An assessment of ensemble streamflow predictions in the semi-arid Andes Cordillera

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HS4.3/AS1.10/NH1.13

Background and Objectives

- Current operational water supply forecasting in Chile is solely based on regression-based methods that incorporate in-situ meteorological variables observed in winter as predictors.
- Official forecasts rely on a strong subjective criteria, based on the expertise of a few National Water Bureau forecasters.
- The strong dependence of streamflow on snowmelt suggests that forecast skill could be enhanced by explicitly incorporating hydrologic predictability.
- **The experiment described in this poster aims to assess the potential of the ensemble streamflow prediction (ESP) methodology to improve seasonal forecasts in high mountain basins in Central Chile.**

Key questions

1. How well can the GR4J model simulate streamflow and catchment behavior in Chilean high-mountain basins?
2. How good is the ESP approach in this region for different forecast initializations?

Study domain

- Our test domain is the semi-arid Andes region, with basins that span a range of hydroclimate regimes (snow/rain dominance) and that are relevant for multi-objective water management purposes.
- We choose 10 high mountain basins located in Central Chile, distributed from the IV Region of Coquimbo to VI Region of O'Higgins.

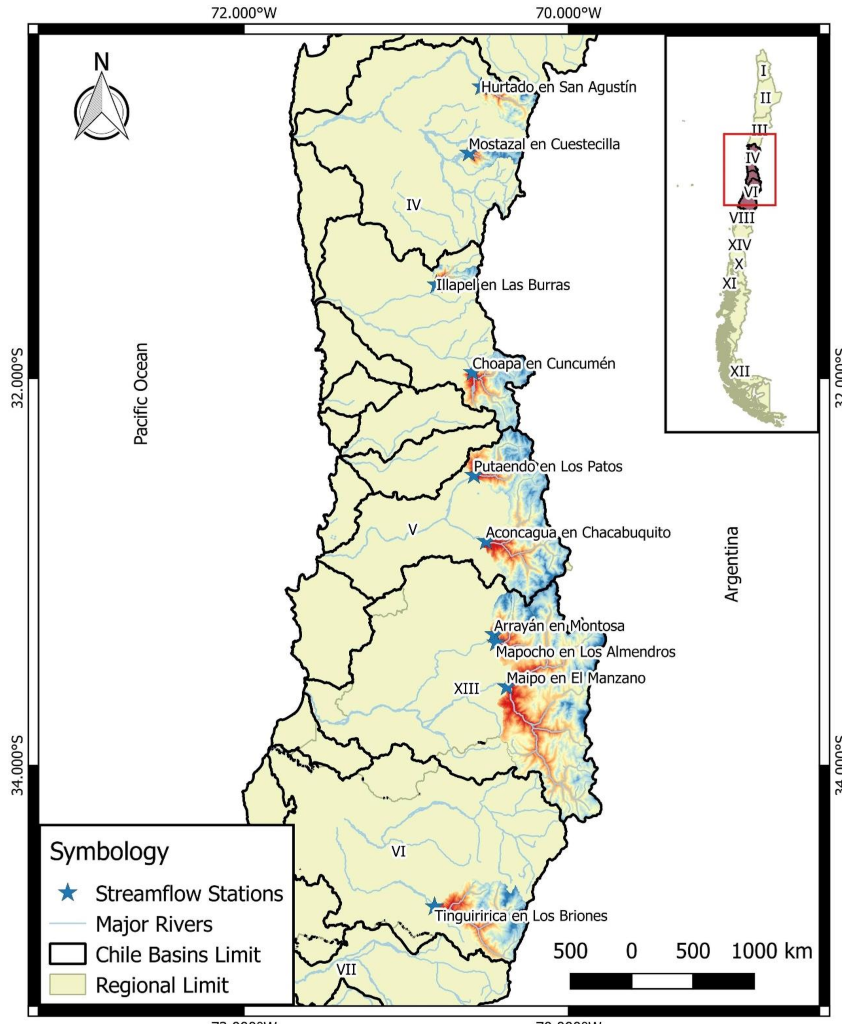

Figure 1. Case study basins

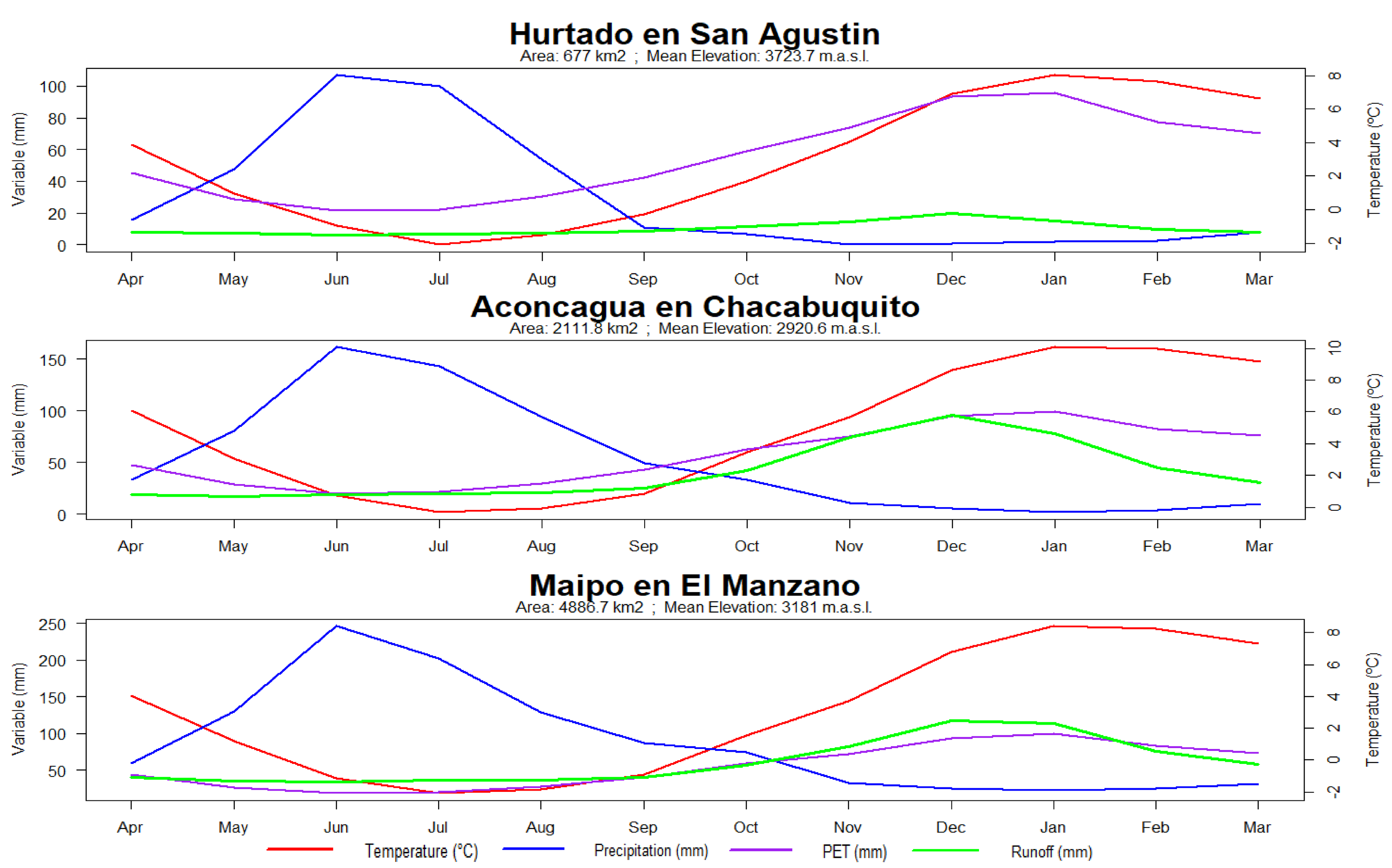

Figure 2. Seasonal cycles of basin-averaged hydroclimatic variables for representative basins in the study domain. The variables displayed are temperature, precipitation, potential evapotranspiration and runoff (period 1980-2016), obtained from the CAMELS-CL dataset.

Methodology

- We apply the ESP methodology using the **GR4J rainfall-runoff model** – as implemented in the airGR package – combined with the **snow accumulation and ablation model CemaNeige**. The model was forced with historical climate sequences to produce 35-member ensemble streamflow hindcast.

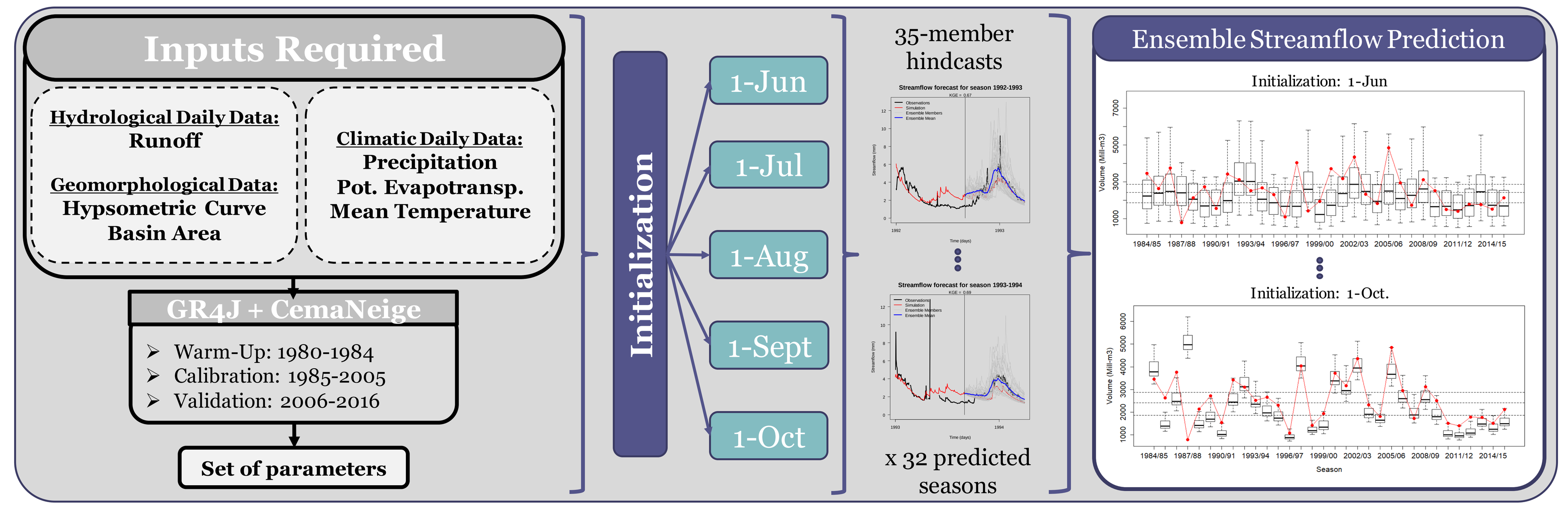

Figure 3. Schematic figure showing our experimental design.

Model Performance

- Efficiency criteria: KGE, NSE, log-KGE, log-NSE, correlation.
- Signature measures: %BiasRR, %BiasFMS, %BiasFHV

Forecast evaluation

- Deterministic scores: correlation, %Bias, RMSE.
- Probabilistic verification: continuous ranked probability skill score (CRPSS), reliability indices from QQ plots.

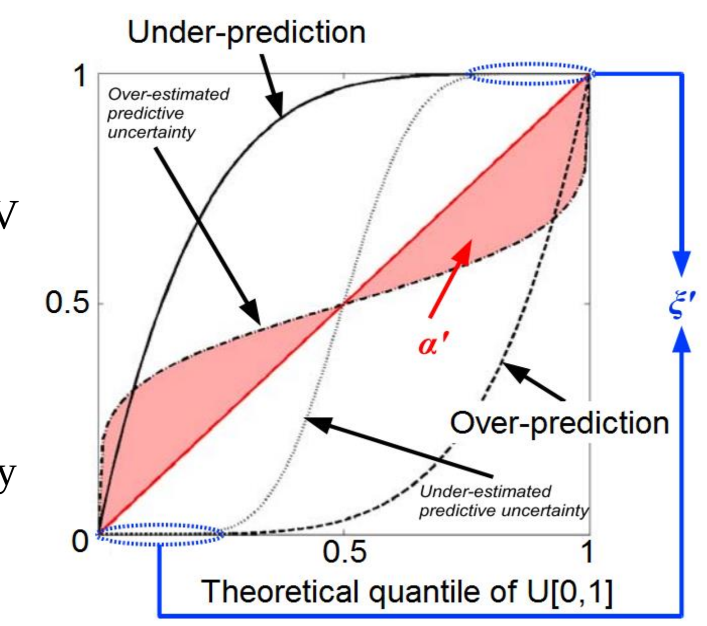

Figure 4. The predictive QQ plot (Renard et al. 2010)

Results

Can the model represent hydrologic behavior in each basin?

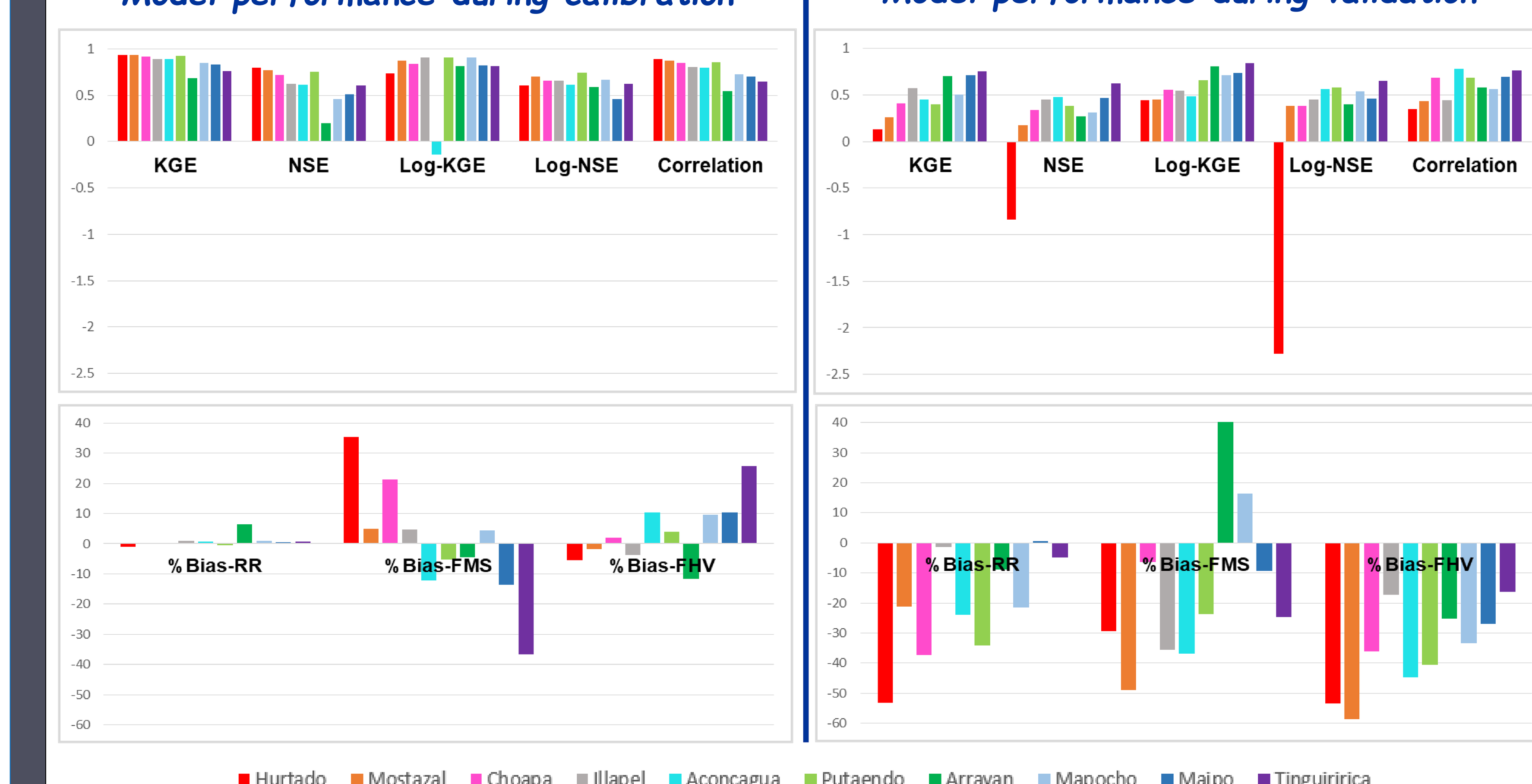

Figure 5. Model efficiency scores and biases in hydrological signature measures during calibration and validation periods.

Performance at various lead times

*CRPSS is computed with mean observed climatology (seasonal volume) as the reference

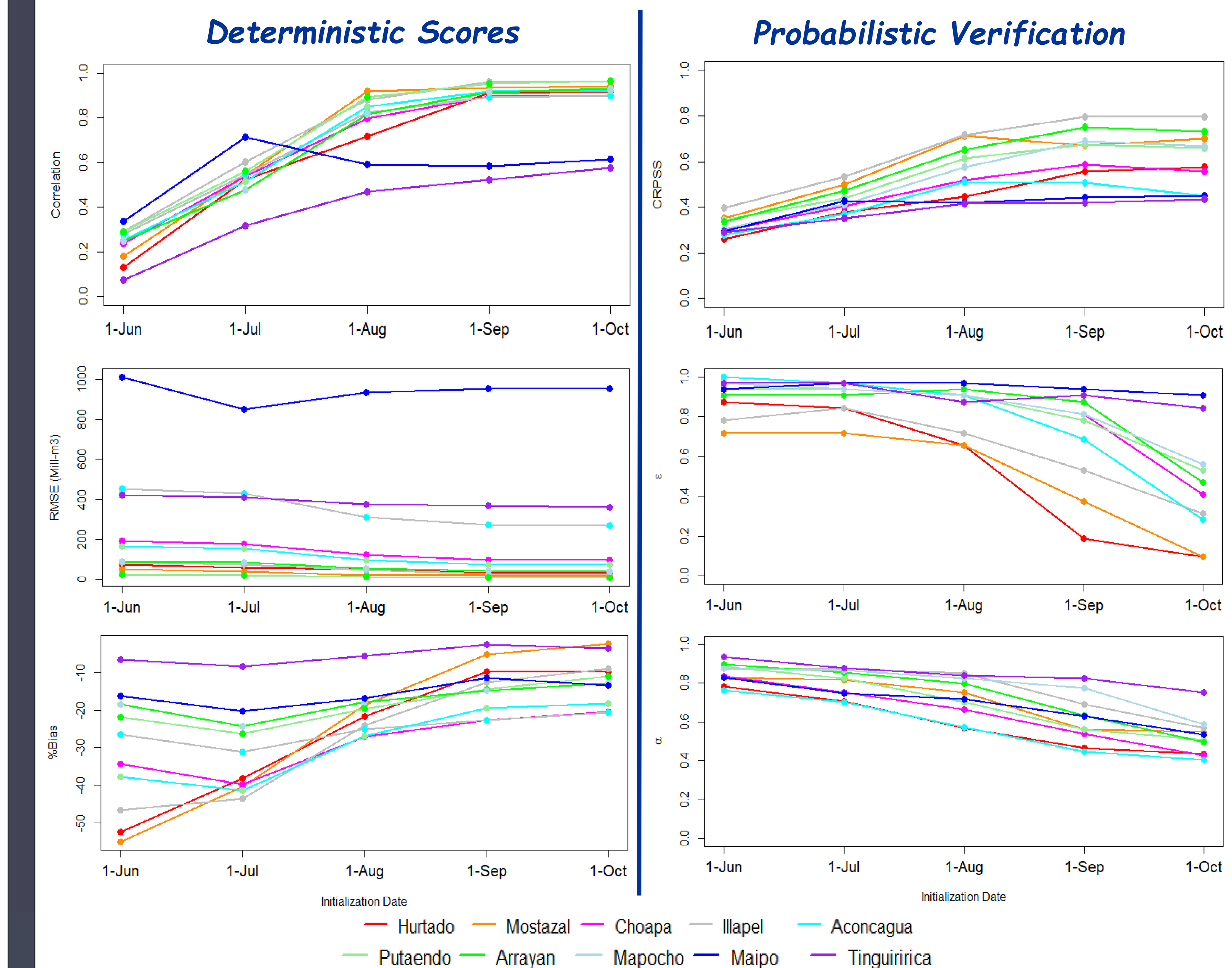

Figure 6. Deterministic and probabilistic verification metrics. Left side from top to bottom: correlation, root mean squared error (RMSE), % bias. Right side from top to bottom: continuous ranked probability skill score (CRPSS), and reliability indices $\alpha=1-2\alpha'$ and $\xi=1-\xi'$ (Figure 4) All metrics were computed for September-March runoff volume forecasts.

- Overall, forecast performance is better as we approach to the beginning of the melting season, in agreement with ESP results reported for similar hydroclimatic regimes worldwide.
- CRPSS results show that probabilistic forecast errors decrease for later initializations.
- α-index and ε-index results indicate decreased reliability as we approach October 1.
- Detailed evaluation should be conducted for dry years, when large biases for flow duration curve were obtained (Fig. 5).

Summary and future work

- GR4J coupled with CemaNeige provided a generally good performance, and in most cases acceptable simulated catchment behavior.
- Forecast skill is strongly dependent on the amount of water stored in the catchment at the forecast initialization date.
- In general, these results provide **the foundation to develop hybrid techniques that leverage climatic and hydrologic predictability in Central Chile**.
- In this work, calibration was conducted using the local search algorithm implemented in the package airGR. Future improvements will include a global search algorithm (e.g., SCE-UA), and potentially multiple objective functions.

Acknowledgments and contact

- PM received financial support from Fondecyt grant Nº 3130079.
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