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Almost ready to merge...

NIX in Modular TERRA

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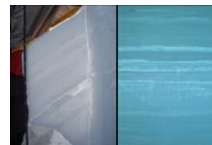
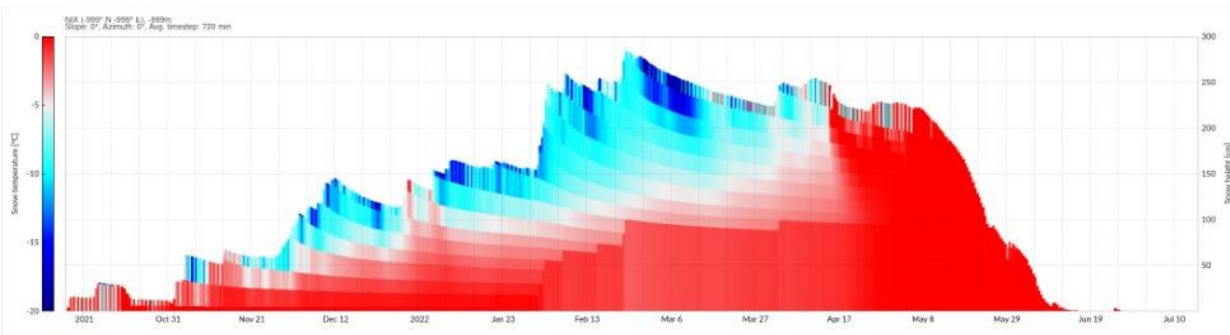
Background

- Concerted effort from MeteoSwiss and the Swiss WSL Institute for Snow and Avalanche Research SLF (Nander Wever) and DWD (Sascha Bellaire) to improve the representation of snow processes by implementing NIX
- **End of 2024, we decided to integrate NIX inside Modular TERRA, and to integrate NIX inside JSBACH (fully coupled with mass and energy balance)**



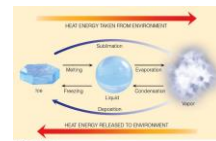


- Multi-layer, physics-based snow cover model, based on the detailed SLF SNOWPACK model
- From Essery et al. (2012): "There is no clear link between model complexity and performance, **but the most consistent results come from configurations that have prognostic representations of snow density and albedo and that take some account of storage and refreezing of liquid water within the snow.**"



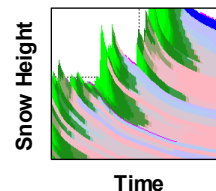
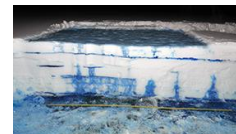
Layering (create/aggregate/split)

Heat Equation_(implicit) $\frac{\partial T}{\partial t} = \alpha \frac{\partial^2 T}{\partial x^2}; \quad 0 \leq x \leq L; \quad t \geq 0$



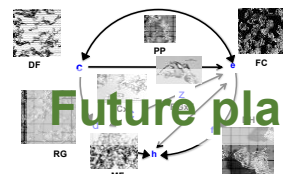
Phase Changes

Water transport



Settling

Snow microstructure



Future plans

3



General implementation concept TERRA + NIX

sfc_terra_main.f90

lnix = .FALSE.

lnix = .TRUE.

sfc_terra_snow.f90

```
PUBLIC :: snow_single_prepare
PUBLIC :: snow_single_soil_forcing
PUBLIC :: snow_single_melt
PUBLIC :: snow_single_calc_temperature
PUBLIC :: snow_single_update_new_state

PUBLIC :: snow_multi_prepare
PUBLIC :: snow_multi_handle_snowfall
PUBLIC :: snow_multi_soil_forcing
PUBLIC :: snow_multi_calc_heat_conduction
PUBLIC :: snow_multi_melt
PUBLIC :: snow_multi_update_new_state

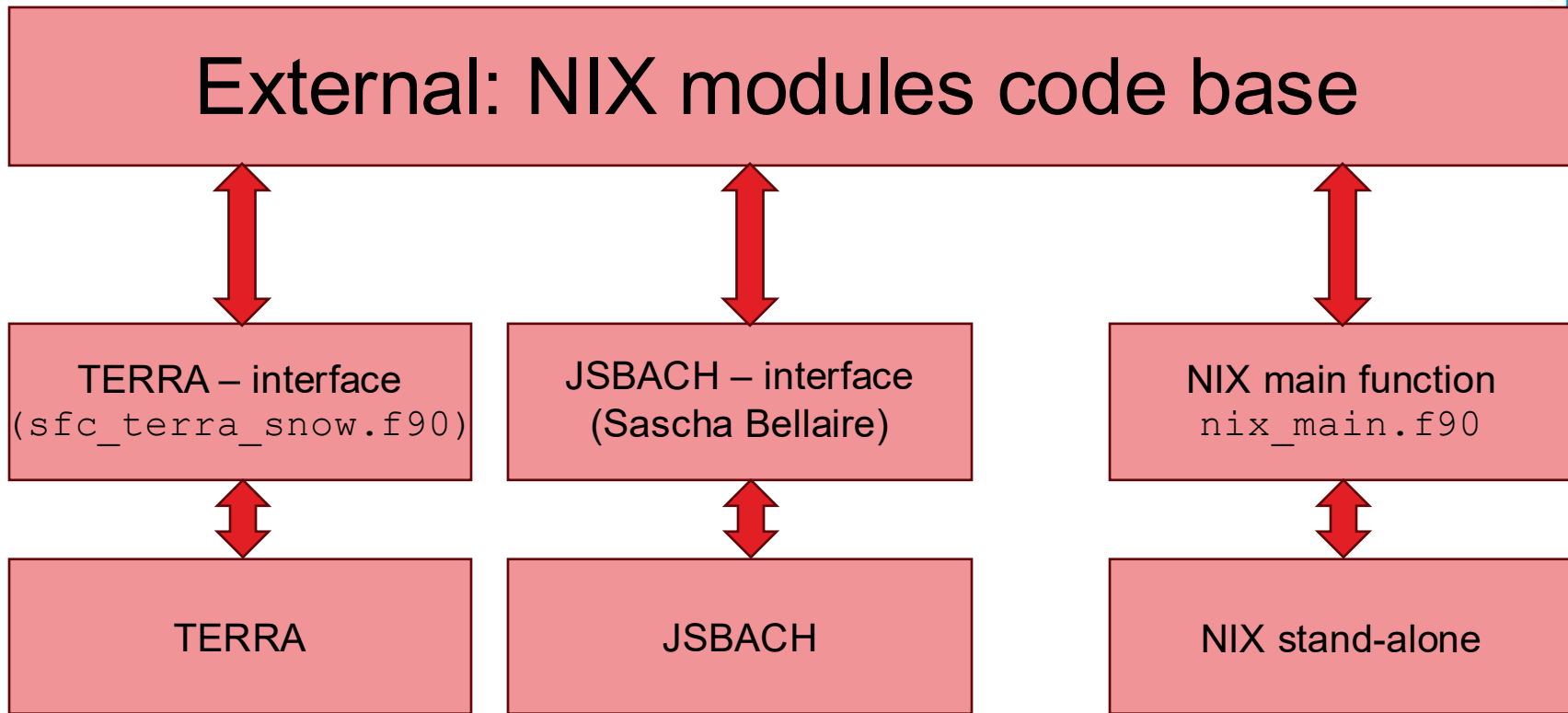
PUBLIC :: snow_nix_prepare
PUBLIC :: snow_nix_handle_snowfall
PUBLIC :: snow_nix_energy_balance
PUBLIC :: snow_nix_mass_balance
PUBLIC :: snow_nix_update_new_state
```

NIX modules

- New snow density
- Adding snowfall
- Heat equation
- Phase changes
- Water transport
- Compaction
- Updating state



Long-term vision for NIX



MeteoSwiss

Development status for NIX in TERRA



Status:

- Implementation has been finalized
- NIX branch now passed Scientific Review
- Buildbots are green
- Technical review ongoing
- Merge expected very soon now!

Features:

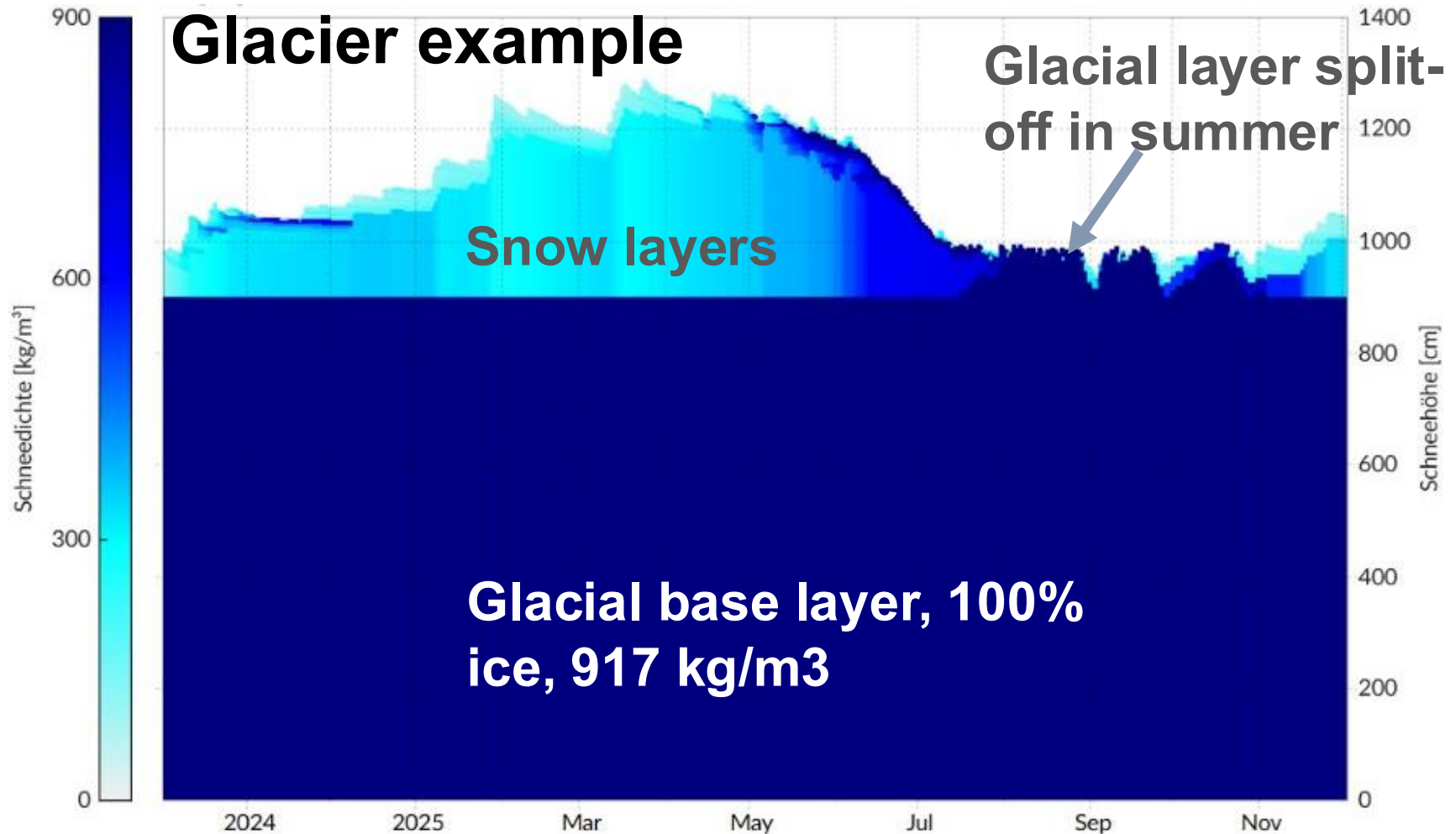
- Fully integrated into the heat and mass balance of TERRA
- We removed the per-tile enabling/disabling: NIX is now either active for all tiles, or none
- Support for forest tiles in similar approach as with the single layer scheme
- Support for snow analysis (IAU snow increments)
- Support for APT parameters
- First version of a glacier model



Glacier support

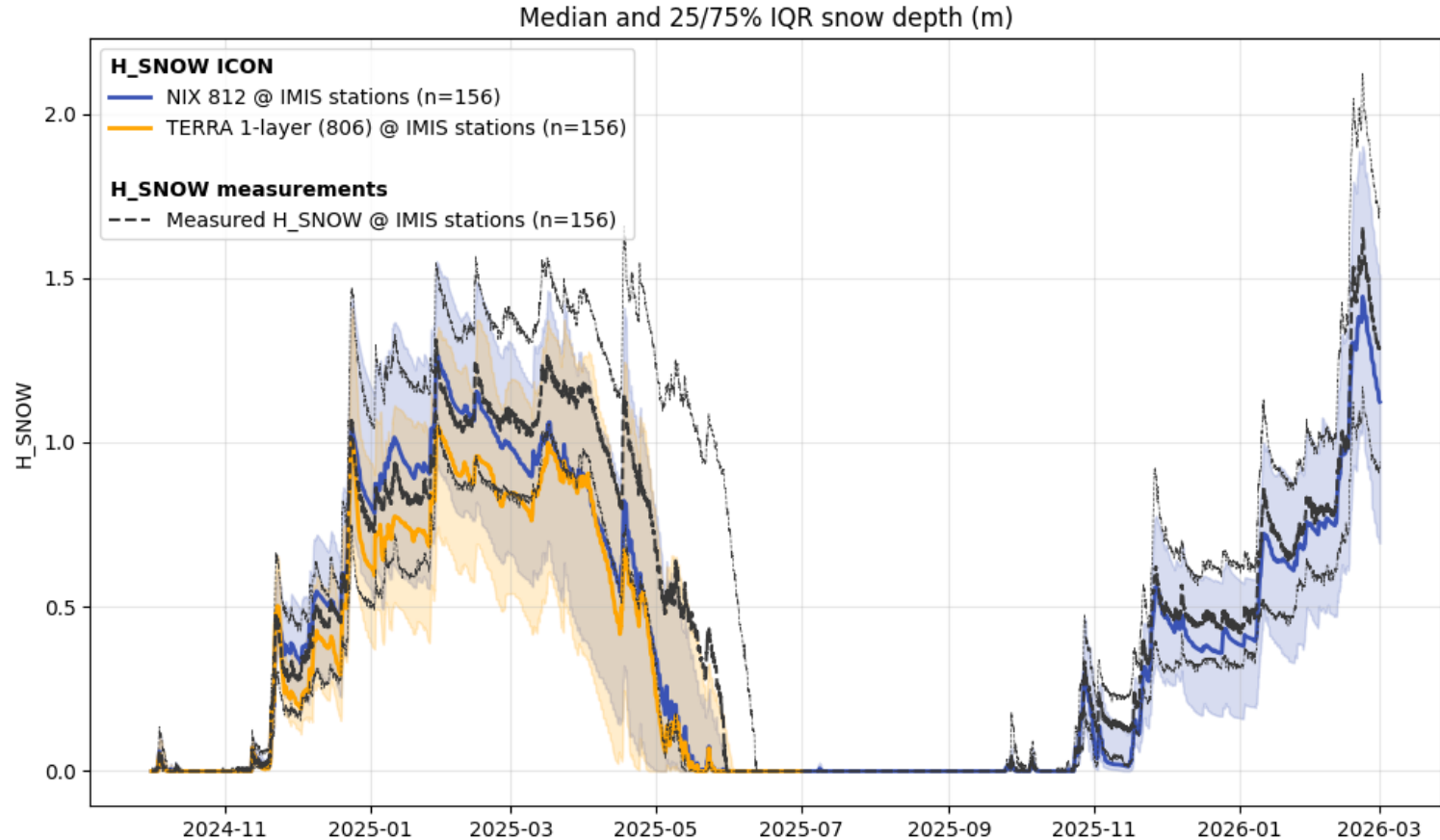
- NIX now also has a basic glacier model
 - Permanent snow and ice land use classes get a 9m thick glacial base layer, with optional snow layers on top
 - When snow layers disappear, glacier layers may be split-off from the basal layer, to keep fine spatial resolution near the surface to represent the temperature gradients there
 - Upon snowfall, those split-off ice layers get merged back into the basal layer
- Limitations:
 - No albedo tuning for whether or not glacial ice is at the surface
 - Inconsistencies can be expected translating initial conditions from bulk fields W_SNOW and H_SNOW calculated using TERRA 1-layer scheme to NIX
- Future work:
 - Have H_SNOW and W_SNOW represent the snow layer on glaciers only, excluding the basal ice layer

Glacier example



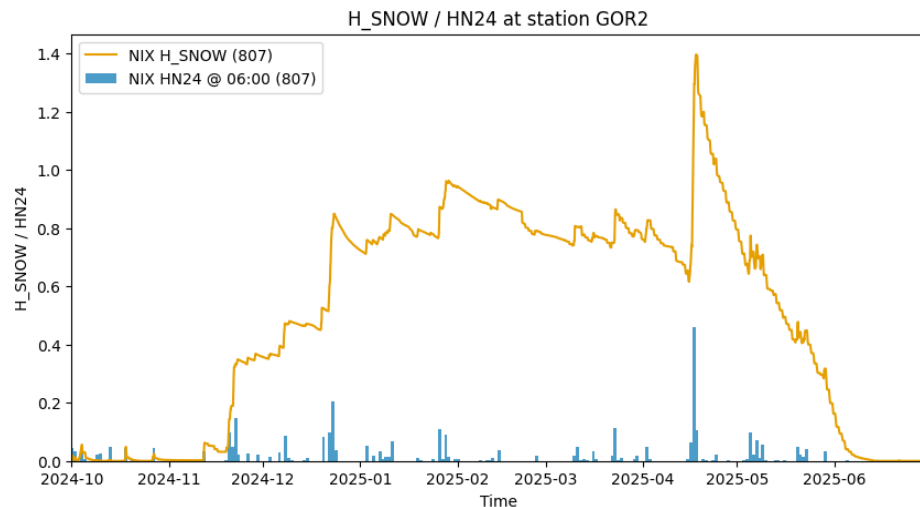


Averaged snow height

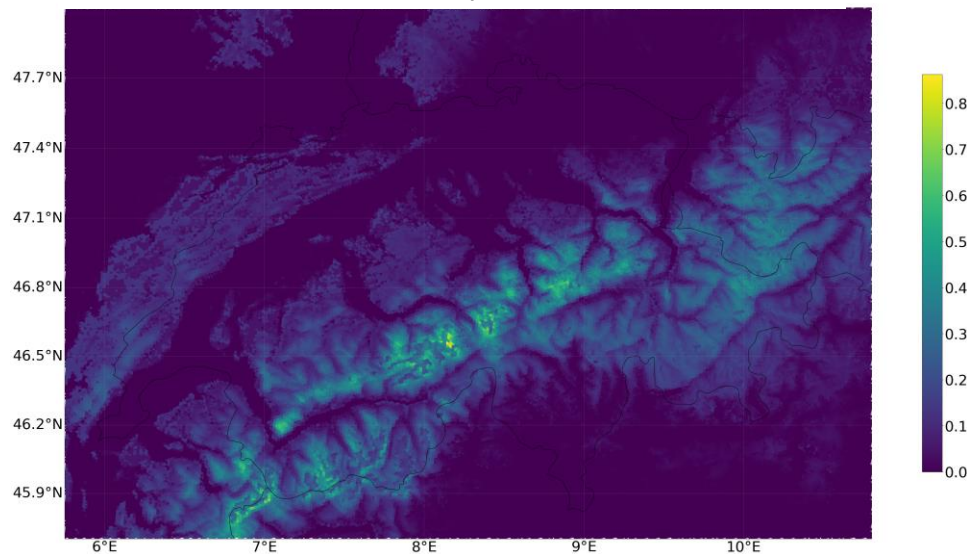




New snow on the ground (HN24)

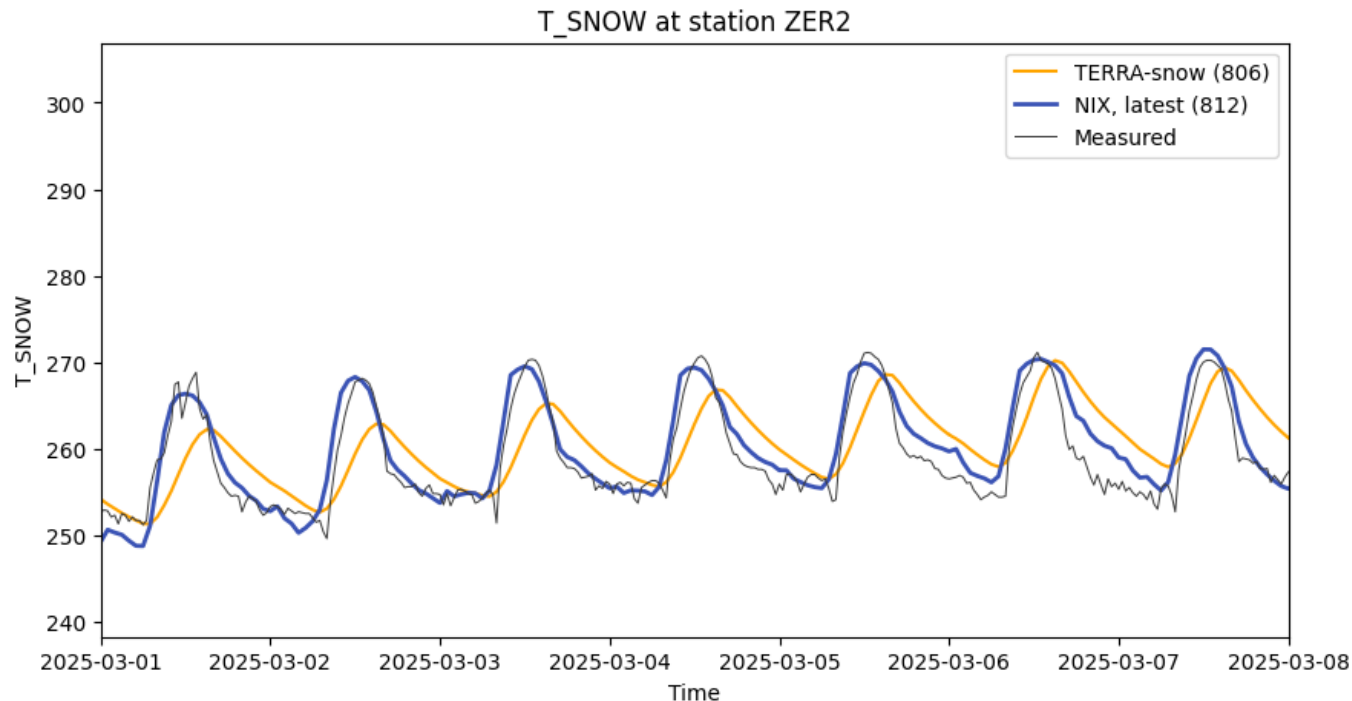


HN24 [m], 17.02.2026 (avalanche danger level 5 in parts of Wallis)





Snow surface temperature (T_{SNOW})



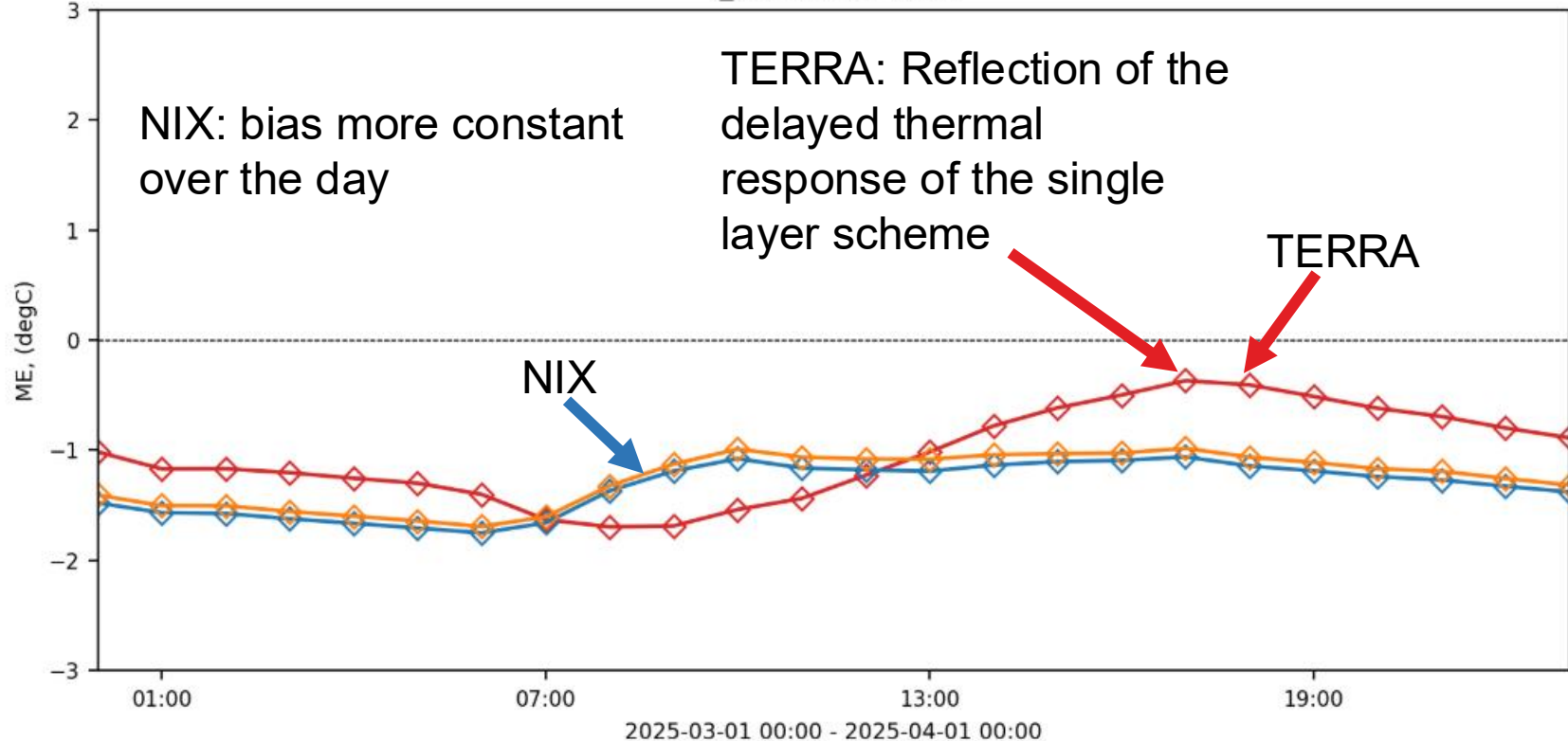
Single layer snow model has delayed response to the surface energy balance, due to the high heat capacity of the single layer

The multi-layer NIX model has shallow surface layers, that respond much faster, in excellent agreement with T_{SNOW} measurements.



T_{2M} Mean Error Alpine Mountain stations (diurnal cycle)

T_{2M}: ME, LT: 01-24





Validation scores NIX compared to TERRA single-layer

Parameter	STDE				ME				Remarks
	ch	ch-sp	ch-am	ch-av	ch	ch-sp	ch-am	ch-av	
	01-24	01-24	01-24	01-24	01-24	01-24	01-24	01-24	
ATHD_S	+2 %	-0 %	+0 %	+3 %	+5 %	+1 %	+6 %	+8 %	
GLOB	+0 %	+1 %	-0 %	+1 %	+1 %	+0 %	-1 %	+2 %	
DURSUN1	+1 %	+0 %	+1 %	+1 %	+1 %	+0 %	+1 %	+1 %	
T_2M	+2 %	-0 %	-2 %	+2 %	+7 %	+0 %	+16 %	-9 %	
TD_2M	+1 %	-2 %	-2 %	+4 %	-8 %	-3 %	-8 %	+8 %	
RELHUM_2M	+3 %	-0 %	+1 %	+5 %	-3 %	-2 %	-5 %	+3 %	
FF_10M	+1 %	+1 %	+1 %	+2 %	+1 %	-0 %	+0 %	+3 %	
DD_10M	+1 %	-1 %	+1 %	+0 %	+0 %	-0 %	+1 %	-1 %	
PS	+1 %	+3 %	+1 %	+1 %	-5 %	-3 %	+2 %	-8 %	
PMSL	+2 %	+1 %	n.a.	+2 %	+3 %	+2 %	n.a.	-5 %	



Limitations

- Only consistent when snow cover fraction is either 0% or 100%: thus, it only works with:
`lsnowtile = .TRUE.`
- Not fully energy- and mass balance conserving, for example caused by:
 - o Using implicit boundary conditions for numerical stability
 - o Maintaining glacier ice thickness
- Several tunings have not been evaluated in-depth, such as:
 - o Albedo and snow-cover fraction parameterizations
 - o APT parameters (included, but not fully tested)
 - o Several tuning approaches in TERRA are not tested (for example: if using `idiag_snowfrac == 20`, it is recommended to switch to `idiag_snowfrac = 2` when enabling NIX).
- Not all setups supported:
 - o Requires snowtiles
 - o Does not yet support nested domains that start during runtime

A word on the merge request process

- Due to a variety of reasons, the merge request takes a long time, and has led to frustrations with all parties involved
- Scope creep:
 - o going from: a snow model for the Swiss setup that leads to improvements for MCH forecasts and can be used for some land use classes, with potential future expansion
 - o to NIX also having a glacier model, including modifications for forests, having support for APT parameters, having support for future changes in turbtran, checking inlining of functions, and vectorization on NEC, provides neutral to positive results for all global setups, all in one merge request and one review process
- It was difficult to agree on the minimum requirements for merge

I think we should all do our best to avoid this in the future, otherwise developing for ICON becomes painful and unattractive.



Next steps / Outlook



- Merging with main (should be within weeks now)
- Testing at MCH in parallel suite for winter 26/27
- Scientific publication (paper)
- Update of stand-alone version (with help of AI-coding agents)
- Dust has to settle a bit...

Personnel information:

- Nora Helbig will start on Oct. 1 as my successor
- Master student Antonia Berndt from the University of Bern for 11 months to further validate and test NIX