Modelling of Ionospheric Corrections for High Accuracy GNSS Positioning using the GINAN toolkit

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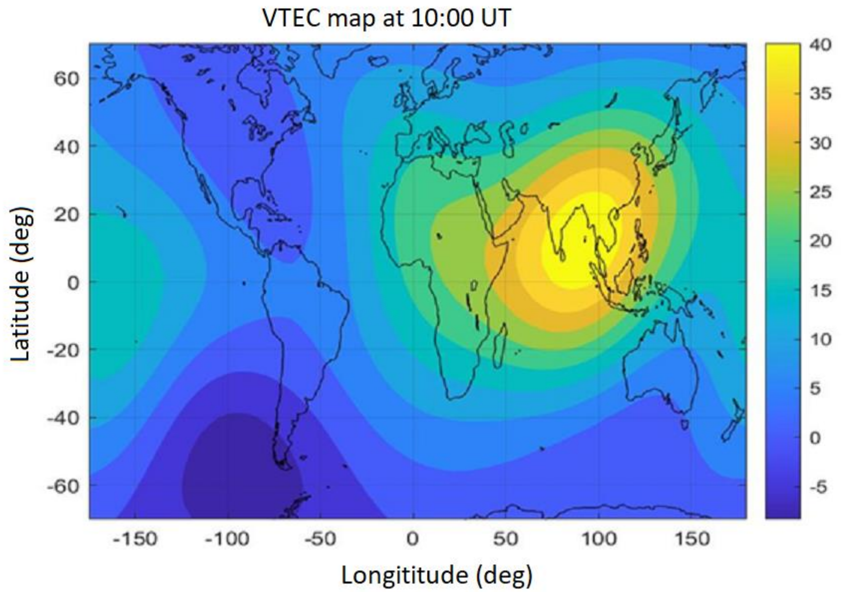
I. Contents

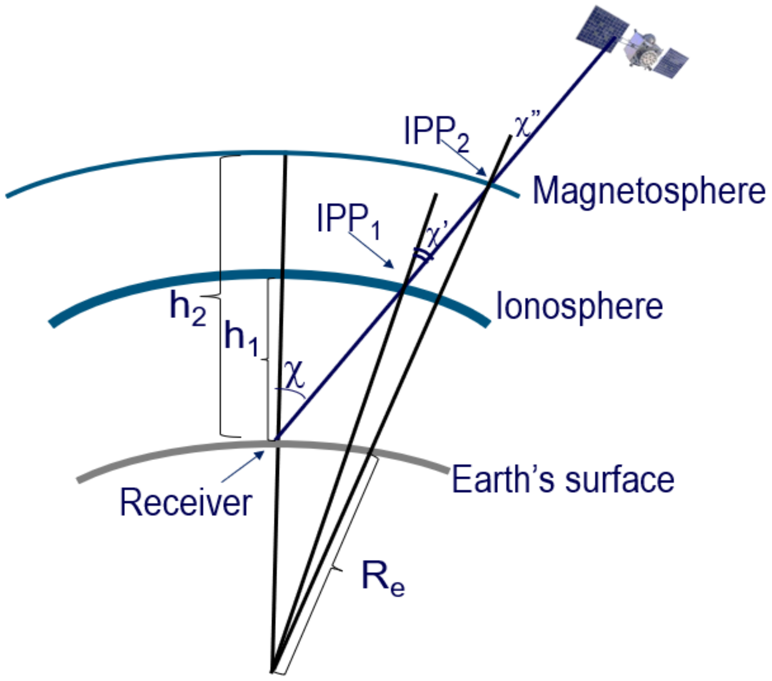
We evaluate the ionospheric corrections obtained from the ionospheric model in GINAN software.

1. The regional model is projected at 350 km height and mapped using the bilinear interpolation method for each region.

2. The global model, electron content is assumed to be concentrated in double-thin shells at fixed altitudes and mapped using the spherical harmonic function.

3. Fault detection and adaptation algorithm for global model.





Dual-layer model

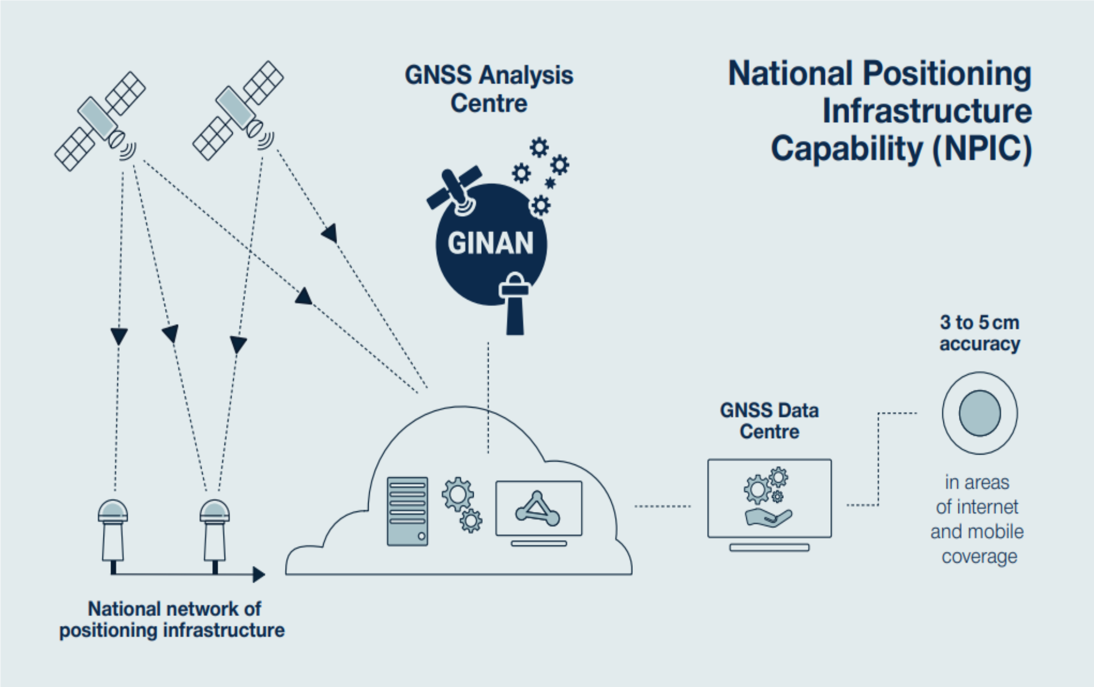
II. GINAN software

Ginan is a GNSS processing toolkit developed by Geoscience Australia for processing GNSS observations for high accuracy GNSS applications.

Ginan is made up two software:

- The Precise Orbit Determination (POD)
- The Parameter Estimation Algorithm (PEA).

PEA uses a Kalman filter to estimate precise satellite orbits from a global CORS network as well as satellite clocks, ionospheric and troposphere delays.



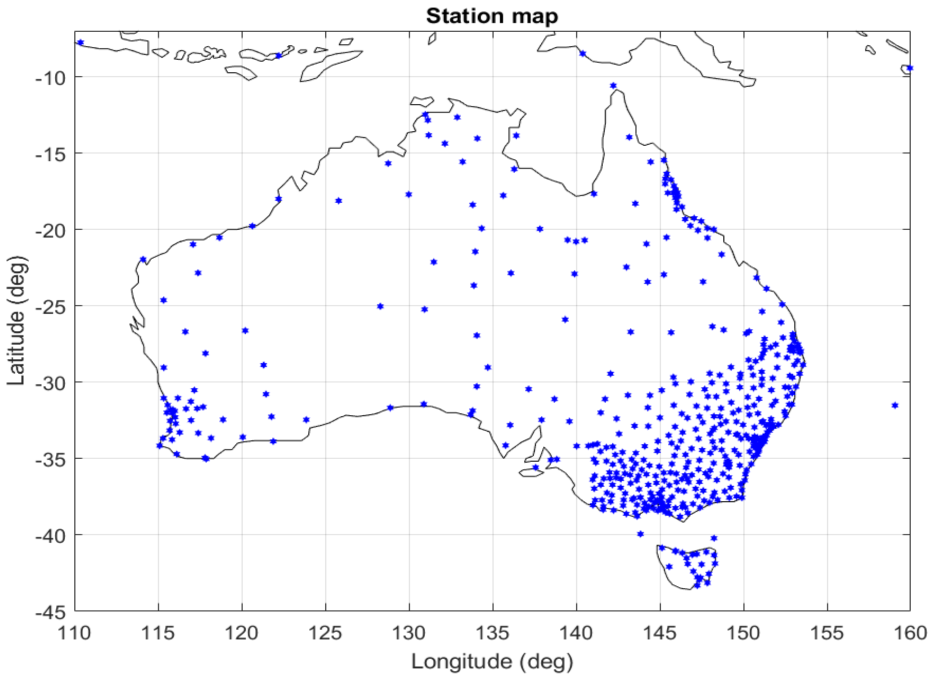
https://geoscienceaustralia.github.io/ginan/page.html

The undifferenced and uncombined solution has been implemented in Ginan for post-processing and real-time applications.

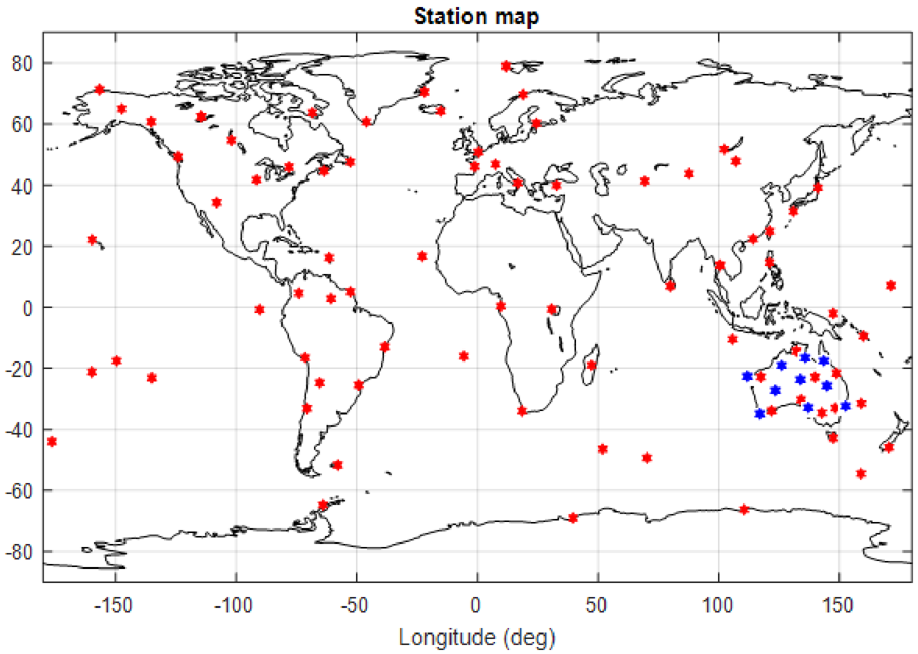
III. Evaluation of ionospheric models

We evaluate the ionospheric model based on the accuracy of:

Regional ionospheric model



Global ionospheric model



1. Regional mapping

- Regional mapping can be created for an area of 5º x 10º in latitude and longitude.
- Based on the availability of GNSS receivers, some regions with at least 8 stations are selected for mapping and testing.

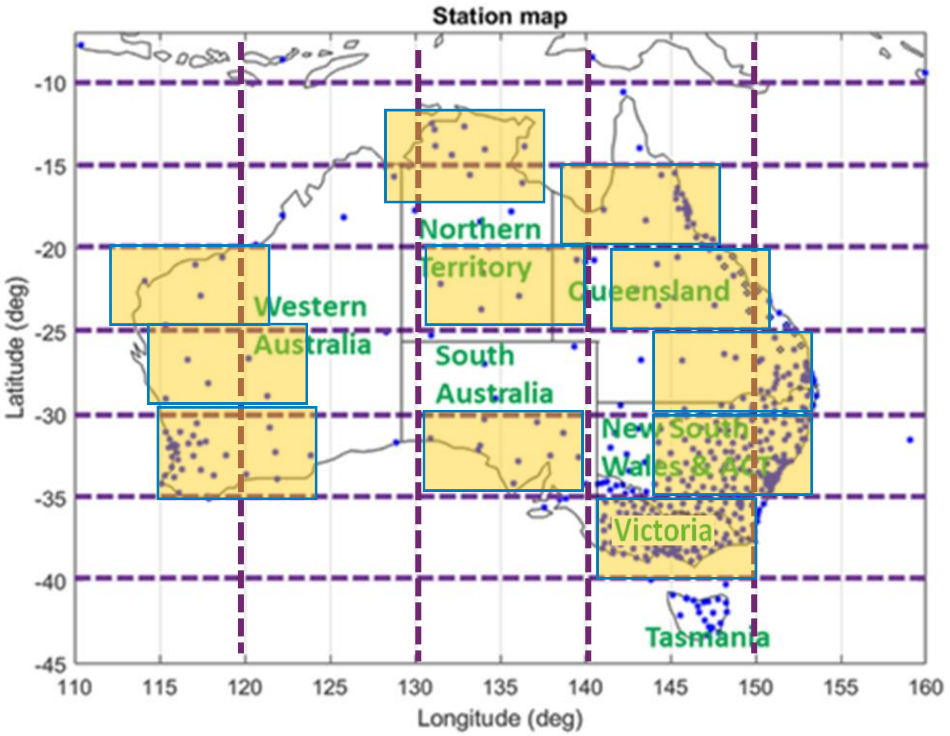
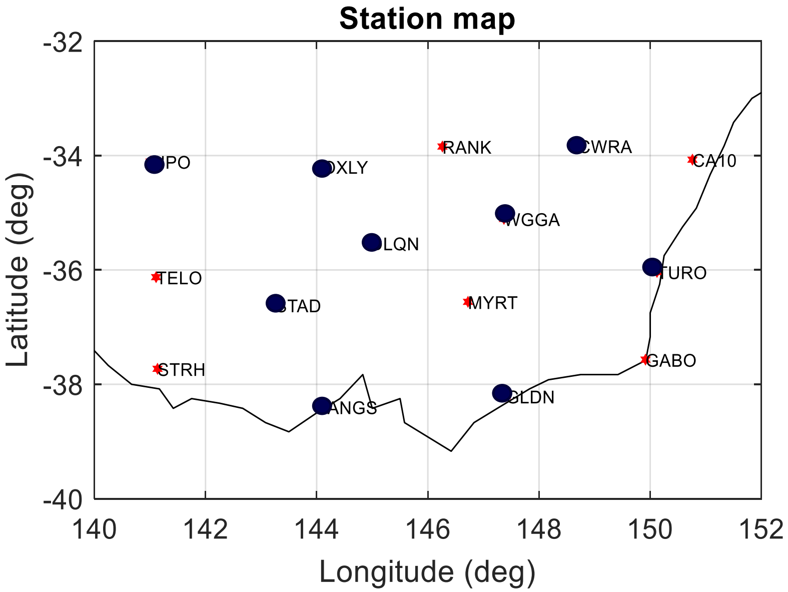


Fig. current CORS network in Australia

1.1 Mapping method

- Select testing station
- Mapping using bilinear interpolation of ionospheric delays in the network and predict I delay at the missing station.
- Calculate the difference of predict value and measurement at the testing station



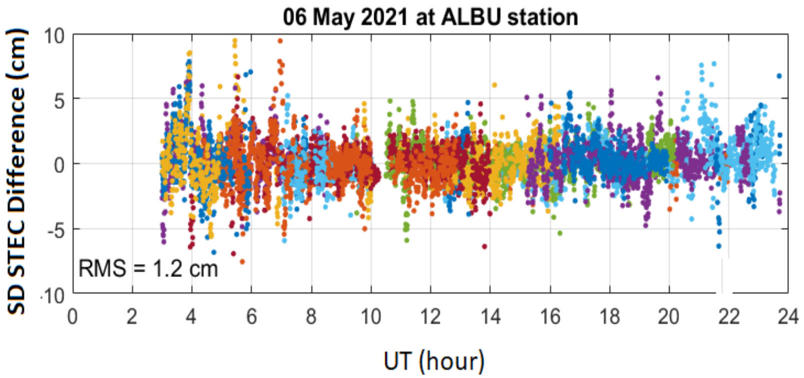
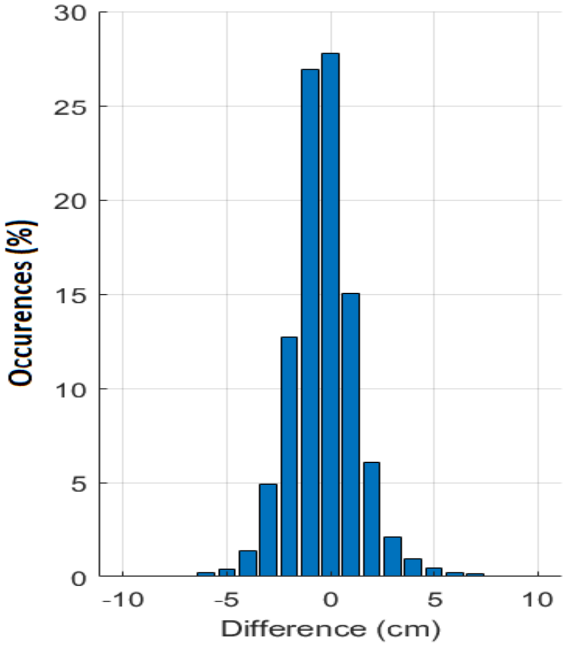
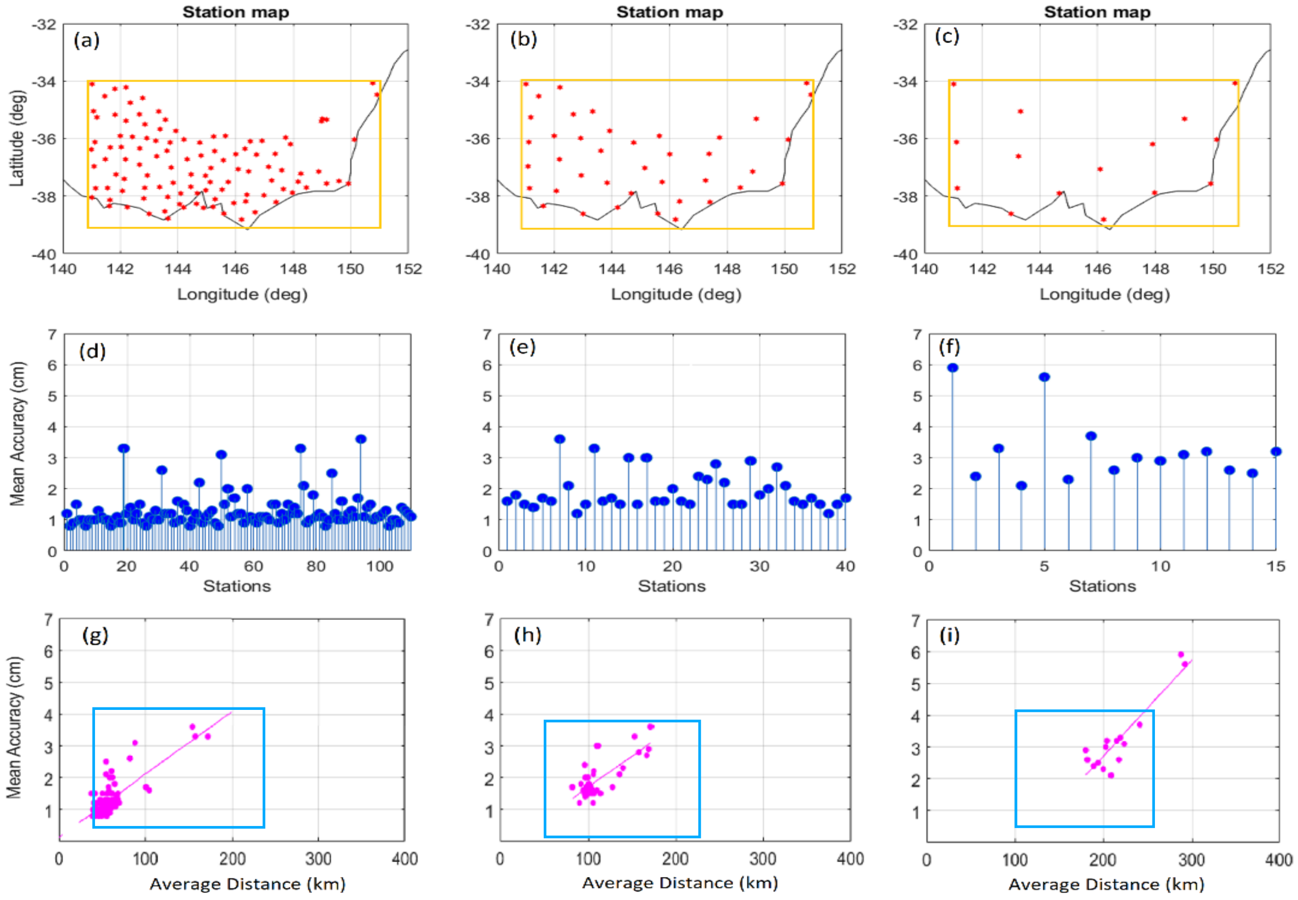


Fig. The accuracy of model in each satellite-receiver path



1.2 Network configuration

112 40 15 stations



The average distance between the testing station to the three nearest stations in this test region is up to 250 km.

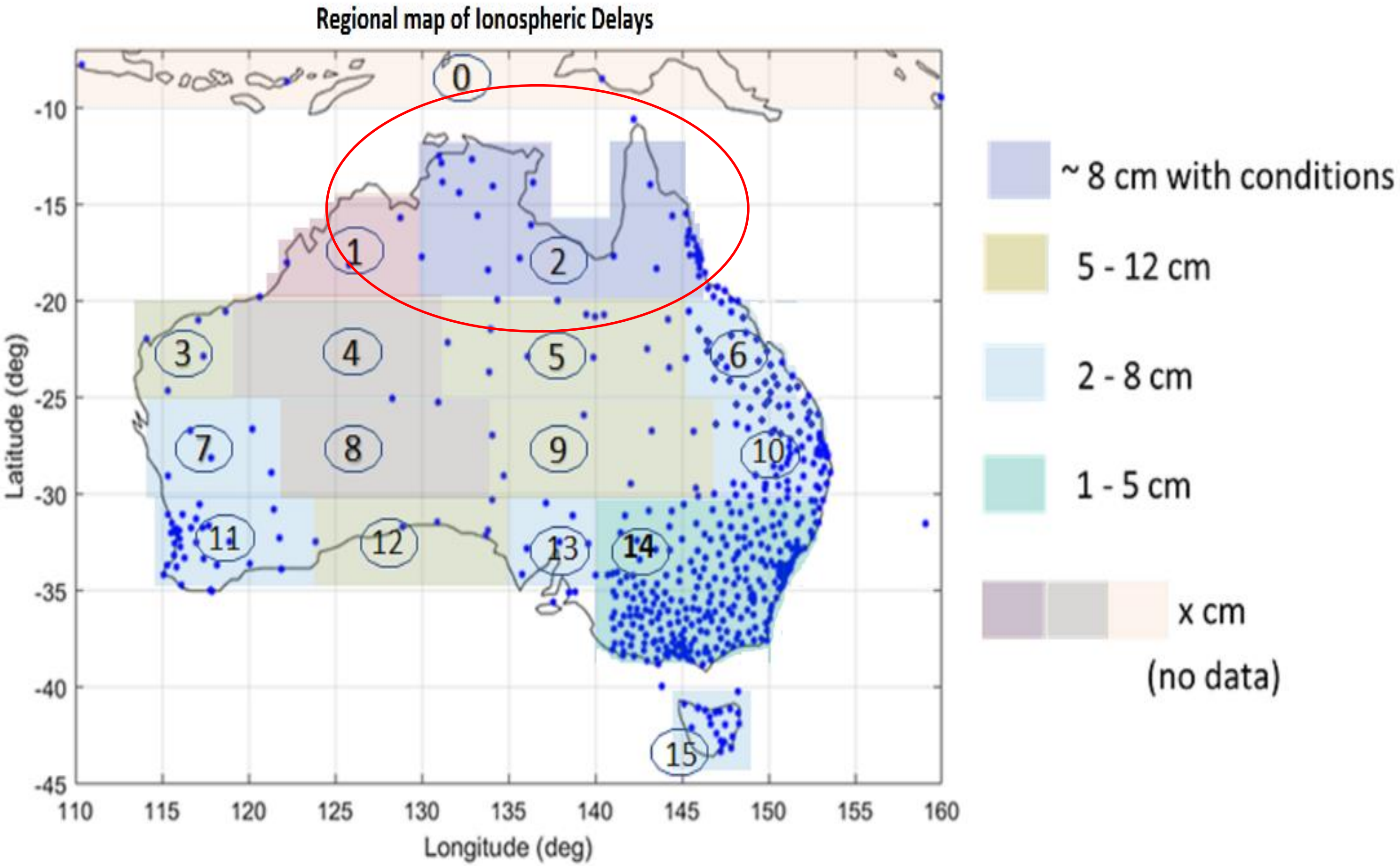
With this network configuration, an average of 5 cm accuracy can be achieved for all stations in the local area.

1.3 Accuracy of local model

The accuracy of the regional model is based on the distribution of the CORS network and latitudinal region.

Using the network method in Ginan Ver1, the accuracy of the regional model is 5 cm as normal for a region of at least 15 CORS stations.

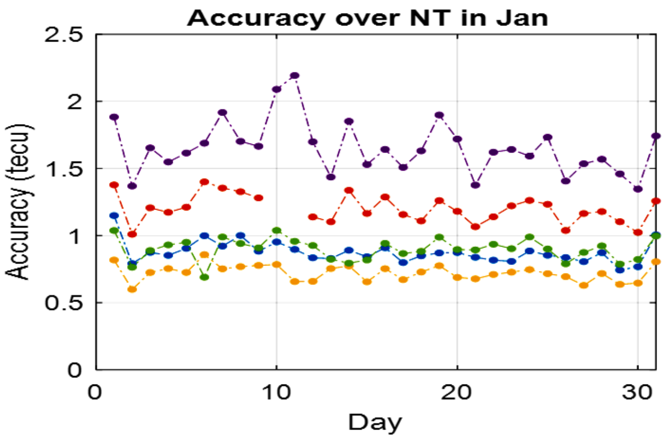
North Territory is facing low accuracy because of the limited CORS stations and located in low latitudes.

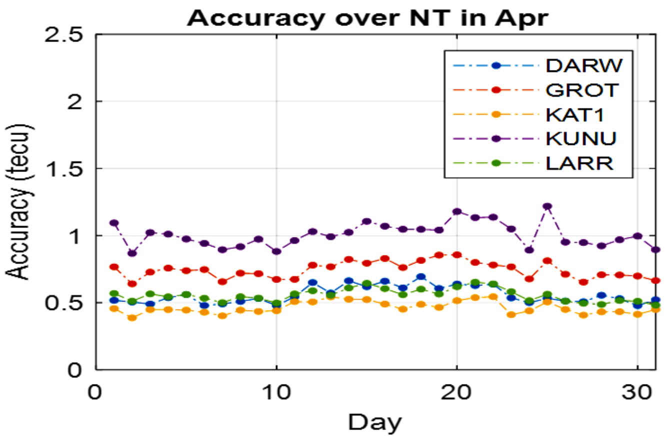


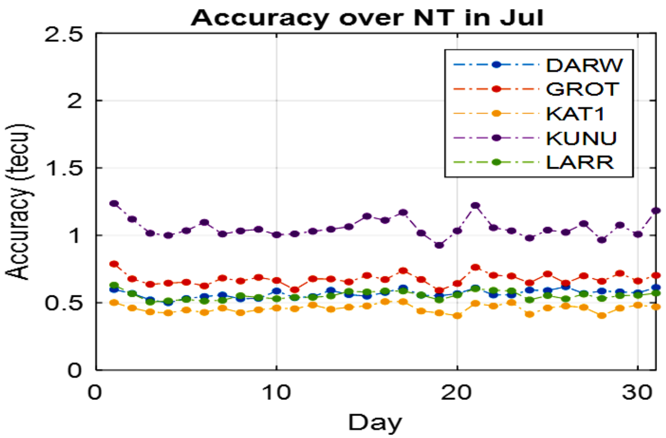
Dao et al., 2022. https:// doi.org/10.3390/rs14102463

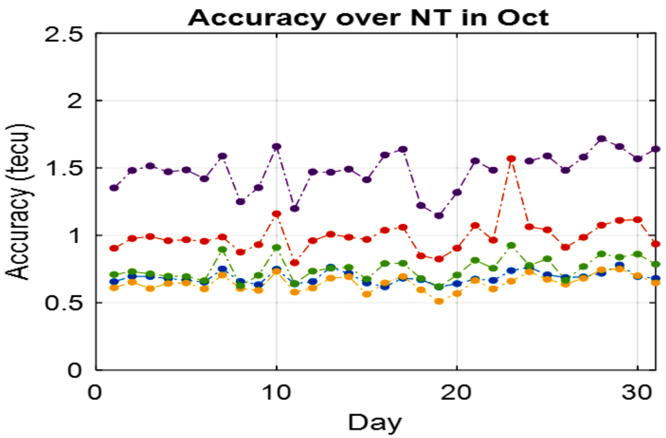
1.4 Accuracy (PPP solution)

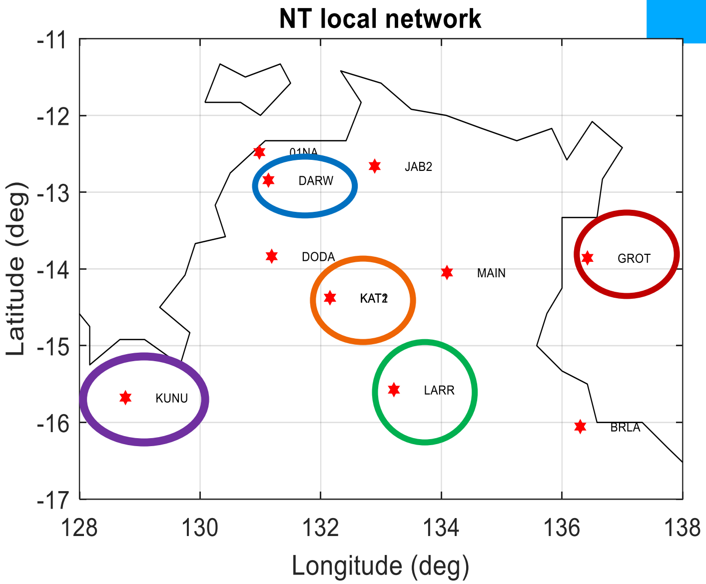
The PPP solution implemented in Ginan Ver.2 has been using for modelling and testing over North Territory in different seasons.









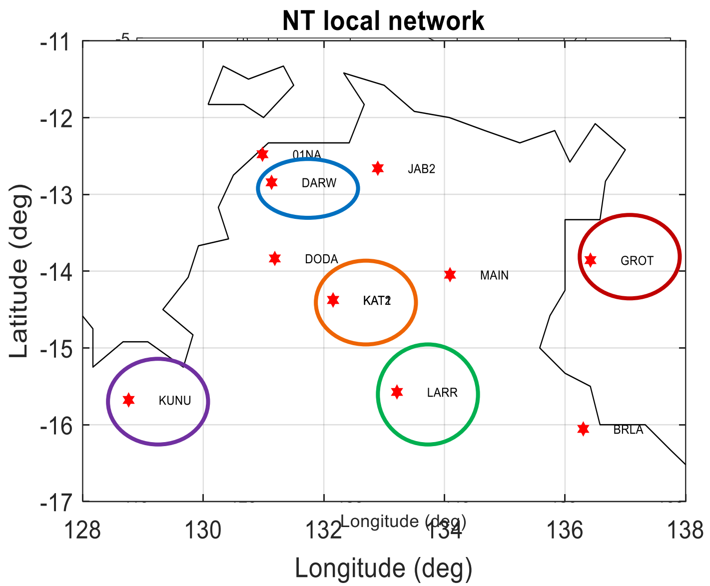


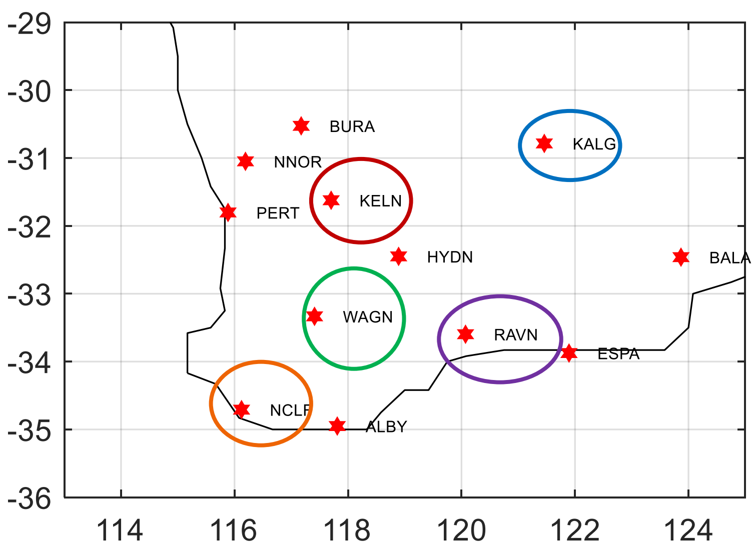
tecu	DARW	GROT	KAT1	KUNU	LARR
Jan	0.88	1.20	0.72	1.65	0.90
Apr	0.56	0.74	0.46	1.01	0.56
Jul	0.57	0.68	0.46	1.06	0.55
Oct	0.69	1.00	0.65	1.48	0.75

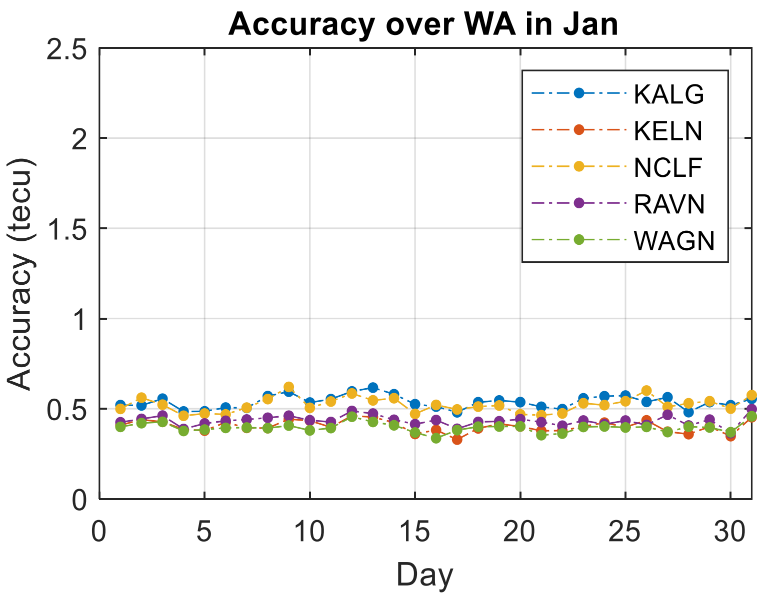
cm	DARW	GROT	KAT1	KUNU	LARR
Jan	14.0	19.2	11.6	26.5	14.4
Apr	8.9	11.9	7.4	16.1	8.9
Jul	9.1	10.8	7.3	16.9	8.9
Oct	11.0	16.0	10.3	23.7	12.1

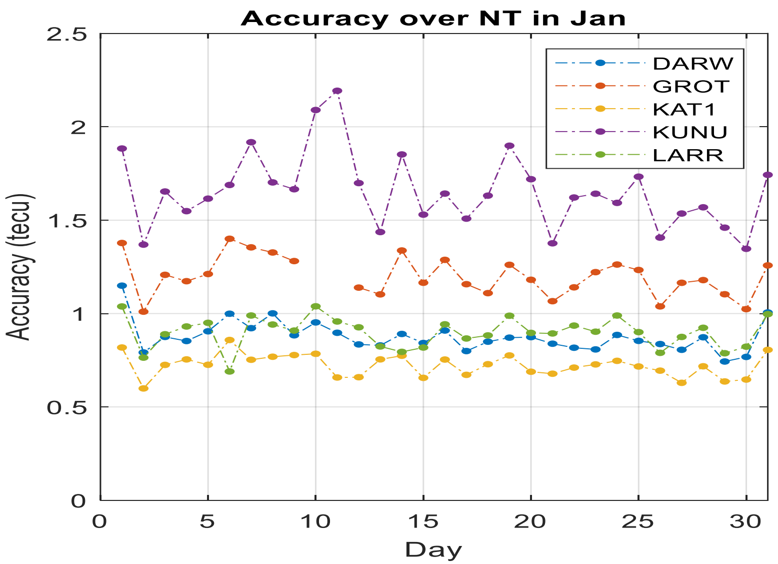
1.4 Accuracy (PPP solution)

West Australia (WA) locates in the mid-latitude region. The number of network stations is comparable with the NT region, but the accuracy of regional mapping is high and stable for all testing stations inside and outside the network.

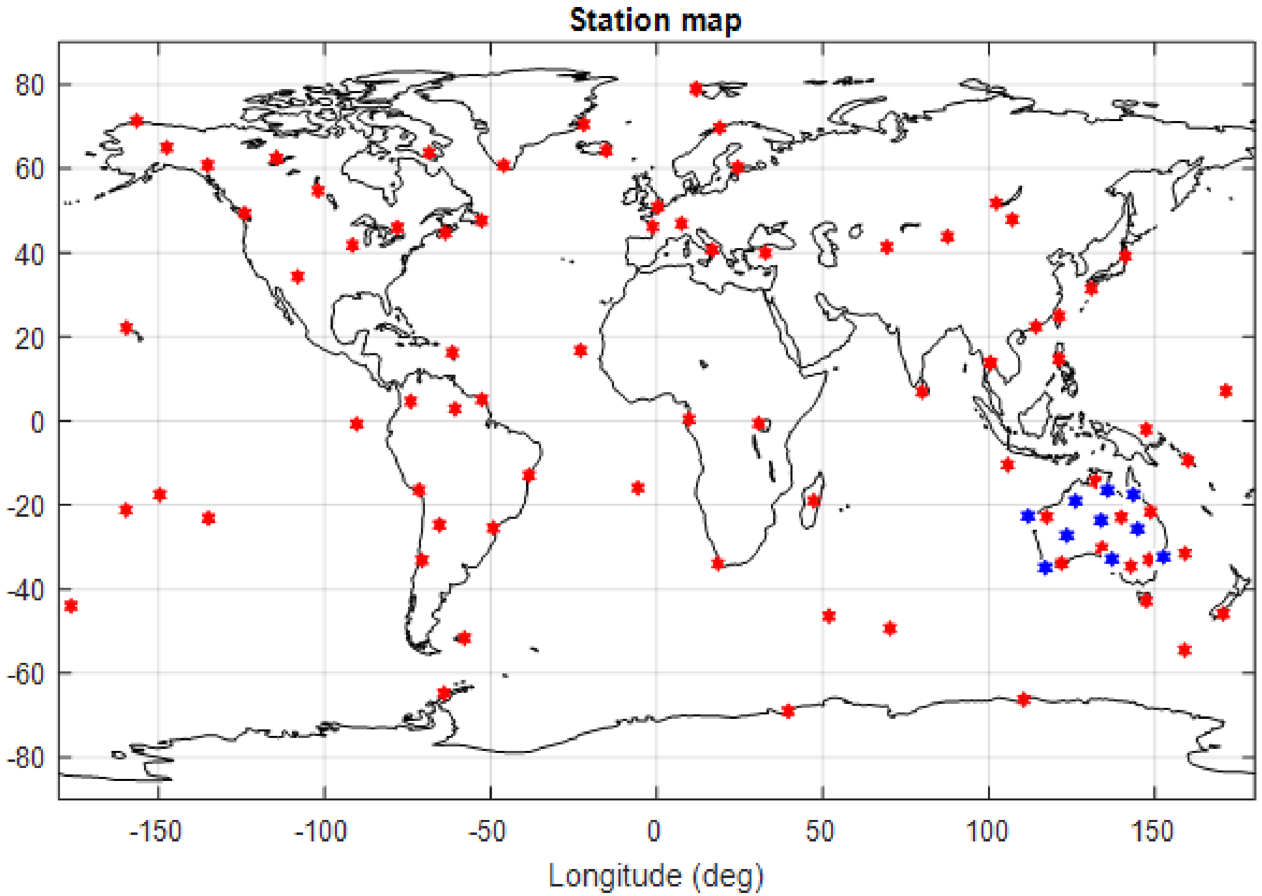


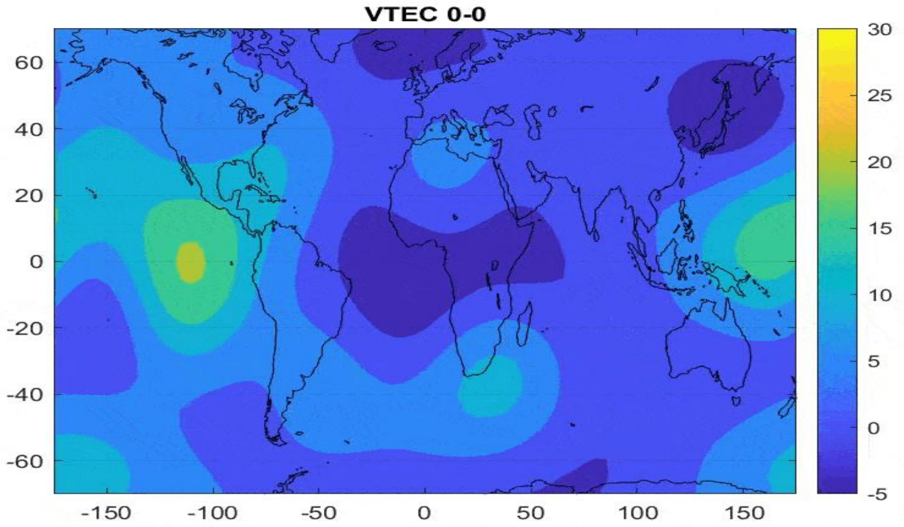






2. Global model





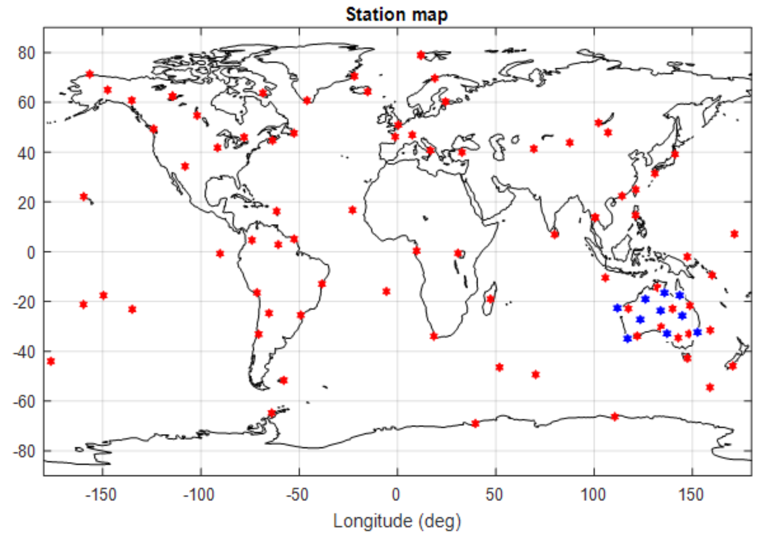
★ Network

★ Testing stations

Totally, 100 stations are used in each processing

2.1 Testing methodology

1. Measure the I delays at testing stations (blue).
2. Build the global SPH model from 100 CORS network (red).
3. From the model, compute I delays at testing stations.
4. Compare the I delays from SHM with measurement.



<u>Note</u>: Calculate Ionospheric delays from the SPH model

$$I_{delay} = \frac{40.3}{frq^2}\left(\sum_{j=0}^{N_{har}} M_{hgt} a_j H_j(lat', lon')\right) + DCB_{rec} + DCB_{sat}$$

frq is carrier frequency; N_{har} is the Number of spherical harmonics;

j is index of spherical harmonics

M_{hgt}: VTEC to STEC mapping function (from *.stec files)

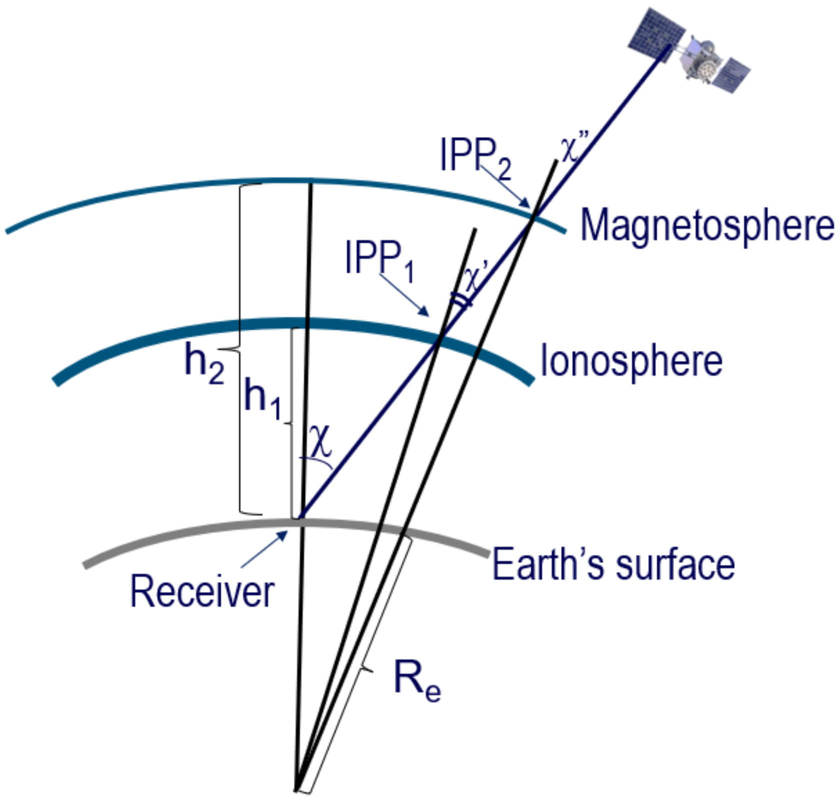
a_j coefficient for spherical harmonics

$H_j(lat', lon')$: spherical harmonic basis for co-latitude lat' and co-longitude lon'

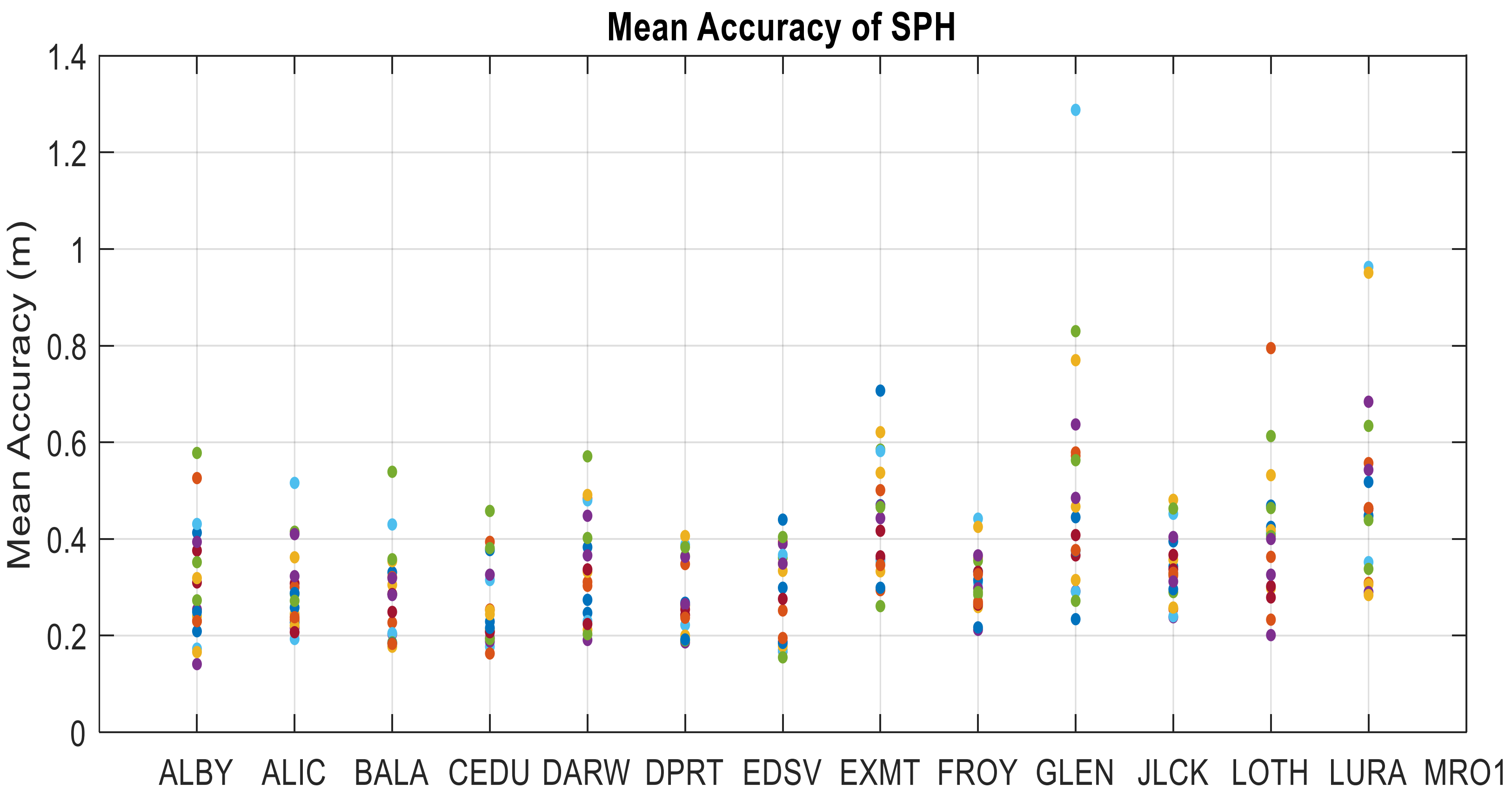
2.2 Inputs into the Global model

Optimal parameters in Ginan global model

1. The fixed altitudes of 2 layers in the SPH models: Can be chosen a bottom top layers below and above the transition height (~ 1000 km). In our model, we chose 300 km and 1600 km heights.
2. The optimal K degree (number of maximum order) is selected at 9.

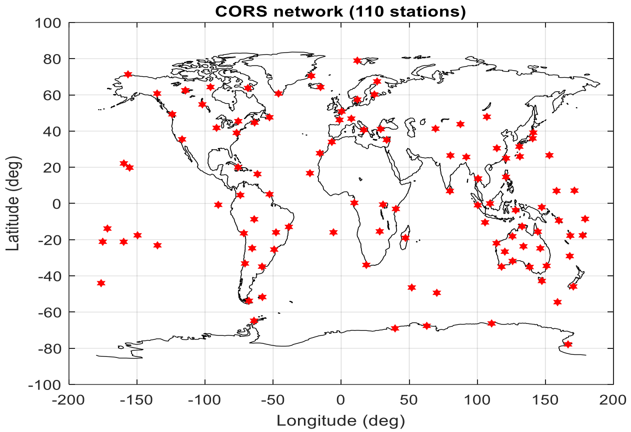


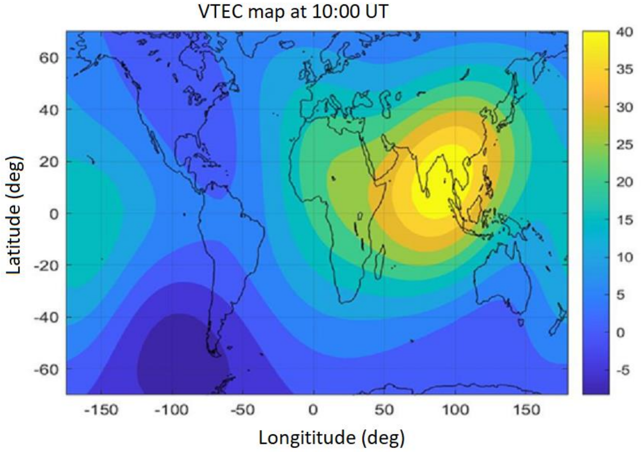
2.3 Model Accuracy

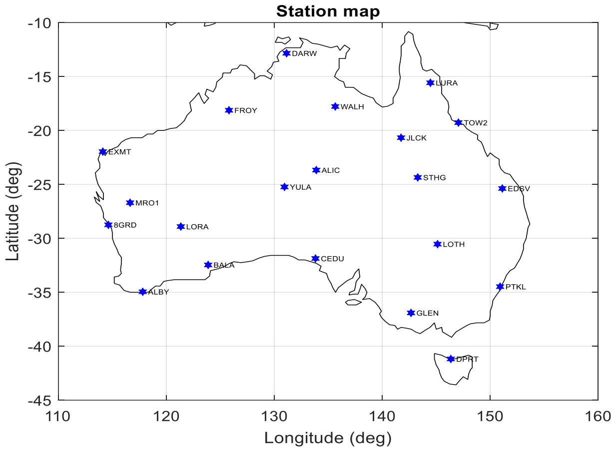


The accuracy of ionospheric delays using dual-layer global model in Ginan are from 20 to 60 cm.

IV. Fault Detection in the Global model







STEC measurements Global network → Spherical Harmonic Modelling → Estimate/testing data at Australia

Faulty measurements & Model misspecification

Faulty measurement

Big Errors, outliers, discontinuity in data evaluation

4.1 Fault Identification

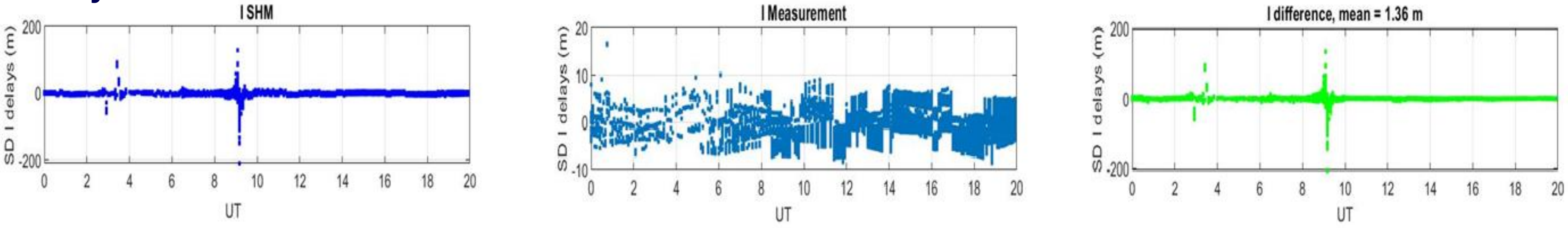
Network STEC

SPH modelling

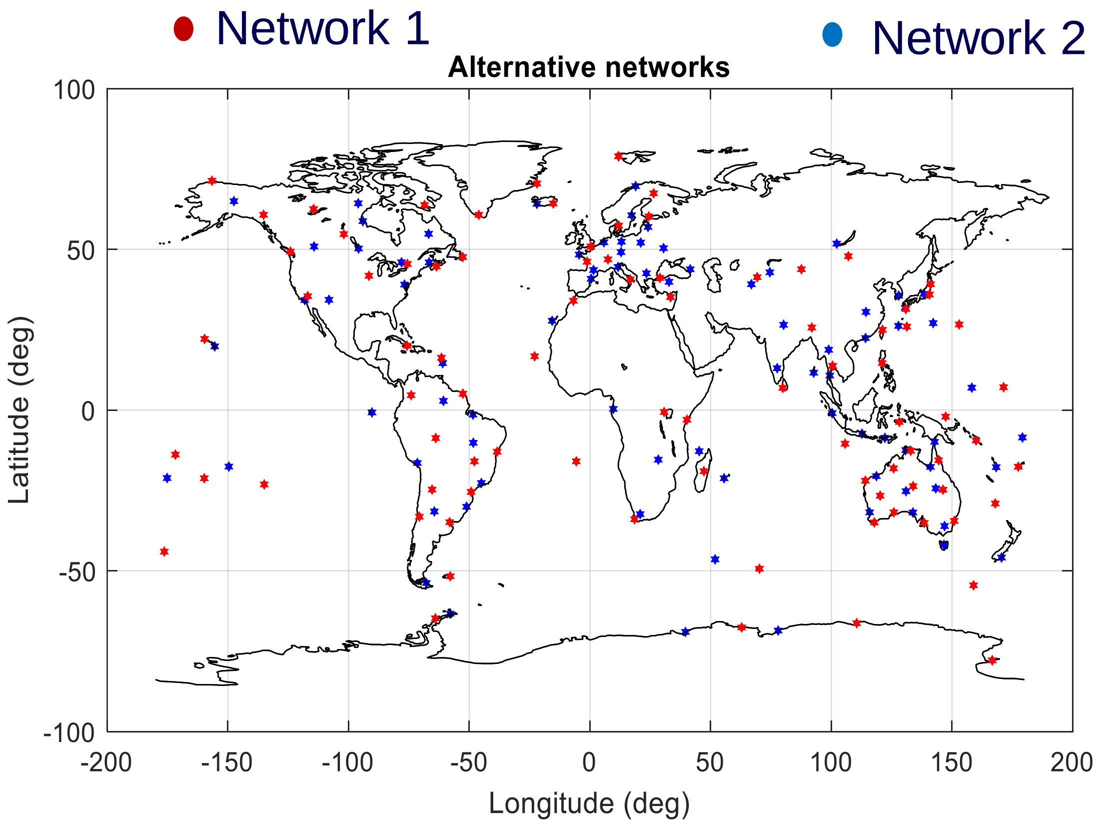
(Testing station) STEC

Errors detected

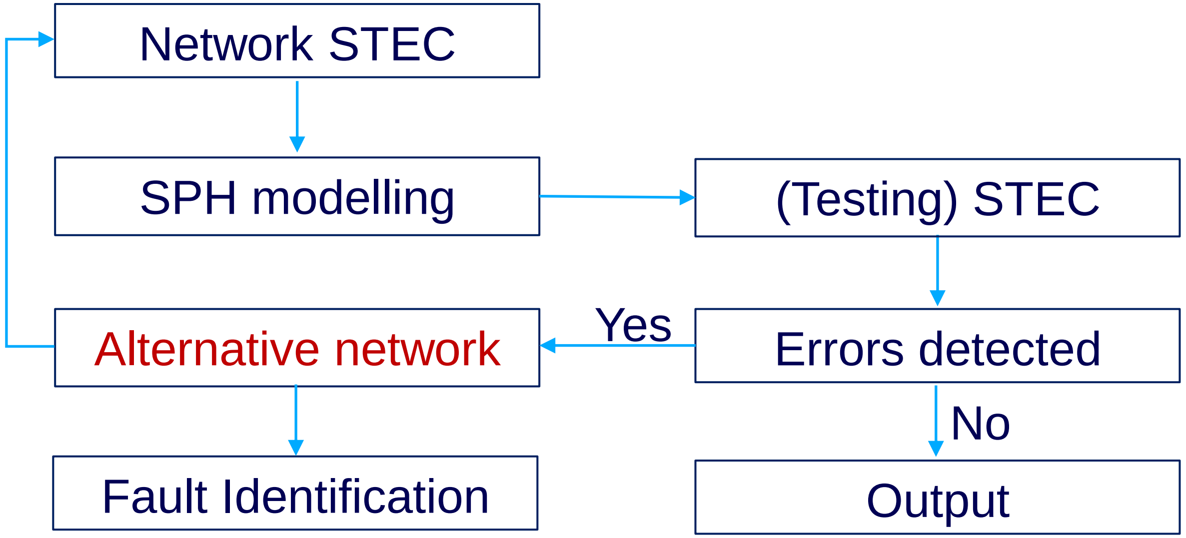
Day 018



4.2 Fault detection



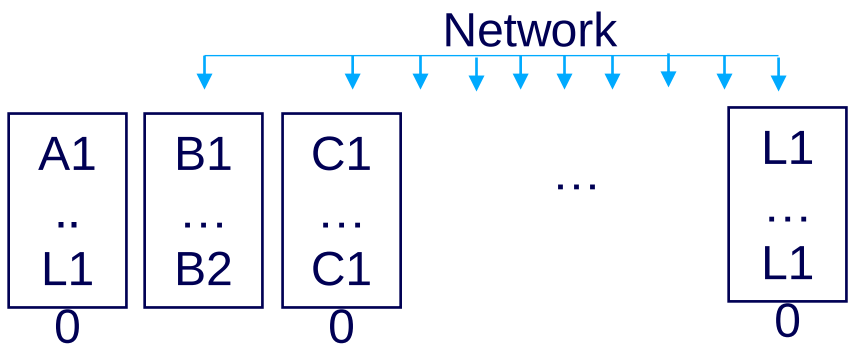
Two global networks (90 stations) is used to test model and compare each other

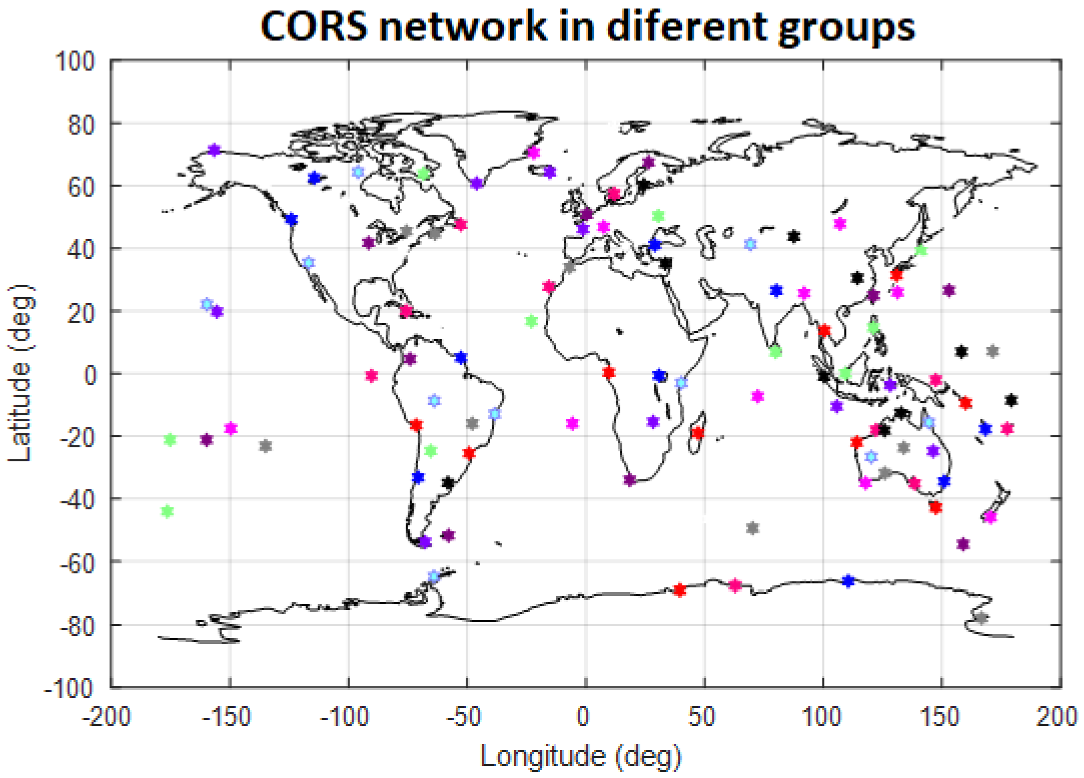


In case of both alternative networks result the faulty detections → find faulty stations in the main network

Using RAIM (Receiver Autonomous Integrity Monitoring)

4.3 Receiver monitoring





- Created 9 groups of ten stations from the network
- Process 80 CORS network each time
- Compare and evaluate

- If the faults occurred in 1 or 2 groups, we could find the faulty stations by repeating the processing.
- If most of the processing creates bad results → make alerts

Summary

1. In the local model with sufficient GNSS CORS coverage, about 15 stations well distributed in an area of 5°×10°, the 5 cm mean accuracy of the ionospheric corrections can be achieved.
2. The current global model presents an accuracy of 20 to 60 cm based on the PPP method.
3. The outlier detection has been partially implemented into the ionospheric models in the GINAN software to enable high-accuracy positioning and support real-time applications.
4. More evaluations are ongoing to get the optimised operational ionosphere parameters in GINAN.

Thanks for listening!