SWOT ST Working Group on High-Resolution Ocean Modeling

Brian Arbic, Julien Le Sommer, Patrice Klein, & Lionel Renault

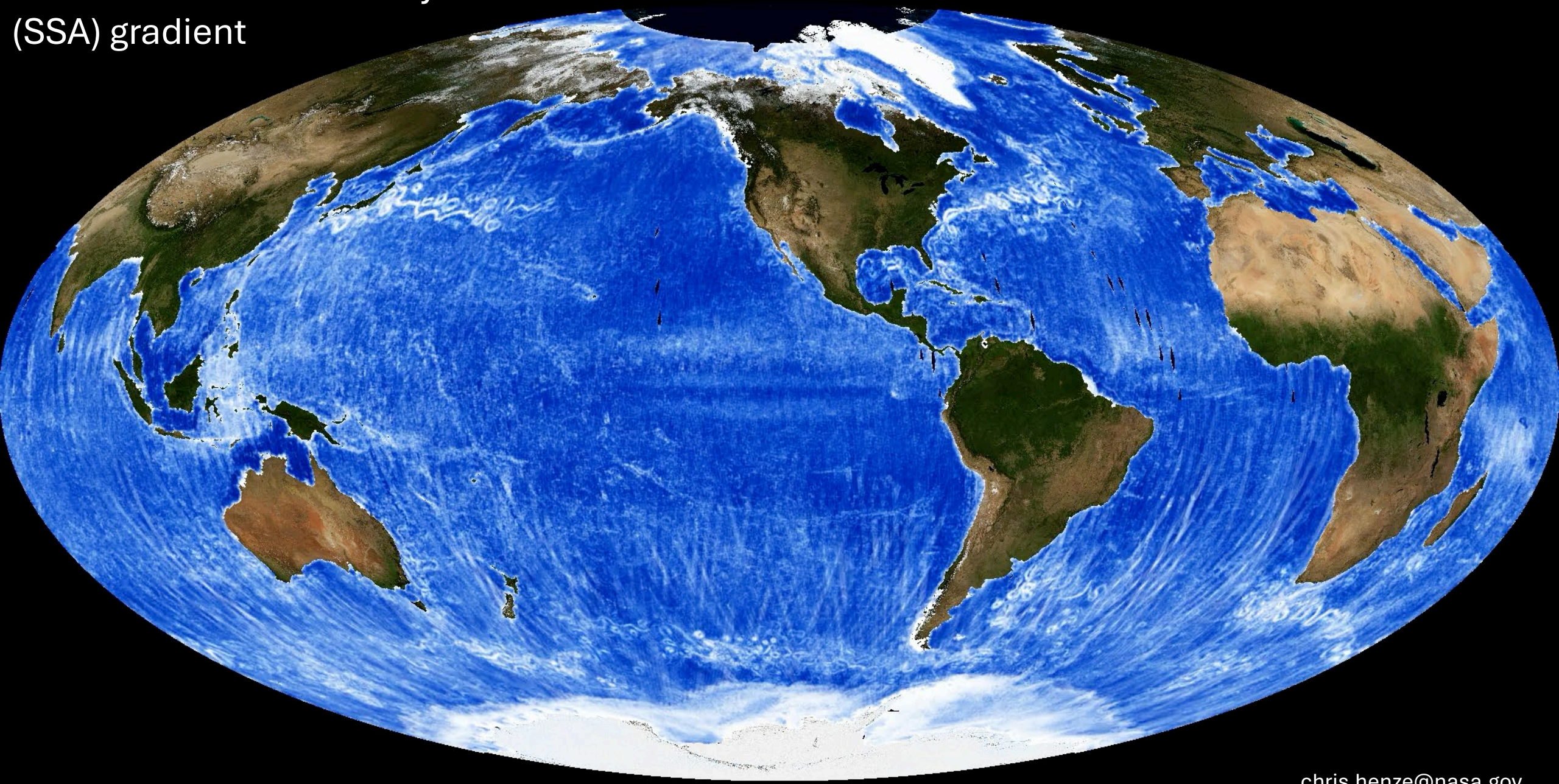
Proposed new member: Dan Whitt

Agenda (45 minutes, Thursday, June 20)

- 8 minutes: Some representative results
- 5 minutes: Is SWOT meeting requirements, pre-launch expectations?
- 15 minutes: New results being revealed
- 15 minutes: Challenges remaining: steps forward

We are excited that we finally have SWOT data to challenge the models. Previous ST has 60 members in HR modeling group.

SWOT Sea Level Anomaly (SSA) gradient



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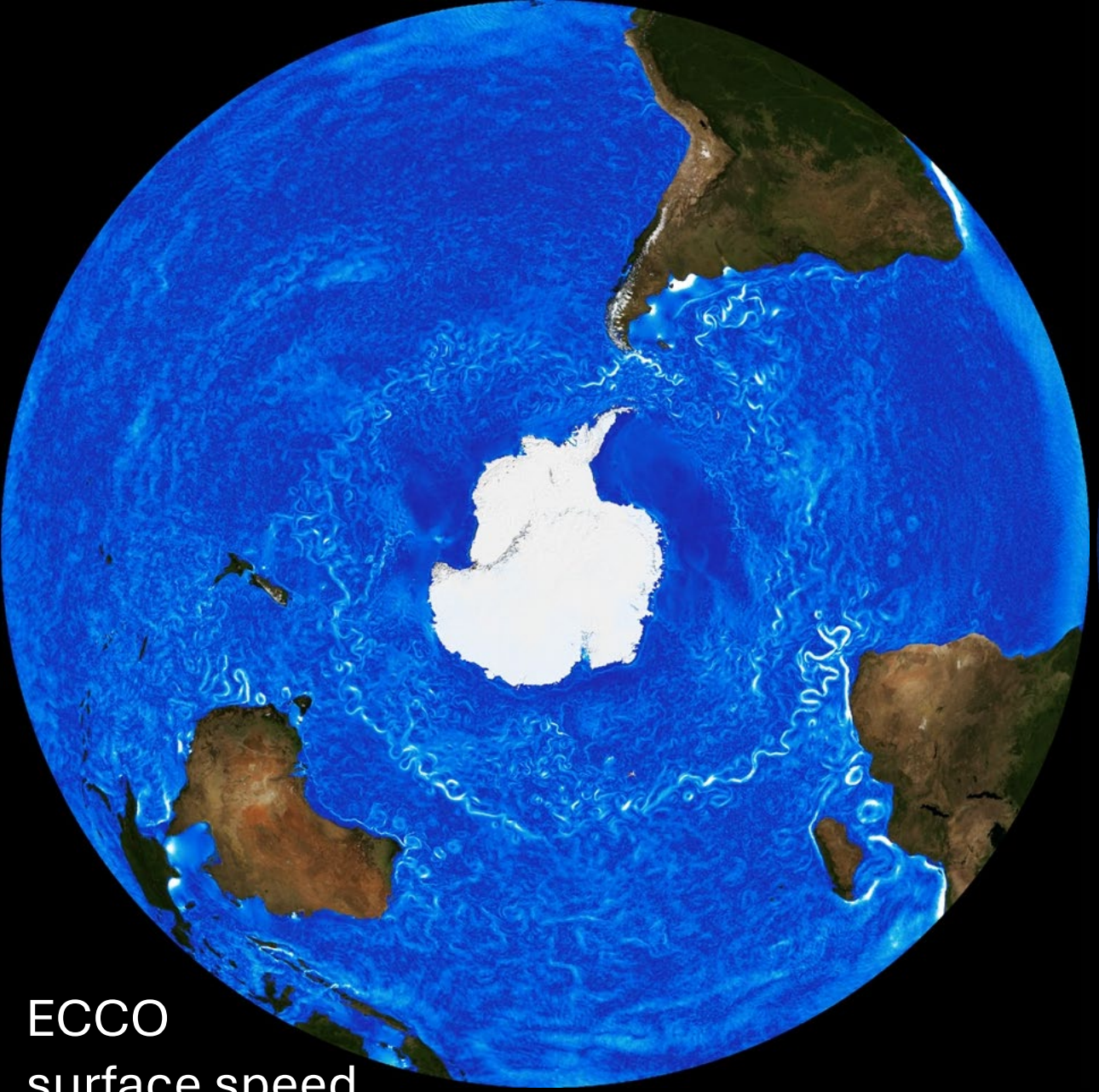
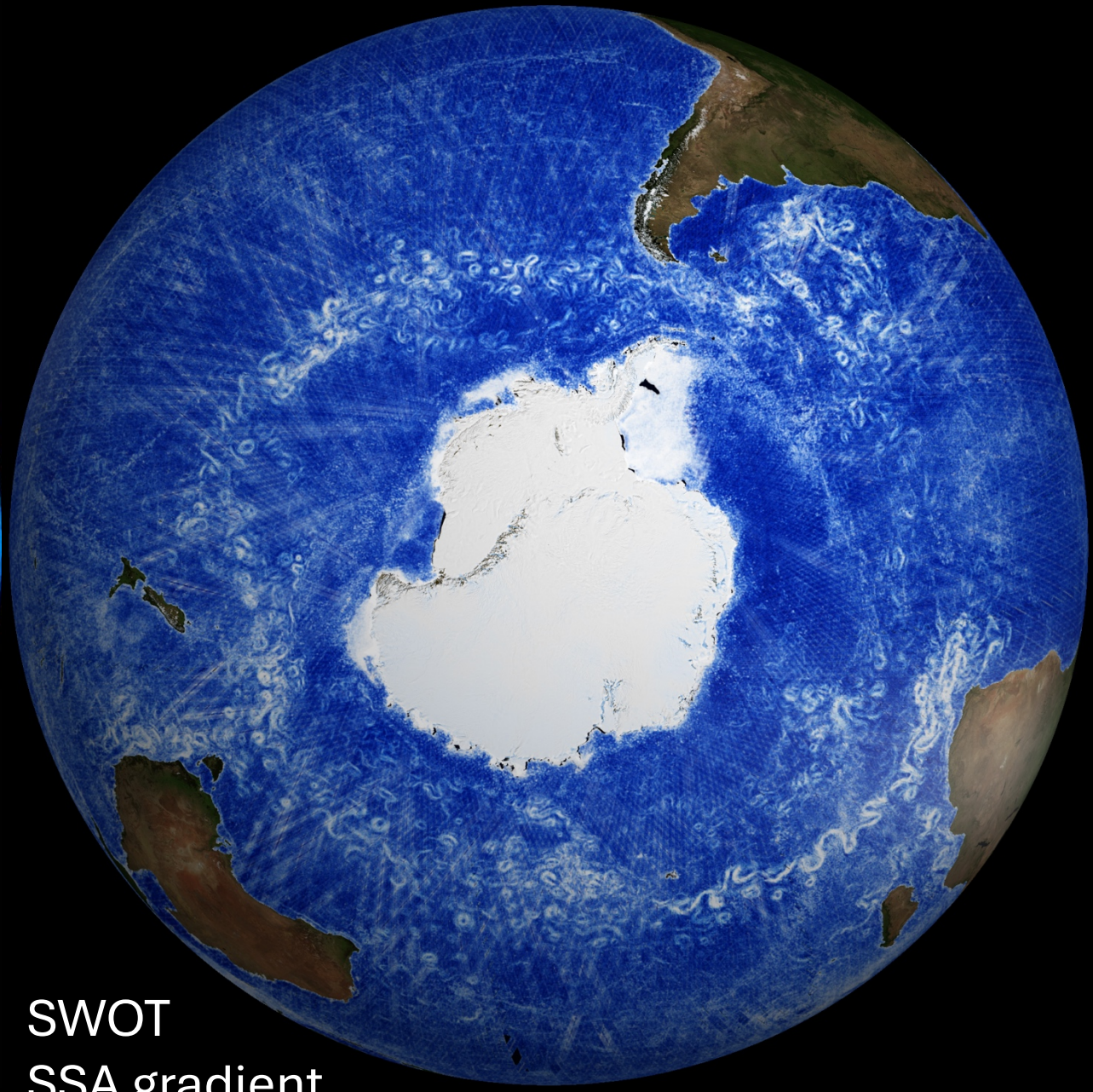
NASA Ames mirror of L2 and L3 SWOT data: /export1/nmccurdy/public/swot



ECCO
surface speed



SWOT
SSA gradient

GEOS/ECCO animations available at https://data.nas.nasa.gov/geoseccoviz

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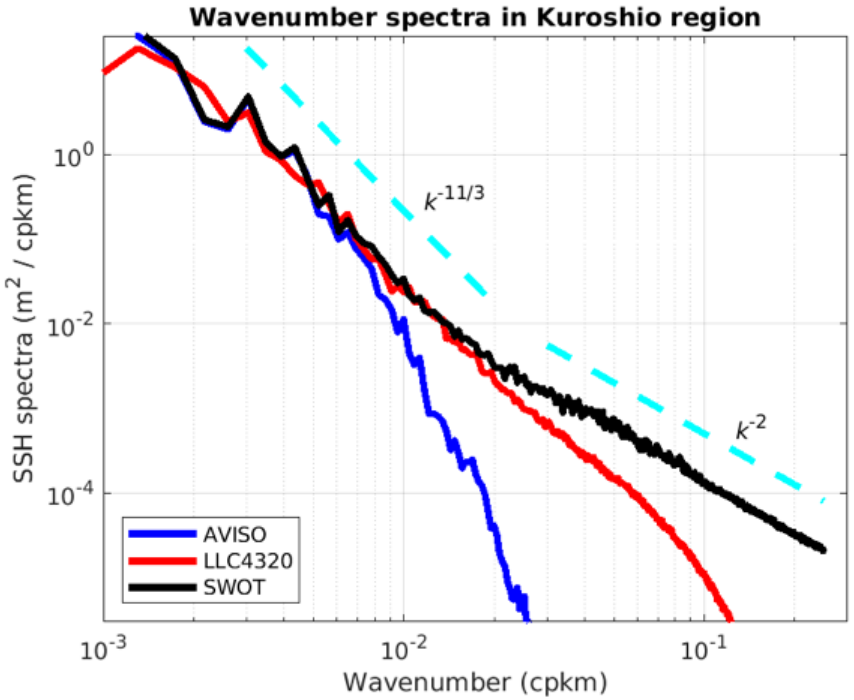
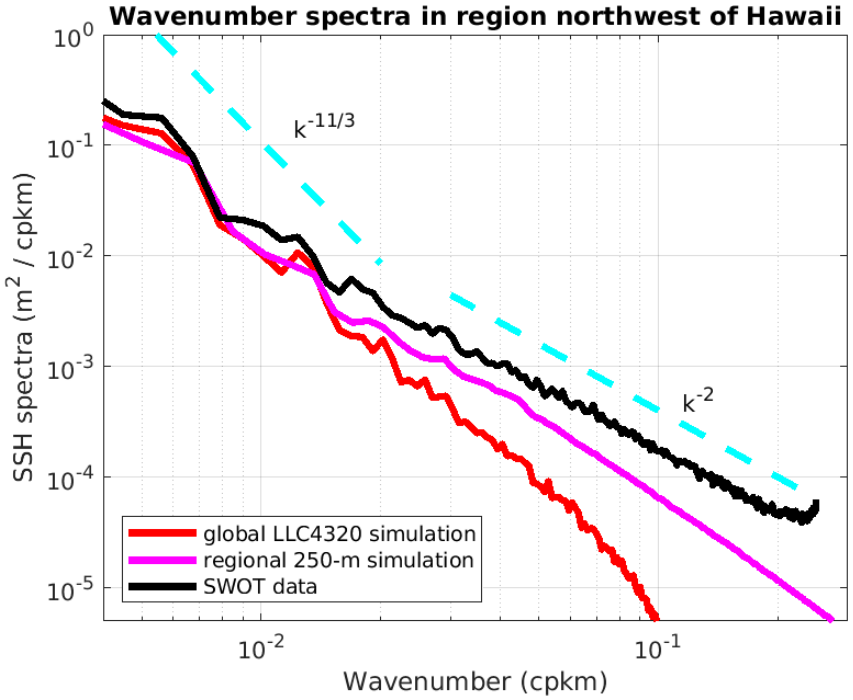
SWOT high-wavenumber signals confront our models with a need for improvement





The wavenumber spectra in global high-resolution models capture more high-wavenumber activity than gridded AVISO products made from nadir altimetry, and lie close to the SWOT spectrum down to about 50 km.

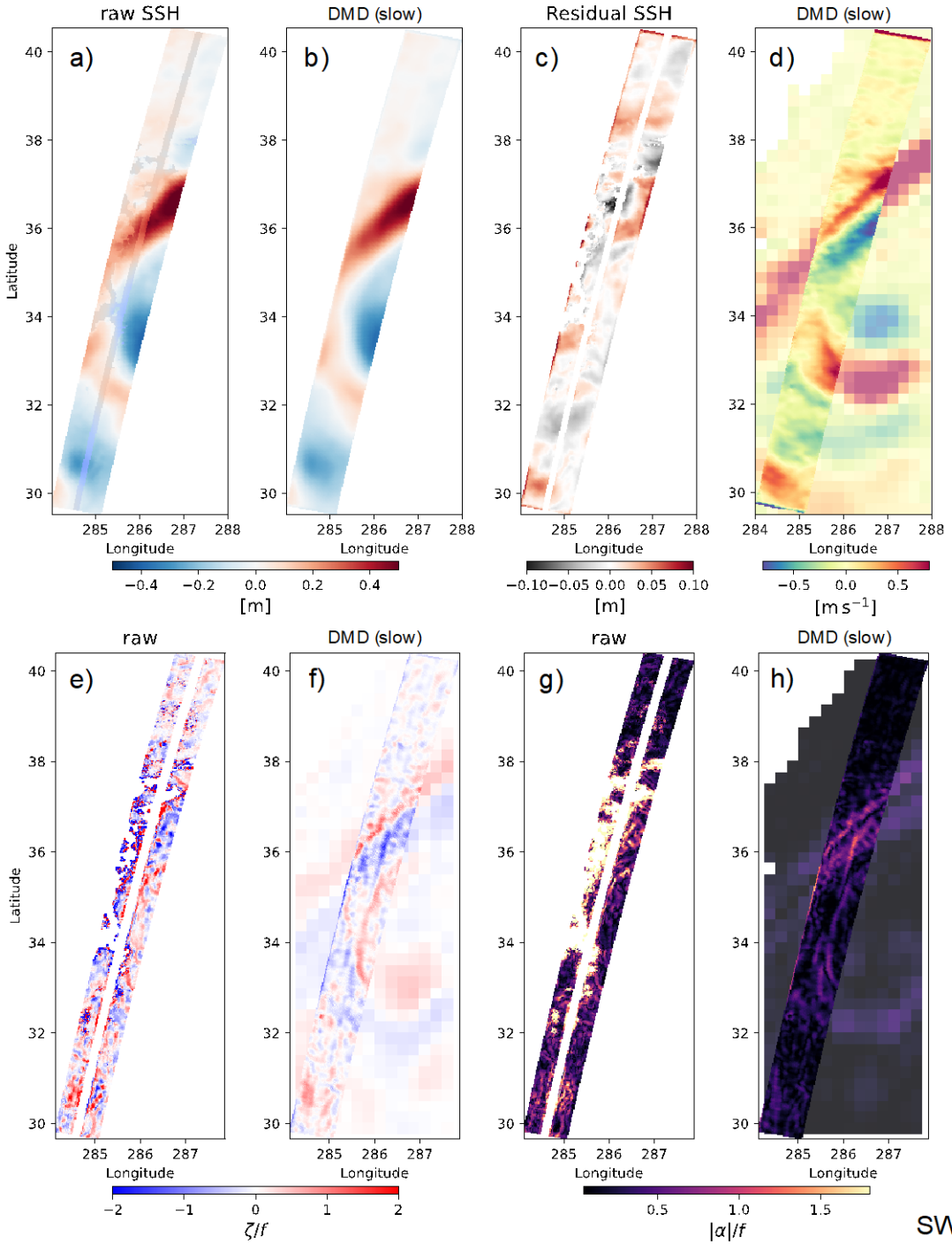
However, the SWOT spectrum has more energy than the global models at high wavenumbers.

What is this high-wavenumber energy? Internal waves? Something else? Whatever it is, it is missing from even the highest-resolution global models.

Our regional simulations (Thakur et al. 2022) feature much finer horizontal and vertical grid spacing than global LLC4320, and they include remotely generated internal waves (from global LLC4320) at their lateral boundaries. The regional models come closer to the SWOT data but are still insufficiently energetic at high wavenumbers.

So, what is missing? Do we need to improve the global models that serve as boundary conditions? Do we need even higher resolution in the regional models? Larger supercomputers would help!

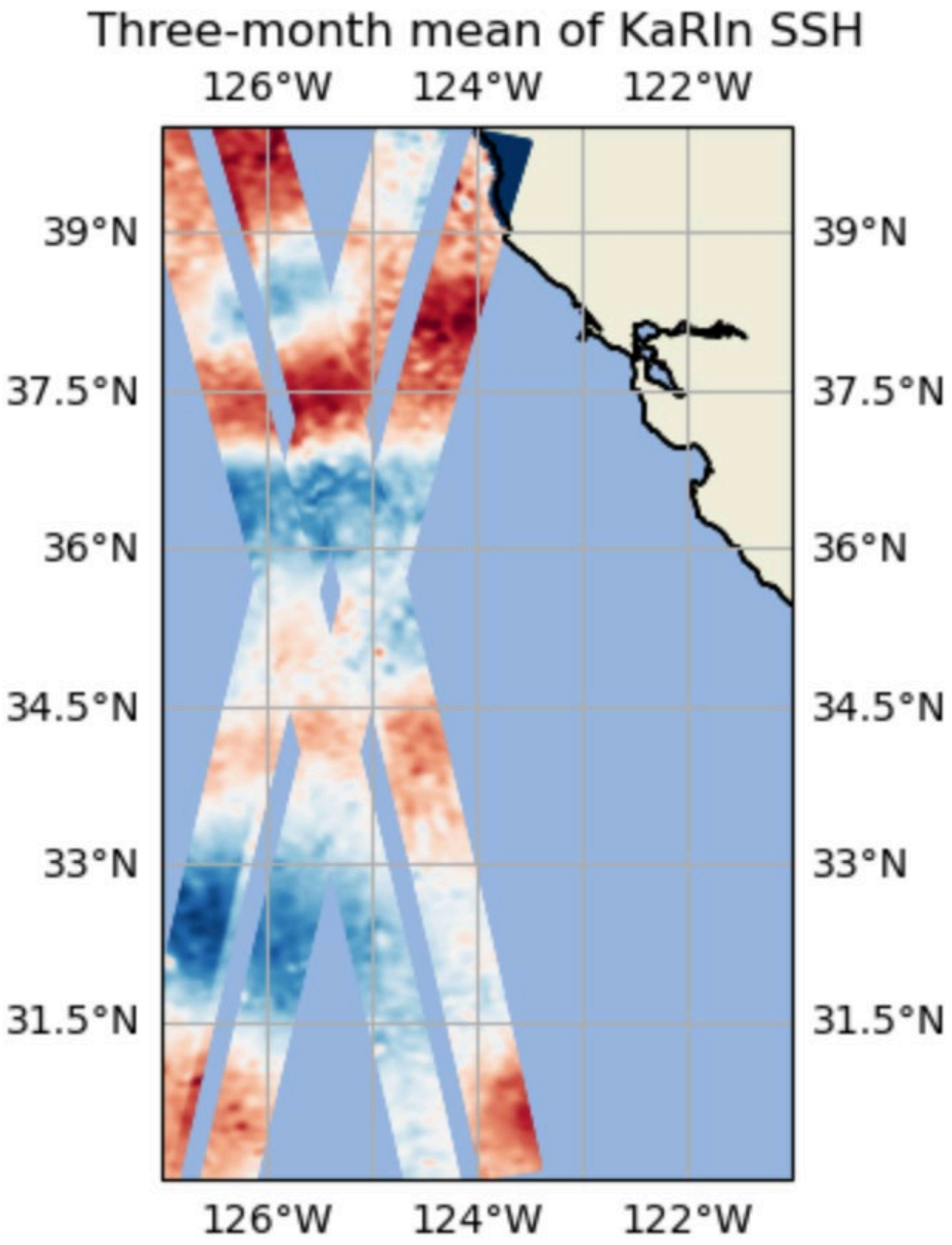
B. Arbic (arbic@umich.edu), D. Memenenlis (menemenlis@jpl.nasa.gov), J. Wang (jinbo.wang@jpl.nasa.gov), and other co-authors of Thakur et al. 2022 GRL.



- Dynamic-Mode Decomposition (DMD) is applied to SWOT in order to extract the slowly varying component in geostrophic balance;
- Applying geostrophy to raw SWOT data results in fictitiously large and noisy values in relative vorticity and strain rates (panels e, g);
- DMD slow modes can be used to diagnose geostrophy (panels d, f, h);
- There is some spatial coherence between the DMD slow modes diagnosed from SWOT and daily 0.25° gridded AVISO but the former has sharper spatial features (panels d, f, h).

SWOT data from June 21, 2023

- The three-month mean of KaRIn SSH shows large-scale ocean circulation as well as small-scale residual mean surface
- The small-scale features are due to unresolved small-scale bathymetry.
- These will change ocean bottom roughness. How does ocean simulation especially deep-ocean mixing respond to refined bathymetry?



TROPIC-SWOT: Submesoscale ocean currents in the tropical Pacific

Daniel B. Whitt, Kydd Pollock, Dimitris Menemenlis, Santha Akella, Morgan Gilmour, Brian Arbic
A partnership with NASA JPL & GSFC, The Nature Conservancy, and University of Michigan

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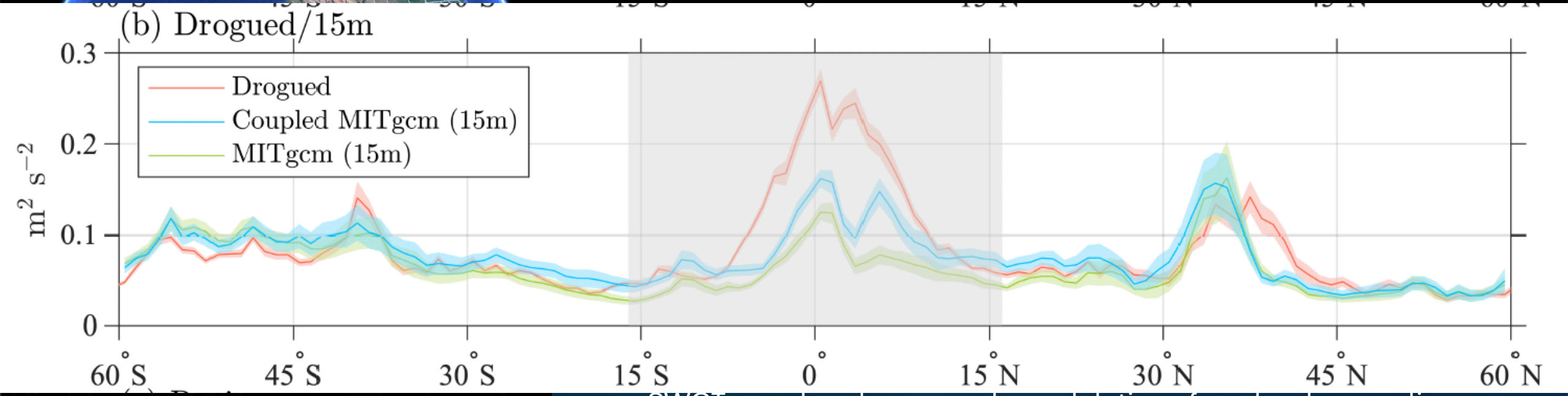
Goals

1. Explore submesoscale (< 500 km) SSHA variability in tropical Pacific using SWOT observations and high-resolution models
2. Evaluate surface current estimates from drifter clusters released ~monthly under SWOT overpasses near 6N,162W / Palmyra Atoll
3. Discover how submesoscale sea level and currents participate in the strong 2023-2024 El Niño and aftermath (likely La Niña).

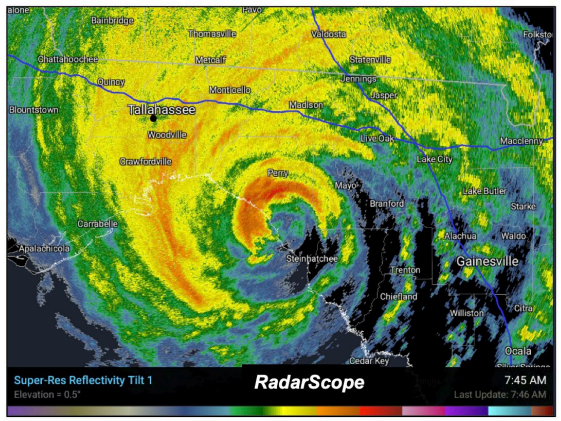


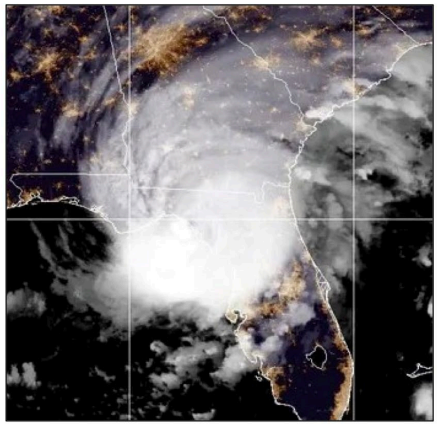
SWOT observes high sea level in the east Pacific in Nov 2023 in strong El Niño

SWOT reveals submesoscale modulation of sea level anomalies, modulated by tropical instability vortices for first time (red/orange)

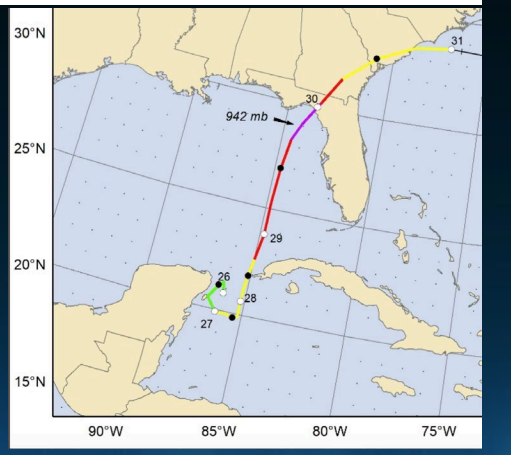
SWOT mission

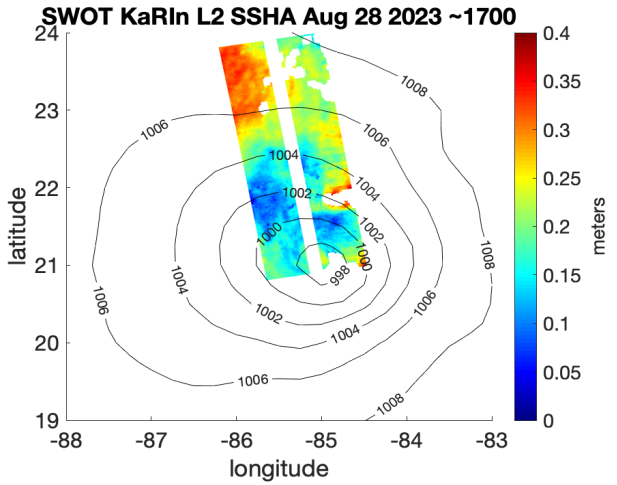
Can we learn about air-sea interaction/upper ocean phys under hurricane idalia from SWOT?

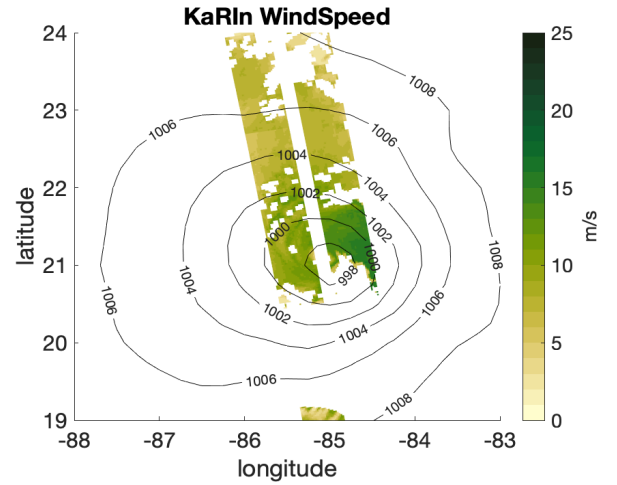


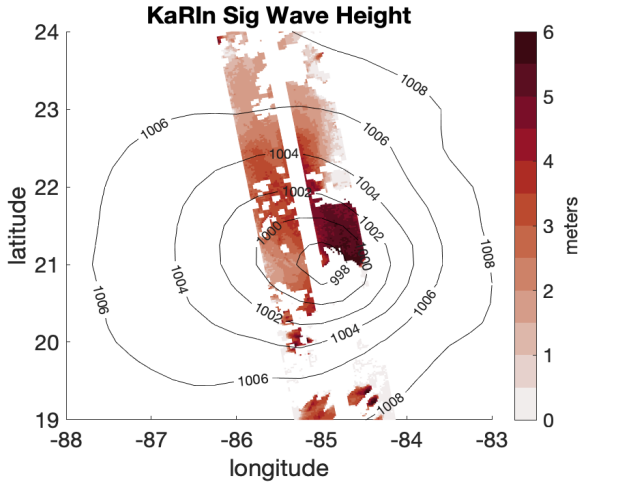


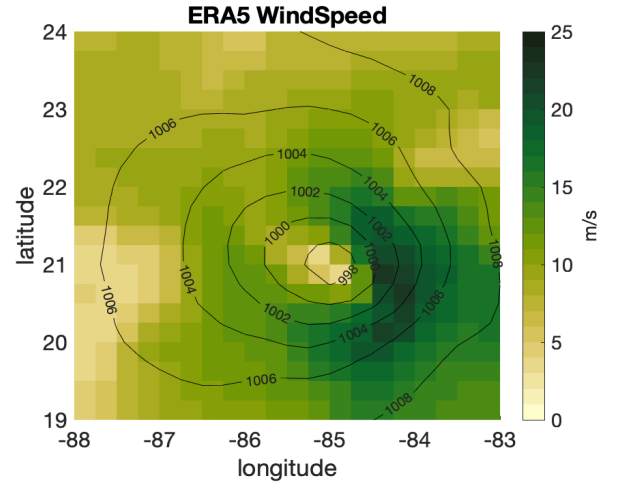
Idalia 2023
12 lives lost
$4B in damage





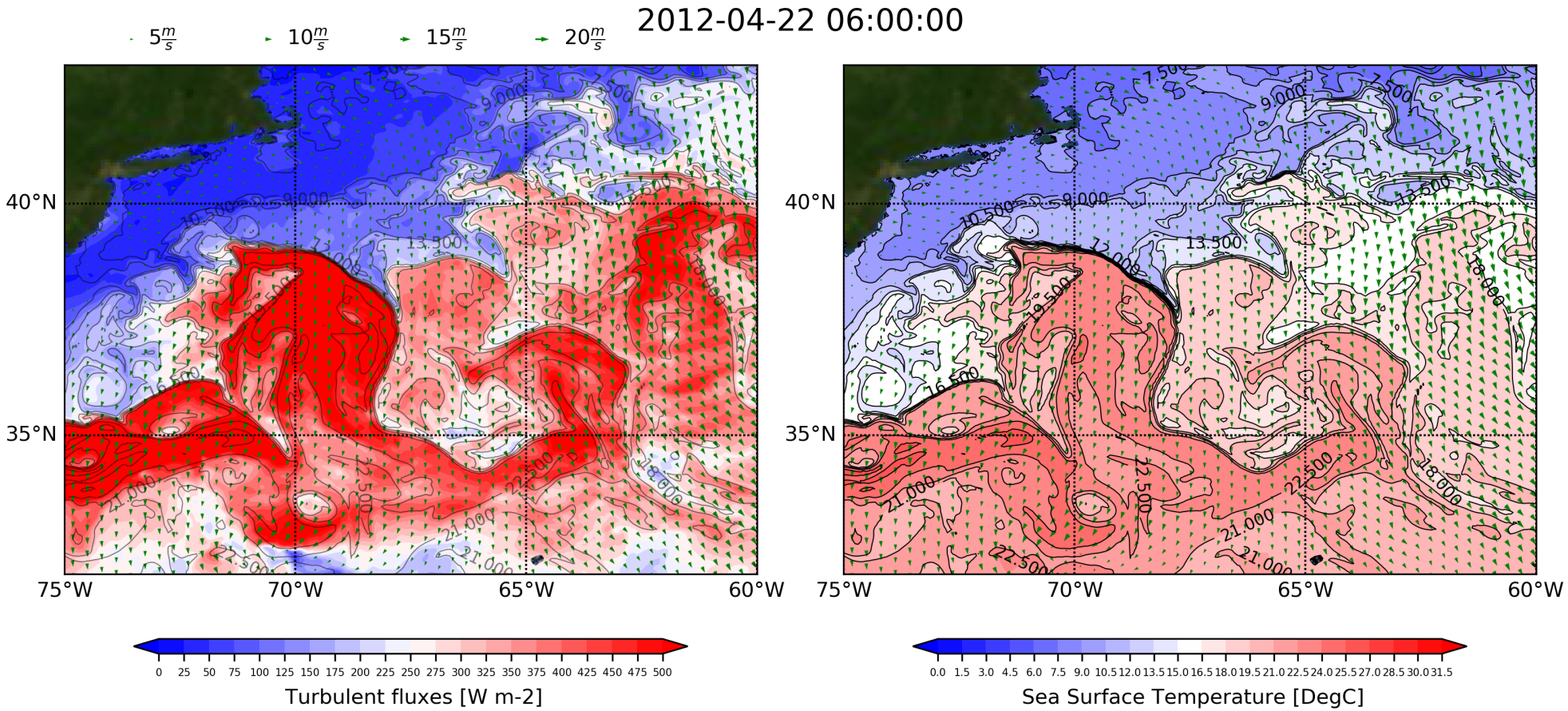






Ocean eddies observed by SWOT explain 30 to 50% of moisture supply from ocean to atmosphere. As such, these eddies are a significant driver of the global hydrological cycle.

One key factor is the spatial resolution of ocean eddies and associated currents. High-resolution ocean currents from SWOT observations, combined with microwave and infrared Sea Surface Temperature (SST) images, enable reconstruction of SST fronts around mesoscale eddies, which are critical to the estimation of latent heat fluxes at the air-sea interface and therefore of moisture supply to the atmosphere.



Adapted from Strobach et al.. (2022) https://doi.org/10.1029/2021GL097003

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Is SWOT meeting requirements, pre-launch expectations?

- The noise floor of the SWOT wavenumber spectrum appears to be at very small scales
- Pre-launch models suggested a spectral break with vigorous energy at small scales
- SWOT data is even more energetic at small scales than models predicted

New results being revealed

- Again: High-wavenumber variance very high, exciting to ask why this is.
- SWOT reveals relationships and scale interactions between submesoscale and larger flow features, e.g. Tropical Instability Waves, Gulf Stream rings
- Submesoscale air-sea interactions
- David Sandwell's high-resolution bathymetry will be super helpful for high-resolution modeling

Challenges remaining: steps forward

- Long list!
- Models can help with many SWOT challenges.
- Connecting SSH to other key variables such as SST, horizontal and vertical velocities.
- Connecting SWOT to other large missions e.g. PACE, ODYSEA
- Separating vortical eddies from divergent wave motions remains a major challenge
- What about the effect of surface wind waves? Is it possible that they fold into spectra at larger scales?
- How do we use high-resolution models to help answer some of these questions?

Key messages

- Models must improve greatly to catch up with SWOT!
- Models can help to interpret SWOT data and relate it to, for instance, subsurface ocean dynamics, air/sea interaction, carbon cycle.
- Some models have high temporal sampling.
- Regional models can help interpret small scales seen by SWOT.