Foreword to the Special Issue on the Remote Sensing of the World Oceans

SINCE the launch of the first spaceborne satellite, SEASAT, targeted for ocean research in 1978, traditional remote-sensing technologies based on the original four major instruments (radiometer, altimeter, scatterometer, and synthetic aperture radar or SAR) onboard SEASAT, have greatly contributed to major advances in many marine science fields. In the past decades, ocean research works using novel remote-sensing technologies and data from new missions were carried out worldwide and we have learnt about the sea surface wind, current, ocean color, temperature, salinity, etc. and their short- and long-term variability with greater and greater details. There has also been an increasing trend in the synergistic use of multisensor remote-sensing observations with models, especially based on data assimilation systems for ocean studies. In order to compile cutting-edge research in remote-sensing oceanography and to facilitate the exchange of ideas among colleagues, we proposed to organize a Special Issue (SI) of IEEE JOURNAL OF SELECTED TOPICS IN APPLIED EARTH OBSERVATIONS AND REMOTE SENSING (JSTARS) to demonstrate the state-of-the-art in utilizing remote-sensing data for ocean research in 2014. After two years of hard work by the authors, reviewers, and guest editors, we have published 36 papers in this SI. The papers were authored by over 100 scientists from more than 40 universities, academic institutions, government agencies, and companies. The contents of this SI are organized in six areas.

1) Ocean applications with SAR remote sensing.
2) Meso-scale and large-scale oceanic variability studies using altimeter data.
3) Ocean surface and bathymetry feature detections with high-resolution true-color imagery.
4) Ocean color remote sensing.
5) Instrument calibration and validation.
6) Ocean surface wind retrieval with new instruments.

1) Ocean applications with SAR remote sensing: Included are 12 papers that demonstrate SAR applications in oceanic, coastal, and oil spill research. There have been many SAR satellites launched since Seasat including those of the European Space Agency or ESA (ERS-1/2, Envisat), the Canadian Space Agency (RADARSAT-1/2), the Japan Aerospace Exploration Agency (ALOS-1/2), the German DLR (TerraSAR-X; Tandem-X), Italian Space Agency (COSMO-SkyMed), among others. Especially in 2014 and 2016, ESA launched the Sentinel-1 A and B, and for the first time SAR data are made available to general public free and open. SAR measures normalized radar cross-section (NRCS) backscattered from the Earth's surface. Therefore, different types of objects on Earth can be distinguished in SAR images due to different scattering mechanisms. Researchers have developed image classification scheme to delineate the coastline from the ocean body and monitor its long-time changes [1]–[3]. Oil slicks and oil spills also have distinct signatures in both the single-polarization SAR intensity image as they smoothed the ocean surface capillary waves and the scattering matrices measured by multipolarization SAR [4]–[9]. Wave breaking mechanism is discussed in [4] and oil spill drifting models have been used to track the movement of the oil [7]. There has been development of geophysical model function to relate the SAR-measured NRCS to various geophysical parameters. One of the most important parameters, sea surface wind, is presented in [10]. Multipolarization and along-track InSAR applications in ice and ocean tidal energy studies are given in [11], [12], respectively.

2) Meso-scale and large-scale oceanic variability studies using altimeter data: There are nine papers using altimeter data for ocean studies. Altimeter measures the dynamical topography. Sea surface height anomalies derived from multisatellite altimeter data during the past 20 years have been used to study sea state's bias affecting altimeter data [13], meso-scale eddies [14], western boundary current's meandering [15], weakening [16], and intraseasonal variability [17], and sea surface height interannual and decadal variability [18]. Several studies take advantage of the synergy between the sea surface height (radar altimeter data), sea surface wind (radar scatterometer data), sea surface temperature (radiometer data) and optical imagers for storm surge modeling [19], ocean surface and interior information retrieval [20], and ice/ice sheet monitoring [21].

3) Ocean surface and bathymetry feature detections with high-resolution true-color imagery: Three papers address the use of high-resolution true-color RGB images for coastline extractions [22], coastal bathymetry mapping [23], and oil spill monitoring [24]. The capability of these high-resolution images is demonstrated.

4) Ocean color remote sensing: Eight papers deal with ocean color image applications and geophysical parameter retrieval algorithm development. The National Aeronautics and Space Administration (NASA) MODIS (or Moderate Resolution Imaging Spectroradiometer) still plays a key role in these studies. Ocean color data are used to study coastal upwelling along the China Sea coast [25], algal blooms in Kuwait Bay [26], Green Tide in the Yellow Sea [27], and surface suspended sediment concentration [28]. MODIS and Landsat images were combined to study plumes in the Baltic Sea [26]. Remotely sensed sea surface temperature and Chlorophyll a (Chl-a) data are used to estimate the maximum carbon fixation rate and ocean primary production [30]. There are also two papers on future ocean color sensors simulation [31] and requirements [32].

5) Instrument calibration and validation: There are two papers on instrument calibration and validation, one on Aquarius radiometer calibration and the other one on Chinese HY-2A

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altimeter derived sea surface height and significant wave height validation against GNSS buoys.

6) Ocean surface wind retrieval with new instruments: Transitionally, ocean surface winds are measured by spaceborne scatterometer. In this SI, there are two papers on ocean surface wind retrieval: one from the NASA Tropical Rainfall Measuring Mission Precipitation Radar and one from the Chinese Beidou GNSS signal.

The collection of 36 papers in this SI demonstrates the start-of-the-art applications of remote-sensing technologies to ocean wind, wave, current, sea surface temperature, ocean color, coastline change, bathymetry, sensor calibration and products validation, and system requirement studies. It also shows the synergy between multisource remote-sensing data to address difficult scientific questions. We believe that this SI serves as a new milestone for future ocean remote-sensing research.

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