Treatment of the sun-related effects in climate and atmospheric models: status and development

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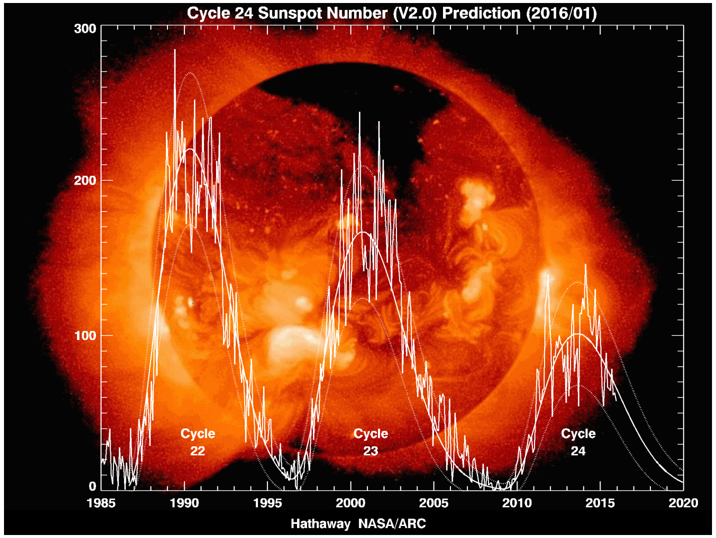
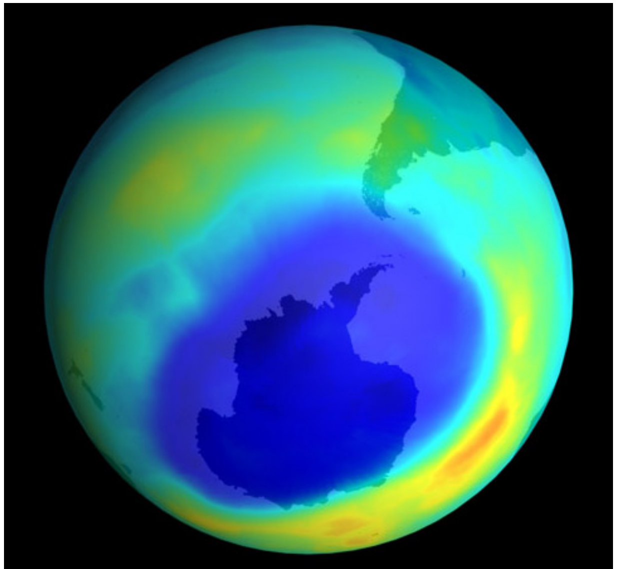
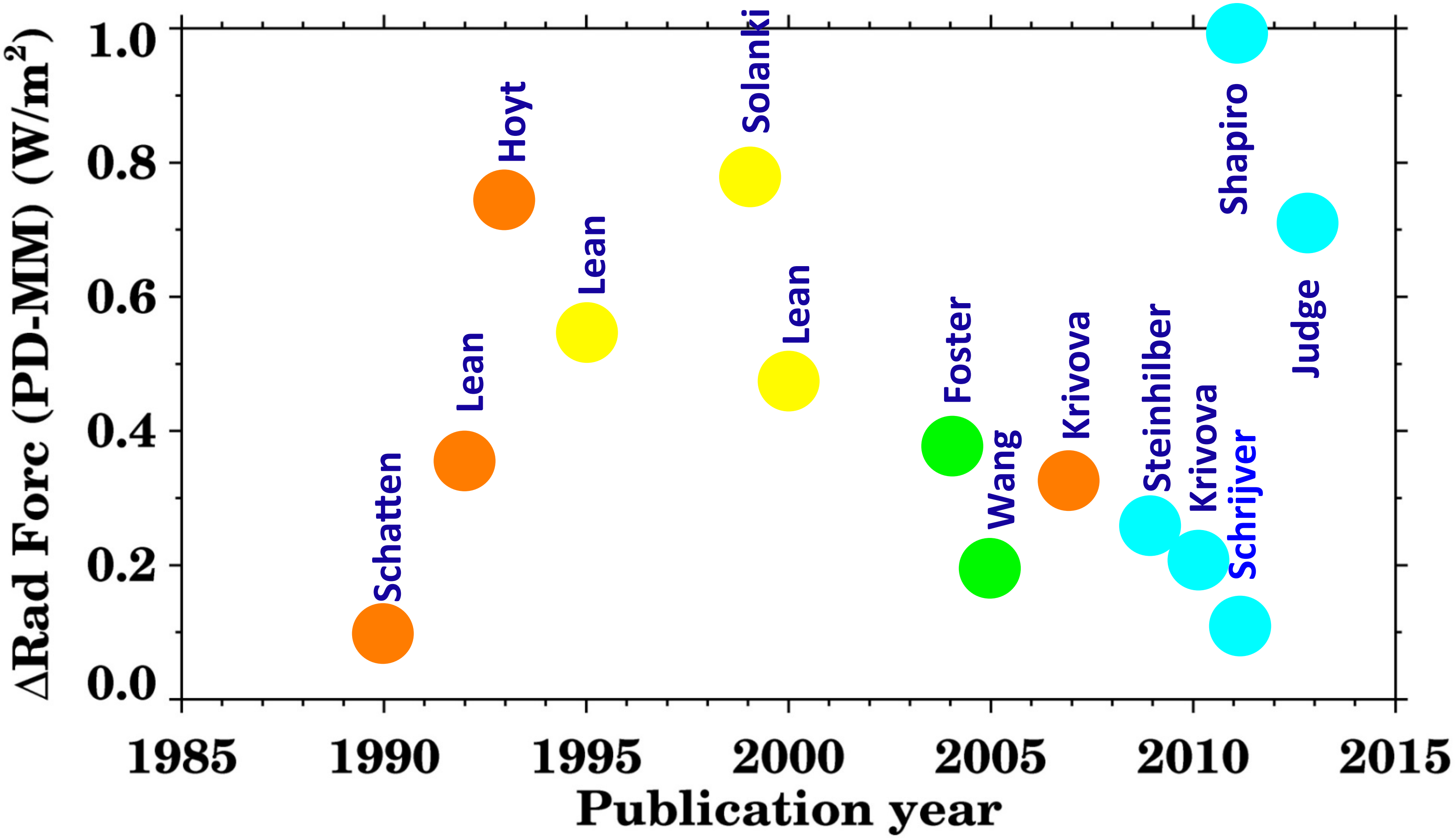
Motivation



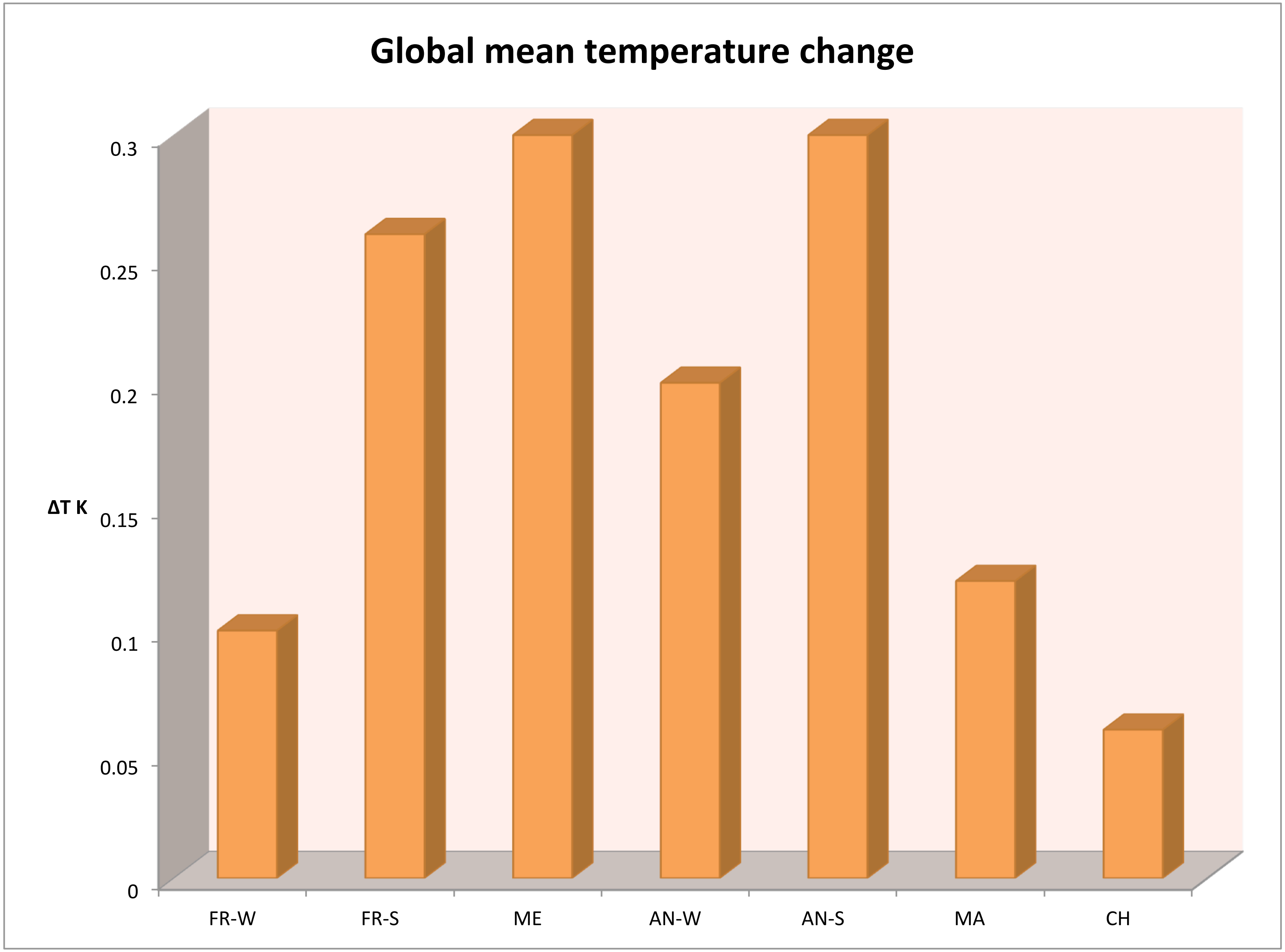


Antarctic ozone hole at its record size, September 10, 2000. Image credit: NASA

Instantaneous Radiative Forcing for present day relative to Maunder Minimum

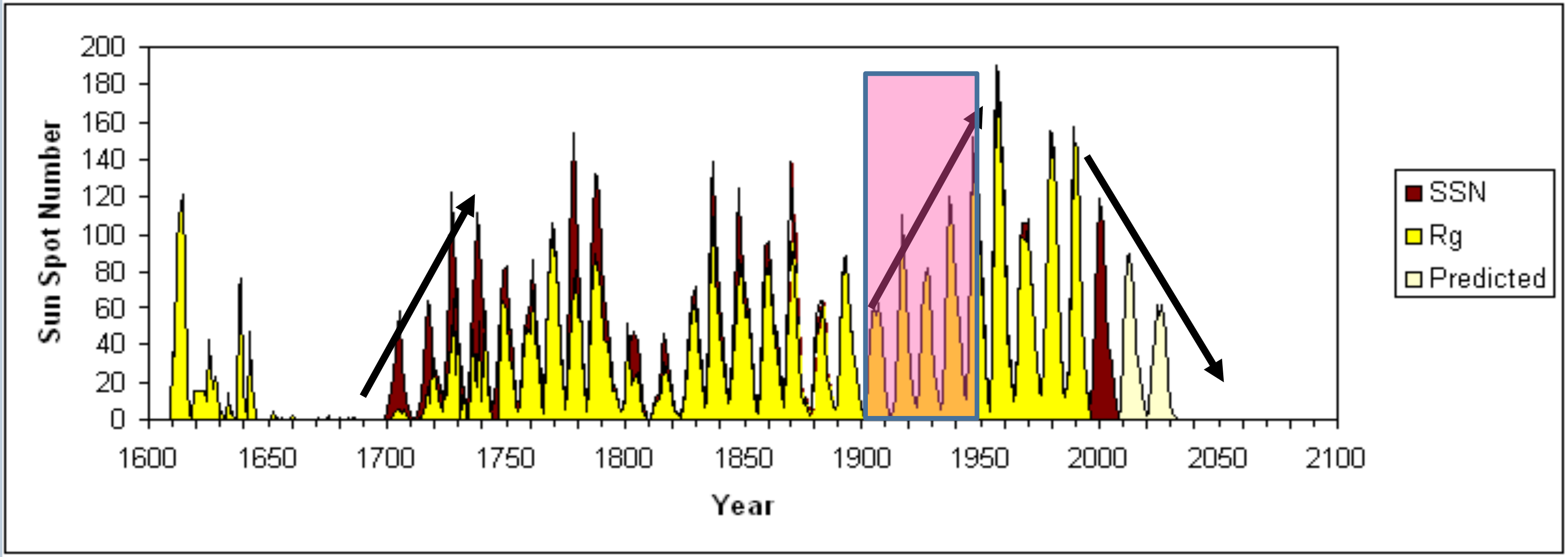


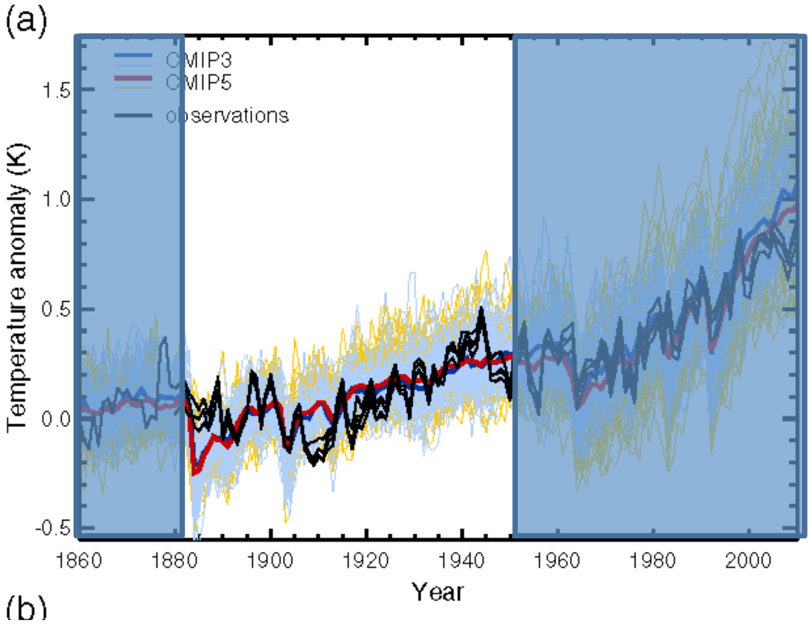
Global mean temperature response



Space Climate 6, Levi, Finland, 7 April, 2016

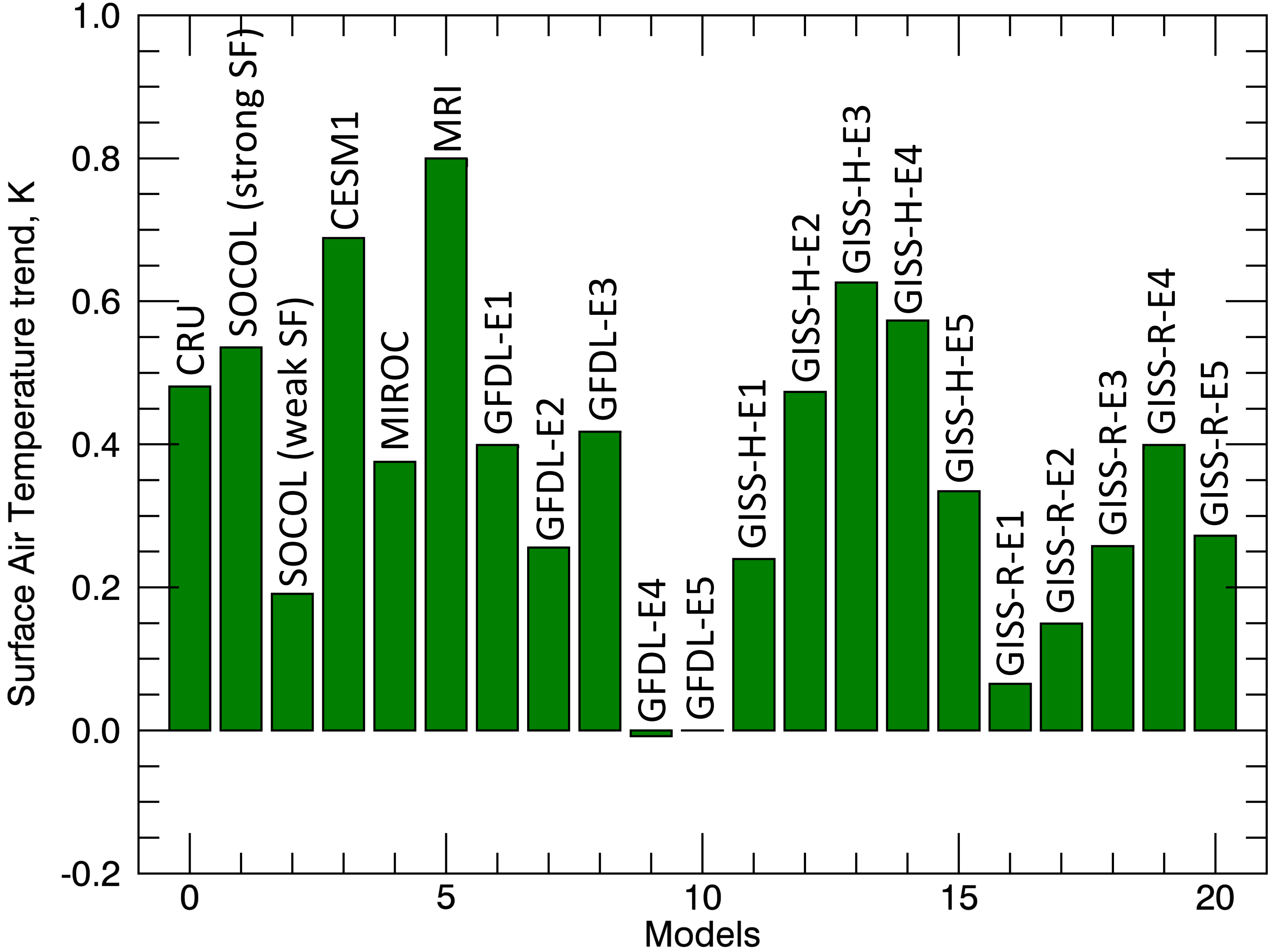
Global mean temperature response





From Jones et al., 2013

Surface air temperature trends



Global mean temperature response

GHG forcing range 2.6-8.5 W/m2**
GHG warming range 1-4 K, 100 years

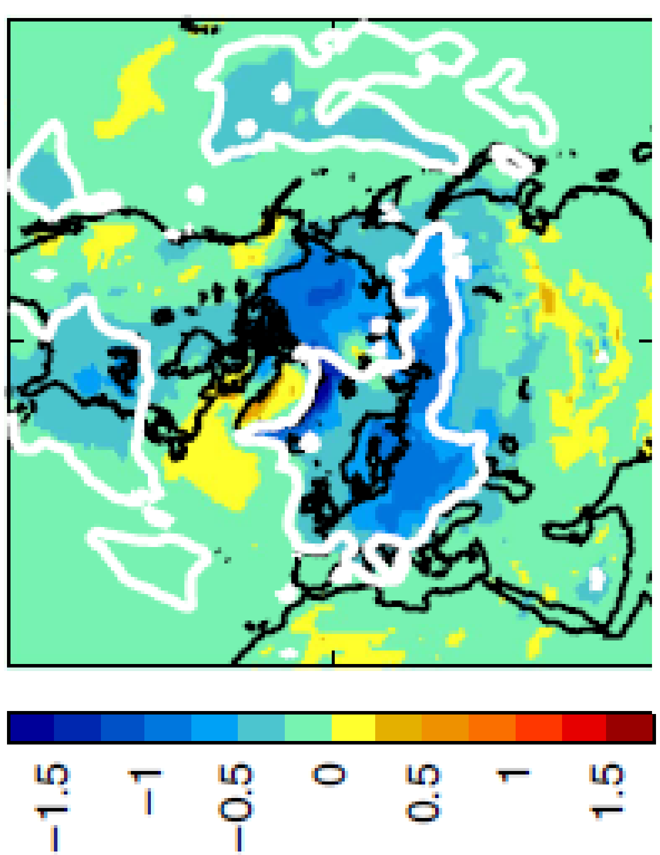
1. The simulated response depends mostly on the applied forcing

2. All models properly maintain energy balance

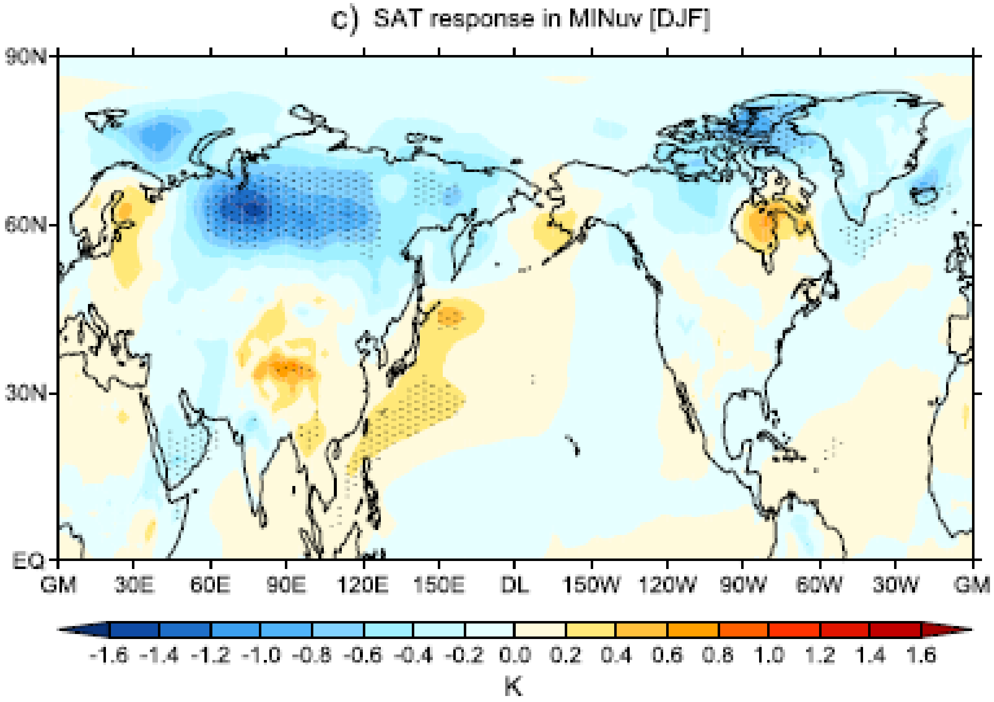
3. Even the extreme forcing cannot compete against GHG

4. The extreme values of forcing cannot be excluded

Temperature response on seasonal/regional scale

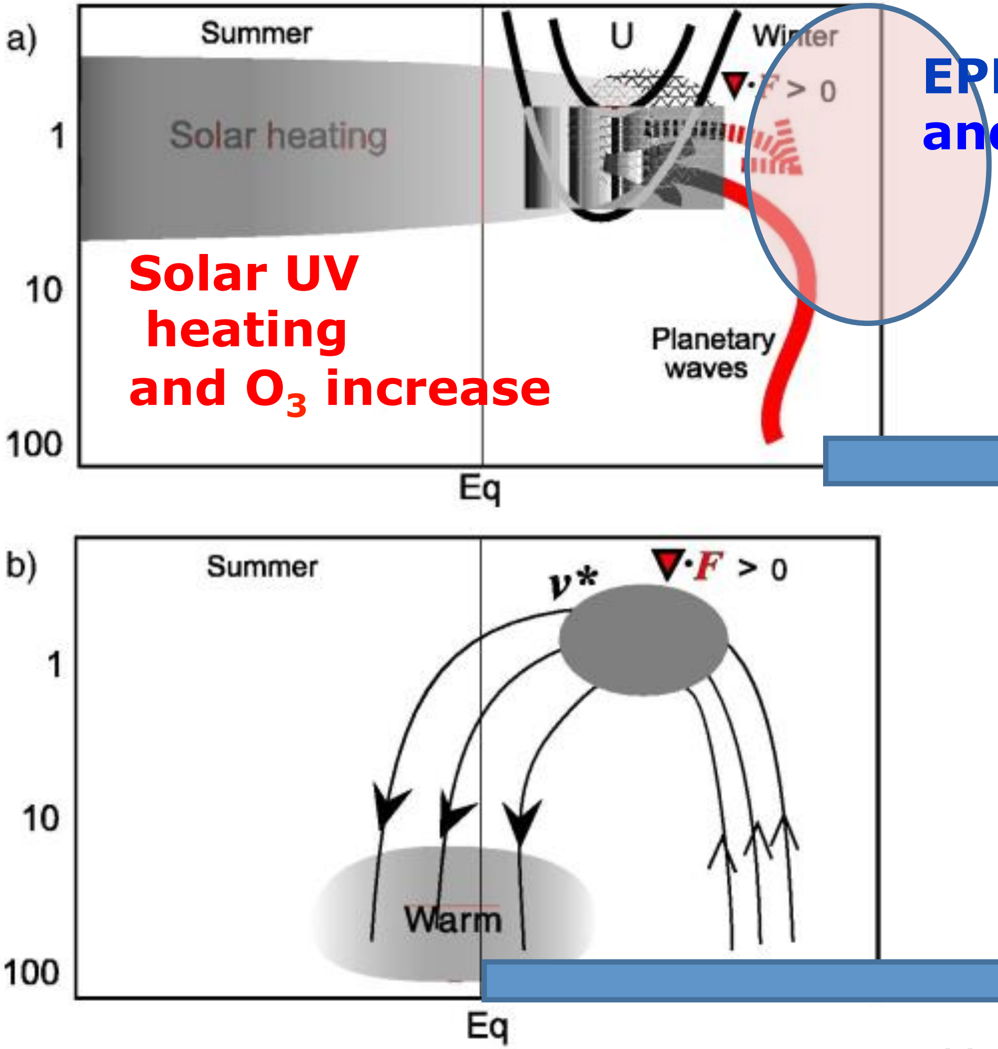


Ineson et al. (2015)


c) SAT response in MINuv [DJF]

Chiodo et al. (2016)

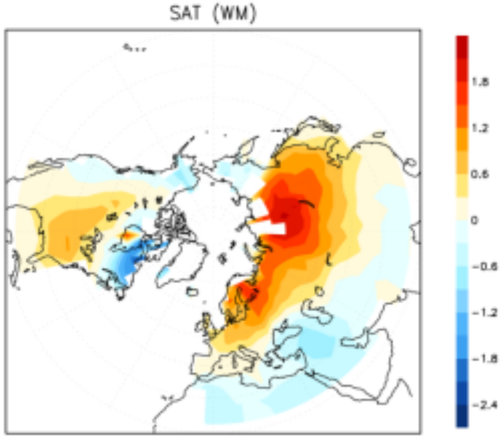
Temperature response on seasonal/regional scale



Solar UV heating and O$_3$ increase

EPP cooling and O$_3$ decrease

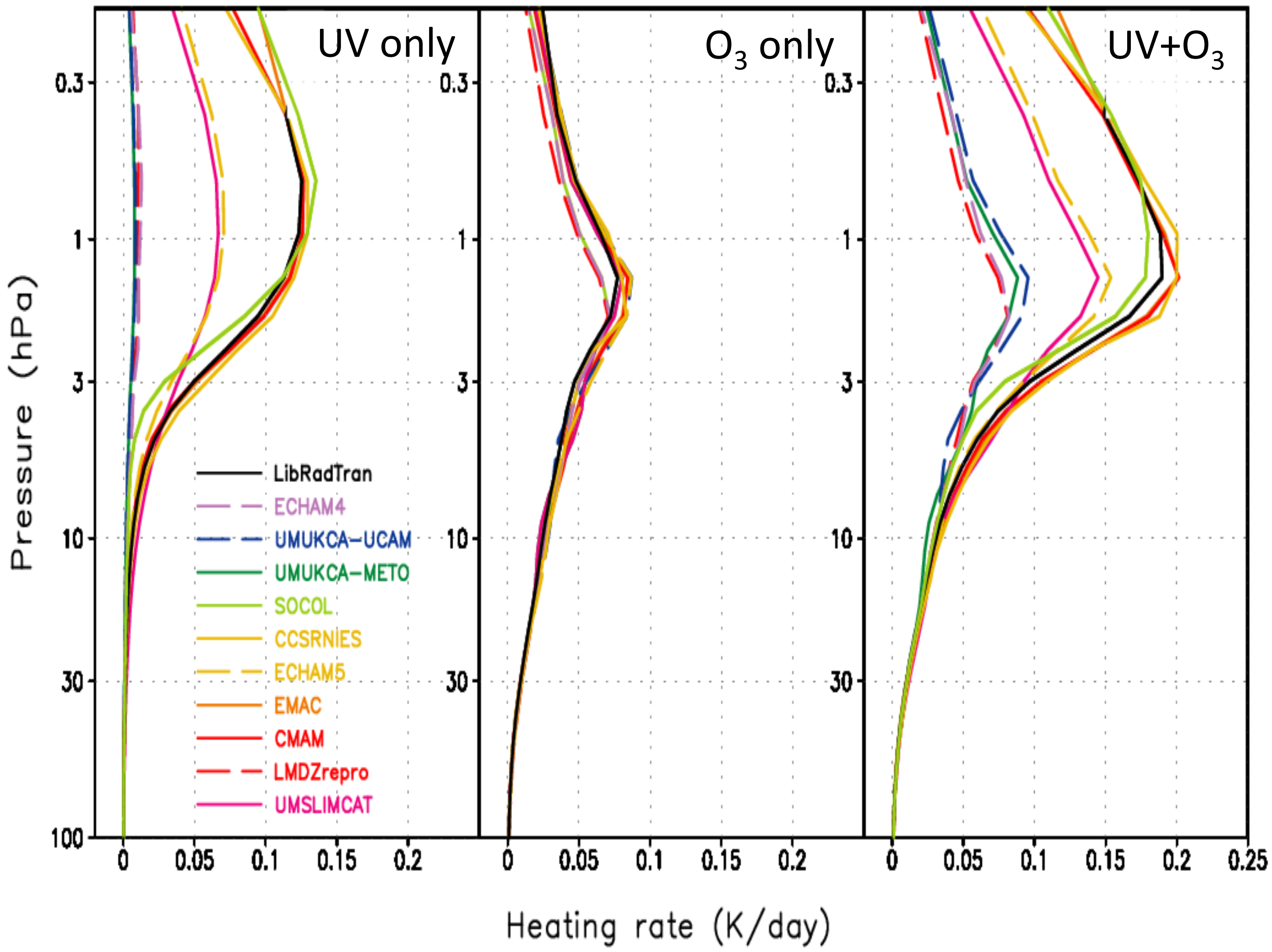
Kodera and Kuroda, (2002)



Thomson & Wallace (1998)

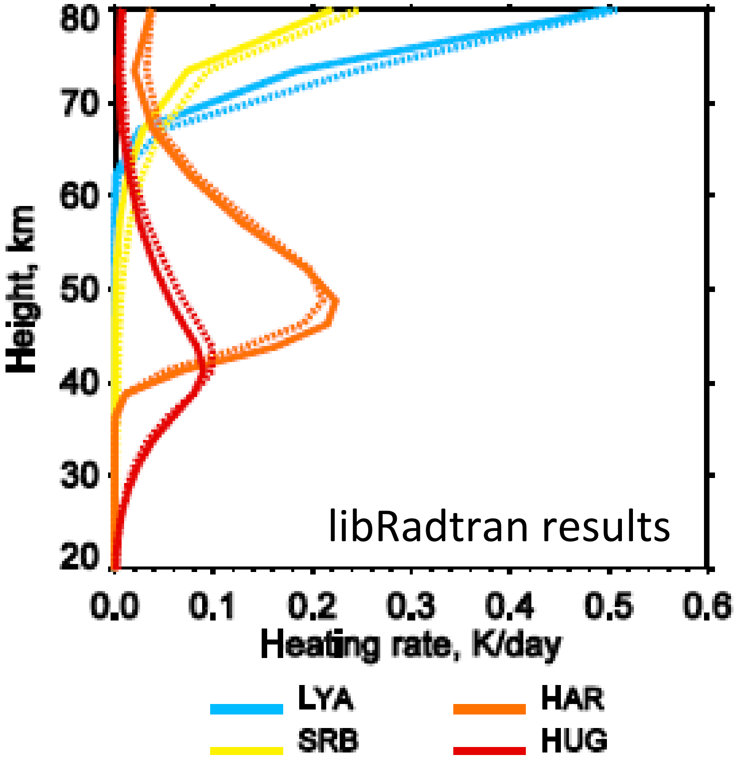
Hadley sell shift and ... (J.Haigh)

Performance of the radiation codes



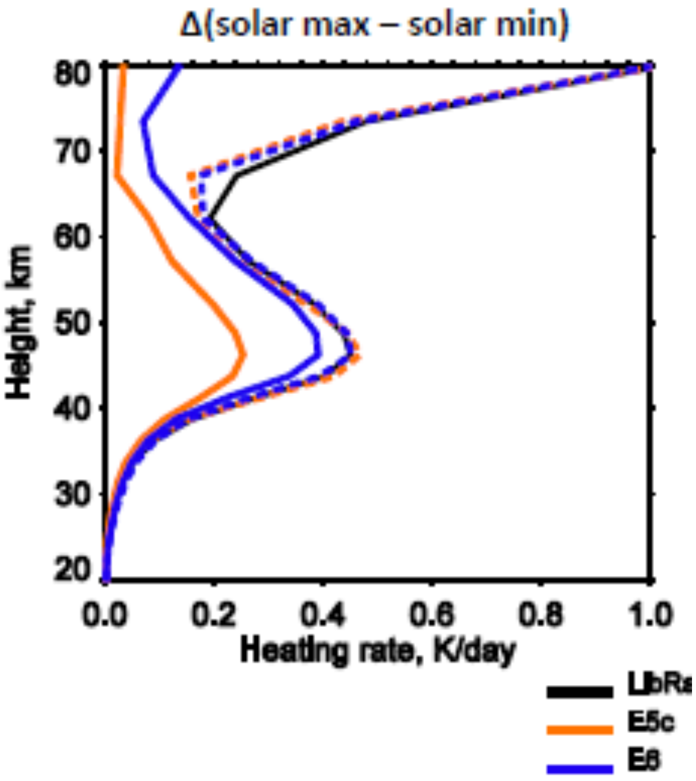
Near-global mean, short-wave heating rate differences between minimum and maximum of the 11-year solar cycle in January (K/day), from Forster et al. (2011)

Which spectral intervals are important?



LYA 121.0–122.0
SRB 175.0–205.0
HAR 250.0–280.0
HUG 280.5–360.0

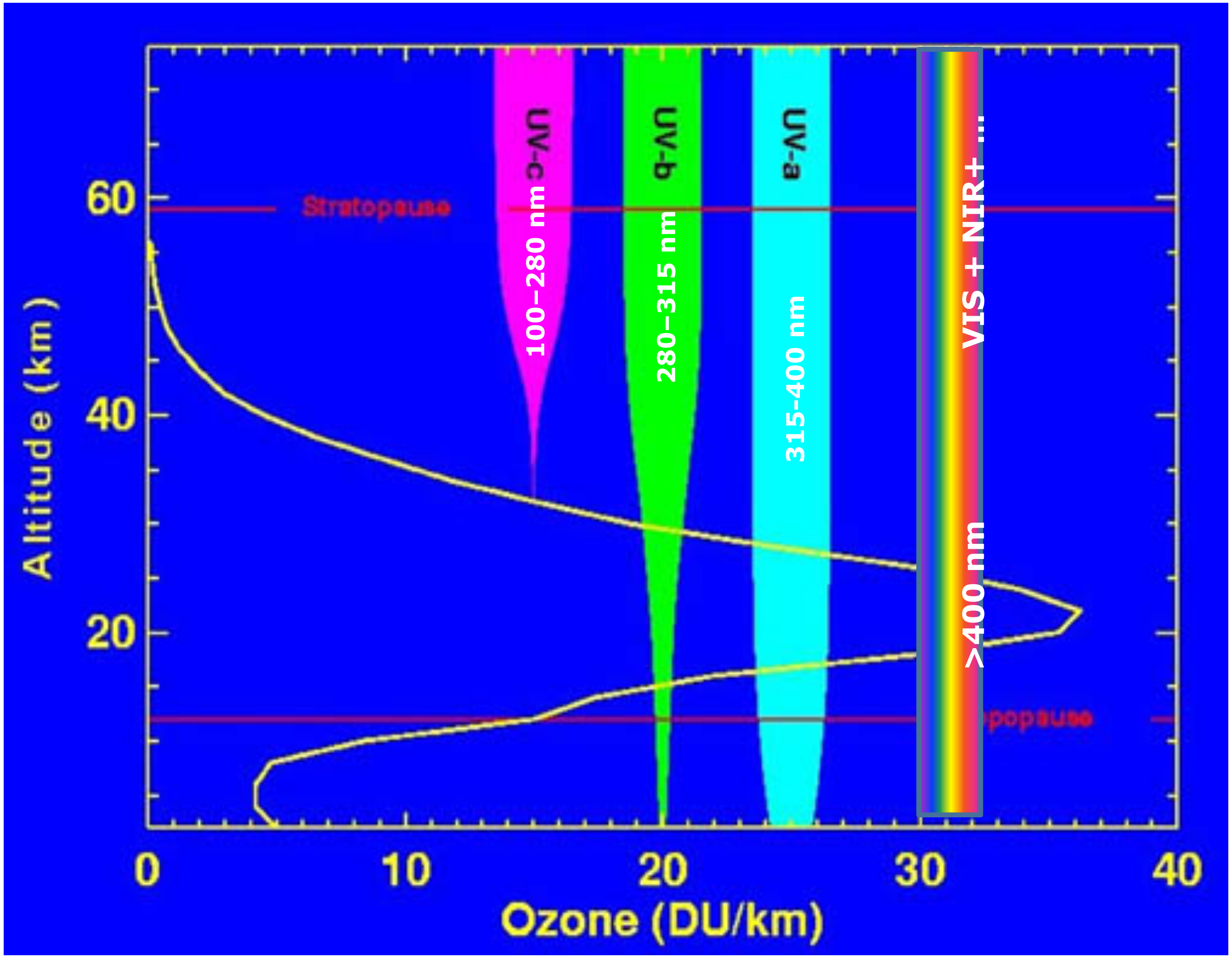
Sukhodolov et al. (2014)



Ineson et al. (2015)
UV (200–320 nm) !!

Chiodo et al. (2016)
UV (200–350 nm) !!

Spectral dependence of the penetration depth



Chiodo et al. (2016)

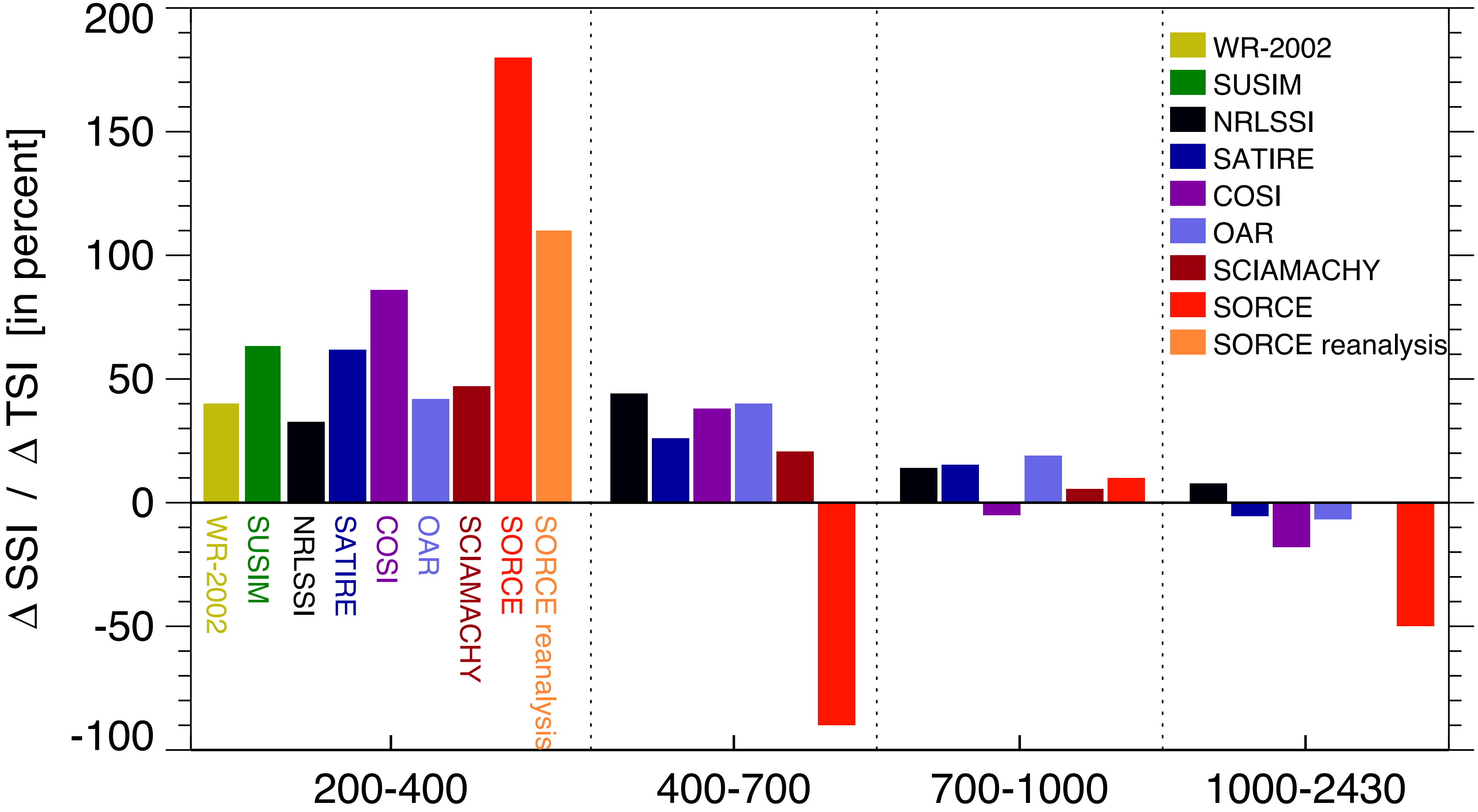
UV (200–350 nm) !!

Solar heating response

1. Oxygen absorption controls mesospheric heating, but it is absent in many models;

2. No all UV is absorbed in the stratopshere, therefore careful description of the UV forcing is necessary to distinguish between stratopshere and surface driven mechanisms

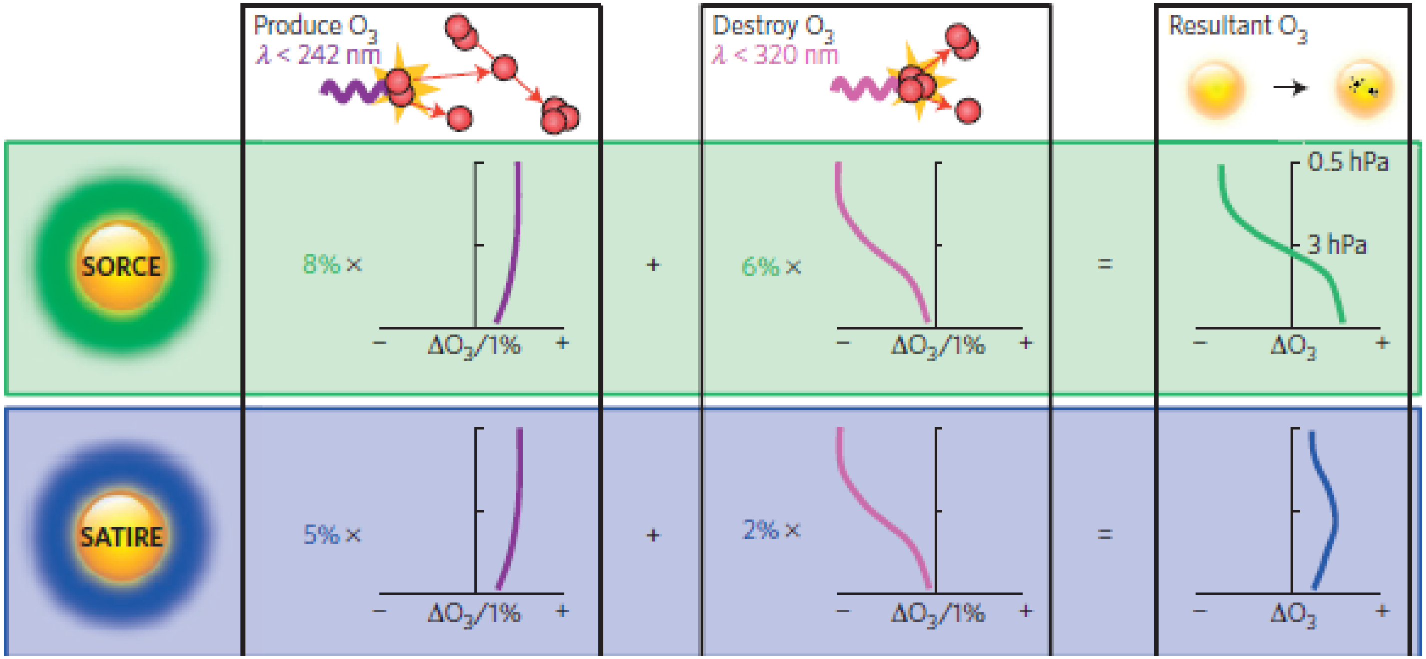
Magnitude of SSI variability

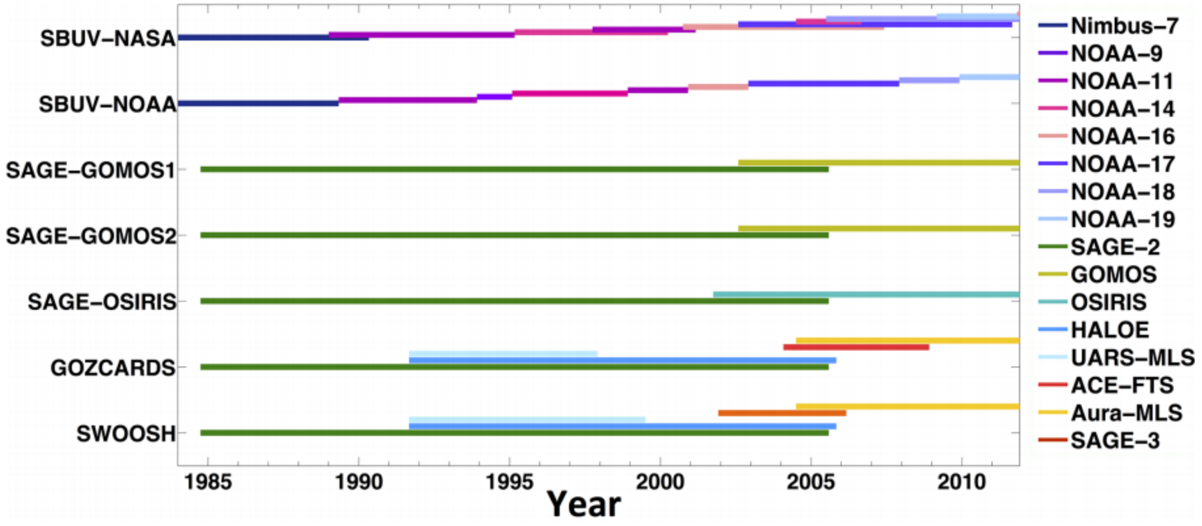


Ermolli et al. (2013)

Ineson et al. (2015) applied 6.43% UV (200–320 nm) reduction based on the SORCE data extrapolation

How it can be constrained?





How it can be constrained?

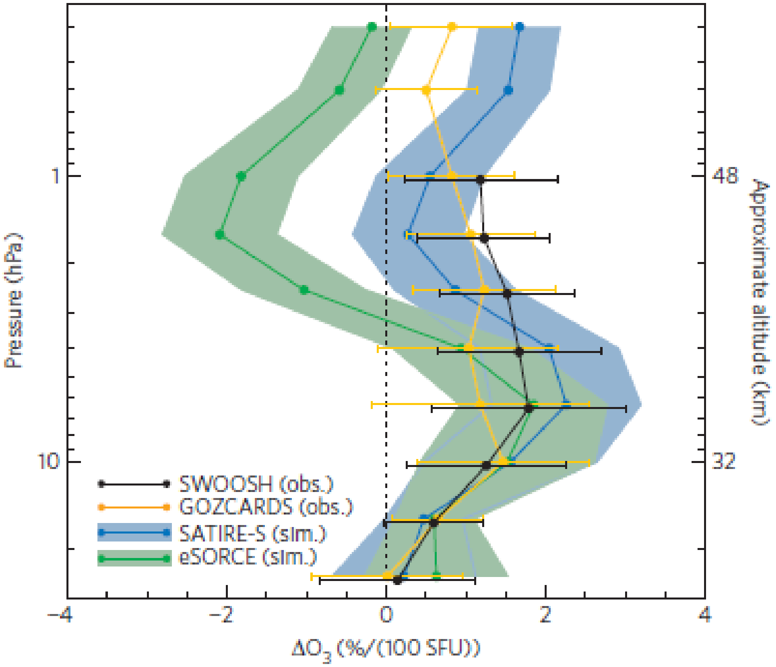
Experiment setup

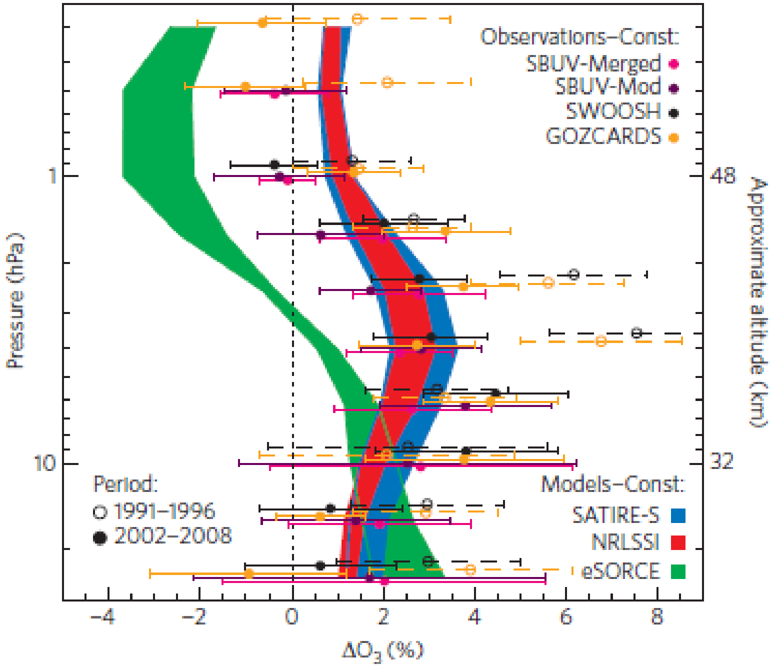
- ***CCM SOCOL in Nudged mode*** (winds,T, surface pressure)
- ***Prescribed*** SSTs, source gases, aerosol
- Identical runs, ***except SSI***

Constant Sun **SORCE***

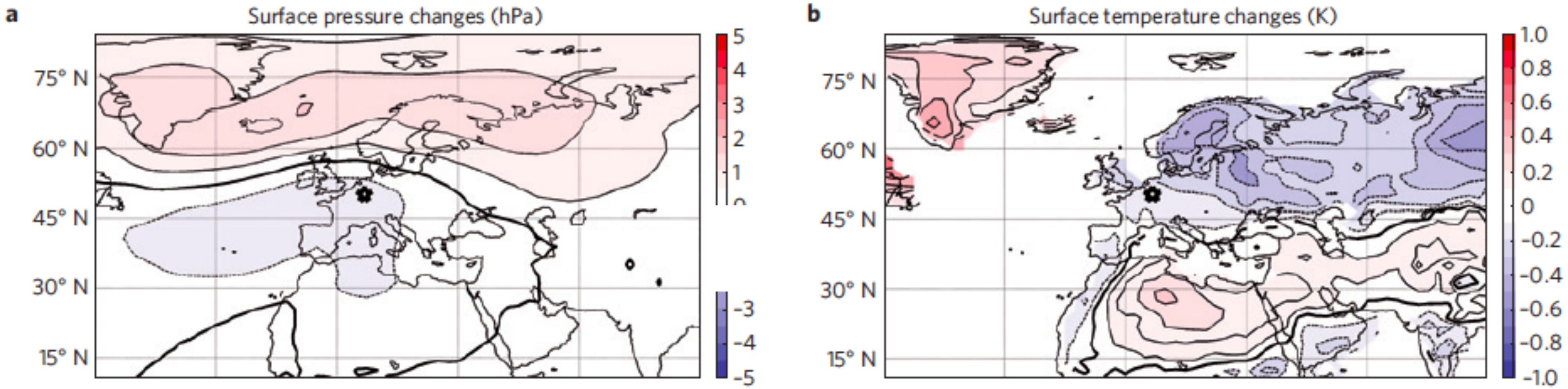
NRLSSI **SATIRE-S**

Ball et al. (2016)





Implications



Surface Pressure changes (hPa)

Surface Temperature changes

Martin-Puertas et al., 2012
WACCM 3.5 results

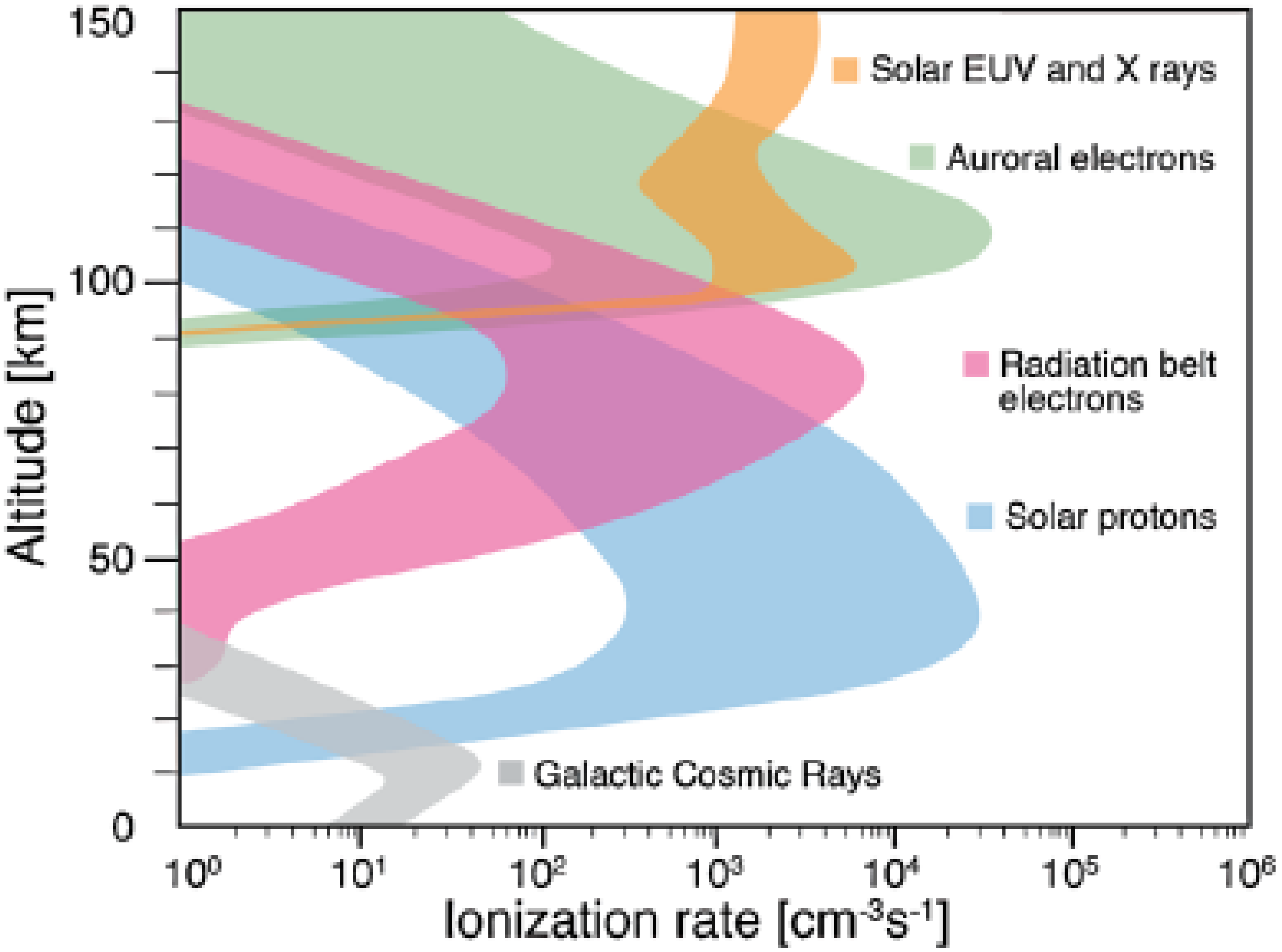
Also true for :
Ineson et al., Nature Geo, 2012
Ineson et al., Nature Geo, 2015

Magnitude of the solar variability

1. High variability obtained from SORCE data is not supported by ozone measurements;

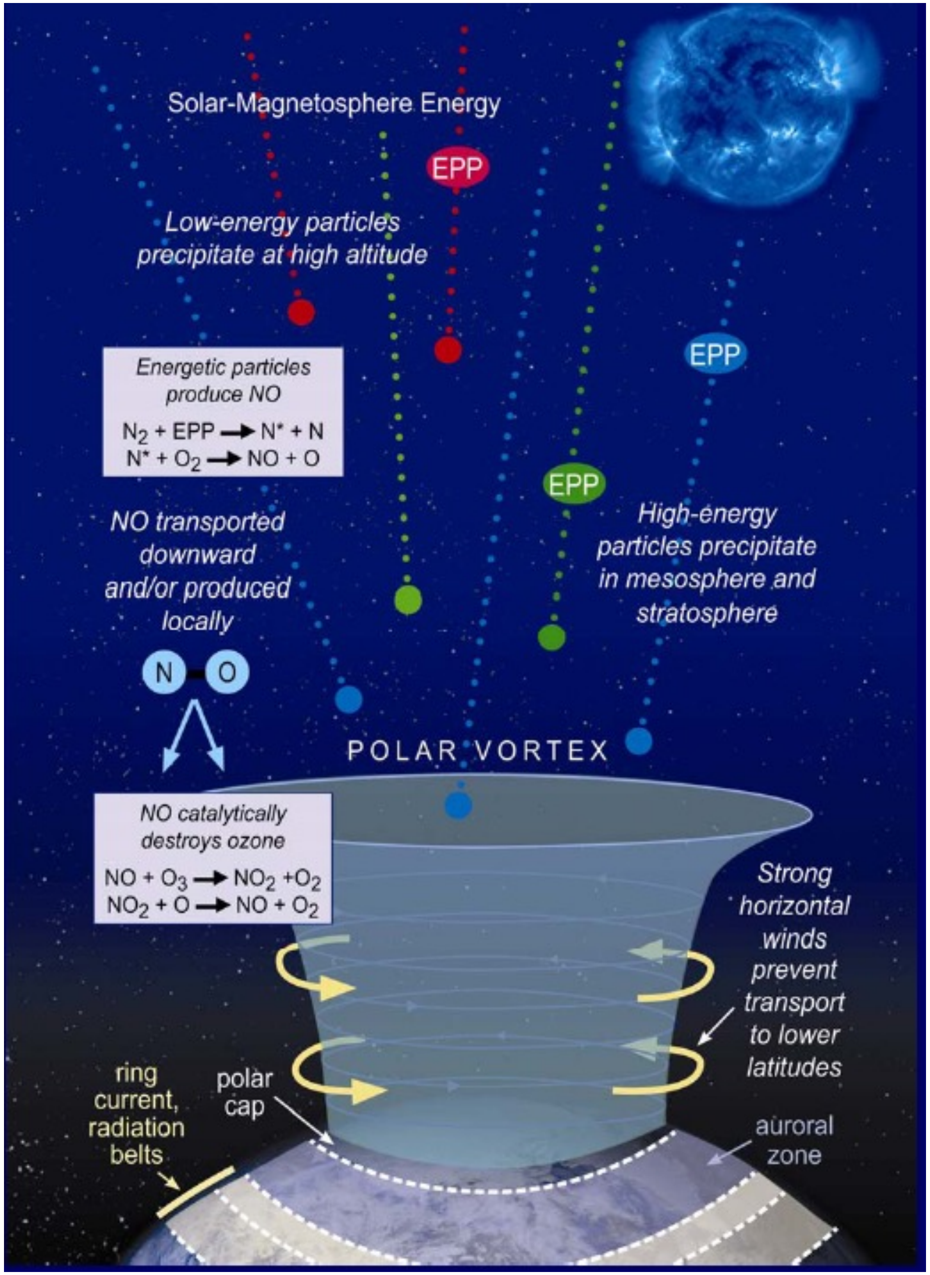
2. New efforts in the study of top-down (stratosphere driven) mechnism are necessary

Precipitating energetic particles



Mironova et al., 2015

Precipitating energetic particles



Baily et al., 2009

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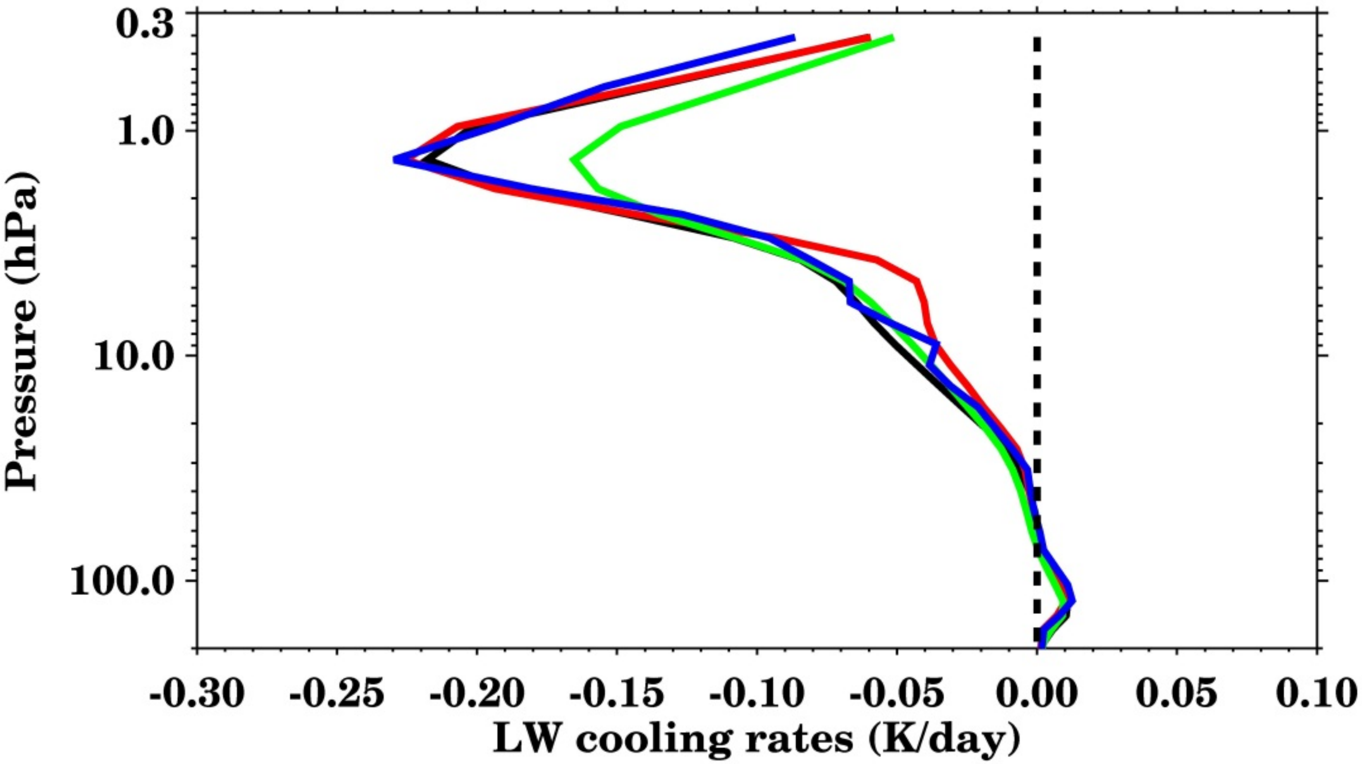
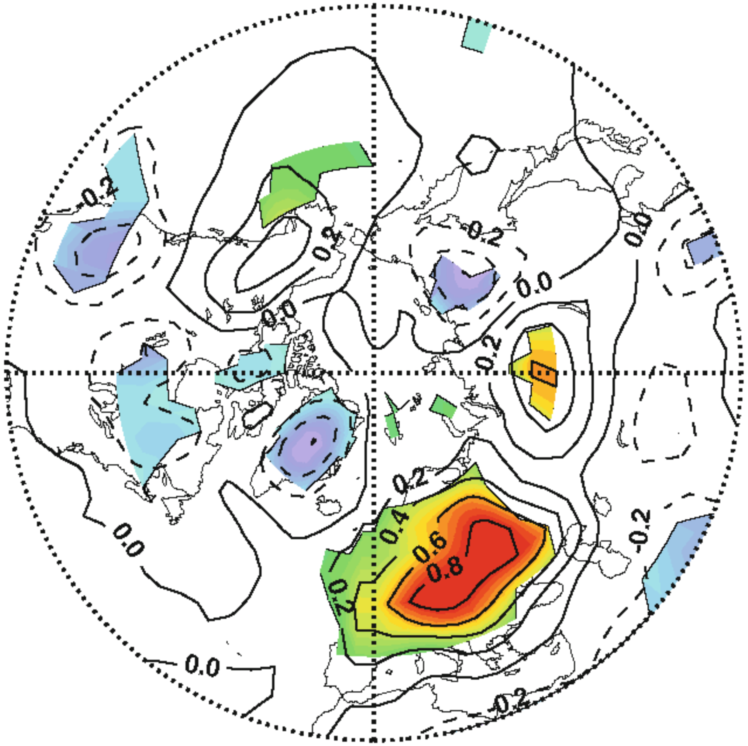
Cooling rate due to polar ozone depletion

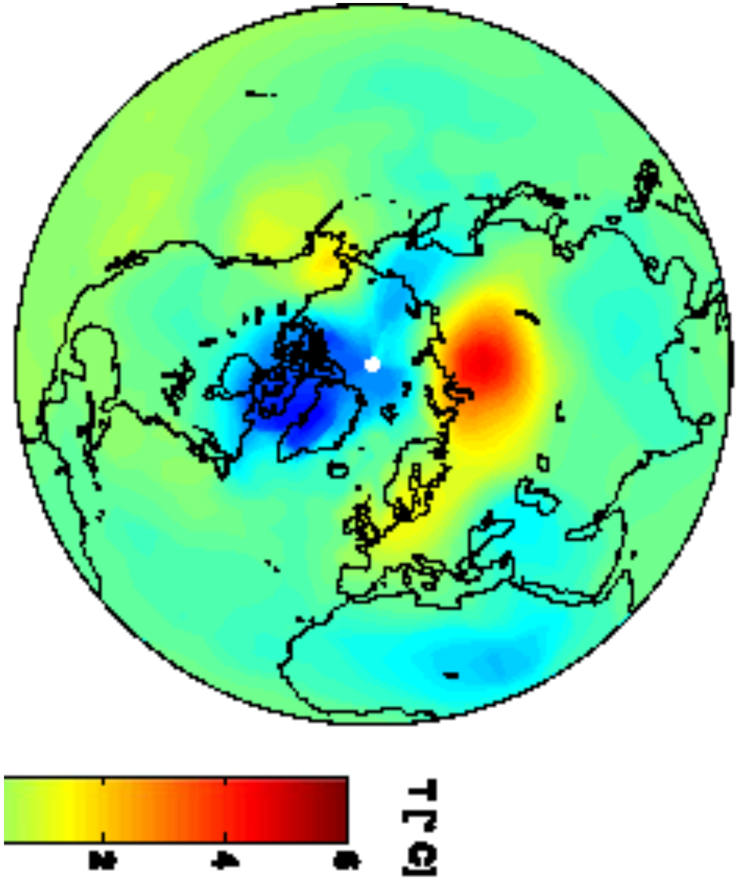


January
Polar
AER LBL code

Auroral electron influence on SAT

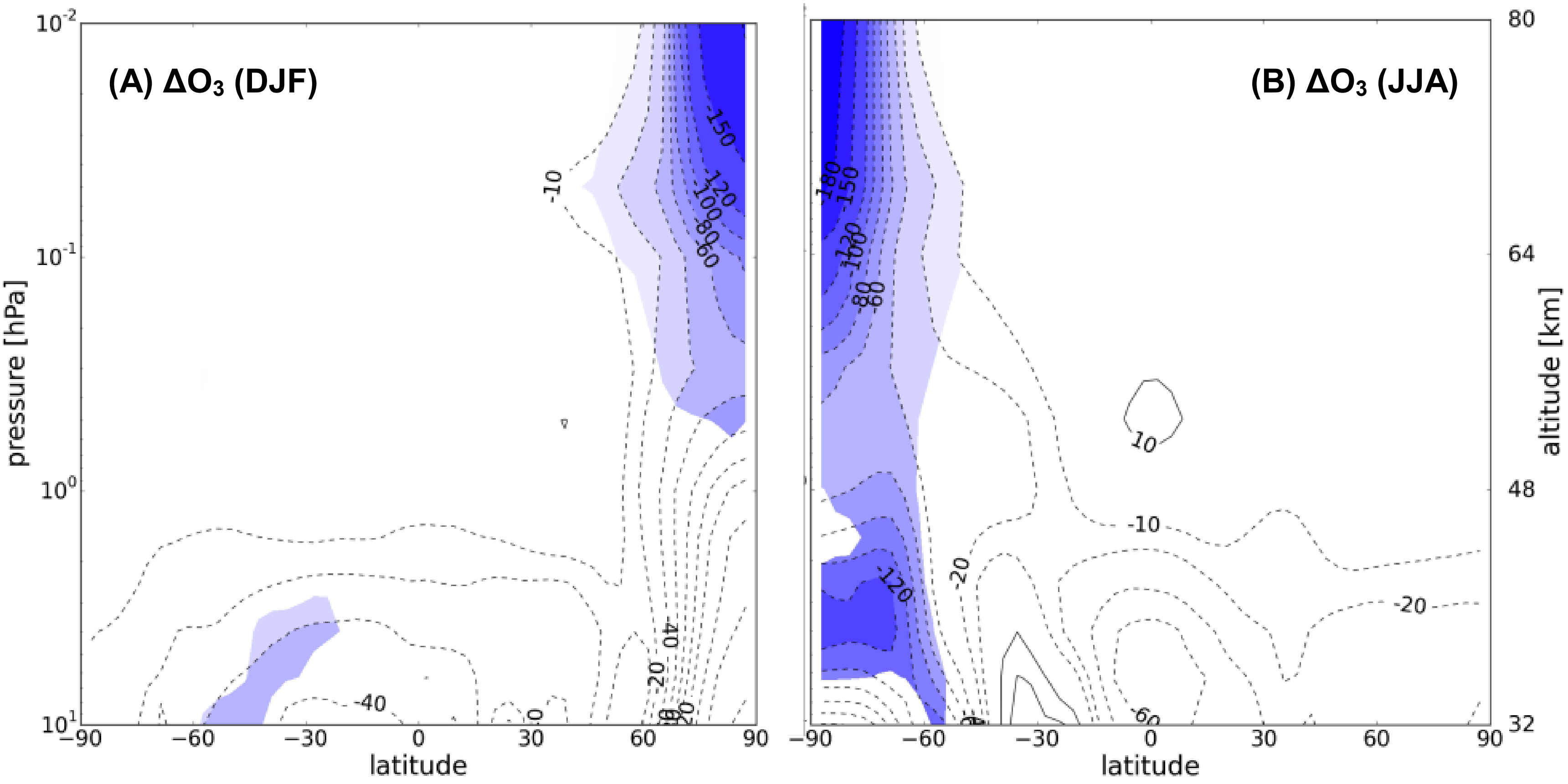


DJF, SOCOL v2.0,
all EP
Rozanov et al.,
2012



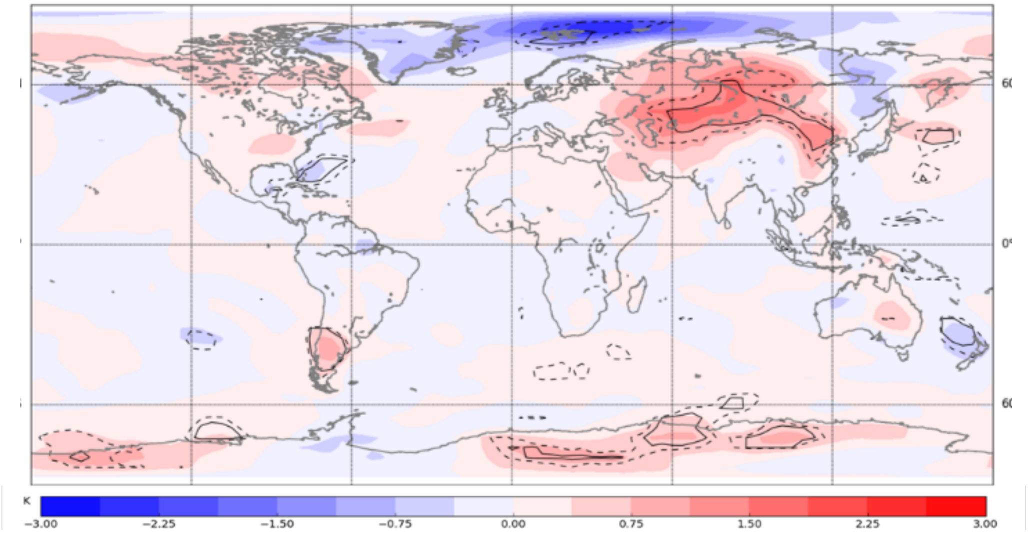
NDJ composite
High D1-
Low D1
from GISS
Maliniemi et al., 2013

Impact of middle range energy electrons Zonal mean ozone



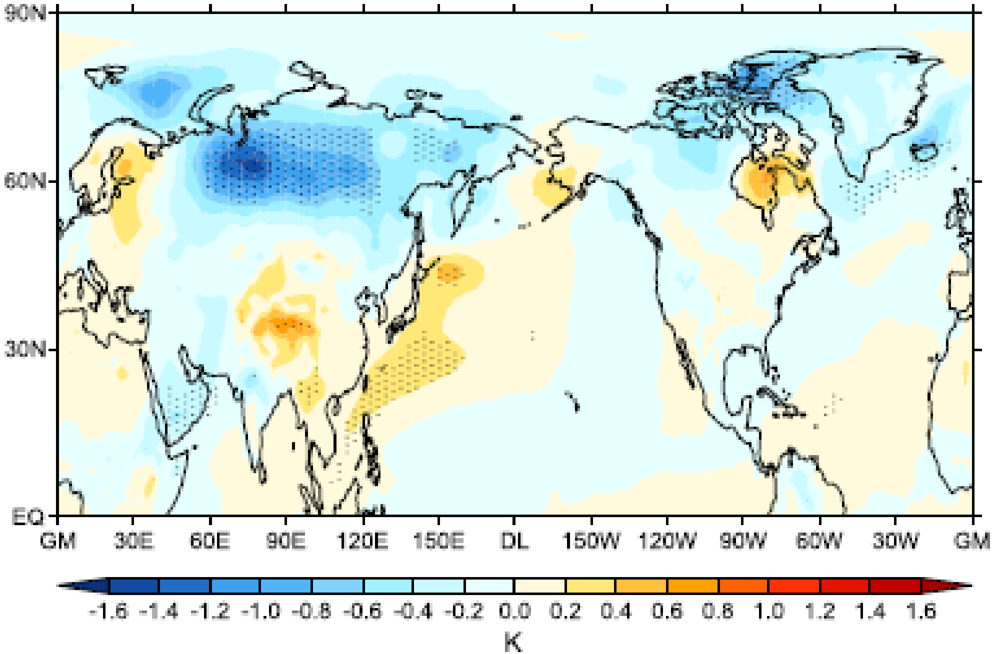
Arsenovic et al., 2016

Implications



MEE
Arsenovic et al., 2016

c) SAT response in MINuv [DJF]



UV
Chiodo et al., 2016

Space Climate 6, Levi, Finland, 7 April, 2016

Middle range energy electrons

1. MEE are potentialy important and can be treated in the models using existing ionization rate compiltaion;

2. The effect of MEE is comparable with the UV impact

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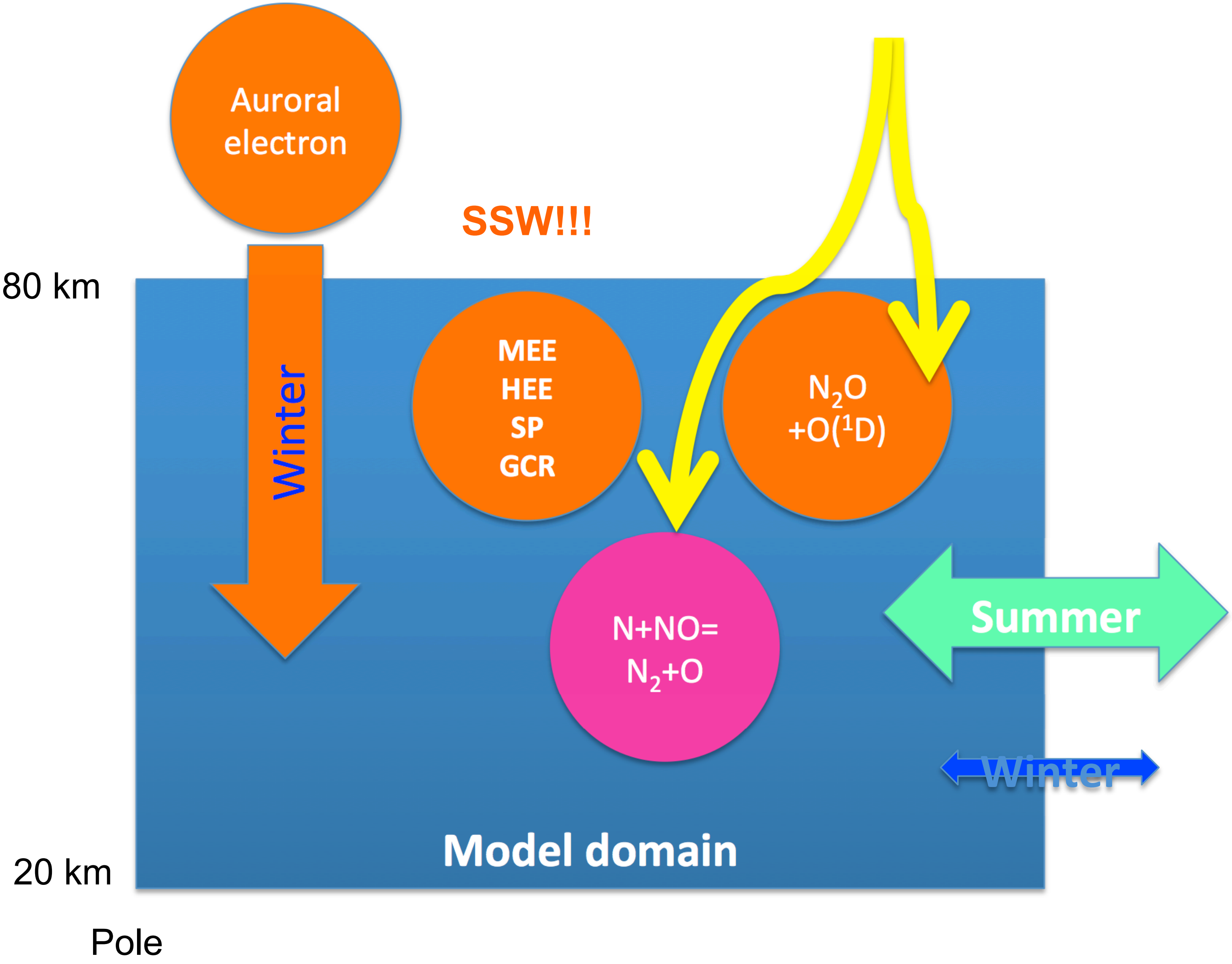
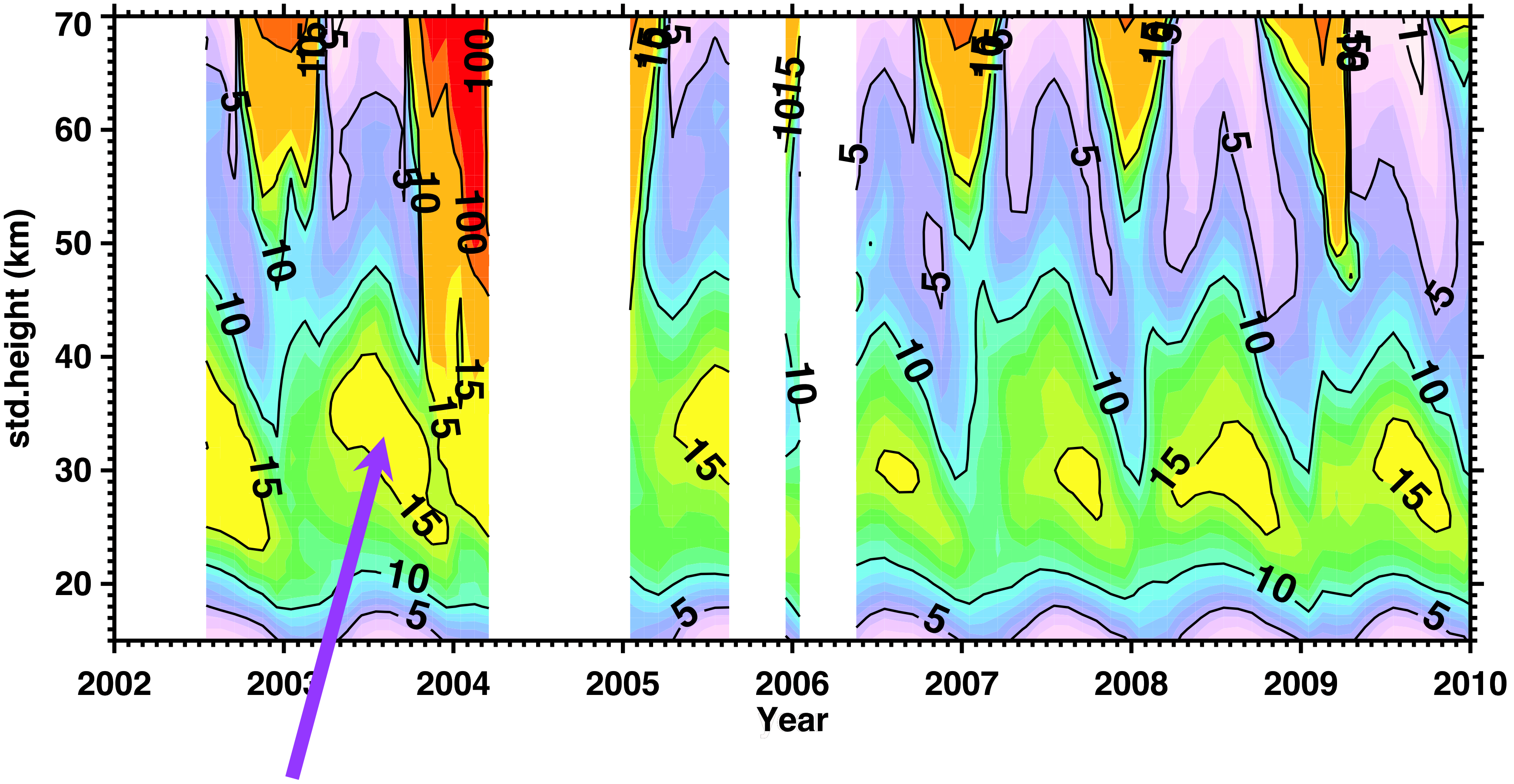
NO_y in the polar middle atmosphere



NO_y in the polar middle atmosphere
MIPAS, 60º-90º North

MEE

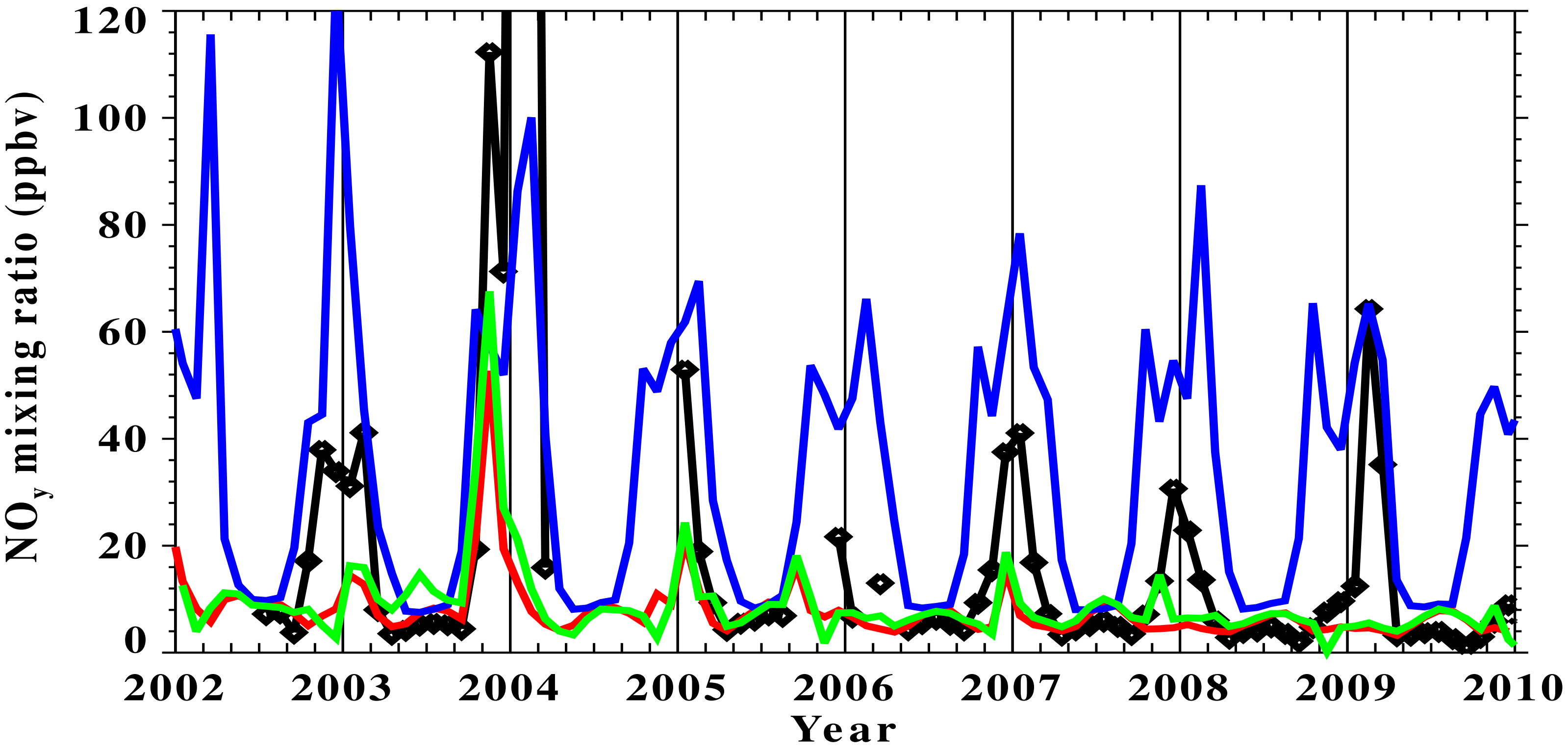
AE+SSW



Meridional transport

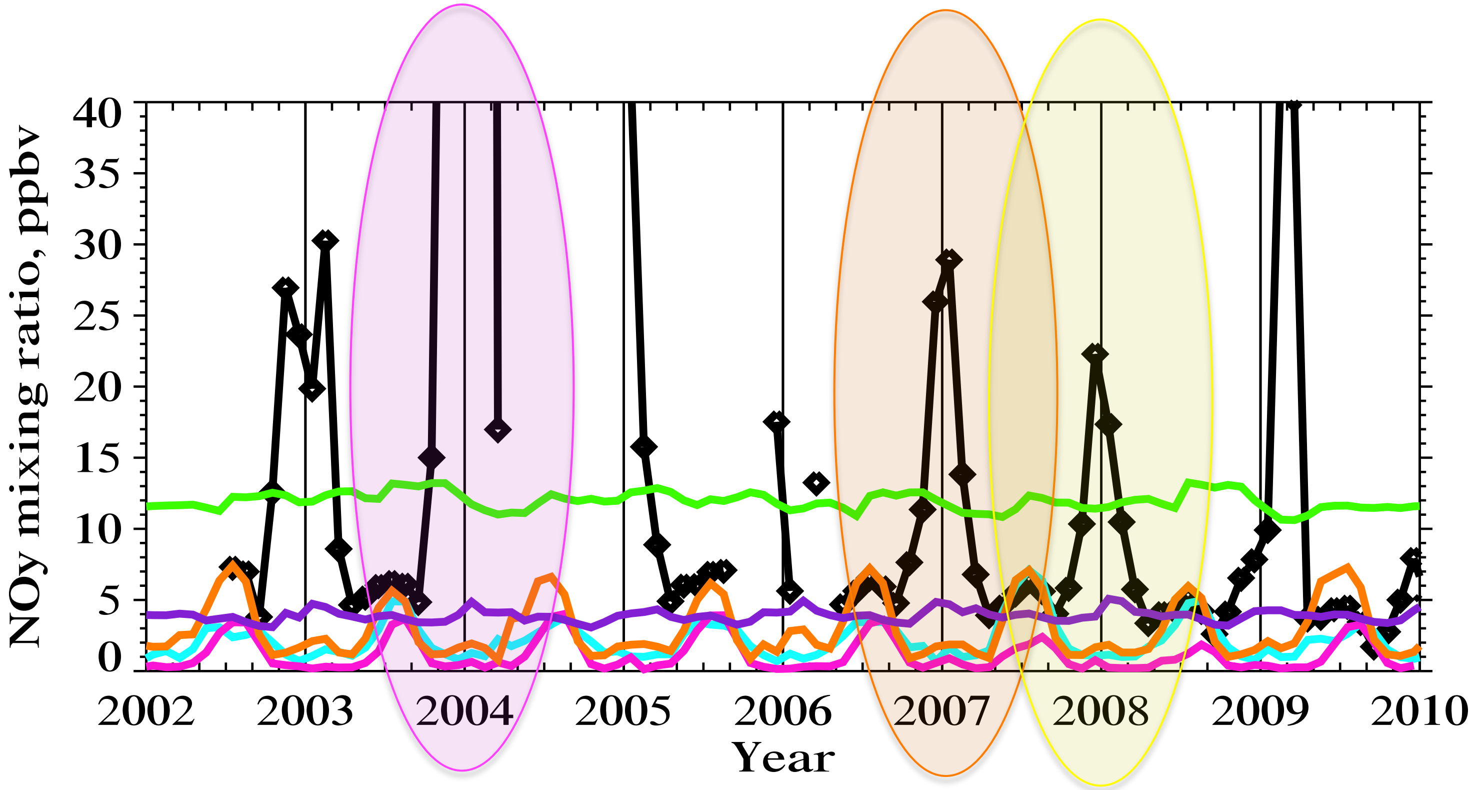
MIPAS data provided by B. Funke

NO_y at 60 km
MIPAS+models 60°-90° North



MIPAS SOCOL3: AE+SPE AE+SPE+MEE AE+SPE+MIPAS Assimilation

NO$_y$ at 60 km
MIPAS+models 60°-90° North



SLIMCAT GEOSCCM HADGEM3 IPSL CCSRNIES

MIPAS data provided by B. Funke

NO_y in the polar middle atmosphere

1. **Models significantly underestimate NO_y in the polar middle atmosphere;**

2. **Proper treatment of thermospheric sources are necessary (high top models, assimilation of MIPAS data)**

End