GEOPHYSICAL RESEARCH LETTERS, VOL. 27, NO. 2, PAGES 241-244, JANUARY 15, 2000

Validation of AVHRR Pathfinder SST's over the Mediterranean Sea

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Abstract. Pathfinder Sea Surface Temperatures (SST) have been validated for the Mediterranean Sea using independent data obtained from MEDATLAS CTD and XBT casts. The Mean Bias is, in most of the case less than 0.5° C, with a mean value of 0.2 °C. The bias was uncorrelated to the number of Mediterranean matchups points used to evaluate the coefficients of the SST Pathfinder algorithm. This implies that Pathfinder data over the Mediterranean Sea represents a coherent time series of temperature that can be used for climatological applications. As an example of such an application the time series of the mean Mediterranean SST is discussed for the entire period of available data (1985-1996). The analysis shows evidence of interannual variability but does not suggest an evident increasing trend for SST as suggested by previous works. Comparison with corresponding meteorological data (COADS) confirms the close correlation between meteorological forcings and SST field.

1. Introduction

During last decade, investigations of the Mediterranean Sea have benefited from the use of satellite data. Since the 90's remotely sensed data have been used to complement the analysis of in situ data (Crepon et al. 1982, Böhm et al. 1986, Taupier-Letage and Millot, 1986) as well as to organize in situ measurements where new circulation had been remotely observed (Alpers and Salusti, 1983; Böhm et al. 1987; TEMPO group, 1991).

The first systematic analysis of a multi-year time series of AVHRR data has been done by Santoleri et al. (1994). They analysed a nine-year satellite data set of 18 km/weekly AVHRR-MCSST (Multi Channel Sea Surface Temperature) images to study the Western Mediterranean Basin's seasonal and interannual thermal variability both as an indicator of the circulation variability and the long-term Sea Surface Temperature (SST) variability. The analysis revealed an increasing trend of 0.15 °C/year and strong interannual variability of the SST field that is seasonally and regionally dependent.

Other authors used AVHRR-MCSST data to observe recurrent mesoscale eddies in the eastern Mediterranean Sea (Anna et al. 1996) or to force real-time nowcast/forecast models of the circulation of the Mediterranean Sea (Horton et al. 1997). Artale et al. (1999) was the first to use daily Pathfinder AVHRR data to force a General Circulation Model and were able to model the deep and intermediate water formation and circulation of the Mediterranean Sea.

The primary objectives of this paper are (1) to validate Pathfinder SST data over the Mediterranean Sea using independent CTD and XBT casts obtained from the MEDATLAS data set; and (2) to study the seasonal and interannual variability of the SST field over entire Mediterranean Basin from 1985 to 1996.

2. The Data

The SST data used in this paper is a Mediterranean subset of the AVHRR Pathfinder product. Pathfinder is a joint NASA/NOAA project devoted to the production of global SST maps from 1981 to the present. Pathfinder data are available at daily/9 km time/space resolution, for day and night passes separately, and are derived from 4-km Global Area Coverage (GAC).The details of the processing can be found in work by Evans and Podesta (1996) and the description of the method used to derive SST algorithms is described by Kilpatrick et al. (1999). The in situ data used for the regression are archived in the so called "matchups files" that contain co-temporal, co-located AVHRR and in situ observations. The SST values included in the Pathfinder matchup data base are obtained from buoys deployed and operated by various meteorological and oceanographic agencies or programs in the U.S. and other countries (Podestà et al. 1995) .

In the particular case of the Mediterranean Sea, matchups data are available from 1991 to 1997 and represent a small fraction of the total data. A detailed analysis of the matchups data files revealed that the number of cloud free Mediterranean matchups points that contributed to the definition of the SST algorithm parameters varies from 1% to 5% of the total with a maximum of ~8% in summer 1996 (figure 1, lower panel).

3. SST Validation

In order to validate the Pathfinder SST estimates over the Mediterranean Sea, we used independent (i.e. not included in the matchups files) SST measurements obtained from MEDATLAS CTD and XBT casts. The hydrological data set of the MEDATLAS data bank consists in a collection of 50665 temperature and salinity profiles collected with CTD, Bottle, XBT and MBT. These data sets originate from various European laboratories and projects.

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Paper number 1999GL002357.
0094-8276/00/1999GL002357$05.00

In this work CTD(or XBT) data interpolated at standard MEDATLAS levels using a weighted parabolic interpolation (Reiniger and Ross, 1968) are used. The surface temperatures used for the comparison correspond to the first observed value if any measurement is available above the second standard MEDATLAS level (5 m).

Figure 1 shows the results of the comparison between night passes Pathfinder SST and MEDATLAS SST's separately for CTD (fig .1, upper panel) and XBT (fig. 1, central panel) and indicates the number of satellite/in situ data pairs used to estimate the bias. The Mean Bias Error, (MBE =MEDATLAS CTD[XBT] – Pathfinder SST) has been calculated for each season as well as the standard deviation (error bar in fig. 1). In most of the cases, the MBE is well under 0.5° C with a mean value of 0.2 °C. An exception is represented by winter 1985 where MBE reached 1 °C, but in this case only 5 data points were available for the comparison. The MBE time series do not exhibit any general trend, apart for the period spring 1988 to spring 1992 when MBE continuously increased from -0.5 °C to 0.5 °C. This time period corresponds to the first 4/5th of the NOAA-11 life span. A similar trend is not visible in the comparison with the XBTs; this implies that it would not be correct to ascribe the trend to some instrumental drift. In general the comparison with the XBTs show a slightly higher MBE (0.4 °C in the average) but essentially confirms the good performance of the Pathfinder SSTs. Finally it is important to note that the bias does not depend from the percentage of Mediterranean matchups data points utilized for the estimates of the coefficients of the SST algorithm; this is true even when the percent of the Mediterranean matchups points goes to zero.

Comparison using radiometric skin temperature measurements and Pathfinder estimates, made at low and mid latitudes, suggests that the bias is 0.07 ± 0.31 °C (Kearns et al., 1999) where the reference temperature is the skin radiative temperature. The mean skin to bulk temperatue difference is –0.12 ± 0.17 (Kearns et al., 1999). Thus the bias between Pathfinder and bulk SST should be essentially zero (bulk SST – Satellite SST = 0.05 °C). These observations apparently disagree with the 0.2 °C bias we found between MEDATLAS CTD and Pathfinder SST. On the other hand, supposing still valid the 0.12 °C bulk to skin bias for the Mediterranean Sea, the same argument implies that, in the Mediterranean, Pathfinder underestimate the skin surface temperature by only 0.08 °C.

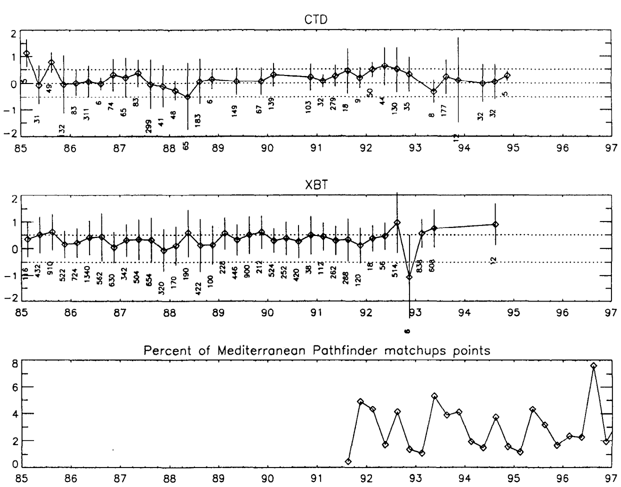

Figure 1. Seasonal behaviour of the MBE (CTD–satellite in upper panel; XBT–satellite in central panel) and percent of Mediterranean matchup points (lower panel).

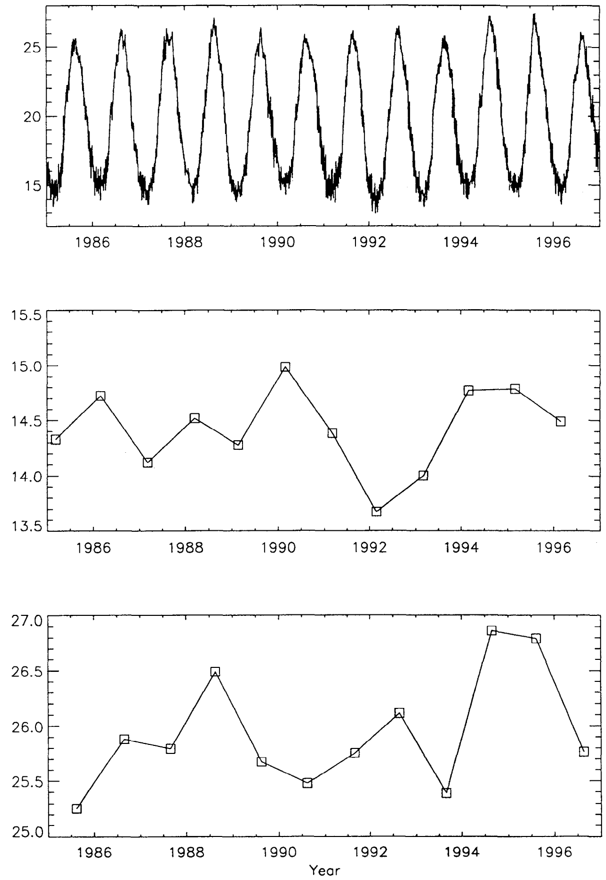

Figure 2. Time series of the mean Mediterranean Sea surface temperature (upper panel). Time series of the 30 coldest day of each year (central panel) and 30 warmest days of each year (lower Panel).

The conclusion that one can derive from the validation of the Pathfinder SSTs is that re-analysis of the AVHRR data performed by the Pathfinder project have produced a consistent time series of Mediterranean SST data that can be utilized to study seasonal and year-to-year variations over the whole decade 1985-1996. In the next section we will analyse the time series of SST from 1985 to 1996 over the Mediterranean Sea.

4. Time Series of Averaged SST

Figure 2 (upper panel) shows the time series of the mean sea surface temperature of the Mediterranean Sea. Apart from the seasonal signal the time series exhibits an evident interannual variability that becomes more evident starting from 1992 when the minimum temperature of the time series has been reached. There was year to year variation in the temperature minima and maxima during winter and summer. The central and lower panel of figure 1 display the behaviour of the mean value of the sea surface temperature during the 30 coldest and warmest days of each year respectively. Both "winter" and "summer" time series show large oscillations of varying amplitude.

The time series of the winter minima can be divided into two distinct periods. From 1985 to 1989 the winter SST weakly oscillates from 14.1 °C to 14.7 °C with an absolute minimum in 1987. After the 1990 maximum of 15 °C, the temperature drops down to 13.7 °C in two years, reaching the 1992 absolute minimum. After a second cold winter in 1993 with temperature slightly less than 14 °C, the temperature rises to values observed in 1990 with a further decrease in 1996. The two coldest events of 1987 and 1992 corresponds to the 1986-87 and 1991-92 El Niños. Even if it is not correct to directly correlate the two phenomena it is interesting to underline this coincidence. The same coincidence has already been found by Santoleri et al. (1994) for years 1983 and 1987, using MCSST data over the Western Mediterranean Sea.

During summer, excluding the two maxima observed in 1988 (26.5 °C) and 1994-1995 (26.8-26.9 °C), the temperature varies from 25.2 °C to 26.2 °C. Peak values of the SST time series (upper panel of figure 2) for the 1988 and 1994 differ by less than 0.1 °C and 1995 is 0.2 °C warmer than both. On the other hand the 30 days average (lower panel of figure 2) shows a 1988 0.3 °C colder than 1995 and 0.4 °C colder than 1994.

The seasonal and interannual variability of the SST is essentially linked to the meteorological forcing, namely the wind intensity (and direction) and the near surface air temperature. Northerly cold dry wind produces enhanced sea-air heat fluxes that could induce cold SST and air temperatures. This hypothesis can be confirmed by analysing the meteorological data relative to the same period of the SST time series. Gridded COADS (Comprehensive Ocean-Atmosphere Data Set) data can be used to study the correlation between SST and the meteorological forcing. COADS include fully quality-controlled reports and summaries primarily obtained by ships-of-opportunity. These global marine data have been collected, edited and summarised statistically for each month, using two degrees latitude by two degrees longitude boxes (Slutz et al., 1985).

We select Mediterranean Sea wind intensity and near surface air temperature for the years 1985-1993 (gridded COADS data after 1993 are not yet available). Figure 3 shows the time evolution of the mean wind intensity (upper panel) and near surface air temperature (lower panel). The comparison between the SST satellite data and the meteorological data confirms the hypothesis of the direct correlation between cold SST events and air-sea interactions. The most evident features is the coincidence of the cold SST event occurred in 1992 (figure 2 central panel) and the relatively stronger winds observed between the end of 1991 and the beginning of 1992. These strong winds are associated with cold values of the near surface air temperature measured in winter 1992. A second less intense minima have been detected in the SST's of 1987. Also in this case this minimum is associated with cold air temperature minima and stronger winds. Conversely the absolute winter SST maximum of

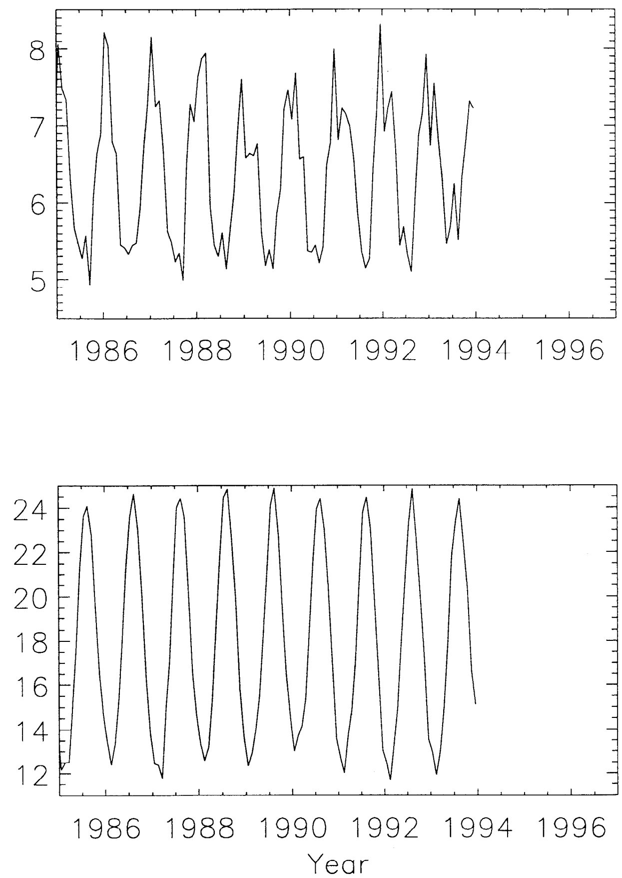

Figure 3. Time series of mean wind intensity (upper panel) and mean near surface air temperature (lower panel) from gridded COADS data.

1990 corresponds to lower winds (upper panel in figure 3) and higher value of winter air temperature (lower panel of figure 3). Of course a more detailed analysis at sub-basin scale will be more appropriate to discriminate the role of the various Mediterranean areas on the whole basin climate but this is out of the scope of this short note.

5. Conclusions

Twelve years of satellite SST data have been used to validate the NASA Pathfinder data set over the Mediterranean Sea. The validation has been done by comparing Pathfinder SST's with corresponding in situ data derived from MEDATLAS CTD and XBT (separately).

The mean bias is, in most of the cases, well under 0.5° C with a mean value of 0.2 °C. Moreover no trends are observed in the MBE time series. This means that re-analysis of the AVHRR data performed by the Pathfinder project has produced a consistent time series of Mediterranean SST data that can be utilized to study seasonal and year-to-year variations over the whole decade 1985-1996. Considering that satellite-buoy matchup points, used to estimate the parameters of the AVHRR SST algorithms are very scarce or either absent for the Mediterranean Basin (no matchup points are present before 1991) the good result of this validation is of fundamental importance for Mediterranean Pathfinder users.

The analysis of the SST time series have shows an evident seasonal and interannual variability but do not suggest any particular increasing (or decreasing) trend. Other authors have observed local trends of 0.01-0.02 °C/year off Barcelona (Bethoux et al., 1999; Pascual et al., 1995) and in the Naples bay (Mazzocchi and Ribera, 1995) using in situ data for the periods 1973-1994 and 1984-1991 respectively. Differences in the observed trend can be explained considering time periods and (mainly) area extents.

The more evident signatures of the year to year variability observed in 1987 and 1992 are due to the colder winters. Warm events are observed in 1994 and 1995. Moreover the comparison with corresponding COADS data indicate that the two data sets are essentially consistent and underlines the close relationship between meteorological forcing and sea surface temperature.

Acknowledgements, We thanks the JPL PO.DAAC that make the Pathfinder SST data freely available and Dr. R. Evans for the stimulating discussion and help in revising the manuscript. The work was carried out with the support of the Agenzia Spaziale Italiana (ASI). The editor would like to thank the reviewer of this manuscript.

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(Received, June 25, 1999; revised October 01, 1999; accepted November 08, 1999)