Accuracy assessment of airborne LiDAR bathymetry in shallow coastal regions

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Japan is susceptible to natural disasters, such as typhoons, earthquakes, tsunamis and volcanic eruptions from geographical conditions. These natural disasters not only disturb water quality, bottom sediments and aquatic organisms, but also change the seabed topography itself. Therefore, it is necessary to quickly update the land deformation after the natural disaster for ensuring the security of the national land and marine transportation. For the reasons, the demand for measurement of seabed topography is increasing. Echo sounders have been widely used to measure water depth. By using multi-beam echo sounders, a map of seabed topography can be created with a resolution of a few centimeters in the shallow water area. However, it is impossible to measure in a shallow reef area where the survey ship can not pass. Also, it takes a lot of time and labor to measure large areas by small vessels. In recent years, an airborne laser bathymetry has attracted attentions as a method of quickly observing large areas.

The airborne laser bathymetry utilizes the LiDAR (Light Detection And Ranging) system to estimate water depth from the differential time-of-flight of an optical pulse transmitted from the aircraft to the water bottom through the air-water interface. The LiDAR system in terrestrial environments is recognized as a surveying tool with high quality. However, there are few studies on the bathymetric LiDAR system. Only the Japan Coast Guard (JCG) has innovated since 2003 in Japan. It is necessary to investigate under what circumstances the bathymetric LiDAR system can be used in water environments. In this study, the bathymetric LiDAR data are evaluated through a comparison to the existing data derived from acoustic and other bathymetric LiDAR (owned by JGC) instruments.

As a result, the vertical accuracy of bathymetric LiDAR data satisfied the International Hydrographic Organization’s Order 1 standards (±0.50 m) as compared to the reference data of water depth. Moreover, the bathymetric LiDAR data were strongly correlated with data derived from acoustic (R2=0.923, RMSE=0.243 m) and JGC bathymetric LiDAR (R2=0.983, RMSE=0.139 m) instruments. The wider swath width and faster acquisition speed were advantages of airborne LiDAR bathymetry. The combination of topographic-bathymetric LiDAR data also creates a seamless elevation map across the land/water boundary. These results indicate there is potential for applying airborne LiDAR bathymetry in water environments. However, the airborne LiDAR bathymetry was sensitive to turbidity and bottom material. Measurable water depth varied somewhat depending on the location. In this study areas, measurable water depth was shallower than approximately 30 m. It would be necessary to choose the bathymetric methods in consideration of the purpose of seabed mapping, required time, target area, economic cost, etc.

Keywords: airborne LiDAR bathymetry, seabed topography, multi-beam echo sounder

Development of the air-sea flux observing system

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Although there are many global air-sea flux products in these days, evaluation and improvement of global air-sea flux products are still crucial for atmospheric, oceanographic and climate research and weather and climate prediction. For that purpose, in situ observations by research vessels and mooring buoys are essential. As a part of the TAO (Tropical Atmosphere and Ocean)/TRITON (Triangle trans-ocean buoy network) array, we are conducting the air-sea flux observation in the western Pacific and eastern Indian Ocean. Basically, sensors for ocean surface wind, air temperature, humidity, barometric pressure, shortwave radiation, and precipitation are installed on the surface buoy of the TRITON mooring. The mooring observation has the advantage to acquire detailed direct measurement record at a fixed point, however it takes relatively high cost to keep many sites. Because of progress of the development of unmanned ocean surface vehicles, such as the Wave Glider and the Saildrone, we can use these vehicles as a platform for air-sea flux observation. Using the Wave Glider, we are conducting development of air-sea flux observing system. As payloads, we install three types of meteorological sensor units; the Weather Station (Airmar), Weather Transmitter (Vaisala), and JAMMET (JAMSTEC). The observed parameters are air temperature, relative humidity, barometric pressure longwave radiation, shortwave radiation, and wind. Underwater sensors for temperature, conductivity and pressure and thermistor chain for temperature profile within 10 m depth are also installed. The acquired data are recorded on logger system and transmitted to land station via iridium satellite communication system. We have conducted a series of field experiments mainly in the western tropical Pacific in the last year. Results of the experiments will be introduced in the presentation.

Keywords: Air-sea flux, Wave Glider, in situ neasurements

Development of Absolute Salinity measuring tequnique

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Conductivity sensor is widely used for seawater salinity measurement around the world. Salinity measurement by conductivity assumes that composition of the dissolved material in seawater is constant around the world ocean. However, some non-ionic species (such as silicate) or river water may cause discrepancy between salinity (Practical Salinity) determined by conductivity sensor and actual salinity (Absolute Salinity): e.g. the difference is about 0.02 g/kg for deep water in the Pacific Ocean. The thermodynamic properties of seawater have been re-defined as the International Thermodynamic Equation of Seawater –2010 (TEOS-10) in 2009 after the passage of thirty years, and a simple algorithm for estimating Absolute Salinity anomaly which is difference between Absolute Salinity and Practical Salinity (Reference-Composition Salinity for more exactly) is adopted as a practical method. Absolute Salinity anomaly can be mainly represented by silicate, nitrate, total alkalinity and dissolved inorganic carbon. The simple algorithm for estimating Absolute Salinity anomaly uses silicate concentration because those properties related to Absolute Salinity anomaly change often correlatively in the ocean and relatively many data are available for silicate in the world ocean. However, the error of the simple algorithm may be large for seawater affected largely by river water such as surface water of the Arctic Ocean, and the algorithm can't estimate time variation of Absolute Salinity anomaly such as the increase of dissolved inorganic carbon in the ocean by anthropogenic carbon emissions since it used climatological mean field of silicate concentration. To solve this problem, a method to measure Absolute Salinity directly and precisely in the ocean is developed by using a sound velocimeter. Instead of determining salinity as a function of conductivity, temperature and pressure, it is possible to calculate Absolute Salinity as a function of sound speed, temperature and pressure with a resolution of 0.001 g/kg, but uncertainty of thus estimated Absolute Salinity is quite large (about 0.04 g/kg near the surface and 0.4 g/kg at 6000 m depths) for practical use due to error of sound velocimeter and the equation of sound speed for seawater. Therefore, the estimated Absolute Salinity need to be corrected in situ by using more precise Absolute Salinity data measured for discrete water samples by a vibrating tube densitometer with a resolution of 0.0013 g/kg. A vibrating tube densitometer is usually calibrated with a pure water measurement to agree with density calculated from the equation of state of water. However, seawater density measured by the vibrating tube densitometer may have a non-negligible error due to nonlinearity of the densitometer. Therefore, density of standard seawater is determined with a traceability to the International System of Units (SI units) based on a hydrostatic weighing method, a primary method of density measurement, and the standard seawater is used to calibrate the vibrating tube densitometer. They give the in situ measurement system of Absolute Salinity.

Keywords: Absolute Salinity, Sound speed, Density

Pulsed & Gated FMCW Waveform for Simultaneous Observables with Coastal HF Radar

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The use of commercial High Frequency Surface Wave Radar (HFSWR) for mapping coastal ocean surface currents introduced in 1982 and has since proliferated into extensive coastal HFR networks around the world. Surface current maps reveal spatially robust and temporally refined features of ocean circulation that, when used in conjunction with other tools and data layers, are a key component in numerous applications, including emergency search and rescue operations, oil spill response, hurricane tracking and analysis, oceanographic research, and numerical model assimilation. Other coastal HFSWR observables include wave parameters, tsunami detection, and vessel tracking, each of which has different temporal and spatial resolution requirements.

Surface current maps are measured and averaged over time scales of 20 –60 minutes for most applications. However, tsunamis with periods of 20 –40 minutes requires much more rapid updates, on the order of 2 –4 minutes. Vessel tracking also requires similar timed updates to properly track changes in position and heading. Wave parameters such as significant wave height, wave period and direction require longer averaging. While the SeaSonde® HFSWR is best known for its compact cross-loop antenna design, it is its waveform that is uniquely adaptable to a wide variety of spatial characteristics and timescales. By employing a pulsed and gated Frequency Modulated Continuous Wave (FMCW) transmission with nanosecond sweep timing accuracy, a single coastal station can simultaneously process all the above observables at their optimum time scales.

The precise sweep timing allows for multiple systems in the same region to transmit on the same frequency, reducing the amount of bandwidth required for a network and allowing all systems to operate simultaneously and continuously, which is critical for tsunamis and vessels. Each sweep is processed for range and stored locally, allowing for multiple processing threads to read variable numbers of sweeps over time scales that depend on the observable. In addition to the precise, continuous sweeping, the shaped pulsing is also a critical component of the waveform. It allows for closer spacing of transmit and receive antennas at a single site for systems below 11 MHz and combined transmit and receive antenna above 11 MHz. In addition, it allows for close spacing of multiple stations in confined areas of high resolution by timing stations to maximize bistatic sea echo and minimize the direct bistatic transmissions. The most recent benefit of pulsing is allowing for ITU–mandated call sign capability that can be broadcast without interruption of data collection and heard as Morse code on a simple AM receiver.

Keywords: HF Radar, Surface Currents, Waves, Tsunami

In-situ observation of the rain drop size distribution over the ocean by the instruments onboard R/V Mirai

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The drop size distribution (DSD) of precipitation, including the information about the number of droplets in each size bin, is the important parameter to estimate the fresh water flux from radar, to estimate the surface mechanical mixing by impacts of falling rain, and to estimate the cloud microphysics aloft. However the past in-situ measurements of DSD have been made over landmass, not over ocean, while the previous studies pointed that the precipitation characteristics differ between continental and oceanic ones. To tackle this issue, we installed optical disdrometers onboard the research vessel Mirai, who cruises various climate regime ranging from tropics and polar region. In the present study, the data in the tropical area (i.e. only for raindrops) are analyzed as the R-Dm relationship, which is one simple expression of the DSD. The obtained R-Dm relationships slightly differ from that obtained from "global average" by Kozu et al. (2009) with excess of large drops, while the land-based observations by similar instruments resembles to Kozu et al. (2009). The excess of large drops are more significant (1) over ocean than land, (2) in case of Pre-YMC near coast of Sumatra Island in the Maritime Continent than other tropical cruises, (3) under the stratiform precipitation than under the non-stratiform precipitation, and (4) in data by LPM than by Parsivel. The instrumental dependency was further examined by comparing the other raingauges.

Keywords: drop size distribution, oceanic rainfall, research vessel Mirai

Automatic Detection of Spurious Differential Phase

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Differential phase is one of the important parameters measured by a polarimetric radar. It has been widely used in attenuation correction and quantitative precipitation estimation (QPE). Unfortunately, however, the differential phase is often contaminated by noises and the QPE may be significantly spoiled by spurious differential phases. Therefore, a quality control of data of the differential phase is mandatory.

A simple algorithm has been developed to automatically detect spurious differential phases. The algorithm utilizes the relationship between radar reflectivity and specific differential phase. The ability of the algorithm is tested by using the data from the measurements of the polarimetric radar on board the research vessel Mirai. It is found that the algorithm can effectively ascertain the data quality of differential phases. The possible application of the algorithm for the quality control of polarimetric radar measurements is discussed.

Keywords: Mirai, polarimetric radar, quality control

