Daytime seasonal variation of Longitudinal structures of electron density and temperature measured with DEMETER satellite

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Introduction: observations of longitudinal structure

- Air glow [Sagawa et al., 2005; Immel et al., 2006]
- Equatorial electro jet [England et al., 2006]
- Total electron content [Scherliess et al., 2008]
- Plasma drift [Kil et al., 2007]
- Neutral wind at lower thermosphere [Forbes et al., 2003]
- Ne profile obtained by radio occultation [Lin et al., 2007]
- In-situ plasma observation [Liu & Watanabe 2008]
- Neutral density [Liu et al., 2009]
- Ne in the top side ionosphere [Bankov et al., 2009]
- Etc…

Many observations have confirmed the wave-4 longitudinal structure

[Lin et al., 2007]
Motivation

- Longitudinal structures of Te & Ne in the topside ionosphere have been reported by Ren et al. [2008]
  - However, …
    - Using 11 years integrated data of DMSP(800km)
    - Data were divided into 4 season
    - They concluded that Te variation is related to in-situ Ne variation

- Therefore, these results might be included solar activity variation

- Further, we confirm detail of seasonal variation of longitudinal structure of Ne & Te

- We found the evidence Te in the topside ionosphere does not necessary correlate with in-situ Ne
Seasonal variation observed by DEMETER ~ Ne

- Maximum Ne is high around magnetic equator in December sol. & low in June sol. due to seasonal variation of O/N₂
- Ne in summer hemisphere is higher than that in winter hemisphere due to neutral wind
- Longitudinal structure has seasonal variation
  - Wave-4: May-Oct.
  - Wave-3: Nov.-Apr
Seasonal variation observed by DEMETER ~ Te

- Te generally shows negative correlation of Te
- Minima of Te are high around magnetic equator during Jul.-Aug. & low during Oct.-May due to Ne variation
- However, it does not correspond exactly
- Longitudinal variation
  - Wave-4: Jul.-Sep.
Ne & Te in the magnetic equator (|dip Lat.| < 5)

- Maximum of Ne are seen around 90, 190, 250 and 330 °E
  - 190°E: high during Aug.–Mar.
  - 330°E: low during Sep.–Apr. and almost disappears during May–Aug.
- The minima of Te are seen around 90, 190, 250, and 330°E.
  - 90°E: not always the lowest
  - 190°E: Feb.–Sep.
- Although the maximum of Ne at 190°E is larger than the other maxima of Ne during
- Te variation does not correspond to Ne exactly

![Fig.8](image-url)
Wave number of Ne & Te in the magnetic equator

- Ne
  - Since one or two peaks are more pronounced than other small peak, wave-1 or -2 are always pronounced

- Te
HINOTORI

- Japanese satellite
- 23 Feb. 1981-14 June 1982
- Solar activity: maximum and medium
- Latitude: -32°~32°
- Height: 576~644 km
- Electron Density (Ne) & Temperature (Te)
- All LT range

Fig. 2

Impedance Probe [Oya, et al., 1986]
Electron temperature Probe [Hirao and Oyama, 1970]

[Kakinami et al., 2008]
LT variation observed by HINOTORI

1. Median during July-October under Kp<4
2. LT=0900-1100
3. Wave-4 like structure can be seen
4. Near the magnetic equator, correlation between Ne & Te is negative
HINOTORI ~LT variation observed by HINOTORI(2)

- The same condition of Fig. 4 but different LT
- LT=1300-1500
- 4 maxima of Ne are seen
- Peak Ne are shifted to eastward
  - Basic feature of nonmigrating tide of wave number 4 (DE3)
- In the magnetic equator, correlation between Ne & Te is positive
Discussion

- Seasonal variation of wave-3/-4 structure of Ne & Te is similar to DE2/DE3 zonal wind at dynamo region
- However, seasonal variations of Ne & Te show discrepancy
- Cause of Ne variation
  - Electric field which produces the fountain effect is modulated by zonal wind [Jin et al., 2008]
  - Ne in the topside is also affected by meridional wind in the topside ionosphere [Watanabe & Oyama, 1996]
- Cause of Te variation
  - Heat conduction is dominant in the top side ionosphere
  - Te is correlated with integrated Ne along the magnetic field line below the satellite height in the topside [Kakinami et al., 2011 submitted to JGR]
  - Therefore, lower ionosphere condition might reflect Te in the topside ionosphere
  - Meridional wind might produce the discrepancy

DE2/3: eastward propagating diurnal tide with wave number 2/3
Summary

- Longitudinal structure (wave-3/-4) are seen during both low and high solar activity
- Wave-3/-4 of both Ne & Te are seen when zonal component of DE2/DE3 is enhanced
- One of 4 or 3 Ne peaks are pronounced
  - Only Strong fountain effect which can reach the satellite height can be detected
- Discrepancy between Ne & Te
  - Ne May-Oct. (wave-4) Nov.-Apr. (wave-3)
  - Maximum of Ne often appear around 190 deg.
  - Minimum of Te often appear around 90 deg.
  - Therefore, cause of longitudinal structure is different between Ne & Te
- In the topside ionosphere, correlation between Ne & Te is not always negative
  - The correlation is positive when Ne is significantly high
- Ne easily affected by meridional wind
- Therefore, Te is a better indicator for nonmigrating tidal effect at topside ionosphere than the Ne.
Discussion (2)

- Positive correlation between Ne & Te
  - No significant seasonal variation
  - Magnetic latitude dependency

[Hinotori@600km]

Each line indicate magnetic latitude region

[Lei et al., 2007]
Discussion (3)

- Each symbol indicates the same Ne region.
- $T_e$ decreases with increasing magnetic Lat. during daytime when Ne is the same region.
- $T_e$ does not fully depend on in-situ Ne but rather integrated Ne.

Integrated Ne along field line between 0 and 600 km below the satellite height.
Discussion (2)

- December solstice
- March equinox
- June solstice
- September equinox
DEMETER

- French satellite
- Detection of Electro-Magnetic Emissions Transmitted from Earthquake Regions
- January 2004
- Solar activity: low
- Magnetic field, Electric field (DC to 3.25MHz), Te & ion temperature (Ti), Ne & ion density (Ni), ion velocity, electron spectrum (> 30 KeV)
- Inclination: 98°, sun-synchronous (1030, 2230 LT)
- Altitude: ~710 km, 660 km after December 2005
- In this study, data in 2006 & 2007 are used