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GNSS-based ship-borne multi-sensor data analysis for ocean surface determination and atmosphere sounding

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Ship-borne GNSS can provide precise information of ocean surface variation and tropospheric delays over oceans using the kinematic precise point positioning technique. This could be an efficient way to validate satellite altimeter results and to improve the global coverage of GNSS meteorology. Due to the different observing environment from inland static stations, special concerns should be paid to the data processing and additional corrections must be applied in order to achieve proper results.

In this case study, we concentrate on the processing of the high-rate GNSS observations over about three weeks in a GNSS reflectometry experiment for measuring ocean and sea ice properties in the Fram Strait via the regular cruises of the Norwegian research vessel (R/V) Lance. In addition to the raw GNSS observations, data from other sensors, e.g., meteorology data and ship attitude data are also available and employed. With some essential hydrostatic and hydrodynamic corrections, we demonstrate that it is possible to estimate the ocean wide precise in-situ sea surface height (SSH) and to sense the atmosphere.

We will present the data processing strategy for the kinematic PPP with GPS and GLONASS combined solution from Day of Year (DOY) 238-257, 2016. First we applied the hydrodynamic corrections on the antenna height estimates, i.e. the ocean tide, atmosphere pressure loading, geoid undulation and ocean surface topography. The DTU10 ocean tide model is used for ocean tide correction, and both the DTU15 and the CNES2015 mean sea surface are used and compared for the geoid undulation and ocean topography correction. For atmosphere pressure loading correction, both the inverted barometer method using measured meteorology data and the NWM-based dynamic atmosphere correction provided by AVISO are used and compared. With the antenna coordinate estimates after hydrodynamic corrections, we applied the heave and attitude correction to obtain the coordinate of ship's center of mass (CoM). Due to the lack of antenna coordinate in ship body-frame, we conduct the attitude correction with the assumption that the antenna height remains stable for short period. With all these hydrostatic and hydrodynamic corrections, we achieve daily STD values of 10 cm of the CoM, and the derived SSH agrees with CNES2015 with an accuracy of 20 cm. The short-term precision is analyzed in detail together with the sea surface state, e.g., wind speed and significant wave height.

Furthermore, we pay special attention to the stochastic modeling of Zenith Tropospheric Delay (ZTD) parameters, which are validated using the ECMWF numerical weather model. An accuracy of 1 cm for ZTD is achieved, which is equivalent to about 1.5-2 mm of precipitable water vapor.