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Operational protocol for the sighting and tracking of Portuguese man-of-war in the southeastern Bay of Biscay: Observations and modeling

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ABSTRACT

This paper describes the operational protocol established in the southeastern Bay of Biscay (study area) for the sighting and tracking of Portuguese man-of-war. This action protocol combines sightings of Portuguese man-of-war at sea with hourly surface currents and winds obtained with the Regional Ocean Modeling System (ROMS) and the Weather Research and Forecasting model (WRF), respectively. These data are used in the Sediment, Oil spill and Fish Tracking model (SOFT) to estimate the drift of Portuguese man-of-war. Here we provide information on sightings of Portuguese man-of-war in the study area and show the most relevant results of the SOFT calibration obtained using trajectories from eight satellite pop-up tags for fish tracking. These tags have similar characteristics (such as weight and density) to the Portuguese man-of-war that reach the study area. In 2012 and 2013, there were a total of 48 sightings of Portuguese man-of-war, most of them located in the Zarautz beach area (Basque Country coast). The SOFT calibration shows that the tag drift is mainly controlled by the wind. With winds from the southern and western sectors (third quadrant), SOFT is able to reproduce the tag drift using surface current velocities estimated as ~1.8% of the WRF wind velocities. The SOFT simulations carried out using the ROMS current velocities (with or without the WRF wind velocities) do not improve the results.

1. Introduction

One of the most common problems in summer along coasts and beaches is the arrival of gelatinous organisms, which may cause a significant socioeconomic impact (Condon et al., 2013). Identifying the causes of the proliferation of these organisms and predicting their physical behavior in the marine environment by numerical tools are of interest for a correct and appropriate management of the problem, thus responding to the affected sectors of society. The present work describes the operational protocol established in the southeastern Bay of Biscay for the sighting and tracking of *Physalia physalis* (phylum: Cnidaria, class: Hydrozoa, order: Siphonophora, suborder: Cystonectae, family: Physaliidae). The aim of this protocol is to prevent the stings of this gelatinous organism in bathing areas.

Physalia physalis, better known as Portuguese man-of-war or blue bottle, is not a true jellyfish. This species is a colony of numerous polyps (Totton and Mackie, 1960; Bardi and Marques, 2007). One of the polyps develops into a gas-filled float that looks like a sail (pneumatophore) and others develop into digesting polyps (gastrozooids), reproductive polyps (gonozooids) and long defending and hunting tentacles (dactylozooids). The float is asymmetric and the tentacles are equipped with stinging capsules that serve to paralyze and trap prey. If these tentacles come in contact with human skin, they can inflict significant damage. Fig. 1 shows the organization of the colony in a Portuguese man-of-war.

Nowadays, the response of Portuguese man-of-war and jellyfish to physical forcing (both in terms of life cycle and advective transport) is rather unknown, which makes difficult its implementation in biophysical models. However, some researchers have attempted to describe the physical behavior of these organisms, as for example Iosilevskii and Weihs (2009). These researchers addressed the sailing of Portuguese man-of-war; in particular, the hydrodynamics of their trailing tentacles, and the interaction between these tentacles and the float to obtain the best sailing performance. In their study, the tracked Portuguese man-of-war were observed sailing with their sails aligned with the wind under strong wind conditions.

In addition to describing the operational protocol for the sighting and tracking of Portuguese man-of-war, the main objectives of this work are the following: (1) To provide information on sightings of Portuguese man-of-war in the southeastern Bay of Biscay; and (2) to calibrate the Lagrangian particle-tracking model

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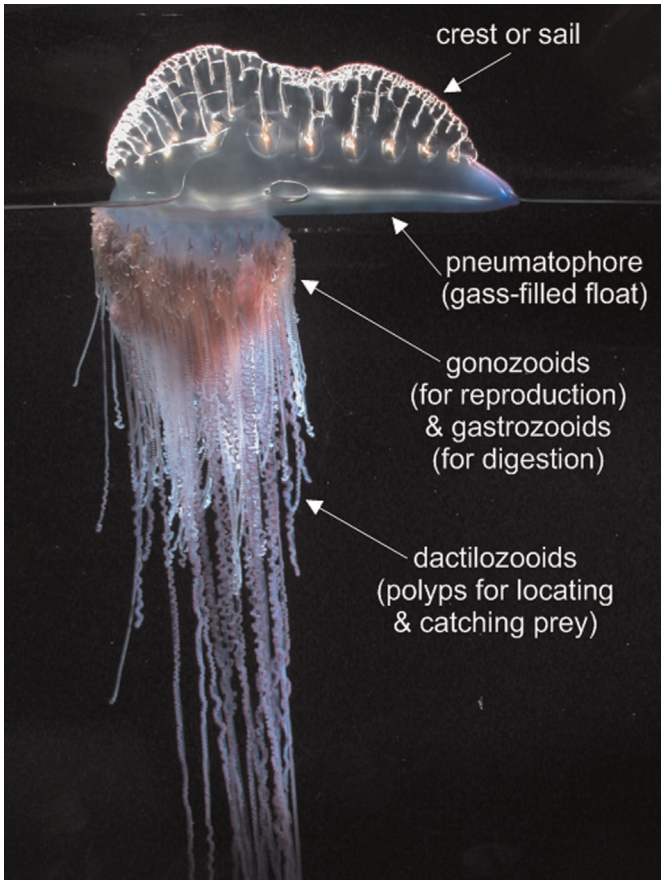

Fig. 1. Organization of the colony in a Portuguese man-of-war (*Physalia physalis*). Photograph by Casey Dunn.

used in the operational protocol to estimate the drift of Portuguese man-of-war. This calibration is important because this model is the base to estimate the risk of Portuguese man-of-war along the Basque Country coast.

2. Methodology

2.1. Study area

The Bay of Biscay extends approximately from 43.5°N to 48.5°N in latitude, and from Cape Ortegal, northwestern Spain (8°W), to the French coast (1°W). The water circulation in the Bay of Biscay is weak ($\sim$1–2 cm s^{-1}) and is characterized by the frequent presence of eddies together with a persistent poleward flow (see Fig. 2). This poleward flow is also known as the slope current (Pingree and Le Cann, 1992a, 1992b; Koutsikopoulos and Le Cann, 1996; Puillat et al., 2004; Serpette et al., 2006; Ferrer and Caballero, 2011). Over the Basque Country shelf, the circulation in the upper water column is mainly controlled by the wind, tides, and density currents induced by river discharges (Ibáñez, 1979; González et al., 2004; Fontán et al., 2006; Caballero et al., 2008; Ferrer et al., 2009).

Several papers have demonstrated that surface currents in the ocean are significantly dependent on wind and wave conditions (e.g., Ursell, 1950; Longuet-Higgins, 1953, 1960; Hasselmann, 1970; Pollard, 1970; Huang, 1979; Wu, 1983; Jenkins, 1989; Perrie et al., 2003; Tang et al., 2007; and Song, 2009). These authors conclude that the effects of wind and waves on the classical Ekman currents are important, as they change the nature of the Ekman layer. More information about the characteristics of this layer can be found in Ekman (1905). In the Bay of Biscay and in the northwestern coastal area of Spain, Sotillo et al. (2008) and Abascal et al. (2009, 2012) analyzed buoy trajectories and compared them with simulated trajectories. For their simulations, they used a combination of outputs from numerical models (wind, waves and ocean currents) and HF radar data. The conclusion of these papers is that the estimation of surface currents in the ocean with numerical models should include the effects of wind and waves in the upper centimeters of the water column, in order to reduce the discrepancies between the classical Ekman theory and the observations. These effects can be particularly significant for floating objects such as Portuguese man-of-war.

2.2. Observing system

The operational protocol established in the southeastern Bay of Biscay for the sighting and tracking of Portuguese man-of-war was launched in the summer of 2012. It consists of an observing system and a modeling system (Fig. 3). The observing system involves the participation of several stakeholders: Department of Security of the Basque Government, AZTI, Euskalmet and EKP (meteorological agency and marinas of the Basque Country, respectively), SASEMAR (Spanish maritime safety agency), City Council of Donostia-San Sebastián, Provincial Councils of Gipuzkoa and Bizkaia, and Red Cross. Evidently, the participation of fishermen and any marine user in this observing system is crucial, because most of the information on sightings of Portuguese man-of-war and jellyfish is provided by them.

Prior to the summer season, the first step of the observing system is the delivery of informative leaflets, posters and sighting registration forms in ports, beaches, associations, university and coastal tourist sites. This is carried out by the Department of Security of the Basque Government. In addition, e-mails are sent to the people involved in the early warning system. The informative leaflets consist of: (1) an identification guide of the main species of jellyfish, including the Portuguese man-of-war, listed in order of abundance on the Basque Country coast and indicating their level of hazard; and (2) a brief version of the action protocol established in case of sighting (Ferrer et al., 2013). The informative posters are exclusively dedicated to the Portuguese man-of-war.

If there are sightings of gelatinous organisms, the first step is to identify the species. If this is a Portuguese man-of-war, people are asked to call 112 (SOS-Deiak, Basque emergency service) or contact SASEMAR (via VHF channel 16), indicating the following: GPS or approximate location, time, number of organisms and their approximate dimensions. In this case, SOS-Deiak fills in a data sheet that sends immediatly to AZTI in order to run a Lagrangian particle-tracking model and obtain a 96-h forecast of the drift of Portuguese man-of-war. This forecast, with information of possible impacts along the Basque Country coast, is sent to SOS-Deiak, who distributes it among the competent authorithies and the people involved in the early warning system. In case of no Portuguese man-of-war, people are asked to fill in a form at www.itsasnet.com. This information is of great value since it allows us to make a database on the different species of gelatinous organisms that have reached the Basque Country coast.

2.3. Modeling system

Regarding the modeling system established for the tracking of Portuguese man-of-war, two models are run by AZTI. The first one is the Regional Ocean Modeling System (ROMS), which is the hydrodynamic model used to estimate current, temperature and salinity fields in the Bay of Biscay. ROMS is an evolution of the S-Coordinate Rutgers University Model (SCRUM), as described by Song and Haidvogel (1994). It has been expanded to include a