Naval Research Laboratory



Keeping an eye on the world's oceans... http://www7320.nrlssc.navy.mil

The Energetics of the Global Ocean Models

The impact of model resolution and data assimilation James Richman, Patrick Hogan and Prasad Thoppil

> Oceanography Division Naval Research Laboratory

Presented at Layered Ocean Model Workshop Miami, FL February 8, 2011

What controls the energetics of the ocean?

- The ocean circulation ultimately evolves from the external forcing by the atmosphere and lunar-solar tides and dissipation due to mixing and topographic interaction.
- The pathway redistributing the work done by the forcing and loss by dissipation is complicated with instabilities of the mean circulation acting to transfer energy in the vertical and over various horizontal scales.
- The eddy variability can interact with topography to establish mean flows and feedback into the surface circulation to intensify boundary currents.

How well do we simulate the energetics of the global ocean?

 We examine the energetics of a series of twin experiments using global Hybrid Coordinate Ocean Model (HYCOM) forced by the Navy Operational Global Atmospheric Forecast System (NOGAPS) and compare the model energetics with altimeter, surface drifter and deep current meter moorings.

We use three simulations and a hindcast for our analysis,

- a multi-year global simulation at 1/12° resolution (Expt 18.2),
- a multi-year hindcast with the same 1/12° resolution model and data assimilation (Expt 74.2),
- a doubled resolution (1/25°) global model (Expt 4.2) and
- a new 1/12° global model with tidal potential forcing in addition to the NOGAPS forcing (Expt 18.5)

What happens in the simulations?

- We find that the resolution of the present generation of ocean general circulation models of ~1/10° is inadequate to establish a vigorous abyssal circulation and the surface eddy kinetic energy (EKE) is only about 85% of the observed.
- Adding tidal forcing has a minimal impact on the surface circulation but increases the deep EKE by 12% and the deep kinetic energy of the mean flow (KEM) by 25%.
- Doubling the horizontal resolution of the model increases the surface EKE to levels comparable to the drifter observations and increases the KEM by 40%, which is greater than the drifter estimates. The deep EKE and KEM also are increased to levels consistent with the deep current meters.
- Data assimilation increases the surface EKE to levels consistent with the drifter observations and increases the deep EKE and KEM. Surprisingly, data assimilation weakens the KEM at the surface and upper thermocline to levels below the 1/12° simulation.

Kinetic Energy of the Mean Flow at the Surface

Mean Kinetic Energy at Surface (cm²/s²)



Eddy Kinetic Energy at the Surface

Eddy Kinetic Energy (cm²/s²)



Correlation between HYCOM surface EKE and Drifter EKE

Surface EKE

EKE scatter plots



Eddy Kinetic Energy at the Surface in the Gulf Stream

The 1/25 model has the highest EKE with a larger southern recirculation gyre

Data assimilation brings the EKE close to the observations from the drifters



Summary of Surface EKE

Increasing the resolution or assimilating data increases the EKE to levels comparable to the drifter observations Increasing the resolution increases the KEM while assimilating data decreases the KEM Part of the doubled resolution EKE increase may be associated with surface quasigeostrophic motions Interannual variability about 15 cm²/s² in EKE and 20 cm²/s² in KEM

	Surface*		Upper Ocean ^a	Abyssal Ocean*		Abyssal Ocean†	
Model Exps.	EKE (cm ² s ⁻²)	KEM (cm ² s ⁻²)	EKE (cm ² s ⁻²)	EKE (cm ² s ⁻²)	KEM (cm ² s ⁻²)	EKE (cm ² s ⁻²)	KEM (cm ² s ⁻²)
1/12° FR (2005-09)	340 (0.80)‡	155 (x.xx)	125 (0.61)	8.374	2.808	13.27 (0.71)	6.84 (0.51)
1/25° FR (2005-09)	423 (0.81)	174 (x.xx)	188 (0.65)	12.610	4.439	18.28 (0.80)	8.54 (0.54)
1/12° DA (2008-09)	387 (0.77)	145 (x.xx)	122 (0.80)	12.235	3.476	14.17 (0.80)	6.83 (0.33)
Obs.	430	135	157			17.73	8.21

Abbreviations used: EKE, eddy kinetic energy; KEM, kinetic energy of mean flow; FR, free-running simulations; DA, data-assimilative nowcast

*Mean over the global ocean (80°S-80°N)

^aMean over the global ocean (80°S-80°N) excluding the tropical ocean (5°S-5°N) where the assumption of geostrophy leads to potentially large errors

†Mean values obtained at the ~700 current meter mooring locations

‡The correlation coefficient between the model and observed kinetic energy

Eddy Kinetic Energy at 150m



What happens at 150m compared to the surface?

 The energy levels at the surface are much greater than the corresponding levels at 150m in both the models and the observations (assuming that the altimeter geostrophic estimates are representative of 150m)

- There surface has ageostrophic wind driven motions, Ekman layer and inertial currents
- In the 1/25 model are we seeing the beginning of submesoscale motions?
- The general patterns for the surface and 150m are the same
 - Doubling resolution increases KEM and EKE
 - Data assimilation increases EKE but weakens KEM
 - Tidal forcing has little impact on the upper ocean KE

Kinetic Energy of the Mean Flow at 1000m



Eddy Kinetic Energy at 1000m



Kinetic Energy of the Deep Mean Flow



Deep Eddy Kinetic Energy



Deep Eddy Kinetic Energy in the Gulf Stream Region



Correlation between Model Deep EKE and Current Meter Observations



What happens in the simulations?

- We find that the resolution of the present generation of ocean general circulation models of ~1/10° is inadequate to establish a vigorous abyssal circulation and the surface eddy kinetic energy (EKE) is only about 85% of the observed.
- Adding tidal forcing has a minimal impact on the surface circulation but increases the deep EKE by 12% and the deep KEM by 25%.
- Doubling the horizontal resolution of the model increases the surface EKE to levels comparable to the drifter observations and increases the KEM by 40%, which is greater than the drifter estimates. The deep EKE and KEM also are increased to levels consistent with the deep current meters.
- Data assimilation increases the surface EKE to levels consistent with the drifter observations and increases the deep EKE and KEM. Surprisingly, data assimilation weakens the KEM at the surface and upper thermocline to levels below the 1/12° simulation.