NICT’s Space Weather Research & Operation for GNSS

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Space Weather

Effects from lower to upper atmosphere

[Pedatella, 2018]
Impact of SW on GNSS

The Ionospheric storm on Sep. 8, 2017 made GPS positioning error ~3 times larger.

X 9.3 flare caused rapid TEC increase (SID) on dayside, causing loss-of-lock for GNSS signals, degradation of SBAS availability, degradation of Precise Point Positioning (PPP) accuracy [Berdermann et al., 2018].
Operational SW nowcast/forecast as an ISES member
- Solar flare occurrence
- High-energy particle condition at geosynchronous orbit
- Geomagnetic field condition over Japan
- Ionospheric condition over Japan

Web access: 160,000/month
No. of e-mail address: 10,000
And also on Facebook, twitter

Domestic Users:
satellite operator, aviation office and companies, power plant companies, HF telecommunicators / broadcasters, resource survey, Univ. and research institutes, amateur radio operators
Ionospheric Monitoring by Ionosonde

- Ionospheric sounding from the ground, 4 sites in Japan and 1 in the Antarctica
- First observation in 1937, and regular operation from 1957, normally 15 minutes interval
- Monitoring of Ionospheric storms, Flare effects, and so on.

Flare effect (Echo disappearance)

Positive Ionospheric storm
Ionospheric Monitoring by TEC

- Total Electron Content (TEC) map is derived from a dense GNSS receiver network in Japan (GEONET) provided by GSI
- High resolution (30sec, 0.15 by 0.15 deg)
- Monitoring of Ionospheric storms, Traveling Ionospheric disturbances (TIDs), Plasma bubble, and so on.
- Global version -> DRAWING TEC project (see our ICG-12 presentation [Tsugawa et al])

Plasma bubble observation
Update of GNSS-TEC Exchange Format (GTEX, v 3.0)

GTEX is a format of slant TEC data.

By sharing slant TEC, various researches would be possible without affected by specific analysis procedures (e.g., bias estimation).

GTEX v3.0 can treat data from multi-GNSS satellites, and the format similar to RINEX 3.

Header

TEC data section

- GTEX DATA
- 20180525 021508 UTC
- TEC values in 10^-16 el/m² (1 TEC Unit)
- Types of data

- Raw slant TEC including bias derived from d
- Absolute slant TEC derived from d
- d are combination of carrier phase and pseudorange
- ZNI: Satellite zenith angle
- AZI: Satellite azimuth angle

Satellite System:
- GPS
- GLONAS
- Galileo
- SBAS
- QZSS
- Beidou
- IRNSS

OBSERVATION records format is as follow:
- Satellite number
- Observation, TEC status flag
- m (m(F10.4, I1, X1))
- TEC status flag= 0 or blank: Normal data
- 1: Lack of observables (TEC=99999.9999)
- 2: Too large TEC (TEC=99999.9999)
- 3: Cycle slip (TEC discontinuity)
- 4: Cycle slip (LLI)
- 5: Beginning of arc

When set ZNI or AZI, TEC status flag is blank.

MTK1080.18o  MTK1070.18o  MTK1060.18o  MTK1050.18o  MTKB

JAVAD Alpha-GST
NOV750.R4  NOVS
-394733.2646  336424.9281  3699425.5842
0.0000  0.0000  0.0000
GAIA is a 3D global model from troposphere to thermosphere and ionosphere.

GAIA reproduces meteorological phenomena, vertical coupling, neutral-plasma interaction, ....

Meteorological Reanalysis has been assimilated into GAIA. Assimilation of upper atmospheric observations are underway.

**Comparison of plasma bubble occurrence**

- **2012**
  - GPS
  - EAR

**Effects of Stratospheric sudden warming on Ionosphere**

- **GAIA simulation**
- **Satellite observations**

[Shinagawa et al., 2018]

[Jin et al., 2012]
HIRB is a high-resolution model of equatorial ionosphere, which reproduces detail structures and features of plasma bubbles.

Global-regional model coupling is on-going, and forecast of plasma bubble occurrence and growth will be treated by HIRB.
Solar flare prediction method has been developed using deep learning technique, which gives categorical prediction with occurrence probability at each active region.

The real-time operation using Deep Flare Net (DeFN) will start in FY2018.

Prediction of 2D TEC map against latitude and LT has been developed using a neural network technique.
Summary

- We are operationally providing space weather nowcast and forecast information as a member of ISES.
- The ionospheric nowcast is based on observations by ionosonde and TEC, which have long history.
- For ionospheric forecast, we are developing physics based models, machine learning models, and data assimilation.

Observations and other data products available at: [http://wdc.nict.go.jp/IONO/]