Historical and projected drought characteristics across different hydrological regimes in Central Chile

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EGU23-9349

Motivation

Drought is one of the main hydroclimatic hazards worldwide, affecting water availability, ecosystems and socioeconomic activities. Since 2010, Central Chile (30–38°S) has been experiencing a drought with unprecedented duration and severity (also known as the **Central Chile megadrought**), producing drastic reductions in river flows, snow cover in the Andes Cordillera, and reservoir levels. Nevertheless, there is limited understanding of how hydrological processes have been altered and whether such variations will persist during the 21st century. **In this study, we characterize the magnitude, frequency, and duration of meteorological, hydrological and agricultural drought events** under historical conditions and future climate scenarios (CMIP6) across different hydrological regimes in Central Chile.

Study Area and Data

We selected six basins across continental Chile with different hydrological regimes and climatic conditions, including semi-arid and Mediterranean (**Figure 1**). Hydrologic model simulations were forced with meteorological time series from CR2MET (Boisier et al., 2018) and ERA5-Land.

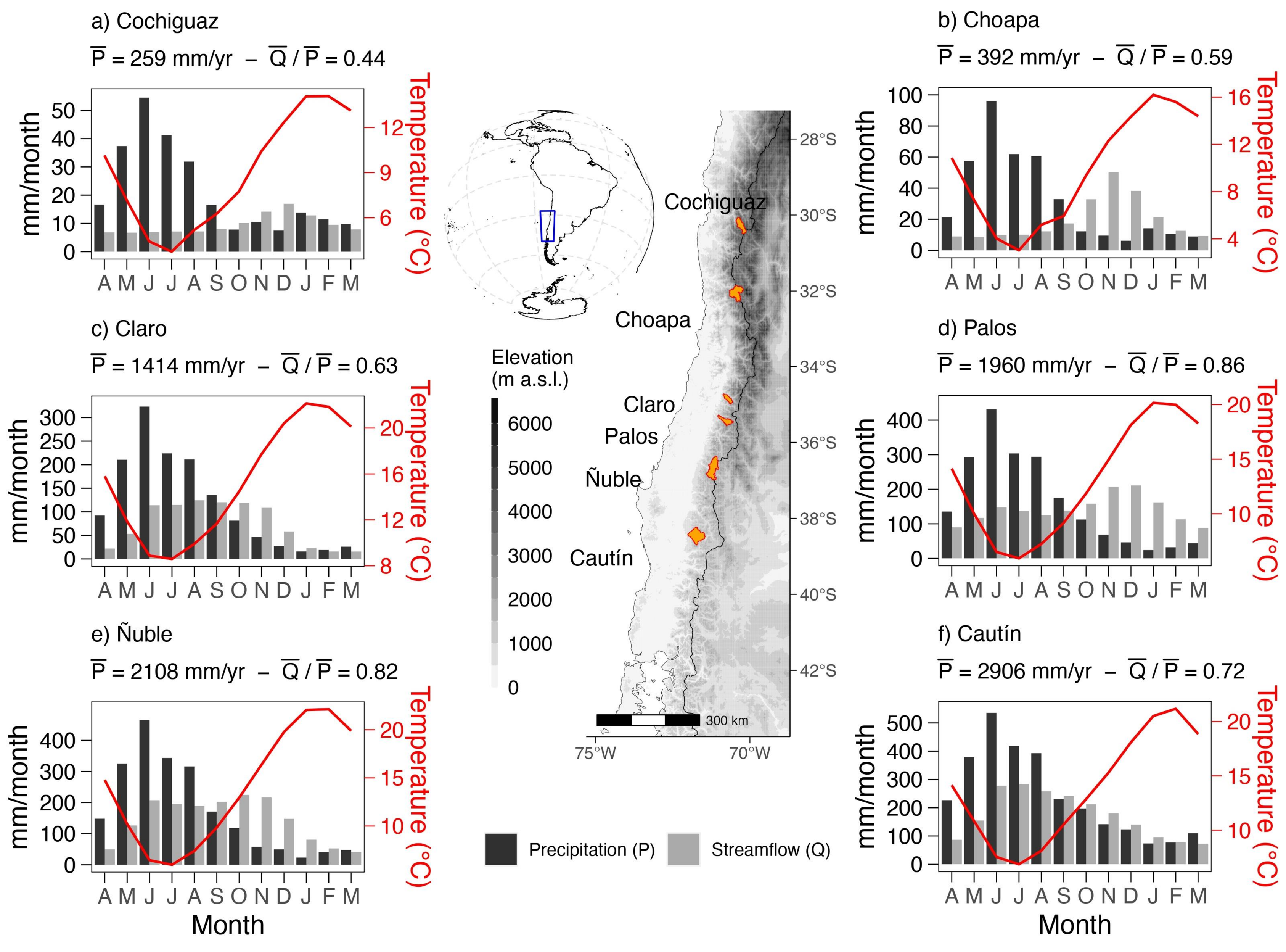

Figure 1: Location and hidroclimatology of the selected case study basins

Methodology

We run 3-hourly simulations with the Structure for Unifying Multiple Modeling Alternatives (SUMMA, Clark et al., 2015) hydrological model coupled with the mizuRoute (Mizukami et al., 2018) model for river routing. The parameters were calibrated using the DDS algorithm (Tolson and Shoemaker, 2007). We characterized drought events for historical and future climate scenarios obtained from bias corrected CMIP6 Global Climate Model output. Finally, we computed standardized indices for meteorological, agricultural and hydrological droughts.

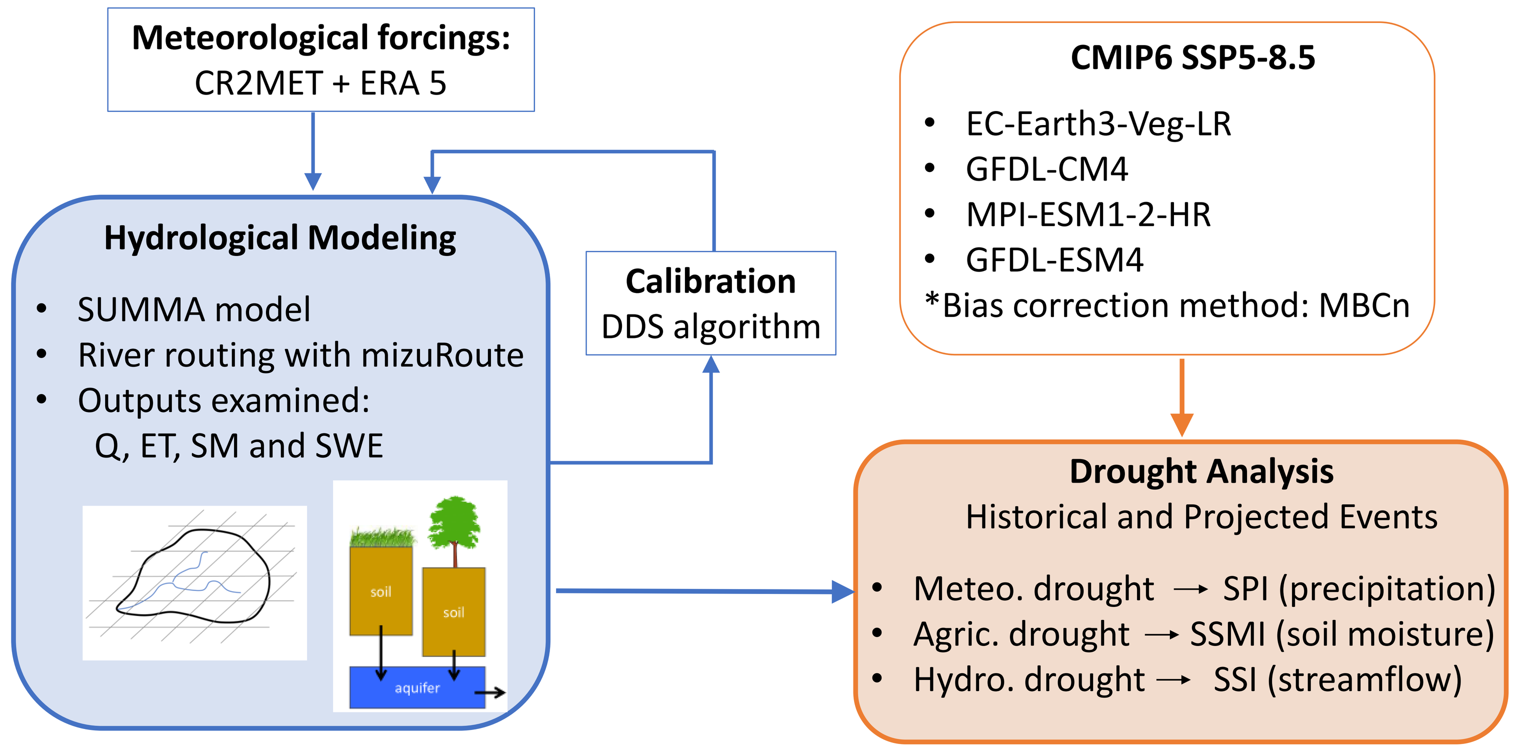

Figure 2: Scheme of the methodology used in the study

Results

Hydrological Model Calibration

We assess hydrologic model performance using several metrics. **Figure 3** shows a summary for the best set of parameters, along with a comparison of the seasonality of streamflows in the six basins.

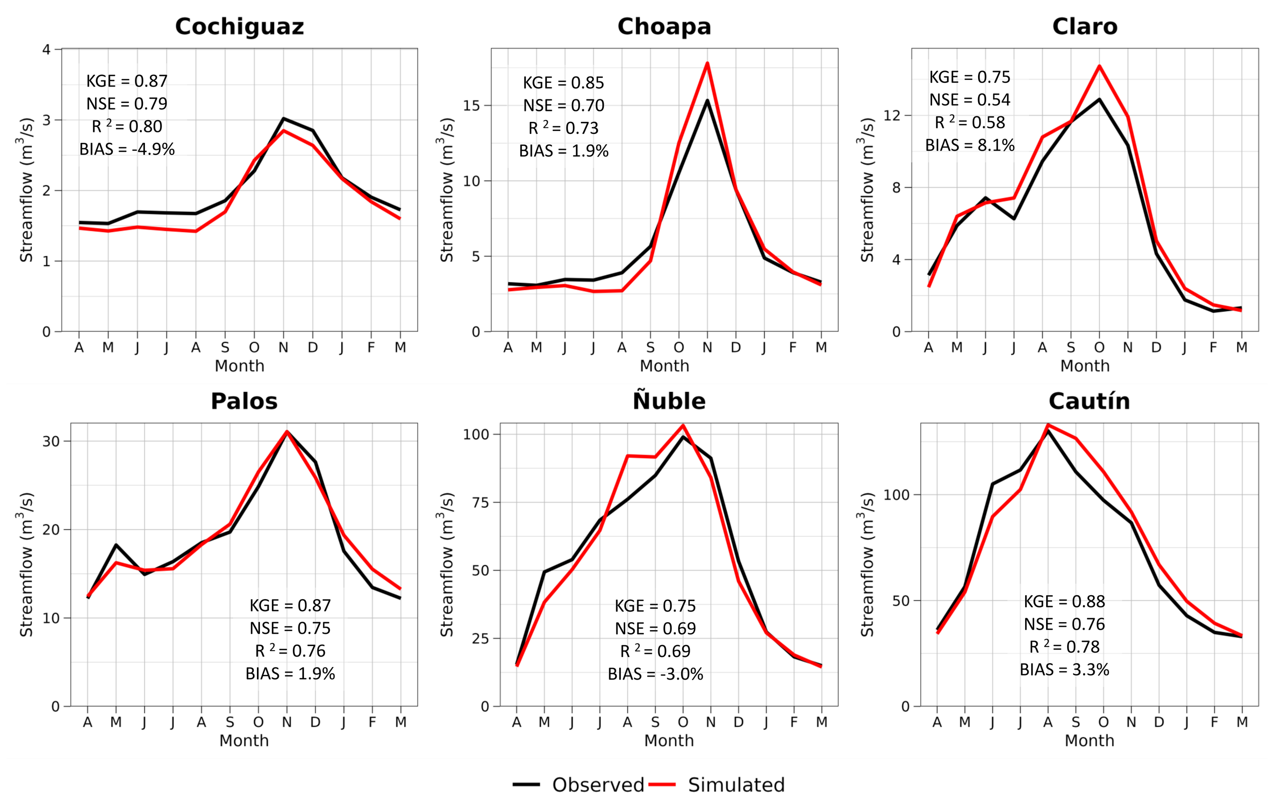

Figure 3: Summary of hydrologic model performance

Historical drought events

The standardized drought indices were computed with an aggregation time of six months. A drought event was detected when the value of the index was below -0.84 (20th percentile). **Figure 4** illustrates the approach for identifying different types of drought events in the Claro River basin, which has a Mediterranean climate and a mixed hydrological regime.

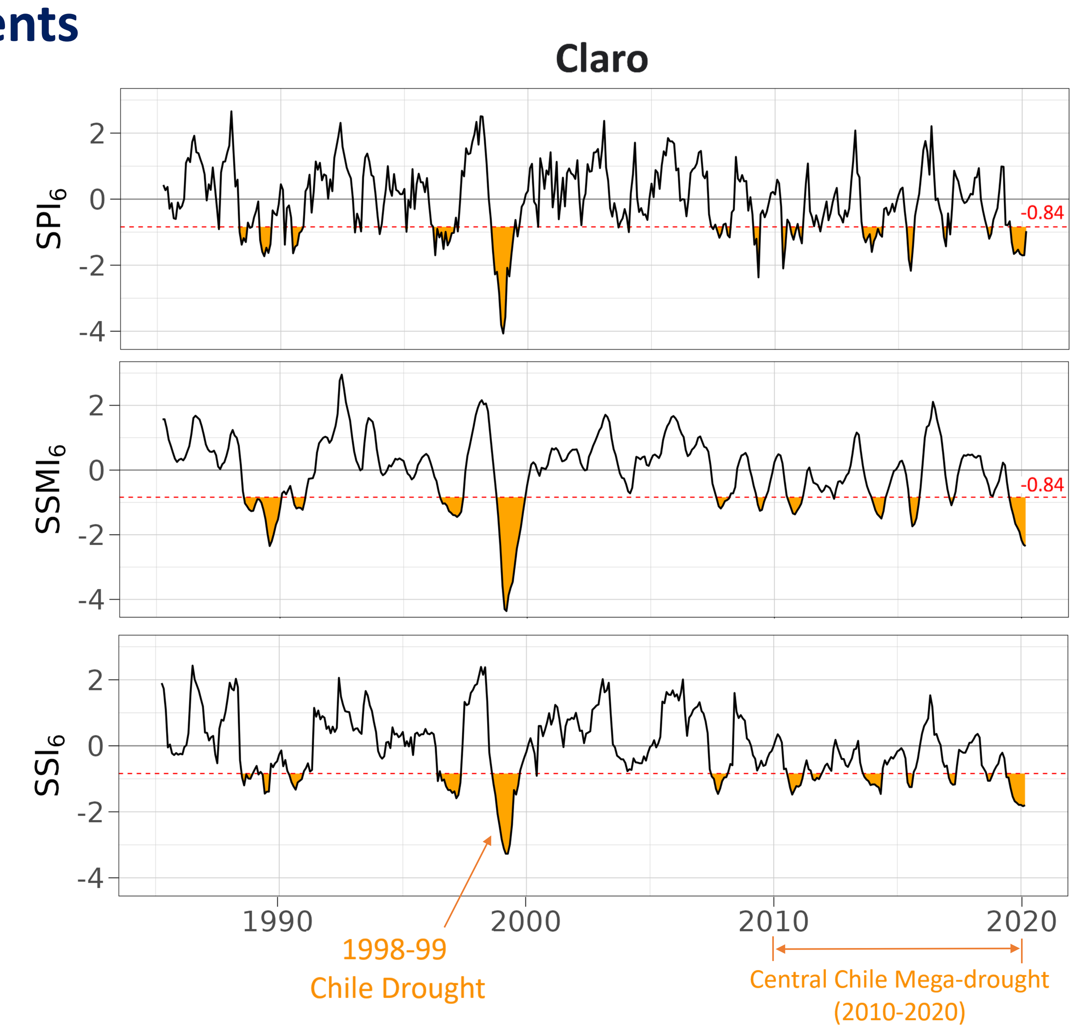

Figure 4: Historical drought events identification in Claro basin

Climate Change projections

We conducted climate change analyses for two future periods: 2040-2070 and 2070-2100 (**Figure 5**). In all basins, mean annual air temperature is expected to increase up to 4°C, while precipitation and streamflow might decrease between 10% and 50%. The sign of ET changes depends on the basin and period examined. **Figure 6** shows historical and future drought characteristics (frequency, duration and intensity). Although we project an increase in the frequency of meteorological droughts, mixed results are obtained for agricultural and hydrological droughts. On the other hand, the average duration and intensity of projected drought events (all types) is expected to increase over time.

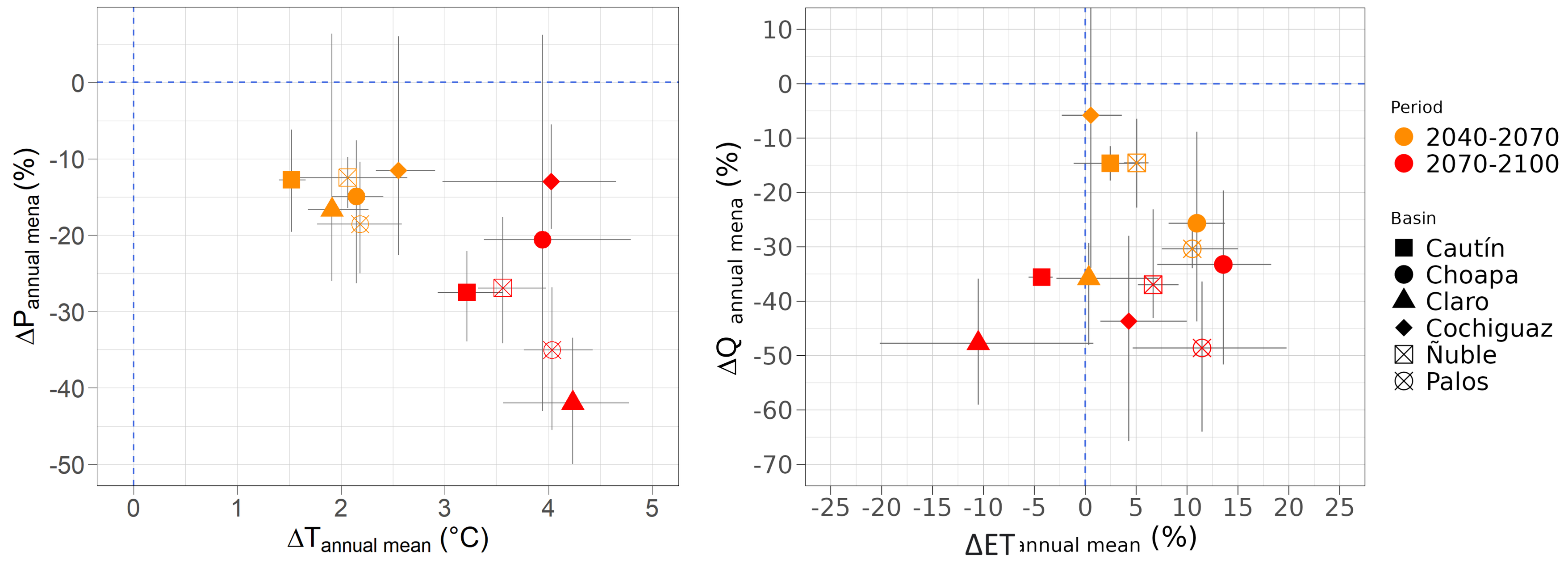

Figure 5: Changes in precipitation (P), temperature (T), streamflow (Q) and evapotranspiration (ET) projected by the bias corrected GCMs.

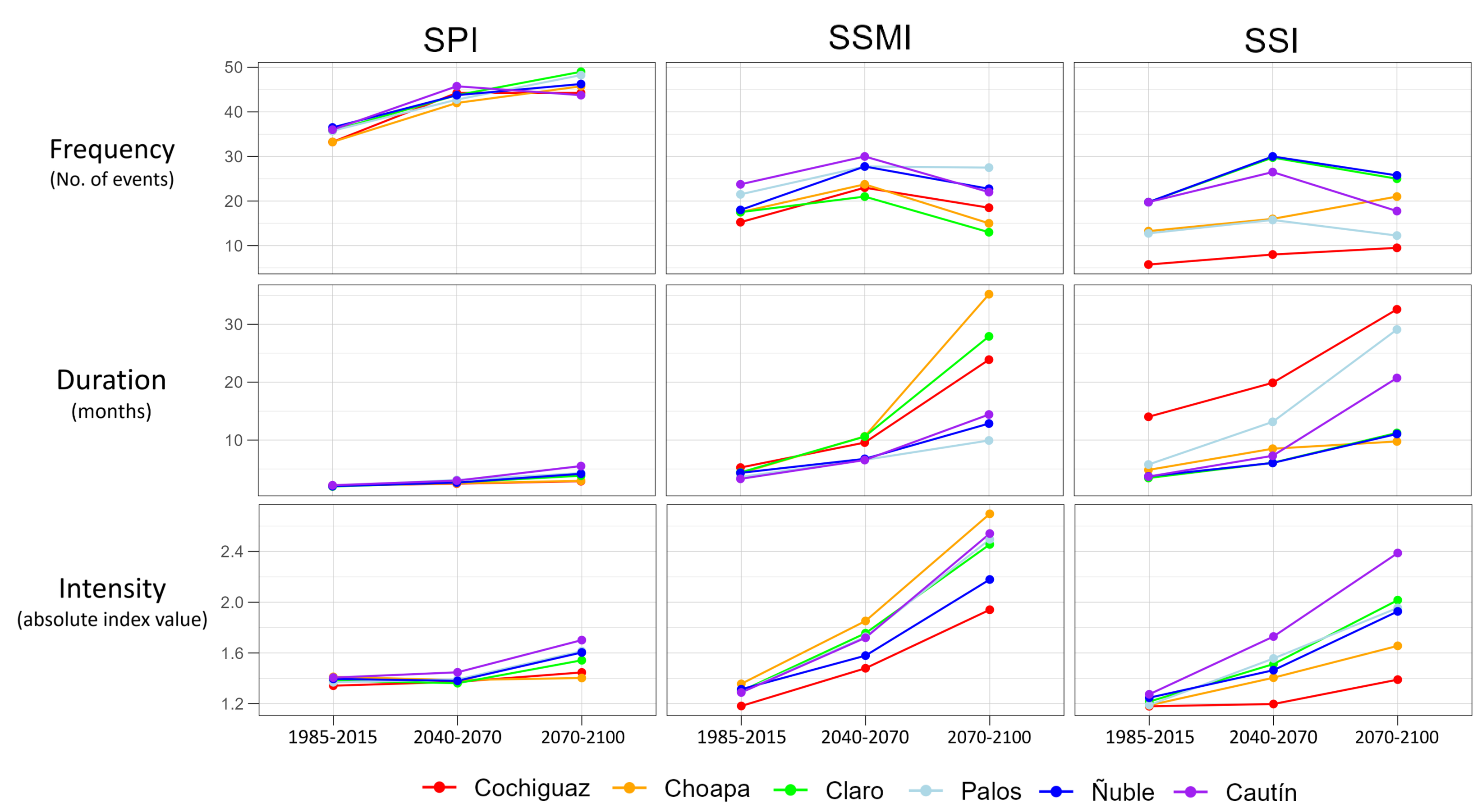

Figure 6: Historical and projected frequency, duration and intensity of drought events

Conclusions

- The hydrological modeling approach reproduced the seasonality in basins with different hydroclimatic regimes.
- Historical drought events, including Central Chile Megadrought (2010-2020), were detected through standardized drought indices.
- The projected hydroclimatic changes will impact each type of drought differently, with important variations in the characteristics of agricultural and hydrological droughts.

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Powered@NLHPC: This research was partially supported by the supercomputing infrastructure of the NLHPC (ECM-02). The authors also acknowledge the funding from the Fondecyt Project N° 11200142.