Measuring Winds and Currents During SPLASH with DopplerScatt

E. Rodríguez, A. Wineteer,
D. Perkovic-Martin, T. Gal, N. Niamsuwan, B. Stiles
Jet Propulsion Laboratory
California Institute of Technology

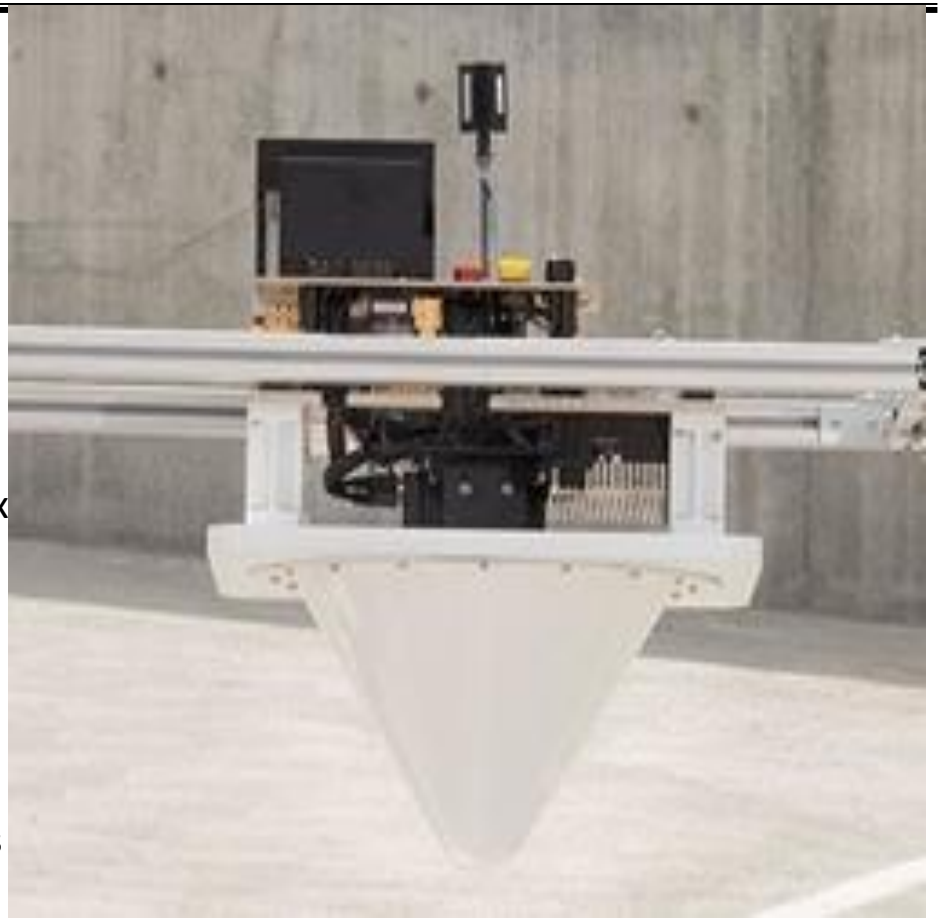
DopplerScatt Overview

DopplerScatt Overview

- Scanning Doppler radar developed under NASA's IIP program
- Becoming operational under NASA AITT program
- **Data Products:**

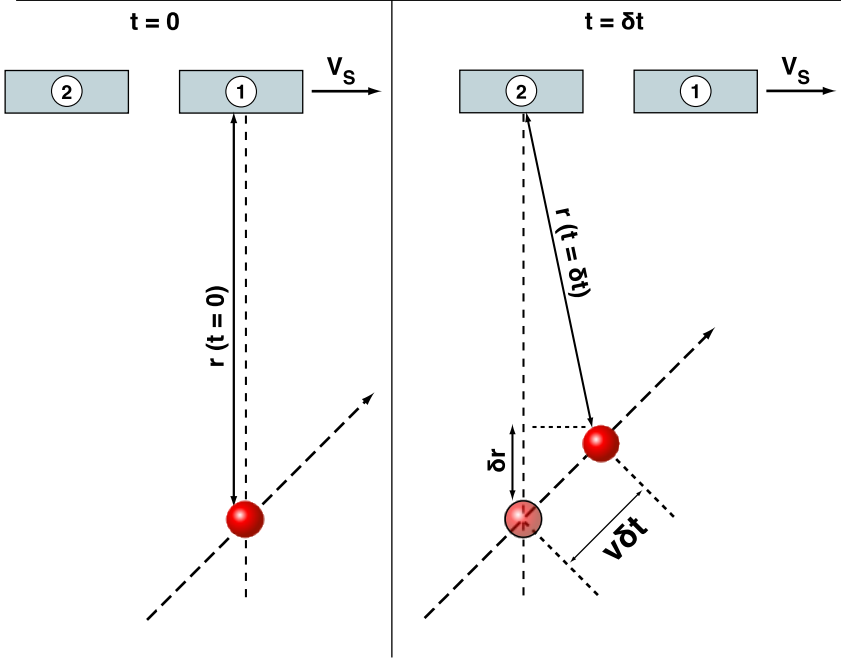
1. Vector ocean surface currents
2. Vector ocean surface winds
3. Radar brightness maps (sensitive to surfactants such as oil films)

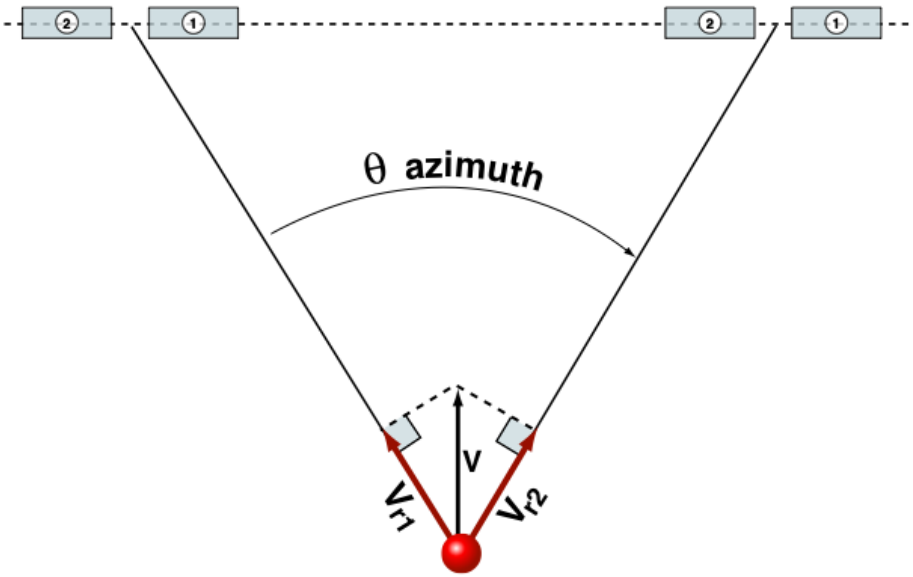
- **Mapping capabilities**: 25 km swath; maps 200km x 100km area in about 4 hrs; 200m data product resolution; ~5-10cm/s radial velocity precision.
- **Current status**:
  - Instrument hardware completed
  - Instrument currently undergoing final calibration and validation
  - CalVal campaigns: SPLASH (Submesoscale Processes and Lagrangian Analysis on the Shelf) in Mississippi River Plume (CARTHE) & Taylor Oil Platform Plume (NOAA), April 18-28; KISS-CANON in Monterey Bay May 1-4.



DopplerScatt instrument. It has been deployed on a DOE King Air and will transition to an operational instrument in the NASA King Air B200.

Doppler Current Measurement Concept





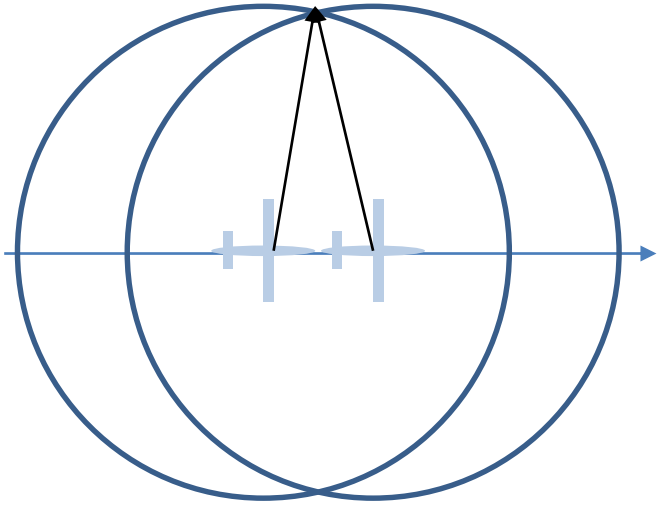
Doppler Phase Difference: $\Delta\Phi = 2k\Delta r = f_D\delta t$

Radial velocity component: $v_r = \Delta r/\delta t = \Delta\Phi/(2k\delta t)$

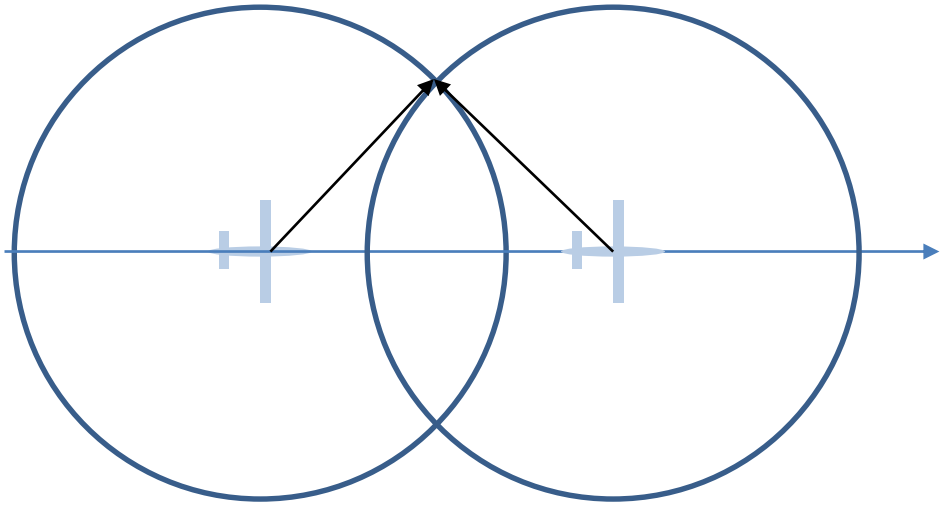
Vector currents are estimated by combining multiple (≧2) azimuth observations and projecting vector to the ocean surface.

- Radars provide coherent measurements: both the phase and the amplitude of a scattered signal are measured.
- The phase is proportional to the 2-way travel time (or range)
- The amplitude is proportional to the scattering strength of the traget
- Doppler measurements, f_D, are obtained by measuring the phase difference between pulses, $\Delta\Phi$. Noise is reduced by combining multiple pulses.

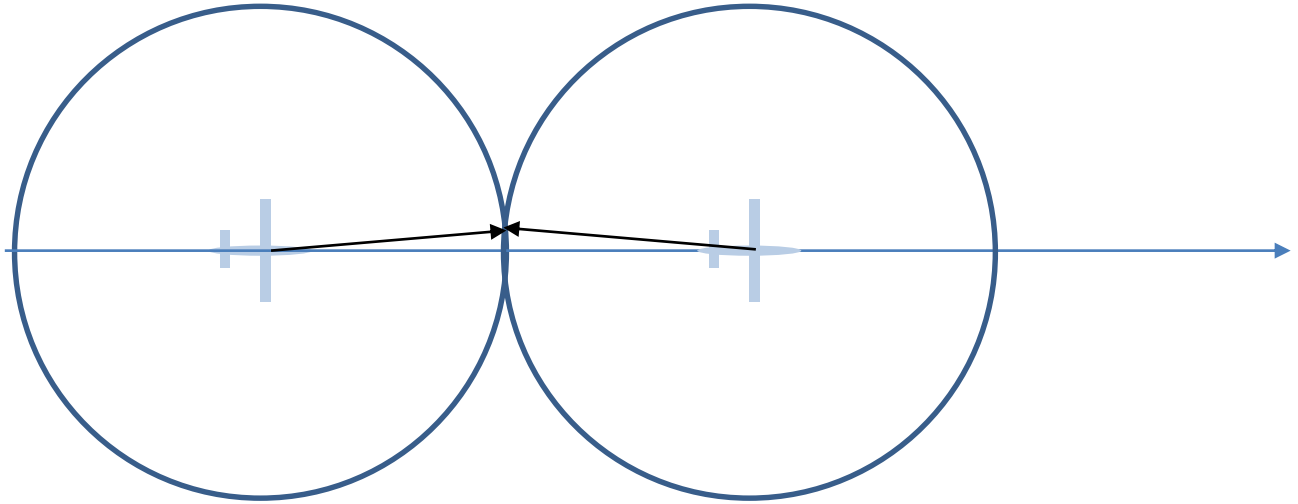
DopplerScatt Vector Velocity Estimation



Bad azimuth diversity

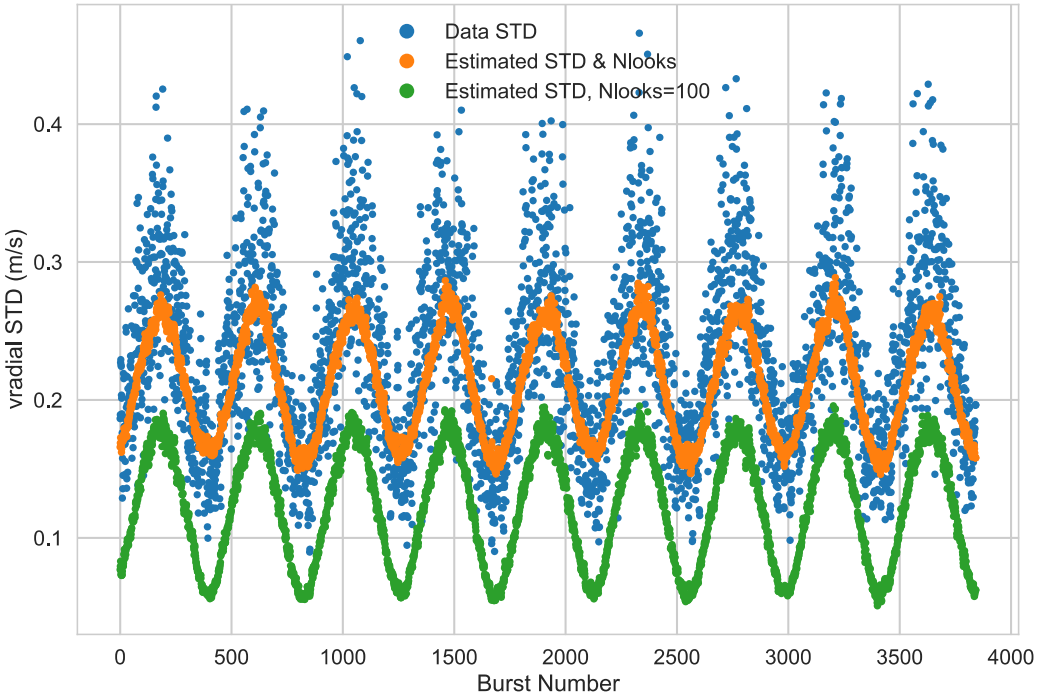


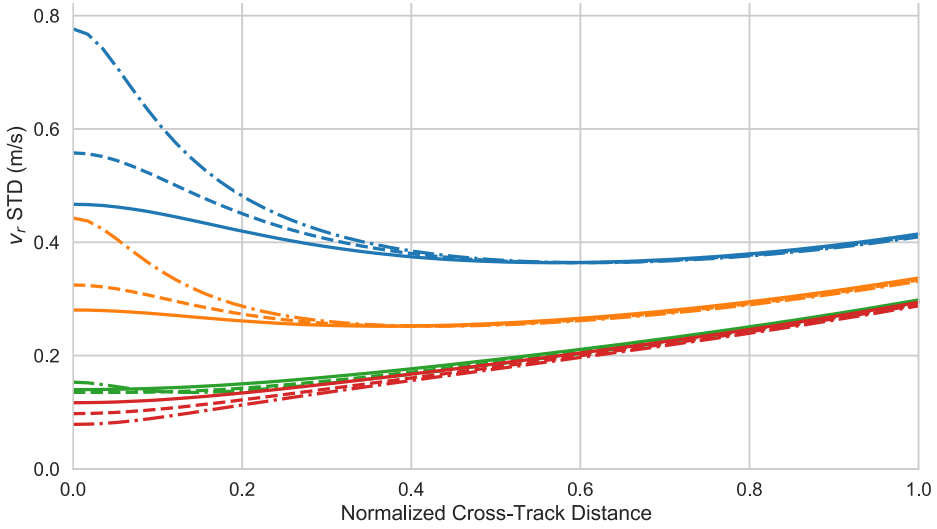
Good azimuth diversity

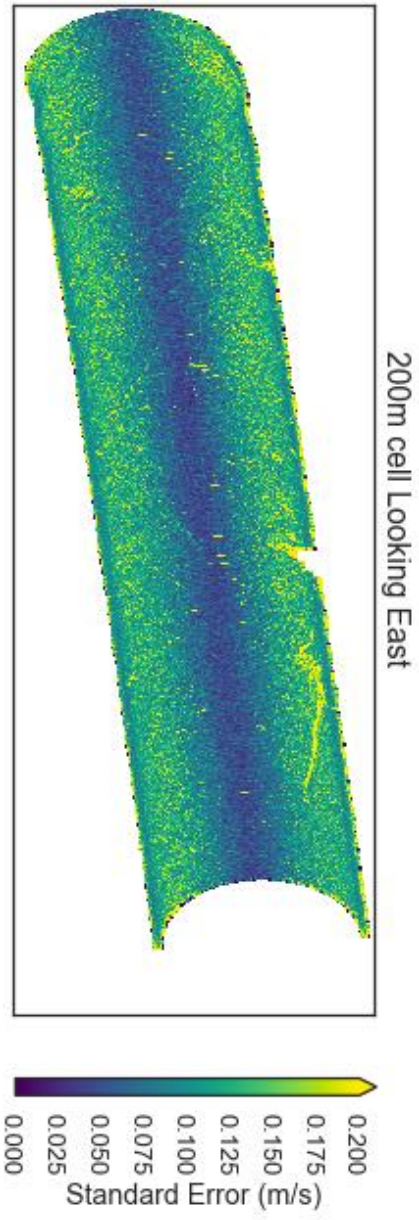


Bad azimuth diversity

Random Errors

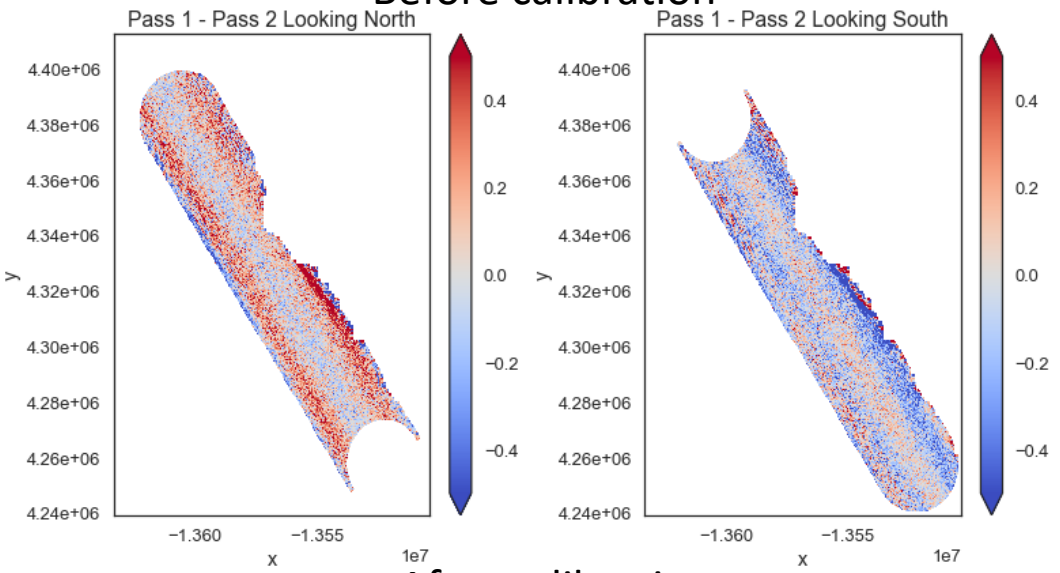




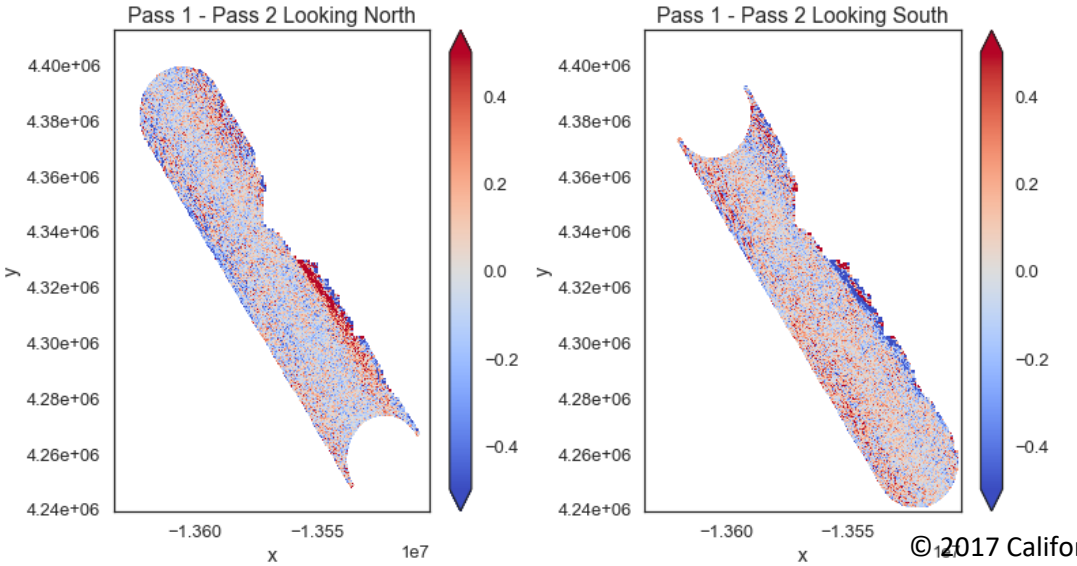


Radial Velocity Pointing Calibration

Before calibration



After calibration



Radial velocity sensitivities

$$
\begin{aligned}
v_r &= \hat{\ell} \cdot (v_p - v_s) \\
\hat{\ell} &= \sin\theta[\hat{x}\cos\phi + \hat{y}\sin\phi] - \cos\theta\hat{z} \\
\delta v_{r\phi} &= \frac{\partial \hat{\ell} \cdot v_p}{\partial \phi}\delta\phi
\end{aligned}
$$

Errors in look angle θ is from range and is very accurate.

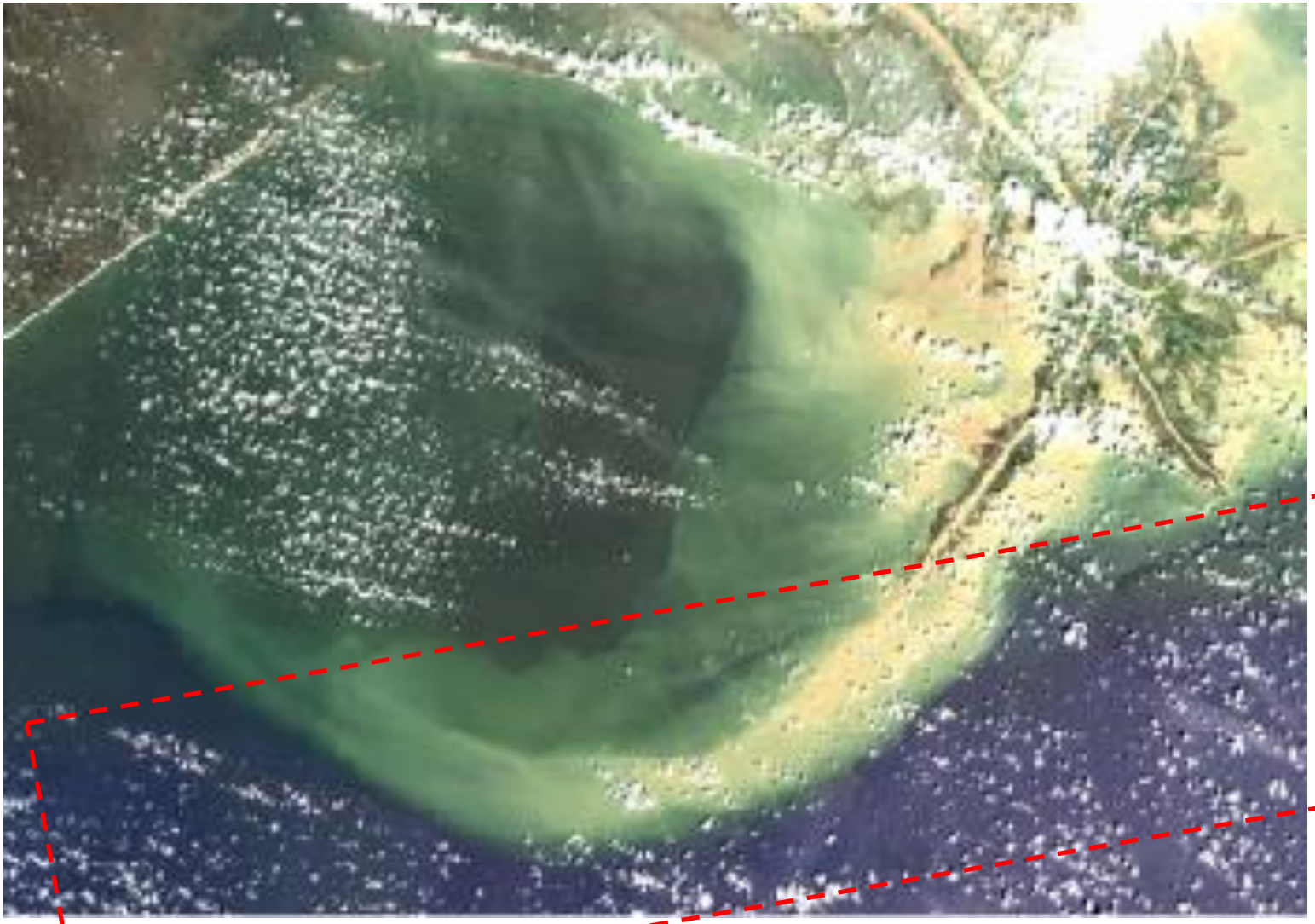
Airplane velocity from IMU is O(cm/s)

Calibration model

α is antenna rotation angle from encoder

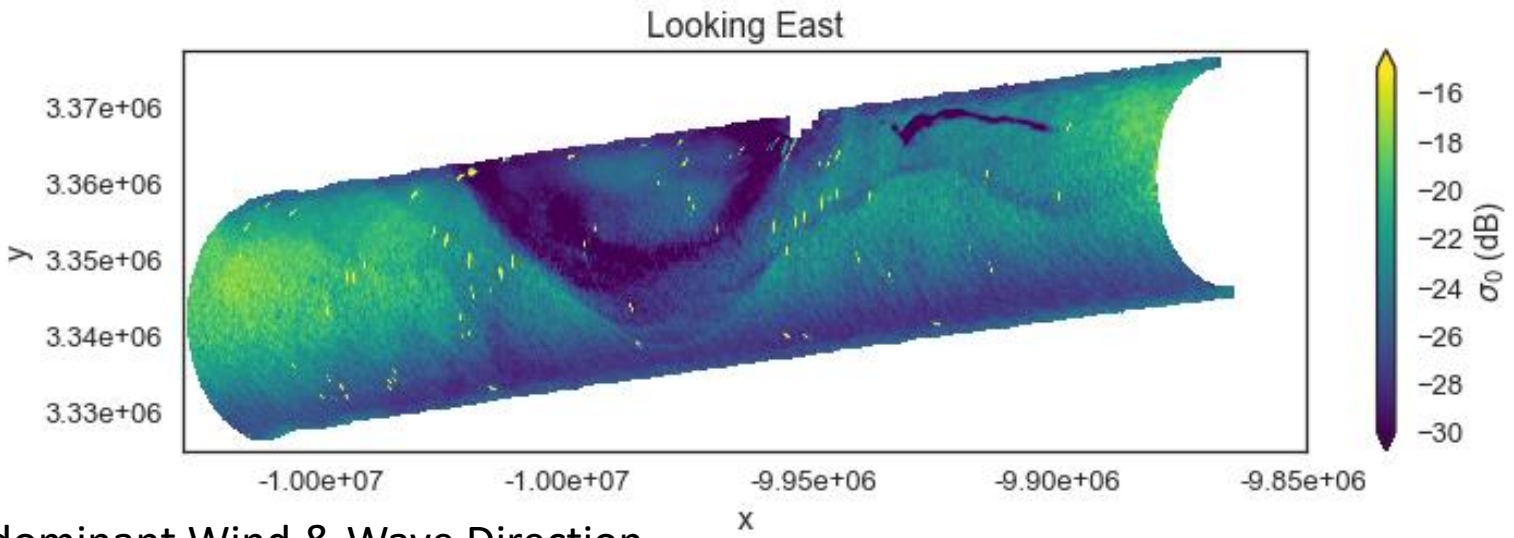
$$\delta\phi(\alpha) = a_0 + \sum_n a_n \cos(n\alpha) + b_n \sin(n\alpha)$$

Sentinel 3 Image on 2017-04-18

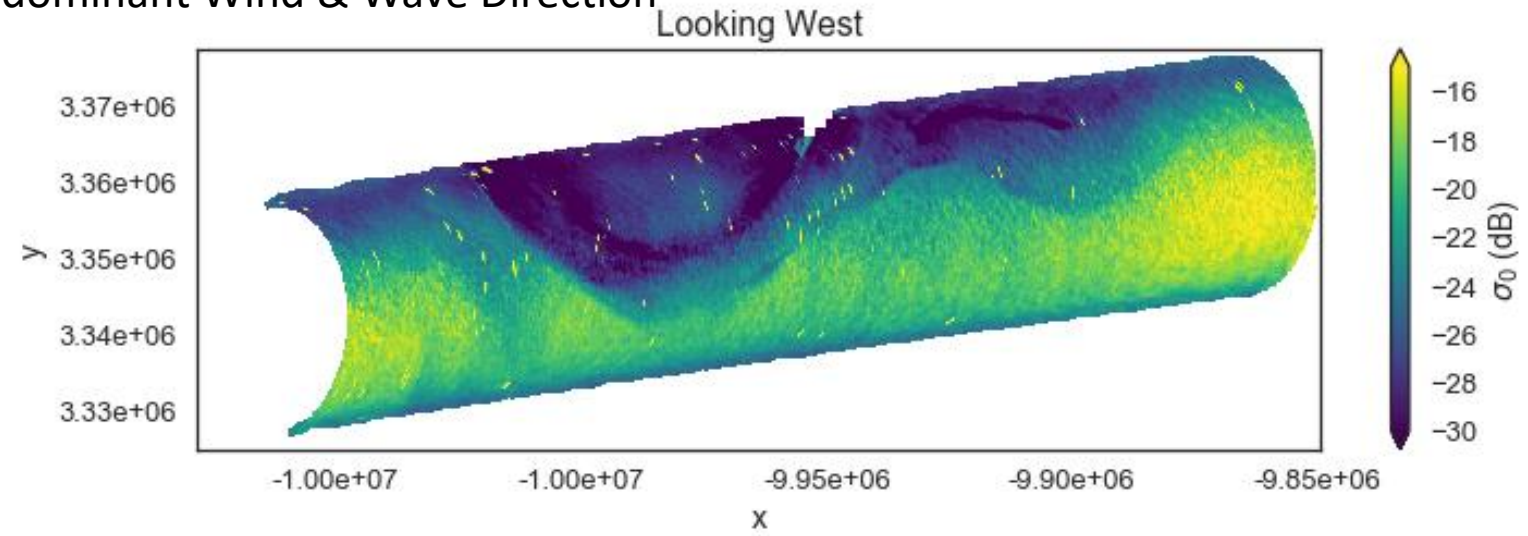


Courtesy of Copernicus Sentinel, processed by ESA

Modulation of σ_0

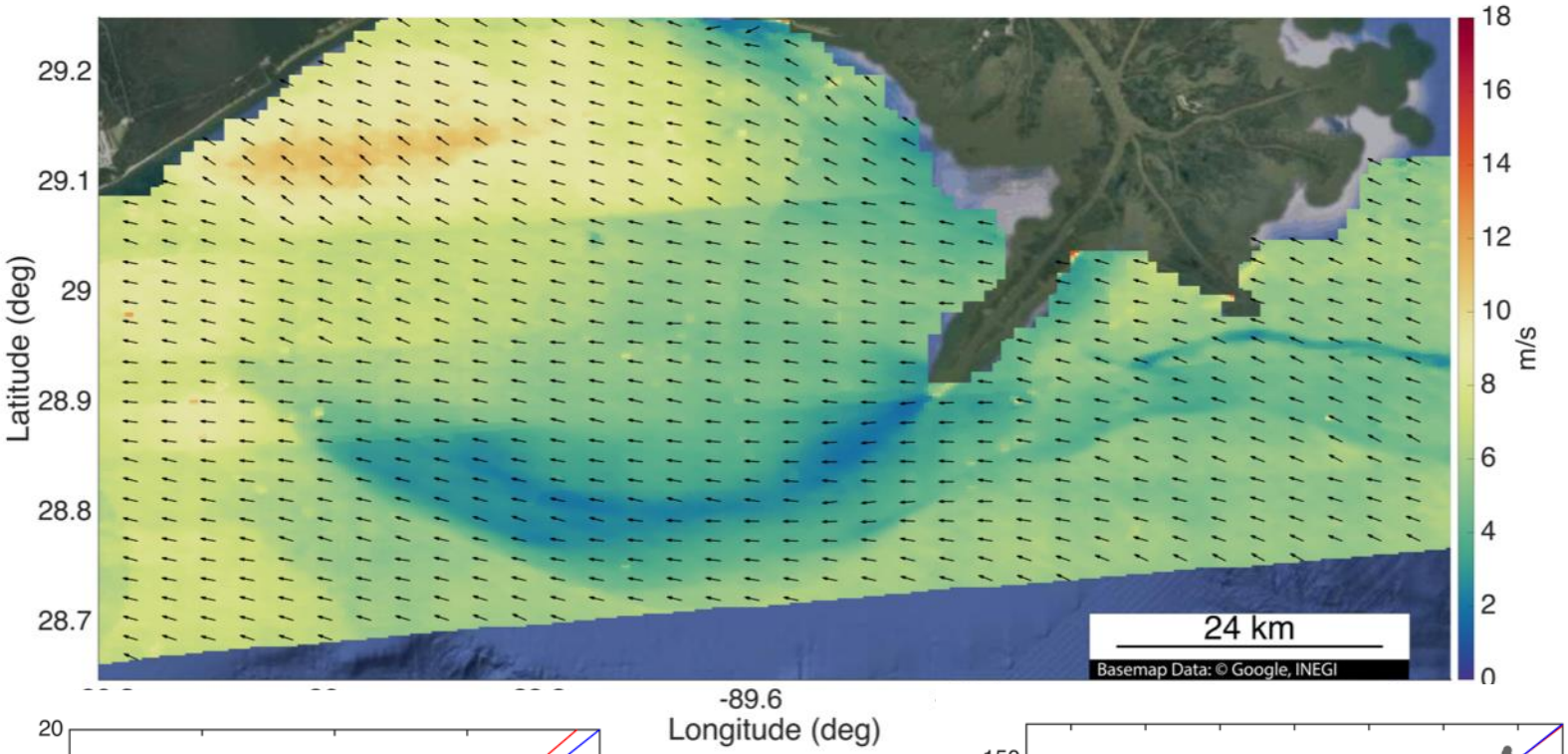


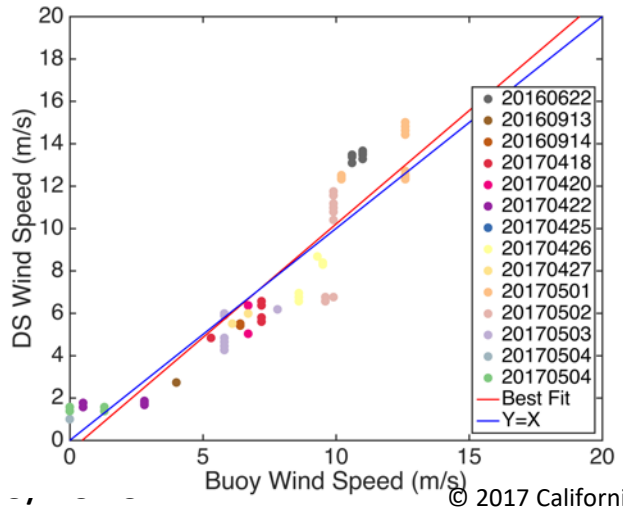
Predominant Wind & Wave Direction

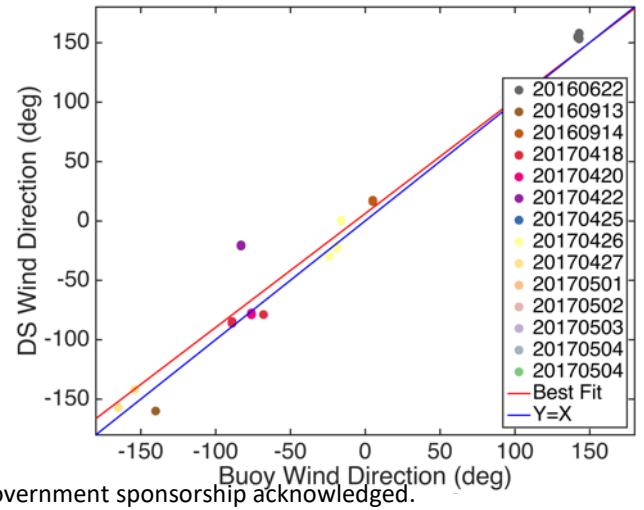


σ_0 shows significant "instantaneous" modulation by surface velocity and at oil spill plume.
Potential effects due to surfactants, kinematic moving frame effects of stress, or SST need further investigation.

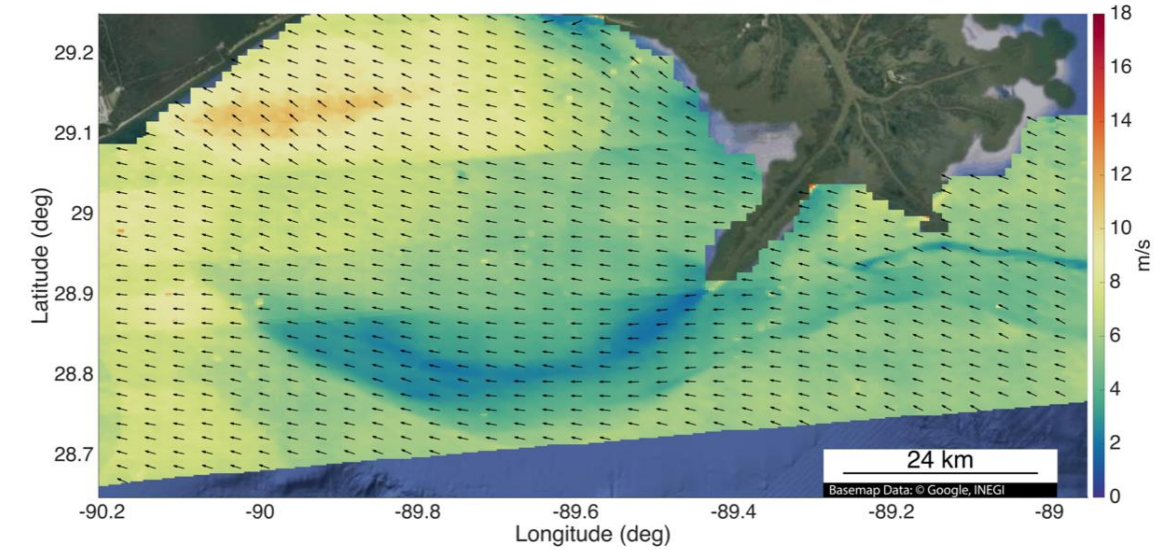
Retrieved Vector Winds 04-18-2017



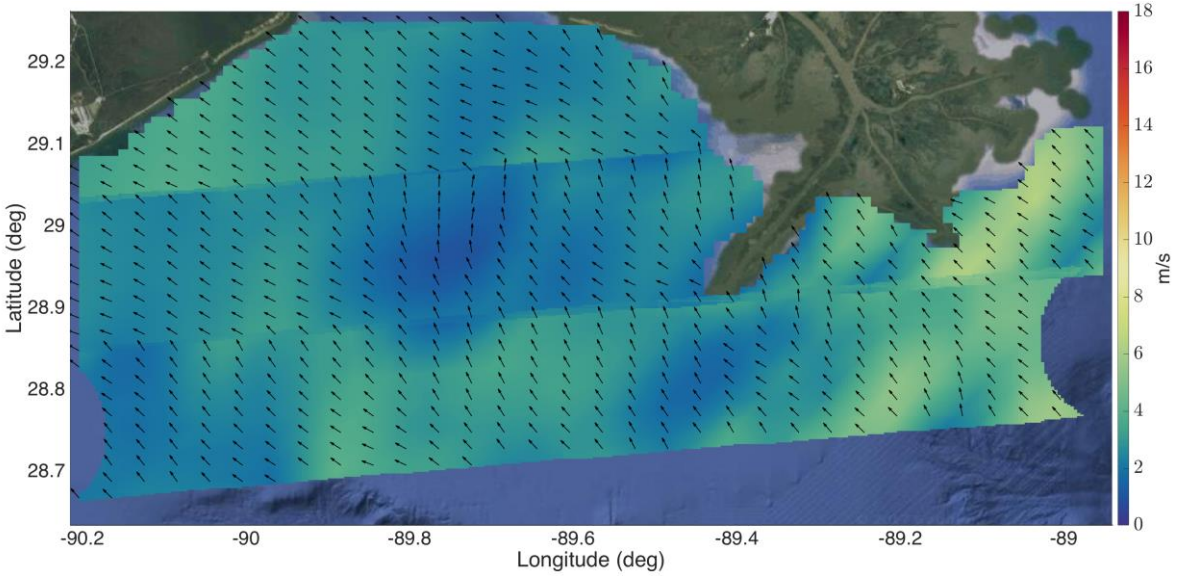




Comparison to RSMAS Model Winds

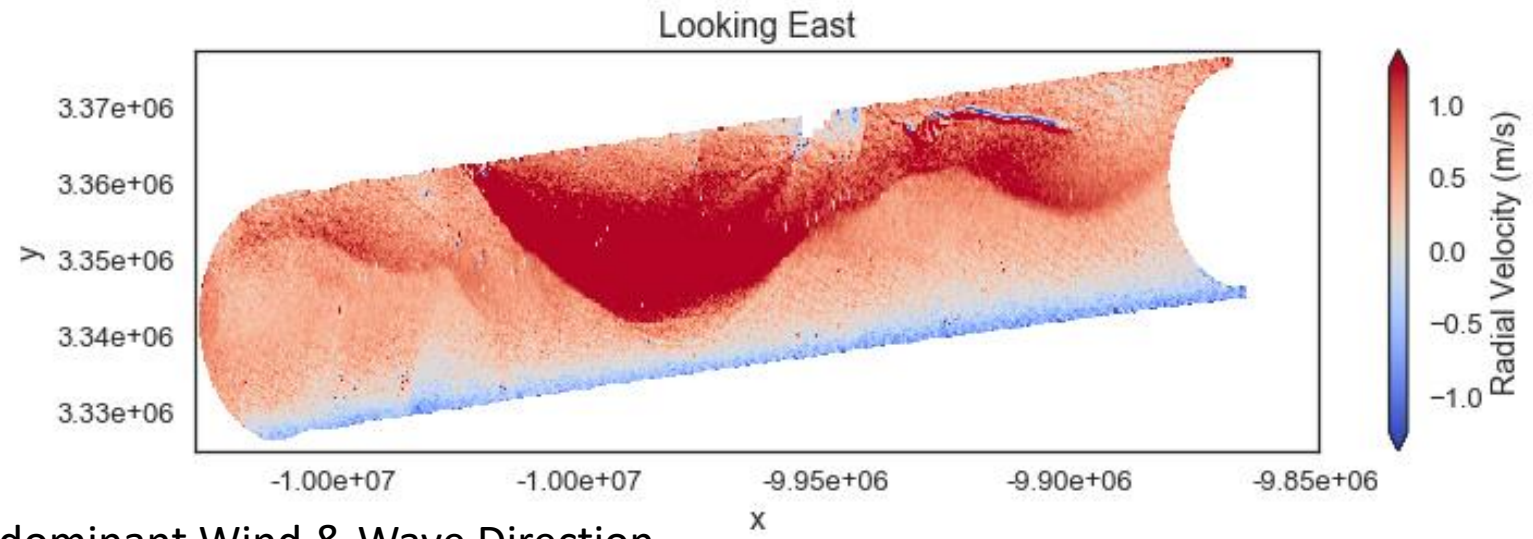


Scatterometter winds measure 10m neutral winds, which are closely related to wind stress and include surface interaction effects (motion and SST modulation)

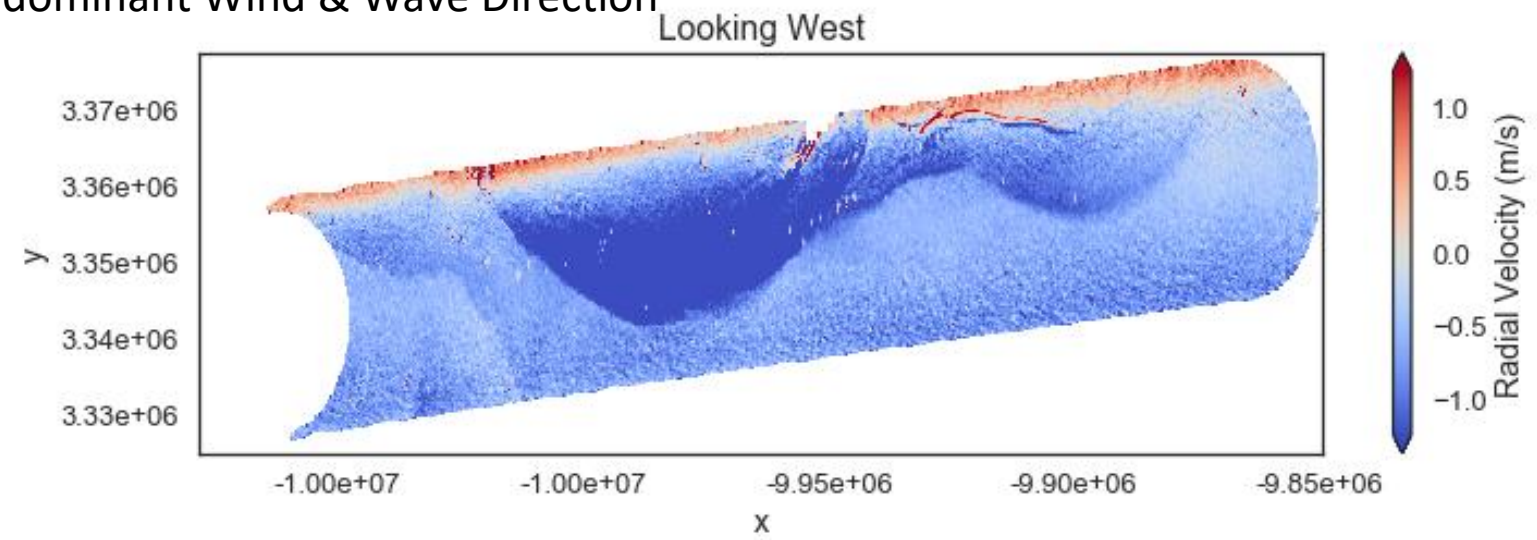


For this case, model winds are lower speed and miss the modulation of the wind stress by surface currents.

Radial Velocities
No Wind Correction



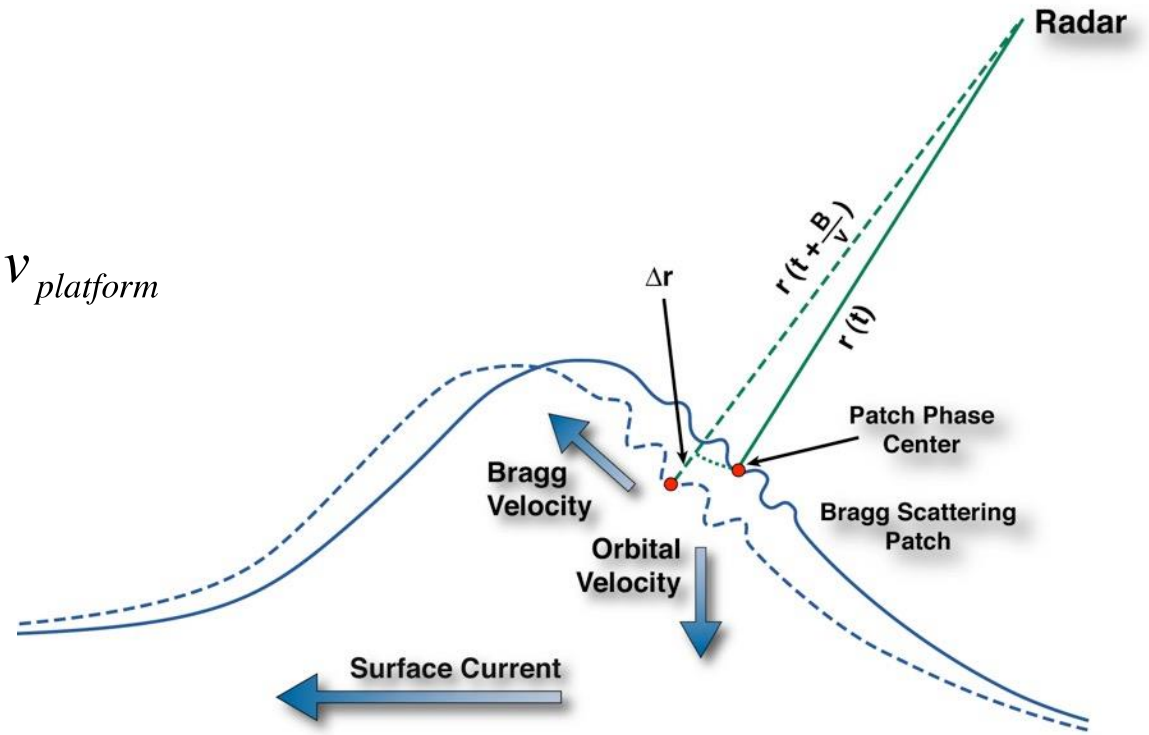
Predominant Wind & Wave Direction



What Velocity are we Measuring?

$$\Phi = \frac{2\pi}{\lambda}\Delta r$$

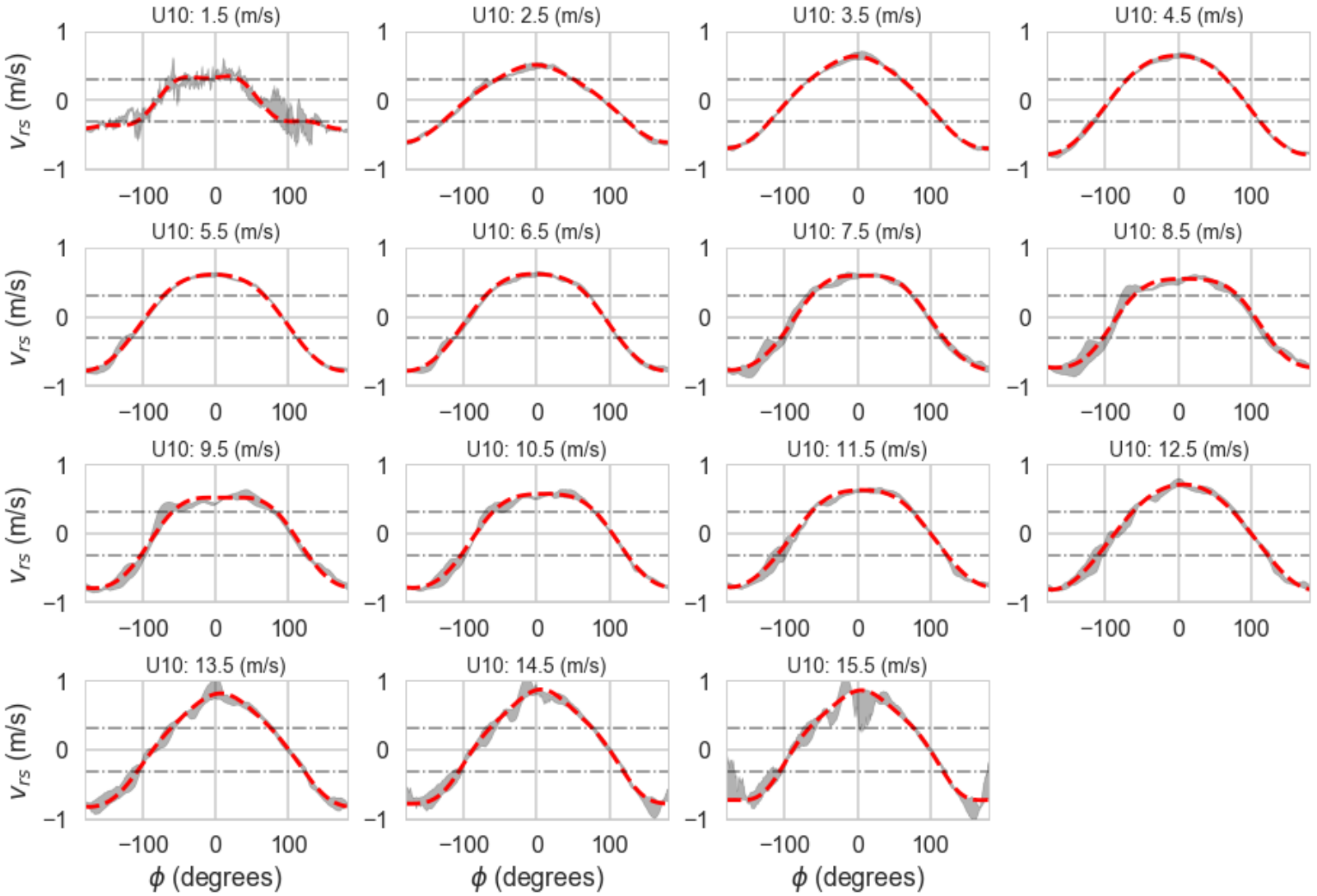
$$v_{scatterer} = \frac{\Delta r}{B} v_{platform}$$



Surface scatterers (resonant gravity/gravity-capillary waves satisfying the Bragg condition) motion is due to several effects: 1) group velocity of resonant patch; 2) orbital wave velocity; 3) advection due to surface currents (including wind & Stokes drift?)

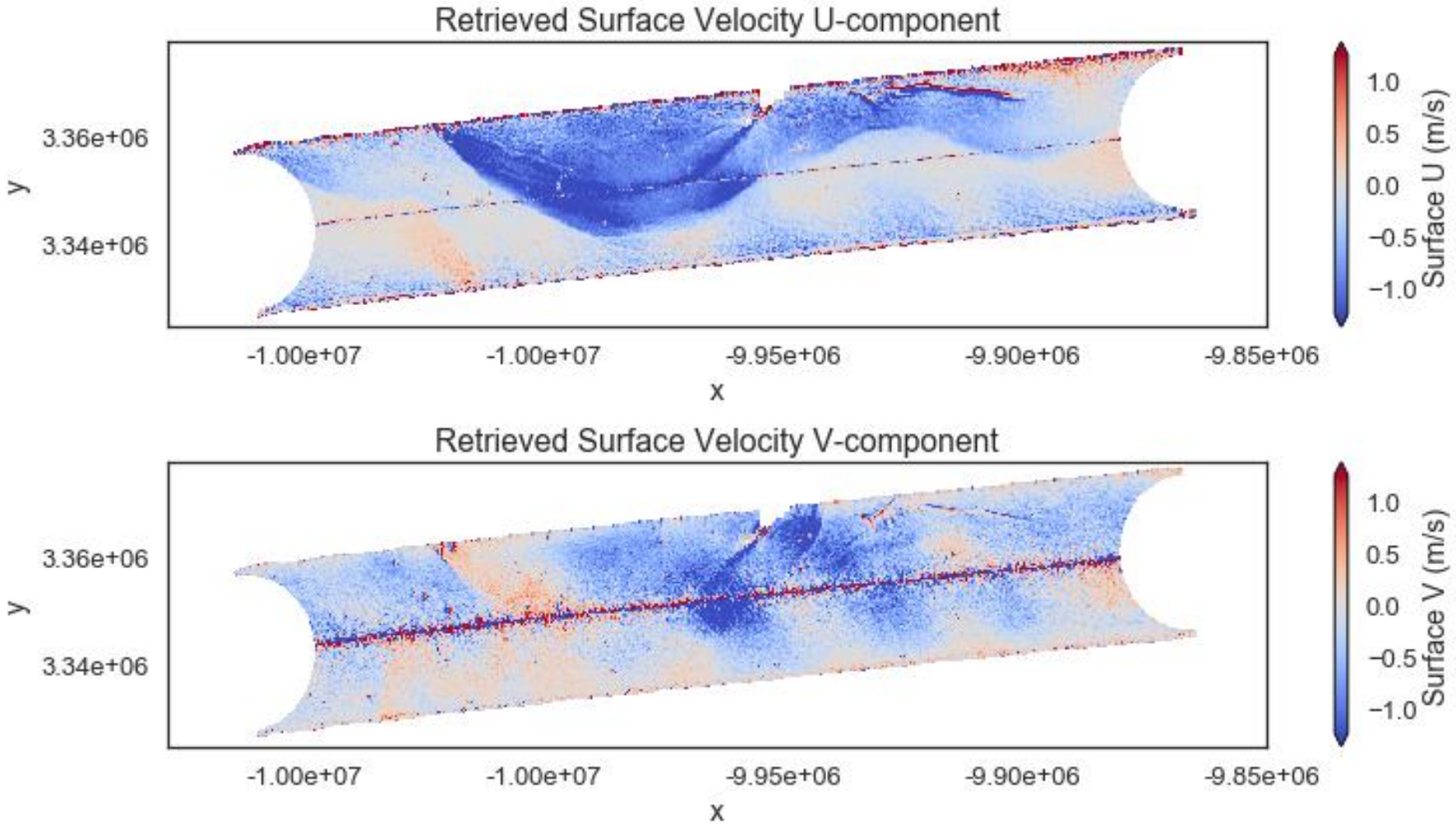
Bragg group velocity can be estimated using the dispersion relation and knowledge of the wind direction. Orbital wave velocity would average out if Bragg waves were uniformly bright over the long waves (but we expect some hydrodynamic and tilt modulation, so residual wind dependent effects could be present).

Data and Fits with V79 Winds

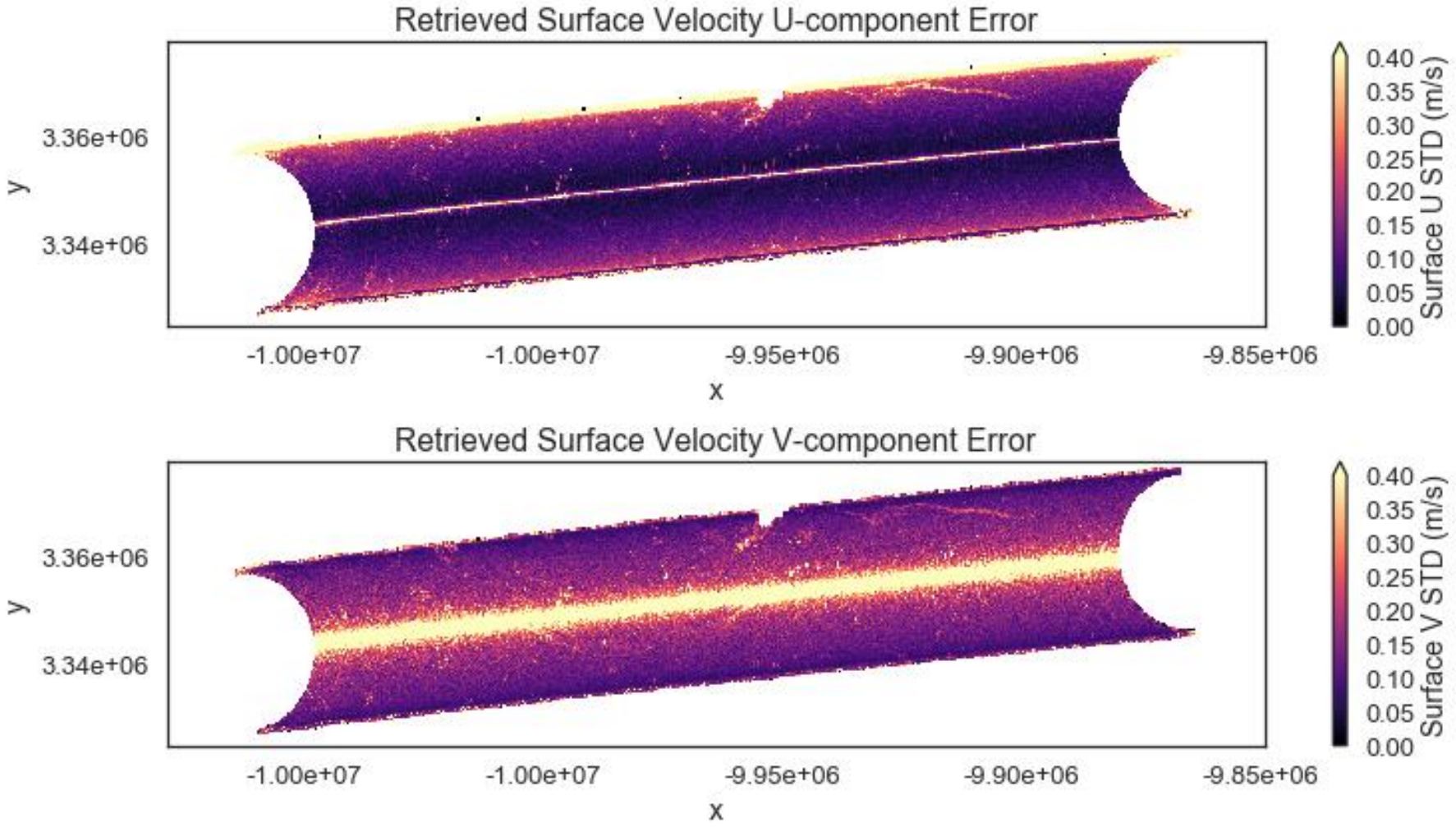


Dot-dash lines indicate Bragg phase velocities

Retrieved Surface Velocity Components



Retrieved Surface Velocity Errors



2017-04-18

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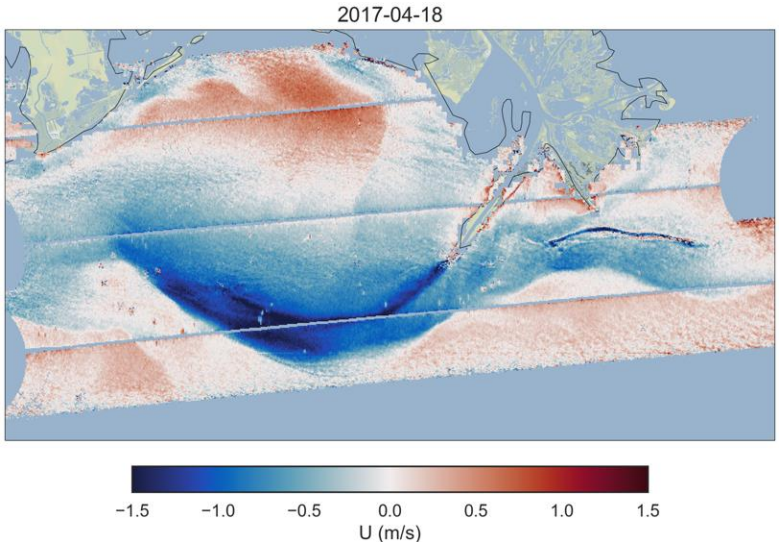
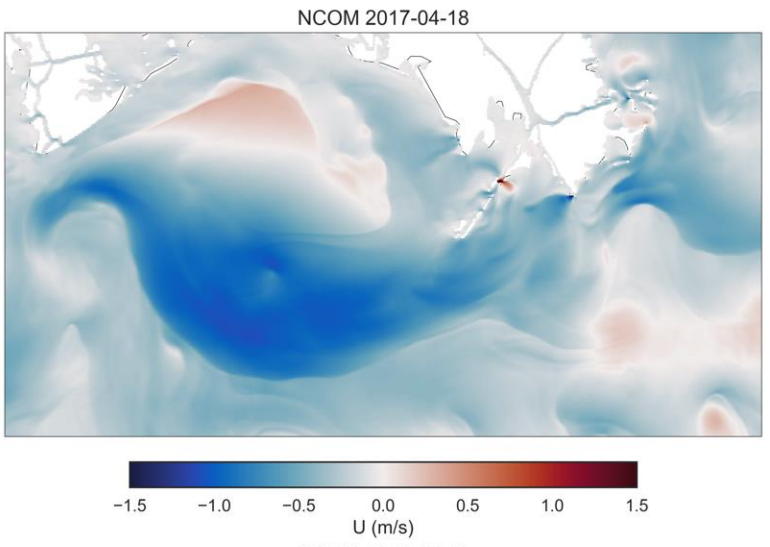
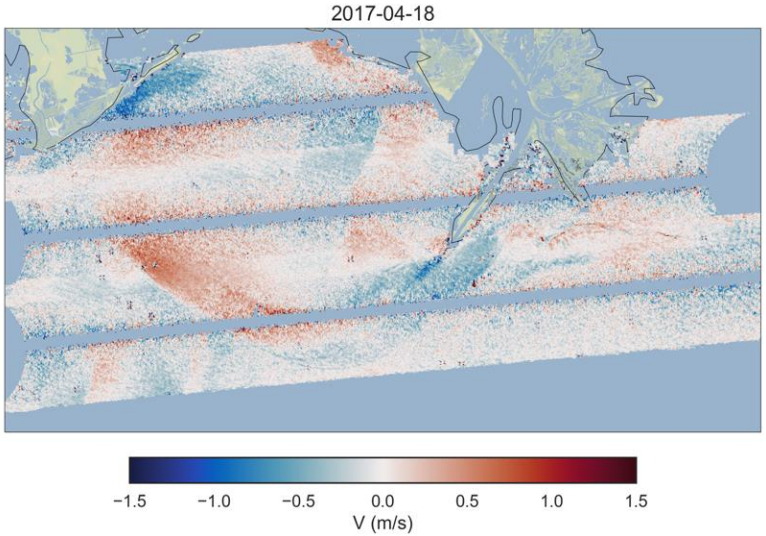
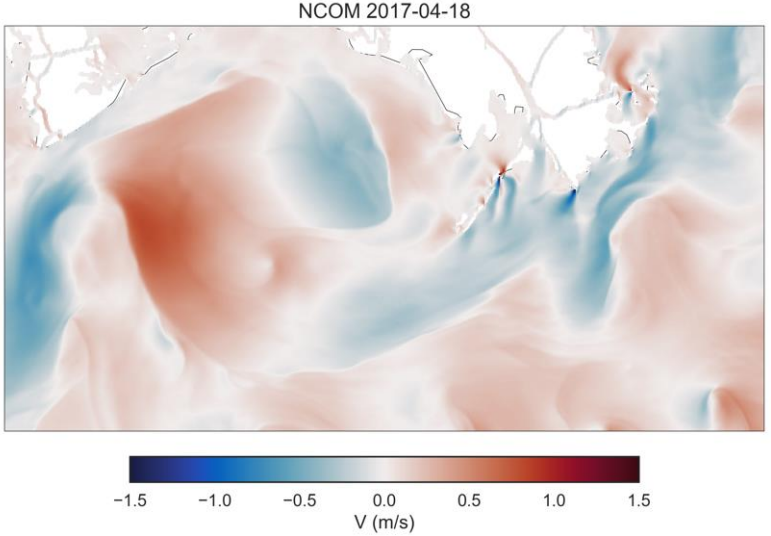
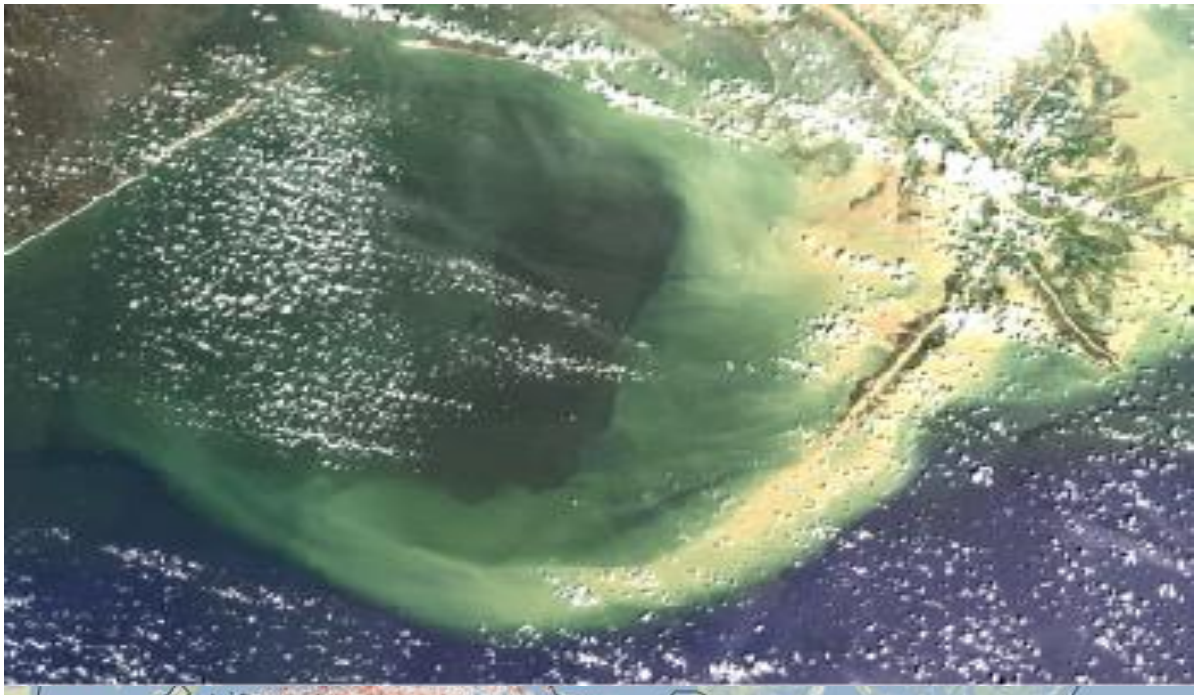




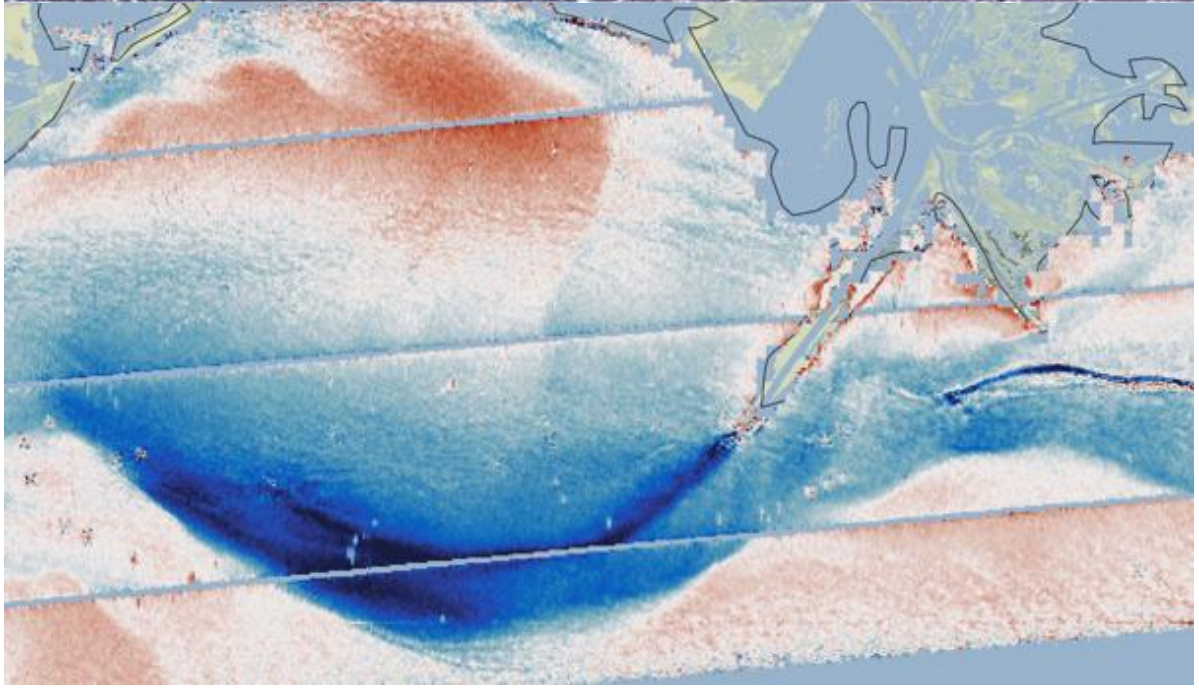
V







Sentinel 3 2017-04-18
Courtesy of Copernicus Sentinel, processed by ESA



DopplerScatt surface current U component.

Circulation pattern matches Sentinel 3 color pattern very closely.

2017-04-20

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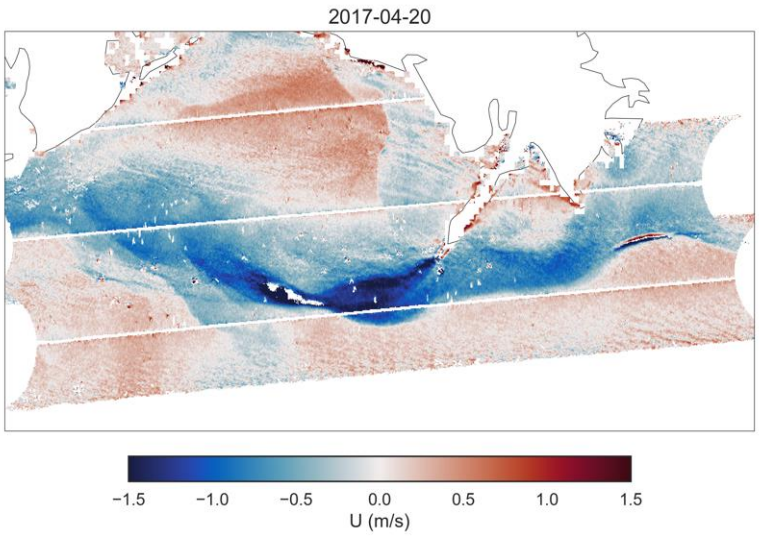

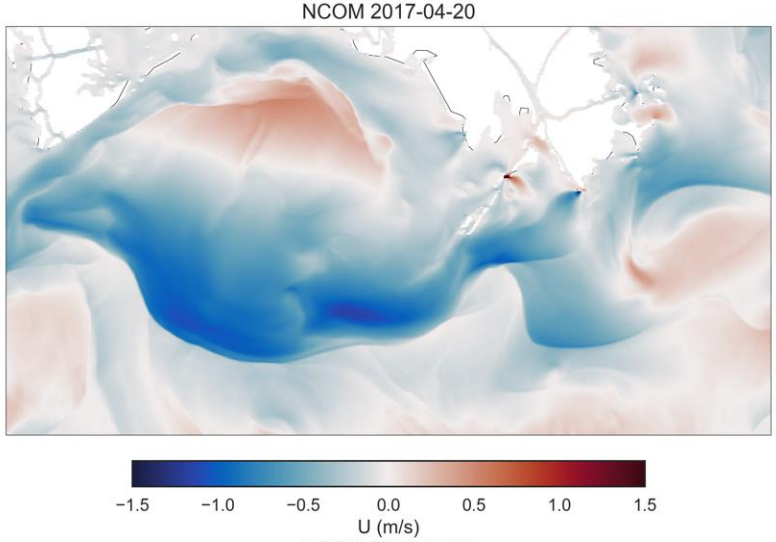

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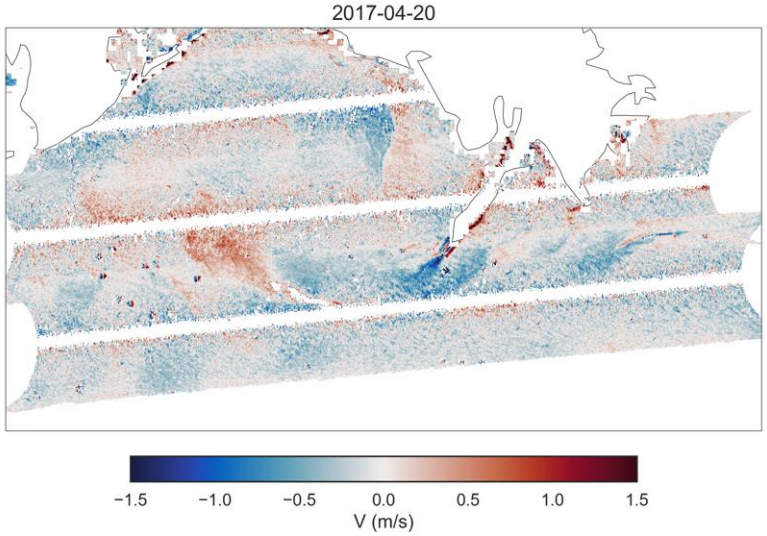

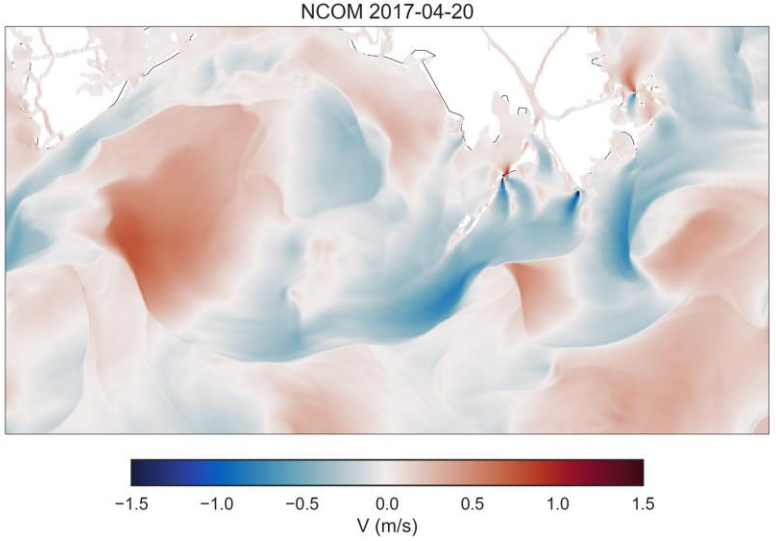

2017-04-24

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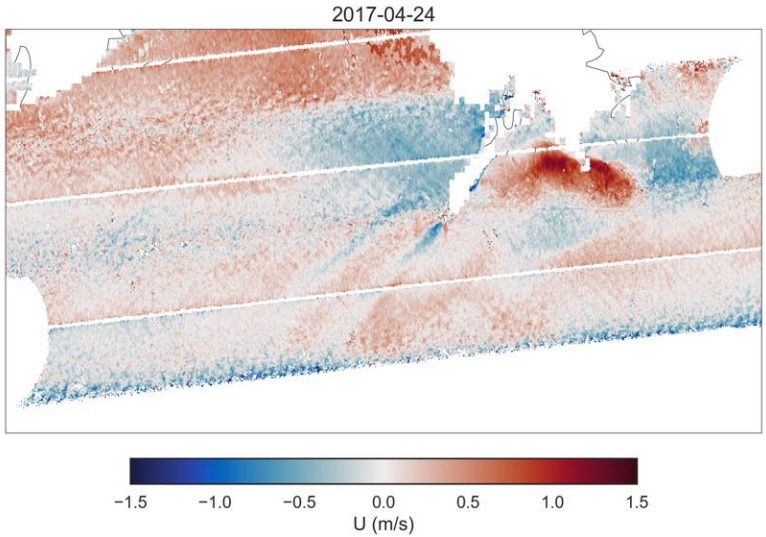

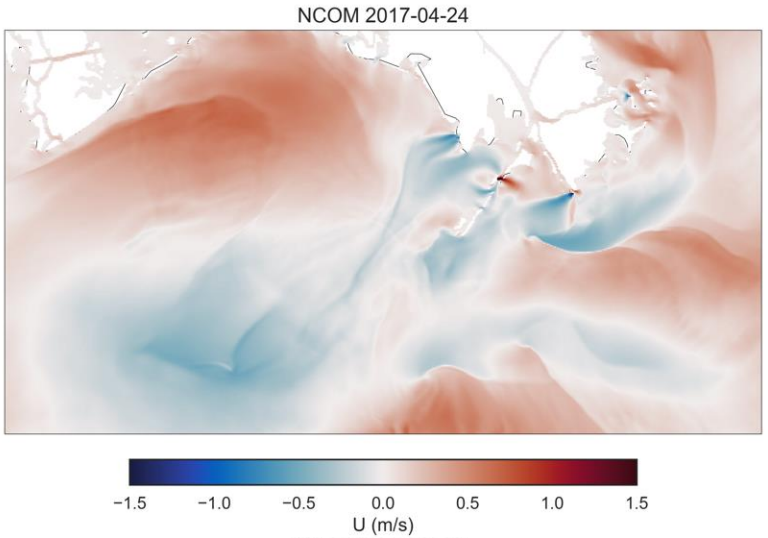

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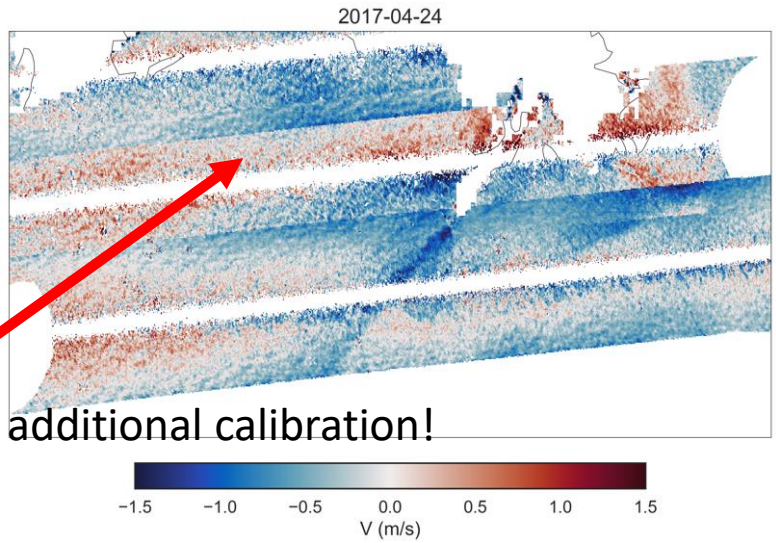

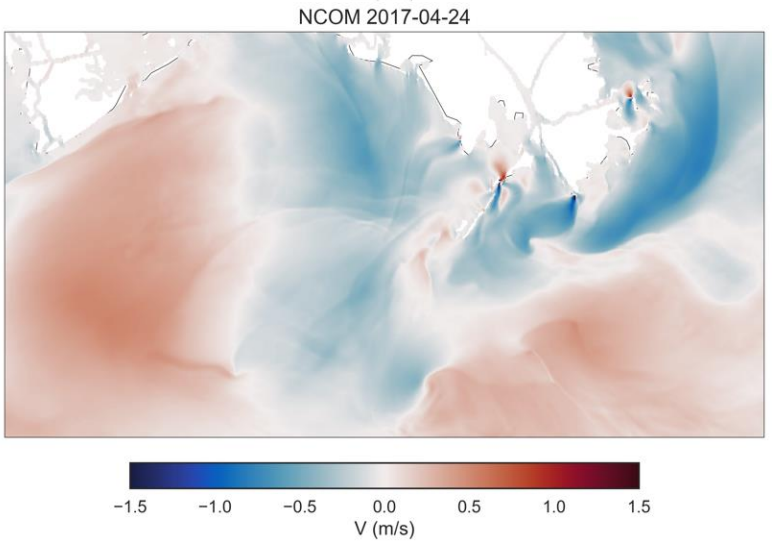

Needs additional calibration!

2017-04-27

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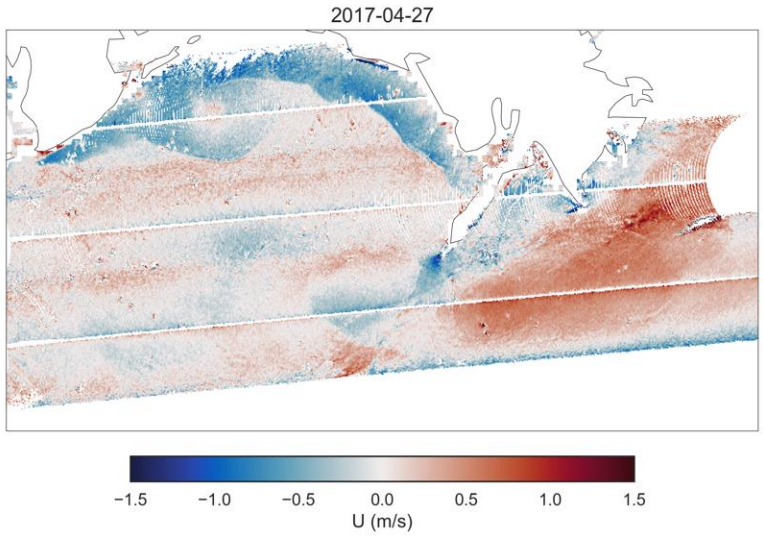

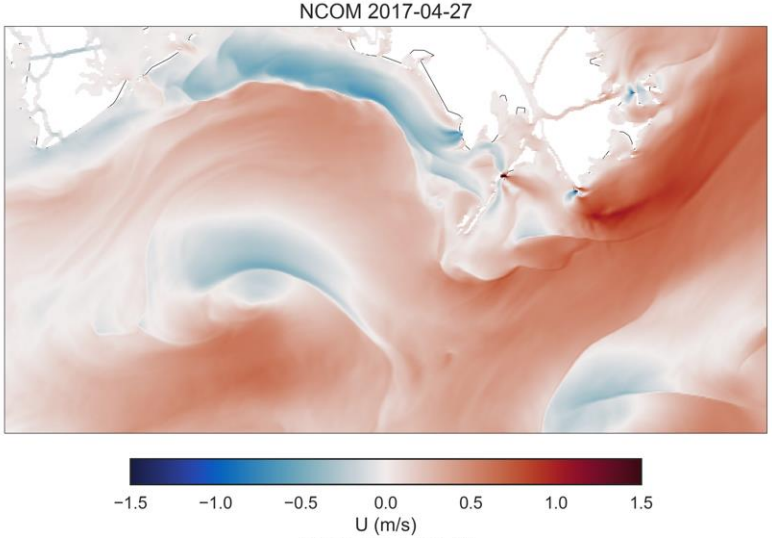

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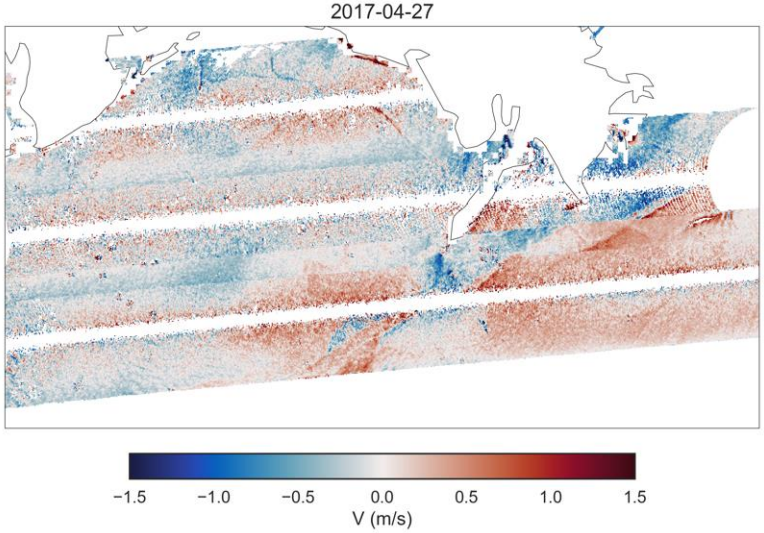
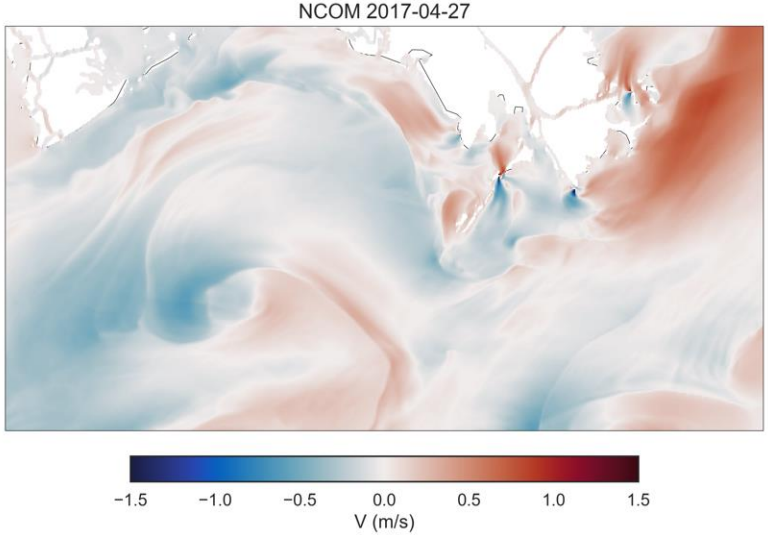


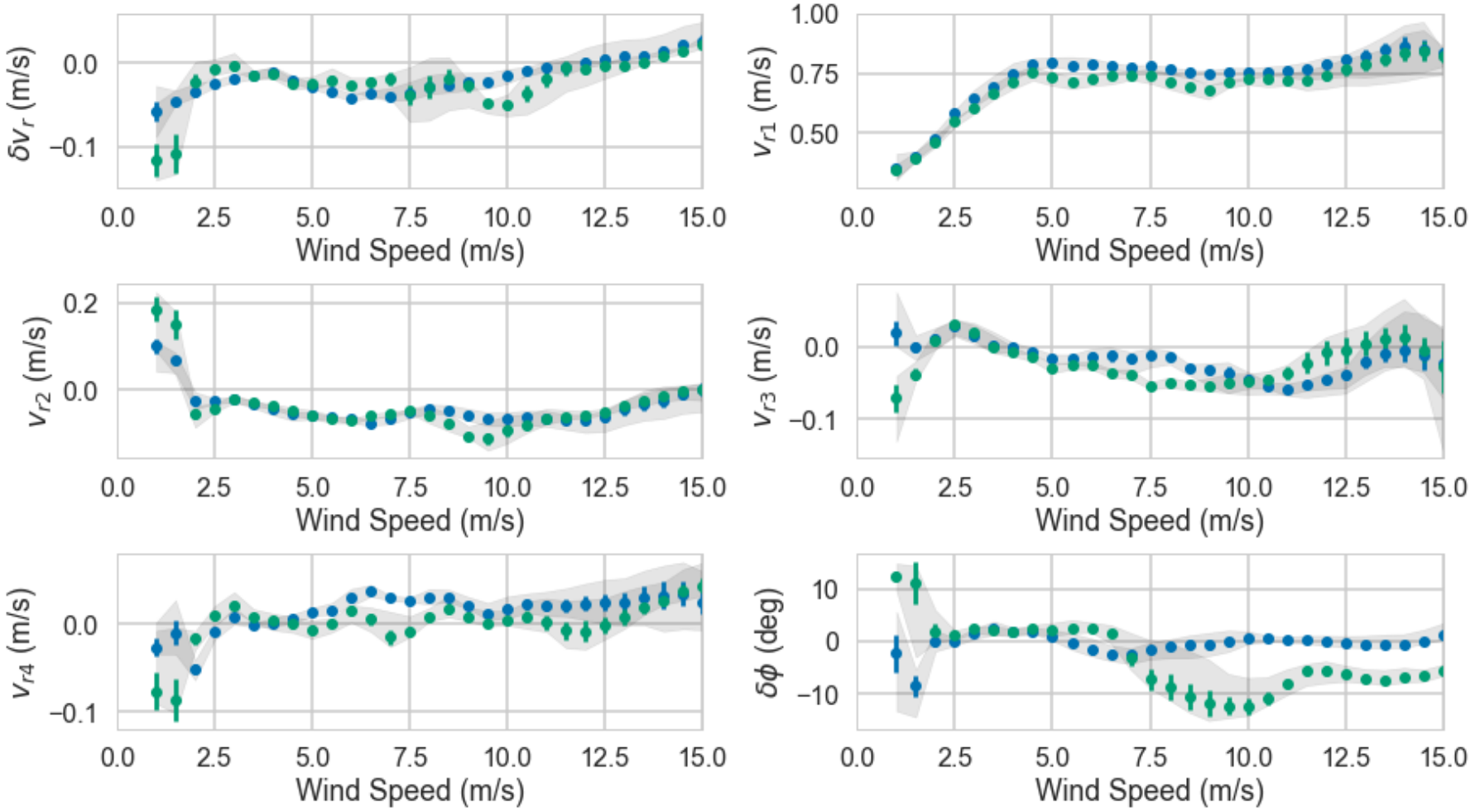


Summary and Prospects

- DopplerScatt calibration is proceeding satisfactorily (although not finished for all lines)
- Preliminary surface current estimates show qualitative agreement with NCOM, but feaures can be displaced and of different magnitude.
- Looking forward to making surface current velocity comparisons against SPLASH drifter array and other collaborations that might develop with SPLASH team.
- NASA ROSES-Physical Oceanography has funded a proposal (Rodriguez, PI; Molemaker, co-I) to make science use of these data.

Backups

Fit Parameters



V78: Blue V79: Green