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Impact of spatial climate variability on catchment streamflow predictions

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The ability of hydrological models to predict a catchment's streamflow response serves several important needs of our society, such as flood protection, irrigation demand, domestic water supply, and preservation of fish habitat. However, spatial variability of climate within a catchment can negatively affect streamflow predictions if it is not explicitly accounted for in hydrological models. In this study, we examined the changes in streamflow predictability when a hydrological model is run with spatially variable (distributed) meteorological inputs instead of spatially uniform (lumped) meteorological inputs. Both lumped and distributed versions of the EXP-HYDRO model were implemented at 41 meso-scale (500 – 5000 km2) catchments in the Pacific Northwest region of USA (Oregon, Washington, and Idaho). We used two complementary metrics of long-term spatial climate variability, moisture homogeneity index (IM) and temperature variability index (ITV), to analyse the performance improvement with distributed model. Results showed that the distributed model performed better than the lumped model in 38 catchments, and noticeably better (>10% improvement) in 13 catchments. Furthermore, spatial variability of moisture distribution alone was insufficient to explain the observed patterns of model performance improvement. For catchments with low moisture homogeneity (IM < 80%), IM was a better predictor of model performance improvement than ITV; whereas for catchments with high moisture homogeneity (IM > 80%), ITV was a better predictor of performance improvement than IM. Based on the results, we conclude that: (1) catchments that have low homogeneity of moisture distribution are the obvious candidates for using spatially distributed meteorological inputs, and (2) catchments with homogeneous moisture distribution benefit from spatially distributed meteorological inputs if those catchments have high spatial variability of precipitation phase (rain vs. snow). Our use of spatially uniform model parameter values within a catchment ensured that any performance improvement obtained with the distributed model was solely based on the spatially distributed representation of meteorological inputs. However, this assumption will have to be relaxed for future investigations of the effects of spatially variable land use, soil types, and/or geology on catchment streamflow predictions.