Annex A:

Project description: Snow cover Atmosphere INTeractions (COSMO-SAINT)

An improved snow cover scheme for numerical weather prediction and climate models

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The proposed research builds on work conducted during a joined – and currently ongoing – project between MeteoSwiss and the WSL Institute for Snow and Avalanche Research SLF, which officially started in June 2017. Within this project, fundamental work has been carried out towards developing a new multi-layer snow cover scheme for COSMO.

Today, a stable version of this new multi-layer snow cover scheme (MLS) including all essential physical parametrizations is implemented in the latest COSMO version (6.0), which shares the same surface scheme (TERRA) with ICON, the future model of the COSMO consortium, making the transition to the ICON model feasible. Note that the new MLS scheme was implemented in a way that it is independent of changes to the surface scheme as well as the choice of the host model, i.e. COSMO or ICON. However, for ICON adjustments will still be required due to e.g. the tile approach.

Verification of the new MLS scheme shows good performance in snow-cover build-up and melt comparable to e.g. the highly sophisticated snow cover model SNOWPACK when forced with measured as well as forecasted input data. However, the MLS scheme shows shortcomings in terms of snow cover duration as well as atmospheric parameters when used in long-term (seasonal) simulations, especially for lower elevations. These shortcomings most likely stem from an inadequate coupling of the MLS scheme – especially of the turbulent fluxes – to the atmosphere. Investigations and finding potential solutions for the problem are still ongoing and are performed in close collaboration with DWD colleagues.

Given the aforementioned shortcomings, we propose a prolongation of the SAINT project for another 12 month, which will be separated into three phases. The three phases will be briefly described in the following.

Phase 1 – Consolidation of the MLS scheme (2 months)**:** As written above, the first stable version of the MLS scheme was implemented into the current version of COSMO (6.0). However, this version needs to be further validated to identify and fix the current shortcomings of the scheme and to ensure numerical stability. For example, a strong cold bias currently prevents MeteoSwiss to runthe new MSL scheme within COSMO for production. Although, the root of this shortcoming might have already been identified, i.e. a mismatch of turbulent fluxes provided by the MLS scheme and the turbulent transfer scheme, this still needs to be addressed and solved including validation and verification. For the verification at least one full winter season (October – June) should be simulated. We propose using a

small domain, i.e. covering Switzerland, with 2 km horizontal resolution to limit computational costs. This setup is already available and can be used right away once the new code base is available.

Milestone 1: Validated, verified, and consolidated fully coupled MLS scheme

Phase 2 – Pre-operational test phase (2 months): After a positive validation and verification of the fully coupled MLS scheme in COSMO 6.0 performed during Phase 1, the new code needs to be integrated into the current workflow at MeteoSwiss. Depending on the outcome of Phase 1 a few scenarios are possible. The ideal scenario would be that the fully coupled version shows acceptable verification scores and runs numerically stable. In this case a new operational release of the code needs to be generated and tested in a close to operational setup ("e-suite").
For the case that the aforementioned shortcomings, i.e. the coupling with the atmosphere cannot be solved in due time one can still run the MLS scheme in COSMO in the KENDA cycle or run a stand-alone version offline forced with atmospheric analysis.

Milestone 2: Fully coupled multi-layer snow cover scheme ready for production

Phase 3 – Additional model developments (8 months): During the course of the project it became evident that computational costs of the MLS scheme can be significant depending on the number of snow layers used. In order to reduce these costs one can reduce the number of layers to achieve acceptable costs for operations. The current default for the number of snow layers is ten, which still provides reasonably good results compared to the more sophisticated snow cover model SNOWPACK, which technically utilizes an infinite number of layers. Another way to reduce the computational costs is to increase the time-step, i.e. the time between two consecutive calls to the MLS scheme, e.g. to 10 minutes rather than the currently used 10 seconds. However, this approach requires an implicit solver for the heat equation, which can handle these longer time-steps as opposed to the currently implemented semi-implicit solver. This implicit solver is also required for ICON, which uses longer time steps – up to 6 minutes – for the global runs.
Currently, snow in, on top, or under canopy is not treated in COSMO nor in ICON in a physical way. However, SNOWPACK already includes a canopy interaction scheme, which can be integrated into the MLS scheme and would already be an improvement or first step on treating snow canopy interactions in a more physical way. Again, this can also be used directly in ICON where snow canopy interaction are a significant source of error especially on the global scale.
Furthermore, potential shortcomings (absorption of short wave energy, rain on snow, etc.) of the MLS scheme as well as related atmospherics shortcomings (e.g. 2m temperature diagnostics) need to be addressed. A crucial point for operational production is the snow analysis and data assimilation cycles, which need to be adjusted to the new MLS scheme.

Milestone 3: Implicit solver and canopy interaction scheme implemented and tested in COSMO.

Additional comments:

ICON compatibility:

Latest in 2023 the NWP model COSMO will be replaced at MeteoSwiss by ICON in its limited area version (LAM). Therefore, it is of paramount importance that all developments done in or for COSMO are compatible with future ICON-LAM use.

This issue has already been addressed by implementing new modules and subroutines for the MLS scheme in a way that the scheme itself can also be used by ICON-LAM as is without further adjustments. Therefore, after Phase 1 the MLS scheme should be fully compatible with ICON-LAM. However, adjustments will be required in ICON itself since ICON uses a tile approach and therefore up- and downscaling to the snow model (atmospheric forcing and feed-back) need to be made consistent and adequate to get the full performance of the MLS scheme and its feed-back on the atmospheric boundary layer. These adjustments will have to be discussed and ideally conducted with ICON developers at DWD. The latter has already been initiated during the course of the current project duration.

Schedule:

The above-mentioned duration and schedule assumes a 50% employment of the main scientific collaborator; in case of part-time employment it changes accordingly.