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En route to a 'new' operational multi layer snow cover scheme. (COSMO)

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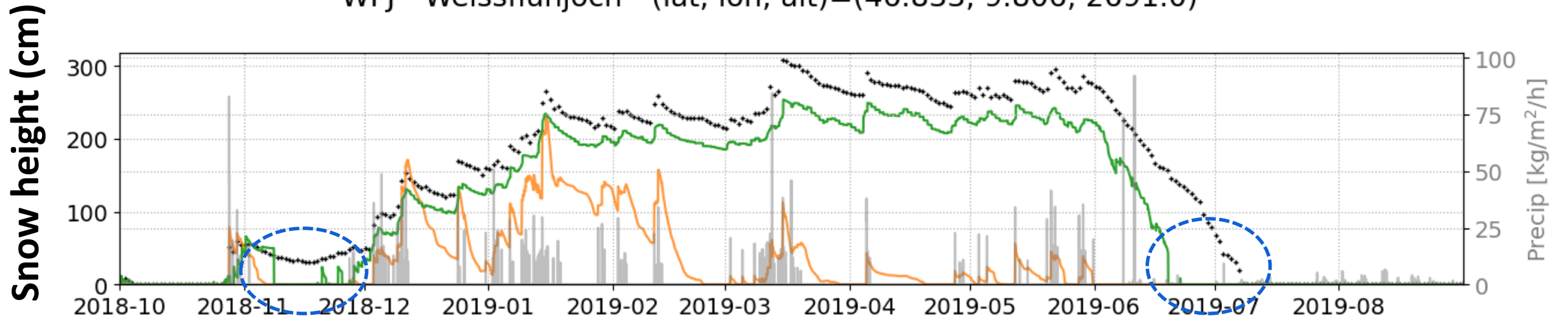
³CRYOS, School of Architecture, Civil and Environmental Engineering, EPFL, Lausanne, Switzerland

⁴DWD, Deutscher Wetterdienst



So what? Why do we need a 'new' model?

WFJ - Weissfluhjoch - (lat, lon, alt)=(46.833, 9.806, 2691.0)

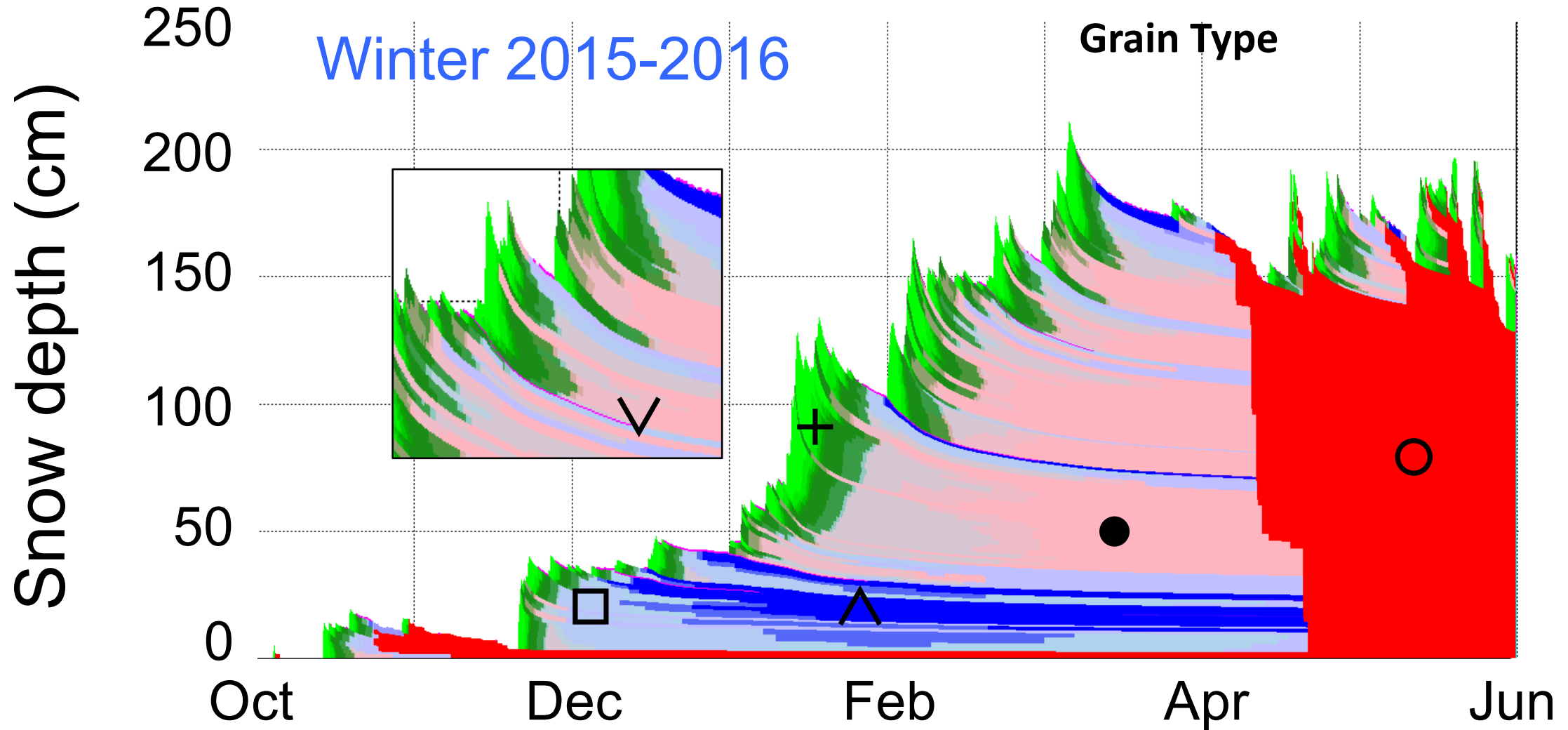


Time

- Measurement
- Single Layer scheme
- Snow analysis

| Precipitation

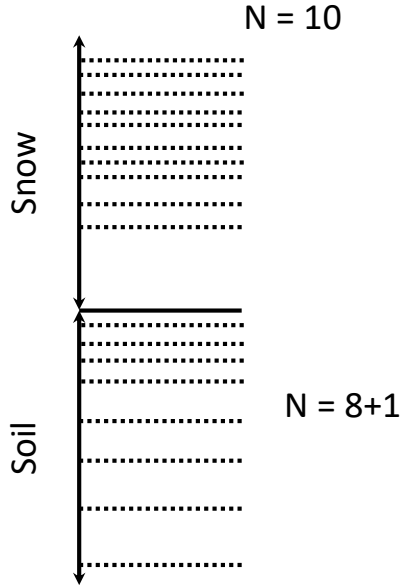
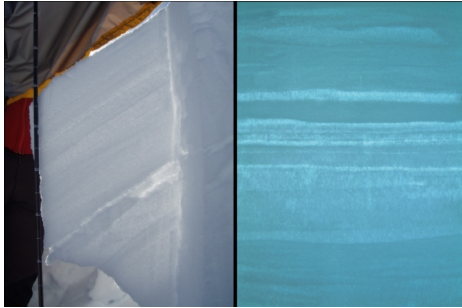
Advanced Swiss snow cover model SNOWPACK





SNOWPOLINO – SNOWPACK’s little ‘brother’

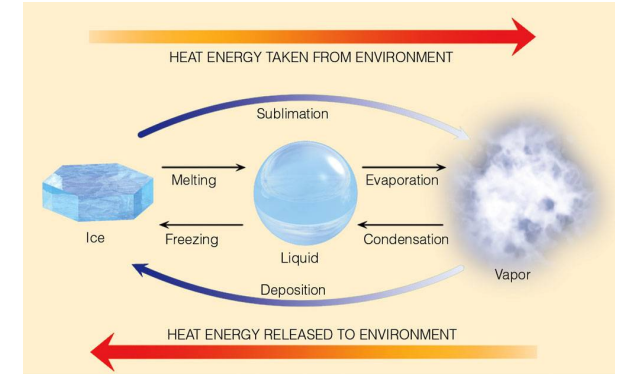
Layering ($n_{\text{def.}} = 25$)



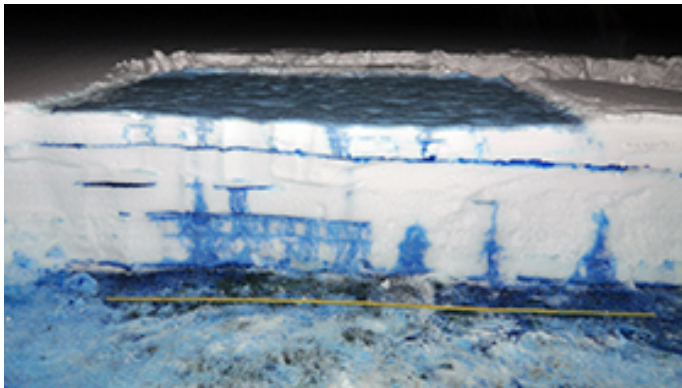
1D heat equation

$$\frac{\partial T}{\partial t} = \alpha \frac{\partial^2 T}{\partial x^2}; \quad 0 \leq x \leq L; \quad t \geq 0$$

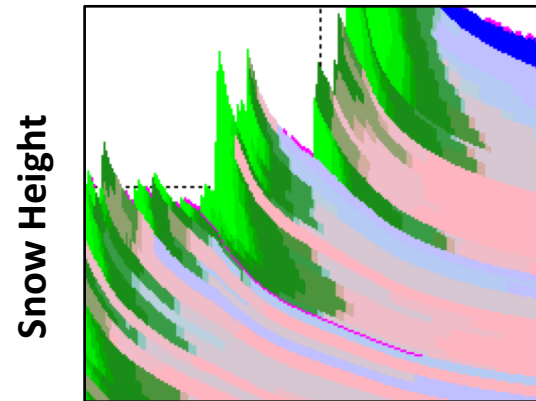
Phase Changes



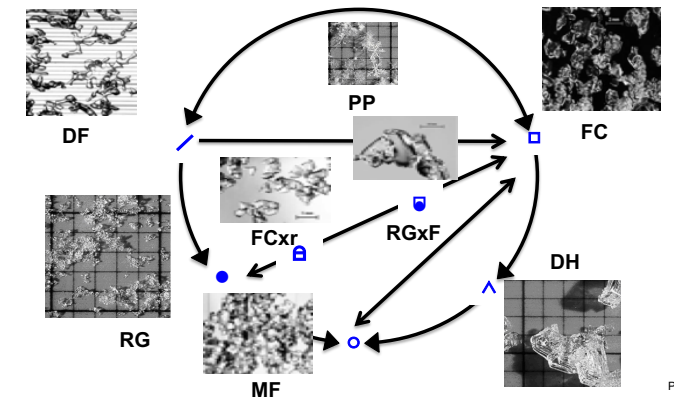
Water transport



Settling/Densification



Metamorphism



Photo's: SLF

PT SAINT – a little project ‘history’

- 2013** March Start of the Austrian Science Fund Project SAINT (**S**now cover **A**tmosphere **I**N**T**eraction) at the **University of Innsbruck** (CO-PI Prof. Rotach);
Project Goal: coupling/forcing of SNOWPACK with COSMO
- 2017** July Revival of the ‘SAINT’ project co-funded by
WSL Institute for Snow and Avalanche Research SLF and MeteoSwiss;
Project Goal: development of a new multi-layer scheme for COSMO/ICON
- 2017** September SAINT became an **priority task project** of the COSMO consortium (**PT-SAINT**)
- 2020** December ‘Official’ end of PT-SAINT (formal extension required)
- 2021** September End of PT-SAINT and potential start of follow up project.

What models currently contain SNOWPOLINO?

SNOWPOLINO_{stand-alone}

TERRA_{stand-alone} **(TSA)**

- decoupled version of COSMO/ICON of the surface scheme TERRA
- TSA can be forced with gridded and non-gridded data
- unified code (with COSMO v6.0)
- Low computational costs

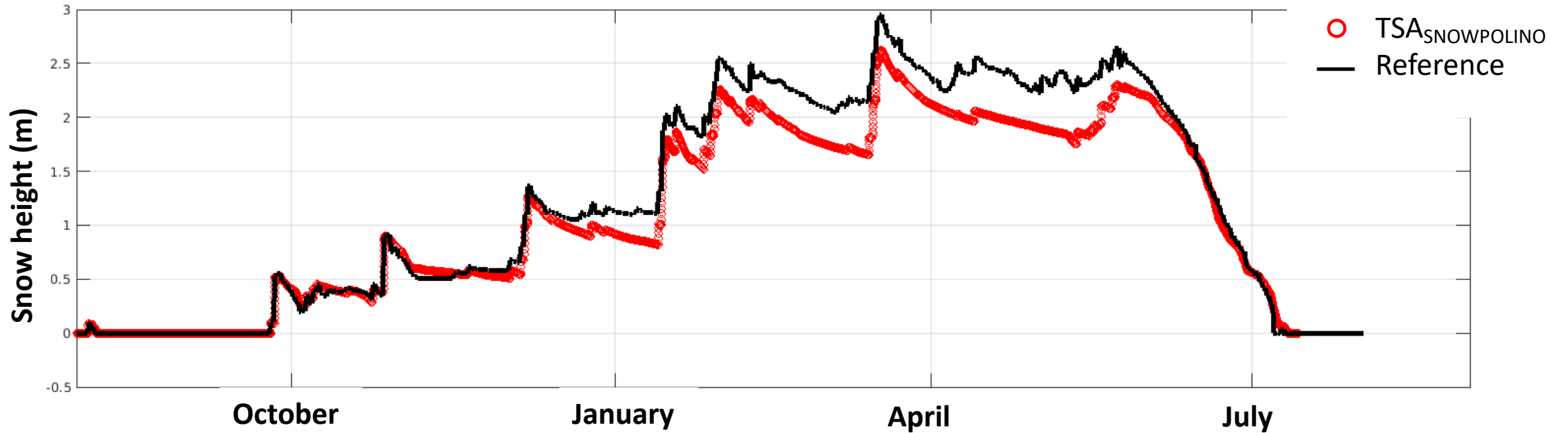
COSMO

- part of official COSMO (v6.0) code
- code is GPU capable
- currently implemented outside of TERRA ...
- hence, transition to ICON and usage for other scheme, i.e. vegetation, urban model, sea/lake ice possible.



Local and regional verification (CH) - H_SNOW_{TSA}

TSA – TERRA Stand Alone; measured forcing

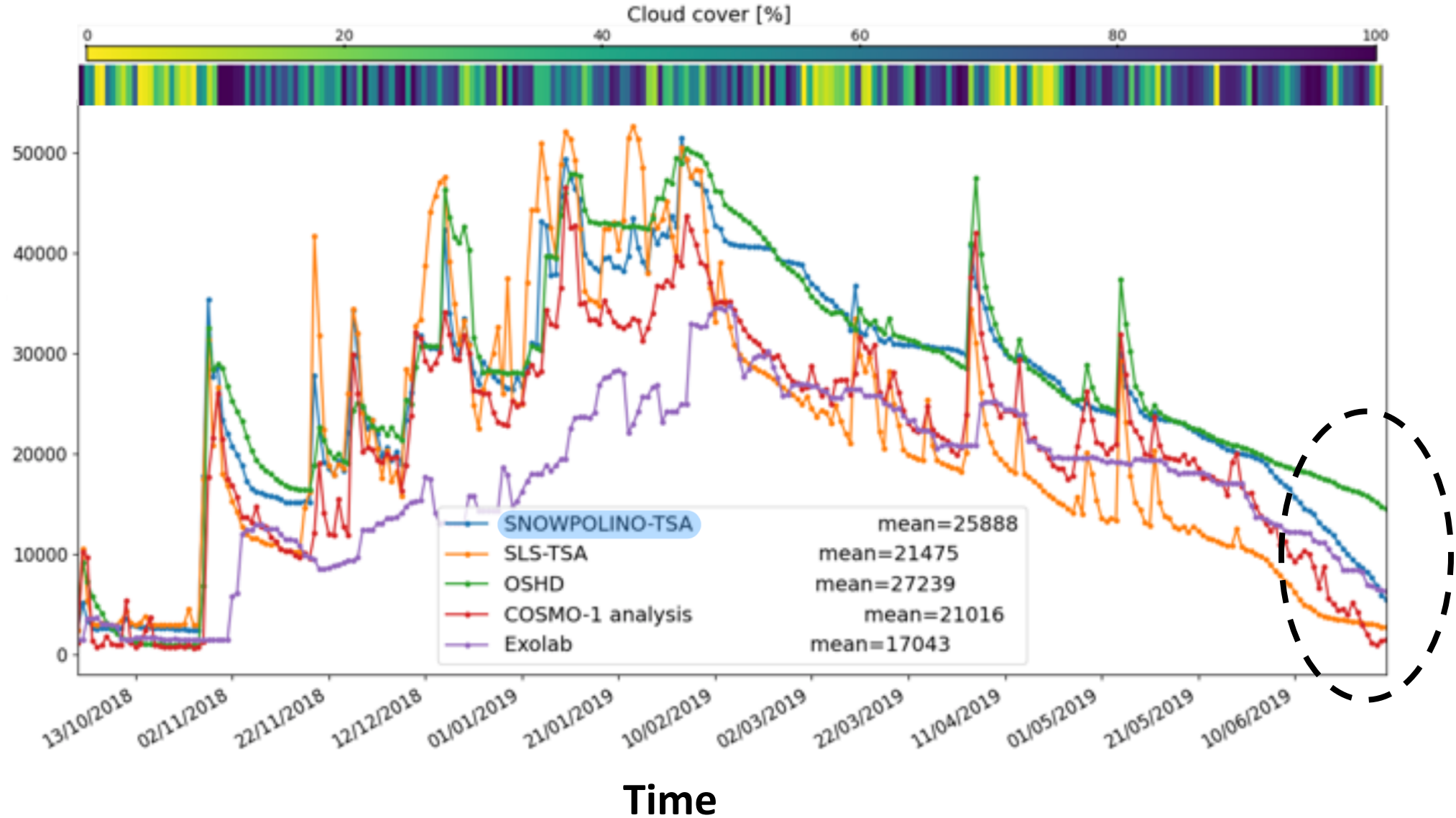


Winter 2020/21 (Weissfluhjoch)



Local and regional verification (CH)

Number of snow cover pixels (-)



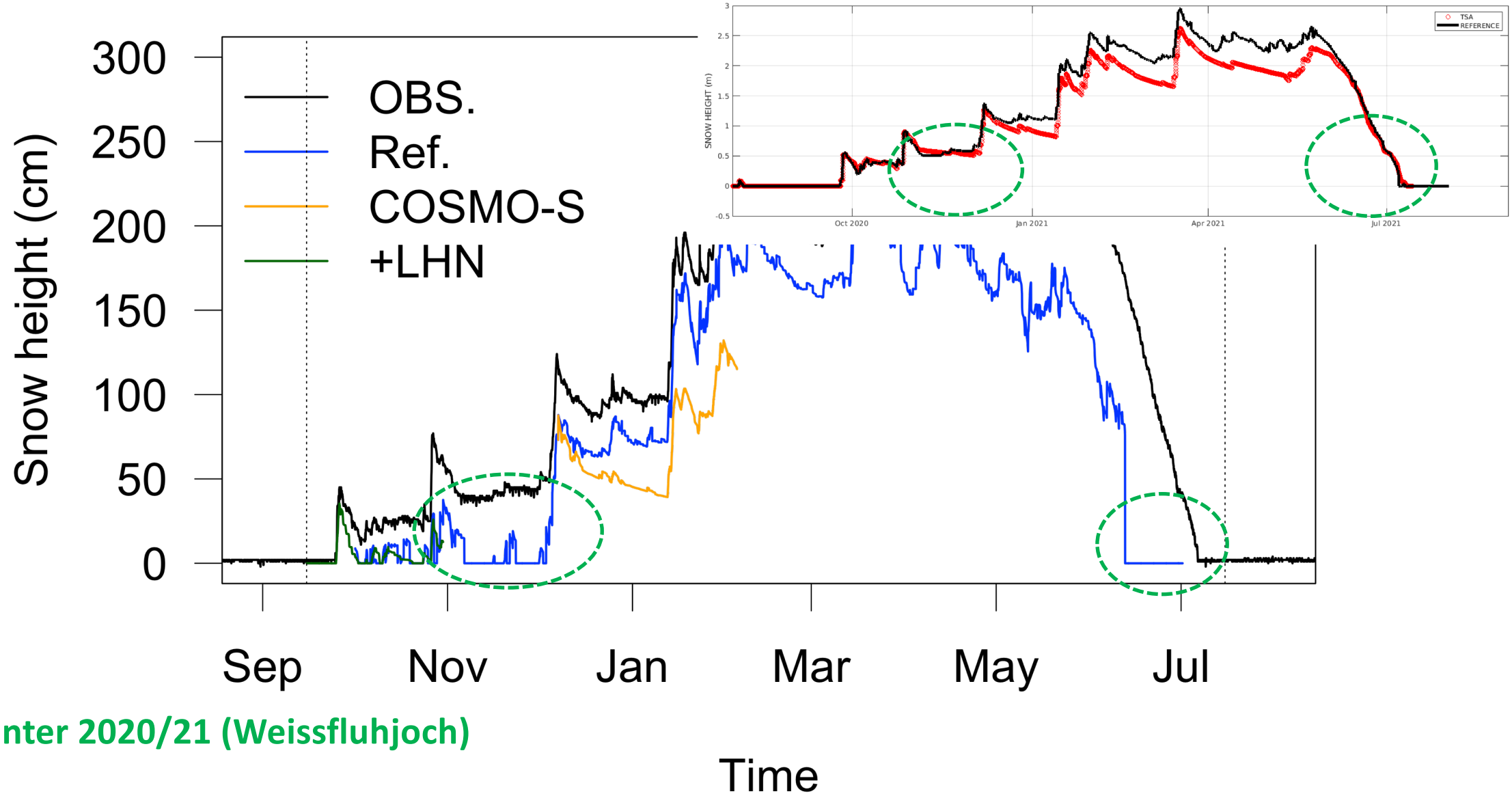


Local and regional verification (CH) – COSMO

- **e_suite**
 - COSMO-2
 - hindcasts, i.e. from analysis (KENDA-1)
 - 24h lead-time
- **itype_snow = 3**
 - new multi layer snow scheme ('SNOWPOLINO')
- **itype_snow_start = 0**
 - warm start from analysis, cycled in from SNOWPOLINO output
- **itype_snow_start = 1**
 - cold start; all snow is wiped out
- **itype_snow_start = 2**
 - 'soft' warm start (required snow fields are derived from available/mandatory fields (W_SNOW, RHO_SNOW etc.)



Local and regional verification (CH) - H_SNOW

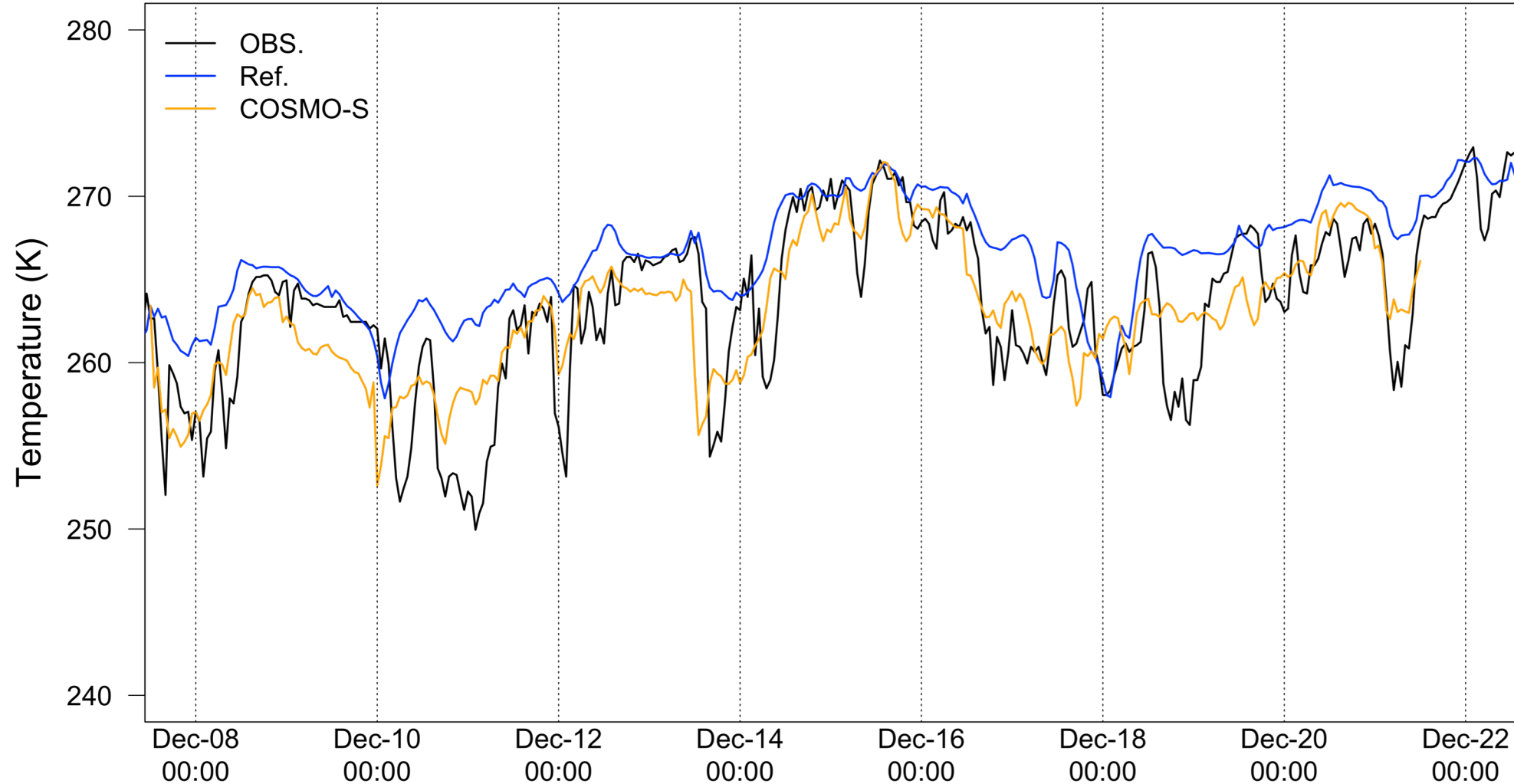


Winter 2020/21 (Weissfluhjoch)

Time



Local and regional verification (CH) - T_SNOW



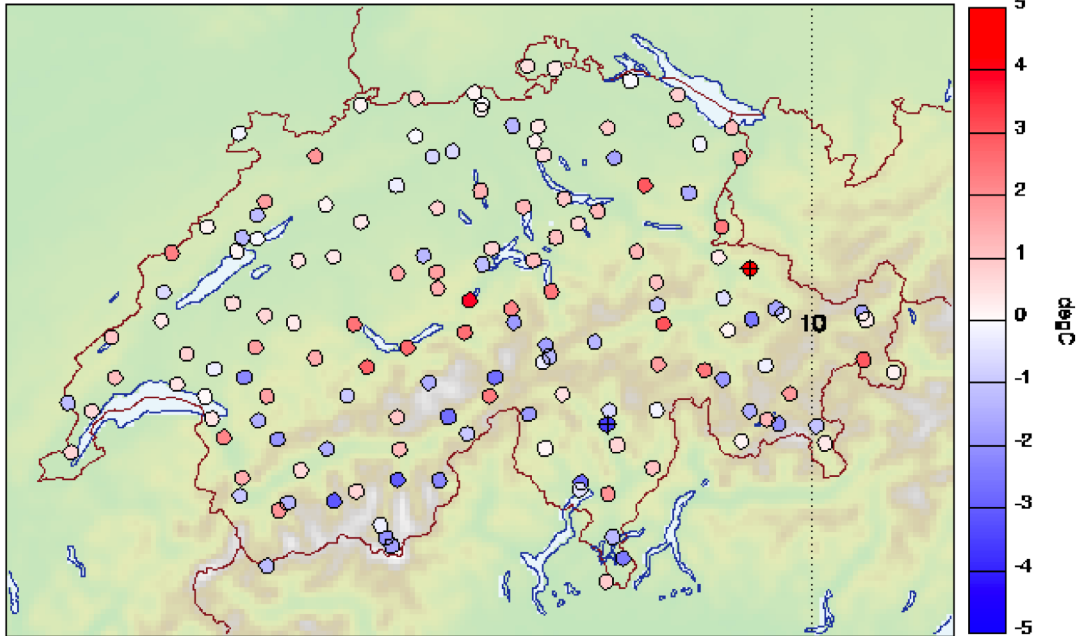
Winter 2020/21 (Weissfluhjoch)



Local and regional verification (CH) - Scores

Reference

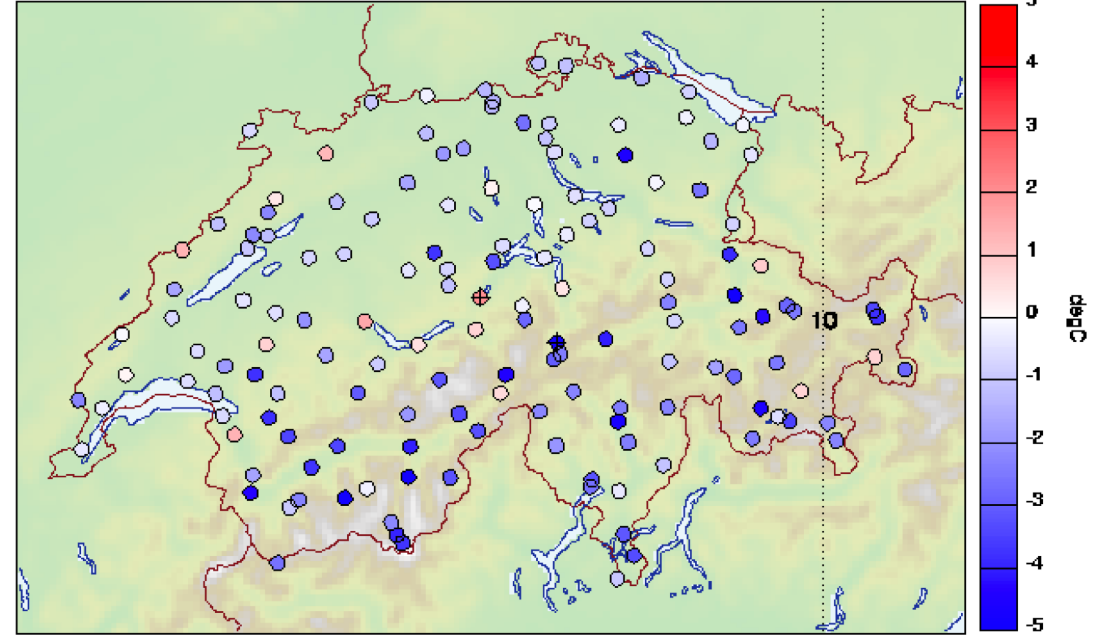
T_2M: ME



200_ch 2020-12-08 13:00 to 2020-12-23 12:00 01-24
+Min: -3.561 degC at station MTR +Max: 4.677 degC at station SRS

COSMO-S

T_2M: ME



204_ch 2020-12-08 13:00 to 2020-12-23 12:00 01-24
+Min: -5.935 degC at station GOS +Max: 2.011 degC at station GIH

CH – 2020-12-08 to 2020-12-23



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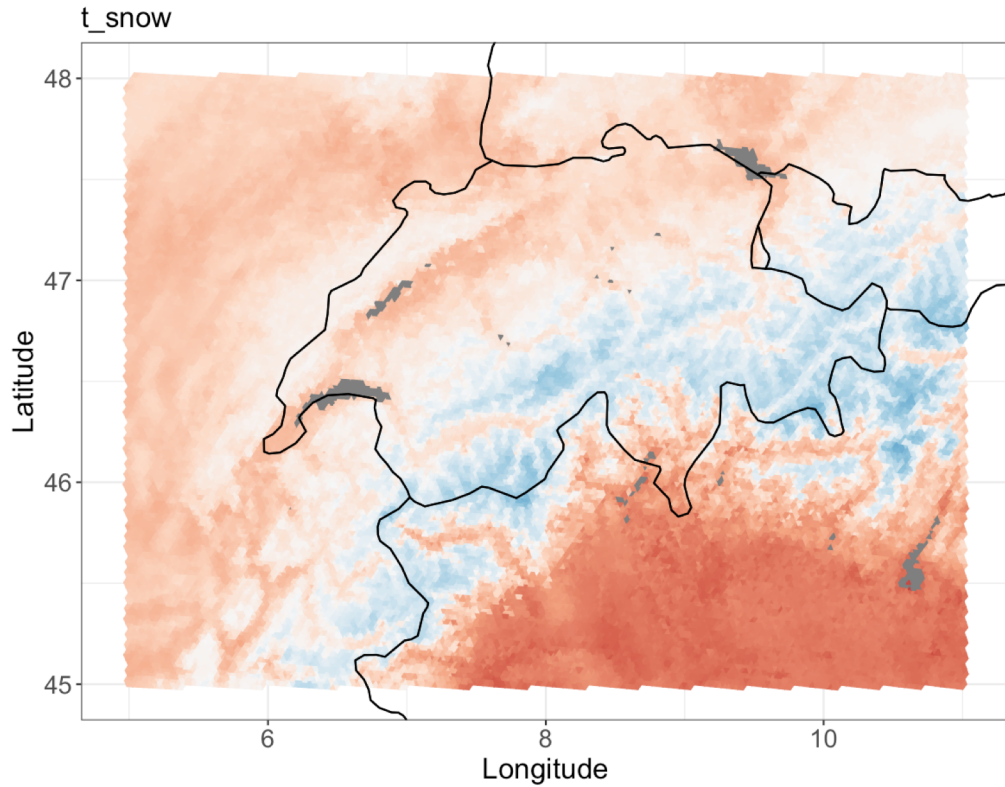
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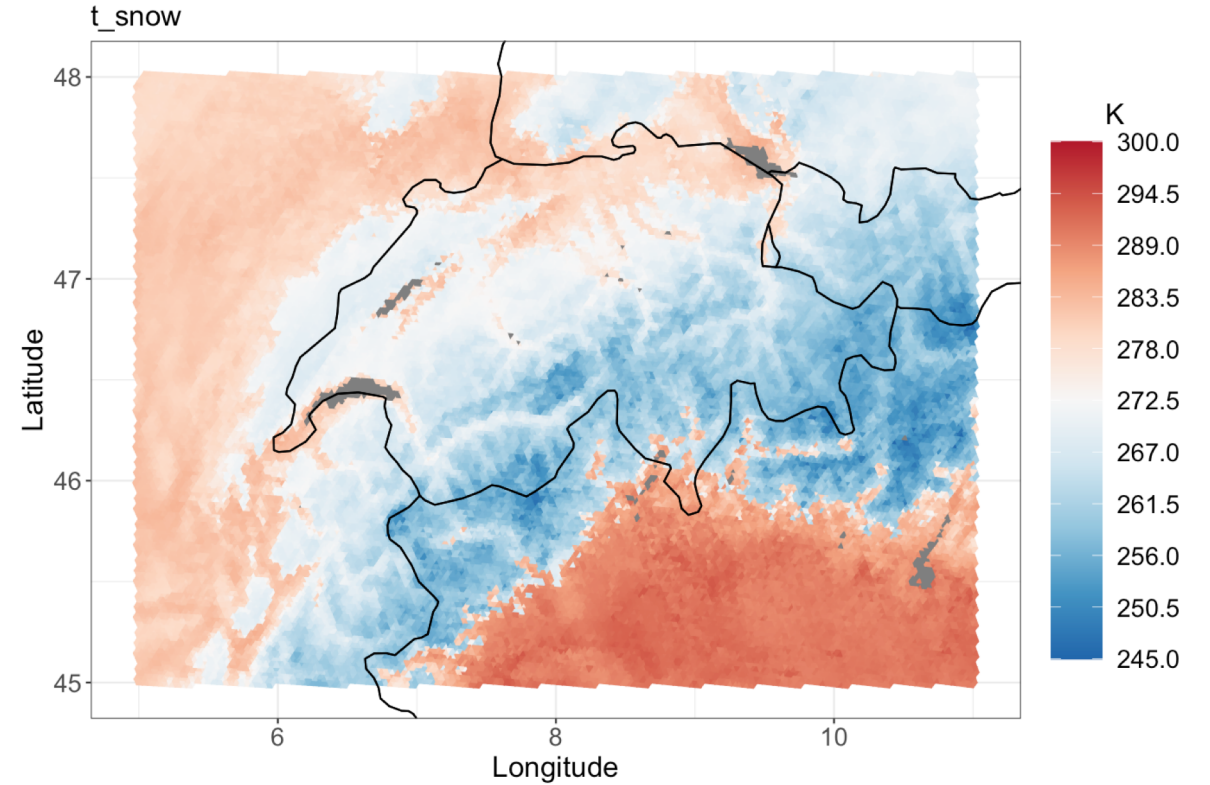


Surface Temperature comparison (CH) - T_SNOW

Reference



ICON-S



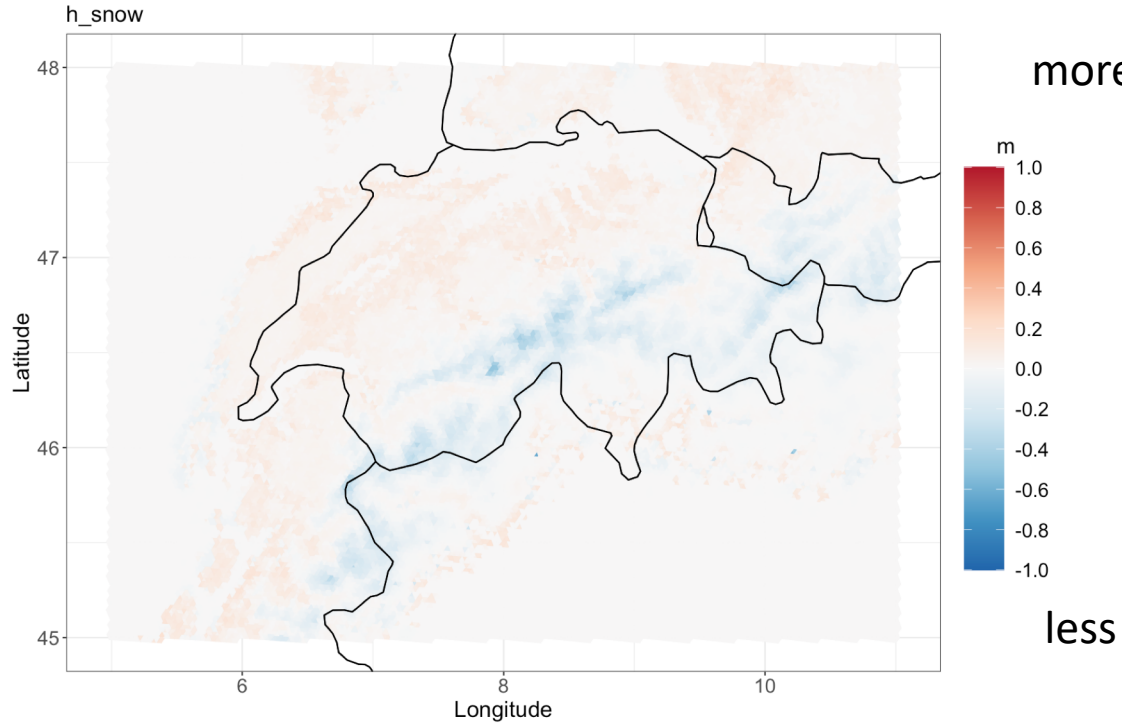
ICON-D2 – 20210317 12 UTC



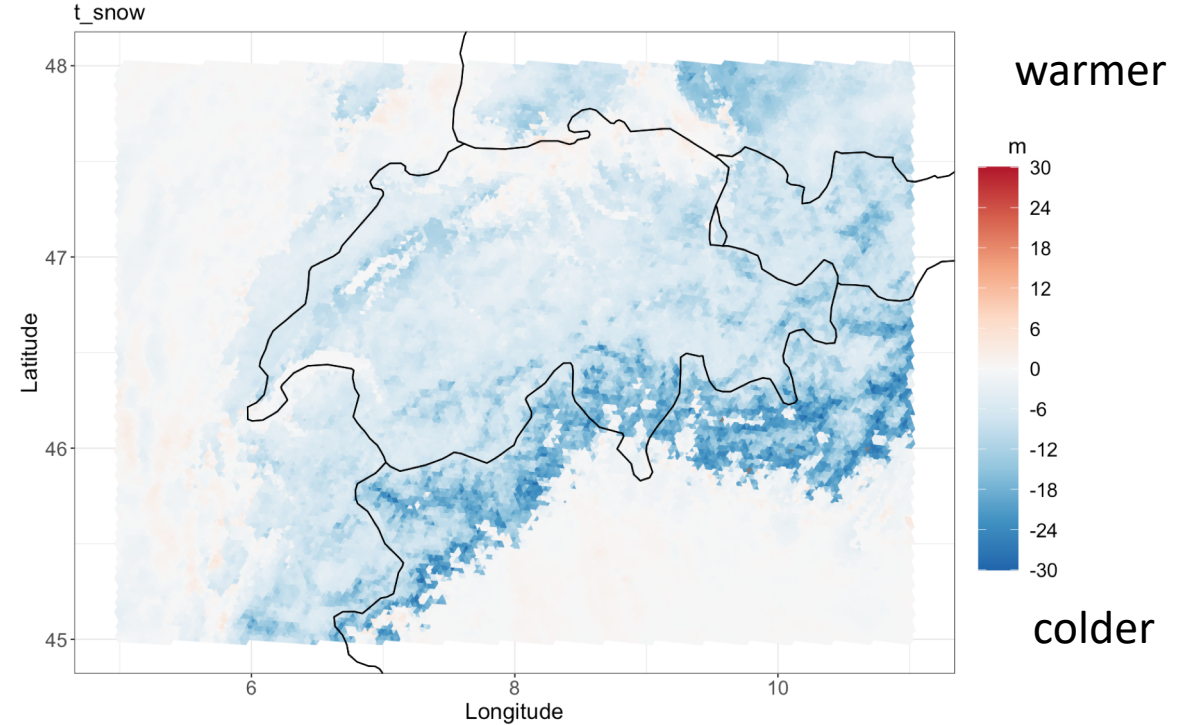
Comparison ('Bias') Alps – H_SNOW & T_SNOW

ICON-S - Reference

H_SNOW



T_SNOW



ICON-D2 – 20210317 12 UTC

Conclusions — COSMO-S & ICON-S

COSMO-S

- Fully coupled GPU Version merged with master (will be part of COSMO-6.0)
- Local/regional validation shows sound results in terms of snow height and surface temperature.
- Full (season) e_suite and verification pending
 - 2 weeks verification shows too cold T_2M
- Integration into KENDA cycle pending.
- No deadline for production (itype_snow_start = 2).

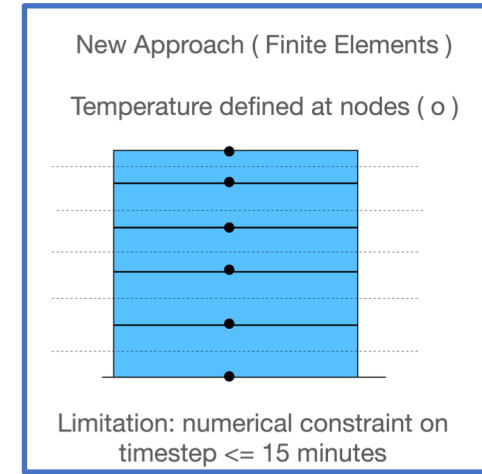
ICON-S

- Implemented into ICON (went through first code review at DWD; Günther Z.)
- Comparable results to COSMO-S however worse!
- Current obstacles:
 - Unknow snow related pitfalls.
 - Code is not ready for vector machine. (major)
 - I/O needs to be implemented (minor)
 - Editorial changes needed. (minor)



Outlook – additional ‘numerics & physics’

- Fully implicit solver for heat equation



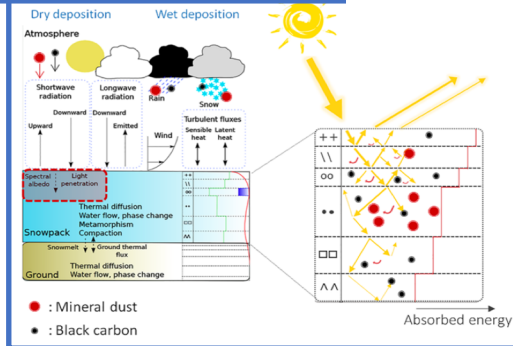
- Snow canopy interactions

The Cryosphere, 11, 2633–2653, 2017
<https://doi.org/10.5194/rc-11-2633-2017>
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The Cryosphere

A multilayer physically based snowpack model simulating direct and indirect radiative impacts of light-absorbing impurities in snow

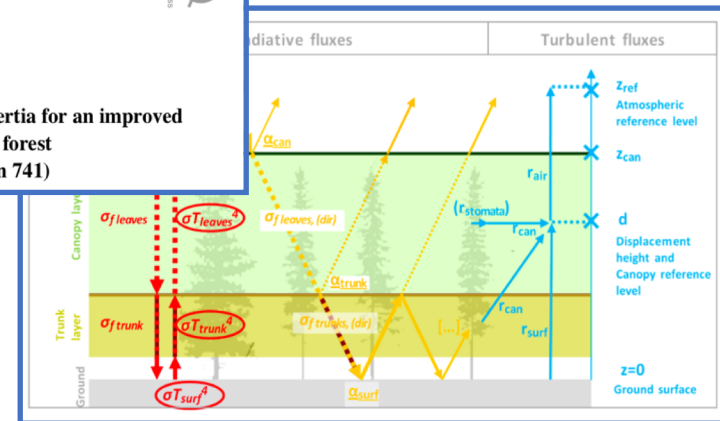
Francois Tuzet^{1,2}, Marie Dumont¹, Matthieu Lafaysse¹, Ghislain Picard², Laurent Arnaud², Didier Voisin², Yves Lejeune¹, Luc Charrois¹, Pierre Nabat¹, and Samuel Morin¹



Geosci. Model Dev., 8, 2379–2398, 2015
www.geosci-model-dev.net/8/2379/2015/
 doi:10.5194/gmd-8-2379-2015
 © Author(s) 2015. CC Attribution 3.0 License.

Geoscientific Model Development

A two-layer canopy model with thermal inertia for an improved snowpack energy balance below needleleaf forest (model SNOWPACK, version 3.2.1, revision 741)



- Aerosol and their impact on snow

Many, many more things to do!!!



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Thanks!
Comments and/or questions?

(COSMO-S & ICON-S)

Contact: Sascha.Bellaire@meteoswiss.ch