HBV-IANIGLA for hydroclimatic studies in the Andes: A model for research purposes

Toum J. Ezequiel*, Masiokas Mariano H., Villalba Ricardo

Instituto Argentino de Nivología, Glaciología y Ciencias Ambientales (IANIGLA-CONICET) CCT-Mendoza-Argentina

***etoum@mendoza-conicet.gob.ar**

Abstract

The HBV (Hydrologiska Byråns Vattenbalansavdelning)model is one of the most used hydrological models around the world due to its robustness, simplicity and results over the past 40 years (Bergström and Lindström, 2015). Despite these advantages, the available versions impose some limits for research studies in mountain watersheds dominated by ice-snow melt runoff (i.e.: no glacier module, limited elevation bands, among other limitations). In this work we introduce the HBV-IANIGLA model, the first version of the HBV model for river basins in Argentina. In this new version we added to the original four modules of the HBV model, a glacier module to simulate the contribution of clean and debris-cover glaciers. The HBV-IANIGLA model purposes are: (1) the modules have been independently conceived, so users are able of building their own models; (2) we write the code in C++ and compiled it in R, a free, high-level, world-wide used language. In addition, in this presentation, we provide examples for debris-cover and debris-free glaciers and for the Tupungato river basin (located in the north of Mendoza province, Argentina).

Introduction

Hydrological modeling is a vital tool for engineers, meteorologists, geographers, geologists and researchers; we need information on river runoff for the next days, to infer the changes associated with temperature and precipitation variations, and following the words of Max Kolher *'we want to show that we understand our science and its complicated interacting phenomena'*.

Figure 1: Upper Mendoza River basin. Photo: NASA.

In 1972, the Swedish Meteorological and Hydrological Institute (SMHI) run the first successful simulation of the HBV model. It was developed with the aim of forecast river runoff for the hydropower industry in Sweden (Bergström and Lindström, 2015). Up to date many versions have been developed: HBV-ETH (Switzerland - Braun and Renner, 1992), HBV-Light (Switzerland- Seibert and Vis, 2012), HBV-D (Germany-Krysanova et al., 1999), HBV-CE (Canada- Stahl et al., 2008), TUWmodel (Austria- Viglione and Parajka, 2016), among others. However, none of the model free versions allow the users to couple the modules according to their demands. In this contribution we introduce, to our knowledge, the first HBV version for mountain river basins in Argentina. The HBV-IANIGLA is part of the first author's PhD thesis.

Model description

HBV-IANIGLA has six modules: **(a) Snow module:** a temperature index model with two temperature thresholds, one to differentiate rain from snow and another to establish the beginning of snowmelt; **(b) Glacier module:** a temperature index model that allows the simulation of snowmelt and ice-free or debris-cover glacier ablation; **(c) Soil module:** the classical formulation of the HBV model to compute abstractions, evapotranspiration and effective rainfall; **(d) Response function:** the current version has five buckets models; **(e) Glacier response function:** the use of the glacier storage concept to simulate the evolution of the glacier drainage throughout the year following the approximation suggested by Stahl et al. (2008); **(f) Transfer function:** the current version offers a triangular unit hydrograph with a single parameter.

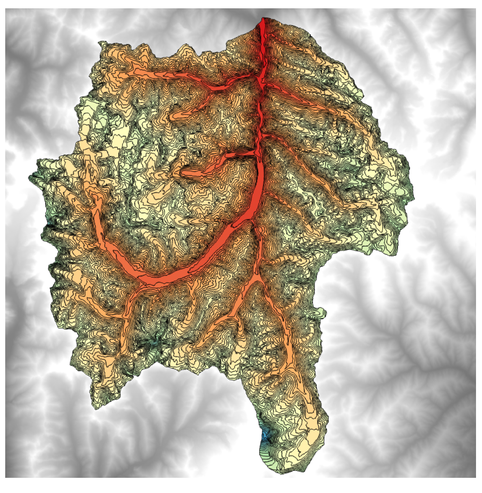

Figure 2: Discretization of the Tupungato River basin.

We have written the modules in C++. They can be compiled in R (R Core Team, 2017), a free and high-level language. R has packages to produce nice plots, make statistical analysis and calibrate model parameters.

Figure 3: The model is written in C++ and runs in R.

Results

We have applied HBV-IANIGLA to simulate the runoff of the Tupungato river Catchment, the ice-melt of the Juncal Norte Glacier (Ragettli and Pellicciotti, 2012) and the ice-melt of the debris covered Piramide glacier (Ayala et al., 2016). We used the GLUE methodology with limits of acceptability (Beven, 2006) for calibration and uncertainty estimation.

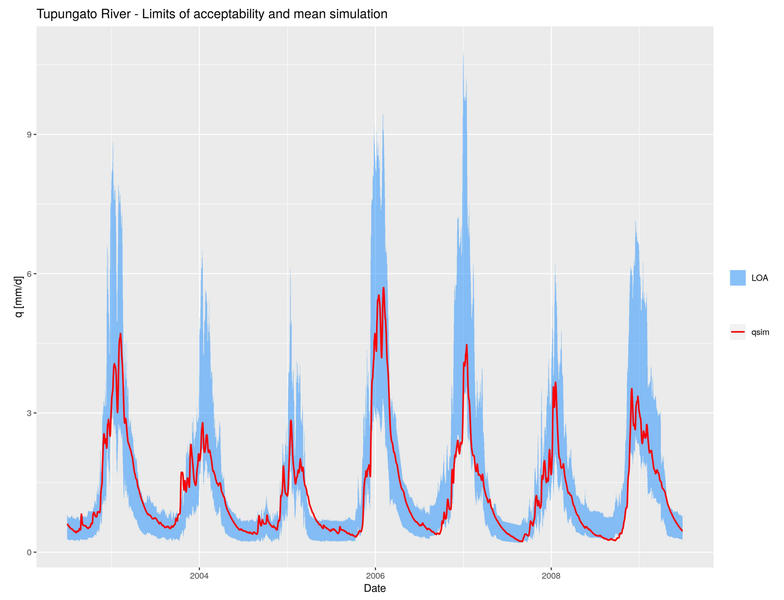

Figure 4: Output example of river runoff simualtion.

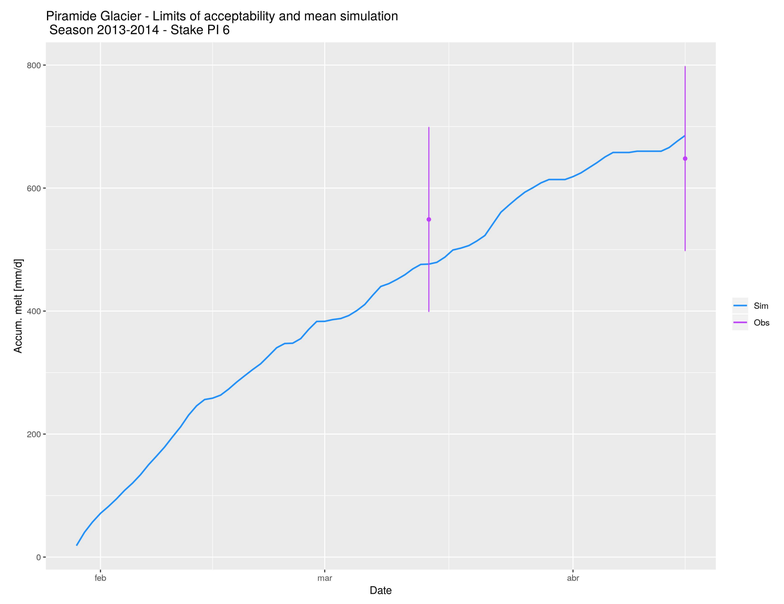

Figure 5: Ice-melt simulation of the debris-cover Piramide glacier.

Conclusions

(1) We developed an HBV-IANIGLA version of the HBV model. This is part of the first author PhD thesis. HBV-IANIGLA aims, among other issues, to estimate the ice, snow and rain contribution to Andean river basins.
(2) We designed the model in modular steps to allow users building their own-adapted models.
(3) We added a glacier routine, a very useful tool for hydrologists in the Andes mountain of Argentina and Chile.
(4) Presently, we are developing a graphical interface for the model to be ready in the near future.

References

Ayala, A., Pellicciotti, F., MacDonell, S., McPhee, J., Vivero, S., Campos, C., Egli, P., 2016. Modelling the hydrological response of debris-free and debris-covered glaciers to present climatic conditions in the semiarid Andes of central Chile. Hydrol. Process. 30, 4036–4058. https://doi.org/10.1002/hyp.10971.

Ragettli, S., Pellicciotti, F., 2012. Calibration of a physically based, spatially distributed hydrological model in a glacierized basin: On the use of knowledge from glaciometeorological processes to constrain model parameters. Water Resour. Res. 48, W03509. https://doi.org/10.1029/2011WR010559.

Bergström, S., Lindström, G. (2015). "Interpretation of runoff processes in hydrological modelling—experience from the HBV approach." Hydrol. Process. 29, 3535–3545. https://doi.org/10.1002/hyp.10510.

Beven, K., 2006. A manifesto for the equifinality thesis. Journal of Hydrology, The model parameter estimation experiment 320, 18–36. https://doi.org/10.1016/j.jhydrol.2005.07.007.

Braun, L.N., Renner, C.B. (1992). "Application of a conceptual runoff model in different physiographic regions of Switzerland." Hydrol. Sci. J. 37, 217–231. https://doi.org/10.1080/02626669209492583.

Krysanova, V., Bronstert, A., Müller-Wohlfeil, D.I.(1999). "Modelling river discharge for large drainage basins: from lumped to distributed approach." Hydrol. Sci. J. 44, 313–331. https://doi.org/10.1080/02626669909492224.

R Core Team (2017). "R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria." URL https://www.R-project.org/.

Seibert, J., Vis, M.J.P. (2012). "Teaching hydrological modeling with a user-friendly catchment-runoff-model software package." Hydrol Earth Syst Sci 16, 3315–3325. https://doi.org/10.5194/hess-16-3315-2012.

Stahl, K., Moore, R.D., Shea, J.M., Hutchinson, D., Cannon, A.J.(2008). "Coupled modelling of glacier and streamflow response to future climate scenarios." Water Resour. Res. 44, W02422. https://doi.org/10.1029/2007WR005956.

Viglione, A., Parajka, J. (2016). "TUWmodel: Lumped Hydrological Model for Education Purposes." R Package.