Solar Rotation Effects on CHAMP Neutral and Plasma Densities

Federico Gasperini[1], Humberto C. Godinez[2], Josef Koller[2]

Contact: gasperini@colorado.edu

[1]Department of Aerospace Engineering Sciences, University of Colorado, Boulder, CO, USA [2]Los Alamos National Laboratory, Los Alamos, NM, USA

1. Objective

Characterize the solar radiation influence on the ionospheric neutral and electron densities during different phases of the solar cycle

Science questions:

1. To what degree is solar EUV radiation reflected in the ionospheric neutral and plasma densities?
   - Is solar rotation evident in neutral/plasma densities?
   - Does neutral/plasma density correlate well with F10.7 and neutral density?
   - Is this correlation strongly dependent on the phase of the solar cycle?
2. What is the best proxy to describe the absorption of solar EUV radiation in the ionosphere?
   - What solar wavelengths describe better neutral and plasma density variability?
   - Are there EUV irradiances showing a better correlation than the F10.7?

2. Data & Methodology

- CHAMP neutral and plasma densities
  -Orbit: 87.3°
  -Mean Height: 400 Km (2002) – 350 Km (2007)
  -Precession rate: ~ 1.3°/day (24 hrs. in 264 days)
- Ap as proxy for geomagnetic activity, F10.7 and TIMED-SEE irradiances as proxy of solar radiation
- Years analyzed: 2002/2003 (solar max) and 2006/2007 (solar min)
- Time domain – correlation of "mean" residuals (27-day means shifted one day at the time are subtracted from raw data and a 5-day running mean is applied, similarly to *Forbes et al., [2006]*)
- Frequency domain – FFT and Morlet wavelet

3. Correlation During Solar Maximum

2002

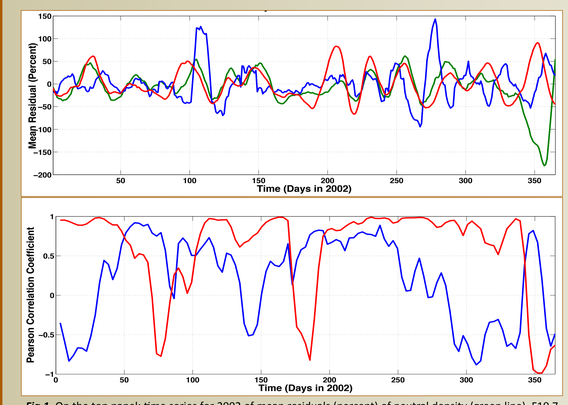

Fig 1. On the top panel: time series for 2002 of mean residuals (percent) of neutral density (green line), F10.7 (red line) and Ap (blue line). On the bottom panel moving Pearson correlation coefficient during 2003 of neutral density with F10.7 (red line) and Ap (blue line).

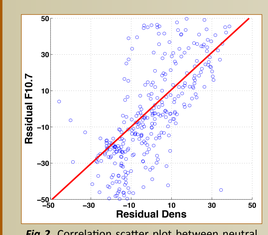

Fig 2. Correlation scatter plot between neutral density and F10.7 for 2002.

Corr Coeff	N Density	E Density
F10.7	0.626	0.570
0.1-7	-0.086	-0.022
27-34	0.567	0.163
30.4	0.533	0.144
33.5	0.385	0.168
36.8	0.528	0.123
121.5	0.590	0.118
133.5	0.580	0.147
145-165	0.566	0.059
Ap	0.111	-0.209

Tbl 1. Pearson correlation coefficients between neutral/plasma densities and solar/geomagnetic indices for 2002.

2003

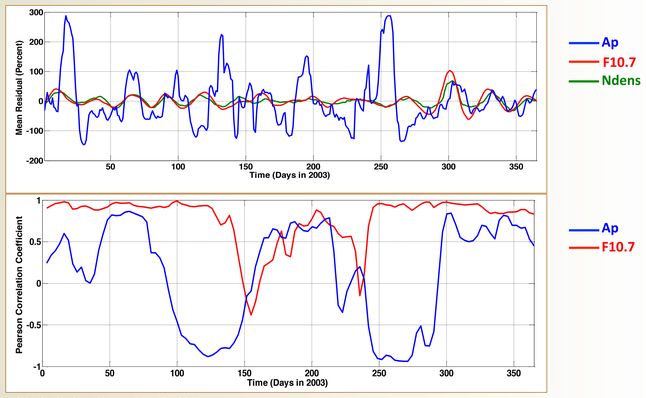

Fig 3. Similarly to Figure 1, but for 2003.

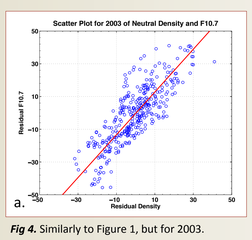

Fig 4. Similarly to Figure 1, but for 2003.

Corr Coeff	N Density	E Density
F10.7	0.875	0.549
0.1-7	0.790	0.464
27-34	0.866	0.563
30.4	0.859	0.535
33.5	0.822	0.511
36.8	0.686	0.442
121.5	0.830	0.584
133.5	0.882	0.583
145-165	0.846	0.588
Ap	0.056	0.099

Tbl 2. Similarly to Table 1, but for 2003.

- Good correlation is found between solar proxies (F10.7 and TIMED-SEE irradiances) and neutral densities at solar maximum (Table 1 and 2).
- Figure 1 and 2 (3 and 4) show significant correlation between F10.7 and neutral density for 2002 (2003) during solar maximum. The correlation drops during parts of the year due to decreased solar radiation variability. Ap is for the most part uncorrelated to neutral density.
- The bottom panel in Figure 1 and 3 shows Pearson correlation coefficients higher than 0.75 for most of the year, this means that over 56% in neutral density variability is captured by F10.7.
- No significant correlation is found between any solar or geomagnetic proxy and electron densities (Table 1 and 2).

References

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Sutton, E. K., J. M. Forbes, and R. S. Nerem (2005), Global thermospheric neutral density and wind response to the severe 2003 geomagnetic storms from CHAMP accelerometer data, J. Geophys. Res., 110, A09S40, doi:10.1029/2004JA010985.

4. Correlation During Solar Minimum

2007

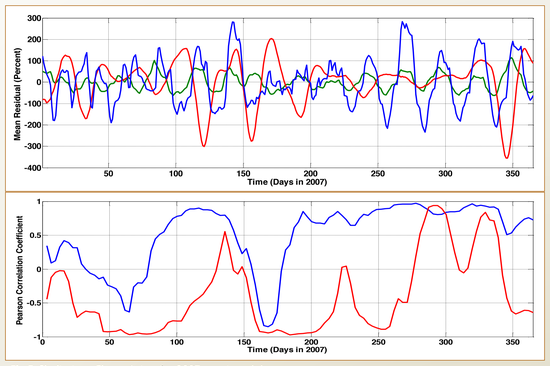


Fig 5. Similarly to Figure 1, but for 2007 at solar minimum.

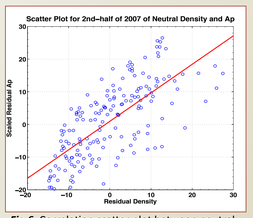


Fig 6. Correlation scatter plot between neutral density and Ap for 2007. The Ap residuals are scaled by a factor of 10.

Corr Coeff	N Density	E Density
F10.7	-0.463	-0.490
0.1-7	-0.499	-0.417
27-34	-0.419	-0.241
30.4	-0.346	-0.305
33.5	-0.419	-0.152
36.8	-0.224	-0.133
121.5	0.500	0.522
133.5	-0.419	-0.508
145-165	0.280	0.254
Ap	0.581	0.099

Tbl 3. Similarly to Table 1, but for 2007.

2008

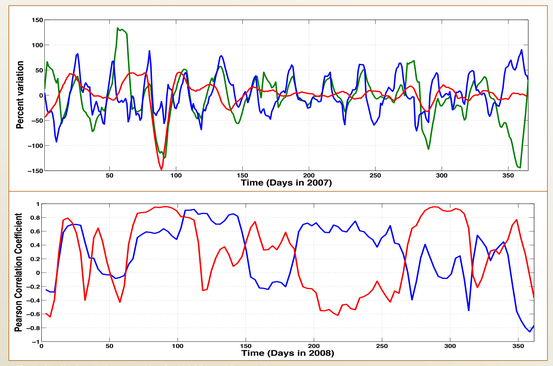


Fig 7. Similarly to Figure 1, but for 2008 at solar minimum.

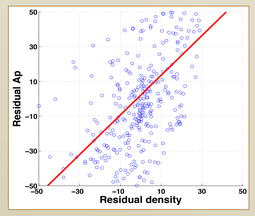


Fig 8. Similarly to Figure 8, but for 2008.

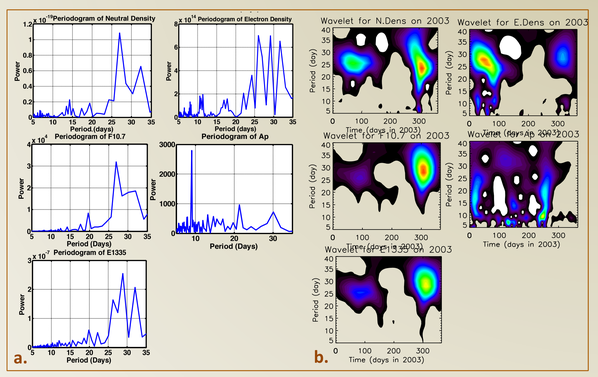
Corr Coeff	N Density	E Density
F10.7	-0.425	0.474
0.1-7	0.163	-0.233
27-34	0.163	-0.234
30.4	0.163	-0.234
33.5	0.164	-0.234
36.8	0.164	-0.234
121.5	0.157	-0.238
133.5	0.164	-0.234
145-165	0.162	-0.237
Ap	0.539	0.015

Tbl 4. Similarly to Table 1, but for 2008.

- As shown in Figure 5 and 6 (7 and 8), F10.7 and neutral density are quite uncorrelated during 2007 (2008) at solar minimum.
- We notice good correlation with Ap (coefficients ranging from 0.7 to 0.95 for most of the years), indicating that geomagnetic effects are dominating (see Table 3 and 4).
- Drops in correlation with Ap correspond to jumps in correlation with F10.7, their source is still being investigated.

5. Periodograms and Wavelets

2003 - Solar Max



2007 - Solar Min

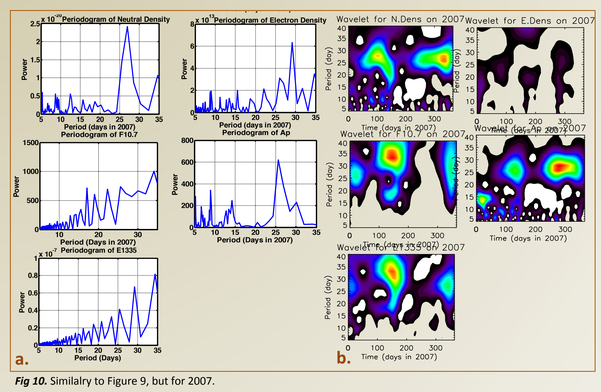


Fig 9. Periodograms (a) and wavelets (b) during 2003 for neutral density, electron density, F10.7, E1335, and Ap.

Fig 10. Similarly to Figure 9, but for 2007.

- The periodograms and wavelets for 2003 and 2007 are shown in Figure 9 and Figure 10 respectively. Results consistent with the previous ones are found. For 2003 we notice the 27-day peak in F10.7, present the neutral density as well. For 2007 we observe the many similar structures between Ap and neutral density.

5. Conclusions

We gained a better understanding of the influence of solar radiation in neutral/electron density variability at 300-400 Km and the processes driving satellite drag variability

a. The phase of the solar cycle highly influence the best proxy for neutral density variability (F10.7 at solar max and Ap at solar min)

b. Far Ultra Violet (FUV) radiation seems more representative of solar energy input in the 300-400 Km region – especially 133.5 nm

Acknowledgements

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