Improving GNSS & SAR Tropospheric Products for Meteorology
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Low-cost GNSS for Meteorology: A receiver comparison

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Abstract

GNSS , particularly the GPS and GLONASS satellite constellations, are commonly used for accurate estimation of atmospheric parameters. The high accuracy is accomplished by sophisticated analysis methods and expensive high-end receivers and antennas along with precise products and bias corrections. The recent market introduction of low-cost dual frequency receivers that can produce raw data from multiple constellations offers an insight into the potential use of these receivers for meteorological applications. Here we demonstrate that GPS and GLONASS measurements from a low-cost dual-frequency receiver can be used to estimate the Zenith Total Delay (ZTD) commensurate to meteorological applications.

GNSS Receivers & Antenna Test Configuration

Two types of inexpensive u-blox GNSS receivers were employed in this study. The ZED-F9P is a dual-frequency, and the EVK-M8T is a single-frequency receivers. These two receivers were compared to three geodetic grade GNSS receivers, i.e., a Trimble NetR9, a Trimble Alloy, and a Septentrio PolaRx5. All five receivers obtained input signal from a single Leica chock ring LEIAR25.R3 antenna through a powered 8-way splitter, see Fig. 1 below. The u-blox GNSS boards are connected by USB to a PC which uses the dedicated u-center software. It is possible to set the output of u-blox from multi-GNSS and save the epoch date in the raw ubx native format. The u-blox receivers are somewhat unique in that they adjust the time stamps to include the clock drift in the RINEX file. Therefore we adjusted the arbitrary time stamp first by converting the native u-blox format to RTCM by using the "–TADJ" receiver option. The RTCM format was then converted back to RINEX using the RTKLIB software (Takasu, 2009).

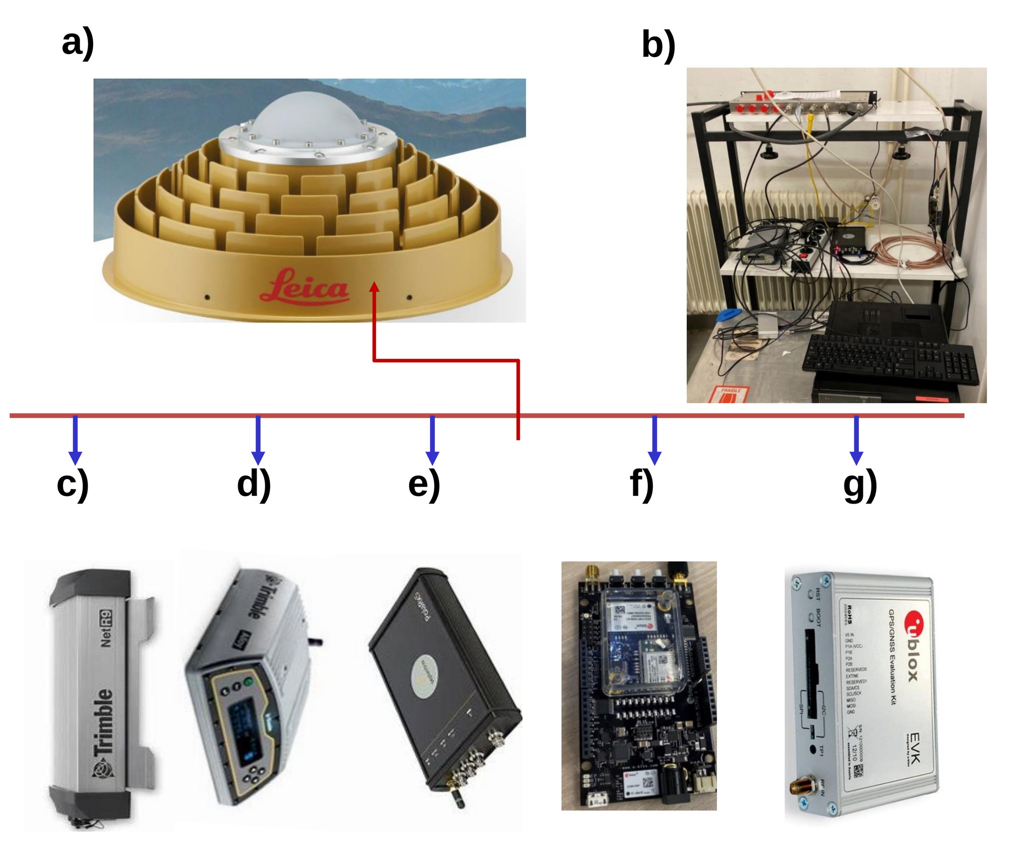


Fig.1. GNSS receivers and antenna with splitter. a) Leica LEAR25.R3 antenna. b) Test configuration setup with splitter, c)Trimble NetR9, d) Trimble Alloy, e) Septentrio Polarx5, f) ZED-F9P, g) EVK-M8T.

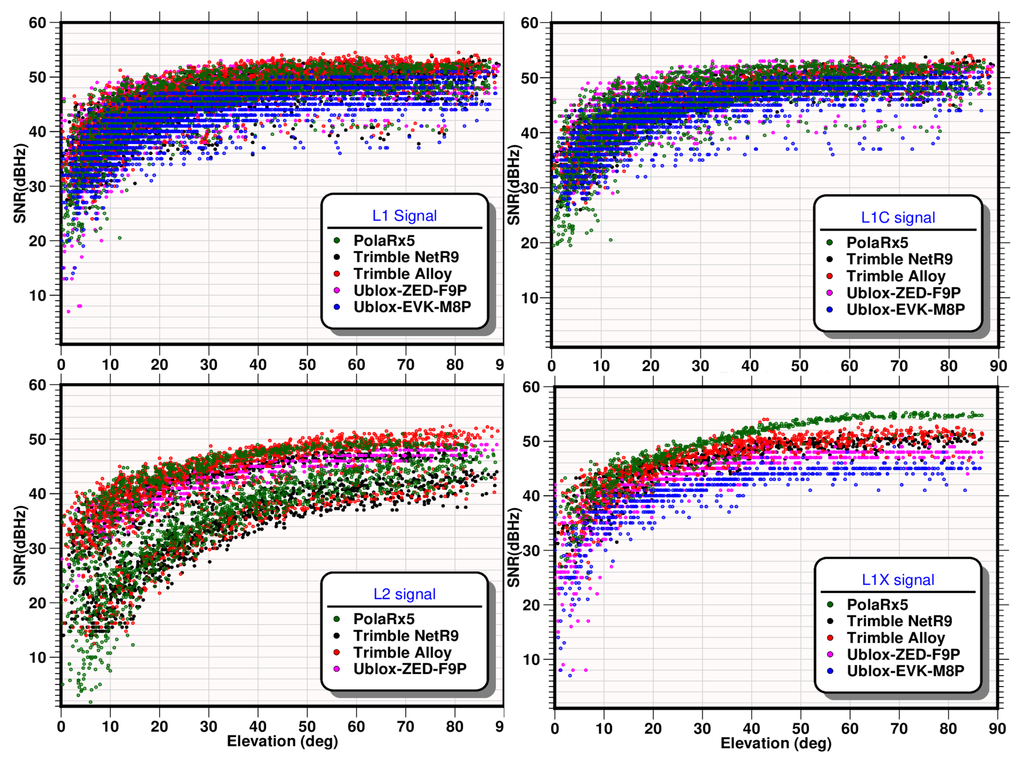
Methods

For data processing, we use the Precise Point Positioning (PPP) online processing service developed by the Canadian Geodetic Survey of Natural Resources Canada (CSRS-PPP v1.05) (Héroux and Kouba, 2001), which employed the IGS final products (orbits, clocks, satellite and ground antenna absolute phase center mapping, and ERP). The service also used standard models for tropospheric delay corrections (VMF1, Boehm et al., 2006) and solid Earth and ocean tide loading corrections (FES 2004, Lyard et al., 2006). An elevation cut-off angle of 7 degrees is used. Two ZTD estimates were produced, one with GPS only and the other GPS + GLONASS combined for the period DOY 357 2019 to DOY 029 2020.

Results

We have processed a single station to retrieve the troposphere zenith total delay (ZTD). The performance of the ZTD estimates of the two u-blox receivers is assessed in terms of accuracy with respect to the Trimble NetR9, which was taken as the reference receiver. The ZTDs are retrieved from the GPS-only and the GPS+GLONASS combined solution. The signal strength ($dB\ Hz$) against elevation was used to assess the characteristics of the signals of each GNSS receiver, see Fig 2.

Fig.2 Average signal strength with elevation for L1, L2, L1C, and L1X



Sky plots of post-fit residuals

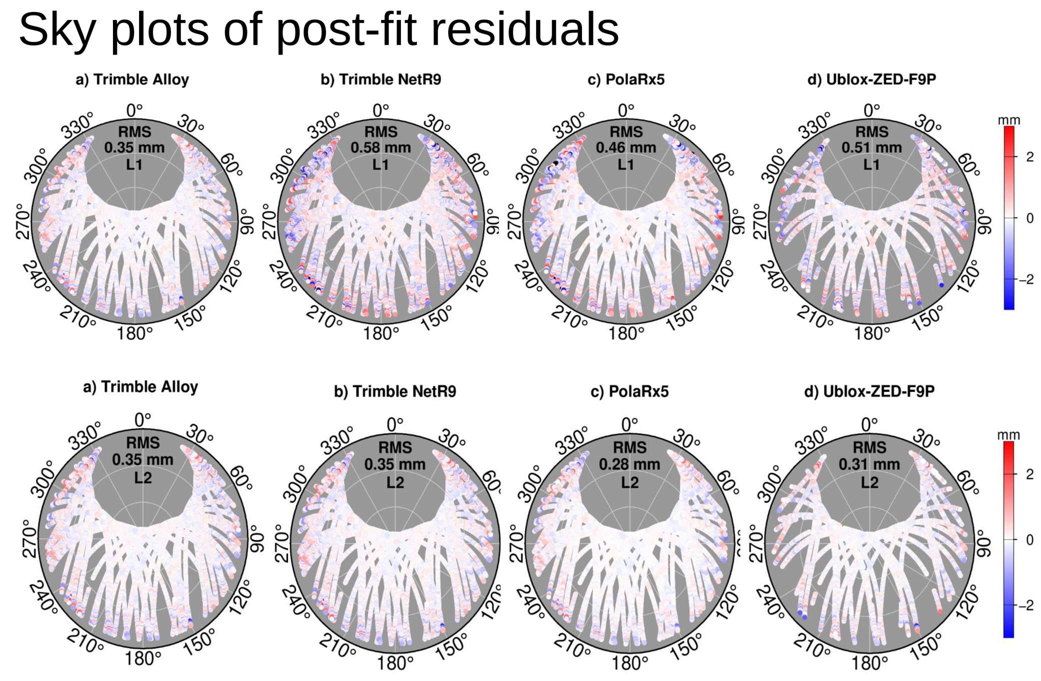


Fig.3 Sky plots of post-fit residuals for PolaRx5, ZED-F9P, NetR9 receivers

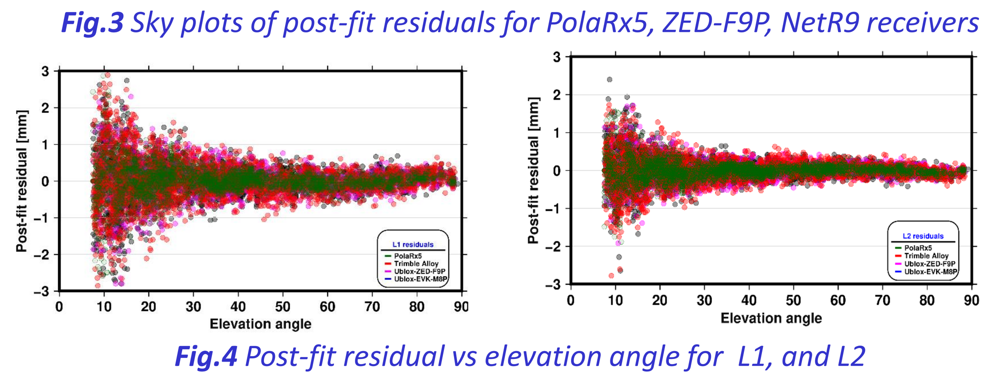


Fig.4 Post-fit residual vs elevation angle for L1, and L2

Results

The time series of ZTD from DOY 357 2019 to DOY 029 2020 is shown for all the five receivers for the GPS only and the GPS+GLONASS solutions at 30 second interval.

Fig.5 ZTD time series from five receivers attached with a the same antenna.

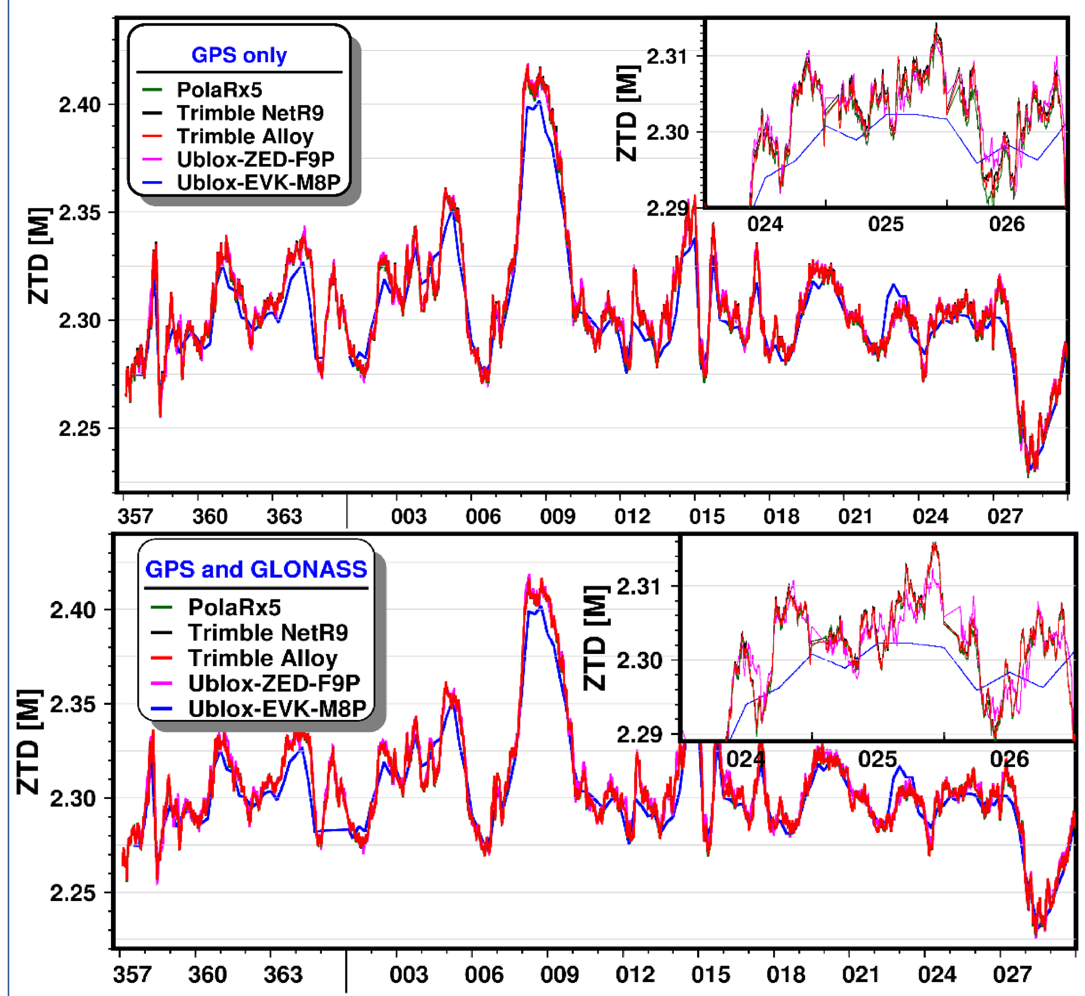
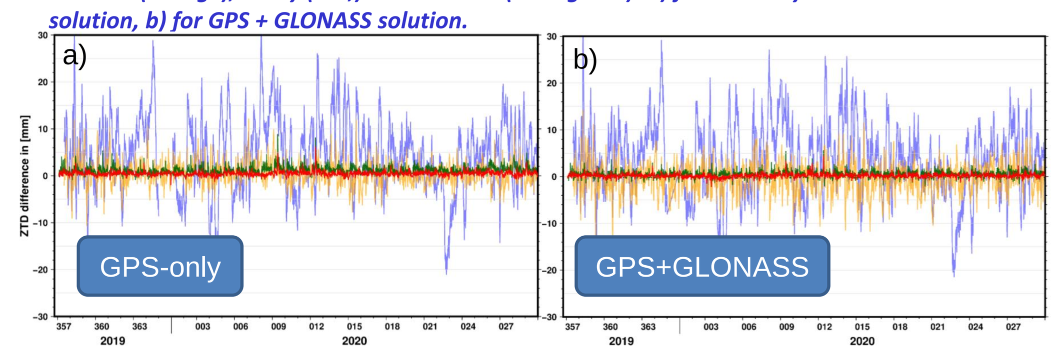


Fig.6 ZTD Difference between the reference against other receivers EVK-M8T (blue), ZED-F9P (orange), Alloy (red,) and PolaRx5 (dark green). a) for GPS-only b) for GPS + GLONASS solution.



Statistics of ZTD estimate

Table 1. Statistics for our case study, left. In blue from GPS-only and red from GPS+GLONASS. On the right the Box-whisker plot.

TRIMBLE NETR9/	Mean [mm]	RMS [mm]	STD [mm]
PolaRx5	0.52	0.80	0.61
PolaRx5	1.21	1.42	0.74
Trimble Alloy	0.21	0.44	0.39
Trimble Alloy	0.48	0.68	0.48
Ublox-ZED-F9P	-0.34	2.90	2.88
Ublox-ZED-F9P	0.47	2.19	2.13
Ublox-EVK-M8T	3.87	8.61	7.69
Ublox-EVK-M8T	4.80	9.10	7.72

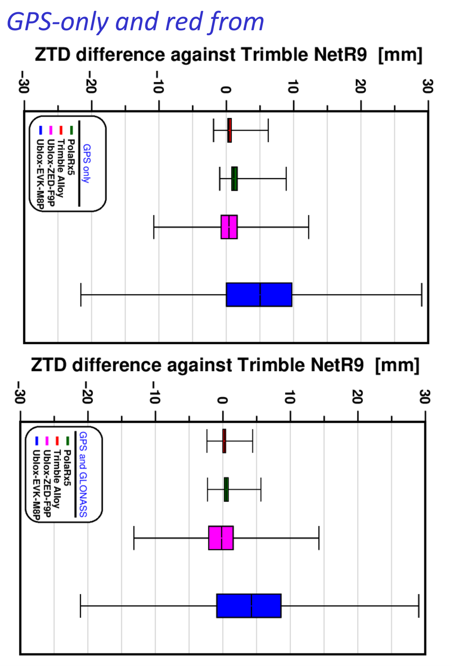
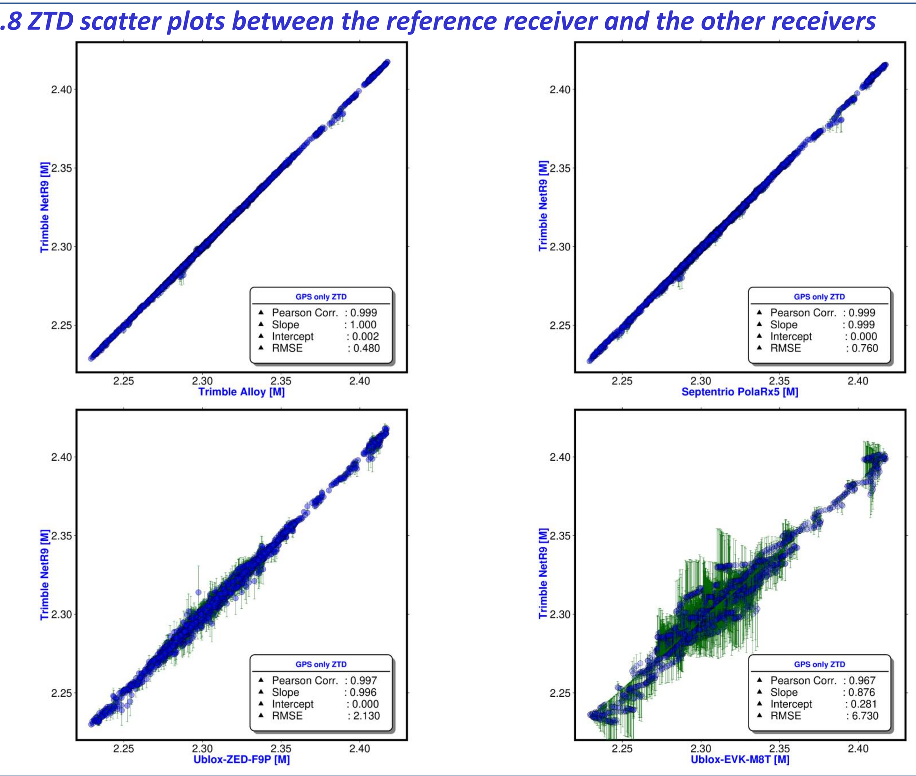


Fig.8 ZTD scatter plots between the reference receiver and the other receivers



Conclusions

- The RMS of the ZTD differences between the NetR9 receiver and the dual frequency ZED-F9P is less than 3 mm for both GPS-only and GPS+GLONASS solutions. The bias is negligible. For the single-frequency EVK-M8T, the effect of the ionosphere is significant and at the present the RMS is between 8-9 mm.
- This study demonstrated that low-cost dual-frequency receivers can provide ZTD estimates with sufficient accuracy for meteorological applications. The result suggest that networks of geodetic receivers can be densified by low-cost dual frequency receivers.

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