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

Ocean observations using Wave Gliders -called AOV in JCG- around Japan coasts

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Japan Coast Guard has started observation using Wave Gliders, called Autonomous Ocean Vehicles (AOV), in 2016.The AOV is an autonomous unmanned ocean platform that individually delivers real-time oceanographic data to land stations for up to a year with no fuel.We overview our AOV and describe the result of ocean current observation by the AOV equipped with Acoustic Doppler Current Profiler (ADCP), for example Kuroshio current.
In addition, we show the result to observe winds and waves during a typhoon T1618 at peak strength, near Nagasaki, Japan.

Keywords: Wave Glider, Ocean observation, Platform

Development of simple CTD calibration method for Argo float.

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The global Argo array produces huge accurate data which can be used for climate and oceanic changes by a lot of deployed Argo float. The Argo float is equipped with a CTD (SBE41; Conductivity (salinity), Temperature, Pressure) sensor, which is made from an US manufacturer: Sea Bird Electronics (SBE). Since long-term stability and accuracy of the CTD sensor are the most important point to detect the climate and oceanic change signals, checking and screening of the SBE41 before deployment is crucial. Therefore, JAMSTEC developed a simple CTD calibration method for SBE41 in a laboratory.

The international Argo program is a global project to monitor temperature and salinity changes of the upper 2000 m ocean by over 3000 Argo floats. The floats can automatically measure them for 3-4 years, sending variable kind of data via satellite in real time. The target accuracies of the SBE41 are within ±0.005°C for temperature and ±0.01psu for salinity, which had been decided by Argo Data Management Team. To maintain the accuracies of the sensors is a key to be better understanding mechanisms of global oceanic changes.

Up to now we has been deployed over 1100 floats with SBE41 since 2000. Although all the CTD sensors are fully checked and passed for the accuracies before shipping from the manufacturer (SBE), the sensors are not accidentally satisfied with the target accuracy due to sipping trouble etc.. To detect the failure sensors and avoid the fault floats, we had operated JAMSTEC’s CTD calibration system which was the same type system as SBE’s and checked the sensors as much as possible. From 2000, we had checked over 500 sensors and found 30 unhealthy ones. The reasons why the number of checked CTD is about a half of all deployed floats are mainly complexity of the system and too much time to check for each sensors (over 12 hours). Difficulty of the operation, such as to open a float and separate a sensor, requires higher skills of technicians. Therefore, we developed new and simple CTD calibration method without opening the float, separating CTD sensor and any special skills for technicians, to be able to check all sensors efficiently within shorter time.

The mechanism of the new CTD calibration method is very simple. Artificial sea water (35 within ±0.1psu, 23 within ±0.3degC), is made by NaCl, degassing in advance, is flown at a constant speed in reference temperature and conductivity sensors and some CTD on floats through a thin pipe, being driven by a high efficiency pump. Within a fixed time (30 minutes), the reference sensors and float sensors automatically measure temperature and conductivity frequently. The checked float sensor is evaluated for healthy or unhealthy by calculation of the difference of temperature and conductivity between the float sensors and reference ones. The important point to get accurate calibration result is to keep uniform air and the artificial salt water. Based on a lot of try and error to maintain temperature environment, we succeeded to reduce temperature gaps in between the laboratory room and checking sensor within ±0.3degC during a calibration, which makes us the same calibration quality of the simple calibration method as SBE’s calibration system.

Keywords: Argo float, CTD sensor, Sensor calibration

An Experimental Study on Distributed Ocean Surface Radar

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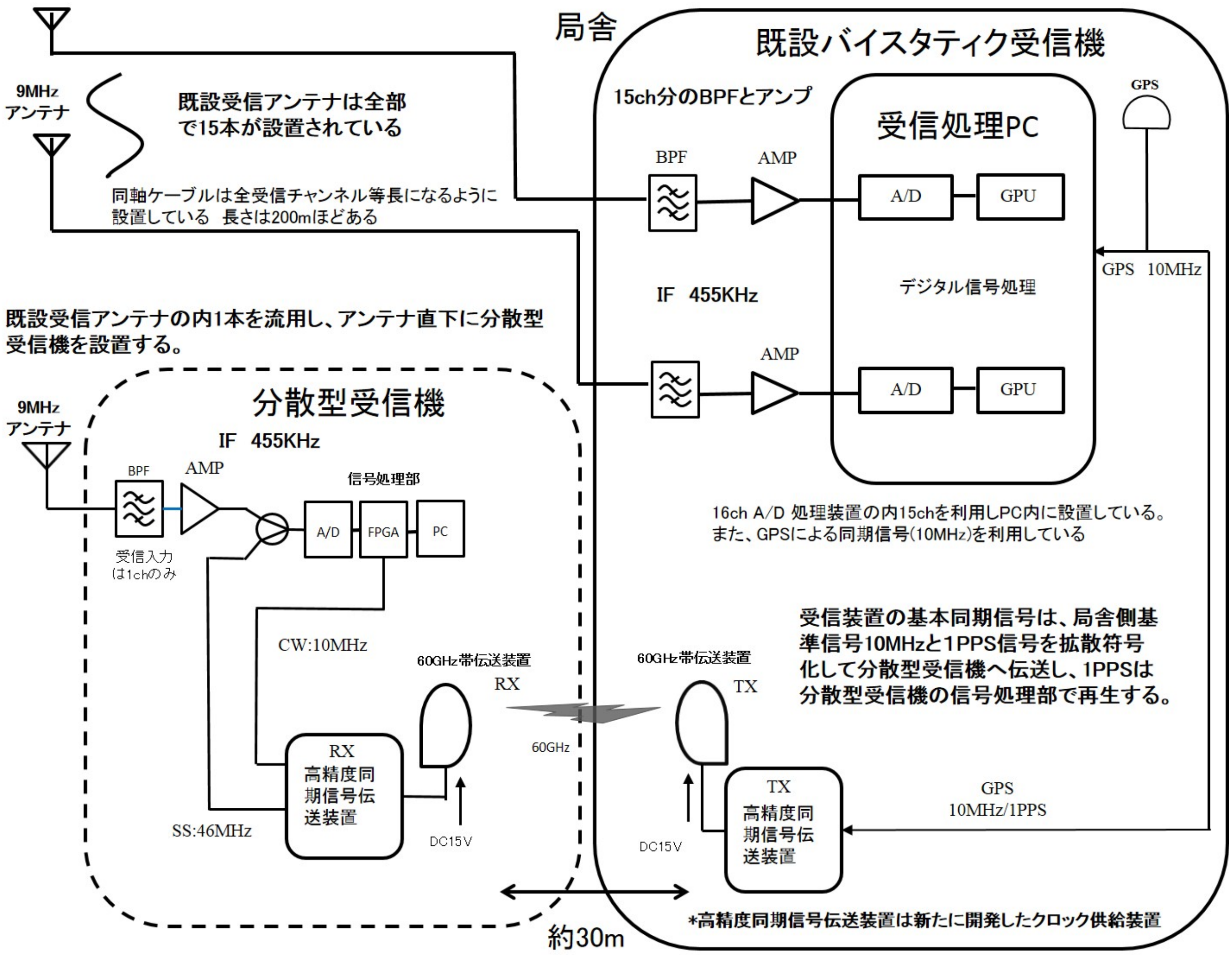
Ocean surface radar is installed along a coastline to observe ocean surface current in the range further than tens of kilometers to about 200km. Phased array antenna system of ocean surface radar needs hundreds of meters of land for its antenna installation as it uses lower frequency in HF bands. We have proposed Distributed Ocean Surface Radar System that enables efficient installation. Distributed Ocean Surface Radar System includes transceivers at each antenna and these transceivers work in synchronization without being-connected by coaxial cables.
This is the report of our first experiment in which we placed one distributed receiver at one of the existing antennas of our 9MHz band radar system.

Keywords: Ocean surface radar



Ocean wave motion detection with Hu-moments invariants using CCD images

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Computer vision (CV) is a research field in computer science for acquiring, processing, analyzing, and understating image and video to produce numerical or symbolic information. Among the various CV techniques, we used image moment to analyze the movements of ocean wave. Image moment is weighted average of image pixel intensities and we find that varying of moment between costal monitoring video frames can be associated with wave movement, such as period and height. Using the varying of image moment we analyze the numeric information of wave movement and tested our algorithm to the Gyoam beach in Gangwon province, Republic of Korea. To prove the algorithm we compared with the wave information collected by an acoustic wave gage (AWAC) and determine the usability of our system. We first extract a list of sample patches in the videos of coastal region that have immunity from external environments such as human or ship. Since general CCD camera is fixed, variance in the time domain of inlier video patch can caused by wave movement. To calculate the variance between the video patch, simple measure by difference the colors or intensity at each pixel can be used. But that is ineffective for a CCD video, because CCD video contains unwanted changes due to light variance or noise which make crucial miscalculation. Instead, we extract seven hu-moments that invariant a translation, scale, rotation and apply these for contour shape matching, which is a well-known technique for measuring the similarities between two shapes, between each sample in the different video frames. To comparing with ground-truth data, we also capture the wave movement by acoustic wave gage. After comparison, we found that the period of real wave were almost identical to the CCD image processing results. And amplitude of EV(i) and height of wave showed similar value changes relatively although absolute values are different. Length of higher amplitude region also has a similar pattern with wave length. Therefore our system can be used as a beach process monitoring system with low cost equipment.

Keywords: CCD, Hu-moments, Wave Period

Numerical Simulation of Wind Flow around an Ocean Observation Tower -First Assessment of the Applicability of Numerical Simulation-

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The drag coefficient, C_D, used to quantify the wind stress, is generally expressed by a function of the wind speed 10 m above the sea surface, U_{10}. C_D, however, has not been established because of variations in field observation data. Alternatively, a number of drag coefficient models have been formulated. To develop a model of C_D, the wind stress needs to be calculated using the eddy-correlation method, which measures the horizontal and vertical wind components. In the field, observations of the wind velocity are difficult to obtain during various sea surface states because wind velocity measurements are limited to fixed installations, and the platform (e.g., the observation tower, and/or ships) affects the wind flow and wind direction. Recently, with the increasing availability of computers, it has become possible to visualize wind flow around an obstacle under various conditions via numerical simulations using computational fluid dynamics (CFD).

In this study, we investigate the applicability of a numerical simulation using CFD for selecting installation locations for measurement instruments and for determining a correction index. SolidWorks for 3D-CAD (computer aided design) was used to modeling of the Hiratsuka Tower, and the SolidWorks Flow Simulation was used in the CFD investigation and visualization of the wind flow around the Hiratsuka Tower. The inflow wind velocities are 5, 10, and 15 m/s, and the wind direction is tested at every 10° from 0° to 350°. In this study, we installed two 3-axis sonic anemometers on a handrail (at a height of 1.75 m) and on a pole (at a height of 3.75 m) on top of the Hiratsuka Tower. We started test measurements using both sonic anemometers on July 29, 2015. The effect of the Hiratsuka Tower on the wind flow was investigated by comparing the results obtained by the numerical simulation with the field measurements from these two sonic anemometers.

For the inflow wind velocities at 5 m/s, the scalar wind velocity, and wind component with flow direction at the sonic anemometer on the handrail is within 1.5 % accuracy of the sonic anemometer in the wind directions of 60° and 70°, where the sonic anemometer is located at the leeward side. The scalar wind velocity and all wind components at the top of the pole are larger than the inflow wind velocity in all wind directions. As a result of the flow visualization around the tower, the scalar wind velocity decreases on both the windward and leeward sides of the tower. The scalar wind velocity above the Hiratsuka Tower increases, owing to the separating flow generated at the windward front of the Hiratsuka Tower. The results of the inflow wind velocities at 10 and 15 m/s show the same tendencies in the differences between the calculated and inflow wind velocities for the same wind direction. The applicability of the numerical simulations is discussed by a comparison with the field measurements. We found that the wind velocity obtained by the numerical simulations tended to be similar to the measured wind speed values. Therefore, we also discussed the applicability of the numerical simulation using CFD to selecting installation locations for the measurement instruments and establishing of a correction index. The effect of the tower at distance from the center of the top of the tower was shown in the flow visualization as a

correction index at the actual installation locations.
Consequently, we showed that the numerical simulation using the CFD could be applied to the observation tower. We also showed the possibility of creating a correction index for the actual installation locations.
In this study, we calculated the numerical simulations using simple conditions as a first approach. In the future, we will investigate applications calculating the numerical simulation using complex conditions, such as shear flow.

Keywords: Wind speed measurement, Flow visualization, Numerical simulation, Computational Fluid Dynamics (CFD), Wind stress

The Mirai lidar for observation of atmospheric water vapor, clouds and aerosols over the ocean

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Lidar is an active remote sensing method; Lidar transmits light pulses to a target, then measures backscattering light intensity and its traveling time. The lidar target diameter extends as small as a molecular size with an adjustment of the light wavelength. A spatially fine resolution and a continuity of the lidar data capture a complex distribution of the target. These lidar characteristics suit to monitor the major atmospheric variables: water vapor, cloud, and aerosol.
Regardless of the lidar suitability, observation platforms for atmosphere over the ocean remain extremely rare, especially if excluding ones in the coastal region and islands. Conversely, a great coverage of the ocean on the earth surface suggests extensive interaction between atmosphere and ocean. Thus, disclosure the interaction requires an observation platform over the ocean. Since ship-borne observation is one approach, we selected the R/V Mirai as a lidar observation platform.
With modifications to the ship, the Mirai lidar has successfully archived vertical distributions of the atmospheric variables over diverse waters. The continuous data illustrated temporal transitions of the variables in details. We converted the obtained data into physical parameters, such as water vapor mixing ratio. After the conversions, we evaluated the lidar data quality thru comparison to other observations conducted on the R/V Mirai.

Keywords: lidar, atmospheric observation over ocean, water vapor, cloud, aerosols, ship-borne observation

