ENSO-like variability in the coupled climate model ECHAM6-FESOM

featuring an unstructured ocean component

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Introduction

- We validate a new global climate model based on the state-of-the-art **ECHAM6** atmosphere model by MPI Hamburg (Stevens et al., 2013) and the Finite-Element Sea-Ice Ocean Model **FESOM** developed at AWI Bremerhaven (e.g. Timmermann et al., 2009).
- The ocean and atmosphere models are coupled with the OASIS3-MCT coupler (Valcke et al., 2012) via an exchange mesh.
- ECHAM6-FESOM is the first climate model with an ocean supporting unstructured triangular surface meshes.

- We analyze two model setups with and without local refinement in the tropics (see Table 1 & Fig. 1).
- The HadISST data set (Rayner et al., 2003) is used as a comparison to test the model ENSO performance (see Fig. 2-6 & Table 2).
- ***QUESTIONS**: Is the model able to reproduce observed ENSO characteristics? Is the high spatial resolution in the tropics of benefit for the simulation of ENSO-like variability?*

Summary and conclusions

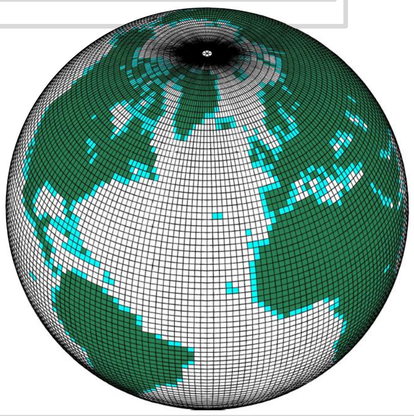
Regarding question 1:

- The power spectral densities of the modelled Nino 3 indices agree well with observations (see Fig. 6).

Regarding question 2:

- In the Setup 2 with high tropical resolution, the equatorial Pacific cold tongue does not extend as far to the west as in Setup 1; accordingly, the bias in annual mean SST and interannual standard deviation of SST is reduced by up to 1°C and 0.2°C, respectively (cf. Fig. 4).
- Main correlation pattern between Nino 3 index and global SST anomalies broadens with higher resolution (cf. Fig. 5); too low correlation over Indian Ocean in both simulations.
- The modelled Nino 3 index statistics (i.e. standard deviation, skewness as well as kurtosis) tend to improve with higher resolution (see Table 2).

- ***IN SUM**, the simulation of ENSO perceptibly benefits from the higher resolution in the ocean in many aspects.*



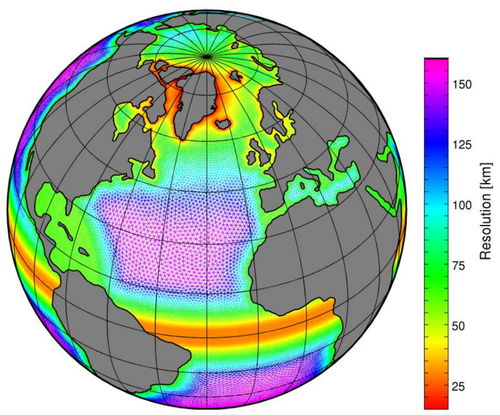


***Figure 1**: The land-sea mask in ECHAM6 corresponding to the T63 spatial resolution (left) and the unstructured FESOM mesh ‚Ref87k' from Setup 2 with increased resolution in the tropics (right).*

Grid boxes where the ECHAM6 land-sea fraction ‚lsm' exceeds 50% are shown in green; cyan and white denote a land-sea fraction with $50\% \geq lsm \geq 0\%$ and $lsm = 0$, respectively.

Model results compared to observations

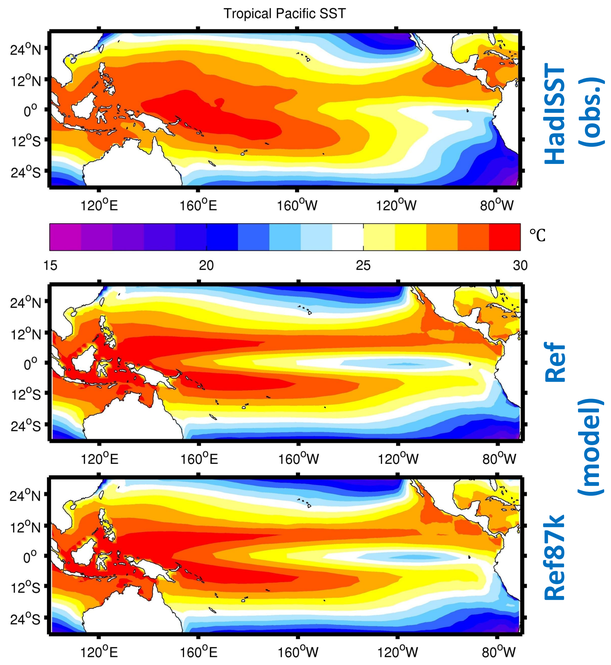


***Figure 2**: Annual mean SST **(top)** from the HadISST data set for the years 1948 to 2004, **(middle)** from the ‚Ref' simulation and **(bottom)** for the ‚Ref87k' simulation with increased spatial resolution in the tropics. The SST for the model simulations is calculated from the same 100 year period. The equatorial cold bias present in the ECHAM6-FESOM simulations is a bias typical for coupled climate models of similar complexity.*

Ocean model setup / Configuration

Ocean model configuration	2D nodes	3D nodes	Resolution between $15°N$ and $15°S$
Setup 1: Ref mesh	43,943	1,250,994	About 1°
Setup 2: Ref87k mesh	86,803 (“87k”)	2,857,515	0.25° at the equator gradually decreasing to 1° at $\pm 15°$

***Table 1**: Summary of the properties for the two different meshes used. Outside the tropics, both meshes are identical.*

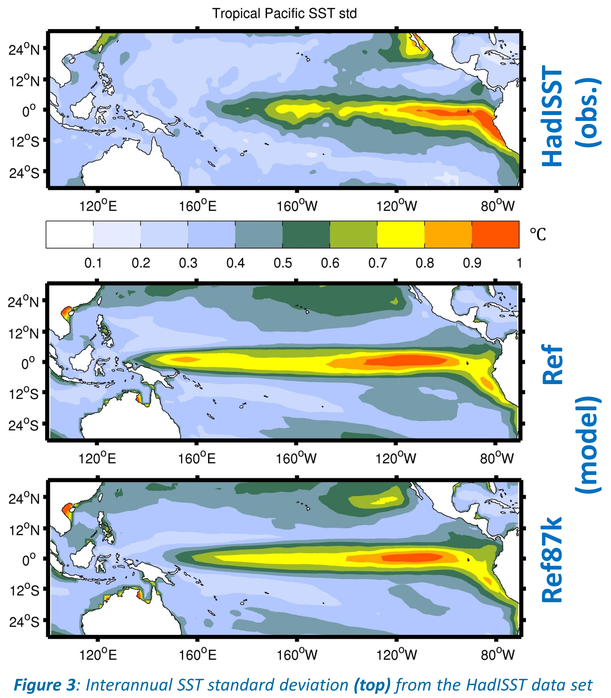


***Figure 3**: Interannual SST standard deviation **(top)** from the HadISST data set for the years 1948 to 2004, **(middle)** from the ‚Ref' simulation and **(bottom)** for the ‚Ref87k' simulation with increased spatial resolution in the tropics. The SST standard deviation for the model simulations is calculated from the same 100 year period.*

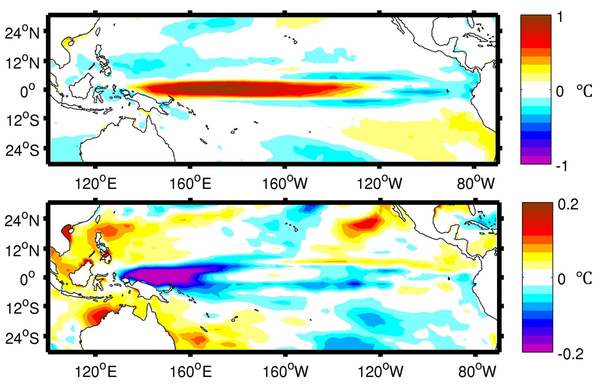


***Figure 4**: Difference in annual mean SST **(top)** and interannual standard deviation **(bottom)** between the ‚Ref87k' simulation with increased spatial resolution in the tropics and the ‚Ref' simulation for the 100 year period in Fig. 2 & 3. Shown is (Ref87k - Ref). The simulation of the warm pool is improved by up to 1°C in the ‚Ref87k' run; the erroneous high standard deviation in the western equatorial Pacific is reduced by more than 0.2°C. Accordingly, the equatorial cold bias is significantly reduced with higher ocean resolution.*

References

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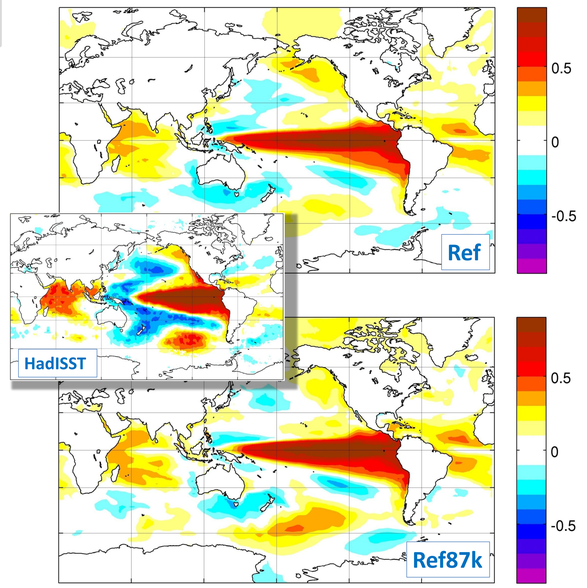

***Figure 5**: Correlation between the Nino 3 index and global SST anomalies for **(top)** the ‚Ref' simulation, **(middle, overlay)** for the HadISST data set, years 1900 to 1999, and **(bottom)** for the ‚Ref87k' simulation. Model results are based on the same 100 year period.*

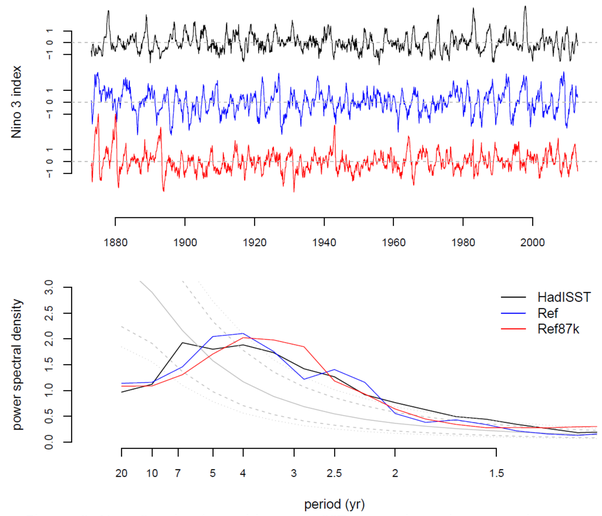

***Figure 6**: Nino 3 index (monthly mean SST anomaly in the region between 150°W – 90°W, 5°N – 5°S) for the HadISST data set (1873-2012) and the two model simulations based on a 140 year period **(top)** as well as their corresponding spectra **(bottom)**. The solid grey line gives the median of 10,000 AR(1) process spectra with HadISST-fitted AR(1) coefficient of ~0.92; dashed grey lines denote the (0.01, 0.05, 0.95, 0.99) quantiles.*

Data set / model simulation	Standard deviation	Skewness	Kurtosis
HadISST (1873-2012)	0.75 ± 0.04	0.69 ± 0.16	4.04 ± 0.27
Setup 1: Ref (100 years)	0.90 ± 0.06	0.03 ± 0.19	2.95 ± 0.31
Setup 2: Ref87k (100 years)	0.74 ± 0.05	0.22 ± 0.19	3.53 ± 0.31

***Table 2**: Statistics for the Nino 3 index from the HadISST data set and the two model simulations with ECHAM6-FESOM, respectively. The seasonal cycle and trends have been removed from all time series. Confidence intervals are estimated via a Monte-Carlo simulation of 10,000 corresponding AR(1) processes.*

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