A snowmodel intended for ISBA

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Background

Within the Swedish climate research program a snow scheme was developed by B. Bringfelt, S. Gollvik and P.Samuelsson, which was based on the old HIRLAM, surface code. This scheme contains, apart from including a separate temperature for forest canopy, also a prognostic scheme for open land snow. The variables in this (single layer) snow scheme are snow amount, liquid water in the snow, snow density, snow albedo and snow temperature. It was decided within the HIRLAM community that the framework within the surface parameterisation is the ISBA framework, where most of the work is done in Spain. Therefore I have worked with the implementation of the Sweclim open land snow scheme in ISBA.

Modification of layers in ISBA

First we have introduced an extra thermal layer (7.2 cm as in old HIRLAM surface scheme) below the ISBA-layer of 1 cm. We have also replaced the force-restore formulation in ISBA with a heat conduction formulation as in HIRLAM. It turned out that these modifications were necessary, if a more physical heat conduction is implemented, since in the time evolution of the "1 cm" layer in ISBA is closely related to the force-restore formulation of the second ISBA-layer.

Fraction treatment

We are at present only treating the snow on fractions 3 and 4 (bare soil and low vegetation) with a separate snow model, while the forest snow is not touched yet. Technically this is done in such a way that the snow fraction (at present simply defined as $Sn/Sncrit$) of fractions 3 and 4 are moved to a separate new fraction 6, with snowcoverage = 1 (here called *open land snow*), each timestep.

Features of the snow scheme

Most of the formulation in this snow scheme follows those of ERA-40. The features of this scheme are:

- Only one snow layer
- Water within the snow
- Some water can refreeze
- Snow density calculations
- Simple albedo estimation

Temperature calculations for open land snow

$$\frac{dT_{sn}}{dt} = \frac{1}{C_{snow} * z_{snow}} [\Phi + \frac{1}{r_{snow}}(T_s - T_{sn})]$$

Here $C_{snow} = vhice * \frac{\rho_{sn}}{\rho_{ice}}$;
where $vhice$ is the volymetric heat capacity for ice ($2.05 \cdot 10^6\, Jm^{-3}K^{-1}$), and the snow depth (z_{snow}) is the actual snowdepth (in m snow) calculated as $\frac{\rho_w * Sn}{\rho_{sn}}$, but maximized to $zsnlayer$ (0.15).

$$r_{snow} \;=\; 0.5\,\frac{z_{snow}}{\lambda_{sn}} + 0.5\,\frac{z_1}{\lambda^*_{soil}}; \quad \lambda_{sn} = \lambda_{ice}\left(\frac{\rho_{sn}}{\rho_{ice}}\right)^{1.88} \quad \text{(ERA 40)}$$

Here we have used $\lambda^*_{soil} = 15$.

Melting / freezing ?

First we estimate the energy available for the snow:

$\Phi_{tot} = \Phi + \frac{1}{r_{snow}}(T_s - T_{sn})$ Dependent on the sign of Φ_{tot}, we then do the following:

$\Phi_{tot} > 0$

If $\Phi_{tot} > 0$, we estimate the time Δt_1 to melt the snow, with the energy given by Φ_{tot}:

$$\Delta t_1 = C_{snow} * z_{snow}\,(T_{sn} - T_{melt})/\Phi_{tot}$$

In cases where $2\Delta t_1 > \Delta t$, we don't have energy enough to reach T_{melt} during the timestep period (Δt). In that case we solve the heat conduction problem for the four variables T_{sn}, T_s, T_{s2} and T_{sd} by solving the following four equations:

$$\frac{dT_{sn}}{dt} = \frac{1}{C_{snow} * z_{snow}} [\Phi + \frac{1}{r_{snow}}(T_s - T_{sn})]$$

$$\frac{dT_s}{dt} = C_T\,[\alpha_1\,(T_{s2} - T_s) - \frac{1}{r_{snow}}\,(T_s - T_{sn})]$$

$$\frac{dT_{s2}}{dt} = \frac{1}{C_s * z_2}\,[\alpha_2\,(T_{sd} - T_{s2}) - \alpha_1\,(T_{s2} - T_s)]$$

$$\frac{dT_{sd}}{dt} = \frac{1}{C_s * z_3}\,[\alpha_3\,(T_{clim} - T_{sd}) - \alpha_2\,(T_{sd} - T_{s2})]$$

Here C_T is the ordinary ISBA coefficient and z_1, z_2 and z_3 are the depths of the three soil layers, respectively. The heat conduction coeffients, α_i, are defined as:

$\alpha_i = 2\lambda_{soil}/((z_i + z_{i+1}) \qquad z_4 = z_3$;

where λ_{soil} is a function of soil moisture. No soil freezing according to Viterbo, 1998, yet.

If $\Delta t_1 < \Delta t$ we devide the timestep into two parts, Δt_1 and $\Delta t_2 = \Delta t - \Delta t_1$. In this case we start by solving the four equations above with a time step of Δt_1, followed by a melting phase during a timestep of Δt_2, during which we solve the equations for T_s ,T_{s2} and T_{sd} with the temperature $T_{sn} = T_{melt}$ as the upper boundary condition.

The amount of melted water is then given by:

$$Sn_{mel} = \Delta t_2 \Phi_{tot}/(\rho_w L)$$

$\Phi_{tot} < 0$

First estimate the fraction of water in the snow that is available for freezing. This is a typical tuning parameter. Here we assume the following estimation of $Freezefrac$:

$$Freezefrac = (Snfrlev * \rho_{sn} * Swsat/(\rho_w Sw_{sn}); \qquad Freezefrac \leq 1$$

where $Swsat$ is the maximum fraction of water that the snow can hold (10%), and $Snfrlev$ is a typical active freezing layer (here put to 3 cm). To be able to take away (to freeze) the last water we assume that if there is very little water left ($Sw_{sn} < Sw_{sncrit} = 0.001$) we put $Freezefrac$=1. We use $Freezefrac$ to estimate the time it takes to freeze a part of the water in the snow:

$$\Delta t_2 = -Freezefrac * \Delta t$$

and in the case when $Sw_{sn} < Sw_{sncrit}$:

$$\Delta t_2 = -\rho_w * L * Sw_{sn}/\Phi_{tot}$$

In this case ($\Phi_{tot} < 0$) the processes are computed in the reversed order, i.e. if Δt_2 is larger than zero we first use this timestep and compute the freezing part, by solving the two equation system, followed by a cooling part (timestep = $\Delta t_1 = \Delta t - \Delta t_2$) using all four temperature equations.

We also have a simple algorithm to calculate the snow density, (a gradual increase after snowfall, of the "dry snow" combined with the amount of water within the snow)

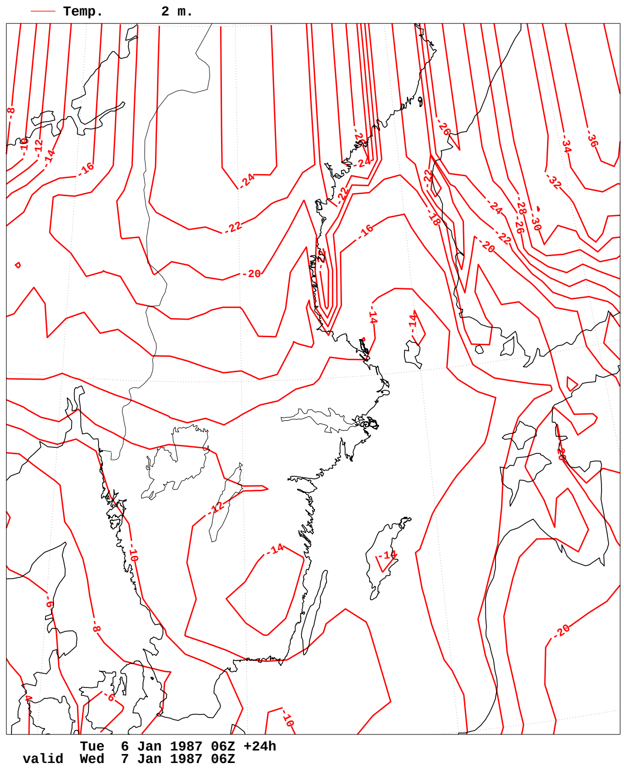
The snow albedo is put to $Albsn_{max} = 0.85$ if we have fresh snowfall with an intensity more than 1 mm (water equivalent) per hour, else the evolution of albedo is given by:

$$\frac{dAlbsn}{dt} = Albsn_{min} + (Albsn - Albsn_{min}) * e^{-\tau_1 \Delta t} \qquad Albsn_{min} = 0.50, \tau_1 = 0.24/86400$$

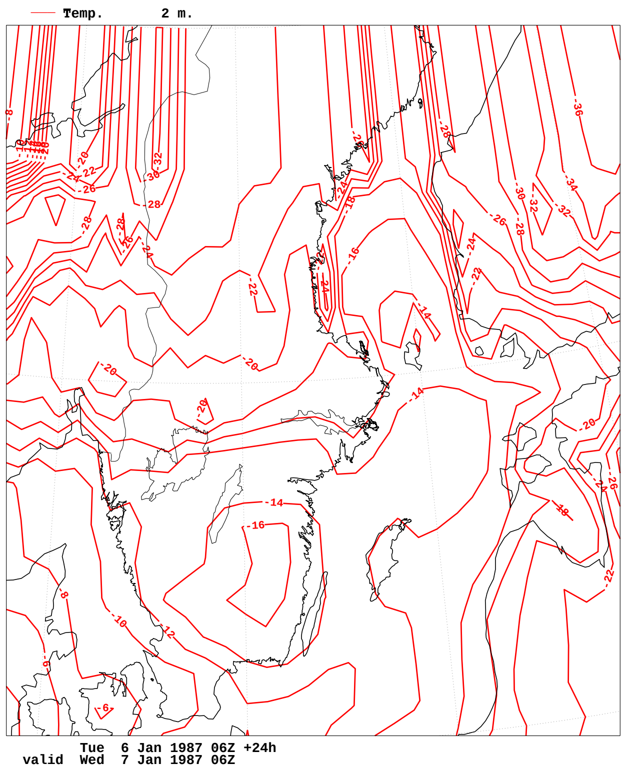
in case of no melting snow, and in case of melting:

$$\frac{dAlbsn}{dt} = Albsn - \tau_2 \Delta t \qquad \tau_2 = 0.008/86400 \quad Albsn \geq Albsn_{min}$$

Just to show that the snow scheme works technically the 2m temperature of two +24 h forecasts are shown:



Original T2m (+24 H)



T2m with snowmodel (+24H)

Further work mainly on roughness lengths for heat and momentum is necessary, the present formulation seems to be a little too cold.