Wind Coupling with Other Geophysical Variables

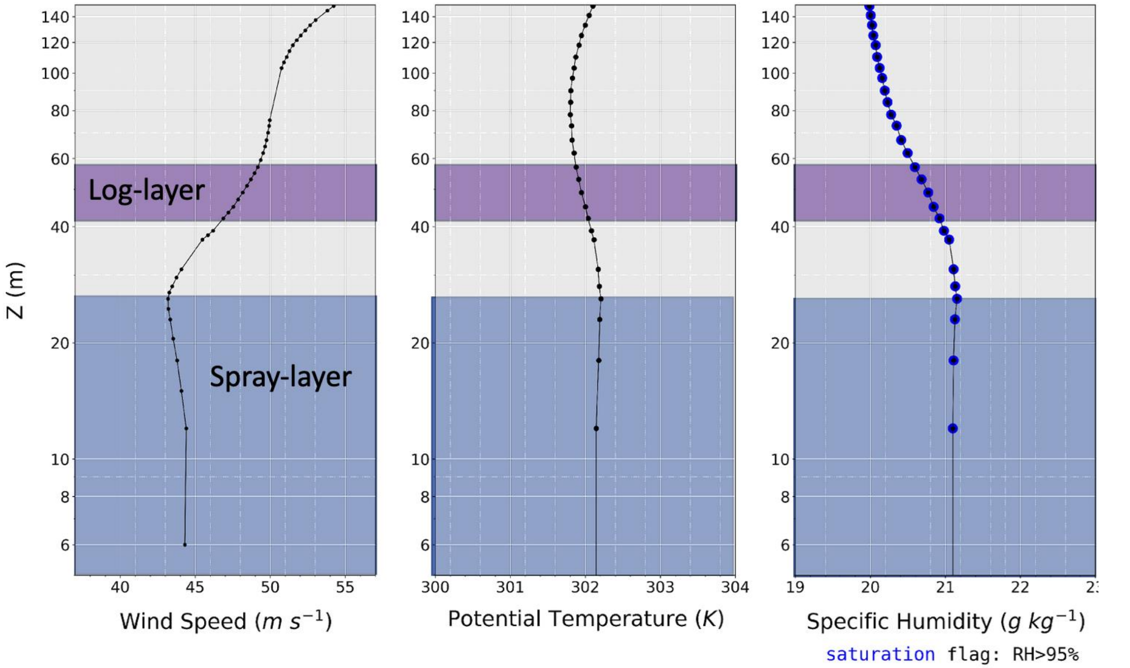
2023 IOVWST Meeting
Day 3
November 15, 2023
Bia Villas Bôas, Luc Deike, Luc Lenain, Marcos Portabella,
Aneesh Subramanian, Ernesto Rodríguez

Sea Spray in Hurricanes Influences Profiles of Wind, Potential Temperature, and Moisture

Danny Wallace, Heather Holbach, Mark Bourassa

Due to limited time, this material could not be included but you can find the presentation here:

https://docs.google.com/presentation/d/1wY3pikDvO7I2tsIGRQmILBZUriB0EWqS/edit?usp=sharing&ouid=101155798790393408482&rtpof=true&sd=true

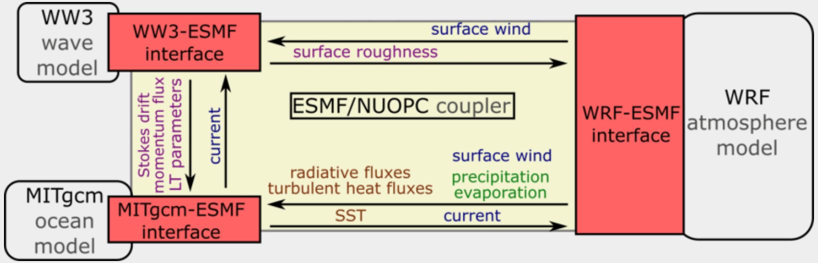


Graphic adapted from Wallace et al.'s 'Log-Profile Analysis of the Near-Surface Layer and Air-Sea Turbulent Fluxes in Hurricanes Using Dropsondes' (in preparation). Please see our poster.

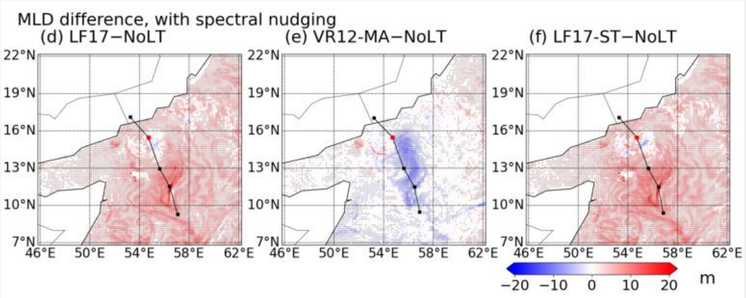
A coupled framework for quantifying interactions between winds, currents, and waves.

Bia Villas Bôas, Gwendal Marechal, Matt Mazloff, and Rui Sun

SKRIPS is a **model framework** developed by our team that **couples** the **MITgcm**, **WRF**, and **WaveWatch III**.



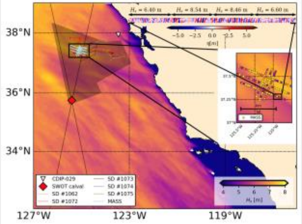
Our main goal is to quantify the contribution of surface waves to air-sea fluxes, ocean mixing and upper-ocean budgets.



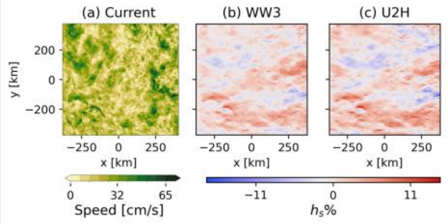
*Sensitivity of the mixed layer depth to different **Langmuir turbulence** parameterization schemes. See Sun et al (2023) for details.*

Modeling and **theory** suggest a scale dependence between **currents** and surface **wave gradients**

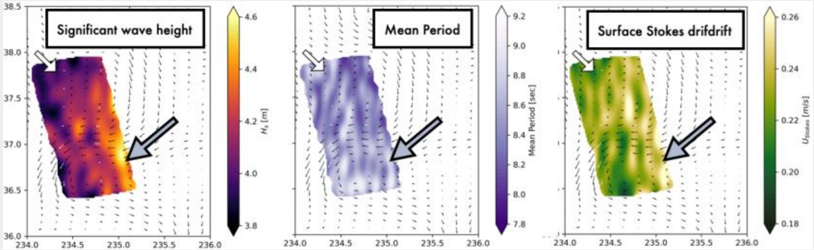
More on Marechal et al poster



See Wang et al. (2023)



We are leveraging observations from S-MODE and SWOT cal/val to better understand sea state gradients and their impact on how we sense winds, currents, and SSH.



*The spatial variability of **Stokes drift** results from a combined response to **wind forcing** and amplitude/frequency modulation due to **wave-current interactions** (Marechal, Villas Bôas, Pizzo, and Lenain – in prep)**.***

NASA Project High fidelity modeling of parasitic capillary wave dynamics for remote sensing

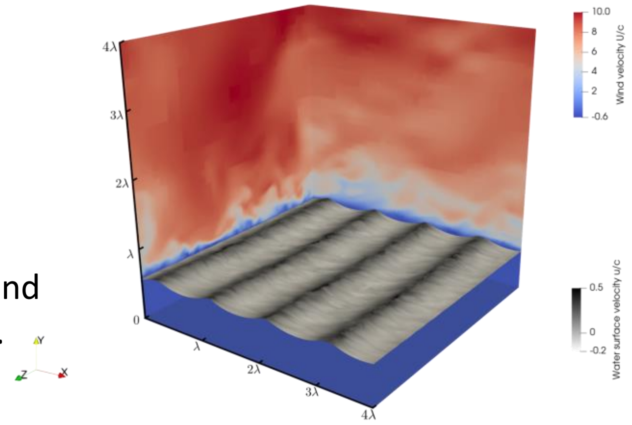
Jiarong Wu, and **Luc Deike.**

Stephane Popinet (Sorbonne University), Bertrand Chapron (Ifremer),

Ernesto Rodriguez (NASA-JPL), Tom Farrar (WHOI)

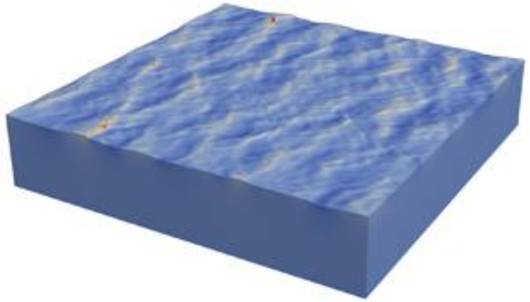
Scope and approach: high fidelity modeling of small scale surface waves coupled with atmospheric and oceanic turbulent boundary layers

Direct numerical simulations of wind-wave-current coupling; including breaking and parasitic capillary waves



Wu, Popinet and Deike, 2022, J. Fluid Mech.

Multi-layer modeling for broad banded wave dynamics coupled with boundary layer processes, including statistics of breaking waves



Wu, Popinet and Deike, 2023, J. Fluid Mech.

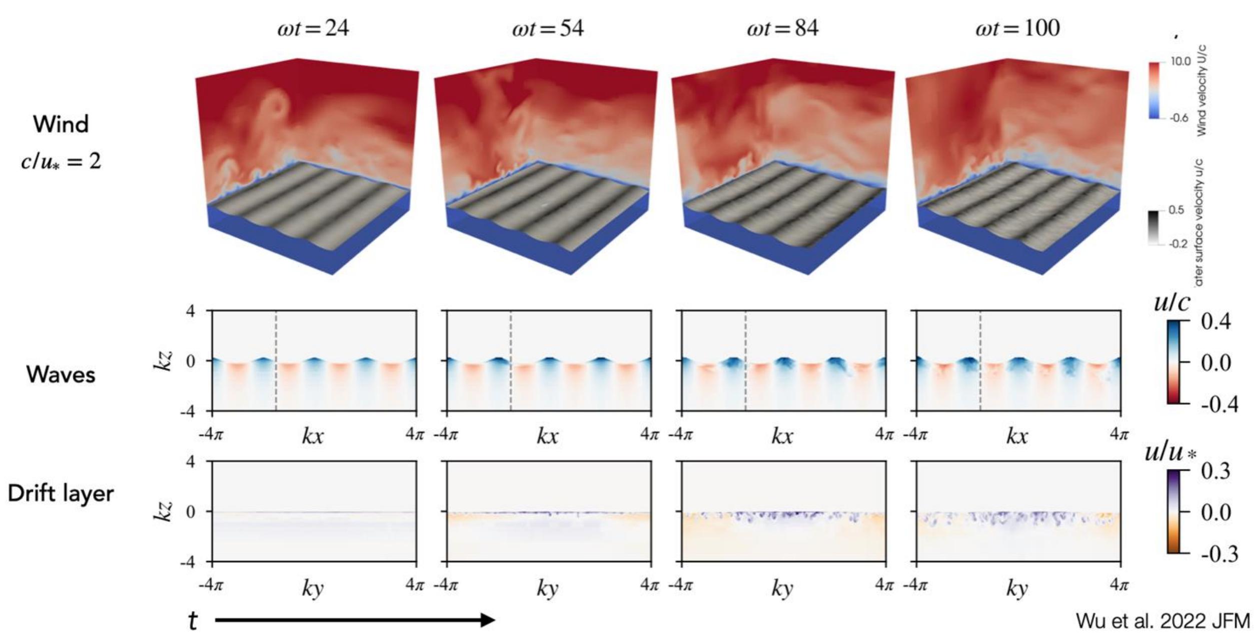
From individual dynamics (scales from mm to meters)

To statistics (scales from meters to km)

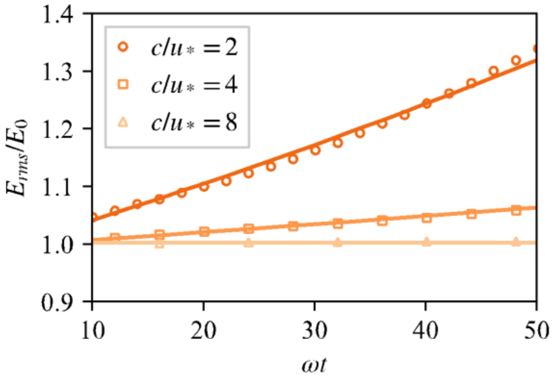
NASA Project High fidelity modeling of parasitic capillary wave dynamics for remote sensing

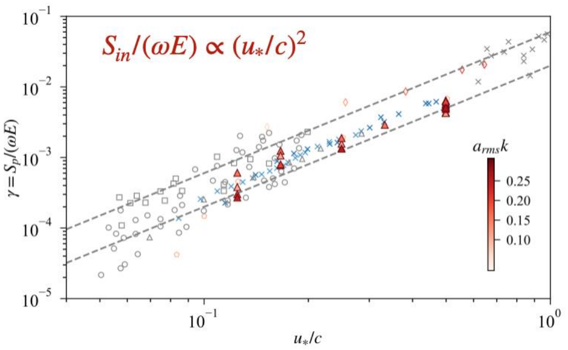
Jiarong Wu, and **Luc Deike,** Stephane Popinet (Sorbonne University), Bertrand Chapron (Ifremer), Ernesto Rodriguez (NASA-JPL), Tom Farrar (WHOI)

Fully coupled simulations of wind-wave-current coupling; including breaking and parasitic capillary waves



Wu et al. 2022 JFM





NASA Project High fidelity modeling of parasitic capillary wave dynamics for remote sensing

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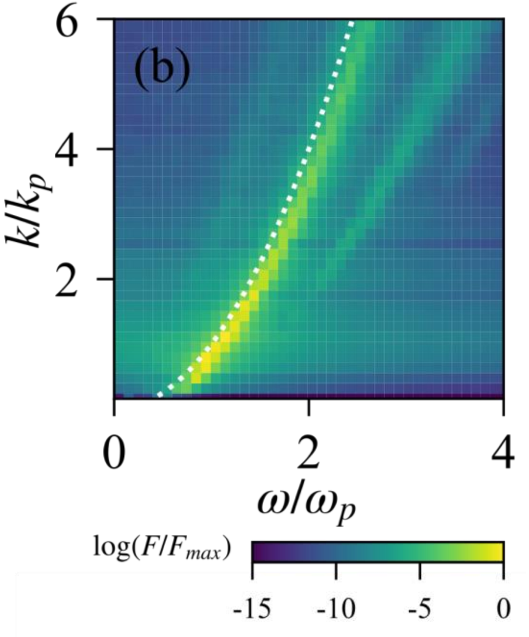
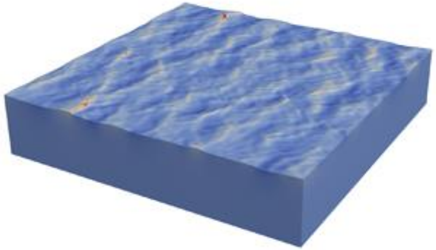
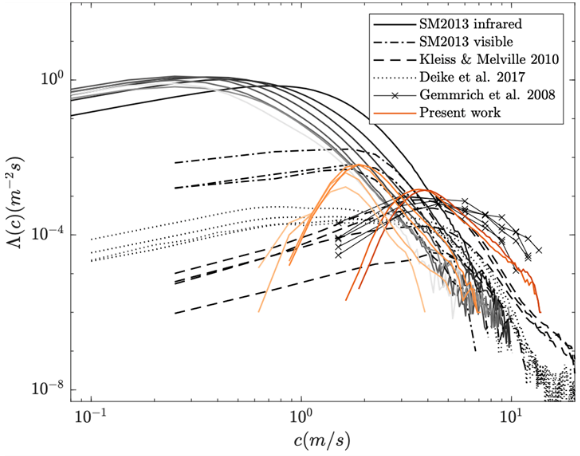
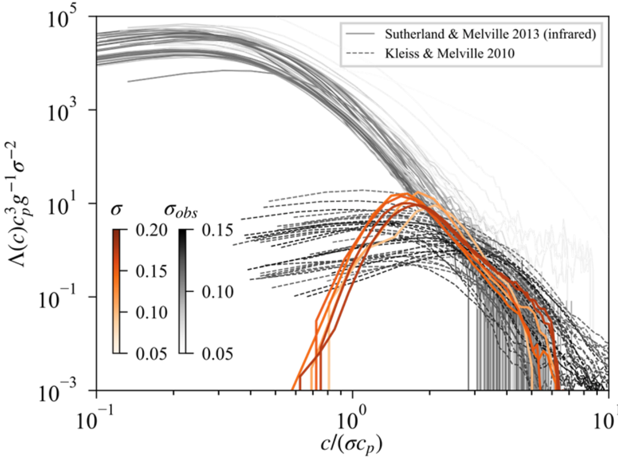
Multi-layer modeling for wave dynamics coupled with upper ocean, including breaking waves







Similar level of breaking freq to field observations.

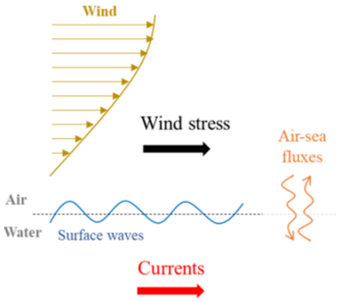


Proposed wave-slope only scaling.

Coupling between the ocean and the atmosphere from meso to submesoscales

Luc Lenain (SIO), Nick Pizzo (URI) and Mara Freilich (Brown)

SIO MASS is an airborne instrument to simultaneously collect observations of **sea surface temperature**, **ocean color**, **winds and mean-square slope**, **surface waves**, **wave breaking statistics**, **ocean topography**, and **currents and upper-ocean shear** at horizontal scales ranging from **submeter to mesoscales**.



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DoppVis Currents

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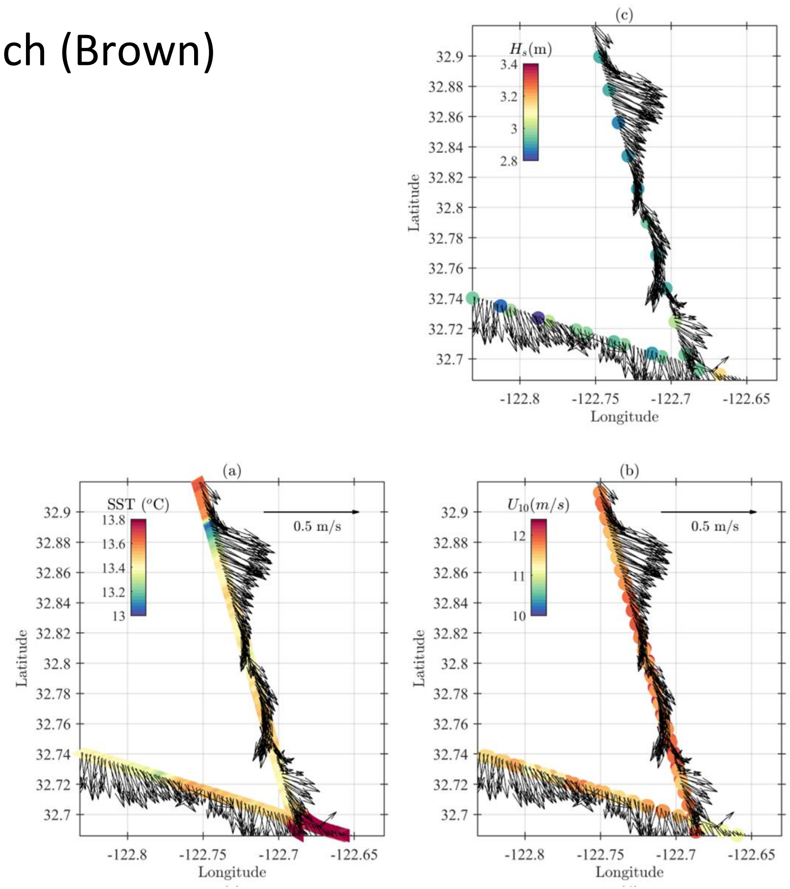
Co-located observations of wind, waves, and currents are necessary to understand air-sea interactions.



Coupling between the ocean and the atmosphere from meso to submesoscales

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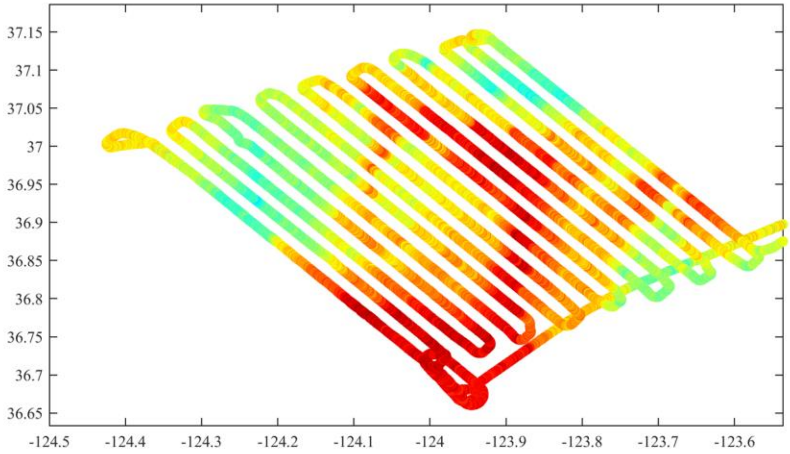
Significant synergy with the S-MODE and SWOT programs

S-MODE IOP2 pencil-beam SST from MASS (April 19 2023)



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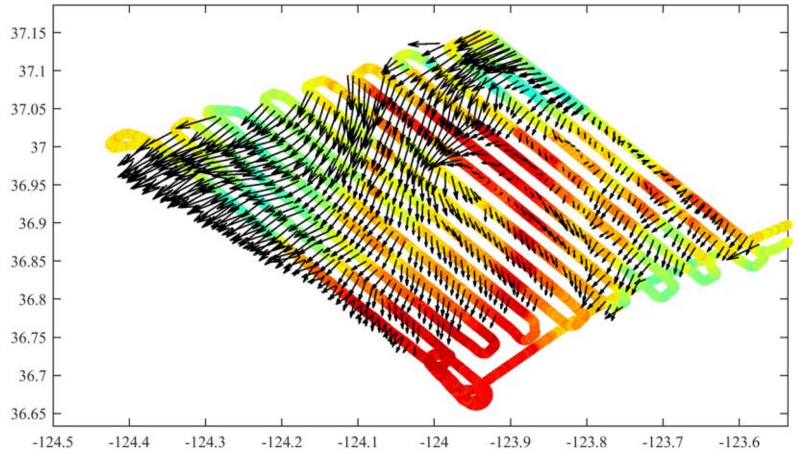
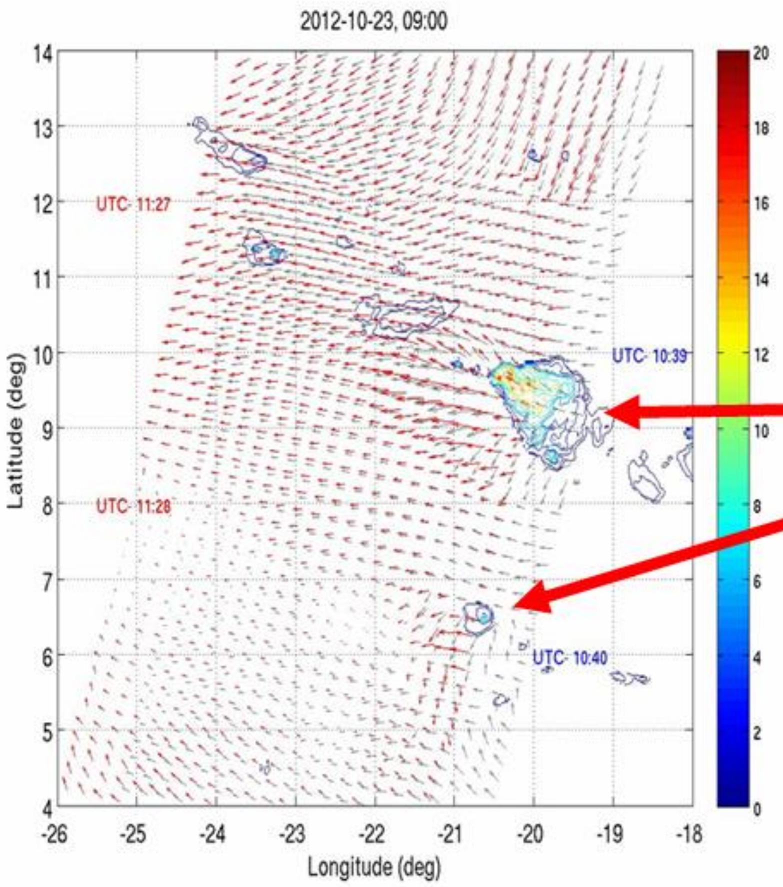
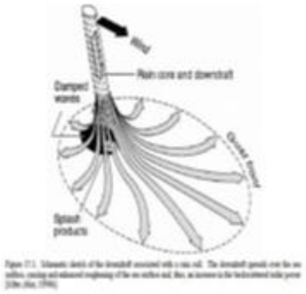


With 1km surface currents products added (MASS DoppVis)

Wind & rain coupling



Rain-induced dynamics

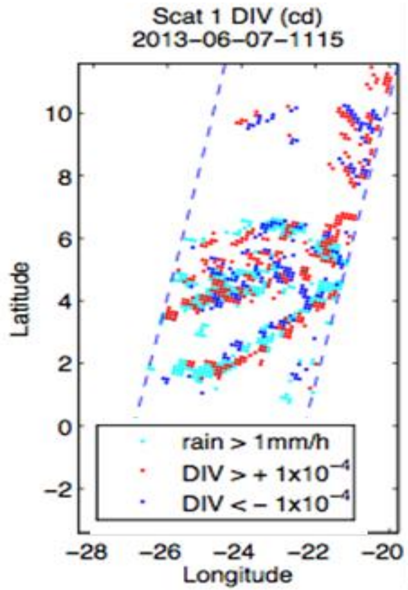


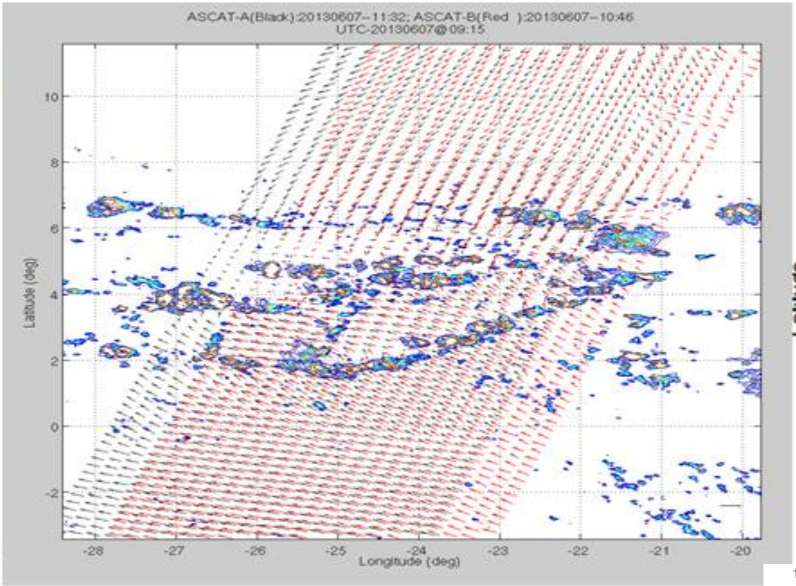
Convective downbursts

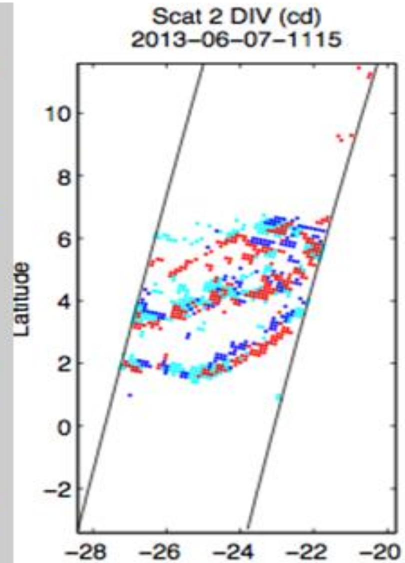
ASCAT-A and ASCAT-B come together. Red arrows:ASCAT-A; Blue arrows:ASCAT-B; color contours: MSG RR.

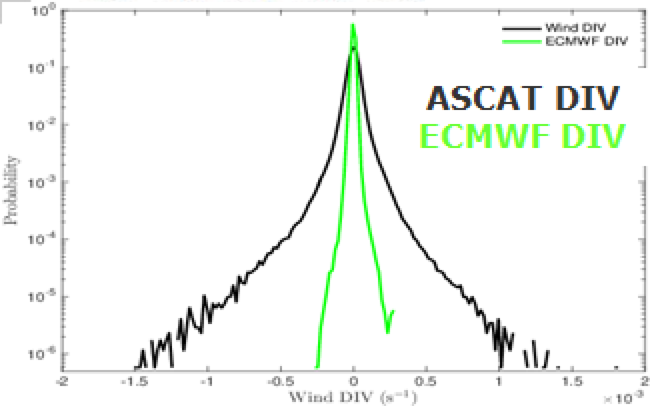
King et al., Rem. Sens., 2022

Analysis of scatterometer wind derivatives under moist convection



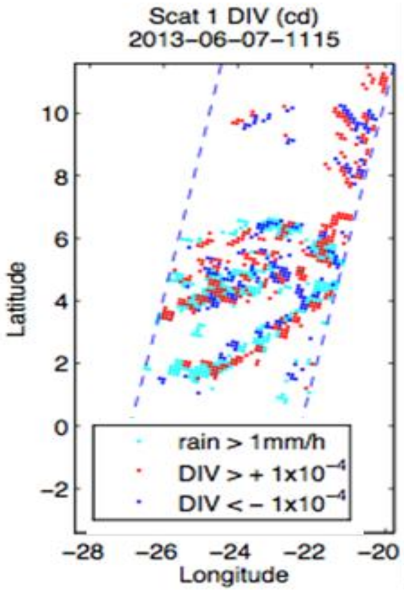


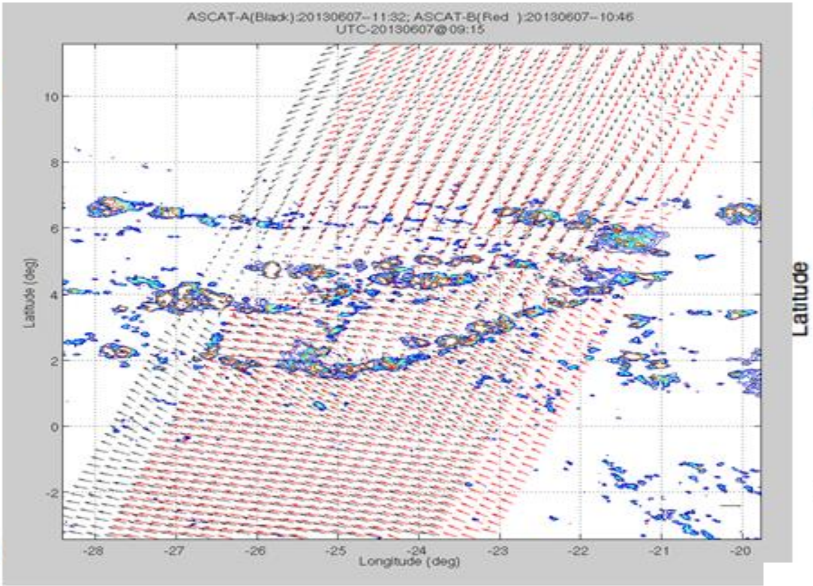


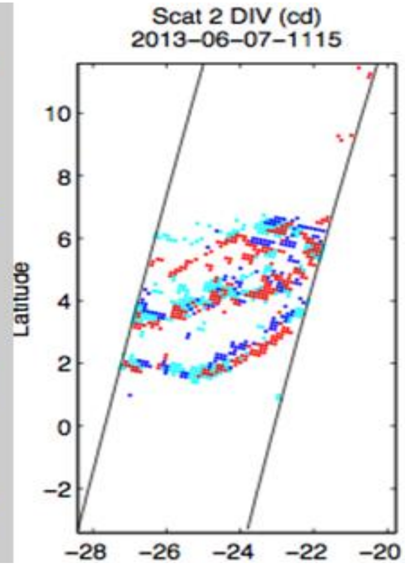


- ASCAT-derived divergence and vorticity well correlates with MSG rain
- ECMWF does not resolved rain-induced dynamics
- Potential of ASCAT to characterize Mesoscale Convective Systems

Analysis of scatterometer wind derivatives under moist convection







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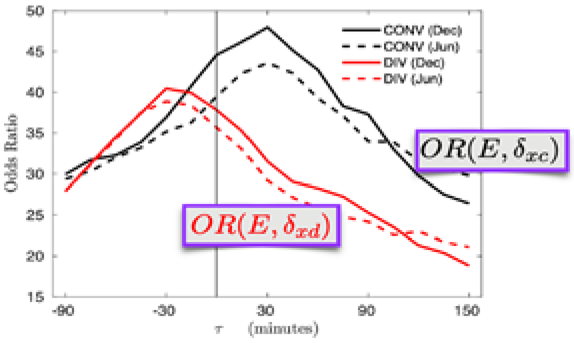


Figure 13. Odds ratios for convergence (black) and divergence (red) for a winter month and a summer month. Rain product lag is relative to SCAT-1 pass ($\tau = 0$).

Additional Wind-Rain at the Poster Session

Rain Detection and Wind Retrieval Using U-NET on ASCAT Measurements. McKinney & Long

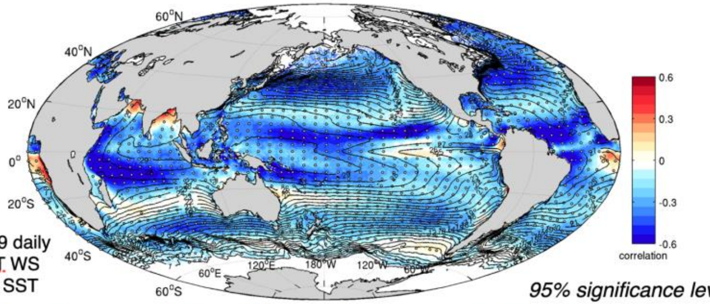
https://drive.google.com/file/d/1gOgI11DGbQi5Kd6x_3yDCXBwgPxUfGyZ/view?usp=sharing

Simultaneous Wind Rain Retrieval Using OSCAT. Fogg & Long

https://drive.google.com/file/d/1jleL_WTJmgVHhhDHRmT0HpAQ4-7LJvPj/view?usp=sharing

BUTTERFLY

Correlation between unfiltered wind speed (WS) and SST

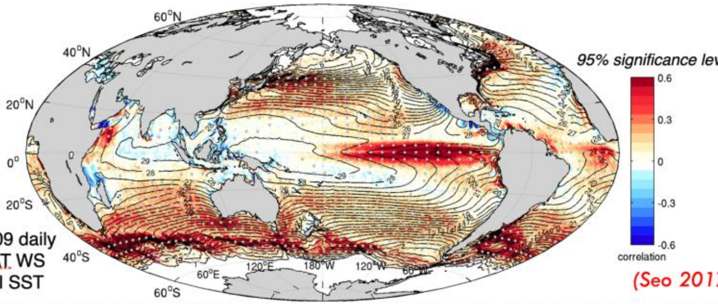


2000-2009 daily
QuikSCAT WS
NOAA-OI SST

95% significance level

Negative correlation: Oceanic response to the atmosphere

Correlation between high-pass filtered WS and SST



95% significance level

2000-2009 daily
QuikSCAT WS
NOAA-OI SST

(Seo 2017)

Oceanic forcing of the atmosphere on frontal and mesoscales

Estimate the air-sea turbulent heat fluxes:

Turbulent heat flux =

Sensible heat flux + Latent heat flux

$$Q_{sen} = \rho_a C_p C_H U(T_{sea} - T_{air}) \qquad Q_{lat} = \rho_a L_v C_E U(q_{sea} - q_{air})$$

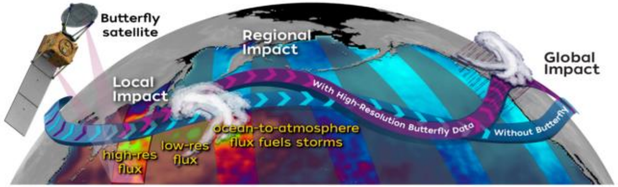
Sensible: ρ_a – Air density; C_p – Air specific heat capacity; C_H – Turbulent exchange coefficient; U – Wind speed; $(T_{sea} - T_{air})$ – Air-sea temperature difference

Latent: ρ_a – Air Density; L_v – Latent heat of vaporization; C_E – Turbulent exchange coefficient; U – Wind speed; $(q_{sea} - q_{air})$ – Air-sea humidity difference

Data Sources: Butterfly Model Coefficients

BUTTERFLY

revealing the oceans' impact on weather & climate

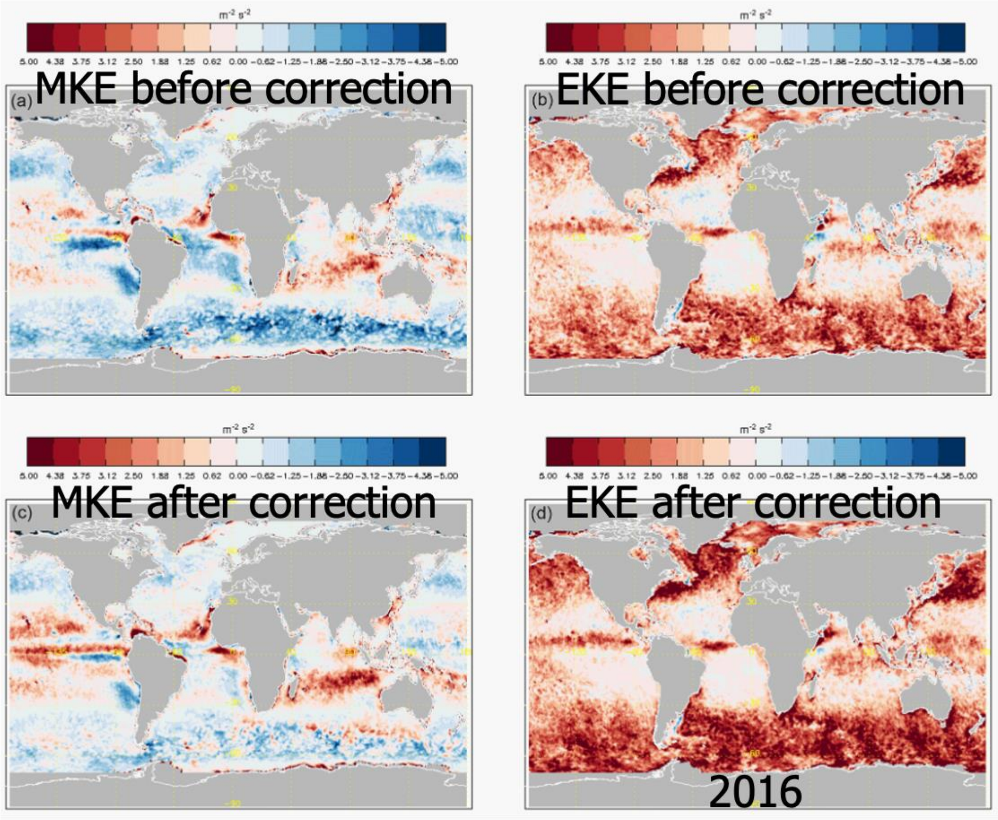


Principal Investigator: Dr. Carol Anne Clayson
Deputy Principal Investigator: Dr. Aneesh Subramanian
Project Scientist: Dr. Tony Lee
Deputy Project Scientist: Dr. Shannon Brown

Science Team:
Mark Bourassa, Hyodae Seo, Kelly Lombardo, Sarah Gille, Tom Farrar, Rhys Parfitt

Impact of currents on winds: ERA5 vs scatterometer

What do we really know?

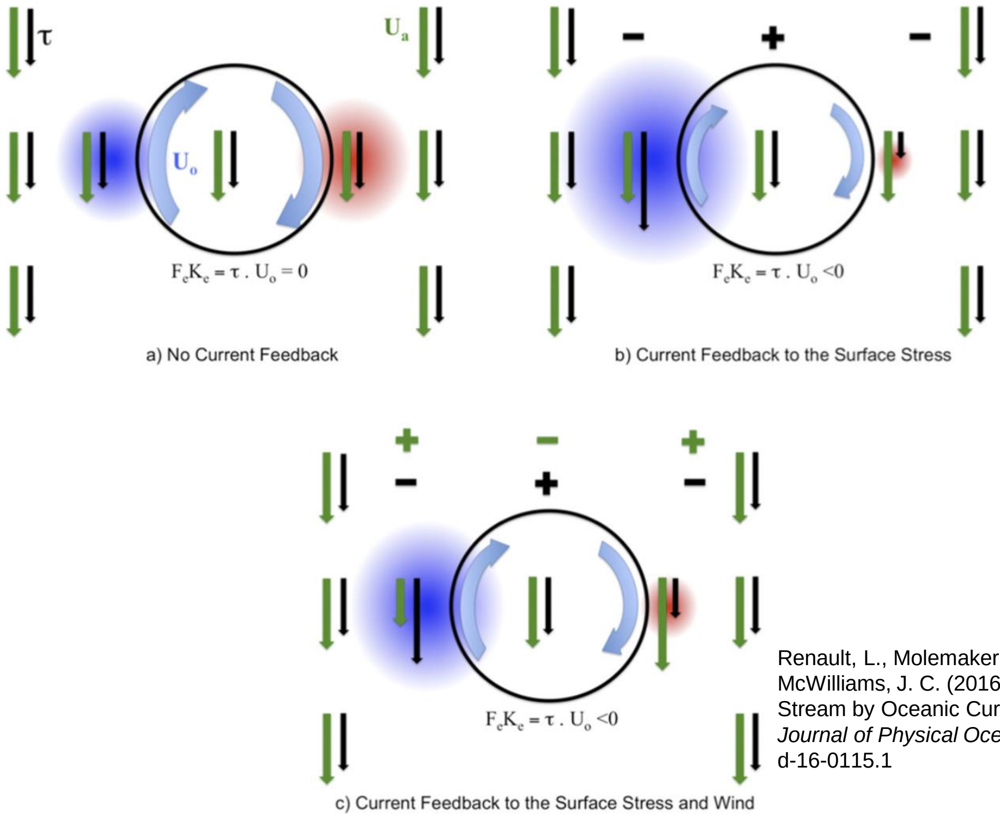


- These currents generally deteriorate the deterministic differences between scatterometer and ERA5 model
- Variances on m/s level, not cm/s

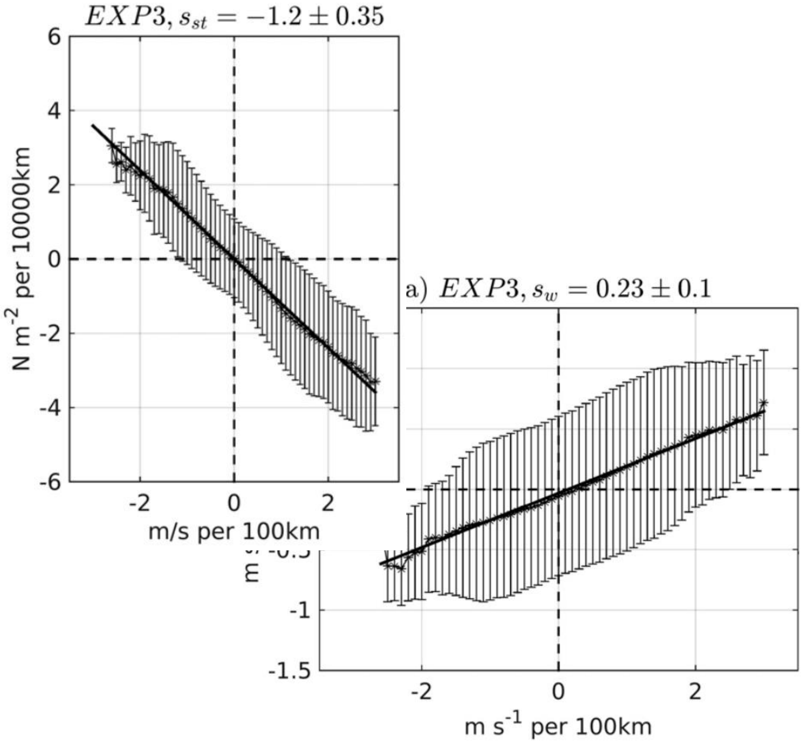
- Errors increase after correction, while they appear closer associated with the currents
- Again, variances on m/s level, not cm/s

Courtesy Ad Stoffelen

Wind-Current Coupling Mechanism



Relative Vorticity - Wind stress curl

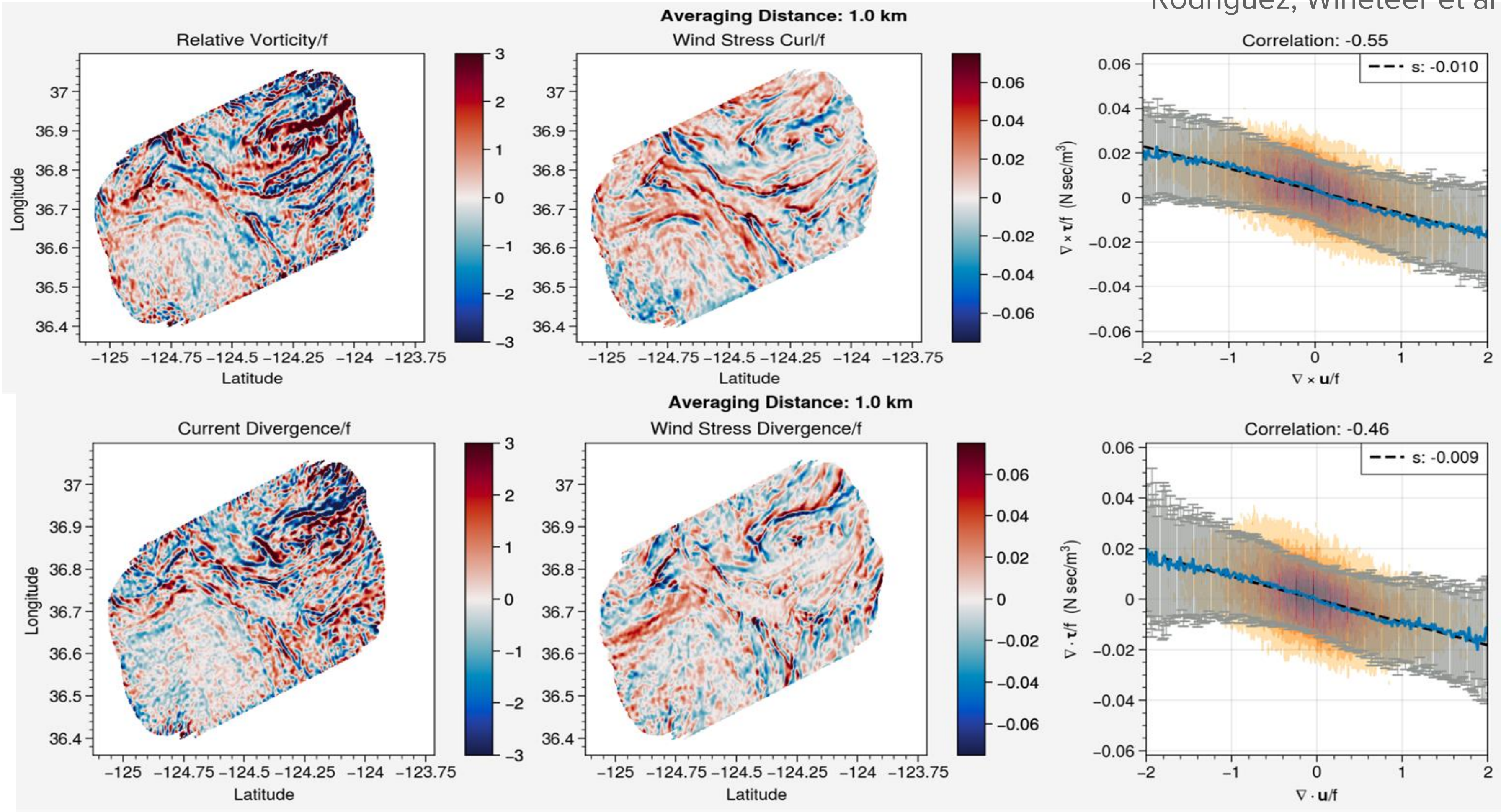


Relative Vorticity - curl atmospheric wind

Renault, L., Molemaker, J. M., Gula, J., Masson, S., & McWilliams, J. C. (2016). Control and Stabilization of the Gulf Stream by Oceanic Current Interaction with the Atmosphere. *Journal of Physical Oceanography*. https://doi.org/10.1175/jpo-d-16-0115.1

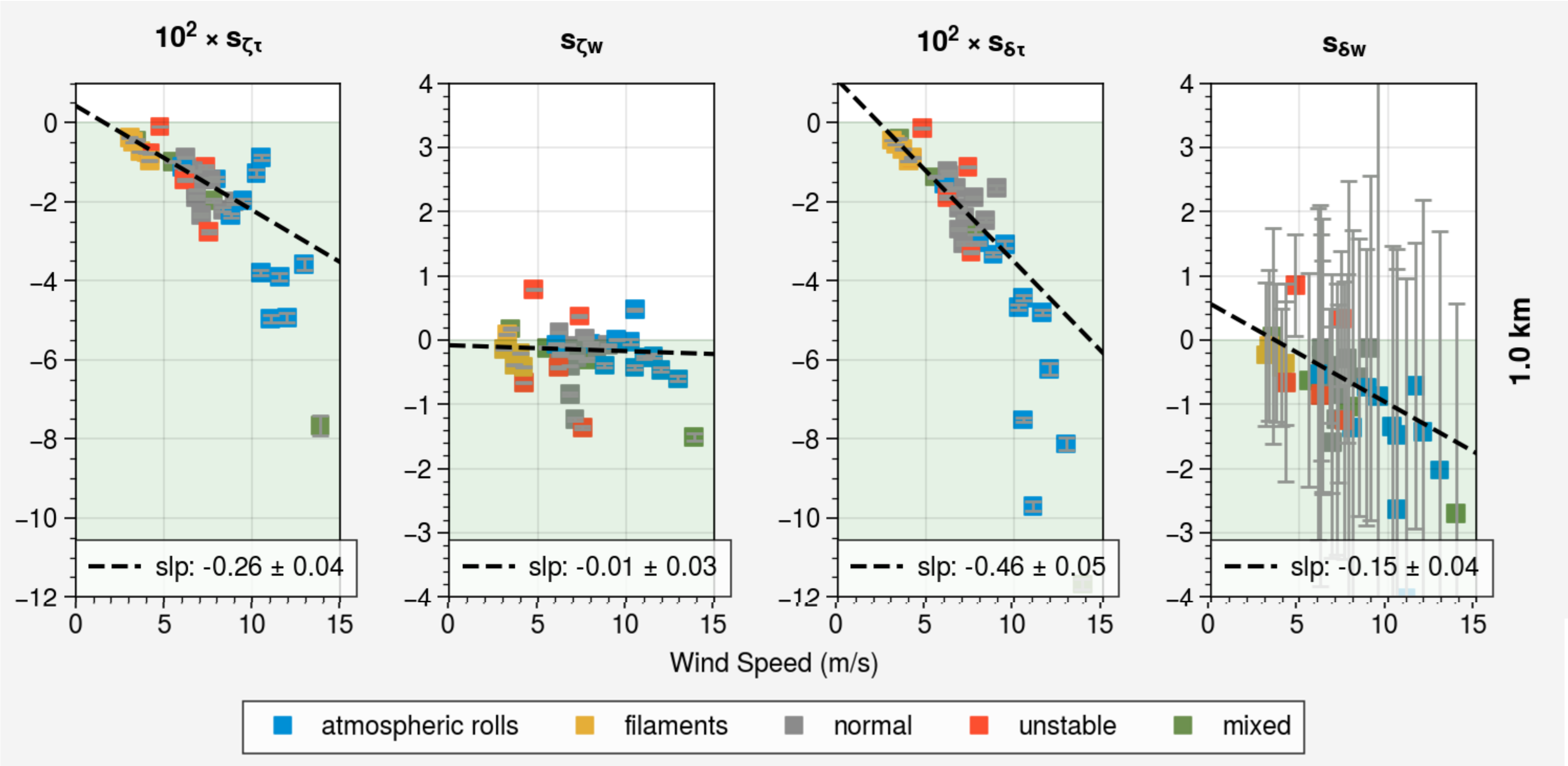
DopplerScatt S-MODE, current-wind derivative correlation

Rodriguez, Wineteer et al 2023



Wind Stress & Atmospheric Wind Coupling Coefficients (1km)

Rodriguez, Wineteer et al 2023



For more details regarding the S-MODE results, see…

https://docs.google.com/presentation/d/1374rGTH9UGjCp9_XhPrAb7VF1n7hwSlE/edit?usp=sharing&ouid=101155798790393408482&rtpof=true&sd=true

Email ernesto.rodriguez@jpl.nasa.gov for questions, comments

Paper to be submitted shortly…

The S-MODE data are available in PODAAC

Additional Posters not Covered in Overview

Exploring PBL coastal transitions and ocean surface properties with an Airborne Doppler Wind Lidar. Emmitt & Greco

https://drive.google.com/file/d/1Xq-eieV4jB8eWnKk90U8_ncrmu2IXfVt/view?usp=sharing