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	2014
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, Linus Magnusson …………………………………………………………………
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	620,000	500,000	18,000
Data storage capacity	(Gbytes)	1000	1570	1000	35

Summary of project objectives

The special project is focused on studying and improving initialisation of coupled systems. The current phase of the work is within a UK NERC project (ERGODICS, running to end 2015). This involves analysis of initialisation shocks and model drifts in existing coupled hindcasts, on daily and seasonal timescales. We will also explore the use of bias correction methods, particularly in the ocean, to improve coupled forecasts and analyses. Later in the project, work is planned on analysis of coupled covariances from coupled reanalyses run at the European Centre as part of the ERA-CLIM2 project.

Summary of problems encountered

This special project originally began in September 2013, with resource allocation for 2013 only (due to a misunderstanding of the format of the late request allocations). After discussions with ECMWF personnel it became clear that for the work planned in the special project to be relevant to operations at the Centre, the most up-to-date model cycle, cy40r1, needed to be used. This cycle became operational around November 2013, but unfortunately remained unavailable to Member State users for 6 months after that, until May 2014. At the same time, the transition in computer system that took place at the Centre in late 2013 meant that there were no earlier versions of the model that were properly set up to run in ‘longrange’ mode, as was required for the seasonal hindcasts planned in the special project, so any experiments of this kind from outside the Centre were essentially ruled out within 2013.

We were however able to utilise the allocated resources to run a set of thirty seasonal hindcasts with cy40r1 with the help of Linus Magnusson at ECMWF, in late 2013. These hindcasts are an appropriate control case for future modified seasonal hindcast experiments.

As the special project ended at the end of 2013, we then reapplied to extend the project for a further 3 years (for a total of 3.5 years). There was a significant delay in this process due to an administrative issue with the UK Met Office over confirming support for the application. When this was agreed, the special project was reactivated in mid-May 2014. In effect, the project spgbhain has been active for around 5 months out of the past year. At this point cy40r1 is available to outside users, so future work should proceed more smoothly.

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

(David Mulholland, Keith Haines)

Analysis of drifts

The primary experimental run so far has been a set of coupled hindcasts in the operational seasonal forecast configuration of model cy40r1. The set included thirty years of 7-month hindcasts, each starting on 1 May. The purpose of this experiment was to determine the extent of model drift occurring in a standard hindcast, to look for the presence and impact of initialisation shocks, and to act as a control set for future hindcasts using a modified initialisation procedure or online bias correction.

Drifts in tropical winds (from an ERA-Interim reference) are seen in the first few days of the hindcasts, as a response to the difference in SST field between the operational product used by ERA-Interim and the initial conditions provided by the ORAS-4 ocean analysis (what may be interpreted as an initialisation shock). This effect is small, though, and by 10-20 days’ lead time wind biases are not correlated with the initial SST discrepancy, as relatively large atmospheric model errors begin to dominate, most notably in the western tropical Pacific (Figure 1). Wind biases then vary on the monthly timescale, reflecting a seasonal dependence in the atmospheric model bias (this was confirmed by different rates of wind drift in the first month for different start dates, in previous tests using the UK Met Office's GloSea4 system). The rate of drift at the beginning of a forecast varies according to the size of the model's climatological biases for that particular start date.

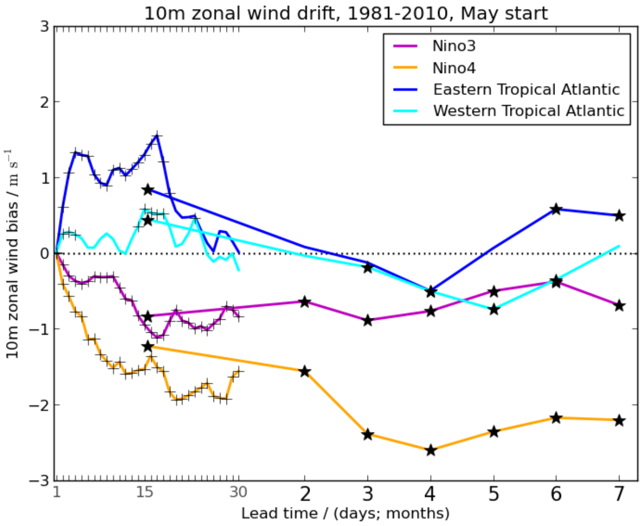

Figure 1 – Drift in 10m zonal winds relative to ERA-Interim, in several tropical regions from the cy40r1 seasonal hindcasts. Crosses (stars) mark daily (monthly) mean biases that are significantly different from zero at the 95% confidence level.

Tropical SSTs drift steadily over the 7 months of the hindcasts due to the presence of the easterly wind bias – there is no evidence of a feedback of SST onto the wind biases, but more than a single start date per year would be required to investigate this fully. The tropical SST drift was found to be a function of the mean state, with more rapid cold drift in the eastern Pacific (significantly so over 2 months) occurring in locally cold years.

The long term bias in the tropical Pacific is one of too-strong easterly winds and an overly steep thermocline, and this is first realised after 2-3 months. In the first month the tendency along the thermocline is in the opposite direction – a cooling in the west Pacific, caused by the early local wind drift. In individual years, near-surface zonal wind biases developing within the first few days can be linked to Kelvin-wave-like signals in Pacific equatorial 20C isotherm depth, though these could not be tracked beyond 30 days' lead time due to the frequency of ocean saved output. Other signals in isotherm depth, apparently unrelated to drifts in the surface wind stress, may be signs of a response in the upper ocean to the removal of the 'pressure correction' increment, which is used during the ocean analysis to correct for erroneous distribution of turbulent wind stress in the vertical direction.

There is the hint of higher forecast skill (in SST, precipitation) in hindcasts in which the bias at 150m depth in the western Pacific after 5 days is small, relative to those in which it is large, at lead times of up to 5 months. This may suggest the generation of erroneous Kelvin waves in the latter case which impact on forecasts at the surface in subsequent months; however with only one realisation of each year in the hindcast set, the comparison is between different years and thus does not exclude the possibility of interannual variation in the inherent predictability of the system.

Quantifying coupling shock

A weakly coupled data assimilation system (CERA) has been developed at ECMWF, providing a possible future alternative initialisation method for seasonal forecasting, by obtaining initial atmosphere and ocean states through coupled analyses rather than separate component analyses.

Test periods of the coupled analysis have been run in April-May 2009 and August-September 2010, along with 10-day forecasts started on each day of these periods. Recently, in collaboration with Patrick Laloyaux at ECMWF, we have begun to use the CERA forecasts in comparison to the existing uncoupled-initialised forecast method as a way of quantifying one aspect of initialisation shock, which may be best termed 'coupling shock', which is that which arises due to the combination of potentially unbalanced atmosphere and ocean model components in the initial conditions (i.e. that which should be avoided in the CERA method). This has been done using a number of forecasts initialised in an uncoupled manner, similar to the standard seasonal forecast method, run by Laloyaux in the August-September 2010 period, and a similar set of uncoupled-initialised forecasts run by Mulholland in the April-May 2009 period.

Results from this comparison so far suggest that coupling shock is a very small effect, but is present and detectable in particular circumstances. Uncoupled-initialised forecasts in the August-September period show a sharp (though small) drift in SST away from the analysis at the beginning of the forecast in the eastern equatorial Pacific (Figure 2) where, at this time of year, tropical instability waves are particularly active, producing strong atmosphere-ocean coupling. This shock is not seen in the CERA forecasts. The cold bias in the uncoupled-initialised SST causes slightly increased root-mean-square error in near-surface temperature in the eastern tropical Pacific in the uncoupled-initialised forecasts compared to the CERA forecasts.

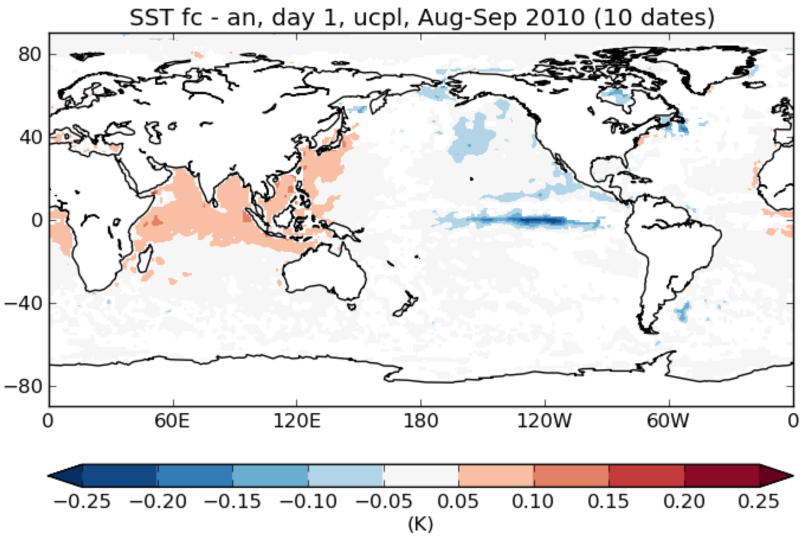

Figure 2 – Difference between forecast and ocean analysis SST in the uncoupled-initialised forecasts in August-September, on the first day (daily mean) averaged over 10 start dates. Only differences that are significant at the 90% level using a t-test are shaded.

In the present system, improvements in forecast skill, as measured by the anomaly correlation coefficient for bias-corrected forecasts of precipitation compared to an 'independent' (i.e. observational: GPCP) reference, are marginal at best (Figure 3), suggesting that coupling shock does no significant damage to a forecast, at least over 10 days. It seems likely that the SST nudging approach used in both ocean analyses acts to maintain a high degree of consistency between ocean and atmosphere initial conditions in the uncoupled case, resulting in smaller shocks than might occur were SSTs not nudged to a gridded observation product. Therefore it should be noted that the impact of uncoupled forecasting shocks may need to be revised when direct SST measurements can be assimilated based on satellite tracks, rather than, as at present, the use of full spatial fields pre-analysed from OSTIA.

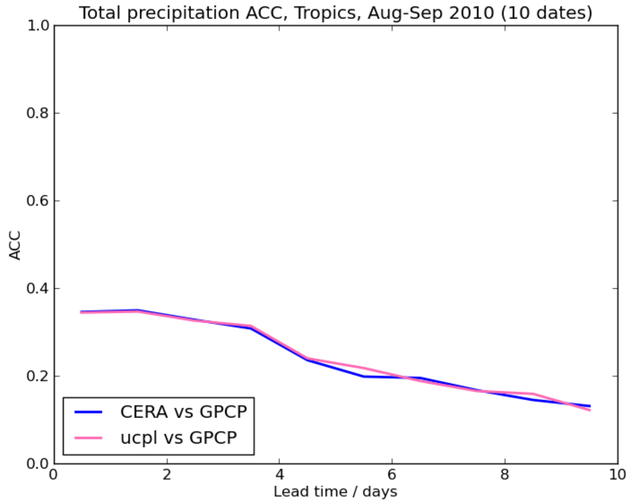

Figure 3 – Anomaly correlation coefficient for daily mean precipitation in the 10 Aug-Sep forecasts, referenced to the Global Precipitation Climatology Project (GPCP) dataset, averaged over the tropical ocean (30N-30S).

List of publications/reports from the project with complete references

Coupled hindcast shocks and drifts following uncoupled initialisation (D. Mulholland & K. Haines) – *poster to be presented at World Weather Open Science Conference, Montreal, 16-21 August 2014*

Summary of plans for the continuation of the project

We will continue the ongoing analysis of coupling shocks using the two available coupled forecast initialisation approaches. Next, we aim to address another, potentially more significant, form of initialisation shock, which is that caused by rapid coupled drift occurring as forecasts are begun away from the model's climatological attractor. In particular, rapid drift has been identified as occurring in near-surface winds in the tropics (in both coupled- and uncoupled-initialised cases), which could excite waves in the thermocline that cause the impact of the shock to remain in the system over a period of months. Experiments using bias correction to reduce the impact of the wind drift will be run to test the impact on the upper tropical ocean. Later, we aim to introduce a 3-d ocean bias correction method, using a 'spectral nudging' approach to test ideas for the reduction of drift in the mean state over the duration of a seasonal forecast. Within the ERA-CLIM2 project, we expect to start to use the CERA products to assess coupled atmosphere-ocean covariances, which are not being used as part of the analysis but which should be calculable from the innovations within the current CERA system.