High resolution brings global DRAKKAR ocean simulations closer to AVISO at large time/space scales

DRAKKAR Modelling Program

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OST/ST supports DRAKKAR to develop various synergies between ocean observations, simulations, and theories. This includes atmospheric forcing, OSSEs, process studies from observations and models, and simulation assessment techniques. In the present study, we collocate **four 1958-2004 global ocean simulations (2°, 1°, 1/2°, 1/4°)** onto the 1993-2004 AVISO database to demonstrate that **increasing model resolution largely improves sea-level variability properties, not only at eddy scales as already known, but also at climatic (large-scale & slow) scales**. We describe the impact of model resolution on the realism of :

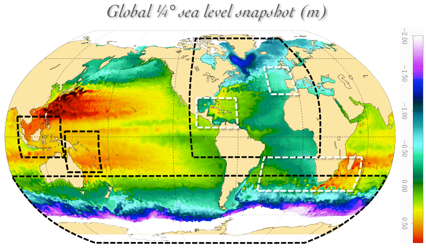
1. Magnitude and Distribution of interannual variabilities (Global)
2. Spatiotemporal modes (EOFs) of interannual variability (North Atlantic)
3. Phase of local interannual variabilities (Global)

The DRAKKAR ocean modelling Group is led by scientists from France, Germany, and the UK, with several collaborations in the operational and research oceanographic communities. This group continuously develops, upgrades, and integrates a hierarchy of global and regional ocean/sea-ice models over the period 1960-present, making continuous use of available observed datasets (forcing, validation, OSSEs).

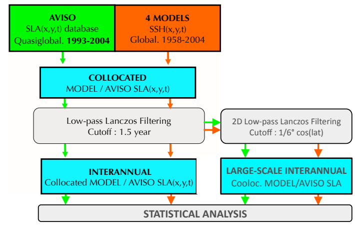
http://www-meom.hmg.inpg.fr/Web/Projets/DRAKKAR/

- NEMO ocean/sea-ice/^{14}C/CFC_{11} z-level code
- Global 2°, Global 1°, Global ½°, Global ¼°
- Stand-alone configurations
- Nested configurations
- Regional & global studies over 1958-2004
- 100+ users collaborating on scientific studies

Global ¼° sea level snapshot (m)



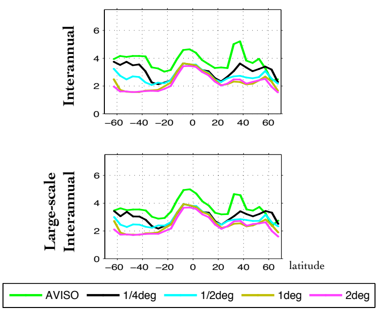
Model-data collocation & filtering



1.a Magnitude of interannual variabilities (Global)

SLA standard deviations (cm)

$\sigma^A(\lambda)$ and $\sigma^m(\lambda)$



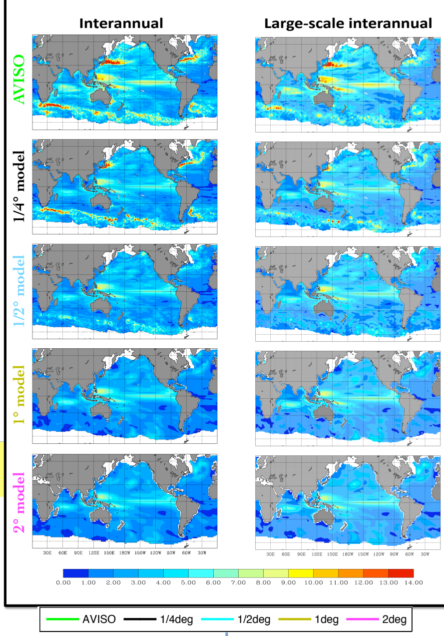
- Strong enhancement of interannual variability at eddy-admitting resolution.
- This is particularly clear where mesoscale eddies are present (i.e. Southern Ocean)
- High resolution strongly enhances the LARGE-SCALE (L>6° or 12°) interannual variability as well, involved in ocean-atmosphere coupling.
- Still room for improvement at 1/4° : higher resolution + finer/stronger surface forcing

Note 1 : the 4 global models have comparable meridional resolutions in 15°S-15°N ➔ weak inter-model differences there.
Note 2 : Gent & McWilliams parameterization used at 1° & 2° only.

Zonal averaging

Model-data spatial correlation

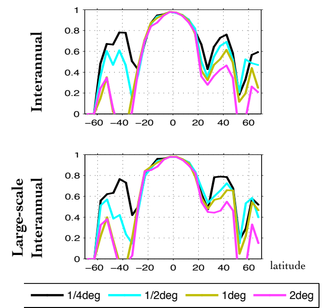
Sea Level Anomaly standard deviation maps of AVISO and DRAKKAR (fields were first **collocated** in time and space)



1.b Distribution of interannual variabilities (Global)

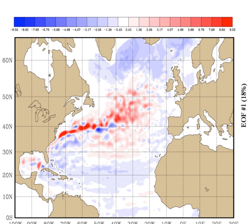
SLA spatial correlations

$C_s^m(\lambda)$



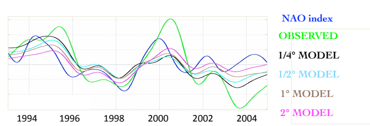
- Strong improvement of SLA interannual variability maps with increasing resolution, especially at mid/high latitudes.
- Like for standard deviations, both laminar models yield very similar variability maps. The 1/2° and 1/4° models yield successive improvements.
- High resolution largely improves the geographical distribution of the LARGE-SCALE (L>6° or 12°) interannual variability as well, involved in ocean-atmosphere coupling.

2. Spatiotemporal modes of interannual variabilities in the North Atlantic



Step 1: compute the leading EOFs of the interannual AVISO SLA(x,y,t)

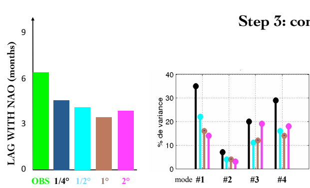
The first EOF of the *observed* SLA in the North Atlantic exhibits the well-known « intergyre gyre » circulation anomaly (Marshall 2001). This mode's Principal Component is shown in green in the figure below, along with the NAO index (blue), which is known to drive this intergyre gyre.



Step 2: project model SLA(x,y,t) on these observed interannual spatial modes

The four models can mimic the observed (green) *spatiotemporal* interannual variability, which lags the NAO by 6.5 months (left figure below). Differences :

Step 3: compare the observed interannual EOFs with the 4 simulations projected onto them



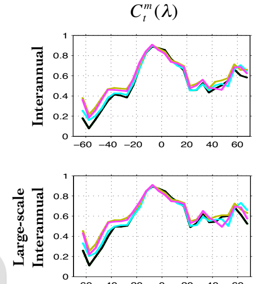
Increased model resolution from 2° to 1/4° improves the spatio-temporal NAO-forced oceanic response in the North Atlantic :
- NAO-ocean lag tends toward observed value
- Interannual variability get enhanced.

Improvement even clearer in the Gulf Stream.

3. Phase of local interannual variabilities

SLA temporal correlations

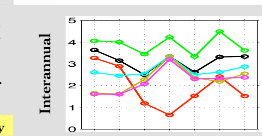
$C_t^m(\lambda)$



Figures on the right show zonally-averaged correlation coefficients between observed and modelled interannual SLA(t) local timeseries. Increased resolution yields a slight but systematic decrease in these terms, especially in the Southern Ocean. This is consistent with higher resolution letting an intrinsic (eddy-driven) interannual variability emerge.

Is this hypothesis plausible?

Zonally-averaged SLA standard deviations are shown on the right. The red line corresponds to a **1/4° global simulation forced by the seasonal cycle only.** Away from the tropics, 40% (Northern hemisphere) up to **90%** (Southern hemisphere) of the total SLA variability (black) emerges **without direct forcing of interannual variability (compare red & black lines)**



➔ Strong eddy-driven interannual ACC variability

Conclusions

The AVISO dataset is essential for model assessment. We use it here as a reference to compare 4 simulations

- Model resolution does not only improve mean & eddy flows, but also interannual & large-scale variabilities
➔ Interannual variability gets stronger, better distributed. Eddy-driven interannual variability in the ACC.
- Large-scale slow variab <-> A/O coupling : our results support the use of 1/4° ocean models for climate forecasts
- Resolution-induced improvements exhibit more complex dependancies (latitude, scales, local features, etc)
➔ More details in *Penduff et al (2009)*

References

- Brodeau, L., B. Barnier, T. Penduff, A.M. Treguier, and S. Gulev, 2007 : An ERA-40 based atmospheric forcing for global ocean circulation models. Ocean Modelling, in revision.
- DRAKKAR Group, 2007: Eddy-permitting ocean circulation hindcasts of past decades. Clivar Exchanges, No 42 (vol 12 No 3), 8–10.
- Marshall, J., H. Johnson, and J. Goodman, 2001: A study of the interaction of the North Atlantic Oscillation with the ocean circulation. Journal of Climate, 14, 1399-1421.
- Penduff, T. B. Barnier, A.M. Treguier, P.Y. Le Traon, 2006 : Synergy between ocean observations and numerical simulations: CLIPPER heritage and DRAKKAR perspectives. Proceedings for *15 years of progress in radar altimetry*, Venice, 16-18 March 2006
- Penduff, T. M. Juza, and B. Barnier, 2007: Assessing the realism of ocean simulations against hydrography and altimetry. Clivar Exchanges, No 42,12, 11-12.
- Penduff, T., M. Juza, L. Brodeau, G.C. Smith, B. Barnier, J.-M. Molines and A.-M. Treguier, 2009 : « Impact of model resolution on sea-level variability characteristics at various space and time scales: insights from four DRAKKAR global simulations and the AVISO altimeter data ». Ocean Science, in revision.