Rainfall runoff modelling for the Upper Indus

Being able to quantify inflows to the Indus River is a key water resource planning and operational requirement. CSIRO has developed a suite of rainfall-runoff models to estimate the inflows to the river from all the Upper Indus catchments. The rainfall runoff models estimate streamflow, snow cover and melt on a daily time step.

A series of rainfall runoff models are under development for those Upper Indus catchments shown in Figure 1. These rainfall runoff models use a modified version of the GR4J rainfall runoff model [1], with additional parameters to account for snow accumulation, snow and ice melt. The model conceptualization uses degree day factors (see [2]) to simulate snow and ice melt.

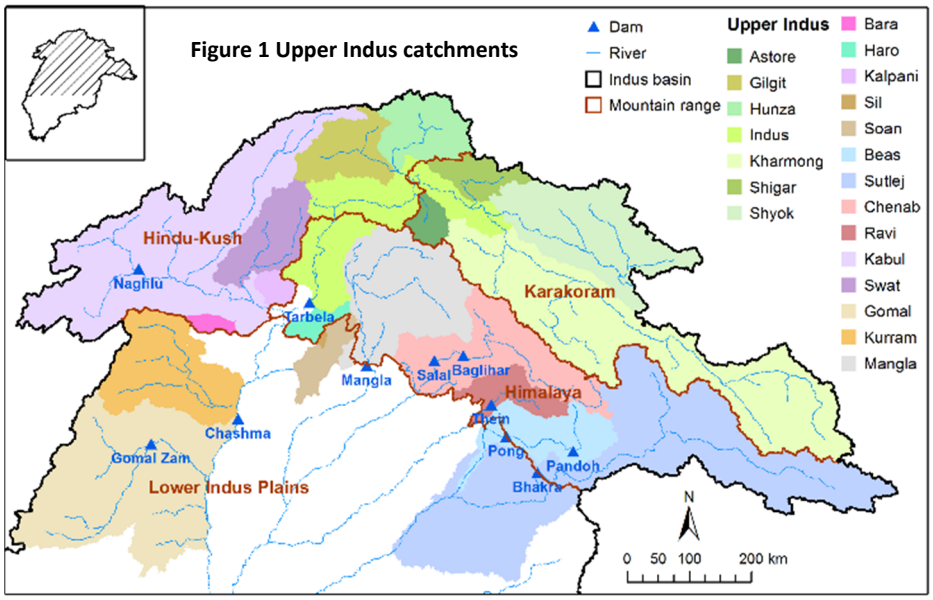

Figure 1 Upper Indus catchments

A schematic of the model is shown in Figure 2, with the original GR4J model shown on the left side and the additional snow and ice stores shown on the right side.

The model uses precipitation, maximum and minimum temperatures and potential evapotranspiration as inputs, and provides estimation of streamflow, snow cover and contribution of rainfall, snow melt and ice melt to the total runoff. All inputs used the gridded surfaces developed as part of the project. Each catchment is divided into smaller units, named functional units, based on elevation and presence/absence of glaciers. All inputs are elevation corrected.

A three-step calibration process has been used. In order, we calibrated:

- the parameters that influence snow accumulation and melt using MODIS snow cover estimates
- the ice melt degree day factor to match the glacier mass change estimated by [3] for Karakoram, Hindu-Kush and Himalaya (Jammu Kashmir) mountain ranges
- the remaining parameters (original GR4J parameters) to translate rainfall and melt components into streamflow.

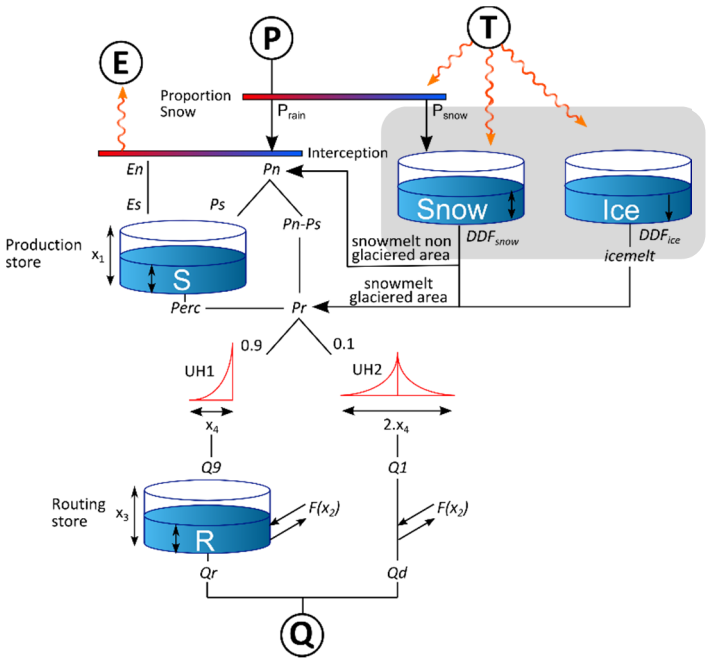

Figure 2 GR4JSG rainfall-runoff model schematic (adapted from [2])

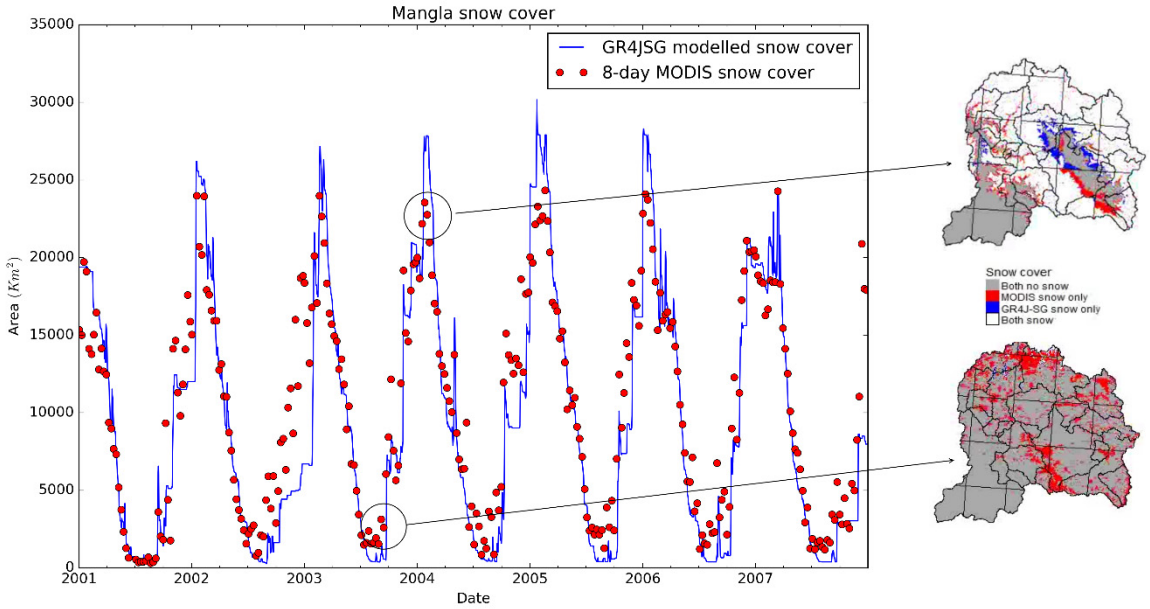

Figure 3 Modelled and 8-day MODIS snow covered area in the Mangla catchment over 2001-2007, and spatial maps for winter (top) and autumn (bottom)

Example outputs

Figure 3 shows an example estimation of the total snow cover in the Mangla catchment for the period 2001–2007 compared to the 8 -day MODIS snow cover estimates. It is clear that the model reproduces the snow cover well for most of the period with some over-estimation of snow cover in winter. It is also possible to further post process the model results to obtain spatial coverages as shown in the right side of Figure 3.

An example of the streamflow estimation for Tarbela is shown in Figure 4, with the black lines showing the gauged streamflows and the blue and green lines showing results for calibration and validation periods respectively. The model reproduces the flow patterns at Tarbela reasonably well for most years and periods, with the exception of the recession curves for years 1996–1998.

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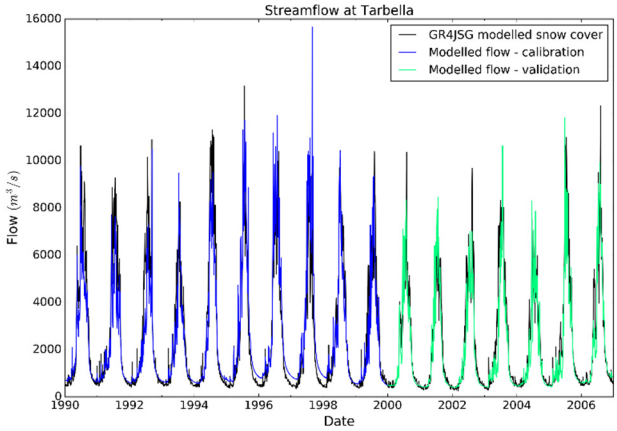

Figure 4 Streamflow estimation for Indus River at Tarbela

References

[1] Perrin C, C Michael, V Andreassian (2003) Improvement of a parsimonious model for streamflow simulations. Journal of Hydrology, 279, 275–289.

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[3] Kääb A, E Berthier, C Nuth, J Gardelle, Y Arnaud (2012) Contrasting patterns of early twenty-first-century glacier mass change in the Himalayas. Nature 488 (23), 495-498.

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