Larissi et al., J Mar Biol Oceanogr 2013, 2:1
http://dx.doi.org/10.4172/2324-8661.1000107

Journal of Marine Biology & Oceanography

Research Article

A SCITECHNOL JOURNAL

Impact of Inter-annual Coastal Upwelling Variability (2001-2010) on the Productivity of the Moroccan Atlantic South Area (21° - 26°N)

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Abstract

The pelagic ecosystem of the Moroccan Atlantic coast is mainly governed by the upwelling variability. The area between Cape Boujdor (26°N) and Cape Blanc (21°N) was water sampled annually during winter and summer from 2000 to 2010. This area is characterized by intense coastal upwelling which's highly variable (seasons and in space basis) and with an active centre localized at 25° 30'N section.

Additionally to the *in-situ* data, satellite data was used for a synoptic view and for a complementary inter-annual study of upwelling impact on the coastal ecosystem. Evolution of physical and chemical parameters such as temperature (*in situ* and from satellite), salinity and nutrients, display a low activity of upwelling during the last autumn (2010) in comparison with the high activity during 2007- 2008.

This inter-annual variability of upwelling activity is confirmed by the calculation of upwelling index derived from SST data satellite (Modis-Aqua). Biologically, the variability of the hydrological environment affects the pelagic ecosystem productivity, and particularly by chlorophyll 'a' and zooplankton biomasses that has a significant effect on small pelagic fish eggs production.

Keywords

Variability; Upwelling; Hydrological parameters; Productivity

Introduction

The coastal upwelling area off Northwest (NW) Africa is one of the four large systems of Eastern Boundary Currents (EBC) within the trade wind belts of the subtropics. Many aspects of this coastal upwelling have been verified by observations and modeling during the last 30 years. Important aspects of this EBC regime was reviewed by Barton [1] on the base of observations along both the Northwest African and Iberian coast while. Equatorial upwelling allows nations such as Morocco to have major worldwide fishing industries.

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Received: December 06, 2012 **Accepted:** January 21, 2013 **Published:** January 25, 2013

The Canaries Current ecosystem is divided in three areas: first the northern Moroccan coast with seasonal upwelling in summer, secondly the south Moroccan and north Mauritanian coast with permanent upwelling (Sahara Desert) which it will be treated in this paper and finally the south Mauritanian and Senegalese coast with boreal upwelling. The southern part of Morocco is characterized by high seasonal variability, alternating between an ecosystem under tropical influence in summer and a coastal upwelling ecosystem in winter. This alternation is accompanied by a migration of certain tropical species (tuna and tuna-like fishes) up to 21°N during summer, and by a southward extension of the habitat of temperate species such as the pelagic species *Sardina pilchardus* during winter.

Moreover, the pelagic ecosystem along the Atlantic Moroccan coast is governed by both variability in space and time regarding upwelling activity. Upwelling has a consequence to sustain high biological productivity and hence a high fisheries production, mainly in the south area between 26°N (Cape Boujdor) and 21°N (Cape Blanc) where the activity as regards fishing is very important [2]. In addition, this ecosystem is subjected to a space-time variability on different scales, which plays an important role in life cycles and in fish population distribution, as well as on plankton populations [3].

The Inter-annual studies are very rare in the area. There were long-term studies of upwelling intensity e.g. by Arfi, 1987 [4]. However it was restricted to hydrographic features only. In this paper, our attention is focused on the follow-up the upwelling of the southern zone through data gathered in situ and by satellite imagery and on the evolution of the hydrological characteristics, particularly at Cape Boujdor (25°30' N) transect which corresponds to the most active center of upwelling in the Moroccan Atlantic coast [5-7]. And it will allow us to illustrate the temporal variability of the upwelling on a decade and to detect the impact on the productivity in this transect.

Materials and Method

Data result used were collected from the national and international hydrological cruises (INRH and jointly with Russian V/R "Atlantida"). The cruises were carried out twice a year during autumn and summer from 2001 to 2010. The temperature and salinity were collected by a multi-probe using (Neil Brown) and mounted on a 24 bottle GO rosette sampler equipped with 12-l Niskin bottles. Water samples for chlorophyll 'a', phosphates and dissolved oxygen analysis were taken at various levels of the water column. Chlorophyll 'a' was analyzed by fluorometry method [8] by means of a Turner Designs bench fluorometer, previously calibrated with pure chlorophyll 'a' (Sigma) [9] phosphates by spectrophotometry method and dissolved oxygen by Winkler method [10]. The collection of the zooplankton was carried out using a Bongo net on the water column and the results are expressed in wet biomass. The network of sampling is composed of stations along transects. The number of stations along each transect is variable according to the width of the continental shelf.

This network will be useful for the surface distributions of temperature and phosphates. For the other analysis, only data from the coastal station of 25°30'N transect will be used (temperature, salinity, phosphates and dissolved oxygen) and for the maximum

doi:http://dx.doi.org/10.4172/2324-8661.1000107

of chlorophyll ‘a’ and zooplankton biomass an average along this transect were used.

Moreover, the previous and known literature show that the upwelling can be observed by different indexes one calculated through wind data as the Ekman transport component in the direction perpendicular to the shoreline [11-13] and other calculated through SST data. We have chosen to calculate a mean of upwelling index (UI) as the difference between the SST value at a coastal location and the SST value at an oceanic location with the same latitude following the method described by Nykjaer and Van Camp, Santos et al. and deCastro et al. [12,14,15].

Results

Surface distributions

Sea surface temperature time series analysis shows that’s in summer season and during every year, the Cape Boujdour upwelling is almost always active, with a maximum of activity in 2007. Indeed, the minimal values of the temperature (15.24°C) were recorded, at the coast in 25°30’N transect and which coincide with very important contents in phosphates (1.49 µM). Except for the year 2010, the area between 25°30’N and 24°N is featured with cool water that are very restricted to the coast at 25°N. South of 24°N, the weak activity of upwelling between 21 and 22°N was not an obstacle against an important wealth of phosphates which is due mainly to the influence of the Southern Atlantic Central Water (SACW) which is hot (> 21°C), and concentrated in phosphates (> 0.7 µM) (Figure 1).

During autumn season, a weak activity of upwelling is recorded in 2008 and 2009, mainly at cape Boujdor which is evident by surface drift of the 19°C isotherm to the south of 25°N. These upwelled waters start from Dakhla (24°N) and reach their maximum at cape Blanc (21°N). On the other hand, during the other years, upwelling is

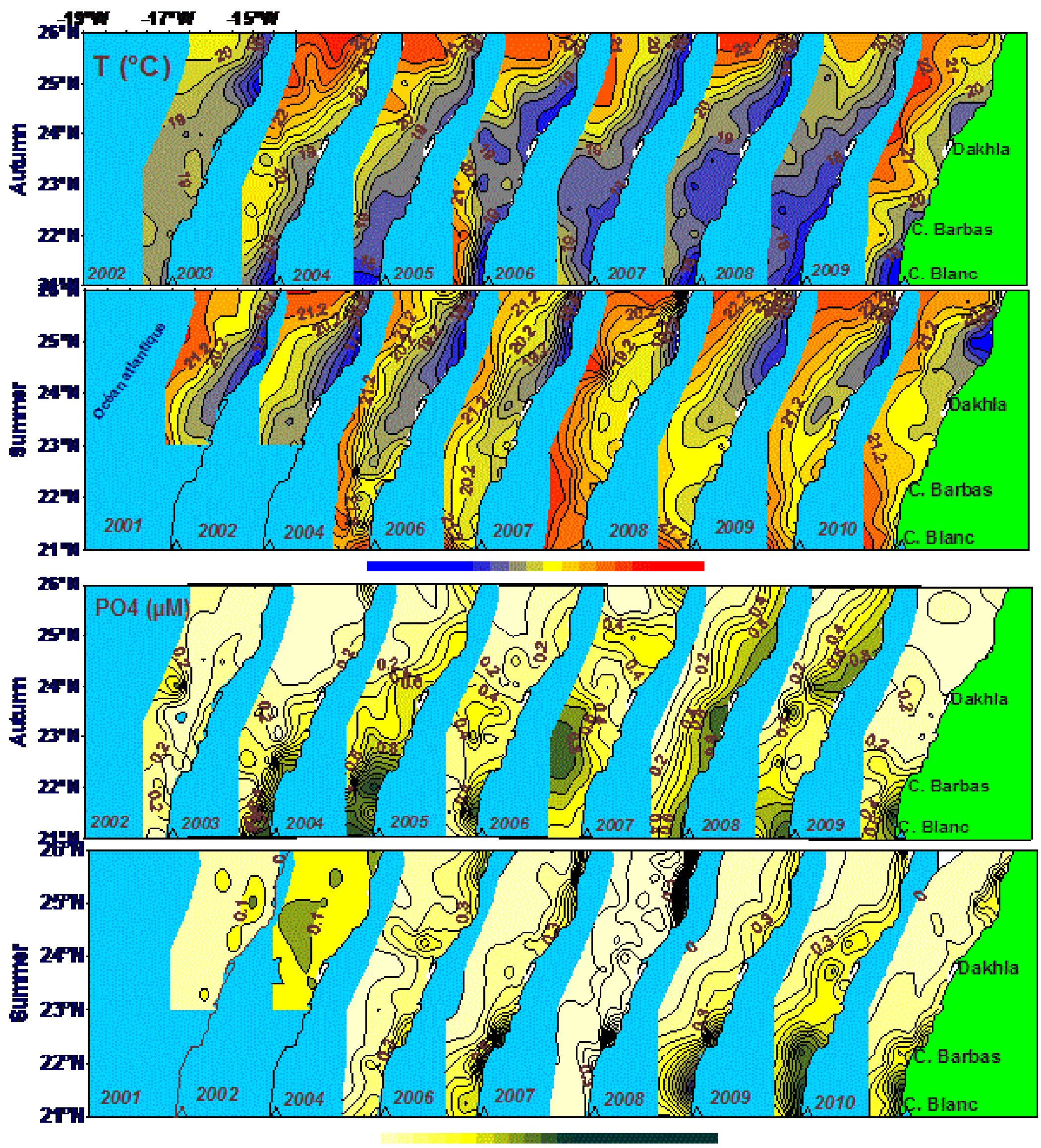

Figure 1: Surface temperature and phosphates distributions in south region 26°N - 21°N (2001 – 2010) (Seasons: Autumn - summer).

important in the southern area (21°-26°N), mainly during 2007 which is characterized by the highest upwelling intensity, the temperature anomaly between coast/offshore was -4,8°C. The contents in phosphates during autumn season vary between 0 and 1.58µM. The strongest concentrations are detected at the coast at Cape Blanc. On the other hand, in the area between Boujdor and Dakhla, high contents in phosphates were recorded in 2007 and 2008 (Figure 1).

In addition, and comparatively to the summer season, which corresponds to the season of strong activity of upwelling, 25°30' N is the transect where the most important active center of upwelling takes place whose origin between 200 and 300m depth. Vertical distribution of temperature and phosphates at this area (25°30' N), shows that in summer 2007, upwelling is located at 300m and confirms a strong activity of upwelling through cool water occurrence (15.5°C and 0.2 µM) (Figure 2).

Interannual variability at 25°30' N transect

Physical and chemical parameters: Inter-annual evolution of sea surface temperature at the coastal station of 25°30' N transect during summer seasons of 2001 to 2006, shows that values fluctuate between 17° and 18°C. In 2007, a remarkable decrease in temperature (15.2°C) was recorded. After a resumption of warming in 2008, which is accentuated in 2009 (18.9°C), a downward trend is observed in 2010 (18.1°C) (Figure 3). In autumn, inter-annual variability is more pronounced (16.7 - 20.7°C). 2003 and 2009 are characterized by the highest temperatures.

Time series analysis of sea surface temperature anomalies (SST year – SST mean) of every year confirms the inter-annual variability in upwelling activity and in addition confirms the strong activity of summer 2007 and the warming of 2009 and 2010 (Figure 4).

For the other physical and chemical parameters, variability of the water surface salinity is not as marked as that of temperature during two seasons. However that of dissolved oxygen and phosphates indicates changes of contents accentuated from year to year. The strong high content in phosphates during summer 2010 is probably due to another origin other than the contribution of upwelling (Figure 5) and probably this provenance is from the agricultural areas development.

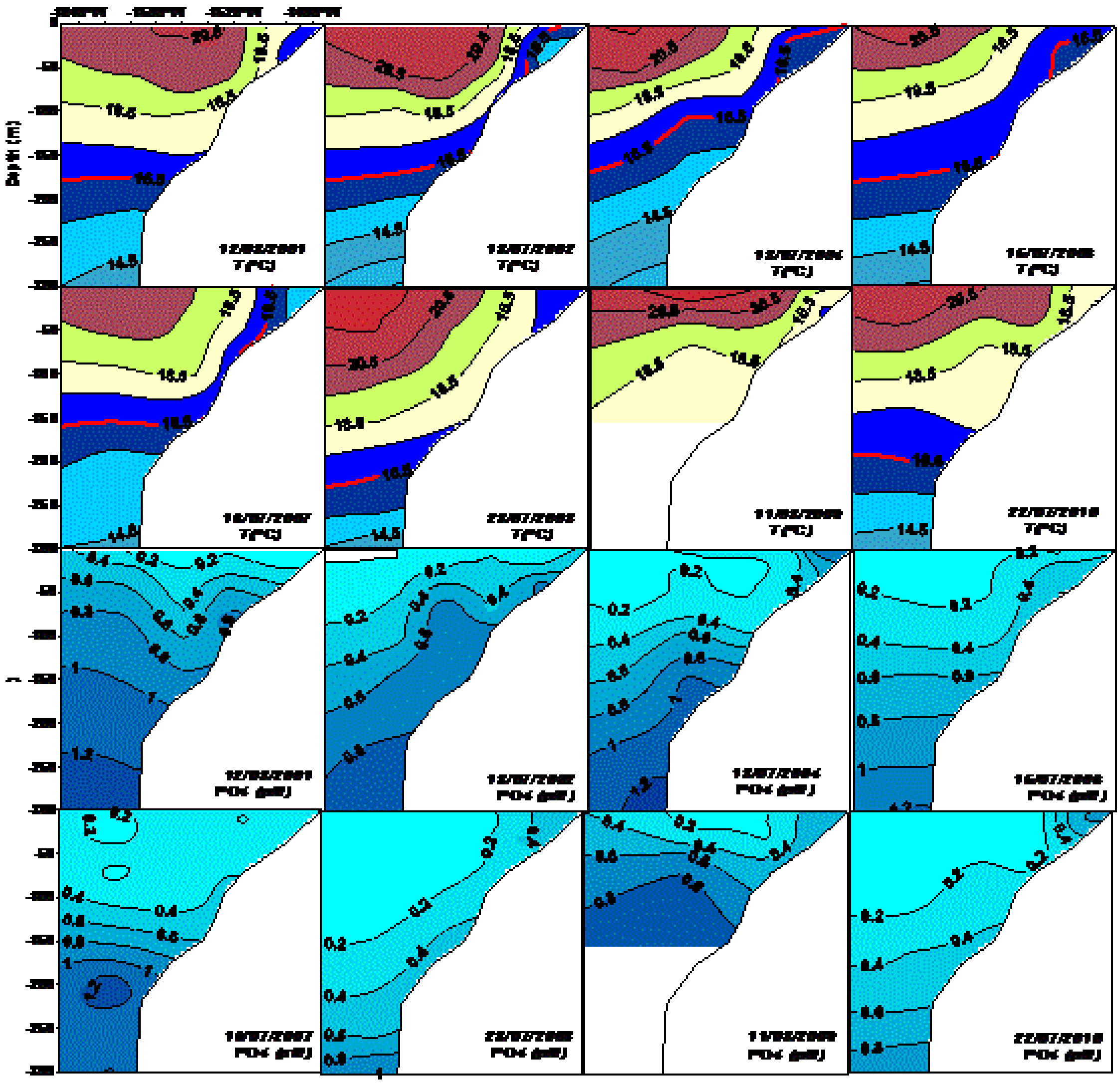

Figure 2: Vertical distributions of temperature and phosphates in 25°30N transect (2001 – 2010) (summer season).

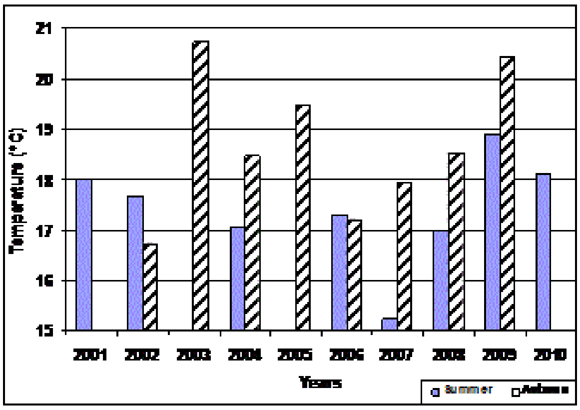

Figure 3: Inter-annual variability of sea surface temperature (25°30'N).

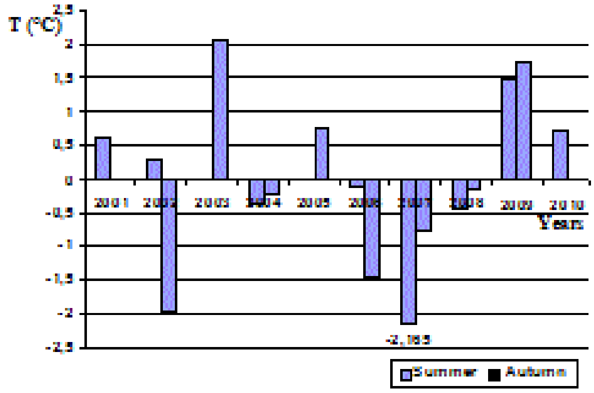

Figure 4: Sea surface temperature anomaly in the coastal station at (25°30'N).

Variability of SST using satellite imagery: An analysis by remote sensing is carried out based on Modis /Aqua sensor data over the period 2002-2010 where data were available in real-time.

According to the sea surface temperature distribution (Figure 6), Coastal Upwelling Index (CUI), shows that water started to be warm during year 2008.

During year 2007, plumes of cool upwelled water were well set up. 2007 is regarded as the year of intense upwelling activity. In addition, autumn upwelling has practically disappeared in the south, with a warming of coastal water. Temperature anomaly was 2°C.

The hovmoller diagrams show homogeneity in the space variability of the coastal Upwelling index during 2002-2011. A zoom around 25°30' N zone also prints the same trend in the duration of upwelling activity as a "decreasing". This variability is, probably, related more to large scales variability than with local variability such as the general context of global warming (Figure 7).

Moreover, the inter-annual variability of upwelling index between (2002) and (2010) diverted from the infrared thermal imaging of the sensor Modis-Aqua along the Moroccan zone of upwelling (21-33°N), show a clear oscillation of the years with a strong activity of upwelling (2002, 2004, 2007, 2008) and the second half-year of 2010

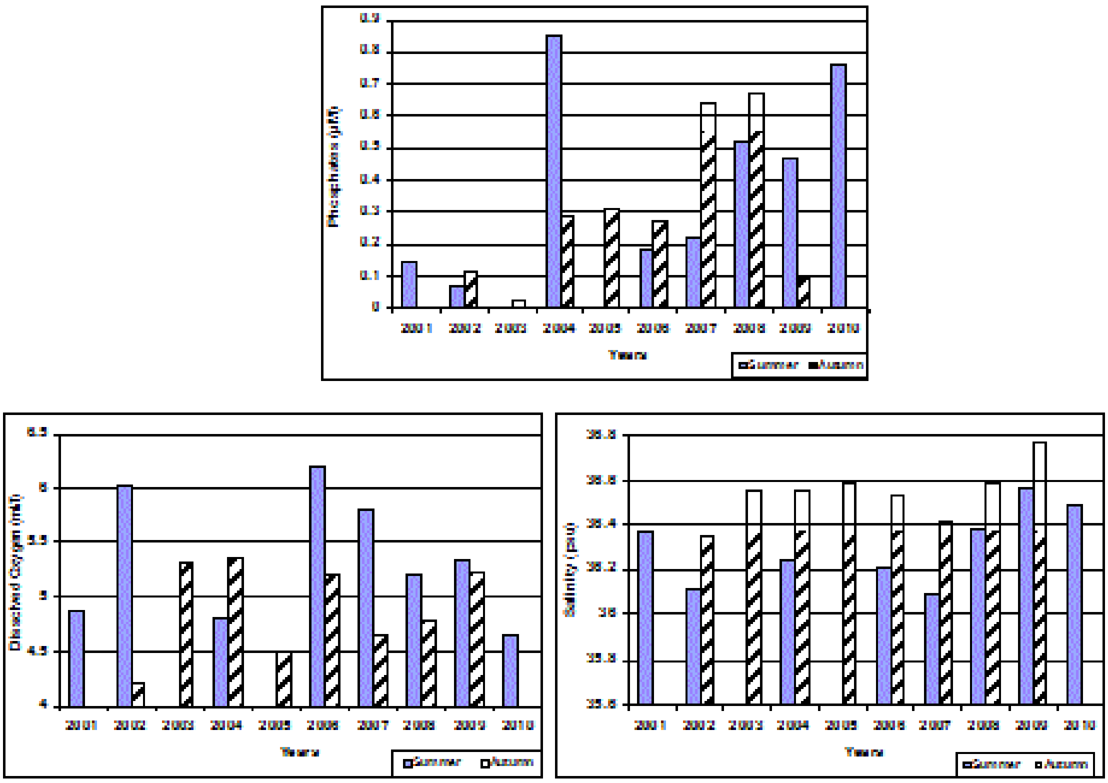

Figure 5: Inter-annual evolution of physical and chemical parameters (25°30'N).

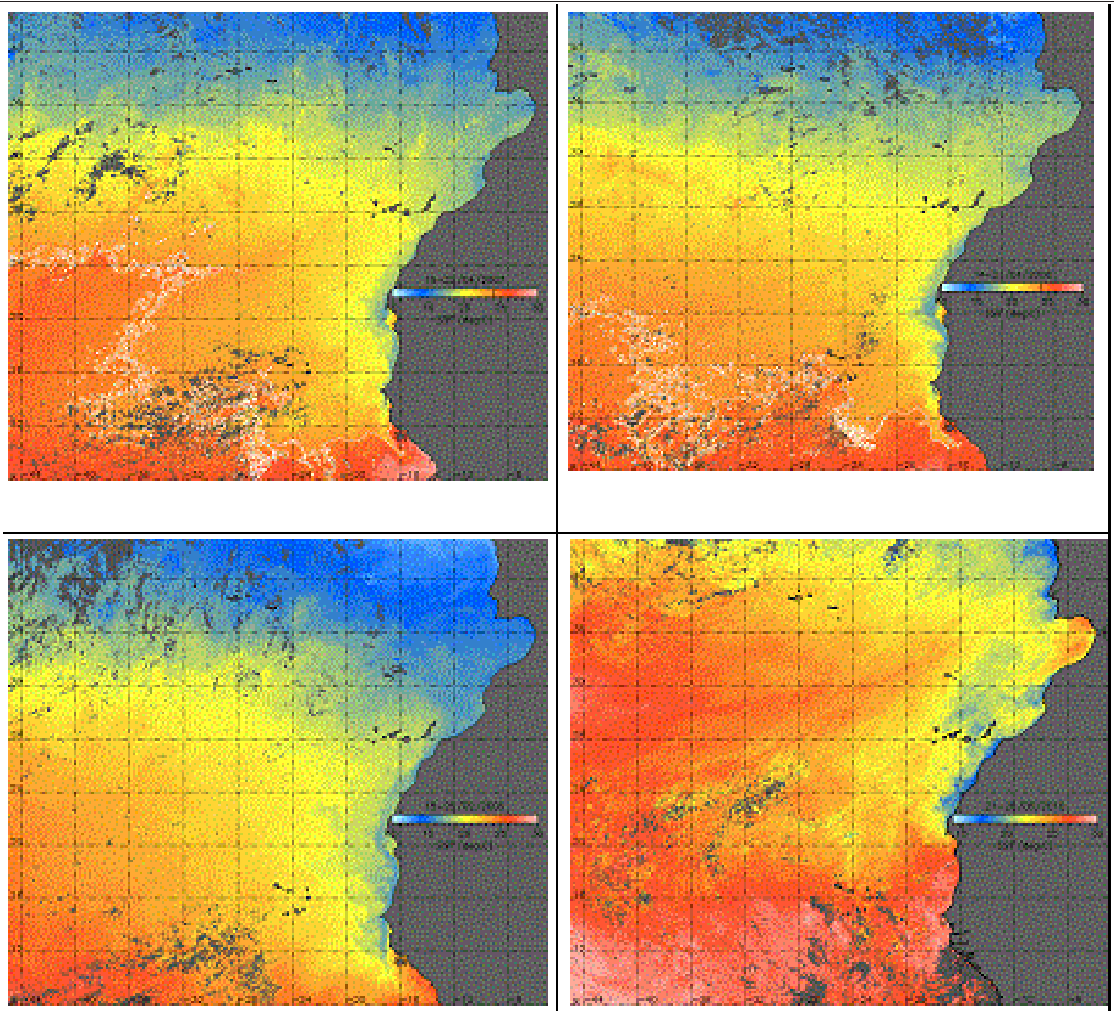

Figure 6: Satellites images (Modis/Aqua) showing the spatial distribution of Sea Surface Temperature (SST) during the last week of April (2007, 2008, 2009 and 2010).

and the years with a weak activity of the upwelling (2006 and the first half of the year 2010), for the other years the activity of the upwelling is regular.

Production indicators variability: Although the fact that the set of data relating to the average of chlorophyll 'a' maximum is discontinuous, it shows a downward trend of 2006 to 2010 during summer season. The situation in 2007, where upwelling activity was intense, can be explained by a shift between upwelling and phytoplankton development. With regard to zooplankton biomass, the average along 25°30'N transect shows a peak in summer 2008 and a downward trend around 2010. In autumn, the observations between 2003 to 2008 show a peak in 2007 which corresponds a minimum in summer (Figure 8).

Discussion and Conclusion

The African north-western area governed by the Canary System, is one of the four major areas of upwelling in the world. Generally, upwelling is observed on a coastal strip of approximately 50 km of width which corresponds to the continental shelf [16]. The Moroccan southern zone between 20° and 25°N is characterized by permanent upwelling with an intense activity in summer [12,16,17]. This zone is limited to north and the south by seasonal upwelling systems, respectively in summer and winter.

However, since that upwelling phenomenon is governed primarily by easterly winds, all resulting fluctuations modifying the intensity of the north-western wind system, causes an inter-annual change of the North-Western African coastal upwelling [18-20].

During 2000 decade, surface temperature analysis during summer and autumn seasons, a maximum of activity in 2007 with a downward trend from 2008. This is well visualized at latitude 25°30'N whose upwelling active center is the most important of all Moroccan Atlantic coasts [21].

The weak activity of upwelling illustrated by a warming of temperature could be explained by a local warming which could occur due to the weakness of trade winds. This same situation was observed during the Nineties where the positive values of Sea surface temperature anomalies reach their maximum in 1997 [5]. According to Furnestin [22], a succession of hot and cold years which depend on the local conditions (atmospheric conditions) that originate upwelling.

doi:http://dx.doi.org/10.4172/2324-8661.1000107

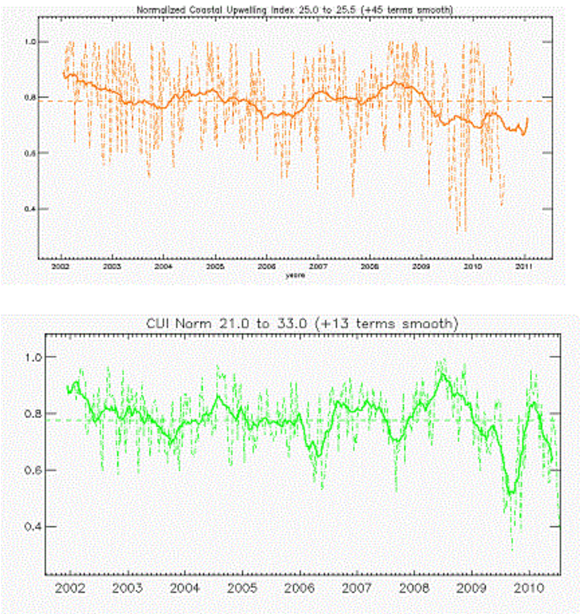

Figure 7: Interannual variability of the normalized coastal upwelling index derived from SST (Modis/Aqua) during 2002-2010 extracted from the hovmoller (a) in the transect (25N-25.5N) and (b) between 21N (Cape Blanc) and 33N (Casablanca) of Morocco.

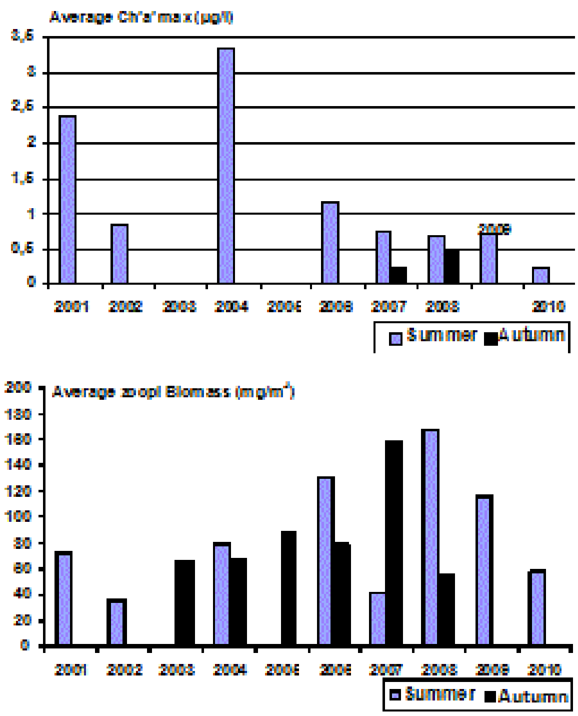

Figure 8: Variation in the mean of the chlorophyll 'a' maximum and the mean biomass of zooplankton at 25°30'N.

Generally, it was shown that the hydrodynamic mode in an area influences and controls the distribution in space and time and the composition of phytoplankton and zooplankton [23-25]. Thus, the variability of the marine productivity at 25°30' N transects is closely with the variability of upwelling. The low richness of chlorophyll 'a' in 2007, in spite of the strong activity of upwelling is a consequence of the dispersive character of this phenomenon and whose relaxing phase supports the primary productivity and thereafter the secondary.

References

1. Barton ED (1998) Eastern boundary of the North Atlantic: Northwest Africa and Iberia. The Sea. John Wiley & Sons Inc 11: 633–657.
2. INRH (2002) Ressources halieutiques marocaines: situation et niveaux d'exploitation. Institut National de Recherche Halieutique 167.
3. Saavedra KN (2009) Variabilité océanique de méso-échelle dans les systèmes d'upwelling du Humboldt et des Canaries : une comparaison à partir des données satellite. Thèse de Doctorat, Espagne.
4. Arfi R (1987) Variabilité interannuelle de l'hydrologie d'une région d'upwelling (bouée Bayadère, Cap Blanc, Mauritanie). Oceanologica Acta 10: 151-159.
5. Makaoui A, Orbi A, Hilmi K, Zizah S, Larissi J, Talbi M (2005) Lupwelling de la côte atlantique du Maroc entre 1994 et 1998. C R Geoscience 337: 1518-1524.
6. Benazzouz A, Hilmi K, Orbi A, Demarcq H, Attilah A (2006) Dynamique spatio-temporelle de l'upwelling côtier Marocain par télédétection de 1985 à 2005. Geo Observateur 15: 15-23.
7. Arístegui J, Mendonça A, Vilas JC, Espino M, Polo I, et al. (2009) Plankton metabolic balance at two North Atlantic seamounts. Deep Sea Res Part 2 56: 2646–2655.
8. Holm-Hansen O, Lorenzen CJ, Holmes RW, Strickland JDH (1965) Fluorometric determination of chlorophyll. ICES J Mar Sci 30: 3-15.
9. Yentsch CS, Menzel DW (1963) A method for the determination of phytoplankton chlorophyll and phaeophytin by fluorescence. Deep Sea Res 10: 221-231.
10. Aminot A, Chaussepied M (1983) Manuel des analyses chimiques en milieu marin. Centre national pour l'exploitation des oceans: 395.
11. Bakun A (1973) Coastal Upwelling Indices, West Coast of North America, 1946–71. NOAA Technical Report NMFS SSRF 671: 103.
12. Nykjær L, Van Camp L (1994) Seasonal and interannual variability of coastal upwelling along northwest Africa and Portugal from 1981 to 1991. J Geophys Res 99: 14197-14207.
13. Gomez-Gesteira M, Moreira C, Alvarez I, deCastro M (2006) Ekman transport along the Galician coast (northwest spain) calculated from forecasted winds. J Geophys Res: 111.
14. Santos AMP, Kazmin AS, Peliz A (2005) Decadal changes in the Canary upwelling system as revealed by satellite observations: Their impact on productivity. J Mar Res 63: 359–379.
15. deCastro M, Gomez-Gesteira M, Alvarez I, Lorenzo M, Cabanas JM, et al. (2008) Characterization of fall–winter upwelling recurrence along the Galician western coast (NW Spain) from 2000 to 2005: Dependence on atmospheric forcing. J Mar Syst 72: 145–148.
16. Van Camp L, Nykjaer L, Mittelstaedt E, Schlittenhardt P (1991) Upwelling and boundary circulation off Northwest Africa as depicted by infrared and visible satellite observations. Prog Oceanogr 26: 357-402.
17. Mittelstaedt E (1991) The ocean boundary along the Nothwest African coast: circulation and oceanography properties at the sea surface. Prog Oceanogr 26: 307-355.
18. Cruzado A (1972) Coastal upwelling between cap Bojdor and point Dunford. Téthys 6: 133-142.
19. Le Floch J (1974) Quelques aspects de la dynamique et de l'hydrologie des couches superficielles dans l'ouest marocain. Téthys 6: 53-68.
20. Roy C (1991) Les upwellings: le cadre physique des pêcheries côtières ouest-africaines. Pêcheries ouest africaines : variabilité, instabilité et changement. ORSTOM: 38-66.
21. Makaoui A (2008) Etude de l'upwelling côtier de la côte Atlantique marocaine

et sa contribution à la sédimentologie du plateau continental. Thèse de Doctorat, Université Hassan II, Casablanca: 162.

22. Furnestin J (1959) Hydrologie du Maroc Atlantique. Rev Trav Inst Pêches marit 23: 5-77.
23. Carr ME (2002) Estimation of potential productivity in Eastern Boundary Currents using remote sensing. Deep Sea Res Part 2 49: 59 – 80.
24. Somoue L (2004) Structure des communautés planctoniques de l'écosystème pélagique de l'atlantique sud marocain entre Cap Boujdor et Cap Blanc (26°30' – 21°N). Thèse de Doctorat. Océanographie, Université Hassan II, Ain Chock: 211.
25. Lorenzo LM, Arbones B, Tilstone GH, Figueiras FG (2005) Across-shelf variability of phytoplankton composition, photosynthetic parameters and primary production in the NW Iberian upwelling system. J Marine Syst 54: 157-173.

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