Investigations on the impact of permafrost on weather

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High-latitude terrestrial variables and processes (e.g., permafrost, soil freezing and thawing, snow, interaction of soil moisture and soil temperature states, etc.) have received little systematic study in the context of numerical weather prediction (NWP) models. Many of the NWP models apply the force-restore method with two or three reservoirs. However, force-restore models are fundamentally limited in their ability to resolve the various soil horizons (Montaldo and Albertson 2001), as well as the vertical variation of root distribution and soil frost processes.

NWP models require information on the water and energy fluxes to the atmosphere at time steps of several minutes or so as lower bounary conditiona. It is obvious that at such time scale highly resolved permafrost models are computationally prohibitive. The thermo-dynamic soil vegetation scheme (HTSVS) was developed for determining these fluxes at the biosphere/snow-atmosphere interface in atmospheric models. HTSVS considers one canopy layer, multiple snow and soil layers. It describes (1) the exchange of momentum, heat, and moisture at the vegetation-soil-atmosphere interface, with special consideration given to the heterogeneity on the micro-scale by the mixture approach (i.e. a grid cell can be only partly covered by vegetation), (2) the insulating effect of snow and its retardation of infiltration, achieved by the inclusion of an explicit snow model, (3) the heat conduction and water diffusion (including the Richards-equation) within the soil as well as cross-effects like the Ludwig-Soret effect (i.e., a temperature gradient contributes to the water flux and changes soil volumetric water content) and Dufour effect (i.e., a moisture gradient contributes to the heat flux and alters soil temperature) as postulated by the linear thermodynamics of irreversible processes, (4) soil freezing and thawing and the related release of latent heat and consumption of energy, (5) the effects of frozen soil layers on the vertical fluxes of heat and moisture, (6) water vapor fluxes within the soil, (7) water uptake by plants including a vertically variable root distribution, dependent on vegetation-type, (8) a variable ground water depth responding to the previous meteorological conditions, and (9) the temporal variation of soil albedo as well as of the albedo and emissivity of snow (e.g., Kramm et al. 1996, Mölders et al. 2002a, b, Fröhlich and Mölders 2002). In addition to the 16 soil classes that HTSVS usually includes, HTSVS takes into account moss and lichen, which are of special relevance for the moisture distribution within the soils and for permafrost dynamics (e.g., Beringer et al. 2001). HTSVS was implemented into the PennState/NCAR Mesoscale Meteorological Model MM5 in a two-way coupled mode within the framework of DEKLIM funded by BMBF (Germany). Simulations with and without considteration of soil frost processes are being performed to examine the influence of permafrost on the regional weather in Alaska.

The inclusion of soil frost processes leads to altered fluxes of heat and water to the atmosphere, which modify the cloud and precipitation formation on the local scale (Fig. 1). Figure 1 exemplary compares the 48 hour accumulated precipitation distribution as obtained from running the coupled MM5-HTSVS-system without and with consideration of soil frost processes for a two-day episode in March. It has to be expected that permafrost has an even greater impact in summertime and a noteable impact on the long-term annual accumulated precipitation. Thus, to examine the influence of permafrost on climate HTSVS will be integrated in the NCAR Community Climate System Model (CCSM) within the framework of the International Arctic Research Center (IARC) CAMP iniative funded by NSF (USA).

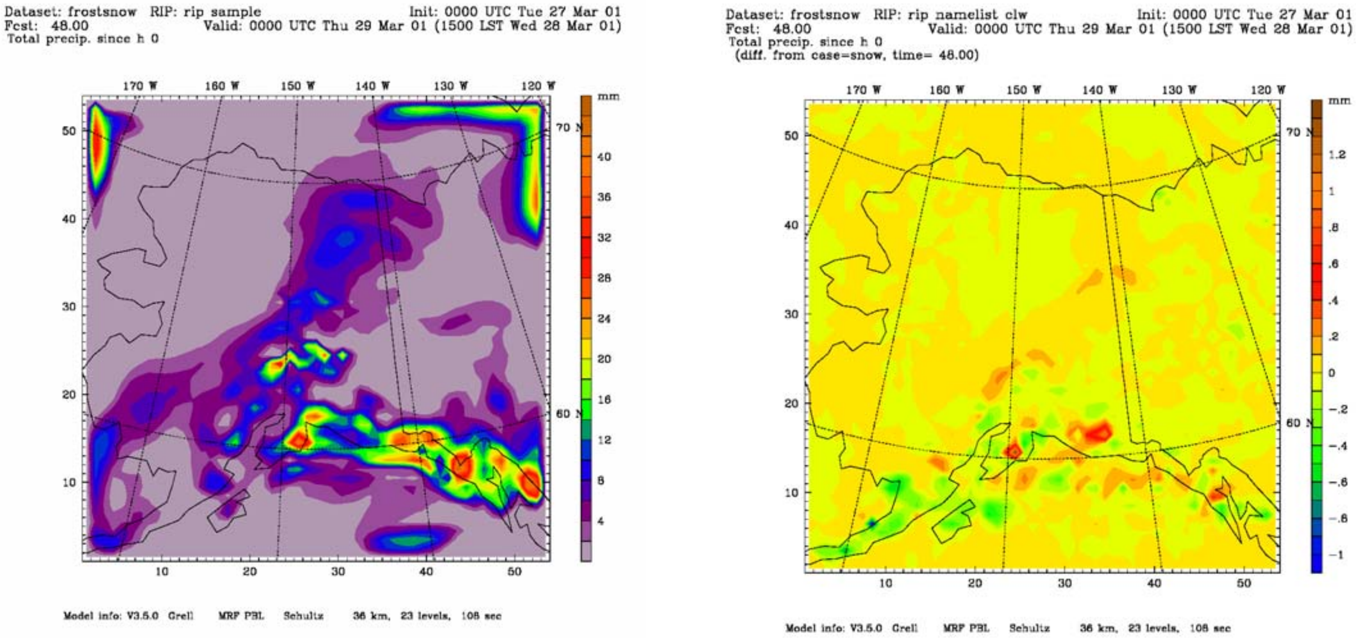

Fig. 1. 48 hour accumulated precipitation as simulated for March 27, 2001 0000 UT to March 29, 2001 0000 UT with inclusion of permafrost in MM5 (left) and difference with – without permafrost (right).

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