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 the current operational version of COSMO, respectively ICON.

During the course of the project the current code – with regard to the available snow cover schemes implemented in the - to date - latest version of COSMO has been validated and a new multi-layer snow cover scheme as well as its implementation has been proposed to the consortium.

A first stable version of this new multi-layer snow cover scheme (MLS) including all essential physical parametrizations is available and currently implemented in the latest COSMO version (5.06b), which shares the same surface scheme (TERRA) as the future model of the COSMO consortium ICON 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 TERRA as well as the choice of model, i.e. COSMO or ICON. However, for ICON adjustments will still be required due to e.g. the tile approach.

Initial verification – up to 3-month – shows good performance in snow-cover build-up and melt comparable to e.g. the highly sophisticated snow cover model SNOWPACK. Although the MLS scheme shows good performance a full validation in a close to operational setup is pending before it can be used for operational production.

In addition, the MLS scheme can still be improved and additional parametrizations such as absorption of solar energy should be implemented. Furthermore, shortcomings of the

MLS scheme as well as related atmospherics shortcomings (e.g. 2m temperature) could arise during the verification and need to be addressed. A crucial point for operational productions is the snow analysis and data assimilation cycles, which need to be adjusted to the new MLS scheme.

We therefore propose a prolongation of the SAINT project – starting January 2020 – with a duration of total 12 month, which can be separated into 3 phases. The 3 phases will be briefly described in the following.

Phase 1 – Consolidation of the MLS scheme (3 months). As written above, the first stable version of the MLS scheme was implemented into the current Version of COSMO (5.06b). However, this version needs to be further validated to identify potential shortcomings of the scheme and to ensure numerical stability. Therefore, we propose a stepwise validation of each component in an offline version, i.e. outside of COSMO. This task has already been started and will allow a systematic validation of all relevant physical parameterizations of the MLS scheme in a more capsulated environment. This approach has the advantages of relatively low computational costs with the by-product of a first standalone version.

Merging the validated routines back into COSMO should not been an issue since the standalone version will use the same subroutines and modules as the fully coupled version.

Currently, the MLS scheme is only available on CPU, but a GPU capable version is required for extensive close to operational validation due to limited computational resources. Therefore, Phase 1 will also include porting the CPU code to GPU including running first initial test suites according to MCH standards.

Milestone 1: Validated and consolidated MLS scheme, first initial standalone version, GPU capability of the MLS scheme.

Phase 2 – Snow analysis and data assimilation (6 months): For an operational numerical weather prediction a snow analysis as well as data assimilation are required. Ideally, the MLS scheme would provide an accurate assessment of the seasonal snow

cover on the ground in terms of properties, especially snow height and snow surface temperature, which are not only essential for the evolution of the snow cover, but also represent the lower boundary condition of any NWP model. However, shortcomings of the MLS scheme as well as accumulated forecasting errors will cause deviations from the observations. To minimize or compensate these deviations a snow analysis is run daily at MCH using in-situ data, remotely sensed snow cover information, as well as COSMO output as a first guess. This snow analysis is currently designed for the operationally used single layer snow cover scheme and needs therefore to be adjusted to the new MLS scheme.

Therefore, we propose for this Phase 2 a) an assessment of the currently used snow analysis in terms of how it can be adjusted to the multi-layer scheme and b) how already in house (SLF) products, e.g. of the hydrological warning service can be used in addition or potentially replace the currently used snow analysis. Note that technically only a snow height is required to initialize the MLS scheme, which is already available for Switzerland with high horizontal resolution down to 250 m.

Milestone 2: review of the current snow analysis of MCH as well as available snow analysis available and developed in the COSMO consortium; COSMO snow analysis adjusted for the multi-layer scheme

Phase 3 – Verification & pre-operational test phase (3 months): As mentioned above the MLS scheme as well as an adjusted and improved snow analysis needs to be validated and verified in a pre-operational test phase. For this test phase we propose to run re-forecasts of selected winters, i.e. shallow and thick snow covers, preferably as close as possible to the operational setup. One possible test environment would be a 2 times daily 48-hour COSMO-2 forecasts over the COSMO-E domain. Such an e_suite is already setup and can also be used for validation of the MLS scheme immediately once ported to GPU.

Milestone 3: Fully coupled multi-layer snow cover scheme ready for production

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.

The snow analysis developed during Phase 2 for COSMO should also be compatible with ICON-LAM, because it is targeted to the new MLS scheme. However, again considering the ICON tile approach will be the biggest obstacle here in terms of e.g. fractional snow cover.

Schedule:

The above-mentioned duration and schedule assumes a 100% employment of the main scientific collaborator; in case of part-time employment it changes accordingly.