Current status and recent progress of NICT's ionospheric observations in the Southeast Asia by GNSS-TEC and SEALION

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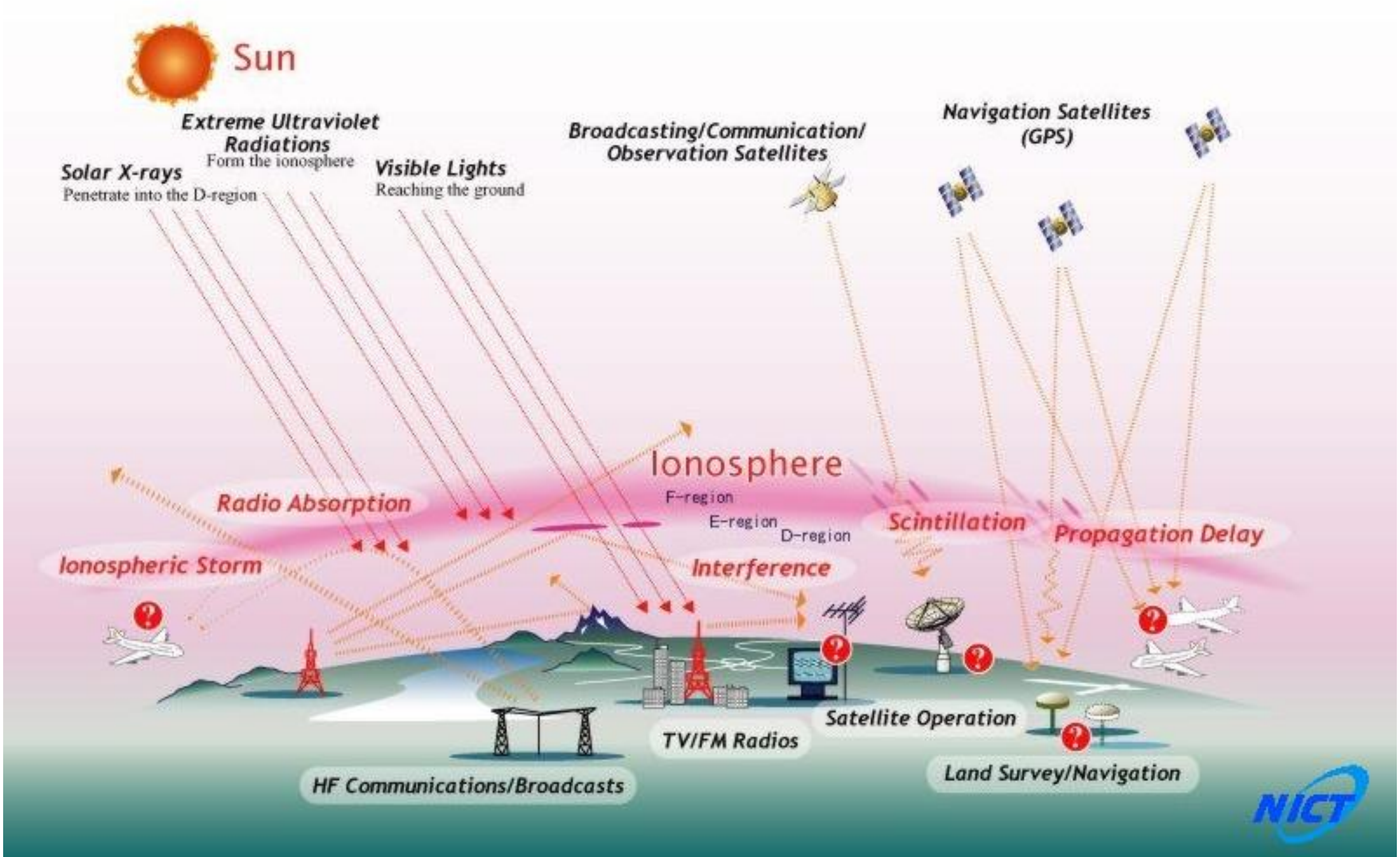
Ionospheric effects on radio applications



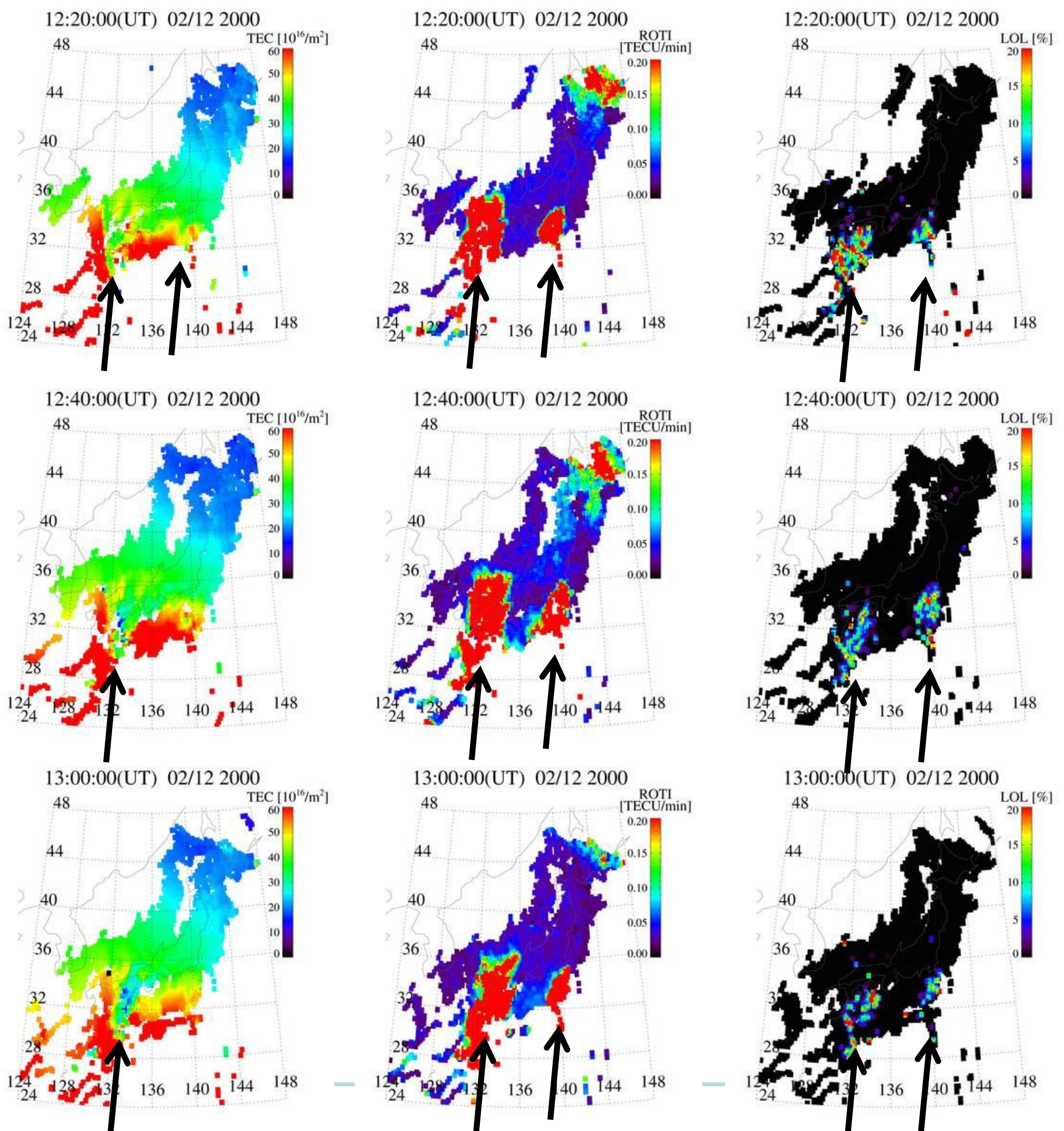
GPS loss of lock caused by plasma bubble

Absolute TEC | ROTI (~10km scale irregularity) | Loss-of-Lock (~100m scale irregularity)

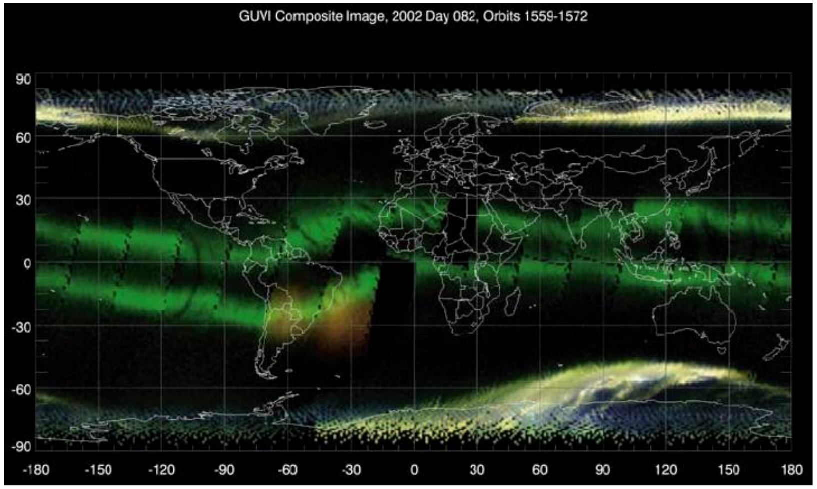
12:20 UT (21:20 JST)

12:40 UT (21:40 JST)

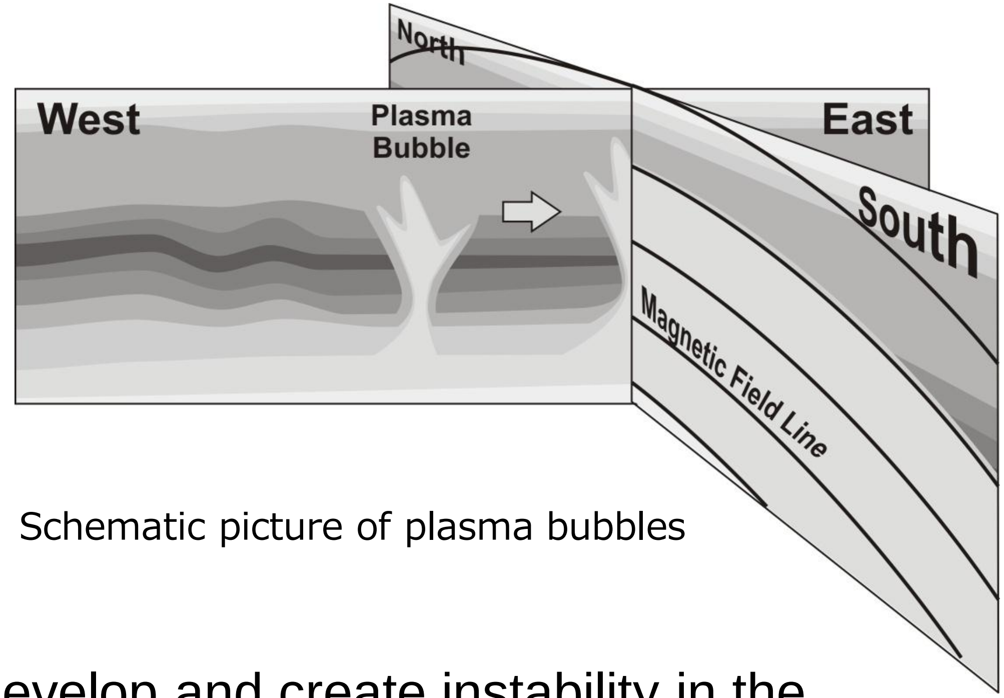
13:00 UT (22:00 JST)



Plasma Bubble



135.6nm airglow images observed by TIMED/GUVI [Christensen et al., 2003]



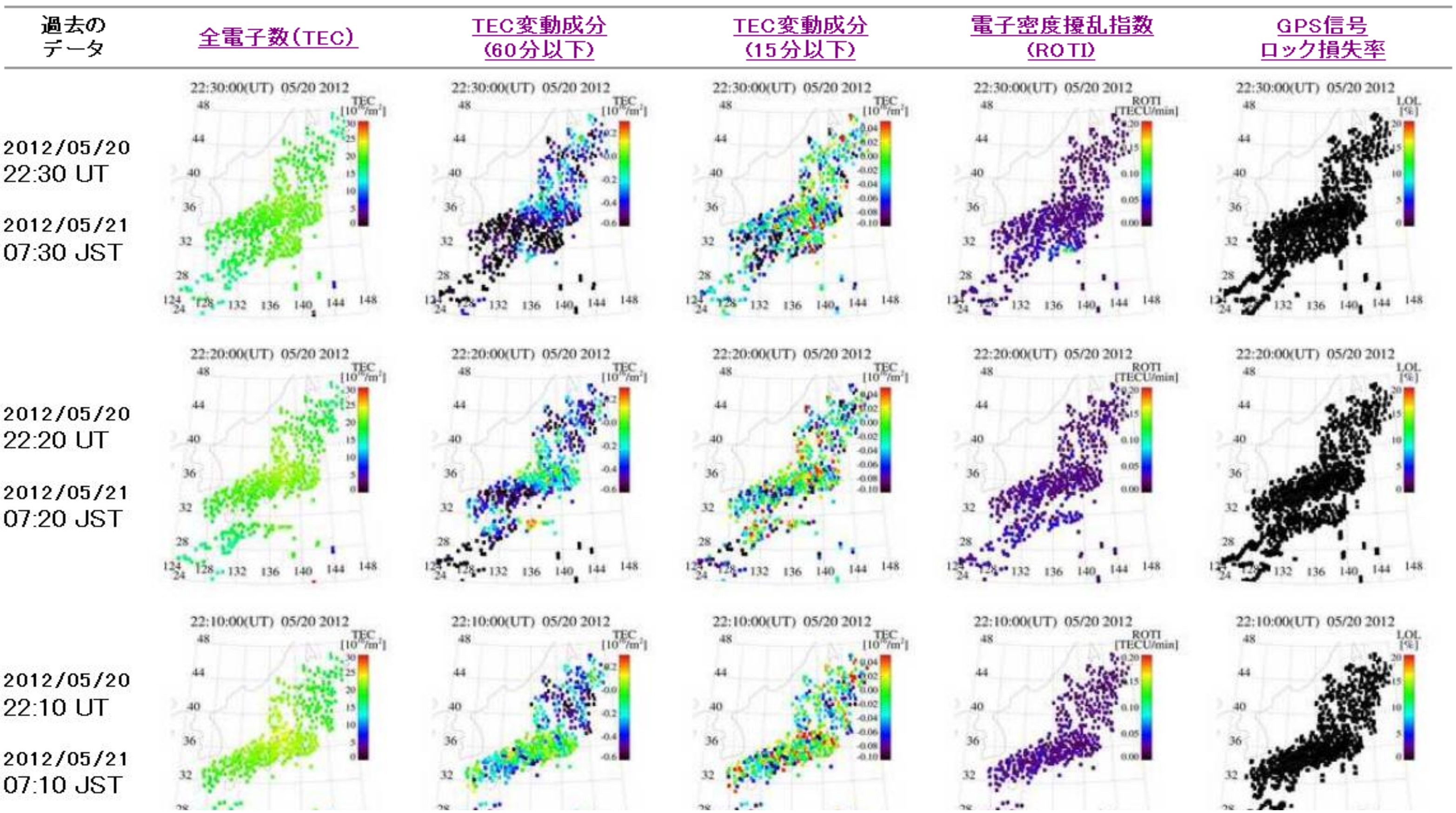
Schematic picture of plasma bubbles

- Plasma bubbles generally can develop and create instability in the low-latitude ionosphere after the sunset.
- Plasma bubbles generally drift eastward and have the structure extending along the magnetic field line.
- A prompt penetrating magnetospheric electric field during the magnetic storm helped to trigger the super plasma bubble observed at mid-latitudes.

Realtime TEC observation in Japan

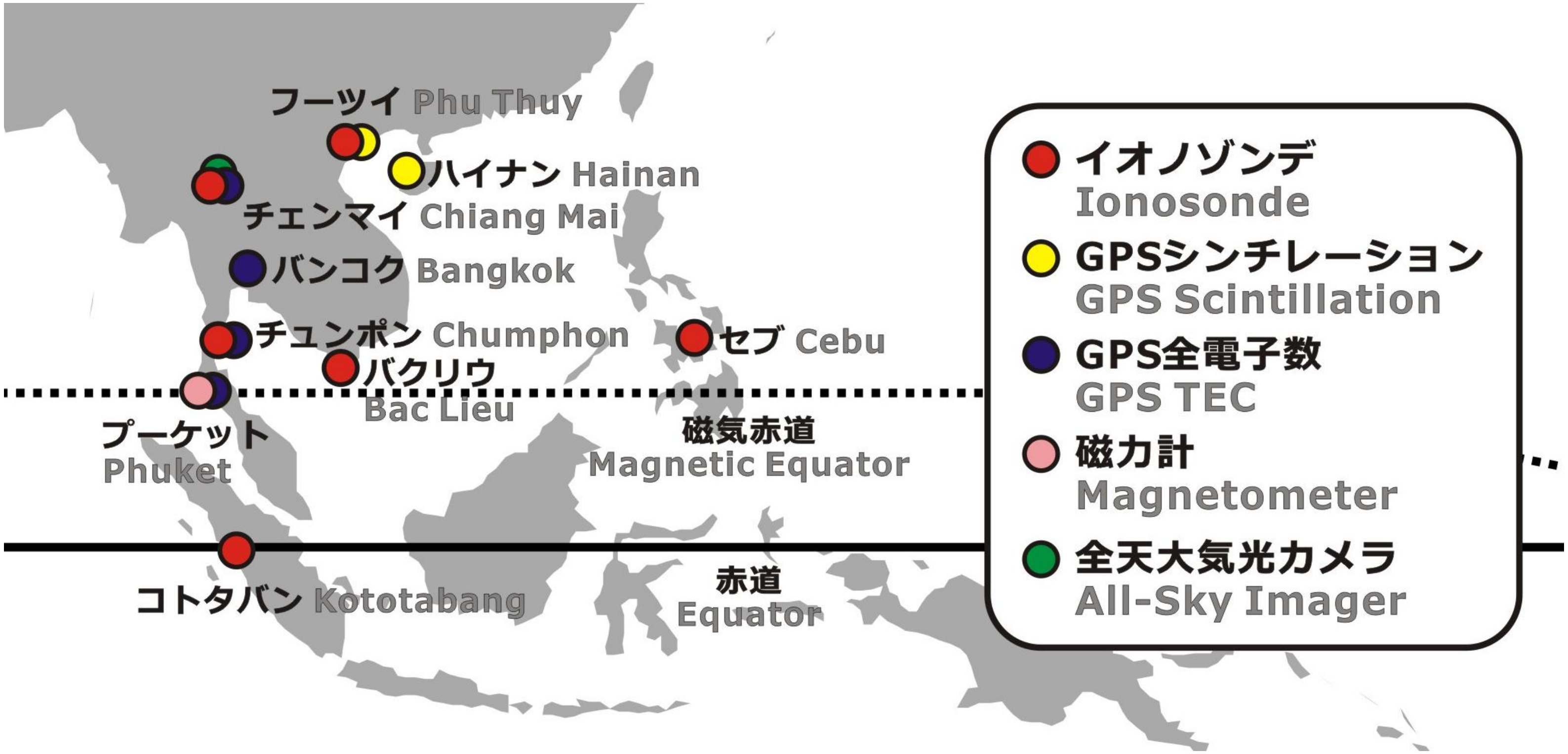
NICT started realtime (now 10-30 min delay) two-dimensional TEC observation using realtime GEONET data in the collaboration with ENRI, Kyoto-U., and Nagoya-U.

http://seg-web.nict.go.jp/GPS/RT_GEONET



Current status of SEALION

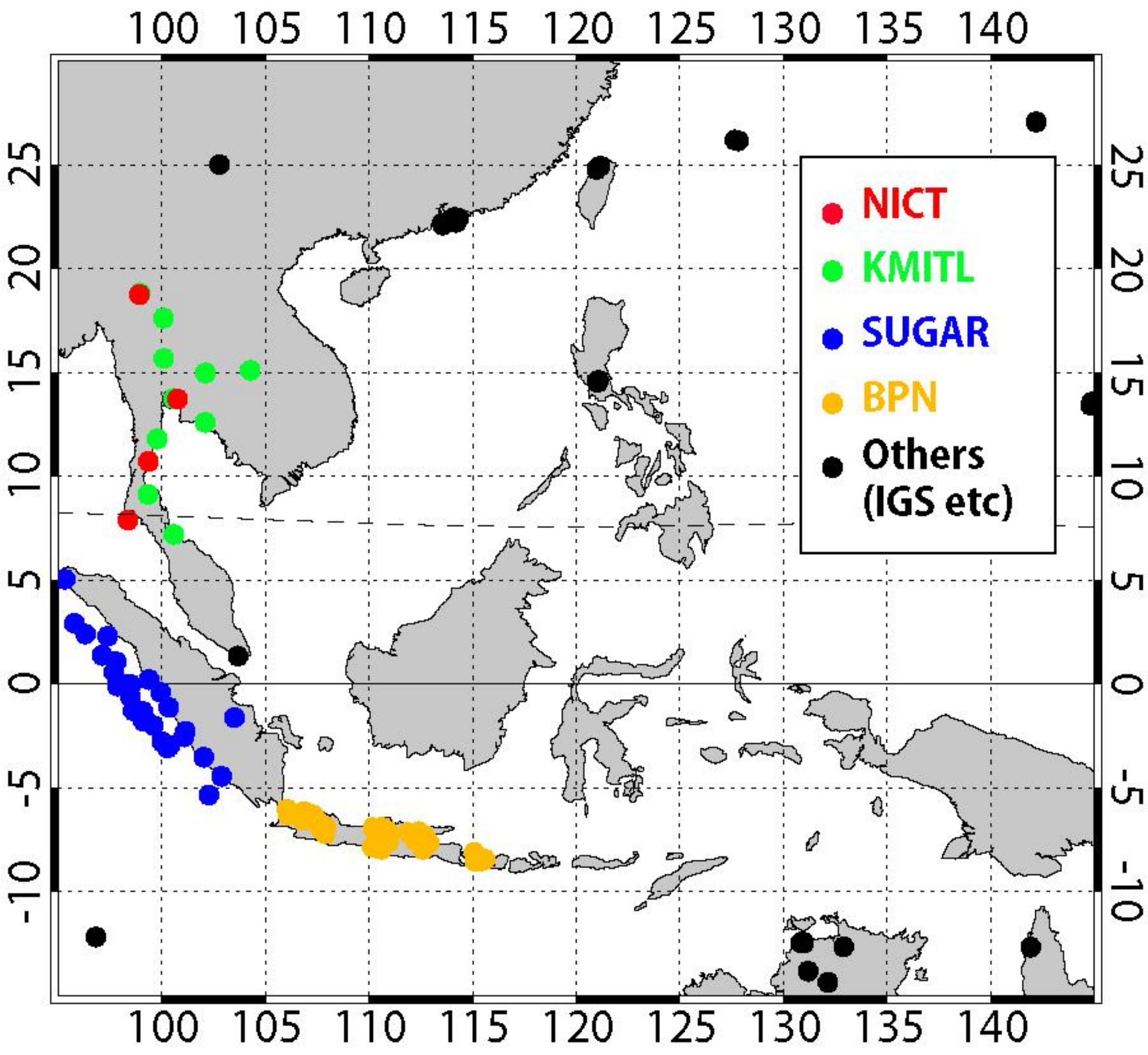
(SouthEast Asia Low-latitude IOnospheric Network)



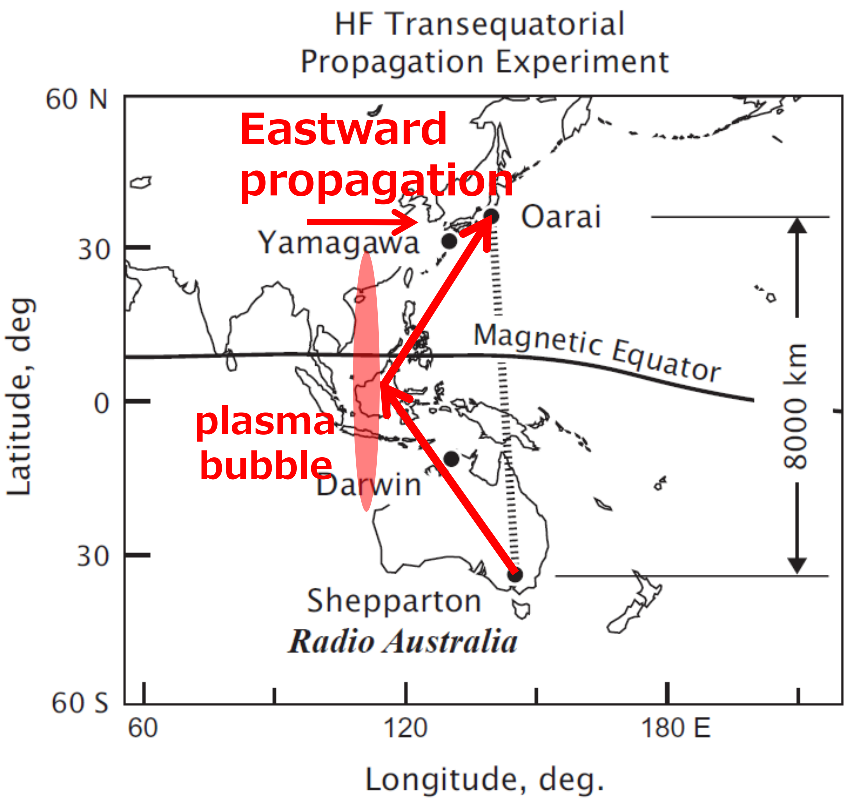
SEALION is a joint project among the following institutions and countries:

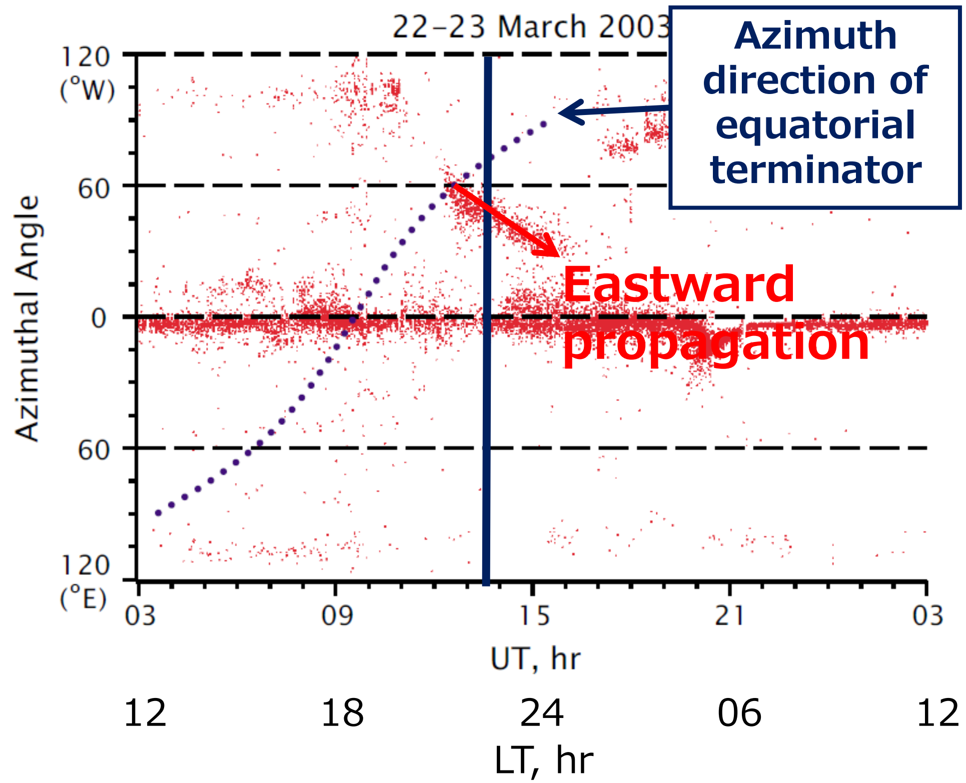
- National Institute of Information and Communications Technology (NICT), Japan
- King Mongkut's Institute of Technology Ladkrabang (KMITL), Thailand
- Chiang Mai University (CMU), Thailand
- National Institute of Aeronautics and Space (LAPAN), Indonesia
- Hanoi Institute of Geophysics (HIG), Vietnamese Academy of Science and Technology, Vietnam
- Center for Space Science and Applied Research (CSSAR), Chinese Academy of Sciences, China
- University of San Carlos (USC), Philippines
- Kyoto University, Japan

GPS receiver networks in Southeast Asia



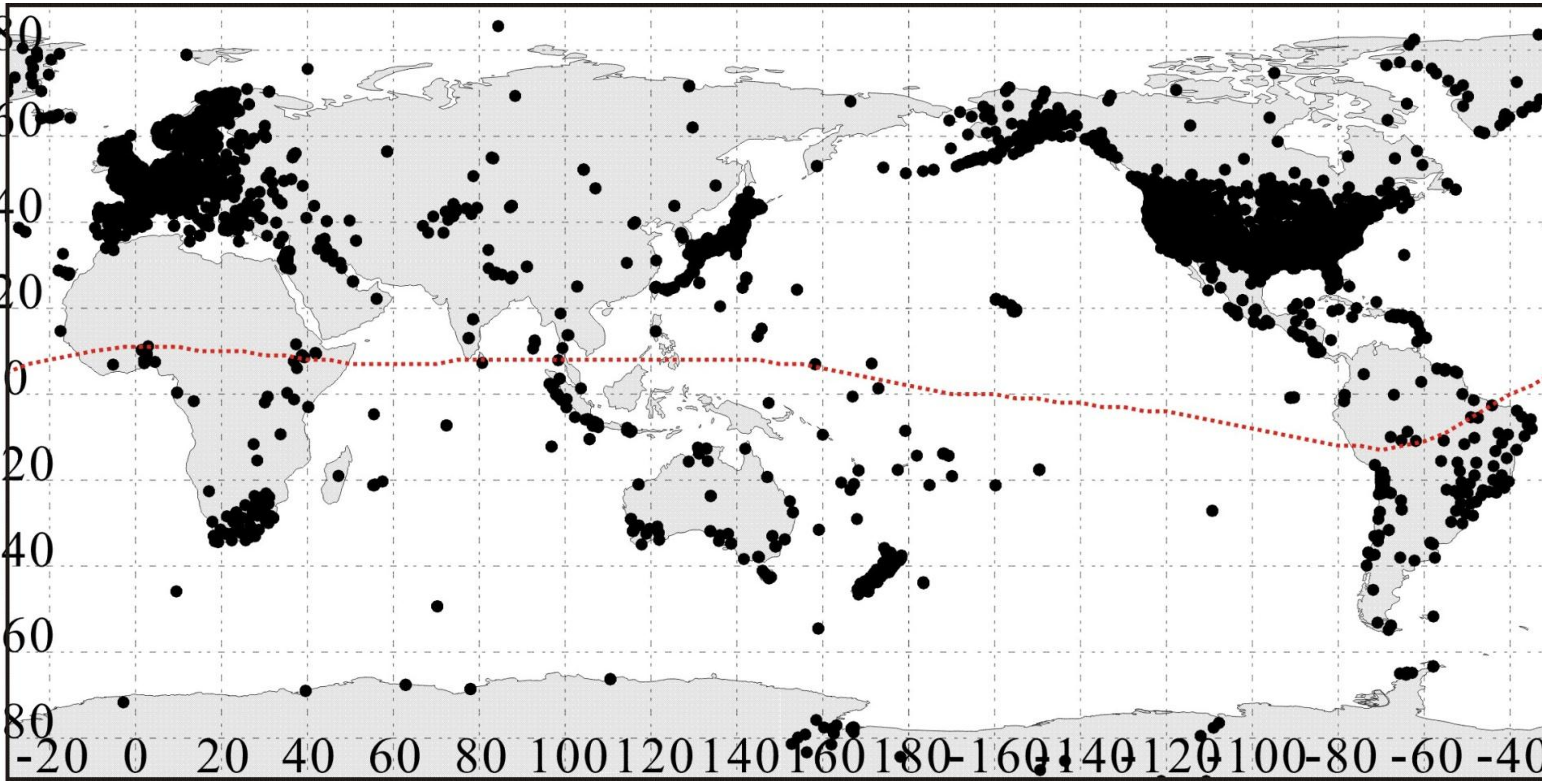
HF Transequatorial Propagation (HF-TEP) Experiments





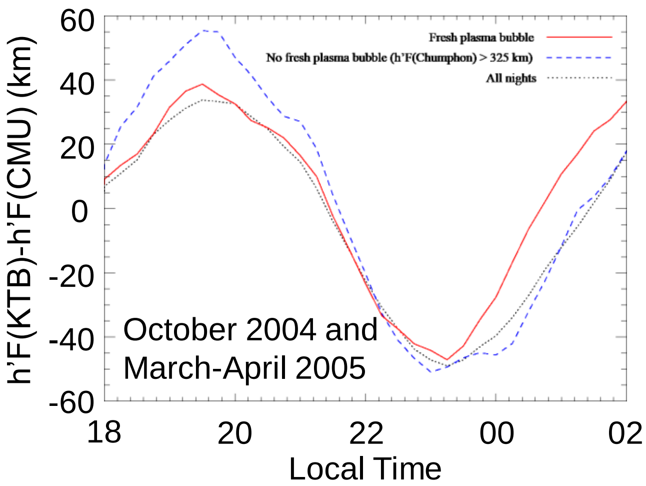
[*Maruyama and Kawamura*, AG, 2006]

GNSS Receiver Networks



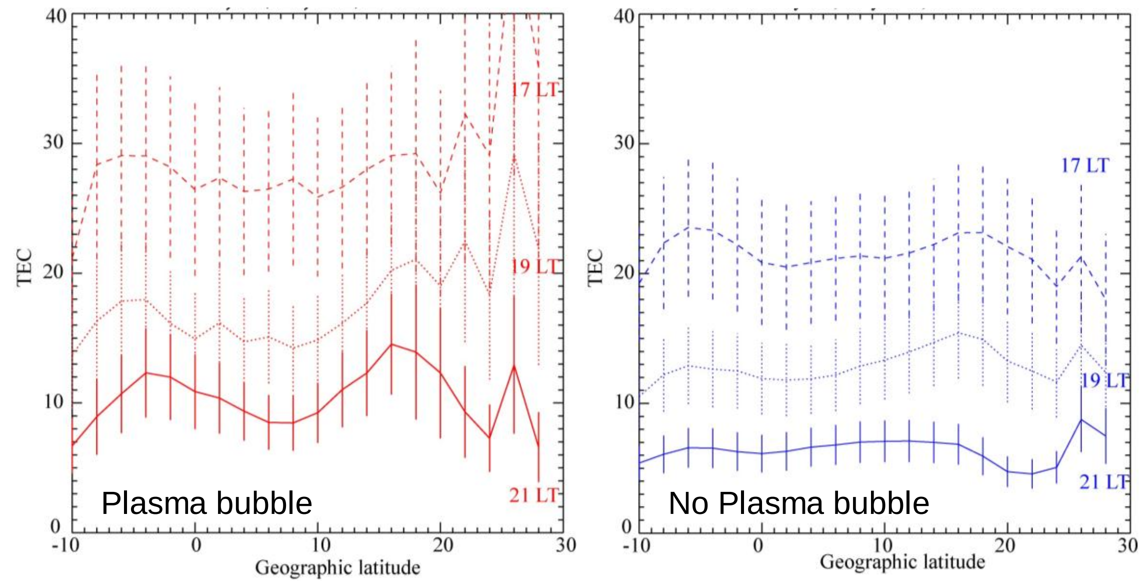
- As of Jan 2010, we are collecting all the available GNSS receiver data (more than 5,000 receivers) which belong to GEONET, UNAVCO, SOPAC, IGS, CORS, EPN, etc.
- We have developed regional/global high-resolution maps of absolute TEC, detrended TEC, ROTI, loss-of-lock on GPS signals.

Some results of SEALION and GNSS-TEC observations



Differences between h'F observed at Kototabang and Chiang Mai. [Saito and Maruyama, 2006]

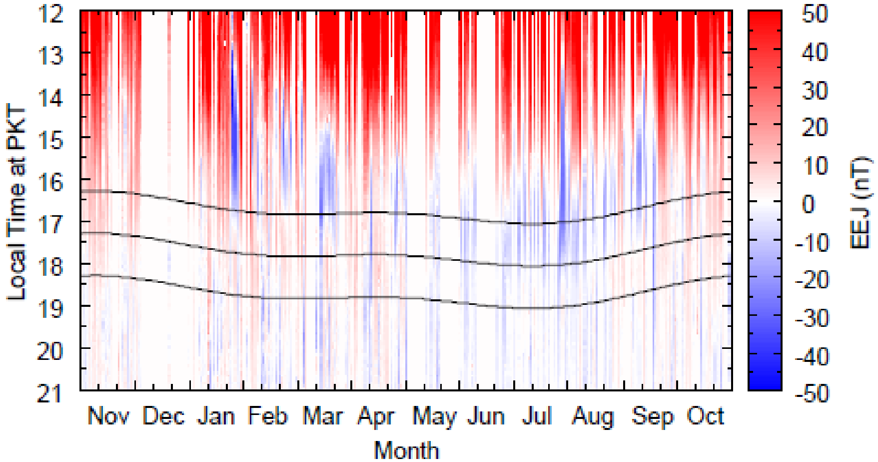
Latitudinal profile of absolute TEC during 2006-2010



Latitudinal profiles of daily average of TEC along 100 deg E longitude during 2006-2010 for plasma bubble (left) and no plasma bubble observed days. [Courtesy of Dr. M. Nishioka (NICT)]

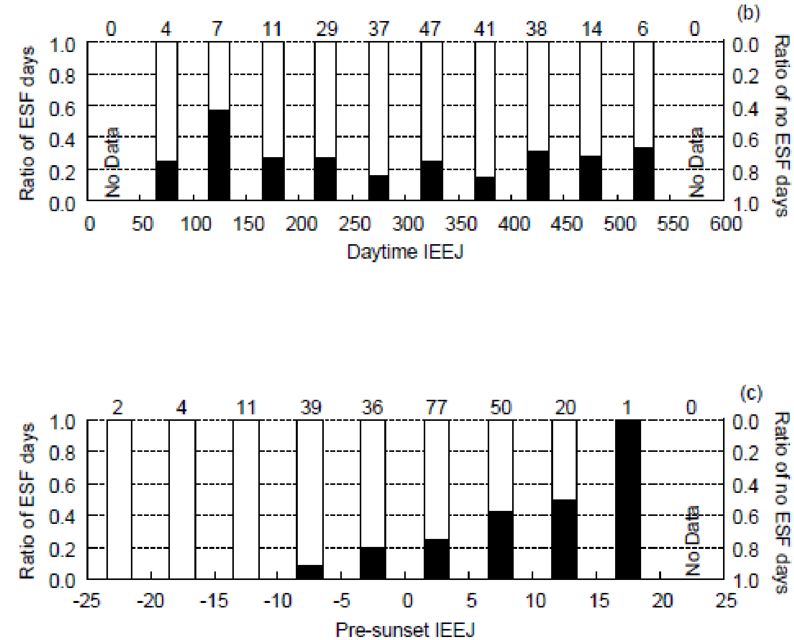
- North-south asymmetry of plasma density structure suppresses the plasma bubble [Saito and Maruyama, 2006]
- EIA is developed even in the nighttime for post-sunset plasma bubble observed days.
- EIA is very weak or negligible for no plasma bubble observed days.

Some results of SEALION and GNSS-TEC observations



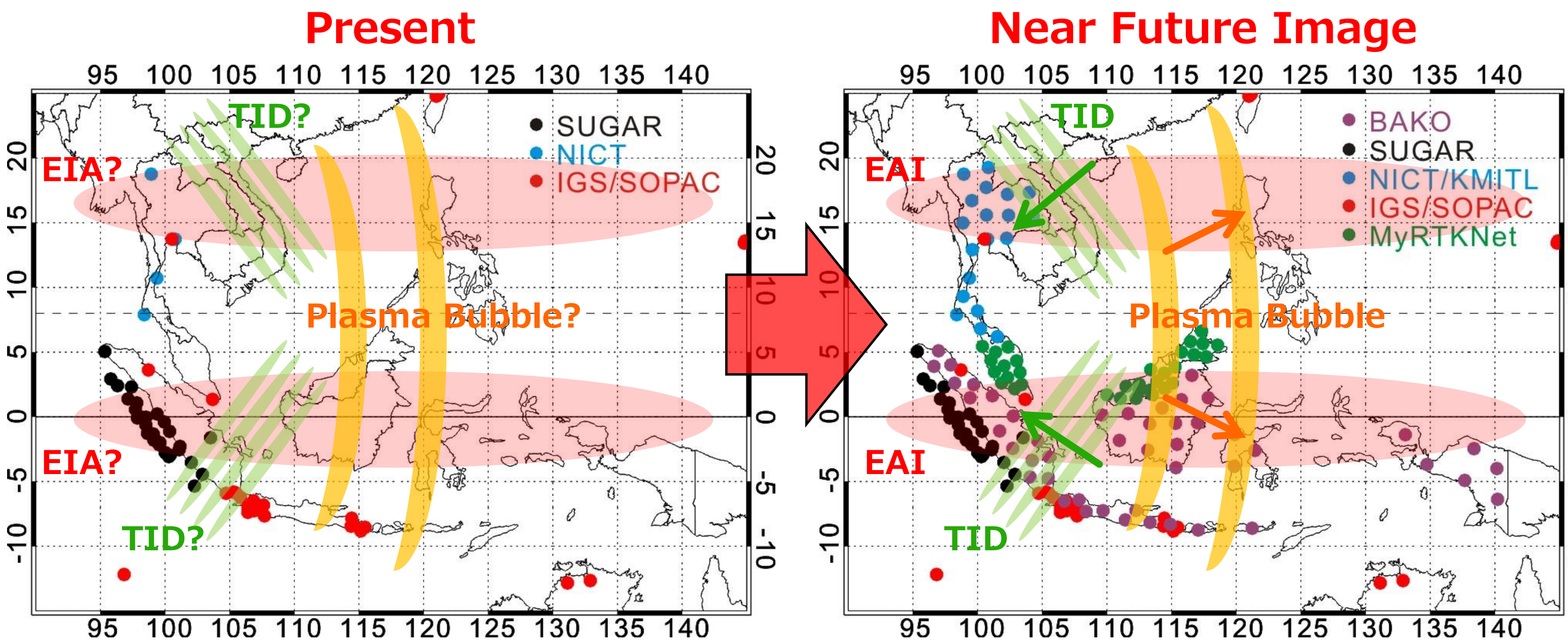
Contour plot of the EEJ ground strength during the period from November 2007 to October 2008. [Uemoto et al., 2010]

- The h’F and ESF onsets at Chumphon were compared with EEJ ground strength at Phuket during Nov. 2007 – Oct. 2008.
- Increase in the F-layer height and ESF onsets during the evening hours were well connected with the EEJ ground strength before sunset.
- E-region dynamo current and/or electric field are related to the F-region dynamics and ESF onsets around sunset.



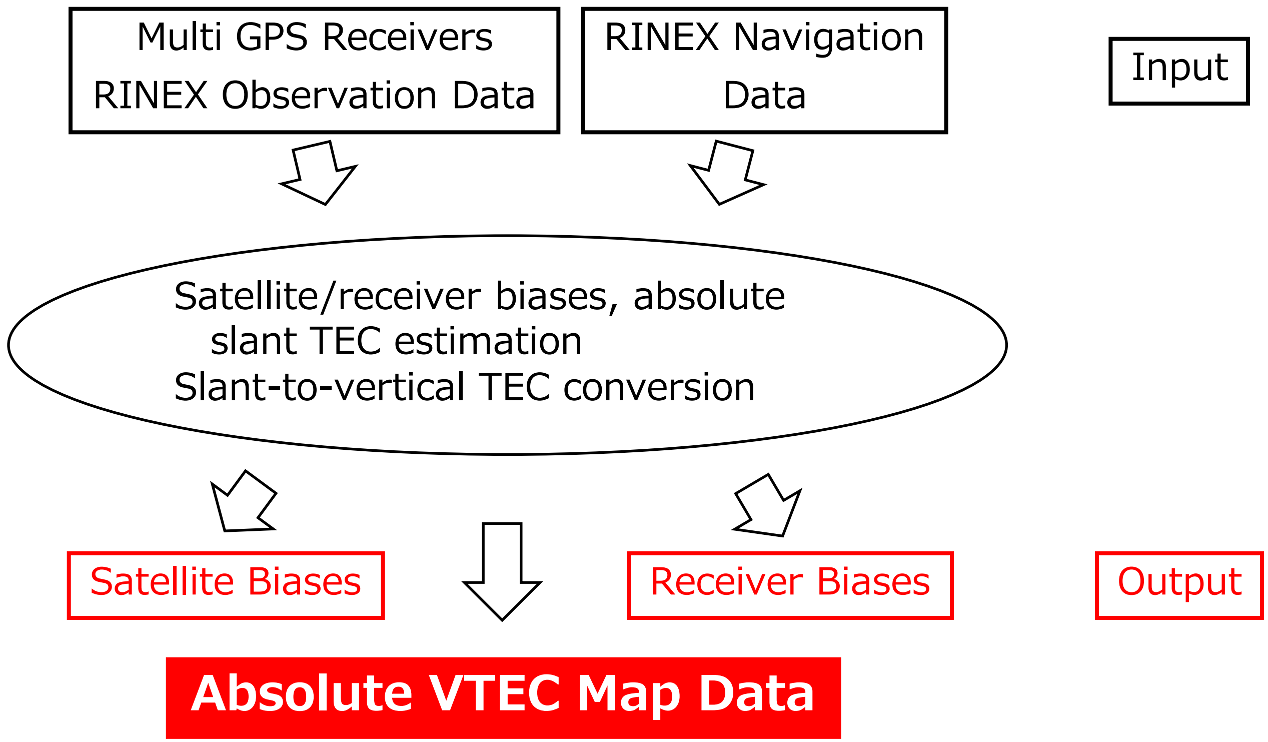
Dependence of the ESF occurrences on the peak h’F of PRE (a), daytime (b) and pre-sunset IEEJ (c). Solid and open bars indicate the ratios of ESF and no ESF days to the total number of days contained in each bin. The total number of days in each bin is given on the top of each bar. [Uemoto et al., 2010]

Southeast Asian GPS Networks Available for Ionospheric Researches



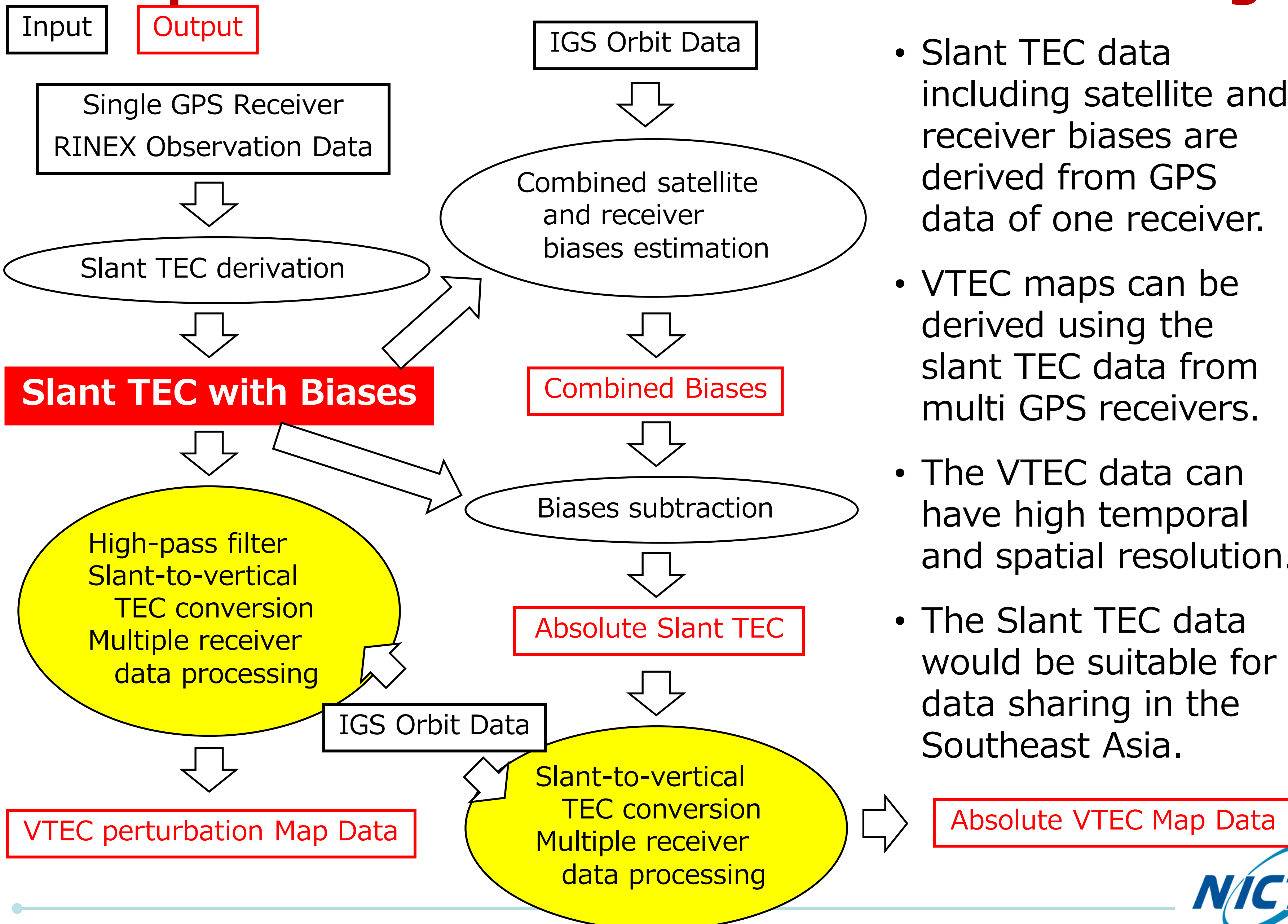
- Dense and wide-coverage GPS receiver network can reveal their spatial structures, propagation directions, and temporal evolutions.
- The GPS-TEC maps greatly contribute to the ionospheric researches and the nowcast/forecast of space weather.
- However, it is difficult to collect or share the GNSS data in some countries.

General GPS-TEC data (ex. IONEX)



- Vertical absolute TEC (VTEC) map data and instrumental biases of satellite and receiver are simultaneously derived from multi GPS receiver data and satellite orbit data.
- Temporal and spatial resolution of VTEC Map data are too low to observe small-scale ionospheric disturbances such as plasma bubble and ionospheric waves.

Proposed GNSS-TEC data for data sharing



- Slant TEC data including satellite and receiver biases are derived from GPS data of one receiver.
- VTEC maps can be derived using the slant TEC data from multi GPS receivers.
- The VTEC data can have high temporal and spatial resolution.
- The Slant TEC data would be suitable for data sharing in the Southeast Asia.

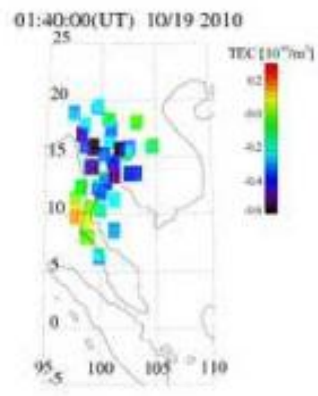
NICT

GNSS-TEC exchange (GTEX) format

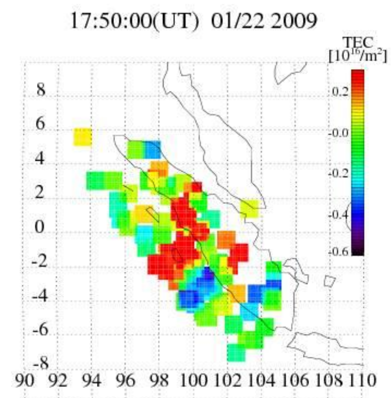
```
     2               TEC DATA             GPS                 TEC VERSION / TYPE
RNX2TEC V2.6        NICT, JAPAN                               PGM / RUN BY
     0                                                        EXPONENT OF TECU
     TEC values in 10^16 el/m^2 (1 TEC Unit)                  COMMENT
     TEC Status Flag = 0 : Normal data                        COMMENT
                     = 1 : Lack of observables (TEC=999.)     COMMENT
                     = 2 : Too large TEC (TEC=999.)           COMMENT
                     = 4 : Cycle slip (TEC discontinuity)     COMMENT
                     = 5 : Cycle slip (LLI)                   COMMENT
                     = 6 : Beginning of arc                   COMMENT
01321310.12o  01321320.12o  01321330.12o                      RINEX FILE NAME   ←RINEX files used of the TEC calculation
0132                                                          MARKER NAME
00000                TPS NETG3            3.4 EG3 Jul,02,2010 REC # / TYPE / VERS
                     TRM29659.00     GSI                      ANT # / TYPE
 -3690821.3891  2897721.3097  4305504.4426                    APPROX POSITION XYZ
       42.7294        141.8640        0.0486                  POSITION LAT LON ALT
     6     L1     C1     L2     P2     S1     S2              # / TYPES OF OBSERV
    30.0000                                                   INTERVAL
  2012     5     11      0      0     0.0000000     GPS       TIME OF FIRST OBS
                                                              END OF HEADER             1epoch
 12  5 11  0  0  0.0000000  0   9G21G 9G18G15G28G 5G27G 8G26 ←year, month, date, hour, minute, flag,  #of PRNs, PRNs
 -61.7242  0 ←TEC derived from PRN 21 data
 -33.4733  0 ←TEC derived from PRN 9 data
 -49.7988  0 ←TEC derived from PRN 18 data
 -55.8391  0 ←TEC derived from PRN 15 data
 -43.6837  0 ←TEC derived from PRN 28 data
 -38.7060  0 ←TEC derived from PRN 5 data
 -44.8228  0 ←TEC derived from PRN 27 data
 -31.3004  0 ←TEC derived from PRN 8 data
 -48.7940  0 ←TEC derived from PRN 26 data
 12  5 11  0  0 30.0000000  0   9G21G 9G18G15G28G 5G27G 8G26
 -61.6869  0
```

GNSS-TEC data sharing based on GTEX

- NICT have developed the database of "GTEX" data for more than 6,000 GNSS receivers in the world. These data are available via the NICT science cloud, OneSpaceNet (OSN):
- Since the 1st AOSWA workshop held in Chiang Mai, Thailand in February 2012, we are now developing the GTEX data of Thailand, Indonesia, South Korea, an China collaborated with KMITL, LAPAN, KMA, and CMA, respectively.

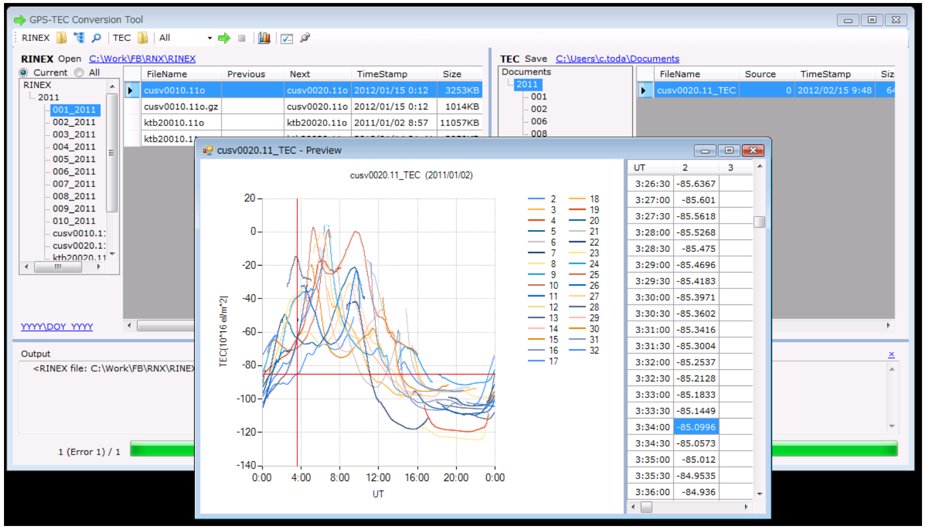


Detrended TEC over Thailand. [Courtesy of K. Watthanasangmechai (KMITL)]



Detrended TEC over Indonesia by SUGAR network.

- We can provide softwares to convert RINEX data to GTEX data (Fortran 77) , and to make high-resolution TEC maps (IDL).
- NICT recently released a Windows software "RNX2GTEX" which are available via the NICT website:



http://seg-web.nict.go.jp/e-sw/download/index_e.html

Summary

- Current status and recent progress of GNSS-TEC and SEALION observations in the Southeast Asia are introduced.
- These data have been used for monitoring and researching severe ionospheric disturbances which can degrade GNSS navigations and cause loss-of-lock on GNSS signals.
- The dense GNSS receiver networks in the Asia-Oceania region would be a powerful tool for the nowcast/forecast of ionospheric disturbances such as plasma bubbles.
- We have developed GNSS-TEC data sharing system based on "GTEX" collaborated with LAPAN, KMITL, KMA, and CMA. A Windows software "RNX2GTEX" are now available.

Acknowledgement

GNSS receiver data are provided by GSI, UNAVCO, IGS, SOPAC, CORS, WCDA, CHAIN, PANGA, KASI, EPN, BKGE, OLG, IGNE, DUT, ASI, ITACyL, ESEAS, SWEPOS, SATREF, BIGF, TrigNet, Geoscience Australia, IPS, RBMC, SUGAR, DPT, and KMITL.