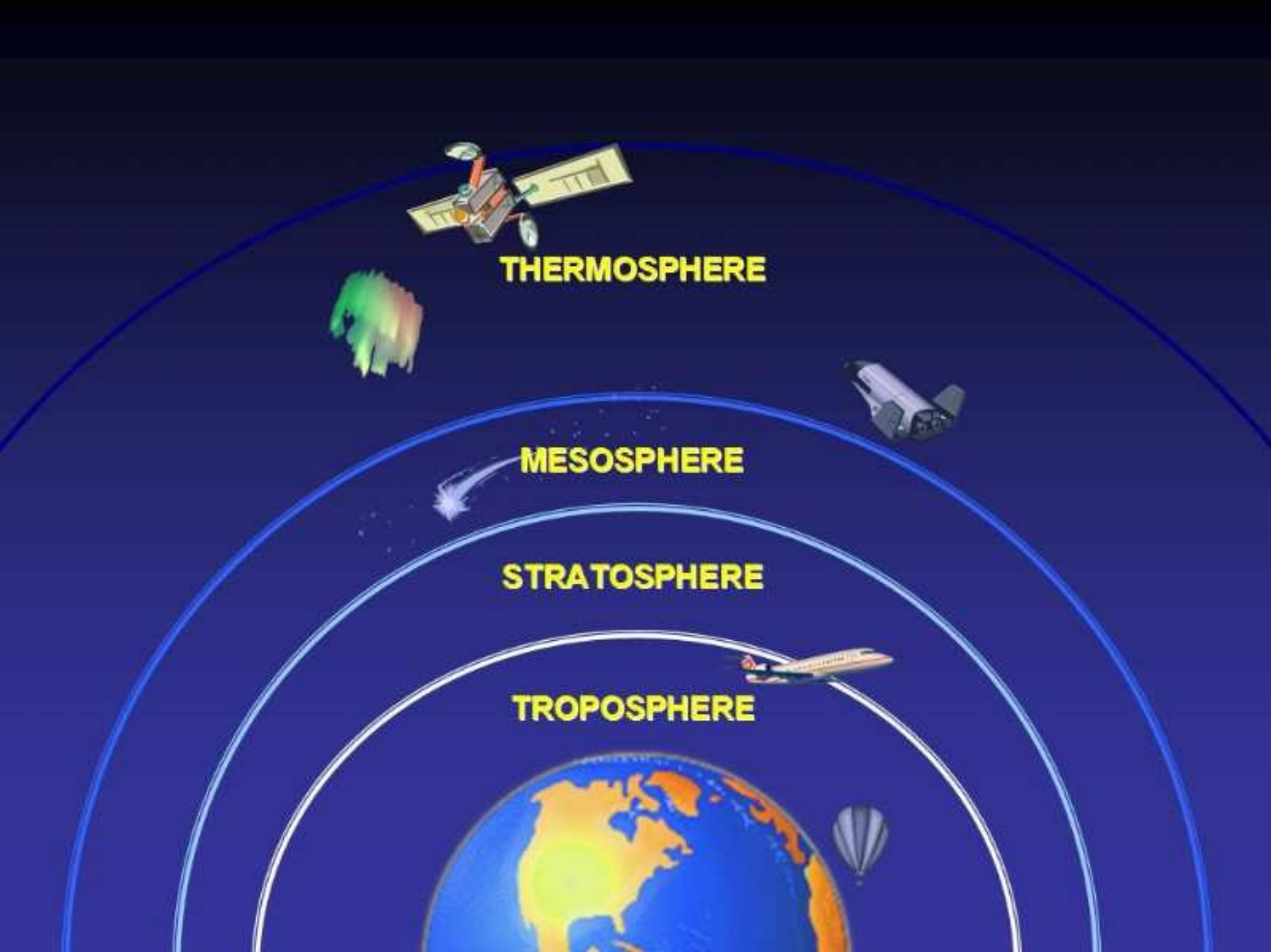
# Thermospheric Neutral Density Variation

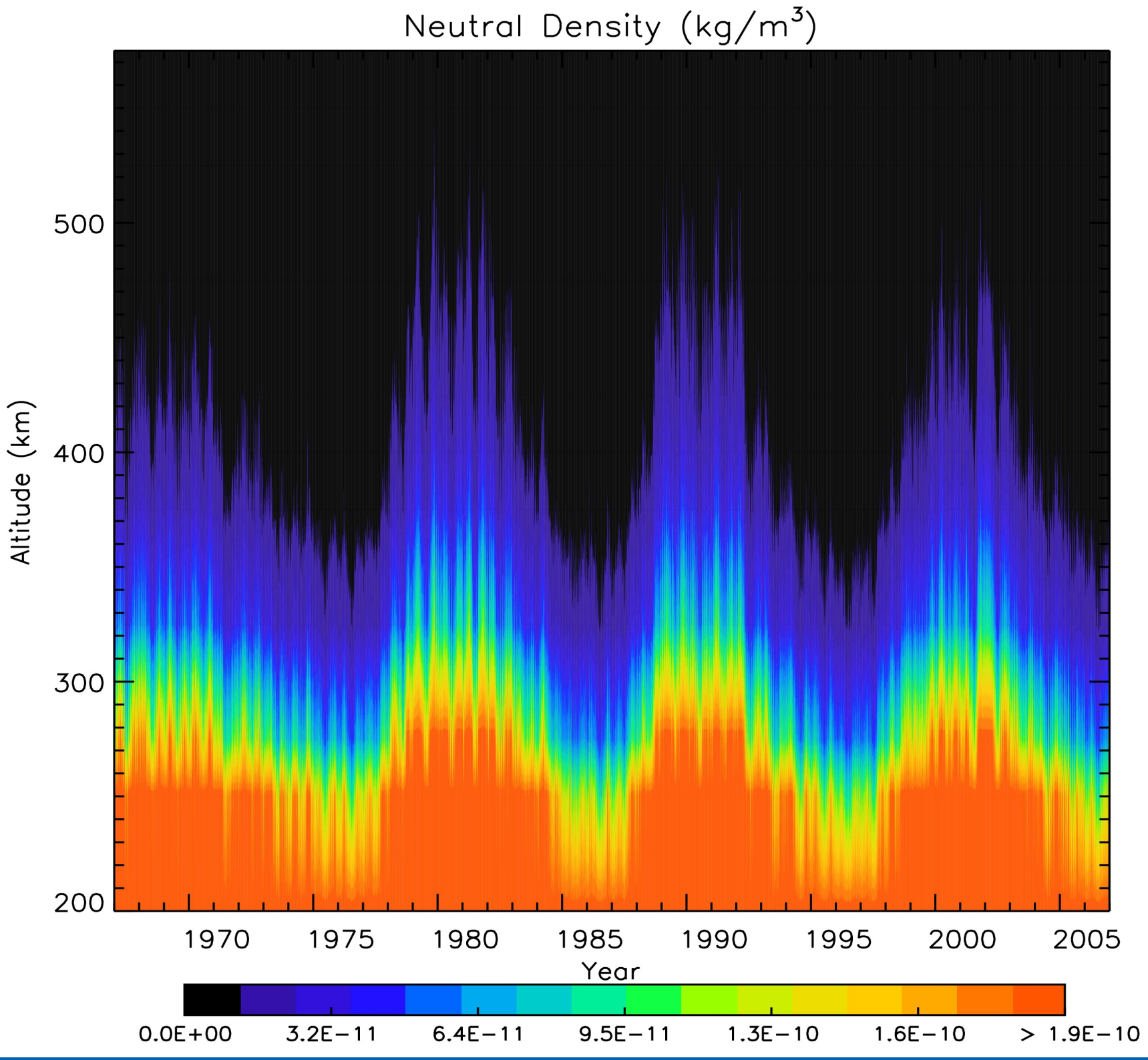
Christina Chu

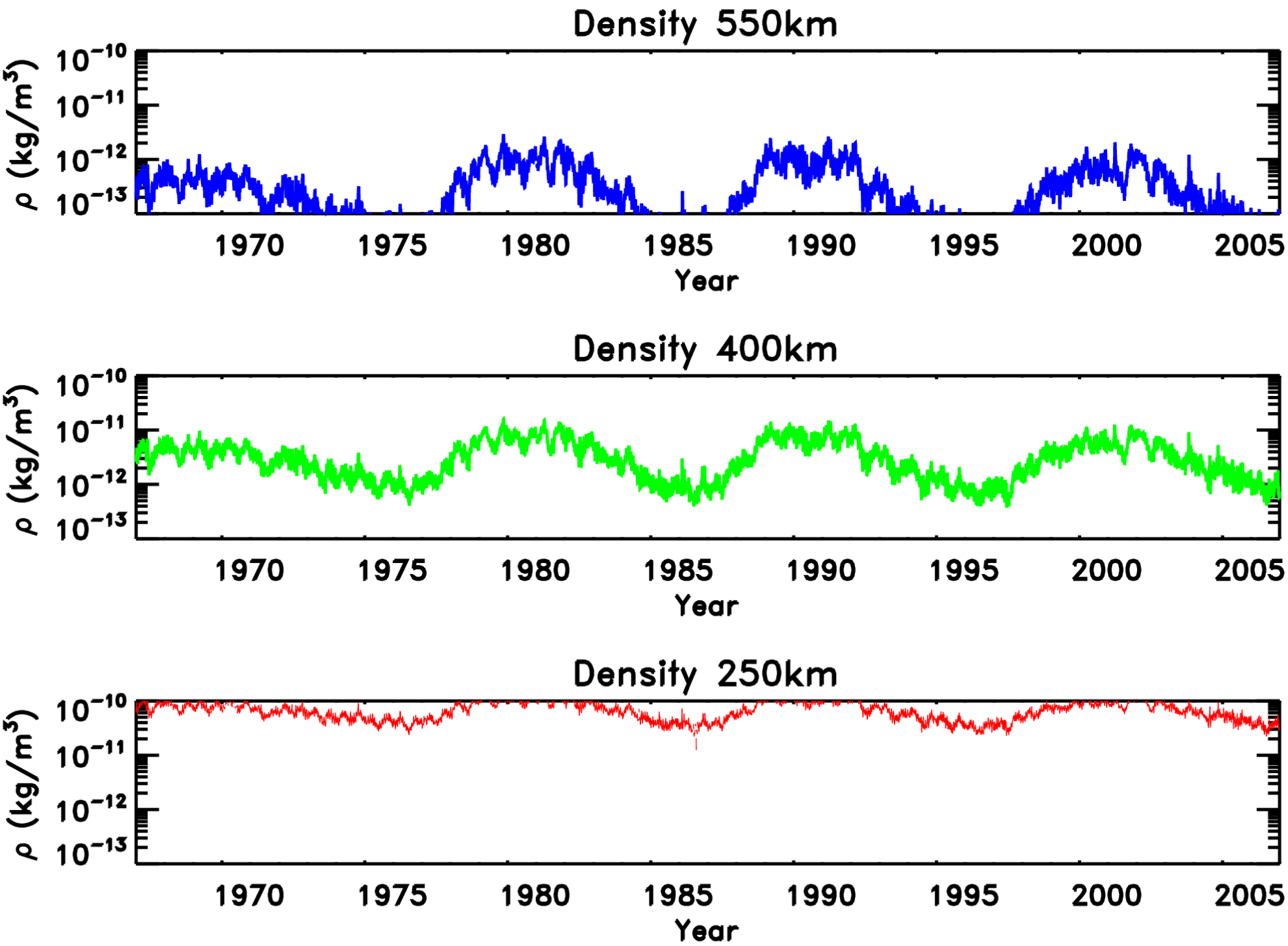
Mentor: Liying Qian

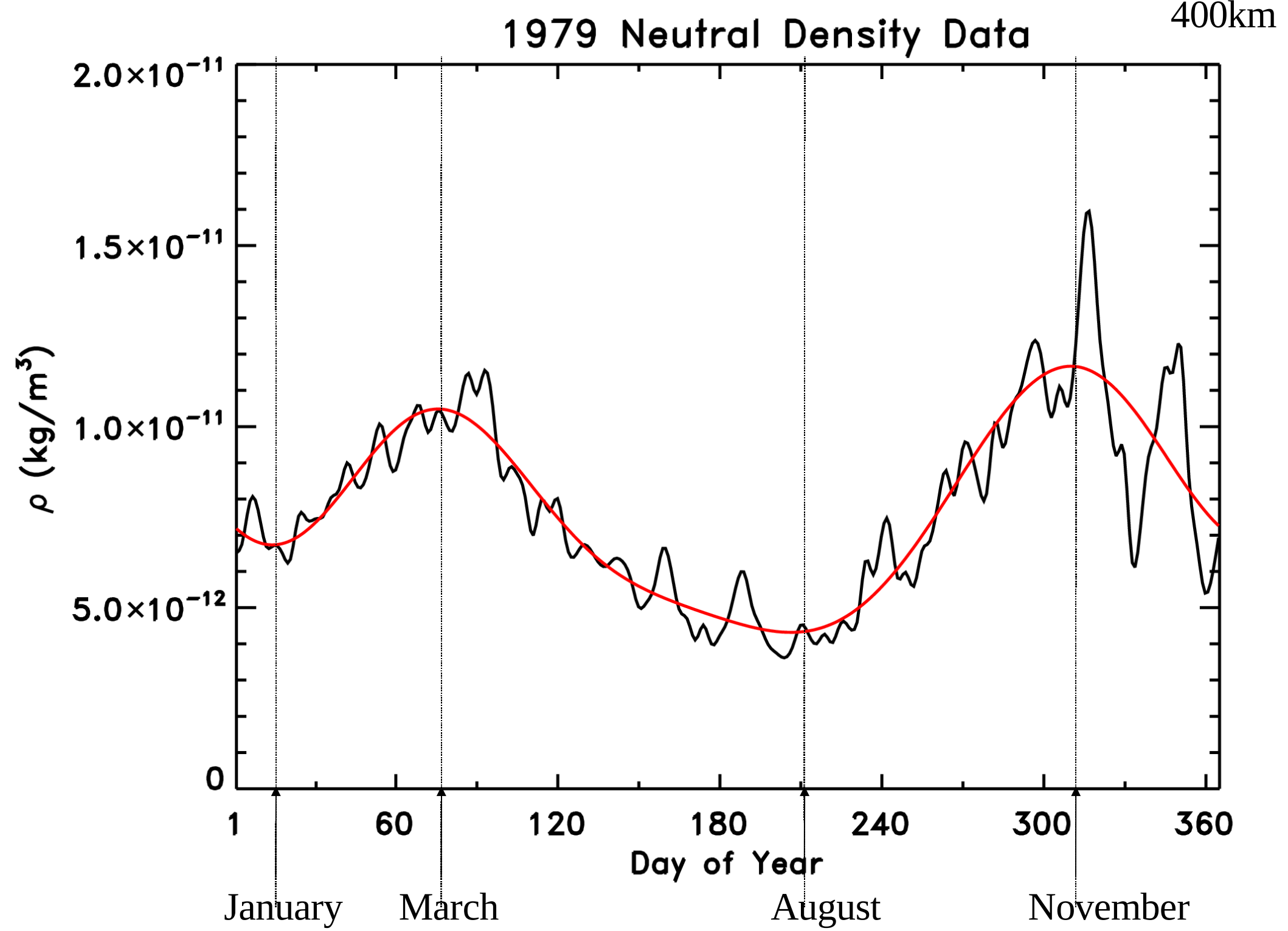
# Background

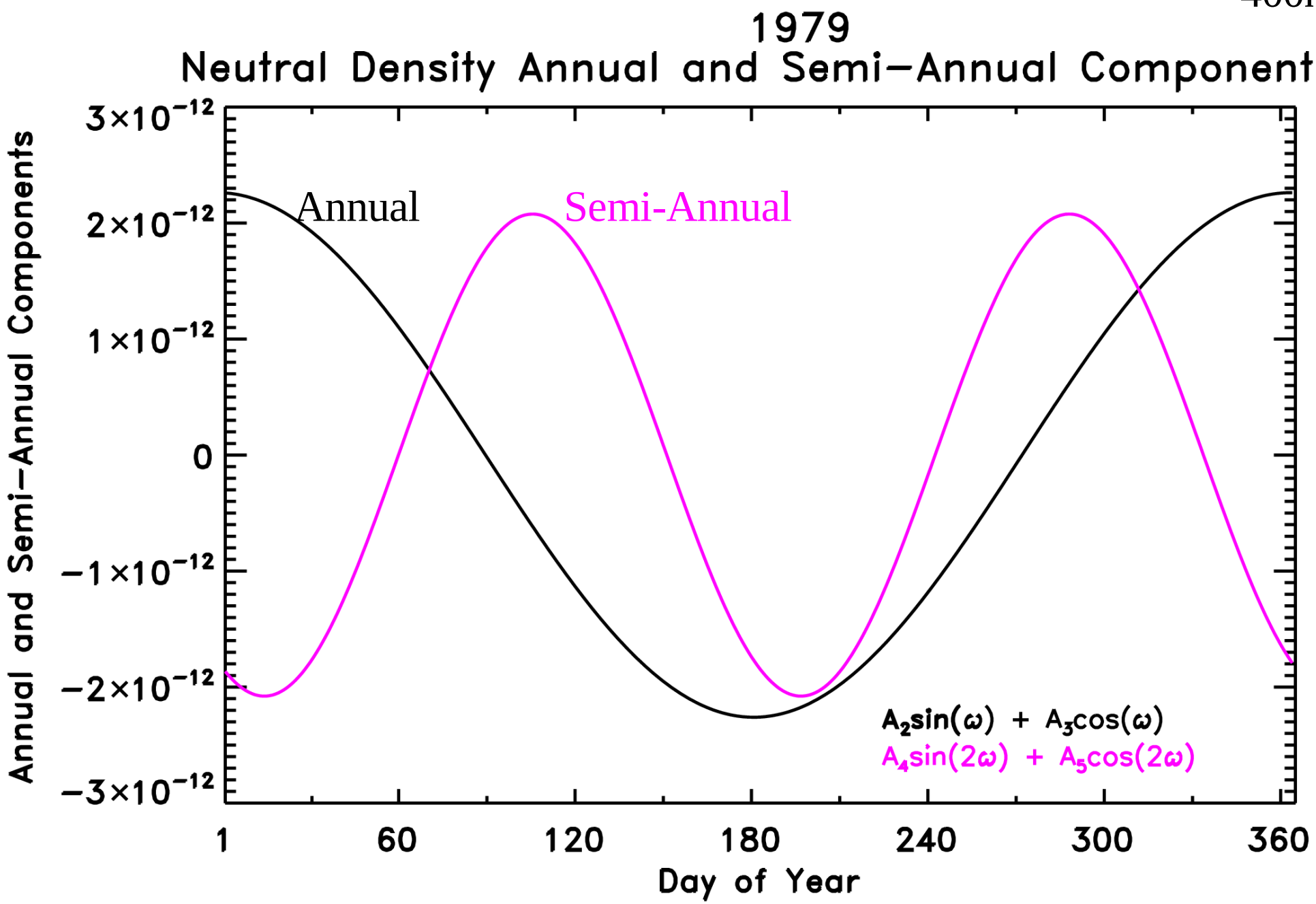

THERMOSPHERE
MESOSPHERE
STRATOSPHERE
TROPOSPHERE

# Analysis


Neutral Density (kg/m3)
Altitude (km)
500
400
300
200
1970
1975
1980
1985
1990
1995
2000
2005
Year
0.0E+00
3.2E-11
6.4E-11
9.5E-11
1.3E-10
1.6E-10
> 1.9E-10

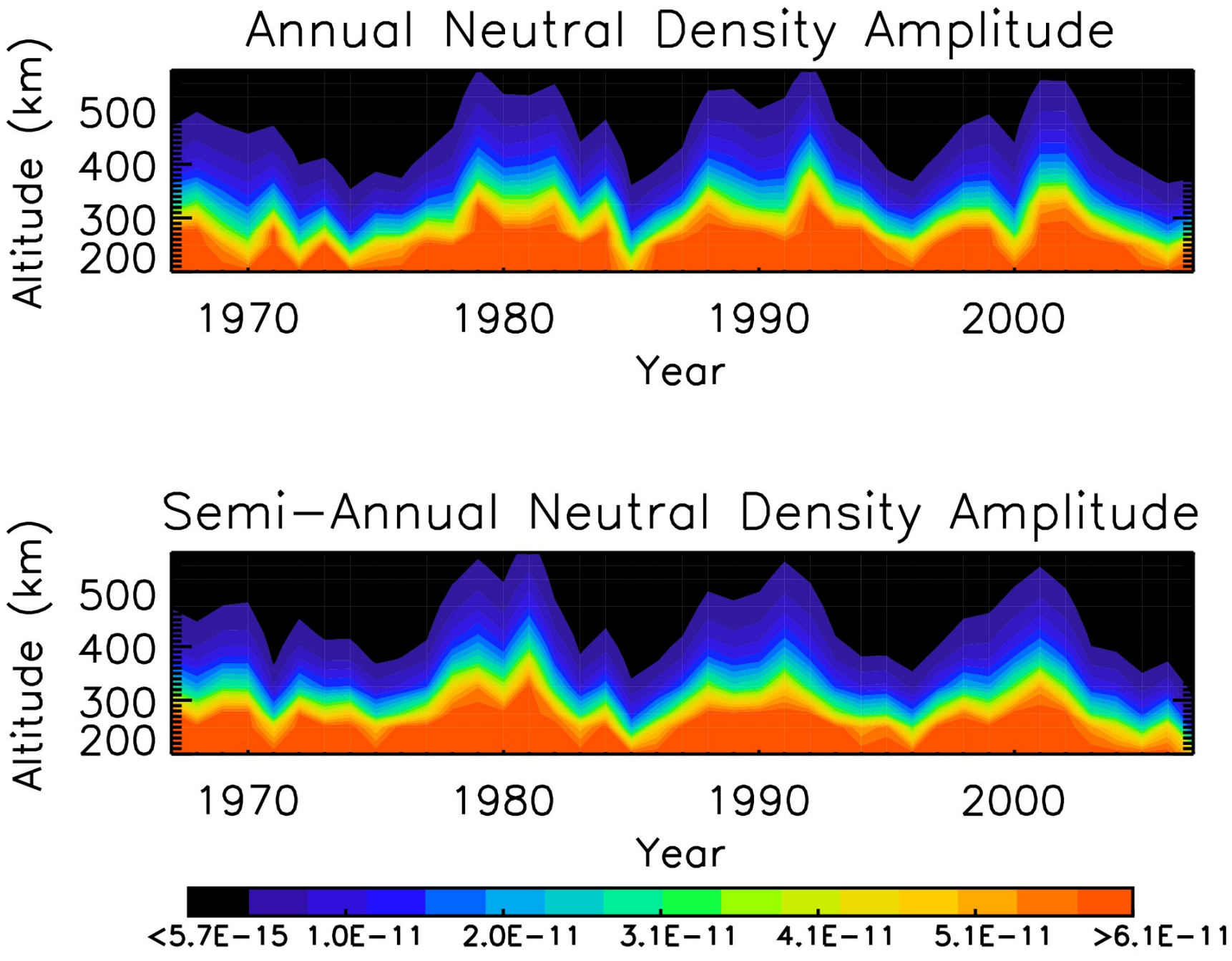

Density 550km
ρ (kg/m³)
10⁻¹⁰
10⁻¹¹
10⁻¹²
10⁻¹³
1970
1975
1980
1985
1990
1995
2000
2005
Year
Density 400km
ρ (kg/m³)
10⁻¹⁰
10⁻¹¹
10⁻¹²
10⁻¹³
1970
1975
1980
1985
1990
1995
2000
2005
Year
Density 250km
ρ (kg/m³)
10⁻¹⁰
10⁻¹¹
10⁻¹²
10⁻¹³
1970
1975
1980
1985
1990
1995
2000
2005
Year


400km
1979 Neutral Density Data
2.0×10⁻¹¹
1.5×10⁻¹¹
1.0×10⁻¹¹
5.0×10⁻¹²
0
ρ (kg/m³)
1
60
120
180
240
300
360
Day of Year
January
March
August
November




Fourier Harmonic Function:

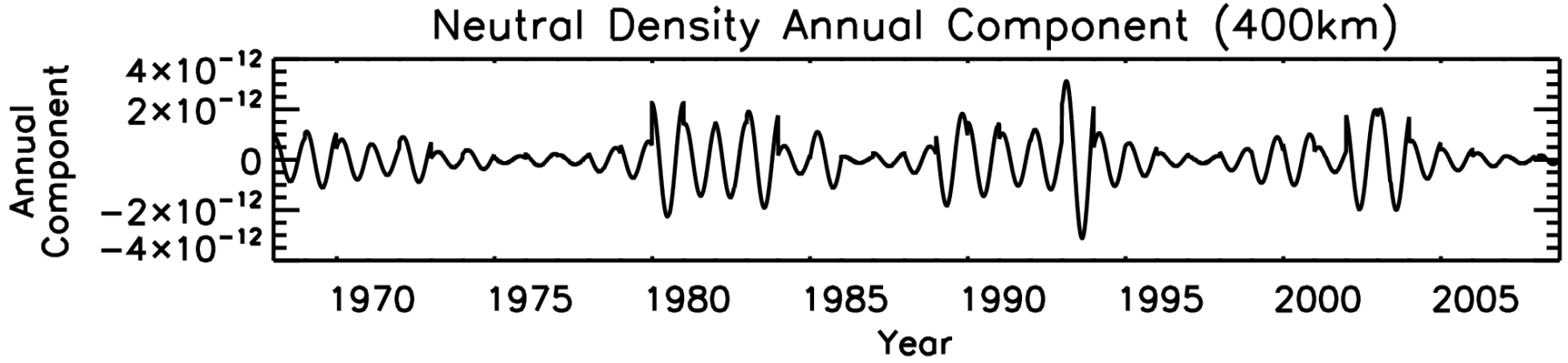
$$\rho = A_1 + A_2\sin(\omega) + A_3\cos(\omega) + A_4\sin(2\omega) + A_5\cos(2\omega) + A_6\sin(3\omega) + A_7\cos(3\omega) + A_8\sin(4\omega) + A_9\cos(4\omega)$$

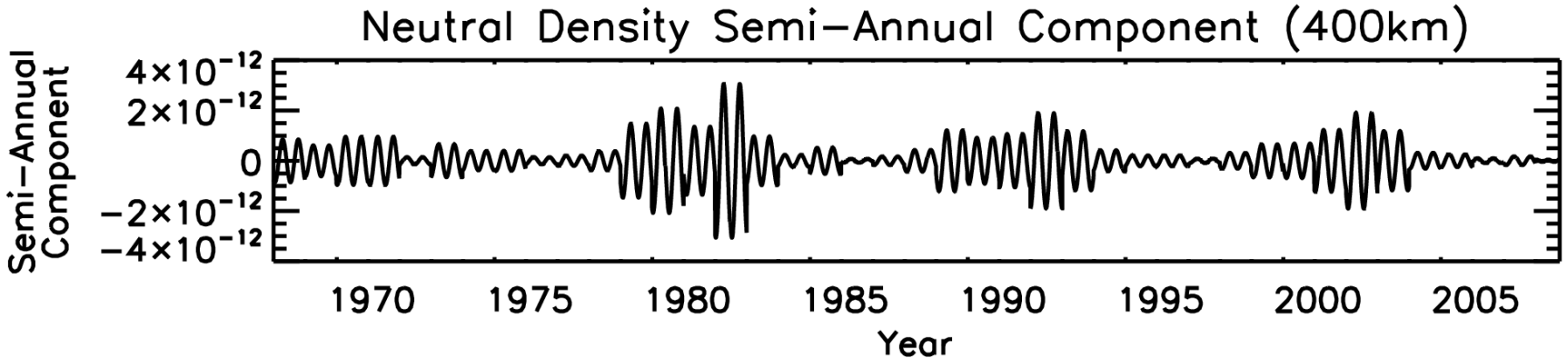

Annual Neutral Density Amplitude
Altitude (km)
500
400
300
200
1970
1980
1990
2000
Year
Semi–Annual Neutral Density Amplitude
Altitude (km)
500
400
300
200
1970
1980
1990
2000
Year
<5.7E–15
1.0E–11
2.0E–11
3.1E–11
4.1E–11
5.1E–11
>6.1E–11

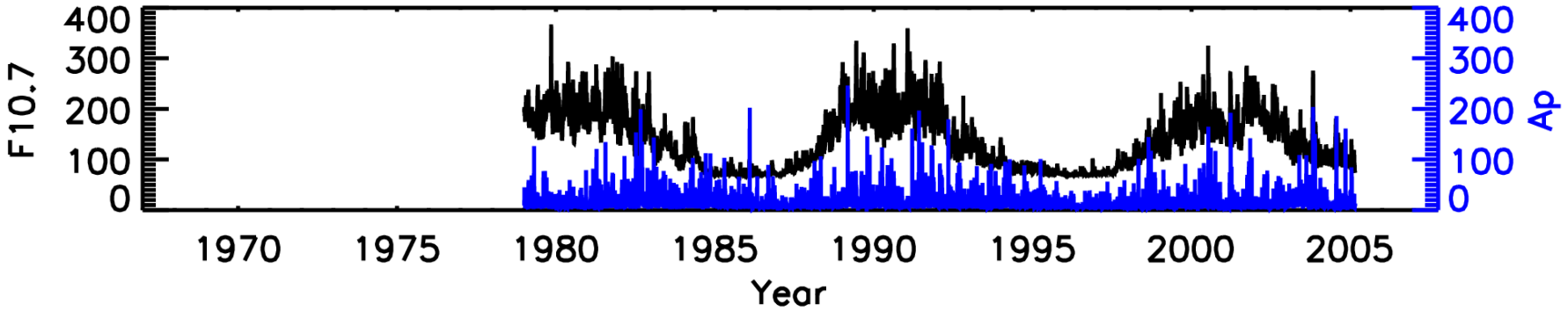
# Possible Mechanisms

- 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/semiannul variation of eddy diffusion near mesopause, Qian et al., 2009

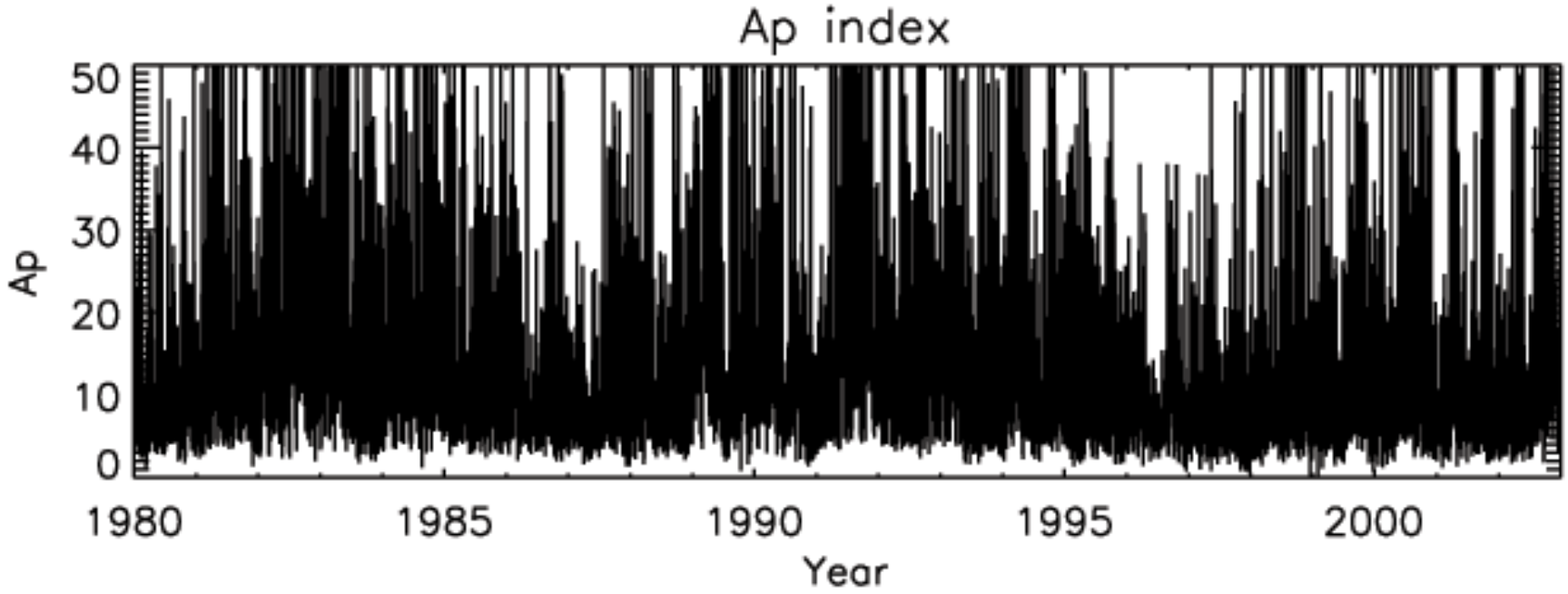
# Correlation with Solar Activity (F107)

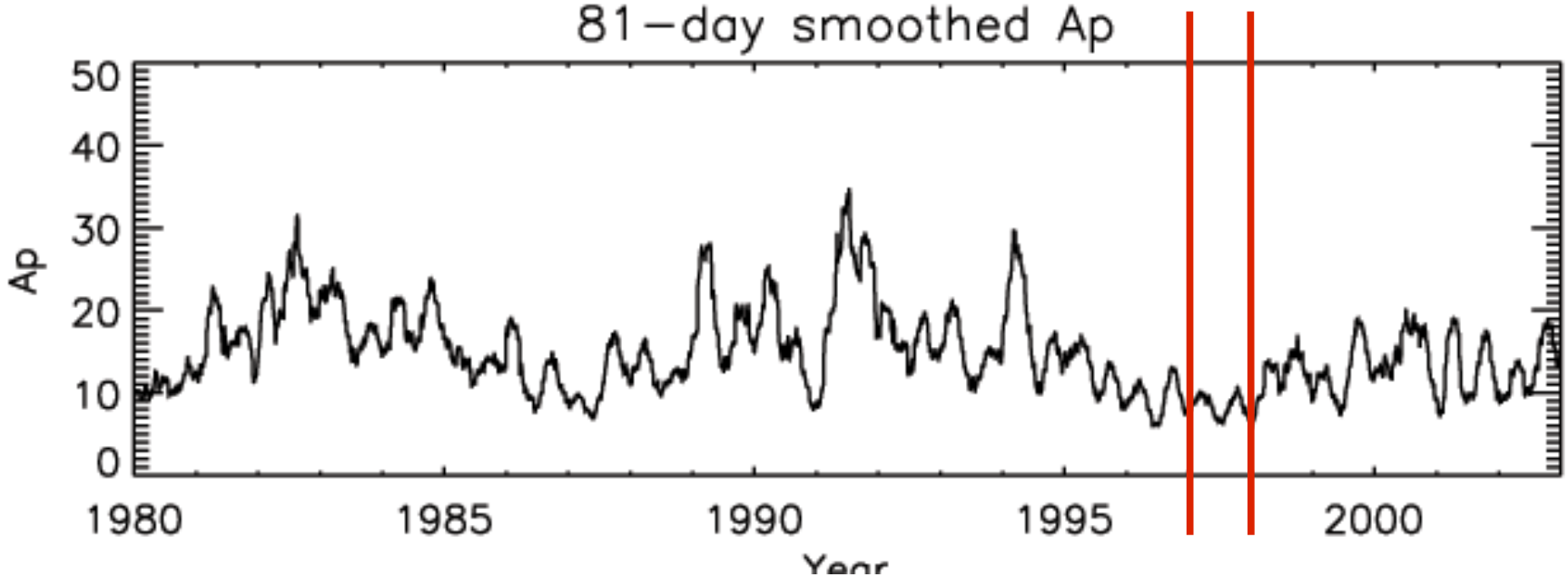


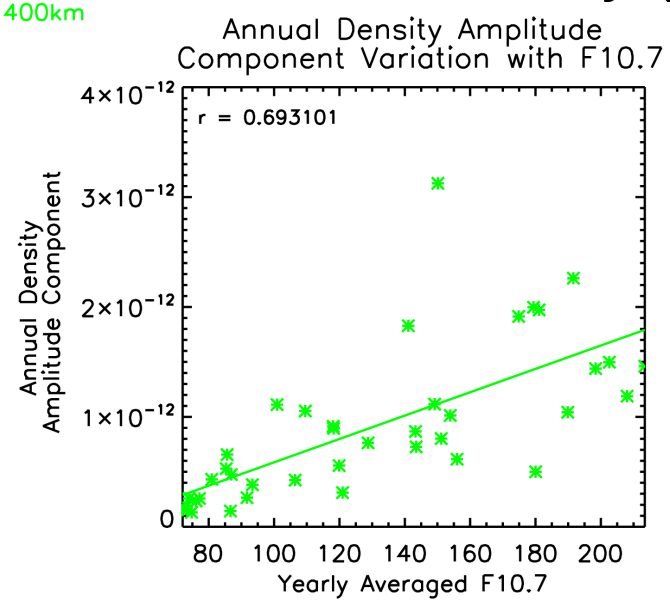
# Correlation With Geomagnetic Activity (Ap)

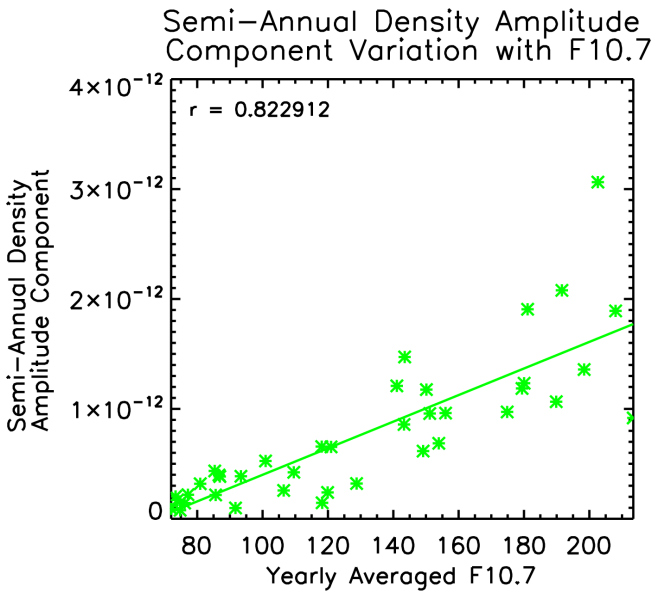


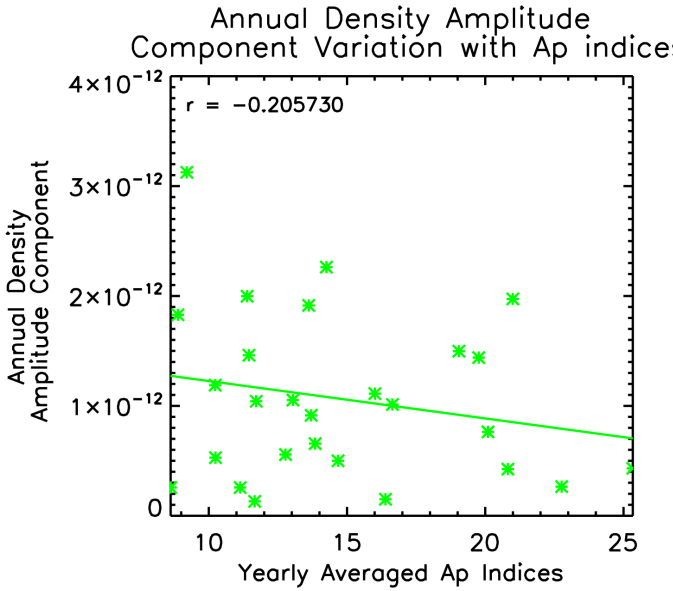



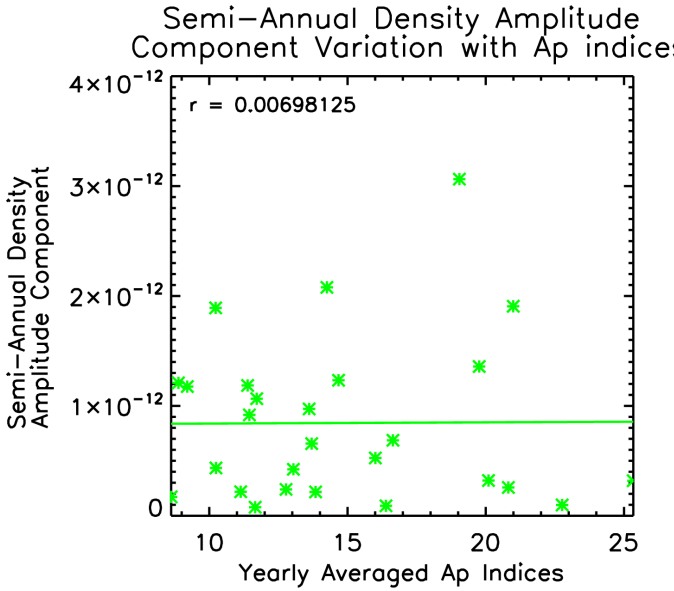
# Correlation with Solar Activity (F107) and Geomagnetic Activity (Ap)

400km



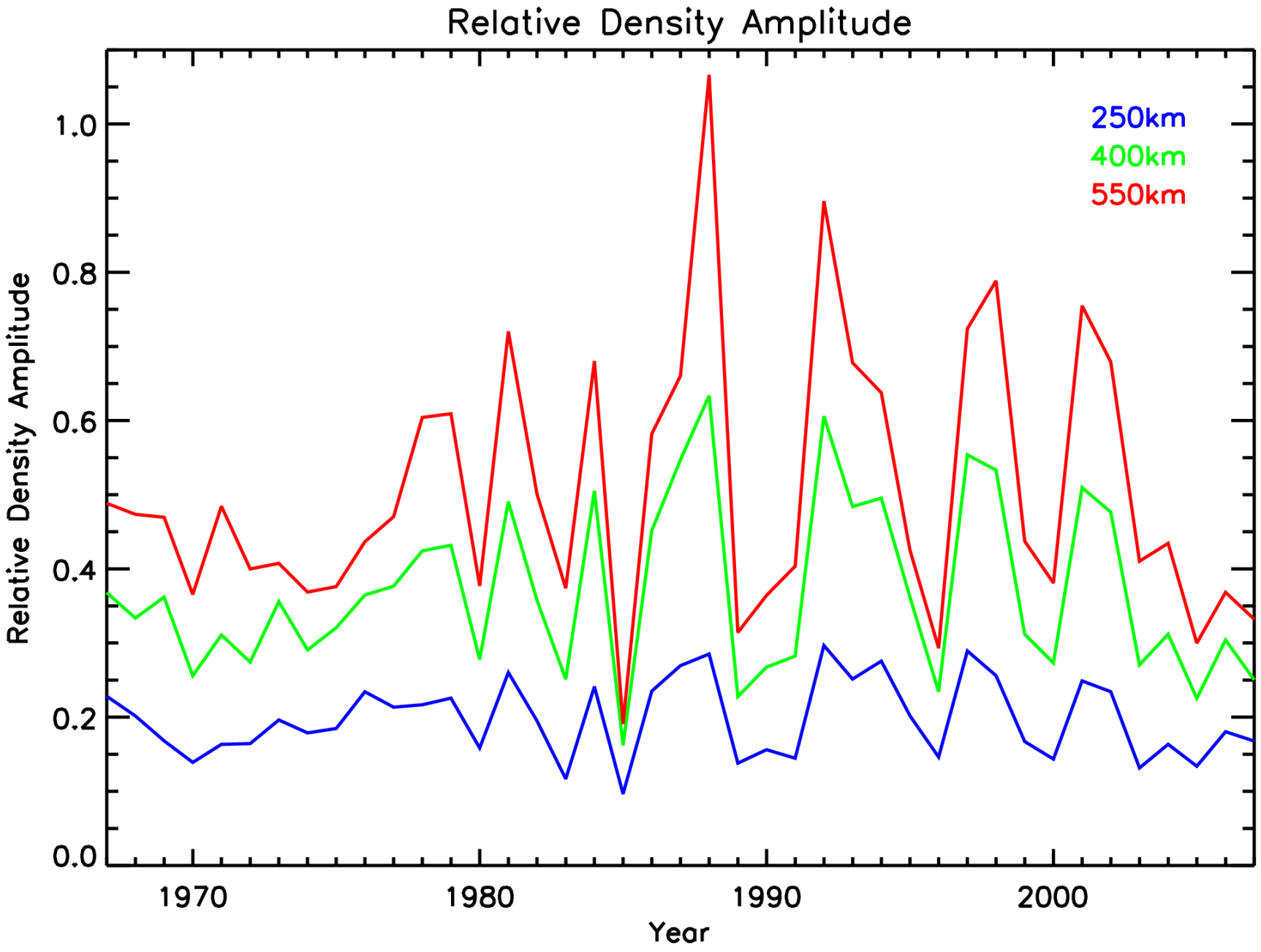



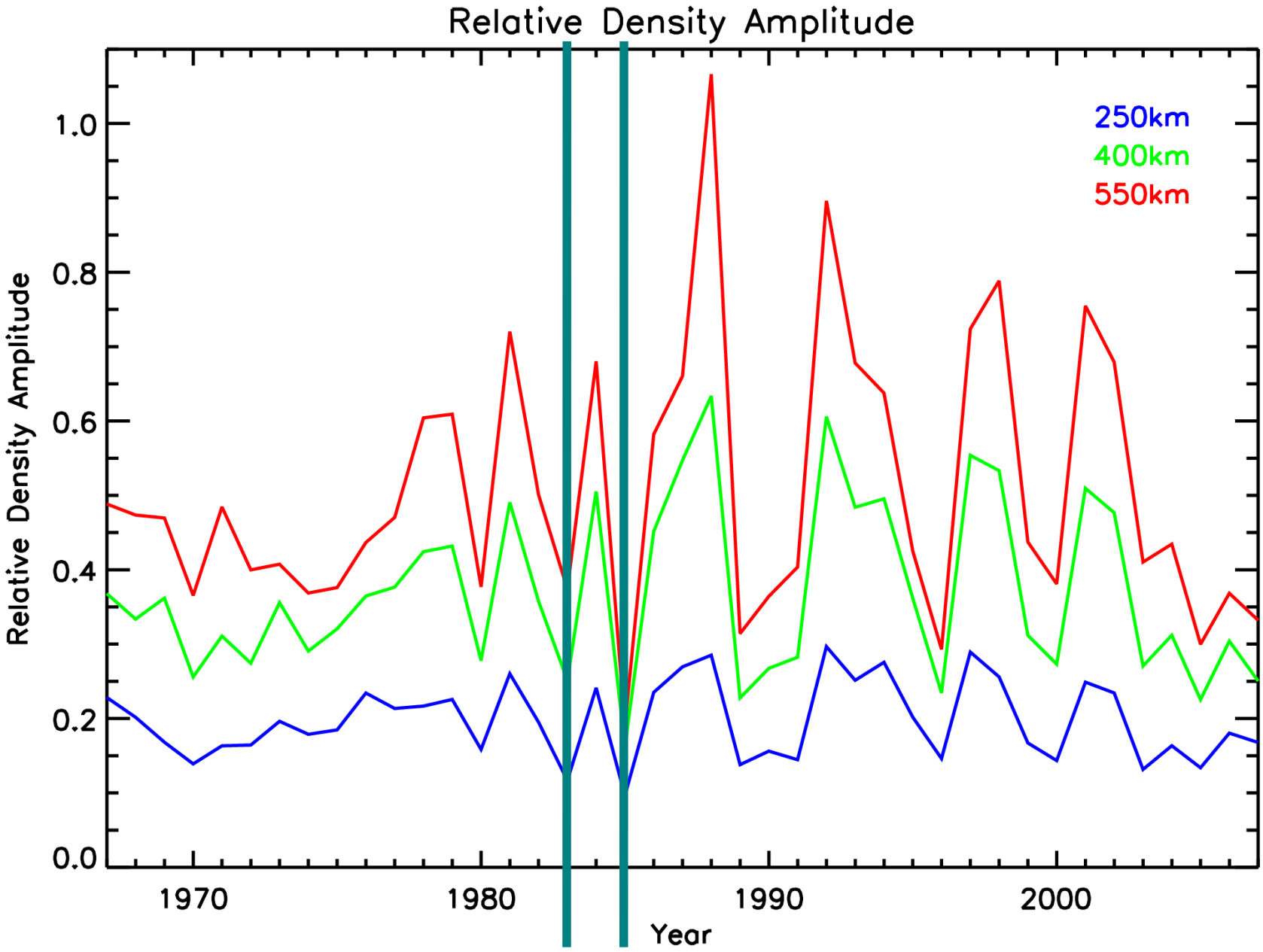

Linear Pearson Correlation Coefficients

| | 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 |

# Density Amplitude Variation with Altitude

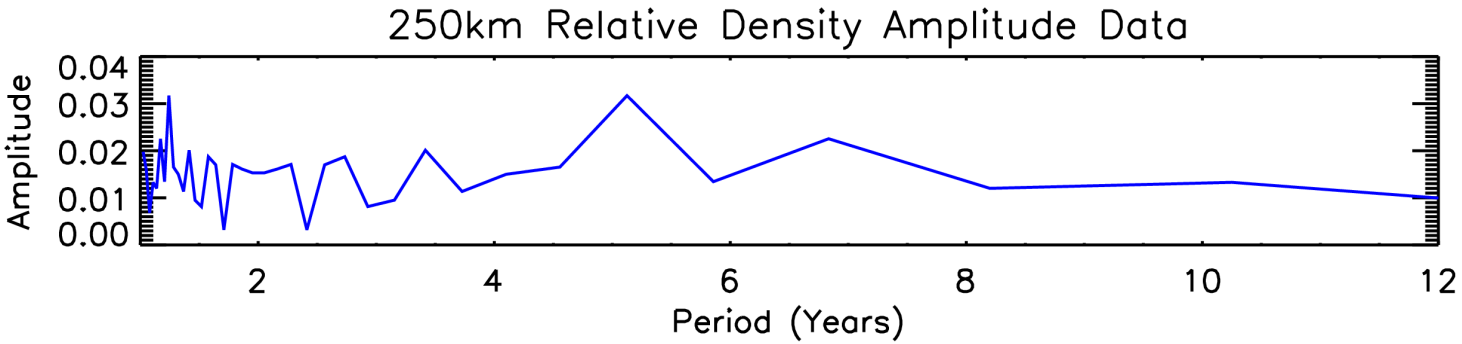


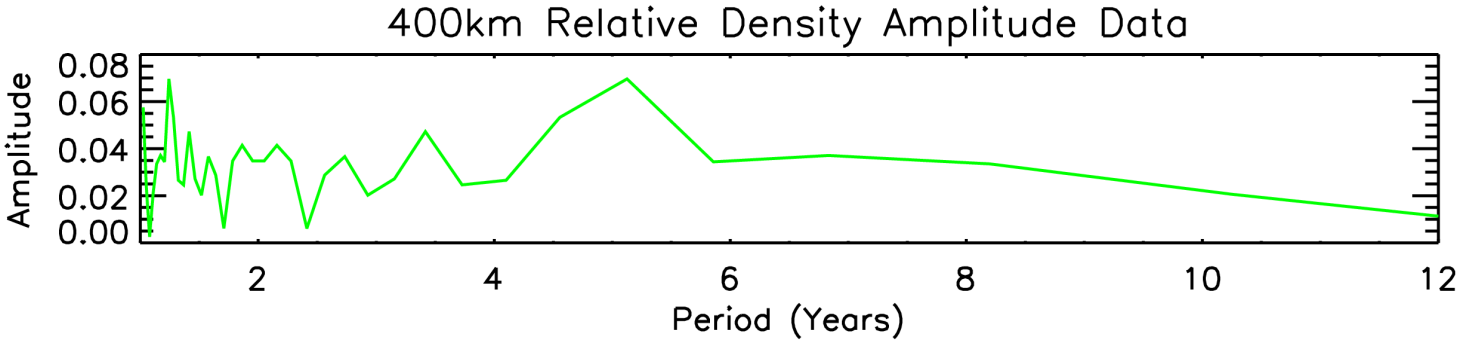
# Lower Atmospheric Forcing?

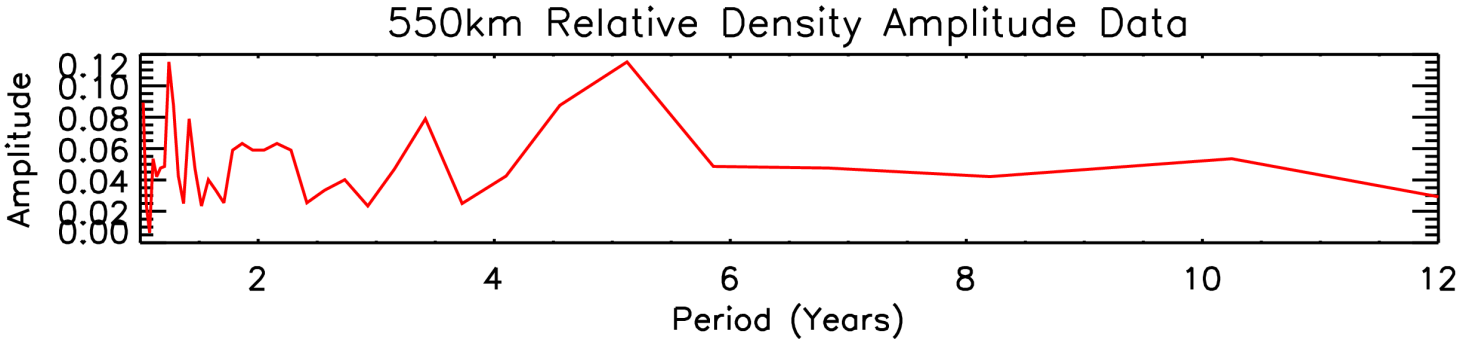


# Lower Atmospheric Forcing?

## FFT Analysis



# Conclusions

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- 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

# Future Steps

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