OBSERVATIONS AND MODELIZATION OF THE RHONE RIVER PLUME

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It is often observed that the Rhone river discharge in the Mediterranean sea takes the form of a buoyant surface plume of brackish water spreading horizontally far off-shore over a few tenth of kilometres. In the majority of cases, the river water is found to preserve its individuality on fairly great distances off-shore, and is accordingly confined in a thin layer floating over the underlying sea water. This freshened tongue of brackish water is vertically separated from the ambient marine water by a sharp halocline (thickness of a few metres). It is partially surrounded by an hydrological front with a marked contrast in salinity values on each side, and which is sometimes visible from a boat as a foam line separating the two water masses of different appearance (colour, surface roughness). This front is also a zone of high dynamic horizontal gradients since a frontal convergence of surface currents generally occur there, as evidenced on maps of radial components measured by the VHF radar, or by *in situ* drifter tracking.

The experiments operated by the LSEET laboratory off the Rhone mouth have provided a great amount of current data (one map every half an hour during two months) which could be combined sometimes with in situ observations, and from which a statistical analysis on various typical oceanic and meteorological situations can be well investigated. A morphological insight is provided every times the frontal boundaries of the plume are visible on such maps. Aside of this kind of information, different quantities such as radial acceleration or speeds of displacement of the whole structure can be calculated from one map to another. This gives access to orders of magnitudes for typical scales, both on a temporal and on a spatial point of view. One of the prominent feature is that the response of the system to a wind reversal can be quite fast (few hours), as it is often the case during transient events associated with sea breeze regimes, during while a high temporal variability is likely to occur. Another striking aspect of the phenomenon is its persistance and its approximately well defined location even during events of gusts of winds (Mistral). These are the situations on which we have decided to focus in a first step of a modelization approach.

A reduced-gravity non-linear layer model is developed in order to study river plumes. This stationary model, based on a simpler one found in literature (GARVINE, 1981), considers mass and momentum exchanges in the frontal zone. Interfacial friction has been introduced to take into account the wind and underlying current effects. Supercritical flow is assumed in the outlet channel, so that characteristics method is used for numerical resolution. It provides a variable grid, strongly akin with the flow properties. Finite difference method along characteristic lines and stream lines is used to solve the governing equations. Numerical stability is inherent to the model, as the grid verifies the Courant-Friedrich-Levy stability criterion. For a given accuracy the number of grid points is reduced by several orders of magnitude compared with a fixed orthogonal mesh grid. More over, this grid seems to be optimal for implementing data assimilation because the adjoint model and the direct model possess the same characteristics lines, so only a few additional computational time is needed.

The shape of the river mouth governs the initial expansion of the plume and its orientation. Near the river's mouth, the flow dynamics is mainly a balance between non-linear advective terms and the pressure gradient, whereas far off-shore the model tends towards an Ekman equilibrium. The wind appears as a major forcing term, and the computed flow is comparable with measurements made with the VHF radar of the laboratory near the Rhone's mouth.

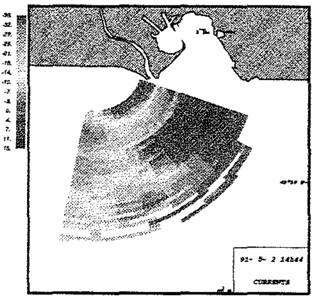

Fig 1: Radial components of sea surface currents (in cm/s) mapped by VHF radar during a Mistral event. Warm colors for currents receeding from the radar.

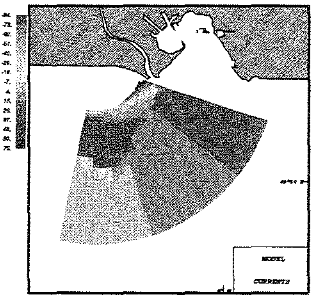

Fig 2: Modelized radial components of inside plume currents.

The agreement between the two kinds of results is mainly found on the basis of a morphological comparison. This is partly due to the ability of the model to restitute the frontal boundaries as lines of discontinuities. A quantitative comparison is specifically explored between the mean location of the plume for a given class of quasi identical meteorological forcing conditions and the model restituted location. Another analysis focuses on the comparison of accelerating terms which can be estimated from radar maps, to gain insight on the dynamic balance transcribed by the model equations; physical interpretations are looked for when discrepencies greater than the expected experimental inacurracies are found. Finally a detailed discussion is conducted concerning the parametrisation of the frontal mass and momentum exchange coefficients linked to the (observed) frontal velocity jump, and which will be probably chosen as model controls to be fitted in a future data-assimilation procedure.

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