SMHI

Investigation of the sensibility of snow and energy-flux conditions to surface and vegetation parameters for a forest site using the Multi-Energy Balance option in SURFEX

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Vegetation and snow

versus

Studies have shown that

- peak snow amount (SWE) in boreal conifer forests is in general less than that over open land due to sublimation loss of intercepted snow in forest (0-60% difference) (Rutter et al. 2009).

Rutter, N. et al. 2009: Evaluation of forest snow processes models (SnowMIP2). J. Geophys. Res. 114, D06111, doi:10.1029/2008JD011063
Moore and Wondzell 2007 DOI: 10.1111/j.1752-1688.2005.tb03770.x
Schelker et al. 2013 http://dx.doi.org/10.1016/j.jhydrol.2013.01.015

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- in the north-west pacific forest harvesting generally increases the fraction of precipitation that is available to become streamflow and increases rates of snowmelt (Moore and Wondzell 2007).

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- in the north-west pacific forest harvesting generally increases the fraction of precipitation that is available to become streamflow and increases rates of snowmelt (Moore and Wondzell 2007).
- in northern Sweden clear-cutting increased snow accumulation (SWE), made snow melt to occur earlier, created more rapid stream responses and made snowmelt runoff to increase. But not all years! (Schelker et al. 2013)

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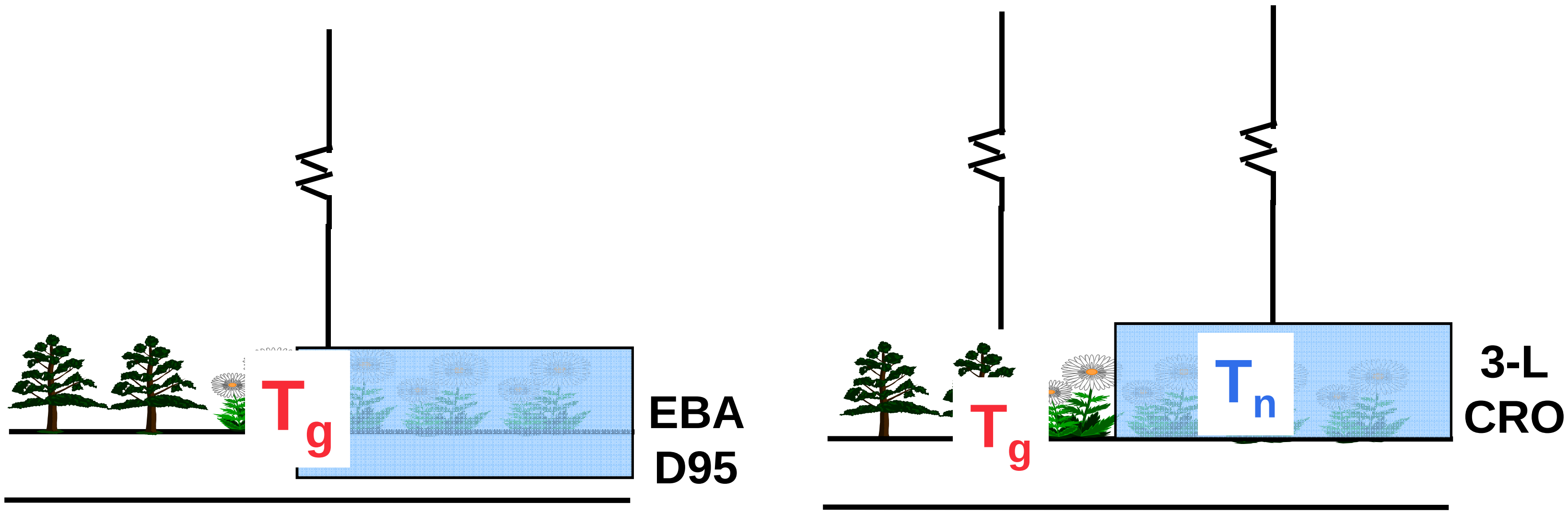
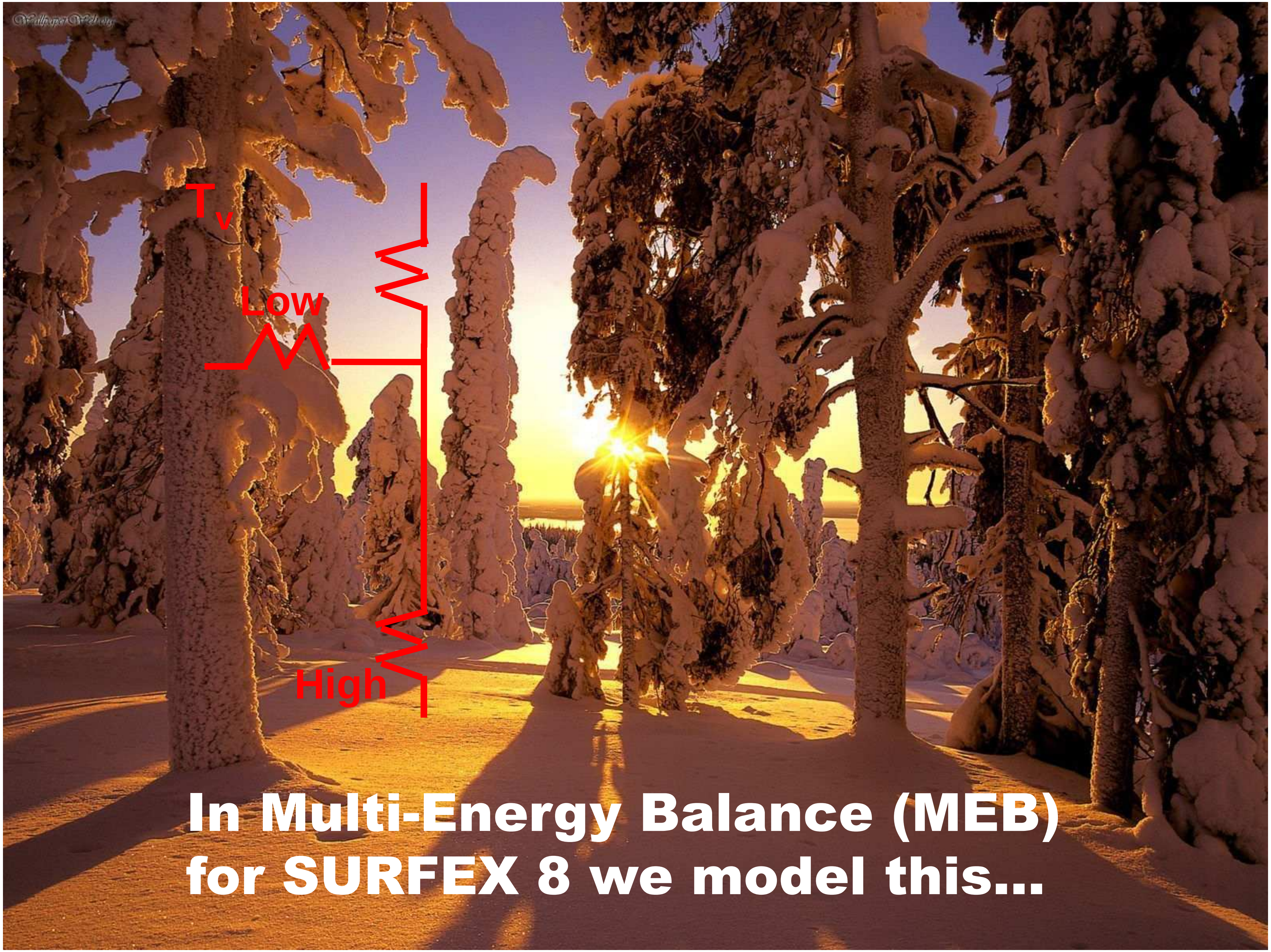
SURFEX versions -7.3



No explicit canopy vegetation energy balance (temperature)!


T_v
Low
High
In Multi-Energy Balance (MEB)
for SURFEX 8 we model this...


...and this!
High
T
v
Low


...and this!
Low
High
T_v

High
Low
T_v
...and in future this!

Aerodynamic resistances in MEB

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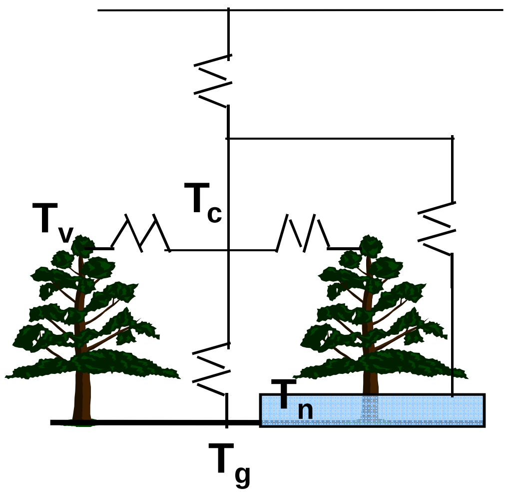
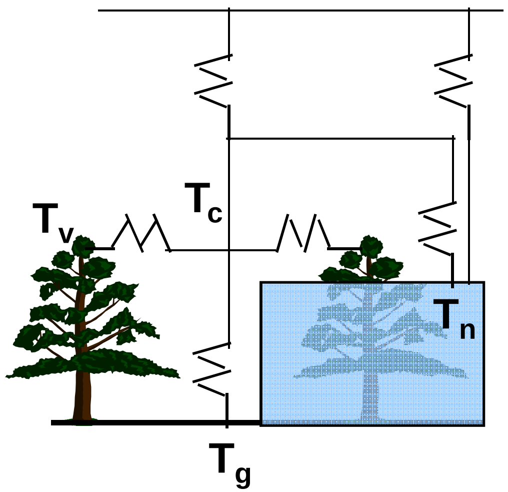
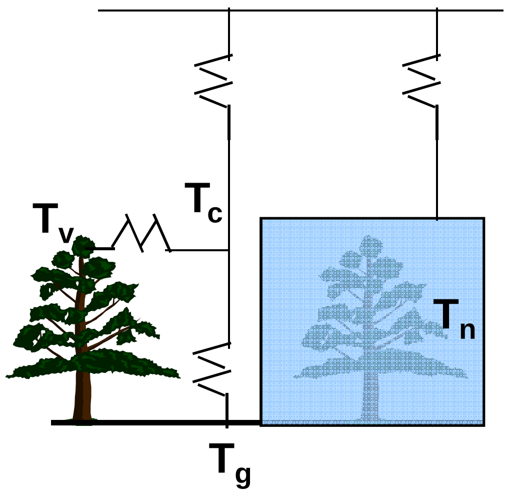
Snow well below the canopy



Snow partly buries the canopy



Snow buries the canopy



Radiation in this MEB SURFEX7.3 setup

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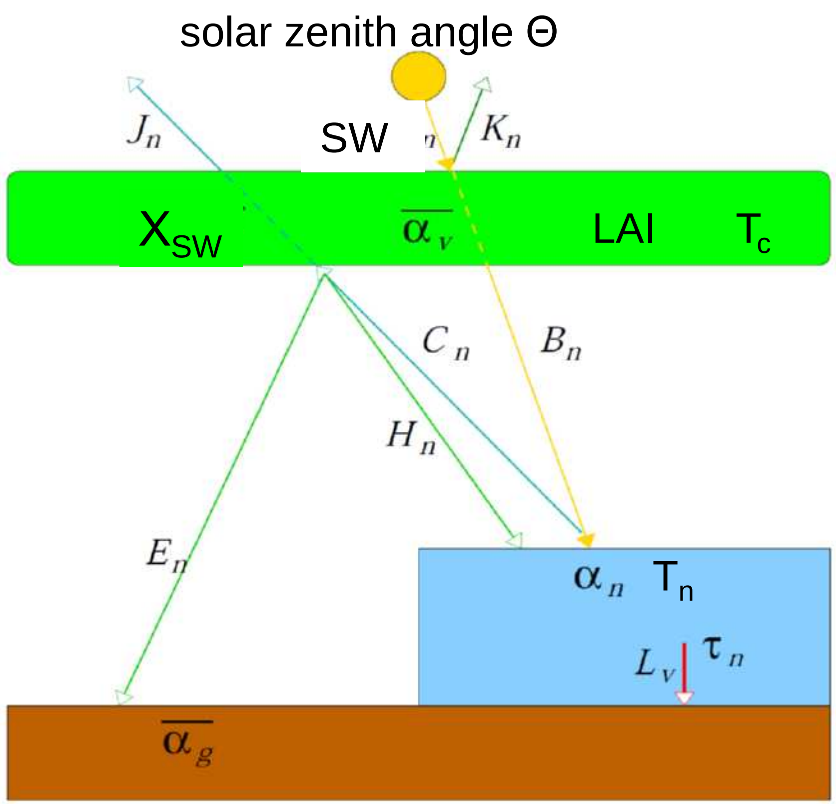
Short-wave radiation with reflections for snow well below the canopy



View factors:

$$\chi_{LW} = e^{-\tau_{LW}\,LAI}$$

$$\chi_{SW} = e^{-\tau_{SW}\,LAI/\cos\Theta}$$

Please note:

In MEB in SURFEXv8 the default canopy radiation scheme is TR_ML (Carrer et al. 2013) which is different from the ones used in this study!

Sensitivity test of parameters

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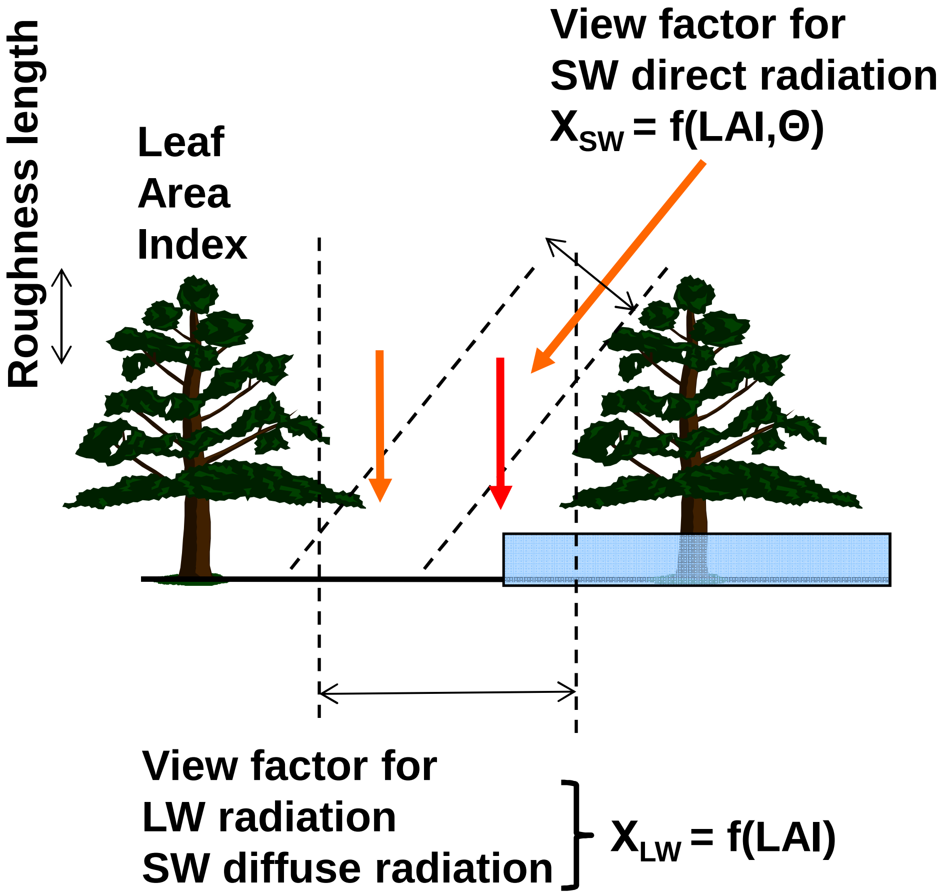
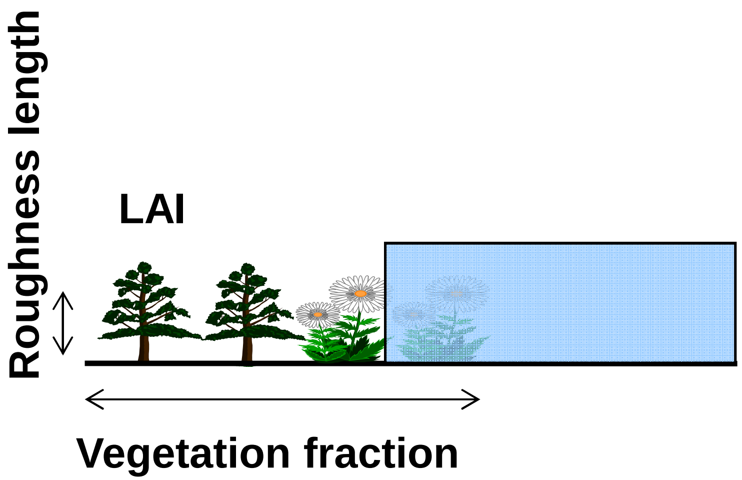
MEB

Ratio momentum/heat roughness



Classical ISBA

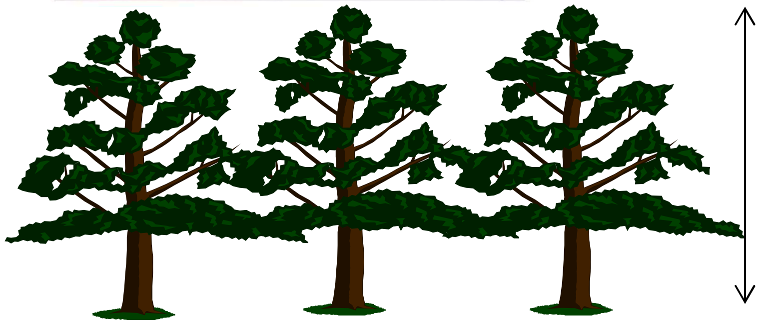
Ratio momentum/heat roughness



FMI site Sodankylä, northern Finland

Observations for the period January 1 2008 – December 31 2009:

For forcing and validation at 18 m:
Temperature
Specific humidity
Wind
Sensible heat flux
Latent heat flux

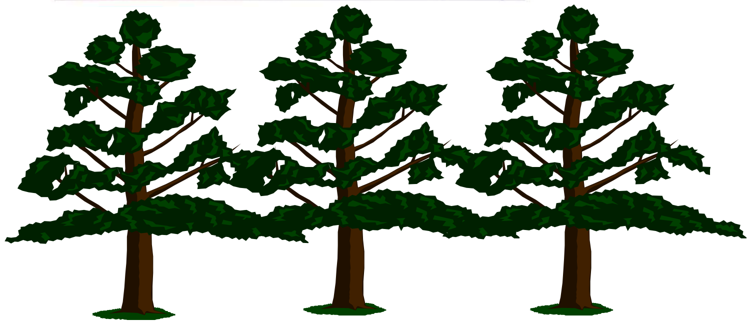


12.5 m pine forest with LAI~1.3

Other forcing:
Incoming short- and long-wave
Precipitation

For validation of snow:
Snow depth

FMI site Sodankylä, northern Finland

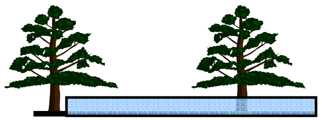
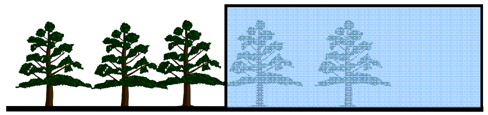


Heat fluxes are measured over the forest while snow depth is measured in a clearing. Thus, different sets of surface parameters (e.g. LAI) should be needed to find optimum correspondence between simulated and observed heat fluxes and snow depth, respectively.

What are the optimal sets of parameters?

Also, how does MEB physics perform compared to classical ISBA physics?

SURFEX offline simulations

	MEB	Classical ISBA
		
Soil	**diffusion (11 layers)**	
Snow model	**3-L**	
Time step	**600 s**	
Period	**1/1 2008 – 31/12 2009**	
LMEB	**true**	**false**

Cost functions for each simulation

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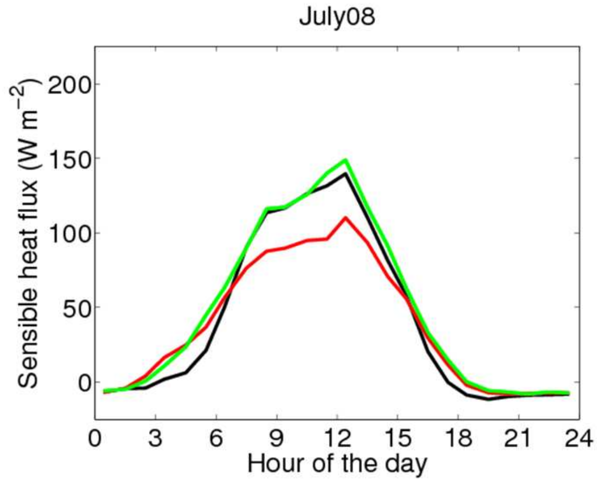
Cost function for heat fluxes:

$$cost_{flux} = \sum_{periods} \left(\overline{\|H\|_2} + \overline{\|LE\|_2} \right)$$

where each period represents a mean daily cycle for July 2008, September 2008, March 2009, April-May 2009



Definitions of L^p norm = $\|data\|_p = \|sim - obs\|_p = \left(\sum_{i=1}^{n} |sim_i - obs_i|^p\right)^{1/p}$

normalized L^p norm = $\overline{\|data\|_p} = \dfrac{\|sim - obs\|_p}{1/2\left(\|sim\|_p + \|obs\|_p\right)}$

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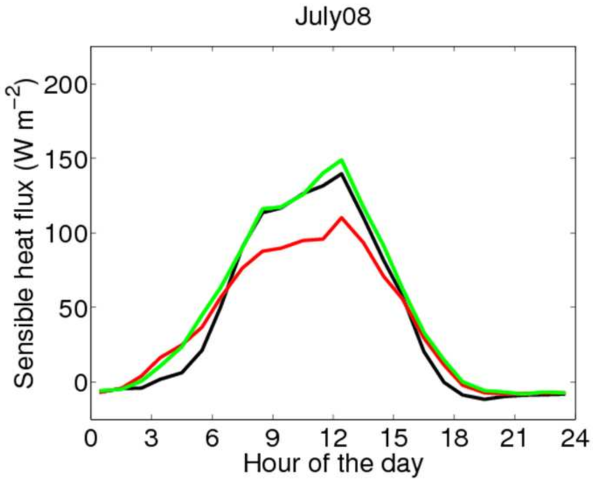
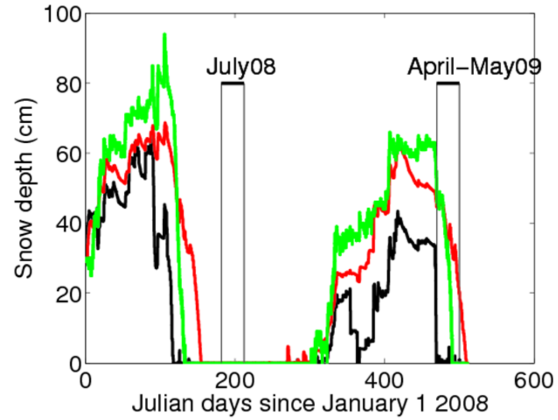


Cost function for time of vanishing snow:

$$cost_{snow} = \overline{\|snow\ depth < 25\ cm\ at\ end\ of\ snow\ season\|_2}$$



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Sensitivity test of parameters

SMHI

For MEB and classical ISBA:

Leaf Area Index, LAI (-)	0.45, 0.7, 0.95, 1.2, 1.45
Roughness length, z_{0m} (m)	0.5 (MEB), 0.7, 0.9, 1.1, 1.3, 1.5 (ISBA)
Ratio z_{0m} / z_{0h} (-)	1.0 (ISBA), 10.0

For MEB only:

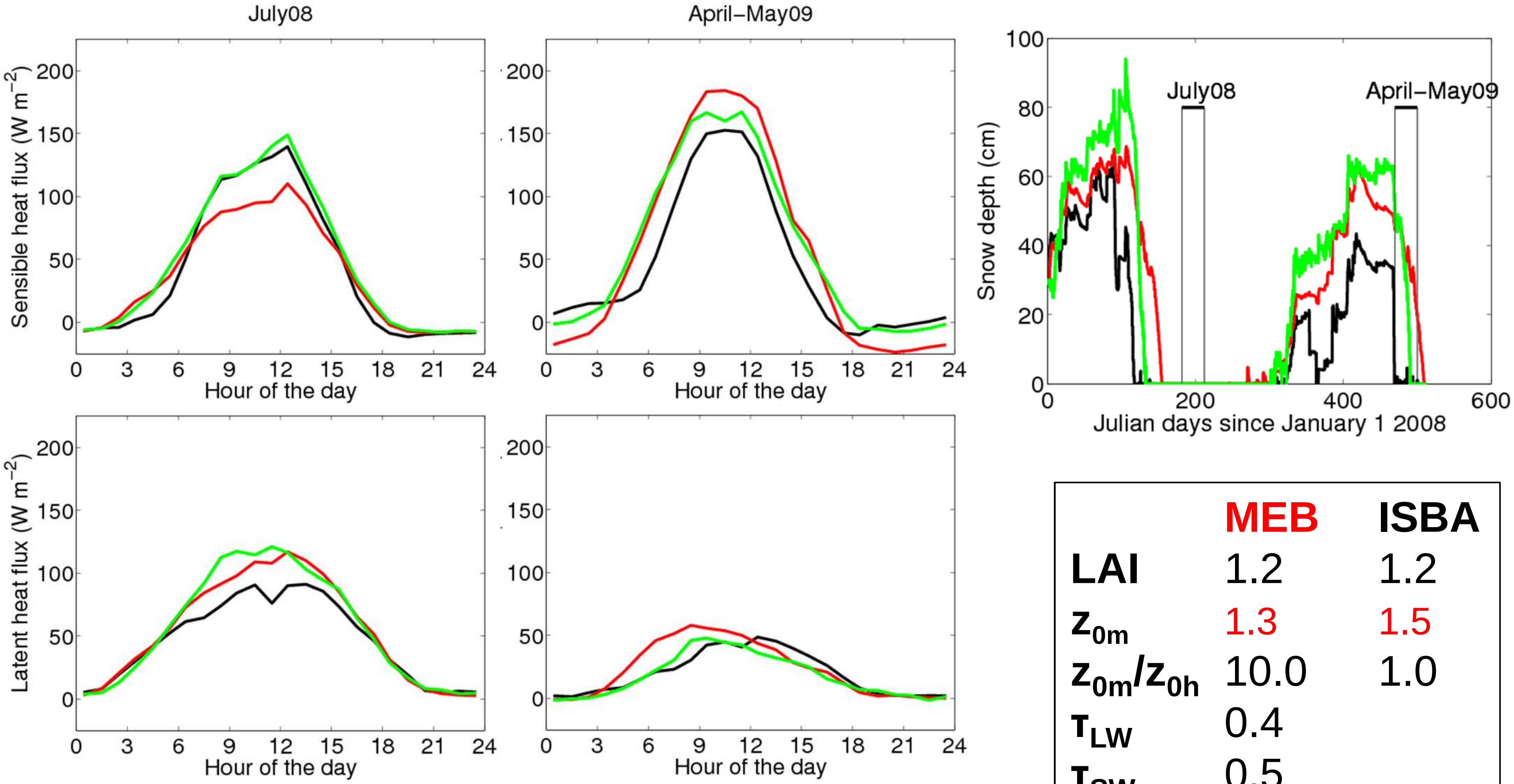
Extinction coefficient, τ_{LW} (-)	0.3, 0.4, 0.5, 0.6, 0.7
Extinction coefficient, τ_{SW} (-)	0.3, 0.4, 0.5, 0.6, 0.7

For classical ISBA only:

Fraction of vegetation, veg (-)	0.4, 0.6, 0.8, 1.0

All together these combinations give
625 simulations for MEB
200 simulations for classical ISBA

Results optimized for heat fluxes

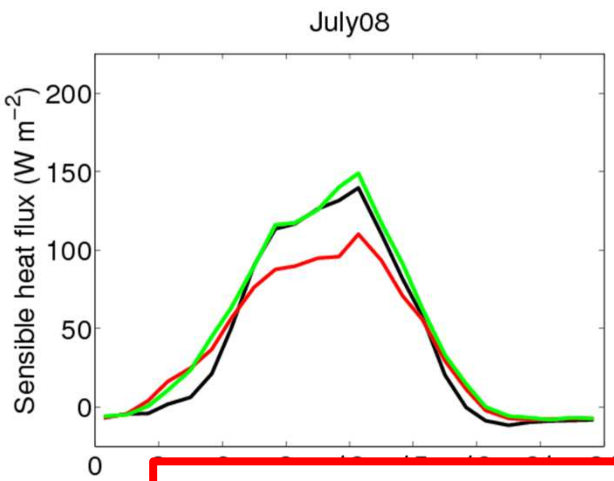


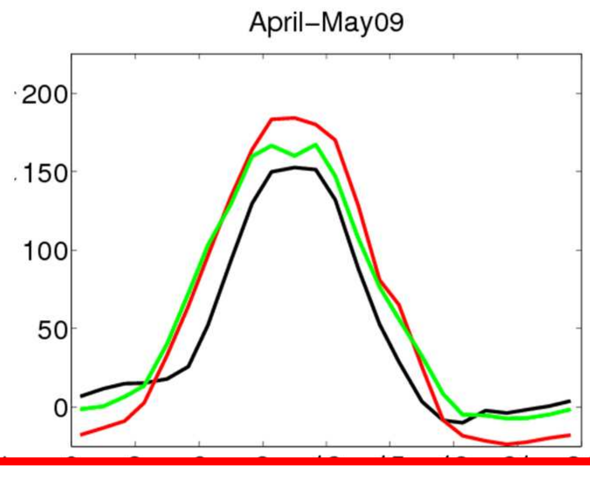
	MEB	ISBA
LAI	1.2	1.2
z_{0m}	1.3	1.5
z_{0m}/z_{0h}	10.0	1.0
τ_{LW}	0.4	
τ_{SW}	0.5	
veg		1.0

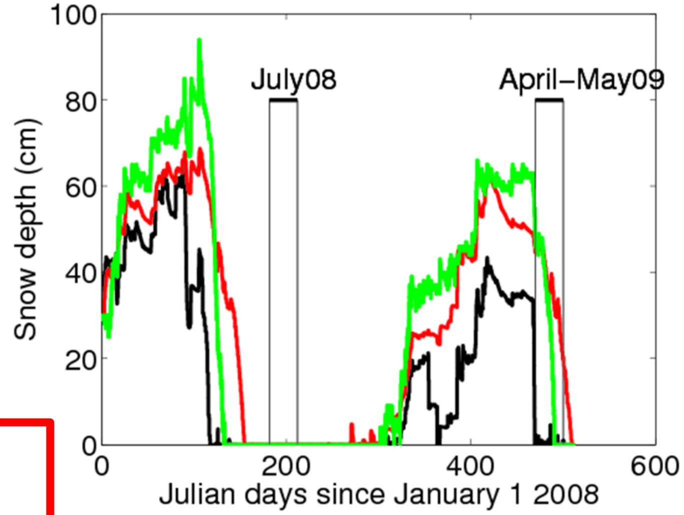
Observations
MEB
Classical ISBA

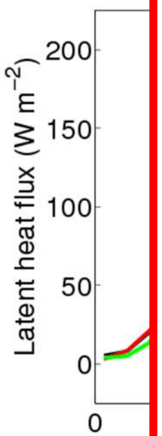
Results optimized for heat fluxes

SMHI









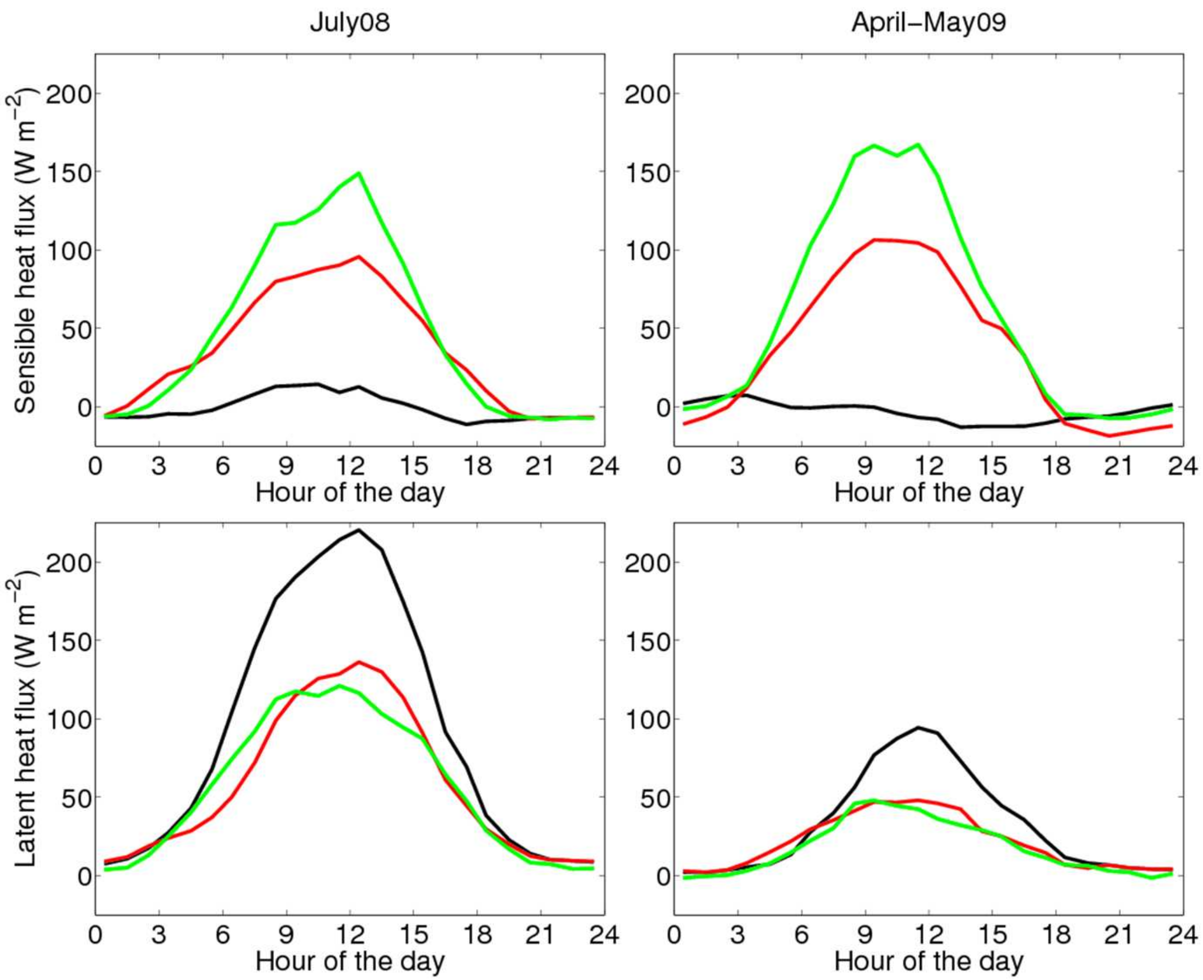
- **Fluxes simulated fairly well of course**
- **LAI similar to observed, 1.2-1.4**
- **z_{0m} at its upper limit!**
- **T-values close to typical value 0.5**
- **MEB snow-depth peak underestimated**
- **MEB vanishing snow too late**
- **ISBA snow underestimated**

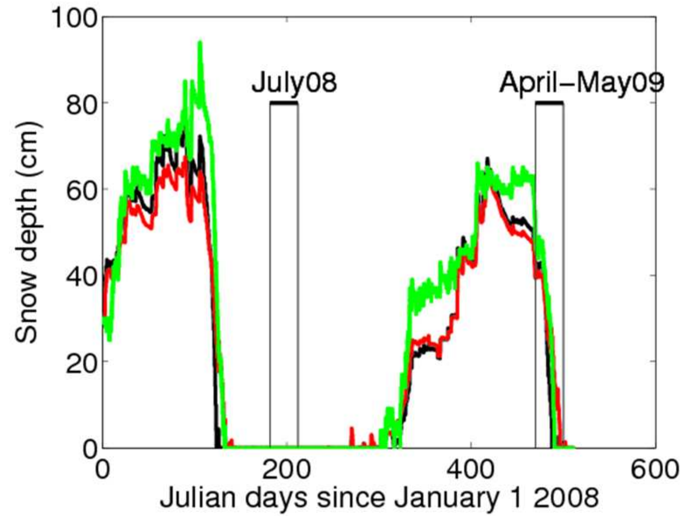
Observations
MEB
Classical ISBA

	MEB	ISBA
LAI	1.2	1.2
z_{0m}	1.3	1.5
z_{0m}/z_{0h}	10.0	1.0
τ_{LW}	0.4	
τ_{SW}	0.5	
veg		1.0

Results optimized for snow disappearance

SMHI

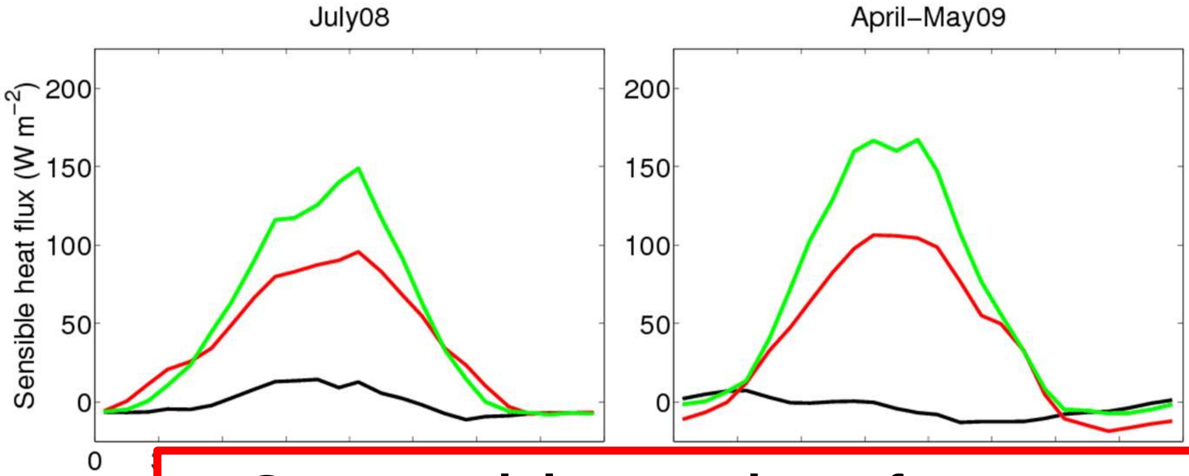


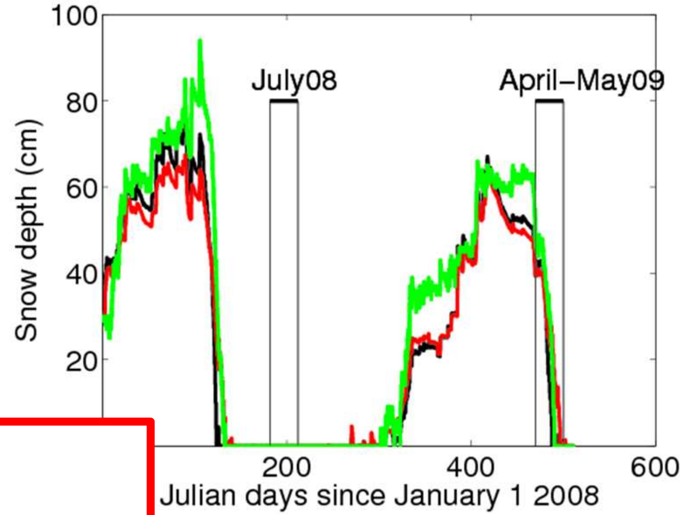


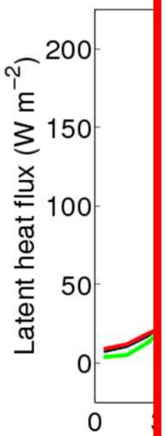
	MEB	ISBA
LAI	0.45	1.45
z_{0m}	1.1	0.7
z_{0m}/z_{0h}	10.0	10.0
τ_{LW}	0.5	
τ_{SW}	0.6	
veg		0.4

Observations
MEB
Classical ISBA

Results optimized for snow disappearance







- Snow vanishes on time of course
- Snow depth still underestimated
- MEB latent good, sensible underestimated
- ISBA latent too large, sensible too small
- LAI at its lower/upper limit!
- T-values close to typical value 0.5
- ISBA veg at its lower limit!

	MEB	ISBA
AI	0.45	1.45
0m	1.1	0.7
0m/z_{0h}	10.0	10.0
LW	0.5	
SW	0.6	
veg		0.4

Observations
MEB
Classical ISBA

Snow fraction in SURFEX

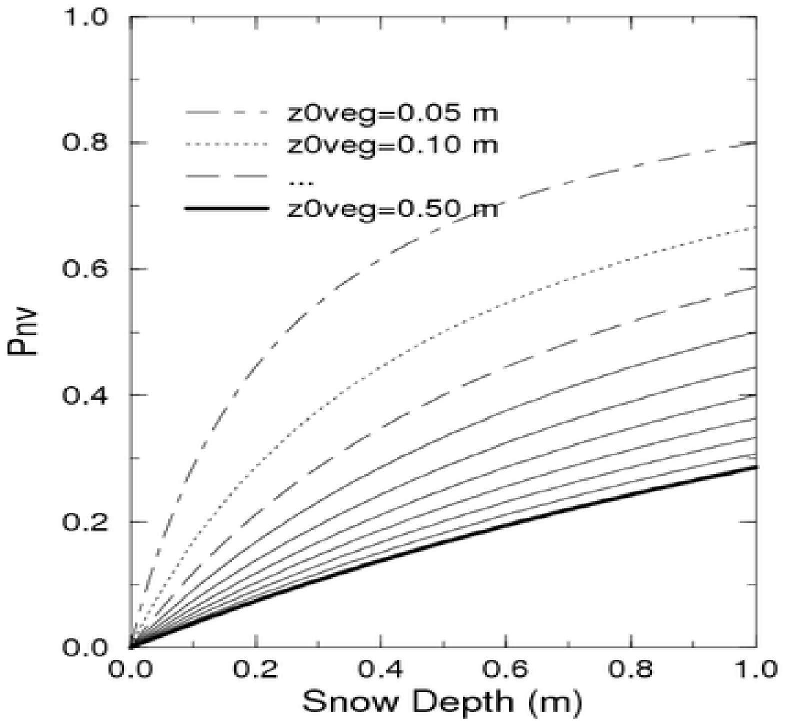
SMHI

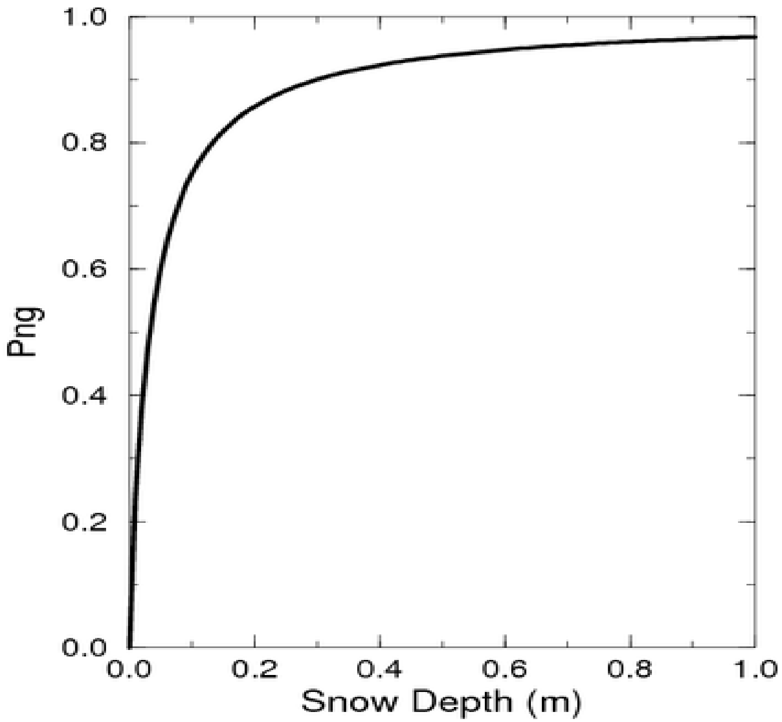
soil → $p_{ng} = W_n / (W_n + W_{crn})$ $(W_{crn} = 10\ \mathrm{kg\,m}^2)$

veg → $p_{nv} = S_n/(S_n + \rho_{sn} * 5 * z_{0veg})$ Douville et al. (1995)

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

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

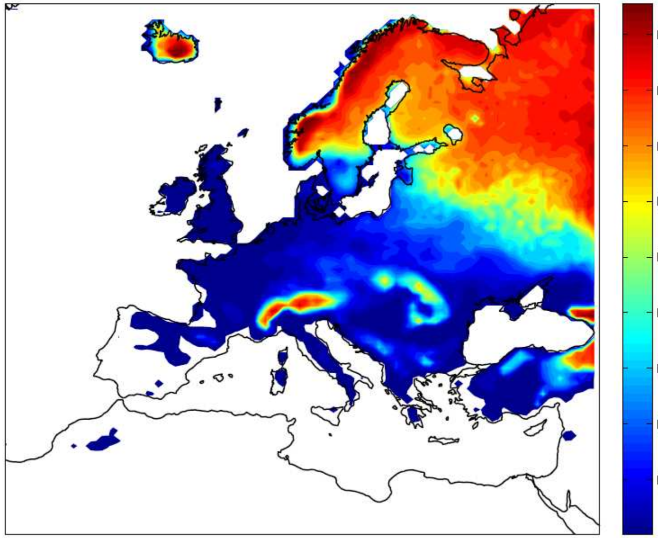


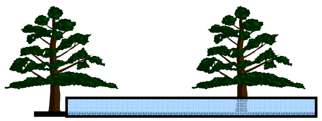


Douville, H., J.-F. Royer, J.-F. Mahfouf, 1995. A new snow parameterization for the Météo-France climate model, Clim. Dyn., 12, 21–35.

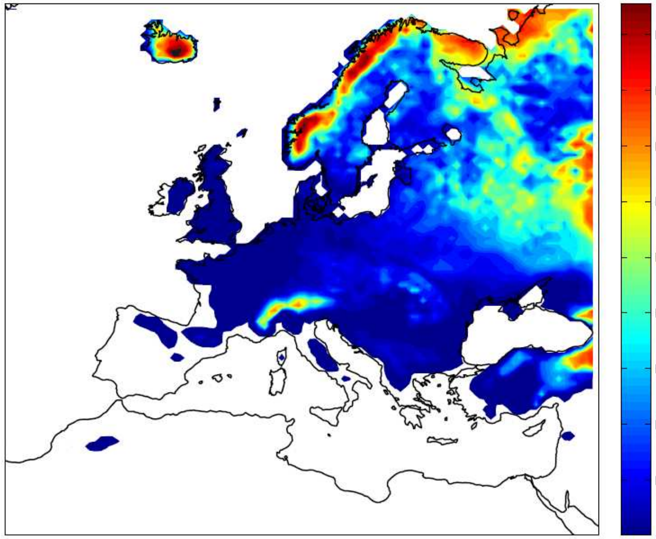
Winter (DJF) snow fraction in SURFEX

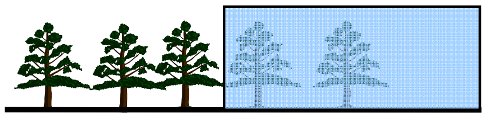
With MEB





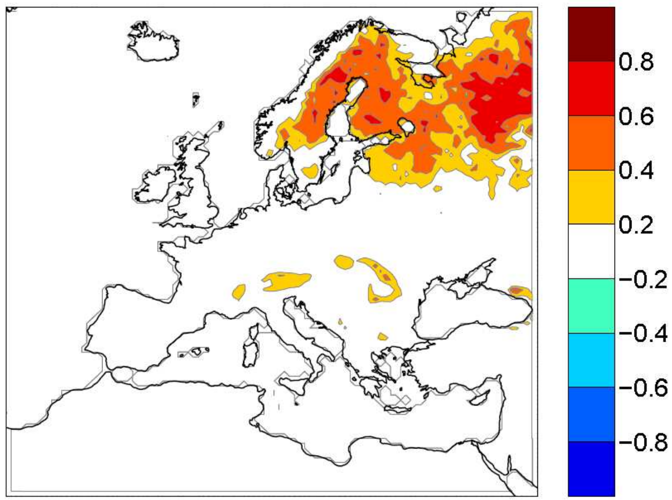
With classical ISBA





SURFEX offline for 1987-1989 forced by output from SMHI RCM model.

Difference MEB - ISBA



Comments

- With classical ISBA physics it becomes difficult to realistically simulate both energy fluxes and snow depth/cover for a forest landscape. Explicit canopy in MEB offers a much more physically consistent parameterisation of the relevant processes.
- The cost function formulations in combination with multi simulations could be further developed by e.g. steepest decent or Monte Carlo technic. This is a valuable tool for development and tuning!
- More forest observational sites will be included in further development and tuning of SURFEX-MEB.
- 2-3 papers are currently in the pipeline to document MEB.
- MEB is available as option in SURFEXv8. For now recommended for forest vegetation types only.


THANKS!