

# ECCO high-res model updates

AKA “High-resolution ocean modeling and SWOT (including coupled)”  
AKA “Dimitris will introduce the worst-named MITgcm ocean simulation”

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## KEY CONTRIBUTORS

**NASA Ames: Dan Whitt\***, Nina McCurdy, Chris Henze, Bron Nelson, and David Ellsworth

**NASA GSFC:** Andrea Molod, Atanas Trayanov, Abdullah A. Fahad, and (formerly at GSFC) Ehud Strobach

**JPL/Caltech:** Hong Zhang, Hector Torres, Ian Fenty, Anup Nambiathody, and Angelica Rodriguez

**MIT:** Oliver Jahn, Jean-Michel Campin, Chris Hill, Gaël Forget, and (formerly at MIT) Nadya Vinogradova Shiffer

**MLML/SJSU:** Dimitris Menemenlis and Dustin Carroll

**UTAustin:** Patrick Heimbach and An Nguyen

**University of Toronto:** Kayhan Momeni and Dick Peltier

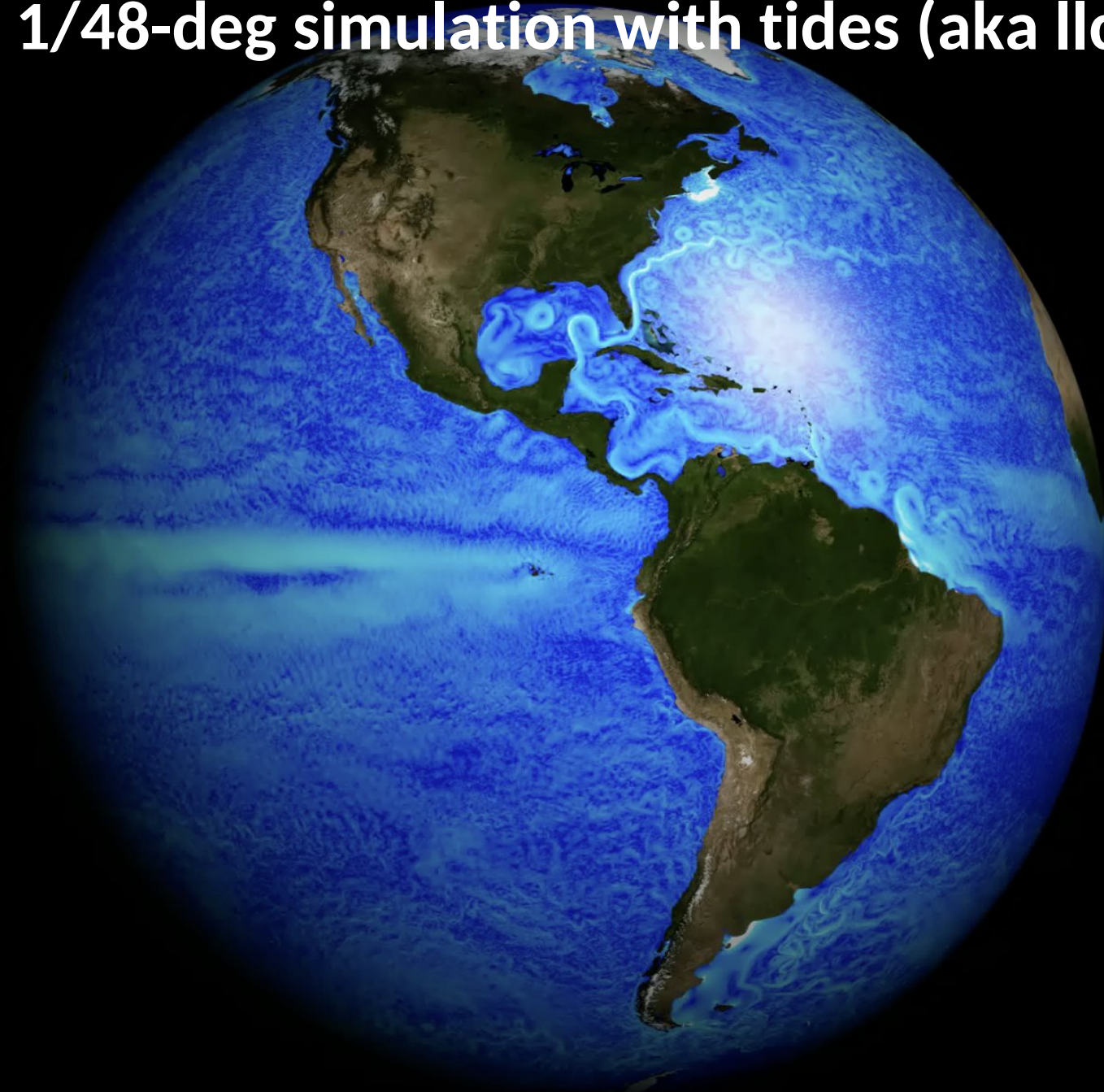
**University of Michigan:** Hugo Plombat and Brian Arbic

**WHOI:** Joe Skitka and Kurt Polzin

**UCLA:** Kate Q. Zhang

\*Dan says: “I would emphasize that this opportunity and growing resource for the community was really initiated AND facilitated by the NAS at Ames (not by me). I keep the thing moving on the new machine. But I have a continuous teams chat with ~15 engineers/managers across a wide range of NAS areas of expertise, and they quietly (and sometimes less quietly) make this possible in so many ways at all hours of the days, nights, and weekends.”

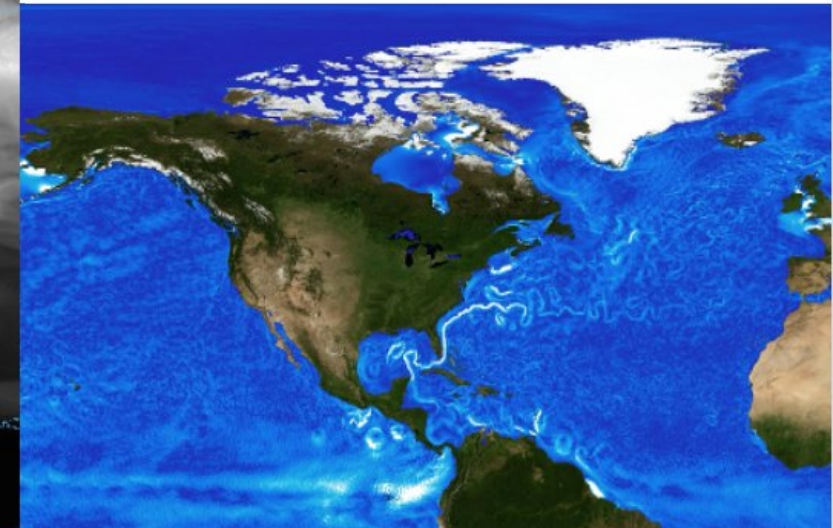
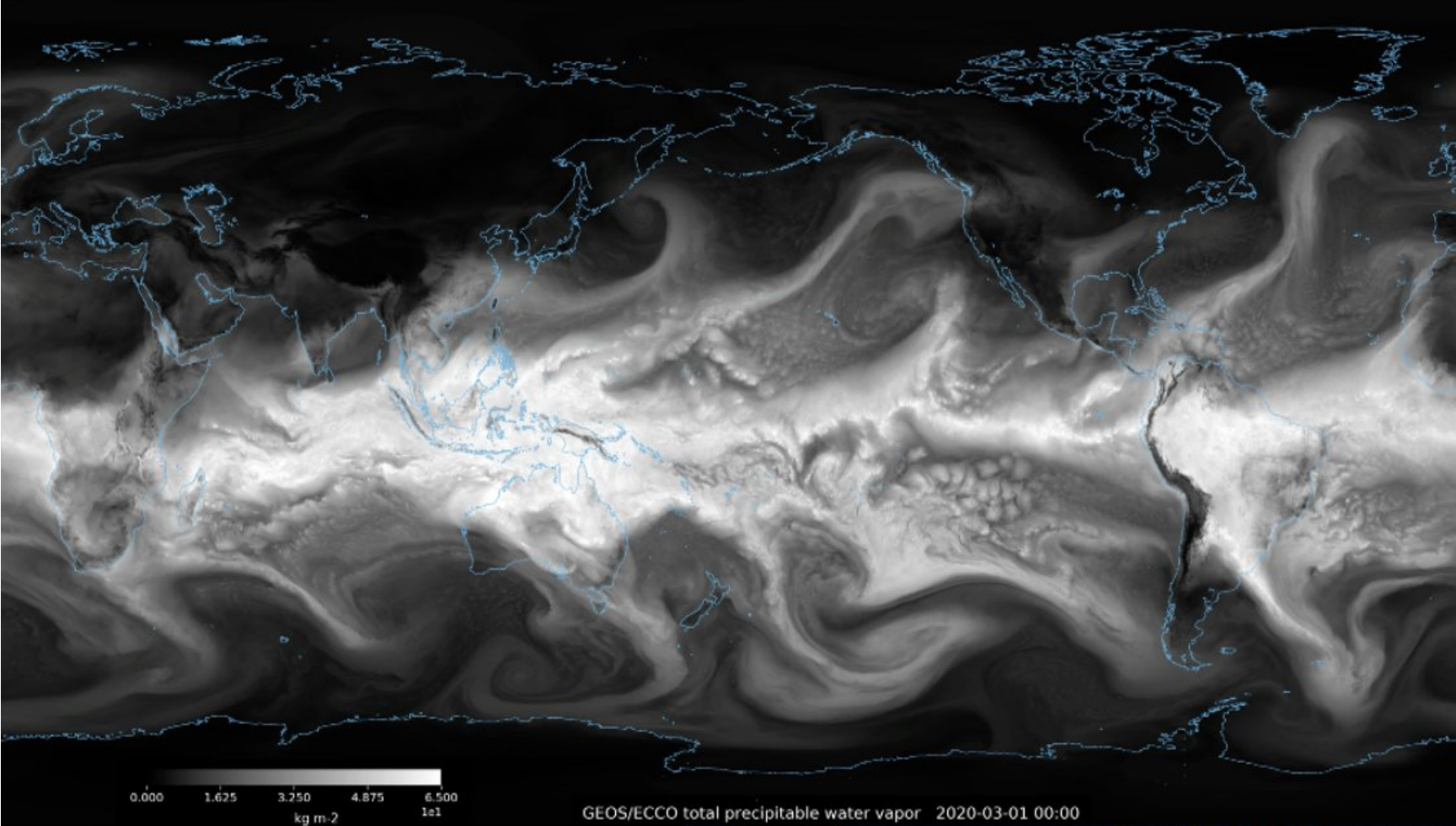
# Global 1/48-deg simulation with tides (aka Ilc4320)



Model output available at <https://www.poseidon-ocean.net/products/datasets/ilc4320-dataset/>

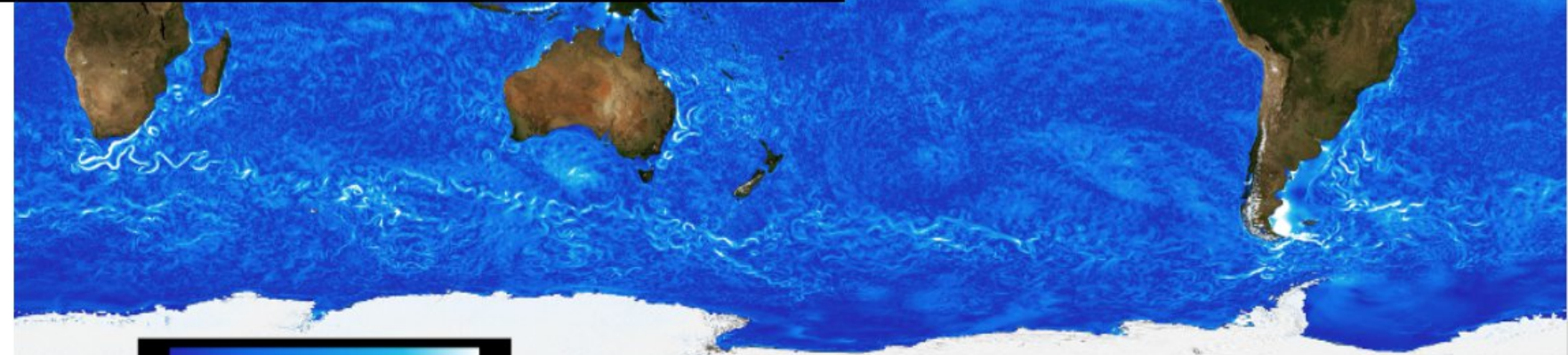
# 1/16° GEOS water vapor

[https://data.nas.nasa.gov/geoseccoviz/c1440\\_llc2160/MITgcm/](https://data.nas.nasa.gov/geoseccoviz/c1440_llc2160/MITgcm/)



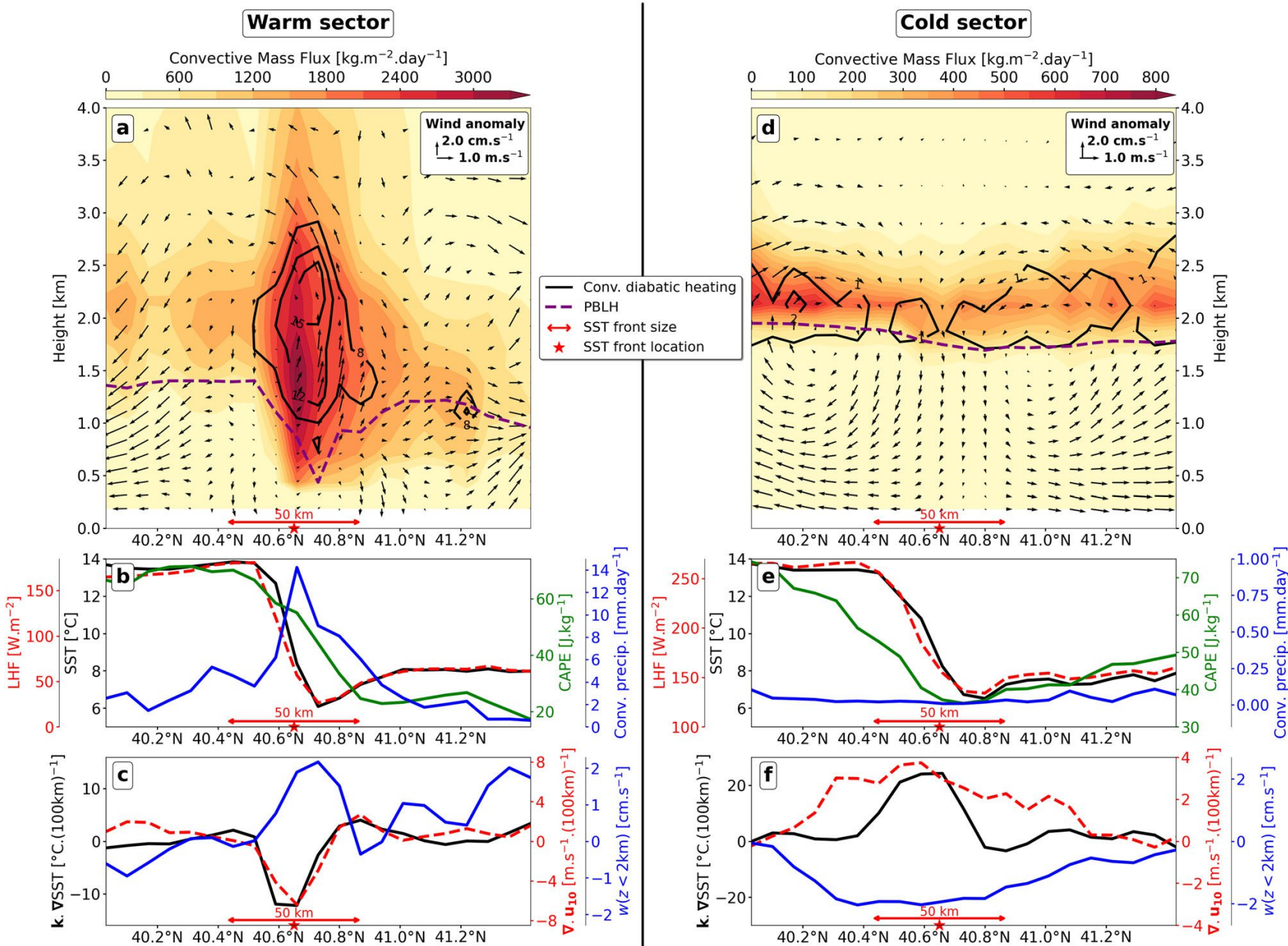
[https://data.nas.nasa.gov/geoseccoviz/c1440\\_llc2160/GEOS/](https://data.nas.nasa.gov/geoseccoviz/c1440_llc2160/GEOS/)

# 1/24° ECCO surface speed



Model output available on NAS HEC as well as on NAS and Johns Hopkins data servers.

# Ocean submesoscale fronts induce diabatic heating and convective precipitation within storms



Example of submesoscale-induced convection in the GEOS/ECCO simulation at 153°E in Kuroshio region.

The fields are averaged over five days (Dec. 16 to Dec. 21) for a–c southerly winds and d–f northerly winds

(Vivant et al., 2025)

# Some issues with the classic LLC4320 simulation

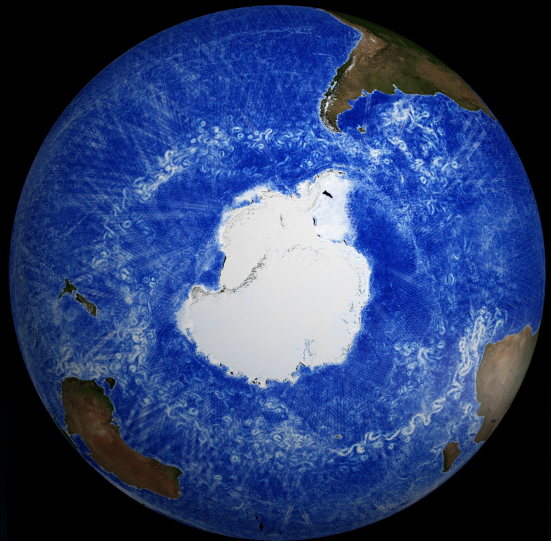
LLC4320 (classic) has been used for over 240 published studies but:

- Disk crash has led to loss of 50% of model output at NAS\*
- Limited resolution of submesoscale processes
- Gulf Stream in wrong location (slides 8–10)
- Problematic equatorial dynamics (Kate will discuss tomorrow)
- Too strong tidal forcing due to wrong SAL correction (slide 12–14)
- Problematic bathymetry, especially around Antarctica (slide 15–17)
- 6-hourly atmospheric forcing leads to weak near-inertial currents
- Linear free surface, which restricts accuracy of coastal circulation

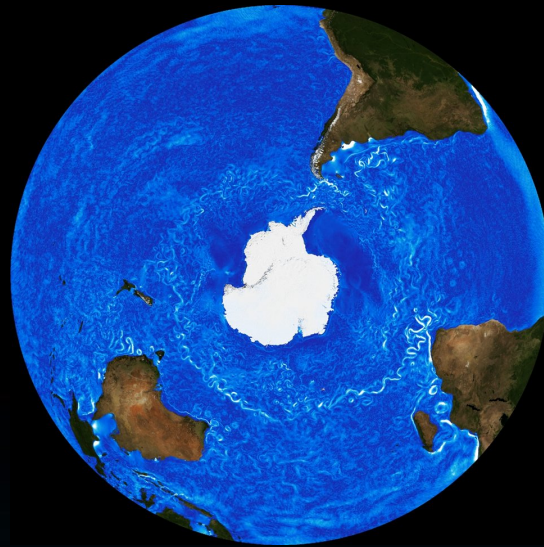
\* But full simulation available on SciServer: <https://www.poseidon-ocean.net/products/datasets/llc4320-dataset/>  
and visualizations available at: <https://data.nas.nasa.gov/eccoviz/llc4320/>

# Ultra-high resolution ECCO simulations on Athena

Building on legacy helping scientists turn NASA observations into discoveries and predictions



**SWOT**  
sea level gradient



**ECCO**  
surface speed

## Near-term objectives:

- Deploy, benchmark, & optimize configuration of high-res ECCO on Athena with latest developments
- Run one simulated year at 1/48° resolution
- Deliver science-quality data to NASA-funded scientists, visualization experts, and mission teams

## Perceived benefits:

- Data can be used in conjunction with recent Surface Water and Ocean Topography (SWOT) mission data
- Turnkey configuration reduces barrier to new ultra-high-resolution coupled ocean-biogeochemistry and ocean-atmosphere simulations
- Drive advances in data visualization
- Inform future space missions to observe the ocean



**Code T Viz Group**  
**POC: Nina McCurdy**

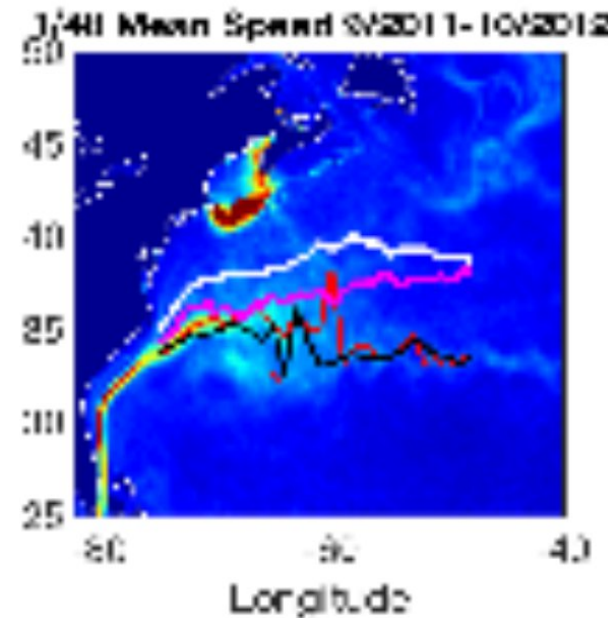
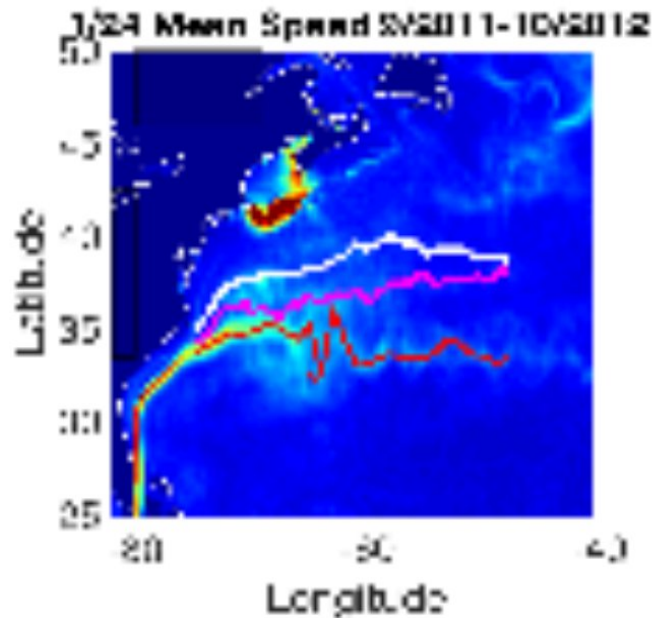
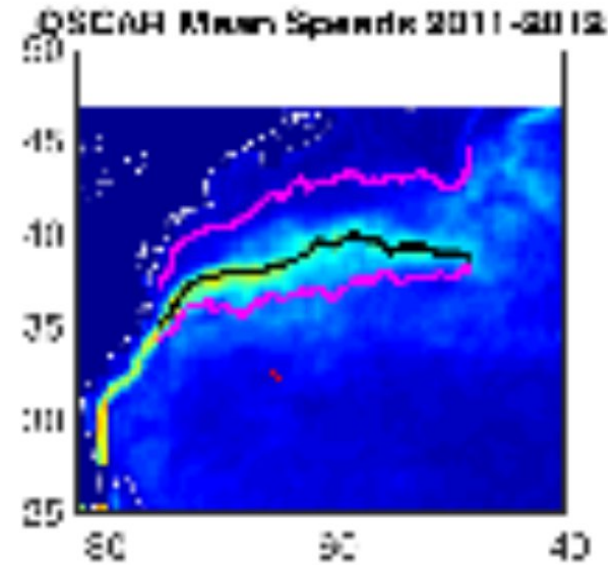
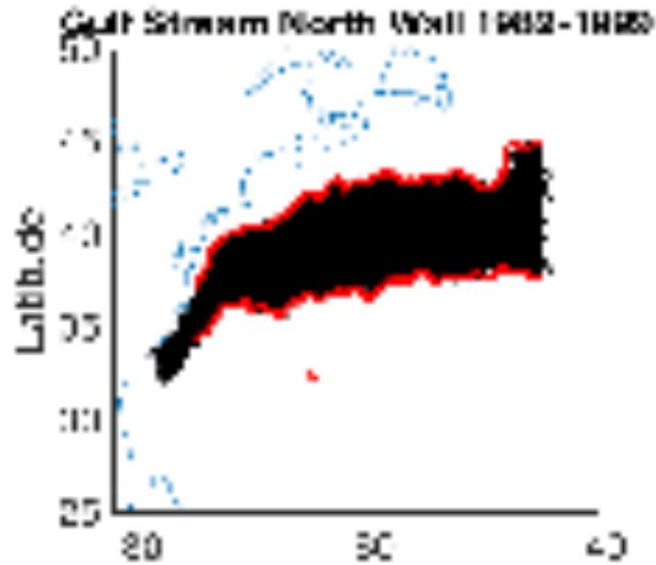
**Science POC: Dan Whitt (Code S)**

# **Announcing: ECCO Ilc4320v2 a global-ocean-ice-river-tides simulation**

A follow-on to the Ilc4320 (1/48°) simulation that includes:

- newer bathymetry (GEBCO 2025)
- non-linear free surface and zStar vertical coordinates
- ice shelf cavities based on Bedmachine around Greenland and Antarctica
- 173 vertical levels based on global mean WOA23  $N^2$
- carried out during the NASA SWOT period, i.e., starting in January 2023
- initial conditions from GLORYS12 followed by Ilc1080 spin-up
- hourly atmospheric forcing from ERA5 with Large/Yeager 2009 bulk formulae
- daily river discharge from JRA55-do followed by GloFAS, including river temperature
- tidal forcing from JPL's SPICE library with accurate, online SAL corrections

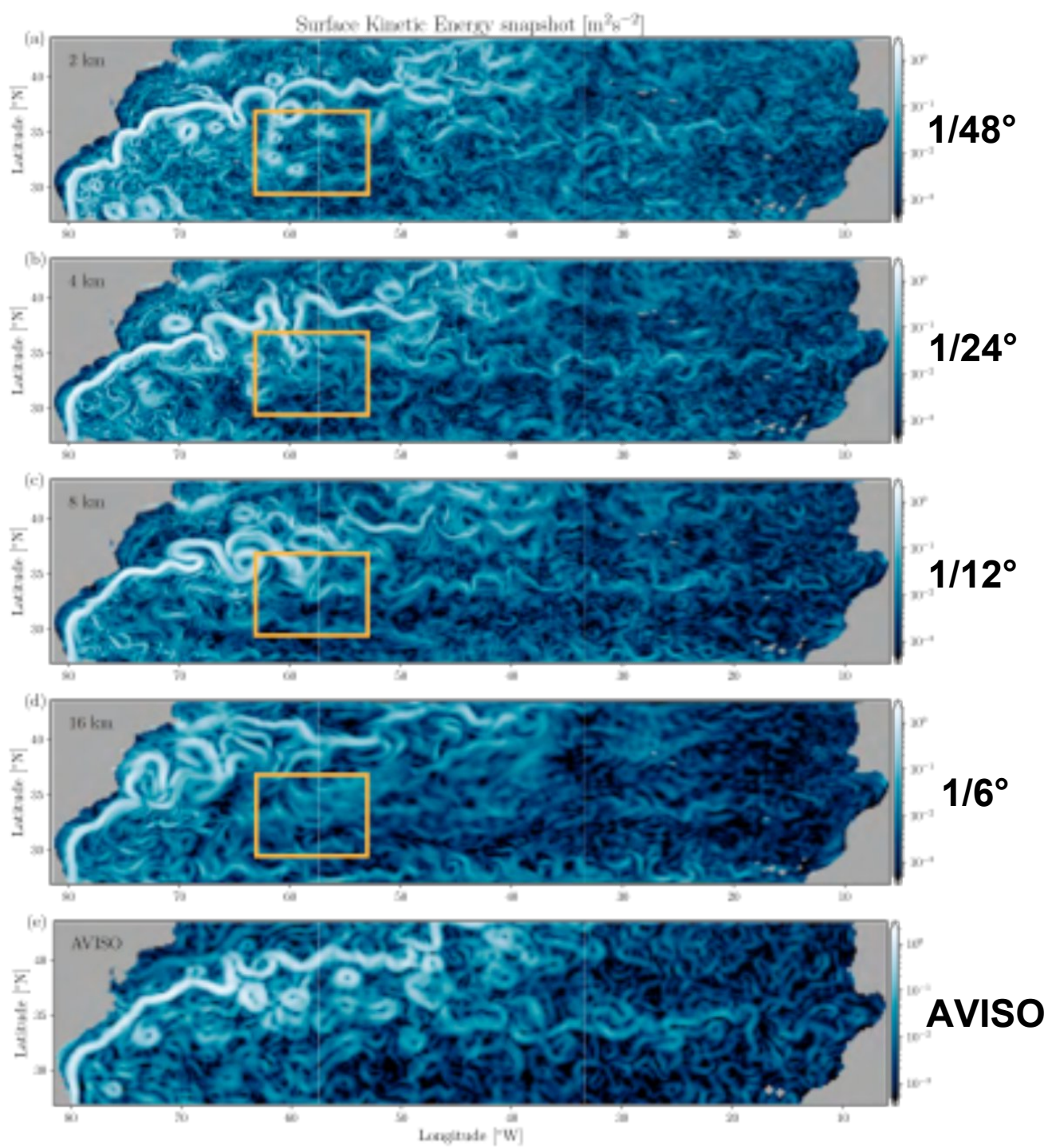
# Critic #1: Peter Cornillon on Gulf Stream location



***The Gulf Stream:  
Yikes What's It  
Doing Down  
There?***

***Peter Cornillon***

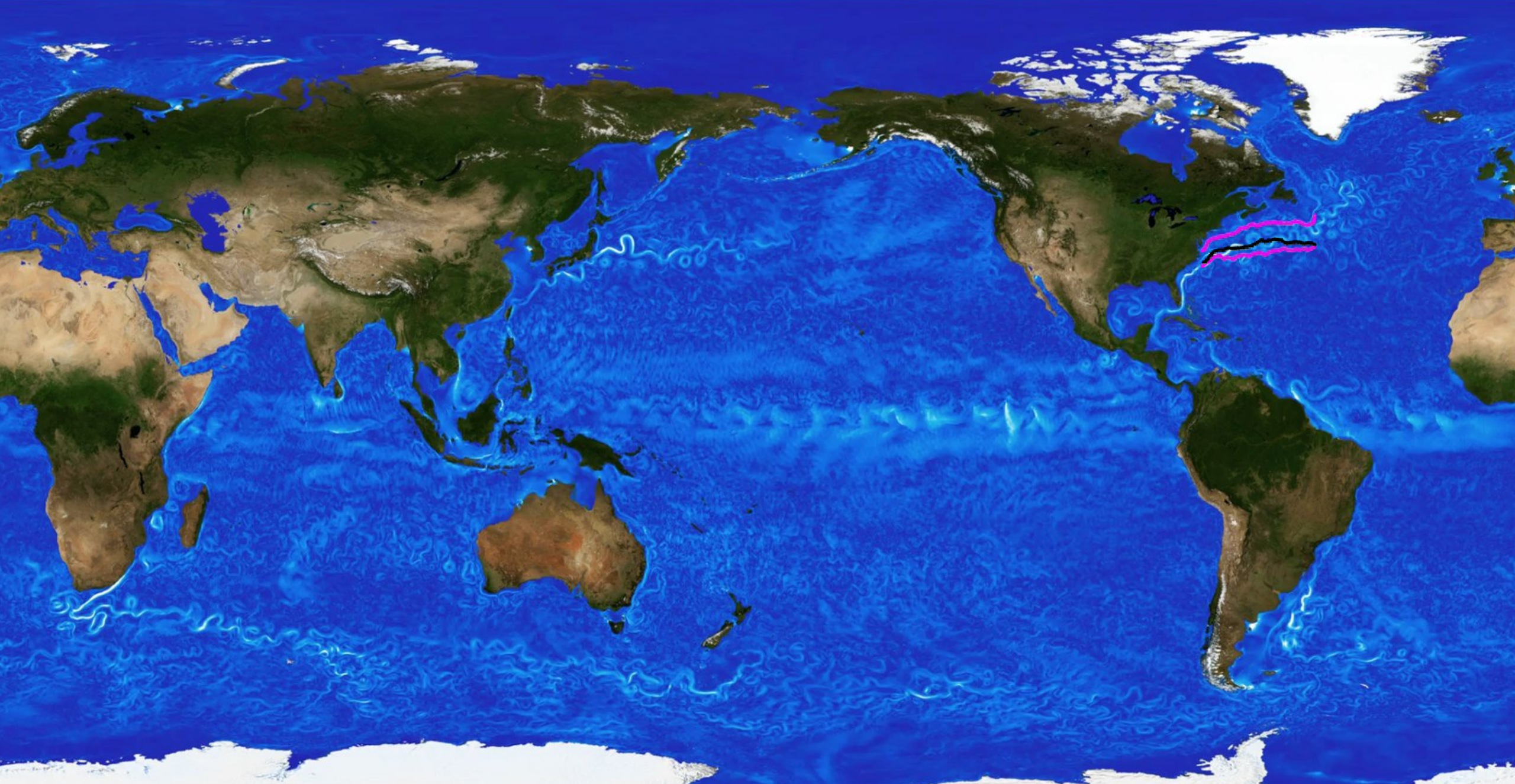
*Annual ECCO meeting  
Austin, TX  
October 2018*



The Gulf Stream location is fixed in Anirban Sinha's Atlantic simulation. Is it due to:

- Prandtl number,
- Florida Current transport,
- updated bathymetry,
- something else?

(from Sinha, Callies, and Menemenlis, 2023)



llc4320 sea-surface speed 2023-01-01 00:00

Animations by Nina McCurdy and David Ellsworth

## Critic #2: Kate Zhang on equatorial dynamics

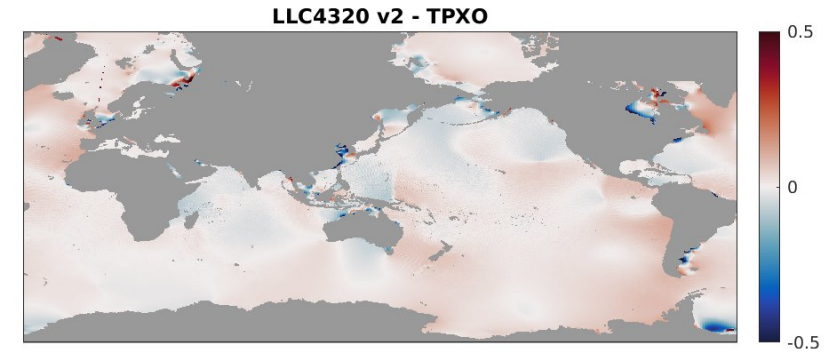
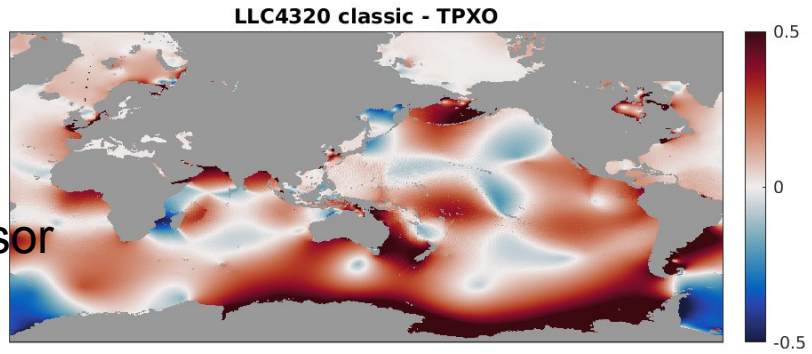
Kate will discuss tomorrow:

<b>2:30–2:50</b>	Kate Q. Zhang	JIFRESSE / UCLA	Sensitivity of the Equatorial Undercurrent to background mixing
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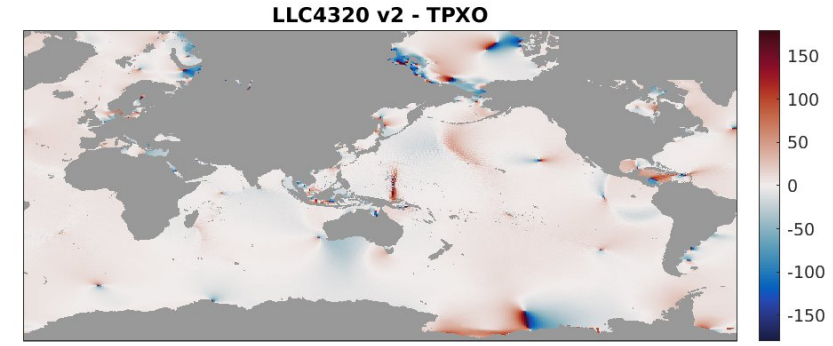
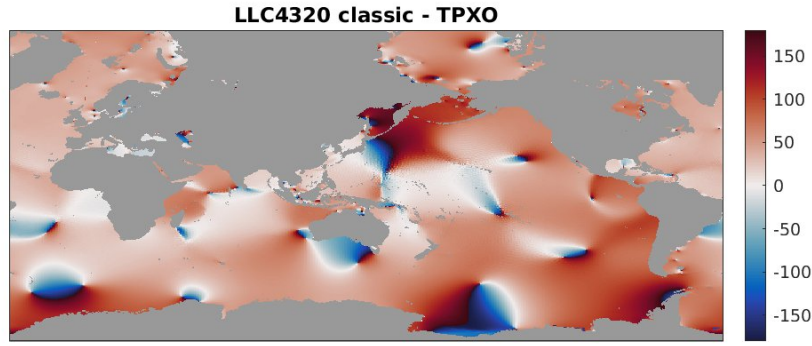
# Critic #3: Brian Arbic on tides

M2 diff wrt TPXO

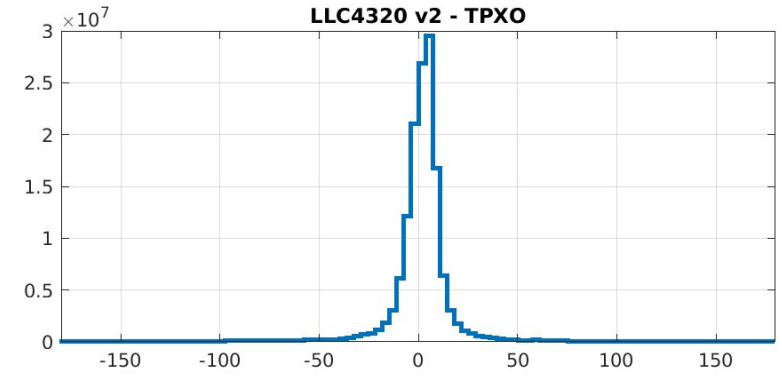
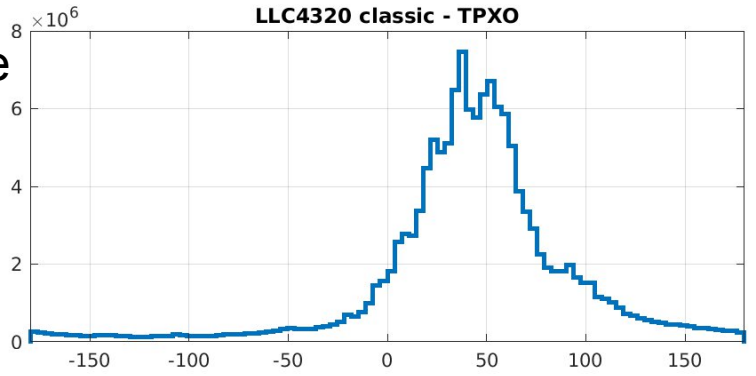
Amplitude  
RMSE of amp/phases  
16.88 / 31.02 cm  
5.31 / 7.12 cm

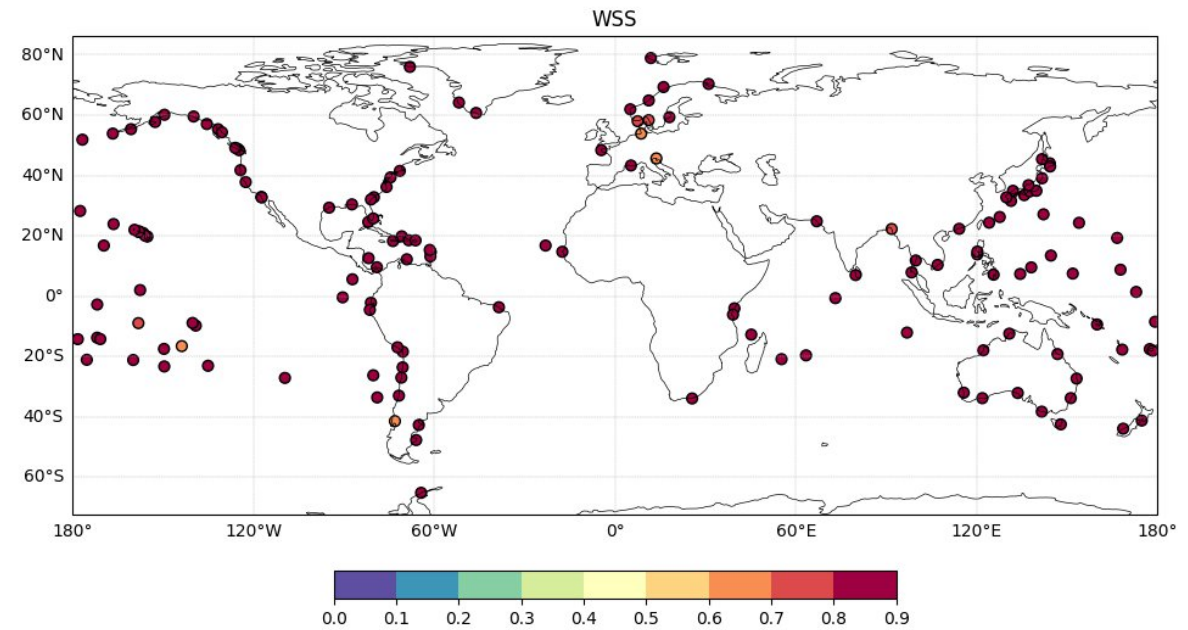
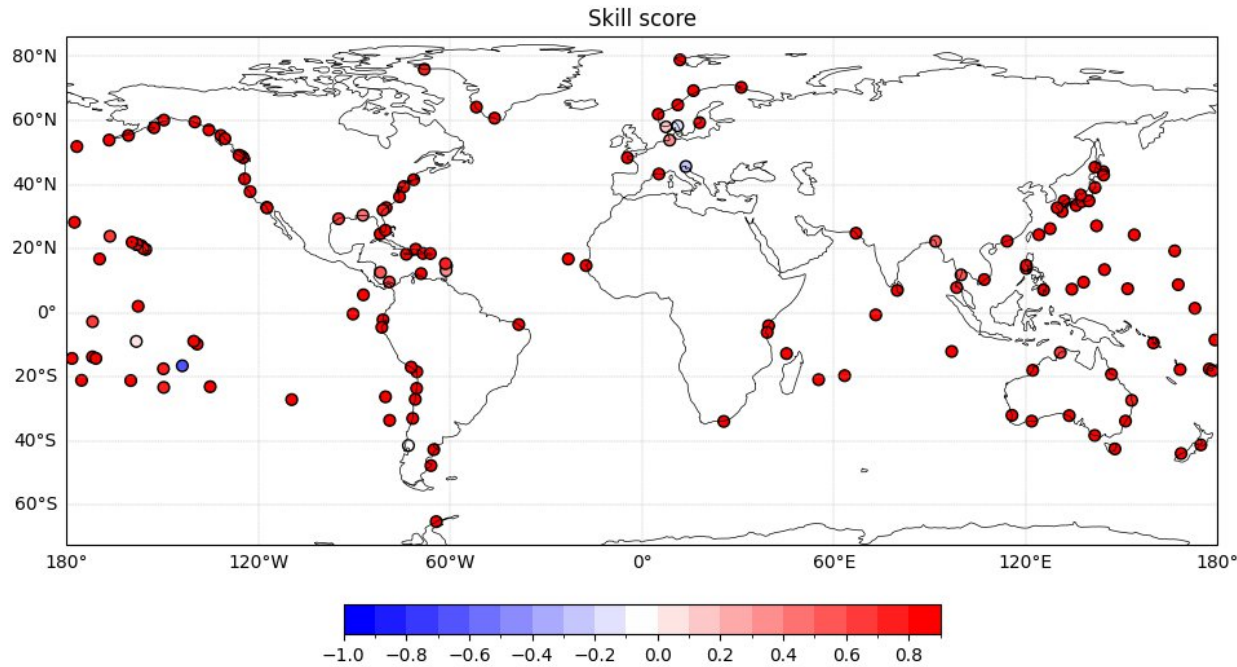
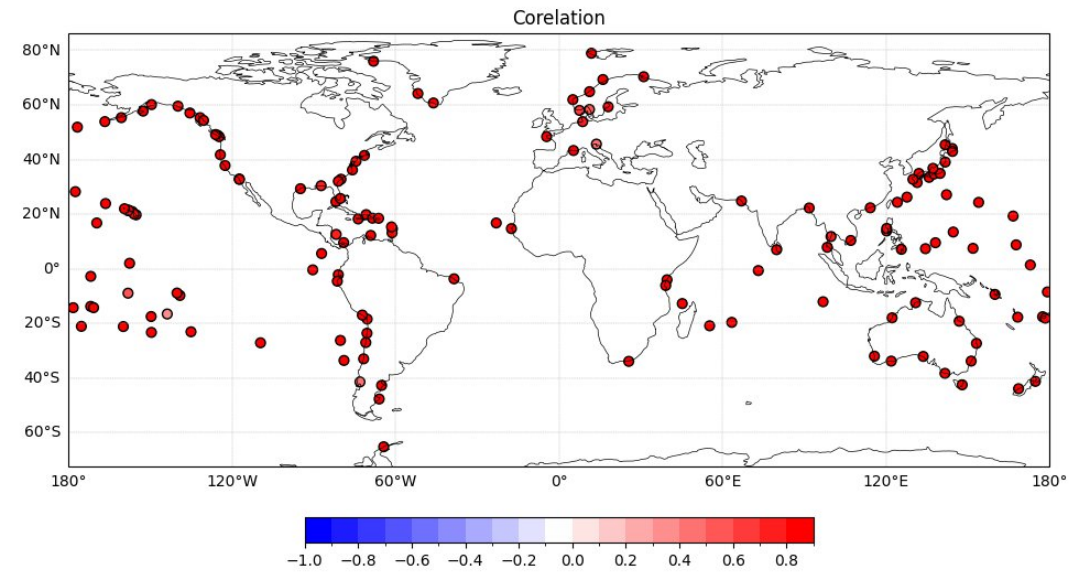
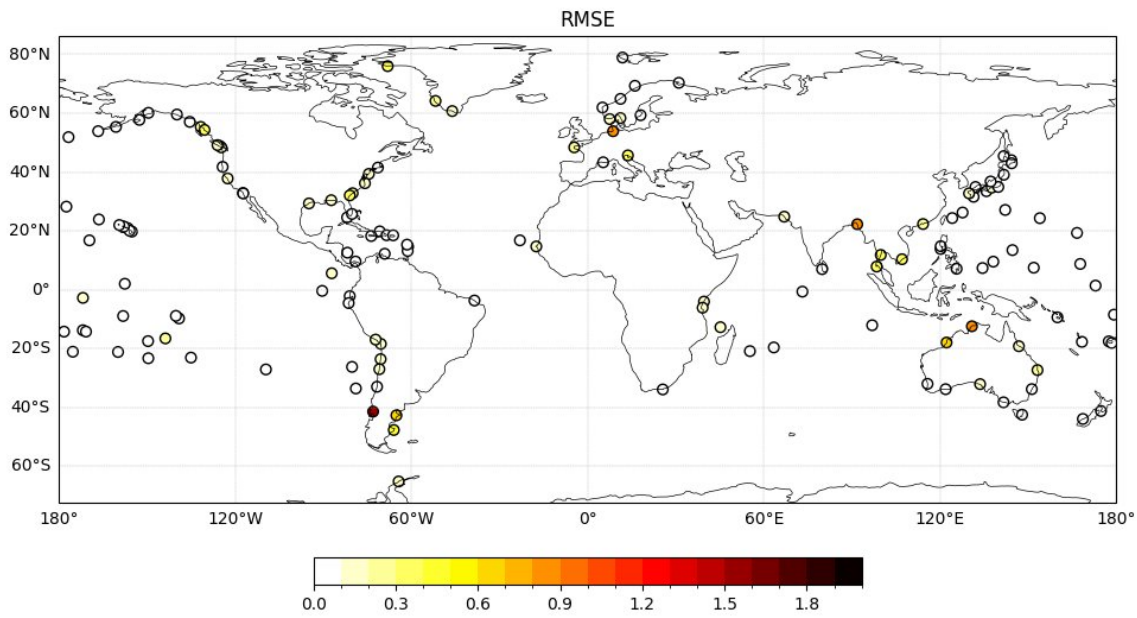


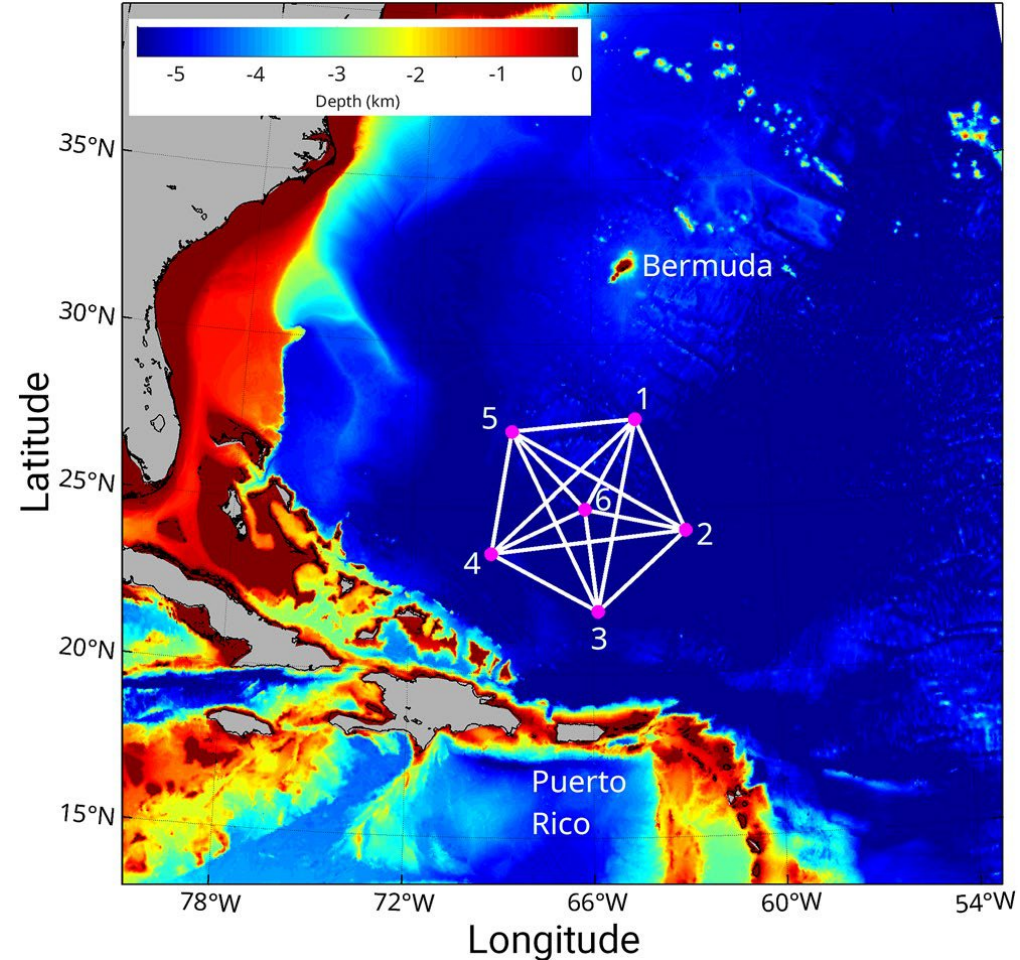
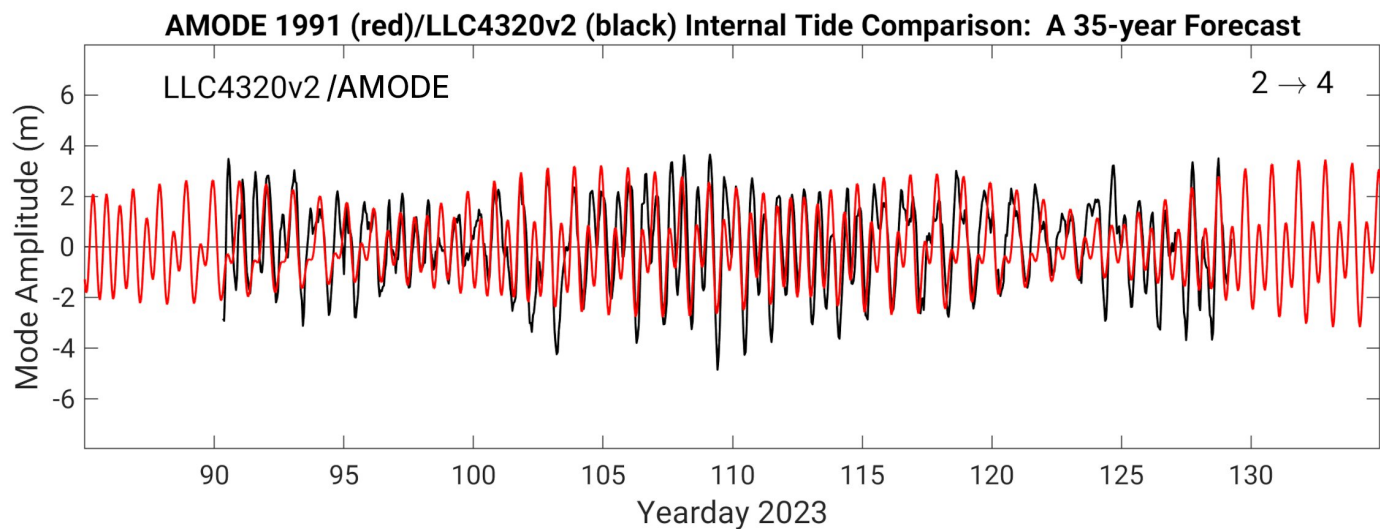
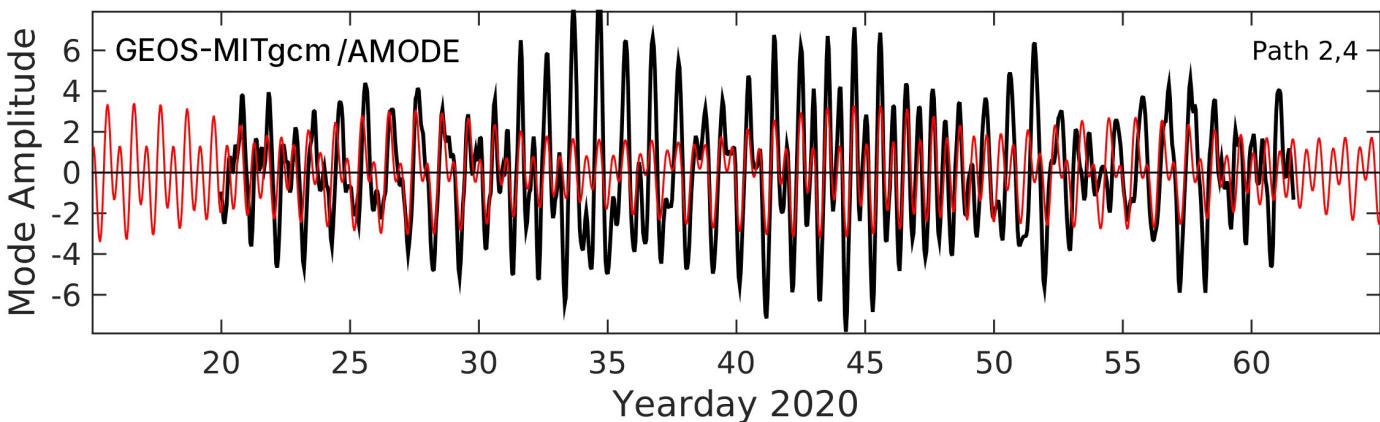
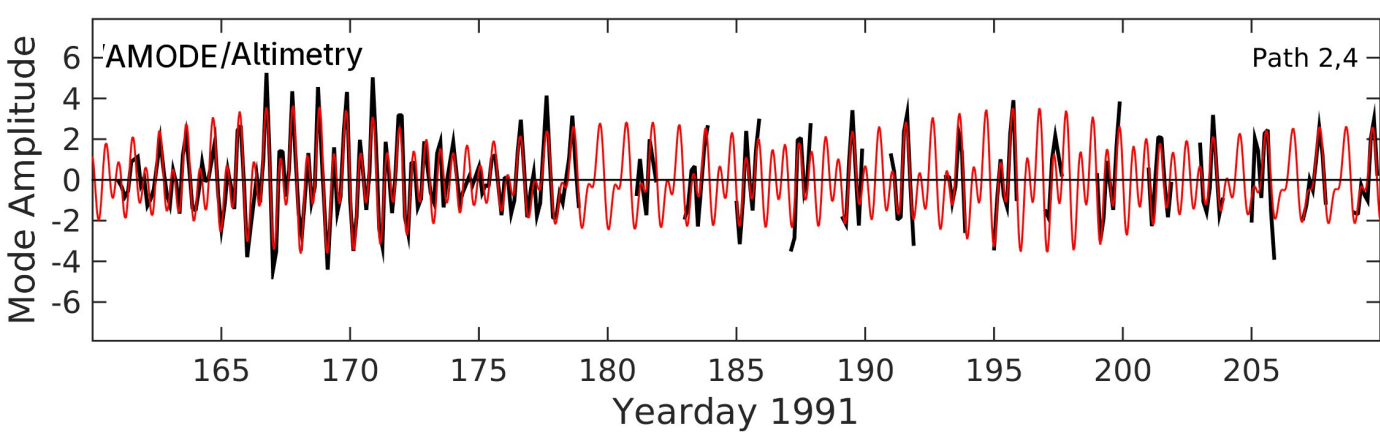
Phase  
RMSE of phase  
57.4deg  
15.2deg



Phase  
mean/std of phase  
36.4/48.6deg  
1.8/16.6deg

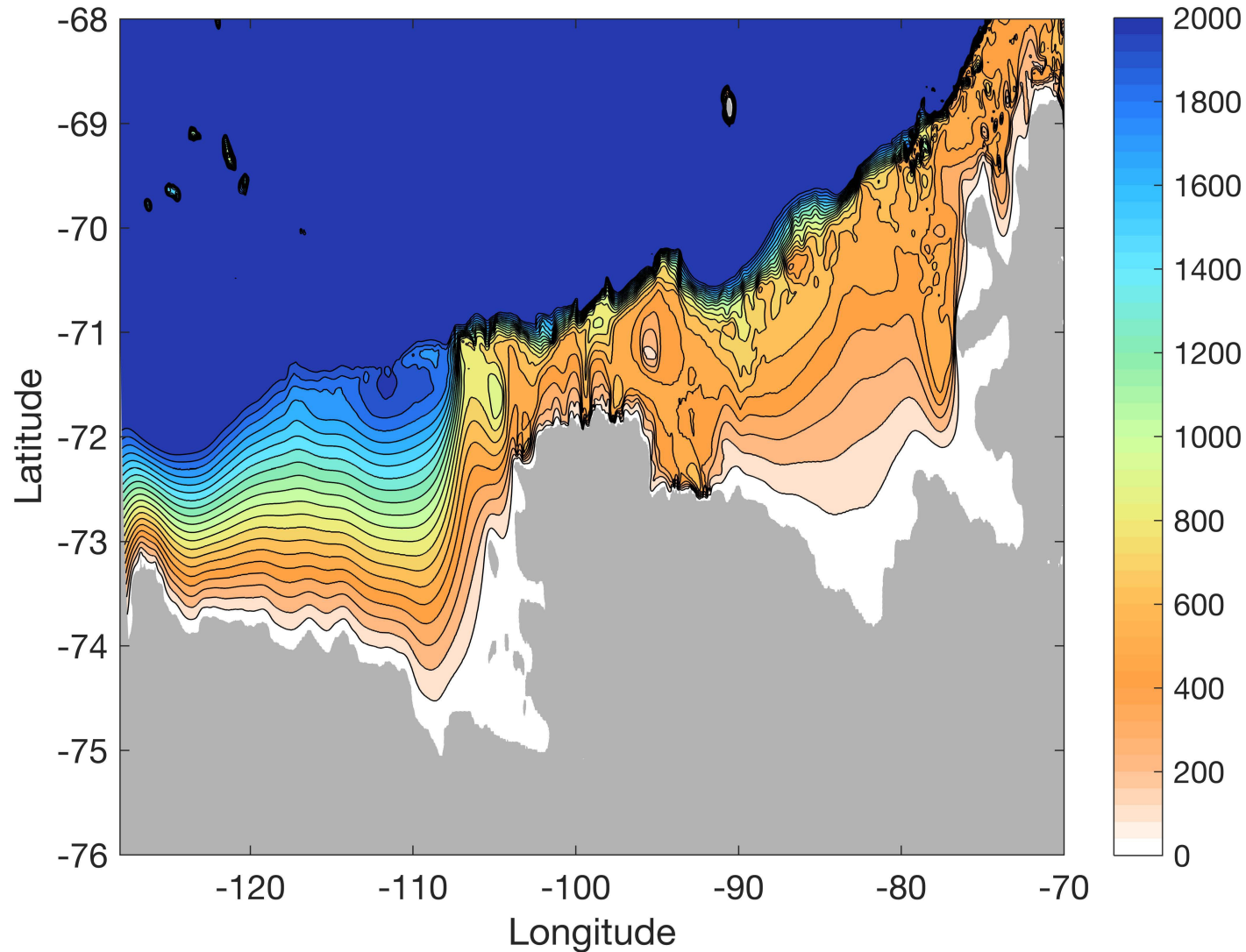






AMODE data have been made available here:  
<https://doi.org/10.5281/zenodo.6662719>  
<https://doi.org/10.5281/zenodo.6659034>

## Critic #4: Andrew Stewart on bathymetry

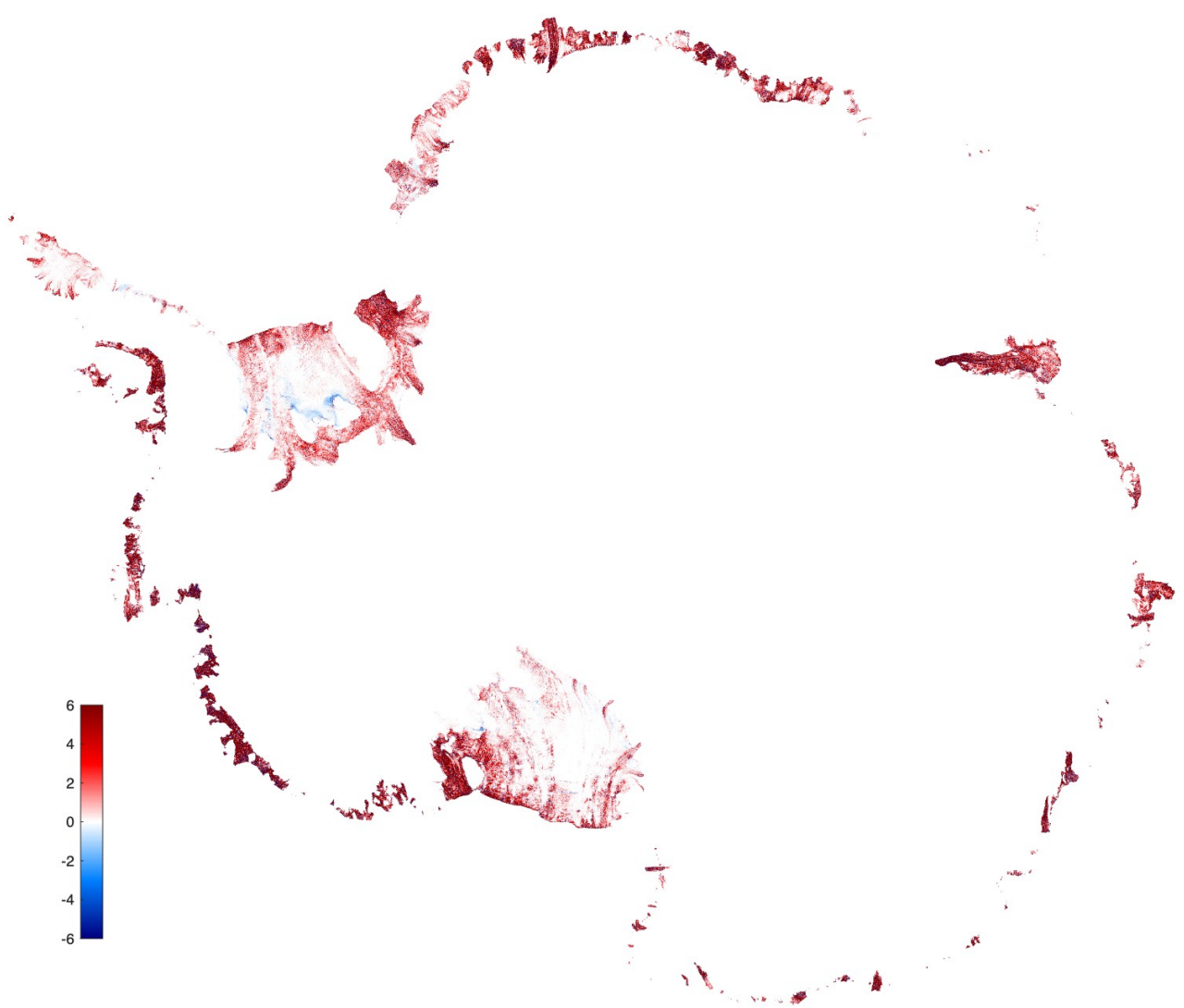
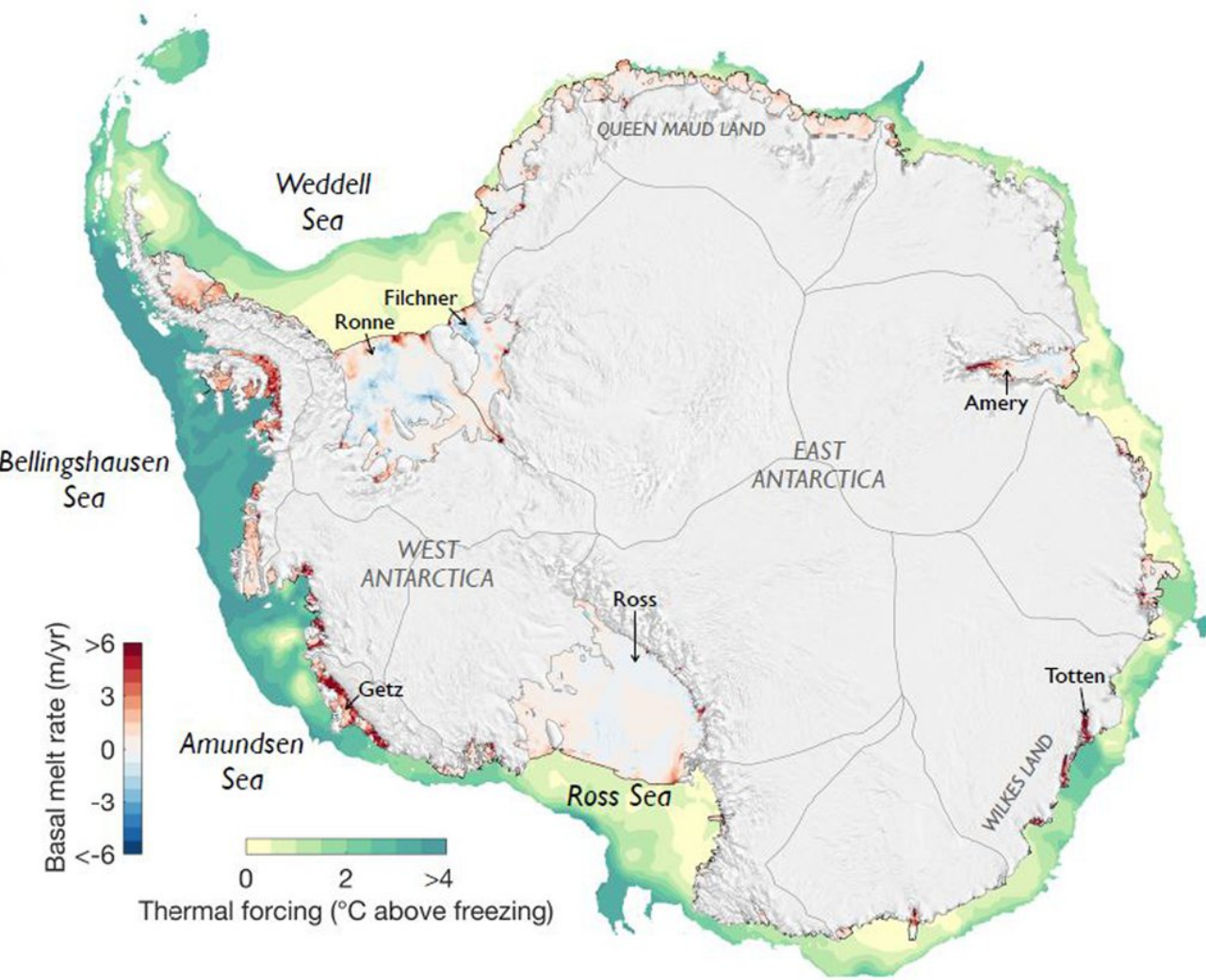


*Model bathymetry in the Amundsen and Bellinshausen Seas.*

*The model bathymetry is derived from Smith and Sandwell [1997]. This product omits recent high-resolution measurements and linearly interpolates between depth measurements over the continental slope and an assumed depth of zero at the coastline, leading to a representation of the continental shelf that differs qualitatively from reality. We therefore omit discussion of shoreward heat transport in the Amundsen and Bellinshausen Seas sectors in the main text.*

*The model bathymetry also omits the cavities under Antarctica's floating ice shelves, so we cannot directly determine the relative roles of eddies and tides in transporting heat to the base of the ice.*

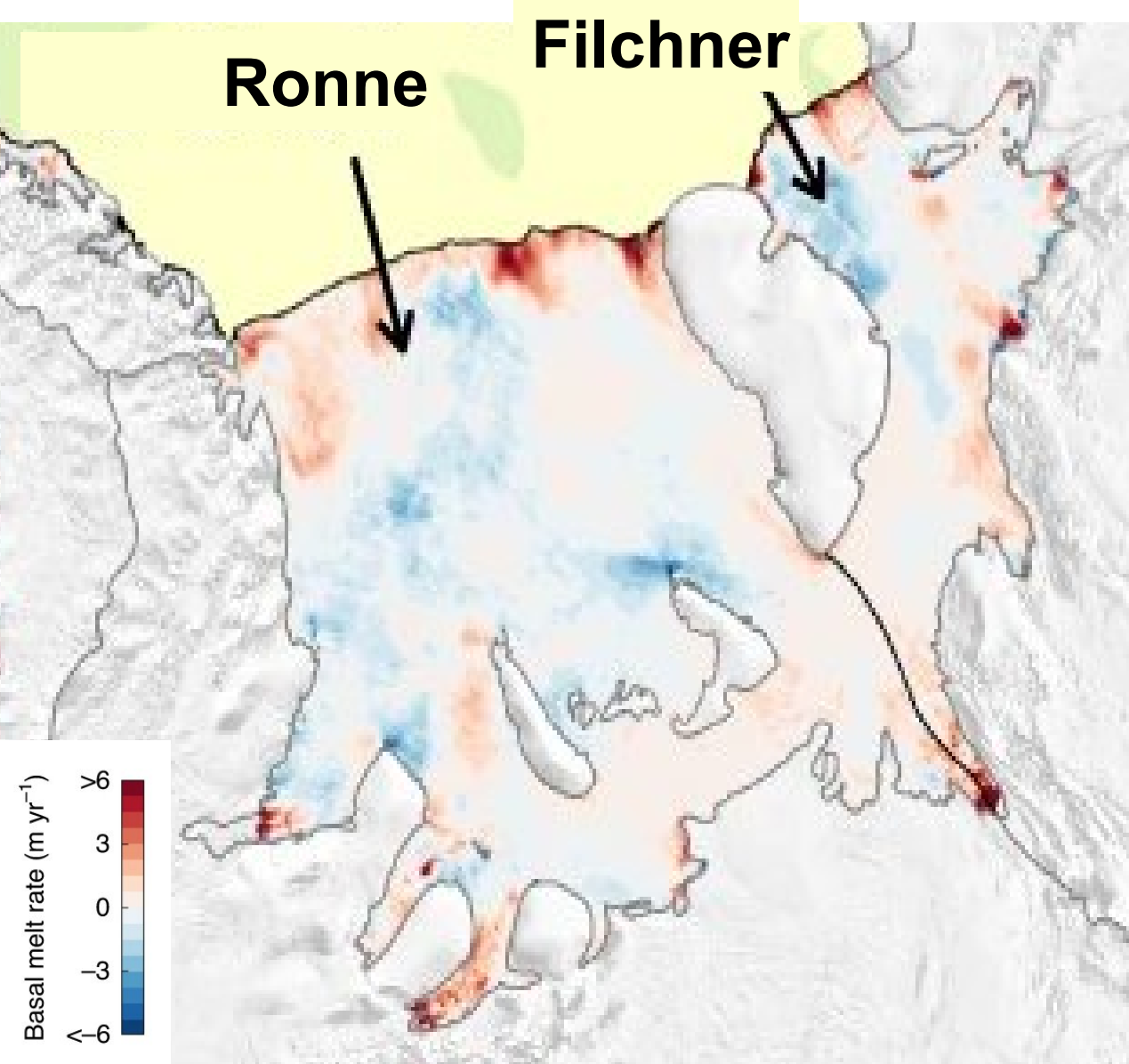
From Stewart et al., GRL 2018.



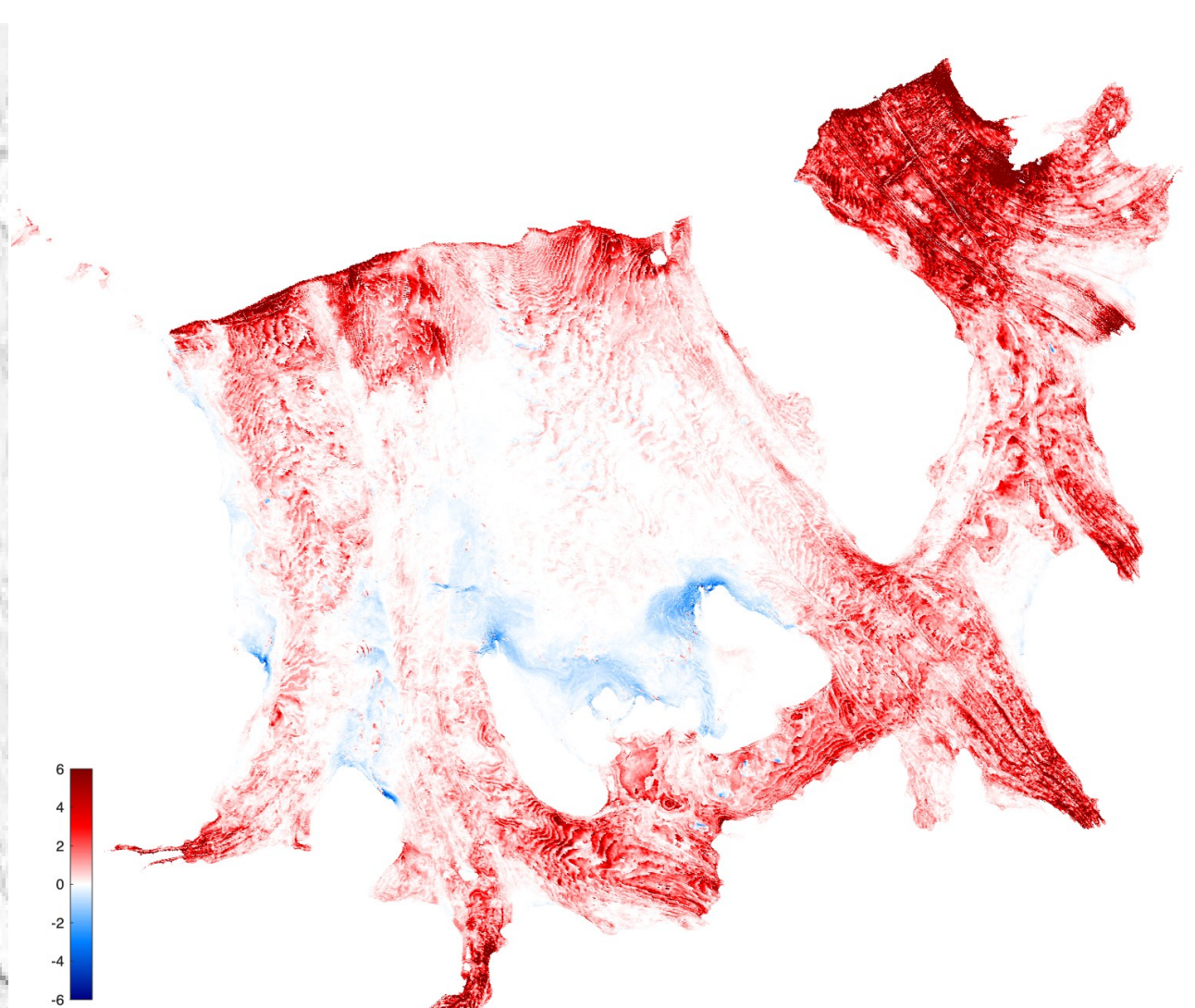
**Adusumilli et al., *Nat Geosci.*, 2020.**

**April 15, 2023 basal melt rate in m/yr for llc4320v2.**

- Ice shelf cavities initialized January 1, 2023 from ECCOv4r5 + 2 years of spin-up @ llc1080.
- Ocean bathymetry from GEBCO 2025, includes SWOT data.
- Ice shelf bed data from BedMachine Antarctica, Version



**Adusumilli et al., *Nat Geosci.*, 2020.**



**April 15, 2023 basal melt rate in  $\text{m/yr}$  for Ilc4320v2**

# Status of Ilc4320v2 (1/48°) simulation on athena yesterday evening (May 27, 2026)

- Initial conditions from GLORYS12 January 1, 2022. One year spin-up on Ilc1080 (1/12°), except for ice shelf cavities that have one extra year of spin-up.
- Start Ilc4320v2 (1/48°) on January 1, 2023.
- Self Attraction and Loading (SAL) and added on March 22, 2023
- River temperature added on May 1, 2023.
- ~9.5 months (January 1 to October 14, 2023) of simulation completed

Code: [https://github.com/MITgcm-contrib/Ilc\\_hires/tree/master/athena/Ilc\\_4320](https://github.com/MITgcm-contrib/Ilc_hires/tree/master/athena/Ilc_4320)

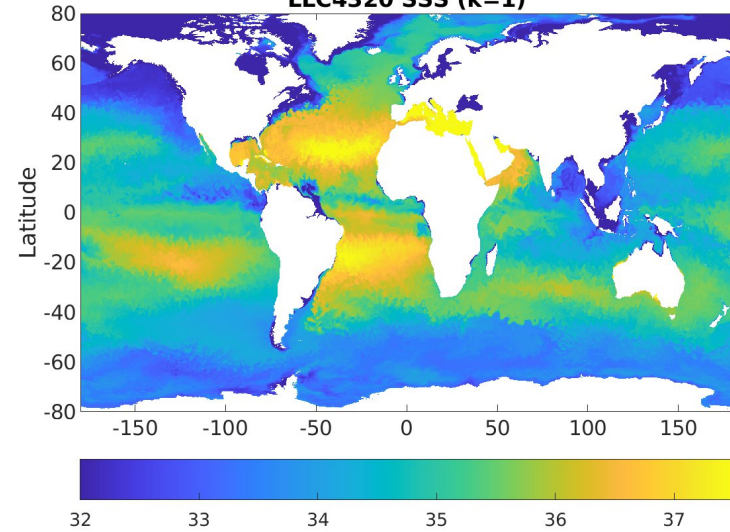
Prelim animations: <https://nasa-ext.box.com/s/owzdbdwpo710jcgup4sd0wkrcyxk6f53>

Output on NAS HEC, soon to be available on NAS and John Hopkins data servers.

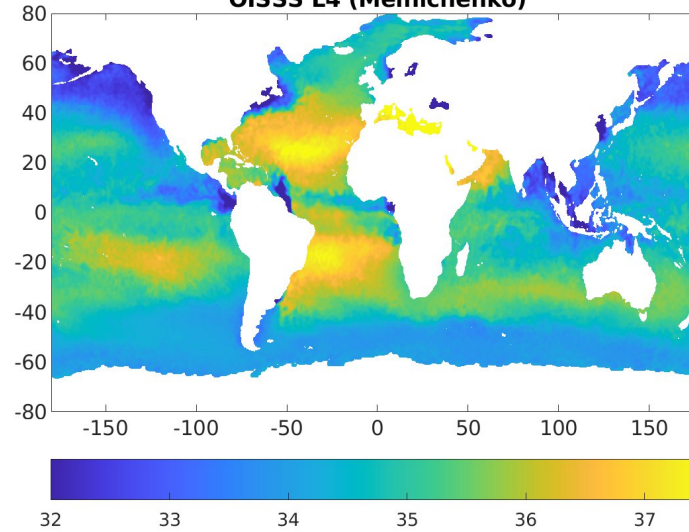
# llc4320v2 evaluation vs OISSS and OISST (Dan Whitt)

## SSS Comparison [PSU]

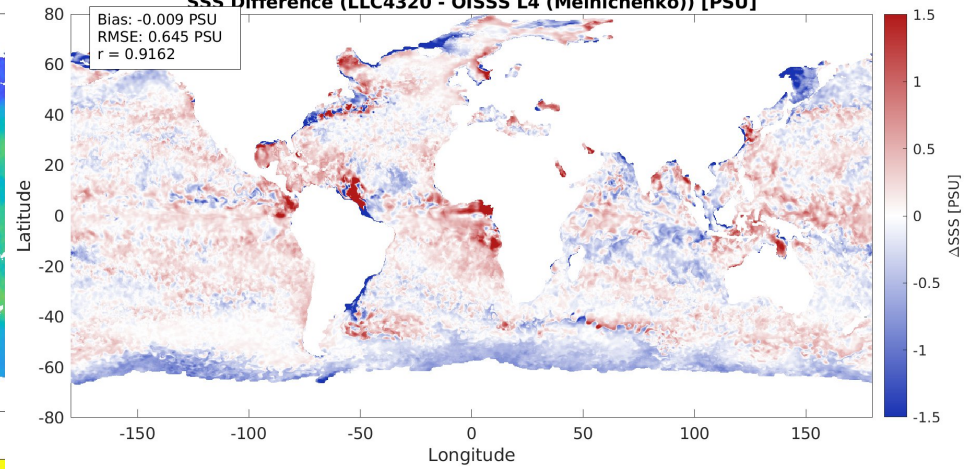
LLC4320 SSS (k=1)



OISSS L4 (Melnichenko)

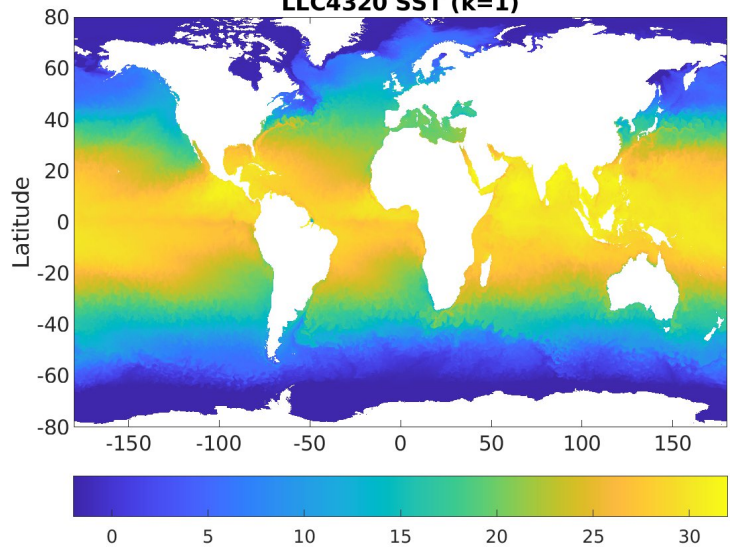


SSS Difference (LLC4320 - OISSS L4 (Melnichenko)) [PSU]

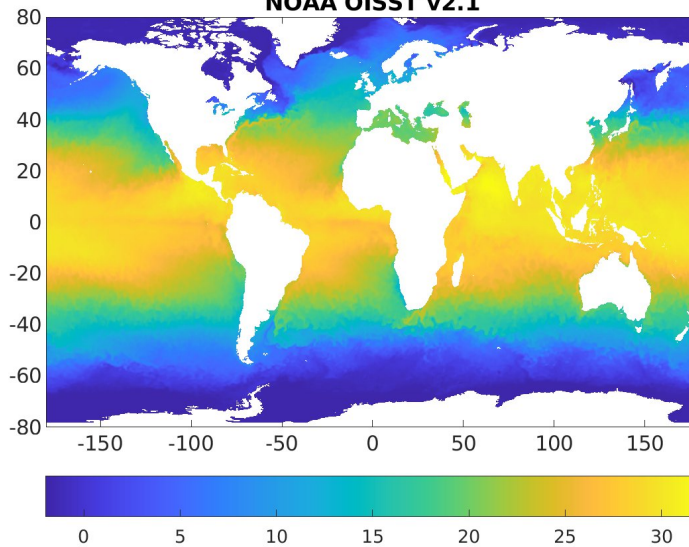


## SST Comparison [°C]

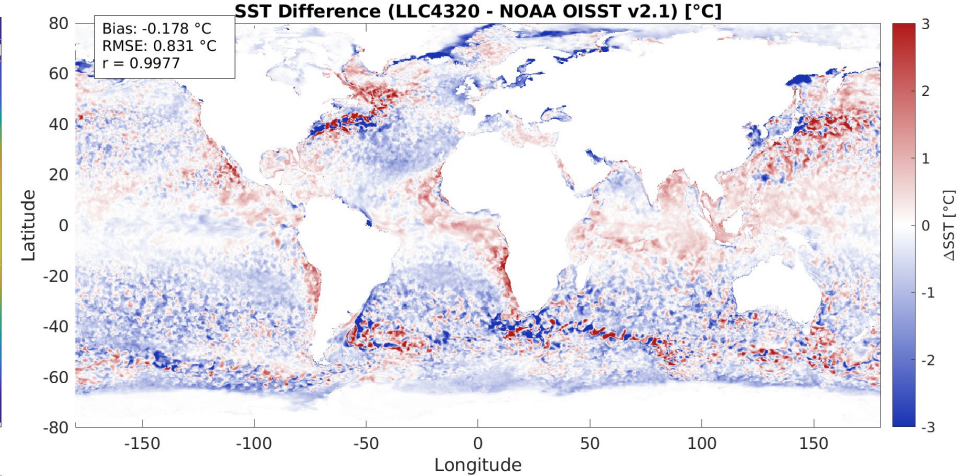
LLC4320 SST (k=1)

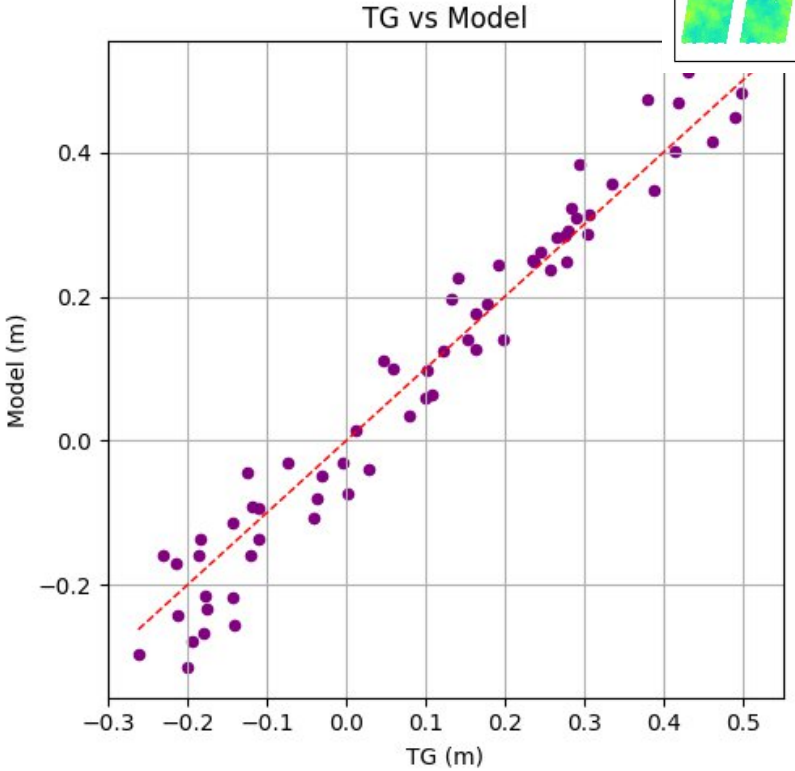
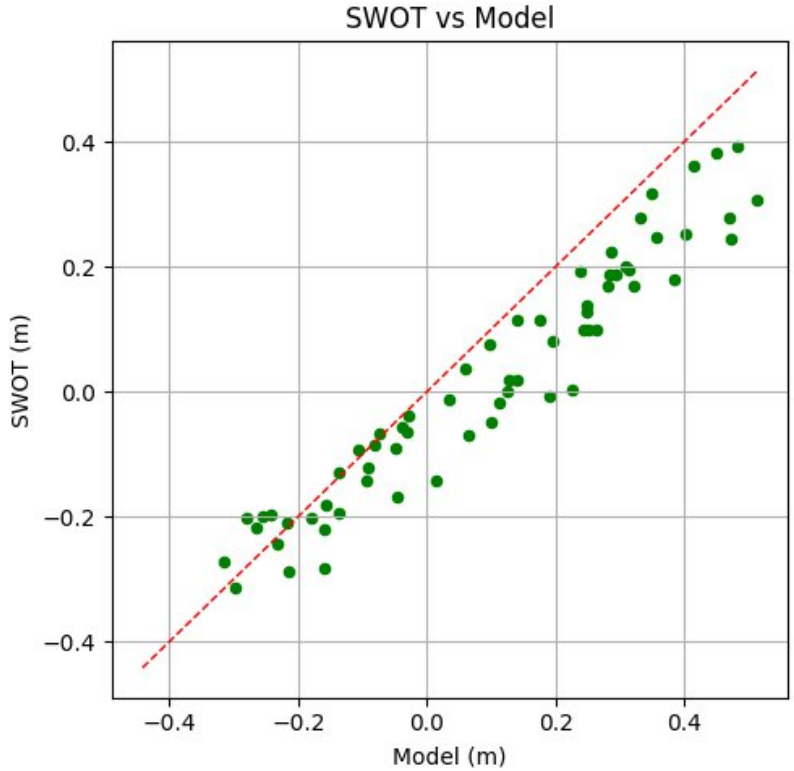
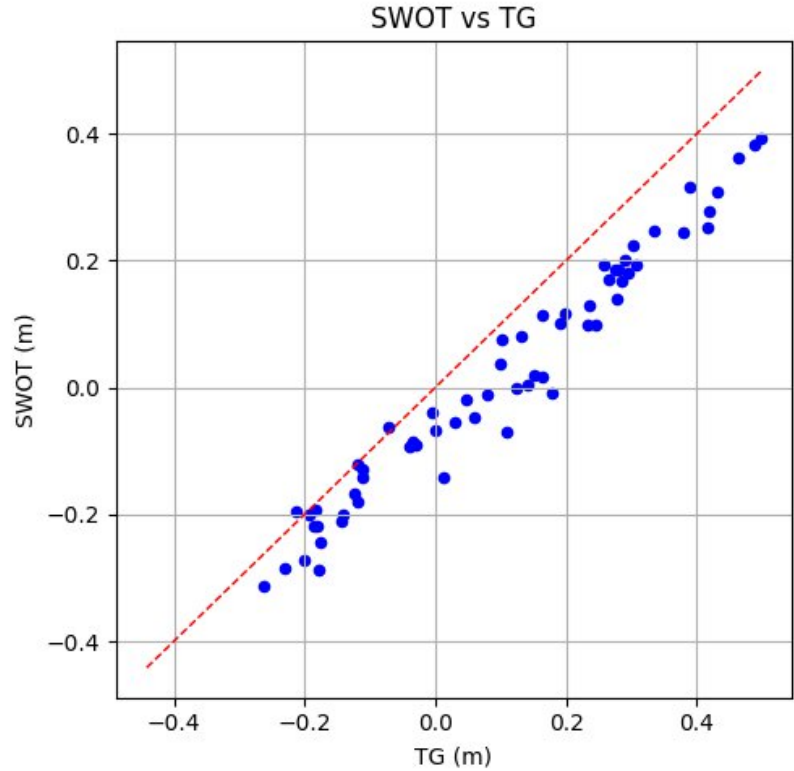
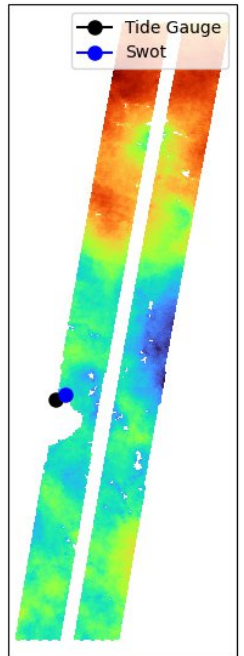
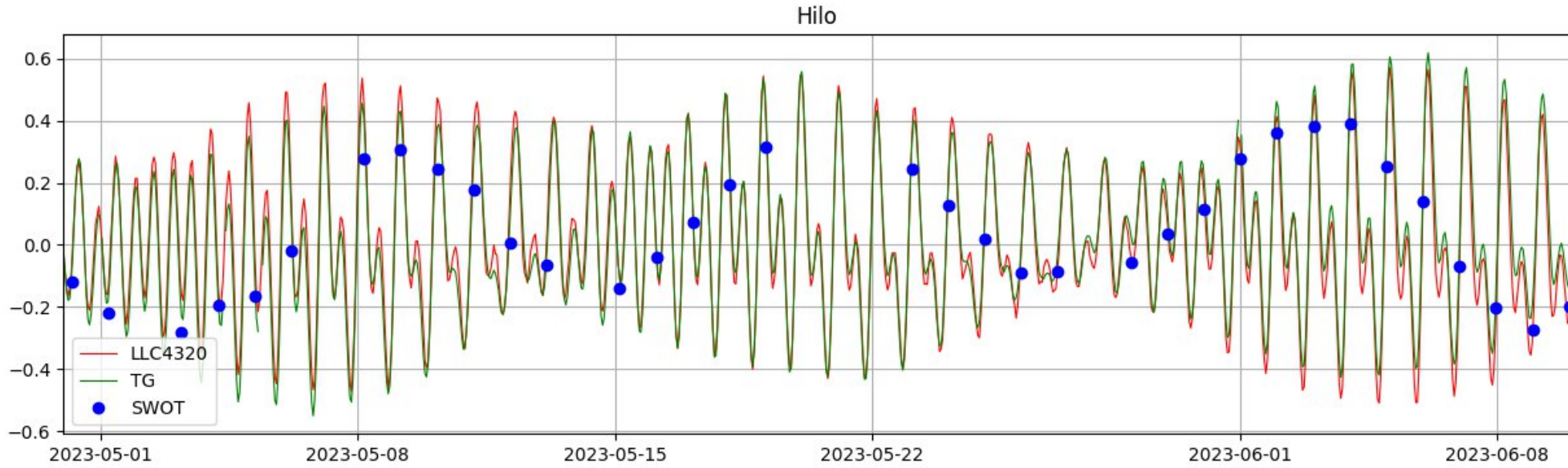


NOAA OISST v2.1



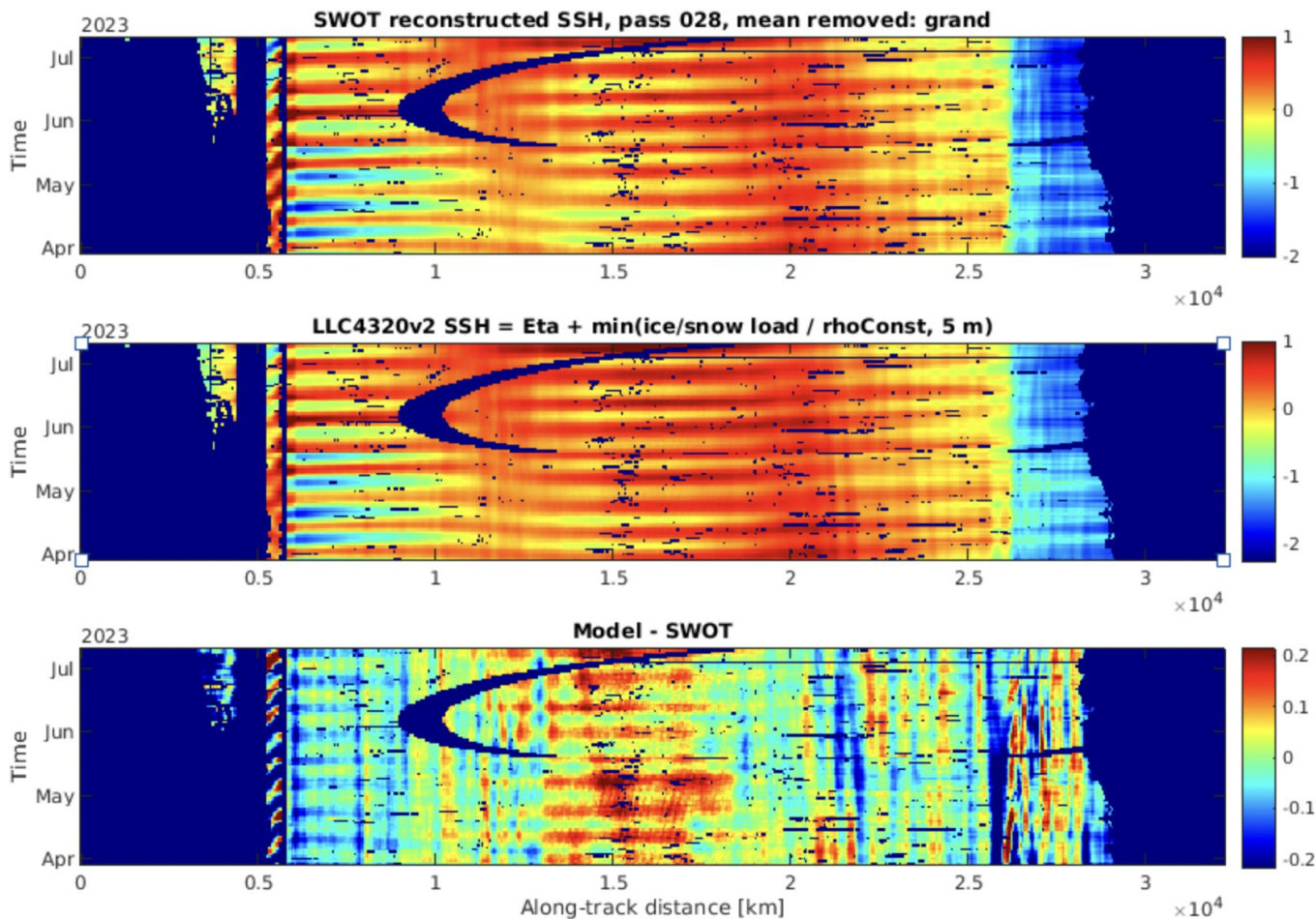
SST Difference (LLC4320 - NOAA OISST v2.1) [°C]





Slide provided by Anup Nambiathod

# SWOT vs LLC4320v2 in pass 28 of the cal/val orbit (Dan Whitt)

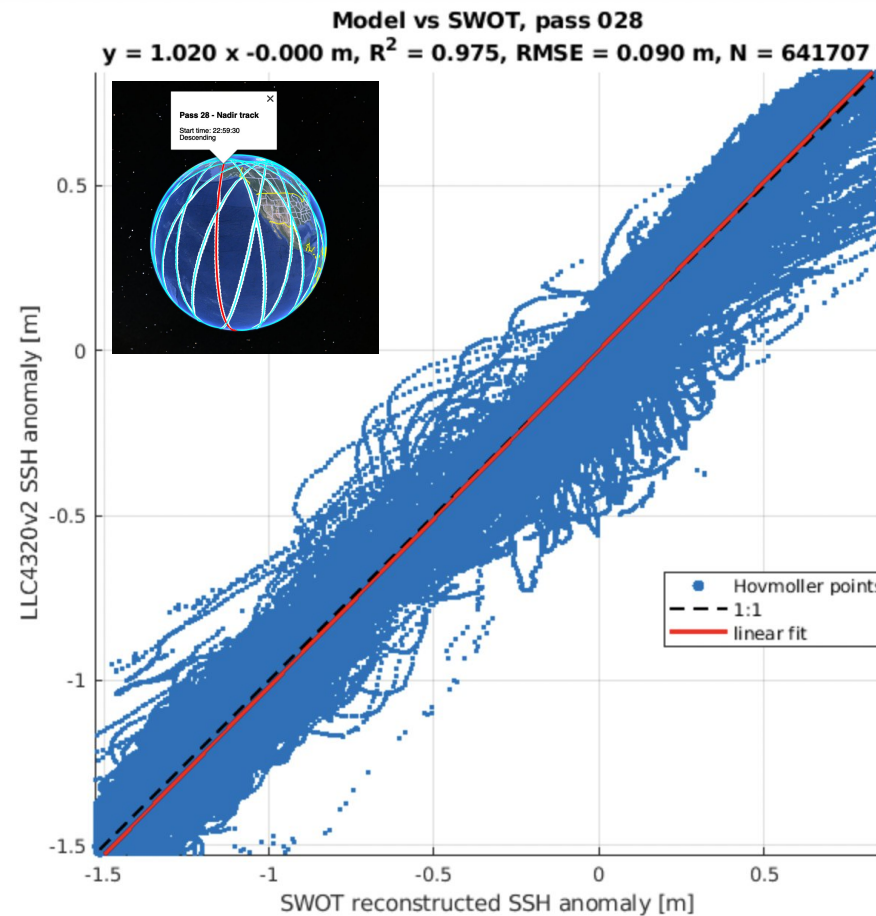


Regression/stats over Hovmoller points

N = 641707  
 slope = 1.0197  
 offset = -0.0000 m  
 R = 0.9874  
 R<sup>2</sup> = 0.9749  
 bias = -0.0000 m  
 RMSE = 0.0895 m  
 MAE = 0.0652 m

Grand means before removal:

model = +0.0125 m  
 SWOT = +0.5925 m  
 model-SWOT = -0.5800 m



```

sliceLoad = SIheff .* SEAICE_rhoIce + SIhsnow .* SEAICE_rhoSnow;
sliceLoadscale = min(sliceLoad ./ rhoConst, maxIceLoadSSH=5m);
ssh_model = eta_model + sliceLoadscale;
ssh_swot = ssha + xover + itide + otide + dac + mdt;
    
```

\*Dan says: "My main priority would be to highlight the numerous new features and improvements to the model, opportunities for synergistic analysis with SWOT and latest geostationary satellites and field campaigns associated with SWOT cal/val, as well as ancillary infrastructure that have been incorporated and highlight the amazing work that has been done by many."