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Short communication

A surface ocean trajectories visualization tool and its initial application to the Galician coast

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ABSTRACT

Alavai is a free tool built with Processing to visualize forecasts of drift trajectories in the sea in a very fast and user-friendly graphic environment. It plots trajectories of both passive particles trapped near the ocean surface and oil slicks. Input data come from an operational configuration of the ROMS ocean model focused on the Euroregion Galicia (Spain) – North Portugal, however, this tool is easily adaptable to run with outputs coming from any operational high resolution ocean model configuration. The Prestige accident is used here in hindcast mode to demonstrate the main characteristics of Alavai.

Software and/or data availability

Name Alavai
Code developers Pablo Otero and Neil Banas.
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Year 2013
Hardware requirements 512 Mb of RAM memory. Internet connection.
Software requirements Java Runtime Environment (JRE) 1.7 or later.
Code availability https://github.com/PabloOtero/Alavai
Web (Spanish version) http://centolo.co.ieo.es:8080/alavai/; (English version) http://centolo.co.ieo.es:8080/alavai_en/
Costs Free. Under Creative Commons Licence Attribution-NonCommercial-ShareAlike 3.0 Unported.
Program language Built with Processing (http://www.processing.org/),
Program size ~20 Mb.
Data repository http://centolo.co.ieo.es:8080/thredds/catalog.html
Size of archives 4 Mb
Access form Distributed Oceanographic Data System (DODS) protocols for client/server data access.

1. Introduction

The computation of drift trajectories in the sea is a hard although necessary task, useful to predict the evolution of oil spills, harmful algae blooms, or to help in fish egg and larvae dispersion studies, among others.

In particular with pollution contingencies, these computations must be done in predictive mode, taking advantage of the present state-of-the-art in operational oceanographic models, in order to prevent impacts on coastal areas or environmental sensitive areas (Hackett et al., 2006). Similarly, forecasting drift trajectories helps Search and Rescue teams in case of maritime accidents. For all these cases, the base information comes from oceanographic and meteorological numerical predictions. Many operational services

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disseminate currents and wind speed predictions as vector maps through their websites. But it is of more interest to the public and decision-makers to know how these physical variables affect the drifting of objects in the sea. In spite of that, trajectories summarizing the drift history are rarely shown in operational services. Most of the tools available through the web that do allow visualization of drift trajectories are Lagrangian models that need to be run offline by a technician (e.g., the General NOAA Operational Modeling Environment, GNOME; MEDSLINK-II, De Dominicis et al., 2013; ROFF, Carr et al., 2008), have a restricted list of users (e.g., POSEIDON-OSM System, implemented at the Hellenic Centre for Marine Research) or are run on demand (e.g., NCSU forecast system at http://omgsrv1.meas.ncsu.edu:8080/ocean-circulation/trajectory.jsp; MOTHY implemented by Météo-France; Daniel et al., 2005, 2004). In addition, some of these tools require very complex input information, or their outputs are simply hard to understand by a non-expert.

Previous difficulties are part of a wider problem, which is illustrated by the growing need within the management community and the general public for easy access to the wealth of environmental data coming from monitoring systems and models, and also for effectively communicating their intrinsic spatial and temporal variability. Consequently, many tools that use state-of-the art data visualization and processing schemes to communicate complex environmental information are being adopted in a variety of fields (e.g., Demir and Krajewski, 2013; Gronewold et al., 2013; Kokkonen et al., 2010; Warne et al., 2013).

In this paper, we present a very fast, free and user-friendly visualization tool of predicted Lagrangian trajectories at the sea surface, named Alavai. This tool has been implemented off the Euro-region Galicia (Spain)-Northern Portugal Iberia as part of the Iberian Margin Ocean Observatory (RAIA, http://www.marnaraia.org). An automated system uploads ocean and meteorological forecasts to a public server. Alavai uses the latest available predictions to provide the end-user with a visualization of the predicted drift trajectory starting from any location in the Observatory area. Trajectories are usually displayed in less than one minute —depending on the internet connection—, facilitating a quick response strategy to combat hazardous substances at sea, or simply providing information to researchers about advection of biological material trapped near the surface. Moreover, the interface has been designed to be as intuitive as possible.

The application is based on a simple random walk model in the horizontal, with no vertical advection. In case of oil spill trajectories, a wind drag coefficient is also added to compute the displacement. The Prestige accident in 2002 will be used here in hindcast mode to demonstrate Alavai capabilities.

Alavai is open source and has been built using the open source programming language Processing (http://www.processing.org), an extension of Java. Processing is a widely used environment for developing visually oriented applications with an emphasis on animation and providing users with instant feedback through interaction (Fry, 2007). Alavai has been coded to accept input from ROMS (Regional Ocean Modeling System: Haidvogel et al., 2000) which makes it easily adaptable to any region by any ocean modeling group with operational capability.

2. Material and methods

The Alavai plots forecast drift trajectories of both surface passive particles and oil spill, the last driven by the combined action of the sea surface dynamics and the direct dragging of the wind. Thus, the base data come from results of a hydrodynamic and a meteorological model executed in operational way.

2.1. The operational configuration

Forecast sea currents are obtained from an operational configuration of ROMS, a free surface primitive equation ocean model. The current configuration is maintained and executed by the Instituto Español de Oceanografía in the frame of the Iberian Margin Ocean Observatory. In this configuration, two grids are nested during online execution through the employ of the AGRIF version of the model (Penven et al., 2006). Data from the coarser (4 km horizontal resolution) 236 × 181 grid force the lateral open boundaries of the finer (~1.3 km) 312 × 167 embedded grid (right panel in Fig. 1). More details and some validations of this configuration can be found in Otero et al. (2013, 2009).

The ocean model is forced at the surface with meteorological data from a 12 km spatial and 1 h temporal resolution configuration of the Weather, Research and Forecasting (WRF) model, operationally run by the regional meteorological agency MeteoGalicia and disseminated through the RAIA Observatory.

Every day, and once the meteorological forecasts are available, these data are downloaded and interpolated to the grid of the ocean model configuration, which restarts from the output of the previous day. After the execution has finished, hourly ROMS standard outputs are interpolated from their original terrain following coordinates to levels of constant depth (to facilitate interpretation) and subsequently, converted to the NetCDF Climate and Forecast (CF) convention format (http://cf-pcmdi.llnl.gov/). Finally, these data are uploaded to a public data repository (THREDDS server, Thematic Realtime Environmental Distributed Data Services http://www.unidata.ucar.edu/projects/THREDDS/; https://www.unidata.ucar.edu/software/thredds/current/tds/) for dissemination purposes.

2.2. The Alavai Lagrangian model

Alavai displays drift pathways and simulates the motion of virtual particles by means of the advective transport induced by surface currents and wind, plus turbulent horizontal diffusion. The diffusivity velocity depends on the sea turbulent characteristics, simulated here as a Brownian motion of particles by means of a random walk process (e.g., Csanady, 1973; Visser, 1997). For an individual particle, the equation to solve is:

$$\frac{d\vec{x}_i}{dt} = \vec{u}_{sea}(x_i,t) + C_D\vec{u}_{wind}(x_i,t) + R\left(2K_h dt^{-1}\right)^{1/2} \quad (1)$$

where x_i is the particle position, u_{sea} is the advective velocity of the sea surface at x_i, u_{wind} is the 10 m height wind velocity at x_i, C_D is the wind drag coefficient, K_h is the turbulent horizontal diffusion (set here to be 1 $m^2\ s^{-1}$) and R is a random process; here, we use a standard normal distribution (e.g., North et al., 2006). The wind component is only used in the computation of oil spill trajectories, with $C_D = 0.03$. This value is dependent on wind speed and sea state (e.g., Abascal et al., 2009; Castanedo et al., 2006), although the value selected here has proven to produce good results during the simulation of the Prestige oil spill (e.g., Montero et al., 2003; Marta-Almeida et al., 2013). Sea surface currents are obtained from the child grid in the operational configuration of the ocean model (Fig. 1), whereas the wind speed fields are directly obtained from the outputs of the meteorological model.

Although the specific role of waves in the drift of oil slick becomes important in near-shore areas (e.g., Abascal et al., 2009), the present operational configuration does not compute waves, and therefore, the term has not been included in Equation (1). To not to lose focus on the scope of this tool (to obtain a very fast and user-friendly visualization tool), effects of oil weathering have not been taken into account.

Much of the efficiency of Alavai comes from the fact that the two advective terms are computed in advance once the model forecasts are ready. The displacement by advection (in both horizontal directions) that a particle departing from the center of each grid cell will experience in one time step is stored as a series of NetCDF files. These intermediate file are uploaded on a public THREDDS server, from where any THREDDS-enabled data analysis and display tools like Alavai can efficiently access them. Each of these intermediate files is in effect a Lagrangian return map that gives the final position in the model grid of an array of particles released at the grid centers after a given time interval. Banas and Hickey (2005) used a static version of this method (and a single return map, not a time series) to produce an interactive visualization of the tidal circulation of Willapa Bay, Washington, USA (http://coast.ocean.washington.edu/willapa/tidemodel.html; Banas et al. (2009) used a similar method to generate larval trajectories for a study of invasive green crab in Willapa Bay). Here, we have made a step forward and now we have a set of return maps, one for each time step (3600 s), but dynamically changing depending on the results of the operational model. In the present application, when the user locates the mouse cursor over the canvas, the software starts to plot the particle track from the correspondent pixel. The number of pixels in the canvas (in both directions) is higher than the number of model grid cells, which increases the resolution of the Lagrangian model. The software reads the displacement matrix in the intermediate file (lookup in the return-map) and interpolates data from the model grid to the current pixel. The software draws a first line linking the start and the end points (pixels in the canvas), after adding to the end location a random displacement (integration of the diffusive term in (1)). In iterative process, the software reads the displacement data for the next timesteps and repeats the steps, resulting in a complete drift track. One general advantage of the Lagrangian return map approach is that it separates the integration of three-dimensional model fields from the generation of the trajectory visualization. Thus, for other applications, one could