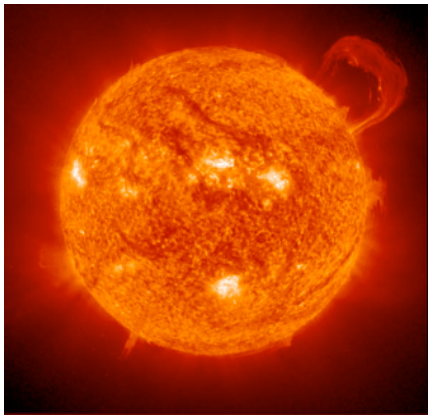
Improvements in Coupled Ocean-Atmosphere Model Responses to Solar Activity



Gavin Schmidt, David Rind, Susanne E. Bauer,
Marvin A. Geller, Drew T. Shindell, Tiehan Zhou

Potential Mechanisms

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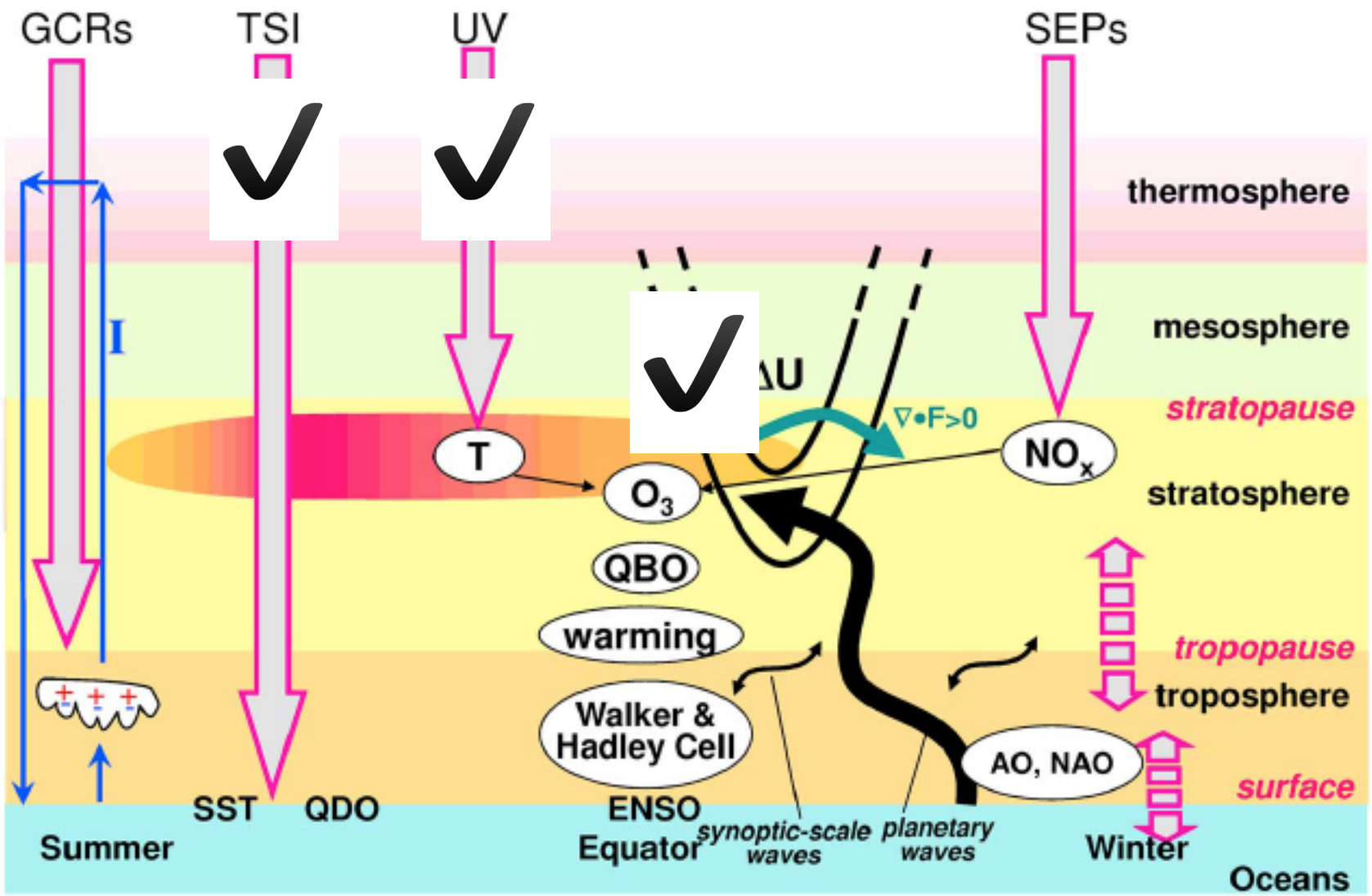
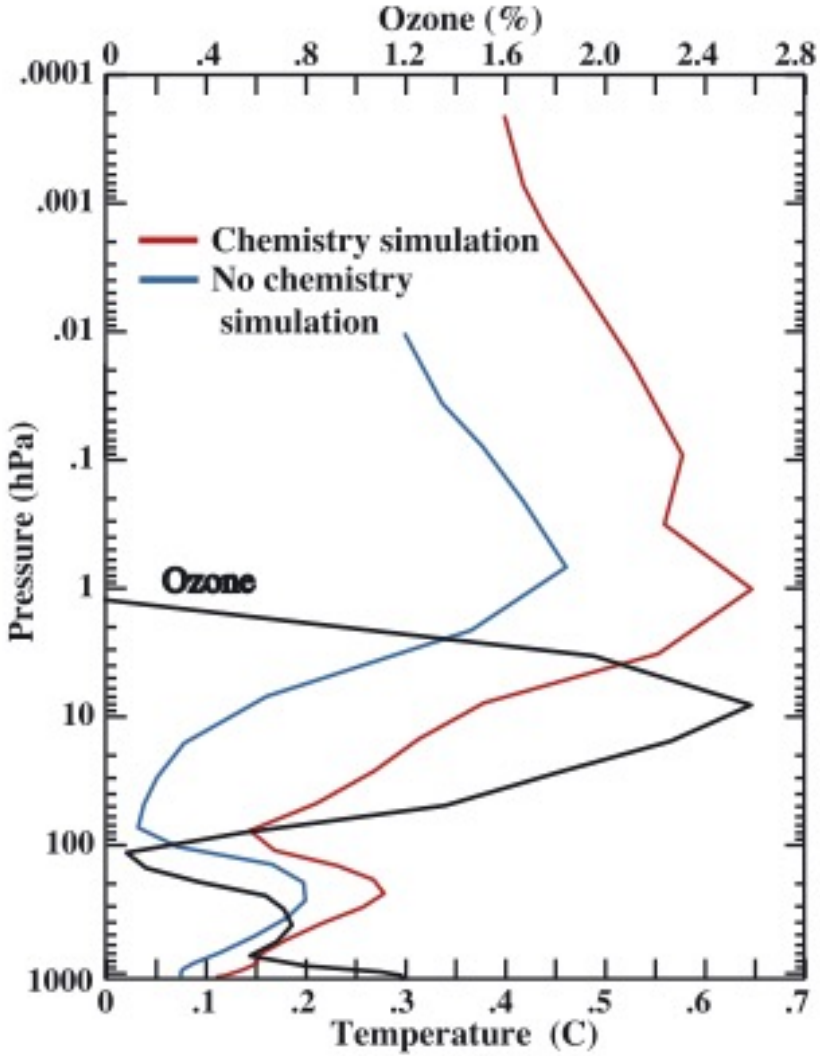
Space Studies

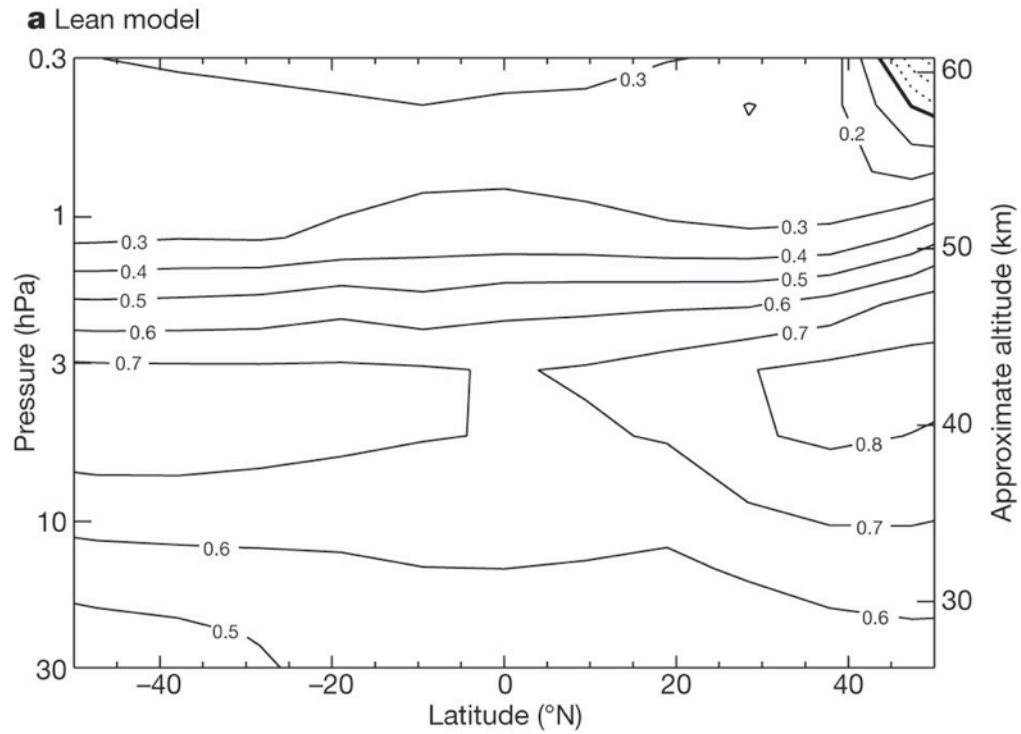


Gray et al, 2010

Previous modelling (Solar max to min)



Shindell et al , 2006



Haigh et al., 2011

Goddard Institute for Space Studies

GISS modelling of solar impacts

CMIP5: interactive, OAGCM 20th C transients

- **NINT**: non-interactive aerosols/chemistry (~AR4)
- **TCADI**: Interactive all-atmosphere chemistry (bulk aerosols) + first indirect effect
- 5 member ensembles
- two ocean models (**GISS-E2-R** & **GISS-E2-H**)
- All-forcings + solar-only + ozone only

TCADI/MATRIX (aerosol moment scheme)

- Includes nucleation/ionisation

Forcing:

- 20th C: Spectral: Lean (2009) TSI: Wang et al. (2005)

Potential Mechanisms - CMIP5

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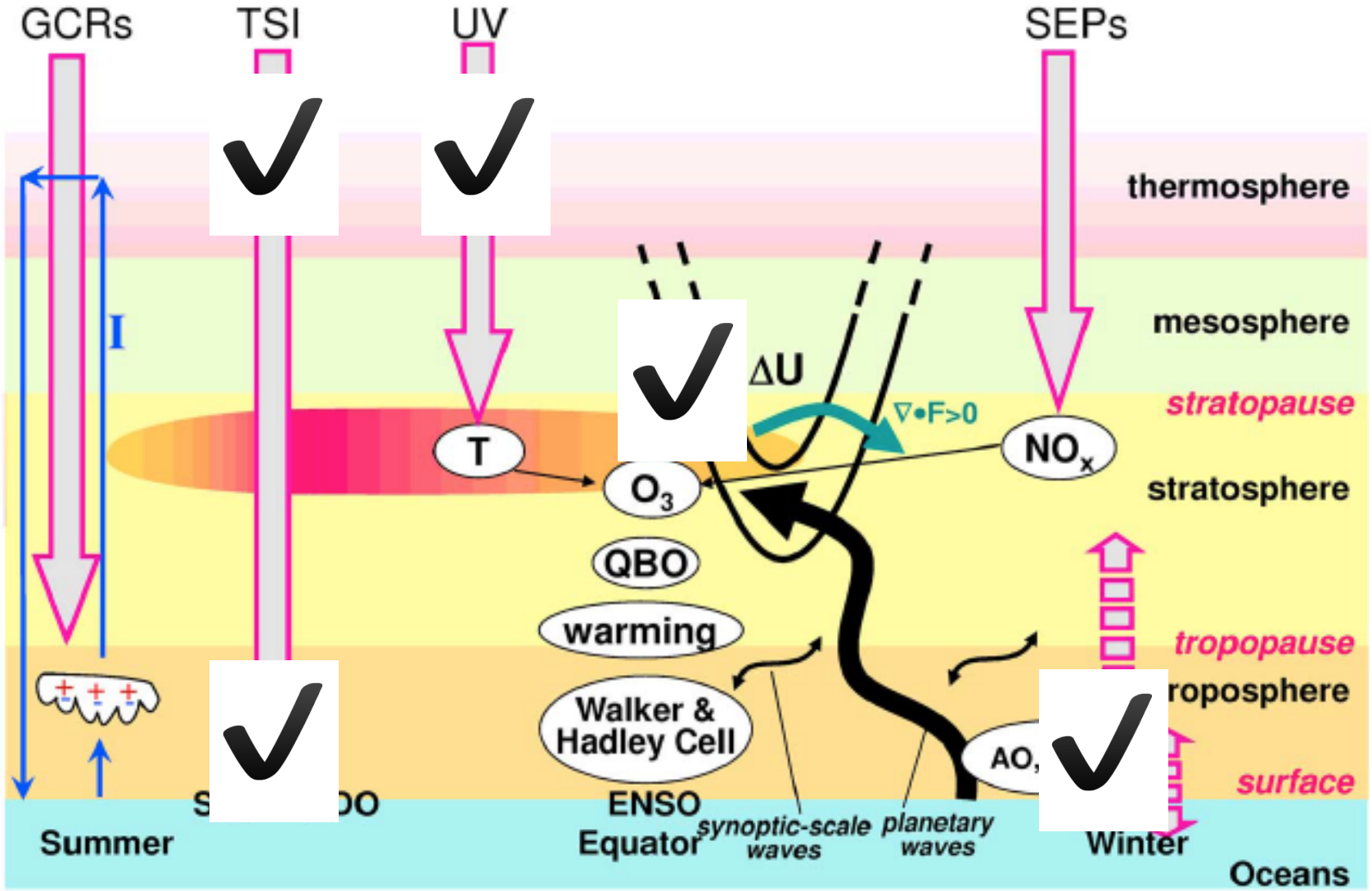
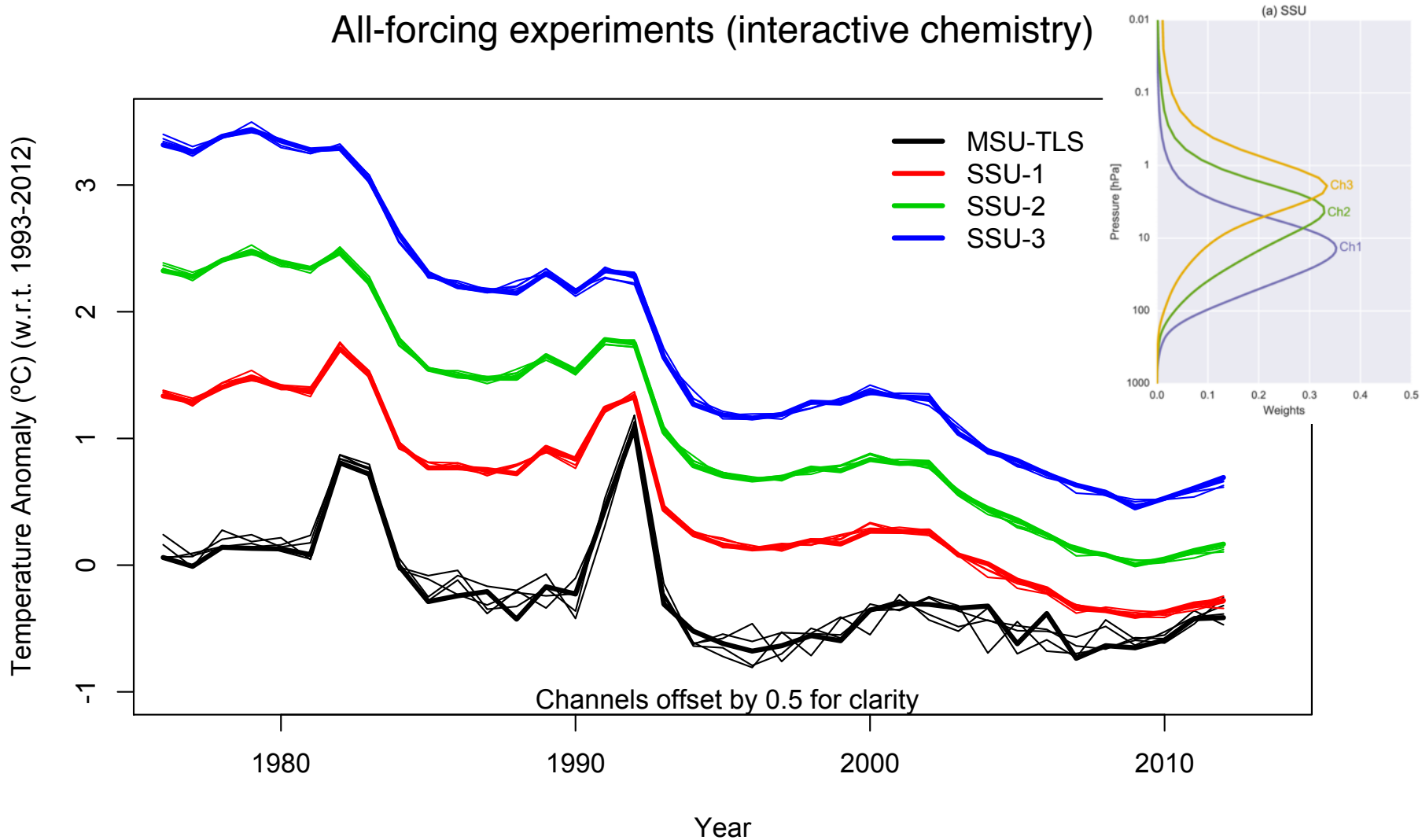


Gray et al, 2010

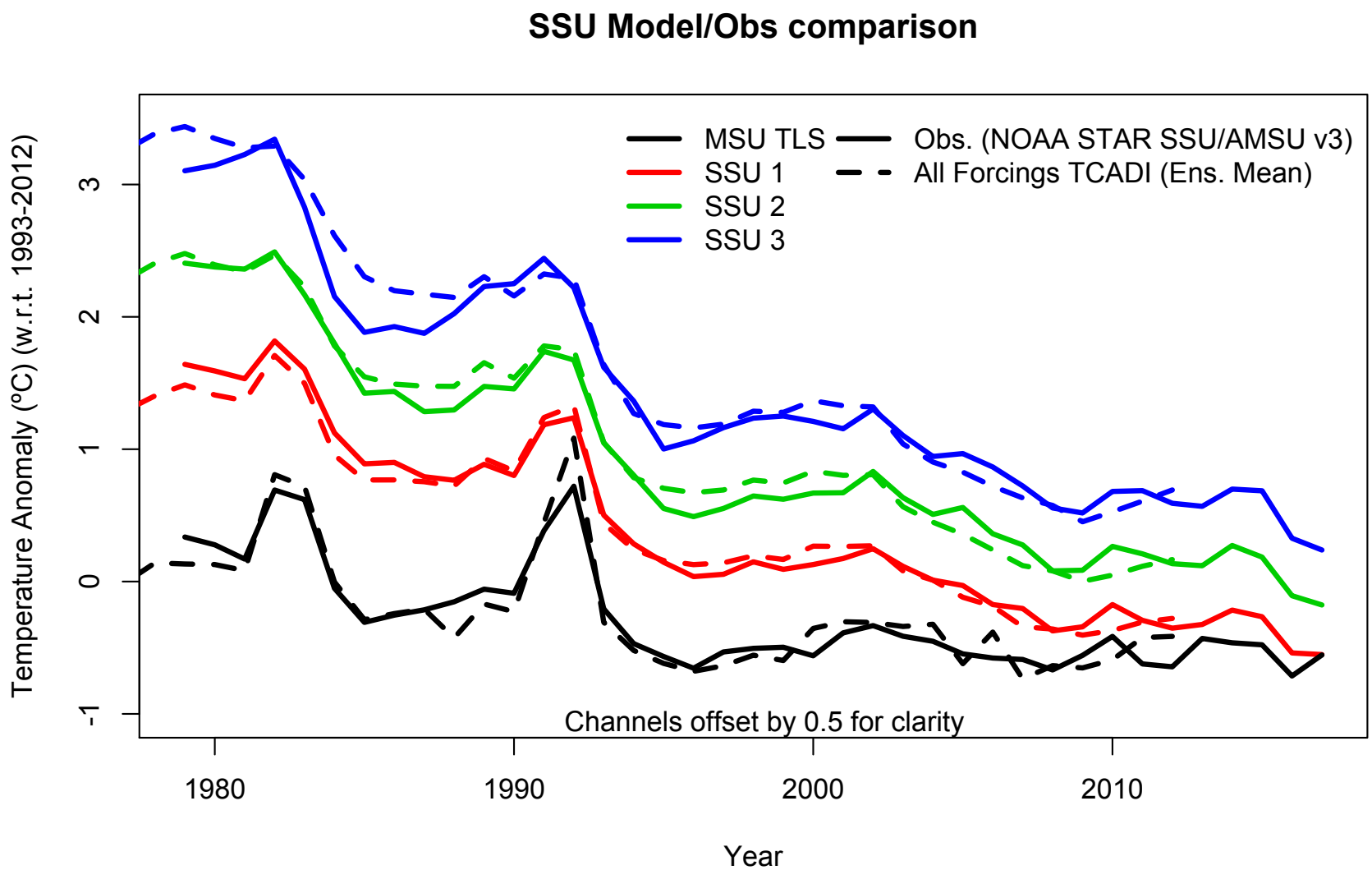
Stratospheric time-series (SSU+TLS)

Goddard Institute for
Space Studies



Stratospheric time-series (SSU+TLS)

Goddard Institute for
Space Studies



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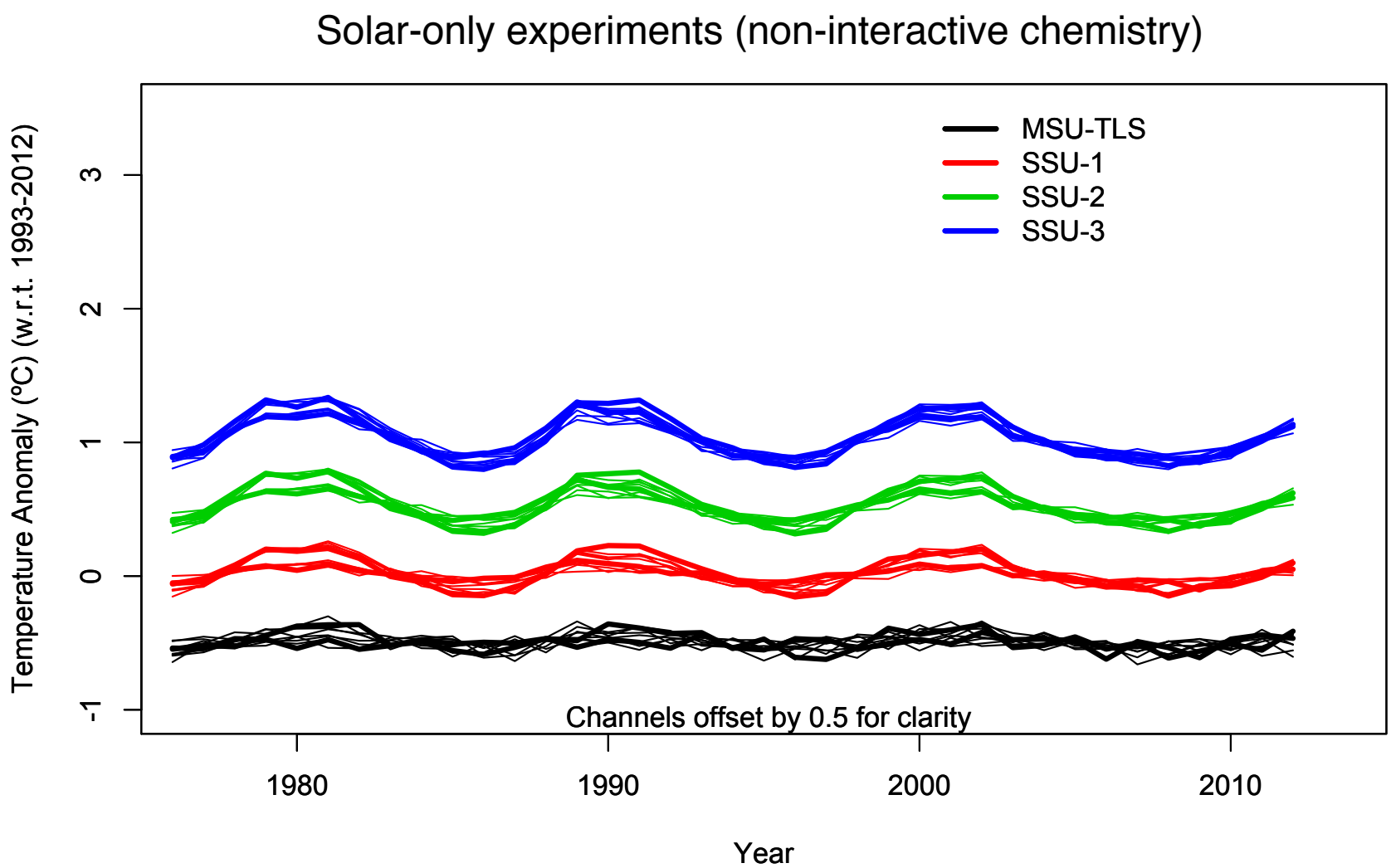
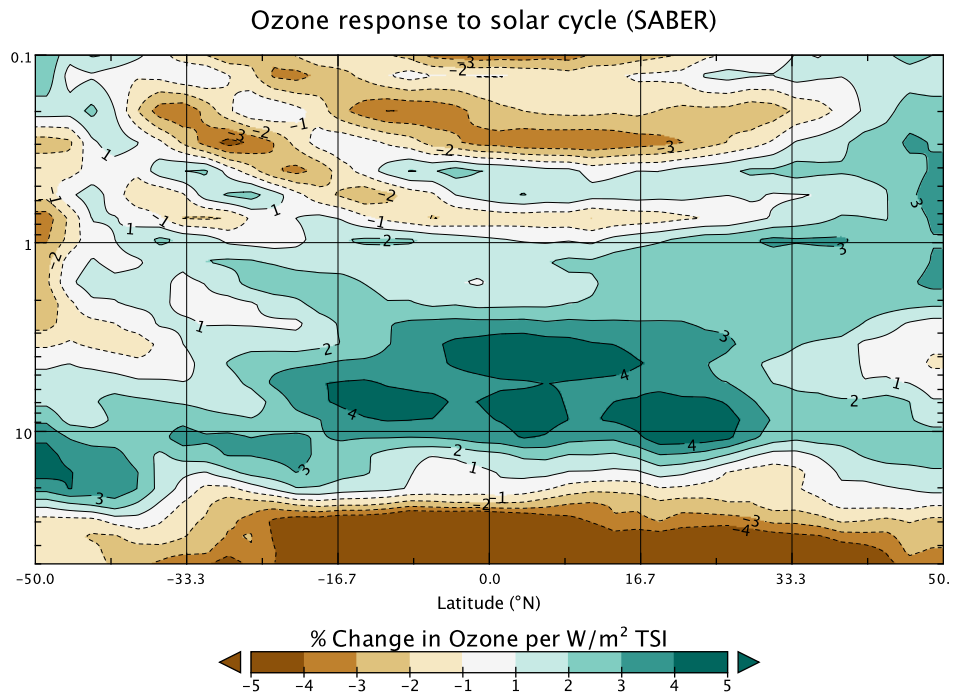
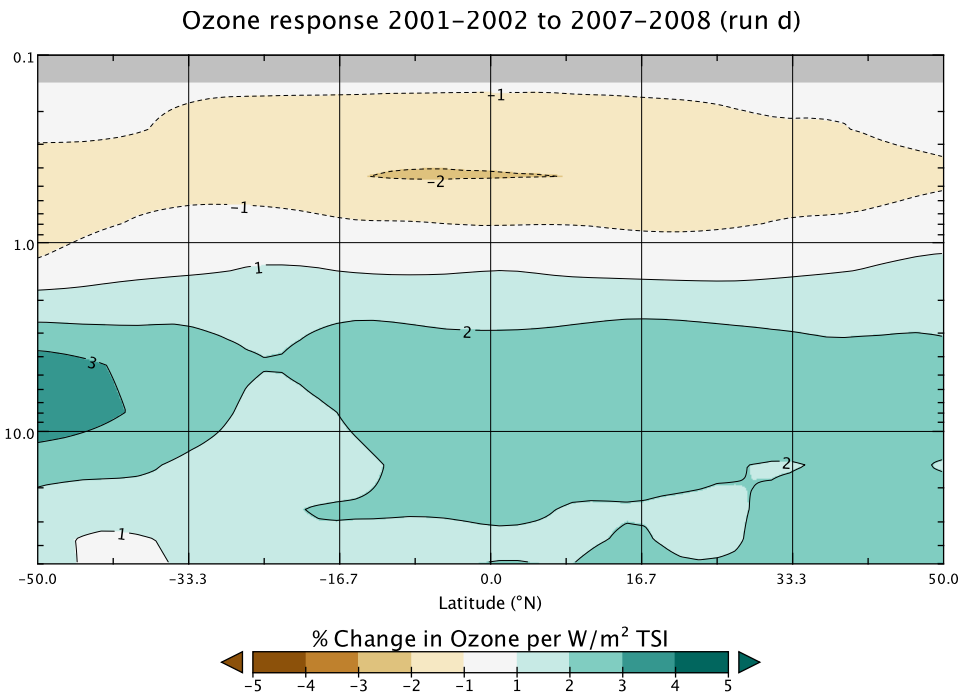
Stratospheric time-series (SSU+TLS)



Ozone solar cycle response

Goddard Institute for Space Studies





SABER: Merkel et al. (2011)
(One cycle: 2002/3 - 2008/9)

Model: single ensemble member
(2001/2 - 2007/8)

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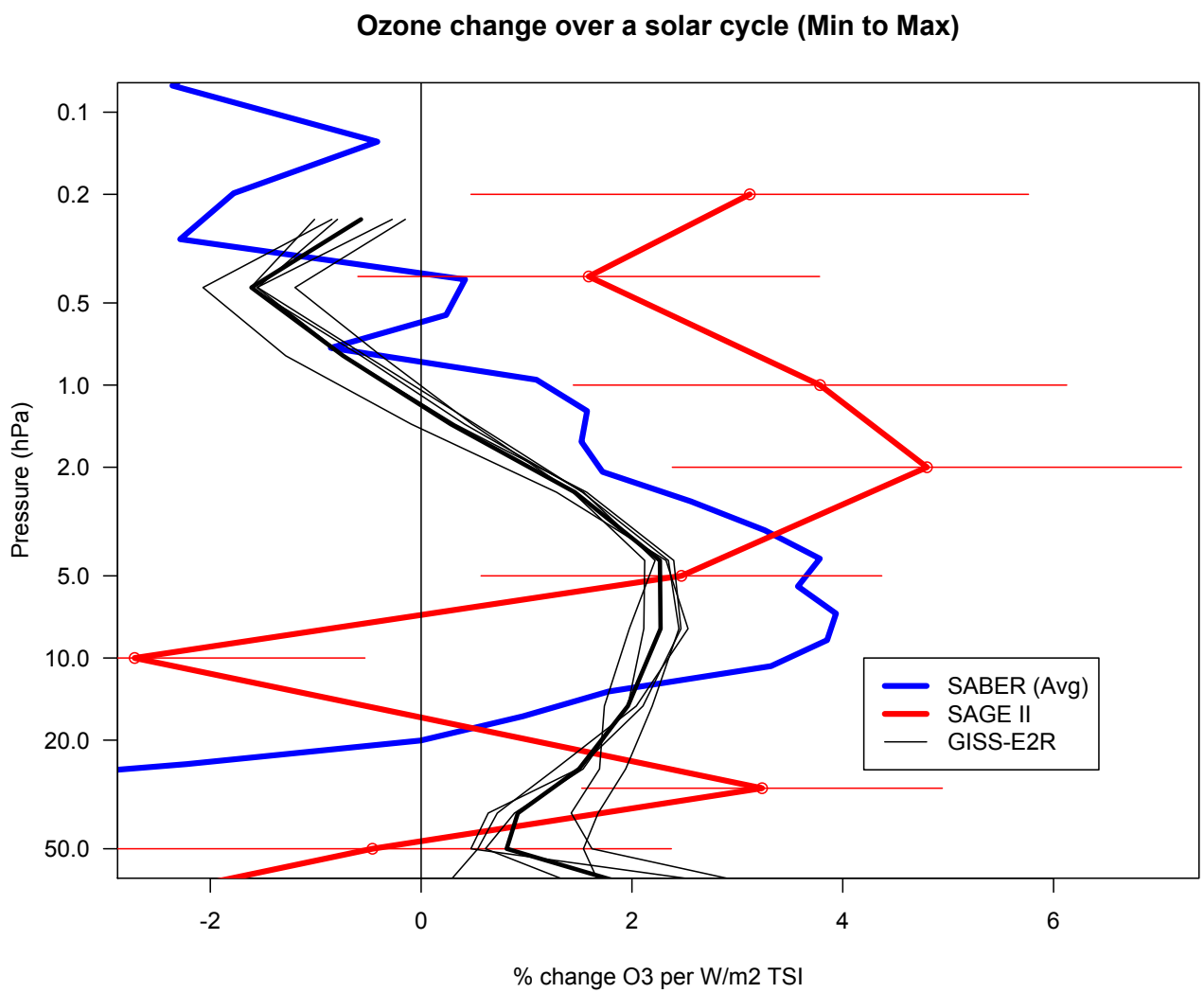
Stratospheric profile of ozone changes



Solar-only regression (~70 cycles)

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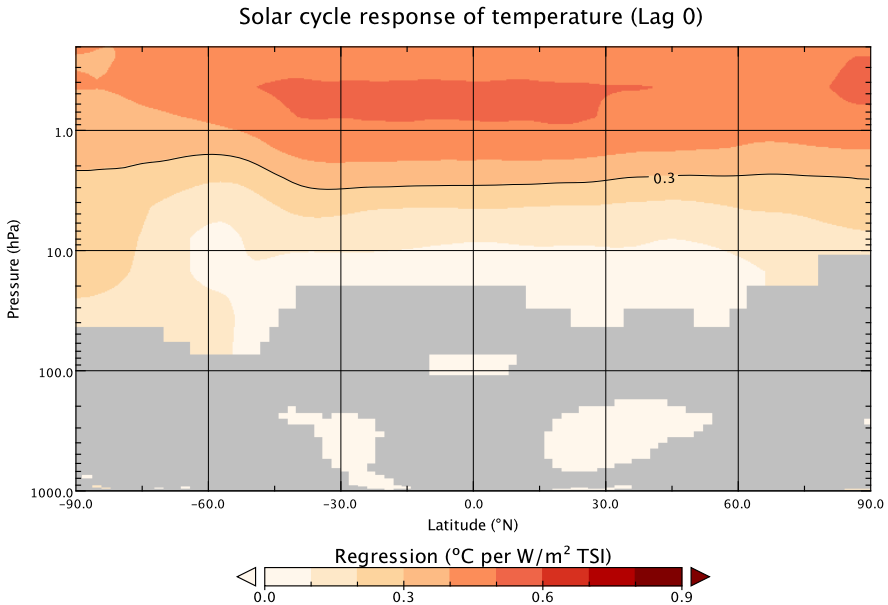

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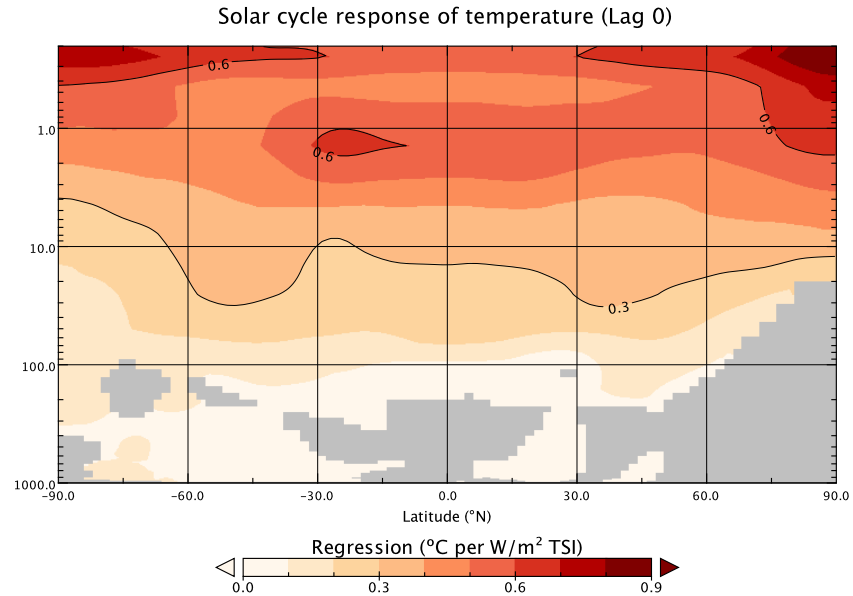

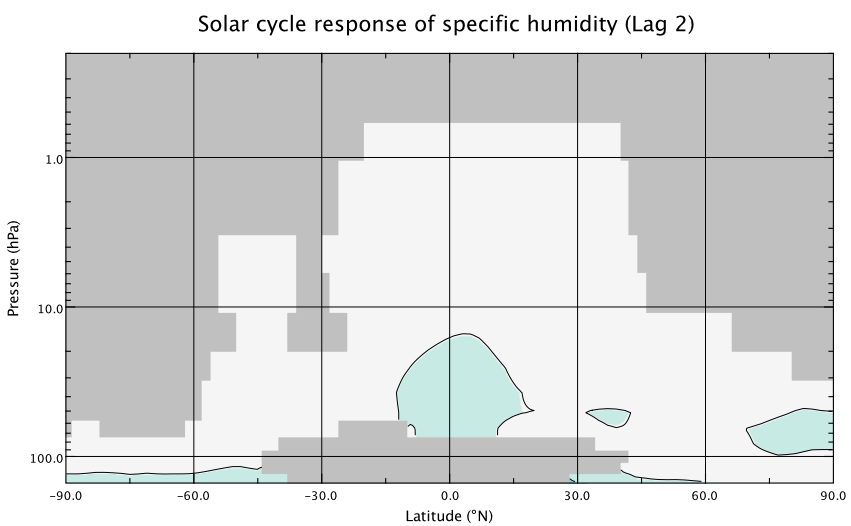

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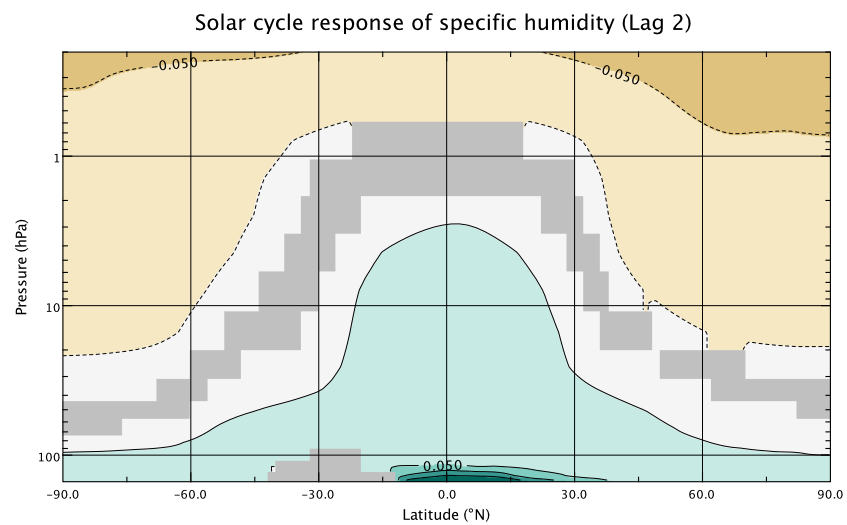
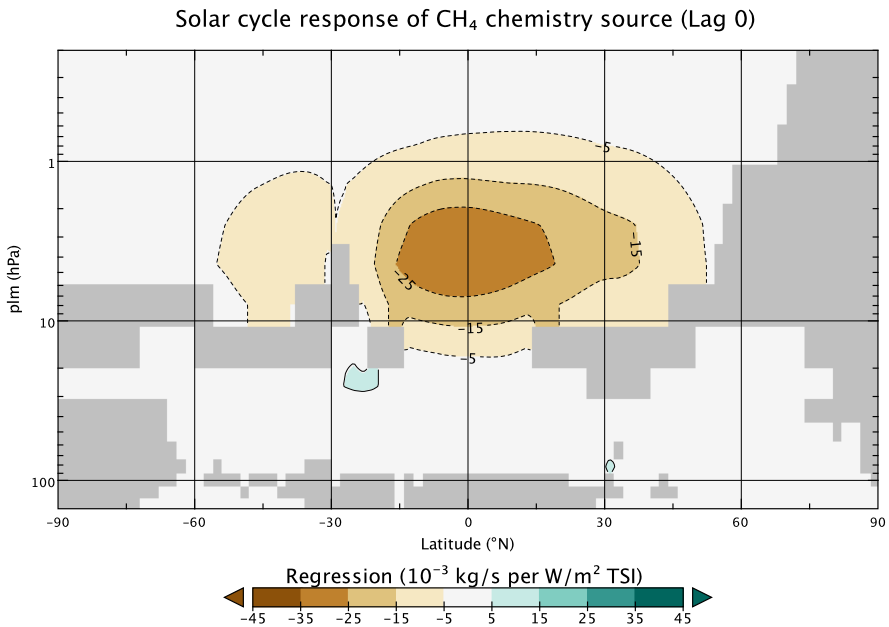
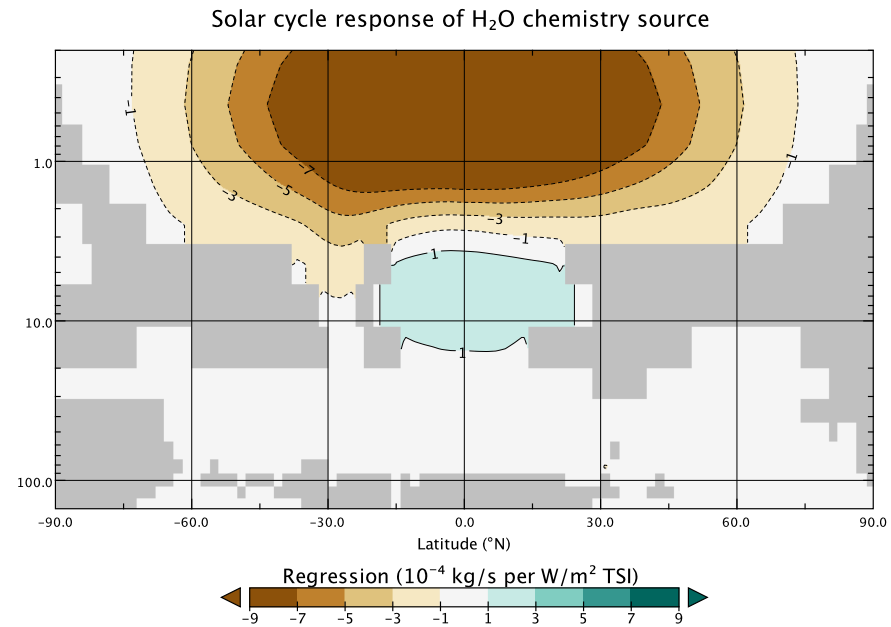


TCADI Chemical impacts

Goddard Institute for Space Studies





O_3 response photochemical and dynamic - strat & trop

=> increase of CH_4 oxidation

& photolytic reduction in upper strat H_2O (~0.2 ppmv)

=> warms upper stratosphere

=> provides memory for longer term impact...

Trop. warms, increases trop H_2O and strat input

Global Mean Response

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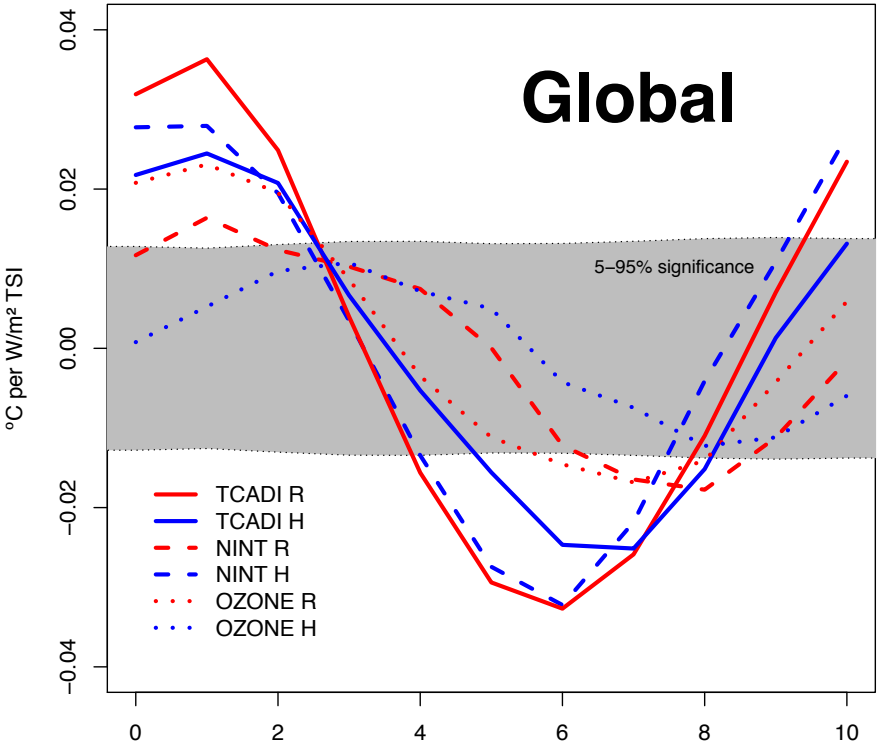
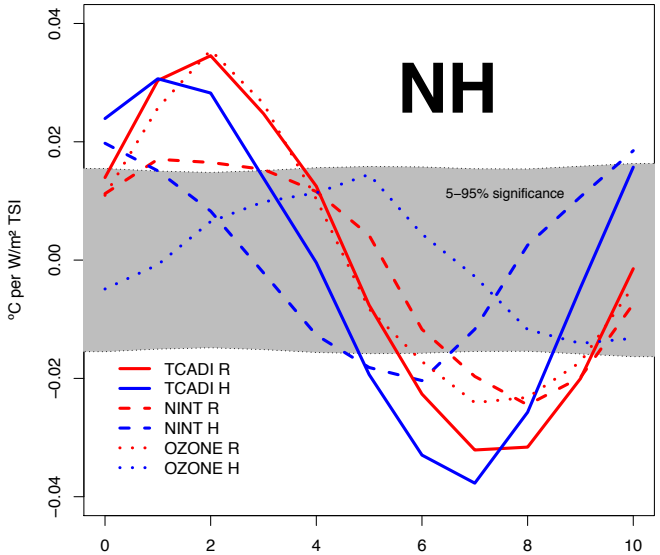
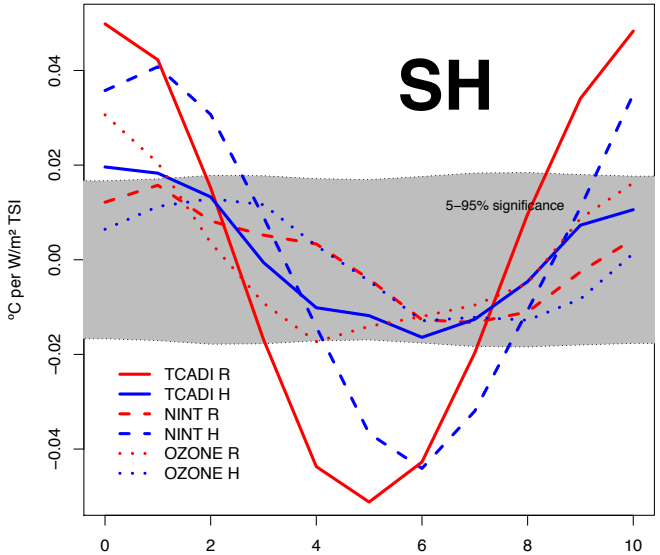
Space Studies



Lag to peak TSI





Surface Air Temperature

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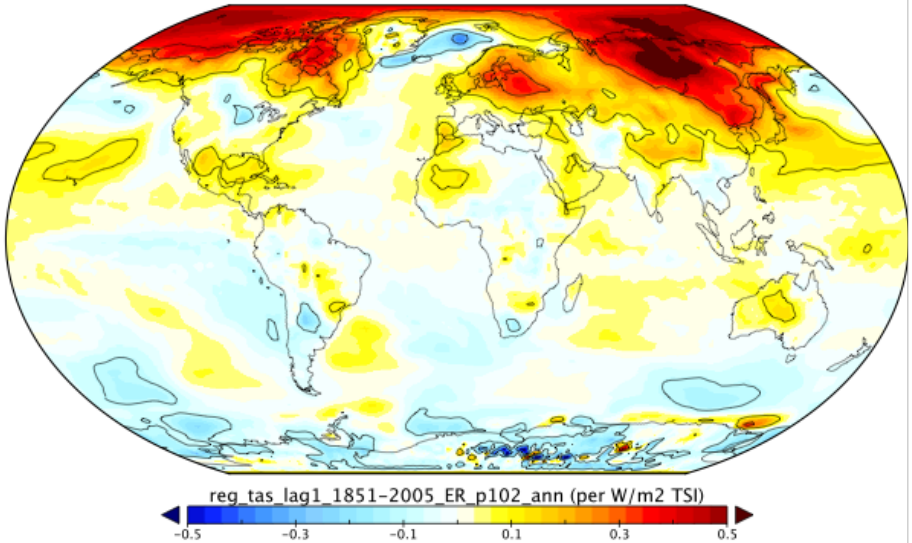
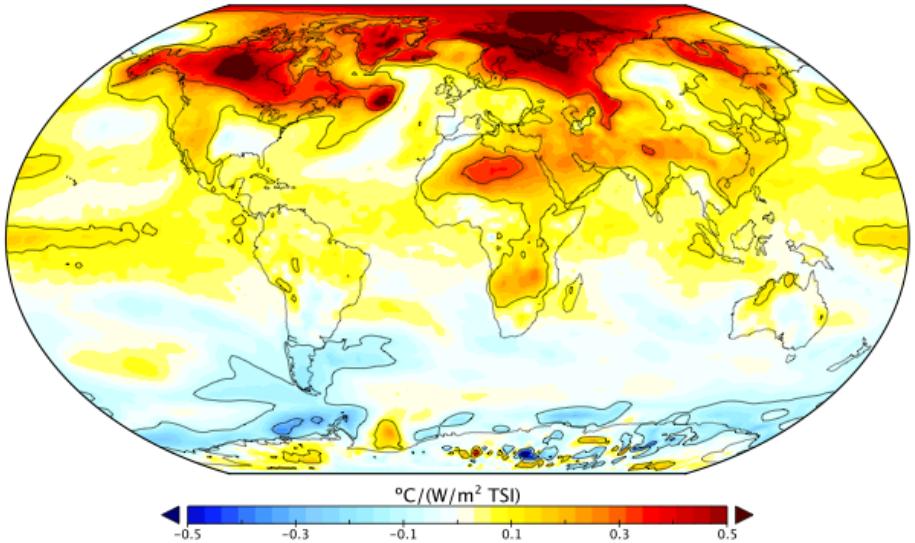
NINT-R: Lag 1



TCADI-R: Lag 1



Regression on SST ~0.1°C/(W/m^2 TSI)

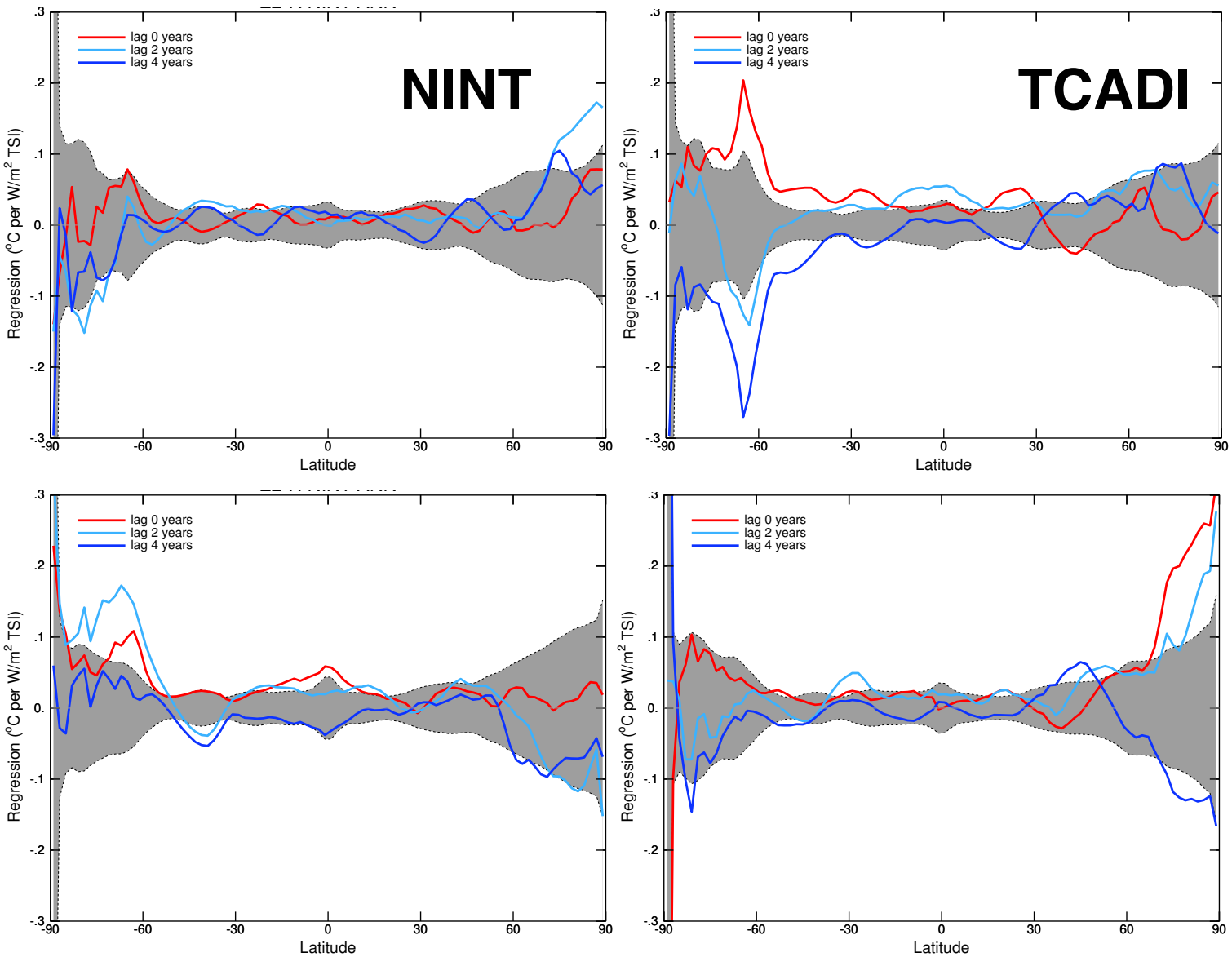
Obs: ~0.1°C over solar cycle
White et al (1997); Camp & Tung (2008)

Zonal T responses depend on ocean/lag

Goddard Institute for Space Studies

GISS-E2R

GISS-E2H



Annular mode responses are complex

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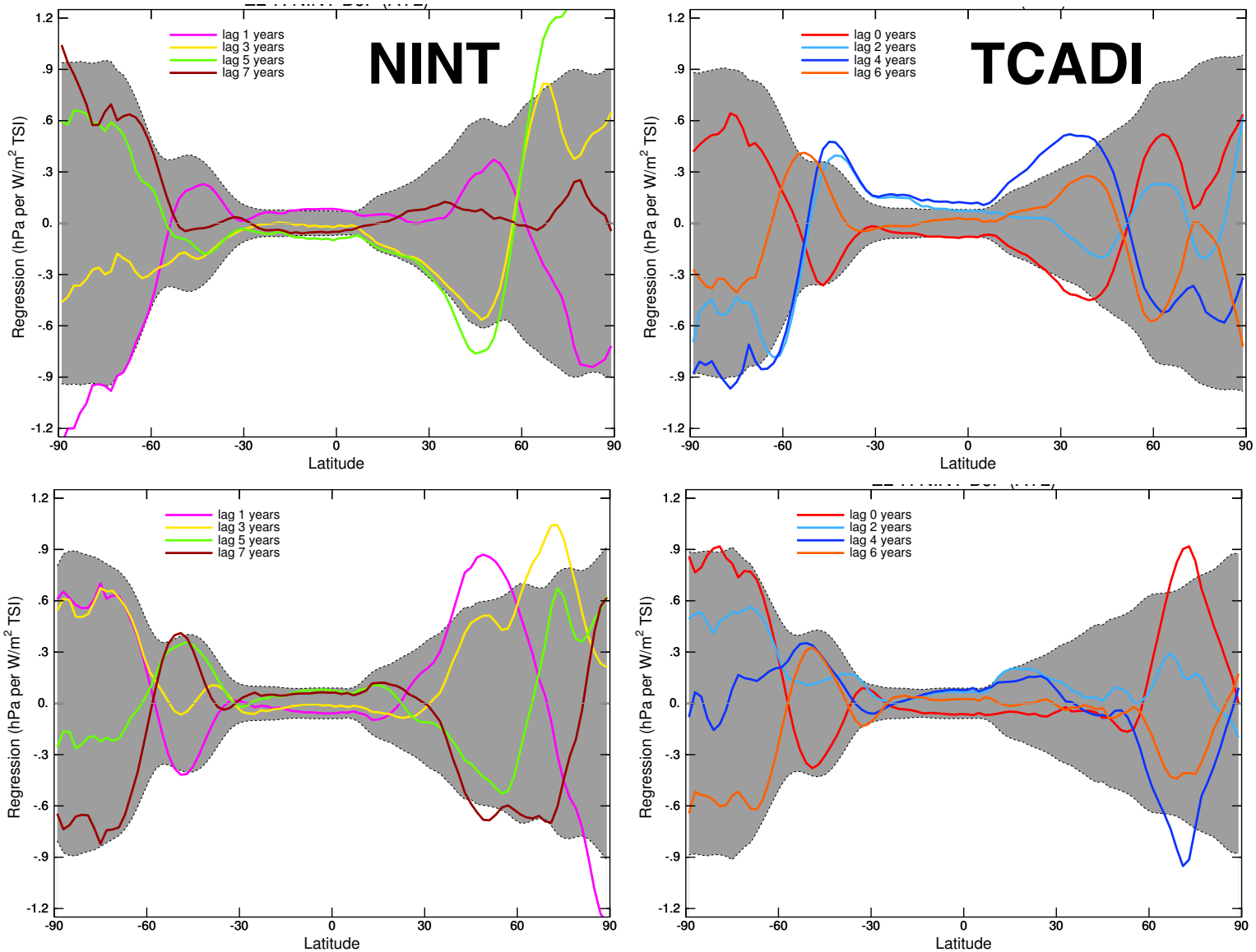
GISS-E2R

DJF

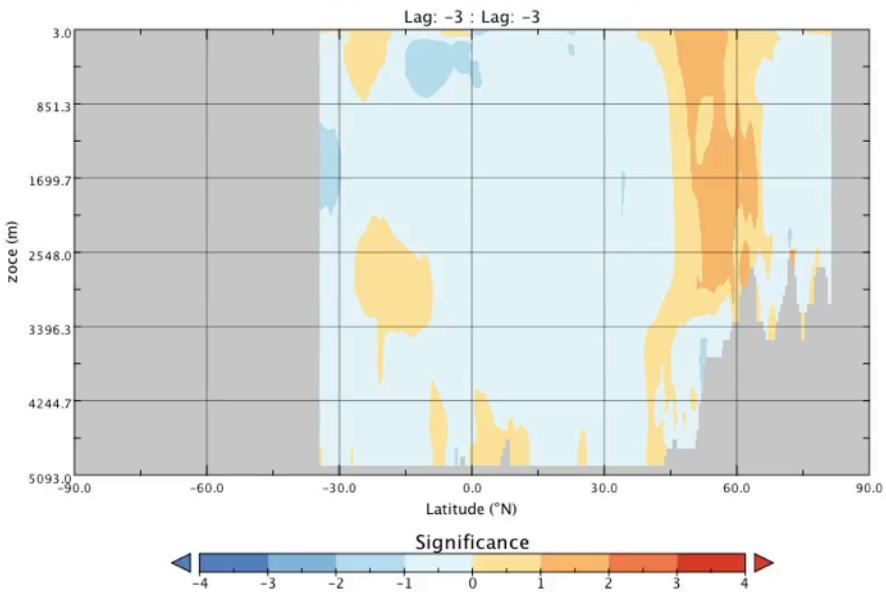
GISS-E2H



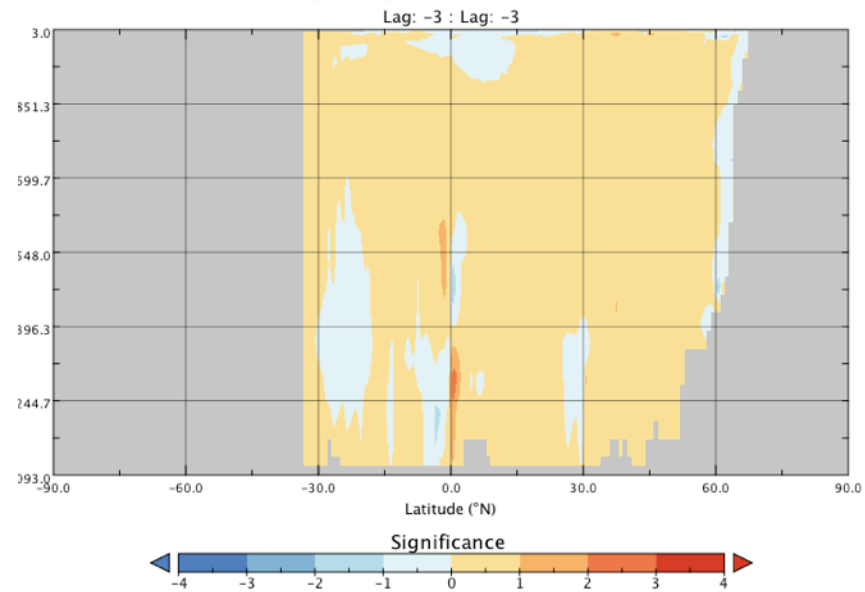
Impact on North Atlantic Ocean?

Goddard Institute for Space Studies

TCADI-R



TCADI-H



Lagged regression to TSI

± 0.5 Sv over a solar cycle

Max. +ve change 8-6 yr lag to TSI

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Summary of CMIP5 results

Clear enhancement of stratospheric 11yr signal w/ interactive chemistry

- Temperature over solar cycle ~ observations
- Hint of detectable humidity effect

Surface responses mixed and depend on ocean-atmosphere coupling and/or climatology

Annular modes sensitive but noisy

Some hint of an ocean circulation response (unlikely to be detectable)

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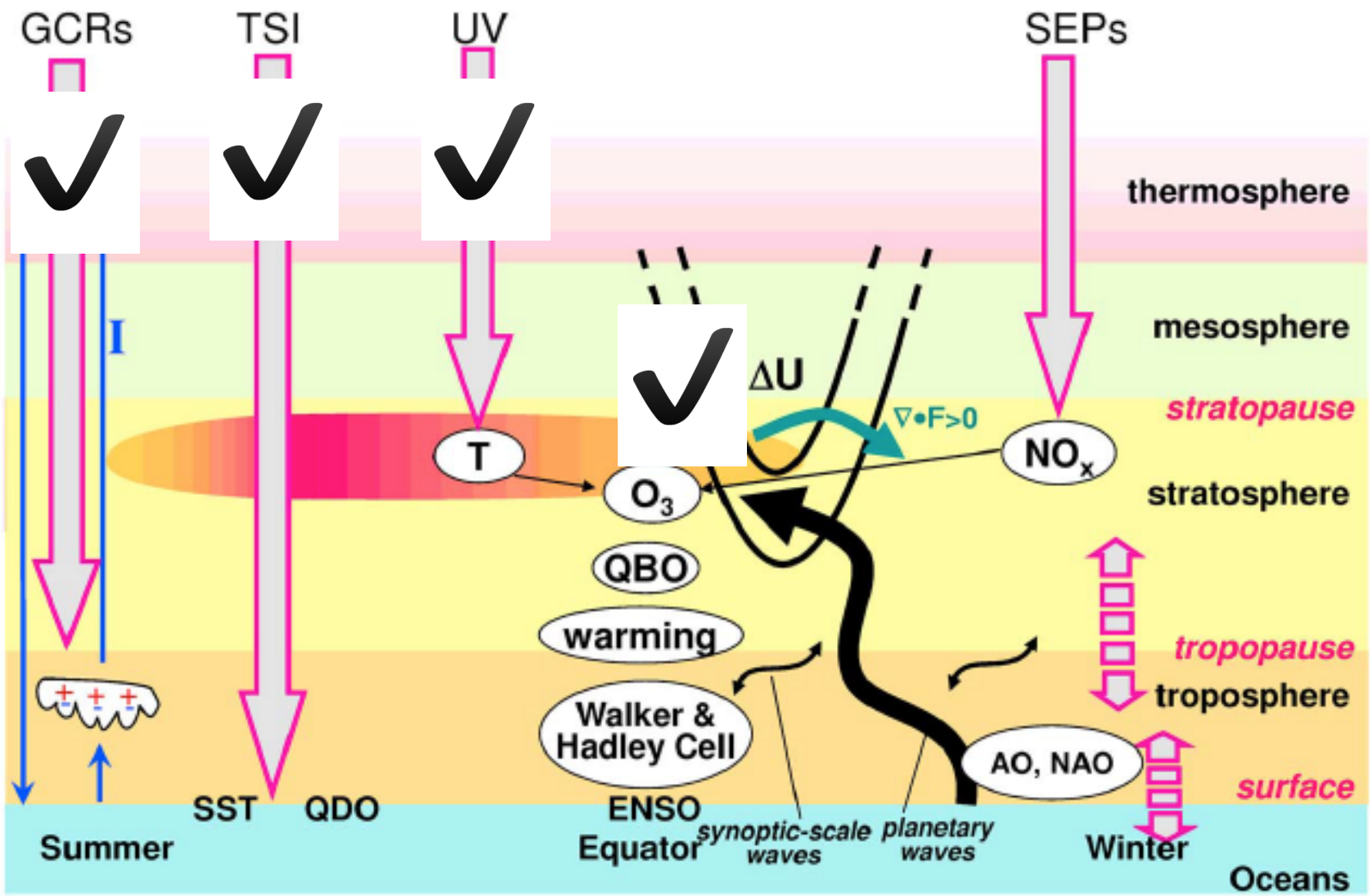
Potential Mechanisms - post-CMIP5



Gray et al, 2010

TCADI/MATRIX: Aerosol microphysics

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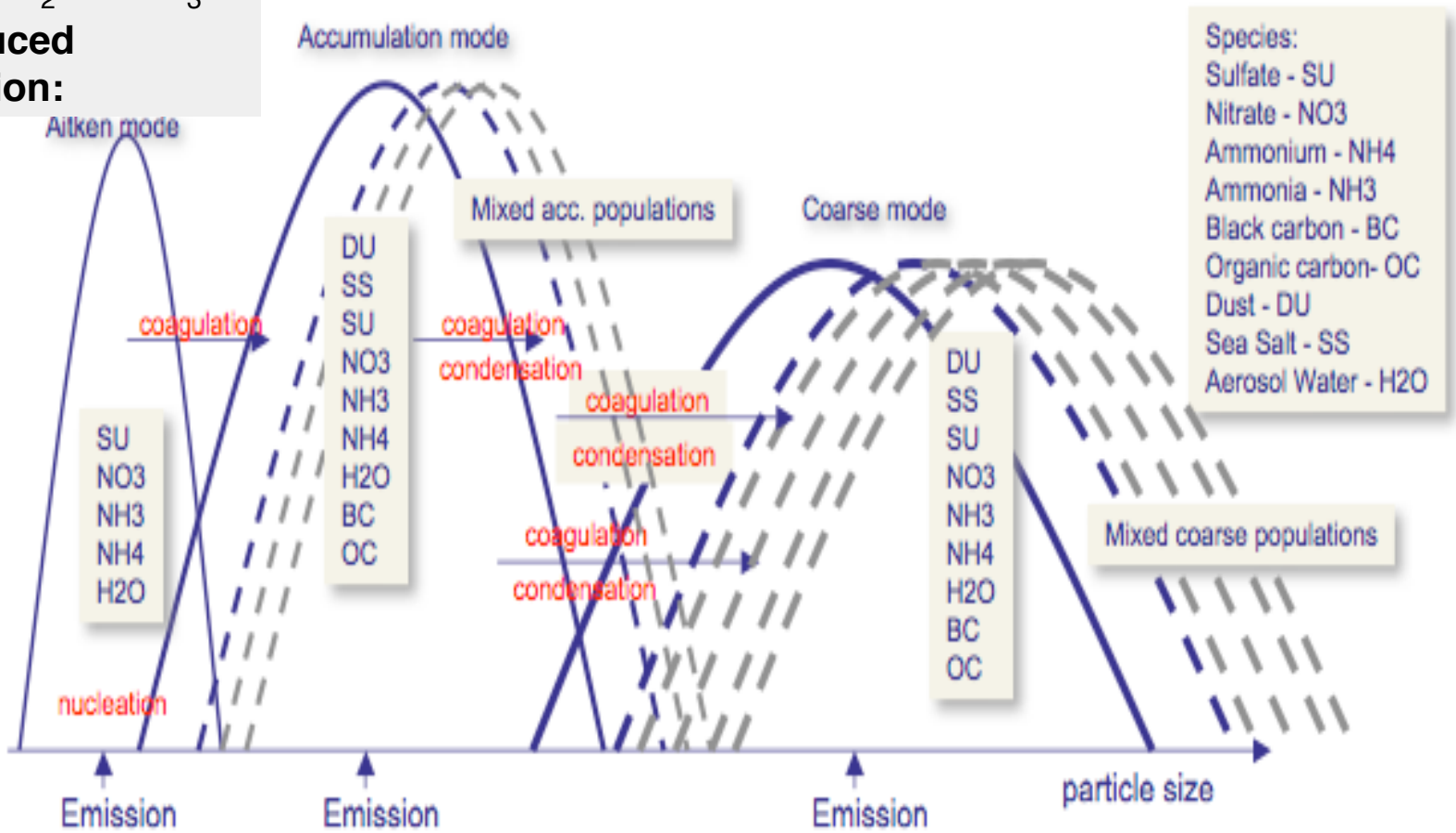
Ternary Nucleation:
$H_2SO_4 – H_2O – NH_3$
Ion induced nucleation:



Bauer et al., 2008, 2010, 2011

Production response to nucleation

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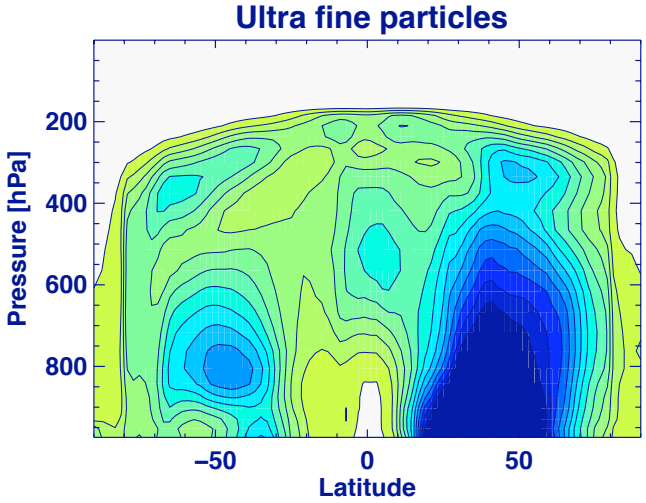
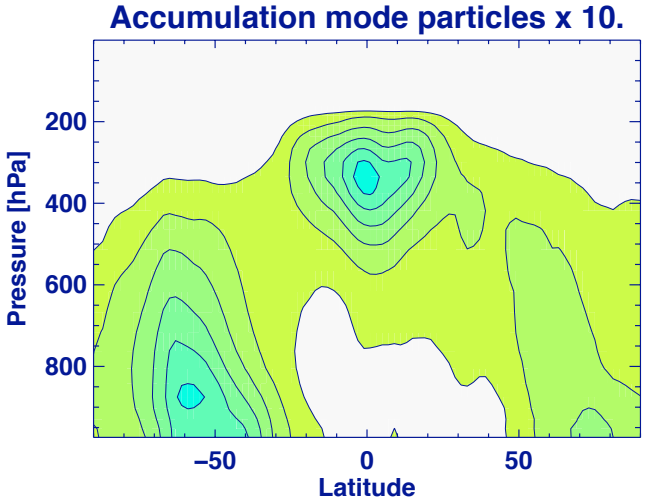
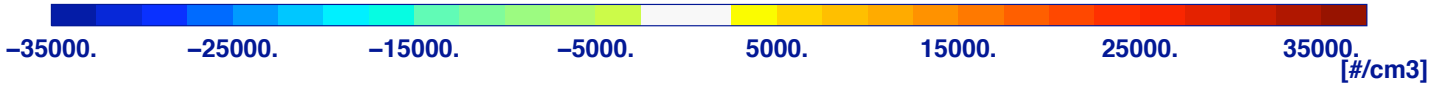




Impact of removing all nucleation



Nucleation: Homogenous vs. ion-induced

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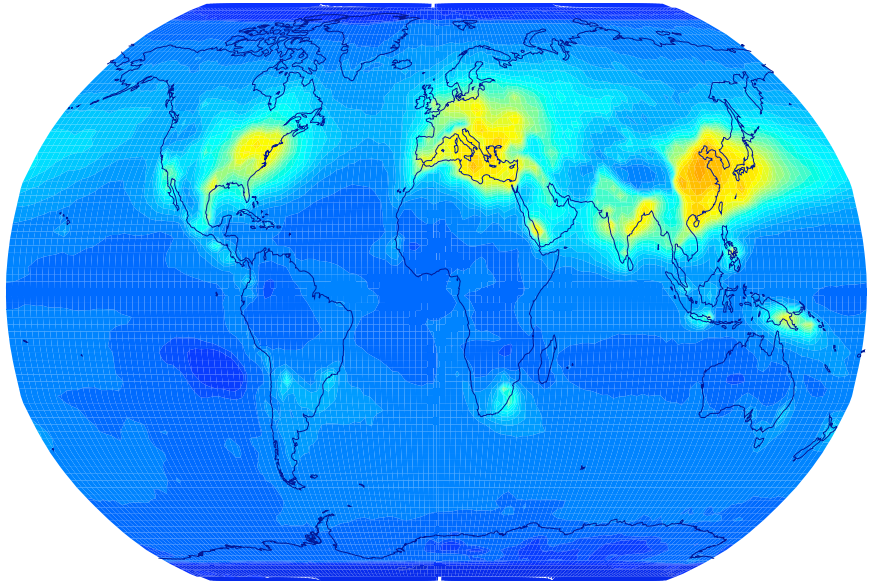
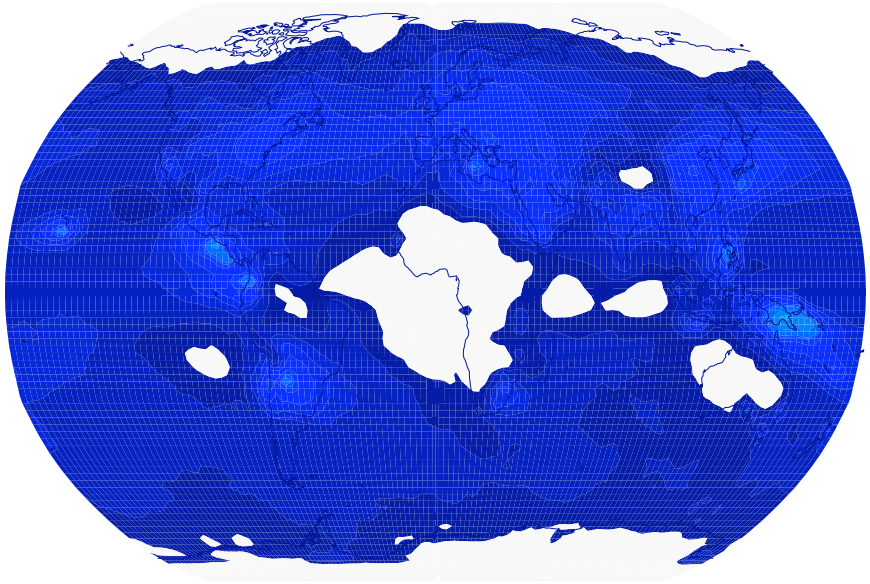
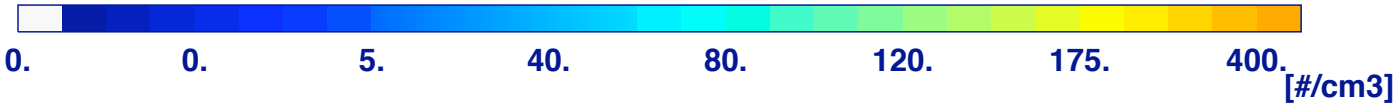
Total Nucleation Rates



Ion induced Nucleation Rates





Total Nucleation:	4.92×10^{26} #/a	6.5 $Tg(H_2SO_4)/yr$
Ion induced nucleation:	5.62×10^{24} #/a	0.069 $Tg(H_2SO_4)/yr$

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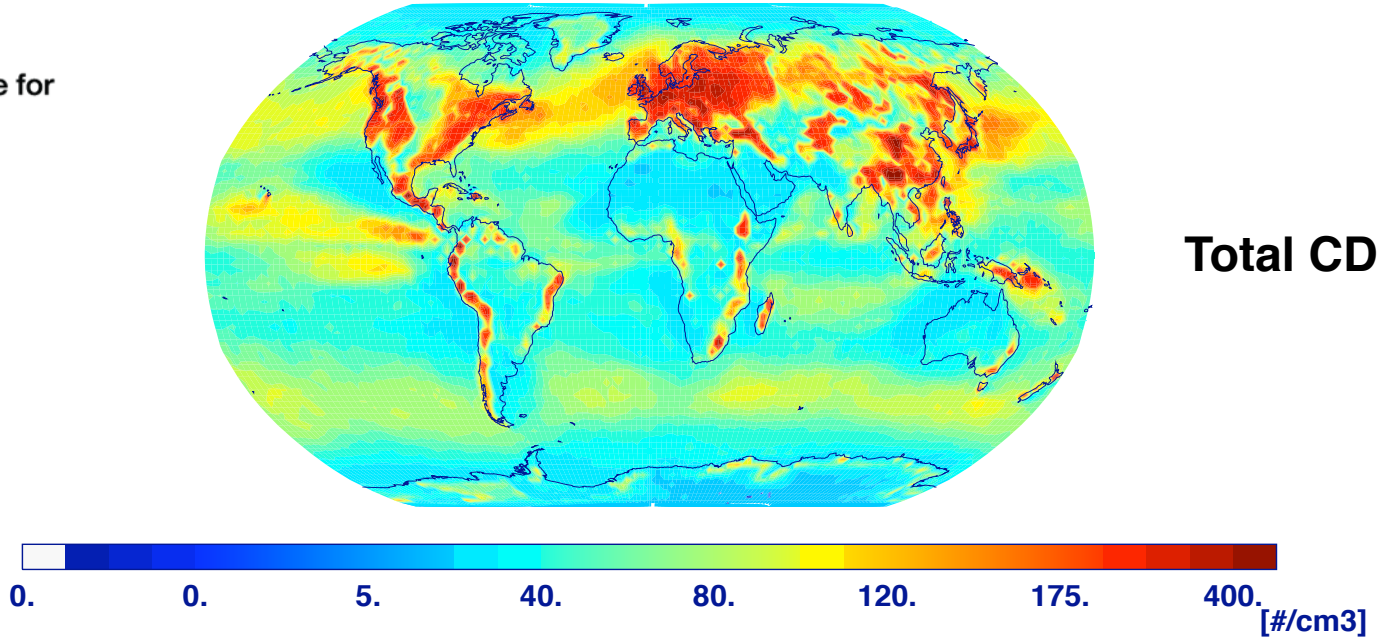
Impact on CDNC?



Total CDNC

Potential Mechanisms

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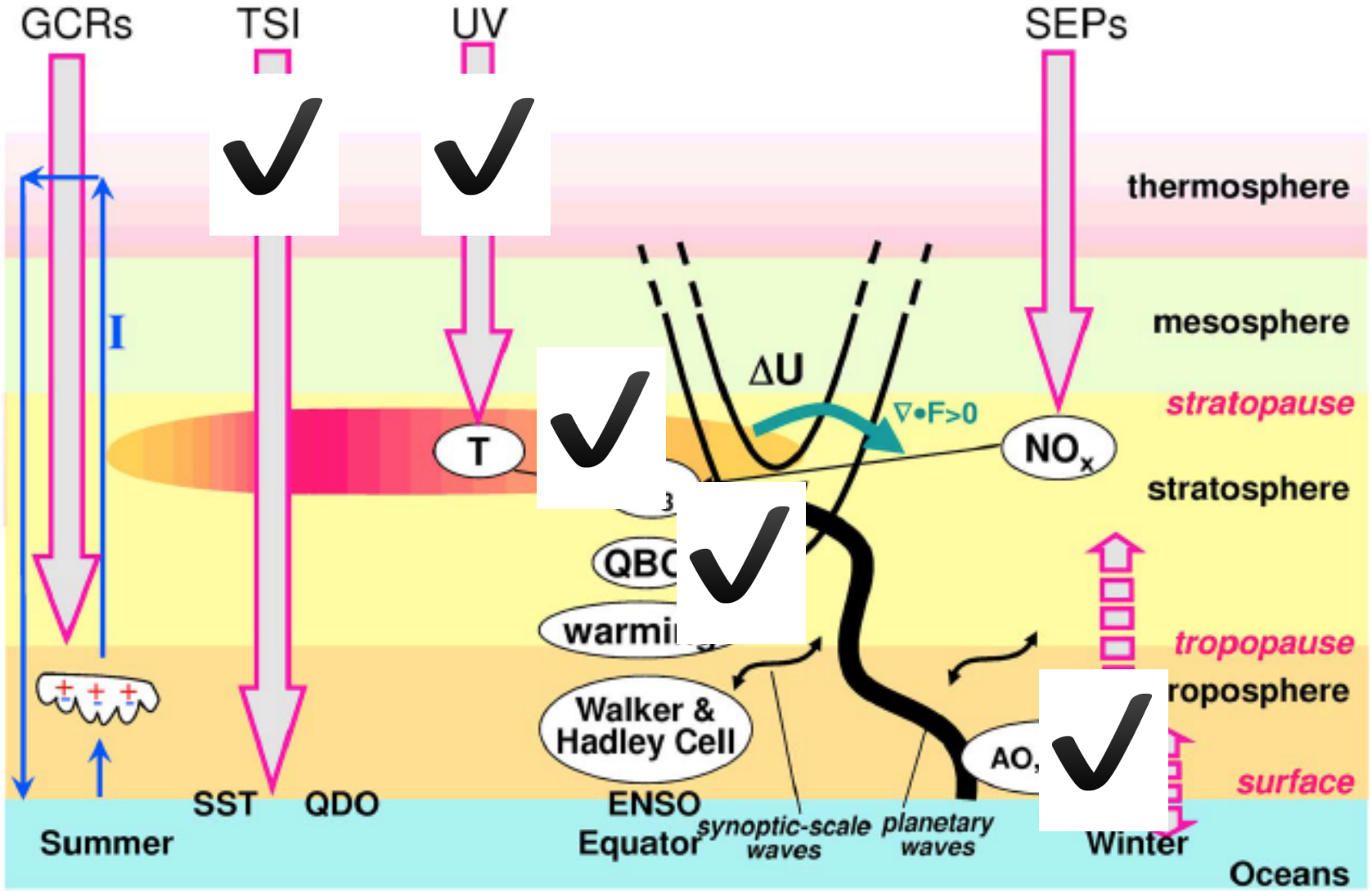
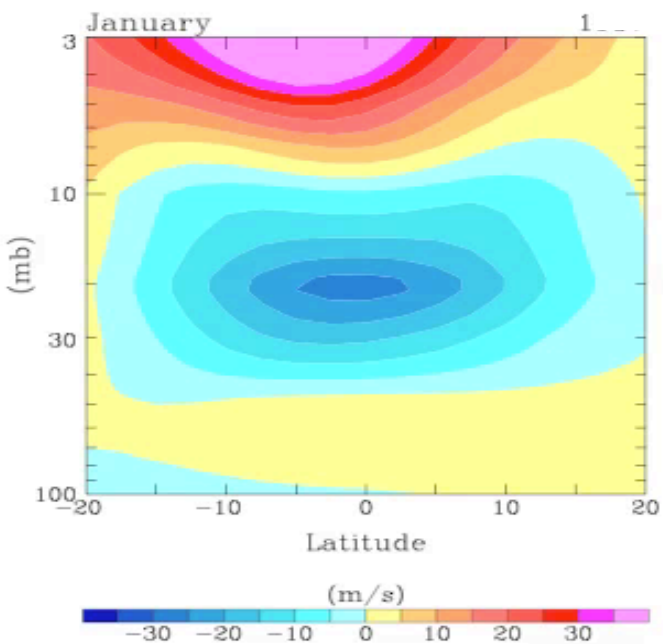


Gray et al, 2010

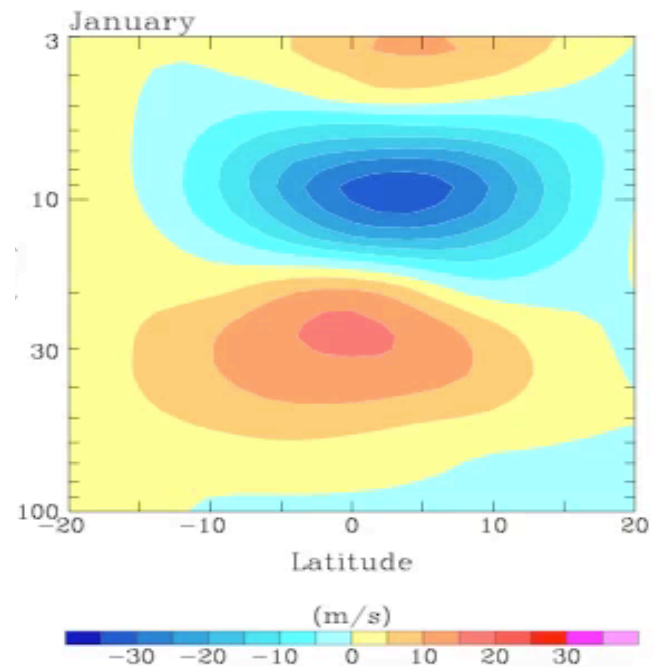
Self-generating stratospheric Quasi-Biennial Oscillation

Tropical winds in lower stratosphere

Observations



GISS Model



102 Layers + Model Top 0.002 hPa

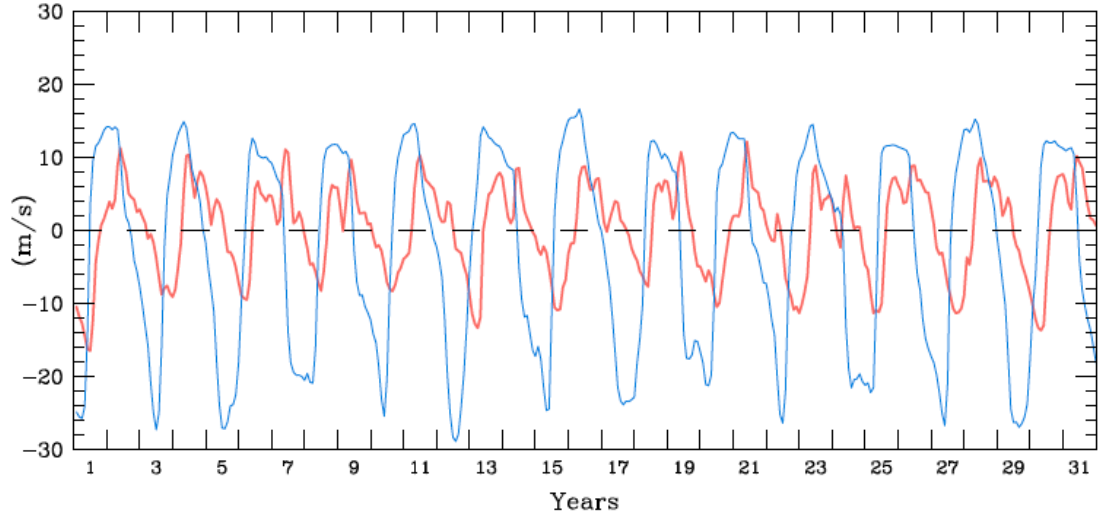
Rind et al (2014)

Modelled Solar/QBO interactions

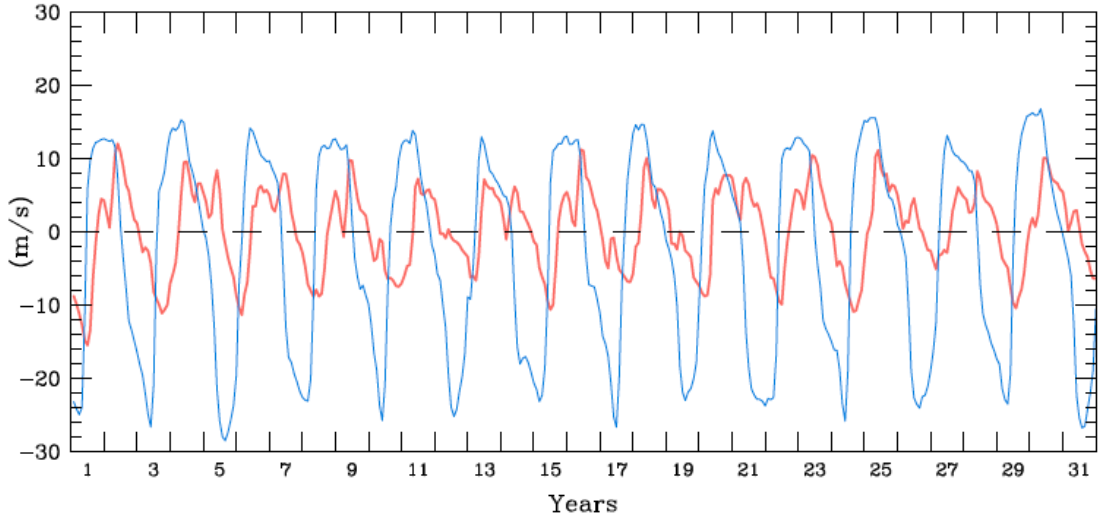
Goddard Institute for Space Studies

Tropical Zonal Winds (62+32 hPa)

Solar Max



Solar Min



20 yrs constant TSI + LINOZ + fixed 1980s SST

Modelled Solar/QBO interactions

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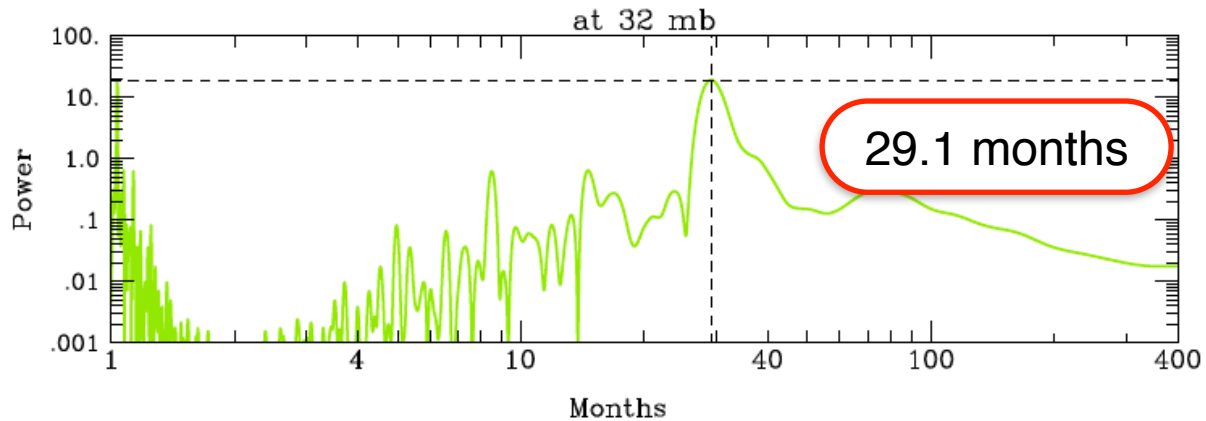
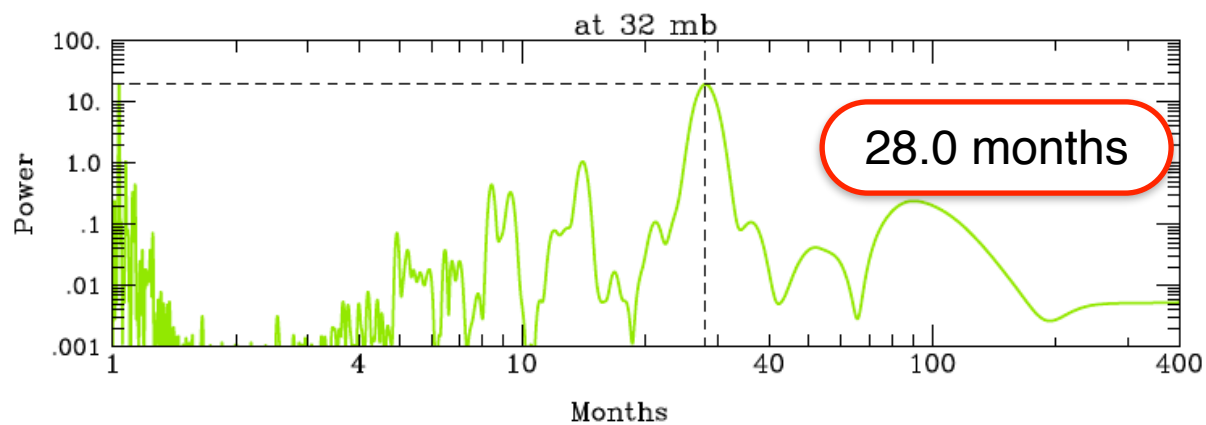
Spectral change

Solar Max



Solar Min



Background T/circulation change due to solar max lengthens QBO

Modeled Mechanisms - CMIP6

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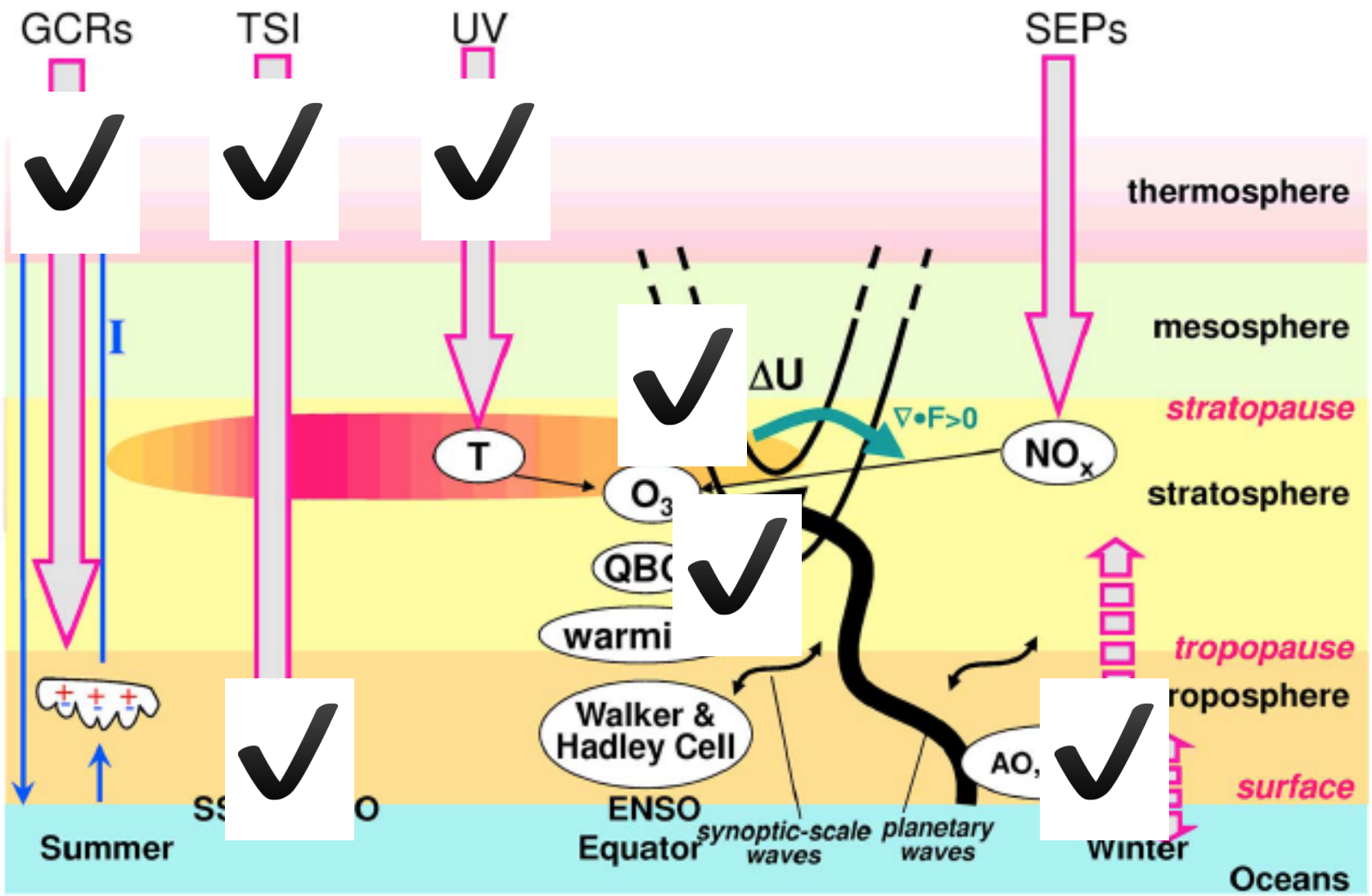
Space Studies



Gray et al, 2010