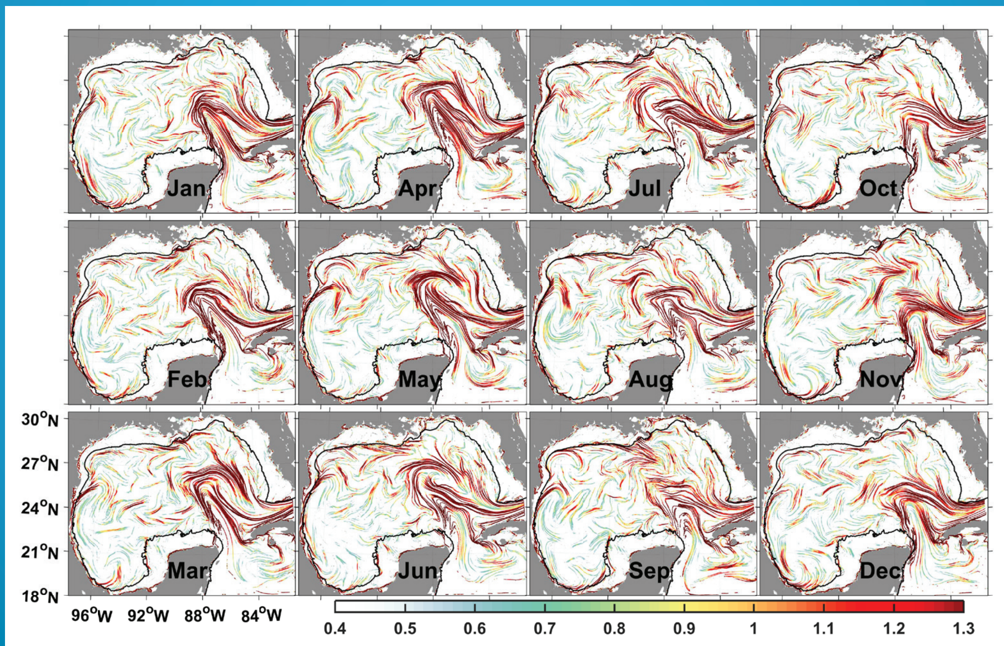
EXTRACTING PERSISTENTLY ISOLATED OR ATTRACTING REGIONS FROM THE OCEAN CIRCULATION: THE CLIMATOLOGICAL ISOLATION AND ATTRACTION MODEL



Lines (squeezelines) represent climatologically persistent sea-surface trajectories that attract nearby trajectories. Red means increased attraction strength while white means negligible attraction, which in turn implies isolation or stagnation. These lines tend to organize transport at the sea surface.

NETL

NATIONAL ENERGY TECHNOLOGY LABORATORY

BACKGROUND/INTRODUCTION

The U.S. Department of Energy's (DOE) National Energy Technology Laboratory (NETL) engages in basic and applied research to support DOE's objective to produce science-based evaluations of engineered and natural systems to ensure sustainable, environmentally responsible access to domestic resources, and help prevent future hydrocarbon spills.

Lagrangian transport is a difficult oceanographic problem for which solutions are frequently needed e.g. for oil-spill simulations using NETL's blowout and spill model BLOSOM, among other applications. Sensitivity to initial conditions or to the precision of the velocity field require more attention to detail than what researchers are usually able to afford. Ensemble modeling, extensive calibrating, repeated re-initialization and stochastic methods are commonly used in an attempt to compensate for the problems inherent to trajectory computations.

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PROJECT GOAL

In search of a broader picture, the goal of this project is to find persistent structures that organize trajectories in the ocean. If found, these persistent structures would provide a broad, general outlook for how contaminants or other tracers are likely to disperse due to the ocean's surface circulation. Finding regions in the ocean that are more likely to be impacted is essential to DOE's mission of oil-spill prevention and response.

PROJECT OBJECTIVES

The objectives of this project include:

- Find recurrent or persistent transport patterns in the ocean
- Find the strength with which these recurrent transport patterns influence nearby water parcels
- Find regions that persistently attract nearby water parcels
- Additionally, find regions that are isolated or stagnant, and are therefore unlikely to be impacted if an oil spill initiated outside of such a region

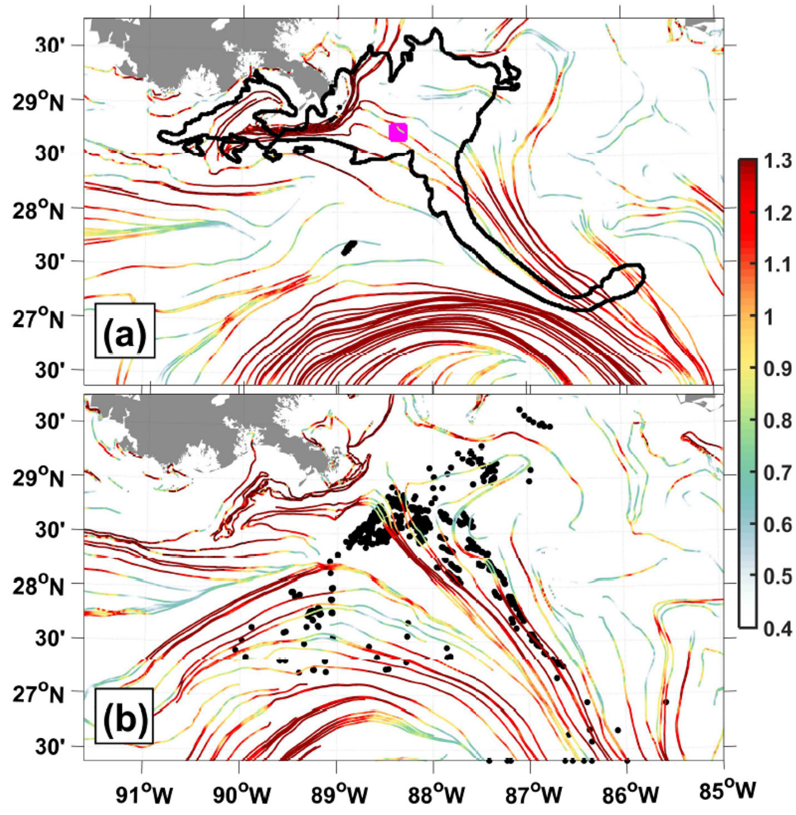

Figure 1. (a) Oil motion during the Deepwater Horizon as seen on May 17, 2010, closely conforms to climatological squeezelines for May. These squeezelines tend to organize transport at the sea surface during any given May. (b) Daily positions of drifters from July 29 to August 2, 2012 during the Grand Lagrangian Deployment experiment, stretch along the climatological squeezelines for any given July.

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PROJECT DESCRIPTION

A long record of surface currents in the Gulf of Mexico (GoM) from a data-assimilative simulation was analyzed using tools from the theory of nonlinear dynamical systems. These tools enable objective (i.e. observer-independent) identification of key material lines that organize Lagrangian transport, often referred to as Lagrangian coherent structures (LCSs). Researchers found an objective way to compute climatological LCSs that strongly constrain the circulation in the Gulf of Mexico. Other successful applications of the method are underway in different regions of the world.

NETL CAPABILITIES

NETL has created an integrated data and modeling system to support DOE's objective to produce science-based evaluations of engineered and natural systems to ensure sustainable, environmentally responsible access to domestic resources, and help prevent future hydrocarbon spills.

The Blowout and Spill Occurrence Model (BLOSOM) is an integrated system designed to simulate offshore oil spills resulting from deepwater (>500 feet) and ultra-deepwater (>5,000 feet) well blowouts. BLOSOM assists with risk assessment and can help to prevent future hydrocarbon spills. In addition, BLOSOM serves as a comprehensive tool for response planning.

To analyze broad risks associated with various forms of energy production and exploration, NETL developed the Cumulative Spatial Impact Layer (CSIL) tool. Utilizing a spatiotemporal approach, the CSIL tool integrates datasets related to various social, economic, and environmental information for a region (e.g., oil and gas infrastructure, tourism, local parks, etc.) to rapidly assess potential impacts and inform environmental risk reduction efforts.

Building on the CSIL approach, the Spatially Weighted Impact Model (SWIM) integrates the CSIL with user-defi ned weights related to potential impacts to support research and regulatory decision needs. Originally designed to evaluate simulated offshore hydrocarbon spills, both CSIL and SWIM tools can be utilized with NETL's Blowout and Spill Occurrence Model (BLOSOM) to evaluate different scenarios. These results can then be used to identify knowledge gaps, support spill prevention efforts, and inform regulatory decisions.

PROJECT BENEFITS

The benefits of this research include:

- CIAM can detect the location of persistent jets and maximal velocity shear, which are of interest to the oil industry
- Maps generated using the new method, the Climatological Isolation and Attraction Model (CIAM), identify regions at high risk of being visited by contaminants, as well as regions that are isolated or stagnant
- CIAM constitutes a breakthrough, providing a technique to compute highly-accurate Lagrangian transport climatologies, a difficult oceanographic problem with a wide range of applications including:
  - Fisheries and larval recruitment
  - Search and rescue operations
  - Environmental pollution planning, prevention response
  - Optimizing navigation

CIAM is being incorporated to the broader Offshore Risk Modeling suite of data, tools and methods. All of which improve prediction of offshore systems to prevent spills, improve decision making, and reduce "costs" of offshore oil and gas operations.

Integrating CIAM with CSIL and SWIM would allow stakeholders to identify and weigh climatological risks or absence of risks, thus providing a long-term outlook that has so far escaped quantification. Future research will focus on using CIAM to weigh predominant transport patterns during oil-spill forecasts, thus complementing models like the National Energy Technology Laboratory blowout and spill model BLOSOM, or the NOAA's General NOAA Operational Modeling Environment (GNOME).

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ACCOMPLISHMENTS/SUCCESSES

Over the last several decades, researchers have come to understand the ocean as a fluid in perpetual turbulent motion, rich with temporal variability. This study has shown for the first time, the existence of persistent structures that, hidden behind the ever-changing currents, strongly influence how water parcels move at the ocean's surface. Maps generated using the new method can be used to identify regions at high risk of being visited by contaminants (attracting regions), as well as regions that are isolated or stagnant.

Compared to similar approaches, the new method provides more information by rapidly and clearly depicting likely pathways as well as the relative strength with which these pathways attract nearby fluid parcels – valuable information that assists with oil-spill forecasts. Additionally, the new method is more general than approaches used so far, because one does not need to know the location of a pollution source *a priori.*

This research shows that it is possible to find quasi-steady, general patterns that describe important aspects of the inherently time-dependent, chaotic problem of oceanic Lagrangian transport—this appraises new applications as practical. The method behind CIAM has been published by Scientific Reports, from the prestigious publisher Nature.

REFERENCES

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