# Snow handling in SURFEX/ISBA

Patrick Samuelsson
with material from Aaron Boone

Rossby Centre, SMHI
patrick.samuelsson@smhi.se

# A SURFEX grid box

- The surface is divided into 4 main **Tiles**, which are treated by different models
- The tile **Nature** is divided into 1-12 **patches**
- **Snow occurs separately in each tile and each patch.**

  **Thus, for the nature tile we can have up to 12 separate prognostic snow storages.**

| | |
|---|---|
| Sea/Oceans | Lakes |
| Nature (bare soil/ vegetation) | Towns |

| | |
|---|---|
| NO no vegetation | C3 (C3 crops) |
| ROCK (bare rock) | C4 (C4 crops) |
| SNOW (snow and ice) | IRR (irrigated crops) |
| TREE (deciduous broadleaved forest) | GRAS (temperate /C3 grassland) |
| CONI (evergreen needleleaved forest) | TROG (tropical /C4 grassland) |
| EVER (evergreen broadleaved forest) | PARK (wetlands) |

# SURFEX snow options

**CSNOW in &NAM_PREP_ISBA_SNOW**

**EBA - Bazile composite scheme, 2 prognostic variables**
ALADIN & ARPEGE NWP(?)

**D95 (default)- Douville composite scheme, 3 prognostic variables**
ARPEGE climate

**3-L - Boone (ISBA-ES: Explicit Snow), 4 prognostic variables (3-N layer variables, 1 single layer var)**
Tests with AROME
Ongoing developments: new modifications with snow grain variables, history variables, 10 layers....coupling with vegetation canopy

**CRO – Crocus snow avalanche multi-layer model**

# Snow prognostic variables

D95 - Composite snow scheme
EBA - Composite (**no** density prognostic eq)

$$\frac{\partial W_n}{\partial t} = P_n - E_n - F_n$$

$$\frac{\partial \rho_n}{\partial t} = \frac{\tau_f}{\tau}\left(\rho_{\max} - \rho_n\right) \qquad \left(\rho_{\min} \leq \rho_n \leq \rho_{\max}\right)$$

$$\frac{\partial \alpha_n}{\partial t} = \frac{-1}{\tau}\left[\delta_\alpha\, \tau_f \left(\alpha_n - \alpha_{\min}\right) + \left(1 - \delta_\alpha\right) \tau_a\right] + \frac{P_n}{W_{crn}}$$

$$\left(\alpha_{\min} \leq \alpha_n \leq \alpha_{\max}\right)$$

# SURFEX snow options

D95 - Composite snow scheme
EBA - Composite (**no** density prognostic eq)

$$\frac{\partial W_n}{\partial t} = P_n - E_n - F_n$$

$$\frac{\partial \rho_n}{\partial t} = \frac{\tau_f}{\tau}\left(\rho_{\max} - \rho_n\right) \qquad \left(\rho_{\min} \le \rho_n \le \rho_{\max}\right)$$

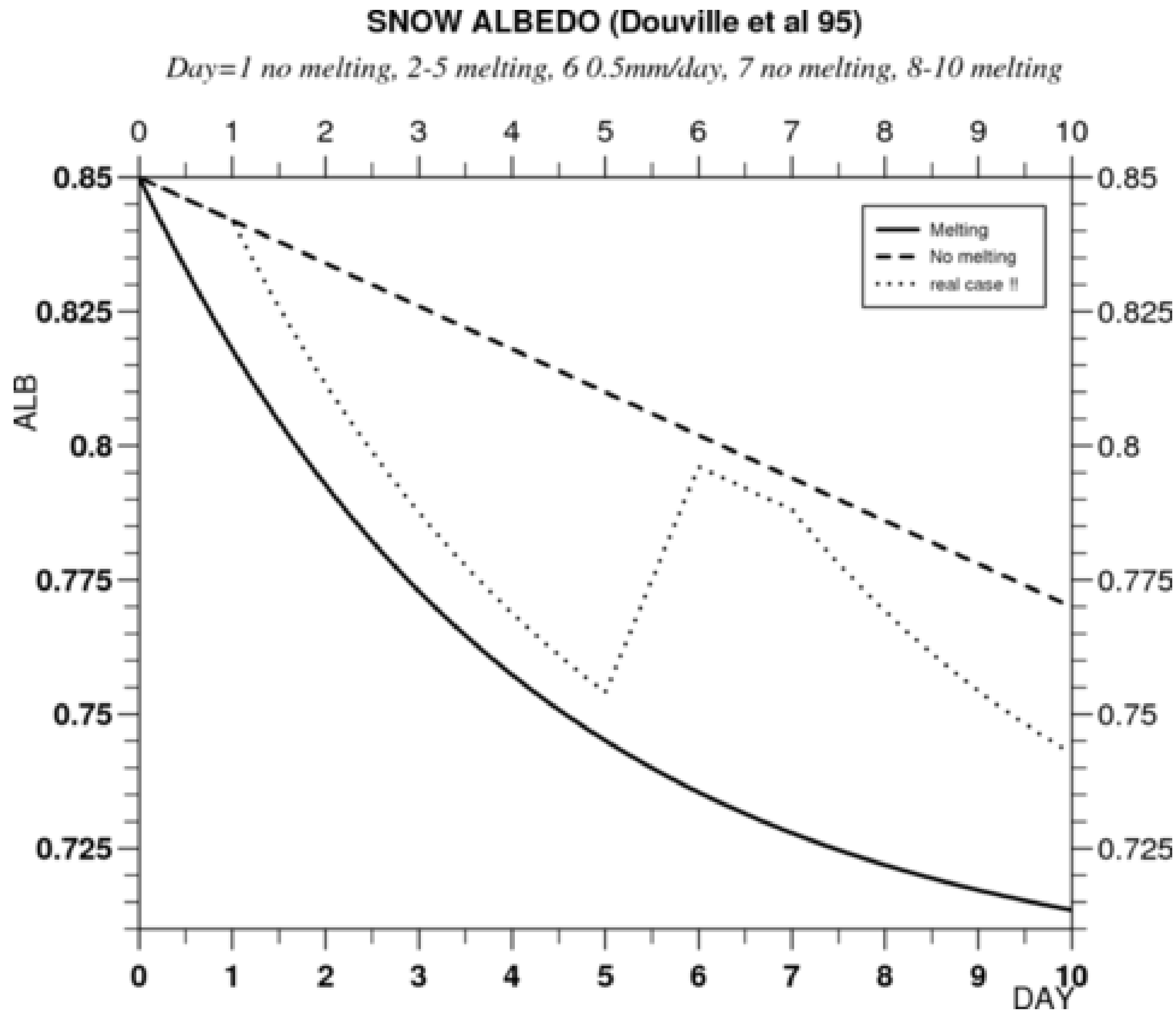
$$\frac{\partial \alpha_n}{\partial t} = \frac{-1}{\tau}\left[\delta_\alpha\, \tau_f \left(\alpha_n - \alpha_{\min}\right) + \left(1 - \delta_\alpha\right) \tau_a\right] + \frac{P_n}{W_{crn}}$$

$$F_n = p_n \frac{(T_n - T_f)}{C_n L_f \Delta t} \qquad (F_n \ge 0)$$

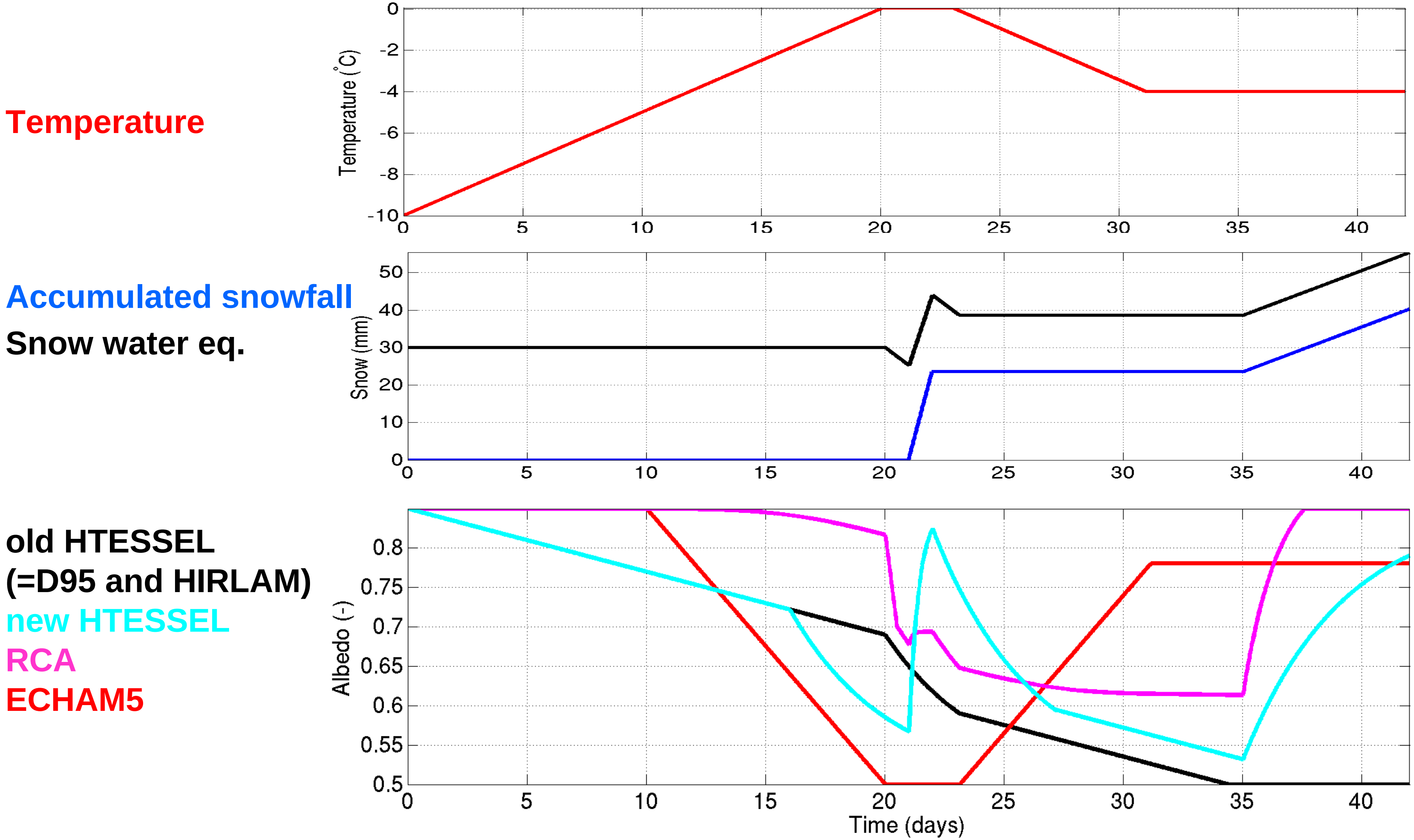
$$T_n = (1 - veg) T_s + veg\, T_2$$

**Comoposite=**
Single soil-vegetation-snow energy budget

# Albedo in EBA, D95 and 3-L



# Different parameterisations of snow albedo



# Snow fraction in EBA, D95 and 3-L

Snow fraction for bare soil according to $p_{ng}$ for all models

Snow fraction for vegetation according to $p_{nv}$ for 3-L and D95
For EBA based on *LAI* and *age* also (results in significantly improved T2m air temperatures over Northern Hemisphere /AAB)

soil → $$p_{ng} = W_n / (W_n + W_{crn}) \qquad (W_{crn} = 10 \text{ kg m}^2)$$

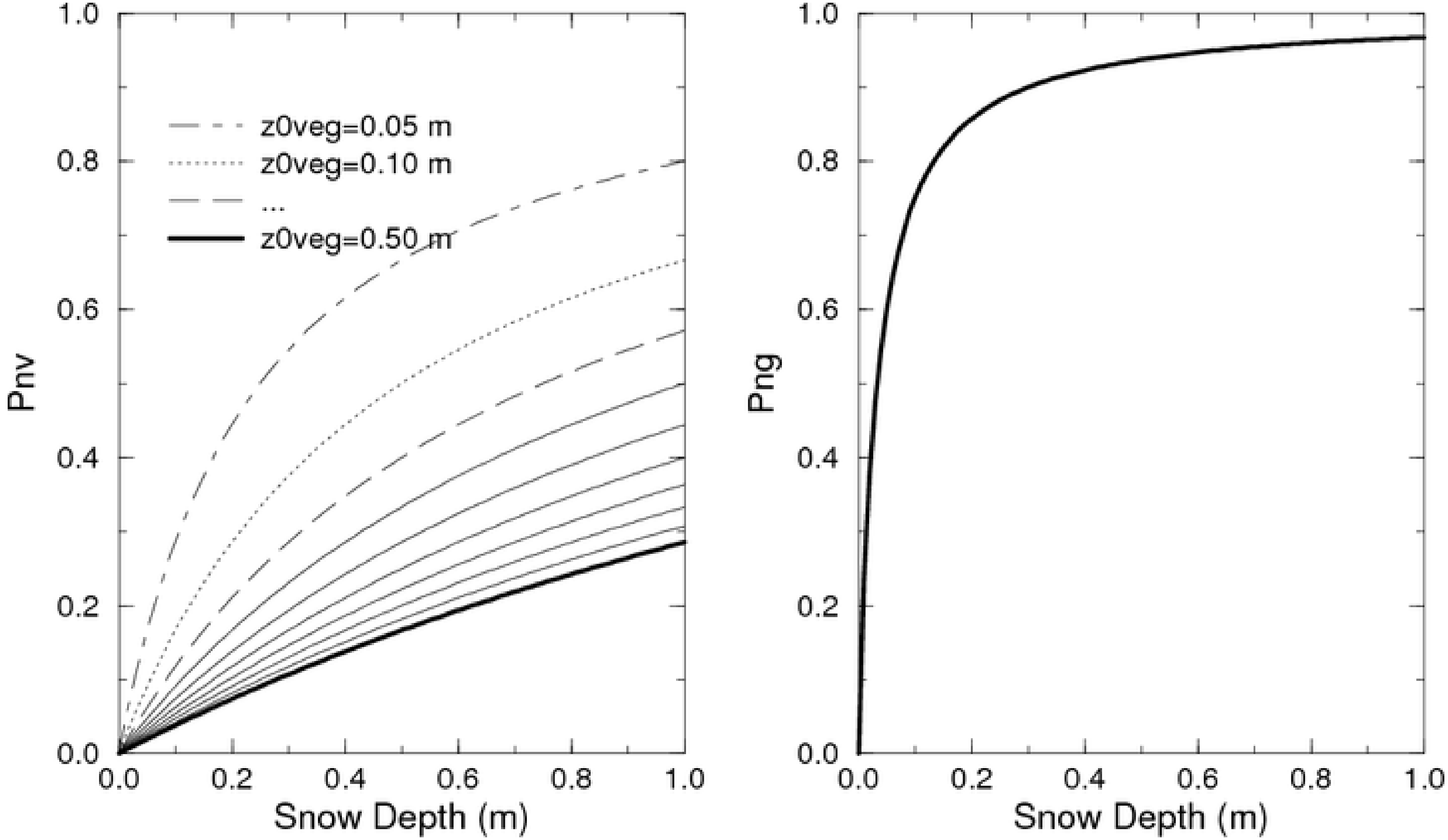
veg → $$p_{nv} = S_n/(S_n + \rho_{sn} * 5 * z_{0veg})$$

$$p_n = veg\, p_{nv} + (1 - veg)\, p_{ng}$$ , TOTAL snow cover fraction

# Snow fraction in EBA, D95 and 3-L

SMHI

Basic ideas:  cover bare-ground faster...and taller vegetation with lower pnv



# Snow cover fraction

Simpler parameterizations of snow cover fraction (SCF) usually relates SCF to the snow water equivalent (SWE) or the snow depth (Hsn) along with some critical value. Two examples are

$$c_{sn} = \min\left(1, \frac{S}{15}\right).$$

ECMWF / Old HTESSEL

$S_{crit}$=15 mm

---

$$P_{ncv} = \frac{h_n}{h_n + 5 \times z_0}$$

The fraction $P_{nc}$ is calculated as:

$$P_{nc} = \min(1, W_n/W_1) \qquad (W_1 = 70\ mm)$$

ARPEGE-Climate Version 5.1

# Snow cover fraction

SMHI

However, the relationship between SCF and Hsn shows a clear seasonality dependence (a hysteresis effect); the increase of SCF with Hsn in autumn is more rapid than the decrease of SCF with Hsn during the spring melting period.

$$f_{sno} = \tanh\left(\frac{h_{sno}}{2.5 z_{0g} (\rho_{sno}/\rho_{new})^m}\right)$$

NCAR CLM

Niu and Yang (2007)

$z_{0g}$=0.01 m, $\rho_{new}$=100 kg $m^{-3}$, m~1.6

$$c_{sn} = \min\left(1, \frac{S/\rho_{sn}}{0.1}\right).$$

ECMWF / New HTESSEL

Dutra et al. (2010)

$SCF=S_n/(S_n+ \rho_{sn} * 5 * z_{0veg})$

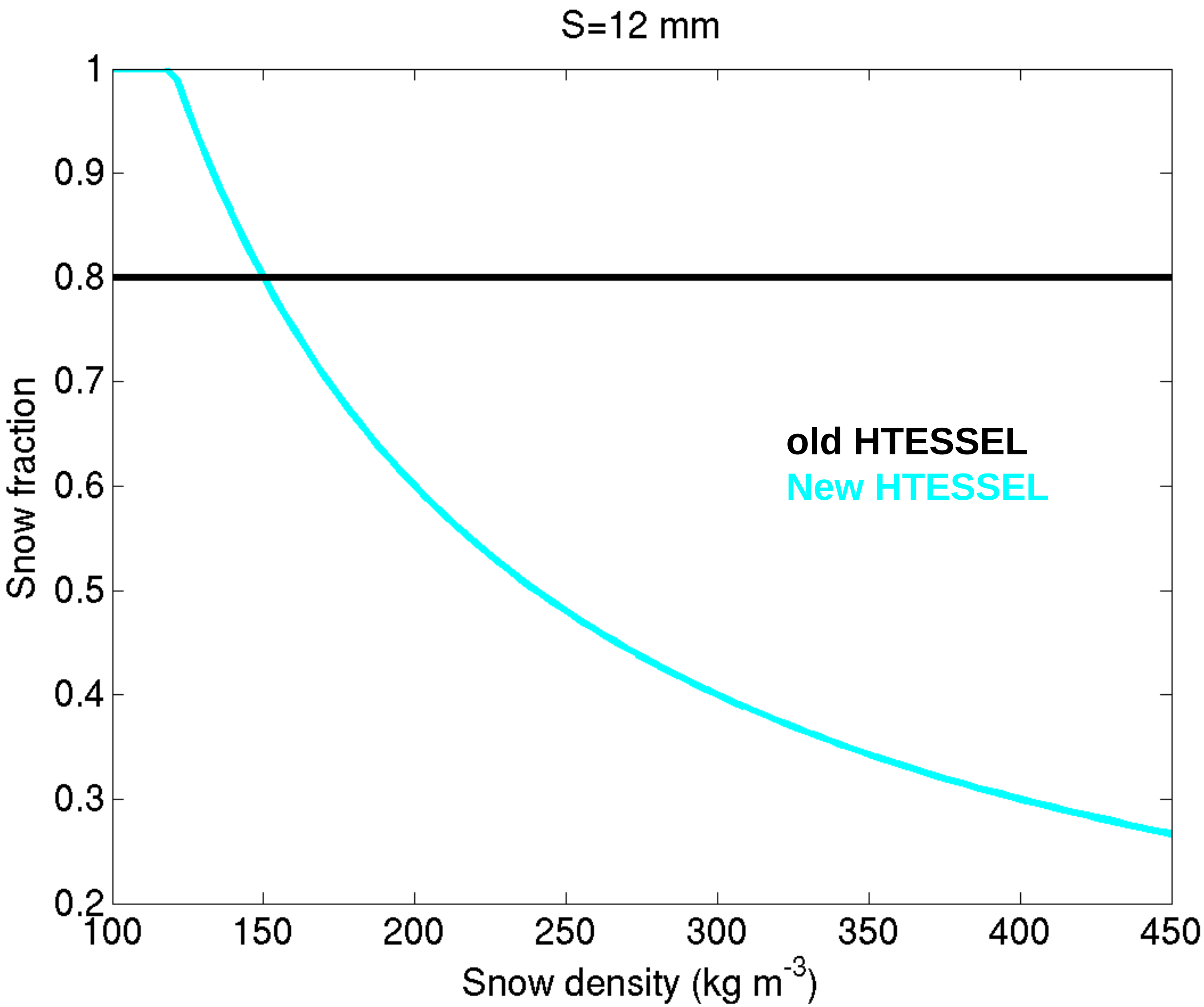
SURFEX/ISBA

D95 and 3-L

Douville et al. (1995)

Douville, H., J.-F. Royer, J.-F. Mahfouf, 1995. A new snow parameterization for the Météo-France climate model, Clim. Dyn., 12, 21–35.
Niu G.-Y and Z.-L. Yang, 2007. An observation-based formulation of snow cover fraction and its evaluation over large North American river basins, J. Geophys. Res., 112, D21101, doi:10.1029/2007JD008674.

# Different parameterisations of snow fraction



# 3-L details

**3-L: ISBA-ES is more detailed:**
- an N-layer scheme (default 3)
- explicit compaction (and melt densification)
- radiative transfer
- explicit energy budget: prognostic variables = albedo, density, SWE and ***H***
- liquid water content (using enthalpy concept)

$$H_{s\,i} = c_{s\,i}\,D_{s\,i}\,(T_{s\,i} - T_f) - L_f\,(W_{s\,i} - W_{l\,i})$$

New prog. variable

2 prognostic variables “for the price of one”...

$$T_{s\,i} = T_f + (H_{s\,i} + L_f\,W_{s\,i})\,/\,(c_{s\,i}\,D_{s\,i}) \qquad (W_{l\,i} = 0)$$

$$W_{l\,i} = W_{s\,i} + (H_{s\,i}/L_f) \qquad (T_{s\,i} = T_f)$$

# 3-L details

3-L - Explicit snow scheme: 4 prognostic variables
(N-layers, default=3, have used 10…)

***Separate Explicit Snow Energy Budget**:
Snow scheme ONLY called where snow is falling or where it exists already

$$\frac{\partial W_s}{\partial t} = (P_n + P_{rn} - R_{l\,N} - E_n)$$

$$\frac{1}{\rho_{s\,i}}\frac{\partial \rho_{s\,i}}{\partial t} = \frac{\sigma_{s\,i}}{\eta_{s\,i}(T_{s\,i}, \rho_{s\,i})} + a_{sc}\exp\left[-b_{sc}(T_f - T_{s\,i}) - c_{sc}\max(0,\ \rho_{s\,i} - \rho_{sc})\right]$$

$$H\left[\begin{aligned} c_{s\,i} D_{s\,i}\frac{\partial T_{s\,i}}{\partial t} &= G_{s\,i-1} - G_{s\,i} - F_{s\,i} \\ \frac{\partial W_{l\,i}}{\partial t} &= R_{l\,i-1} - R_{l\,i} + F_{s\,i}/L_f \qquad (W_{l\,i} \le W_{l\,i\,\max}) \end{aligned}\right.$$

Plus the same albedo Eq

# 3-L details

Simple downgradient thermal transfer, plus transmission of solar radiation

$$G_{s\,i} = J_{s\,i} + Q_{s\,i}$$

$$Q_{s\,i} = R_g\,(1 - \alpha_n)\exp\left(-\nu_{s\,i}\,z_{s\,i}\right)$$

$$J_{s\,i} = 2\,\overline{\Lambda}_{s\,i}\,\frac{(T_{s\,i} - T_{s\,i+1})}{(D_{s\,i} + D_{s\,i+1})}$$

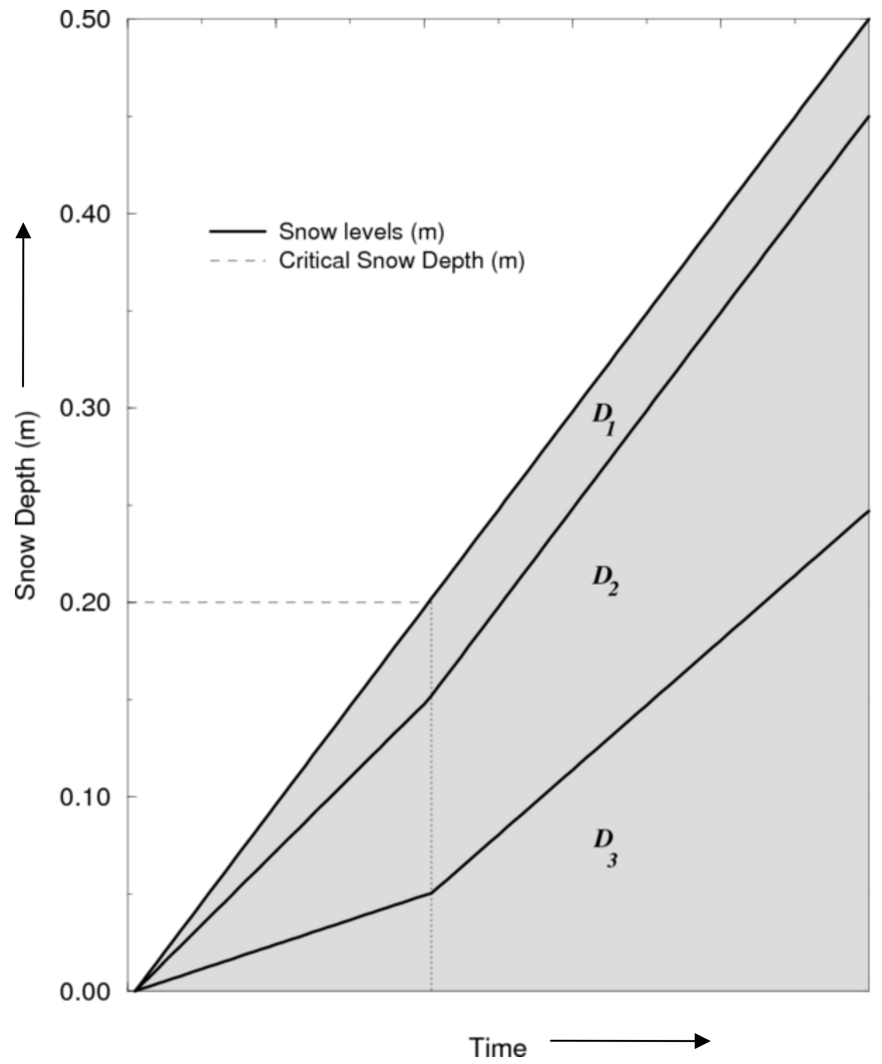
$$\overline{\Lambda}_{s\,i} = \frac{D_{s\,i}\Lambda_{s\,i} + D_{s\,i+1}\Lambda_{s\,i+1}}{D_{s\,i} + D_{s\,i+1}}$$

Coupling with the soil-vegetation currently very simple (given uncertainty in snow fraction, roughness parameterizations…)

# 3-L details

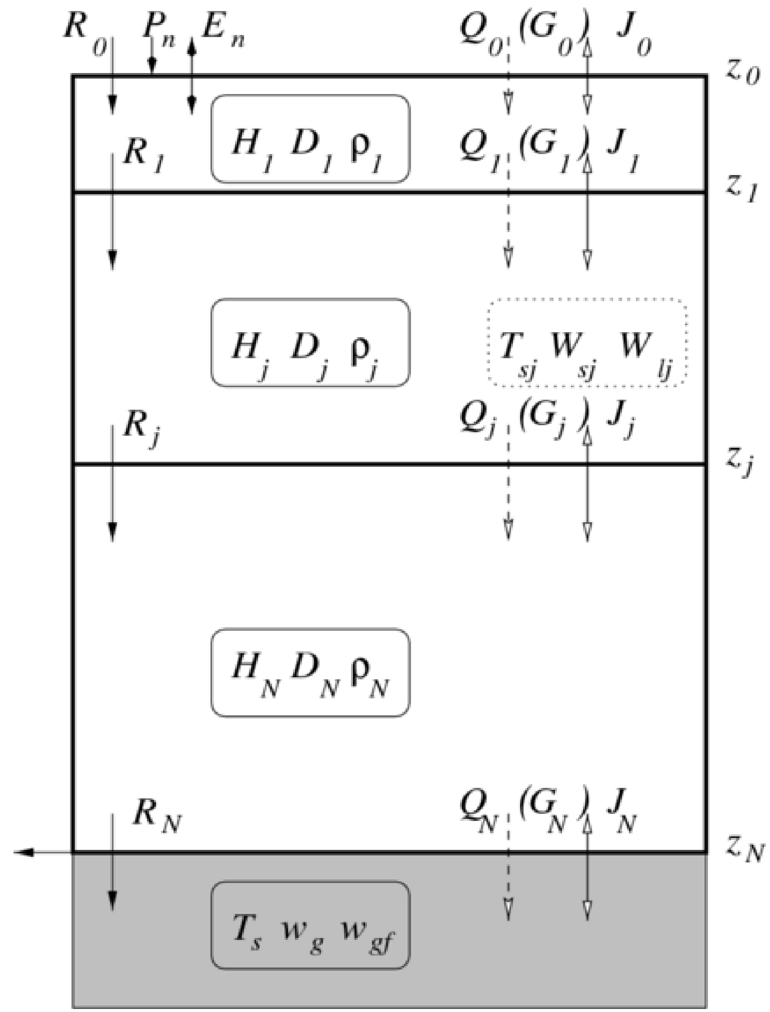
**Time varying layer thicknesses**

Total snowpack mass and energy conserved as grid changes in *t*

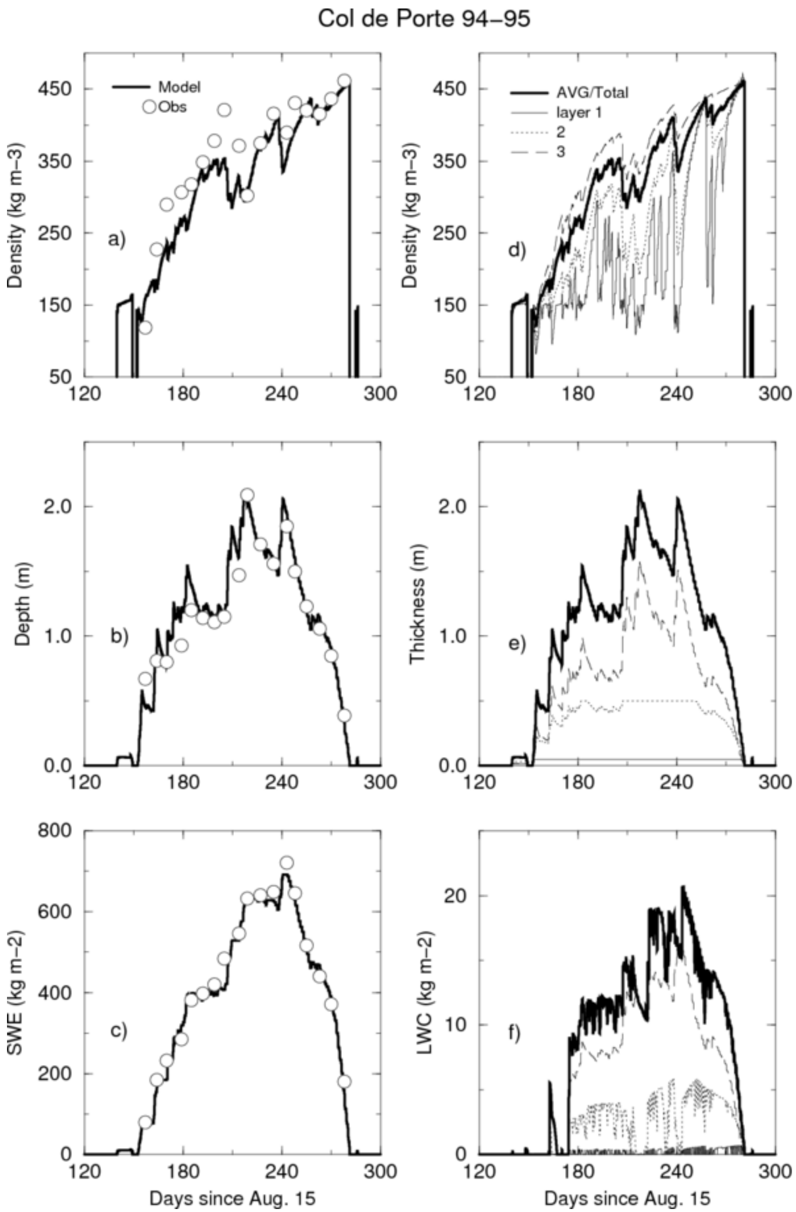


# 3-L details

Grid and numerical setup essentially the same as for the soil heat diffusion Equation (DIF)



# 3-L details




**ISBA-ES**

Off-line simulation for Col de Porte (1994-95)

Observed SWE, Depth

Using default 3L configuration


THANKS!