

Dear Editor,

Please find below our replies to the comments and suggestions from the reviewers. We found these suggestions extremely useful to improve our manuscript, and would like to thank both reviewers sincerely for their constructive inputs.

The comments from the reviewers are shown below in red, our replies in green.

We hope you find that these replies and the several changes we have made to the manuscript are now adequate and acceptable for publication in the R Journal.

Best wishes and many thanks again for your help,

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Reviewer #2

General comments:

- The manuscript pitches the model as a specific implementation for the Andes of Argentina. I don't think that this is necessary. The additions (explicit elevation bands, snow and ice routines) are useful for a lot of different regions with steep topography and/or cryospheric processes. So I recommend to present the model more broadly as an enhanced version of HBV, applied here for illustration to an Argentinian example, but valid anywhere the relevant processes occur (and probably beyond - I suppose that these routines can be switched of or are inactive in basins without glaciers).

- We agree with the reviewer in that the model is useful beyond the Andes. Now the model is presented in the abstract as follows:

"... Here we present HBV.IANIGLA, a tool for hydroclimatic studies in regions with steep topography and/or cryospheric processes which provides a modular and extended implementation of the HBV model as an R package. To our knowledge, this is the first modular version of the original HBV model..."

- The function "glacier_hbv", which is part of the example, does not seem to exist in the version that I installed with `install.packages()`. Might this be renamed to `glacio_hydro_hbv`?

- The function "glacier_hbv" (*Computation times and Semi-distributed glacier mass balance sections*) is part of the vignette entitled *Chapter 5: Simulating the Alerce glacier surface mass balance* (see `vignette(package = 'HBV.IANIGLA', 'alerce_mass_balance')`). In the article we explicitly state: *The definition of this functions are included in vignette("alerce_mass_balance")*.

Specific comments:

- "In this work we focus on the HBV.IANIGLA package" -> Here we present HBV.IANIGLA, which provides a modular and extended implementation of the HBV model as an R package.

- Improved. Now it reads:

Here we present HBV.IANIGLA, a tool for hydroclimatic studies in regions with steep topography and/or cryospheric processes which provides a modular and extended implementation of the HBV model as an R package.

- "allows users revise" -> allows users to revise

- Fixed

- "was build" -> was built

- Fixed

- "model structure in the hope that it will serve as" -> model structure to serve as

- This sentence has been improved. It now reads:

“The main objective of this article is to present the HBV.IANIGLA model structure through its implementation as an R package to serve as a practical guide to better understand how it works.”

- Section "Why using the HBV model?": I suggest simply calling this subsection "The HBV model"

- Agreed. Now the section is entitled: *"The HBV model"*

- "The HBV model was selected for further development as it has been used" -> "The HBV model has been used"

- Fixed

- "unlike" -> unlike

- This part of the sentence has now been removed to improve readability (see reply to Reviewer 3).

- " The user will notice that there are" -> There are

- Fixed

- "we encourage the user to read the" -> we refer the user to the

- Fixed

- "System Era": not sure what this refers to

- We removed this sentence to avoid confusions with readers unfamiliar with the System Era concept.

- "a language with a massive number of packages and functions to implement specific hydrological workflows (from data retrieval to results analysis)": probably redundant

- Agreed. The sentence now reads: *“... a language where it is easy to implement specific hydrological workflows (from data retrieval to results analysis)...”*

- " $c(T(^{\circ}C))$ ": I suggest not using special symbols such as the degree sign; they may cause issues between operating systems (I got an error message when copying the code from the pdf into R). Just using "T(C)" should be clear enough.

- Corrected. Now the columns are called by their position "c(2, 3)".

- " suggesting that the model needs some calibration": remove. Even with calibration, the simulation will not precisely reproduce observed basin discharge.

- We put it to encourage the user to work in the calibration as a training exercise. We agree with the reviewer in that real world simulations never precisely reproduce observations, but in this case they will because the example is about a synthetic case. The basin discharge was taken from a specific parameter combination of the lumped model.

- "The simulation of glacier mass balances is relevant in the Andes Mountains, where ice bodies have an important contribution to catchment discharge (Masiokas et al., 2020).": remove. The introduction already motivates the including of a glacier mass balance routine.

- Agreed. This has been removed.

- "Since this article focuses on the model and not its applications, only two examples are presented."
-> "We present 2 examples".

- Fixed

Reviewer#3

Article

I found some typos :

- "In this work we focus on the the HBV.IANIGLA..." p1 (abstract)

- Fixed. This sentence has been changed to: *"Here we present HBV.IANIGLA, a tool for hydroclimatic studies in regions with steep topography and/or cryospheric processes which provides a modular and extended implementation of the HBV model as an R package."*

- "The user will notice that there are another three functions" p3. I would say The user will notice that there are three other functions.

- Corrected. Now it reads: *"There are three other functions..."*

- This model is described instead of "these model is described" p4.

- Corrected. Now it reads: *"this model is described..."*

"DEopt (Ardia et al., 2016)" p7. DEoptim (Ardia et al., 2020)

- Corrected. Now it says: *"DEoptim"*

"This is an aspect where future improvements can be made" p13.

- Fixed

- *"The main objective of this article is to present the HBV.IANIGLA model structure in the hope that it will serve as a practical guide to better understand how the package works."* p1. I would formulate the objective differently: *The main objective of this article is to present the HBV.IANIGLA model structure through its implementation as an R package in the hope that it will guide and improve its application.*

- Agreed. We took suggestions from both reviewers and now the sentence reads: *"The main objective of this article is to present the HBV.IANIGLA model structure through its implementation as an R package to serve as a practical guide to better understand how it works."*

- *"The HBV model was selected for further development as it has been used for 40 years for hydrological studies in mountain regions around the world (Bergström and Lindström, 2015)"* p2. I still do not like the formulation, as it would imply that one of the objectives of this paper is to find the most appropriate model for mountainous regions. I would suggest removing "was selected for further development as it" from this sentence.

- Removed. Now the sentence reads: *"The HBV has been used for 40 years for hydrological studies in mountain regions around the world (Bergström and Lindström, 2015)"*

- I would remove *"and no strong assumptions about water runoff generation (unlike TOPMODEL)." p2*, as it would imply that the HBV model does not make strong assumptions about water runoff generation, which I do not think is accurate. If you think that it is important to keep this statement, I would suggest adding several references that support this statement.

- With this sentence we mean that HBV model doesn't account for subsurface and groundwater runoff generation explicitly as it does TOPMODEL; HBV just considers this part of the hydrological cycle as interconnected linear reservoirs. But we agree with the reviewer in that is still an assumption, so we decided to remove it.

- I think it would be relevant to cite this recent article that deals with hydrology modelling R packages: <https://hess.copernicus.org/preprints/hess-2020-498>
Especially when you discuss the computation times and when you compare HBV.IANIGLA with other existing hydrology modelling R packages in the introduction. It is a preprint, so I let you decide whether you want to cite it or not.

- Thanks for the suggestion. We think that this article is a useful guide and input for the R-hydro community, and has now been included in the *Computation times* section.

- “*The data matrix must not contain missing values (NA's).*” p4. Maybe say why this is important for a continuous hydrological model.

- Agreed. Now the sentence reads: “*The data matrix must not contain missing values (NA's) because HBV.IANIGLA is a continuous hydrological model, meaning that it simulates all the variables in every time-step.*”

- “*inputData = as.matrix(lumped_hbv[, c("T(oC)", "P(mm/d)")])*,” p8. I would not use a special character to index a matrix.

- We changed this as well. Now the columns are called by their position “c(2, 3)”.

- Regarding the semi-distributed catchment case (example in the article and package vignette), I found it difficult to understand how flows are routed from upstream spatial units to downstream spatial units. For the lumped case, the unit hydrograph (or transfer function) does this task. But how does it work for the semi-distributed case?

- In the article we just use a lumped hydrological model and we showed how to build a semi-distributed glaciological model. Despite this fact, and as the reviewer mention, in the vignettes we elaborate two semi-distributed reproducible examples: the first one being a hydrological model (*vignette(package = 'HBV.IANIGLA', 'semi-distributed_basin')*) and the second one a glacio-hydrological model (*vignette(package = 'HBV.IANIGLA', 'glacio-hydrological_model')*).

In the vignettes, the code reflects what we illustrate in the article's figure 1. For the hydrological model case, we run in every polygon (e.g.: elevation band) a `SnowGlacier_HBV()` and a `Soil_HBV()` routine. After that, the effective water that comes out from the `Soil_HBV()` function (scaled according to the polygon's relative area) pass towards the `Routing_HBV()` routine. In the next step, the total amount of water output of this function enters in the transfer function (UH). In this case, we are assuming that the routing routine is implicitly accounting for the subsurface flow route. In the article we make a reference to this in the *Routing module* section:

“*An early engineering-based solution to this issue, was to consider this multicausal delay as a water storage effect at **catchment scale** (Dooge, 1973)*”.

Then the transfer function accounts for the hydrograph timing (again at catchment scale) .

This brief explanation is not the only possible scheme, the user could use one `Routing_HBV()` and `UH()` function for every polygon (or unit) inside the watershed (as the `TUWmodel` package does - see the *Distribute input case (6 zones)* example provided by the package documentation).

In our **bias view**, the advantage of HBV.IANIGLA is that the user is not tied to the package developer (in this case **us**) catchment perceptual model (Beven, 2012). In other words, (s)he can decide how to assemble the different modules of the package. This facet also gives transparency to the modeling exercise, since the modeler is explicitly showing how (s)he decided to build the model (and it also gives the opportunity to the reviewers to discuss it).

Package

- I really appreciate all the efforts the authors have made to create vignettes and to provide a more extensive documentation. I think that it will greatly help future users of the package.

- We acknowledge all the constructive suggestions that both reviewers have done to greatly improve the package documentation and article.

References

Beven, K. J. (2012). Rainfall—Runoff Modelling (2 edition). Wiley.

Dooge, J. (1973). *Linear Theory of Hydrologic Systems*. Agricultural Research Service, U.S. Department of Agriculture.