The effects of stratosphere-troposphere coupling on the decadal predictability of the climate system

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ABSTRACT

The coupled ocean-atmosphere CMCC-CMS model is used to investigate the influence of the stratosphere on the decadal predictability. As part of the EU-funded COMBINE Project, a set of decadal prediction experiments are performed for the 1960-2005 period, following the CMIP5 protocol using historical radiative forcing conditions, followed by RCP4.5 scenario settings from 2006 onward. The decadal predictions consist in 3-member ensembles of 10-year simulations starting at 5-year intervals, with the ocean initial states provided by ocean reanalyses differing by assimilation methods and assimilated data. A purpose of this work is to asses the impact of the initialization to reproduce climate variations with respect to an uninitialized climate simulation performed for the same time period of the predictions using identical forcing conditions. Focus will be also laid on the differences between simulations by high-top configuration (CMCCCMS), including a well-resolved stratosphere and equivalent simulations using a low top model (CMCC-CM) differing in vertical extent and vertical resolution, to estimate how the inclusion of a well represented stratosphere could impact climate predictability on the decadal time scales.

Method:

The CMCC-CMS Coupled Model

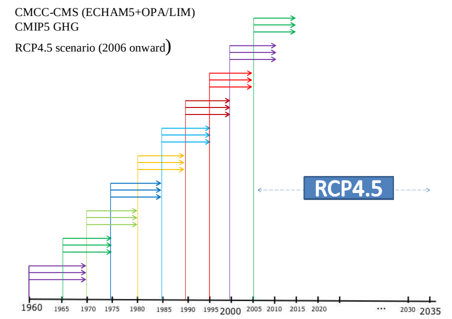
ATMOSPHERE ECHAM5
Res. = T63L95

COUPLER OASIS 2.3
Coupling frequency = 1.5h
NO FLUX ADJUSTMENT

OCEAN OPA 8.2 + **SEA ICE** LIM
[Madec et al., 1998, Fichefet 1997]
Horiz. Res. = ORCA2 **(0.5° to 2°)**
Vertical Res. = 31 Levels

EXPERIMENT SETUP

Decadal predictions: experiment setup



A **full field** initialization technique is adopted.

The 10 year hindcast-forecast simulations are grouped in 3 member ensembles

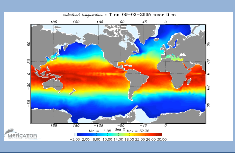
The different start dates are starting at 5-year intervals.

As a predictive skill evaluation measure, anomaly correlations are computed over lead-times 1, 2–5 and 6–9 years for observations and simulations sub-sampling for each start date.

INITIALIZATION

The ocean initial states provided by ocean reanalyses differing by assimilation methods. The three schemes are performed with:

- Optimal Interpolation (OI)
- 3DVAR1 three-dimensional variational data assimilation system
- 3DVAR2



Results:

High –top model

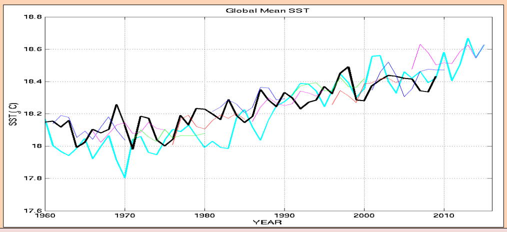


Figure1: Time series of globally averaged annual mean sea surface temperature [°C] for reanalysis (black) and the ensemble mean of the decadal simulations initialized (blue, green, magenta, red), and uninitialized (cyan blue) after bias correction. Global mean SST anomalies (relative to 1960–2010) from HadISST .

- The full value initialization approach provide to a drift from the observation as the hindcast-forecast progresses beyond the initial conditions.
- A drift removal procedure is applied to model data by subtracting the average forecast from the individual raw forecasts.
- In figure1 is shown the global mean of SST for 1960-2015 time period of the predictions and for the same period of uninitialized climate simulation using identical forcing condition; the global mean of HadISST observations is performed over 1960-2010.

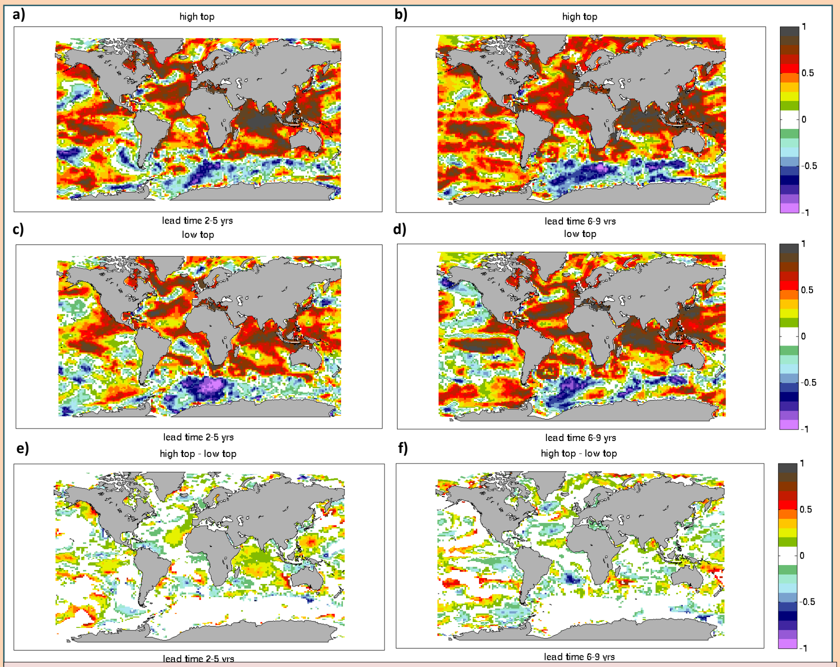


Figure2: Anomaly correlation coefficient of SST hindcasts for years 2–5 (left) and 6–9 (right) for Hight-top model [T63L95](a-b); for Low-top model [T159L31] (c-d); The aritmetical difference assuming that negtive correlations are meaningless (e-f).

- To assess the relative virtues of the forecast systems, the predictive skill of the annual mean surface temperature is evaluated, through anomaly correlation coefficient (ACC) patterns of the ensemble mean for the period 1960–2010.
- The same evaluation is computed with respect to a low-top model CMCC-CM with a T159 horizontal resolution (80 Km) and 31 level;
- The ACC patterns for SST is provided at lead times 2–5 and 6–9 years evaluated using HadISST temperature.
- The difference between the high-top and low-top ACC in figure2 e-f shows that the high-top model in the Indian ocean is more skilful than the low-top.

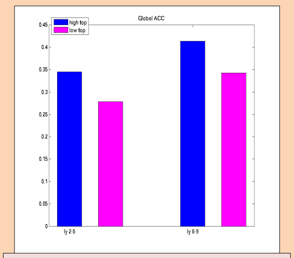


Figure3: Global anomaly correlations coefficient of SST, at 2-5 and 6-9 lead-times, for high-top blue bar and for low-top magenta bar.

- The global anomaly correlations coefficient is around 0.4 for the high-top model at 6-9 lead year. Figure3.
- The discrimination of natural variability of the AMO index from the global warming signal is
- provided by subtracting the global mean SST that leads to a revised AMO, showed in Figure 4.

High – top model

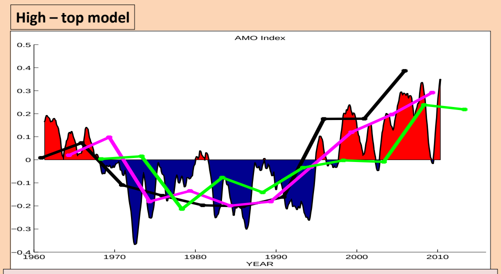


Figure4: Observed (shading) and predicted Atlantic SST index for year 1 (black), years 2–5 (purple) and years 6–9 (green). Observed index is based on monthly HadISST data, low-pass filtered with a 12-month moving average

Conclusions: From figure1 we deduce that the initialization of SST hindcasts leads to more accurate predictions with respect to an uninitialized climate simulation. A significant predictive skill is found in Indian ocean with the high-top model who also shows an improved coherence between observations and the predicted AMO index for the 2–5 year and 6-9 year variations of the AMO.

Acknowledgements

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Reference:

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