Nitric Oxide Radiative Cooling and Concentration in Earth's Atmosphere Derived from SABER

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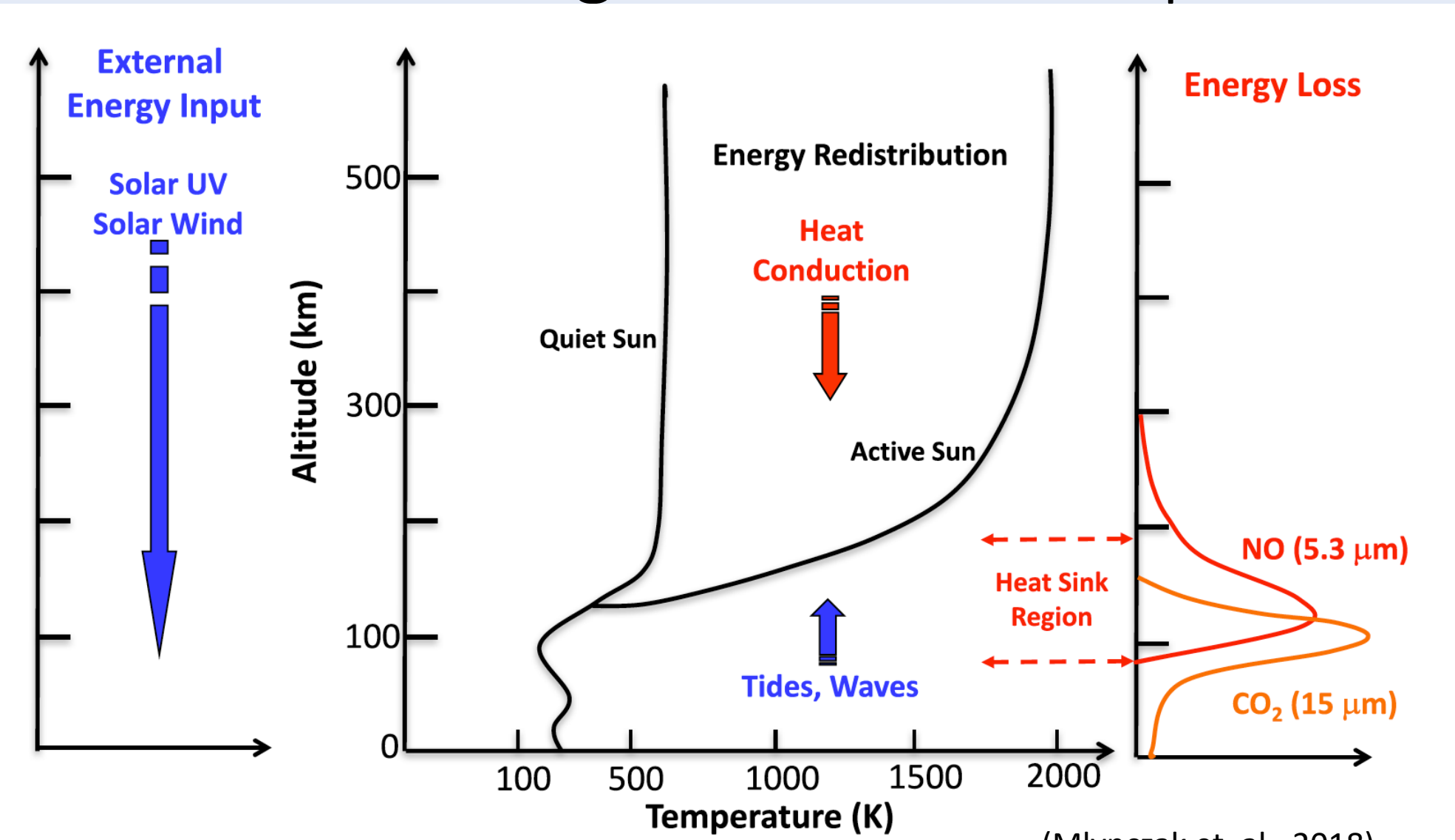
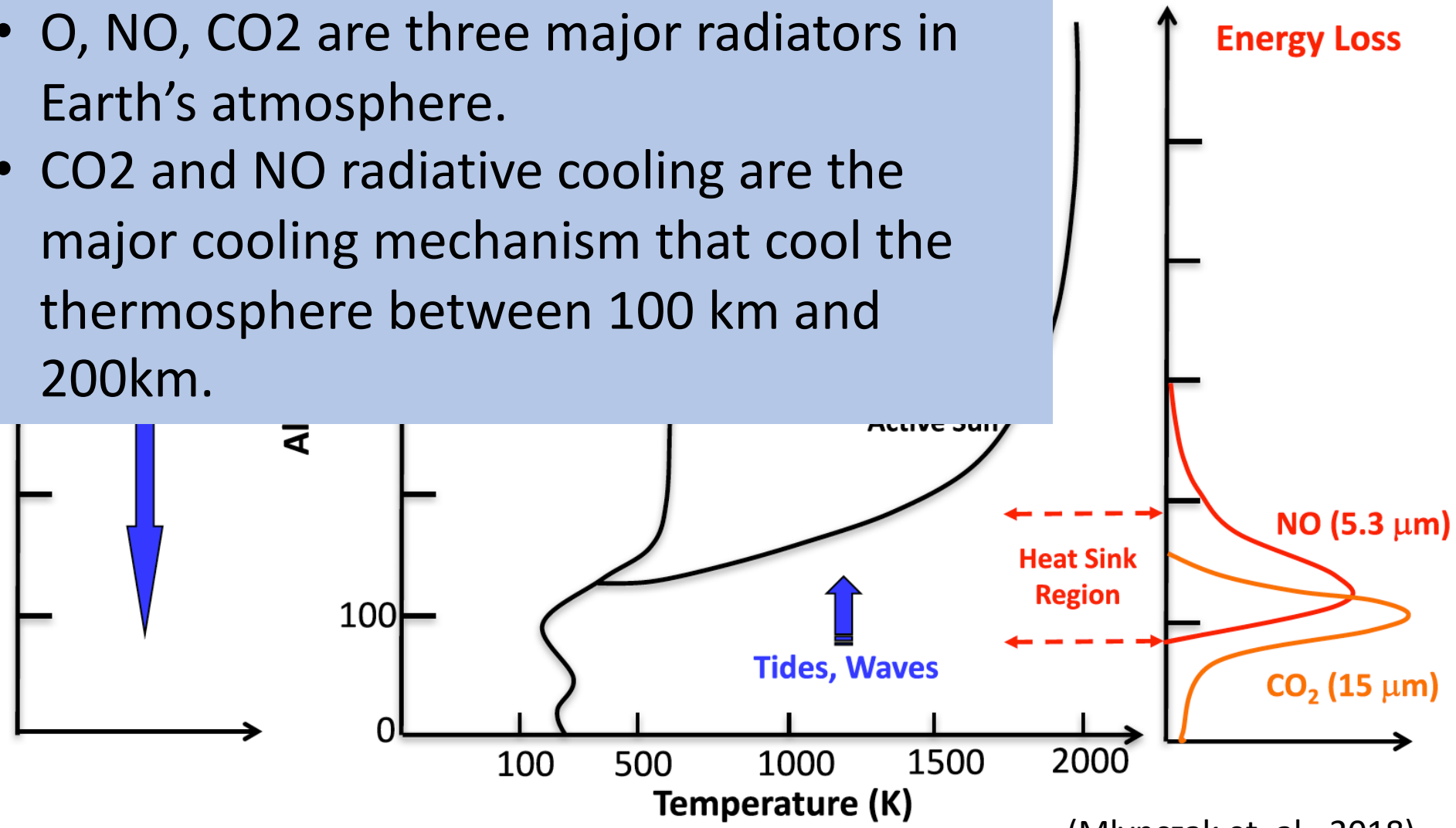
Radiative Cooling in the Thermosphere



(Mlynczak et. al., 2018)

Radiative Cooling in the Thermosphere

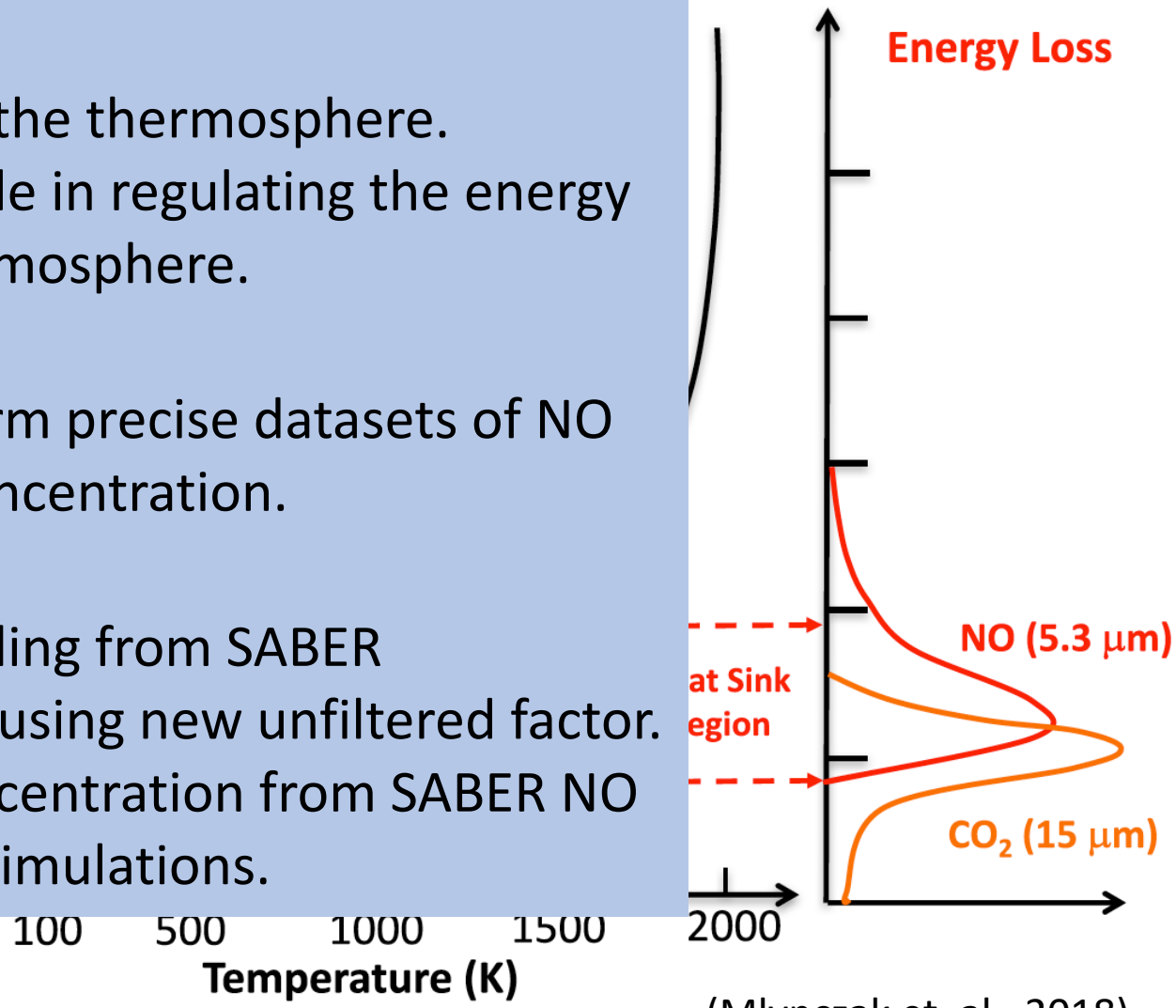
- O, NO, CO2 are three major radiators in Earth's atmosphere.
- CO2 and NO radiative cooling are the major cooling mechanism that cool the thermosphere between 100 km and 200km.



(Mlynczak et. al., 2018)

Motivation and Objective

- Nitric Oxide :
  - Is a thermostat of the thermosphere.
  - plays important role in regulating the energy budget in the thermosphere.
- Motivation:
  - To provide long term precise datasets of NO cooling and NO concentration.
- Objective:
  - Derive the NO cooling from SABER measurements by using new unfiltered factor.
  - Derive the NO concentration from SABER NO cooling and MSIS simulations.



(Mlynczak et. al., 2018)

NO Cooling Derived from SABER Measurements

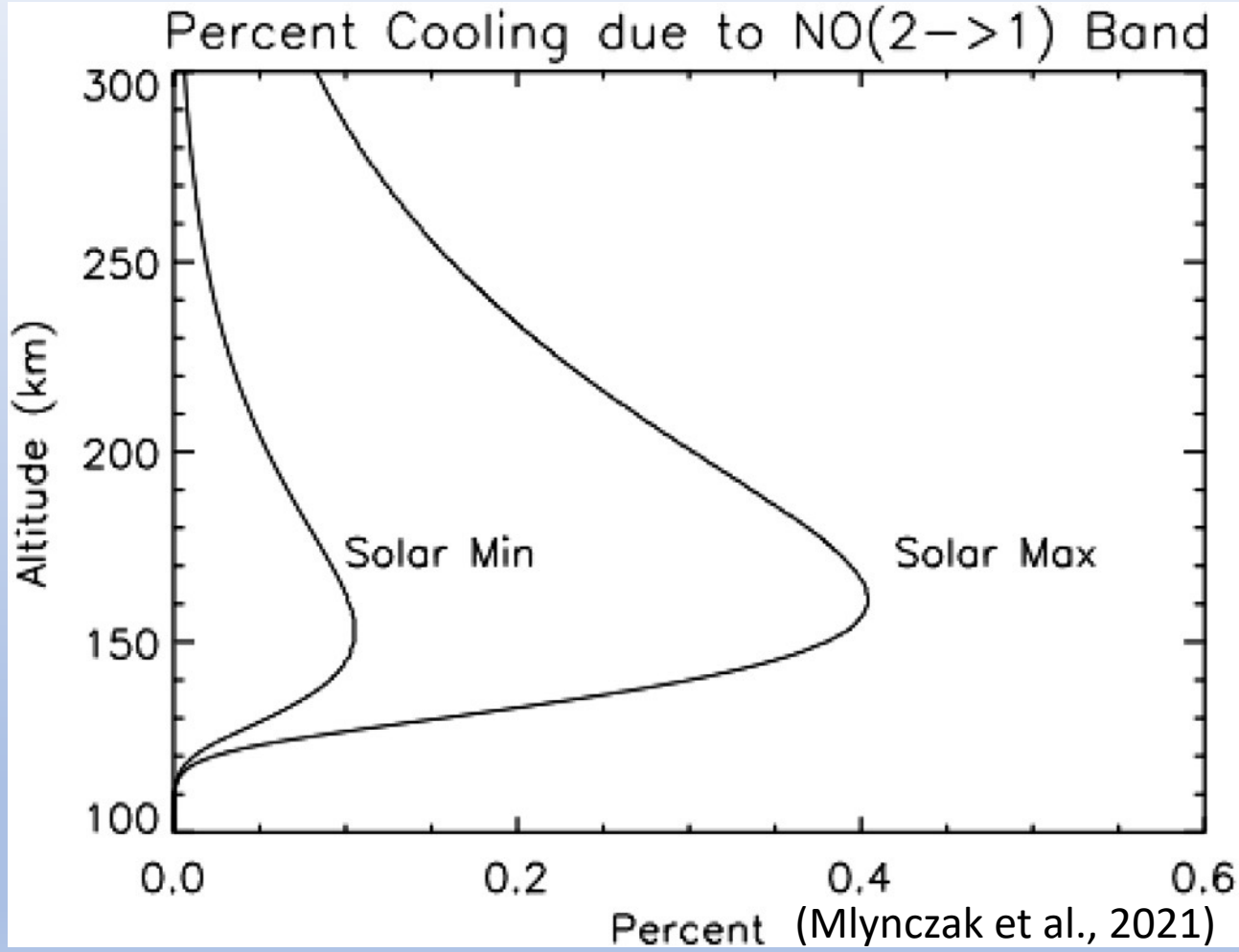
- SABER (Sounding of the Atmosphere using Broadband Emission Radiometry) instrument:
  - Scans the Earth's limb from 400 km to the hard surface.
  - Measures profiles of infrared limb radiance in a spectral interval.
  - Encompasses ~60% of the emission lines from NO bands of 1 to 0, 2 to 1, and 3 to 2.
- The in-band NO cooling is converted into the full band NO cooling by a unfiltered factor:

$$V(z) = I(z) \times U(z)$$

  - Where **I(z)** is the in-band measurements, **U(z)** is the 'unfiltered factor', and **V(z)** is the full band NO cooling, **z** is altitude.

Unfiltered Factor U(z)

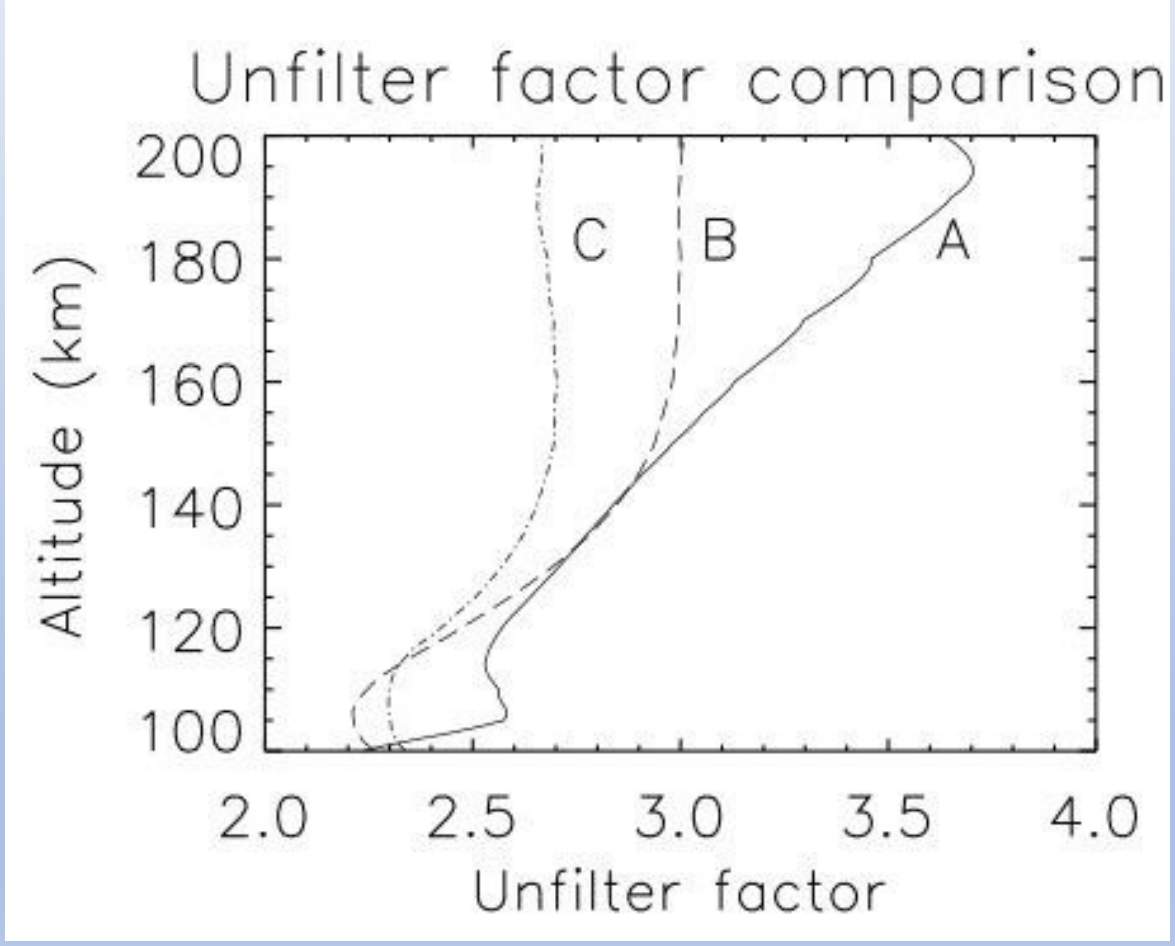
- For the current SABER NO cooling,
  - The unfiltered factor includes the fundamental, first and second vibrational energy levels.
  - A single factor for the entire SABER profiles
- Recent work shows that the NO cooling is most entirely from the fundamental band.
  - The cooling due to NO (2 to 1) is less than 0.5% of the cooling due to NO fundamental band for solar maximum year and 0.1% for the solar minimum year.



(Mlynczak et al., 2021)

New Unfiltered Factor $U^*(z)$

- For the new SABER NO cooling
  - Only consider the fundamental band.
  - Include the solar activity.
  - Use different factors for day time and night time.



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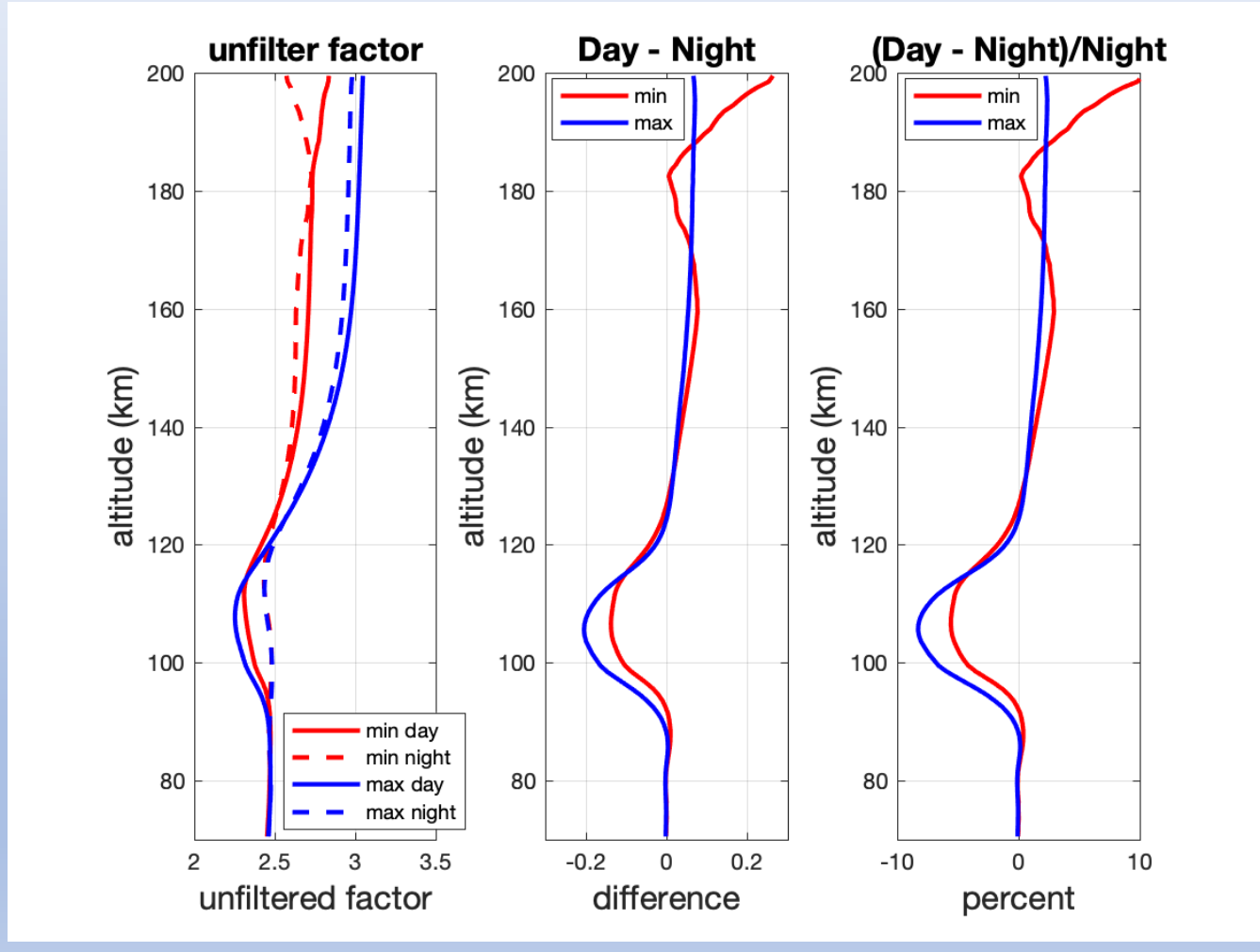
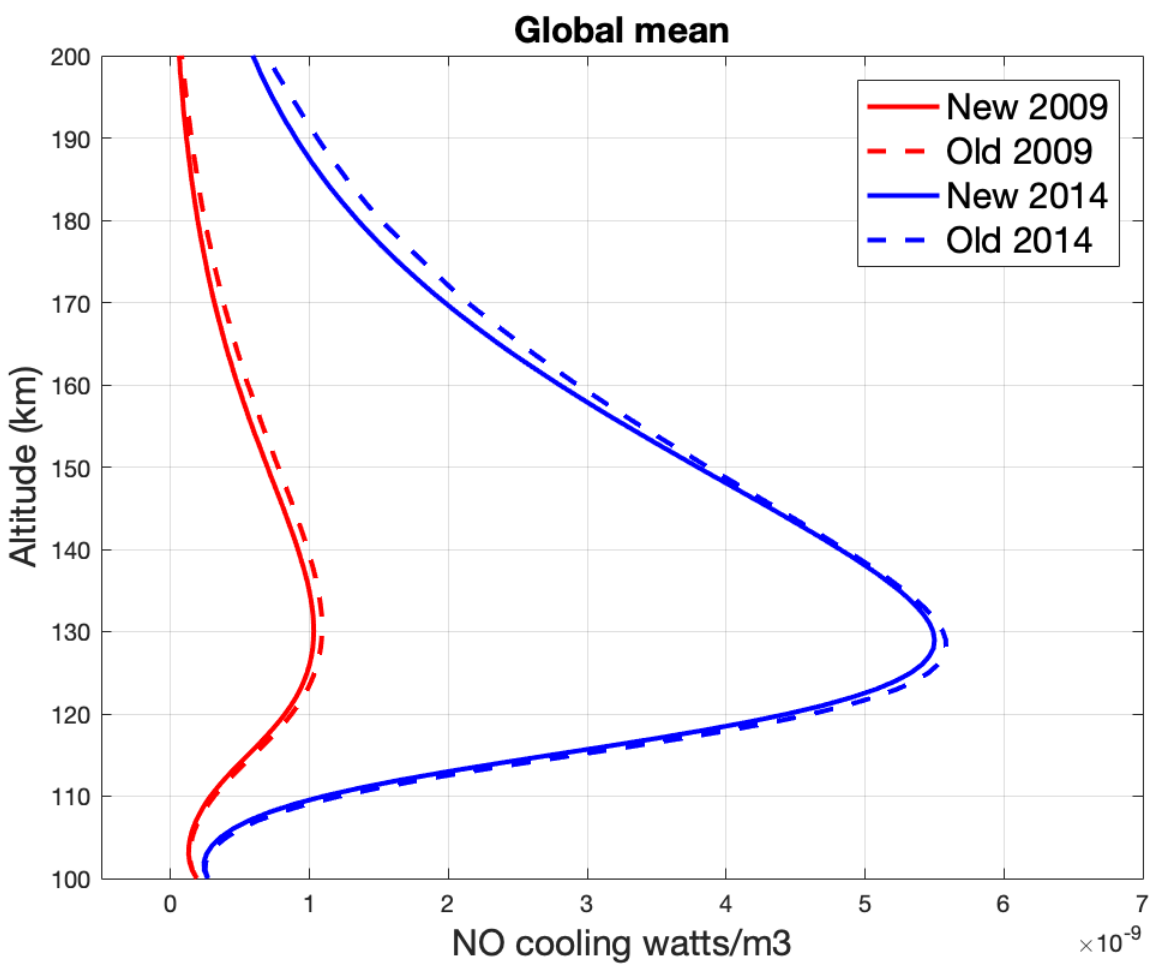
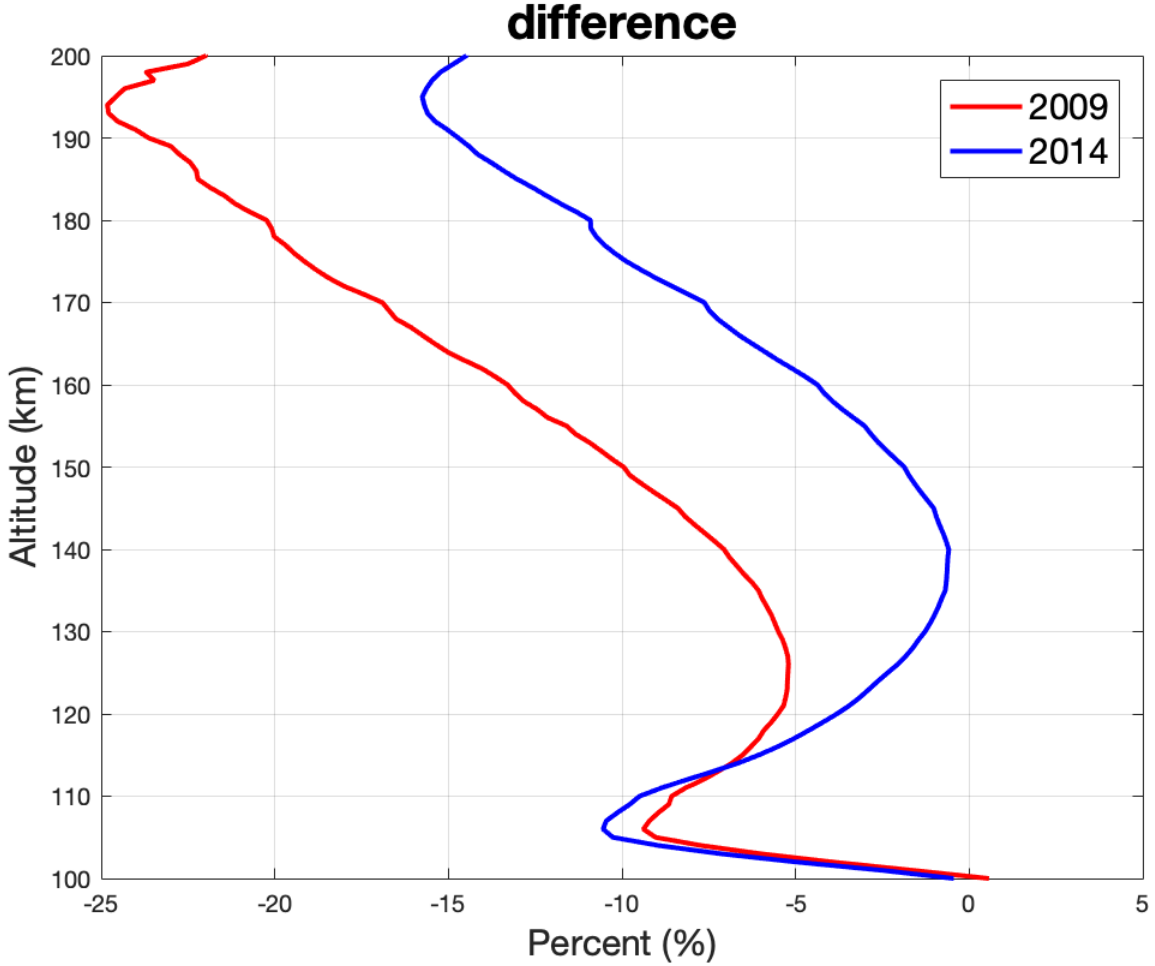
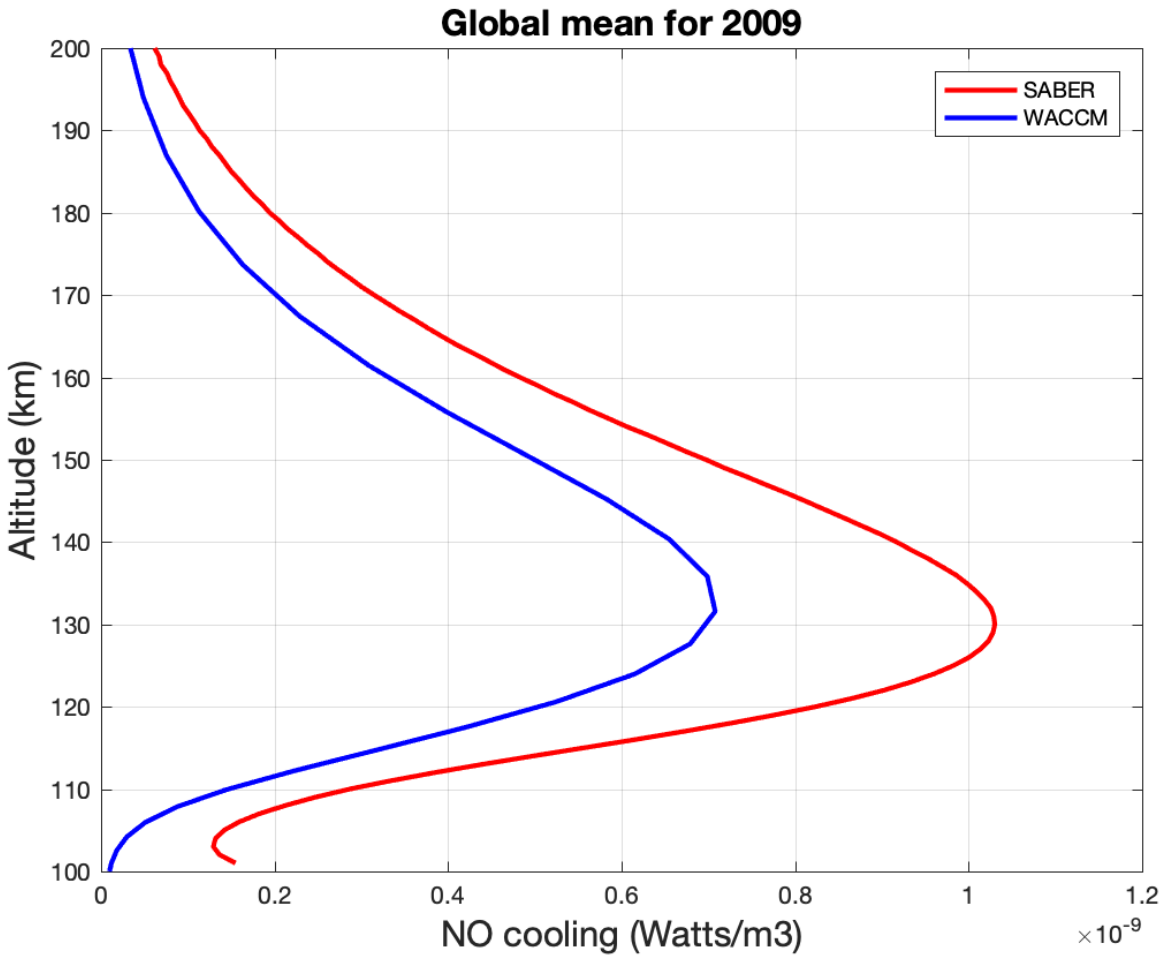


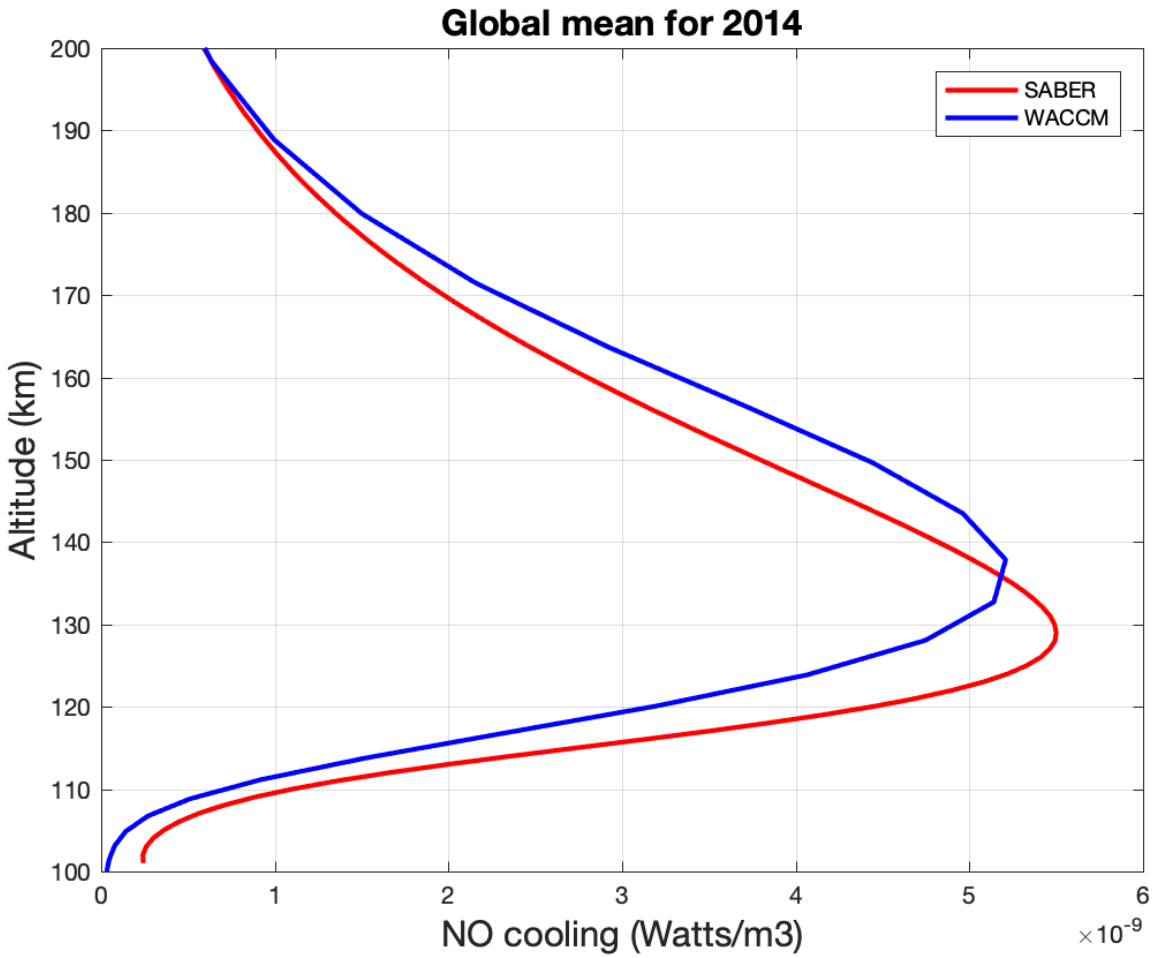
NO Cooling Results: New VS Original



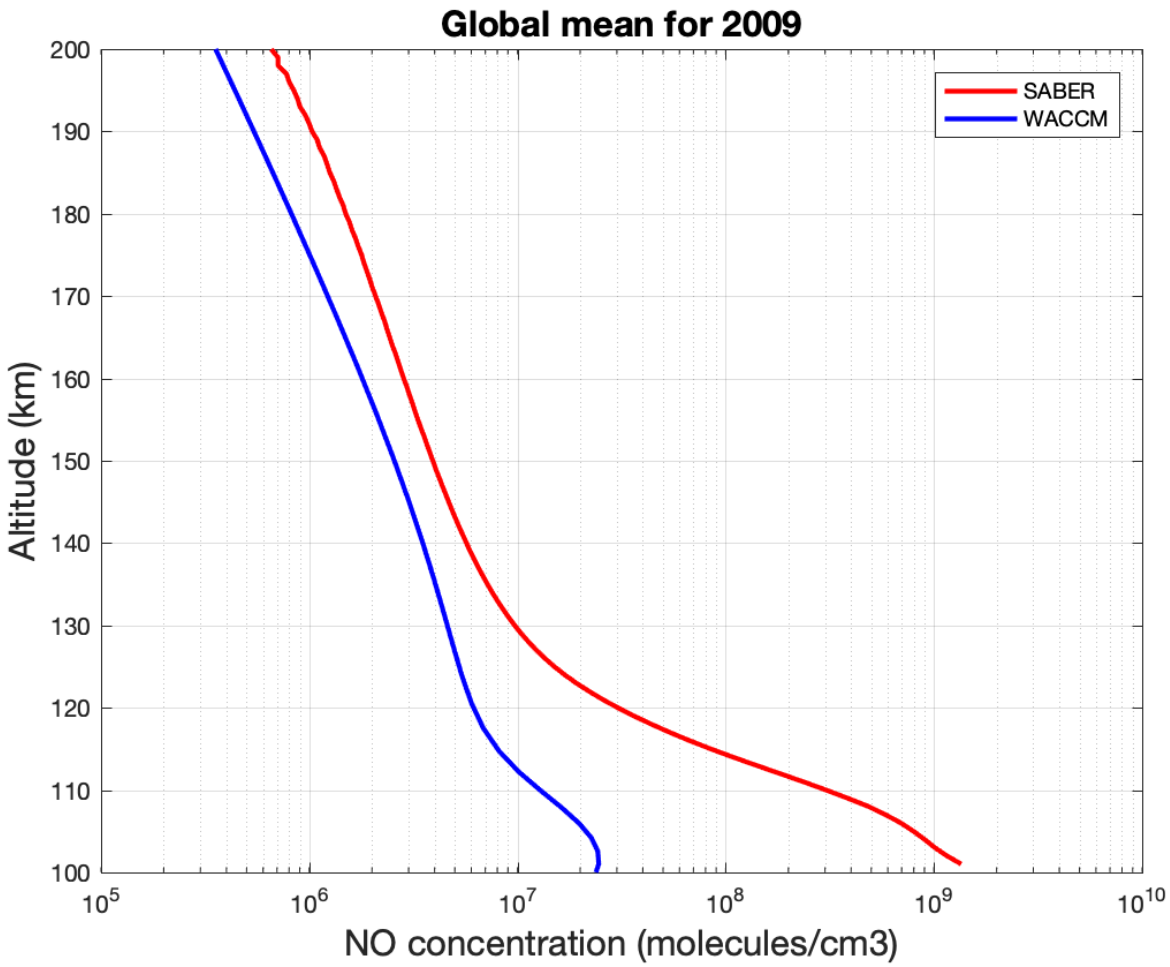


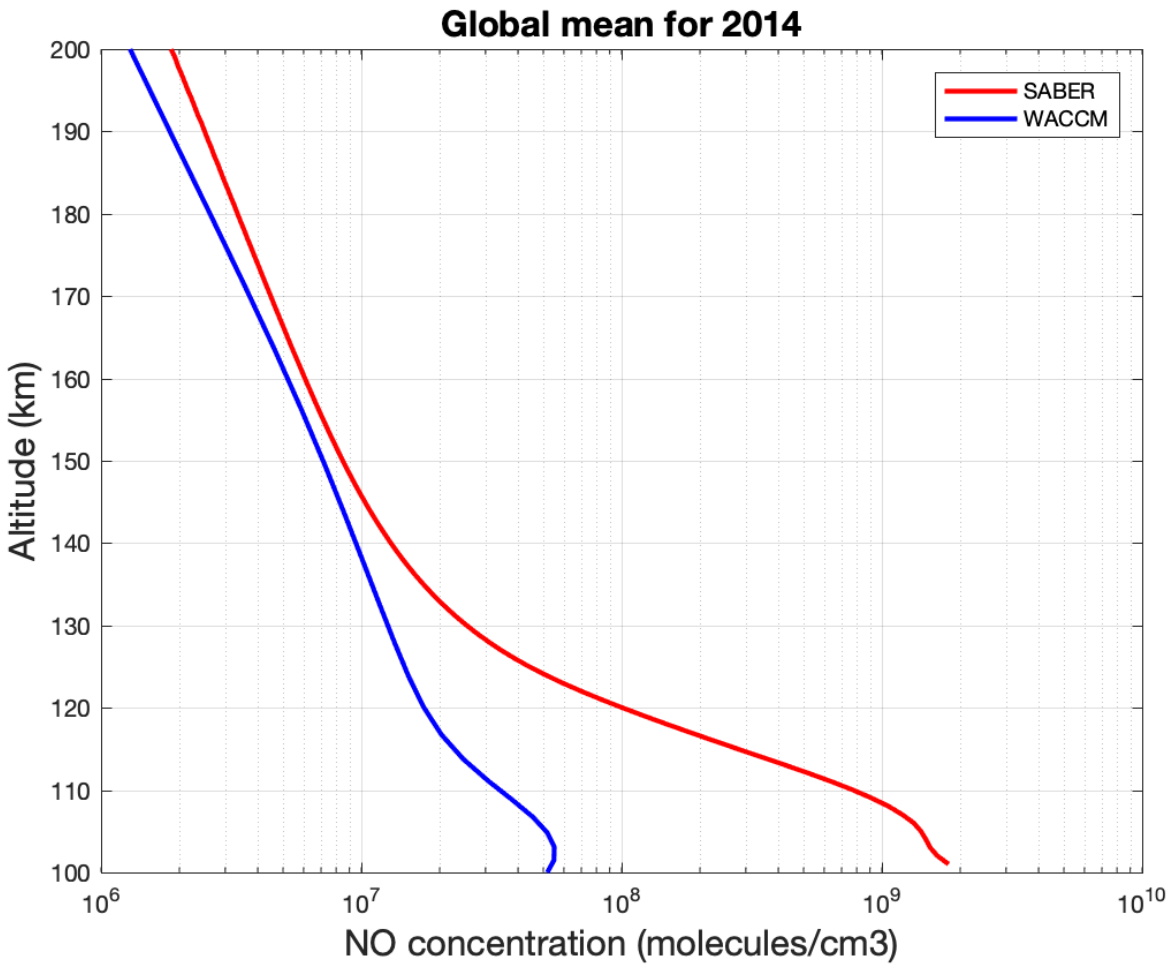
NO Cooling Results: New SABER VS SD-WACCM





NO Concentration Results: SABER VS SD-WACCM





Summary

- NO cooling and NO concentration are derived from SABER measurements with the NEW unfiltered factor and MSIS 2.0 simulations.
- The newly derived NO cooling profiles are smaller than the old NO cooling profiles as expected.
- The difference between the newly derived NO cooling and the old NO cooling profiles are smaller during solar maximum year (2014) than during solar minimum year (2009).
- SD-WACCM simulations match SABER NO cooling better during solar maximum year than during solar minimum year.
- SABER NO concentration is larger than SD-WACCM simulation for both 2009 and 2014.

Extra slices

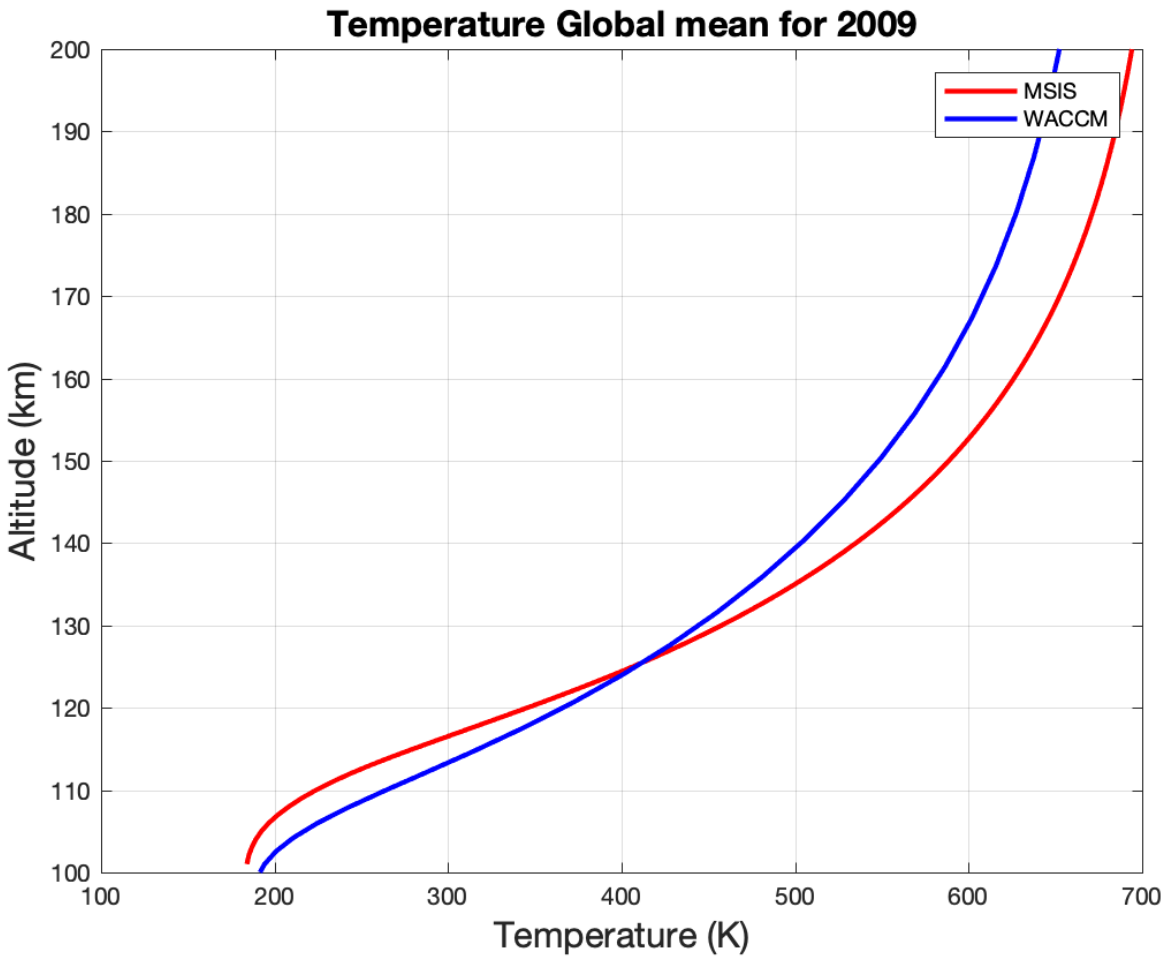
Unfiltered factor

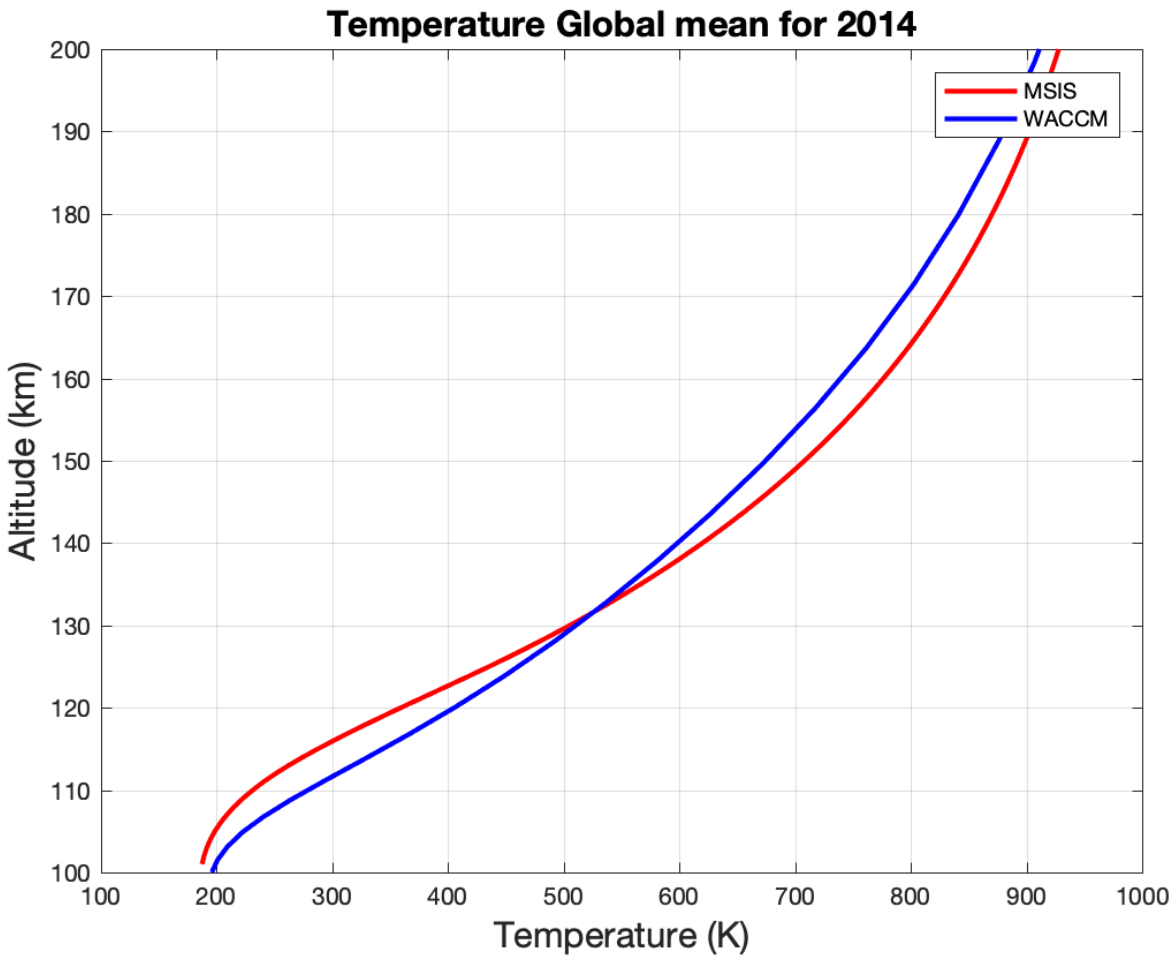
- The unfiltered factor is dependent on the departure from local-thermodynamic equilibrium (LTE) in both vibrational and rotational states of NO.
- A fast rotational non-LTE model is used to generating unfiltered factors for every vertical cooling rate profile the entire SABER record.
- The unfiltered factor is:
- $\boldsymbol{U}^{*}(\boldsymbol{z})= \Sigma Ni \times Ai \,/\, (\Sigma Ni \times Ai \times F(\nu,i)\,)$
- Where Ni are the upper state populations, Ai are the Einstein coefficients for each vibration-rotation transition, and F(ν,i) is the SABER spectral response function at wavenumber ν for emission line i. The sum in the numerator covers the fundamental band while the sum in the denominator covers the 3→2, 2→1, and 1→0 bands.

NO concentration

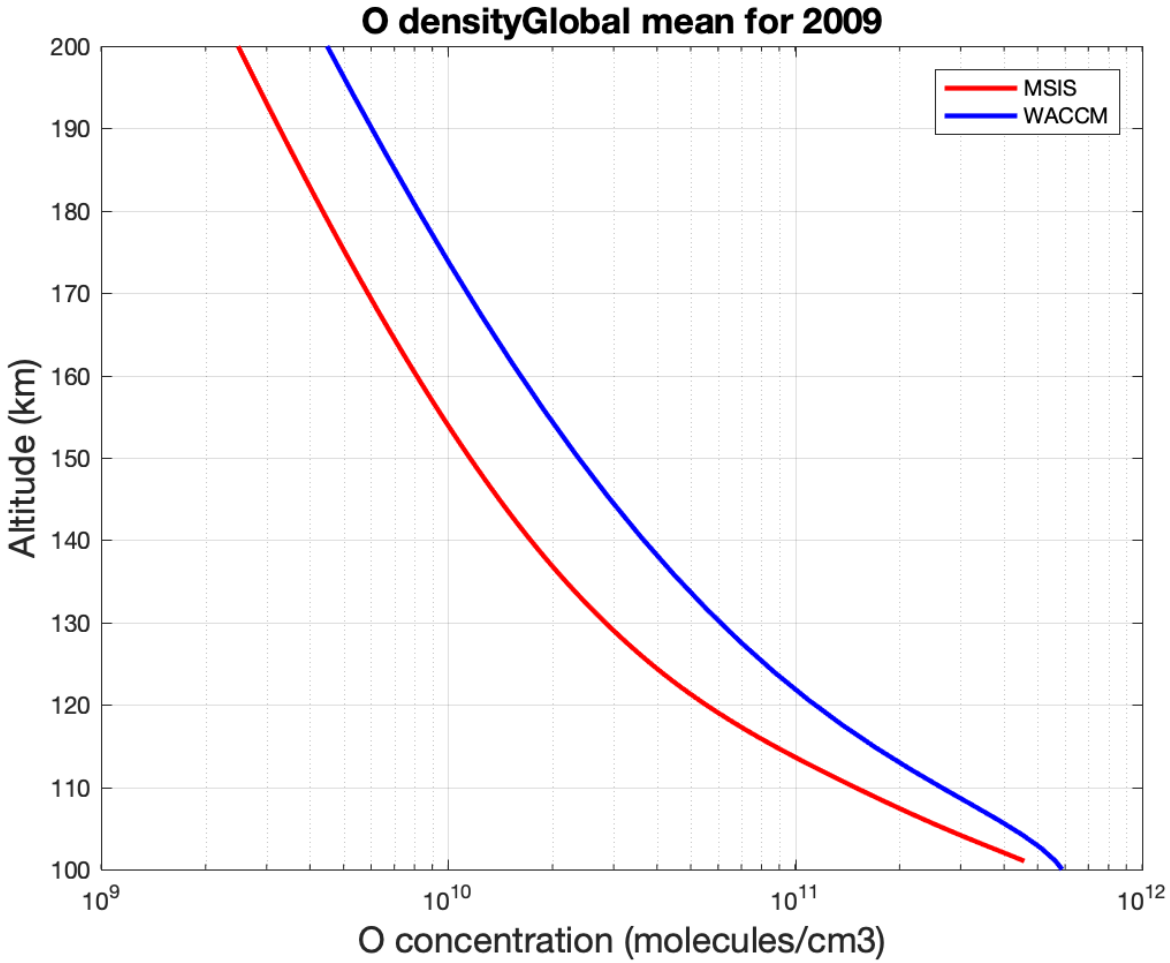
- NO cooling from SABER
- Temperature and atomic O from MSIS 2.0
- $n(NO) = \frac{V}{A_{10}} \times \left[\frac{A_{10}+K_{10} \times n(O)}{K_{10} \times n(O) \times \exp(-2700/T)}\right]$

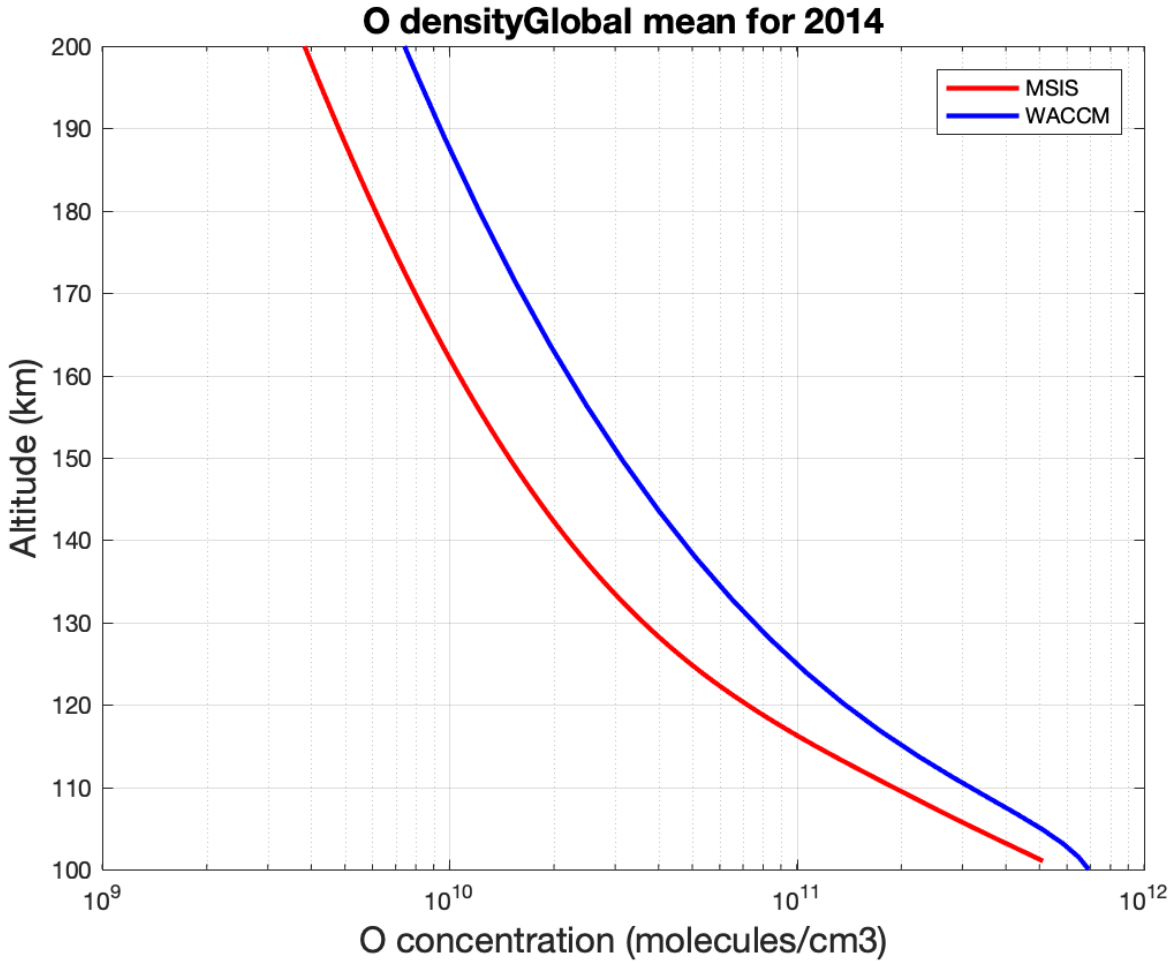
MSIS vs WACCM: Temperature

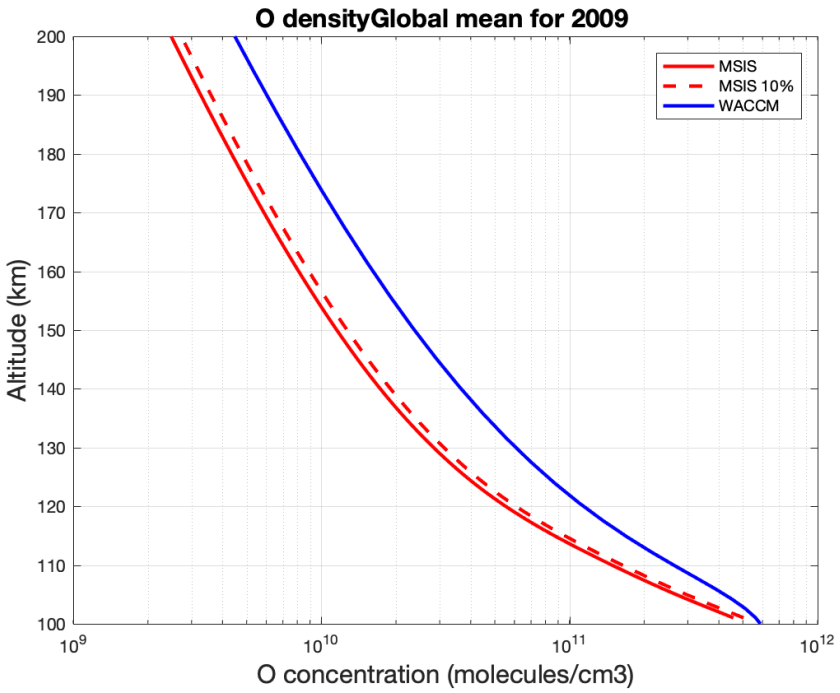


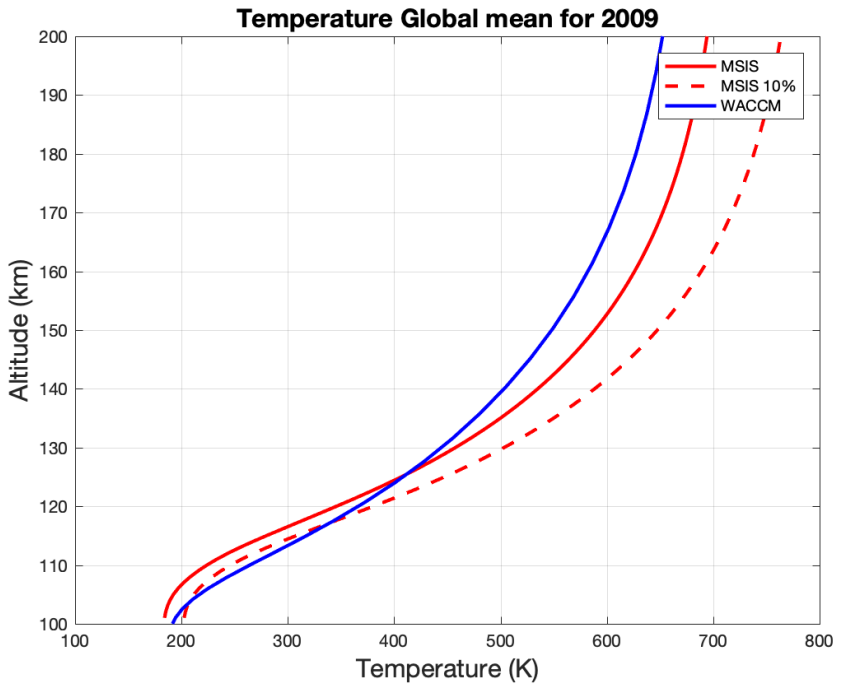


MSIS vs WACCM: O density






O densityGlobal mean for 2009
MSIS
MSIS 10%
WACCM
Altitude (km)
O concentration (molecules/cm3)


Temperature Global mean for 2009
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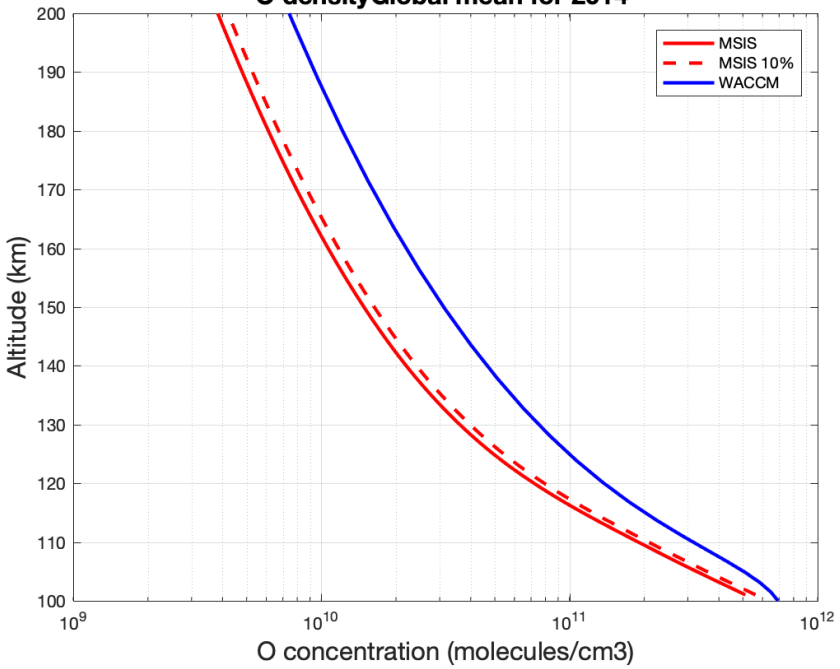
Altitude (km)
Temperature (K)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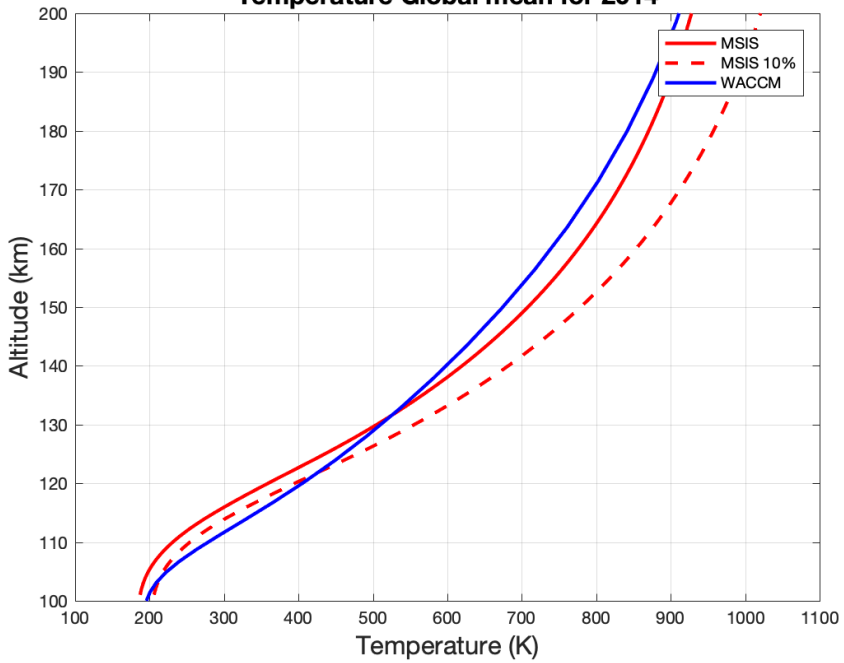
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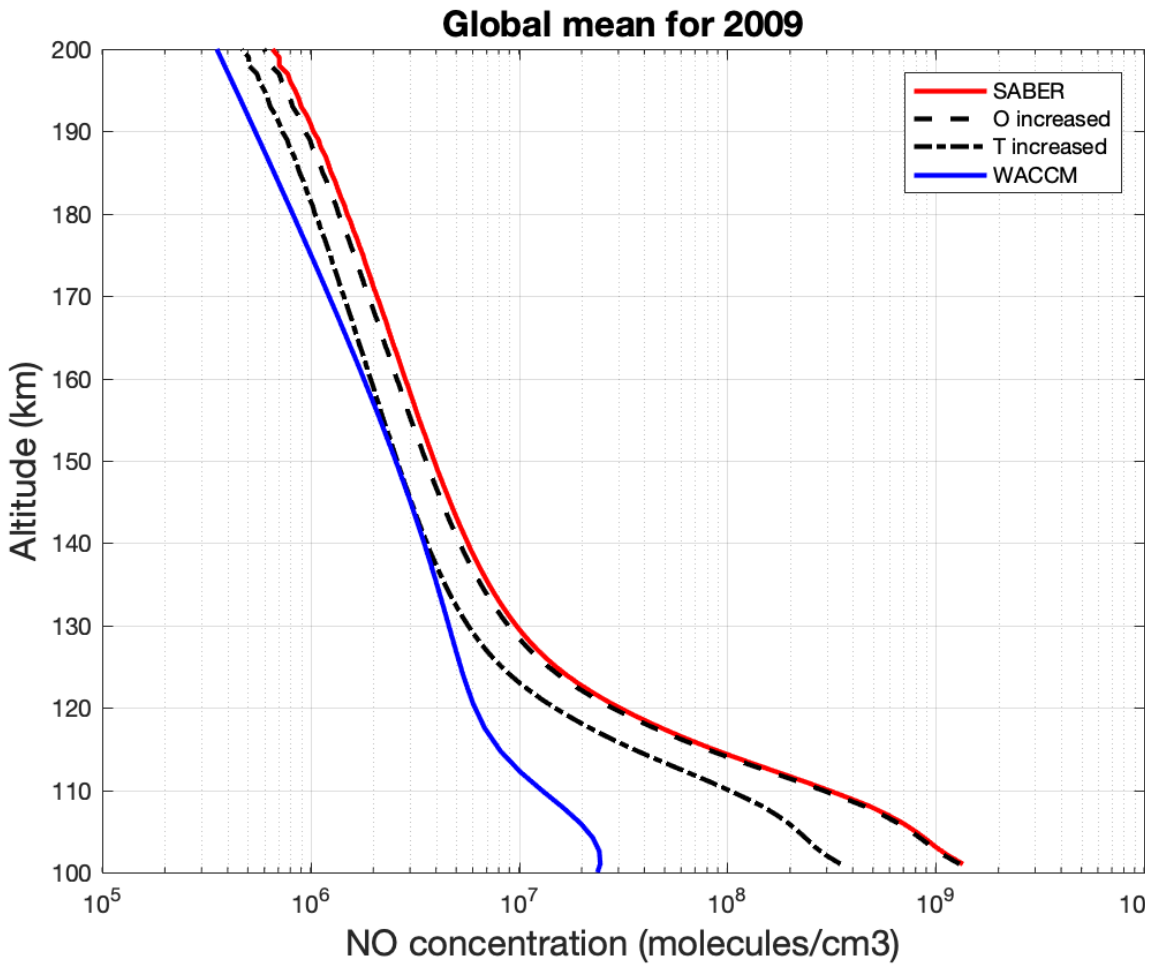
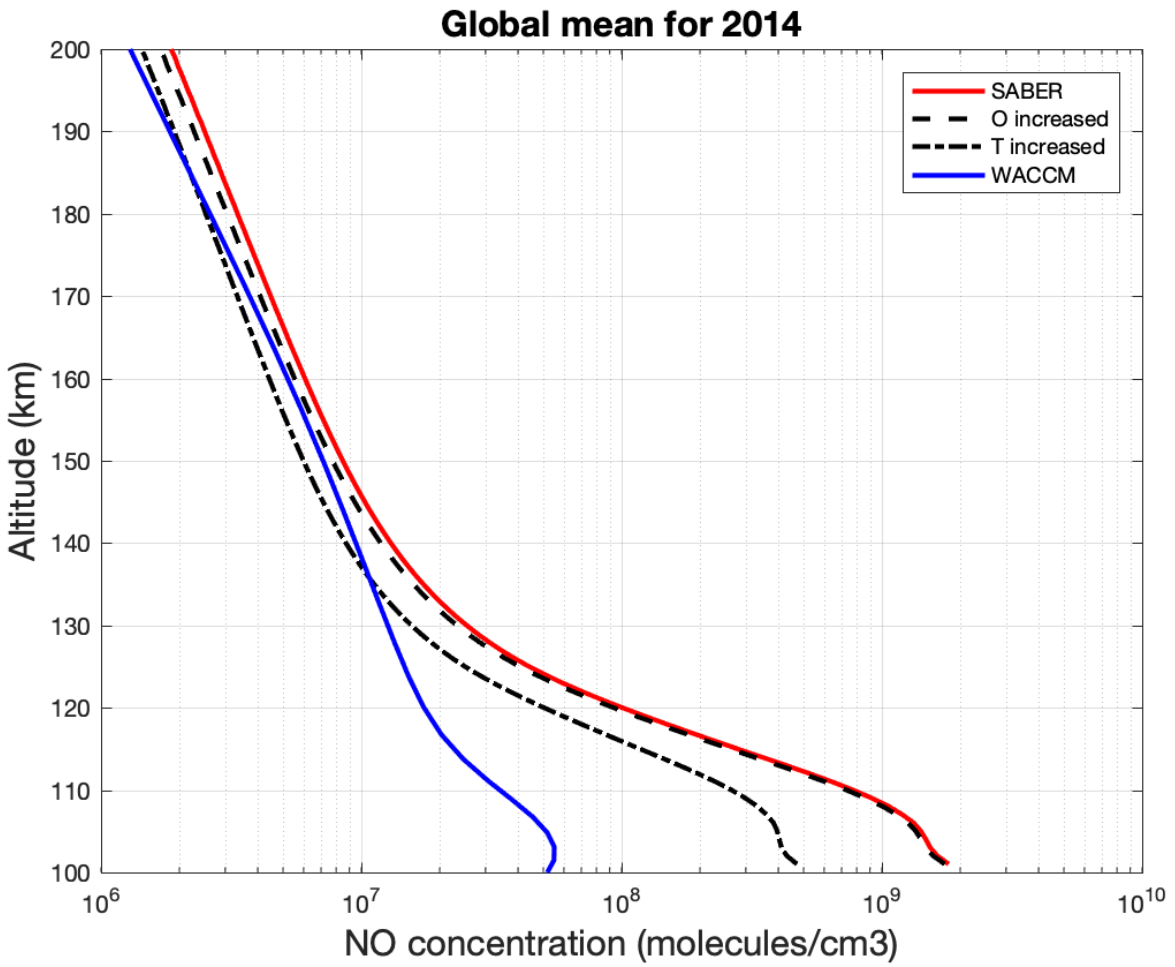
Adjust MSIS T and O by 10%





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