

Searching for topside ionospheric structures in multi-instrumental studies.

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Outline

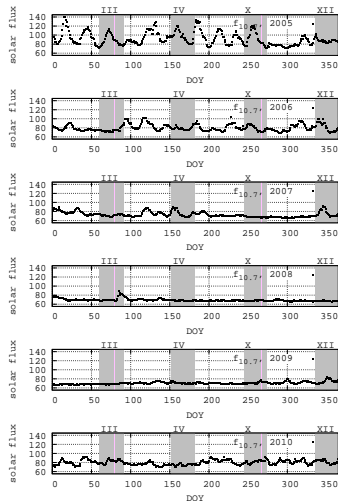
- Motivation
- Data overview
- Methodology and proposed approach
- Results
- Summary

Motivation

Focal point: Set of data acquired by the French micro-satellite DEMETER. More than 6 years of operational data provides:

- consistent set representing the topside ionosphere;
- multi-instrumental in-situ measurements, performed in equal external conditions;
- measurements in the period of the deepest solar minimum;
- reliable set of data, crucial for accurate estimation of the ionospheric background for various types of case studies.

Figure: Daily averaged solar flux (<http://omniweb.gsfc.nasa.gov>)



Goals and Adressed Questions...

- 1 What is typical “picture” of various ionospheric parameters measured by the DEMETER satellite?
- 2 What is the global morphology of T_e and T_i for the topside ionosphere? (More precisely at the altitude of the DEMETER satellite)
- 3 How this pattern is affected by changing solar conditions?

Briefly about DEMETER

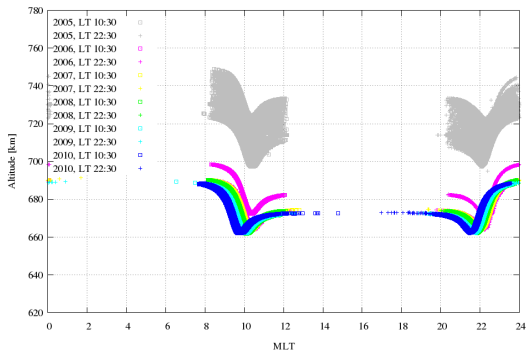
DEMETER satellite

Detection of **E**lectro-**M**agnetic **E**missions **T**ransmitted from **E**arthquake **R**egions - first satellite from the CNES MYRIADE micro-satellite series was launched in June 2004. Mission accomplished in December 2010.

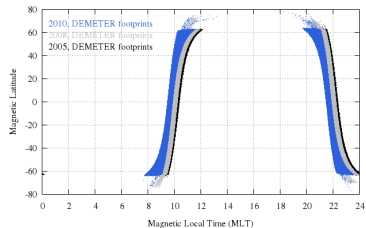
DEMETER provides permanent in-situ observations of the ionospheric plasma parameters:

- in the latitude range: 65° S to 65° N (invariant latitude),
- the altitude of 710 km (initial configuration),
- on a quasi Sun-Synchronous circular orbit (inclination 98.23°), performed observations in two LT 10:30 and 22:30. [▶ Demeter Configuration](#)

DEMETER Configuration



- altitude adjustment
- slight time-shifts when crossing over equator



Satellite payload and examined data

- ISL - Langmuir probe experiment - analysis of plasma parameters: N_e , T_e ,
- IAP - Plasma analyser - density of ions (H^+ , He^+ , O^+), ions velocity along the satellite O_z axis and ions temperature T_i .
- ICE - Electric field experiment - analysis of power spectrum of one electric field component in the VLF range from 19.53125 / 78.125 Hz to 20 kHz (Number of spectrum frequencies (Nbf): 1024 or 256)
- IDP - Energetic particles detector: 3 energetic bands: B1 from 90.7 keV to 526.8 keV, B2: from 526.8 keV to 971.8 keV, B3: from 971.8 keV to 2342.4 keV;
- IMSC: three magnetic sensors from a few Hz up to 18 kHz

To enhance impact of seasonal variations following months of registrations has been selected:

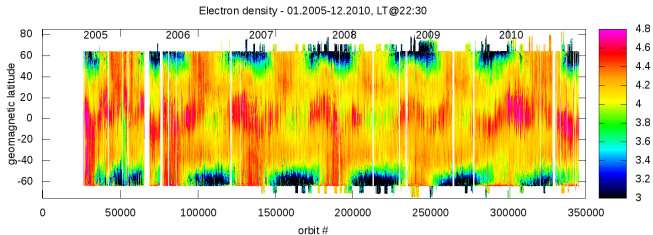
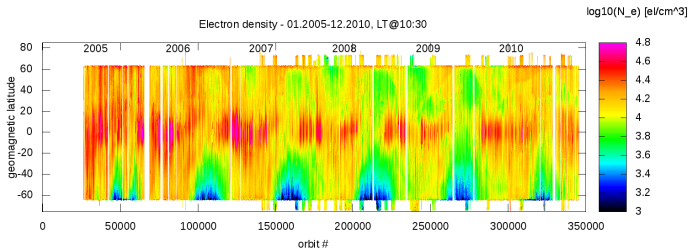
- months of equinoxes: March and September,
- months of solstice: June and December

In details comparison between registrations obtained in 2005 (disturbed ionosphere) and 2008 (calm ionosphere).

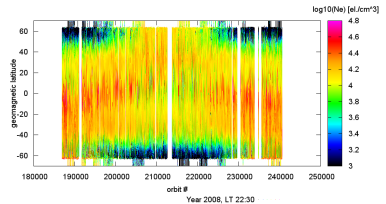
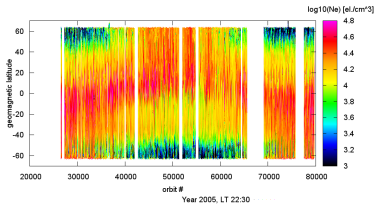
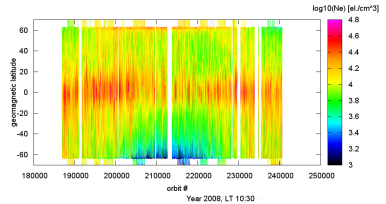
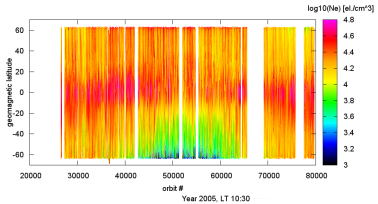
Approach to the gathered dataset - Location and/or Time

- ④ **Time series analysis** - Measured Values vs. Time vs. Geomagnetic Latitude -
 - Set of consecutive orbits reveal seasonal trends
 - Signatures of asymmetries in hemispheric distribution
 - Satellite behaviour
- ② **Ionospheric global mapping** - With respect to location - in order to extract typical structures.
 - Monthly averaged maps
 - One month period provides a satisfactory coverage for global maps with data averaged over 1° (latitude) per 2° (longitude) cells.

Temporal evolution of the ionospheric plasma density N_e

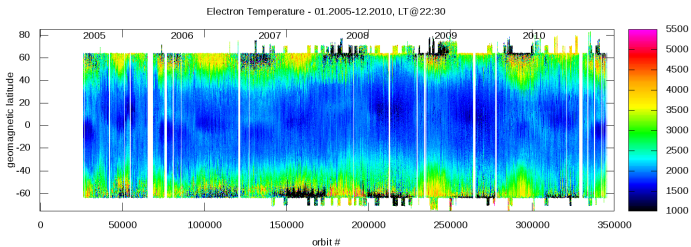
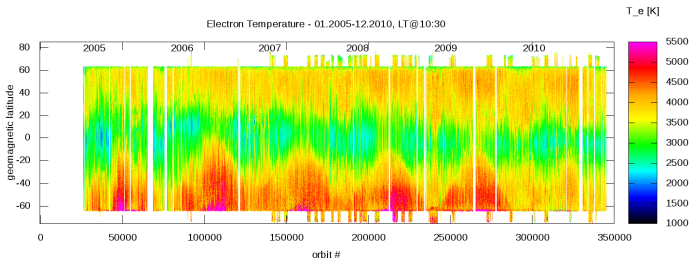


Seasonal variability - N_e

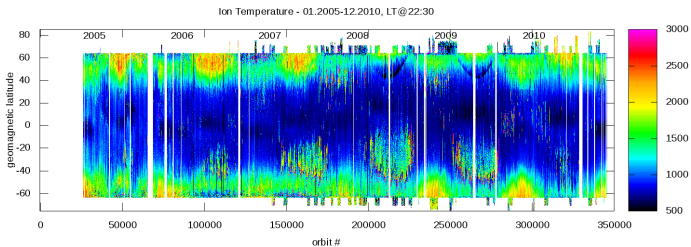
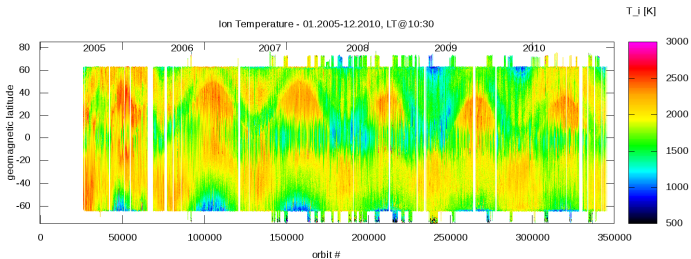


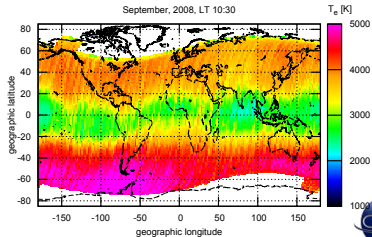
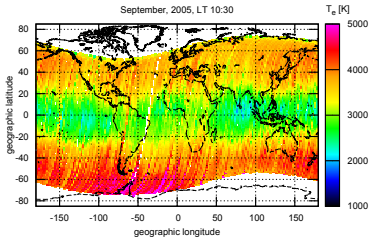
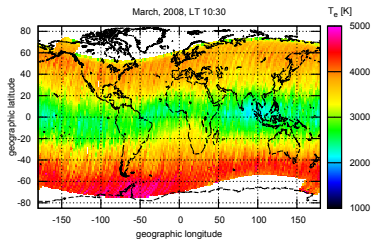
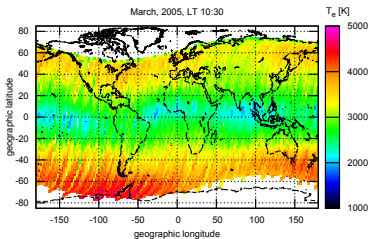
- At higher latitudes - Significant difference between local summer and winter
- Much greater plasma density during disturbed year (left column)

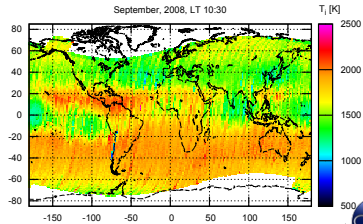
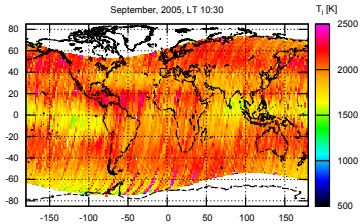
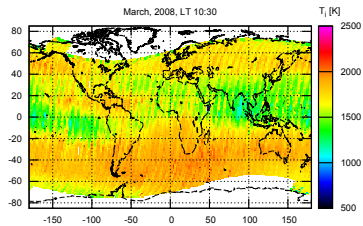
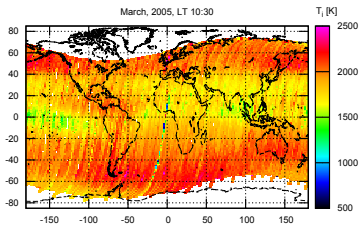
Temporal evolution of the ionospheric plasma temperatures - T_e

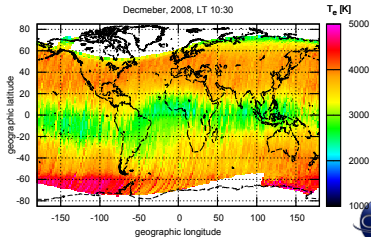
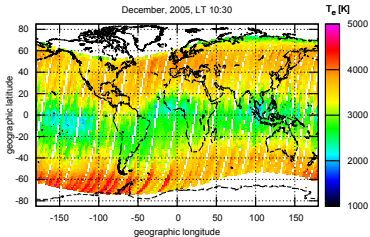
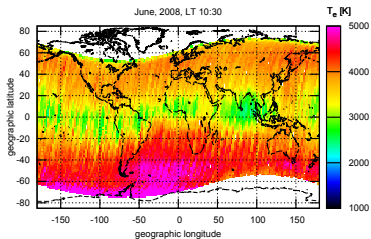
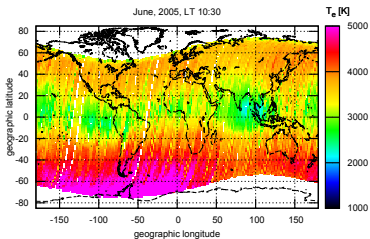


Temporal evolution of the ionospheric plasma temperatures - T_i

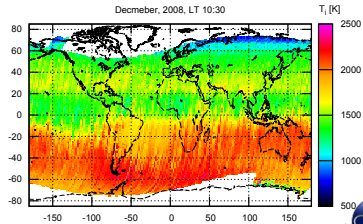
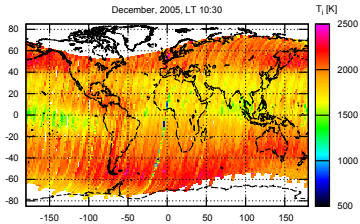
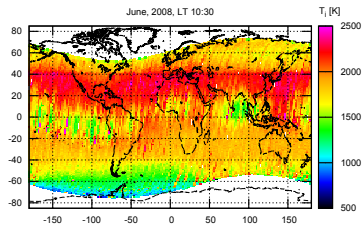
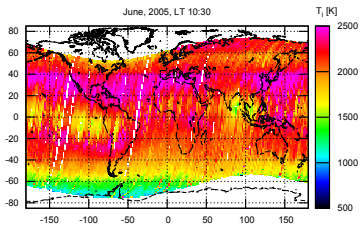


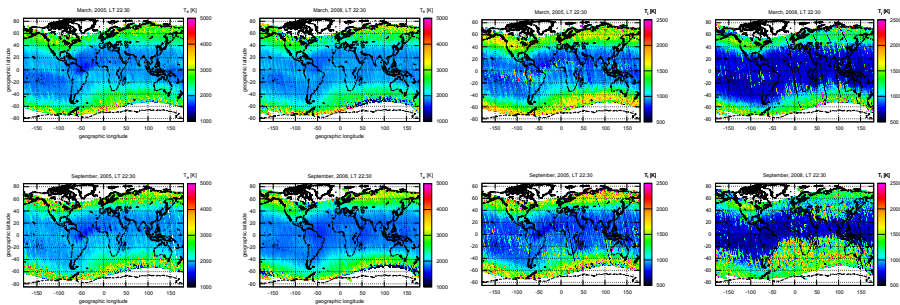
Months of equinoxes - Dayside registrations - T_e vs. T_i 

Months of equinoxes - Dayside registrations - T_e vs. T_i 

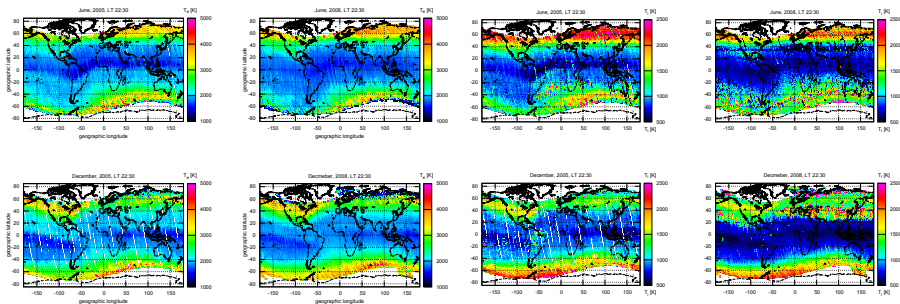
Months of solstices - Dayside registrations - T_e vs. T_i 

Temperatures morphology

Months of solstices - Dayside registrations - T_e vs. T_i 

Months of equinoxes - Nightside registrations - T_e vs. T_i 

- Electron temperature greater than ions (as expected).
- In comparison to dayside registration, global pattern is much more uniform.
- Field aligned structure is conserved:
 - equatorial zone of minimal temperatures,
 - mid-latitude zone of moderate temperatures,
 - and finally high-latitude regions with not only the highest temperatures, but also the most complex structure.

Months of solstices - Nightside registrations - T_e vs. T_i 

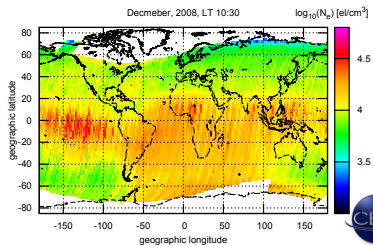
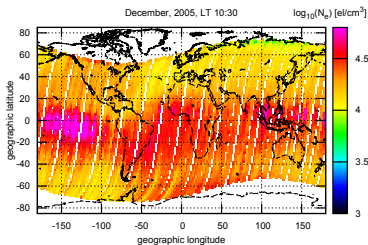
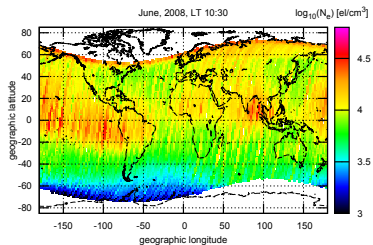
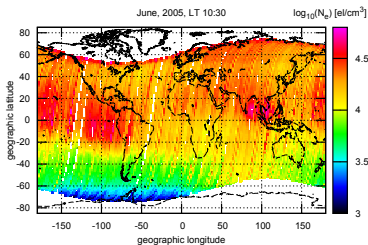
- During equinoxes (especially in September) the temperature gradient is the lowest, but in case of solstices, temperature maxima are assigned to local summer.
- Higher electron temperatures dominate in the Southern hemisphere (effect especially well visible between 2006 - 2009).

T_e vs. T_i - statistics**Table:** Estimated temperature extrema for electron and ions temperatures

Extremum [K]	March	June	September	December	LT
T_e^{min}	2900	3400	3100	3100	
T_e^{max}	3850	4700	4200	3800	Dayside
T_e^{min}	2000	1900	1950	2000	
T_e^{max}	2500	2950	2600	2950	Nightside
T_i^{min}	1700	1600	1750	1750	
T_i^{max}	1900	2100	1900	2000	Dayside
T_i^{min}	950	950	950	950	
T_i^{max}	1250	1550	1300	1450	Nightside

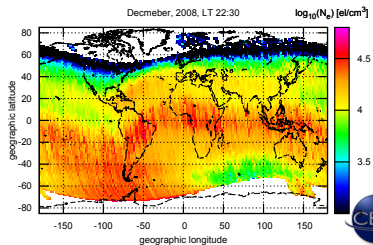
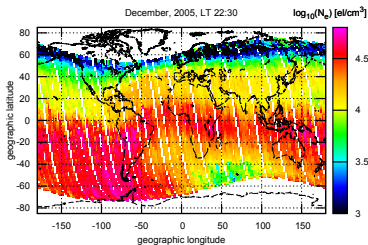
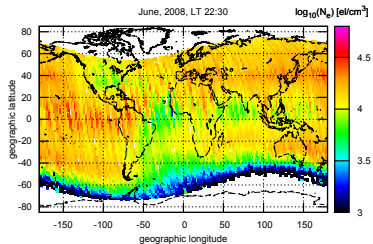
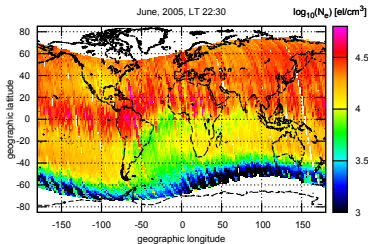
Spatial distribution of the ionospheric plasma density

Months of solstices - Plasma density - Dayside registrations



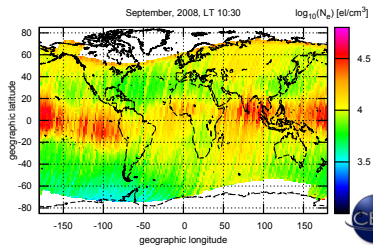
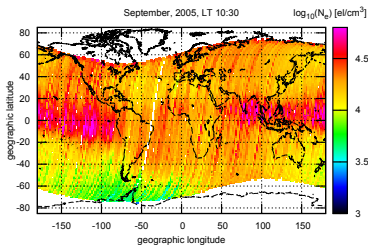
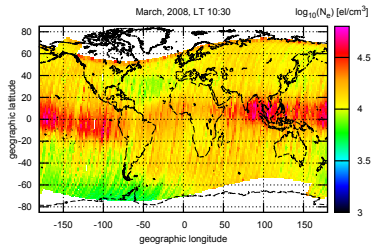
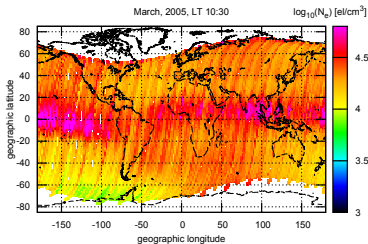
Spatial distribution of the ionospheric plasma density

Months of solstices - Plasma density - Nightside registrations



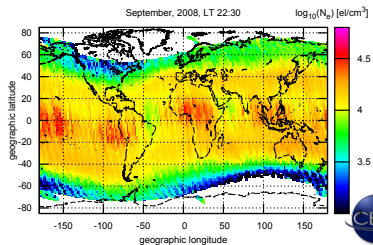
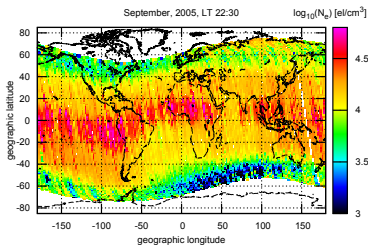
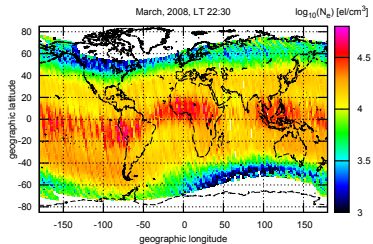
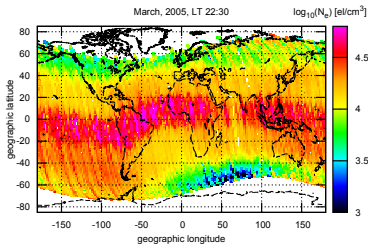
Spatial distribution of the ionospheric plasma density

Months of equinoxes - Plasma density - Dayside registrations



Spatial distribution of the ionospheric plasma density

Months of equinoxes - Plasma density - Nightside registrations



Statistics

Table: Statistics on examined data. "0" and "1" refer to morning and evening overpasses. Merged burst and survey mode data.

Time Period	ISL (0)	ISL (1)	IAP (0)	IAP (1)
2005.03	640	620	645	624
2005.06	545	551	533	541
2005.09	534	523	606	594
2005.12	466	467	466	466
2008.03	733	729	733	729
2008.06	501	472	501	472
2008.09	733	701	733	699
2008.12	722	668	722	667

Summary

- DEMETER data provides valuable source of information about the topside ionosphere.
- Presented set of results can be used for further validation of common ionospheric models, but also provides general background for wide sort of case studies.
- Influence of geomagnetic conditions on all registered parameters has been observed: With decreasing solar activity electron and ions temperature reveal a decrease, while plasma density increases (reversal relation).

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