Bundesministerium für Bildung und Forschung

NORDATLANTIK II AP 4.2

Max-Planck-Institut für Meteorologie

Initialisierung eines globalen Klimamodells aus ozeanischen Reanalysen

Projektträger Jülich
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Ergebnisse Nordatlantik II

1. In the near term (interannual to decadal timescales), climate variations are influenced by the combination of anthropogenic forcing, natural forcing, and internal variability; near-term climate predictions must hence be started ("initialized") from the present climate state reflecting the present phase of internal variability. This subproject aims at improving the forecast skill of climate predictions through the use of ocean synthesis data as initial conditions of a coupled climate model. For this purpose, the coupled model ECHAM5/MPI-OM is initialized with oceanic synthesis data from the GECCO project (AP 4.1, Ref.1). As an alternative approach to GECCO initialization (Ref.2), we use temperature and salinity data from an ensemble of MPI-OM ocean-only runs forced with the NCEP-NCAR atmospheric reanalyses (Ref.3). The role of initial condition for interannual to decadal climate predictions is investigated in hindcast experiments over the second half of the 20th century.

2. Towards skilfull decadal climate predictions of the North Atlantic/European climate: dependence on the ocean state estimate (Ref.3)

This study investigates the impact of different ocean initialization strategies on the forecast skill of decadal prediction experiments performed with the ECHAM5/MPI-OM coupled model. The ocean initializations assimilate three-dimensional temperature and salinity anomalies from two different ocean state estimates, the ocean reanalysis GECCO (GECCO hindcasts) and an ensemble of MPI-OM ocean experiments forced with the NCEP-NCAR atmospheric reanalysis (NCEP hindcasts).

The results show that:

❑ North Atlantic and Mediterranean SST variations can be skilfully predicted up to a decade ahead with far greater skill than the noninitialized historical simulations (Fig.1).
❑ Higher skill is found for NCEP hindcasts in the first pentad and for GECCO hindcasts in the second pentad (not shown).
❑ Skillful predictions of SAT are obtained over north-western Europe, northern Africa and central-eastern Asia.
❑ North Atlantic subpolar gyre stands out as the region with the highest predictability beyond the global warming trend for both SST and OHC variations. Here the NCEP hindcasts deliver the best results (Fig.2 Left) due to a more accurate initialization of the observed variability.
❑ The dominant mechanism for the North Atlantic climate predictability can be attributed to initialization of AMOC, thus explaining the reoccurrence of high predictive skill within the second pentad of the hindcast experiments (Fig. 2 Right).

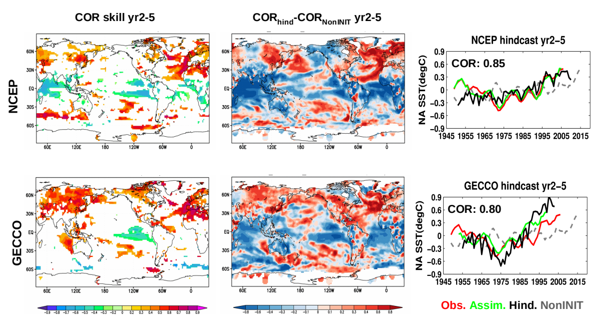

*Fig.1: **(Left)** Anomaly correlation coefficient between the surface temperature variations in observations (SST from HadISST/ land temperature from GHCN/CAMS) and hindcasts at lead time yr2-5. Only the significant COR (at 95% level) are plotted. **(Middle)** Difference in COR skill score between the hindcasts and NonINIT experiments. **(Right)** Time series of the North Atlantic SSTA in observations (red), assimilation (green), NonINIT (grey dashed) and hindcast (black) experiments at lead time yr2-5. Top panels show results from the NCEP initialized hindcasts, bottom panels show results from the GECCO initialized hindcasts.*

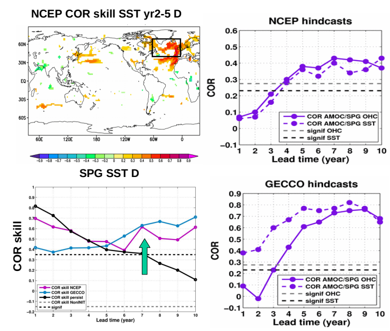

*Fig.2: **(Top Left)** Anomaly correlation coefficient between the linearly detrended SST variations in observations and NCEP hindcasts at lead time yr2-5. Only the significant COR (at 95% level) are plotted. **(Bottom Left)** COR skill between the linearly detrended SPG SST in observations and hindcasts at lead time 1 to 10 years from the NCEP system (violet) and GECCO system (blue). The predictive skill of the persistence forecast is shown in black and of NonINIT experiments in dashed grey. **(Right)** COR between the AMOC variations and the SPG SST are shown in solid violet, while COR between AMOC and SPG OHC are depicted by dashed violet line. Top panel shows results from the NCEP initialized hindcasts, bottom panel shows results from the GECCO initialized hindcasts. AMOC strength is the zonally integrated northward flow at 26.5ºN above 1000 m depth.*

3. Multiyear Prediction of the Monthly-Mean Atlantic Meridional Overturning Circulation at 26.5ºN- NCEP initialization (Ref.4)

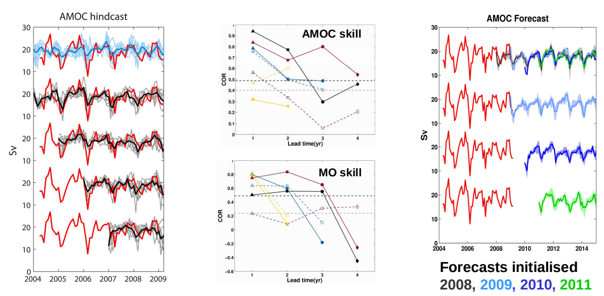

*Fig.3: **(Left)** Multi-year AMOC transport hindcasts compared with observations and non-initialized climate model simulations. The observed transports are from RAPID/MOCHA (red), the individual hindcasts and their ensemble mean are shown in grey and black, respectively. Transports from the non-initialized climate simulations (ens20C) are shown in the upper plots in light blue for individual experiments and dark blue for the ensemble mean. **(Middle)** Correlation (COR) skill scores of AMOC (Top) and Upper Mid-Ocean (MO, Bottom) transports for the hindcasts started in Jan 2004/Jan 2005/Jan 2006/Jan 2007 are plotted in solid black/violet/blue/yellow. The COR skill scores of the persistence forecasts are plotted using dashed lines. The significance level is plotted as a dashed black line, and the averaged COR skill score of the ens20C is shown in dashed grey. **(Right)** Multi-year predictions of AMOC transport. RAPID/MOCHA time-series are shown in red, ensemble mean forecast in dark grey/light blue/dark blue/green for the forecasts starting in Jan 2008/Jan 2009/Jan 2010/Jan 2011. The shading represents the 95% confidence intervals of the nine-member forecast ensembles.*

Multi-year climate predictions have so far been limited to predicting surface temperature variations and hurricane frequency; whether there is multi-year prediction skill for any element of the large-scale atmospheric or oceanic circulation has remained unclear. Here we took advantage of the first half-decade-long observed estimate of the Atlantic Meridional Overturning Circulation (AMOC) at 26.5ºN (from the RAPID/MOCHA project) to quantify the predictive skill of initialized multi-year predictions performed with the ECHAM5/MPI-OM coupled climate model (Ref.4).

❑ The skill of our prediction system is assessed by performing ensemble hindcasts that start in January of each year between 2004 and 2007. The AMOC strength in the hindcasts closely follows the observations for up to 4 years; the best resemblance to the phase of the observed variability is simulated by the hindcast ensemble mean (Fig. 3 Left).
❑ We find that AMOC variations are predicted with significantly greater skill by the initialized hindcasts than by the persistence forecast and noninitialized climate simulations (ens20C) for up to 4 years in advance (Fig. 3 Middle Top).
❑ AMOC predictive skill arises predominantly from the basin-wide upper-mid-ocean geostrophic transport (Fig. 3 Middle Bottom), which in turn can be predicted because we have skill in predicting the upper-ocean zonal density difference (not shown).
❑ Ensemble forecasts initialized between January 2008 and January 2011 indicate a stable AMOC at 26.5ºN until at least 2014, despite a brief wind-induced weakening in 2010 (Fig. 3 Right).

Summary and Outlook

❑ Forcing an ocean model with the observed atmosphere is a simple yet effective way to produce an ocean state estimate for initialising climate predictions.
❑ We found significantly enhanced predictive skill through initialization for North Atlantic and Mediterranean SST up to a decade in advance. Over land, SAT skill improvement is found over north-western Europe, Northern Africa, and central-eastern Asia.
❑ The North Atlantic Subpolar Gyre region stands out as the region with the highest predictive skill beyond the warming trend, in both SST and OHC analyses.
❑ The dominant mechanism that extends the predictive skill of North Atlantic SST and OHC in the second pentad, beyond the skill of persistence, is of dynamical origin and can be attributed to the initialization of the AMOC. Therefore, our results (Refs. 3-5) affirm AMOC as an important carrier of climate predictability.
❑ Interannual AMOC@26N variations are predictable up to 4 years in advance. We forecast a stable Atlantic Meridional Overturning Circulation at 26.5ºN until at least 2014, despite a brief wind-induced weakening in 2010.
❑ Next step: the robustness of our results needs to be tested in the new generation of high resolution models used for the CMIP5 and MiKlip decadal prediction systems.

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