SPECIAL PROJECT PROGRESS REPORT

Progress Reports should be 2 to 10 pages in length, depending on importance of the project. All the following mandatory information needs to be provided.

Reporting year 2015

Project Title: Reducing drift and correcting biases in coupled seasonal hindcasts

Computer Project Account: spgbhain

Principal Investigator(s): Keith Haines

Affiliation: University of Reading

Name of ECMWF scientist(s) collaborating to the project (if applicable) Patrick Laloyaux, Magdalena Balmaseda ………………………………………………………….……

Start date of the project: September 2013

Expected end date: December 2016

Computer resources allocated/used for the current year and the previous one

(if applicable)

Please answer for all project resources

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	500,000	350,000	500,000	0
Data storage capacity	(Gbytes)	1000	600	1000	0

Summary of project objectives

The special project is focused on studying and improving initialisation of coupled systems. The first strand of the work is within a UK NERC project (ERGODICS, running to 2016), and involves analysis of initialisation shocks and model drifts in existing coupled hindcasts, on daily and seasonal timescales. We are also exploring the use of bias correction methods, particularly in the ocean, to improve coupled forecasts and analyses. A second piece of work, on analysing coupled covariances from coupled reanalyses run at the European Centre as part of the ERA-CLIM2 project, began in late 2014. This is preliminary work to assess the benefits and difficulties of creating a 'strongly coupled' data assimilation system, and so is also relevant to our goal of improving initialisation of coupled systems.

Summary of problems encountered (if any)

Following the change in computer system at ECMWF in late-2014, and with the embargo period used for operational model version changes, there has been a period at the beginning of 2015 where there has not been a working version of the coupled ocean-atmosphere model available to member state users outside the centre. We do not expect this issue to impact our plans for the remainder of 2015, however.

Summary of results of the current year (from July of previous year to June of current year)

To measure the size and assess the impact of initialisation shocks, a number of coupled forecasts were performed, in collaboration with Patrick Laloyaux at ECMWF. These differed in their methods of initialisation, using variously the analysis from the newly developed weakly coupled data assimilation system, CERA; equivalent uncoupled analyses; and existing reanalysis products produced at ECMWF with previous model versions/configurations (ERA-Interim, ORAS4).

The importance of the CERA-initialised forecasts is that they provide a reference situation in which the problem of initialisation shock due to inconsistency between the main component fields in the atmospheric and oceanic analyses that have not been in communication during the analysis phase, is avoided by virtue of the design of CERA which always runs the coupled model wherever needed in the assimilation. This also means that forecast error that is caused by the development of model biases – and is therefore unavoidable at present, and not a property of the initialisation method – can be separated from the error that is caused specifically by flaws in the initialisation process. Using this experimental framework, we were able to identify atmospheric initialisation shocks that occur when uncoupled analyses are used for the initialisation of the coupled forecast, but do not occur when CERA is used for the initialisation (Figure 1).

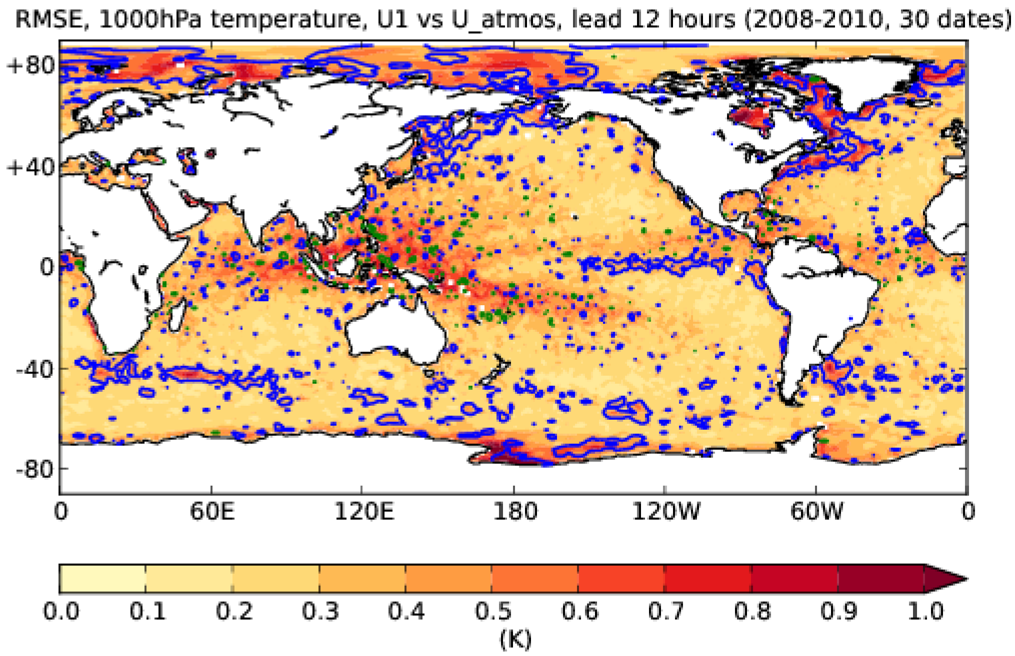

Figure 1: The error in 1000hPa temperature after 12h in forecasts initialised by uncoupled analyses (shading), and the difference between this error and the equivalent error in forecasts initialised by CERA (blue contours mark an increase in error of 0.15K).

These shocks were found to cause increased near-surface temperature RMSE over the duration of the 10-day forecasts, in areas where SST model bias and/or temporal variability is particularly large, leading to large discrepancies between the uncoupled ocean analysis and the SST forcing product used during the atmospheric analysis. However, forecast skill, as evaluated using the anomaly correlation coefficient in both precipitation and near-surface air temperature, using independent reference datasets, showed only marginal gains in the CERA-initialised forecasts, which were in some cases not statistically significant. Therefore, while initialisation shocks do exist due to the use of uncoupled DA, it is unclear if they degrade short-to-medium-range forecasts to any significant extent.

Larger initialisation shocks were found to follow a change in model version between analysis and forecast, due to changes in model dynamics and/or physical parameterisations. This was found to be particularly prominent in the equatorial Pacific and Atlantic oceans, where replacing an older version of the NEMO ocean model, used for a reanalysis, and subsequently for initialisation of hindcasts (i.e. ORAS4), with the more current version for the coupled forecast model resulted in strong upwelling and surface cooling. These results make it clear that operational forecasts should always, ideally, be initialised using exactly the same models that are to be used to perform the forecasts. This applies also to the calibration hindcasts that are commonly run to allow the removal of model drifts in post-processing in seasonal forecasts.

This study is presented in a paper (Mulholland et al., see below), which should very soon be accepted in Monthly Weather Review.

More recent work has focused on the separate class of initialisation shock that results from the use of equatorial ocean bias correction during the initialising analysis, and the removal of this correction term at the beginning of the forecast. Although the bias correction technique leads to the production of a more accurate ocean analysis (one not so seriously affected by spurious circulations that otherwise form due to upper ocean model error), it has been found that the instantaneous removal of the correction term excites additional, spurious, oscillations in the equatorial thermocline. These signals appear to spread away from the equator in subsequent weeks, are long-lasting, and may lead to a reduction in tropical SST forecast skill on the seasonal timescale.

Work has also been done to calculate coupled background error covariances, as part of WP2 of the ERA-CLIM2 project. We have used output from the test period of the CERA system, both the analysis and forecasts initialised from it, to explore the feasibility of calculating covariances by various methods, and gauge the level of agreement between the different methods.

An example is shown in Figure 2, where the correlation between errors in forecast SST and 2m air temperature at 24h lead time is estimated using the ‘NMC (National Meteorological Center) method’, for a two-month period December 2010-January 2011. Correlations are found to be significantly positive in the midlatitudes of the southern (summer) hemisphere, where the ocean mixed layer is relatively shallow, and hence the coupling between the upper ocean and lower atmosphere layers is relatively strong.

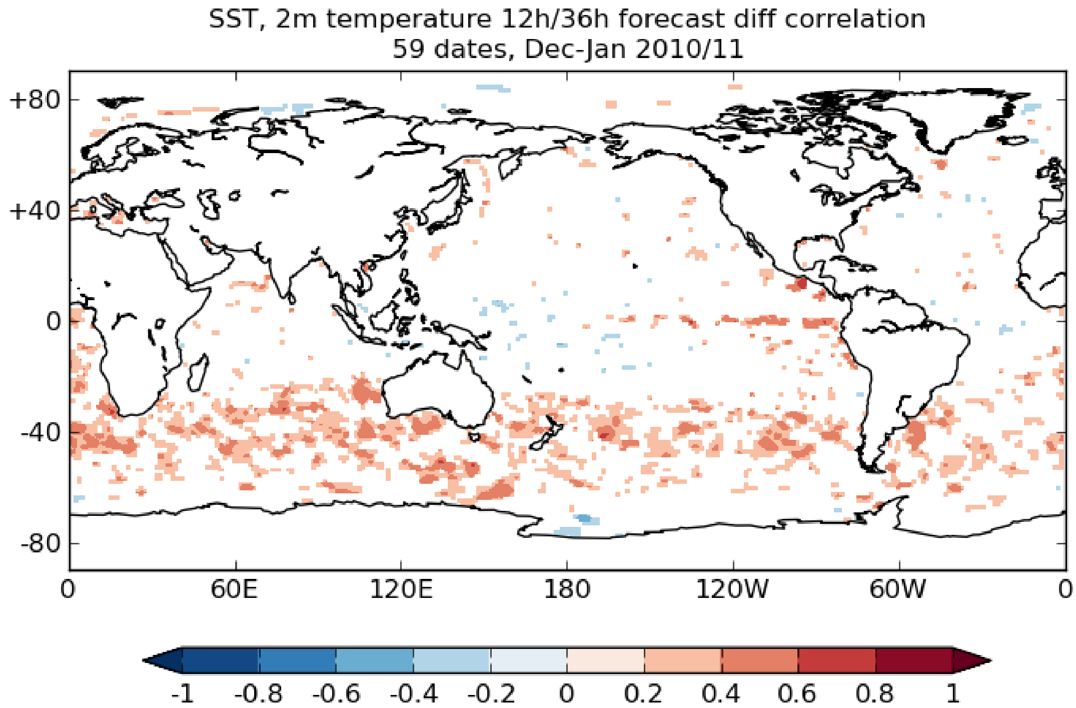

Figure 2: Correlation between SST and 2m air temperature errors, estimated using the NMC method, for forecasts in December 2010-January 2011.

The NMC method was found to provide a good estimate of covariances using forecast data alone. In order to obtain a closer link to observational data, we have also investigated the feasibility of calculating coupled covariances using innovations from the CERA coupled analysis. The spatial and temporal frequency of observational coverage has proved to be an important limiting factor in this calculation, though some significant error correlations have been detected using the method. Work is ongoing to refine the methodology to target the correct spatial scales for atmosphere-ocean error correlations.

The results to date will be summarised as part of an ERA-CLIM2 interim project report, soon to be submitted (Waters et al., see below).

List of publications/reports from the project with complete references

D. P. Mulholland, P. Laloyaux, K. Haines and M.-A. Balmaseda, 2015. Origin and impact of initialisation shocks in coupled atmosphere-ocean forecasts. *Monthly Weather Review* (under revision)

J. Waters, D. Mulholland, X. Feng, I. Mirouze and M. J. Martin. Techniques for estimating coupled ocean/atmosphere forecast error covariances. ERA-CLIM2 Deliverable Report D2.9 (in preparation)

Summary of plans for the continuation of the project

We are currently setting up new forecasts to test different strategies for maintaining ocean bias correction (from the analysis) into the forecast, for a certain period of time, in order to minimise the initialisation shock that is currently produced in ocean or coupled simulations initialised from ORAS4. Later in the year, if possible, we hope to extend this approach to enable the use of bias correction in the CERA system and forecasts initialised from it. (D. Mulholland, K. Haines)

Work on investigating coupled covariances will continue over the next year, to use the full amount of CERA data currently available and to try to improve the methodology used when calculating covariances between analysis innovations. We will also explore the use of the ensemble method to estimate error covariances, using ensemble coupled forecasts already available and/or the forthcoming 100-year CERA reanalysis that is being run in ensemble mode for ERA-CLIM2. (X. Feng, K. Haines)