



A multi-layer snow cover model for numerical weather prediction and climate models.

Sascha Bellaire¹, Michael Lehning^{1,2}, Jean-Marie Bettems³, Oliver Fuhrer³

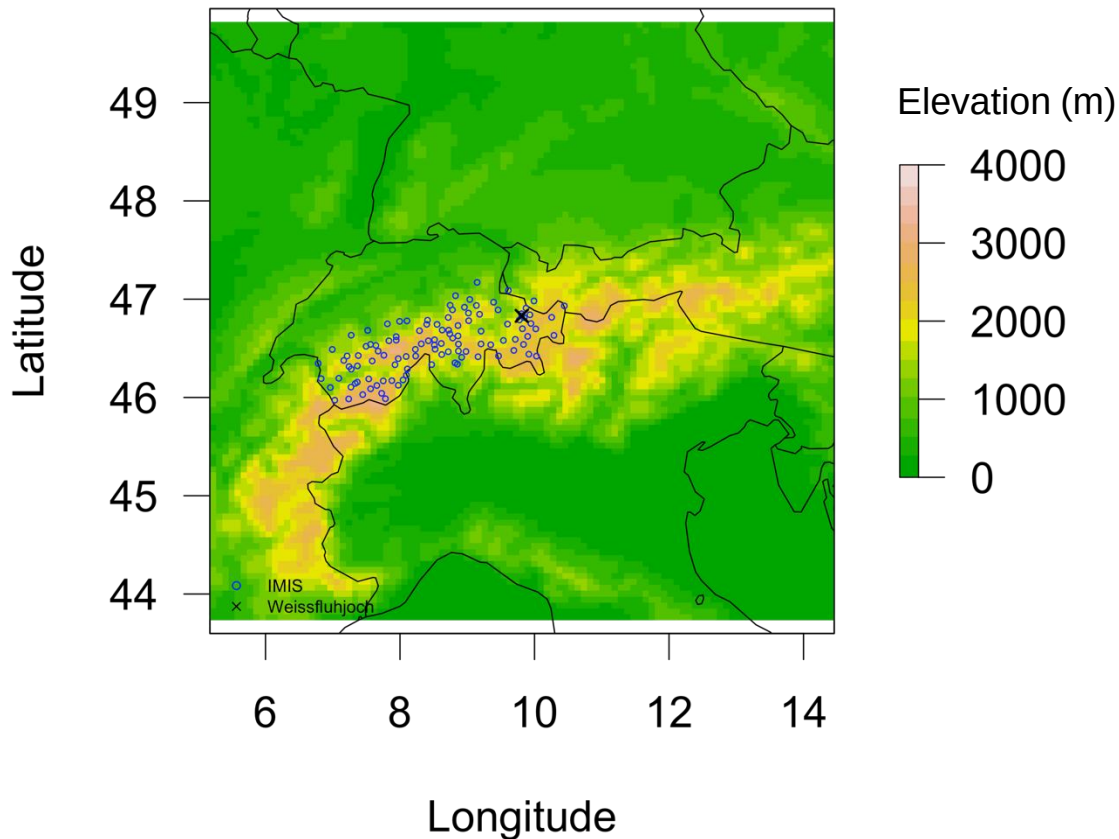
¹WSL Institute for Snow and Avalanche Research SLF, Davos, Switzerland

²CRYOS, School of Architecture, Civil and Environmental Engineering, EPFL, Lausanne, Switzerland

³MeteoSwiss, Zurich, Switzerland

Budapest, 31.10.2018

Phase II: Implementation/Validation – COSMO-7 Setup



- o ... ~ 700 km x 700 km domain centered around Davos ...
- o ... covering most of the Alpine ridge ...
- o ... computationally inexpensive ...
- o .. boundary conditions from COSMO-7 analysis ...
- o ... 72-hour forecast/hindcast
16 February 2017 00UTC

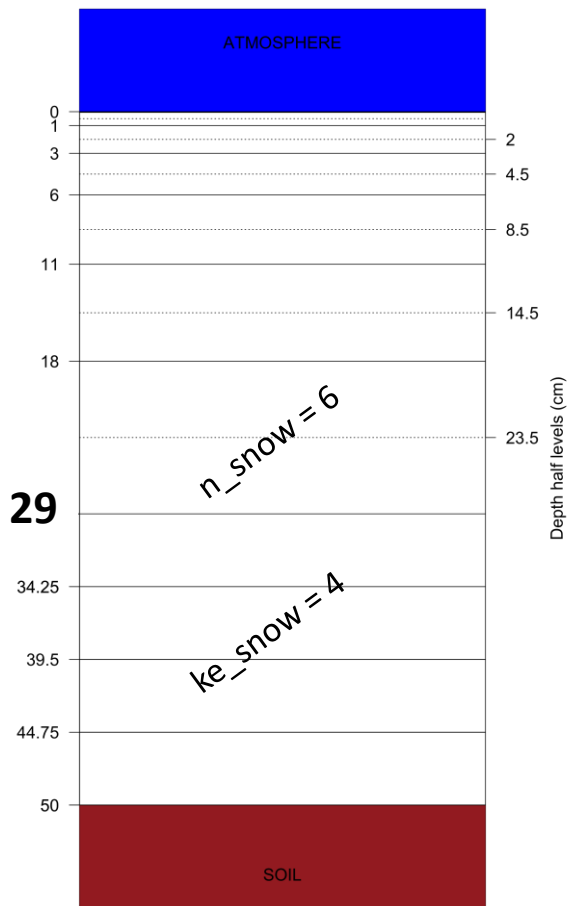
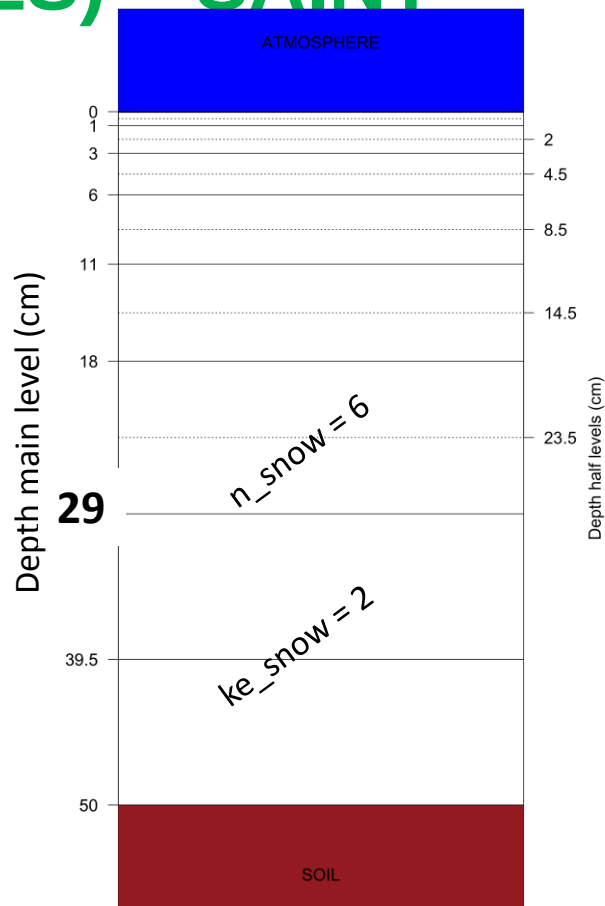
Intercantonal Measurement and Information System (IMIS)



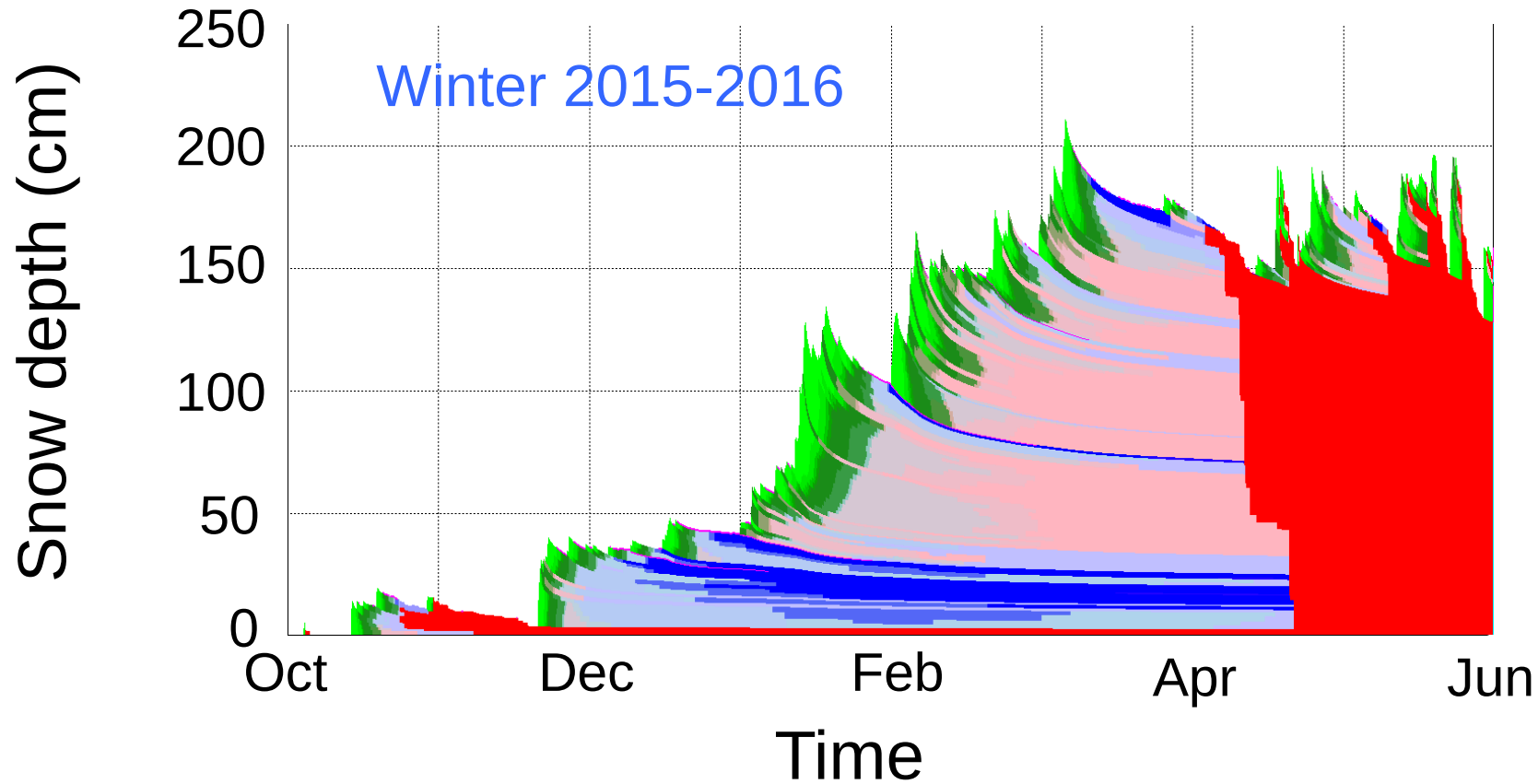
Experimental Site Weissfluhjoch, Davos, Switzerland



Phase II: Snow cover scheme schematic (MLS) – SAINT

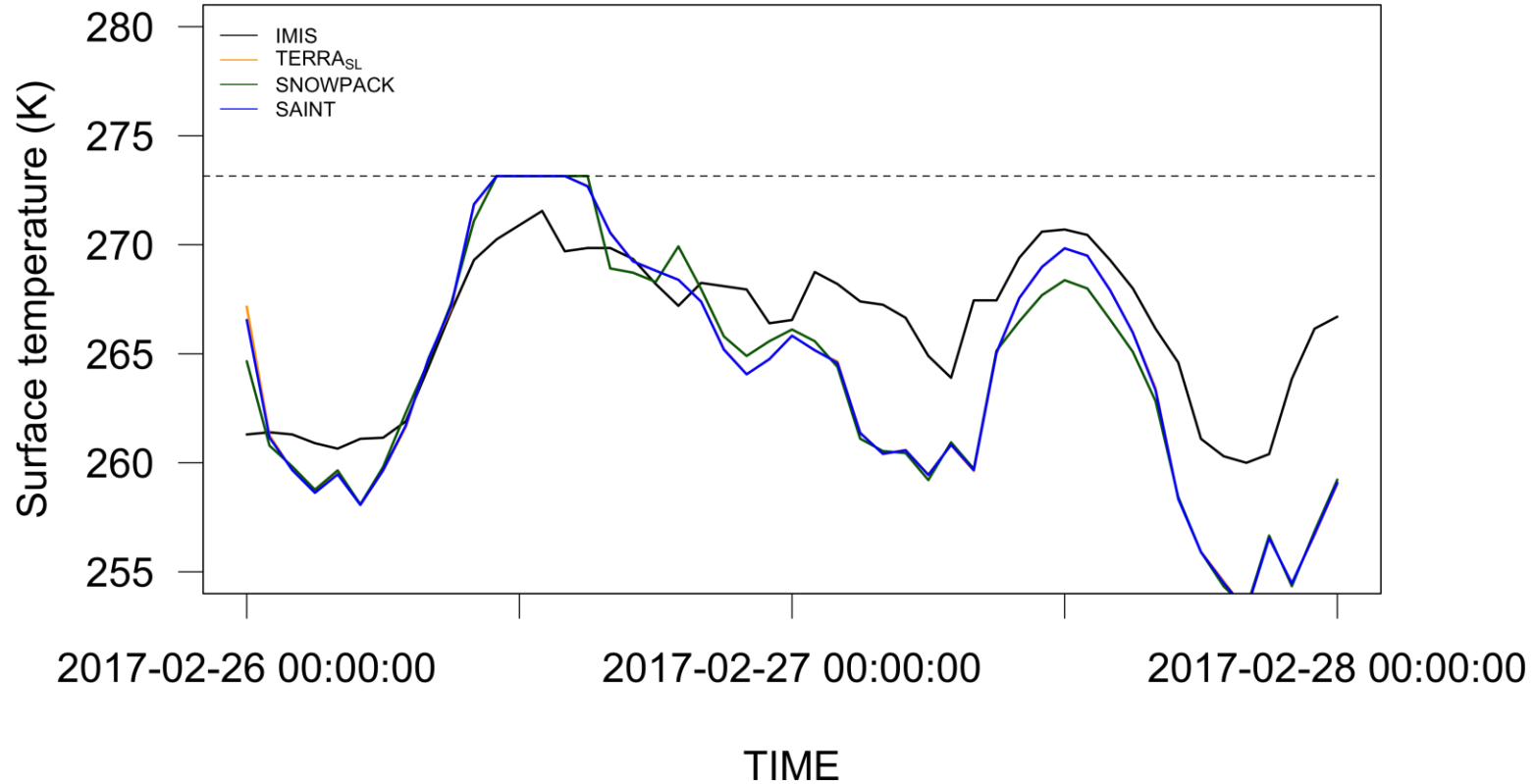


Phase II: Benchmark simulations – SNOWPACK vs. MSL



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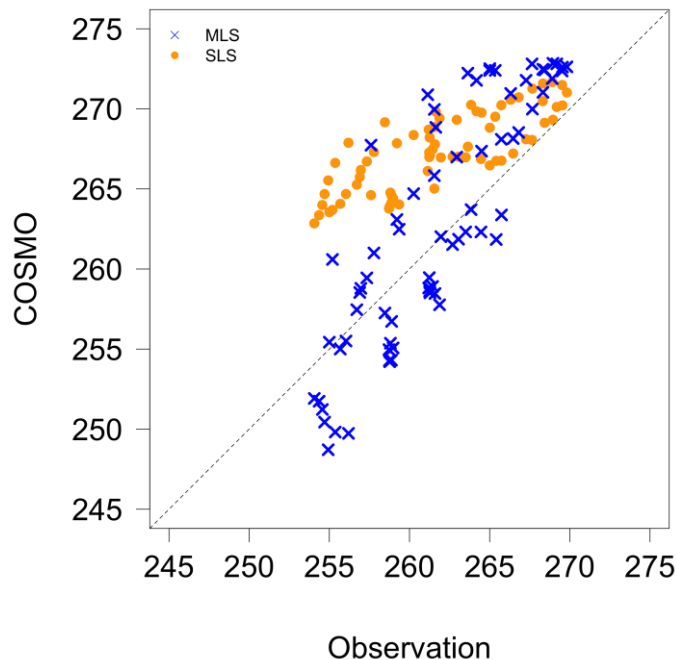
Weissfluhjoch



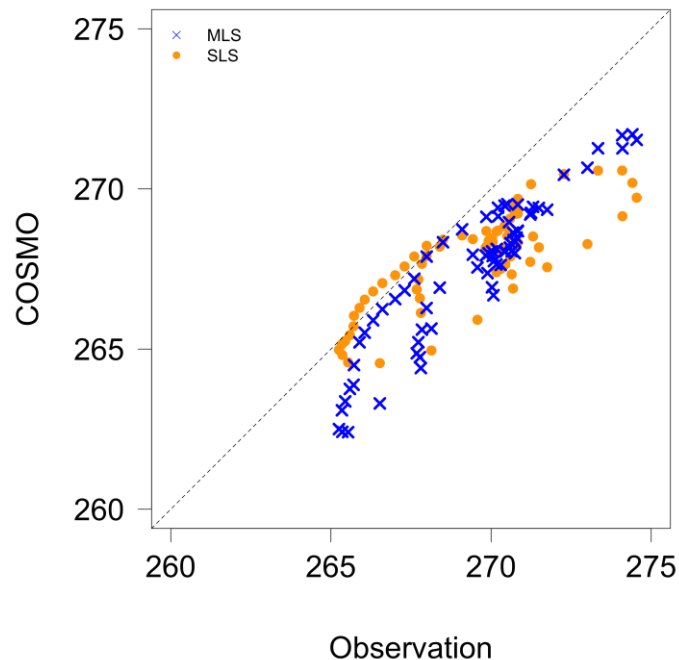
Phase II: Snow cover scheme (MLS) – Initial Results

All IMIS (N = 112)

T_SNOW



T (1st level)

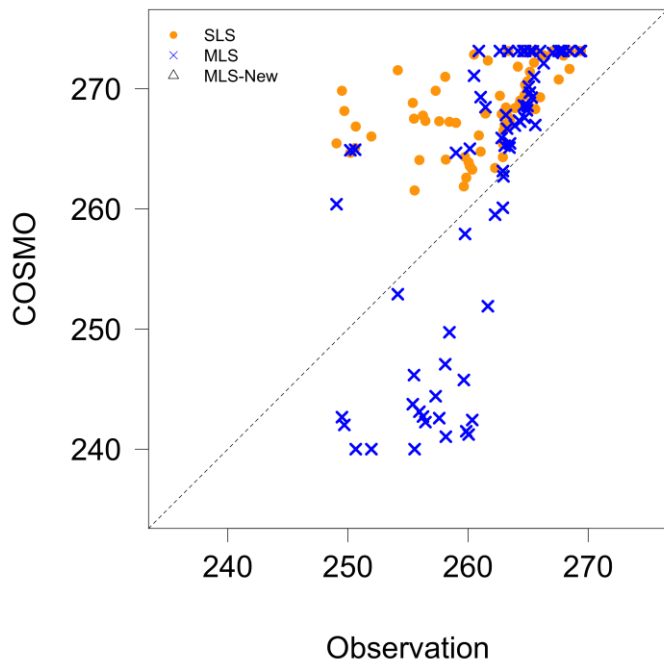


● = Single layer snow cover scheme (SLS)

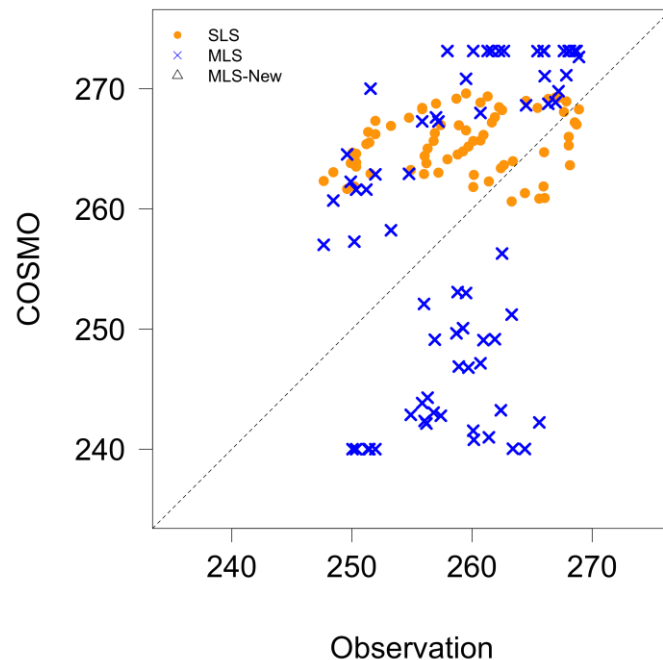
✕ = Multi-layer snow cover scheme (MLS)

Phase II: Snow cover scheme (MLS) – Initial Results

Weissfluhjoch
(FOR_E + FOR_D = 0.93)



Boveire-PointedeToules
(FOR_E = FOR_D = 0)



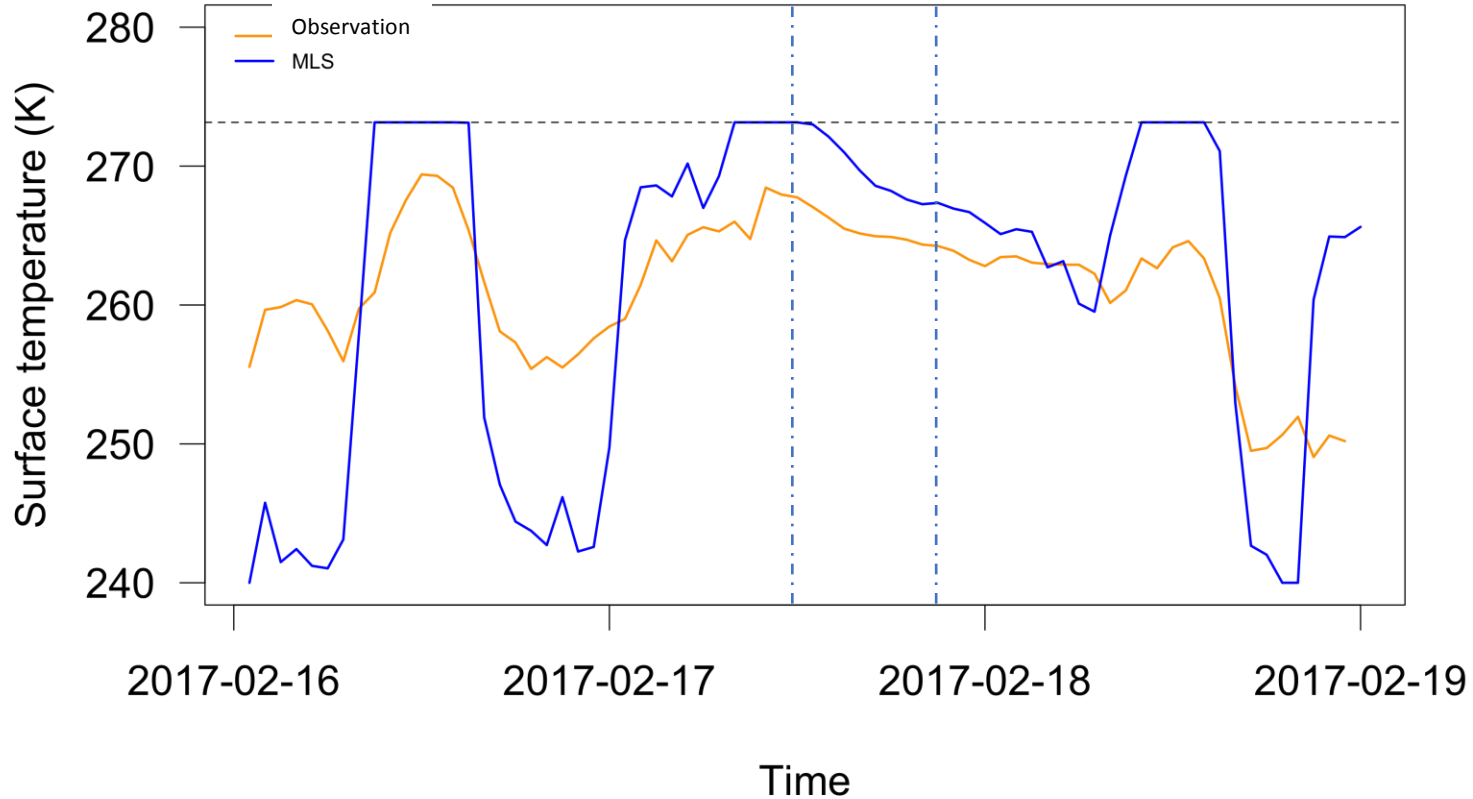
● = Single layer snow cover scheme (SLS)

× = Multi-layer snow cover scheme (MLS)

Phase II: Snow cover scheme - Meteorology

Weissfluhjoch

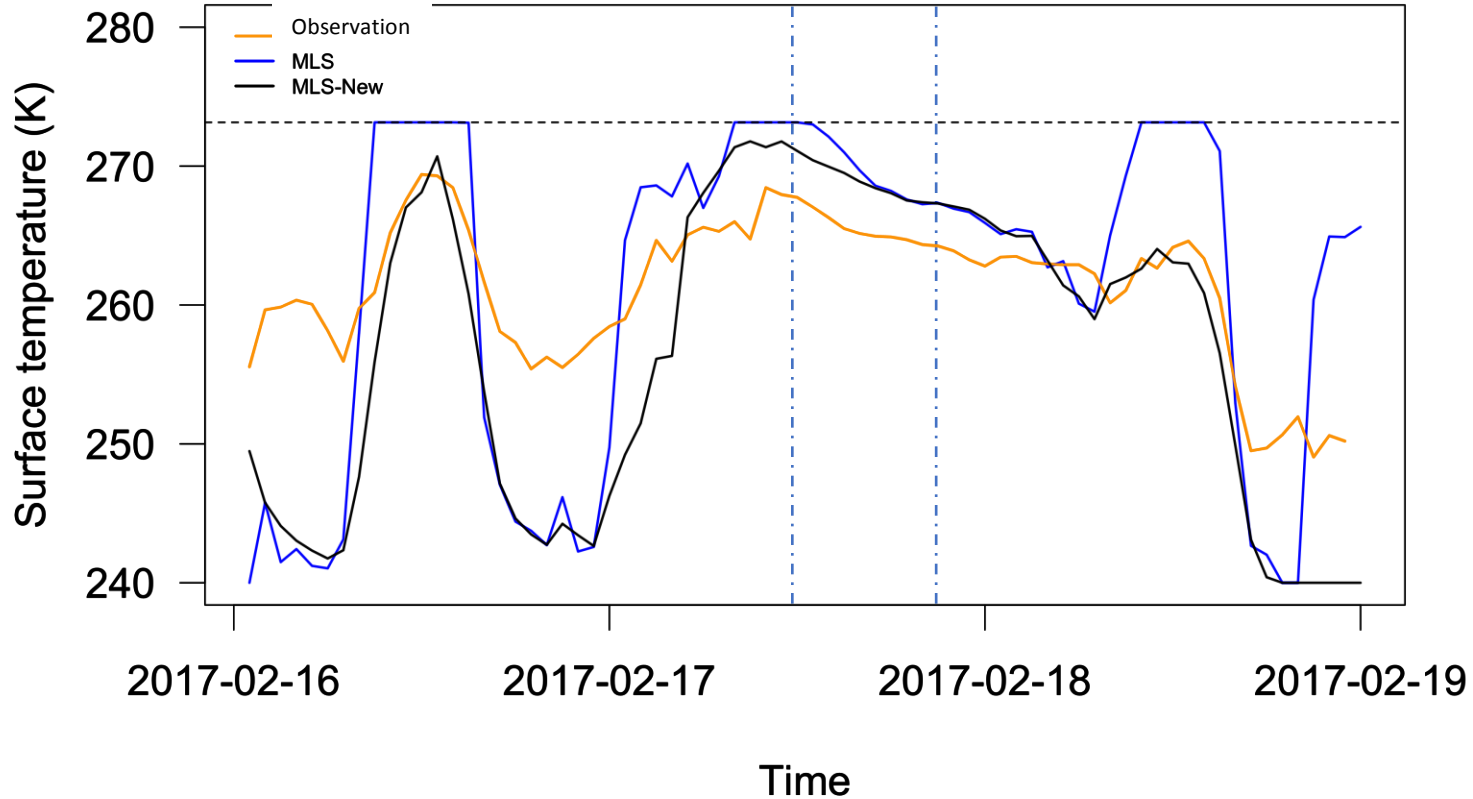
Snow



Phase II: Snow cover scheme - Meteorology

Weissfluhjoch

Snow




Phase II: Snow cover scheme (MLS) – TCH

Boundary-Layer Meteorology

October 2017, Volume 165, Issue 1, pp 161–180 | [Cite as](#)

How do Stability Corrections Perform in the Stable Boundary Layer Over Snow?

Authors [Authors and affiliations](#)

Sebastian Schlögl , Michael Lehning, Kouichi Nishimura, Hendrik Huwald, Nicolas J. Cullen, Rebecca Mott

Sensible heat flux:

$$H = \rho c_p C_H \bar{U} \Delta\theta,$$

Transfer Coefficient:

$$C_H = \frac{k^2}{\left[\ln\left(\frac{z_{\text{ref}}}{z_{0M}}\right) - \psi_m(\zeta) \right] \left[\ln\left(\frac{z_{\text{ref}}}{z_{0M}}\right) - \psi_s(\zeta) \right]},$$

Stability Corrections:

$$\psi_m(T, T_{sn}, \bar{U}) = a_1 B + b_1 S,$$

$$\psi_s(T, T_{sn}, \bar{U}) = a_2 B + b_2 S,$$

$$B = \Delta T / \bar{T}$$

$$S = z_{\text{ref}} g / \bar{U}^2$$

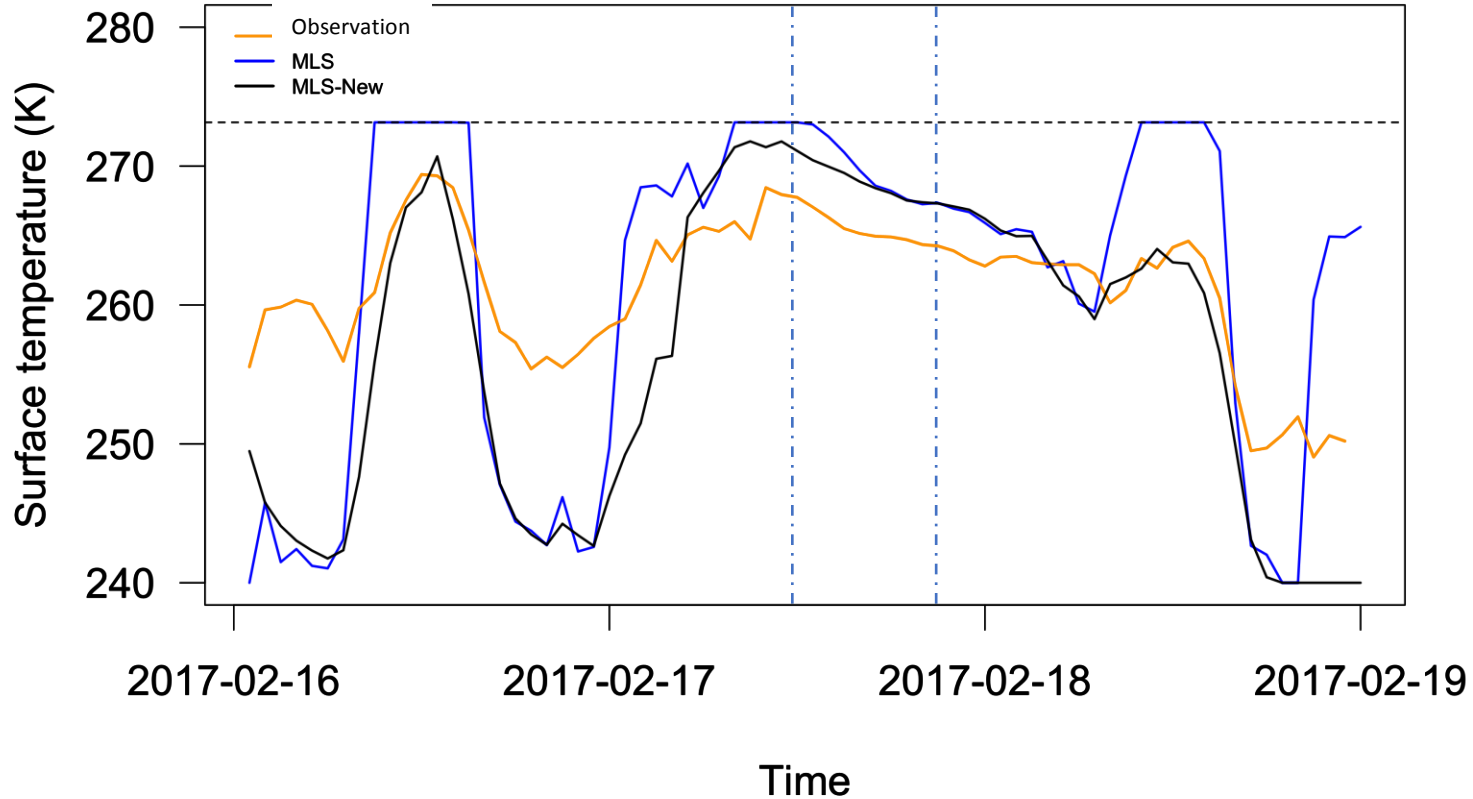
test site	a_1	b_1	test site	a_2	b_2
WFJ07 (3 m)	3.227	0.0043	WFJ07 (3 m)	-982.90	-0.0005
WFJ07 (5 m)	-4.441	0.0025	WFJ07 (5 m)	-642.51	0.0009
WFJ11	-30.74	0.0008	WFJ11	-1135.4	-0.0015
PM07 NWW	-191.93	0.0008	PM07 NWW	-751.73	-0.0005
PM07 SEE	-29.55	0.0090	PM07 SEE	-692.74	-0.0123
GR00 (1 m)	-145.41	-0.0914	GR00 (1 m)	-378.92	-2.0489
GR00 (2 m)	-179.56	-0.0369	GR00 (2 m)	-243.93	-0.7448
Universal	-65.35	0.0017	Universal	-813.21	-0.0014

where $k = 0.4$ is the von Kármán constant, $\zeta = (-k z_{\text{ref}} g T_*) / (\theta_s u_*^2)$ is the modelled stability parameter (stability parameter henceforth), $u_* = k \bar{U} (\ln(z_{\text{ref}}/z_{0M}) - \psi_m)^{-1}$ is the modelled friction velocity, $T_* = k (\theta_s - \theta_{z_{\text{ref}}}) (\ln(z_{\text{ref}}/z_{0M}) - \psi_s)^{-1}$ is the modelled temperature scale, z_{0M} is the aerodynamic roughness length and ψ_m and ψ_s are the stability corrections for momentum and scalars. In our analysis, we used the simple approach that the roughness

Phase II: Snow cover scheme - Meteorology

Weissfluhjoch

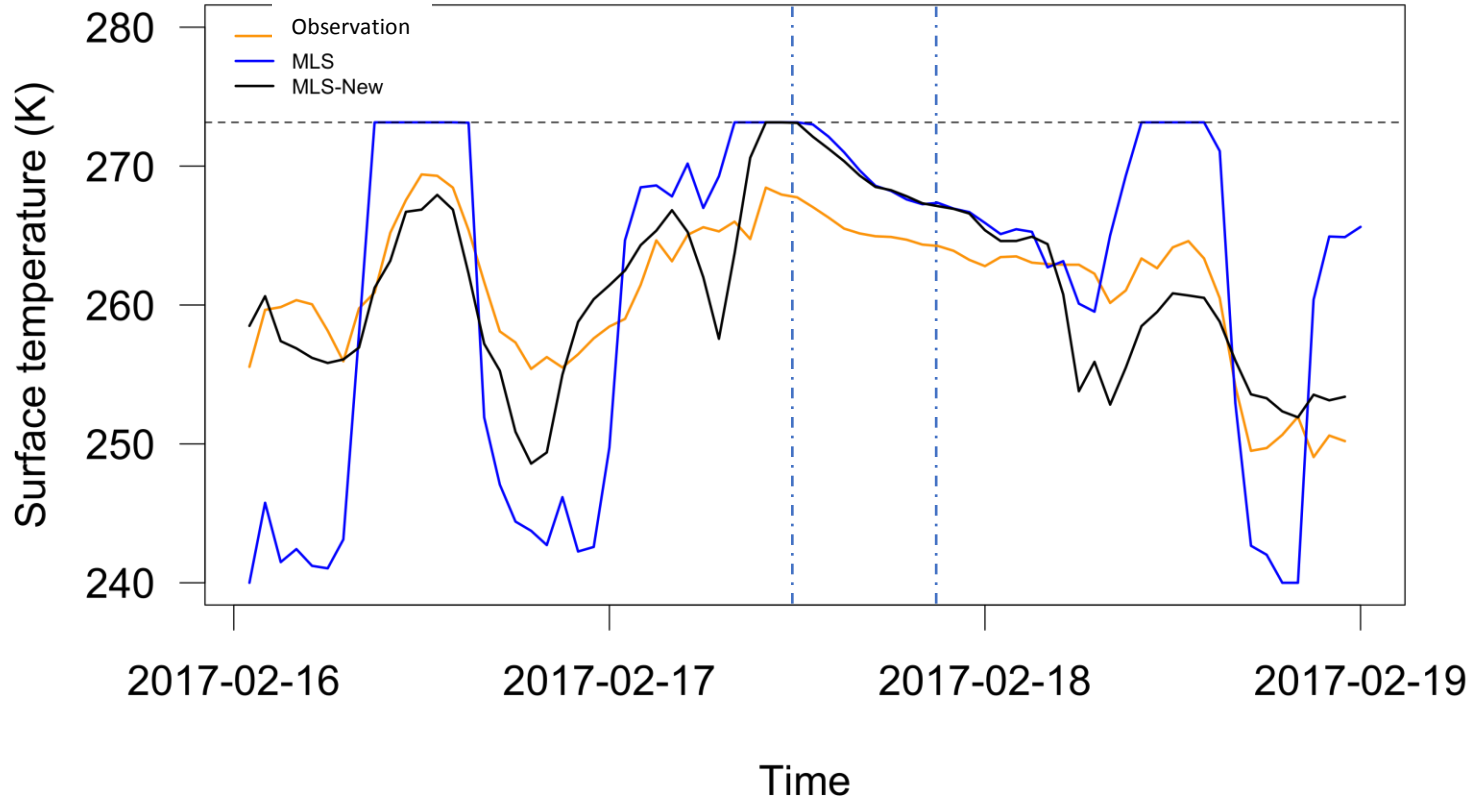
Snow



Phase II: Snow cover scheme - Meteorology

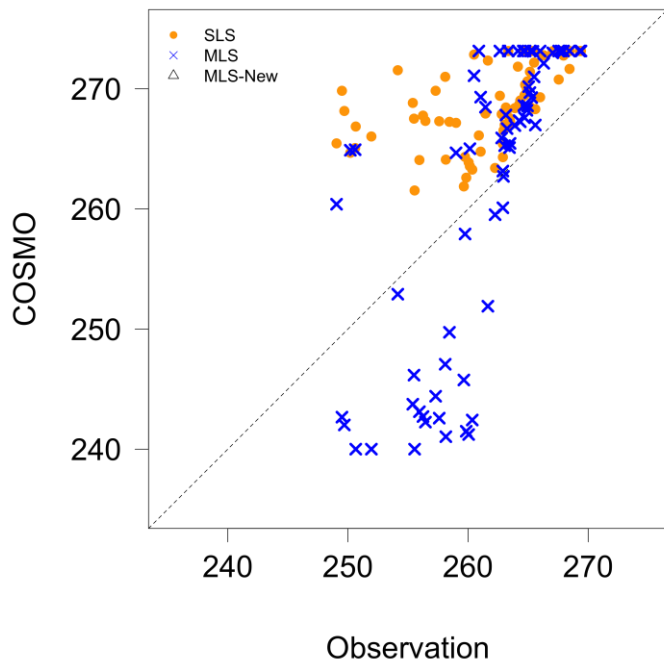
Weissfluhjoch

Snow

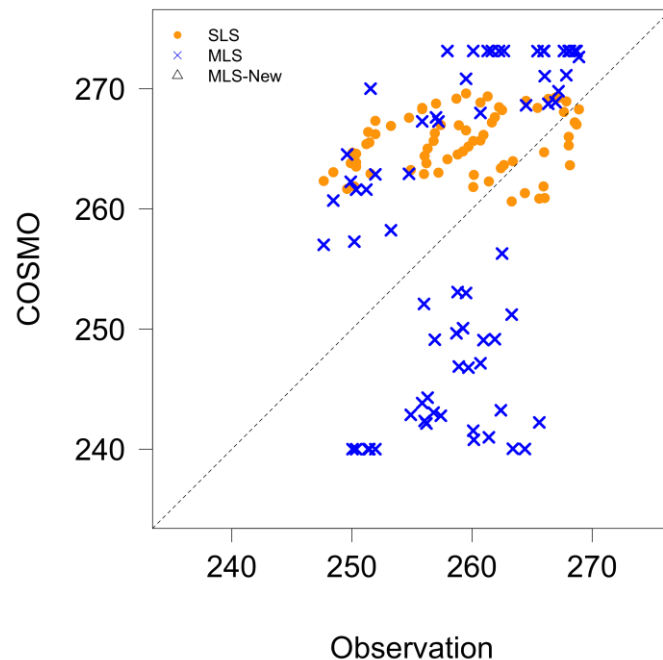


Phase II: Snow cover scheme (MLS) – Initial Results

Weissfluhjoch
(FOR_E + FOR_D = 0.93)



Boveire-PointedeToules
(FOR_E = FOR_D = 0)

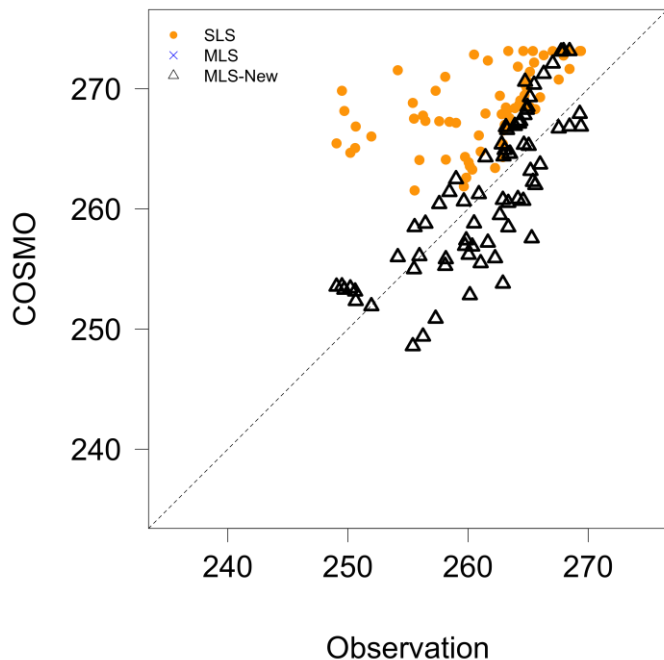


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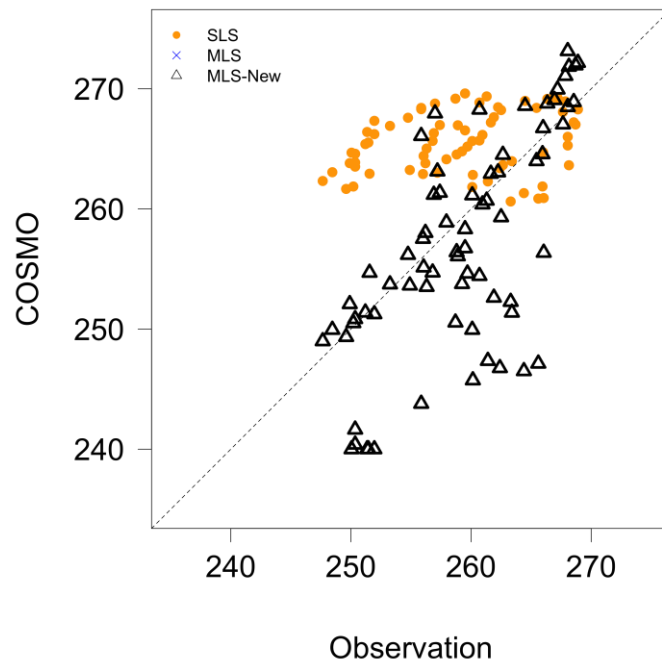
X = Multi-layer snow cover scheme (MLS)

Phase II: Snow cover scheme (MLS) – Initial Results

Weissfluhjoch
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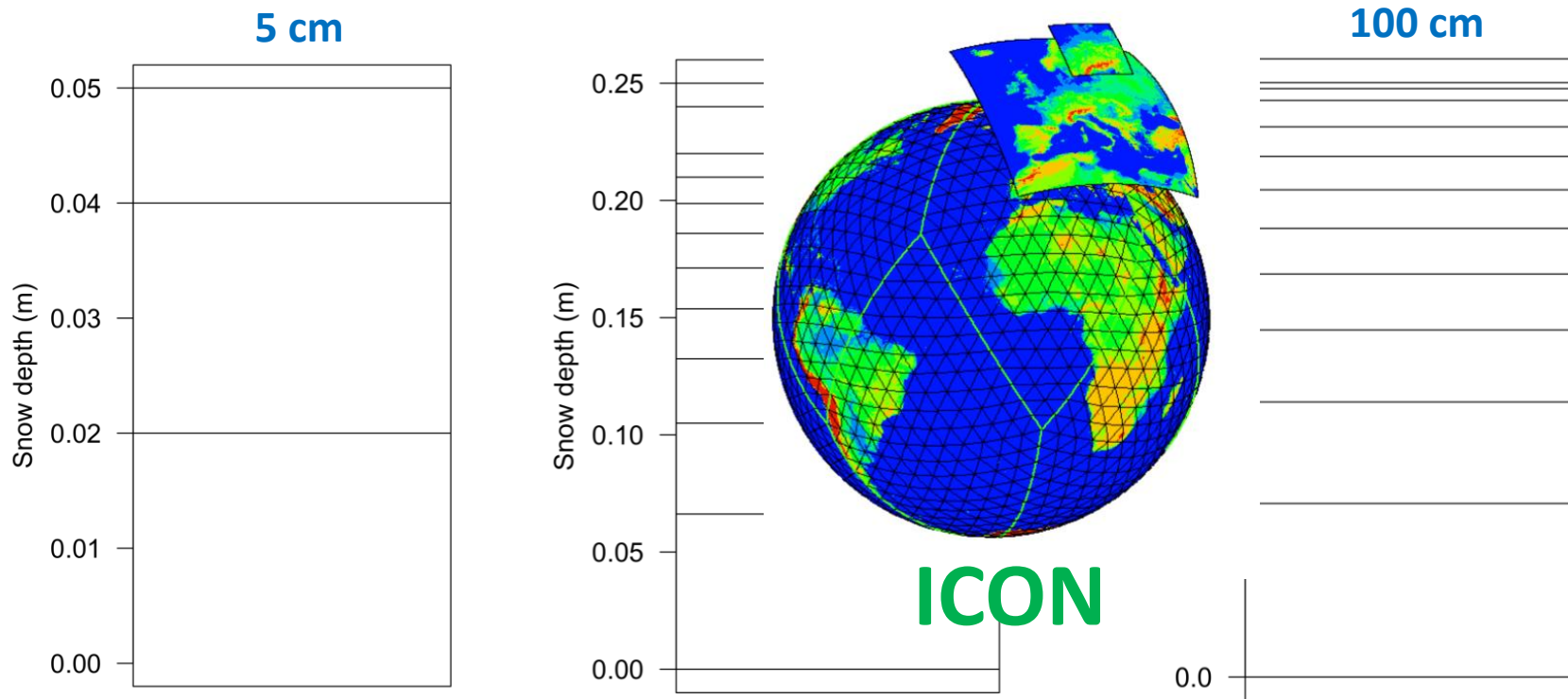


△ = Multi-layer snow cover scheme (MLS) with new flux parameterizations

Phase II: Snow cover scheme (MLS) - Status

- Code development based on COSMO version 5.04h
- Call of a subroutine (*snow_on_soil*) in TERRA, which ...
 - ... uses a fixed number of snow layers ($n_{\text{snow}} = 6$) and an additional number of layers set by namelist (default $ke_{\text{snow}} = 2$)
 - ... solves the heat equation for the whole column (snow + soil = 16 layers)
 - ... calculates a snow specific atmospheric forcing (new albedo parameterization & transfer coefficients required).
 - ... melting, re-freezing, water transport (bucket) through snow column only (INTENT(OUT) > soil, runoff, storage(?))
 - ... settling, absorption solar energy, dust on snow, snow deposition/redistribution ...
- Call of subroutine (*snow_on_xxx*) ... (*snow_in_xxx*) ...

Phase II: Snow cover scheme (MLS) - Alternative



Logarithmic layer thickness with depth (max. # layers = 10) + 2 layers (1 and 2 cm)



Thanks!

Questions and/or comments?

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Email: bellaire@slf.ch