CONGRESO INTERNACIONAL DE GESTIÓN INTEGRAL DEL AGUA

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Open source tools as an instrument for decision-making for adaptation to climate change: airGR GR2M streamflow projections

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Herramientas basadas en software libre como instrumento en la toma de decisiones para la adaptación al cambio climático

Open source tools as an instrument for decision-making for adaptation to climate change: airGR GR2M streamflow projections

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ABSTRACT

Future projections of hydroclimatic variables, such as precipitation, temperature and streamflow, are key tools for decision-making under a climate change scenario. Runoff estimations can be obtained by calibrating and validating the open-source hydrological model “airGR GR2M”, forced by monthly potential evapotranspiration and precipitation times series, against observed data. Regarding the inputs of the model, precipitation time series are relatively easy to collect, however, evapotranspiration measurements are often not available over long periods of time. To overcome this difficulty, potential evapotranspiration can be calculated from the same R package using the Oudin method, forced by temperature and latitude data for the region of analysis. The main objective of the study is to present the results of modelled-based runoff projections over two specific basins in Chile using global climate model (GCM) data under a high radiative concentration pathway future scenario (RCP; 8.5 W/m2). Precipitation and temperature monthly data from 75 CMIP5 simulations under the RCP 8.5 scenario for the 2025-2050 and 2055-2080 periods were collected and scaled to the observed climate using a delta-change approach. The main results indicate important decreases in annual runoff, which range from 23% to 28% towards the end of 2080 compared to 1980-2006 period. Based upon the results, and the new and easily accessible open source tools to assist decision making process, the future projections of runoff should be considered in water management task such as the water use and water rights administration.

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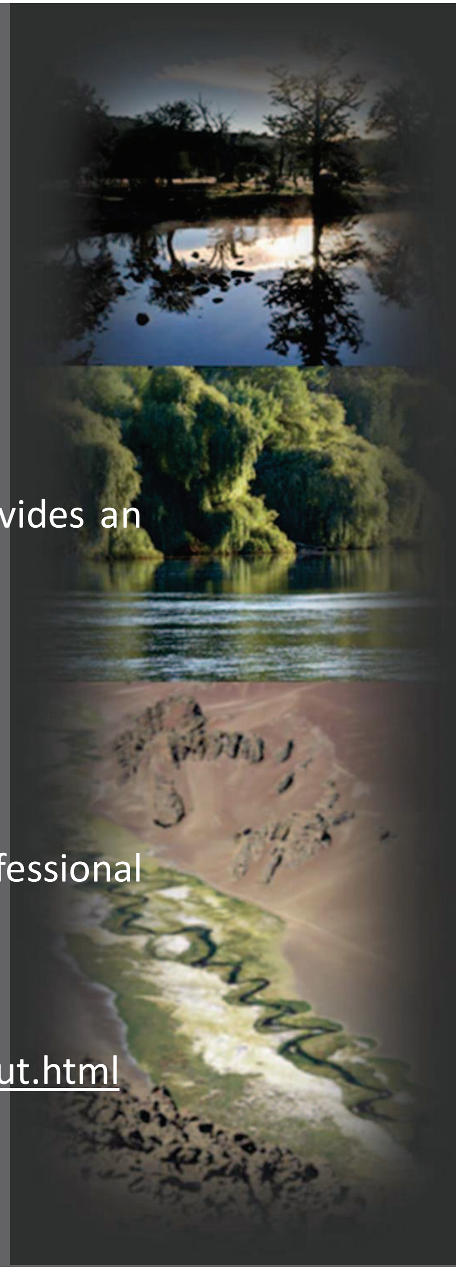
R/RStudio

- R is a programming language focused on statistical analysis.
- It is considered as a different implementation of the S language.
- R provides a wide variety of statistical and graphic techniques and is highly extensible.
- “The S language is often the vehicle chosen for research in statistical methodology, and R provides an open source path to participate in that activity”.

- RStudio has a mission to provide the most widely used open source and enterprise-ready professional software for the R statistical computing environment.

https://www.r-project.org/about.html
https://rstudio.com/about/



airGR hydrological model

- The GR models are a group of rainfall-runoff models developed in France by the research unit in hydrology of the Cemagref d'Antony. These models are characterized by using precipitation and temperature as input data.

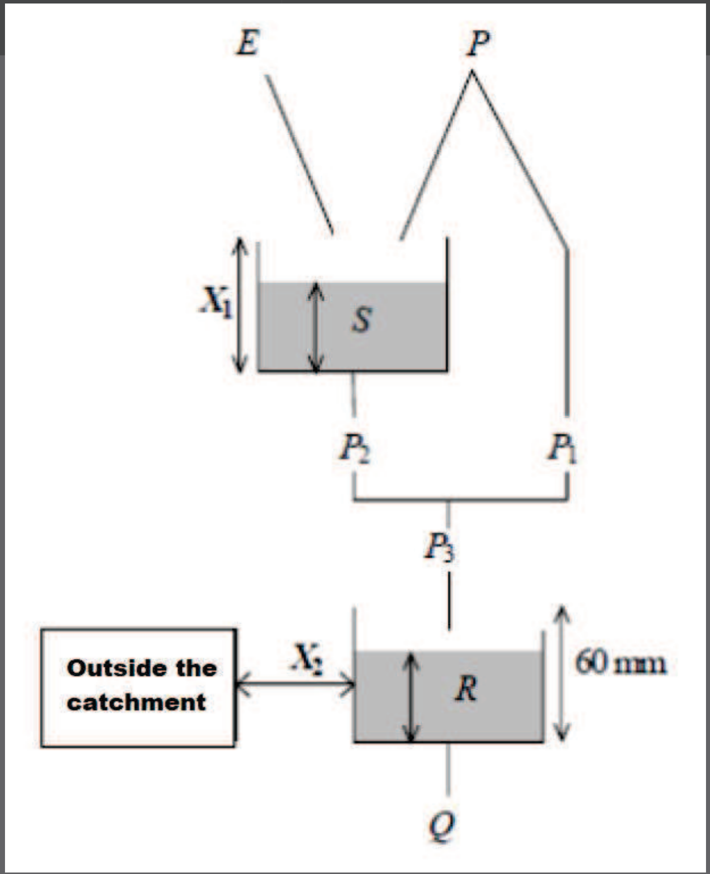
The models can be called within airGR using the following functions:

- `RunModel_GR4H()` : four-parameter hourly lumped hydrological model (Mathevet 2005)
- `RunModel_GR4J()` : four-parameter daily lumped hydrological model (Perrin, Michel, and Andréassian 2003)
- `RunModel_GR5J()` : five-parameter daily lumped hydrological model (Le Moine 2008)
- `RunModel_GR6J()` : six-parameter daily lumped hydrological model (Pushpalatha et al. 2011)
- `RunModel_GR2M()` : two-parameter monthly lumped hydrological model (Mouelhi 2003; Mouelhi et al. 2006a)
- `RunModel_GR1A()` : one-parameter yearly lumped hydrological model (Mouelhi 2003; Mouelhi et al. 2006b)
- `RunModel_CemaNeige()` : two-parameter degree-day snowmelt and accumulation model (Valéry, Andréassian, and Perrin 2014)
- `RunModel_CemaNeigeGR4J()` : combined use of **GR4J** and **CemaNeige**
- `RunModel_CemaNeigeGR5J()` : combined use of **GR5J** and **CemaNeige**
- `RunModel_CemaNeigeGR6J()` : combined use of **GR6J** and **CemaNeige**

- GR2M is an aggregate model that simulates runoff at monthly intervals (mm) from 1. accumulated monthly precipitation (mm) and 2. accumulated monthly potential evapotranspiration (mm)

Coron et al., 2017, 2019
https://webgr.irstea.fr/en/models/monthly-model-gr2m/

GR2M model



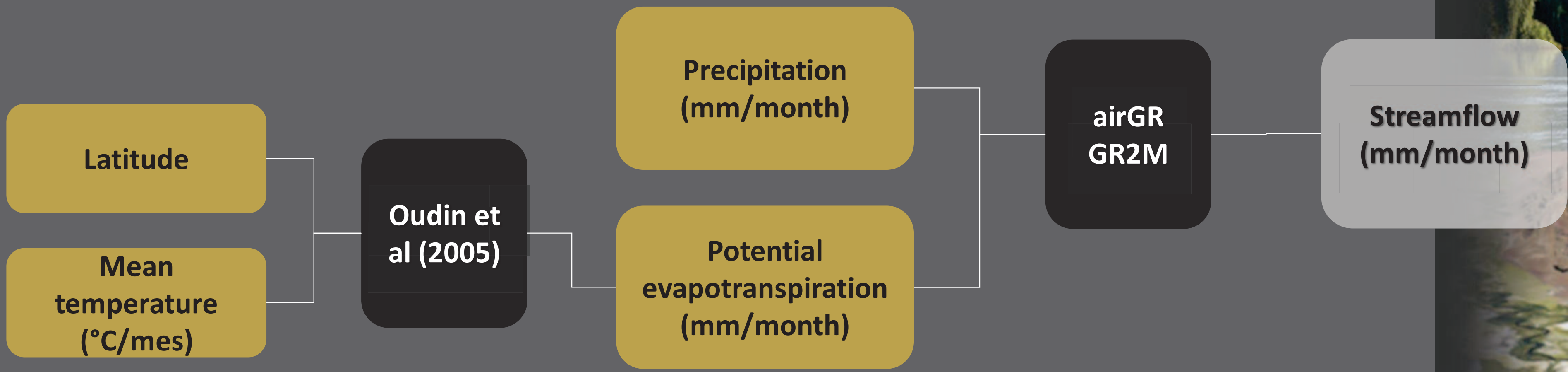
P = Precipitation
E = Potential evapotranspiration
S = Production store
X1 = Maximum capacity of the production store
P1 = Excess precipitation
P2 = Percolation
P3 = Total precipitation that reaches the routing store
R = Routing store
X2 = Exchange coefficient (adimentional)
Q = Streamflow

Simulated streamflow depend on two parameters to optimize in the calibration of the model:

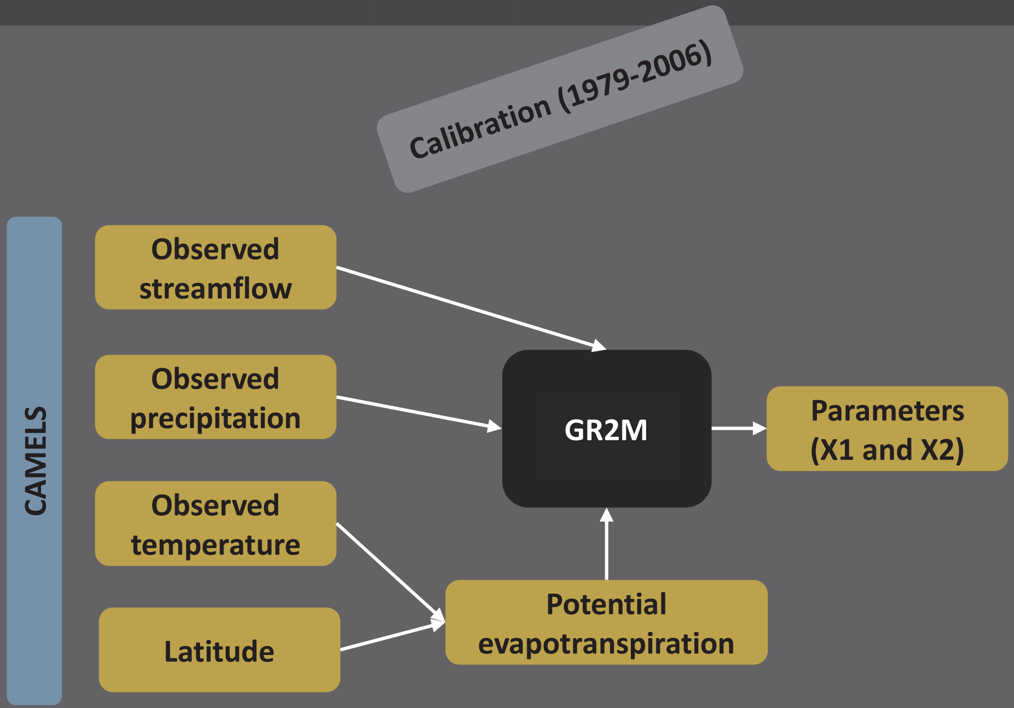
X1: Maximum capacity of the production store (mm)
X2: Exchange coefficient (adimentional)

Cabrera, 2010
Coron et al., 2017, 2019

Inputs/outputs GR2M



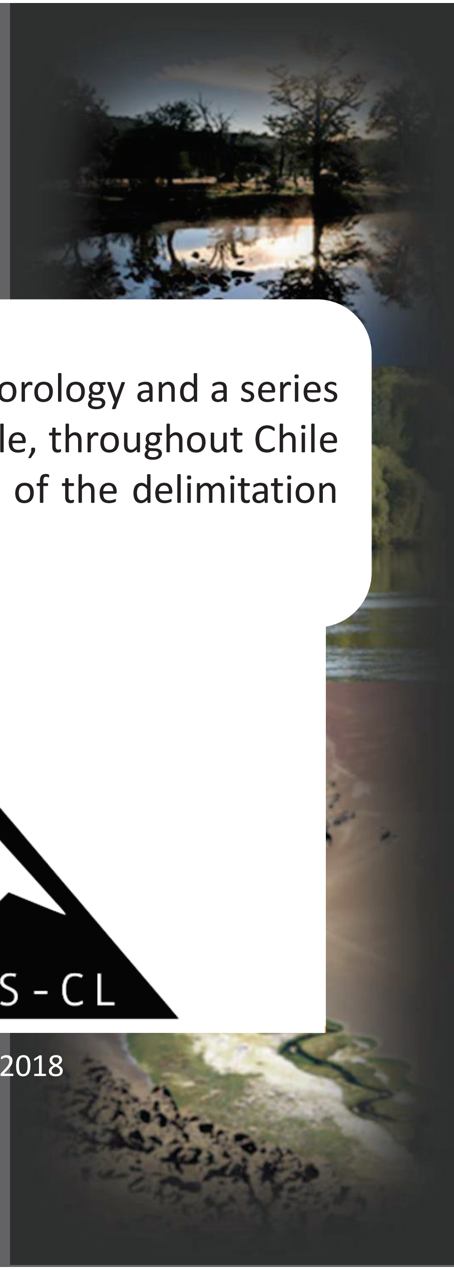
Data and methodology



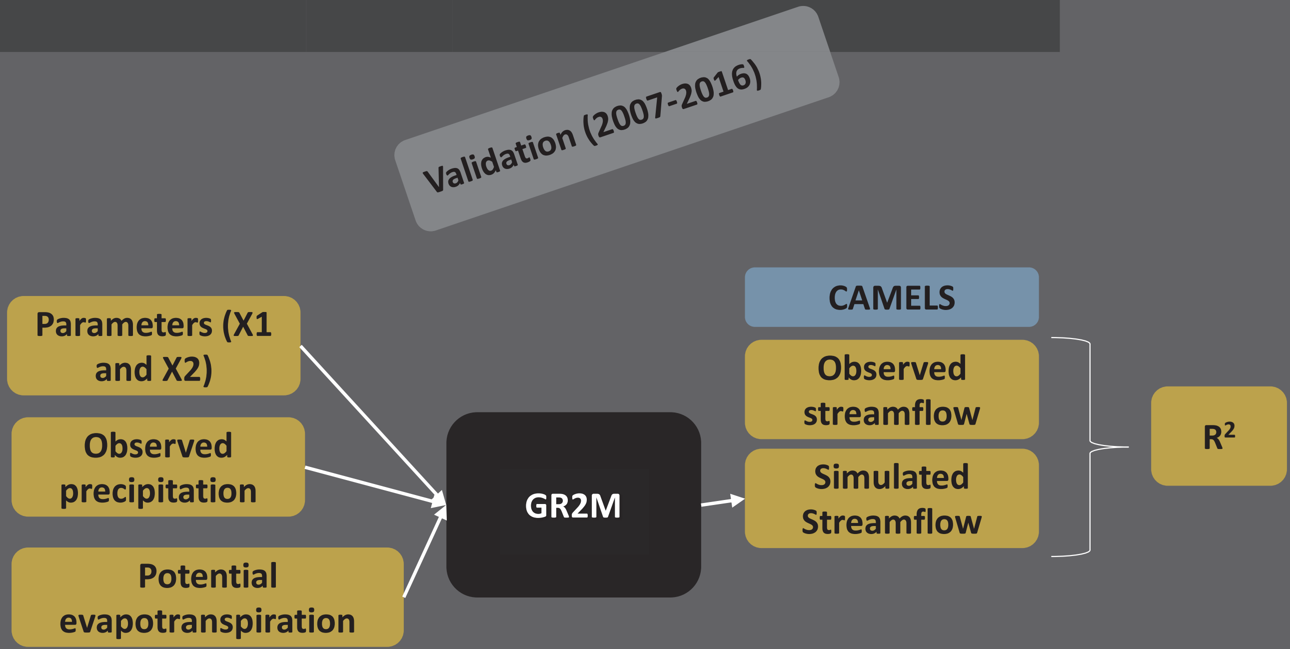
This database contains hydrology, meteorology and a series of attributes integrated at the basin scale, throughout Chile (17.8 S - 55.0 S). The database consists of the delimitation of 531 basins throughout Chile

CAMELS-CL

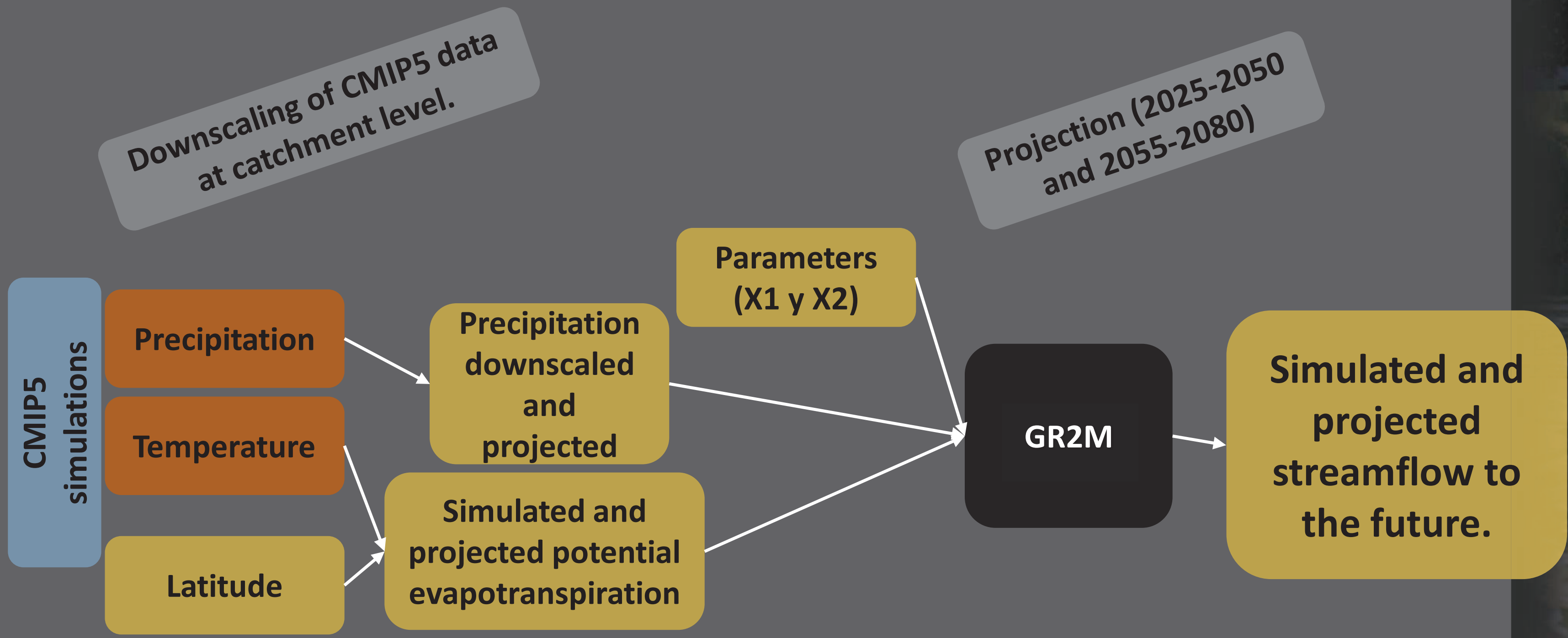
Alvarez-Garreton et al., 2018



Data and methodology



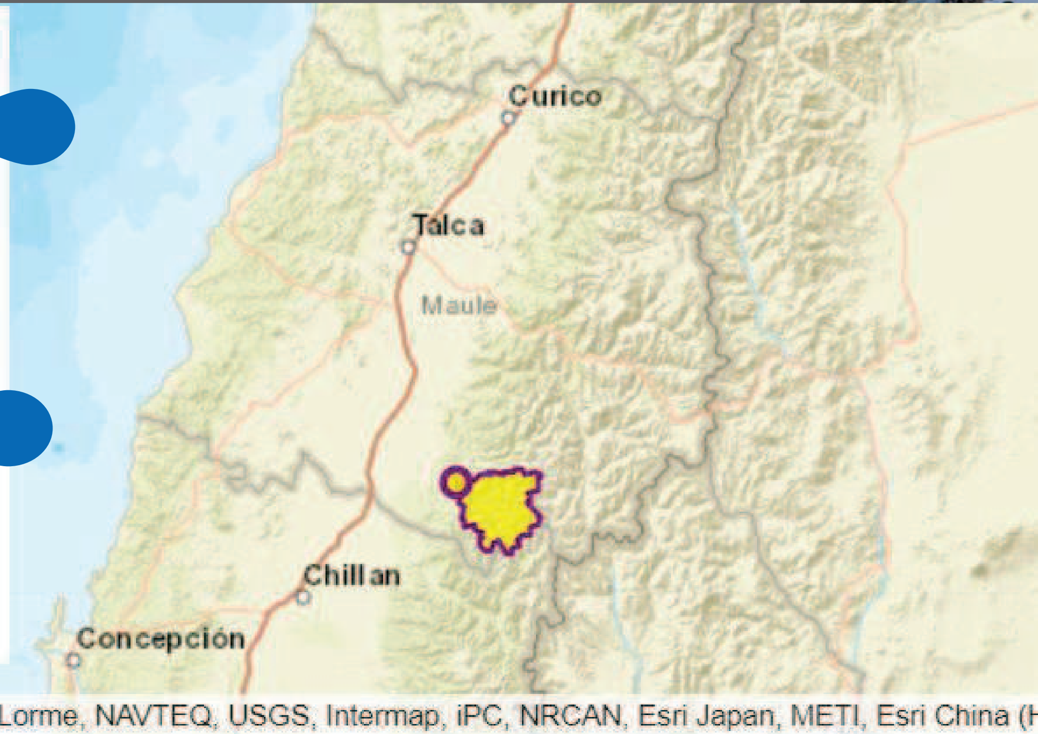
Data and methodology



Selected catchments

Catchment attributes 7350001

Area	**668.9**	km2
Outlet elevation	**456**	m a.s.l.
Catchment mean elev.	**1401**	m a.s.l.
Catchment max elev.	**3195**	m a.s.l.
Mean slope	**247.1**	m/km
Annual precip. (CR2MET)	**2270**	mm
Aridity index	**0.4**	-
Human intervention degree	**0.003**	
Large dam in catchment	**yes**	-



Catchment 7350001

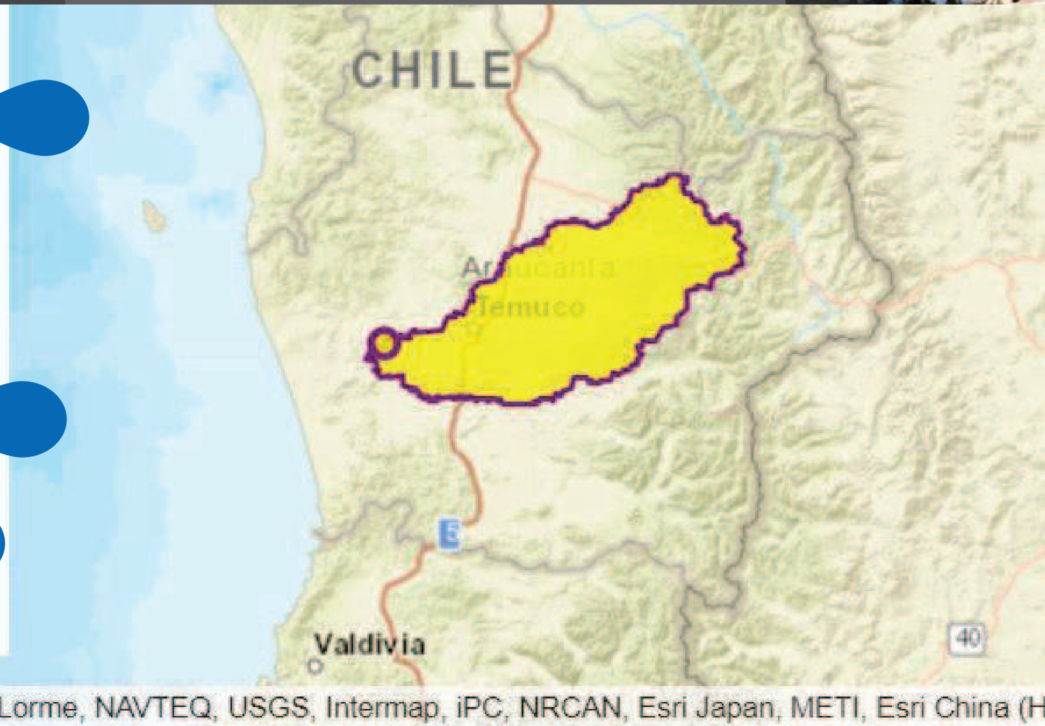
Streamflow gauge at catchment outlet: Rio Longavi En La Quiriquina (Lat. -36.2303 S, Lon. -71.4569 E)

http://camels.cr2.cl/

Selected catchments

Catchment attributes 9140001

Area	**5549.4**	km2
Outlet elevation	**17**	m a.s.l.
Catchment mean elev.	**553**	m a.s.l.
Catchment max elev.	**3093**	m a.s.l.
Mean slope	**102.8**	m/km
Annual precip. (CR2MET)	**1840**	mm
Aridity index	**0.6**	-
Human intervention degree	**0.022**	
Large dam in catchment	**no**	-



Catchment 9140001

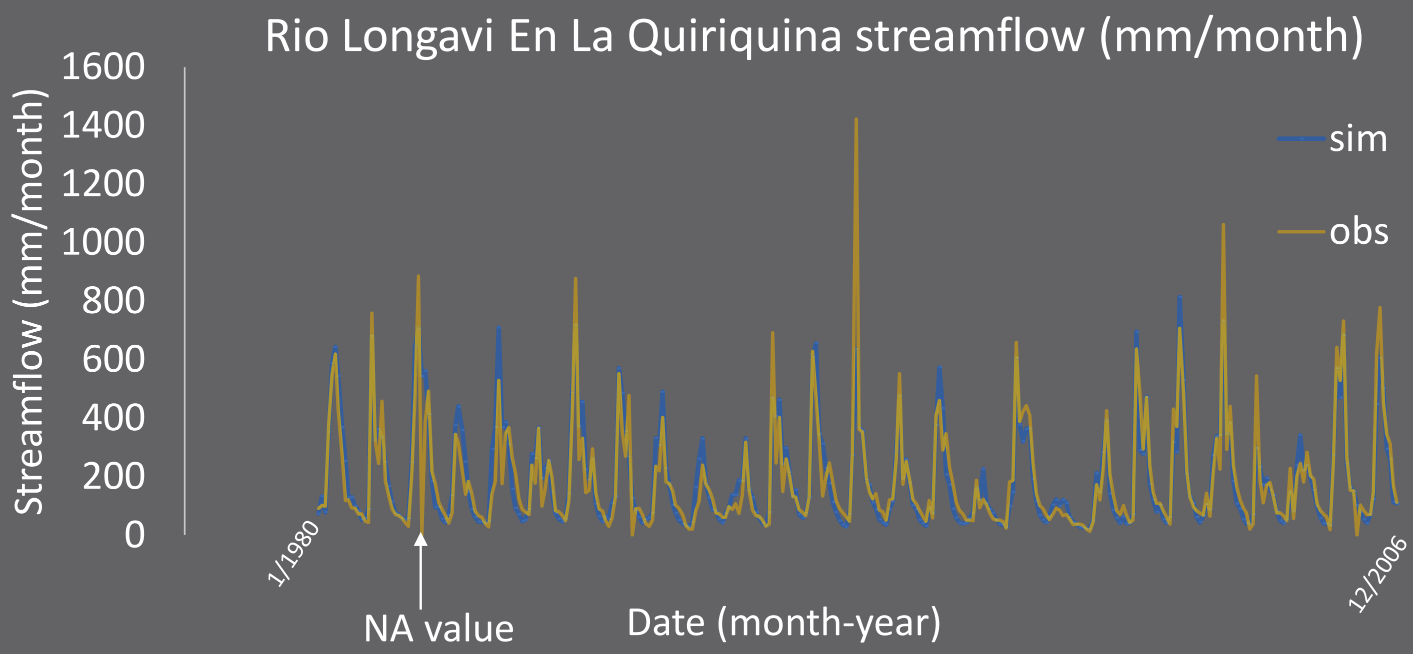
Streamflow gauge at catchment outlet: Rio Cautin En Almagro (Lat. -38.78 S, Lon. -72.9469 E)

http://camels.cr2.cl/

1. Evapotranspiration calculation
2. Calibration
3. Simulation for validation

Code in R: In case you need code please write to contact email.

Calibration

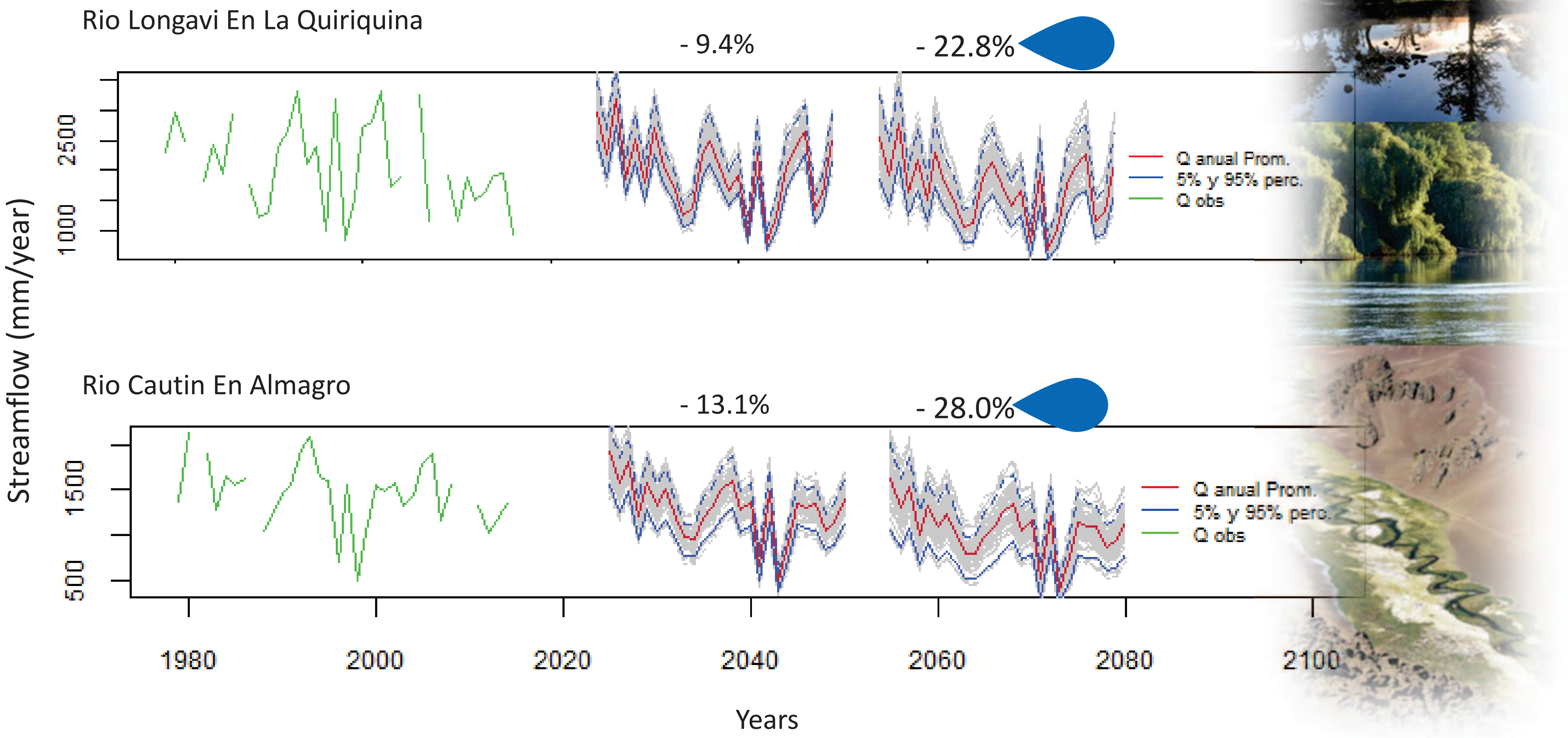


Simulation for projection

- Follow same procedure and functions indicated in simulation for validation.
- The change consists of future precipitation and evapotranspiration inputs.
- Precipitation and temperature were downscaled and projected (using "Delta Change") based on the 75 simulations of CMIP5 in each catchment and in the periods of interest.
- Future potential evapotranspiration was calculated with Oudin et al. (2005) in airGR package of R from the future scaled and projected temperature.
- Therefore, when running GR2M model, a loop with "for" function must be added in R code to generate simulation with the 75 simulations of CMIP5.

Results

Changes in the average of the simulations respect to observed streamflow (1980-2006 period)



Final comments

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- Open source R programming is based on the collaboration of experts throughout the world. This same collective effort is increasingly positioning R in the scientific work of hydroclimatology and other sciences.
- The R implementation of airGR models is an excellent free tool for modeling streamflows at different time scales at the basin level. The model to be used must be chosen based on data availability and the final purpose of the simulation.
- Observed data must be available for proper use. In Chile this is facilitated by the CAMELS-CL database.
- The catchment selected in this work obtained Nash-Sutcliffe efficiencies in calibration greater than 0.8, which is considered a very good hydrological model (Moriasi et al 2007). In turn, the R2 in the validation period were also high (greater than 0.7).
- Our results indicate decreases of over 23% of the annual streamflow (calculated from monthly) in both basins (greater towards the south) towards the end of 2080.
- This must be considered in adaptation to climate change, for example through reassessing the granting of rights water use future for the different economic activities of the country.

References

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