# ODYSEA

## Ocean Dynamics and Surface Exchange with the Atmosphere

# The ODYSEA Satellite Concept: Simultaneous Winds and Surface Currents via Doppler Scatterometry

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with the ODYSEA team: Tong Lee, Fabrice Ardhuin, Justin Boland, Mark A. Bourassa, Paul Chang, Sophie E. Cravatte, J. Thomas Farrar, Melanie R. Fewings, Fanny Girard-Ardhuin, Gregg A. Jacobs, Zorana Jelenak, Florent Lyard, Jackie C May, Elisabeth D Rémy, Lionel Renault, Ernesto Rodriguez, Clément Ubelmann, Ana Beatriz Villas Bôas, and Alexander G. Wineteer

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*Image: Hurricanes Idalia and Franklin August 29, 2023*

# The ocean drives disruptive weather

ODYSEA

## *Latest Atmospheric River Brings Heavy Rain, Flooding and Thunderstorms to California*

The New York Times

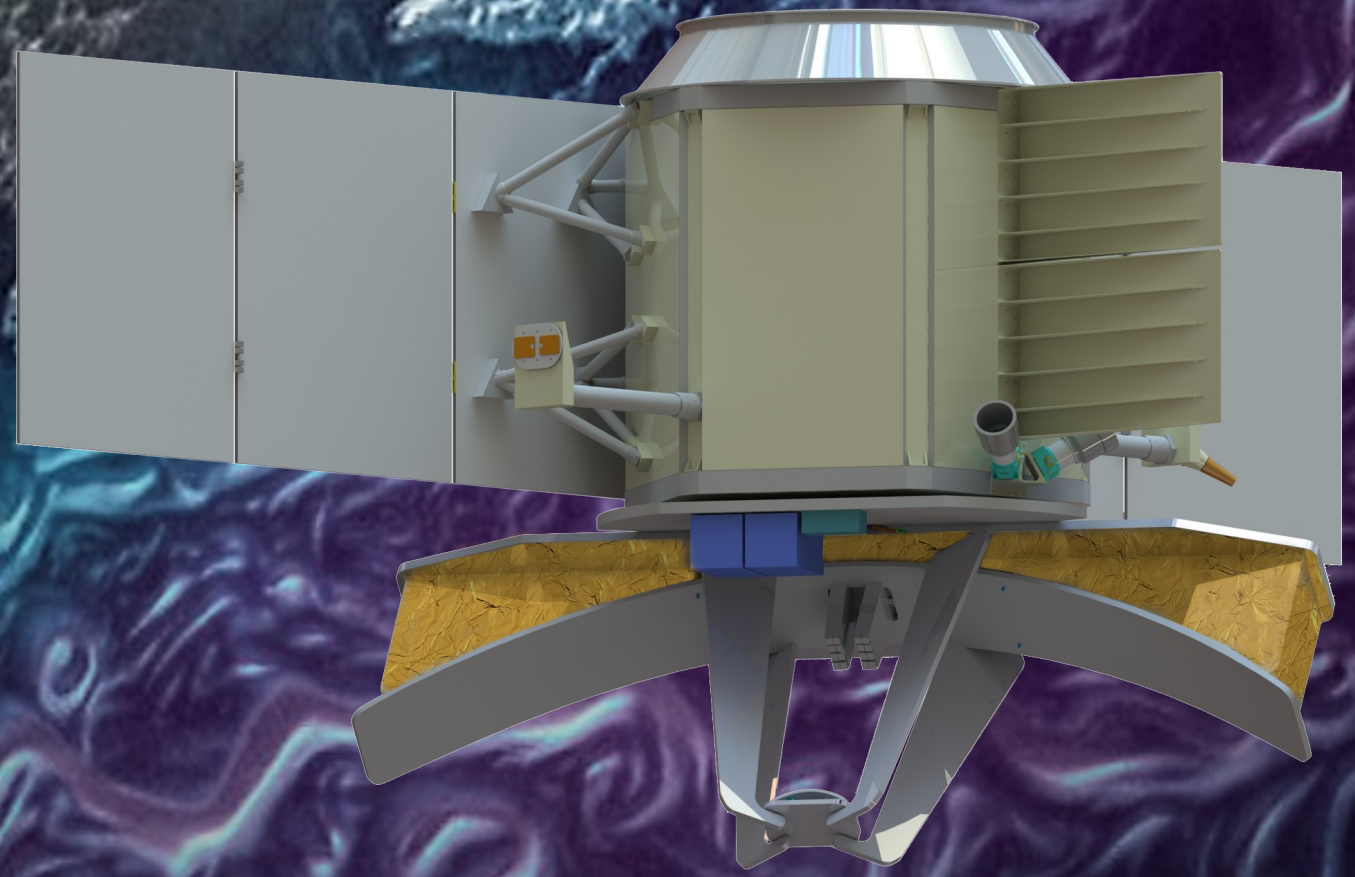

## *Storm That Could Threaten Gulf Coast Takes Shape in the Caribbean*

Details are still fuzzy, but the likelihood that Potential Tropical Cyclone Nine will turn into Hurricane Helene and affect the Gulf Coast later this week is increasing.


https://www.nytimes.com/2024/09/23/weather/gulf-of-mexico-helene.html

# ODYSEA

Ocean Dynamics and Surface Exchange with the Atmosphere



## Objectives:

- What are our knowledge gaps?
- How does ODYSEA address these gaps (and how does it work)?
- What's the status?  And how can you be involved?

# Fluxes from space

- Momentum: wind loses (and gains) strength from the upper ocean

stress: $\boldsymbol{\tau} = \rho\, CD\, (\boldsymbol{u}_a - \boldsymbol{u}_s)\, |\boldsymbol{u}_a - \boldsymbol{u}_s|$

wind work: $W = \langle \boldsymbol{\tau} \cdot \boldsymbol{u}_s \rangle$

*ODYSEA (Earth System Explorer)*

- Heat:

Shortwave: $Q_{sw}$, longwave radiation: $Q_{sw}$

Sensible: $Q_s = \rho\, cp\, CH\, |\boldsymbol{u}_a - \boldsymbol{u}_s|\, (\theta_a - \theta_s)$

Latent: $Q_L = \rho\, Le\, C_E\, |\boldsymbol{u}_a - \boldsymbol{u}_s|\, (qa - qs)$

*Butterfly (Earth Ventures Mission)*

- Freshwater:

Precipitation: $P$

Evaporation: $E$ linked to latent heat flux

- Gas exchange: ocean uptake and release of $CO_2$ and other gases

Gas flux: $F_g = C_G\, (G_s\text{-}G_{10}/H) |\boldsymbol{u}_a - \boldsymbol{u}_s|$

*Zephyr (to get winds) (EVM)*

# Goal 1: Measure the wind to fill gaps in observing system



ODYSEA

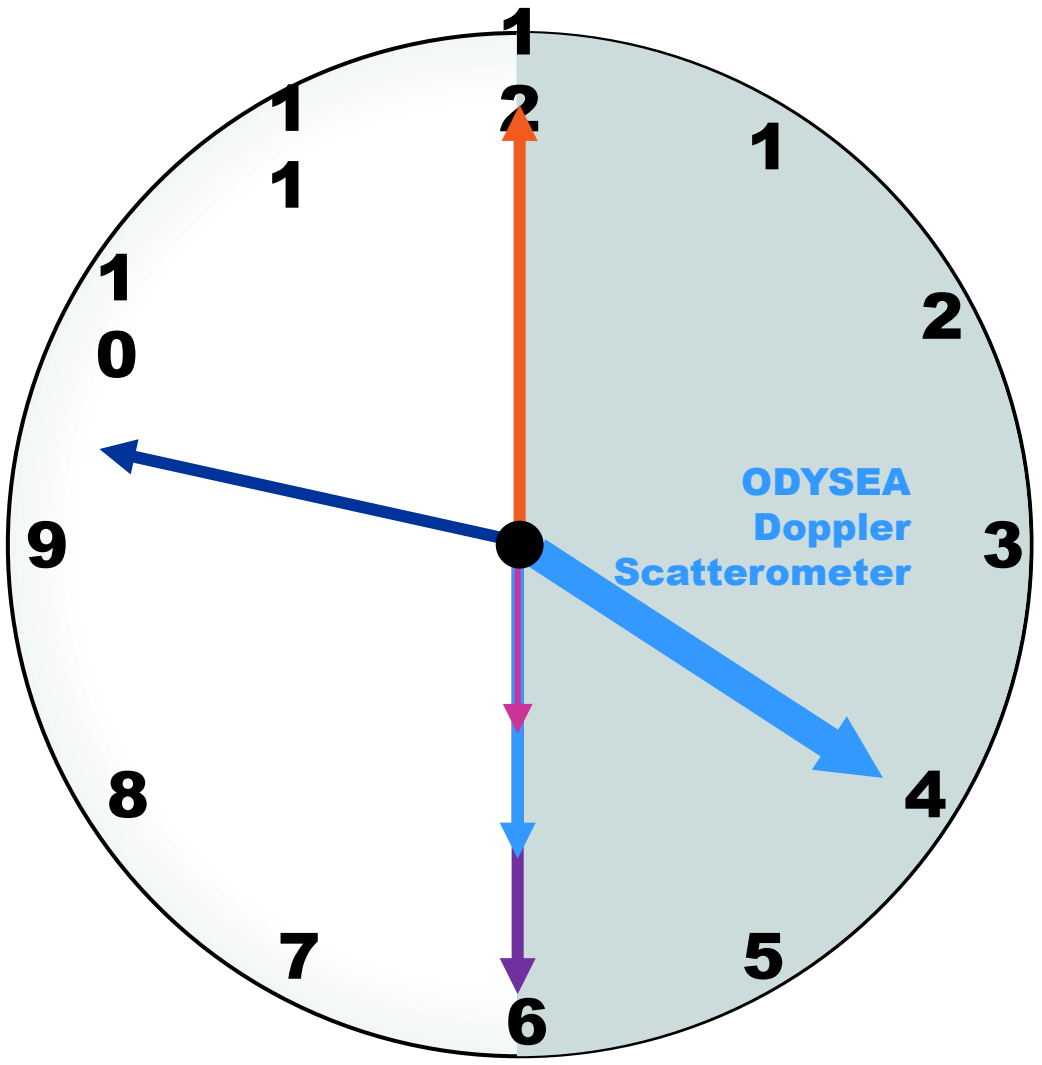
**WSF-M**
(U.S., passive)

**OceanSat**
(India)

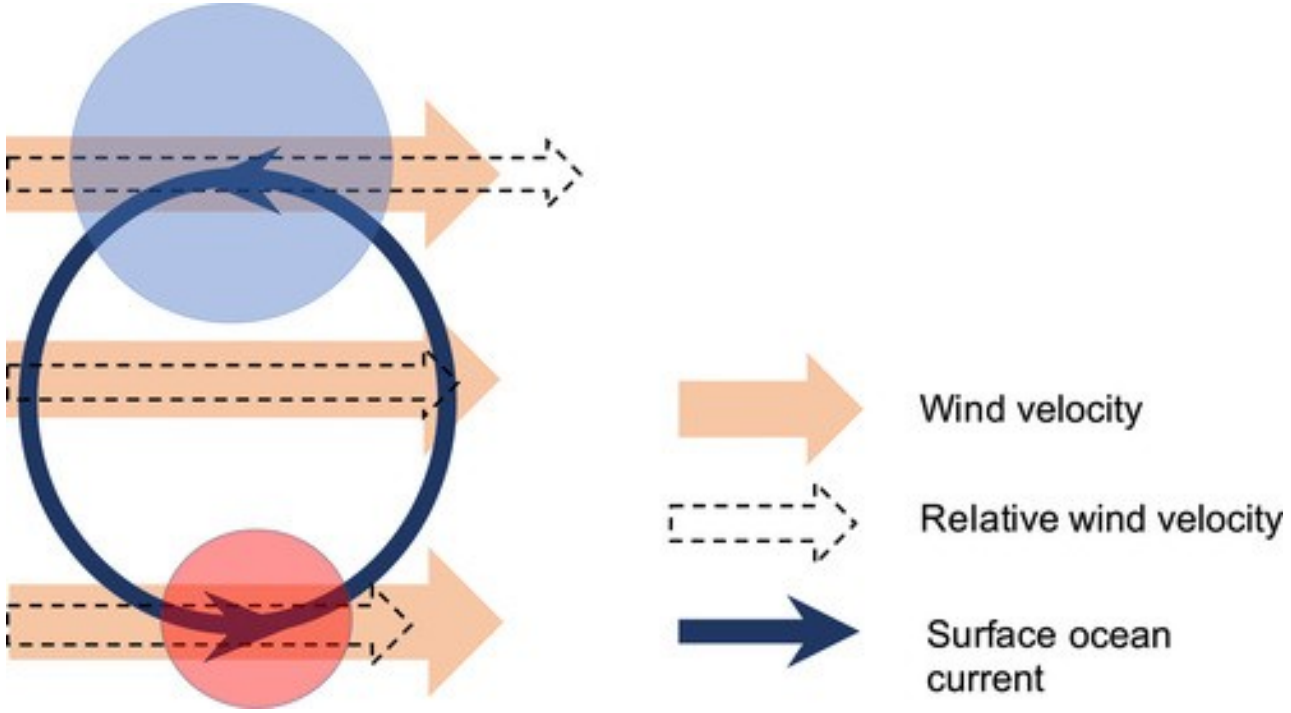
**Metop SG**
(Europe)

**CIMR**
(Europe, passive)

**Harmony**
(Europe)



# Goal 2: Winds and currents together




*Rai et al, Science Advances, 2021*

Winds counter to currents strengthen the relative wind and exert more stress on the ocean

Winds aligned with currents imply less relative wind and less stress to drive the current.

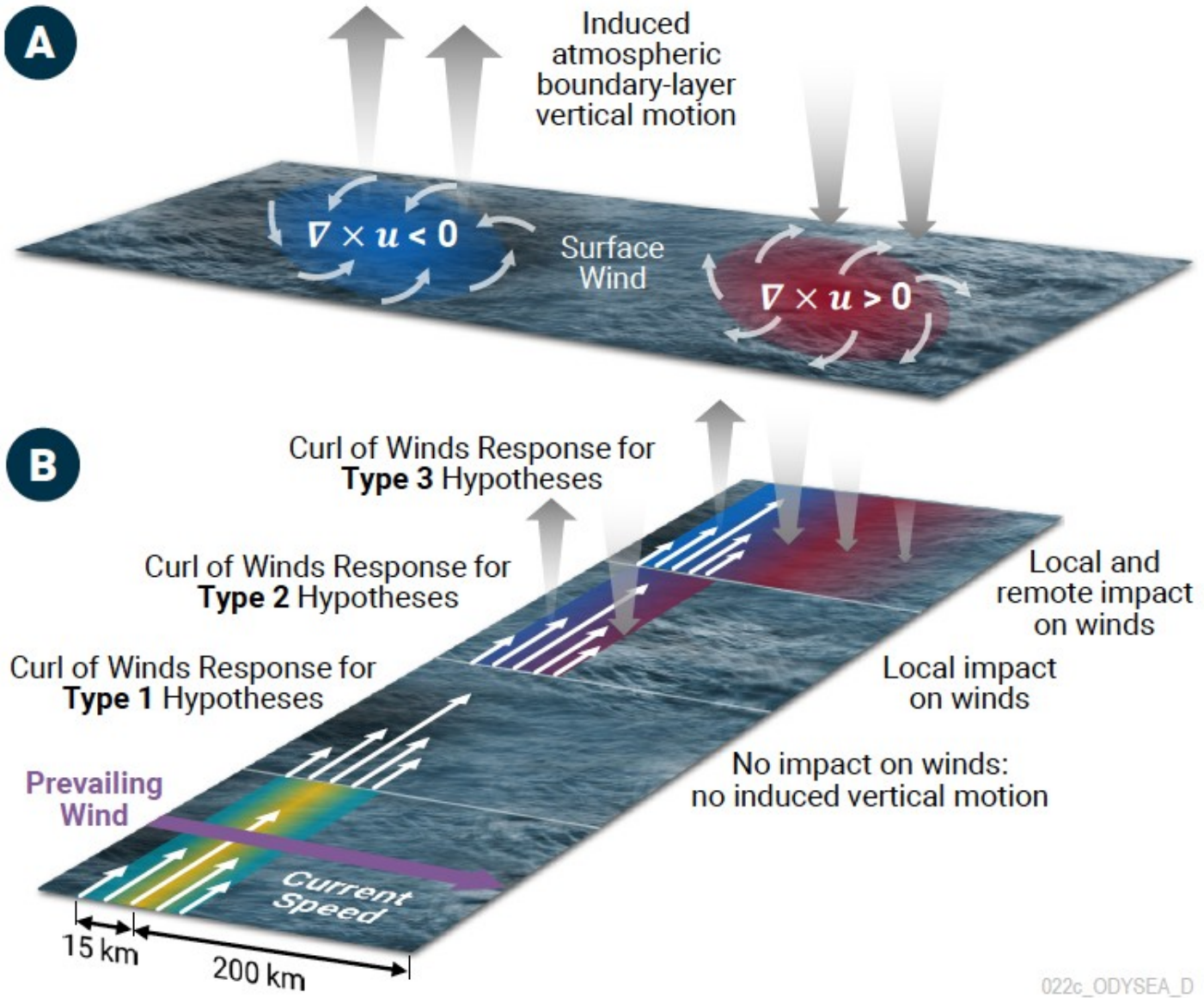
- Satellites measure wind relative to current, so if satellites were our only means to measure wind, we could ignore relative winds.
- But we calibrate to in situ winds and use models without relative effects, so, we need to be able to tease these components apart.

# Goal 2: Unravel competing hypotheses of wind—current coupling

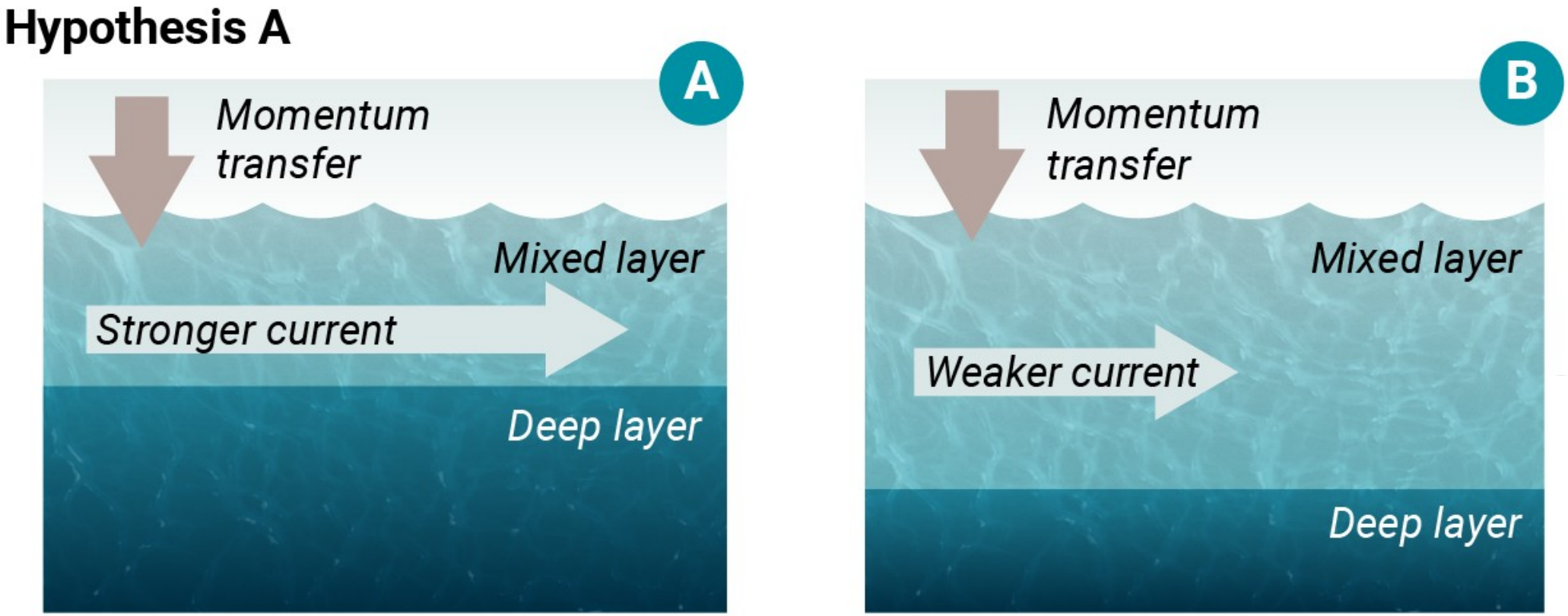
Type 1 examples: Hughes and Wilson, 2008; Eden and Dietze, 2009

Type 2 examples: Renault et al, 2018, Seo et al, 2016

Type 3 examples: Renault et al, 2016; Small et al, 2008



# Goal 3: How do currents respond to wind?
# Hypothesis A: High stratification implies faster surface currents

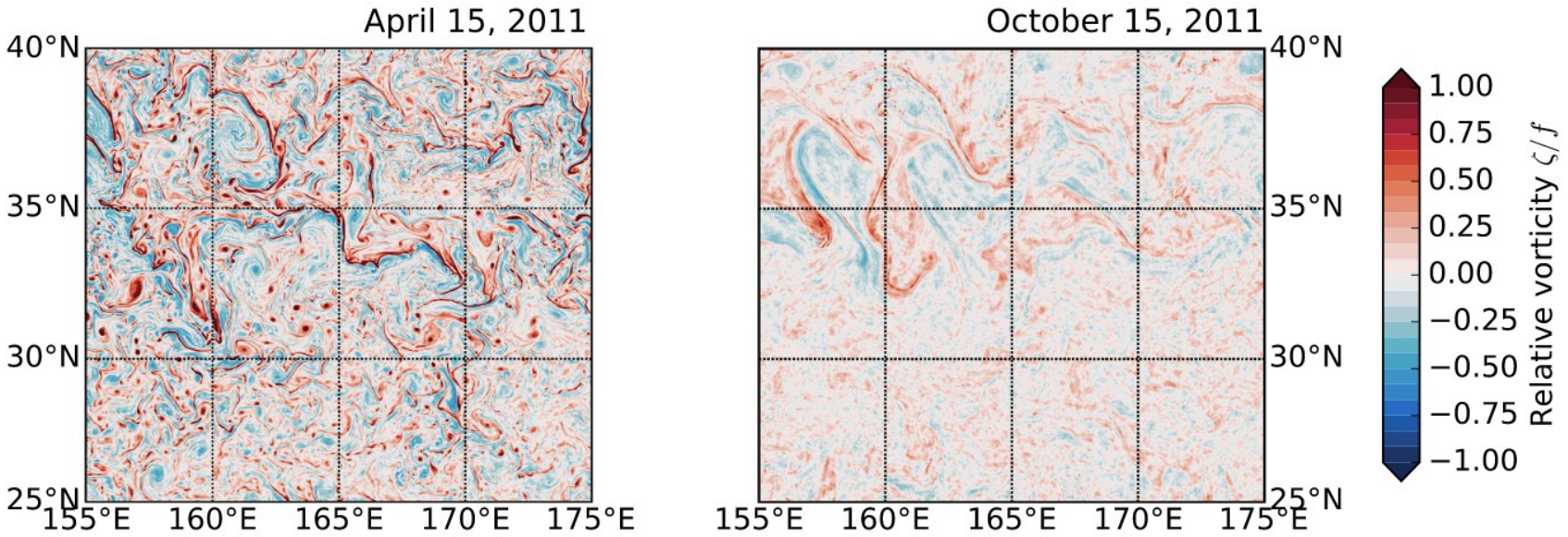



e.g. Wunsch, 2020; McMonigal et al, 2023; Peng et al, 2022

# Or seasonal sub-mesoscale dynamics govern velocity?

End of winter

End of summer

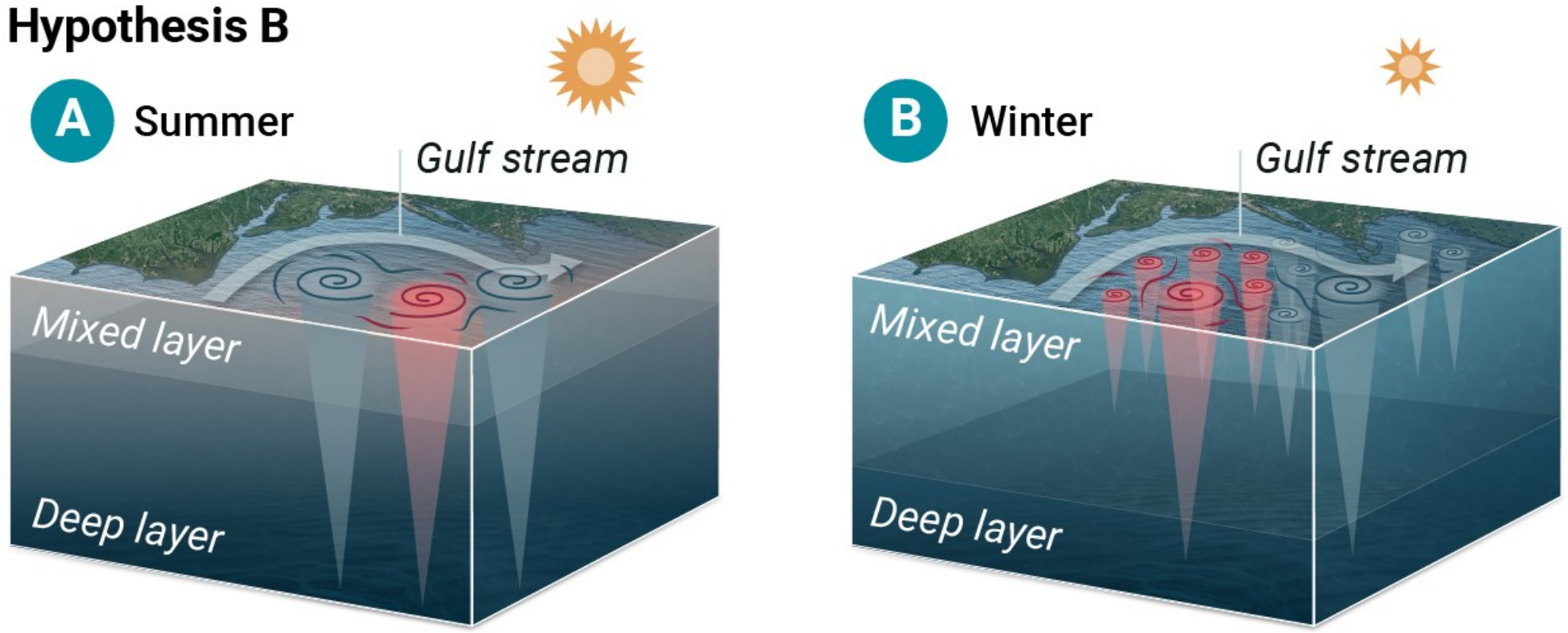



Kuroshio Extension submesoscale motions energized in late winter/spring

Available potential energy lower in summer due to stratification.

Rocha et al, *GRL*, 2016

# Hypothesis B:  Low stratification means more potential energy storage and ultimately faster currents

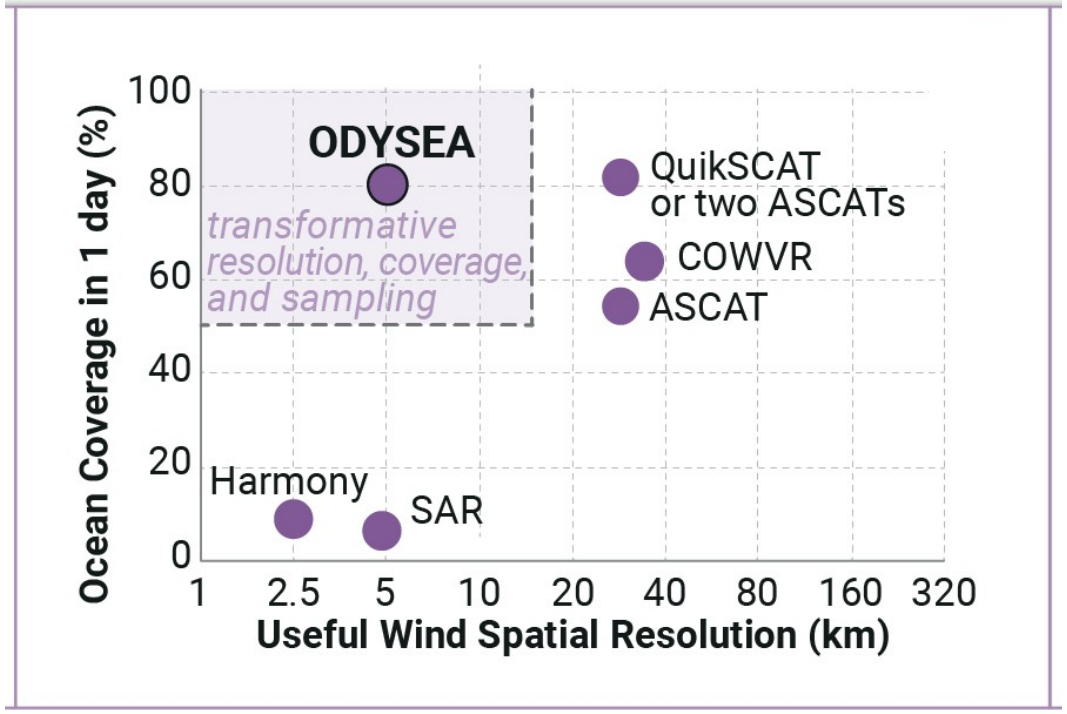



e.g. Callies et al, 2015; Rocha et al, 2016; Qiu et al, 2017

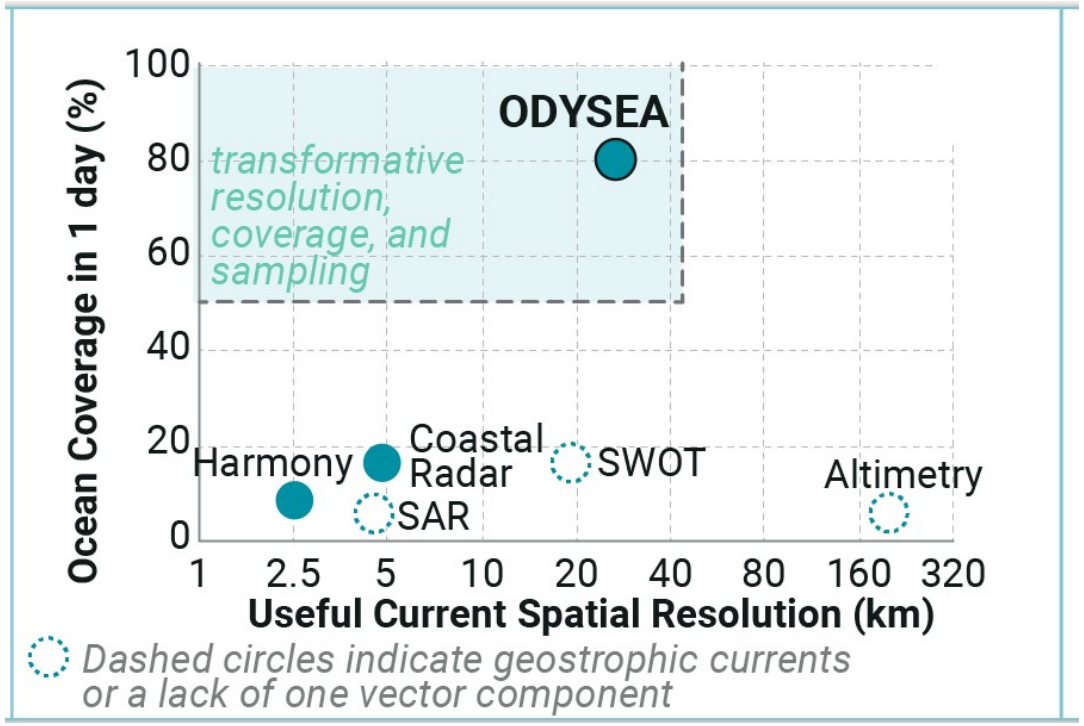
Underscores need for more extensive global observations of winds and currents

# Big improvement in spatio/temporal coverage

## Winds

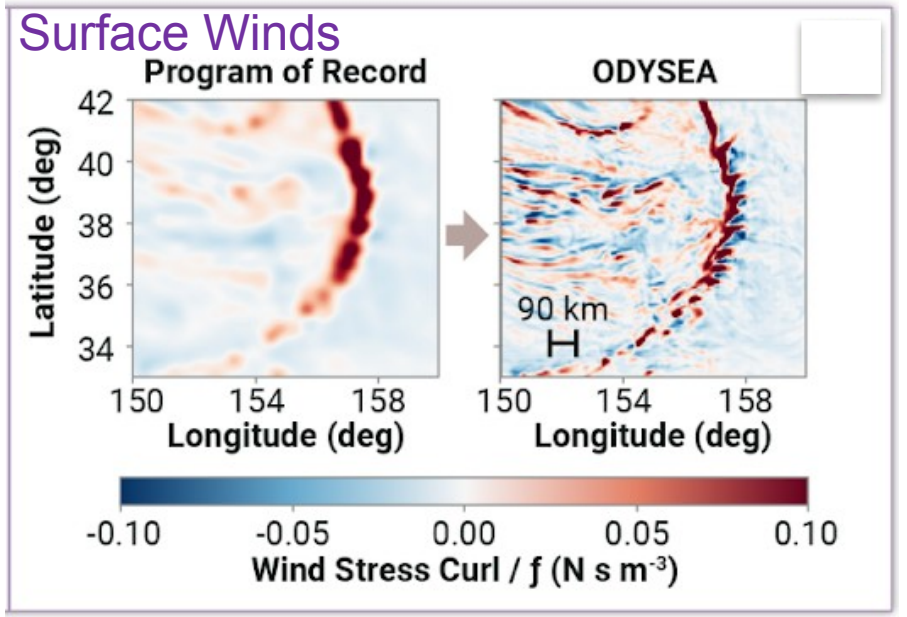


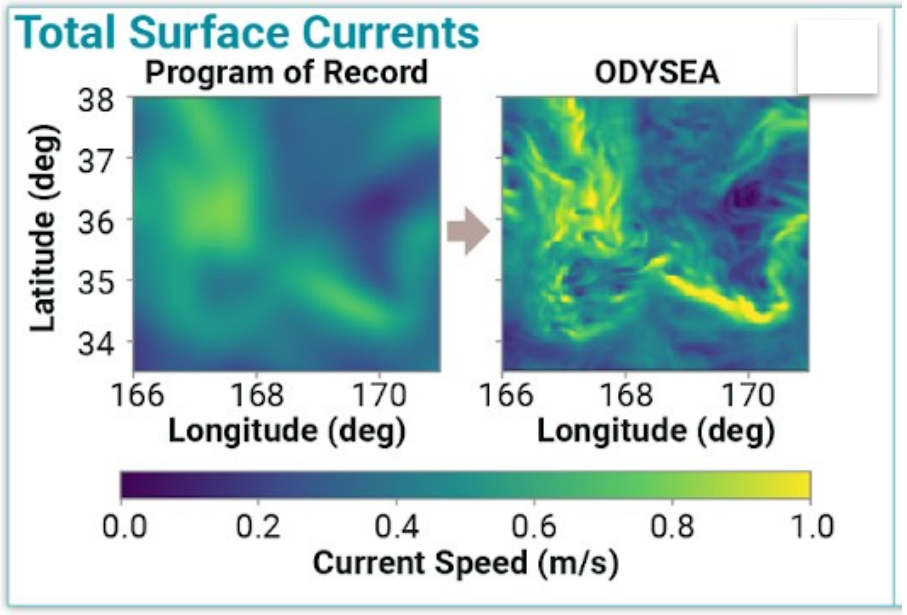

## Currents



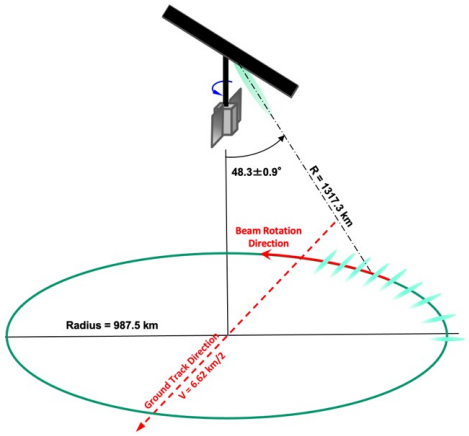
# ODYSEA will meet operational needs

- Near real time winds and currents
- Storm evolution, surface waves, maritime safety, debris transport
- Support NOAA, Navy, Coast Guard Search and Rescue, Mercator Ocean international



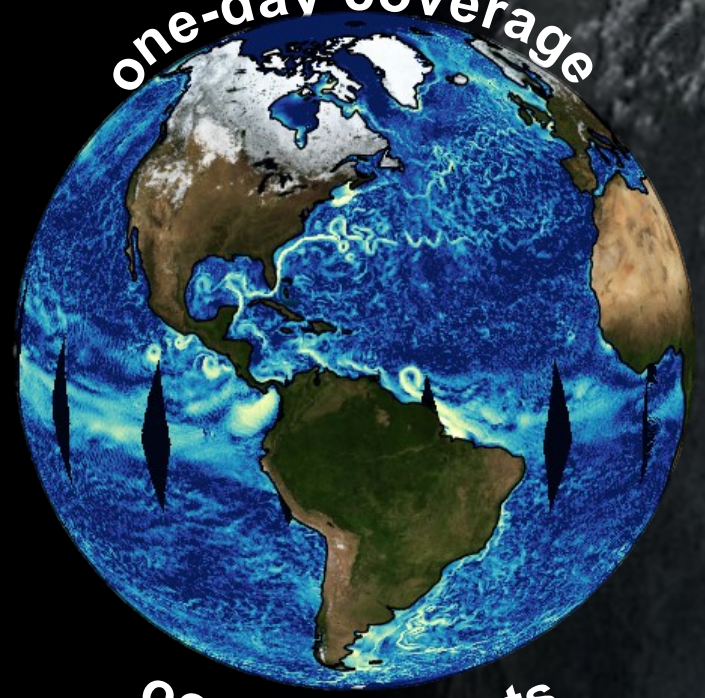
# ODYSEA Mission Overview

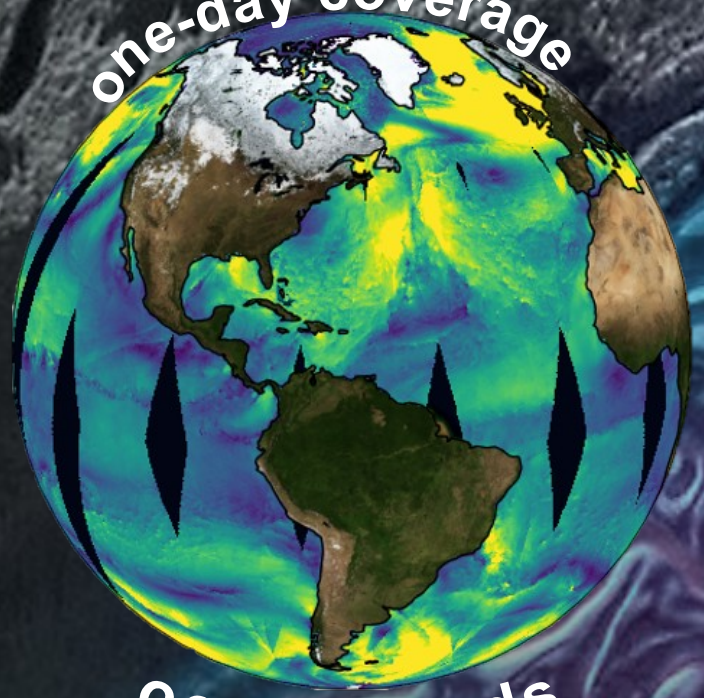


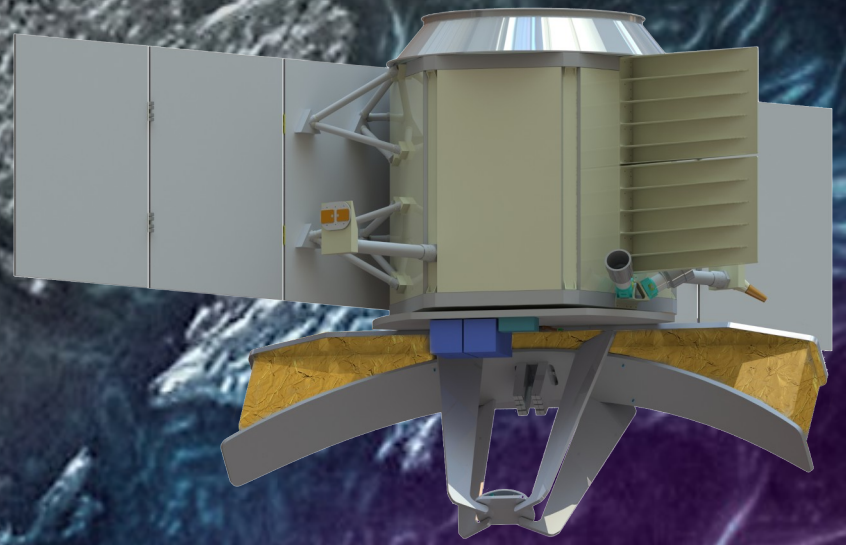

- Science and operational capabilities fill a void
  - No satellites measure total surface currents
  - No US scatterometers measure winds, no 5-km postings, no sun synchronous measurements in midnight—6 am time range

- 90% global coverage < 1 day (2x/day in many places)
- ~600 km sun-synchronous terminator (4 am/4 pm) orbit
- Near-real time ocean wind and currents data products (<6 hour latency)
- One of four Earth System Explorers selected for 9 months of further study
  - Science has been reviewed; now demonstrate that goals can be achieved on time and on budget
- Concept Study Report due June 17; site visit in October 2025

**ODYSEA will provide the first daily, simultaneous, global measurements of surface currents and winds at unprecedented resolution.**



**ODYSEA is one of four Earth System Explorer missions selected into a competitive phase A by NASA. Two will be selected in 2025 for flight in 2030 and 2032.**

# How can you get involved?

1. Test science ideas using the ODYSEA simulator (https://odysea.ucsd.edu)

2. Let us know if you want to be an early adopter or contribute to operational/science enhancements

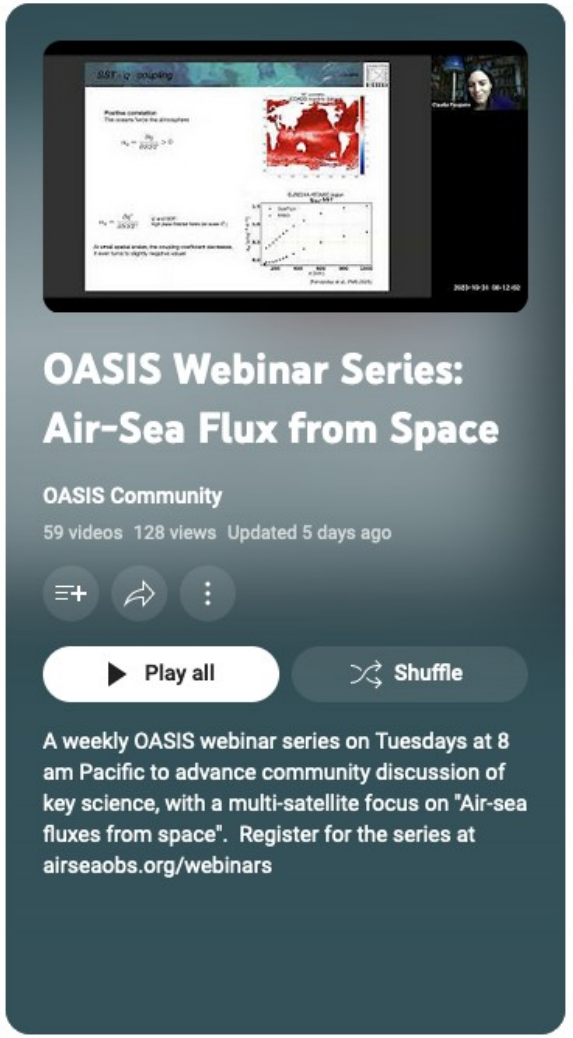
3. Join the discussion:

OASIS Grand Idea #2: Air-Sea Fluxes from Space

Webinar Tuesdays at 8 am PT, 11 am ET, 5 pm CET

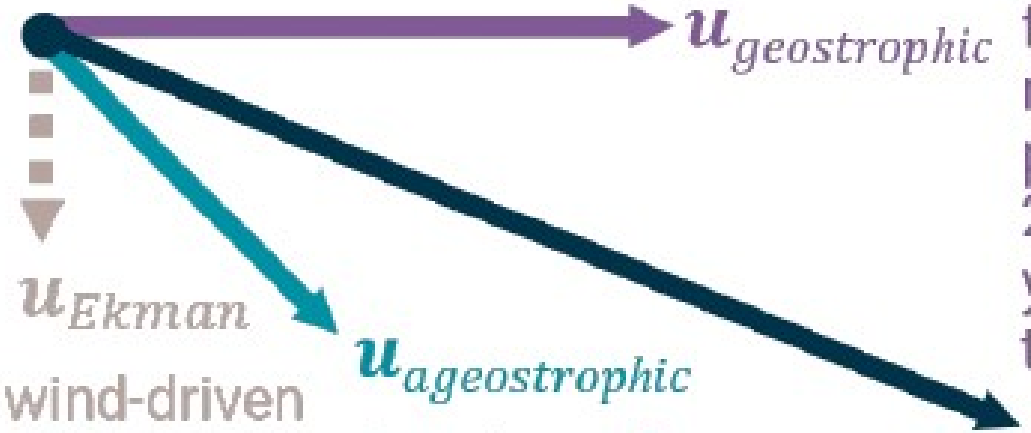
Sign up from the OASIS web site: https://airseaobs.org/

Find previous recordings on youtube



# Backup

$$u_{total\_curr} = u_{geostrophic} + u_{ageostrophic}$$




The blurred lens through which we see large-scale currents today; approximated from altimeter sea surface height measurements at scales ≳200 km. SWOT provides sea surface height gradients at 21-day intervals within 100-km wide swaths, yielding $u_{geostrophic}$ but only to the extent that geostrophy holds on scales < 100 km.

The wind-driven component of currents, approximated from wind measurements. Relevant on time scales ≳1 day.

Consists of many physically important processes. Unmeasured, it is often approximated as $u_{Ekman}$, but this misses a major fraction of the surface current.

$u_{total\_curr}$

**ODYSEA** measures the true ocean surface current without approximations, enabling study of all these processes.

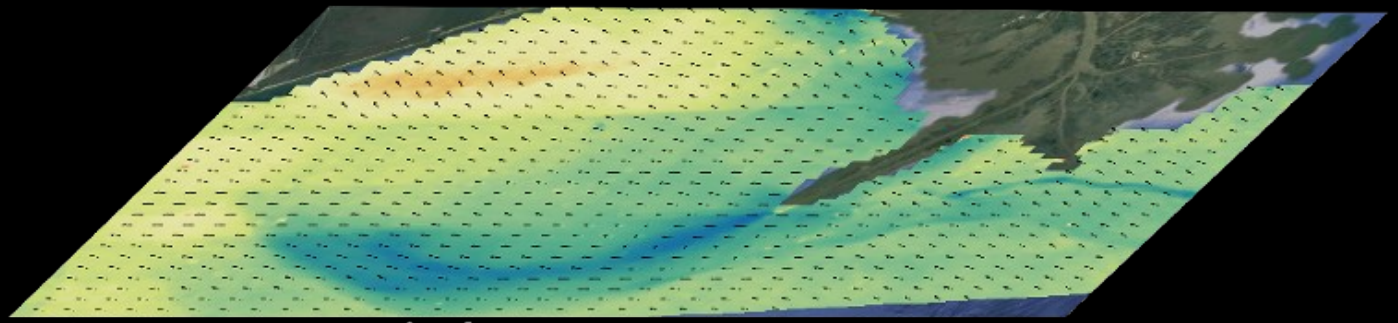
024d_ODYSEA_D

# ODYSEA

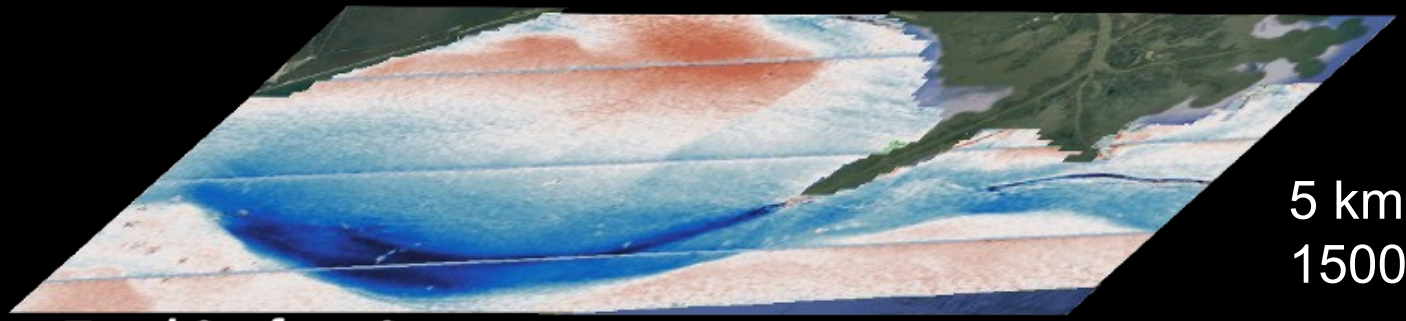
**Ocean Dynamics and Surface Exchange with the Atmosphere**

**ODYSEA's Ka-band Doppler Scatterometer**

Provides the **first-ever** global measure of total surface currents.
Includes simultaneous ocean vector winds with improved resolution for coupled air-sea science and applications closer than ever to the coast.



**Ocean Vector Winds**



**Total Surface Currents**

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*Earth System Explorer proposal to NASA with strong support from CNES (+ US Space Force).*

*Web: odysea.ucsd.edu*
*PI: Sarah Gille sgille@ucsd.edu*

*Deputy PIs: Melanie Fewings (Oregon State), Mark Bourassa (Florida State)*

*French lead: Fabrice Ardhuin*

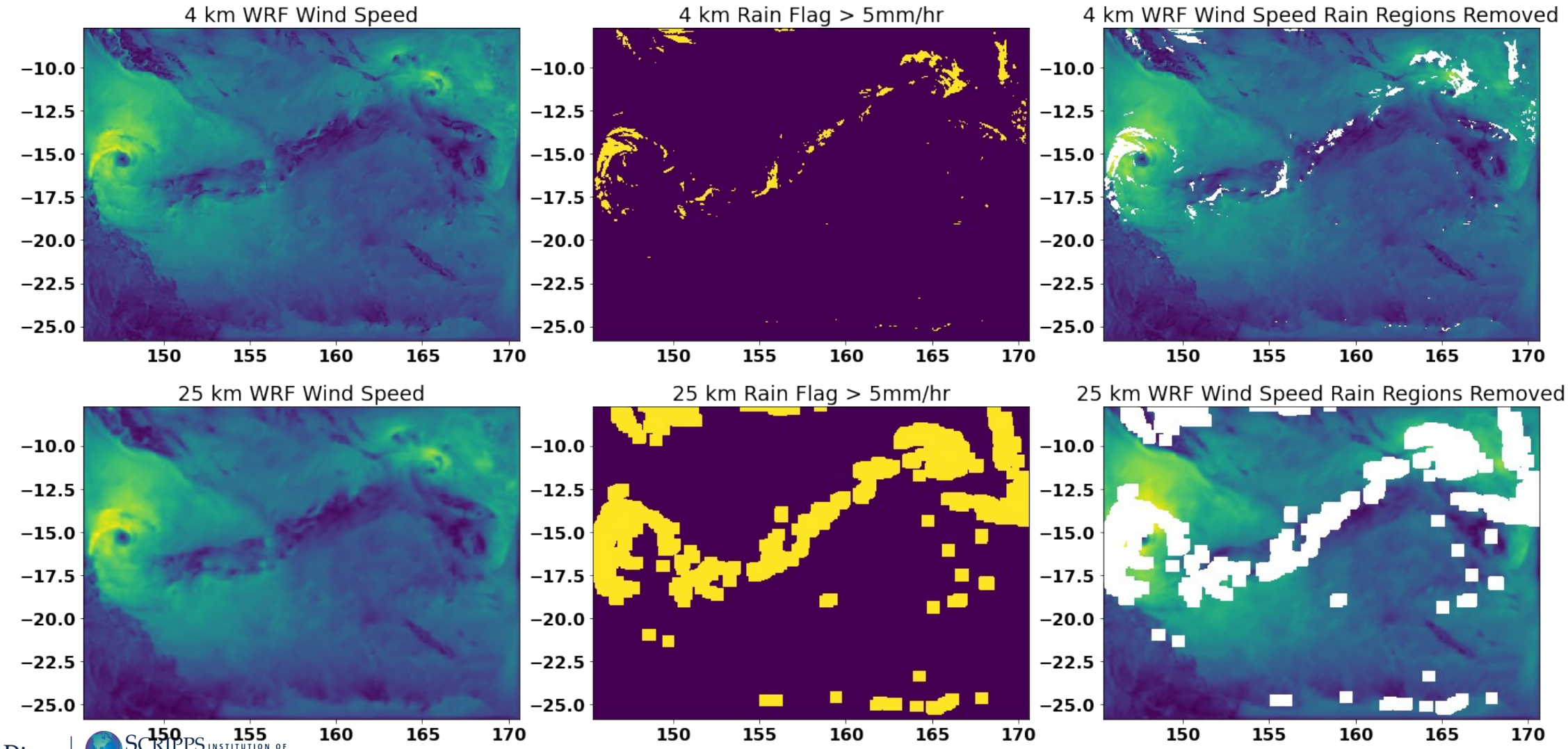
5 km postings
1500 km swath

*Daily coverage, near-real time*

# ODYSEA's 5-km data allow better view of winds around & between small-scale, patchy rain cells that would contaminate other satellite winds with ≥25 km footprints

ODYSEA

Weather Research & Forecasting (WRF) model simulation (Alex Wineteer, JPL)

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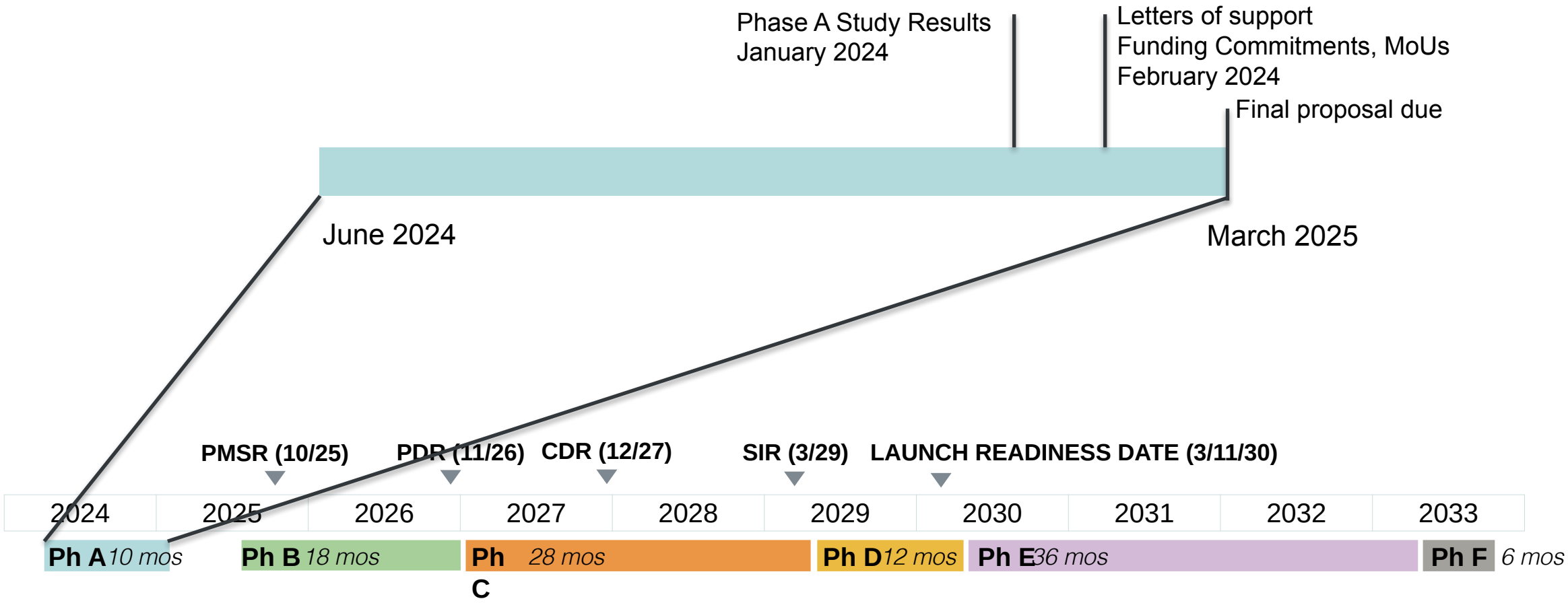
# ODYSEA Schedule and Input Needs

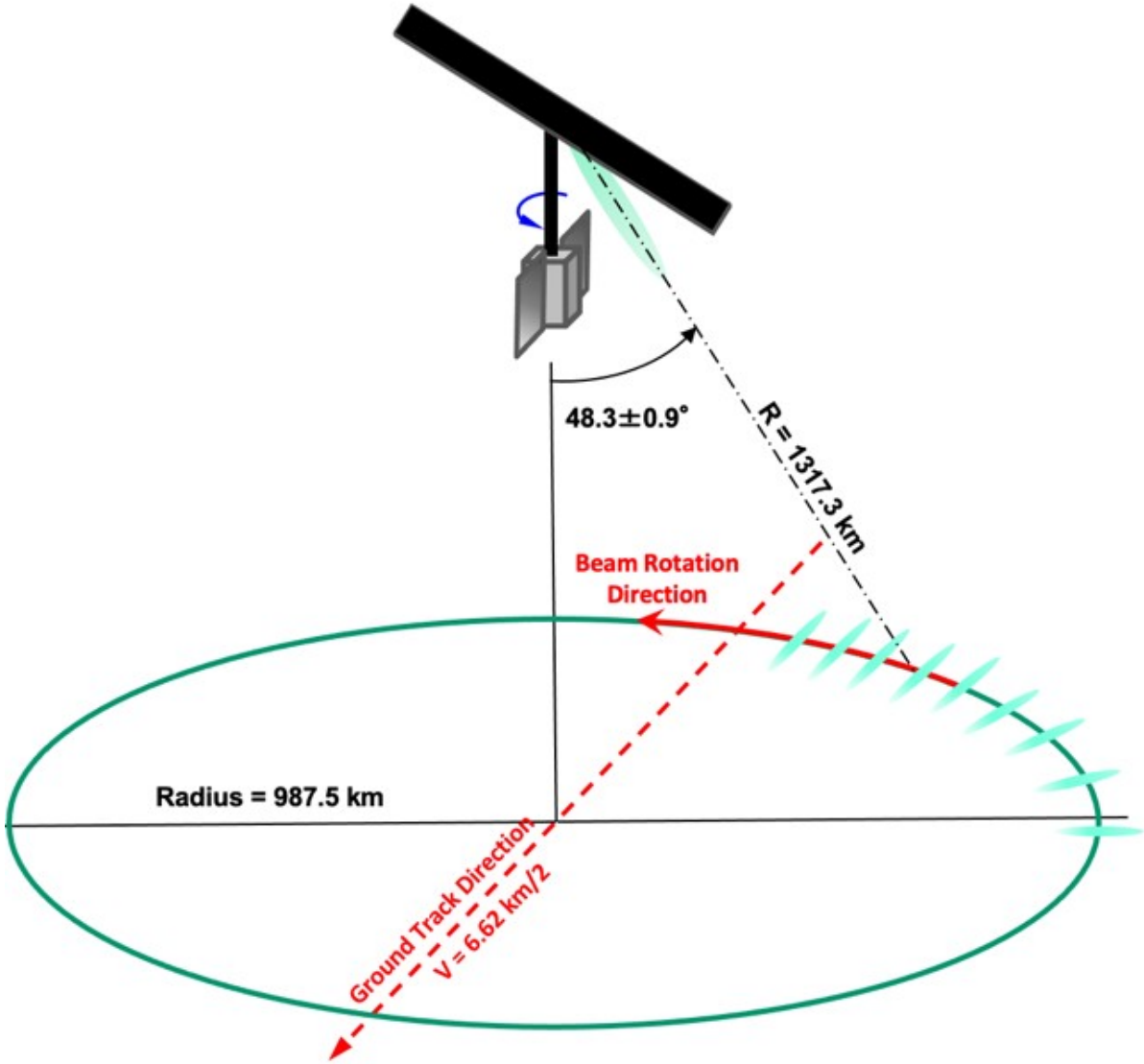
ODYSEA is in competed phase A, with a step 2 proposal due in March 2025.



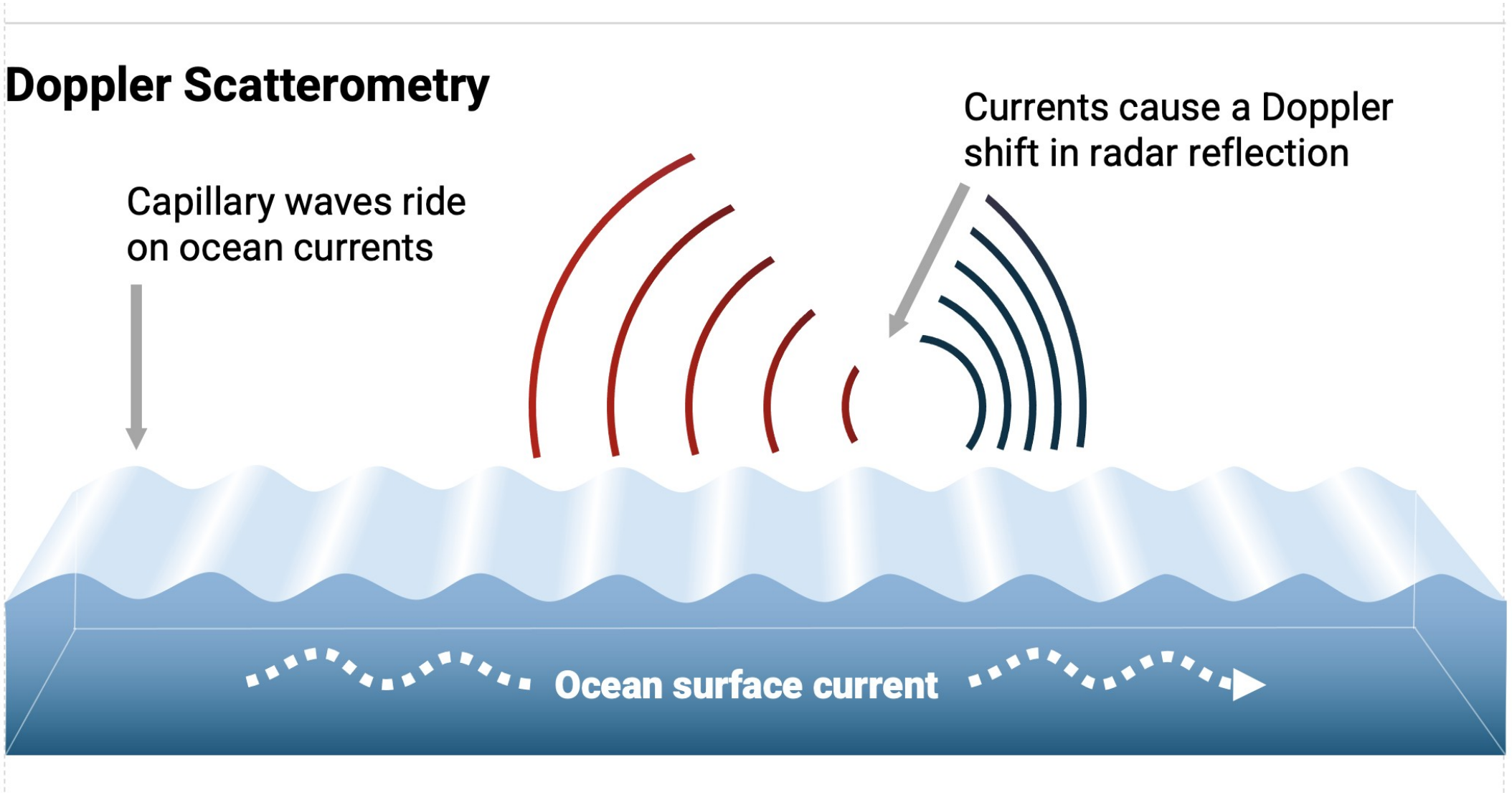
# Measuring wind with scatterometry

ODYSEA achieves better results than previous scatterometers with low noise and 2 looks

ODYSEA in Ka band is designed for 5 km resolution

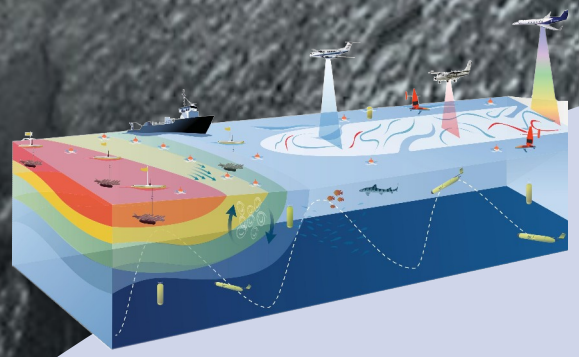


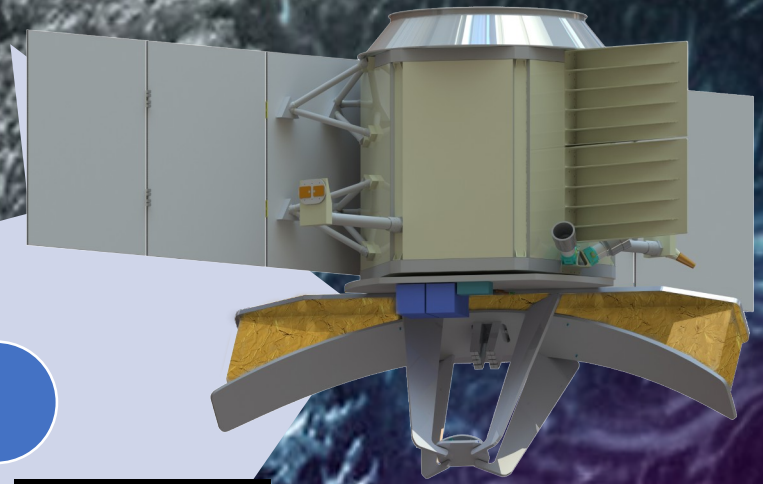
# Moving surface Doppler shifts radar phase



# ODYSEA

Ocean Dynamics and Surface Exchange with the Atmosphere

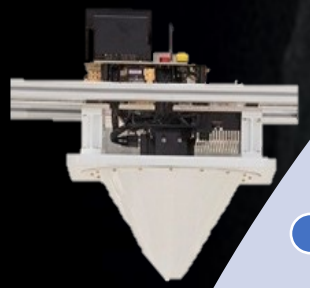




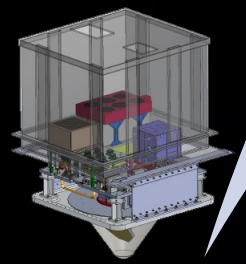
ODYSEA ESE (2023)

S-MODE EVS-3 (2019)

DopplerScatt AITT (2016)



DopplerScatt IIP (2014)



DopplerScatt Concept (2013)

OASIS

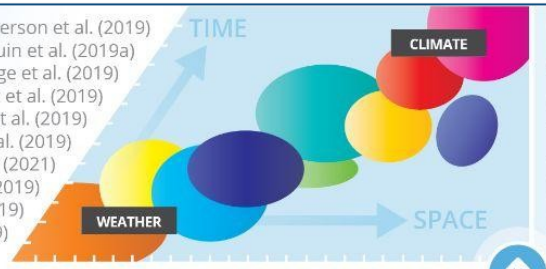
2021 2030 United Nations Decade of Ocean Science for Sustainable Development

ODYSEA

# Observing Air-Sea Interactions Strategy (OASIS) is harmonizing community recommendations from OceanObs'19 and UN Decade Laboratories...

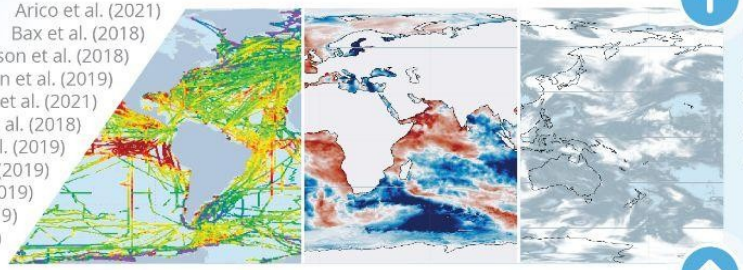
## ...into three Grand Ideas

Anderson et al. (2019)
Ardhuin et al. (2019a)
Bange et al. (2019)
Bax et al. (2019)
Canonico et al. (2019)
Domingues et al. (2019)
Estes et al. (2021)
Penny et al. (2019)
Pinardi et al. (2019)
Powers et al. (2019)



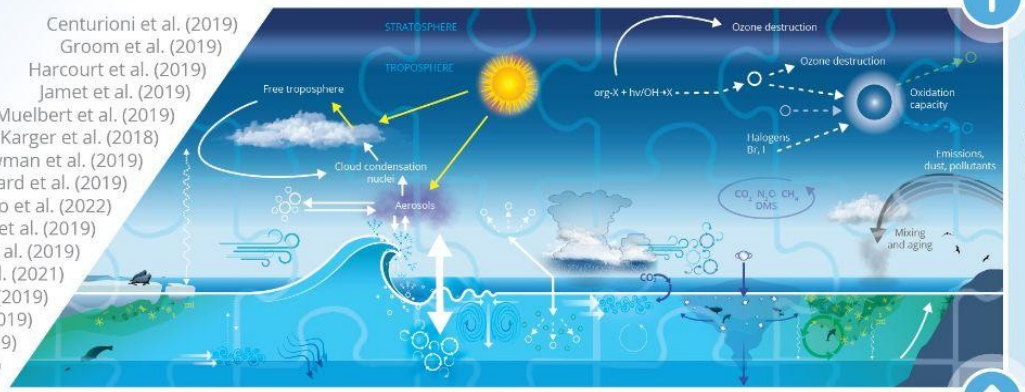

Improved Earth system *(including ecosystem)* forecasts for a predicted, clean, accessible, healthy, safe & productive ocean

Arico et al. (2021)
Bax et al. (2018)
Benson et al. (2018)
Cronin et al. (2019)
Cronin et al. (2021)
Fennel et al. (2018)
Foltz et al. (2019)
Hermes et al. (2019)
Maximenko et al. (2019)
Smith et al. (2019)
Speich et al. (2019)
Wanninkhof et al. (2019)



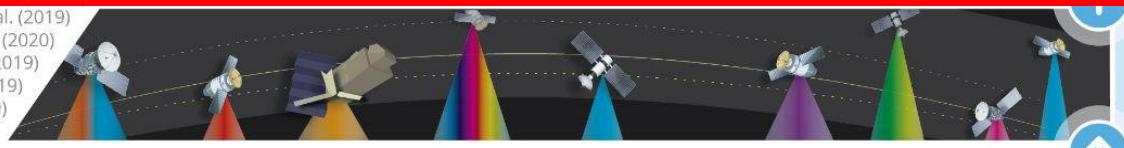
Improved ocean information serving stakeholders around the world

Centurioni et al. (2019)
Groom et al. (2019)
Harcourt et al. (2019)
Jamet et al. (2019)
Muelbert et al. (2019)
Muller-Karger et al. (2018)
Newman et al. (2019)
Lombard et al. (2019)
Marandino et al. (2022)
Kent et al. (2019)
O'Carroll et al. (2019)
Sequeira et al. (2021)
Steinhoff et al. (2019)
Subramanian et al. (2019)
Swart et al. (2019)
Villas Bôas et al. (2019)



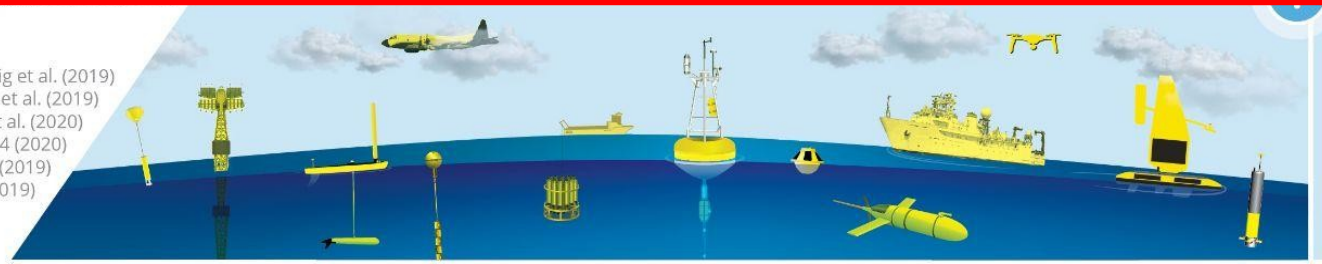

**Grand Idea #3**
Improved models & understanding of air-sea interaction processes

Ardhuin et al. (2019b)
Bourassa et al. (2019)
Gentemann et al. (2020)
Gommenginger et al. (2019)
Morrow et al. (2019)
Rodríguez et al. (2019)
Shutler et al. (2020)
Vinogradova et al. (2019)



**Grand Idea #2**
Satellites optimized for air-sea fluxes

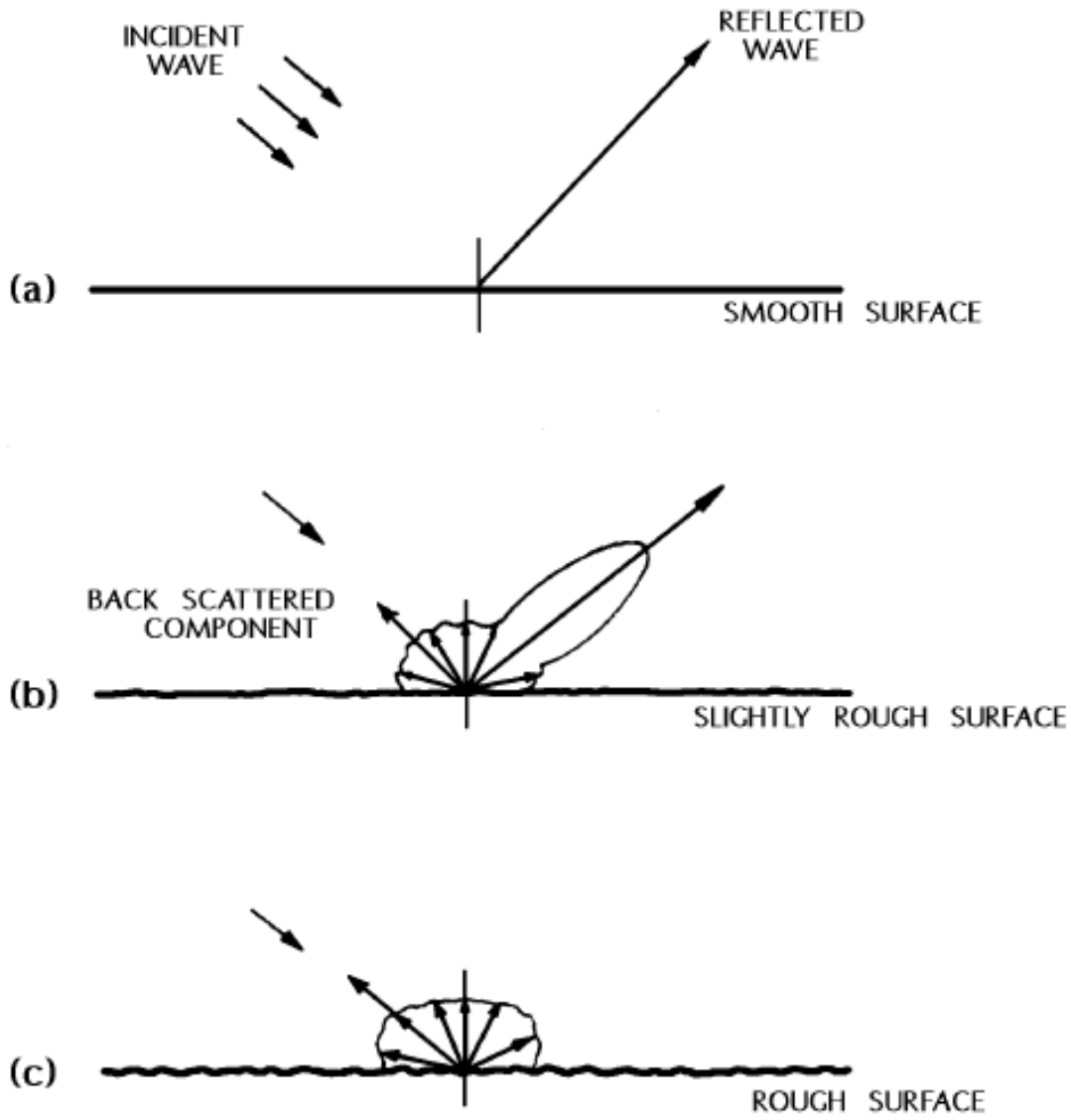
Meinig et al. (2019)
Pearlman et al. (2019)
Sabine et al. (2020)
SCOR Working Group 154 (2020)
Smith et al. (2019)
Wang et al. (2019)



**Grand Idea #1**
A globally distributed in situ air-sea observing network built around an expanded array of time series stations

Image: Sarah Battle/NOAA visit: airseaobs.org

# Backscattered energy




http://www.eumetrain.org/da