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On the Chandler periodicity (Polar Motion, LOD and Climate)

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Abstract. The 14-month Chandler period is associated with the free nutation of the Earth about its spin axis. The observed value of the Chandler period comes usually from the analysis of astronomical series of polar motion data as well as from superconducting gravimeter measurements. At the observation level a periodicity of about 420–440 days also was noticed in microseismic activities. Recently we found evidence of a signal with period similar to the Chandler one in the Sardinia rainfall time series.

1. Introduction

Whether the Chandler period is constant or variable and whether it consists of single or multiple components remains till now unresolved while theoretical estimates of the value of this period are generally model dependent. There are also intriguing theories speculating that the Chandler frequency or the Chandler wobble beat of about 6.2 years may be related to lunar and planetary periodicities (Fairbridge 1991). Recently we found evidence of a signal with period similar to the Chandler one in the Sardinia region rainfall time series.

Originally the aim of this work was to investigate the possible existence of a correlation between polar motion and climatic variables, but considering recent literature, the topic of this work has been extended to the search for correlations between geodynamics (Chandler wobble, LOD) and climatic processes (temperature and precipitation fields, ENSO and NAO indices).

Links between climatic anomalies and variability in the atmospheric circulation are monitored and the derived climatic indices are available for analysis and forecasting purposes. Two of the major sources of interannual variability in the atmospheric circulation are the El Niño-Southern Oscillation (ENSO) and the North Atlantic Oscillation (NAO).

El Niño has been shown to have a direct and strong impact on the climate fluctuation in the tropical Pacific. The NAO (Hurrel 1996) is associated with changes in surface westerlies across the Atlantic onto Europe and characterizes a meridional oscillation in atmospheric mass with centers near the Icelandic Low (IL) and the Azores High (AH). The NAO is measured as the difference between the normalized mean winter sea-level pressure anomalies at locations representative of the AH and IL. In the present case the NAO index time series were obtained considering sea level pressure (SLP) anomalies from Lisbon, Portugal and Stykkisholmur, Iceland. The NAO accounts for more than $\frac{1}{3}$ of the total

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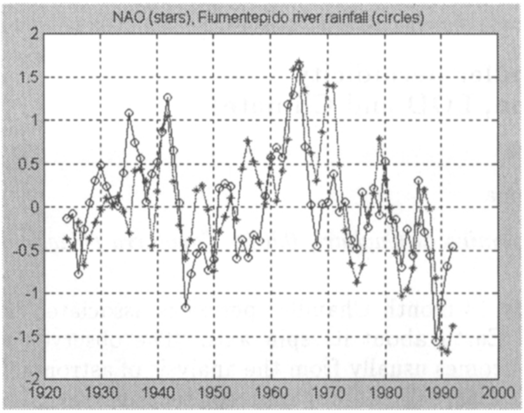

Figure 1. Comparison between NAO and Flumetepido river rainfall time series.

variance of the SLP field over the North Atlantic. The NAO can be seen trough the lens of several environmental variables. For examples SLP, storm-tracks, sea surface temperature (SST), temperature and precipitation fields are strongly correlated with NAO. The NAO is generally conceptualized as existing in one of two extreme states, positive or negative: a positive (negative) NAO refers to an intensified (weakened) poleward pressure gradient resulting from a synchronous strengthening (weakening) of the AH and deepening (shallowing) of the IL. Resultant changes in mean circulation show increased (decreased) moisture transport in Europe and severe drought conditions in the Mediterranean. The recent decade-long winter dry condition over southern Europe are related to the persistence of NAO index anomalies.

In Figure 1 the normalized NAO time series is compared with the normalized rainfall annual time series of the Sardinia Flumentepido river (Buffa *et al.* 1999). Both series have been smoothed. Figure 1 shows that NAO oscillation is strictly related to rainfall trends in Sardinia. Note that the NAO index is multiplied by -1 to facilitate the comparison.

Recently the existence of some links between the ENSO and the NAO has been proposed. This relationship seems to indicate that the ENSO modulates the NAO variation through wavelike patterns which would change the jet stream and storm track location over the North Atlantic.

Multiresolution cross-correlation analysis shows in this case the presence of a 5 to 6-year period band and a 2- to 4-year period band (Huang *et al.* 1998) documenting associated changes in the atmospheric circulation patterns. We applied the wavelets cross-correlation technique (Onorato *et al.* 1996) trying to correlate the NAO directly to the rainfall time series of the Tirso river, the most important Sardinian river. Figure 2 shows the presence of the same features observed in the ENSO-NAO case. This fact represents a confirmation of the existence of connections between the Mediterranean climate and the ENSO-NAO frequencies.

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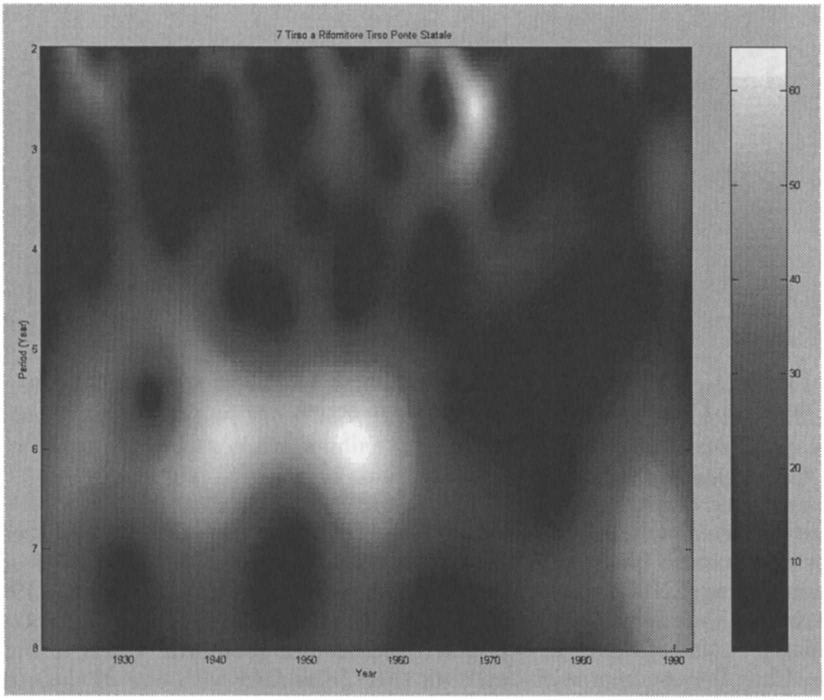

Figure 2. Cross-correlation spectrum of NAO index and Tirso river rainfall time series.

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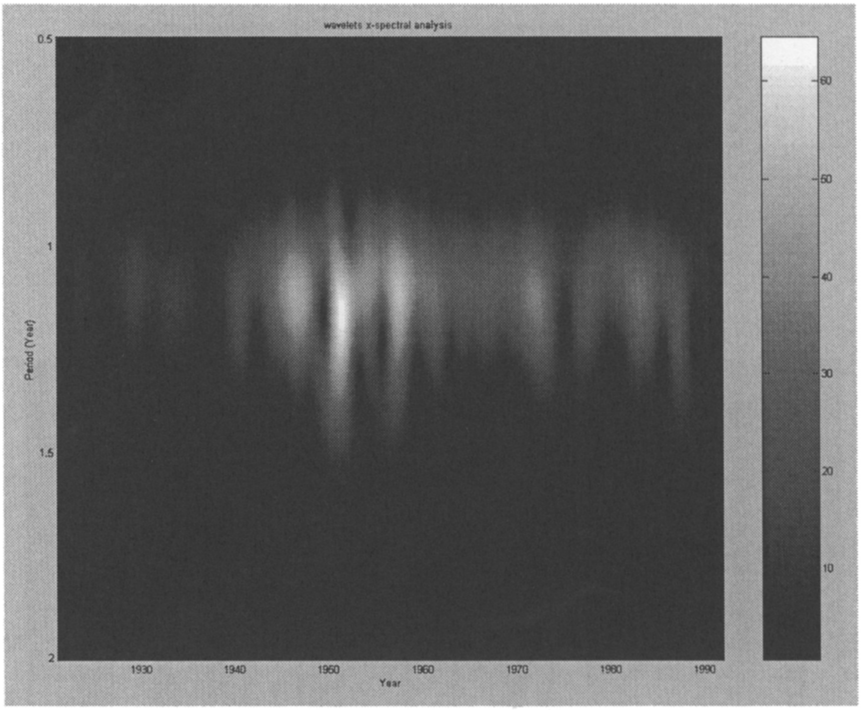

Figure 3. Cross-correlation spectrum of Chandler x-component index and Flumendosa river rainfall time series.

2. Chandler wobble and climate

There is a great number of works on the ENSO impact on LOD but recently some authors also investigated the possible existence of a disturbance of polar motion during ENSO events (Frède & Mazzega 1999, Kołaczek *et al.* 1999). The rainfall time series we considered in this work show many different spectral components, one of them corresponds to a period of about 1.2. years. In Figure 3 the Chandler x-component has been then correlated with one of these time series (Flumendosa river rainfall). Results seem to indicate the existence of a coupling in correspondence with the Chandler frequency. In the same figure a strong increase in the amplitude of the cross-correlation signal may be also noticed in 1951. In effect, it is well known that Chandler amplitude exhibits a large variation around 1950, while all of the Mediterranean area was strongly perturbed from a climatic point of view. In any case such results in absence of any physical interpretation should be used with much caution.

3. LOD and climate

A nonlinear interaction between seasonal length of day (LOD) and the El Niño-Southern Oscillation phenomenon has been extensively reported in many papers (*e.g.* Gipson & Ma 1999). Climate changes can be expected to affect the pole to equator temperature gradient, thereby inducing changes in the atmospheric

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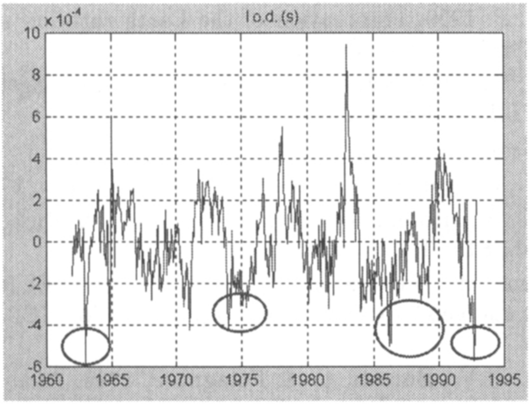

Figure 4. LOD and last drought episodes in Sardinia (circles).

zonal winds, and by conservation of angular momentum, may cause changes in the length of day. We analyzed then the LOD to unveil the fingerprints of NAO in general circulation.

Because of the existence of large decadal variations in LOD that are difficult to be modelled, we filtered out this long-term drift by using a fifth order polynomial in order to better analyze the short-term oscillations. The second term we subtracted is a seasonal mean obtained by monthly averaging the LOD series. This seasonal term is due to tidal forces as well as to zonal wind circulation. So we obtained the values plotted in Figure 4. In the same figure we marked the LOD data corresponding to the periods of the last drought episodes in Sardinia. Dry periods seem to coincide with negative anomalies in LOD (*i.e.* decreases in length of day) but obviously such results should be considered very preliminary. Note that positive anomalies of LOD and noticeable disturbances of polar motion typically occur during ENSO events, while the negative phase of ENSO (La Niña) corresponds a negative anomaly in LOD. Spectral analysis (Jordi *et al.* 1999) shows that two concomitant frequencies are present in LOD and ENSO, corresponding to 3–4 and 2–2.5 years respectively. Cross-correlation analysis performed on NAO and LOD show the existence of correlation peaks in correspondence with the 3–4 year peak while there is no evidence of a 2–2.5 years peak. The 2–2.5 year period in ENSO-LOD is generally explained in terms of a pattern of propagation of anomalies in zonal mean fields of atmospheric angular momentum across the globe. The lack of this signal in the NAO-LOD correlation should be investigated in order to better understand connections between NAO and ENSO.

References

Buffa, F., Fadda, A., Orrù, N., & Silvano, R. 1999, Studio dell'Idrologia Superficiale della Sardegna, Ente Autonomo del Flumendosa.

Fairbridge, R. W. 1991, Planetary and geology, in New Approaches in *Geomagnetism and the Earths Rotation*, S. Flodmak, World Scientific.

https://doi.org/10.1017/S0252921100061534 Published online by Cambridge University Press

Frède, V. & Mazzega, P. 1999, Fluctuation of the Earth rotation and El Niño events, IERS Technical Note 26, 37.

Gipson, J. M. & Ma, C. 1999, Signature of El Niño in the length of day as measured by VLBI, IERS Technical Note 26, 17.

Hurrel, J. W. 1996, *Geophys. Res. Lett.*, **665**, 23.

Huang, J., Higuchi, K., & Shamar, A. 1998, *Geophys. Res. Lett.*, **2707**, 25.

Jordi, C., Morrison, L. V., Rosen, R. D., Salstein, D. A., & Russell G. 1994, *Geophys. J. Int.*, **811**, 117.

Kołaczek, B., Nuzhdina, M., Nastula, J., & Kosek, W. 1999, El Niño impact on atmospheric and geodetic excitations of polar motion, IERS Technical Note 26, 23.

Onorato, M., Salvatti, M.V., Buresti, G. & Petagna P. 1996, Analysis of DNS velocity signals in a coaxial jet configuration, Atti Dipartimento di Ingegneria Aerospaziale, University of Pisa.

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