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Texas and Louisiana coastal vulnerability and shelf connectivity

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ABSTRACT

A numerical study of connectivity between the continental shelf and coast in the northwestern Gulf of Mexico using a circulation model and surface-limited numerical drifters shows that despite seasonal changes in winds, the overall connectivity of the shelf with the coastline is similar in the winter and summer, though it extends more offshore in Texas in summer. However, there is a spatial pattern to the connectivity: more of the inner shelf is connected with the coast in Texas as compared with Louisiana. Subsets of the coast do have seasonal variability: the coast near both Galveston and Port Aransas has more connectivity from upcoast in the winter and from offshore and downcoast in the summer. In both seasons, we find drifters reach the Port Aransas coast most frequently, with a stronger trend in the summer. These results are important for assessing likely pathways for spilled oil and other potentially hazardous material.

1. Introduction

The Texas coastline is at risk of impact by material from many sources including those related to the oil and gas industry, which plays a significant role in the state economy. However, not all areas along the coast are equally at risk for oil spill impacts. We seek to understand which areas along the Texas and Louisiana coastlines are more likely to be hit by oil spills, under what conditions, and from where the material can originate. Analogously, we want to know what areas are not likely to be impacted.

Numerical drifter tracking has often been used for understanding connectivity between regions of interest, and where released material will travel. Biological applications have included studies on larvae movement and regional connectivity for lobsters in the Gulf of Maine (Xue et al., 2008), coral in the Gulf of Mexico (Lugo-Fernández et al., 2001), larvae into Texas bays (Brown et al., 2000), and several species along the coast of Australia (Roughan et al., 2011); connectivity for several applications in Southern California (Mitarai et al., 2009) and especially harmful algal blooms in the Gulf of Maine (Li et al., 2014); and transport pathways for phytoplankton leading to harmful algal blooms in the Pacific Northwest (Giddings et al., 2014) and the Gulf of Mexico (Henrichs et al., 2015; Olascoaga et al., 2008; Thyng et al., 2013; Walsh et al., 2002). Transport of oil from spills is a major area of application as well. NOAA's Oil Spill Response group runs a particle tracking system (GNOME) which is used for emergency response during a spill (NOAA, 2014). Additionally, they have the ability to run other scenarios in order to determine the threat level and sensitivity of various regions to likely spill locations (Barker, 1999). In the aftermath of the Deepwater Horizon oil spill in 2010, many groups ran numerical circulation models with drifter models to follow the trajectory of oil from the oil spill (*e.g.*, Barker, 2011; Dietrich et al., 2012; Huntley et al., 2011; Liu et al., 2011; MacFadyen et al., 2011; North et al., 2011; Weisberg et al., 2011).

The Deepwater Horizon oil spill led to a focus on transport in the north Gulf of Mexico, but less is known in the northwestern Gulf of Mexico. Several relatively large groups of drifters were released in the 1990s in the SCULP experiment to study the circulation of the Texas-Louisiana and Florida-Alabama shelves (LaCasce and Ohlmann, 2003; Ohlmann and Niiler, 2005). Drifter data has shown little connectivity between the Texas-Louisiana and west Florida shelf (LaCasce and Ohlmann, 2003; Ohlmann and Niiler, 2005). On the Texas-Louisiana shelf, flow tends to move along-shore – parallel to isobaths – but with cross-shore movement possible on the inner shelf due to convergent winds, and cross-shelf movement due to deeper Gulf eddies impinging at the shelf edge (Cho et al., 1998; Cochrane and Kelly, 1986; Ohlmann and Niiler, 2005). Oil spilled near Texas City in March 2014, traveled mostly downcoast (NOAA, 2015; Walpert et al., 2014). Smaller scale studies have examined larval transport and settlement in Texas bays and also noted the importance of along-coast

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movement (Brown et al., 2004, 2005, 2000). In a study of the physical mechanisms for harmful algal bloom initiation in the northwest Gulf of Mexico, researchers found evidence of connectivity between the southern and northwest Gulf of Mexico (Thyng et al., 2013).

In this paper, we use numerical drifters in a high resolution circulation model of the Texas-Louisiana shelf to determine connectivity with the coast. We will show that while seasonal connectivity between the inner shelf and coast is largely uniform, there are seasonal variations for particular coast segments. Additionally, particular coastal areas, especially Port Aransas, have the potential to be impacted with drifters at a much higher rate than other areas in both the summer and winter.

2. Methodology

2.1. Numerical circulation model

Velocity fields for this study are taken from a numerical ocean circulation model run using the Regional Ocean Modeling System (ROMS) (Shchepetkin and McWilliams, 2005). The model domain includes the Texas and Louisiana continental shelves (Fig. 1) (Hetland, 2015). This model has been used in several studies of the area (*e.g.*, Fennel et al. (2013), Thyng et al. (2013), Zhang and Hetland (2012)). It has been previously validated with salinity data in order to understand how well the mixing processes are working (Zhang et al., 2012b), and with sea surface heights, currents, and temperature (Zhang et al., 2012a). The seasonal behavior of sea surface height, temperature, and velocities as well as the significant inertial oscillation signal are captured by the model. Additionally, the surface salinity field is spatially represented in the model output.

The grid is curvilinear and has been stretched to have higher horizontal resolution near the Mississippi river delta (∼500 m) and lower near the open boundary (∼1–2 km). There are 30 vertical layers, which are stretched between 3 and 3000 m to capture the top and bottom of the water column. The ocean circulation model is one-way nested inside a HYCOM model of the Gulf of Mexico (HYCOM Consortium, 2013) for realistic boundary forcing, with surface forcing additionally of 2D wind, sea surface heat (short wave), and salt fluxes from the North American Regional Reanalysis (NARR) dataset. Data from eight rivers are input into the model domain as inflowing fresh water fluxes from the USGS (US Geological Survey) Real-Time Water Data for the Nation. More model setup details can be found in Zhang et al. (2012a).

2.2. Lagrangian trajectory model

Transport and connectivity properties on the shelf are calculated using simulated drifters that represent passive parcels of water. Numerical drifters are run offline using velocity fields predicted by the ROMS model, which are saved every 4 h. The algorithm of the Lagrangian trajectory model is from TRACMASS, which steps numerical drifters in time natively on a staggered Arakawa C grid in such a way that allows for the maximum drifter trajectory accuracy possible given a numerical grid and the temporal frequency of circulation model output (Blanke and Raynaud, 1997; Döös, 1995; Döös et al., 2013). TRACMASS has been used in both oceanography and atmospheric studies for fundamental studies and applications. The TRACMASS algorithm, which is written in Fortran, has been wrapped in Python for running in batches of simulations; the Python system is named TracPy (Thyng and Hetland, 2014). This

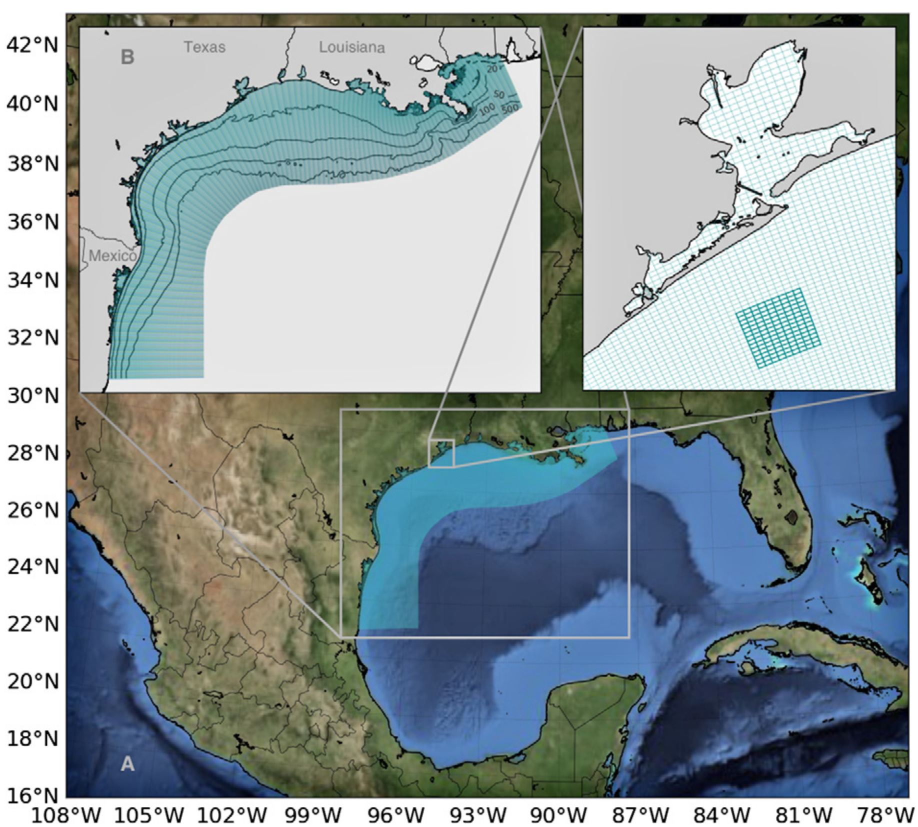

Fig. 1. The region of interest. The Gulf of Mexico with the numerical domain indicated [turquoise] (A), a magnified view of the numerical domain grid with 20, 50, 100, and 500m isobaths shown (B), and a view of Galveston Bay with the actual grid resolution shown (C). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

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