Satellite Measurements of Ocean Surface Currents – Critical Applications

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1. *What are the key challenges or questions for Earth System Science across the spectrum of basic research, applied research, applications, and/or operations in the coming decade?*

Surface current is a critical ocean variable that is not measured by today's global observing system. Although geostrophic currents may be deduced from satellite altimetry data, these currents are generally not representative of surface currents, which have strong ageostrophic contributions. Because of the substantial, but yet poorly understood, vertical shear near the ocean's surface (Figure 1), ocean models still struggle to accurately simulate and predict the surface currents. Yet it is the surface current that most directly affects human activities and the results of those activities. A **key challenge** for Earth System Science in the coming decade is to be able to observe and predict the surface currents over the global ocean.

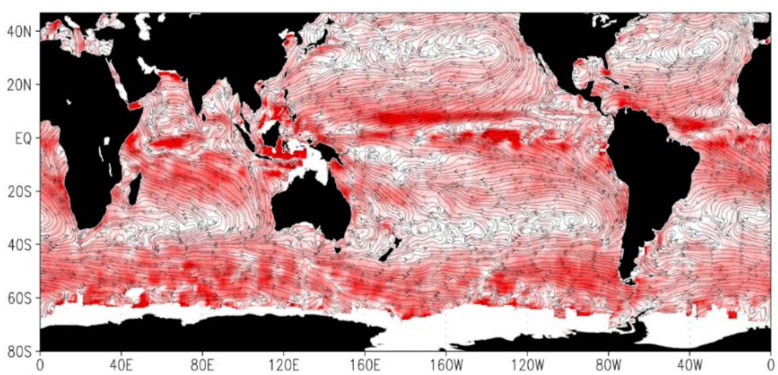

Figure 1. Map of mean shear between the surface and 15m depth inferred from satellite-tracked drifting buoys in the ocean, considering buoys with drogues at 15m and those that have lost drogues.

2. *Why are these challenge/questions timely to address now especially with respect to readiness?*

Lessons from recent disasters including major oil spills and debris releases from tsunamis have taught us that our present understanding and depiction of surface currents that move this material is sorely lacking. Though technology to remotely sense surface currents is well established using ground-based sensors, these data are only available for instrumented locations of the coastal ocean in developed nations. Advances in acquiring and processing microwave backscatter data (e.g., Doppler scatterometry) now allow for the possibility of observing the global ocean's surface currents from space-based platforms, providing not only a valuable new data source of a previously unobserved variable for scientific discovery and contribution to the climate data record, but important observations that have profound practical applications ranging from human safety to mitigation of environmental disasters. International interest (specifically from Indian and Japanese space agencies) in collaborating on instrument design and activities related to the mission make this a very tractable effort in terms of technology and cost in the coming decade.

Typically a difficult variable to measure, surface currents are related to the underlying ocean velocity and overlying atmospheric forcing through complex ocean mixed layer dynamics. Satellite observations of surface currents with uniform coverage and quality will help to elucidate the rectified effects of surface waves (including Stokes drift by linear waves, momentum injection by breaking waves, and wave-induced turbulence), the diurnal cycle and many other high-frequency processes not resolved by the observing system, improving their theoretical description and numerical modeling capability. Combined with the existing and advanced satellite observations of surface winds, surface current observations will improve understanding of the atmosphere-ocean interaction through fluxes of momentum and energy. This interaction is of critical importance for the Earth Climate System.

A non-exhaustive list of applications to society of satellite-based observations of surface currents includes:

- *Tracking of Contaminants and Debris*

  During the 2010 DeepWater Horizon oil spill in the Gulf of Mexico, substantial uncertainty existed in predictions of the movement of the surface oil (Figure 2), despite the availability of extensive observing systems and operational and experimental ocean and weather models (Liu et al., 2011). The 2011 tsunami that devastated parts of the Japanese coast released a very large amount of debris into the Pacific Ocean. Floating objects within this debris field are expected to impact coastal areas throughout North America in the coming years (Maximenko et al., 2015).

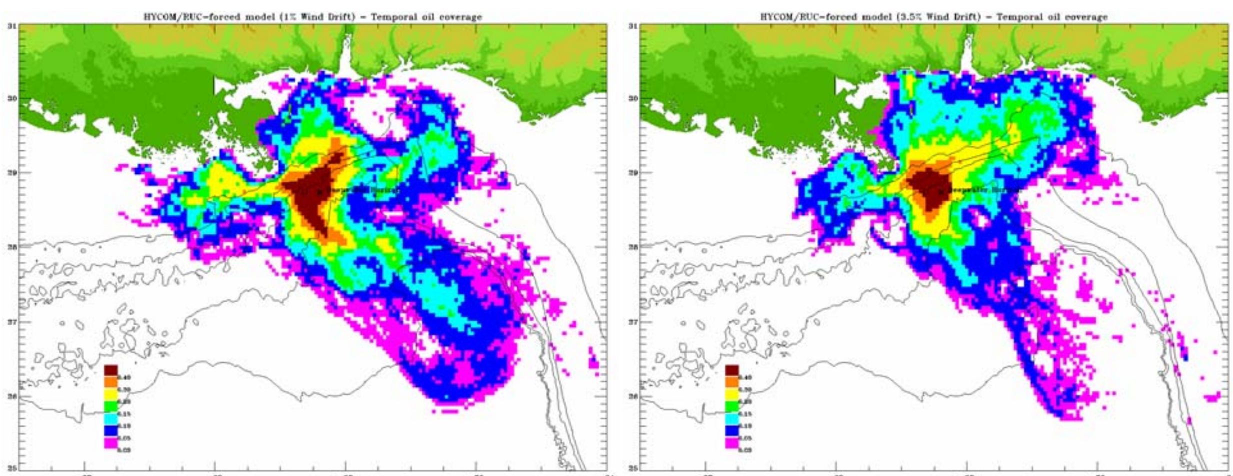

Figure 2. Temporal coverage of surface oil (fraction of total time period 22 April 2010 – 14 July 2010 that oil was present in each 5km x 5km grid cell) from two simulations of the BP Deepwater Horizon oil spill using different methods of computing surface drift from ocean model currents.

Nearly no data on surface currents are available from observing networks (e.g., coastal radar) in coastal areas of less developed nations or over the open ocean that can be used for tracking oil or floating debris, and global ocean models suffer from uncertainties in wind forcing over poorly observed regions. Since floating material moves with the current at the very surface of the ocean and numerical models instead simulate the current averaged over a layer typically several meters deep, rather crude methods are typically used to parameterize the surface currents from models accounting for vertical shear dependent on wind. Thus, uncertainties in the wind-driven model currents as well as in methods of inferring surface currents from model currents proves to be the most challenging factors in predicting surface drift. Tracking of floating contaminants and debris would benefit greatly from near-real-time observations of global ocean surface currents.

- *Biological Applications*

  At a recent NOAA/NASA funded workshop on fisheries and climate (St. Petersburg, October 2015), enhanced observations of physical oceanographic variables including surface currents were identified as a high-priority need, which was particularly interesting considering the overwhelming majority of participants were from the biology disciplines. However, the larvae of many aquatic species are buoyant and future advances in management will consider larvae transport in determining recruitment for stock assessment. A recent episode of anomalously thick Sargassum (a floating aquatic plant) in the Caribbean has had profound impacts on the marine ecosystem, and the source of this Sargassum is not known (Johnson et al., 2012). These are just examples of biological material transported by surface currents, satellite observations of which would have important applications in marine ecosystem research and management.

- *Forecasting and Operational Applications*

  Maritime safety, transportation, and military operations depend critically on analyses and forecasts of surface currents. These activities are supported by private and governmental operational centers that analyze available observations and use ocean model forecasts to provide data on surface currents directly to users in the field for activities including: search-and-rescue, naval operations and ship routing. The availability of near-real-time observations of global surface currents would have a profound impact on these activities, reducing shipping time and fuel usage, reducing loss of life at sea, and enhancing warfighting capabilities.

3. *Why are space-based observations fundamental to addressing these challenges/questions?*

Presently, the ability to respond to disasters and provide data on surface currents for applications such as those listed above depends fundamentally on geographic location. The availability of coastal and marine-based observations and veracity of models for providing surface current data varies widely throughout the world. A large majority of applications of surface currents Space-based observations of the ocean surface currents will not only provide direct observations of a key variable of high relevance to society, but can also readily be used in conjunction with other space-based observations (for example, altimetry and winds) and *in situ* observations (upper ocean velocity from surface drifters and current meter moorings) to address the outstanding scientific questions in the oceanographic and atmospheric science communities regarding the vertical structure of the near-surface ocean currents, air-sea fluxes of momentum and kinetic energy, and turbulence in the upper ocean, as a lack of understanding of the vertical structure of the near-surface velocity field is a major source of uncertainty in the ability to predict the movement of oil, debris, people, and biological material. A combination of currents and ocean color will be highly useful for coupling physical and biological ocean modeling.

References

Johnson, D.R., D.S. Ko, J.S. Franks, P. Moreno, and G. Sanchez-Rubio (2012), The Sargassum invasion of the eastern Caribbean and dynamics of the equatorial North Atlantic, 65th Gulf and Caribbean Fisheries Institute, Columbia, http://www.usm.edu/gcrl/sargassum/docs/Johnson.et.al.Sargassum.event.in.Caribbean.2011.65th.GCFI.Presentation.pdf

Liu, Y. Y., Weisberg, R. H. R. H., Hu, C. C. and Zheng, L. L. (2011), Trajectory Forecast as a Rapid Response to the *Deepwater Horizon* Oil Spill, in Monitoring and Modeling the Deepwater Horizon Oil Spill: A Record-Breaking Enterprise (eds Y. Liu, A. Macfadyen, Z.-G. Ji and R. H. Weisberg), American Geophysical Union, Washington, D. C.. doi: 10.1029/2011GM001121

Maximenko, N., A. MacFadyen, and M. Kamachi (2015), Modeling the drift of marine debris generated by the 2011 tsunami in Japan, PICES Press, 23(2), 1-5.