SECTORAL IMPACTS OF THE HYDROCLIMATE VARIABILITY AT DIFFERENT TIME SCALES OVER NORTHEASTERN ARGENTINA

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RESUMEN

Este estudio discute los impactos de la variabilidad hidroclimática de interanual a multidecadal en los recursos hídricos, la agricultura y los asentamientos humanos sobre el nordeste de Argentina (NEA). Los patrones dominantes de precipitación, caudal y temperatura, sus tendencias no lineales y ciclos se identifican con un Análisis por Componentes Principales (PCA) y un Análisis Espectral Singular (SSA). La variabilidad interanual se concentra en dos bandas de frecuencias: 2.5-6.5 años y aproximadamente 9 años. La variabilidad interdecadal se caracteriza por tendencias de baja frecuencia y oscilaciones multidecadales que indujeron una transición desde un clima más seco y frío a décadas más húmedas y cálidas a partir de mediados del siglo XX. La variabilidad hidroclimática en todas las escalas temporales tuvo importantes impactos sectoriales. Eventos húmedos frecuentes entre 1970 y 2005 favorecieron inundaciones que afectaron la productividad agrícola-ganadera y forzaron evacuaciones de poblaciones. Por otro lado, sequías agrícolas produjeron déficits de humedad de suelo que afectaron los períodos críticos de los cultivos. Las sequías hidrológicas afectaron los recursos hídricos superficiales ocasionando escasez de agua y alimentos y disminuyendo la capacidad de generación de energía hidroeléctrica. Por último, los incrementos en temperatura mínima redujeron los rendimientos de trigo y cebada.

ABSTRACT

This study discusses the impacts of interannual-to-multidecadal hydroclimate variability on water resources, agriculture and human settlements over northeastern Argentina (NEA). The leading patterns of precipitation, river streamflow and temperature, their nonlinear trends, and cycles are identified by means of a Principal Component Analysis (PCA) and a Singular Spectrum Analysis (SSA). Interannual hydroclimatic variability centres on two broad frequency bands: one of 2.5-6.5 years and the second of about 9 years. Interdecadal variability is characterized by low-frequency trends and multidecadal oscillations that have induced a transition from dryer and cooler climate to wetter and warmer decades starting in the mid-twentieth century. The hydroclimate variability at all time scales had significant sectoral impacts. Frequent wet events between 1970 and 2005 favoured floods that affected agricultural and livestock productivity and forced population displacements. On the other hand, agricultural droughts resulted in soil moisture deficits that affected crops at critical growth stages. Hydrological droughts affected surface water resources causing water and food scarcity and stressed the capacity for hydropower generation. Lastly, increases in minimum temperature reduced wheat and barley yields.

Keywords: Hydroclimate variability, sectoral impacts, northeastern Argentina.

1) OBJECTIVE, DATA AND METHODS

This study (a) reassess the joint variability from interannual to multidecadal scales of precipitation, streamflow and temperatures (maximum and minimum) over NEA and (b) discuss the impacts of hydroclimate variability at different time scales on water resources, agriculture and human settlements.
We used monthly time series with 0.5° x 0.5° degrees resolution from the Global Precipitation

Climatology Centre dataset version 7 (GPCC v7, Schneider et al., 2015) for precipitation (1901-2013), and from the Climatic Research Unit (CRU TS 3.23, Harris et al., 2014) for maximum and minimum temperature (1901-2014). Monthly streamflow data of the Paraná River covers the period 1904-2014.
The variables are filtered applying low-pass Lanczos filters with 36 weights and cut-off periods at 18 and 120 months to emphasize the interannual and low frequency behaviour respectively. A PCA is applied to extract the leading precipitation fields. A SSA (Ghil et al., 2001) is used to study the temporal variability of leading PCs of precipitation, streamflow and temperature anomalies time series.

2) RESULTS AND DISCUSSION

The precipitation, streamflow, and temperature over NEA exhibit spectral peaks on interannual and decadal-to-multidecadal time scales (Table 1). On interannual time scales, hydroclimate variability centres on two bands: one with frequencies between 2.5 and 6.5 years and the other with periodicities close to 9 years. For each variable, interannual modes represent more than 50% of their temporal variability; except for minimum temperature, which modes explain 30% of its variance. On decadal-to-multidecadal time scales, nonlinear trends and multidecadal oscillations (dec. osc.) account for most of the variability, while the interdecadal modes (about 11-25 years) have a lesser effect.
The analysis of the time series suggest that short-period cycles of the ENSO-related interannual precipitation variability (a) favoured extreme events after 2000, even during moderate extreme phases of the El Niño Southern Oscillation (periodicities of 2-4 years) and, (b) contributed to the Low Paraná river streamflow with periodicities of near 2 years. Interannual hidroclimatic variability induced frequent extreme events that altered the management of surface and groundwater resources. Frequent floods affected agricultural productivity in riverine and rural areas causing damages to pastures and crops and forcing cattle displacement. Populations were also affected, including impacts on infrastructure, transportation and trade. Conversely, agricultural droughts disrupted critical periods of crops and hydrological droughts impacted water supply for cattle and favoured soil erosion.

Time scale	PC1 Pr	PC2 Pr	Q	Tmx	Tmn
Interannual (18-m low-pass filtered time series)	2.4 (17)	2.5 (15)	2.4*(7)	2.4 (13)	
	4 (14)	3.4 (16)	3.7 (18)	3.5 (17)	3.5 (17)
	6.5 (24)		5.8 (15)		6.5 (14)
		9 (19)	8.8 (27)	8.8 (26)	
Decadal-to-multidecadal (120-m low-pass filtered time series)	15 (4)	11.5 (25)			
	20 (9)		18-24 (20)	24 (34)	19 (24)
	Trend (60)	Dec. Osc. (58)	Dec. Osc. (62)	Trend (21)	Trend (55)

Table 1. Leading frequencies (years) of precipitation patterns, streamflow (Q), and area-averaged maximum and minimum temperature (Tmx and Tmn). In () the percentage of variance explained by each mode.

On decadal-to-multidecadal time scales, NEA transitioned from dry and cooler to wet and warmer decades since the 1970s. The wet period favoured agriculture over relegated regions and also led to land use changes. The combined effect of increased precipitation and land use changes led to extraordinary floods. Increases in minimum and maximmum temperatures reduced wheat yields and altered maize life-cycles, as well as affected energy demand in several cities of the region. Finally, the combination of interannual and multidecadal hydroclimatic variability intensified extreme events, leading to the most severe droughts in the early 20th century and largest floods after 1970. Since the mid-2000s, NEA has been showing signs of a reversal in the wetting period on multidecadal time scales.

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