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A multi-layer snow scheme for NWP applications: In-situ evaluation and impact on near-surface forecasts

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Snow has a significant impact on the surface energy and water budgets of a large part of earth's land and ice masses. Therefore a correct representation of snow cover and its physical properties is crucial for modelling the weather and climate. Physically-based multi-layer snow schemes of different complexity have been adopted in land-surface and hydrological models in the last decades, showing to improve the snowpack simulation compared to single-layer schemes. Despite of this, the evaluation in numerical weather prediction (NWP) models have been received less attention so far.
In this work a new multi-layer snow scheme (ML5) is evaluated and the impact on global short- and medium-range forecasts analyzed using the ECMWF Integrated Forecasting System (IFS).
The new snow scheme is evaluated over 9 sites of the ESM-Snow Model Intercomparison Project, for which meteorological and snow fields are available for at least 7 years, and compared to the current single-layer snow scheme (SL). Results of the in-situ evaluation demonstrated the added value of the increased physical complexity of the new scheme for the representation of snow depth. Mean (over all sites) root-mean-square-error (RMSE) is reduced by about 33% and 31% for Winter and Spring months, respectively, mainly because of the improved description of snow internal density. The latter leads also to a better description of the heat transfer trough the snowpack, due to the functional dependency of snow heat conductivity from density. Hence also the simulation of snow mass by ML5 is improved, particularly in springtime for which the RMSE reduces by 12%.
The benefit of using ML5 compared to SL in 10-day global coupled forecasts is evaluated for the wintertime 2016/2017. Coupled forecasts using either SL or ML5 are initialized each day at 00UTC from the ECMWF operational analysis. To produce equilibrated snow initial conditions for each of the forecasts, surface initial conditions are derived from long integrations with the offline land-surface model using ML5 and SL, respectively.
The evaluation of the coupled forecasts in the northern hemisphere using standard observations (synop) shows an improved representation of the snow for ML5 at all lead times, extending the results of the site simulations to the global scale. Regarding the impact on weather parameters, the increased snow insulation and reduced thermal inertia of the top snow layer improve the simulated minimum 2-metre temperature in the Arctic and Subarctic regions, increasing the amplitude of the diurnal cycle. At the Sodankyla site (located 67N) the increase of the amplitude of the diurnal cycle is of the order of 1 K on average. The impact of compensation errors and implications for deterministic and probabilistic (ensemble) forecasts are discussed.