North Atlantic circulation in three simulations of 1/12°, 1/25°, and 1/50°

Xiaobiao Xu and Eric Chassignet

Center for ocean-atmospheric prediction studies

Florida State University

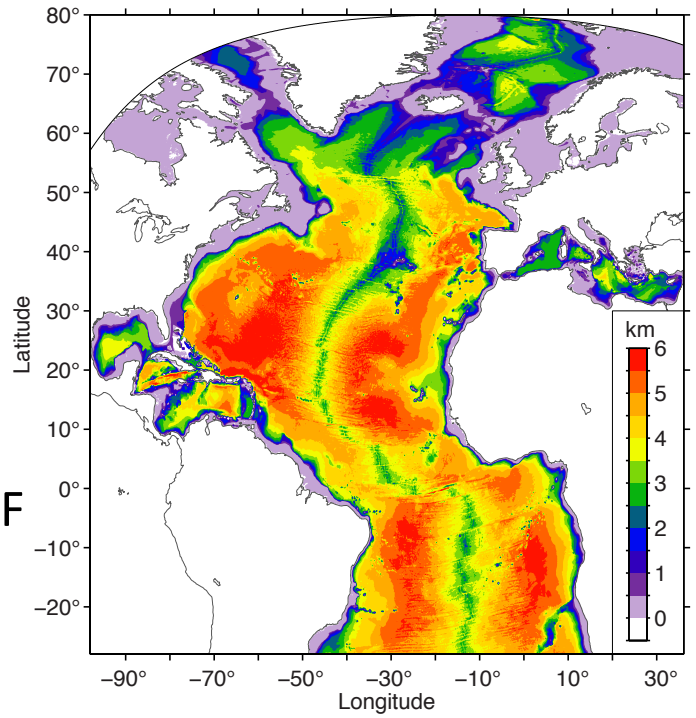
Motivation

- Numerical models with different goals vary widely on horizontal resolutions, from 1° long-term climate simulations (no eddy), to 1/10° ocean simulations (resolve most of mesoscale eddies) and, more recently, to 1/60° simulations (resolve some sub-mesoscale physics).

- Will (or when) the ocean model results converge? Specifically, how sensitive is large-scale circulation to the horizontal resolution in eddying regime?

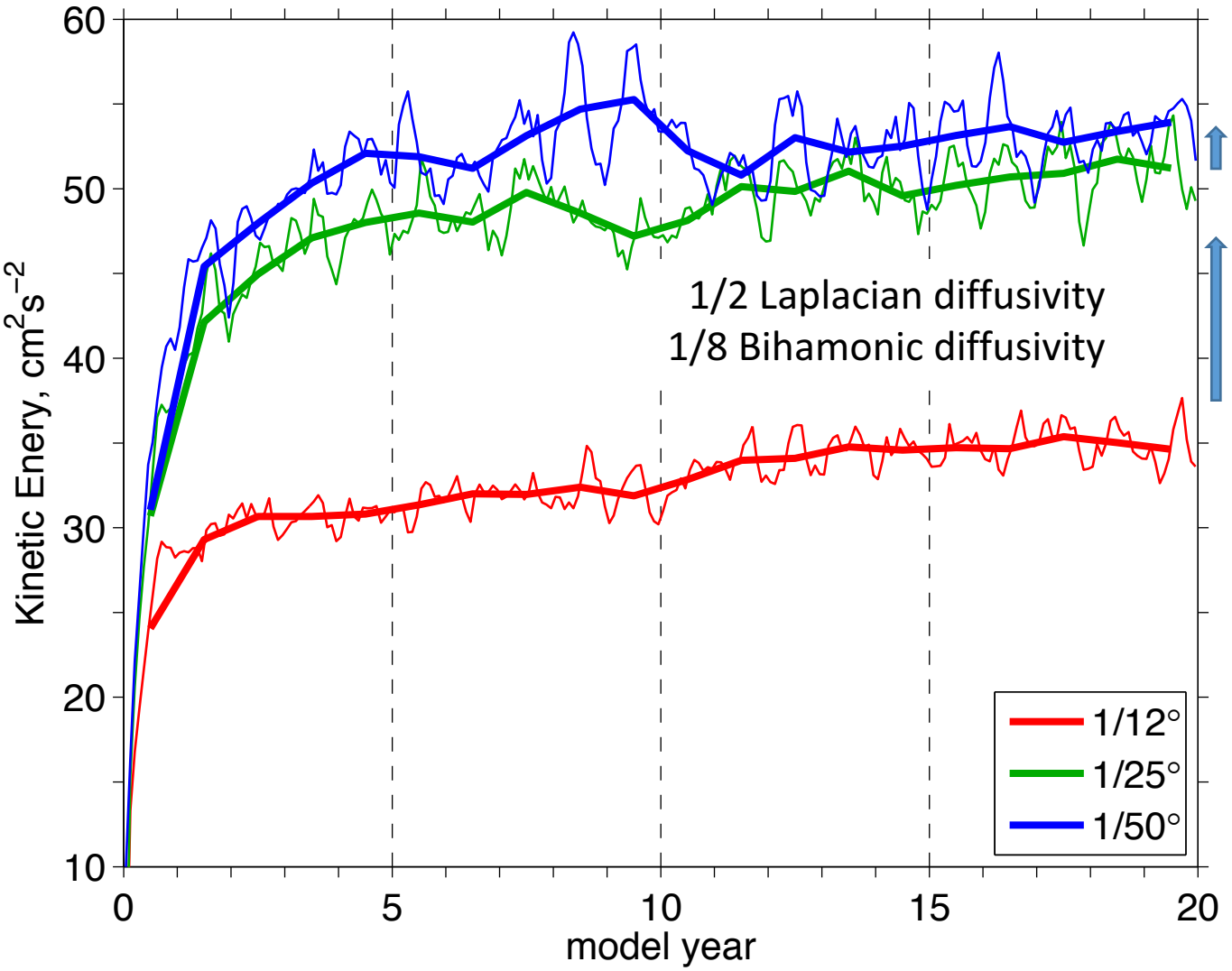
Experiments

- 3 nearly identical experiments with 1/12°, 1/25°, 1/50°.
- Same 32 layers in the vertical. Bathymetry in 1/25° and 1/50° is linearly interpolated from 1/12°.
- All initialized from climatological T/S and zero velocity.
- Same climatological forcing from monthly ECMWF Reanalysis (ERA40) and high-frequent wind from NOGAPS for 2003 (no interannual variability).



Diffusion Parameters	1/12°	1/25°	1/50°
Laplacian deformation-dependent viscosity coefficient	0.05	0.05	0.05
Laplacian (background) viscosity for momentum	20 m^2/s	10 m^2/s	10 m^2/s
Biharmonic diffusion velocity for momentum	1 cm/s	1 cm/s	4 cm/s
Biharmonic diffusion velocity for layer thickness	1 cm/s	1 cm/s	4 cm/s
Laplacian diffusion velocity for temperature/salinity	0.5 cm/s	0.5 cm/s	1 cm/s

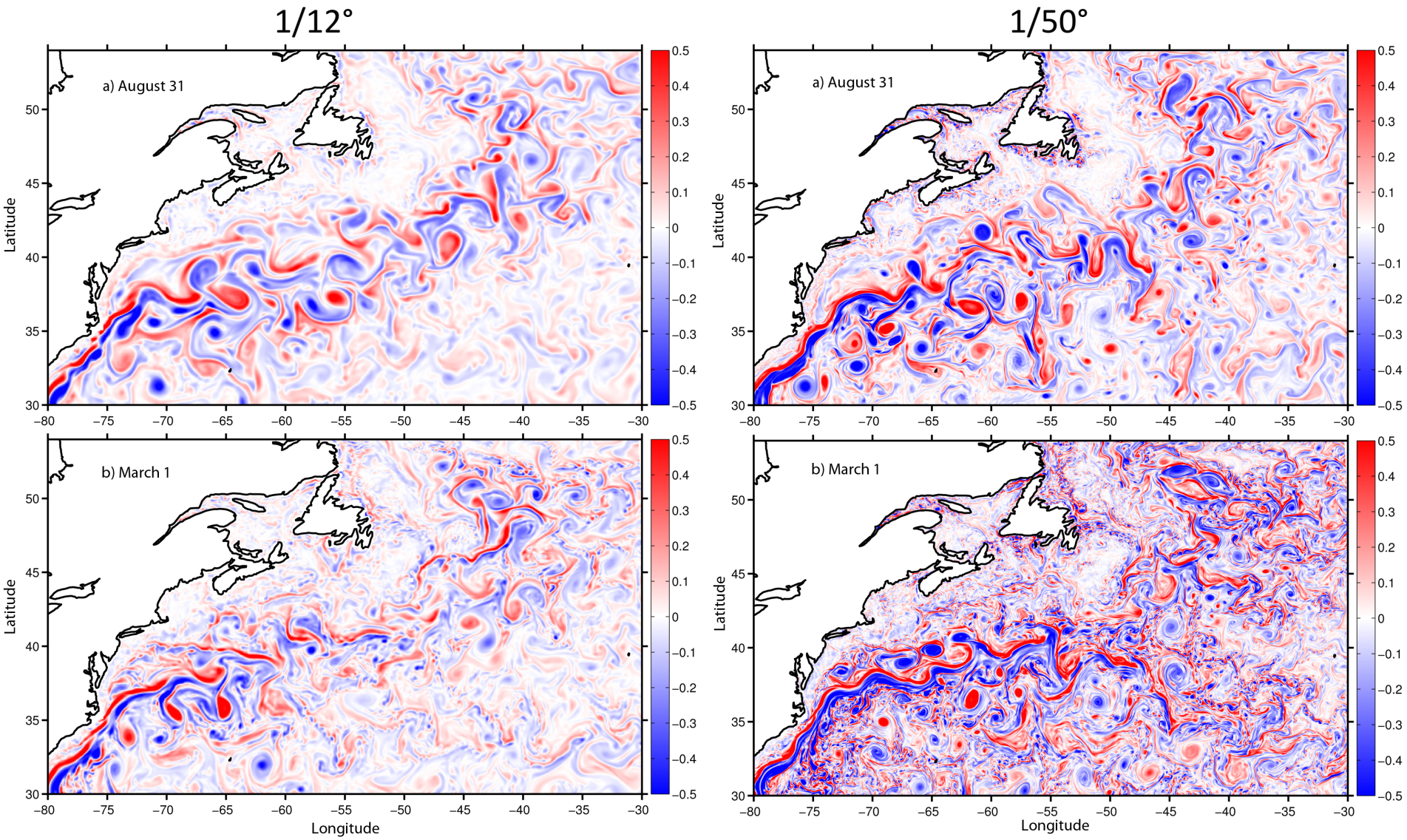
Kinetic Energy



½ Biharmonic diffusivity (for momentum and layer thickness)

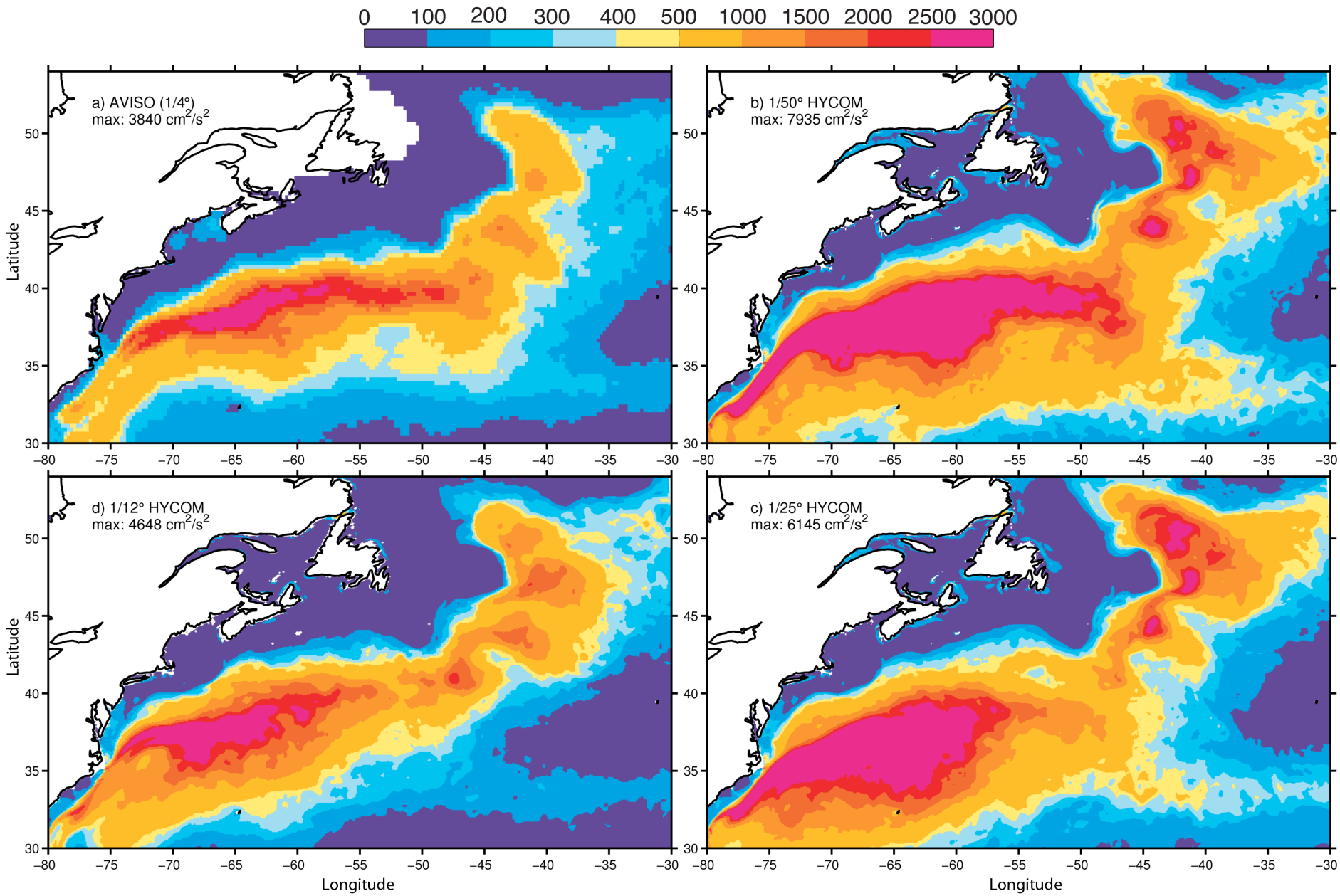
Time evolution of the 3-d domain averaged kinetic energy in three simulations

Surface eddy activity

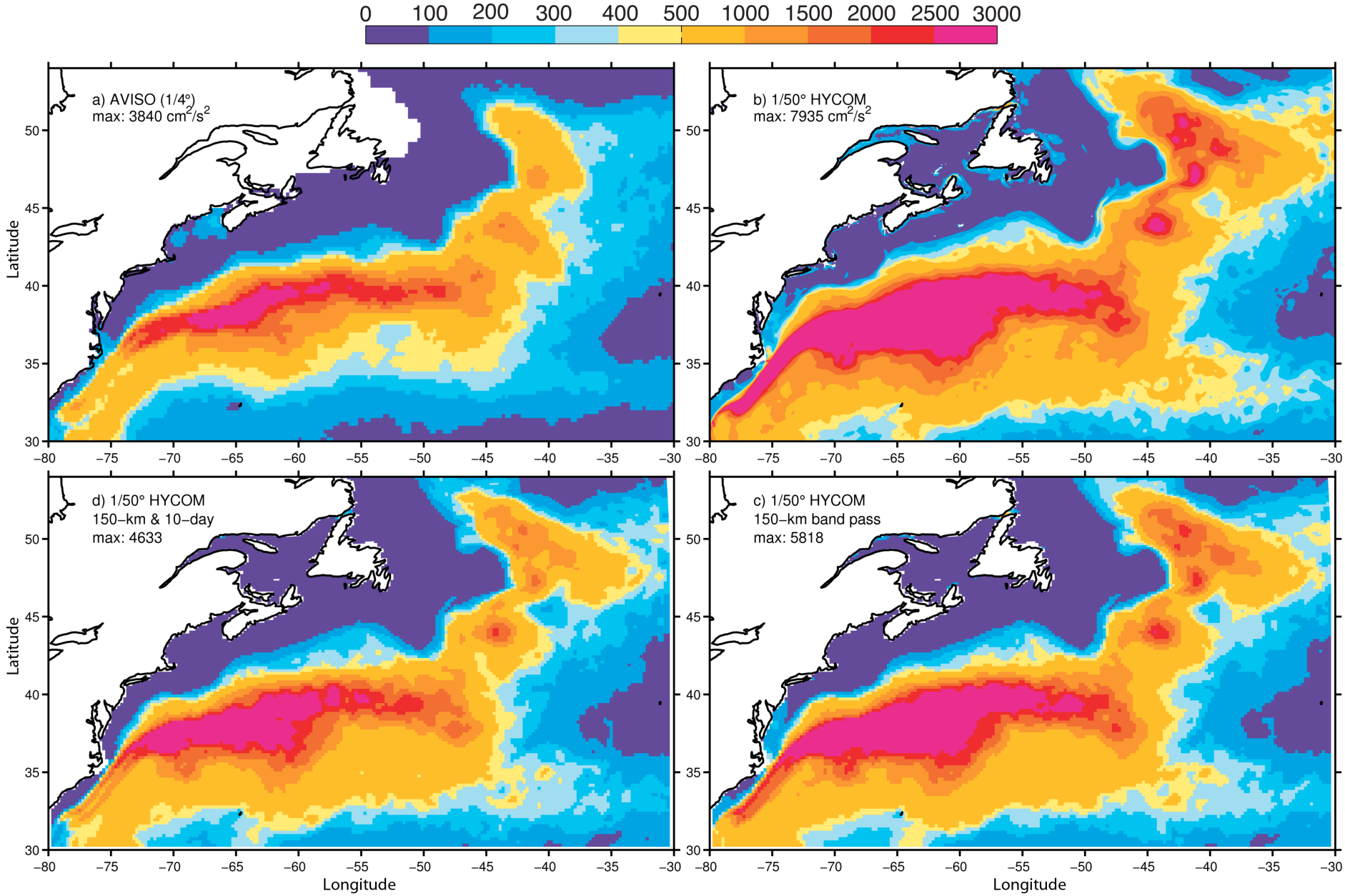


Ratio of relative vorticity to Coriolis parameter *f*

Eddy Kinetic Energy (EKE)

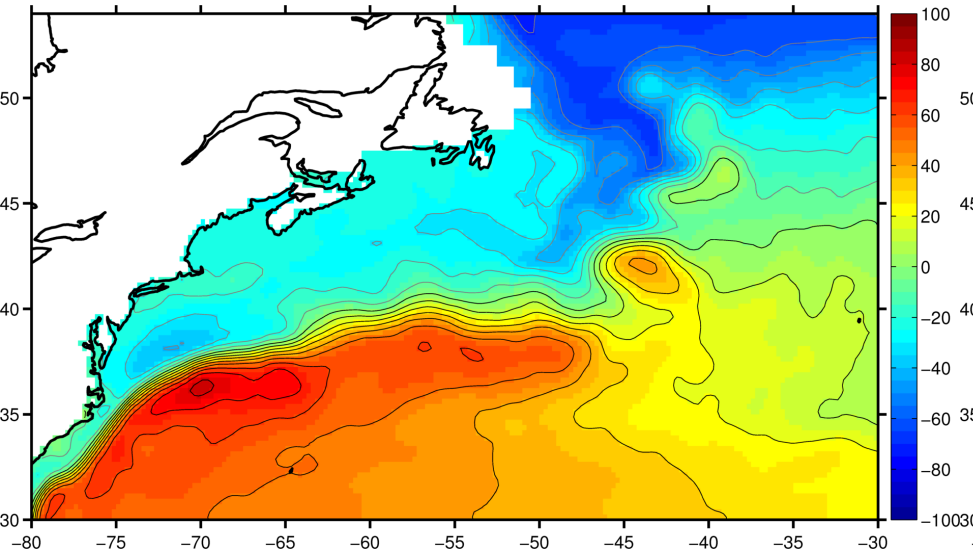


Impact of filtering to EKE

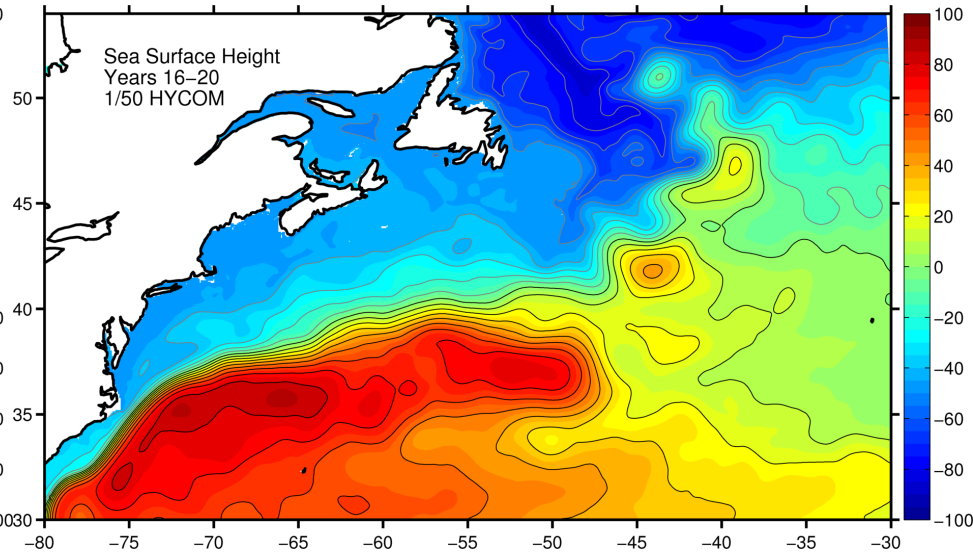


Mean SSH

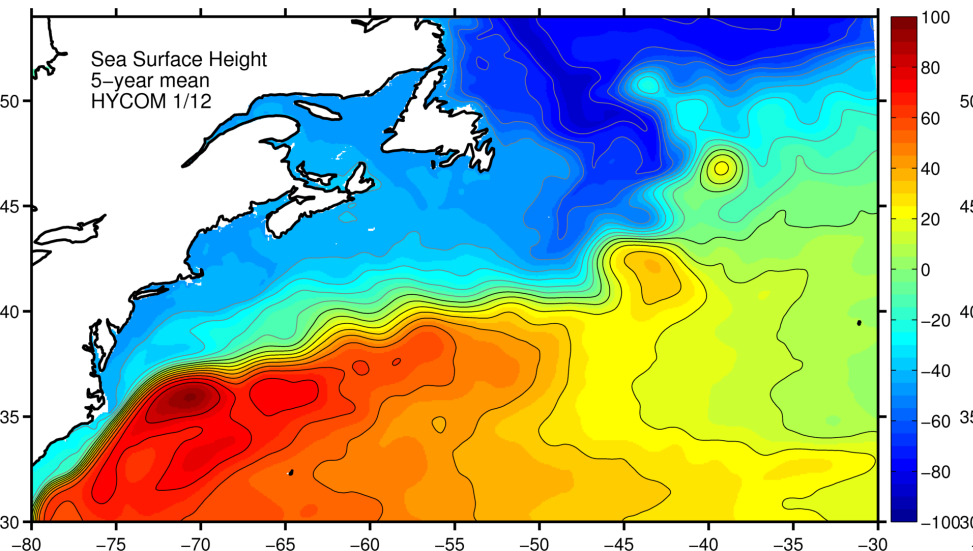
AVISO (1993-2012)



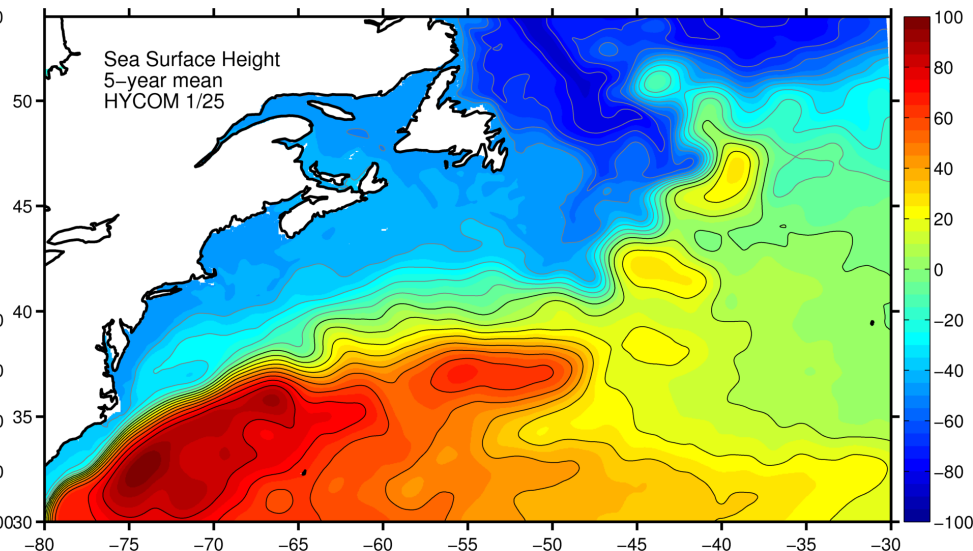
1/50 (years 16-20)



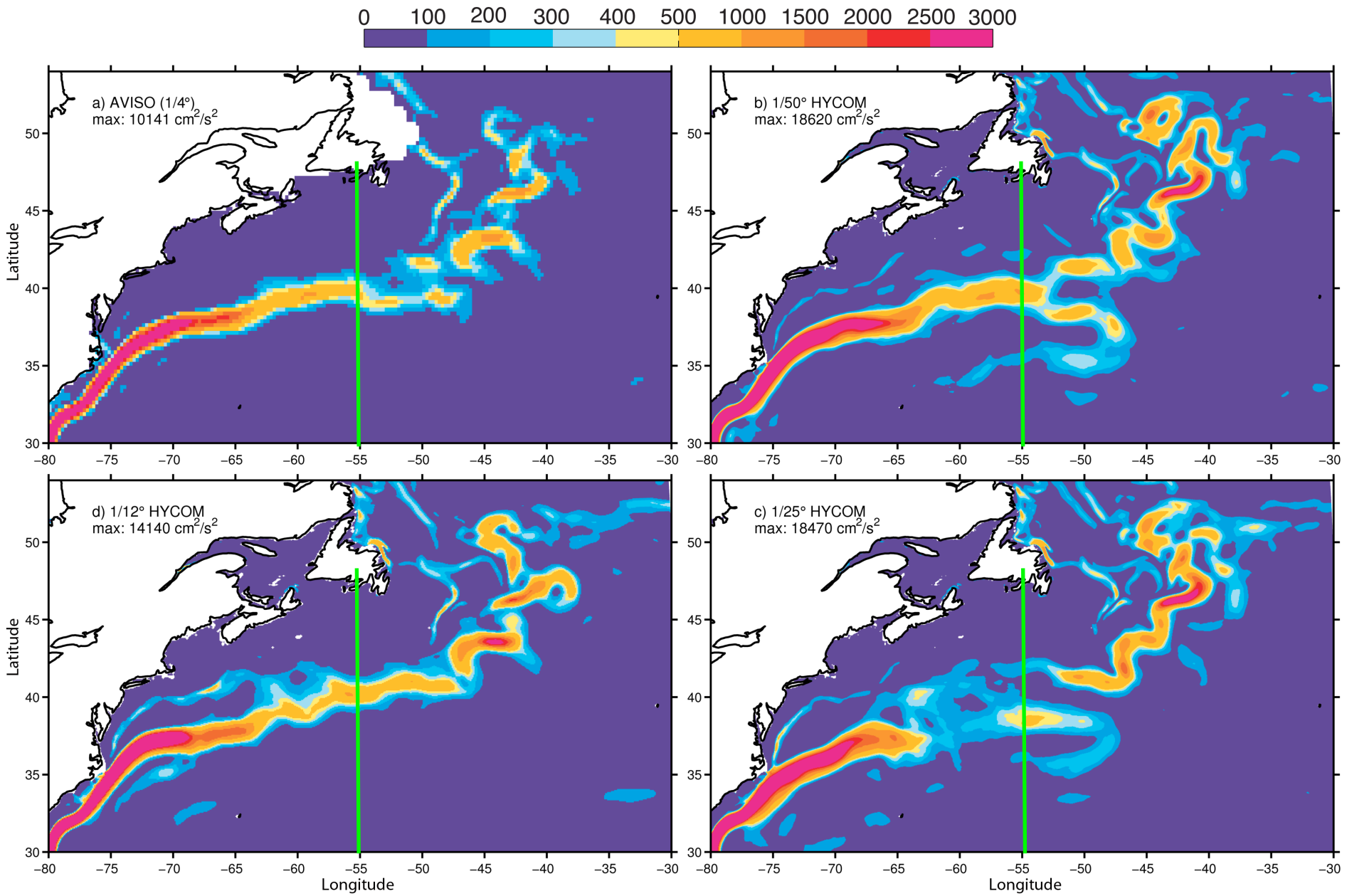
1/12 (years 16-20)



1/25 (years 16-20)



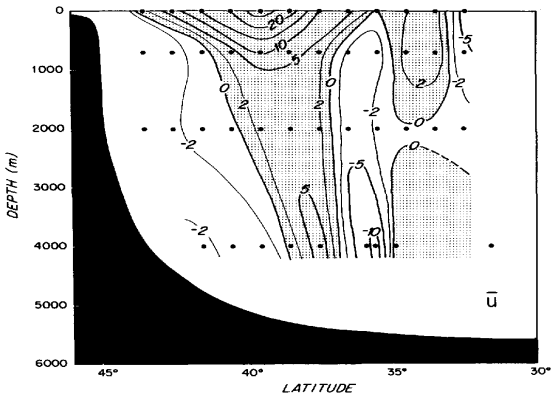
Mean flow Kinetic Energy (MKE)



Mean flow and EKE at 55°W

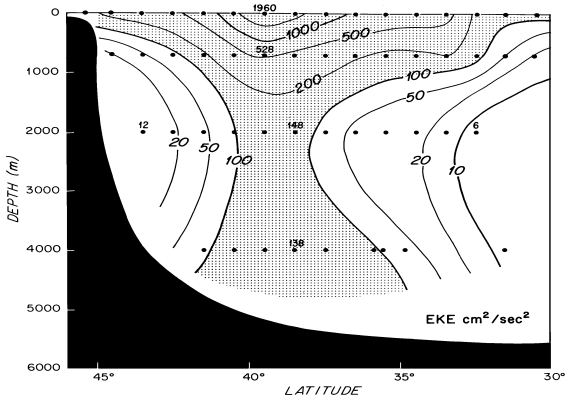
Observations

Zonal velocity, u



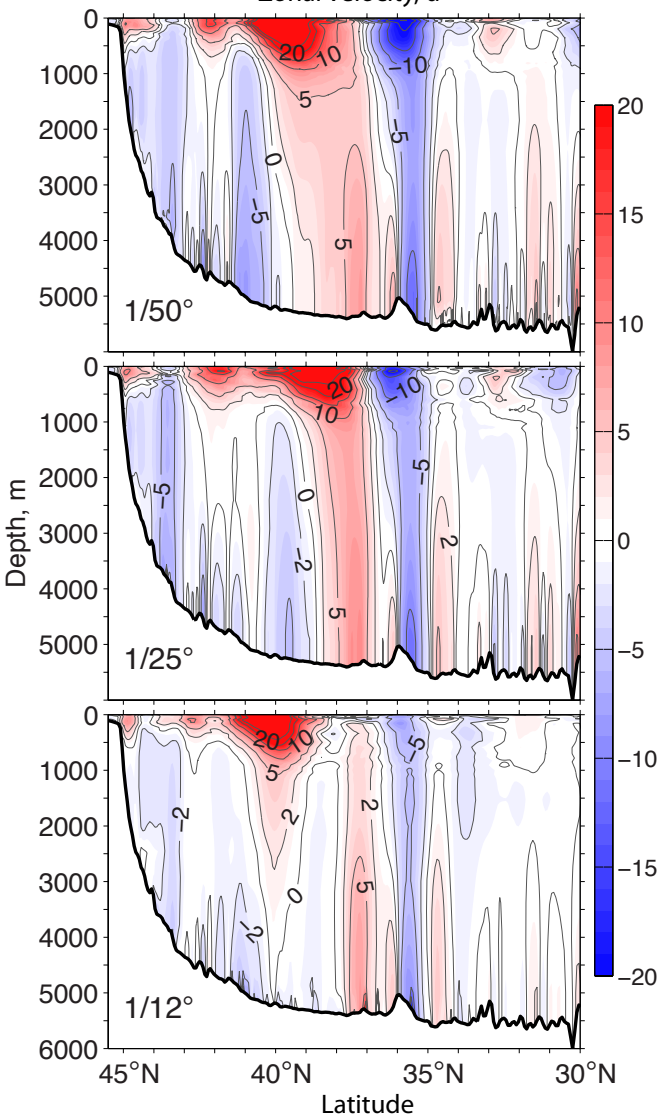
from Richardson (1985)

Eddy Kinetic Energy (EKE)

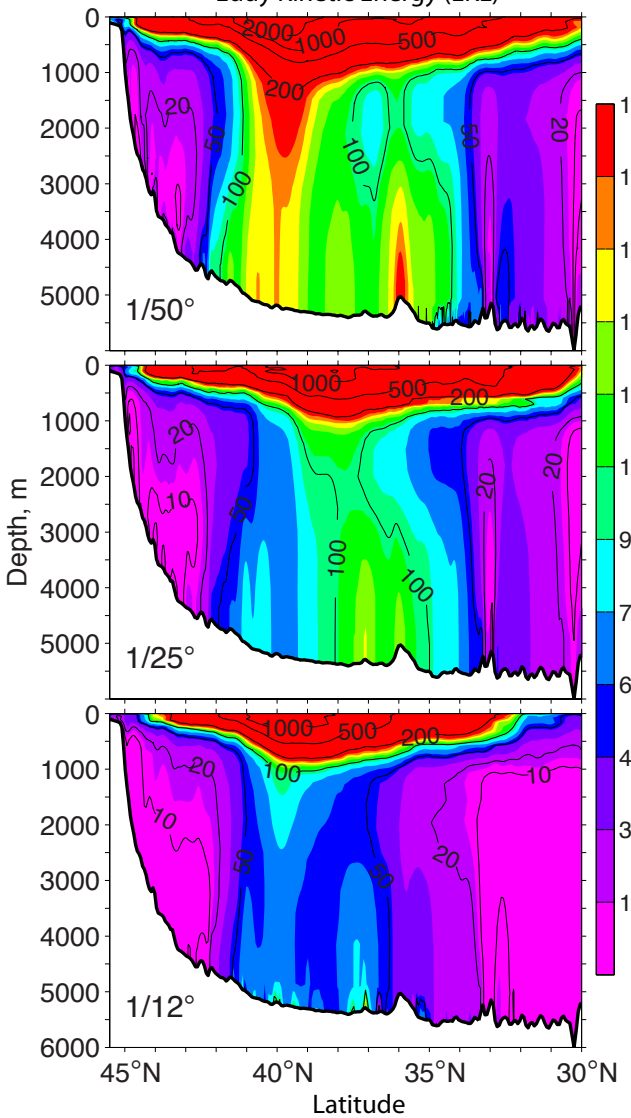


Model

Zonal Velocity, u



Eddy Kinetic Energy (EKE)



Summary I

- Increasing the horizontal resolution to 1/50° leads to a significant improvement on the representation of the Gulf Stream penetration and the associated recirculation gyres, not seen in simulations at 1/12° or 1/25°.

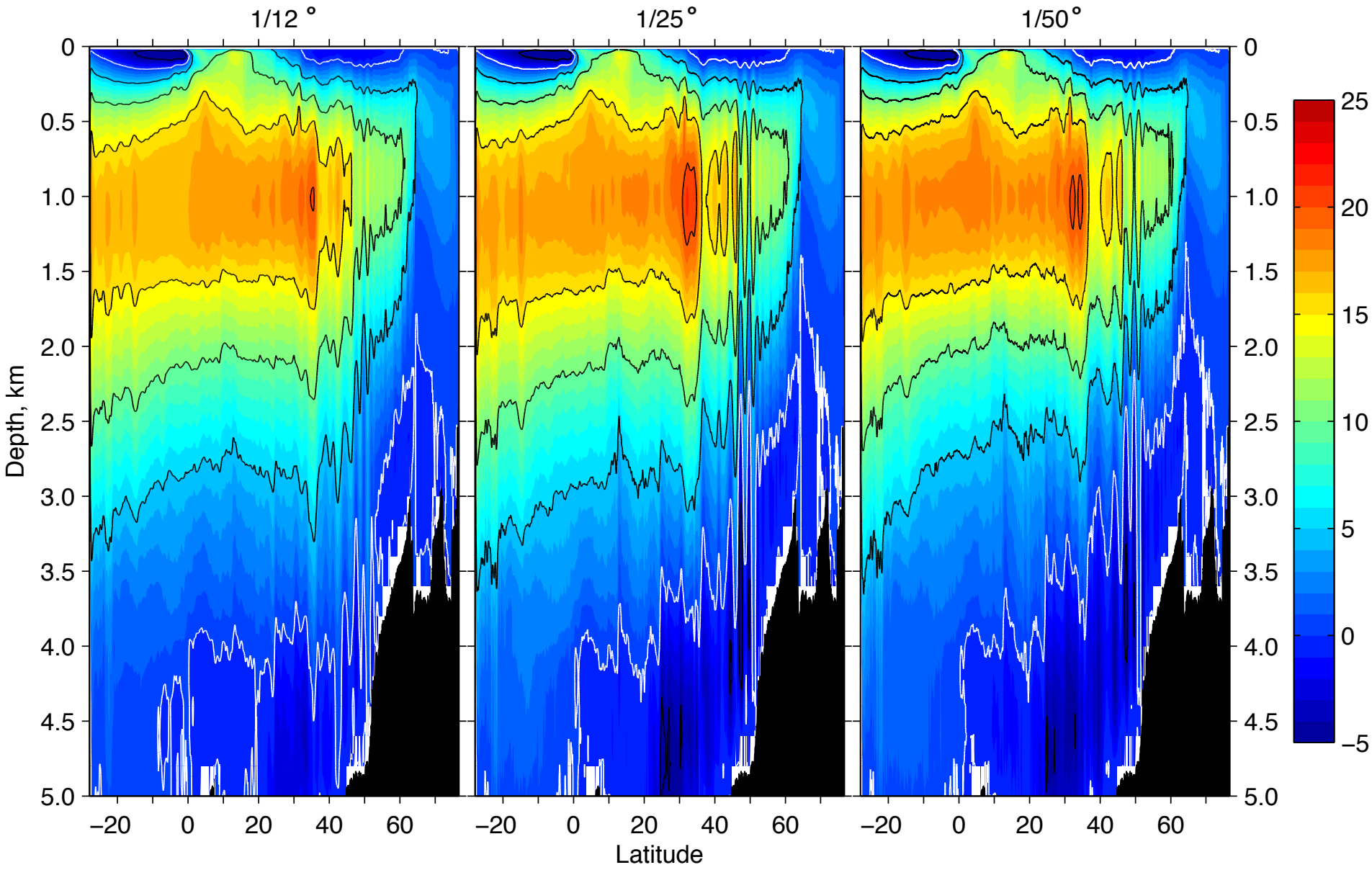
- This is consistent with earlier results obtained by Hurburt and Hogan (2000) using a 6-layer hydrodynamic model NLOM in the subtropical North Atlantic configuration and by Levy et al. (2010) using NEMO model in an idealized configuration.

More details, including spectra analysis, in the revised manuscript to JPO (Chassignet and Xu)

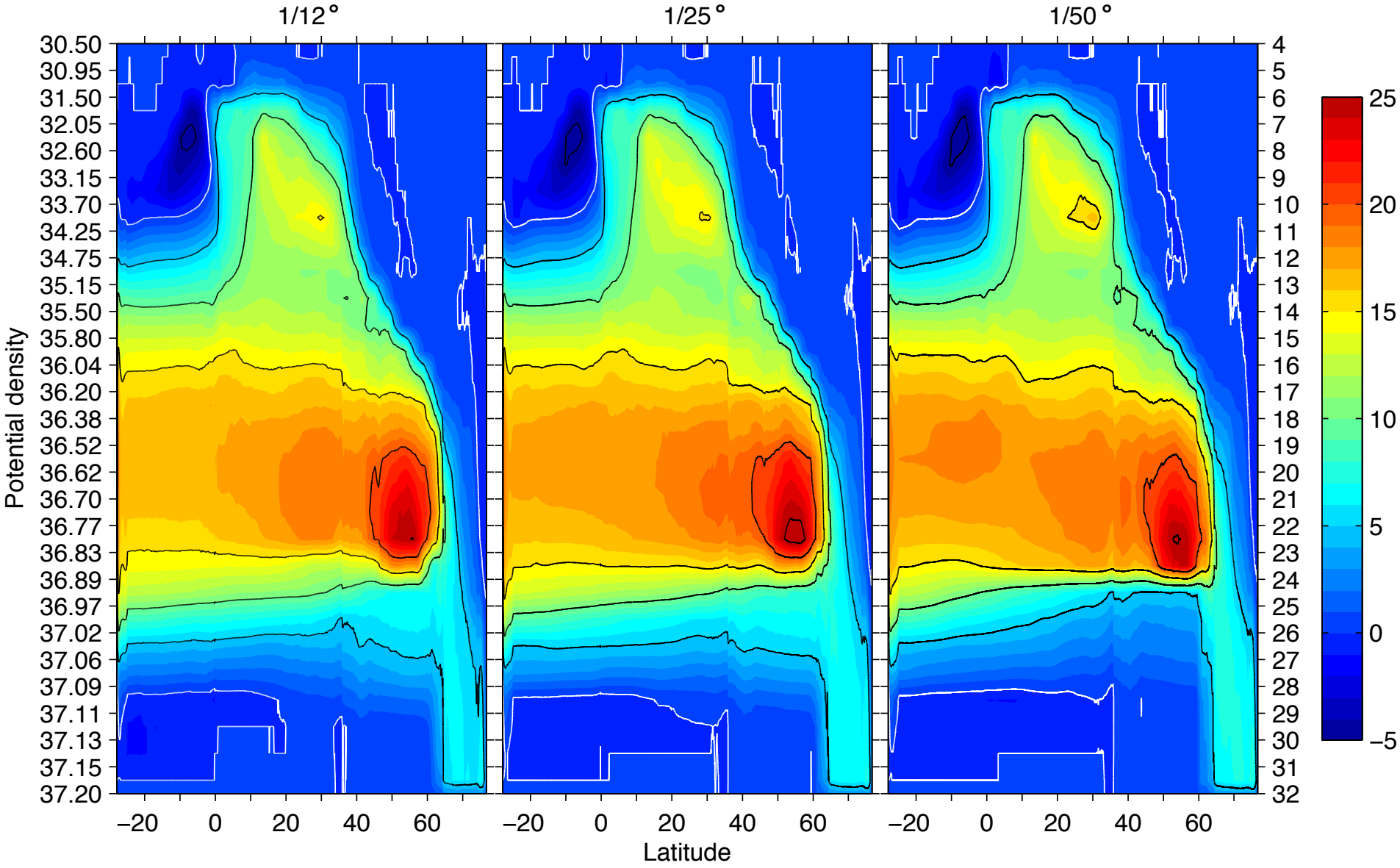
How about even larger scale circulation patterns

- AMOC
- Subtropical gyre
- Subpolar gyre

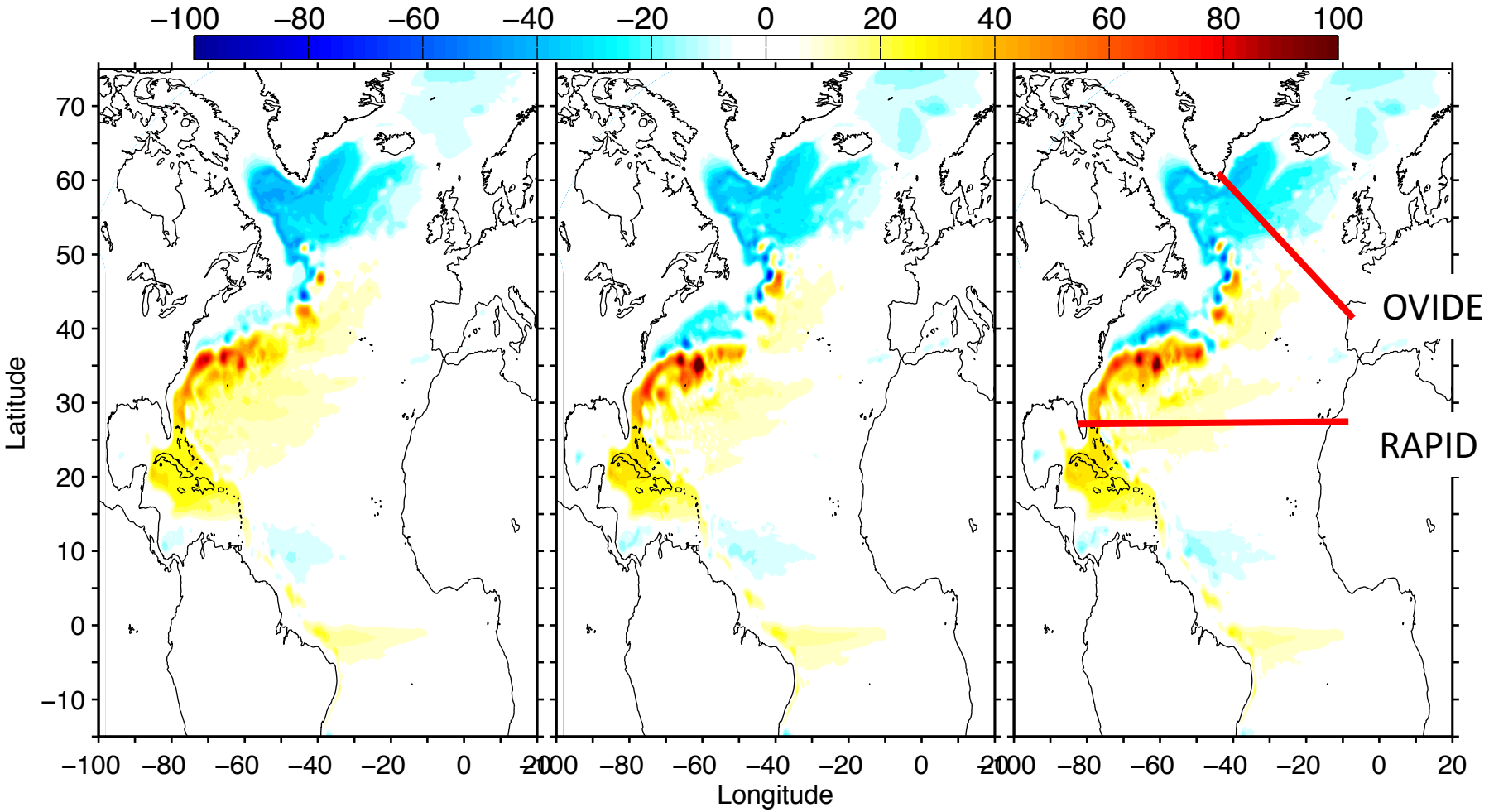
AMOC streamfunction (z)



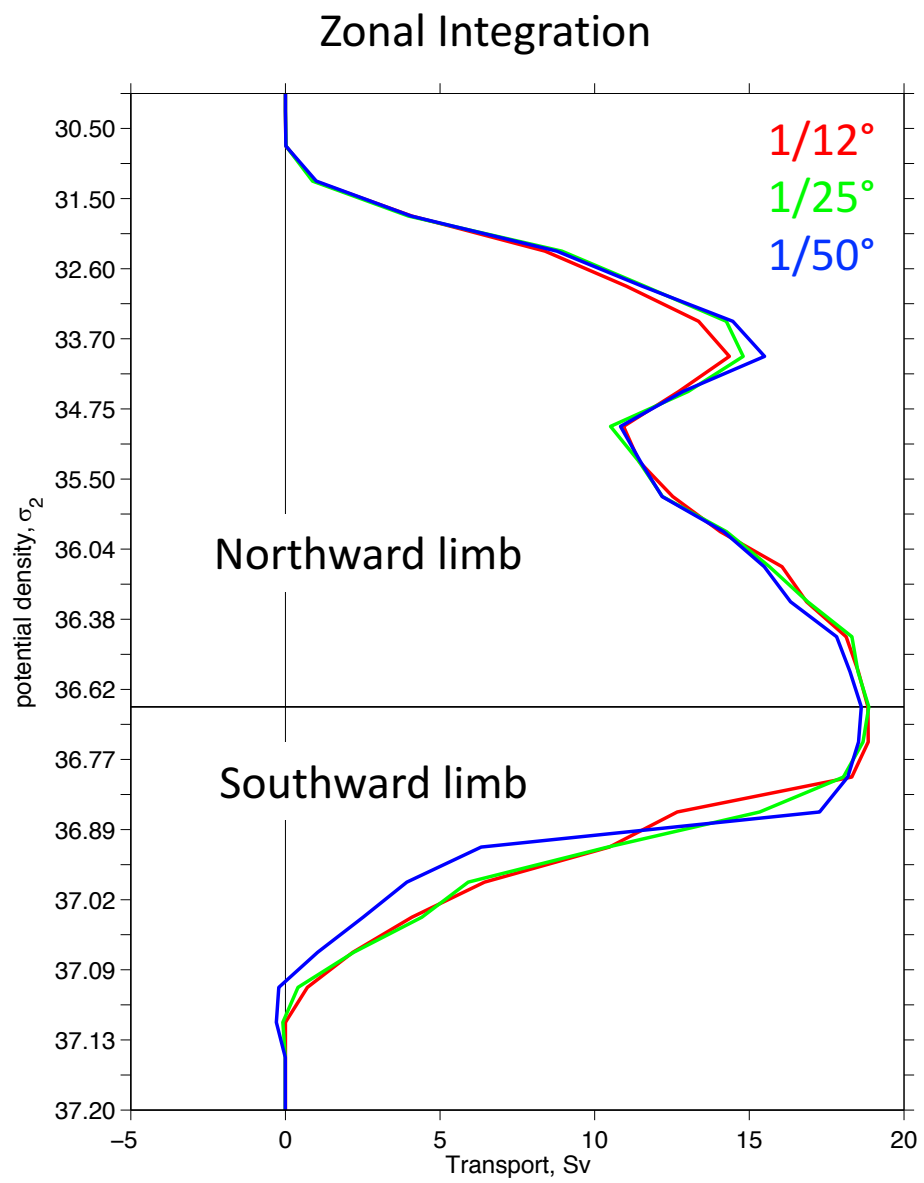
AMOC streamfunction (σ_2)

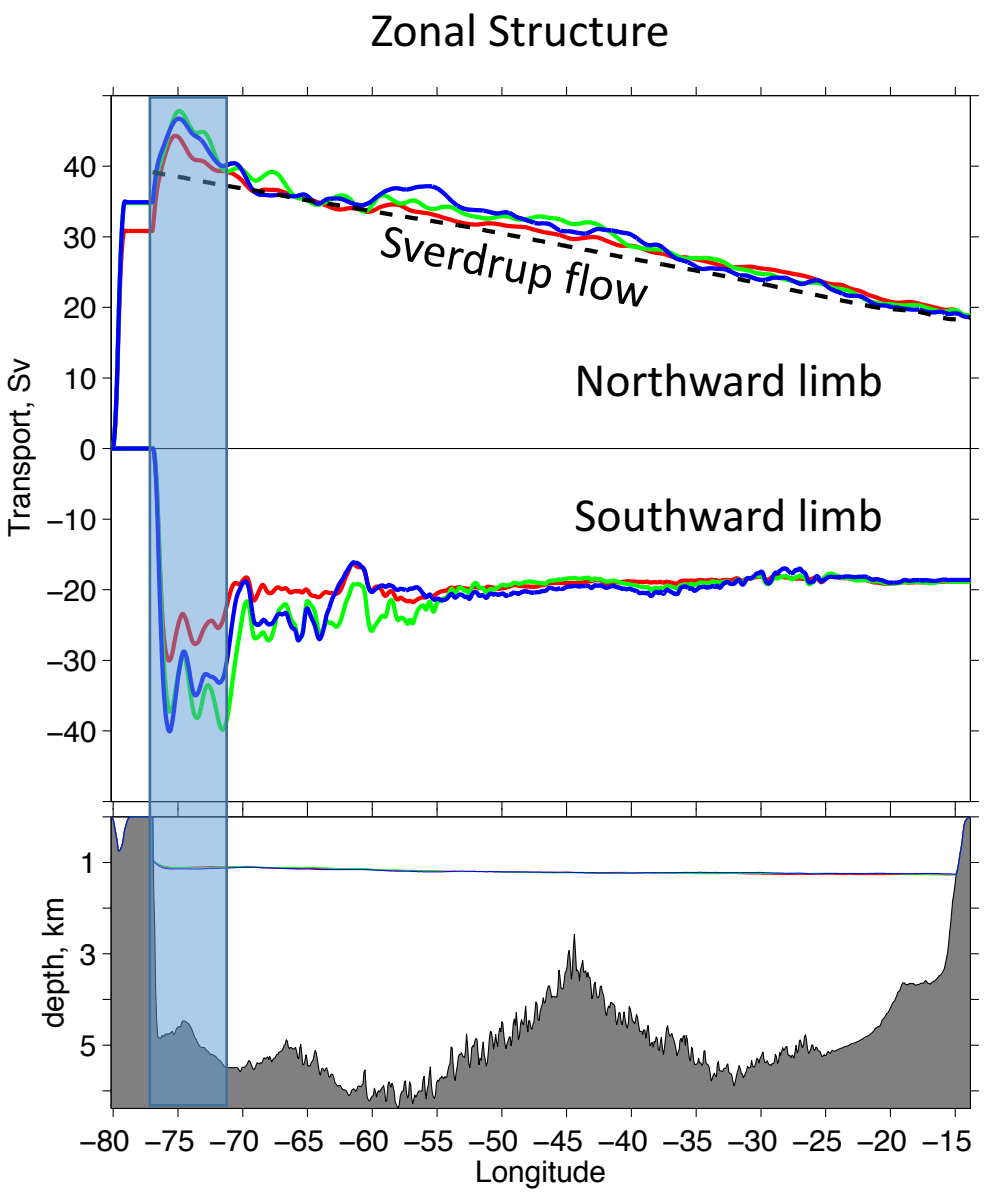


Basin-scale barotropic streamfunction



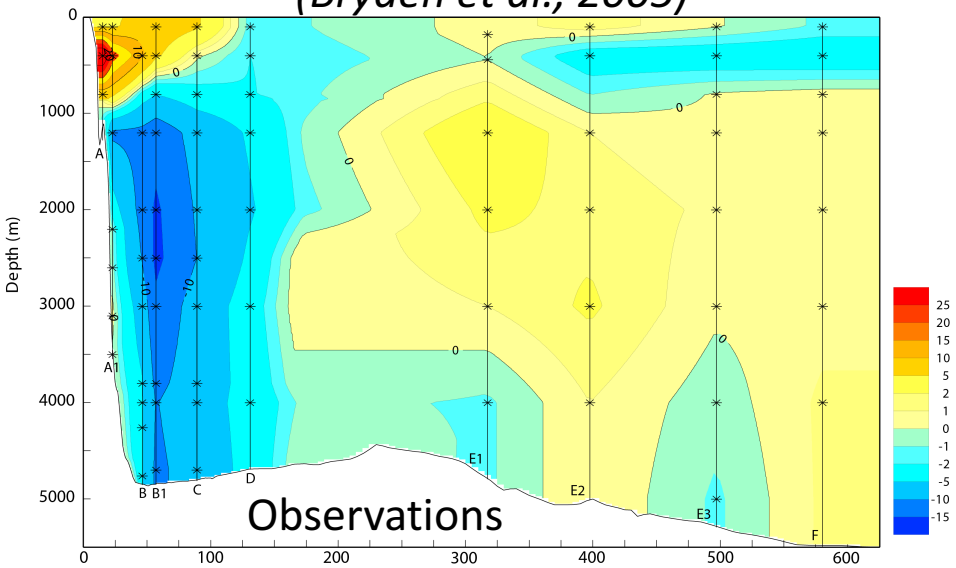
Subtropical North Atlantic (26°N)

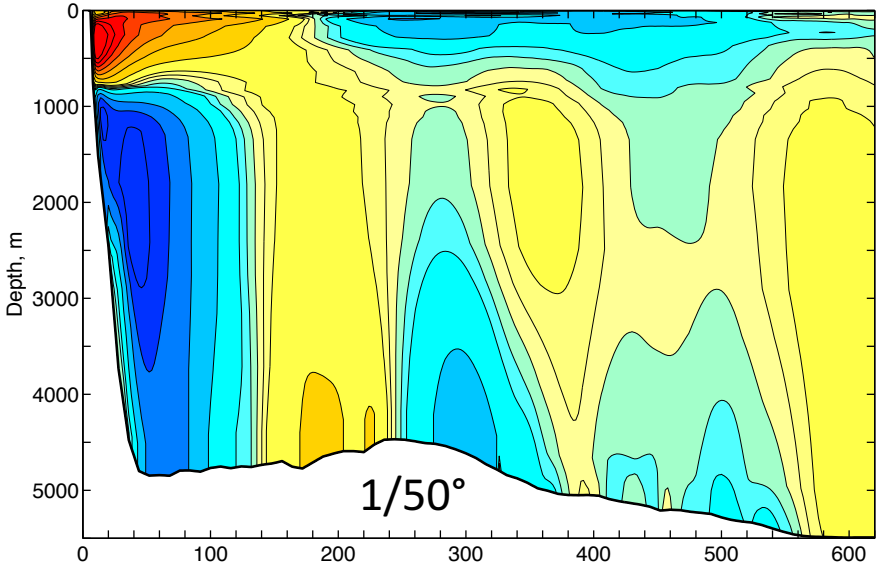


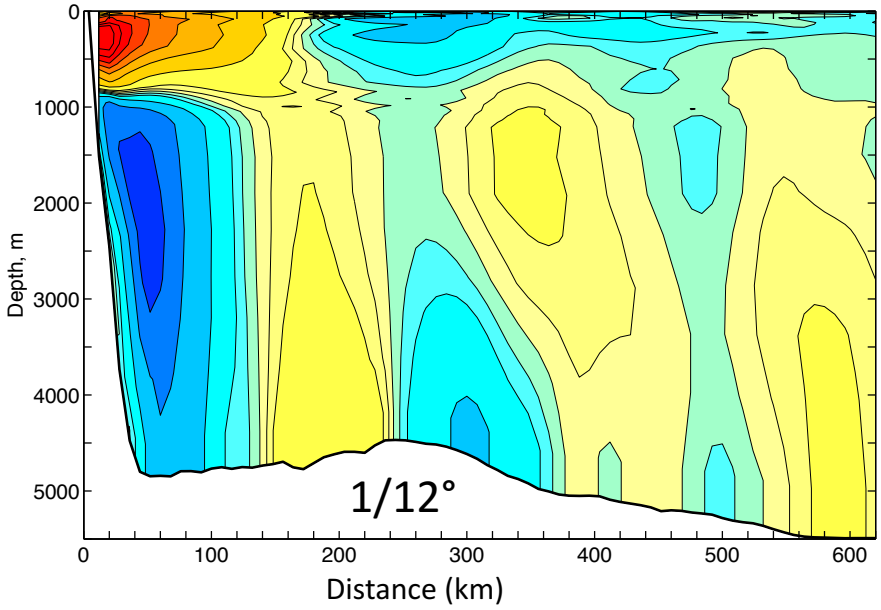


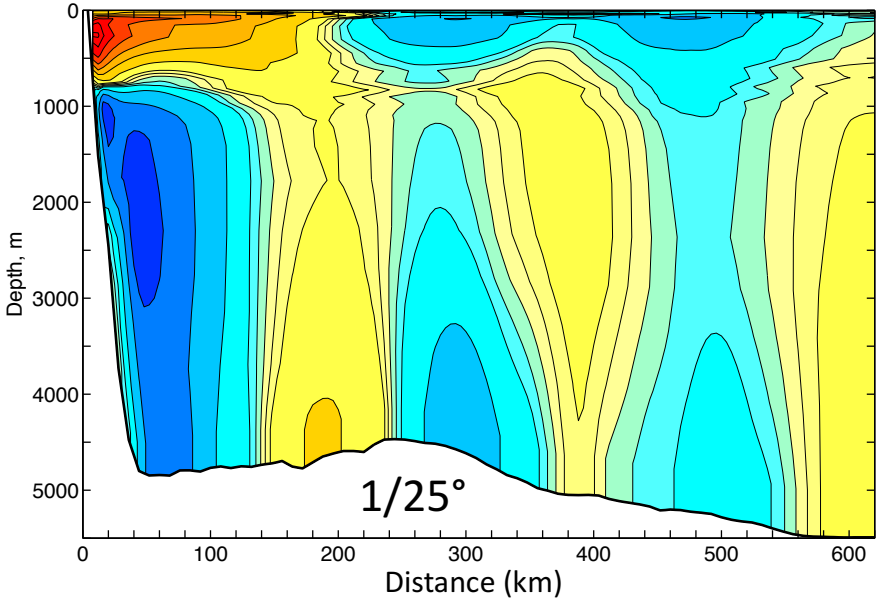
WBC east of Abaco at 26°N

(Bryden et al., 2005)



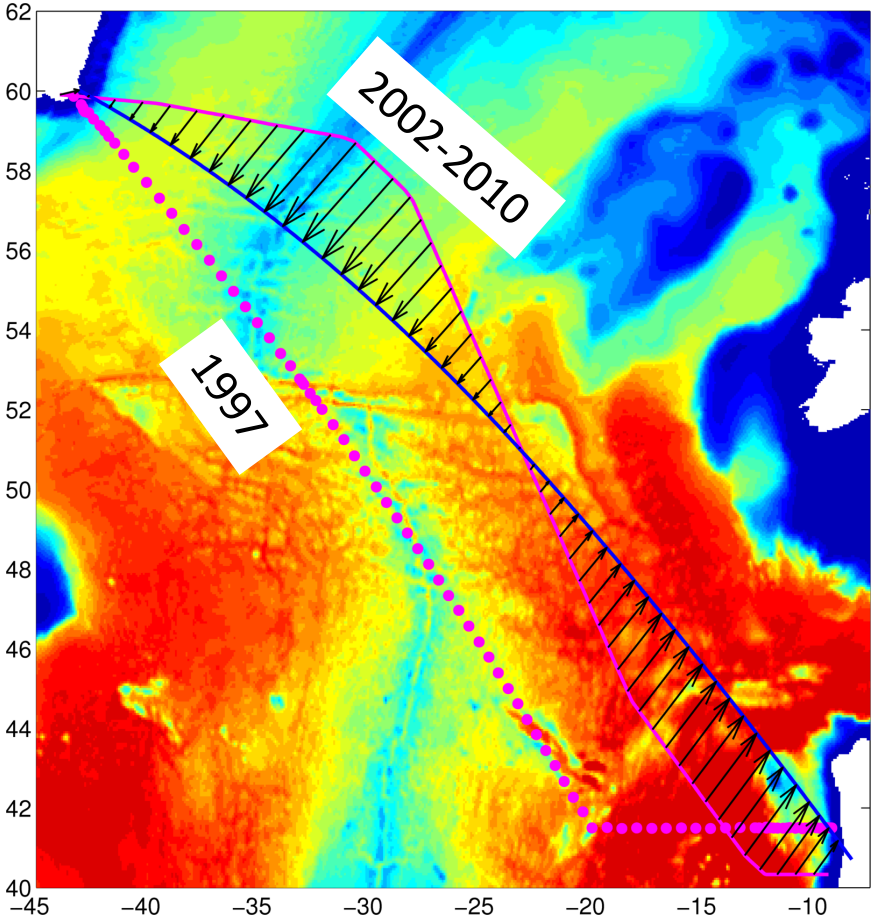




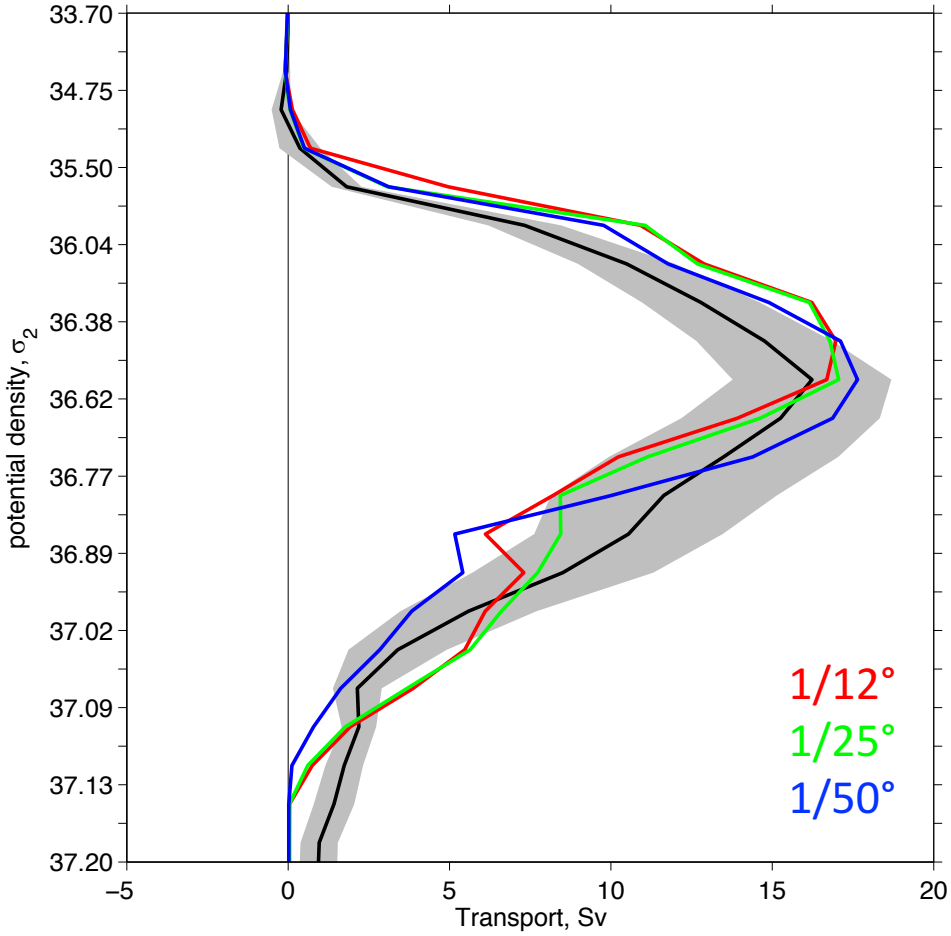


Subpolar (OVIDE section)

Section map

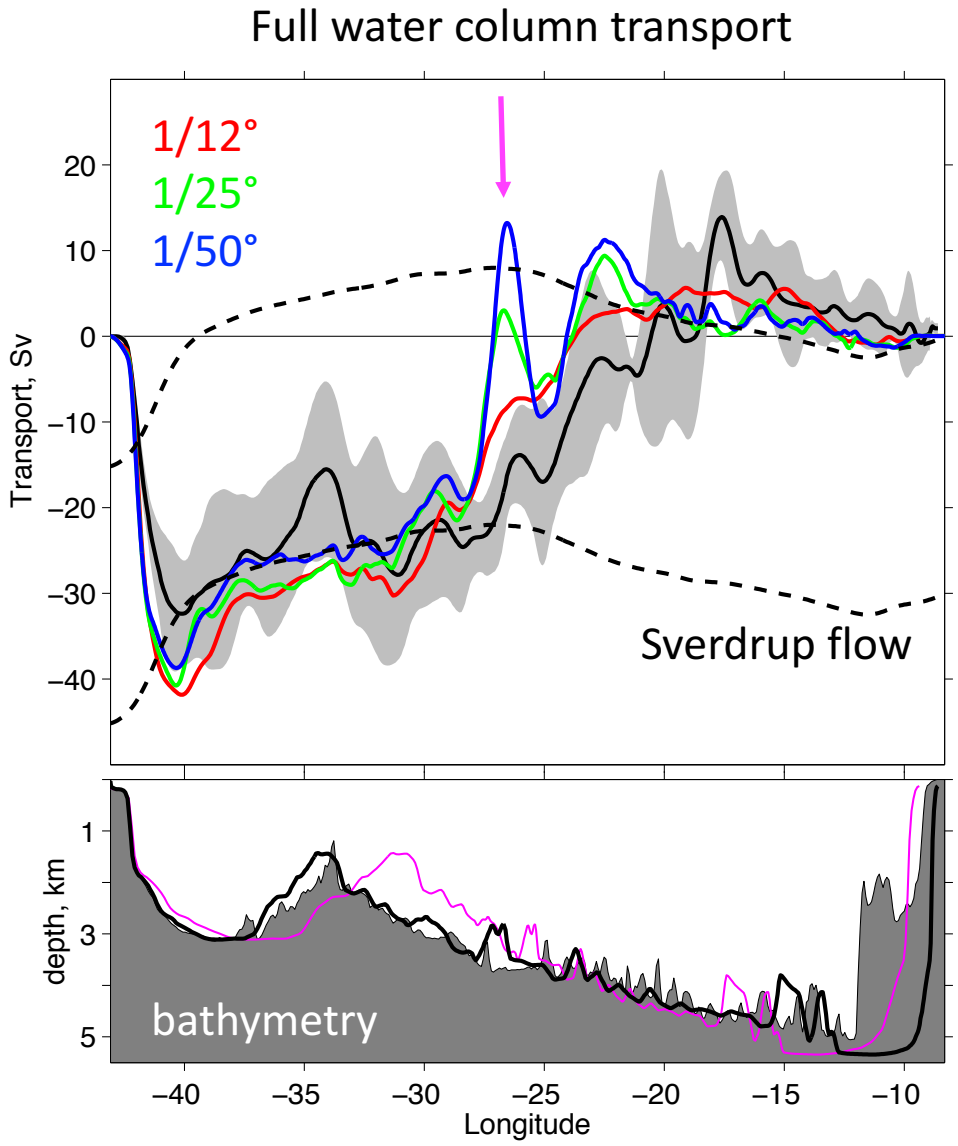


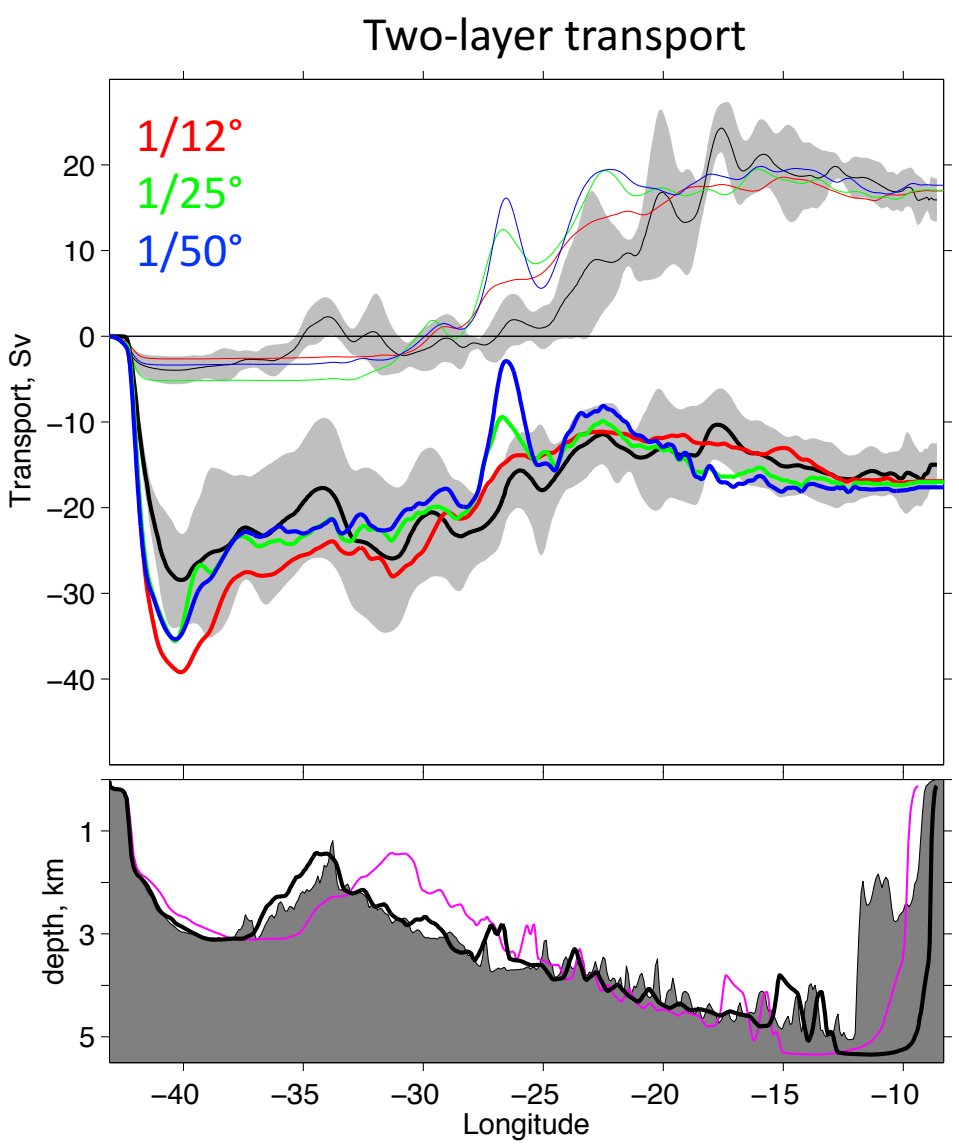
Overturning streamfunction



Observations from Daniault et al. (2016)-PO

Spatial distribution

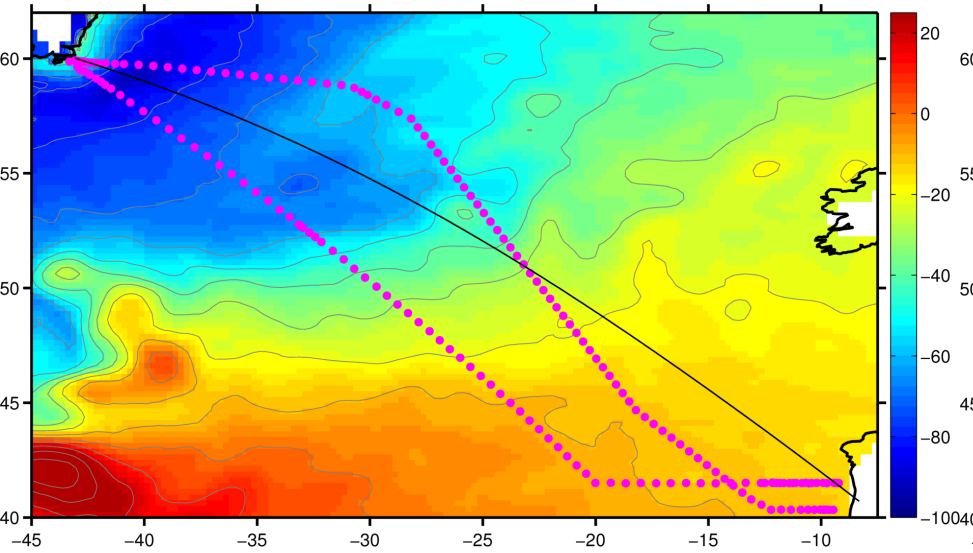




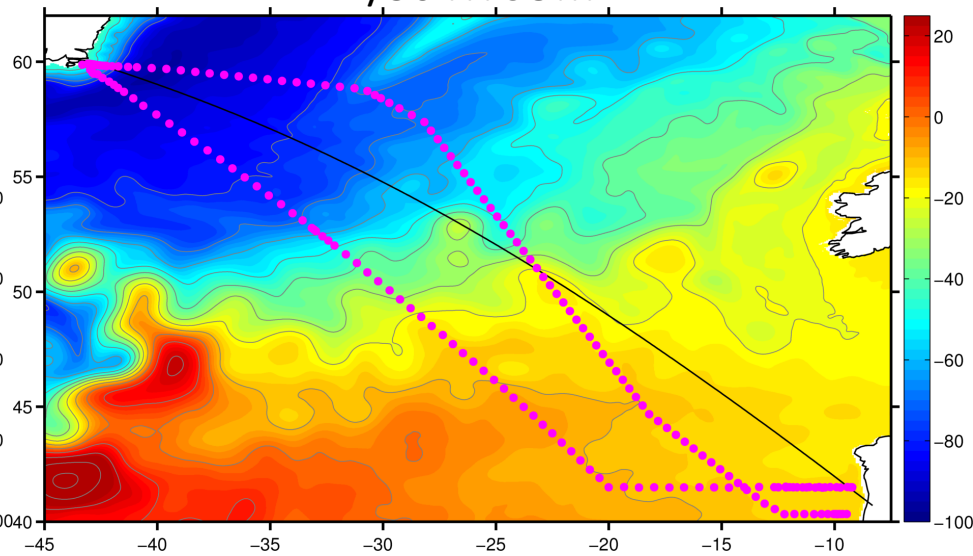
Observation from Daniault et al (2016)-PO

SSH in the subpolar North Atlantic

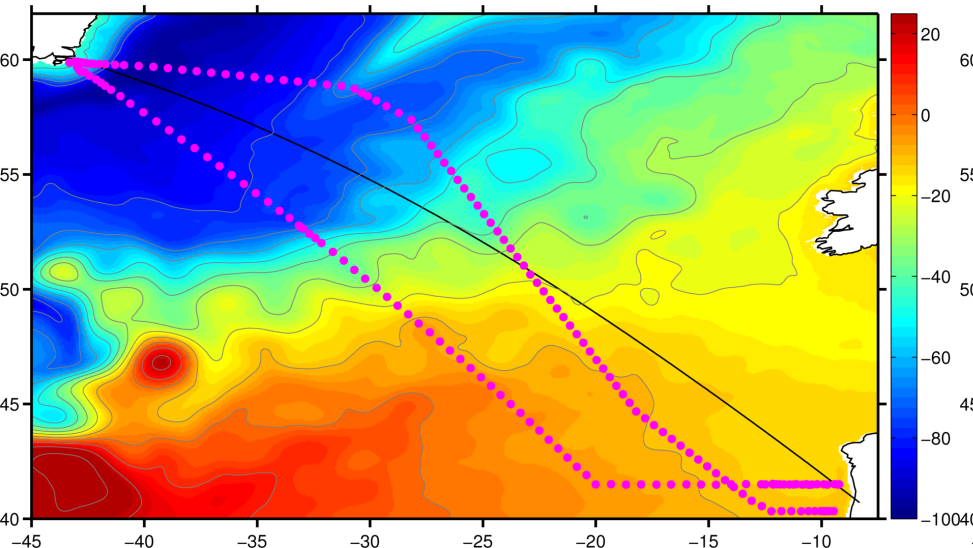
CNES-CLS-2013



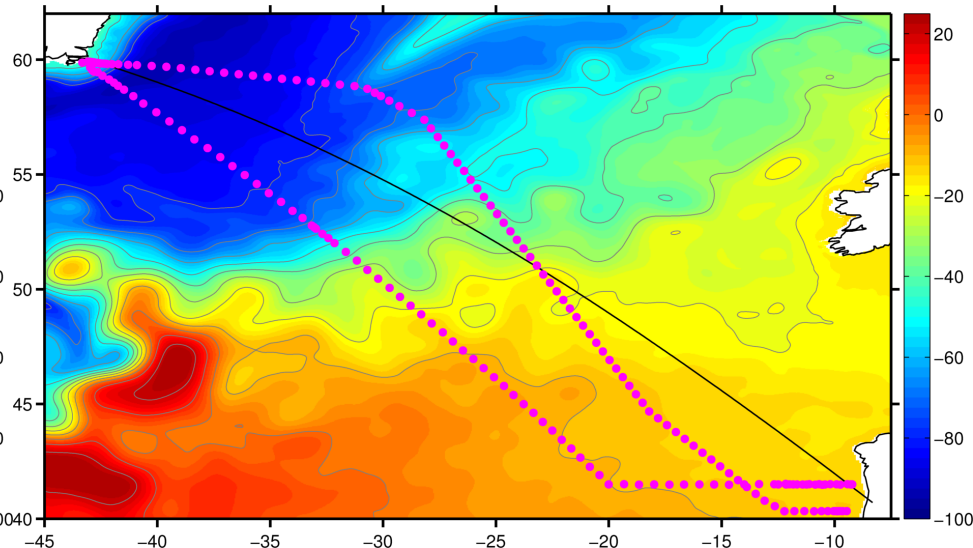
1/50 HYCOM



1/12 HYCOM



1/25 HYCOM



Summary II

- The transport structure of the large-scale AMOC and the subtropical/subpolar gyres is consistent among the 1/12°, 1/25°, and 1/50° simulations.