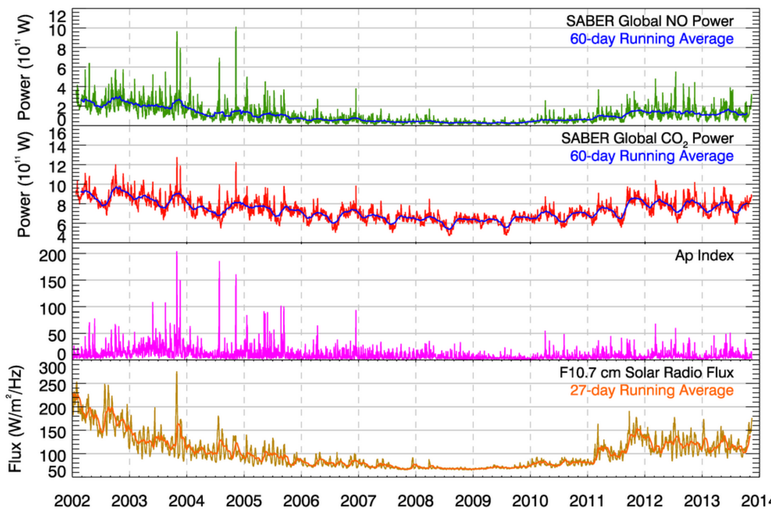
Has the Solar Cycle 24 Maximum Already Occurred?

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Overview

Infrared radiative cooling of the thermosphere by carbon dioxide and nitric oxide has been observed continuously since January 2002 by the Sounding of the Atmosphere using Broadband Emission Radiometry (SABER) instrument on the NASA Thermosphere-Ionosphere-Mesosphere Energetics and Dynamics (TIMED) satellite. SABER has documented dramatic variability in the radiative cooling on timescales ranging from days to longer than the nominal 11-year solar cycle.

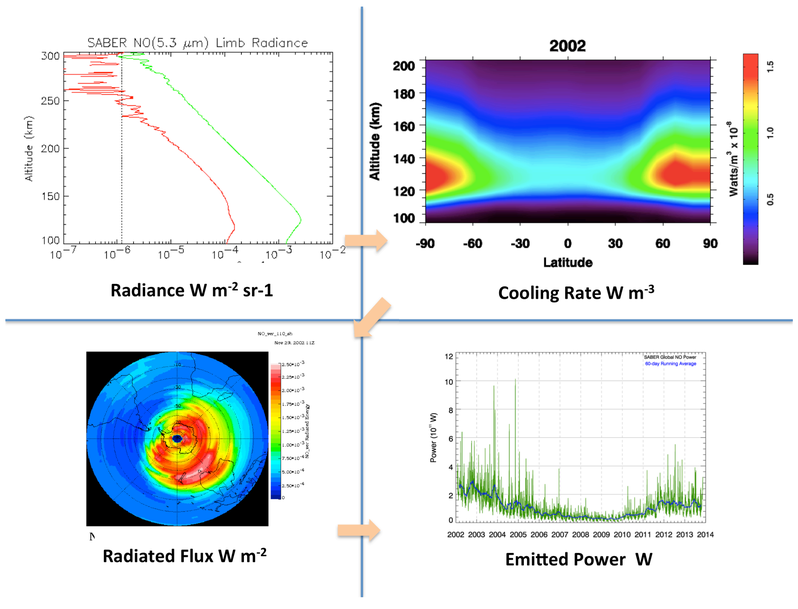


SABER radiance measurements from emission by CO_2 (at 15 µm) and NO (at 5.3 µm) are used to calculate global daily emitted thermosphere power. This unique dataset shows the direct effects of solar variability on the temperature (via CO_2 emission) and composition (from NO emission) for nearly twelve years. The deep solar minimum between solar cycles 23 and 24 is evident in the low values of global mean radiative cooling that occur in the 2008-2009 period. Since then radiative cooling has been observed to increase in response to the transition into solar cycle 24.

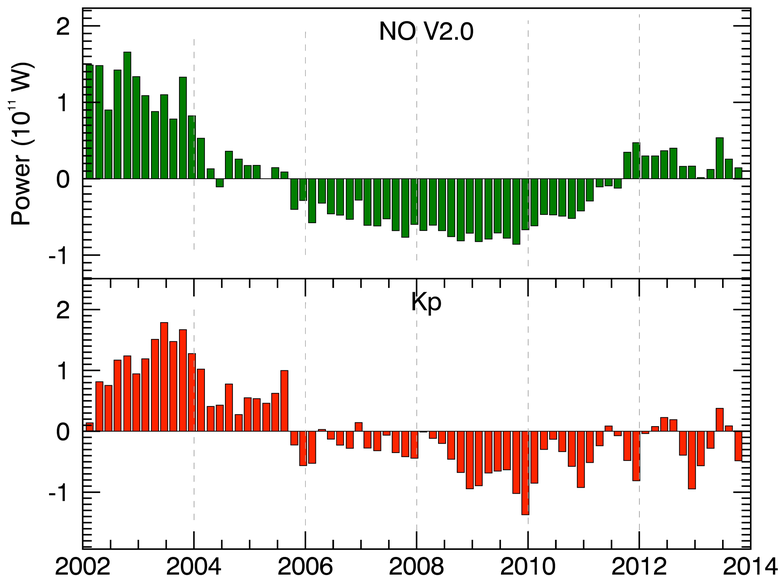
Methodology

The SABER instrument is a limb scanning radiometer that records vertical profiles of infrared emission from approximately 300 km tangent altitude down to the Earth's surface in ten distinct channels from 1.27 to 15 µm. Infrared radiance profiles (W m^{-2} sr^{-1}) for NO at 5.3 µm are inverted to yield vertical profiles (~1500 per day) of infrared cooling rates (W m^{-3}) between 100 and 250 km at approximately 0.2 km altitude spacing. For CO_2, SABER processes radiative cooling rates in Kelvin per day; cooling rate profiles in W m^{-3} are then calculated from 100 to 140 km by applying the first law of thermodynamics.

The cooling rate profiles are vertically integrated to yield the flux (W m^{-2}) of infrared emission exiting the thermosphere, either to the atmosphere below or to space above. Further integration around latitude circles gives the power (W) radiated by NO and CO_2 at specific latitudes. A final integration from pole to pole gives the total global average power radiated by these molecules on a daily basis.



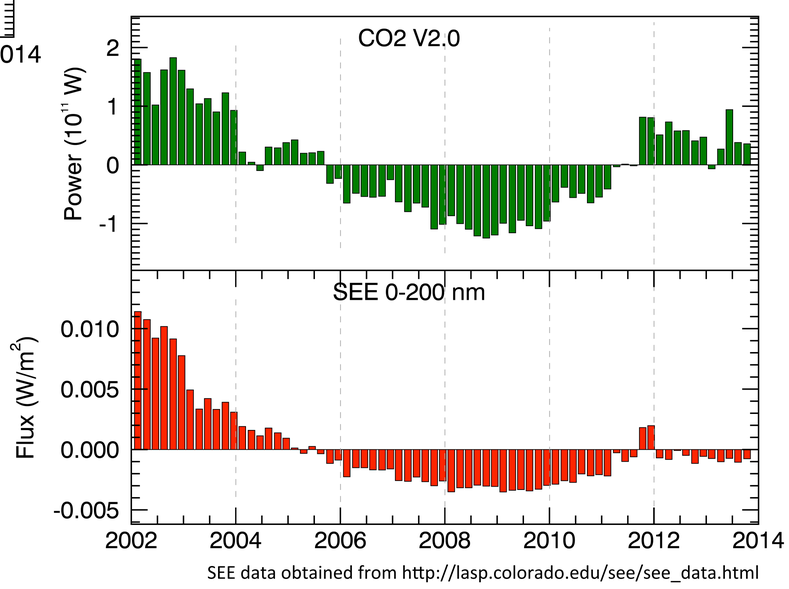
Deseasonalized Global Power



Kp data obtained from http://www.swpc.noaa.gov

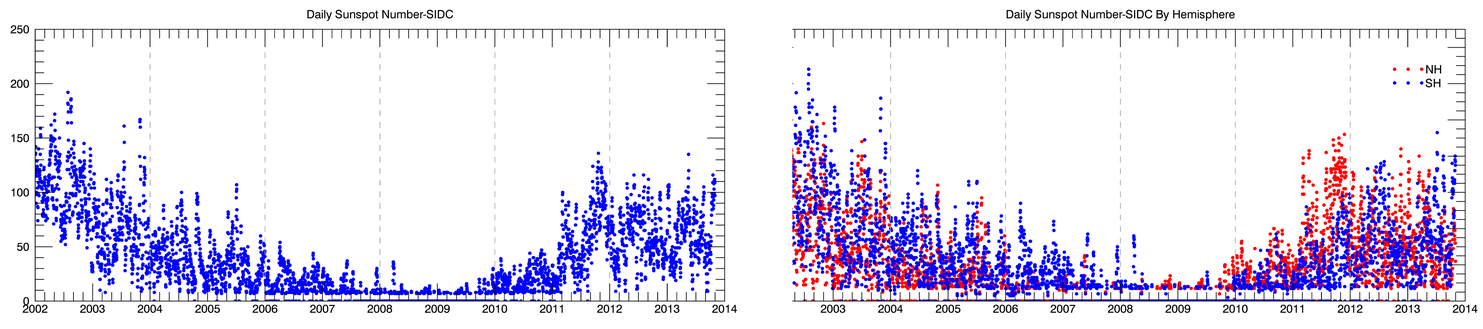
To more clearly identify extrema in the time series of radiative cooling, NO and CO_2 cooling rates are deseasonalized to remove effects of the spacecraft yaw cycle. The TIMED satellite undergoes a yaw maneuver every 60 days to keep the SABER instrument on the cold side of the spacecraft. There are six yaw periods each year. To perform the deseasonalization, first the average "seasonal" global power is calculated over all years for each of the six two-month yaw periods. The mean global power for each yaw period is then deseasonalized by subtracting from it the appropriate "seasonal" average. This calculation was done on the NO and CO_2 cooling data and on the SEE integrated flux which are all from instruments on the TIMED satellite. For the Kp data, the values shown are the difference from the long term mean for the average of the data over the time period of each of the yaw cycles.

The adjacent figures show "deseasonalized" global average radiated infrared power (Watts) emitted by CO_2 and NO from the thermosphere between 100 and 250 km, for each yaw period from January 2002 to the present, to elucidate the effects of the solar cycle. The deseasonalized CO_2 and NO infrared power decrease from the beginning of the mission in 2002 and reach a minimum in late 2008 which lasts into 2009. The radiative power starts to increase in late 2009 for both NO and CO_2 and continues to increase. The deseasonalized data show a clear peak of radiative cooling in NO and CO_2 occurring in Yaw Period 6 of 2011 (mid-November to mid-January). This peak in cooling correspond to a similar peak in the ultraviolet flux emitted from the Sun measured by the SEE instrument on TIMED. A later cooling maximum occurs in Yaw Period 3 of 2013 (May-July). This peak corresponds to a peak in the Kp index which indicates geoeffective solar activity.



SEE data obtained from http://lasp.colorado.edu/see/see_data.html

The Sunspot Record



Sunspot data obtained from the Solar Influences Data Analysis Center (SIDC), Royal Observatory of Belgium, http://sidc.oma.be

The sunspot number is a widely used indicator of solar activity and the peaks in the total sunspot number, shown above on the left, coincide with the peaks seen in the deseasonalized data. Dual solar maxima, as have been seen in late 2011 and mid-2013 often result from activity peaking at different times in the solar Northern and Southern Hemsipheres, as seen the above right plot. Other indicators of solar activity such as irradiance and the solar flare index follow a similar pattern of activity.

Reprocessing of the SABER dataset to version 2.0 was recently completed and these results use this new release. The SABER NO and CO_2 thermosphere power datasets will be continually updated as new data are acquired to monitor the occurrence of solar maximum from the perspective of atmospheric cooling. The SABER data are available from http://saber.gats-inc.com. The thermosphere power data set may be obtained by contacting Linda.A.Hunt@nasa.gov.

References:

Mlynczak, M. G., L. A. Hunt, 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, A3, doi:10.1029/2009JA014713, 2010.

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