

Working Group PHYS

Soil & surface activities

Jean-Marie Bettems / MeteoSwiss

Currently active fields

- *EXTPAR software (Mikael/C2SM)*
- *Soil properties & hydrology (Juergen, Linda/DWD)*
- *Topography & radiation (Christian/MCH)*
- *Snow model – NIX (Nander/MCH, Sacha/DWD)*
- *Urban model – PP CITTA' (Jan-Peter and team/COSMO)*
- *Surface to atmosphere transfer – ConSAT (Matthias, Guenther/DWD)*

EXTPAR software

- Mikael Stelio, new **source code administrator** since April 2025
- Zonda finalized (**web interface to EXTPAR** and grid generator)
- EXTPAR **code cleanup** on going, possible freezing and removing of COSMO support (→ SMC)

Topography & radiation

On going

New **external parameters**

- Digital Elevation Model (**MERIT** @ 90m, **COPERNICUS** @ 30m, global)
- Background albedo (@ 1km)

Radiation-topography (radtopo) **grid-scale** scheme

Radiation-topography **subgrid-scale** scheme



New EXTPAR topography: Copernicus DEM

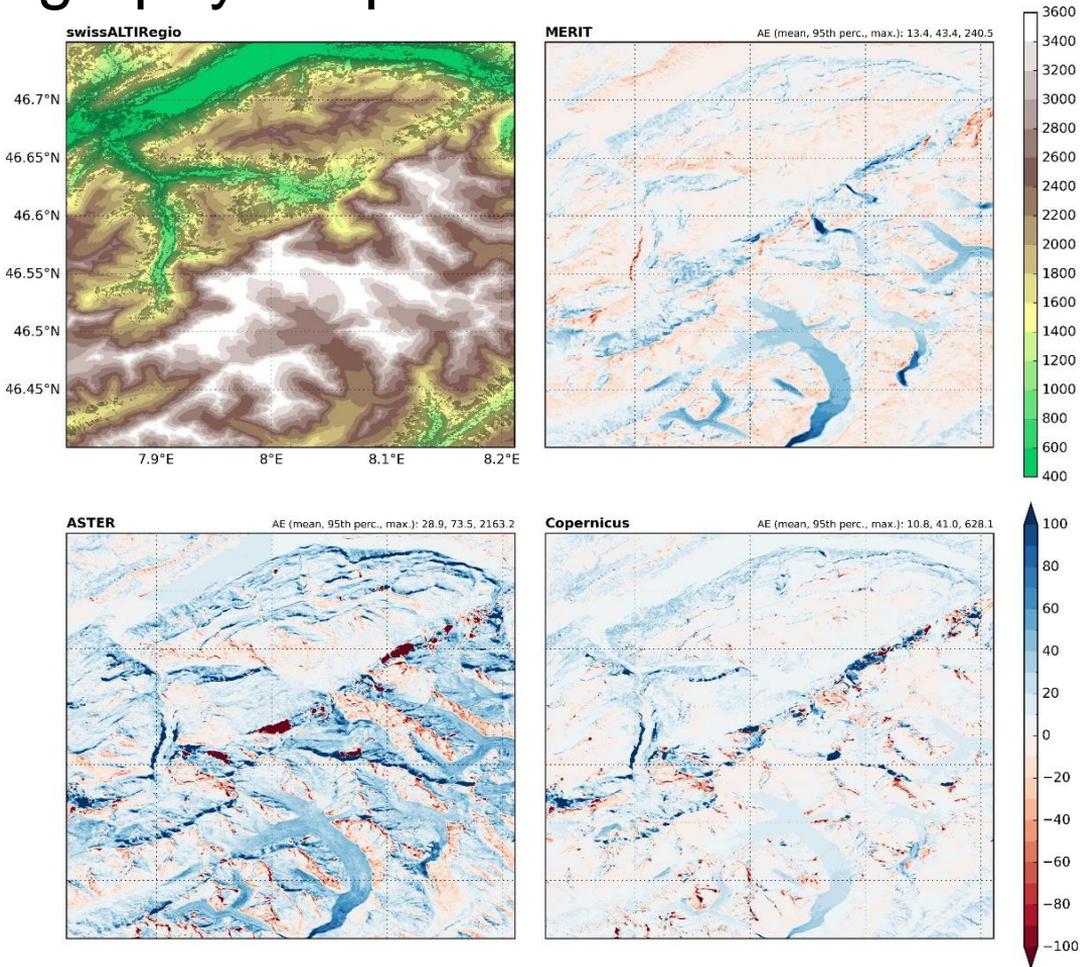
Copernicus DEM characteristics

- 30 m resolution
- Data from TanDEM-X mission (2011 - 2015)

- Replacement for **ASTER**, which is less accurate and occasionally suffers from severe artefacts in complex terrain
- ASTER artefacts also translate to **SSO parameters**
- Copernicus DEM better for **glaciated area** due to more recent data

Abs. dev.	Mean	95 th perc.	Max.
ASTER	13.1 m	41.4 m	2163.2 m
MERIT	7.0 m	23.7 m	240.5 m
Copernicus	4.7 m	16.6 m	645.5 m

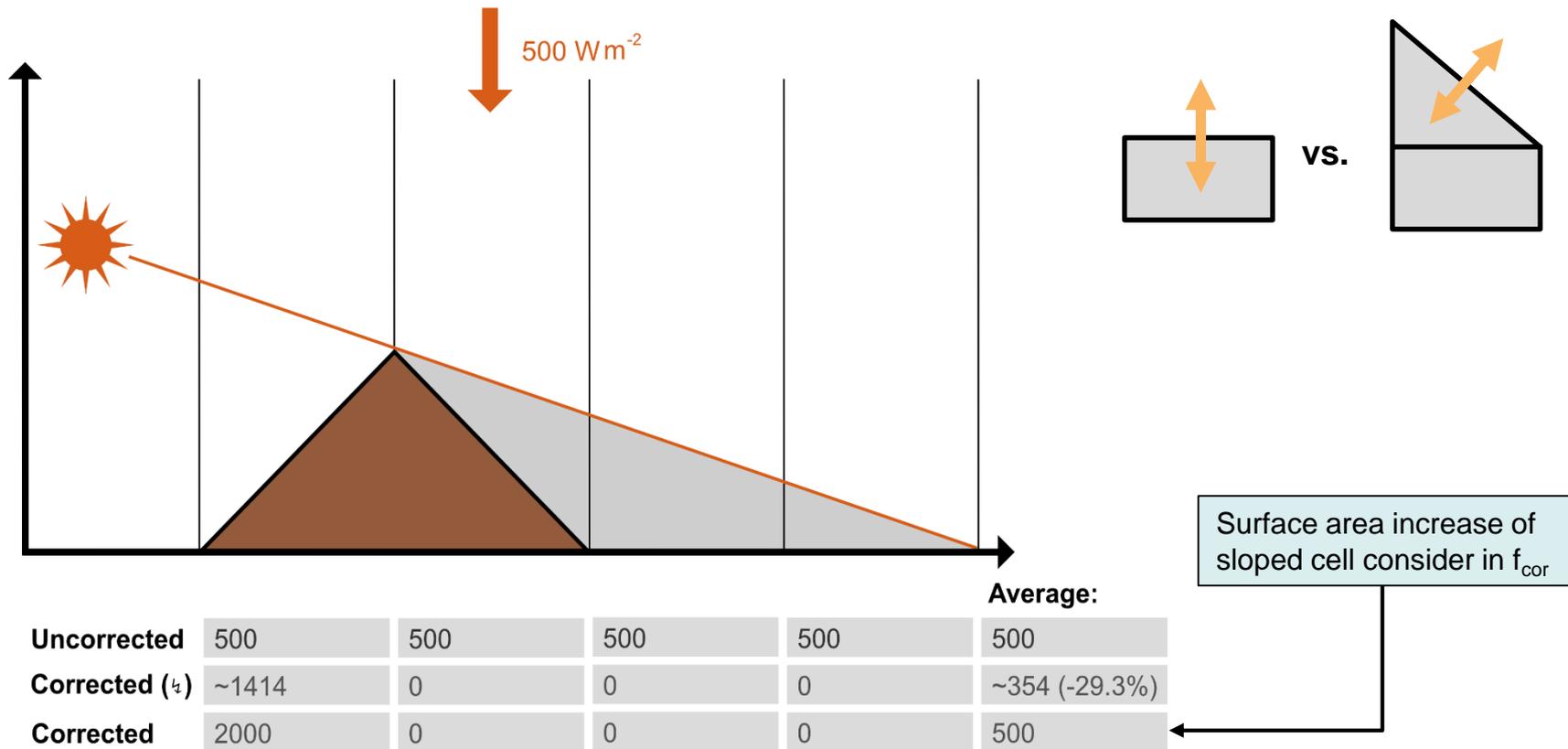
(for Switzerland)





Radtopo grid-scale

Improvement II: energy conservation



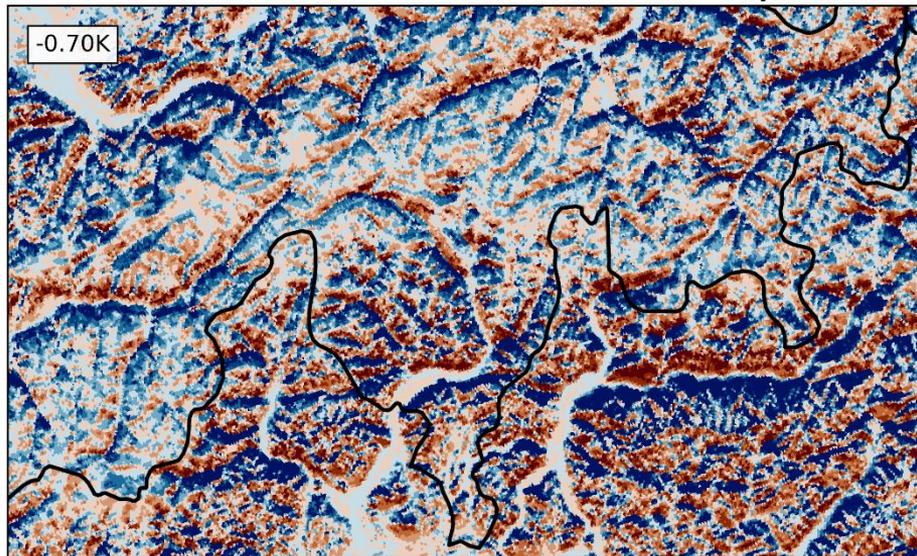


Radtopo grid-scale

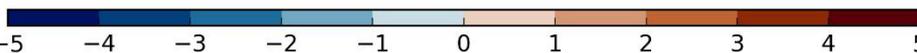
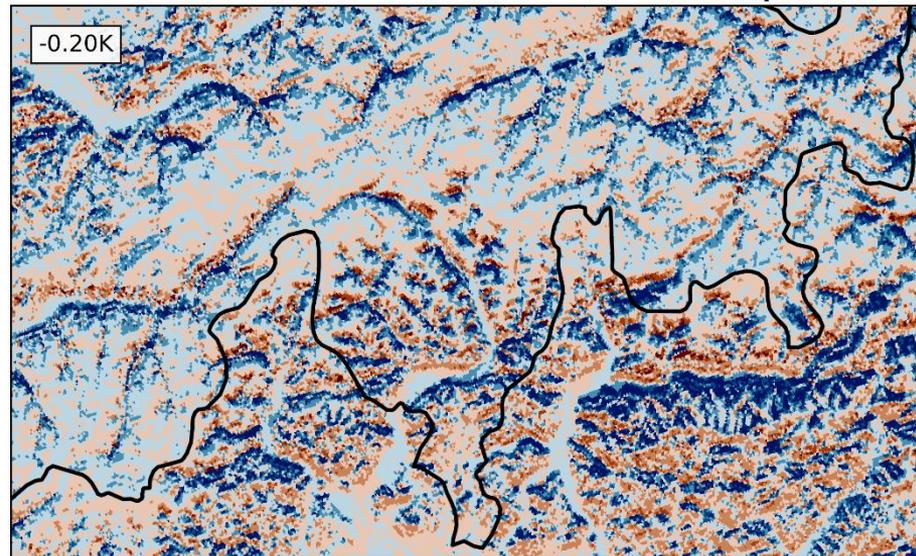
Effect on near-surface temperature

2024-12-25T12:00 UTC

Ground temperature [K]



2m temperature [K]



Soil properties & hydrology

On going

New **external parameters** and **model adaptations**

- soil composition (**SoilGrids** @ six depths, 250m, global)
- soil hydraulic properties (**HiHydroSoil** @ 250m, global)
- wetlands (**GLWD** @ 500m)

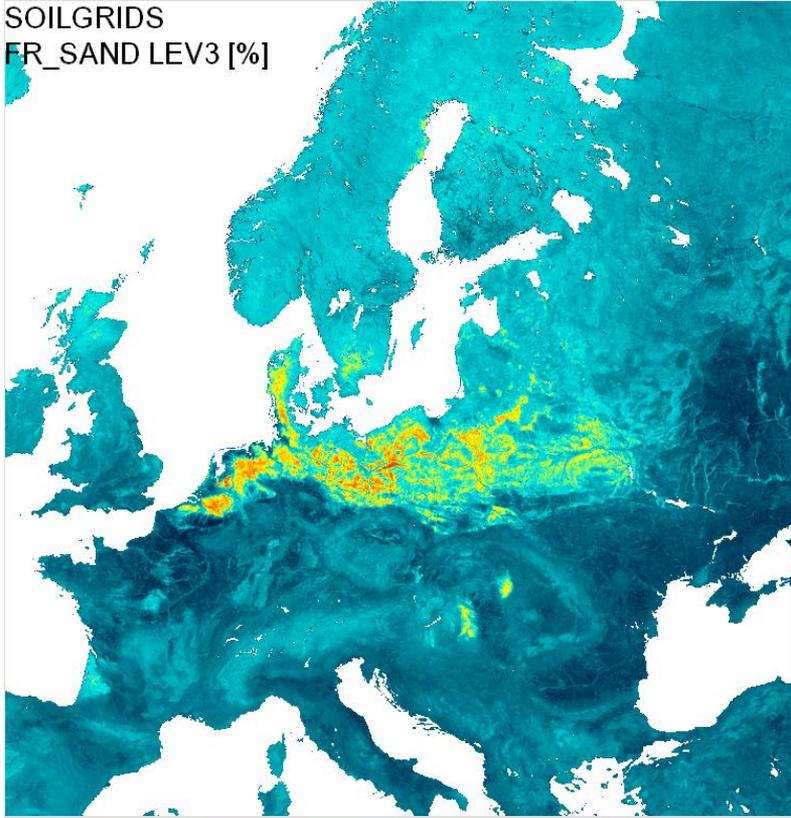
Strong cooperation with ECMWF and EWGLAM/SRNWP in ancillary data implementation.

Improve dust emission in ICON-ART, hopefully enhancing of dust-related phenomena.

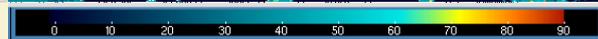
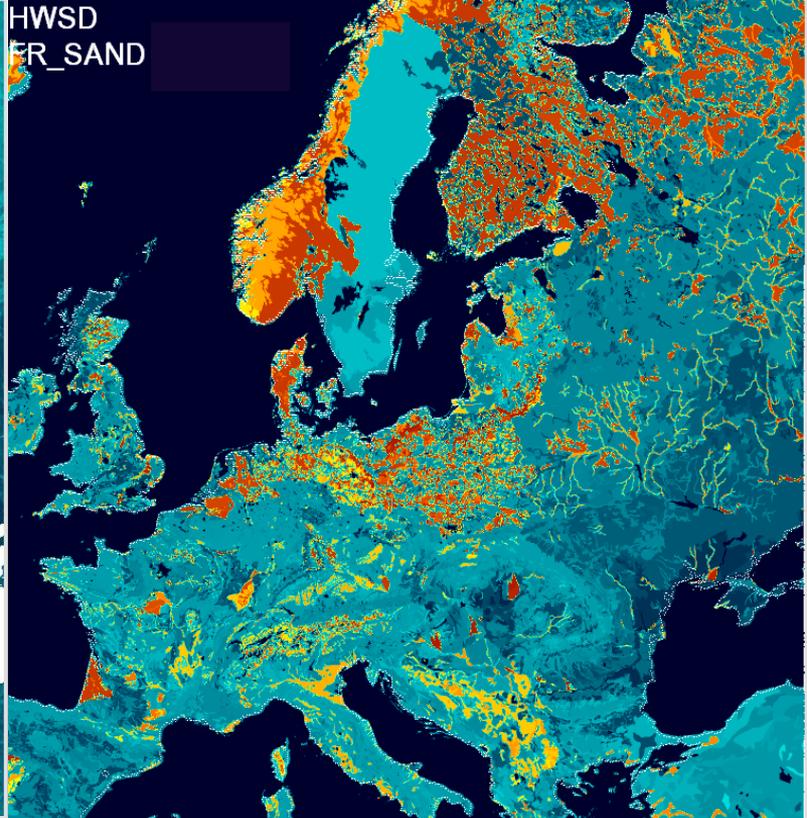
J.Helmert, L.Schlemmer, J.Förstner / DWD

Fraction of sand in soil data sets

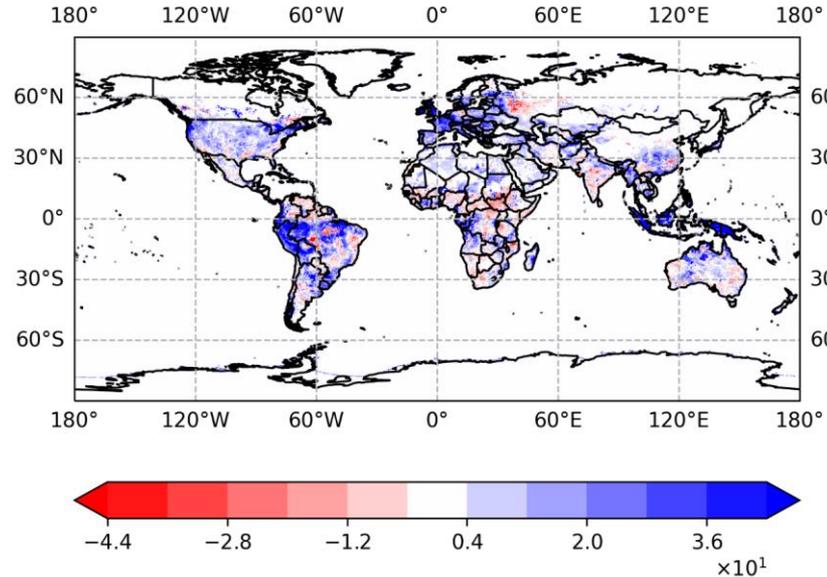
SOILGRIDS
FR_SAND LEV3 [%]



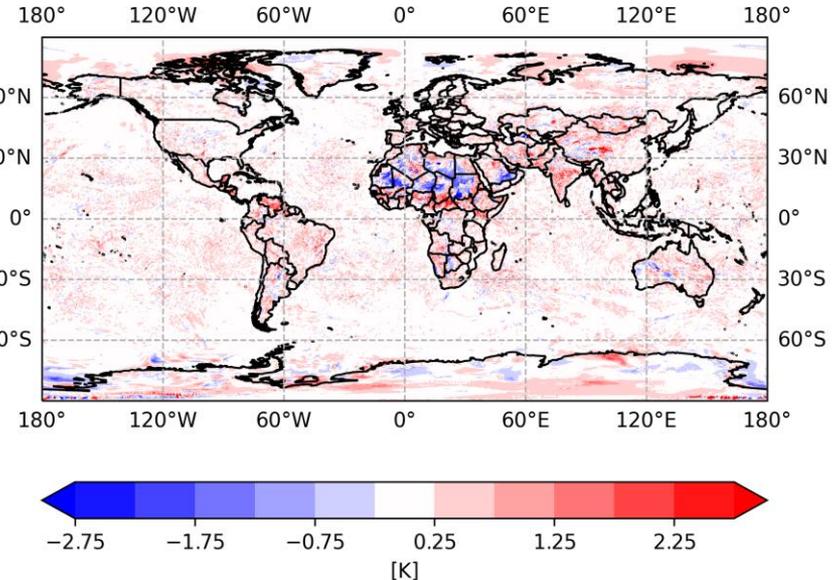
HWSD
FR_SAND



Hydraulic properties – Impact study



Difference in soil water (m) between HHS+MVG and FAO+Rijtema at layer 1



Difference in 2m temperature (K) between HHS+MVG and FAO+Rijtema.

Average over all fields valid at 2024-03-25-00



Surface to atmosphere transfer *On going*

- Piecewise transfer of some private ConSAT developments into master
- Scientific documentation

Future ConSAT work : TERRA-related implementations

- Step-wise introduction of bug-fixes, corrections and extensions done in 'mrsurf' into the current 'master'
 - Energy-conserving phase-transitions of interception water
 - Mathematically steady relation for snow-height and snow-fraction as a function of snow-water
 - Energy-conserving aggregation of surface-variables for dynamic sn and sf sub-tiles considering partial overlap with previous sub-tile domains
 - Semi-implicit evaporation from interception-water or snow-cover in terms of available water mass
 - Consideration of not-evaporating vegetation-parts (stems, branches and stomata-free side of leaves)
 - Implicit treatment of sl snow-temperature without singularity at vanishing snow.
- Adaptations of TERRA-implicit-code in ICON-branch 'mrsurf' to make it compatible with master
 - Modularization of TERRA-code
 - Introduction of snow-hydrology from NIX



Snow model (NIX)



Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Federal Department of Home Affairs FDHA
Federal Office of Meteorology and Climatology MeteoSwiss



Updates and outlook on **NIX** in **Modular TERRA**

Nander Wever^{1,2}, Sascha Bellaire³, Michael Lehning^{1,4}, Jean-Marie Bettems²

Daniel Hupp², Lukas Jansing²

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

²MeteoSwiss, Zurich, Switzerland

³Deutscher Wetterdienst (DWD)

⁴CRYOS, School of Architecture, Civil and Environmental Engineering, EPFL, Lausanne, Switzerland



Background

- Concerted effort from MeteoSwiss and the Swiss WSL Institute for Snow and Avalanche Research SLF (Nander Wever) and DWD (Sascha Bellaire) to make NIX broadly available
- The refactoring of TERRA ("Modular TERRA") made integration in TERRA feasible
- **End of 2024, we decided to integrate NIX inside Modular TERRA, and to integrate NIX inside JSBACH (fully coupled with mass and energy balance)**



NIX

- 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.**"

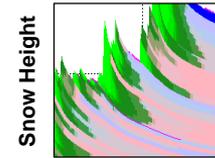
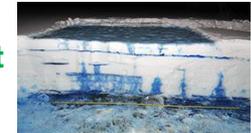


Heat Equation (implicit) $\frac{\partial T}{\partial t} = a \frac{\partial^2 T}{\partial x^2}; 0 \leq x \leq L; t \geq 0$



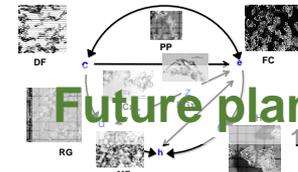
Phase Changes

Water transport



Settling

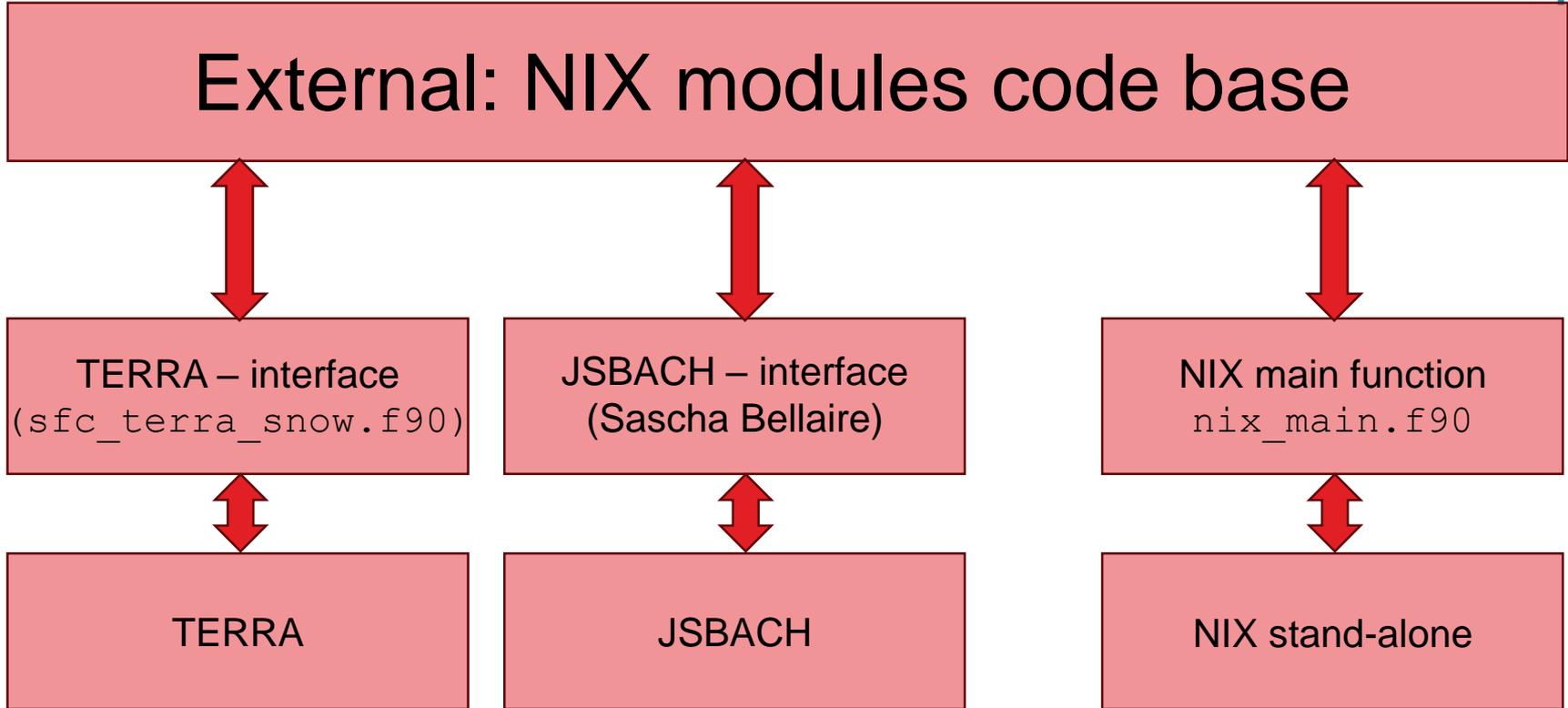
Snow microstructure



Future plans



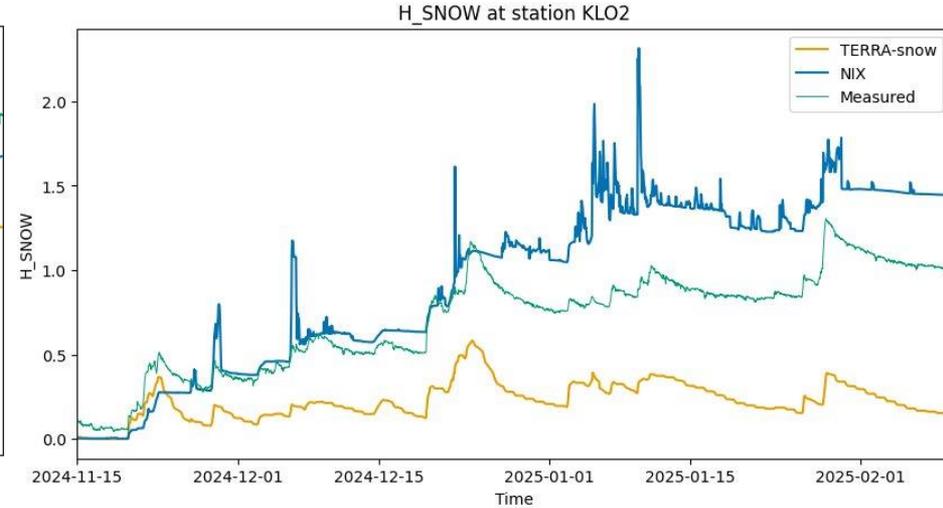
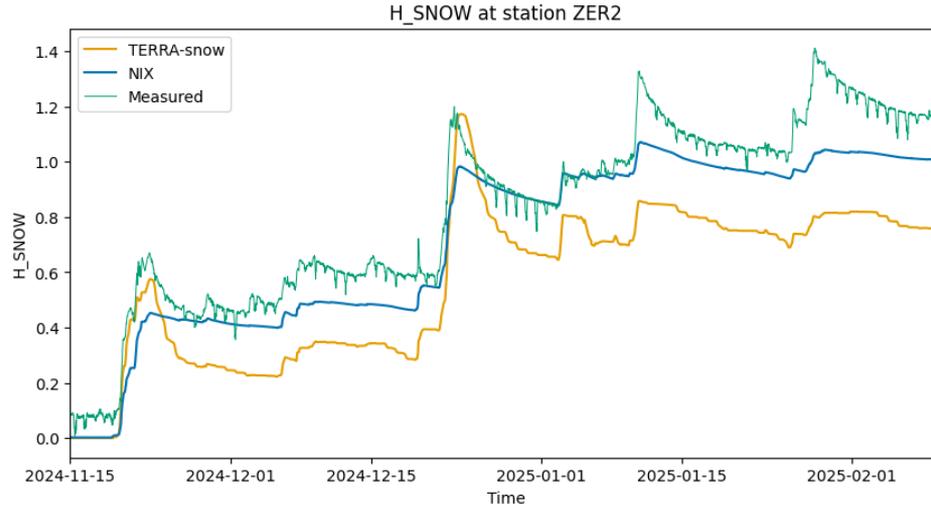
Long-term vision for NIX



MeteoSwiss



ZER2 and KLO2 snow height



- Snow height generally better reproduced than single-layer snow model with snow analysis
- Overestimated new snow density / underestimated settling



Conclusion



1. Integrating NIX inside modular TERRA is an important step for the future of modelling snow in TERRA
2. What works:
 - Able to run NIX **fully coupled** inside TERRA, also on GPU
 - First results of fully coupled mass and energy balance are consistent
 - Snow height well reproduced (note that this also implies good snowfall rates from ICON), without snow analysis
3. What needs work:
 - ~~Occasional bad feedback between turbulent fluxes, soil fluxes and heat equation solver, particularly with shallow snow covers (few cm) Might have been solved yesterday.~~
 - Missing some daily cycle dynamics in snow surface temperatures
 - Snow cover fraction scaling
 - Snow analysis
 - Some tuning for new snow density and compaction



Outlook



Short term (2025):

- Merge with main

Long term (2026 and beyond):

- NIX as an external: unified code base between TERRA, JSBACH and NIX stand-alone
- Implementation canopy interactions → strong community interest
- Microstructure (grain size) → geographical independence
- Extension to glaciers, ice sheets and sea ice

Urban model (CITTA' and beyond)

A new urban parameterisation for the ICON atmospheric model

Jan-Peter Schulz, Paola Mercogliano, Massimo Milelli, Angelo Campanale, Marianna Adinolfi, Carmela Apreda, Francesca Bassani, Jean-Marie Bettems, Edoardo Bucchignani, Davide Cinquegrana, Ron Drori, Rodica Dumitrache, Stefan Gabrian, Valeria Garbero, Witold Interewicz, Amalia Iriza-Burca, Adam Jaczewski, Pavel Khain, Yoav Levi, Bogdan Maco, Myriam Montesarchio, Mario Raffa, Alfredo Reder, Hendrik Wouters, Andrzej Wyszogrodzki,

and the COSMO PP CITTA' team

COSMO General Meeting, 1-5 Sep. 2025, Basel, Switzerland

Task 1: Implementation of TERRA_URB in ICON

Modifications in ICON:

Radiation scheme:
 Modify albedo
ALB

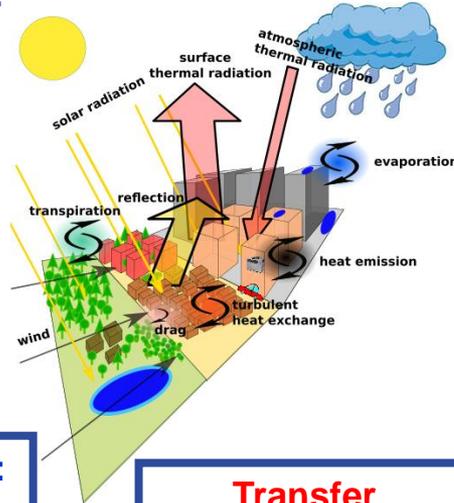
Land surface scheme:
 Modify heat capacity and thermal conductivity
THERM

Transfer scheme:
 Modify thermal roughness length
TURB

Land surface scheme:
 Introduce puddles
PUDDLE

Land surface scheme:
 Set infiltration and bare soil evaporation to zero
NOEVAP

Land surface scheme:
 Introduce anthropogenic heat flux
HFLUX



Task 2: Description of LCZs classes – ECOCLIMAP-SG

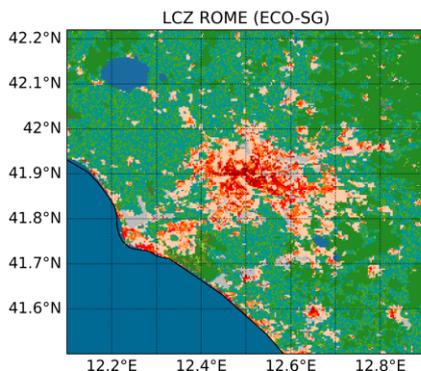
Dataset/Producer	Classes*	Descriptions
ECOCLIMAP-SG/CNRM	 24. LCZ1: compact high-rise	<ul style="list-style-type: none"> Strong built-up NDVI ≤ 0.2 and high rise buildings (3D roughness 50-100m) Strong built-up NDVI ≤ 0.2 and very high rise buildings (3D roughness > 100m)
	 25. LCZ2: compact midrise	<ul style="list-style-type: none"> Continuous urban fabric (from CLC) Strong built-up NDVI ≤ 0.2 and medium rise buildings (3D roughness 25-50m)
	 26. LCZ3: compact low-rise	<ul style="list-style-type: none"> Strong built-up NDVI ≤ 0.2 and low rise buildings (3D roughness <25m)
	 27. LCZ4: open high-rise	n.a. - Despite the class is included in the legend of ECOCLIMAP-SG, the data are not available in the European map. Technical documentation doesn't provide further details.
	 28. LCZ5: open midrise	<ul style="list-style-type: none"> Medium built-up $0.2 < NDVI \leq 0.3$ (o 6)
	 29. LCZ6: open low-rise	<ul style="list-style-type: none"> Light built-up $0.3 < NDVI \leq 0.4$
	 30. LCZ7: lightweight low-rise	n.a. - Despite the class is included in the legend of ECOCLIMAP-SG, the data are not available in the European map. Technical documentation doesn't provide further details.
	 31. LCZ8: large low-rise	<ul style="list-style-type: none"> Industrial or commercial unit, Airports (from CLC) Built-up with highly reflecting roof (associated to productive and commercial use) Roads
	 32. LCZ9: sparsely built	<ul style="list-style-type: none"> Road and rail networks and associated land, Mineral extraction sites, Dump sites, Construction sites, Green Urban Areas, Sport and leisure facilities (from CLC) Very light built-up NDVI > 0.4
		33. LCZ10: heavy industry

*Stewart I.D., Oke T.R., 2012. Local Climate Zones for Urban Temperature Studies. Bull Am Meteorol Soc., 93(12):1879-1900. doi:10.1175/BAMS-D-11-00019.1



Local Climate Zones

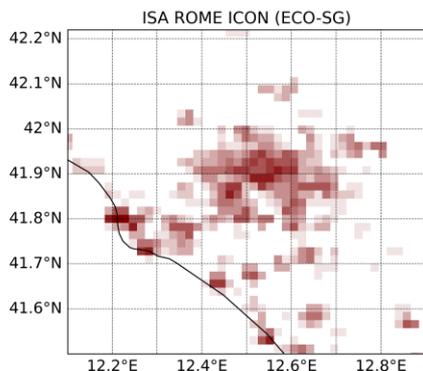
ECOCLIMAP-SG
10 LCZ urban classes



Rome

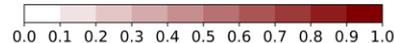
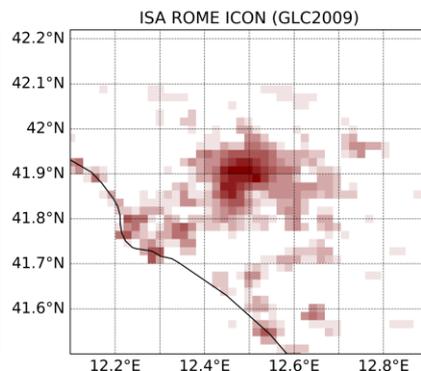
New land use dataset

ECOCLIMAP-SG, 33 classes
10 LCZ urban classes



Operational land use dataset

GlobCover 2009, 23 classes
Class 19: **Artificial surfaces**



ECOCLIMAP-SG:
Heterogeneity increased,
appears more realistic!

J.-P. Schulz (DWD, CMCC), A. Campanale (CMCC), A. Wyszogrodzki (IMGW-PIB), A. Jaczewski (IMGW-PIB), C. Aprea (CMCC)

WMO WWRP Research Demonstration Project Paris 2024 Olympics



Research Demonstration Project Paris 2024 Olympics

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Jan-Peter Schulz

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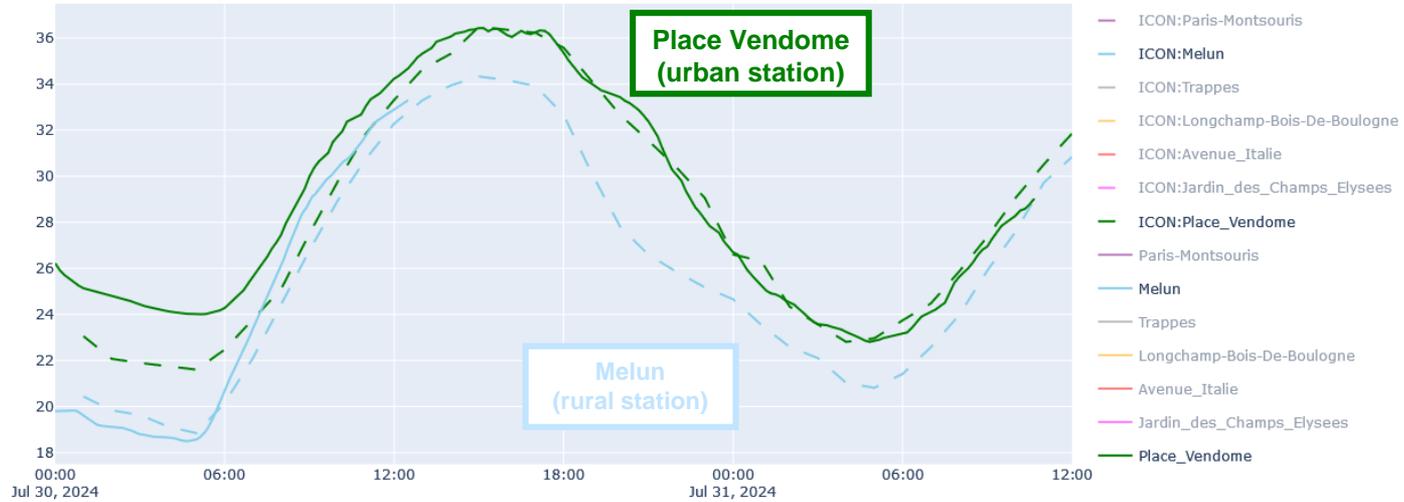
The strategic objective of the Research Demonstration Project (RDP) is to focus on the Olympic Games of Paris in 2024 in order to advance meteorological research on the theme of the "future Weather Forecasting systems at 100m (or finer) resolution for urban areas". Such systems would prefigure the numerical weather prediction at the horizon 2030.

The international research team is composed of meteorological services and universities of many countries, including Canada, China, USA, United Kingdom, Sweden, France, Australia, Austria. The RDP is endorsed by the World Weather Research Program of the World Meteorological Organization (WMO), the special agency of the United Nations for weather, climate and water. It is also supported by the GURME (Global Atmospheric Watch Urban Research Meteorology and Environment) project, also from WMO.



Coordinator: Valéry Masson

WMO WWRP Research Demonstration Project Paris 2024 Olympics 30-31 July 2024



J. Wurtz (Meteo France), S. Ulbrich (DWD)

Conclusions

- The first tasks of the COSMO Priority Project CITTA' were:
 1. Implement the urban canopy scheme TERRA_URB in ICON.
 2. Provide new urban canopy parameters for TERRA_URB in ICON.
- Status:
 1. TERRA_URB is now fully implemented and tested in ICON. It is available in the gitlab icon-nwp master. It is already operational at IMS (2023) and DWD (2025).
 2. The global land use dataset ECOCLIMAP-SG was made available in NetCDF. Preliminary look-up tables were developed. ECOCLIMAP-SG was implemented in the preprocessor EXTPAR, in github, and in ICON.
- Experiments with TERRA_URB in ICON-LAM are on-going in several groups of the project. The results look very promising. Characteristic urban features are well represented, for instance the Urban Heat and Dry Island effects.

Conclusions

- With the participation in the RDP Paris 2024 Olympics the COSMO PP CITTA' managed to join the community of international Meteorological Services maintaining urban models for NWP applications.

Future work

- Scientific applications of the new model system, for instance studying extreme weather events in urban areas (heat waves, thunderstorms), the urban boundary-layer, or air quality.
- Hectometric-scale modelling studies (ECOCLIMAP-SG).