浅海域における航空LiDAR測深の精度評価
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.

キーワード：航空LiDAR測深、海底地形、マルチビーム音響測深

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.

キーワード：大気-海洋フラックス、ウェーブグライダー、現場観測
Keywords: Air-sea flux, Wave Glider, in situ neasurements

絶対塩分測定技術の開発
Development of Absolute Salinity measuring tequnique

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海水の塩分の測定には電気伝導度計が広く用いられている。電気伝導度による塩分の測定は、海水の組成比が世界中どこでも一定という仮定に基づく。しかし、ケイ酸塩など非イオン溶存物や河川の影響などにより、電気伝導度計で求めた塩分（実用塩分）と実際の塩分（絶対塩分）は異なる場合がある（例えば、太平洋深層で0.02 g/kg程度）。2009年に30年ぶりに改訂された新しい海水の状態方程式（TEOS-10）では、絶対塩分と実用塩分（正確には標準組成塩分）の差である絶対塩分偏差を求める簡便な推定式が採用された。絶対塩分偏差に関わる主な溶存物としては、ケイ酸塩、硝酸塩、アルカリ度、全炭酸がある。外洋域ではこれらの溶存物は相関を持って変化することが多いので、データが豊富なケイ酸塩の関数として絶対塩分偏差を推定している。しかし、北極海表層など河川水の影響を強く受ける海域では、推定式の誤差が大きい。また、ケイ酸塩の気候学的平均分布を用いた推定式では、人為起源二酸化炭素の増加に伴う全炭酸濃度の増加などの時間変化を評価できない。これらの問題を解決するために、音速計を用いて、絶対塩分を海洋の現場で高精度に直接測定する手法を開発した。通常の電気伝導度・水温・圧力の関数として塩分を求める代わりに、音速・水温・圧力の関数として0.001 g/kgの分解能で絶対塩分を求めることが可能になる。ただし、音速計や音速方程式の誤差が大きく、そのままでは実用的な精度で絶対塩分を求めることができない（絶対塩分の誤差は表層で0.04 g/kg、6000 mで0.4 g/kg程度）。そのため、採水試料に対して振動式密度計で求めた絶対塩分（分解能は0.0013 g/kg）を基に、音速計で求めた絶対塩分を現場校正が必要になる。振動式密度計は、通常、純水の測定値を基に、状態方程式で計算される密度に一致するように校正される。しかし、振動式密度計の非線形性により海水の測定値には誤差が含まれる。そこで、密度の絶対測定法である液中ひょう量法を基に、標準海水の密度を国際単位系SIにトレーサブルに求め、標準海水を用いて振動式密度計を校正する。これらにより、現場での絶対塩分測定システムを実現した。

キーワード：絶対塩分、音速、密度
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

研究船「みらい」搭載機器による海洋上の雨滴粒径分布の現場観測
In-situ observation of the rain drop size distribution over the ocean by the instruments onboard R/V Mirai

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雨滴粒径分布 (DSD)、すなわちサイズ別の雨滴数のデータは、レーダーを用いた淡水フラックス(雨量)測定や雨滴衝突による海洋表層混合を考える上で重要である。しかし過去の観測の殆どは陸上で行われたものである。大陸性と海洋性で異なる降水メカニズムが指摘されている中、海洋上での観測データの欠落は問題である。そこで筆者らは、光学式雨滴粒径分布計を研究船「みらい」に設置し、その熱帯から北極に渡る広い行動範囲においてデータの取得を続けている。今回は熱帯での雨滴粒径分布に絞り、R-Dm関係(R:降水強度、Dm:平均粒径)に落とし込んだ解析を行った。結果、Kozu et al. (2009)で提案された全球平均としてのR-Dm関係と比較し、幾つかのケースで大粒径粒子が多いという結果が得られた。この傾向は、以下の場合により顕著であった：(1) 陸上よりも海上、(2) 特に海洋大陸域スマトラ島沿岸での "Pre-YMC" 観測期間のデータにおいて、(3) 層状性降水域において、及び、(4) Parsivel よりもLPMで測定したデータにおいて、である。最後に指摘した機材による差異については、他の機材と比較してその是非を検討した。

キーワード：雨滴粒径分布、海洋性降雨、研究船「みらい」
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.

キーワード：みらい、偏波レーダー、品質向上
Keywords: Mirai, polarimetric radar, quality control