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OCEANO-METEOROLOGICAL CONDITIONS IN THE SE BAY OF BISCAY FOR THE PERIOD 2001-2005. A COMPARISON WITH THE PERIOD 1986-2005 AND OTHER REFERENCE PERIODS.

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Abstract

In spite of the local character of the meteorological and oceanographic data collected along the Basque coast, they are representative of mesoscale features in the Bay of Biscay and also indicate teleconnections with global scale factors such as the NAO. On the other hand, some seasons of the first 5 year period of the 21st Century have been defined as “extreme” (the warm summer in 2003; the cold and long winter in 2005; the very dry spring and summer seasons in 2005, etc.) in the southeastern Bay of Biscay and other areas. Consequently, frequent seasonal anomalies are apparent; this means that winter-summer duality prevails over the establishment (in terms of values and mean duration) of spring and autumn, as typical transitional seasons at mid-latitudes and the intergyre region of the northeastern Atlantic Ocean. The aim of this paper is to analyse the coupling between meteorological and oceanographic data, for the period 2001-2005, in comparison with the period 1986-2005 and other reference periods, in the southeastern Bay of Biscay. This will be studied from several viewpoints: i) relationships between atmospheric temperature, SST and heat content; ii) salinity in relation to the precipitation-evaporation balance and river flow; and iii) dynamic aspects related to the wind velocity and direction, e.g. the upwelling-downwelling duality as a factor combining *in situ* modifications and variations related to the advective-convective transport. Other purposes are to examine trends and anomaly patterns of several periods and to make a comparative assessment (in terms of slope, absolute or accumulated anomalies) depending on the reference period as well as the start and end points of the observation period itself. In addition, practical reference periods are proposed for some oceano-meteorological variables in the southeastern Bay of Biscay.

Keywords: Oceano-meteorological coupling, climate, time-series, Bay of Biscay.

Introduction

Several reference periods have been defined in order to compare different climate indices from different parts of the world. The ‘World Meteorological Organization’ (WMO) defines "normal" reference periods as "period averages computed from uniform and relatively long period comprising at least three consecutive 10-year periods" (WMO, 1984). Hence, the climatological reference or standard periods of 30 years are defined as follows: 1901-1930, 1931-1960, 1961-1990, etc. The latest standard reference period is 1961-1990, which will be updated in 2021. For instance, the United States has adopted other reference periods (1921-1950, 1931-1960, 1941-1970, 1951-1980, 1961-1990 and 1971-2000). Depending upon the adopted reference period, century-long data or sub-

periods, there will be differences between climatological averages. Moreover, different 30-year periods have been shown to exhibit differences in regional annual mean baseline temperature and precipitation of up to ±0.5ºC and ±15%, respectively (IPCC, 2001a).

Within this context, the distribution patterns, trends and anomalies are dependent highly upon spatial and temporal scales; frequently, it is possible to observe opposing trends, when different time periods are considered. Thus, the SST for the period 1947-1997, in the southeastern part of the Bay of Biscay, indicates a decreasing trend for the mean annual temperature, in relation to the warm periods at the end of the 1940s and the 1960s (Borja *et al*., 2000). However, Koutsikopoulos *et al*. (1998), studying a SST series commencing in the 1970s cool period and extending from 1972 until 1993, define an increasing trend for the temperature in the southeastern Bay of Biscay.

With regard to the geographical location of the observations, Koutsikopoulos *et al*. (1998) found that the southeastern part of the Bay of Biscay showed the strongest warming trend for the period 1972-1993. In the southeastern corner of the Bay of Biscay, relatively strong continental influence modifies both the temperature and salinity of the shelf waters. Thus, the offshore surface waters are less saline, colder in winter and warmer in summer, than in the western areas at comparable latitude. Convergence and downwelling accumulate surface waters of oceanic origin in the southeastern Bay of Biscay; this mechanism modulates to some extent, the "overcontinentalisation". This term expresses the influence of the land climate and inputs on the ocean; it is related to the degree of enclosure of the adjacent sea, by the surrounding land (Valencia *et al.*, 2004). Hence, the southeastern Bay of Biscay can be considered as being less continentalised than typical enclosed or semi-enclosed embayments; nonetheless, it is more continentalised than other typically open sea areas. Moreover, the synergy (of two concave right-angled coastlines (Figure 1)) is enhanced, by the active land and river runoff throughout the coastlines.

In spite of the local character of the data collected along the Basque coast, the time-series are representative of mesoscale situations in the Bay of Biscay and indicate teleconnections with global scale factors such as the NAO. For instance, during the seventies, the low water temperatures in the area were related to the “Great Salinity Anomaly” (Dickson *et al*., 1988; Usabiaga *et al*., 2004). Thus, the time series from the Aquarium and AZTI showed that the period at the end of the eighties and the beginning of the nineties was characterised by the presence of warm and salty water at the NE Atlantic intergyre area (Pérez *et al*., 1995; Pérez *et al*., 2000; Valencia *et al*., 2003).

Within this context, this study compares the coupling of oceanographic and meteorological conditions, for the period 2001-2005, with those of the last two decades (1986-2005), in the southeastern Bay of Biscay.

Methodology

The study area is located in the innermost part of the Bay of Biscay (the Basque coast), between the west-east oriented coast of Spain and the north-south oriented coast of France (Figure 1). The Basque coast is clearly a marginal area of the northeastern Atlantic and, even, of the Bay of Biscay itself; it has some distinctive climatic and geographic characteristics. Thus, the concavity of the southeastern corner of the Bay of Biscay results in a continental influence in this region and, consequently, the shelf waters of the area are colder in winter and warmer and less saline in summer than the waters of western areas at equivalent latitudes (Valencia *et al*., 2003, 2004).

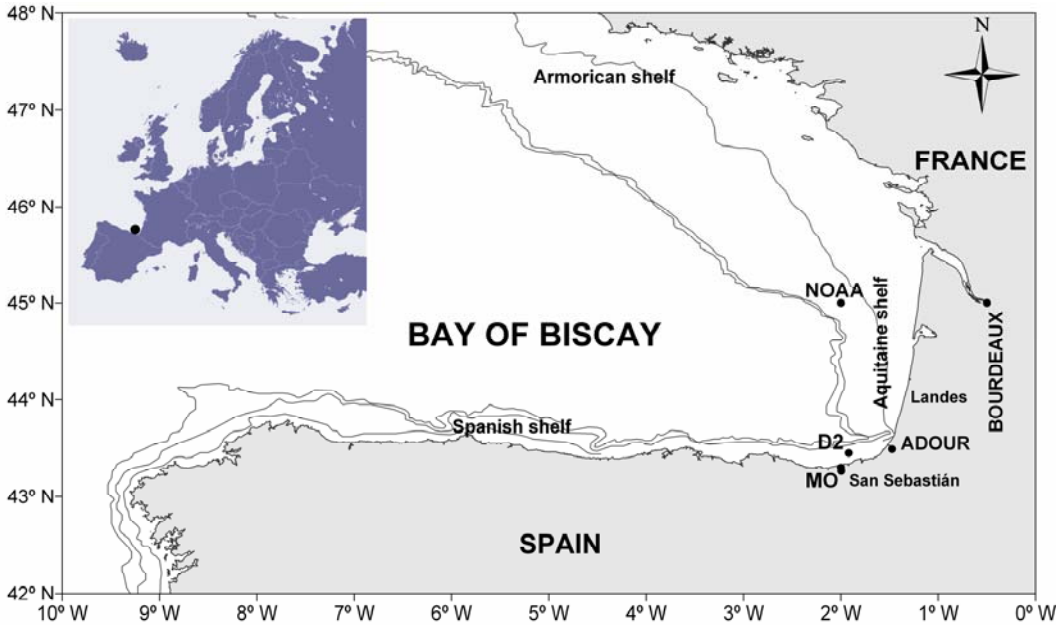

Figure 1. Location of the study area, showing the position of data series. Contour lines indicate 100 m, 200 m and 500 m isobaths. MO: Meteorological Observatory of San Sebastián; D2: AZTI's hydrographical station; NOAA: PFEL-NOAA; BORDEAUX: Bordeaux Port Authority; ADOUR: Adour River.

A brief description of the available data sets, including source, record length and sampling rate is listed in Table 1. In addition, the location of the sampling stations is shown in Figure 1. The Meteorological Observatory of San Sebastián (The National Institute of Meteorology, Spain) has supplied meteorological monthly data (atmospheric temperature, precipitation and evaporation), since 1986. The Aquarium of San Sebastián (Oceanographic Society of Gipuzkoa, Spain) has monitored SST since 1947; it constitutes the longest oceanographic series of the southeastern Bay of Biscay. Vectorial data of wind velocity, provided by the Pacific Fisheries and Environmental Laboratory, from the National Oceanic and Atmospheric Administration (PFEL-NOAA), forms the basis of the Upwelling Index (Borja *et al.*, 1996, 1998) (for location, see Figure 1). In addition, Gironde River flow daily data have been obtained from the Bordeaux Port Authority, whilst Adour River flow daily data have been provided by the National database on hydrometry and hydrology (HYDRO) (www.hydro.eaufrance.fr/accueil.html).

Table 1**.** Description of presented data sets, including source, record length and sampling rate. For locations, see Figure 1.

DATA	LOCATION	SOURCE	RECORD LENTGH	SAMPLING RATE
SST	San Sebastián	Oceanographic Society of Gipuzkoa	1947-2005	daily
Meteorological	San Sebastián	Meteorological Observatory	1986-2005	monthly
Vectorial data of wind velocity	45º N, 2º W	PFEL-NOAA	1967-2005	6 hours
River flow	Gironde	Bordeaux Port Authority	1952-2005	daily
River flow	Adour	HYDRO	1967-2005	daily
Hydrographical data	Basque shelf 43º 27'N, 1º 55'W	AZTI Foundation	1986-2005	monthly

Moreover, since 1986, AZTI Foundation has been undertaking monthly hydrographical surveys over the Basque continental shelf (Valencia, 1993; Valencia *et al.*, 1989, 1996, 2003, 2004) (for location, see Figure 1). Research has been undertaken into short-term and long-term variability, at meso- and local scales. As a result of this pluriannual sampling programme, the main oceanographic

variables are represented by two decades of observations (1986-2005) for the Basque coast; they constitute a time-series of monthly temperature and salinity values, over a water column of about 100 m in depth.

Results and discussion

The oceanographic data collected in this study show a coupling with the meteorological conditions observed over the southeastern Bay of Biscay. The monthly air temperature and SST over the period 2001-2005, in relation to the mean ± standard deviation for the period 1986-2005, are shown in Figure 2.

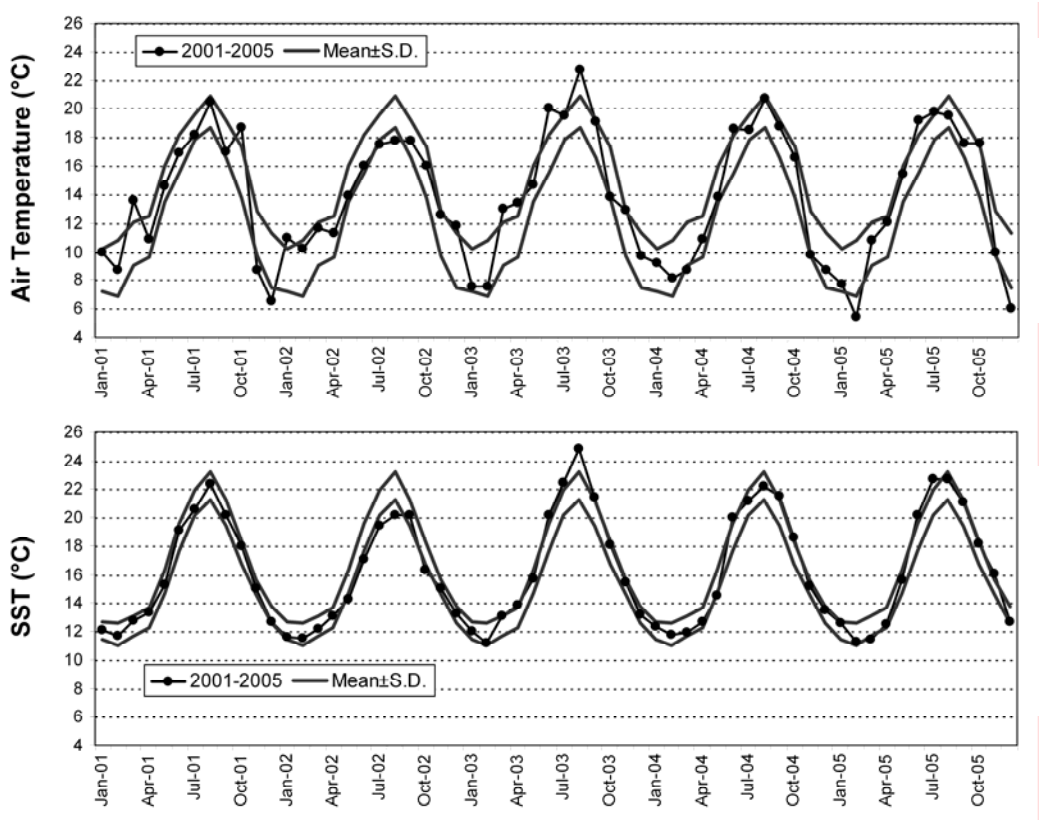

Figure 2. Monthly average air temperature (°C) and sea surface temperature (°C) in San Sebastián, over the period 2001-2005, in comparison with the mean ± standard deviation for the period 1986-2005. Data courtesy of the Meteorological Observatory of San Sebastián and the Oceanographic Society of Gipuzkoa, respectively.

With reference to the air temperature, extreme events can be inferred from Figure 2: a cold autumn in 2001; a warm winter and autumn and cold and long spring in 2002; a cold winter in 2003, followed by extremely warm spring and summer in 2003; a cold and long winter in 2004 and warm and long summer in 2004; and a long and warm spring season in 2005. Within this context, the period 2003-2005 is characterised by the prevalence of winter and summer seasons. The latter observation appears to indicate a “deseasonalisation”, in relation to the classical seasonal cycle of the Atlantic climatic regime, at mid-latitudes. This means that winter-summer duality prevails over the establishment of spring and autumn, as transitional seasons. Within the period 2003-2005, 2004 can be defined as the most representative case of "deseasonality". Nevertheless, it can be described as an average year, resulting from a cold winter and a warm summer.

Although frequent seasonal anomalies are evident for the past 5 years in comparison with the last two decades, the anomalies are scarce in terms of annual values. Thus, the annual mean air

temperature over the southeastern Bay of Biscay, during 2001, 2002, 2004 and 2005, have remained at nearly the same value as during the last two decades; however, 2003 can be defined as an anomalous year, in comparison with the last two decades, i.e. 0.9°C over the 1986–2005 average.

With regard to the SST, the pattern is similar to that observed for the air temperature. Differences are related to the thermal properties of the water (high specific heat), as well as the dynamic aspects such as upwelling-downwelling duality, turbulence, etc. The annual SST over the southeastern Bay of Biscay during 2001, 2004 and 2005 has remained at nearly the same value as during the last two decades, excluding 2002 and 2003; there are 0.8°C below and 0.7°C over the 1986–2005 average, respectively.

With regard to the water balance, the evolution of the seasonal average precipitation in San Sebastián is shown in Figure 3.

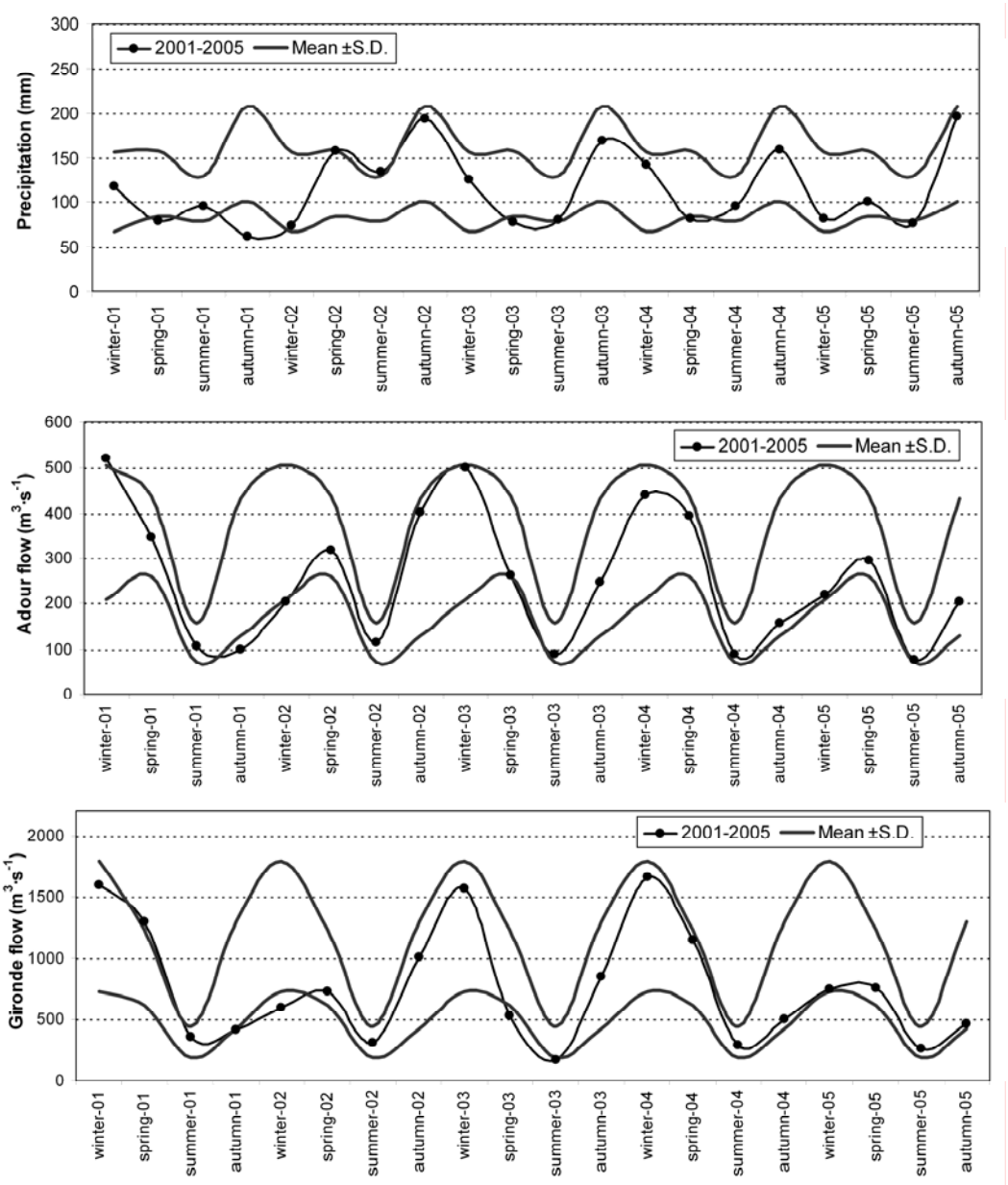

Figure 3. Seasonal average precipitation (mm) in San Sebastián and seasonal average Adour and Gironde River flows ($m^3 \cdot s^{-1}$), over the period 2001-2005, in comparison with the mean ± standard deviation for the period 1986-2005. Data Courtesy of the Meteorological Observatory of San Sebastián, the National database on hydrometry and hydrology (HYDRO) and the Bordeaux Port Authority, respectively.

The peculiarities of the precipitation in the period 2001-2005 are characterised by a very dry spring and autumn in 2001 and the winter in 2002; these are followed by rainy weather in spring, summer and autumn 2002. Following this period, the beginning of 2003 showed a slight recuperation in precipitation followed by a very dry spring and summer. After that, the precipitation shows a recovery, until the winter of 2004. Spring in 2004 and winter, spring and summertime seasons in 2005 were once again very dry. In this way, despite frequent seasonal anomalies for the period 2001-2005, in comparison with the last two decades, the anomalies are less evident in terms of annual values. Hence, only 2001 can be characterised as an extremely dry year, in comparison with the 1986-2005 average. However, 2002 has remained at nearly the long-term mean + standard deviation for the period 1986-2005.

Anomaly patterns and general trends are very similar if the Adour River flow (or even the Gironde River flow) is considered as representative of the land runoff, the input of continental water into the study area and, subsequently, as a complementary factor regulating the salinity of the offshore waters (Figure 3). The Adour River and the Gironde River flows (to a lesser degree), represent well the water inputs into the southeastern Bay of Biscay.

With regard to the dynamic aspects related to the wind velocity and direction, the upwelling-downwelling balance over the period 2001-2005, in relation to the mean ± standard deviation for the period 1986-2005, is shown in Figure 4. Several extreme events related to the wind conditions can be observed, e.g. the prevalence of downwelling conditions in 2001, with the exception of November; this event should reinforce the vertical mixing of the water column in this period. In general, extreme conditions, in terms of upwelling-downwelling balance, were counterbalanced by extreme events in the opposite direction (October-November 2001, September-October 2002, October-November 2004 and October-November 2005). The upwelling-downwelling evolution in the period 2001-2005 shows frequent anomalies; however, these are less frequent, in terms of annual values. Within this context, 2005 can be defined as an anomalous year in terms of upwelling-downwelling balance, due to the prevalence of upwelling conditions in winter.

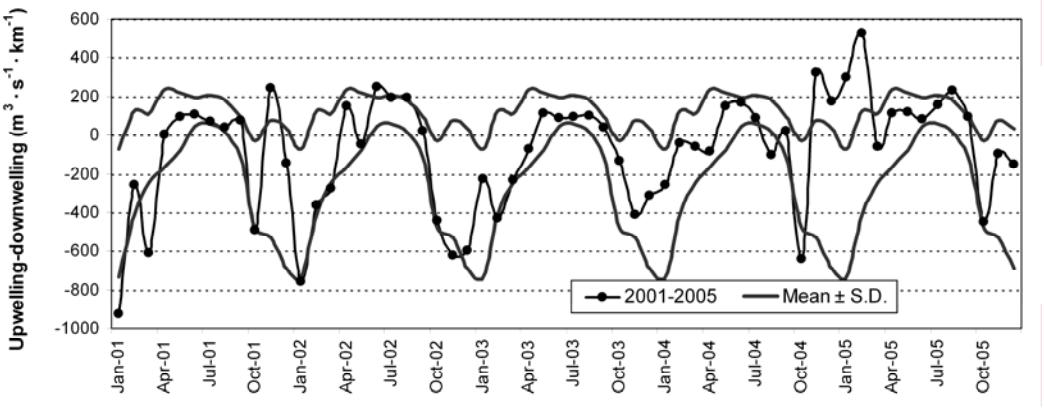

Figure 4. Monthly average upwelling-downwelling balance ($m^3 \cdot s^{-1} \cdot km^{-1}$) over the Landes plateau (45°0′N 02°0′W), for the period 2001-2005, in comparison with the mean ± standard deviation for the period 1986-2005. Data Courtesy of the NOAA (FNMOC: Fleet Numerical Oceanographic Centre; and PFEG: Pacific Fisheries Environmental Group).

Conclusions

The coupling of oceanographic and meteorological conditions for the period 2001-2005, in relation to those over the last two decades, is presented for the southeastern Bay of Biscay. The main conclusions are summarised below:

- The time-series presented here constitute valuable oceanographic and meteorological data extending over about two decades; they include the basic descriptors of the water masses over the continental shelf and slope, as well as meteorological variables over the Basque coast. In spite of the local character of the data collected along the Basque coast, the time-series shows trends that agree with the anomaly patterns depicted for the northeastern Atlantic Ocean, for previous and recent periods.

- The period 2001-2005 is characterised by extreme events that tend to favour or establish a "deseasonality", against the classical seasonal cycle of the Atlantic climatic regime in mid-latitudes. Although frequent seasonal anomalies are evident in the period 2001-2005, in relation to the complete time-series, scarce anomalies in terms of annual average values can be found.

Acknowledgements

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