SATELLITE OBSERVATIONS OF COLD FILAMENTS IN THE MEDITERRANEAN SEA

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Abstract

Thermal satellite images relative to the years 1997-2000 are analyzed, in order to infer cold filament and surface jet dynamics in the Mediterranean Sea. The main zones in which these phenomena are seen to occur are characterised by upwelling and/or the funnelling of strong cold winds by a somewhat irregular coastal orography. In the Mediterranean Sea the geographical zones with a higher frequency in these jets are the two lobes of the southern Sicilian coast, the sea off Olbia in Eastern Sardinia, that south of the island of Crete, and the Balkanic coast of the Adriatic Sea.

Keywords: Filaments, entrainment, potential vorticity, Mediterranean Sea

The problem

Thermal and ocean color satellite imagery has recently allowed considerable progress in the observation and modelling of the response of coastal currents to strong air-sea interaction. A particularly interesting case is that of transient jets or cold filaments observed off coastal areas. For a detailed overview, see [1] and, more recently, [2]. In all these studies, filament space scales are found to be 100-300 km in length, 10-20 km in width, and 30-50 m in thickness; the time scales are of one-two weeks, and typical velocities are 10-50 cm s^{-1}, irrespective of the elementary physical mechanism originating the phenomenon. This regularity of filament characteristics, independently from the physical mechanisms at its origin, is an open and interesting physical problem. For all the above reasons, a set of thermal satellite images of cold filaments or jets in the Mediterranean Sea was examined .These images allowed to estimate the entrainment coefficient E^* from the analysis of along-flow warming.

The images

The entire set of NOAA AVHRR SST images relative to the period 1997-2000 was acquired, processed, archived and analyzed using the DSP software at the ISAC-CNR Sezione di Roma. The number of examined images is about 1500 for each year (4-5 daily passes, relative to the NOAA 14 satellite). The attention was focused on the southern Sicilian coast, the eastern Sardinian coast, the sea south of the island of Crete, and also the Balkanic coast of the Adriatic sea as these sites were found to be the most abundant in filament events.

A set of 44 images distributed between these relevant sites was finally chosen for a quantitative analysis. For each analyzed cold filament, at selected cross sections characterized by progressive numbers, the filament width $W(\xi)$ and the difference between the environment and filament mean temperatures $\Delta T(\xi)$ have been measured, ξ being the along-stream coordinate. Furthermore, the total along-stream length L, mean temperature T_m and mean width W_m have been measured, as well as the average along-stream temperature difference decrease $A = \partial[\Delta T(\xi)/\Delta T(\xi=0)]/\partial\xi$ between two given sections, hereafter referred to as 'thermal slope'. Time series of SST and chlorophyll images reveal that during their fully developed phase one can reasonably assume filament stationariety on a time scale of one-two days.

The analysis of only a few cross sections per filament scene has thus induced us to calculate a more reliable estimation of A, using the entire collection of filaments at each site, with a linear regression between ξ and $\Delta T(\xi)/\Delta T(\xi=0)$. We assume that this along-stream thermal variability of the filaments is due to entrainment of warmer ambient water and proceed to estimate an 'overall' entrainment coefficient E^* from the thermal images, after establishing the relationship between A and E^*. We adopt here the definition of E^* given by [3]), which assumes that the increment in filament thickness can be approximated by $E^*|\underline{u}|$, i.e. proportional to the filament's mean along-stream velocity modulus $|\underline{u}|$.

In synthesis, it is interesting to note that the order of magnitude of the overall E^*/h values stays the same, which suggests this value to be typical for Mediterranean Sea. The data show some low correlation coefficients indicative of large scatter in the regressions, as in the case of the north Adriatic (R=0.30) and eastern Crete (R=-0.13), which cannot be regarded as statistically significant. Finally, the use of satellite SST as ambient water temperature is among the limits of validity of this analysis, since T_a should be a lower 'bulk' average temperature. This is because entrainment occurs along the entire filament interface, which shoals only towards the edge of the filament; the same holds for h, which therefore is considered as a mean depth in our conceptual model.

It could also be of interest that during the SYMPLEX 99 cruise (21 October – 6 November 1999, carried out by ISAC-CNR Sezione di Roma) a CTD transect allowed to determine the thermal structure of the cold filament flowing off Cape Passero, at the southernmost tip of Sicily. The CTD transect is ≈ 25 km long; the thermal anomaly is $\Delta T \approx$ 2 °C, the potential density σ vertical section reveals that the filament is moving southward with a velocity ≈ 10-20 cm s^{-1}. In reality, this velocity estimate is a lower limit, expressing the bottom to surface shear. Indeed ADCP measurements during the cruise revealed absolute velocities up to 50 cm/s. A fact of general interest is that the filament is in contact with underlying colder waters, while only in the upper 20 m, say, it comes in contact with warmer waters. This gives an idea of our approximation in treating the filament as embedded in warmer homogeneous water.

References

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