Towards a regional drought monitoring and warning system in southern South America: an assessment of various drought indices for monitoring the 2007-2009 drought in the Argentine Pampas

UNIVERSITY OF MIAMI
ROSENSTIEL SCHOOL of MARINE & ATMOSPHERIC SCIENCE

Presenter: Hernán Veiga, Servicio Meteorológico Nacional (hernan.veiga@smn.gov.ar)

Authors: Podestá, Guillermo [1]; Herrera, Natalia [2]; Veiga, Hernán [2]; Pujol, Gloria [2]; Skansi, María de los Milagros [2]; Rovere, Santiago [3]

1 - University of Miami, Rosenstiel School USA; 2 - Servicio Meteorológico Nacional Argentina; 3 - Independent consultant

Summary

The severe drought in eastern Argentina from late 2007 to early 2009 had important economic impacts.

This event was characterized by the unusual combination of high severity, large spatial extent and extended duration of dry conditions.

Four indices were compared for the study of dry and wet periods, giving similar behavior. The analysis of this drought were performed with the Standardized Precipitation Index (SPI).

The impact on climate-sensitive sectors were analized through maize yields.

Motivation

A strategic partnership between the Regional Climate Center for southern South America (RCC-SSA) – a multi-national effort to produce usable climate information on an operational basis – and a multi-national, multidisciplinary Cooperative Research Network (CRN) on climate services funded by the IAI, is focusing on the multi-dimensional consequences of drought, one of the costliest natural disasters.

Early efforts of the RCC-CRN partnership focus on exploring the components needed for a regional drought monitoring and warning system. We are assessing several indicators or metrics for their usefulness in characterizing the severity, duration, spatial extent and impacts of dry events in SSA.

Drought indices examined

We compared time series of four alternative drought indices or metrics (Fig. 1). For each index, we computed values on several temporal scales, all indices were based on the reference period 1961-2010. We computed the following indices:

- SPEI: Standardized Precipitation-Evapotranspiration Index - Vicente-Serrano et al. (2010)
- SPI: Standardized Precipitation Index - McKee et al. (1993)
- Decil: Gibbs and Maher (1967)
- PN: Percent of normal precipitation

	Correlation			
6 months	Decil	SPEI	SPI	PN
Decil	1.000			
SPEI	0.947	1.000		
SPI	0.952	0.972	1.000	
PN	0.931	0.959	0.984	1.000

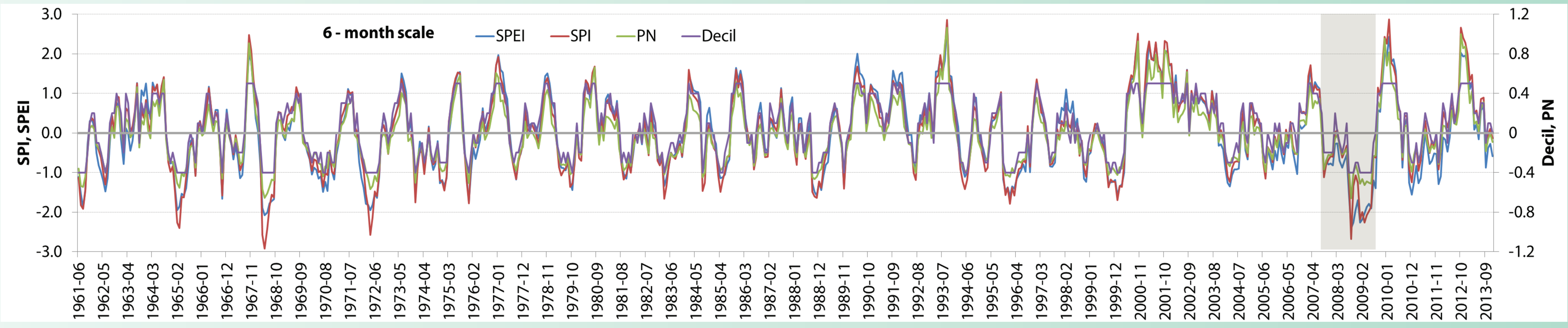

Fig. 1. Junín (E87548) drought indices in 6 - month scale: SPEI, SPI, PN and Decil. Decil and PN were transformed as: [(Decil - 5)/10] and [(PN - 100) / 100].

Study Area and Data

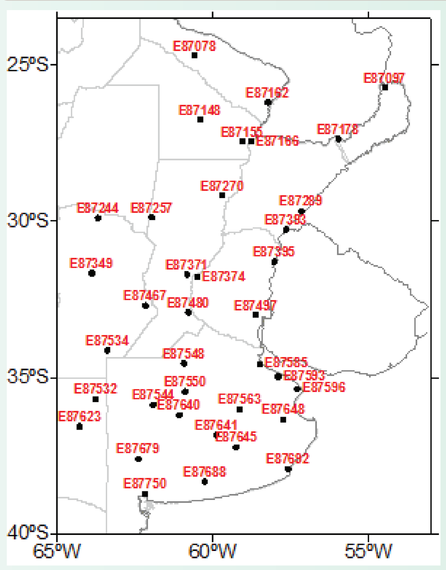

Fig. 2. Stations analyzed in eastern Argentina.

Daily data from 1961 to 2013:
- Precipitation
- Maximum temperature
- Minimum temperature
(Servicio Meteorológico Nacional - Argentina)

Annual maize yields from 1961 to 2012, from Sistema Integrado de Información Agropecuaria, Argentine Ministry of Agriculture.

Standardized Precipitation Index

As all indices show a similar behavior and as recommended by the World Meteorological Organization (2012), the study of this drought was performed with the SPI.

SPI values can be assigned to different categories of wet and dry conditions (see table)

SPI Classification		
SPI	Category	Probability of recurrence
≤ -2.00	Extremely dry	1 in 50 years
-1.50 to -1.99	Severely dry	1 in 20 years
-1.00 to -1.49	Moderately dry	1 in 10 years
-0.50 to -0.99	Slightly dry	1 in 3 years
0.49 to -0.49	Normal	
0.50 to 0.99	Slightly wet	
1.00 to 1.49	Moderately wet	1 in 10 years
1.50 to 1.99	Severely wet	1 in 20 years
≥ 2.00	Extremely wet	1 in 50 years

2007-2009 Drought

To illustrate use of the SPI to monitor droughts, we study a major dry event in 2007-2009.

The map (Fig. 3) shows SPI-24 values (that involve rainfall between Nov 2007 and Oct 2009). Most of the area shows extremely dry conditions: in fact, 62% of the stations showed the lowest SPI value since 1962.

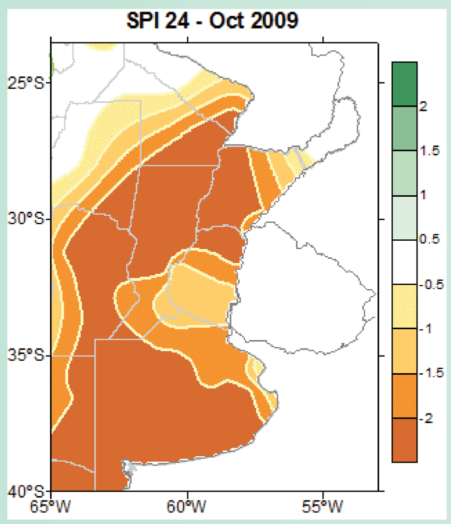

Fig. 3. SPI for 24 - month scale, October 2009.

On scales of 6 months, most of the stations have negative SPI values since mid-2007 (Fig. 4). The upper portion of Figure 4 (which includes stations in the northern half of the region) shows two dry periods separated by a normal spell (Mar-Sep 2008 / Apr-Oct 2009). In contrast, the southern half shows a single, continued dry event (Dec 2008-Jun 2009).

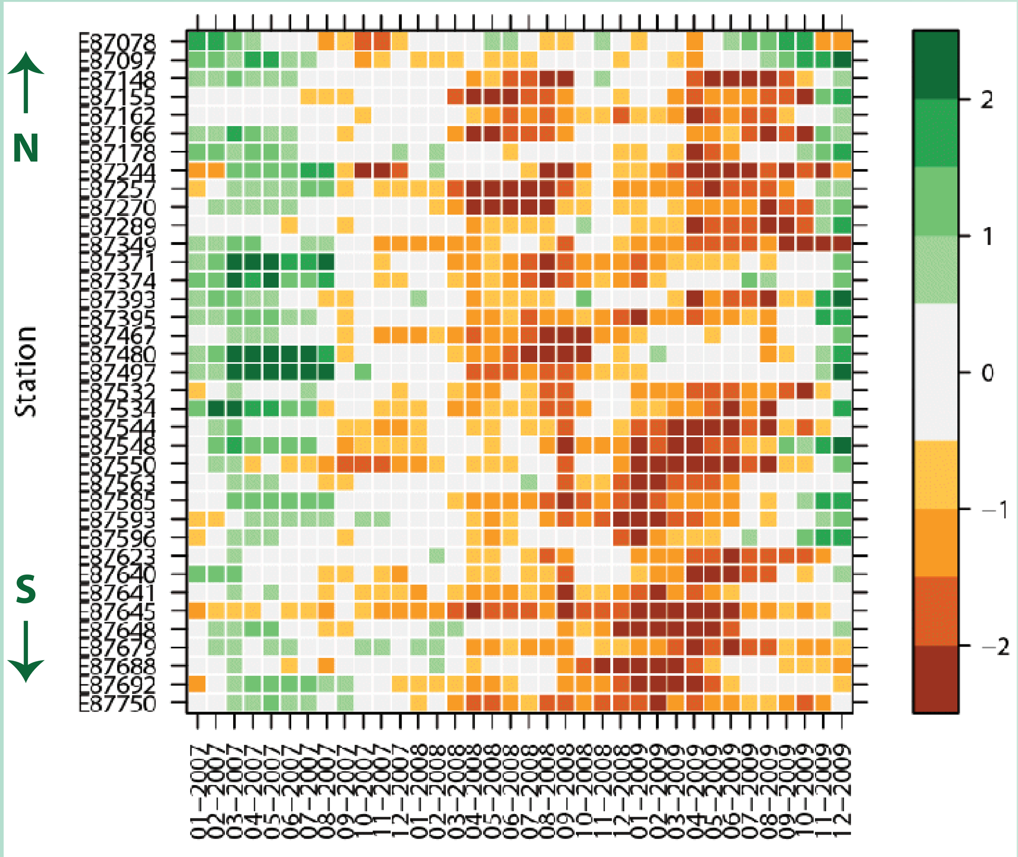

Fig. 4. SPI 6 values, 2007-2009. Each row corresponds to a meteorological station.

The protracted drought resulted in record sequence lengths of SPI values (at different scales) below -1.0 (at least moderately dry). Figure 5 shows that the length of continuous dry sequences at various scales was in the historical top, or at worst among the top 3 historical values in Junín, in the center of the Pampas.

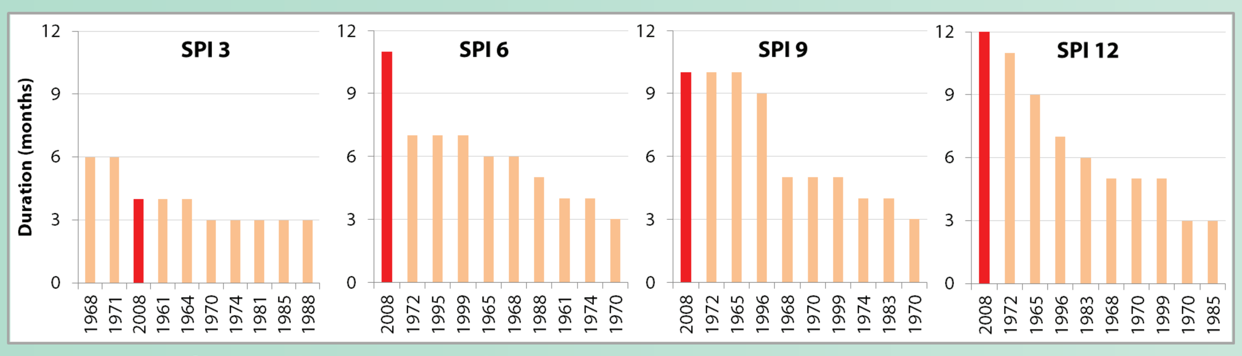

Fig. 5. Junín first 10 dry events ranking.

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Impacts: MaizeYield

To quantify impacts of the 2007-2009 event on climate-sensitive sectors, we explored yields of maize in the Pampas (Junín).

County-level yield series from Argentina's Min. of Agriculture were adjusted for technological improvements using a low-frequency filter (loess, the orange line on Fig. 6, top). We calculated "Relative yield anomalies" by subtracting the tehnology trend (i.e., the "expected" value) from the actual yield and dividing by the trend value. This produced yield anomalies (Fig. 6, bottom) independent of average yield levels.

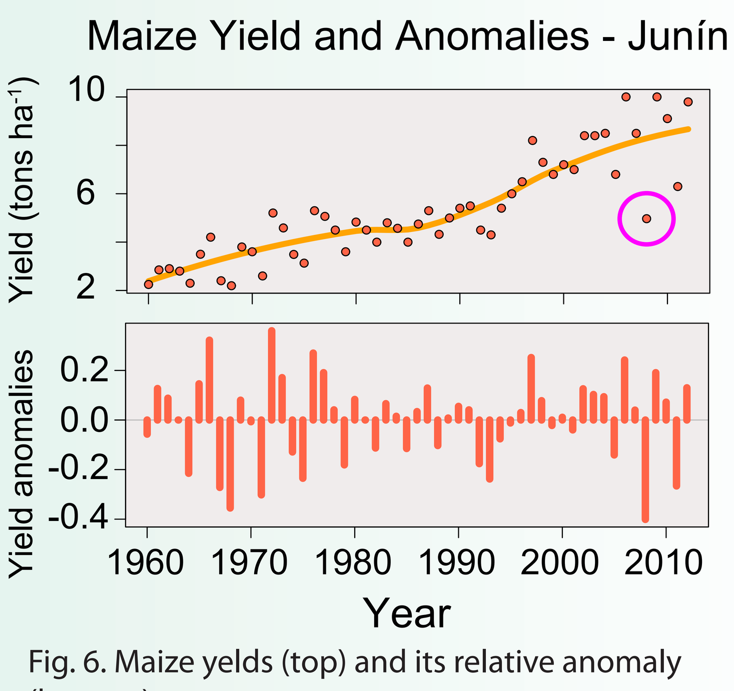

Fig. 6. Maize yelds (top) and its relative anomaly (bottom).

Junín	SPI 3	SPI 6	SPI 9	SPI 12
SEP	-0.036	0.091	0.018	-0.005
OCT	-0.039	0.040	-0.020	0.062
NOV	0.128	0.126	0.024	0.088
DEC	0.332	0.286	0.279	0.203
JAN	0.510	0.359	0.366	0.249
FEB	0.445	0.407	0.392	0.269
MAR	0.275	0.421	0.389	0.372
APR	0.108	0.391	0.311	0.321
MAY	0.046	0.325	0.319	0.308
JUN	-0.194	0.143	0.322	0.295
JUL	-0.123	0.045	0.344	0.267
AUG	-0.224	-0.077	0.259	0.264

To identify which SPI scale and month had the highest predictive value for maize yields, we calculated correlations betwen yields and various SPIs. The SPI 3 for January showed the highest correlation with maize yield (see table, significative correlations in red shading). That is, in January, we may have an estimation of yield levels for maize to be harvested two months later in March.

Figure 7 shows a positive association between yield anomalies in Junín (1961-2012) (x-axis) and SPI 3 values for January (y-axis). Most points fall in the lower left (low yields, dry conditions) and upper right (high yields, wet conditions) quadrants.

The 2008/09 maize yield and the January 2009 SPI 3 were both the lowest values for the entire series (red circle in Fig. 7).

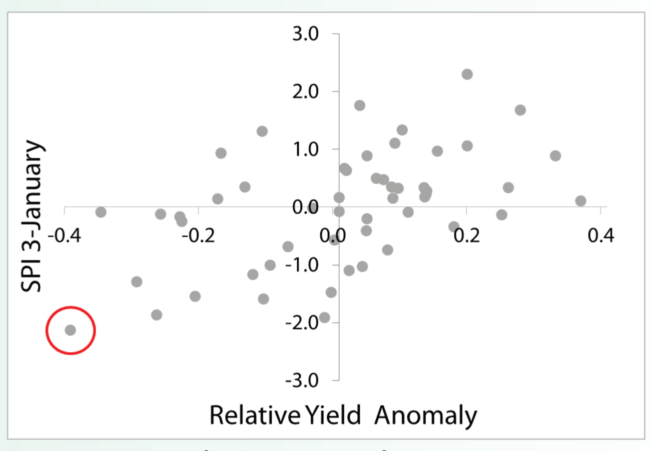

Fig. 7. Junín relative anomaly vs. SPI 3-January.

Conclusions

- **We explored various drought indices. All indices had similar behavior, representing well the occurrence of dry and wet periods.**
- **The 2007-2009 drought was highlighted by the unusual combination of a high intensity and large spatial and temporal extents.**
- **The 2007-2009 event had considerable impacts on agriculture. For example, in Junín (center of the Pampas) maize yield was 40% lower than expected.**
- **There is good correlation between SPI-3 for January (reflecting rains in November, December and January) and maize yields in Junín.**

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