

Observation of the 2014 February heavy snow fall in Yamanashi with the GNSS snow depth meter

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Here we report the case in which we estimated the snow depth by using multipath of Global Navigation Satellite System (GNSS). Multipath is the interference between direct microwaves from GNSS satellites and those reflected somewhere, such as the ground surface, and causes, e.g. measurement errors repeating every sidereal day (the orbital period of the satellites is a half sidereal day). Recently, several attempts have been made to utilize multipath to measure various quantities around the antenna, such as soil moisture contents, vegetation, and sea surface height. Larson et al. (2009) estimated the apparent height of the antenna (which is lowered by snowpack) by analyzing the frequencies of periodic variation of S/N ratio of the received signals caused by multipath. On the other hand, Ozeki and Heki (2012) showed that the fluctuation of the phase differences (L4) between L1 and L2 carriers could also be used for snow depth measurements. They analyzed both L4 and S/N ratio at the Shinshinotsu GNSS stations, one of the GEONET (GNSS Earth Observation Network) station in Hokkaido, and showed that they are accurate to ~6 cm and ~4 cm, respectively, by comparing them with the conventional snow depth meter records at a nearby AMeDAS station.

In this study, we used data at GEONET site 950263 in Kobuchizawa, Kitamori-city, Yamanashi, from January to March in 2014, and analyzed periodic changes in S/N ratio immediately before satellites set beneath the horizon. In this city, 2014 February heavy snowfall has caused cutoffs of public traffic lines and damages on agricultural facilities. This GNSS antenna is installed at the SW corner of the playground of an elementary school, and there is an extensive flat terrain in the NE direction. This is a good condition for observing the interference between the direct waves and those reflected by the ground. We used GPS satellites #12, #20, and #32 sinking in the NE horizon, and analyzed S/N ratio changes during two hours period before the disappearances of the satellite signals. We shifted the time window by ~4 minutes earlier every day to maintain the same geometry of the antenna and the satellites. The frequency of the S/N ratio changes of L2 carrier is normally ~4.6 mHz, and this corresponds to the original antenna height of ~6 meters. This frequency peak lowers by ~0.75 mHz by one meter snow depth (5 meter antenna height). We first prepared the calibration curve by calculating the theoretical S/N ratio changing frequencies for various antenna heights, and we inferred the snow depths by correlating the daily S/N ratio change peak frequencies with the calibration curve.

In the present study, we could reproduce the two heavy snowfall episodes, first on February 7th and second on February 14th, which eventually resulted in snow depth exceeding one meter at the Kobuchizawa GNSS station. The snow depth data become noisy occasionally at the beginning of increasing snow depth, possibly by artificial disturbances by the reflecting snow surface (which is located within a playground of a school). As the snow depth increase, the data became less noisy, which would mean decrease of human disturbances in a meter thick snow pack. AMeDAS snow depth meters are not densely deployed in the region where it snows little in normal years, and GNSS snow depth meters using GEONET are expected to complement the AMeDAS network.

References

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Keywords: GNSS, GPS, snow depth, multipath, interference, 2014 Yamanashi heavy snowfall