A new surface scheme for Hirlam

Stefan Gollvik, SMHI

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This scheme is based on an earlier developed version of the Hirlam ISBA-scheme, with a separate snow temperature (S.Gollvik, B.Navasques), and a new forest tile, from the RCA climate model (P.Samuelsson, S.Gollvik)
The coding for 6.3.4 is done mainly by S.Gollvik, and the adaptation to 6.3.5 is done by E.Rodriguez.

1 Features of the new surface scheme

The main changes from the earlier 5-tile Hirlam-ISBA, is that the force-restore formulation for temperature is replaced by heat conduction, and also that the snow and canopy have prognostic temperatures. The force-restore formulation is kept for soil moisture:

- Totally 7 tiles, sea, ice, snowfree open land, snowfree low vegetation, snowfree forest, open land snow and forest snow. With "open land snow" we mean the snow that is covering both the open land and low vegetation tiles.
- For all land tiles: three prognostic soil temperatures with depths 1 cm, 7.2 cm and 43.2 cm. A climatological deep temperature is used and the heat conduction is calculated.
- The forest tile has a common canopy temperature, for the snowfree and snow part, and is technically treated at the same time. Radiation is calculated both for canopy and forest floor.
- The two snow covers (open land and forest snow) are treated separately. They have, apart from the temperatures, also varying albedo, density and liquid water content (to allow for refreezing).

At present, we have the older barrier formulation for soil-freezing (Viterbo et.al.,1999), and a simpler formulation of sea-ice, whithout a separate temperature for the snow. This scheme calculates the heat conduction of the ice with two layers. The layers are 7 cm and 43 cm in the Baltic, and 7 cm and 93 cm elsewhere. The ice has a weak heatflux at the bottom, dependent on the water temperature.

2 Formulation of the snow parameterizations

The snow is formulated in the same way for open land and forest, using two separate snow packs. The value of the fraction of snow ($frsn$) is more critical in this scheme, than in the old scheme, since the snow temperature is strongly dependent on the snow depth, which has to be computed as a function of e.g. snow amount (sn). Here we use the simple formulation:

$frsn(x,y,t) = sn(x,y,t)/sncrit(x,y,t) \quad frsn \leq 0.95$

Since the relation between the snow amount and snow cover is different during the growth and also where we expect the snow cover to be more patchy. By analysing both snow amount and snow cover, *sncrit* can be calculated, but the analysis of snow cover is not ready yet. At present we simply let *sncrit* vary with time of the year and latitude according to:

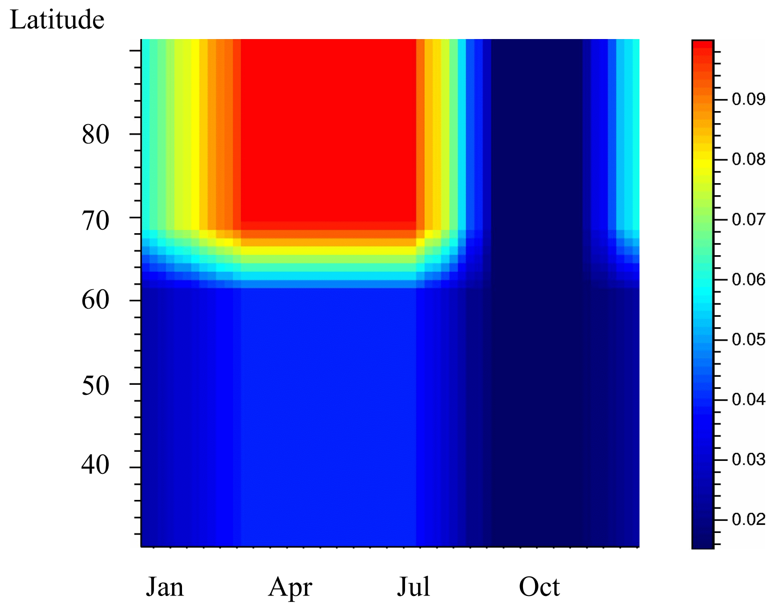

Figure 1. Sncrit as a function of time of the year and latitude

The snow is described by one layer, with the prognostic variables temperature, T_{sn}. If the snow is deep, only a part of the snowpack is thermally active, i.e. only a part of the snow is contributing to the heat capacity, in that case. The heat conduction between the snow and the uppermost soil layer is a function of snow depth, which is a parameterization of a temperature profile within the snow:

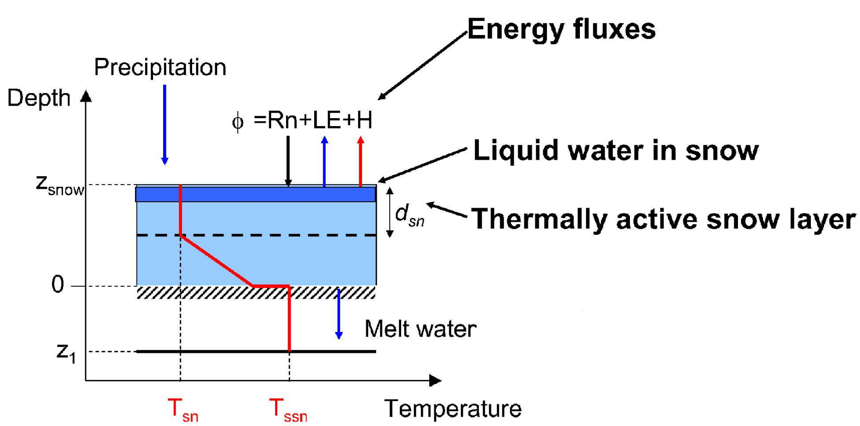

Figure 2. The snow formulation

The snow melting starts when the snow temperature reaches zero degrees C, and the melted snow is stored within the snow pack, and starts to drainage when reaching a critical value *swsat*. This value is a varying linearily with snow density, from 12 % in low density snow, until 4 % in high density snow, (simulating that the snow gradually forms to ice). Here we use a modification of a method from Douville et.al. 1995. The density of the dry snow (snow at the old timestep - liquid water in the snow) is increasing with time (e-folding time about 4 days). The density at the new time step is then modified by the liquid water and frozen liquid water. The ice is not a variable in the model, but only modifying the density. Also the snow albedo is

fallen snow.
Technically the heat conduction is solved implicetely, where the timestep is split into two parts, melting/freezing and heating/cooling. During the phase shift we have the melting temperature of the snow as a boundary condition, and during the heating/cooling of the snow pack, we have the energy flux as the boundary condition.

3 The forest tile

The forest tile use many different prognostic variables, see Figure 3. Within the forest, the snow scheme is treated as that over open land, but the fluxes are calculted in the sane way as the no snow part of the forest. The general assumption is that we calculate an equilibrium temperature, canopy air temperature, T_{ca},(and corresponding q_{ca}) without any heat capacity, so that the total flux of sensible and latent heat is zero in the canopy air.

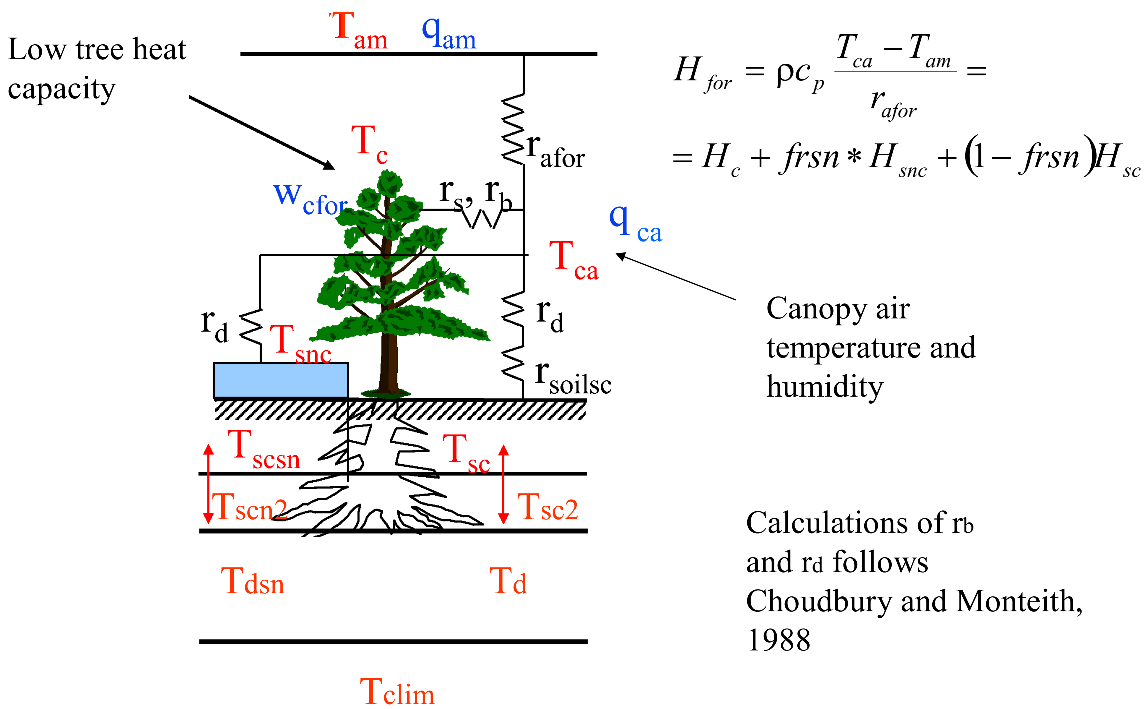

Figure 3. The forest tile

This implies that the fluxes at the forest floor are only between the canopy air and the floor, and are characterized by the resistance r_d (and for the no snow part, also by the surface resistance r_{soilc}), while the atmosphere is only feeling the forest, via T_{ca} and the atmospheric resistance r_{afor}.

3.1 Radiation in the forest

We assume that there is a "view factor", $viewfs$, that is defining how much of the incoming short wave radiation, that is passing the canopy and reaching the forest floor. At present the same factor is used also for the long wave radiation. It is a function of leaf are index, LAI, as: $viewfs = exp(-0.5 * LAI)$

An improvement would be to let the view factors be different for the short wave and long wave

depend on the vegetation density (*veg*).
We then calculate the radiation budgets separately for the canopy and the two parts of the forest floor.

4 Heat conduction in the soil

The temperature evolution is solved implicitly, for each vertical column in all possible cases:

Open land
Low vegetation
Open land snow
Forest without snow
Forest with snow

As mentioned before, the solution splits into two separate columns when melting/freezing occurs. Nothing is done to the soil moisture formulation as compared to the original code, but the heat conduction is strongly dependent on soil moisture. This has a strong implication on the data assimilation of soil moisture. If we use the present assimilation, where the soil moisture is corrected to account for errors on 2m humidity and temperature, there is a strong feedback to the temperature evolution via the heat conduction coefficient.

5 Changes in the surface analysis

There are some modifications in the surface analysis in the new scheme, and also some assumptions:

- The two snow temperatures are adjusted in the same way as the other surface temperatures, based on the 2m-analysis.
- The soil temperature changes under the snow are neglected in the analysis.
- Below the snowfree tiles, the soil temperatures are updated by solving the heat conduction (see below)

The updating of the layers below the surface layer is done in the following way. Analysed values of the surface temperature from the previous cycle (-6h) before and +3h forecasted values from that time, is used together with the analysed value at the current time, to produce a time serie of surface temperatures. This time serie is used as a a forcing on the temperatures below, in a heat conduction, formulated in the same way as in the model. By this formulation, consistancy between the model and the analysis is achieved.

6 References

Douville, H., Royer, J.F., Mahfouf, J.F., 1995: A new snow parameterization for the meteo-france climate model. Part 1: validation in stand-alone experiments. Climate Dyn. 12, pp 21-35.

Viterbo, P., Beljaars, A., Teixeira, J., 1999i: The representation of soil moisture freezing and its impact on the stable boundary layer. Quart. J. Roy. Meteorol. Soc. 125, pp 2401–2426.