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Tracking Land-derived Pollution by Satellite in Eastern Mediterranean

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Abstract

Large, high chlorophyll plumes are visible on satellite imagery in the eastern Mediterranean Sea, especially along the Egyptian coast and off Tel Aviv, Haifa and Tyre. These large-scale features are particularly visible during spring and summer, due to the high contrast between coastal water and oligotrophic open sea. Plumes origin and dynamics are still unclear. Previous work by various authors has postulated the interplay of autochthonous (upwellings) or allochtonous (Nile coastal drift, rivers, sewage) nutrient sources inducing enhanced primary production.
In this work, we attempt to follow the development of these chlorophyll plumes through a time-series of SeaWIFS satellite images, and to track their origin using Normalized Water Leaving Radiance (L_{NW}) spectra.

1. Data acquisition and treatment

Our work focuses on satellite imagery of the eastern Mediterranean from the beginning of June till the end of September 2001. On these, high chlorophyll-concentration plumes or filaments are visible, coinciding most of the time with warm sea surface temperature (SST) anomalies. On the basis of water-leaving radiance profiles and ancillary data, we examine the possible origins of these plumes. Up to fifteen SeaWIFS images have been ordered for each month. Using the SeaDAS software (SEADAS (2004), scenes with sufficiently low cloud cover were processed to retrieve the concentration of chlorophyll-a (OC4[2] algorithm) and the normalized water-leaving radiance L_{WN} for 8 visible and near-IR SeaWIFS channels. Nine-layer stacks were created for each date with ERDAS software, enabling us to compute spectral profiles computed inside as well as outside the high-chlorophyll plumes. Chromaticity coordinates were also calculated to describe the colour of the water masses (Bukata et al. 1995).

For comparison purpose, we also processed SeaWIFS imagery of the Rhône and Pô river deltas.

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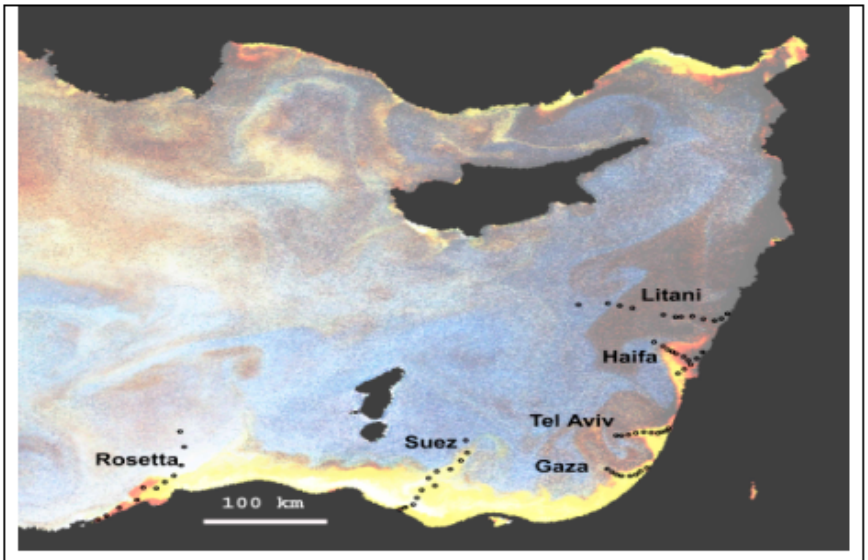
[2] Standard SeaWIFS algorithm for atmospheric correction.

SST images of the Levantine basin were acquired through the SISCAL 2004 system, for the same period as the SeaWIFS images.

Finally, in order to better understand coastal water circulation, the bathymetry of the Levantine basin (GEBCO DIGITAL ATLAS, Centenary Edition, 2003) was overlaid on the nine-layer stacks.



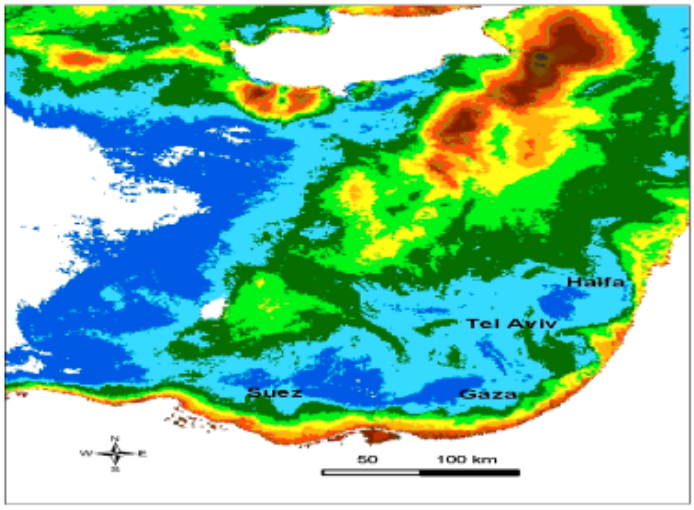


Figure 1a & b
a: Histogram-equalized, color composite of SeaWifs LWN bands 1 (red), 2 (green), 3 (blue) for the 11 June 2001 and localization of transects along the plumes. A L_{WN} spectral profile is computed at each point.
b: SST map for 11 June 2001. Temperature ranges from 24 °C (dark blue) to 27°C (red) by steps of 0.5 °C.

2. Results

The six transects studied are shown on fig. 1a, stretching from western Nile delta in the SW to Litani river (Tyre) in the N. They were drawn following the main direction of each chlorophyll plume, from the coast to the open sea, on the 11 June 2001 image.

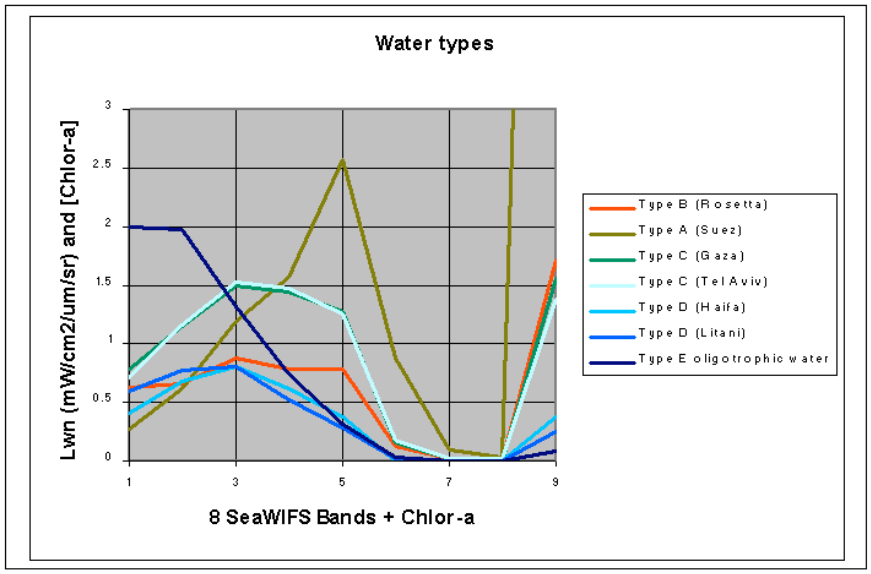


Figure 2
Typology of normalized water-leaving radiance profiles (11 June 2001), (L_{WN}: chanels 1-8, chlor-a: channel 9)

Following an approach similar to that of Karabashev et al (2002), the spectral L_{WN} profiles computed at each coastal-most point on the transects can be classified in four types (fig 2); A: coastal water influenced by land derived pollution (Suez); B: deltaic waters (Rosetta); C: green-blue coastal waters (Gaza and Tel Aviv); D: blue-

green coastal waters (Haifa and Litani). Type E profile represents the signature of oligotrophic water (out of the plumes).

The chromaticity diagram of fig 3 depicts the water colour evolution along the Suez, Rosetta, Tel Aviv and Litani transects.

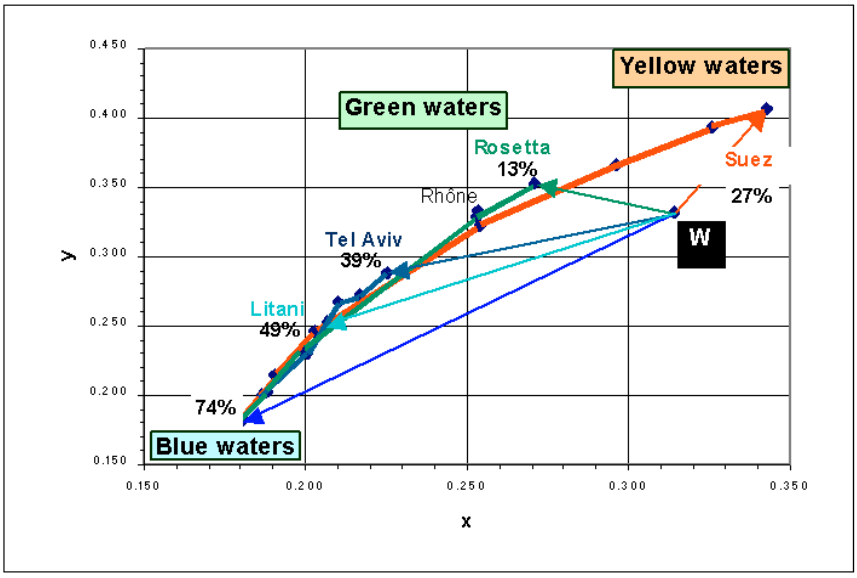


Figure 3
Chromaticity loci of Mediterranean chlorophyll plumes of Suez (type A), Rosetta (type B) and Tel Aviv (type C), 4 & 11 June 2001. Rhône river and Litani shown by a single point. Percentage figures: colour saturation.

3. Discussion

The plume situated near the Suez Canal (type A, fig. 2) has a very characteristic profile with a peak maximum in band 5 (555 nm) and a high concentration in chlorophyll. On the chromaticity diagram (fig. 3), the colour is yellow, with a 27% saturation. The Cairo sewers and agricultural drainage waters heavily contaminate the Suez Canal and surrounding coastal lagoons. The deltaic water type (B), found on the Rosetta transect show characteristics quite similar to those of the Rhône delta (fig. 3). The spectral profiles have maxima in band 3 (490 nm), 5 (555 nm) and 4 (510 nm) inducing a quite flat profile with a „M“ shape, and a low saturation (13%) due to the discolouring effect of mineral suspensoids. The Gaza and Tel Aviv profile are quite similar, with a dominant wavelength at 480 nm (green-blue) and a saturation at 39%. The northernmost plume, located at the latitude of Litani river, is blue-

green (type D, dominant wavelength at 475 nm) and well sturated at 49%. All the transects terminate in blue oligotrophic water with spectrum maxima in bands 2 (443 nm) and 1 (412 nm), with a high saturation (74%).

There is an obvious and regular colour gradient between the A (yellow) and E (blue) water types, which proceeds in parallel with the distance from the Nile river mouth.

Finally, a comparison between water color and SST patterns shows a similarity in their shape, with warm anomalies corresponding to high chlorophyll concentration (fig 1b).

4. Conclusions

Based on chromaticity analysis, the high chlorophyll plumes or filaments jutting from the Levantine coast seem to consist of a varying mixture of two water types; (a) yellow, chlorophyll and suspensoids-laden water, influenced by terrigenous inputs (Nile and sewers) and (b) blue, very oligotrophic water dominant in the pelagic zone of the Levantine basin.

The coincidence of colour and warm thermal plumes precludes an input of nutrients by cold upwellings, pointing instead towards land-derived sources. The major input is the Egyptian Nile river/sewer/agricultural runoff system, which is distributed to some extent northwards by the prevailing currents, with additional sources from cities such as Tel Aviv and Haifa or rivers (Litani): plumes are indeed quasi-permanent offshore these locations.

The large extent and quasi-persistence of these colour features can be explained by the strong buoyancy of the warm, fresh water river and sewer inputs. These are distributed offshore the margin of the northward current by eddies influenced by the irregular topography of the continental shelf.

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