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Developing robust spatial interpolation techniques for temperature and precipitation in a data-sparse alpine catchment

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Providing adequate input data are available, distributed and physically-based hydrological models should constitute the most detailed and realistic possible representation of catchment hydrology. However, the combination of sparse monitoring networks and the high spatio-temporal variability of climate in alpine environments makes such models challenging to implement. Here, a fully distributed hydrological model (WaSIM) is implemented for the Clutha river, New Zealand, at a spatial resolution of 1 km^2. The Clutha catchment (21680 km^2) is the largest in New Zealand and is situated in the lower half of the South Island, extending eastwards from the Southern Alps. The interaction of the predominant westerly winds with the steep orography of the Southern Alps leads to a large precipitation gradient decreasing sharply from annual totals above 10 m near the main divide to less than 0.5 m inland. In the upper catchment, large amounts of precipitation are stored as seasonal snow, which significantly influences the annual discharge regime. As such, a correct spatial representation of precipitation totals and high elevation temperature is fundamental to the realistic simulation of river flow. However, there are no long term precipitation sites in the headwaters, and only two (relatively short) high elevation temperature records. Furthermore, the majority of long-term temperature records are located in inter-montane valleys that are prone to strong winter lapse rate inversions. Consequently, standard interpolation techniques or fixed lapse rates do not provide suitably realistic temperature or precipitation fields that are fundamental to accurately simulate the spatial variation in catchment hydrology.

In order to overcome these issues of data availability, a variety of geostatistical techniques have been investigated as the basis for generating realistic climate fields. The development of the precipitation field was based on a trivariate spline and a 30-year rainfall normal surface. Development of the temperature field was more complex, in part owing to different lapse rates and the range of physical processes controlling daily maximum and minimum temperature (Tmax and Tmin, respectively). Based on short term high elevation records Tmax lapse rates were found to vary between coastal and inland sites. A linear regression model based on distributed monthly relative humidity grids was used to approximate the spatial variation of lapse rates across the catchment. Spatial variation in Tmin is shown to be captured by a simple inversion model combining variable monthly inversion strengths in the lower atmosphere with negative lapse rates above the inversion layer. Validation of the Tmax and Tmin fields with independent weather stations demonstrates that these techniques provide a substantial improvement over previous spatial interpolations of temperature for the upper Clutha. Finally, the newly generated spatial fields were used as input to the hydrological model, with discharge from multiple points across the upper catchment used to assess the resultant model skill in terms of simulating daily and monthly discharge. In a last step, the modelled seasonal snow field was validated, both spatially and temporally, using remotely sensed (MODIS) snow cover data.