Hydrological response to meteorological drought: a case study in La Plata Basin

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Summary

The quantitative knowledge of the properties of droughts in a region is an important aspect of the planning and management of water resources. This work analyzes the relationship between meteorological droughts and hydrological droughts for a specific location over Uruguay River, belonging to La Plata Basin (LPB), one of the largest basins in the world. The basin generates around 70% of the Gross National Product of Argentina, Brazil, Paraguay and Uruguay, and has a population of over 100 million inhabitants. The LPB is also one of the major producers of hydroelectric power in the world, therefore, extreme low flows are critical for hydroelectric production and water resources management in the region.

Database and methodology

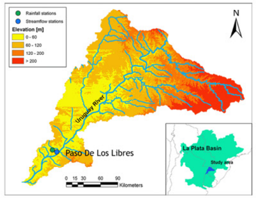

Figure 1. Location and relief of the study area

Streamflow data are subjected to human interference, which can result in errors for low flow conditions. Therefore, we selected an unregulated station to ensure an unbiased analysis. Daily precipitation and streamflow data from Paso de los Libres station (Figure 1) for the period 1961-2007 were used in this study. The **Standardized Precipitation Index (SPI)** (McKee et al., 1993), which is the most widely used drought index, is used to characterize meteorological droughts at different time scales. In order to define the streamflow drought events in the region, we used the **Q70 threshold**, the flow which is equaled or exceeded for 70% of the time (Hisdal et al., 2001).

Since the Q70 is a daily index, we consider the monthly averaged differences between the streamflow Q and the Q70 threshold. This deficit volume was compared with the SPI at different time scales considering **two approaches**: for the whole time series, considering all the months as a continuum, and seasonally, considering the Southern Hemisphere seasons. For comparison we used the Pearson correlation coefficient.

B - Comparison between precipitation and streamflow deficits

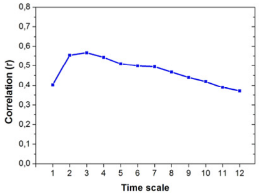

Figure 5. Correlation between Q-Q70 monthly averages and the SPI at different time scales.

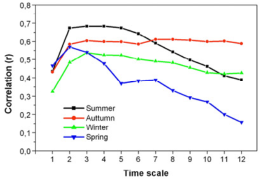

Figure 6. Correlation between Q-Q70 monthly averages for the Southern Hemisphere seasons and the SPI at different time scales.

i- Annual approach

Higher correlations have been obtained with the SPI on shorter time scales (2-4 months) (Figure 5). The maximum correlation is found on the time scale of 3 months -SPI3- (r = 0.56)

This indicate that river discharges are more determined by precipitation of the current month and the previous two months than considering wider periods.

ii- Seasonal approach

- ✓ The highest correlations between SPI values and the deficit volumes were obtained in **summer** (Figure 6), which is the low flow season, for the time scales of 2 to 5 months.
- ✓ During **autumn** the evolution of a drought from precipitation to streamflow better responds to longer time scales.
- ✓ The behaviour during **winter** is similar to the findings for the annual approach.
- ✓ In the **spring** months we find the lowest correlations between SPI and Q-Q70 values for time scales longer than 3 months.

iii- Comparison during the drought of 1962/63

We made a comparison of the two time series for the historical drought episode of 1962/63, which is the extreme drought event on record considering both SPI6 and SPI12 (Figure 2).

The general behaviour of these indices are similar for the illustrated drought event (Figure 7), demonstrating their viability for studying time scales of various droughts and their interdependences. The dry year of 1981 shows a similar behaviour, but during 2006 the maximum deficiencies were found during autumn season. This shows that extreme events do not usually behave in the same way and the synergy between them must be assessed separately.

Results

A - Drought evolution in middle part of the Uruguay River

i- Meteorological drought

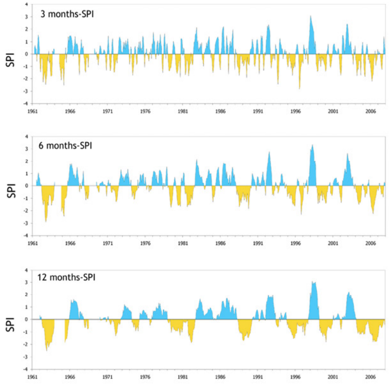

Figure 2. Evolution of the SPI at different time scales

The analysis of the 3-month SPI and 6-month SPI time series for the period 1961-2007 indicates that the record minimum SPI was observed in July 1996 and October 1962 respectively.

As the time period is lengthened to 6 and 12 months, the SPI responds more slowly to changes in precipitation.

The 12-month SPI time series indicated that six main dry periods were revealed. The first period occurred between 1962 and 1966 and it was the extreme drought on record. The last period occurred during 2004-2006 and is characterized by the longest dry event.

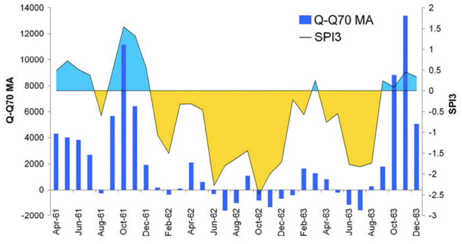

Figure 7. Graphical comparison of SPI3 and the deficit volume (Q-Q70 monthly averages) during the 1962/63 extreme drought episode.

ii- Streamflow deficiency

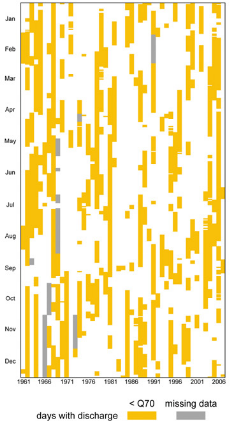

Figure 3. Streamflow deficiency periods below the varying threshold level Q70

Low flows generally occur every time of the year (Figure 3). The driest years were 1962, 1964, 1968, 1981 and 2006, with more than 200 non-consecutive days with Q<Q70 (Figure 4).

The streamflow deficiency during 2006, with 209 dry days, caused the lowest amount of energy generated at Salto Grande Dam, located downstream of Paso de los Libres station.

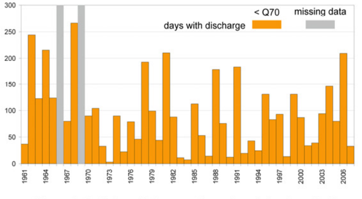

Figure 4. Evolution of the annual cumulated duration of all drought events (days)

Discussion

In general, different studies indicate that there is a considerable time lag between departures of precipitation and the point at which these deficiencies become evident in surface components of the hydrologic system. Our findings prove that the surface runoff respond to short SPI time scales (2-4 months). The maximum correlation is found on the time scale of 3 months (SPI3). The seasonal comparison shows that the highest correlations were obtained in summer, which is the low flow season. These results could be useful for forecasting and monitoring hydrological drought severity and in developing a drought preparedness plan in the region.

Acknowledgments

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References

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