

SAINT PT: status, plan and discussion

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Proposed COSMO Priority Task (PT) Project – SAINT

- **Phase I: validation of current multi-layer scheme – update as needed**
- **Phase II: implementation – adjustment of currently implemented parametrizations ; radiation (albedo), turbulence , tile approach …**
- **Phase III: validation of implementation especially diagnostic parameters (e.g. T_2m)**
- **Phase IV: documentation (paper, technical report etc.)**
- **Duration: 2 years (50%), Start July 2017, End June 2019**

Proposed COSMO Priority Task (PT) Project – SAINT

October 07-12 ISSW 2018 INNSBRUCK

A MULTI-LAYER SNOW COVER MODEL FOR NUMERICAL WEATHER PREDICTION AND CLIMATE MODELS

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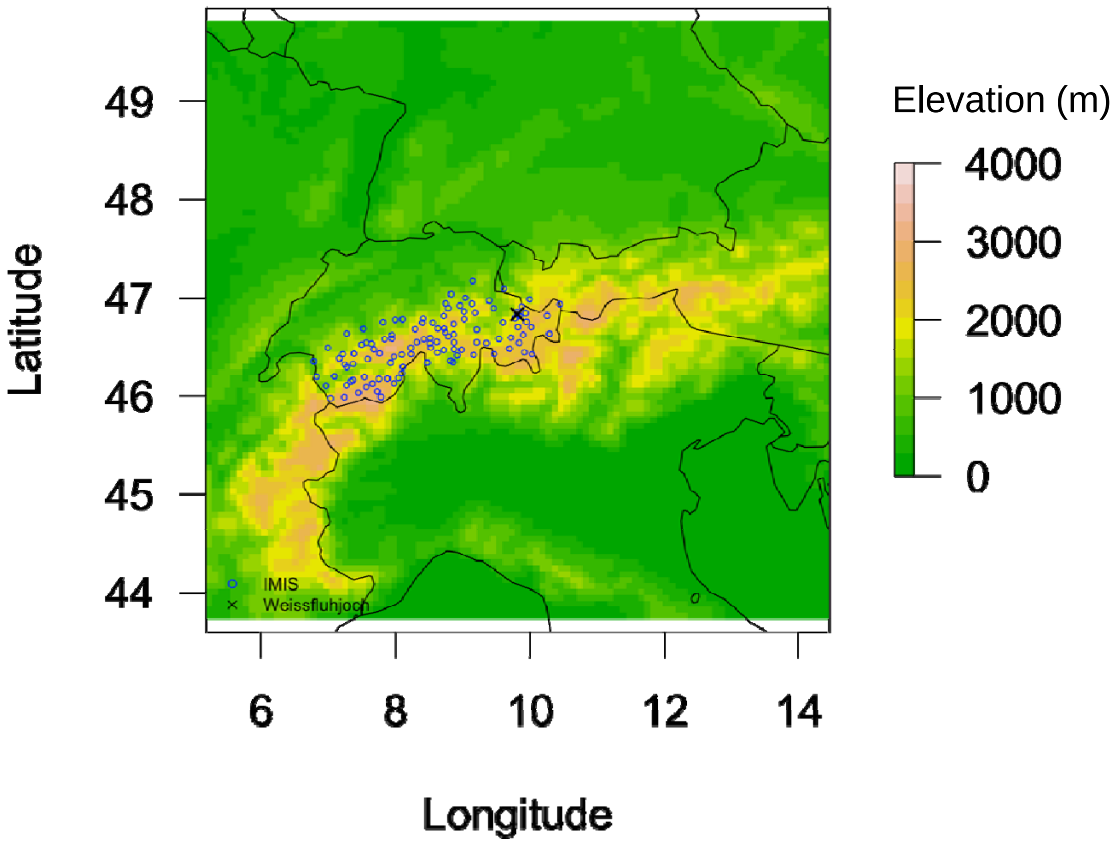
ABSTRACT: The seasonal snow cover strongly influences boundary layer processes such as turbulence and radiation. Therefore, knowledge of the current state of the snow cover on the ground is of paramount importance for numerical weather prediction (NWP) and climate models. This is especially true since the horizontal resolution (up to 1 km) of NWP models strongly increased in recent years. Currently, most NWP models use simplified – typically one snow layer – snow cover schemes, which are in general not capable to simulate snow cover formation, evolution and melt with adequate accuracy. Within the framework of the COSMO consortium (Consortium for Small-scale Modelling) we are developing a new multi-layer snow cover module for the regional weather forecasting and climate model COSMO and the global model ICON (Icosahedral Nonhydrostatic). The snow cover model consists of six snow layers with increasing but constant thickness for the upper part (top 29 cm) of the snow cover and a variable amount of snow layers (minimum = 2) in the lower part of the snow cover. Preliminary results indicated an improvement of the snow surface temperature with only minor effects on the near surface air temperatures, when compared to the single layer counterpart at the location of a network of high-alpine weather stations.

KEYWORS: snow cover modelling, numerical weather prediction, climate modelling

1. INTRODUCTION

The seasonal mountain snow cover can lead to hazardous situations (e.g. avalanches, flooding), provides water resources during the melt phase and constitutes an important factor for global and regional weather and climate. Forecasting the snow cover evolution in complex terrain provides heat conduction into the snow cover. Heat conduction from the surface, through the snow cover, to the snow/soil interface depends on the surface temperature, the snow cover layering, i.e. density, as well as the current temperature distribution as well as phase changes happening in the snow. Therefore, it has been shown that

Phase II: Implementation/Validation – COSMO-7 Setup

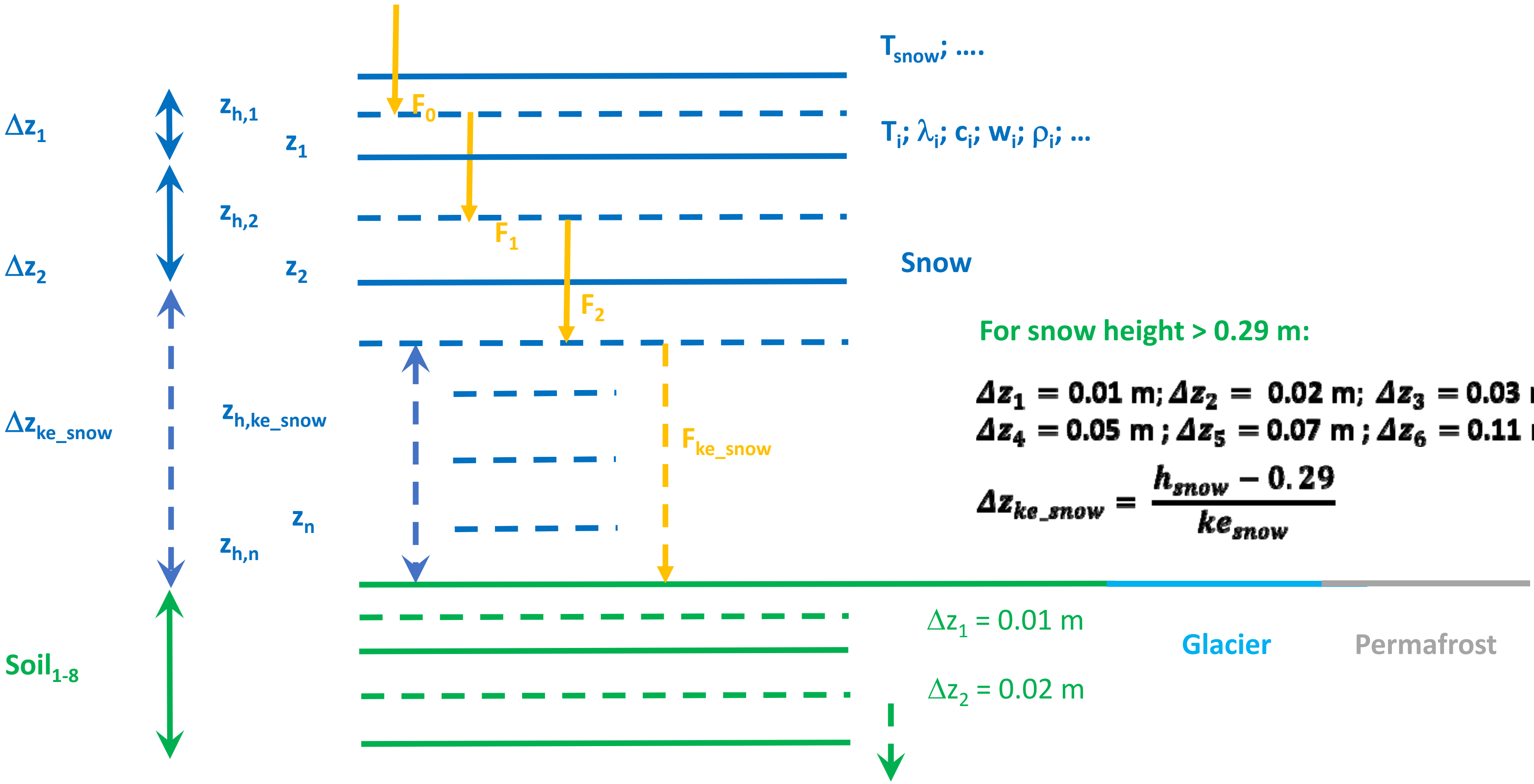


- o … ~ 700 km x 700 km domain centered around Davos …
- o … covering most of the Alpine ridge …
- o … computationally inexpensive …
- o .. boundary conditions from COSMO-7 analysis …
- o … 72-hour forecast/hindcast 16 February 2017 00UTC

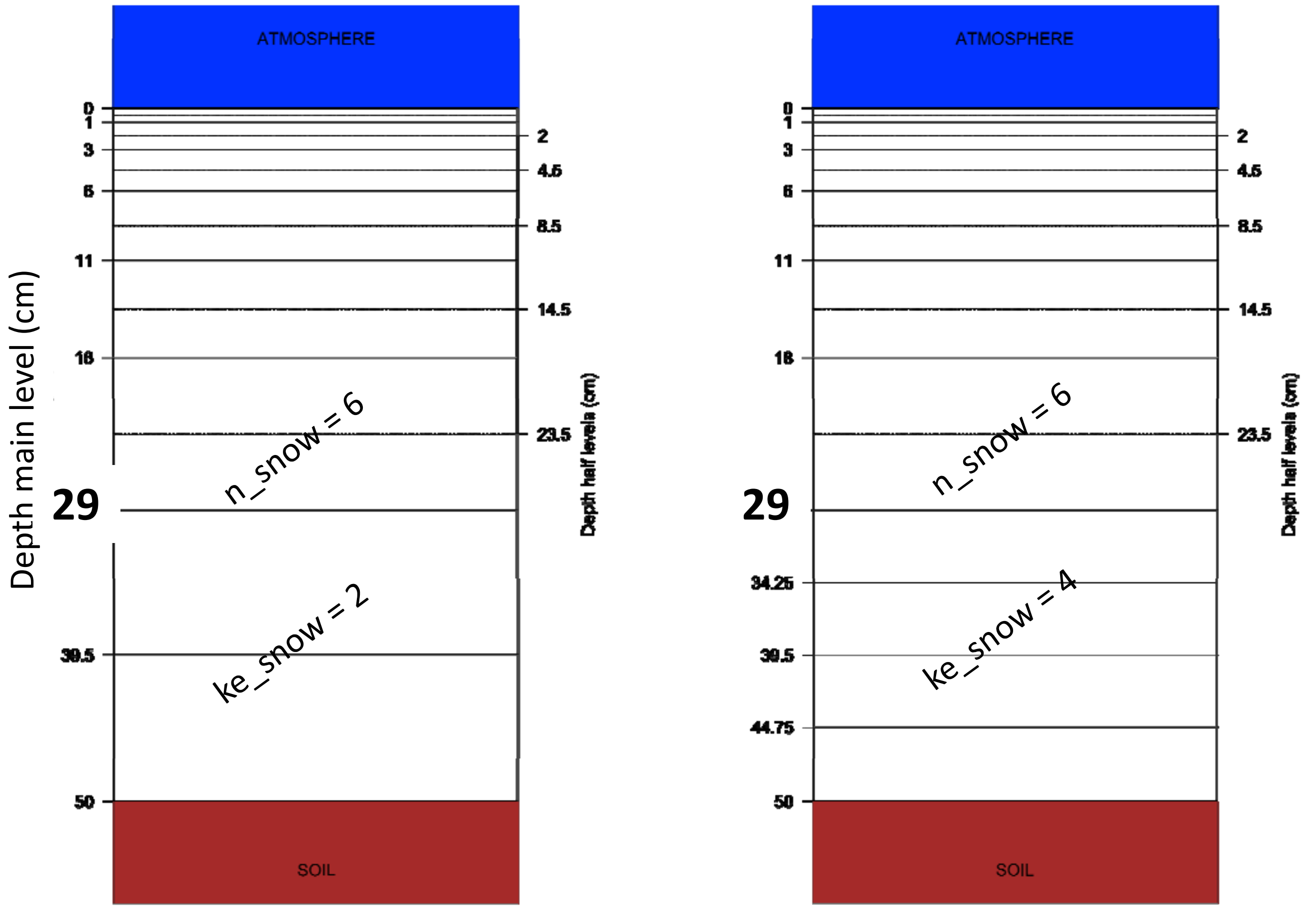
Intercantonal Measurement and Information System (IMIS)

Experimental Site Weissfluhjoch, Davos, Switzerland

Phase II: Snow cover scheme (MLS) – Schematic



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



Phase II: Snow cover scheme (MLS) – Implementation

```
!!==========================

MODULE sfc_terra

!=====
```

```
!SB <
USE sfc_snow
US
!S
!-
```

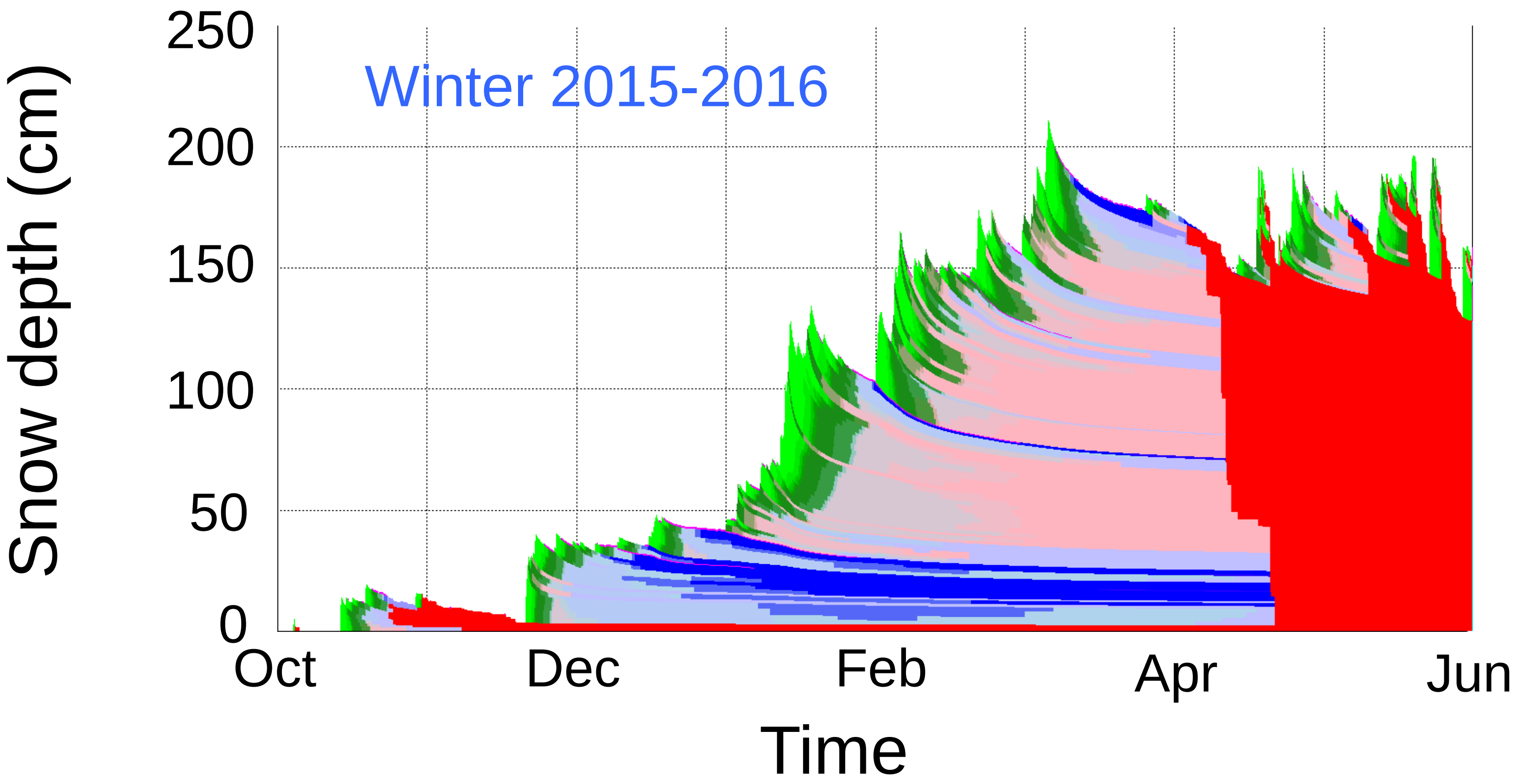
```
! Call subro
CALL snow_or
```

```
! -----------------------------------------------------------------
! Setup tridiagonal matrix for set of linear equations for each layer ...
! -----------------------------------------------------------------

  ! ... TOP LAYER
  dz_low = zm_sn_so(2) - zm_sn_so(1)

  a(1) = 0.0_wp
  b(1) = 1 + (1 - cn) * alpha(1) * hcon_sn_so(1)/dz_low - alpha(1)*dlw_u_sn
  c(1) = -   (1 - cn) * alpha(1) * hcon_sn_so(1)/dz_low

  d(1) = t_sn_so(1) + alpha(1) * (for_sn - dlw_u_sn*t_sn_so(1) + cn*hdif_sn_so(1))


   ! ... INNER LAYERS
   DO i = 2,  n-1, 1

     dz_up  = zm_sn_so(i)   - zm_sn_so(i-1)
     dz_low = zm_sn_so(i+1) - zm_sn

     a(i) = - (1 - cn)    * alpha(i)
     b(i) = 1 + (1 - cn) * alpha(i)
     c(i) = - (1 - cn)    * alpha(i)

     d(i) = t_sn_so(i) + cn*alpha(i


   ENDDO


  ! ... BOTTOM LAYER

  dz_up = zm_sn_so(n)   - zm_sn_so(n

  a(n) = - (1 - cn)    * alpha(n) * h
  b(n) = 1 + (1 - cn) * alpha(n) * h
  c(n) = 0.0_wp

  d(n) = t_sn_so(n) - cn*alpha(n-1)

! ---------------------------------
! Solve the system - Thomas Algorith
! ---------------------------------
```

```
&
&
&
&
&
&
&
&
```

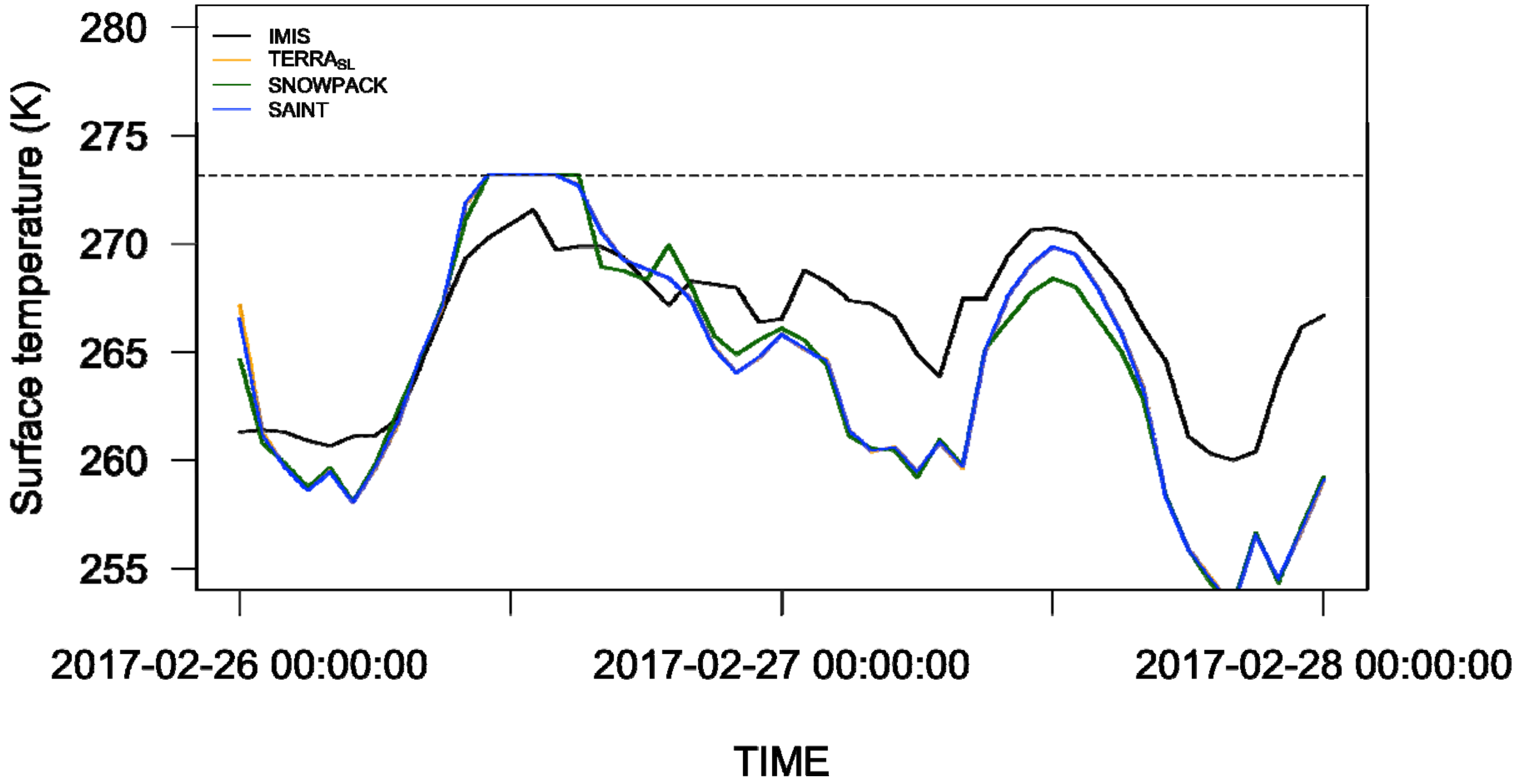
```
! ===========================================================
! Section VIII: Updating
! ===========================================================


DO ksn = 1, n_snow+ke_snow

  IF(ksn == 1) THEN

  t_sn_now(ksn) = MAX( MIN(e(ksn),t0_melt), 240.0_wp)

  ELSE

  t_sn_now(ksn) = e(ksn)

  ENDIF

END DO


  h_snow = h_snow

  t_sn_sfc_now = MAX( MIN(e(1),t0_melt), 240.0_wp)
```

Phase II: Benchmark simulations – SNOWPACK vs. MSL



Phase II: Benchmark simulations – SNOWPACK vs. MSL

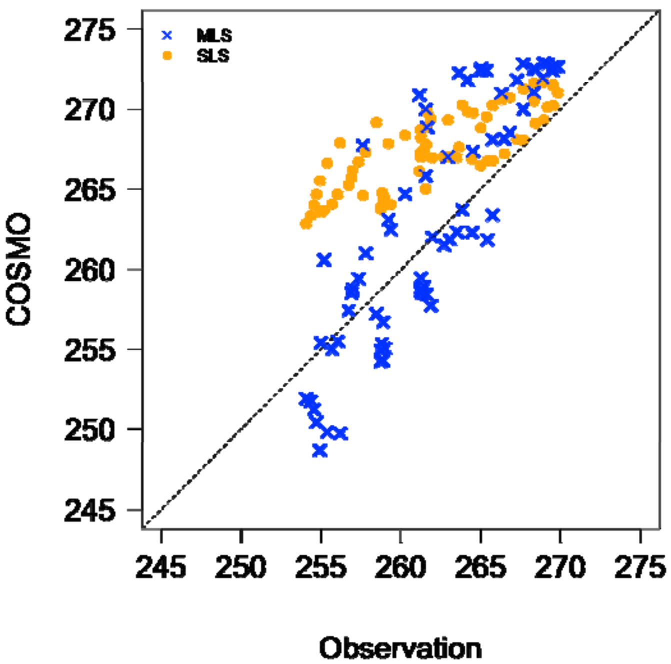
Weissfluhjoch



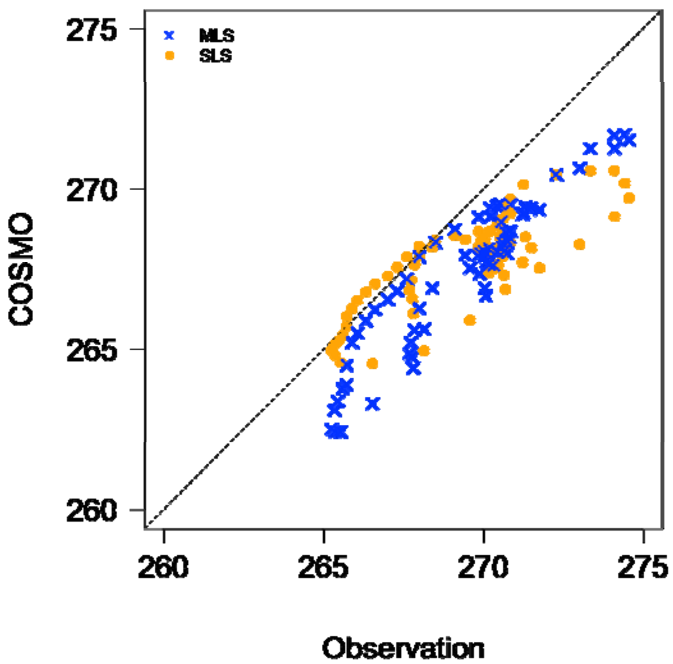
Phase II: Snow cover scheme (MLS) – Initial Results

All IMIS (N = 112)

T_SNOW



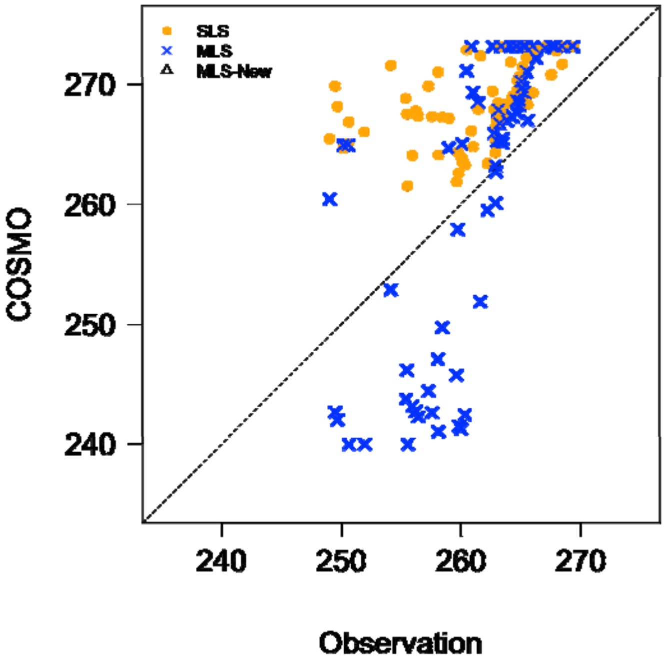
T (1st level)



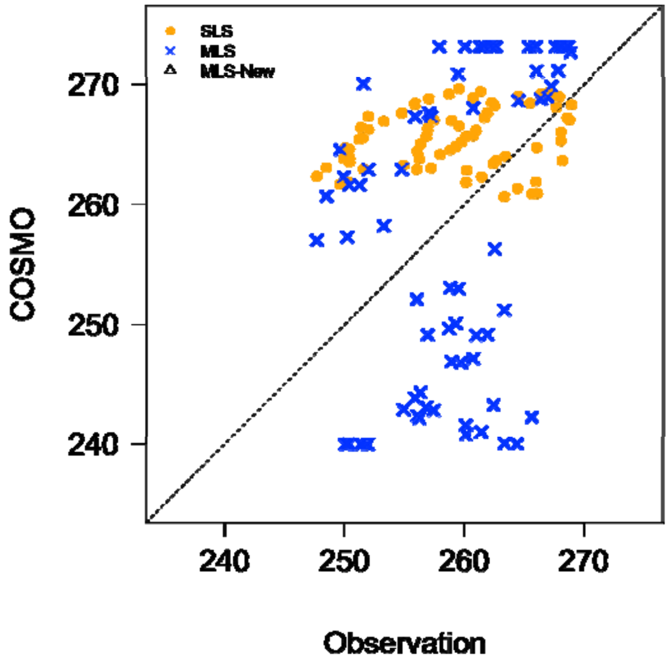
● = Single layer snow cover scheme (SLS) X = Multi-layer snow cover scheme (MLS)

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

Weissfluhjoch
(FOR_E + FOR_D = 0.93)

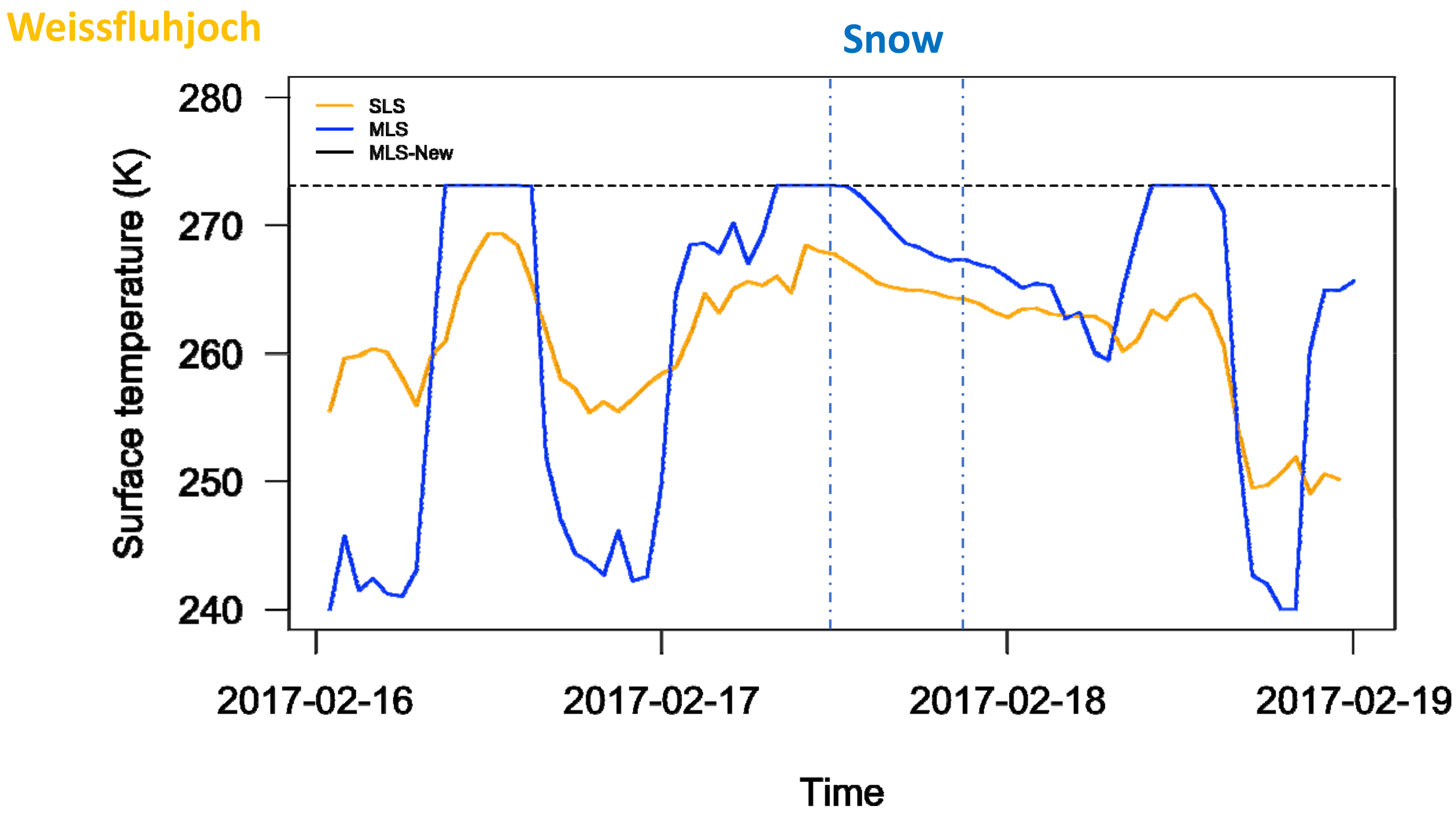


Boveire-PointedeToules
(FOR_E = FOR_D = 0)



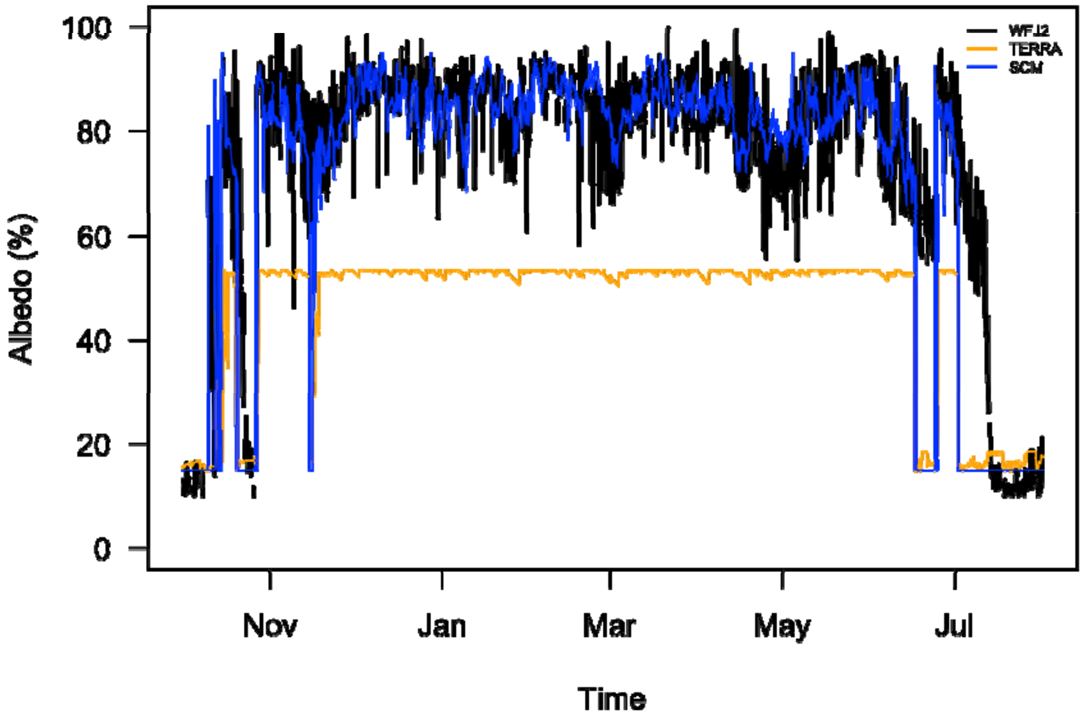
● = Single layer snow cover scheme (SLS)   X = Multi-layer snow cover scheme (MLS)

Phase II: Snow cover scheme - Meteorology



Phase II: Snow cover scheme (MLS) – Albedo

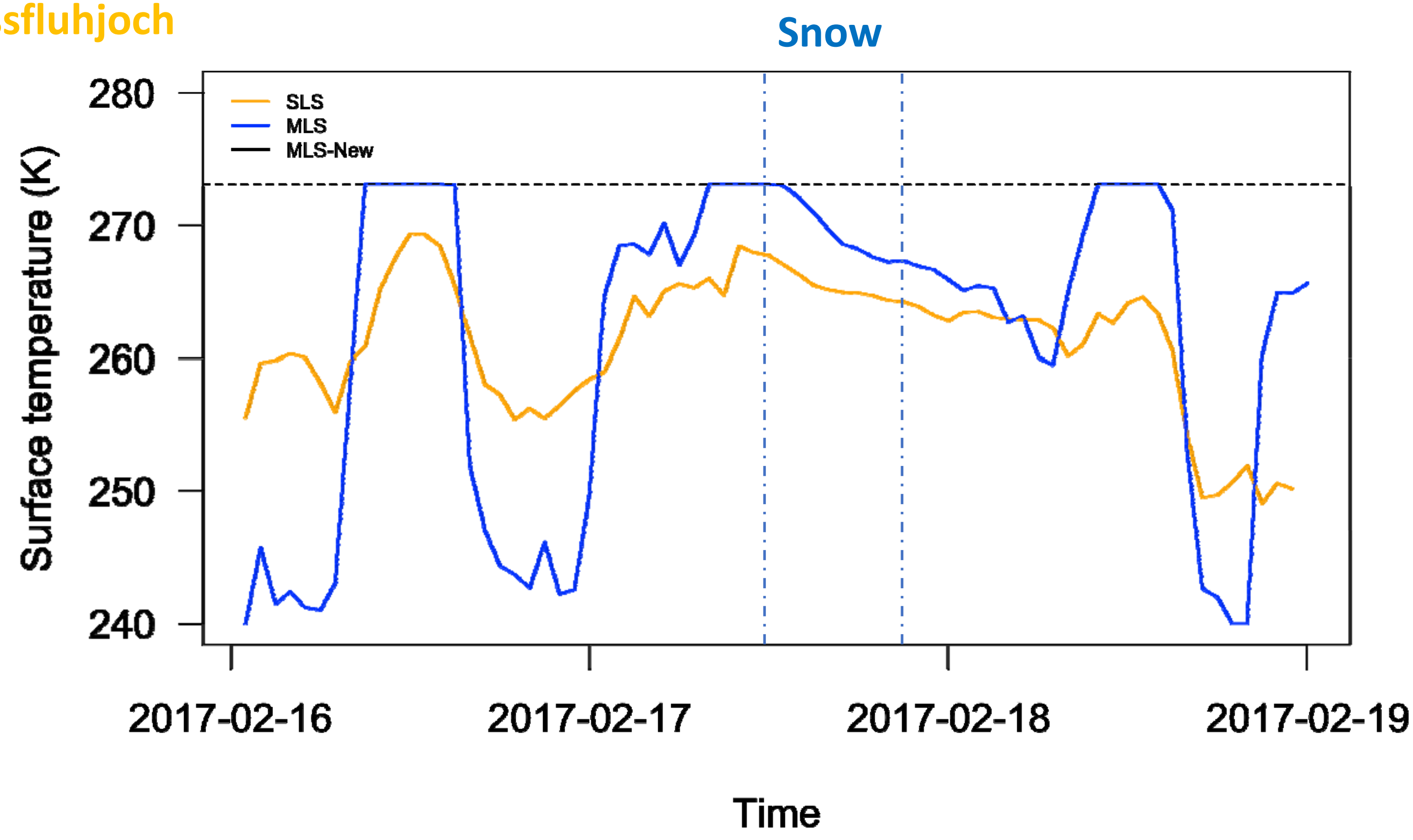
$$\alpha_{SCM} = a + b \times P_{rate} + c \times T_{SFC} - d \times T_{10m}$$



T_{10m} = Air Temperature 10 m

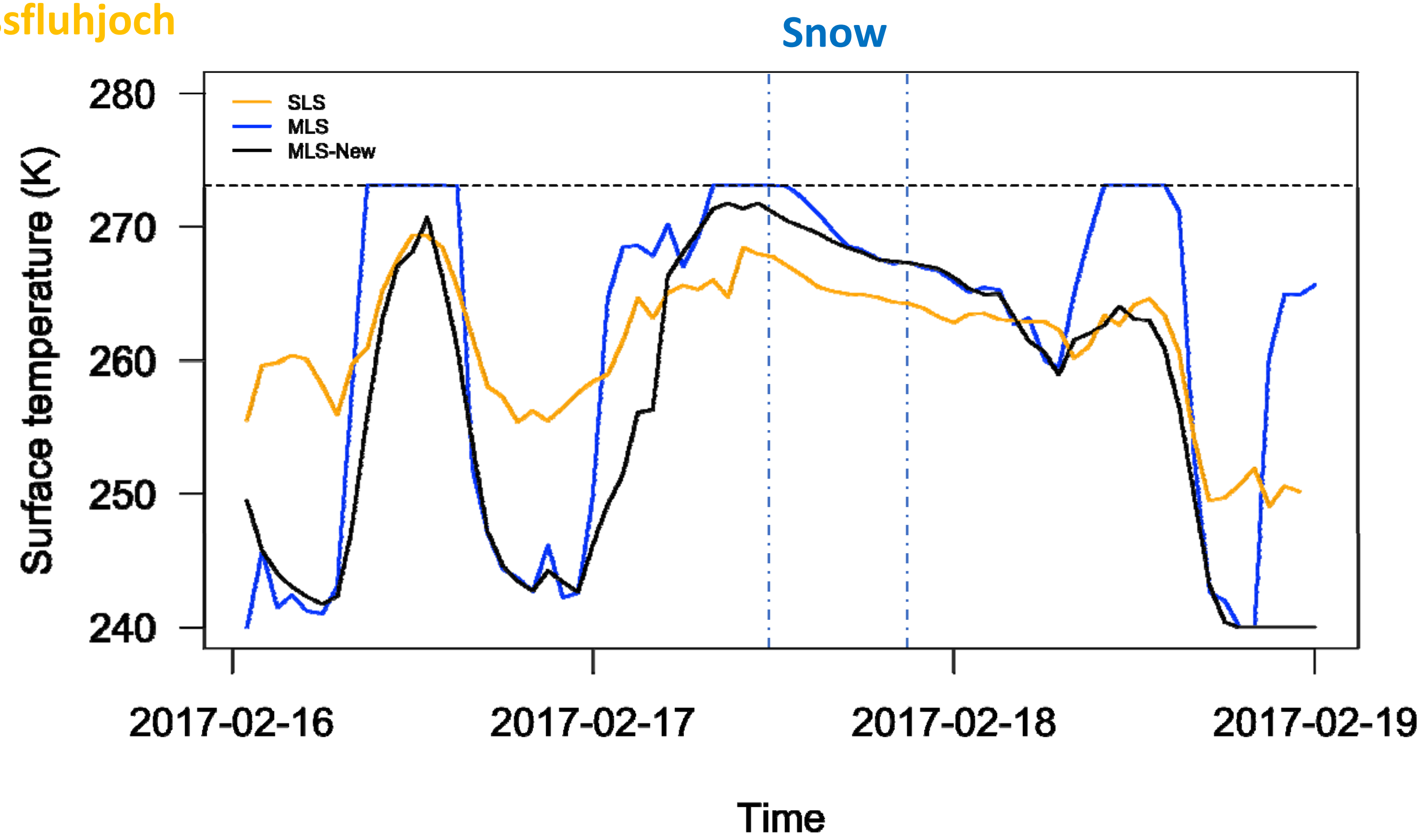
Phase II: Snow cover scheme - Meteorology

Weissfluhjoch



Phase II: Snow cover scheme - Meteorology

Weissfluhjoch



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:

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

where $k = 0.4$ is the von Kármán constant, $\zeta = (-k\, z_{ref}\, g T_*) / (\theta_s u_*^2)$ is the modelled stability parameter (stability parameter henceforth), $u_* = k\bar{U}\left(\ln(z_{ref}/z_{0M}) - \psi_m\right)^{-1}$ is the modelled friction velocity, $T_* = k\left(\theta_s - \theta_{z_{ref}}\right)\left(\ln(z_{ref}/z_{0M}) - \psi_s\right)^{-1}$ 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

Stability Corrections:

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

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

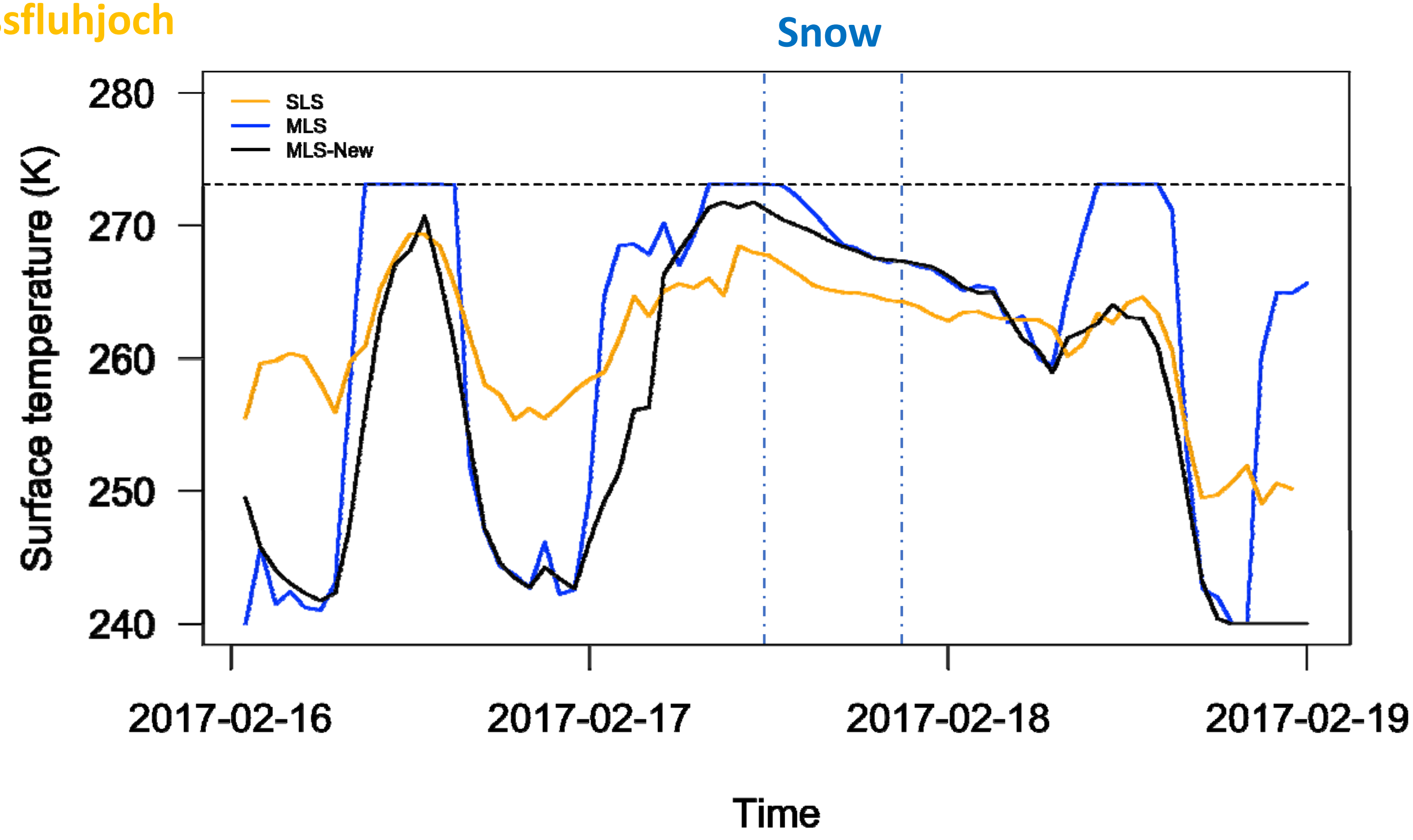
$$B = \Delta T / \bar{T}$$

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

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

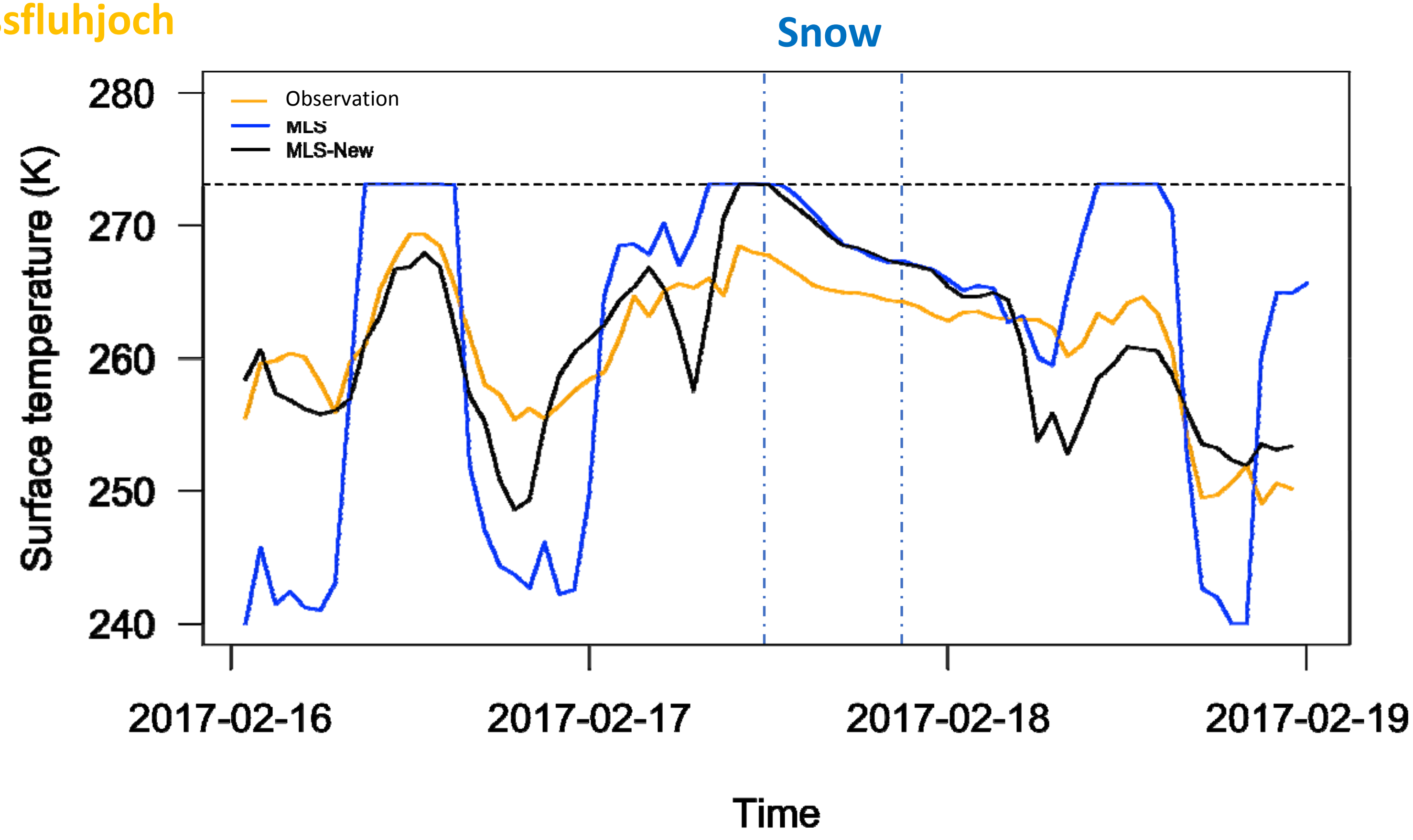
Phase II: Snow cover scheme - Meteorology

Weissfluhjoch



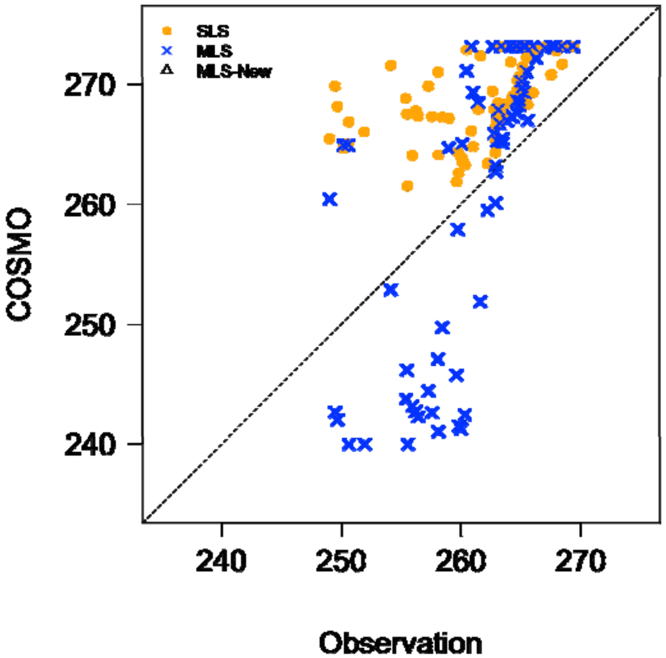
Phase II: Snow cover scheme - Meteorology

Weissfluhjoch

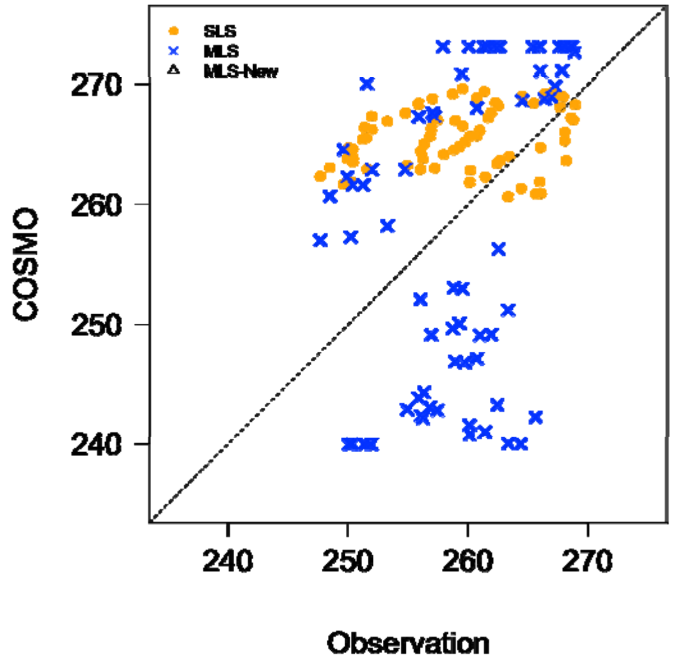


Phase II: Snow cover scheme (MLS) – Initial Results

Weissfluhjoch (FOR_E + FOR_D = 0.93)

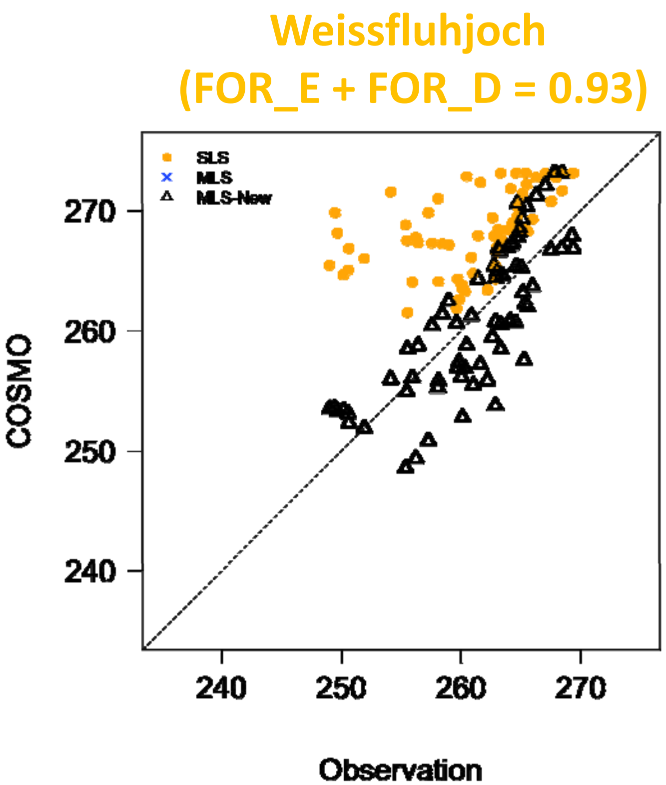


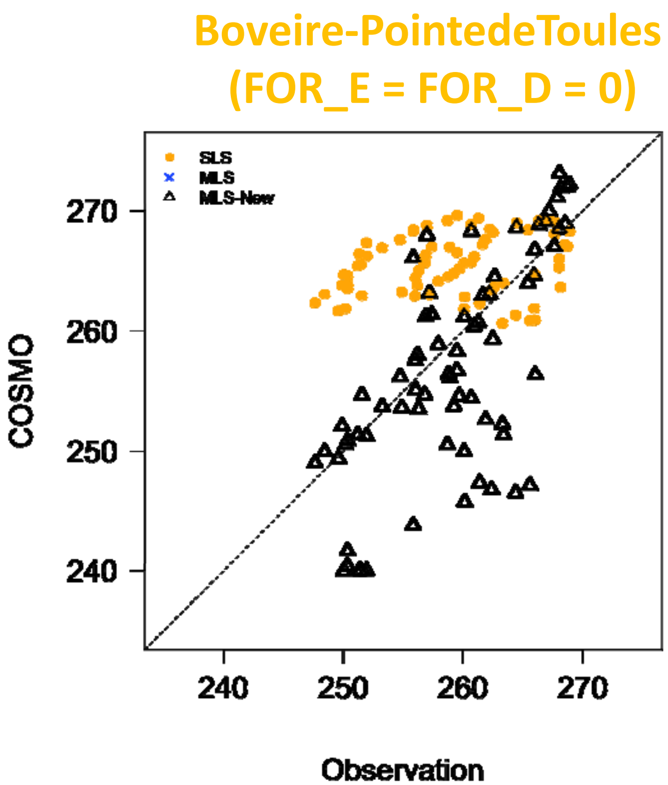
Boveire-PointedeToules (FOR_E = FOR_D = 0)



● = Single layer snow cover scheme (SLS)   X = Multi-layer snow cover scheme (MLS)

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





△ = 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 including ‘latest’ developments by Matthias R.**
- **Call of a subroutine (*snow_on_soil*) in TERRA, which …**
  - **… uses a fixed number of snow layers (n_snow = 6) and an additional number of layers set by namelist (default ke_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).**
  - … water transport (bucket) through snow column only (INTENT(OUT) > soil, runoff, storage(?))
  - … settling, absorption solar energy, dust on snow, snow deposition …
- Call of subroutine (snow_**on**_xxx) … (snow_**in**_xxx) …

Phase II: Snow cover scheme (MLS) – Q & A

- We need to calculate the fluxes in a different way! Problem?
- How to tackle the problem of different forcing for snow covered fractions?
  - Tile approach?
  - Updating T_SNOW only?
  - Other option?
- **Should we switch to ICON (ASAP)???**
- Are we missing something?
- What other problems might be solved using MLS, but need investigation?
  - Snow data assimilation with SMRT?
  - Compatibility with snow analysis?
  - ….

Thanks!
Questions and/or comments?

Sascha Bellaire[1], Michael Lehning[1,2], Jean-Marie Bettems[3], Oliver Fuhrer[3]

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