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The cold regions hydrological modelling paradox: why complex models can be run successfully with uncalibrated parameterisations

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Hydrological modelling includes models with physically identifiable parameters that can be observed and conceptual parameters that must be assigned by other methods. Cold regions experience a wide range of hydrological processes, many of which are dominated by energy exchanges and phase changes, which add complexity, and therefore uncertainty, to models. However, when the processes are modelled adequately, cold-regions hydrological models can successfully simulate streamflow hydrographs without calibration.

In warm and temperate regions, streamflows are generally driven by the responses of basins to rainfall. Rainfall varies tremendously in space and time, and runoff can occur very quickly. Biases in the measurement of rainfall, and difficulty in incorporating the spatial variability, are sources of the general impetus to calibrate models.

The hydrology of a cold region is usually dominated by the seasonal accumulation and ablation of the snowpack. While rainfall and snowfall are forcings, the snow water equivalent (SWE) is a state variable, which can be sampled directly, or by remote sensing. The accumulation of snowfall over a winter will generally show far less spatial variability than will a single event. The transformation of snowfall to SWE is governed by processes such as snow transport and sublimation during blowing snow, canopy snow interception and sublimation, and mid-winter melting which can be simulated well by physically-based models which have identifiable parameters. All the snowfall transformation processes are governed by surface properties, meaning that the parameters are observable and amenable to remote sensing or surface observation.

The spring melt of the snowpack is usually dominated by solar radiation, which is predictable from topography and vegetation type, and the cold content of the snowpack which depends on its SWE and meteorological history. Because snowmelt generally takes place over extended periods, the rates of snowmelt, and therefore of meltwater production, are relatively small thereby reducing the importance of temporal variability in the forcing variables.

Thus there is a paradox, whereby cold regions hydrological processes require difficult and complex representations of their physics, but which are comparatively easy to model without calibration because of their simpler scaling, slower responses and dependence on observable surface properties. The success of cold regions hydrological models provides a possible path forward for scientific modelling in hydrology and example of how improving physical accuracy of process representations by algorithms in models can reduce the need to calibrate parameters.