WCRP Open Science Conference:
Climate Research in Service to Society
24-28 October 2011, Denver, Colorado, USA.
Session C39 - Poster TH93B

Comparison of the performance of five indices for drought characterization in La Plata Basin. Perspectives towards a multi-scale monitoring system

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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. There are numerous natural drought indicators that should be monitored routinely to determine the onset and end of drought and its spatial characteristics.This work compares the performance of five indices for drought monitoring in the La Plata Basin (LPB) region, one of the largest basins in the world. The indices used include the Standardized Precipitation Index (SPI), the Deciles Index (DI), the Effective Drought Index (EDI), the Percentage of Normal Precipitation (PRCT) and the Lack of Rain Index (LORI). The SPI is likely the best choice for detecting the onset of drought and its spatial and temporal variation in LPB.

Datasets and methods

Five drought indices have been selected for this study. They include the **Standardized Precipitation Index** (SPI) (McKee et al., 1993), the **Deciles Index** (DI) (Gibbs and Maher, 1967), the **Effective Drought Index** (EDI) (Byun and Wilhite, 1999), the **Percentage of Normal Precipitation** (PRCT) (Lyon et al., 2009) and the **Lack of Rain Index** (LORI) (Rivera and Penalba, 2009). These drought indices have been used to quantify deficits in water resources and as a drought monitoring tool in several regions of the world. A common feature of the indices selected is that they all are calculated using precipitation data only.

Monthly rainfall data were obtained from the CLARIS LPB Data Base for 68 of its stations, which were subjected to quality control procedures and have less than 10% of missing values. We used a common comparison period of 48 years (1961-2008). The comparison was performed for the time scales of 3 and 12 months, in order to have a broad approach of the different precipitation shortages.

The **assessment criteria** to determine the most appropriate index for monitoring droughts include their *characteristics, statistical properties and variability*, their *interpretability*, a *detailed spatial and temporal analysis of the major historical droughts*, and their *flexibility in the time scale*, among others.

Although the comparison was performed in 5 locations in LPB, we only show the results of Ceres station.

Study area

The La Plata Basin (LPB) is 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, droughts are critical for hydroelectric production and water resources management in the region. The economic wealth of LPB strongly depends also on agriculture, which set a major challenge: the increase in the prediction capacity of the impacts of drought for stakeholders.

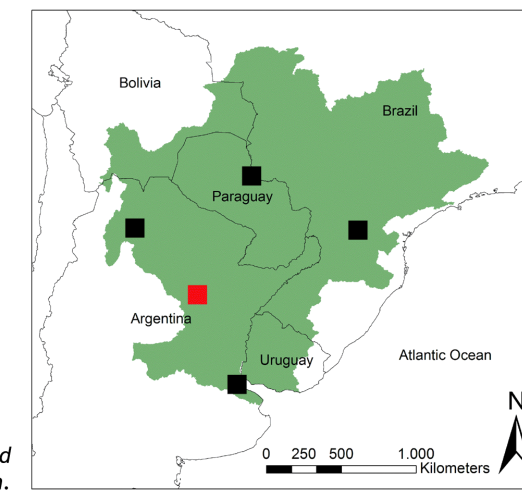

Figure 1*. La Plata Basin and the locations of the stations used for the comparison. The red dot correspond to Ceres station.*

Results

i. Comparison in 3-months time scale

Linear regressions between the values of the indices indicated that the SPI, the EDI and the PRCT have a good relationship. LORI showed a lack of strong relationships with the other indices.

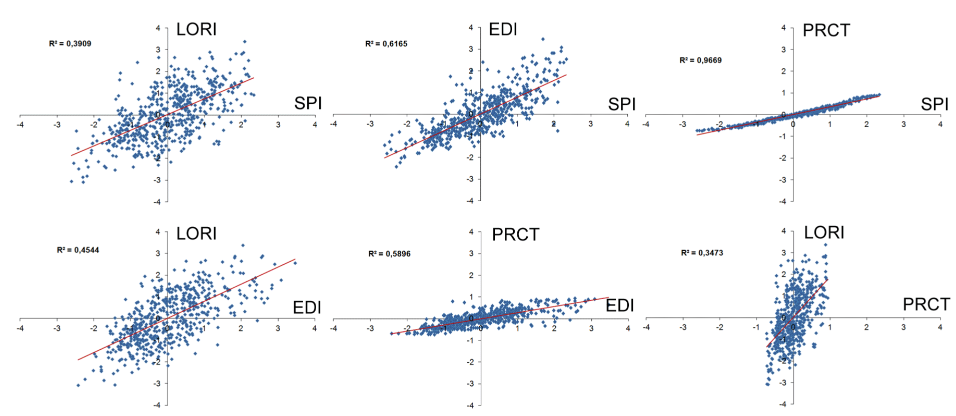

Figure 2*. Scatter diagrams of the SPI, EDI, LORI and PRCT for Ceres station (1961-2008).*

Although several differences, the behavior of the indices during the 1961-2008 period is similar. LORI tends to overestimate the extreme dry and wet events. The histograms of SPI and EDI showed a Normal distribution shape. One of the major historical droughts in the basin were recorded during 1988-1989 and was analyzed in detail in both time scales.

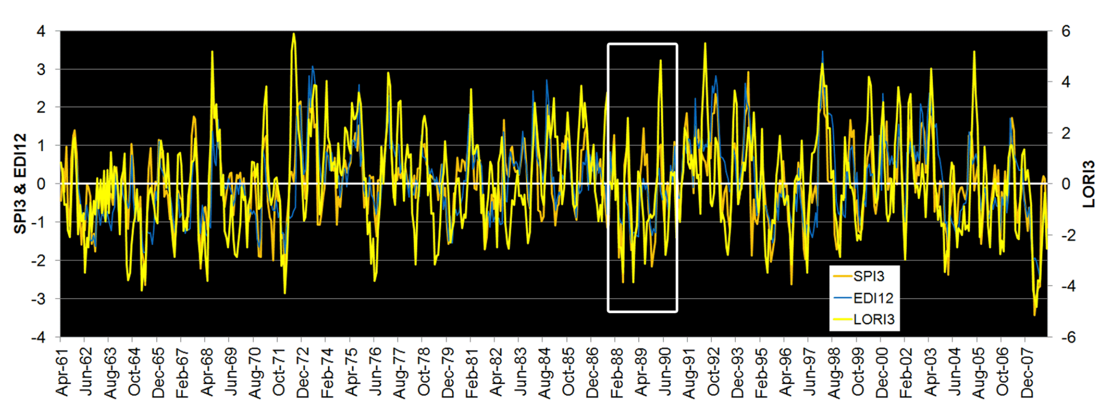

Figure 3*. Comparison between the time series of the SPI3, EDI12 and LORI3 in Ceres station.*

A categorization of the indices was made according to the works of McKee *et al.* (1993) (SPI); Kim *et al.* (2009) (EDI) and Morid *et al.* (2006) (DI). LORI and PRCT were multiplied by a factor scale in order to have values comparable to those of the SPI and EDI.

Values	Class	SPI	EDI	DI (%)	LORI*	PRCT*
3	Extremely wet	≥ 2	≥ 2	≥ 90	≥ 2	≥ 2
2	Severely wet	1,5 to 1,99	1,5 to 1,99	80 to 90	1,5 to 1,99	1,5 to 1,99
1	Moderately wet	1,0 to 1,49	1,0 to 1,49	70 to 80	1,0 to 1,49	1,0 to 1,49
0	Normal	-0,99 to 0,99	-0,99 to 0,99	30 to 70	-0,99 to 0,99	-0,99 to 0,99
-1	Moderately dry	-1,0 to -1,49	-1,0 to -1,49	20 to 30	-1,0 to -1,49	-1,0 to -1,49
-2	Severely dry	-1,5 to -1,99	-1,5 to -1,99	10 to 20	-1,5 to -1,99	-1,5 to -1,99
-3	Extremely dry	≤ -2	≤ -2	≤ 10	≤ -2	≤ -2

Figure 4*. Categorization of SPI, EDI, DI, LORI and PRCT values into classes.*

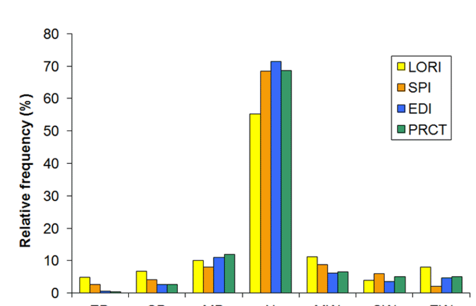

Figure 5*. Histograms of the drought frequency classes of the LORI3, SPI3, EDI12 and PRCT3 for Ceres station.*

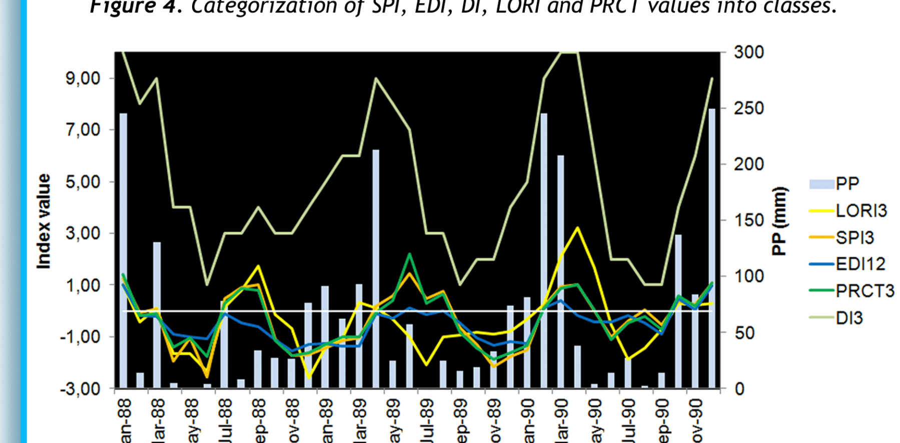

Figure 6*. A comparison between monthly precipitation, LORI3, SPI3, EDI12, PRCT3 and DI3 during the 1988-1989 drought in Ceres station*

Three dry pulse were evident during the drought period of 1988-1989 in the SPI3, EDI12, LORI3 and PRCT3, while DI3 showed two peaks of extreme dry conditions. The low precipitation amounts recorded during spring of 1988 were reflected in the values of the SPI3, PRCT3, EDI12 and LORI3, but DI3 showed near normal conditions. The spatial pattern of the last dry peak (Aug-89 to Feb-90) was analyzed by the SPI3 and DI3 (Figure 7 and 8).

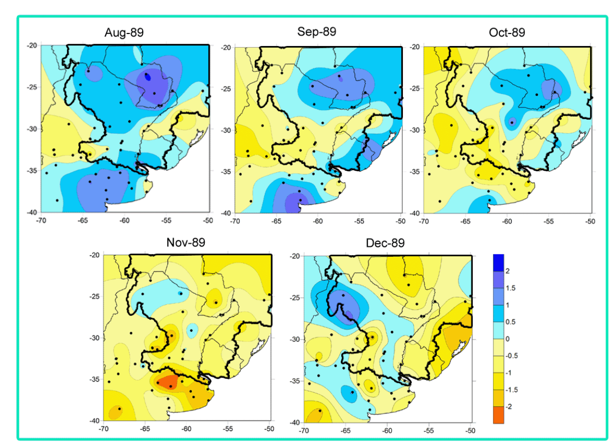

Figure 7*. Spatial pattern of SPI3 during the 1988-1989 drought.*

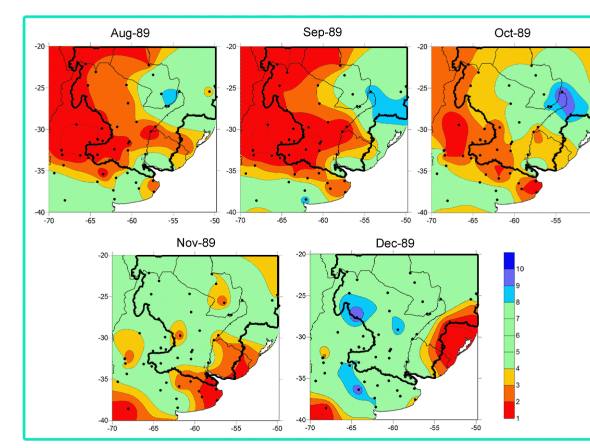

Figure 8*. Same as Figure 7 for DI3.*

The spatial pattern of the 1988-1989 drought shows moderately dry conditions for SPI3, although some locations recorded severe and extreme dry conditions. Deciles shows a lack of spatial detail, with an overestimation of dry locations and a subestimation of wet locations.

ii. Comparison in 12-months time scale

As the time period is lengthened to 12 months, all the indices respond more slowly to changes in precipitation. It is apparent that EDI12 tends to be skewed towards wet conditions.

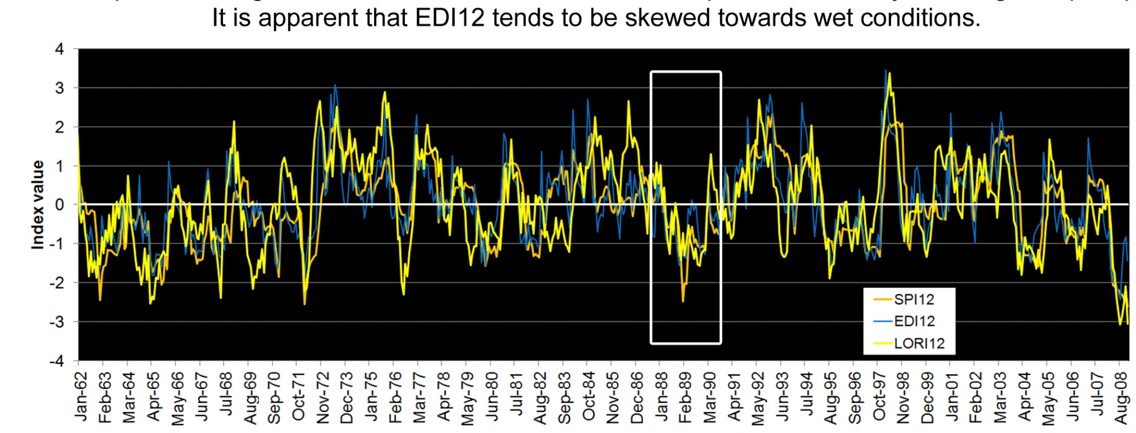

Figure 9*. Time series of the SPI12, EDI12 and LORI12 in Ceres station.*

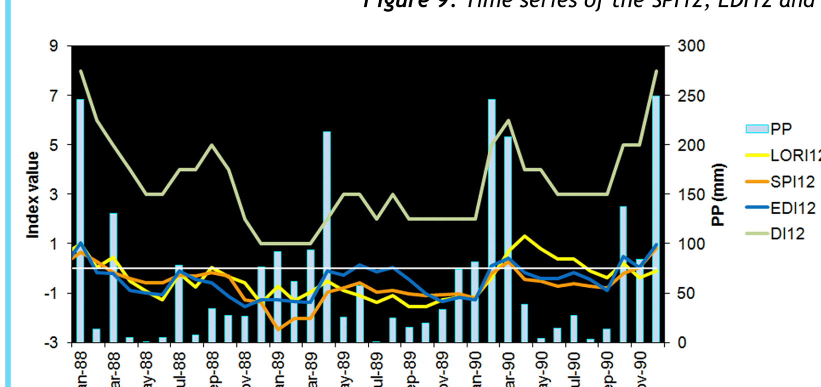

Figure 10*. Same as Figure 6, for monthly precipitation, LORI12, SPI12, EDI12 and DI12.*

All the indices showed a similar behavior, but SPI12 and DI12 indicated extreme dry conditions during the beggining of 1989, while LORI12 and EDI12 minimized the severity of the drought.

During January 1989, in Ceres station was recorded one of the lowest 12-months precipitation amount. This is in agreement with the extreme value of SPI12. EDI12 reacted rapidly as precipitation increased. The spatial pattern of SPI12 shows a generalized extreme drought, in concordance with works which analized the event.

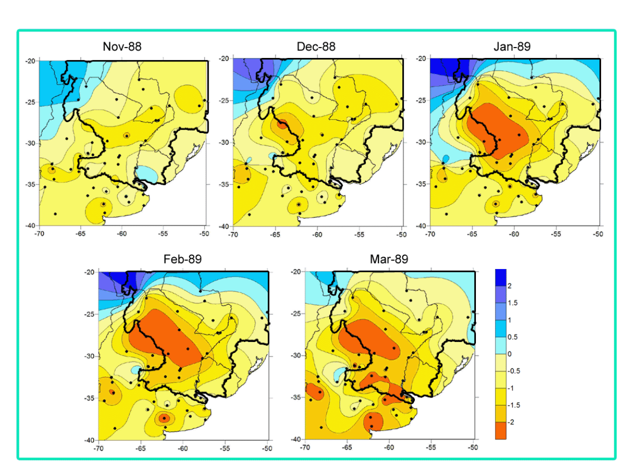

Figure 11*. Same as Figure 7 for SPI12.*

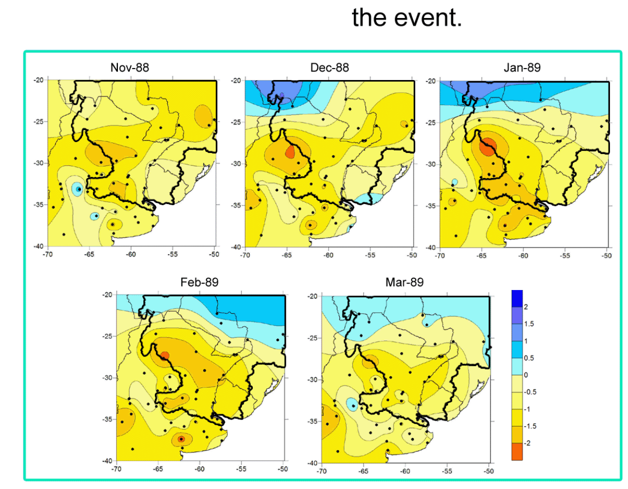

Figure 12*. Same as Figure 7 for EDI12.*

Discussion

The SPI, which is the most widely used drought index, is likely the best choice for detecting the onset of drought and its spatial and temporal variation in LPB, bacause it can be computed at any time scale, is easy to interpret and showed a good behavior in the analysis of temporal and spatial variations of drought. The responses of the different indices point to the need of using several indices for drought monitoring in the study area. Besides the time scales evaluated, we suggest that the monitoring should be performed over a broad time scales, which allows the effects of precipitation deficits on different water resource components to be assessed.

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Acknowledgments

The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under Grant Agreement N° 212492 (CLARIS LPB. A Europe-South America Network for Climate Change Assessment and Impact Studies in La Plata Basin); CONICET PIP 11220100100227 and UBA 20020100100789 grants.