Enhancing the Ensemble Spread of Land Surface Variables

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CopERnIcus climate change Service Evolution - CERISE

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Introduction

In recent work at ECMWF, it has been shown that utilising flow-dependent background information from the Ensemble of Data Assimilations (EDA) the Land Data Assimilation System (LDAS) can improve atmospheric forecasts of 2-meter temperature and relative humidity. However, the EDA can suffer from under-dispersed surface fields, potentially limiting the effectiveness of its use within the LDAS. In the current EDA identical surface climatological ancillary fields are used across all members of the ensemble. To increase ensemble spread at the surface we have tested the perturbation of two of the land parameters provided in the climatological fields, namely vegetation fraction and leaf area index. The perturbations for these fields are generated following the Stochastically Perturbed Parameter (SPP) methodology, adding spatiotemporally correlated noise to the distinct ensemble member ancillary files. In Figure 1 we show an example snapshot of the noise added to these fields.

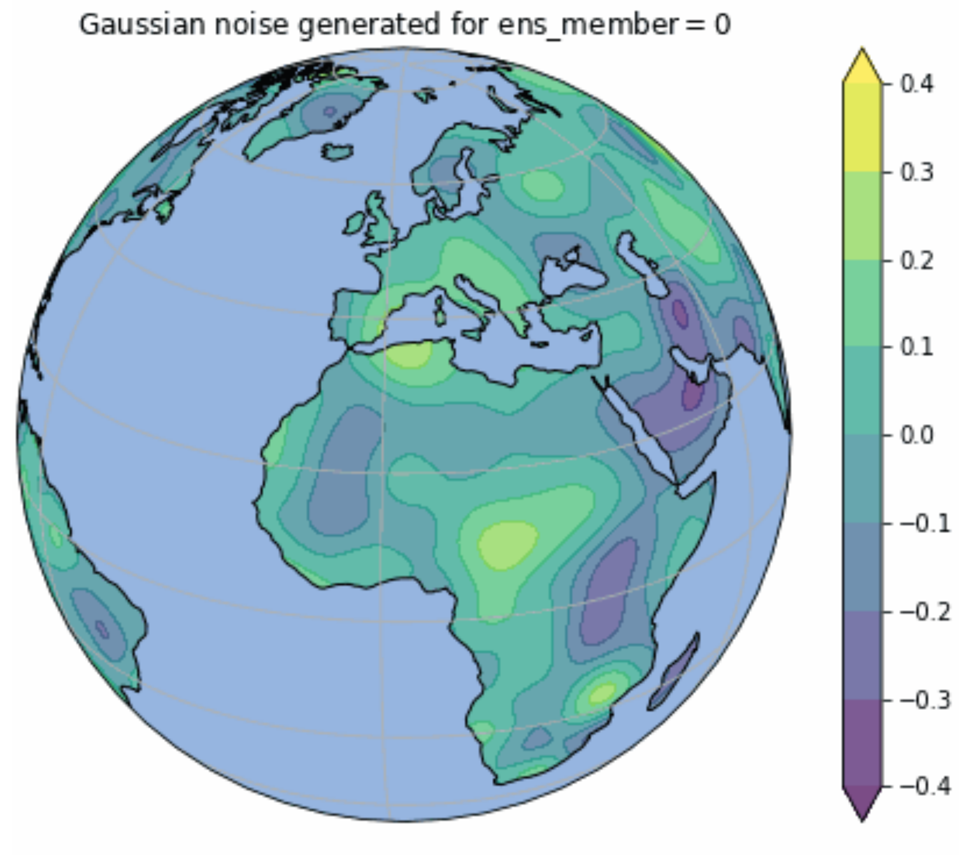

Figure 1: Example spatiotemporal noise added to vegetation fraction and leaf area index climate fields

1. Flow-Dependent Background Error

In Cycle 50R1 we have included flow-dependent information from the EDA in the Land Data Assimilation System for the background errors of Soil Moisture, Soil Temperature and Snow Temperature. This has improved forecast scores for surface temperature and humidity. In Figure 2 we show the change in RMSE for forecasts using the flow-dependent information (EDA B) versus the control forecast without these updates (CTRL), we can see improvements in forecast scores near the surface for all forecast lead times (up to 5-days shown). These improvements start at the surface but then propagate higher into the atmosphere for day 2/3. By further improving the characterisation of ensemble spread at the surface we hope that further improvements to forecast scores can be found.

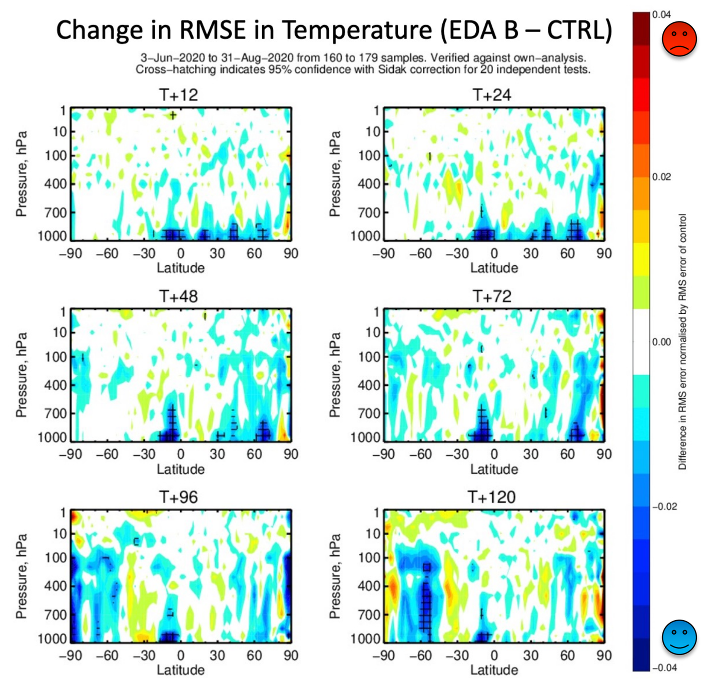

Figure 2: Change in RMSE of atmospheric temperature forecasts when using ensemble information for the specification of background errors in the LDAS

2. Improving EDA Spread at the Surface

In the introduction we described how perturbations have been added to the climate fields of leaf-area index and vegetation fraction across the Ensemble of Data Assimilations, taking inspiration from Draper et al. (2021). In Figure 3 we show how these perturbations look for a time-series of leaf-area index at a single grid cell. The control EDA time-series is in orange (*i.e.* the unperturbed values), while the corresponding time-series for each of the 10 perturbed EDA members are shown in blue.

We first ran an "offline" land experiment with these perturbations (*i.e.* no atmospheric coupling). Figure 4 shows the increase in spread compared to the control with the addition of the leaf-area index and vegetation fraction perturbations. We find good increases in spread of between 20-40% when incorporating the surface ancillary perturbations.

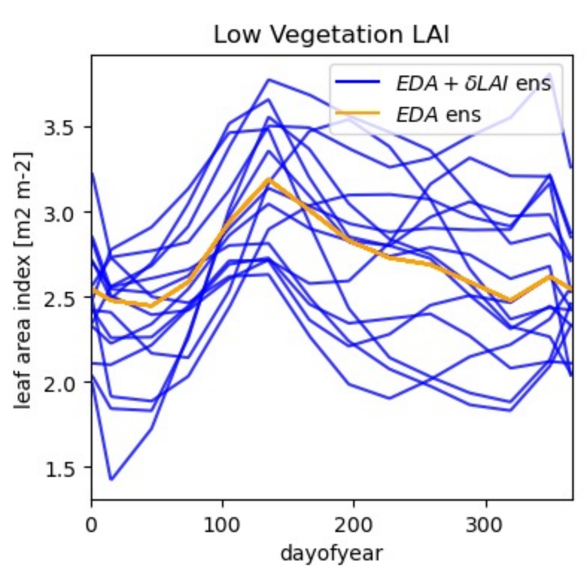

Figure 3: Example leaf-area index perturbations at a single grid cell

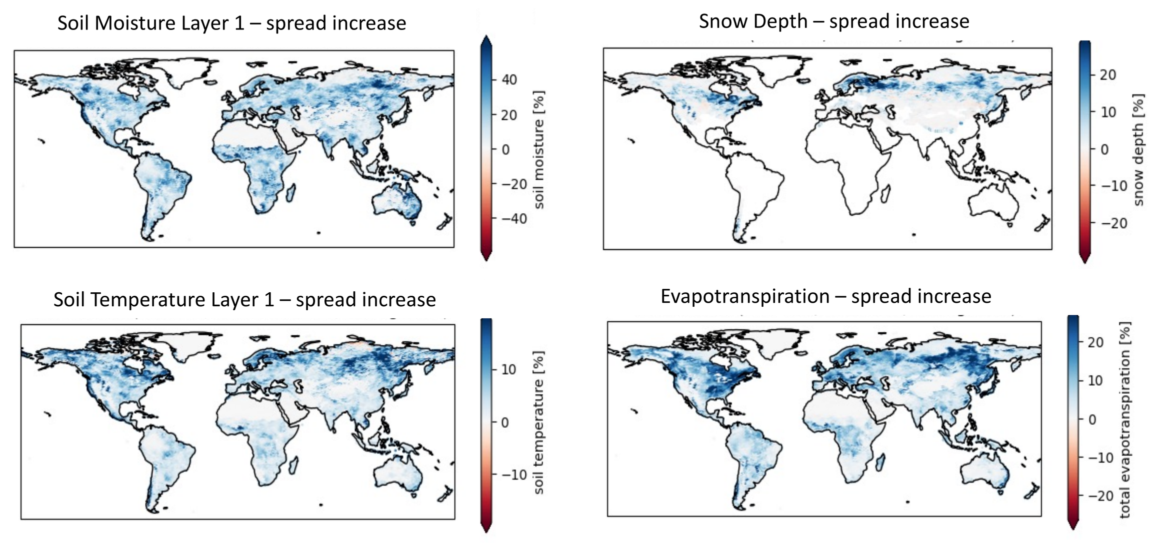

Figure 4: Increase in standard deviation for different surface variables when using perturbations in offline land model experiments

3. Results for Coupled Experiments

After promising results in "offline" experiments we tested the leaf-area index and vegetation fraction perturbations in reduced resolution coupled EDA experiments where feedback with the atmosphere was also present. In Figure 5 we show the globally averaged spread for the different model levels of soil moisture and soil temperature. Whereas for the initial "offline" tests we allowed for a 3-year model spin-up before analysing the spread this was not possible in the more computationally demanding coupled experiments. We can therefore see a similar initial value in spread between the control "EDA" and the perturbation experiment "EDA-SPP", then (after an initial period of spin up) the spread for all parameters is greater in the experiment containing the SPP perturbations. This bodes well for future Land Data Assimilation activities and better specification of surface uncertainties. It is now under investigation how best to include these perturbations in a future operational cycle.

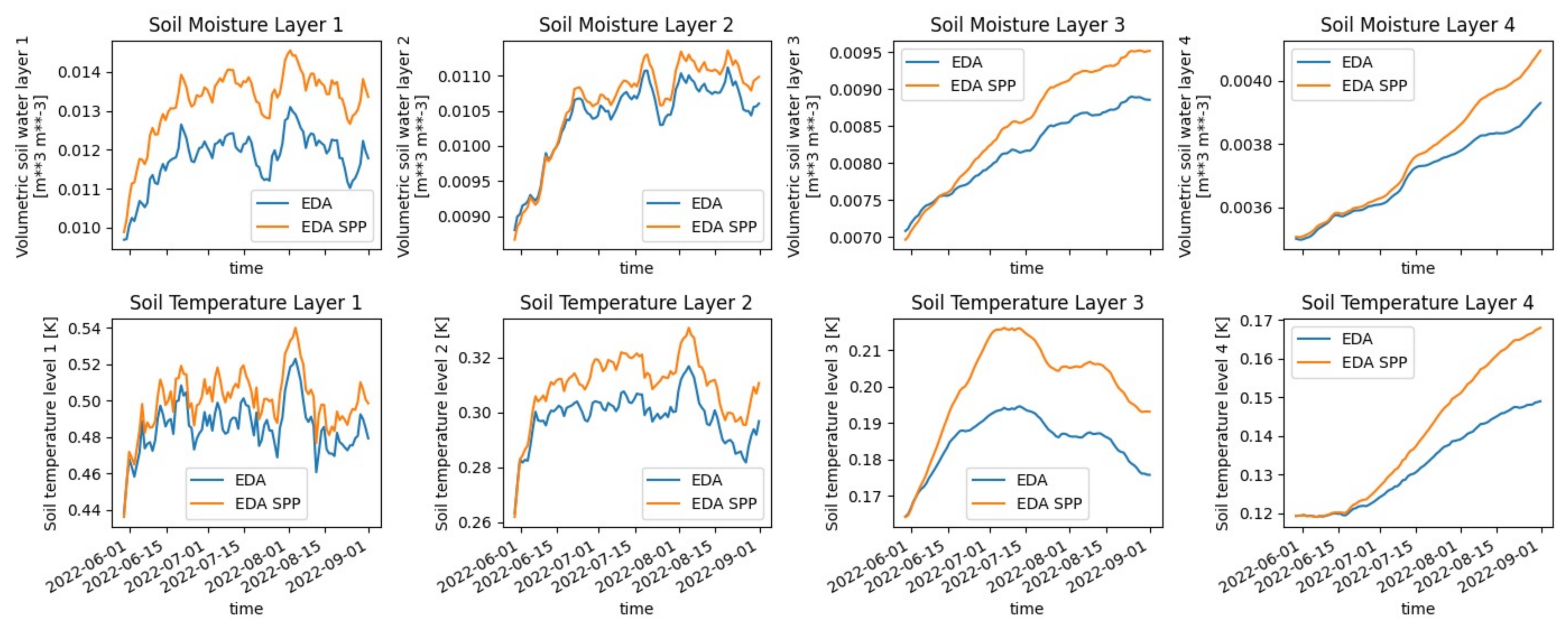

Figure 5: Change in ensemble standard deviation of soil moisture and soil temperature when perturbing vegetation parameters

References

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Draper, C. S., 2021: Accounting for Land Model Uncertainty in Numerical Weather Prediction Ensemble Systems: Toward Ensemble-Based Coupled Land–Atmosphere Data Assimilation. J. Hydrometeor., 22, 2089–2104, https://doi.org/10.1175/JHM-D-21-0016.1.

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