Australian Government
Geoscience Australia

Near-Real Time Zenith Total Delay Estimation System Using GPS with Precise Point Positioning Strategy in Australian Region

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Abstract

Geoscience Australia has started routinely producing two Troposphere Zenith delay estimation products. We use a Precise Point Positioning processing (PPP) strategy using the Bernese software package. To estimate the near-real time ZTD. we rely upon the IGS Real Time clock products and the IGS ultra-rapid orbits. ZTD estimates are provided every hour with a latency of approximately 40 minutes from approximately 160 stations. We use a sliding window of 24 hours of raw observations obtained from real-time streams sourced from the ARGN, Auscope, South Pacific and LINZ GPS networks. The system is currently being trialled to aid weather forecasting in the Australian region. To help us validate our ZTD estimates we also produce a rapid solution, which relies upon the rapid IGS orbit and clock products. For the rapid solution we process over 600 stations from a global network dominated by stations in the Asia Pacific region. The system has been established in the Amazon Web Services (AWS) cloud to help aid in reliability and scalability.

Introduction

Only around 30 weather balloon stations are established over Australian region [http://slash.dotat.org]. There is thus a great need for the additional techniques to aid Australian region and Southern Hemisphere in understanding the change of weather and climate. Geoscience Australia (GA) cooperatively operates and maintains GNSS networks of approximately 200 Continuously Operating Reference Stations (CORS) across the Australian region and the South Pacific. It is the great opportunity for GA to establish the system based on the ground GPS network for contributing the weather forecasting and climate research in Australian region and Southern Hemisphere.

Methodology

The currently popular used strategy for the retrieval of atmospheric parameters from ground-based GPS is the network solution with Double-Difference (DD), for example, EGVAP and SuomiNet. Although the more benefits can be obtained from DD approach for GPS data processing, it really relies on the computing ability and the scale of the GPS network. In 2003, there was a new processing approach was proposed by using Precise point positioning (PPP) with raw GPS measurements for the IGS Final Troposphere (IGSFT).The latency with around four weeks is not satisfied for the application of weather.GA started to establish the Australian Near-Real Time ZTD Estimation System using ground-based GPS in 2016 using PPP approach under Bernese software package with less one hour latency. The distribution of GNSS stations is demonstrated in Figure 1.

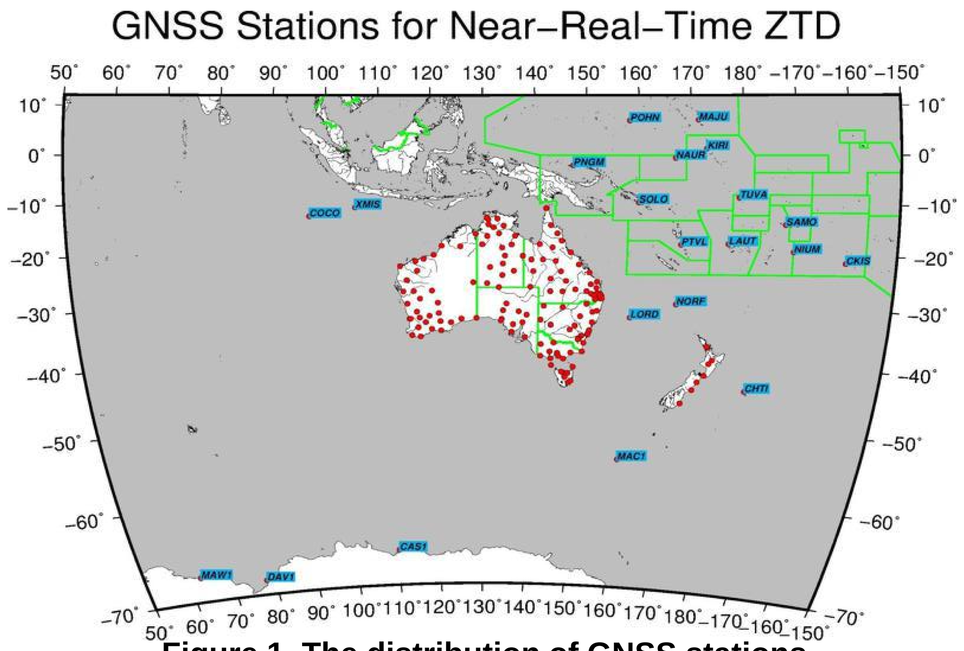

Figure 1. The distribution of GNSS stations

The comparison between PPP (IGS Rapid) and DD (IGS Final) was conducted for the testing. The derived ZTD from DD will be the reference. The period of comparison was from DoY 200 to Doy 229, 2015 and the number of GPS stations is 110.

There were 13 stations with root-mean-square (RMS) between 4-9 mm comparing PPP with DD. The RMSs for the others were between 1-4 mm.

The results of testing present the good agreement between two strategies. The Figure 2 is the comparison between PPP and DD for MOBS station as example. The distribution of RMSs for all stations is presented in Figure 3.

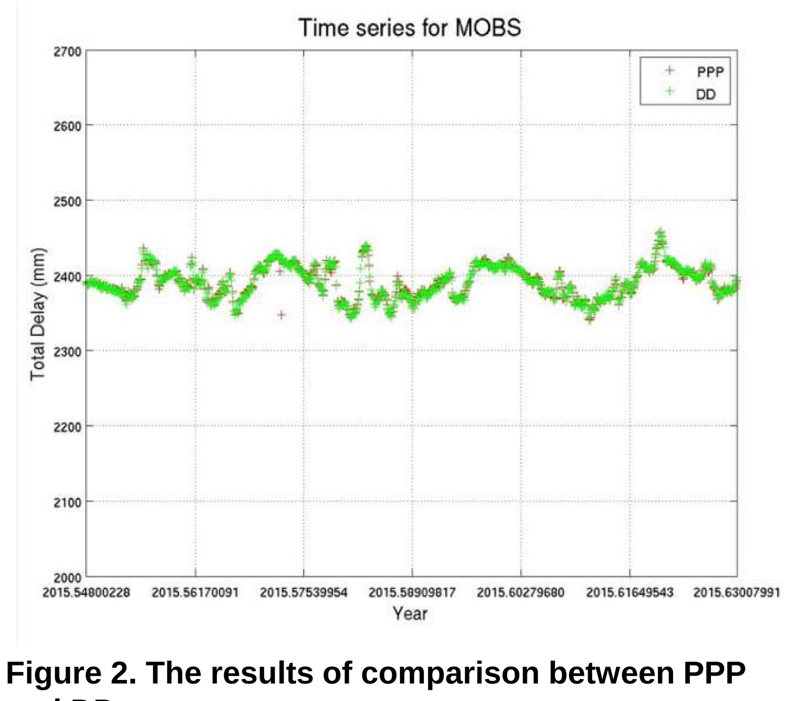

Figure 2. The results of comparison between PPP and DD

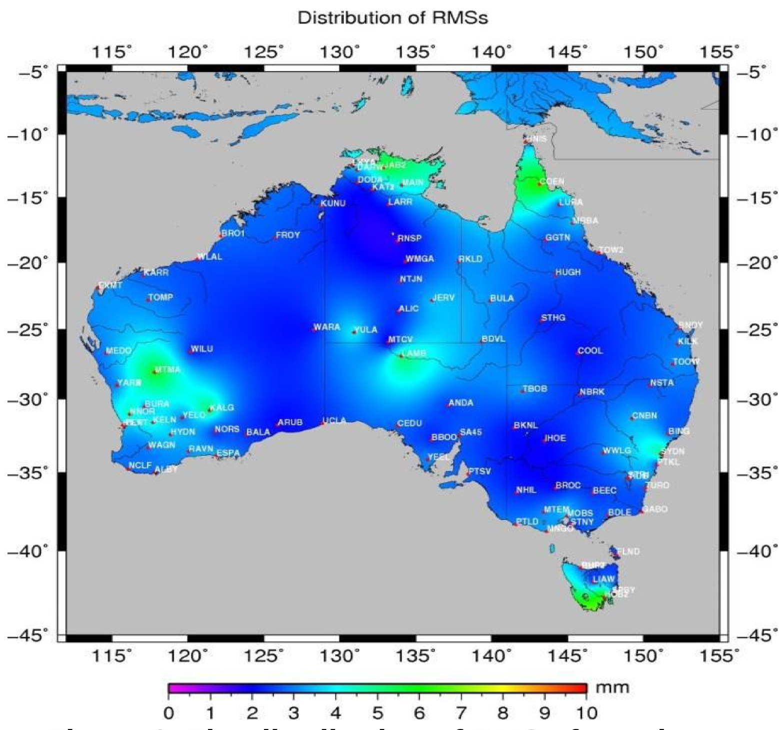

Figure 3. The distribution of RMSs from the comparison

There were four different combinations, Ultra-Rapid orbits and clocks extracted from Ultra-Rapid ephemeris (UR orbit + UR clock), Rapid orbits and Rapid clocks (R orbit + R clock), Ultra-Rapid orbits and Rapid clocks (UR orbit + R clock), Ultra-Rapid orbits and IGS02 clocks (UR orbit + IGS02 clock), were applied and processed for the further PPP testing.

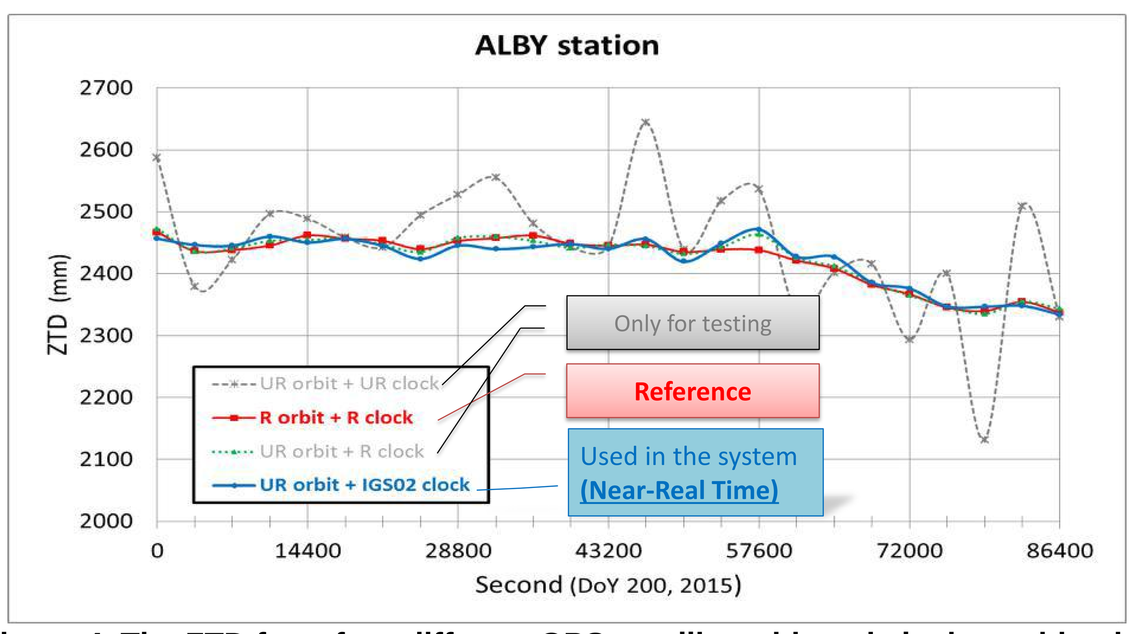

Figure 4. The ZTD from four different GPS satellite orbit and clock combinations.

The results of the further PPP testing using four combinations individually for ALBY station are presented in Figure 4 as example.

The results from R orbit + R clock combination is treated as reference. The UR orbit + IGS02 clock combination will be used for the NRT purpose.

System Design

The system including the real-time GPS observations stream and real-time clock stream is based on the cloud computing services belong to AWS. It will be the easy way to extend the scope of the ZTD retrieval via adding computing ability, memory and storage immediately.

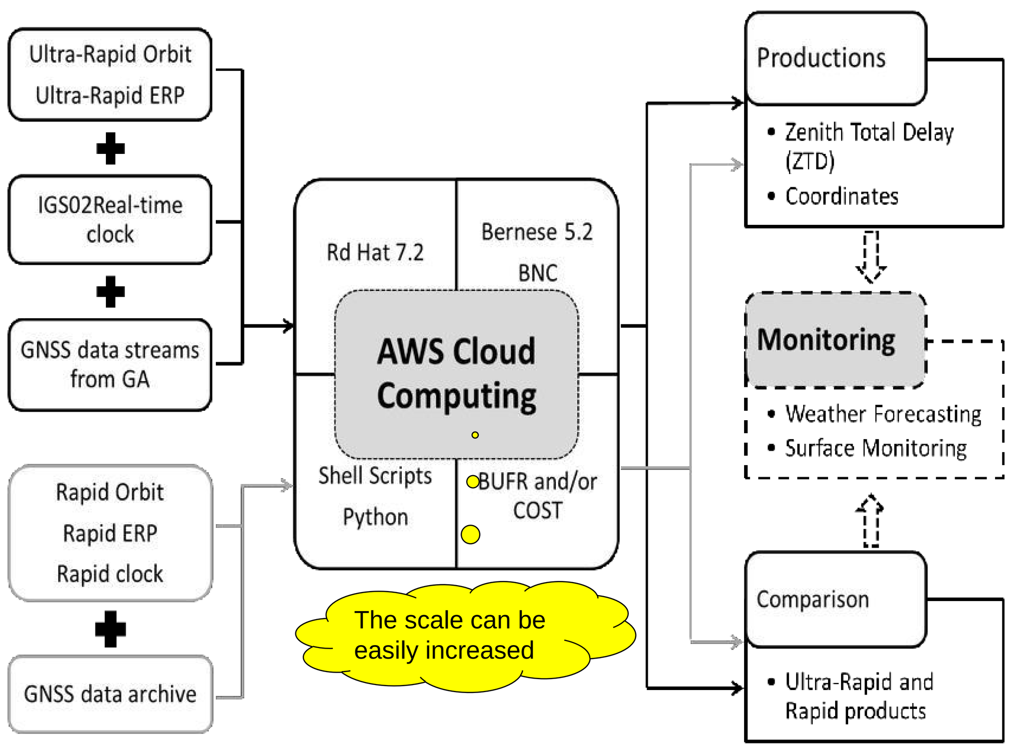

Figure 5. The structure and flowchart of the system

In addition to the ZTD products, the coordinates of GPS stations also are the part of outcome from the system. Not only the system contribute the weather forecasting and climate change, but also the monitoring of surface deformation can be obtained. The structure and flowchart of the system are presented in Figure 5. The outcomes are renewed and uploaded for public access after every calculation. Figure 6 and Figure 7 are presented as the example. The web address of the figures are also attached.

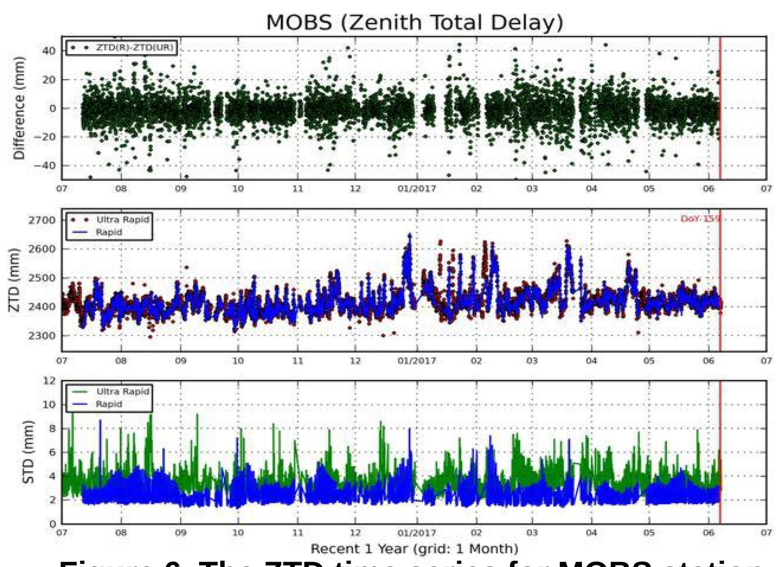

Figure 6. The ZTD time series for MOBS station (https://s3-ap-southeast-2.amazonaws.com/gnss-analysis/status/rapid/ztd/yearly_MOBS_ztd.png)

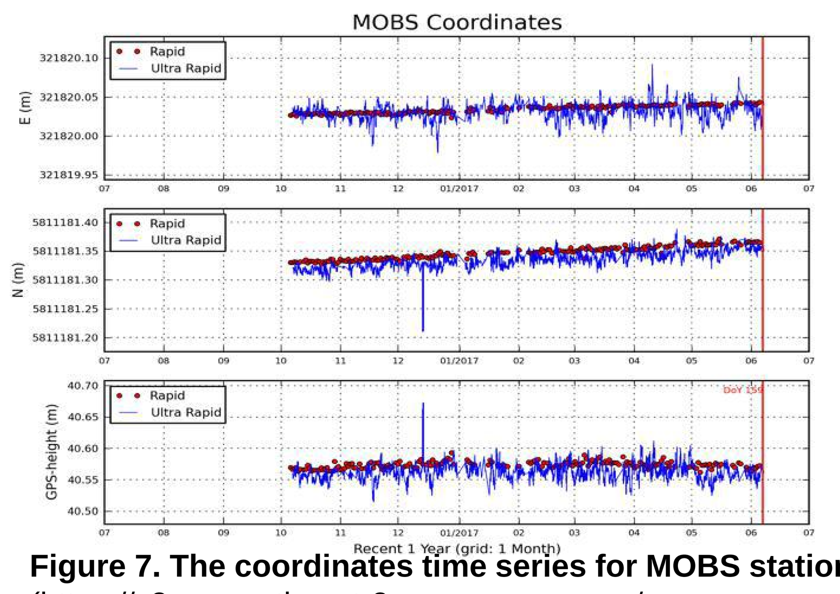

Figure 7. The coordinates time series for MOBS station (https://s3-ap-southeast-2.amazonaws.com/gnss-analysis/status/rapid/neh/yearly_MOBS_neh.png)

Evaluation

The output from the system during the period from 12-July-2106 to 31-July-2016 were analysed for evaluation. In general, around 93% GPS stations can provide the UR ZTD derived from UR processing with less 5% difference compared to R ZTD from daily processing. The results of comparison are presented in Figure 8.

For the means of difference in ZTD between Ultra-Rapid and Rapid processing shown in Figure 9, only 2 stations are with the mean of difference over 3mm and 7 stations with the means of the absolute value of differences over 10 mm.

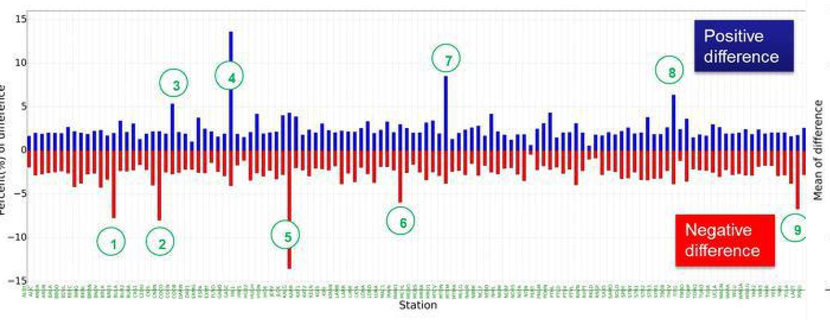

Figure 8. The difference between UR ZTD and R ZTD

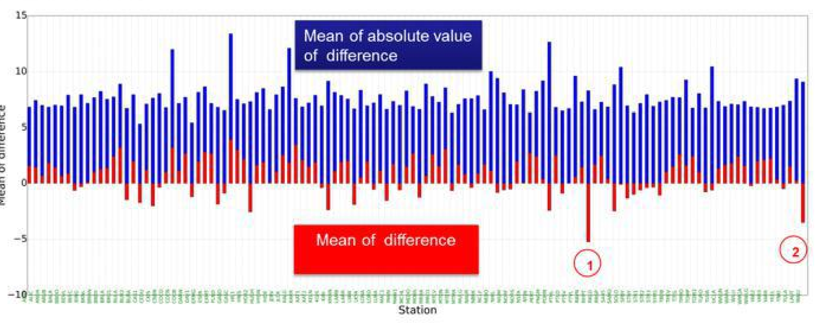

Figure 9. The mean of difference and absolute value of difference between UR ZTD and R ZTD

Event Monitoring

Heavy rainfall continued along the north NSW coast to the south NSW coast during 05-06-2016 to 06-06-2016. The situations of ZTD were obtained from the system for BNDY, TOOW and PKVL site which is along the coast line are presented in Figure 10. The time points of the ZTD fluctuation have good agreement with the rainfall. Before the heavy rainfall started, the ZTD was almost at the top of the trend. When the rainfall happened along the coast line in NSW, the curves of ZTD dropped down quickly caused by the transformation from water vapour to liquid water.

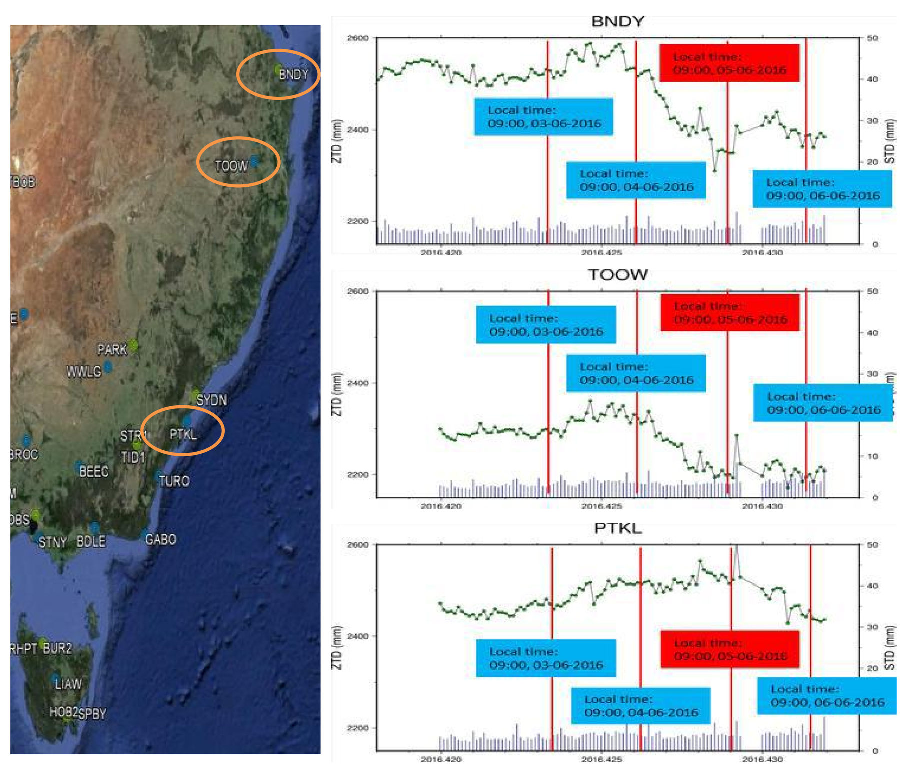

Figure 10. The variations of ZTD for the BNDY, TOOW and PKTL

Conclusions

Geoscience Australia has built the system and started routinely producing two ZTD estimation products by using PPP strategy of Bernese software package. To estimate the near-real time ZTD, we rely upon the IGS Real Time clock products and the IGS ultra-rapid orbits. ZTD estimates derived from the sliding window of 24 hours of raw observations are provided every hour with a latency of approximately 40 minutes from approximately 160 stations.
The system is currently being trialled to aid weather forecasting in the Australian region. To help us validate our near-real time ZTD estimates we also produce a rapid solution, which relies upon the rapid IGS orbit and clock products. For the rapid solution we process over 600 stations from a global network dominated by stations in the Asia Pacific region. The system has been established in the Amazon Web Services (AWS) cloud to help aid in reliability and scalability.

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