Ionospheric irregularities detected by GEONET

Guanyi Ma[(1)] Qi Li[(1)] Takashi Maruyama[(1), (2)] Jinghua Li[(1)] Qingtao Wan[(1)]
Jiangtao Fan[(1)] Xiaolan Wang[(1)] Jie Zhang[(1)]

[(1)]*National Astronomical Observatories, CAS, Beijing, China*
[(2]*National Institute of Information and Communications Technology, Tokyo, Japan*

Ionospheric Irregularities

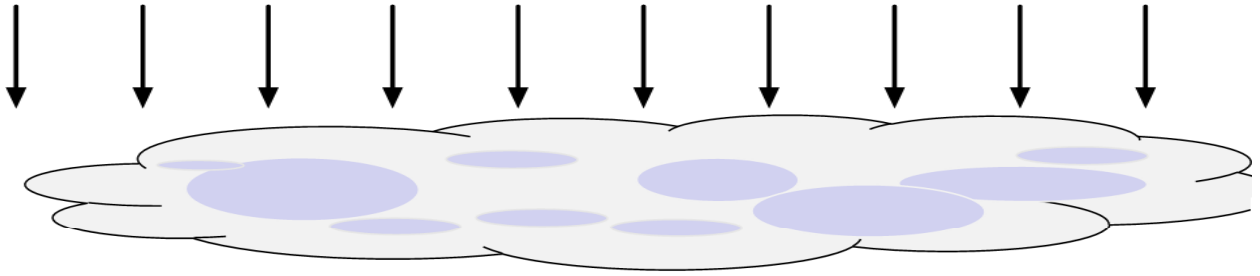
The ionospheric irregularities are spatially irregular variation of electron density or fluctuation of TEC with scale lengths from a few meters to several tens of kilometers.

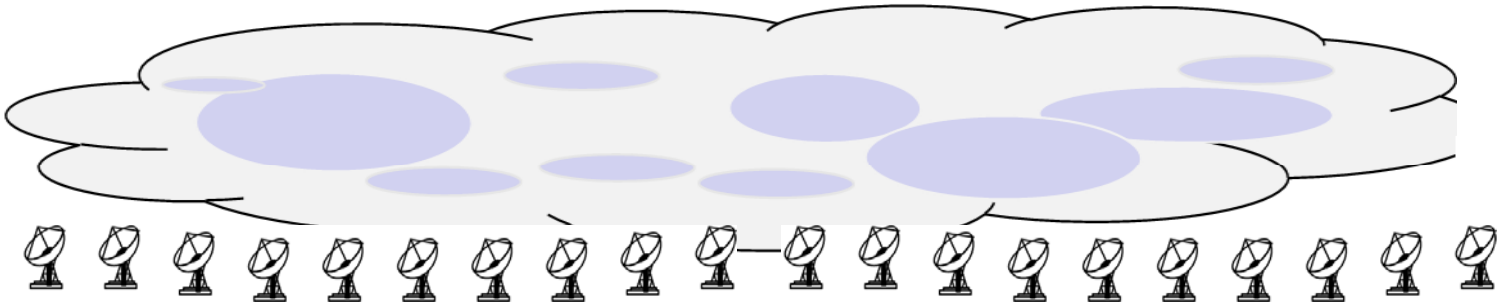
The most intense irregularities are equatorial plasma bubbles (EPB).

These plasma irregularities disturb radio communication and navigation by causing phase and amplitude scintillations.

Ionospheric Irregularities

The ionospheric irregularities are random field!



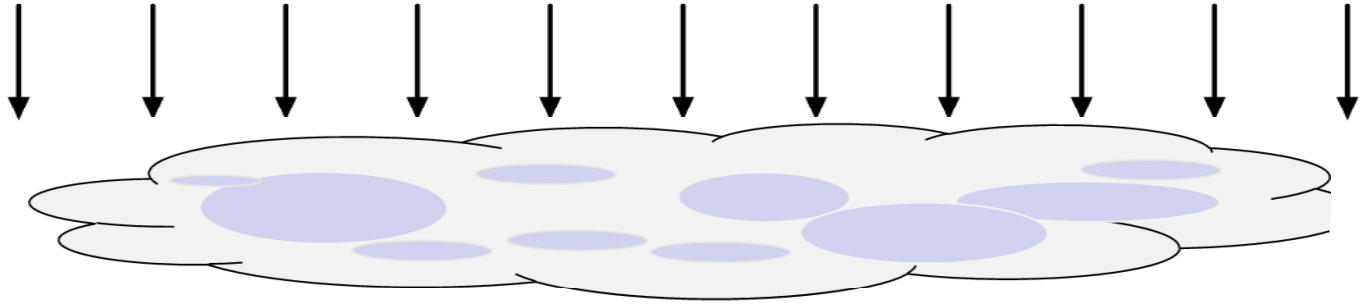


Irregularity Observation

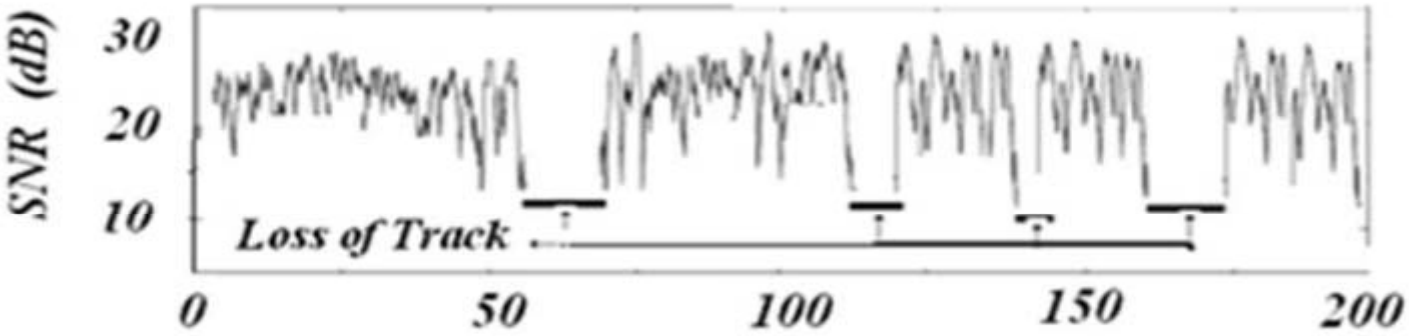
The ionospheric irregularities are often observed with ionosonde, radar, and satellite beacon. With different methods, we have different terms, such as, Spread F, radar plume, ionospheric scintillation, accordingly.

Since GPS was open to public use, the ionospheric irregularities have been most often observed with scintillation measurement of the GPS satellite signal or rate of TEC index (ROTI) from dual frequency GPS receiver.

Scintillation Measurement



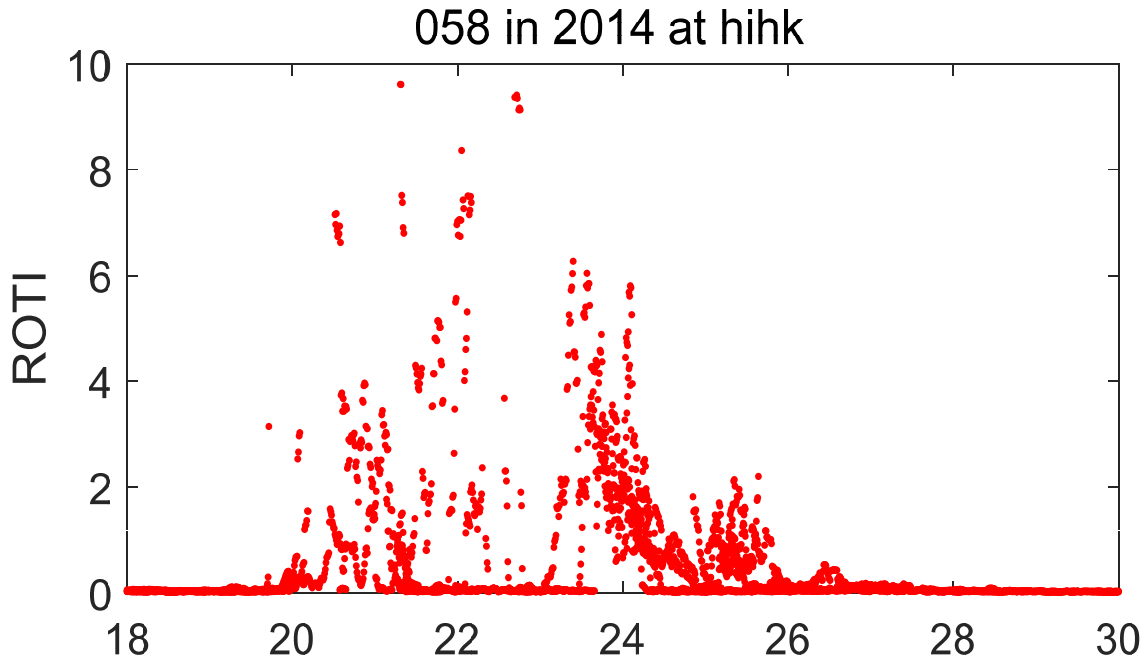
$$S_4 = \sqrt{\langle I^2 \rangle - \langle I \rangle^2} \,/ \langle I \rangle$$



ROTI Measurement

$$ROT_i = (STEC_i - STEC_{i-1})/(t_i - t_{i-1})$$

$$ROTI = \sqrt{\langle ROT_i^2 \rangle - \langle ROT_i \rangle^2}$$



Spatial structure of ionospheric irregularities

* ROTI measurements rely on frozen-in assumption.

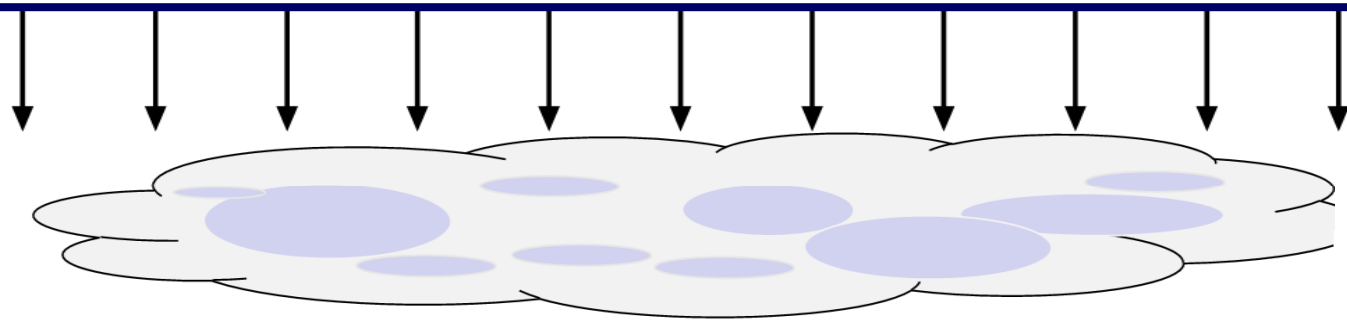
* Effects of Satellite movement are included.

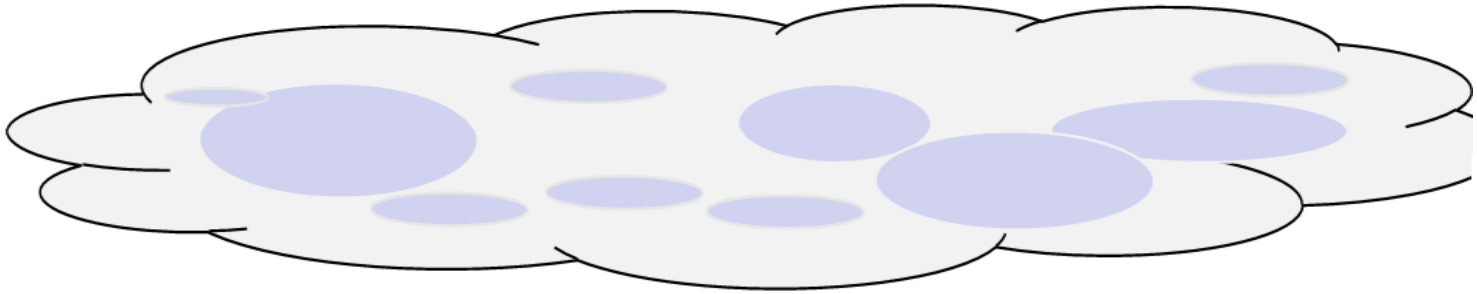
They blends the temporal change with spatial variation of the ionosphere and does not necessarily represent correctly the precise physical characteristics of irregularities.

The ionospheric irregularities are random field!

The best way to observe them is with receiver arrays!

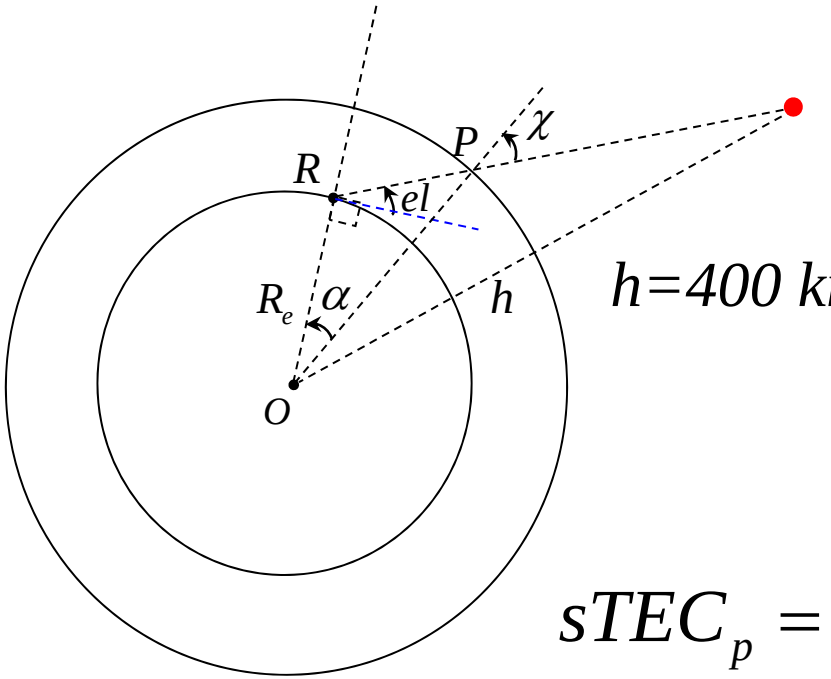
Spatial fluctuation of TEC





GPS receiver network is kind of receiver arrays!

TEC derivation with phase observable



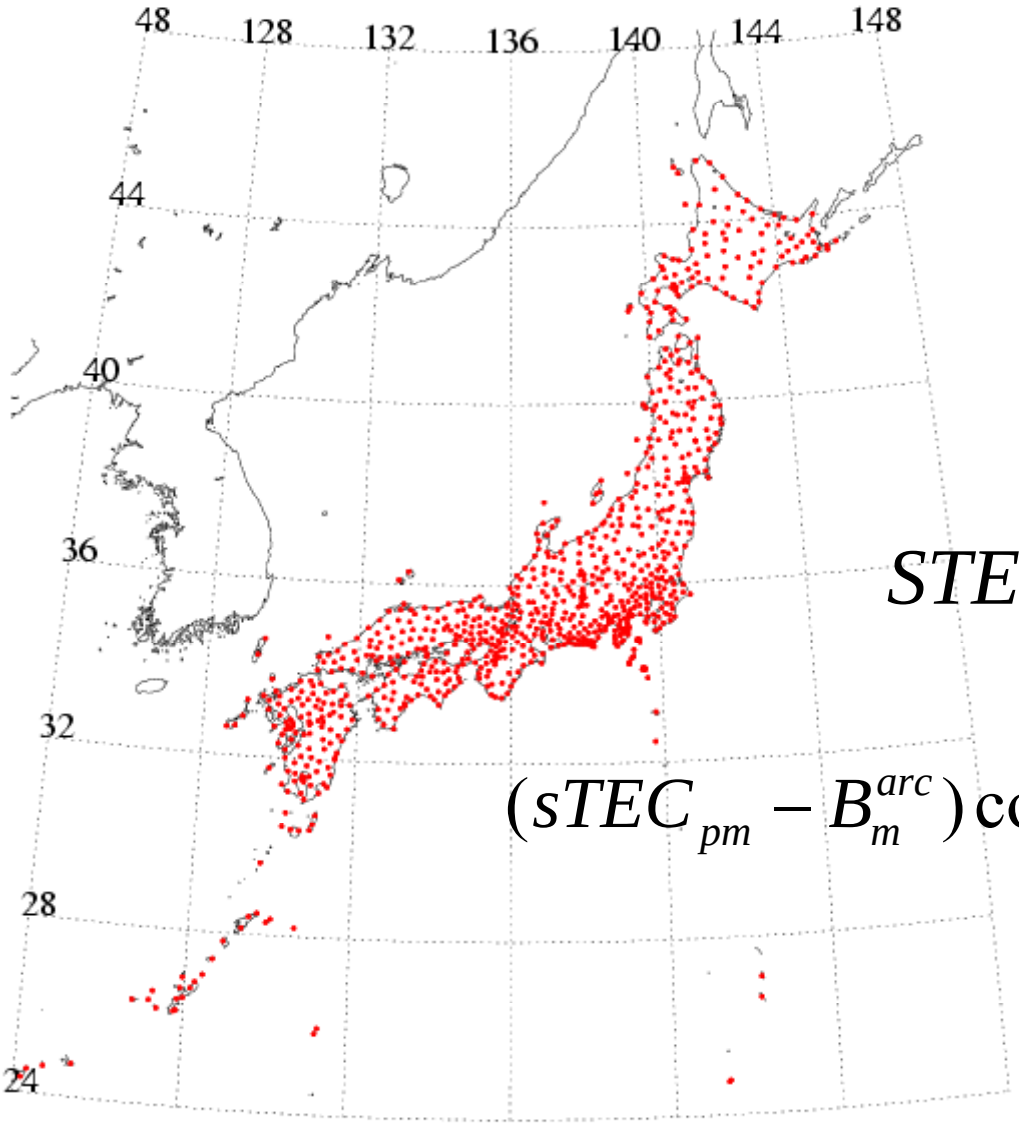
h=400 km

$$sTEC_p = \frac{2(f_1 f_2)^2}{k(f_1^2 - f_2^2)}(L_1\lambda_1 - L_2\lambda_2)$$

$$STEC = sTEC_p - B^{arc}$$

$$VTEC = STEC * \cos\chi$$

TEC derivation from GEONET



Within a 0.1×0.1 grid, VTEC is identical.

$$VTEC_m = VTEC_n$$

$$STEC_m \cos\chi_m = STEC_n \cos\chi_n$$

$$(sTEC_{pm} - B_m^{arc})\cos\chi_m = (sTEC_{pn} - B_n^{arc})\cos\chi_n$$

TEC derivation from GEONET

For the signal from satellites j , j' to receiver k, k' going through a cell at time t,

$$B_{jk}^{arc}\cos\chi_{ijk} - B_{j'k'}^{arc}\cos\chi_{ij'k'} = sTEC_{ijk}\cos\chi_{ijk} - sTEC_{ij'k'}\cos\chi_{ij'k'}$$

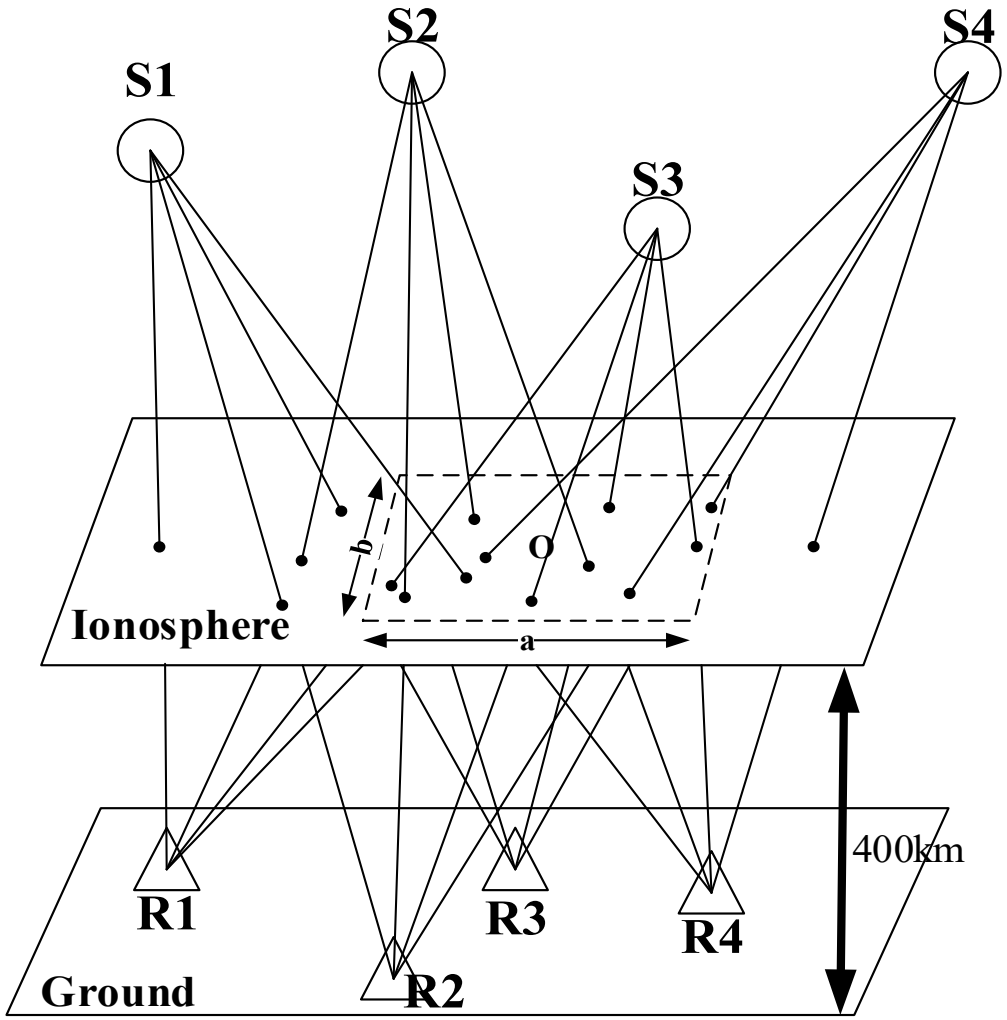
$$\begin{bmatrix} \cdots & \cdot & \cdots & \cdot & \cdots \\ \cdots & \cdot & \cdots & \cdot & \cdots \\ \cdots & \cos\chi_{\mathrm{ijk}} & \cdots & -\cos\chi_{ij'k'} & \cdots \\ \cdots & \cdot & \cdots & \cdot & \cdots \\ \cdots & \cdot & \cdots & \cdot & \cdots \end{bmatrix} \begin{bmatrix} B_{11}^{arc} \\ \cdot \\ B_{jk}^{arc} \\ \cdot \\ B_{j'k'}^{arc} \\ \cdot \\ B_{JK}^{arc} \end{bmatrix} = \begin{bmatrix} \cdot \\ \cdot \\ \cdot \\ sTEC_{ijk}\cos\chi_{ijk} - sTEC_{ij'k'}\cos\chi_{ij'k'} \\ \cdot \\ \cdot \\ \cdot \end{bmatrix}$$

$$VTEC_{ijk} = (sTEC_{ijk} - B_{jk}^{arc})\cos\chi_{ijk}$$

SFT parameter

Spatial Fluctuation of TEC ----dispersion of VTEC in a small area.

$$SFTI = \sqrt{< VTEC^2 > - < VTEC >^2}$$



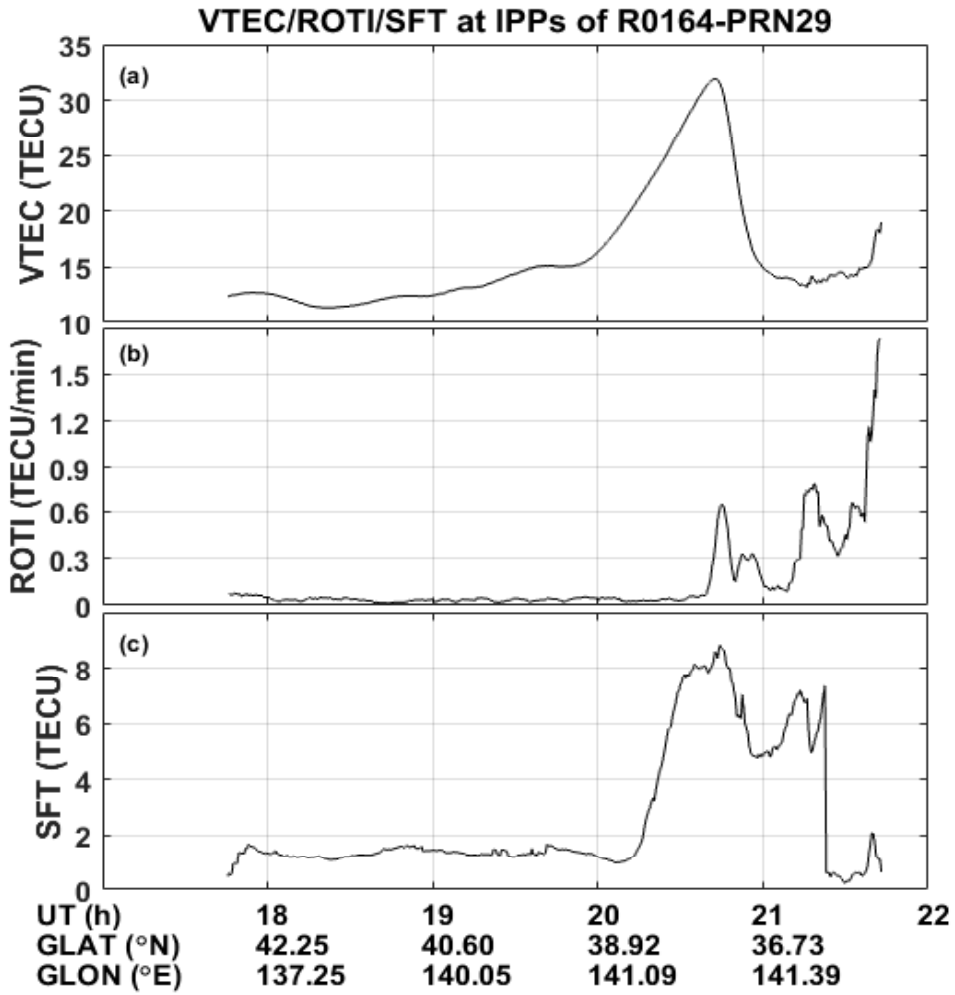
>10 IPPs

GEONET

0.8° ×0.8° in longitude and latitude

which is about 77 km×95 km at 35° N at 400 km height.

VTEC/ROTI/SFT

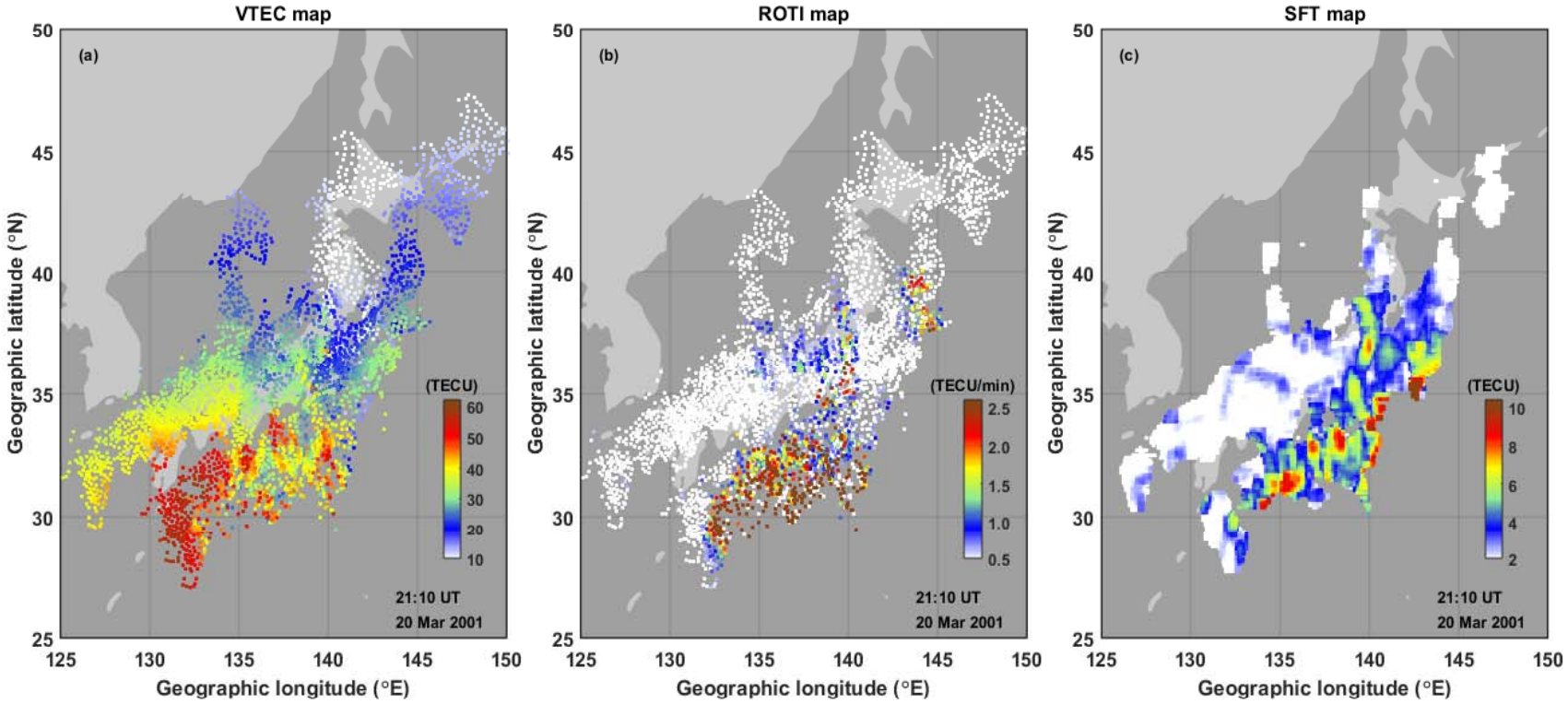


VTEC/ROTI/SFT at IPPs of R0164-PRN29 from observations made by the GEONET on 20 March, 2001. GLAT and GLON refer to geographic latitude and longitude of IPPs at the corresponding time, respectively. Note that SFT is calculated with all VTECs within the unit area centering at the IPP between receiver 0164 and PRN29.

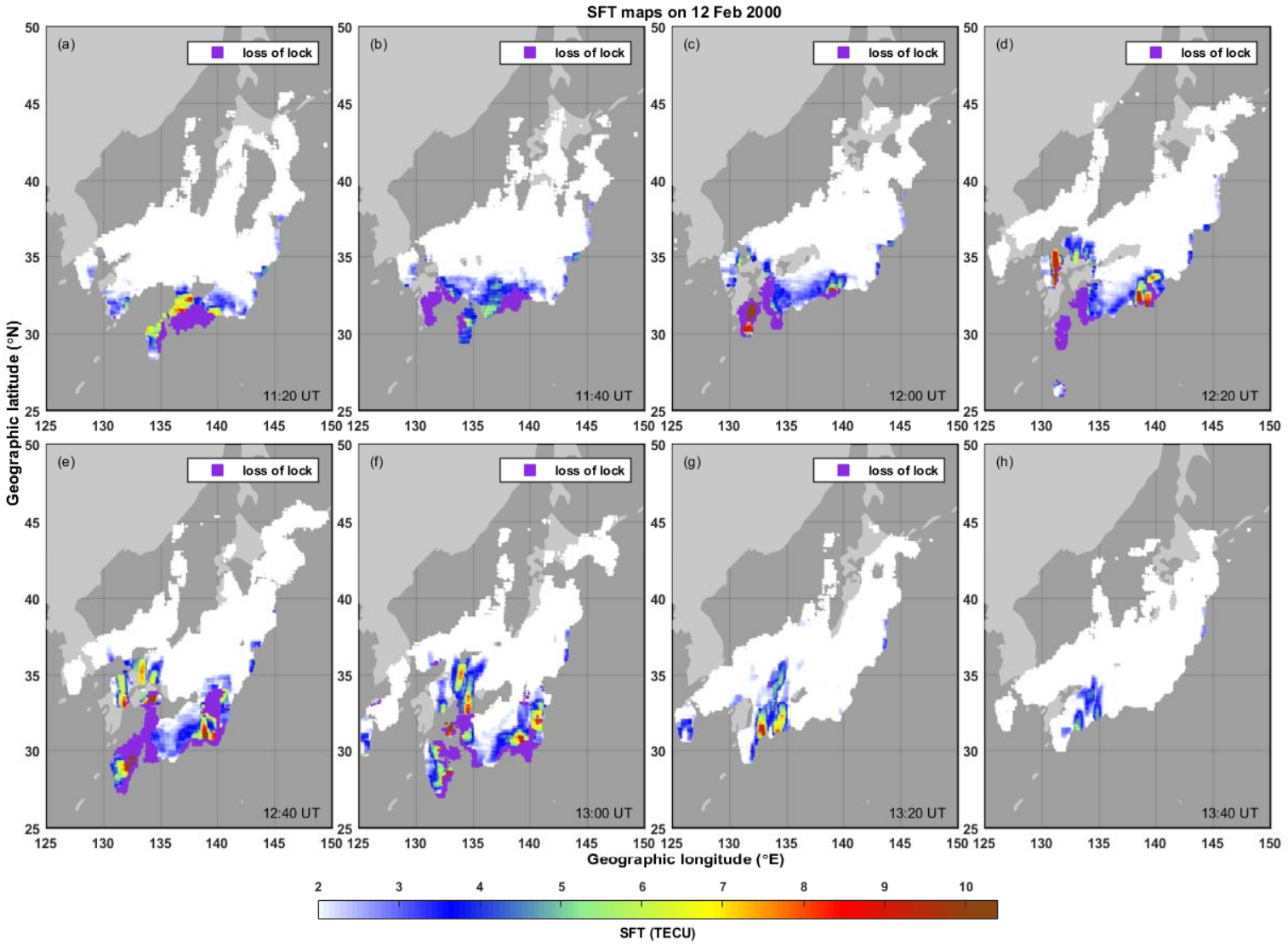
SFT>2 TECU for irregularity detection

SFT map

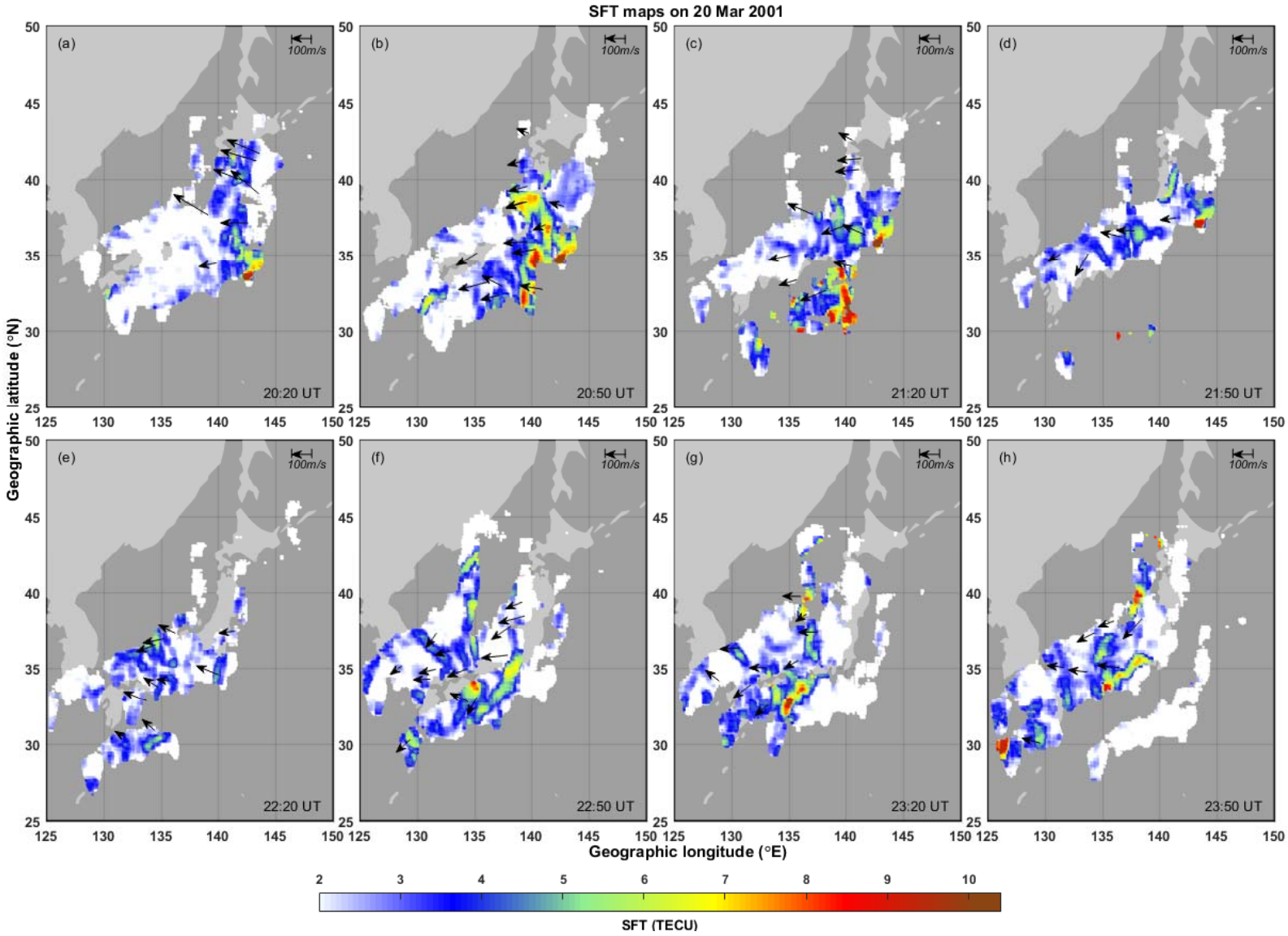
An SFTI map is obtained by using a sliding window with a step size 0.1°



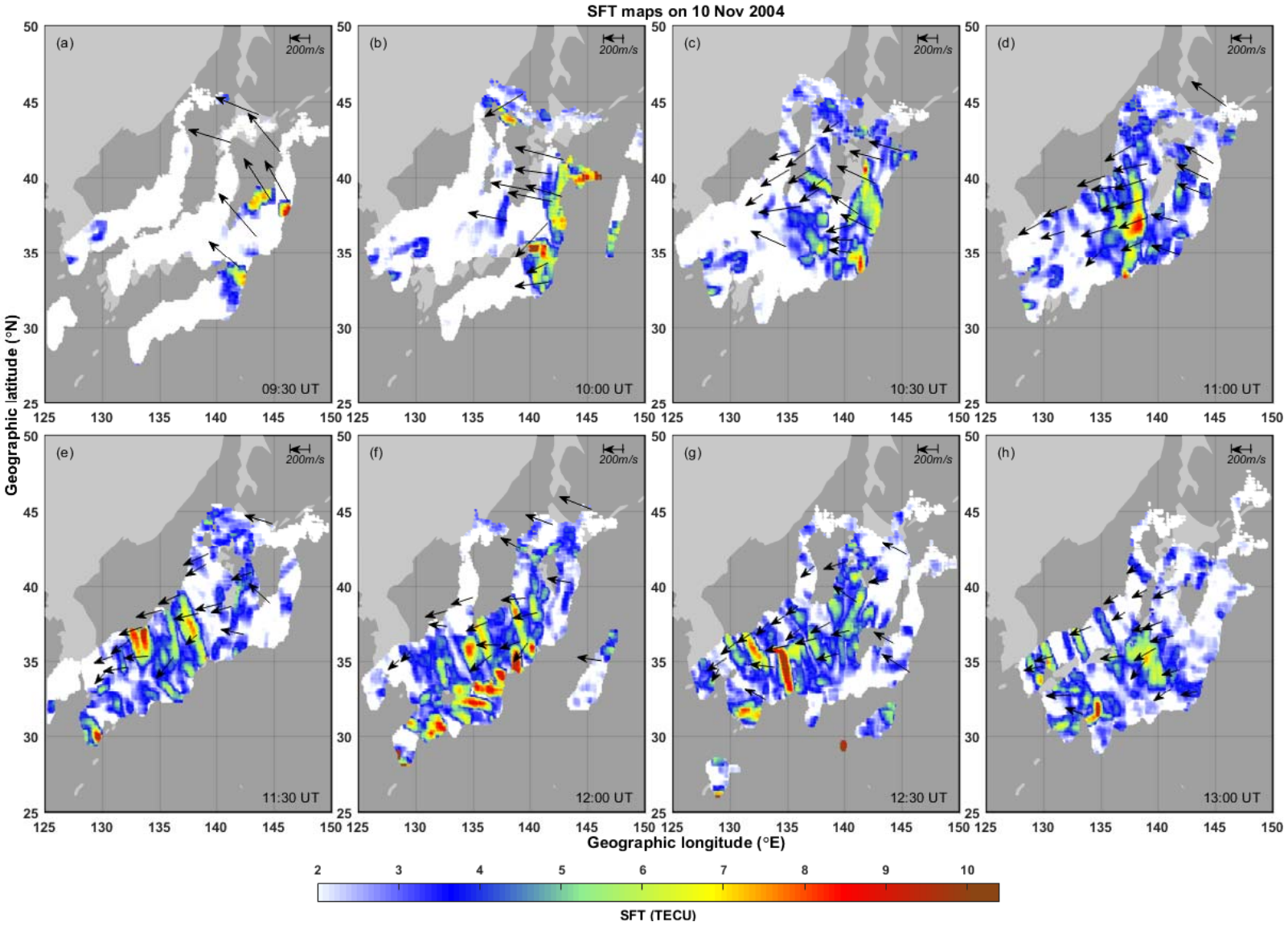
Irregularity event on 12 February 2000



Irregularity event on 20 March 2001



Irregularity event on 10 November 2004



Summary

* A new parameter, SFT is proposed to detect the spatial structure of ionospheric irregularities.
* An SFT map can display size, shape, orientation and intensity distribution of the irregularity structures.
* The strong irregularities usually exhibit large or small anisotropic branching structures, which tend to elongate in the north-south direction when first appeared at low latitudes inclined striations.
* A series of SFT maps can show the evolution of the irregularity structures.

Thank you!