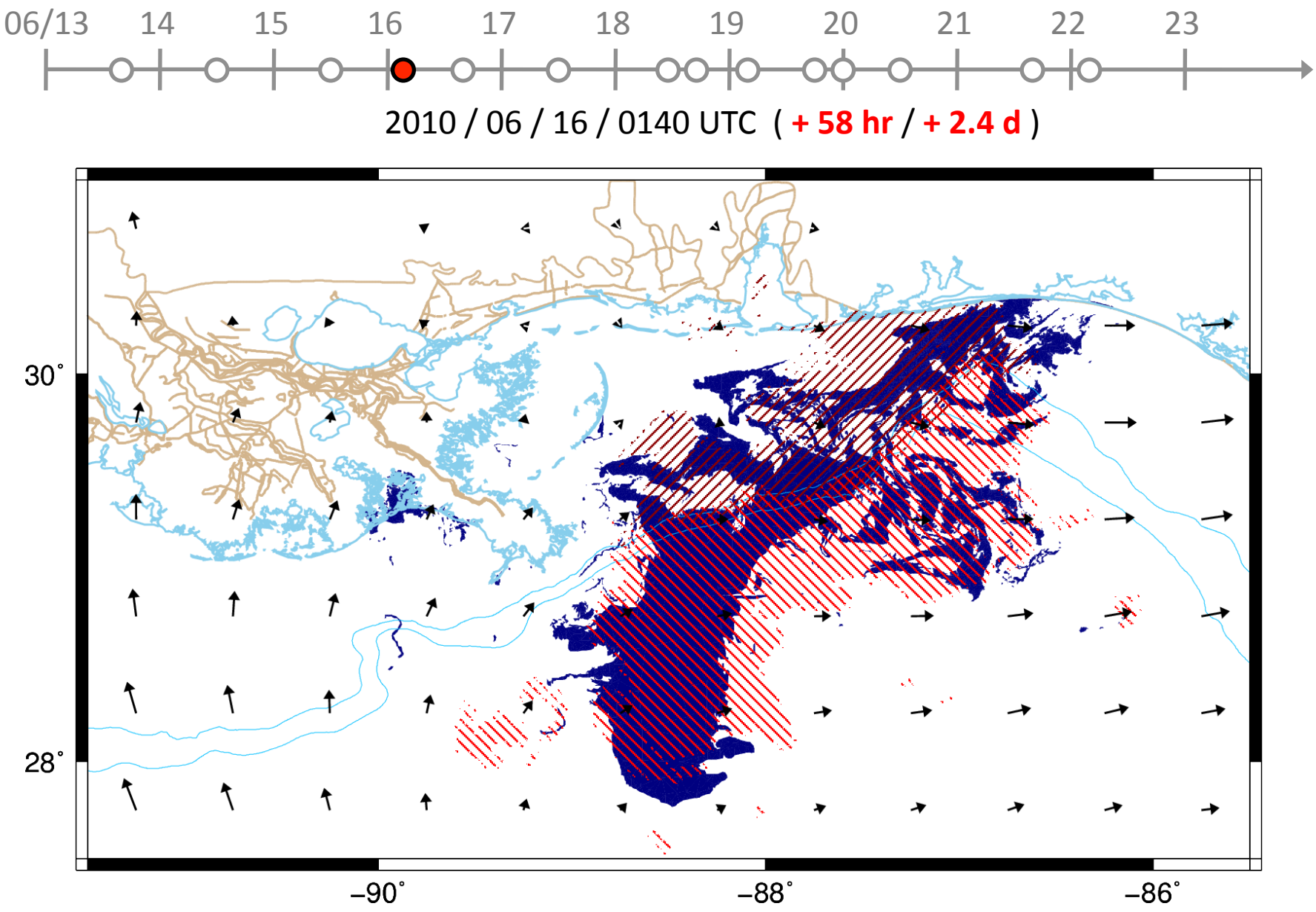
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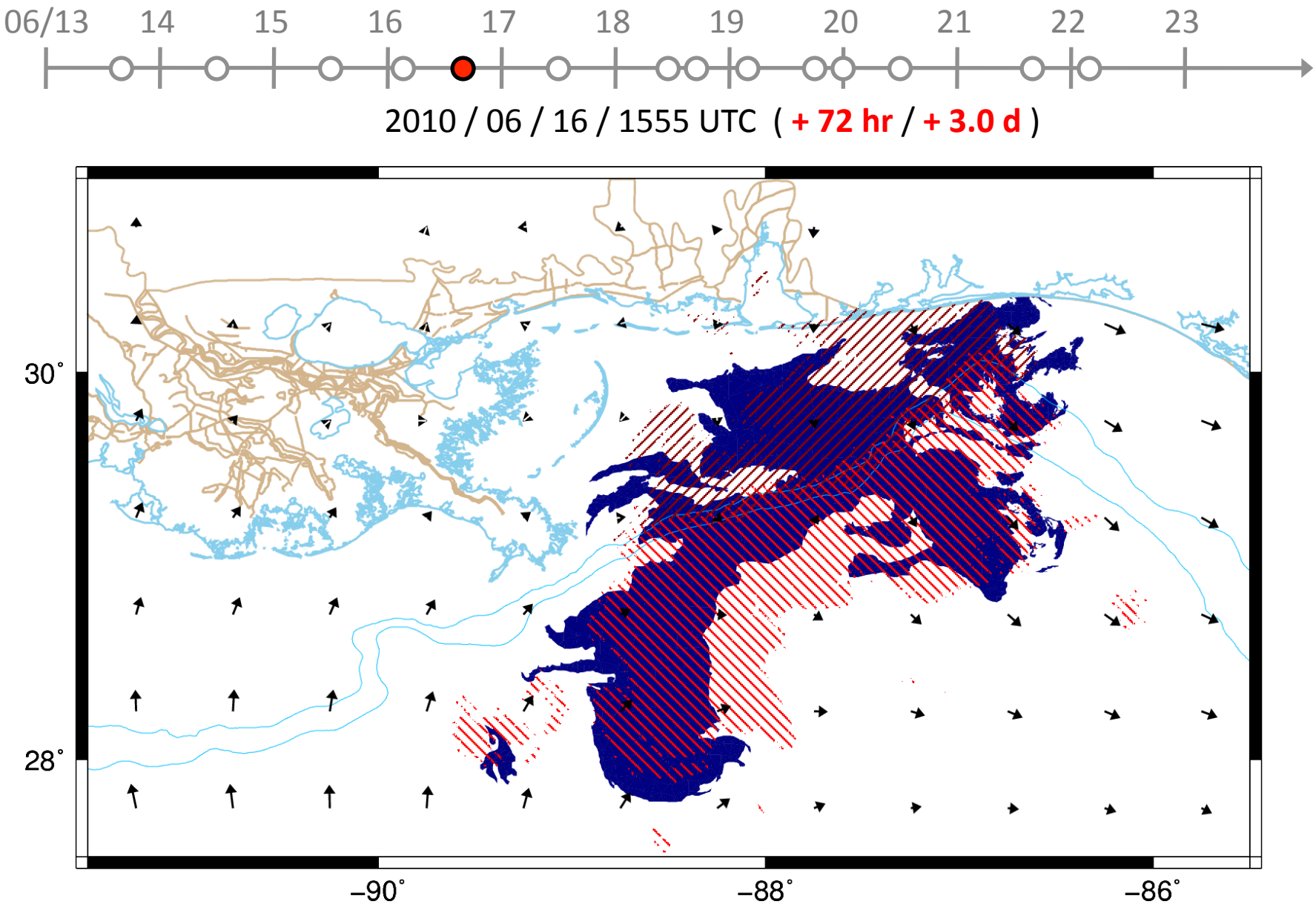
Satellite Imagery
Predicted Particle Locations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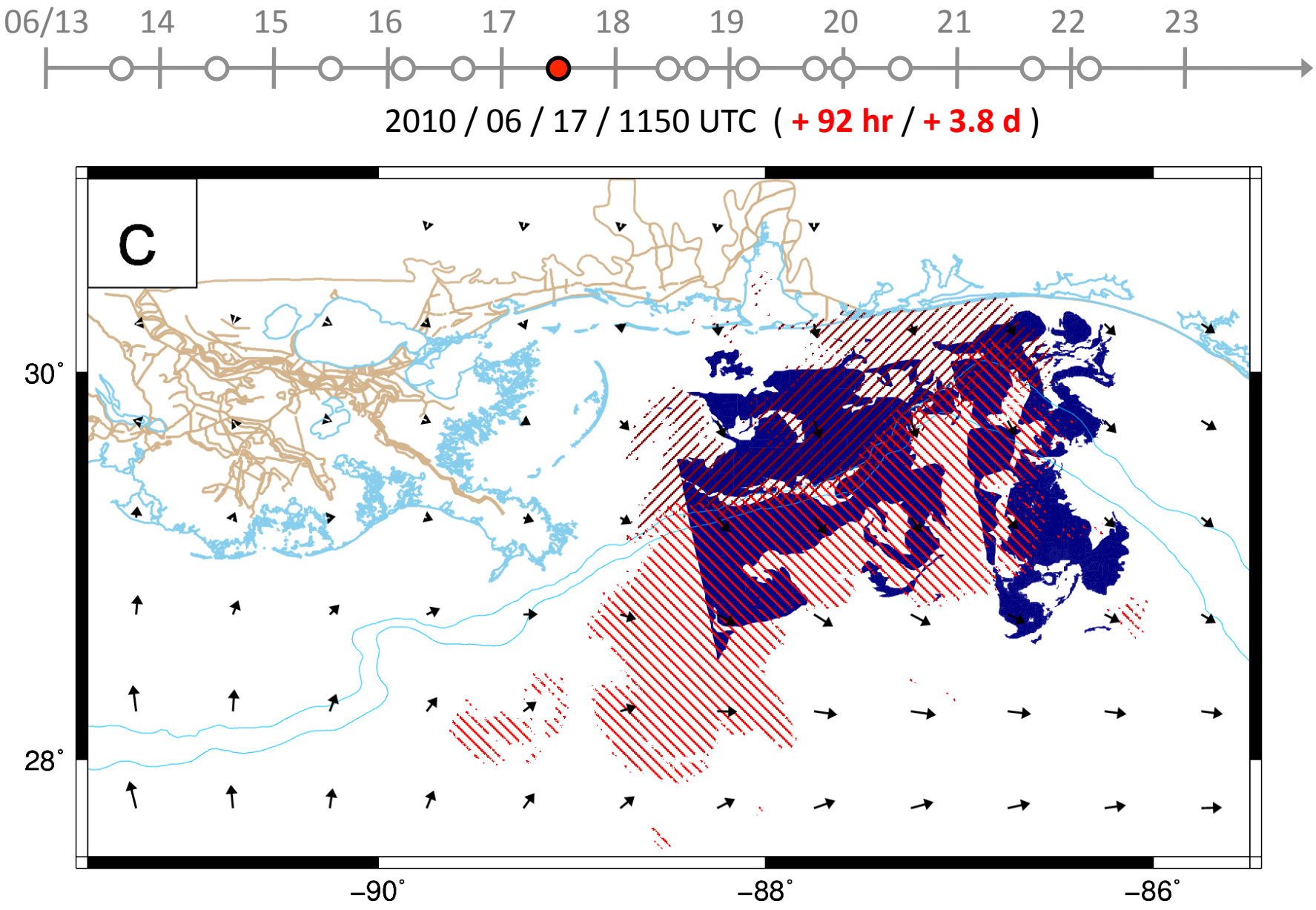
Satellite Imagery
Predicted Particle Locations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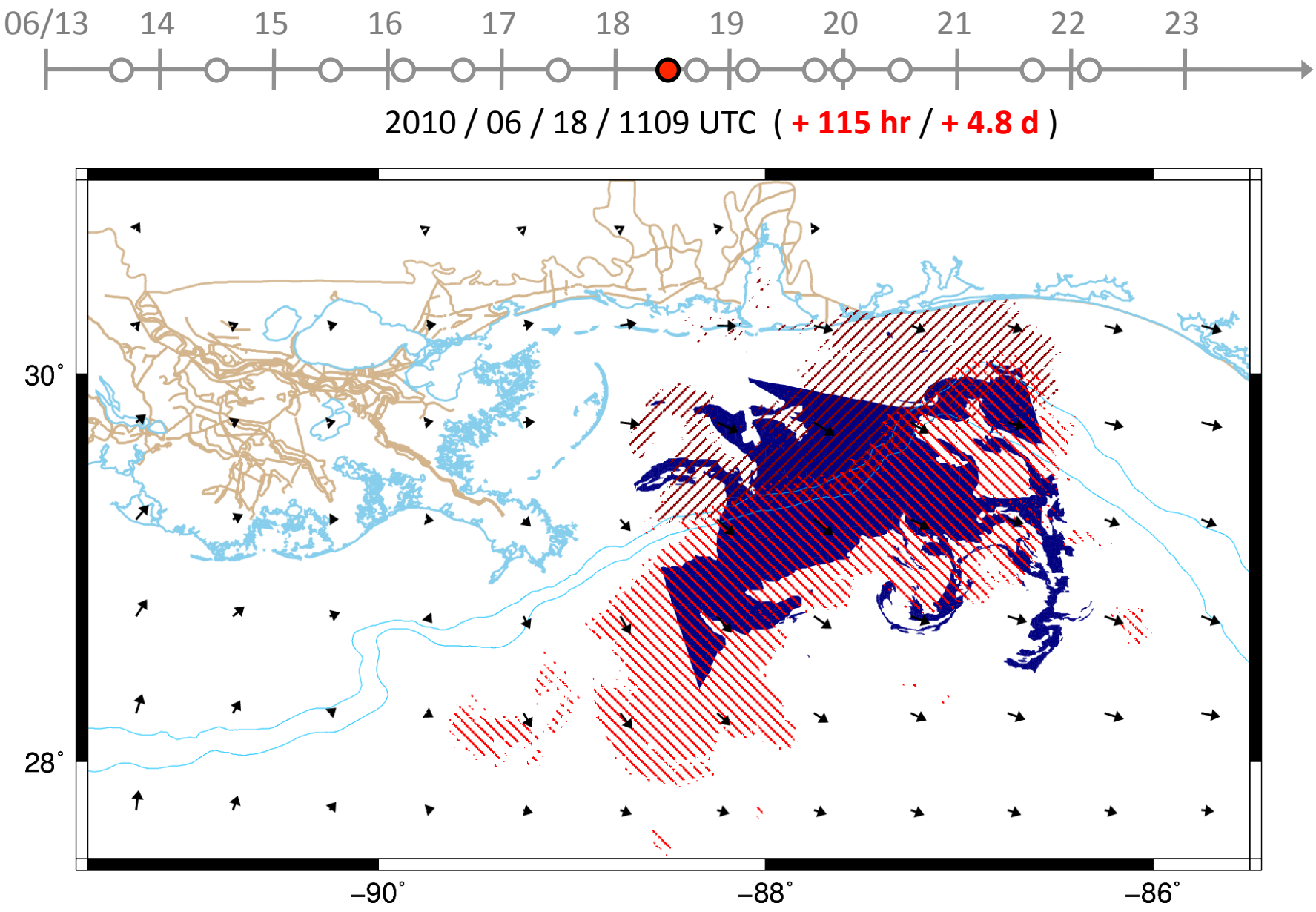
Satellite Imagery
Predicted Particle Locations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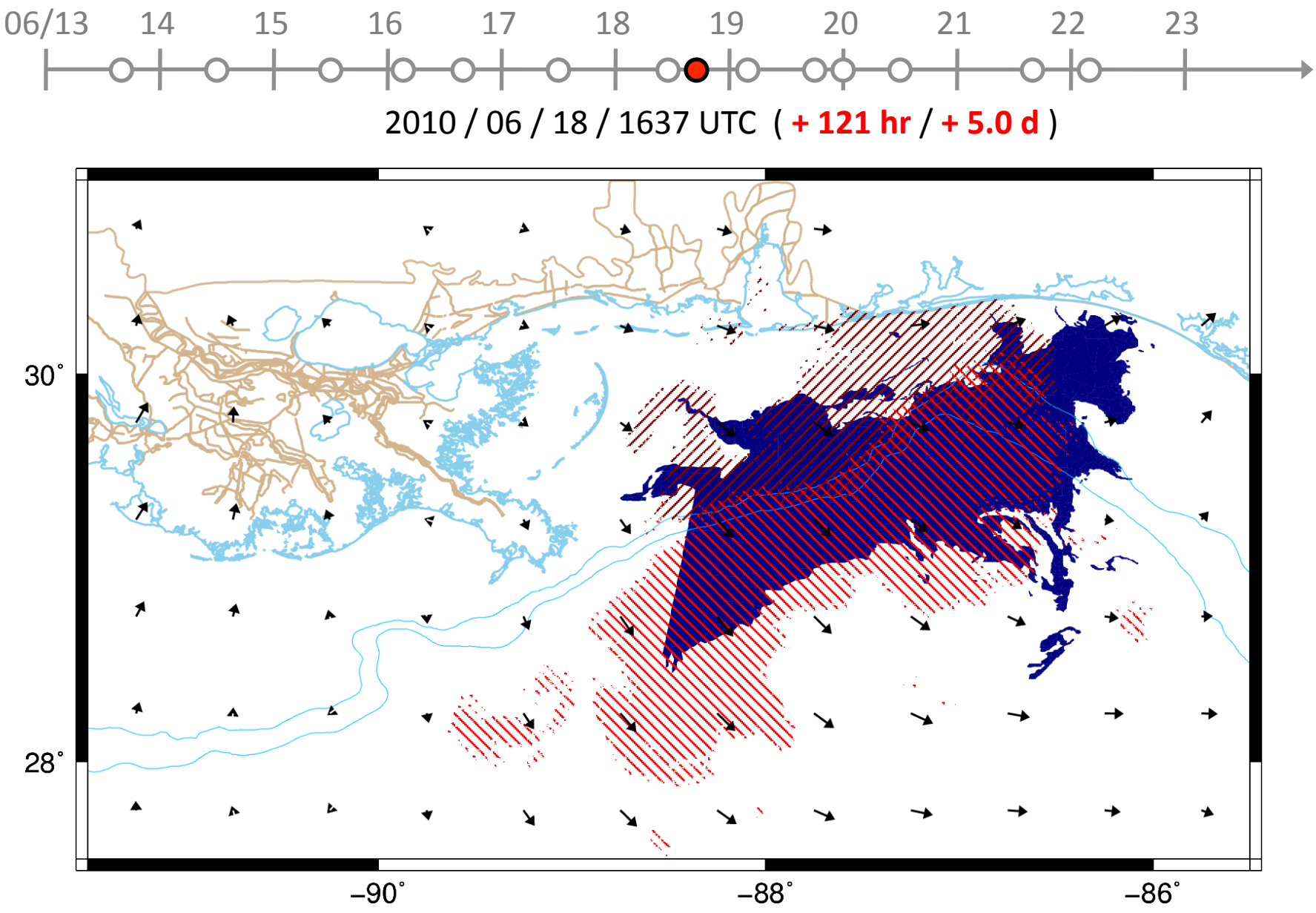
Predicted Particle Locations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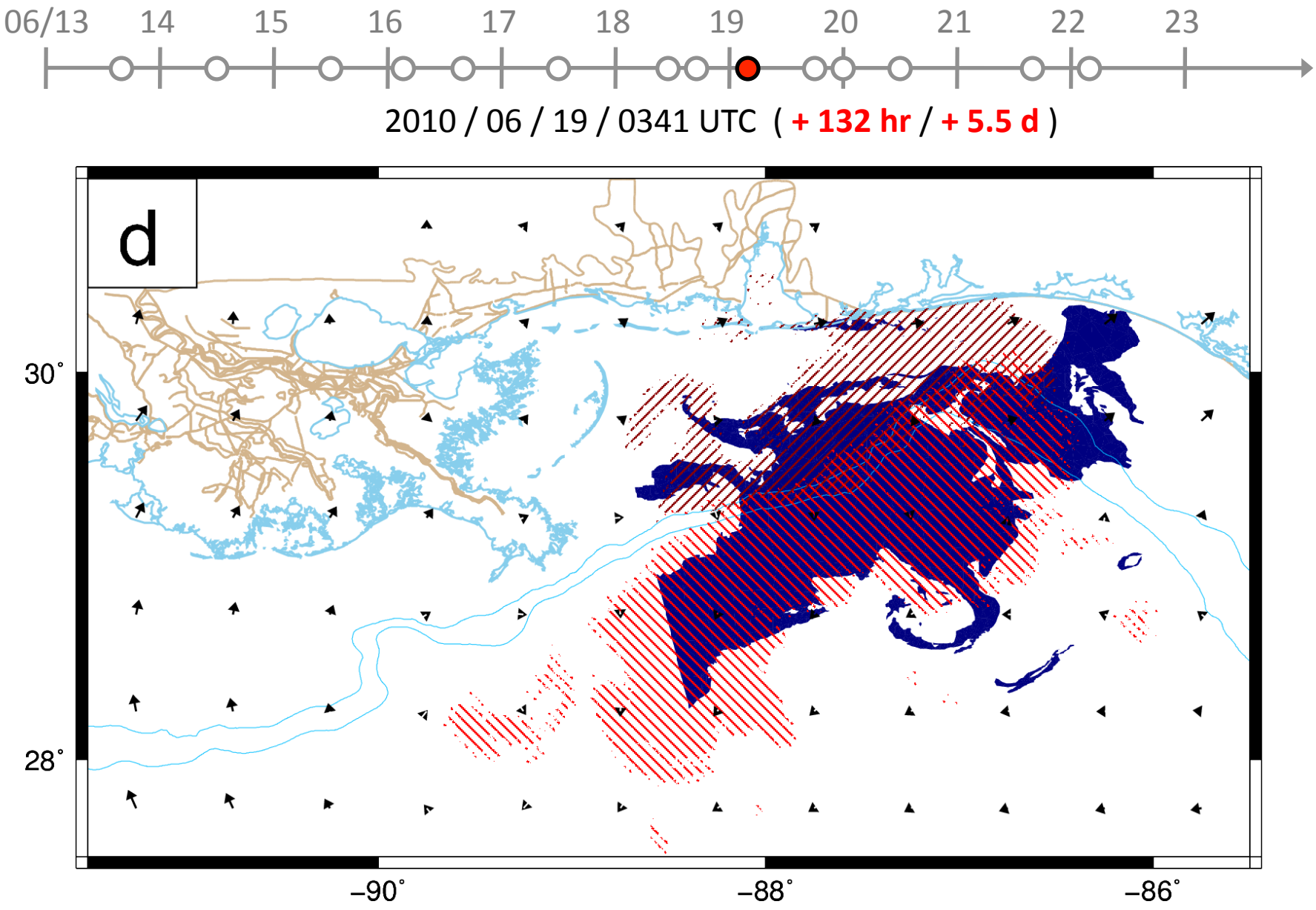
Satellite Imagery
Predicted Particle Locations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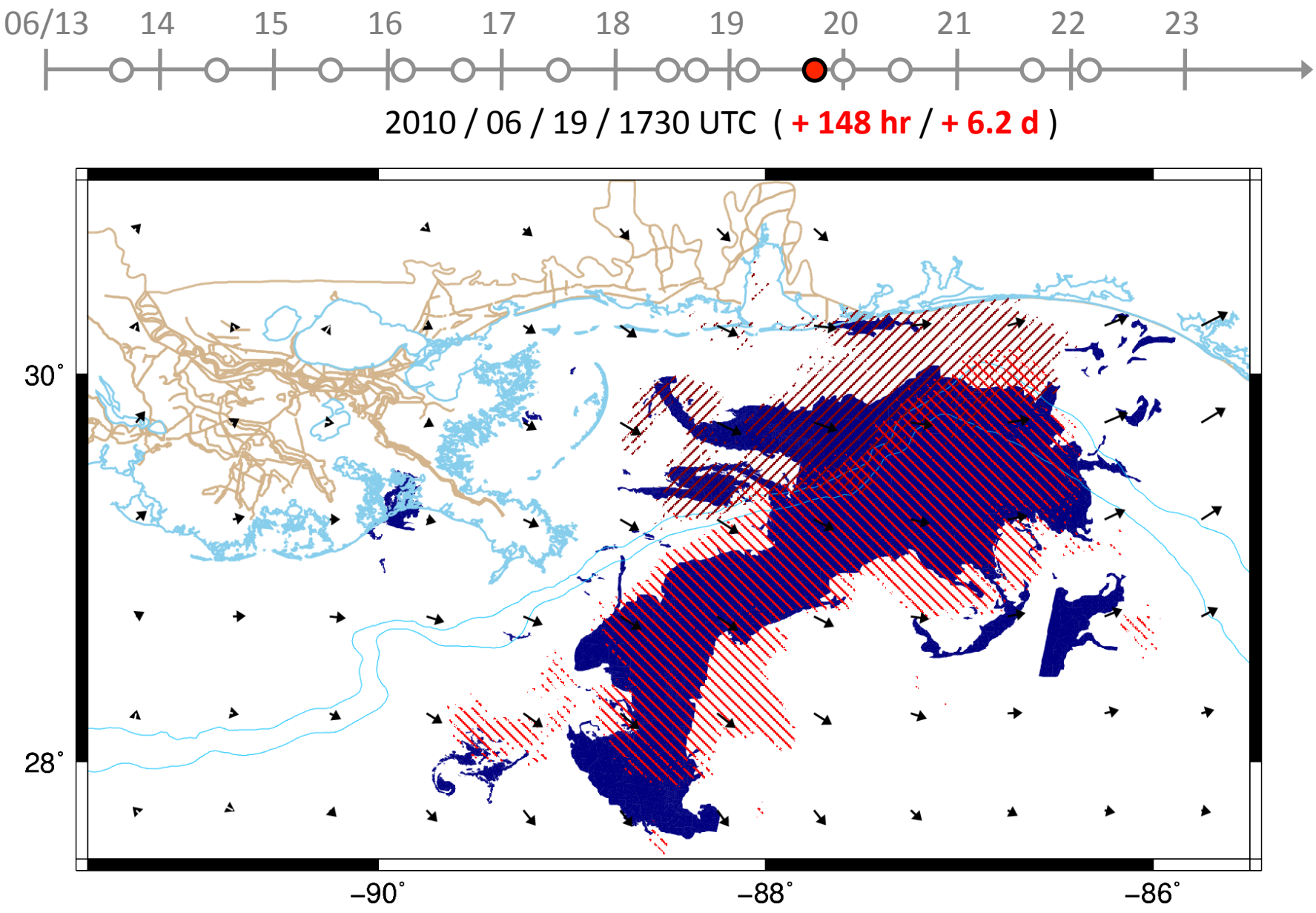
Satellite Imagery
Predicted Particle Locations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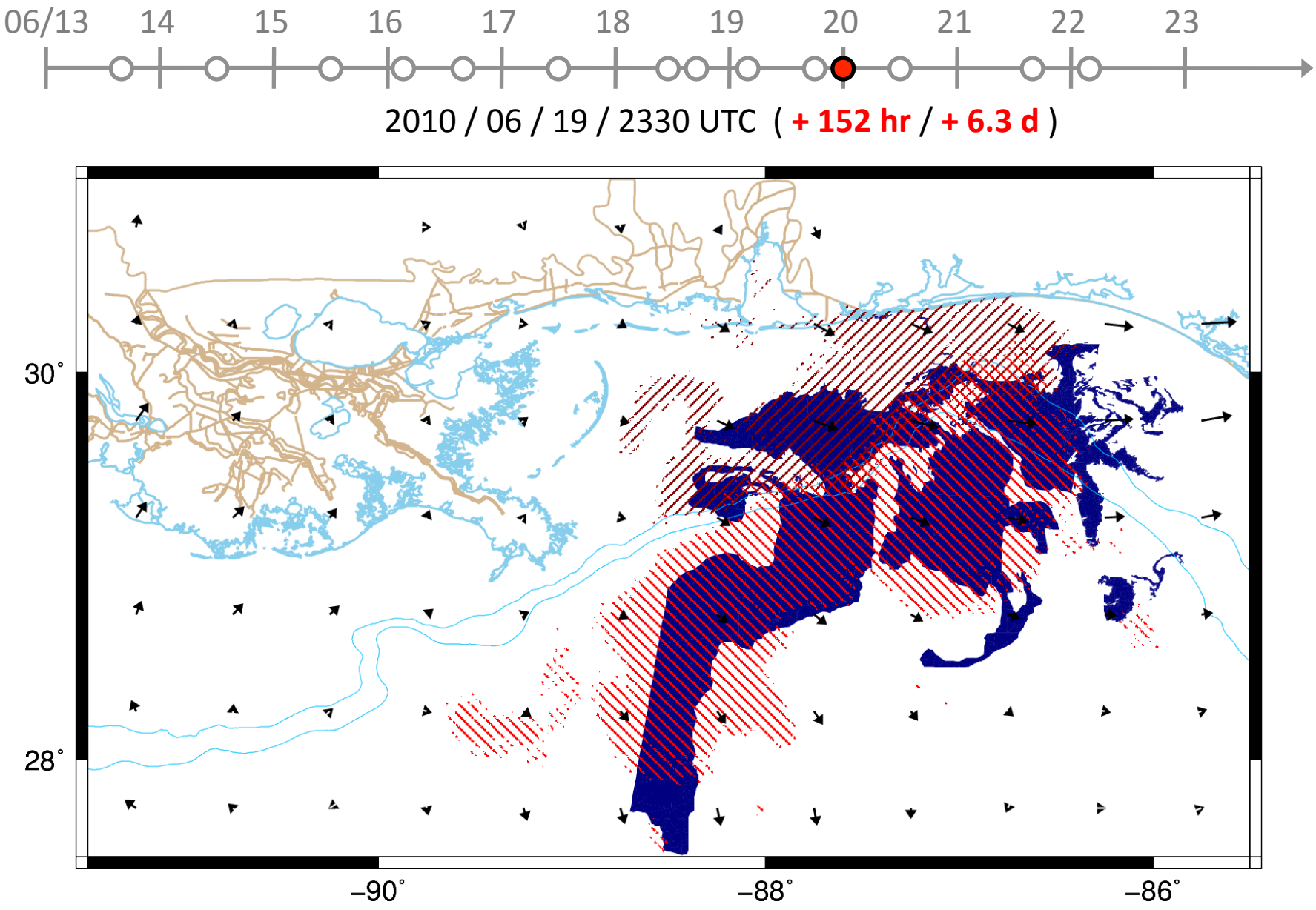
Satellite Imagery
Predicted Particle Locations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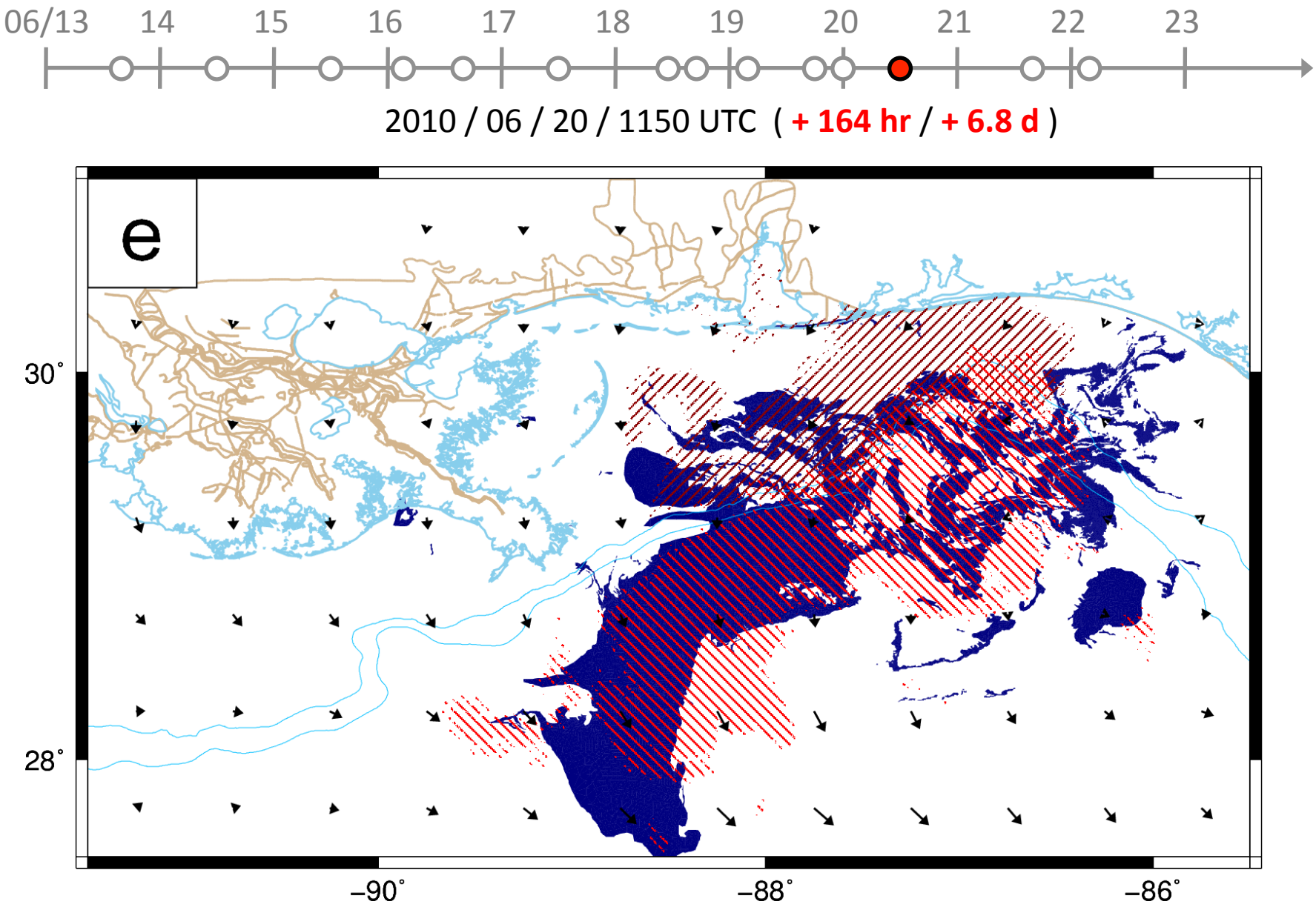
Satellite Imagery
Predicted Particle Locations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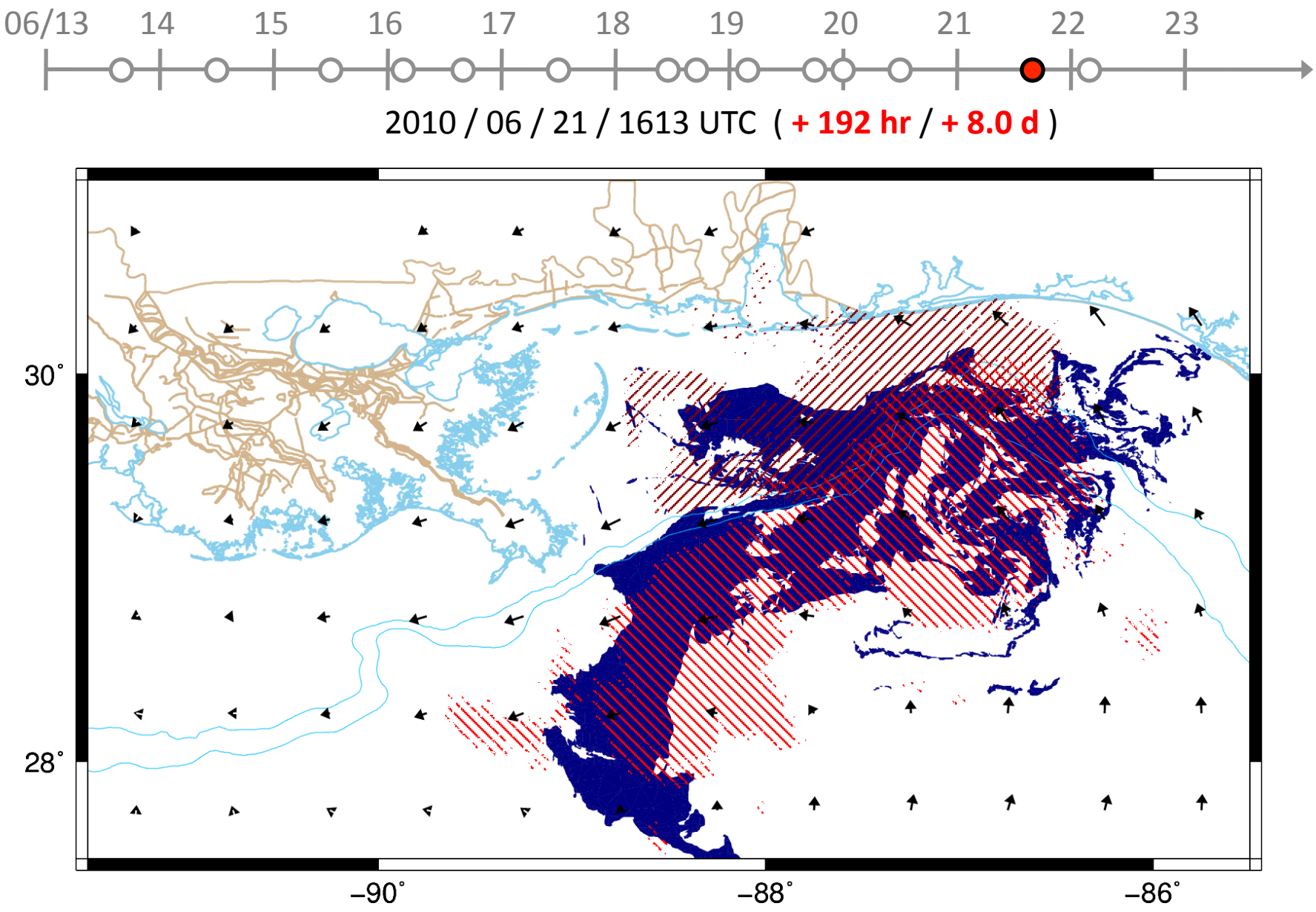
Satellite Imagery
Predicted Particle Locations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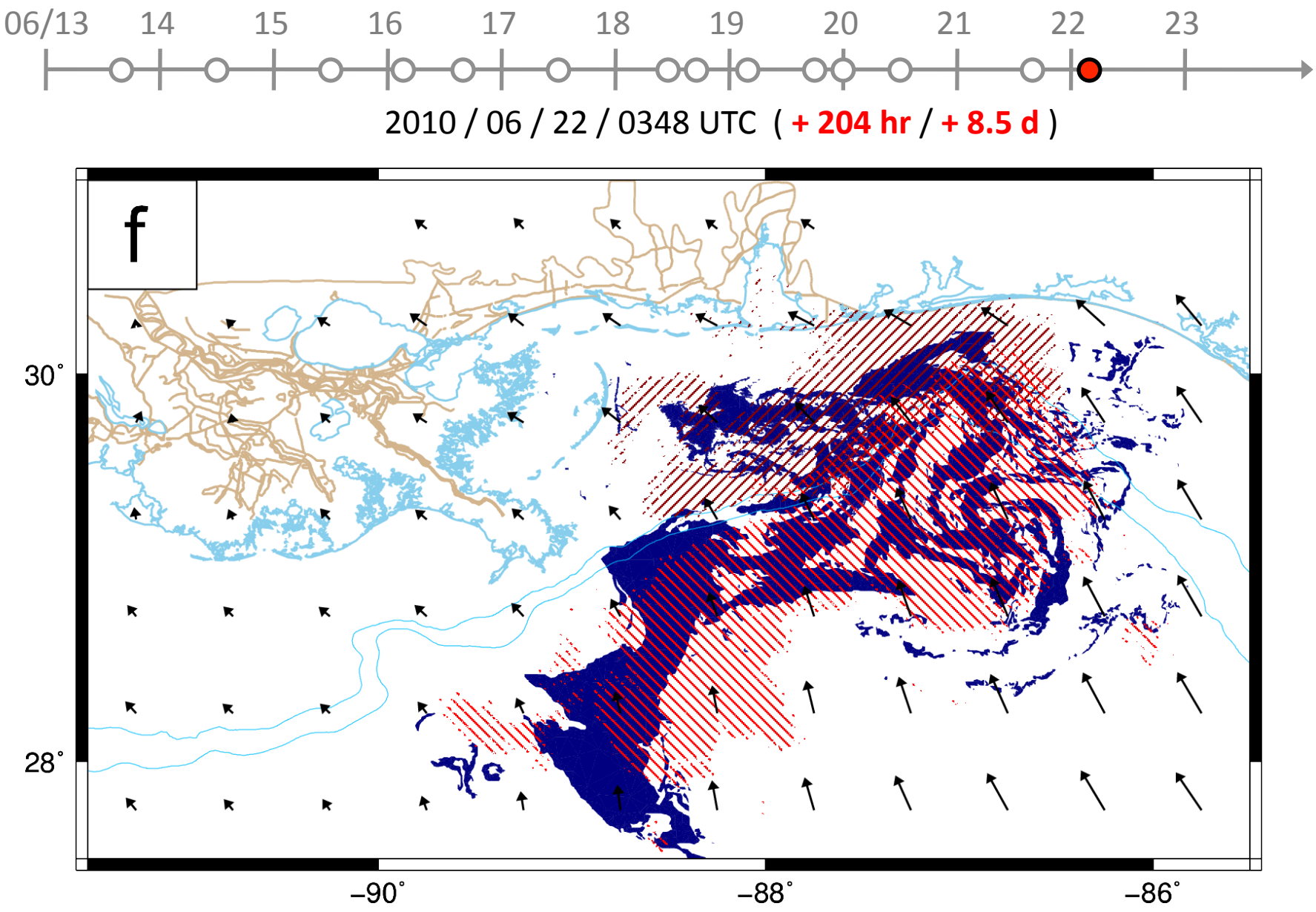
Satellite Imagery
Predicted Particle Locations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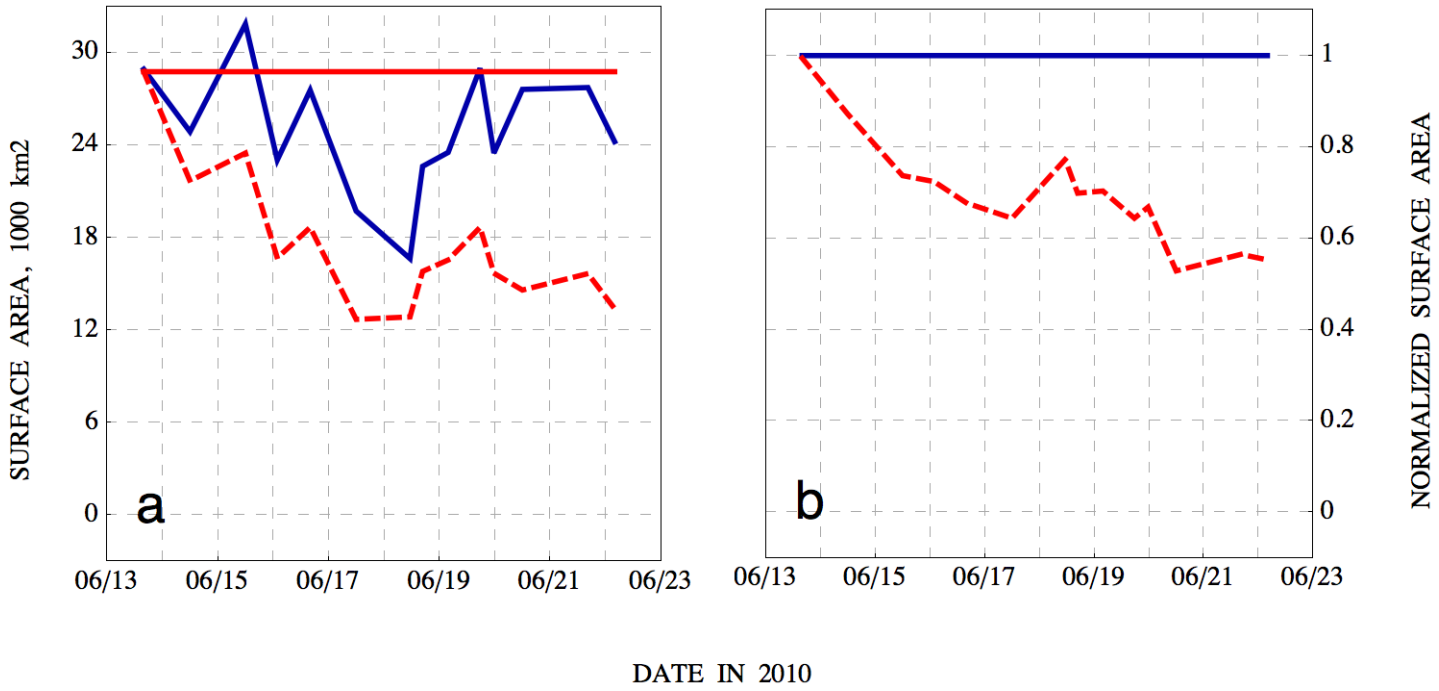
Satellite Imagery
Predicted Particle Locations

Validation : Mid-June : Computed Overlap



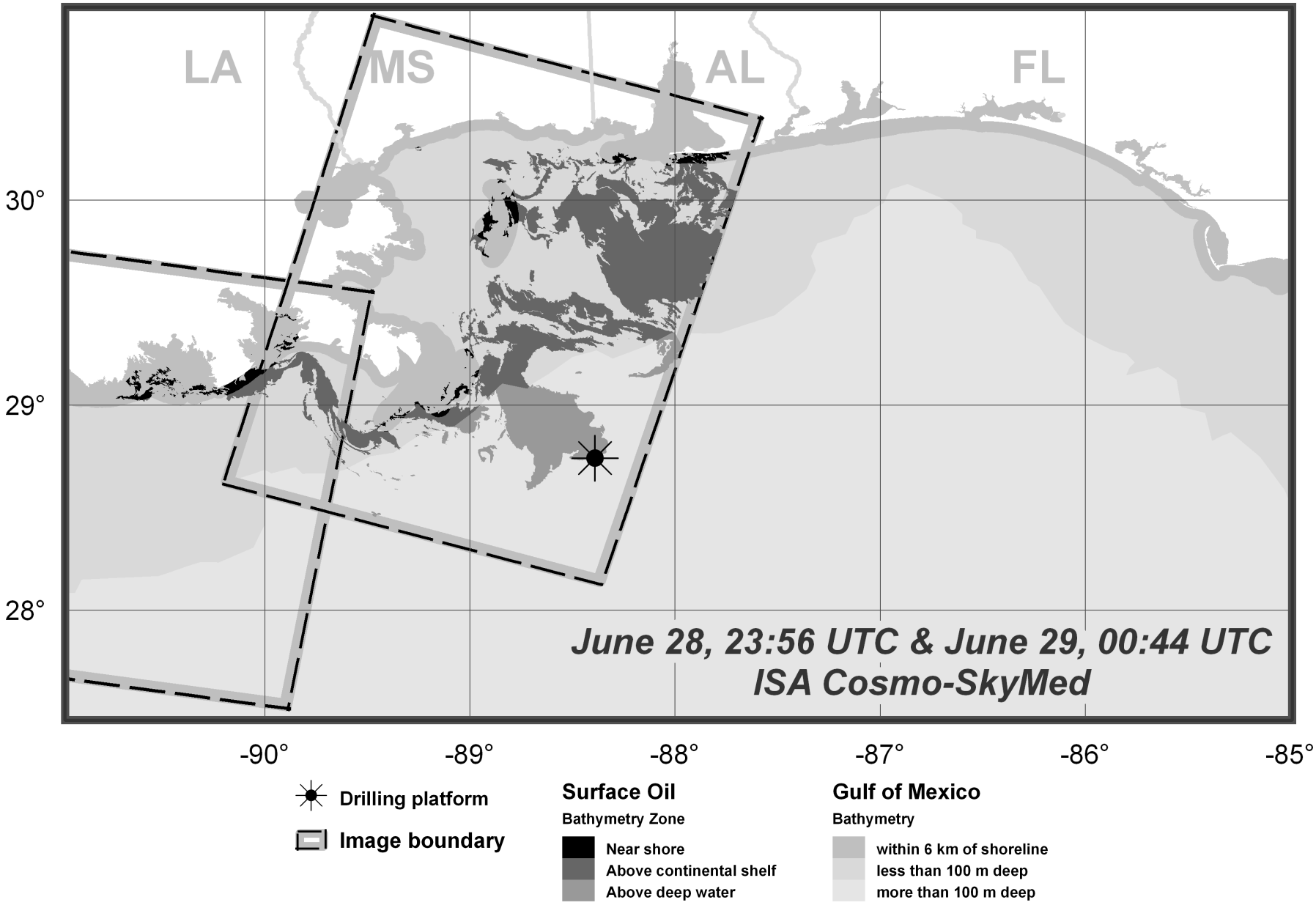
Overlap of our predictions to observations:

- **Solid blue** - Total areas of observed oil in satellite imagery
- **Solid red**- Total areas of predicted locations of Lagrangian particles
- **Dashed red** - Overlap between predictions and observations

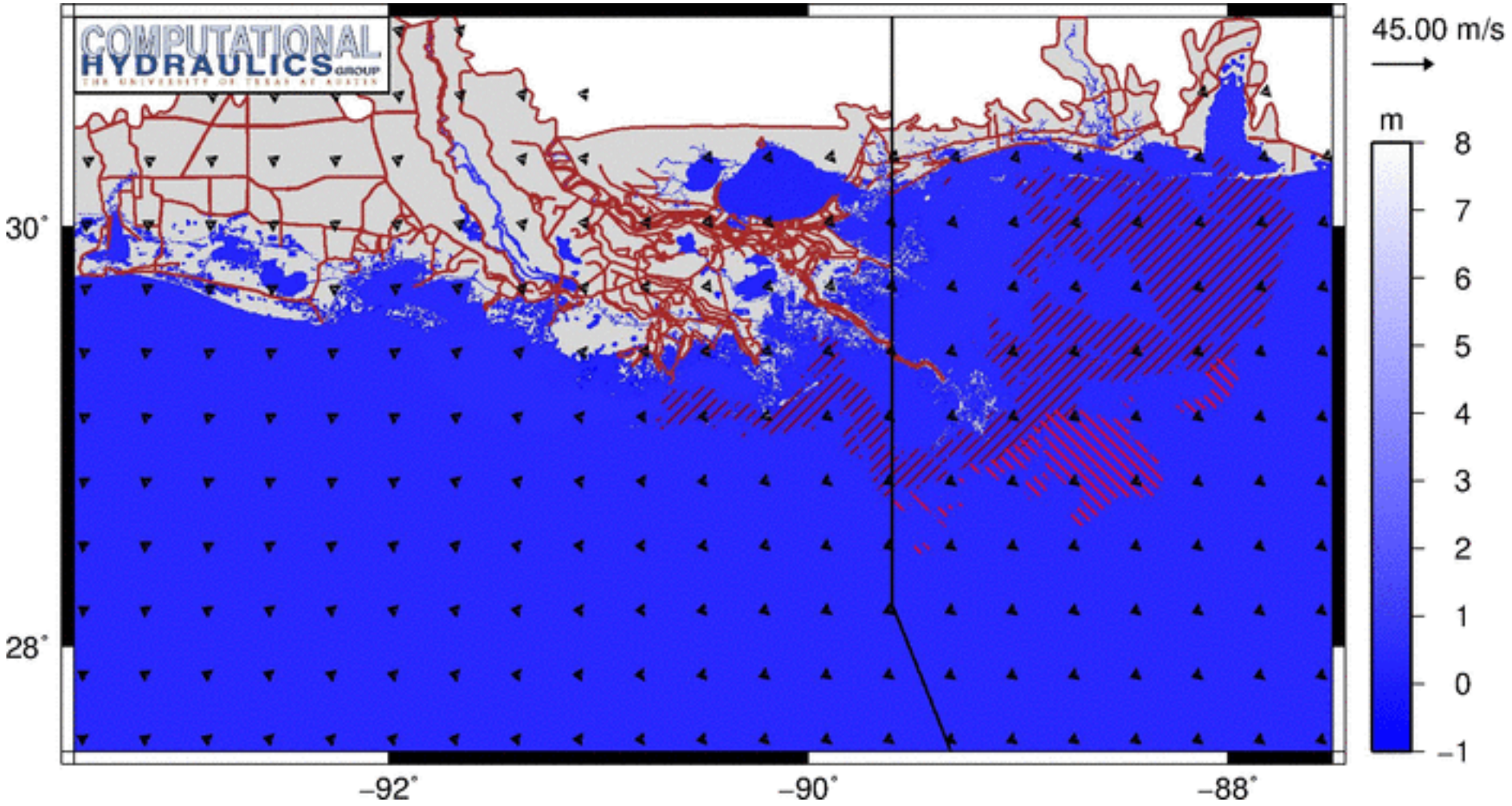
After one week of simulation, overlap is about 60 percent

- Good qualitative and quantitative match to observations

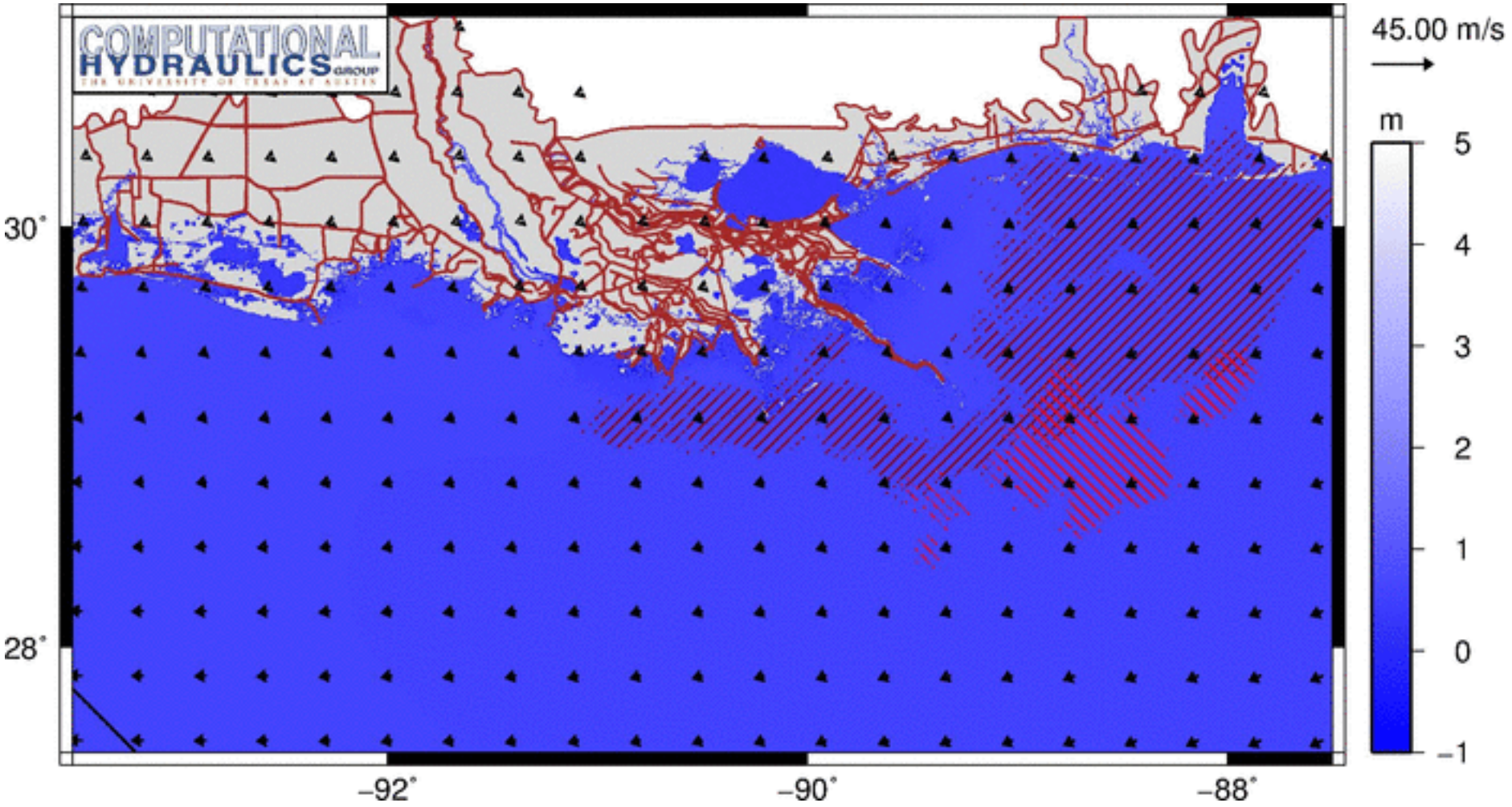
Hypothetical : Initial Conditions



Hypothetical : Hurricane Katrina (2005)



Hypothetical : Hurricane Ike (2008)



Conclusions

Automated system runs successfully in real-time

Good match to overall movement of oil spill

- Some small-scale features are modeled successfully

Validation is highly sensitive to quality of overhead imagery

Oil would have been influenced heavily by a hurricane in the region

- Movement into marshes of southern Louisiana
- Movement along the coastline toward Texas