A new project to investigate ionospheric effects on GNSS in ASEAN region

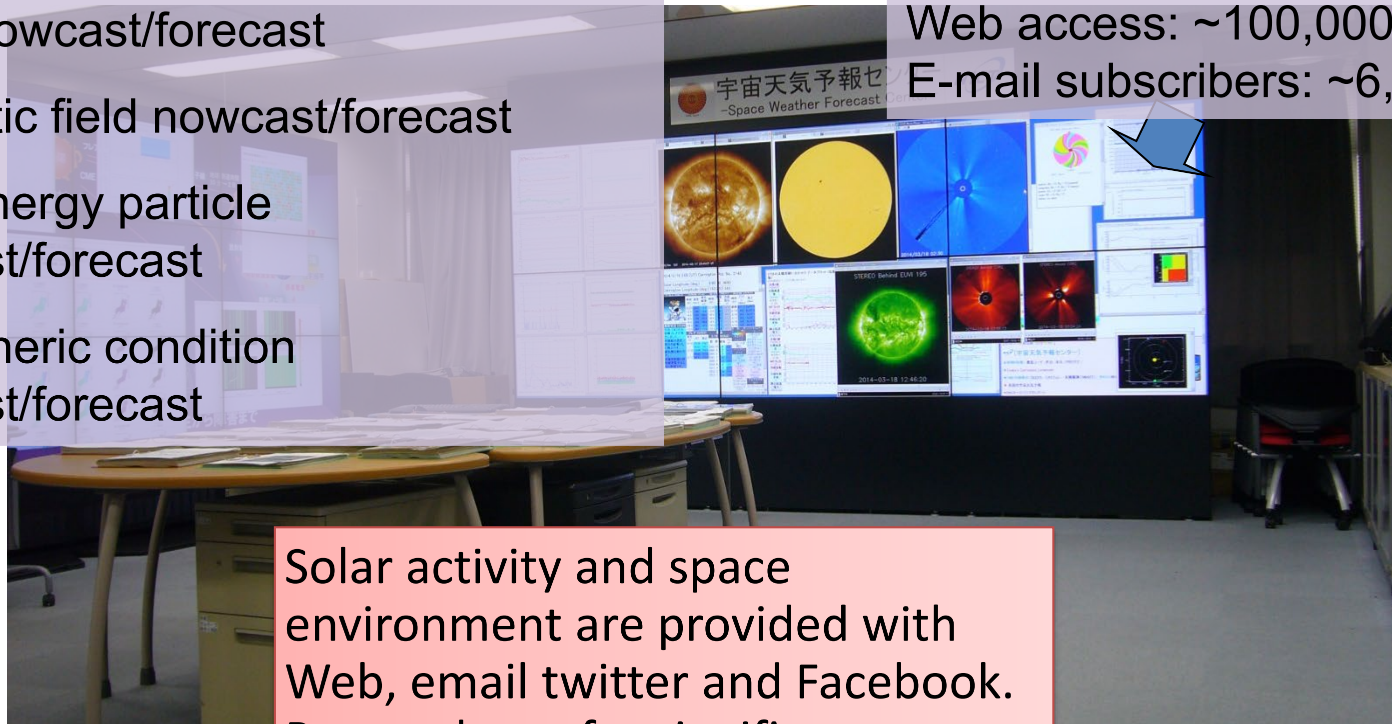
T. Tsugawa (Tsugawa@nict.go.jp),
K. Hozumi, S. Hama, and M. Ishii
NICT, Japan

NICT Space Weather Forecast Center

We manage operational space weather forecast in Japan. We have a briefing of space weather at 2:30pm every day and provide forecast information via email and website.

- Flare nowcast/forecast
- Magnetic field nowcast/forecast
- High-energy particle nowcast/forecast
- Ionospheric condition nowcast/forecast

Web access: ~100,000/month
E-mail subscribers: ~6,000



Solar activity and space environment are provided with Web, email twitter and Facebook. Press release for significant event.

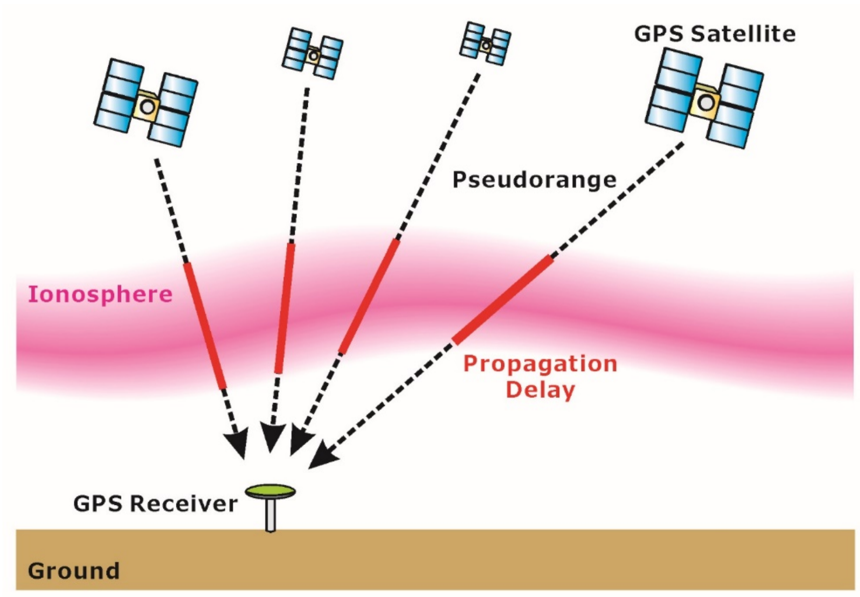
Domestic users: satellite operator, aviation office and companies, power plant companies, HF telecommunicator/broadcaster, GNSS user/companies, resource survey, Univ. and research institutes, amateur HF operators

GNSS Users/Companies

- In recent years, inquiries about the ionospheric variations from GNSS users/companies (e.g., GNSS receiver provider, GNSS positioning service provider, construction machine provider, etc.) increased due to the progress of high precision GNSS positioning utilization.
- Needs for the GNSS users/companies:
  - Quantitative relationship between ionospheric phenomena and GNSS positioning/navigation errors
  - Useful indices and scales of ionospheric disturbances for the GNSS positioning errors
  - Nowcast/forecast of these indices
  - Method to mitigate and/or prevent the GNSS large positioning errors

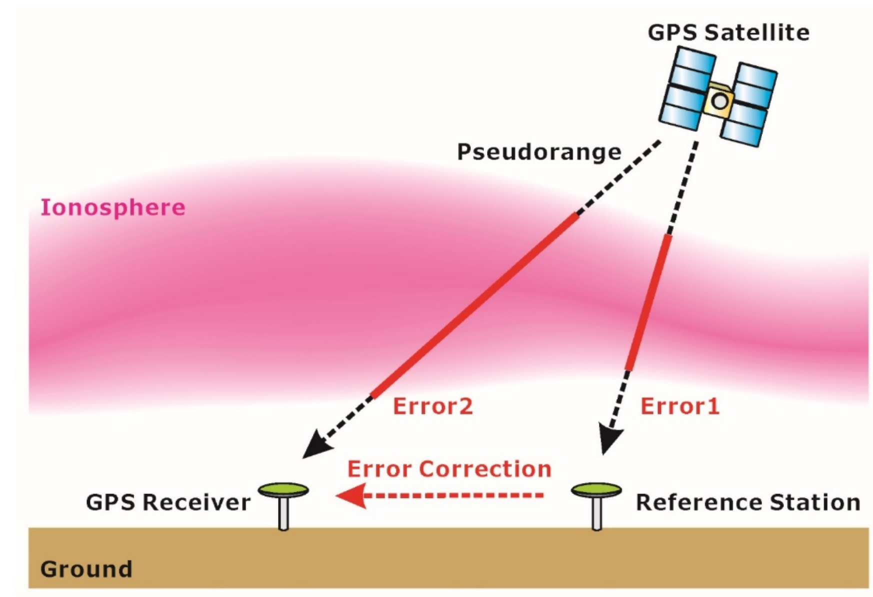
Ionospheric effects on GNSS positioning

Single point positioning



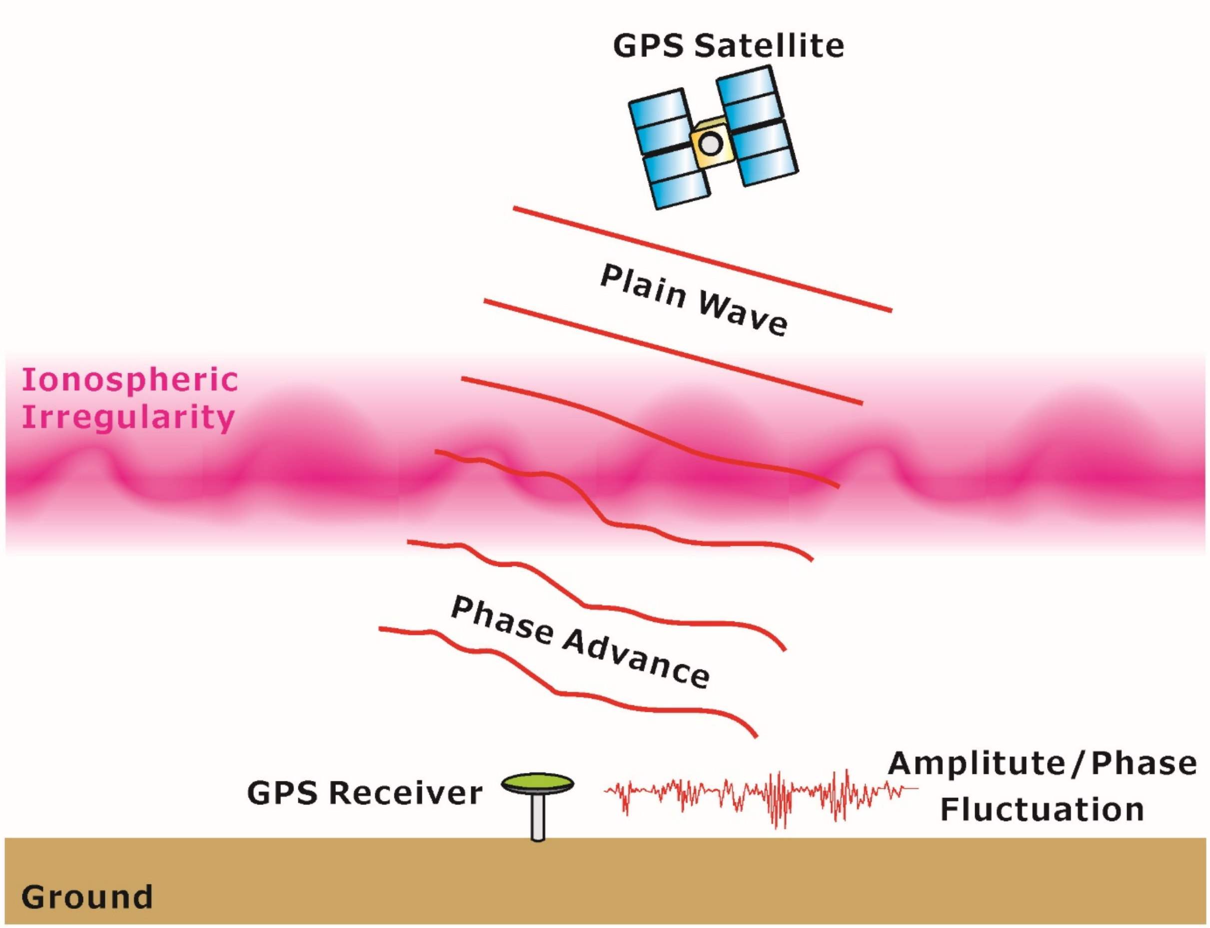
Pseudorange includes ionospheric propagation delay which is the largest error of GPS positioning/navigation for general single-frequency GPS receivers.

Differential GPS positioning



Steep spatial gradient of ionospheric electron density causes differential GPS positioning errors (e.g., GBAS).

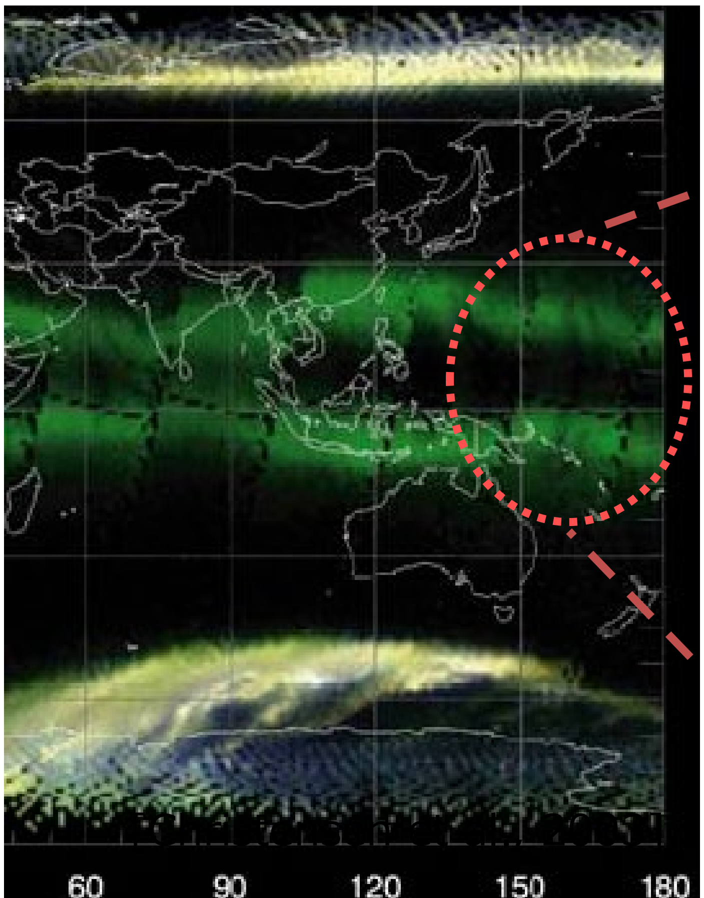
GPS scintillation



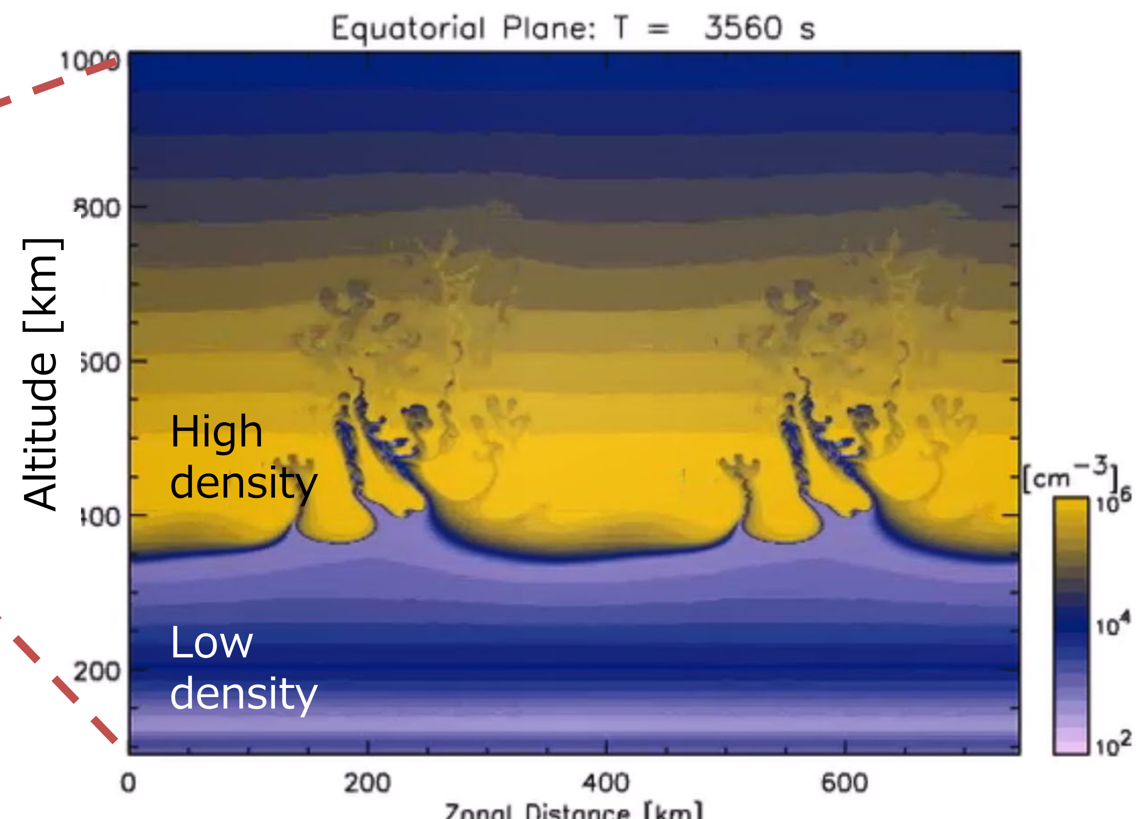
- Several 100m scale ionospheric irregularity causes GPS scintillation which results in loss-of-lock on GPS signals in the worst case.

EPB (Equatorial Plasma Bubble)

Plasma Bubble is a ionospheric “Bubble” generating in the ionosphere over the magnetic equator just after the sunset. It is one of the source of largest error of GNSS in low-latitude region due to spatial gradient of TEC and GNSS scintillation.



Plasma bubbles by HIRB model[Yokoyama et al., 2015]



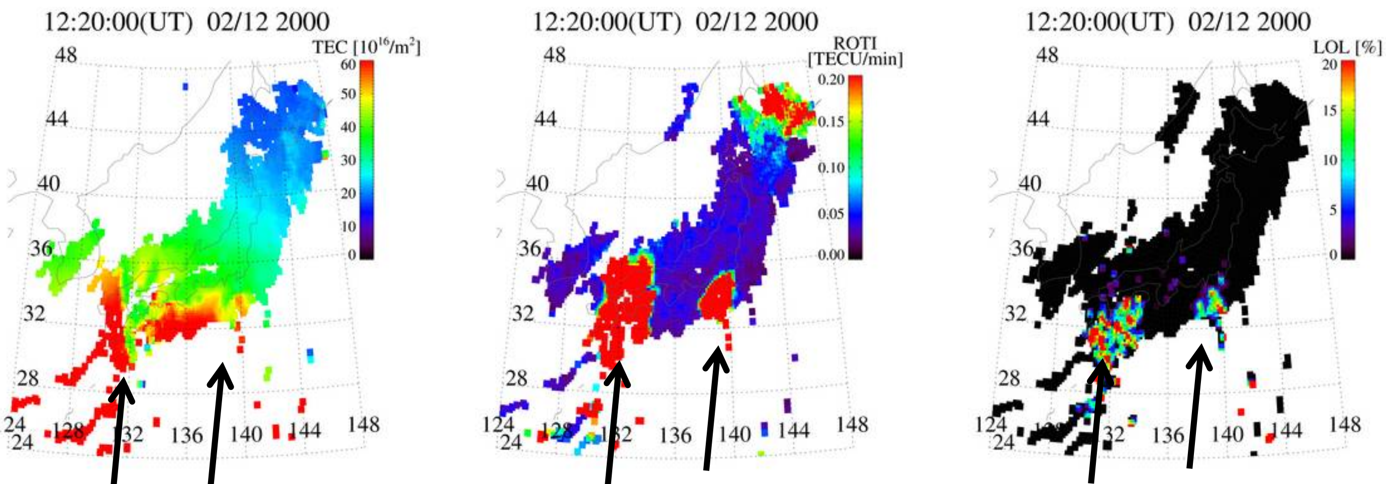
GPS Loss-of-Lock Caused by Plasma Bubble

12:20 UT
(21:20 JST)

Absolute TEC

ROTI
(index for ~10km scale irregularity)

Loss-of-Lock
(index for ~100m scale irregularity)



TEC depletion due to EPB

Ionospheric irregularity in the EPB

Increase in rate of LOL in the EPB structures

- EPB generated in the equatorial region sometimes developed to high altitude/latitude reaching the southern part of Japan when the background ionosphere is uplifted at mid- and low latitudes.
- The EPB causes TEC depletions which have zonal widths of several 100 km and extend in the meridional direction in the southern part of Japan.
- In the EPB structures, ROTI (index for ~10km scale irregularity) and the rate of loss-of-lock on GNSS increase.

“Ionospheric effects on GNSS” project

<u>“Ionospheric effects on GNSS” project</u>

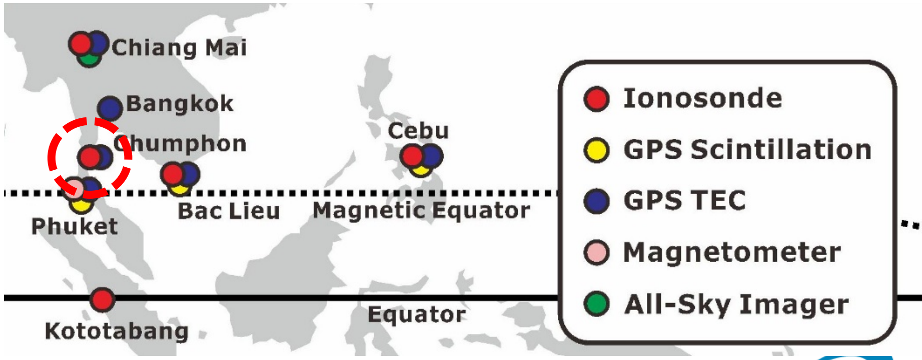
- Since 2017, NICT have started the research program (2017-2019) to verify the ionospheric effects on the precise positioning technique using GNSS including QZSS.
- This project consists of
  - Empirical investigation on the ionospheric effects on GNSS positioning in the Southeast Asia region
  - More precise observations of plasma bubbles to determine their location, generation time, and scale by means of additional ionospheric measurements.
  - Investigation of ionospheric effects on individual positioning techniques (single frequency, DGPS, and RTK-PPP) and consideration of methods to mitigate and/or prevent the positioning errors under sever ionospheric conditions.

“Ionospheric effects on GNSS” project

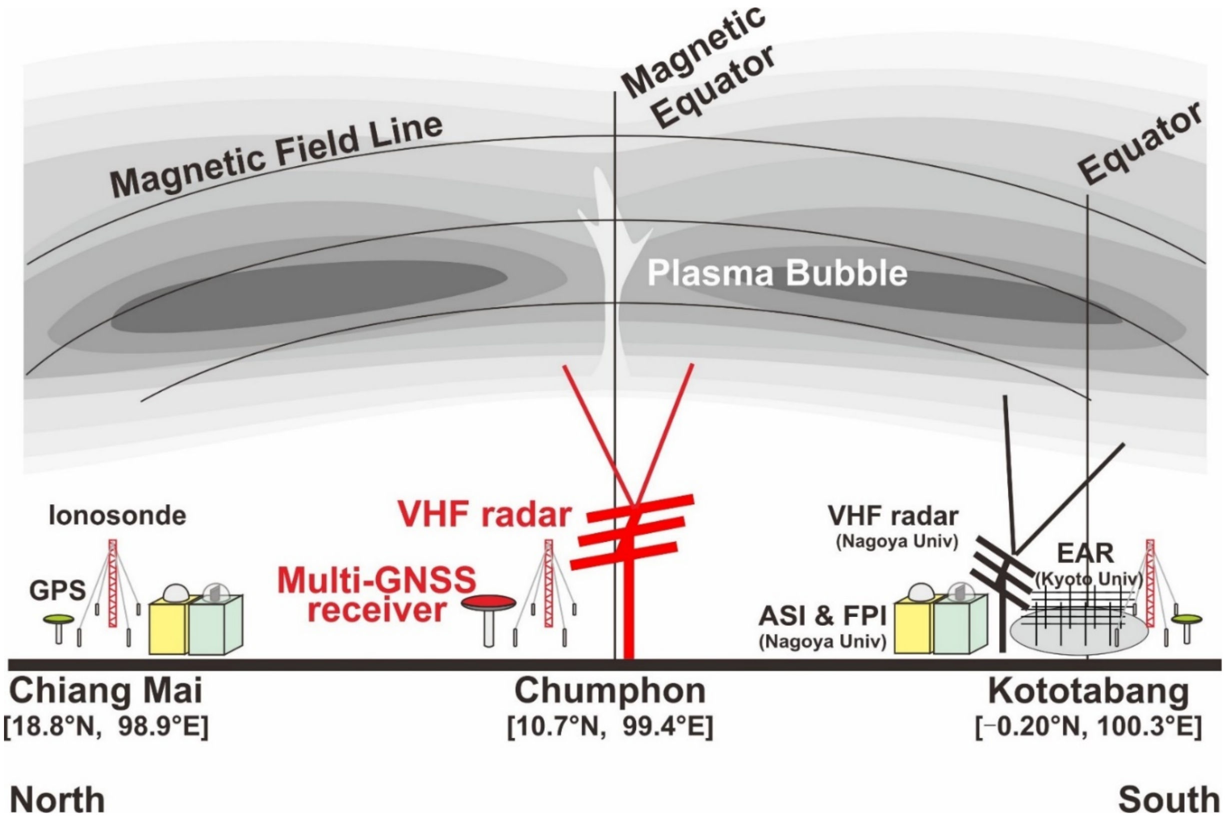
For precise observation of plasma bubble structures

- It is important to identify which satellite-receiver path suffers from plasma bubble structures for verifying the ionospheric effects on GNSS positioning.
- Among several observation methods for plasma bubble listed below, we have decided to install VHF radar at the magnetic equator. Chumphon is the best site for its installation.
  - Ionosonde: only occurrence of spread-F due to plasma bubble
  - All-sky imager: 2D structures (at clear sky conditions)
  - GNSS receiver network: 2D structures (dense network is needed)
  - VHF radar: 3D structures (assuming extent along the magnetic field line)
  - IS radar: 3D structures (very expensive both for installation and operation)

Southeast Asia Low-latitude Ionospheric Network (SEALION)

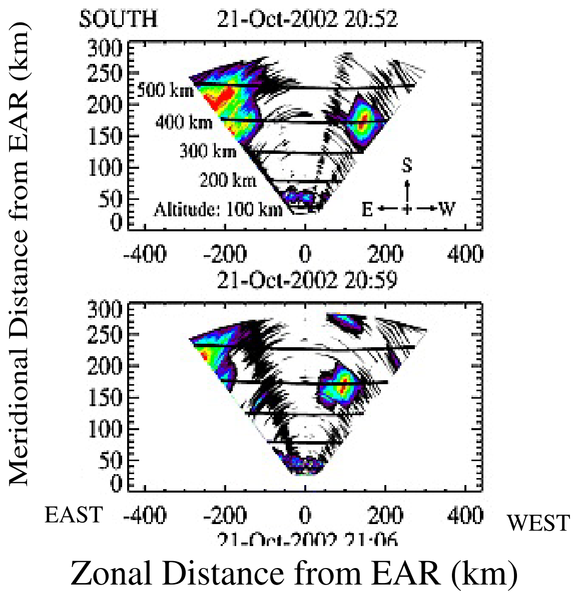


VHF radar and Multi-GNSS observations at the magnetic equator



Nagoya Univ. VHF radar at Kototabang

Fan-sector echo intensity from EAR



[Fukao et al., 2004]

- A VHF radar can monitor 2D (altitude and east-west direction) structure of plasma bubble.
- Various instruments have been installed at low latitudes in both hemisphere along the same geomagnetic field line.

Other R&D plans for ionospheric observations

- Replacement of GNSS scintillation monitor (GSV4004B) to multi-GNSS receivers at the three magnetic equator sites.
- Development of TEC derivation method using multi-GNSS data
- GNSS TEC Exchange Format (GTEX) 3.0 database in the Southeast Asia region

Summary

- Since 2017, NICT have started the research program (2017-2019) to verify the ionospheric effects on the precise positioning technique using GNSS including QZSS.
- To monitor precise plasma bubble structures, we have a plan to install a VHF radar Chumphon, Tahiland, one of SEALION stations at the geomagnetic equator
- VHF radar observations will start in June 2019.
- Scientific as well as engineering collaborations are welcome.