

Sea surface salinity in the ECCO Ilc4320v2 global-ocean-ice-river-tides simulation

Dimitris Menemenlis
dimitris.menemenlis@sjsu.edu

May 19, 2026

KEY CONTRIBUTORS

NASA Ames: [Dan Whitt*](#), [Nina McCurdy](#), Chris Henze, Bron Nelson, and David Ellsworth

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

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

MLML/SJSU: Dimitris Menemenlis and Dustin Carroll

University of Toronto: Kayhan Momeni and Dick Peltier

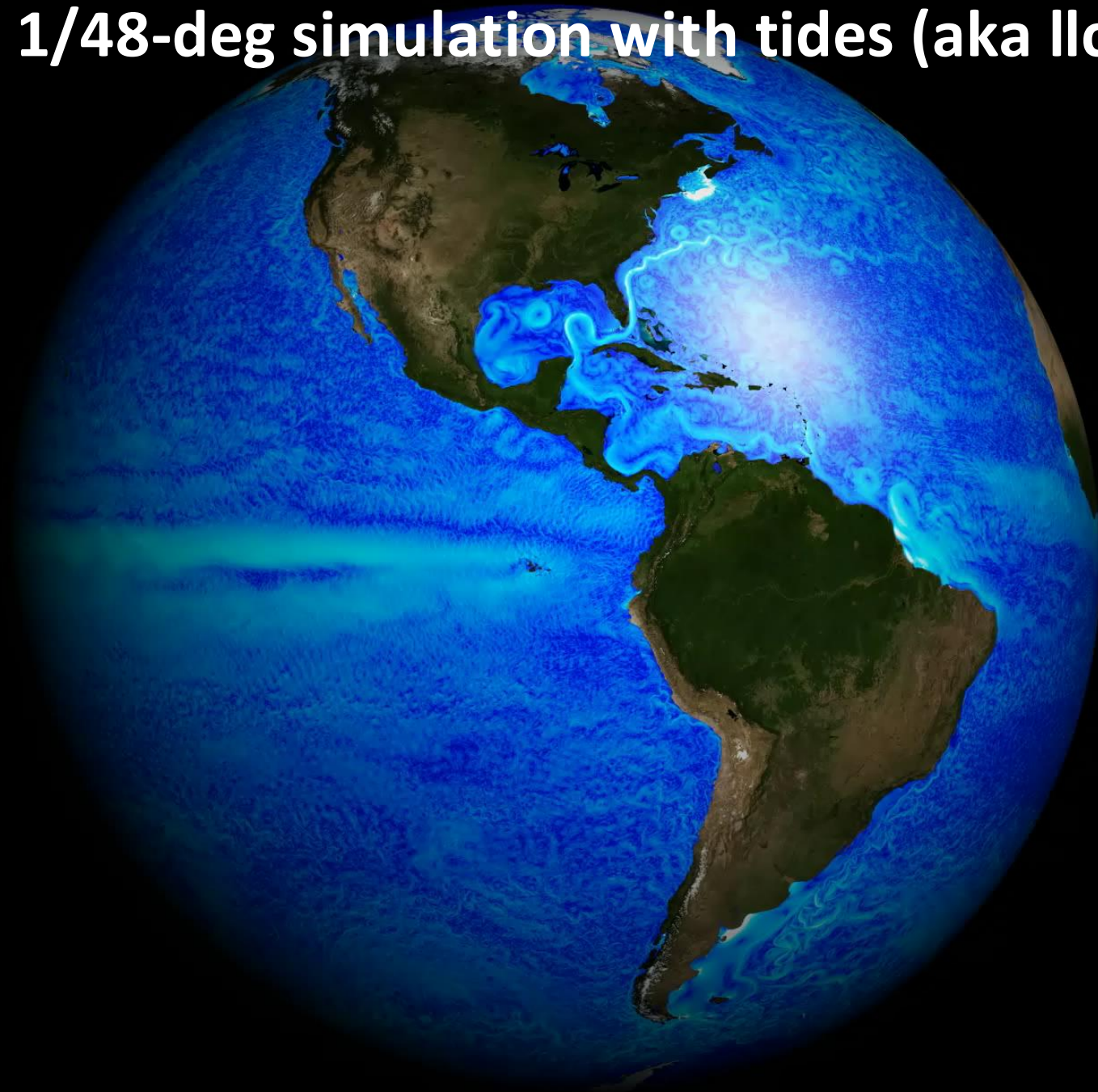
University of Michigan: Hugo Plombat and Brian Arbic

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)



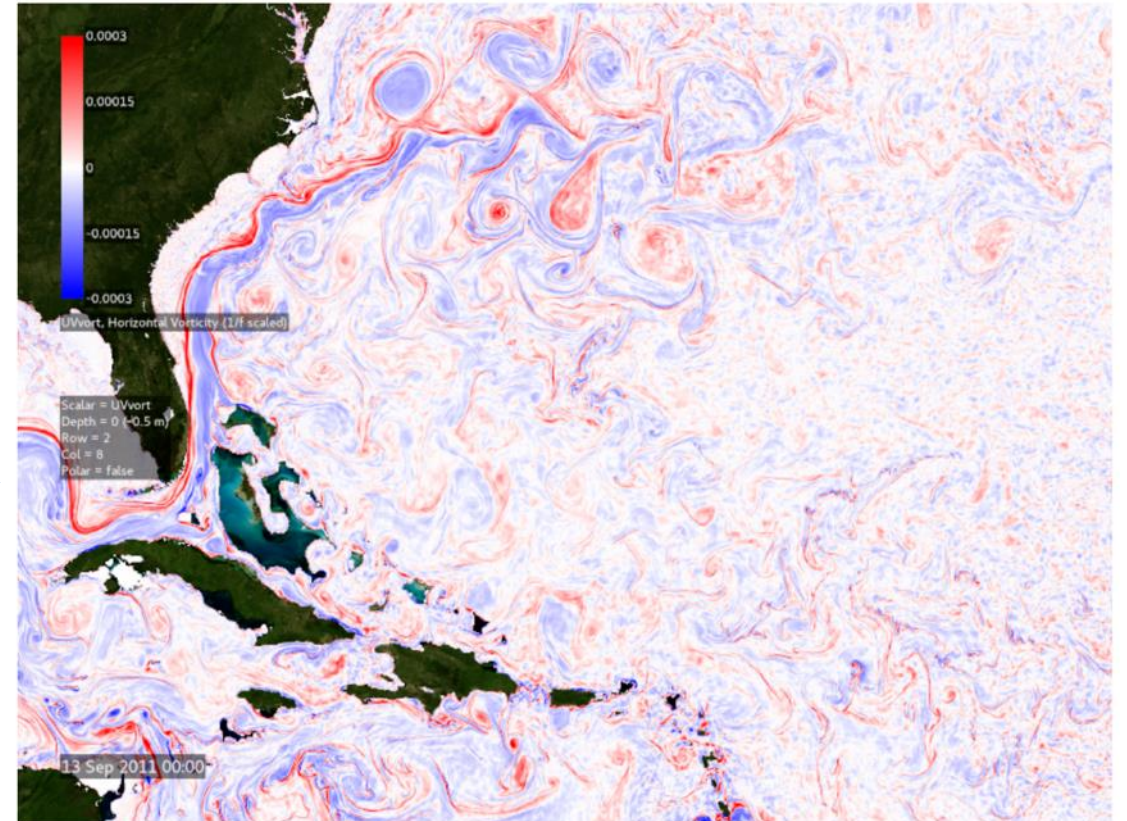
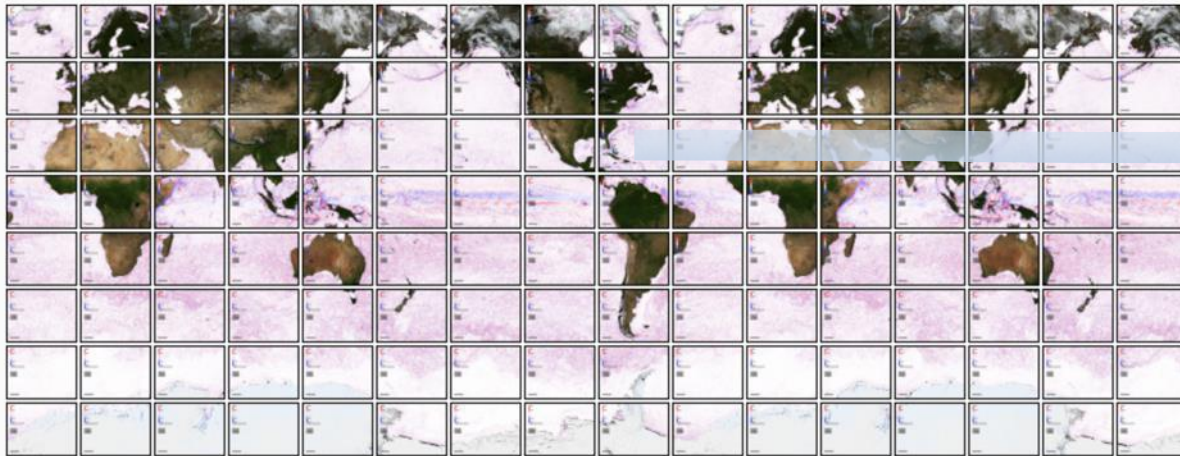
Model output available at <https://www.poseidon-ocean.net/products/datasets/Ilc4320-dataset/>

Hyperwall at home (created by David Ellsworth)

<https://data.nas.nasa.gov/eccoviz/llc4320/>

Series: 128 regions (2-5km) | Scalar: UVvort (vertical vorticity) | Level: Level 0 (-0.5 m)

Click on one of the 128 images below to see the available animations for UVvort level 0 at that geographic location in a new tab.



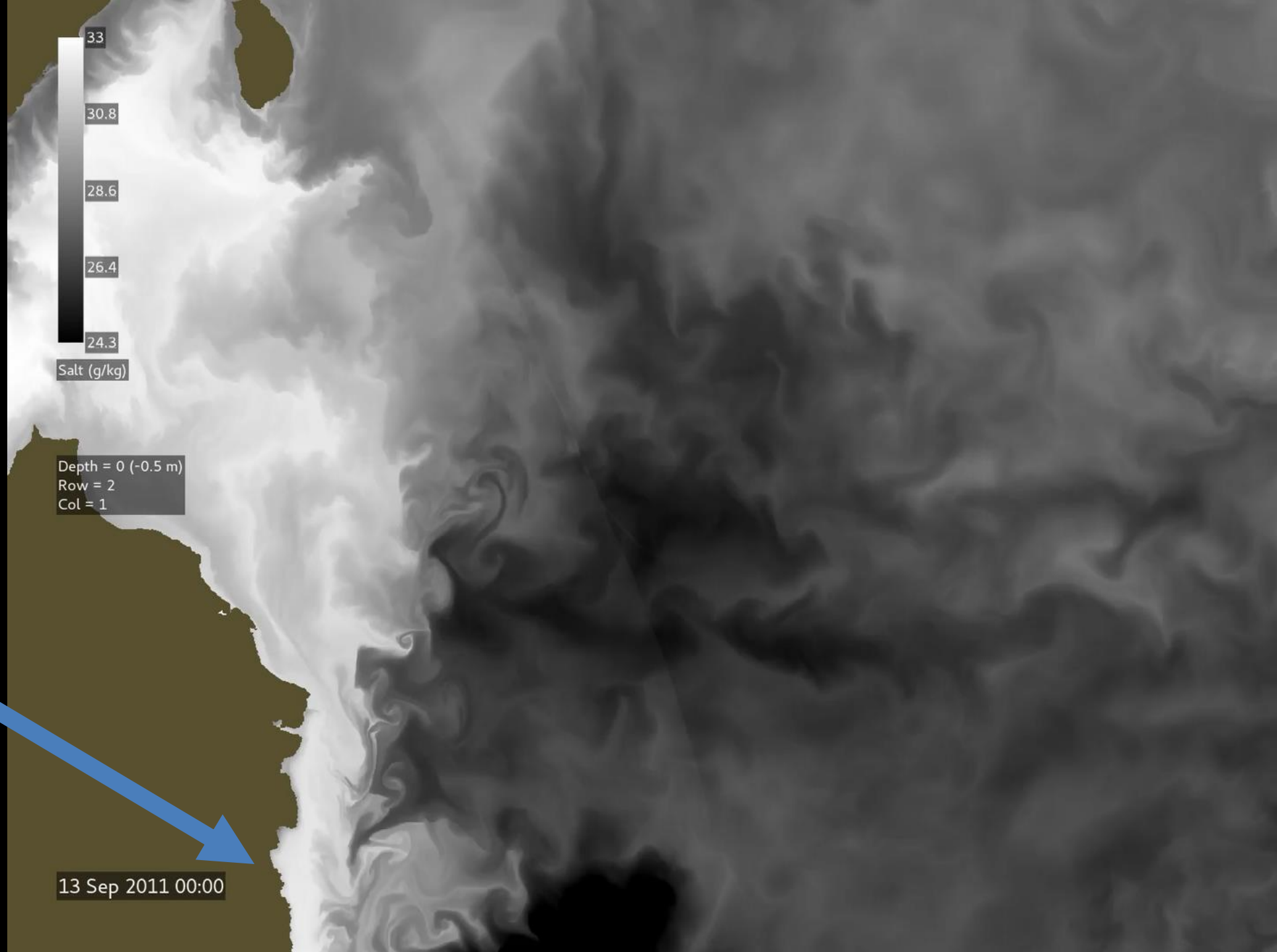
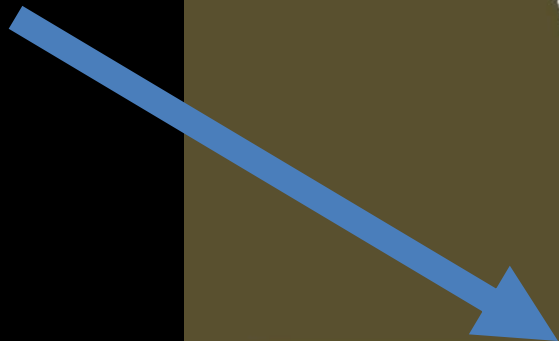
The buttons below will select a visualization of UVvort (horizontal vorticity) level 0 (depth -0.5 m) located at row 2 column 8 in the 128-region series of animations. The different buttons are for either a MP4 animation or a full size image. Animations are available for different resolutions and image sizes, and for a range of time steps. The sizes listed are for the MP4.

Hyperwall at home capability allows visual exploration of the hi-res simulation from a remote workstation.

Timestep	Animation Pixel Resolution and File Size							
	5.4 km / 800x600				2.7 km / 1600x1200			
1 hour	172 MB	Play MP4	Download MP4	Image	788 MB	Play MP4	Download MP4	Image
3 hours	58 MB	Play MP4	Download MP4	Image	313 MB	Play MP4	Download MP4	Image
6 hours	39 MB	Play MP4	Download MP4	Image	199 MB	Play MP4	Download MP4	Image
12 hours	22 MB	Play MP4	Download MP4	Image	110 MB	Play MP4	Download MP4	Image
24 hours	14 MB	Play MP4	Download MP4	Image	65 MB	Play MP4	Download MP4	Image

**Ic4320
sea surface salinity
from Hyperwall
at home**

**Colville River
North Slope
Alaska**



Some issues with the classic LLC4320 simulation

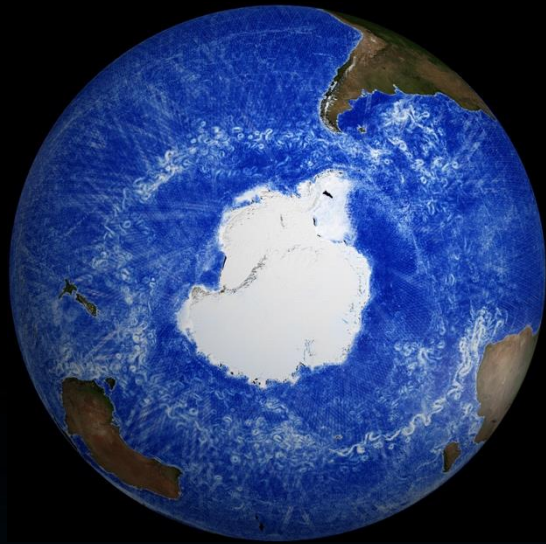
LLC4320 (classic) has been used for over 240 published studies but:

- Disk crash has led to loss of 50% of model output at NAS*
- Limited resolution of submesoscale processes
- Gulf Stream in wrong location
- Problematic equatorial dynamics and anemic TIWs
- Tidal forcing 11% too strong due to wrong SAL correction
- Problematic bathymetry, especially around Antarctica
- 6-hourly atmospheric forcing leads to weak near-inertial currents
- Linear free surface, which restricts accuracy of coastal circulation

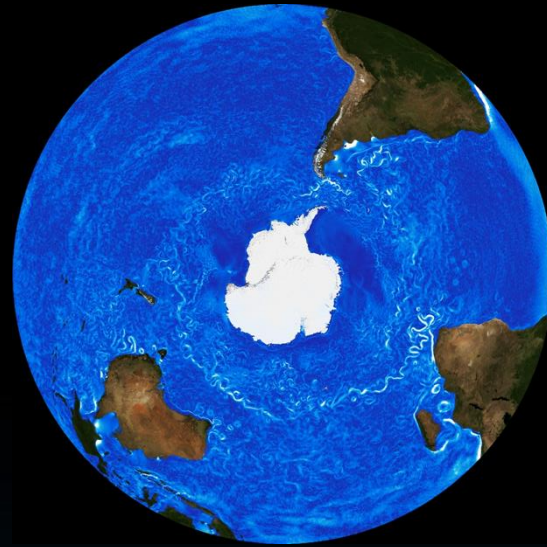
* But full simulation available on SciServer: <https://www.poseidon-ocean.net/products/datasets/llc4320-dataset/>
and visualizations available at: <https://data.nas.nasa.gov/eccoviz/llc4320/>

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

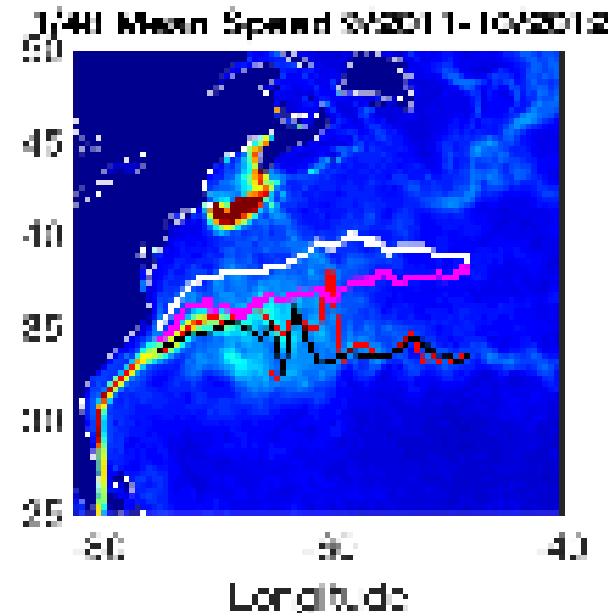
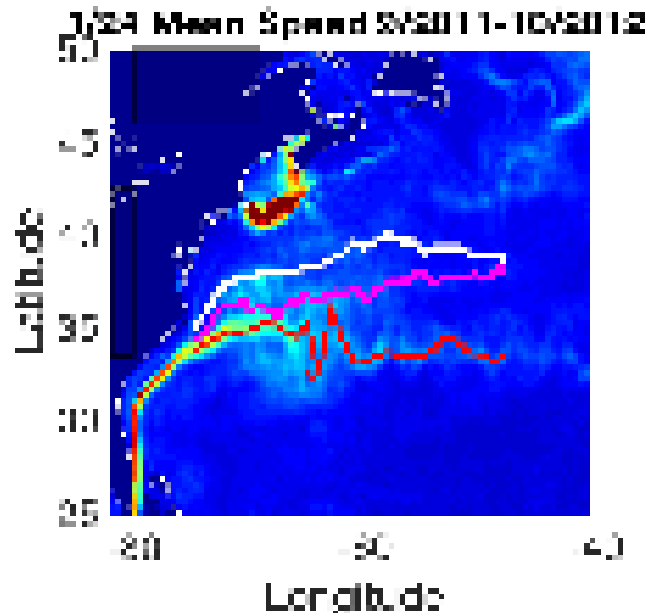
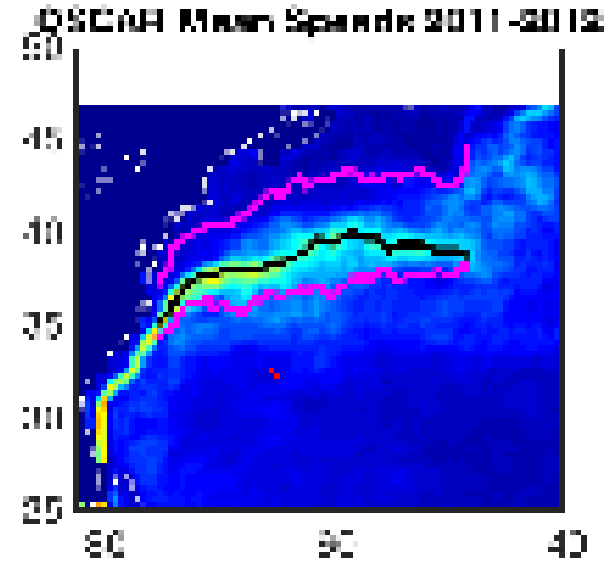
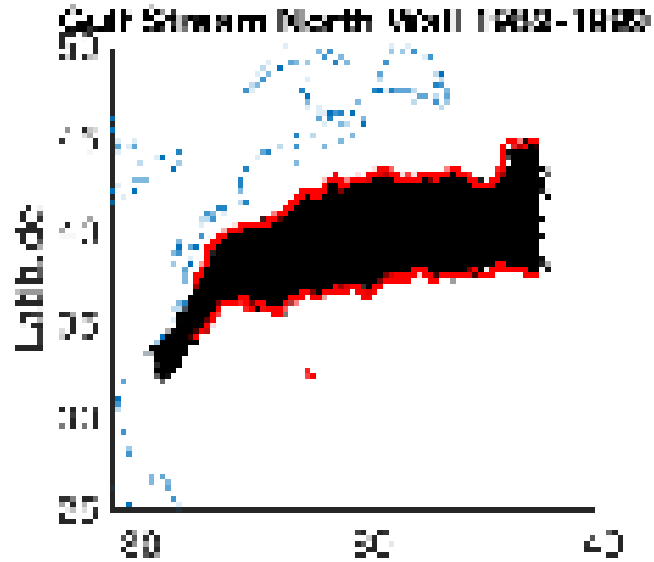
Science POC: Dan Whitt (Code S)

Announcing: ECCO llc4320v2 a global-ocean-ice-river-tides simulation

A follow-on to the llc4320 (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 llc1080 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



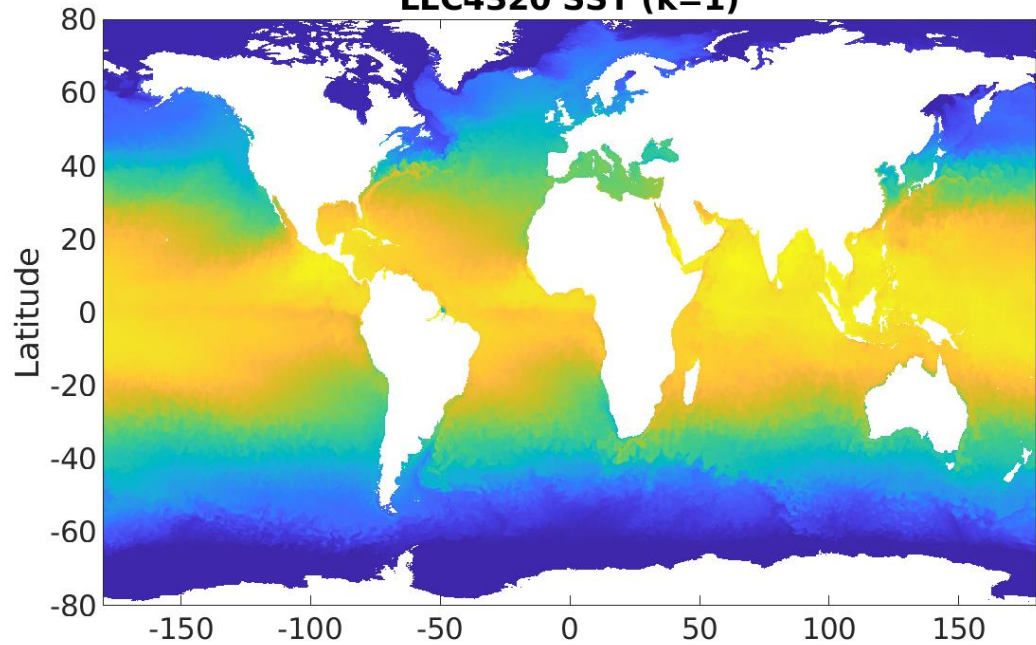
***The Gulf Stream:
Yikes What's It
Doing Down There?***

Peter Cornillon

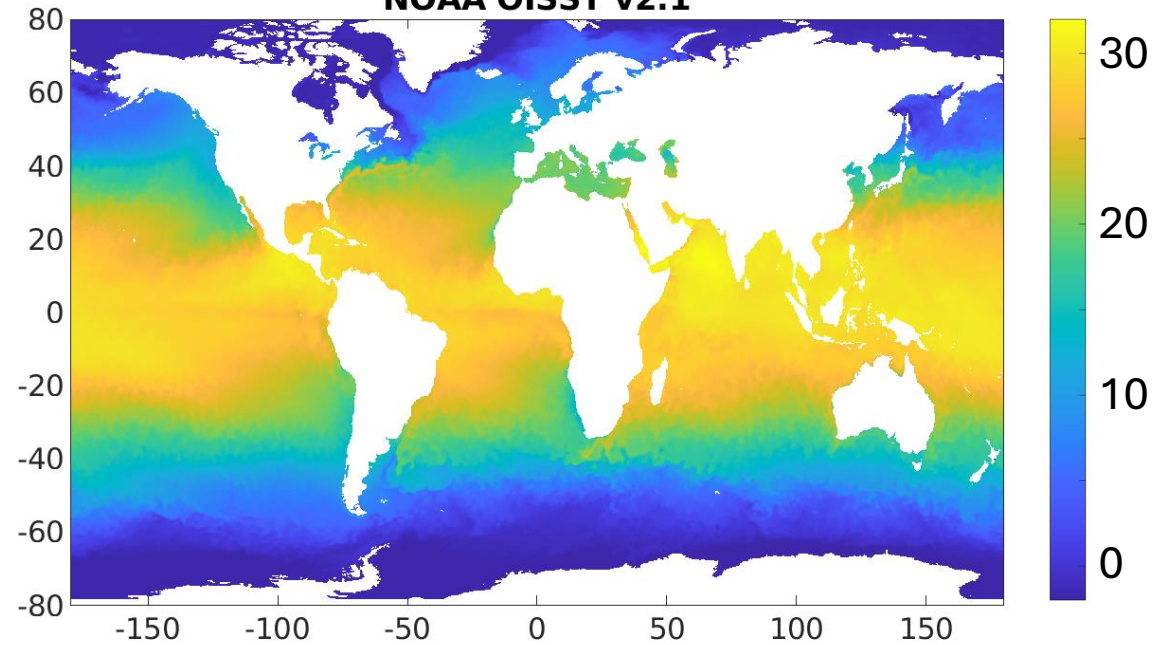
*Annual ECCO meeting
Austin, TX
October 2018*

SST Comparison [°C]

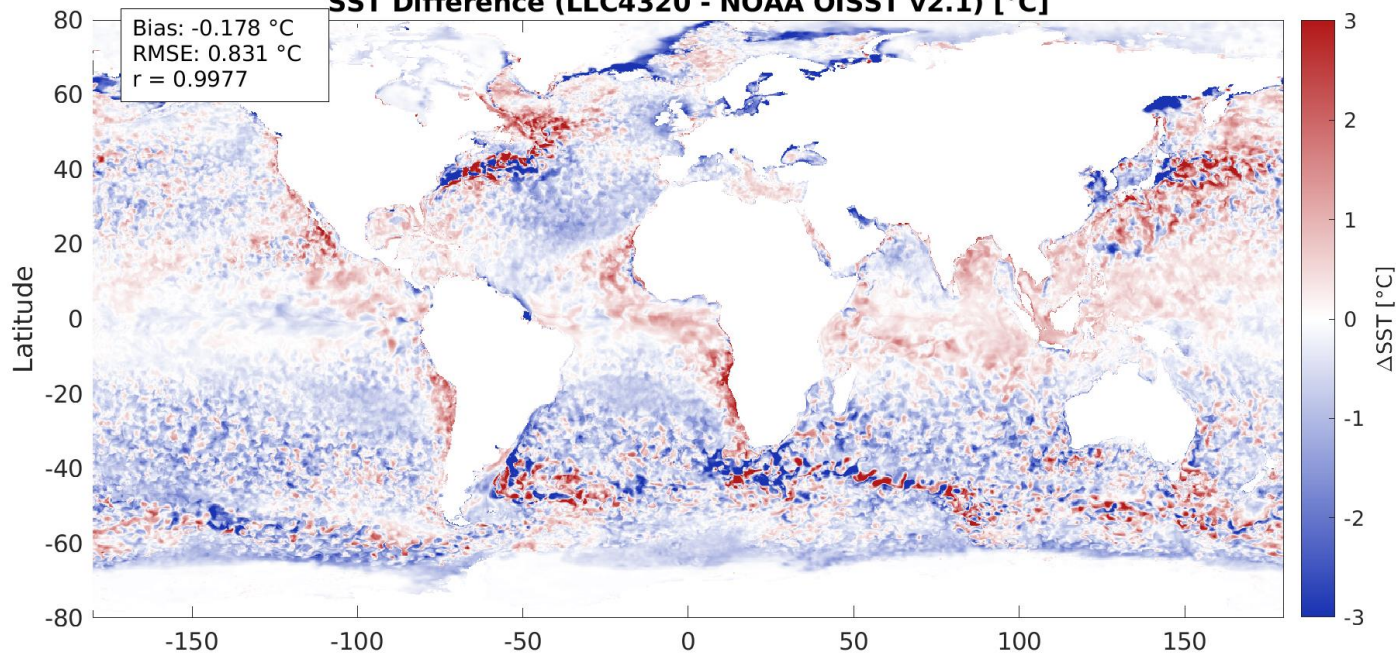
LLC4320 SST (k=1)



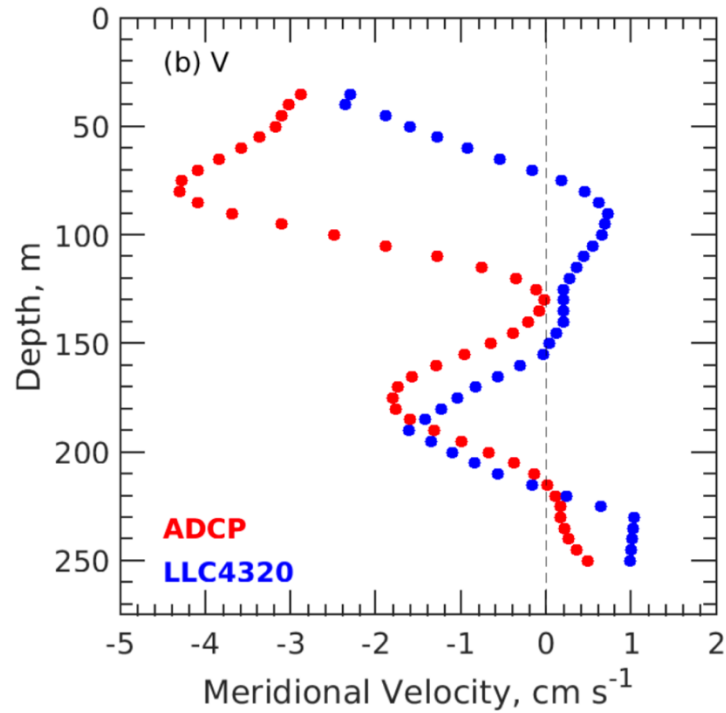
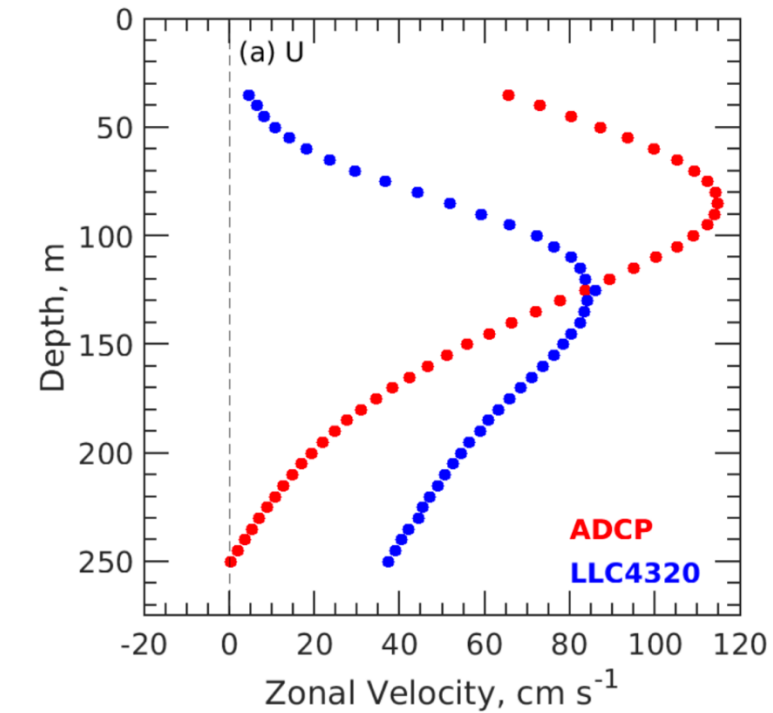
NOAA OISST v2.1



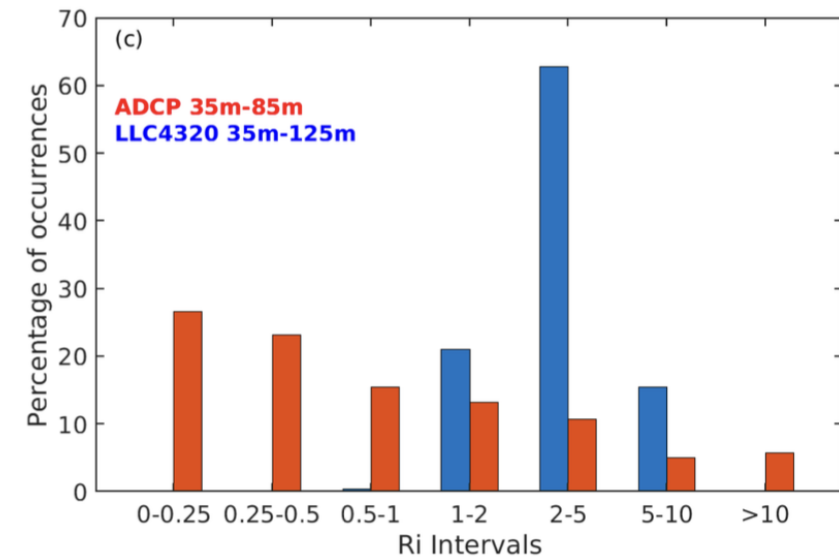
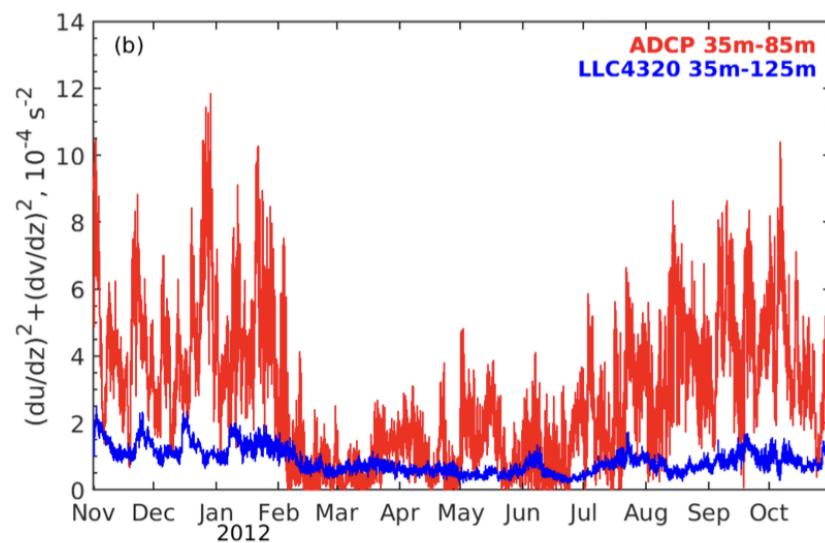
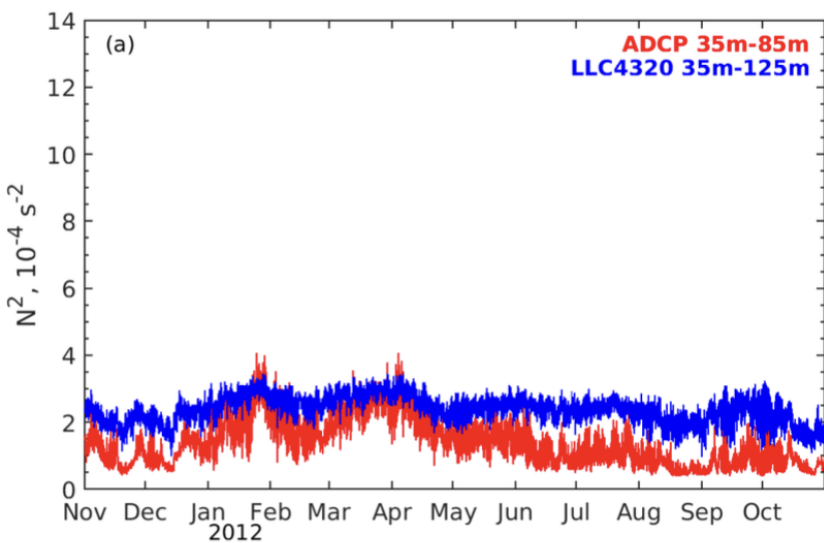
SST Difference (LLC4320 - NOAA OISST v2.1) [°C]

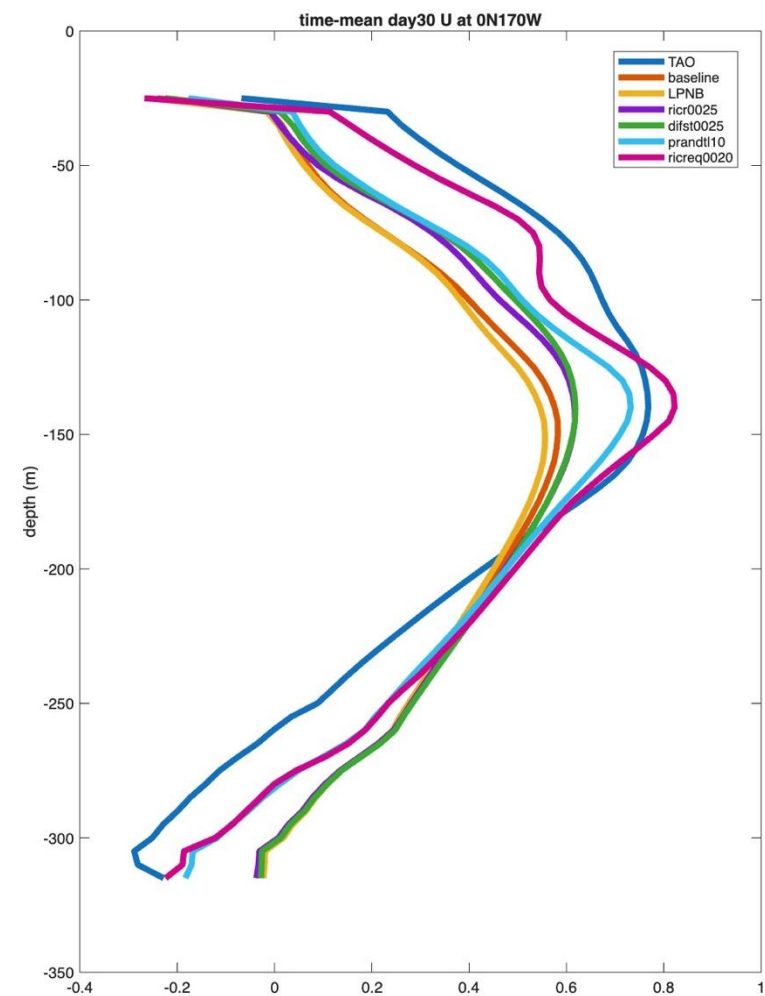
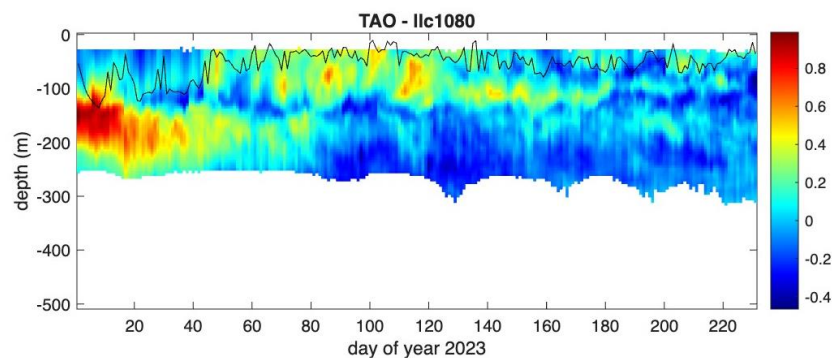
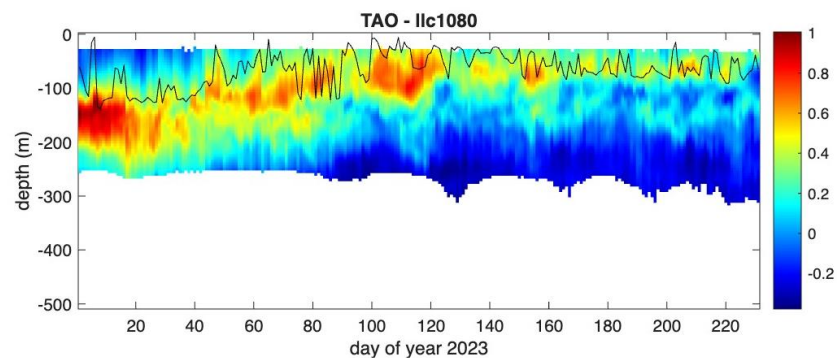
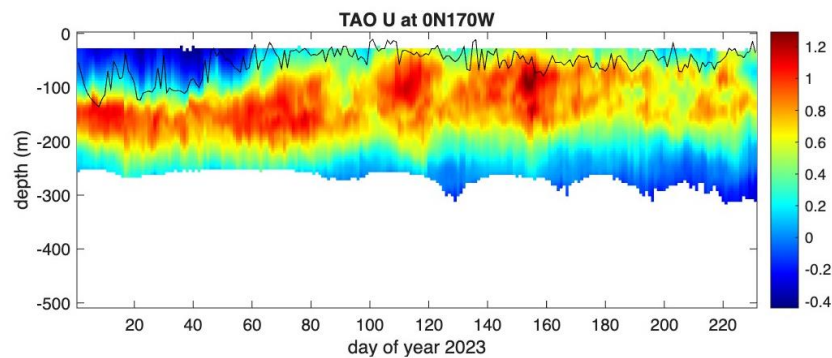
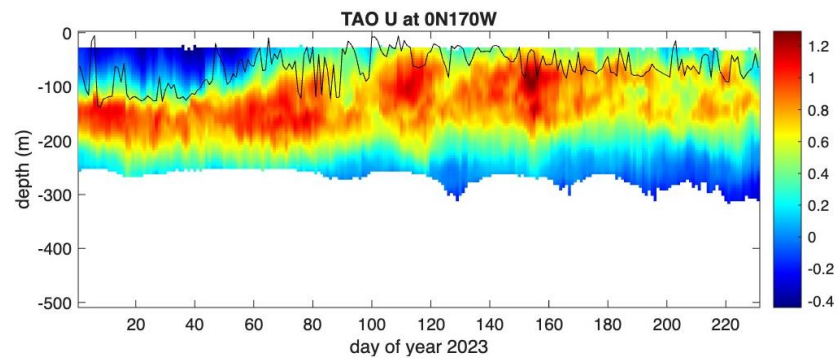
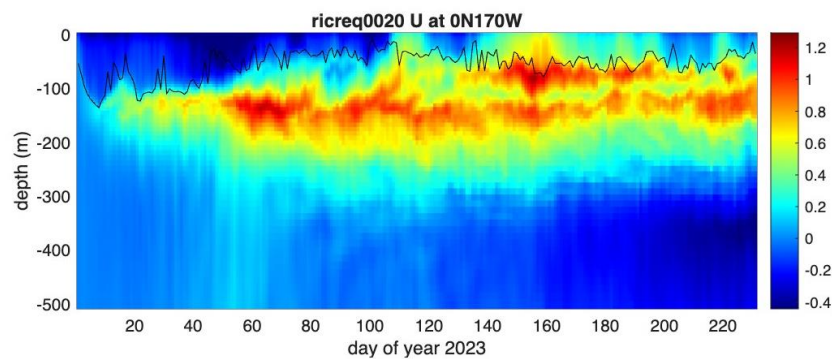
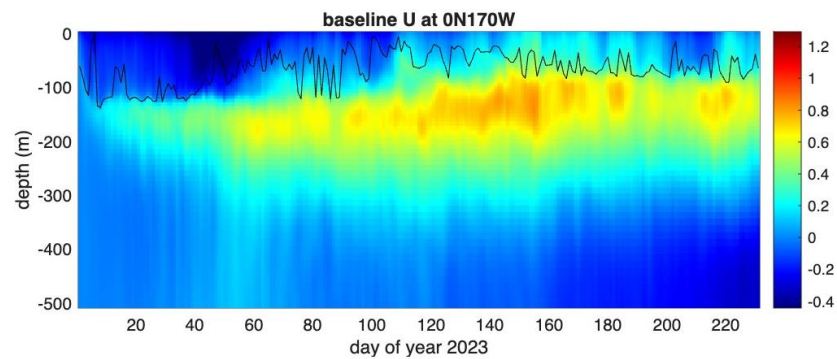


Critic #2: Kate Zhang on Equatorial Dynamics



Figures from submitted manuscript by David Halpern and Kate Q. Zhang that compares ADCP observations to classic LLC4320 at 0° , 140°W

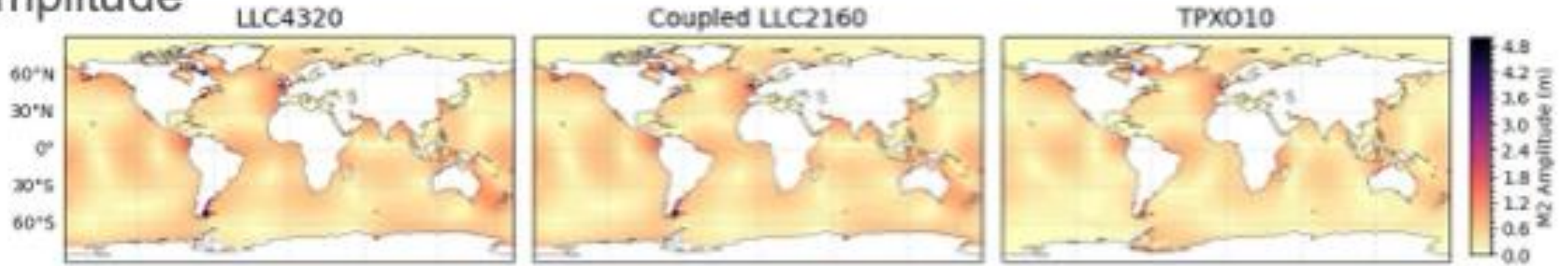




(simulations: Kayhan Momeni; analysis: Kate Q. Zhang)

Critic #3: Brian Arbic on tides

amplitude



phase

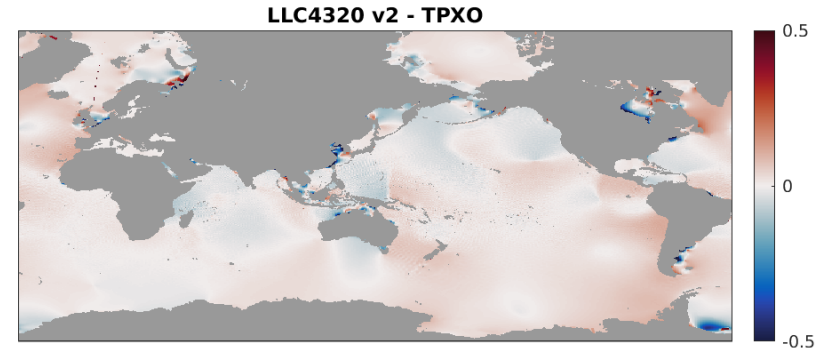
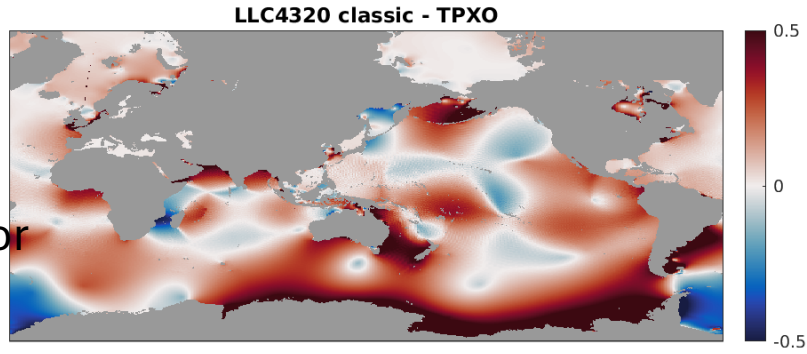


Figure showing amplitude and phase for M2 tidal constituent (a) LLC4320 (b) coupled (c) TPXO10.

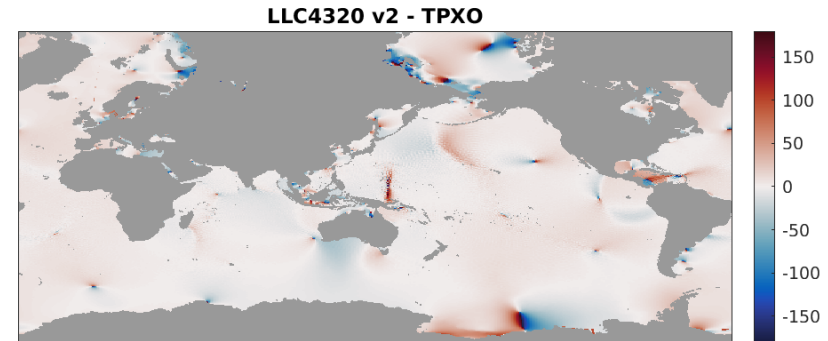
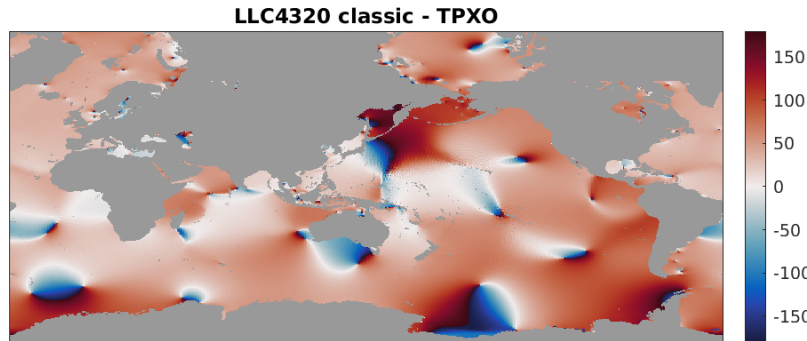
(from paper in preparation by Anup Nambiathody and Angelica R. Rodriguez)

M2 diff wrt TPXO

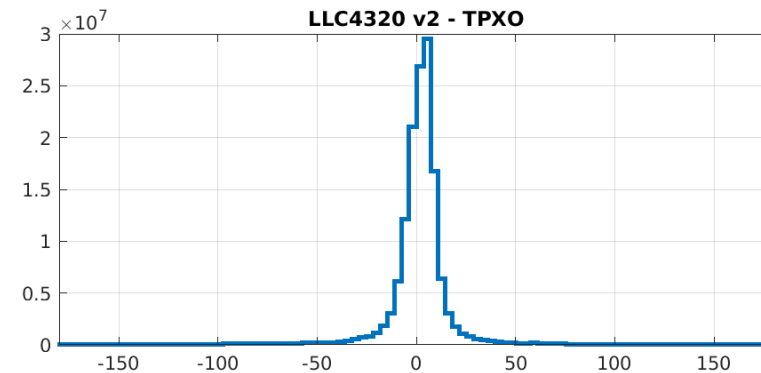
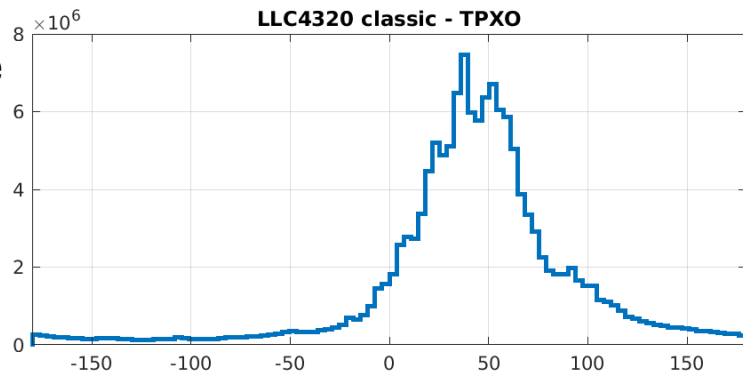
Amplitude
RMSE of amp/phasor
16.88 / 31.02 cm
5.31 / 7.12 cm



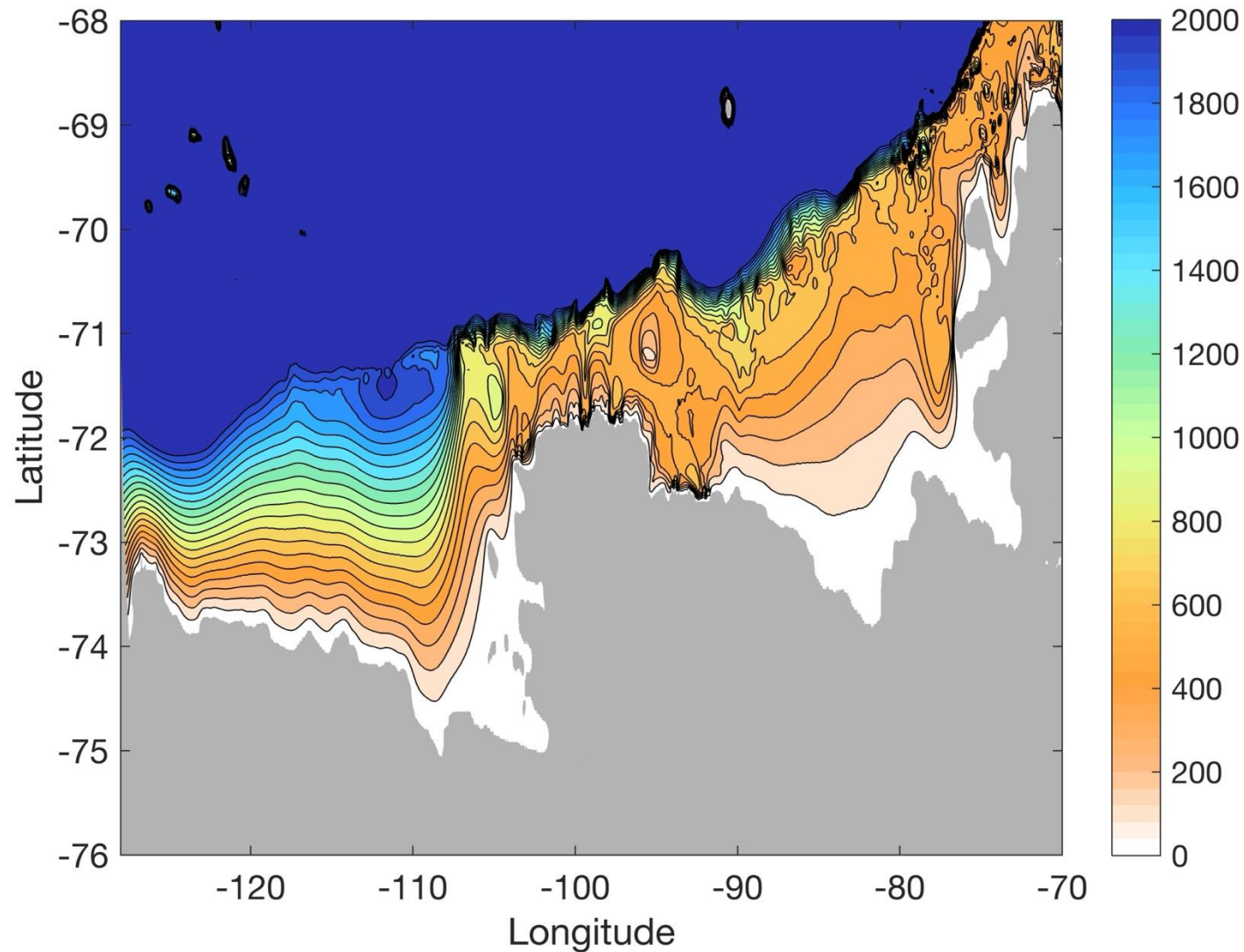
Phase
RMSE of phase
57.4deg
15.2deg



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



Critic #4: Andrew Stewart on bathymetry

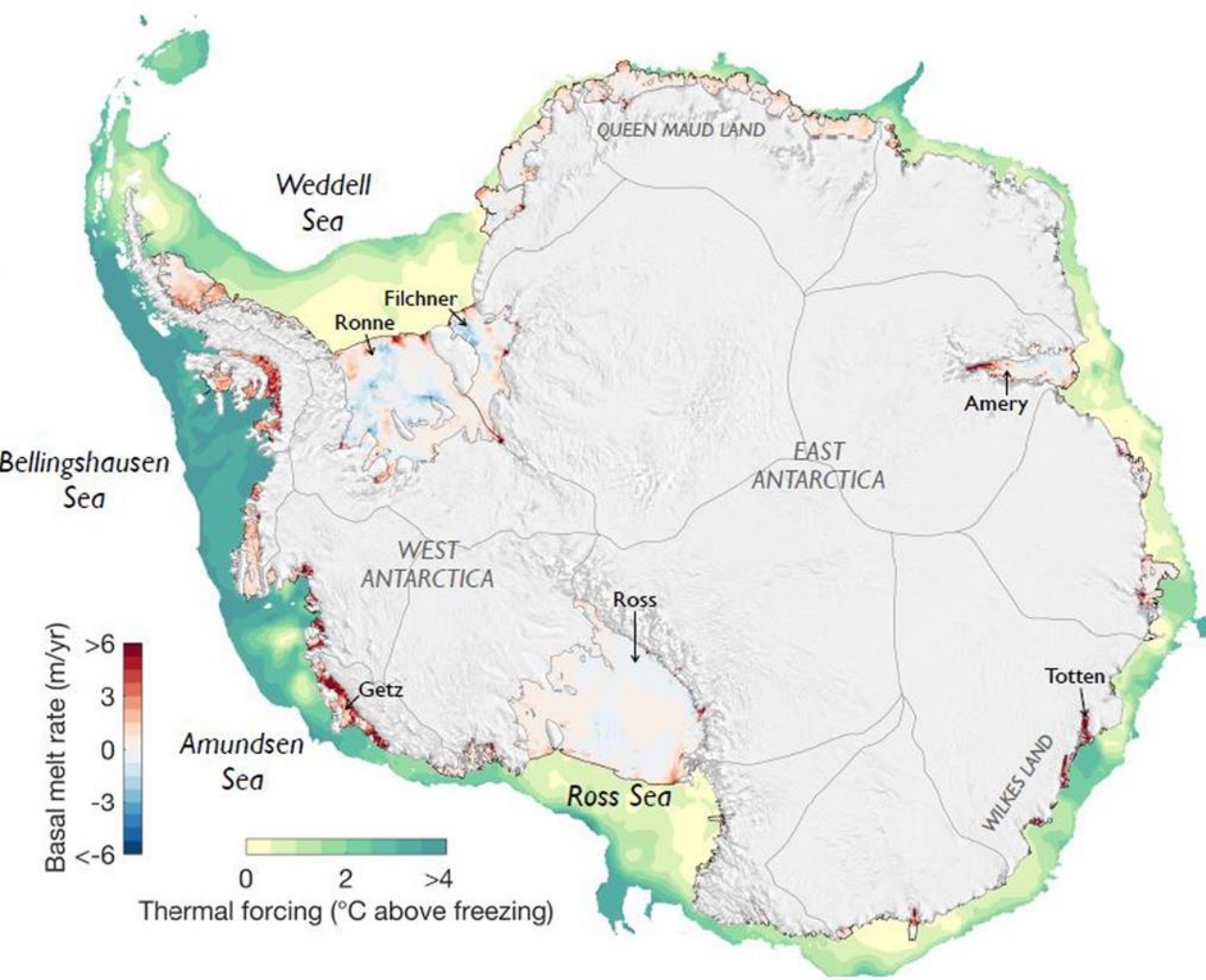


Model bathymetry in the Amundsen and Bellinshausen Seas.

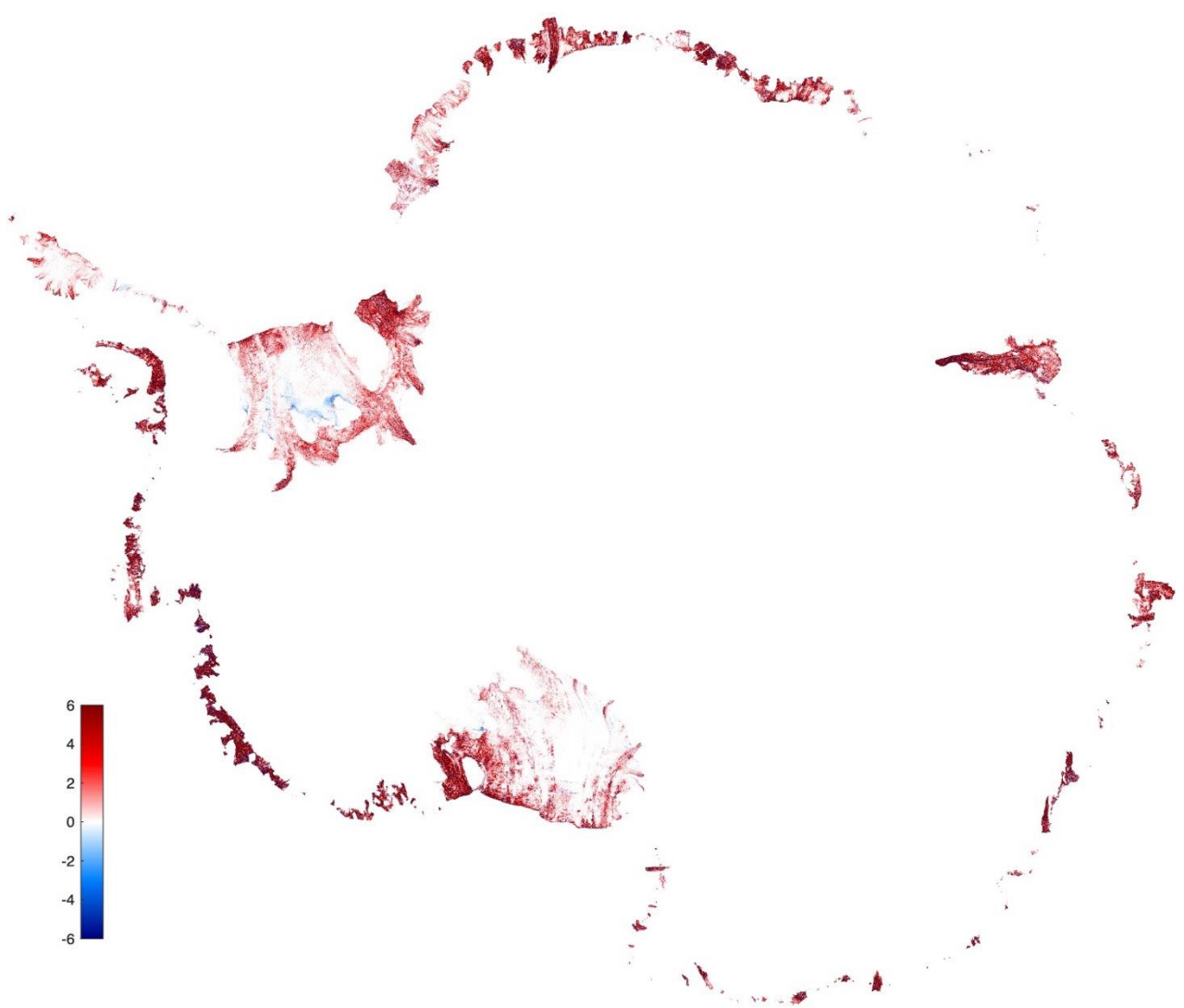
The model bathymetry is derived from Smith and Sandwell [1997]. This product omits recent high-resolution measurements and linearly interpolates between depth measurements over the continental slope and an assumed depth of zero at the coastline, leading to a representation of the continental shelf that 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 2.

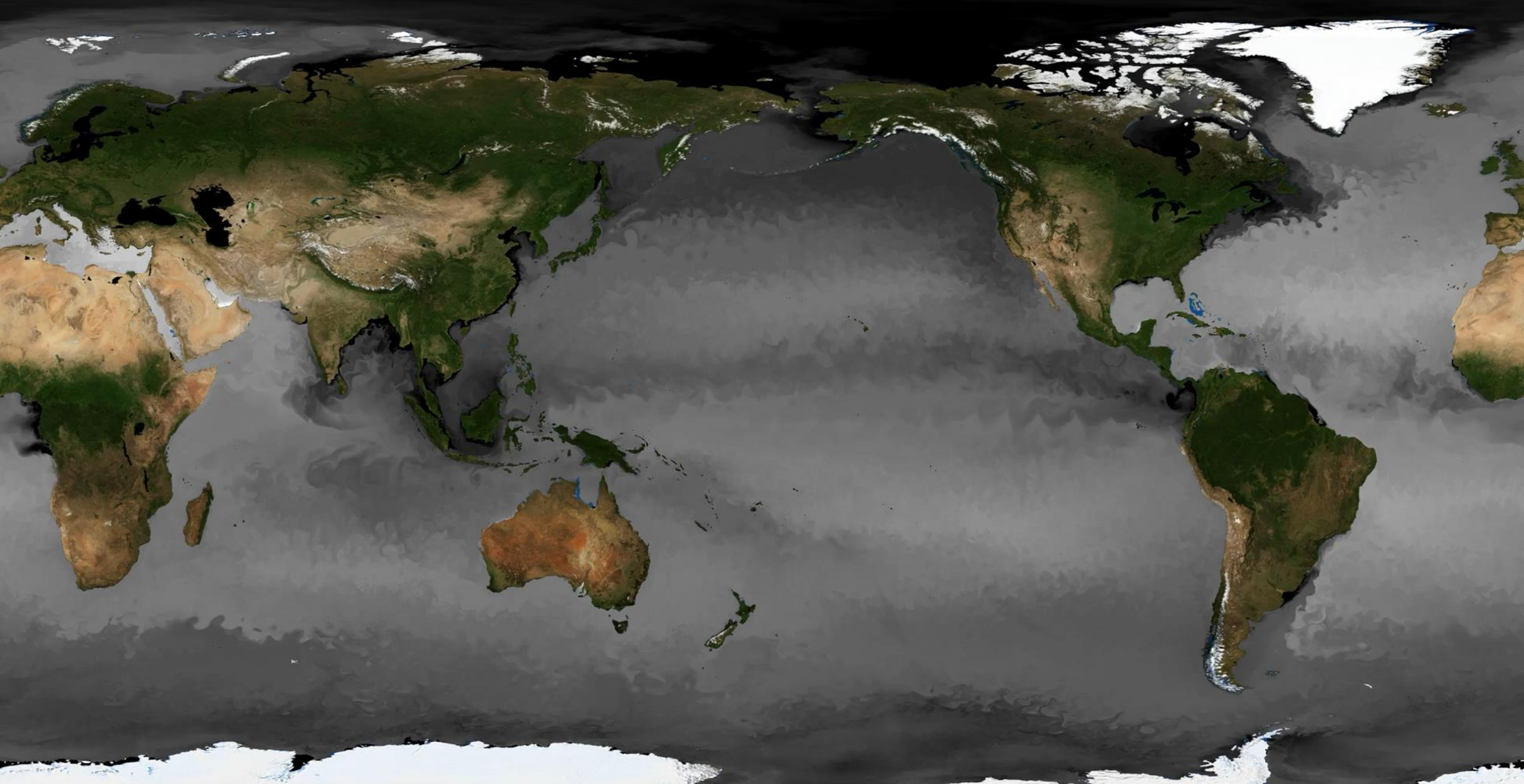
Status of llc4320v2 (1/48°) simulation on athena earlier this morning (May 19, 2026)

- Initial conditions from GLORYS12 January 1, 2022. One year spin-up on llc1080 (1/12°), except for ice shelf cavities that have one extra year of spin-up.
- Start llc4320v2 (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 months (January 1 to September 21, 2023) of simulation completed

Code: https://github.com/MITgcm-contrib/llc_hires/tree/master/athena/llc_4320

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

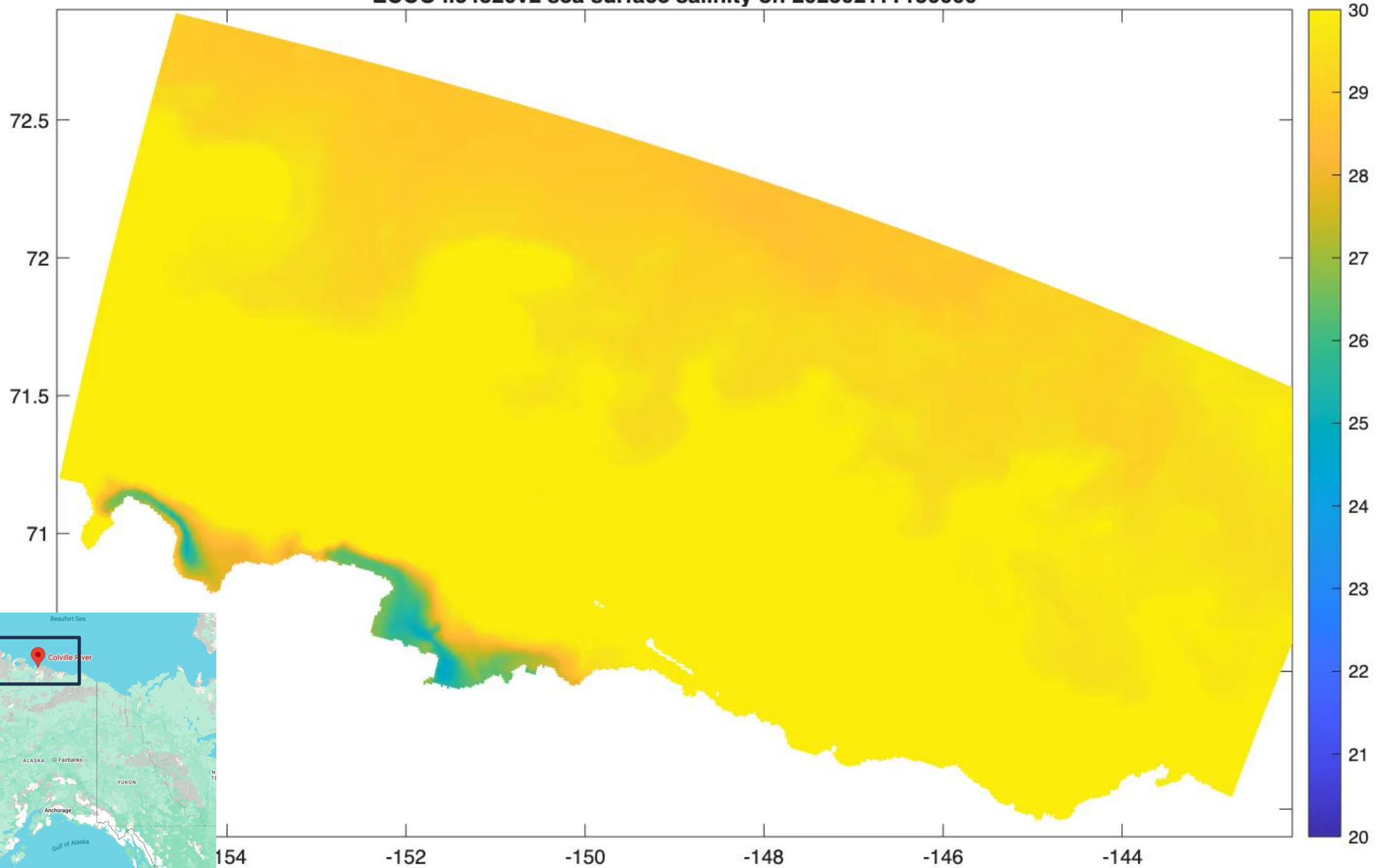
Output on NAS athena, soon to be made available on NAS data server.



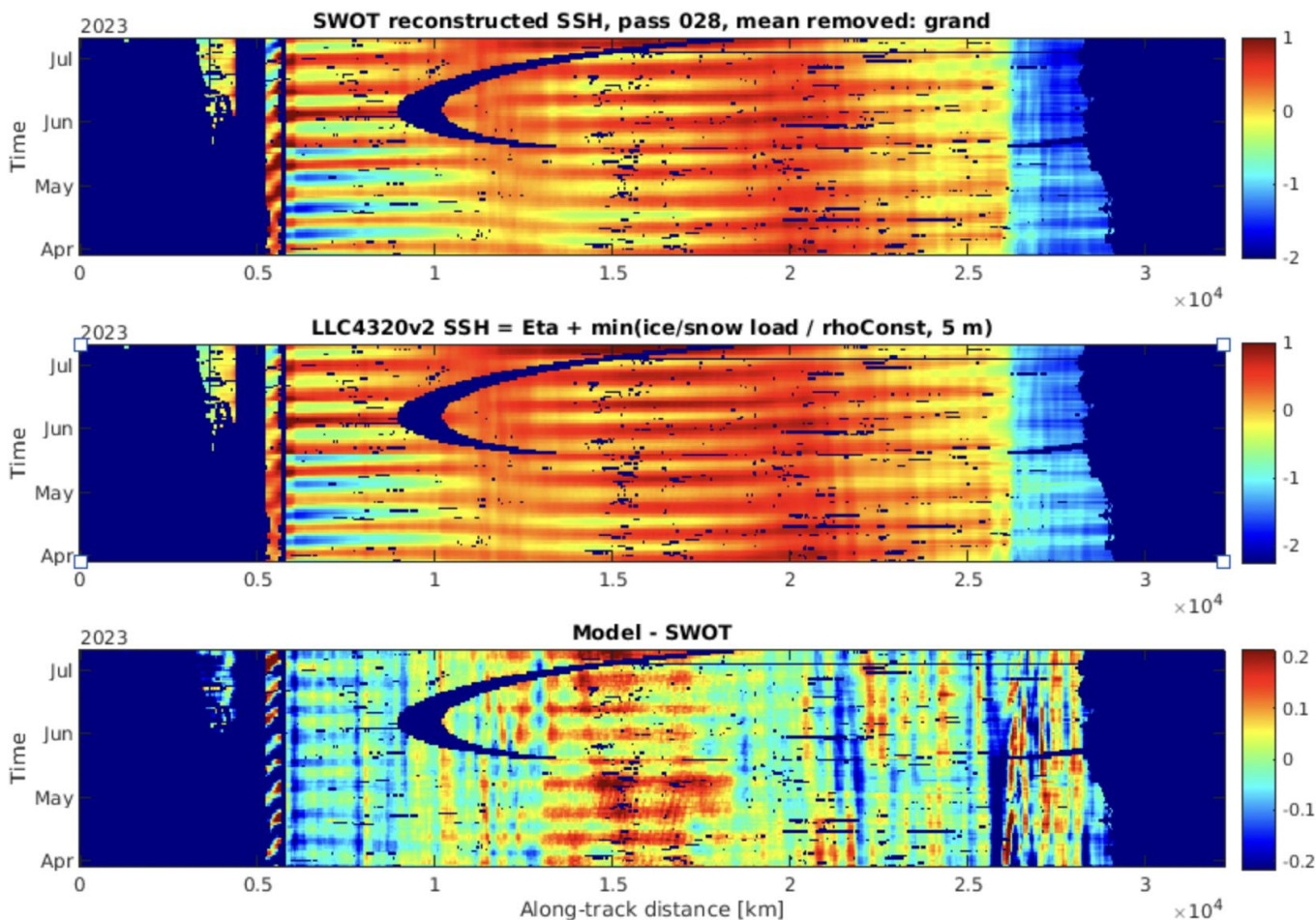
llc4320 sea-surface salinity 2023-01-01 00:00

Animation by NAS viz group, N. McCurdy, D. Ellsworth, and C. Henze
<https://nasa-ext.box.com/s/owzdbdwp0710jcgup4sd0wkrpyxk6f53>

ECCO Ilc4320v2 sea surface salinity on 20230211T150000



SWOT vs LLC4320v2 in pass 28 of the cal/val orbit

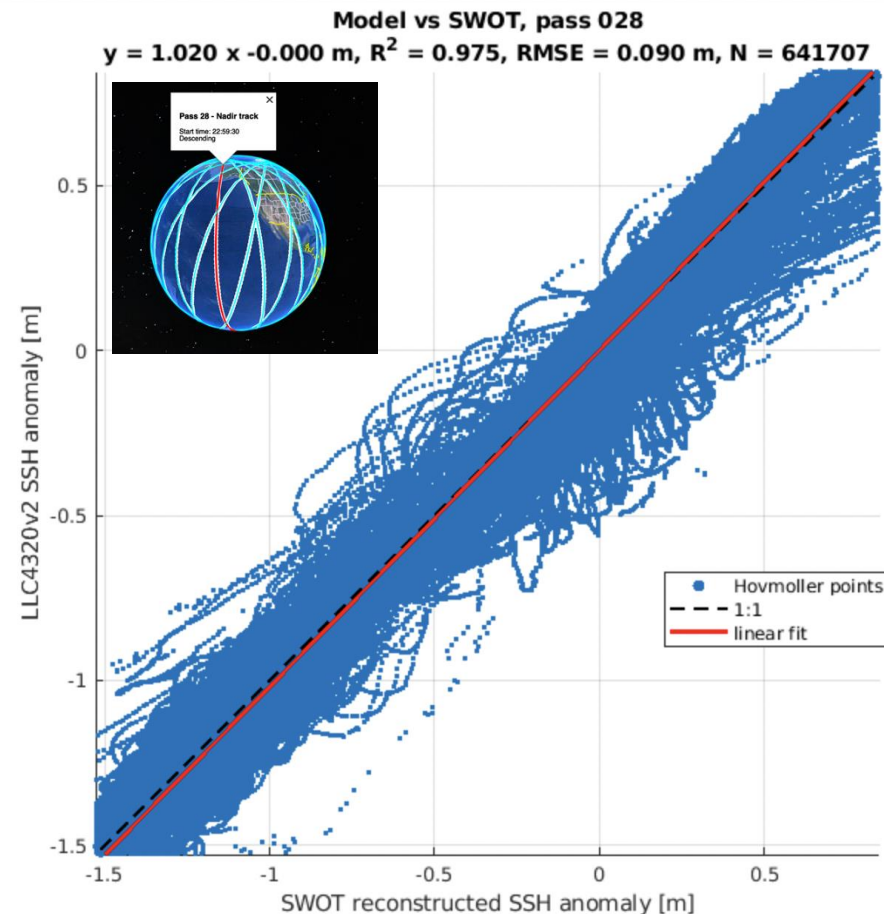


Regression/stats over Hovmoller points

N = 641707
 slope = 1.0197
 offset = -0.0000 m
 R = 0.9874
 R² = 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 = ssh_a + 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."