Measuring Ocean Vector Winds and Currents with DopplerScatt

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Alexander Wineteer, Dragana Perkovic-Martin, Ernesto Rodriguez, Tamas Gal, Noppasin Niamsuwan, Raquel R. Monje, and Fabien Nicaise

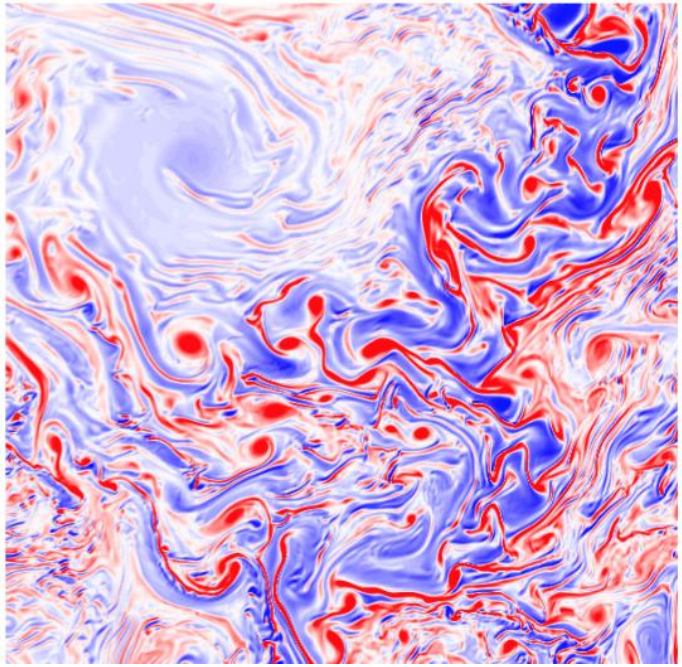
Jet Propulsion Laboratory, California Institute of Technology

Why Winds and Surface Currents? Why Submesoscale?

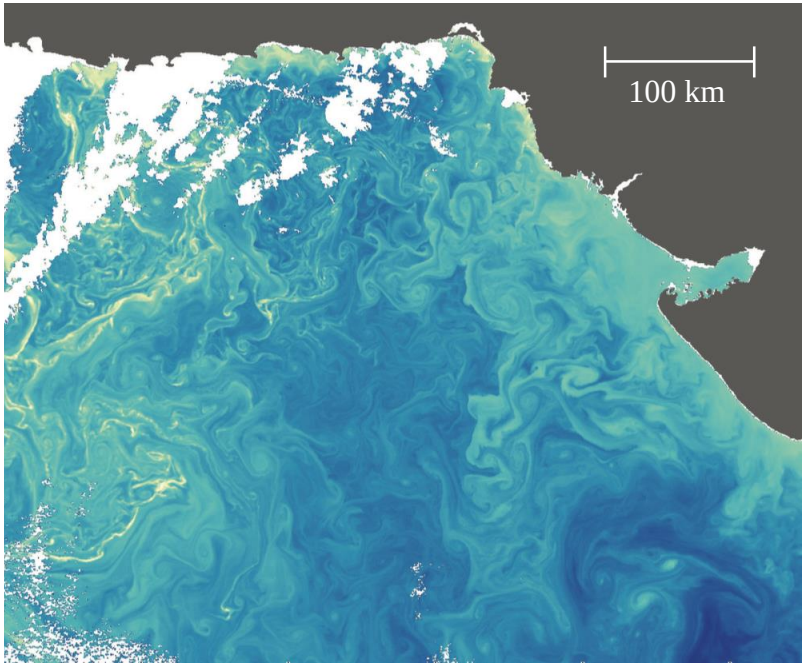
- Winds and currents are essential climate variables that have a tight two-way coupling
  - Winds drive both horizontal and vertical circulation in the ocean.
  - Currents provide a moving reference frame for winds and also modulate winds through heat transport/SST.
- The 2017 NRC Decadal Review has identified "***Coincident high-accuracy currents and vector winds to assess air-sea momentum exchange and to infer upwelling, upper ocean mixing, and sea-ice drift***" as a targeted observable for a potential Earth System Explorer mission.
  - Doppler scatterometry identified as a measurement technique.
  - DopplerScatt (NASA IIP) is a proof of concept instrument to validate measurement physics, algorithms, technology readiness.
- ***Submesoscale ocean circulation*** (spatial scales 200m – 25 km) is suspected to be responsible for significant vertical air-sea fluxes that can be larger than the global radiation imbalance associated with the greenhouse effect (Su et al., 2018) and cannot be measured yet from space.

Why Measure Ocean Surface Currents and Winds?

- Small scales (1 km to 25 km) dominate vorticity/convergence and are responsible for most vertical transport in the ocean.
- Knowledge of ocean surface currents and winds will improve our knowledge of energy transfer between the atmosphere and the ocean and our understanding of the advection of heat, nutrients, and pollutants in the ocean.
- The interaction between winds and currents has been identified as the next frontier by the US winds and currents communities.



Left: Ocean relative vorticity in the California Current from ROMS 1 km spacing model (J. Molemaker, UCLA, D. Chelton OSU)



Right: Chlorophyll concentration in the Arabian sea as seen by MODIS, 02/22/2005

DopplerScatt Overview

DopplerScatt Programmatic Overview

Scanning Doppler radar developed under NASA's IIP program
Becoming operational under NASA AITT program by 2019

Data Products:

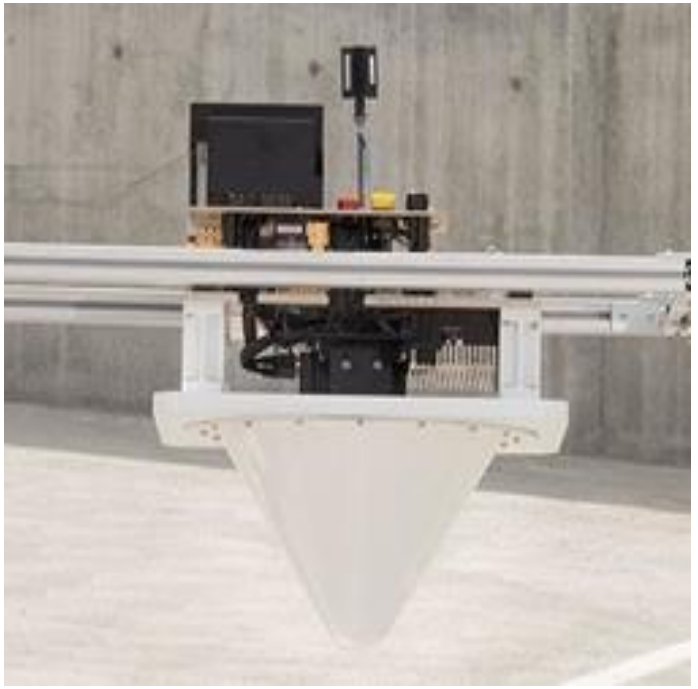
1. Vector ocean surface currents
2. Vector ocean surface winds
3. Radar brightness maps (sensitive to surfactants like oil films)
4. Surface wave 2D spectra (experimental)

Mapping capabilities:

- 25 km swath
- maps 200km x 100km area in about 4 hrs
- 200m data product posting
- Mapping within ~600 m of coast
- ~5-10 cm/s radial velocity precision.
- ~ 1 m/s wind speed, <20^{o} wind direction.

Campaigns flown/planned:

- Oregon coast (2016)
- SPLASH (Submesoscale Processes and Lagrangian Analysis on the Shelf) in Mississippi River Plume (CARTHE) & Taylor Oil Platform Plume (NOAA), April 18-28, 2017.
- KISS-CANON in Monterey Bay May 1-4, 2017.
- Gulf of Mexico Eddy/Chevron (March, 2018)
- California current (August, 2018)



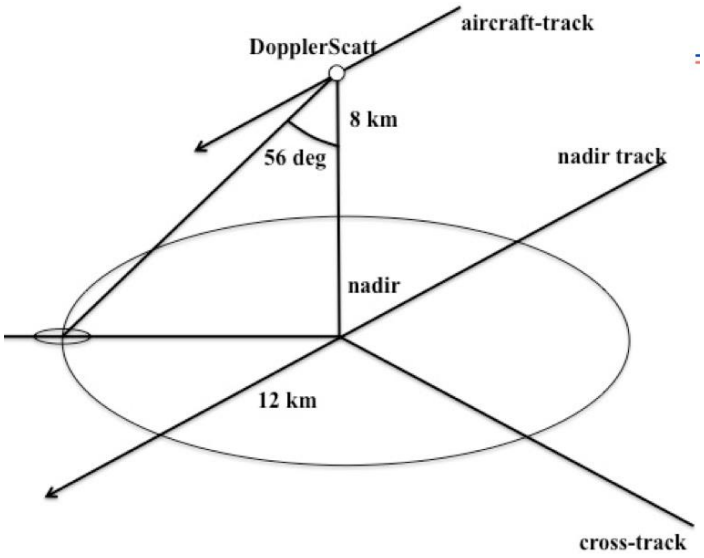
DopplerScatt instrument. Deployed on the NASA King Air B200.

The DopplerScatt Concept

- Coherent radars can measure radial velocities by measuring Doppler shifts.

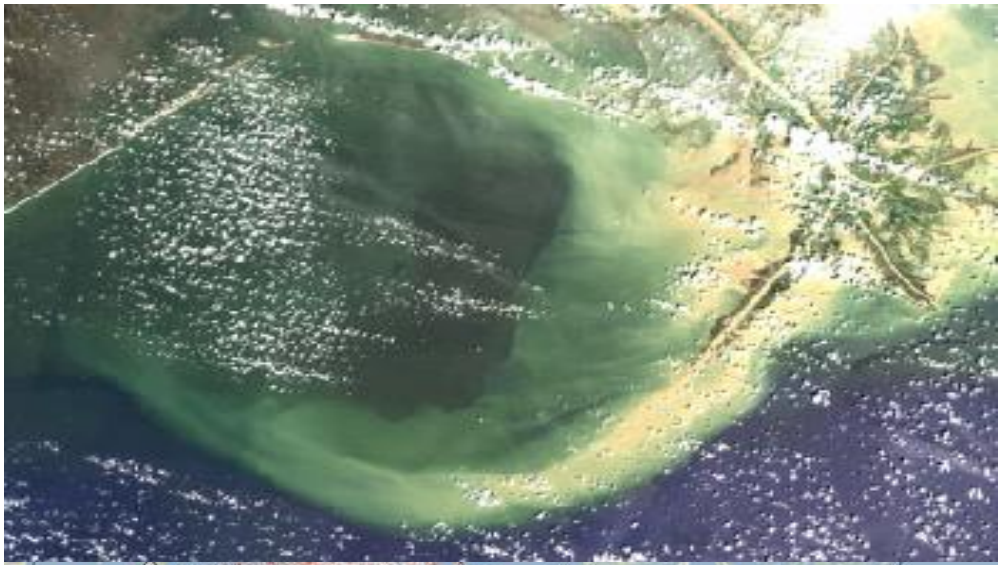
- Rodríguez (2012, 2014) has outlined the spaceborne concept to be able to measure ***vector velocities*** by using a pencil-beam scanning scatterometer.
  - A wide swath enables global coverage in one day.
  - The same instrument also measures high resolution winds.

- DopplerScatt is a proof-of-concept airborne instrument demonstrating the feasibility and accuracy of this measurement technique with the results applicable to future spaceborne missions.

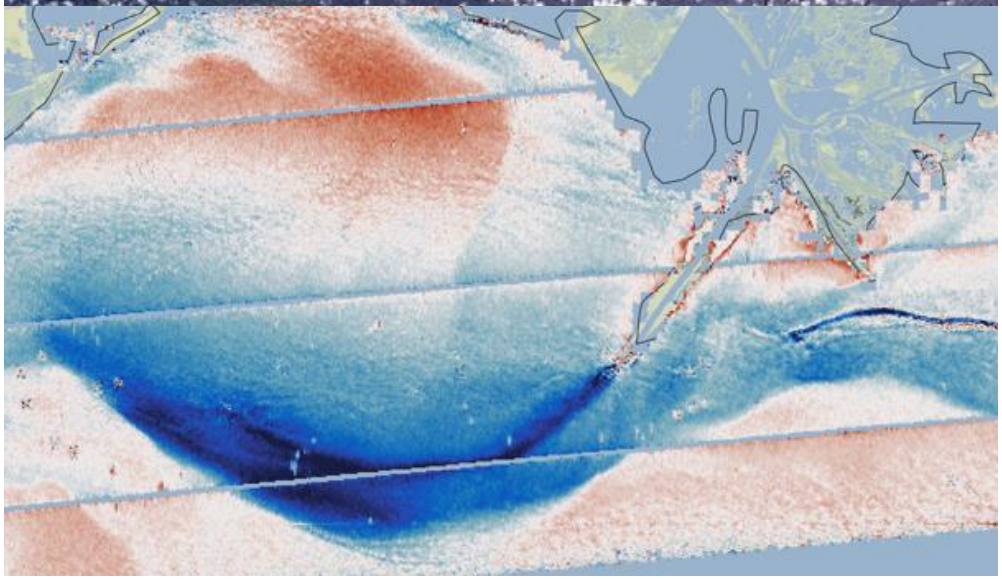


Pencil-beam concept for the airborne DopplerScatt with wide-swath coverage

DopplerScatt Surface Currents



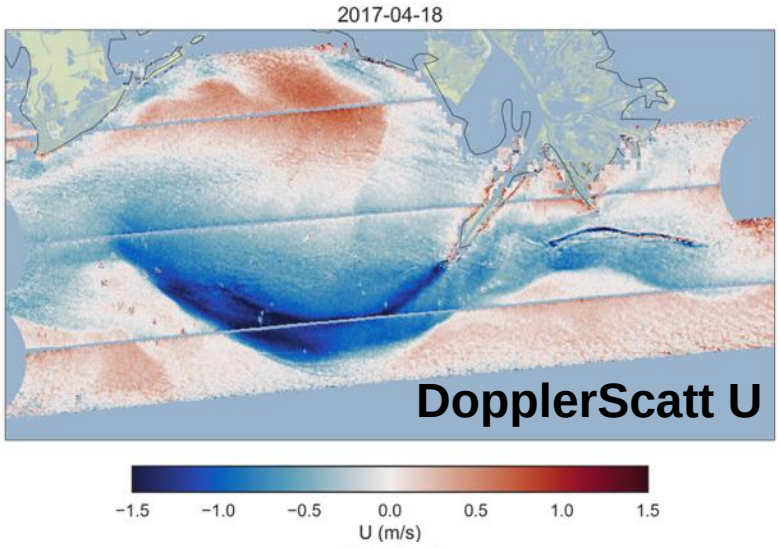
Sentinel 3 2017-04-18
Courtesy of Copernicus Sentinel, processed by ESA

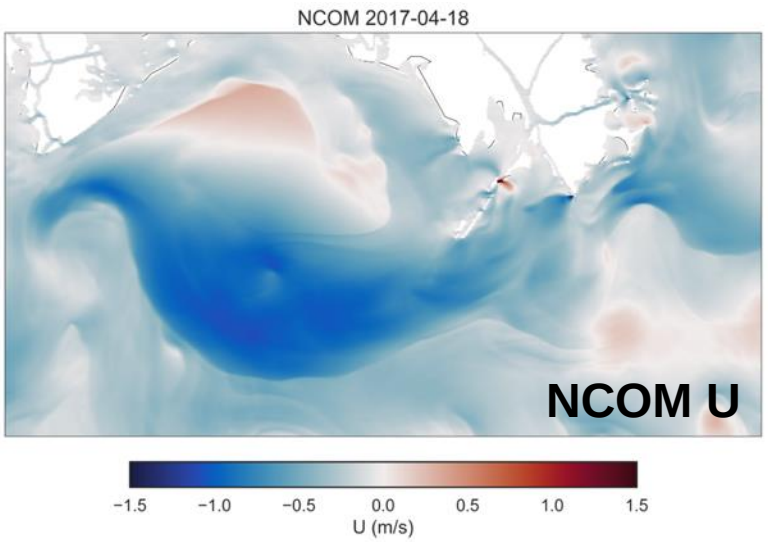


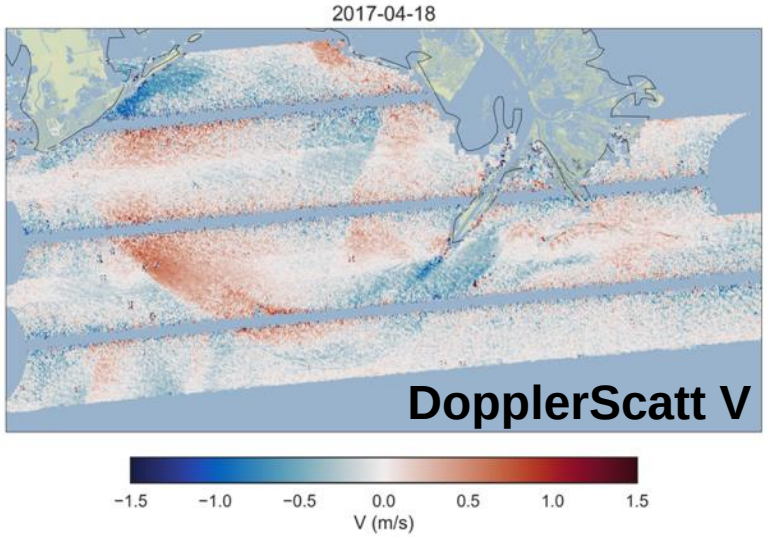
DopplerScatt surface current U component.

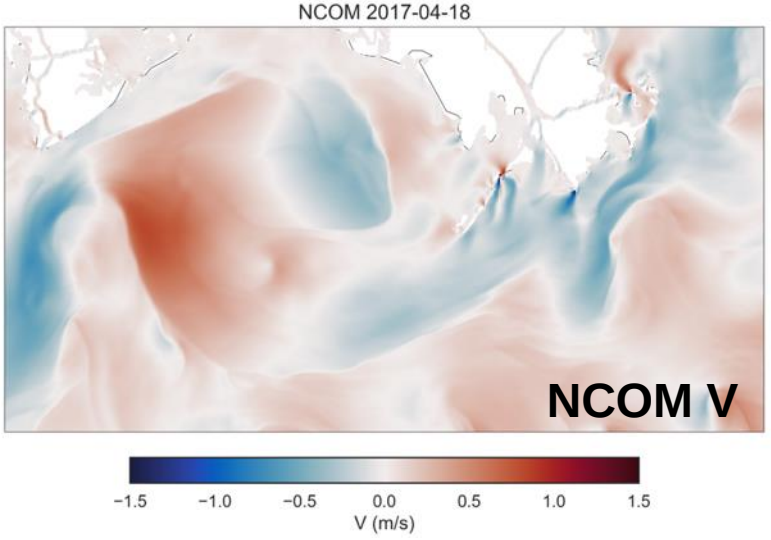
Circulation pattern, including submesoscale front, matches Sentinel 3 color pattern very closely.

SPLASH 2017-04-18

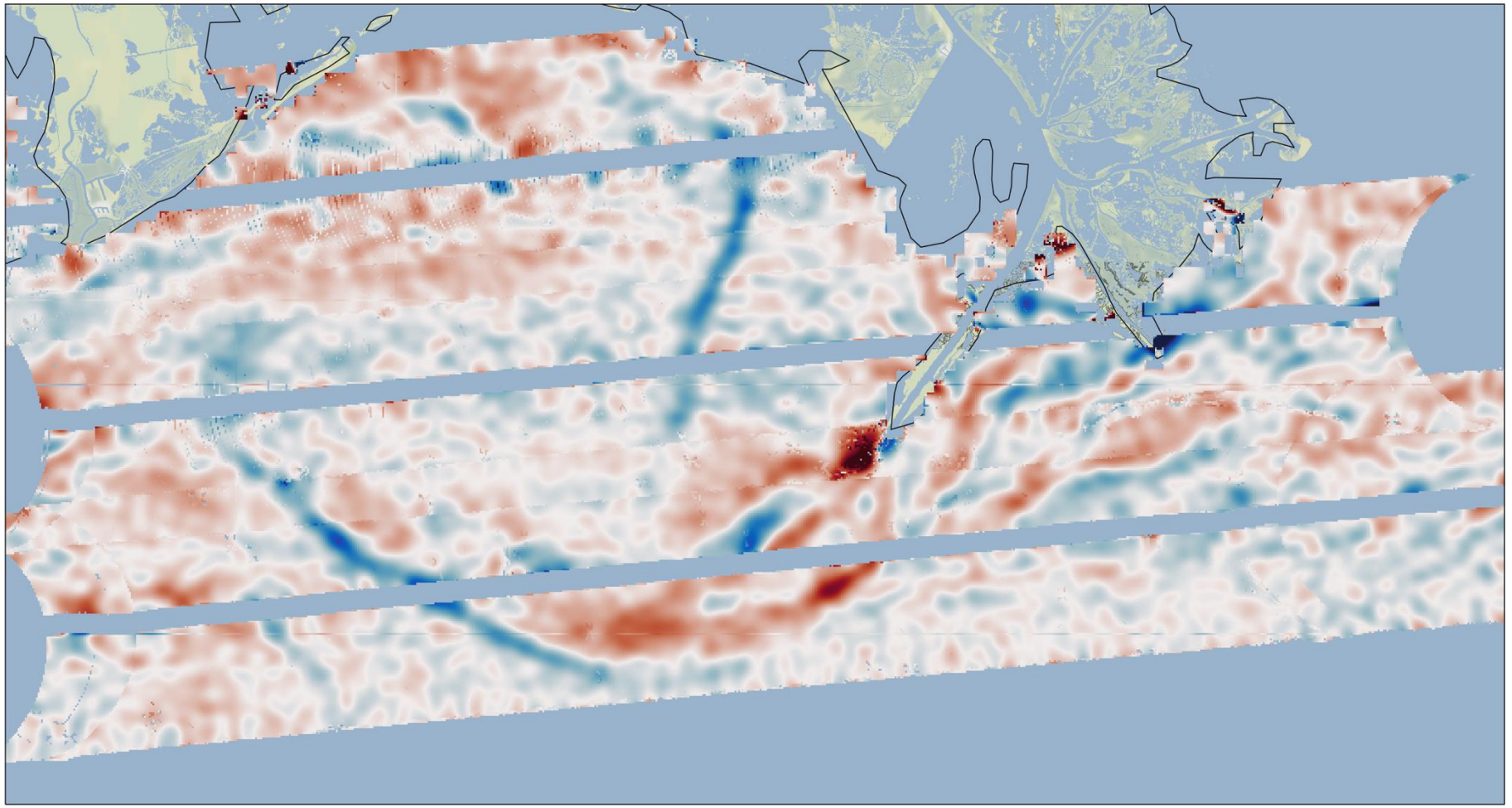


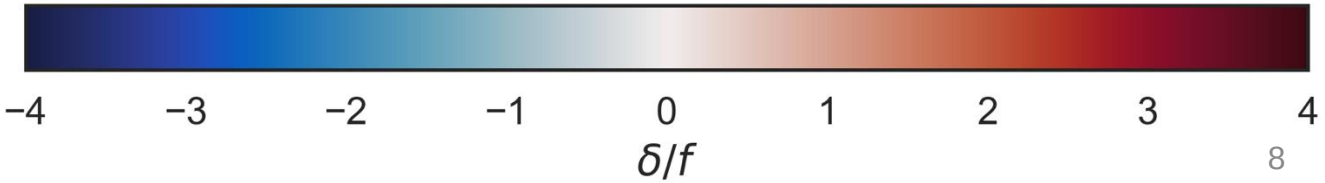




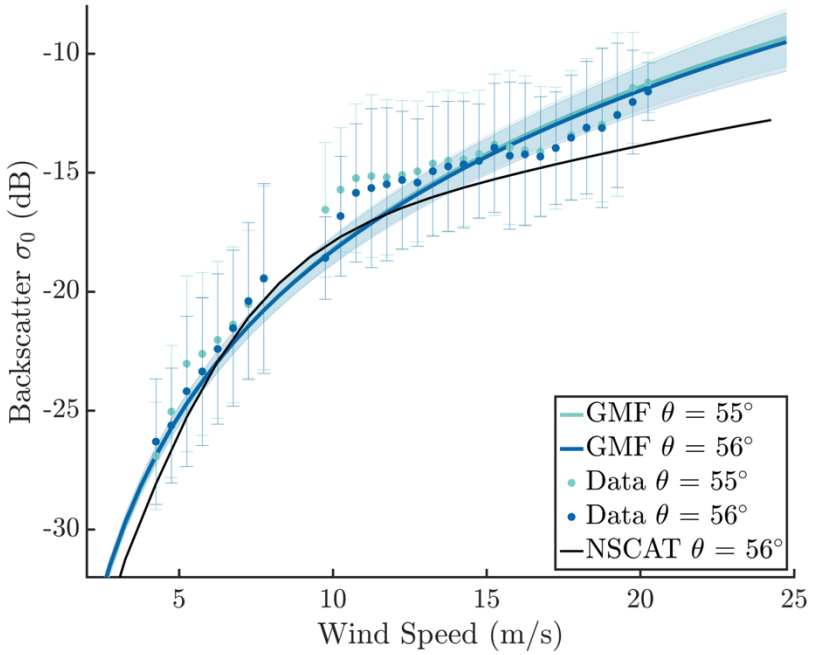


Divergence



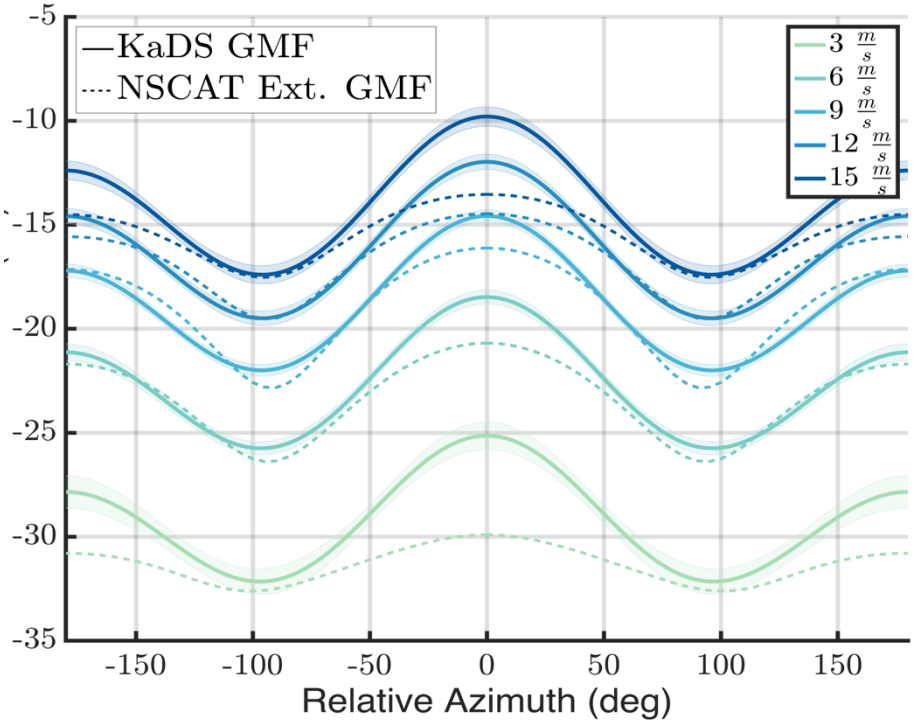


DopplerScatt Wind Model Function

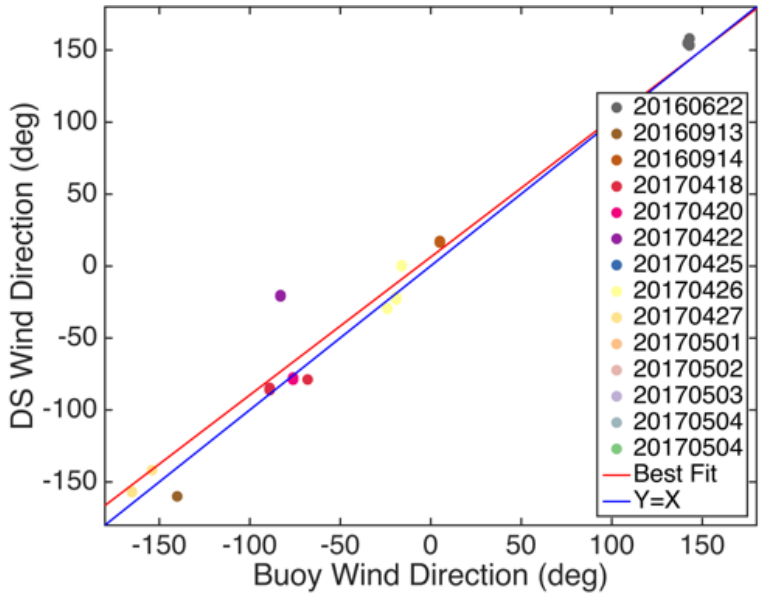


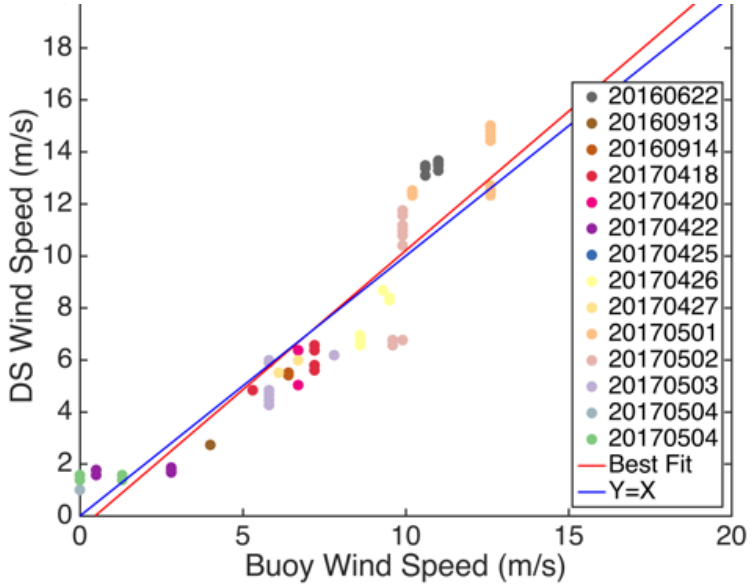
- Ka-band sensitivity to wind speed is very similar to Ku-band (NSCAT, QuikSCAT, RapidScat)
- **Ka-band seems to show less saturation at high winds than Ku-band**, perhaps due to the higher impact of wave breaking (TBC with more data)
- DopplerScatt data and model indicate higher modulation at Ka-band than Ku-band between cross wind and up/down wind over a large range of wind speeds, which **makes wind direction estimation easier at Ka-band for high wind speeds.**
- **Ka-band scatterometers offer a feasible continuation of the Ku-band scatterometer climate data record.**

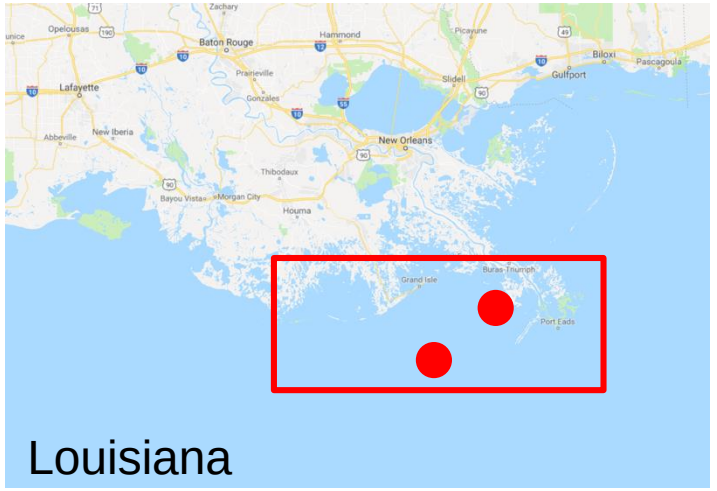
- Heritage scatterometers have operated at C/Ku-band (QuikSCAT, NSCAT, ASCAT, among many).
- Ka-band has very little heritage, both in terms of missions and model functions. → Need for Ka-band model functions.
- The DopplerScatt model function was trained using high resolution model winds.



DopplerScatt Winds and Buoys

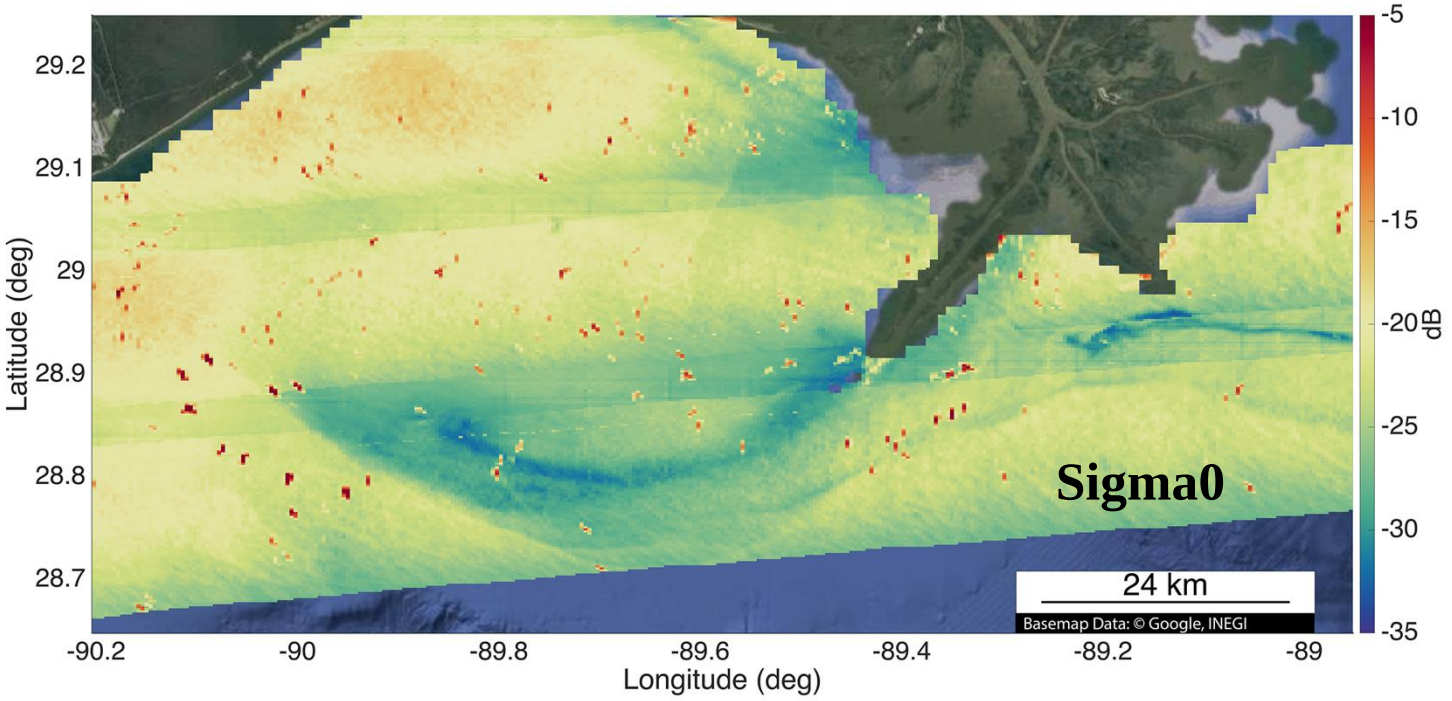




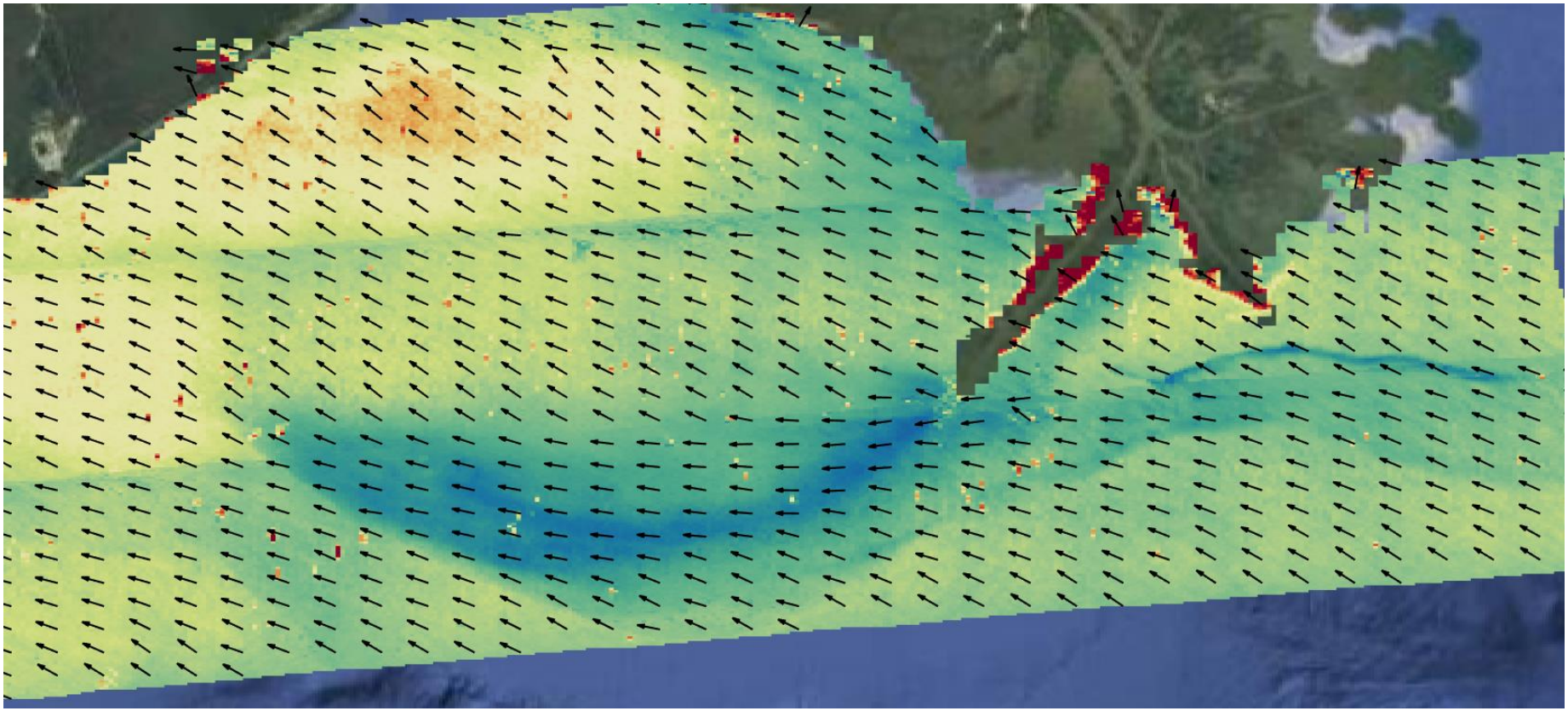


What are we measuring?

- Backscatter is a measurement of the normalized return power of the ocean surface.
  - At Ka-band, we are primarily measuring the scattering due to capillary waves driven by the wind. Capillary waves are measured relative to surface currents.
  - Affected by surface characteristics (SST, viscosity, dissolved solids)
- In the areas that DopplerScatt flies, there are typically river outflows and internal waves that will appear in backscatter.
- At the resolution DopplerScatt operates, many non-wind small scale processes will appear in the retrieved wind fields.

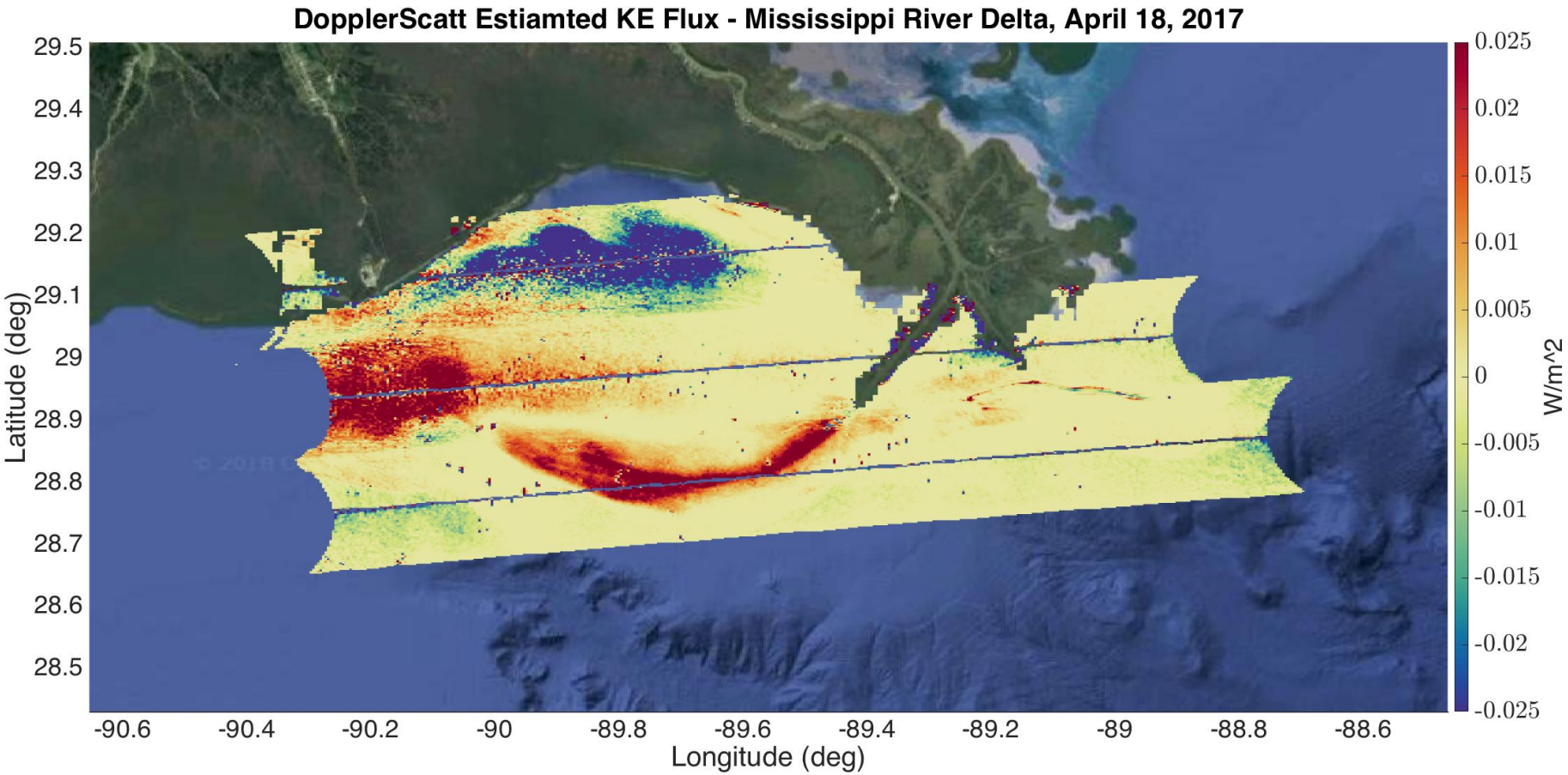


Vector Winds



Ocean vector winds as retrieved by DopplerScatt near the outlet of the Mississippi river. Since scatterometers are sensitive to wind stress (which depends on the relative winds and currents), we see the Mississippi river current prominent in the winds.

DopplerScatt Kinetic Energy Flux

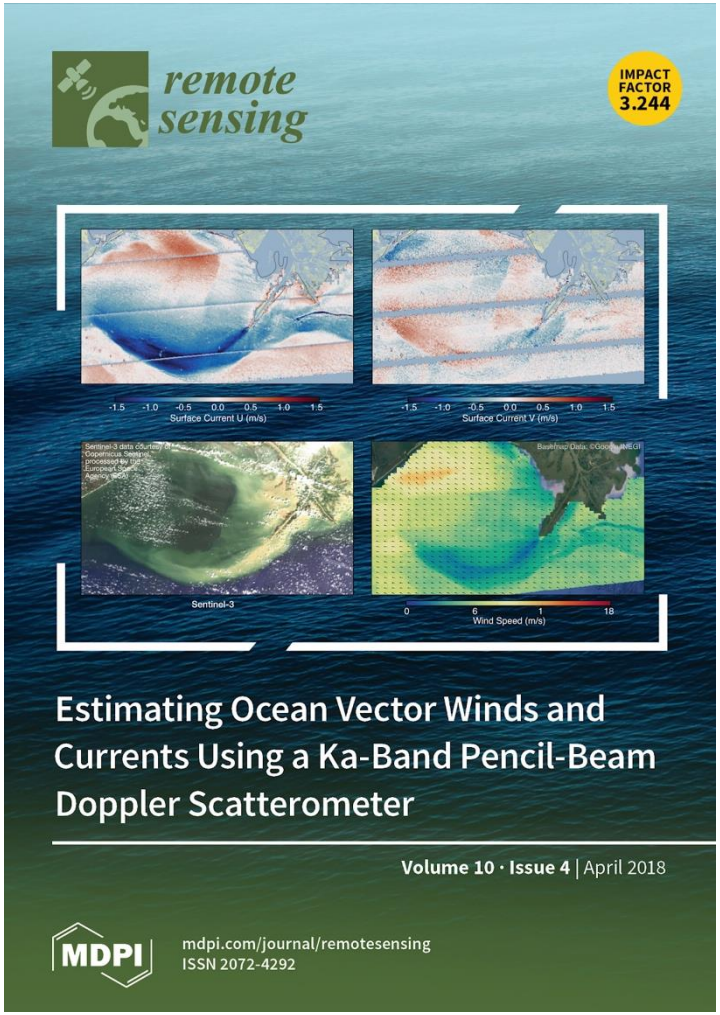


Kinetic energy flux is a measurement of the transfer of wind mechanical energy into the ocean via the interaction of winds and surface currents.

Thank you!

For more, see:

Rodríguez, E.; Wineteer, A.; Perkovic-Martin, D.; Gál, T.; Stiles, B.W.; Niamsuwan, N.; Rodriguez Monje, R. Estimating Ocean Vector Winds and Currents Using a Ka-Band Pencil-Beam Doppler Scatterometer. *Remote Sens.* **2018**, *10*, 576.



References:

O'Neill, L. W., Chelton, D. B., & Esbensen, S. K. (2012). Covariability of surface wind and stress responses to sea surface temperature fronts. *Journal of Climate*, *25*(17), 5916-5942.

Wineteer, A., 2016: Towards Improved Estimates of Upper Ocean Energetics. California Polytechnic State University Masters Thesis, https://doi.org/10.15368/theses.2016.19

Yurovsky, Y., V. N. Kudryavtsev, S. A. Grodsky, and B. Chapron, 2016: Ka-Band Dual Copolarized Empirical Model for the Sea Surface Radar Cross Section. 1–19, doi:10.1109/tgrs.2016.2628640.