Characteristic analysis of measurement error in GNSS-R UAV Altimeter

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The GNSS signal reflected from the water surface is longer than the signal path that arrives directly from the GNSS satellite. The method of measuring altitude from the distance difference between them is called GNSS-R altimetry. In Ichikawa et al. (2019), the drone is equipped with a GNSS signal receiver, estimates the height of the drone based on the GNSS-R height measurement method, performs a time average of about 7 minutes, and performs an accuracy of about several cm. Achieved. This system uses independent signal receivers for direct and reflected signals to reduce cost. Therefore, a time difference occurs between the receivers (hereinafter referred to as “receiver time difference”), and it is necessary to obtain both the altitude and the receiver time difference as unknowns for each epoch. Since these unknowns are amounts common to a plurality of satellites received at the same time, they can be estimated by using the least squares method for observation data of a plurality of satellites for each epoch. When the altitude and receiver time difference were actually calculated for each epoch of 5 Hz, it was suggested that the receiver time difference did not show a rapid change between epochs, but fluctuated slowly and continuously over time. If the receiver time difference can be approximated by a long-period function and corrected as a known value, the only unknown value for each epoch is the altitude, and an estimate of the altitude (including the observation error) of each satellite must be obtained. Can be. Therefore, in this study, first, the receiver time difference obtained by Ichikawa et al. (2019) is approximated and corrected by a quadratic function of time, and an altitude estimate is obtained for each satellite at each epoch. The error component included in the value is extracted. After that, what kind of time-varying characteristics of the obtained error component has is examined, and the relation with the elevation angle of each satellite is examined. Specifically, in a study by Ichikawa et al. (2019), UAV hovered at altitudes above 100 m and measured relatively stably for 3 minutes from 12:27 to 12:30 on January 7, 2017 Was analyzed. The number of satellites during this time was almost 5, and the elevation angles were 9.8 degrees, 11.3 degrees, 43.3 degrees, 44.3 degrees, and 58 degrees. The error distribution of the estimated value was obtained from the difference from the estimated altitude of each satellite, using the UAV height separately measured by precision positioning as the true value. The error is distributed differently for each satellite. For a satellite with a high elevation angle, the error analyzed for 3 minutes is only a slow fluctuation and does not include a short-period change, but as the elevation angle decreases, the period increases. Both the frequency and amplitude of occurrence of short-term fluctuations of about 1-2 seconds increased. For the lowest elevation satellites, the short-term error amplitude reached 60 m. However, extremely short periods shorter than one second were not significantly included even in a satellite having a low elevation angle. The characteristics of the period of such a short-period fluctuation component suggest that this error is due to the effect of waves on the water surface. The GNSS-R height measurement method solves geometrically by assuming that the reflected water surface is horizontal, but if the water surface is inclined by the wave, the reflection point deviates from the assumption, so the actually measured reflected wave Path becomes large, causing an error. Furthermore, even with the same wavefront tilt, this error increases as the elevation angle of the satellite decreases, so that there is no contradiction that the amplitude of the error of the short-period fluctuation increases as the elevation angle of the satellite decreases.

Keywords: GNSS−R, Altimeter, UAV, Satellite elevation, Wavefront gradient

