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Ionosphere anomalies during the SURA – ISS experiments program

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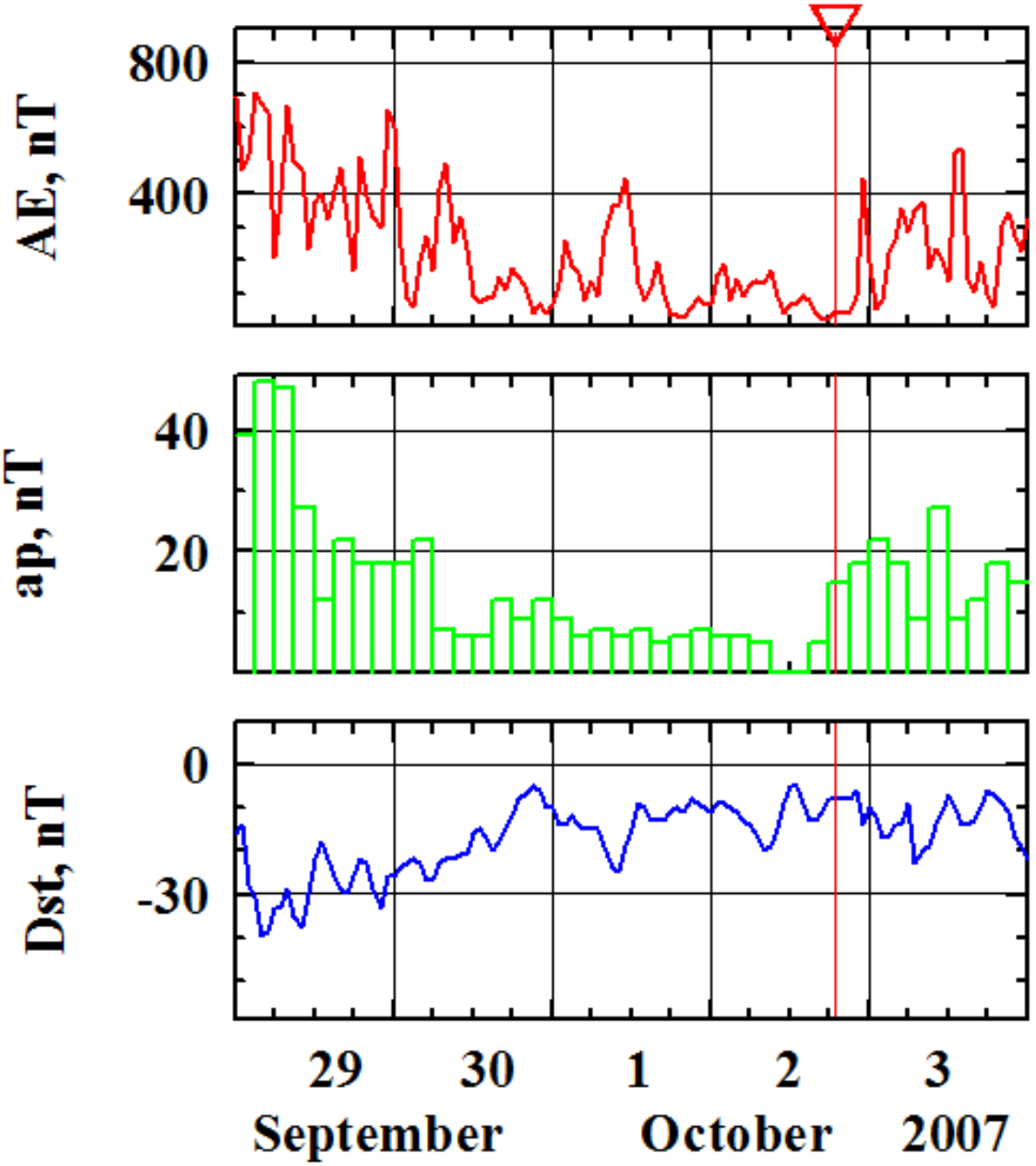
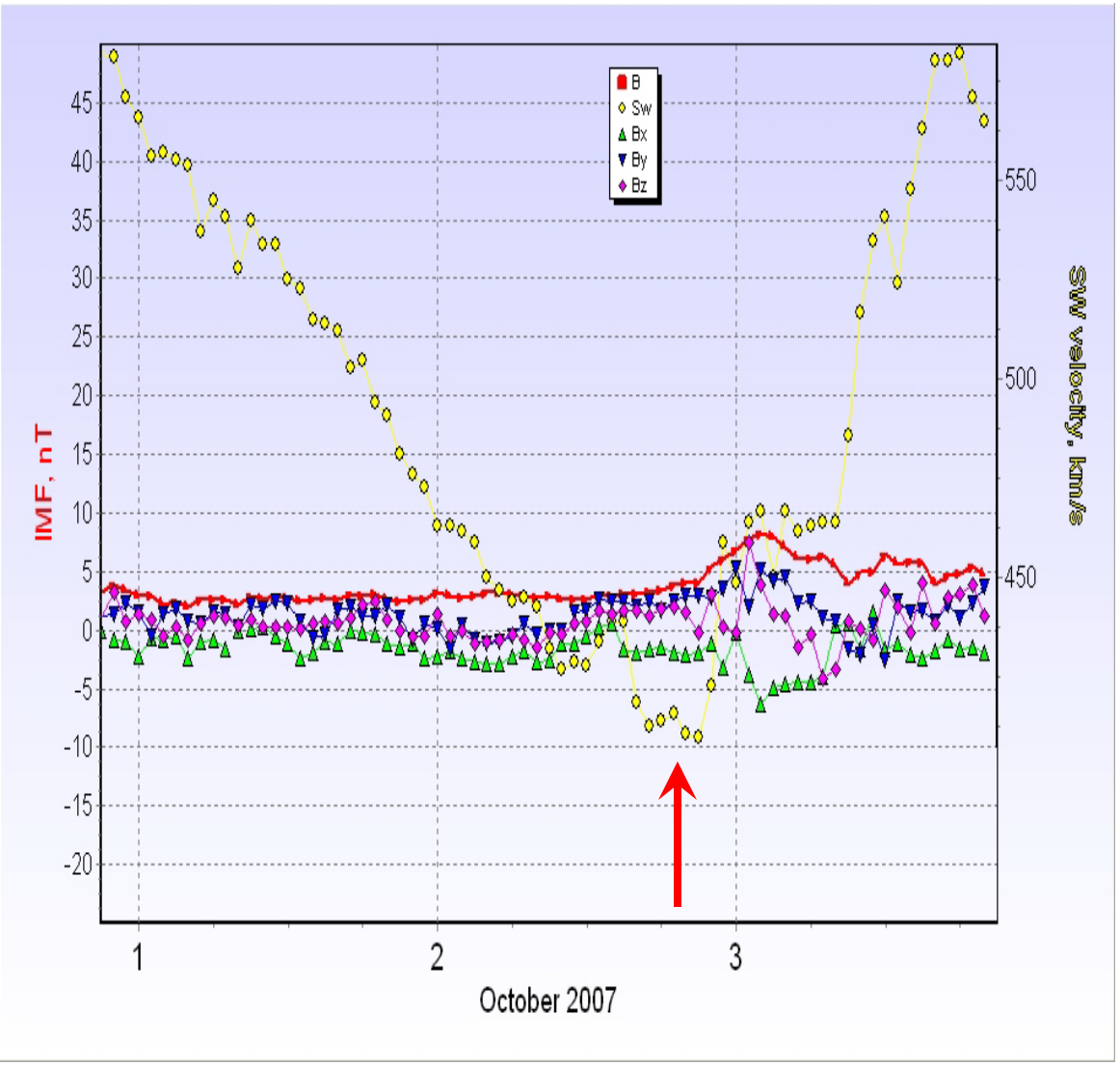
ABSTRACT

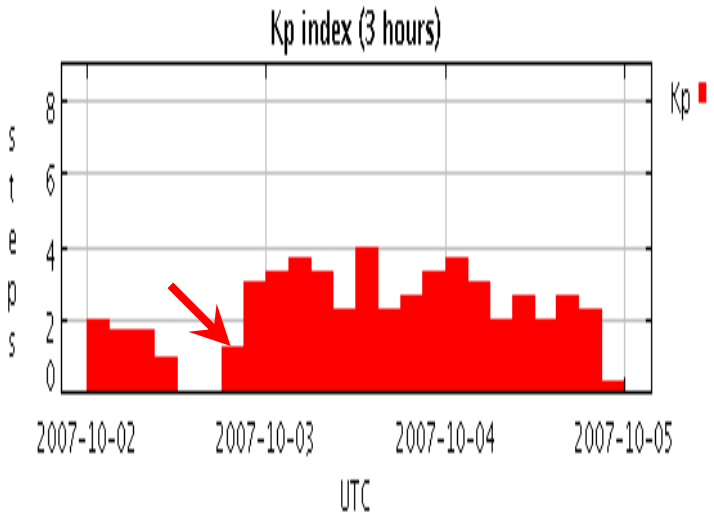
Artificial substorms were repeatedly stimulated when series of ionospheric experiments with the ionosphere heating facility SURA were carried out in frames of SURA – ISS (the International Space Station) program. Substorms were observed at higher latitudes to the north from the SURA facility location (56.1°N; 46.13°E). The effect was directly proved by localization of an artificial aurora (ISS onboard optical measurements) and specific substorm-like magnetic field variations which were identical in a form, amplitude and temporarl parameters (IZMIRAN and GEOMAGNET network observations). The analysis of ionosphere state under quiet geomagnetic conditions was made according to DEMETER satellite, IZMIRAN ionosonde and GPS network data. It has revealed that the plasmasphere border was observed in the northern direction 150-200 km apart from the SURA heating facility.

A beam radio tracing was accomplished, the horizontal gradient of *F2* layer critical frequencies in plasmapause area (based on a full data complex) being considered. The possibility of ionosphere modification in the north direction from the SURA facility by means of redistribution and refocusing of radio emission radiated by the SURA was confirmed. The IRI - 2007 model calculations for geophysical conditions during SURA − ISS experiment did not confirm the fact of localization of the observed gradient and, in an indirect way, the plasmapause position. Thus, the abnormal ionosphere condition within the plasmasphere border, registered in experiments for premidnight conditions, was not confirmed by the model and therefore demands its further studies.



Data of satellite radiophysical observations of mid-latitude ionosphere along the time of October 2, 2007 experiment on SURA heat facility is analyzed.



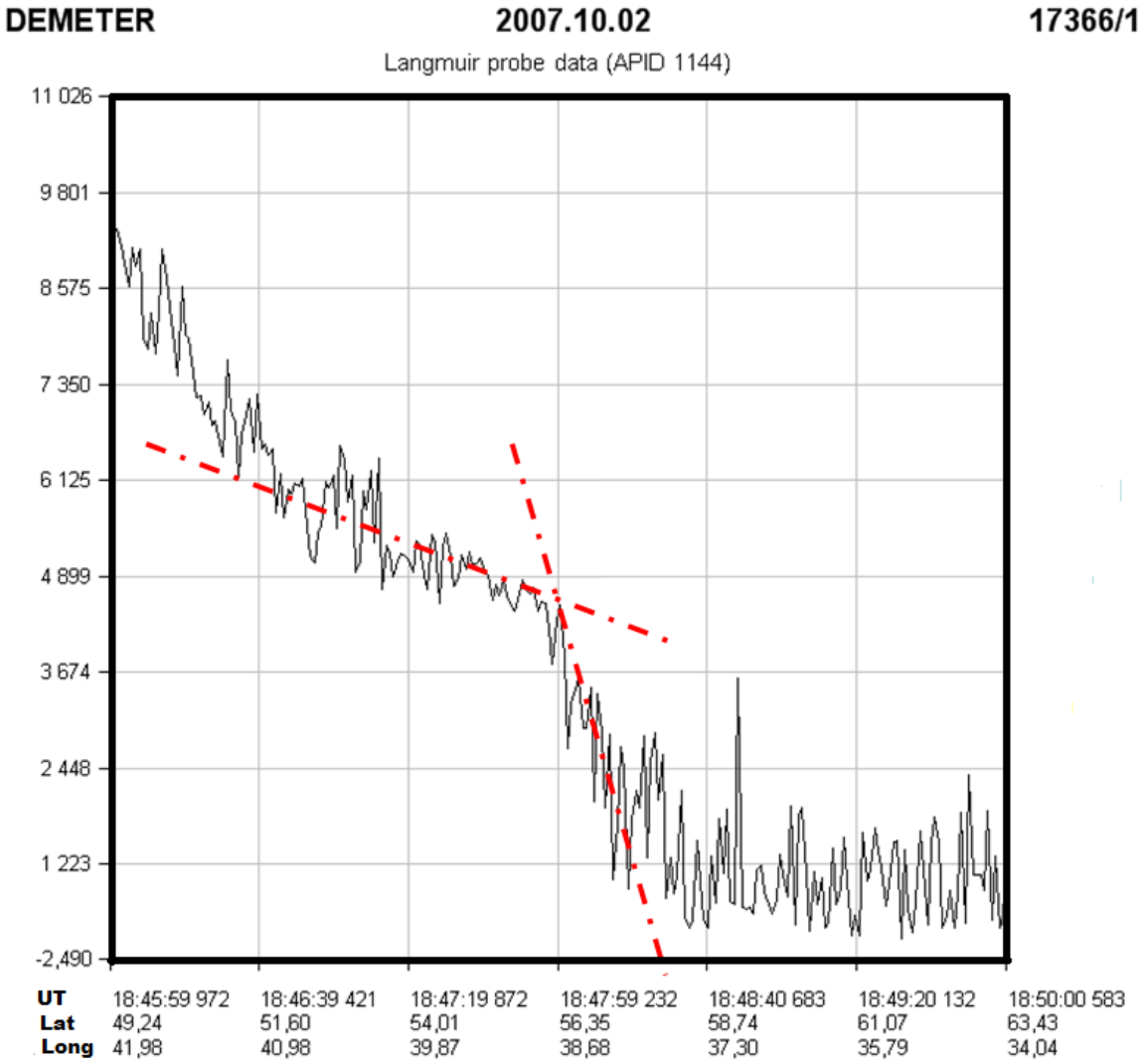


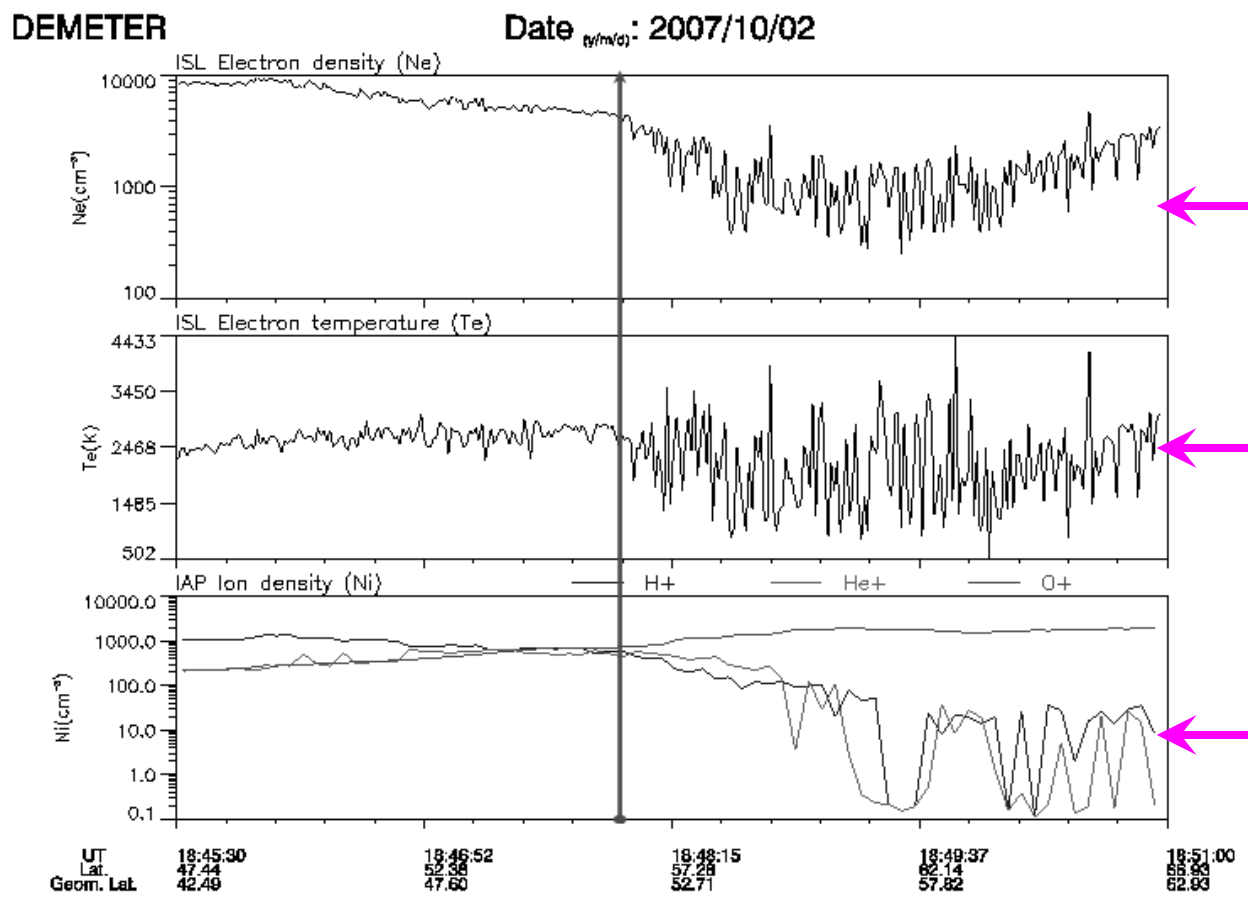
Planetary Kp-index in October 02-05, 2007. Note that during the experiment (18-19 UT on October 2) Kp=1.5

Interplanetary magnetic field (IMF) and speed of a Solar wind (SW) for October 1-3, 2007. During the experiment (18-19 UT on October, 2) IMF was very quiet, and speed SW minimum.

DEMETER data

A steep gradient of ionosphere plasma density with the spatial scale of 100-150 km along the orbit was detected at latitude equal to SURA heat facility latitude by means of DEMETER satellite data. The results of Langmuir probe measurements shown in Figure demonstrates that the sharp depletion of plasma density (or reduction of plasma frequency) occurs in latitude range of 56-58º N.



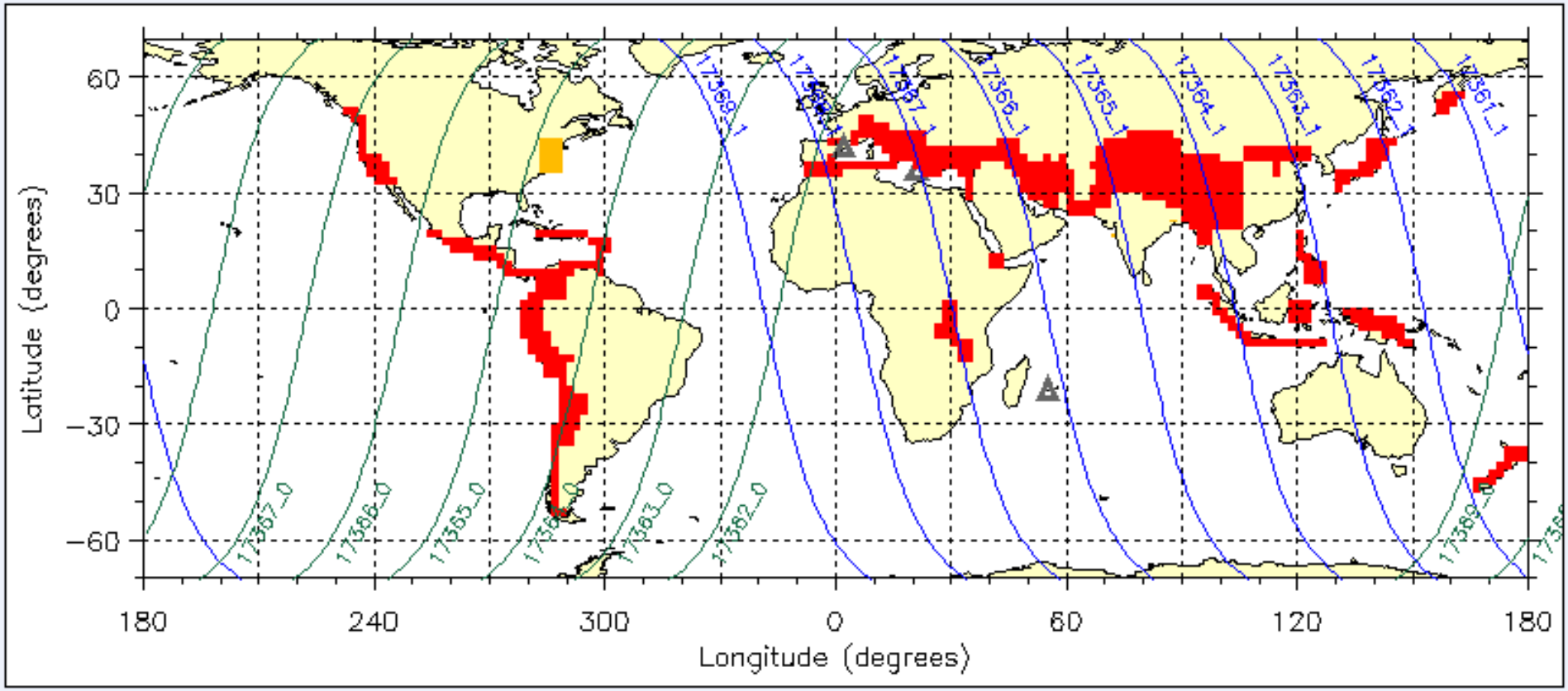


Plasma density

Electron temperature

Ion density: H^+, He^+, O^+

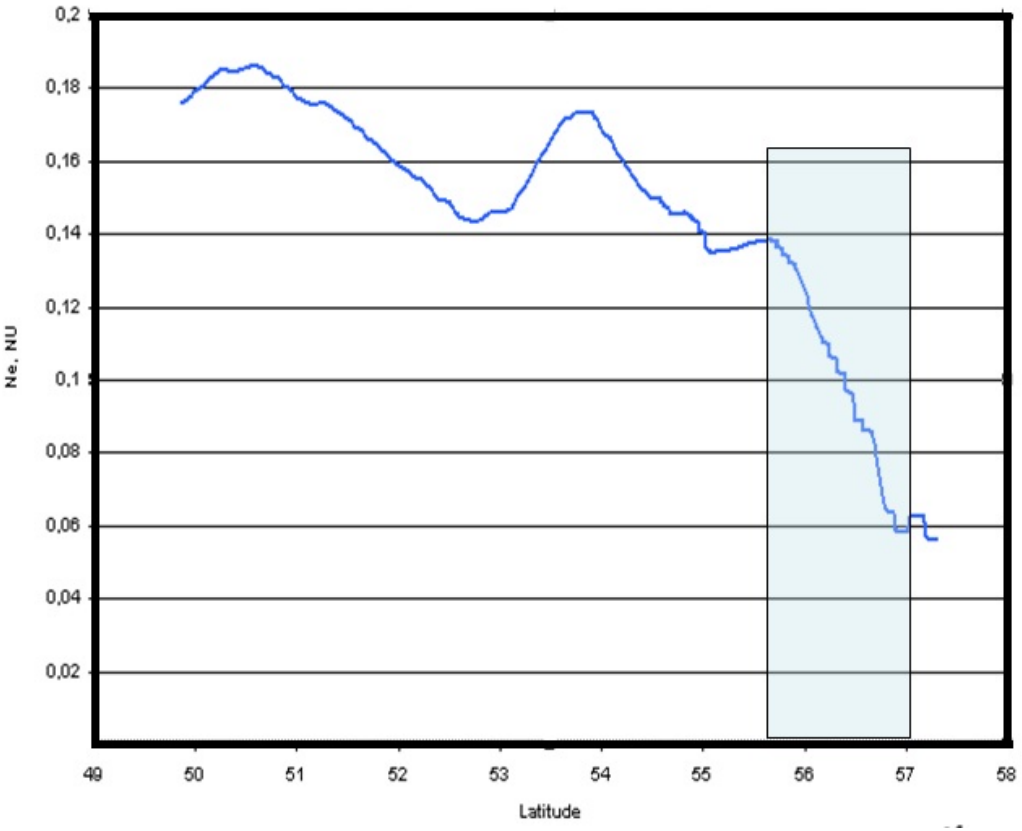
DEMETER satellite crosses the SURA facility latitude (point of maximum approach) are marked by vertical lines. Sharp plasma density fall at 56ºE and signs of strong plasma density (top panel) and electron temperature (middle panel) instabilities appearance support the assumption that the plasmasphere border is located quite here, being considerable southward from its usual position. At the same place energetic electron beams and heavy ion density start to increase sharply. The oxygen ions become the dominating ones (bottom panel).



Orbit No.	UT	Longitude (≈ 55°N) ====== Latitude (equator)	Latitude of the effect appearance		
			Ne	O+	1 MeV
17363	13:54	115/9.7	58	54	55
17364	15:30	90/9.1	58		
17365	17:10	65/7.6	56	56	
17366	**18:40**	**40/5.8**	**55**	**55**	**55**
17367	20:26	15/3.6	55	55	60

Five consecutive passes of DEMETER satellite ($\Delta \lambda \approx 100°$) confirm the presence of above mentioned anomaly (depletion of electron (plasma) density and its enhancement for O+ ions) at the same local time.

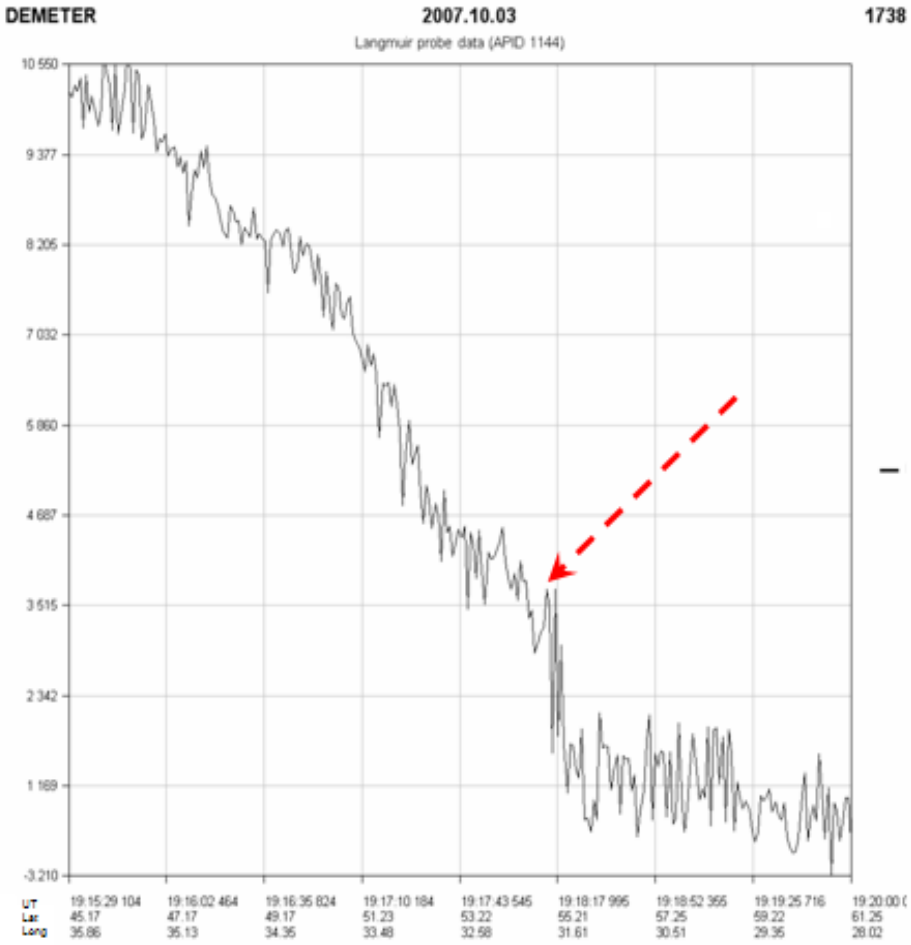
GPS signal analysis

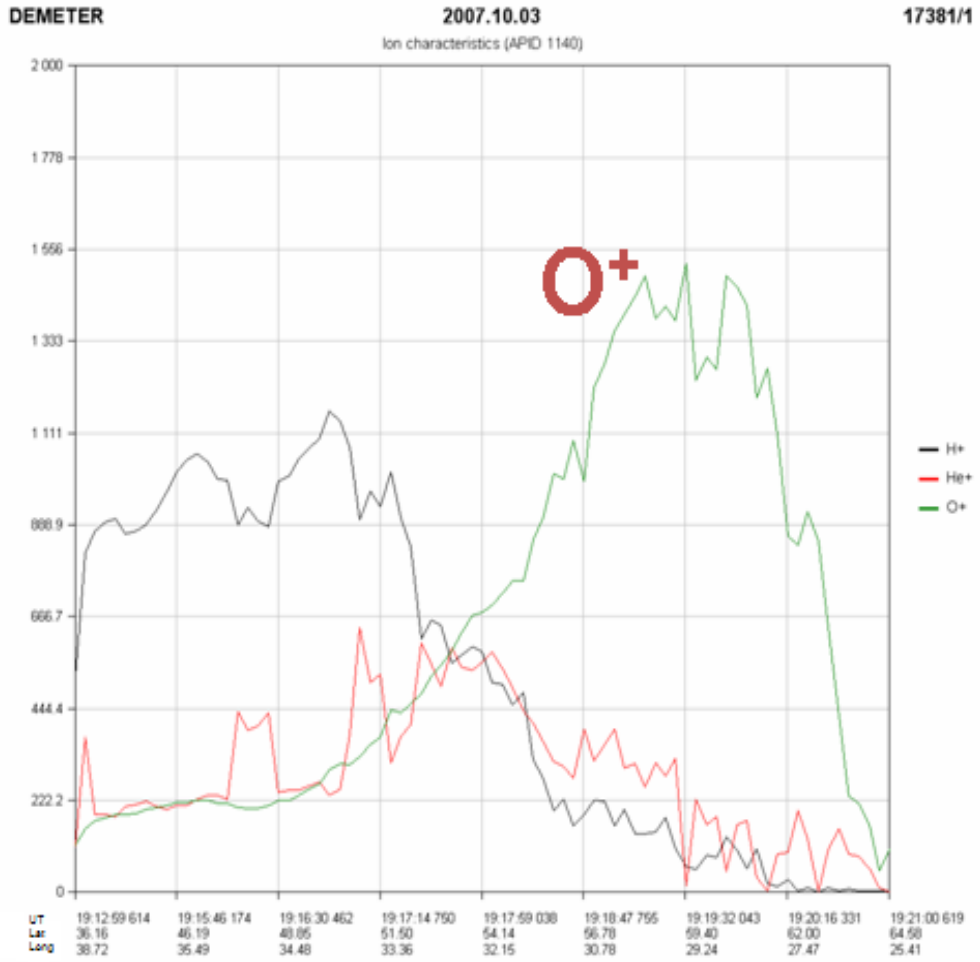


The additional information about the ionosphere condition in the region of interest was obtained using GPS satellites. Parameters of the plasma were defined by *radio translucence method* on a line the satellite - the Earth. Data of GPS14 satellite phase measurements as most appropriate in time and location were used to obtain ionosphere peak parameters.

***F2* peak density gradual reduction was also detected northward SURA location (blue box in Figure).**

The methodical aspects of ***radio translucence method*** were developed by Smirnov V. et al. in The investigation of the ionospheric variability by the radio translucence method. ***Advances in Space Research***. 2001, Vol. 27, No.6-7, pp.1327-1331.

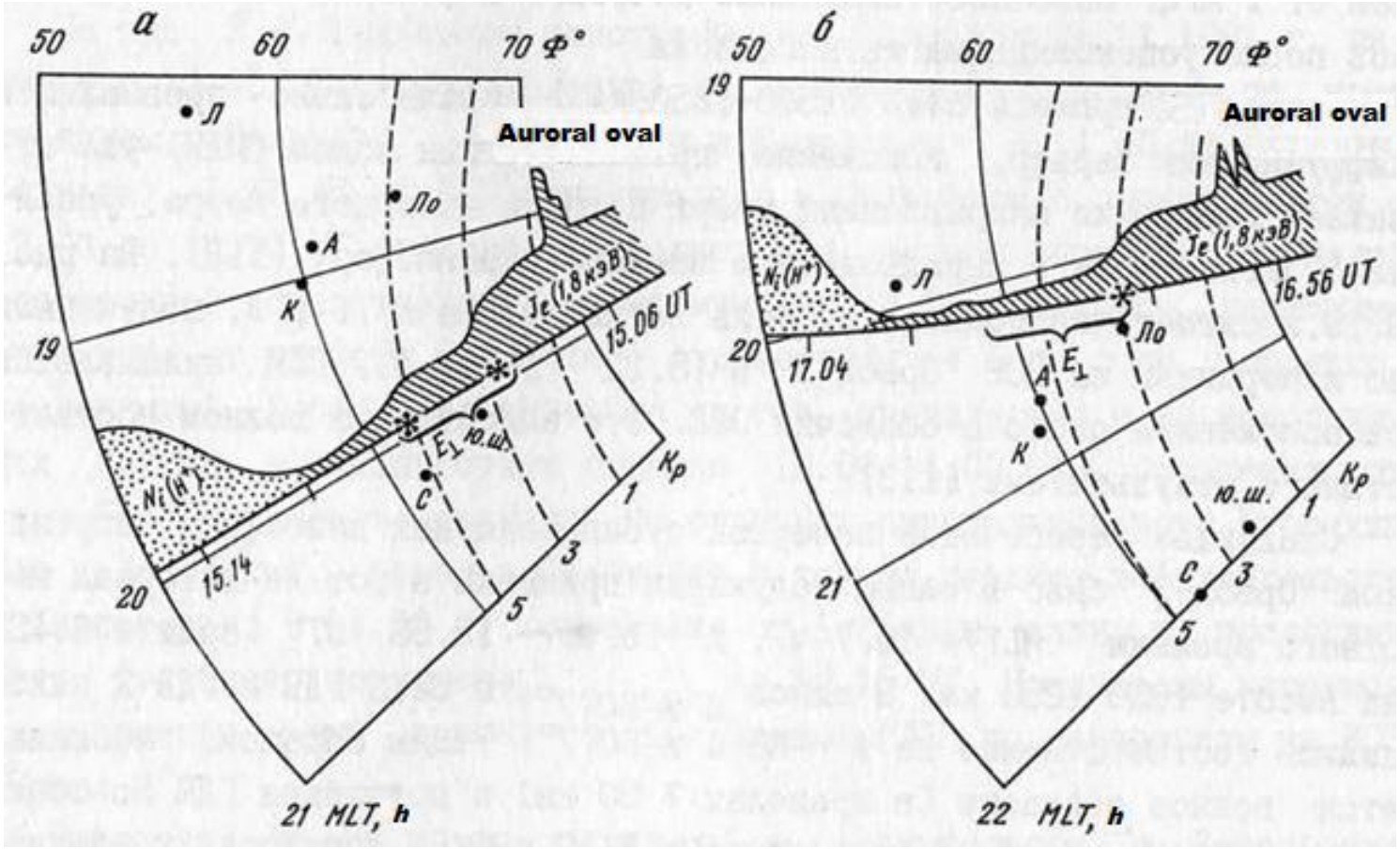




DEMETER orbit No.17381, one day after the experiment - the same effect has been observed around 55ºN latitude:

- sharp depletion of electron density (left panel);

- O+ ions become prevailing (right panel).

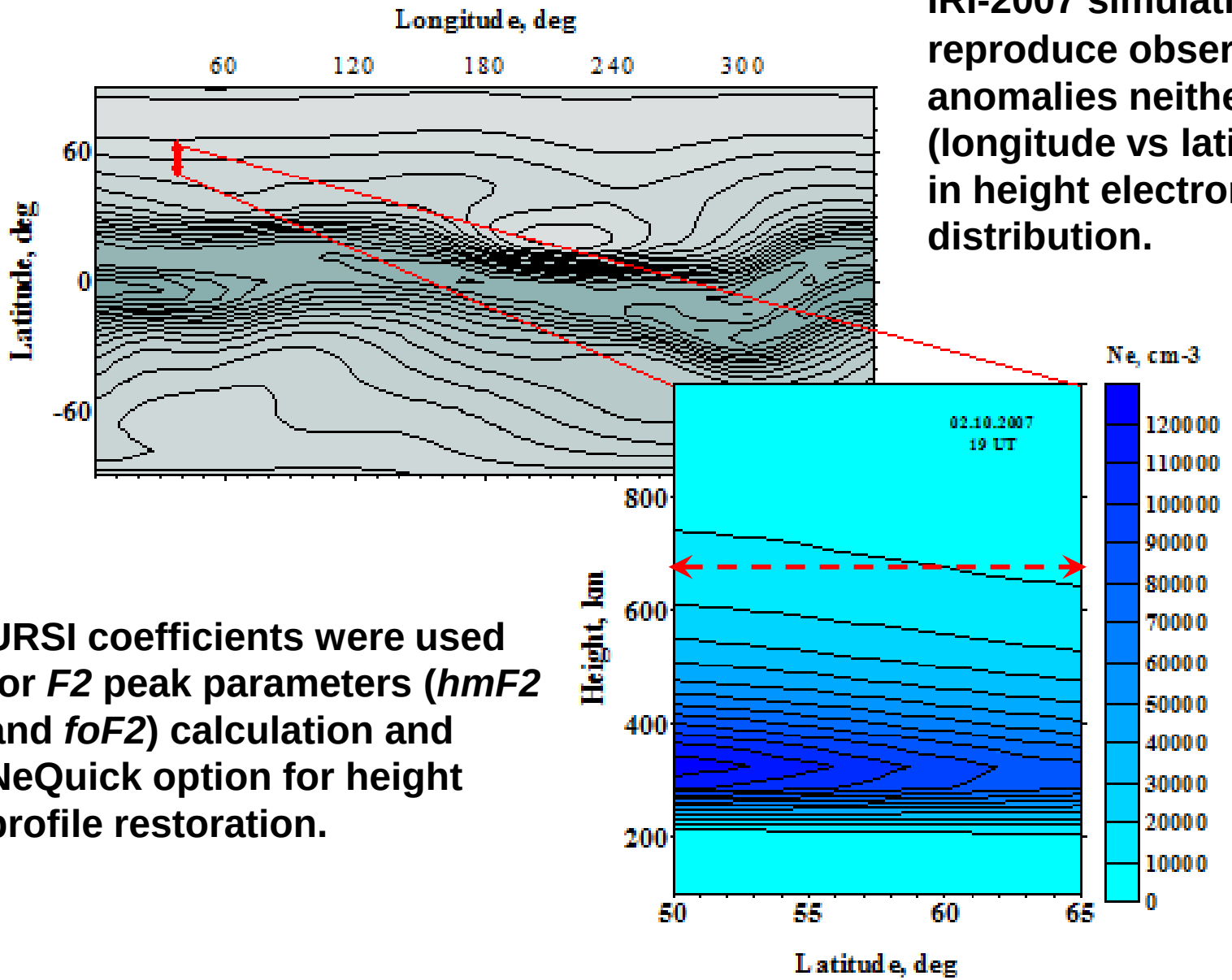


An example of Intercosmos-18 measurements at 1500-1750 UT on November 24, 1981. Sharp depletion of light ions density (and enhancement of O+) at 56-58^{o} N has been observed during two consequent passes.

In Figure: Л denotes Leningrad (St.Petersburg), K – Karpogory.

Ben'kova N.P., Kozlov E.F., Kochenova N.A., Samorokin N.V., and Fligel M.D. ***Structure and Dynamics of the Sub-Auroral Ionosphere***. Nauka. Moscow. 1993. 144 p.

IRI simulation



IRI-2007 simulation do not reproduce observed anomalies neither in spatial (longitude vs latitude), nor in height electron density distribution.

URSI coefficients were used for *F2* peak parameters (*hmF2* and *foF2*) calculation and NeQuick option for height profile restoration.

Conclusion

1. **The analysis of ionosphere state under quiet geomagnetic conditions was made according to DEMETER satellite, IZMIRAN ionosonde and GPS network data. It has revealed that the plasmasphere border was observed in the northern direction 150-200 km apart from the SURA heating facility.**
2. **A beam radio tracing was accomplished, the horizontal gradient of *F2* layer critical frequencies in plasmapause area (based on a full data complex) being considered. The possibility of ionosphere modification in the north direction from the SURA facility by means of redistribution and refocusing of radio emission radiated by the SURA was confirmed.**
3. **The IRI - 2007 model calculations for geophysical conditions during SURA − ISS experiment did not confirm the fact of localization of the observed gradient and, in an indirect way, the plasmapause position. Thus, the abnormal ionosphere condition within the plasmasphere border, registered in experiments for premidnight conditions, was not confirmed by the model and therefore demands its further studies.**

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