LONG TERM VARIABILITY OF THE MEDITERRANEAN LARGE SCALE CIRCULATION

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Abstract

It is now well established that the Mediterranean Sea general circulation exhibits a strong interannual variability, appreciably affected by seasonal influence, and notably dependent on decadal and interdecadal changes. The purpose of this contribution is to show that existing long term global data sets contain sufficient information to diagnose a significative part of this signal. In particular, an analysis of SST interannual anomalies over the gulf of Lions is presented, revealing a clear signature of 2, 3 and 6 years periodicities in that region.

Key-words : circulation models

The Mediterranean Sea general circulation has been found recently to be strongly dependent on the time variability of the forcing at the air-sea interface (1). In various part of the basin, observations clearly indicate that currents can be very different form season to season and from year to year. Water masses formation rates are found to vary interannually and water mass properties can evolve on much longer time scales.

The outstanding coupled seasonal and interannual signal stands out from many observation. In particular, the Winter season shows the greatest water mass formation interannual variability due to the strong air-sea coupling at the level of momentum, heat and water fluxes. The Summer season shows instead the largest interannual variability in the current regimes, anticyclonic versus cyclonic surface flow field, temperature of the mixed layer.

Even sub-basin scale gyres can change or disappear from year to year. For example, the Shikmona gyre was not present from 1979 to 1982 but became persistent ever since or with occasional disappearances (2, 3) ; the Iera-Petra gyre, not previously mentioned in the Levantine basin circulation, has been the largest sea surface height anomaly from 1992 to 1994, as revealed by satellite dynamic topography (4).

Decadal or interdecadal changes are recorded by strait transports and by the recently discovered change in the Eastern Mediterranean abyssal circulation (5). The latter occured during the first pentade of the nineties, perhaps due to a combination of decadal salinity changes and interannual variability of the atmospheric forcing over the Levantine and Aegean sea regions.

Despite of all those observational evidences, theories explaining seasonal-interannual-decadal changes in the Mediterranean Sea general circulation and its associated water mass properties have not been formulated for the whole interacting system. Seasonal and interannual variability has only been interpreted as a response of the basin to the atmospheric forcing variability at the corresponding time scales (6, 7). In particular, wind forcing was found to be responsible for more than 70 % of the basin current kinetic energy ; its changes in magnitude and direction can cause very rapid changes in circulation structures (8).

Numerical simulations show already that anomalous amplitude of the winter wind stress curl can induce changes susceptible to modify the regular occurence of the seasonal cycle in the basin (1).

But observation suggest that other sources of energy should be searched for. It seems for instance quite difficult to explain such radical changes in sub-basin scale gyres (especially in the Eastern Mediterranean) without invoking additional mechanisms, such as internal non-linear energy redistribution / dissipation or topography trapping. However, initial results from numerical simulations suggest that the internal variability due to nonlinear processes can be small with respect to the interannual signal directly forced by atmospheric forcing. Theoretical investigation should continue to investigate the possibility of topographic interactions as directly responsible for the persistence of anomalous features in the basin.

However, a general conclusion that comes out from that observational as well as theoretical picture, is the necessity of a global approach across the time scales (from seasonal to decadal) and over the whole basin. Indeed, due to the strong coupling between the different processes involved, there is a need for a comprehensive and coherent study of atmospheric forcing and hydrographic parameters together with long term numerical modelling. The purpose of this contribution is to show that long term global data sets contain an interannual variability signal as well as numerical simulations.

As surface atmospheric data, we use the COADS fluxes (9), extending from 1946 to 1993. Theses fluxes are used to force a general circulation model implemented on the Mediterranean (1), with an horizontal resolution of a quarter of a degree and 31 vertical levels. On the other hand, the MODB and MEDATLAS hydrographic data bases provide an adequate interannual data coverage for about the same period. It is indeed possible to show that, using the final MODB monthly climatological cycle (10) as reference, we can obtain a relevant estimation of the interannual temperature signal for this full period, nearly everywhere in the basin. This remarkable property comes from the very long horizontal correlation length that we can use to analyse temporally the interannual anomalies.

As an example, we present here (fig. 1) the interannual SST signal objectively analysed from the MODB data, in the Gulf of Lions area, using a 45 days correlation time scale. The solution obtained, sampled every month, extends from 1950 to 1990. A spectral analysis of this time serie (fig. 2) reveals three powerful periodic components emerging from the noise, at the 6, 3 and 2 years time period (respectively 1/6, 2/6 and 3/6 years^{-1} frequencies). Let us also note that the peaks observable at the frequencies 0 years^{-1} (annual climatic mean) as well as at 1 years^{-1} (with all harmonics, seasonal cycle anomaly) represents a correction that this time analysis would suggest to the background climatology that we have used (that did not care of the year to year repartition of the data).

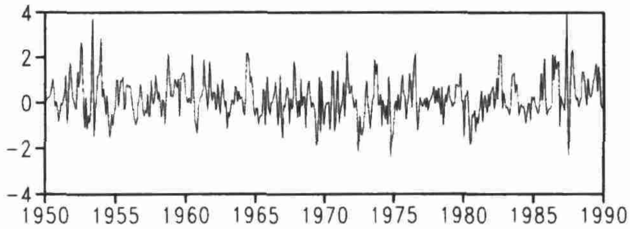

Figure 1 : SST interannual anomaly in the gulf of Lions area, objectively analysed from the MODB data, using a 45 days correlation function. The solution, sampled every month, extends on 40 years from 1950 to 1990. It is expressed in Celsius degrees.

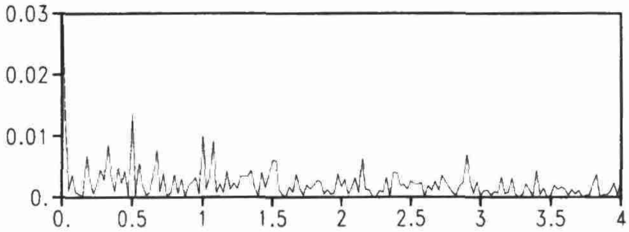

Figure 2 : Power spectrum (computed by FFT) of the time serie represented on figure 1. Frequencies are in years-1. The 2, 3 and 6 years periods are clearly emerging.

Figure 3 compares the reconstructed signal for the window of period ranging from 2 to 10 years (dashed line) to the 6 years periodic signal reconstructed from the three main frequencies (continuous line). (The latter was reconstructed for a spectrum computed for the last 36 years, in order for the main frequencies to correspond exactly to the spectrum discretisation values). Except for the 1964 to 1972 period where a 3 years signal seems to come up, this figure shows that this time window (2 to 10 years) is strongly dominated by the 3 frequencies mentionned before. We should consequently be able to track back those periodicities in the atmosphere, especially in the North Atlantic Oscillation which governs the Western Mediterranean