GEOGRAPHICAL PROVINCES OF THE MEDITERRANEAN SEA FROM THE SURFACE COLOUR AND TEMPERATURE HISTORICAL RECORD

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Abstract
Sea surface colour and temperature images, derived from time series of CZCS (1978-1986) and AVHRR (1982-1991) data, have been used to assess the main features of the Mediterranean basin. The data were processed to apply sensor calibration, to correct for atmospheric contamination, and to estimate chlorophyll-like pigment concentration and surface temperature. Long-term composites derived from the images show differences between western and eastern sub-basins, inshore and offshore domains, northern and southern coastal areas. Continental runoff and wind-driven mixing, geo-morphology and meteorology of basin margins, appear to influence water dynamics and bio-geo-chemistry.

Key-words : Remote Sensing, Biogeography, Hydrography, Mesoscale Phenomena

Remote Sensing (RS) techniques provide the means to investigate environmental processes at the scale of entire marine basins. Optical and thermal RS data are of considerable interest for the Mediterranean Sea, due the combination of low cloudiness, predominance of waters optically dominated by plankton alone (dissolved organics and suspended sediments render the surface colour field more difficult to interpret) and marked thermoaline density gradients. The compilation of historical time series of RS data on the Mediterranean Sea - primarily Coastal Zone Color Scanner (CZCS) and Advanced Very High Resolution Radiometer (AVHRR) - has pointed out, for the first time, the space/time heterogeneity of surface parameters derived from optical and thermal indices [1, 2]. The variability observed in the satellite data record points at specific geographical provinces, where a relationship seems to exists between such indices and the climatic features of the region.

Sea surface colour and temperature images give complementary views of the Mediterranean water bodies. Historical time series of CZCS (1978-1986) and AVHRR (1982-1991) data have been used to derive composite images of the entire basin. The raw data (2465 CZCS and 9396 AVHRR original images) were processed to apply sensor calibration algorithms, to correct for atmospheric contamination, and to derive chlorophyll-like pigment concentration and surface temperature [3, 4]. Single images were generated for each available day, co-registered using the same geographic equal-area projection and resolution, and then averaged pixel by pixel, to compute monthly and annual composites. The composites cover an area of 4000 x 2000 km^2, with a 1 km pixel size, and retain only persistent features of the surface colour and temperature fields. Given the pixel by pixel correspondence of the long-term composites, a new multi-band image could be constructed, for the annual and monthly intervals, in which the colour and temperature histogram-matched images constituted two different bands. An unsupervised classification was performed, using spectral distance to assign each pixel to a cluster, and highlight the patterns inherent in the data.

Marked differences appear in both the pigment and the temperature mean annual composites (Figure 1) between western and eastern sub-basins, inshore and offshore domains, as well as northern and southern near-coastal areas. The western basin is characterized by higher pigment concentrations and lower temperatures than the eastern basin - where the Aegean Sea represents a notable exception. Contrary to common geographic subdivisions, this qualifies the Adriatic Sea - and the northern Aegean, up to a point - as one of the western sub-basins, at least as far as the pigment and temperature fields are concerned. The classification of Mediterranean waters (see also Figure 1) suggests that the transition between the western and the eastern regimes corresponds with the line of straits going from the Sicily Channel, to the Strait of Messina and the Strait of Otranto - and perhaps the central Aegean. The classification of western sub-basins seems to be dominated by the stronger pigment signal, while that of the eastern sub-basins by the more pronounced temperature signal.

A single class groups together all of the plumes due to the main rivers entering the Mediterranean Sea, *i.e.* the Ebro, Rhone, Po, and Nile. The same class also includes the areas influenced by river discharges and coastal runoff along the Italian coast in the Thyrrenian Sea, along both the Italian and Albanian coastlines in the Adriatic Sea, along the northern shores of the Aegean Sea and the Marmara Sea. Another area included is the shallow bank off southern Tunisia, where however the enhanced pigment signal is due to other factors than runoff and/or mixing, *i.e.* to direct bottom reflection through the clear waters (coupled to a distinct temperature signature, colder in winter and warmer in summer).

A second, broader class appears to account for most of the near-coastal areas of the Mediterranean. The southern coastal areas do have different characteristics, but this may be simply due to the fact that along the African coastline, in the eastern basin in particular, the data are somewhat altered by signal contamination due to the notorious CZCS sensor ringing in the downscan direction, after imaging a bright

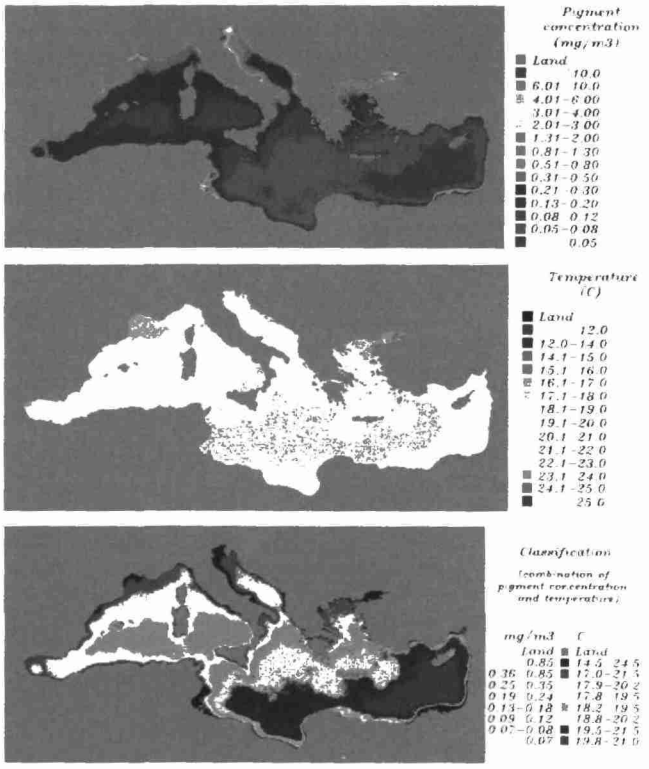

Figure 1 : Upper plate: annual mean of chlorophyll-like pigment concentration derived from the CZCS (1978-1986) data set; the colour coding represents mg/m^3. Middle plate: sea surface temperature derived from the AVHRR (1982-1991) data set; the colour coding represents °C. Lower plate: unsupervised classification of the Mediterranean Sea surface characteristics derived from a combination of the annual pigment and temperature images; the arbitrary color coding highlights the 8 different classes obtained. **See color figure in p. 214.**