The use of HydEOMEx data to validate a land surface model over the UK

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1. Introduction

Satellite derived observations of soil moisture are a potentially valuable tool for the land surface modelling community to benchmark and validate their models against. These data have the scope to help improve to weather forecasting, flood modelling and climate prediction by improving the underlying models. A barrier to this however can be the availability and usability of Earth Observation (EO) data sets which often require expert knowledge to be used effectively.

One solution to this problem is the use of portals, such as the HydEOMex demonstrator portal, which can provide access to a diverse range of EO data, tailored for a specific application. This use-case looks at the ability of the HydEOMex portal to provide soil moisture information for validating the Joint UK Land Environment Simulator (JULES), the land surface scheme of the Met Office.

2. Data and methodology

2.1. Observational data

The HydEOMEx portal was used to manually download satellite-derived soil moisture data from the European Space Agency's Climate Change Initiative (ESA CCI) Compressed dataset (hereafter referred to as Essential Climate Variable soil moisture, ECV SM), using the NetcdfSubset service[1]. The data are expressed as a percentage of saturation soil moisture, covering the UK (British National Grid) at 1 km spatial resolution and covering the period 2010-2014 at a daily timestep. See Figure 1 for a screenshot of the download page, showing the spatial and temporal coverage. Here, only 3 years were used (2010-2012), to match the period covered by the land surface model (see below for details). Due to limitations in the amount of data that can be downloaded at once, the 3 years were downloaded individually and subsequently combined.

The data contain a lot of missing values; 3 days were completely missing, and on all other days certain (and different) pixels across the domain were missing. Figure 2 shows the percentage of days where each pixel contains actual days, for 4 seasons: December-February (DJF), March-May (MAM), June-August (JJA) and September-November (SON). Immediately obvious is the fact that the 4 seasons are almost identical, implying that for any given pixel data were missing throughout the year. The southern half of England, Wales and southern Ireland have the highest number of days with actual data, reaching 70-80% in places. The exception to this is London where the percentage of days with actual data drops to 30%, but this is presumably just the effect of the capital's increased urban coverage. Further north many more data are missing, and over Scotland, in particular, only 30-40% of the days contain actual data. In all subsequent analysis, missing values were ignored.

1 Available from http://filkravm.cloudapp.net:8080/thredds/hydeomexcompressed.html

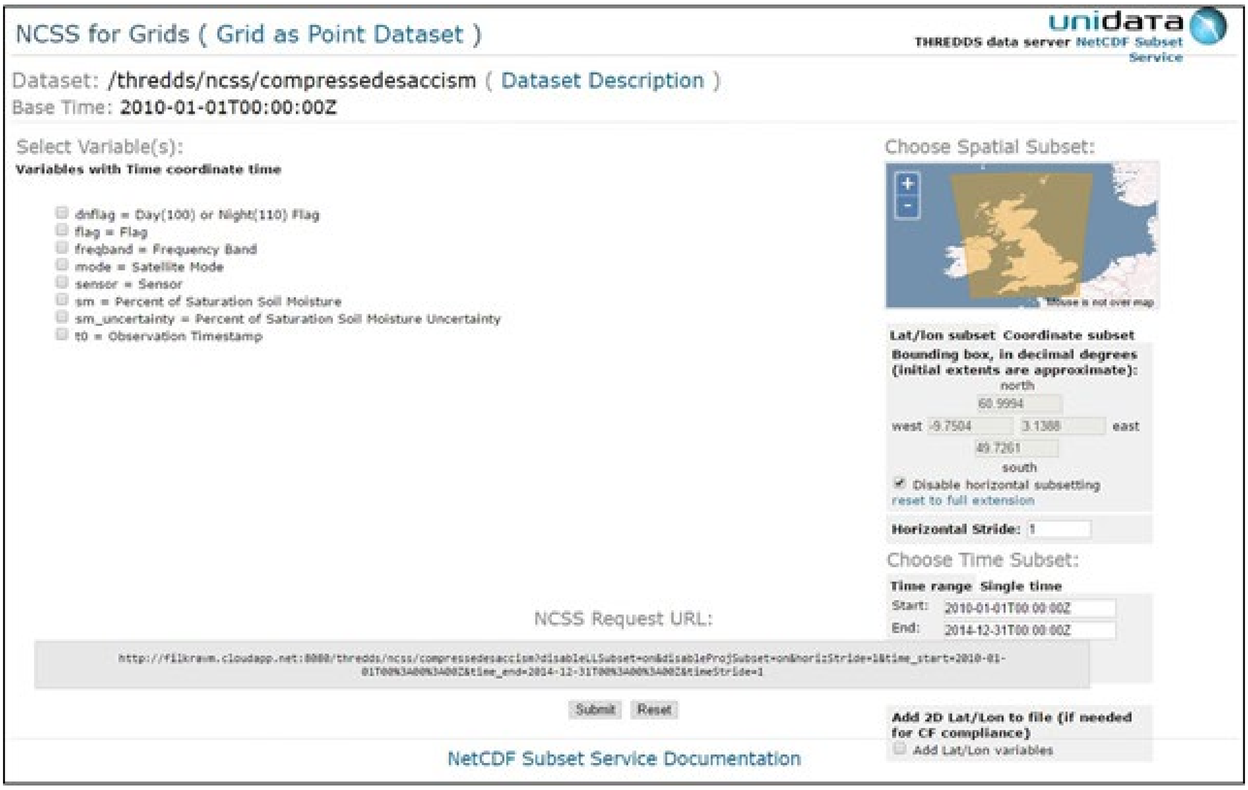

Figure 1 *Screenshot of the NetcdfSubset service, from the HydEOMEx portal*

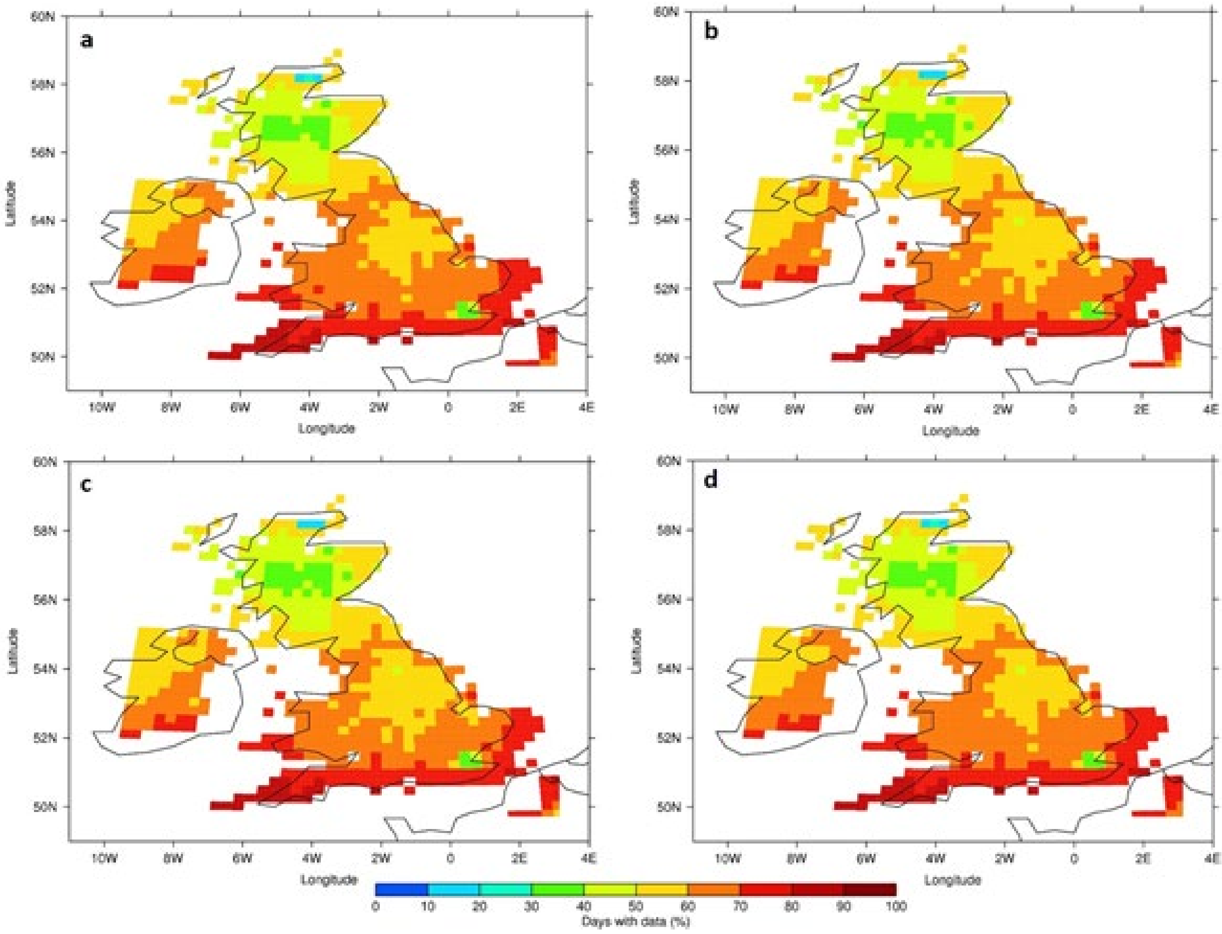

Figure 2 *Percentage of days with actual data from ECV SM, for various seasons: a) DJF, b) MAM, c) JJA, d) SON*

2.2. Land surface model

The land surface model used here was the Joint UK Land Environment Simulator (JULES), version 4.3. This model evolved from the Met Office Surface Exchange Scheme (MOSES), and can be run either off-line (i.e. stand-alone) or coupled to the Met Office Unified Model (UM). Within JULES, various land surface processes (e.g. surface energy balance, hydrological cycle, carbon cycle, dynamic vegetation, etc) are allowed to interact, with a view to providing a framework for assessing the impact of changing a certain process on the entire ecosystem. For full details on JULES, see Best et al. (2011) and Clark et al. (2011).

2.3. Methodology

Here, JULES was run off-line, at 0.5° spatial resolution over the UK (see Figure 3 for the spatial domain), from 1 January 2010 until 31 December 2012. A basic control simulation was run, using the TOPMODEL hydrology scheme and with both river routing and dynamic vegetation turned off (to increase computational speed). The control simulation was forced with driving data from WATCH-Forcing-Data-ERA-Interim[2] (WFDEI), which consists of 6 meteorological variables (surface downward shortwave radiation, surface downward longwave radiation, surface pressure, surface temperature, wind speed and specific humidity) at a 3 hourly timestep. A further two variables, rainfall and snowfall rate, are included within WFDEI but stem from different sources. The control simulation was run twice, once with rainfall and snowfall rate from the Climate Research Unit[3] and one with these two variables from the Global Precipitation Climatology Centre[4] ; the purpose of these two simulations (hereafter referred to as JULES CRU and JULES GPCC respectively) was to assess the impact of different driving data on the model's simulated soil moisture.

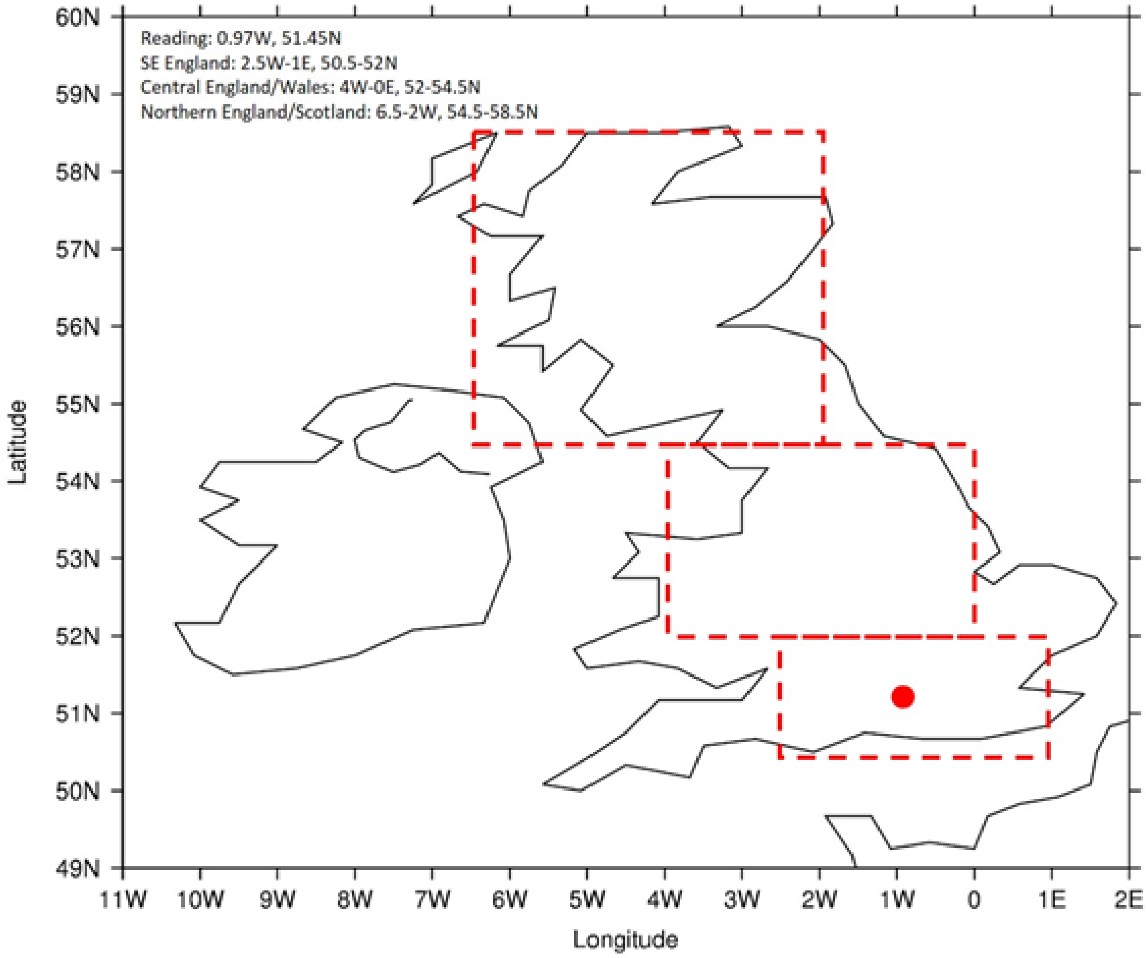

Figure 3 *Domain used to run JULES and compare its output with ECV SM. SM was either spatially averaged over entire domain, or over subdomains (marked in red), or for a single point (red dot)*

2 http://www.eu-watch.org/data_availability

3 http://www.cru.uea.ac.uk/

4 https://www.dwd.de/EN/ourservices/gpcc/gpcc.html

Once both runs had been completed, the simulated daily soil moisture was compared to ECV SM, spatially averaged over the entire UK and a number of smaller subdomains (northern England and Scotland, central England and Wales, south-east England), as well as for a single point, the town of Reading (see Figure 3). To show the spatial distribution of SM across the UK, the data were also plotted as a climatological map, for the 4 different seasons.

3. Results

Figure 4 shows the daily timeseries of soil moisture for the UK as a whole, the various subdomains and Reading. Immediately obvious is the fact that JULES CRU and JULES GPCC are virtually identical at this spatial resolution (within a correlation coefficient of 0.99), and are indistinguishable on the timeseries. The interannual variability in both the model runs and observations is most obvious when averaged across the UK as a whole (Figure 4a), but is still evident in other subdomains and Reading. All domains show higher soil moisture (and much higher variability) in ECV SM compared to the two JULES runs, suggesting that the model is underestimating both absolute values and variability. Nevertheless, the annual cycle of soil moisture across the 3 years is clearly shown in all domains, and the annual cycle in the model runs matches ECV SM reasonably well. The correlation coefficient of soil moisture between ECV SM and either of the model runs is 0.57, 0.47, 0.53, 0.36 and 0.45 for the UK, south-east England, central England, northern England and Reading respectively, suggesting that the model reproduces the annual cycle best when averaged over a larger area. This is to be expected, given that greater spatial averaging smooths out noise and therefore increases the larger scale signal, resulting in a better match.

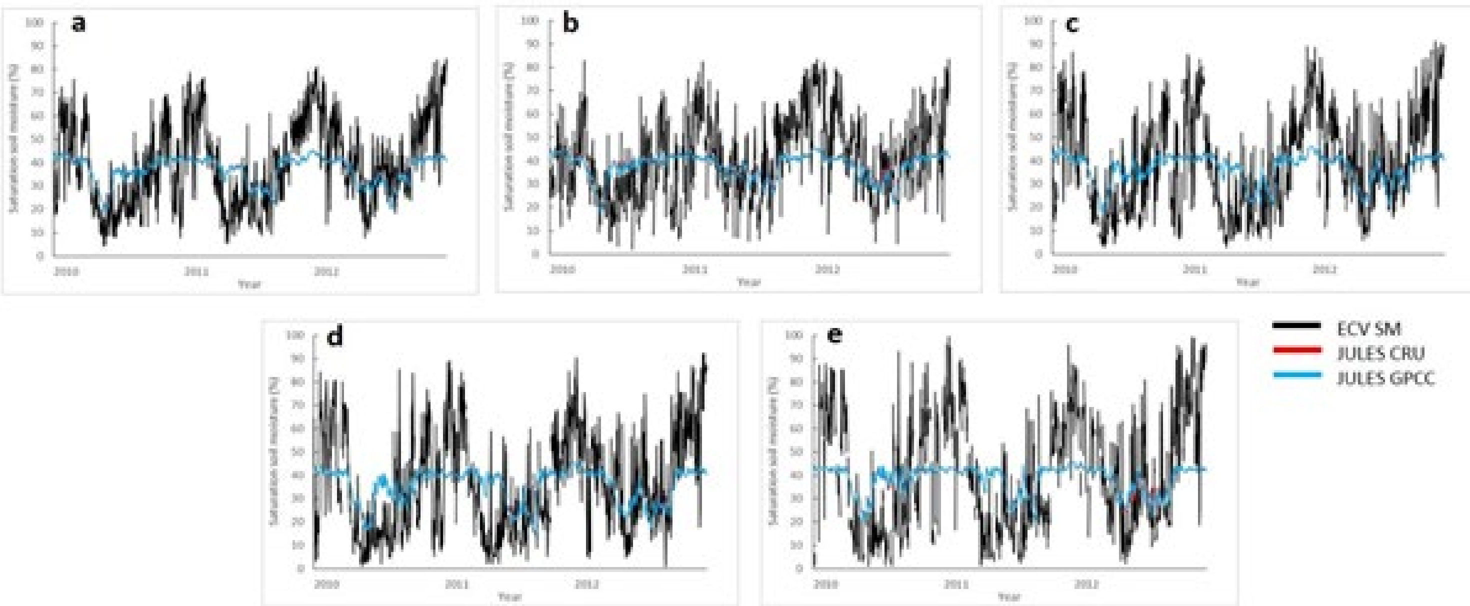

Figure 4 *Timeseries of daily soil moisture from the ECV SM and the two JULES runs, spatially averaged over various domains: a) UK as a whole, b) northern England and Scotland, c) central England and Wales, d) south-east England, e) Reading*

Spatially, mean soil moisture (averaged over the 3 years) from ECV SM and the two JULES runs is shown in Figure 5, for two example seasons (DJF and JJA). In this figure, soil moisture is plotted at its original spatial resolution i.e. 1 km in ECV SM and the coarser resolution 0.5° (~ 50 km) in the two model runs. In ECV SM, as expected there is higher soil moisture across the majority of the UK during DJF (top panel), with only Scotland (and, to a lesser extent, eastern England) displaying any substantial soil moisture during JJA (bottom panel). Again, JULES is underestimating soil moisture in both seasons, however the spatial patterns are roughly correct relative to ECV SM. For example, JULES correctly identifies higher mean soil moisture over northern England and Scotland during JJA (bottom panel).

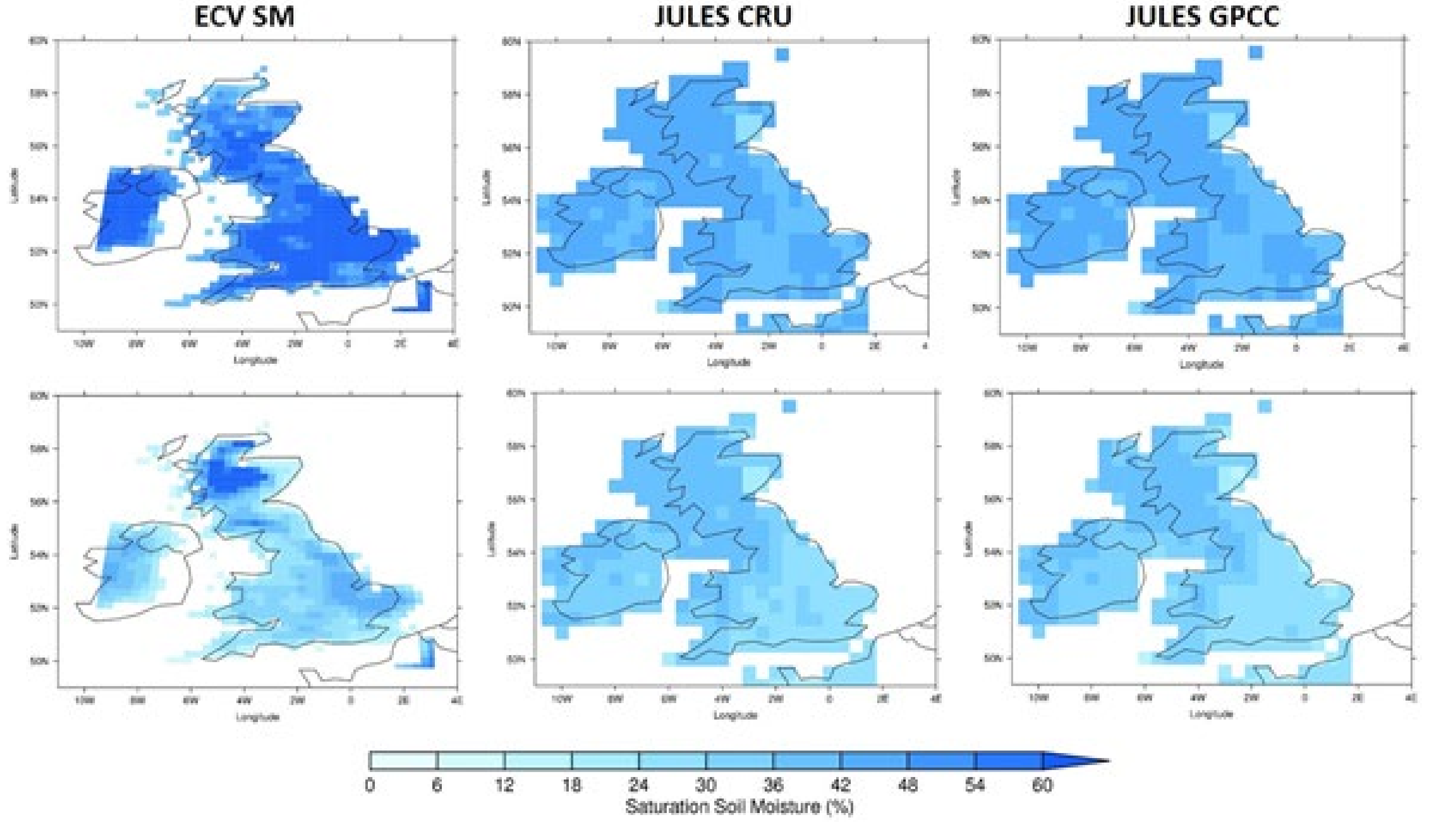

Figure 5 *Mean daily soil moisture from ECV SM and the two JULES runs, temporally averaged over the 3 years, for two example seasons: top panels show DJF, bottom panels show JJA*

The differences between JULES CRU and ECV SM are more clearly shown in Figure 6, where ECV SM was regridded to the model's spatial resolution and then compared. Most noticeable is the change in sign of the differences throughout the year. During the winter months of DJF, the model is underestimating soil moisture relative to ECV SM over almost all of the UK, showing a difference of up to 40% in places (Figure 6a). During MAM, these differences have decreased everywhere except Scotland, where JULES is still largely underestimating soil moisture. Elsewhere, the model appears to be underestimating by a small amount (<10%), and is actually overestimating (by up to ~10%) over southern England, parts of Wales and eastern Ireland (Figure 6b). This pattern continues and is strengthened the summer months of JJA, when JULES is overestimating soil moisture (by up to ~20%) over much of the UK, especially the west coast, Wales, northern England and Ireland. Only Scotland and parts of eastern England suggest underestimation in the model (Figure 6c). Lastly, as the autumn season progresses during SON, the differences resemble winter again with JULES underestimating soil moisture relative to ECV SM over almost all of the UK, but especially Scotland and eastern England (Figure 6d). The differences were also assessed for JULES GPCC, but these were virtually identical to those from JULES CRU (not shown).

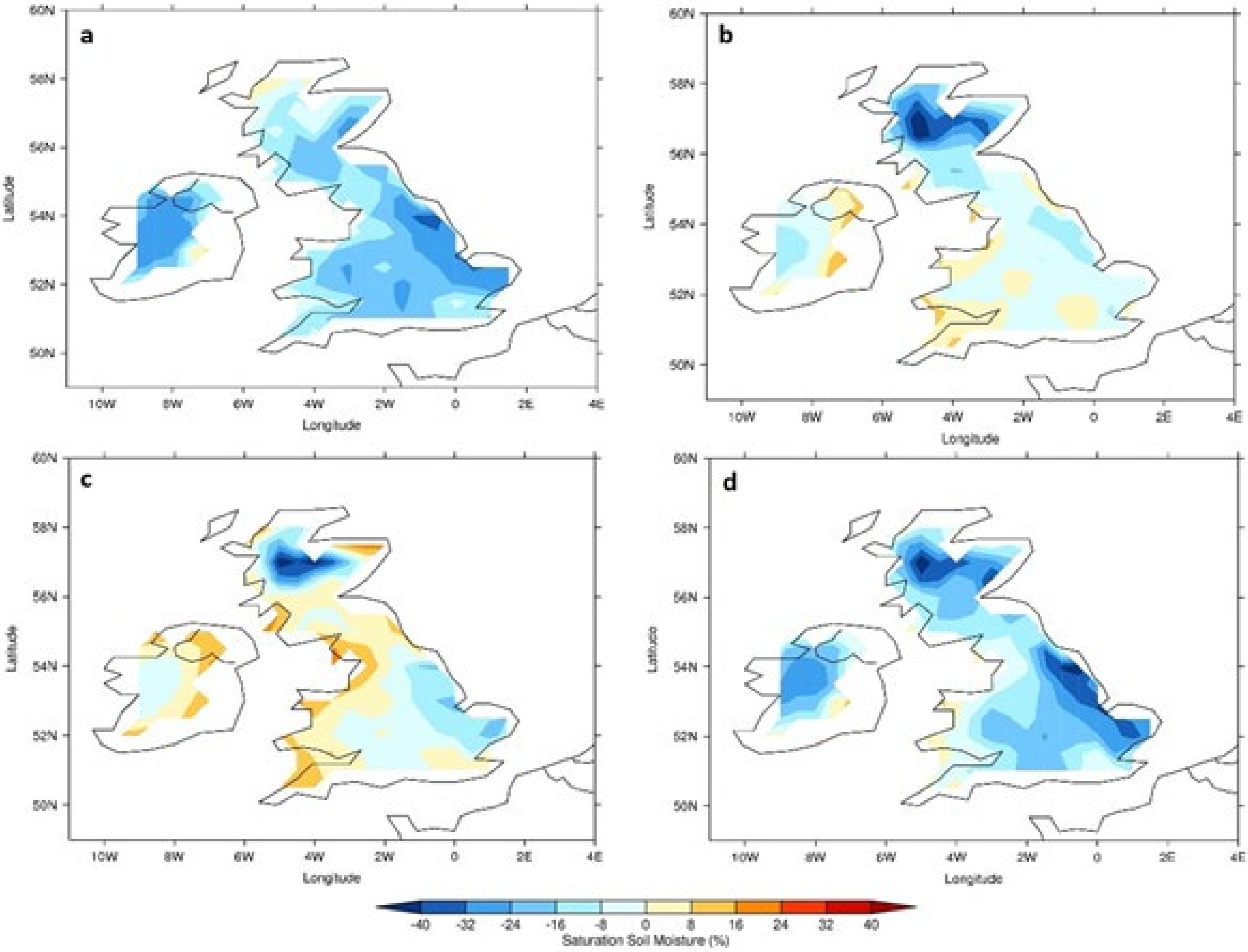

Figure 6 *Mean daily soil moisture differences (JULES CRU - ECV SM), temporally averaged over the 3 years, for various seasons: a) DJF, b) MAM, c) JJA, d) SON*

4. Summary and conclusions

In this short study, a land surface model was run for 3 years over the UK, and the resulting simulated soil moisture was compared to satellite-derived soil moisture, accessed via the HydEOMEx portal. A brief analysis of these data shows many missing values across the UK, especially in northern parts and Scotland. The land surface model, JULES, was run twice with two different forcing rainfall datasets, but the resulting simulated soil moisture appeared to be insensitive to the forcing rainfall datasets, with the differences between the two being virtually indistinguishable.

When comparing JULES to the satellite-derived soil moisture, the model appears to do reasonably well in simulating temporal and spatial patterns. In terms of temporal variability, when averaged over the entire UK and various subdomains JULES underestimates both absolute values and variability in soil moisture, but correctly simulates the seasonal cycle. Likewise, in terms of spatial variability, JULES correctly identifies the large-scale spatial patterns of soil moisture across the UK, but shows differences in magnitude which vary in sign according to season.

The above work was designed to illustrate the use of the HydEOMEx portal in designing and implementing a simple study on UK hydroclimate. The results provide some confidence in JULES, suggesting that the model's ability to simulate regional soil moisture is reasonably good.

References

Best et al. (2011). 'The Joint UK Land Environment Simulator (JULES), model description – Part 1: Energy and water fluxes'. Geosci. Model Dev. 4: 677-699

Clark et al. (2011). 'The Joint UK Land Environment Simulator (JULES), model description – Part 2: Carbon fluxes and vegetation dynamics'. Geosci. Model Dev. 4: 701-722