International Ocean Vector Winds Science Team Meeting
Oct 4, 2023

# Wind-Related Ocean Processes Overview

Kathleen Dohan (ESR), Luc Lenain (UCSD), Roger Samelson (OSU)

# Ocean processes at play on the coupling between ocean and atmosphere

- Ocean-Wind Coupling/ Air-Sea Interaction
  - Mesoscale
  - Submesoscale
- Near-surface shear and wave dynamics
    - Wind drift and wave drift
      - Stokes-drift from wave state and Stokes-Coriolis
      - equilibrium-sea momentum balance
    - Wave-state dependence
    - Kinetic energy balance of the surface layer
- Coupling in Extreme Weather
- Upwelling Processes
- Relative-Wind Coupling Damping Effect of the ABL
- Requirements of the constellation to capture surface currents
- Long-term shifts in circulation patters and long-term wind trends

# Wind-Related Coupling on the Mesoscale

Mesoscale and Frontal-Scale Air-Sea Interactions Workshop (US CLIVAR March 2023, leads: Seo & O'Neill)

- **Overarching goal US CLIVAR Working Group**: Formulate and coordinate observational and modeling efforts to quantify oceanic mesoscale and frontal-scale air-sea coupled processes and evaluate their integrated impacts on Earth's climate and hydrological cycle

Seo et al. 2023 Review of current understanding and demonstrated influence of air-sea coupling on a wide variety of high-level processes in Earth's climate system

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SPECIAL
Climate Implications of Air-Sea Interaction
COLLECTION

REVIEW

## Ocean Mesoscale and Frontal-Scale Ocean–Atmosphere Interactions and Influence on Large-Scale Climate: A Review

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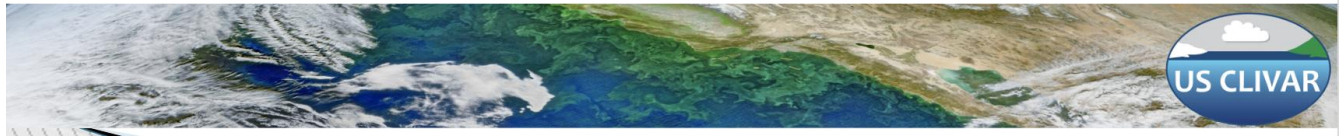
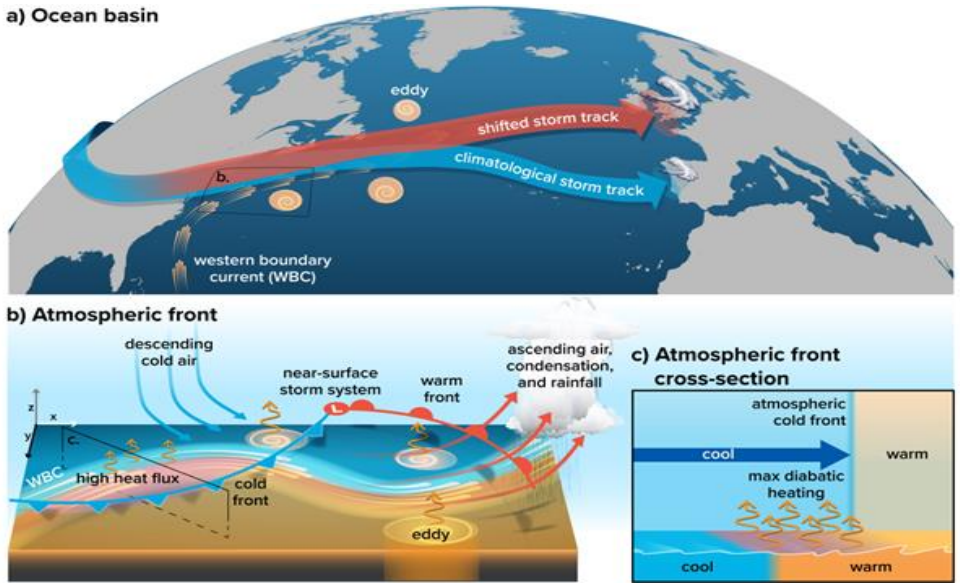
Open Access: https://doi.org/10.1175/JCLI-D-21-0982.1

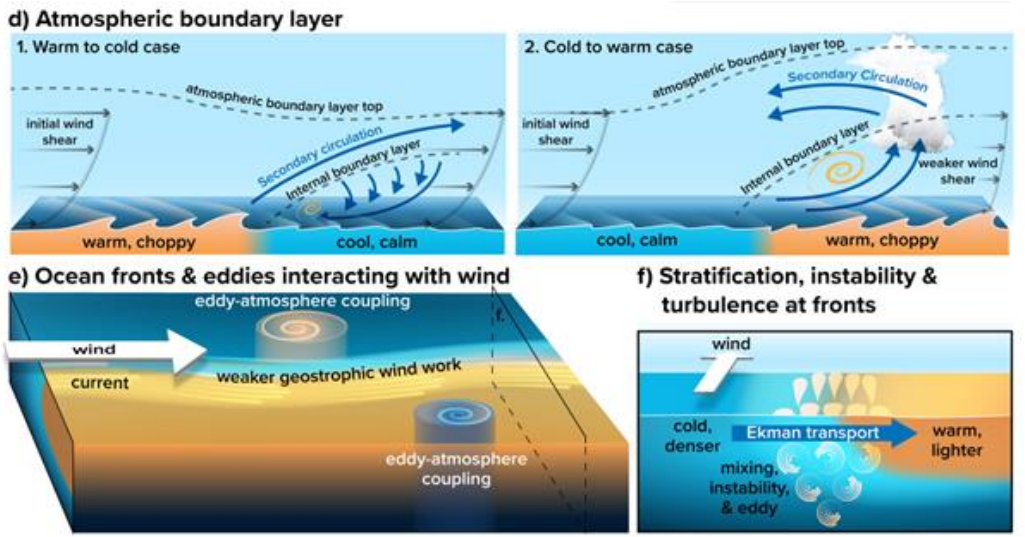



Focused on coupling processes on scales of 10–1000km and weather to climate timescales

# Wind-Related Coupling on the Mesoscale

## Wind-Related Ocean Processes Overview in the Northern Atmosphere




Seo at al. (2023) review paper

a) Shifted storm track by WBC leads to downstream rainfall
b) Cold and warm fronts in a low pressure system traversing SST front, asymmetric diabatic heating, precipitation
c) Cold front crossing over SST front close up
d) MABL processes with cross-frontal winds: warm-to-cold, cold-to-warm. Vertical mixing, shear, drag different regimes
e) Meandering currents and eddies under wind: mechanical and thermal feedback, adjusted wind-stress curl and up/downwelling
f) Ekman transport at fronts

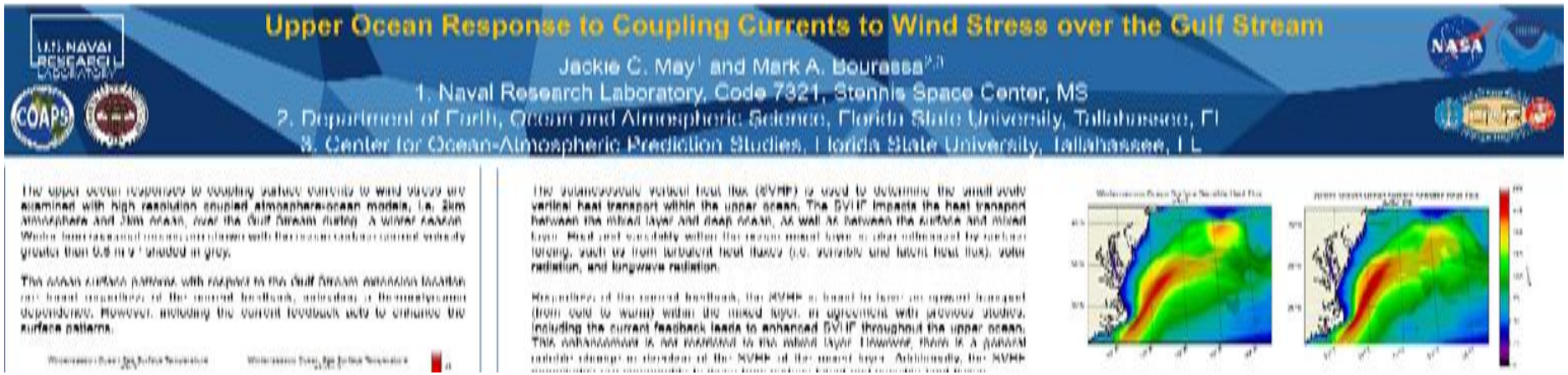
# Wind-Related Coupling on the Mesoscale

*Reading materials*

- Strub, P.T. and C. James (2022), Evaluation of Nearshore QuikSCAT 4.1 and ERA-5 Wind Stress and Wind Stress Curl Fields over Eastern Boundary Currents. Remote Sensing, 14(9), 2251, doi:10.3390/rs14092251
- Chacko, N., M. M. Ali, and M. A. Bourassa, 2022: Impact of Ocean Currents on Wind Stress in the Tropical Indian Ocean. Remote Sensing, 14, 2547. https://doi.org/10.3390/rs14071547

*Poster in this session: Jackie May and Bourassa*

- The upper ocean response to coupling surface currents to wind stress using high-resolution coupled atmosphere-ocean models over the Gulf Stream. Looking at the ocean mixed layer vorticity response and its impact on the submesoscale vertical heat flux.



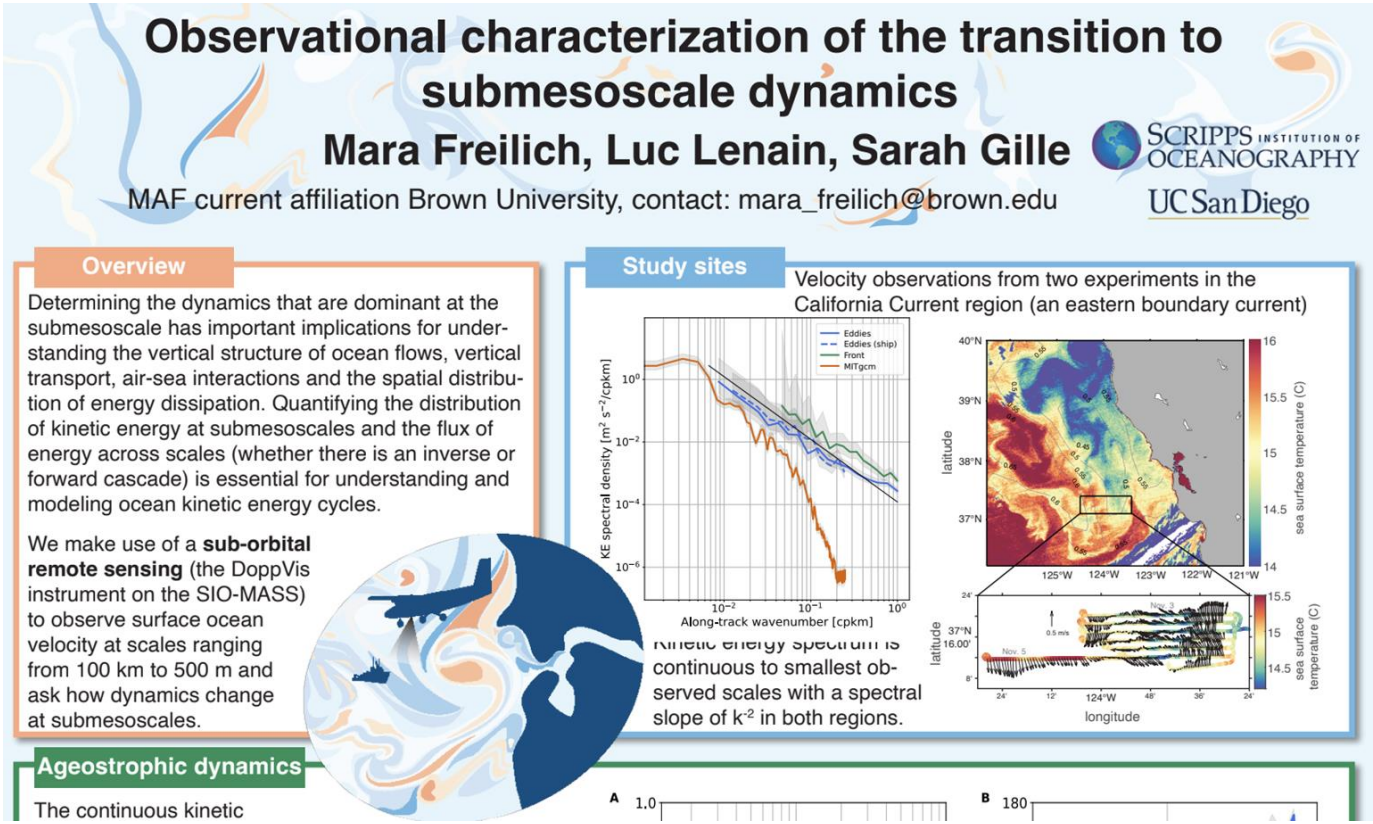
# Wind-Related Coupling on the **Sub**mesoscale

*Reading materials and recent workshops*

- Lorentz Center workshop on Air-sea Interaction at the (Sub)mesoscale (held last week).
- Chen, X., W. Dewar, E. Chassignet, M. Bourassa, S. Morey, and G. Gopalakrishnan, 2022: On the Feedback Between Air-Sea Turbulent Momentum Flux and Oceanic Submesoscale Processes. J. Geophys. Res. Oceans, 127(10), e2022JC018767

*Poster in this session: Mara Freilich et al.*

- Characterization of the transition to submesoscale dynamics
- Observations at edges of upwelling filaments: kinetic energy flux at fronts
- Cross-scale interactions at fronts and filaments

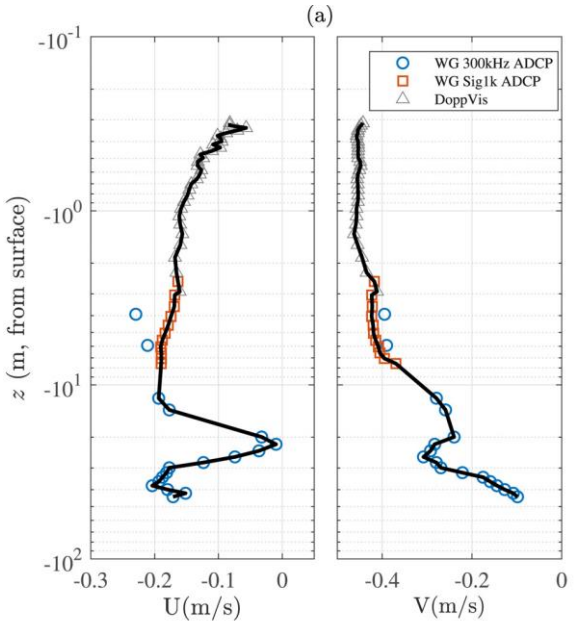


# Near-Surface Shear and Wave Dynamics

*Reading materials and recent developments*

- A major goal of the NASA EVS-3 S-MODE project
- Pizzo et al. 2023 - The role of Lagrangian drift in the geometry, kinematics and dynamics of surface waves. Inferring currents from the wave field is a central aim of remote sensing instruments. What current are we measuring?

- Dispersion relationship using remote sensing techniques to observe near-surface shear (DoppVis, Lenain et al. 2023) DoppVis enables airborne remote sensing of near surface current profiles from few 10's of cm below the surface down to few meters, using georeferenced video of the ocean surface to capture the wave dispersion relationship and invert for current as a function of depth.
- Wave-state dependence: e.g. Sauvage et al.
- Kinetic energy balance of the surface layer
  - Partitioning of wind-work is necessary for understanding surface-layer KE balance e.g. Zippel et al
- "Stokes wind-work" and turbulence in the surface layer
  - Physical meaning of “Stokes wind-work” (product of stress and surface Stokes drift) that appears in LES (WAB) KE balance (e.g., Skyllingstad et al doi: 10.1175/JPO-D-22-0150.1)

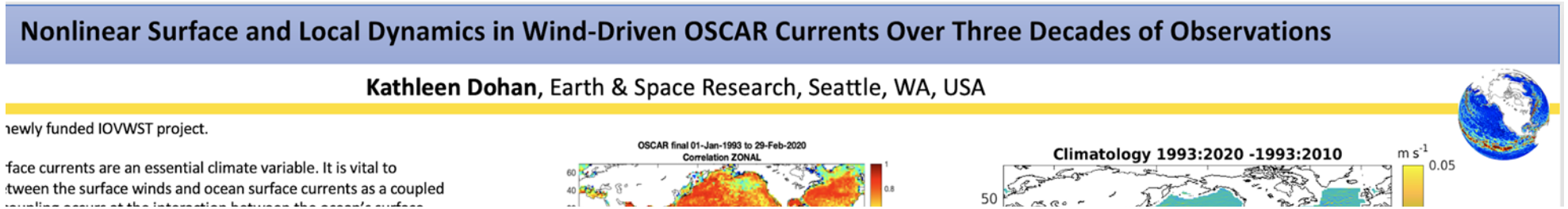



Lenain et al. 2023
An example of current profile collected from DoppVis (figure 1 of Lenain et al. 2023), along with deeper observations from collocated Wave Glider ADCPs

# Near-Surface Shear and Wave Dynamics

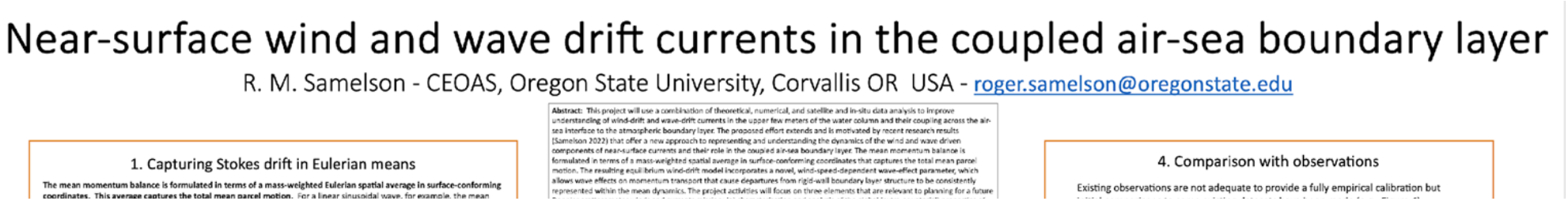
*Poster in this session: Dohan*

- Adding Stokes-Coriolis term and vertical variation to OSCAR



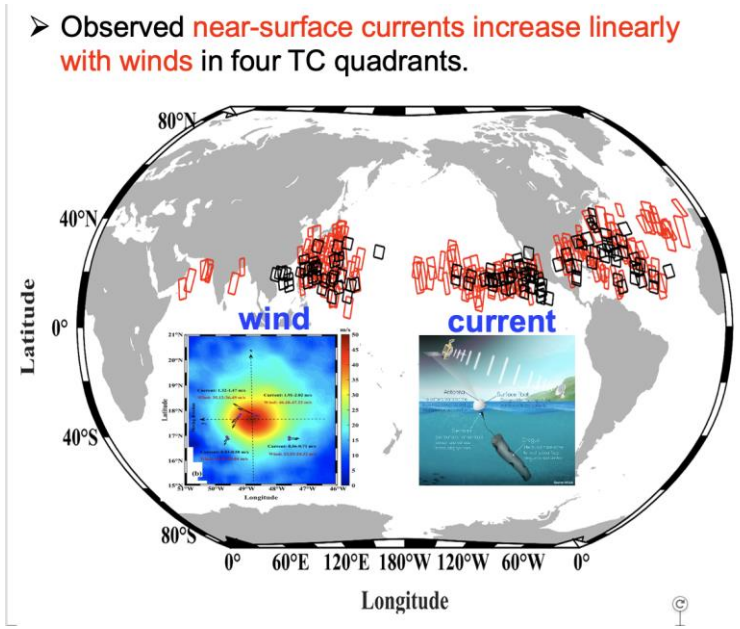

*Poster in this session: Samelson*

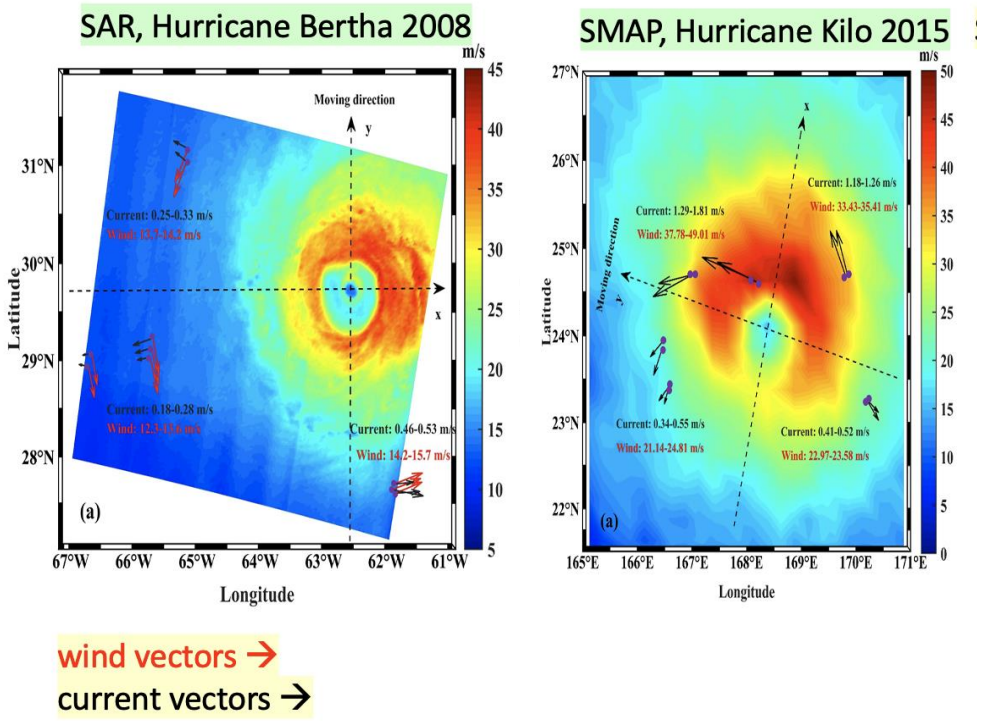
- Equilibrium wind-drift model to improve understanding of wind-drift and wave-drift currents in the upper few meters of the water column and their coupling across the air-sea interface to the ABL. The equilibrium wind-drift model incorporates a novel, wind-speed-dependent wave-effect parameter, which allows wave effects on momentum transport. Model, coupled numerical simulations, in-situ analysis.



# Relative-Wind Coupling in Extreme Weather

- Will Perrie & Biao Zhang, Bedford Institute of Oceanography, Canada
- Work on marine winds and ocean processes derived from SAR, tropical cyclone remote sensing, wind and current observations under extreme weather
- Observed near-surface currents increase linearly with winds in four TC quadrants but satellite + drifting buoy observations show TC surface winds and currents have asymmetric characteristics with the wind direction alignment with current directions dependent on the quadrants.




- Fan, Zhang, Perrie, Mouche. 2022, Observed Ocean Surface Winds and Mixed Layer Currents Under TCs etc. …*JGR*

# Upwelling Processes

## Development of Multi-Metric Satellite-Based Coastal Upwelling Indices

Steven Morey – Florida A&M University

Extension of traditional upwelling index metrics based on

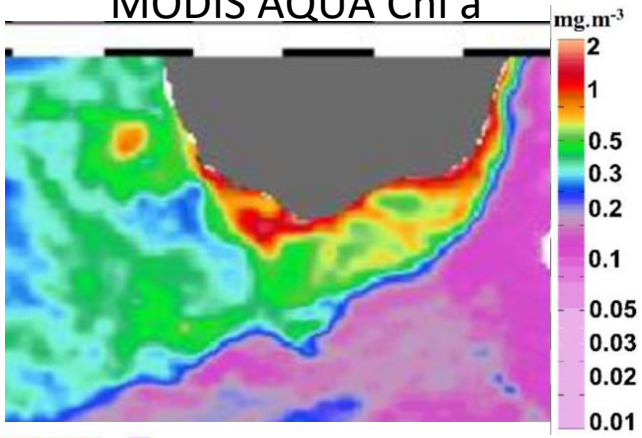
- Winds (along-coast component of stress and Ekman transport)
- SST
- Ocean Color

Individual variables are related differently to coastal upwelling at different locations

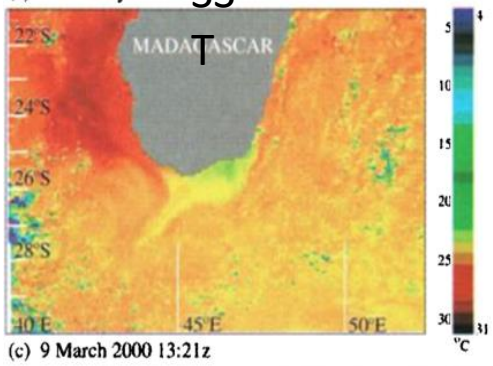
- Local winds are not always good indicators of upwelling near complex coastlines.
- SST is also influenced by air-sea heat exchange.
- Ocean Color is not a good indicator near regions of riverine input.
- Wind-Derived indices are related to instantaneous vertical motions whereas SST and Ocean Color are related to time integrated vertical motion.

Using model and satellite analyses, statistical and machine learning methods are trained to produce multi-metric indices for coastal upwelling that are better indicators of coastal upwelling than indices based on individual variables.

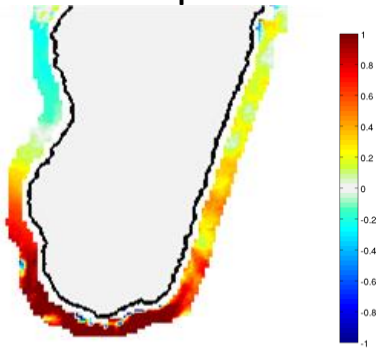
MODIS AQUA Chl a




SST




CCMP Offshore Ekman Transport



# Dependence of Relative-Wind Damping Effect on ABL turbulence

## Dependence of surface-current (relative-wind) damping effect on marine atmospheric boundary turbulence characteristics

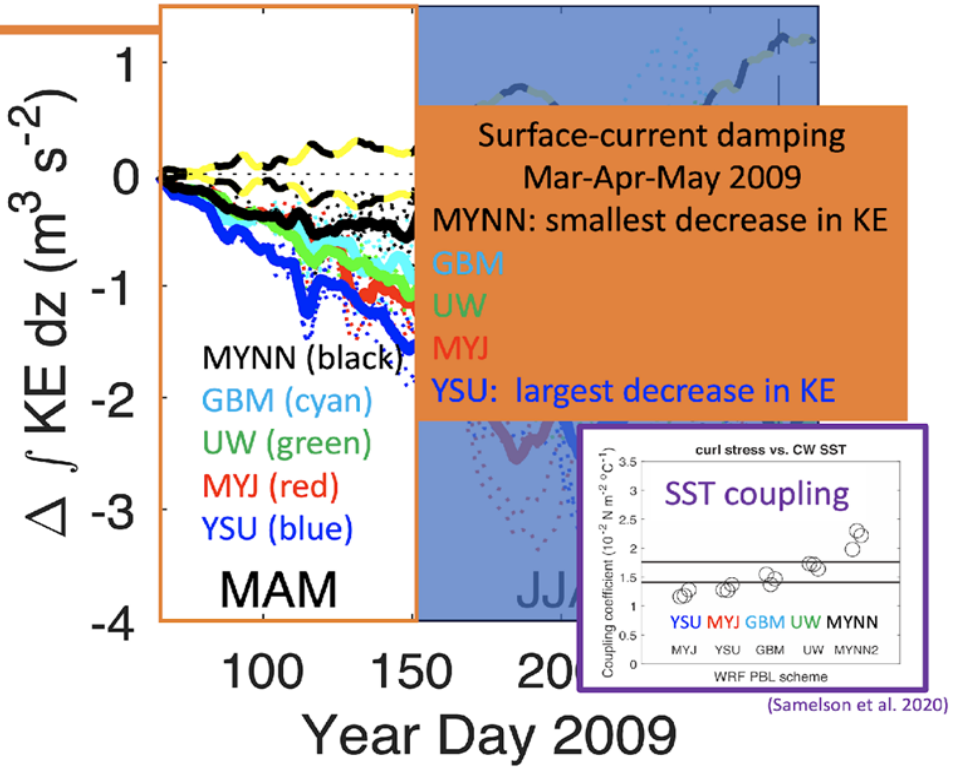
A preliminary result from coupled ocean-atmosphere simulations of the northern California Current System

R. M Samelson - CEOAS, Oregon State University, Corvallis OR USA

During the early (Mar-Apr-May) year-2009 upwelling season, SST fluctuations from instability growth are small. During this period, the **decrease in mean depth-integrated ocean kinetic energy for** ensembles of **simulations with surface-current coupling** relative to those with SST coupling only **depends systematically on the PBL turbulence scheme** used in the **atmospheric component** of the coupled model.

**This dependence** on PBL **scheme is opposite to the dependence** (Samelson et al. 2020) **of SST-stress coupling** on the same set of PBL schemes, with MYNN showing the weakest surface-current damping and strongest SST-stress coupling, and YSU showing the strongest surface-current damping and weakest SST-stress coupling.

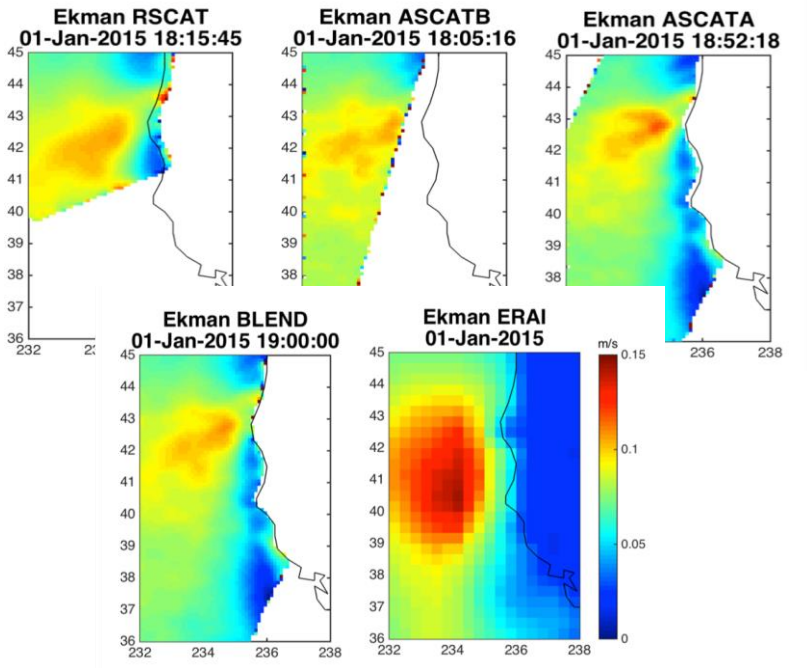
This anti-correlation suggests that **surface-current damping is stronger when vertical mixing in the marine atmospheric boundary layer is weak, and weaker when vertical mixing is strong**. Such a dependence might be explained by differences in the degree of equilibration of stress to pressure-gradient or other terms in the horizontal momentum balance of the atmospheric boundary layer.




(Samelson et al. 2020)

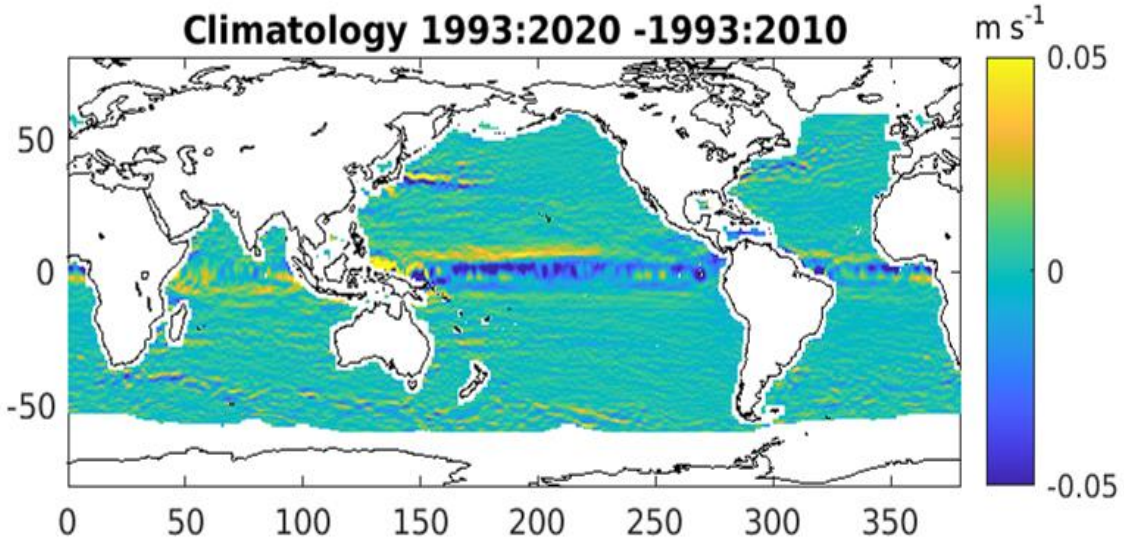
## Requirements of the constellation to capture surface currents

*Dohan Poster in this session*




**Importance of small scales and the vector wind constellation**: Demonstration of difference in Ekman current calculated from differently measured and sampled winds

## Long-term shifts in large-scale circulation patterns and long-term wind trends




**Shifting circulation patterns observed over decades of satellite data:** OSCAR zonal velocity climatology from 1993:2020 – climatology from 1993:2010. Meridional shifts of currents are the most noticeable, seen as the banded blue/yellow lines.

# Closing remarks

Discussion Point:

Did we miss anyone? (We are sure we did)

2 dominant research areas, although not independent:

- Coupled ocean atmosphere dynamics, namely mesoscale and fronts
- Wind/wave upper ocean dynamics. Contact us if you're interested in keeping in touch

Etc.

Posters:

M. Freilich, L. Lenain, S. Gille – Dynamics of transition to submesoscale
J. May and M. Bourassa – Coupling surface currents to wind stress over Gulf Stream
K. Dohan – Adding Stokes-Coriolis and vertical variation to OSCAR surface currents
R. Samelson – Modeling near-surface wind and wave drift currents