Wind and Current Coupling

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1. Wind and current coupling at the air/sea interface is extremely poorly known and adversely impacts our understanding of large and small scale processes, including those that impact regional economies

The air-sea interface is a critical link in the Earth's climate system; incomplete knowledge of the dynamics at this interface causes significant errors in the representation of horizontal and vertical mass and heat transports in the upper ocean, and limits the accuracy of climate and seasonal forecast models. Global surface currents are the most important and least directly observed ocean currents. The global relation between the surface wind and the speed and direction of wind-driven surface currents is unknown and unobserved. Theory and inferences from near-surface measurements suggest that velocity differences comparable to the magnitude of the wind-driven current itself likely often occur over the upper few meters of the ocean.

Evidence exists that near-surface currents due to momentum exchange between the ocean and the atmosphere are substantially different from those inferred from existing, indirect observational techniques, and that these differences have important implications for vertical and horizontal transports of upper-ocean heat. Theoretical differences are also substantial. The lack of understanding of surface currents and their relation to surface winds limits our ability to represent in predictive models such phenomena and processes as: meridional and zonal tropical heat transport; equatorial currents and upwelling; ENSO and MJO dynamics; tropical eastern Pacific and Atlantic sea-surface temperature and air-sea interaction, as well as dispersal of pollutants and floating marine debris.

Wind-driven circulation accounts for much of the poleward heat transport by the ocean. Vigorous air-sea exchanges of heat and carbon dioxide preferentially take place over upwelling and western boundary regions because of wind-driven circulation. Through momentum and heat fluxes, surface winds are a key variable mediating the interaction of the ocean and atmosphere. The interaction gives rise to observed climate variability such as El Nino/Southern Oscillation and is the physical basis for climate prediction. Scale interaction remains a challenge for atmospheric and climate dynamics, with well documented upscale effects from meso-scale cloud clusters to the planetary-scale intraseasonal Madden-Julian Oscillation (MJO). The circulation of the former is poorly sampled in time by existing satellite scatterometry. By exciting large-amplitude planetary-scale waves in the equatorial ocean, MJO affects the evolution of ENSO events and is an important source of uncertainty in ENSO prediction (Chen et al. 2015; McPhaden 2015). Both ENSO and the MJO influence the likelihood of hurricanes forming. Hurricanes can have a large impact on property and infrastructure. ENSO has a large impact on interannual shifts in weather and hence large impacts on agriculture as well as aquaculture.

The upper ocean supports productive fisheries that are essential to the global economy, and bears an increasing burden of human impacts, including pollutants associated with offshore resource extraction and, in coastal regions, high-density economic development and at-sea activity. Ocean surface currents and wind coupling are also important to the transport of ice and melt water in high latitudes. These Arctic wind and currents strongly influence the vertical and horizontal heat transport in the Arctic Seas, and have been hypothesized to influence similar transports in the North Atlantic Ocean. In all of these contexts and more, the role of the near-surface ocean is paramount: it supports the exchange of heat and dissolved gases with the atmosphere, it supplies the primary biological productivity that drives fishery ecosystems, and it determines the spread and fate of surface pollutants. The vertical exchange of fluid and materials between the near-surface (the uppermost 10-100 m of the water column) and the deeper ocean, especially the systematic upwelling of nutrient-rich deeper waters into the upper ocean, strongly affects the properties and dynamics of the near-surface ocean and upper ocean ecosystems. Model-based assessments of near-surface/deep ocean vertical transports vary widely, in part because they rely on relatively sparse measurements relative to the appropriate space and time scales.

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

With climate projected to warm, regional information on climate change is in high demand but remains highly uncertain. A recent review identified the atmospheric circulation change as the leading cause of the regional uncertainty (Xie et al. 2015). Measurement errors and large internal variability prevent ship-based historical observations from providing strong constraints on surface wind change (Tokinaga et al. 2012; L'Heureux et al. 2013). The decadal cooling of the tropical Pacific, coupled with strengthened equatorial trade winds and temporarily slowing down the global temperature increase, is a sober reminder of the complex interaction of anthropogenic climate change and internal variability. Sustained, cross-calibrated global observations of surface wind vectors from space are essential to reduce measurement and sampling errors and constrain climate model projections regarding the atmospheric circulation change and the interaction with the ocean.

Surface winds drive ocean circulation both locally through Ekman dynamics and remotely through planetary waves. Both the local and remote mechanisms are at work in generating the equatorial cold tongue, home to El Nino/Southern Oscillation. While satellite altimetry offers global observations of planetary wave propagation and estimates of geostrophic current, surface currents include a large ageostrophic component (especially in climatically important equatorial oceans), and have never been observed globally from space. Concurrent observations of evolving winds and currents will open new opportunities to study their interaction and three-dimensional advective processes that generate sea surface temperature variability.

New technology exists (space-based microwave Doppler radar scatterometry) to address this fundamental gap in the global ocean-atmosphere observing system. This new technology offers the first opportunity to obtain the contemporaneous collocated global observations of surface winds (or stress) and surface currents that are required to address these basic Earth science questions.

3. Why are space-based observations fundamental to addressing these

challenges/questions?

Space-based observations are the most effective and perhaps the only way to obtain sufficient spatial coverage observations of surface winds and surface currents. While the need for measurements of surface currents has been recognized by space agencies (e.g., ESA) there has yet to be a funded mission. Several methods have been proposed to retrieve vector surface currents, the most cost effective of which is a Doppler scatterometer. Such an instrument would also simultaneously measure currents and surface winds, which would be highly advantageous. Both the Indian and Japanese space agencies have expressed interest in collaborating with NASA on activities related to such an instrument, to the extent of possibly covering the costs of a launch vehicle, a satellite bus, and collaborating on antenna design, thus greatly reducing the cost of such a mission. The technology for such a mission has been developed, and surface observations have been used to address the key technical questions: the investment that is still needed is construction of the instrument and fostering of these collaborations.

The value of this investment will be multiplied by simultaneous spaced-based high-resolution ocean topography and in-situ near-surface current and water property measurements from global drifter and float arrays. It could also be increased by placement in a satellite train that included observations of microwave SST, microwave profilers (that can be used with scatterometers to estimate surface turbulent fluxes), and observations of ocean color.

Anticipated benefits include new understanding of upper ocean dynamics and air-sea exchange relevant to a broad array of ocean-atmosphere processes; improved climate, seasonal, and weather forecasting models; improved practical prediction of pollutant dispersal and marine debris, as well as improvement related to the coupled ocean/atmosphere system when coupled with the instruments mentioned in the above paragraph.

Relevant science communities include physical oceanography, climate/seasonal/weather forecasting and dynamics, biological & chemical oceanography, high latitude Arctic oceanography and Southern Ocean oceanography. Operational communities from naval operations, ship routing, weather and ocean forecasting, and climate forecasting would gain a great deal from a mission that included a Doppler scatterometer.

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