Available online at www.sciencedirect.com
ScienceDirect
Advances in Space Research 57 (2016) 1391–1401
ADVANCES IN SPACE RESEARCH (a COSPAR publication)
www.elsevier.com/locate/asr

Precipitation over two Southern Hemisphere locations: Long-term variation linked to natural and anthropogenic forcings

Teresita Heredia [a,*], Ana G. Elias [a,b]

[a] Universidad Nacional de Tucumán, Facultad de Ciencias Exactas y Tecnología, Departamento de Física, Av. Independencia 1800, 4000 Tucumán, Argentina
[b] Consejo Nacional de Investigaciones Científicas y Técnicas, CONICET, 4000 Tucuman, Argentina

Received 30 May 2015; received in revised form 2 November 2015; accepted 10 December 2015
Available online 18 December 2015

Abstract

The precipitation over Tucuman (26.8°S, 65.2°W), Argentina, and Sidney (33.8°S, 151.2°E), Australia, present similar long-term variation patterns. In this work anthropogenic and solar forcings are analyzed as possible drivers of this behavior. Due to the nature of the processes that lead to precipitation, the discernment between solar and anthropogenic effects, and the link between precipitation and solar activity are highly complex and hard to detect. The aim of this work is to convey the importance of recognizing and quantifying the different forcing acting on precipitation which sometimes are not exposed by a statistical analysis. Annual mean precipitation time series together with solar and geomagnetic activity indices and atmospheric CO_2 are analyzed. In order to survey the role of different forcing on precipitation variation we used wavelet and regression analysis with CO_2, Rz and aa as independent variables acting as anthropogenic, solar and geomagnetic activity forcing respectively. In the long-term, all of them, considered separately, would induce a similar mean increase in precipitation. The increasing concentration of greenhouse gases, which is thought to be the main factor causing the global warming, is expected to induce an increasing trend of ~0.8 mm/year, according to some authors. In our case, we obtain a much smaller value: ~0.15 mm/year which in addition, is similar to the expected forcing from Rz or aa. The wavelet analysis yield significant results for the quasi-decadal and longer-term variations only in the case of Sydney. Significant correlations at time-scales longer than 22 years are also obtained through the regression analysis for Sydney. Although Tucuman do not present significant results, there is a clear similar behavior in the long-term trend. In spite of the fact that the present analysis do not allow us to determine the “true” forcing of the overall increasing trend observed in precipitation, it points out not only anthropogenic but natural mechanisms as possible origins of the precipitation variations.

Keywords: Precipitation; Solar forcing; Anthropogenic forcing; CO_2; Wavelet

1. Introduction

Understanding climate-driving mechanisms has become an important topic in many current research projects and various scientific fields due to climate high impact on life, economy and urban planning, among others. Data series with long time span are needed in order to do this. Also, future predictions require insight into past climatic behavior. Unfortunately, historic reports of climatic parameters are scarce, and most of them date back to 1850’s (Versteegh, 2005), where climate was already influenced by anthropogenic activity (Tiwari and Ramesh, 2007). Furthermore, direct measurements of sun output energy dates back to ~1980’s (Versteegh, 2005; Lockwood, 2010; Gray et al., 2010). Thus, both observations are too short to allow statistically significant conclusions on natural climate behavior. Despite this issue, several authors reported a

* Corresponding author. Tel./fax: +54 381 4365710.
E-mail addresses: theredia@herrera.unt.edu.ar (T. Heredia), aelias@herrera.unt.edu.ar (A.G. Elias).

http://dx.doi.org/10.1016/j.asr.2015.12.009
0273-1177/

positive correlation between sun and climate (Beer et al., 2000; Versteegh, 2005).

Global warming has become a major concern to the scientific community. The increase in greenhouse gases is believed to be the main cause of this global change in the lower atmosphere, and corresponds to a cooling in the middle and upper atmosphere. However, there are natural sources, such as the sun and volcanic eruptions, which can also produce global changes in the atmosphere. The present work is focused on solar variation as a natural forcing in the lower atmosphere. For global warming studies, it is essential to elucidate the natural variability in climate parameters (Solomon et al., 2007).

Because of the complexity of the climate system and although there are many papers showing statistically significant correlations between climate parameters and solar variations, there is not a convincing physical explanation for these results yet (Hoyt and Schatten, 1997; Brunetti, 2003; Friis-Christensen and Lassen, 1991; Svensmark and Friis-Christensen, 1997; Bucha, 2002; Palamara and Bryant, 2004; Agnihotri et al., 2011; Heredia and Elias, 2013).

In the present work the link between precipitation at two Southern Hemisphere stations with anthropogenic and solar forcings is analyzed. Precipitation regimes are highly complex but also of high climatological interest since an understanding of their characteristics has economic, agricultural and energetic relevance (Rusticucci and Penalba, 2000; Neukom et al., 2010).

In general, Southern Hemisphere studies on climate long-term variability are much less than Northern Hemisphere ones. Most studies which analyze Southern Hemisphere climate data series are focused on hydrological cycle variability (Compagnucci and Vargas, 1998, Compagnucci et al., 2013; Waylen et al., 2000; Boninsegna and Delgado, 2001) linked to solar variability. They found cyclic fluctuations on decadal-to centennial-times scale often attributed to solar variations. Compagnucci et al. (2013) for example, analyze the relationship between solar activity described by the sunspot number and South American rivers, and found a statistically significant 30 year periodicity.

Few studies analyze rainfall in the Southern Hemisphere associated to solar activity. Gianibelli et al. (2001) found a link between precipitation from La Plata, Argentina, and geomagnetic aa index. Souza Echer et al. (2008) showed that rainfall at Pelotas, Brazil, and sunspot number are associated at 11 and 22-year time scales. De la Casa and Nasello (2012) find a strong association between the precipitation in Córdoba, Argentina, and the occurrence of maxima in the sunspot cycle. Rampelotto et al. (2012) observed that solar activity probably play an important role in the climate system over Southern Brazil through the analysis of rainfall in Santa Maria, Brazil.

In addition to the Sun's intrinsic variations, external factors can modify the solar energy reaching the Earth (Cionco and Abuin, 2016). Many papers have been published indicating that solar dynamics, and consequently solar activity variability, is influenced by planetary movements and the solar motion around the center of mass of the solar system (Jose, 1965; Fairbridge and Shirley, 1987; Charvatova, 2000; McCracken et al., 2014). The hypothesis of a gravitational influence of the planets on the solar magnetic cycle is an old idea based on correlations between Sun's movement around the barycenter and sunspots that was recently revisited by Cionco and Compagnucci (2012). Climate on Earth may be also influenced by planetary movement (Leal-Silva and Velasco Herrera, 2012; Scafetta, 2010, 2014; Cionco and Abuin, 2016, and references therein) showing associations at several cycles, like quasi-decadal, 20, 30, and 60-year variations. This hypothesis is a new insight to the solar-climate

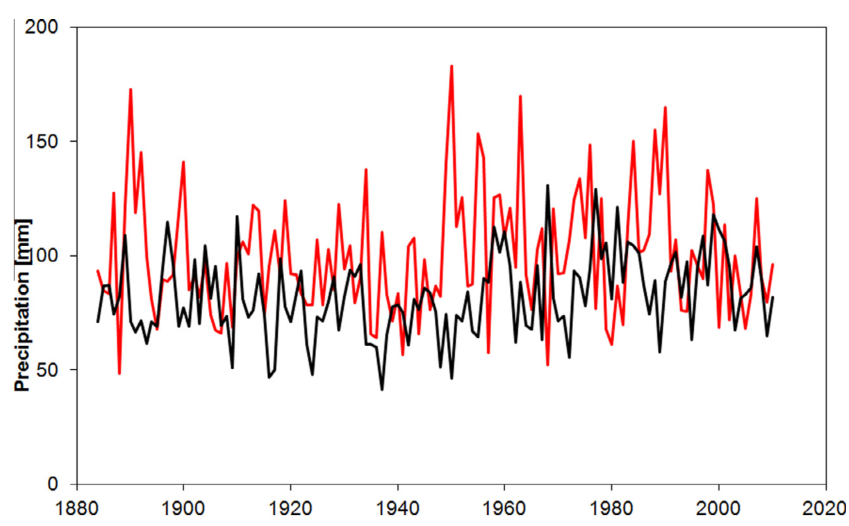

Fig. 1. Annual mean precipitation over Tucuman, black line, (26.85°S; 65.2°W), Argentina, provided by "Laboratorio Climatológico Sudamericano"; and Sidney, red line, (33.8°S, 151.2°E), Australia, from the Bureau of Meteorology (www.bom.gov.au). Period analyzed January 1884–December 2010. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)