Sporadic E signatures in radio signals and their application for the study of MSTIDs

Woo Kyoung Lee[1], Hyosub Kil[2]

[1]Korea Astronomy and Space Science Institute

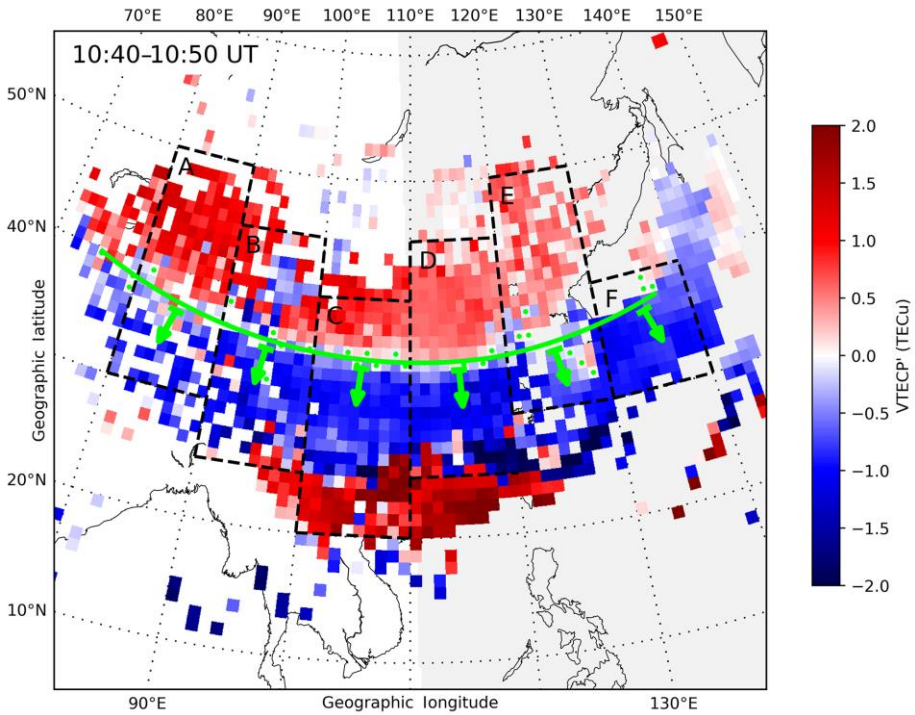
[2]Johns Hopkins University Applied Physics Laboratory

Traveling Ionospheric Disturbances (TIDs):

Horizontally propagating wave-like disturbances of the electron density in the F region

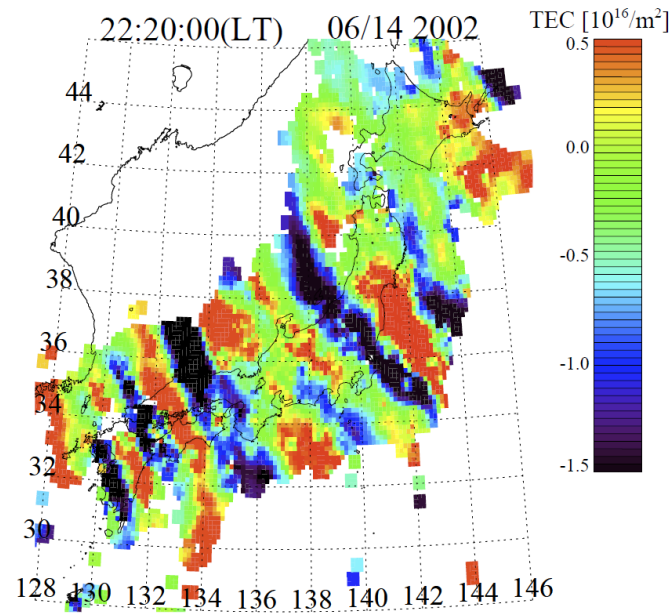
Large-Scale TIDs

wavelength > 1000 km



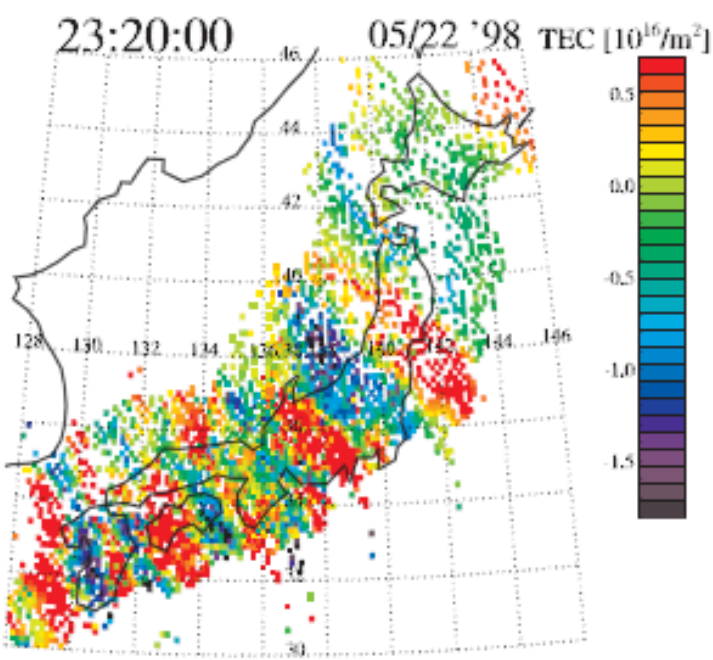
Medium-Scale TIDs

wavelength < 1000 km



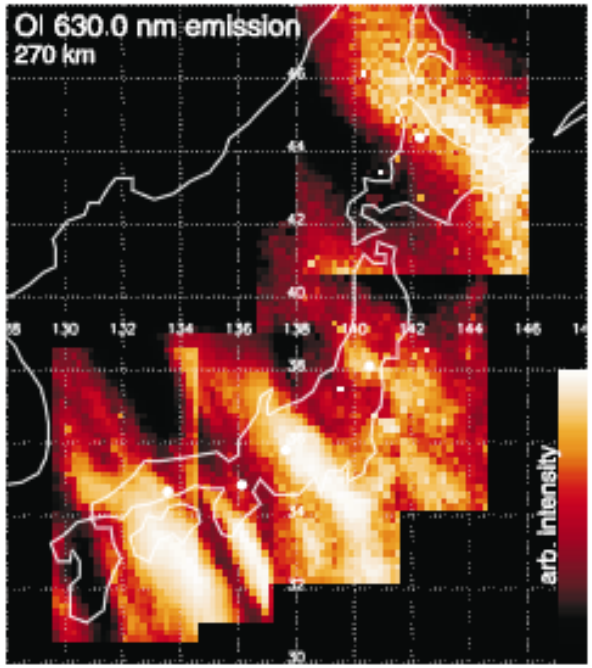
Two-dimensional images of MSTIDs have been observed using dense GNSS networks and all-sky imagers

Detrended TEC map over Japan



*TEC: total electron content

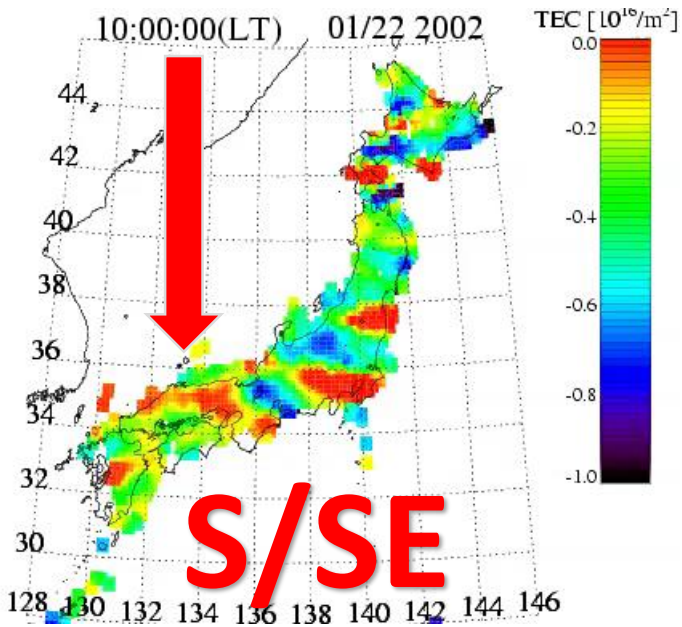
Airglow image



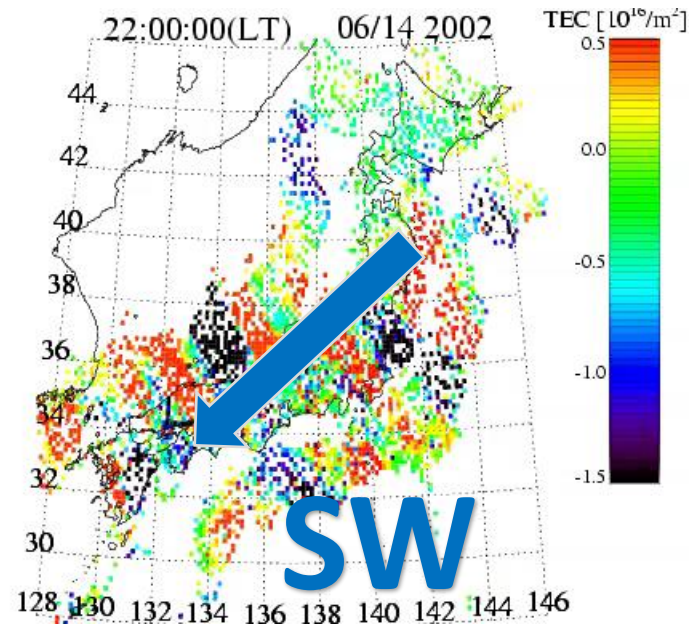
[Saito et al., 2001]

The characteristics of MSTIDs from ground-based observations

Daytime



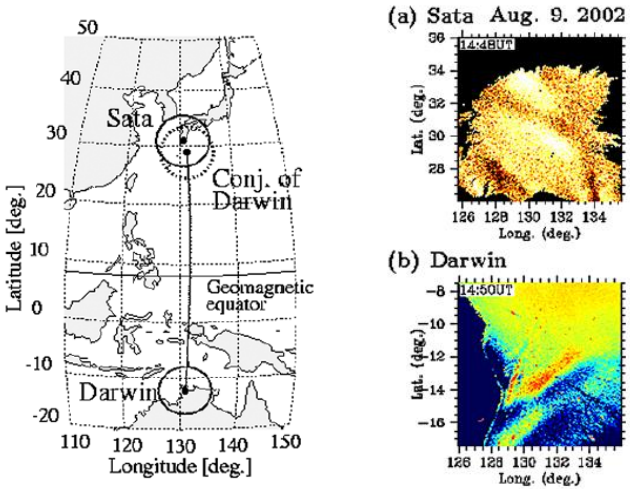
Night-time



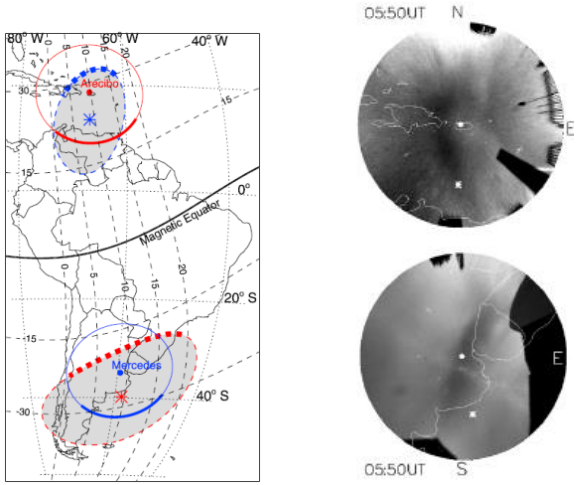
- Equatorward propagation
  -> induced by gravity waves?
- High occurrence rate in winter

- South(north)westward propagation in northern (southern) hemisphere
- High occurrence rate in June (Japan)

Conjugate observations of night-time MSTIDs

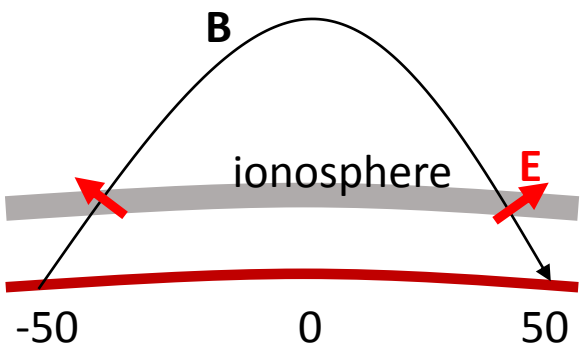


[Otsuka et al., 2004]



[Martinis et al., 2011]

- Night-time MSTIDs could be generated by **electro-dynamical processes** (E-field mapping along the magnetic field lines)

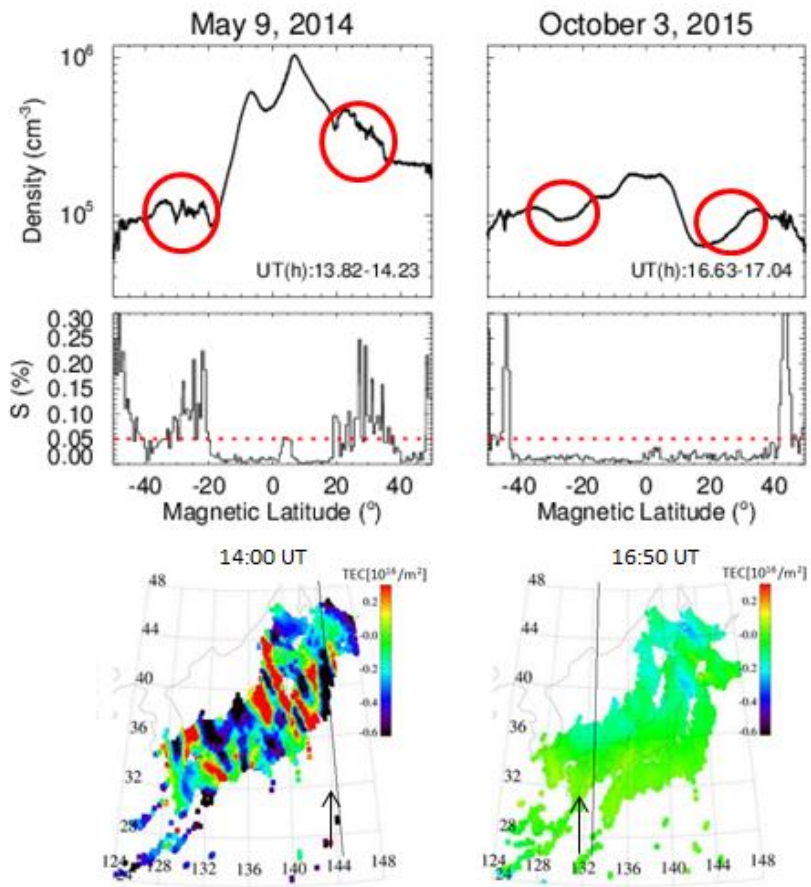


- Ground-base observation only provides local characteristics. So we need confirm whether these features are global or not

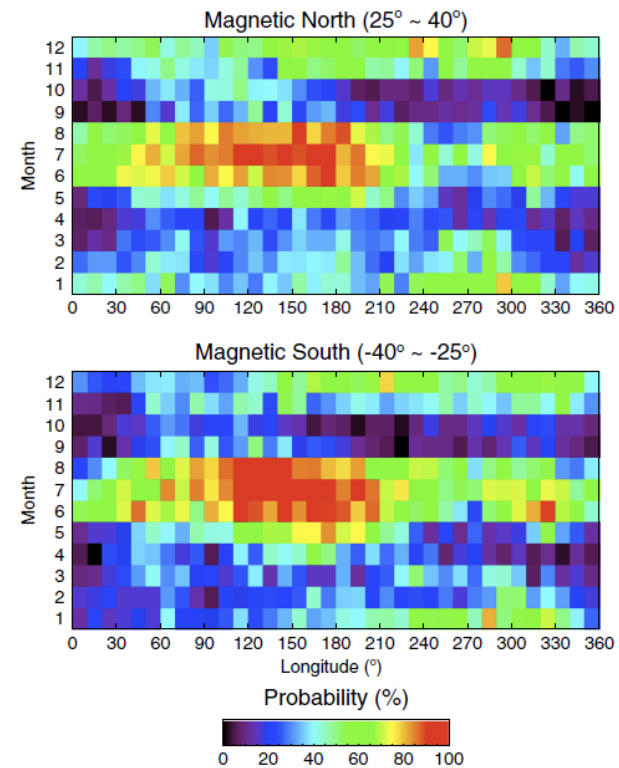
→ Satellite observation !

Swarm-A satellite observations

Swarm-A
ALT: 470 km



2014 – 2016
LT: 21 – 03

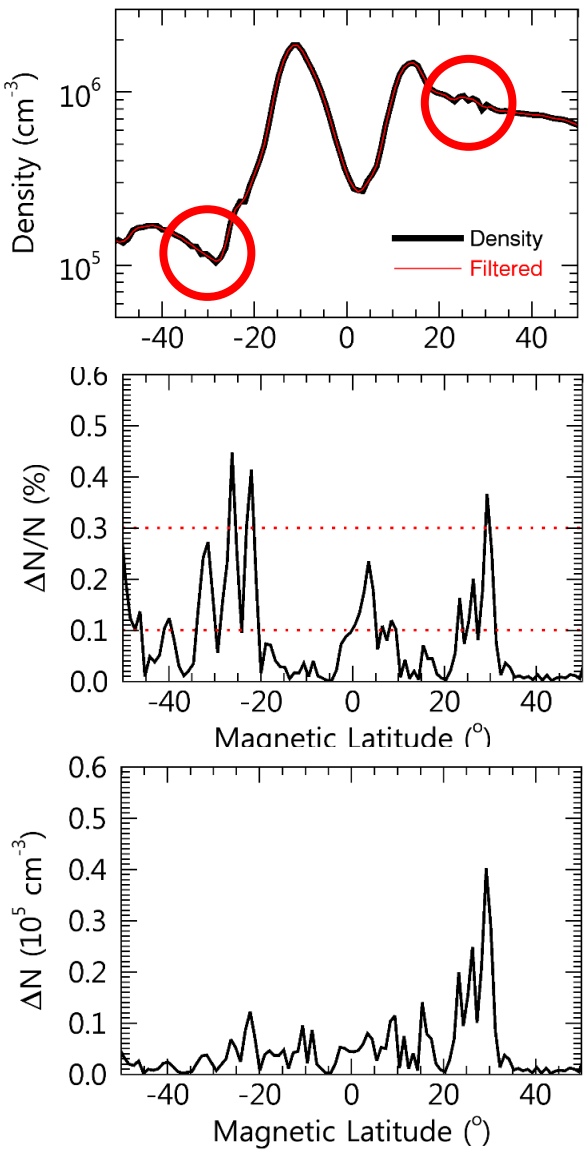


Irregularities are detected when MSTIDs occur.

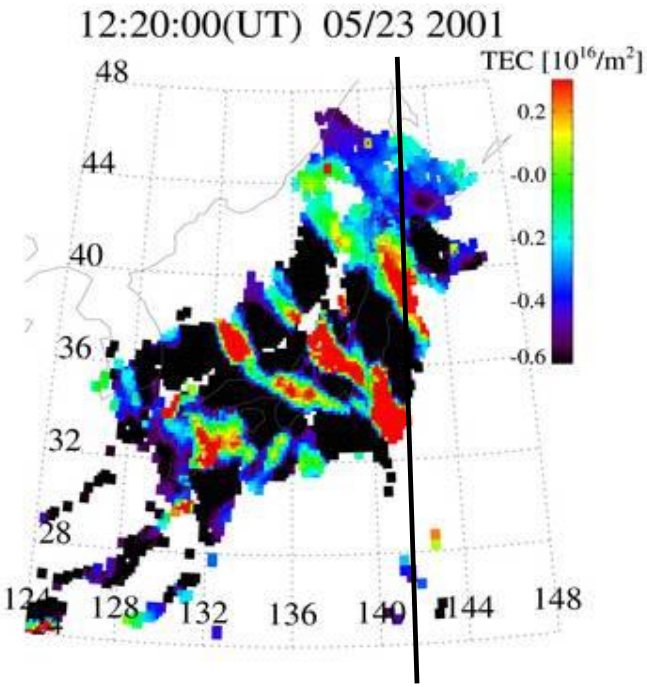
Kil and Paxton [GRL, 2017]

The MSTID distribution derived from ΔN/N shows **semi-annual variation, hemispheric symmetry**, and **highest occurrence rate in the Asian sector during the June solstice in both hemispheres**.

Detection of MSTIDs from CHAMP electron density data

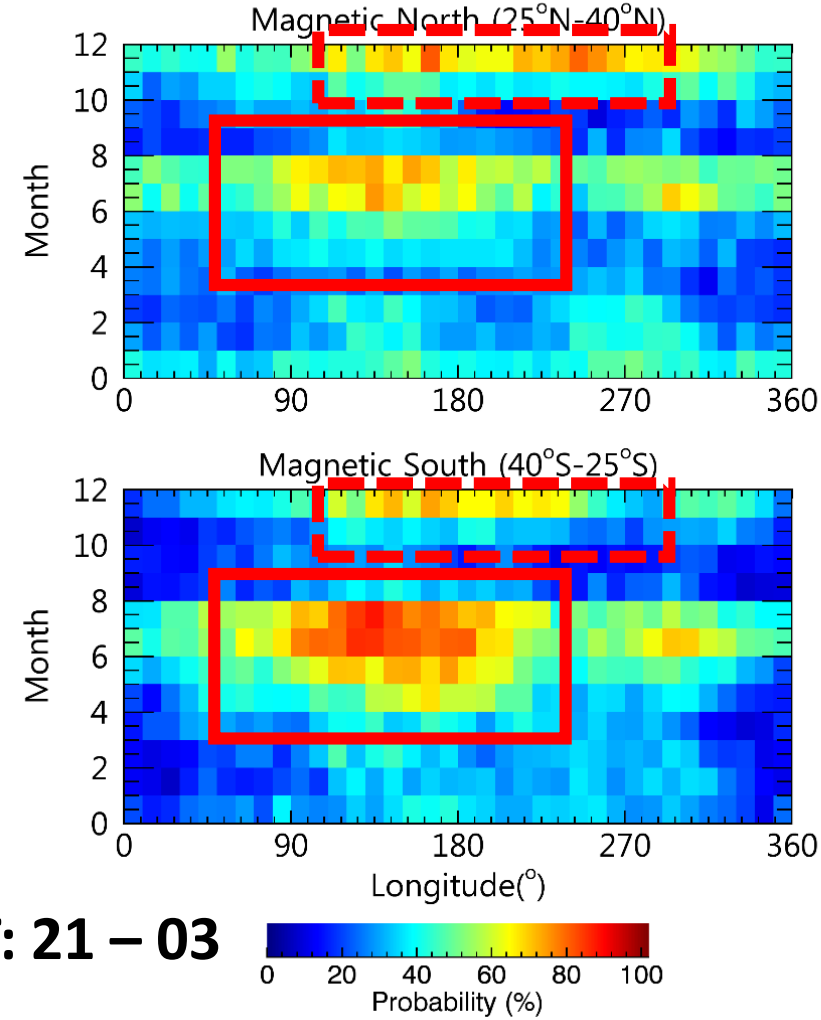


1. Background density: Savitzky-Golay filter
2. ΔN = log (n) – log (SG filter)
3. ΔN/N = ΔN/ log (n)



Seasonal and longitudinal variations of nighttime MSTIDs

CHAMP(2004-2006)



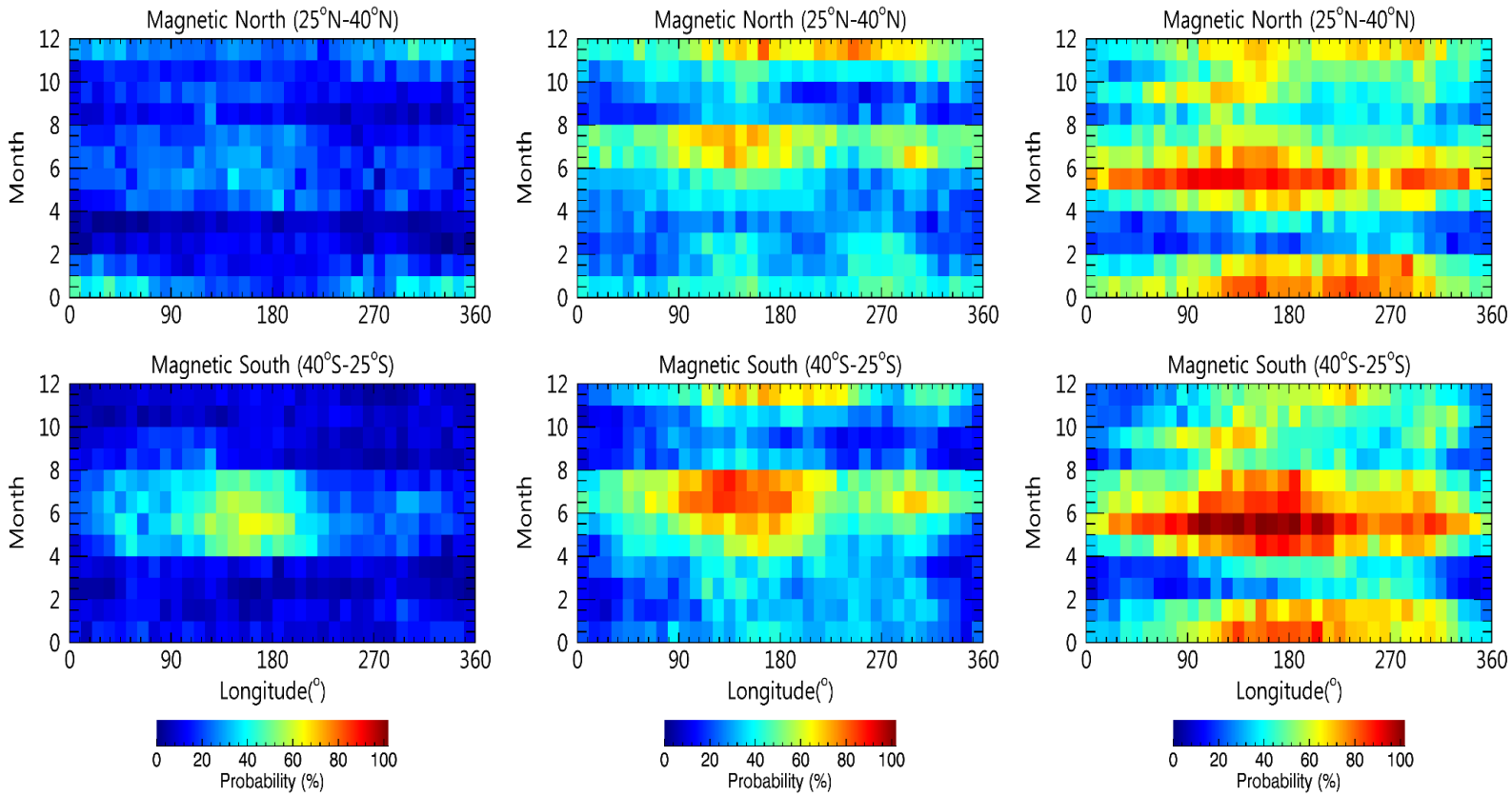
LT: 21 – 03

- **Semi-annual variation** with the primary and second peaks during the June and December solstices
- Highest occurrence rate in the **Asian Sector during the June solstice in both hemispheres**
- **Conjugacy** is the common characteristics of night-time MSTIDs

Solar cycle dependence of nighttime MSTIDs

The occurrence rate of MSTIDs increases with the decrease of the solar flux – consistent with ground-based observations.

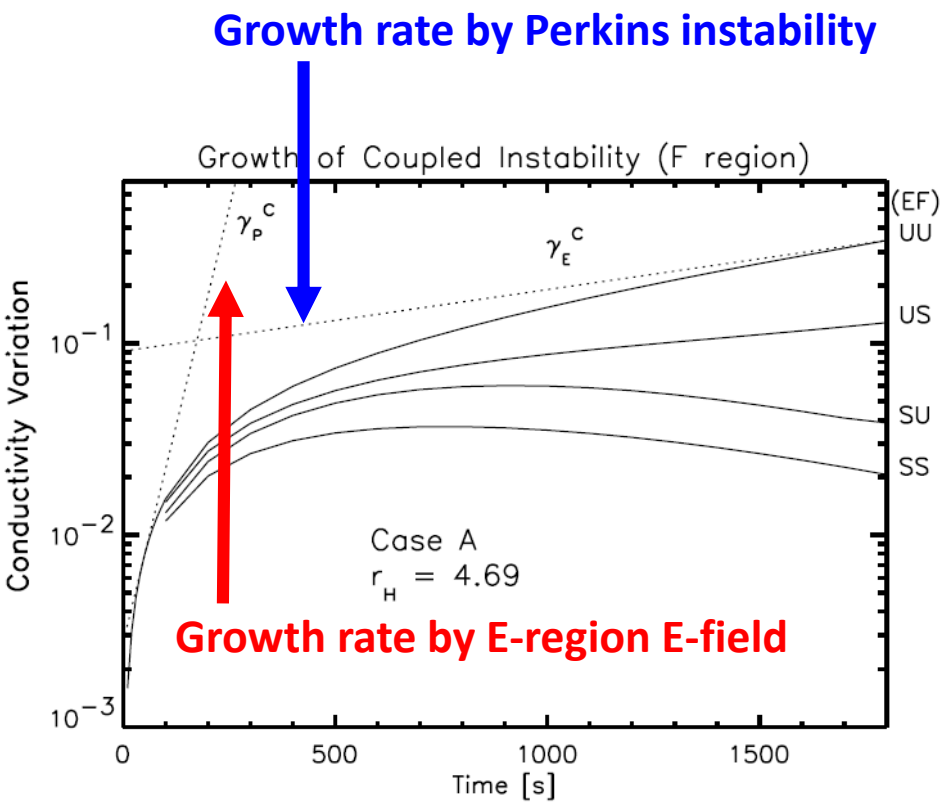
2001-2003 (Smax) 2004 – 2006 2007-2009 (Smin)



What causes distinct seasonal and longitudinal variations of nighttime MSTIDs?

→ Coupling with sporadic E (Es) layer?

Coupling with E region



3D model simulation done by T. Yokoyama (2009)

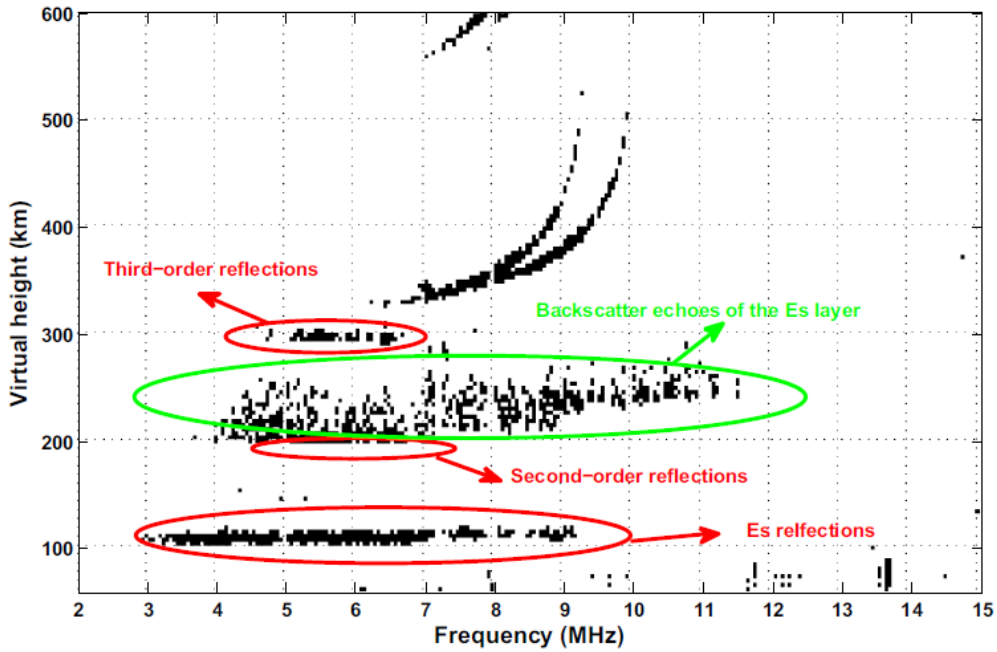
- Growth rate of the Perkins instability is too small to explain observations
- Propagation direction cannot be explained by Perkins instability

→ **Coupling between E- and F –region** (Es-layer instability, Cosgrove and Tsunoda, 2003)

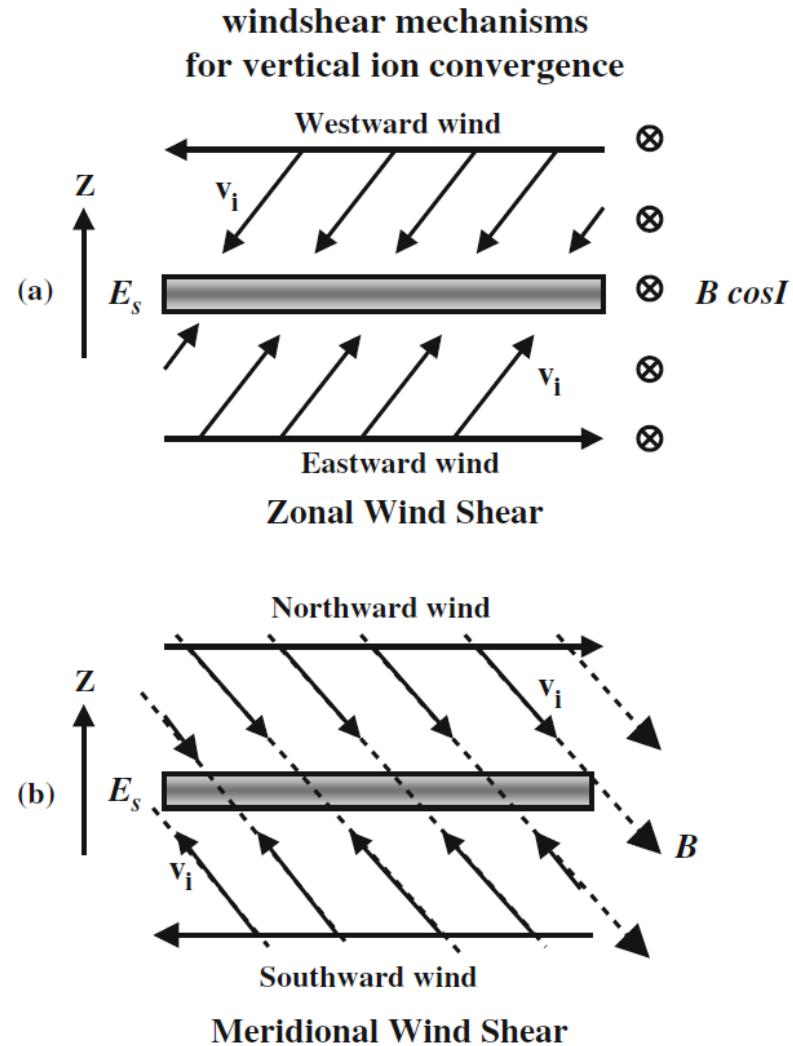
Is Es layer also responsible for longitudinal and seasonal variations of night-time MSTID?

Sporadic E layers

- A thin transient ionospheric layer with high electron density and occurs at 95-120 km altitude.
- convergence of metallic ions by the vertical shear in zonal wind

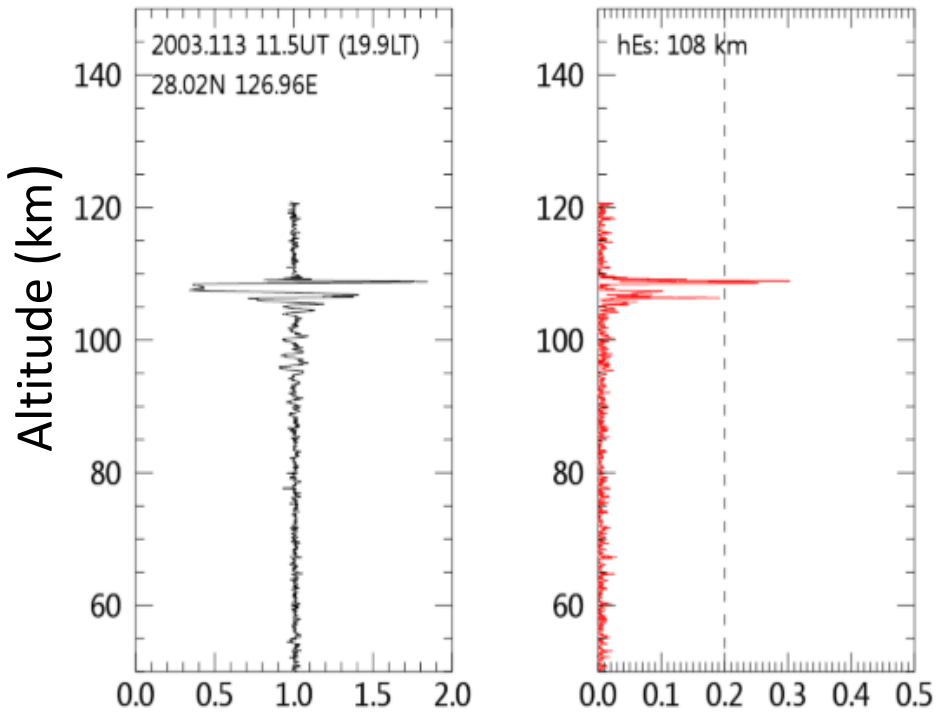


[Jiang et al, 2015]



[Haldoupis, 2011]

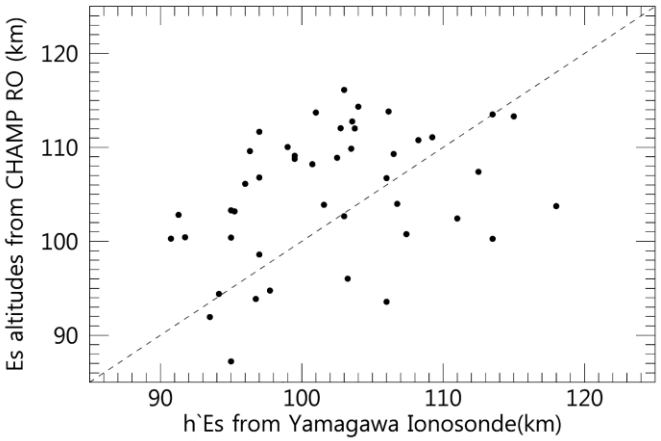
Sporadic E detection from CHAMP GPS RO data



Normalized SNR

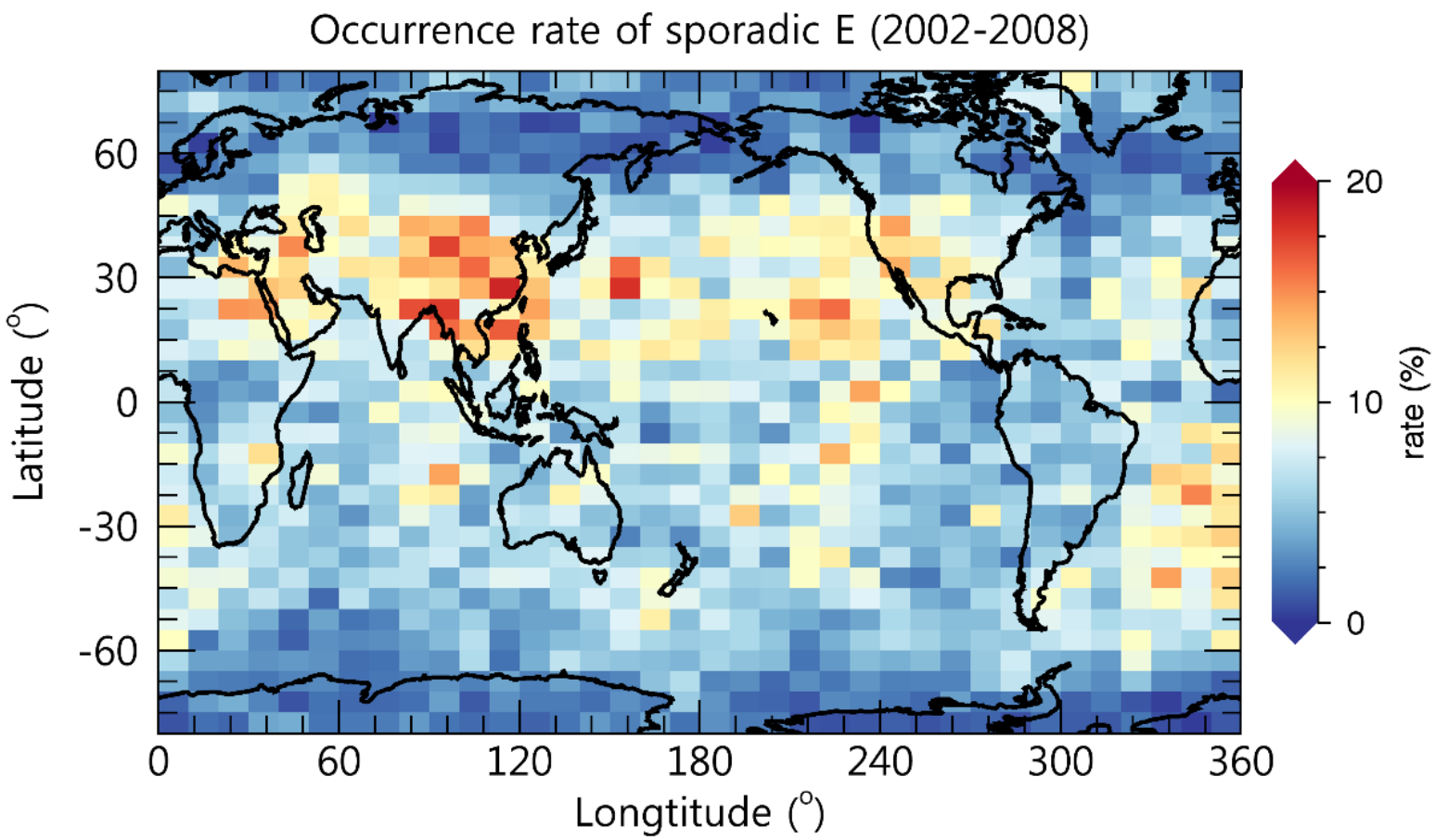
Residuals

- SNR profiles of GPS L1 signal (50Hz, 50-150 km)
- Period: 2002.139-2008.279
- Extract perturbation through normalization and smoothing using high band pass filter
- Threshold: residuals > 0.2

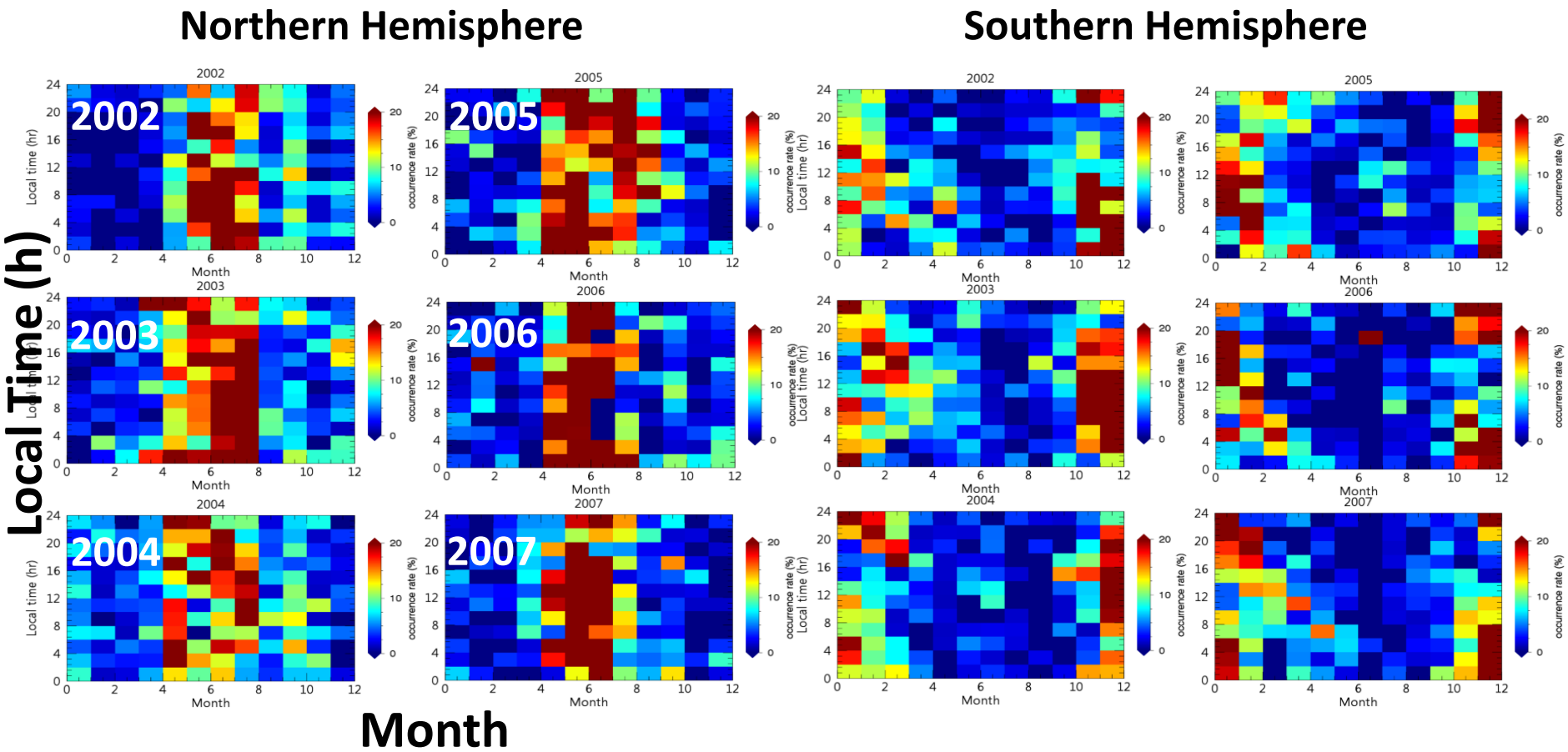


GPS RO vs. Ionosonde

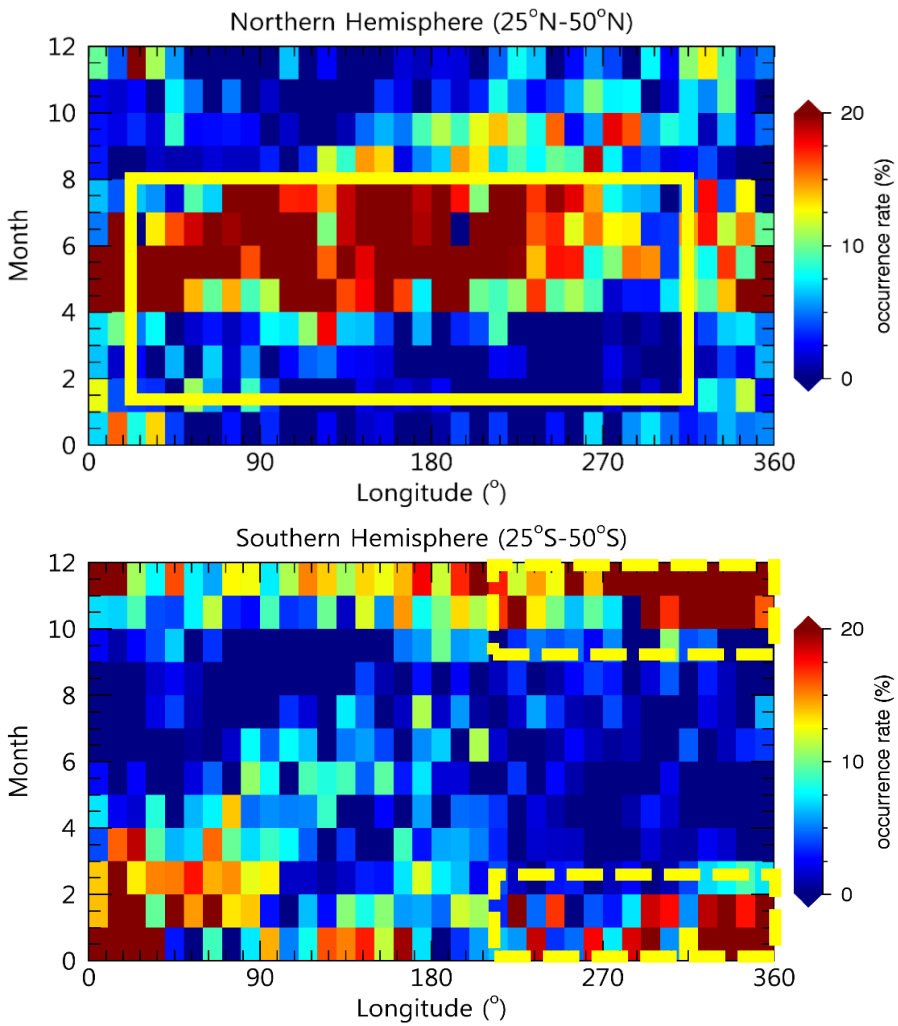
Global distribution of Es occurrence



- Used data at ±25°–50° magnetic latitude
- Sporadic E occurs preferentially during summer months
- No pronounced solar cycle dependence
- Local time dependence is not obvious



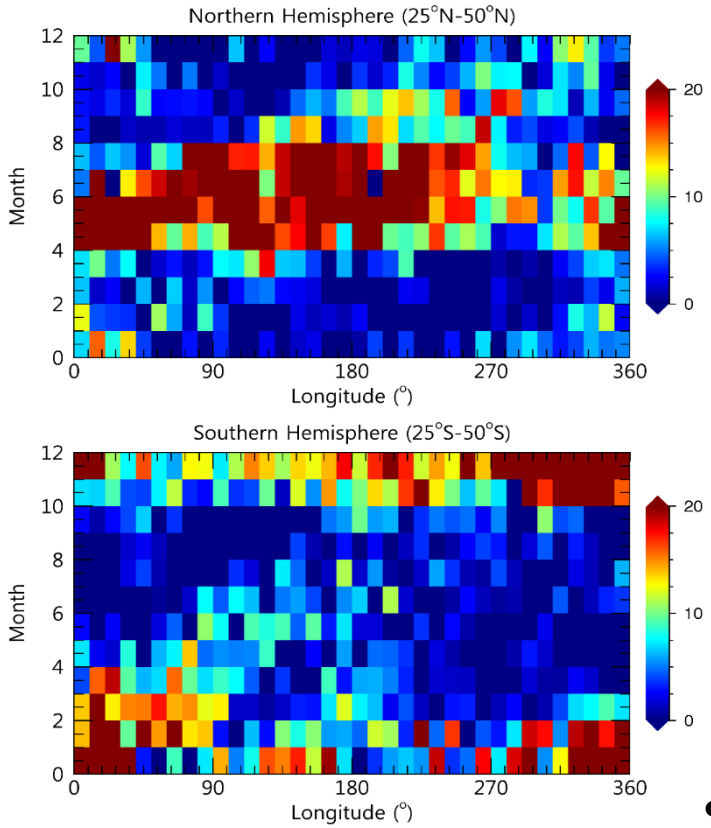
Seasonal and longitudinal variations of Es occurrence



LT: 18 – 06

- High occurrence rate in the summer hemisphere
- Highest occurrence rate in the **Asian (American) Sector during the June (December) solstice**

Comparison with MSTID distribution



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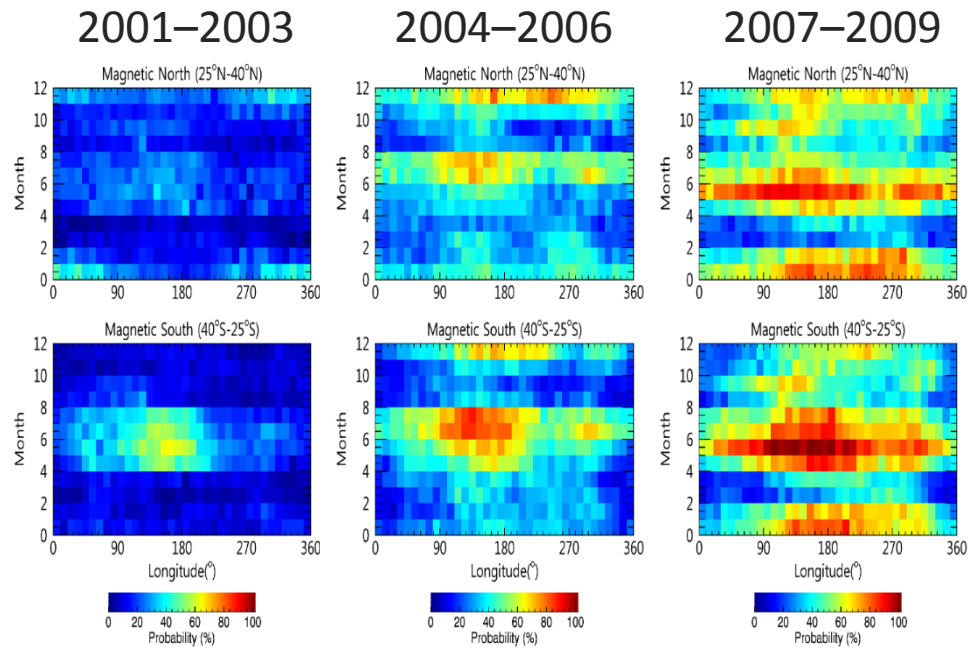
MSTIDs



- Consistent features:
  Seasonal variation, longitudinal variation
- Inconsistent features:
  Solar cycle dependence, hemispheric distributions, longitudinal variation

Conclusions and future works

- **Nighttime MSTIDs** shows clear seasonal and longitudinal variations : highest occurrence rate in **Asian sector during the June solstice in both hemispheres**
- Es is dominant in summer hemisphere. The occurrence rate of Es has a major peak in Asia during the June solstice and in America during the December solstices
- **Longitudinal and seasonal variation of MSTID activity could be related to the E- and F –region coupling process.**
- We will further investigate the sporadic E distribution by using other observation data (COSMIC).
- The effect of sporadic E and thermospheric conditions on the development of MSTID and conjugacy will be investigated by conducting model simulations.