Ion Concentrations in the Upper Ionosphere and in the Magnetosphere: Comparison of DEMETER and GOES measurements

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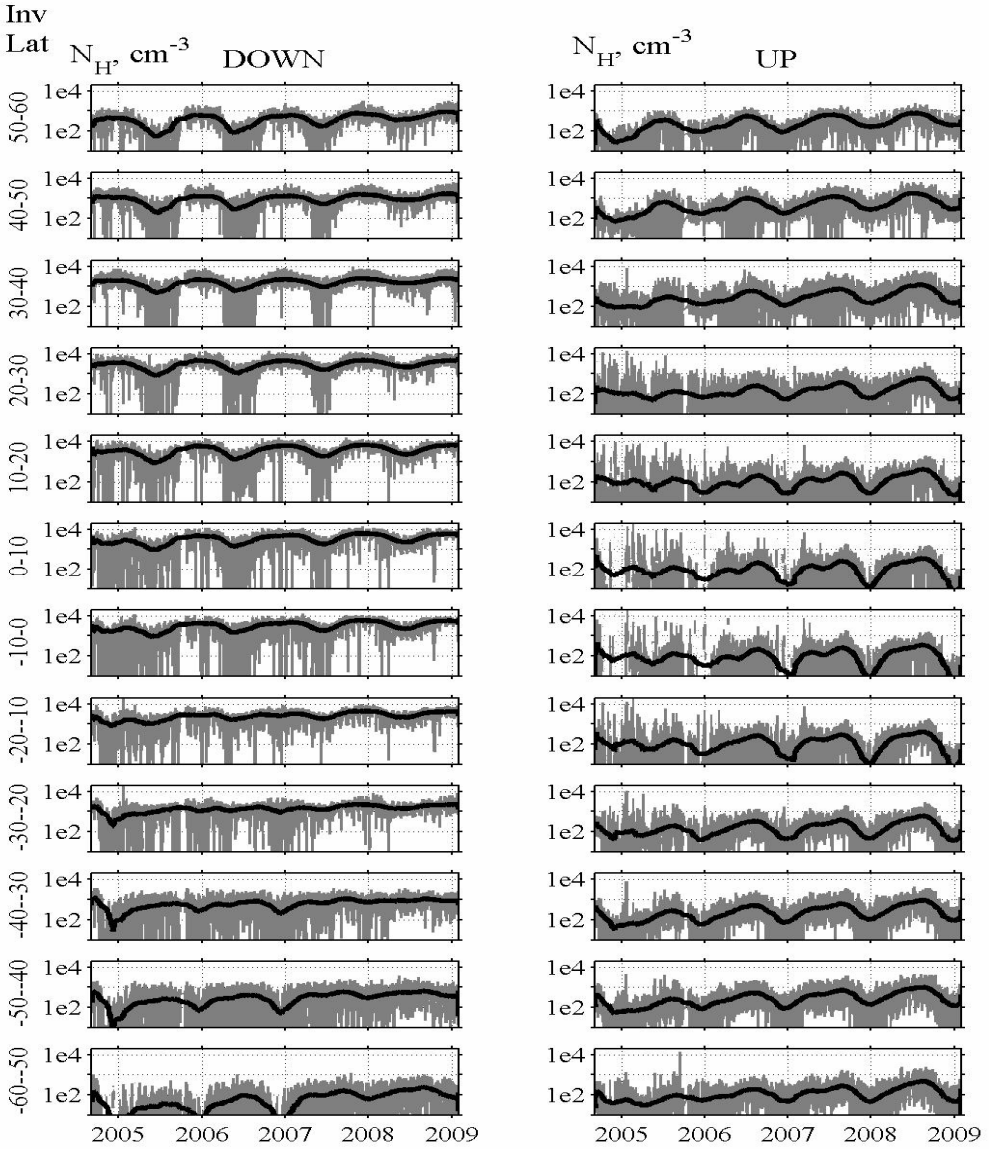
Abstract

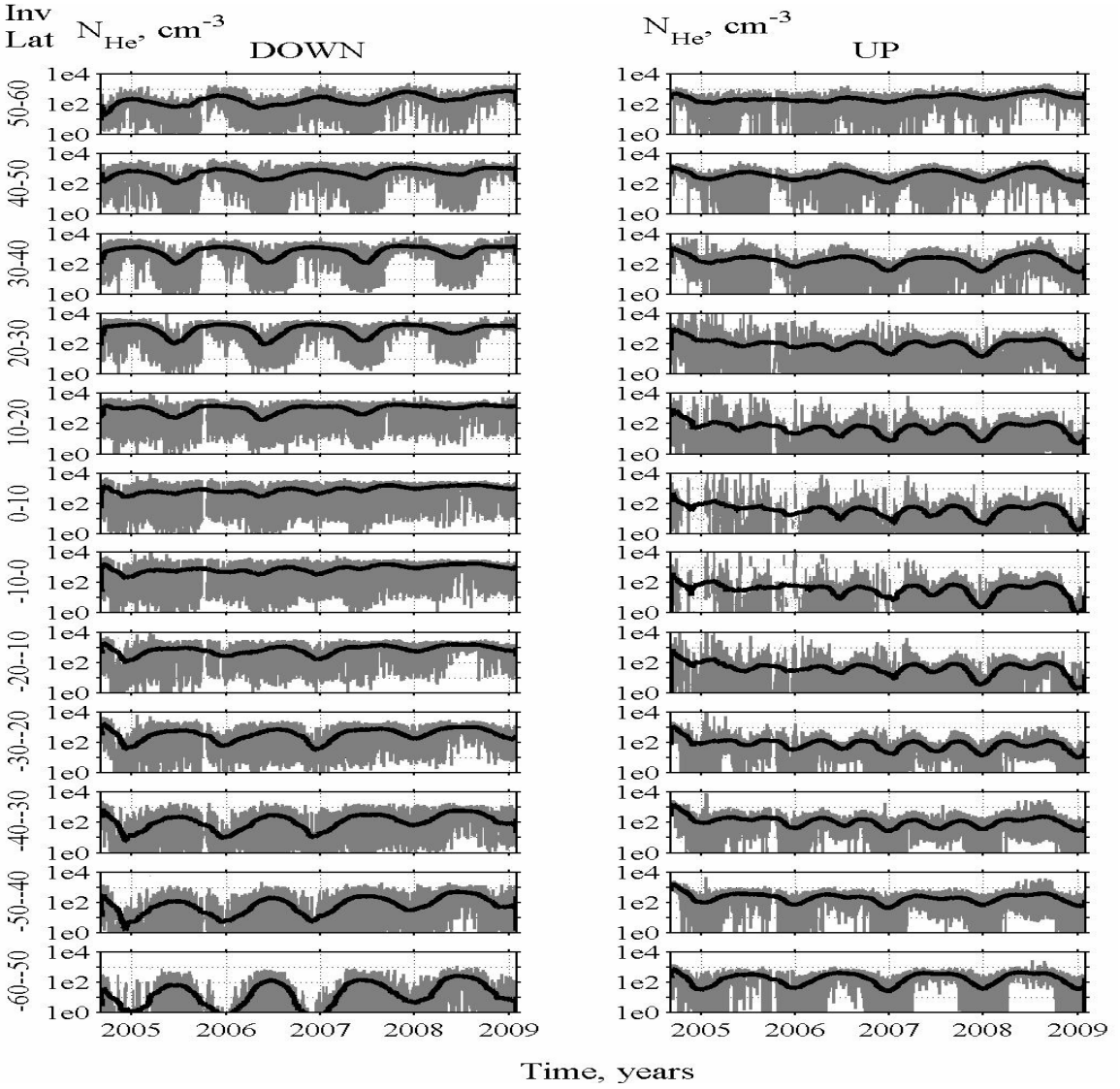
- The variations of concentrations of H+, He+ and O+ in the upper ionosphere are analyzed in dependence on solar and geomagnetic activity. The study is based on the data of DEMETER during more than four years of continuous measurements from 2004 to 2008, i.e. at declination and minimum of the solar cycle.
- It is shown that seasonal and solar cycle variations and latitude distribution differ essentially for oxygen ions and for light (H+ and He+) ions. Variations of concentration of O+ are controlled predominantly by solar radiation, while the variations of concentration of light ions in the upper ionosphere depend predominantly on the geomagnetic activity. The correlation between ion concentration and a corresponding activity index depends on the value of a guiding parameter. A good correspondence is found between H+ concentrations in the upper ionosphere and at the geostationary orbit.

H+ variation in 11-year Solar activity cycle



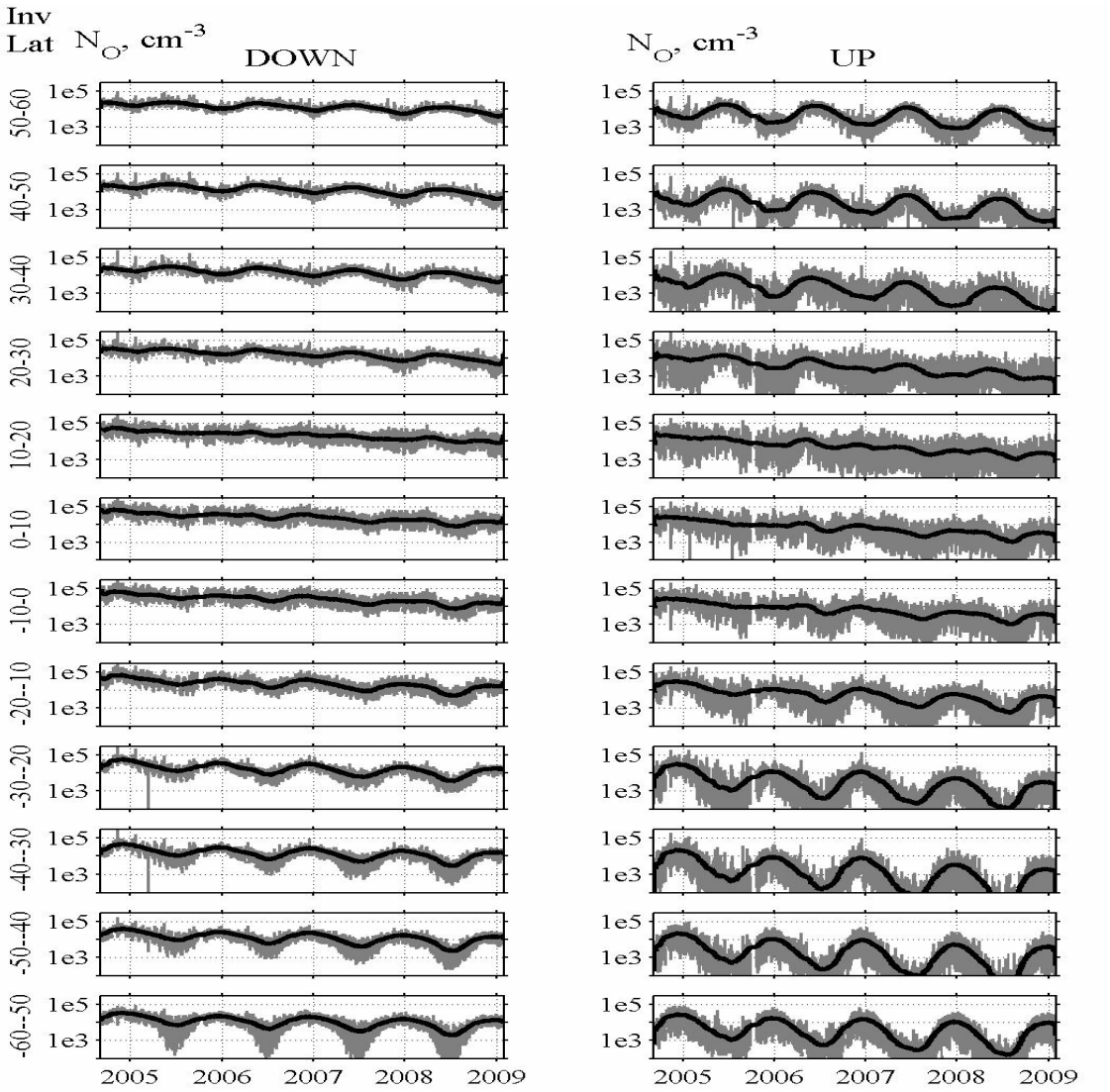
- The concentration of light ions grows with solar activity decreasing. At nightside dependence of H+ concentration on solar activity is stronger than at daytime for all latitudes.

He+ variation in 11-year Solar activity cycle



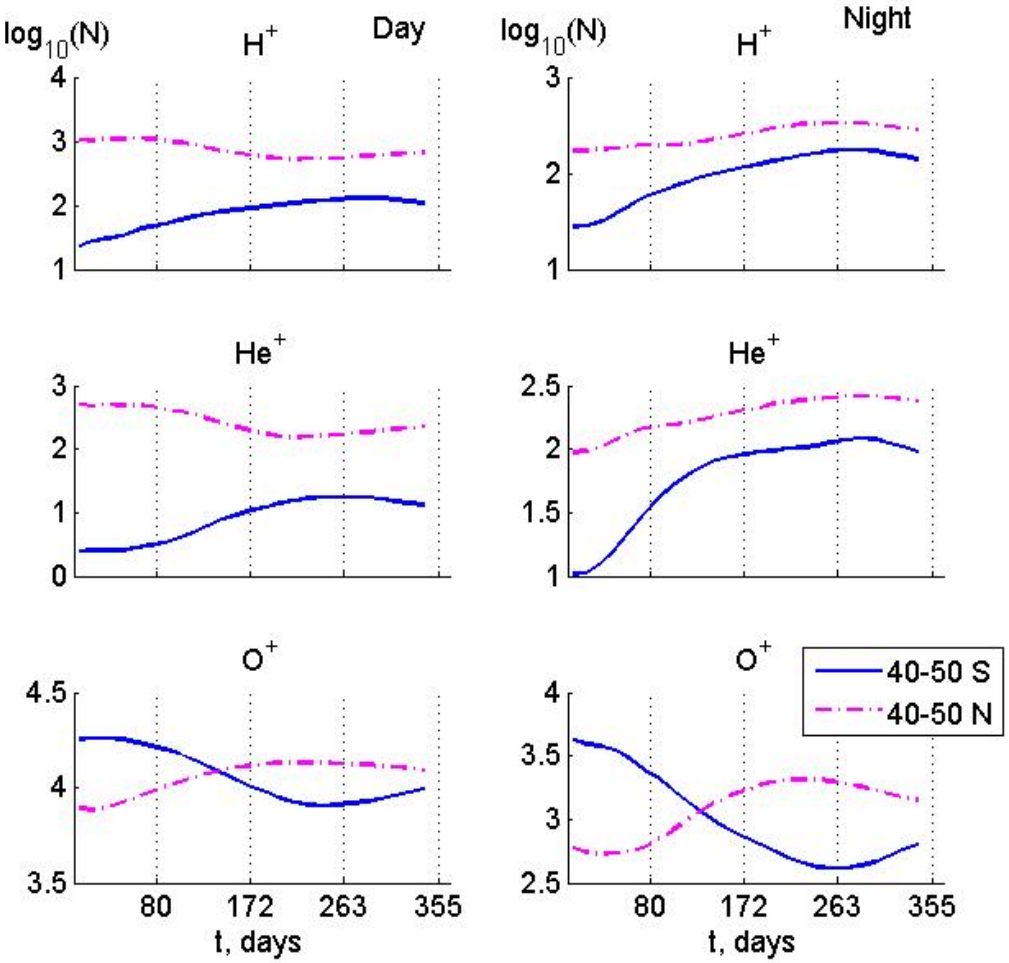
- The variation of concentration of He+ with solar activity (Figure 3) is qualitatively similar to the variation of concentration of H+ for all latitudes and both for dayside and nightside, but the difference in He+ concentration between intervals of low (2008) and moderate (2005) solar activity is lower than for H+.

O+ variation in 11-year Solar activity cycle



- Contrary to light ions, concentration of O+ demonstrate direct dependence on solar activity. The concentration of O+ decreased from 2005 to 2008 3 to 5 times in dependence on latitude.
- In the latitude band 30-60^o N O+ concentrations are $1.6 \cdot 10^4$ см$^{-3}$ and $5 \cdot 10^3$ см$^{-3}$ in 2005 and 2008, respectively. At low latitudes the decrease of concentration is even more essential: from $2.0 \cdot 10^4$ см$^{-3}$ in 2005 to $5 \cdot 10^3$ см$^{-3}$ in 2008.

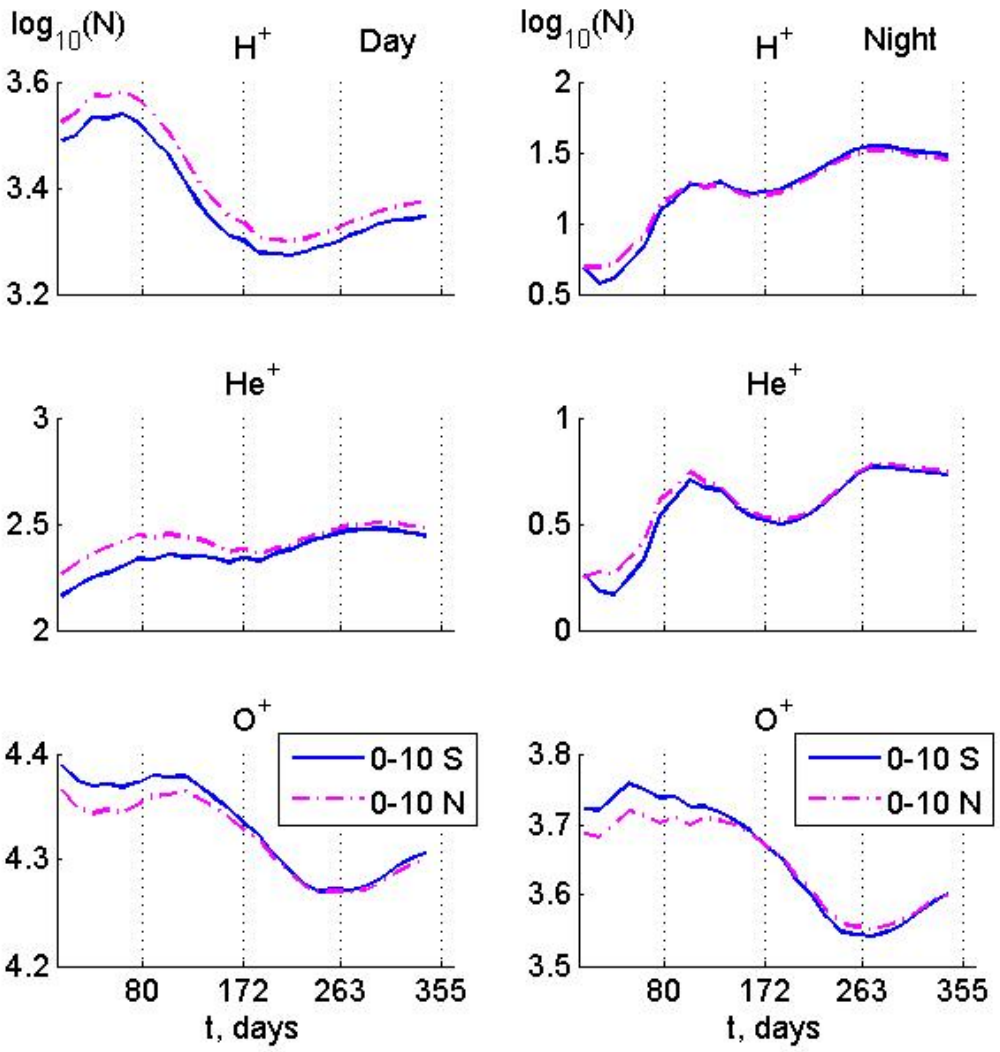
Seasonal variation. Middle latitudes



- At the dayside the concentration of H+ and He+ has a yearly main maximum in winter (January-February) in the Northern hemisphere and in local spring (October) in the Southern hemisphere. The absolute values of concentration are essentially higher in the Northern hemisphere, and the ratio of maximal to minimal concentration is higher in the Southern hemisphere. At nightside the yearly main maximum is in October for both Hemispheres.

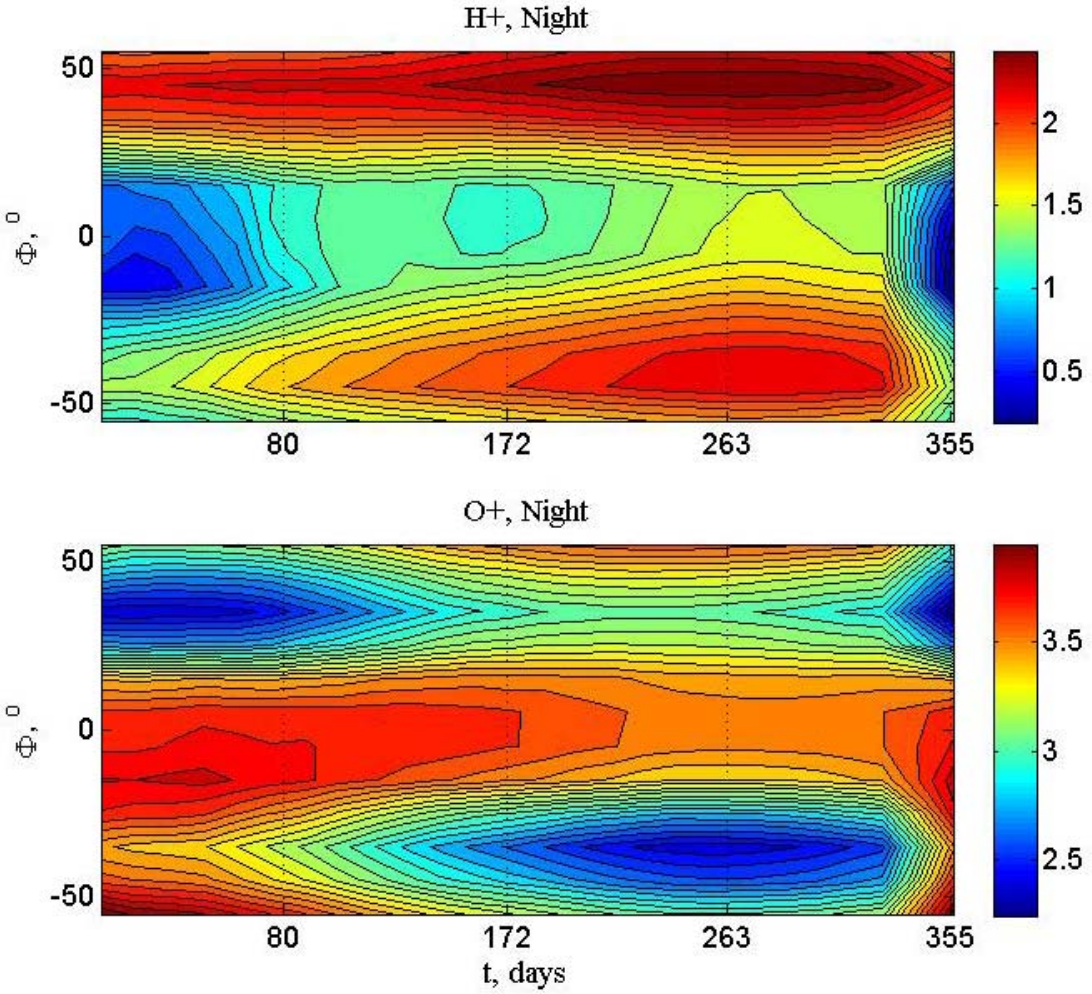
- For O+ the yearly main maximum of concentration falls on local late summer (February in the Southern hemisphere and August in the Northern hemisphere). The position of maximum is nearly the same for dayside and nightside.

Seasonal variation. Low latitudes



- The dayside seasonal variation for the concentration of H+ qualitatively repeats the seasonal variation in the Northern hemisphere at higher latitudes with the yearly main maximum in February. At nightside the concentration of both H+ and He+ change at low latitude the type of seasonal variation and two maxima: the main in October and a minor in April are seen in Figure 6. For He+ the two-maximal seasonal variation exists also at dayside. As for dayside picture for O+, it the seasonal variation also has two maxima in January and in April. The nightside seasonal variation for O+ is more or less similar to that at dayside, but two maxima, seen at dayside, merge into one.

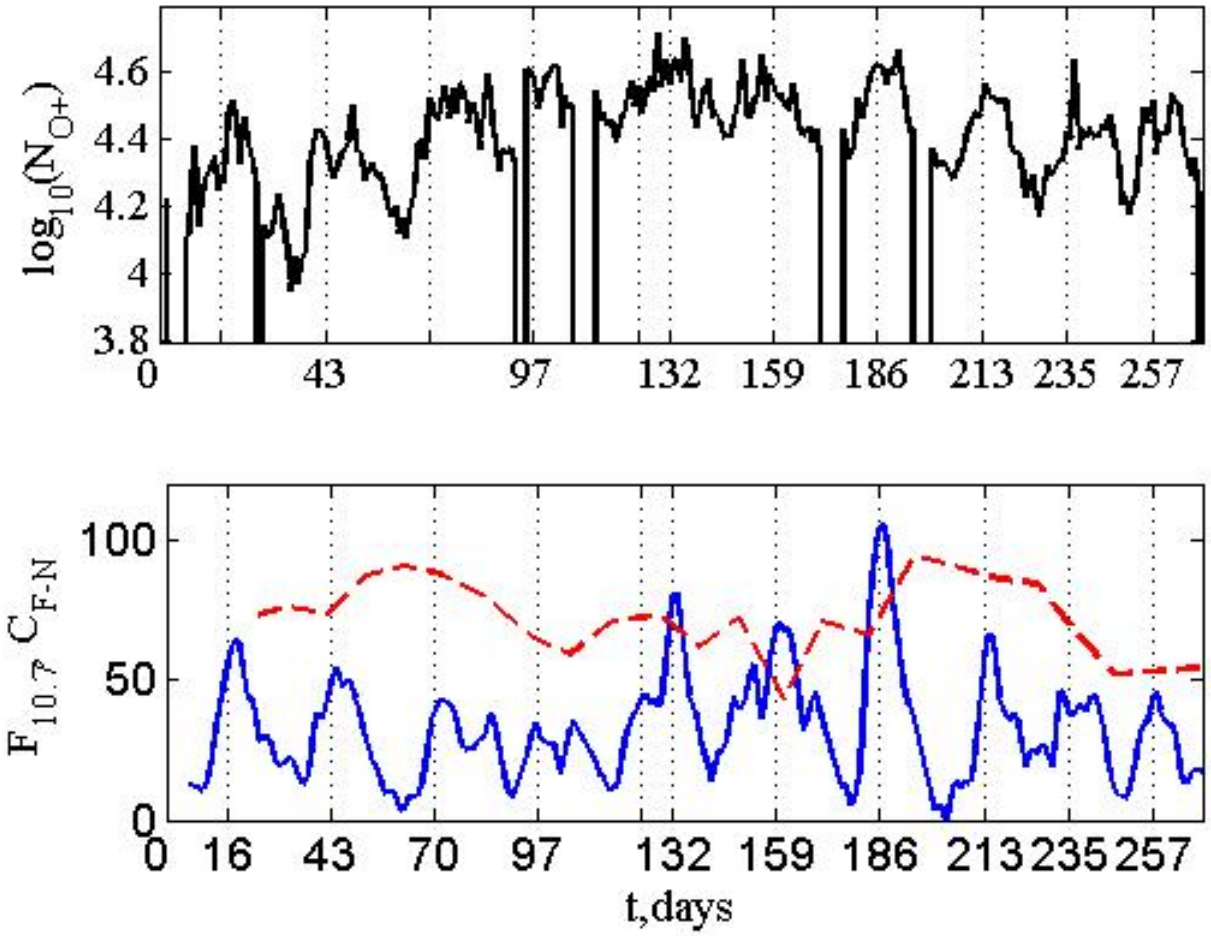
Latitude-Seasonal Distribution



The density of H+ at middle latitudes reaches maximum simultaneously in October in both hemispheres At low latitudes an additional April maximum occurs in the seasonal variation of the concentration of H+.

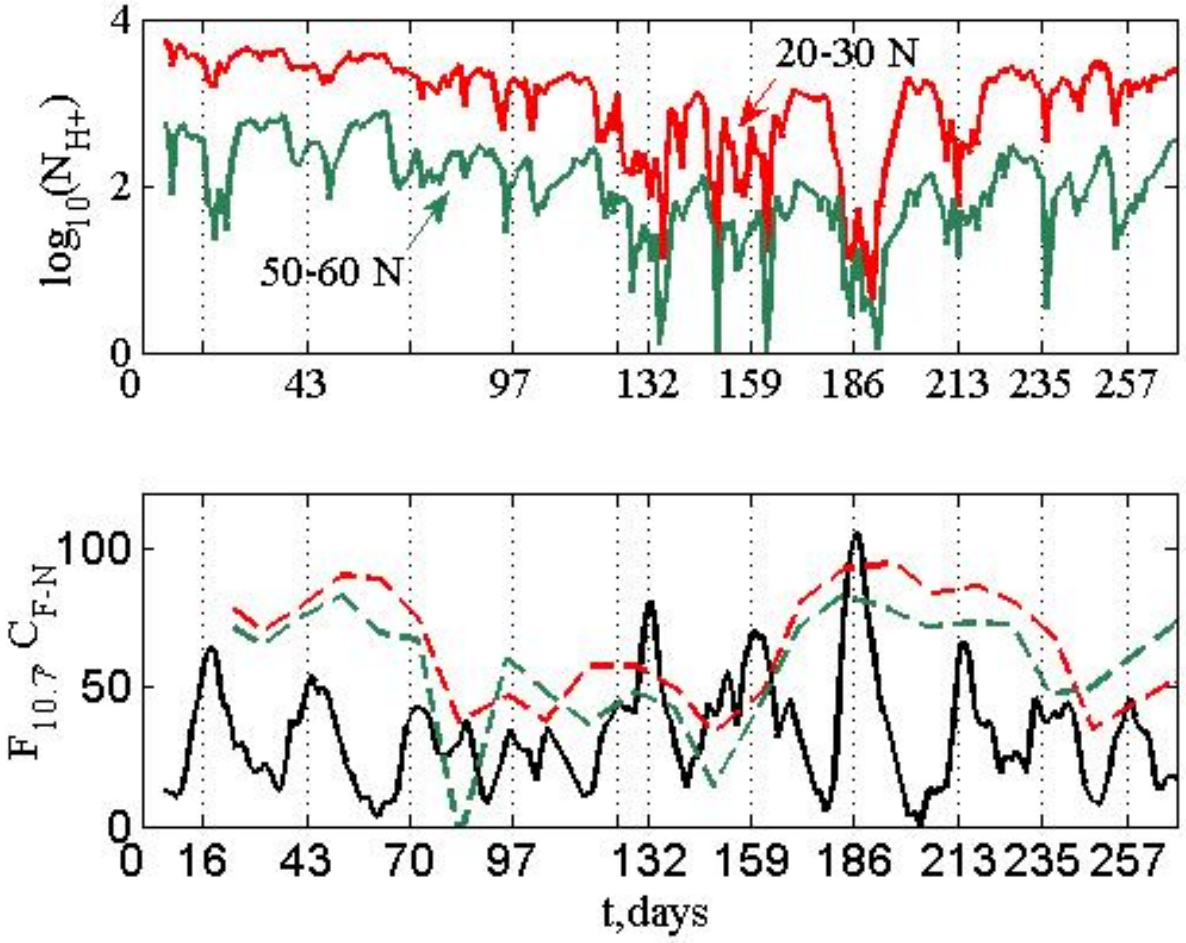
The seasonal variation of O+ is at mid-latitude characterized with the only maximum at local late summer. An additional low latitude maximum of O+ concentration occurs in February. It is shifted from the equator at about 15^{o} to the south

27-day Solar Rotation Cycle and O+



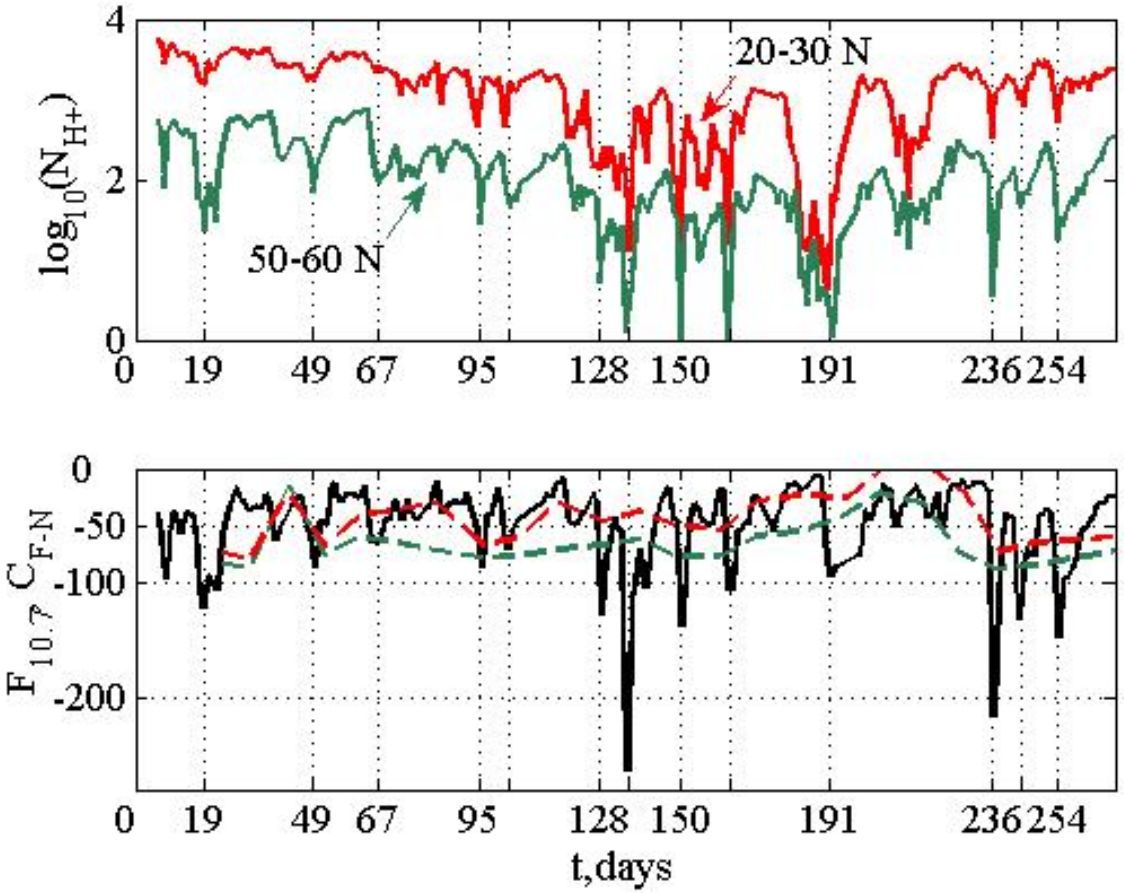
At the decreasing of solar activity the effects of solar rotation are seen best of all. For 2005 F10.7 solar index is given in the Figure together with O+ concentration (it is highly correlated in a wide range of latitudes) . Close agreement of positions of maxima is seen.

27-day Solar Rotation Cycle and H+



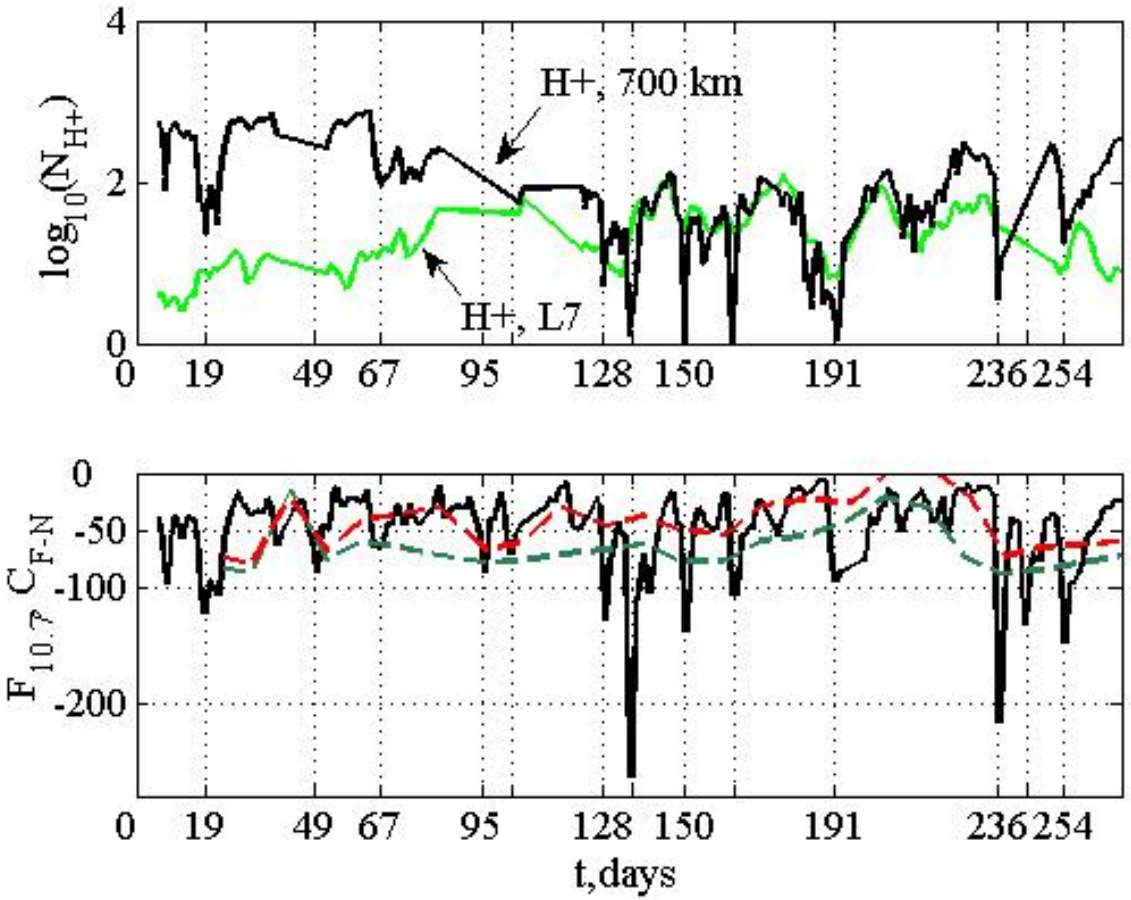
- Averagely concentration of H+ is in anticorrelation with both O+ concentration and solar activity.
- However, zone of low absolute values of correlation is seen in March-June and the positions of N_{H+} minima are often shifted several days in respect to solar activity maxima.

Geomagnetic activity and concentration of light ions



The average correlation coefficient for 50-60^{o}N latitude band is C_{F-N}=0.7 and the positions of all the meaningful minima of Dst coincide almost exactly with positions of minima of concentration. At lower latitudes the correlation decreases, but the peak positions still agree well. The interval of low correlation in July-August correspond to very low geomagnetic activity.

H+ at low geomagnetic activity. DEMETER-LANL comparison



- The result of fitting procedure for the correlation coefficient between LANL7 low energy ion density and DEMDETER H+ density for the interval 130<DOY<240, 2005.
- The best correlation
- $C_{L7\text{-}D}$=0.78 was found at interval from noon to midnight 12<MLT<24, at timeshift τ=5 days and time width Δt=6 days.

Discussion and Conclusion

- In the upper ionosphere at 700 km oxygen and light ions (H+ and He+) demonstrate qualitatively different behavior and dependence on physically different factors.
- O+ at these altitudes is still a ionospheric ion with typical for lower altitudes seasonal variation and dependence on solar radiation
- For light ions the processes in magnetosphere become important. Their seasonal variation and dependence on solar activity are, in fact the artifacts of geomagnetic processes. The clear anticorrelation of H+ concentration with the geomagnetic activity follows the processes of depletion and refilling of the plasmasheric field tubes.