Climate predictability from Met Office decadal prediction system

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1. Introduction

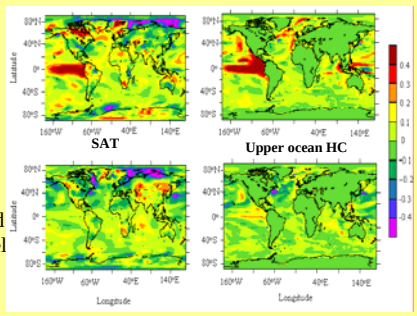
The Met Office Hadley Centre decadal prediction system (Smith et al 2007), based on HadCM3, was imported to the Reading computer cluster and the effect of initial conditions on climate prediction skill has been assessed with 4 or 5 member ensembles initiated with (ASSIM) and without (NOASSIM) data assimilation. Hindcasts are performed over 2 year periods, initialised in May and November 1990-1999. It is shown that assimilation improves the prediction skill for surface air temperature (SAT) globally in the first year, mainly due to improved skill over ocean areas, (skill improvement over land areas is more limited, as found by Collins 2002).

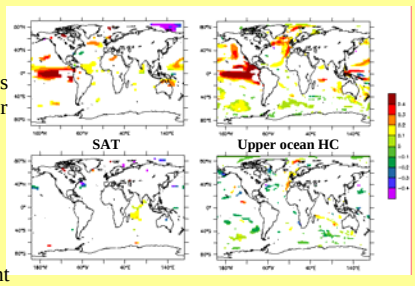
The predictability of climate is mainly due to the predictability of upper ocean heat content, so the reanalysis of ocean history plays an important role in initialisation. We examine the effect on forecast skill of initial states obtained from different ocean datasets (DePreSys-using HadCM3 covariances, EN3-a model independent ocean analysis and ORCA1-NEMO model reanalysis) processed with totally different methods. Results show that certain measures of skill are robust and generally comparable when initialising with the different ocean datasets.

The assimilation into HadCM3 uses a simple nudging technique where atmospheric wind, temperature and surface pressure anomalies from ERA40, and analysed ocean temperature and salinity anomalies from the different sources, are combined with the models own climatology and nudged hard into the coupled system. To produce a forecast this nudging is simply switched off allowing the free coupled run to continue. SST noise is added to initial conditions to generate an ensemble of predictions. Critically the model is run in coupled mode at all times.

2. Skill

Following Haines et al (2009), the standard deviation (STD) is used as the skill measure because when root mean square error (RMSE) is applied to forecasting anomalies, results are sensitive to the mean climatology period chosen. The STD of the 1st and 2nd year anomaly error between model and observations is calculated. Upper fig shows NOASSIM-ASSIM STD differences of SAT (left) and upper ocean heat content for the top 113m (right), using the DePreSys ocean conditions for ASSIM. Positive values mean an improvement of ASSIM over NOASSIM.



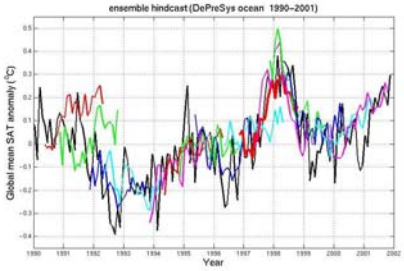


The main skill gained in the 1st year (1st row) is due to the well predicted 1998 ENSO. There is also improved skill in the North Atlantic around the subpolar gyre, which maybe important for North West European climate. This area affects the NAO and storm tracks and may affect the MOC and hence even longer timescale forecasts. Skill in the 2nd year (2nd row) is much lower as the model becomes less sensitive to initial conditions.

It is clear that the ocean areas with improved skill in SAT correspond to those with more skill in upper ocean heat content. A Significance test (95% confidence level) filter on these same results is shown in the lower plot. There is little significant skill improvement over land. Since NOASSIM and ASSIM have the same external forcing, the improved skill comes from the improved initial conditions, i.e. the oceans.

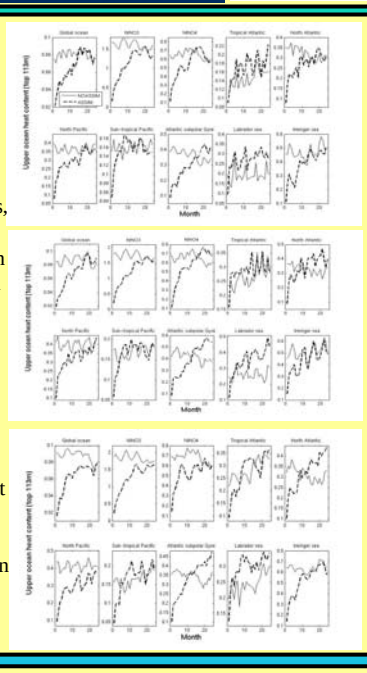
3 Global SAT hindcasts

The improved skill in SAT (using the DePreSys ocean conditions) over different areas contributes to the global mean SAT forecast shown. The global mean SAT anomalies from ERA40 (truth=black line) and the four member ensemble mean hindcasts (coloured lines) are shown. The discrepancy for hindcasts starting from May and November 1990 is due to the unknown Pinatubo volcanic eruption which is not "predictable". The eruption happened in June 1991 and hindcasts starting from November 1991 successfully captures the initial SAT decrease and later increase during the volcanic aerosol affected period. The continuous increase of SAT from 1993 to 1995 is well hindcast. The decrease from 1995 to 1996 and then the increase due to ENSO is also captured by the model. The ENSO can be predicted successfully from as early as November 1996 (thick red line). The recovery of SAT skill from the decrease after the ENSO event is also captured by the hindcasts starting from May 1998 and May 1999.



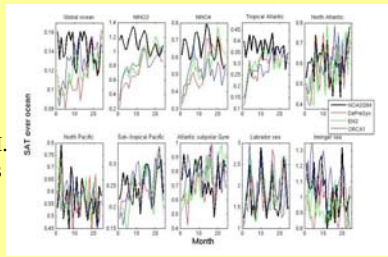
4 Skill in Ocean heat content

Using areas defined by Collins (2002), the area mean upper ocean heat content for different regions, based on initialisation and verification against the three ocean datasets, are shown (upper: DePreSys, middle: EN3, lower: ORCA1). For all three ocean datasets, the improved skill in the global ocean, NINO3 area and North Pacific last more than 2 years. Skill lasts about 1 year for the North Atlantic, NINO4 area and sub polar gyre. It lasts only a couple of months for the tropical Atlantic and sub-tropical Pacific. Although skill in the Labrador sea is lower than NOASSIM, there is about one year of skill improvement in the Irminger sea region. Comparing these results between ocean datasets, the skill in most cases is similar, but the skill for the EN3 and ORCA1 ocean datasets in the North Atlantic and subpolar gyre decreases slightly faster. Different ocean analyses therefore have only a small impact on predictability. We do not find 5-10 year mean skill reported in Smith et al (2007).



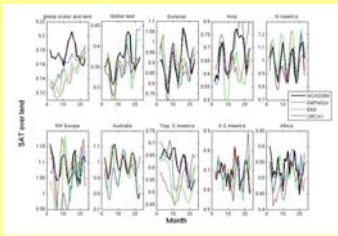
5. SAT skill over oceans

The corresponding SAT STDs over ocean areas from all three hindcasts generated from the three different ocean datasets are plotted together with that from NOASSIM. Generally the SAT STDs over ocean areas follow the STD patterns in upper ocean heat content, but the SAT skill is lower than for ocean heat content itself, except for the tropical Atlantic region where the SAT skill period is extended, probably due to remote influences from the tropical Pacific. There is no sign of skill improvement over the North Pacific and this needs further investigation. For the global ocean the DePreSys ocean dataset shows slightly more skill than the other two datasets, but the skill from the three ocean datasets over different regions are again comparable.



6. SAT skill over land

For regions over land, three month running mean SAT skill is shown. For the entire globe skill lasts about two years mainly from ocean areas. Over land areas alone there is some skill over NW Europe, but no skill improvements over Eurasia or north America. Over Europe skill is probably related to skill in north Atlantic upper ocean heat content.



Results from the three ASSIM hindcasts again show similar patterns of SAT skill, suggesting all three ocean datasets allow more or less similar levels of predictability. This also suggests the STD method is a robust skill measure.

Estimated improved forecast period (month)

Area	From Collins	Ours
Tropical Atlantic	18	20
Sub-tropical Pacific	9	6
N. Atlantic	decadal	7
N Pacific	6	0
NW Europe	5	8
African	12	12
Trop. S. America	14	15
Eurasian	4	0

The improved SAT forecast period for selected areas from the perfect HadCM3 twin expts. of Collins (2002) and our results are shown in the Table. One expects lower skill than the twin experiments but in many cases the skill periods are comparable. The longer predictability of the north Atlantic in Collins is not detectable in 2 year hindcasts but no signs can be seen. All results should be confirmed with larger ensembles and over different time periods.

7. Future work

The following topics still need further investigation.

- Climatology effect on anomaly assimilation and anomaly skill
- Longer period prediction of indices (MOC, NAO, Heat Transport, Precipitation, Storm Statistics, …)
- Sensitivity to anomaly assimilation using different models

References:

Collins, M. 2002: Climate predictability on interannual to decadal time scales: the initial value problem. Climate Dynamics, vol. 19, 671-692.

Haines K., L. Hermanson, C. Liu, D. Putt, R. Sutton, A. Iwi, D. Smith, 2009 : Decadal climate prediction (project GCEP), *Phil. Trans. Roy. Soc. A*, ***367***, 925-37, DOI: 10.1078/rsta.2008.0178

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