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	2017
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 2017

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)	1,500,000	1,500,000	500,000	0
Data storage capacity	(Gbytes)	1000	2000	1000	0

Summary of project objectives

Over the last year the special project has been focused on studying the coupled CERA-20C reanalysis system. The first strand of the work is within a UK NERC project (ERGODICS, running to 2016), and involving analysis of initialisation shocks and model drifts in existing coupled hindcasts, on daily and seasonal timescales was completed with 2 publications. In the ERACLIM2 project we have been analysing coupled covariances from the coupled reanalyses run CERA-20C. For the remainder of this year we will focus on exploring the use of bias correction methods in this coupled system, particularly in the ocean. This work is on assessing the benefits and difficulties of creating a ‘strongly coupled’ data assimilation system, and so is also relevant to our original goal of improving initialisation of coupled systems.

Summary of problems encountered (if any)

Over the last year it has been very useful to have this special project mainly to give access to the ECMWF system for the purposes of analysing the large volumes of data from the CERA-20C, which would not have been possible if had been necessary to copy the data externally.

We have been testing new approaches to bias corrections by rerunning short periods of reanalysis in the coupled system however because CERA is such a recent system it has not been possible to do this independently of ECMWF staff. We have worked closely with Eric d’Boissason who has performed the new runs. Because of this we have not actually used the computing resources allocated to the special project and are unlikely to do so. However we emphasise it is still very much needed for accessing MARS and doing data analysis on the ECMWF system.

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

The paper on improved bias correction treatment appeared over the last year. Two new papers we submitted, one Feng et al (2017) on coupled covariances in CERA-20C is in the second round of reviewing. An overview paper on ERACLIM2 has also just been submitted Buizza et al (2017) to BAMS.

Work to study coupled atmosphere-ocean covariances is reported in Feng et al (2017). We have used the ensemble approach to calculating the covariances, using the 10 members of the CERA-20C coupled reanalysis. Daily outputs of SST, near-surface air temperature and near-surface winds have provided a large dataset with which to measure covariance patterns on different timescales and variations through the 20th century under different data availabilities.

Figure 1 shows the SST and 2m air temperature (T2m) monthly mean ensemble spreads and their correlations throughout the 20th century in mid-latitudes of the northern and southern hemispheres. The overall spread decline as observations improve can be seen. The correlations show the degree to which the variations are coupled. Anomalies are seen, eg. during the war years and also when satellite data are introduced around 1979-80. Results are discussed in more detail in Feng et al (2017).

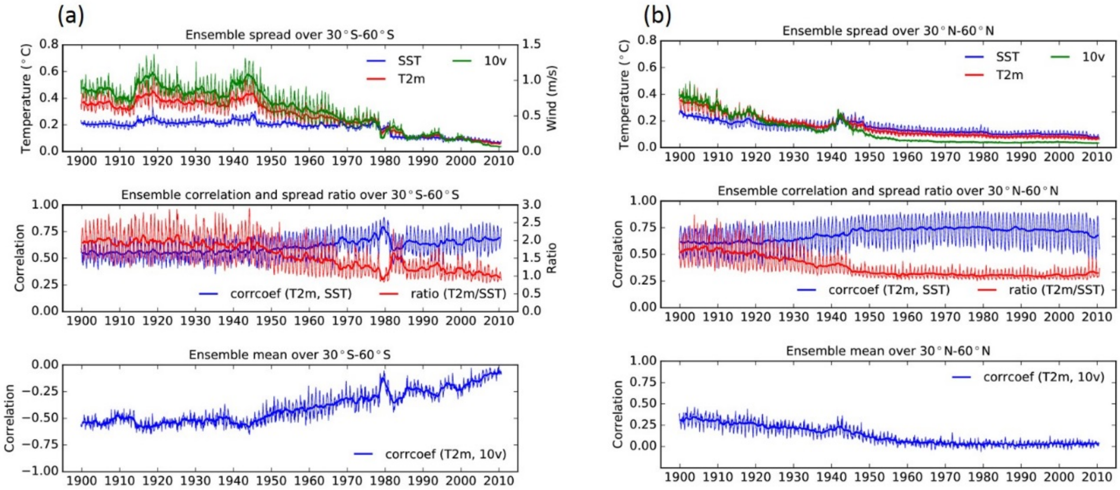

Figure 1: (Top) monthly ensemble spreads of SST, T2m and 10v (meridional 10-m wind speed), (middle) T2m-SST monthly ensemble spread ratio and ensemble correlation, and (bottom) T2m-10v monthly ensemble correlation, for 30°S-60°S average with land and sea-ice covered areas excluded, over 1900-2010. (b): same as (a), but for 30°N-60°N average. Thin lines are for the monthly values, while thick lines are for the moving 12month average. Note the high–frequency spikes presented in the monthly values as the seasonal variations.

We have also calculated increment biases from the CERA reanalysis which can be compared to the bias in the ORAS4 and ORAS5 systems. In CERA-20C no bias correction has been performed because the normal approach at ECMWF has been to perform a long runs first and use the increments from that to calculate an "offline bias corrections" which is then used for a 2^{nd} bias correction run. However an online bias correction scheme also exists and this has been shown to work effectively alone by the UK Met Office. It is important to note that the online bias correction scheme updates the bias corrections in a continuous basis and therefore can be implemented on the first run of the reanalysis and it therefore more practical for big reanalysis jobs such as CERA. Previously when low resolution ocean only reanalyses were performed the time an expense of 2 reanalysis runs was not that great but with both coupled reanalysis where the atmosphere is involved, and with high resolution ocean reanalyses (1/4 degree or higher) the online scheme has big advantages. We have therefore repeated part of the CERA-20C reanalysis with bias correction, both online and offline versions.

The offline bias correction is based on a monthly seasonal cycle of increments from 1989-2008 using the CERA-20C product. We have then repeated the CERA-20C reanalysis for the whole of 2009. Figures 1 and 2 below show the 2009 SST increments and the vertical profile of increments at the equator respectively. The control run shows the increments added in the original CERA run. The other figures are obtained using online bias correction alone, offline bias correction alone, and both the offline and online schemes together (as has previously been used in ORAS4, Balmaseda et al ()).

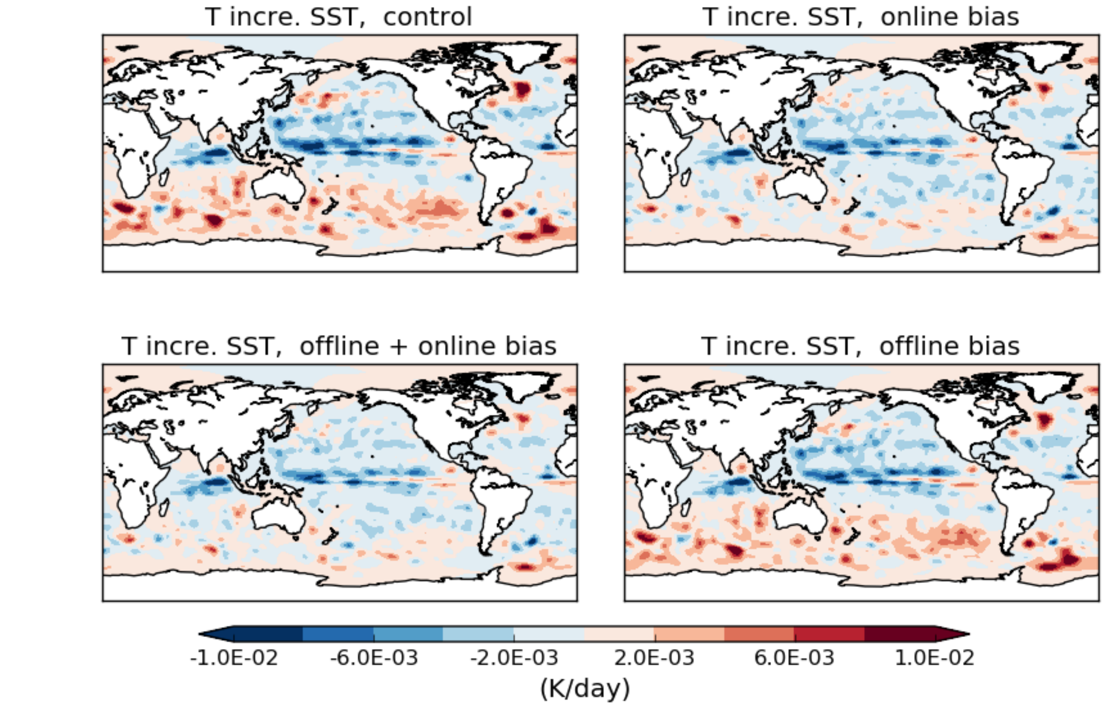

Figure 2: Sea surface temperature increments in CERA-20C coupled reanalysis over 2009. The control run is the original CERA-20C without bias corrections. The other experiments use offline bias correction based on 1989-2008 increments, an online bias correction, or both.

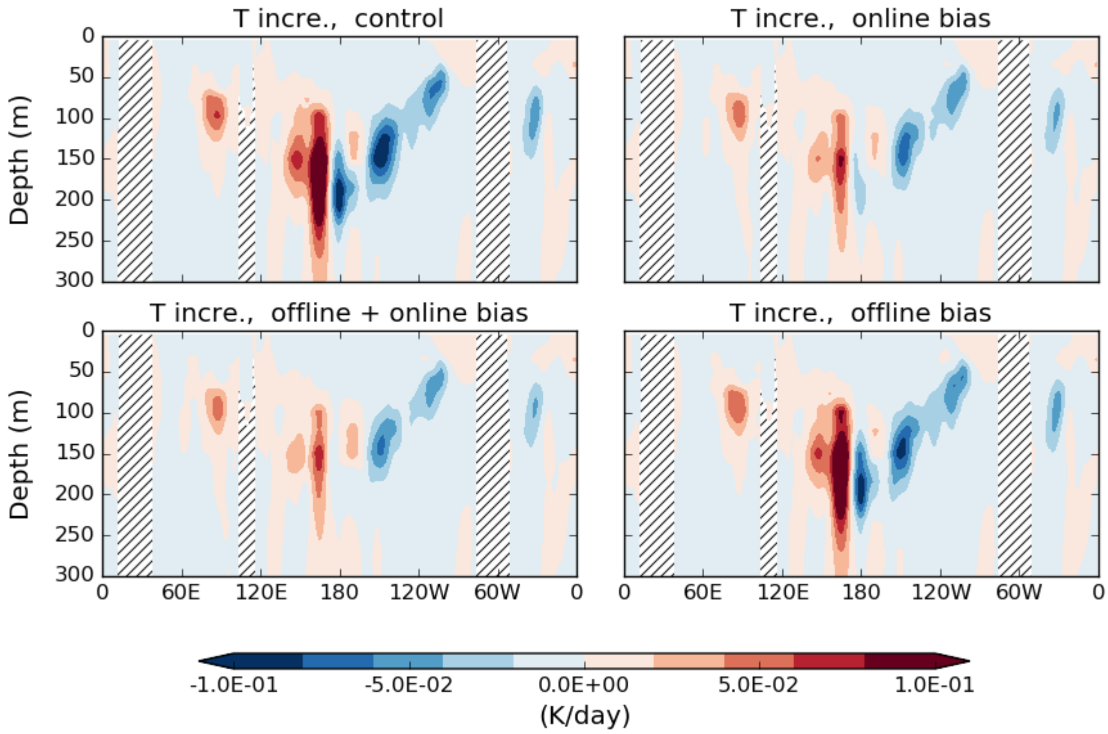

Figure 3: Vertical profiles of mean temperature increments in CERA-20C during 2009. The control run is the original CERA-20C without bias corrections. The other experiments use offline bias correction based on 1989-2008 increments, an online bias correction, or both.

It can be seen that the online scheme is actually more effective at performing the bias correction and reducing the persistent increments than the offline scheme. More analysis are being performed and some tuning.

List of publications/reports from the project with complete references

Feng, X., and K. Haines, 2017 Atmospheric response and feedback to sea surface temperatures in coupled and uncoupled ECMWF reanalyses, In preparation

Feng, X., K. Haines and E. de Boissason, 2017 Uncertainties of sea surface and air temperature in the CERA-20C coupled reanalysis ensemble, Submitted to QJRMS

Buizza R., et al. (2017) The EU-FP7 ERACLIM2 project contribution to advancing science and production of Earth-system climate reanalyses. Submitted to BAMS

D. P. Mulholland, K. Haines and M. A. Balmaseda. Improving seasonal forecasting through tropical ocean bias corrections. *Quarterly Journal of the Royal Meteorological Society*, QJRMS 142, 2797-2807, DOI:10.1002/qj.2869

D. P. Mulholland, P. Laloyaux, K. Haines and M. A. Balmaseda, 2015. Origin and impact of initialization shocks in coupled atmosphere-ocean forecasts. *Monthly Weather Review*, 143(11):4631-4644.

X. Feng, D. Mulholland and K. Haines, 2015. Strengths and weaknesses of coupled ocean/atmosphere data assimilation systems. ERA-CLIM2 Deliverable Report D2.8.

J. Waters, D. Mulholland, X. Feng, I. Mirouze and M. J. Martin, 2015. Estimating forecast error covariances for coupled models. ERA-CLIM2 Deliverable Report D2.9, available at http://www.era-clim.eu/ERA-CLIM2/Products/.

Summary of plans for the continuation of the project

We will assess whether the bias correction schemes shown in Figs 2,3 affect other aspects of the reanalysis, in particular associated with tropical instability waves, air-sea coupling, and any atmospheric differences, eg in precipitation. We may also be interested in performing some short bias correction experiments with CERA-SAT (perhaps just 10 days of analysis). A report will be prepared on this for the ERACLIM2 deliverable at the end of 2017 and we would expect to write this up as a paper.

If possible, we also hope to deploy the bias correction schemes in a short test run of hindcasts based on the CERA-20C reanalysis, with the intention that a gradual removal of the correction field, as in the work previously reported in Mulholland et al (2016). This work will be performed by our ERACLIM2 PDRA Dr Xiangbo Feng and proceed in close collaboration with Eric d'Boissason at ECMWF.