Dependence of Amplitude and Phase of Seasonal Variation of Thermospheric Neutral Density on Geophysical Conditions

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Abstract

Thermospheric neutral density exhibits seasonal variation with maximum during equinox seasons, a primary minimum near June solstice and a secondary minimum near December solstice. The amplitude and phase of this seasonal variation change from year to year, and possible mechanisms of this seasonal variation are the sun-earth distance, large-scale circulation, lower atmospheric forcing, and geomagnetic activity. Using thermospheric neutral density data derived from 5000 space objects from 1967 to 2007 with perigees lower than 600 km, statistical relations between amplitude and phase of seasonal density variation with geophysical conditions such as solar activity, altitude, and geomagnetic activity are examined. These statistical relations provide information about the mechanisms of the seasonal variation.

Density Components

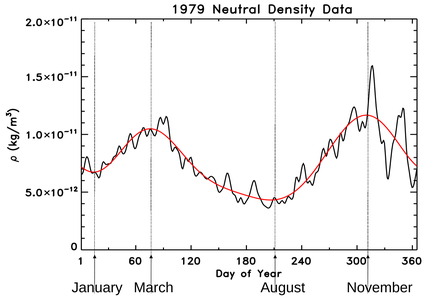


Figure 2: Fourier fit to 1979 density data at 400km

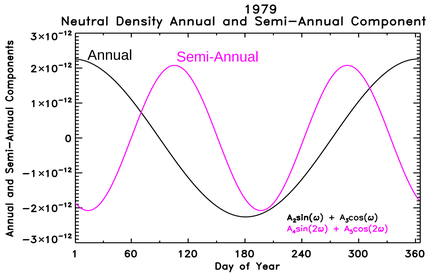


Figure 3: 1979 density Fourier fit decomposed into annual and semiannual components at 400km

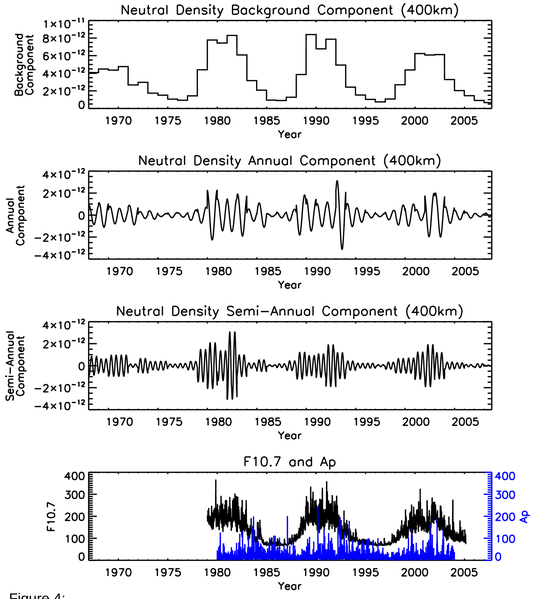


Figure 4:
Neutral density Fourier fit background, annual, and semiannual component from 1967 to 2007; F10.7 and Ap from 1980 to 2004.

Fourier Harmonic Function:

$$\rho = A_1 + A_2\sin(\omega) + A_3\cos(\omega) + A_4\sin(2\omega) + A_5\cos(2\omega) + A_6\sin(3\omega) + A_7\cos(3\omega) + A_8\sin(4\omega) + A_9\cos(4\omega)$$

Possible Mechanisms

- Annual Component
  - Sun-earth distance
- Semiannual Component
  - Semiannual variation in Ap
  - Semiannual variation of large-scale circulation: “thermospheric spoon”, Fuller-Rowell, 1998
- Additional annual/semiannual variation
  - Annual/semiannual variation of eddy diffusioni near mesopause, Qian et al., 2009

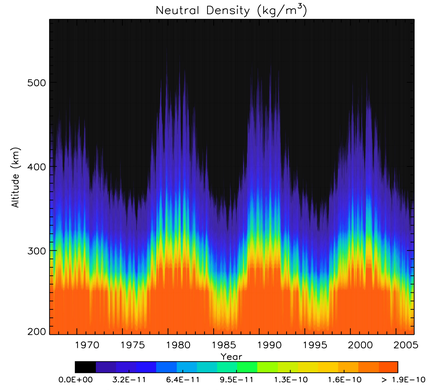


Figure 1:Neutral density derived from drag data of 5000 satellites

Correlation with Solar Activity (F10.7) and Geomagnetic Activity (Ap)

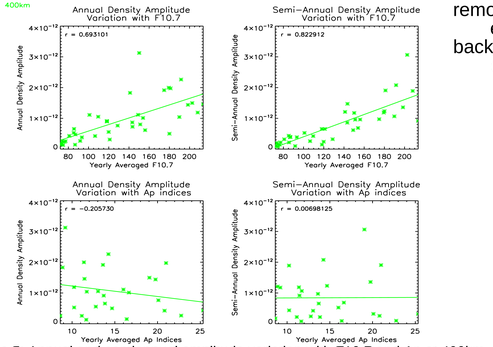


Figure 5: Annual and semiannual amplitude variation with F10.7 and Ap at 400km

Linear Pearson Correlation Coefficients

	Yearly Averaged F10.7 vs:		Yearly Averaged Ap Indices vs:	
	Annual Amplitude	Semi-annual Amplitude	Annual Amplitude	Semi-annual Amplitude
250 km	0.4301800	0.7139140	-0.2149410	0.0181020
400 km	0.6931010	0.8229120	-0.2057300	0.0069813
550 km	0.7683370	0.8072910	-0.2050220	0.0122551

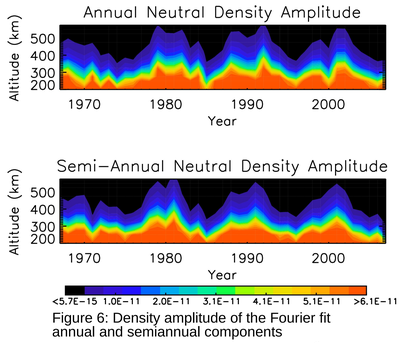


Figure 6: Density amplitude of the Fourier fit annual and semiannual components

$$relative\ density\ amplitude = \log_{10}\left(\frac{\rho_{max}}{\rho_{min}}\right)$$

Using relative density amplitude removes the effect of background density.

Altitude Dependence

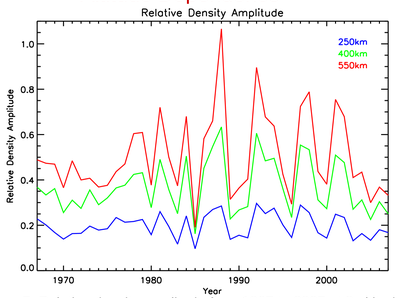


Figure 7: Relative density amplitude from 1967 to 2007 at 3 altitudes

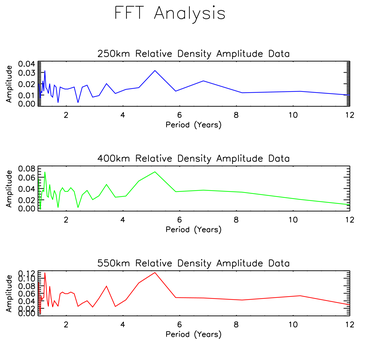
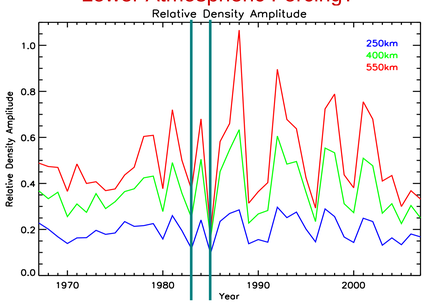


Figure 8: Fast Fourier Transform analysis of relative density amplitude data at 3 altitudes

Because the period of these oscillations are less than the 11 year period of the solar cycle, this suggests another source of forcing for the seasonal variation.

Lower Atmospheric Forcing?



Conclusions

- The main components of density variations are annual and semiannual variation,
- Both the annual and semiannual components clearly correlate to solar activity,
- Density amplitudes shows a weak correlation with geomagnetic activity,
- Density amplitudes increase with altitude in the altitude range 250-550km,
- Density amplitudes also show variation in the range from 2-5 years that suggest lower atmospheric forcing.

Future Steps

- Investigate correlations with lower atmospheric forcing, e.g., Quasi Biannual Oscillation (QBO) using wind data