Geophysical Research Abstracts
Vol. 20, EGU2018-13807-1, 2018
EGU General Assembly 2018

Impact of a multi-layer snow model on the land-atmosphere coupling in the ECMWF Integrated Forecasting System

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The description of cold processes associated to snow in high latitude regions is of primarily importance both for weather forecasts and climate projections, as the partitioning of the surface energy fluxes is largely influenced by the presence of snow. This is both related to the reduction of net shortwave radiation (due to the high albedo of the snow) and to changes in the land-surface coupling due to the thermal insulation of the snow, which can lead to extremely low near-surface temperatures and to the formation of very stable boundary layers in snow-covered regions during night-time. As the snow is a stratified medium characterized by vertical temperature and density gradients, a detailed representation of these vertical characteristics using multi-layer snow models is crucial to model correctly the land-snow-atmosphere interactions at the sub-diurnal time-scales.

In this study the impact of a new multi-layer snow scheme in the ECMWF land surface model on the land-atmosphere coupling is analysed. Different configurations are tested for surface-only simulations and coupled continuous (free-running) and nudged simulations, the latter consisting of continuous simulations in which vorticity and temperature in the upper troposphere are nudged to the ERA-Interim values.

The evaluation of the surface-only numerical simulations using snow depth observations in the Arctic region indicates that the new multi-layer model reduces the mean absolute error and root-mean-square error of 10% and 17%, respectively, compared to the current single layer model. The analysis of the coupled land-atmosphere simulations focusses on the representation of the amplitude and phase of the diurnal cycle of the near-surface temperature. Results indicate that the use of a multi-layer snow model increases the amplitude of the diurnal cycle over snow-covered regions, compared to the current single-layer snow model. This mainly stems from the reduction of the minimum temperature, which is due to the weaker land-atmosphere coupling and the reduced snow thermal inertia in the multi-layer snow model. Sensitivity experiments varying the snow thermal conductivity and snow density are performed, discussing the possible impacts on climate signals like near-surface temperature trends.