The health of an Eddy Permitting model.

The Problem.

Increasing resolution is seen as a key step for model fidelity. High resolution is costly, and it is tempting to "tune" models to allow dynamical effects seen as important. Explored here is the effect of tuning viscosity to allow eddies in an intermediate "eddy permitting" (1/4 °) forced ocean model. Eddy permitting model resolutions are interesting, as they are between the non-eddy (1°) and eddy-resolving resolutions, e.g. 1° and 1/12 ° . Exploring the resulting dynamics, we present cause for optimism--as largescale features improve, but interactions with bathymetry raise concers due potential changes in the geostrophic and ageostrophic partitioning of the bottom flow.

WHAT DID WE DO?

RAN A SUITE OF SISTER SIMULATIONS. Realistic and free running non-eddy (1 °), eddy permitting (1/4 o) and eddy-resolving resolutions (1/12 °) for 30 years. Parameters were kept as similar as possible. Allowing eddies and changing the resolution suggests that the eddy driven component of the flow should increase.

ESTIMATED THE OVERTURNING. *The overturning in density coordinates can illustrate how the bulk ocean responds. We can also split overturning into its barotropic (depth averaged, BT) component overturning and its baroclinic (BT) component and the resolution sensitive barotropic (BC) part.*

ESTIMATED THE BOTTOM PRESSURE TORQUE (BPT). *The BPT is a direct result of changing bathymetry (H), and without cancellation, this would increase.*

ESTIMATED JEBAR. *The BPT can be seperated into its BT and BC (JEBAR) components. JEBAR indicates the degree of compensation between the BT and JEBAR parts of BPT.*

ESTIMATED BOTTOM VERTICAL VELOCITY (WB). *If the flow were geostrophic, BPT = -fw$_b$. Departures from this indicates that the ageostrophic component increases.*

We hope that our inference regarding interesting changes from tuning eddy permitting models could help model fidelity.

AFFILIATIONS

1. MASSACHUSETTS INSTITUTE OF TECHNOLOGY

2. NATIONAL OCEANOGRAPHY CENTRE

3. MET OFFICE, UK

ABOUT US

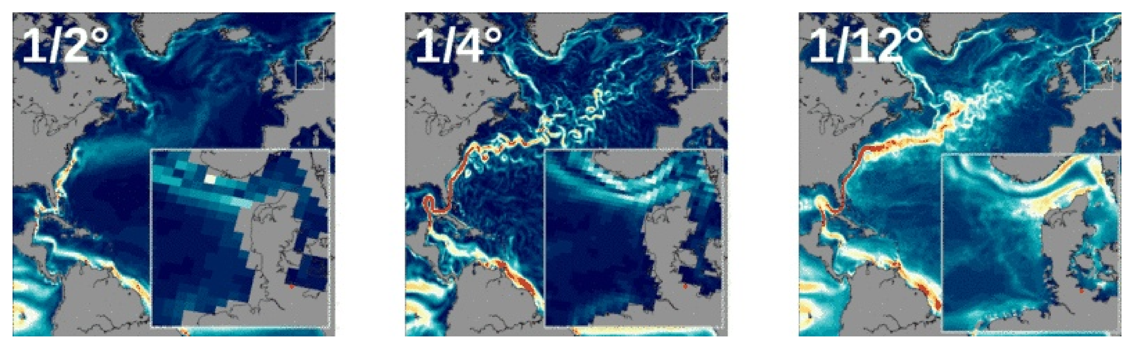
MAIKE SONNEWALD, 1

YVONNE FIRING, 2

GEORGE NURSER, 2

JOEL J.-M. HIRSCHI, 2

PATT HYDER, 3



NUCLEUS FOR EUROPEAN MODELLING OF THE OCEAN (NEMO)

Interpretation.

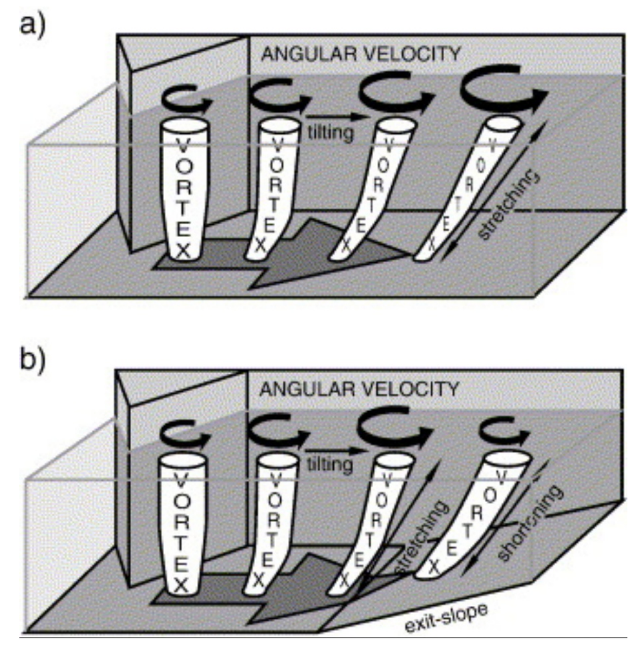
GEOSTROPHIC OR AGROSTROPHIC BOTTOM FLOW? The BPT term should equal the bottom vertical velocity (w$_b$) if the bottom flow is geostrophic. Departures can be due to e.g. bottom drag or other parameter choices.

WHAT IS "REASONABLE" WB WHEN ENCOUNTERING ROUGH BATHYMETRY? The interrogating the sister NEMO runs let us diagnose "reasonable" bounds for the geostrophic and ageostrophic bottom flow through the BPT and wb relation. We suggest that wb could be a good constraint on the success of parameterizations.

WHAT CAN BOUNDARY LAYER PARAMETERIZATION DO? Incentives for understanding and building intuition for the bottom boundary layer parameterisation could include more targeted tuning of e.g. bottom interactions where the geostrophic/ageostrophic flow components are expected to be important, e.g. being able to skew this balance diagnosing w$_b$ to assess if the model is aligned within the "reasonable" bounds. interrogating the sister NEMO runs let us diagnose "reasonable" bounds for the geostrophic and ageostrophic bottom flow through the BPT and wb relation. We suggest that w$_b$ could be a good constraint on the success of parameterizations.

INTERPRETING BPT AND JEBAR. The BPT term effectively represents vortex stretching (right Fig. from Thompsen, 2006). Using JEBAR, one assumes that bottom geostrophic flow is larger than the ageostrophic. If this is not the case it is problematic (Cane, 1998). This does not influence the BPT=-fw$_b$ infeterce discussed.

CARTOON OF VORTEX STRETCHING



Results.

The vertical levels were kept the same, but horizontal eddy viscosity helds the same in 1/4 ° and 1/12 °. Removing spin-up, we used the 30 year mean.

MODEL PARAMETERS

Name	ORCA1-N406	ORCA025-N401	ORCA0083-N01
Resolution	1°	1/4°	1/12°
z, x, y	75,292,362	75,1021,1442	75,3059,4322
GM active	Yes	No	No
Horiz. laplacian eddy viscosity (m^2s^{-1})	10^4	500	500
Horiz. bilaplacian eddy viscosity (m^4s^{-1})	-1.25×10^{10}	-2.2×10^{11}	-2.2×10^{11}
Isopycnal eddy tracer diffusivity (m^2s^{-1})	10^3	300	125
Timestep (s)	3600	1440	200

$$\Psi_{\sigma y} = \frac{1}{\Delta t}\int_t^{t+\Delta t}\int\int_{\sigma'\leq\sigma} v dx dz dt.$$

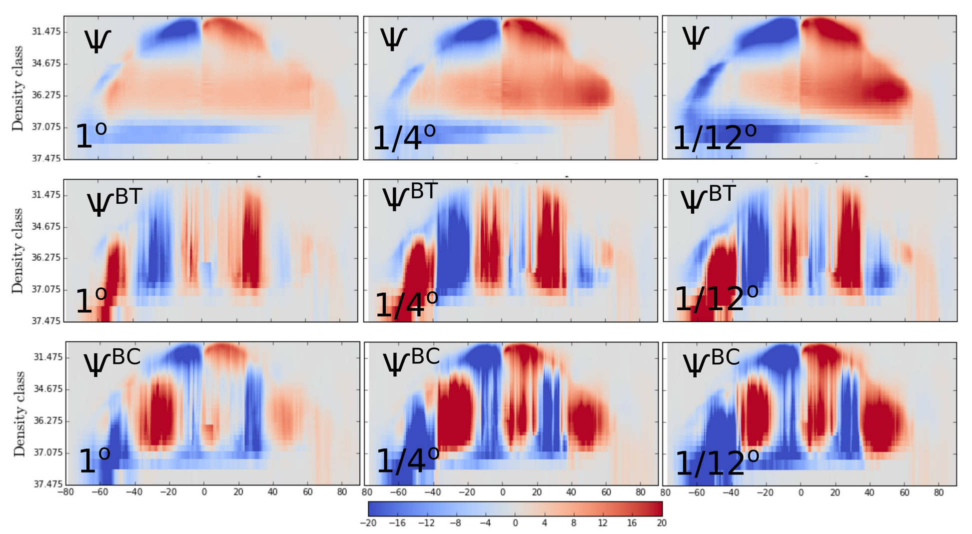
$$\psi_{\sigma y}^{BC} = \int\int_{\sigma'\leq\sigma} v_{BC} dx dz,$$

$$\psi_{\sigma y}^{BT} = \int\int_{\sigma'\leq\sigma} v_{BT} dx dz,$$

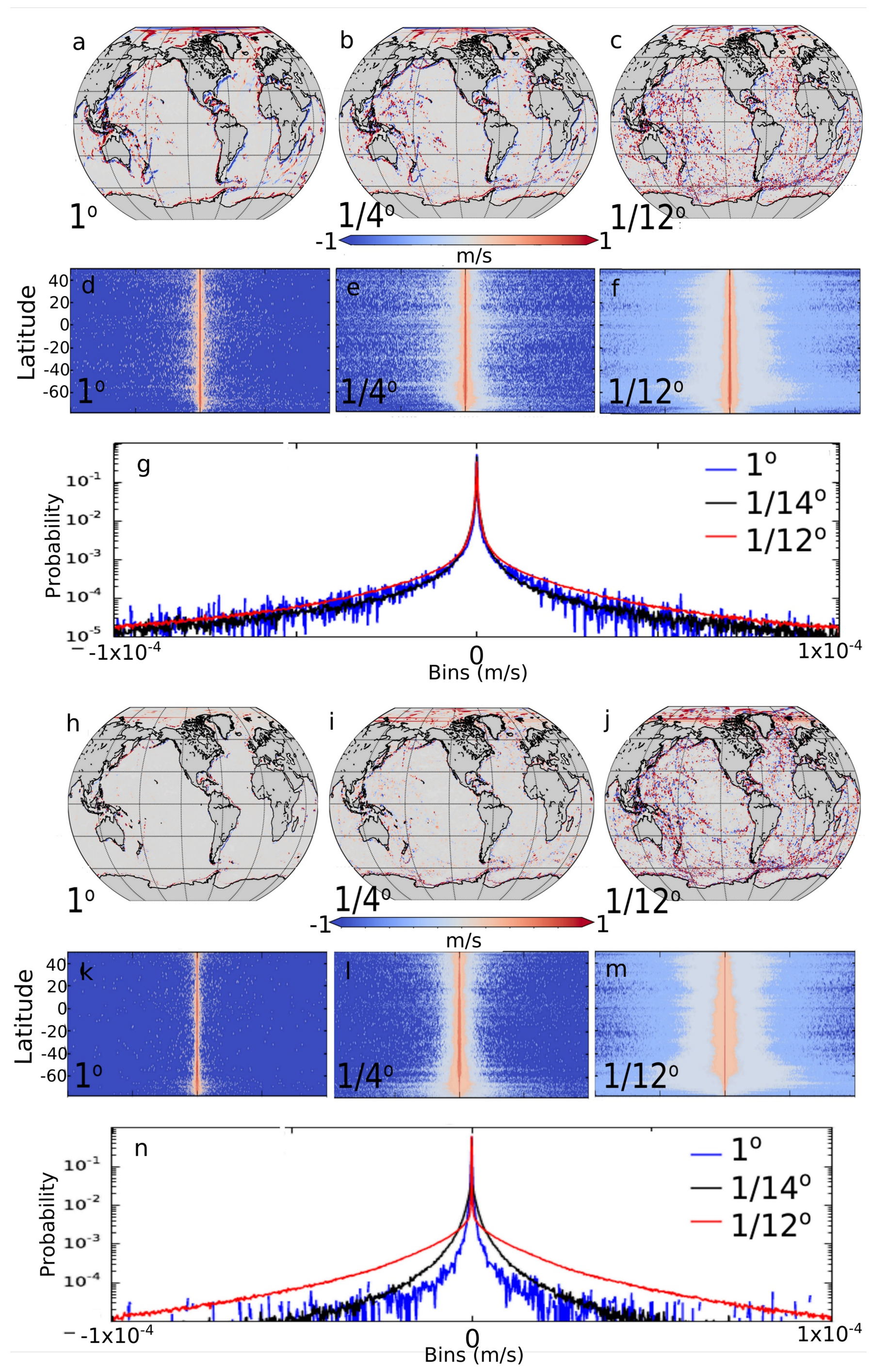
$$\psi_{\sigma y} = \psi_{\sigma y}^{BC} + \psi_{\sigma y}^{BT},$$

The overturning (eqs. lef, Fig. below) and BT and BC components were seen to be similar in 1/4 ° and 1/12 °, but weaker and with less BC contribution in 1o. The BPT (Right Fig. a-g) and JEBAR (Right Fig. h-n) reveal similar BPT, but large JEBAR different suggesting compensation. Looking at a Southern Ocean section (above left Fig.a,c,e), rough H (g) is seen to enhance BPT/JEBAR and they compensate e.g. a location w positive BPT has negative JEBAR (upper Eq. below). The wb would equal BPT if it was geostrophic (lower Eq. below). Since BPT was similar across resolution, the wb should be similar across resolutions too, assuming the bottom from is geostrophic.

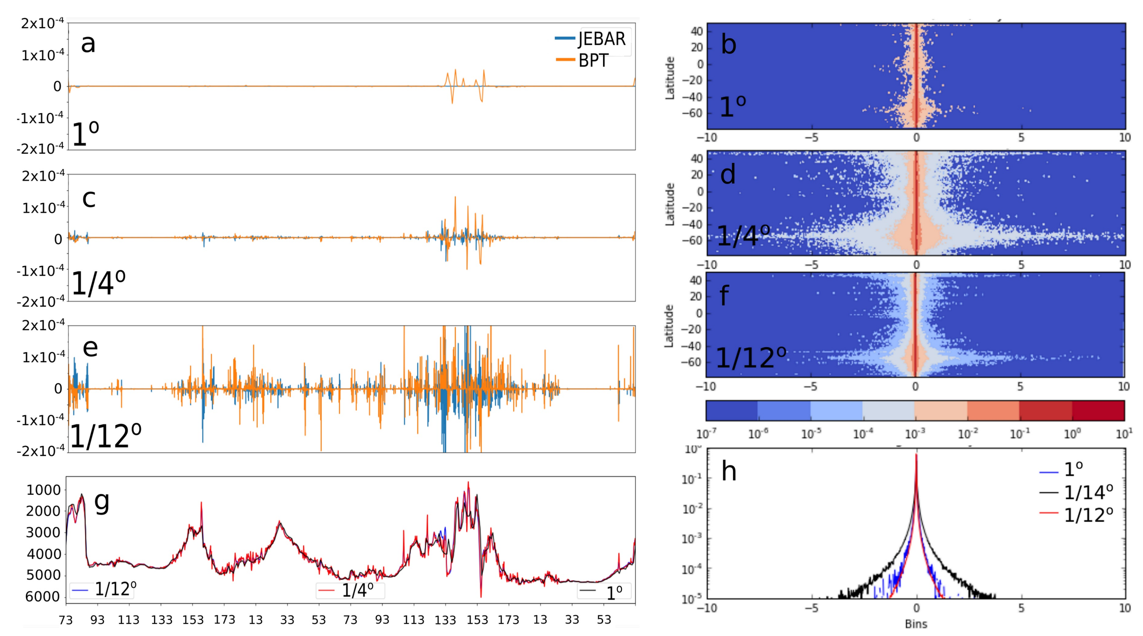
GLOBAL OVERTURNING



BPT (A-G) AND JEBAR (H-N)



COMPENSATION (LEFT) AND WB (RIGHT)



$$\frac{1}{\rho_0}J(p_b, H) = f\mathbf{v}_{gb}\cdot\nabla H = \overbrace{f(v_{gb}-\overline{\mathbf{v}}_g)\cdot\nabla H}^{\text{Baroclinic}} + \overbrace{f\overline{\mathbf{v}}_g\cdot\nabla H}^{\text{Barotropic}}.$$

$$w_b = u_b\cdot\nabla(H) = \frac{1}{\rho_0 f}J(p, H)|_b.$$

Interpretation.

The w$_b$ is similar in both the 1o and 1/12 °, while the 1/4 ° has a higher wb. This suggests that the 1/4 ° departs significantly from the geostrophic/ageostrophic partitioning of the bottom flow, even between drastically differentresolutions where it is expected to be in the middle. Departures from the BPT=-fw$_b$ relation can be interpreted as changes in the way the flow feels the bottom drag through e.g. the Ekman component.

RESOLVING HORIZONTAL VISCOUS BOUNDARY LAYERS. This layer represents the the boundary between the bathymetry and the flow. Changes in viscosity impact this layer. The coherence between the 1 ° nd 1/2 ° BPT=-fw$_b$ suggests that the 1/4 ° resolution could not resolve the horizontal viscous boundary layer suficiently.

LARGE SCALE FEATURES GIVE RISE TO CAUTIOUS OPTIMISM. We saw that the overturning, both in terms of the BC abd BT succeeded in mimicing the 1/12 ° when tuning the 1/4° model. This suggests that the overall transports effectively result in similar large scale circulation.

GEOSTROPHIC OR AGEOSTROPHIC. DOES IT REALLY MATTER? *Our results suggest that there is a from marked change between the geostrophic and ageostrophic components of the flow. This will likely have knock on effects on dynamics.*

WAY FORWARD

1. Use w$_b$ to ballpark geostrophic vs. ageostrophic flow components.
2. If only bulk properties are interesting; should one bother?
3. Probably prudent to consider long term impacts on dynamics.