Networks of fluid transport in the ocean

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The transport of particles or substances in fluids is a fundamental process of relevance in contexts ranging from cell biology to geophysics. In this last setting, the transport of nutrients or heat in the oceans or of pollutants and humidity in the atmosphere determine most of the biogeochemical cycles in the Earth and the related climatic phenomena.

We have analyzed transport phenomena in the ocean by using techniques from modern *network theory*. The aim is to search for connectivity patterns between sources and receptors determined by the ocean currents, and to use the power of the new techniques, for example regarding community detection, to assess questions about mixing, transport barriers, coherent regions, etc.

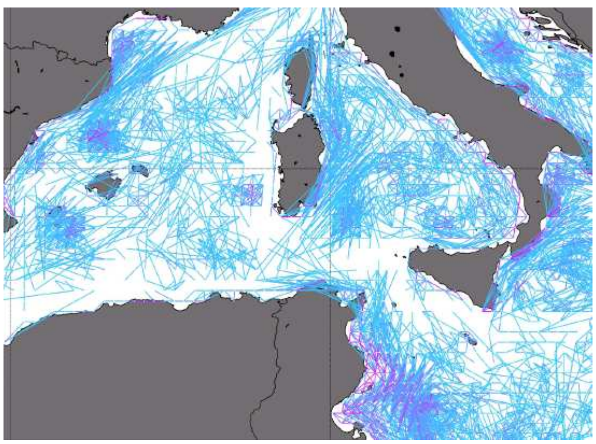

FIG. 1. A part of a weighted Lagrangian network obtained by particle advection in the Mediterranean during one month.

We have first applied this methodology to surface currents in the Mediterranean Sea obtained from a realistic ocean circulation model (NEMO[1]) with a spatial resolution of about 1/16 degrees. We simulate then the motion in this velocity field of more than 1,000,000 ideal fluid particles following their trajectories. After this first step we discretize the sea domain and construct a transport matrix that describes the strenght of transport between ideal cells in which the sea is divided. By interpreting this transport matrix as the connectivity matrix of a weighted and directed graph –the *Lagrangian Network*– we can use graph theory techniques to characterize the transport and connectivity patterns[2].

Figure 1 shows an example of Lagrangian network obtained in this way. Figure 2 shows the communities identified by the Infomap algorithm[3] in such network. The communities are interpreted as regions that remain relatively coherent after the integration time, and the boundaries between them act as barriers to transport.

Application of these ideas to larval transport in the sea and its role in the design of marine reserves will be also discussed[4].

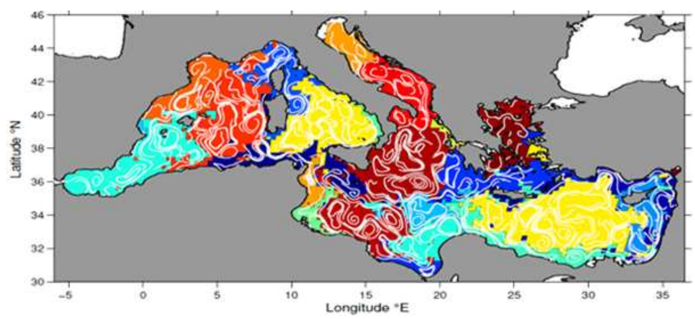

FIG. 2. Communities identified in the 1-month Lagrangian network of the Mediterranean by the *infomap* algorithm. White lines are average streamlines.

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[2] E. Ser-Giacomi, E. Hernández-García, C. López and V. Rossi, in preparation (2014).

[3] M. Rosvall, M., C.T. Bergstrom, *Maps of random walks on complex networks reveal community structure*, P. Natl. Acad. Sci. USA **105**, 1118–1123 (2008).

[4] V. Rossi, E. Ser-Giacomi, C. López, E. Hernández-García, *Hydrodynamic provinces and oceanic connectivity from a transport network help designing marine reserves*, http://ifisc.uib-csic.es/publications/publication-detail.php?indice=2463, submitted (2013).