Community Atmosphere Model (CAM)

CAM4 (Track 1)/CAM5(Track 5)

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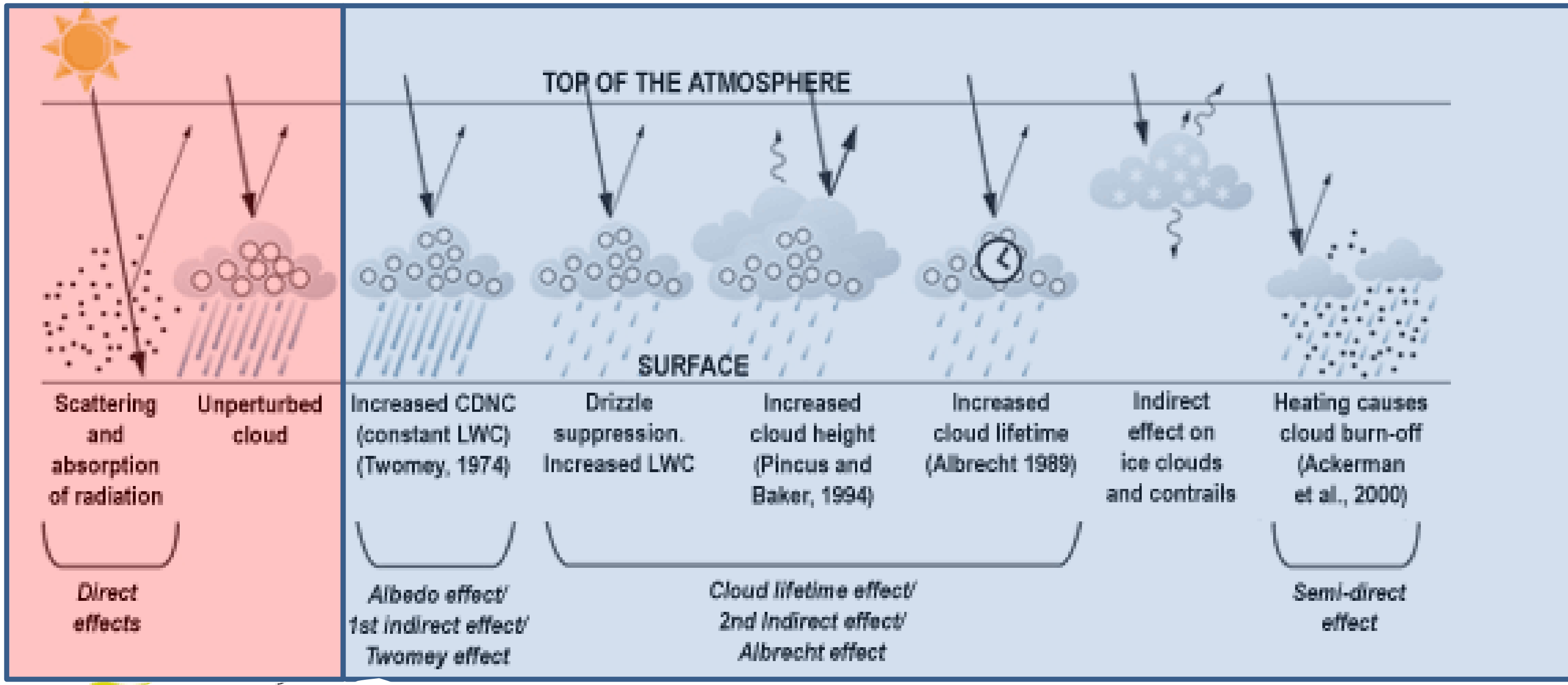
CAM Evolution

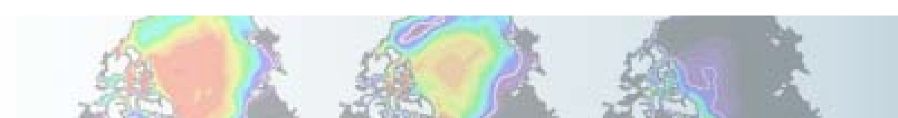
Model	CCSM3 *(2004)*	CCSM3.5 *(2007)*	CCSM4 *(Apr 2010)*	CESM1 *(Jun 2010)*
Atmosphere	CAM3 (L26)	CAM3.5 (L26)	CAM4/Track 1 (L26)	CAM5/Track5 (L30)
Boundary Layer	Holtslag and Boville (93)	Holtslag and Boville	Holtslag and Boville	UW *Diagnostic TKE* Park et al. (09)
Shallow Convection	Hack (94)	Hack	Hack	UW *TKE/CIN* Park et al. (09)
Deep Convection	Zhang and McFarlane (95)	Zhang and McFarlane Neale et al.(08), Richter and Rasch (08) mods.	Zhang and McFarlane Neale et al., Richter and Rasch mods.	Zhang and McFarlane Neale et al., Richter and Rasch mods.
Stratiform Cloud	Rasch and Kristjansson (98) *Single Moment*	Rasch and K. *Single Moment + freeze drying*	Rasch and K. *Single Moment + freeze drying*	Morrison and Gettelman (08) *Double Moment* Park Macrophysics Park et al. (10)
Radiation	CAMRT (01)	CAMRT	CAMRT	RRTMG Iacono et al. (2008)
Aerosols	Bulk Aerosol Model (BAM)	BAM	BAM	Modal Aerosol Model (MAM) Ghan et al. (2010)
Dynamics	Spectral	Finite Volume (96,04)	Finite Volume	Finite Volume
Ocean	POP2 (L40)	POP2.1 (L60)	POP2.2	POP2.2 - *BGC*
Land	CLM3	CLM3.5	CLM4 - *CN*	CLM4
Sea Ice	CSIM4	CSIM4	CICE	CICE

Microphysics and modal aerosols permit the study of aerosol indirect effects

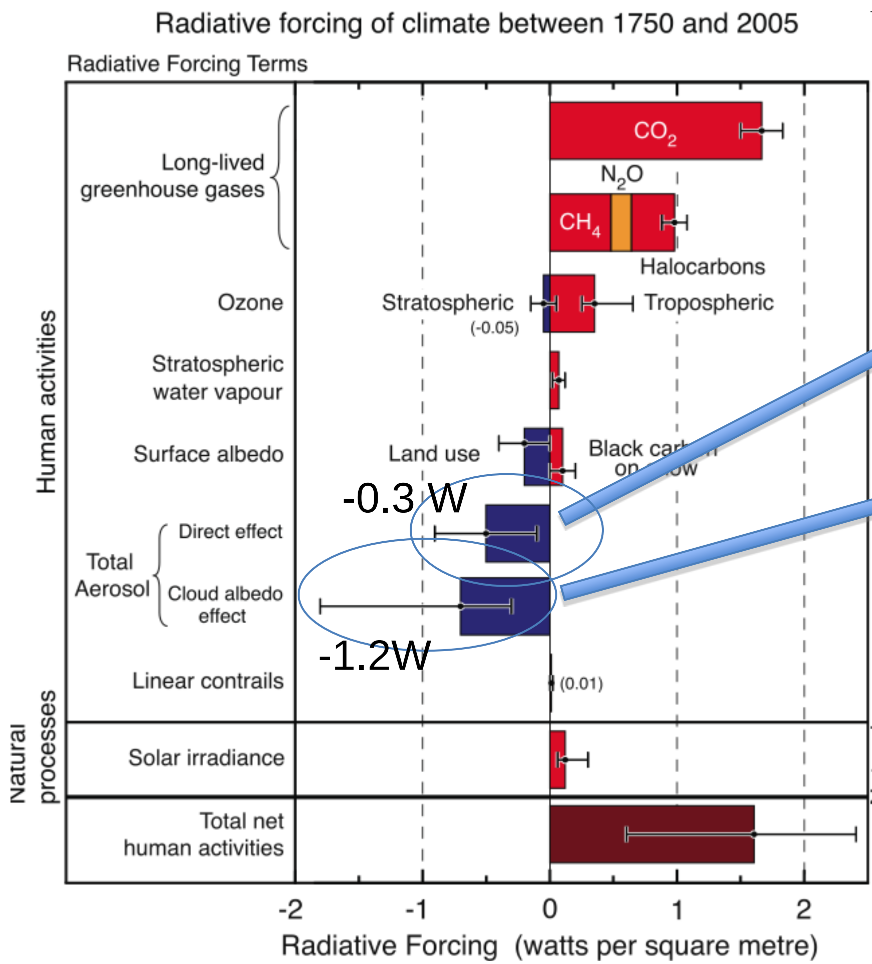
CAM4

CAM5





Addressing Forcing Uncertainty



Forcings

Aerosols (MAM) + radiation (RRTM)

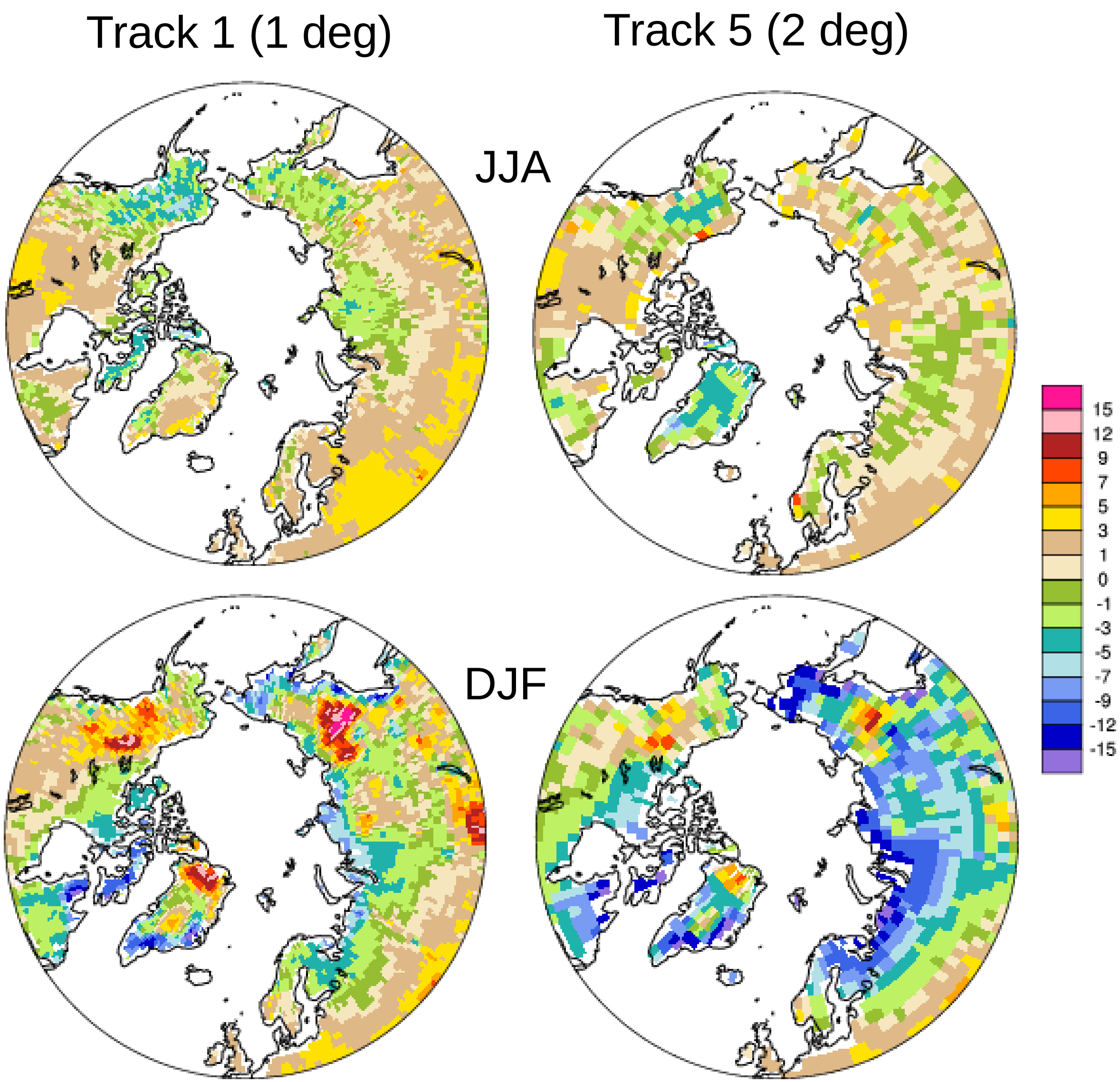
Aerosols + microphysics (MG, #/c) + clouds (UW) + radiation

Feedbacks

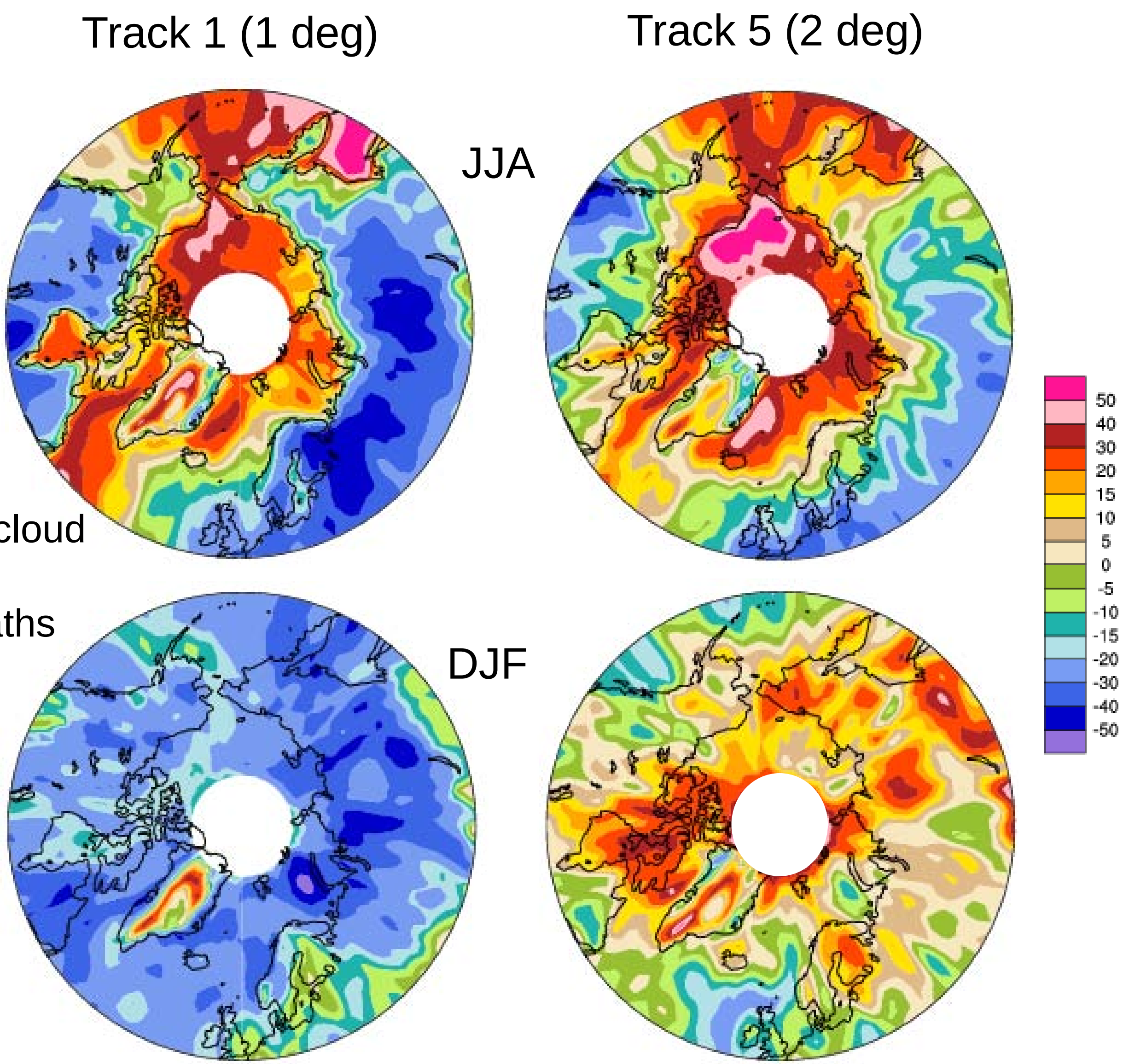
Clouds -> f(moist PBL, ice #/c)

Radiation -> f(Water vapor)

Arctic Surface Air Temperature Bias (K)
in 1850 - Warren



Arctic Surface Low Cloud
Bias (%) in 1850 - Cloudsat

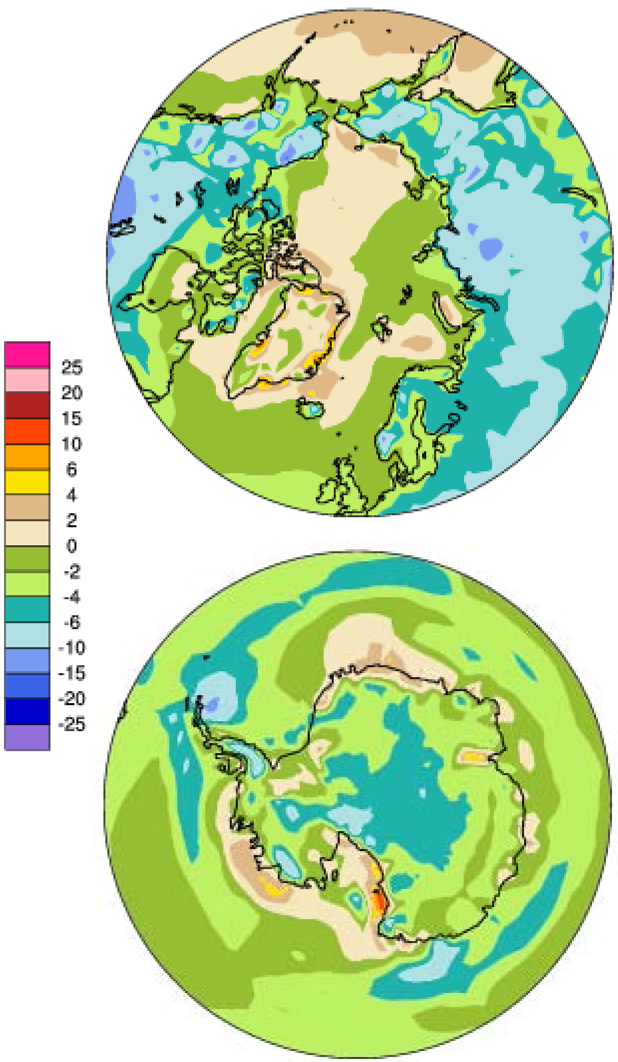


- ✓Freeze drying
- ✓Stability based cloud over ocean
- ✓Higher water paths

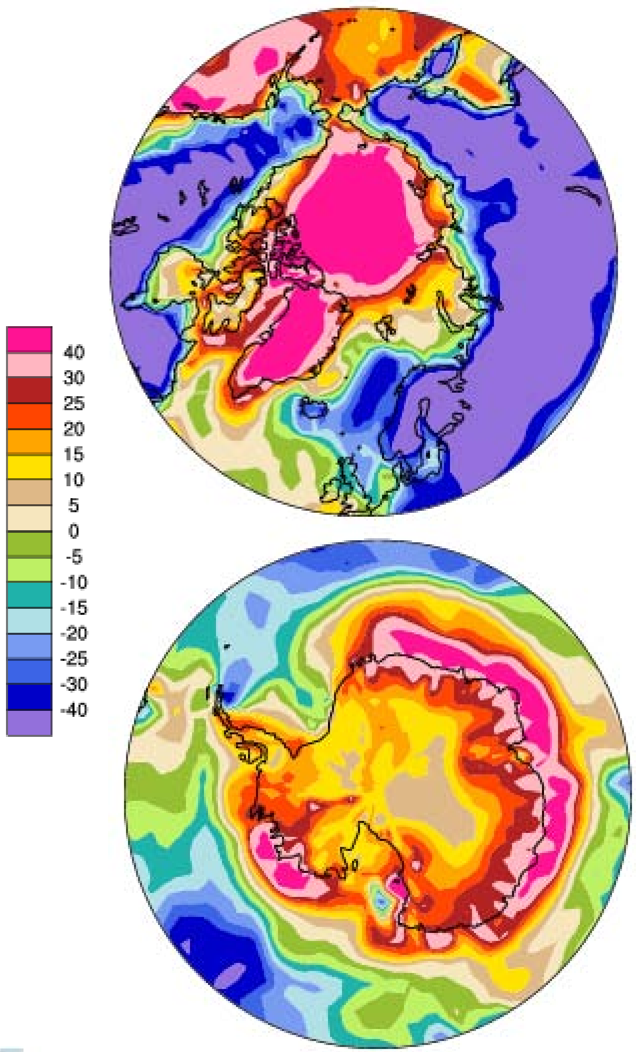
Summer Surface Shortwave Down Differences (NH-JJA,SH-DJF)

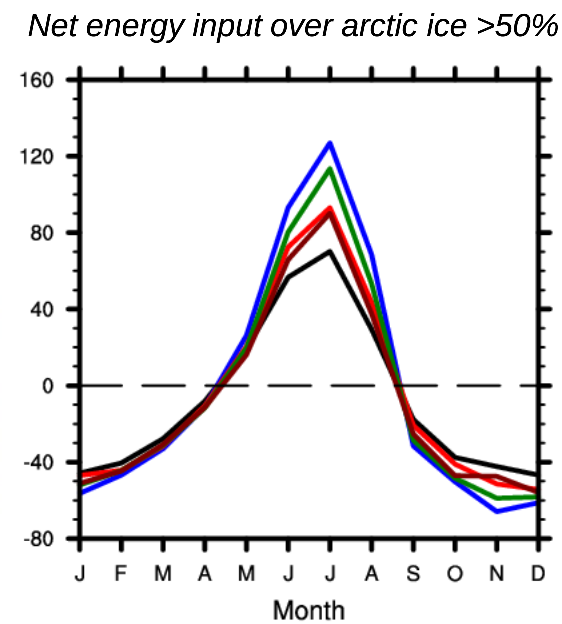
Track 5 (2 deg) minus Track 1 (1 deg)

Clear Sky



All Sky



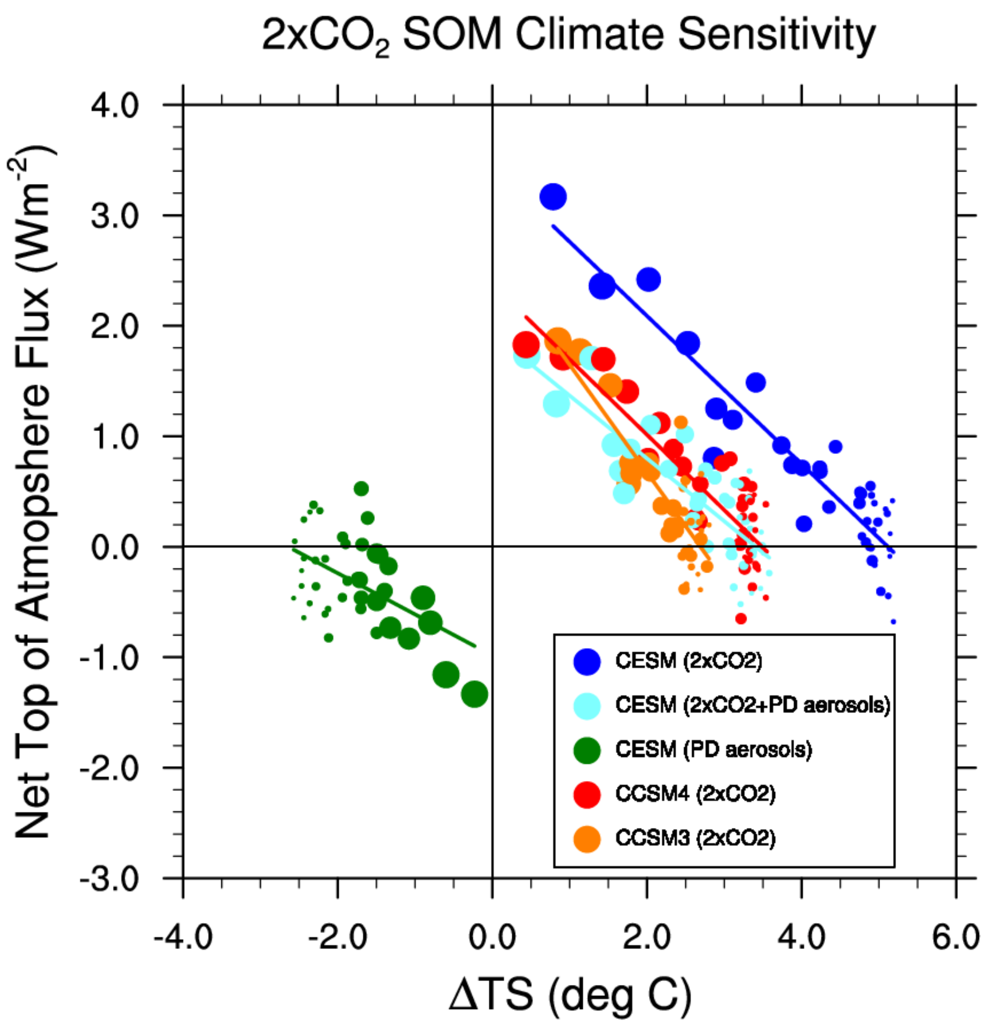


Track 1

Track 5

Track 5 has snow albedos higher than Track 1

Climate Sensitivity

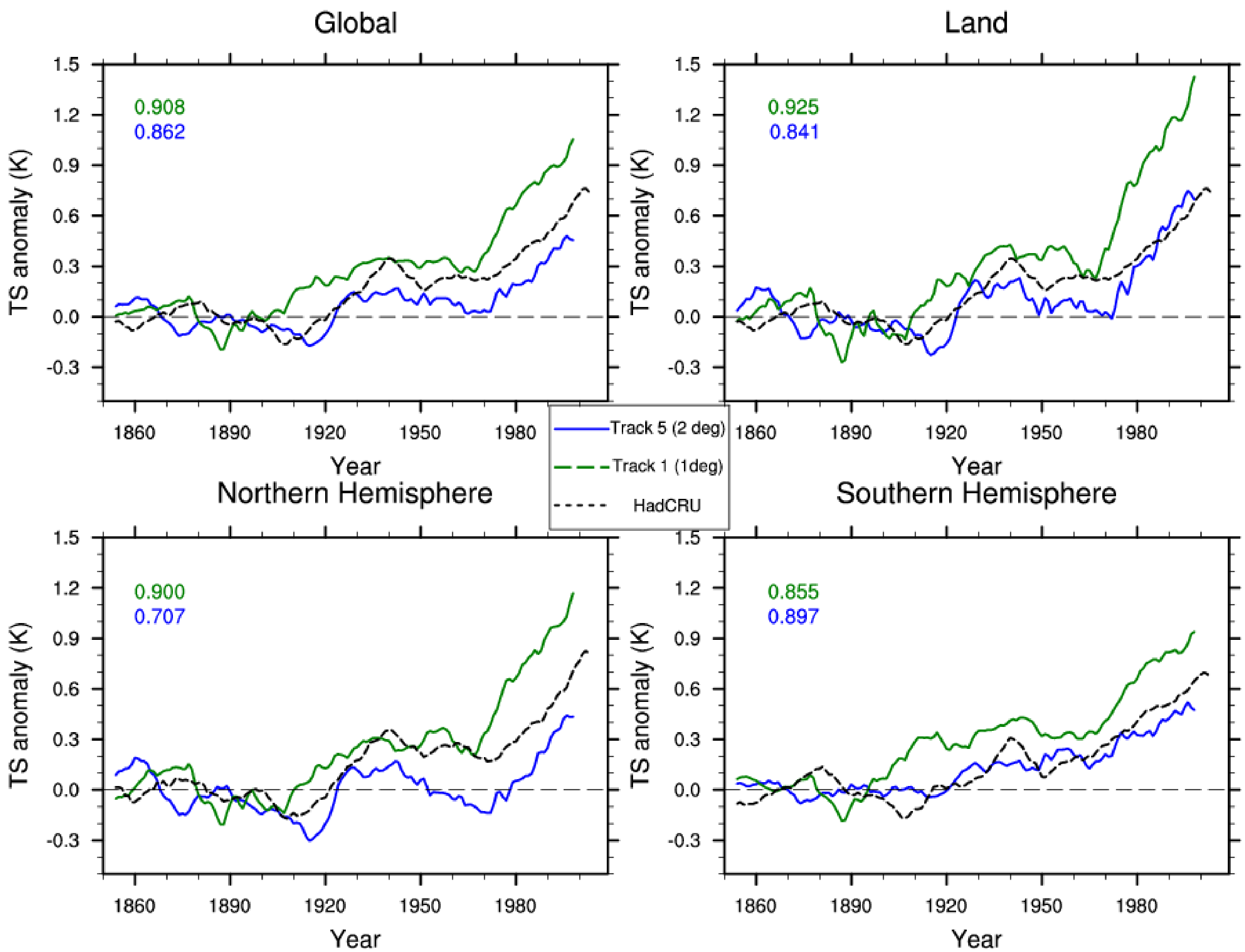


Track 1	3.4 K
Track 5	4.5 K
Track 5 PD aerosols	3.5 K
Track 5 1850 PD aerosols	-2.2 K
CCSM3	2.8 K

20th Century All Forcing Coupled Simulations

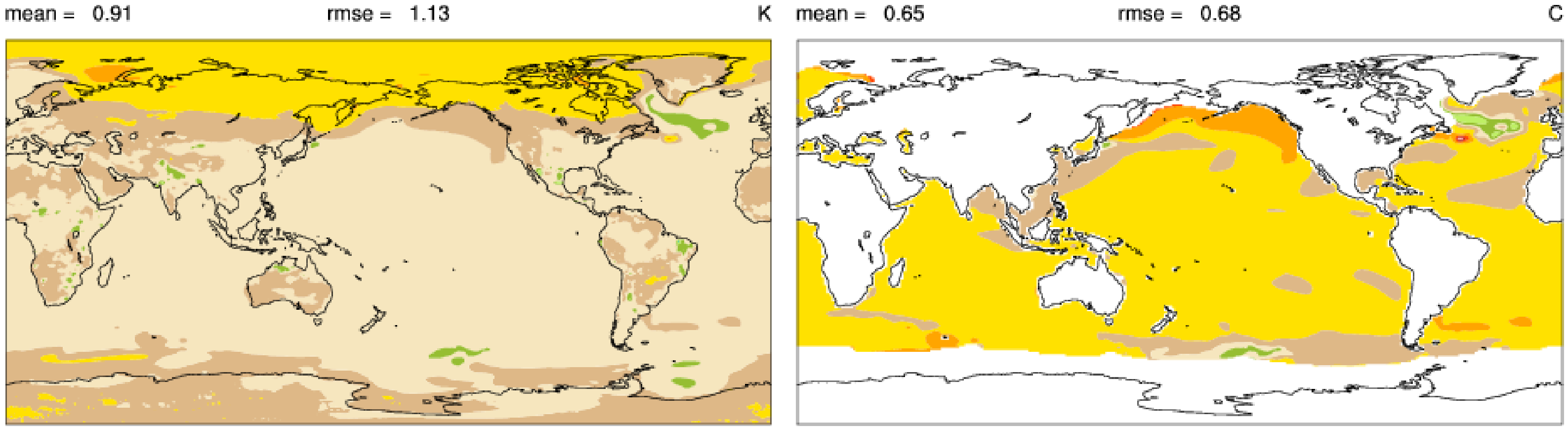
- 1850-2005 forcing fields
  - CCSM4/Track 1 (1 deg), from year 134
  - CESM1/Track 5 (2 deg), from year 893
  - GHGs, solar, large volcanoes burdens
  - Prescribe aerosol burdens and surface deposition (Track 1)
  - Prescribe aerosol emissions predicted surface deposition (Track 5)
- Global, land, hemispheric timeseries

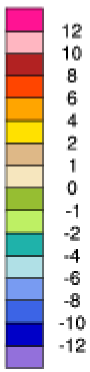
Surface Temperature Change

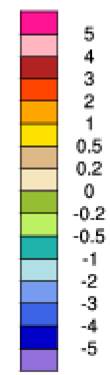


Surface Temp Change (1990-2004) (K)

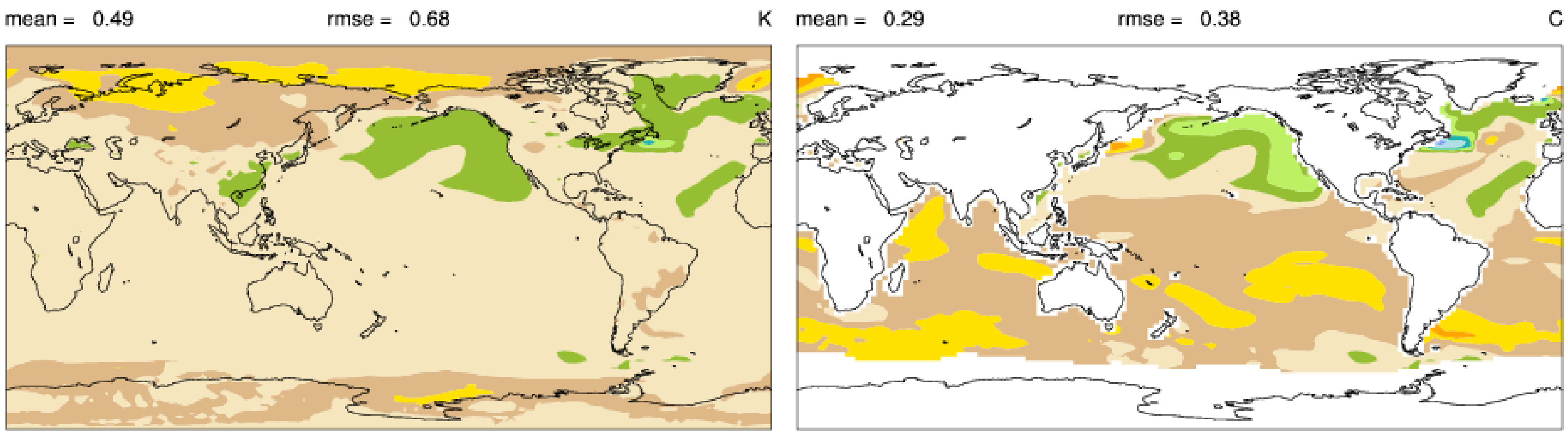
Track 1 – 1 deg



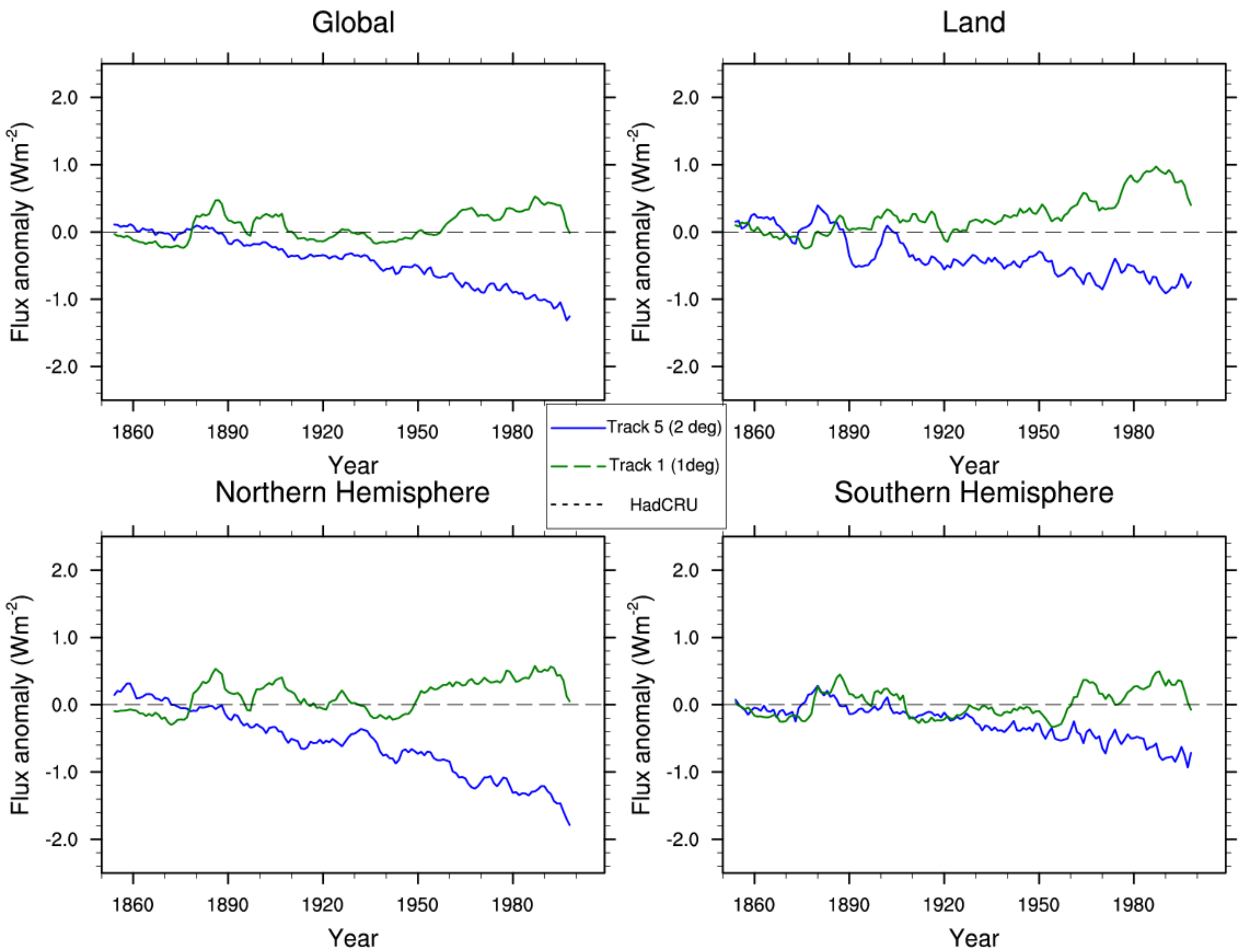




Track 5 – 2 deg

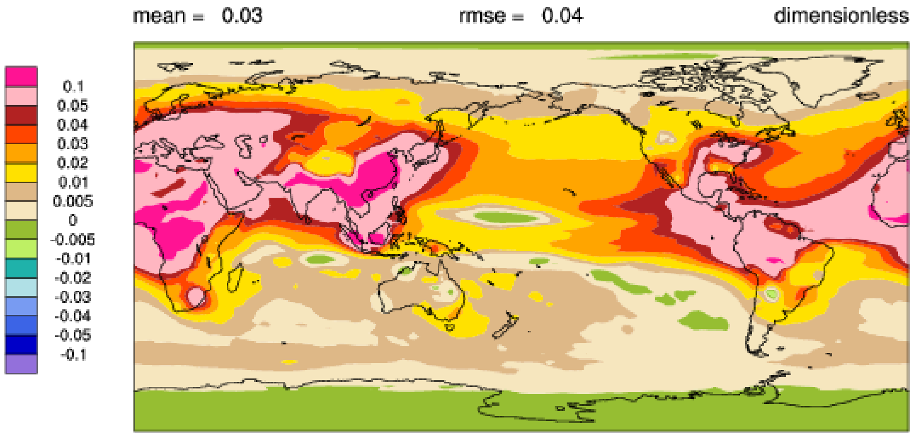


Short Wave Cloud Forcing Change

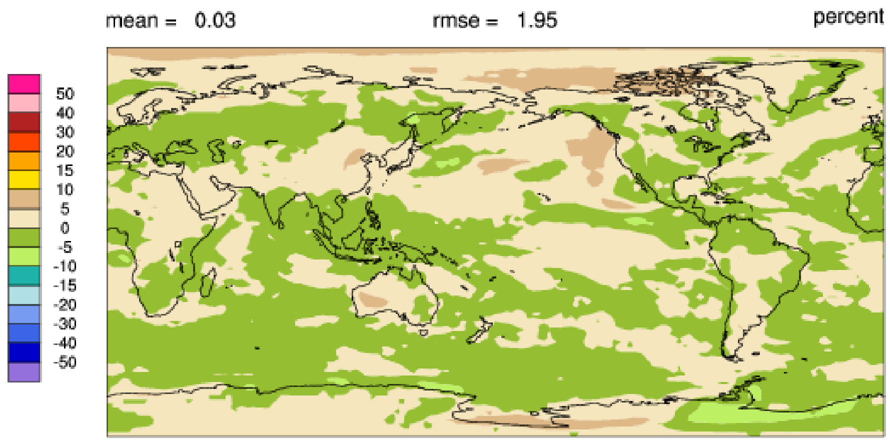


Aerosol and Cloud Changes (1990-2004) (Track 5)

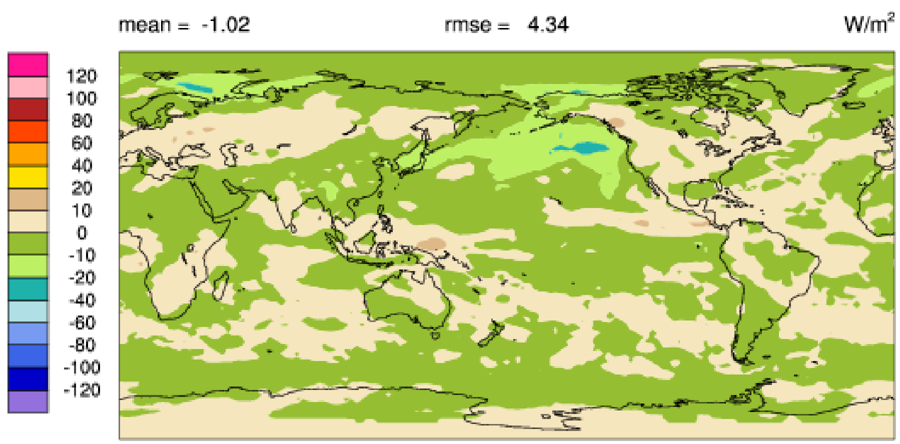
Aerosol Optical Depth (ANN)



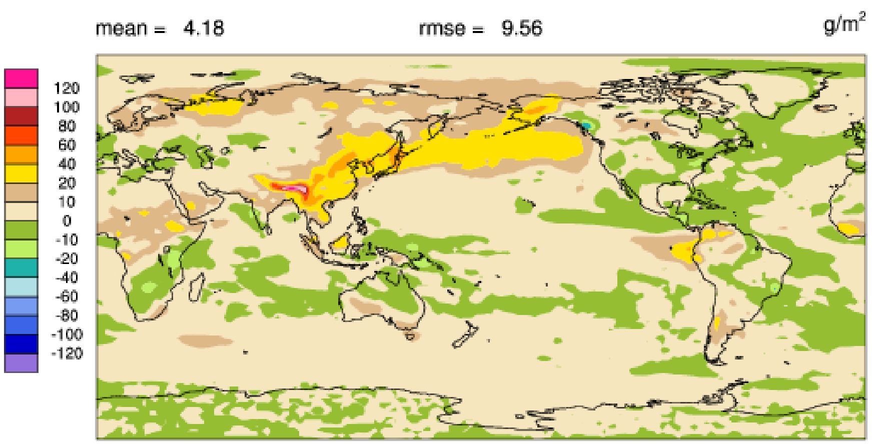
Low Cloud Fraction (JJA)



Short Wave Cloud Forcing (JJA)

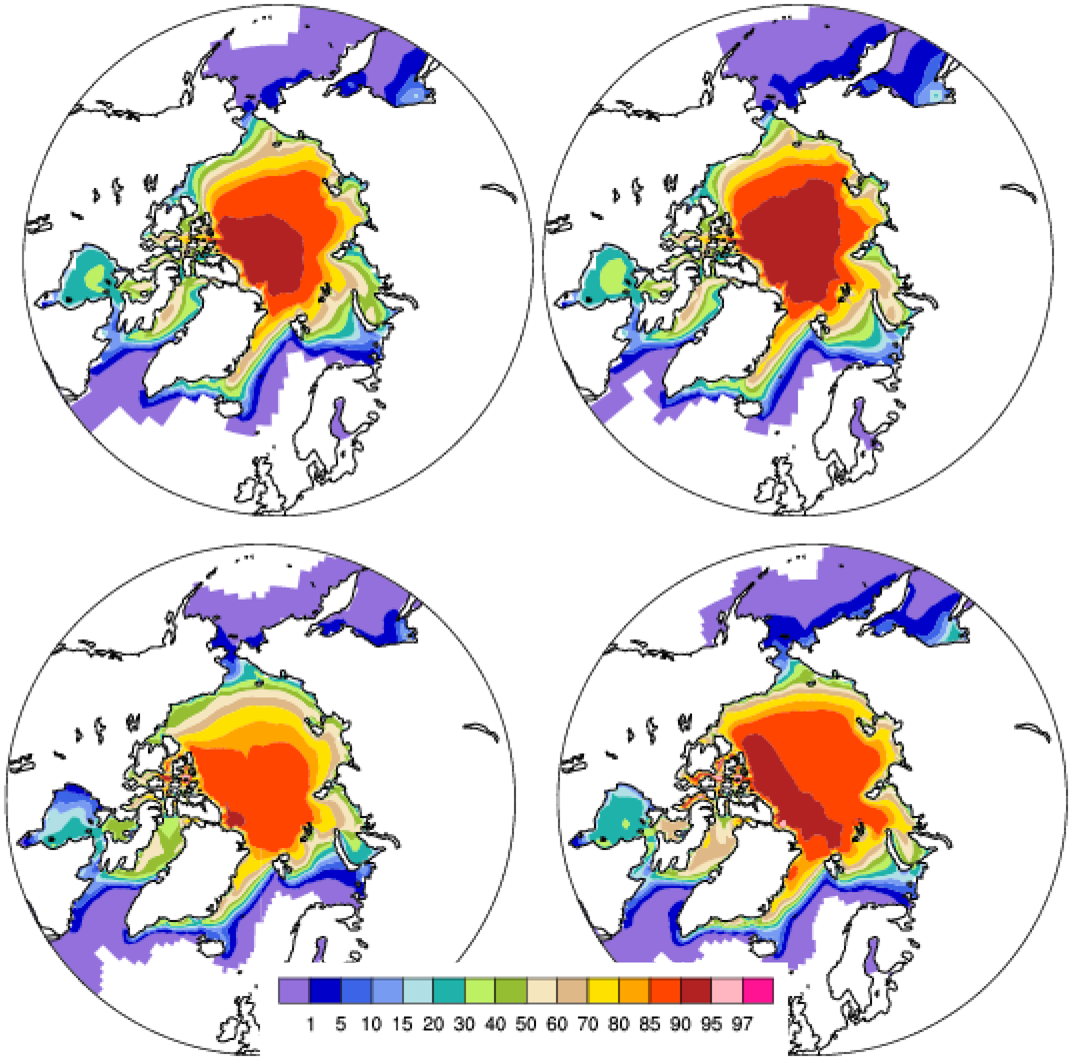


Total Grid Ave. Water Path (JJA)



20^{th} C JJA Arctic Sea Ice Change

1990-2004 | *1850 control*

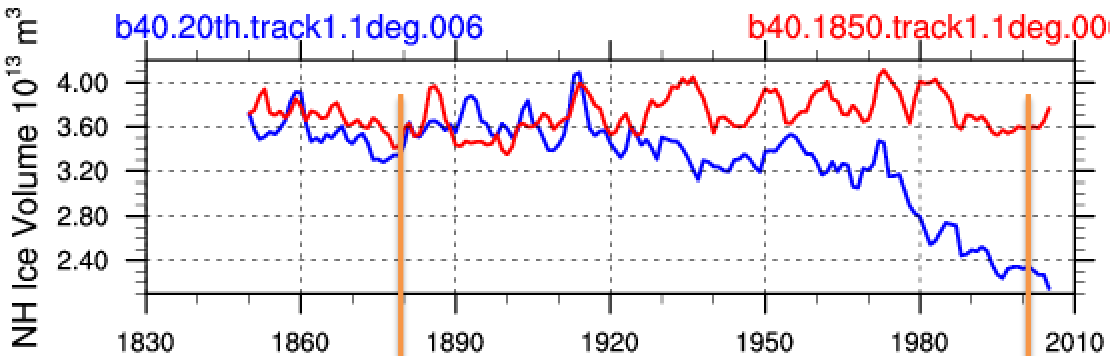


Track 1 (1 deg)

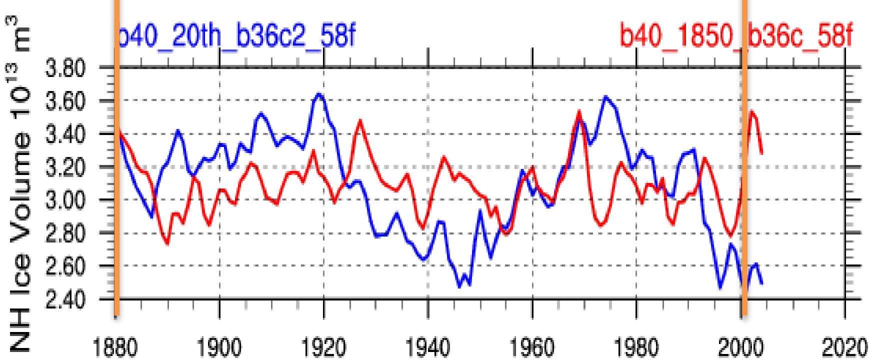
Track 5 (2 deg)

20thC Sea Ice Change

Arctic



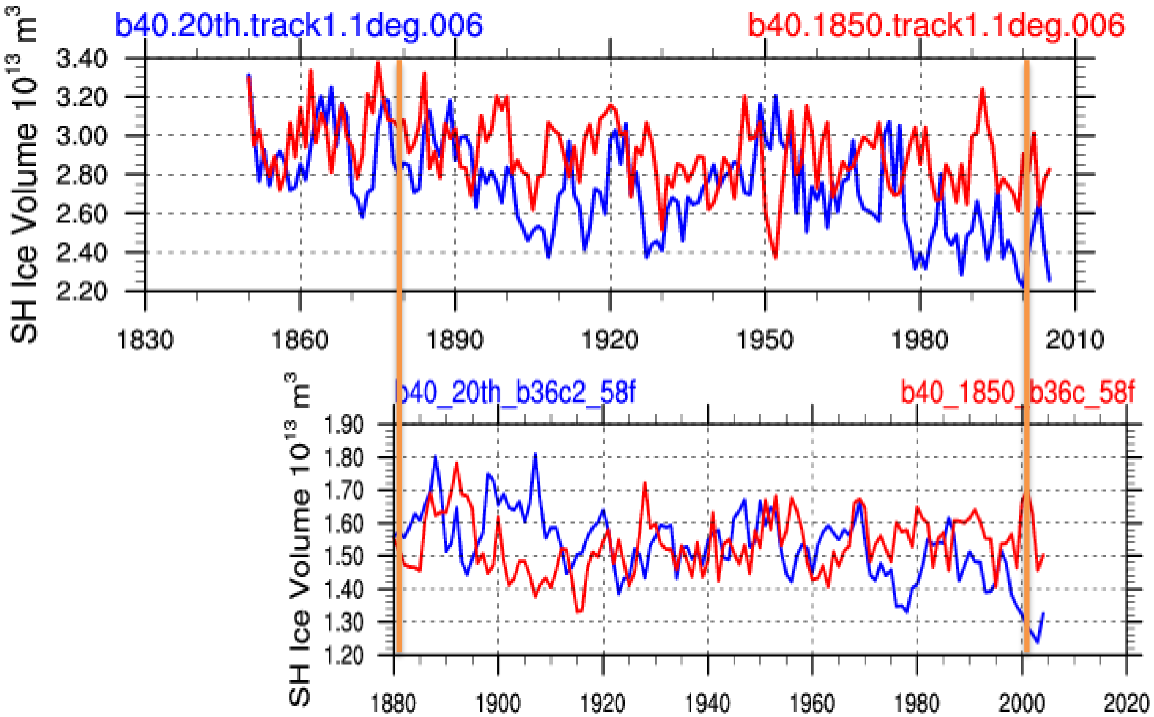
Track 1 (1 deg)
Control
20thC



Track 5 (2 deg)
Control
20thC

20thC Sea Ice Change

Antarctic



<u>Track 1 (1 deg)</u>
Control
20thC

<u>Track 5 (2 deg)</u>
Control
20thC

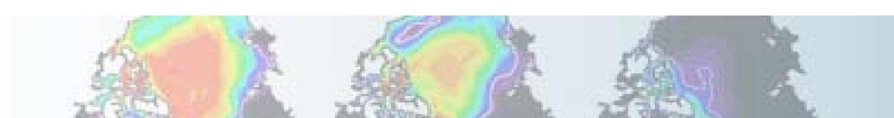
Summary

- CAM4/Track 1 climate has similar behavior to CAM3.5 climate
- Higher resolution (1 deg) results in decreased short-wave cloud forcing in mid-latitudes
- CAM5/Track 5 includes a significant number of physics enhancements
- Aimed at addressing uncertainty in *indirect effects* and *cloud feedbacks*
- Coupled climate is competitive with Track 1 (1deg/2deg)
- Arctic climate has more low cloud cover, but lower water; increased cold bias in winter
- Arctic sea ice sees a significant summer increase in downwelling shortwave
- Necessary for higher albedos at the present
- Although Track 5 has higher climate sensitivity 20th century response finishes cooler than observed and Track 1
- Different response between hemispheres
  - S. Hem. follows observations and Track 1 well
  - N. Hem. remains cool until mid century followed by strong warming in 1980s (AIE)
- Polar sea-ice volume shows significant decline in late 1990s (< track 1)
- Inclusion of turbulent mountain stress has negative impact in Antarctic sea-ice

CAM3 -> CAM5

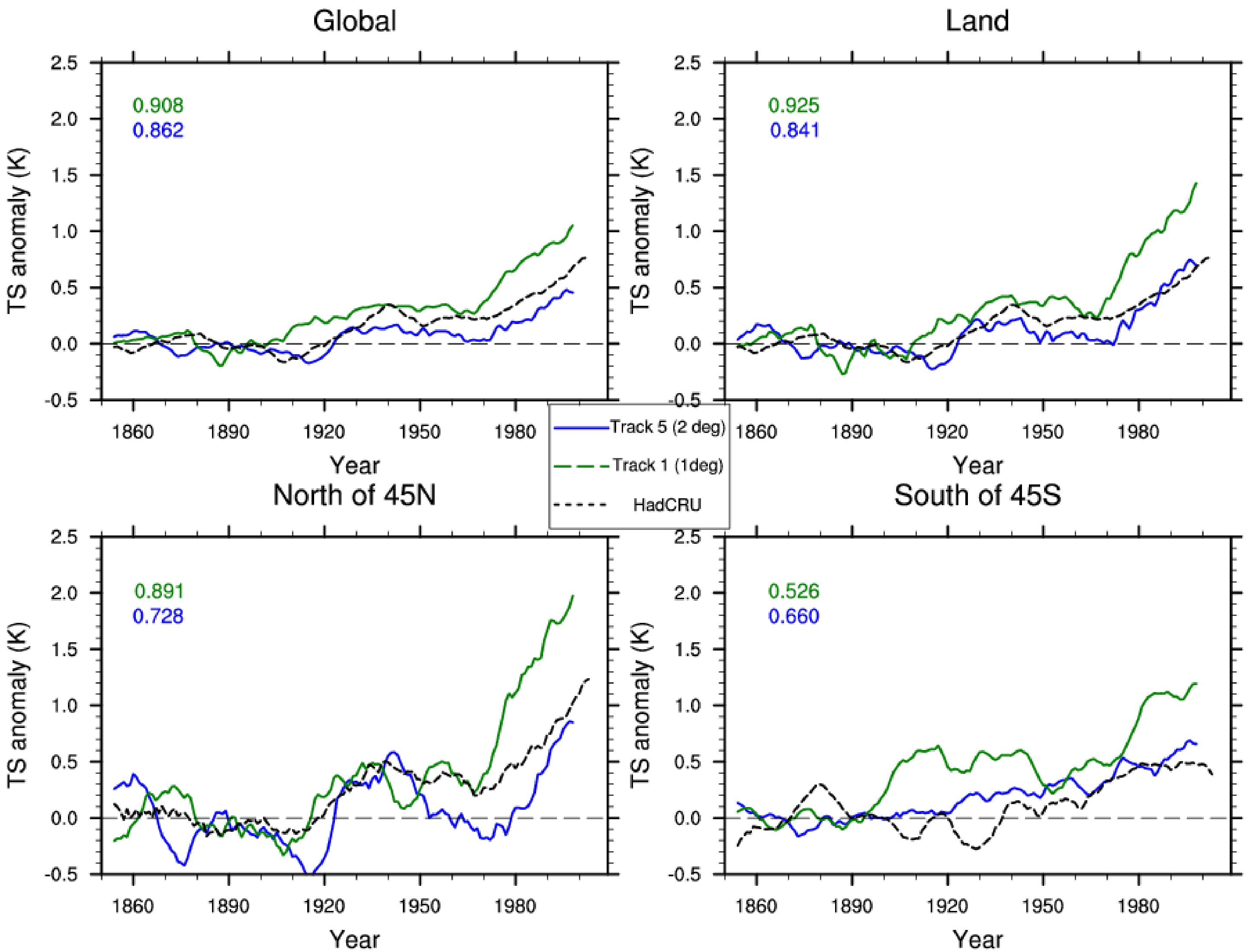
Physics Changes

CAM3.5	CAM4	CAM5
✓Deep convection dilution and convective momentum transports *Increase sensitivity to tropical humidity; improves diurnal cycle, variability and ENSO* ✓Freeze drying of cold cloud	✓Deep convection dilution and convective momentum transports ✓Reduced ice cloud fall speeds at 2 degree resolution *More accurate water transport into stratosphere*	✓Deep convection dilution and convective momentum transports ✓Land vs. ocean tuning for autoconversion efficiency *Implicit representation of the affects of aerosols on cloud drop size* ✓Modal Aerosol Model (MAM3) *Accounts for aerosol species interaction; predicts aerosol deposition* ✓2 moment microphysics (number + size) for ice and liquid *Allows for activation of aerosols based aerosol number availability* ✓University of Washington (UW) TKE based moist boundary layer *Accurate representation of stable, moist boundary layers* ✓University of Washington (UW) CIN/TKE based entraining shallow convection *Boundary layer turbulence driven shallow cumulus* ✓Rapid Radiative Transfer Model *Improved radiative calculation of the water vapor continuum*



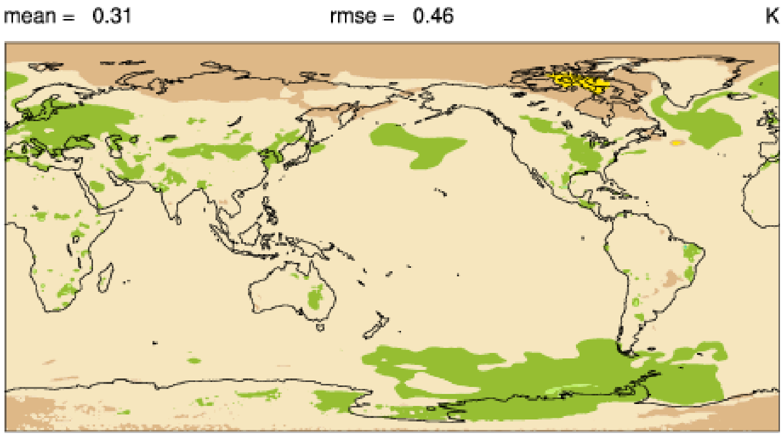
Surface Temperature Change

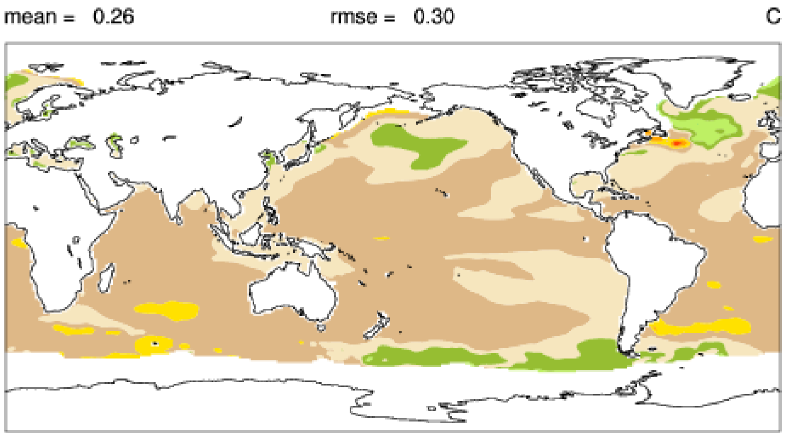
High Latitudes

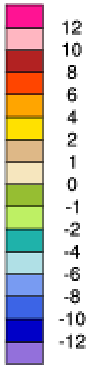


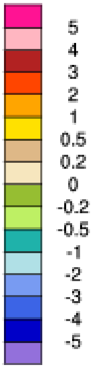
Surface Temp Change (1960-1979) (K)

Track 1 – 1 deg

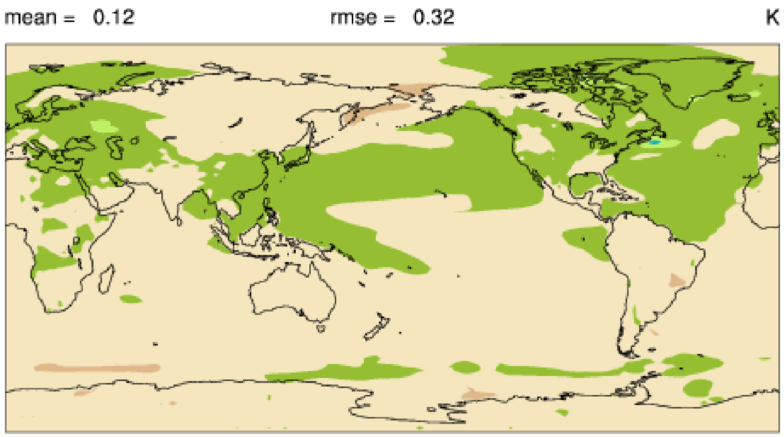


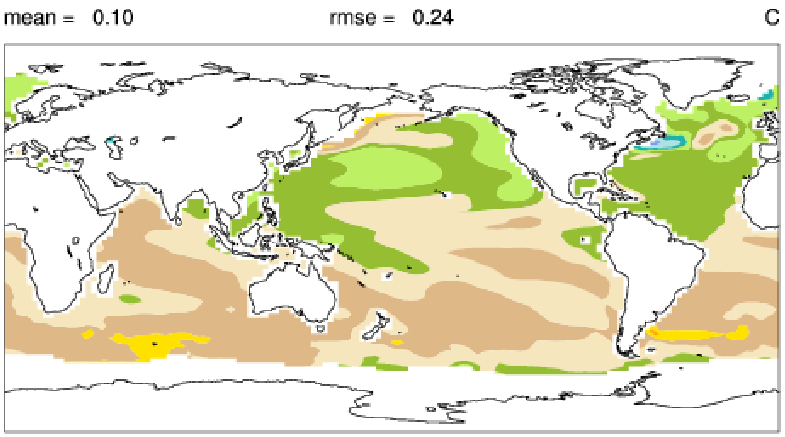






Track 5 – 2 deg





Surface Temp Change

2xCO2 experiments