



Climate Responses to Spectral Solar Forcing in the GISS Global Climate Middle Atmosphere Model

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¹NASA/Goddard

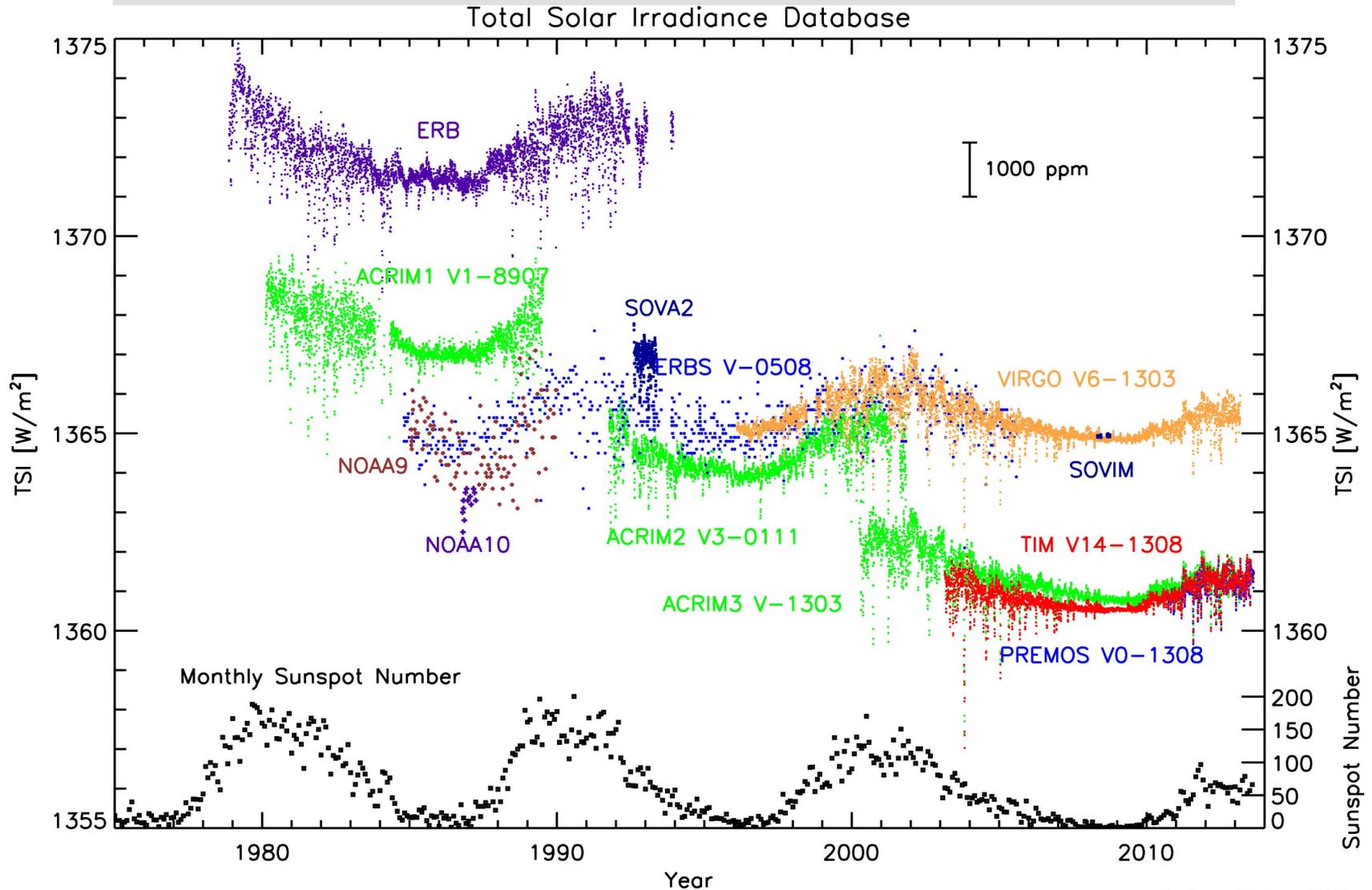
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³NASA/GISS

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⁵Max Planck Institute

Well Established TSI 11-year variability (0.1%), accuracy and uncertainty ($1360.8 \pm 0.5 \text{ W/m}^2$)



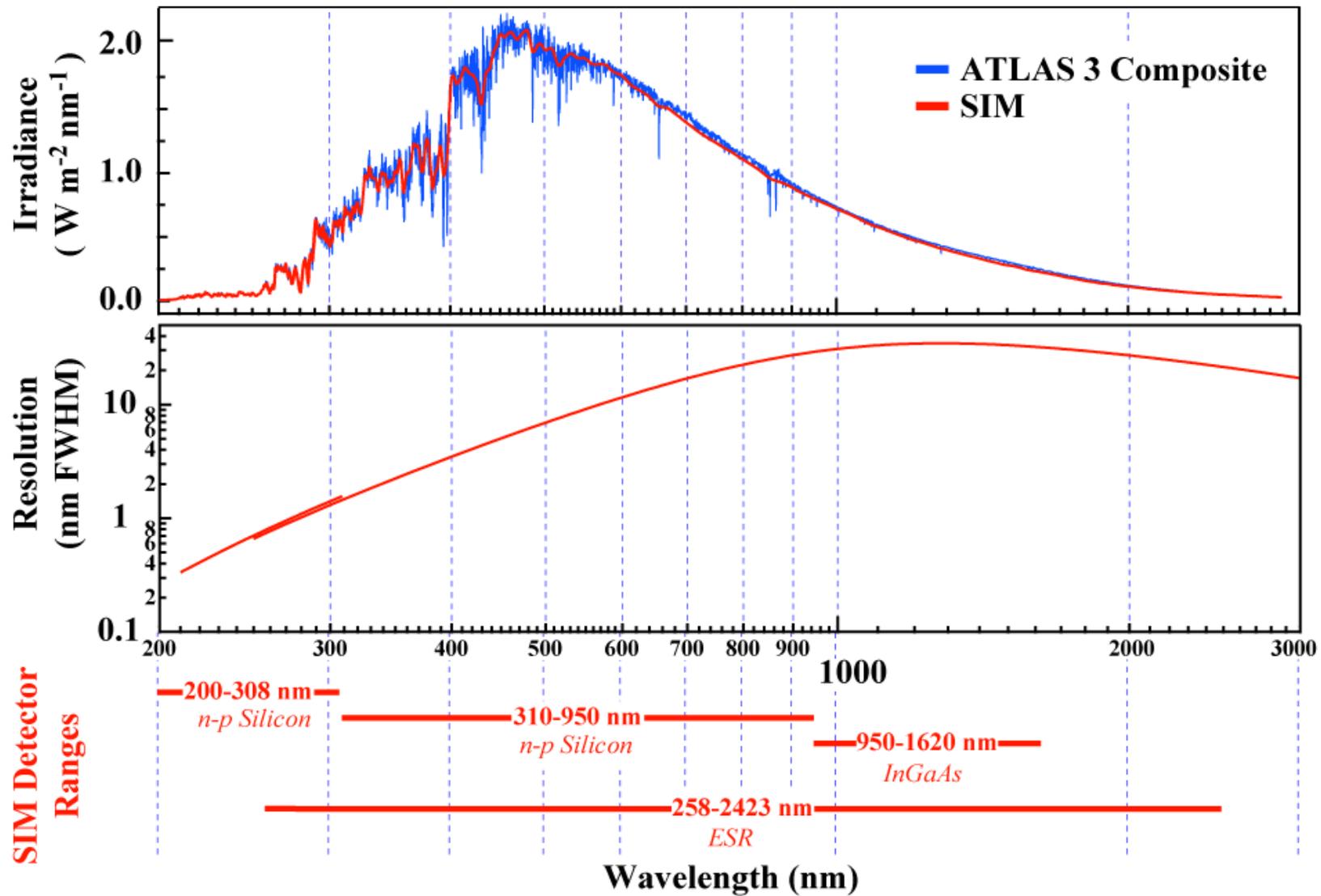
G. Kopp, 18 Sep. 2013

Kopp, G., and J. L. Lean (2011), A new, lower value of total solar irradiance: Evidence and climate significance, *Geophys. Res. Lett.*, **38**, L01706, doi:10.1029/2010GL045777.

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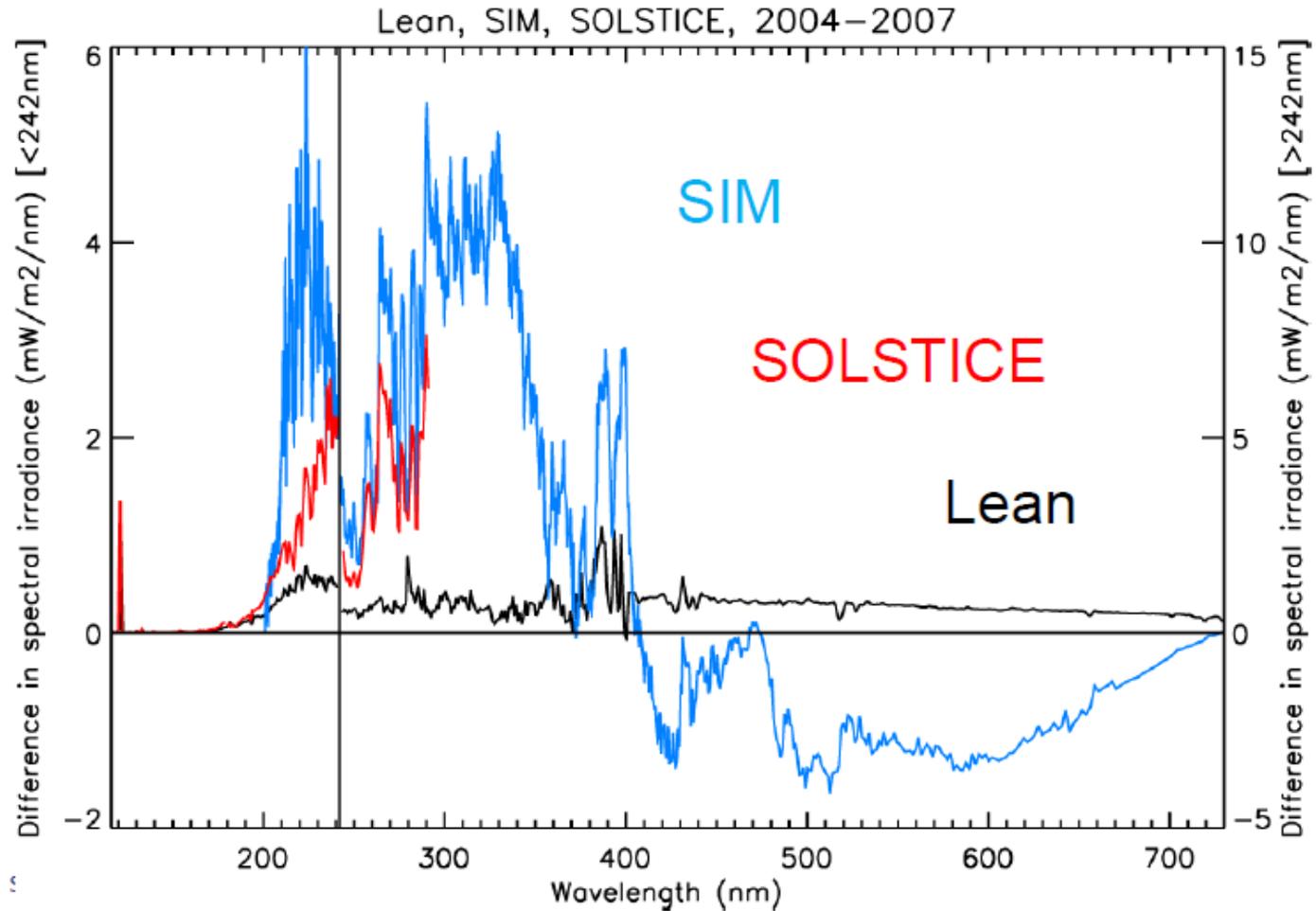
Guoyong Wen, Page 2

SIM and SOLSPEC Irradiance Spectra



Variation, accuracy and uncertainty of SSI are not well established.

Some Relevant Studies:
Cahalan et al, 2010
Haigh et al., 2010
Merkel et al., 2011
Ineson et al., 2011
Swartz, al., 2012



Haigh et al, 2010

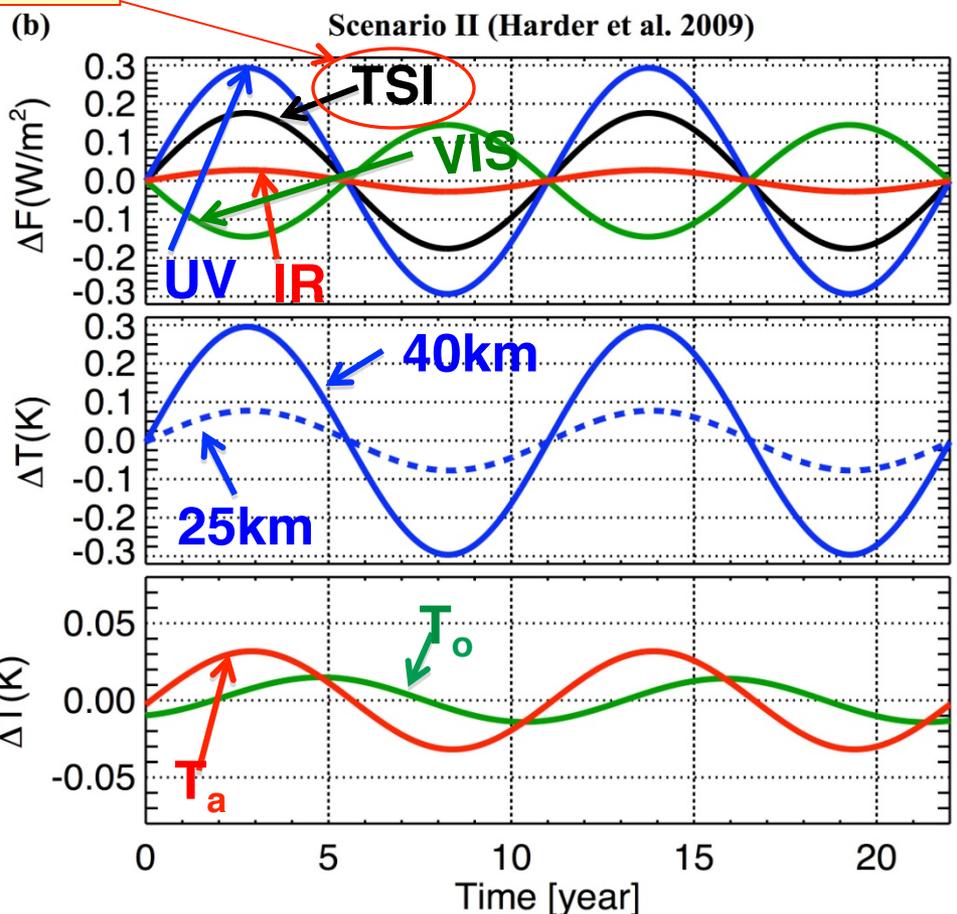
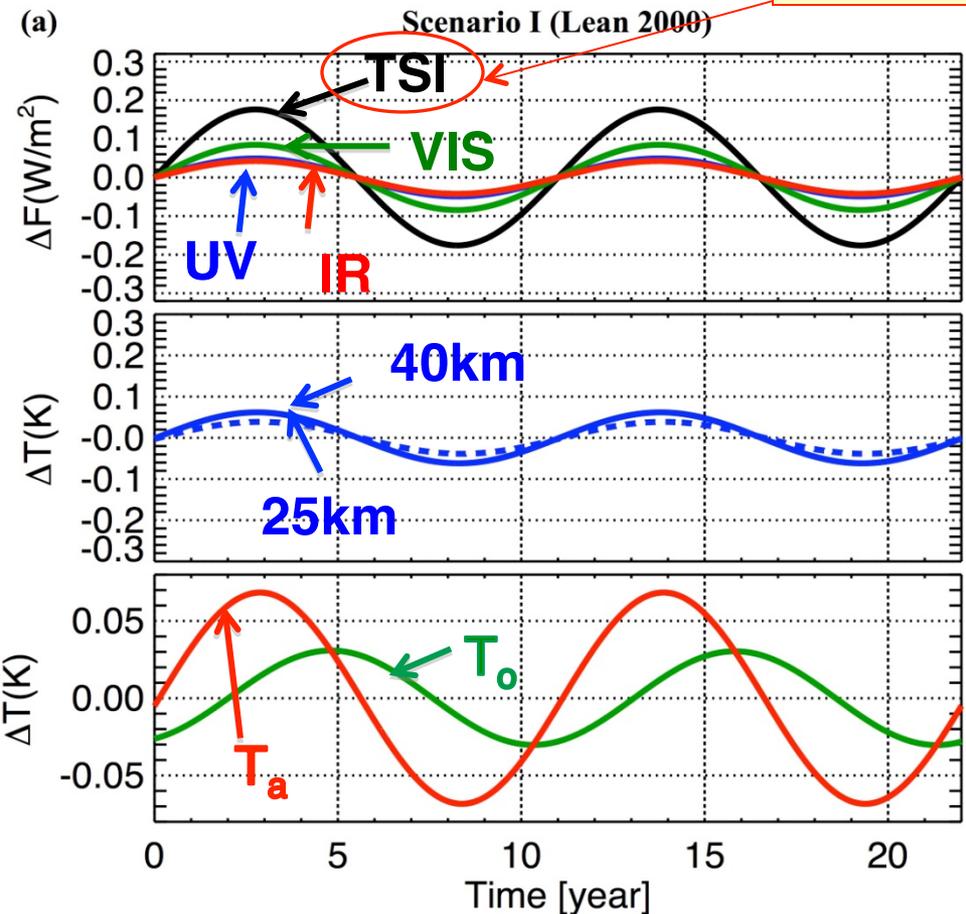
What we did before?

Cahalan et al., GRL, 2010

Solar Variations (Lean 2000)
And RCM Response

Identical TSI

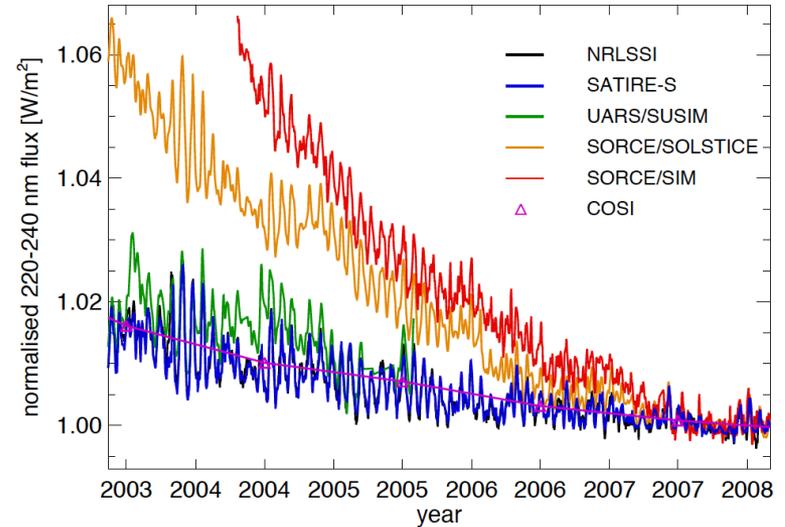
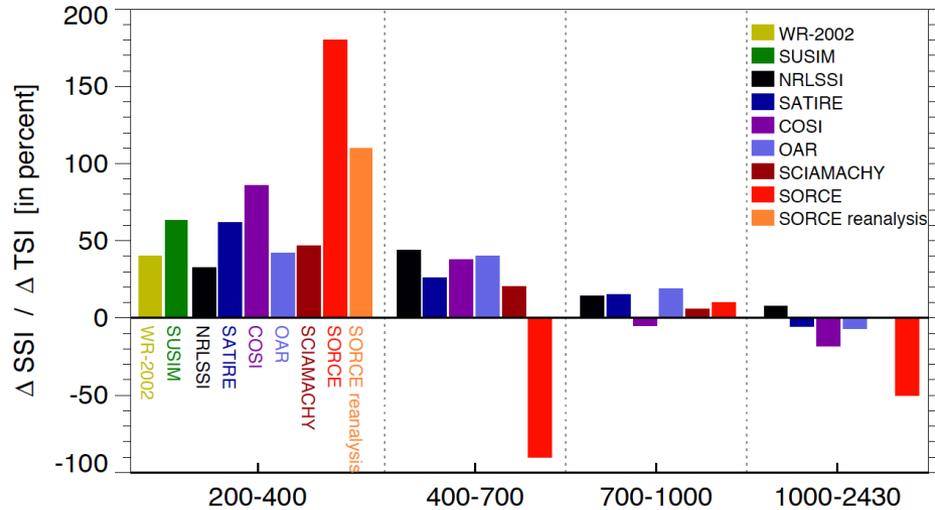
Solar Variations (Harder et al 2009)
And RCM Response



Increased 11-yr in Stratosphere ☝

Decreased 11-yr At Surface & Oceans ☝

Motivations of This Study



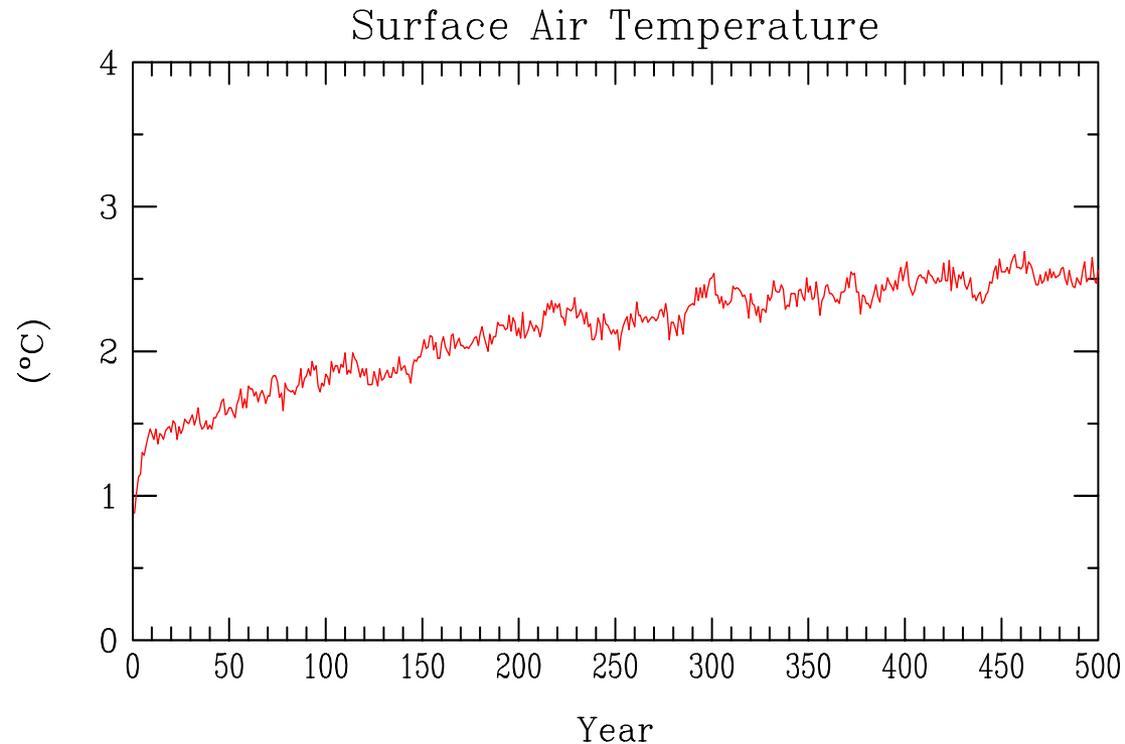
From Ermolli et al. (2013)

What the community needs to do?

“It is necessary (1) to understand the recent SORCE SIM measurements of spectrally resolved irradiances and assess their implications for solar influence on climate; (2) to determine an accurate value of the total and spectrally resolved solar irradiance during a grand solar minimum such as the Maunder Minimum” Gray et al., (2010)

- Reconstruct SIM-based historical solar forcing
- Use GISS GCM to simulate climate responses

- Full Coupled Ocean-Atmos. Model (Rind et al., 2007)
- 53 Layers Atmosphere (top at mesopause), 13 layer ocean (Russell et al., 1995)
- Interactive chemistry
- Model has a sensitivity of 2.8C to doubling of CO₂

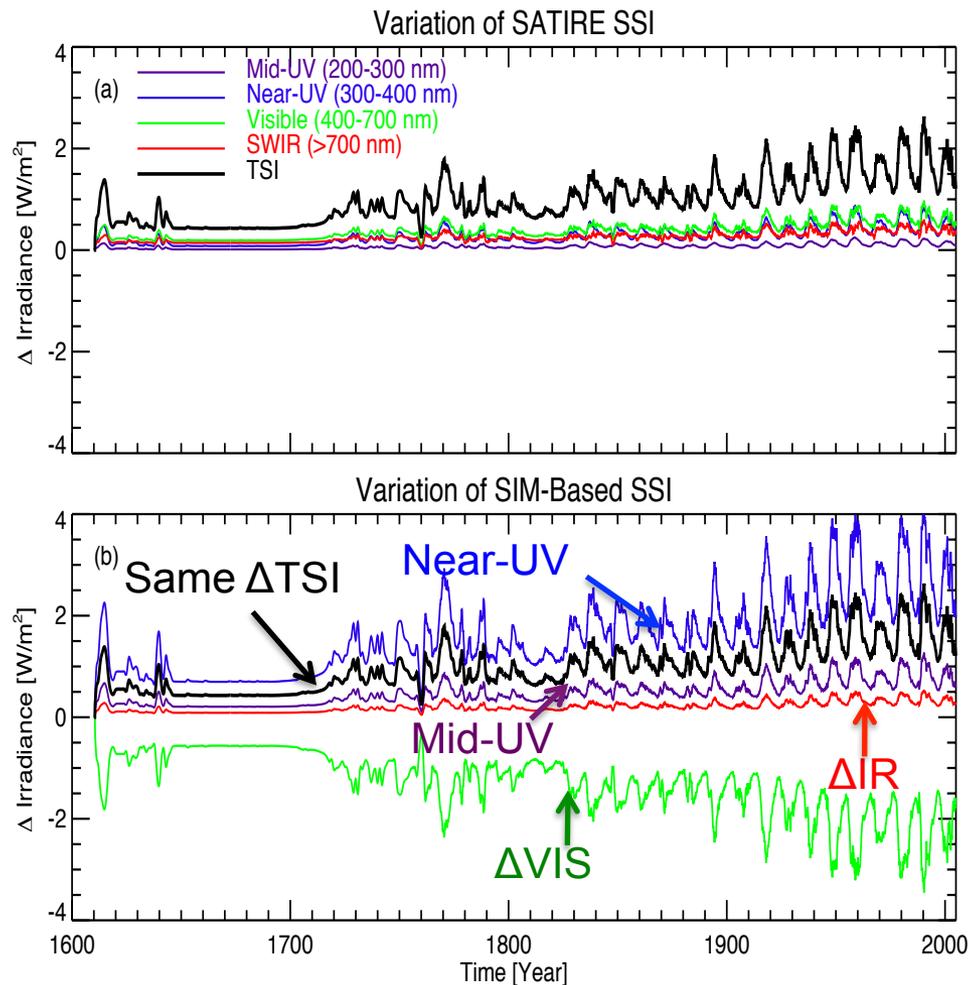


Global average surface air temperature response to doubling CO₂.

Experiments

- I. SATIRE modeled SSI
- II. SIM-based SSI

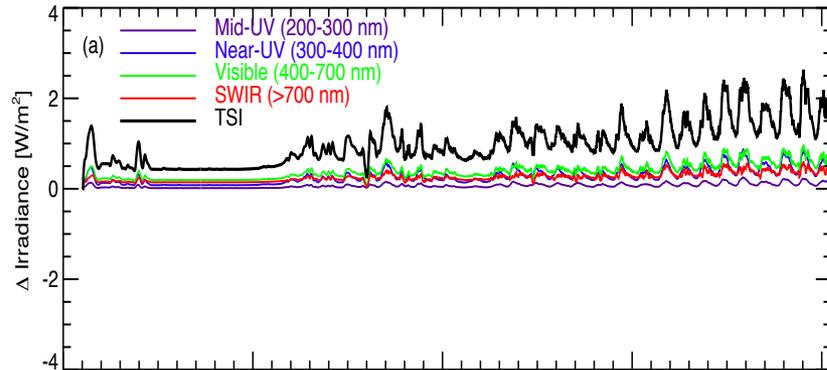
- Fixed GHGs, aerosols
- Centennial time scale
- Averaged 11-year SC



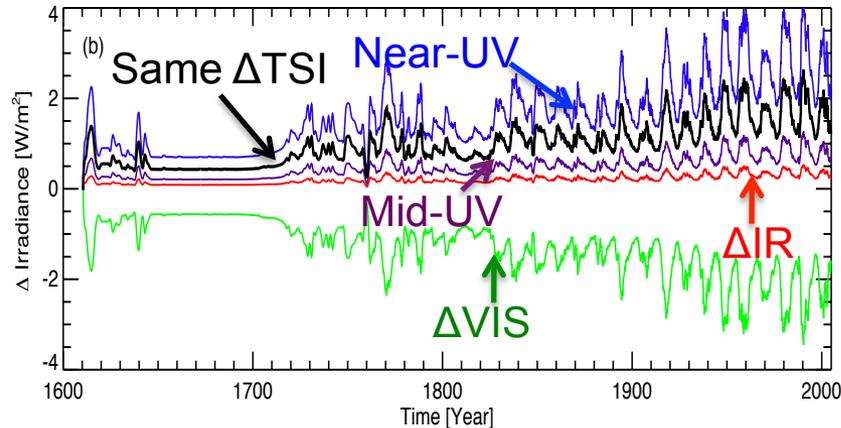
Centennial and Longer Time Scales: Trend and Variability

Spectral Solar Forcing Same ΔT_{SI} (fixed GHGs)

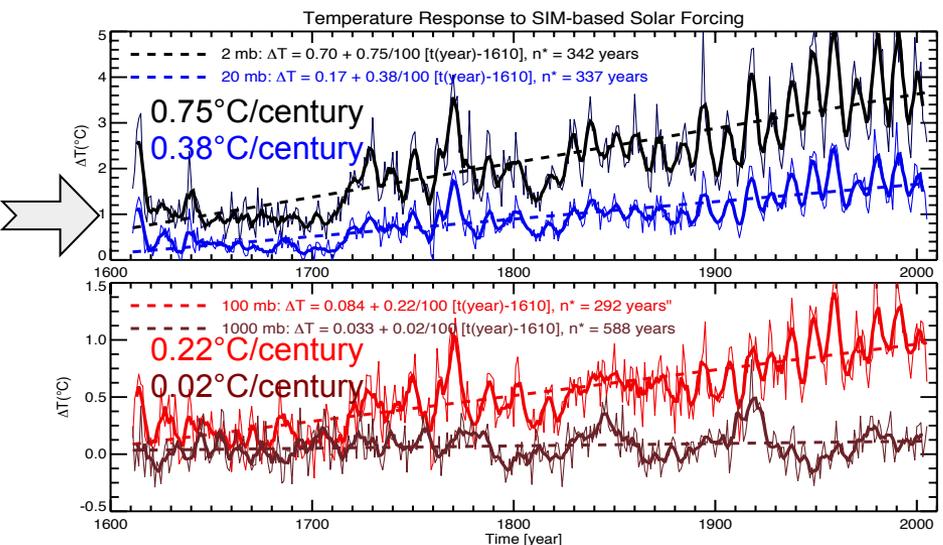
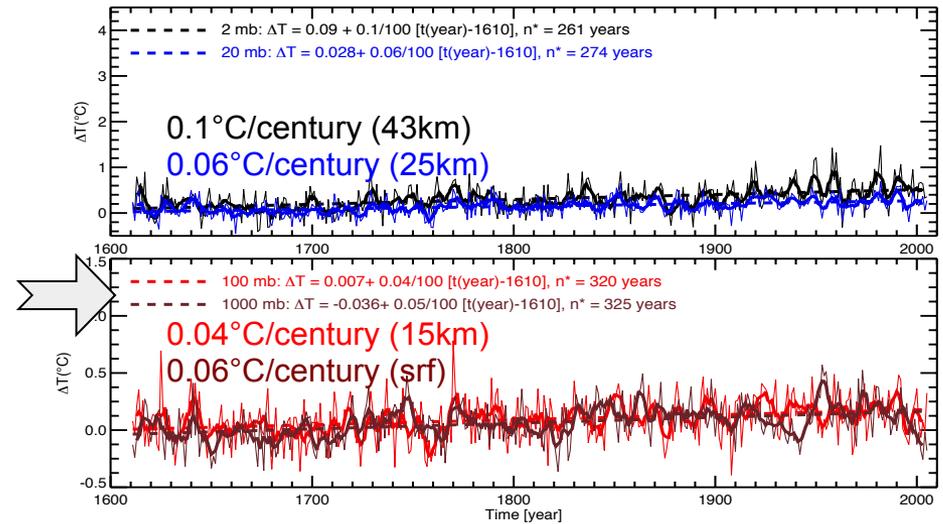
Variation of SATIRE SSI



Variation of SIM-Based SSI



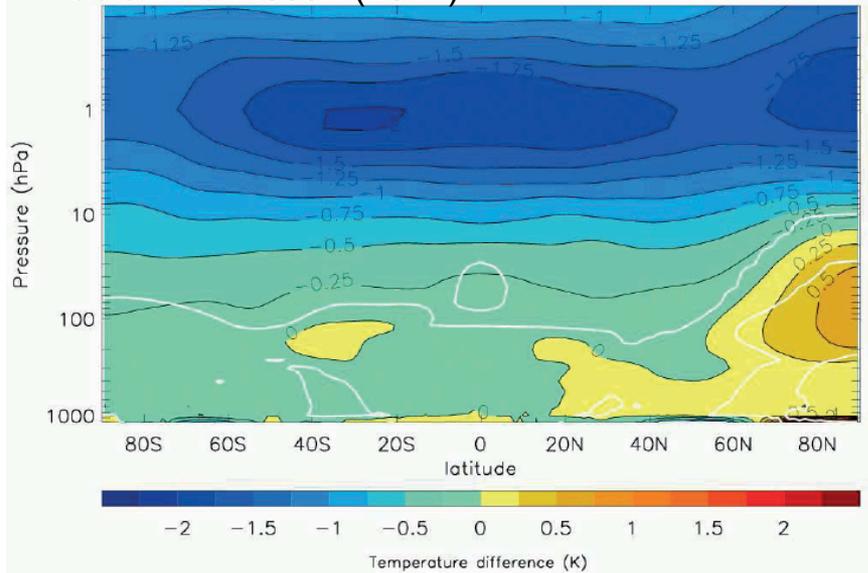
Global Temperature Response



- Increased trends and variability in the stratosphere ☝
- Decreased trends ☹ and increased variability at surface ☝
- Decreased signal (trend) to noise (variability) ratio at surface ☹

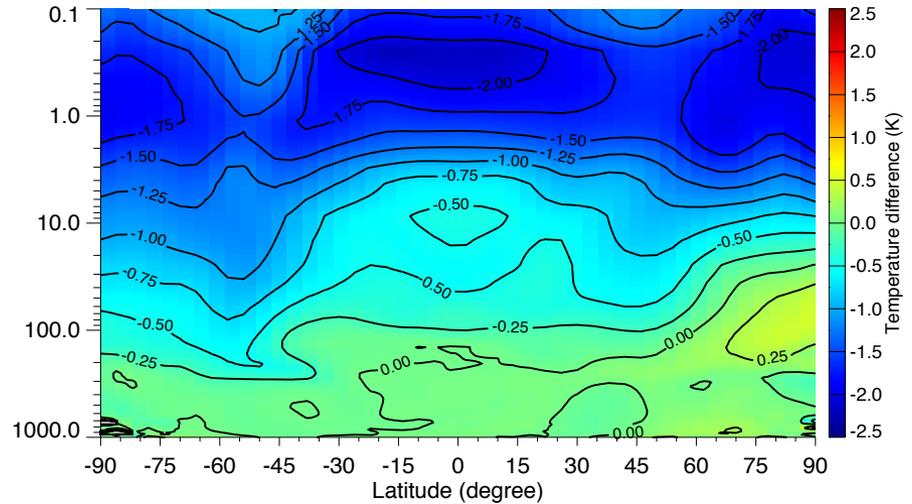
11-Year SC: Averaged Responses of ANN Zonal Mean T

HadGEM3 Ineson (2011)

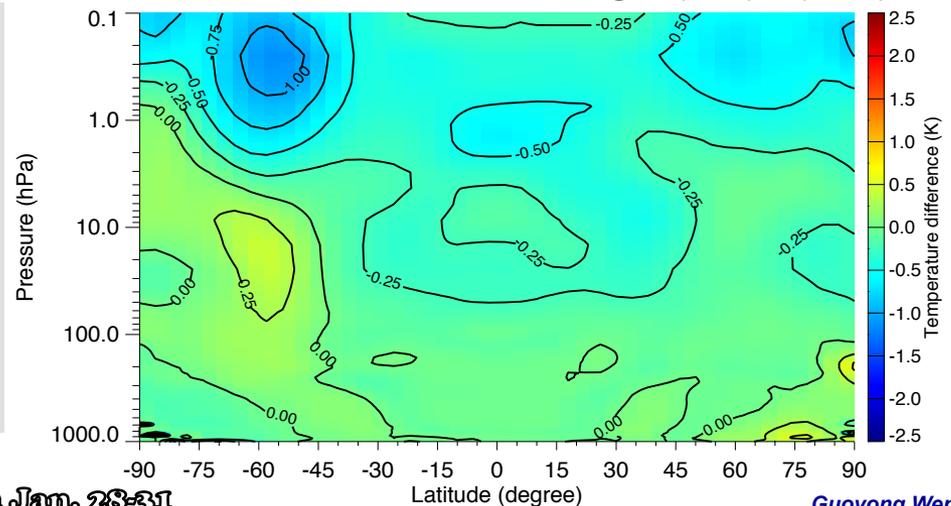


GISS GCMAM

SIM-based SSI Forcing: T(min)-T(max)

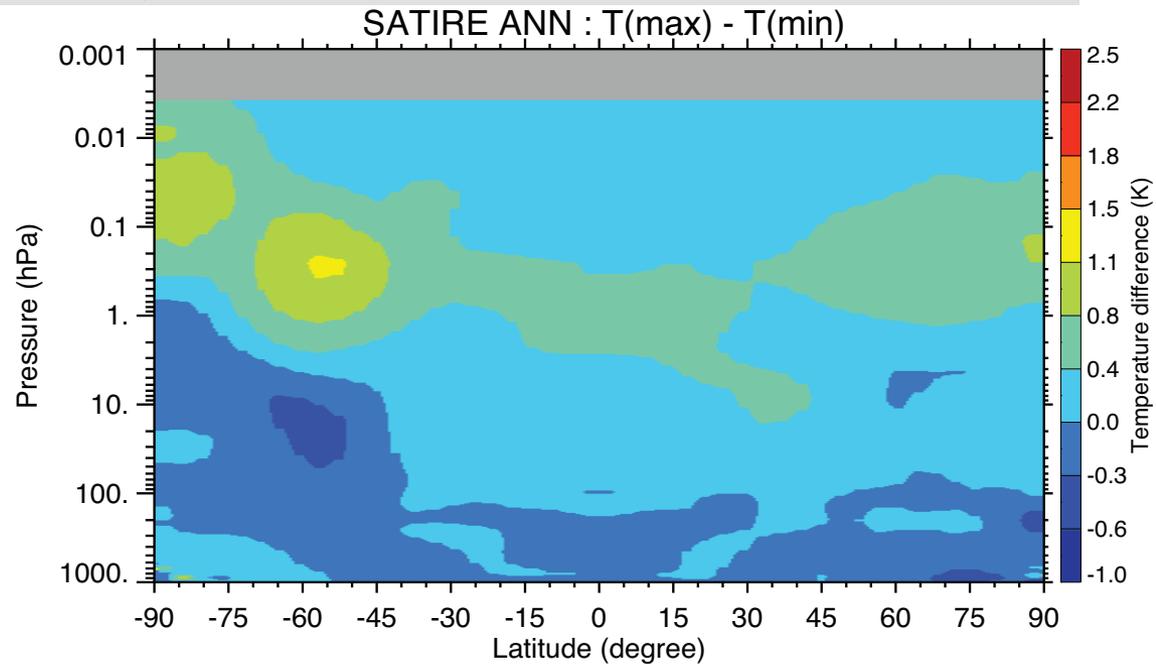
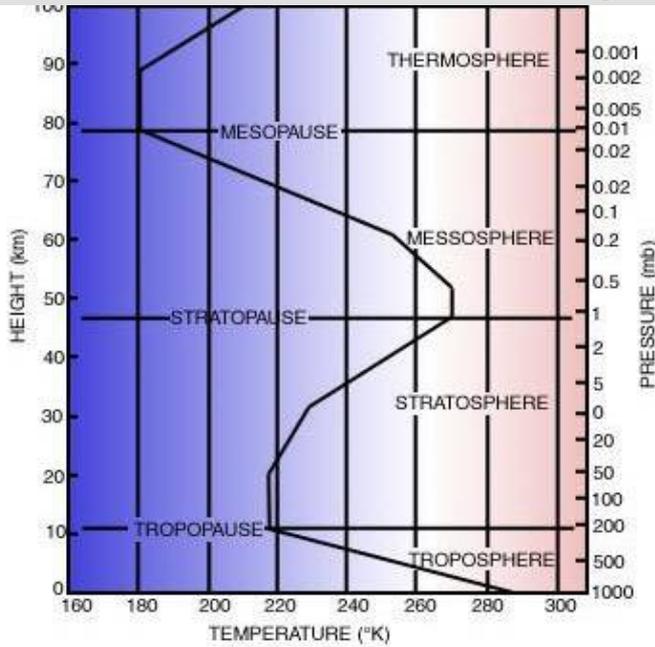


SATIRE Modeled SSI Forcing: T(min)-T(max)

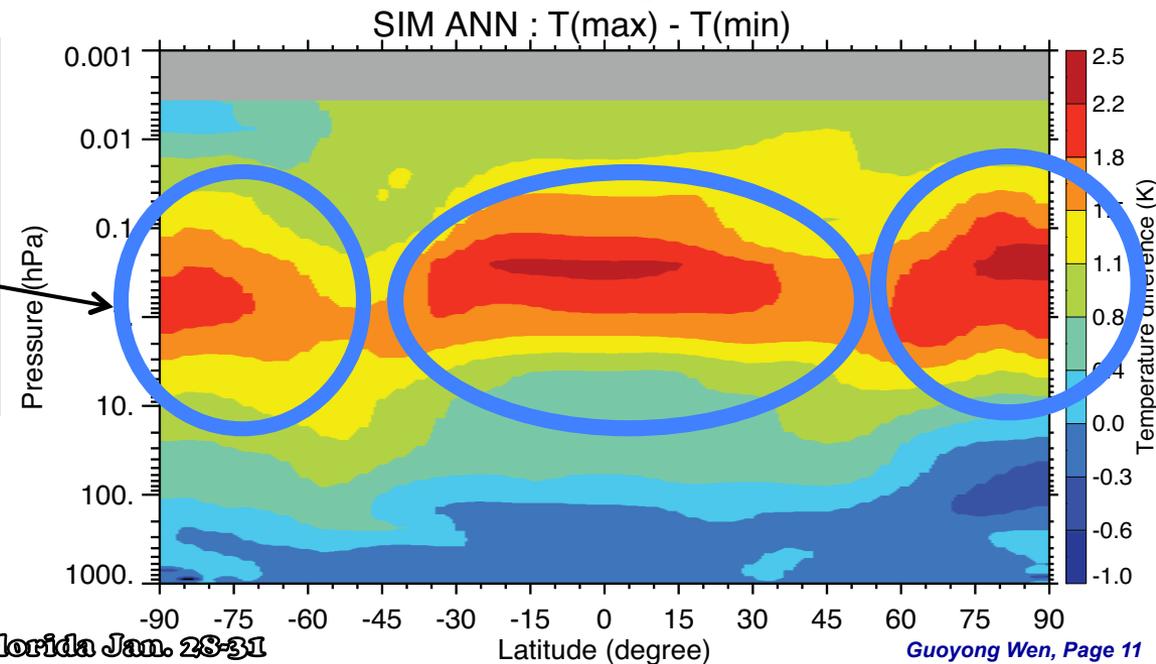


- Strong N.H. polar stratospheric response to SIM-based solar forcing similar to that from HadGEM
- Much stronger stratospheric response to SIM-based solar forcing in general
- Unique pattern in S.H polar response to SATIRE modeled solar forcing

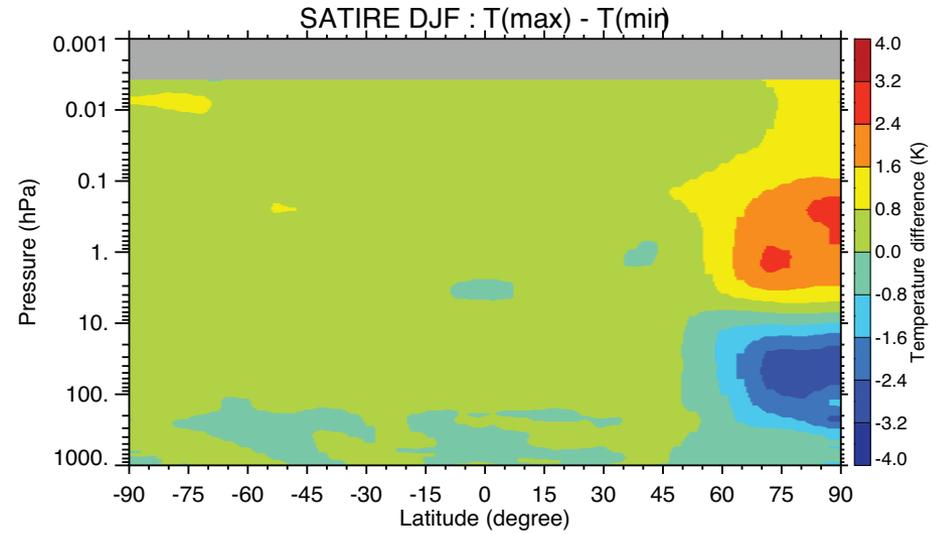
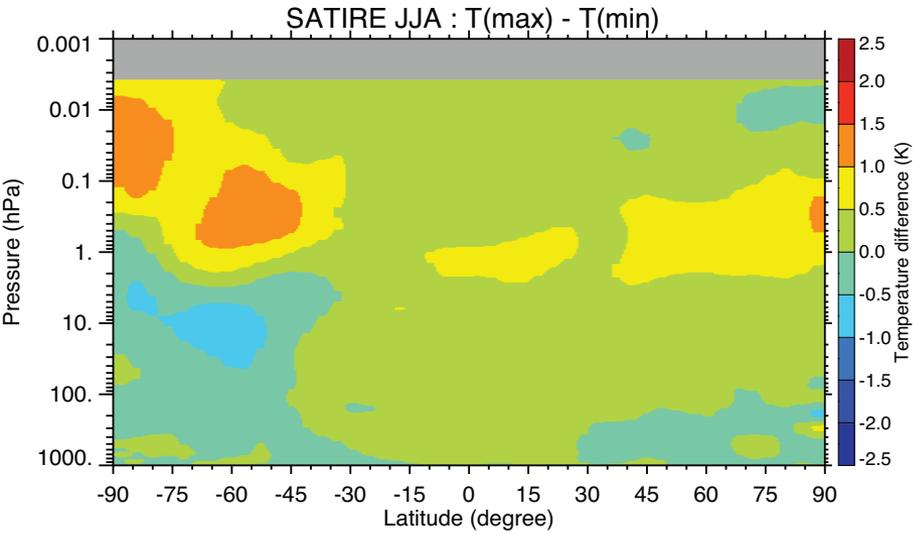
11-Year SC: Averaged Responses of ANN Zonal Mean T



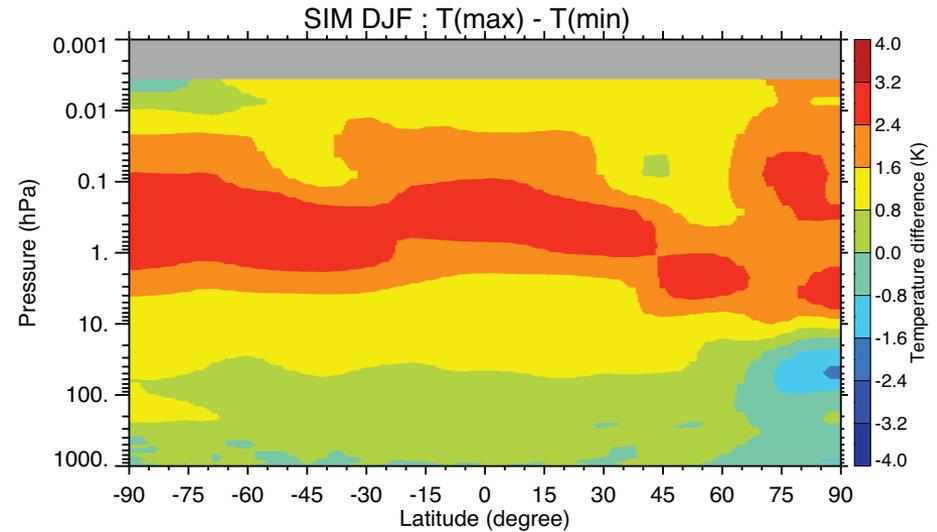
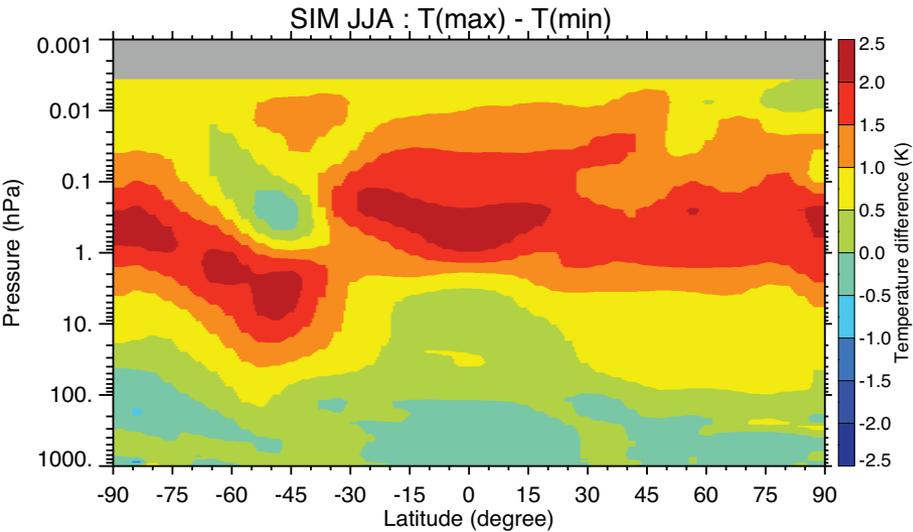
- Max ΔT near lower mid mesosphere
- Tropical and both N.H. & S.H. Polar
- ~3 times as large as ΔT for SATIRE



11-Year SC: Averaged Responses of Seasonal Mean T

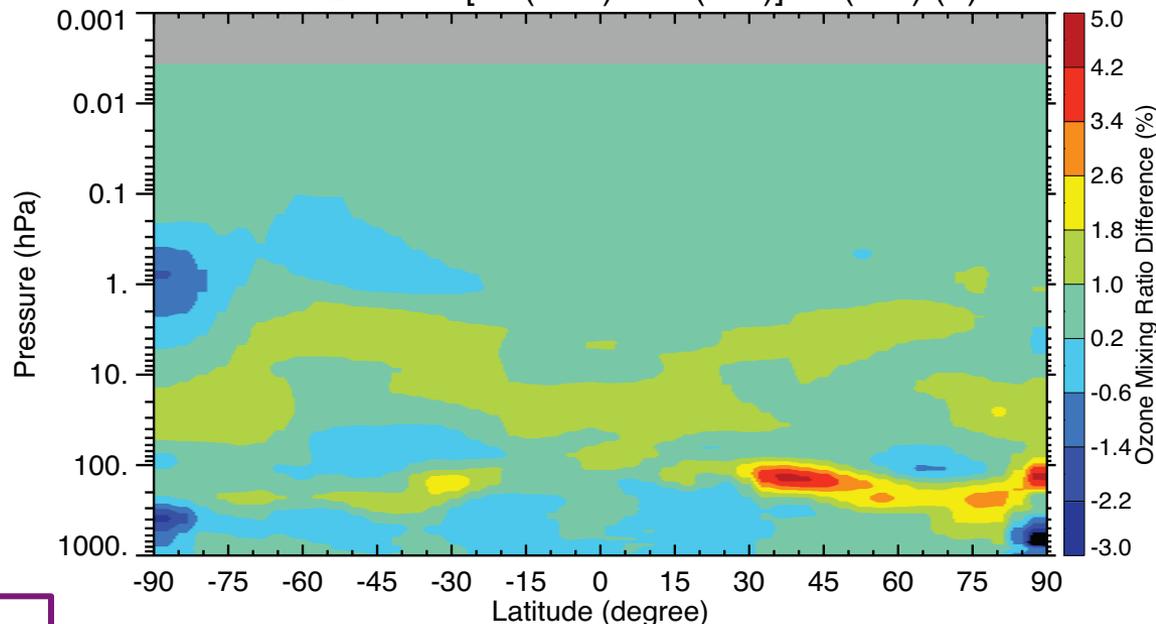


Seasonal Changes are different.

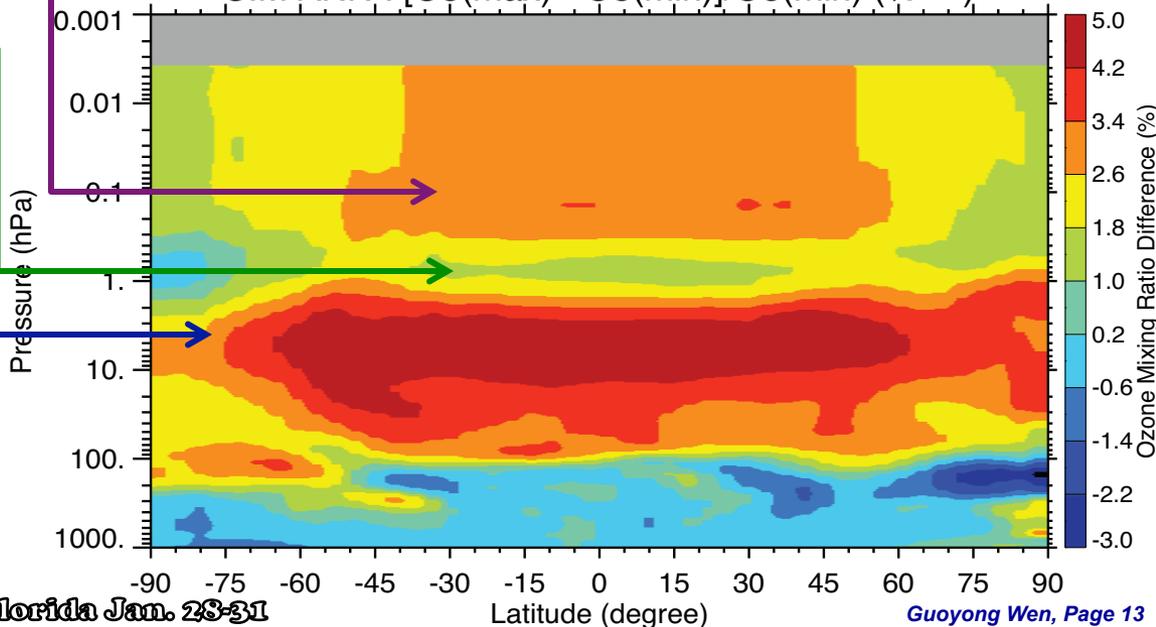


11-Year Solar Cycle: Averaged Responses of Zonal Mean O₃

SATIRE ANN : [O₃(max) - O₃(min)]/O₃(min) (%)

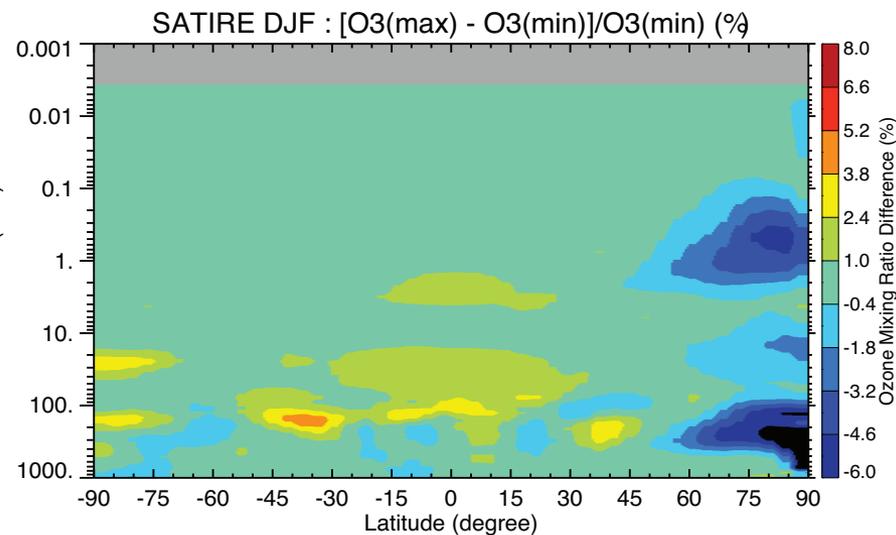
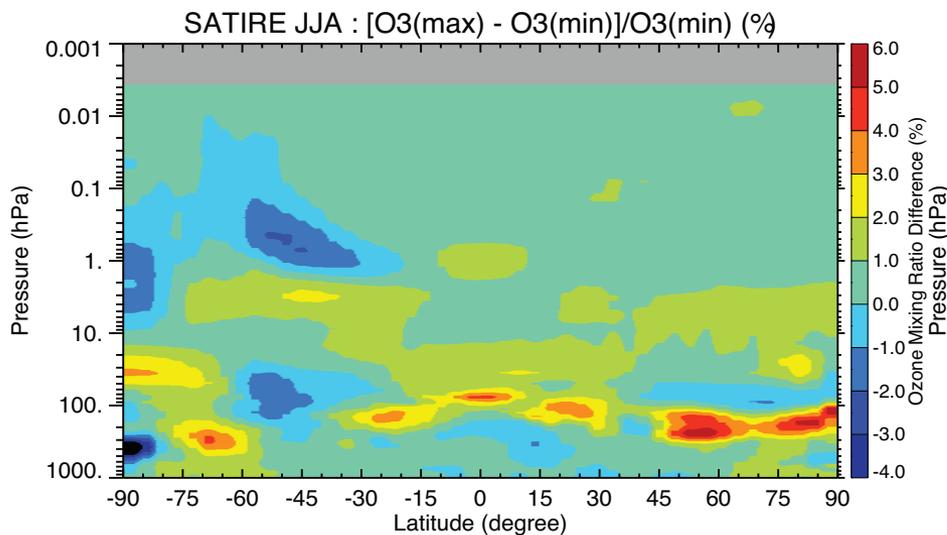


SIM ANN : [O₃(max) - O₃(min)]/O₃(min) (%)

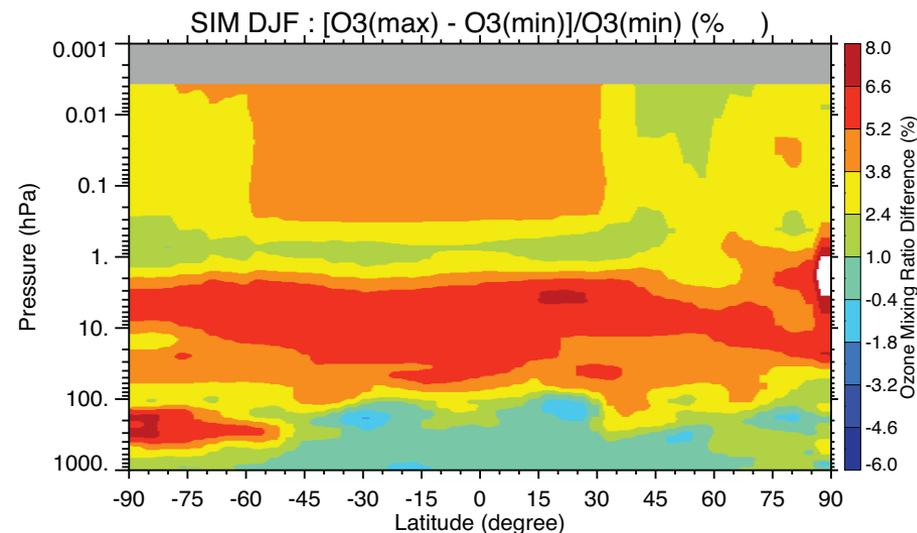
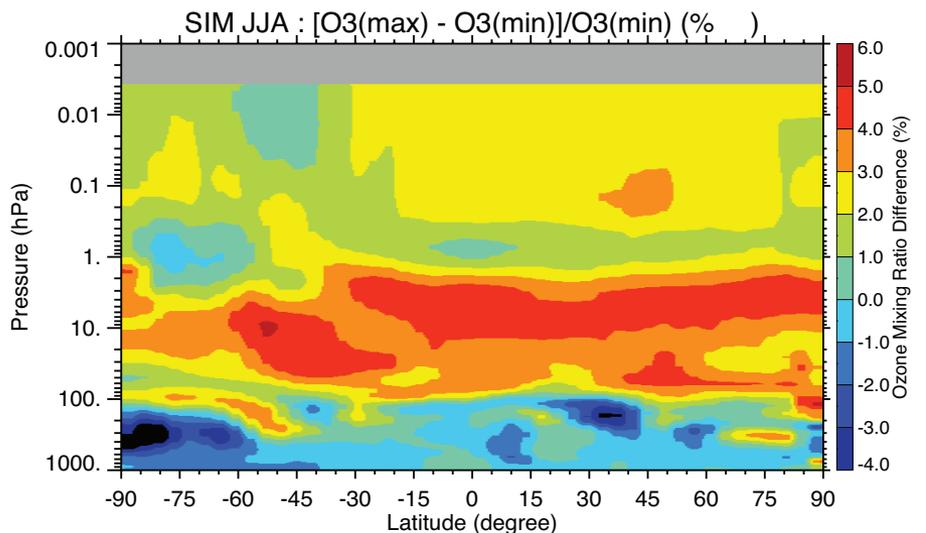


- Max ΔO_3 near mid stratosphere (4-5%) vs 1-2% for SATIRE forcing
- Secondary max ΔO_3 near in the mid-upper mesosphere (2.6-3.4%) vs 0.2-1% for SATIRE forcing
- Local min near stratopause (1%)
- ~3 times as large as ΔO_3 for SATIRE

11-Year SC: Averaged Responses of Seasonal Mean O3

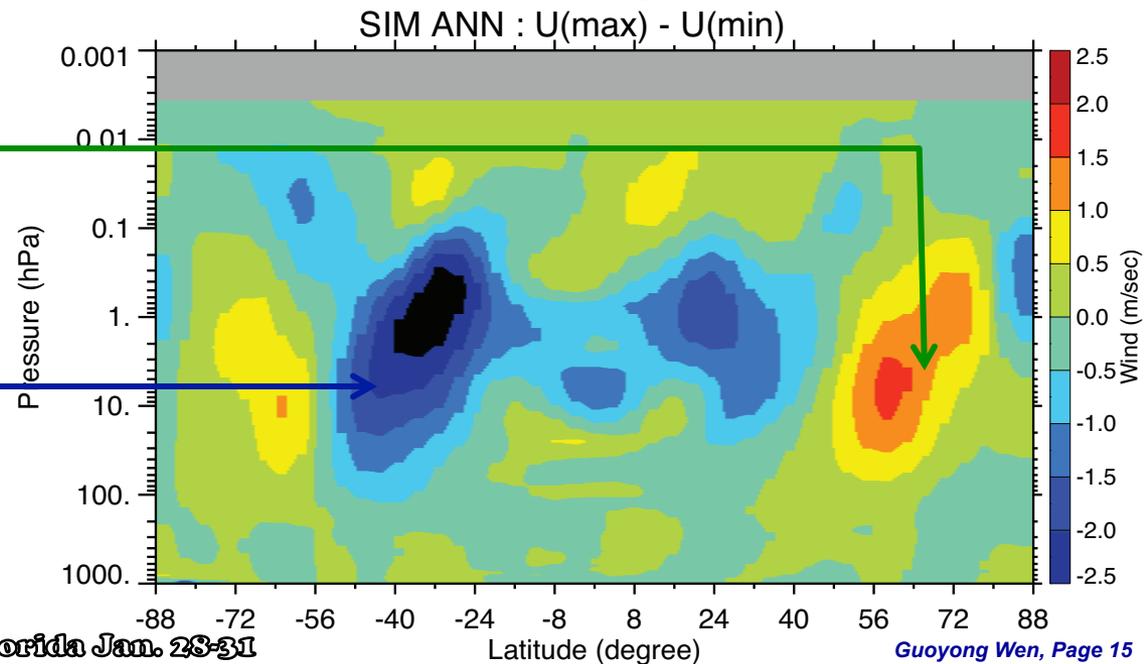
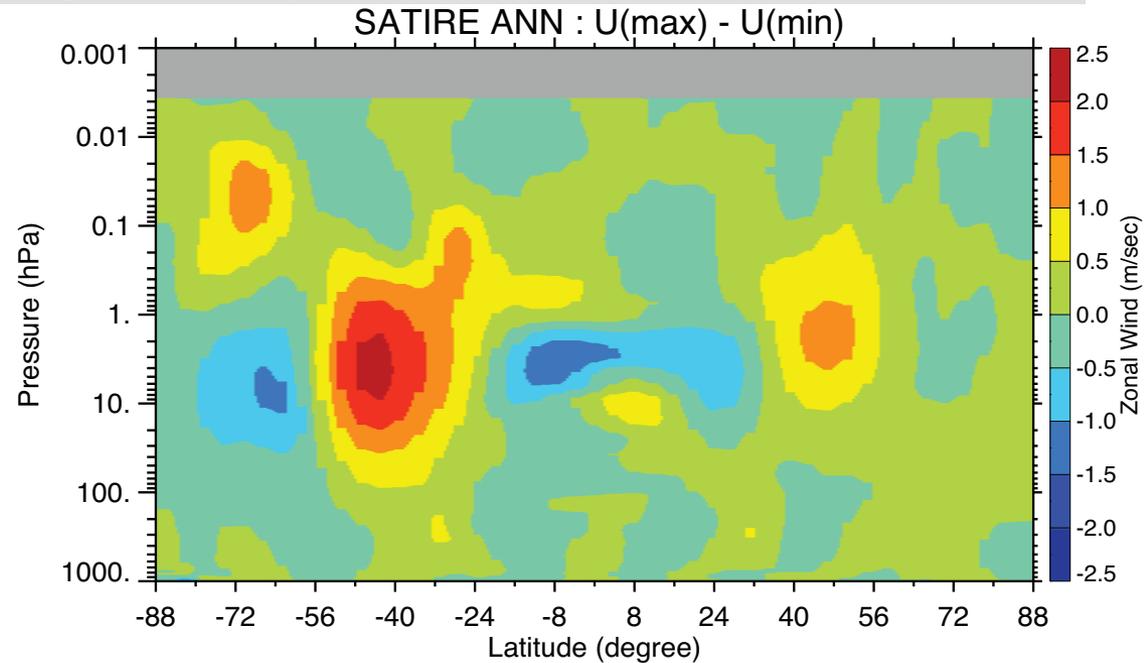


Seasonal Changes are different.

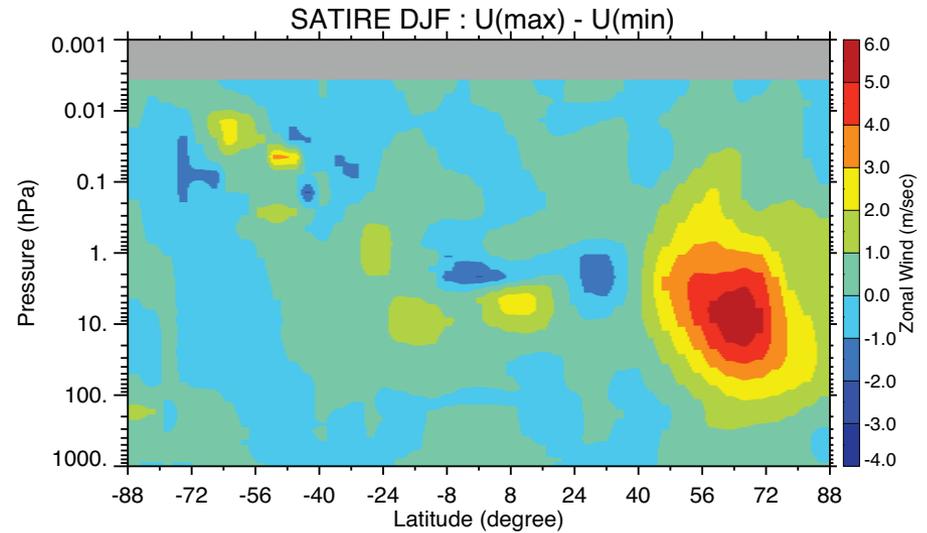
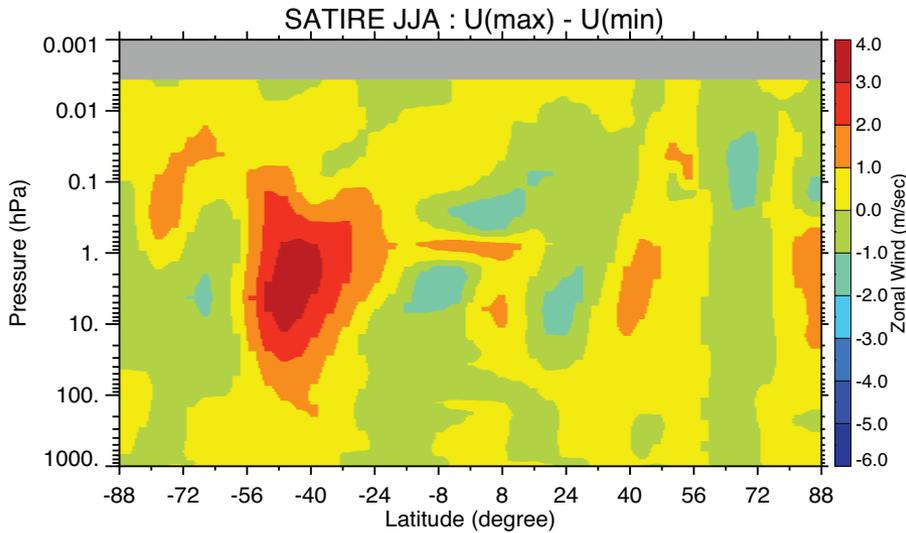


11-Year Solar Cycle: Averaged Responses of ANN Zonal Wind

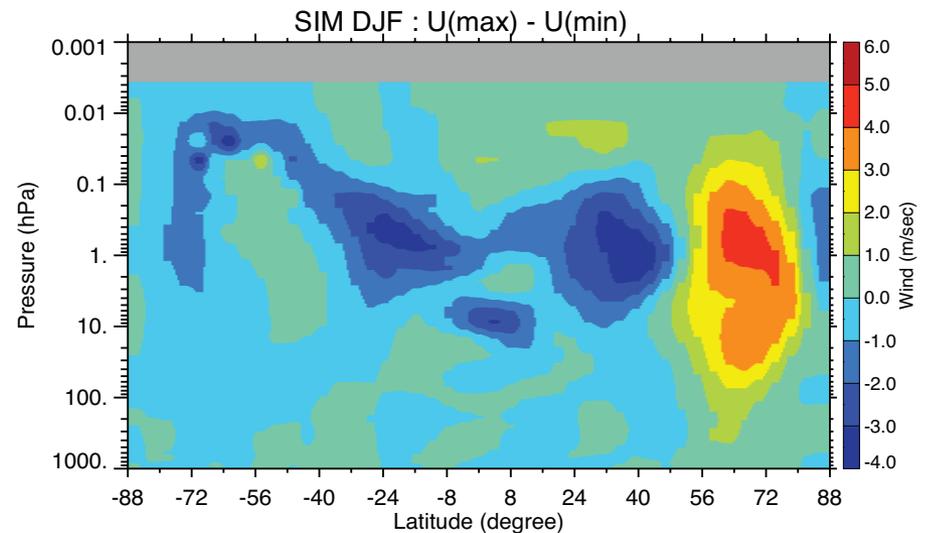
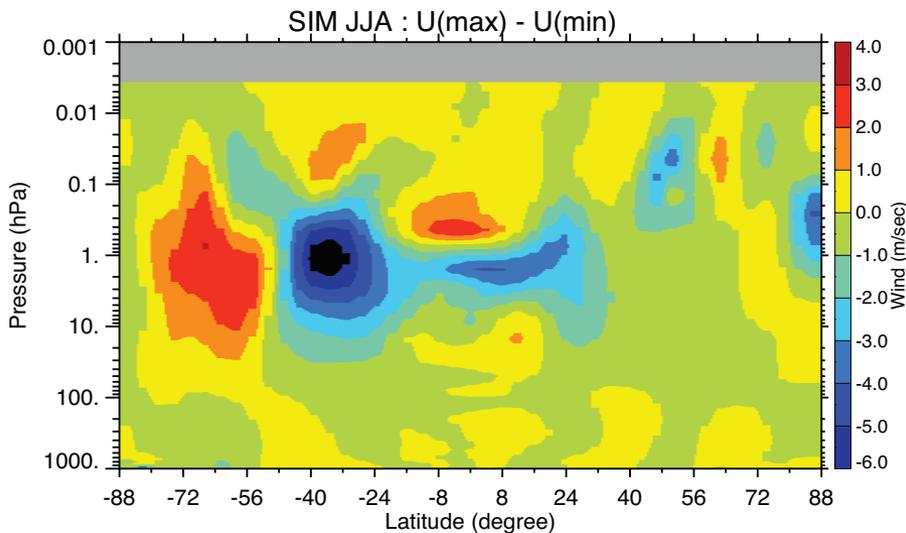
- Max ΔU (-2.5m/sec) centered at lower mesosphere in S.H. mid-lat and out-of-phase with solar activity.
- S.H. patterns are similar to those for SATIRE, but out-of-phase
- N.H. patterns are similar to those for SATIRE with shift in lat.



11-Year SC: Averaged Responses of Seasonal Wind



Seasonal Changes are different.



Summary

- On centennial time scales, SIM-based solar forcing implies (i) **increased** temperature trend in the stratosphere and **decreased** trend at surface, (ii) **increased** temperature variability throughout the atmosphere, (iii) **increased** temporal variation of surf T on multi decadal time scales.
- Solar variations under either scenarios do not cause the temperature increase since the industrial revolution.
- On decadal time scale (11-year SC), SIM-based SSI implies much larger temperature and O₃ responses, and out-of-phase zonal wind response in S.H.
- SSI in the rising phase of SC 24 and implications of solar influence on climate? What about uncertainties?
- What are the requirements of SSI observation for climate studies?