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:	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)	
Start date of the project:	1st Jan 2014
Expected end date:	31st 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)			8,000,000	4,350,000
Data storage capacity	(Gbytes)			10,000	

Summary of project objectives

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)

None

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

Perturbed parameter hindcasts with IFS/NEMO in seasonal forecasting mode have been produced, with a 25 member ensemble where two key land surface parameters have been perturbed. The parameters perturbed are the Van-Genuchten alpha parameter, and the saturated soil conductivity. These are soil-type dependent, and are used in the equations for hydraulic conductivity in the soil.

The hindcasts follow a standard setup, initialised on May for the period 1981-2012. The control experiment used is a 25 member ensemble produced by System 4 (where members are different due to initial perturbations and atmospheric stochastic physics – these are also present in the experimental hindcasts).

Experiments where the tendencies from the HTESSEL land surface parameterization are perturbed stochastically have also been carried out. These were based on the SPPT scheme for the atmosphere, where the tendencies to temperature, humidity and wind fields from the atmospheric physics parameterizations are perturbed, using an autoregressive AR1 process with 3 scales (the spectral pattern generator, SPG). The scales of the SPG for SPPT are chosen to represent typical short, medium and long temporal/spatial scales, with more weight given to the short/small scales.

For the stochastic perturbation to the HTESSEL tendencies, the fields perturbed were the soil temperature and wetness fields, for all four vertical soil levels. Three stochastic experiments were carried out, which differ in the relative weight given to each of the SPG scales

1. 'SPPT': Same standard deviation as SPPT default scales (0.52/0.18/0.06-short/medium/long)
2. 'Equal': Equal weight given to each of the scales (0.32/0.32/0.32)

3. ‘Mirror’: More weight given to the long time/space scale (0.06/0.18/0.52)

The rationale for modifying these scales comes from a consideration that typical anomalies in the land surface tend to have a much longer lifetime than those in the atmosphere (for soil moisture particularly). In each case the weights are chosen such that the combined standard deviation from the 3 scales is equal.

Analysis of experiments has shown little effect of the perturbation on the mean state, which suggests that it is possible to perturb the land surface whilst keeping the model climate intact. Further analysis of the skill of the perturbed parameter experiments has shown potential improvement in the model representation of heatwaves over Europe, see figure 1. With the perturbation included, the probability given to a significantly warm event is increased. Note that this is one year, and skill in warm air temperature events measured across the hindcast is not seen. However there is *a priori* reason to expect this - land-atmosphere coupling is not constant and for Europe generally it has a much larger impact in some years than others. This suggests that any improvement in the prediction of atmospheric variables from improved uncertainty representation in the land surface will also not equal across the hindcast.

This improvement in simulation of the 2003 heat wave is not seen for the stochastic experiments. Further analysis of atmospheric variables suggests that the stochastic experiments do not perform significantly better than the control. Analysing the top-level soil temperature field has shown that these create a significantly over dispersed ensemble, particularly over Africa. This is shown in the spread/error diagnostic in figure 2. The reason that this over dispersion is centred over Africa is unknown, as is the reason for the dispersion being largest for the ‘mirror’ scale. However, it does suggest that to perturb the soil temperature field in this way is not appropriate.

Analysis of further variables has shown that the perturbed parameter experiment has significantly improved the skill and spread of latent heat flux globally, across the hindcast (figure 3). This is seen for all metrics considered and up to four months from initialisation. This is very promising, however more investigation and experiment is needed, since no concurrent improvement in the forecast skill for the soil temperature and moisture is observed.

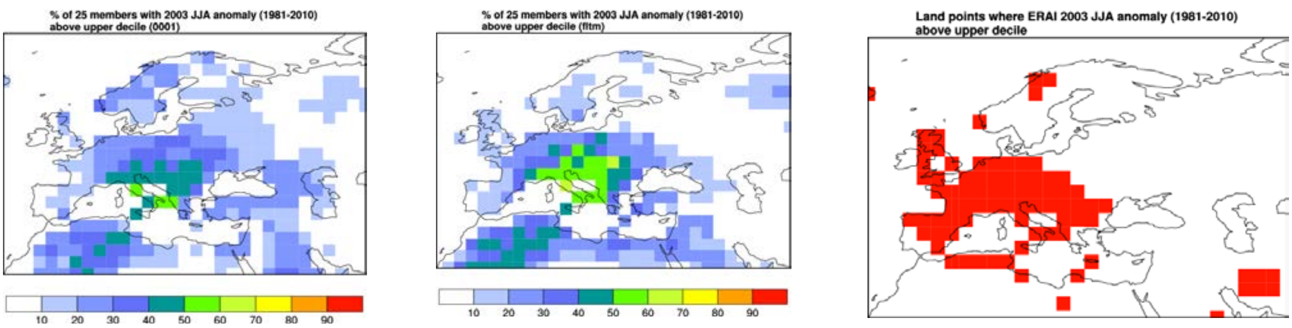

Figure 1: Improved forecast of 2003 European heatwave with perturbed land surface parameters. Proportion of ensemble members indicating JJA lying in the highest decile for the control (left) and the perturbed land surface parameter experiment (central). Also shown are the land points where the 2003 summer was in the highest decile in ERA-Interim.

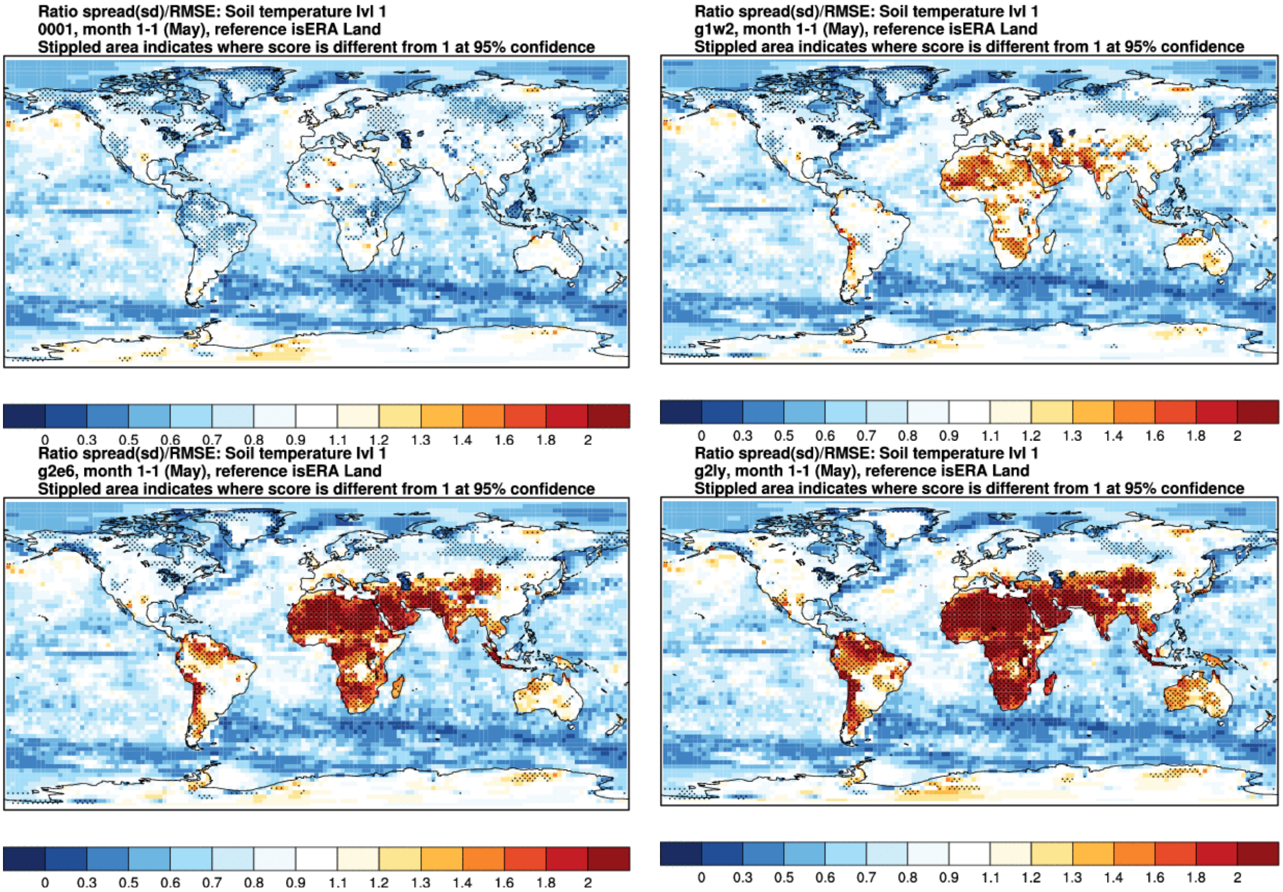

Figure 2: Ratio of spread/RMSE for top level soil temperature, for control (top left), and stochastic experiments ('SPPT', top right, 'Equal' bottom left and 'Mirror' bottom right).

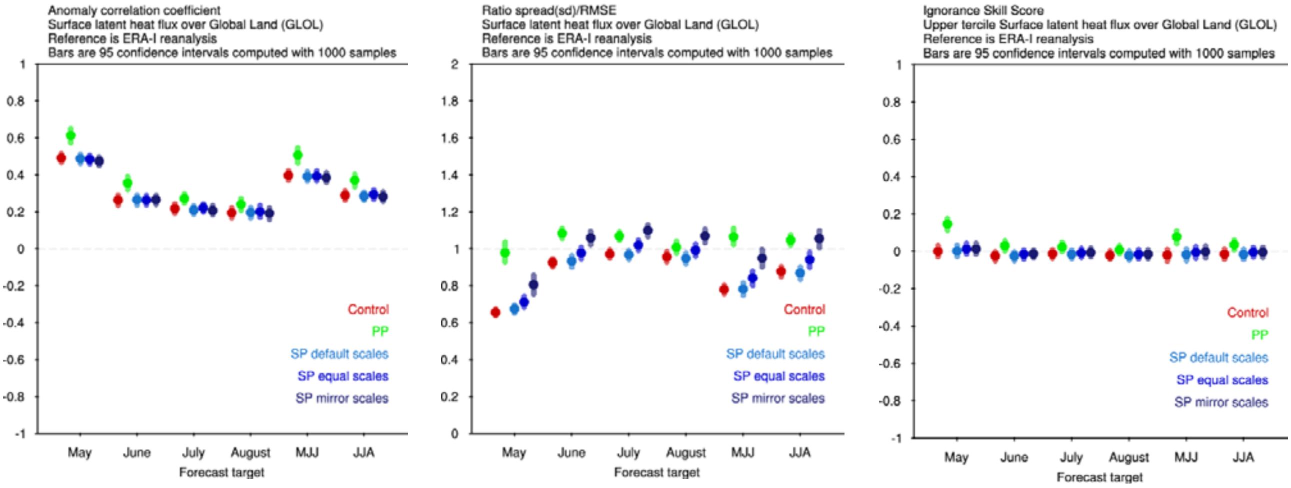

Figure 3: Scores for latent heat flux across global land points, measured across the hindcast 1981-2012, for all experiments. Scores shown are the anomaly correlation coefficient, the ratio of spread to error and the ignorance skill score for upper tercile events. ERA-Interim is used as the reference.

List of publications/reports from the project with complete references

None

Summary of plans for the continuation of the project

Literature and discussion with land surface modellers has led us to consider that land surface uncertainty lies primarily in the representation of soil moisture, particularly in the parameter values used in the soil moisture equations. For this reason our planned upcoming experiments are:

1. Stochastically perturbed tendency experiments (similar to those already carried out), with only the moisture field perturbed (no perturbation to the temperature field).
2. Stochastic perturbation of land surface parameters (i.e. using non-stationary parameters throughout the simulation).

Along with these experiments, we will continue analysis of current experiments. We are also investigating the use of an ultra high resolution (30 arcsecond) land surface parameter dataset to estimate spatial heterogeneity of the surface, and potentially use this to weight regions with more or less perturbation.