A comparison of the JB2008 and NRLMSISE-00 neutral density models.

Daniel R Weimer
Center for Space Science and Engineering Research, Virginia Tech

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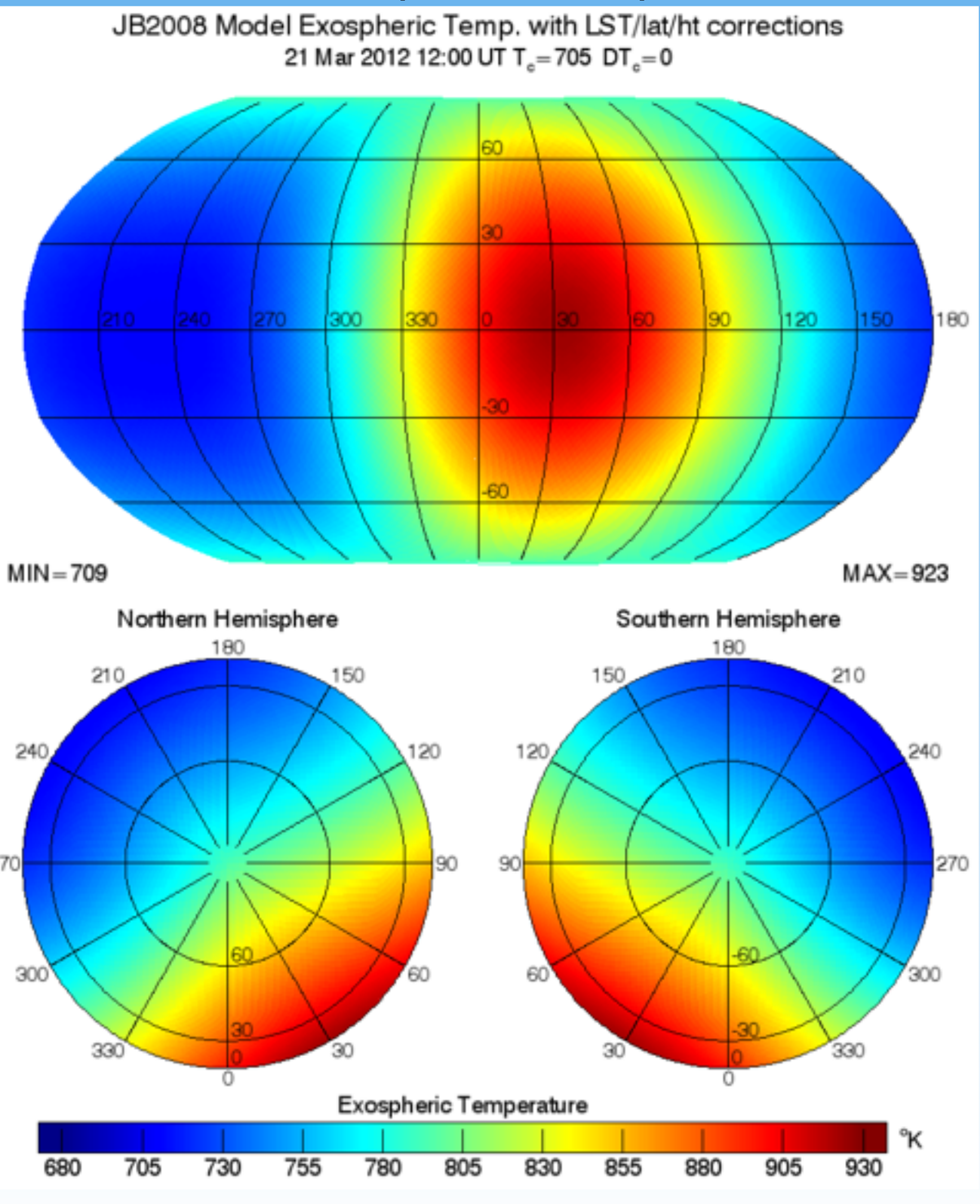
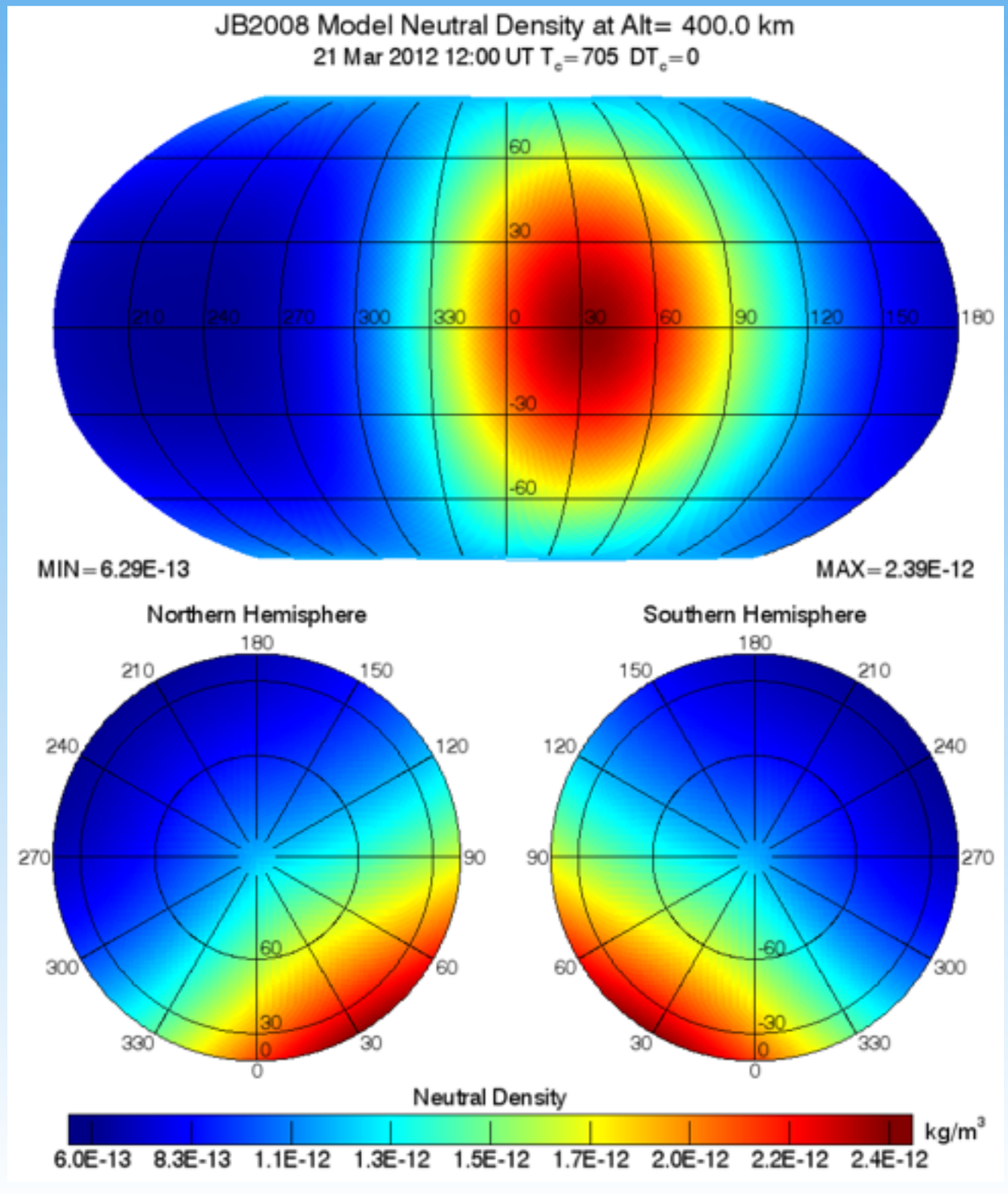
Space @ Virginia Tech
Center for Space Science and Engineering Research

The Jacchia-Bowman 2008 model gets the “global nighttime minimum exospheric temperature,” Tc, from four solar indices plus Dst. Global exospheric temperature and neutral densities derived from this.

JB2008 Exospheric Temperatures

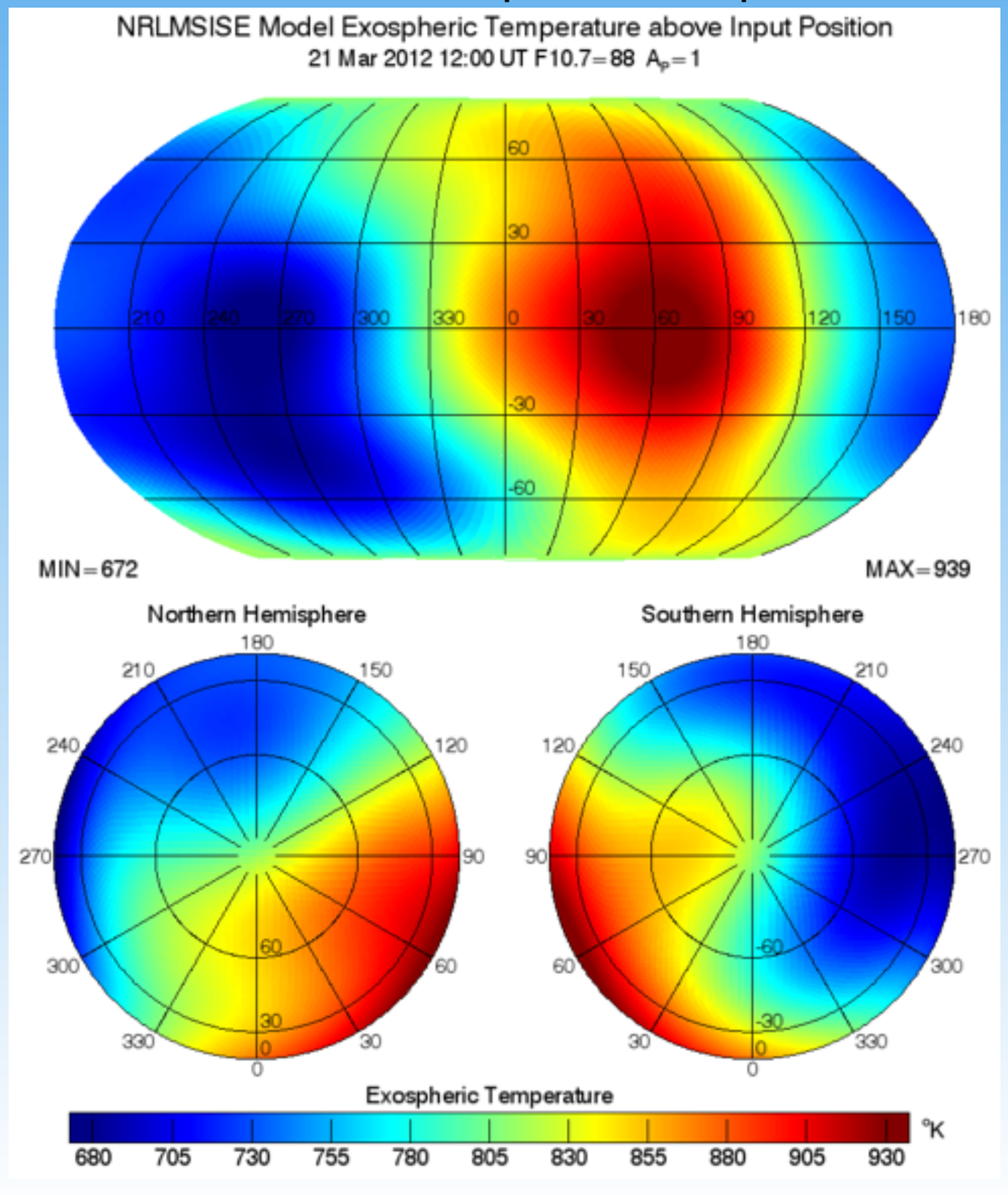


JB2008 Neutral Densities, 400 km

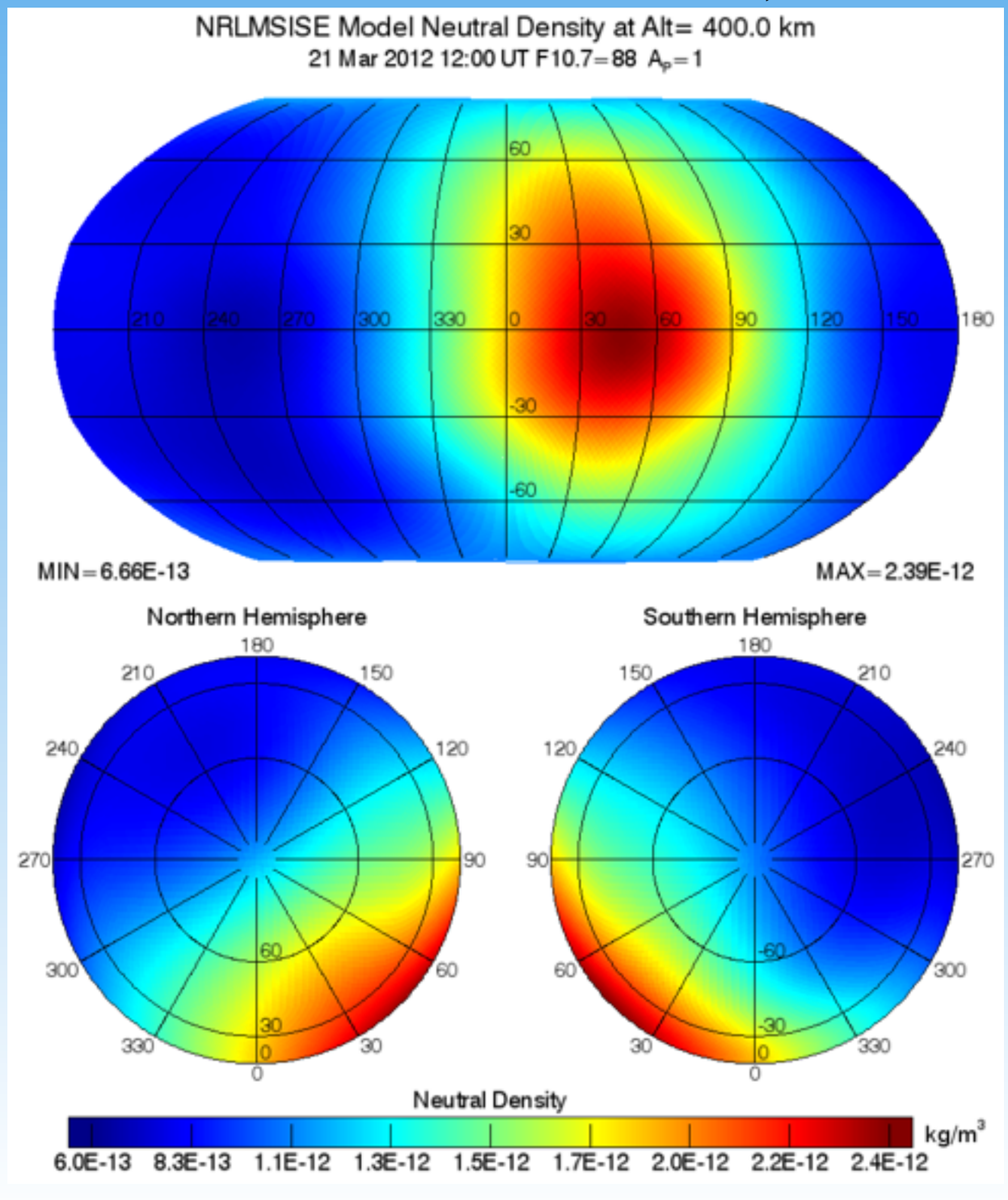


The NRLMSISE-00 model works in a similar fashion, but has other variables and higher order spherical harmonics. In this example the $F_{10.7}$ and A_p indices were adjusted to match the peak density in JB2008.

NRLMSISE-00 Exospheric Temperatures

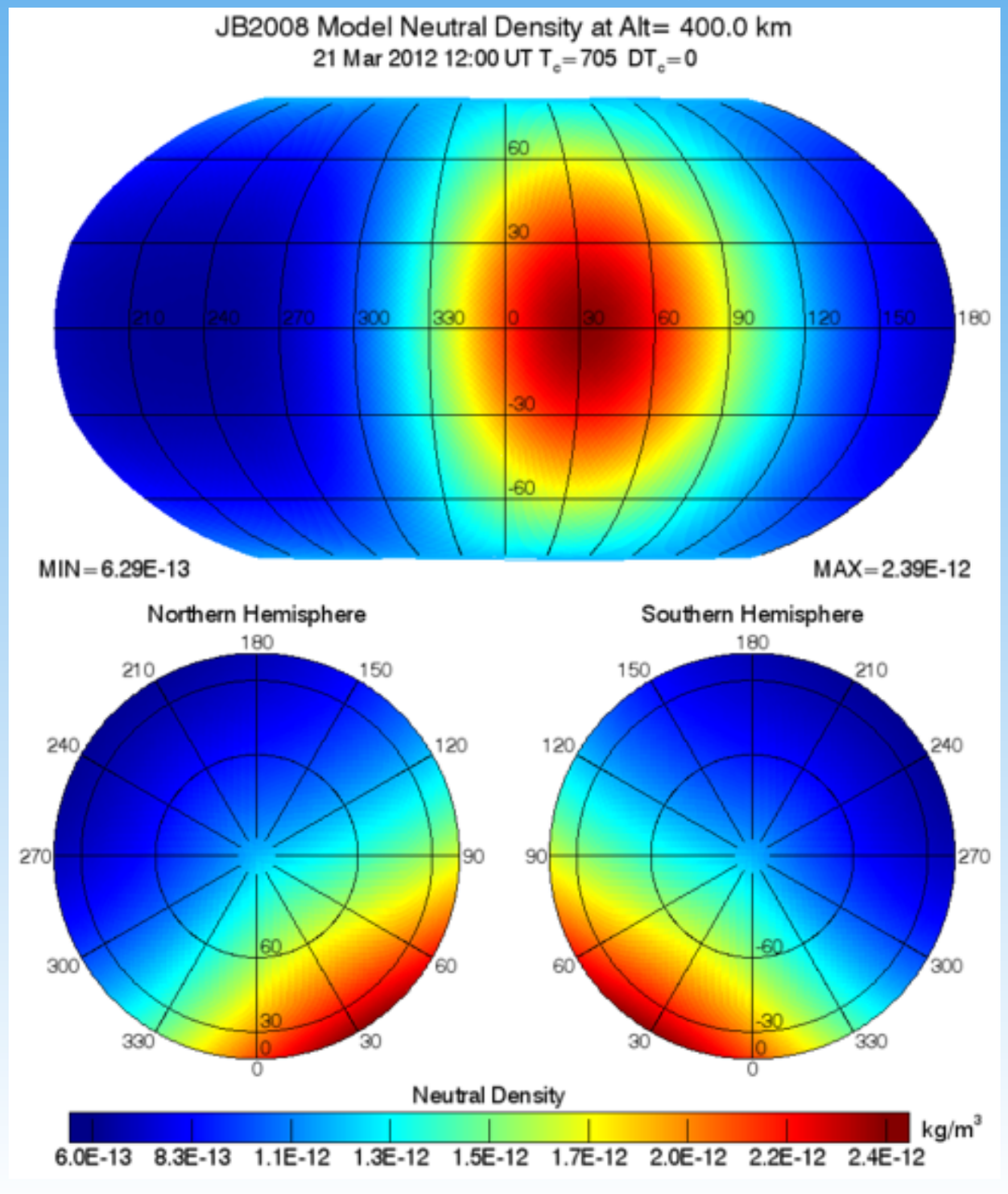


NRLMSISE-00 Neutral Densities, 400 km

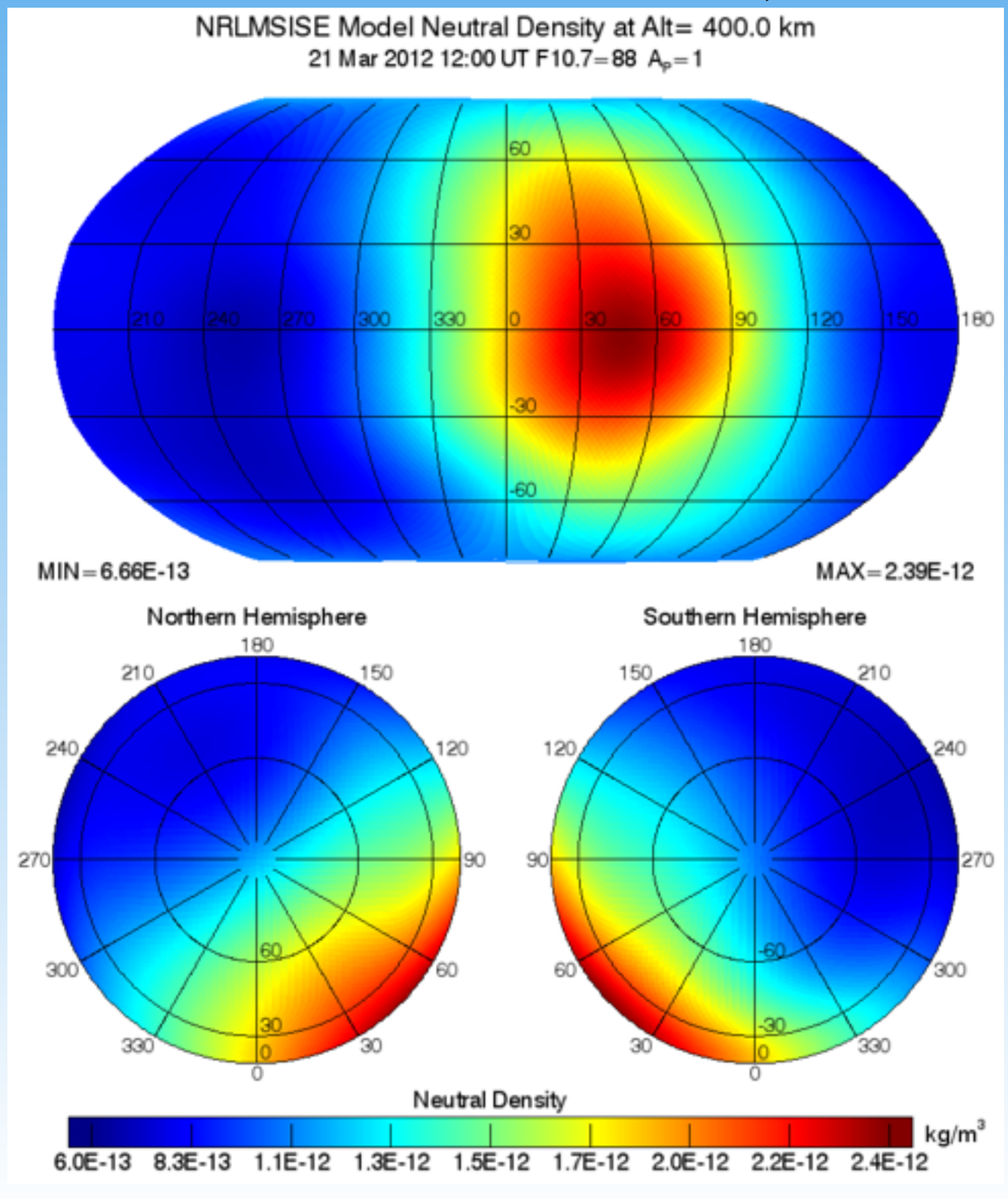


The location of the dayside peak density in the NRLMSISE-00 model tends to be shifted farther away from noon, compared to JB2008.

JB2008 Neutral Densities, 400 km

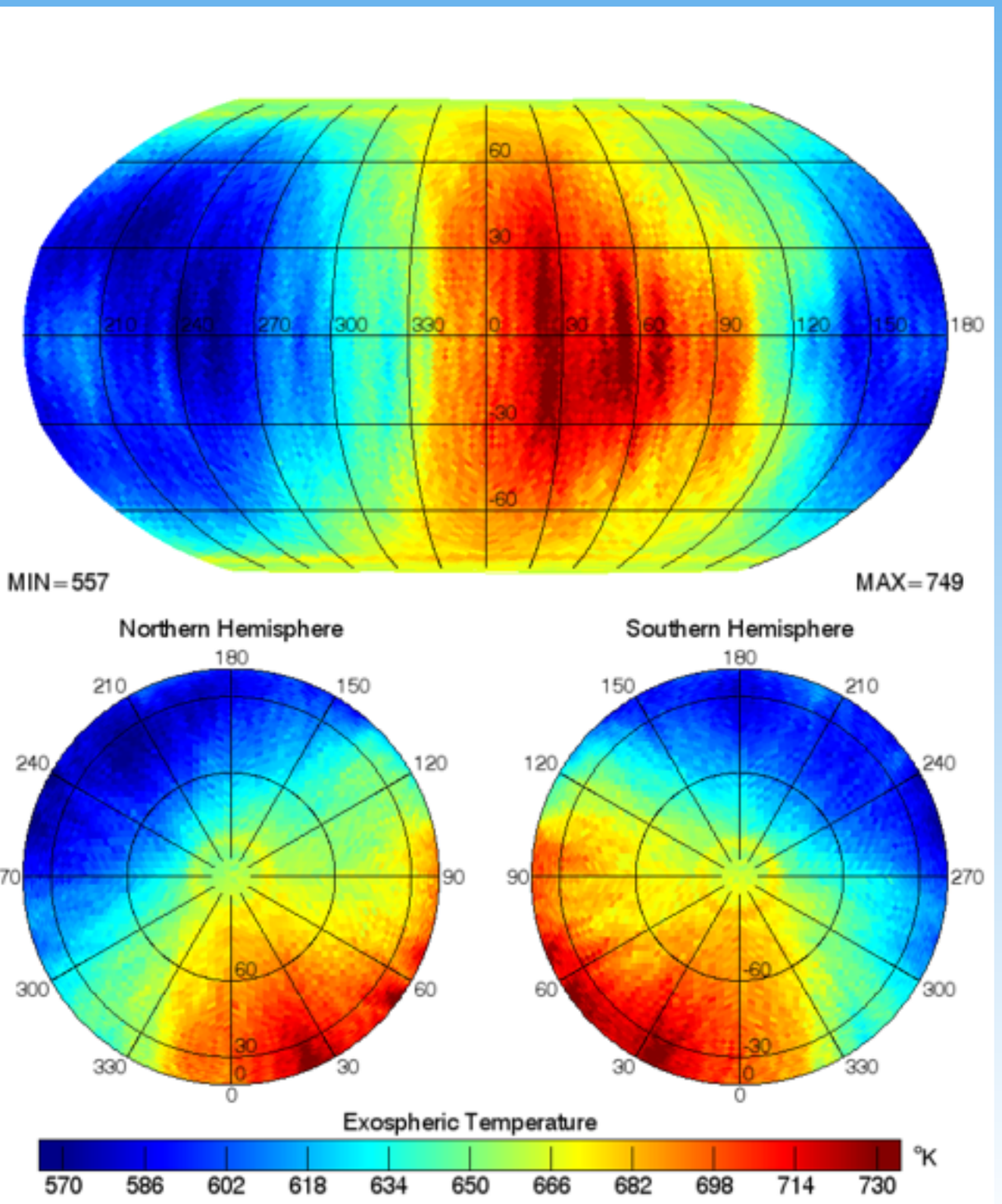


NRLMSISE-00 Neutral Densities, 400 km

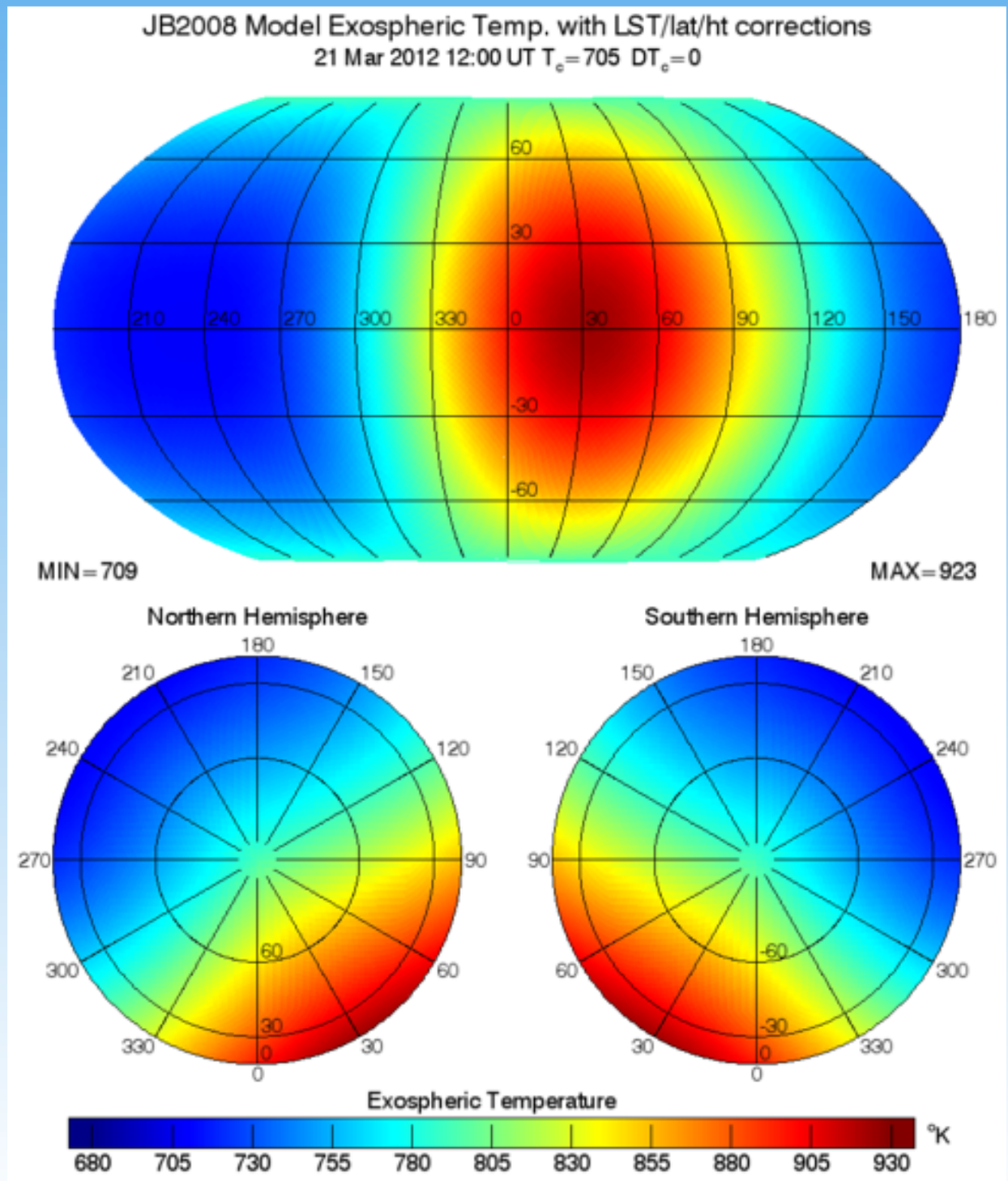


Neither model has an auroral oval enhancement, as seen in the data, nor exactly the right mapping

CHAMP and GRACE Data, SM Coordinates

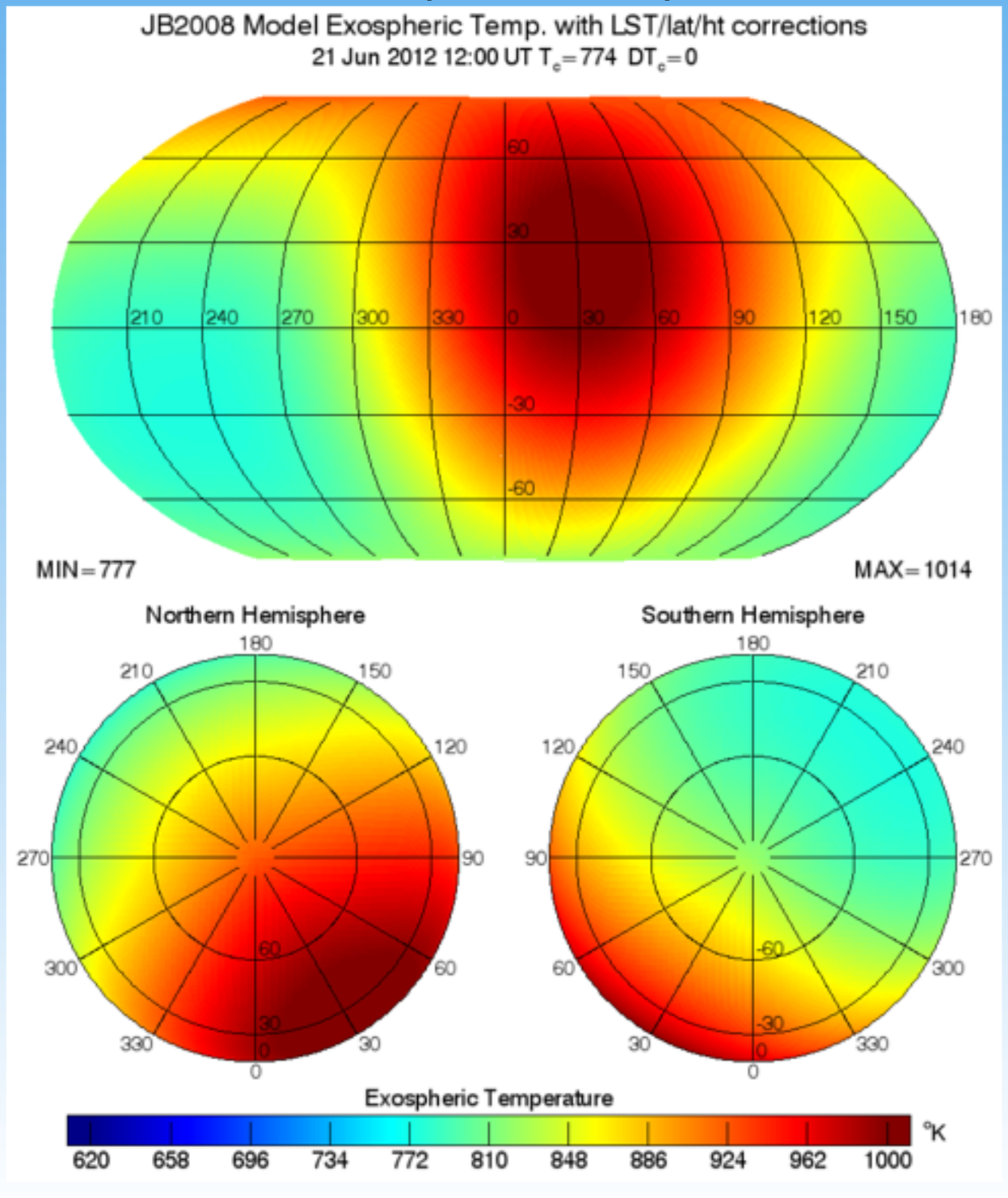


JB2008 Exospheric Temperatures

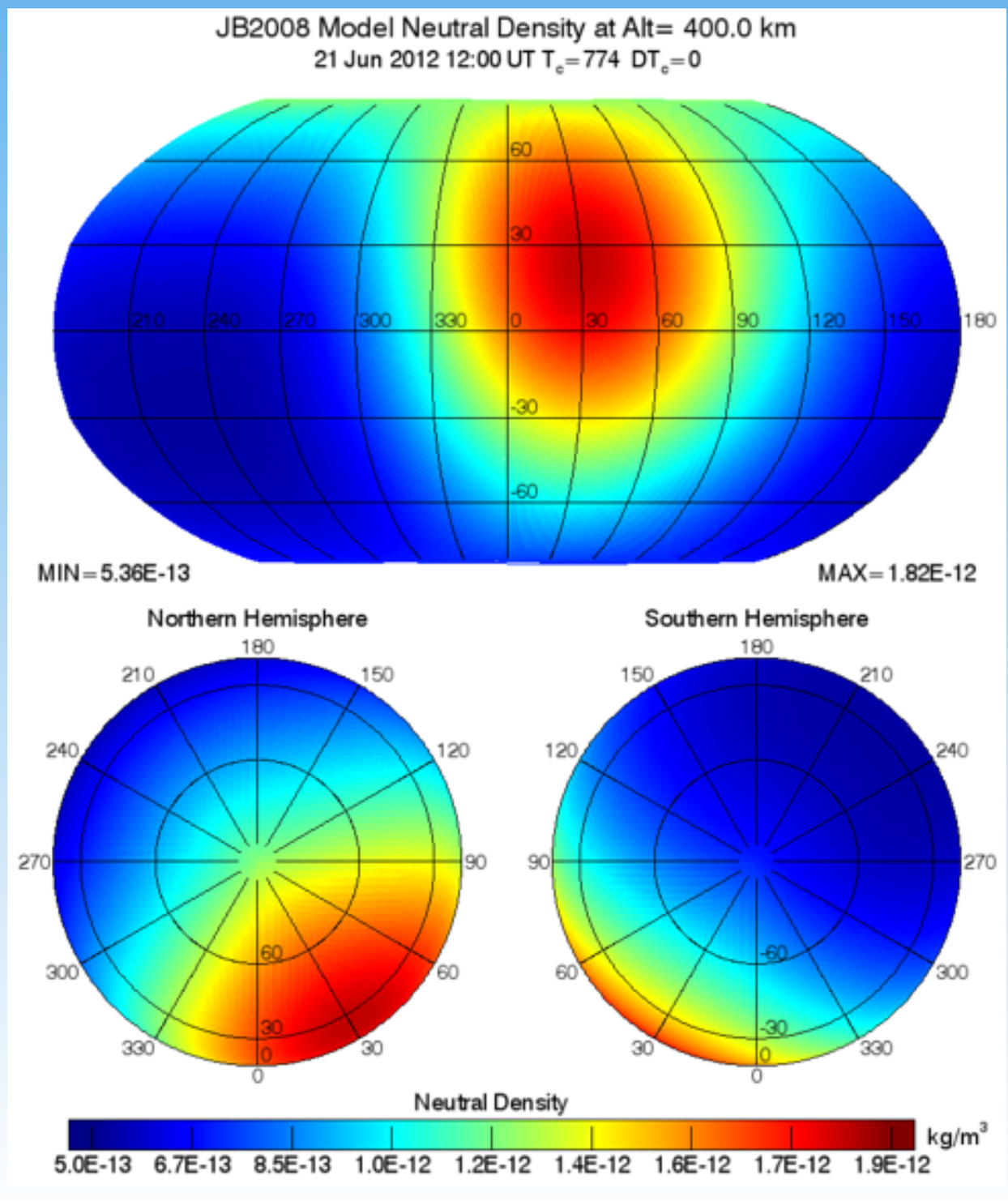


Another example, at the summer solstice.
These temperatures and densities are from the JB2008 model.

JB2008 Exospheric Temperatures

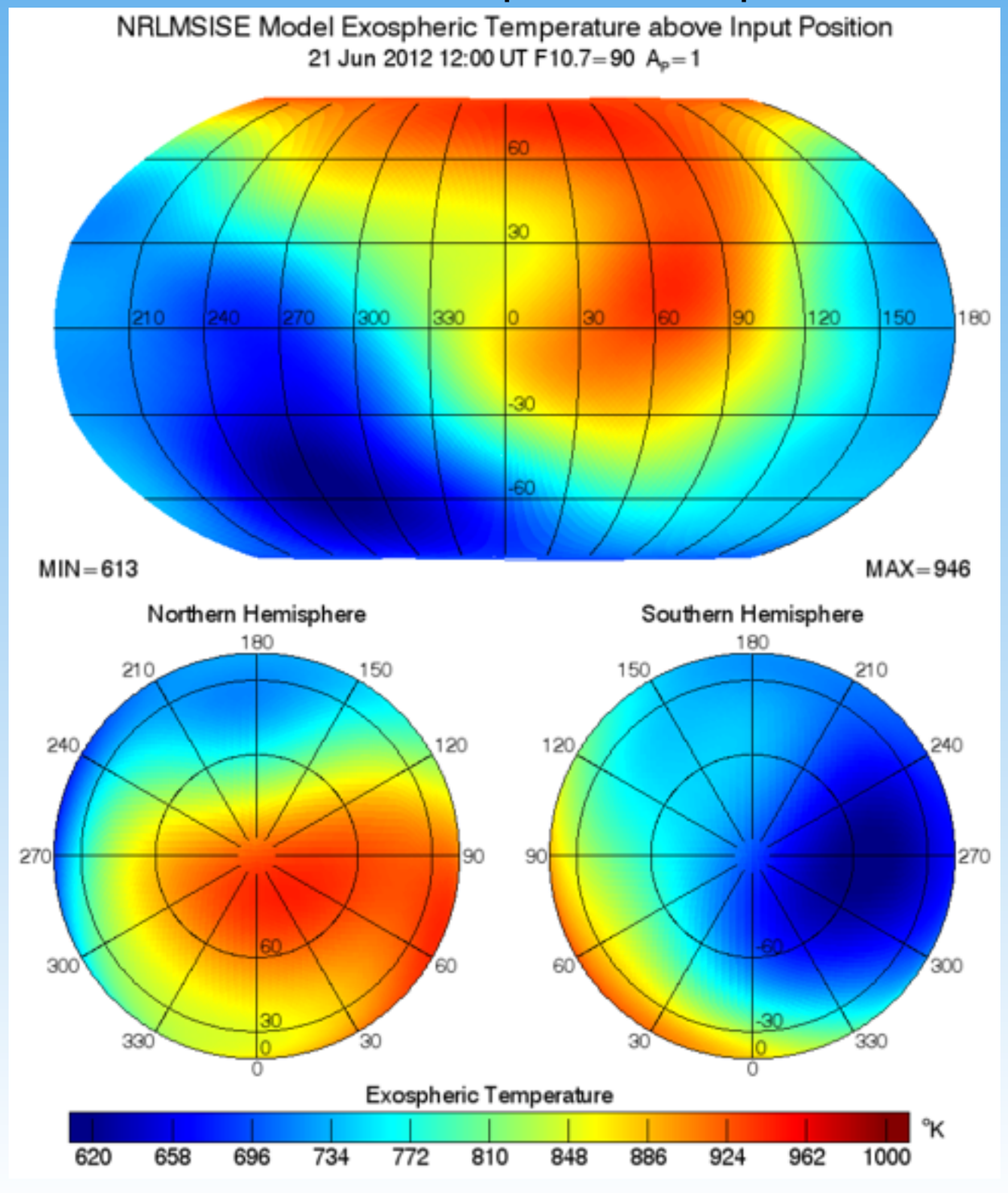


JB2008 Neutral Densities, 400 km

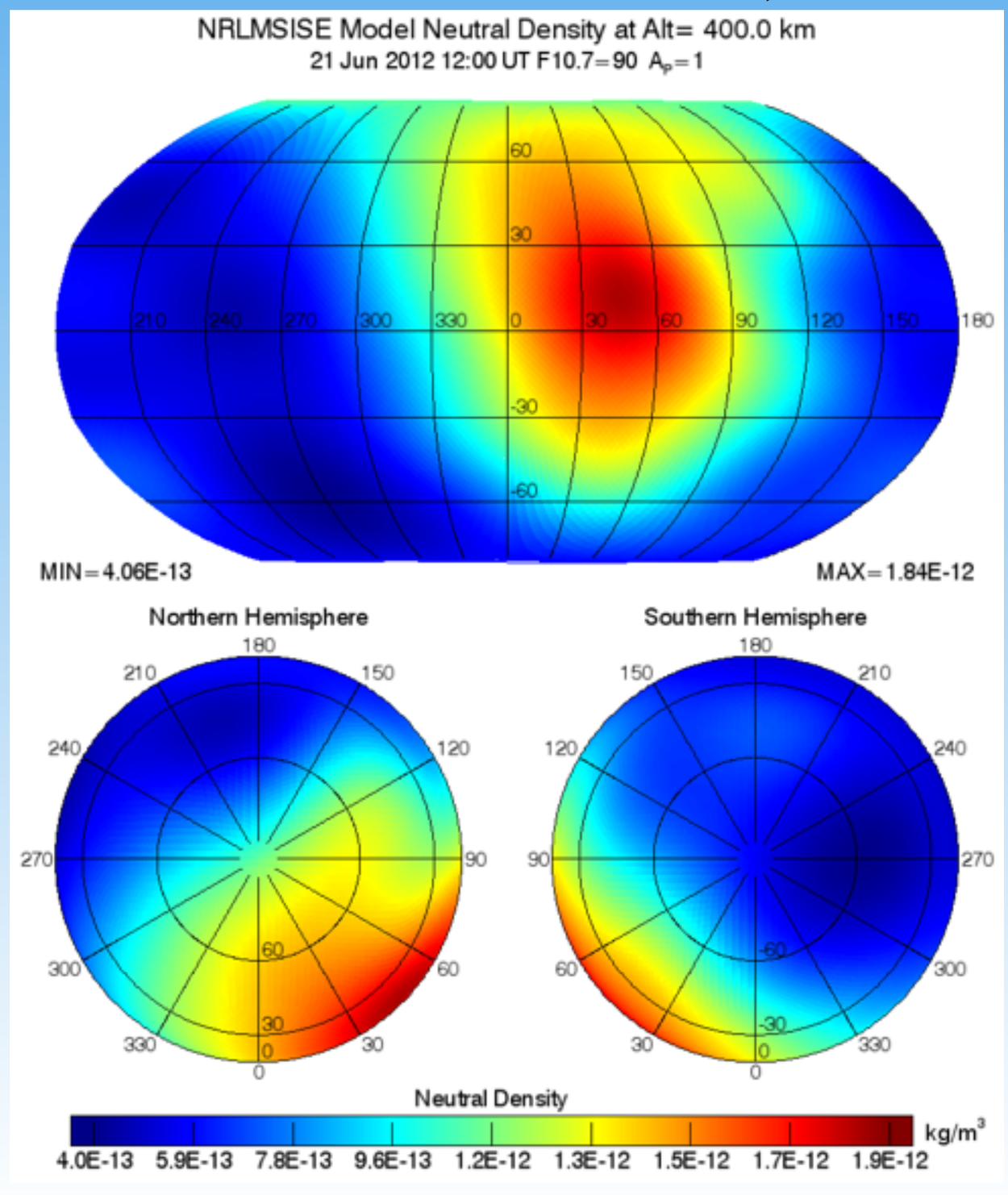


Another example, at the summer solstice.
These temperatures and densities are from NRLMSISE-00.

NRLMSISE-00 Exospheric Temperatures

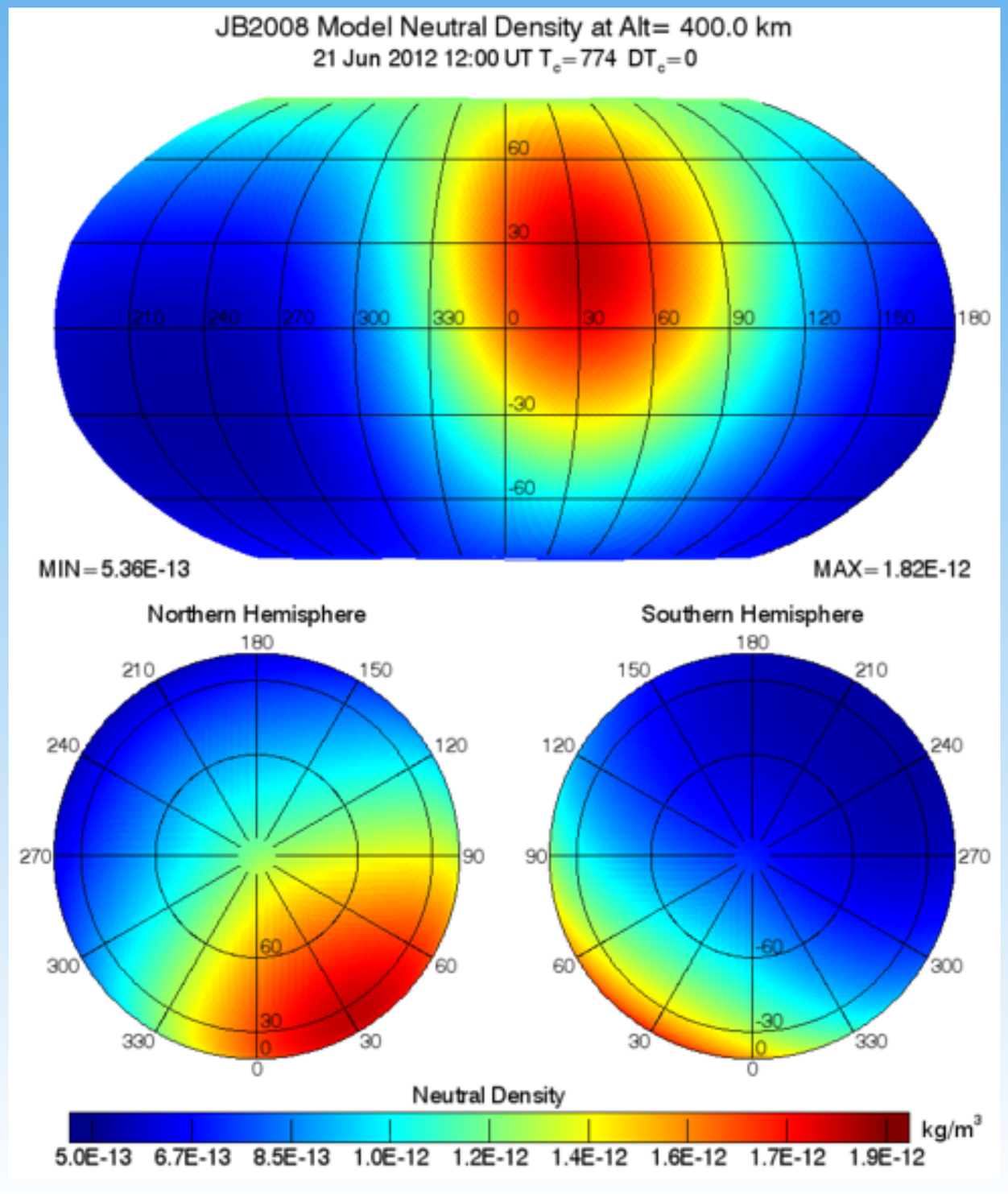


NRLMSISE-00 Neutral Densities, 400 km

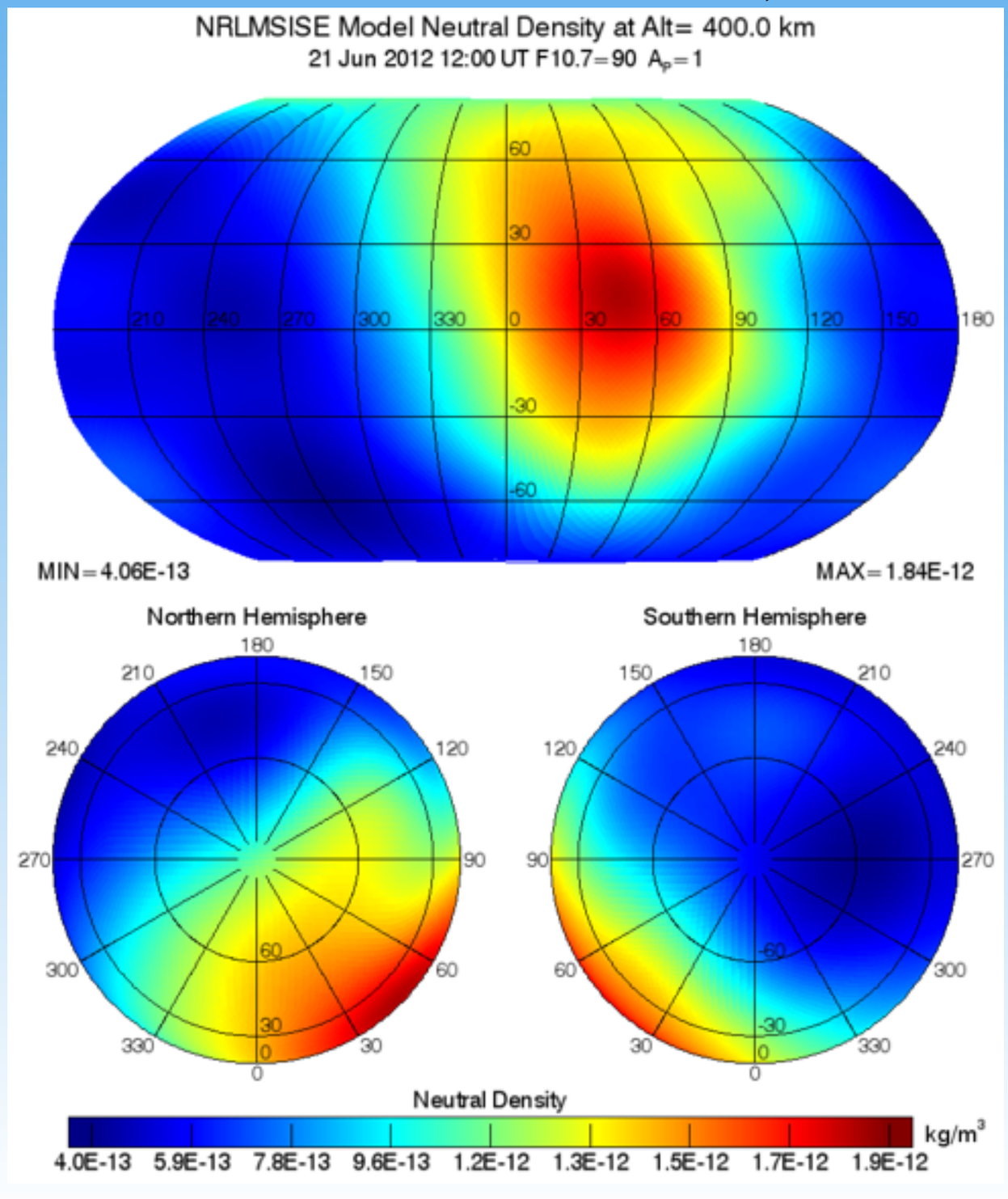


Again, the dayside peak density in the NRLMSISE-00 model tends to be shifted farther away from noon, compared to the JB2008 model, while JB2008 peaks farther to the North.

JB2008 Neutral Densities, 400 km

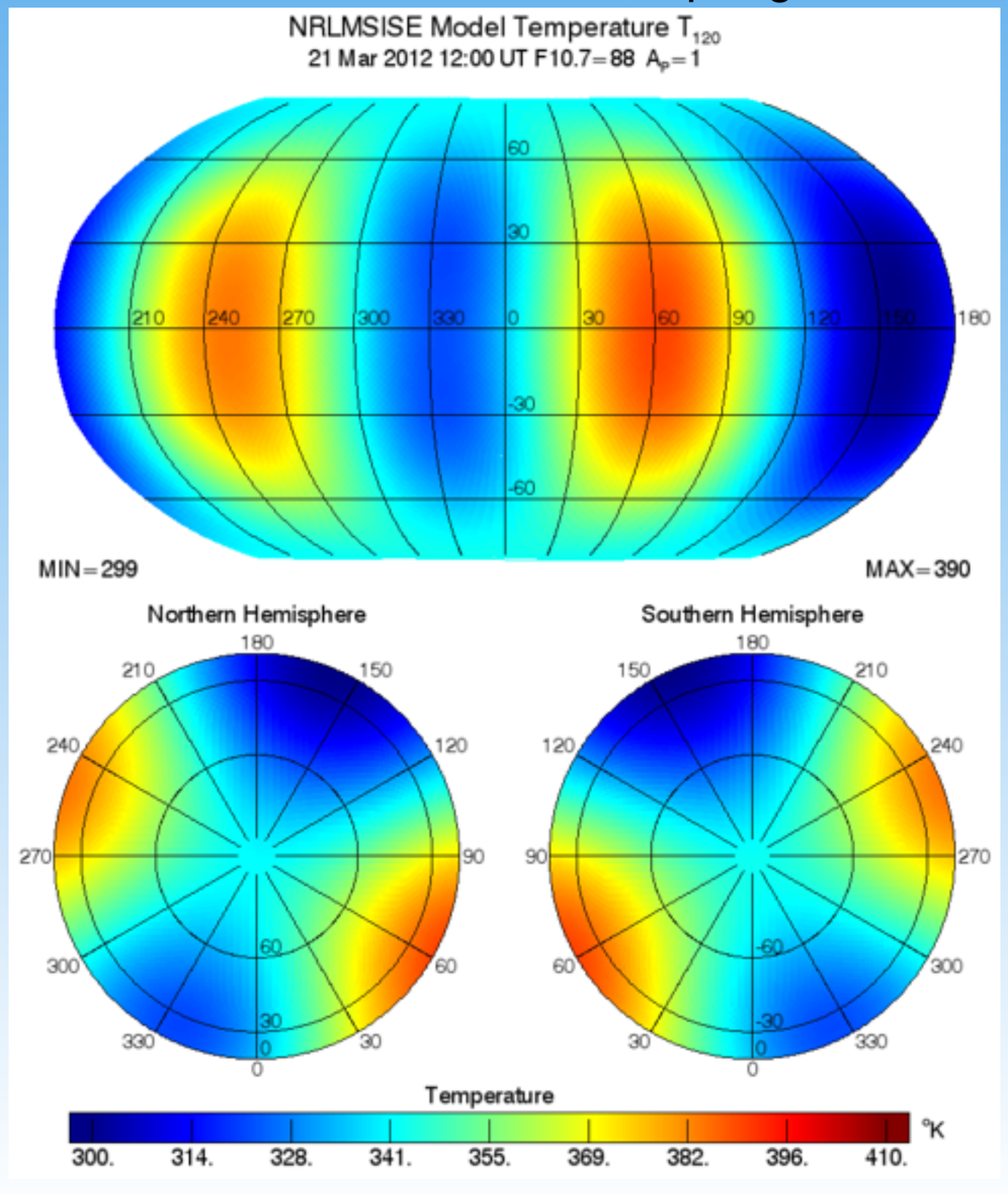


NRLMSISE-00 Neutral Densities, 400 km

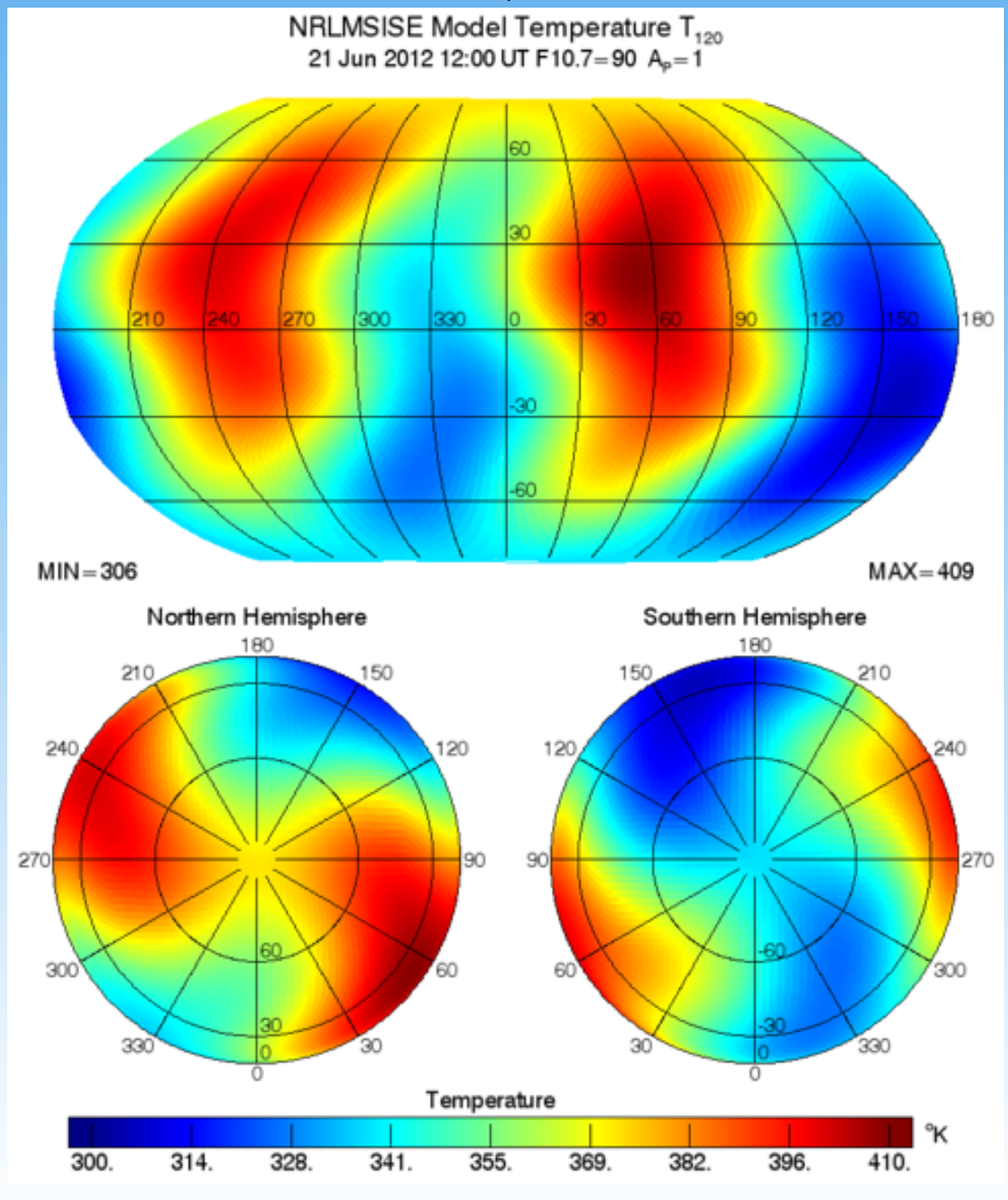


JB2008 has a fixed temperature at the lower boundary, while NRLMSISE-00 uses a $T_{lb}=T_{120}$ (at 120 km altitude) that has considerable spatial and seasonal variability. T_{120} also varies with $F_{10.7}$.

NRLMSISE-00 T_{120}, Spring



NRLMSISE-00 T_{120}, Northern Summer



The Semi-Annual Variation (SAV)

The neutral density has two low and high peaks each year, resulting in lower densities during the Northern hemisphere's summer, compared to summer in the south. The physical cause of the SAV is unknown.

JB2008 uses an empirical adjustment to the densities, after they are derived from the exospheric temperature. In NRLMSISE-00 the exospheric temperatures are modified before deriving densities.

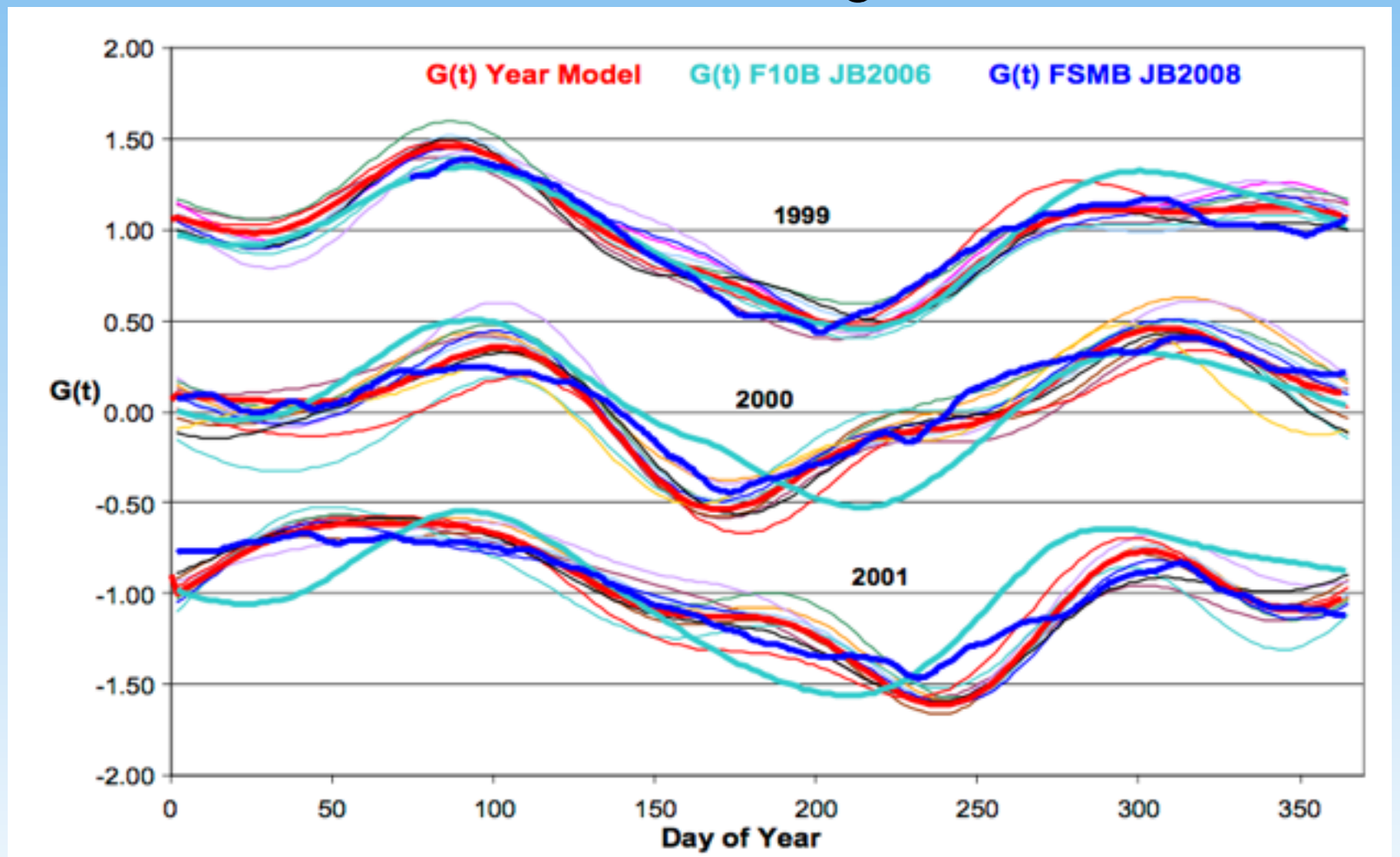


Figure 5. The individual satellite fits for 3 different years is shown. The Year G(t) Model is highlighted. Each set of curves for 1999 and 2001 has been offset by +1.00 and –1.00 respectively in G(t) for clarity. The JB2006 and new JB2008 model curves are also displayed.

The SAV is evident in emissions from CO_2 measured with the Sounding of the Atmosphere using Broadband Emission Radiometry (SABER) instrument* on the TIMED satellite. Nitric oxide (NO) emissions are highly correlated with exospheric temperatures (paper SA21B-02 Tuesday AM).

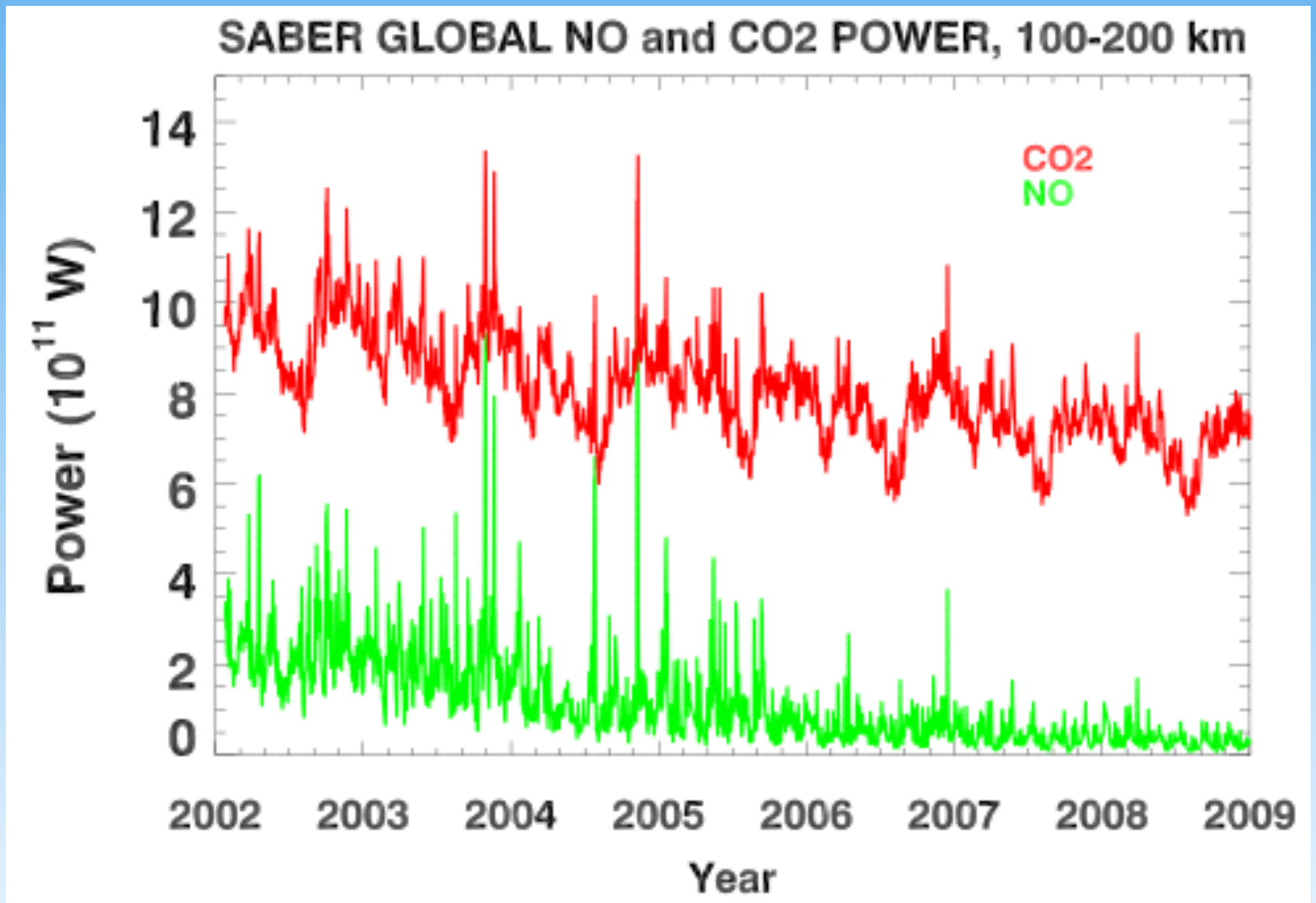
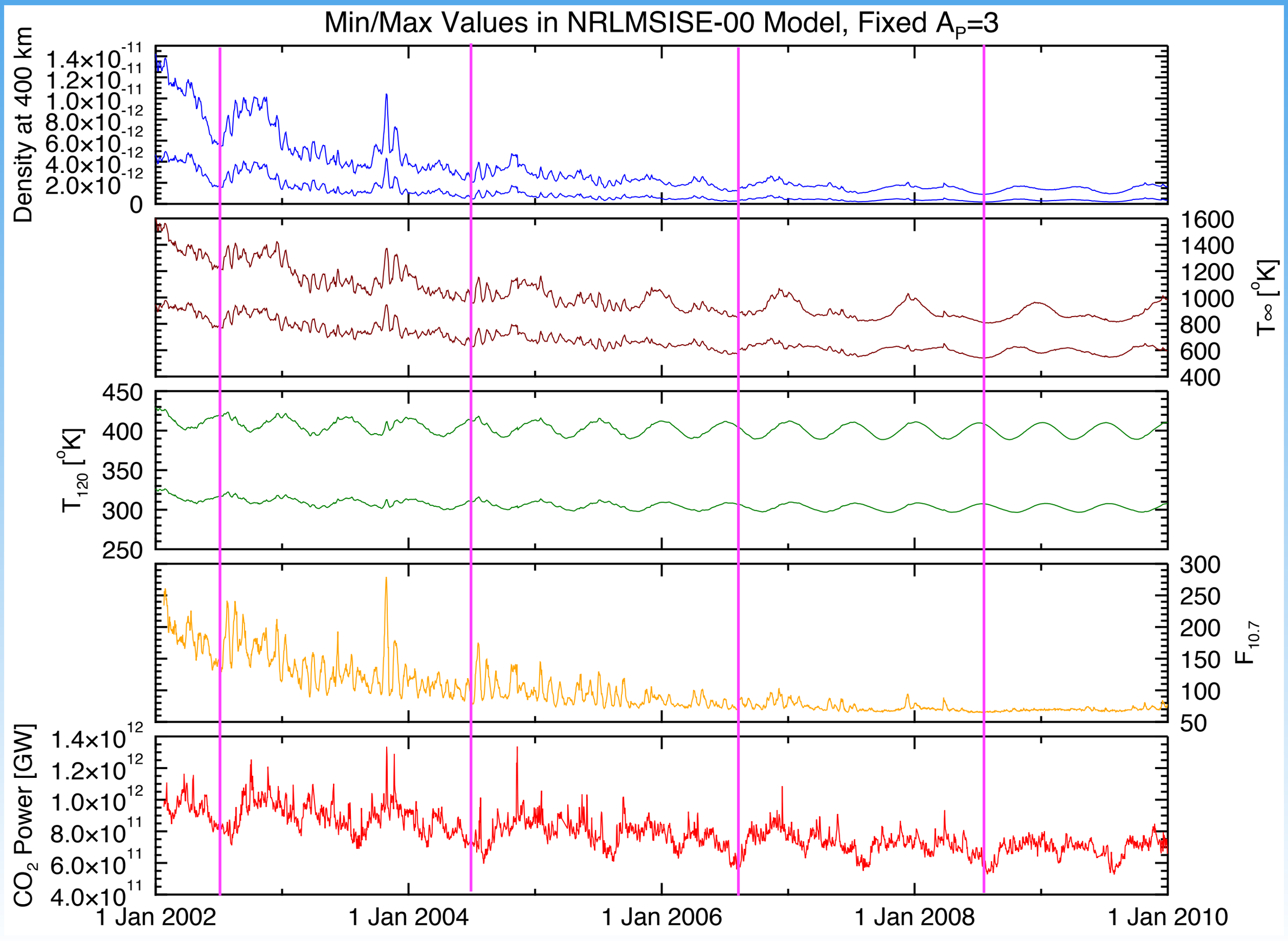


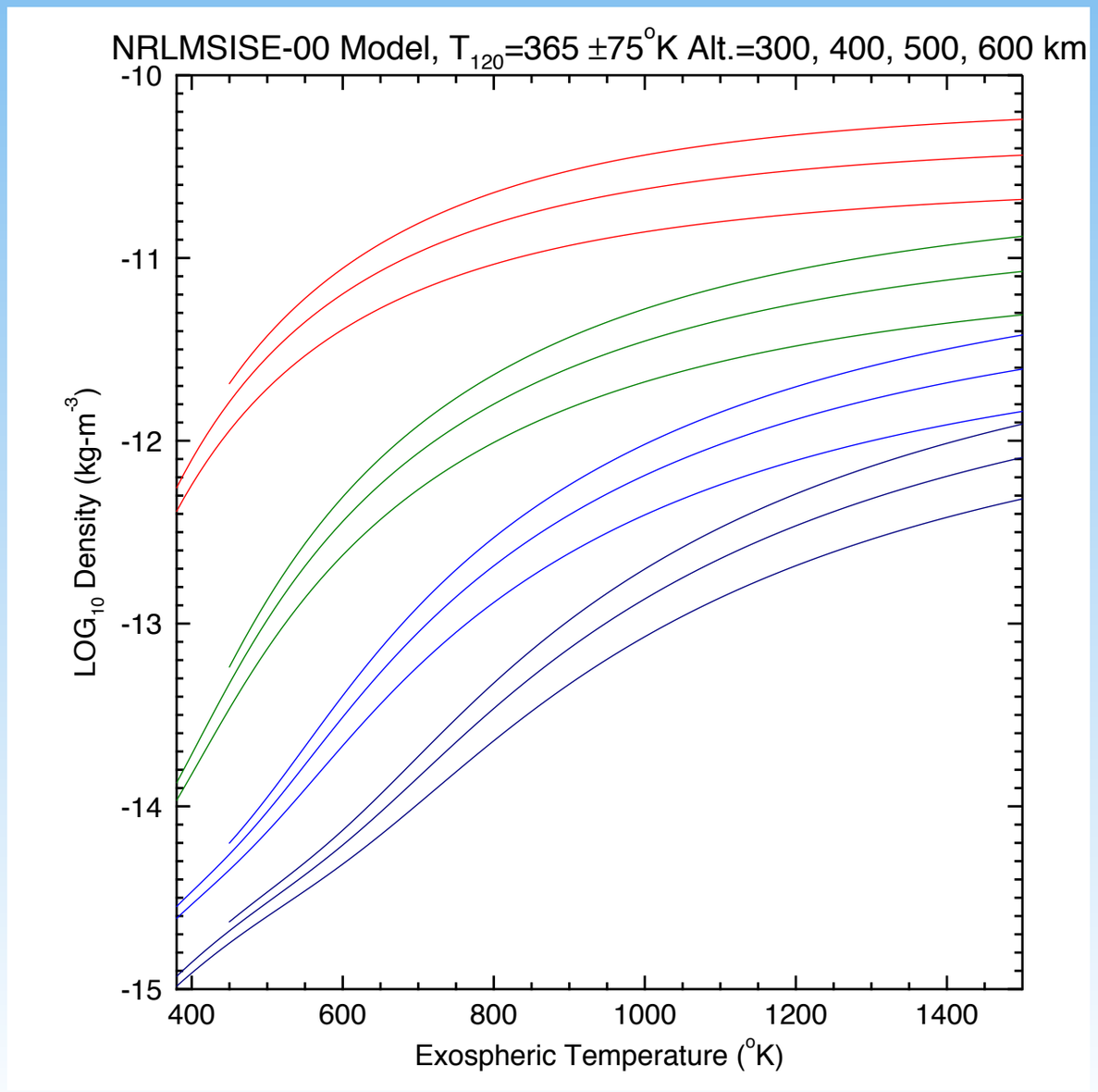
Figure 11. Daily global power (W) emitted from the thermosphere by CO_2 (red) and NO (green) between 100 km and 200 km altitude.

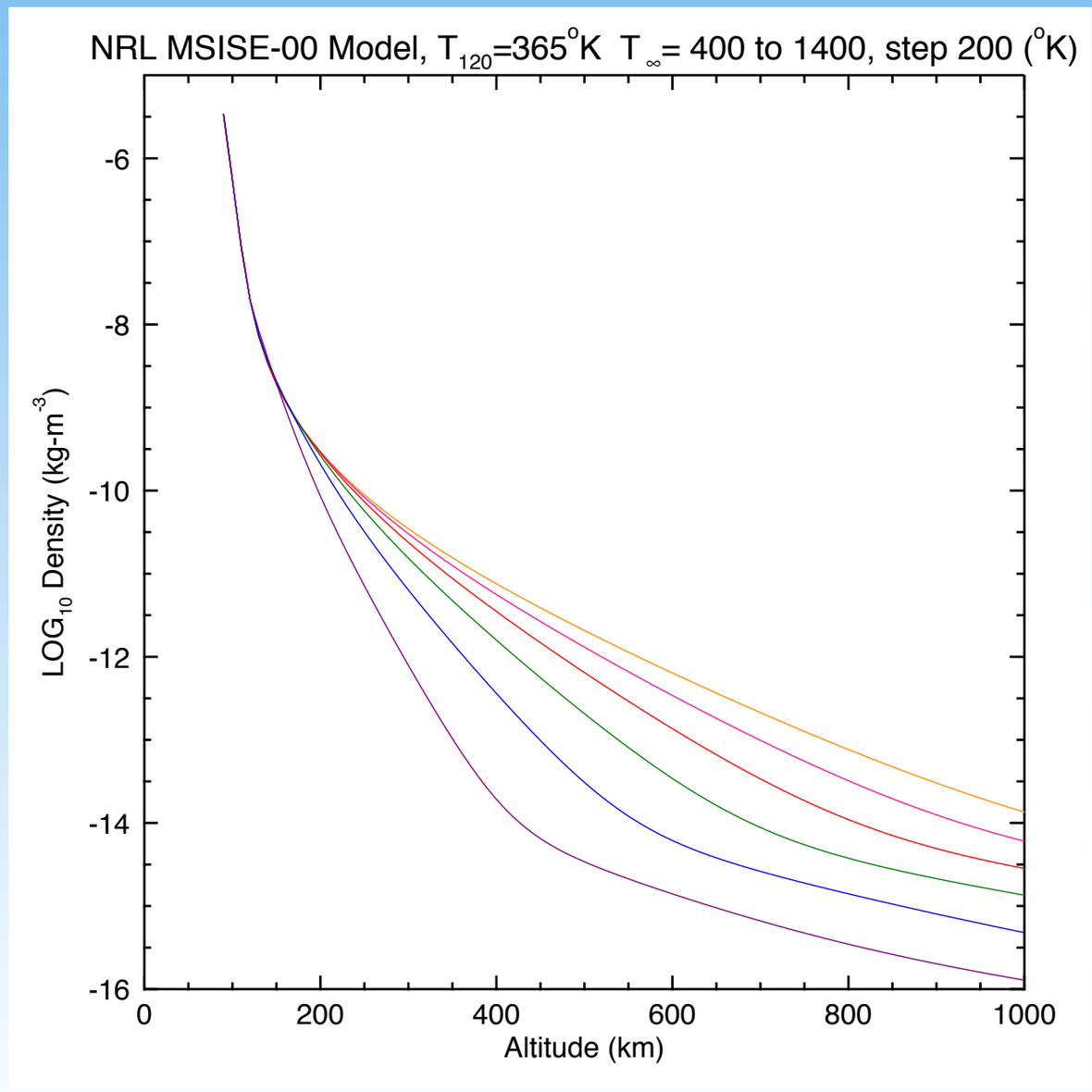
* Mlynczak, M. G., et al. (2010), Observations of infrared radiative cooling in the thermosphere on daily to multiyear timescales from the TIMED/SABER instrument, *J. Geophys. Res., 115*, A03309, doi:10.1029/2009JA014713.

Exospheric Temperature (and Oxygen) in NRLMSISE-00 Controls the SAV



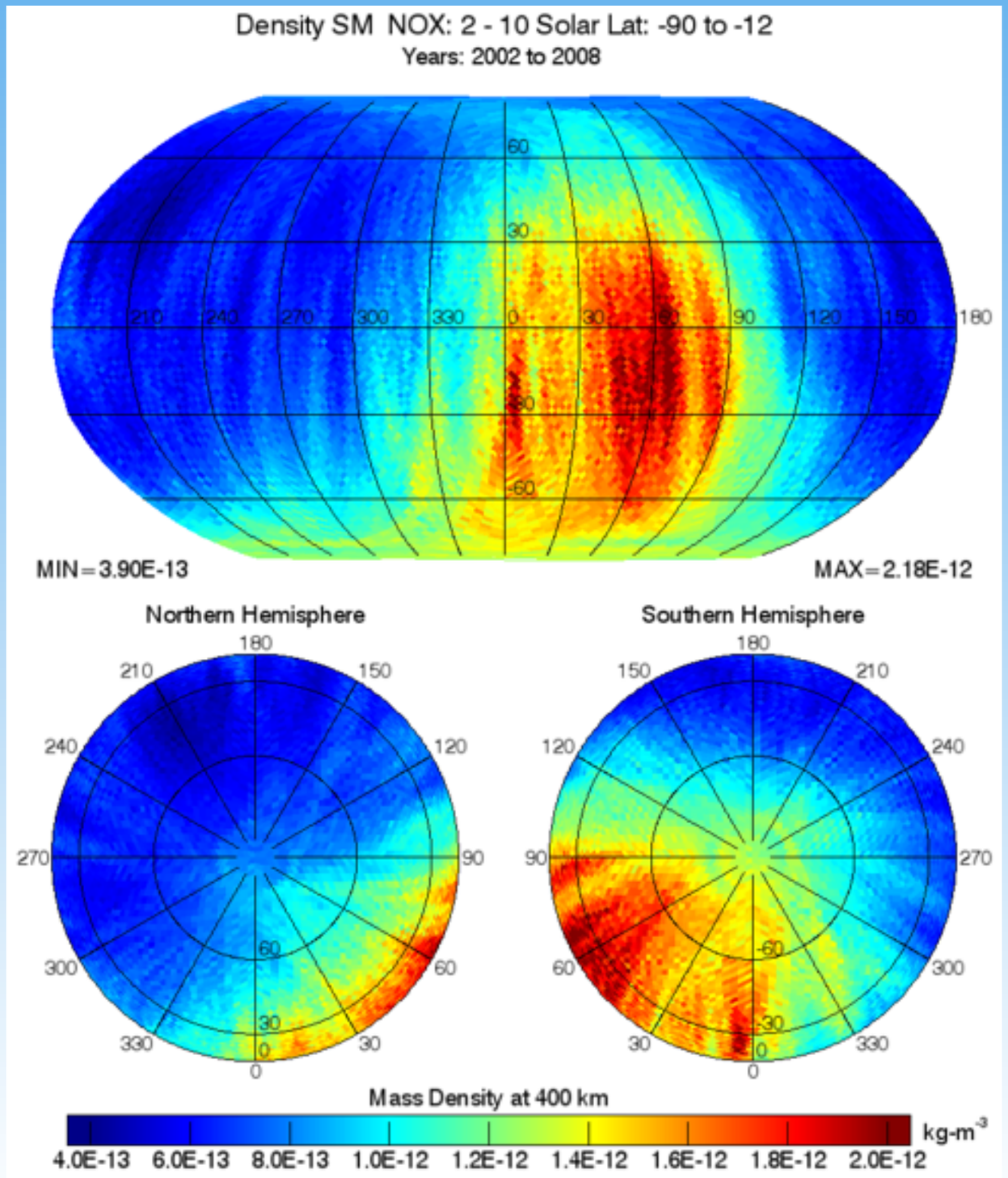
What happens when the global value of T_{120} is made to vary in proportion to the SABER CO_2 emission power? Using only the thermosphere code from NRLMSISE-00, T_{120} was set proportional to the SABER CO_2 measurements. CHAMP and GRACE densities were converted to exospheric temperatures, using the density vs. altitude vs. temperature curves.



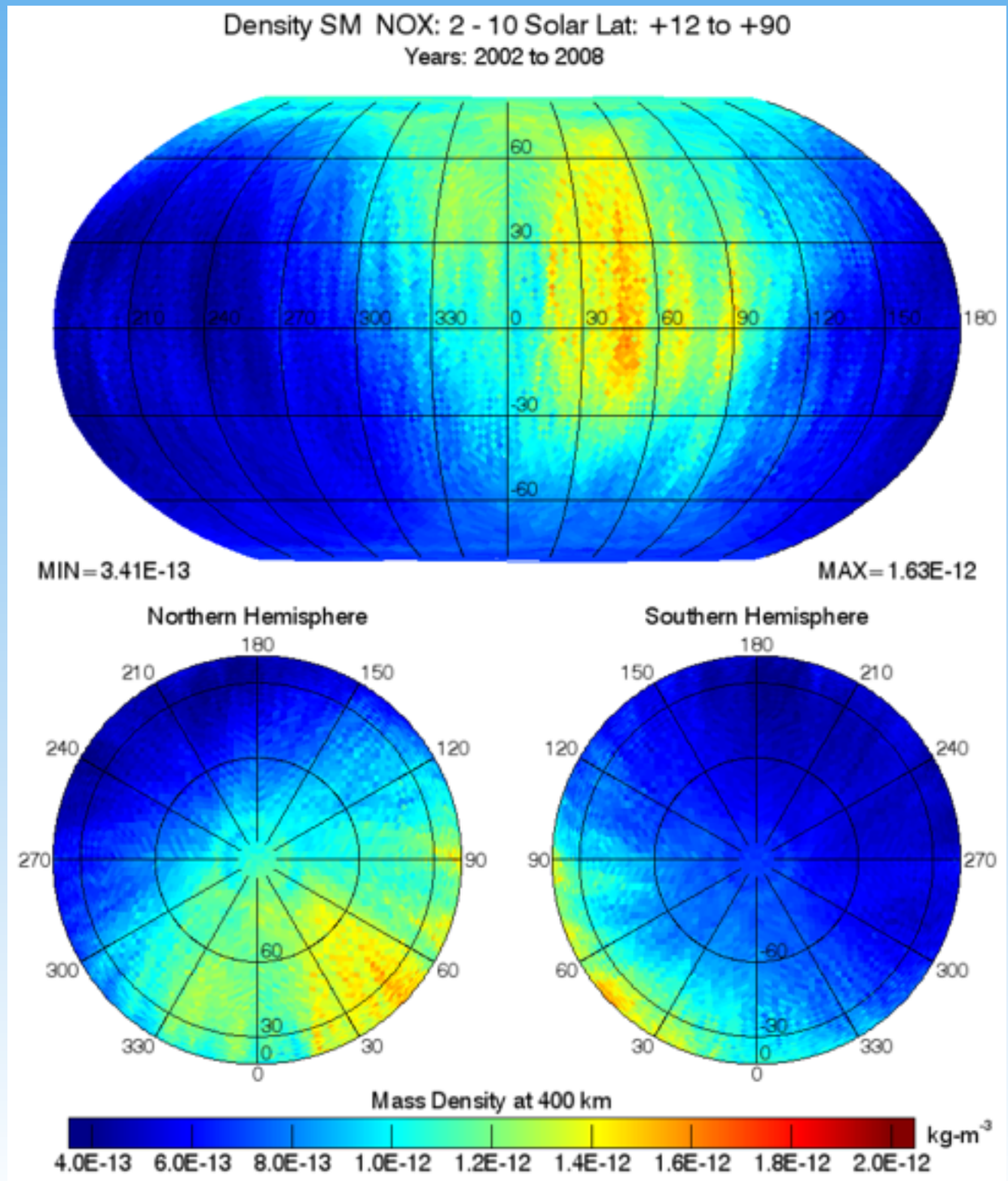


The neutral densities (mapped to 400 km altitude) are lower for positive sub-solar latitudes, when compared to negative latitudes, due to the SAV.

CHAMP and GRACE Data, SM Coordinates, Sub-solar latitude in the South.

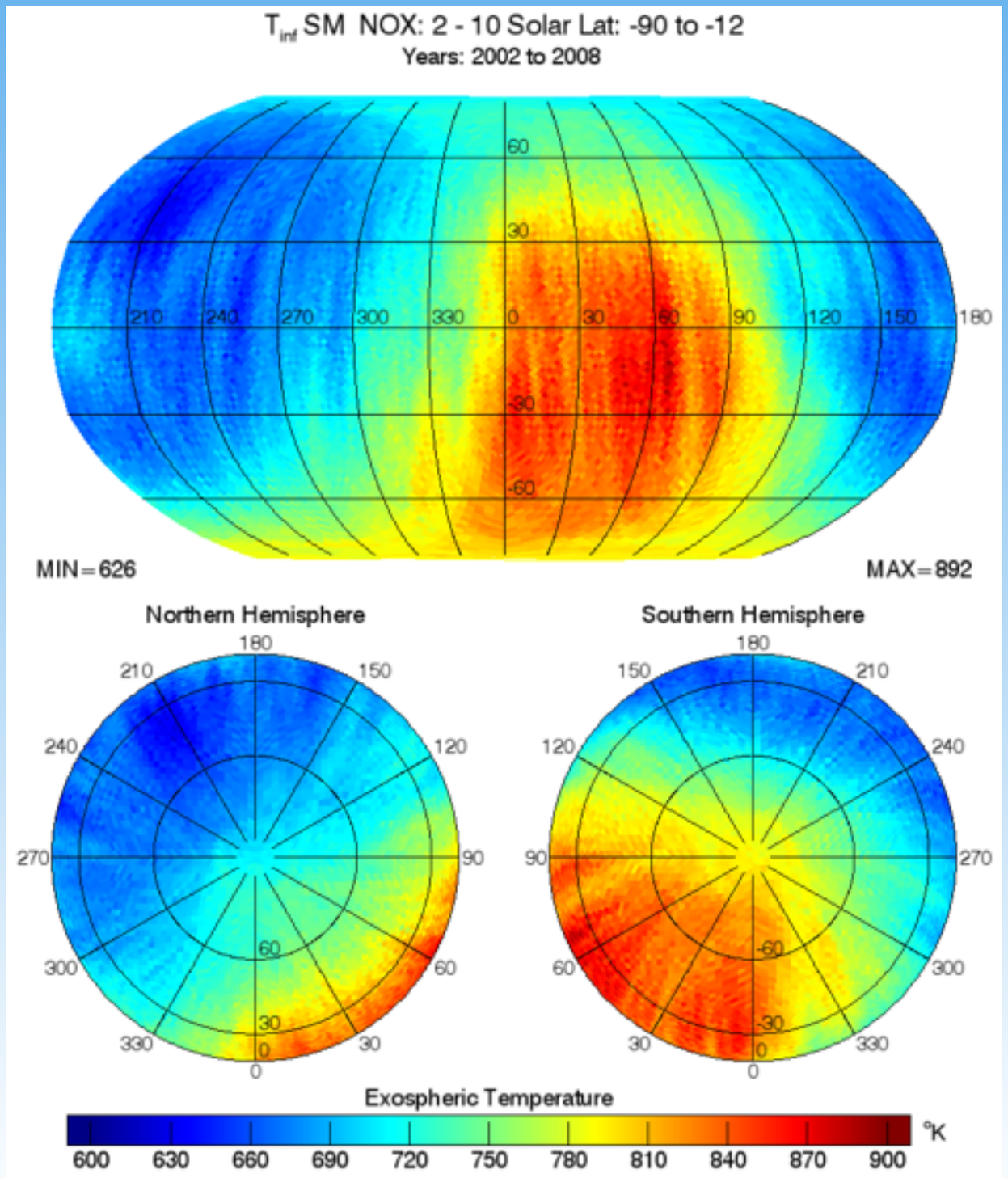


CHAMP and GRACE Data, SM Coordinates, Sub-solar latitude in the North.

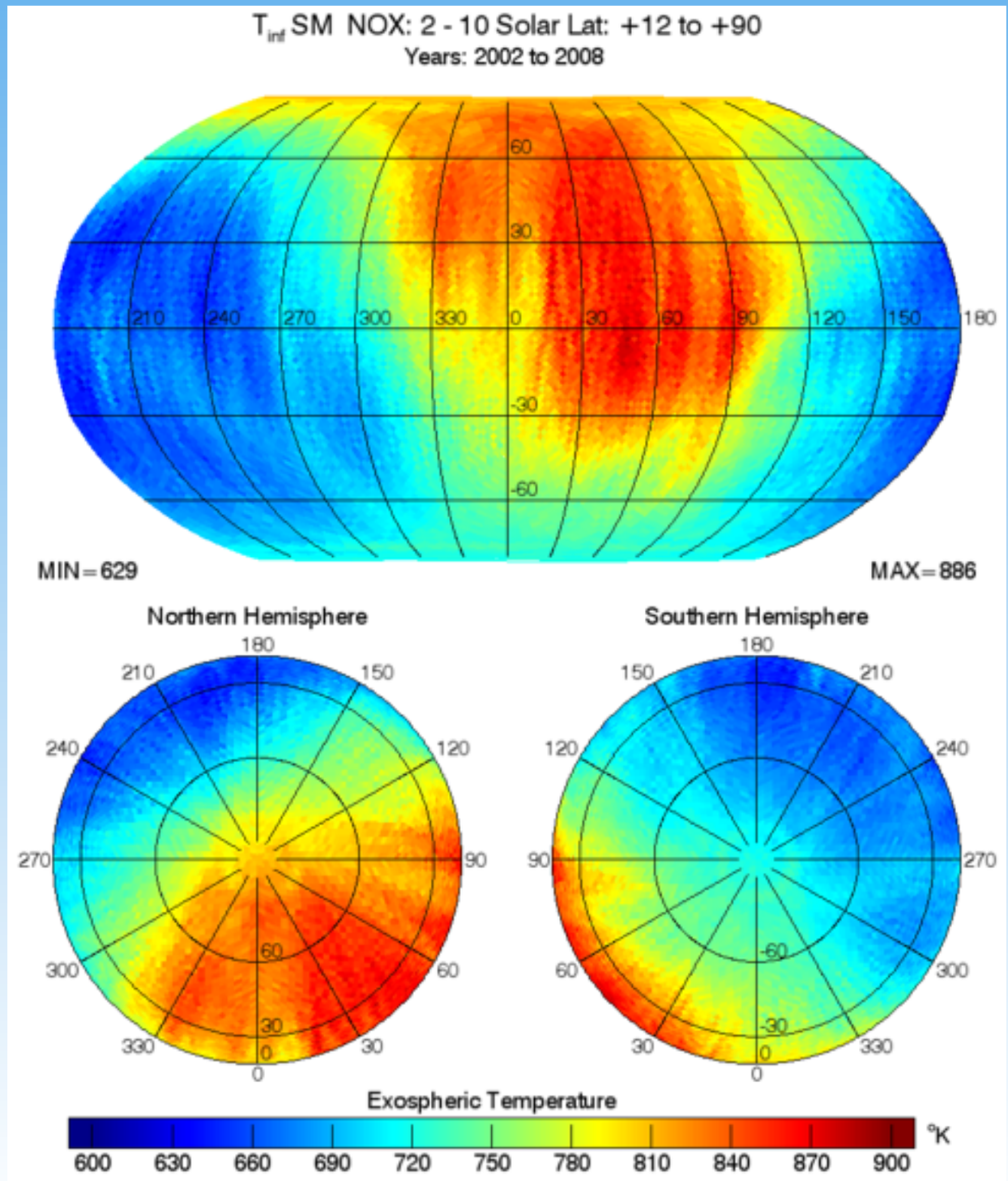


In this trial, the derived exospheric temperatures were found to be very similar for both positive and negative sub-solar latitudes.

CHAMP and GRACE Data, SM Coordinates, Sub-solar latitude in the South.



CHAMP and GRACE Data, SM Coordinates, Sub-solar latitude in the North.



Summary

The JB2008 model has an excellent calibration of densities with respect to solar radiation at four wavelengths, as well as auroral heating. There is rapid response to auroral heating. On the other hand, the global resolution is low, the temperature at the thermosphere base is fixed, and the semi-annual variation is not done with physics-based code.

The NRLMSISE-00 model has more advance physics, has a higher resolution, as well as being much more complicated, with many options. How it works is not clear without plotting internal variables that normally are not available.

In a comparison by *J. S. Shim et al., 2013*, neither model did the best on every single event, though JB2008 was more often better.

My opinion is that to model the SAV, the temperature at the lower boundary should be adjusted, rather than only the composition and exospheric temperatures (NRL), or doing an ad-hoc adjustment to densities (JB08).

T_{120} can be varied in proportion to the SABER CO_2 power, which in addition to better modeling the SAV, also adds a better variation of density with the solar cycle. This temperature can be predicted from solar indices, so that the CO2 measurements are not required.

In work in progress, it is found that adjusting T_{120} in the NRL thermosphere code produces a better agreement between CHAMP and GRACE, in the densities measured at different altitudes.

Acknowledgments

The work at Virginia Tech is supported by NASA grant NNX13AD73G.

Bruce Bowman and Kent Tobiska provided the code for the JB2008 model and the solar indices.

NRLMSISE-00 code provided by M. Picone, A.E. Hedin, and D. Drob, Naval Research Laboratory.

HEALPix software, from http://healpix.jpl.nasa.gov/, developed by Krzysztof M. Gorski.

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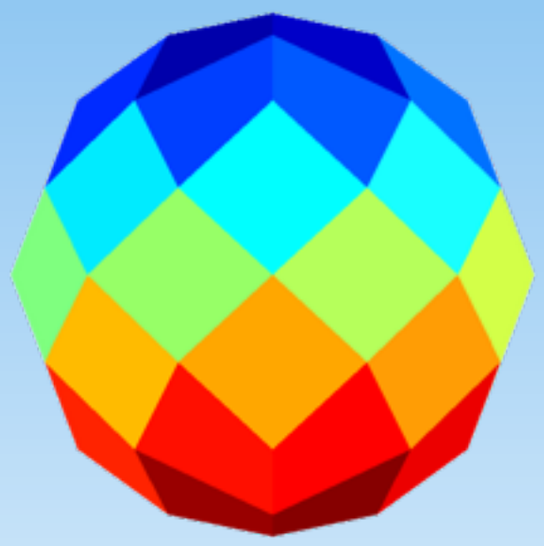
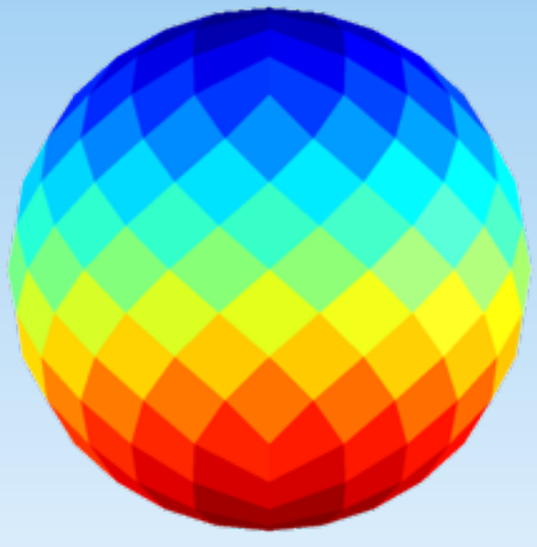
Appendix
Using the HEALPix Grid for Mapping of Exospheric Temperatures

- HEALPIX: Hierarchical Equal Area isoLatitude Pixelization of a sphere.
- Each pixel covers the **same surface area** as every other pixel.
- Pixel centers located on a discrete number of rings of constant latitude.
- Developed within the astrophysics community for all-sky mapping.
- Extensive toolset for analysis, including (spherical) wavelet transforms.

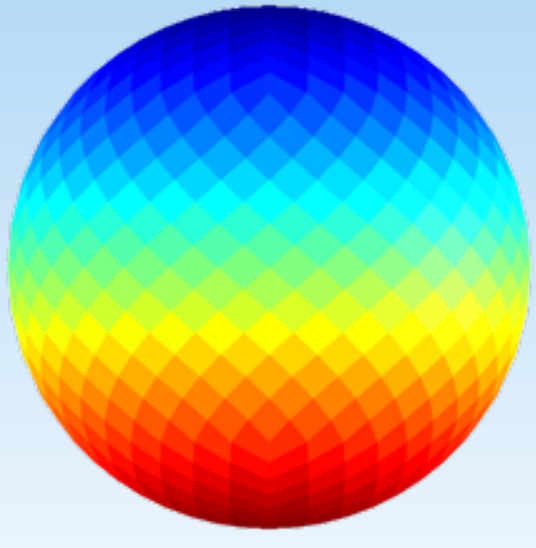


n=2, 48 pixels

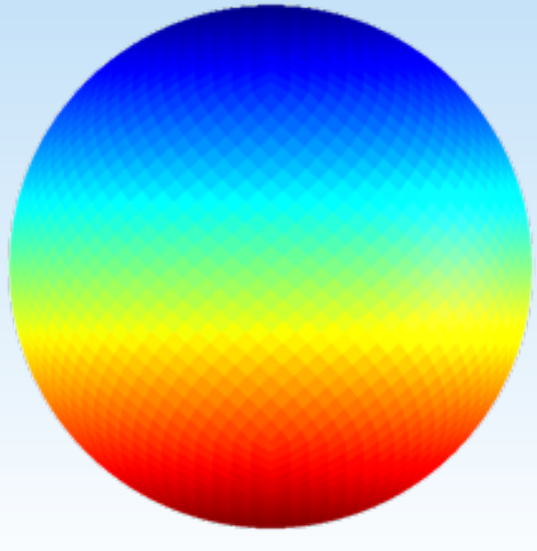


n=4, 192 pixels

n=8, 768 pixels

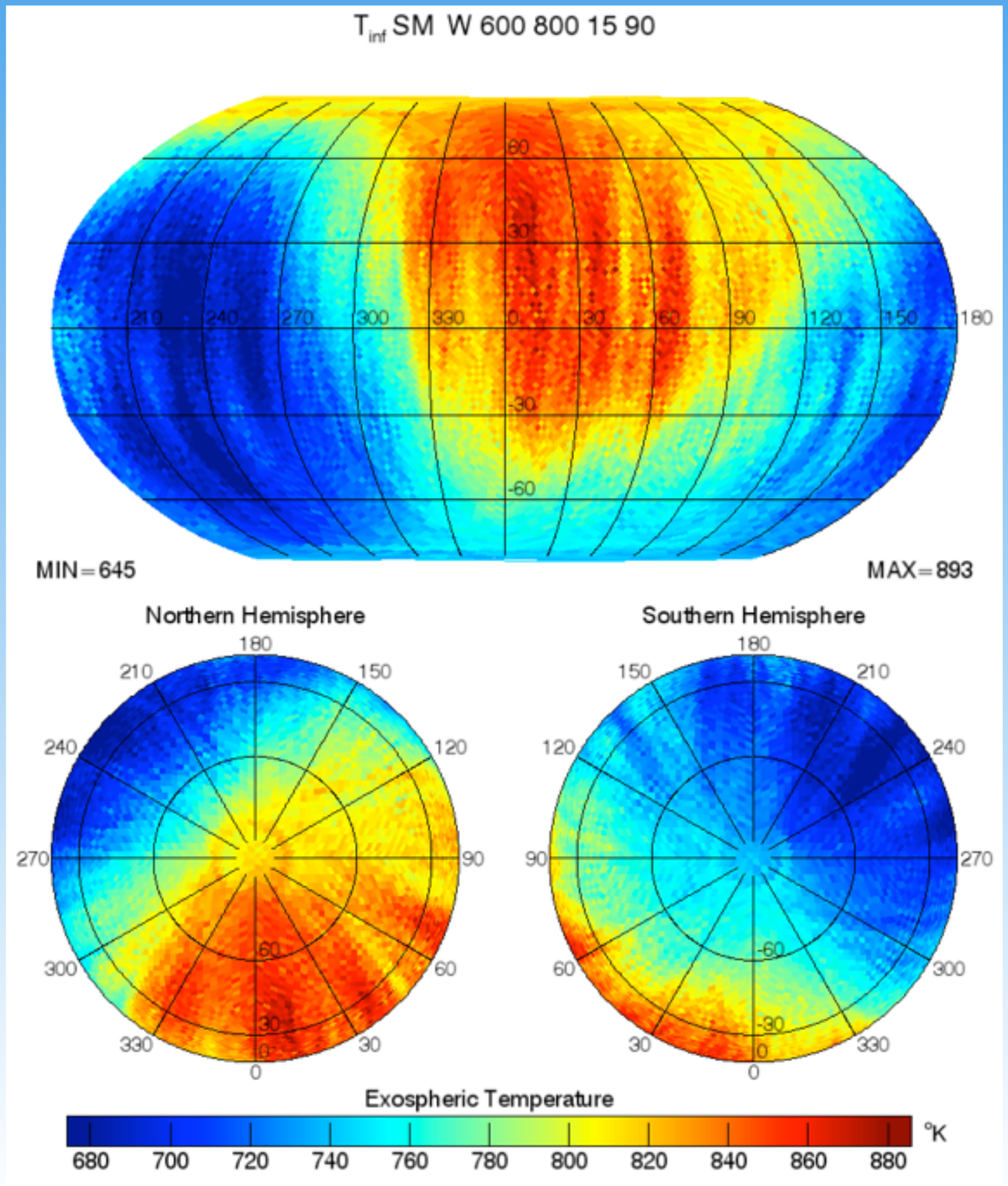


n=16, 3072 pixels



Progressively higher resolutions

Example of Global Map from CHAMP and GRACE data



- Years 2002—2006
- Grid has 12,288 cells
- Means in each cell shown, from times with subsolar lat. > 15°
- JB2008+W05 models predicts that $600 < T_{\infty min} < 800$ °K
- Locations in Solar Magnetic coordinates (SM), rather than geographic
- Resolves density/temperature perturbations in auroral ovals
- Meridional bands are side-effect of 27-day period in solar activity, while satellites precess in local time