Atmósfera 27(1), 91-102 (2014)

Synthetic generation of the North Atlantic Oscillation Index

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Received May 25, 2012; accepted November 29, 2013

RESUMEN

En este artículo se compararon registros sintéticos de longitud más larga que los registrados históricamente para el Índice de Oscilación del Atlántico Norte. Los registros sintéticos se obtuvieron utilizando el método de intercambio de años de Grinevich y el método de fragmentos de Svanidze, así como el método de Fiering. Los registros generados se pueden utilizar en modelos de simulación para el análisis a largo plazo del comportamiento de los índices de teleconexión, principalmente relacionados con escenarios de cambio climático.

ABSTRACT

In this article synthetic records of longer duration than the historic records of the North Atlantic Oscillation Index were compared. The synthetic records were obtained using the year interchange method and the Svanidze fragments method, as well as the Fiering method. These records can be used in simulation models for the long-term analysis of the behavior of the teleconnection index, predominantly *vis-á-vis* climate change scenarios.

Keywords: North Atlantic Oscillation, Svanidze, synthetic generation, Fiering, autocorrelation.

1. Introduction

The teleconnection indices measured by the National Oceanic and Atmospheric Administration (NOAA) identify diverse climatic phenomena that take place on the planet during the different seasons of the year (Rodwell *et al.*, 1999). Particularly, variability in the North Atlantic Oscillation (NAO) Index is directly related with alterations in precipitation and with winter events in different regions of Europe (Parker and Folland, 1988; WMO, 1995; Martín-Vide and Fernández-Belmonte, 2001; Stephenson *et al.*, 2002, 2006). This index, which indicates the variability in atmospheric pressure, has two phases, although in recent years a persistent positive phase has been noted, which has raised some uncertainties regarding the possible effect of climate change (Spokes, 2004). Wunsch (1999) applied autoregressive models AR(1) in an attempt to identify the random nature of the NAO oscillations or its possible relation with climatic changes phenomena. A comparison among reconstruction of the NAO Index from proxy data was made by Schmutz *et al.* (2000). Cook and D'Arrigo (2002) made a multiproxy reconstruction of the NAO Index since A.D. 1400-1979, to research its behavior prior to the twentieth century greenhouse forcing. An analysis about the scaling ranges of its fluctuations upon several delay times trying to identified the NAO Index as a Markov process were made by Collette and Ausloos (2004), who applied historical data from January 1825 to November 2002. Martínez *et al.* (2010) applied different fractal concepts and dynamic system concepts that pointed to the random nature and need of stochastic models to represent time evolution of the NAO Index. An extensive review of historical studies about the NAO Index can be found in Stephenson *et al.* (2002).

Caron and O'Brien (1998) conceived a method that successfully reproduces another index, the sea surface temperature (SST) signatures associated with warm and cold events to study the El Niño/Southern Oscillation (ENSO) extremes. They developed algorithms for generating synthetic data using frequency domain analyses, in order to extract information regarding the contribution of different frequency oscillations to the associated variability of the time series. They found that the return period of an extreme ENSO warm event having a maximum SST anomaly magnitude of 2 ºC occurs approximately every eight warm events, and concluded that a further use for these synthetic data could be as forcing input in coupled ocean-atmosphere or atmospheric numerical models. The envelope of atmospheric response to various SST anomaly forcings associated with ENSO and other pseudoperiodicities can be understood by combining the work of this study and the current modeling studies of coupled air-sea interaction.

The main mechanisms determining the evolution of the NAO are not completely understood (Bojariu and Gimeno, 2003).

Cañellas *et al.* (2010) examinated teleconnections between the NAO and the wave climate of the northwestern Mediterranean Sea (NWM). In order to avoid fictitious cross-correlations, data were prewhitened by fitting a *p*-order autoregressive model. To split the temporal and spatial variability, an empirical orthogonal functions (EOF) encoding technique was applied to residuals before searching for teleconnections. They found the NAO phenomenon contributes to the spatial variability found in the northwestern Mediterranean. When the NAO is in its positive phase there is a reinforcement of the northerly cold and dry air masses from the arctic regions, which generates more severe weather conditions over the NWM.

Chaudhuri *et al.* (2011) analyzed how the NAO affects the Gulf Stream transport by means of an eddy-resolving model.

In order to simulate long-term climate scenarios it is important to have data of longer duration than the historic records; as a consequence, methods for the synthetic generation of time series that reproduce the statistical characteristics of the historic series turn out to be of particular interest. Almost all traditional methodologies of synthetic generation reproduce statistics such as the mean and standard deviation but have difficulties for other type of parameters such as the coefficient of skew or the coefficient of autocorrelation.

In this work, the Svanidze fragments method (Svanidze, 1980), a modification of it (Domínguez-Mora *et al.*, 2001), as well as the Fiering monthly method (Domínguez-Mora and Carlóz, 1982), were used for the generation of monthly synthetic records for a 1000-year record of the NAO Index. These methodologies have been successfully applied in the case of runoff volumes; thus, the Svanidze method has proven to be very practical and relatively simple in its application, with the advantage over other methodologies (for instance, in relation to the autorregresive moving average [ARMA] models) of not requiring data to be normalized, as well as preserving the autocorrelations (Domínguez-Mora *et al.*, 2001, 2005; Domínguez-Mora and Arganis, 2006; Arganis-Juárez *et al.*, 2008).

2. Methodology

2.1 North Atlantic Oscillation Index

The NAO Index is the difference in pressures that exist between the Azores (at 38º N) and Iceland (at 65º N), which becomes of greatest relevance at winter. It has two phases, one positive, associated to warm and humid events, and one negative. Since 1990 and until a short time after the year 2000, the predominance of the positive phase has been observed, as can be seen on Figs. 1 and 2 (NOAA, 2010; European Environment Agency, 2012).

The rotated principal component analysis (RPCA) used by Barnston and Livezey (1987) isolates the primary patterns of teleconnection for all months and allows time series of the patterns to be built. The standardized anomalies are currently calculated based on the re-analysis of the climatological daily mean and the standard deviation for the period 1950-2000 (NCEP/NCAR Climate Data Assimilation System [CDAS]) run in real time. Because other sources of re-analysis (CDC, NCAR, NCDC) may not have the capacity to provide data in a timely basis, a subset of the current database CDAS is available on the Internet. This subset includes monthly and daily means of many standard pressure-level data and surface flux quantities (NOAA, 2010).

2.2 Year interchange method (Grinevich)

This method is originally applied to a series of volumes or flows. Let us assume that a reservoir's