IMPROVING THE PARAMETERIZATIONS OF COLD REGION PROCESSES IN A LAND SURFACE MODEL

Ménard C.[1,2], Clark D.[1], Essery R.[3], Blyth E.[1]

[1]CEH Wallingford, [2]University of Wales, Aberystwyth, [3]University of Edinburgh

Centre for Ecology & Hydrology
Prifysgol Cymru Aberystwyth The University of Wales
Natural Environment Research Council
Climate and Land-Surface Systems Interactions Centre

1.Background

Snow is the single most important feature of land surface-atmosphere interactions at northern latitudes. Its inherent properties play a critical role in the hydrology, ecology and energy and carbon balances of the region.

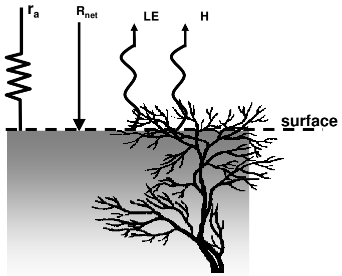
Shrubs capture and hold more snow than other tundra vegetation types. Field observations, satellite remote sensing data and models show that the recent warming has provoked an increase in shrub distribution in the region[1,2,3]. This change in the vegetation structure can significantly affect the distribution and the physical characteristics of snow and as a consequence, the snow-atmosphere-biosphere interactions[4].

The aim of this PhD is to look at the implication the northward shrub-tundra expansion would have at the global scale, focusing on snow and runoff processes and the surface energy balance in the Arctic. The means to attain this aim will be to:

- Assess the performance of the model against ground and remotely sensed observations. This will be performed first at a single point then on gridded runs at a small scale using existing studies, then at the global scale.
- Improve cold region processes in JULES.
- Couple JULES with the climate analogue model IMOGEN (Integrated Model Of Global Effects of climatic aNomalies), used to simulate a range of different climate warming scenarios run in forecast mode at the pan-Artic scale.

2. JULES – Land surface model

JULES (Joint UK Land Environment Simulator) is a land surface model developed by the UK Met Office and the CEH with the aim of serving a wide range of disciplines within the scientific community. It comprises an implicit snow scheme, meaning that when snow is present, the snow cover is represented as an extension of the top soil surface layer rather than being a separate entity. This changes the thermal properties of the "hybrid" layer and, as a consequence, the thermal conductivity is re-calculated. JULES presently represents snow processes in two ways:

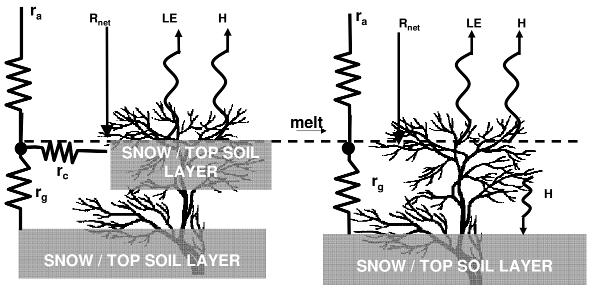


Snow model 1

- Snow is held on the canopy and remains so until complete melt.
- Surface temperature cannot rise above 0°C when there is snow cover.
- Sublimation always occurs at the potential rate because it does not experience resistance from the canopy

Snow model 2

- Snowfall is partitioned into interception by the canopy and throughfall to the ground.
- Intercepted snow may be removed from the canopy by sublimation, unloading or melting[5].
- The canopy layer shelters the ground snow. As a consequence, snow can not sublimate and is removed by melt.



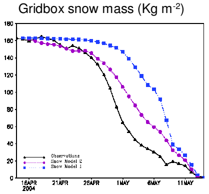
Snow model 2 improves the representation of snow processes during the melt season because: 1/ Snow can now be unloaded from the canopy to the ground rather than remain on the canopy until complete melting 2/ The canopy temperature can now rise above 0°C. Upward turbulent fluxes are now simulated 3/ As the surface now consists of exposed vegetation and snow, the albedo is decreased and net radiation in better agreement with observations.

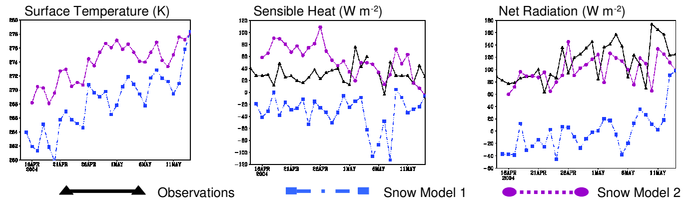
3. Testing the snow models: Wolf Creek melt season 2004

Observational data was collected during the melt period of 2004 at the Wolf Creek Research Basin in Yukon Territory, Canada. Average shrub height was 120 cm[6, 7].

Snow model 2 improves the representation of snow processes during the melt season:

- The snow mass curve during the melt season is in better agreement with observations.
- Because snow can now be unloaded from the canopy to the ground rather than remaining on the canopy until complete melting, the canopy temperature can now rise above 0°C and an upwards sensible heat flux is simulated, in better agreement with observations.
- As the surface now consists of exposed vegetation and snow, the albedo is decreased and net radiation increased, in better agreement with observations.

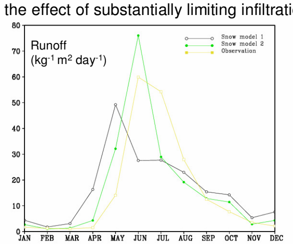




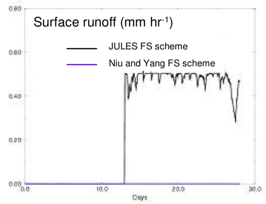
4. Model development: Frozen Soil Processes in JULES

JULES uses the Clapp and Hornberger equations for the soil hydraulic characteristics. The model includes a layered soil representation that uses a finite difference approximation to the Richard's equation to calculate the vertical fluxes of heat and moisture between layers. When calculating the hydraulic conductivity of soil, the standard scheme only considers the unfrozen fraction of the soil moisture, rather than the total moisture, which has the effect of substantially limiting infiltration into frozen or partly frozen soils.

The figure opposite shows how the two snow schemes modify runoff representation and perform against observations from the Abisko catchment averaged over 10 years. The increase in snow lying on the ground caused by the modification to the snow scheme in snow model 2 is reflected in an increase in moisture content in all soil layers. This in turn is reflected in runoff rates in snow model 2 which shows a higher runoff peak and a shorter recession period than observations because most of the extra water is in a frozen state. As the existing frozen soil scheme does not allow for water storage and for heterogeneity in the landscape, all the snowmelt is translated into immediate runoff.



Observational data were obtained from the PILPS2e experiment[8].



The figure opposite shows surface runoff rates at a single point with the existing frozen soil processes scheme and with a modified scheme that includes the implementation of a fractional permeable area (Niu and Yang, 2006) . Preliminary results using a synthetic rainfall event from day 14 onwards show that the new scheme allows for the infiltration of rain water in deeper soil layers while the existing JULES does not. Future work will assess the models' performance against observed streamflow in order to identify the most appropriate frozen soil scheme for large scale applications.

5. References

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