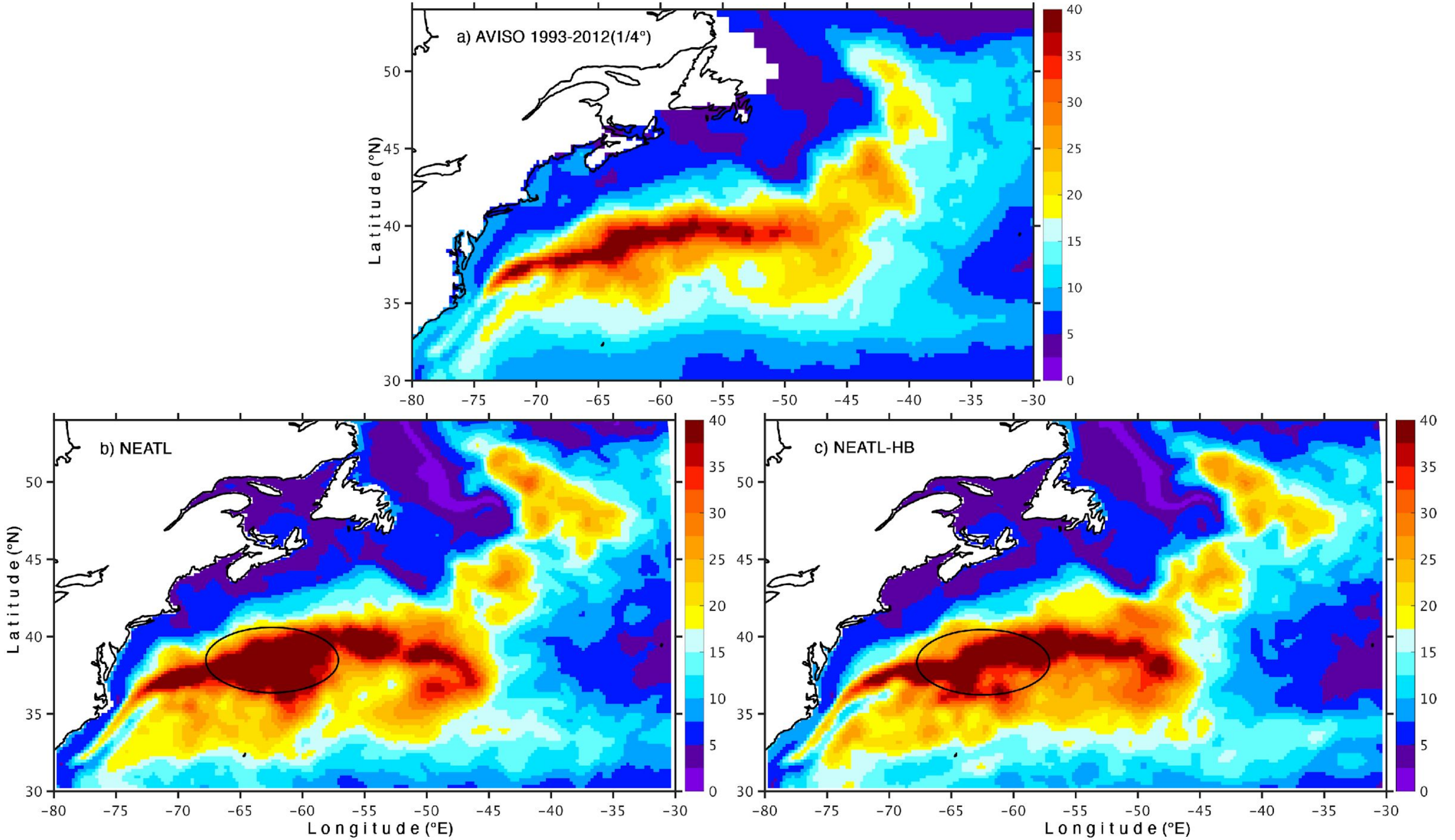
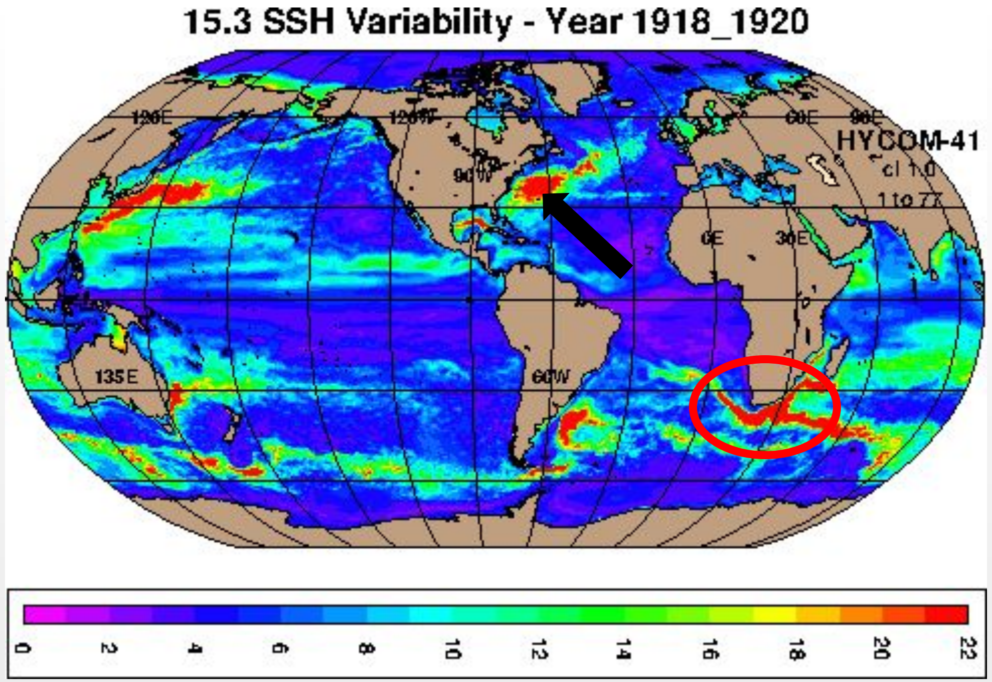
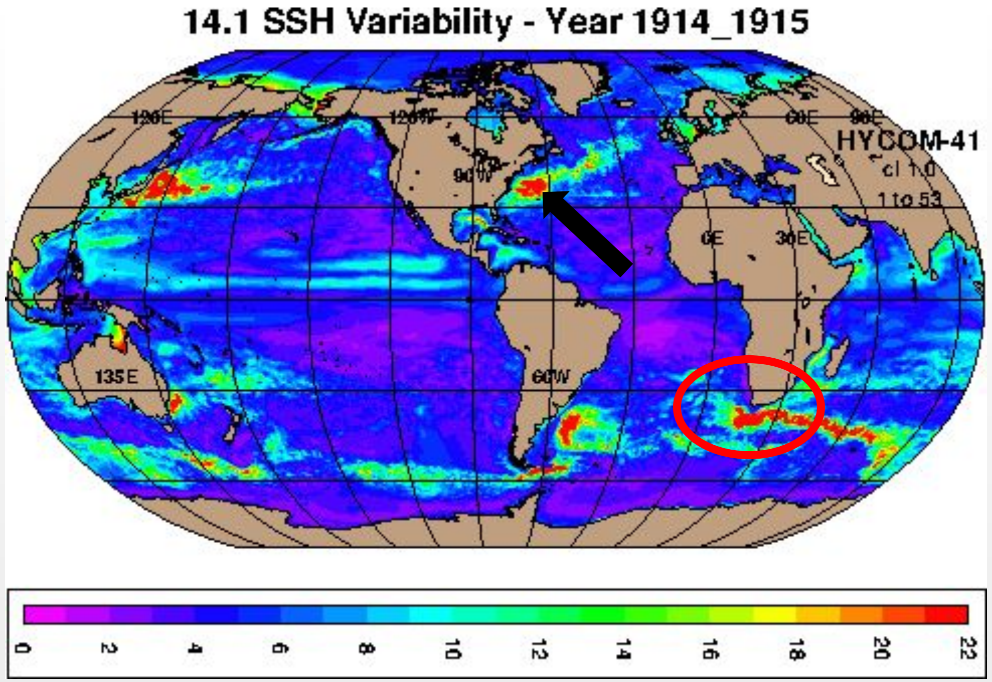
Impact of high-resolution bathymetry on Gulf Stream in 1/50° North Atlantic HYCOM



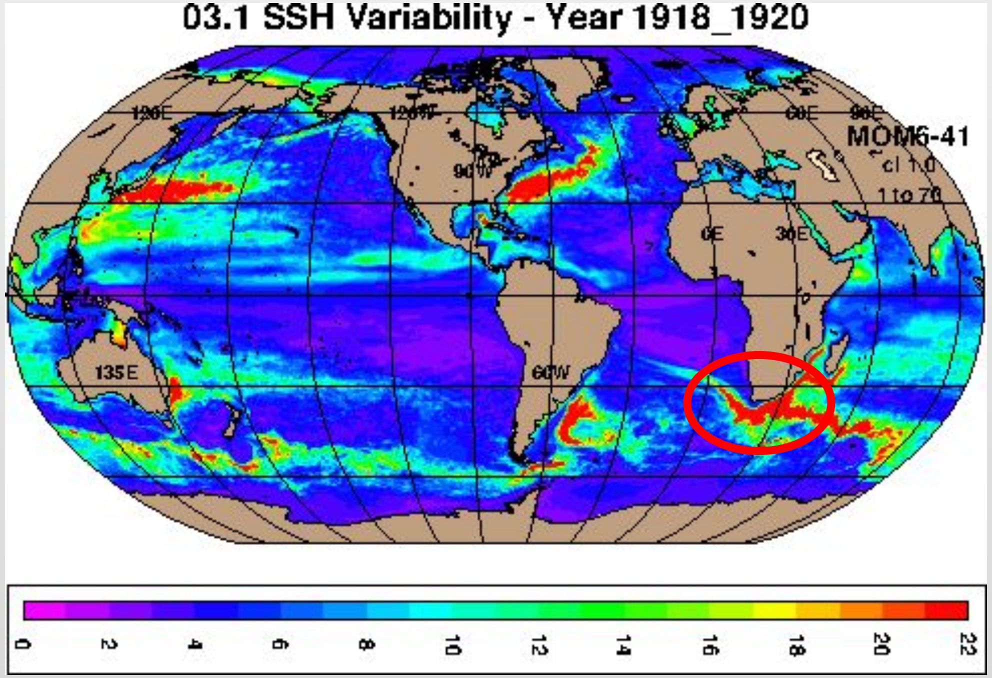
Random thoughts for the OceanPredict coupled TT

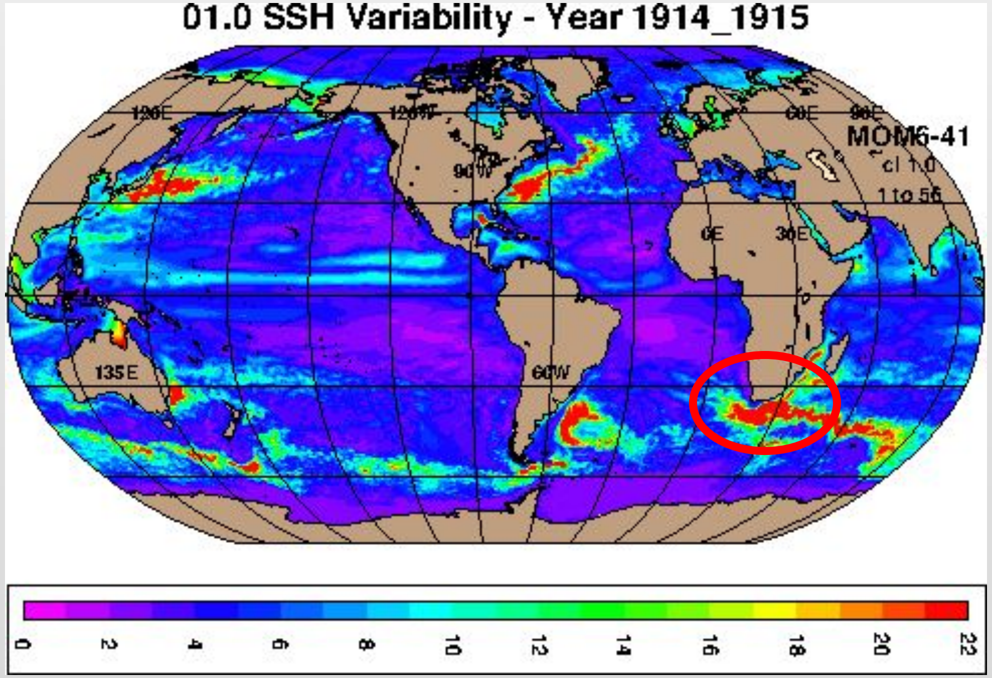
- **HYCOM 1/50^{o} North Atlantic simulations show a level of EKE comparable to observations, but the wind stress was computed from atmospheric wind velocities only.**
- **One should however take into account the wind shear when computing the stress. i.e., $U_{atmosphere}-U_{ocean}$. This results into an eddy-killing effect and a decrease in EKE by 30%. It also does not take into account ocean-atmosphere feedback (Renault et al. , 2019).**
- **<u>Overarching questions</u>: Can ocean-only model configuration provide accurate forecast without any atmospheric feedback? At what ocean horizontal resolution do we have the right amount of EKE?**


15.3 SSH Variability - Year 1918_1920
HYCOM-41
cl 1.0
1 to 77
120E
120W
90W
60E
90E
0E
30E
135E
60W
0 2 4 6 8 10 12 14 16 18 20 22


14.1 SSH Variability - Year 1914_1915
HYCOM-41
cl 1.0
1 to 53
120E
120W
90W
60E
90E
0E
30E
135E
60W
0 2 4 6 8 10 12 14 16 18 20 22

HYCOM


03.1 SSH Variability - Year 1918_1920
MOM6-41
cl 1.0
1 to 76
120E
120W
90W
60E
90E
0E
30E
135E
60W
0 2 4 6 8 10 12 14 16 18 20 22


01.0 SSH Variability - Year 1914_1915
MOM6-41
cl 1.0
1 to 56
120E
120W
90W
60E
90E
0E
30E
135E
60W
0 2 4 6 8 10 12 14 16 18 20 22

MOM6

Ocean prediction – one cannot neglect the ocean-atmospheric feedback

- Current: Use atmospheric forecasts – most often using absolute winds, significant reduction of EKE with relative winds
- Under consideration: Renault et al. (2019) parametrization, higher order operators
- Marine boundary layer implementation: Lemarie et al. (2021)
- Fully coupled DA in both atmosphere and ocean: US Navy 1/25°, ECMWF, MetOffice

Renault et al. (2019) show imprints of surface ocean current on the surface wind in satellite observations and atmosphere–ocean coupled models.

This implies that oceanic mesoscale eddies are losing kinetic energy to the atmosphere and conversely the atmosphere is rectified in the direction of surface oceanic currents, partly compensating the energy loss of the surface currents.

To represent this process in uncoupled ocean models, Renault et al. (2019) suggest two methods:

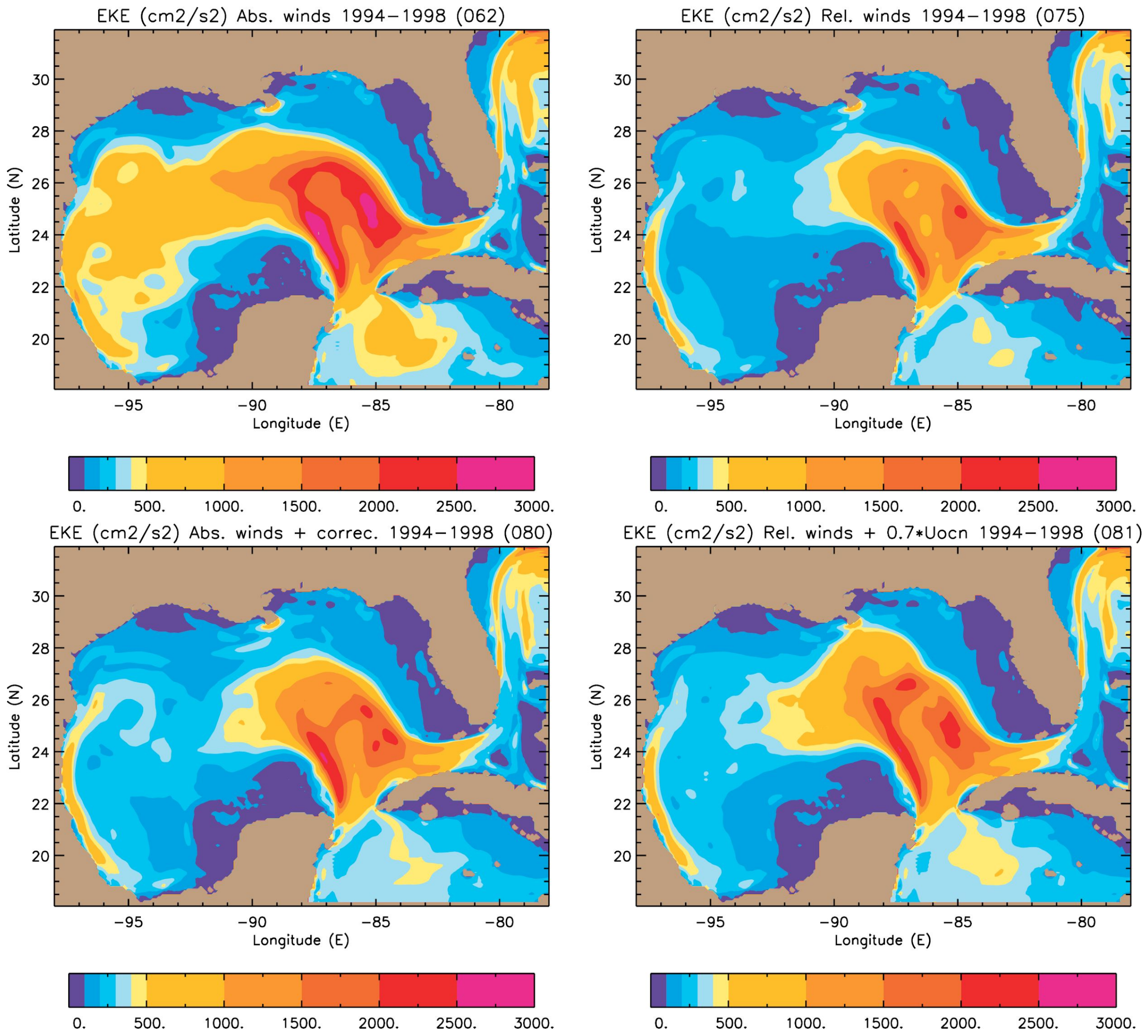
- **Correct the relative wind using a current-wind coupling coefficient s_w defined by $\Delta U = U_a - (1 - s_w) U_o$ with $s_w \approx 0.30$.**
- **Correct the surface stress using a current-stress coupling coefficient s_τ defined by $\tau = \tau_a + s_\tau U_o$ with $s_\tau = -2.9 \times 10^{-3}$ (Nm^{-4} s^2) $|U_a|$ + 0.013 (Nm^{-3}s).**

Test of Renault’s method for wind-stress (1994-1998)

(1/12°)

Absolute Winds

Relative Winds



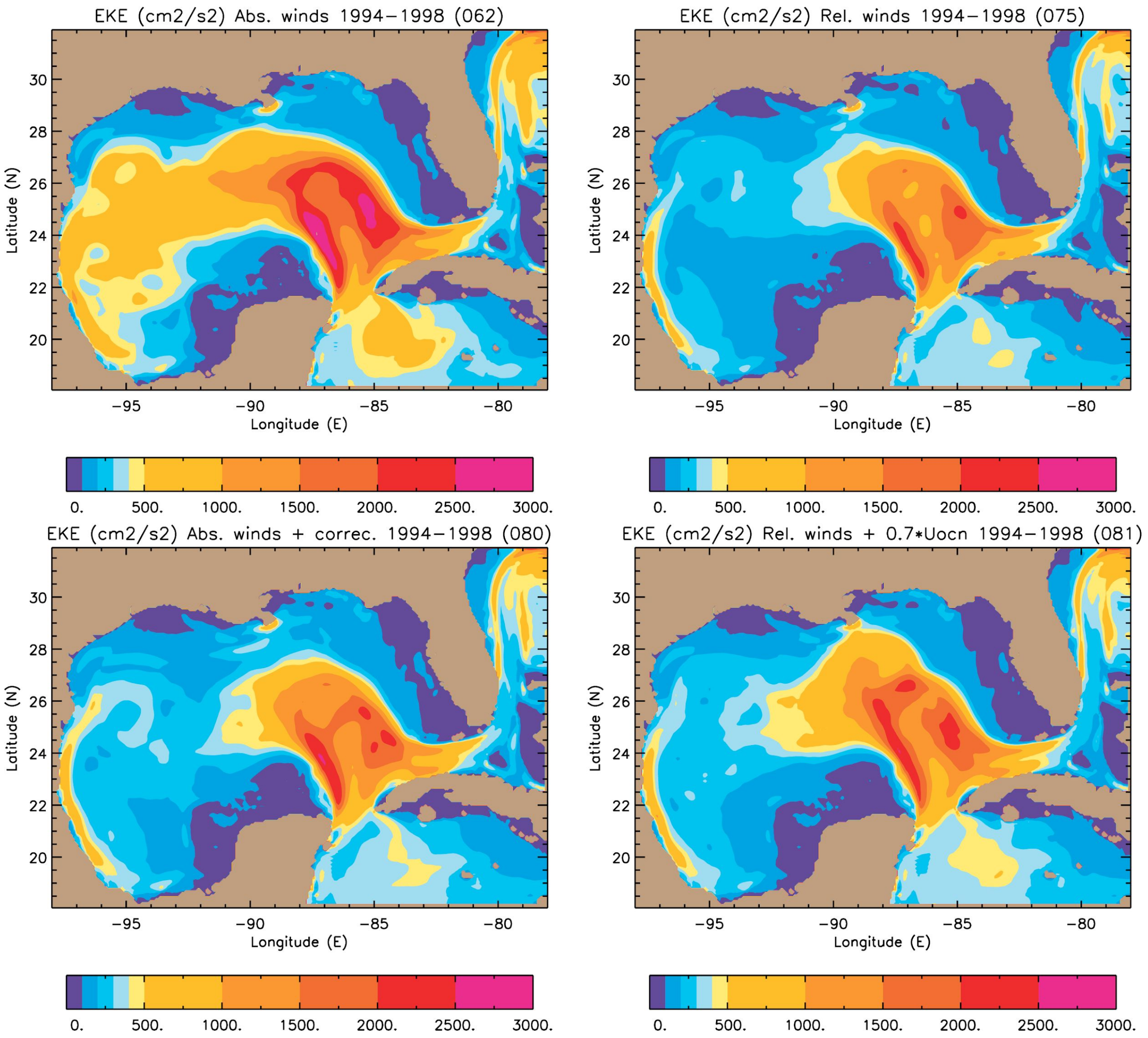
Absolute Winds
+ Correction

Relative Winds
+ 0.7*Uocn

Test of Renault’s method for wind-stress (1994-1998)

Absolute Winds

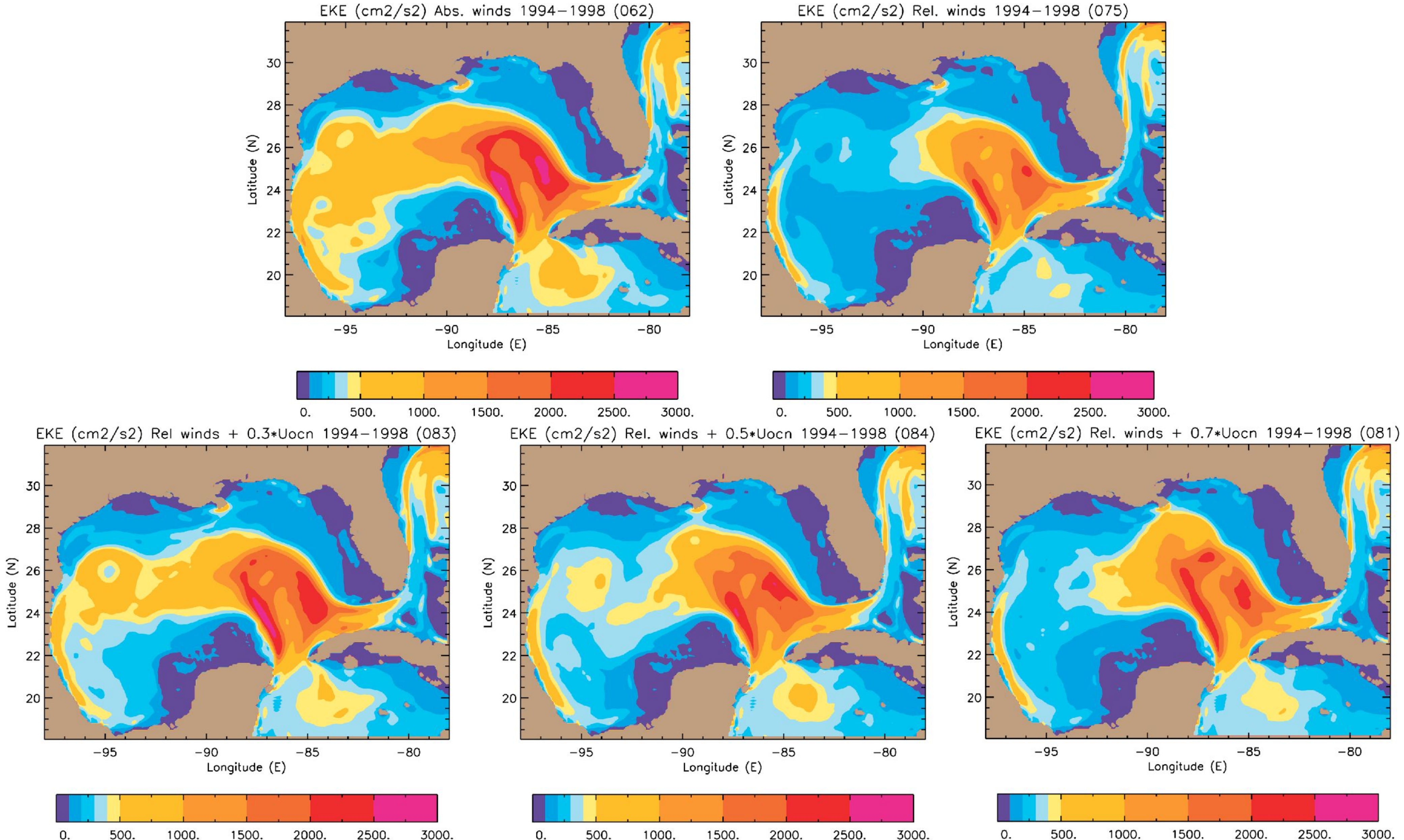
Relative Winds



Absolute Winds
+ Correction

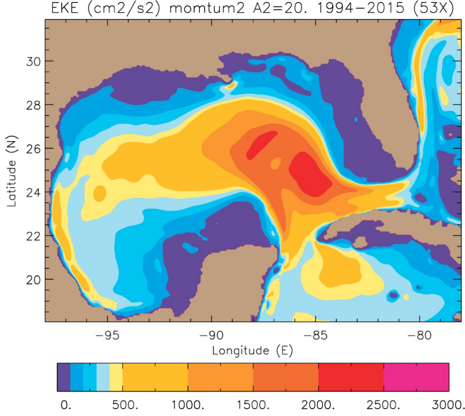
Relative Winds
+ 0.7*Uocn

EKE GOMb0.08: Sensitivity to Uocn



EKE GOMb0.04 : Sensitivity to Uocn

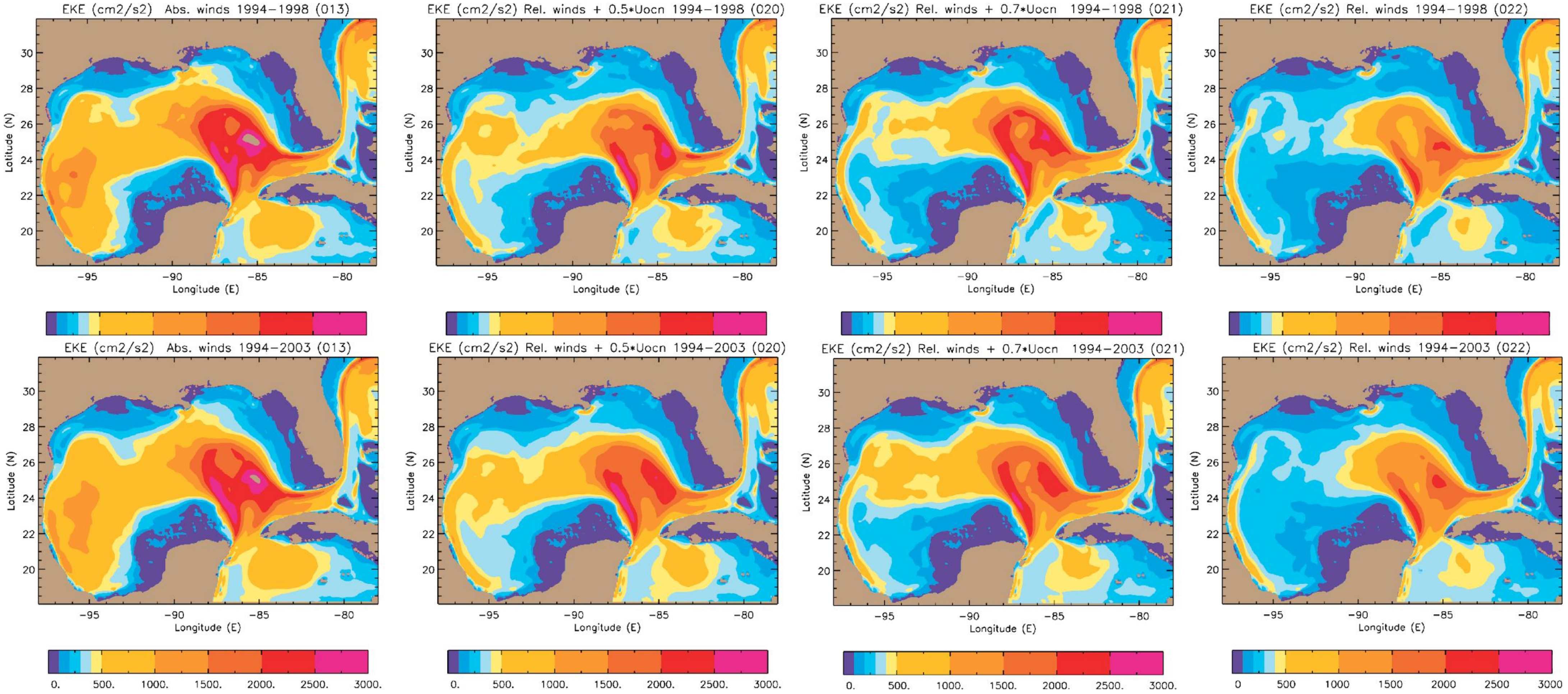
REANALYSIS



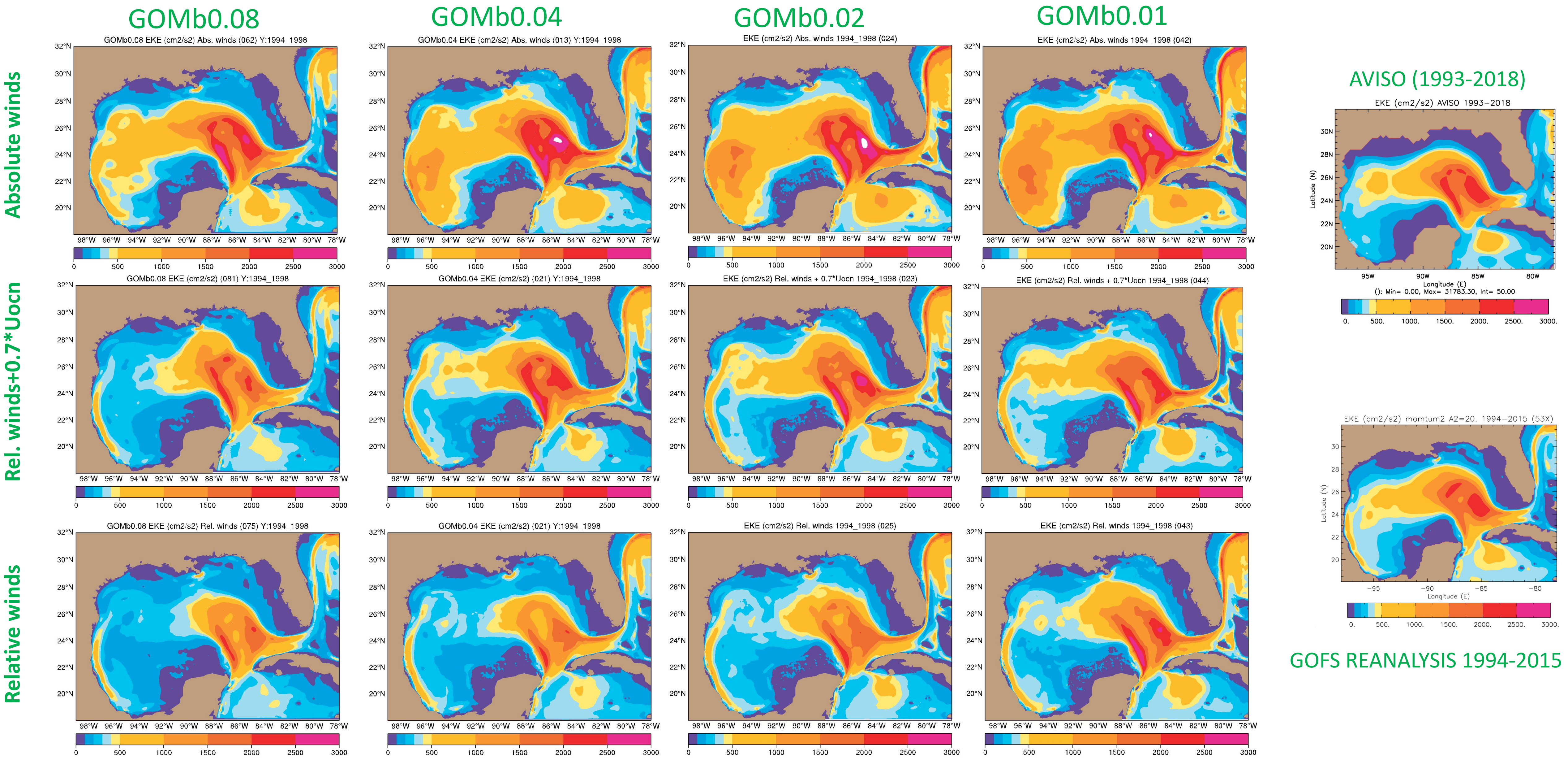
Absolute Winds | Relative Winds + 0.5*Uocn | Relative Winds + 0.7*Uocn | Relative Winds

1994-1998

1994-2003



EKE per resolution and wind-stress formulation (1994-1998)



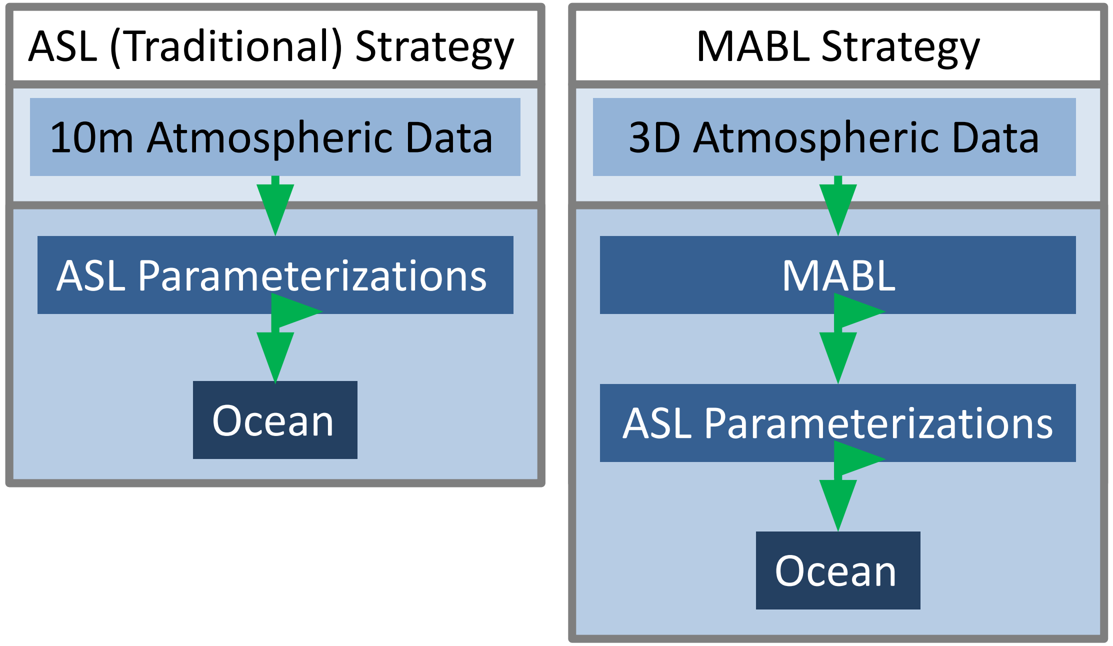
Summary

- Renault et al. (2019) works, but depends on resolution and it is only a parameterization – the atmosphere is prescribed and saw the SST that was prescribed in the atmospheric model.

Ph.D. Fred Soster

How can air-sea interaction be better represented without the computational expense of a fully coupled ocean-atmosphere model?

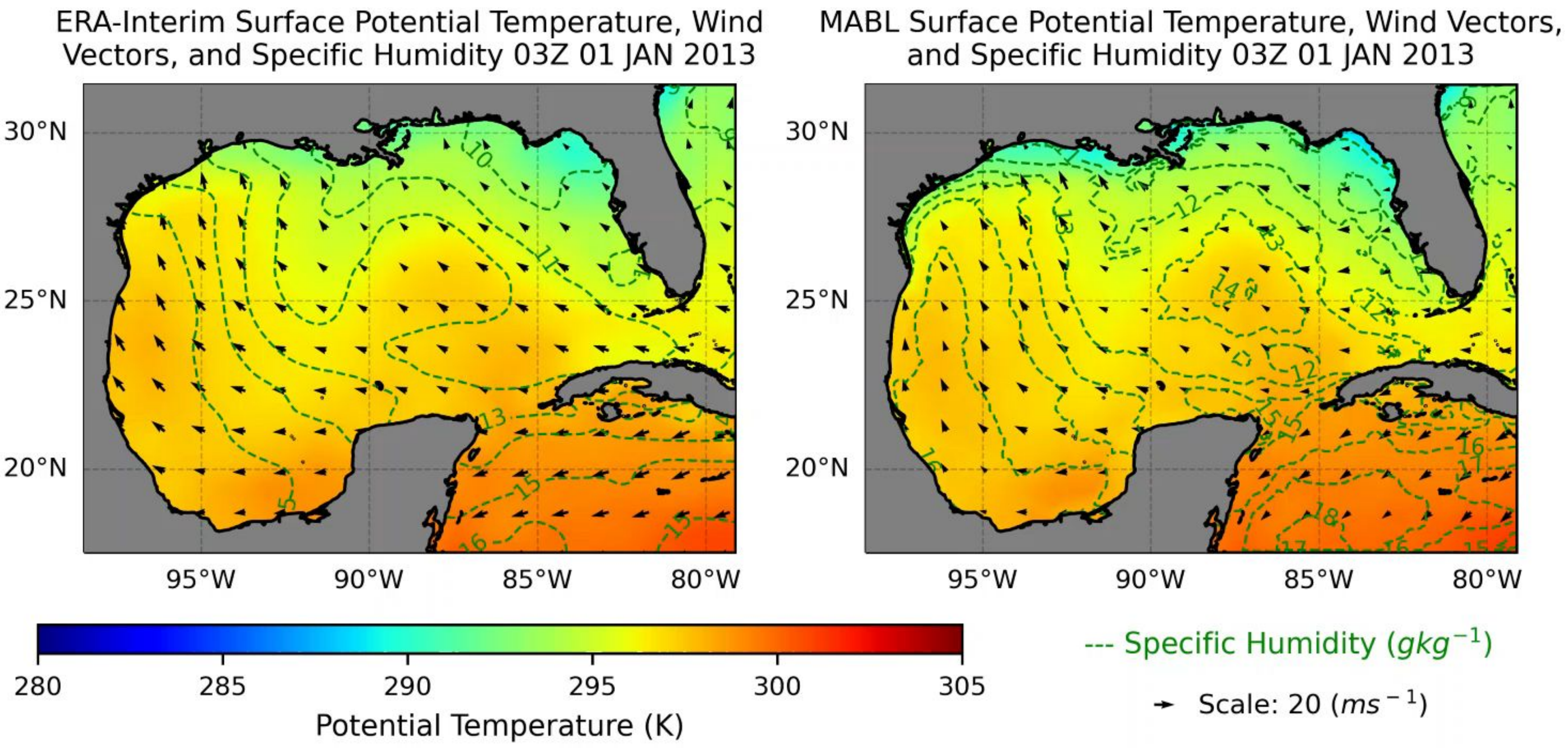
- Combine atmospheric surface layer parameterizations with a 1-D vertically integrated thermodynamically active model (MABL) from Lemarié et al. (2021).
- Represent the air-sea interaction from turbulent mixing from air-sea feedback which is the most important coupling mechanism at oceanic mesoscales. (Lemarié et al. 2021)
- To be coupled with HYCOM



Atmospheric Response to MABL

Input Atmospheric Data

Atmospheric Data from MABL

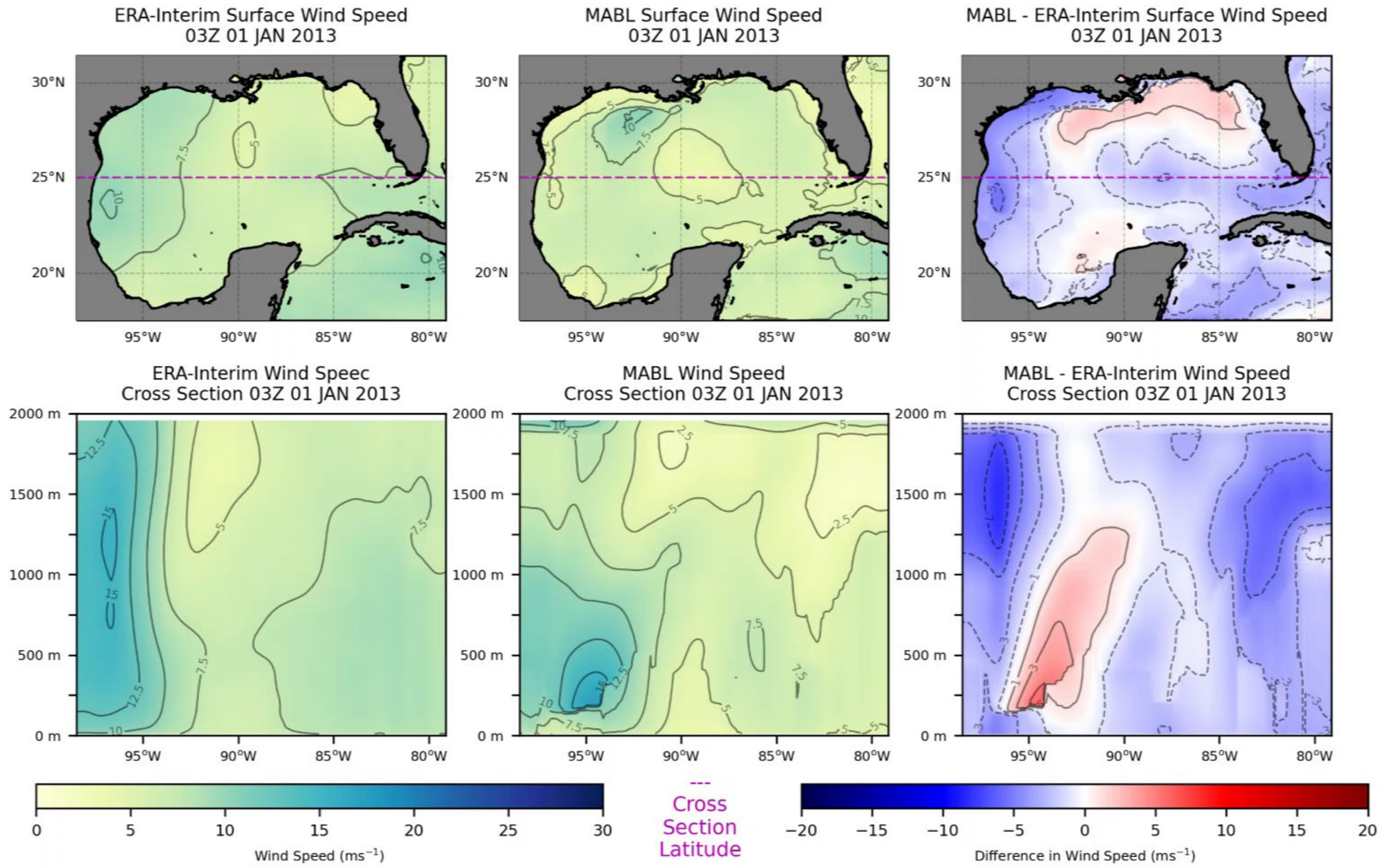


Current Model Configuration

- Atmospheric Data: ECMWF ERA-Interim Reanalysis (Dee et al. 2011)
- Ocean Data: Hybrid Coordinate Ocean Model (HYCOM) Reanalysis (Chassignet et al. 2007)
- Spatial Resolution: 1/12° x 1/12°
- Temporal Resolution: 3 hours

- An atmospheric frontal system moves through the Gulf of Mexico on January 2nd
- What is the atmospheric adjustment by the MABL?

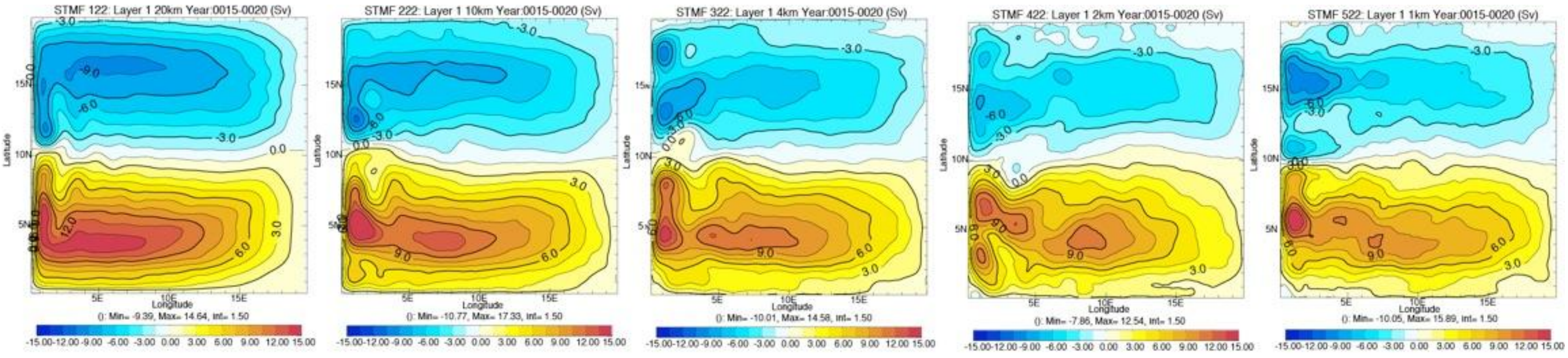
Wind Response



- The resulting wind from the MABL displays larger changes both at the surface and throughout the lowest 2km of the atmosphere.
- For the atmospheric front, the associated wind behind the front is up to 10 ms^{-1} faster than wind from ERA-Interim at the same timestep.
- There are more structure and structural variation in the vertical cross section from the MABL compared to the wind from ERA-Interim.
- The impacts of the MABL on wind speed is still being explored.

Side note: High order operators

- **How do we maintain the existing level of EKE in the 1/50° and use relative winds/current feedback?**
- **Can the EKE be increased by using different viscosity operators or increasing the order of the advection scheme from 2^{nd} to 4^{th}?**

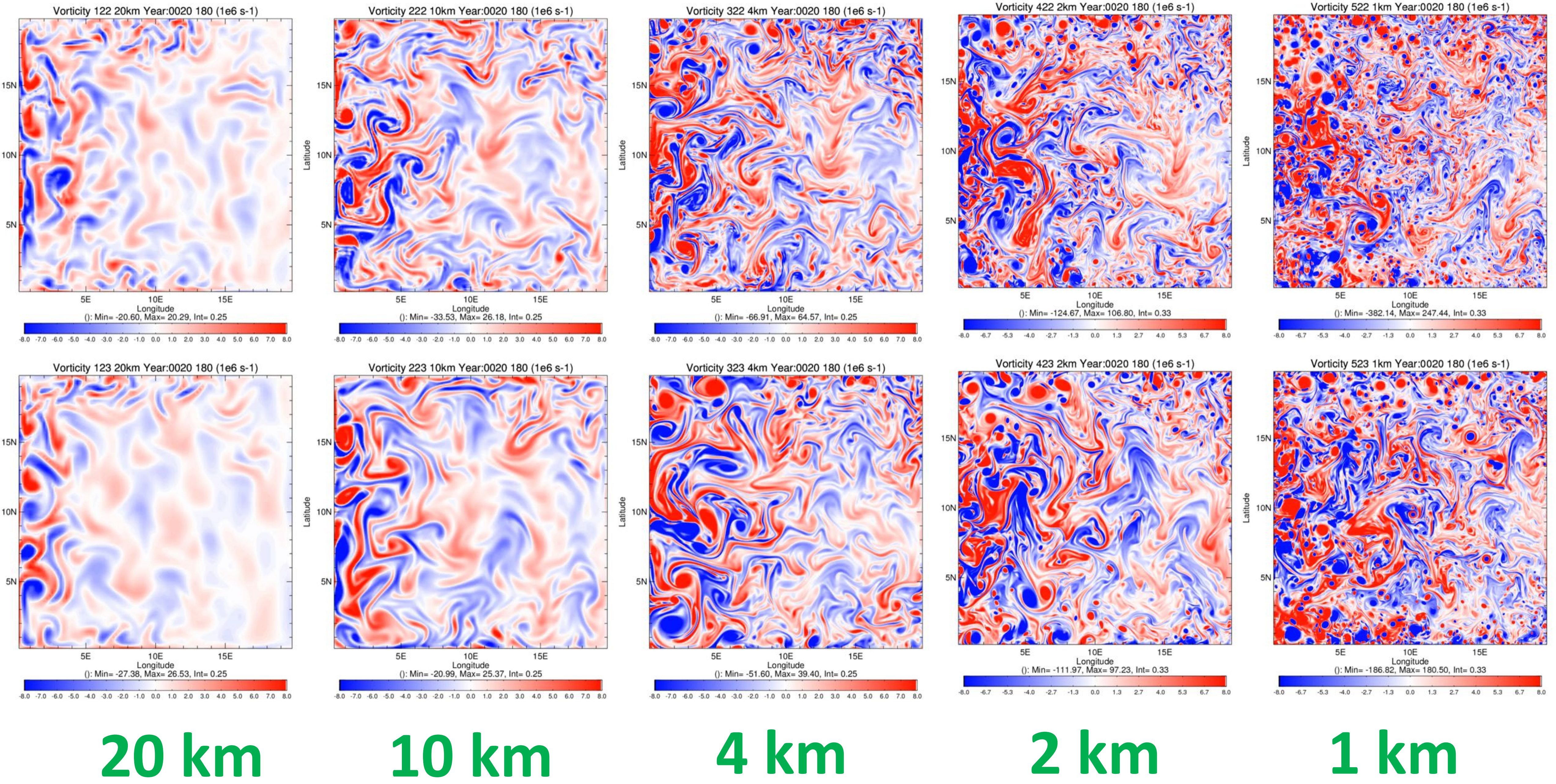


20 km　10 km　4 km　2 km　1 km

Wind driven box configuration

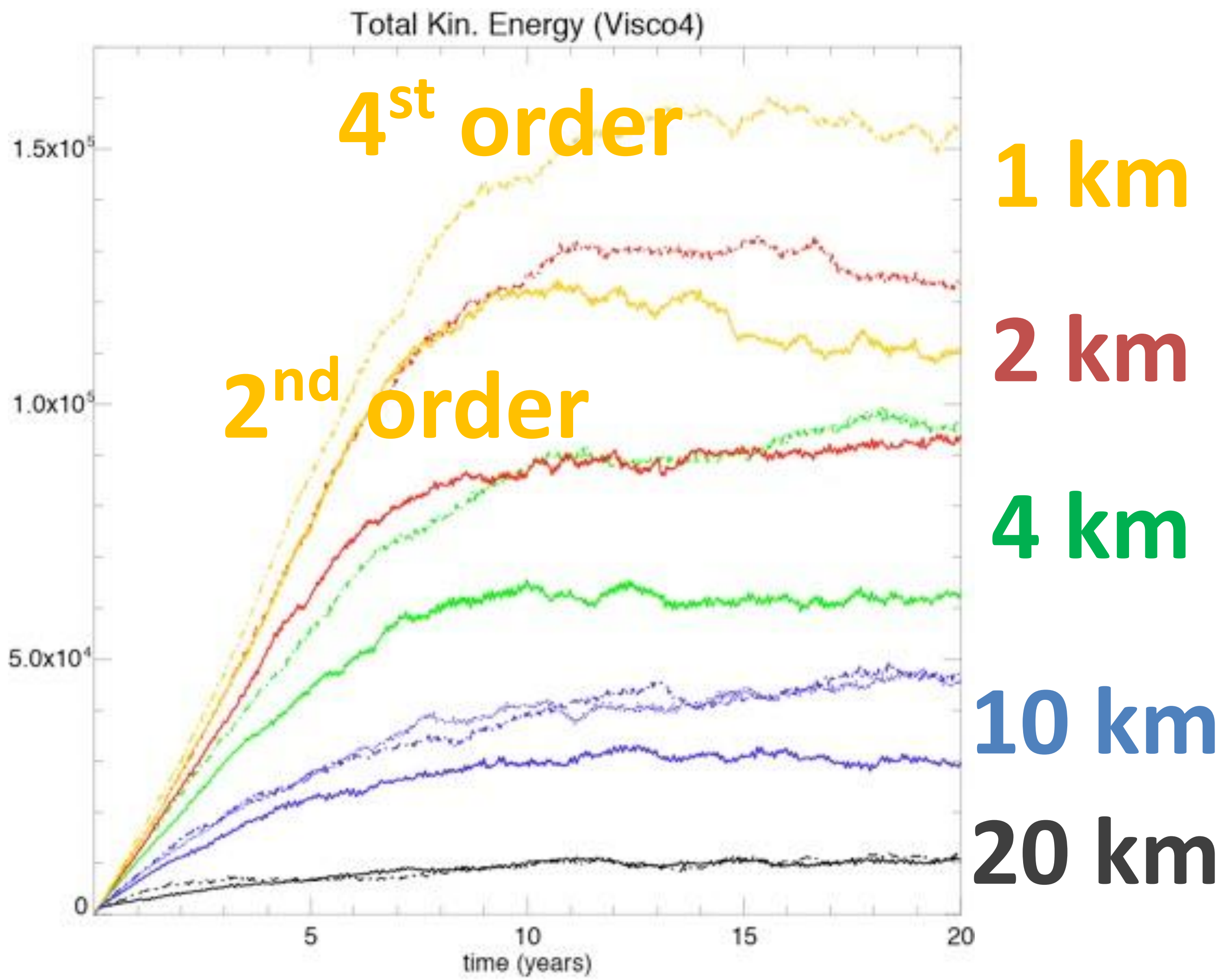
Two layers

Steady two-gyre wind stress



Vorticity 122 20km Year:0020 180 (1e6 s-1)
(): Min= -20.60, Max= 20.29, Int= 0.25
Vorticity 222 10km Year:0020 180 (1e6 s-1)
(): Min= -33.53, Max= 26.18, Int= 0.25
Vorticity 322 4km Year:0020 180 (1e6 s-1)
(): Min= -66.91, Max= 64.57, Int= 0.25
Vorticity 422 2km Year:0020 180 (1e6 s-1)
(): Min= -124.67, Max= 106.80, Int= 0.33
Vorticity 522 1km Year:0020 180 (1e6 s-1)
(): Min= -382.14, Max= 247.44, Int= 0.33
Vorticity 123 20km Year:0020 180 (1e6 s-1)
(): Min= -27.38, Max= 26.53, Int= 0.25
Vorticity 223 10km Year:0020 180 (1e6 s-1)
(): Min= -20.99, Max= 25.37, Int= 0.25
Vorticity 323 4km Year:0020 180 (1e6 s-1)
(): Min= -51.60, Max= 39.40, Int= 0.25
Vorticity 423 2km Year:0020 180 (1e6 s-1)
(): Min= -111.97, Max= 97.23, Int= 0.33
Vorticity 523 1km Year:0020 180 (1e6 s-1)
(): Min= -186.82, Max= 180.50, Int= 0.33
Latitude
Longitude
15N
10N
5N
5E
10E
15E
20 km
10 km
4 km
2 km
1 km

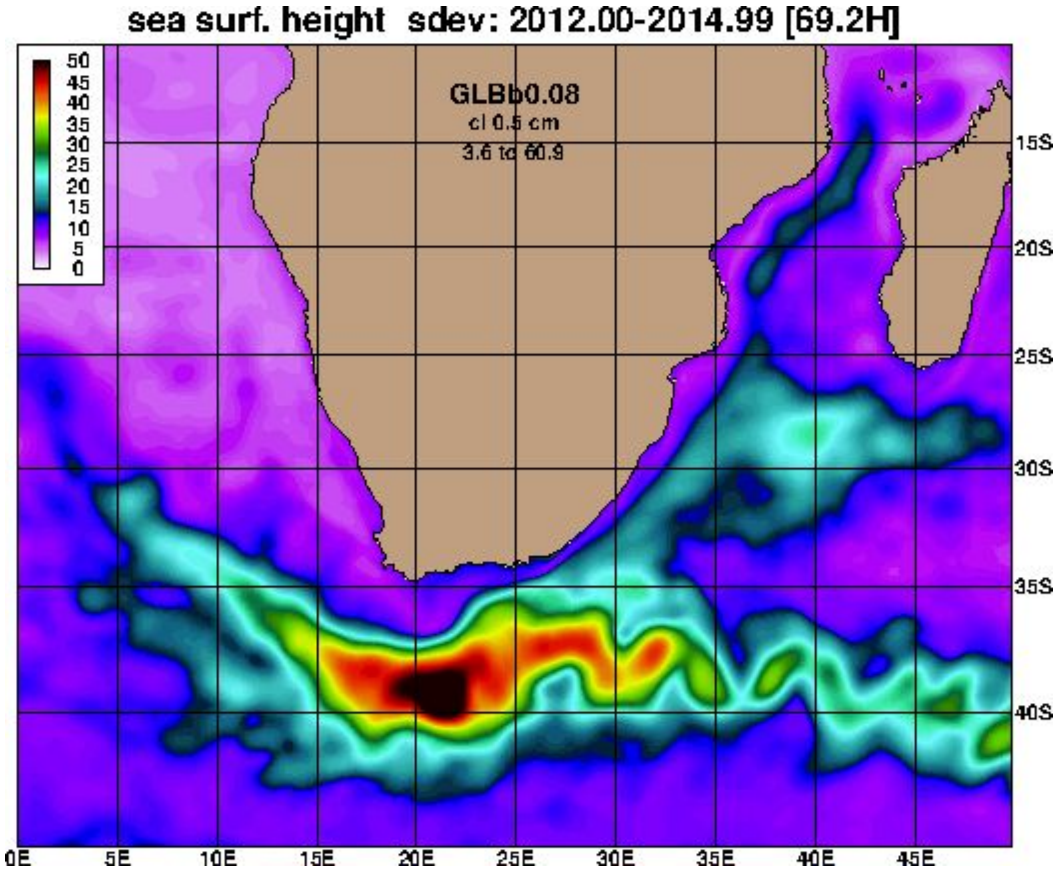
Two-gyre
HYCOM box
configuration



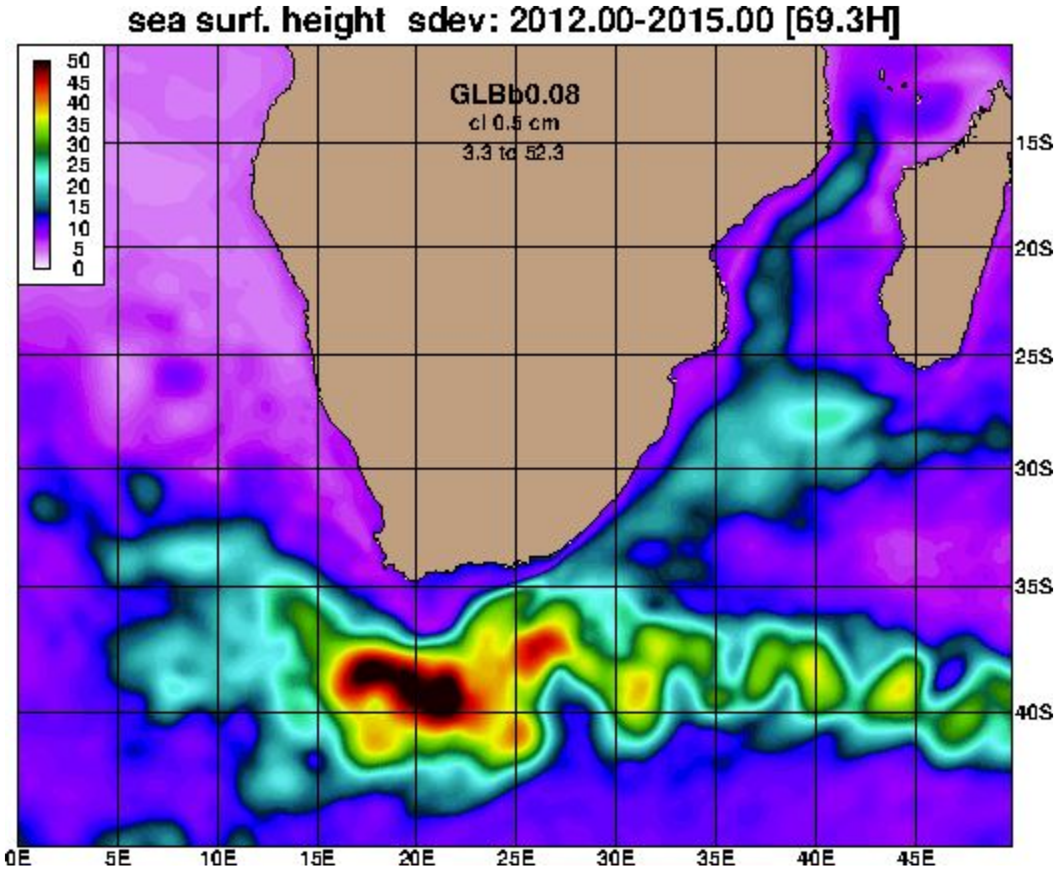
$$F = -\frac{A_4}{h}\nabla^2.(h\nabla^2\mathbf{u})$$

BIHARMONIC

2nd order advection scheme



4th order advection scheme



HYCOM global 1/12°

Suggestions for the coupled TT

- White paper/journal article on current approaches used by ocean prediction systems with respect to atmospheric forcing (absolute/relative, MBL, coupled, etc)
- Impact of choices on ocean prediction systems
- Can ocean-only prediction systems be viable and for how long? (i.e., is the benefit of an increase in horizontal resolution lost because of a non-responsive atmosphere (damping)?)
- Another question is how fine should the resolution of the atmosphere be? Advantage of the MBL approach is that they can use the same grid.