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Recent Advances in Geophysical Sensing of the Ocean: Remote and In Situ Methods

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This special section seeks to address issues related to remote and *in situ* sensing of open and coastal oceans to better understand our planet's large-scale events, such as El Nino and hurricane formation and tracking, long-term events such as global climate change, short-term weather predictions of both the atmosphere and the ocean, and small-scale oceanic properties, such as mixing patterns and biological layers.

Oceanography has been called both the oldest and the youngest discipline in scientific research. While sounding counterintuitive, it makes sense if one looks back both in time and approaches to applications. Traditionally, our understanding toward oceans came from close contact based on our daily needs for food supply, transportation, weather, water condition, and so on. This nonsystematic approach lasted thousands of years until the Challenger Expedition in the 1870s, where the first systematic study of ocean currents, biota, bathymetry, and seafloor was accomplished. However, modern ocean researchers today would not recognize these days as the start of oceanography. The extensive use of electronic sensors in acoustics, magnetics, optics, and other analog devices compounded our ocean knowledge at an accelerated pace, which was driven by the world wars and the Cold War that followed. Ocean sensing was mostly focused on measurements from research vessels where water samples were taken, and sensor packages were deployed into the water and/or the seafloor. This *in situ* sampling approach persisted until the later part of the 20th century, when remote sensing from above the sea surface ushered ocean research into a new era.

It might be surprising to our readers that although the focus of the special section is on both *in situ* and remote sensing advances, all of the contributions are on remote methods. It is understandable as remote sensing is the most cost-effective way to obtain synoptic coverage of measurement in a rapid and convenient manner. However, remote sensing results can be deceiving, since sensors are largely dependent on calibration as well as ground truth.

This is precisely the reason we included "JPSS VIIRS level 3 uncollated sea surface temperature product at NOAA" by Ignatov et al. in this issue. The Visible Infrared Imager Radiometer Suite (VIIRS), as we know, has been widely used since its launch in October 2011 as part of the Suomi National Polar-orbiting Partnership. National Oceanic and Atmospheric Administration (NOAA) generates global level 2 preprocessed (L2P) sea surface temperature (SST) product, which has been assimilated in several ocean models. The NOAA VIIRS L3U (level 3 uncollated) SST product is operationally used or tested in several major international numerical weather prediction centers.

Similar to the fact that SST is a vital component of numerical weather forecasting models, heat penetration into the depth of the ocean is equally important in ocean forecasting. Shuman et al. point out in their paper "Impact of errors in short wave radiation and its attenuation on modeled upper ocean heat content" such influence and the result of the current missing link. Photosynthetically available radiation (PAR) and vertical attenuation with the depth represent the subsurface heating in the oceanic dynamical models. Current ocean models integrate surface PAR from atmospheric models, with the PAR's subsurface attenuation coefficient estimated within the oceanic dynamical model. Their model and measurement from the Monterey Bay area shows the relative error in surface PAR will introduce errors seven times as large into the model heat content as the same magnitude relative error in the attenuation coefficient. While the sensitivities to the errors in surface PAR are all positive, sensitivities to the errors

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in attenuation coefficient have positive and negative values, depending on location. These biases are positive in shallower water for locations on the shelf and negative in deeper offshore waters.

One of the most exciting advantages of the remote sensing approach is that it delivers synoptic coverage on a global scale on a continuous basis. The downside of this is the lack of continuous coverage on areas of interests, which limits our ability to examine many important processes over time. Through smart processing and ground truth, however, one can extend spatial-temporal coverage to examine changes over time. This is what Arnone et al. achieved and described in their paper "Diurnal changes in ocean color sensed in satellite imagery." By taking advantage of the overlapping VIIRS orbits set apart less than 2 hours in time, they are able to show significant differences in ocean color products of biomass or chlorophyll concentration in a certain part of the Gulf of Mexico. Rapid changes in ocean color confirm that sensor validation must account for coincident matchups at time of overpass. Diurnal changes in satellite penetration depth suggests spatial variability in surface upwelling and downwelling variability. New products of the "diurnal difference" in ocean color were shown to identify changing surface processes that occur both spatially and vertically in ocean waters throughout the diurnal cycle. This research demonstrates applications for future geostationary ocean color remote sensors for data collection throughout the day.

Complex dynamics can be derived and monitored by applying these techniques, which is what Cambazoglu et al. accomplished in their "Inflow of shelf waters into the Mississippi Sound and Mobile Bay estuaries in October 2015." The paper addressed methods for coupling physical circulation models, satellite bio-optical properties, and *in situ* salinity data to study episodic exchange of water masses across the Mississippi shelf. The effects of the seasonal river discharge and surface winds on the shelf water exchange were demonstrated by the salinity changes on the coast during the passage of tropical storm Patricia. The research also demonstrated the ability to integrate remote sensing models and observations to identify the response of coastal ocean waters to effects of tropical storms.

Harmful algal blooms (HAB) are one of the most noticeable impacts affecting our coastal environment. Ahmed et al. discuss the use of artificial intelligence to detect such events in their paper "Satellite retrievals of Karenia brevis harmful algal blooms in the West Florida shelf using neural networks and impacts of temporal variabilities." This approach demonstrates using the VIIRS sensor which does not have the fluorescence channels compared to the MODIS sensor for detection of HABS in coastal waters. The new method can be applied to future VIIRS sensors for monitoring the West Florida waters.

Environmental monitoring especially during extreme events, such as oil spills, has gained strong momentum recently. "Kernel parameter variation-based selective ensemble support vector data description (SVDD) for oil spill detection on the ocean via hyperspectral imaging" by Uslu et al. outlines an interesting improvement in this area based on hyperspectral imaging. Improved methods of using hyperspectral imaging for oil detection were discussed. A fast computational method using kernel parameters for the SVDD were tested to demonstrate the capability in hyperspectral sensing. The procedure for detection was evaluated with AVIRIS oil spill imagery in the Gulf of Mexico.

Ocean dynamics prediction requires detailed input and constraints from observations. "Comparison of retracked coastal altimetry sea levels against high frequency radar on the continental shelf of the Great Barrier Reef, Australia" by Idris et al. seeks to address such requirements. Under challenging conditions, consider discrepancies in sensing differences between satellite sensor (Jason-1) and HF, about half of the variations were credited to geostrophic components, which is to be expected.

New remote sensing platforms such as unmanned aerial vehicles or "drones" provide us with more flexibility in sensing capability, higher resolution, and less interference from atmosphere. New sensors are needed to take advantage of these developments. A good pair of examples are "Integrating dynamic and distributed compressive sensing techniques to enhance image quality of the compressive line sensing system for unmanned aerial vehicles application" by Ouyang et al., and "Laser-based water depth measurement system deployed via unmanned aerial vehicle" by Shen et al. These approaches efficiently address the concerns of size, weight, and power (SWaP) for unmanned platforms.

We appreciate the contributions from the authors and many reviewers for their time and suggestions to make these papers into finer shapes. Due to the time constraints, not all submitted papers to the special section were used. We applaud their efforts and expect to see these results in regular JARS issues soon.