Semi-Annual Variations Derived From Both Satellite Drag Measurements and the TIMED SABER Instrument

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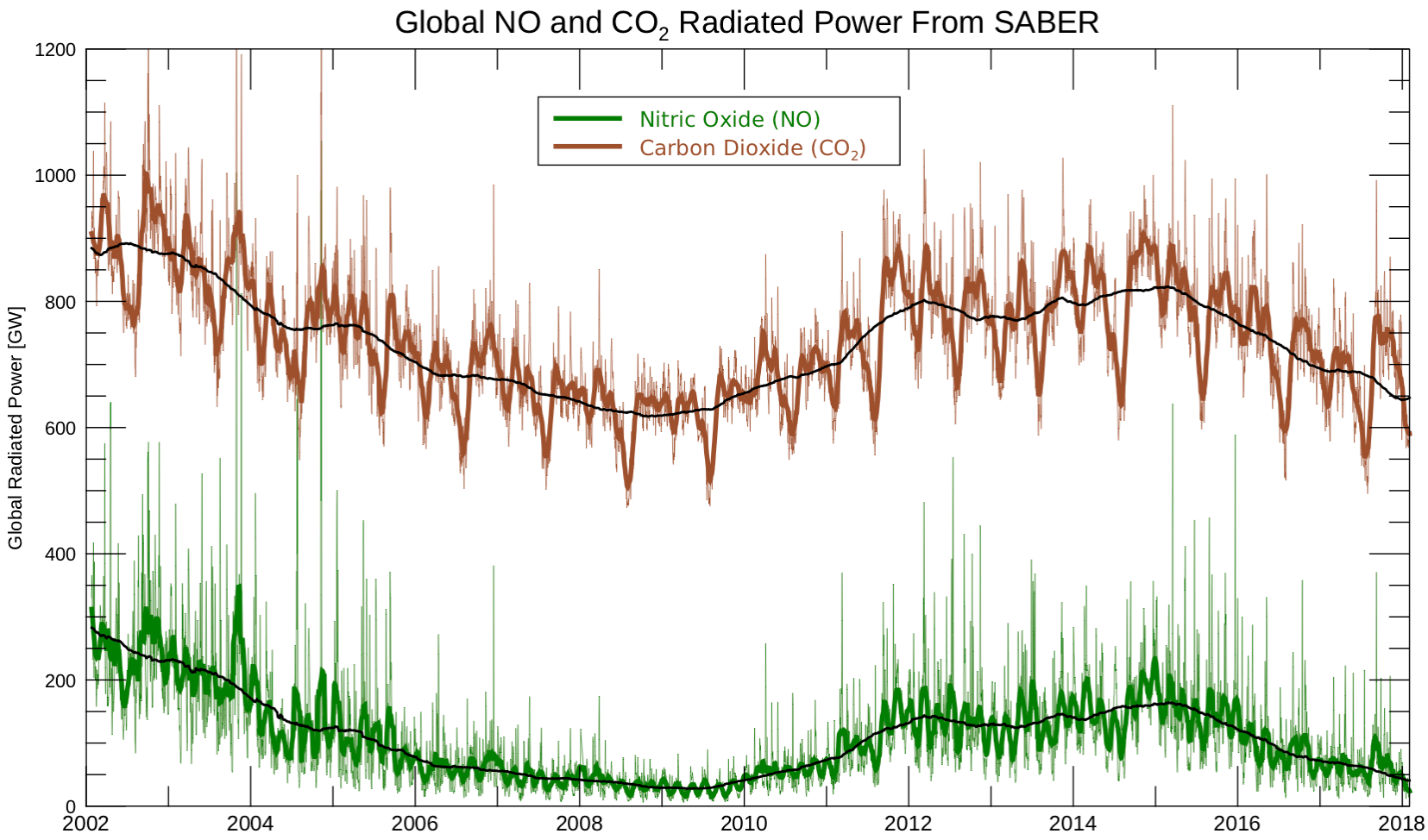
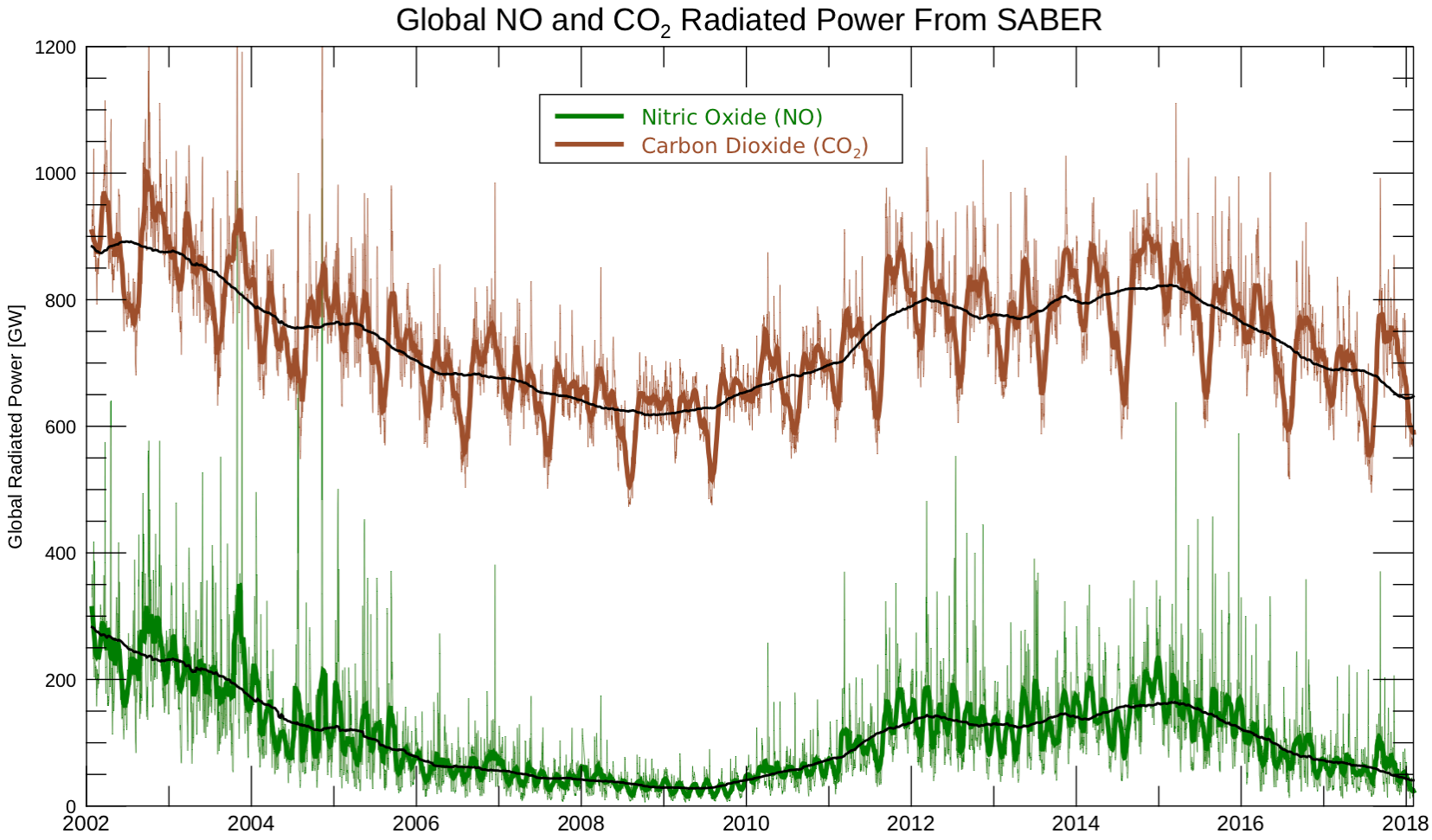
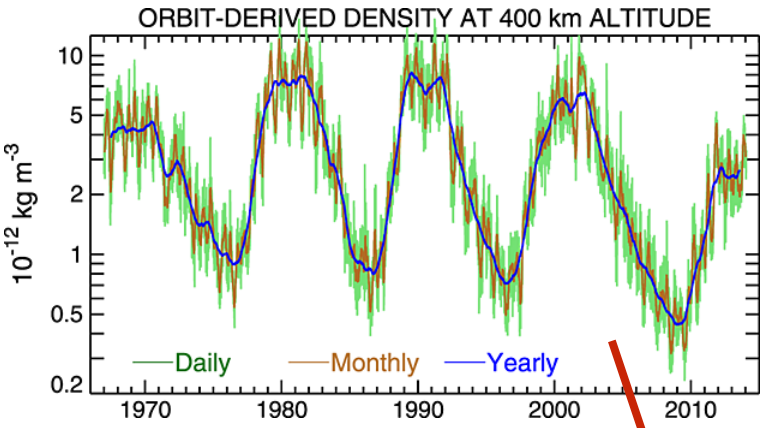
The Sounding of the Atmosphere using Broadband Emission Radiometry (SABER) instrument on NASA's Thermosphere Ionosphere Mesosphere Energetics and Dynamics (TIMED) spacecraft has measured emissions from nitric oxide and carbon dioxide in the thermosphere since 2002



There seems to be a relationship between the CO_2 emissions, and the Semi-Annual Variations (SAO). How well do they agree, and could the CO_2 measurements be used for real-time now casts?

Thick lines: 31 day smoothing. Thin, black lines: one year smoothing.

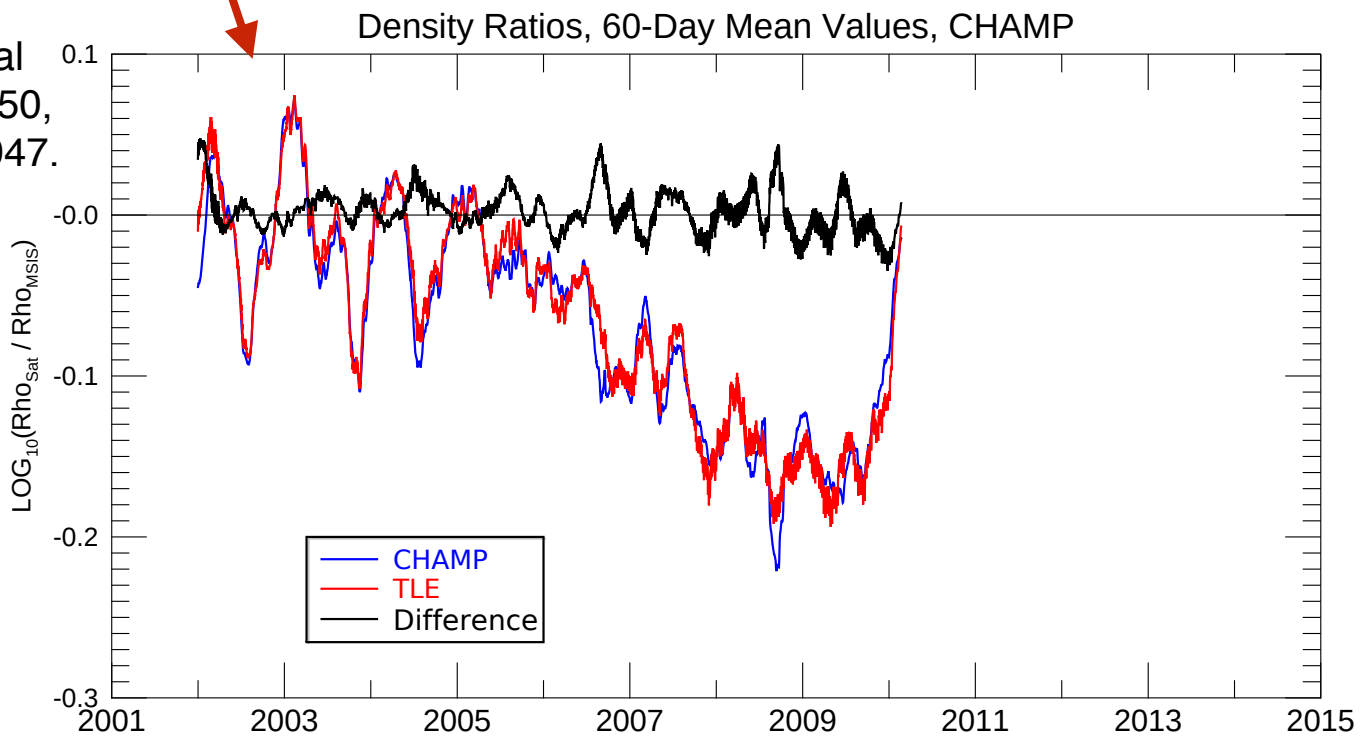


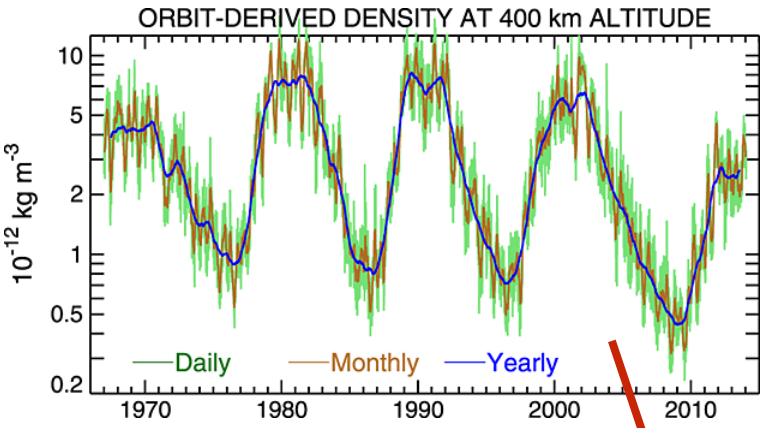


Neutral densities from several satellites are used to measure the SAO. First, calibrations were checked by comparing with the "TLE" database, from radar tracking of ~5000 objects, using the ratio of Measured/ NRLMSISE-00 model densities.

Emmert, J. T. (2015), Altitude and solar activity dependence of 1967–2005 thermospheric density trends derived from orbital drag, *JGR,120*, 2940–2950, doi:10.1002/2015JA021047.

The CHAMP density/MSIS ratios agreed with the TLE ratios, to within 1%





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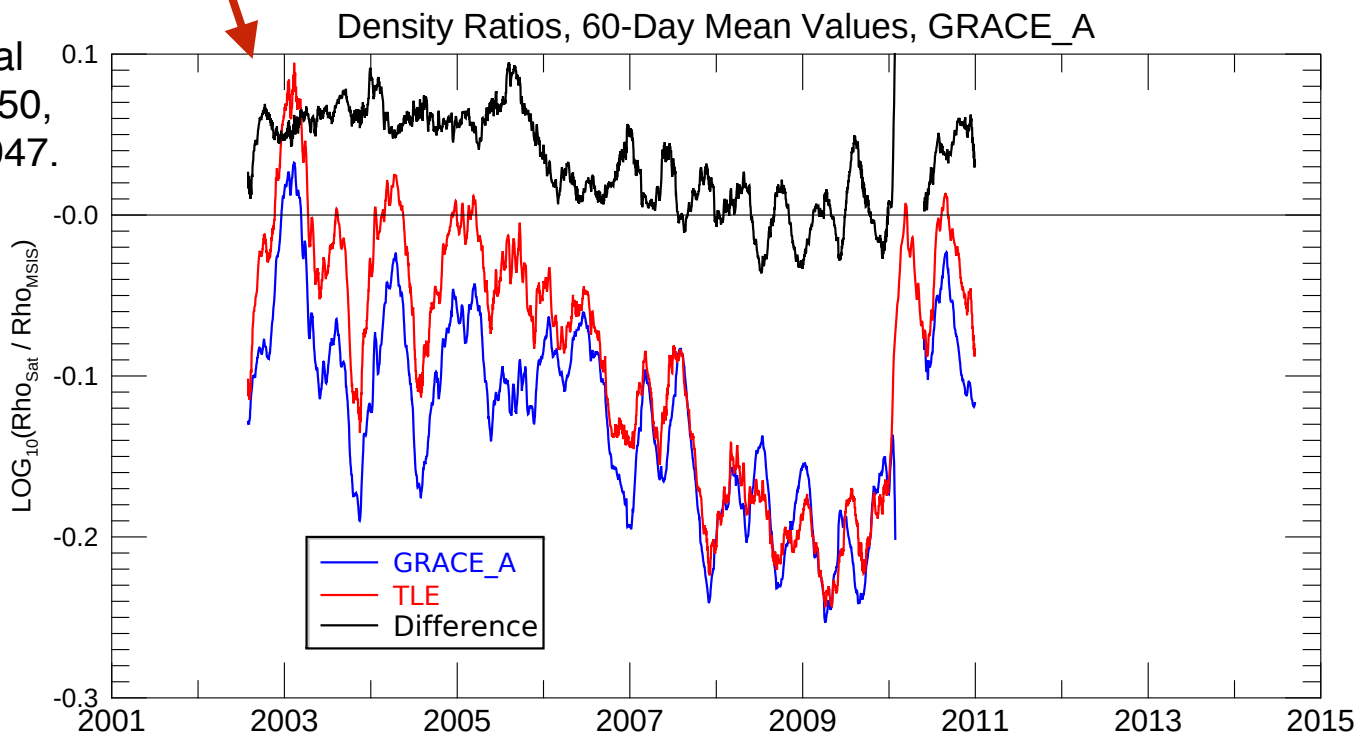
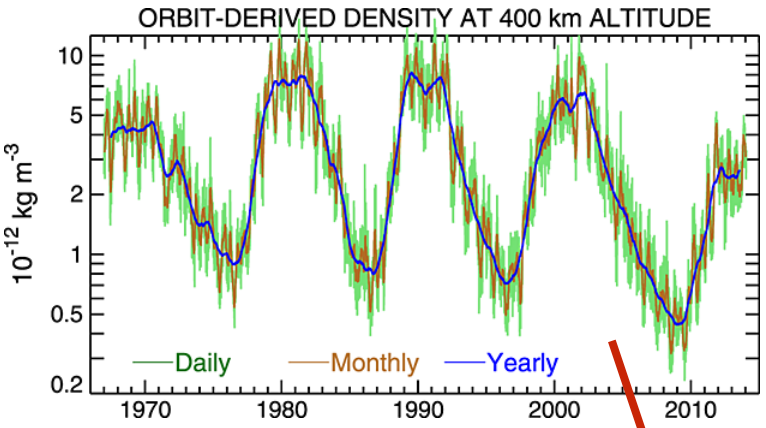
The GRACE-A densities required multiplication by 1.14 prior to 2006, 1.05 afterwards.





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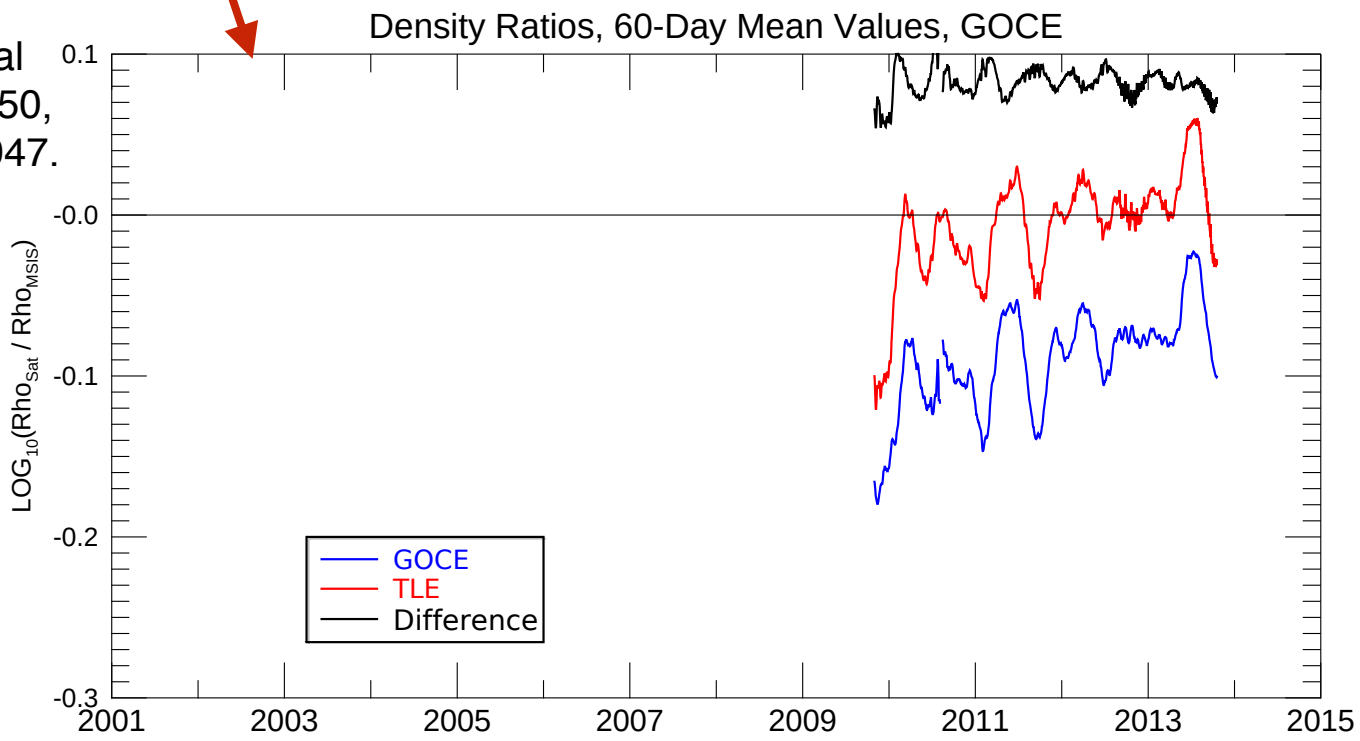
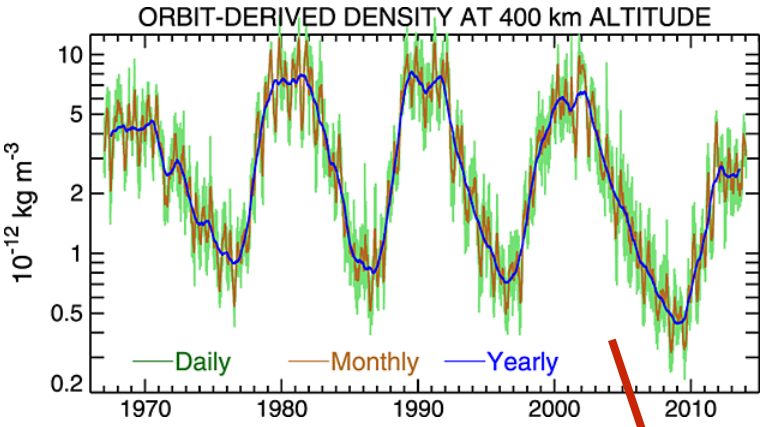
The GOCE densities need multiplication by 1.21 to agree with with the TLE data.

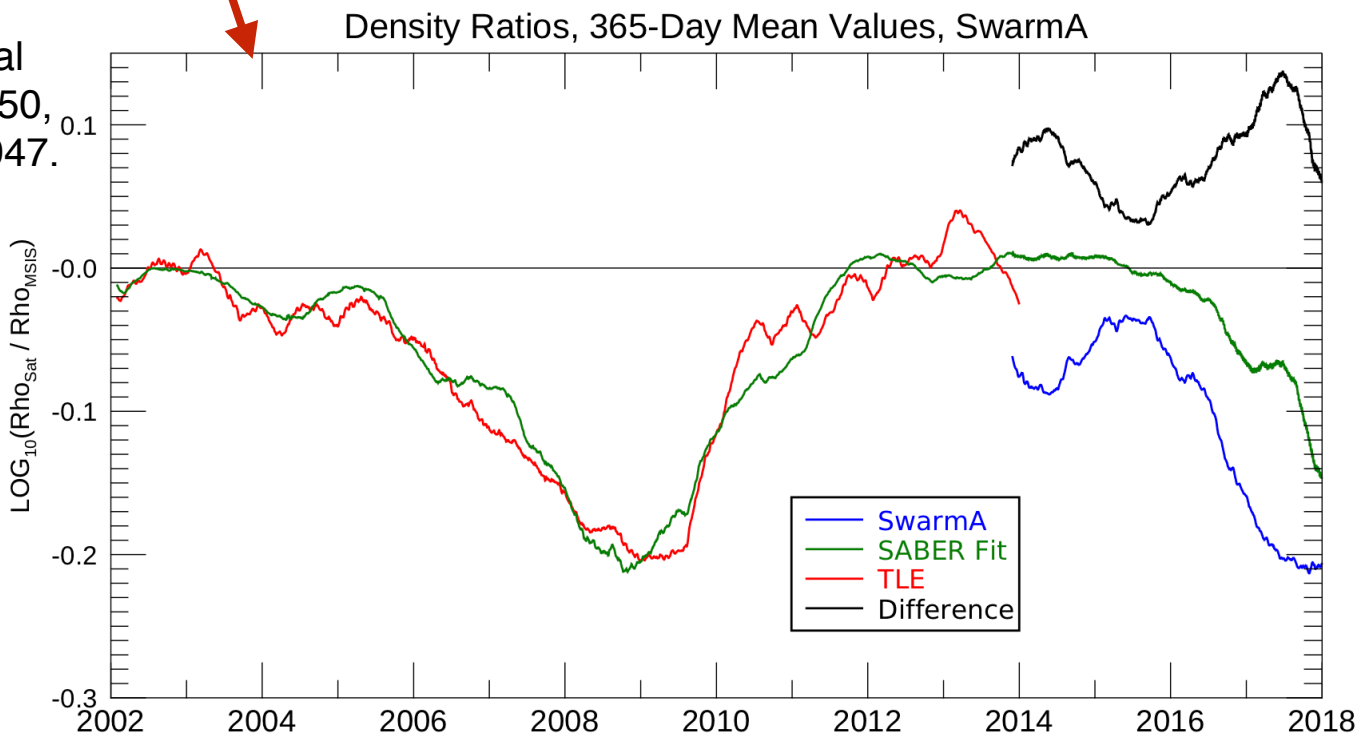




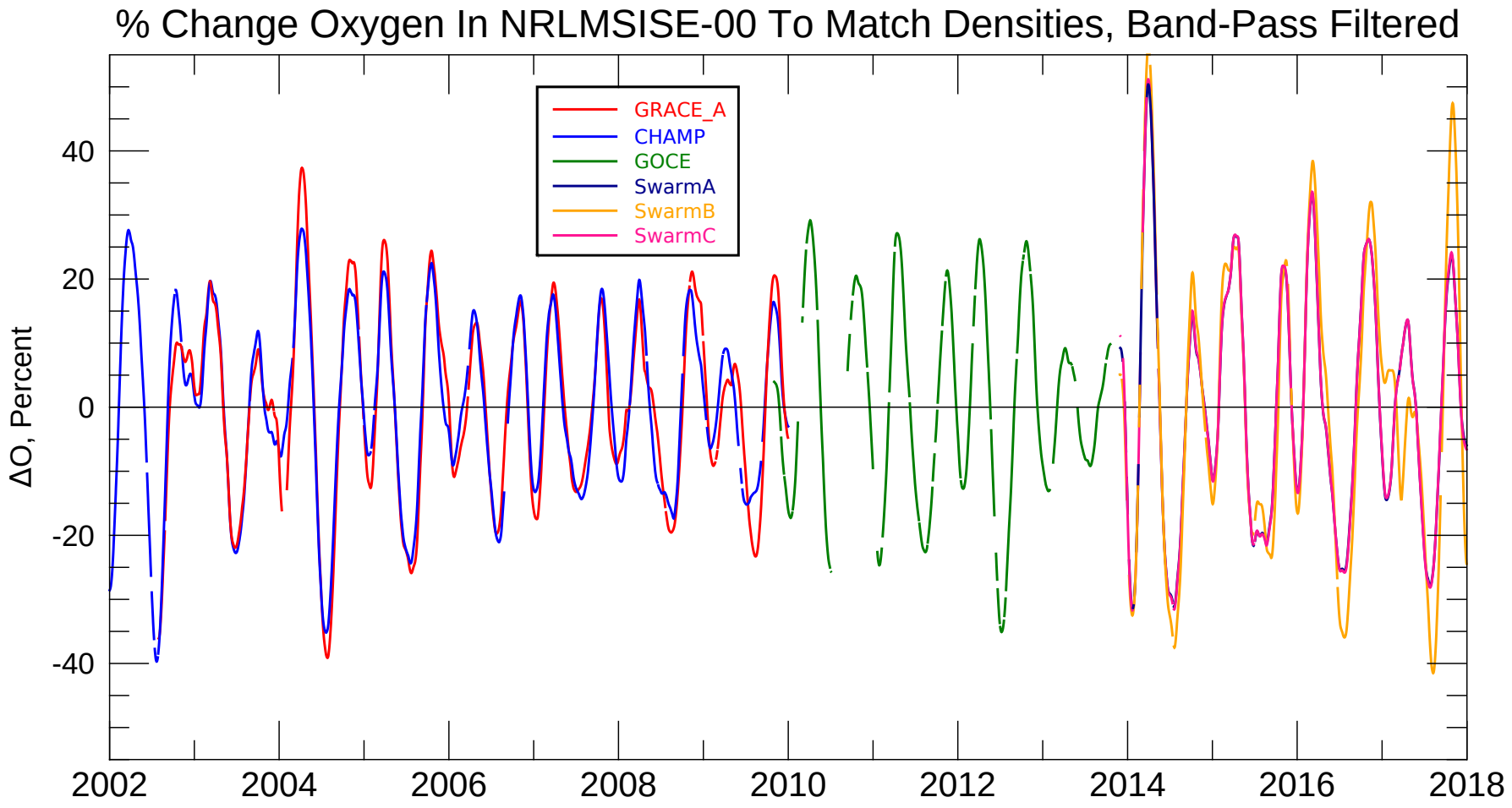
To do the same comparison for the Swarm spacecraft, the TLE results were extended in time, by fitting the measured/MSIS density ratios with the SABER data, at all 10 altitudes, then interpolated to the Swarm altitudes.

Emmert, J. T. (2015), Altitude and solar activity dependence of 1967–2005 thermospheric density trends derived from orbital drag, *JGR,120*, 2940–2950, doi:10.1002/2015JA021047.

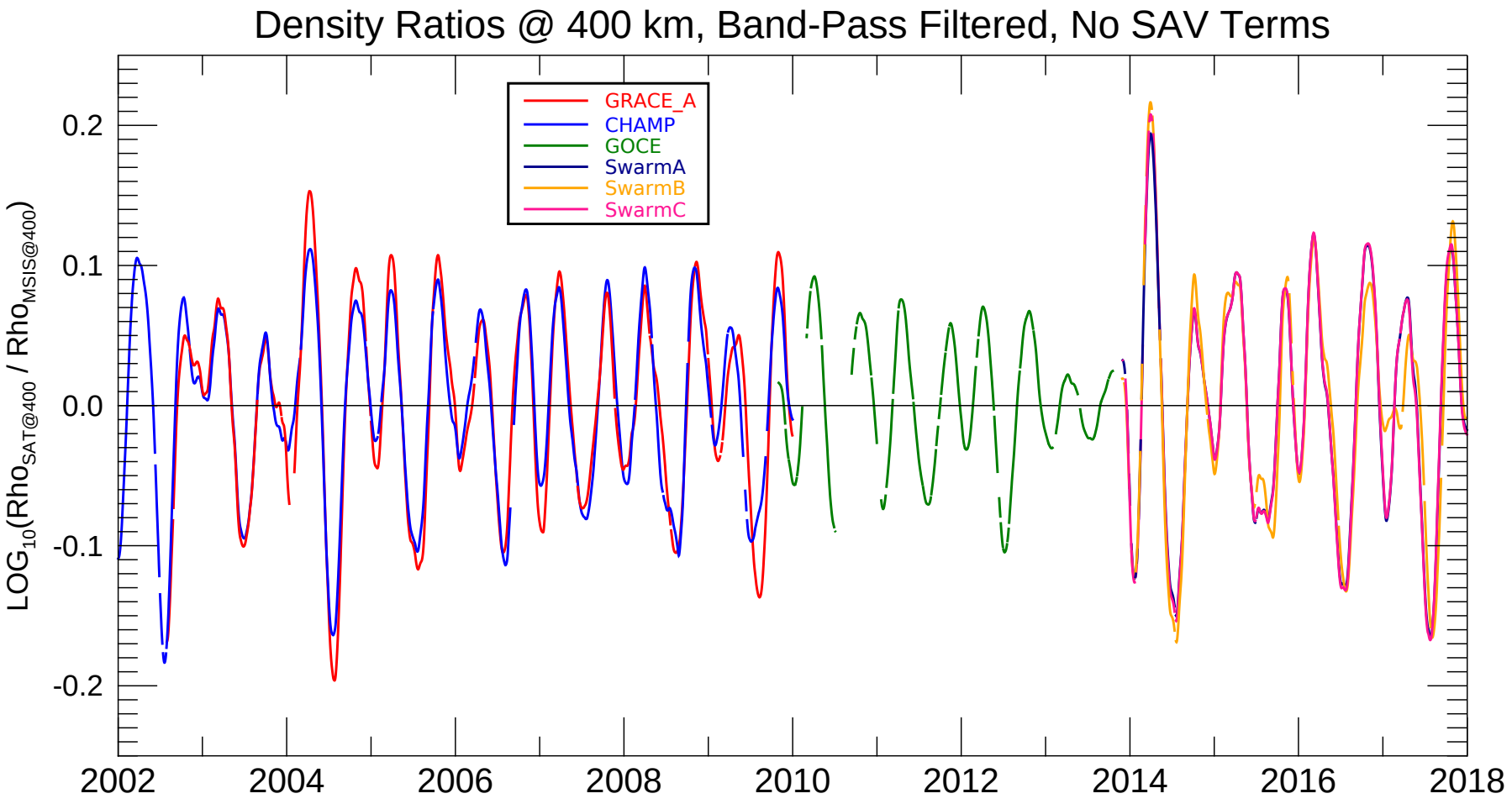
The ratio for all Swarm densities is 1.13.

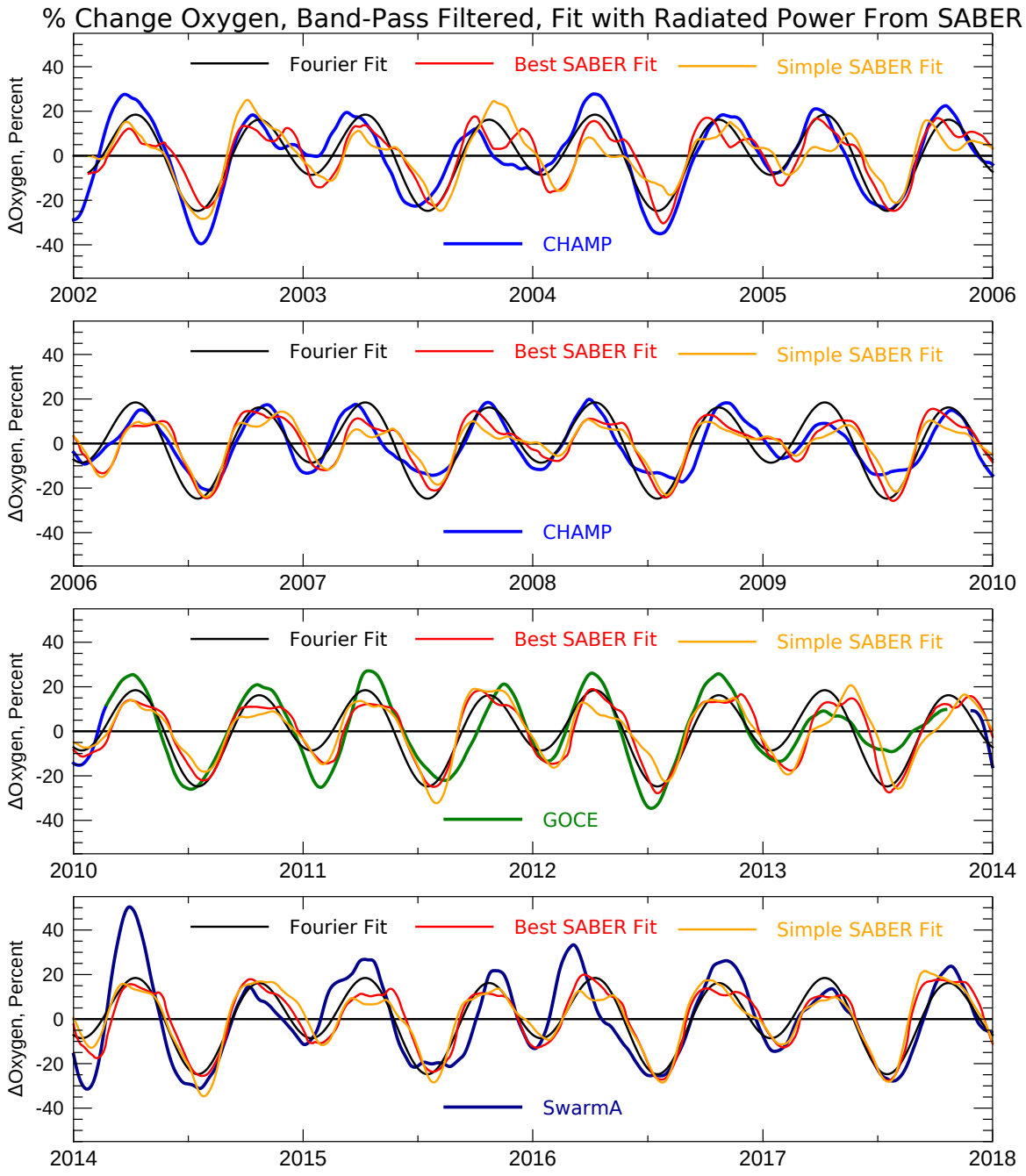


The MSIS model is used, with all annual/semi-annual terms turned off, to derive the percentage change in atomic oxygen that is needed to match the measured densities. Prior results are extended by several years.



The ratio of measured/MSIS densities can also be plotted.
All data have been passed through a digital band-pass filter.





Final Results, Fitting Derived ΔO With SABER Measurements (Swarm data were not used in fit!)

Simple SABER fit:

$$\Delta O = a + b\ CO_{2BP}$$

Correlations= 0.728 , 0.767

Best SABER fit:

$$\Delta O = a + b\ \mathrm{sgn}(CO_{2BP})\,|CO_{2BP}|^{d} + c\ \mathrm{sgn}(NO_{BP})\,|NO_{BP}|^{e}$$

Correlations= 0.802 , 0.793

Fourier Series Fit (better):

$$\Delta O = a + b\sin\Theta + c\cos\Theta + d\sin 2\Theta + e\cos 2\Theta$$

$$\Theta = 2\pi t / 365.25, t \text{ in days}$$

Correlations= 0.887 , 0.860

Fit Results

						Correlations		Std. Dev.	
What	a	b	c	d	e	C/G	Swarm A	C/G	Swarm A
Simple SABER Fit	-0.0301	0.259				0.728	0.767	10.2	11.9
Best SABER Fit	-0.742	0.728	-0.502	0.804	0.857	0.802	0.793	8.86	11.3
Fourier Fit	0.0947	3.11	7.54	-8.05	-14.7	0.887	0.86	6.86	9.84