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El Niño-Southern Oscillation (ENSO) controls on mean streamflow and streamflow variability in Central Chile

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Understanding hydrological extremes is becoming increasingly important for future adaptation strategies to global warming. Hydrologic extremes affect food security, water resources, natural hazards, and play an important role in the context of erosional processes and landscape evolution. The Pacific region is strongly affected by large-scale climatic anomalies induced by the El Niño-Southern Oscillation (ENSO). How these climatic anomalies translate into hydrological extremes is complex, because both temperature and precipitation deviate from normal conditions and the effect of this simultaneous change on hydrological processes in river catchments (e.g., snowmelt, evapotranspiration) is challenging to understand.

In this study, we investigate the effect of ENSO on mean precipitation, mean temperature, mean stream flow, and streamflow variability in Chile. We have applied extensive quality control on a large hydrological dataset from the Dirección General de Aguas in Chile, resulting in ~200 good quality streamflow stations. The dataset envelopes the extent from semi-arid climate in the north (~28°S) to humid climate in the south (~42°S). Additionally, the dataset includes low elevation catchments located in the Coastal Cordillera and high elevation catchments in the Andes. We used the monthly Multivariate ENSO Index (MEI) to classify the 5 strongest El Niño and La Niña years, and 5 non-ENSO years after 1975. Changes in mean streamflow and streamflow variability were calculated based on the monitored data from the streamflow stations. For each river catchment, we calculated mean seasonal precipitation using the 0.25°-resolution gridded dataset from the Global Precipitation Climatology Centre (GPCC) and mean seasonal temperature using the 0.5°-resolution global temperature dataset from the Climatology Prediction Centre (CPC).

The precipitation, temperature, and discharge patterns show seasonal variation, varying in strength over the north-south gradient and between low and high elevation catchments. Mean annual precipitation generally increases significantly during El Niño events, and slightly decreases during La Niña events. For both El Niño and La Niña events the mean temperature predominantly changes between 28°S and 35°S and shows increasing temperatures in the Andes and decreasing temperatures in the low elevation Coastal Cordillera. The mean annual streamflow increases during El Niño events, and shows similarities to the pattern of increased mean annual precipitation. However, at the seasonal level, there is a time-lag between precipitation and streamflow, which is regulated by slower snowmelt processes. During La Niña events, the mean annual streamflow increases in the north (28°S-34°S) and decreases in the south (34°S-42°S). Interestingly, the mean annual precipitation and mean annual streamflow patterns behave inversely in the northern Andes. Mean streamflow increases, whereas mean precipitation decreases. This possibly results from enhanced snowmelt because of increased temperatures, but this needs to be further investigated. Finally, the magnitude and frequency of extreme floods predominantly increases in the northern Andean catchments and decreases towards the south for both El Niño and La Niña events. This study shows that large-scale climatic phenomena like ENSO affect catchment hydrology through both anomalies in precipitation and temperature.