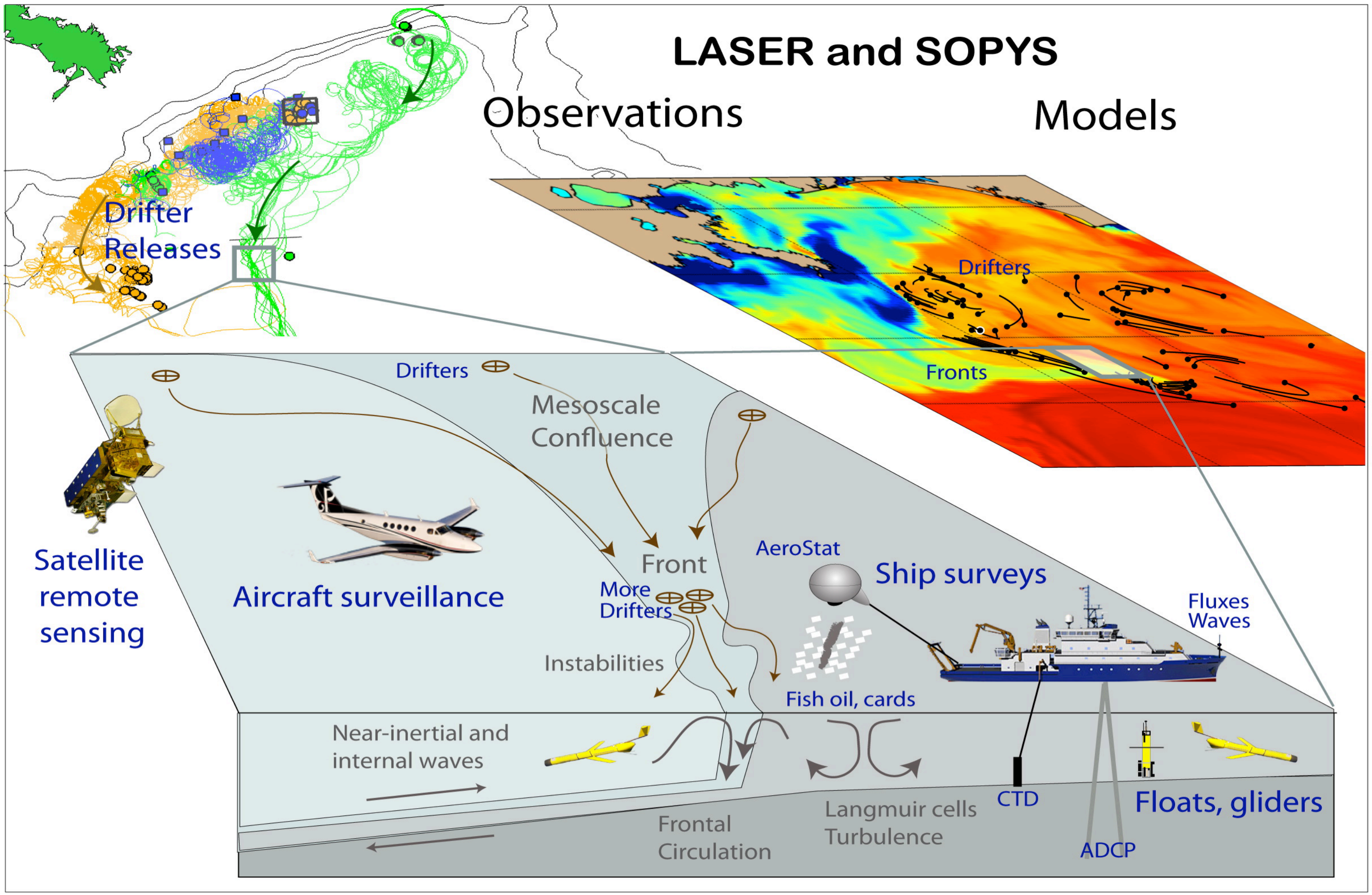
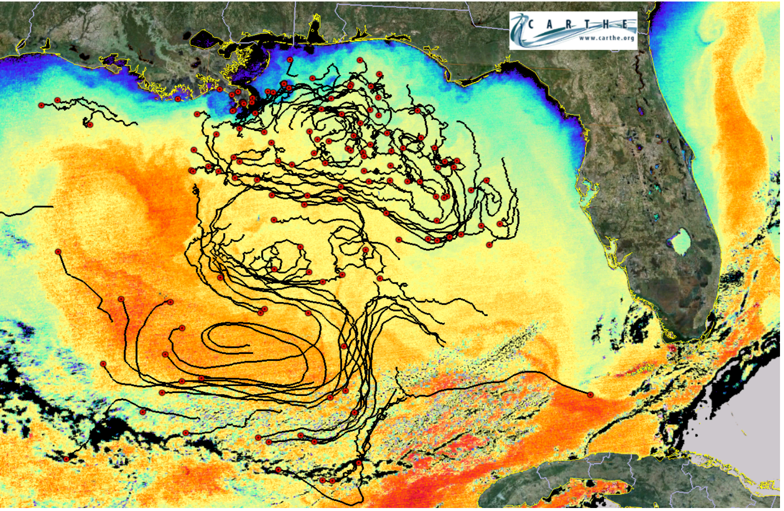
Consortium of Advanced Research of Hydrocarbon Transport in the Environment (CARTHE, www.carthe.org)

Basic Questions: Where will the oil go? How fast? How much?

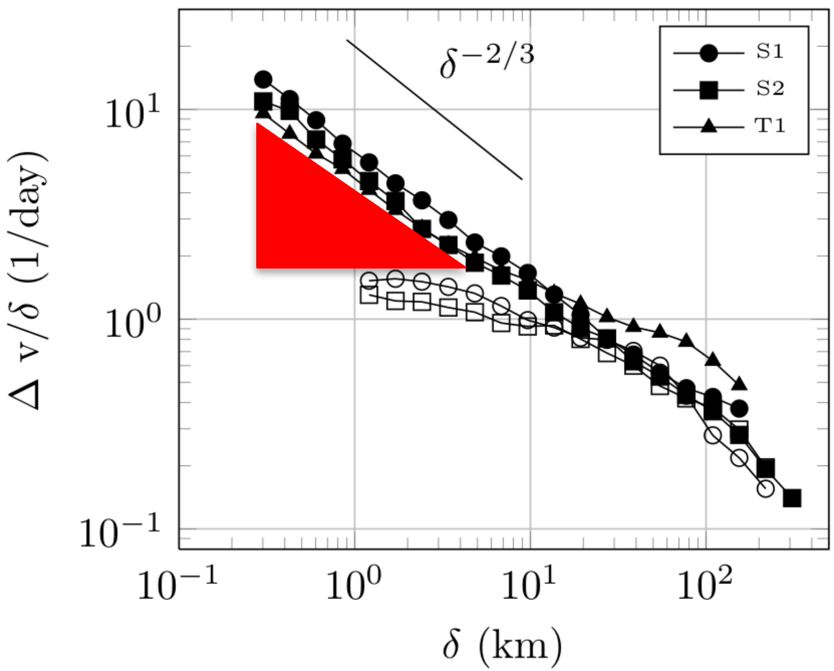
Methods: Large air-sea expeditions and laboratory experiments for model improvement



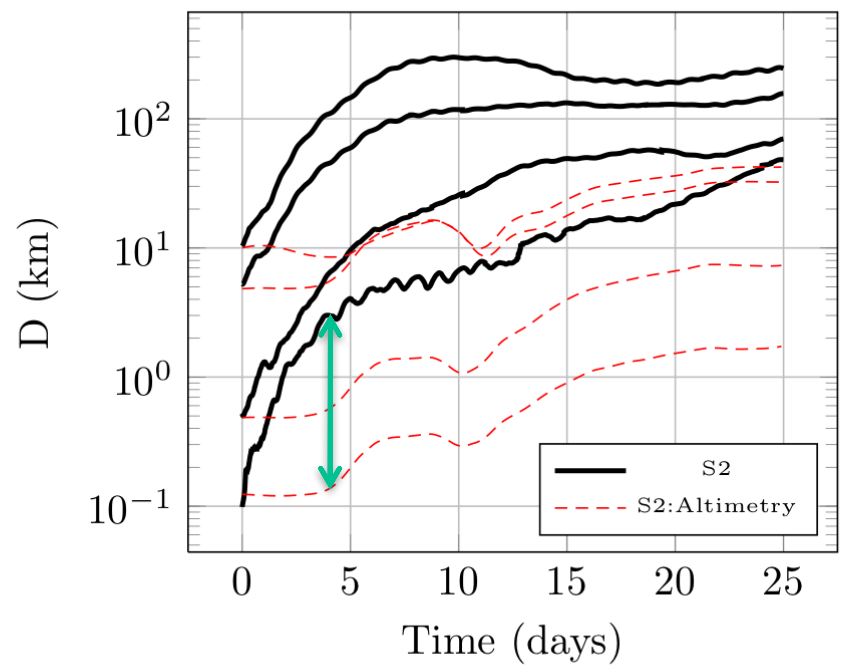


Grand LAgrangian Deployment GLAD:
300 drifters deployed around DwH site
(Poje et al, Proceedings National Academy Sciences, 2014)

GLAD vs 3 km NCOM
(Navy Operational Model)



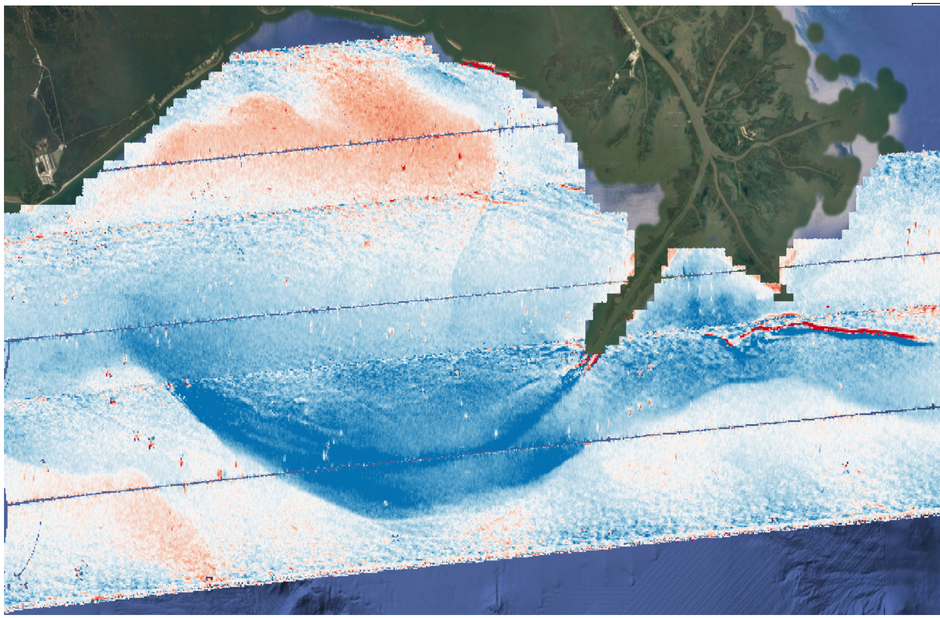
GLAD vs AVISO:
(Satellite Altimeter)

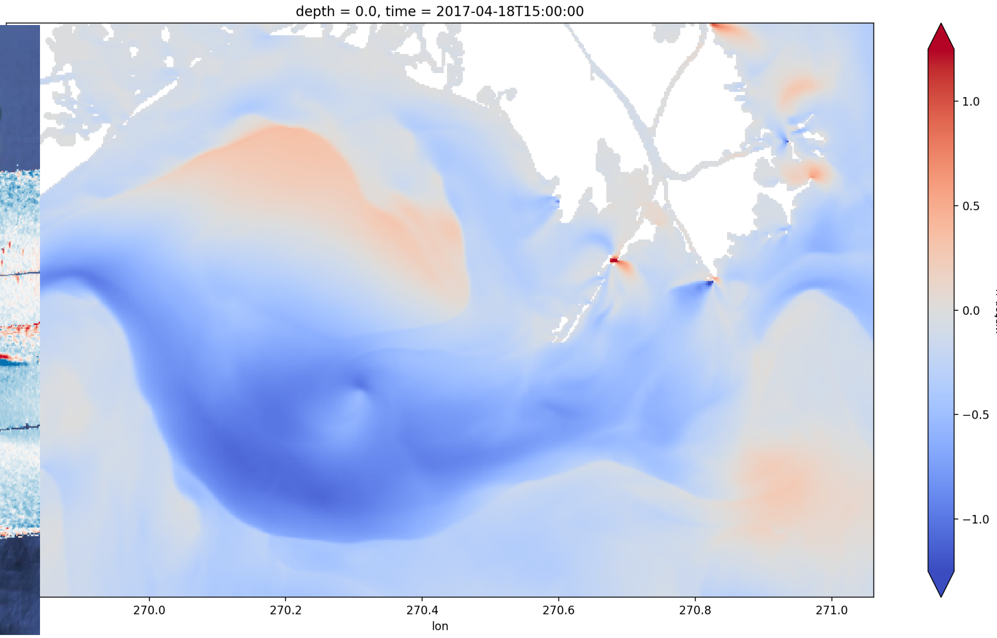


Improvements in Navy Ocean Model and collaboration with JPL/NASA followed.

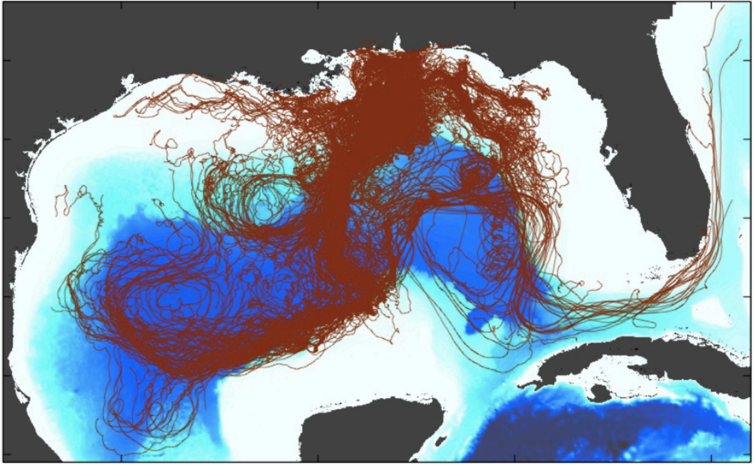
Improvement during SPLASH (2017 Expedition)

DopplerScatt (Ernesto Rodriguez, NASA) vs NCOM (Gregg Jacobs, NRL)





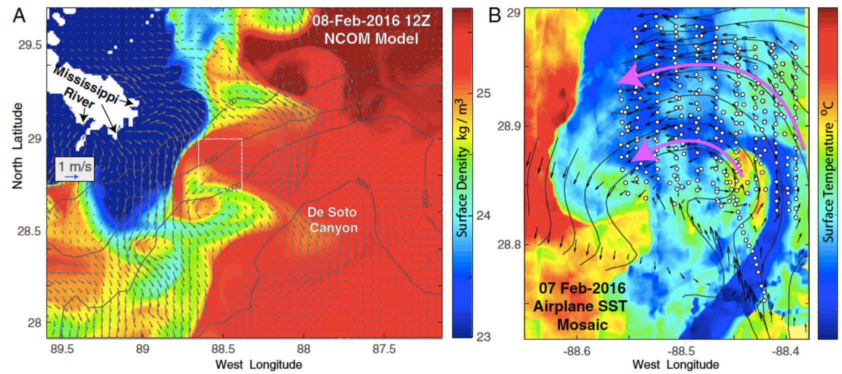
Wave-based surface speed measurement, as opposed to radar altimeter, seems to work better

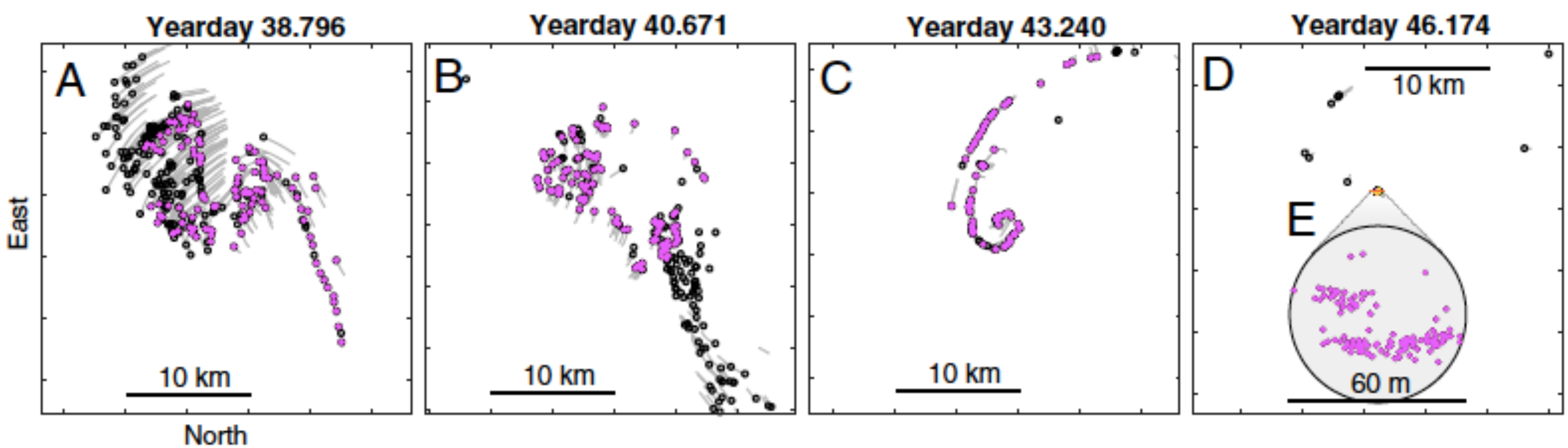


Lagrangian Submesoscale Experiment LASER: 1000 drifters deployed around DwH site

(D'Asaro et al, Proceedings National Academy Sciences, 2018)

Modeling and aerial SST guided deployments:

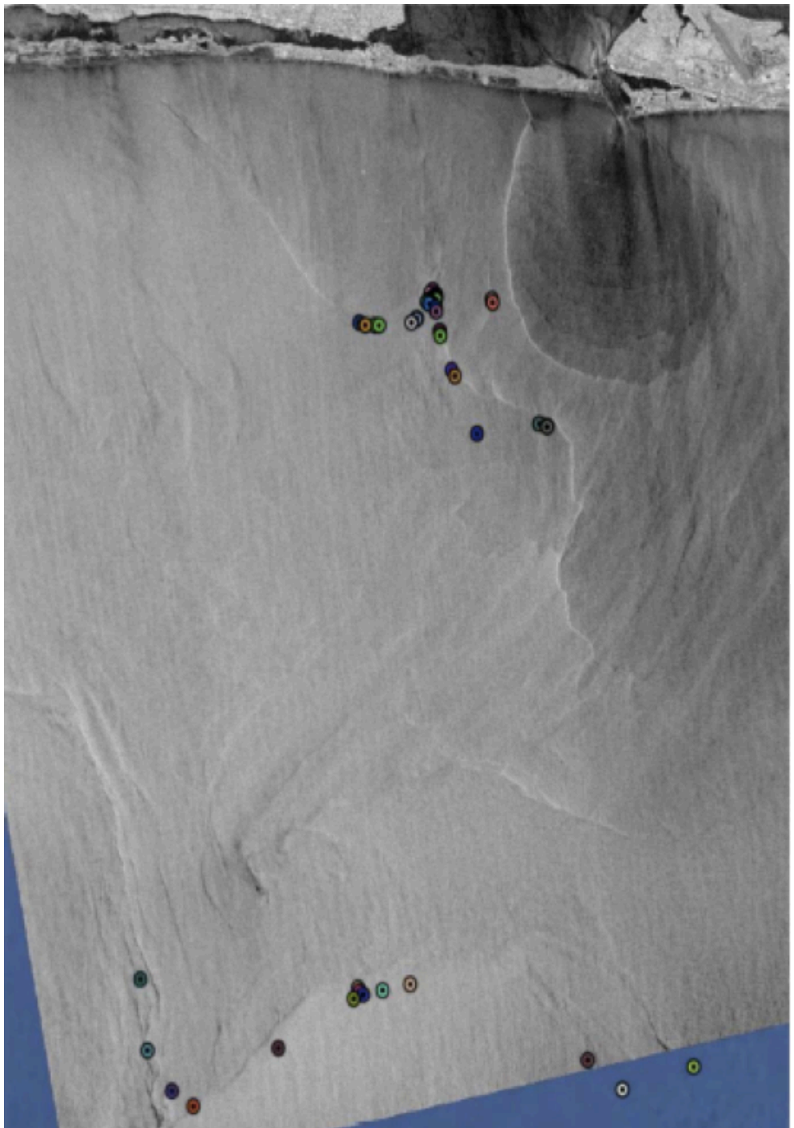


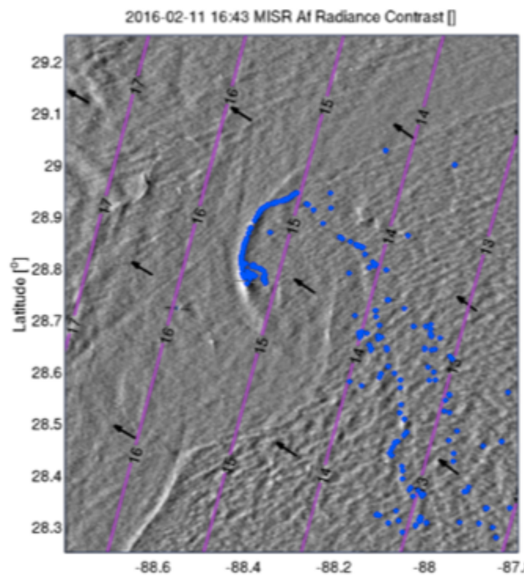


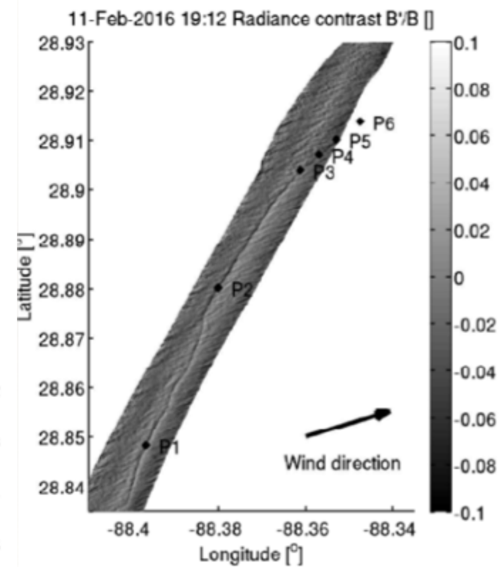
Collapse from the size of a city to the size of a conference room; 1000-fold area reduction!

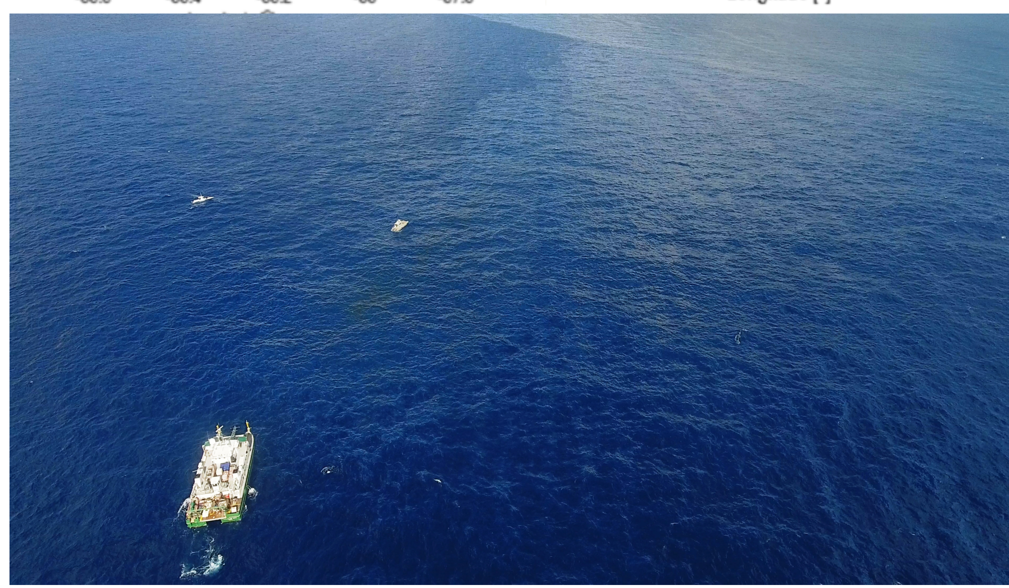
Tendency of Drifters to Collect Along Freshwater Fronts – Natural Booms:

(Hugueard et al., JGR Ocean, 2016; Roth et al, Cont. Shelf Res, 2017; Raschle et al., GRL, 2017; Androulidakis et al, JGR Oceans, 2018)



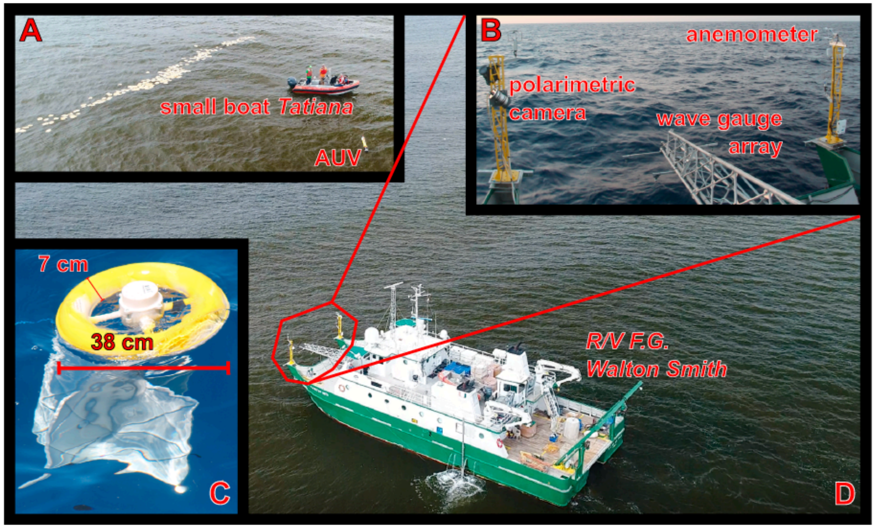






How Fast Do Substances Move at the Air-Sea Interface?

Challenging measurement… Laxague et al., GRL, 2018: ***4 times faster at 1 cm than at 10 m!***



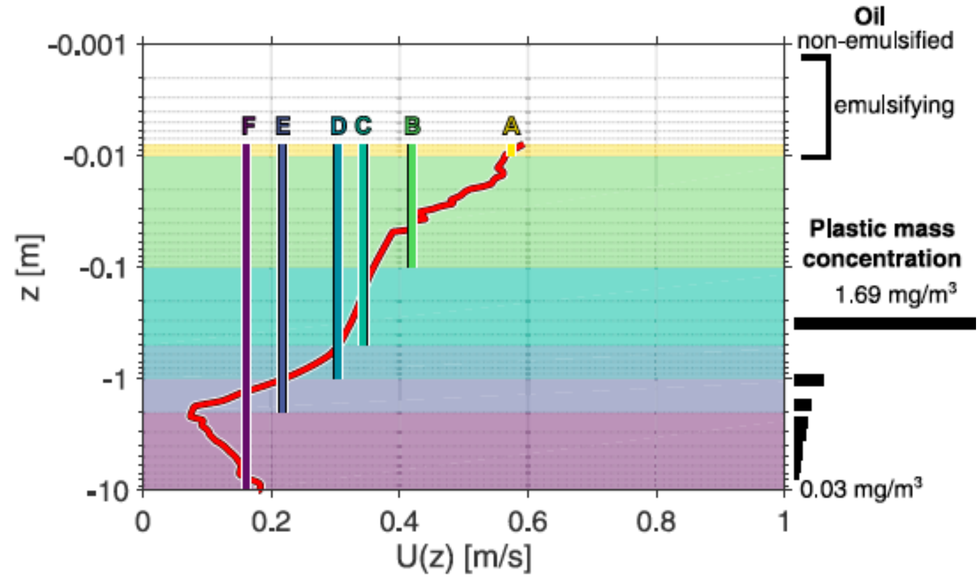


Table 1
Comparison of Drift Speeds by Depth Range Averaged by Each Instrument: Drift Speed, Direction, and Distance for Averages Over Layers of Six Different Thicknesses of the Observed Current Velocity Profile

Segment	Thickness of layer (m)	Measured by	Speed (m/s)	Direction (deg)	Drift distance after 1 day (km)
A	0.01	Surface tracers	0.57 ± 0.01	242 ± 2	49 ± 1
B	0.10	Polarimetric camera, drifters	0.43 ± 0.07	250 ± 14	37±6
C	0.50	Drifters, ADCP	0.35 ± 0.05	245 ± 13	30 ± 4
D	1.00	ADCP	0.30 ± 0.06	231 ± 11	26 ± 5
E	2.00	ADCP	0.22 ± 0.10	219 ± 14	19 ± 9
F	10.00	ADCP	0.16 ± 0.05	162 ± 40	14 ± 4

Note. The error margins given (e.g., 0.57 ± 0.01) represent 1 standard deviation from the mean. Also, included are the segment labels (A–F) corresponding to Figure 3 and the observational and modeling tools which are able to resolve each layer. The mean wind velocity direction was 242°.

Areas Ripe for Technological Advancement:

1) Smaller, cheaper surface drifters capable of aerial deployment, carrying smaller and more diverse sensors and better access to satellite transmission.

   DARPA, being well aware of CARTHE experiments, just launched **50k drifting sensor program - Oceans of Things** to advance naval surveilance capabilities.

2) Use of drones to map surface features around vessels once they are on site. (Aerostats are cumbersome, satellites not useful for real-time, planes are time limited.)

3) Accelerating postanalysis techniques for drone data (now taking weeks, months); bringing this to real time as much as possible.

4) Wave-based (no tracer, drifter, driftcard) surface observations techniques, from drones (CARTHE experiment soon) and planes (e.g., NASA/JPL DopplerScat, was very successful during SPLASH).

Areas Ripe for Technological Advancement:

5) Ship-based X-band high-resolution marine radar to identify fronts (Lund et al., 2018, JTECH, revised).

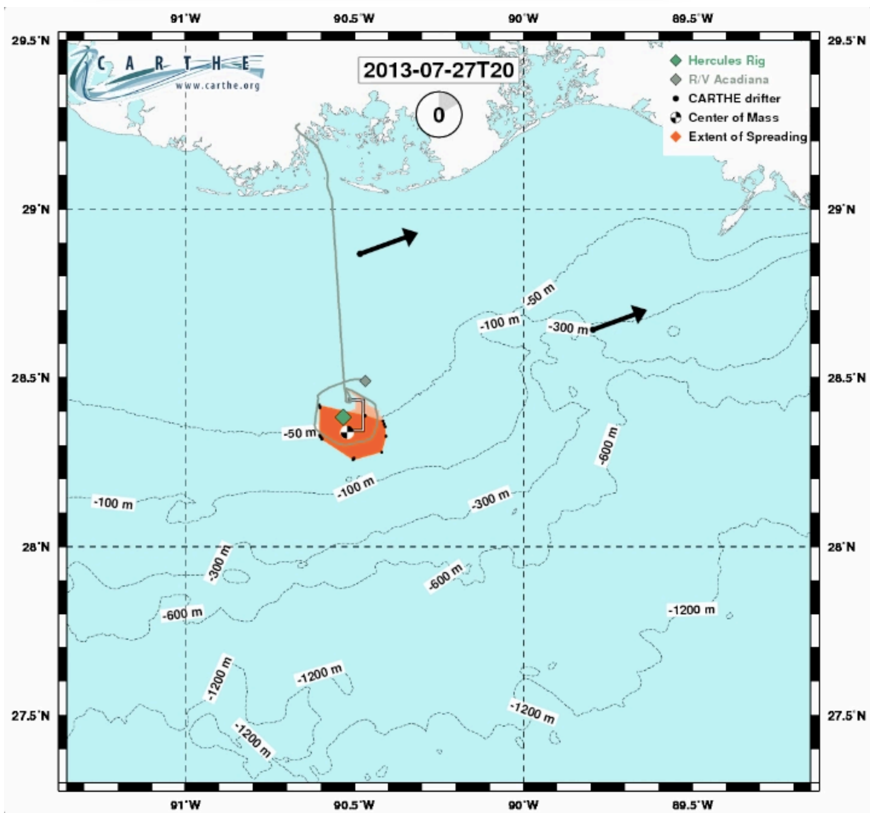
6) Correction of near-surface (upper few centimeters) flows in models using wind and wave information (Haza et al., 2018).

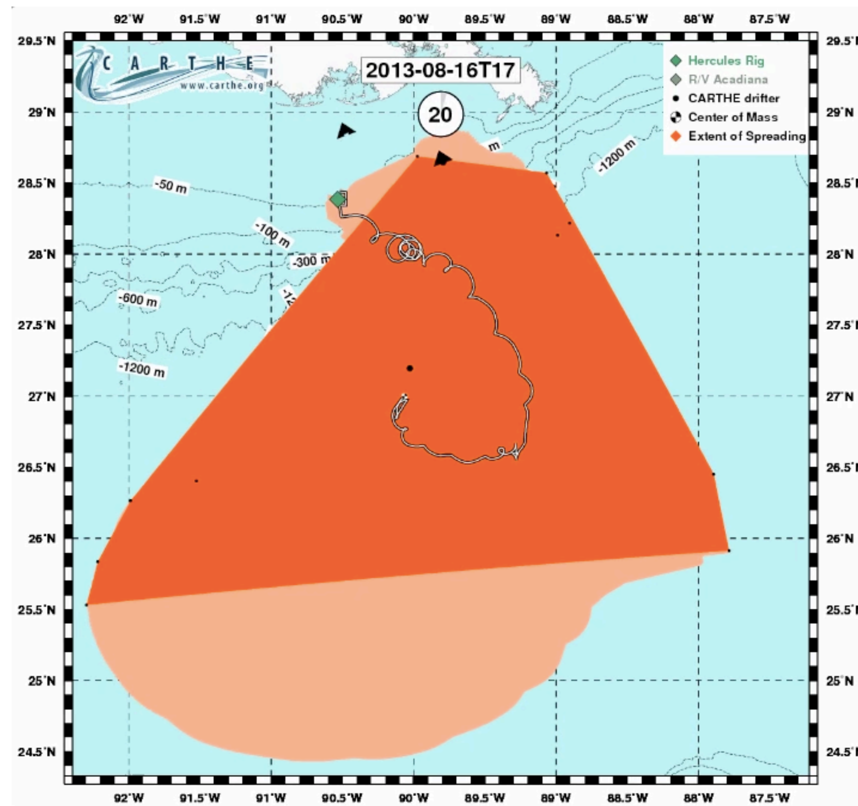
7) Drifter/plate/tracer data assimilation techniques for models; already exists in research mode but not wide-spread for real-time applications.

8) Application of machine learning (deep learning) techniques to oil spill, aerial images, track data and atmospheric forecasts; in parallel to the large modeling and assimilation route that has been followed for the past two decades.

Hercules Gas-Oil Leak

(Romero et al., JGR Oceans, 2016)





Models missed the large–scale expansion into LCE because of satellite altimeter track gaps!