THERMOSPHERE DENSITY

AND UPPER ATMOSPHERIC DRAG ON SATELLITES IN LEO

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SMALL SATELLITE CONFERENCE

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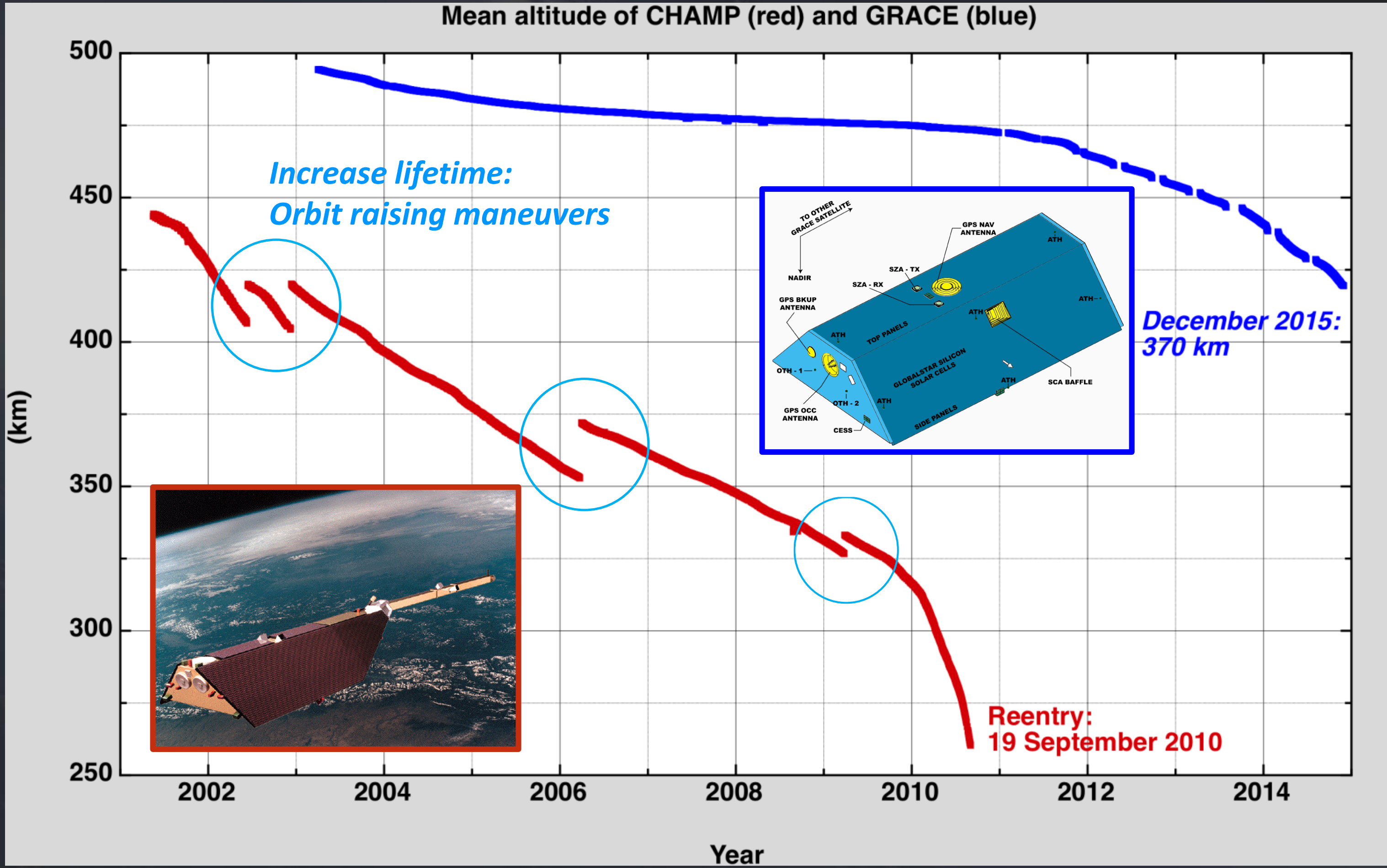
Satellite atmospheric drag

A satellite/object in Low Earth Orbit loses altitude due to interaction with neutral air particles (*thermosphere*).

Ultimately, it reenters the lower atmosphere.



$$a_{drag} = -\frac{1}{2} C_D \frac{A}{m} \rho v^2$$

Satellite drag acceleration:

C_D = aerodynamic coefficient (*model*)

ρ = thermosphere density (*model*)

m = satellite mass

A = satellite surface perpendicular to speed, or ram area

v = satellite speed with respect to co-rotating atmosphere (*orbit*)

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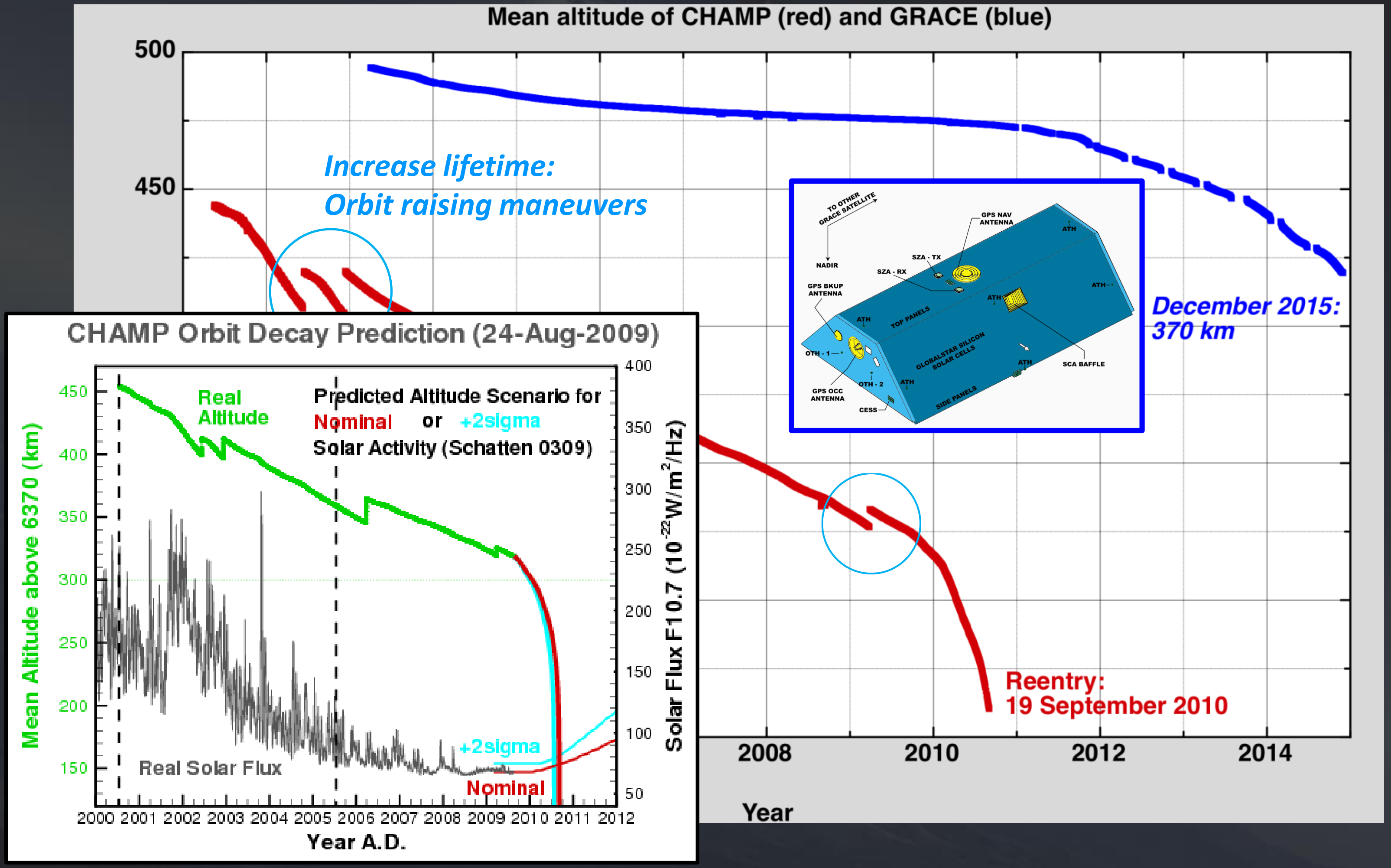

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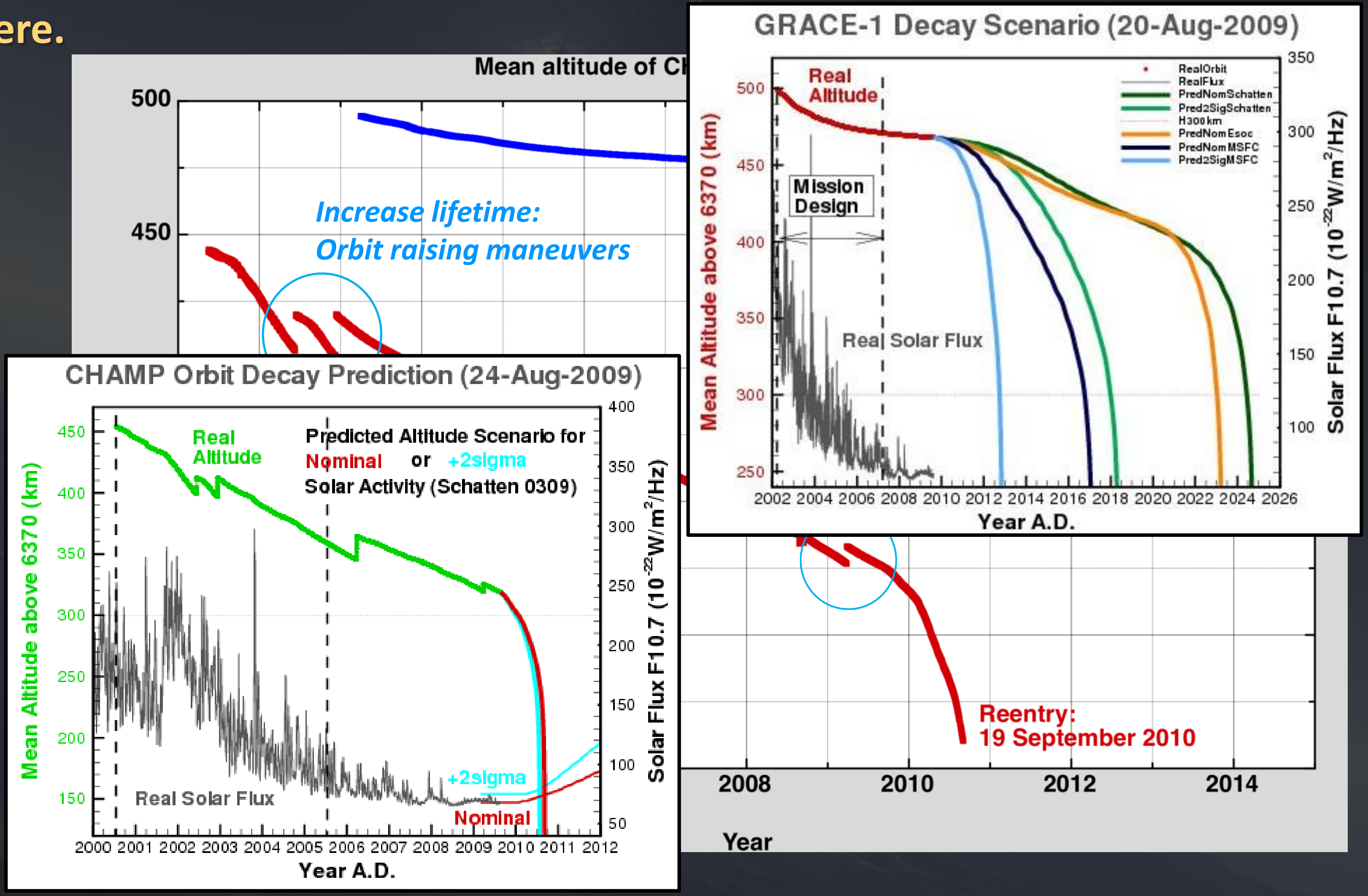

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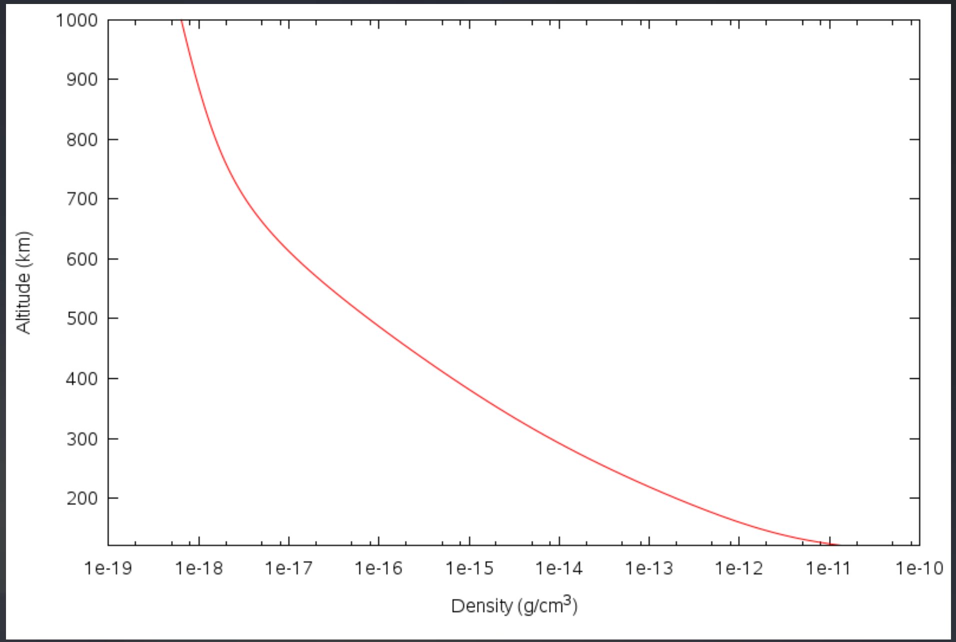
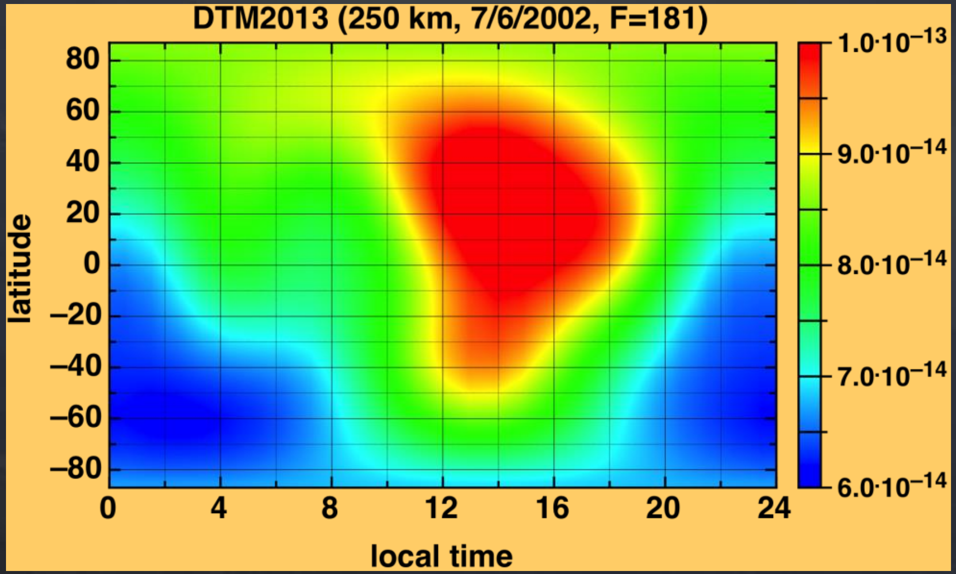
Thermosphere density variability

Thermosphere density is a function of location:

- Altitude
- Latitude, longitude
- Local solar time

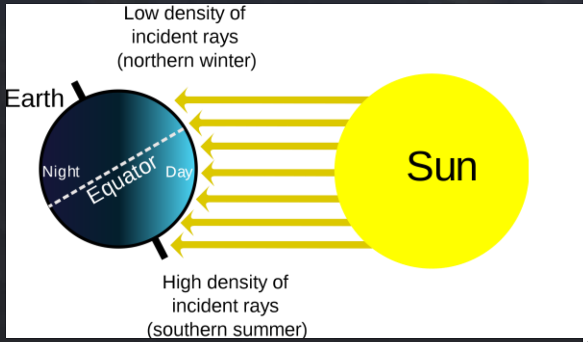


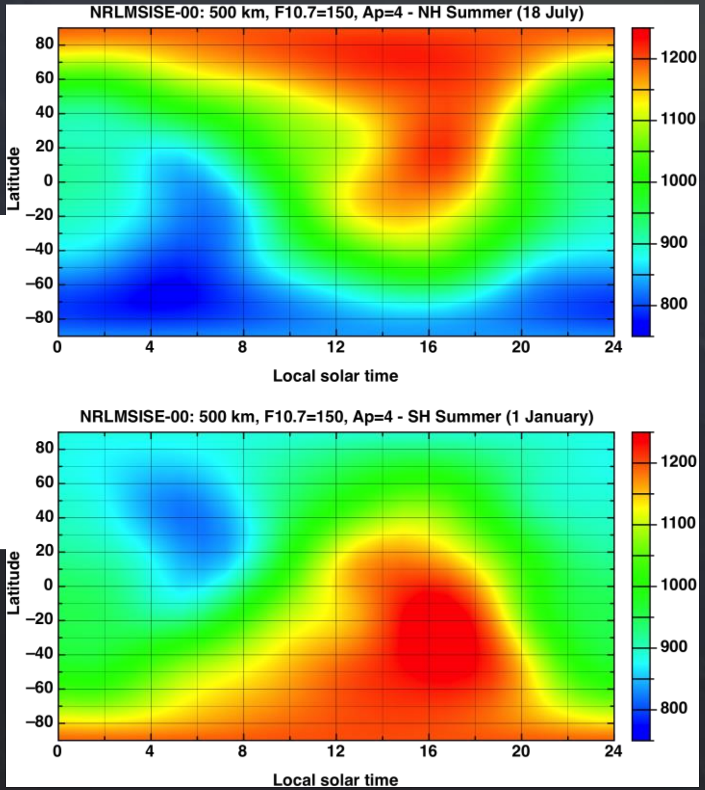


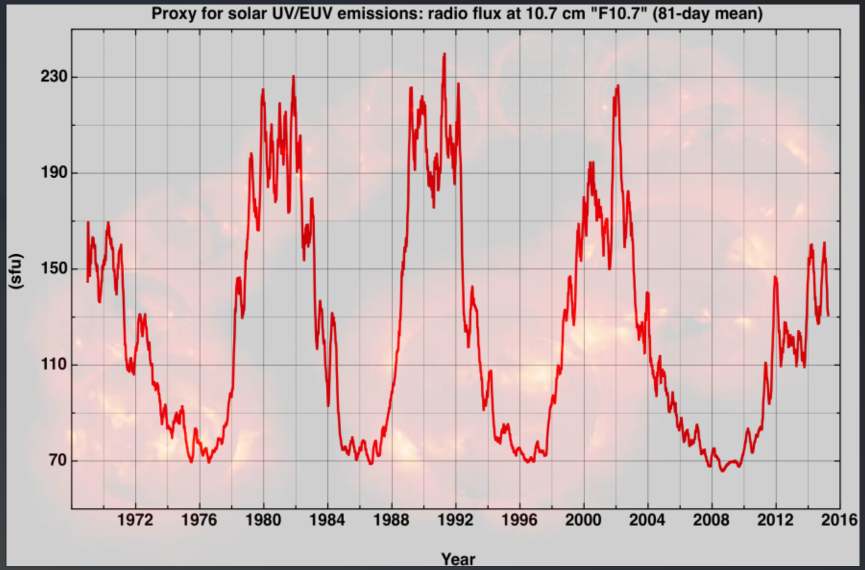
Thermosphere density variability

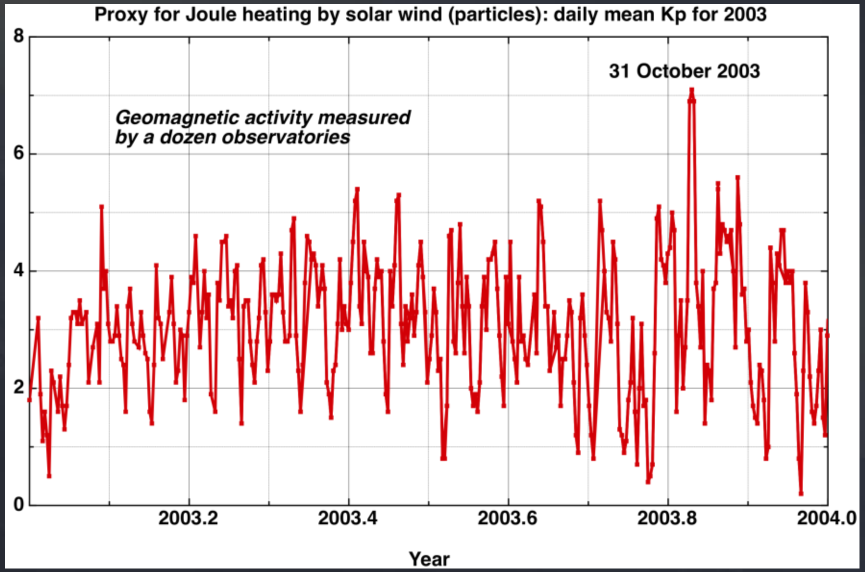
And date:

- Solar and geomagnetic activity
- Season





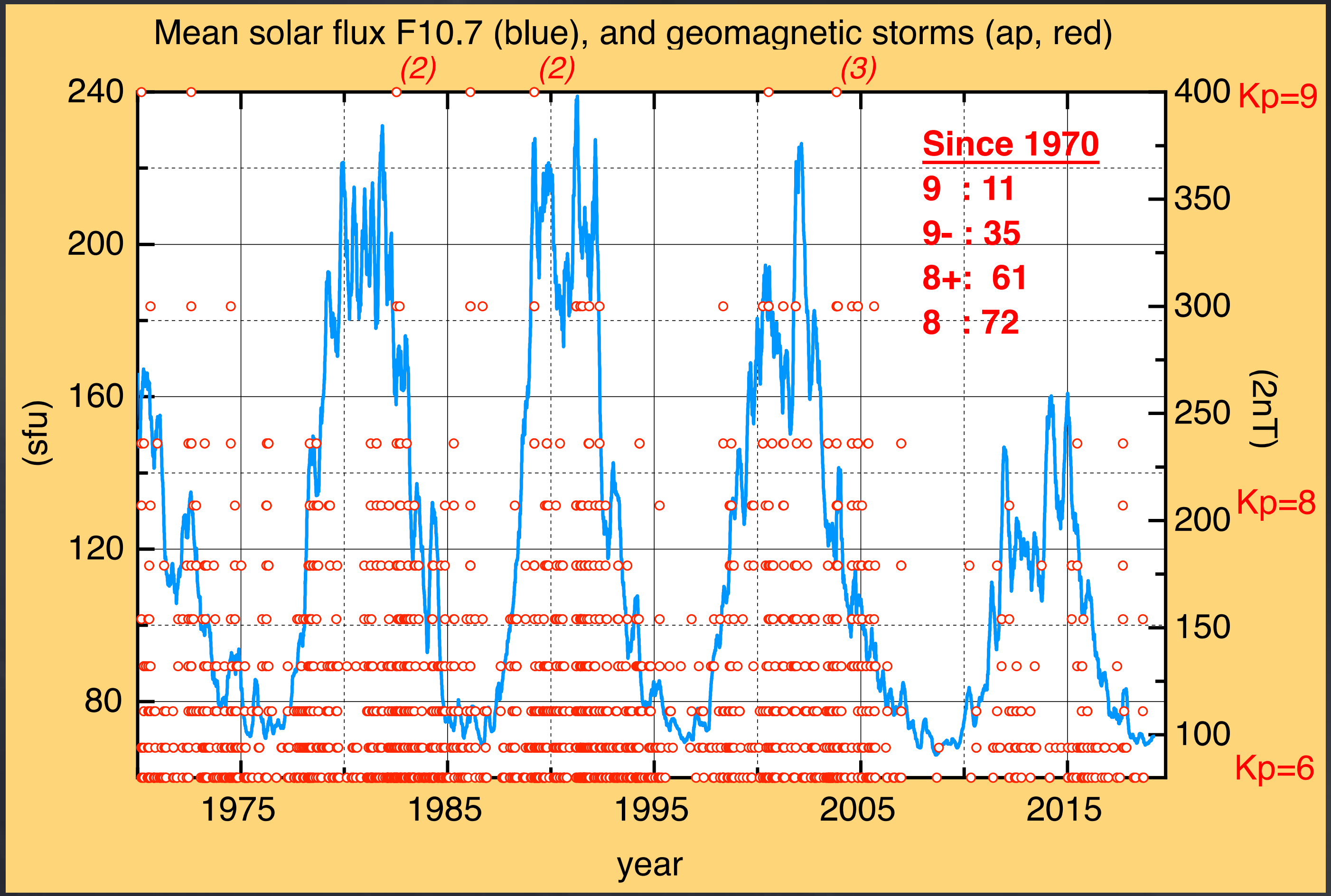




Thermosphere density variability

Slow and fast temporal variations:

- Solar cycle (≈11 years)
- Season (6 months & 12 months)
- Active regions (months)
- Solar rotation (≈27 days)
- Corotating Interaction Regions (9 & 13.5 days)
- Solar/geomagnetic storms (hours – days)
- Solar flares (hours)



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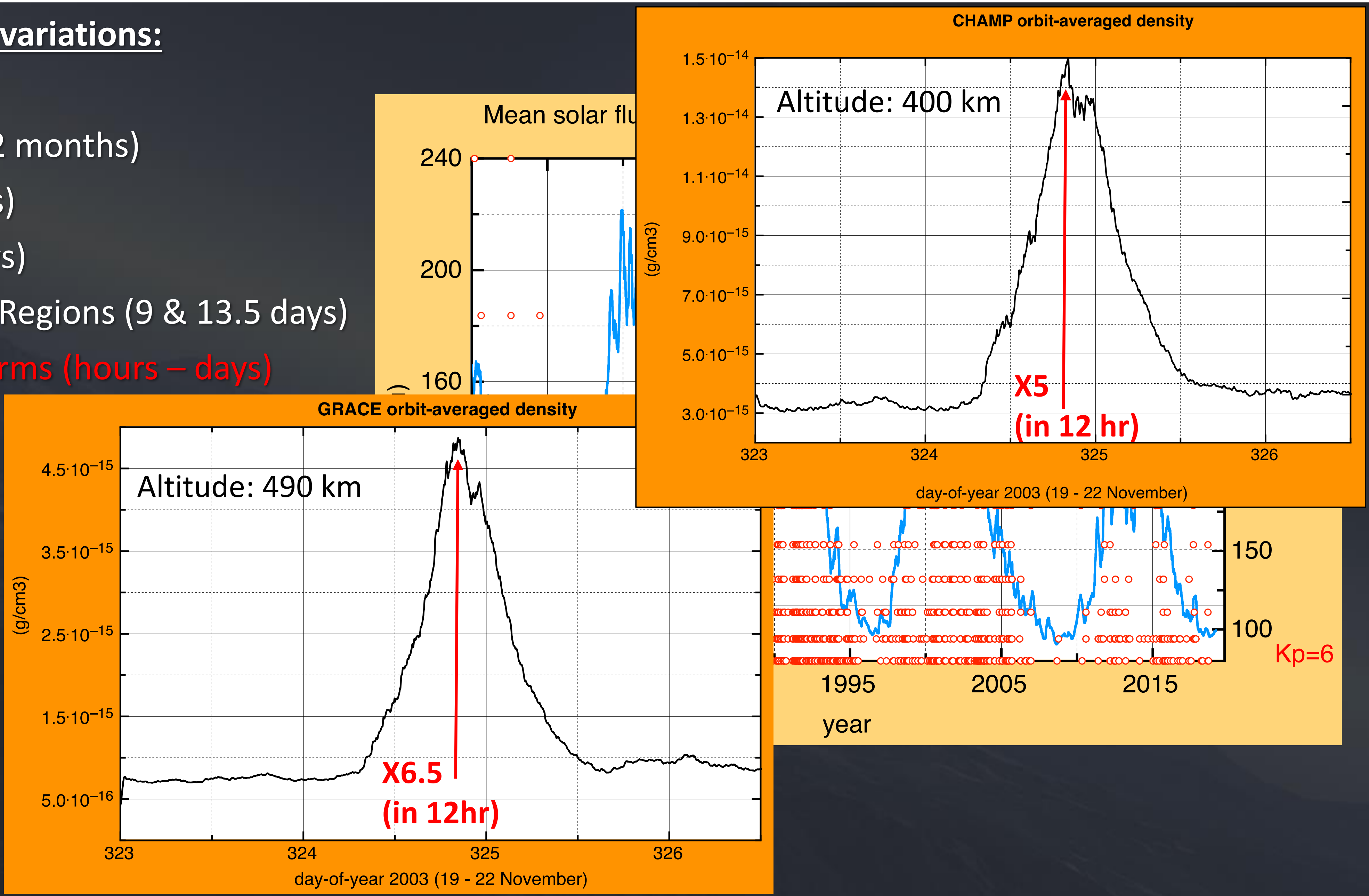
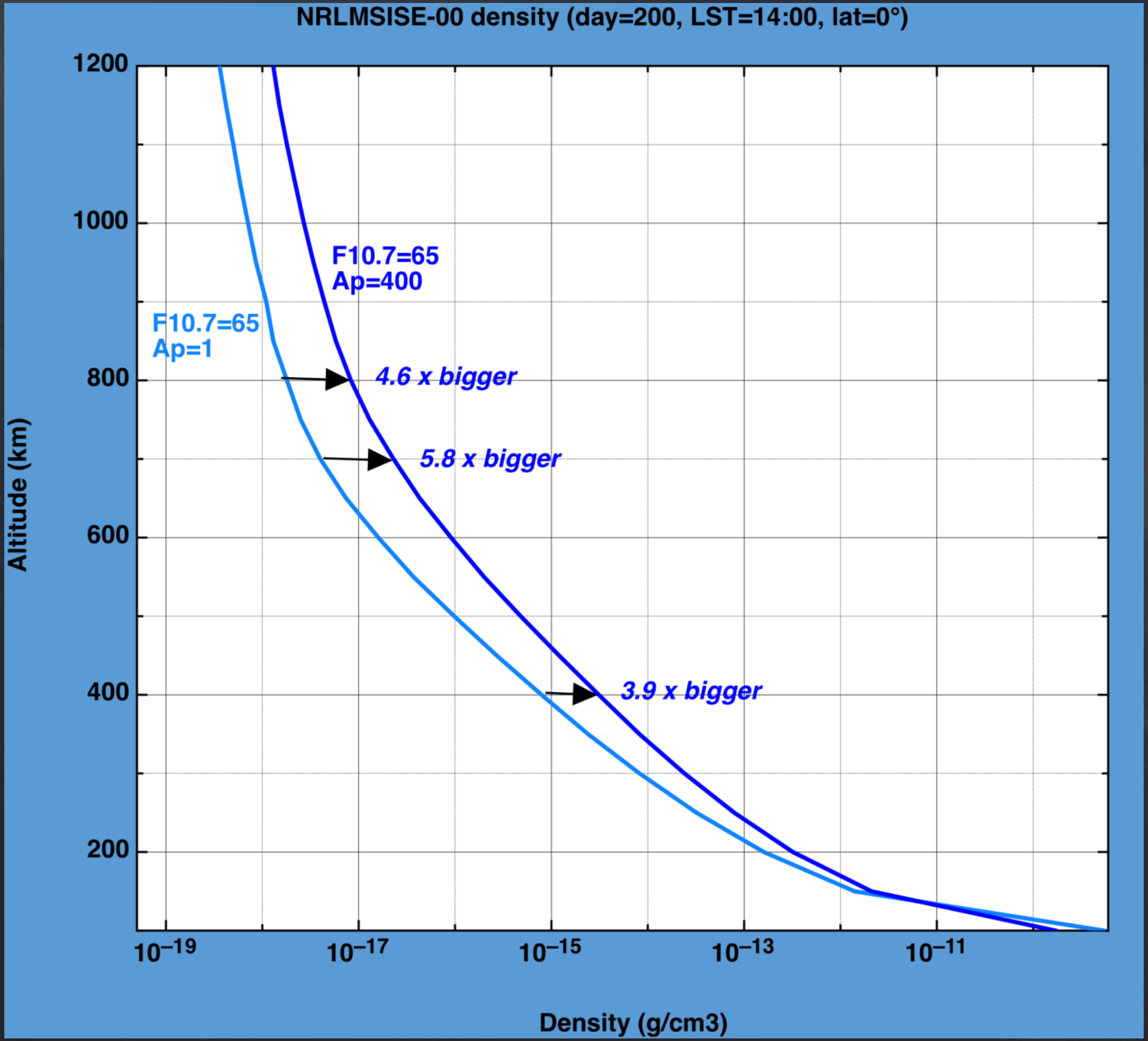


Thermosphere density variability: min-max amplitudes



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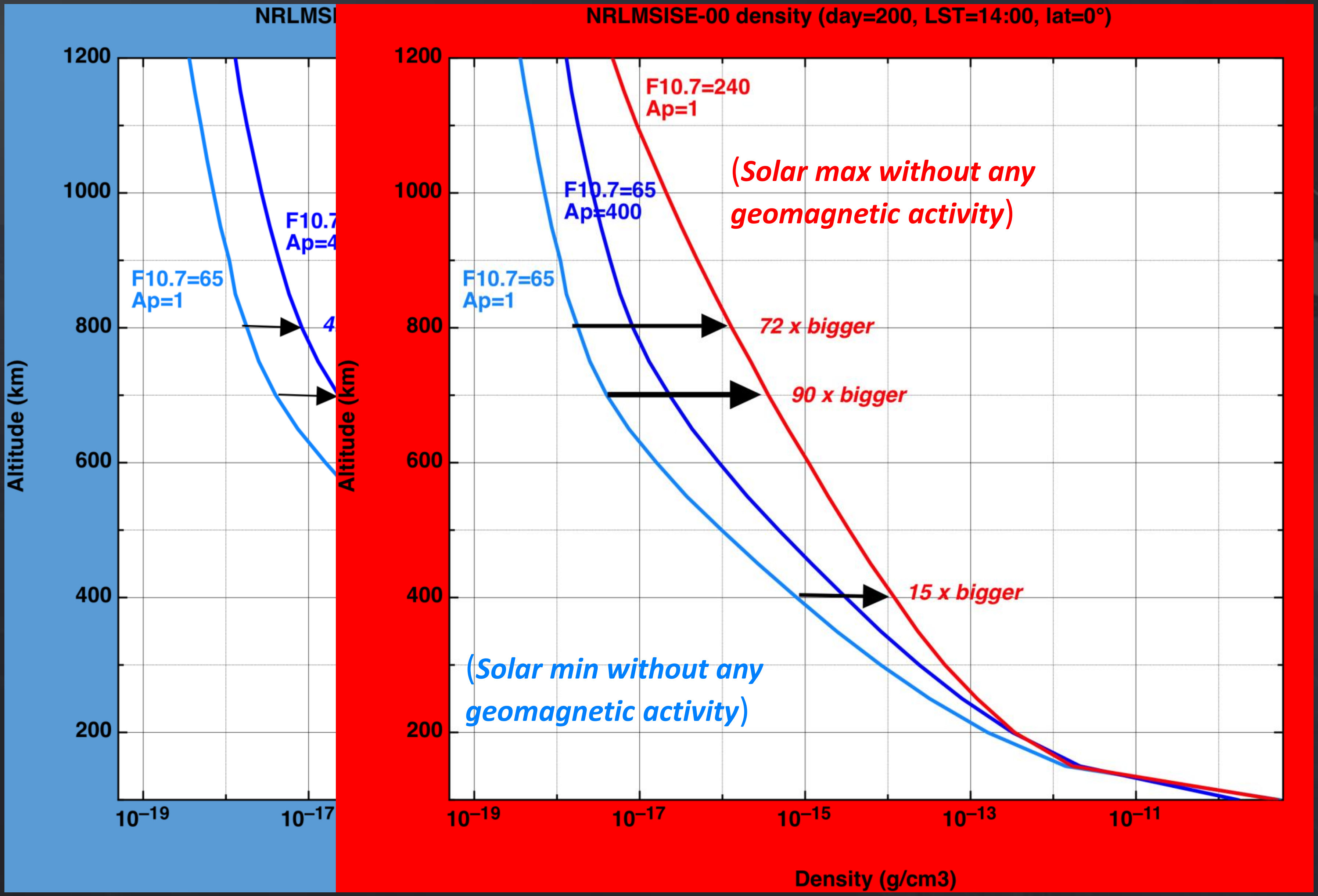

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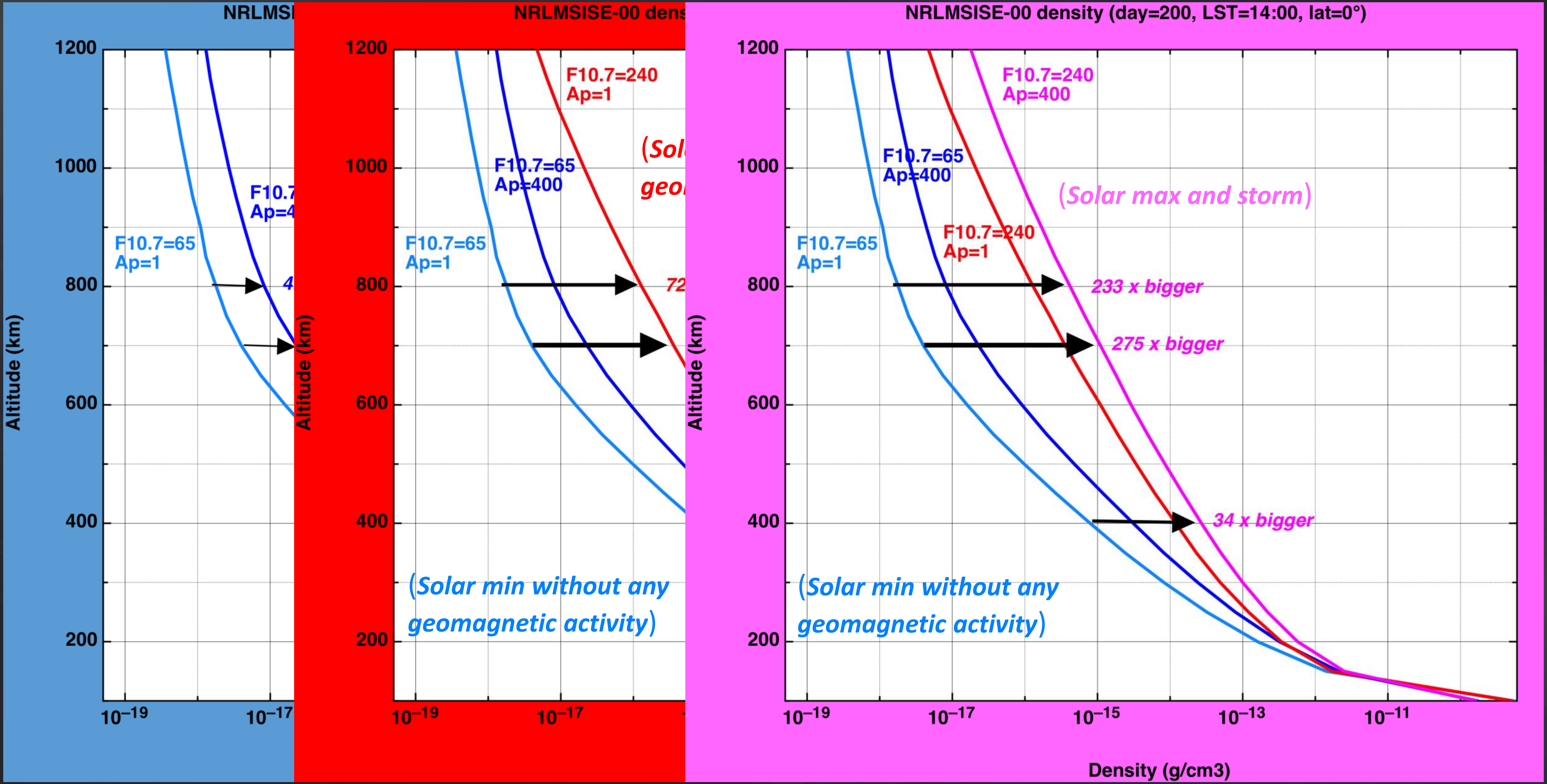
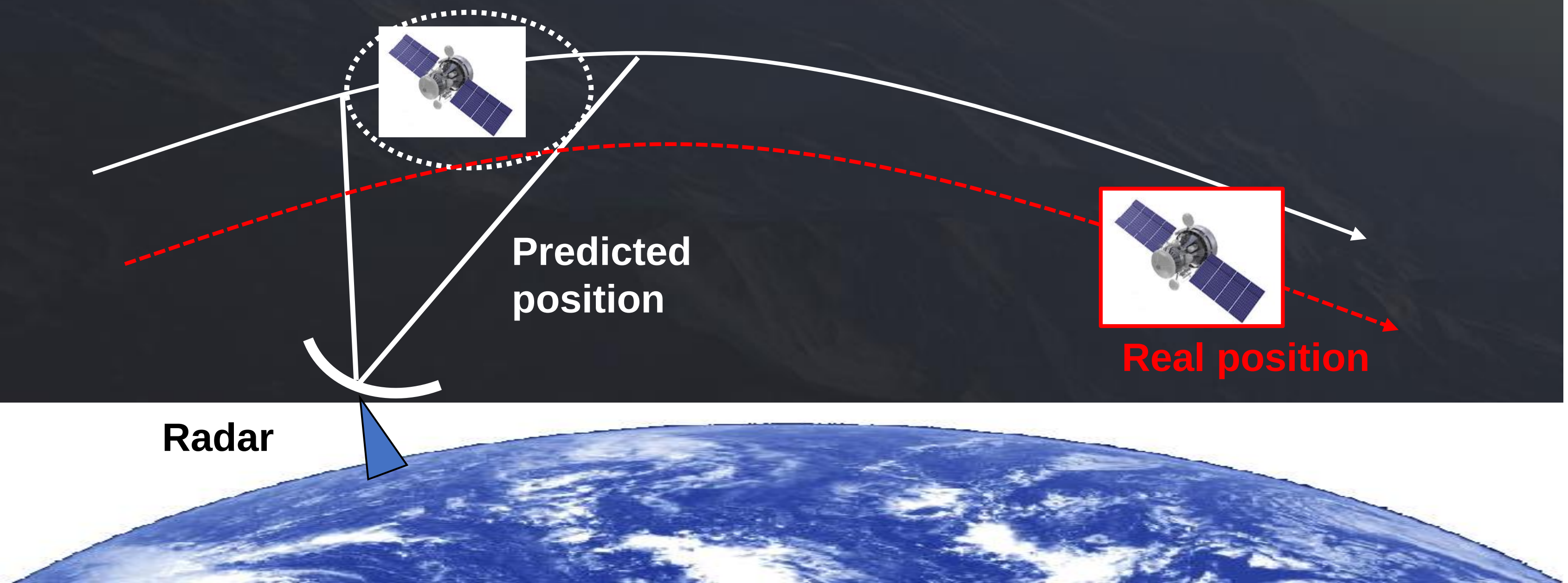


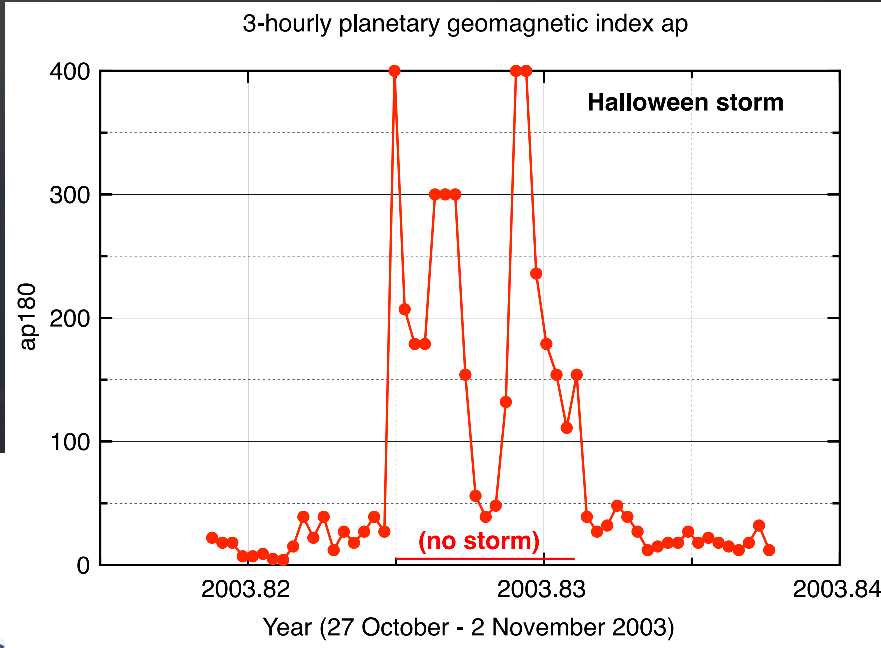
Thermosphere density variability: impact on LEO

Examples of semi-major axis decay due to a severe geomagnetic storm:

- *7-day arc from 27 Oct – 2 Nov 2003, polar and circular orbit*
- *spherical satellite, S/m=0.001 & 0.01 m^2/kg*

Altitude	Total Δa (m) S/m 0.001	Total, no storm	Storm Δa (m)	Total Δa (m) S/m 0.01	Total, no storm	Storm Δa (m) S/m 0.01
250 km	-14643	-10621	-4022	*(reentry)*	-	-
500 km	-175.4	-109.4	-66.0	-1772.0	-1101.2	-670.8
750 km	-9.8	-4.8	-5.0	-98.4	-48.4	-50.0





Take home message

1. Order of magnitude changes in density over a solar cycle for altitudes > 300 km
2. Solar cycle phase (ascending/max/decaying/min) has large impact on satellite lifetime
3. Density increases several 100% during geomagnetic storms within hours
4. Orbit decay can be significant due to a storm, but not dimensioning for lifetime
5. Geomagnetic storms cannot reliably be predicted at the present time

Something to read:

Next Step Space Weather Benchmarks, IDA SCIENCE & TECHNOLOGY POLICY INSTITUTE

https://www.ida.org/

The benchmarks specify nature and intensity of extreme space weather events