Quantifying the role of ocean initial conditions in decadal prediction

D. Matei (1), H. Pohlmann (1,2), W. Müller (1), H. Haak (1), J. Jungclaus (1), and J. Marotzke (1)

(1) Max Planck Institute for Meteorology, Ocean in the Earth System, Hamburg, Germany (daniela.matei@zmaw.de, 0049 40
41173-298),
(2) Met Office Hadley Centre, Exeter, UK

Coupled climate models have undergone significant improvements during recent years by using more advanced parameterizations and higher resolutions (e.g., Jungclaus et al., 2006; Jungclaus et al., 2008). A major breakthrough has been that most models no longer need flux adjustments to maintain a stable climate. The reason for this improvement may be found in the ocean as well as in the atmosphere. A consequence, however, is that the simulated climate may differ significantly from observations. Model surface temperatures deviate by several degrees in certain regions and even subsurface temperatures are off substantially owing to deficiencies in water mass transformation and mixing processes. Constraining the model to observations by stringent data assimilation would keep the solution and hence any forecast based on the model closer to the real attractor. The development of coupled assimilation systems is, however, in its infancy. Moreover, first experiences from forecast systems indicate that the forecast will be contaminated by considerable drift towards the model attractor. This is a fundamental problem for predictions with coupled climate models, particularly on decadal timescales.

The effect of ocean initial conditions on decadal predictability has been demonstrated by various studies suggesting large potential predictability particularly in the North Atlantic region (e.g., Pohlmann et al 2004). The feasibility, however, is still limited by the strength of the mentioned drift partly having the same magnitude as the predictive signal itself. Here we investigate decadal climate predictions with the MPI-M coupled climate model ECHAM5/MPIOM considering two different initialization strategies. First we produce quantitative hindcasts and forecasts starting from ocean initial conditions that are based on a dynamically consistent reanalysis of past and present observational data, provided by the German contribution to the Estimating Circulation and Climate of the Ocean (GECCO) project (Köhl and Stammer 2008). For this an assimilation run is performed by nudging globally distributed anomalous monthly temperature and salinity onto the model climatology. Based on the assimilation run hincasts with 10 year length are performed for every year for the period 1952-2001 (which is constrained by the GECCO data). This method avoids the profound drift since the forecasts are run on the model attractor. However, since there remain mismatches between the ocean climates of GECCO and the MPI-OM model, which also lead to inconsistencies such as in the representation of water masses, we pursue an alternative approach to the representation of the observed North Atlantic climate. Here an ensemble of four MPI-OM ocean model integrations forced by the NCEP surface observations are performed. The ensemble mean temperature and salinity anomalies are then similarly nudged into the coupled model as by the GECCO initialization, and followed by set of hindcast/forecast experiments. The period here is chosen to 1948-2007 constrained by the NCEP data.

The results show promising skill up to decadal time scales particularly over the North Atlantic. Predicted North Atlantic sea surface temperatures (SST) initialized by the GECCO synthesis is shown to follow closely observations up to a decadal timescales, whereas respective integrations forced by 20th century greenhouse gas forcing do not show pronounced skill (Pohlmann et al. 2009). Similar results are found for the Atlantic MOC where the hindcasts rather than the 20th century integrations closely follow the observations described by the GECCO synthesis.

Examinations on grid point scale further reveal regions of significant forecast skill, particularly in the North Atlantic and Southern Ocean (Figure 1). The predictive skill is structurally similar in both methods. For the first year the anomaly correlation is dominated by the NCEP forced approach particularly throughout the Pacific and tropical Indian Ocean. The skill in the GECCO initialized integrations show less pronounced skill but in similar regions such as the Pacific. After 5 yr of integration skill is found in the North Atlantic, Southern Pacific, and parts of the Indian Ocean. Here the skill of the GECCO initialization dominates. Though we have applied different initialization strategies the model captures skill at distinct regions, suggesting some sort of model predictability.

We have further examined processes factoring the Atlantic MOC predictability such as the two main overflow branches in the North Atlantic Polar sea, namely the Denmark Strait (DEN) and Faroe Bank Channel (FBC). These two branches represent a main contributor to the production of North Atlantic Deep Water that feed the lower limb of the Atlantic MOC. The history of both branches are well captured by the NCEP forced runs (Olsen et al. 2008) and its assimilation integration with respect to observations. Furthermore the transport through the DEN and FBC in hindcast integration are significantly correlation with assimilation run suggesting the DEN and FBC overflows potentially predictable up to 5 years.

References:

Jungclaus, J.H., M. Botzet, H. Haak, N. Keenlyside, J.-J. Luo, M. Latif, J. Marotzke, U. Mikolajewicz, and E. Roeckner, 2006: Ocean circulation and tropical variability in the coupled model ECHAM5/MPI-OM. *J. Climate*, **19**, 3952-3972.

Jungclaus, J.H., A. Macrander, and R.H. Käse, 2008: Modelling the overflows across the Greenland-Scotland Ridge. In: R.R. Dickson et al. (eds.), Arctic-Subarctic Ocean Fluxes, 527-549, Springer Science + Business

Media B.V.

Köhl, A., and D. Stammer, 2008: Variability of the meridional overturning in the North Atlantic from the 50 years GECCO state estimation. J. *Phys. Oceanogr.*Pohlmann, H., M. Botzet, M. Latif, A. Roesch, M. Wild, and P. Tschuck, 2004: Estimating the decadal predictability of a coupled AOGCM. *J. Climate*, **17**, 4463-4472.

Olsen, S. M., B. Hansen, D. Quadfasel, and S. Osterhus, 2008: Observed and modelled stability of overflow across the Greenland-Scotland ridge. Nature, 455, 519-523.

Pohlmann, H., J.H. Jungclaus, A. Köhl, D. Stammer, and J. Marotzke, 2009: Improving decadal climate predictability through the initialization of a coupled model with the GECCO oceanic synthesis. *Journal of Climate (accepted).*

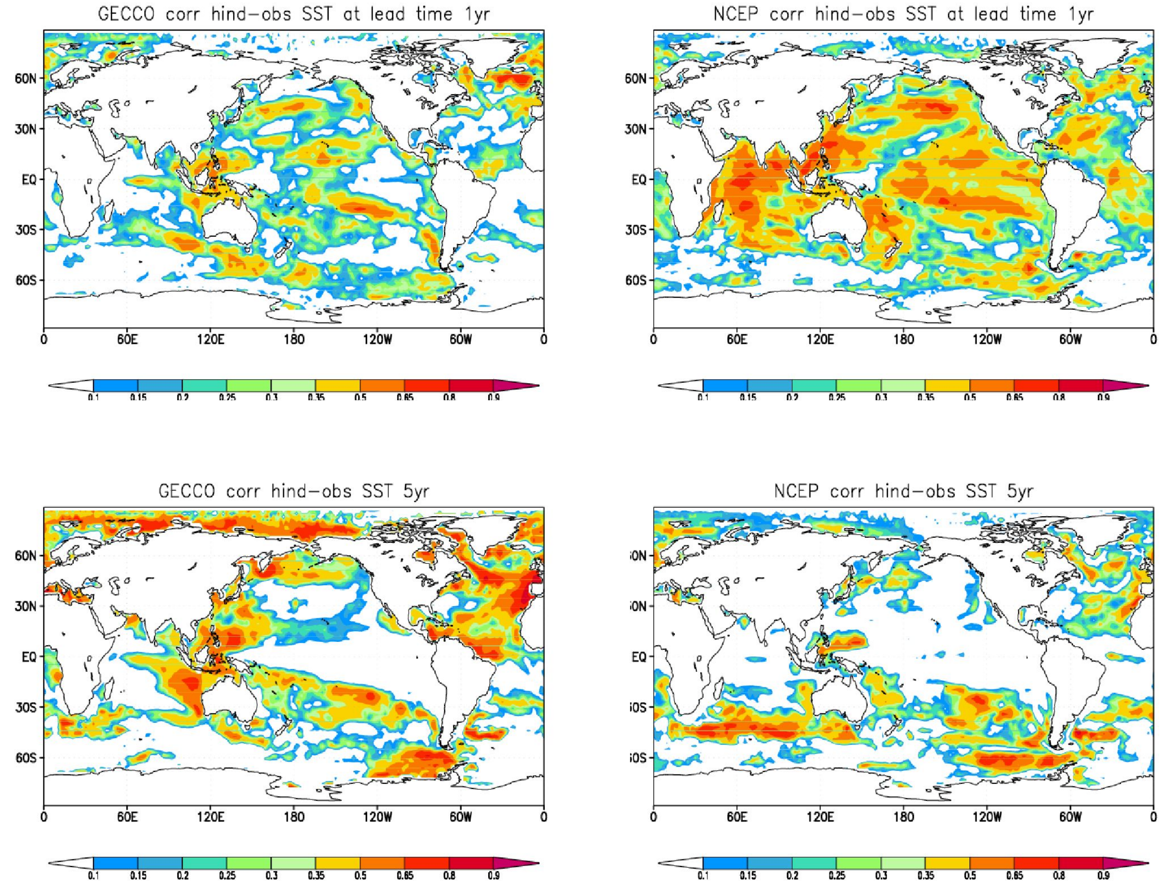

Figure 1: Correlation coefficients of sea surface temperature (SST) between observations and hindcasts performed via (left) GECCO initialization and (right) NCEP forced MPIOM. Upper panel shows results for annual mean and lead time 0 year, lower panel shows 5yr mean and lead time 1 year. For observations HadISST v1.1 is used.