The influence of superficial Lagrangian transport routes in the retention capacity of the Azores Islands

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RESUMEN

Understand the general routes of dispersion mediated by ocean currents are of special interest for fisheries management and conservation biology, being a very useful tool in the definition of protected areas. This knowledge is inestimable in the particular case of the Azores Island, a hot-spot of biodiversity in the Atlantic Ocean. A first approach to identify superficial transport pathways of the northeast Atlantic Ocean used the Regional Oceanic Modeling System to calculate ocean current velocity components (u, v, w), and Ariane (an off-line Fortran code dedicated to the computation of three-dimensional streamlines from velocity fields) to calculate the transport of particles around the numerical model domain. Results were consistent with known connectivity and drifting patterns. A second study was conducted centred on these islands using the Hybrid Coordinate Ocean Model coupled with the Connectivity Modeling System. The Gulf Stream and the westward propagating eddy corridor off the Azores Current were identified as the main transport pathways affecting the Archipelago.

INTRODUCTION

The North Atlantic upwelling region is one of the four major eastern boundary systems of the world. A distinctive characteristic of this system is the discontinuity imposed by the entrance of the Mediterranean Sea, forming two distinct subsystems: the Canary Basin and the Iberian Peninsula. This region is characterized by the presence of the North Atlantic Current, Azores Current (the southeastward branch of the Gulf Stream), and the Canary Current, all part of the eastern anticyclonic North Atlantic subtropical gyre. Moreover, the Iberian system is characterized by a succession of mesoscale structures such as jets, meanders, ubiquitous eddies, upwelling filaments, and countercurrents, superimposed on the more stable variations at seasonal timescales. Understand the role of the different oceanographic phenomena in the colonization, dispersal, fisheries recruitment and speciation processes, will be a very useful information for fisheries management, conservation biology, and the definition of protected areas.

The case of the Azores Archipelago (AZ) is of special interest due to its isolated location in the middle of the North Atlantic Ocean. Moreover, the AZ is considered a hot-spot of biodiversity in the Atlantic Ocean [1]. It consists of nine volcanic islands, several small islets and 461 seamounts, distributed along a ~600 km tectonic zone, rising from the ocean basin ~4000 m below. Its uneven topography and the presence of extreme environments associated with hydrothermal vents, allow the existence of different marine ecosystems with habitats where complex marine food webs are assembled.

The aim of this study is to map the most probable superficial transport routes in the NEA affecting these islands and analyze their capacity to retain incoming particles and organisms that drift with the oceanic currents. To reach these objectives a series of numerical experiments were performed using an off-line Lagrangian tool, attached to an ocean circulation model.

MATERIAL & METHODS

First Study: to map the most probable superficial transport routes in the NEA affecting these islands, this study was carried out using a ROMS-Agrif hydrodynamic model (Institut de Recherche pour le Développment version) [2,3], and Ariane, a Lagrangian off-line numerical tool, that integrates the particles with the 3D velocity fields (u, v, w) of the ROMS solution [4]. A 10-year simulation was conducted to identify the common Lagrangian routes at superficial waters by releasing particles around the Macaronesian islands, along the Iberian Peninsula coast, the Strait of Gibraltar, and along the northwest African coast.

Second Study: to analyze the capacity of the AZ to capture incoming particles and organisms that drift with the oceanic currents the study was carried out using the Connectivity Modeling System (CMS v1.0) [5]. The CMS operates off-line, integrating the particles with the 3D velocity fields (u, v, w) of the hydrodynamic model HYCOM (http://hycom.org/). Passive particles were released along the boundaries of a source box surrounding the islands at superficial depths, and the capture capacity of the islands was estimated counting the number of particles captured by each island sub-group.

RESULTS & DISCUSSION

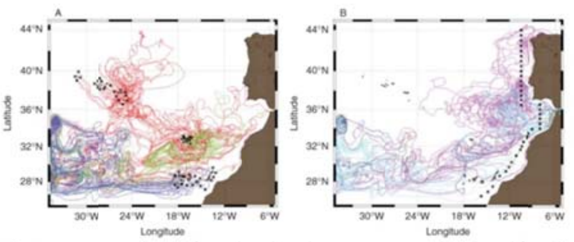

Fig. 1. Lagrangian pathways of particles released at 1–10 m. A: Particles released from the Macaronesian archipelagos (AZ: red lines; MA: green lines; CA: blue lines). B: Particles released along the IP (pink lines), GI (black lines) and NWA (light blue lines). Black crosses represent the release location; circles represent the end location.

Fig. 1 shows the results obtained in the first study. The influence of the Azores Current (AzC) is noticed in the dispersion of particles released around the AZ and Madeira archipelagos (MA). These particles joined their trajectories with the particles released at Canary Islands (CA), following the westward propagation of the Canary Current (CaC). The particles released at the Iberian Peninsula (IP) coast traveled southward, probably influenced by the Portugal Current, reaching the CaC. However, particles released northerly in the IP traveled eastward toward the Cantabrian Sea, probably due to the Navidad Current. The particles released at the Strait of Gibraltar and north-west African coast were directly linked with the CaC southward drift. A particle released in the AZ could reach the MAin 332 d and 767 d to reach the CA.

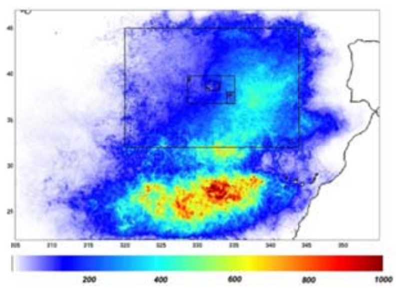

Fig. 2. Particle density distribution along the source box at 5 m depth.

Fig. 2 shows the results obtained in the second study. In the superficial waters, released particles arrived to the AZ mainly from the NW corner of the source box. These particle trajectories were influenced by the Gulf Stream (GS) and its two branches, the North Atlantic Current (NAC) and the AzC, which transport water in a south-east or south direction. This explains the accumulation of particles (high density) on the southeast of the domain, i.e., downstream of these strong currents. While eddies and meanders of the AzC largely propagate westward to the south of the archipelago, eddies from the GS regularly penetrate the region from the northwest, thus contributing to the delivery of particles onto the islands.

Determine the capacity of these small islands and seamounts to capture and retain incoming particles has a direct influence on fisheries recruitment, and our results highlight the role of the GS and its associated eddies injecting particles from the north and west boundaries onto the islands.

ACKNOWLEDGEMENTS

The RAIA Coastal Observatory has been funded by the Programa Operativo de Cooperación Transfronteriza España–Portugal (POCTEP 2007–2013). Numerical model solutions were calculated at CIIMAR's HPC unit, acquired by FCT pluriannual funds (PesT-C/MAR/LA0015/2011), and further expanded with funding from the RAIA.co project.

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