European Commission's 7th Framework Programme
Grant Agreement No. **226520**

Project acronym: **COMBINE**

Project full title: **Comprehensive Modelling of the Earth System for Better Climate Prediction and Projection**

Instrument: Collaborative Project & Large-scale Integrating Project

Theme 6: *Environment* Area 6.1.1.4: *Future Climate*

ENV.2008.1.1.4.1: *New components in Earth System modelling for better climate projections*

Start date of project: 1 May 2009 Duration: 48 Months

Deliverable Reference Number and Title:
D5.3 Assessment of initialization strategy

Lead work package for this deliverable: WP5

Organization name of lead contractor for this deliverable: ECMWF

Due date of deliverable: 28 February 2013
Actual submission date: 30 April 2013

Project co-funded by the European Commission within the Seven Framework Programme (2007-2013)		
Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the Consortium (including the Commission Services)	

Summary

This deliverable discusses and compares three different strategies used to deal with model error in seasonal and decadal forecasts. The strategies discussed are the so-called full initialization, anomaly initialization and flux correction. In the full initialisation the coupled model is initialized to a state close to the real-world attractor and after initialization the model drifts towards its own attractor, giving rise to model bias. The anomaly initialization aims to initialize the model close to its own attractor, by initialising only the observed anomalies. The flux correction strategy aims to keep the model trajectory close to the real-world attractor by adding empirical corrections.

Both anomaly and full initialization approaches are currently in use in decadal and seasonal forecasts, but their relative merits were unclear. One for the prime objective of WP5 was the comparison and assessment of these two initialization strategies. The evaluation has been carried out with the ECMWF and the MetOffice forecasting systems. The two independent evaluations show that at seasonal time scales the full-initialization produces more skilful forecasts, while at decadal time scales there is little different between the approaches. If simulations of the historical period have already been performed for climate change projections, the anomaly initialization may be more practical at decadal time scales, since it requires a less extensive hindcast set. However, these historical simulations are themselves computationally expensive, and if they are not available then full initialization may be more practical despite requiring extensive hindcasts.

The flux correction strategy has been further explored using the ECMWF system, and results show that the erroneous model mean state is responsible for a degraded forecast skill. The best forecast skill is obtained when the model mean state is corrected by empirical corrections. By correcting the mean state, the interannual variability and teleconnections are improved, resulting in higher forecast skill. An important conclusion of this study is that the predictability on annual time-ranges could be higher than currently achieved if model error is reduced.

1.Assessment of Initialization Strategies

1.1. ECMWF

Full initialization, anomaly initialization and flux correction have been implemented in the ECMWF coupled forecasting system. The three strategies have been evaluated at seasonal and decadal timescales. The results are presented in Magnusson et al 2012a (http://link.springer.com/article/10.1007/s00382-012-1599-2), where they also discuss the practical implications of the different strategies. Results show that full initialization results in a clear model drift towards a colder climate (although for other models the drift could be towards a warmer climate). The anomaly initialization is able to reduce the drift, by initialising around the model mean state. However, the erroneous model mean state results in degraded seasonal forecast skill. The best results on the seasonal time-scale are obtained using momentum-flux correction, mainly because it avoids the positive feedback responsible for a strong cold bias in the tropical Pacific. It is likely that these results are model dependent: the coupled model used here shows a strong cold bias in the Central Pacific, resulting from a positive coupled feedback between winds and SST. At decadal time-scales it is difficult to determine whether any of the strategies is superior to the others.

1.2.MetOffice

The anomaly and full initialization approaches have been compared in a comprehensive decadal hindcasts starting each year from 1960 to 2009, made using the Met Office decadal prediction system. Both approaches are more skilful than climatology in most regions for temperature and some regions for precipitation. On seasonal timescales, full-field initialized hindcasts of regional temperature and precipitation are significantly more skilful on average than anomaly initialized hindcasts. Teleconnections associated with the El Niño Southern Oscillation are stronger with the full-field approach, providing a physical basis for the improved precipitation skill. Differences in skill on multi-year timescales are generally not significant. However, anomaly initialization provides a better estimate of forecast skill from a limited hindcast set. The results of the evaluation are reported in Smith et al 2013 (http://link.springer.com/article/10.1007/s00382-013-1683-2).

2.Impact of Systematic Model Error on forecast skill and ENSO variability

Systematic model error remains a difficult problem for seasonal forecasting and climate predictions. An error in the mean state could affect the variability of the system. Magnusson et al 2012b (http://link.springer.com/article/10.1007/s00382-012-1574-y) investigates the impact of the mean state on the properties of ENSO. A set of coupled decadal integrations have been conducted, where the mean state and its seasonal cycle have been modified by applying flux correction to the momentum-flux and a combination of heat and momentum fluxes. They show that correcting the mean state and the seasonal cycle improves the amplitude of SST inter-annual variability and also the penetration of the ENSO signal into the troposphere and the spatial distribution of the ENSO teleconnections are improved. An analysis of a multivariate PDF of ENSO shows clearly that the flux correction affects the mean, variance, skewness and tails of the distribution. The changes in the tails of the distribution are particularly noticeable in the case of precipitation, showing that without the flux correction the model is unable to reproduce the frequency of large events. For the interannual variability the momentum-flux correction alone has a large impact, while the additional heat-flux correction is important for the teleconnections.

These results suggest that the current forecast practices of removing the forecast bias a-posteriori or anomaly initialisation are by no means optimal, since they cannot deal with the strong nonlinear interactions. A consequence of the results presented here is that the predictability on annual time-ranges could be higher than currently achieved. The conclusion from the ECMWF model that the correction of the model mean state by some sort of flux correction leads to better forecasts needs to be assessed in other models. This may also lead to further model improvements since flux correction may be a powerful tool for diagnosing coupled model errors and predictability studies.

References (links provided in the text)

Magnusson, L., M. Alonso-Balmaseda, S. Corti, F. Molteni, T. Stockdale (2012a), Evaluation of forecast strategies for seasonal and decadal forecasts in presence of systematic model errors. Climate Dynamics. doi:10.1007/s00382-012-1599-2.

Magnusson, L., M. Alonso-Balmaseda and F. Molteni (2012b), On the dependence of ENSO simulation on the coupled model mean state. Climate Dynamics, doi: 10.1007/s00382-012-1574-y.

Smith, D. M., R. Eade, and H. Pohlmann (2013), A comparison of full-field and anomaly initialization for seasonal to decadal climate prediction. Climate Dynamics. doi: 10.1007/s00382-013-1683-2.