Energy Budget of the Mesosphere and Lower Thermosphere from SABER Observations

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Outline

- Overview
- Methodology
- Infrared Cooling
- Solar Heating
- Chemical Heating
- Totals
- Thermosphere
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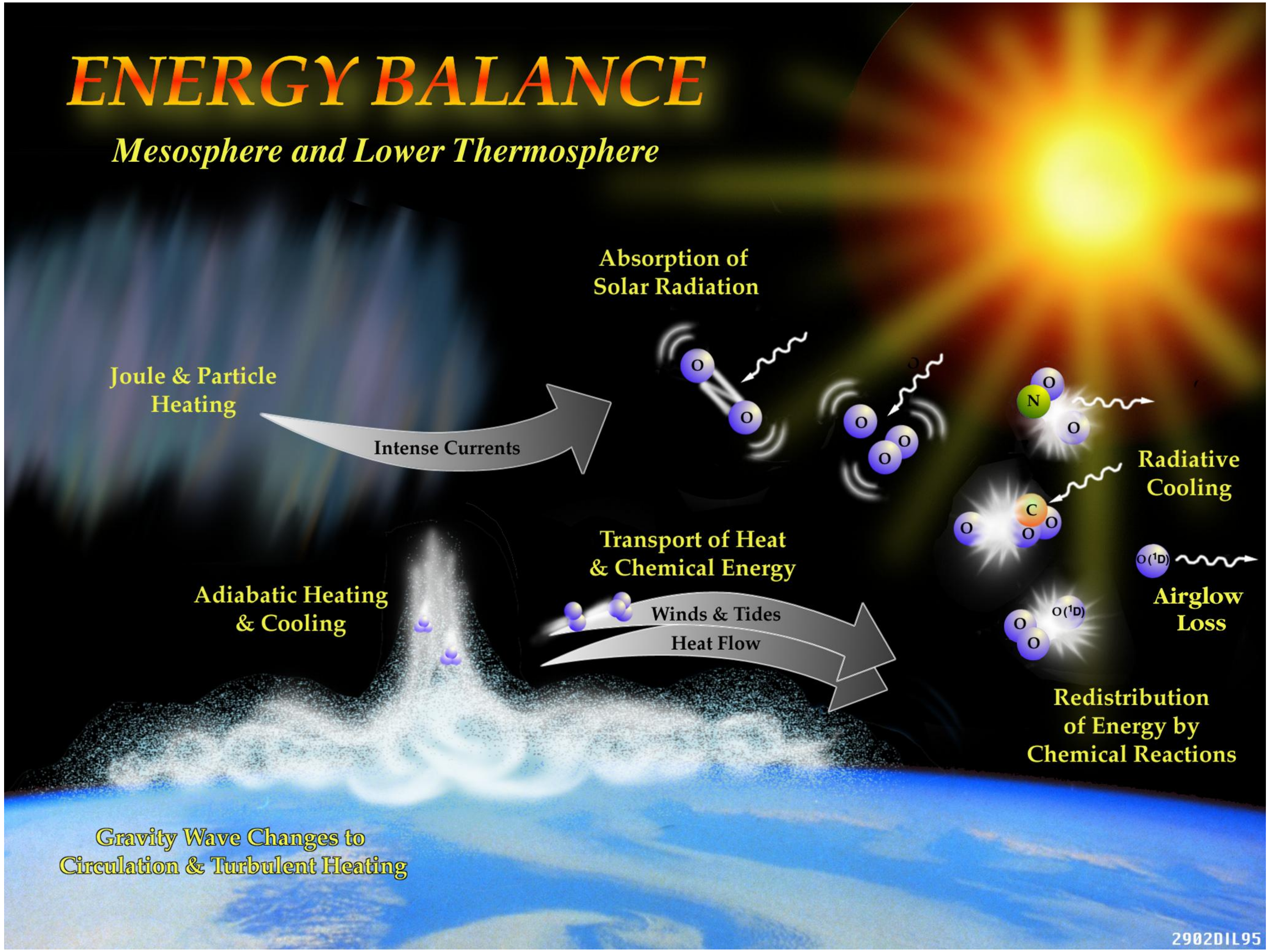
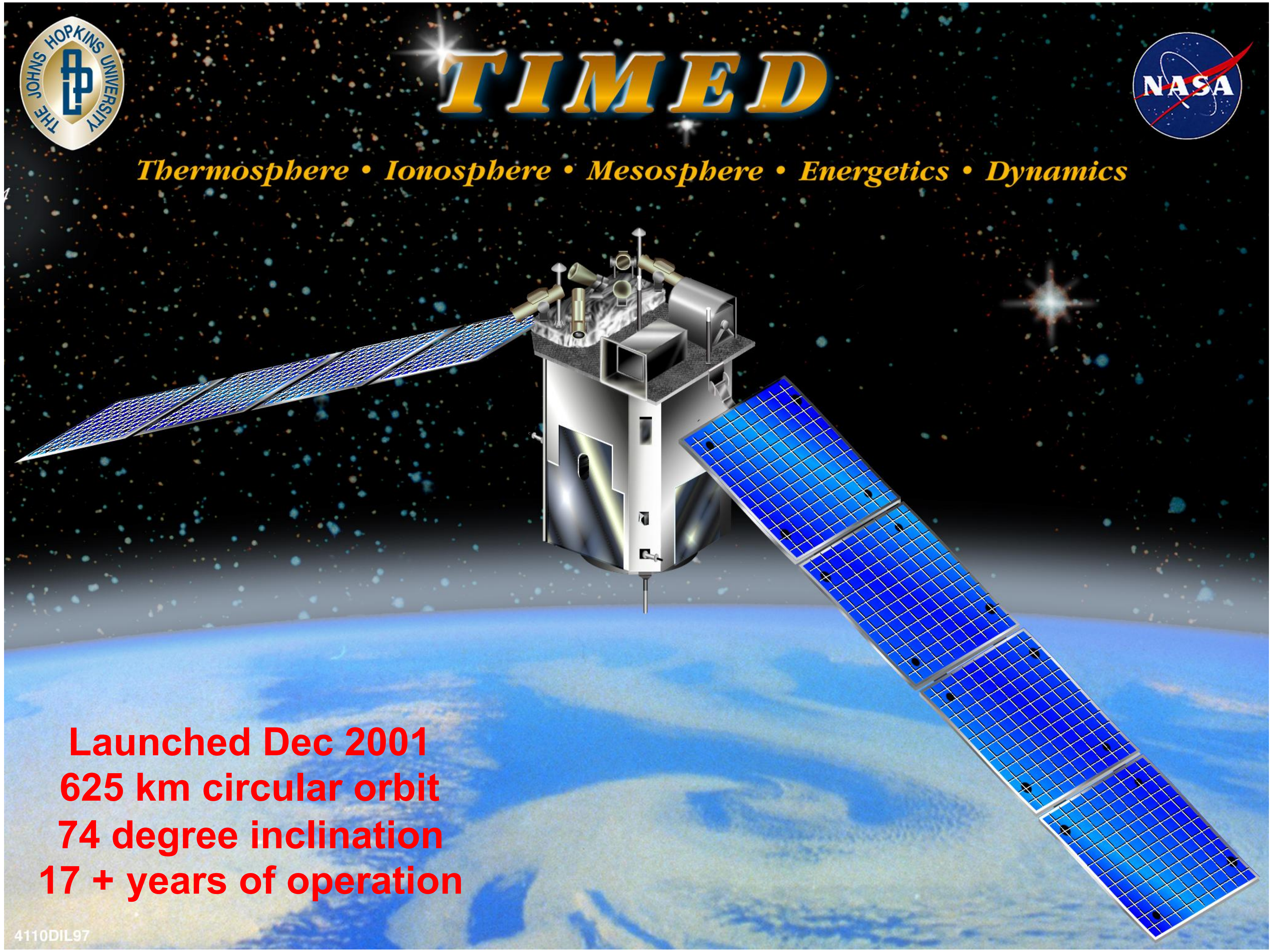
Overview



ENERGY BALANCE
Mesosphere and Lower Thermosphere
Absorption of Solar Radiation
Joule & Particle Heating
Intense Currents
Radiative Cooling
Transport of Heat & Chemical Energy
Adiabatic Heating & Cooling
Winds & Tides
Heat Flow
Airglow Loss
Redistribution of Energy by Chemical Reactions
Gravity Wave Changes to Circulation & Turbulent Heating
2902DIL95

Overview


TIMED
Thermosphere • Ionosphere • Mesosphere • Energetics • Dynamics
THE JOHNS HOPKINS UNIVERSITY
NASA
Launched Dec 2001
625 km circular orbit
74 degree inclination
17 + years of operation
4110DIL97

Methodology

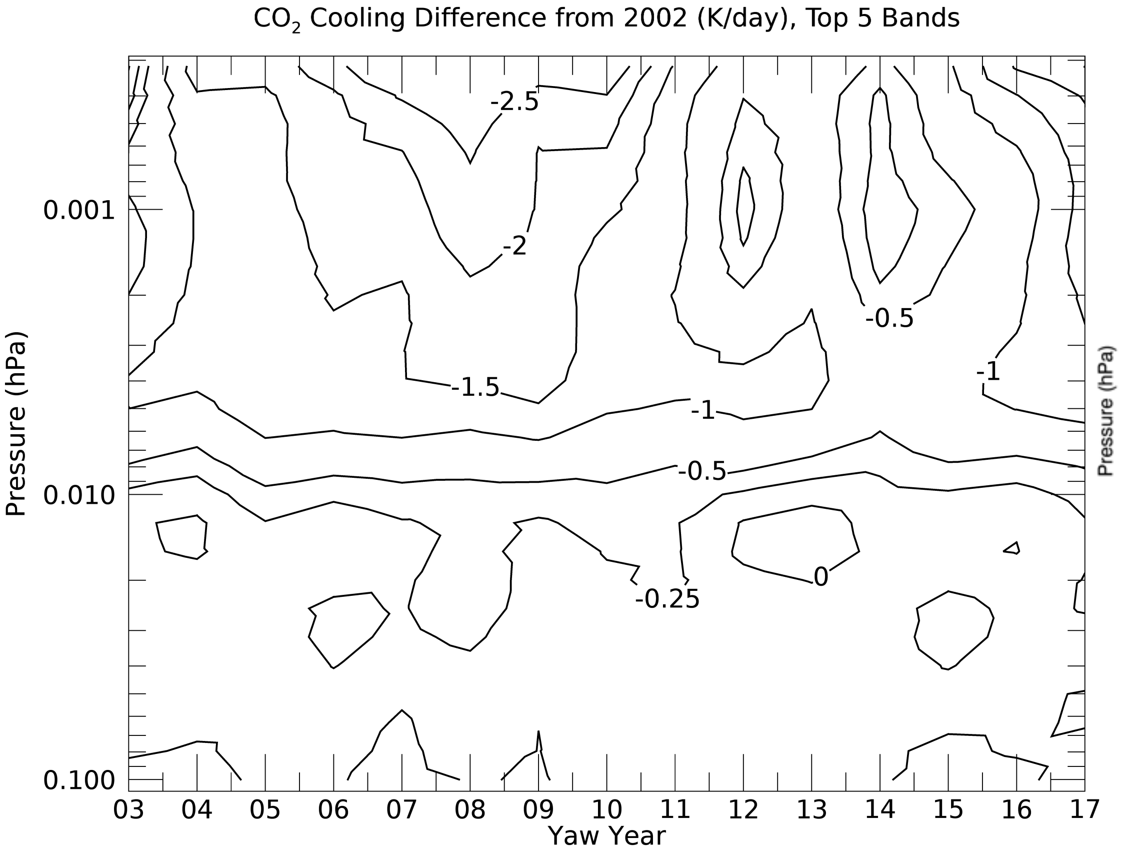
- SABER measures the vertical distribution of infrared radiation emitted by various atmospheric gases (ozone, water vapor, nitric oxide, and carbon dioxide), providing important information about the radiation budget in the upper atmosphere.
- From the SABER radiances, we determine the radiative cooling by CO_2, solar heating by O_3 and O_2, and chemical heating from a suite of exothermic reactions over the vertical range of 65-100 km. These measurements, combined with accurate determination of the temperatures allow the radiative and chemical contributions to the heat budget to be assessed and the net effect of dynamics to be inferred.
- SABER measurements also support the inference of atomic species, including atomic oxygen and atomic hydrogen.

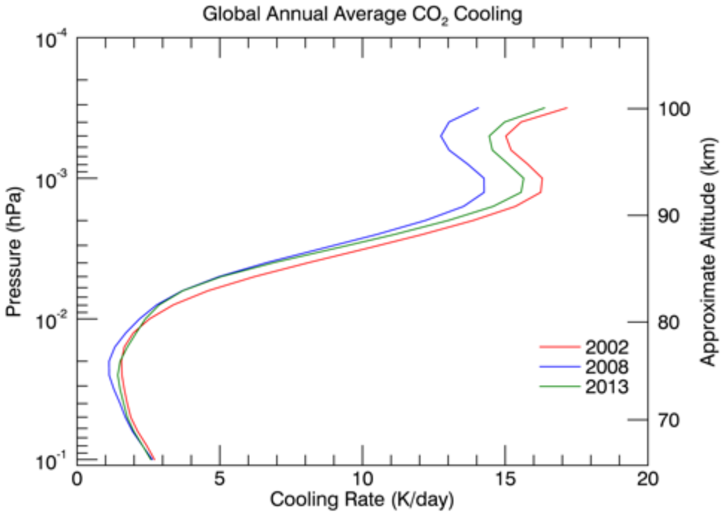
Infrared Cooling

The three major cooling sources in the mesosphere are

- carbon dioxide at 15 µm
- ozone (9.6 µm)
- water vapor at 6.7 µm and in the far-IR (> 20 µm).

CO_2 radiative cooling in the fundamental, isotopic and hot bands at 15 µm is the dominant source of cooling in the 65-100 km altitude range.

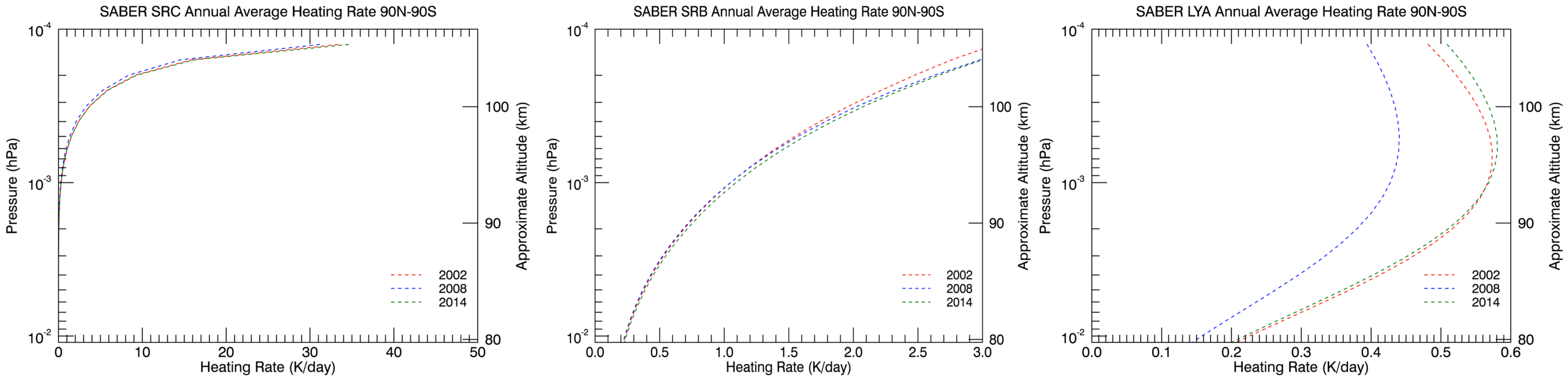




Solar Heating

O_2 Heating

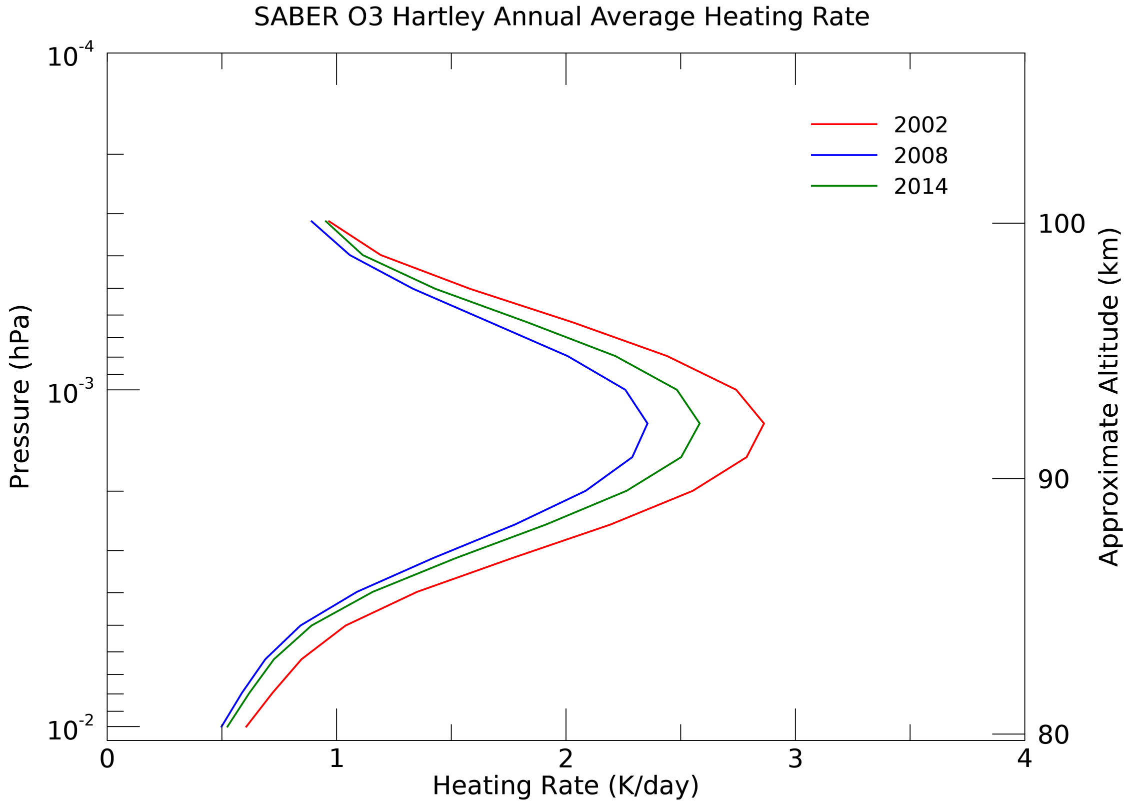
The predominant solar heating mechanisms in the upper mesosphere involving photolysis of molecular oxygen are in the Schumann-Runge bands (175-205 nm), the Schumann-Runge continuum (122-175 nm) ,the Lyman-alpha line (121.5 nm) and the O_2 A-band



Solar Heating

O_3 Heating

- The Hartley band region (~240-310 nm) is of primary importance for heating by photodissociation of ozone in the mesosphere.

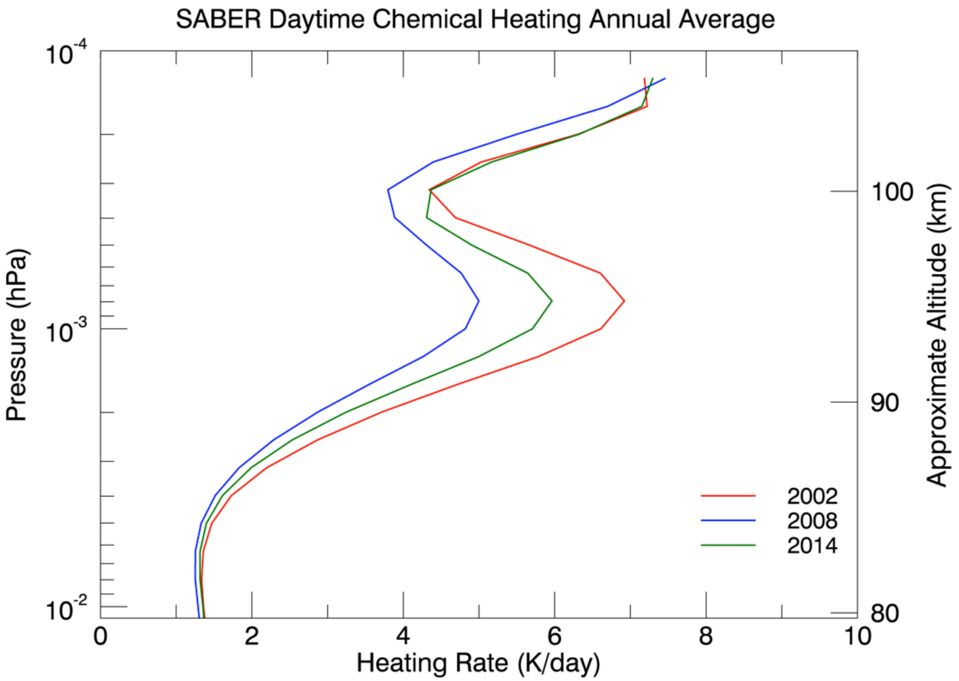


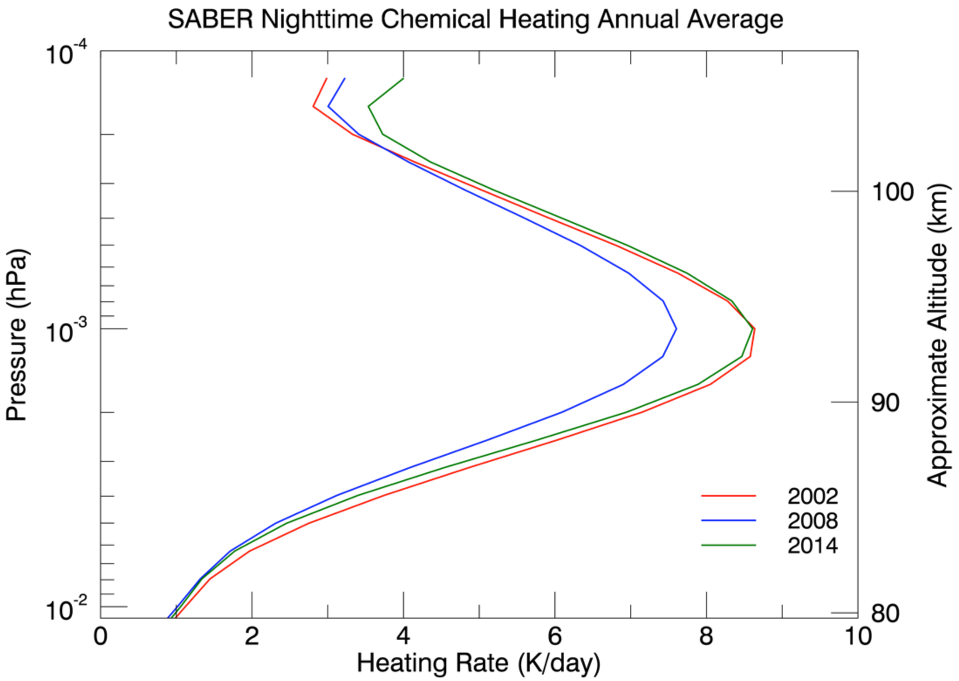
Chemical Heating

A key component of heating in the 80-100 km region is energy released from exothermic chemical reactions:

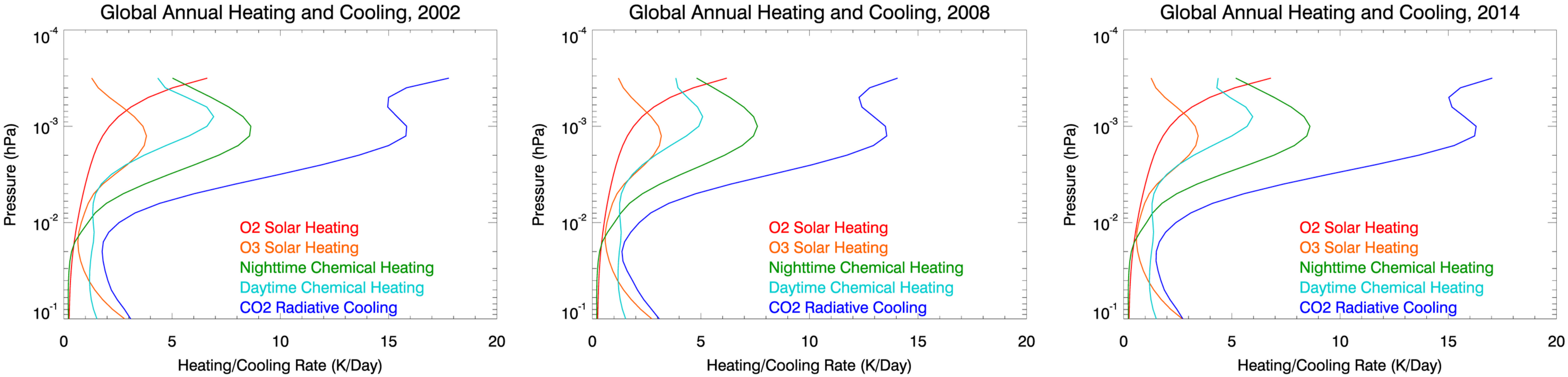
- $O + O + M \rightarrow O_2 + M$
- $H + O_3 \rightarrow OH + O_2$
- $O + O_2 + M \rightarrow O_3 + M$
- $O + O_3 \rightarrow O_2 + O_2$
- $H + O_2 + M \rightarrow HO_2 + M$
- $O + OH \rightarrow H + O_2$
- $O + HO_2 \rightarrow OH + O_2$

Chemical Heating



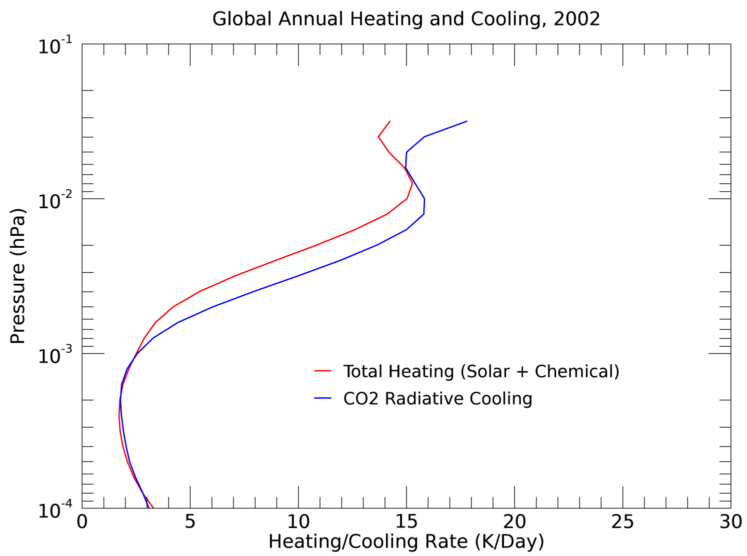


Component Totals

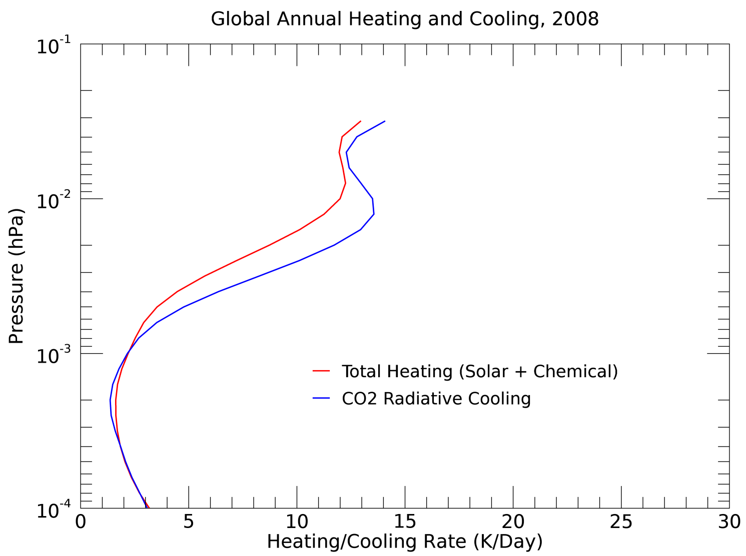


Total Heating & Cooling

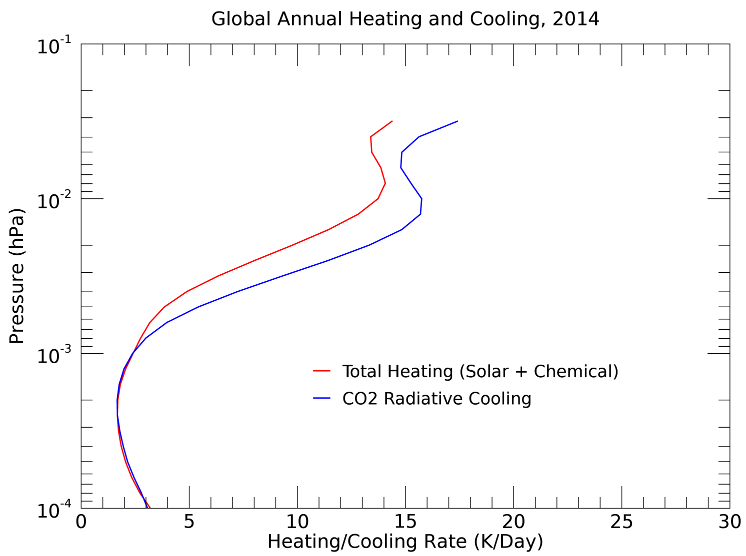
2002



2008

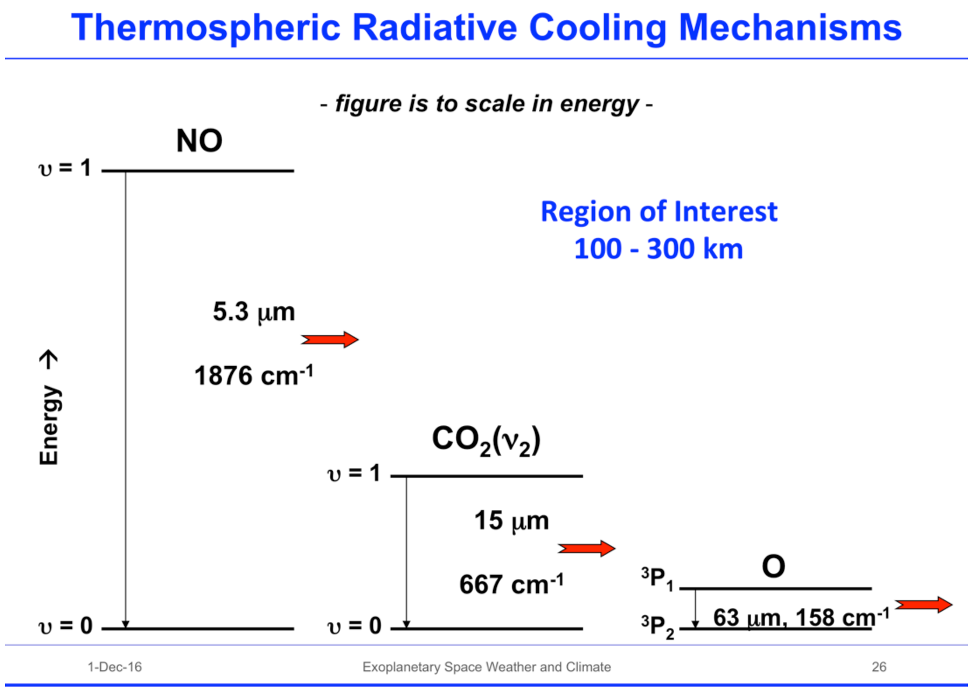


2014

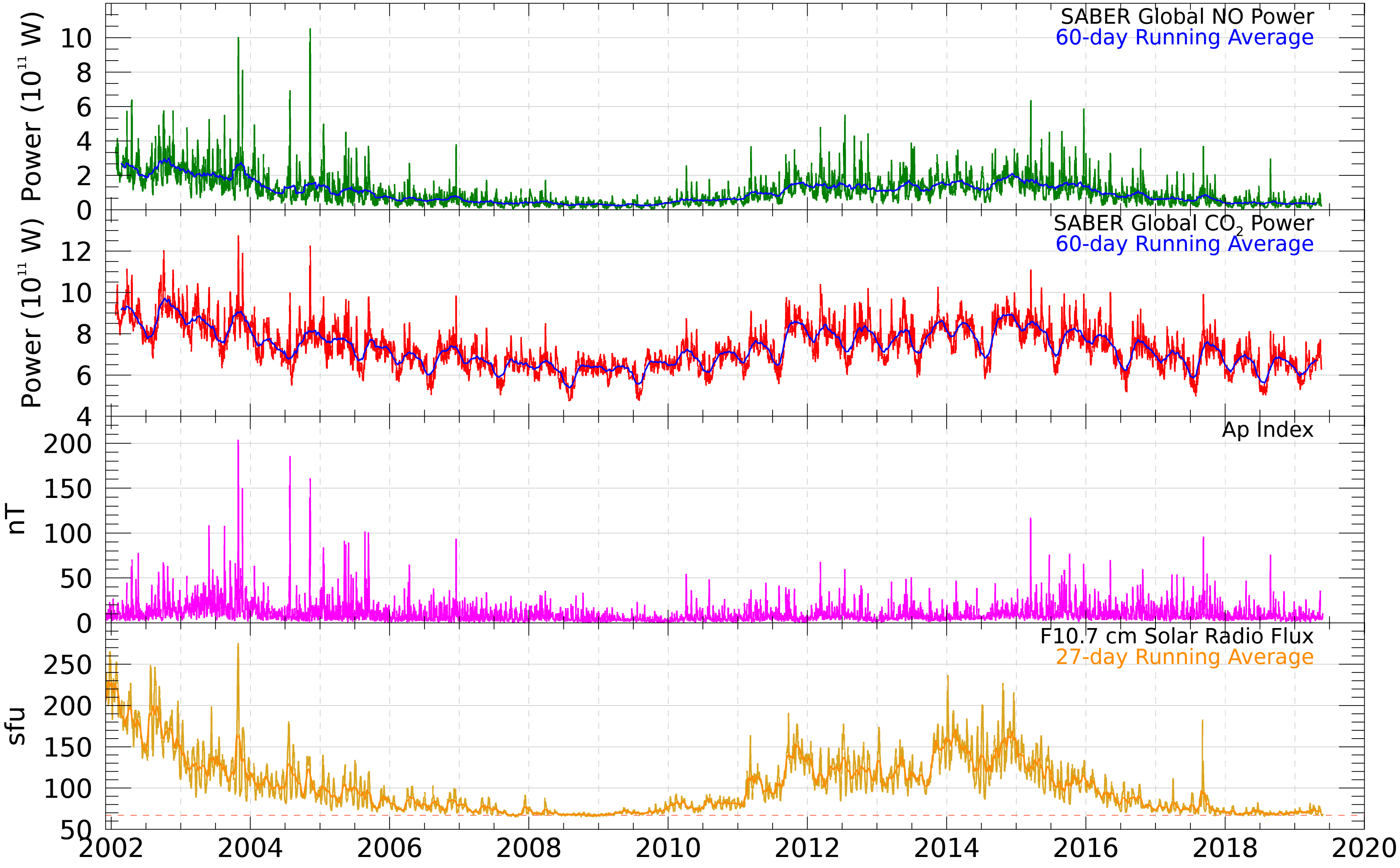


Thermosphere

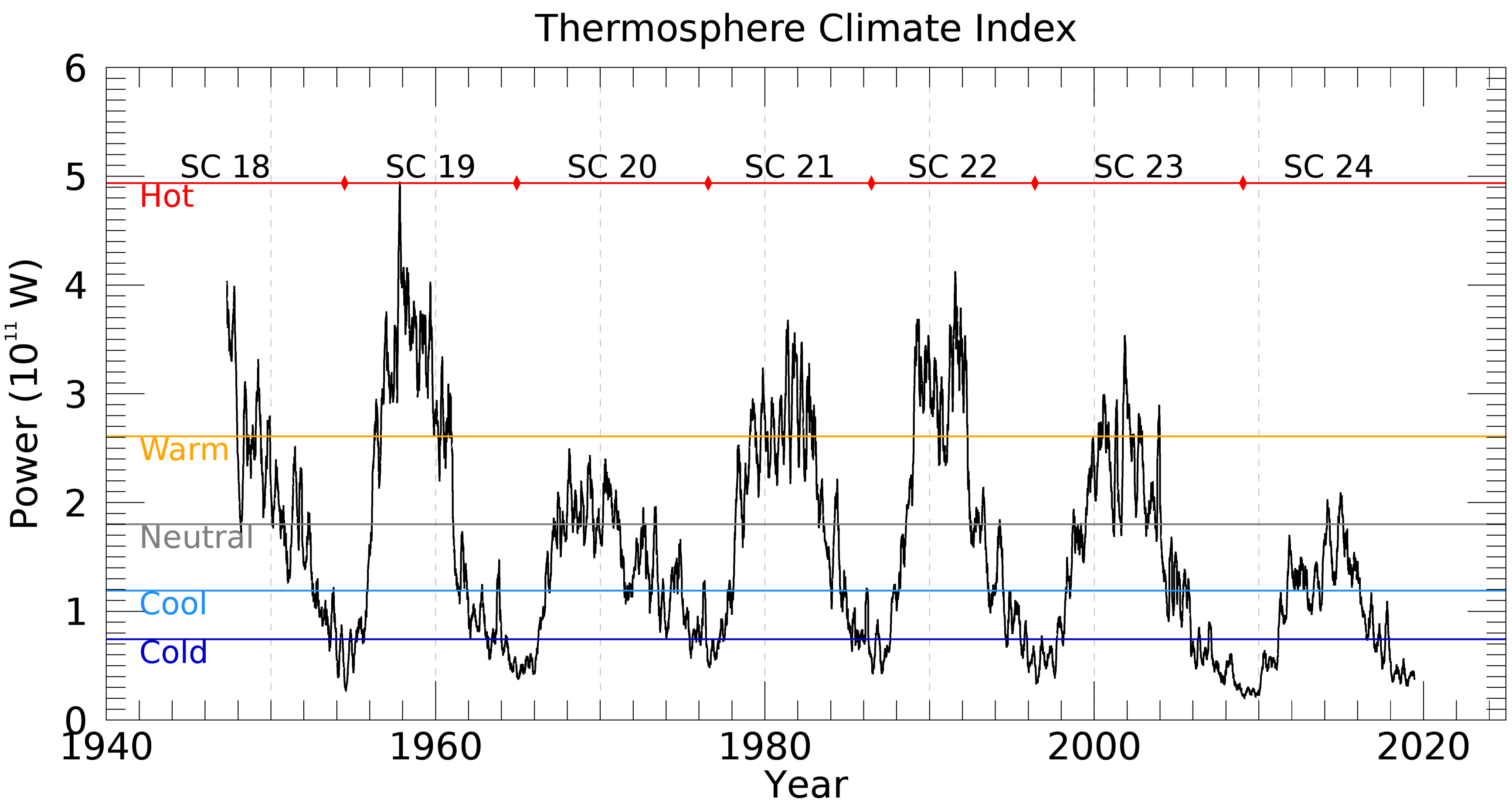
- Radiative cooling in the thermosphere is the action of infrared radiation to reduce the kinetic temperature of the neutral atmosphere. It is accomplished almost entirely by two species, CO2 at 15 μm and NO at 5.3 μm in response to solar input: flare, CME, energetic particles in the solar wind.
- Collisional processes are highly temperature dependent.
- Cooling depends on T, [O], and NO or CO_2 amount
- NO is also chemically active, increasing substantially during geomagnetic storms



Thermosphere



Thermosphere Climate Index



Poster LTVI-02 in the Mesosphere and Lower Thermosphere Session tomorrow

Summary

- The SABER instrument on the TIMED satellite is providing the first comprehensive measurements of key parameters for quantifying the heat budget and chemistry of this region. Key findings:
- Solar variability is observed in every parameter examined to date, including temperature, constituents and energetics (heating and cooling).
- Energetics changes appear consistent with changes in structure.
- Temperature, Atomic Oxygen decrease during the solar cycle minimum
- Atomic hydrogen is observed to increase during solar min consistent with Ly-α decrease
- Ozone variation depends on altitude, but increases during solar min above 60 km
- Within the mesosphere, the largest absolute changes are observed near the mesopause.
- In the thermosphere, NO and CO2 serve as a natural thermostat to convert incoming solar energy to infrared energy that is radiated to the lower atmosphere and to space.
- Solar cycles 23 and 24 are very different in many ways, and that is apparent in the Earth's atmospheric response as well.

Backup Slides

SABER Channels and Data

Species	Wavelength	Data Products	Altitude Range
CO_2	15.2 µm	Temperature, pressure, cooling rates	15-100 km
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CO_2	14.8 µm	Temperature, pressure, cooling rates	15-100 km
O_3	9.6 µm	Day and Night Ozone, cooling rates	15-95 km
H_2O	6.3 µm	Water vapor, cooling rates	15-80 km
CO_2	4.3 µm	Carbon dioxide, dynamical tracer	90-160 km
NO	5.3 µm	Thermospheric cooling	100-300 km
$O_2(^1D)$	1.27 µm	Day O_3, solar heating; Night O	50-100 km
OH(u)	2.0 µm	Chemical Heating, photochemistry	80-100 km
OH(u)	1.6 µm	Chemical Heating, photochemistry	80-100 km