Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

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Using earth observation data to evaluate the performance of a land surface model at high northern latitudes

1. Introduction

Recent decades have seen large changes in the environment of high northern latitude land areas, including warming and changes in snow and vegetation cover, and these are the subject of research using increasingly sophisticated models. There is a need to evaluate the models against observational data. Earth Observation (EO) products are increasingly being used as the only practicable means for evaluation at the large spatial scales over which models are routinely applied. In this study we evaluate a land surface model against observational data from several sources.

2. The land surface model: JULES

The Joint UK Land Environment Simulator (JULES[1,2]) is a process-based model that simulates the fluxes of carbon, water, energy and momentum between the land surface and the atmosphere. JULES includes parameterisations of cold season processes, including a multi-layer model of the snow pack, and soil freezing and thawing processes.

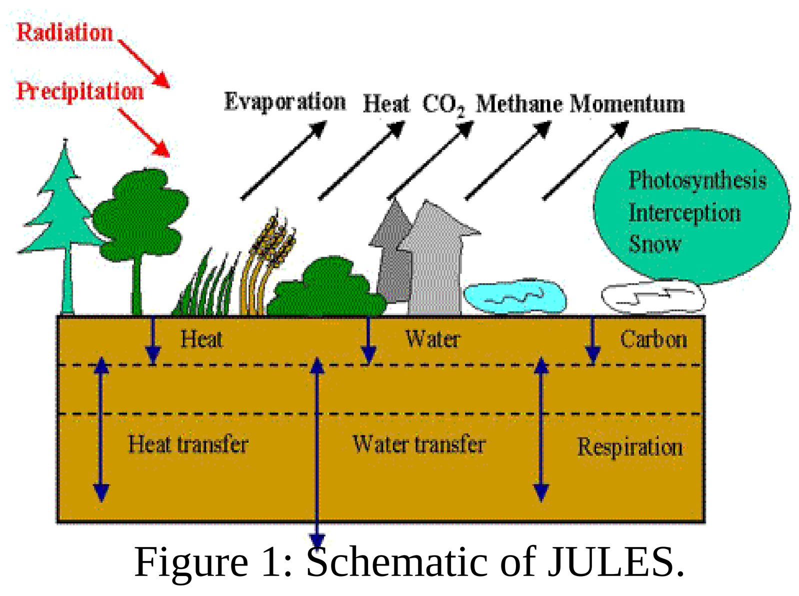

Figure 1: Schematic of JULES.

In this study we use a 1.0° grid to study the simulation of snow across the Northern Hemisphere. We drive the model using 3 sources of meteorological data: the WATCH forcing data (WFD[3]), Princeton data[4] and CRU-NCEP data[5]. These differ in data sources and algorithms used. The analysis focuses on the 4 large river basins shown in Fig.2.

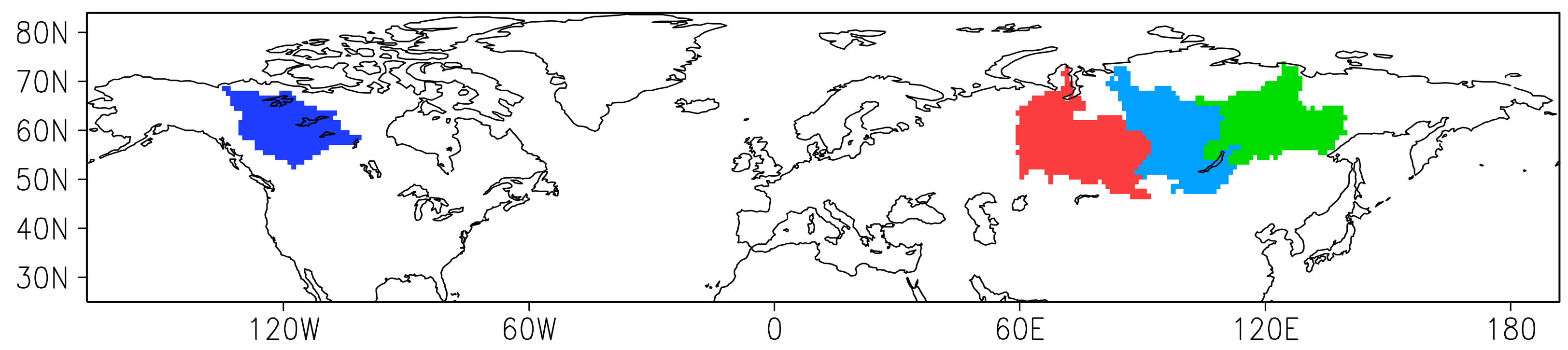

Figure 2: Catchments studied. From the left, the Mackenzie, Ob, Yenisei and Lena.

3. Earth Observation data

We use several sources of Earth Observation (EO) data to describe the spatial extent (Fractional Snow Cover, FSC) and amount of snow on the ground (Snow Water Equivalent, SWE). The EO products differ in the sensors and processing algorithms used, and cover different time periods.

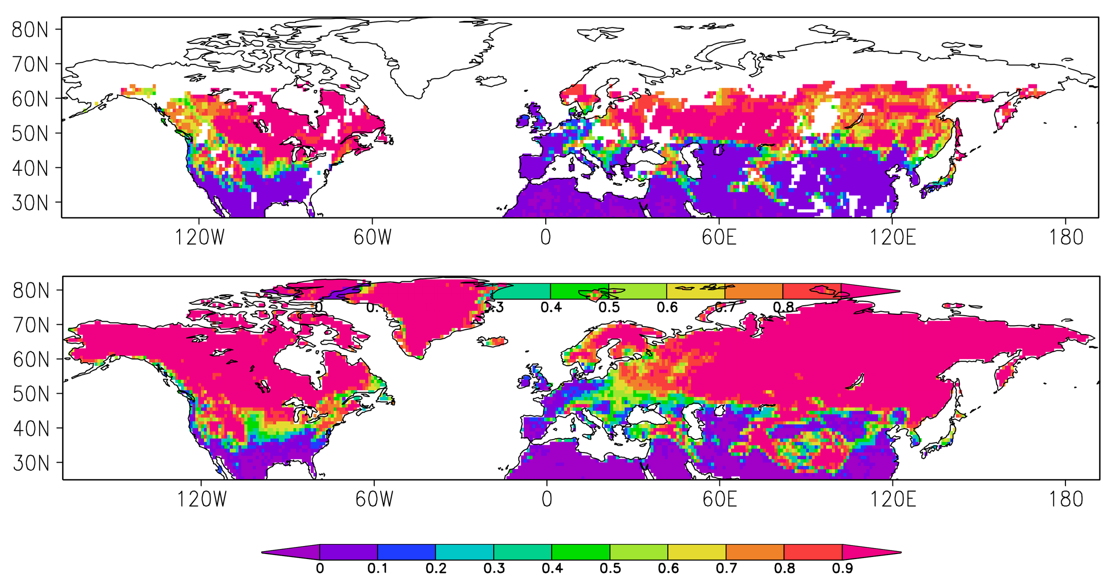

Figure 3: Examples of EO-derived FSC for Feb 2004. Top: Globsnow Bottom: SSM/I.

Products that rely on visible wavelengths, such as Globsnow, cannot retrieve surface information during the Arctic winter or when cloudy (Fig.3 top). Microwave instruments, such as SSM/I (Fig.3, bottom), do not suffer these limitations, but are inherently coarser resolution.

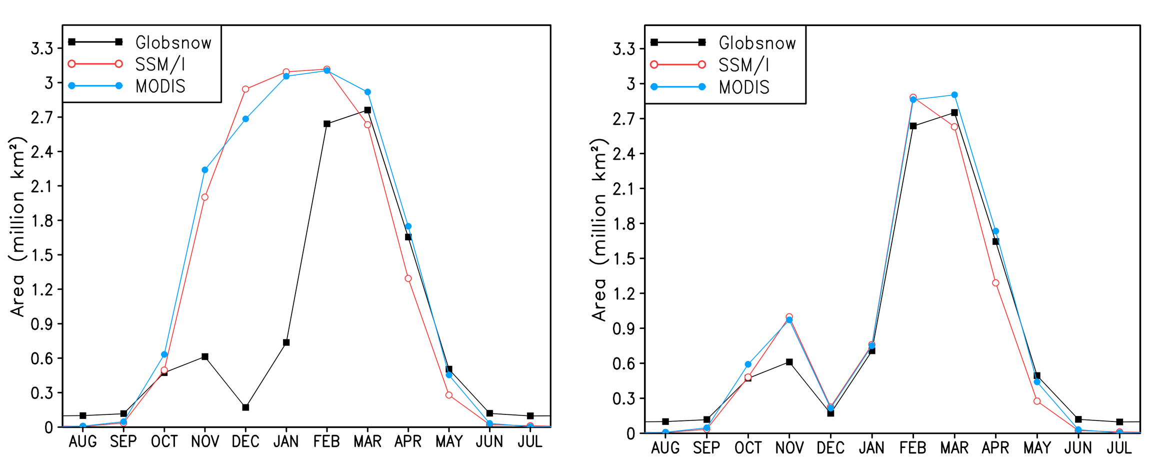

Figure 4: EO-derived FSC for the Ob, 2004-10. Left: all data Right: Masking to common locations and times.

When the same 1.0° pixels are sampled in all products, it is clear that there are often considerable differences between products (Fig.4)..

The limited overlaps between EO products and meteorological data (Fig.5) complicate the study.

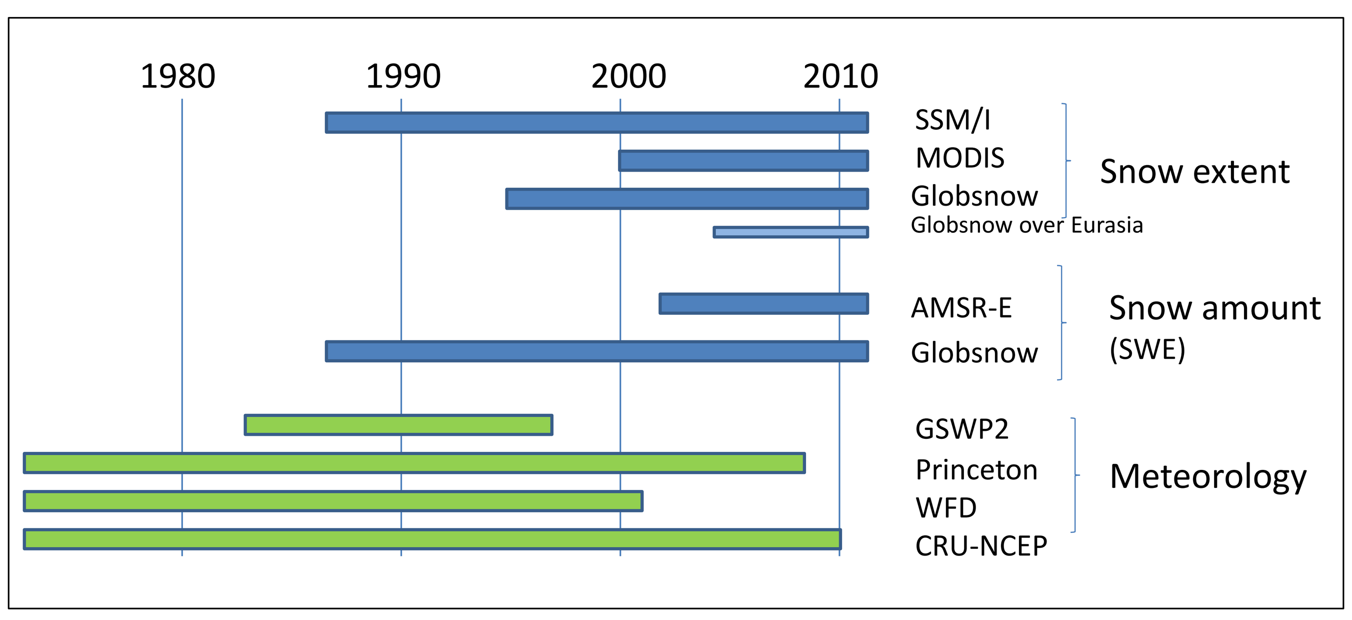

Figure 5: Availability of EO and meteorological data.

4. Comparison with Earth Observation Products

Prior to 2000, only SSM/I provides extensive coverage of FSC for the Siberian area. On this large-scale, JULES appears to match SSM/I reasonably well (Fig.6). Closer inspection shows substantial deviations – e.g. October and April), even in this area average.

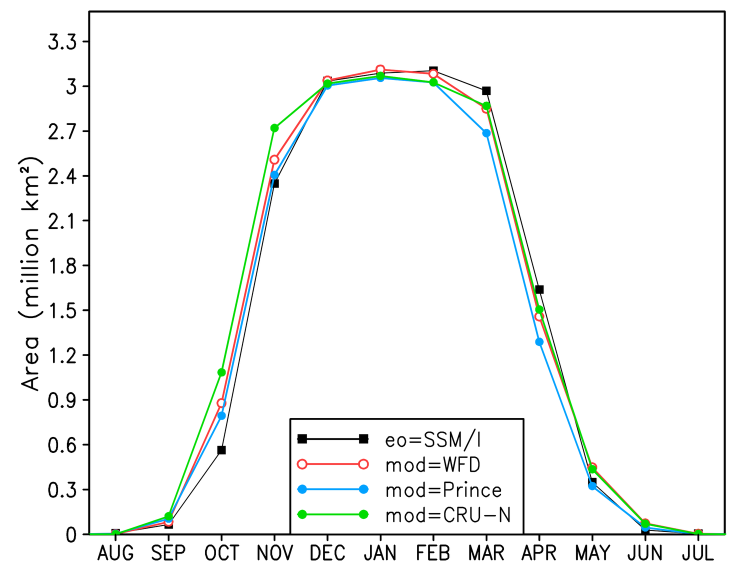

Figure 6: FSC from SSM/I and JULES (forced by 3 meteorological datasets) for the Ob catchment, 1990-99.

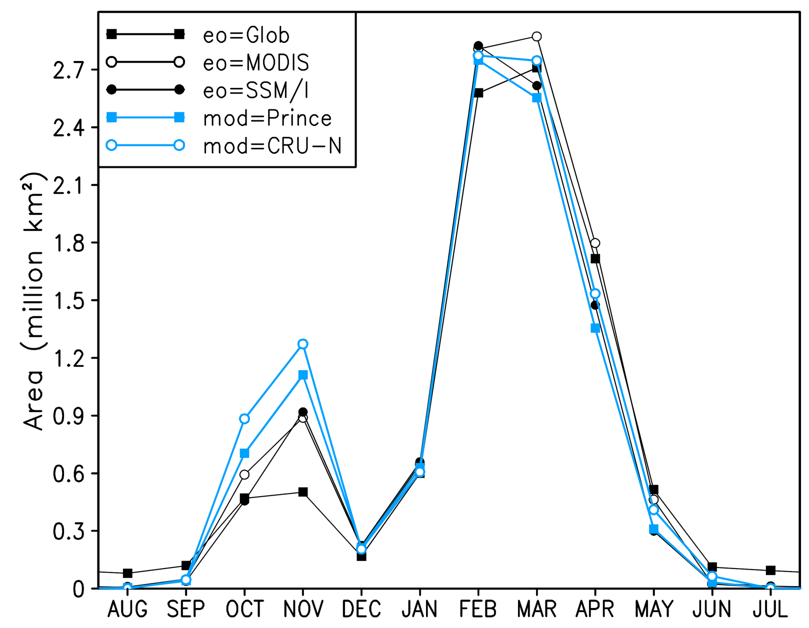

Figure 7: FSC from 3 EO products and JULES (for 2 meteorological datasets) for the Ob catchment, 2004-10. Masked to pixels with all data available.

For the more recent period, we can compare the 3 EO products for FSC against JULES (Fig.7). Again, differences between model and EO are evident. Importantly, the magnitude of the variation between the EO products is similar to that between model runs.

For SWE, the disagreement between model and EO is much larger (Fig.8). In all catchments the model has much less SWE than in the Globsnow product, and there is considerable variation between the model runs. Much, but not all of this variation comes from differences in the snowfall (not shown). Area-average precipitation is difficult to measure and snowfall is particularly difficult. But we only have one EO product for SWE – below we look at alternative data.

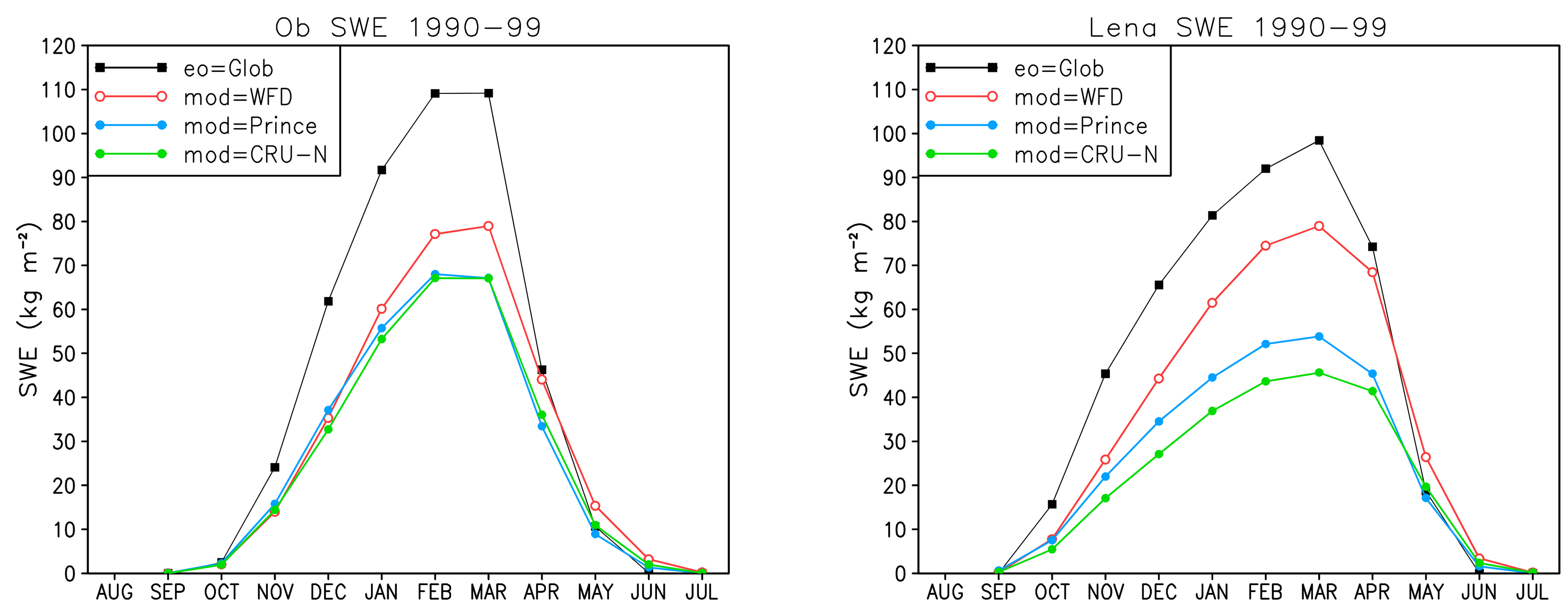

Figure 8: SWE from Globsnow and JULES (for 3 meteorological datasets) for the Ob (left) and Lena (right) catchments, 1990-99.

5. Comparison with river flow data

Measurements of river flow give an independent check on the modelled hydrological cycle, but are less directly linked to snow processes – other processes such as runoff generation and evaporation are also important. Fig.9 shows that the modelled river flow is systematically less than observed in all four catchments. The poor timing of the flow in the model is likely partly a result of other (non-snow) deficiencies in the parameterisation of runoff generation used here. The low river flow supports the conclusion that the input snowfall and modelled SWE are too low.

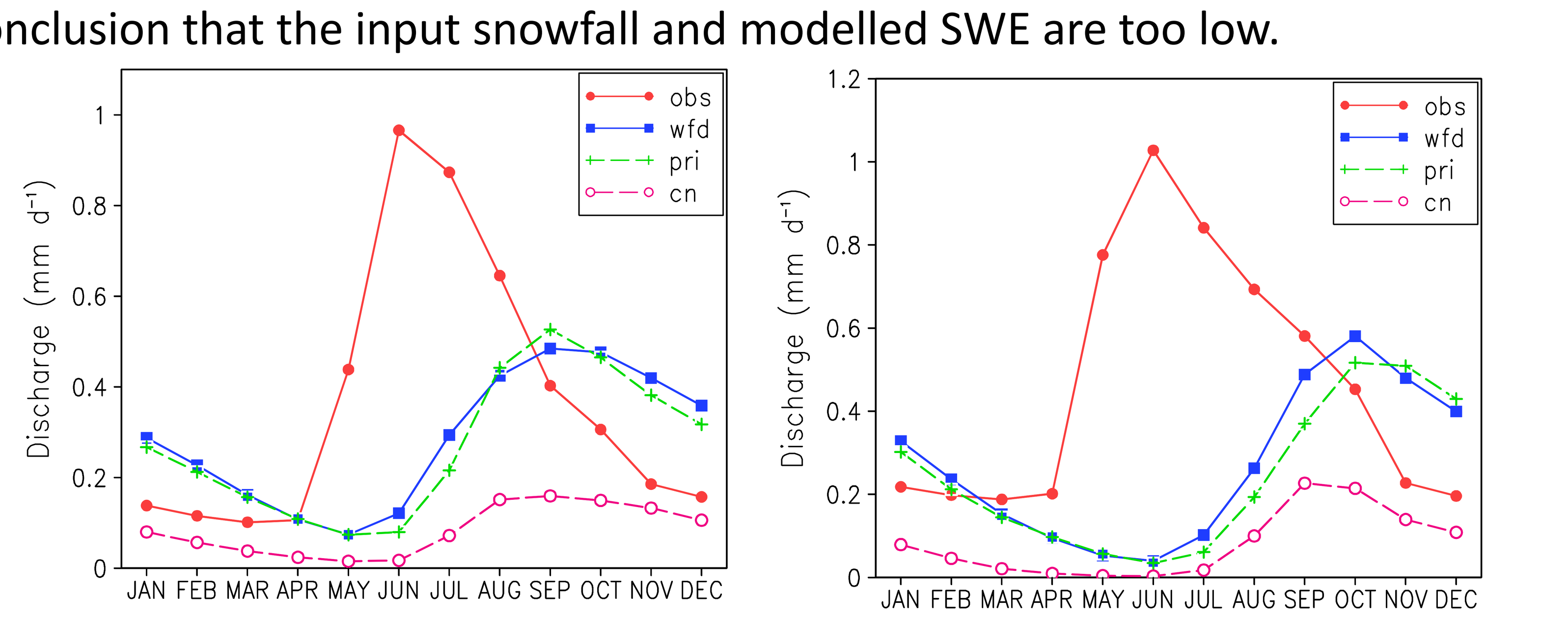

Figure 9: SWE from Globsnow and JULES (for 3 meteorological datasets) for the Ob (left) and Lena (right) catchments, 1990-99.

6. Conclusions and ongoing work

It is important to use multiple datasets, both to drive the model and for evaluation, as conclusions based on a single dataset can often be biased.

It seems likely that all the meteorological datasets provide insufficient snowfall, which reduces our ability to diagnose model errors. Future work will have to consider alternative precipitation data and/or procedures for bias correction.

In the longer term we aim to introduce EO products of snow into the standard model assessment ("benchmarking") system for JULES.

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References: (1) Best et al., 2011, Geosci, Model Dev., 4 (2) Clark et al., Geosci. Model Dev., 4 (3) Weedon et al., 2011, J.Hydromet. (4) Sheffield et al., 2006, J. Climate, 12 (5) Nicolas Viovy, LSCE, Paris.

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