Hydrological forecasts through ensemble modeling in the Andes Cordillera

GEWEX INARCH

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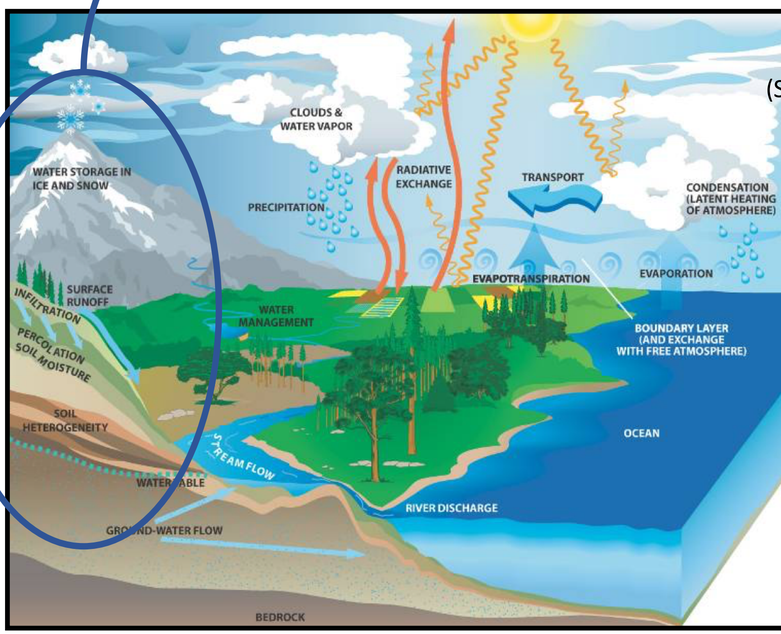
dic INGENIERÍA CIVIL UNIVERSIDAD DE CHILE

UNIVERSIDAD DE CHILE 10 años 2009-2019 amtc

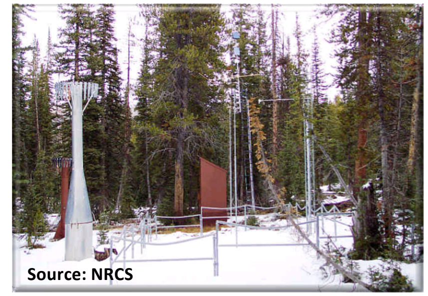
Motivation

Opportunities for prediction

hydrological predictability (land)



Water Cycle (from NASA)

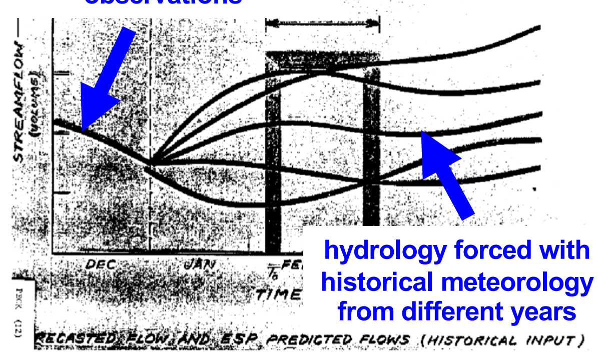


April-July volume Weber @ Oakley =
+ 3.50 * Apr 1st Smith & Morehouse (SMMU1) SWE
+ 1.66 * Apr 1st Trial Lake (TRLU1) SWE
+ 2.40 * Apr 1st Chalk Creek #1 (CHCU1) SWE
- 29.2

Hydrological Prediction:
How well can we estimate water stored on the land?
Statistical and dynamical

Statistical with *in situ* observations

Hydrology model forced with recent meteorological observations

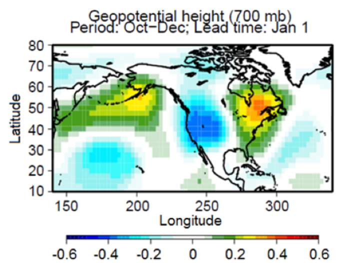


hydrology forced with historical meteorology from different years

Dynamical (ESP)

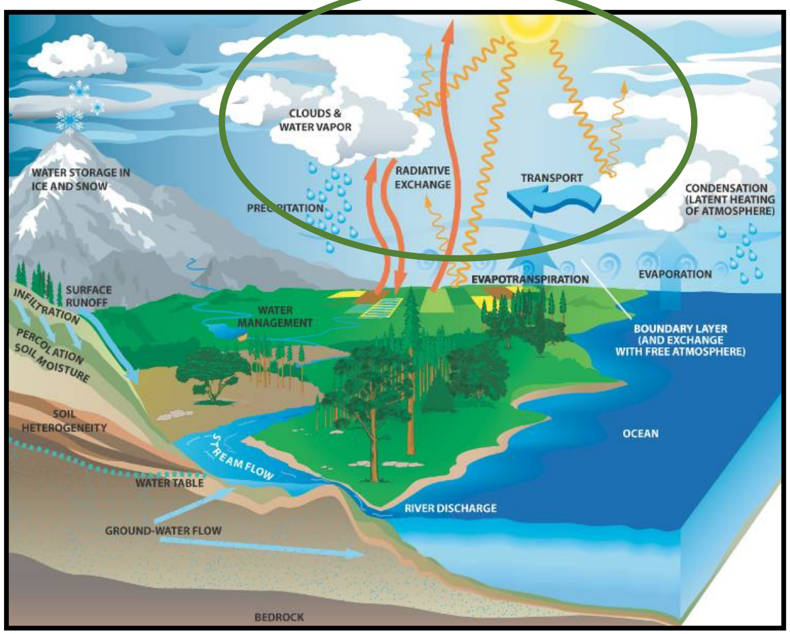
Motivation

Opportunities for prediction



Reanalysis data

meteorological predictability (climate)



Water Cycle (from NASA)

Climate indices

Index	Pattern
Nino 3.4	East Central Tropical Pacific SST
Nino 1+2	Extreme Eastern Tropical Pacific SST
Nino 3	Eastern Tropical Pacific SST
Nino 4	Central Tropical Pacific SST
AMO	Atlantic Multidecadal Oscillation
NAO	North Atlantic Oscillation
PDO	Pacific Decadal Oscillation
PNA	Pacific North American Index
SOI	Southern Oscillation Index
MEI	Multivariate ENSO index
WP	Western Pacific Index
TNA	Tropical Northern Atlantic Index

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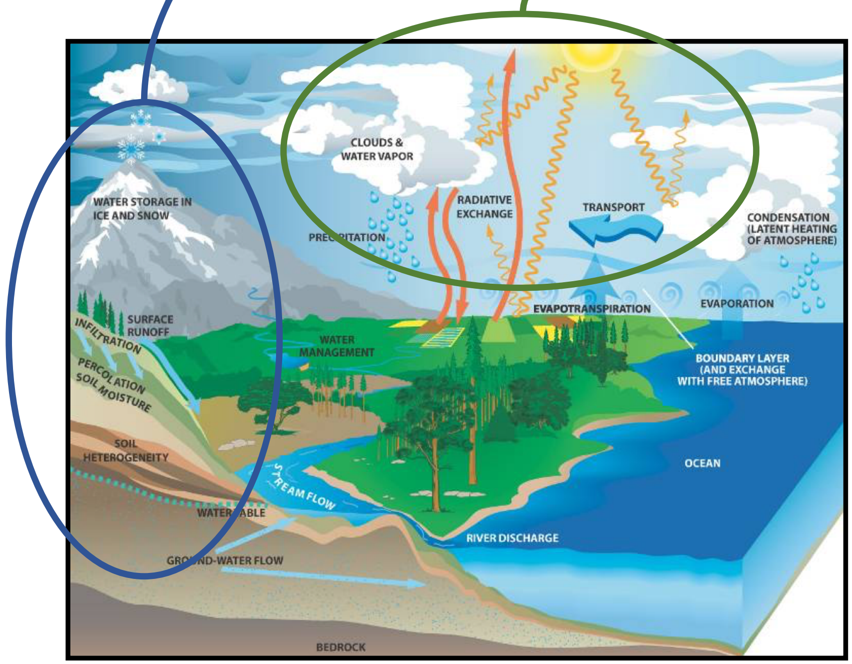
meteorological predictability (climate)



Water Cycle (from NASA)

How can we combine both to improve the predictability of seasonal streamflow?

What is the <u>added value of complexity</u>?

Water resources in Central Chile

- **Andes Cordillera**: largest natural water reservoir.
- Rivers flowing from the Andes are the **main source for water supply**.
- Water resources in this region are highly vulnerable to projected increases in temperature and decrease in precipitation.
- Drought conditions over the last 11 years.
- **Key challenge**: hydrometeorological monitoring network is quite sparse.

La Paloma reservoir, march 2015

Seasonal hydrological forecasts are required for appropriate water management

Informe Canal Melado

10 de abril 2021

ESTIMADOS REGANTES Y ACCIONISTAS
DE LA ASOCIACIÓN CANAL MELADO

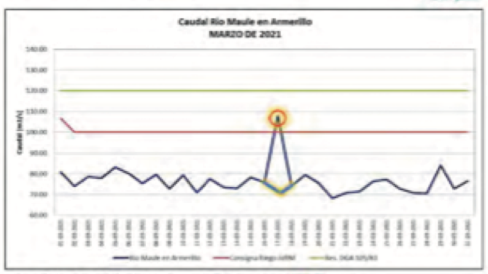
Informe condición hídrica del mes de marzo al 10 de abril de 2021. Iniciada la temporada de riego el 01 de octubre 2020, a la fecha llevamos 192 días de riego, de los 222 días hasta el 10 de mayo, equivalente al 86.4 % de la temporada.

RIO MAULE Y LAGUNA DEL MAULE

El caudal del rio Maule fue disminuyendo lentamente, inferior al pronóstico, pero permitió poder mantener la consigna programada para este mes, se complementó con el uso de los ahorros realizados en Colbún y Pehuenche y el agua que uso generación de la Laguna Invernada.

Caudal del río Maule natural

Río Maule en Armerillo



Caudal Reconstituido Promedio Mensual: 75.6 m3/s

Consigna Promedio JVRM: 100.2 m3/s

Existió un error el día 17 de marzo en la estación de monitoreo

Con un promedio de 100.2 m3/seg, el 50.0 %, de los derechos de riego. La consigna de riego del Maule se mantuvo todo el mes de marzo al 50 %.

Laguna del Maule se mantiene cerrada, esto gracias a los convenios efectuados y al buen manejo de las consignas e incluso un complemento de la Laguna Invernada.

Según lo pronosticado ya no será necesario abrir la Laguna del Maule, logrando un ahorro para riego de 160 Hm3, esto es un excelente

ASOCIACION CANAL MELADO

Canal Melado, le corresponde usar el 50% de sus derechos producto de la consigna del río Maule para el mes de marzo (consigna que corresponde al cauce natural + ahorros, total 12.6 m3/seg).

Esto sumado a la extracción de agua embalsada (2.5 m3/seg) se mantuvo todo el mes con una consigna de 15.1 m3/ seg. Esto gran parte se debe a la disminución de la necesidad de riego, al terminar las chacras y maices, continuando con riego solo los frutales, praderas y segundos cultivos.

Canal Melado a la fecha ha mantenido un riego al 100% de la Tabla de distribución mensual.

Hoy se encuentra trabajando en los cierres contables y programando los proyectos a ejecutar.

Con mayores restricciones producto de la pandemia que afecta a nuestro país, por el alto incremento de infectados cada día.

EMBALSE ANCOA

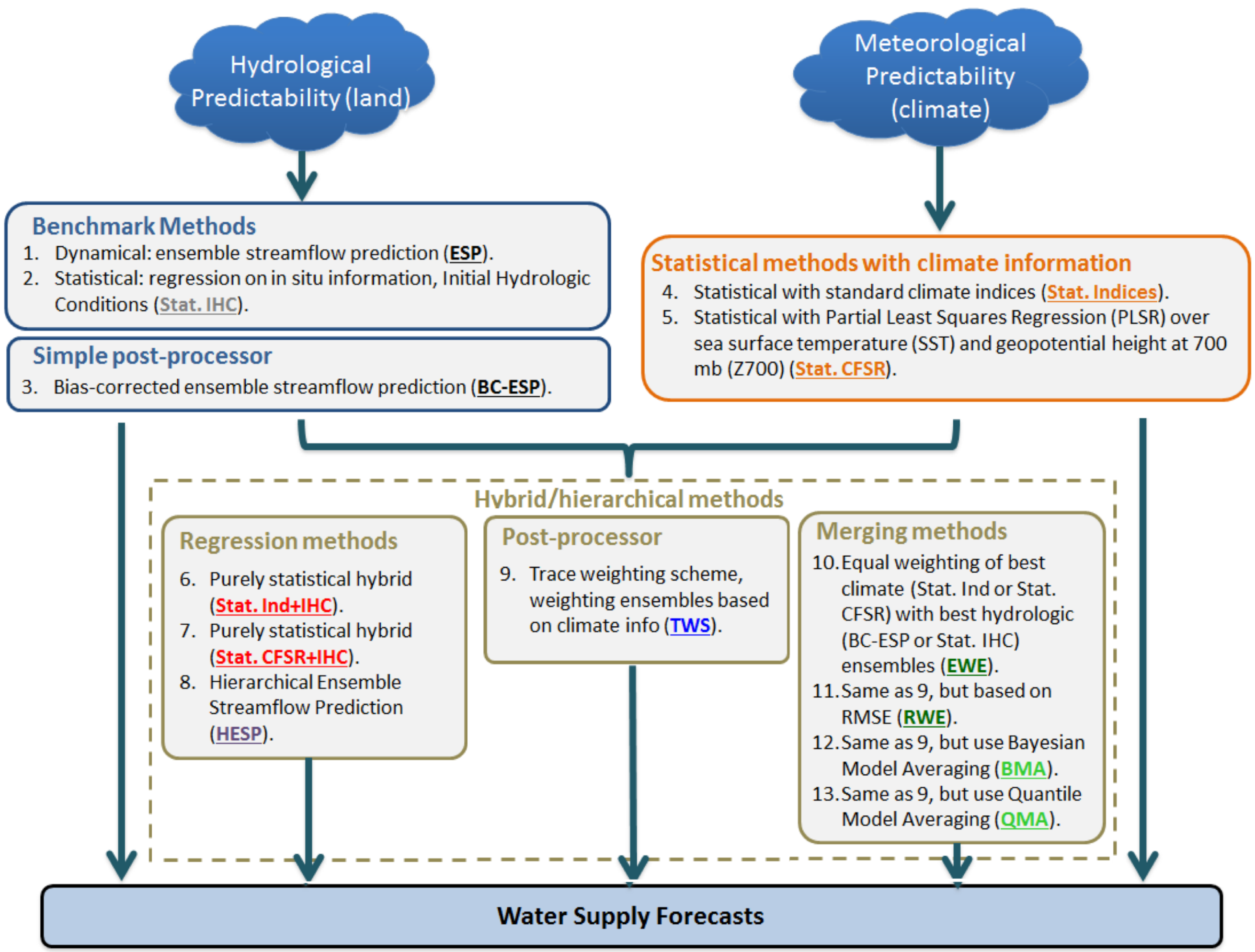
Se extrajeron durante el mes de enero 24.58 Hm3, para complementar los sistemas de riego, hoy con 17.5 Hm3 útiles.

Achibueno extrajo	**13.08 Hm3**
Ancoa extrajo	**7.72 Hm3**
Melado extrajo	**3.78 Hm3**

Water allocation relative to existing water rights

Reservoir operations for hydropower and irrigation

Sources of predictability



Mendoza et al. 2017 (HESS)

Sources of predictability

We build on previous experience testing ensemble forecasting systems in Andean watersheds

AGU PUBLICATIONS

Water Resources Research

RESEARCH ARTICLE

10.1002/2014WR015426

Key Points:
- Multimodel ensemble forecasting systems involve several methodological choices
- A robust framework for decision-making is provided
- The utility of this approach is demonstrated for seasonal streamflow forecasts

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A robust multimodel framework for ensemble seasonal hydroclimatic forecasts

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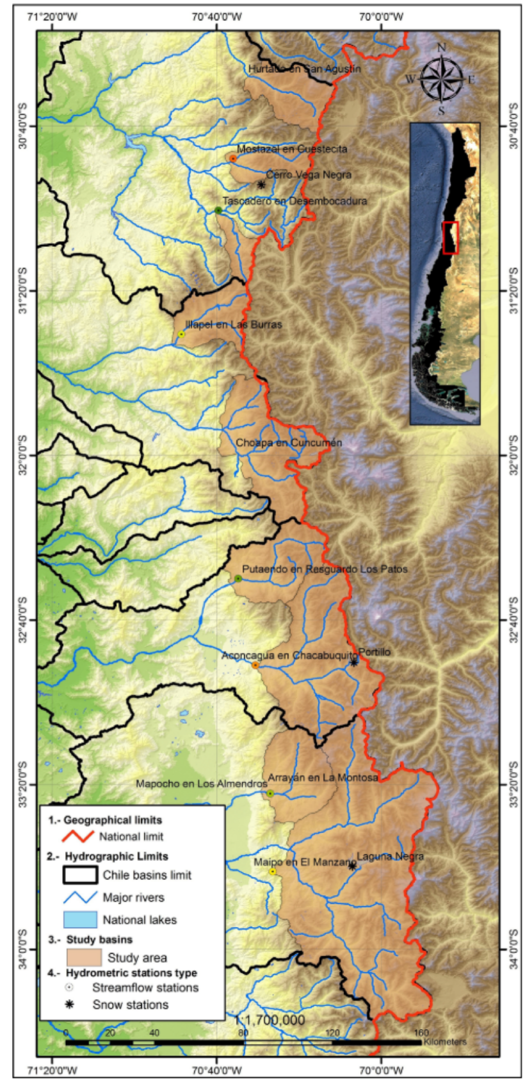
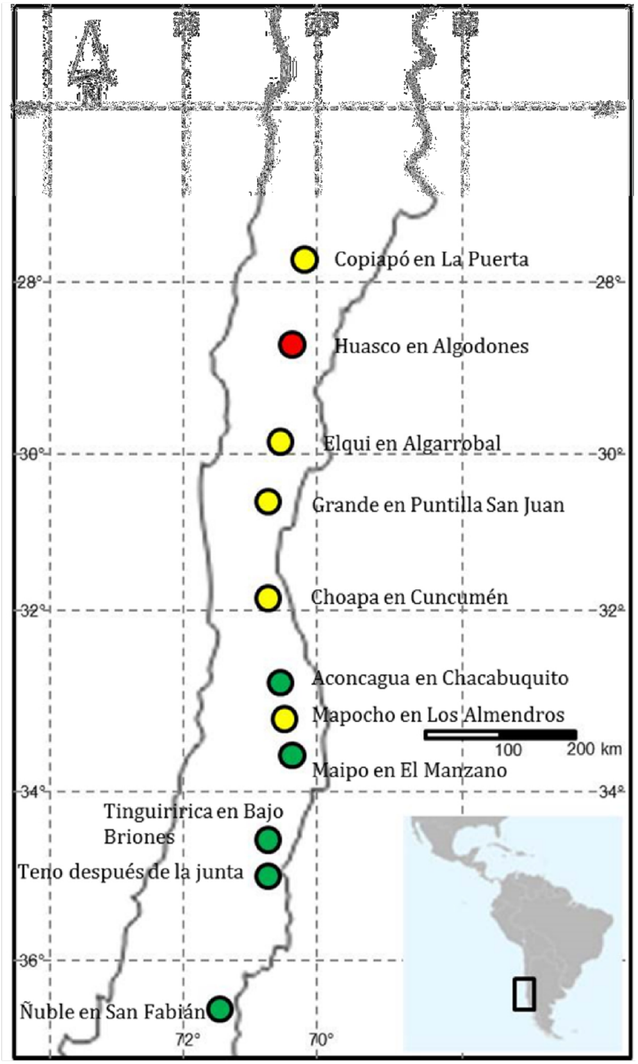
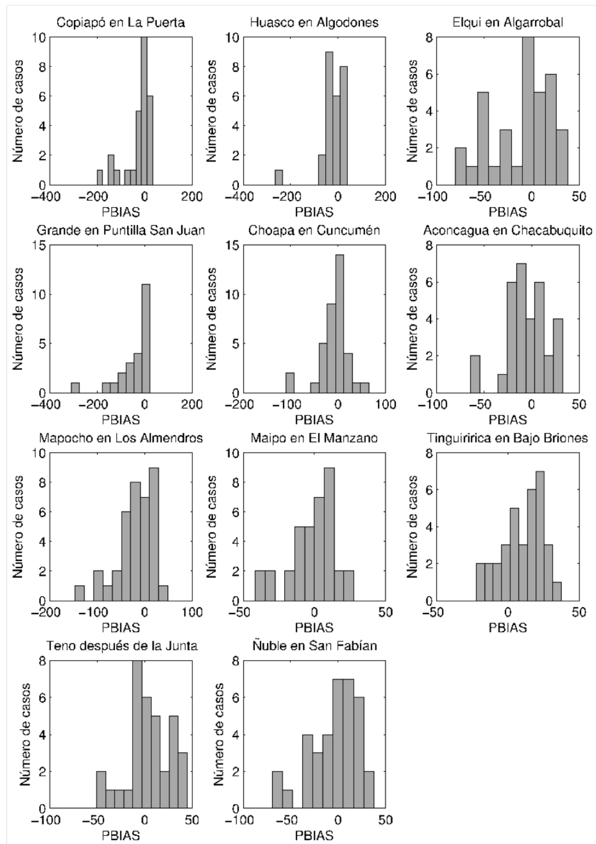
Abstract We provide a framework for careful analysis of the different methodological choices we make when constructing multimodel ensemble seasonal forecasts of hydroclimatic variables. Specifically, we focus on three common modeling decisions: (i) number of models, (ii) multimodel combination approach, and (iii) lead time for prediction. The analysis scheme includes a multimodel ensemble forecasting algorithm based on nonparametric regression, a set of alternatives for the options previously pointed, and a selection of probabilistic verification methods for ensemble forecast evaluation. The usefulness of this framework is tested through an example application aimed to generate spring/summer streamflow forecasts at multiple locations in Central Chile. Results demonstrate the high impact that subjectivity in decision-making may have on the quality of ensemble seasonal hydroclimatic forecasts. In particular, we note that the probabilistic verification criteria may lead to different choices regarding the number of models or the multimodel combination method. We also illustrate how this objective analysis scheme may lead to results that are extremely relevant for the case study presented here, such as skillful seasonal streamflow predictions for very dry conditions.





In Chile, official forecasting program since 1970's, based on regression models and in-situ hydrometeorological observations

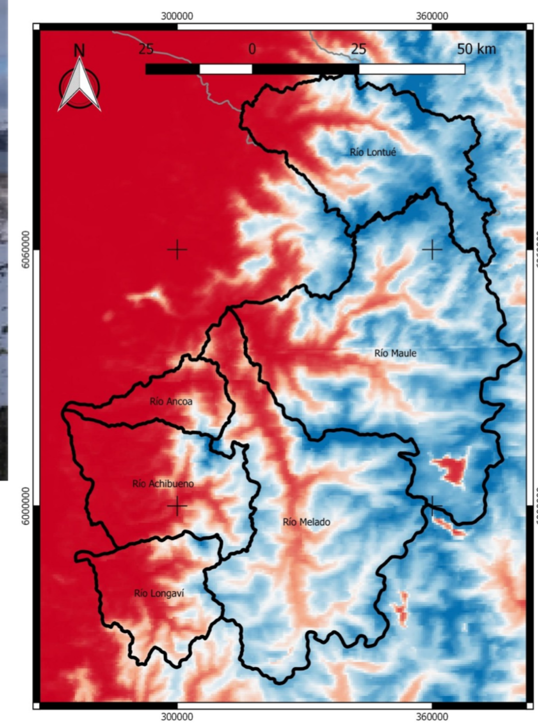


Room for improvement:

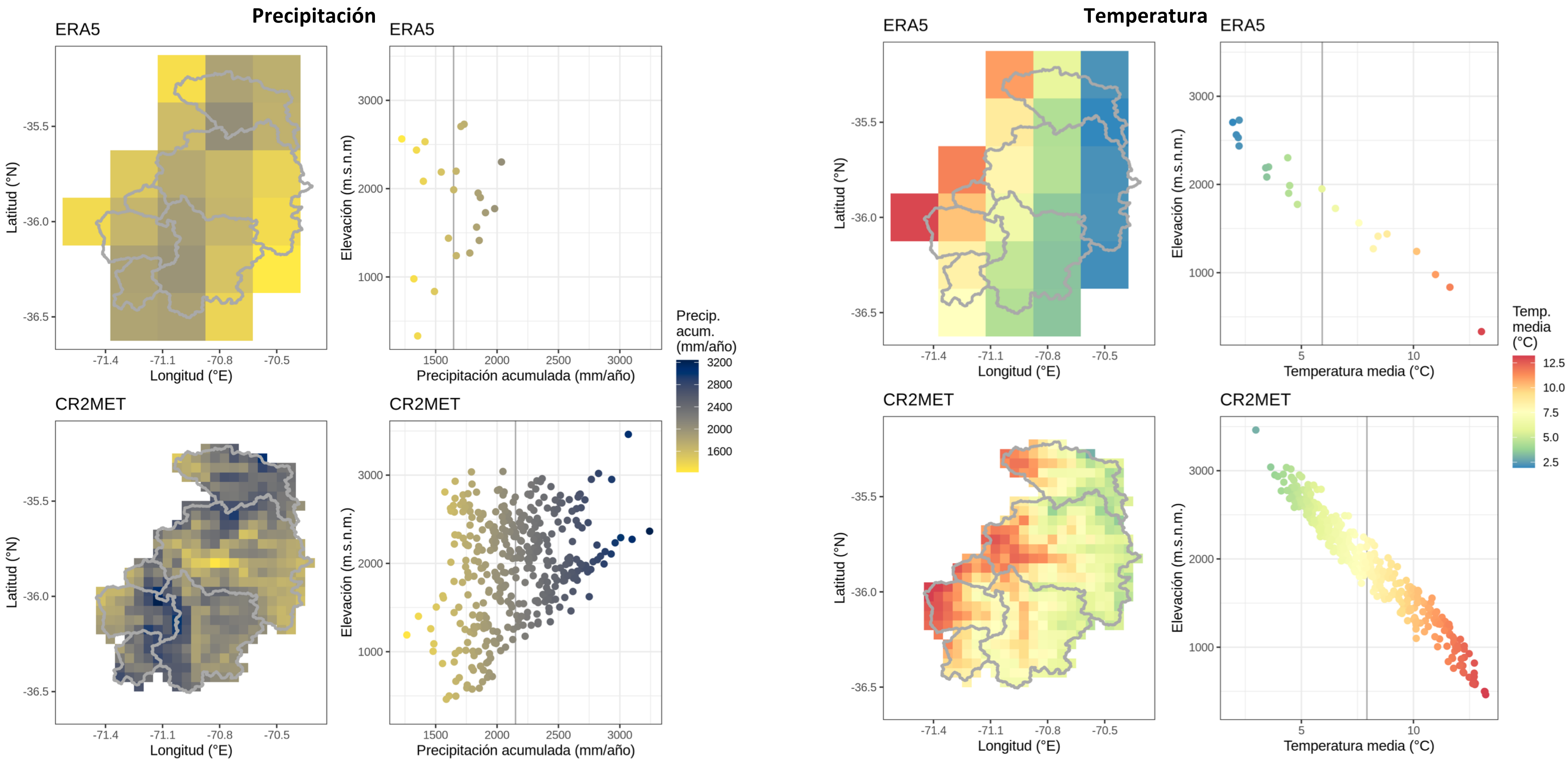
- Probabilistic forecasts
- Skill statistics
- Reliability under changing climate

A case study: the Maule River Basin (aprox. 36ºS)

- 6 subbasins
- Mixed flow regimes (snow and rain dominated)
- 1 Snow station

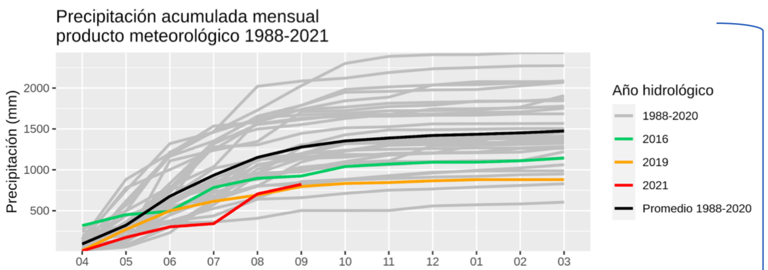


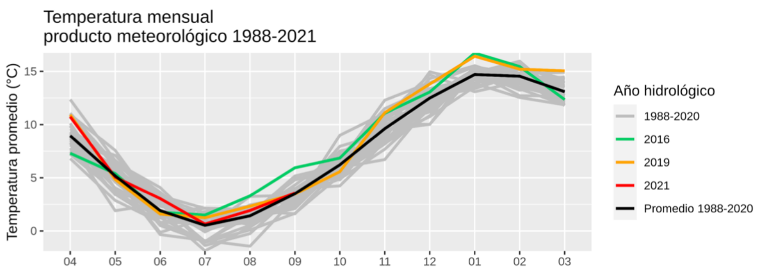
A case study: the Maule River Basin climate data



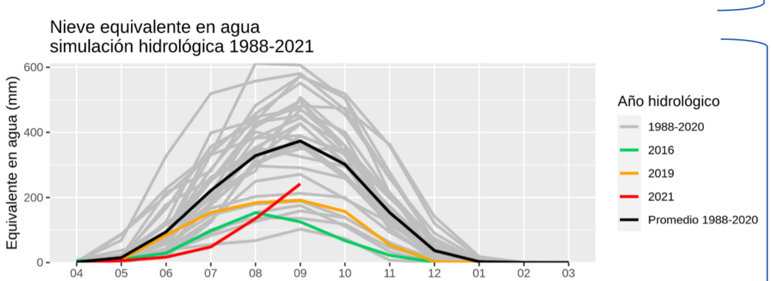
Forecasting algorithms: seasonal

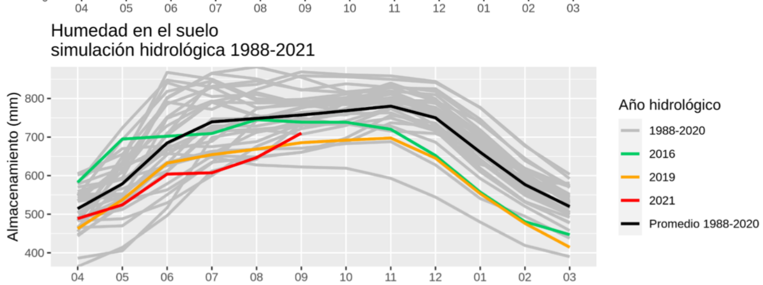
Simulated Initial Hydrological Conditions (IHC) + multiple regression



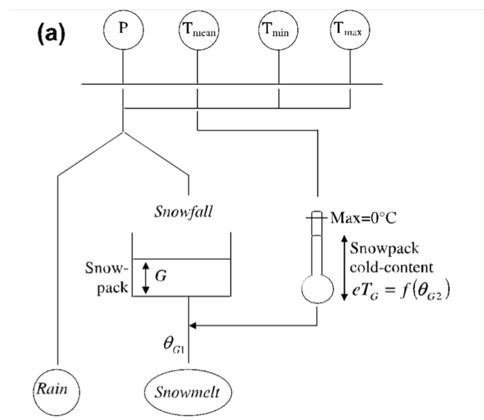


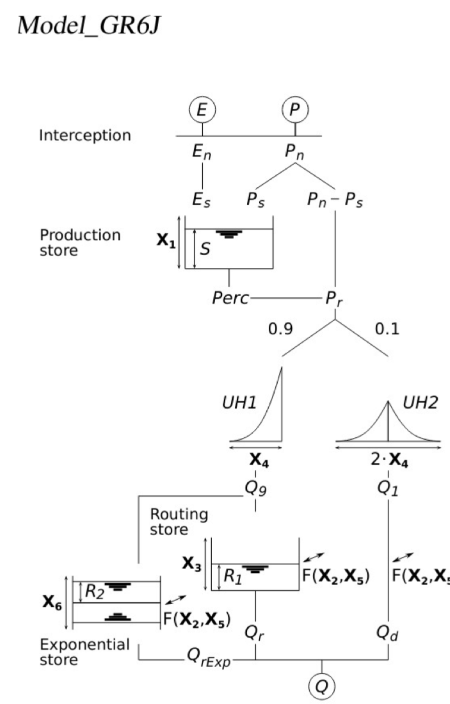
Preprocessed ERA5





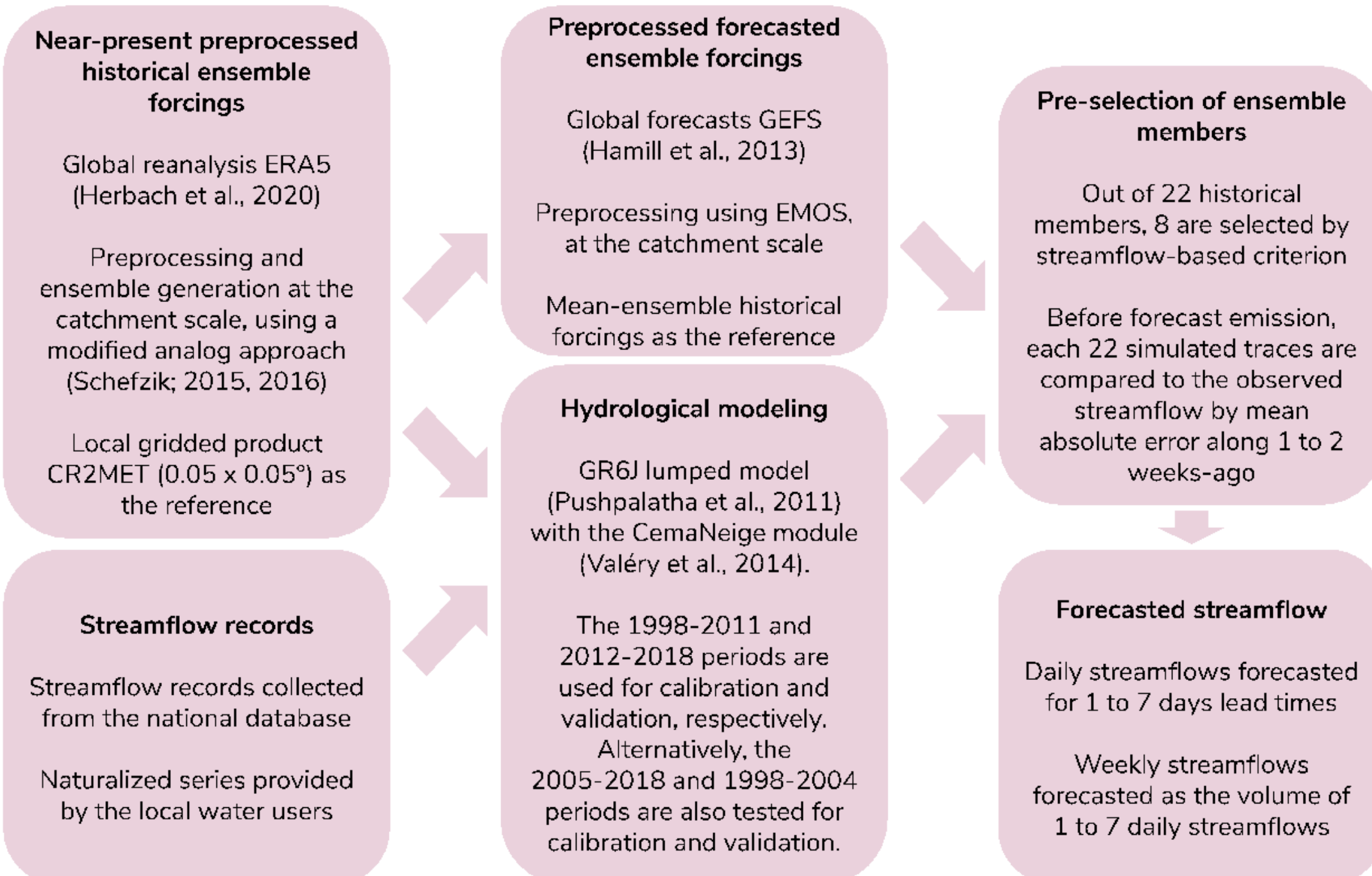
GR6J + CemaNeige



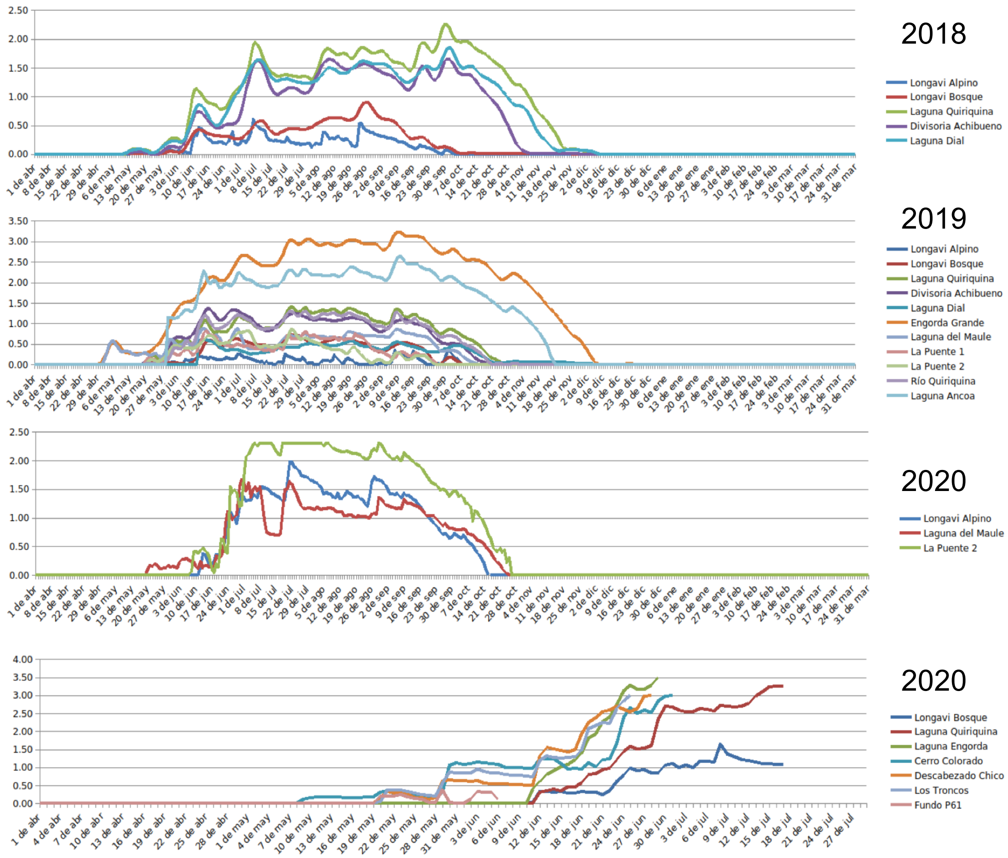


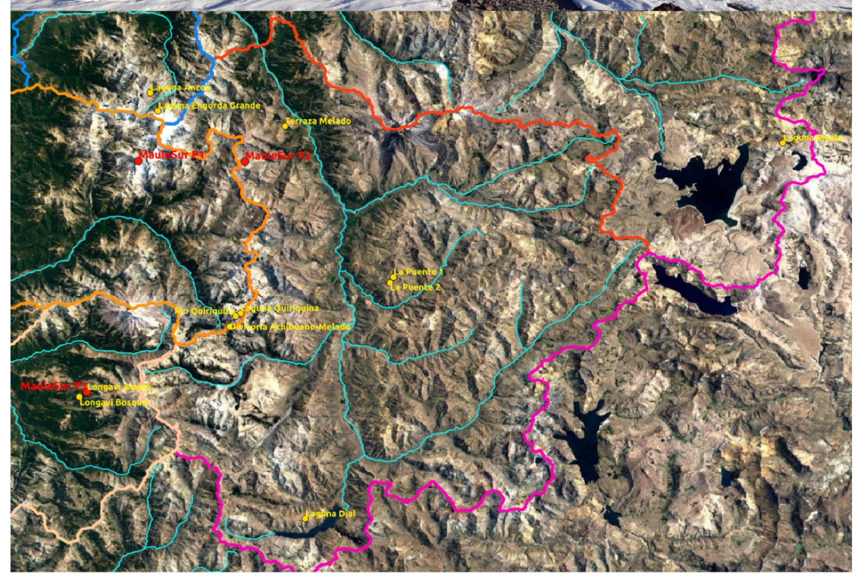
Forecasting algorithms: weekly

Simulated Initial Hydrological Conditions (IHC) + NWP-driven simulation

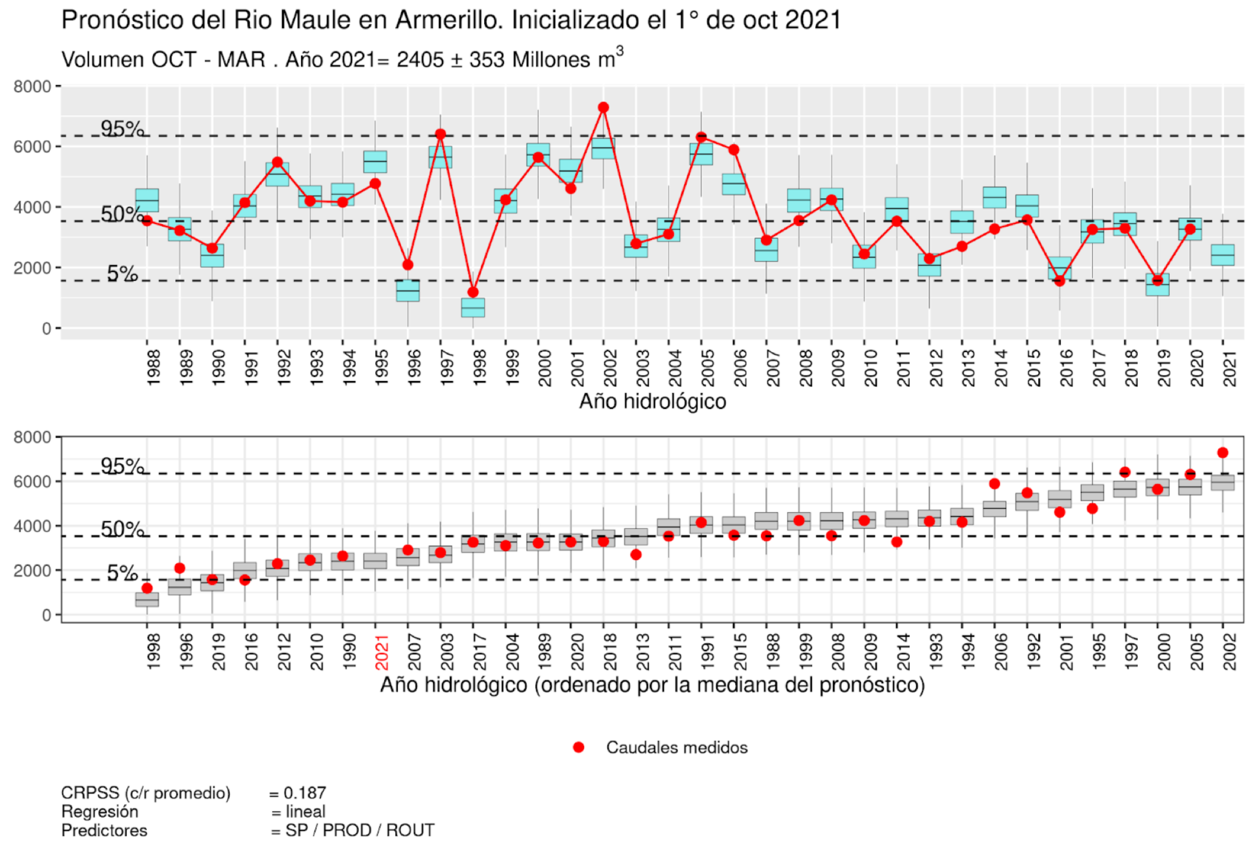


Adding snowpack observations through a low-cost sensing network





Globally available meteorological products and hydrological simulation do provide some predictive power at the seasonal level.



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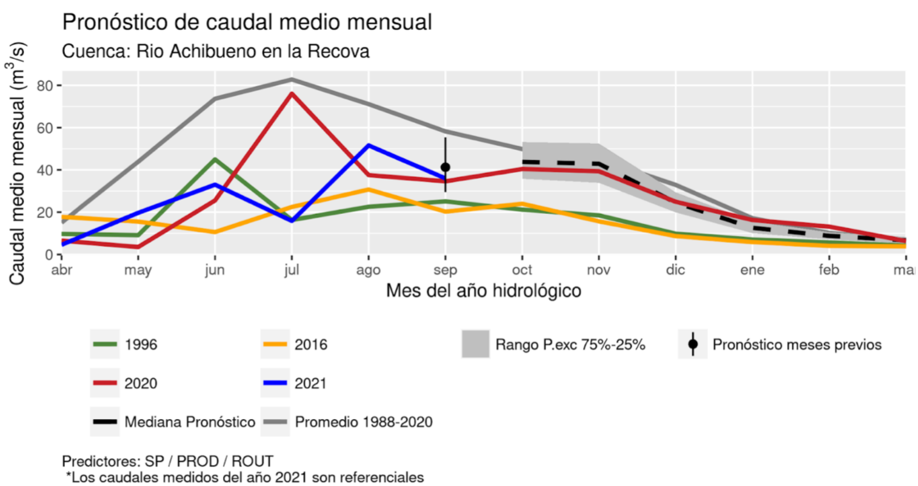
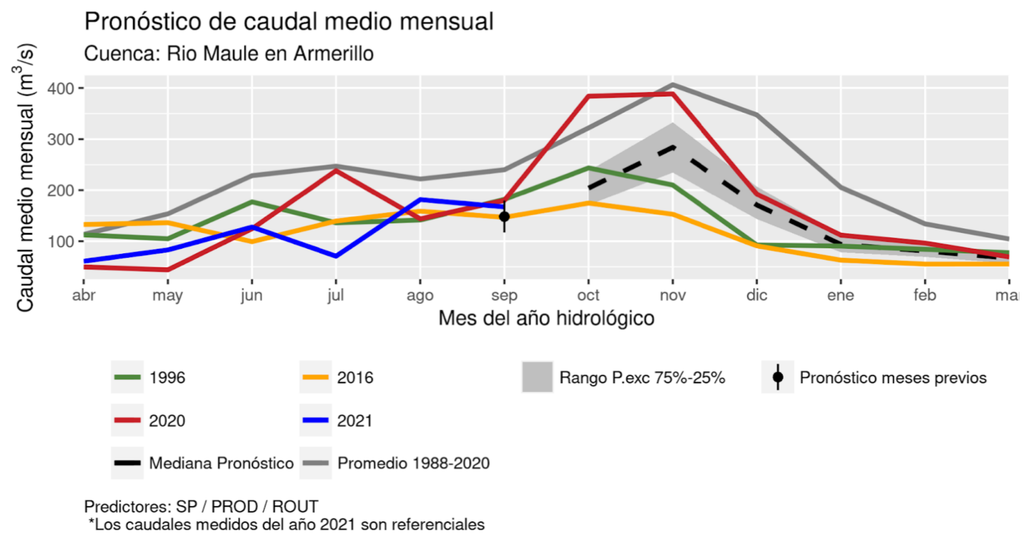
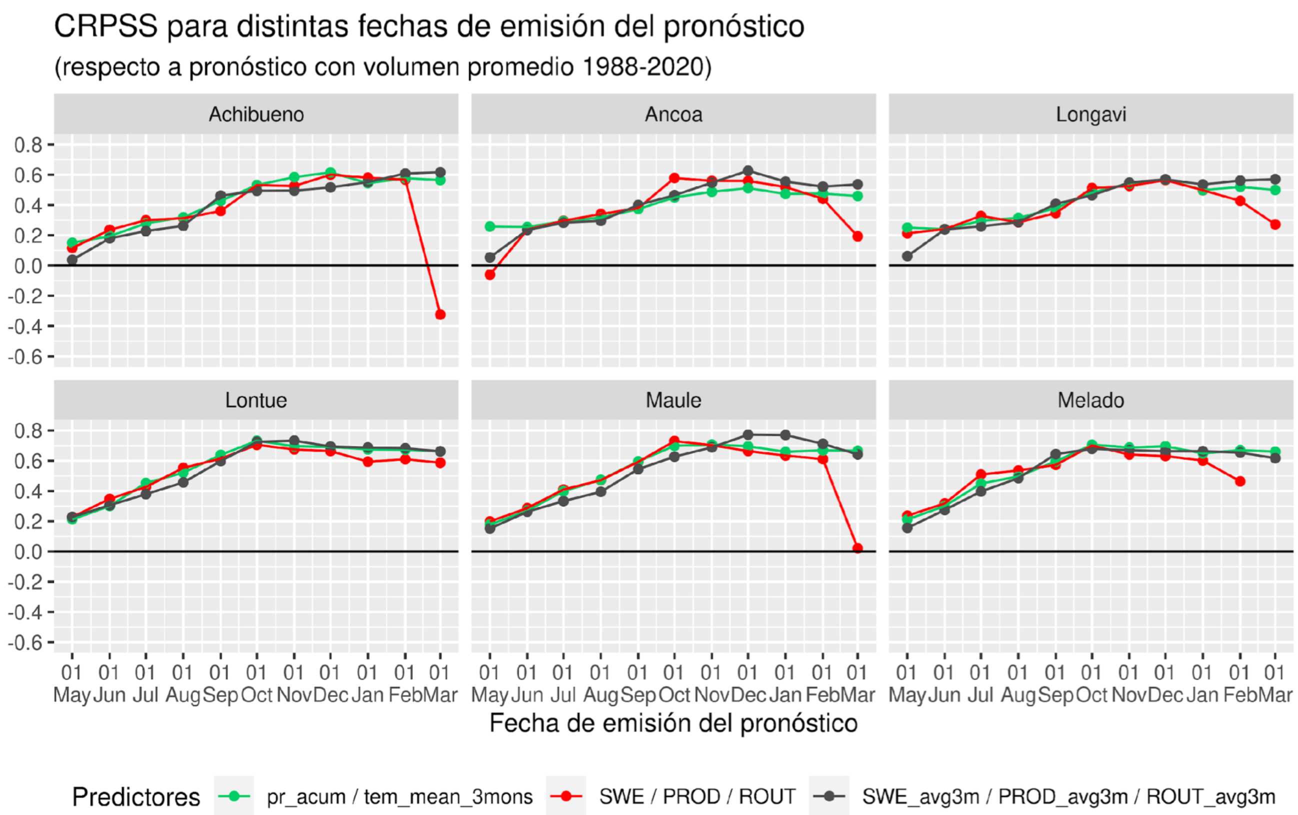
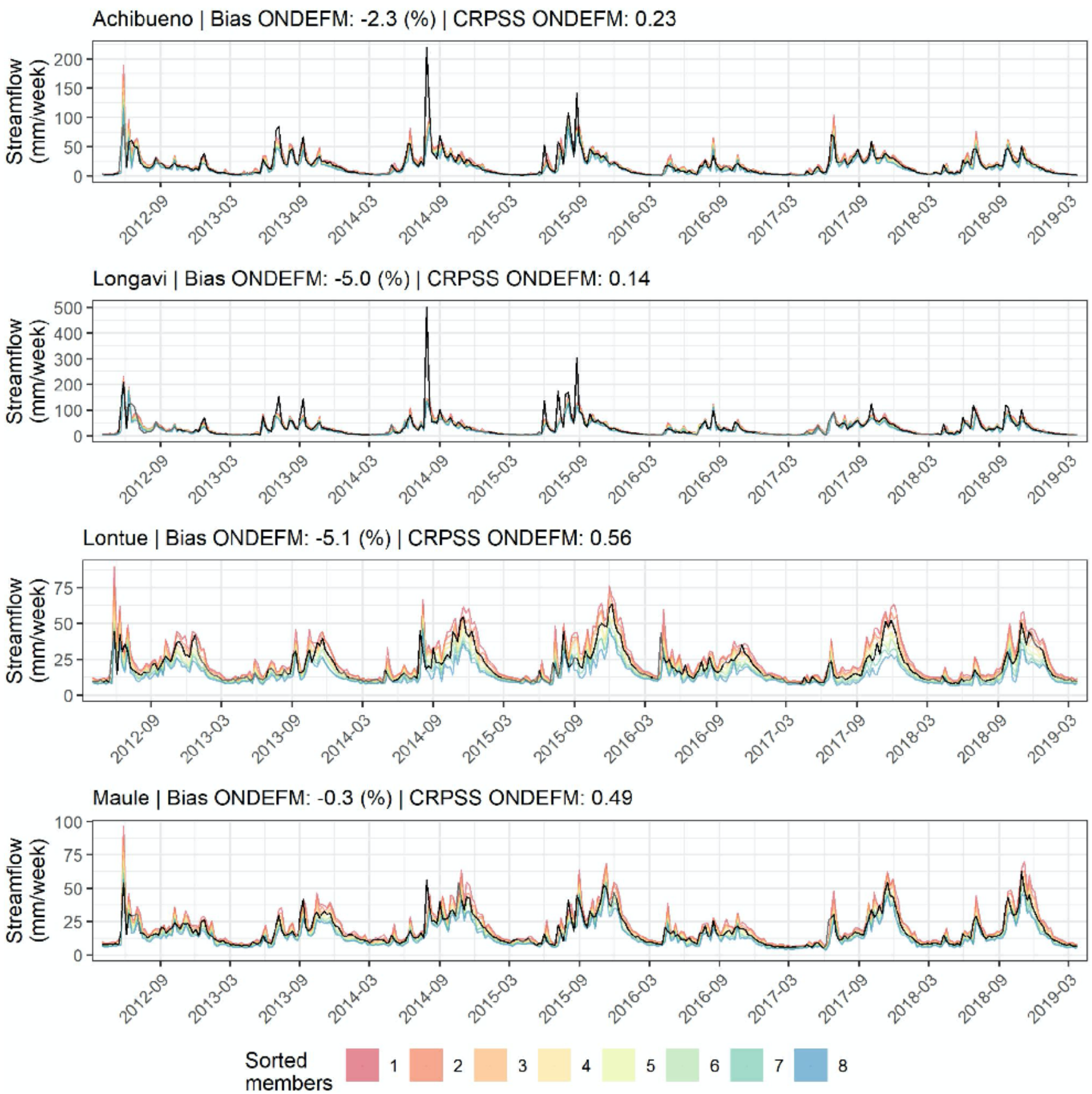


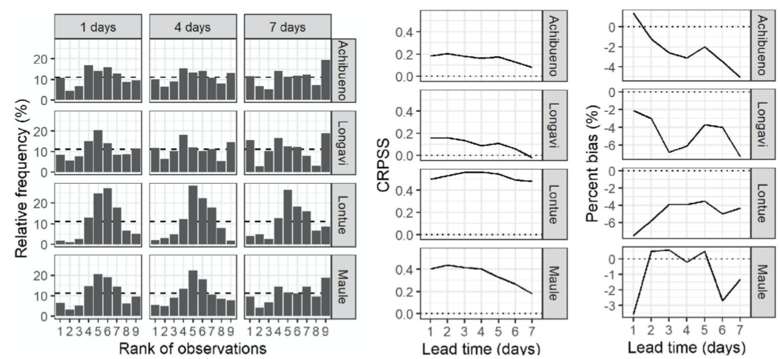


Is it possible to issue earlier forecasts (mid-winter) with increased skill?





Ensemble weekly forecasts capture streamflow observations. Screening (preprocessing) reduces problem size and increases forecast skill.



Ongoing work

- “Assimilate” snow depth observations through screening of ensemble forecast members -> density simulation
- Testing climate forecast products for ESP
- Testing different hydrological model options

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THANKS!