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ScienceDirect
Physics and Chemistry of the Earth 33 (2008) 239–249
PHYSICS and CHEMISTRY of the EARTH
www.elsevier.com/locate/pce

A review of sea level observations and low frequency sea-level variability in South Atlantic

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Accepted 1 February 2007
Available online 25 April 2007

Abstract

Sea-level data from South Atlantic stations were quality-controlled and analysed. Eleven time series, longer than 20 years, were selected to study long-term variability. The main features of South Atlantic sea level were described by computing linear trends, mean seasonal cycles and power spectra for the selected time series. The data sparseness made it difficult to achieve a comprehensive description of the basin. The connection between sea-level variability and ENSO was studied using the composite time series obtained by merging data for Buenos Aires and Palermo, on the Argentinian side of Rio de la Plata. It was possible to recognize that sea-level variability is strongly connected with that of river discharge into Rio de la Plata, which in turn exhibits a lagged teleconnection with ENSO. The time lag between ENSO and sea-level anomalies is about 5 months.

Keywords: Sea level; South Atlantic Ocean; Trends; Multidecadal variability; ENSO

1. Introduction

The South Atlantic Ocean is a very large and inhomogeneous region, since it extends in latitude from the Equator to Antarctica and is locally affected by large river outflows, as in the Rio de la Plata area. South Atlantic plays an important role in the global ocean circulation and climate variability. In fact, it participates in the deep thermohaline circulation that connects the North Atlantic and Indian Oceans and its southern part communicates with the Pacific Ocean via the Antarctic Circumpolar circulation. Recent papers described several features of South Atlantic variability on interannual to multidecadal time scales in connection with the atmospheric forcing (e.g. Venegas et al., 1997, 1998; Wainer and Venegas, 2002). The influence of large-scale climatic patterns was also investigated. For instance, Colberg et al. (2004) studied, by means of a General Circulation Model, the response of South Atlantic circulation to El Niño–Southern Oscillation (ENSO; Philander, 1990). Hughes et al. (1999) recognized, also from model simulations, an ocean variability mode in the wind-driven transport through the Drake Passage. The connection of this mode with the atmospheric Southern Annular Mode was found by Meredith et al. (2004).

In the framework of the ''European Sea-Level Service – Research Infrastructure'' (ESEAS-RI) project world monthly mean sea level (MSL) data were quality controlled and analysed. In the present study South Atlantic sea level was studied in order to describe some features of the multidecadal sea-level variability and possible connections with ENSO. As it will be seen, the available data set could not account for such differences properly and a comprehensive description of the region was not possible. In fact, most of the time series are relatively short and sparse, and, moreover, the data quality control further reduced the number of suitable time series. Nevertheless, some characteristics of sea-level variability could be outlined.

In the next section, the data and methodologies used in this study will be described. Section 3 will present some general features of sea-level variability, while Section 4 will

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doi:10.1016/j.pce.2007.04.001

be devoted to the teleconnection between sea level and climatic patterns. Conclusive remarks will follow in Section 5.

2. Data and methods

2.1. Historical data

The region of interest is defined as the geographical domain within 80°S–10°N latitude and 70°W–20°E longitude (Fig. 1). The historical data set is composed of the monthly MSL data extracted from the Permanent Service for Mean Sea Level (PSMSL) data bank (Woodworth and Player, 2003) in May 2003. The area under study includes 103 stations, that are listed in Table 1 and whose locations are shown in Fig. 1a. Fifty-one stations are provided with a Revised Local Reference (RLR), i.e. the data are referred to a land-based benchmark, while for 52 stations (METRIC) such connection does not exist. The oldest data are found in 1905 (Buenos Aires, Argentina) and the most recent in 2002 (Stanley II, Falkland Islands). Fig. 2 summarizes the data availbility as a function of time for each station. It is evident that the time coverage is irregular, with several short time series, most of which start around 1950 and later. Many gaps are also present. A few time series in Argentina start around 1910, but only two of them, namely Quequen and Buenos Aires, continue after 1950.

All the time series were submitted to quality control in order to identify possible erroneous data, datum changes, unrealistic trends. The basic quality control procedures were agreed in the ESEAS-RI project. One of the most important steps in the quality control procedure is the intercomparison of time series of nearby stations. The visual inspection of time series of differences of sea-level data at neighbouring locations is particularly useful to identify discontinuities and drifts.

Unfortunately, most of the South Atlantic data compose short and interrupted time series and, moreover, the distance between stations can be quite large. This limits the possibility of finding neighbouring stations and obtaining reliable comparisons. To identify suspect data and stations, the comments reported in the PSMSL documentation were also taken into account.

In order to perform a long-term analysis, only the time series with at least 20 consecutive valid years were taken into account. A year was considered valid when, at most, two non-consecutive monthly values were missing. Although short time series were not useful for long-term analysis, they were used in the quality control of the long time series.

After the quality control and taking into account the 20-year threshold, 92 time series out of 103 turned out to be unsuitable for the analysis. The remaining 11 time series, selected for long-term analysis are: Takoradi in Ghana; Argentine Islands in Antarctica; Puerto Williams in Chile; Puerto Madryn, Quequen, Mar del Plata – Naval Base (henceforth simply Mar del Plata), Buenos Aires and Palermo in Argentina; Imbituba, Cananéia and Belém in Brazil. They are identified by thick lines in Fig. 2. Note that only in the cases of Buenos Aires, Imbituba and Belém the available time series were accepted completely, while for the other stations parts of the time series were discarded. All the above-mentioned stations are provided with a RLR.

The teleconnections between sea level and ENSO were studied mainly on the basis of linear correlations. The relevant variables used in the study are: (1) The Southern Oscillation Index (SOI; Ropelewski and Jones, 1987), defined as the normalized pressure difference between Tahiti and Darwin and obtained from the Climate Research Unit, University of East Anglia. It is negative during an El Niño event. (2) The UNESCO river flow data of rivers Paraná and Uruguay, obtained from the National Center for Atmospheric Research database.

Most of the correlations involve 3-monthly standardized anomalies. Each 3-month period will be identified by means of the initials of the three months, namely DJF

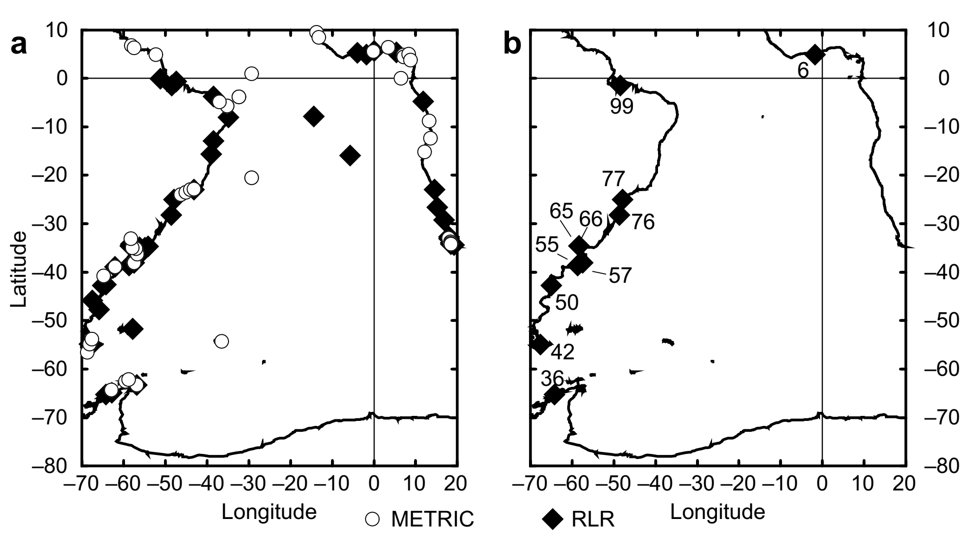

Fig. 1. Maps of the South Atlantic region studied. (a) All stations, (b) only the stations selected for long-term analysis. Black diamonds indicate RLR stations, white circles METRIC stations.