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Parameterising and validating a coupled cryosphere-hydrological model using MODIS data products

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Hydrological modelling of large mountainous catchments with substantial contributions from meltwater runoff from glaciers and seasonal snowpack is extremely complex. Hydrological simulation of these catchments is further complicated by the sparsity of local observations of key climate inputs. This is particulary true of tributary catchments in the Upper Indus Basin where this study is focused. Assimilation of remote sensing data products in the modelling process offers substantial opportunities to improve model skill and realism. In this study two key avenues for model improvement are investigated: 1) use of findings of antecedent remote sensing analyses to guide model parameterisation; and 2) use of remote sensing as "observational data" of land surface conditions to evaluate model outputs on a grid cell/pixel-wise basis to quantify model performance at simulating processes linked to meltwater generation.

Precipitation in mountainous catchments is strongly controlled by terrain features (orographic-enhancement, rain-shadow effects), but because in-situ observations are often spatially sparse, parameterisations are required to spatially distribute available data as model input. This study adopts of novel approach using the hybrid product of snow cover duration, from MOD10A1, multiplied by above-freezing land surface temperature (LST), from MOD11A1, as a proxy for the "degree days" measure of energy-to-runoff conversion used in meltwater generation calculations. This effectively allows assessment of the spatial variability of mass inputs (accumulated snowpack) because in nival regime areas – where complete ablation is regularly achieved – mass in the limiting constraint. Calculation of terrain-classified – elevation and aspect – statistics for the MODIS "degree-day" hybrid product guided model parameterisation of spatial precipitation distribution. Integration of MODIS data products for parameterising shortwave radiation energy inputs by aspect, using LST spatial statistics, and elevation, using cloud cover (MOD06L2) vertical gradients, is also being tested.

In addition to informing model parameterisation, MODIS data products were also used as observations for grid cell/pixel-wise assessment of model accuracy during calibration and validation. The hydrological model used in this study, dc2PyVIC, produces estimates of snow covered area (SCA) and LST in additional to standard hydrological flux outputs (runoff, actual evapotranspiration, etc). The grid spacing used in the model, a 500m UTM grid, matches well with the nominal spatial resolutions of the MODIS SCA (500m, MOD10A1) and LST (one km, MOD11A1) data products. Pixel-wise performance assessment provides greater opportunities for identifying and correct model biases, through improved parameterisation and model formulation, than simple catchment aggregates allow. The use of pixel-wise evaluation will be extended by on-going work to develop multi-decadal analogues to MODIS SCA and LST using historical imagery from the AVHRR instrument flown on successive generations of NOAA POES.