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Impacts of multi-decadal precipitation variability in the humid and sub-humid regions of Argentina

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Summary

- Climate variability on multiple scales has a large impact on the humid and sub-humid regions of Argentina.
- We characterized multi-decadal precipitation changes in this region over the last 100 years (1911-2011).
- We used the state-of-the-art Ensemble Empirical Mode Decomposition (EEMD) to partition rainfall time series into different frequency and amplitude components.

Motivation

The humid portion of central-eastern Argentina is among the main cereal and oilseed production regions in the world. This region is home to a large proportion of Argentina's population and includes major hydroelectric plants that supply energy to Argentina and neighboring countries. For these reasons, the region is highly vulnerable to climate variability and change.

On seasonal to interannual scales, the region shows marked links between the El Niño-Southern Oscillation (ENSO) phenomenon and precipitation in spring/summer, a critical period for important summer crops (maize, soybean).

In addition to the interannual signal, this region also has shown pronounced low-frequency variability in rainfall that contributed to regional land use changes of an unprecedented rate and scale. A thorough analysis of observed decadal-scale variability in the region's rainfall regime is needed, especially in light of forthcoming multi-year predictions and societal concerns about a return to drier conditions.

Data and methods

We analyzed monthly precipitation data from 28 meteorological stations operated by Argentina's Meteorological Service. The data encompass the period 1911-2011. Analyzed meteorological stations region were first clustered into six sub-regions, within which rainfall seasonal patterns and annual totals were relatively similar (Figure 1).

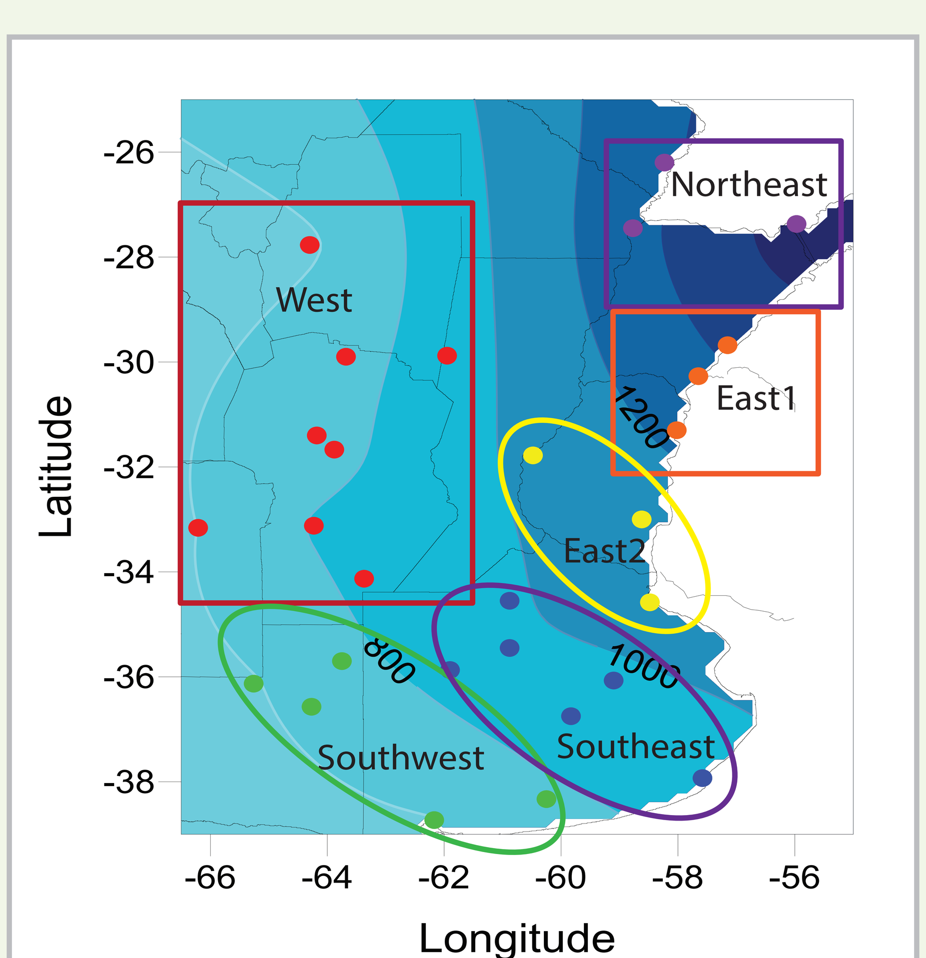

Fig. 1: Annual rainfall isolines (in mm); 1911/2010. Colored points indicate stations in different homogeneous regions.

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Decomposition of time series

To characterize the multi-decadal precipitation changes we used Ensemble Empirical Mode Decomposition (EEMD) (Wu and Huang, 2009; Wu et al., 2008), a recent improvement of Empirical Mode Decomposition (EMD) (Huang et al., 1998; Huang et al., 2003).

EMD and EEMD are useful approaches for the analysis of non-linear and non-stationary time series. EMD allows the partition of a time series into different frequency and amplitude components (Intrinsic Mode Functions-IMFs). The lowest variability component that remains after all IMFs are extracted is referred to as "trend". The trend must be a monotonic function or a function with only one extremum.

Precipitation series averaged over each identified cluster were used as input to EEMD. EEMD results were then grouped into different modes, depending on the average period of each component. We considered three temporal scales of variability : (a) interannual (2-7 years), (b) decadal (7-14 years), and (c) multi-decadal-trend (>14 years).

Results

EEMD produced 9 IMFs plus a trend. The multi-decadal/trend (MDT) was represented by IMFs 7, 8 and 9, plus the trend. In order to eliminate the minor influence of data end effects, the first two and the last two years of the decomposed results were excluded, leaving only the remaining period of 1913–2009 to be further analyzed.

Figure 2 shows the MDT por the Southwest cluster of stations (green dots on Fig. 1). Although the trend increases throughout the analysis period, the inclusion of IMFs 7 and 8 results in up and down fluctuations. These components have a negative contribution up to the 1960s, and then shifted to positive values. Nevertheless,a decreasing trend is detected that started around the mid-2000s.

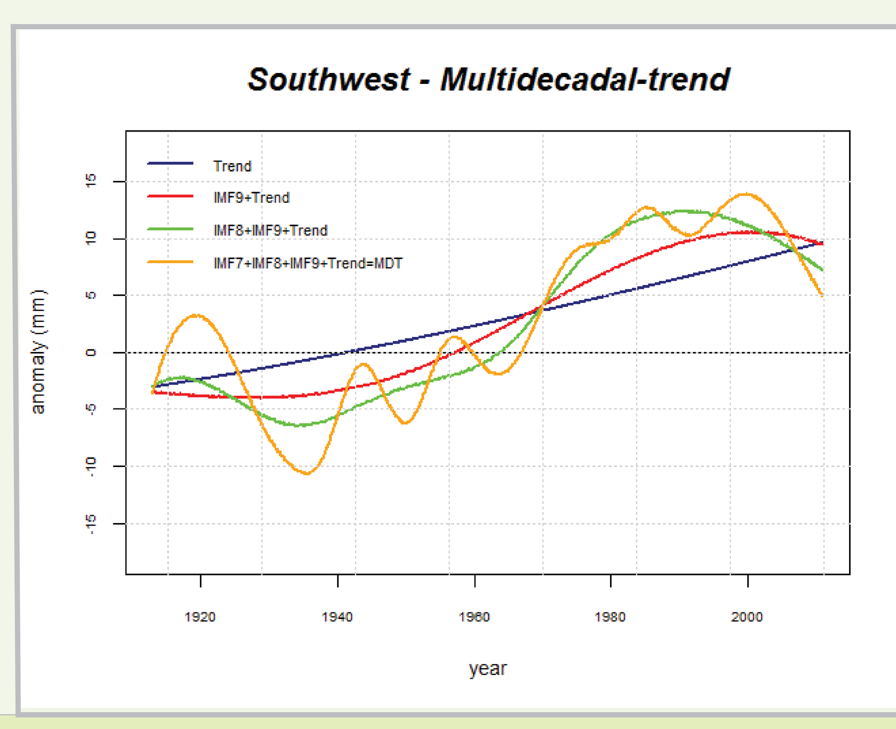

Fig. 2: Multidecadal-trend for the Southwest cluster (orange). Trend (blue), IMF9 plus trend (red), IMF8,9 plus trend (green). Período 1913-2009 .

Figure 3 shows the interannual, decadal and multidecadal components for each cluster of stations.

Interannual variability. This component showed fluctuations not only in amplitude, but also in its frequency. The component is described by IMFs 4 and 5, with average periods of 2-3 years and 4-5 years, respectively. Throughout most of the period analyzed, this component showed the largest magnitude. In contrast, the lower frequency components had a comparable magnitude only during short periods and in some of the regions.

Decadal variability. This component is represented by IMF 6, that has average periods of 7.5 to 13 years. The magnitude of the component varied among the different regions but did not show any clear common patterns.

Multi-decadal variability plus trend. In all six regions, this component showed a negative contribution until at least the 1940s, followed by a positive and larger contribution bertween the 1970s and the end of the 20th century. The last decade showed a shift towards lower values (except for region East 2). In the Northeast and East 1 regions, this component already reached negative values.

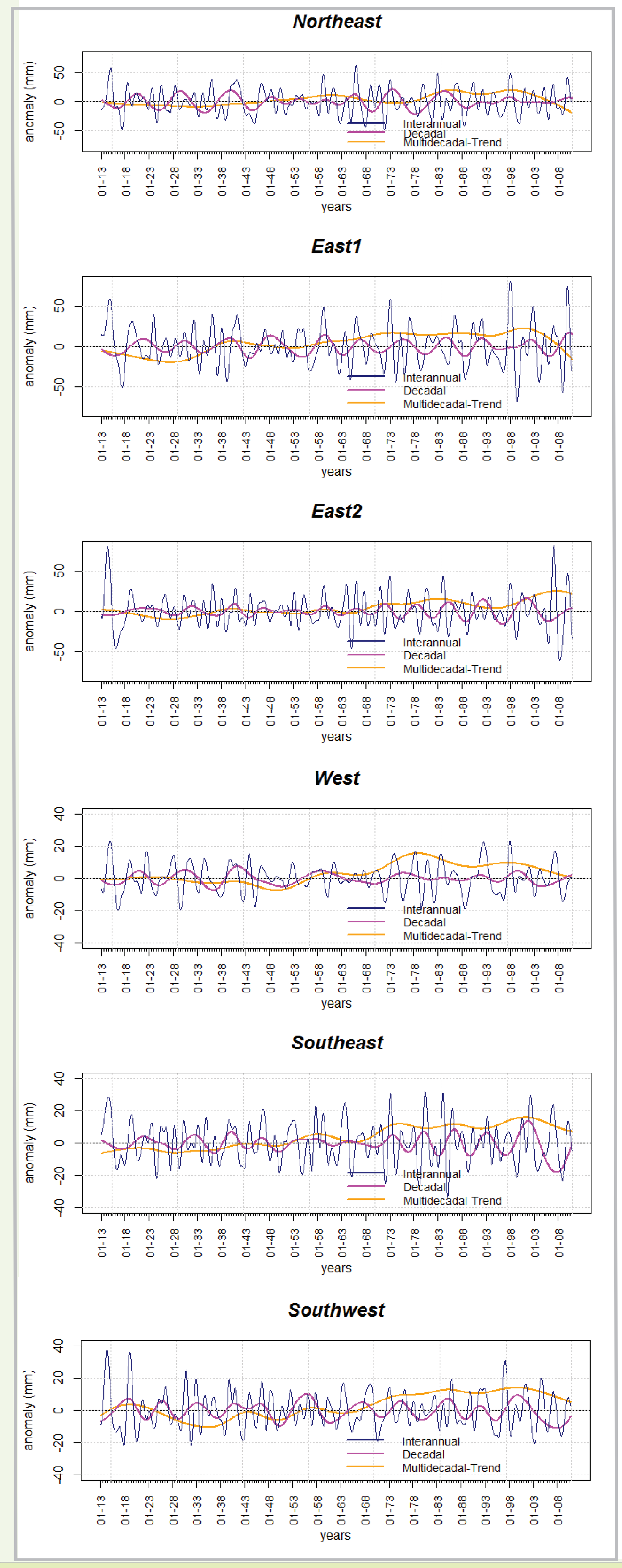

Fig. 3: Components of rainfall variability associated with interannual (blue), decadal (pink) and multi-decadal plus trend (orange) for each cluster of stations identified on Fig.1 (Fig 1). Período 1913-2009 .

Conclusions

We decomposed 101-year precipitation series into components associated respectively with (i) interannual, (ii) decadal, and (iii) multi-decadal scales plus a trend.

The amplitude and frequency of each of these components fluctuated throughout the study period.

The largest contribution to total rainfall variability corresponded to the interannual component. Only in a few locations and times the lower-frequency modes had a magnitude comparable to that of the interannual component.

The multi-decadal + trend component showed an important positive contribution between the 1970s and the first decade of the 21st century.

The rainfall increase associated with this mode played a role in the expansion the boundary of rainfed agriculture towards drier regions and – together with other drivers – contributed to major changes in regional land use.

Nevertheless, production systems that evolved partly in response to increased rainfall may not be sustainable if climate reverts to a drier epoch, as suggested by the recent pattern of EEMD results.

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