# A statistical study of equatorial plasma bubble observed by GPS ROTI measurement along 100°E – 118°E longitude over the years 2008 – 2013.

Suhaila M Buhari[1,2], Mardina Abdullah[2], Tatsuhiro Yokoyama[1], Alina Marie Hasbi[2], Yuichi Otsuka[3], Michi Nishioka[1] and Takuya Tsugawa[1]

[1] National Institute of Information and Communications Technology

[2] Space Science Centre, Universiti Kebangsaan Malaysia

[3] Solar-Terrestrial Environment Laboratory, Nagoya University

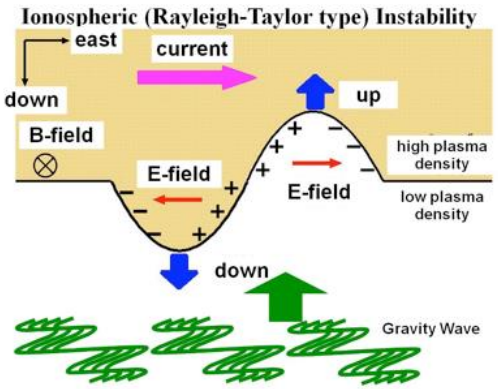
# Outline

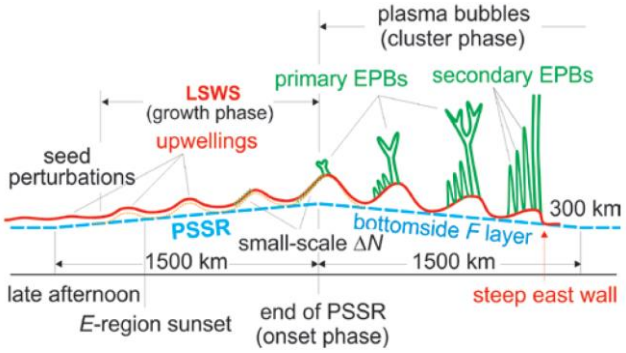
- Two-dimensional structure of EPB.
- Climatology of EPB from previous studies
- Data and observation
- Results

  1) Occurrence day of EPB vs the successive EPBs

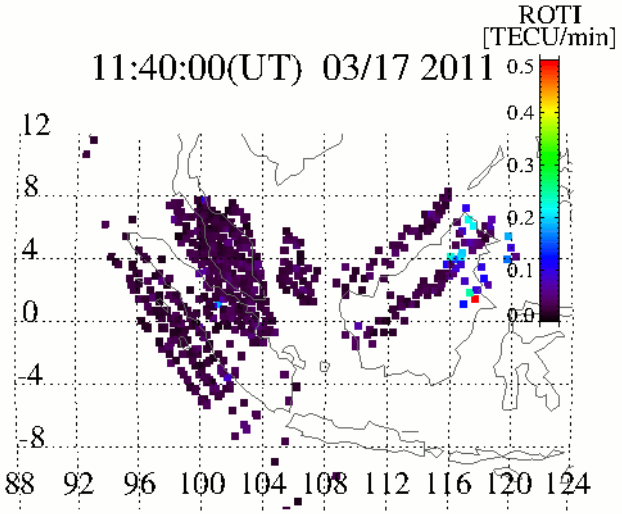
  2) The dependency of EPB with solar activity, seasons, latitude and longitude.
- Summary
- Future work

# EQUATORIAL PLASMA BUBBLE (EPB)



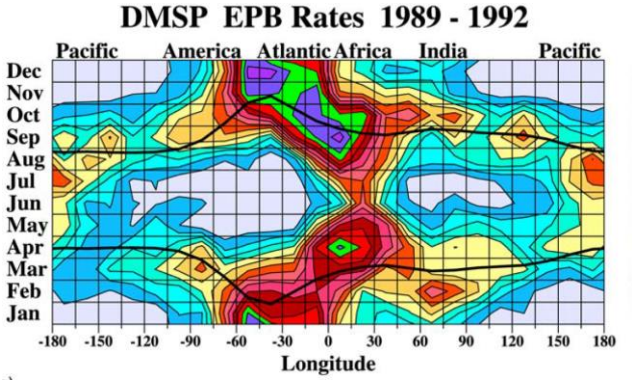




Tsunoda, 2015*

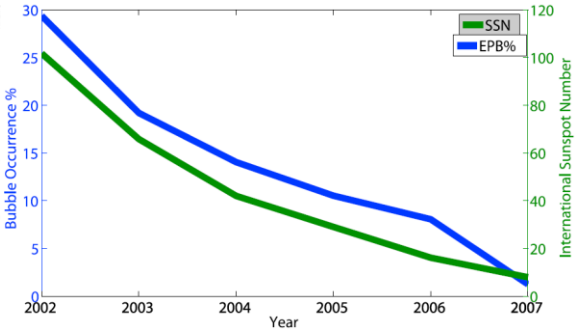



- EPB is 3D structure of depleted plasma density associated with ionospheric irregularities that and could degrade radio and GPS navigation or any system.
- EPB is initiated near the magnetic dip equator through Rayleigh Taylor instability mechanism and drift zonally.
- Rayleigh Taylor instability – perturbation acting at the bottomside of the F layer.
- The seeds of EPB can be the convection of gravity waves from troposphere or the propagating waves (Kelley at al 1981) such as large scale wave structure (Tsunoda, 2005 & 2008).
- The seeds is responsible for the day-to-day variability of EPB occurrence is still not completely understood.

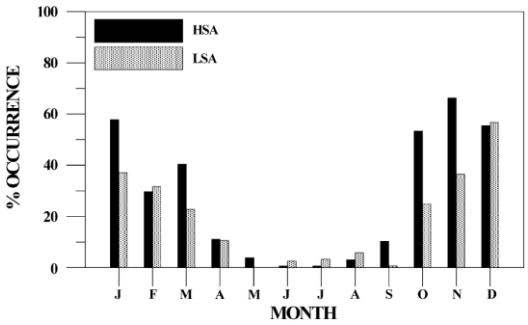
# Climatology of EPB from previous studies



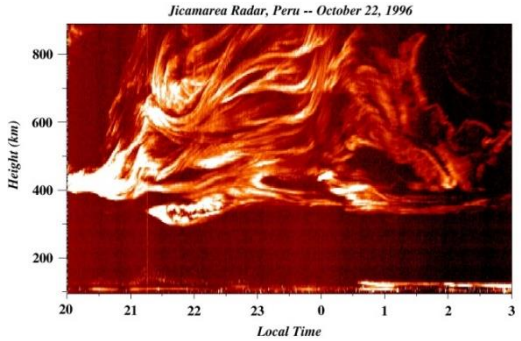

EPBs from 1989-1992 - Global Ultraviolet Imager (GUVI) onboard of TIMED satellite. (Gentile et al., 2006)




EPBs observed from GUVI (2002-2007) with SSN. (Comberiate & Paxton , 2010)




The observation optical imager in Brazil (Sahai et al., 2000) shows the occurrence of EPB has similar characteristics for HSA and LSA

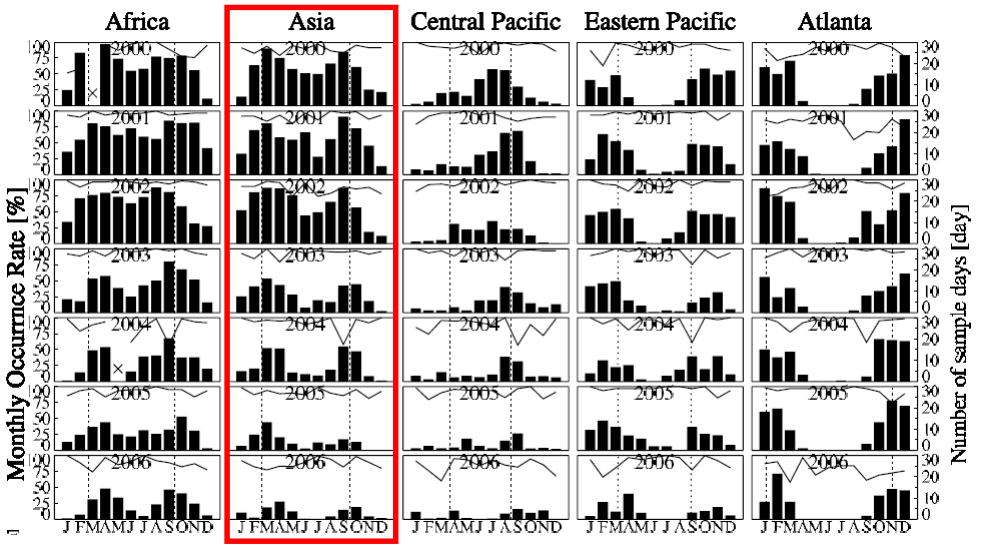


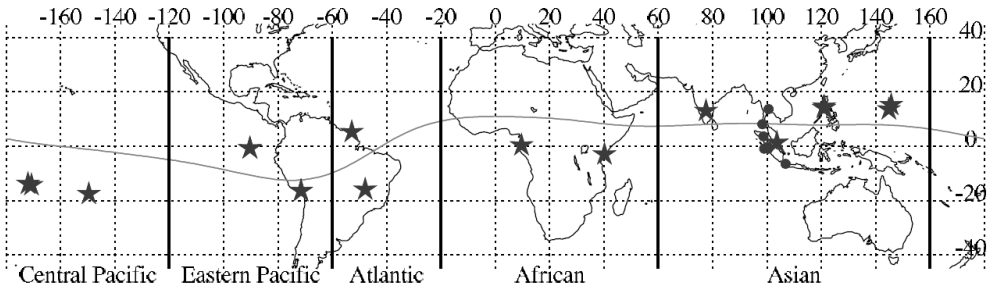

| | $\phi < 90$ | $90 < \phi < 160$ | $160 < \phi$ |
|---|---|---|---|
| none | 12% | 16% | 10% |
| bottom-type | 23% | 27% | 31% |
| bottomside | 15% | 19% | 16% |
| topside | 50% | 38% | 43% |

EPB observed from JULIA radar in Peru (1996-2000) with solar flux, φ. (Hysell and Burcham, JASTP, 2006

# Occurrence rate of EPB using GPS receiver

- The global occurrence rate of EPB observed by a single GPS receiver from 2000-2006. [Nishioka et al. 2008]
- The different climatology due to the longitudinal orientations of magnetic equator.
- EPB tends to occur during the alignment of the solar terminator with the magnetic field lines. [Tsunoda, 1985]
- In this study we present the occurrence rate of EPB using high-density GPS receivers in Southeast Asia.



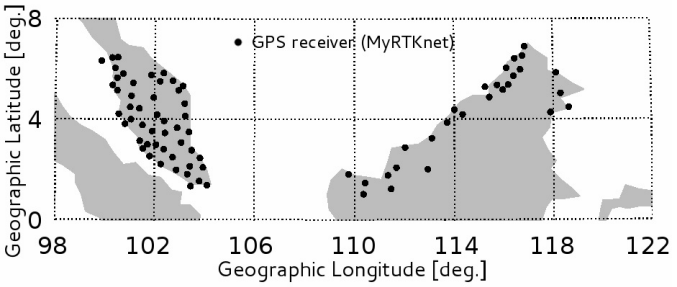
# THE TWO-DIMENSIONAL OBSERVATION OF EPB IN SOUTHEAST ASIA

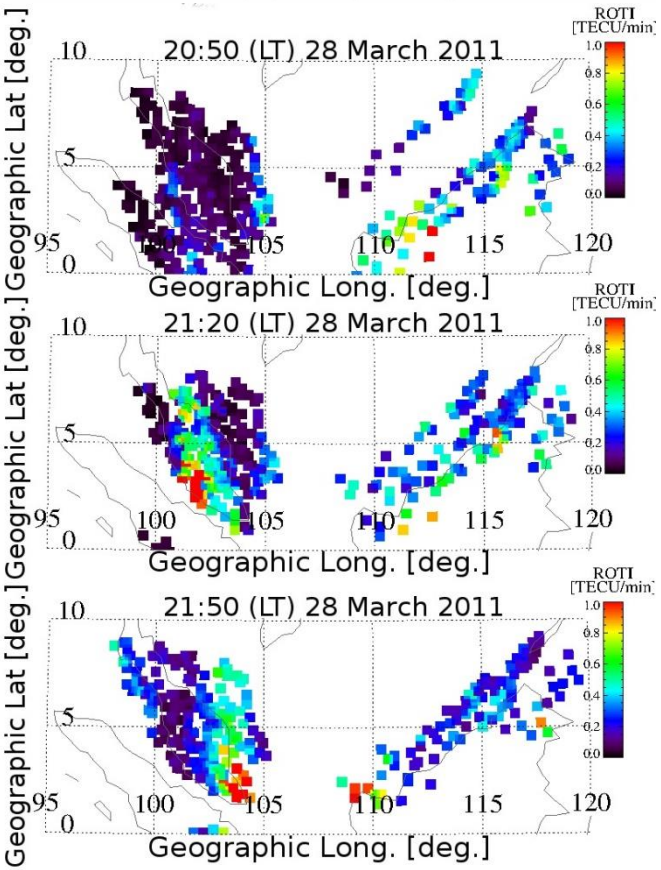
- The GPS data was collected from the Department of Survey and Mapping, Malaysia for the years 2008 – 2013
- The receivers network called Malaysia Real-Time Kinematics GNSS Network (MyRTKnet) has 78 GPS receivers are distributed along 100°E to 120°E with ~50-100 km spacing.
- TEC - the integrated electron density along the signal path ~ the amount of phase advances cause by the ionosphere.

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

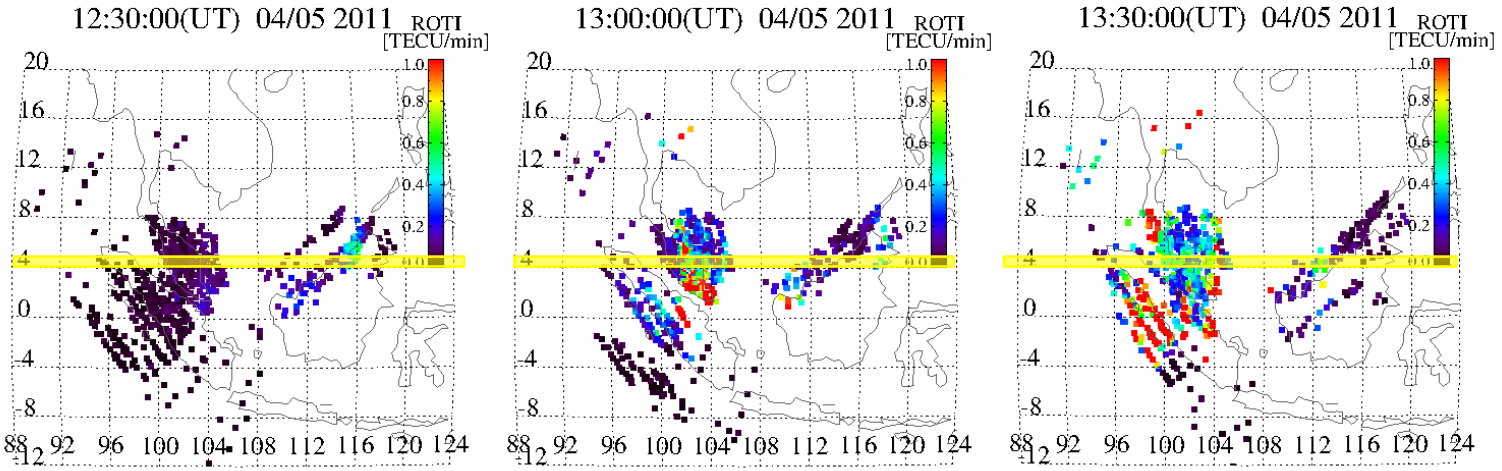
- The irregularities in ionosphere can cause rapid change in amplitude and phase of the TEC

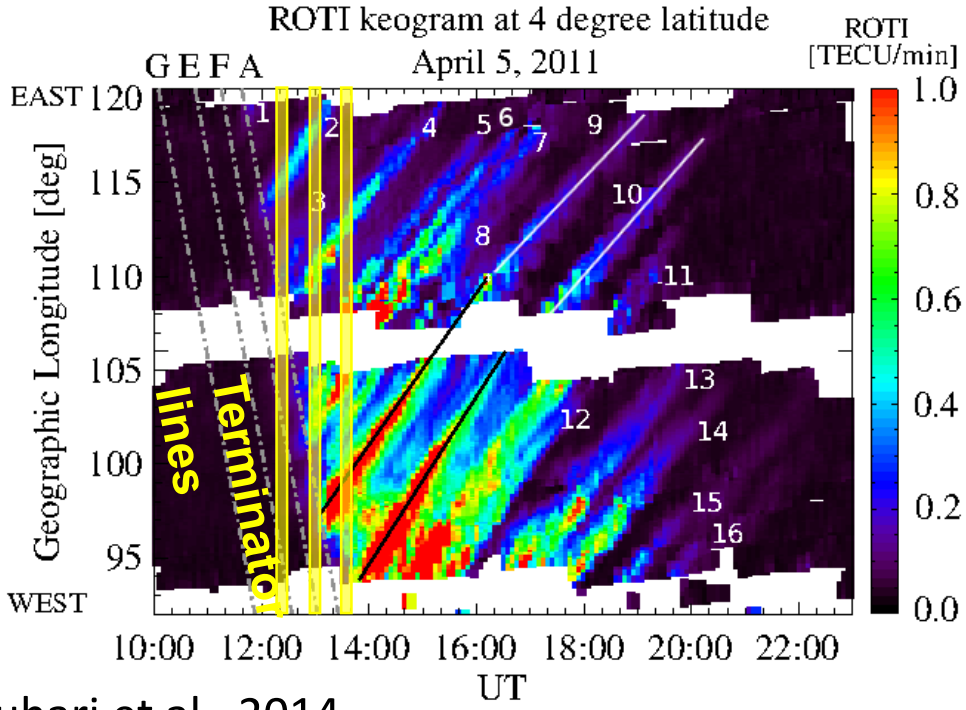
$$ROT = \frac{TEC(t + \Delta t) - TEC(t)}{\Delta t}$$



# ROTI KEOGRAM AT 4°N

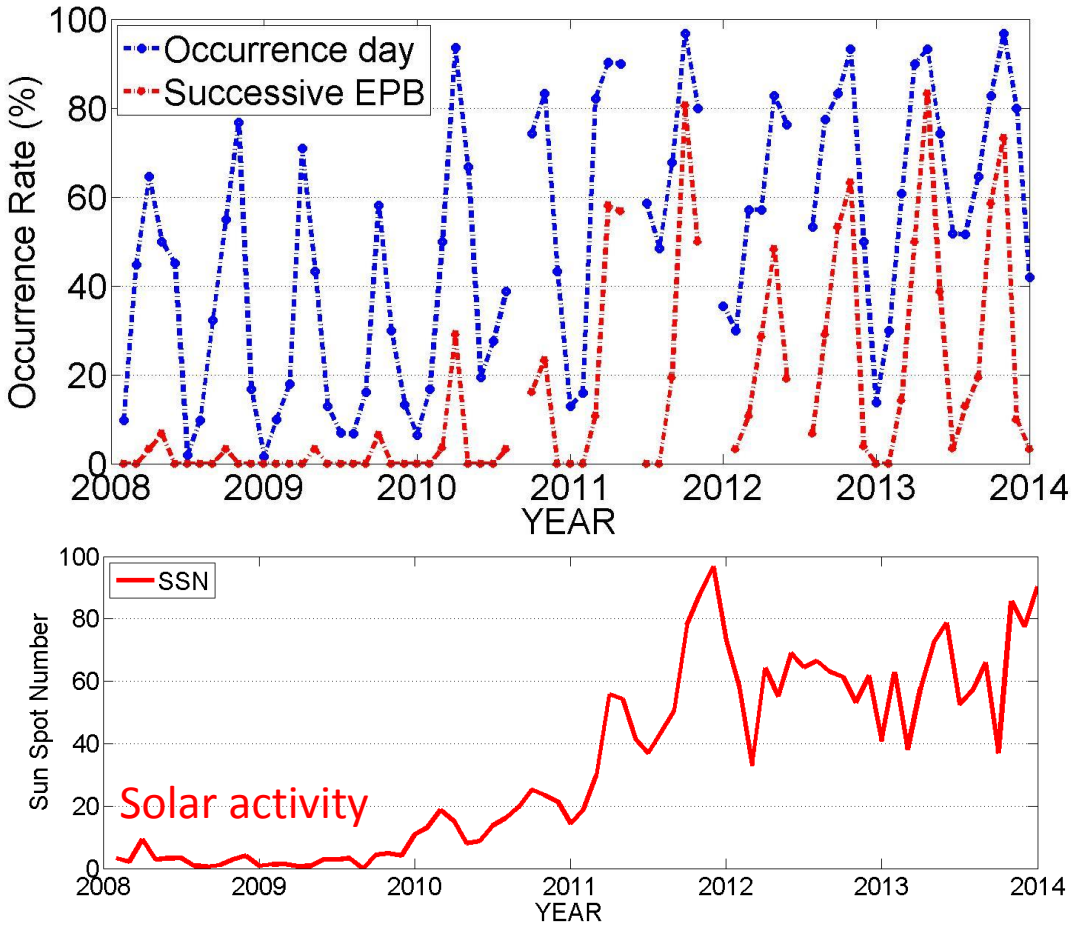



- Obtain time-continuous observation of EPB with high spatial resolution and broad geographical coverage.
- East-west ROTI keogram is created by taking one slice of ROTI (e.g. at 4°N) and arrange it for every 5 minutes.
- ROTI keogram shows the time-longitudinal variations of EPB over 92°E – 120°E.

Buhari et al., 2014

# EPB & SSN

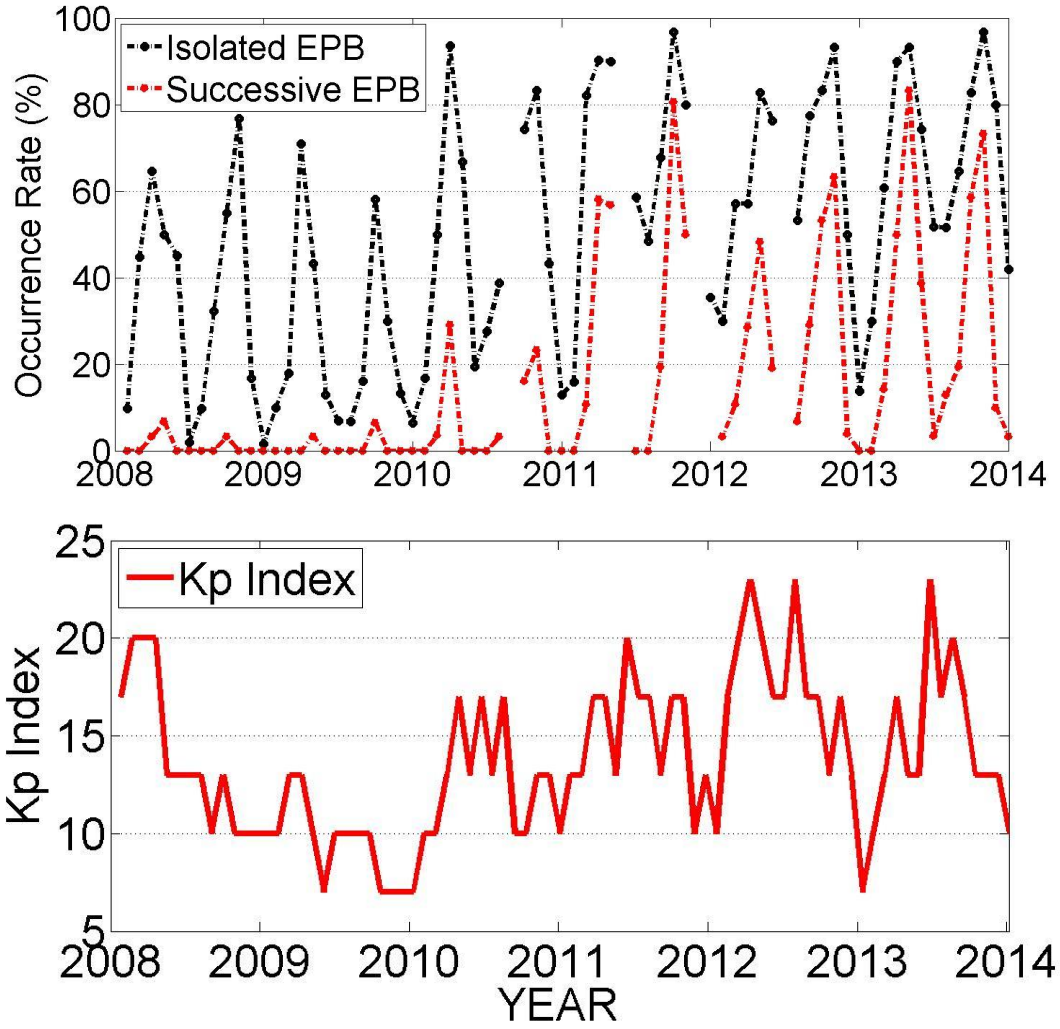



EPBs tend to occur in all longitude during the high solar activity

# Summary

- We have shown the occurrence rate of EPB using high-density GPS receivers in SEA.
- We found high occurrence rate (>90%) during high solar activity, which is consistent with past observation by single GPS receiver in SEA.
- We found a considerably high occurrence rate during low solar activity (60%-80%) and is consistent with past ground based observation from Brazil (>60%) and Peru (>50%).
- The occurrence rate observed by TIMED satellite might have low spatial resolution or too high to observe the EPB at low altitude
- The occurrence day of successive EPBs are in agreement with solar activity shows the EPB tends to propagate in the ionosphere during high solar activity.

# EPB & Kp Index




EPBs tends to occur in all longitude during the high solar activity