

# Hemispheric and Annual asymmetry observed from Formosat-3/COSMIC Radio Occultation observations

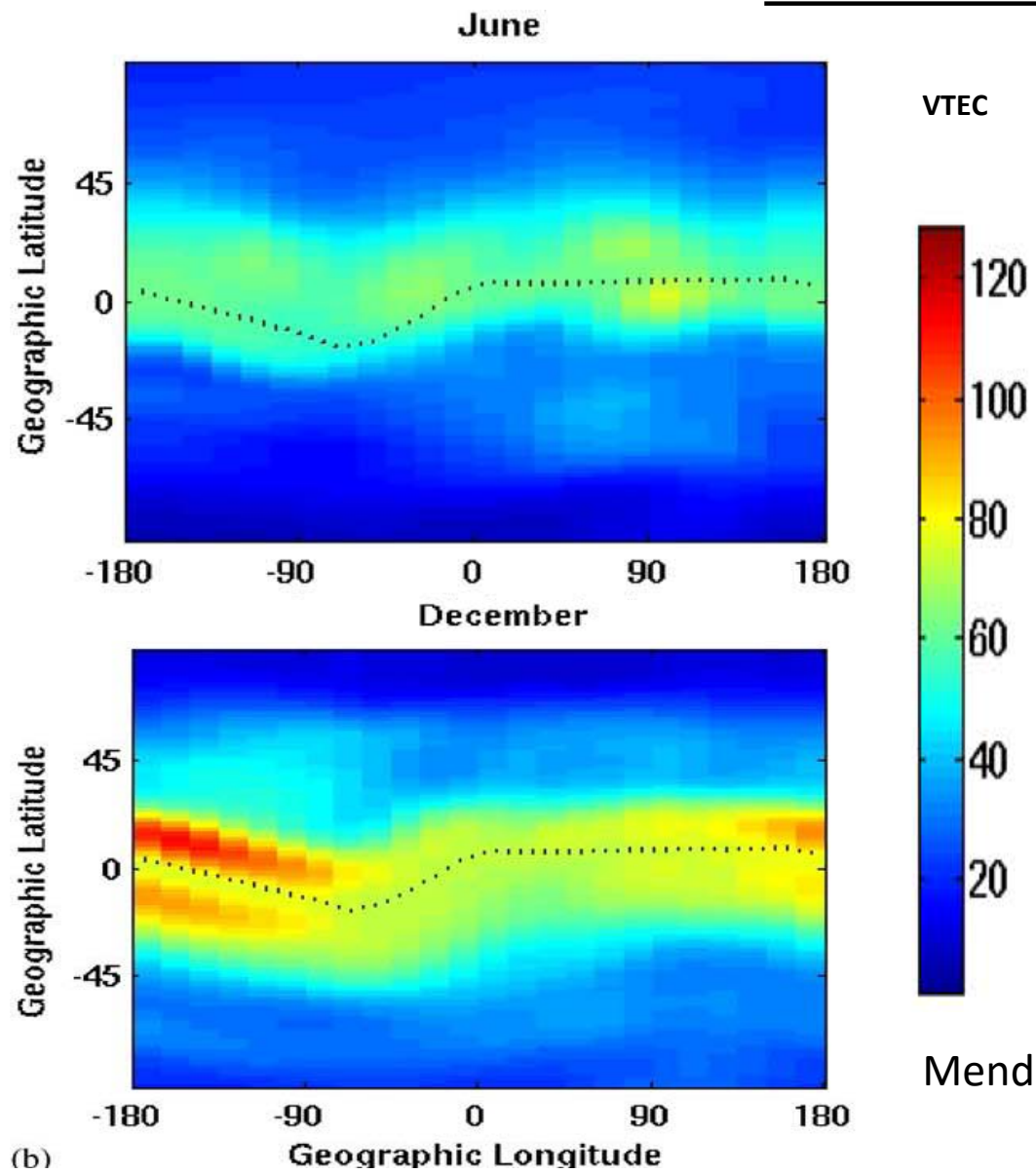
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International Beacon Satellite Symposium (IBSS) – 2016  
June 27 – July 1, 2016, Trieste , Italy.

# Annual anomaly/asymmetry



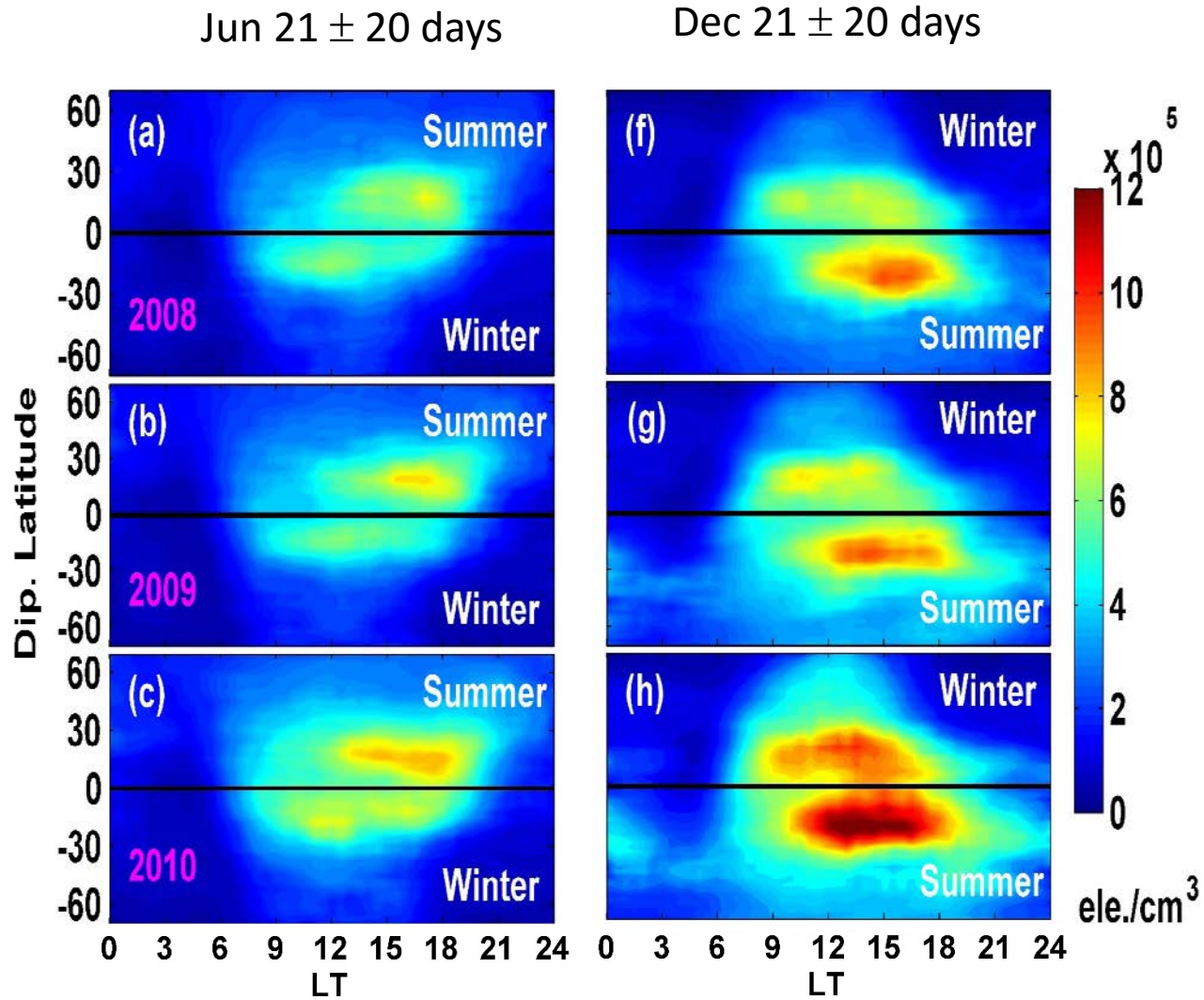
Being one of the top scientific targets of the ionospheric community [H. Rishbeth, 2007], explanation for the Annual asymmetry is still a long-standing puzzle.

The ionospheric annual anomaly or annual asymmetry is characterized by substantially larger ionization in December solstice than in June solstice.

Why is there more ionosphere in December - January than in June - July?

Mendillo et al., 2005

# Formosat-3/COSMIC GPS RO – NmF2:



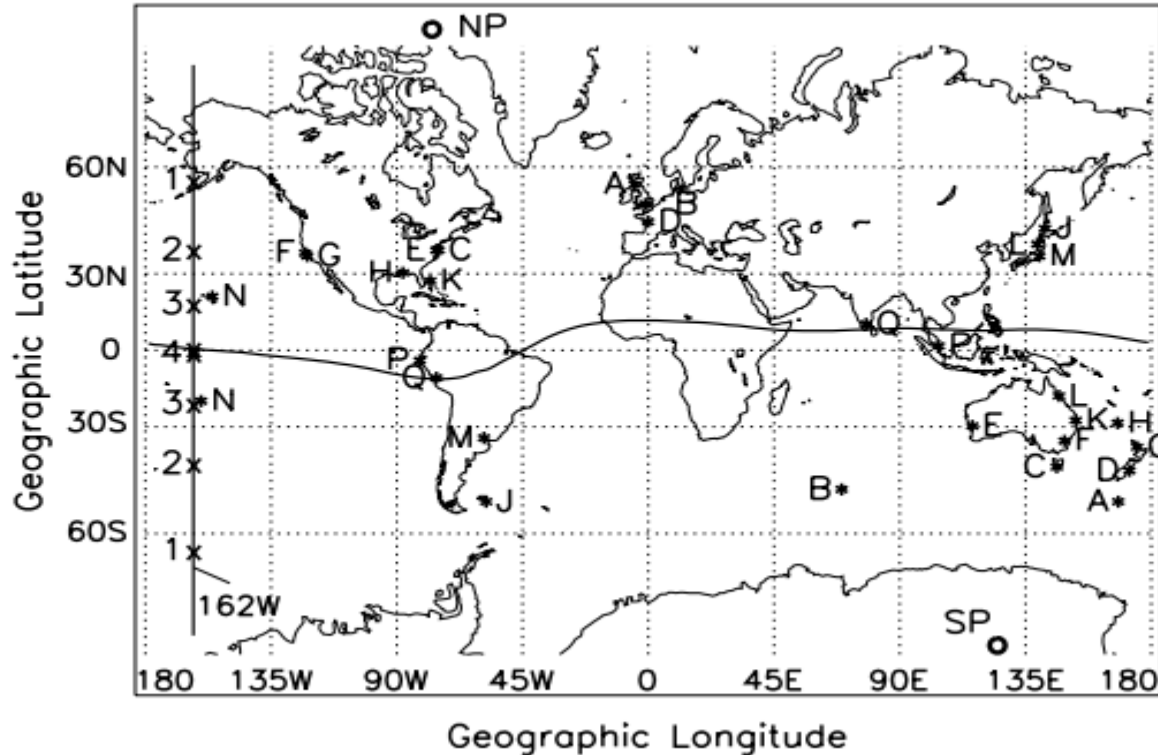
F10.7 solar flux

Year	F10.7 Jun	F10.7 Dec	F10.7 Dec-Jun
2008	67.9610	67.0250	-0.963
2009	70.9415	74.5732	3.6317
2010	75.5951	82.2400	6.6449

## Previous studies:

Annual asymmetry has been studied using the NmF2 data from paired ionosonde stations, the total electron content (TEC) data from a worldwide network of GPS stations.

### Station Pairs



## Annual Asymmetry Index

$$NmF2_{NS}(\theta, \lambda) = \frac{1}{2} \cdot [NmF2(\theta_N, \lambda) + NmF2(\theta_S, \lambda)]$$

$$AI = \frac{NmF2_{NS}(\text{Dec}) - NmF2_{NS}(\text{Jun})}{NmF2_{NS}(\text{Dec}) + NmF2_{NS}(\text{Jun})}$$

-- Rishbeth and Muller-Wodarg [2006]

# Annual Asymmetry Index

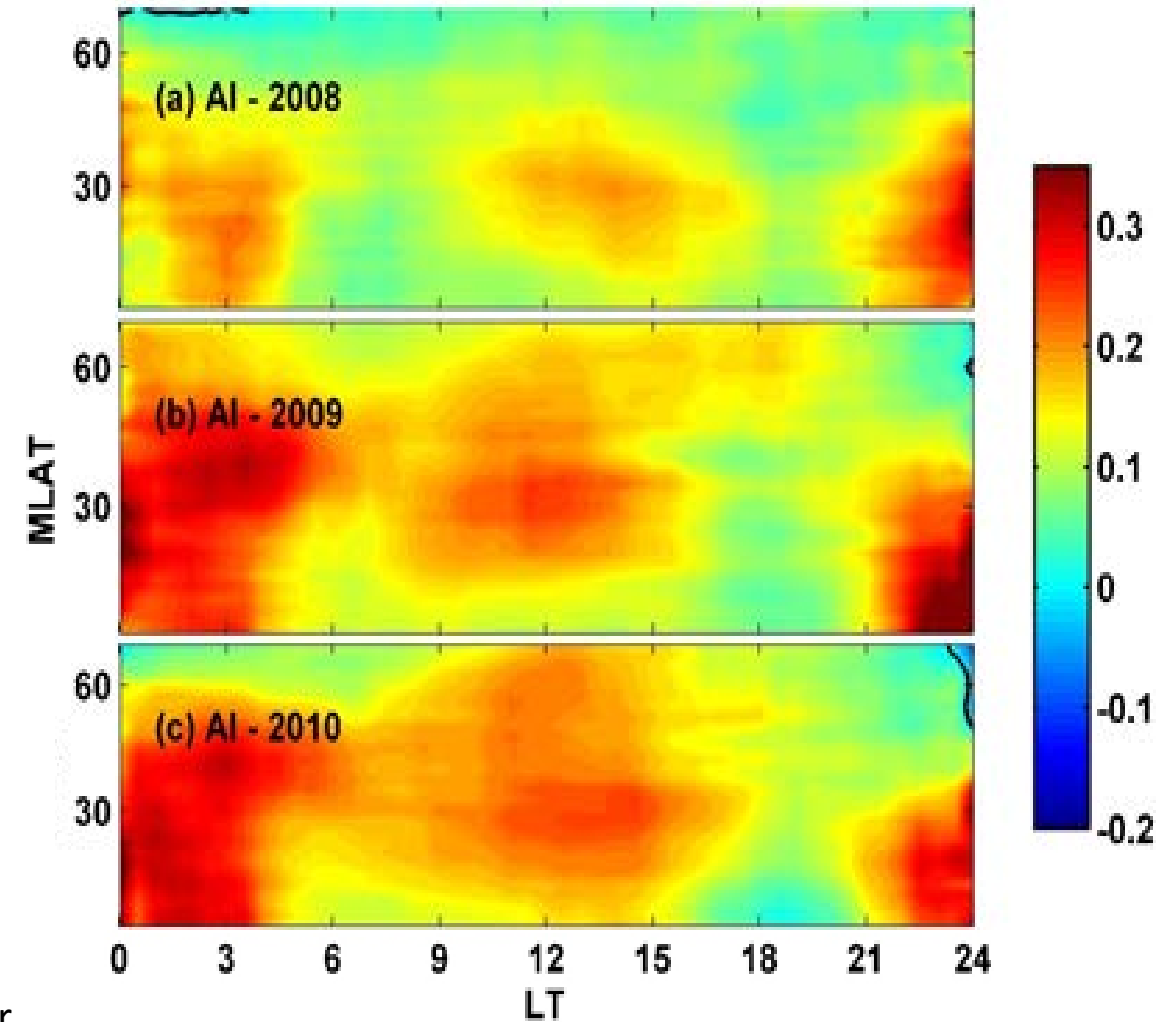
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Global Mean AI

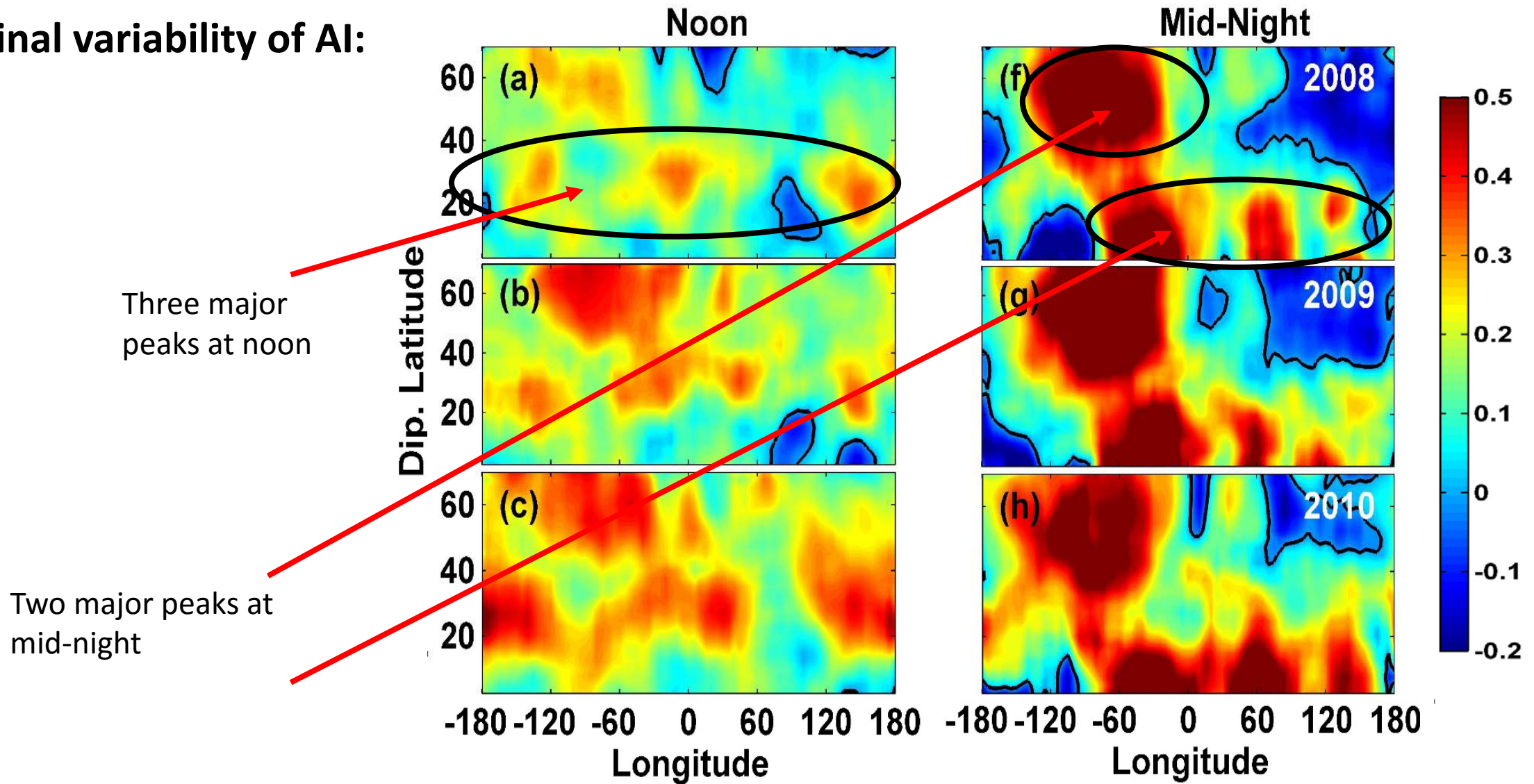
Year	Noon	Mid-night	Total
2008	0.14	0.18	0.16
2009	0.20	0.22	0.21
2010	0.24	0.25	0.24

e.g., AI = 0.2 means 50% higher in December  
0.3 means 66% higher in December

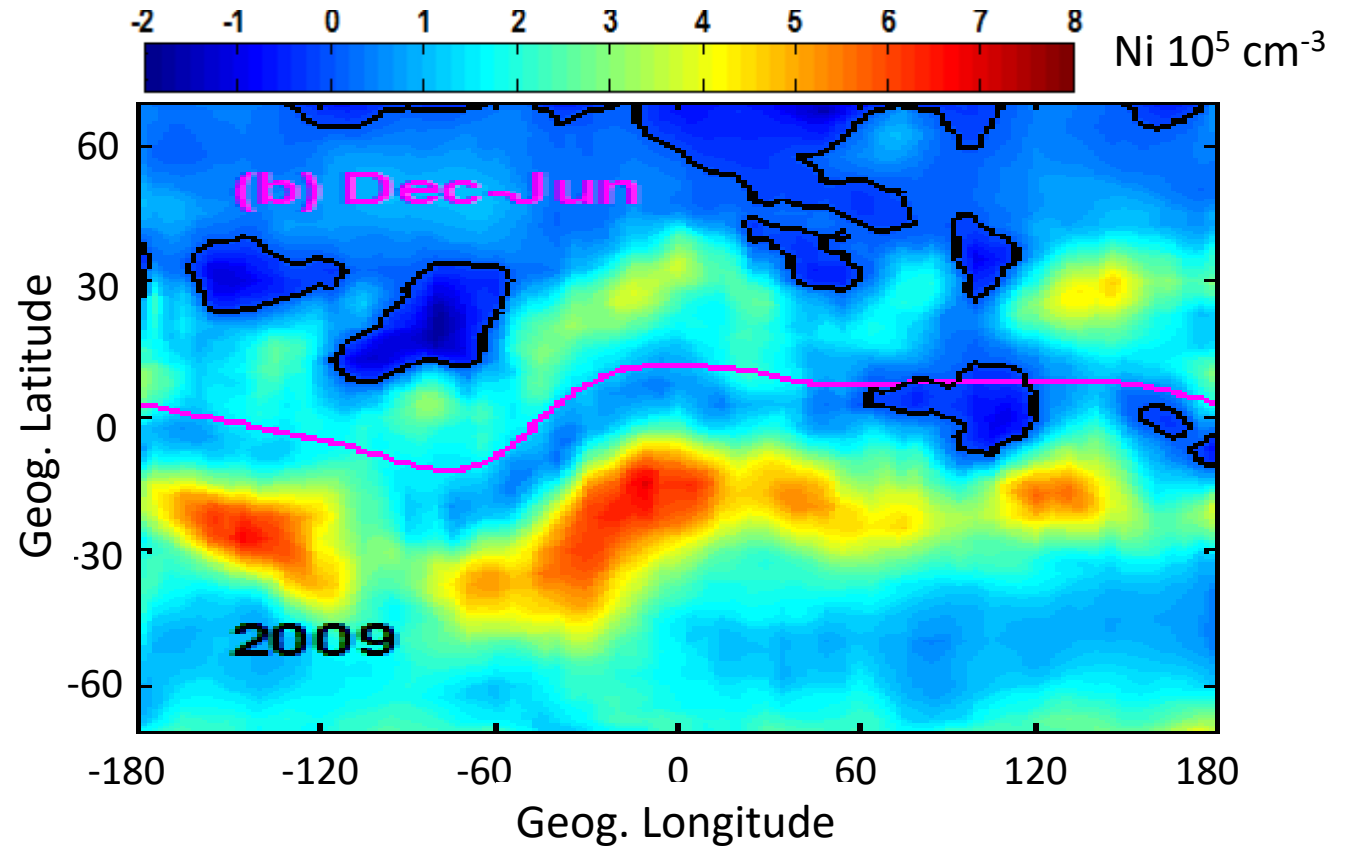
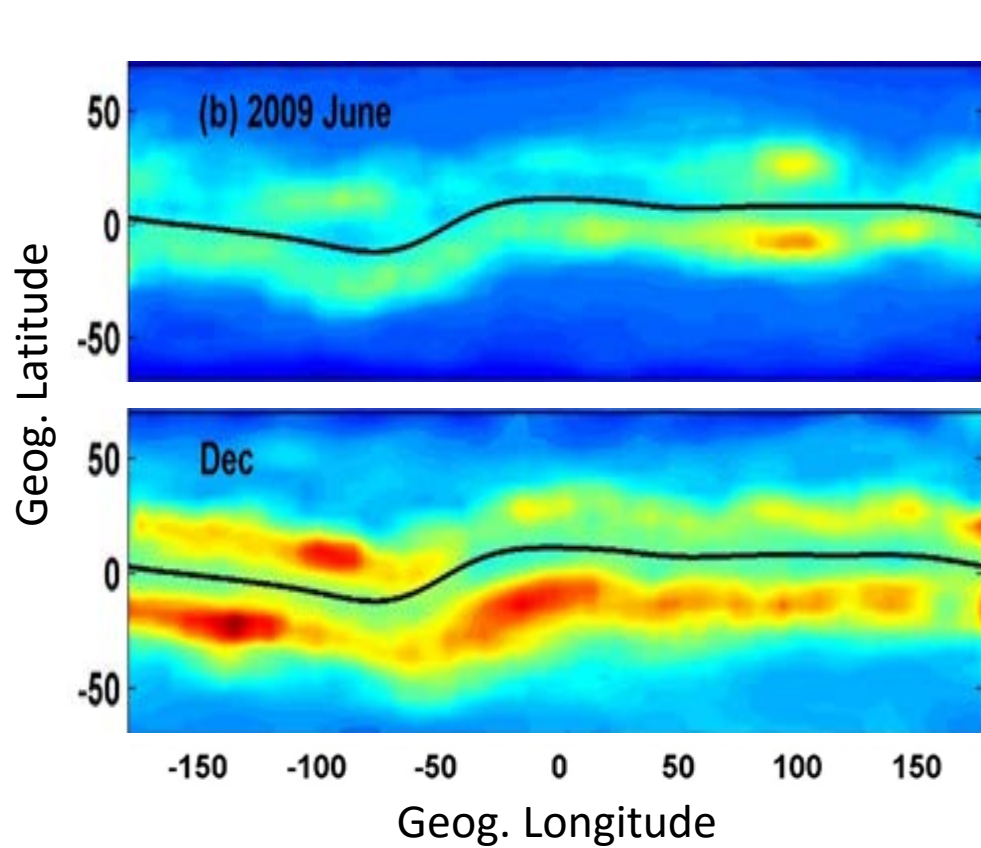




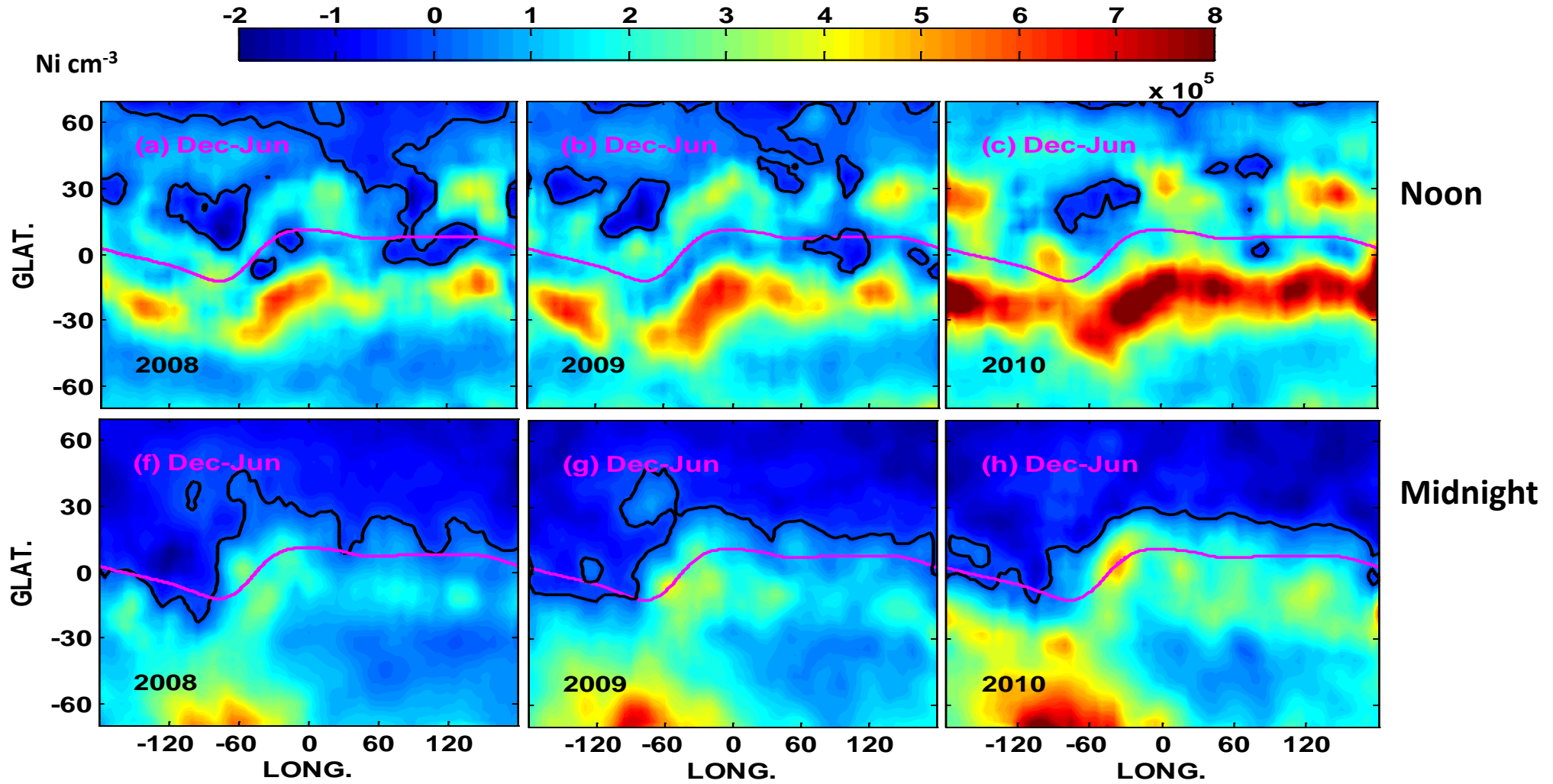
# Longitudinal variability of AI:



# Longitudinal Variability



# Longitudinal variability of $\Delta NmF2$ ( $NmF2_{DEC} - NmF2_{JUN}$ ):

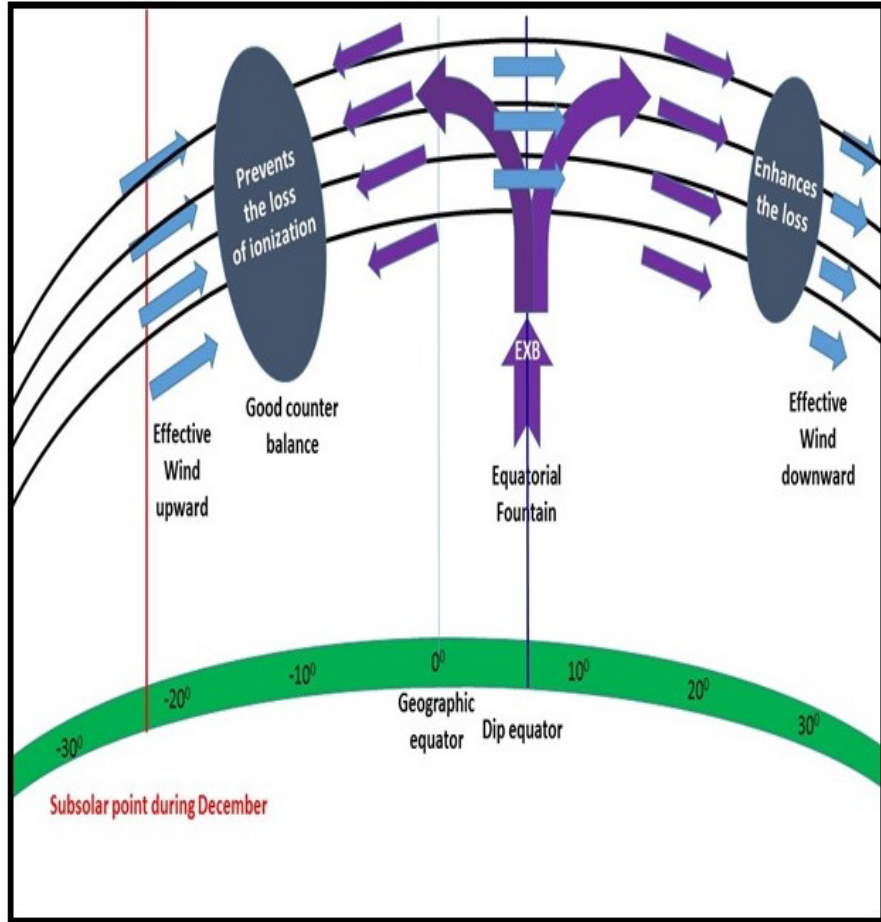




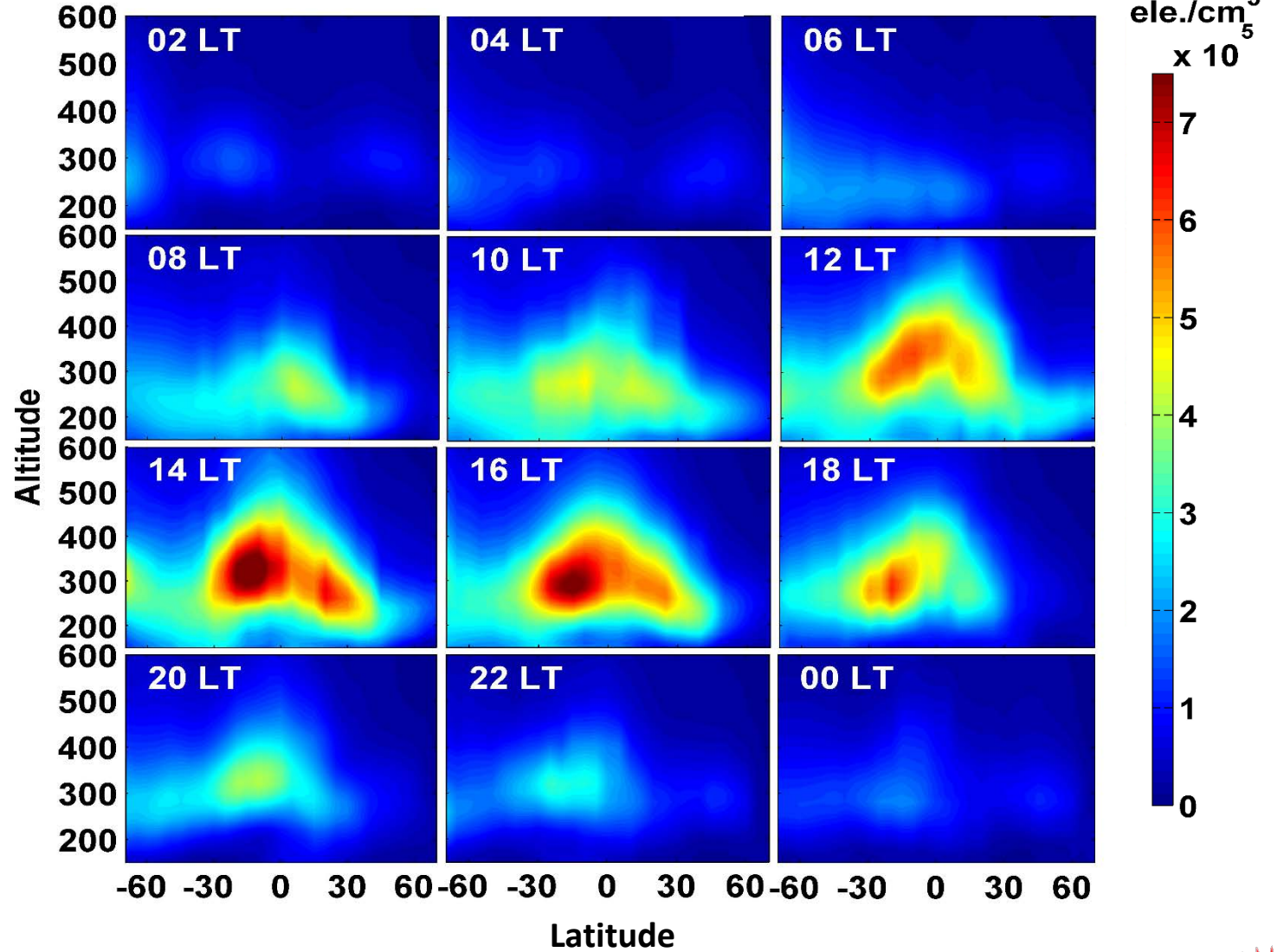
# Possible mechanisms:

- Quite complex due to several responsible factors
  1. Varying Sun-Earth distance (0.983 AU in December, 1.017 AU in June)
  2. Transequatorial neutral winds
  3. Geomagnetic field configurations
  4. Proximity between sub-solar point and geomagnetic equator
  5. Tidal forcing from lower atmosphere

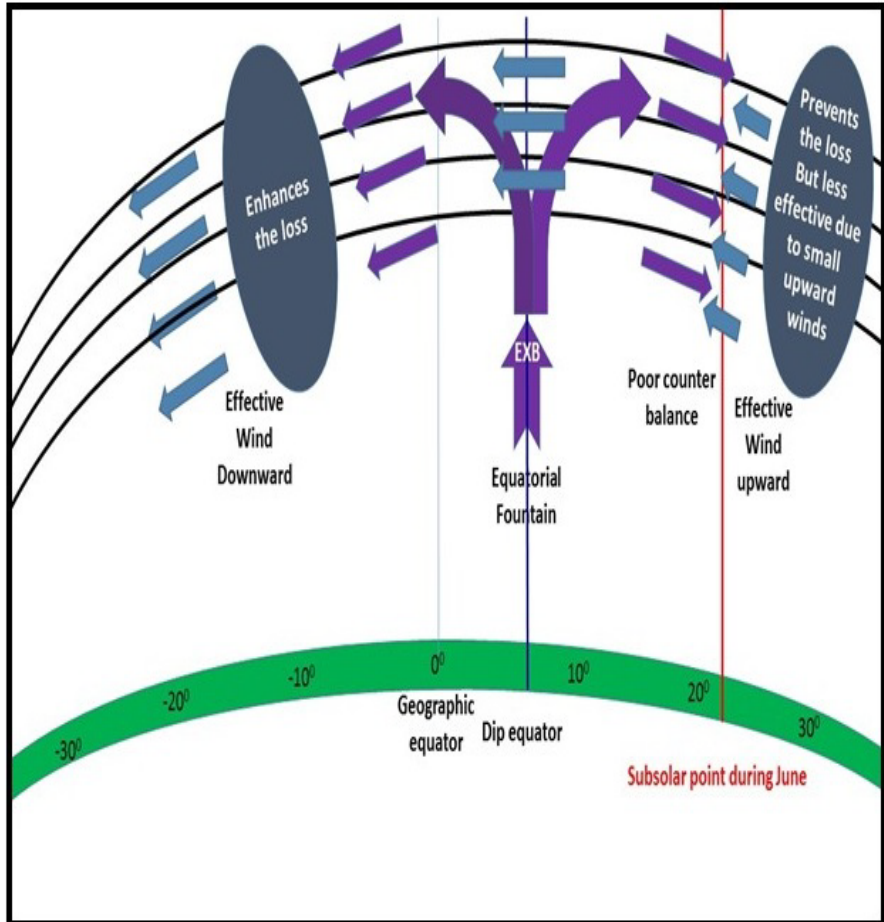
# December



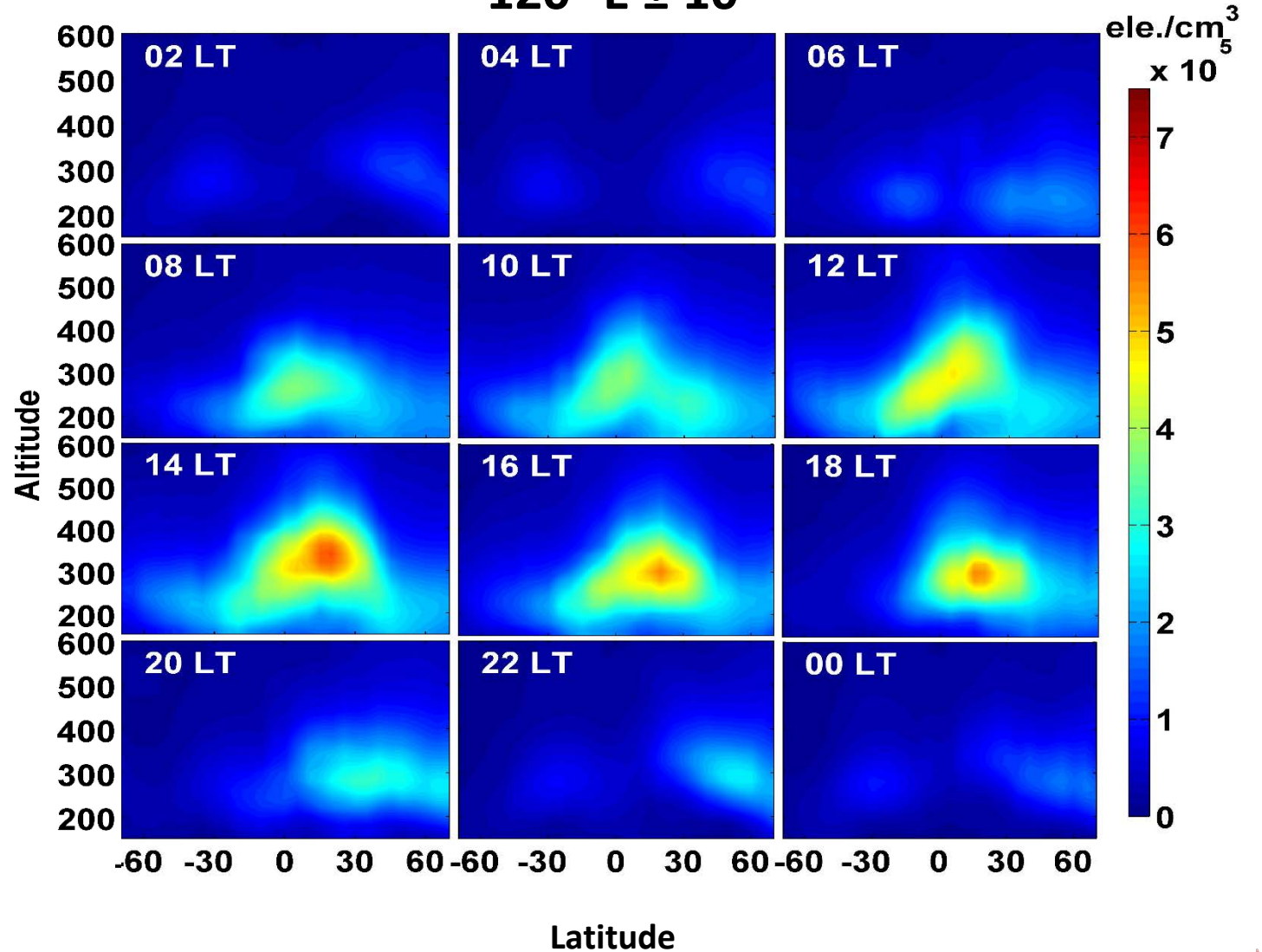
120° E ± 10°



# June



## 120° E ± 10°





# Effective Neutral Wind

Noon Time

Titheridge 1995

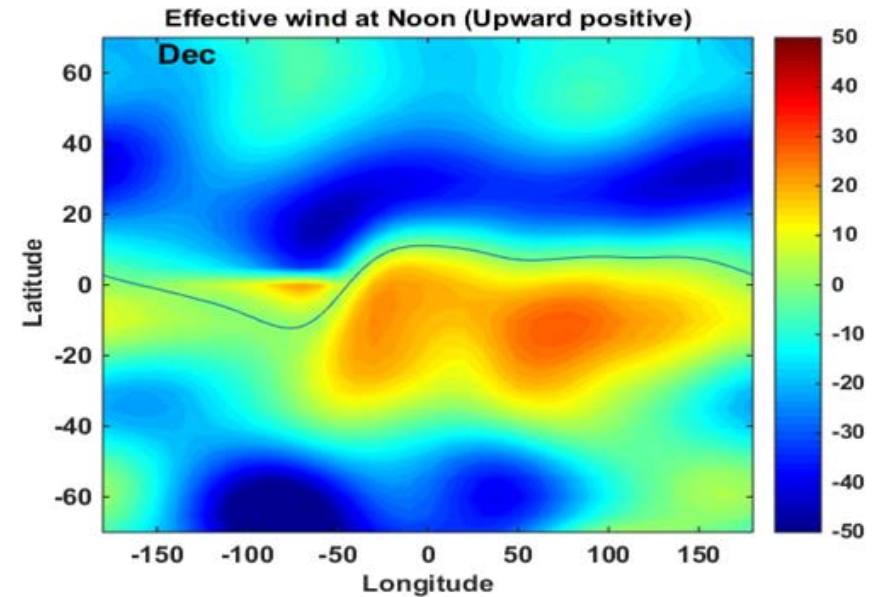
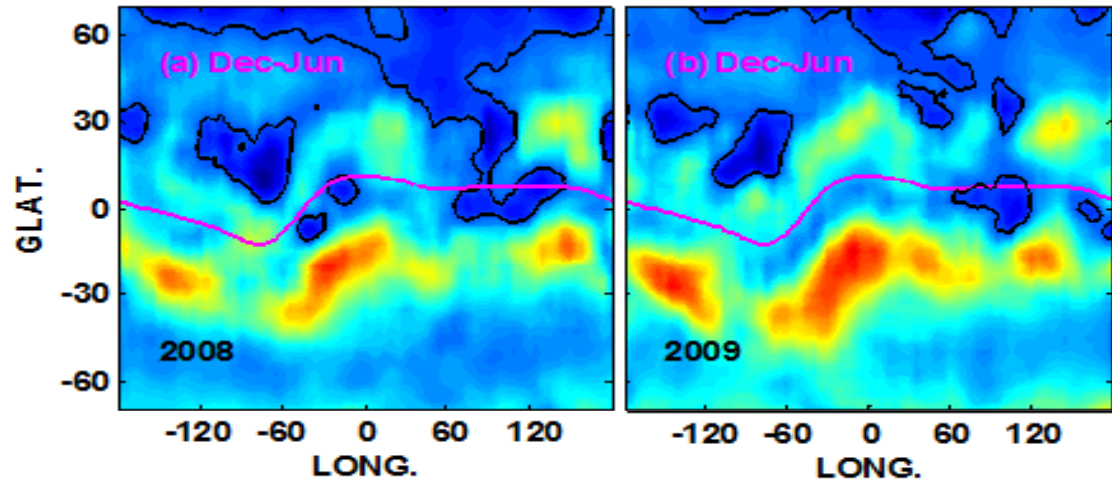
$$W_{\text{eff}} = (V \cos D \pm U \sin D) \cos I \sin I$$

V – Meridional wind (equatorward positive)

U – Zonal wind (eastward positive)

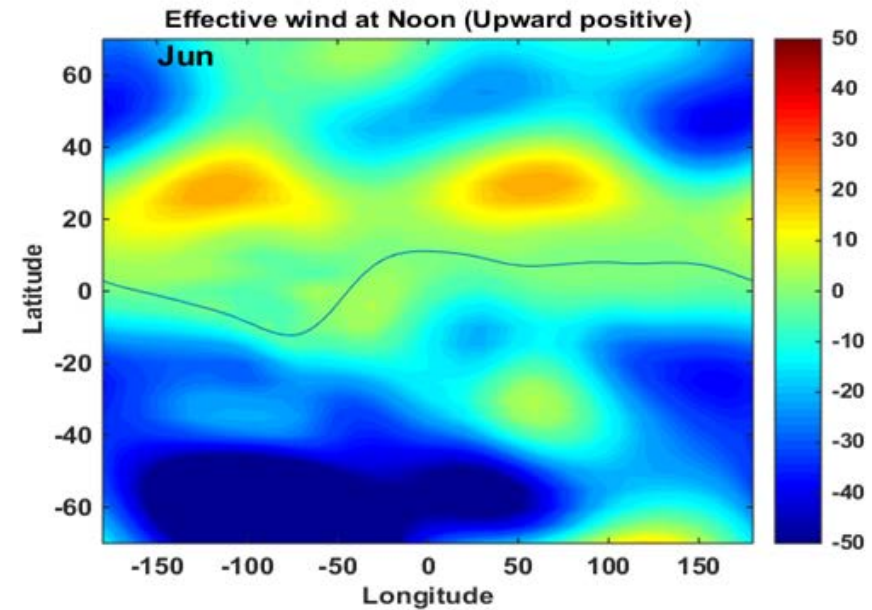
I – Inclination angle

D – Declination angle



HWM 07

December

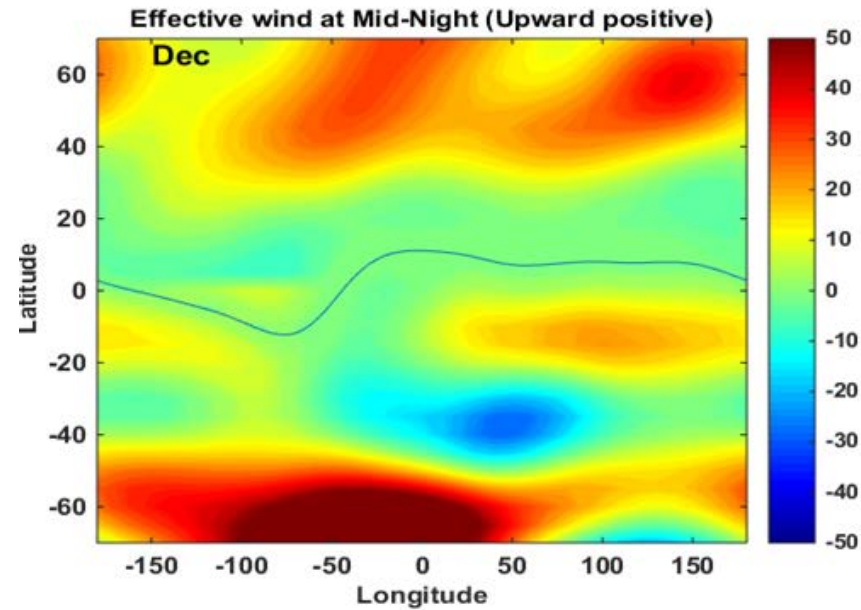
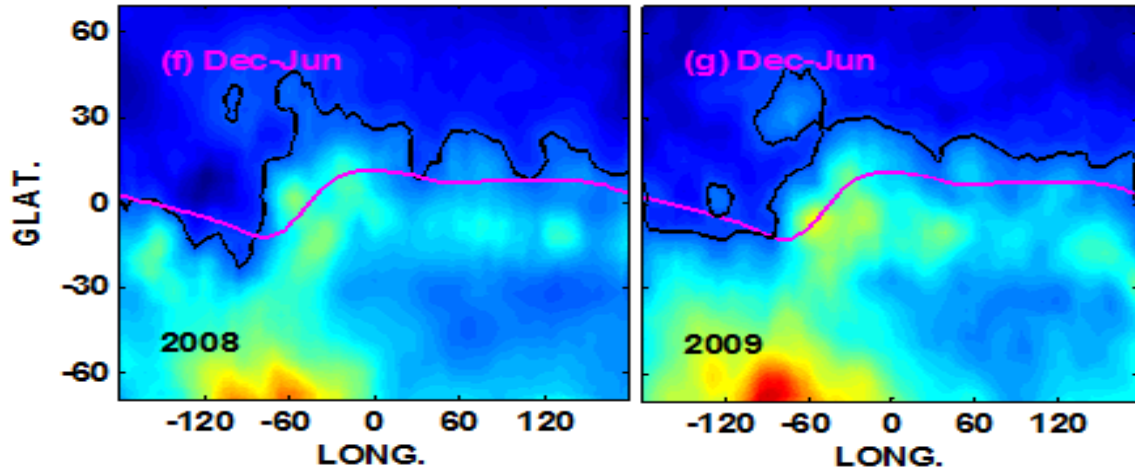


June



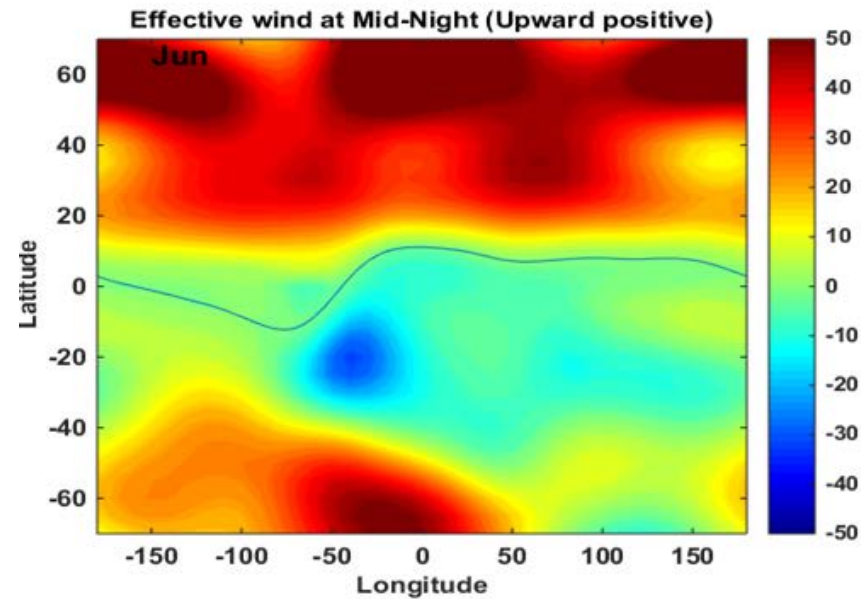
# Effective Neutral Wind

Mid-night



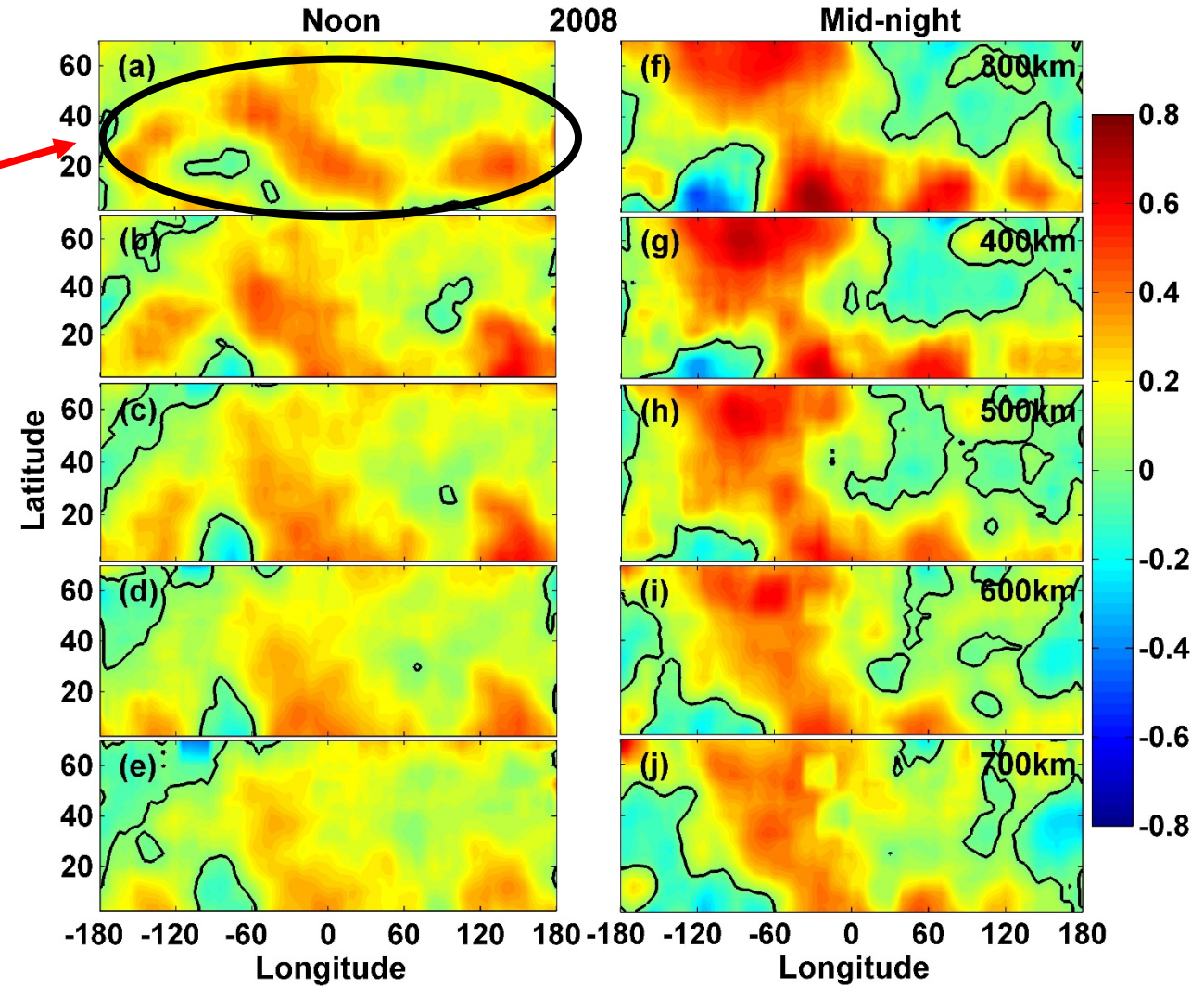
HWM 07

December



June

# AI at different heights (COSMIC ionprf data)



Three peaks structure is constitutently observed at all heights

Why these three peaks?  
Role of ExB and Tides?  
Still need to investigate...

# Conclusions

- The Annual Asymmetry is caused by several influencing factors.
- The varying Sun-Earth distance and the Tidal forcing from lower atmosphere contribute only to a smaller extent

The major part of the Annual Asymmetry caused by,

- The offset between the sub-solar point and the geomagnetic equator and transequatorial neutral winds during day time
- The effective thermospheric neutral winds plays a major role during night times.

# Acknowledgement

- The work of Tulasi Ram is supported by Department of Science and Technology (DST) through India-Taiwan Science and Technology cooperation project (GITA/DST/TWN/P-47/2013).
- The Formosat-3/COSMIC RO data is obtained from UCAR-CDAAC (<http://cosmic-io.cosmic.ucar.edu/cdaac/index.html>).



Thank you...!