Eddy viscosity identification in the Ekman layer in North Western Mediterranean Sea

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The marine upper layer is mainly controlled by wind stress and sun heating with a high temporal variability from the wind gusts to diurnal and seasonal signals, up to climatic time scales. This so called "mixing layer" constitutes a major source of uncertainty of predictive coupled Ocean - Atmosphere models for both climatic and pollutant or biogeochemical dispersion applications.

Tridimensional analyses of spatio-temporal variability of the sea surface currents, temperature, salinity and sea level have been performed in North Western Mediterranean sea from available pluri-annual data bases of surface currents when measured both in horizontal direction by HF radar mapping [1] and in the vertical from acoustic Doppler current profilers on fixed moorings and drifted buoys [2]. In complement, meteorological and sea state data [3] and high precision sea level probes [4] have been deployed in the framework of the HTM-NET network.

Basic processes occurring in the ocean surface layer in the dedicated microtidal site are considered to explain observed inertial motion, Ekman layer, vortex formation, surface and internal waves fields and sea level [5].

Three main purposes are addressed here concerning i) databases analysis in the objective of detecting rare and extreme events, ii) revisiting physical processes including instabilities and iii) identification of turbulent models parameters commonly used in ocean circulation models.

Extreme and rare events

Data processing techniques based on dynamic systems [6,7] have are applied to identify rare and extreme events in plurennial series of data in the marine surface layer. Moreover the analysis of recurrence allows to get and compute new statistical indicators, like local dimensions, whose large excursions are related to extratropical storms or blocking, and the extremal index which was renamed as local persistence indicator, suitable to estimate the average cluster size of the trajectories within the neighborhood of a given state of the system.

Physical processes

This investigation is focusing on the Ekman layer from high resolution vertical profiles of horizontal velocity (Fig. 1) and surface currents maps (Fig2). Spatio-temporal evolution of the Ekman spiral as documented in wind events is investigated by reference to the unsteady Ekman solution [8]. Moreover, theoretical analysis of the impact of varying eddy viscosity both in time and depth on dynamics of the Ekman layer by using Green's function [9] allowed to characterized the Ekman spiral inflectional instability.

Turbulence models identification

The sensitivity of the velocity profiles to eddy viscosity distribution, with and without stratification, is investigated. A stochastic optimal control technique based on Simultaneous Perturbation Stochastic Approximation method [10] has been applied to key parameters of different turbulence closure models on simulated test cases (fig.3).

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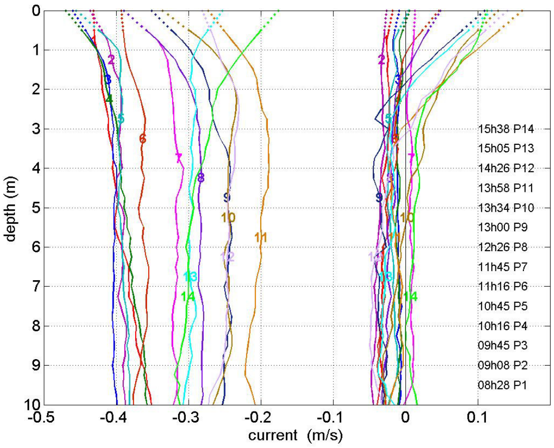

Fig. 1. Horizontal velocity profiles in the surface layer during a wind event : Rotation and deepening of the Ekman layer are sensitive to eddy viscosity.

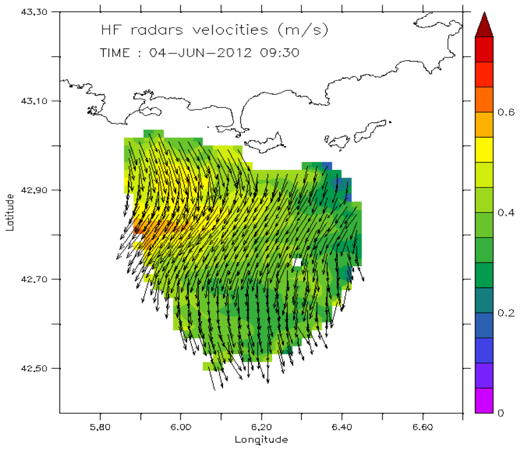

Fig. 2. HF radar surface currents map during the field experiment.

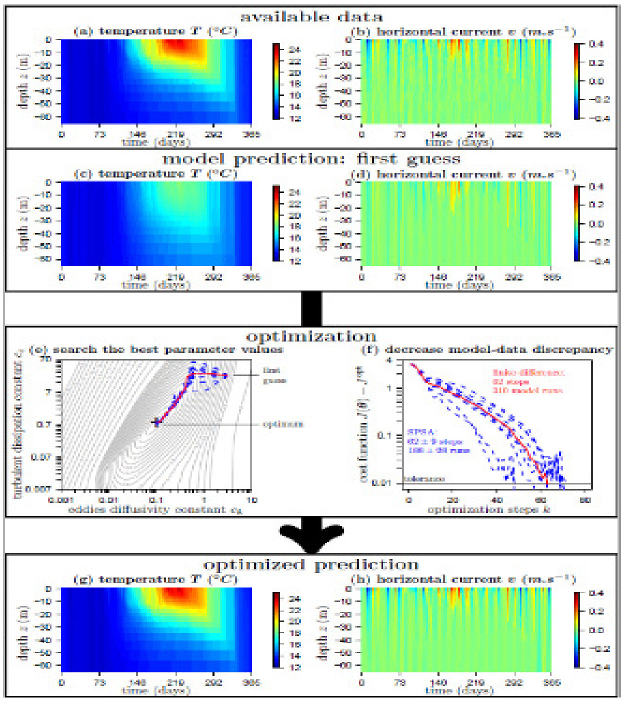

Fig. 3. Sketch of the optimization problem from pseudo-data (a,b) and a model to attempt to describe data (c,d).
Model-data discrepancy is minimized by an optimization procedure that tunes the control parameters: evolution of parameters and map of the cost function (e), and corresponding decrease of the cost function J relatively to its value at optimum J opt in log-scale (f).
Here, one finite-difference gradient descent (red) and 10 SPSA runs (blue) starting from the same first guess are shown. The obtained parameter values lead to model predictions that are closer to observed data (g,h).