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D6.1. Decadal Prediction Experiments Stream 1.

1. Introduction

Deliverable D6.1 concerns the Stream 1 decadal prediction experiments performed by WP6 partners following the CMIP5 protocol, using existing analyses to initialize the coupled system. This set of experiments contributes directly to the CMIP5 effort and constitutes an input to WP8 for studies on scenarios and impacts.

The simulations in WP6 were delayed by 6 months because of a delay on the CMIP5 side in delivering the radiative forcings (GHGs, aerosols and ozone) that were planned to be used also in the COMBINE simulations. The delay affected the activity of all WP6 partners, who were forced to postpone the start of the simulations. Furthermore, for some partners, additional delay occurred due to problems with the experimental set-up and unexpected model bugs. Specifically, the EC-EARTH consortium delivered the final version of the EC-EARTH model in summer 2010, i.e. substantially later than expected. In addition to that a major bug in the treatment of the aerosols was found. These problems delayed the starting of the decadal predictions experiments of both SMHI and DMI. Also MPG changed slightly its experimental set up. Specifically the Stream 1 simulations that in the original plan should have been performed with the new model ECHAM6/MPIOM, due to a delay in the model development have been performed with the older version of the model (ECHAM5/MPIOM). Similarly, also the final release of the CNRM-CM model was delayed until September 2010 due to code corrections.

Most of the WP6 partners have now completed the decadal prediction experiments, and the most significant results are reported below. However, due to the above mentioned delays, only a few partners have started to store the data on CMIP5 archive.

2. METO Contribution

2.1. Experiments

METO has produced near term prediction experiments with its Decadal Prediction System (DePreSys). These are summarized here:

- 10-year hindcast and prediction ensembles (1965, 70, 75, 85, 90, 95, 2000)
- 30-year hindcast and prediction ensembles (1960, 1980, 2005)
- Increased ensemble sizes (10 ensemble members)
- Additional predictions (initialized in 2001, ..., 2009)
- Alternative initialization strategy (full-field instead of anomaly initialization)

2.2. Technical details

DePreSys is based on the third Hadley Centre climate model (HadCM3) with a resolution of $2.5^{\circ} \times 3.75^{\circ}$ in the atmosphere and 1.25° in the ocean.

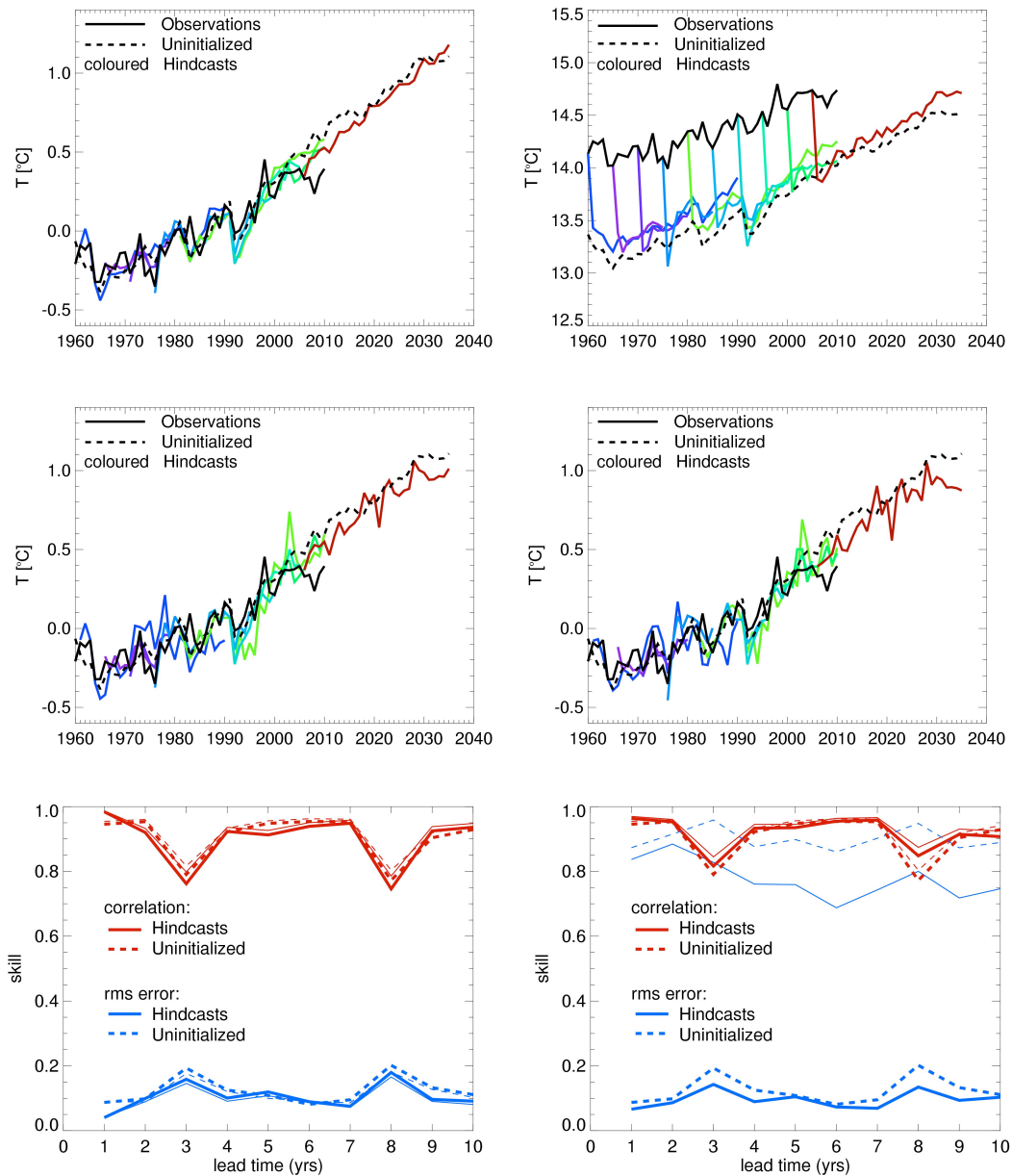


Figure 2.1 Top: Time series of global mean surface air temperature from observations (black) and the ensemble means of the hindcasts (coloured with a different colour for each start date) and the uninitialized experiment (black dotted) for DePreSys CMIP5 using anomaly (left) or full-field (right) initialization technique. Middle: Same as top after the bias correction. Bottom: Correlation (red) and rms-error (°C, blue) prediction skill for the hindcasts (full), and transient (dashed) experiments before (thin) and after (thick) bias correction.

Assimilation experiments, using either the anomaly or the full-field initialization technique, are performed by integrating HadCM3 relaxing oceanic temperature and salinity and atmospheric horizontal winds, temperature and surface pressure to analyses of observations. The atmospheric analyses are taken from the European Centre for Medium-Range Weather Forecasts (ECMWF) reanalysis (ERA40 and operational analysis after 2002). The ocean analyses are created by four-dimensional multivariate optimal interpolation of

salinity and temperature observations using covariances from HadCM3. The DePreSys hindcasts consist of 10 ensemble members starting on 1st November every 5 years between 1960 and 2000, and every year thereafter. The initial conditions for the 10 hindcast members are produced by randomly perturbing the SSTs slightly with white noise. The external forcings follow the CMIP5 protocol, i.e. historical concentrations of greenhouse gas and aerosol concentrations are used until 2005 and those of the RCP4.5 scenario thereafter. In contrast to previous DePreSys experiments, volcanic aerosols were not damped off in the predictions. This may result in prediction skill from (unpredictable) volcanic eruptions but has the advantage that the hindcasts can directly be compared with (uninitialized) transient experiments. The transient experiment consists also of 10 ensemble members, which are performed with the same climate model starting from different initial conditions of a long control experiment.

2.3. Results

Time series of the of the global mean surface air temperature for the anomaly and full-field initialized DePreSys CMIP5 hindcasts and their prediction skills are shown in Figure 2.1. Drift is obviously present in the full-field system, but the bias correction can minimize this problem to a great extent. Drift correction for the anomaly system seems not to be of additional advantage. After the bias correction of the full-field system the skill measurements which are applied here (correlation and root mean square error) give very similar prediction skills for both systems.

3. MF-CNRM Contribution

3.1 Introduction

Our main tool is CNRM-CM5 coupled model, developed and extensively validated by MF-CNRM and CERFACS. It is based on the coupling of NEMO (42 vertical levels, 0.7° average horizontal resolution, and up to 1/3° latitudinal resolution at the equator) and ARPEGE-Climat (1.4° horizontal resolution, 31 vertical levels). This coupled system model includes GELATO, a state of the art sea ice model. GELATO is a multi-category enthalpy model, in which sea ice salinity is interactive. CNRM-CM5 has been used by MF-CNRM to run CMIP5 centennial experiments, and by CERFACS to generate ocean-sea ice initial states and run CMIP5 decadal experiments.

All the decadal prediction simulations we analyzed were run by Cerfacs in the framework of the CMIP5 project. These simulations were run for 10 start dates (1961/01/01, then with an interval of 5 years until 2006/01/01). 10 members per start date were run. As further described in D.5.1, these experiments do not assume any direct constraint on sea ice (e.g. there is no direct correction on concentration, thickness or energy content). However, initial states were produced from coupled experiments run with CNRM-CM5 in which a surface flux correction was applied to constrain SST. However, such

a correction of SST amounts to bounding the maximum ice extent: sea ice that is transported to an area where SST is well over sea water freezing point cannot persist there. Conversely, under the only ocean constraint, a SST at freezing point does not imply that sea ice is present, due to e.g. positive biases in surface net solar flux, which may appear during the summer. Hence, SST restoring does not set any constraint on the minimum sea ice extent. The decadal hindcasts are compared hereafter with the set of all forcings 1850-2012 experiments run by MF-CNRM (uninitialized experiments).

3.2 Preliminary evaluation of the predicted sea ice extent in the Arctic

This evaluation was only done in the Arctic region. It seems that CNRM-CM5 has little skill in predicting Antarctic sea ice volume or extent. Here we focus on Arctic sea ice extent, since results are rather similar for volume.

Fig.3.1 shows that the free coupled model (bottom row) tends to simulate slightly too much sea ice during the winter and too little sea ice during the summer. However, NSIDC observations generally lie within the ensemble spread, and the downward trend in sea ice extent is rather well simulated, even if slightly overestimated in summer.

The decadal experiments simulate too much sea ice in the Barents Sea in March, even during their first year. It suggests that the initialization may disrupt ocean transport into the Nordic Seas (which is correct in the free coupled experiments). This overestimated sea ice extent in the Nordic Seas is probably the reason why most decadal experiments correctly simulate summer sea ice, whereas the free coupled model tends to underestimate it. However, the model seems to have some skill in simulating summer Arctic sea ice extent a few years in advance, even if this skill could be possibly improved by refining the initialisation technique.

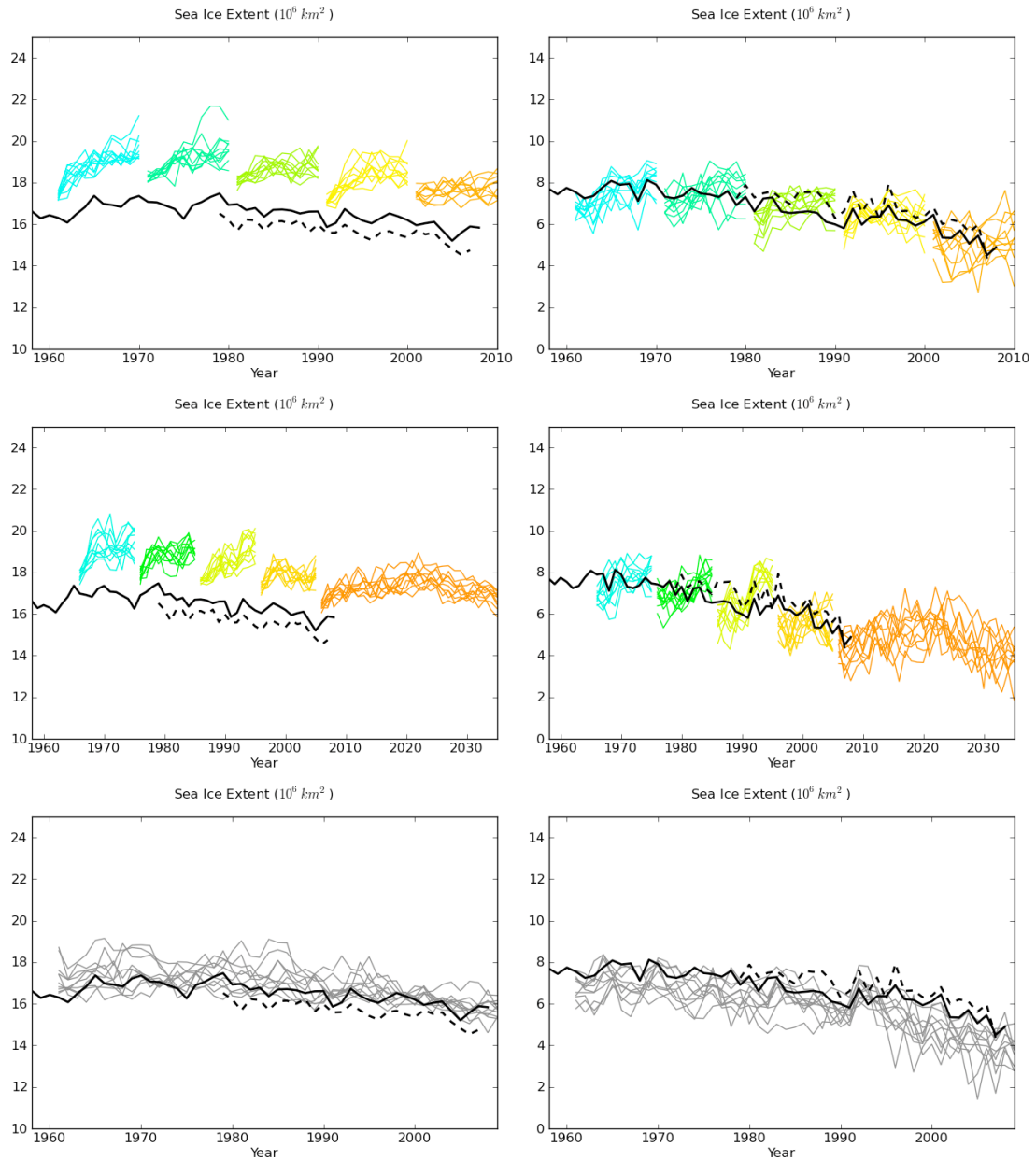


Fig.3.1 Arctic sea ice extent for March (left) and September (right). For all the plots, the black dashed and the black solid lines respectively represent NSIDC satellite observations and HISTNUD15 experiment (providing initial states). Top row: decadal experiments initialized every 10 year, beginning from 1961/01/01 (in color). Middle row: same, but beginning from 1966/01/01. Bottom row: 10-member ensemble of experiments performed with the free (uninitialized) coupled model CNRM-CM5.

Fig. 3.2 compares the skill of the decadal set of experiments and the set of uninitialized experiments (HISTr) in simulating Arctic sea ice extent anomalies with persistence. We focus here on the two months that correspond to the annual minimum and maximum of Northern Hemisphere sea ice extent, respectively March and September. Fig. 3.2 shows that initialization improves sea ice extent prediction over the first 3-4 years. However, it should be noted that this is not the case for all months of the year. Moreover, persistence is better than initialized or uninitialized experiments for September, suggesting

that for sea ice initial states should be more constrained for Combine stream-2 decadal experiments

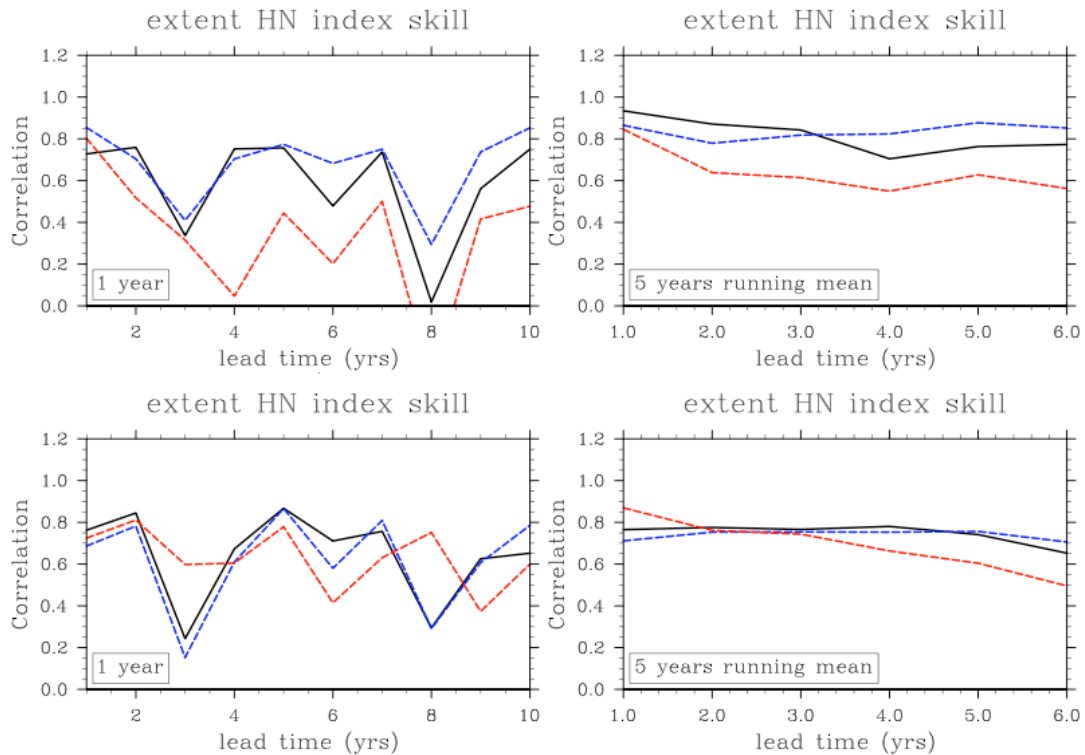


Fig.3.2. Top: correlation of March Arctic sea ice extent anomalies for decadal experiments with HISTNUD15, taken here as a reference (in black) and the CMIP5 historical experiments HISTr (in dashed blue). For a comparison, persistence is plotted in dashed red. Bottom: same, but for September.

4. CERFACS Contribution

4.1 Description of the initialization method

CERFACS has implemented a methodology to obtain the initial conditions for decadal forecast experiments to be performed with the CNRM-CM5 coupled model (see 3.1), developed jointly with the MF-CNRM institution. The method performs a 3D newtonian damping in temperature and salinity of NEMO ocean model towards the NEMOVAR ocean reanalysis, leaving the rest of the components (atmosphere, sea-ice, continental surfaces) free.

Following this idea, several nudging experiments have been performed for the period 1958-2008 in order to test the values of parameters controlling the nudging strength. To avoid spurious currents and to conserve the ocean properties, no nudging is applied near the equatorial band and also near the coasts (300km). The mixed layer is set to evolve freely but a sea surface restoring in salinity and temperature is applied. Finally, two nudging experiments have been retained: the first one (GLOB) the nudging is applied globally except on the equatorial band [1°S , 1°N]. For the second one (EXTROP), the equatorial band with no nudging is larger [15°S , 15°N].

Several tests show that the model initialized from the GLOB conditions presents a stronger initial shock than in the case of EXTROP. This initial shock is mainly due to a very rapid austral ocean warming and also to the formation of El Niño event over the Equatorial Pacific ocean during the first year integration. In view of this, the decadal experiments have been completed by using EXTROP initial conditions.

4.2 Decadal experiments and preliminary results

Following the CMIP5 protocol, a set of decadal experiments has been completed starting from 1st January of 1961 till 1st January of 2006, every 5 years. Initial conditions for the ocean have been taken from EXTROP nudging experiments. To generate the ensembles, only the atmosphere and land surfaces components have been perturbed. For every initial date, CERFACS has completed a 10 members ensemble integrated over 10 years, except for 1961, 1981 and 2006 in which the experiments have been prolonged to 30 years. Volcanoes aerosols have been considered to perform these experiments.

Figure 4.1 shows the annual means for global averaged sea surface temperature (SST) members and ensemble mean for all the dates, together with the NEMOVAR and EXTROP values.

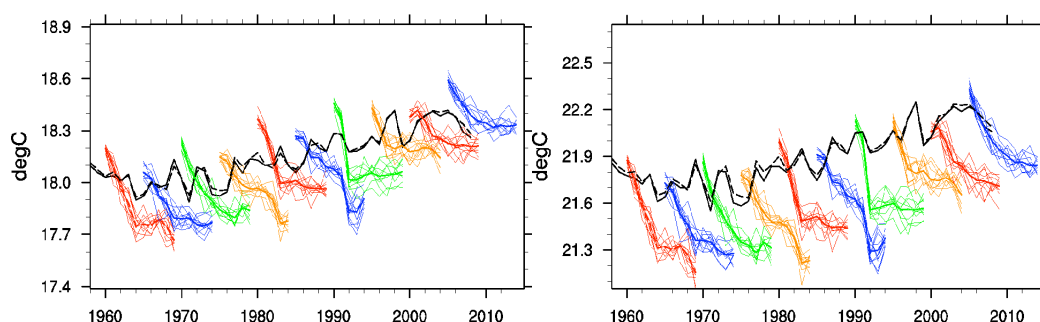


Figure 4.1. (Left) Global average SST annual means for decadal 10 yr experiments (colors), NEMOVAR values (solid line) and EXTROP values (dash line). (Right) The same but the austral ocean (below 35°S) has been removed from the average to see the impact of the initial shock.

From figure 4.1 it is evident the initial shock of the model during the first year of integration. As it has been pointed above, this initial shock is mainly due to a strong and rapid warming over the austral ocean and also, on a lesser extent, to the development of El Niño episodes over the Tropical Pacific. The model drifts to a colder state and seems to reach the equilibrium state after the 3rd year of integration. Note that the model drift is clearly influenced by the volcanoes eruptions of Agung (1963), Chinchon (1982) and Pinatubo (1991).

Figure 4.2 shows the bias corrected integrations (we have removed the model systematic bias) for global averaged SSTs. This figure displays some predictability skill for several periods.

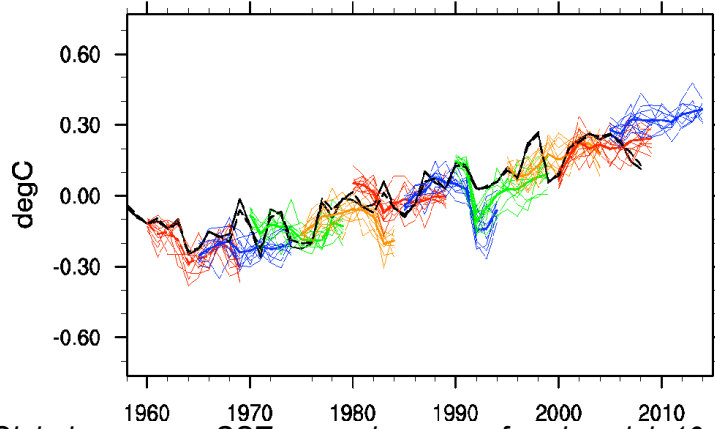


Figure 4.2. Global average SST annual means for decadal 10 yr experiments (colors), NEMOVAR values (solid line) and EXTROP values (dash line). The model systematic bias has been removed.

The goal is to investigate the added value of the ocean initialization for the decadal runs. On this purpose we have compared the forecast skill for SST obtained from initialized decadal integrations and historical (non initialized) experiments, which have been performed by the MF-CNRM. The historical experiments constitute a 10 members ensemble for the period 1850-2012 with CNRM-CM5. We have computed the skill as the correlation between the simulation and the observations, for both the decadal integrations and the historical runs.

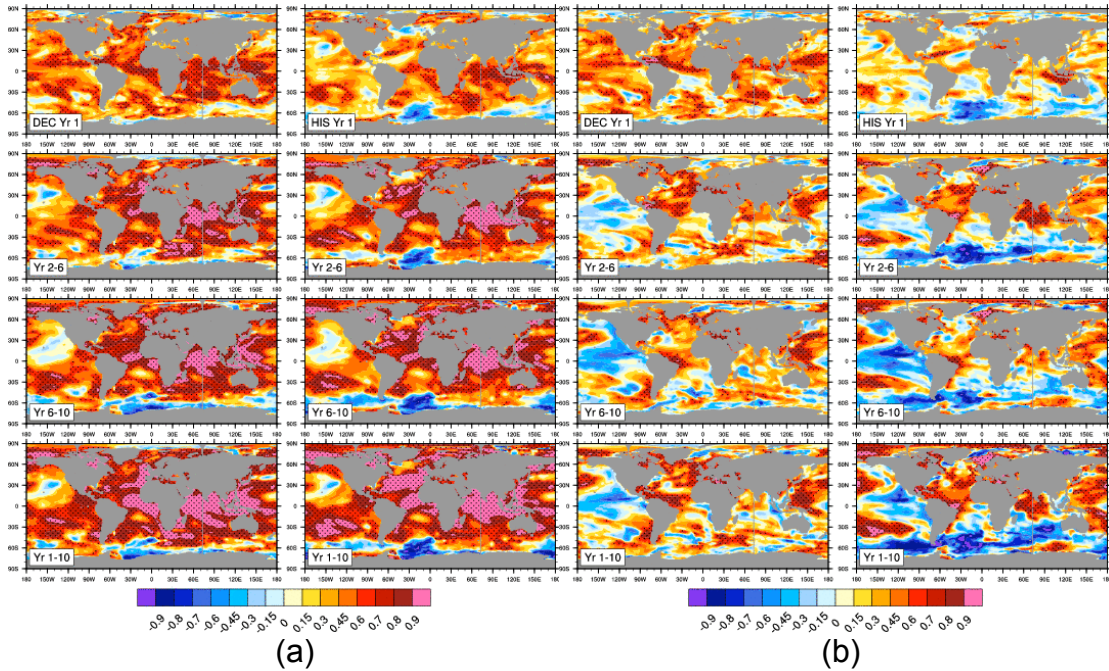


Figure 4.3. (a) Skill (based on correlation) of unbiased decadal integrations (left) and historical runs (right) for SST. The observational data is ERSST3. (b) Skill (based on correlation) of unbiased decadal integrations (left) and historical runs (right) for SST. Data have been detrended. The observational data is ERSST3.

Decadal runs have been unbiased following the WCRP protocol and to compute the skill, several timescales have been considered: first year of

integration, data averaged over the year 2 to 6, from 6 to 10 and from 1 to 10 of forecast. Figure 4.3a shows the skill for decadal and historical integrations. Skill values are almost equivalent in both cases, except for the Yr1 in which, as expected, the initialization clearly improves the skill. Figure 4.3b shows the skill but this time the data have been detrended, in order to remove the global signal mainly due to external forcings (as GHGs). In this case, some differences between decadal and historical runs emerge. In particular, for all timescales, the skill is improved for initialized simulations over the North Atlantic and North Pacific areas. There is also a significant improvement over the austral ocean, but this is surely not significant taking into account the model performances in this region. These preliminary results are quite encouraging and suggest some predictability of the Atlantic Multidecadal Oscillation (AMO) and Pacific Decadal Oscillation (PDO).

5. MPG Contribution

5.1 Background

In COMBINE WP6.1, decadal predictions experiments have been performed following the WCRP/CMIP5 protocol. Owing to the late availability of the new Max Planck Institute Earth System Model designed for CMIP5, MPG has applied a baseline hindcast/forecast system on the basis of the previous ECHAM5/MPIOM model.

5.2 Experimental Design

The numerical model consists of the atmosphere circulation model ECHAM5 (Roeckner et al., 2003) and the ocean model MPIOM (Marsland et al., 2003). The model set-up is similar to the CMIP3 configuration (Jungclaus et al., 2006). The model resolution used here is T63L31 for ECHAM (appr. 1.9° horizontally, 31 vertical levels up to 0.1 hPa). The ocean uses a bipolar grid with the northern pole rotated to Greenland and a nominal resolution of 1.5° (GR15 grid). Following a strategy developed in WP5 (Kroeger et al., 2011), the ORAS3 reanalysis was used as basis for the assimilation. The assimilation run has been performed by nudging temperature and salinity anomalies. Based on this assimilation a full stream of hindcasts and forecasts have been performed: (a) initialization every five years, 1960, 1965, ..., 2005). Hindcasts were started at the beginning of each year with a length of 10 years with an ensemble size of 10. In addition, 30-year hindcasts are performed initialized 1960, 1980, and 2005. The perturbation of the ensemble members are due to lagged initialization with 1-day lag. A set of forecasts is started at 2005.

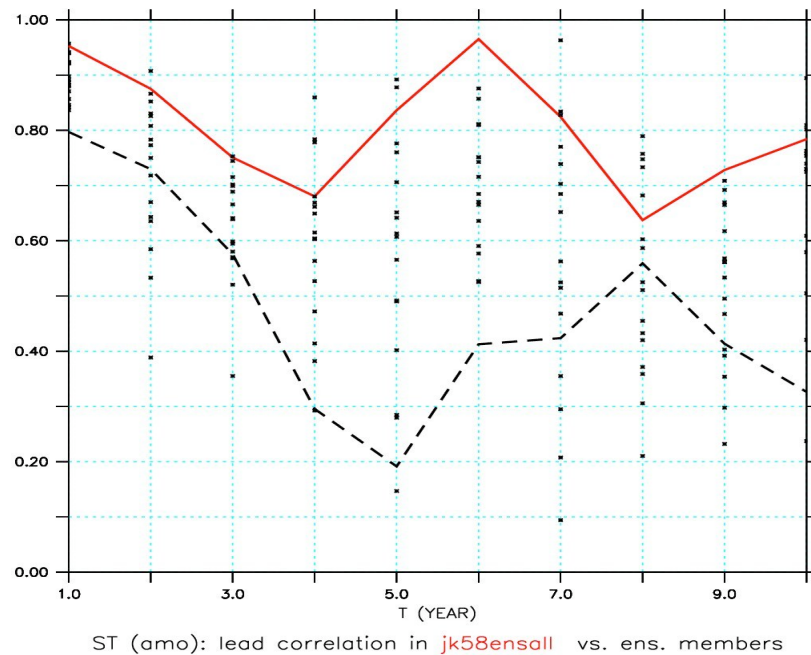


Figure 5.1: Ensemble hindcast: correlation of North Atlantic SST index (80W, 0-60N) for the ensemble mean (red line), individual ensemble members (dots), and for persistence (dashed).

5.3 Results

A preliminary analysis confirms that the assimilation of salinity and temperature is sufficient to improve prediction skills. A SST index over the North Atlantic (0-60°N, 80°W-10°E) is evaluated in comparison with the HadCRUT3 dataset (Figure 5.1). For lead-times up to ten years the ensemble mean outperforms the persistence forecast, but also the individual ensemble members.

5.4 Conclusion

Decadal prediction experiments have been performed using ECHAM5/MPIOM. First evaluations of the hindcast simulations demonstrate the feasibility of skillfull decadal forecasts, in particular in the North Atlantic region. The experiments performed as contribution to the Combine Stream 1 simulations have been instrumental to overcome several technical difficulties and will be useful to perform the upcoming Stream 2 experiments using the ECHAM6/MPIOM model. ECHAM6/MPIOM will be run with higher vertical resolution in the atmosphere and higher horizontal resolution in the ocean.

6. CMCC Contribution

6.1 Experimental design and model description

Decadal prediction experiments following the CMIP5 protocol have been performed. The full set of simulations consists of 3-member ensembles of 30-years experiments, starting at 5-years intervals from 1960 to 2005, using CMIP5 historical radiative forcing conditions (including green-house gases, aerosols and solar irradiance variability) for the 1960-2005 period, followed by RCP4.5 scenario settings for the 2005-2035 period.

The dynamical model used to perform the decadal prediction experiments is the Euro-Mediterranean Centre for Climate Change climate model (CMCC-CM). The model resolution is T159L31 for the atmosphere (corresponding to approximately 80 Km) and $2^\circ \times 2^\circ$ L31 in the ocean, with a meridional grid refinement in the tropical belt, reaching a minimum grid size of 0.5° at the Equator.

The ocean state is initialized using full-values from three different ocean analyses. Specifically, the CMCC-INGV ocean syntheses (Bellucci et al., 2007; Storto et al., 2011) were used. Each analysis differs for the assimilation method and/or for the amount and type of assimilated data. The use of alternative ocean analyses is the criterion adopted to perturb the full three-dimensional ocean state. The ocean analyses have been performed with: 1) an optimal interpolation (OI) scheme and 2) two distinct implementations of a three-dimensional variational (3DVAR) method using different parameterizations of the background error covariance matrix. Moreover, while in the OI analysis only hydrographic observations (i.e., in situ temperature and salinity profiles) are assimilated, the 3DVAR scheme does also assimilate sea-level anomaly data, from 1992 onward. These perturbing elements (assimilation method and data amount and typology) yield the required sampling of the uncertainties associated with the reconstructed state of the ocean.

Since the present experiments were initialized on the 1st of January of each starting year (1960 to 2005), an additional set of predictions initialized on the 1st of November (for the same years) is currently being performed with the two-fold aim of a) having a better compliance with the CMIP5 protocol, and b) increasing the number of ensemble members.

6.2 Results

Patterns of surface temperature anomaly correlation coefficient (ACC; not shown) reveal significant predictability over the Atlantic ocean region, for lead times up to 5-10 years, while substantially lower skill is found over the Pacific ocean and over land.

Figure 6.1 shows the Atlantic Multi-decadal Oscillation index (AMO; Schlesinger and Ramankutty 1994) which is here defined as the area-

averaged SST difference over (40-60N,60-10W) minus (10-40S,30W-10E), for observations (HadISST) and ensemble mean hindcast/forecast simulations. The predicted AMO index is shown for year 1, years 2-5 and years 6-10. Predictive skill is evident not only after 1 year ($r=0.91$) but also over the near-term 2-5 year range ($r=0.6$), while in the longer 6-10 year term no skill is found ($r=0.1$). Interestingly, the lack of skill for longer lead-times appears to be due to a delayed response of the predicted AMO index, causing the hindcasted AMO to be out of phase with respect to the observed one.

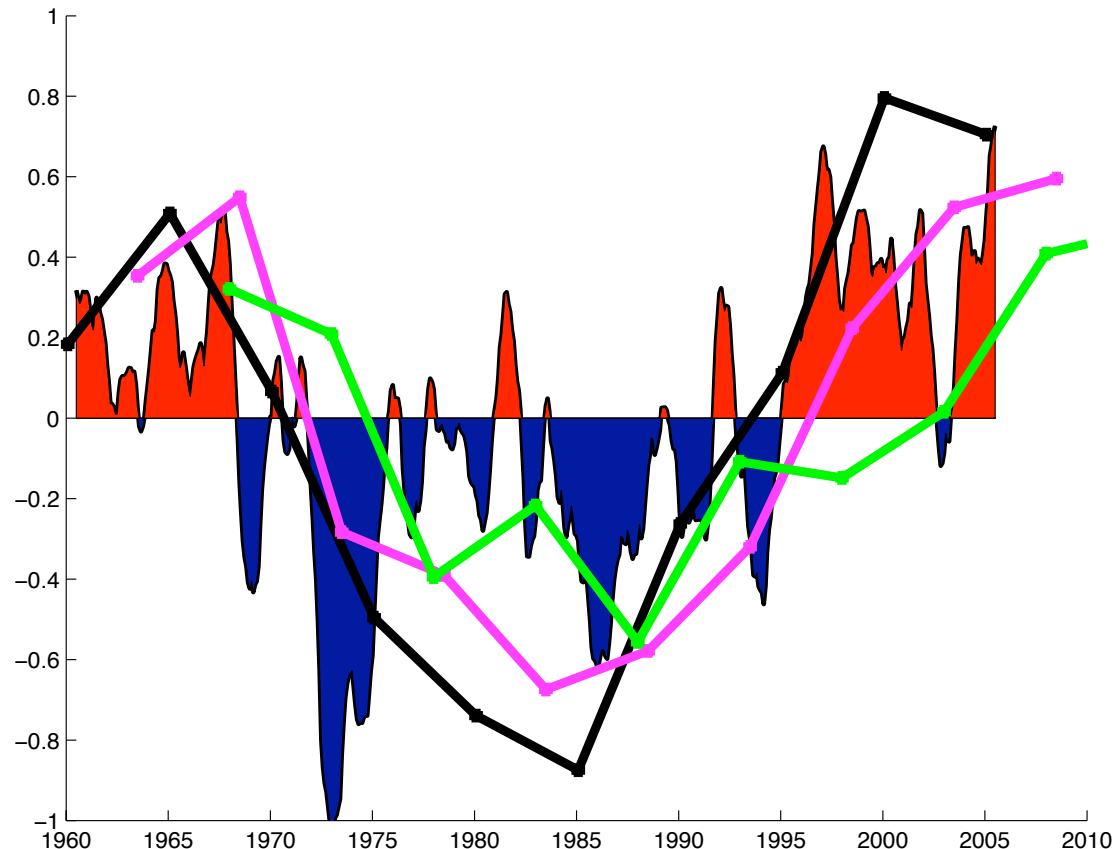


Fig. 6.1 AMO index from ensemble mean predictions after (black) 1 yr, (purple) 2-5 yrs and (green) 6-10 years and from observations (red/blue shading; HadISST).

AMO predictability is then assessed against the specific data assimilation methodologies used for initialization, by separately evaluating the predictive skill exhibited by OI and the two 3DVAR analyses. The analysis reveals that OI initial conditions yield a systematically lower skill, with respect to 3DVAR-1 and -2 (see Table 6.1). Overall, the ensemble mean predictions perform better than single ensemble members. This result, which is well known from seasonal predictions, appears to be robust even for decadal predictions. A similar analysis conducted for the Pacific Decadal Oscillation index (PDO), showed a considerably reduced predictability over the Pacific ocean region (as compared to the Atlantic area) consistent with the results of the ACC analysis.

	1 yr	2-5 yr	6-10 yr
ENS	0.91	0.64	0.14
OI	0.75	0.43	-0.69
3DVAR1	0.92	0.60	0.07
3DVAR2	0.82	0.56	0.37

Table 6.1 Correlation coefficients for predicted AMO index against observations, for ensemble mean (ENS), and single ensemble members (initialized using different ocean analyses), after 1 yr, 2-5 yrs and 6-10 yrs. All *r*-values (except for those in red) are statistically significant at the 90% confidence level, according to a *t*-student statistics (p -value ≤ 0.1).

7. EC-Earth Contribution

EC-Earth consortium takes part to the WP6 activities through the contributions of KNMI, SMHI and DMI. All EC-Earth partners adopt the same dynamical model (EC-Earth) but make use of different strategies to initialize the decadal prediction experiments. Specifically, KNMI uses a full-value initialization approach, while SMHI and DMI opted for an anomaly initialization technique. In other aspects the model configuration and experimental set-up are exactly the same. This allows for a clean comparison between the two initialization methodologies. Details concerning specific contributions from each single EC-Earth partner are reported below.

7.1 KNMI

7.1.1 Experimental setup

The decadal predictions were performed using the ECMWF/NEMOVAR initial conditions. The full initialization approach was followed. Sea-ice coverage was directly computed from NEMOVAR.

Sea-ice thickness is obtained from the spin-up run. The decadal prediction runs have been performed according to the CMIP5 protocol. The start dates are from 1960 to 2030 with an interval of 5 year. The length of the runs is 10 years. The ensemble consists of 5 members. For generating different initial conditions small perturbations were added to the atmospheric initial state. The forcing includes historical greenhouse gases and aerosol concentrations.

7.1.2 Results

Figure 7.1a shows the simulated global 2 meter temperature (T2m) together with the observed T2m (obtained from the NCDC data set). It reveals a strong drift during the first years that stabilizes afterwards (Fig. 7.1a). After the correction of this drift the simulated T2m shows good correspondence with the observed T2m (Fig. 7.1b).

It should be noted that due to the bug in the aerosol forcing the impact of the volcanoes is neglected by the model. Analysis shows high correlations between 0.8 and 0.9 (Fig. 7.2). This is, however, mainly due to the trend. After

detrending (Fig. 7.3) there is still good skill for the first year, mainly due to persistence and the correct simulation of ENSO. For the years 2-5 there is, however, no skill. We hypothesize that this is partly due to the omission of the variability in the aerosol forcing due to the bug. The bug has been fixed and the runs are now being redone.

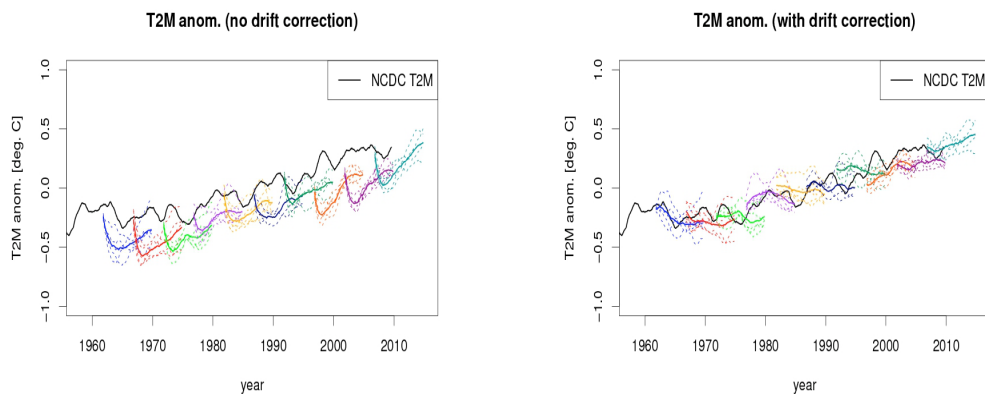


Fig. 7.1 Simulated and observed (black solid line) global mean 2 meter temperature (T2m). The different colors indicate the different start dates. Dotted lines: Individual simulations. Solid lines: ensemble means. A: Before drift correction. B: After drift correction.

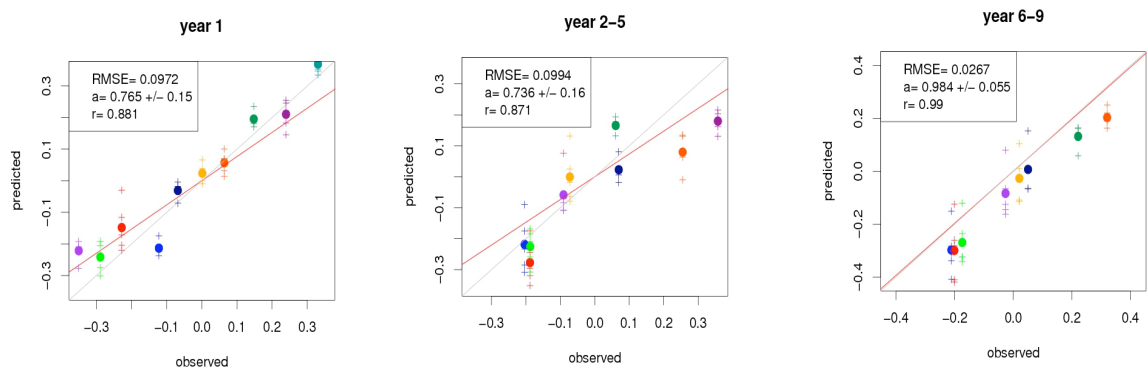


Figure 7.2. Observed and simulated global mean T2m for different lead periods. The different colours indicate the different start dates of the decadal prediction runs. The solid circles denote the ensemble mean and the crosses the individual members. a is the slope of the relationship indicated by the solid red line. r is the correlation coefficient, and $rmse$ the root mean square error.

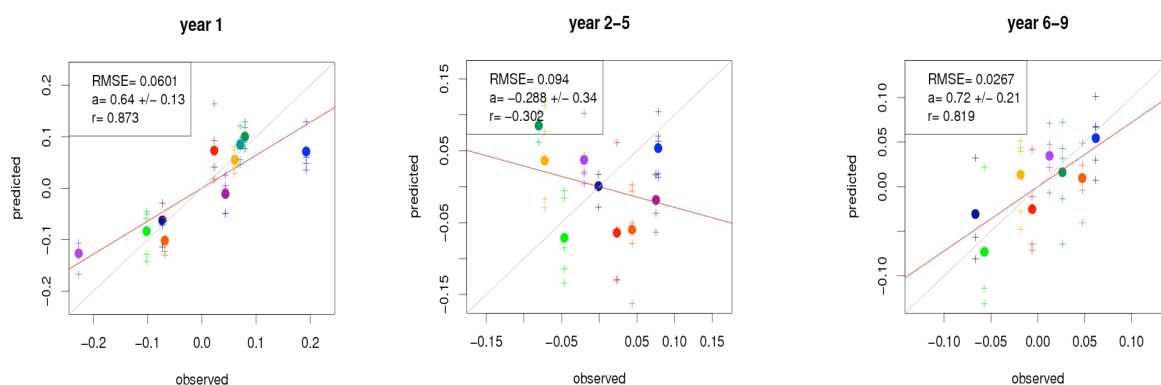


Figure 7.3. As Fig. 7.2, but now after detrending.

Although for the global mean T2m there is no skill after detrending for years 2-5, certain specific regions do reveal significant skill even for years 6-9. The largest skill is obtained in the eastern Pacific, the Indian ocean and the North Atlantic. No skill is obtained over land except for some Arctic regions, parts of Africa and central Asia.

7.1.3 Summary

The analysis of the runs has demonstrated skill full decadal predictions with EC-EARTH. Due to a bug in the aerosol routine variations in aerosol concentrations have not been taken into account. The bug has been fixed and the experiments are now being redone.

7.2 SMHI

7.2.1 The initialization method for decadal experiments

At SMHI an anomaly initialization technique has been implemented within the EC-Earth coupled system for the initialization of ocean and sea-ice subsystems. For both subsystems, a number of coupling issues have been tested in designed experiments, listed below:

- the specification of the anomaly as a function of the basic (reference climate) initial state, the statistical properties of the anomaly, etc.;
- the choice of variables for the initialization in order to ensure the mathematical well-posedness of the problem ;
- the physical coherence of the anomaly initialization for sea-ice (e.g. avoid the unrealistic occurrence of sea-ice-specific parameters over ice-free grid mesh or where the sea surface temperature does not sustain sea-ice).

Results from these tests have led to the current configuration for the anomaly initialization used in EC-EARTH. A subset of ocean/ice variables is used to

compute anomalies relative to the monthly climatology. An additional constraint is applied to the sea-ice to ensure consistency with the ocean temperature. An operational procedure has been implemented and a first set of decadal simulations has been performed.

7.2.2 Decadal experiments

To this stage, one member of a five members ensemble simulations has been accomplished. A serious bug related to the treatment of aerosols in the EC-EARTH model has stopped all further experiments. This bug has now been fixed and a new model climatology has been computed. To this point, our experiments comprise 9 decadal simulations that start every 5 years from 1965 Nov. 1st, to 2005 November 1st.

All simulations have been initialized with anomalies for the ocean and sea-ice. Initial ocean data (and climatology) are taken from the NemoVar-S4 dataset available from ECMWF. Initial ice (and climatology) are taken from a NCEP/NCAR forced NEMO run with the sea-ice model LIM2 (same model version as we used for the decadal simulations).

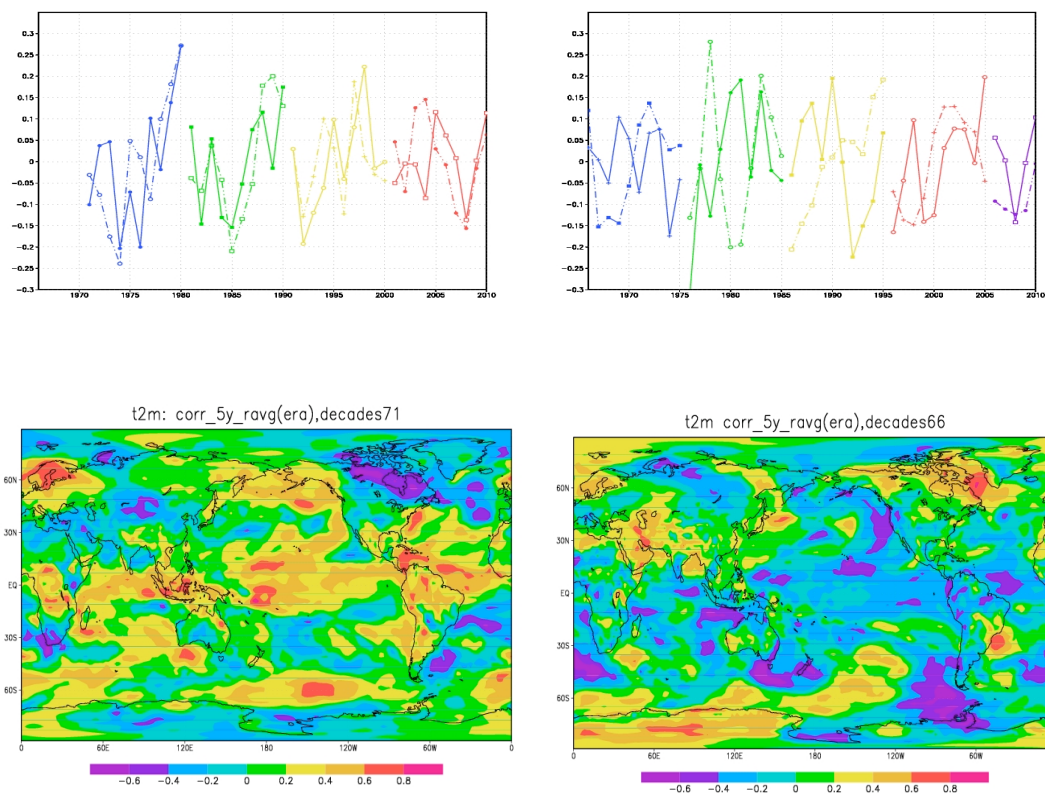


Fig. 7.4 Top: Annual global mean 2m temperature for 2 subsets of starting dates (indicated on the x-axis): model forecast (full lines) against ERA40 analysis (dotted). Bottom: The 5-year running-mean anomaly correlation (AC) with ERA40 analysis, computed for each decade and averaged over each subset is shown in the bottom row panels.

Preliminary results of the research done at SMHI indicate an added value on the decadal predictability from the initialization. The sensitivity experiments

(described above) also show that further improvements could be achieved by optimizing the initialization technique, for example for a better representation of predictability sources at initial time and therefore of their subsequent impact on the model. Fig. 7.4 indicates that higher forecast skill over decade is associated with an improved model skill over predictability-source regions.

Specifically, we note that better yearly variability (the left column subset in fig. 7.4-top) corresponds to better skills for 5-year running-mean correlations (fig.7.4-bottom), e. g. over tropical and North Pacific, tropical and subtropical Atlantic and Northern Europe: this indicates that decadal and multi-decadal oscillations are correctly phased for the simulations in the left panel. This result highlights the existence of decade-sensitivity in the skill of predictions. A preliminary analysis suggests that this could be related to a coupled oscillatory ocean-sea-ice mode with a 10-year typical timescale, which is correctly phased for the left-panel subset (fig. 7.4), but not in the right one, that drives with short leading time the annual global temperature. This result will be further verified once a wider set of simulations will be available.

7.2.3 Summary of results

The simulations were evaluated with the metrics package that was developed for COMBINE.

The preliminary results indicate that initialization leads to improved forecast skill: the undetrended anomaly correlations for the 2m temperature field over the decades increased for the 9 members with anomaly initialization compared to the control experiment without initialization: the better skill is mainly over the ocean but some improvements extend also over parts of land areas.

The anomaly initialization is sensitive to the choices that we made when implementing the method. Improved forecast skills could result from:

- a better choice of variables to be related to model space (climatology) at initial time;
- in the assumption of close structure (highly correlated main mode, normalized) of model and observed climates, the anomaly PDF scaling seems to improve the first forecast years (through better interaction with the mean state, and mainly full-field gradient conserving);
- anomaly specification of the initial state of the two subsystems ice/ocean should preserve the accuracy of the observed state phase in the coupled model space: preliminary tests indicate the direct relation between a higher AC skill over decade and a better representation of the initial phase in coupled model space. This result indicated that an ice/ocean coupled mode of variability may have a role in modulating coupled system's variability at decadal scale. This consequently points to the importance of correctly representing this coupled mode at the initial state for the decadal-range skill.

7.2.4 Future work

The simulations presented here will be repeated using the EC-EARTH model with correct anthropogenic and natural (volcanoes only) forcing. That means decadal simulations starting on the 1st of November from 1960 to 2005, with a 5-year time spacing.

Then, same experiments will be repeated for another 4 ensemble members with perturbed initial state for the ocean (from NEMOVAR S4). In addition to the decadal simulations, the simulations starting from 1980 and 2005 (for each member) will be extended to 30 years.

7.3 DMI

DMI follows the anomaly initialization strategy for decadal predictions, similarly to SMHI, using the initial states provided by SMHI. DMI and SMHI will use exactly the same model configuration and experimental set-up in order to be able to produce together a larger ensemble. This is necessary in order to be able to evaluate the advantages and disadvantages of the anomaly initialisation approach versus the full initialisation approach that is followed by the other EC-EARTH partner, KNMI (see section 7.1). As discussed in the contribution from SMHI (section 7.2) there has been a delay in the generation of the initial states. Therefore DMI has not yet started the decadal experiments for D6.1.

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