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Simulation of high latitude hydrological processes in the Torne–Kalix basin: PILPS Phase 2(e) 2: Comparison of model results with observations

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Abstract

Model results from 21 land-surface schemes (LSSs) designed for use in numerical weather prediction and climate models are compared with each other and with observations in the context of the Project for Intercomparison of Land-surface Parameterization Schemes (PILPS) Phase 2(e) model intercomparison experiment. This experiment focuses on simulations of land-surface water and energy fluxes in the 58,000-km^2 Torne and Kalix river systems in northern Scandinavia, during the period 1989–1998. All models participating in PILPS Phase 2(e) capture the broad dynamics of snowmelt and runoff, but large differences in snow accumulation and ablation, turbulent heat fluxes, and streamflow exist. The greatest among-model

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differences in energy and moisture fluxes in these high-latitude environments occur during the spring snowmelt period, reflecting different model parameterizations of snow processes. Differences in net radiation are governed by differences in the simulated radiative surface temperature during the winter months and by differences in surface albedo during the spring/early summer. Differences in net radiation are smallest during the late summer when snow is absent. Although simulated snow sublimation is small for most models, a few models show annual snow sublimation of about 100 mm. These differences in snow sublimation appear to be largely dependent on differences in snow surface roughness parameterizations. The models with high sublimation generally lose their snowpacks too early compared to observations and underpredict the annual runoff. Differences in runoff parameterizations are reflected in differences in daily runoff statistics. Although most models show a greater variability in daily streamflow than the observations, the models with the greatest variability (as much as double the observed variability), produce most of their runoff through fast response, surface runoff mechanisms. As a group, those models that took advantage of an opportunity to calibrate to selected small catchments and to transfer calibration results to the basin at large had a smaller bias and root mean squared error (RMSE) in daily streamflow simulations compared with the models that did not calibrate.

Keywords: Torne–Kalix basin; PILPS Phase 2(e); hydrological processes

1. Introduction

This paper is the second in a three paper series that describes the design, implementation, analysis, and results of Phase 2(e) of the Project for Intercomparison of Land-surface Parameterization Schemes (PILPS). The first paper describes the history, purpose, design, and implementation of the PILPS Phase 2(e) experiment and provides a summary discussion of results (Bowling et al., 2003a-this issue). The third paper further examines the sensitivities of the land-surface schemes (LSSs) to changes in environmental conditions (Bowling et al., 2003b-this issue). In the current paper, simulation results from each of the LSSs are compared with available observations and with each other, to assess the models' ability to adequately capture the controlling processes in boreal and alpine environments.

The family of PILPS-2 experiments involves off-line testing of LSSs. Off-line testing means that prescribed atmospheric conditions are used to drive the LSSs and that there is no mechanism for representation of feedbacks from the land surface to the atmosphere. In the PILPS-2 series of experiments, observed atmospheric forcing data are used as much as possible (Henderson-Sellers et al., 1995). The objective of the PILPS Phase 2(e) experiment is to "evaluate the performance of uncoupled land-surface parameterizations in high latitudes, in a context that allows evaluation of their ability to capture key processes spatially" (Bowling et al., 2003a-this issue). The Torne and Kalix river systems in northern Scandinavia, which have a combined drainage area of about 58,000 km^2 (Fig. 1), were selected as the study area to take advantage of observations collected by the Swedish Hydrological and Meteorological Institute and the Finnish Meteorological Institute (World Climate Research Programme (WCRP), 1999).

The 21 PILPS Phase 2(e) participants were provided with atmospheric forcings for the period 1979–1998. The first 10 years were available for model initialization and spin-up. Submitted results and the subsequent analyses were limited to the second 10-year period, 1989–1998. Full details of the experimental design, the forcing data and the submitted results can be found in Bowling et al. (2003a-this issue).

9. Conclusions

All models participating in PILPS Phase 2(e) capture the broad dynamics of snowmelt and runoff, but large differences in snow accumulation and ablation, turbulent heat fluxes, and streamflow exist. One of the difficulties in interpreting the results from the PILPS Phase 2(e) experiments is the complexity of the current generation of land-surface schemes. Even in an experiment where meteorological forcings and many of the land-surface characteristics were prescribed, the remaining number of degrees of freedom is large. Because of the nonlinearity of many of the land-surface processes, small differences in model parameters and in model parameterizations can lead to large differences in model outcomes (e.g., Takayabu et al., 2001). For example, differences in the parameterizations of grid cell fractional snow coverage result in differences in grid cell albedo and consequently in net radiation, even if the land surface and snow albedos are the same among the models. Differences in net radiation lead to differences in melt and turbulent exchange. Different parameterizations of land-surface roughness can result in large differences in the latent and sensible heat fluxes, and lead to substantial changes in both the water and energy balance terms as illustrated clearly by the differences between the simulations of the MECMWF (O) and ECMWF (S) models.