Continuous GPS receiver network in Vietnam and application for the ionospheric total electron content study in Southeast Asian region

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Japan, March 2015

Outline

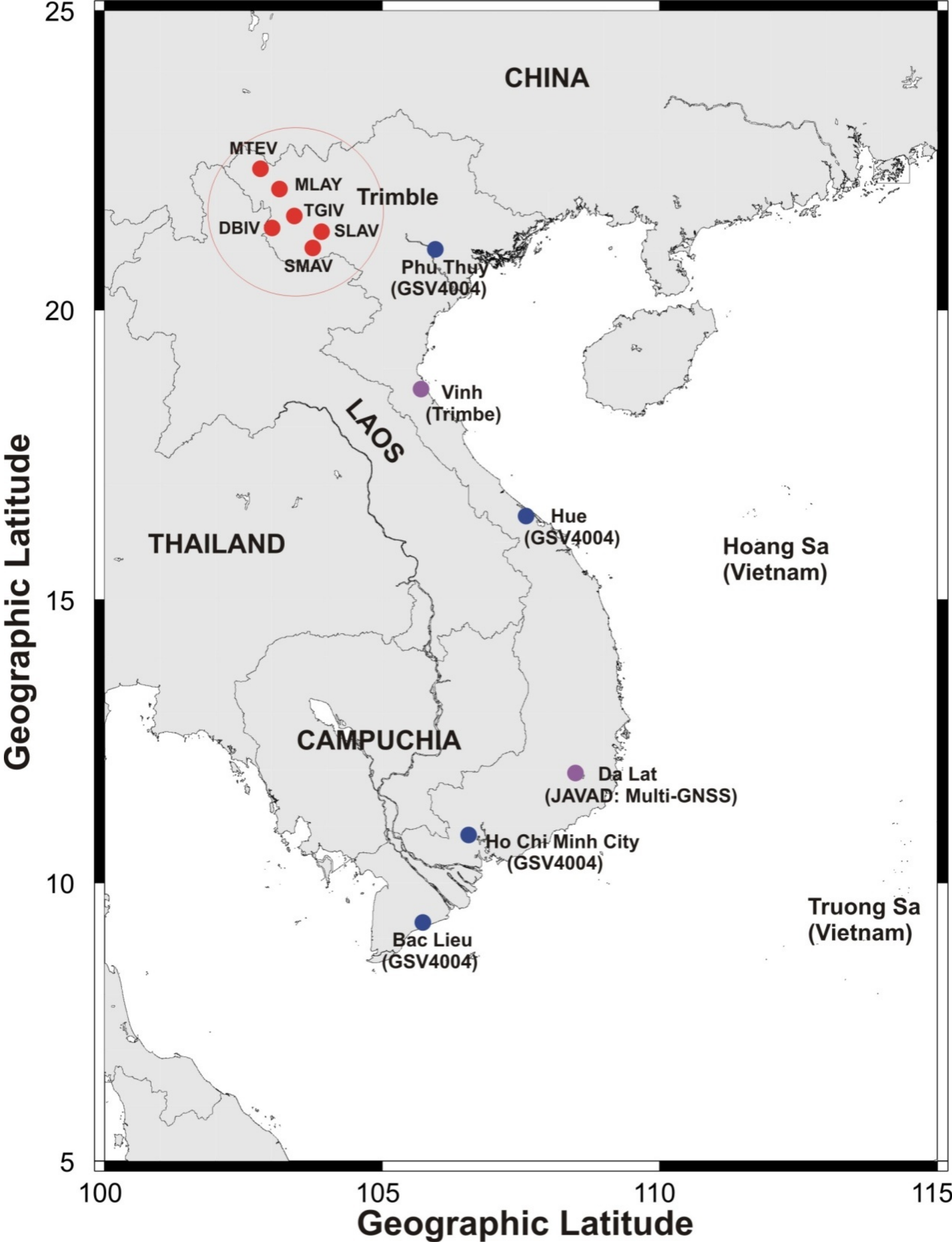
* Continuous GPS stations in Vietnam and Southeast Asian resion.
* Calculation of the TEC
* Time variations of the crests of EIA
* Main Remarks

Continuous GPS stations in Vietnam

4 GSV4004 receivers at Phu Thuy, Hue, Ho Chi Minh city, since 2005; (IGP-CNRS)
Bac Lieu: May 2014 (IGP-NICT)

SMAV, SLAV, TGIV DBIV, MLAY, MTEV, Since 2010, Trimble NETRS, (IGP-NTU)

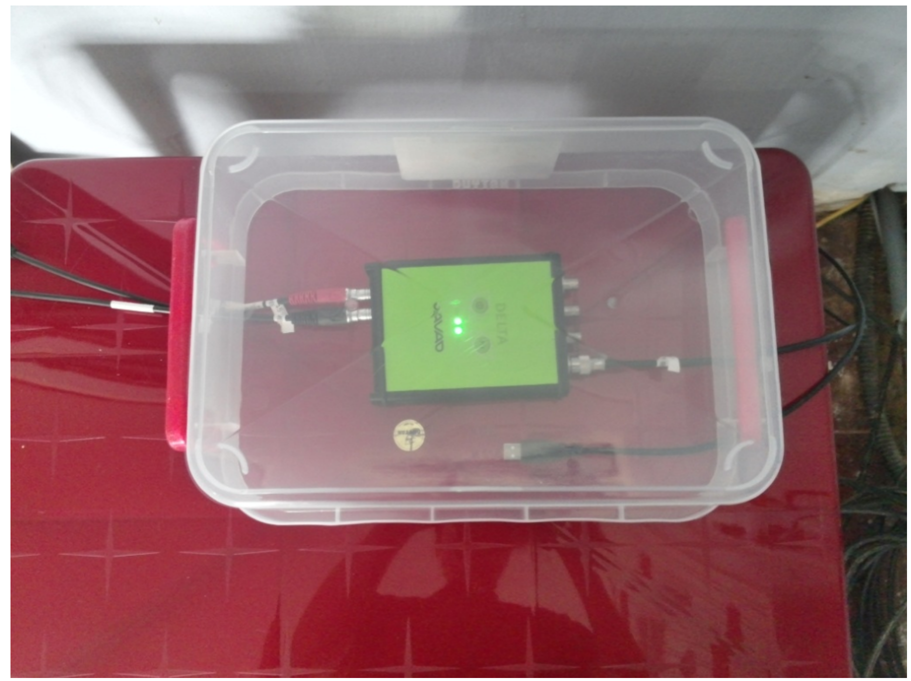
Vinh, since Sep. 2011, Trimble 5700 (IGP)
a Lat, since October 2014 Javad, Multi-GNSS (IGP-JAXA)



GPS Receiver in Hanoi, Hue and HOCM: GSV4004 model

Some other stations: Trimble 5700 CORS systems or
Trimble NetRS GPS receivers

Multi-GNSS receiver at Da Lat observatory

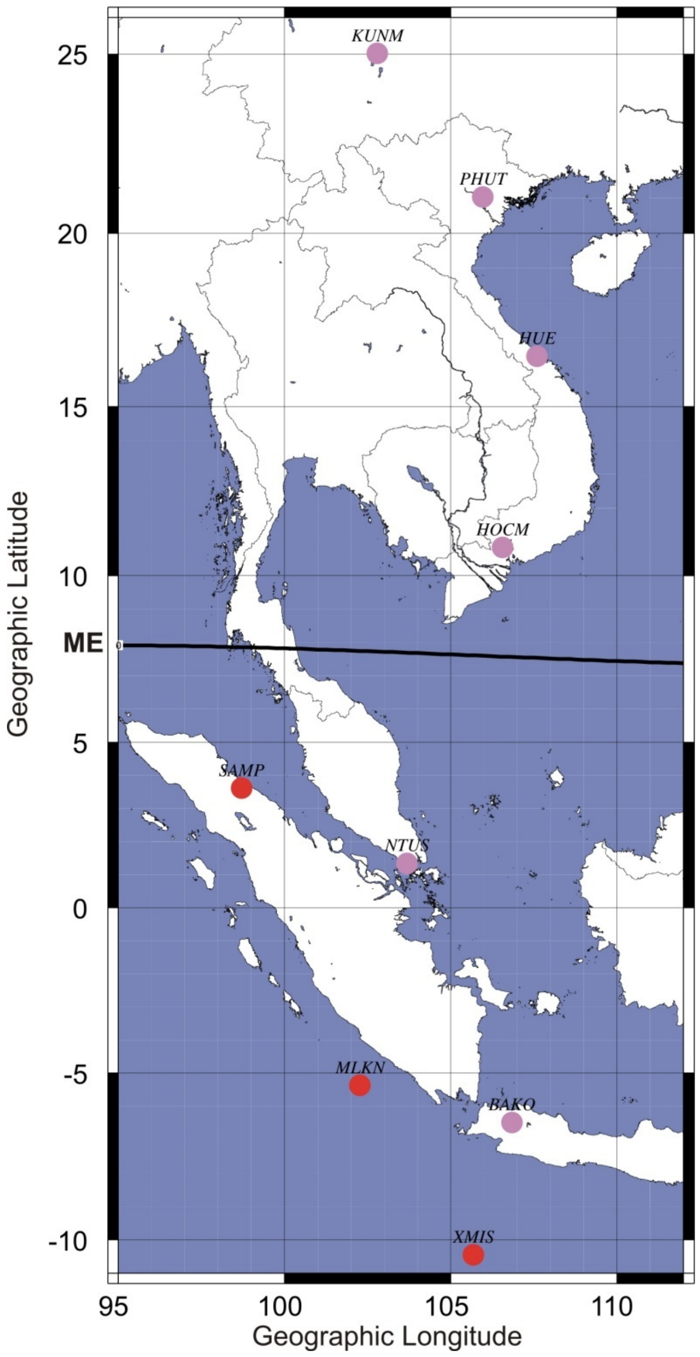


JAVAD DELTA G3T: GPS, GLONASS, GALILEO, …

Continuous GPS stations in the Southeast Asia region nearly along 105º longitude

IGS: KUNM, NTUS, BAKO
SAMP, MNKL, XMIS

Magnetic equator (at about 7-8º latitude) nearly parallel to the geographic equator.



Calculation of the GPS Total Electron Content

$$p^i_{1j} = s^i_{0j} + d^i_{ion1j} + d^i_{tropj} + c(\tau^i - \tau_j) + d^i_{q1} + d_{q1j} + d^i_{resj}$$

$$p^i_{2j} = s^i_{0j} + d^i_{ion2j} + d^i_{tropj} + c(\tau^i - \tau_j) + d^i_{q2} + d_{q2j} + d^i_{resj}$$

i: satellite ; j: receiver, f_1 = 1575.42 MHz, f_2= 1227.60 MHz

p_1, p_2: pseudoranges for frequencies f_1 and f_2

s_0: true distance between receiver and satellite

d_{ion}, d_{trop}: the ionospheric and tropospheric effects

c: the speed of light in free space; τ: satellite or receiver clock offset

d_q: instrument bias of satellite or receiver; d_{res}: other bias

$$d_{ion} = s^l - s_0 = \int_{R_x}^{T_x} \left(\frac{1}{n} - 1 \right) dl = \frac{40{,}3}{f^2} \int_{R_x}^{T_x} N dl = \frac{40{,}3}{f^2} TEC$$

$$TEC = \frac{1}{40{,}3} \left(\frac{f_1^2 f_2^2}{f_1^2 - f_2^2} \right) \left(p^i_{2j} - p^i_{1j} - k^i - k_j \right)$$

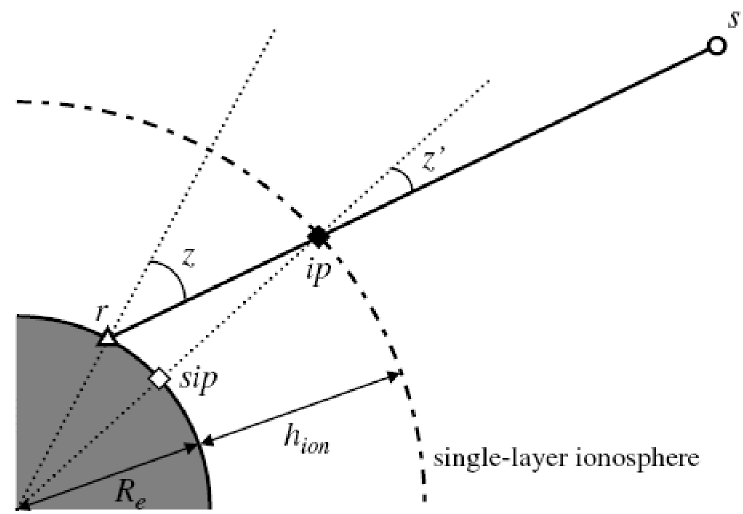
$k^i = d^i_{q2} - d^i_{q1}$: Satellite instrument bias

$k_j = d_{q2j} - d_{q1j}$: Receiver instrument bias

Calculation of vertical ionospheric total electron content

Model of the single-layer ionosphere

z : Zenithal angle at the GPS receiver location
z' : zenithal angle at the ionospheric point



$$z' = \arcsin\left(\frac{R_e}{R_e+h_{ion}} \sin z\right)$$

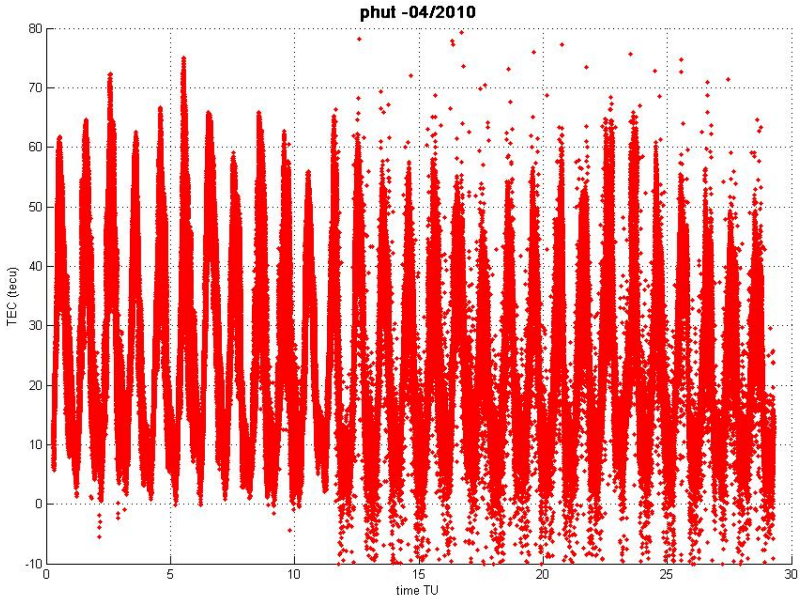
VTEC = TEC * cosz'

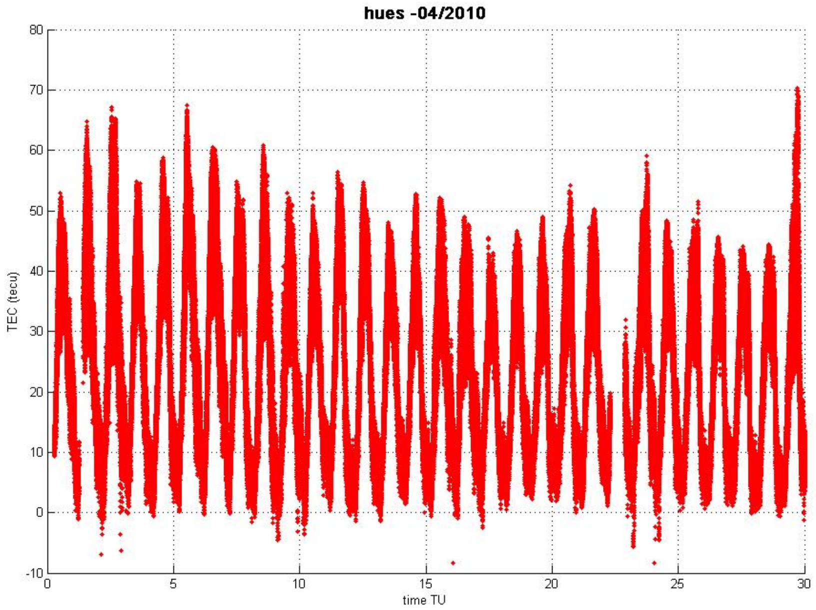
TEC : slant ionospheric total electron content
VTEC: Vertical TEC
R_e = 6371.2 km (Earth's rayon); h_{ion} = 400 km

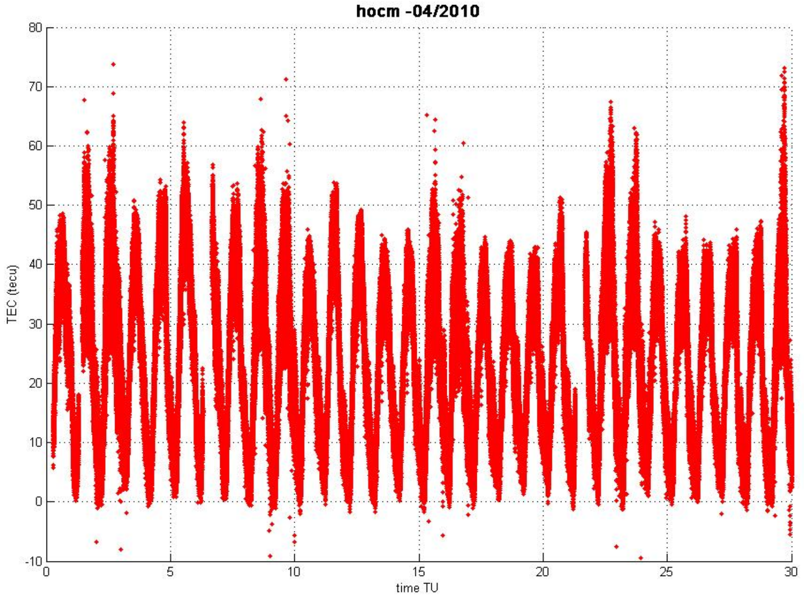
Calculation of vertical ionospheric total electron content

Given $k^i+k_j = 0$, calculate the TECV0
By comparision between TECV0 and TECV from global TEC model → (k^i+k_j) for each day.
Using the median value of (k^i+k_j) values in one month as (k^i+k_j) for the month.

TEC in Hanoi, Hue and HOCM April 2010



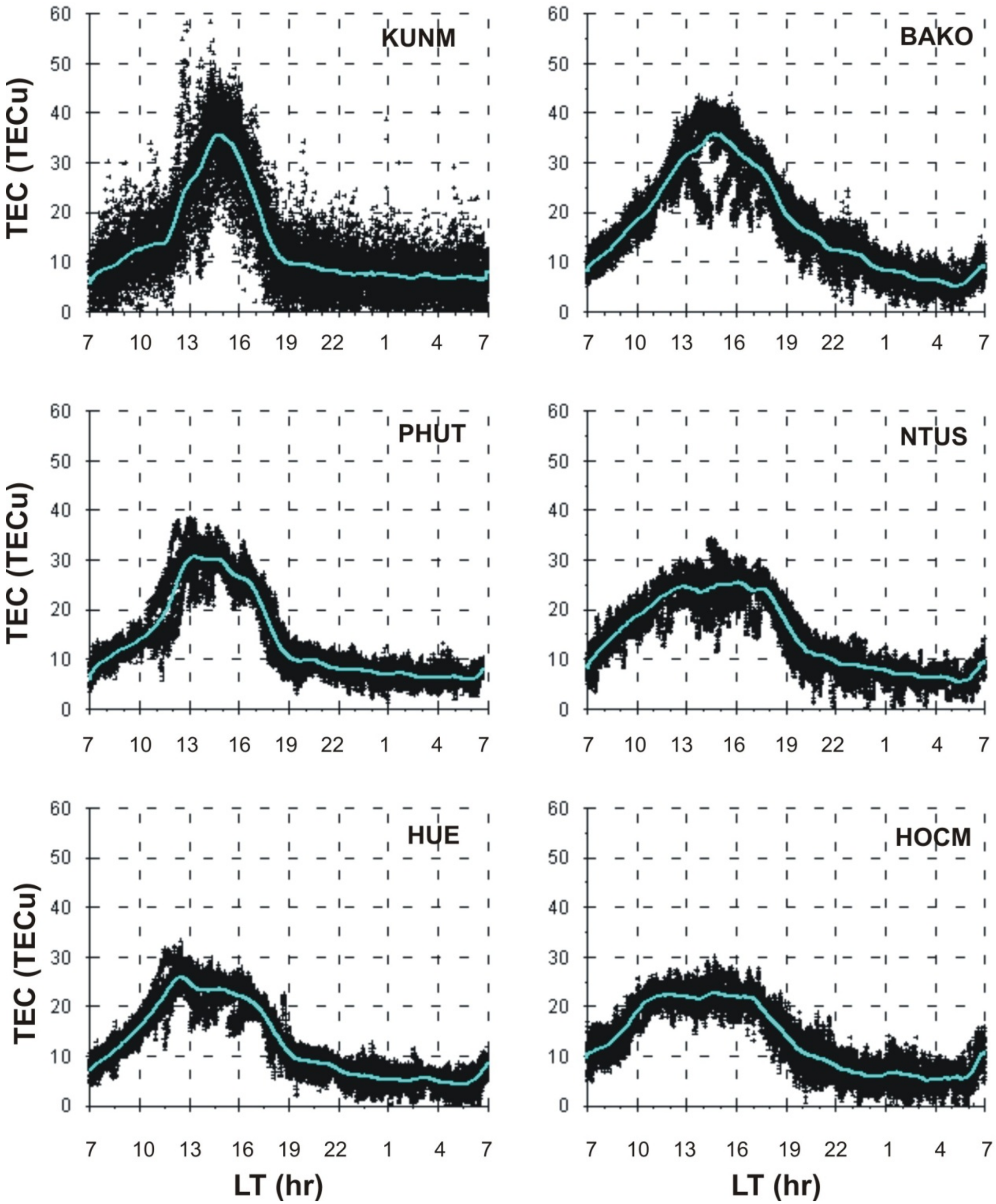




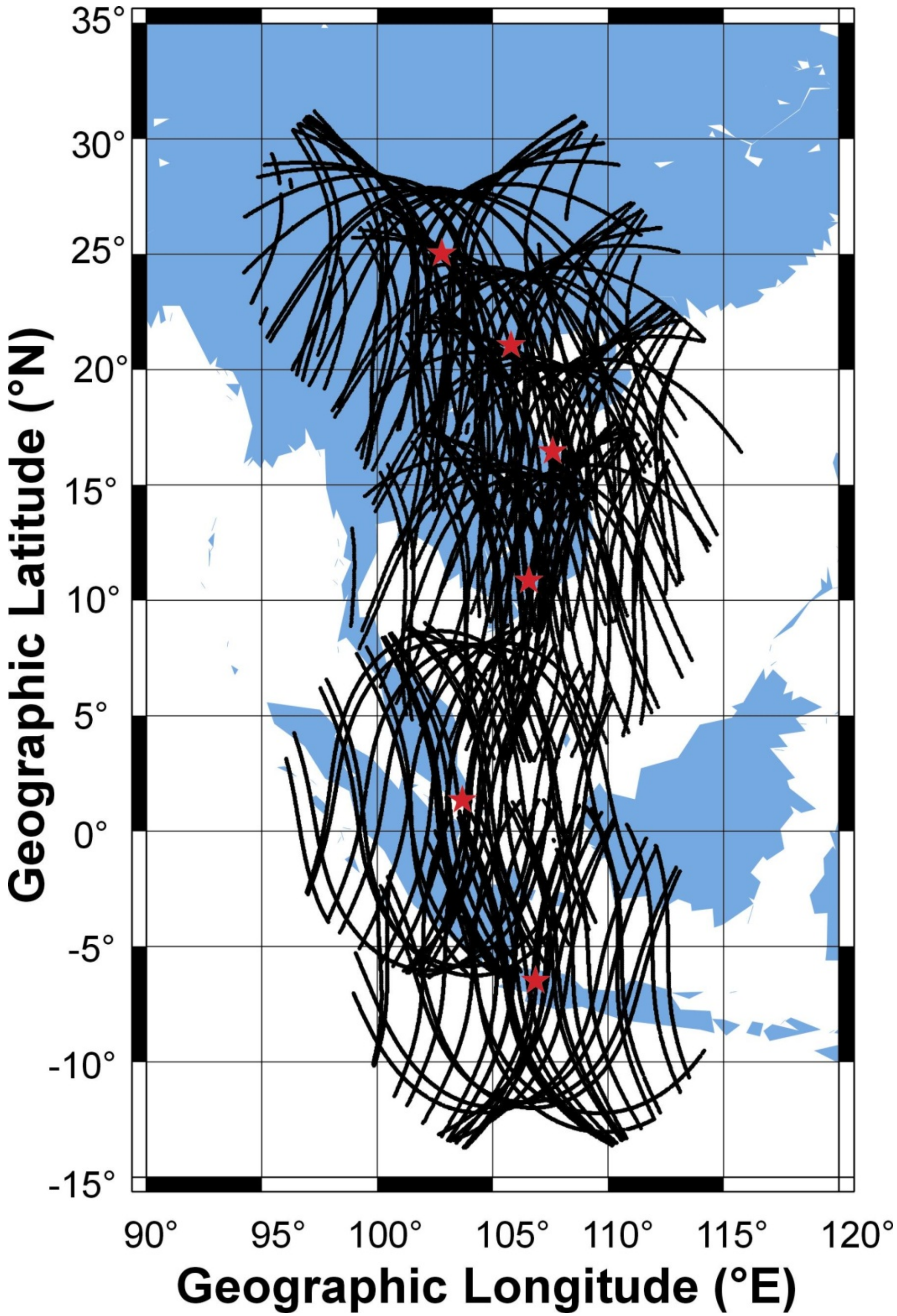
Diurnal variation of the TEC observed at KUNM, PHUT, HUE, HOCM, NTUS and BAKO on January 07, 2010

Shape of the diurnal variation of TEC depends on the latitude: a plateau at the stations near equator: HOCM, NTUS; a Gaussian at the Stations distant from the equator: KUNM, PHUT, BAKO.

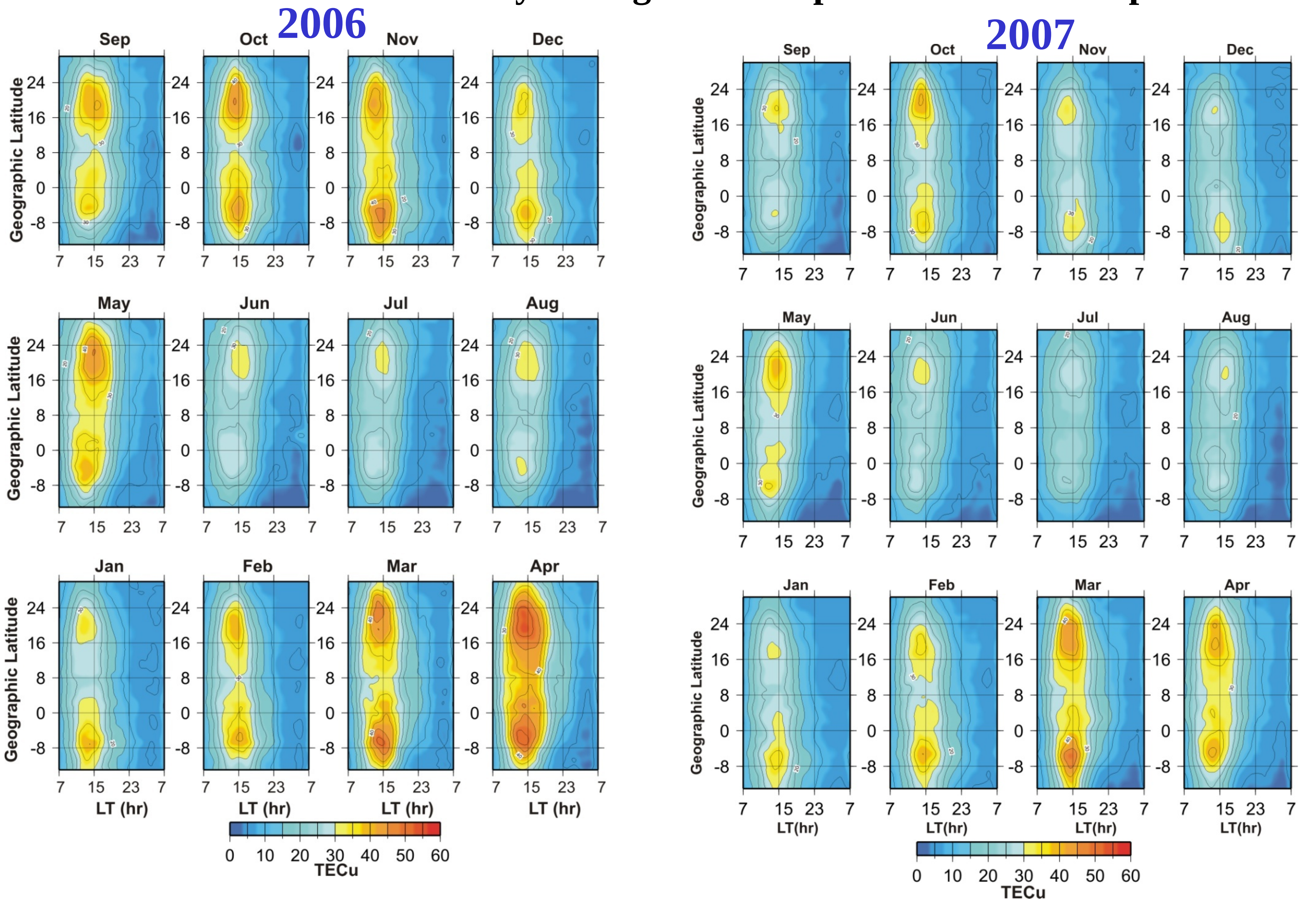
UT = LT-7



Satellite foot prints on the subionosphere observed by the GPS receivers in the Southeast Asian region on the April 12, 2006

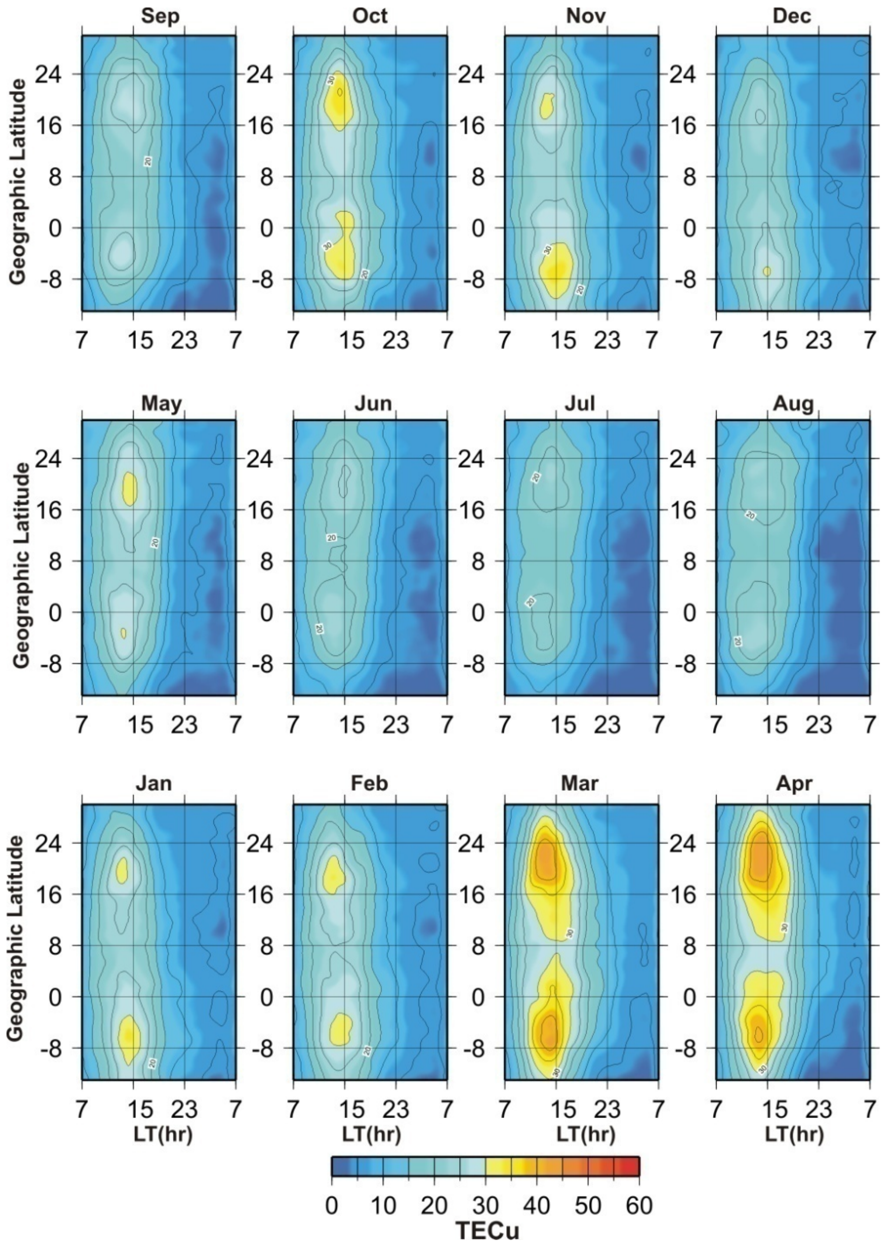


Time and latitudinal monthly average TEC map for the 2006-2011 period



Equatorial ionization anomaly: two crests in two hemispheres, trough on the magnetic equator

2008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LT(hr)
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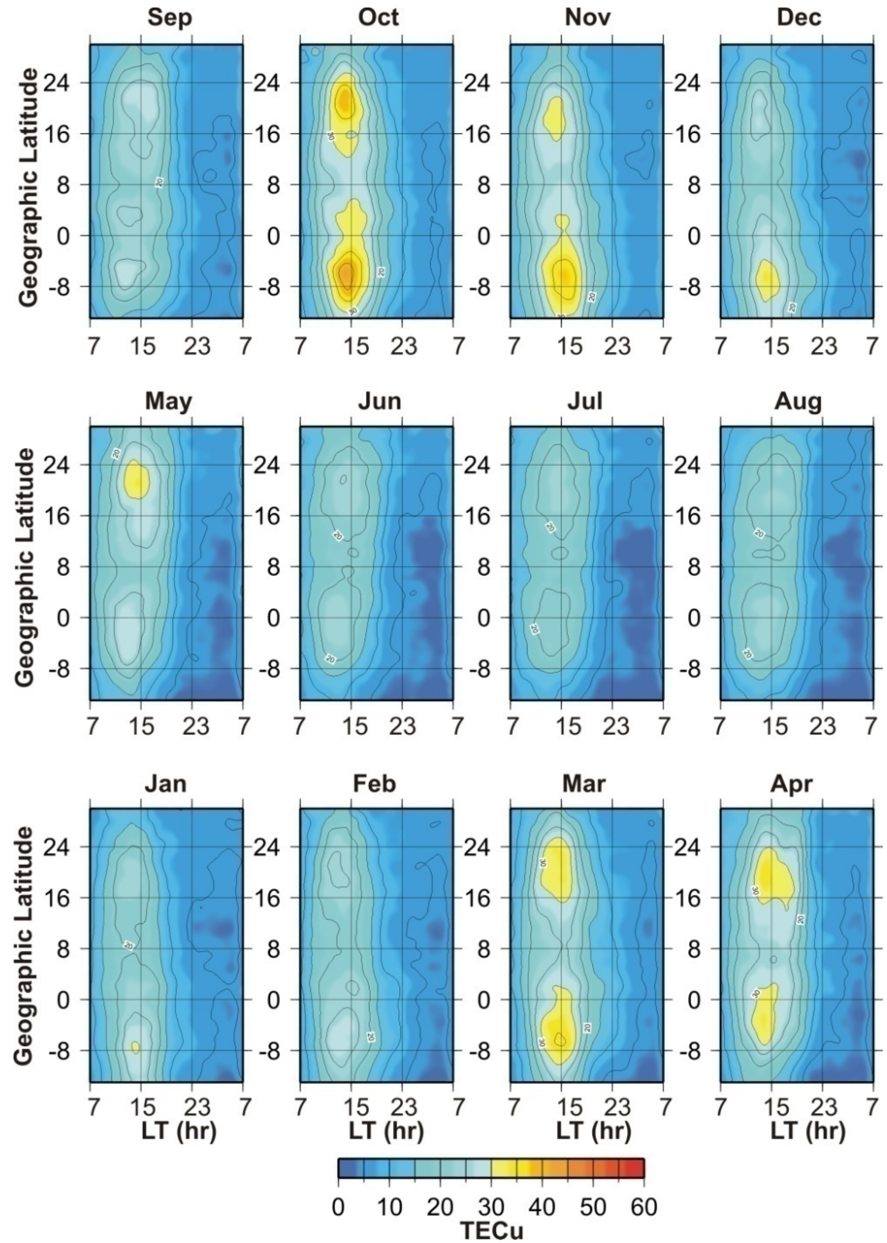
TECu

2009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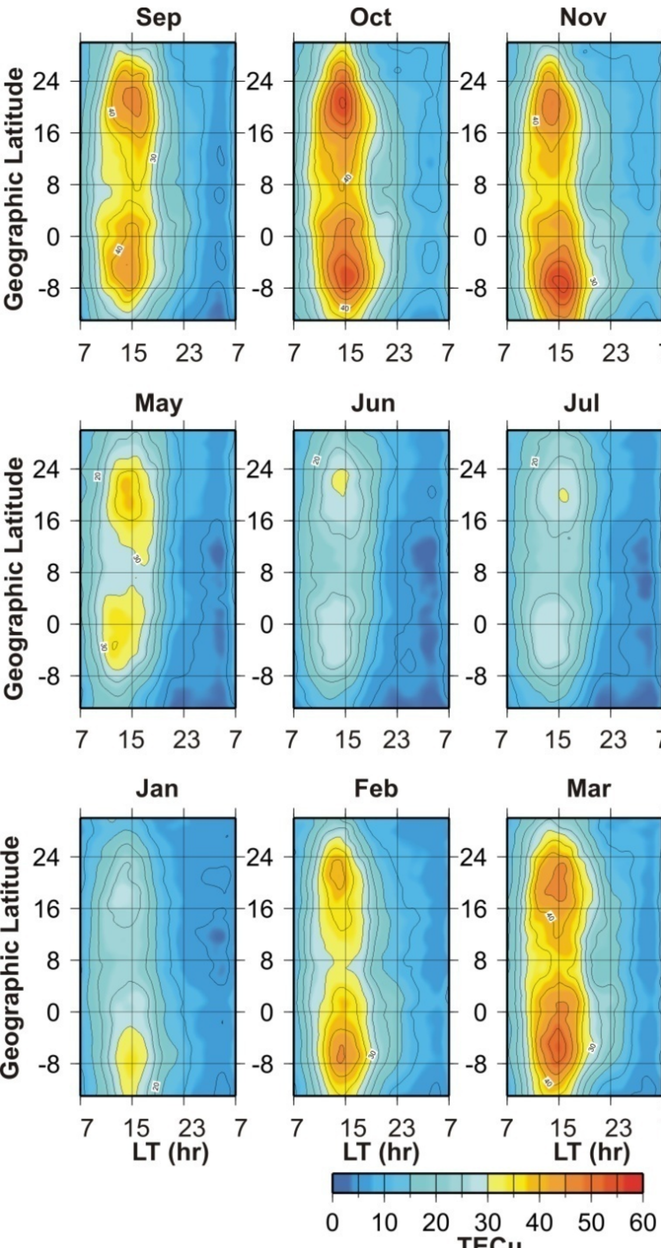
2010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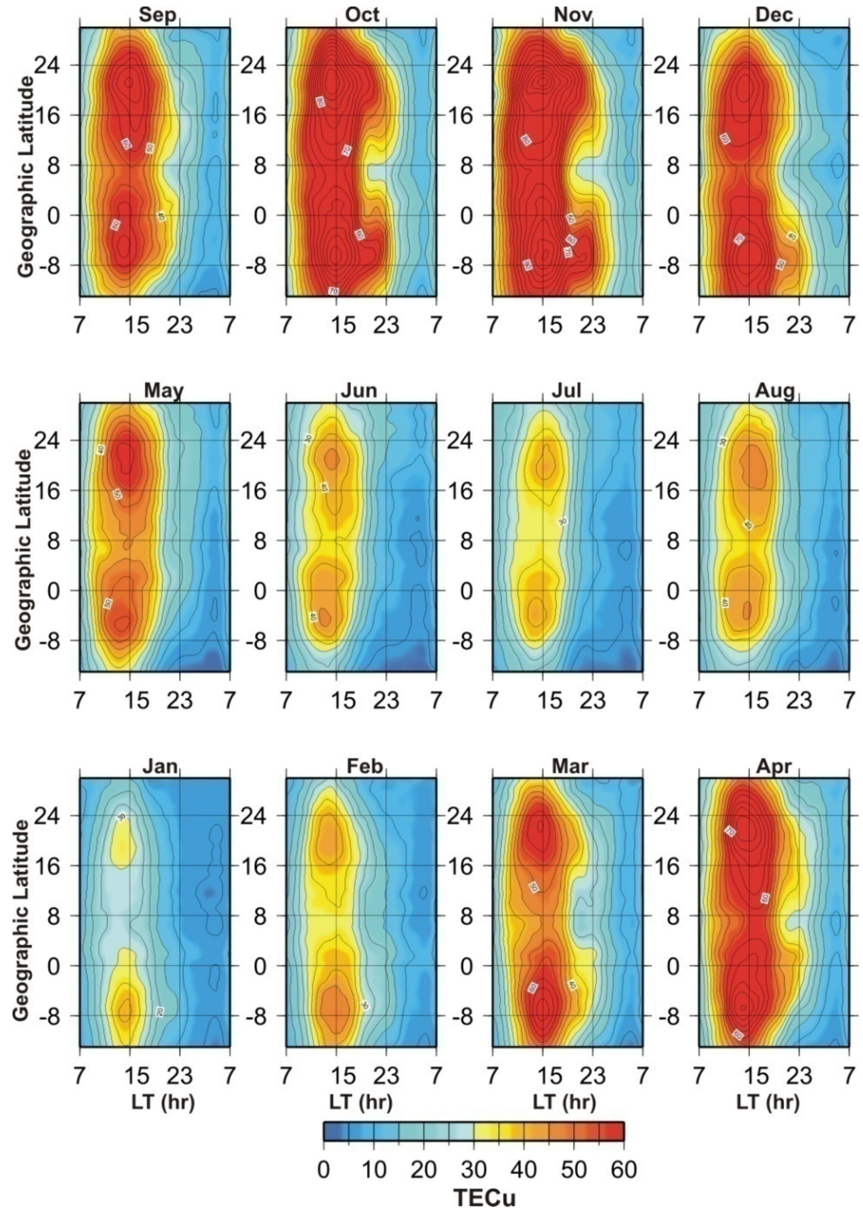
2011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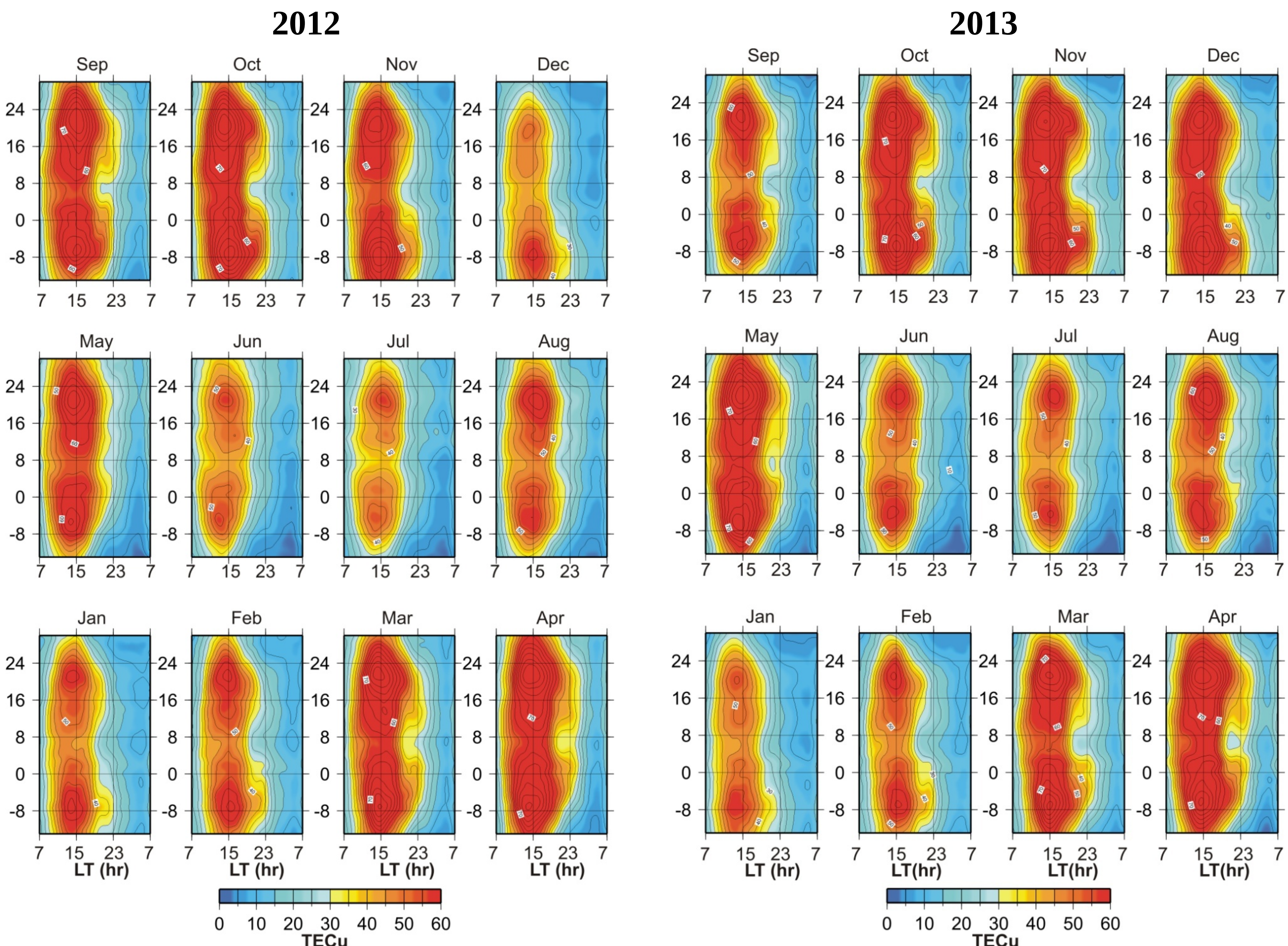
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LT(hr)
TECu
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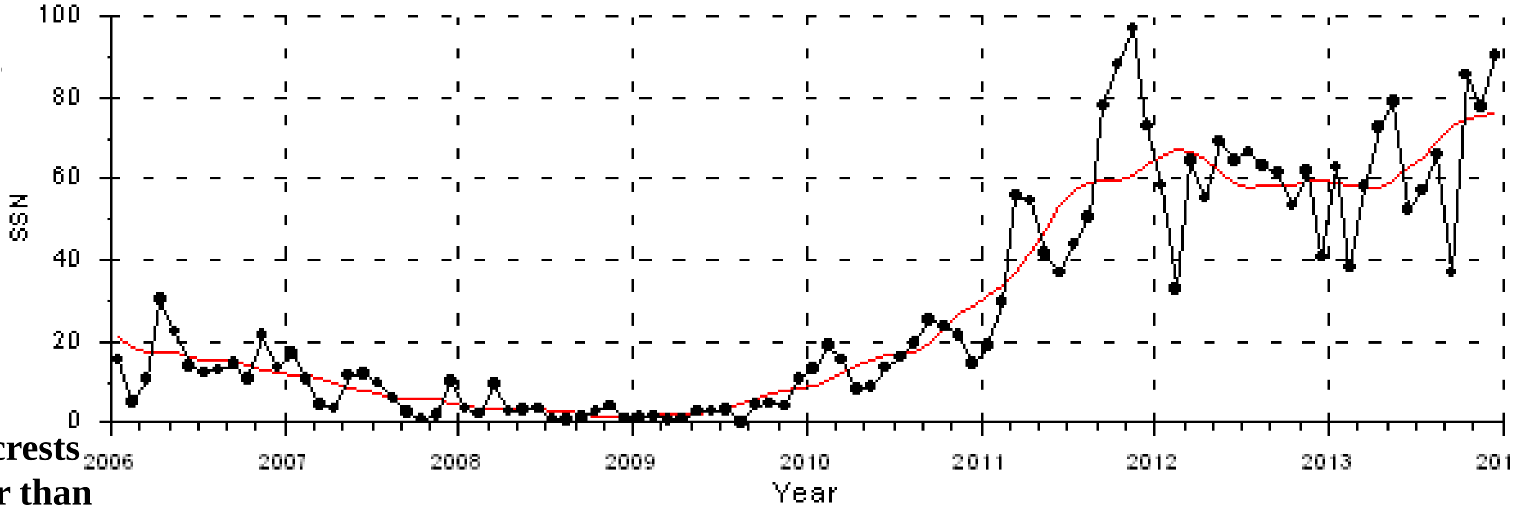
20
30
40
50
60

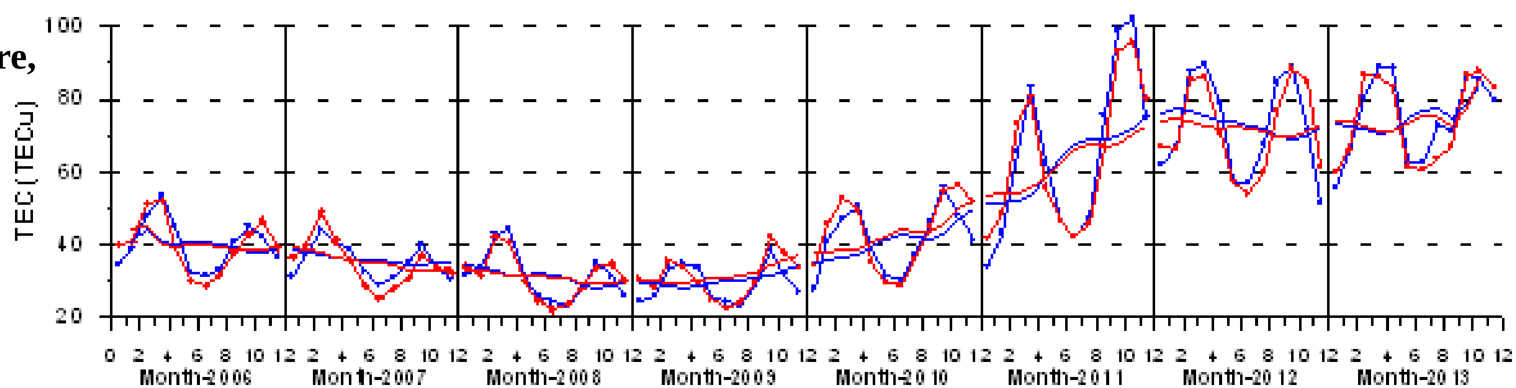
Sunspot number and Magnitude of monthly anomaly crests (blue – northern crest, red – southern one) in the 2006-2013 period

R (SSN-TEC): ~ 0.8

12-month running averages : 0.98



Amplitude of TEC crests in December greater than in July→ This is the winter anomaly for Northern hemisphere, but not in Southern one.



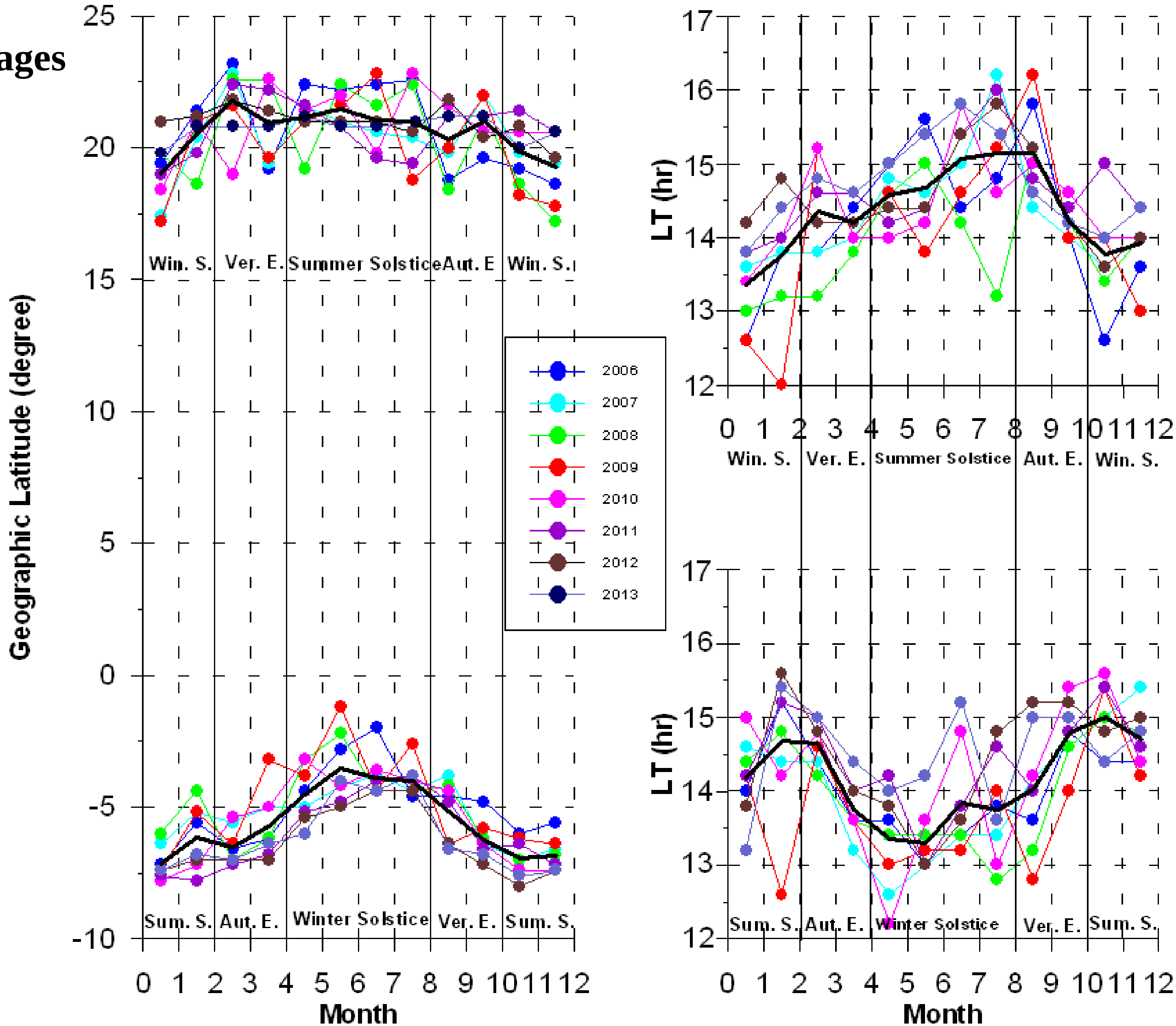
Solid lines: 12-month running averages

LATITUDE and OCCURRENCE TIME OF THE MONTHLY ANOMALY CRESTS

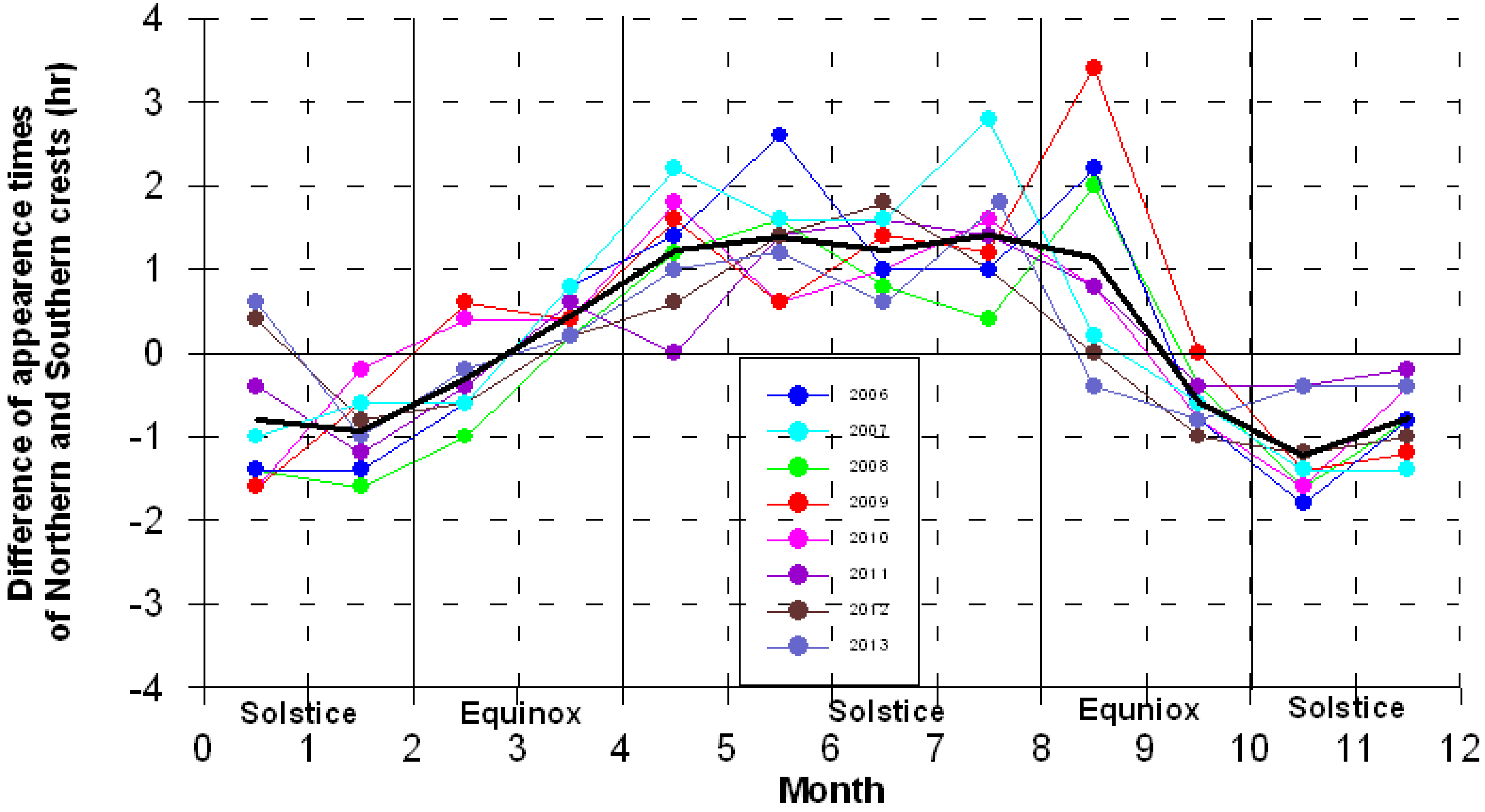
Solide lines: Averages

Both crests move equatoward in winter than other seasons.

There is tendency for both crests to appear ealier in winter and latter in summer.



Difference between the occurrence times of the Northern and Southern monthly anomaly crests for the 2006-2013 period



Main Remarks

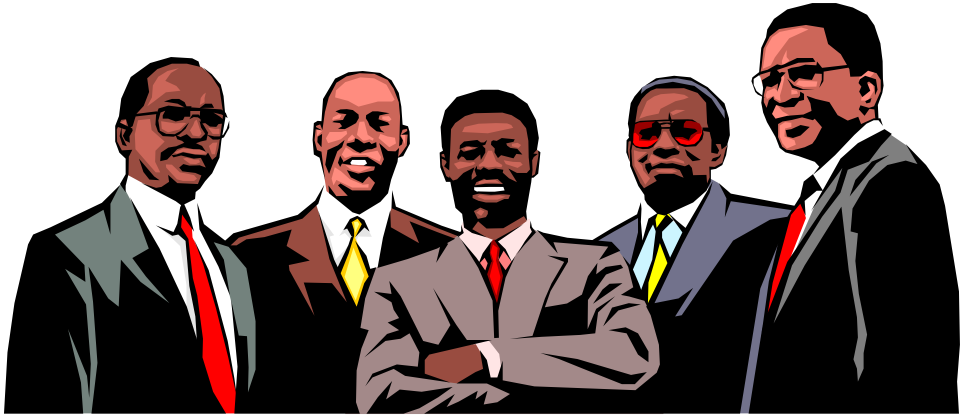
- The GPS receiver chain near the 105°E longitude, including the Vietnamese stations and some ones from adjacent countries, is very good for the studies of the TEC variation in the Equatorial ionization anomaly in the Southeast Asian region.
- The shape of the mean diurnal variation of TEC in the region depends on the latitude: a plateau is observed at the stations near magnetic equator and a Gaussian at the stations near EIA crests distant from the equator
- A semiannual pattern in all the stations with maxima at equinox. In both hemispheres, the amplitude of the crest is larger in spring than autumn from 2006 to 2008 and smaller in spring than in autumn from 2009 to 2013.

Main remarks

- A very high level correlation between the amplitude of the TEC at two crests and the sunspot number: ~0.88.
- During the deep solar minimum 2008-2009, the amplitude of crests of ionization becomes small during several months in summer and winter.
- Both crests move significaltly equatorward in winter than other seasons and there is a tendency for both crests to appear earlier in winter and latter in summer.

Publication

- M. Le Huy et al., 2014. Time variations of the total electron content in the Southeast Asian equatorial ionization anomaly for the period 2006-2011, *Advances in Space Research*, **54**, 355-368.



Thank you for your attentions !