Relationship between errors in ship-borne GNSS derived PWVs and that in vertical coordinates

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In order to reinforce the observation of water vapor at sea, we installed dual frequency GNSS receivers on eight ships mainly sailing in the East China Sea west of Kyushu, and started experimental observations from December 2018. Since then, continuous observation has been continued as of February 2020.
The main instruments used for this observation are dual-frequency GNSS antennas and receivers (Trimble’s Zhyr3 Rugged Antenna and Alloy receiver), and meteorological instrument (WS300 made by EKO Instruments). The sampling interval is set to 1 second for GNSS and 1 minute for meteorological instruments. Observed GNSS data and meteorological data are sent to the Meteorological Research Institute (MRI) every time each ship enters a port, and we perform post-analysis.
We adopt the Kinematic PPP analysis using RTKLIB (ver. 2.4.2, p13) (Takasu 2013) for GNSS analysis applying MADOCA real-time orbits and analyze zenith wet delay and antenna coordinate at 1-second intervals. GMF (Boehm et al., 2006) was used as the mapping function, and the zenith delay gradient was not estimated. The antenna phase center variation (PCV) model is not applied because the antenna rotates and tilts on vessels. Multi-GNSS satellites as GPS, GLONASS, and QZSS are used. The time constraint of the zenith wet delay was set to 0.03mm/sqrt(s), which is about three times stronger than the RTKLIB’s default (0.1mm/sqrt (s)) value. Precipitable water vapor (PWV) is calculated at one-minute intervals using the zenith delay estimated by RTKLIB analysis and the atmospheric pressure and temperature observed by WS300.
In comparisons with the radio-sonde observations launched from the Ryofu-Maru, the averaged difference was -0.70 mm and the standard deviation was 1.83 mm for 63 samples, and with the GCOM-W1 satellite microwave radiometer, the averaged difference was +0.26 mm and the standard deviation was 3.03 mm. This result is comparable with the results of Shoji et al. (2017).
The error of GNSS PWV is inversely proportional to the error of the vertical coordinate estimated at the same time (eg, Shoji et al. 2000). In order to evaluate the relation between coordinate errors and PWV errors, we performed kinematic analysis to one of the GSI’s fixed GNSS station P212 (P Naha) in Naha City, Okinawa Prefecture for about seven months from May to December 2019. Vertical coordinates by Kinematic analysis differed from those by Static analysis by up to 10 cm. The vertical coordinate differences and the PWV differences were inversely proportional, and the slope of the regression equation was -0.014. It was found that when the vertical coordinate by Kinematic analysis was 10cm higher than that of Static positioning, the PWV was underestimated by about 15mm.
To estimate the vertical coordinate error of the shipborne GNSS, it is necessary to obtain the sea level. This time, the tide prediction model NAO.99b (Matsumoto et al., 2000) was used as a reference of sea level. We compared the antenna coordinates by Kinematic analysis of a ship, Yoko-maru (Seikai National Fisheries Research Institute) and the sea level altitude by the tide prediction model NAO.99b, during the period when the Yoko-maru was anchored at a port in Taira-cho, Nagasaki City (Aug. 13-22, 2019). After subtracting the average distance from the GNSS antenna to the sea surface, the two values were almost the same. However, the difference in altitude between the two (dALT) changed with time with an amplitude of about several tens of cm.
Also, we performed Static analysis to a GEONET station nearest to Yoko-maru "0832 (Sotome)" and estimated PWV. We found that there are common features in time variation between PWV differences

(dPWV) and that of dALT. We applied the linear regression equation of the dALT and the dPWV obtained from the P212 GNSS station to correct the analyzed PWV of the Yoko-maru and confirmed that the standard deviation decreased from 2.7 mm to 2.3 mm(Figure).
In the next step, we will investigate whether it can be applied during the ship under way.

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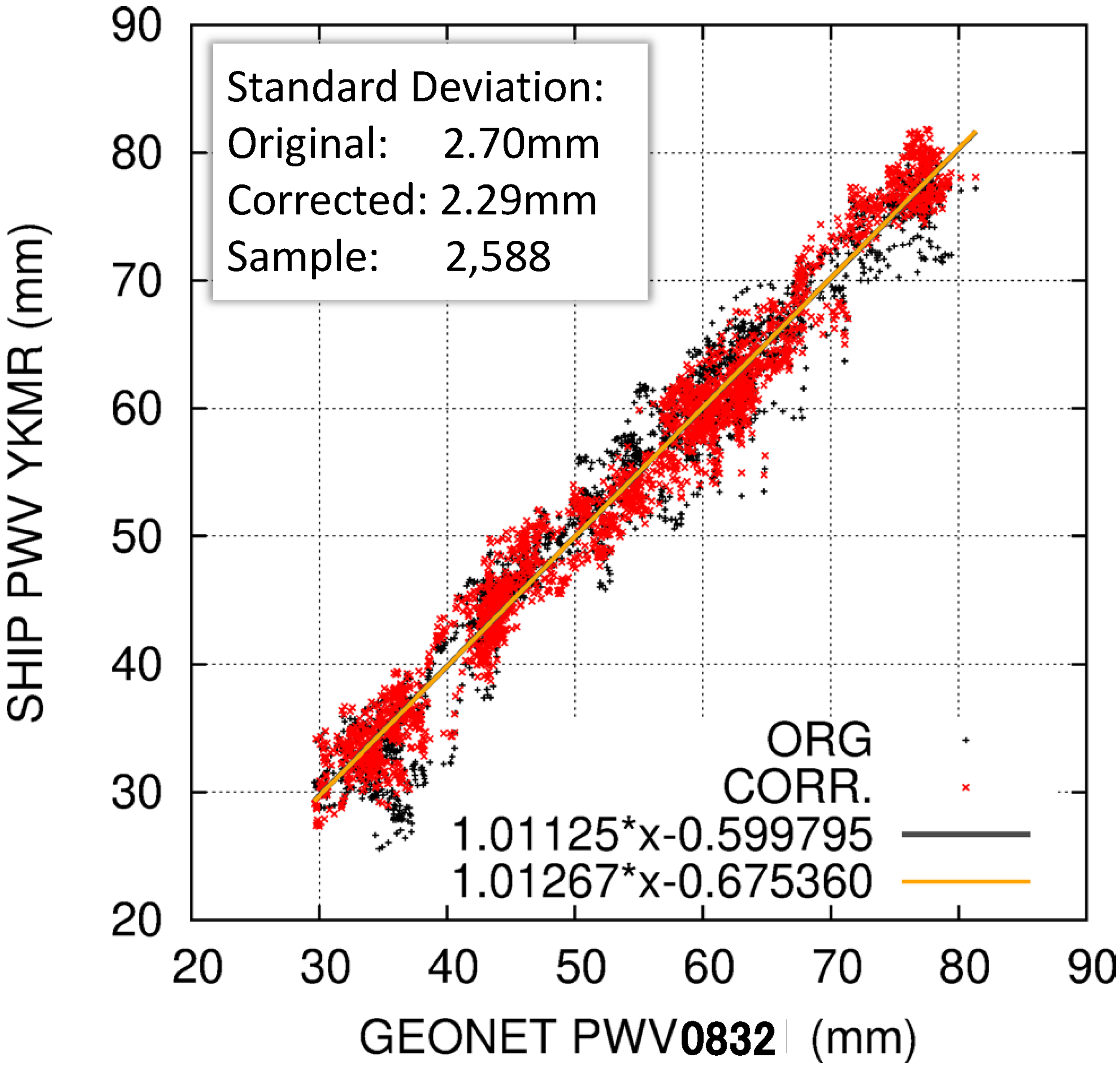

Scatter plot of PWVs at a GEONET station “0832 (Sotome)” and at Yoko-maru during 13-22 Aug. 2019. Black dots are original (before correction) and red dots are corrected. The black and orange lines are the regression lines.