GLOBAL OCEAN DYNAMICS in EDDYING REGIME

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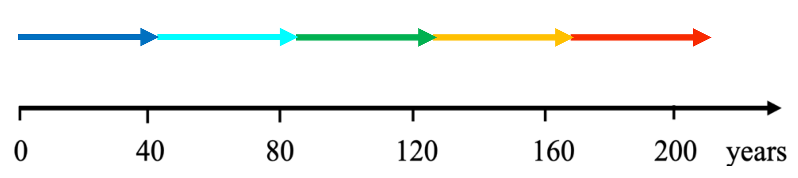
EDDYING OCEAN-SEA ICE SYSTEM

The enhanced realism in representing ocean processes, partially due to increased grid resolution and improved atmospheric forcing, has made the assessment of fidelity of ocean simulations more meaningful and rigorous. It is fundamental to perform simulations in which much of the ocean variability is resolved, and the full dynamics and life cycle of baroclinic eddies are realistically represented. **GLOB16** is a global NEMO implementation (*Madec et al 2016*), with horizontal resolution of 1/16º everywhere and 98 vertical levels, together with the LIM sea ice model (*Iovino et al 2016*). GLOB16 is here used to perform a long hindcast simulation. The experiment design follows a well-established protocol proposed by the CLIVAR Working Group on Ocean Model Development that consists in simulating repeating-cycles of the atmospheric forcing dataset (*Griffies et al 2016*). The JRA55-do atmospheric forcing (*Tsujino et al 2018*) is applied over the period 1975 to 2017. This numerical exercise aims to investigate the dynamics of the 3D ocean circulation and, in particular, the long-term changes in mesoscale activity.



5-cycle hindcast simulation covering the meteorological satellite era (from Jan 2015 to Dec 2017) driven by *JRA55-do v1.3*

PHYSICAL MODEL: NEMOv3.6 ocean configuration coupled to LIM2 (EVP) sea ice model

Mesh: Global structured tri-polar grid from 78S to 90N at 1/16º horizontal resolution (from 6.9 km at the equator to ~2 km in polar regions) with 98 vertical levels (from 1m at the surface to 160m in the deep ocean)
Grid size: 5762 × 3963 × 98 points

Bathymetry: combination of ETOPO2 for the deep ocean, GEBCO for the continental shelves, BEDMAP2 for Antarctic region. Bottom topography represented as partial steps

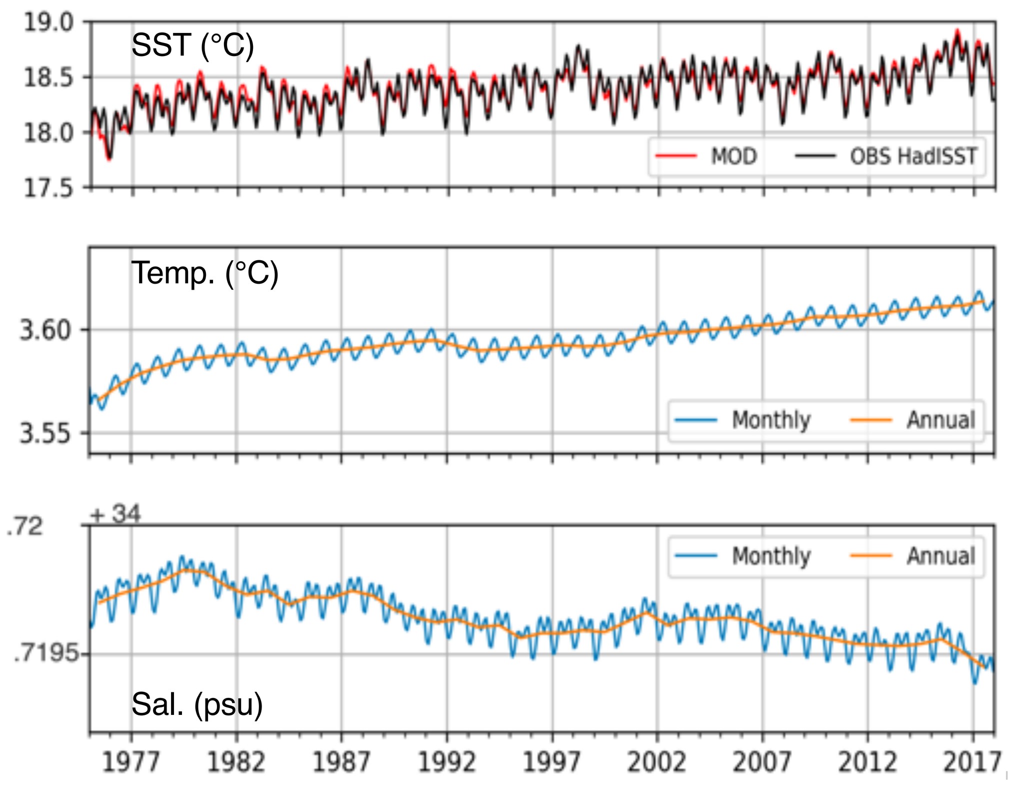
Atmospheric Forcing: JRA55-do v1.3 (≈ 55 km), with JRA runoff climatology; CORE bulk formulation

Initial conditions: temperature, salinity (and sea ice concentration) from WOA13

NO restoring of sea surface salinity and sea surface temperature

Output: Monthly output from 1975 to 2007, daily from Jan 2008 to Dec 2017. 1-year output data: monthly = ~0.5 Tb, daily = ~15 Tb

FIRST-CYCLE TIME EVOLUTION

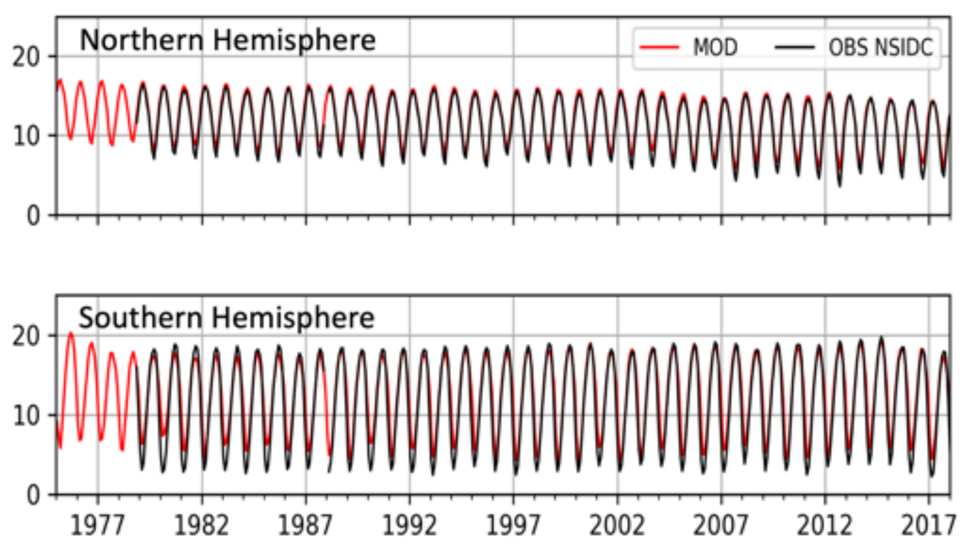


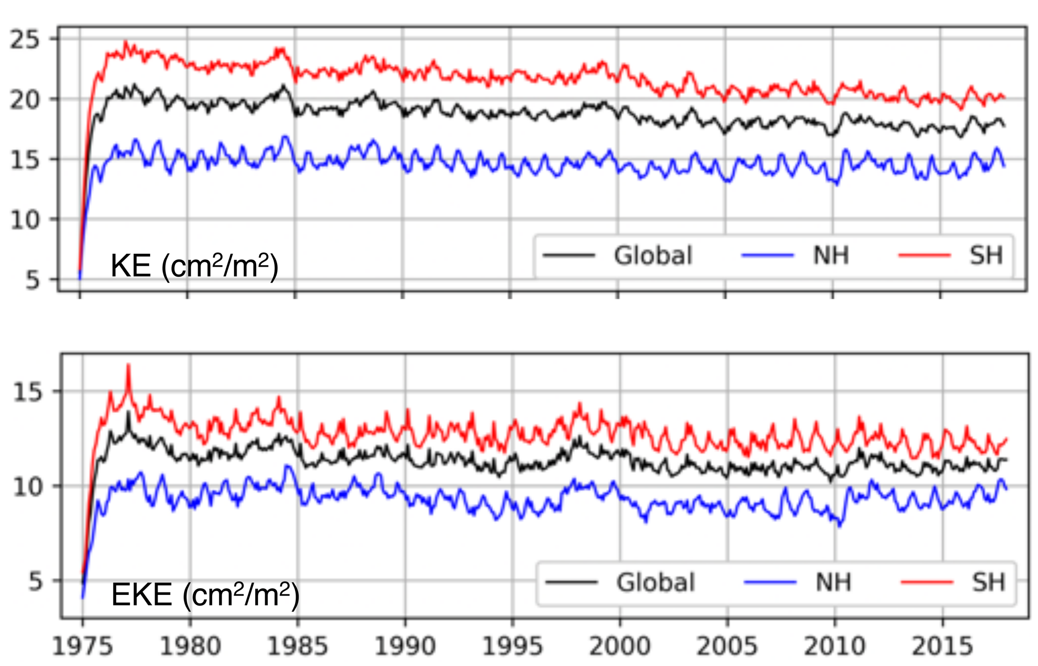
Time series of GLOB16 SST (against HadISST data set) and 3D potential temperature and salinity

Global averaged sea surface temperature (SST) increases by ~0.6ºC over time, and closely follows HadISST data.
Basin-mean potential temperature and salinity show a clear annual cycle. Temperature drifts at a rate of ~0.015ºC per decade.
Salinity drift is removed by a instantaneous constrain of zero global mean freshwater flux.

Time series of sea ice extent (SIE, in 10^6 km²) compared to NSIDC observations for both polar regions

GLOB16 properly reproduces the ice extent variability in time, compared to satellite estimates. Antarctic SIE is also consistent with observations, but generally overvalued in the minima by the model.

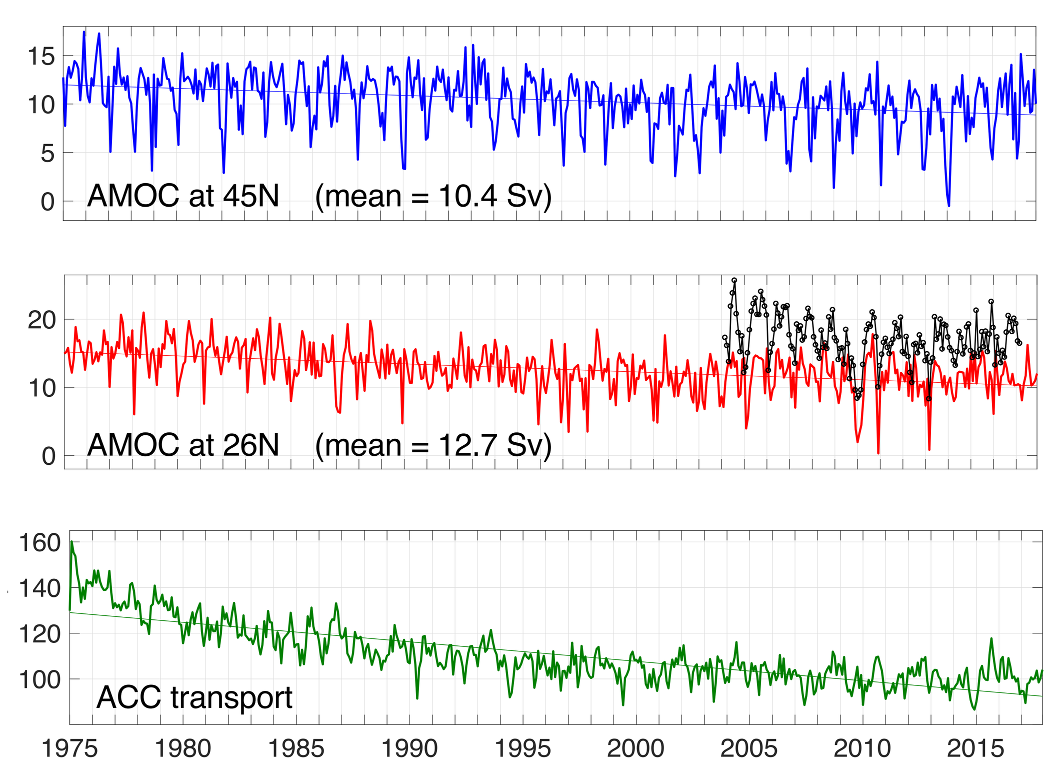




Time variations of volume-averaged total kinetic energy (TKE) and eddy kinetic energy (EKE) in cm² s^{-2} as global basin mean (black), contribution of the Northern (blues) and Southern (red) Hemisphere.

The averaged KE is ~18 cm² s^{-2}, lower than simulations at similar resolution. EKE is ~60% of the total KE.

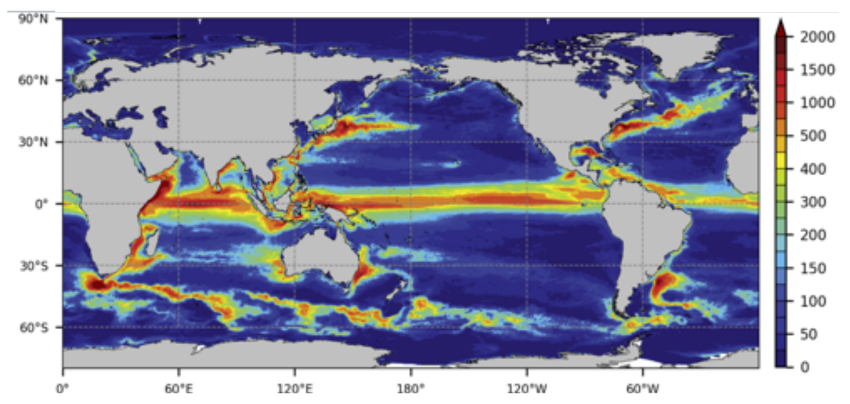
The Atlantic overturning strength (AMOC, in Sv) is lower than observational-based estimates at both latitudes. The observed values at 26.5N (16.9±3.1Sv from April 2004, *McCarthy et al 2015*) is underestimated, while the variability is reasonably consistent with the RAPID-MOCHA record.
In the Southern Ocean, the Antarctic Circumpolar Current (ACC) transport through the Drake Passage is much lower than the the canonical value of 134 Sv (*e.g. Chidichimo et al 2014, Donohue et al 2016*).

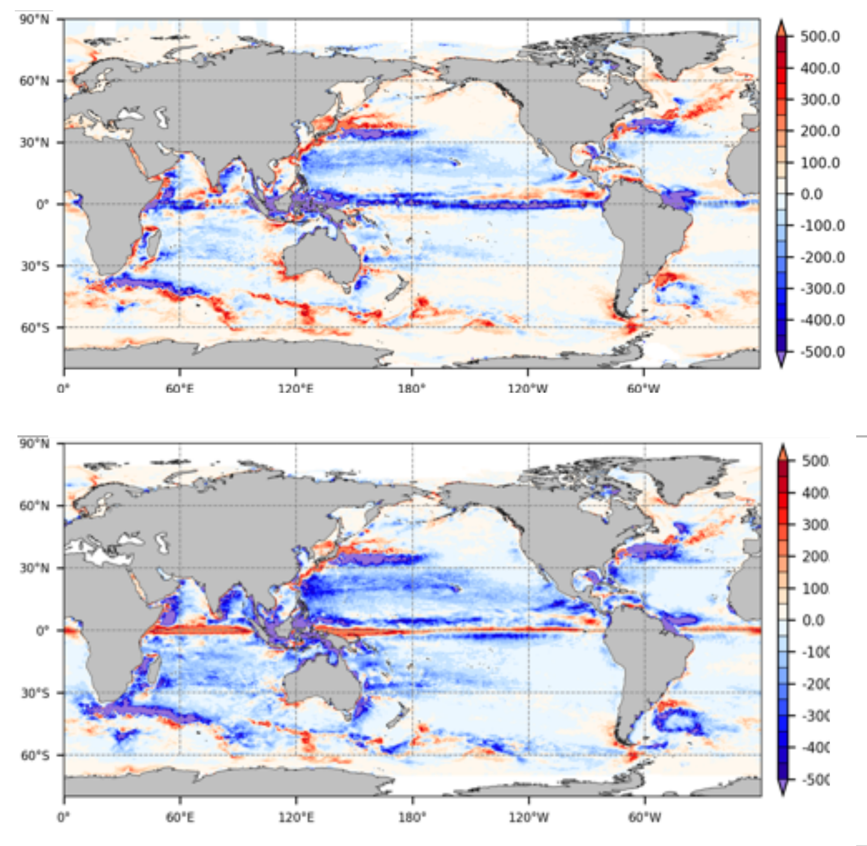


Time series of the Atlantic MOC at 45ºN and 26.5ºN (together with the RAPID estimates (in black), and the ACC transport at Drake Passage

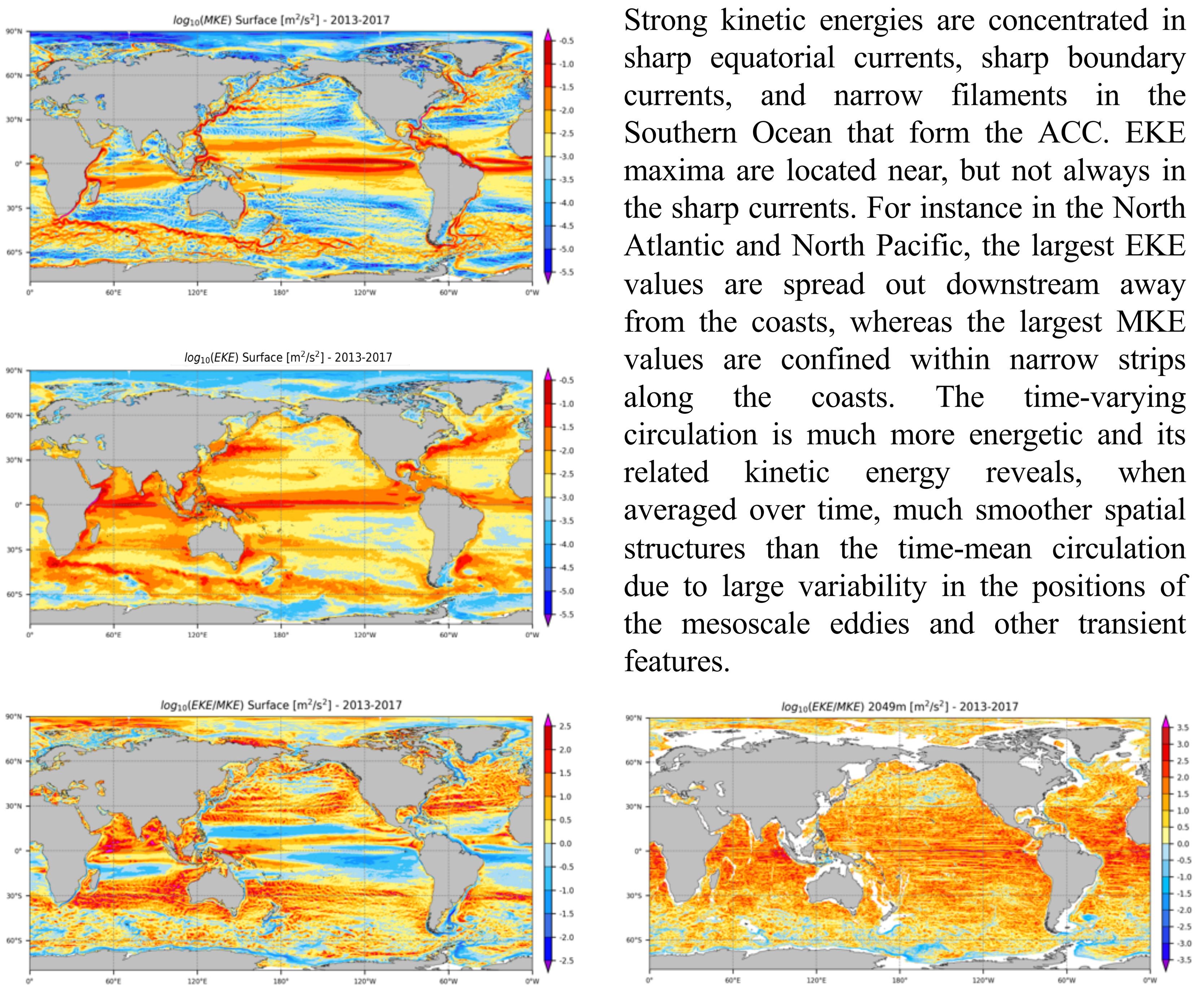
GLOB16 ENERGETICS

Horizontal distribution of surface EKE (in cm² s^{-2}) averaged over the 2013-2017 period, together with the differences between the model and OSCAR (top) and GlobCurrent (bottom).





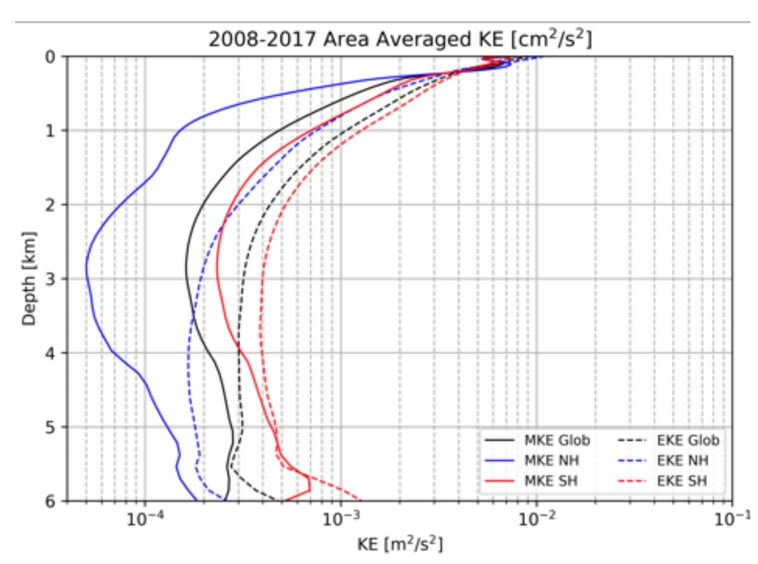
N.B. OSCAR provides near-surface ocean currents on a 1/3° grid with a 5-day resolution, from satellites and in situ instruments, combining geostrophic, Ekman and Stommel shear dynamics, and a complementary term from the surface buoyancy gradient.
The more energetic GlobCurrent combines geostrophic and Ekman currents, interpolated on a 25km grid at and a temporal resolution of 1 day.



Strong kinetic energies are concentrated in sharp equatorial currents, sharp boundary currents, and narrow filaments in the Southern Ocean that form the ACC. EKE maxima are located near, but not always in the sharp currents. For instance in the North Atlantic and North Pacific, the largest EKE values are spread out downstream away from the coasts, whereas the largest MKE values are confined within narrow strips along the coasts. The time-varying circulation is much more energetic and its related kinetic energy reveals, when averaged over time, much smoother spatial structures than the time-mean circulation due to large variability in the positions of the mesoscale eddies and other transient features.

Distribution of mean kinetic energy (MKE), eddy kinetic energy (EKE) at surface, and the ration EKE/MKE at surface and at 2000-m depth from the 2013–2017 period (in log scale).

Kinetic energy decreases drastically with increasing depth and the intensity of the time-varying circulation is stronger than that of the time-mean circulation throughout the water column. Translated into velocity speed, the time-varying circulation is up to ~50% smaller.



Vertical profiles of area averages of MKE (solid), and EKE (dashed) as a function of depth, for the last decade.

Main References: *Iovino et al.*, Geosci. Model Dev. Discuss., 2016. *Madec et al.*, Technical Report ISSN Nº935, 2016. *Griffies et al.*, Geosci. Model Dev, 2016. *Tsujino et al.*, Ocean Modelling, 2018. *McCarthy et al.*, Prog. Oceanog., 2015. *Chidimimo et al.,* J. Phys. Oceanogr., 2014. *Donohue et al.,* Geophys. Res. Lett., 2016.

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