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	2016
Project Title:	Incorporating land-surface model uncertainty into the IFS
Computer Project Account:	spgbweis
Principal Investigator(s):	Antje Weisheimer[1,2] , Dave MacLeod[1] , Tim Palmer[1]
Affiliation:	[1]University of Oxford, [2]ECMWF
Name of ECMWF scientist(s) collaborating to the project (if applicable)	Florian Pappenberger Sarah-Jane Lock Gianpaolo Balsamo
Start date of the project:	1st Jan 2014
Expected end date:	31st Dec 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)	12,000,000	12,000,000	18,000,000	6,600,000
Data storage capacity	(Gbytes)	10,000		15,000	

Summary of project objectives
(10 lines max)

The land surface is a key source of seasonal predictability and it has been shown that land-atmosphere coupling contributes to the development of seasonal heatwaves. It is highly heterogeneous in space and time, which introduces uncertainty when the climate system is simulated on the typical grid resolution used in seasonal forecasting. Uncertain model parameter values are also a source of uncertainty in simulation.

The aim of this project is to improve the representation of uncertainty in the land surface component of the IFS (HTESSEL). This will be first explored using perturbed parameter experiments, and following this methods of stochastic perturbation will be designed and tested.

Cloke, H., Weisheimer, A. and Pappenberger, F. Representing uncertainty in land surface hydrology: fully coupled simulations with the ECMWF land surface scheme, 2011, ECMWF Workshop proceedings.

Palmer, T. N., Buizza, R., Doblas-Reyes, F., Jung, T., Leutbecher, M., Shutts, G. J.,Steinheimer M., & Weisheimer, A., 2009: Stochastic parametrization and model uncertainty. ECMWF Research Department Technical Memorandum n. 598.

Weisheimer, A., F. J. Doblas-Reyes, T. Jung, and T. N. Palmer (2011b), On the predictability of the extreme summer 2003 over Europe, Geophys. Res. Lett., 38, L05704, doi:10.1029/2010GL046455.

Summary of problems encountered (if any)
(20 lines max)

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

Stochastic perturbation of hydrology in seasonal runs

We have continued to develop experiments perturbing hydrological parameters (van Genuchten alpha and saturated hydraulic conductivity: see previous progress reports and MacLeod et al 2015 for further details).

As described in the progress report for 2015, we find that a perturbed parameter experiment (PP) gives improvements for soil moisture reliability, yet stochastic perturbation of these parameters does not have significant impact on the hindcasts.

Based on our previous stochastic parameter experiment (SP), we have developed independent stochastic parameter experiments (SPi) which perturbing the two parameters with two separate independent patterns, when previously both parameters were perturbed by the same pattern.

SPi Experiments have been run using different weightings of the scales making up the pattern:

- SPi-equal: 3 scales with equal weightings (0.32,0.32,0.32 small,medium,large)
- SPi-mirror: scale weighting mirroring SPPT (0.06,0.18,0.52)
- SPi-5th: only one scale makes up the pattern, which is the normally unused 5th scale, which has a decorrelation length scale of 2000km and a timescale of 366 days

The SPi-5th experiment was run in order to approximate as closely as possible the conditions of the perturbed parameter experiment.

Results show that perturbations significantly increase the spread of soil moisture, particularly in the tropics. However the spatial pattern of increase in spread is not consistent between the PP and SPi experiments (see figure 1a-e). SPi-5th impacts the spread in the boreal forest, whilst the PP experiment does not.

Soil temperature and 2m air temperature spread is also impacted by the perturbation, via latent and sensible heat fluxes. Figure 1f-i shows 2m air temperature spread for the experiments. Increasing the temporal/spatial correlation of the perturbing SPi pattern generally increases the spread, though there is minimal difference between SPi-mirror and SPi-5th (comparing 1c/d or 1h/i).

However the comparison between SPi-5th and the PP experiment reveals significant difference in the impact on soil temperature spread, despite the impact on soil moisture spread being relatively consistent between the experiments. PP shows minimal increase in spread, limited to Africa and central, whilst the highest increase in spread in SPi occurs in South America. This is an unexpected result for which we currently do not have a good explanation.

Previously the PP experiment has demonstrated improved forecast reliability for soil moisture quintile events. Some improvement is gained for the SPi experiments, mostly with SPi-5th (see figure 2), however the improvement is not as large as for PP.

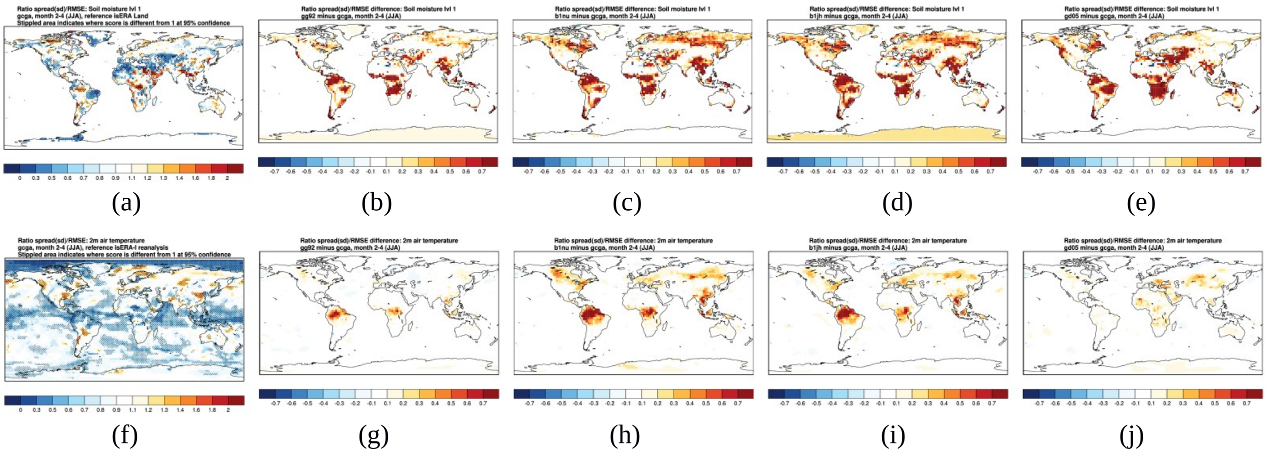

Figure 1: impact on JJA spread in coupled seasonal perturbation experiments. Soil moisture in the top layer is shown in figures a-e, 2m air temperature in f-i. In each case the left hand figure shows the control spread/error, then the following three correspond to SPi-equal, SPi-mirror, Spi-5th and PP.

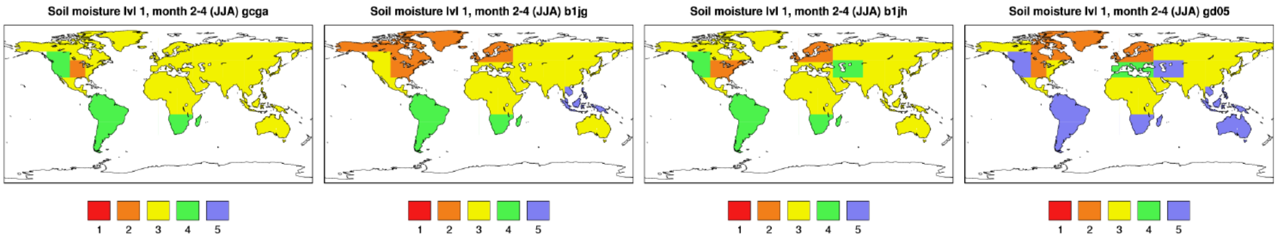

Figure 2: Reliability categories for upper quintile JJA soil moisture. Left-right: control, SPi-equal, SPi-mirror and Spi-5th. For details of reliability categories see Weisheimer & Palmer 2014).

Impact of hydrological parameter uncertainty on soil moisture memory

Using the uncoupled land surface model HTESSEL, we have explored the impact of hydrological parameter uncertainty on soil moisture memory, and the work has been accepted for publication in Hydrology and Earth System Sciences (MacLeod et al 2016).

The persistence of soil moisture is an important aspect of land-atmosphere interactions however estimates are uncertain. No previous work has addressed the question of how uncertainty in hydrological parameters might impact the estimated on soil moisture memory.

We address this question by performing a global sensitivity analysis with HTESSEL forced with ERA-INTERIM, using combinations of initial dates, forcing and parameters to explore the relationship between ensemble spread and lead time. The parameters considered are those used in the coupled experiments above.

We find a significant dependency of estimates of soil moisture memory and its uncertainty on hydrological parameter, and further a dependence on start date (see figure 3). Our results suggest that operational seasonal forecasting models using deterministic hydraulic parameter values are likely to display a narrower range of memory than exists in reality. Explicitly incorporating hydraulic parameter uncertainty in models may then give improvements in forecast skill and reliability, which supports the work of MacLeod, 2015 and above which demonstrating this in the coupled model.

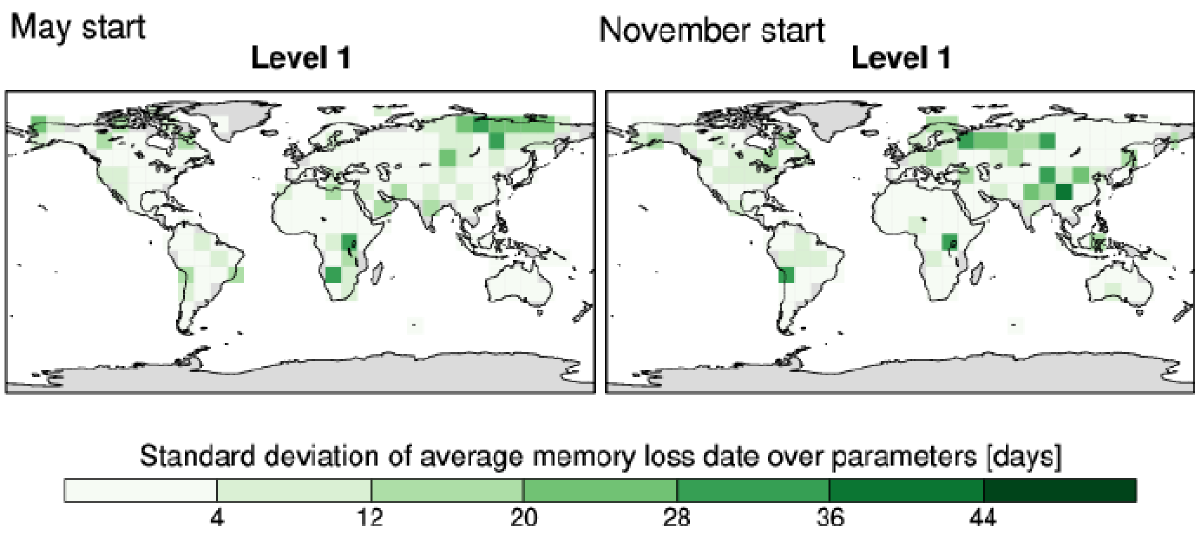

Figure 3: Standard deviation in the memory loss date across parameters, for May and November start dates. Darker green areas indicate regions where the soil moisture memory is particularly sensitive to the uncertainty in hydrological parameters.

Stochastic perturbation of land-atmosphere coupling

From April–June 2016 David MacLeod has been temporarily working at ECMWF in order to investigate the impact of stochastic perturbation of land-atmosphere coupling. This work has been in conjunction with Sarah-Jane Lock and Gianpaolo Balsamo, and involves the application of the new Stochastically Perturbed Parameters (SPP) scheme to the Lambda parameter, which controls the thermal coupling between the skin temperature and surface. There is uncertainty in the parameter, which has a large influence on the diurnal temperature cycle at the surface. Initial experiments with the uncoupled model reveal that perturbation to the parameter gives some impact on the timing of the daily maximum temperature (figure 4) and some a small impact on the mean state. Work is ongoing.

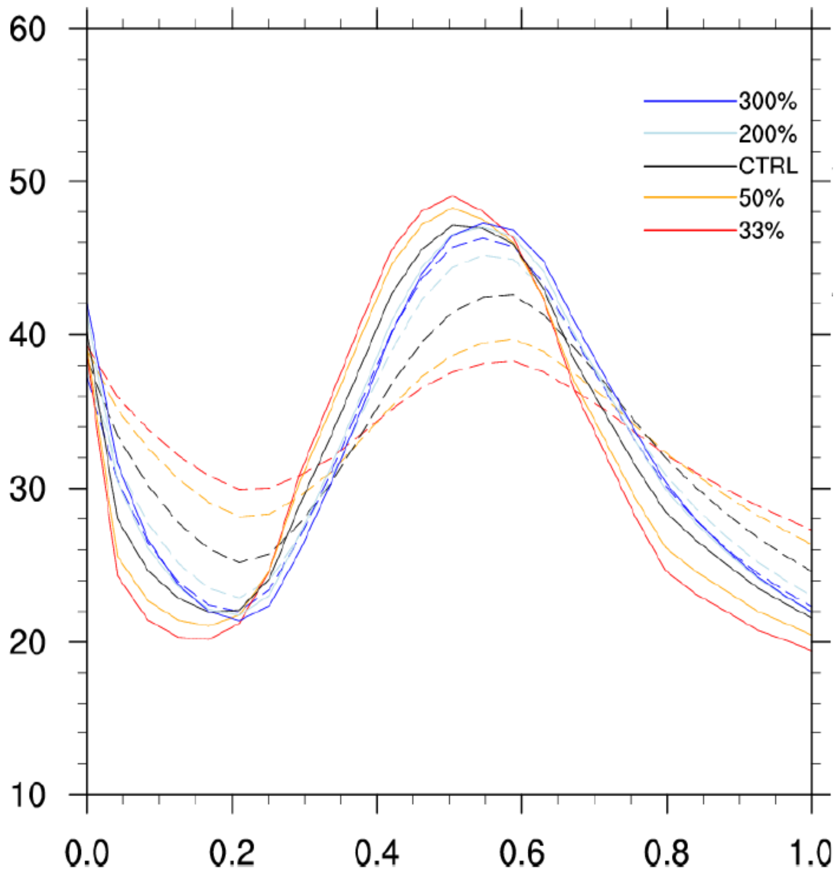

Figure 4: Daily skin (solid) and soil (dash) temperature for one simulation day for one gridpoint. Different coloured lines indicate experiments with perturbation added to the lambda land-atmosphere coupling parameters. Perturbation of this parameter influences both the amplitude and the timing of the daily maxima & minima.

References:

Weisheimer, T. N. Palmer, 2014, On the Reliability of Seasonal Climate Forecasts, J. R. Soc. Interface 2014 11 20131162; DOI: 10.1098/rsif.2013.1162.

Wood, A.W., Lettenmaier, D.P., 2006. A test bed for new seasonal hydrologic forecasting approaches in the western United States. Bull. Am. Meteorol. Soc. 87 (12), 1699–1712

List of publications/reports from the project with complete references

MacLeod, D. A., Cloke, H. L., Pappenberger, F. and Weisheimer, A. (2016), Improved seasonal prediction of the hot summer of 2003 over Europe through better representation of uncertainty in the land surface. Q.J.R. Meteorol. Soc., 142: 79–90. doi: 10.1002/qj.2631

MacLeod DA, Cloke HL, Pappenberger F and Weisheimer A, 2016 Evaluating uncertainty in estimates of soil moisture memory with a reverse ensemble approach, HESS (accepted, see http://www.hydrol-earth-syst-sci-discuss.net/hess-2016-28/ for discussion paper).

Summary of plans for the continuation of the project

(10 lines max)

For the remaining six months of the project, work will continue to look at experiments perturbing land-atmosphere coupling, and we plan to either write this up into either a journal article or a technical memorandum.