MPAS-O Status Update

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MPAS
Model for Prediction Across Scales

Building Global, Multi-Scale Climate System Component Models

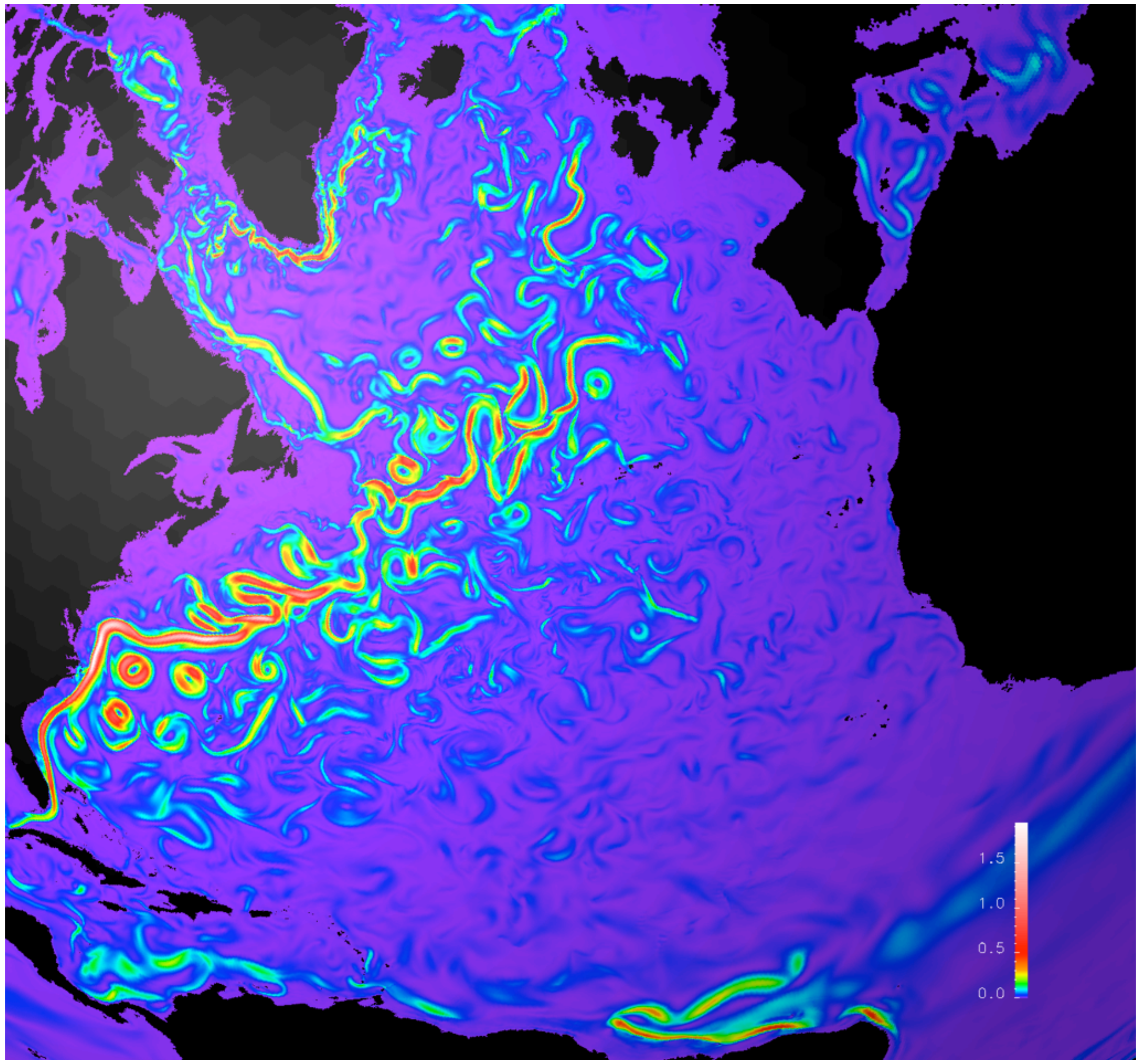
1. MPAS is an unstructured-grid approach to climate system modeling.

2. MPAS supports both quasi-uniform and variable resolution meshing of the sphere using quadrilaterals, triangles or Voronoi tessellations.

3. MPAS is a software framework for the rapid prototyping of single-components of climate system models (atmosphere, ocean, land ice, etc.).

4. MPAS offers the potential to explore regional-scale climate change within the context of global climate system modeling. Multiple high-resolution regions are permitted.

5. MPAS is currently structured as a partnership between NCAR MMM and LANL COSIM, where we intend to distribute our models through open-source, 3rd-party facilities (e.g. Sourceforge).



snapshot of kinetic energy from a global ocean simulation with 7.5 km resolution in the North Atlantic.

We want to start to answer two questions:

1. Is MPAS-O a viable approach to global ocean modeling?

2. Can specific regions of the global ocean system be accurately simulated with local mesh refinement?

How are we going to start to answer these questions?

Model Simulations:

x1.15km: global, uniform-resolution of 15 km
x5.NA.75km_15km: global, variable-resolution with 15 km in the North Atlantic
x5.NA.37.5km_7.5km: global, variable-resolution with 7.5 km in the North Atlantic

Observations:

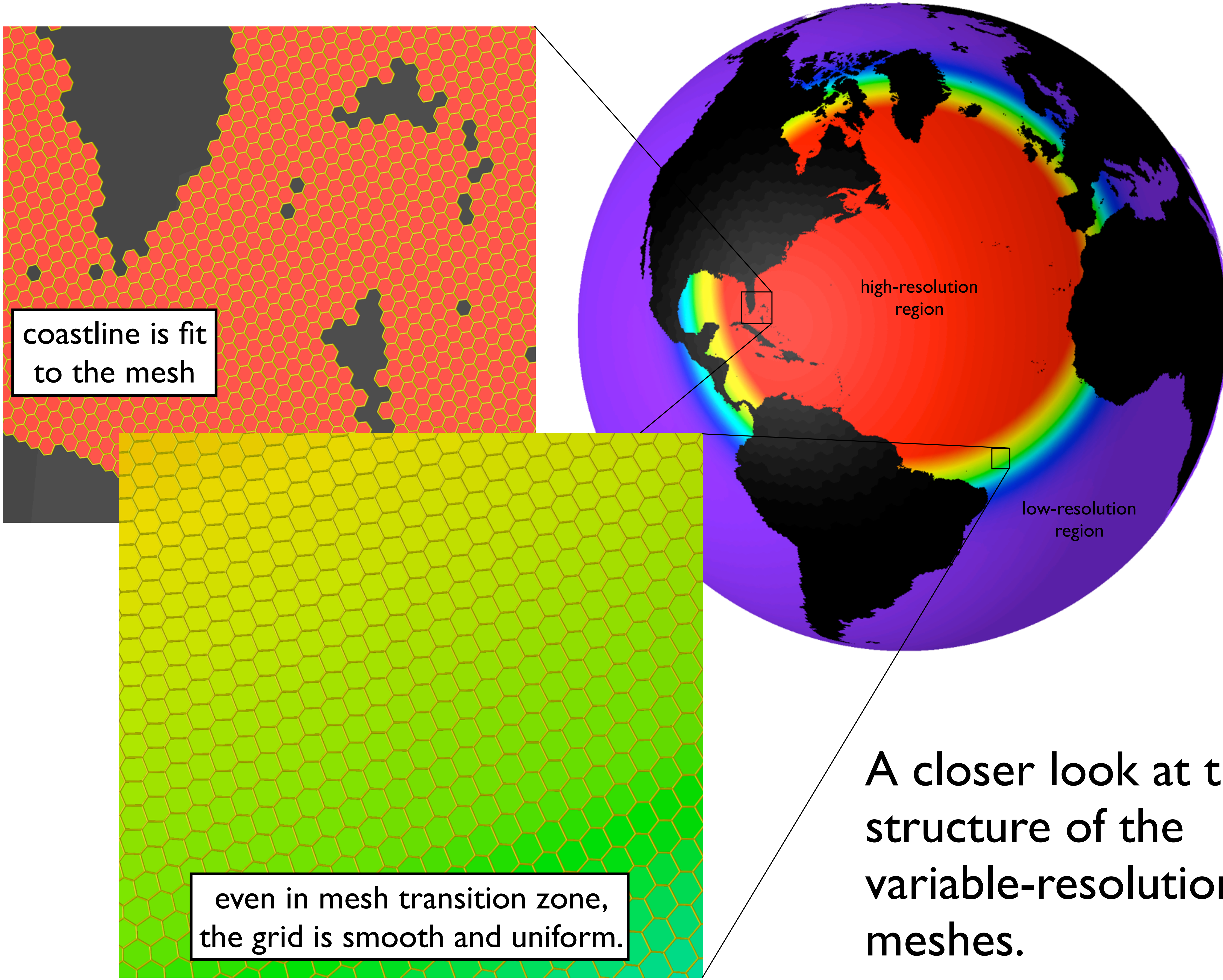
mean SSH: Maximenko (2009) (averaging from 1992-2002)
variance of SSH: AVISO (averaging from 2005-2007)

Answering question #1: compare x1.15km to observations
Answering question #2: compare x5.NA.75km_15km to x1.15km

Why these three simulations:

x1.15km: 1.8e6 cells, dt=600 s (~2 SYPD on 3000 procs)
x5.NA.75km_15km: 2.5e6 cells, dt=600 s (1/7th the FPO* as x1.15km)
x5.NA.37.5km_7.5km: 1.0e6 cells, dt=360 s (same FPO as x1.15km)

(FPO == floating point operations)



A closer look at the structure of the variable-resolution meshes.

Details of model configuration.

Duration: ~20 years. Analysis based on last 10 years.
Forcing: Monthly mean restoring to WOCE SST/SSS with 45 day time scale.
Forcing: Monthly mean normal-year wind stress forcing

Time stepping: Split-explicit with long/short time step of 600s/24s when using 15 km mesh.

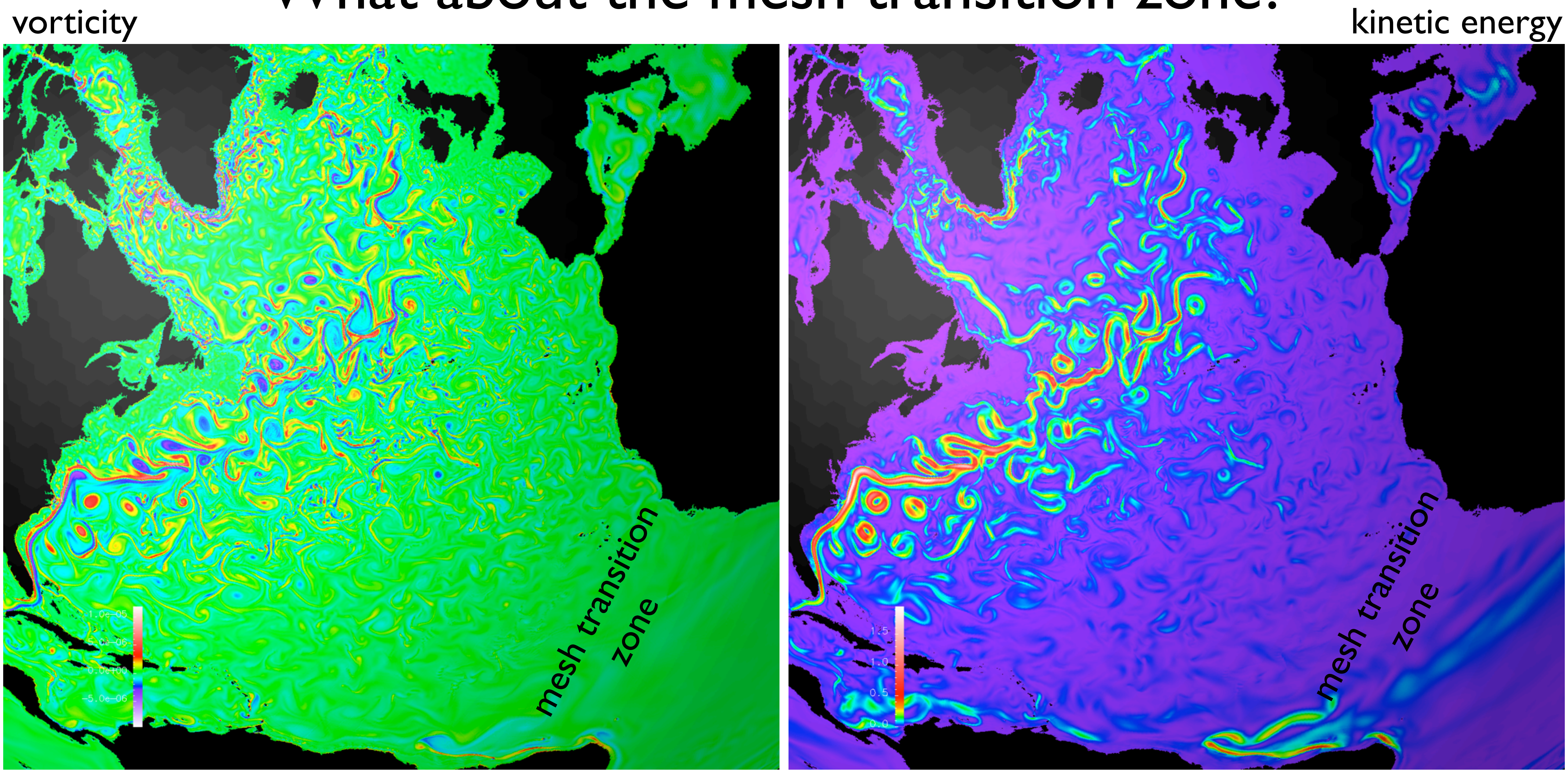
Vertical Discretization: z* with 40 vertical levels (no partial bottom cells)
Vertical Mixing: Solved implicitly with Pacanowski and Philander closure

Horizontal Discretization: C-grid on Voronoi-cell control volumes
Horizontal Mixing, Del4: biharmonic mixing on velocity as visc_0 * (dx/dx_0)^3
visc0 = 5.0e10 m4/s, dx_0 = 15 km
Horizontal Mixing, Del2: Leith enstrophy-cascade turbulence closure on velocity
(NOTE: No mesoscale eddy parameterization in used.)

Transport: 3rd-order polynomial reconstruction with FCT, i.e. monotone transport.
(Tracers written in flux form with local conservation guaranteed.)

Same executable used for x1.15km, x5.NA.75km_15km and x5.NA.37.5km_7.5km simulations. The only difference between simulations is the horizontal mesh and time step.

What about the mesh transition zone?



We have sufficient evidence in shallow-water, 3D atmosphere and 3D ocean systems to declare this a non-issue as far as the dynamics are concerned.

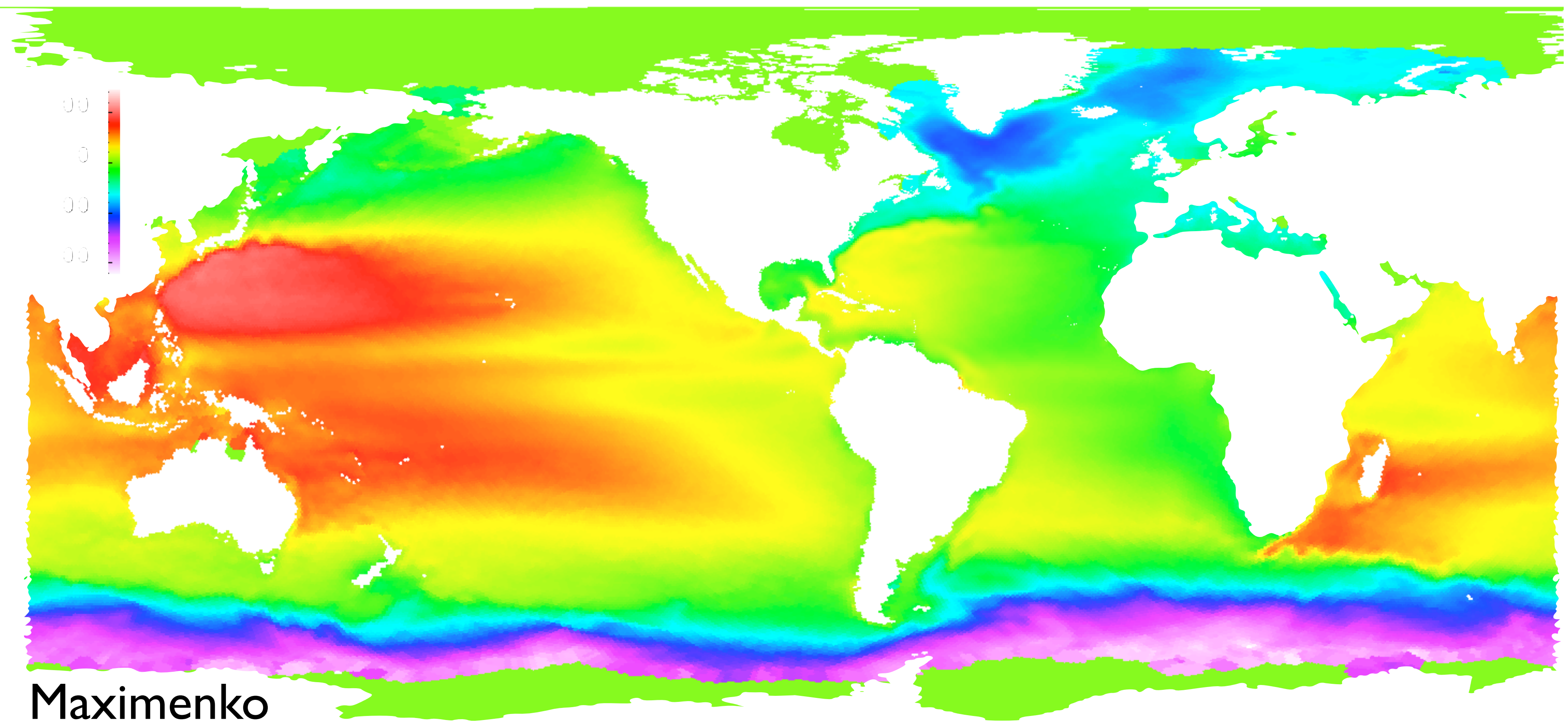
Sea-Surface Height
(+150 cm to -225 cm)

Subtropical gyres are too strong.

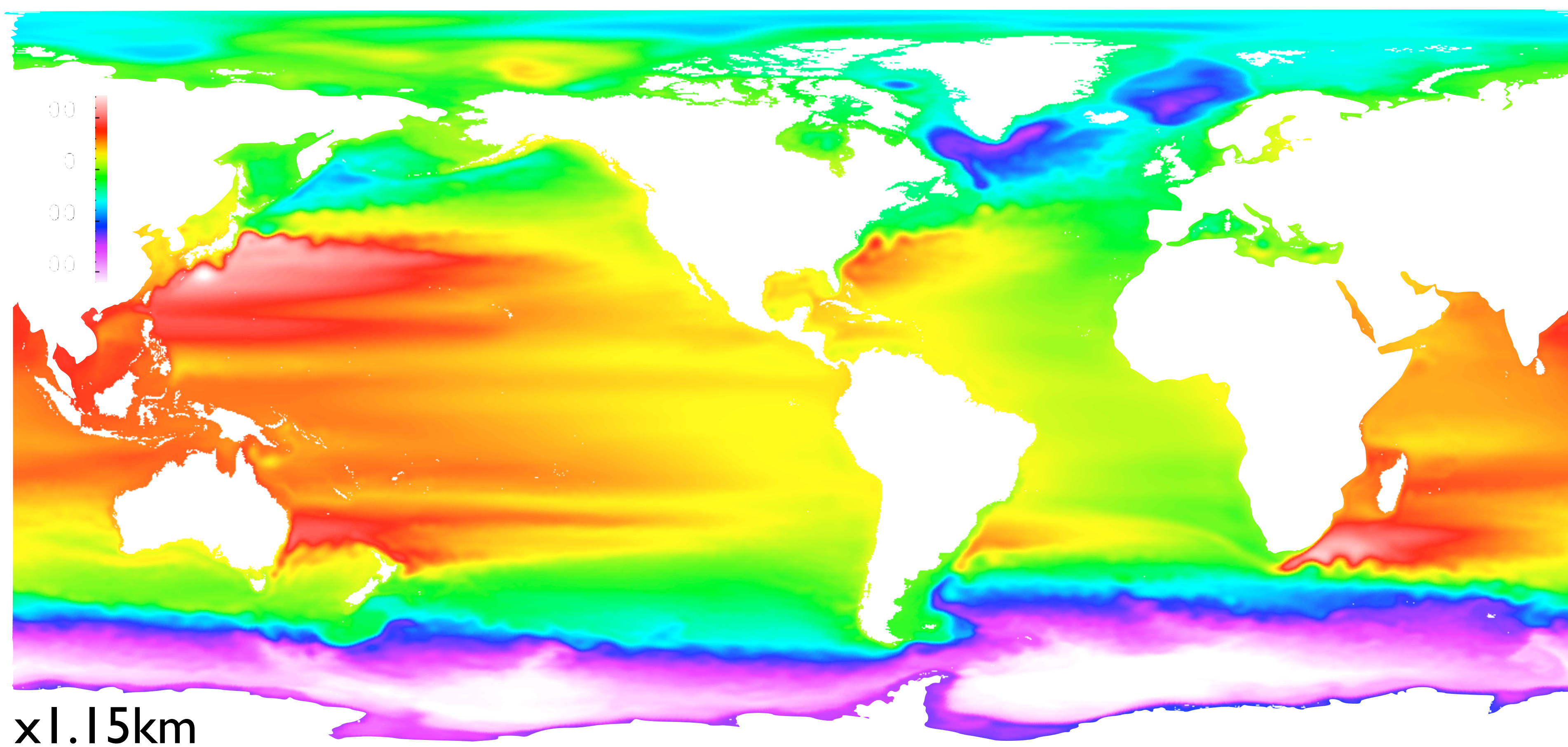
N Atlantic and N Pacific subtropical gyres shifted, O(100km), poleward (i.e. delayed separation).

N Atlantic subpolar gyre correct shape, but is also too strong.

Drake Passage volume transport is 158 +/- 7 Sv in x1.15km simulation.



Maximenko



x1.15km

SSH RMS

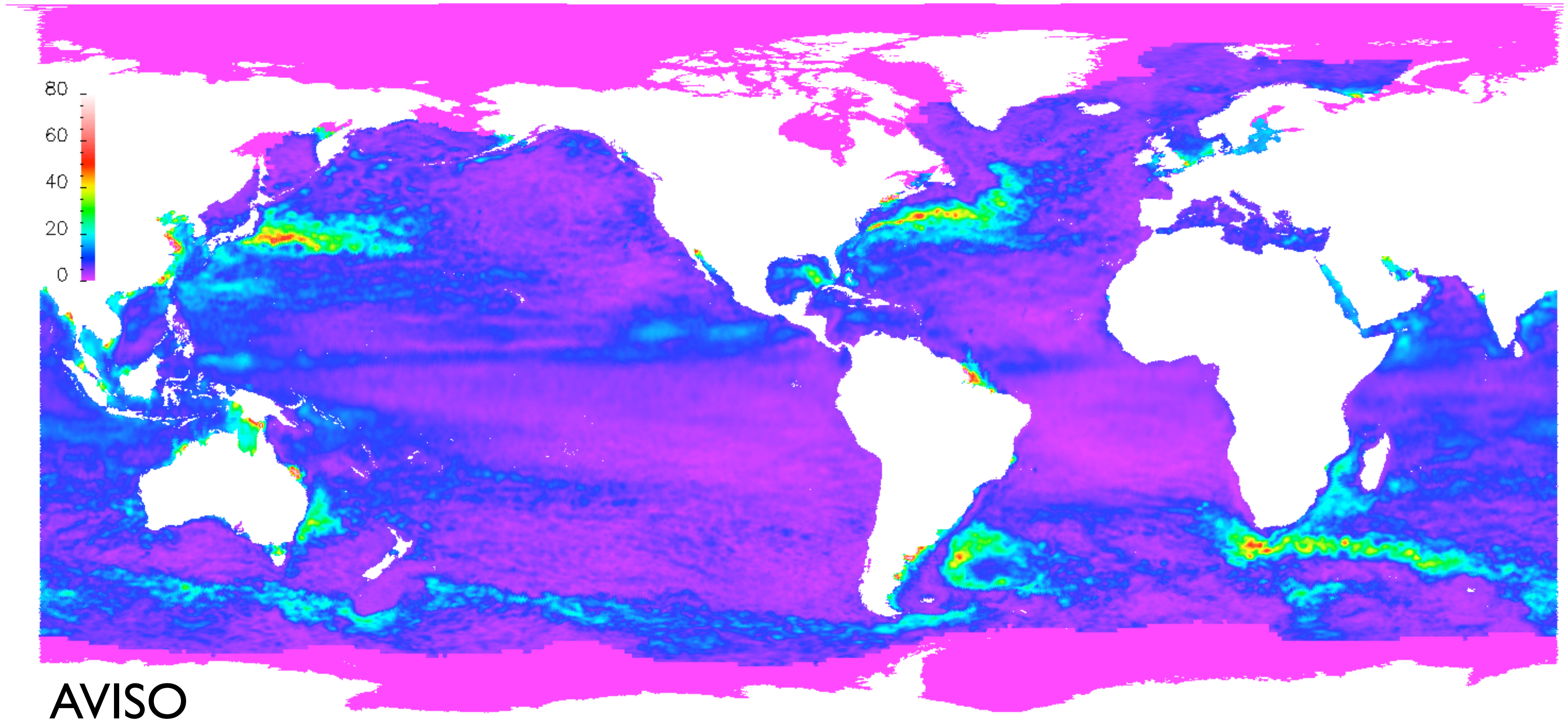
(0 cm to 80 cm)

Eddy activity is of the observed magnitude and structure. Model eddy activity generally too strong, sometimes by a factor of 2.

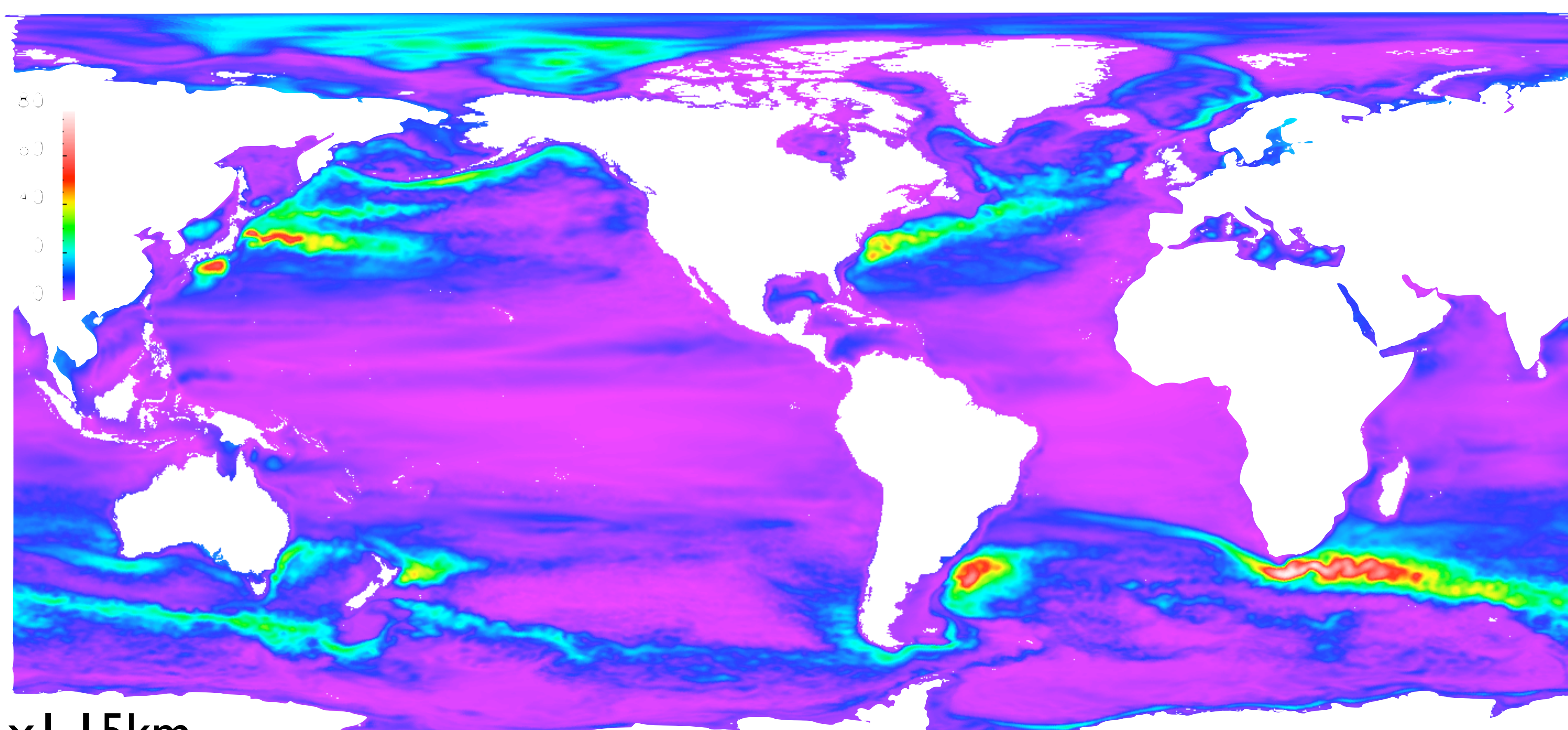
Separation of Gulf Stream and Kurishio is delayed, O(100km), and accompanied by too much variance.

Northwest Corner present with approximately correct position and amplitude.

Agulhas Rings are present, but too regular with a track slightly equatorward of observations.



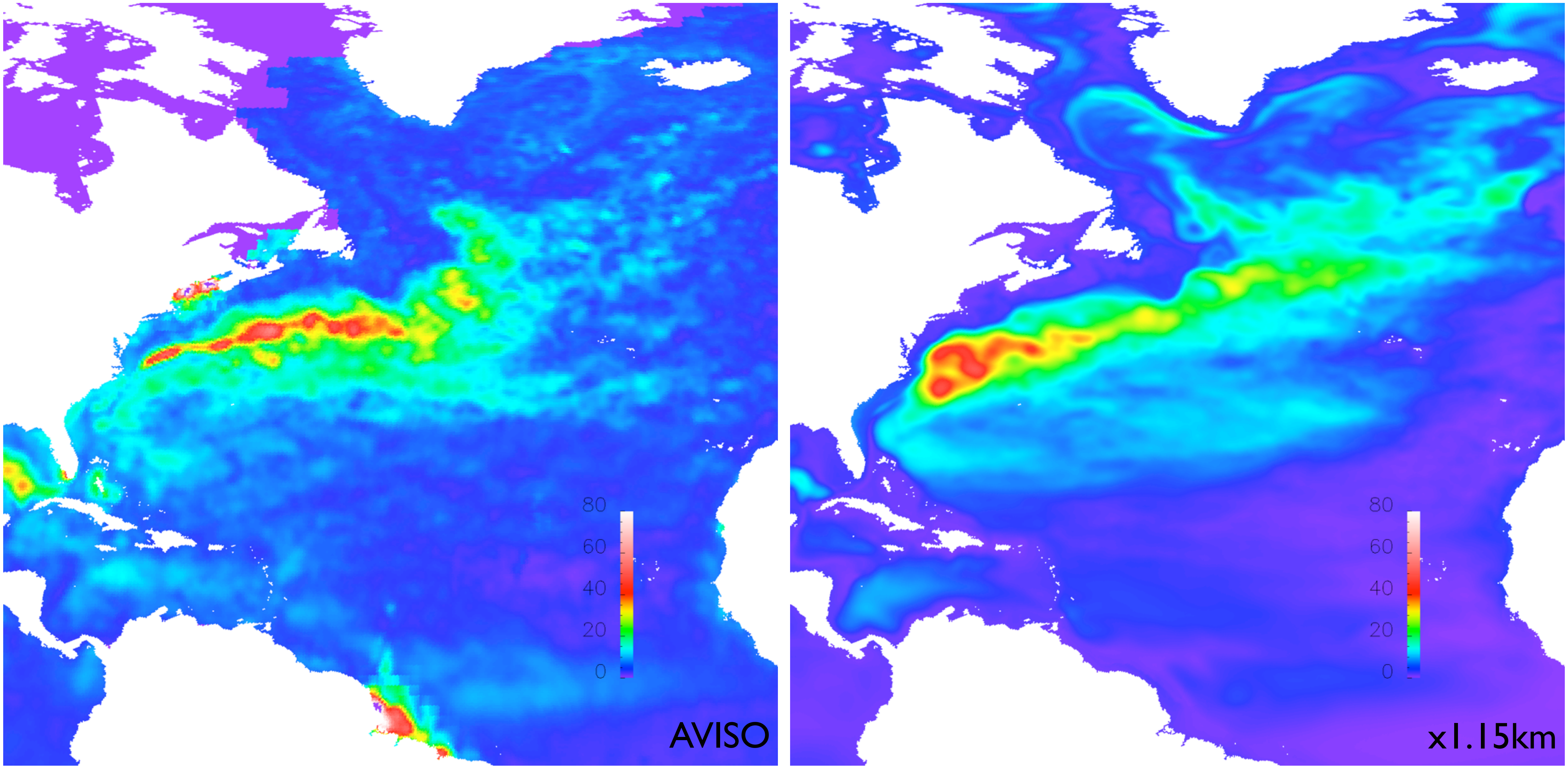
AVISO



x1.15km

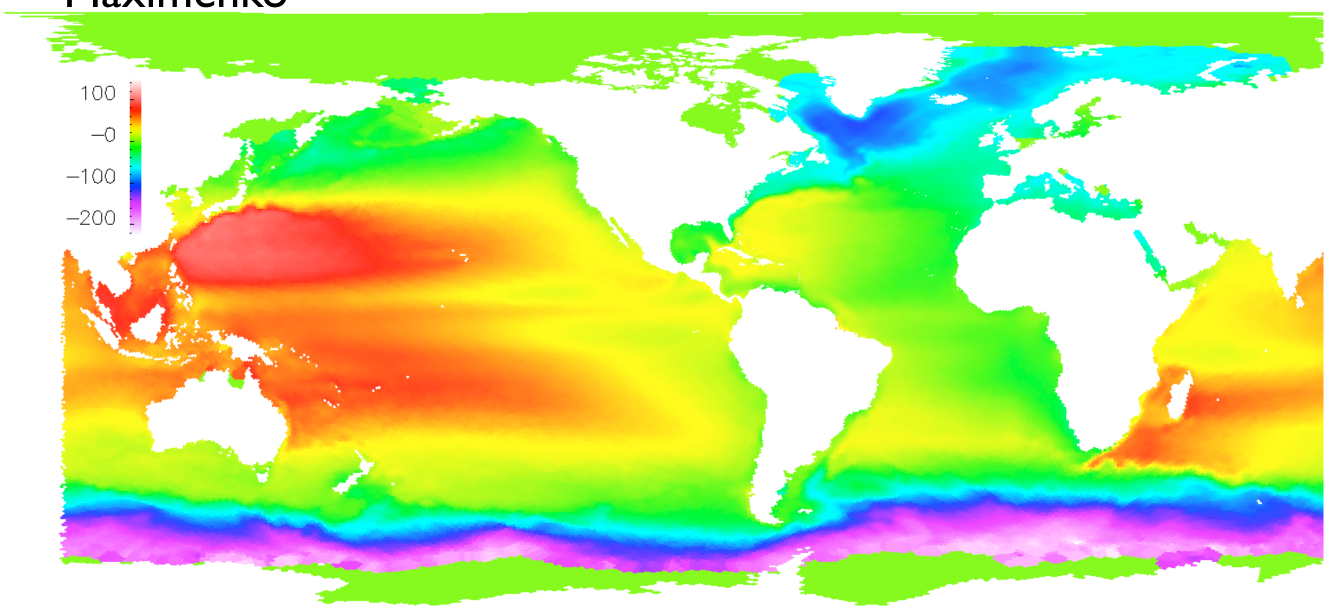
SSH RMS

(0 cm to 80 cm)

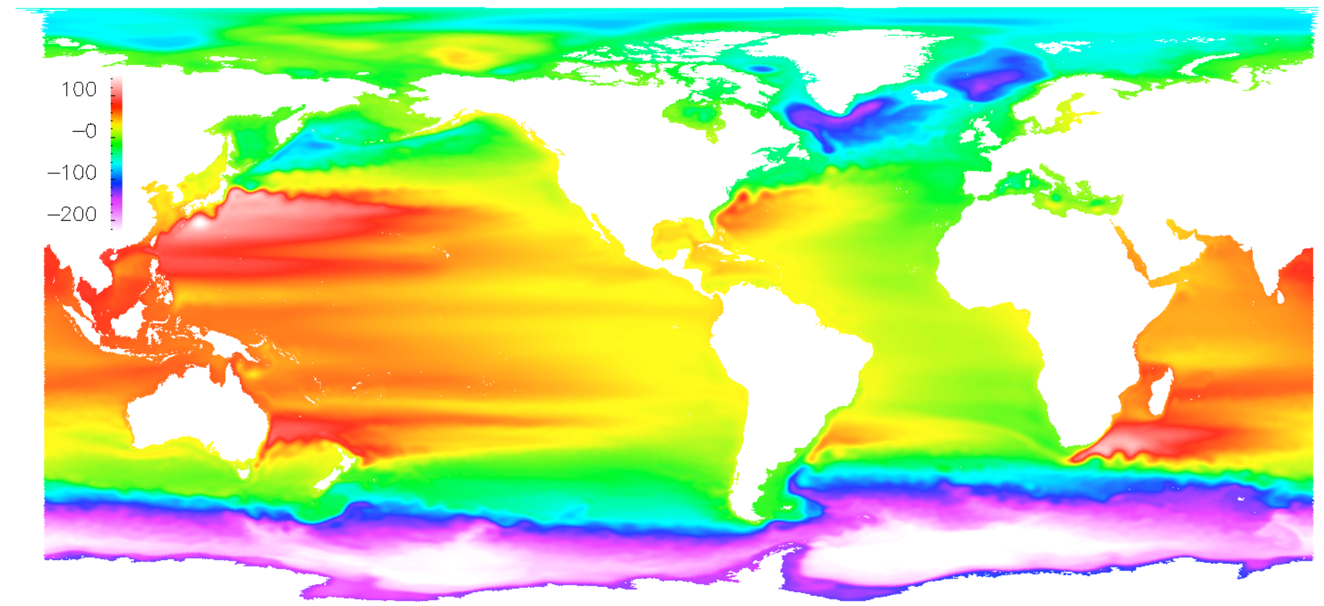


Sea-Surface Height
(+150 cm to -225 cm)

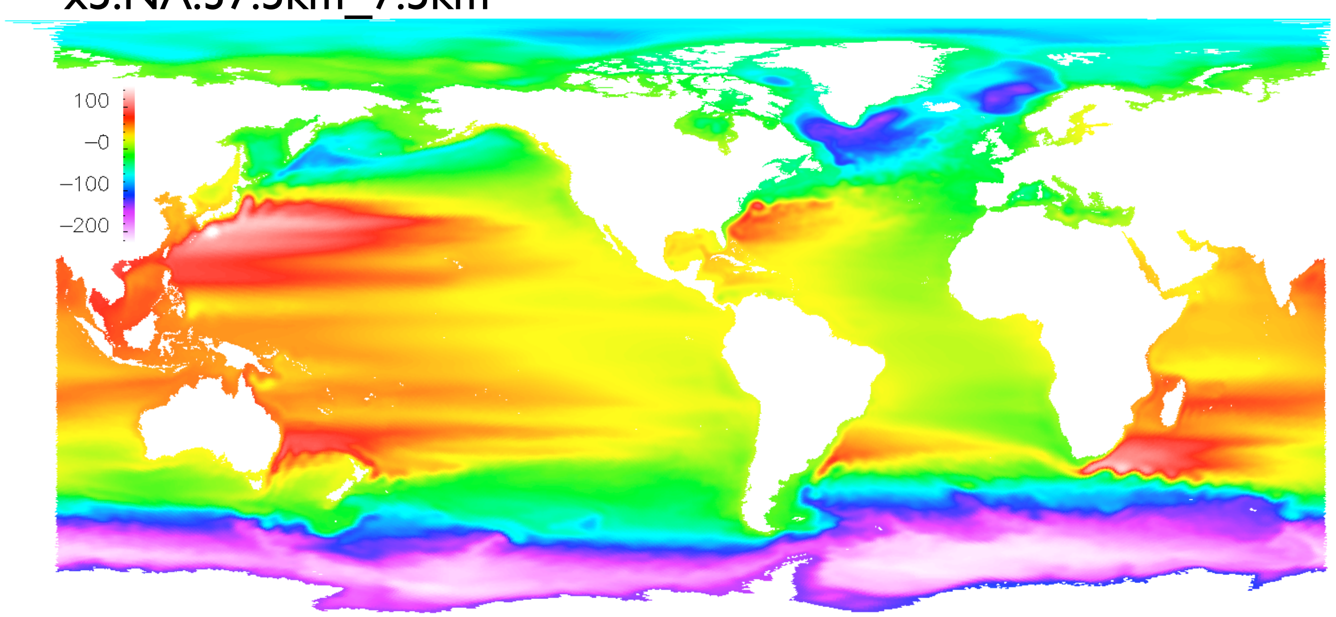
Maximenko



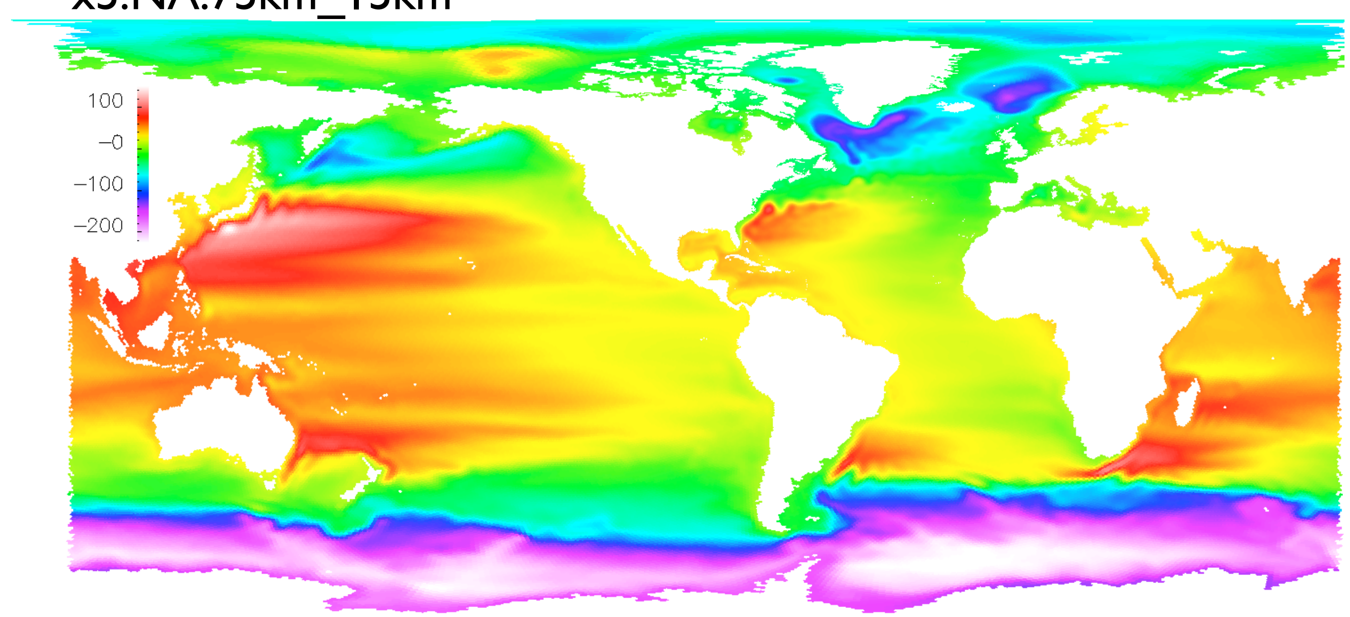
x1.15km



x5.NA.37.5km_7.5km



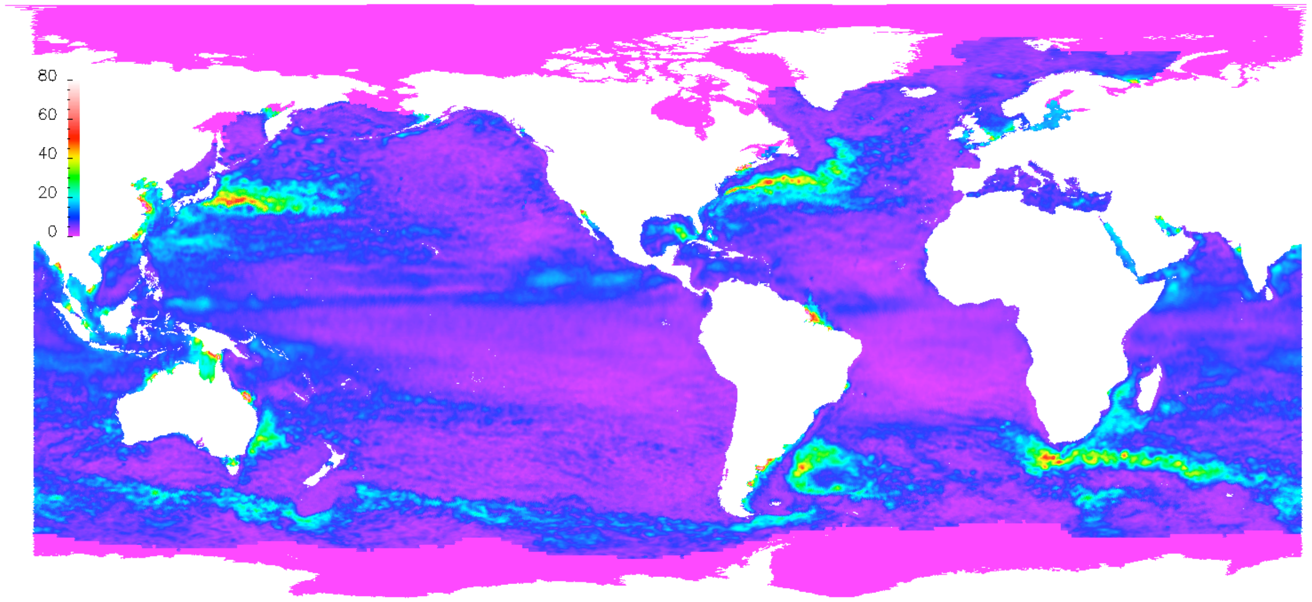
x5.NA.75km_15km



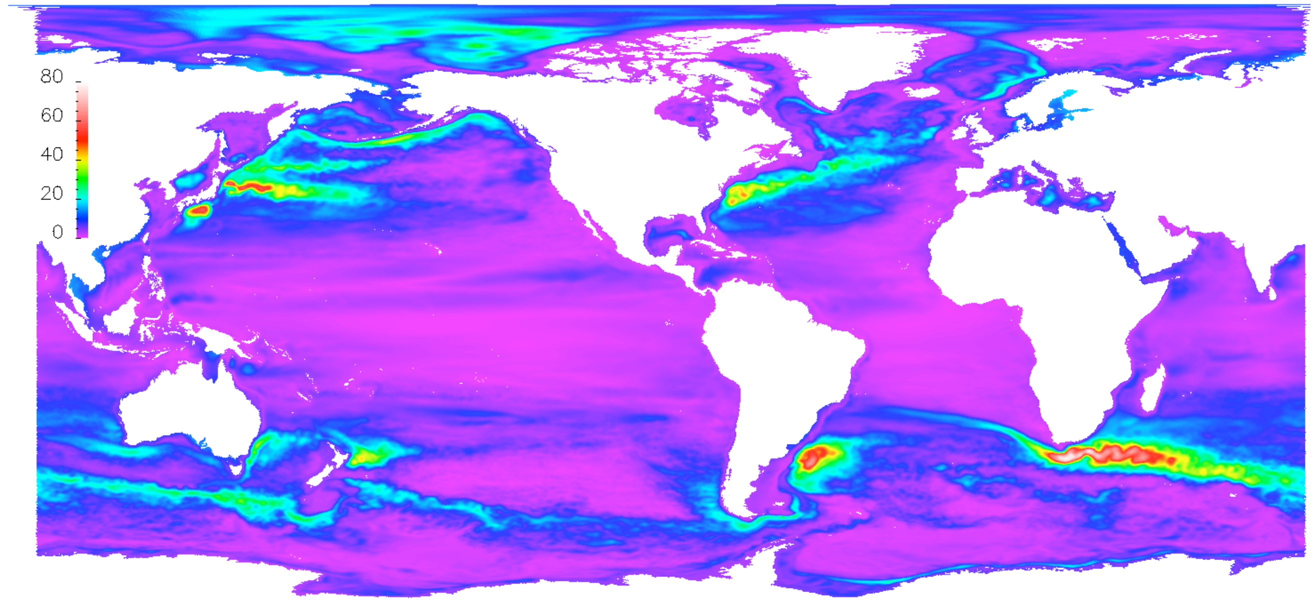
SSH results are largely insensitive to resolution.

SSH RMS
(0 cm to 80 cm)

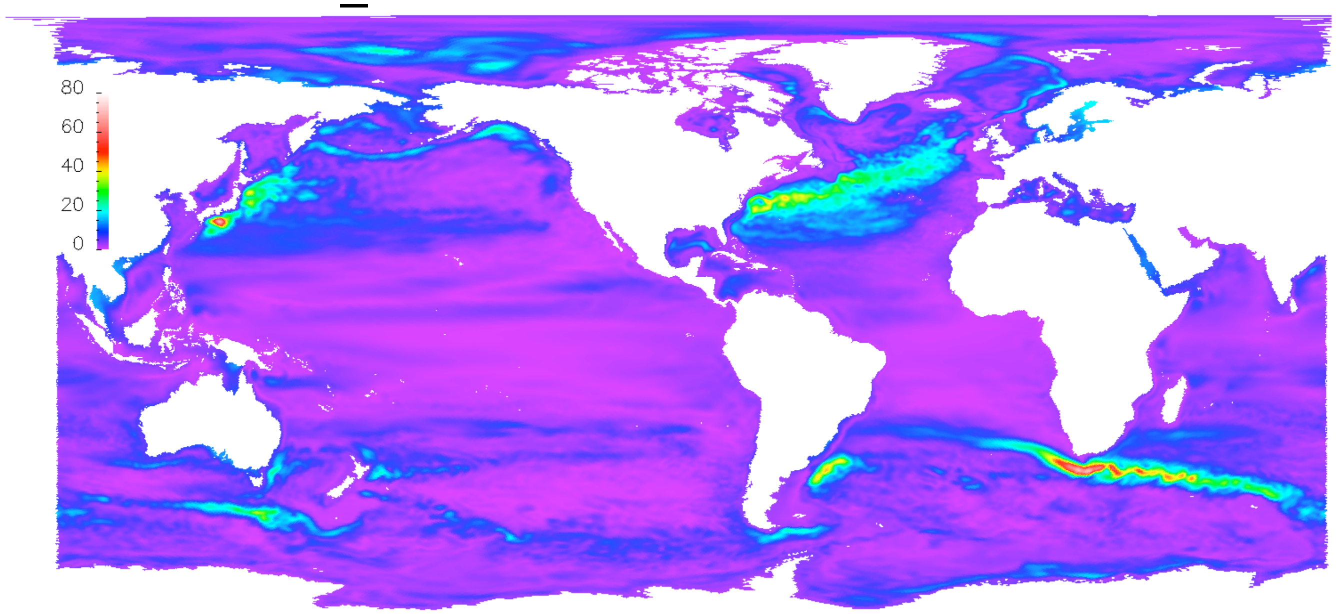
AVISO



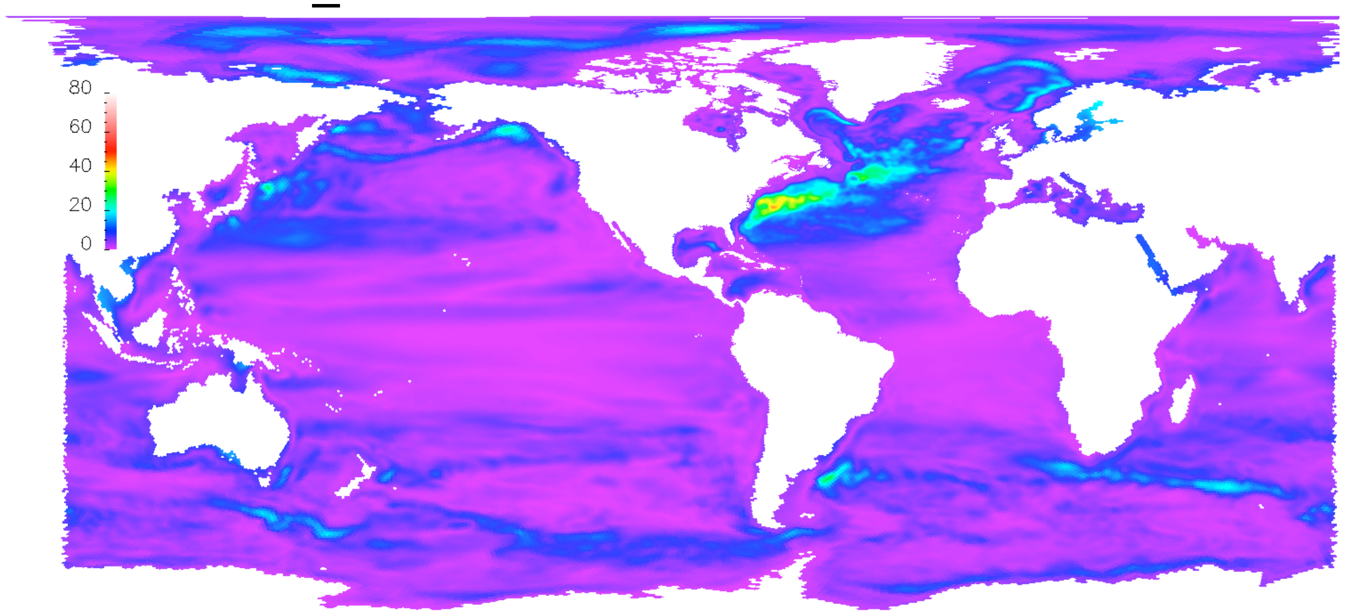
x1.15km



x5.NA.37.5km_7.5km

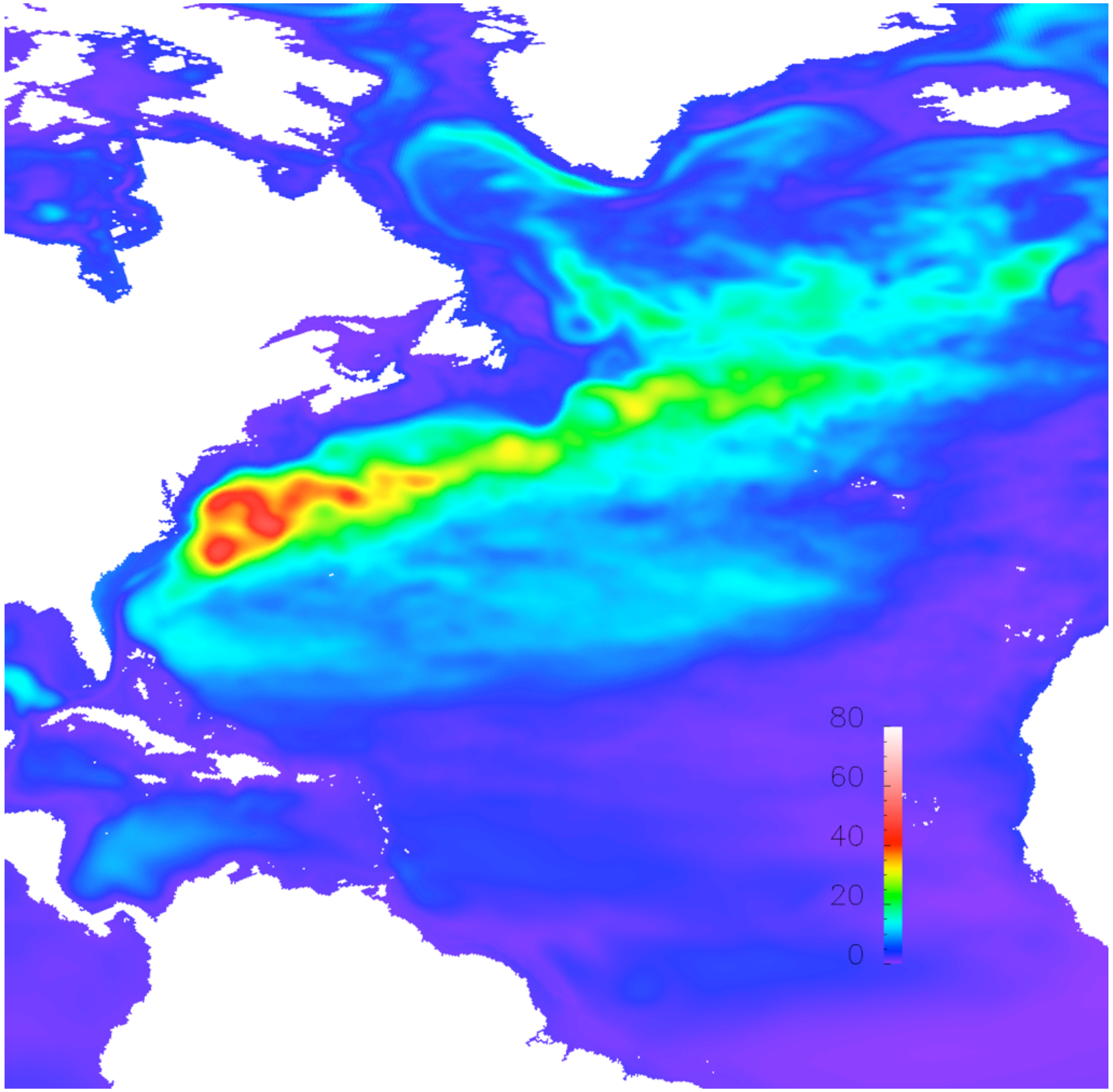


x5.NA.75km_15km

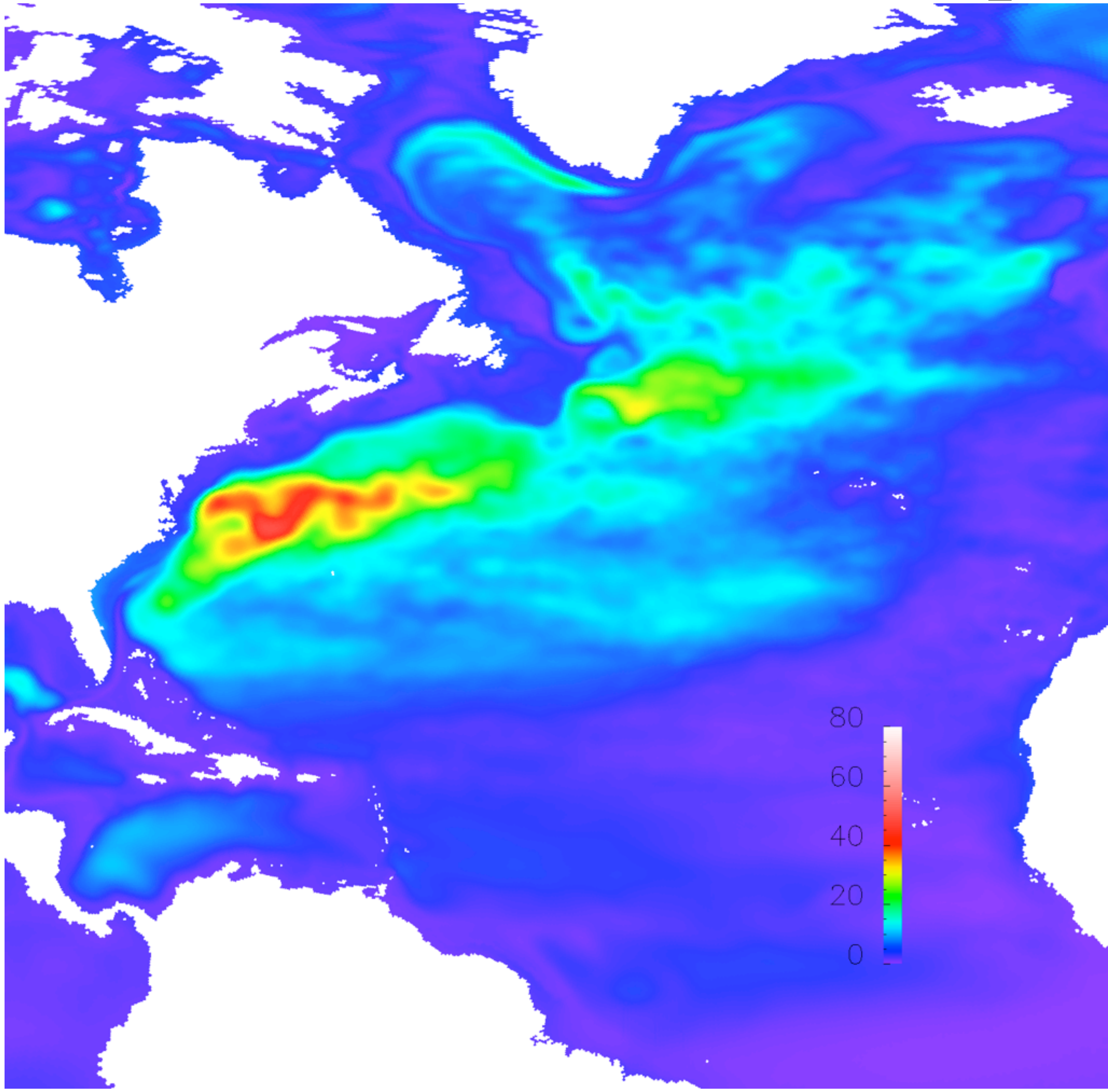


SSH RMS
(0 cm to 80 cm)

x1.15km



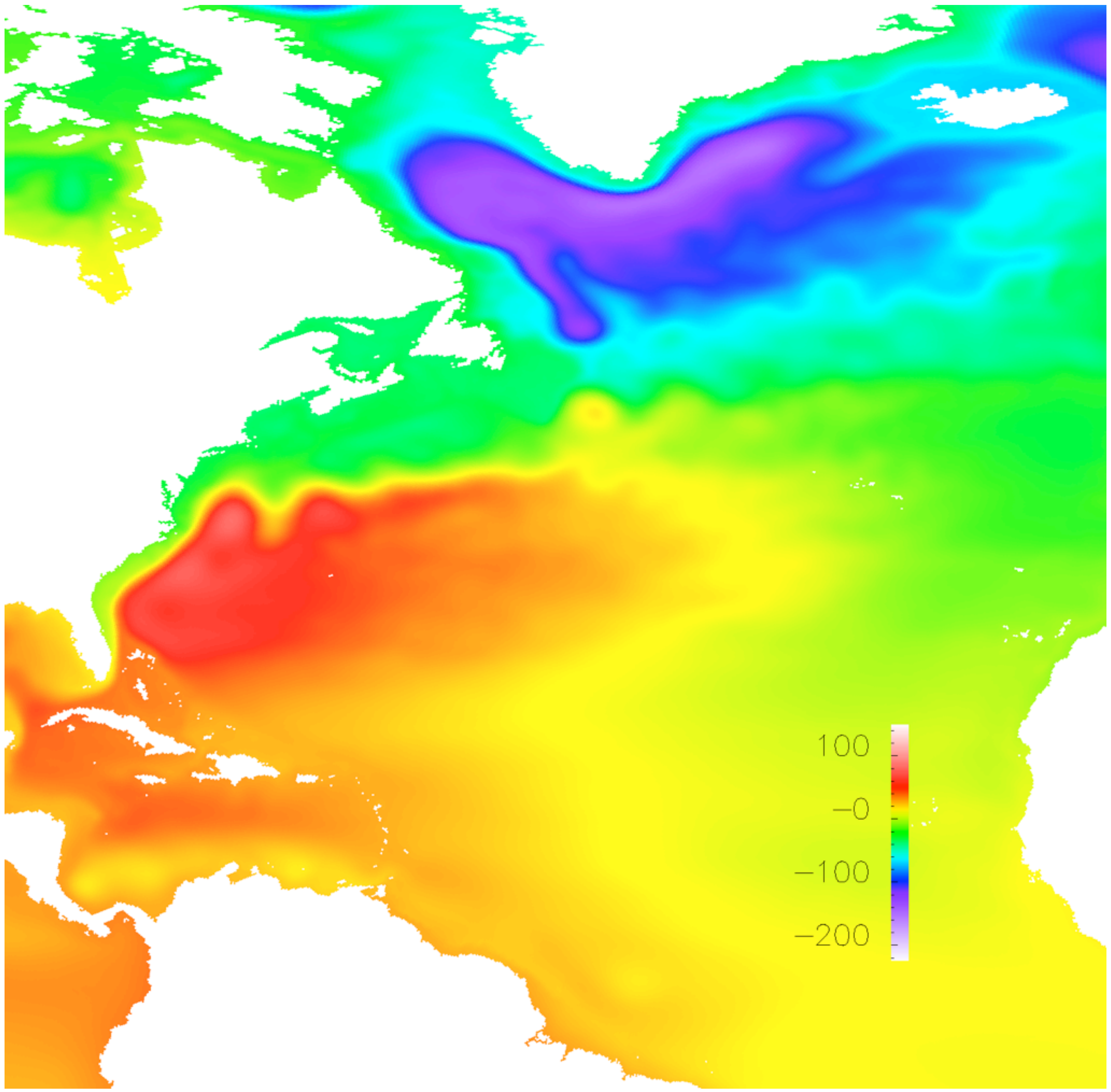
x5.NA.75km_15km



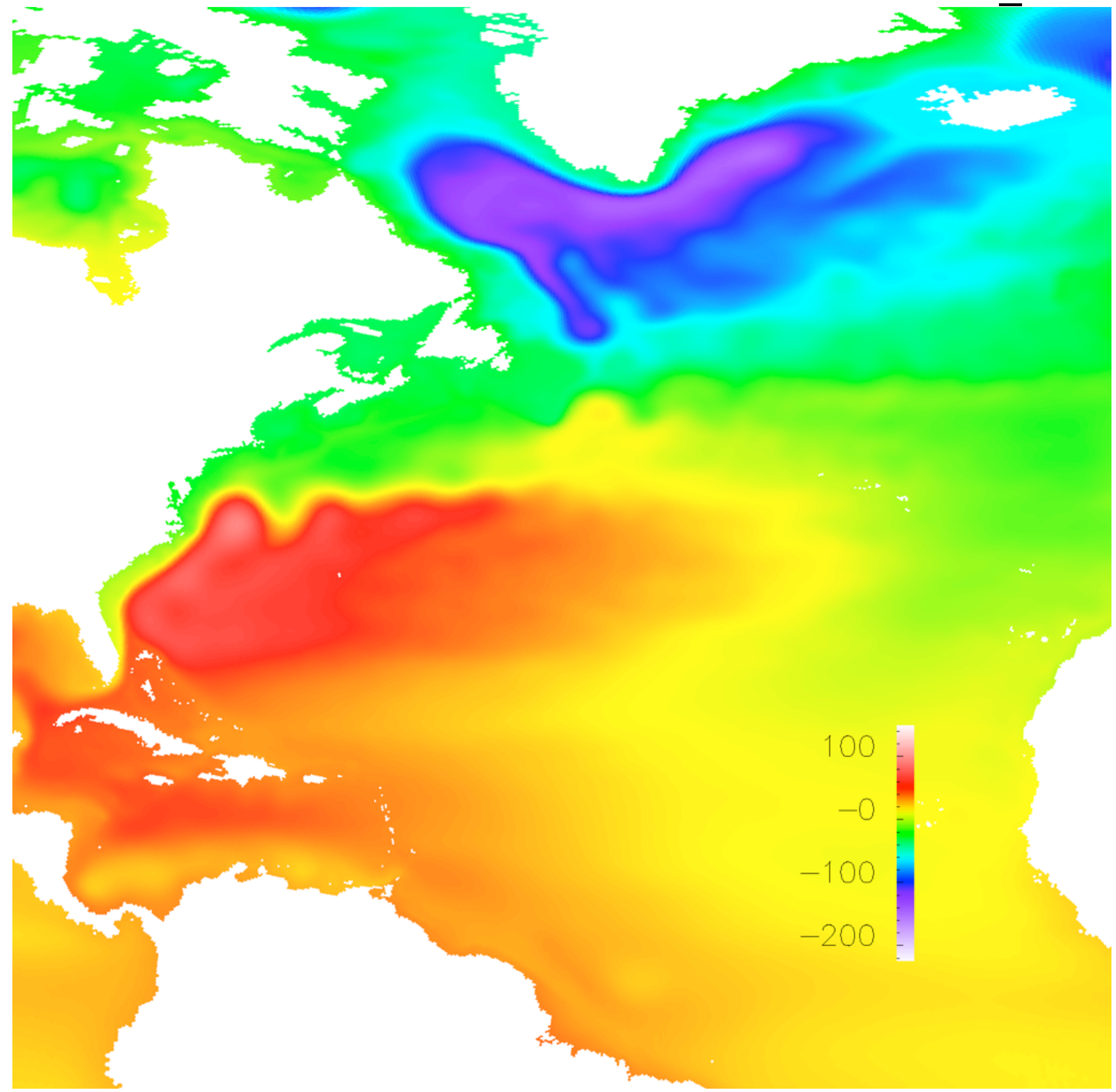
Whether using 15 km resolution everywhere or 15 km in just the NA, the eddy activity in the NA is virtually identical.

Sea-Surface Height
(+150 cm to -225 cm)

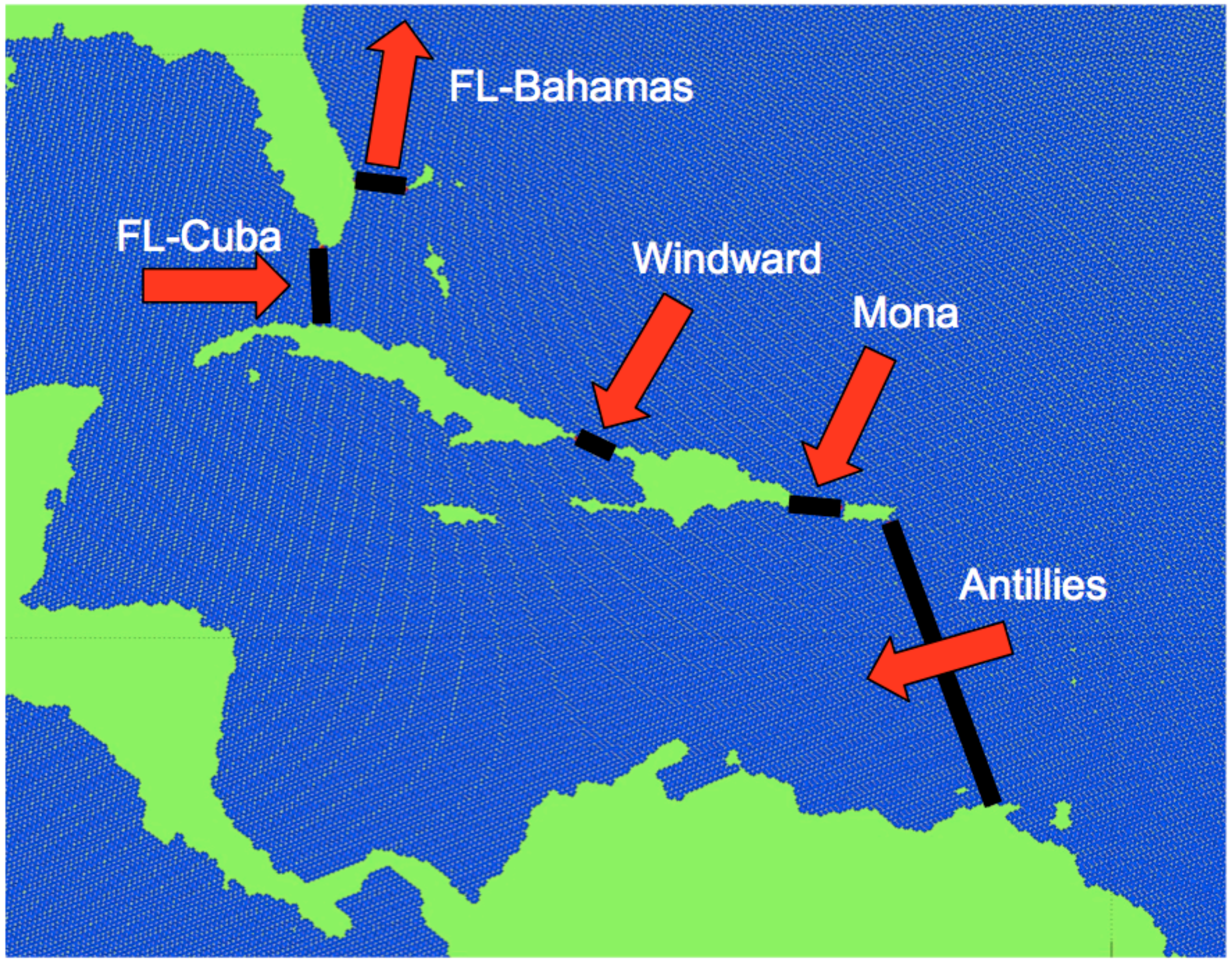
x1.15km



x5.NA.75km_15km



Whether using 15 km resolution everywhere or 15 km in just the NA, the mean gyre structure in the NA is virtually identical.



Simulation	Antillies Inflow	Mona Passage	Windward Passage	Florida-Cuba	Florida-Bahamas
x1.15km mean ± std dev, Sv	7 ± 2	1 ± 0.5	7 ± 2	14 ± 2	16 ± 2
x5.NA.75km_15km	7 ± 2	1 ± 0.5	6 ± 2	13 ± 2	16 ± 2
x5.NA.37.5km_7.5km	10 ± 2	1 ± 0.5	5 ± 2	16 ± 2	21 ± 2
POP 0.1 degree	22 ± 3	0 ± 2	-3 ± 3	NA	21 ± 2
observations mean ± error, Sv	18 ± 5	3 ± 1	7 ± NA	28 ± 2	31 ± 2

← POP results based on different forcing

Back to our original questions ....

1. Is MPAS-O a viable approach to global ocean modeling?

Biases in gyre strength, eddy amplitude and separation structure are within the envelope of global, eddy-permitting ocean models that are forced via surface restoring and do not use partial bottom cells.

Back to our original questions ....

2. Can specific regions of the global ocean system be accurately simulated with local mesh refinement?

At least for SSH and SSH RMS in the North Atlantic, the answer is unequivocal. Furthermore, the degree of similarity would suggest that the ability of the global, variable-resolution approach to quantitatively reproduce global, uniform-resolution results at the basin-scale extends much farther than SSH and SSH RMS.

Where to next?

Write paper. (whole team)

Couple into CESM so that can we easily produce simulations with high-frequency, fluxed-based forcing. (D. Jacobsen)

Implement a mesoscale eddy parameterization. (Q. Chen)

Evaluation/Intercomparison of z-level, z-star, z-tilde vertical coordinate. (M. Petersen)

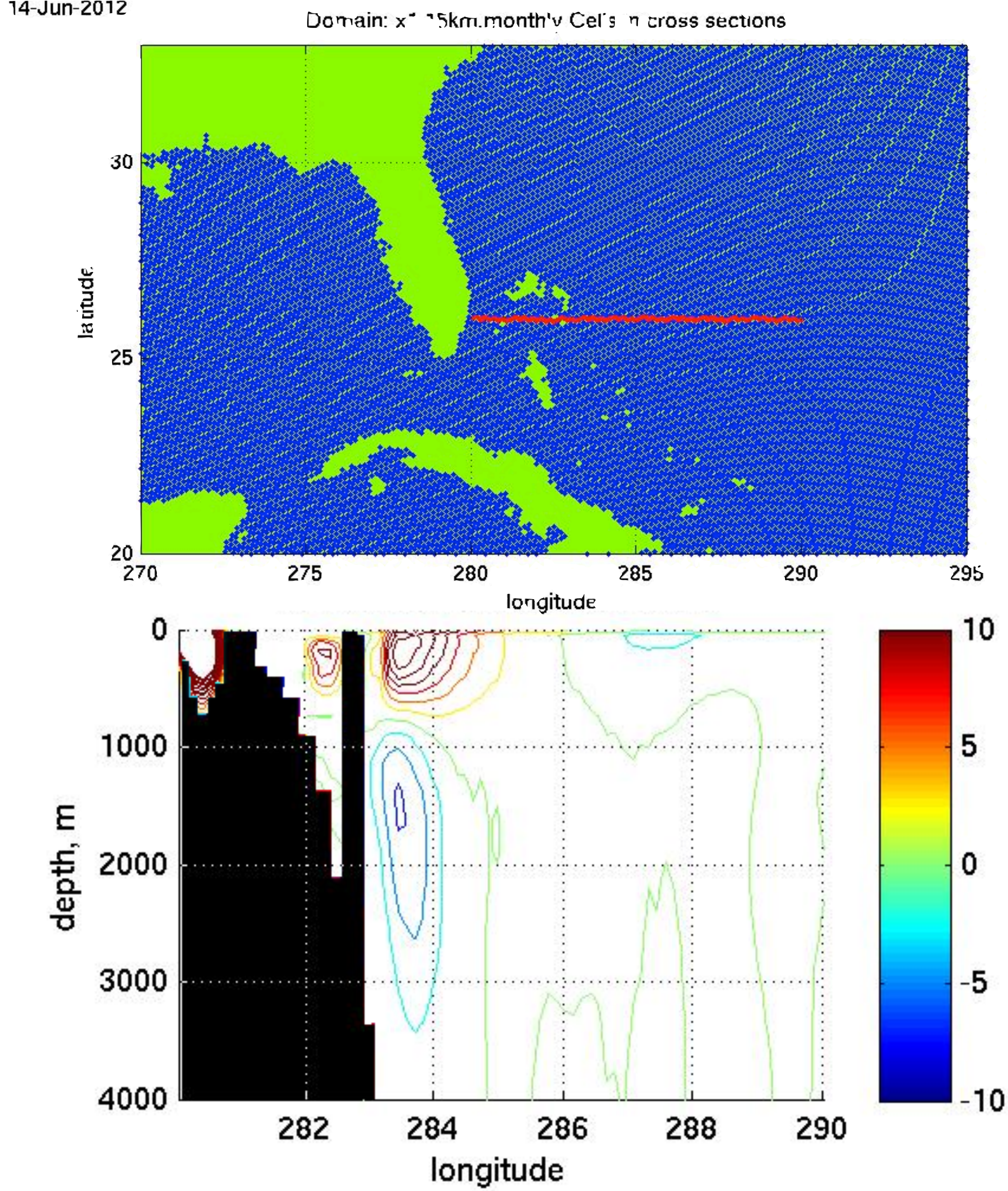
Work with NCAR and GFDL to develop an updated, modular KPP (T. Ringler)

Set-up a similar study in order to assess the tropical dynamics of MPAS-O. (T. Ringler)

See talk by Doug Jacobsen, SEWG, Wed@8:30am for discussion of performance, coupling to CESM and distribution.

See poster by Mark Petersen for a closer look at the results shown here, more information on the analysis package and model performance.

Thanks!


14-Jun-2012
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