Atmosphere and Ocean Responses to Extreme Low Solar Activity and Their Hemispheric Differences

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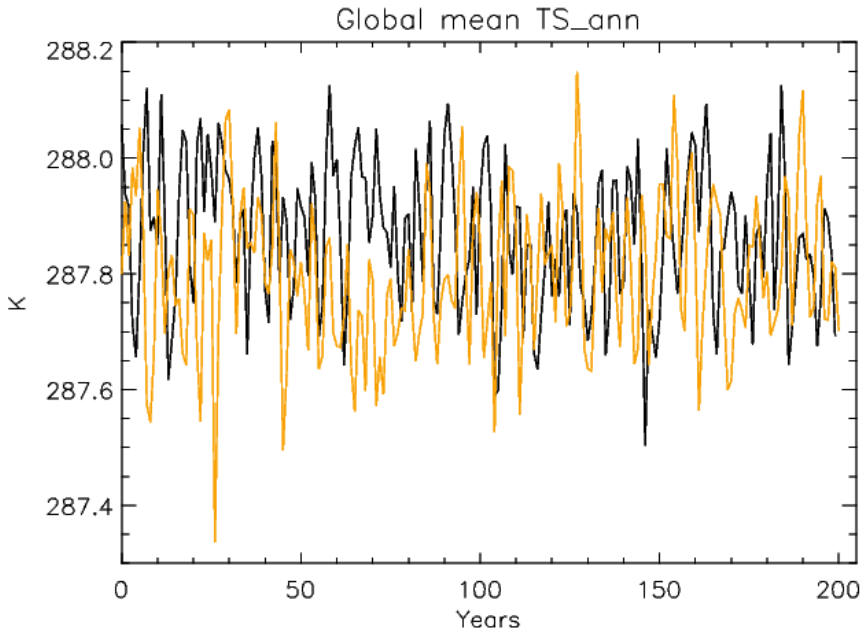
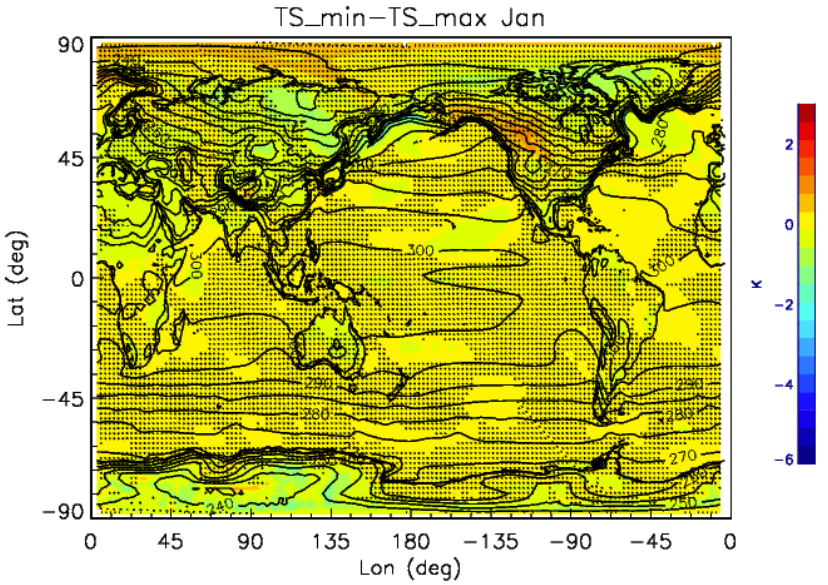
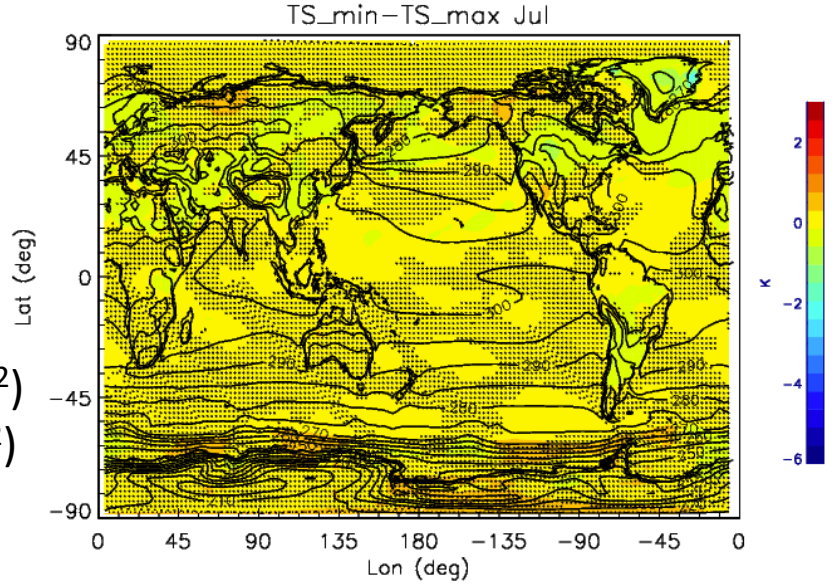
Outline

- Motivation
- Method
- Results and analysis
  - Surface/troposphere/ocean responses
  - Stratosphere and troposphere responses
  - Hemispheric differences

Solar Signal in Surface Temperature?







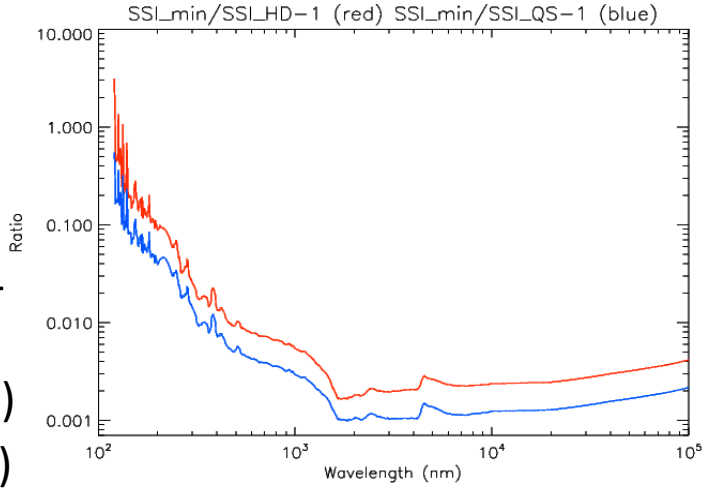
Nominal solar maximum (SOLIN: 340.483 W/m^2)
Nominal solar minimum (SOLIN: 340.107 W/m^2)

Motivation

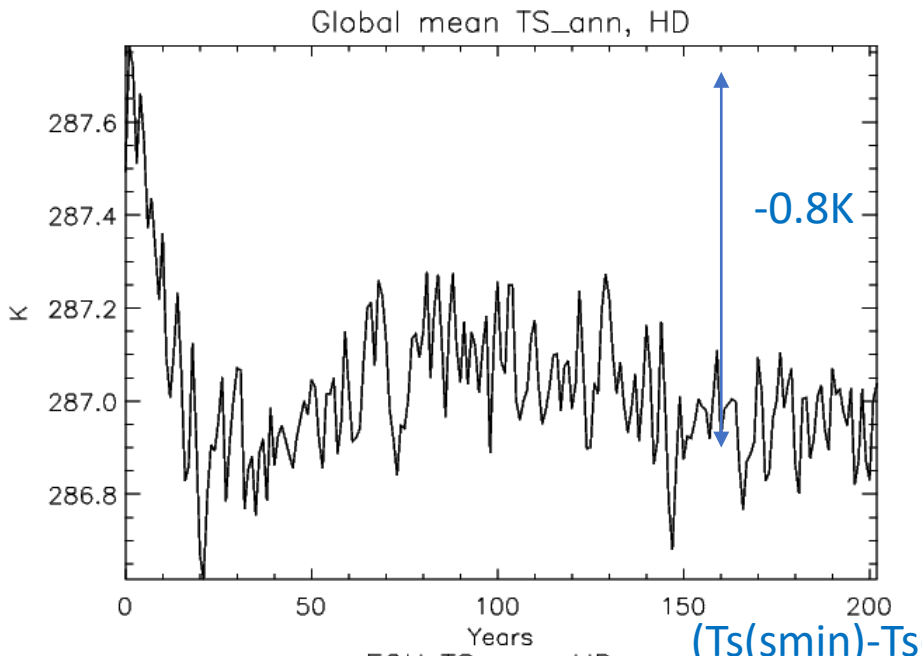
- Solar signal in the tropospheric climate is small compared with the large climate variability.
- Solar variability is large in stratosphere and above, but the downward impact is still unclear.
- Relying mainly on statistics and difficult to examine processes through which solar forcing affects climate.
- Climate sensitivity to solar forcing is thus still not clear.

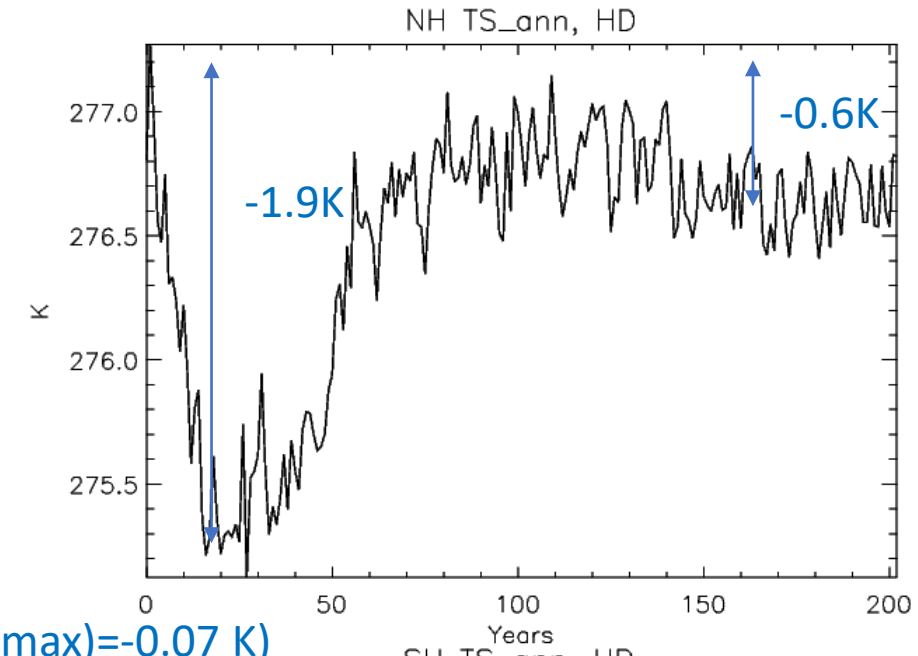
Model Description

- NCAR WACCM CCMI (Chemistry Climate Model Initiative) setup with coupled ocean model.
- WACCM Numerical experiments (200 years for each one)
  - Nominal solar max (SOLIN: 340.483 W/m^2)
  - Nominal solar min (SOLIN: 340.107 W/m^2)
  - SSI/TSI from HD solar simulation (SOLIN: 337.521 W/m^2, 0.86% lower than solar max)
    - <350 nm nominal solar min; >350 nm HD (HD VIS)
    - <350 nm HD; >350 nm nominal solar min (HD UV)
  - SSI/TSI from weak B (48G) MHD solar simulation

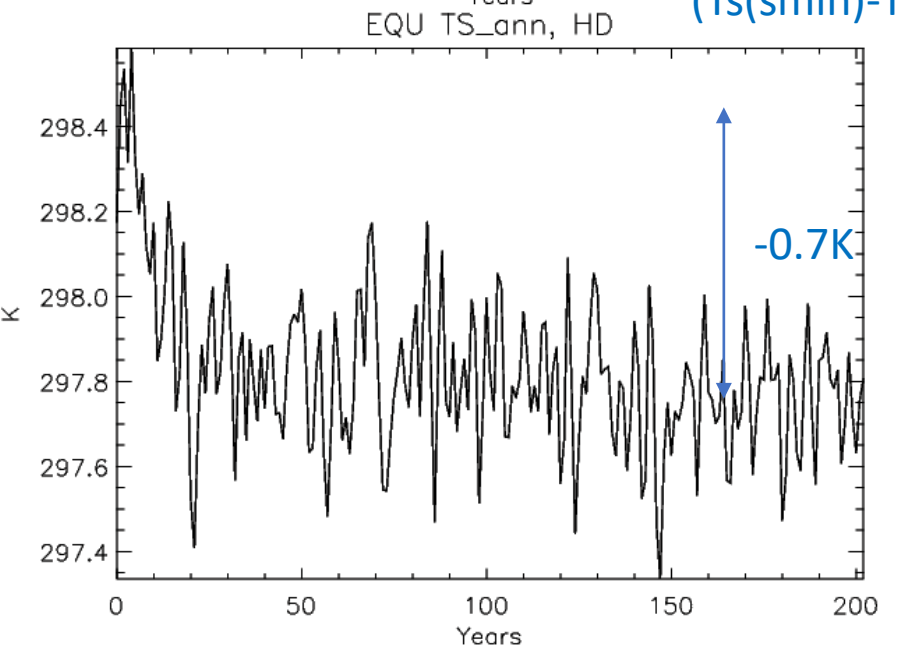


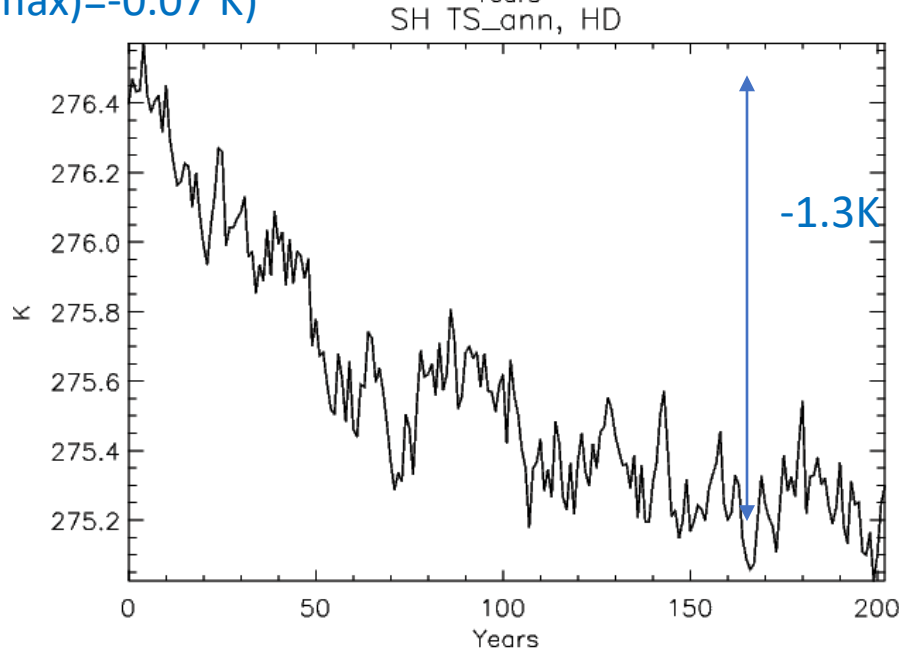
Annual Average TS Time Series



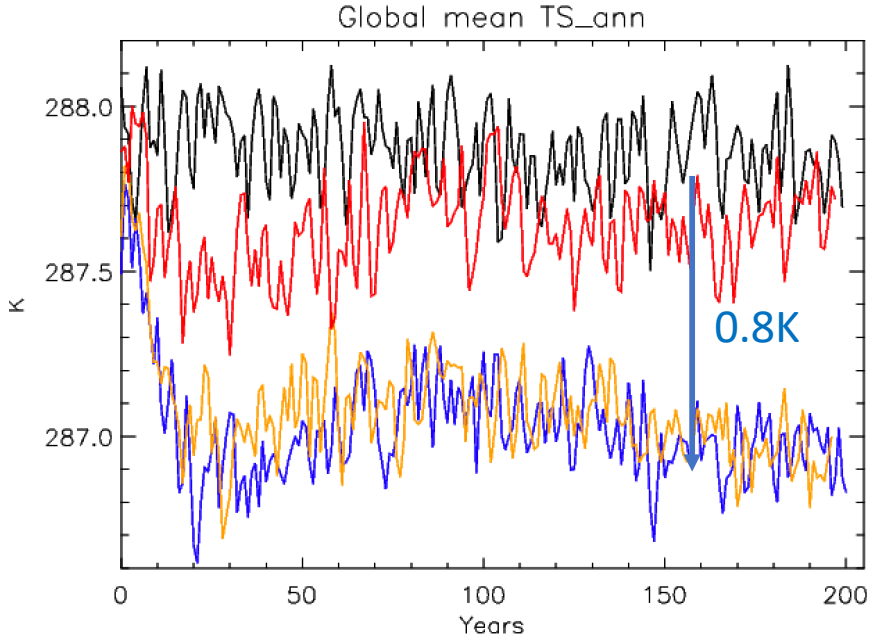


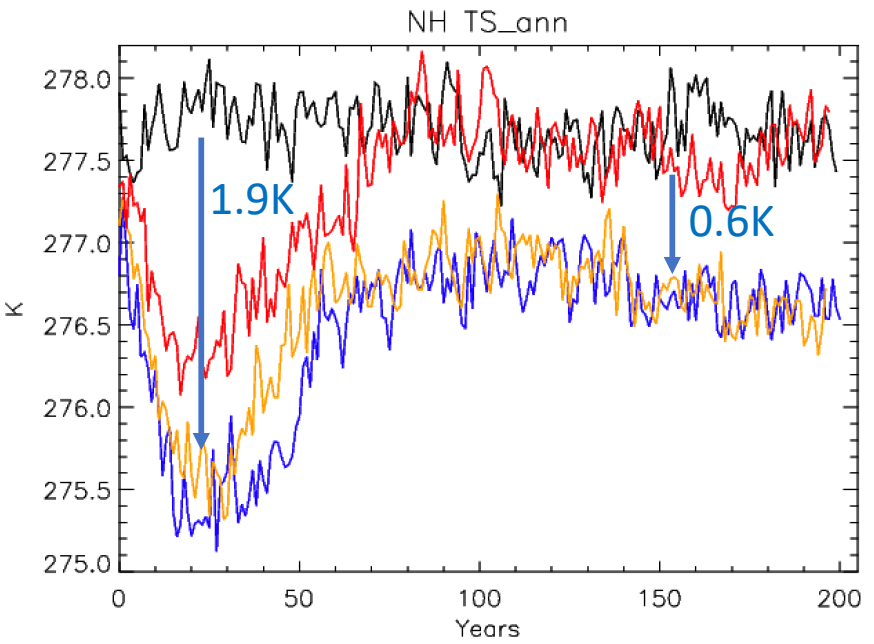
(Ts(smin)-Ts(smax)=-0.07 K)

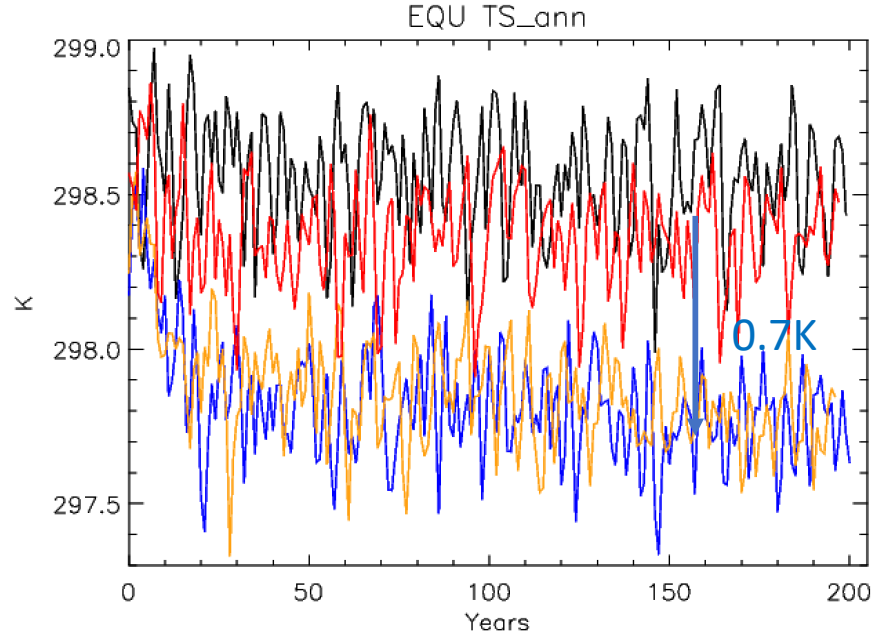


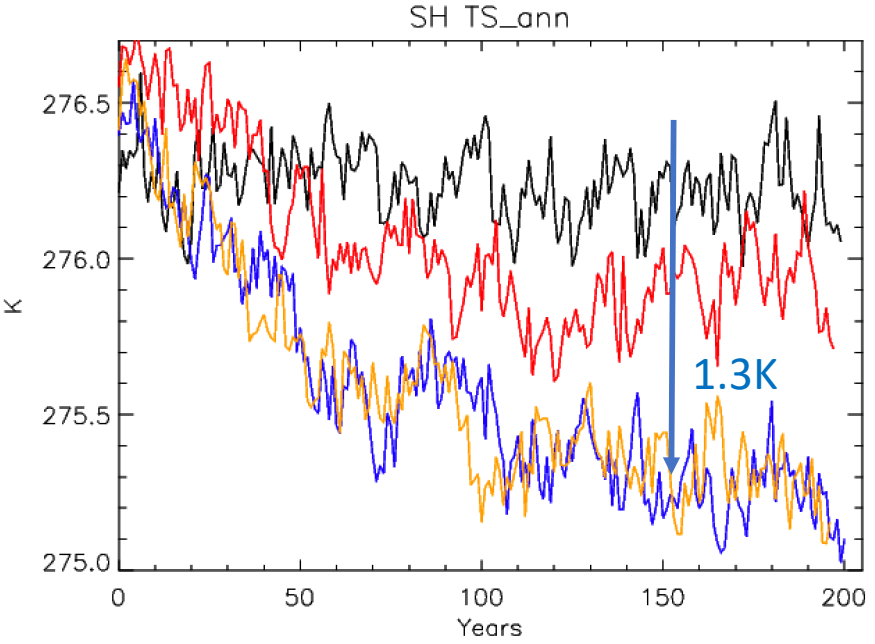


Annual Average TS Time Series

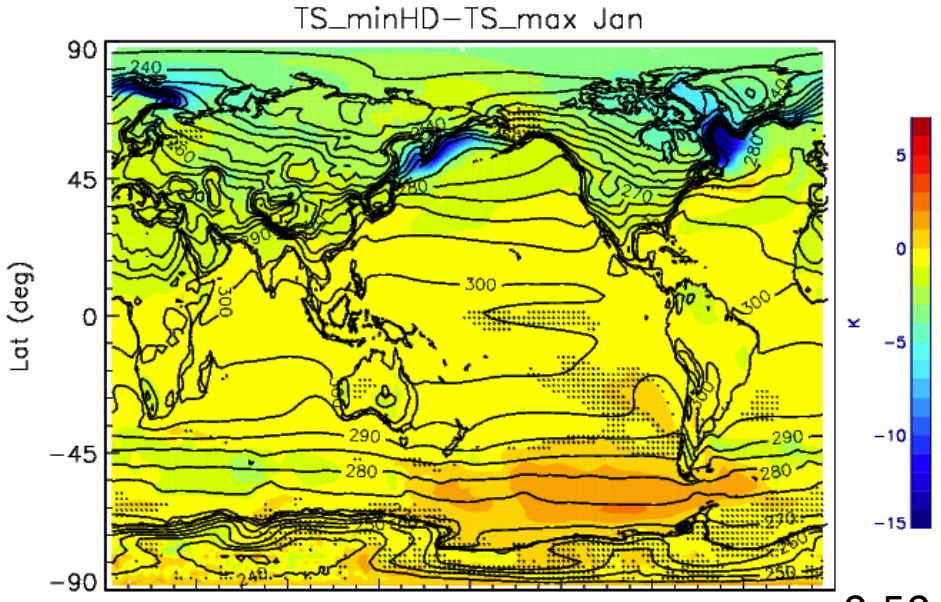


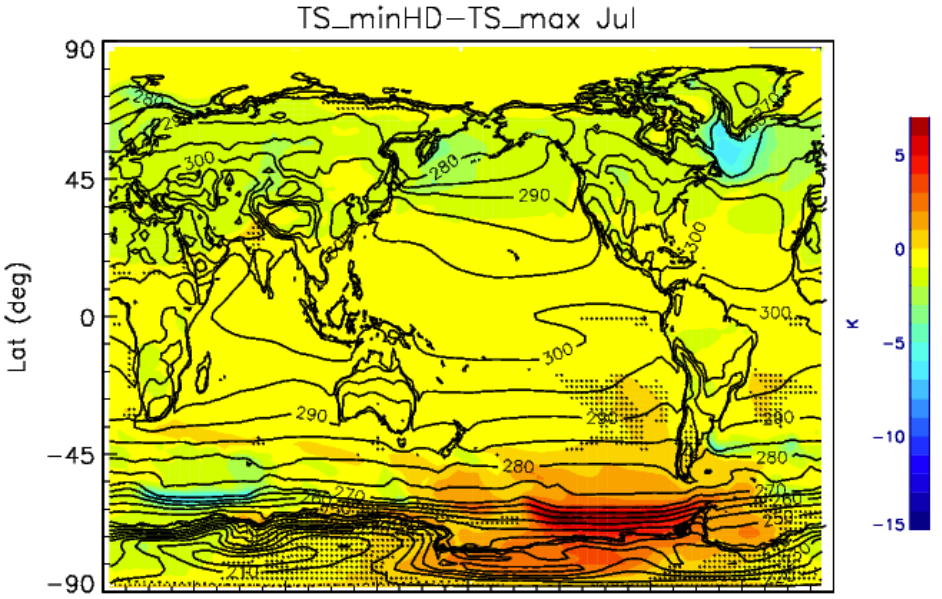




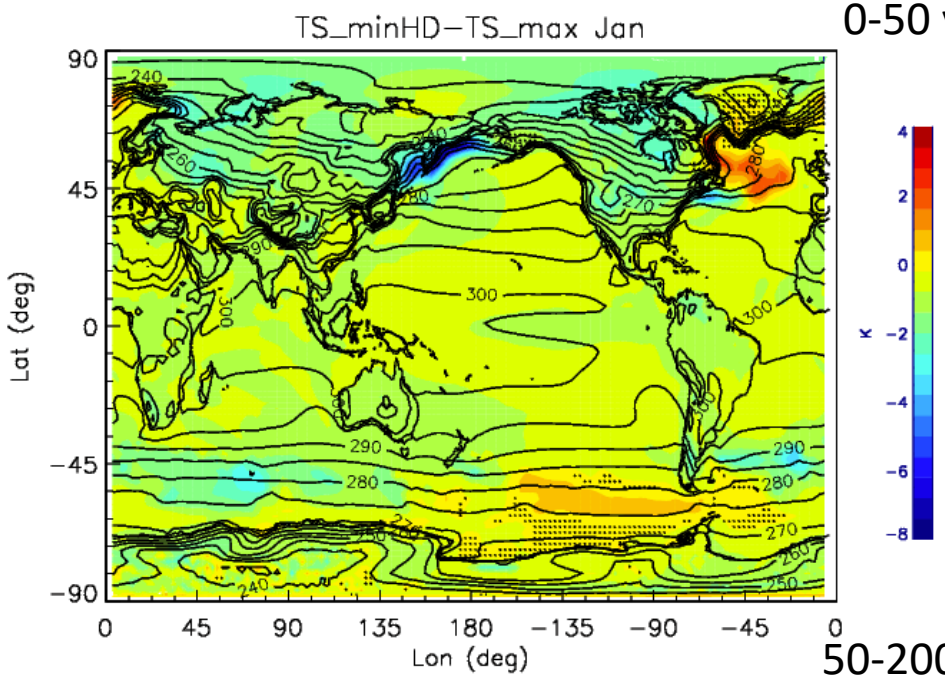


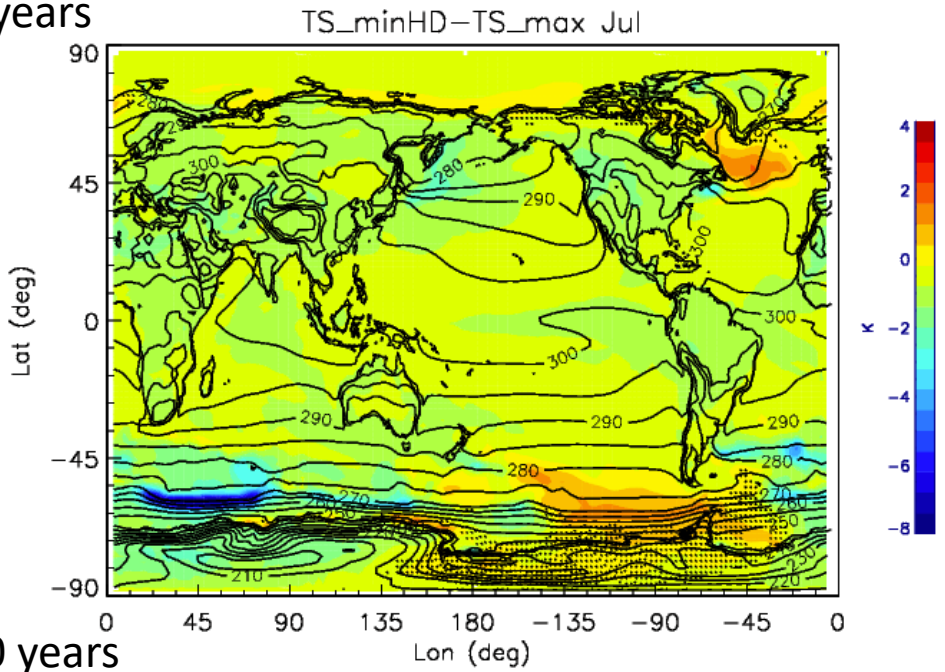
Ts(SminHD)-Ts(Smax)





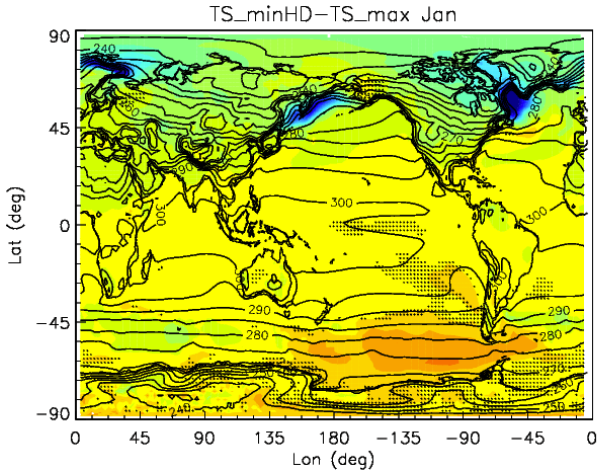
0-50 years

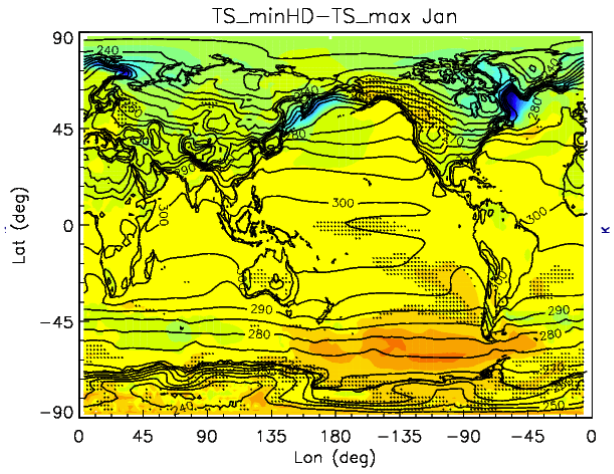


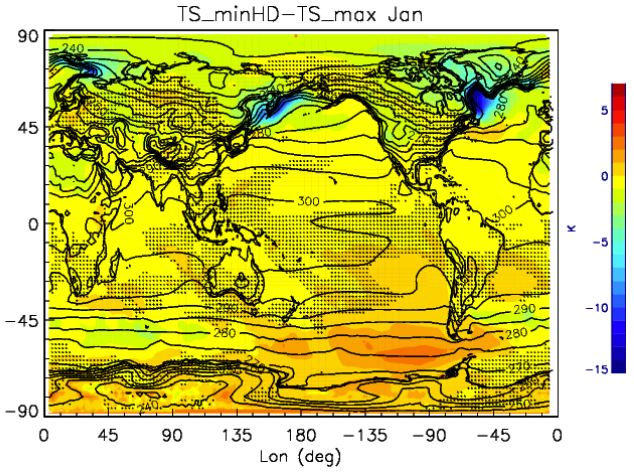


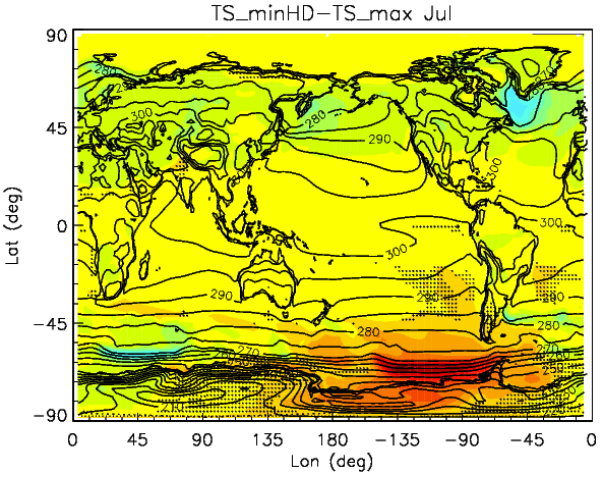
50-200 years

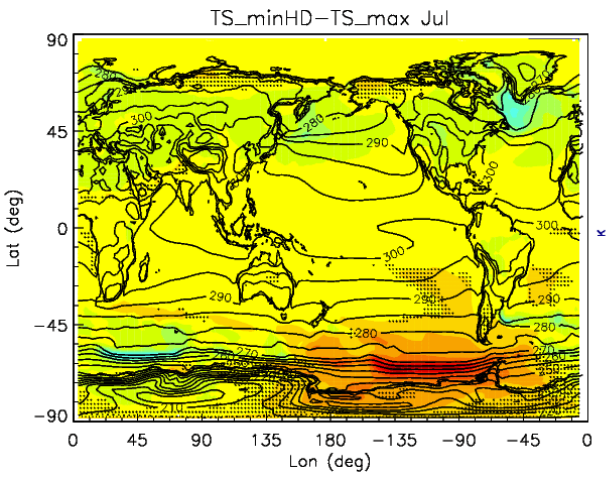
TS: HD/HDVIS/HDUV (0-50 yrs)

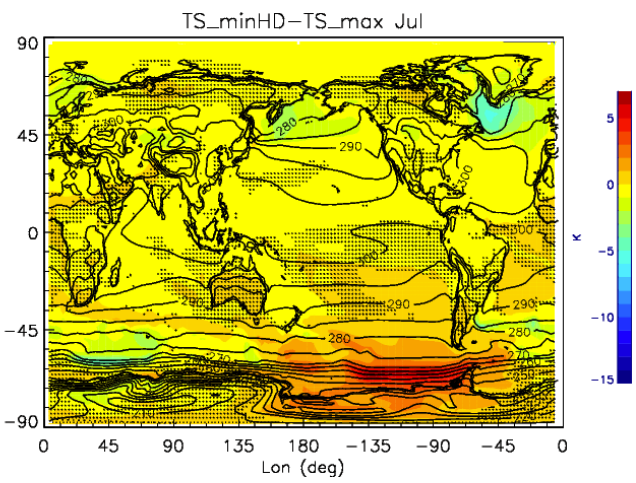




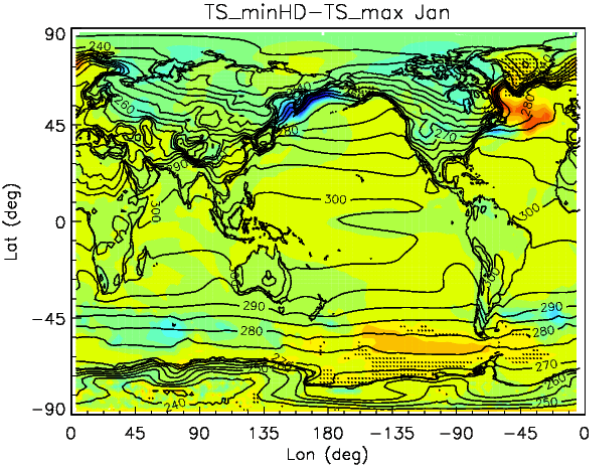


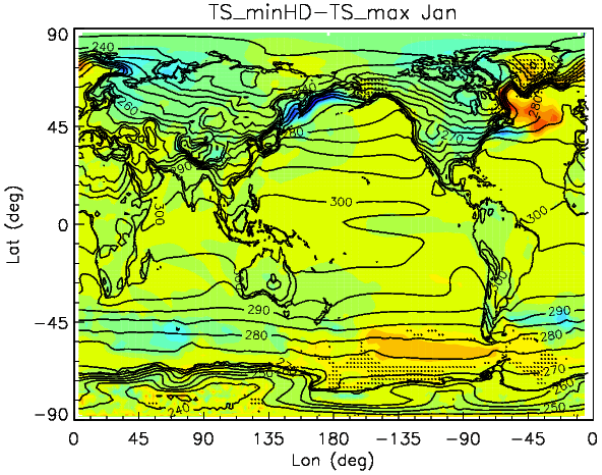


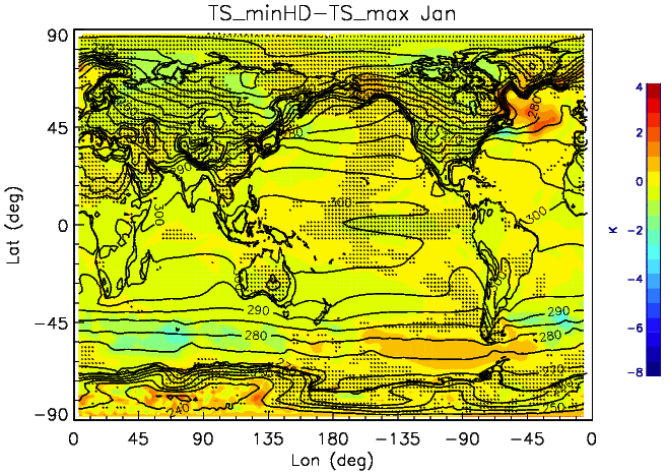


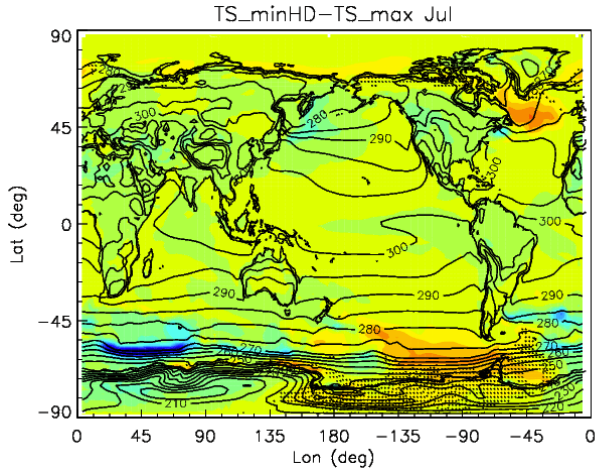


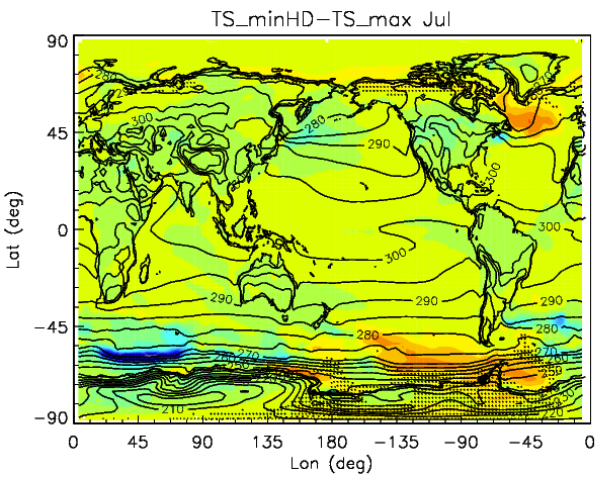
TS: HD/HDVIS/HDUV (50-200 yrs)

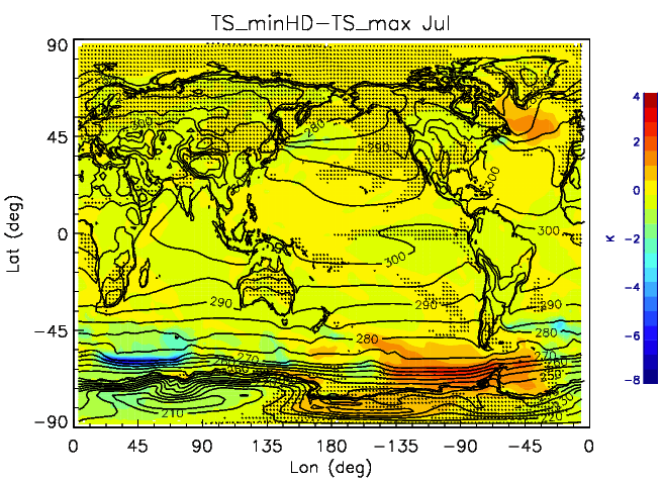




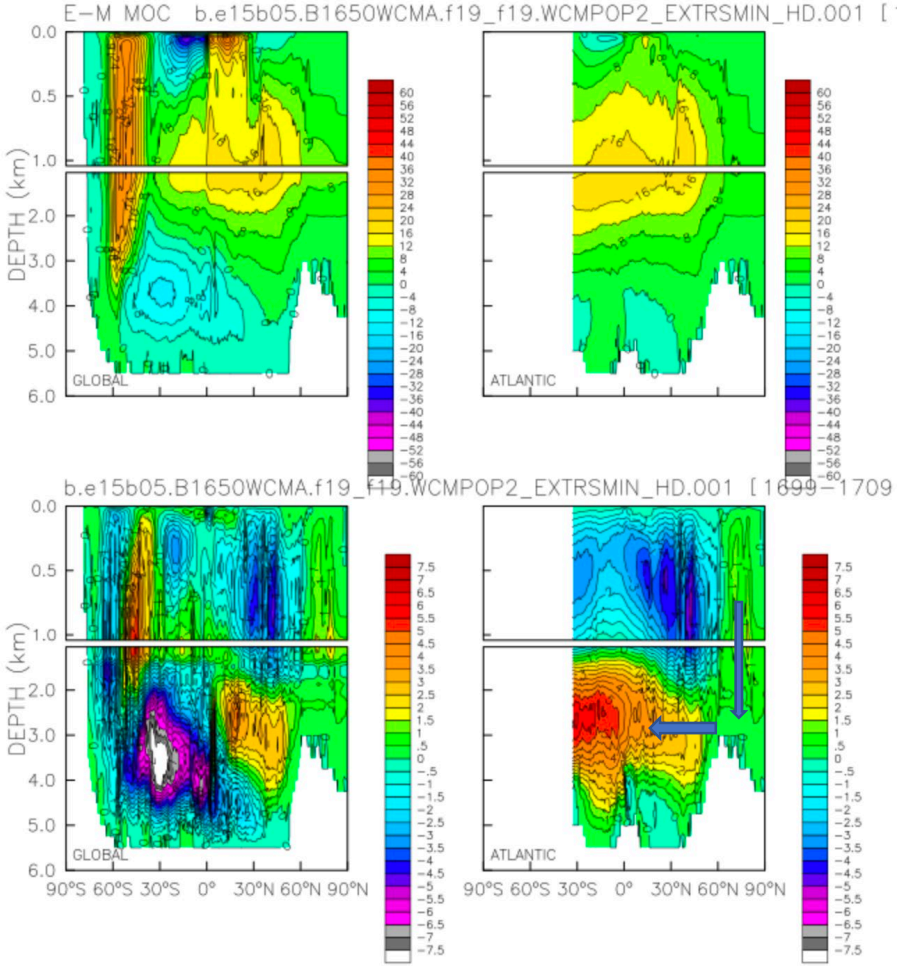


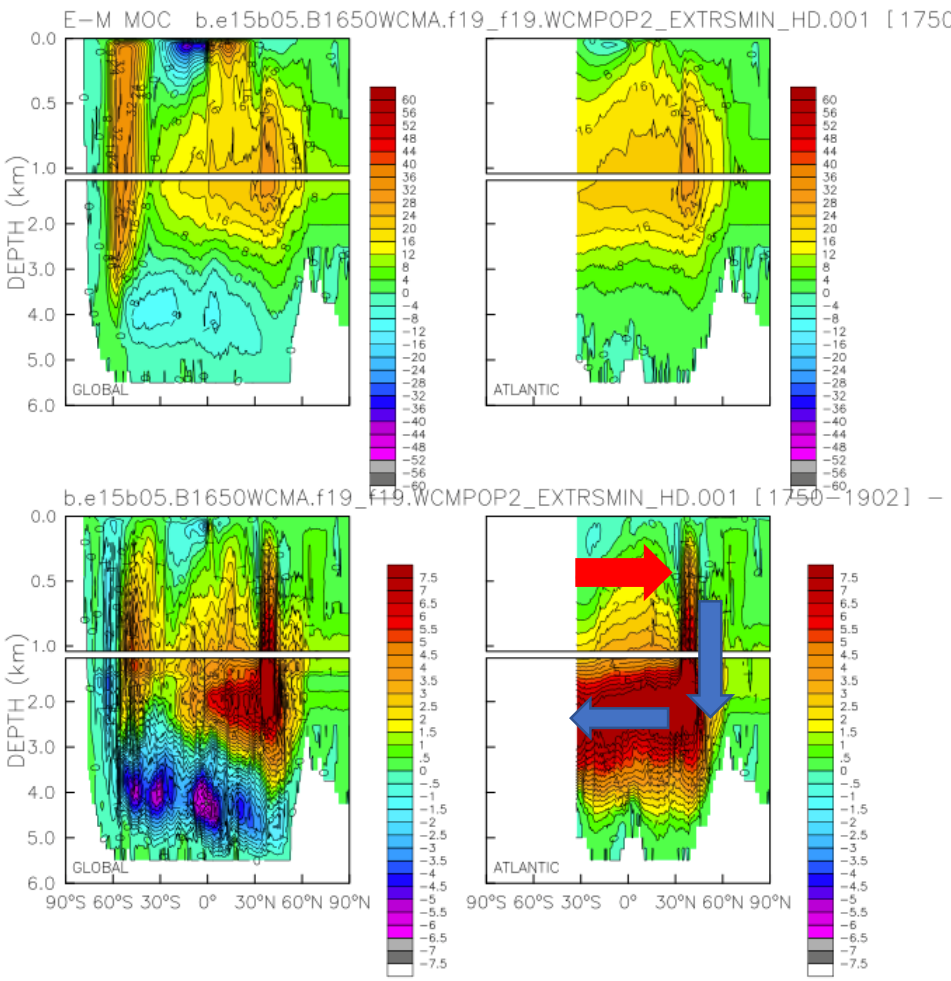




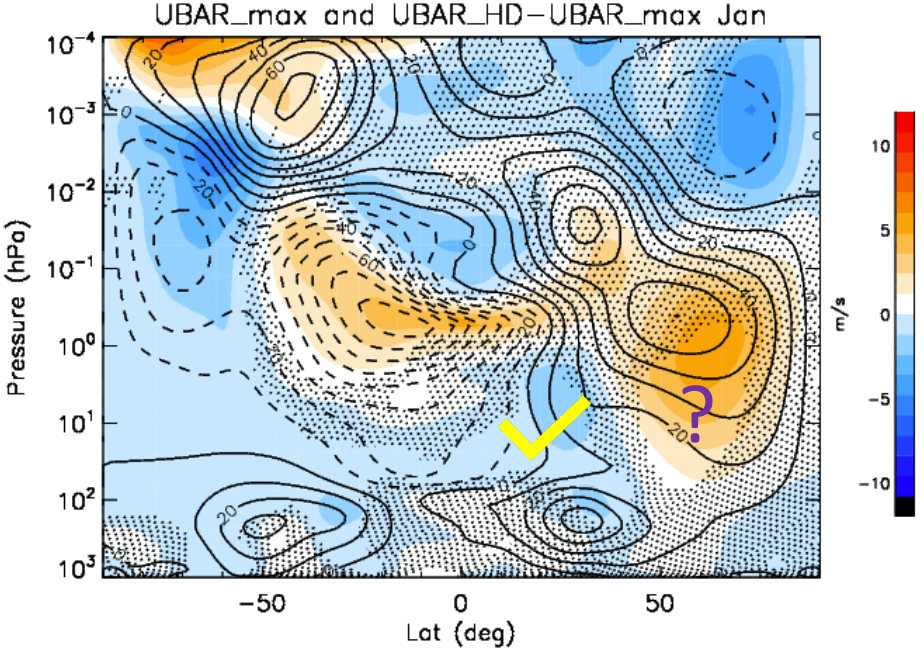


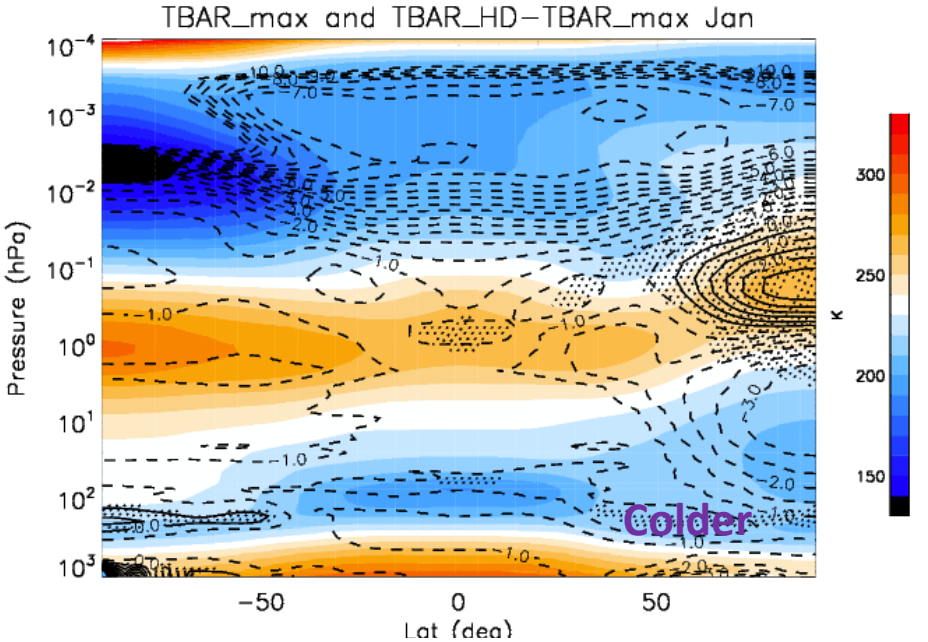
Atlantic Meridional Overturning Circulation (AMOC)

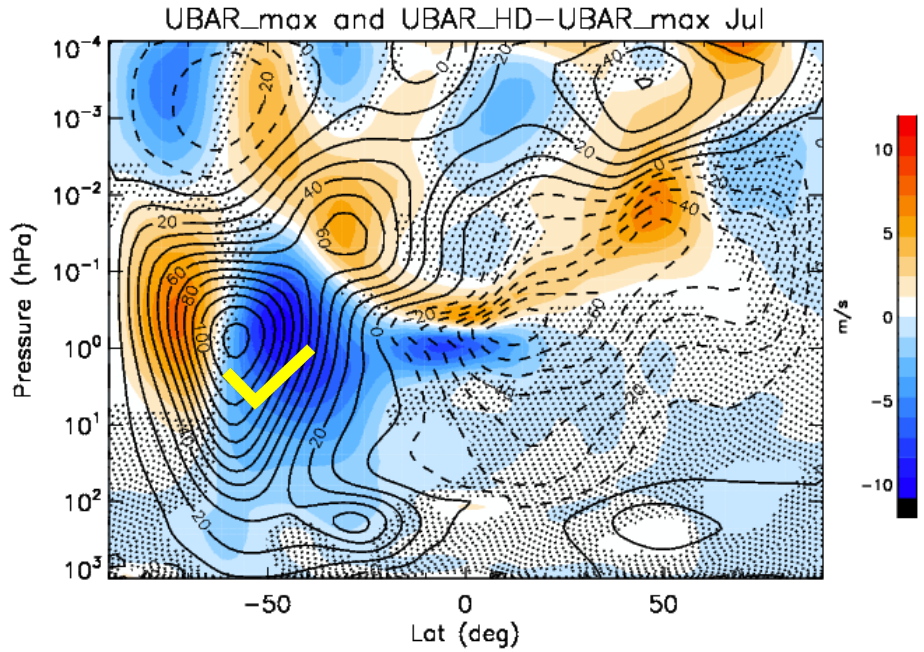


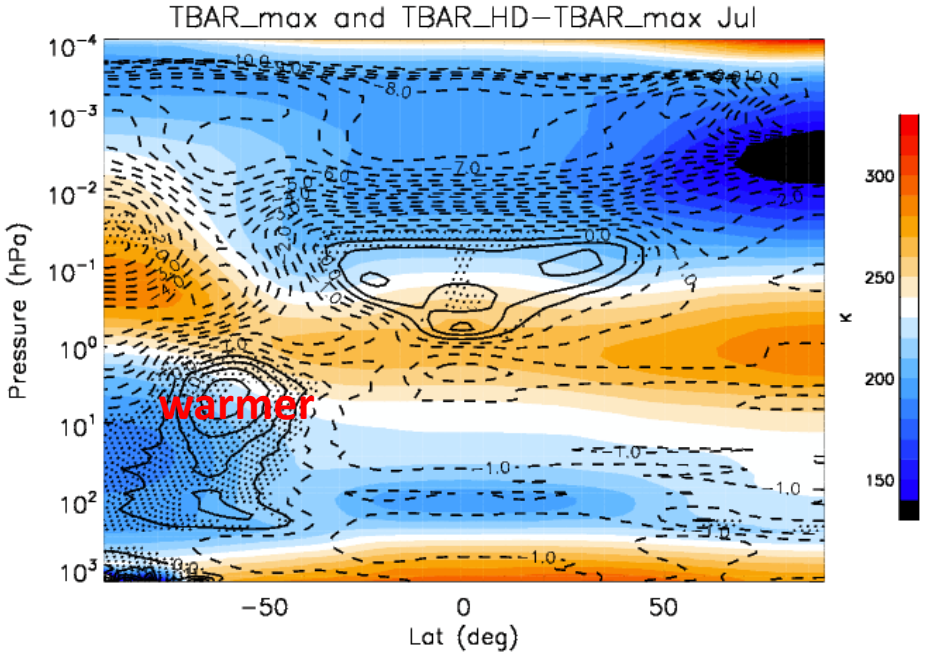


Atmosphere Zonal Wind and Temperature

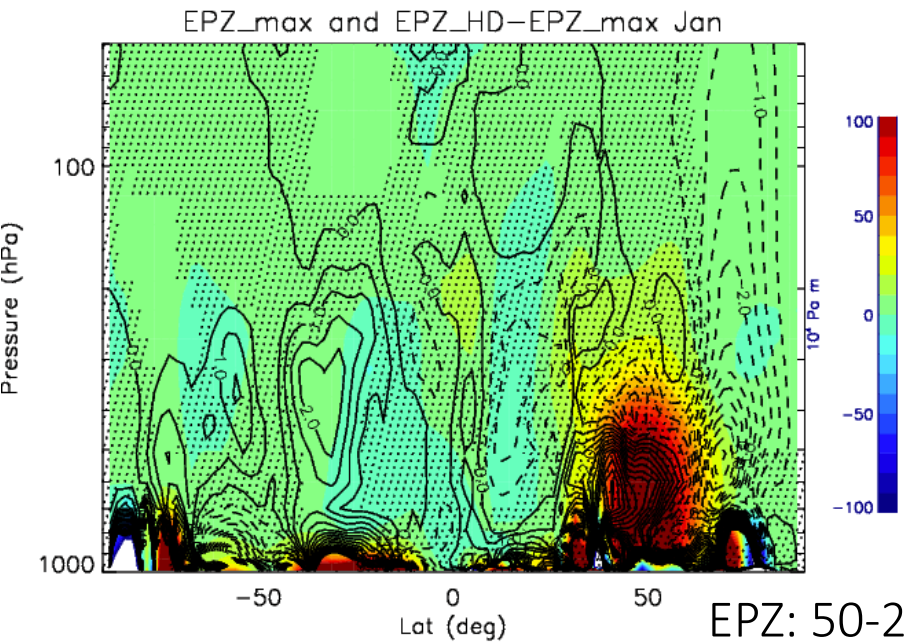


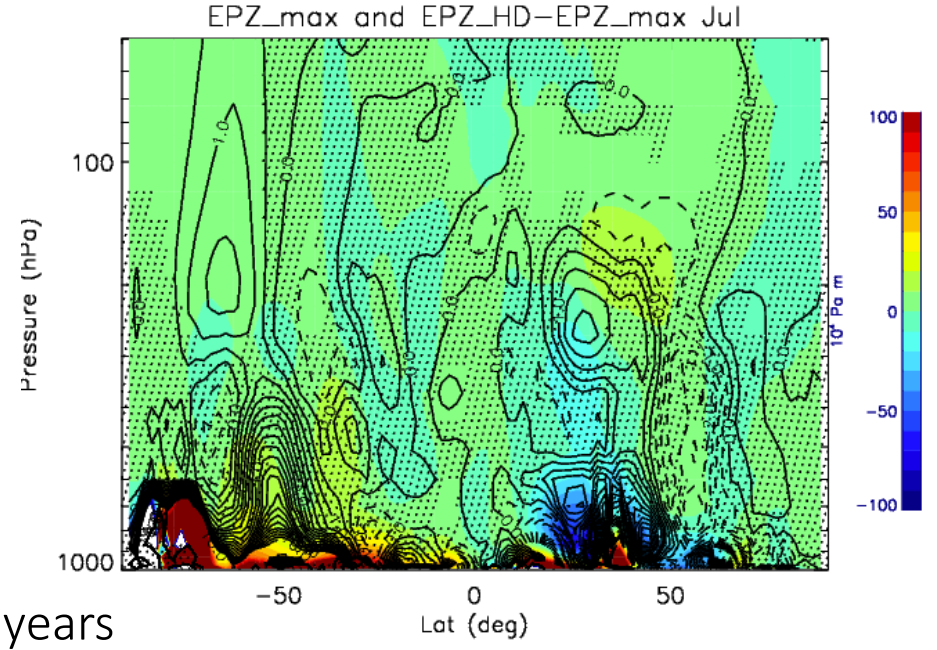




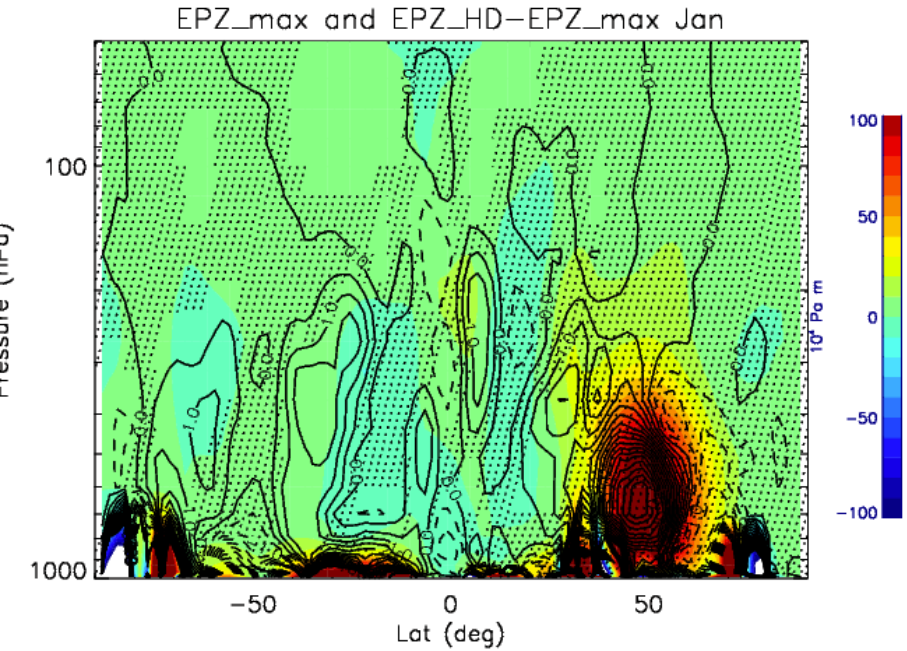


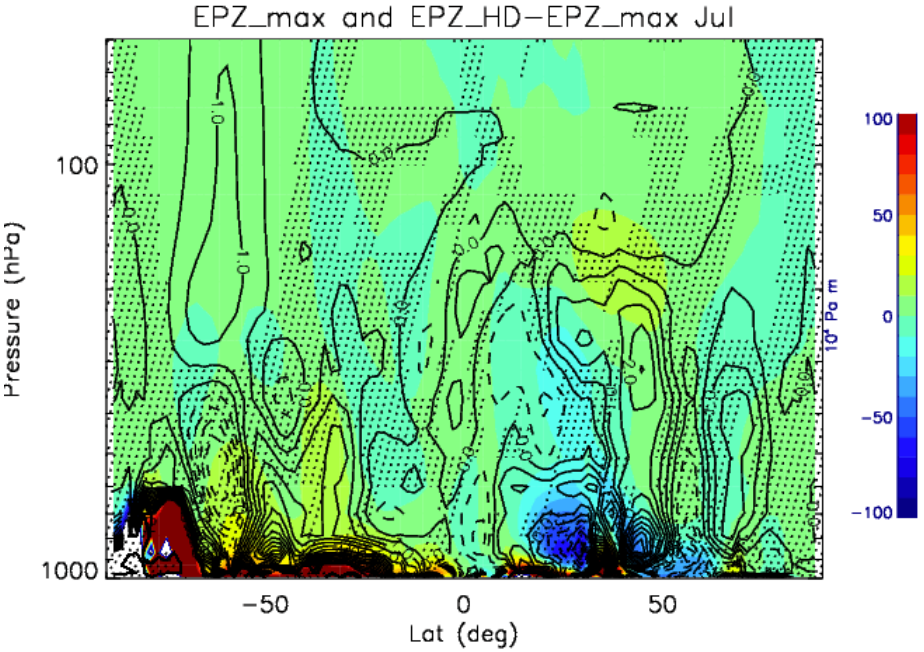
EPZ: 0-50 years





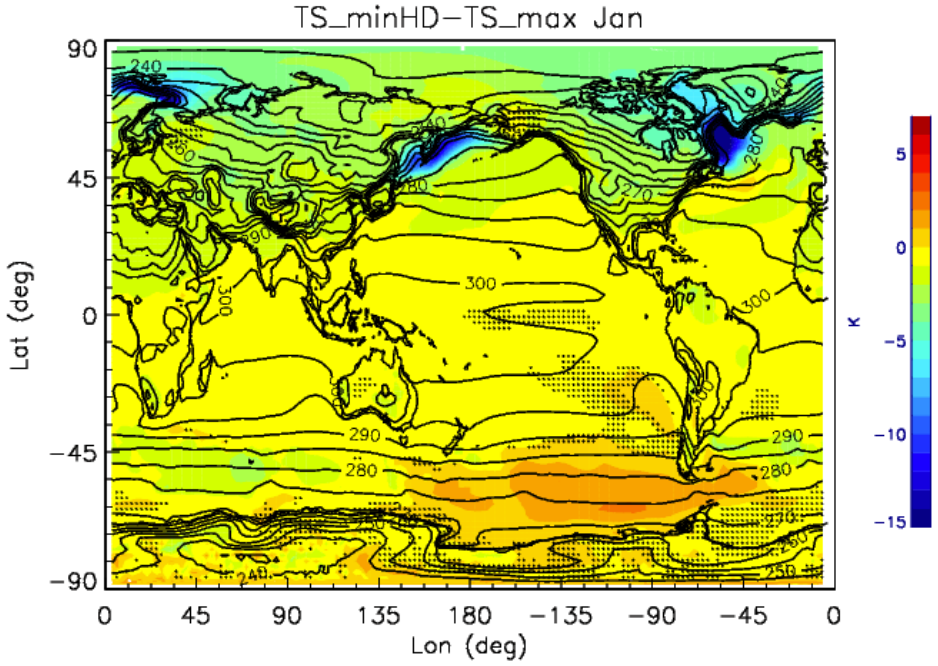
EPZ: 50-200 years

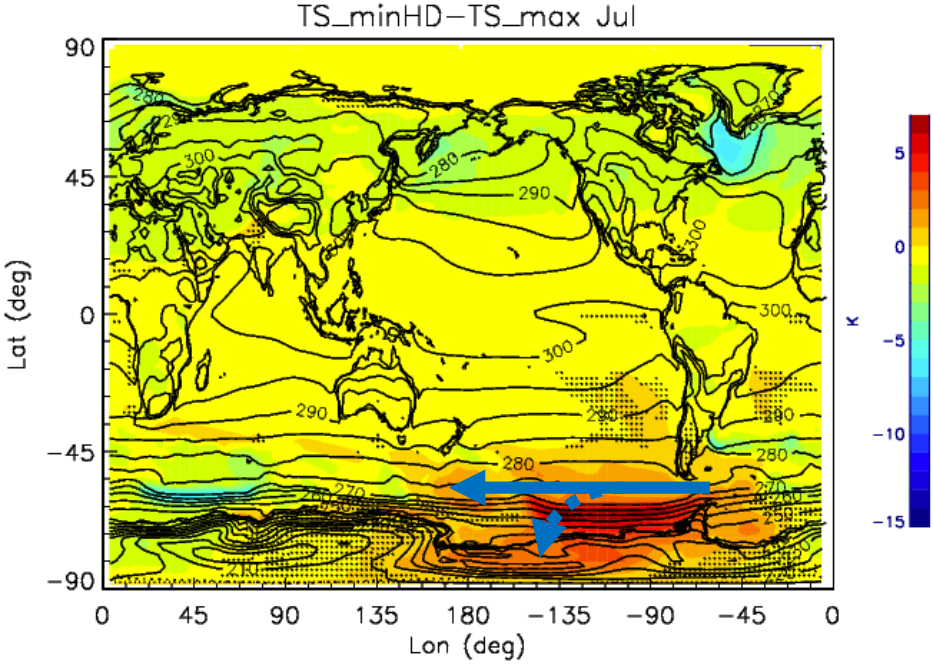




First several decades

	PW(NH)	T(NH)	U(NH)	PW(SH)	T(SH)	U(SH)
Radiative		Cooling	Slower		Cooling	Slower
Dynamics	Weaker (BD Weaker)	Cooling	Faster	Stronger (BD Stronger)	Warming	Slower
Net		Strong Cooling	Variable		Variable	Much Slower
Tropo/Ocean		Cooling				Slower





First several decades

	PW(NH)	T(NH)	U(NH)	PW(SH)	T(SH)	U(SH)
Radiative		Cooling	Slower		Cooling	Slower
Dynamics	Weaker (BD Weaker)	Cooling	Faster	Stronger (BD Stronger)	Warming	Slower
Net		Strong Cooling	Variable		Variable	Much Slower
Tropo/Ocean		Cooling				Slower

AMOC Change

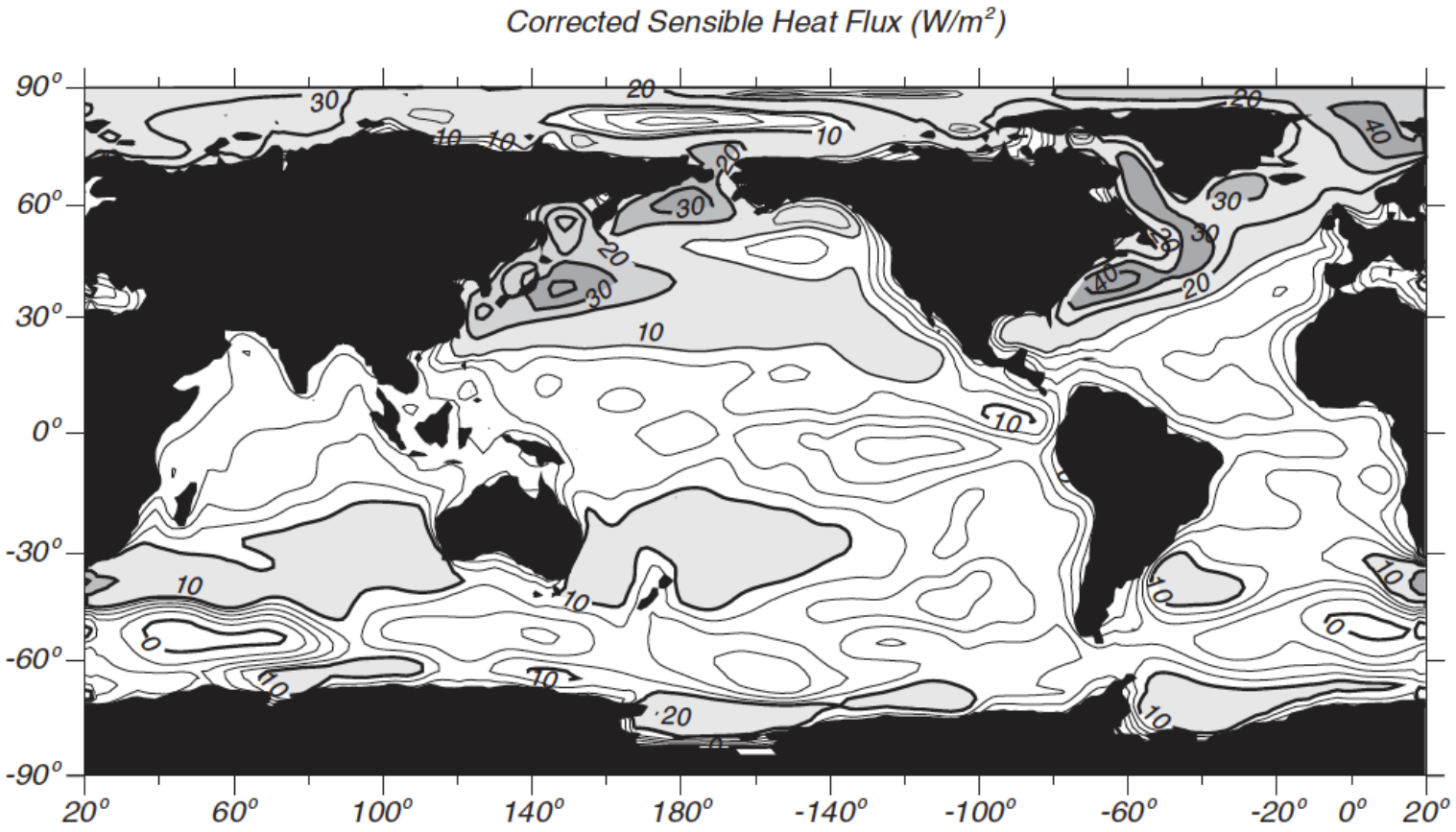
Later period

	PW(NH)	T(NH)	U(NH)	PW(SH)	T(SH)	U(SH)
Radiative		Cooling	Slower		Cooling	Slower
Dynamics	Recover			Stronger (BD Stronger)	Warming	Slower
Net		Cooling	Slower		Variable	Much Slower
Tropo/Ocean		Cooling+Warming (North Atlantic)				Slower

Summary

- Climate sensitivity to solar forcing studied using WACCM/POP simulations with a sudden decrease of SSI to an extreme low condition derived from solar HD/MHD simulations.
- Clear responses are found in the coupled middle atmosphere, troposphere, ocean and sea ice, and the responses in the two hemispheres differ significantly.
  - Downward impact on temperature and wind.
  - Different planetary wave response due to differences in air-sea interaction.
- Even with reduction only in the UV range (<350nm), similar tropospheric and oceanic changes—significant albeit with reduced magnitude—are found in the simulations.
  - Troposphere/ocean responses to UV change and VIS/IR change are in phase and thus enhancing.

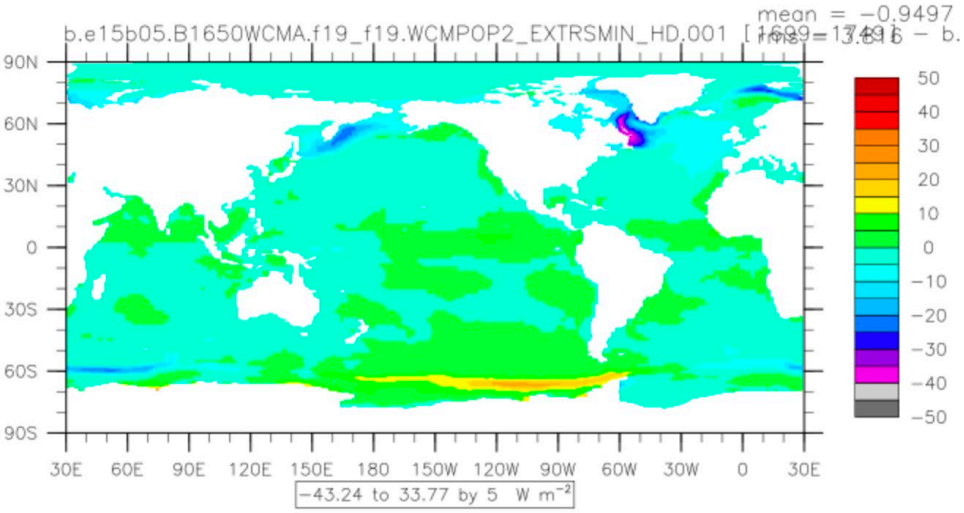
Backup Slides



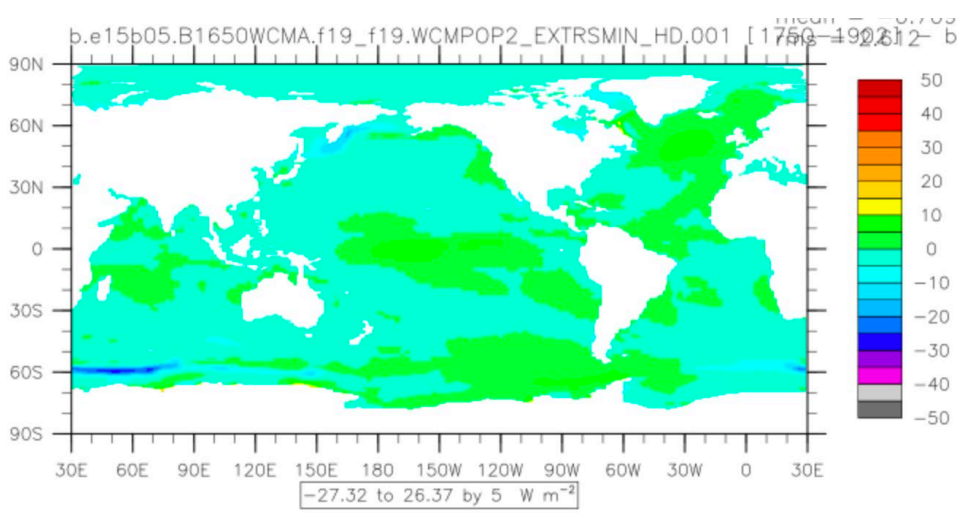
DaSilva et al., 1995

Surface Short Wave Flux

Negatively correlated with ice cover

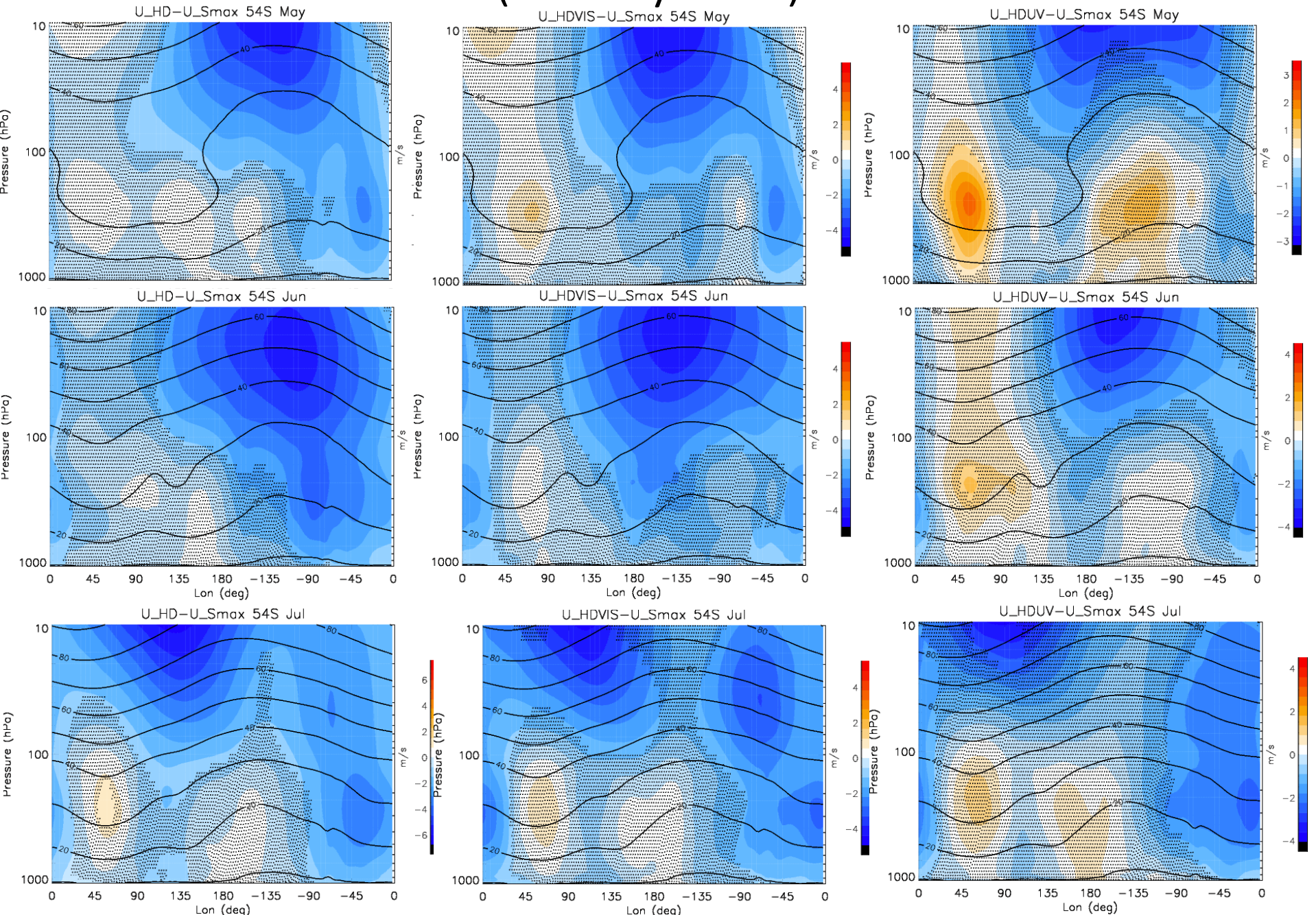


0-50 years

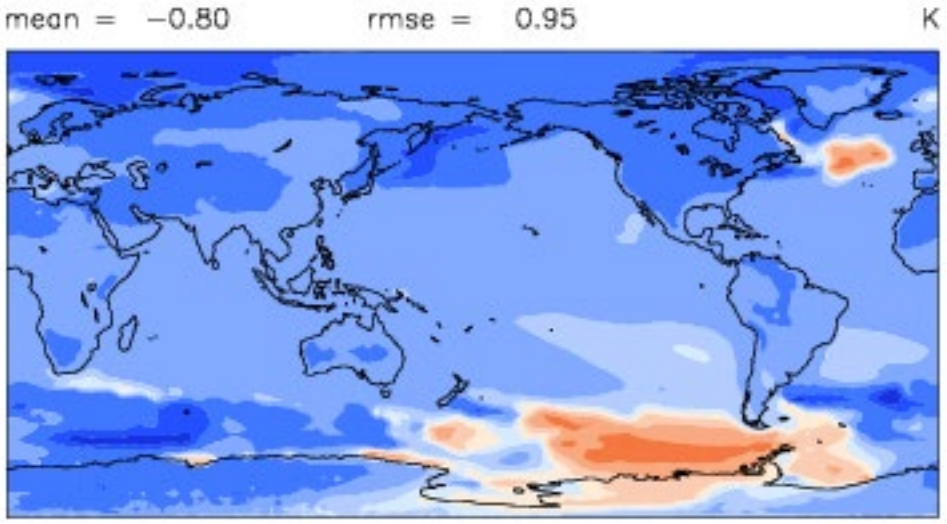


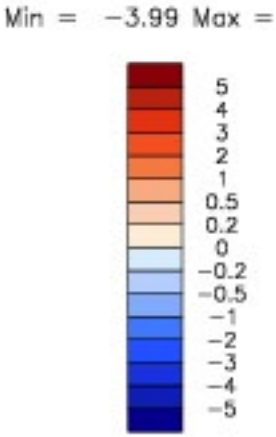
50-150 years

Zonal wind SH (0-50 years)

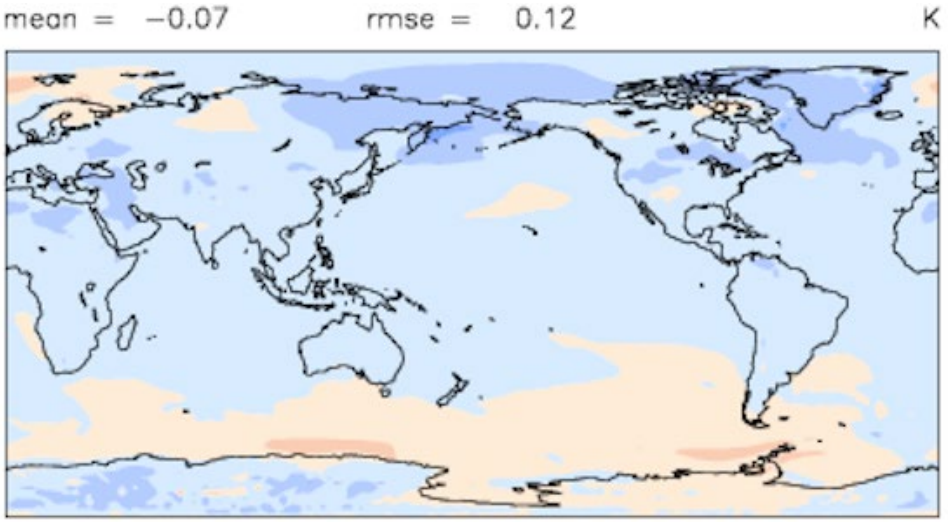


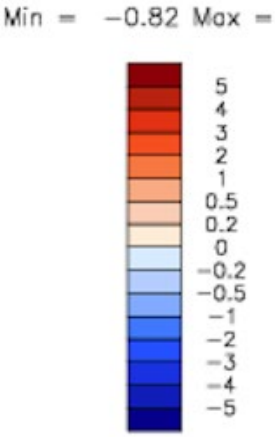
Comparison with Nominal Solar Min/Max





Ts(HD)-Ts (Smax)





Ts(Smin)-Ts (Smax)