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. 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. Further analyses were performed using the high top MPI-ESM-MR coupled model of the Max Plank Institute for Meteorology with ocean-atmosphere every year initialized state. Anomaly correlation coefficient (ACC) of sea surface temperature (SST) and zonal mean zonal wind (ZMZW) were performed to assess the likely skill for climate predictions and analyse the low-frequency variability of the stratosphere through the quasi biennial oscillation (QBO) and the polar vortex.

Method:

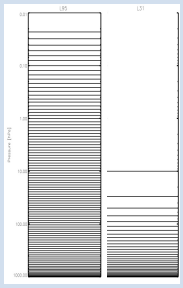
The CMCC-CMS Coupled Model

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 **(0.5º to 2º)**
Vertical Res. = 31 Levels

High –top Low –top



The first approach was laid on the differences between simulations by high-top configuration including a well-resolved stratosphere and equivalent simulations using a low top model 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.

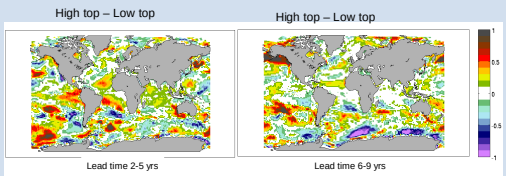


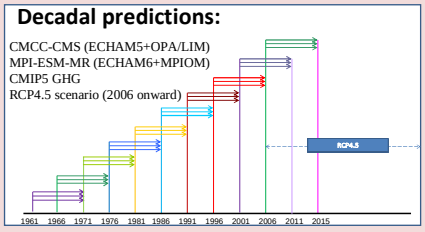
Figure1: Difference of anomaly correlation coefficient of SST hindcasts for years 2–5 (left) and 6–9 (right) between Hight-top model CMCC-CMS [T63L95] and Low-top modelCMCC-CM [T159L31].

EXPERIMENT SETUP

Ocean initialization CMCC-CMS Ocean- atmosphere initialization MPI-ESM-MR

Decadal predictions:

CMCC-CMS (ECHAM5+OPA/LIM)
MPI-ESM-MR (ECHAM6+MPIOM)
CMIP5 GHG
RCP4.5 scenario (2006 onward)



The 10 year hindcast-forecast simulations are grouped in 3 member ensembles start dates are starting at:

- 5-year intervals CMCC-CMS
- 1-year intervals MPI-ESM-MR

Conclusion:

SST

- An higher predictive skill is attained by the model with a well resolved stratosphere
- A systematic improvement of the high-top ocean initialization with respect to the uninitialized simulation

U

- Aliasing problem
- The importance of the initialization of the Atmosphere
- Possible Holton-Tan relationship
- High skill (0,6) at 5 lead time at 50hPa 50N in MPI-ESM-MR model

Results:

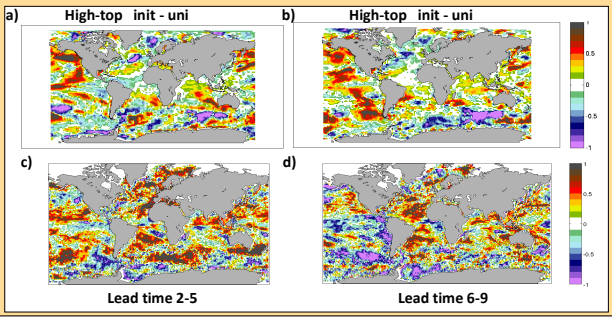


Figure2: Difference of anomaly correlation coefficient of **SST** hindcasts for years 2–5 (left) and 6–9 (right) between initialized and uninitialized Hight-top CMCC-CMS model (a-b); MPI-ESM-MR model (c-d).

ACC SST

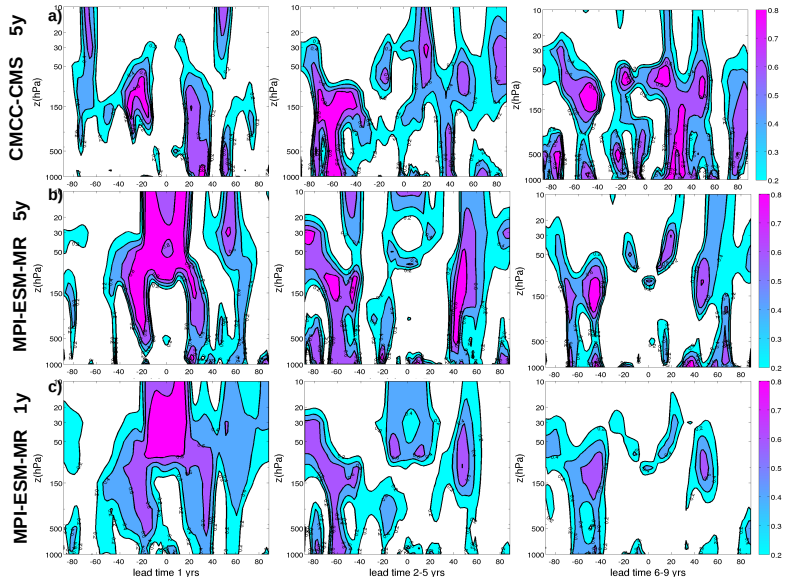
To assess the impact of the initialization for both models:

the ACC of the annual mean SST of initialized case minus uninitializaed of the ensemble mean for the period 1960–2010 are performed using HadISST temperature.

Largest (positive) differences are found in

- Tropical regions
- Pacific basin CMCC-CMS
- North Atlantic, Western Pacific and Southern Oceans MPI-ESM-MR

[Matei et al. 2013, in preparation]



ACC ZMZW

The ACC of the annual mean ZMZW are performed with ERA -40 observation.

- **High correlation in**

a) Polar vortex region 50hPa 50N

b)-c) QBO region 50hPa, -10S 10N and polar vortex region

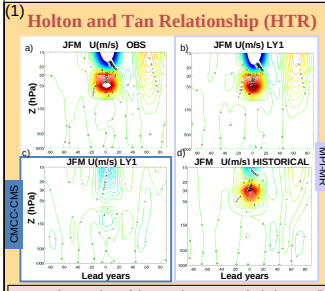
c) Weaker correlation in respect to the 5 year init suggest a sub-sampling problem

(1)
- In the **extratropics** strong evidence that the **QBO** influences the extratropical northern **stratosphere** **[Holton and Tan** 1980]

(2)
- At 50N for all a)b)c) cases high skill for all lead time year

Figure3: Hindcasts skill (ACC) of zonal mean zonal wind ensemble mean for hindcast as a function of latitude and height: for years1 (left); 2–5 (midle) and 6–9 (right) for CMCC_CMS (a); MPI-ESM-MR initialized every 5 year (b); MPI-ESM-MR initialized every 1 year(c) model.

(1) **Holton and Tan Relationship (HTR)**



The composites based on the QBO index show

b) The MPI_ESM-MR model Reproduce the HTR for the first 3 month JFM

- To identify if this is owed to the atmospheric or ocean initialization
- for the same years defined by the index for

c) The CMCC-CMS model shows that the ocean initialization may not affect the HTR

Westerly: u > 5 m/s
Easterly: u < -5 m/s

INDEX:
- 50hPa
- JFM
- at Ly 1

Figure4: Composites of the zonal mean zonal wind anomalies with respect to the westerly phase of the QBO for JFM from ERA-40 observation(a); from 1 years lead time MPI-ESM-MR every year initialized hindcasts (b) MPI-ESM-MR historical (d); CMCC-CMS hincasts (c).

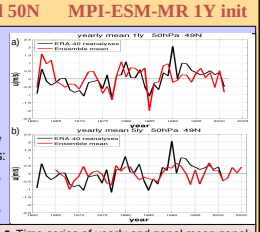
(2) **At 50hPa and 50N MPI-ESM-MR 1Y init**

More focused analyses show an highest correlation (0.6) in that region at **5** lead year

The time series show the ZMZW anomalies:

a) at 1 year lead time

b) at 5 year lead time



To be investigate as future works

Figure5: Time series of yearly and zonal mean zonal wind anomalies at 50 hPa averaged at 50N from ERA-40 (black) together with ensemble means of the first 1 and 5 lead time of the hindcasts (red).

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