

CESM1/CAM5 Coupled Climate

Rich Neale, Cecile Hannay,
Sungsu Park, Andrew Gettleman,
Hugh Morrison, Joe Tribbia, Peter Lauritzen
David Williamson, Julio Bacmeister

NCAR

Phil Rasch, Xiaohong Liu, Steve Ghan

PNNL



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 <i>Diagnostic TKE</i> Park et al. (09) |
| Shallow Convection | Hack (94) | Hack | Hack | UW <i>TKE/CIN</i> 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) <i>Single Moment</i> | Rasch and K. <i>Single Moment</i> | Rasch and K. <i>Single Moment</i> | Morrison and Gettelman (08) <i>Double Moment</i> 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 - BGC | POP2.2 |
| Land | CLM3 | CLM3.5 | CLM4 - CN | CLM4 |
| Sea Ice | CSIM4 | CSIM4 | CICE | CICE |



1850 Control Simulations

- CESM1/Track 5 (2 deg, L30) – no CN
 - 130+ year control (years 101-125)
 - Sea-ice snow albedo properties
- CCSM4/Track 1 (1 deg, L26) - CN
 - 1200+ year control (years 980-1000)
 - 4 ensemble members (only showing one here)
- CCSM4/Track 1 (2 deg, L26) - CN
 - 500+ year control
- CCSM3.5 (2 deg, L26) – no CN
 - 200+ year control (years 150-169)



Taylor Metrics Summary

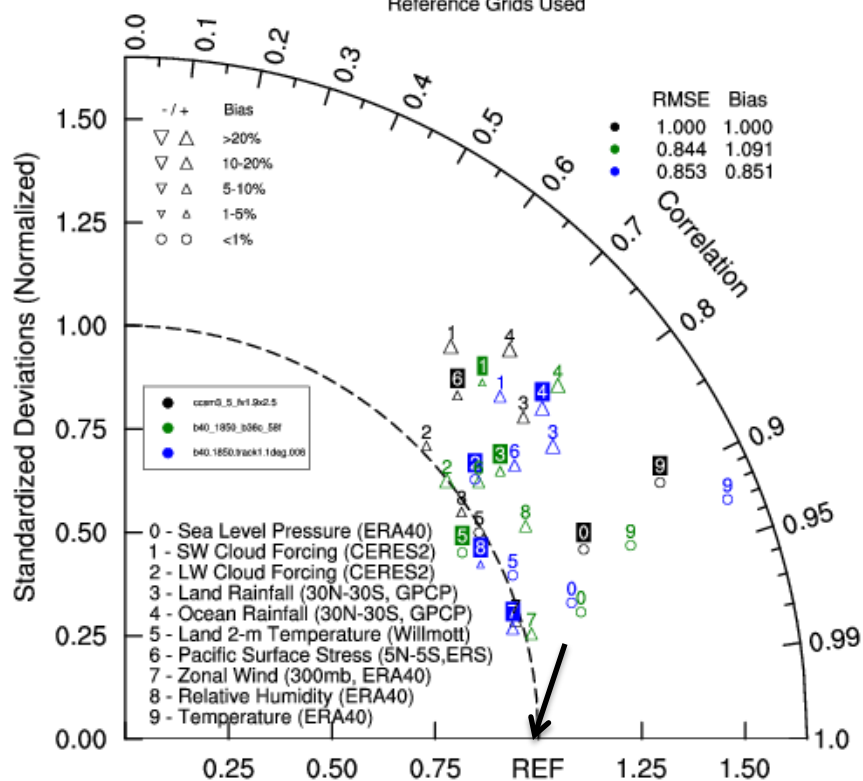
Track 1 – 1 deg

Track 5 – 2 deg
CCSM3.5 – 2 deg

Track 1 – 2 deg

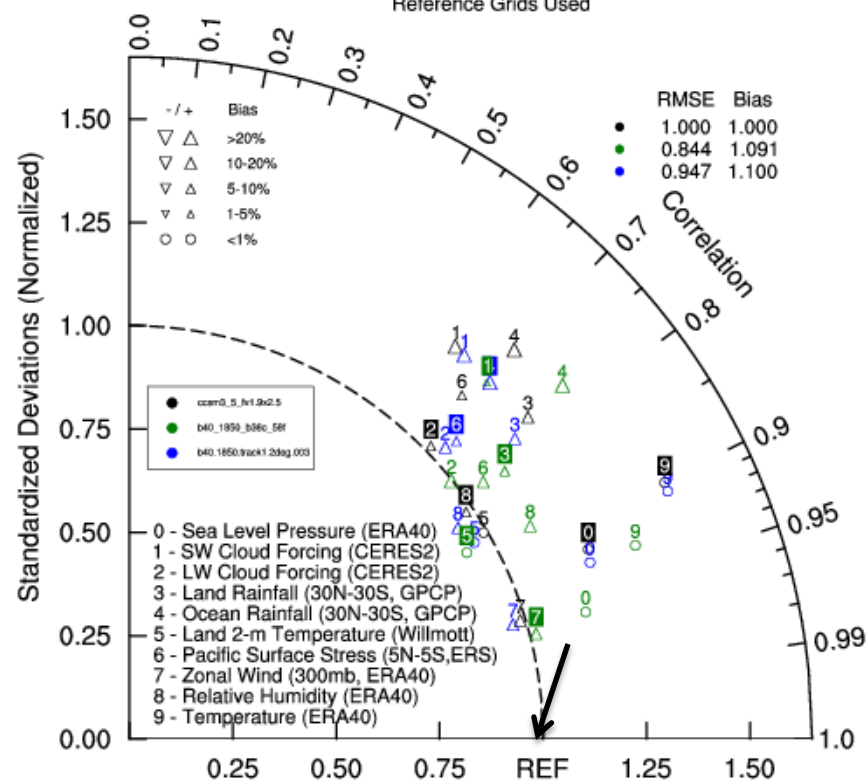
ANN: SPACE-TIME

Reference Grids Used



ANN: SPACE-TIME

Reference Grids Used



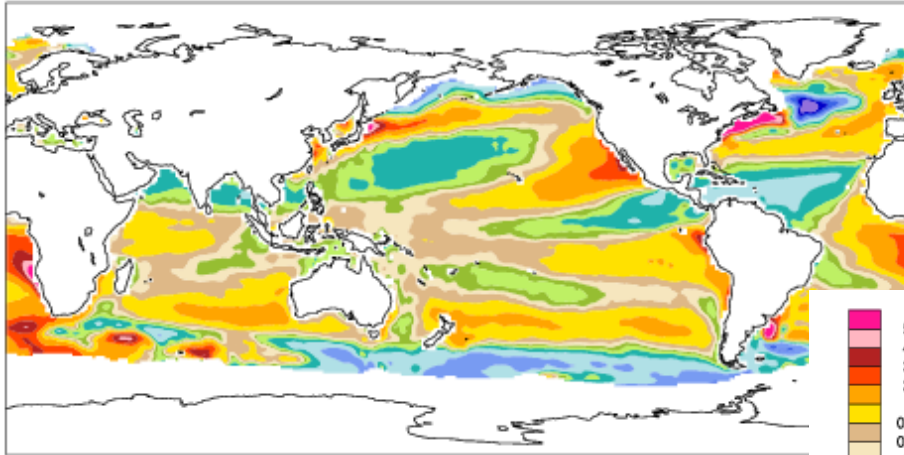
Pre-Industrial SST (K)

Track 1 – 1 deg

mean = 0.24

rmse = 1.07

C

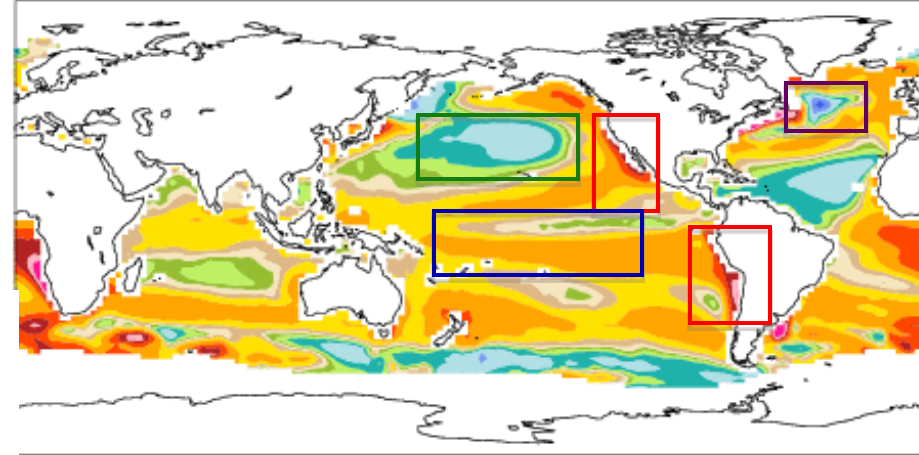


Track 5 – 2 deg

mean = 0.64

rmse = 1.23

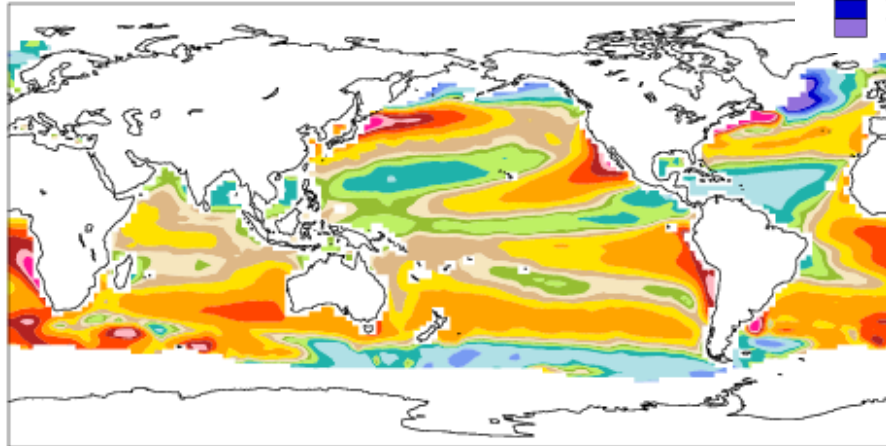
C



Track 1 – 2 deg

mean = 0.50

rmse = 1.38

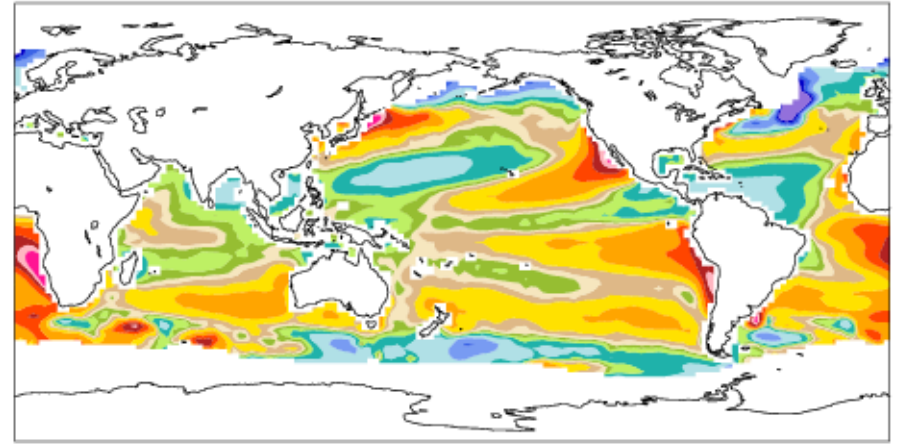


CCSM3.5 – 2 deg

mean = 0.25

rmse = 1.24

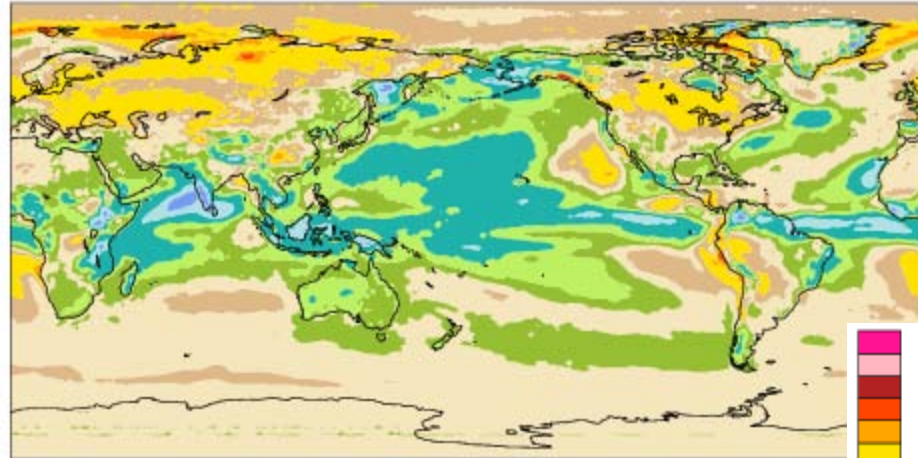
C



Short wave cloud forcing (JJA $-Wm^{-2}$) – CERES-EBAF

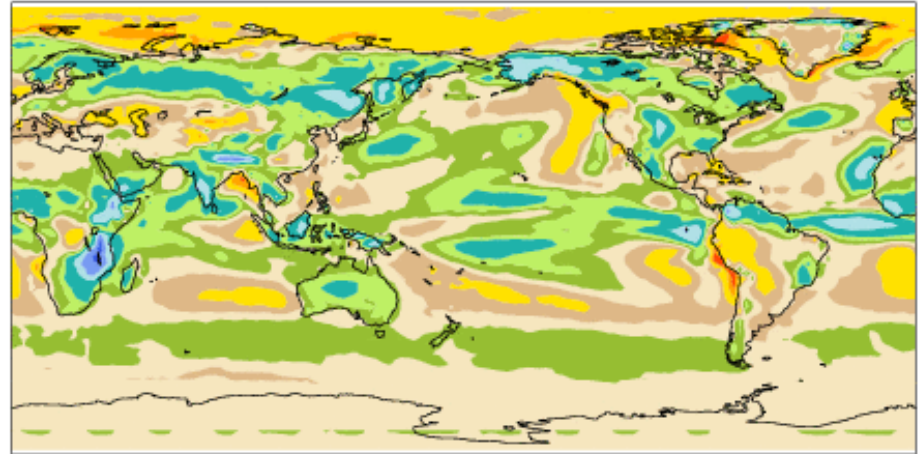
Track 1 – 1 deg

mean = -3.01 rmse = 17.00 W/m^2



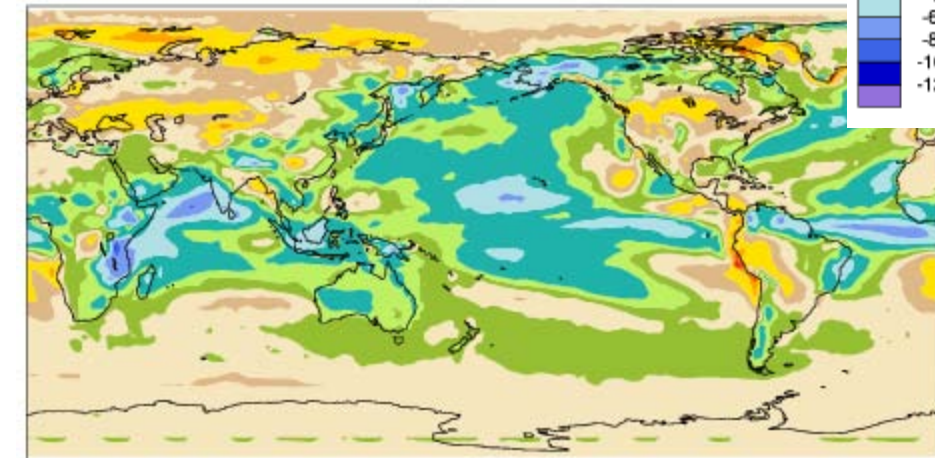
Track 5 – 2 deg

mean = -0.34 rmse = 16.17 W/m^2



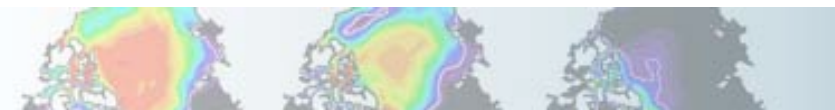
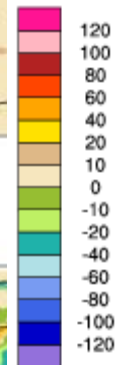
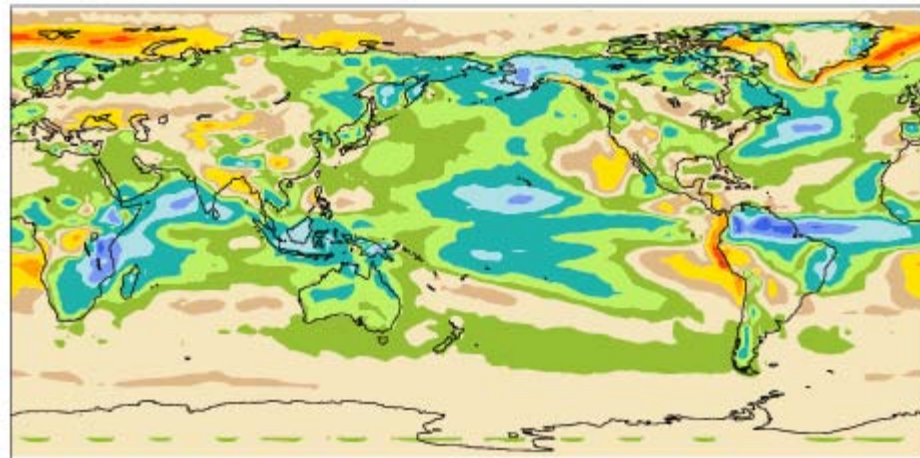
Track 1 – 2 deg

mean = -8.15 rmse = 21.04 W/m^2



CCSM3.5 – 2 deg

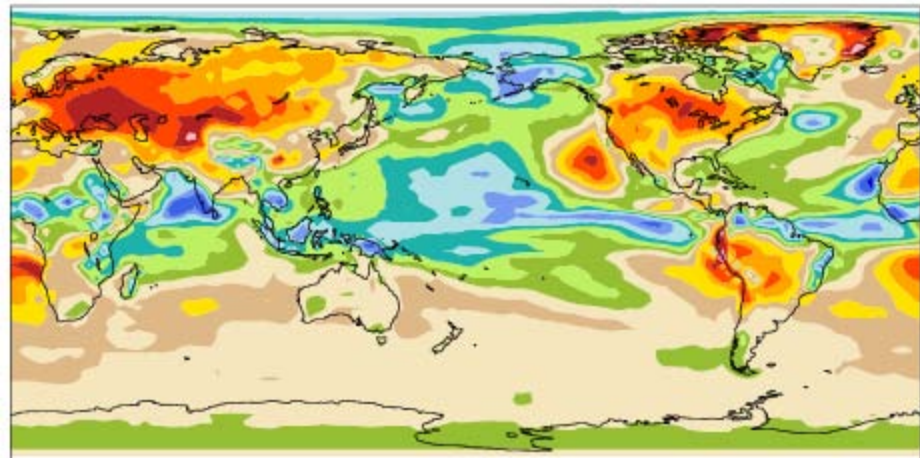
mean = -6.63 rmse = 19.94 W/m^2



Downward Surface Short-Wave (JJA -Wm⁻²) - ISCCP

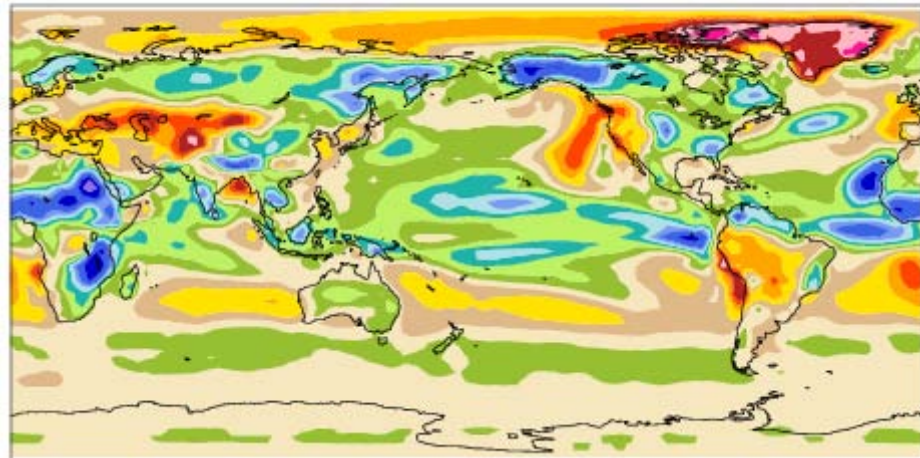
Track 1 – 1 deg

mean = 1.86 rmse = 21.96 W/m²



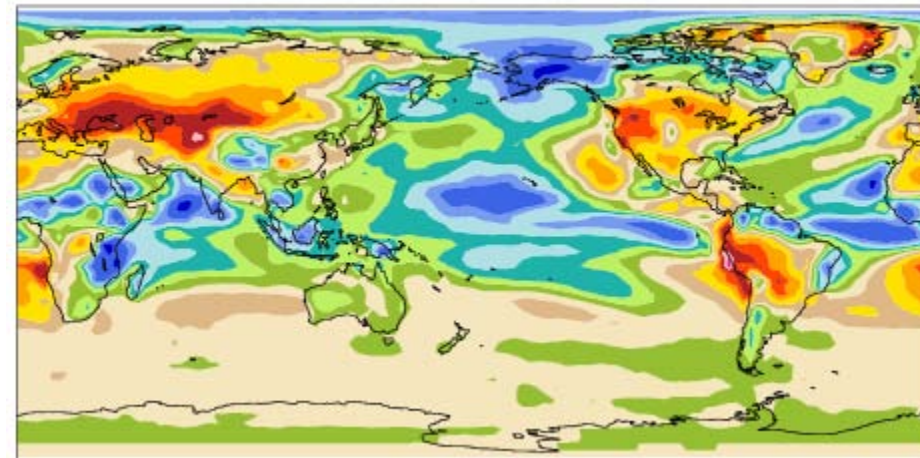
Track 5 – 2 deg

mean = -0.52 rmse = 21.50 W/m²



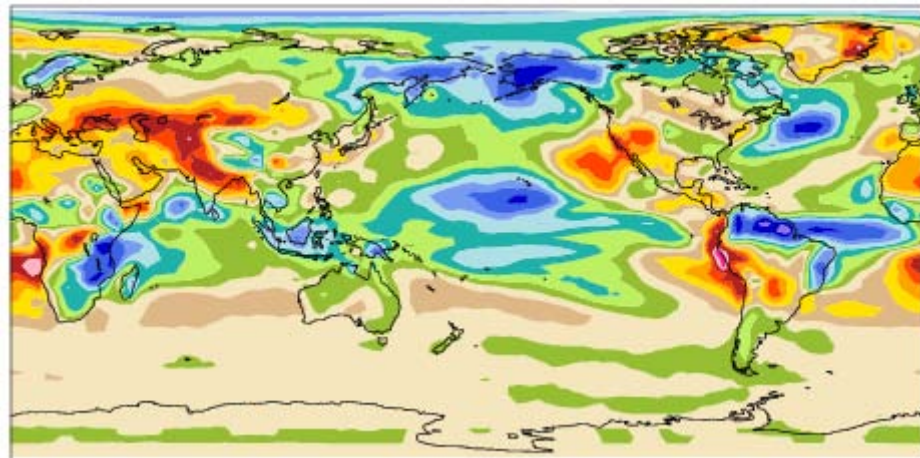
Track 1 – 2 deg

mean = -4.71 rmse = 24.57 W/m²



CCSM3.5 – 2 deg

mean = -2.25 rmse = 23.53 W/m²

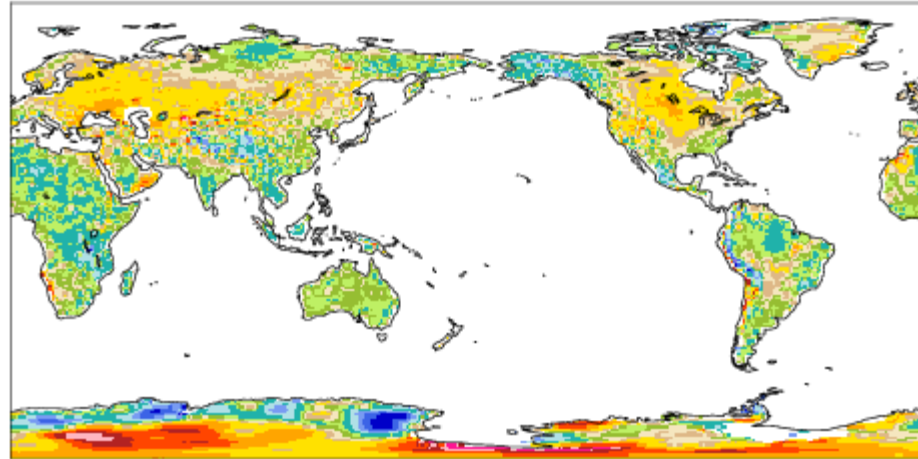


Surface Temperature Bias (1850 model climate, JJA -Wm⁻²) - Willmott

Track 1 – 1 deg

mean = -0.13

rmse = 2.73

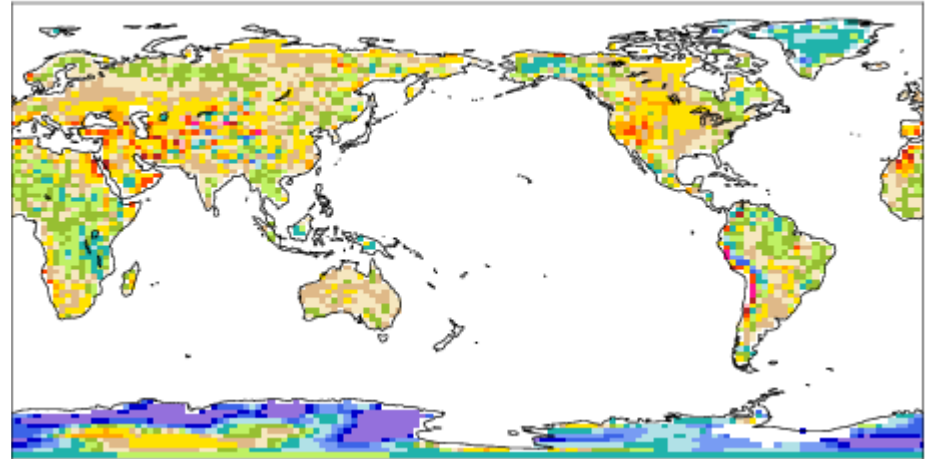


Track 5 – 2 deg

K mean = 0.15

rmse = 3.92

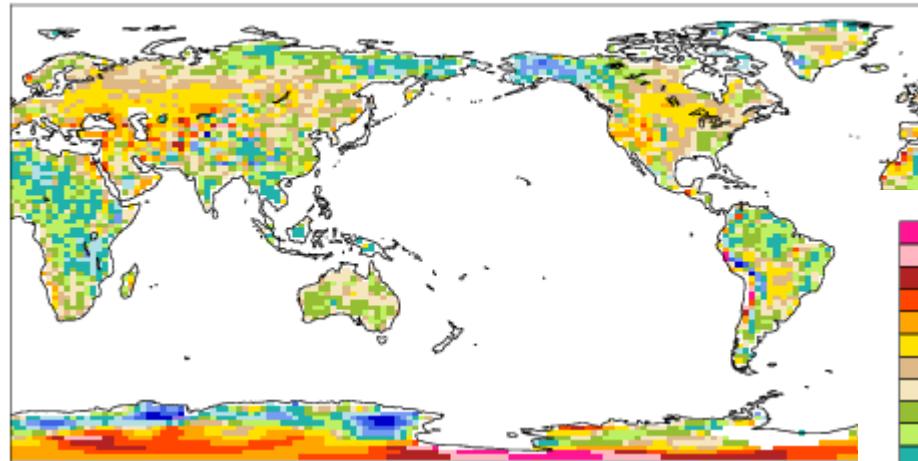
K



Track 1 – 2 deg

mean = 0.09

rmse = 2.99

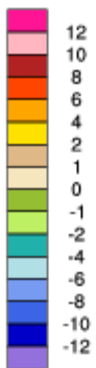
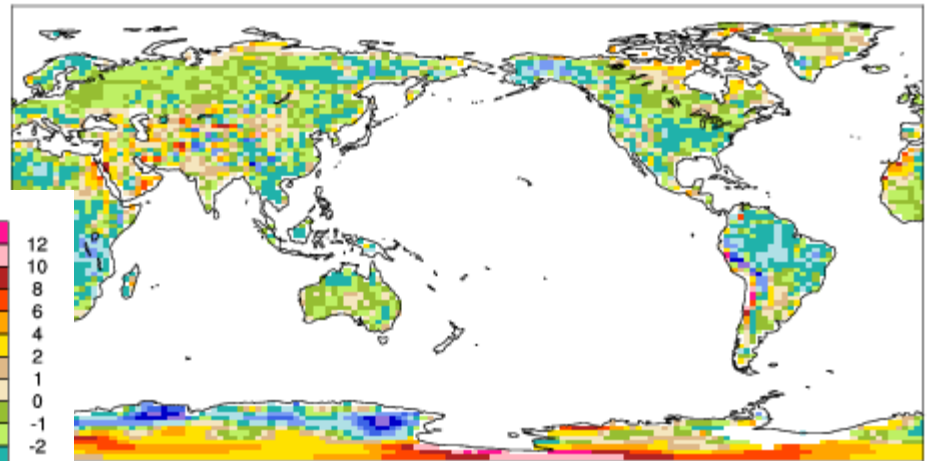


CCSM3.5 – 2 deg

K mean = -1.09

rmse = 3.09

K



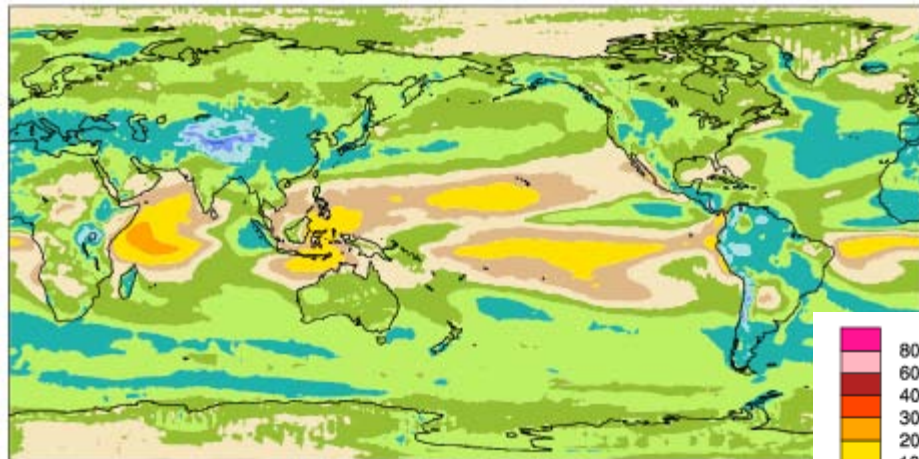
Long wave cloud forcing (Wm^{-2}) – CERES-EBAF

Track 1 – 1 deg

mean = -3.81

rmse = 8.45

W/m^2

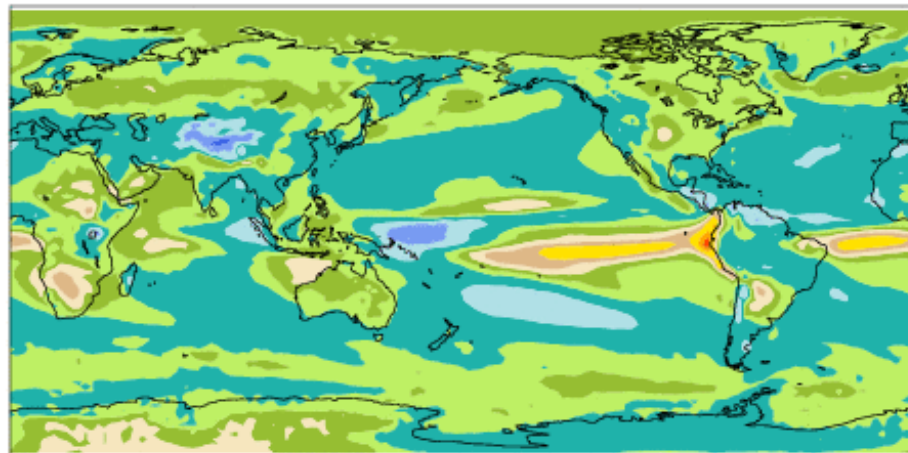


Track 5 – 2 deg

mean = -9.92

rmse = 12.08

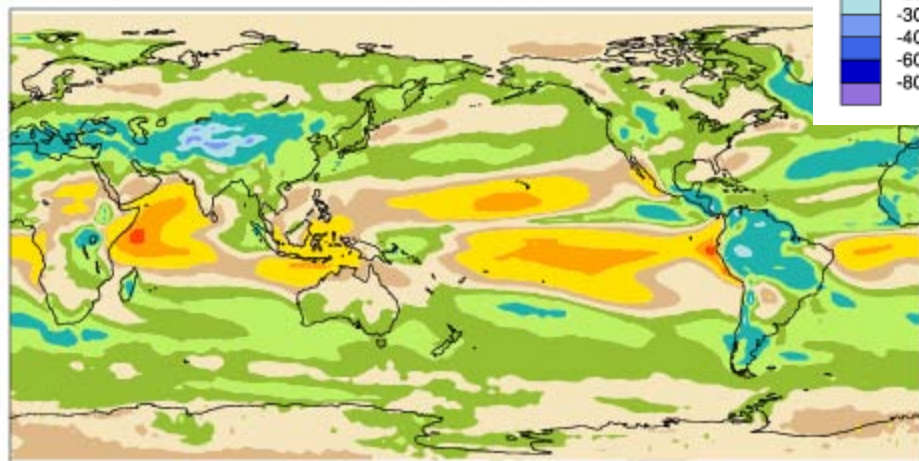
W/m^2



Track 1 – 2 deg

mean = 0.11

rmse = 8.60

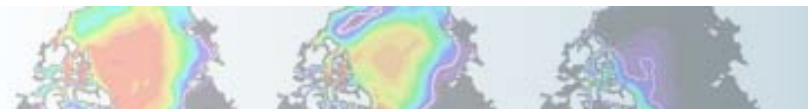
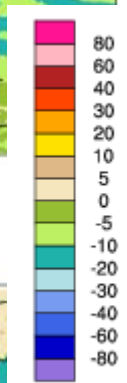
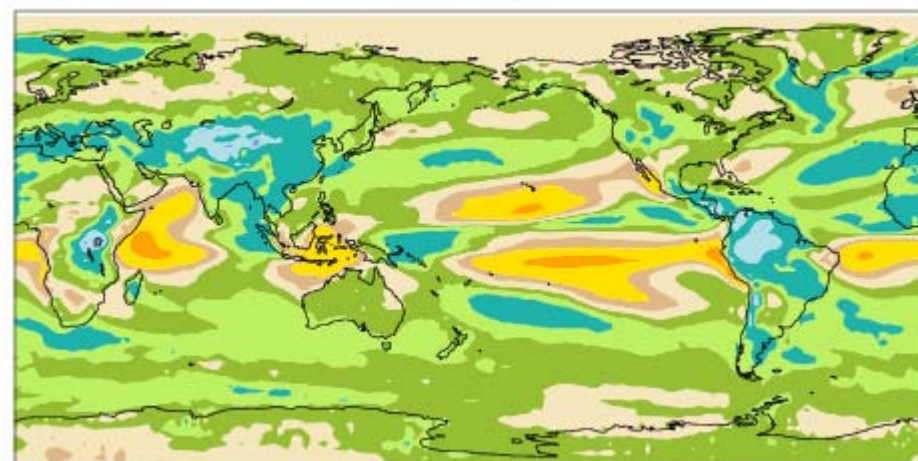


CCSM3.5 – 2 deg

mean = -3.01

rmse = 8.34

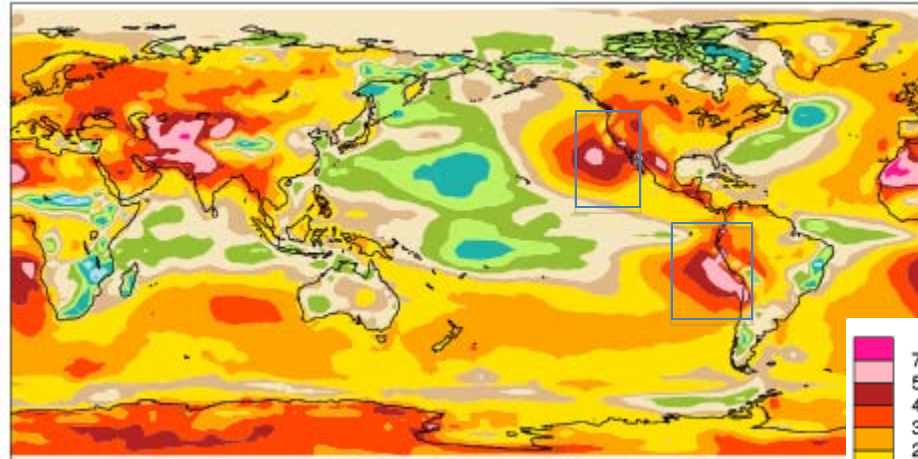
W/m^2



Net Surface Long-Wave (JJA -Wm⁻²)

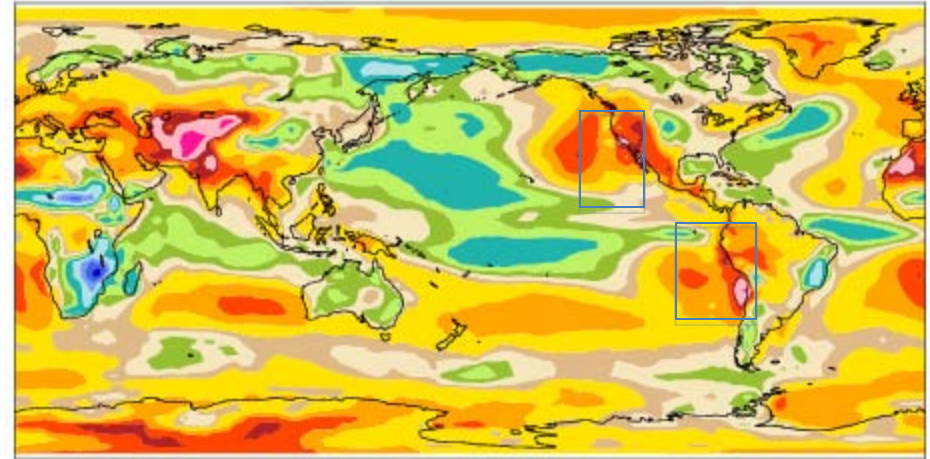
Track 1 – 1 deg

mean = 14.88 rmse = 20.83 W/m²



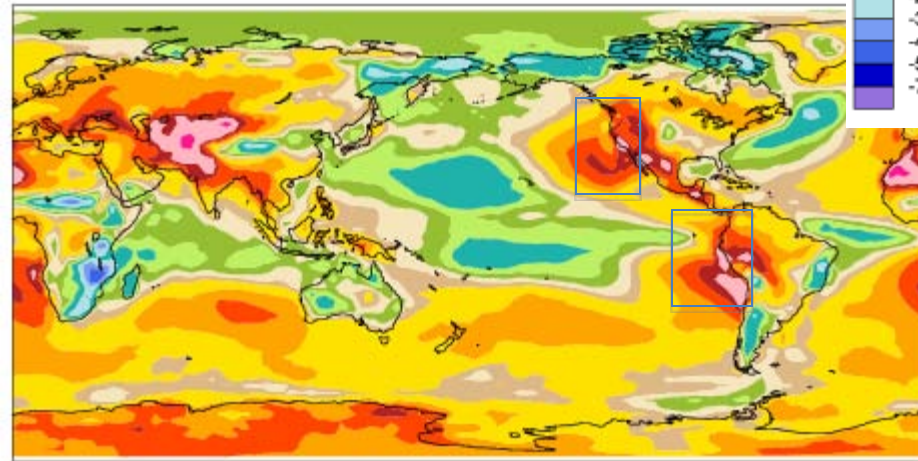
Track 5 – 2 deg

mean = 8.93 rmse = 17.00 W/m²



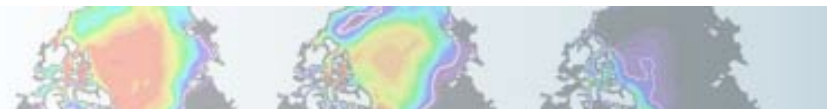
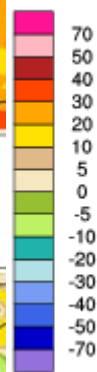
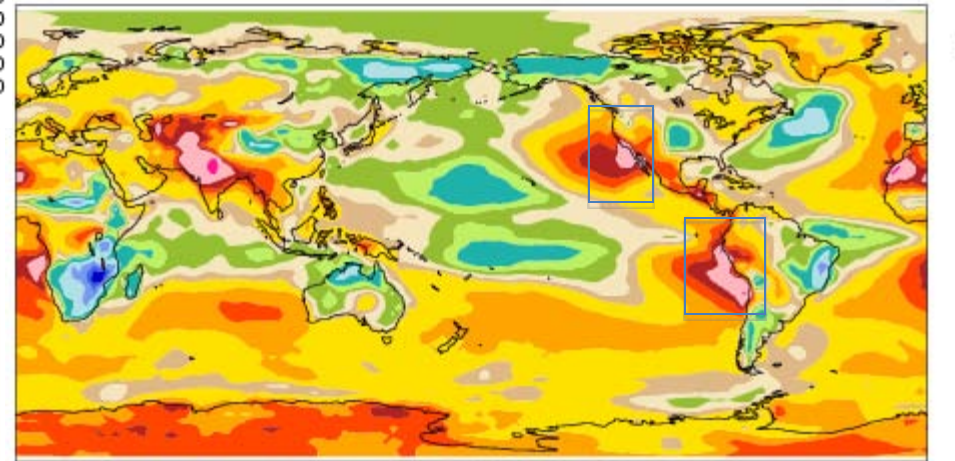
Track 1 – 2 deg

mean = 11.10 rmse = 19.19 W/m²



CCSM3.5 – 2 deg

mean = 11.05 rmse = 18.77 W/m²



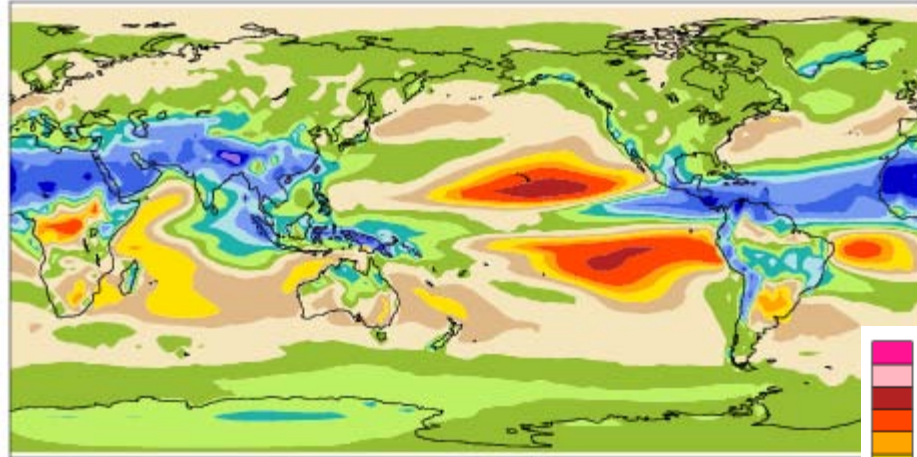
Precipitable Water (mm) - NVAP

Track 1 – 1 deg

mean = -0.49

rmse = 2.69

mm

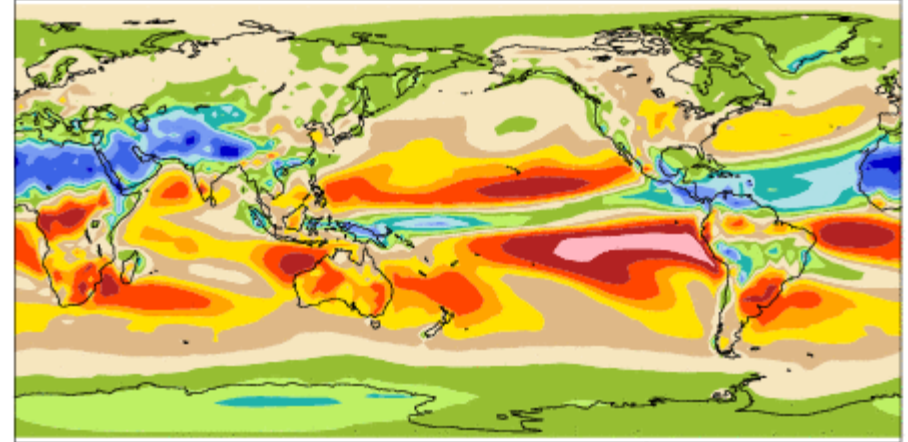


Track 5 – 2 deg

mean = 1.09

rmse = 3.14

mm

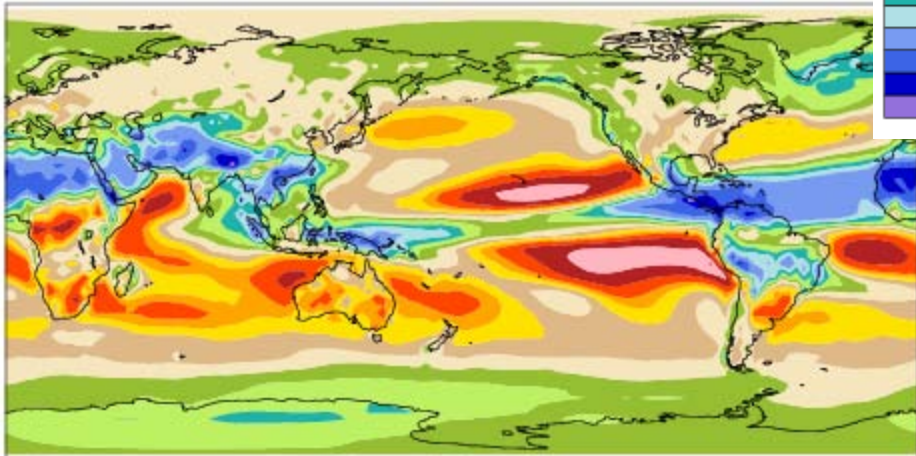


Track 1 – 2 deg

mean = 0.61

rmse = 3.28

mm

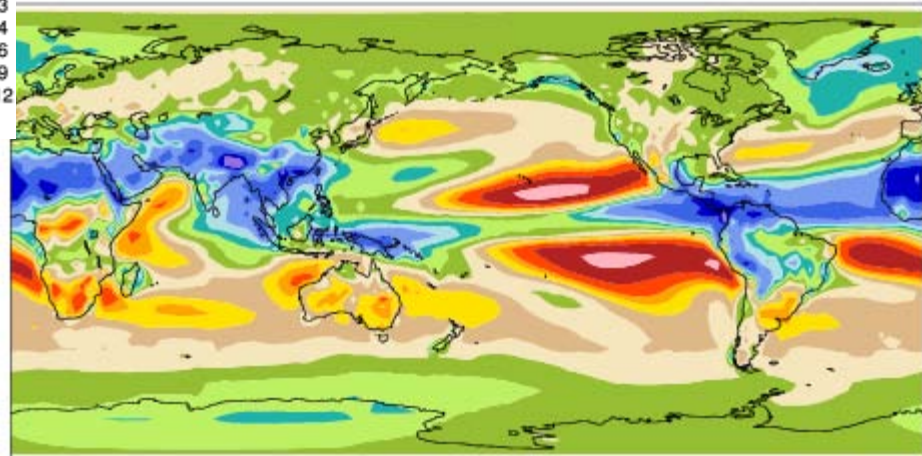


CCSM3.5 – 2 deg

mean = -0.23

rmse = 3.23

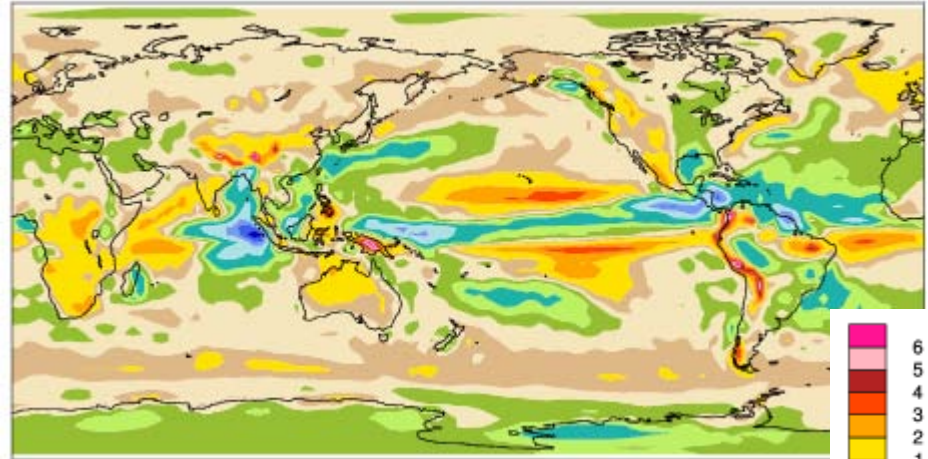
mm



Precipitation (mm/day) - CMAP

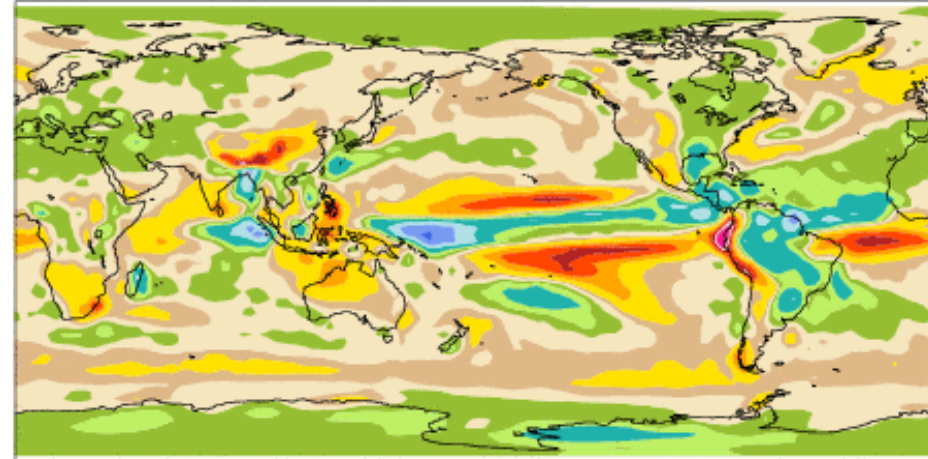
Track 1 – 1 deg

mean = 0.25 rmse = 1.06 mm/day



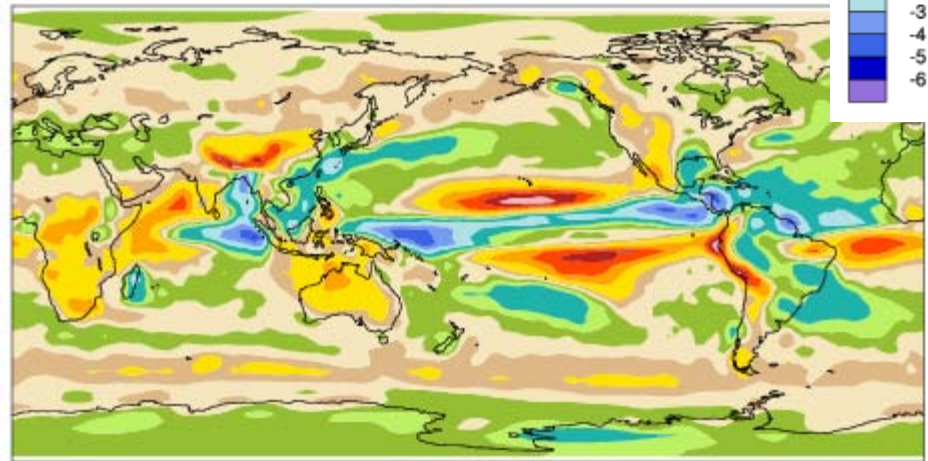
Track 5 – 2 deg

mean = 0.36 rmse = 1.15 mm/day



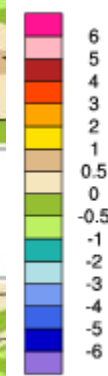
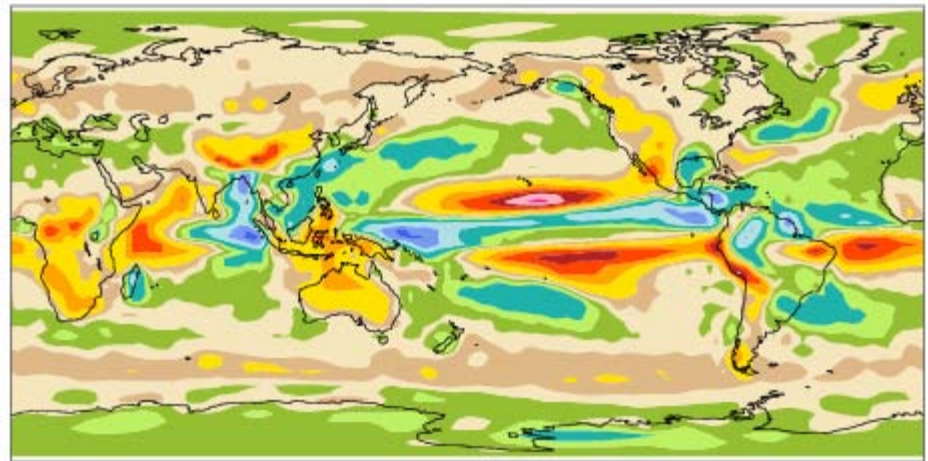
Track 1 – 2 deg

mean = 0.19 rmse = 1.23



CCSM3.5 – 2 deg

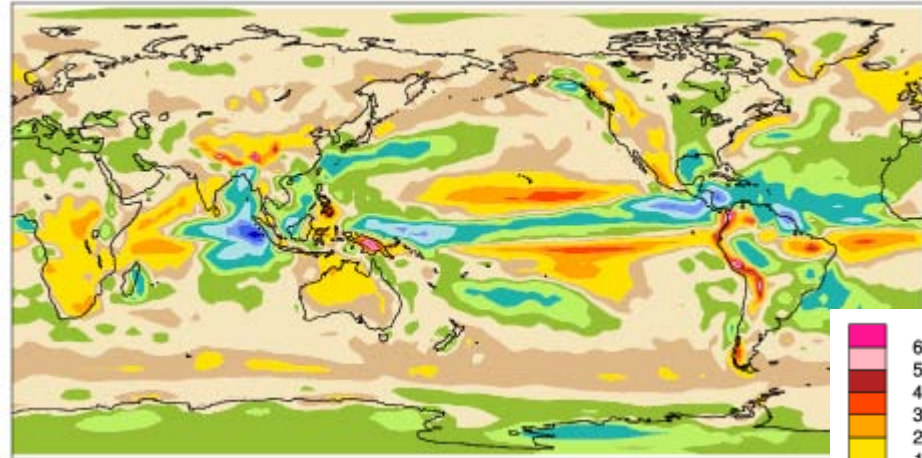
mean = 0.26 rmse = 1.24 mm/day



Precipitation (mm/day) - CMAP

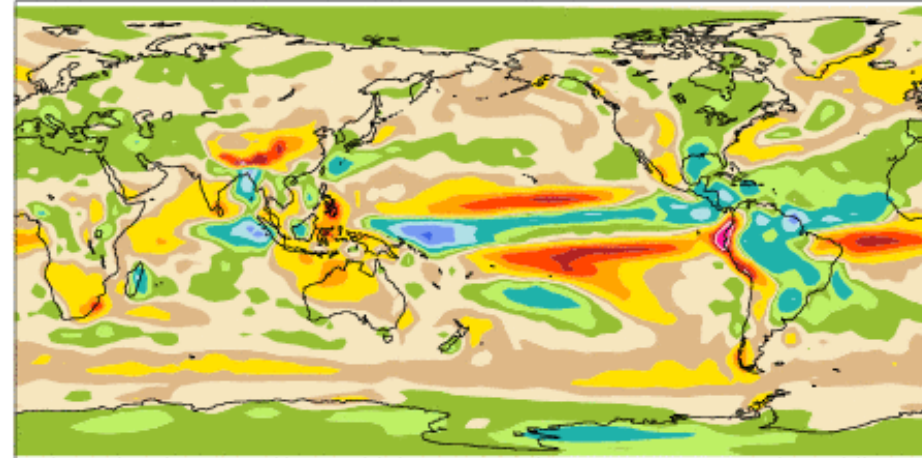
Track 1 – 1 deg

mean = 0.25 rmse = 1.06 mm/day



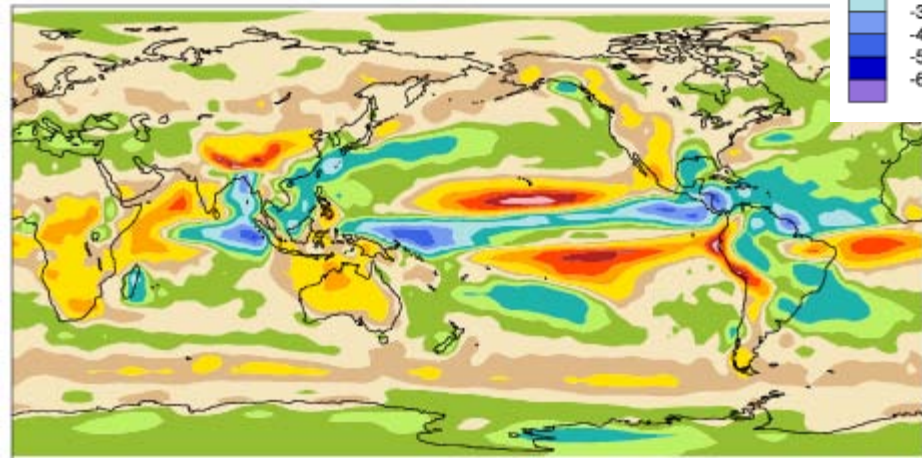
Track 5 – 2 deg

mean = 0.36 rmse = 1.15 mm/day



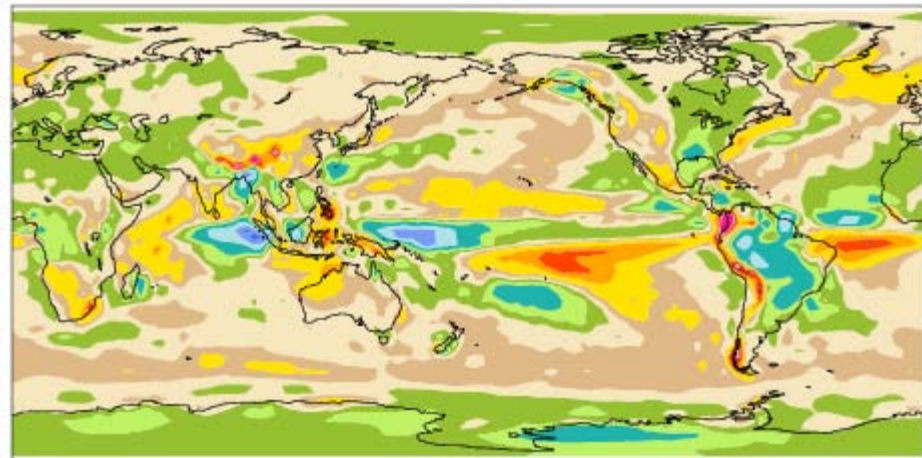
Track 1 – 2 deg

mean = 0.19 rmse = 1.23



Track 5 – 1 deg

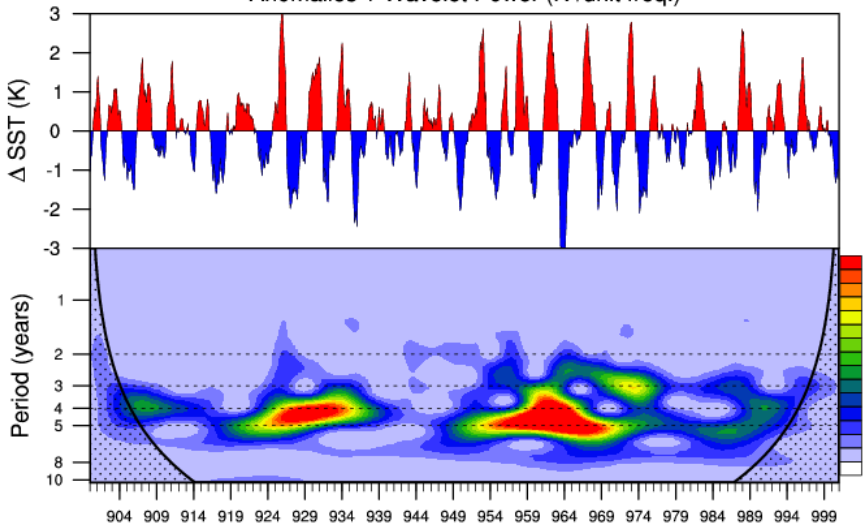
mean = 0.30 rmse = 1.00 mm/day



ENSO (nino3.4)

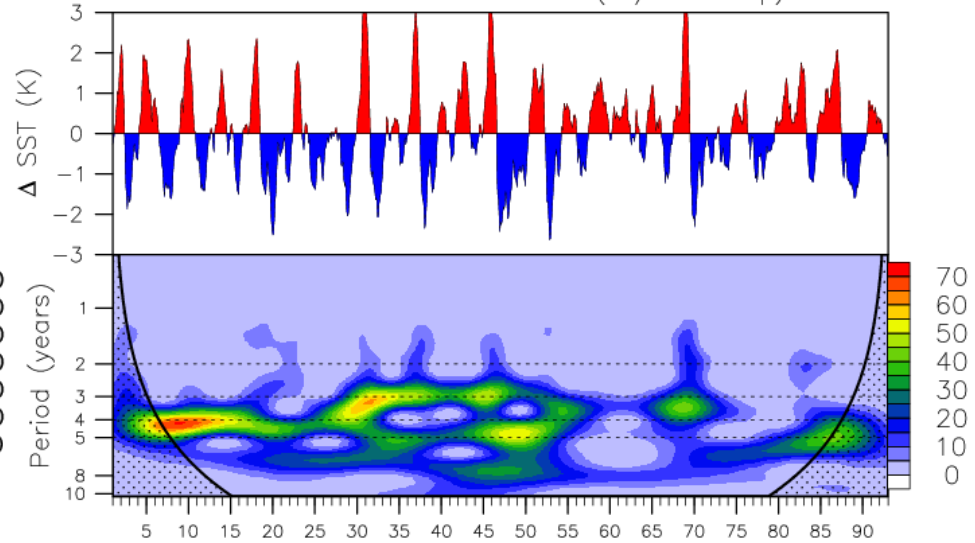
Track 1 – 1 deg

Anomalies + Wavelet Power ($K^2/\text{unit freq.}$)



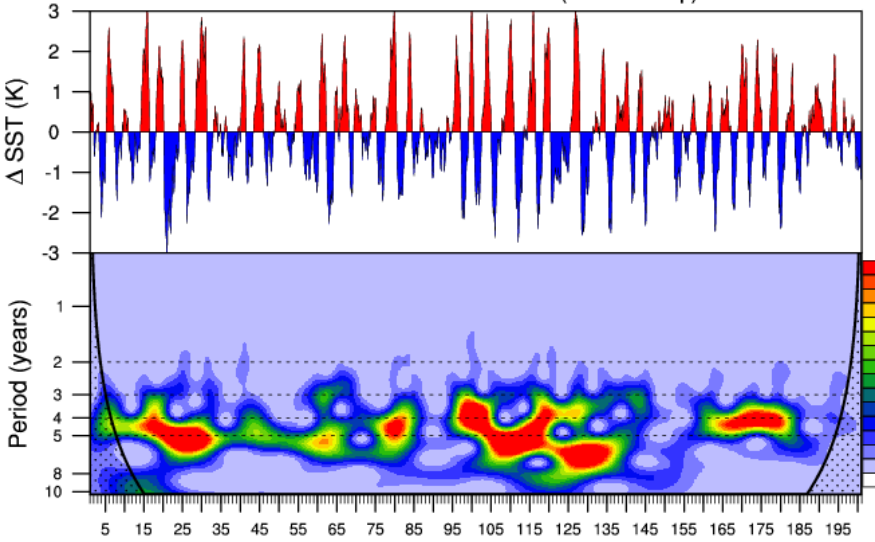
Track 5 – 2 deg

Anomalies + Wavelet Power ($K^2/\text{unit freq.}$)



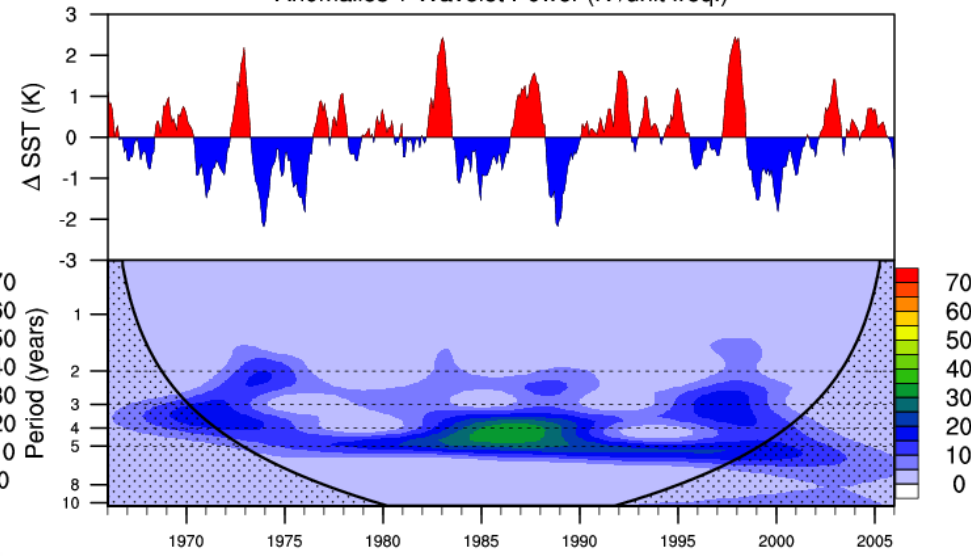
Track 1 – 2 deg

Anomalies + Wavelet Power ($K^2/\text{unit freq.}$)



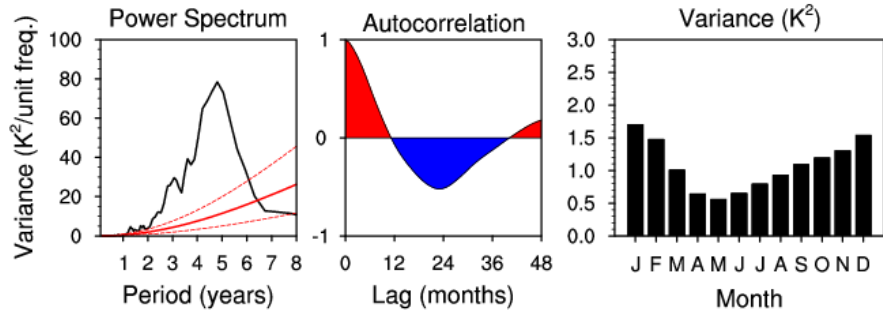
Obs. HadISST-OI

Anomalies + Wavelet Power ($K^2/\text{unit freq.}$)

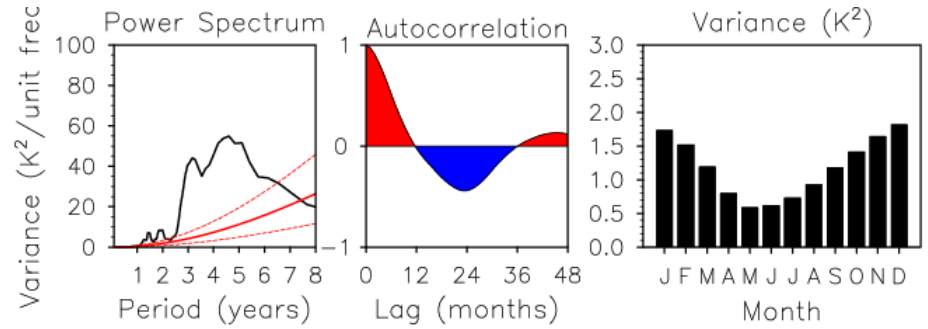


ENSO (nino3.4 SST')

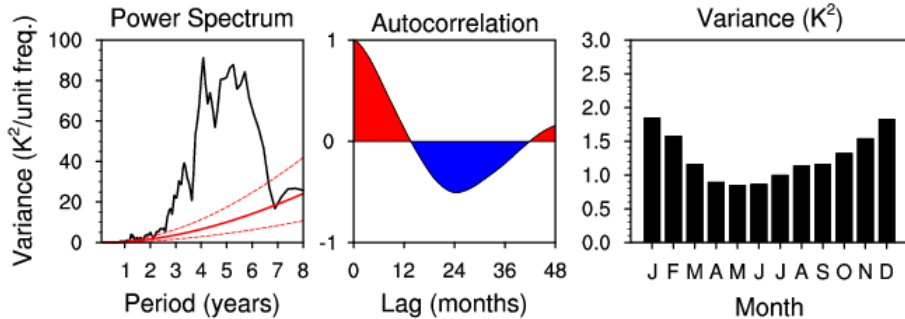
Track 1 – 1 deg



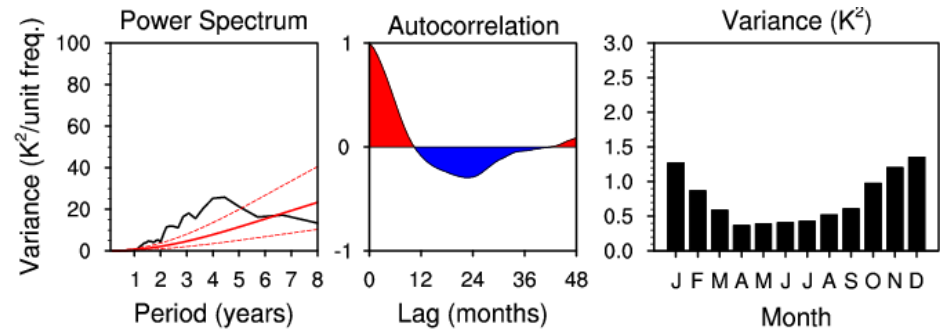
Track 5 – 2 deg



Track 1 – 2 deg



Obs.

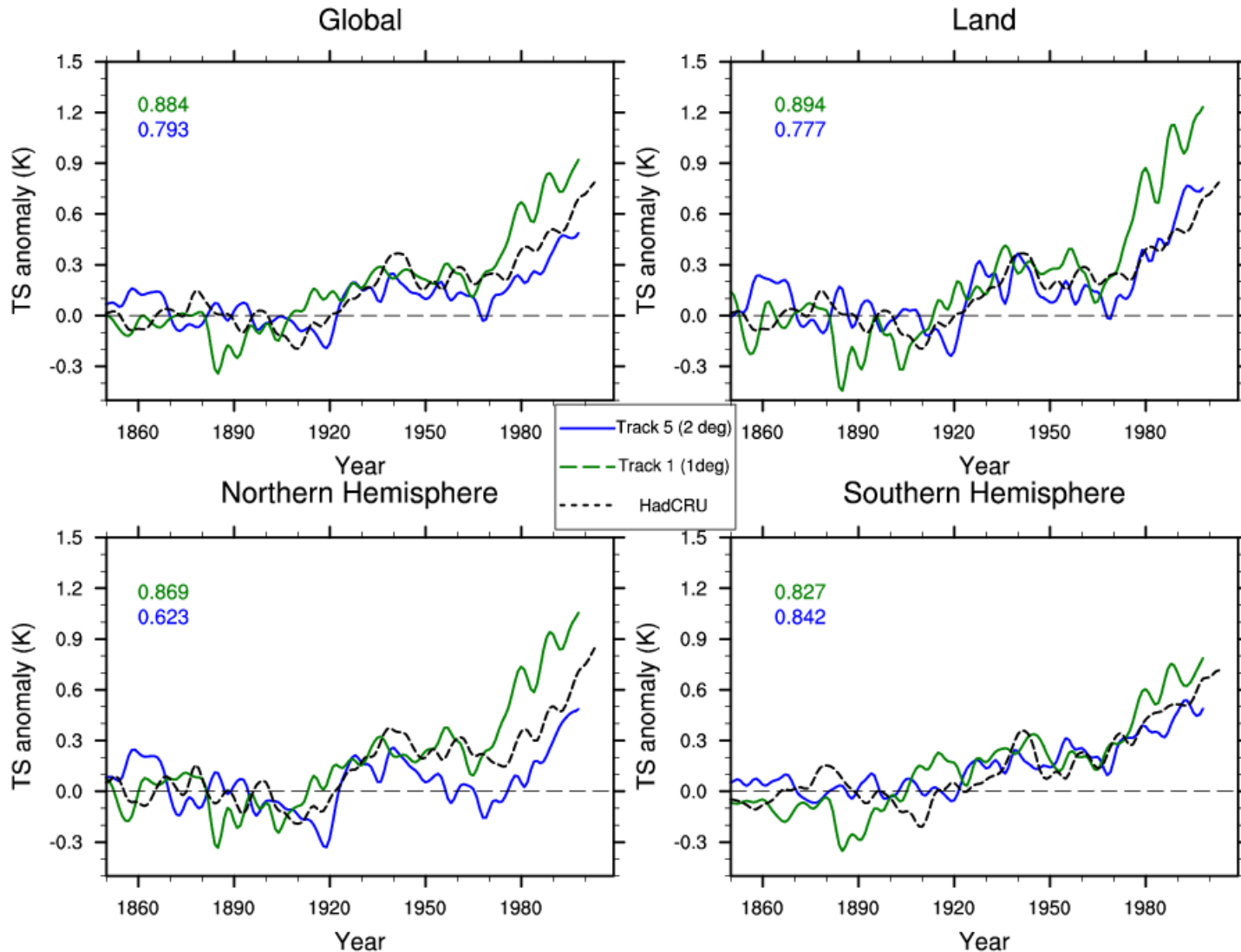


20th Century All Forcing Simulations

- 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 emissions (Track 5)
 - Prescribe aerosol burdens (Track 1)
- Global, land, hemispheric timeseries
- Differences at 1960-1979 and 1990-2004



Surface Temperature (K) – anomalies (1850-99)



Surface Temp Change (1990-2004) (K)

Track 1 – 1 deg

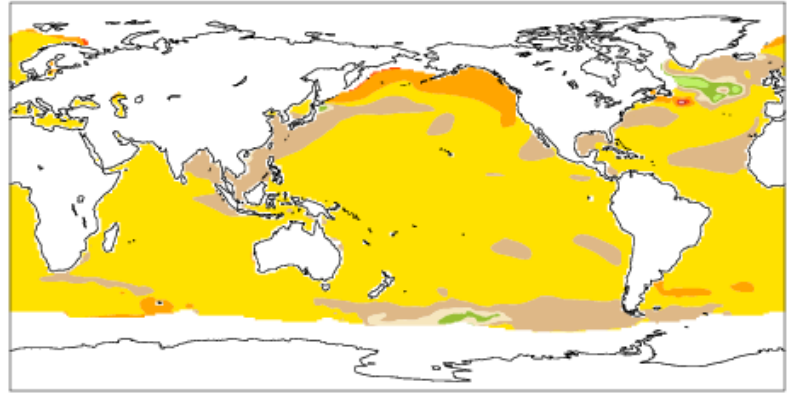
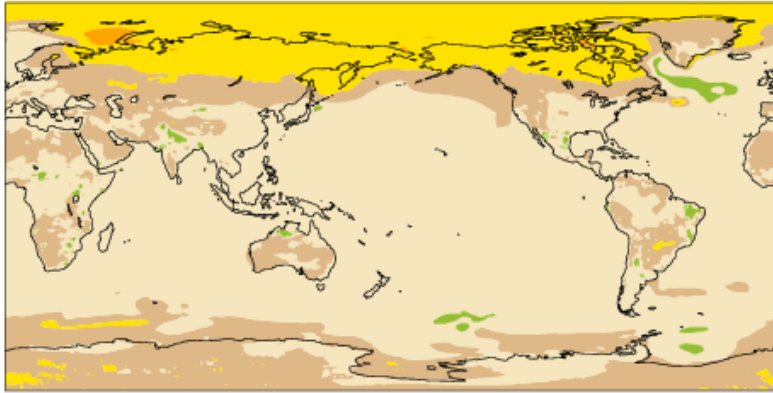
mean = 0.91

rmse = 1.13

K mean = 0.65

rmse = 0.68

C



Track 5 – 2 deg

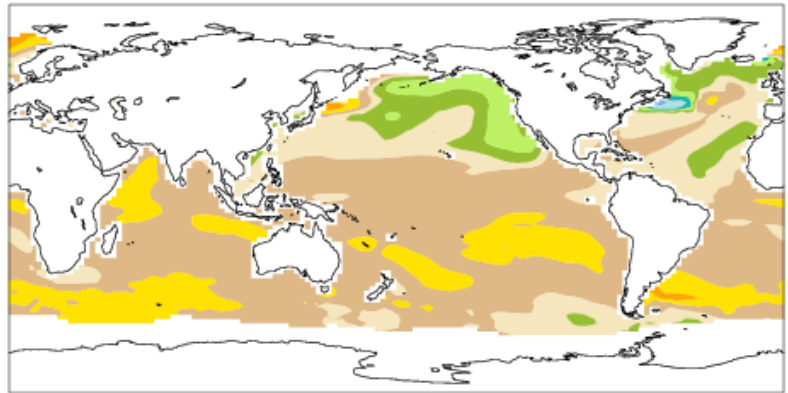
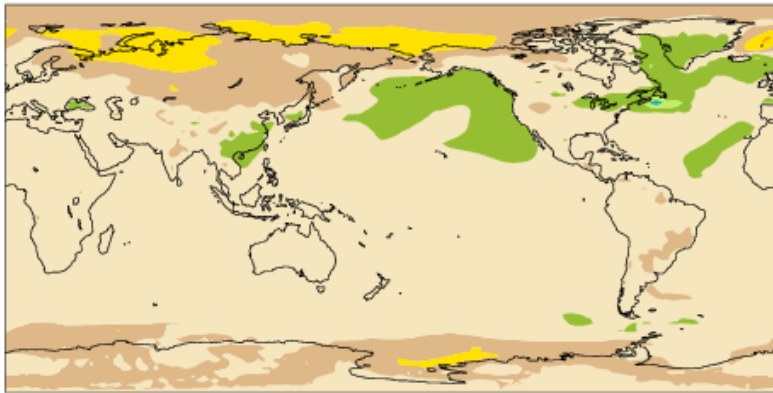
mean = 0.49

rmse = 0.68

K mean = 0.29

rmse = 0.38

C

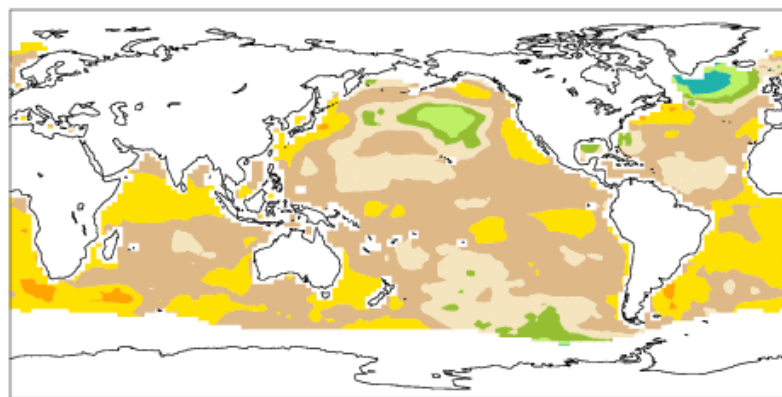
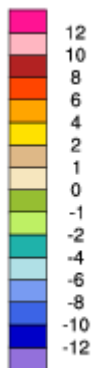


Surface Temp Change (1990-2004) (K)

HadISST
1982-2001
minus
1870-1900

mean = 0.37

rmse = 0.45

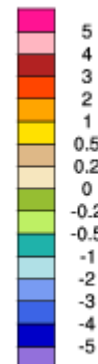
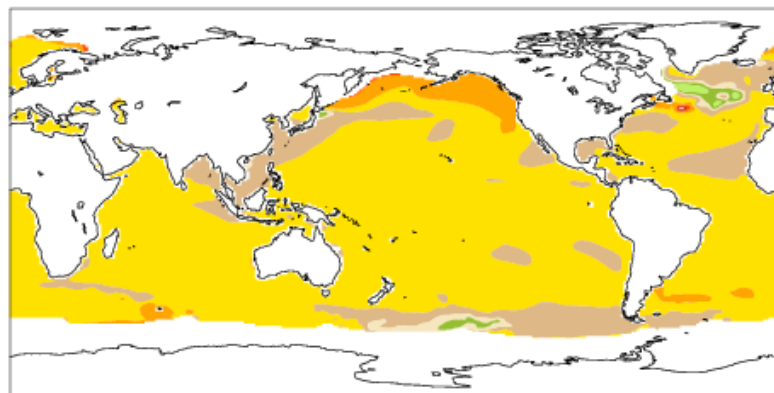


Track 1 – 1 deg

mean = 0.65

rmse = 0.68

C

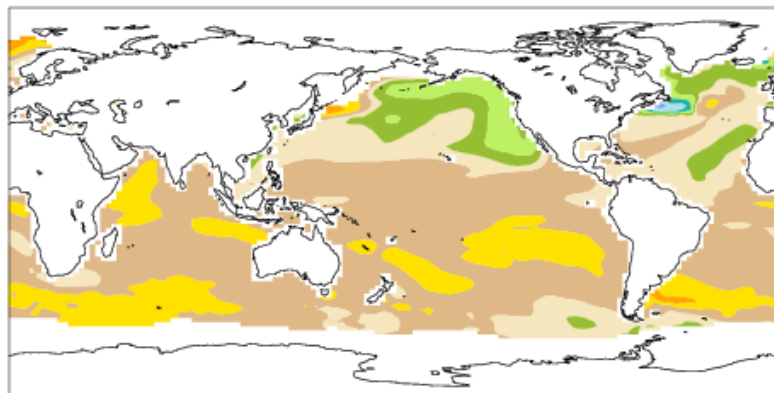


Track 5 – 2 deg

mean = 0.29

rmse = 0.38

C



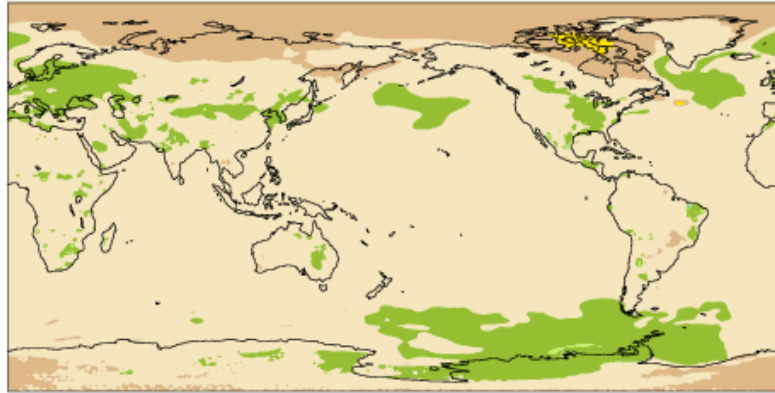
Surface Temp Change (1960-1979) (K)

Track 1 – 1 deg

mean = 0.31

rmse = 0.46

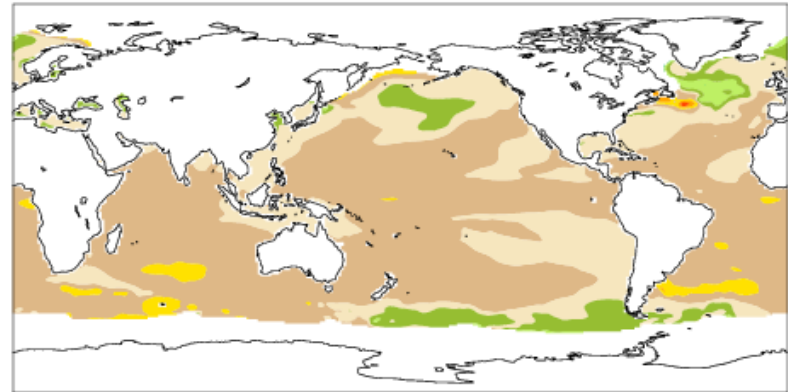
K



mean = 0.26

rmse = 0.30

C

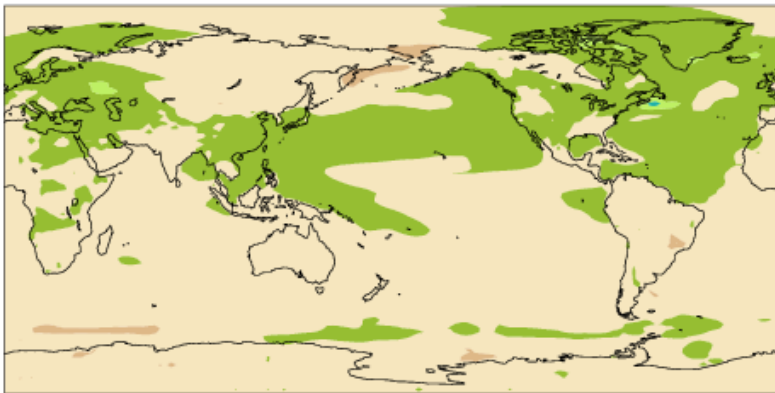


Track 5 – 2 deg

mean = 0.12

rmse = 0.32

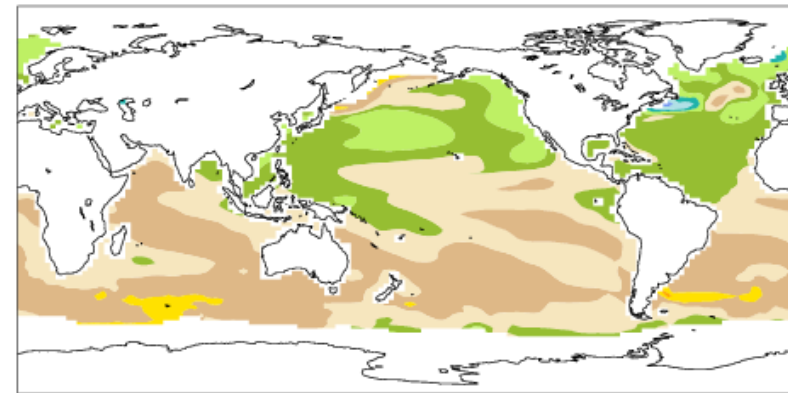
K



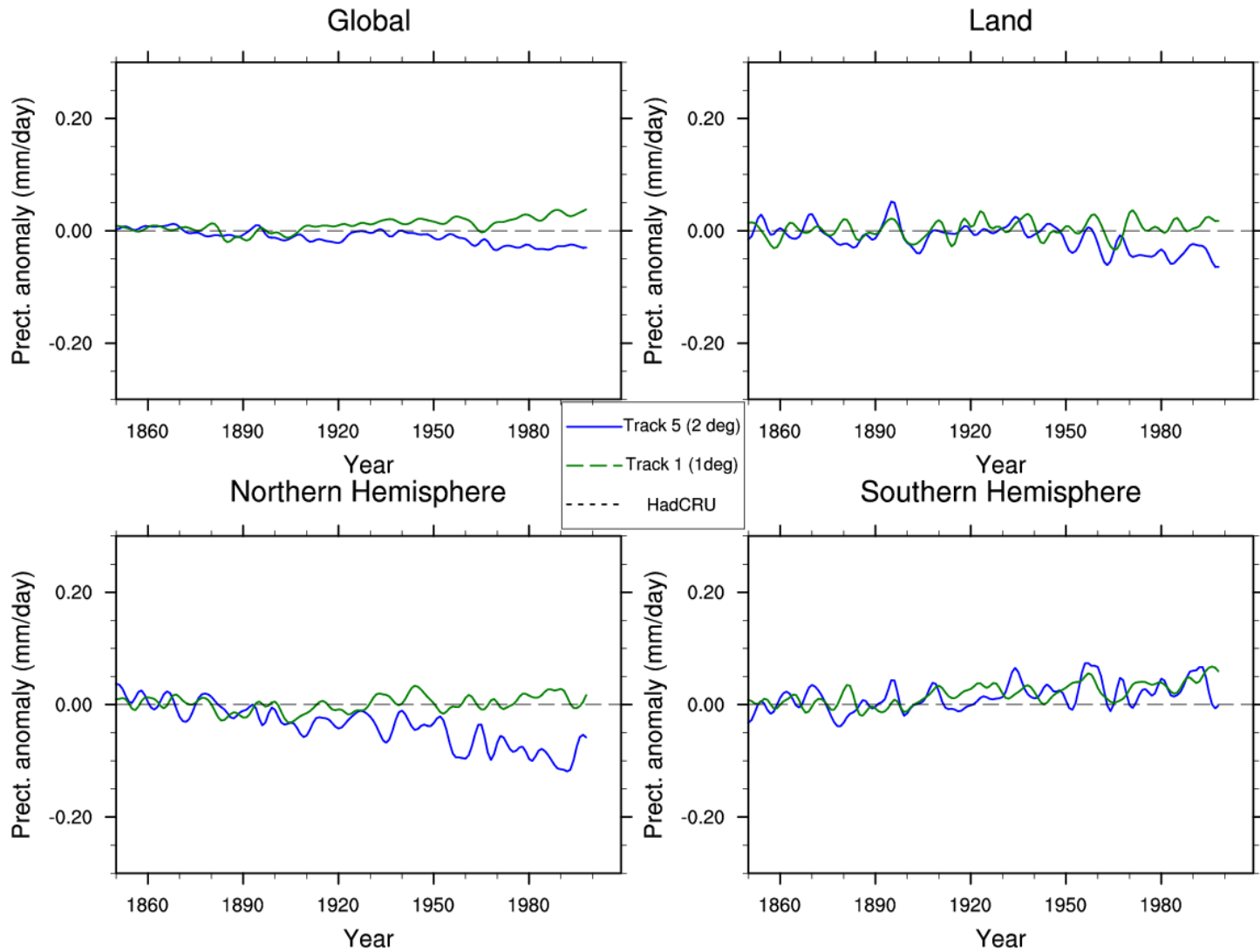
mean = 0.10

rmse = 0.24

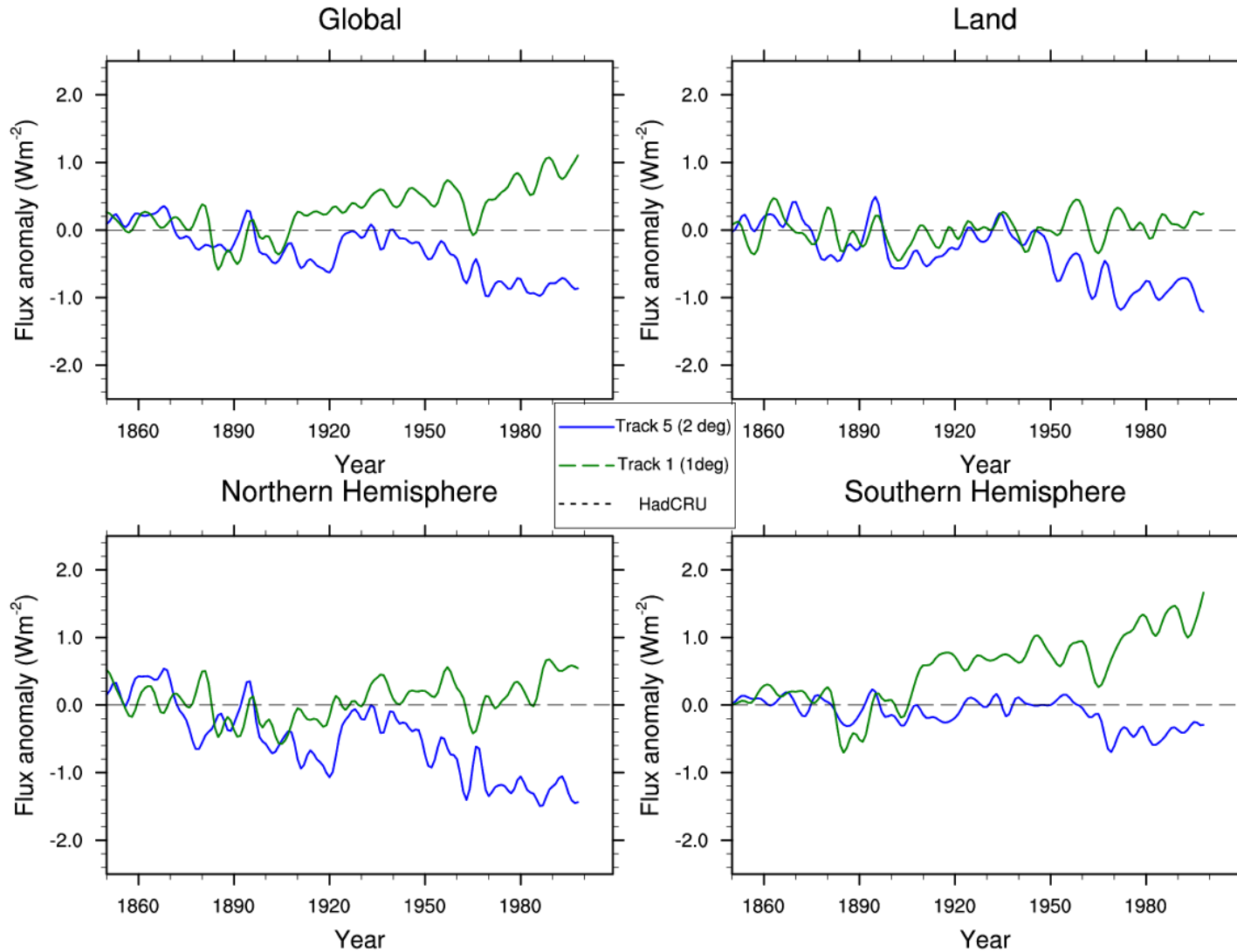
C



Precipitation (mm/day)

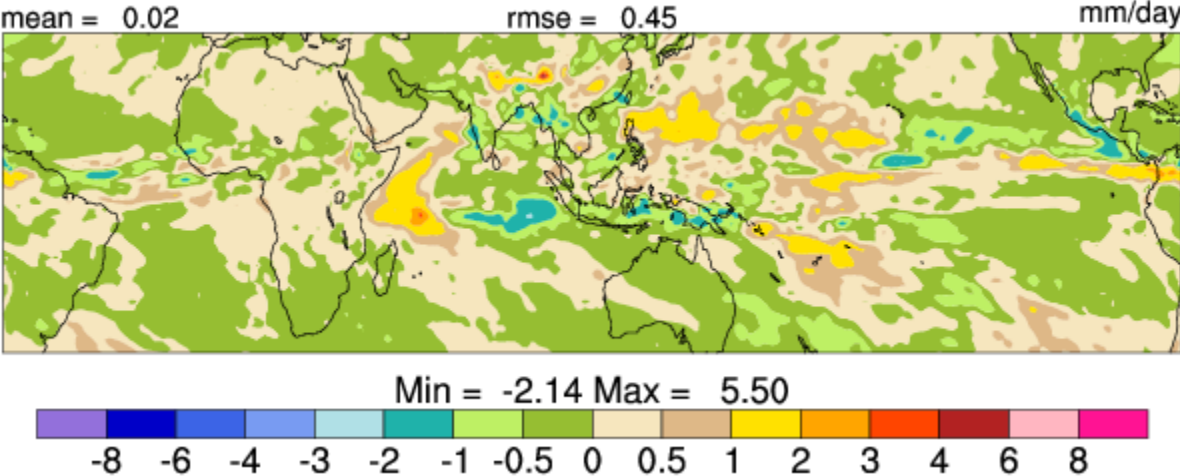


Latent Heat Flux (Wm^{-2})

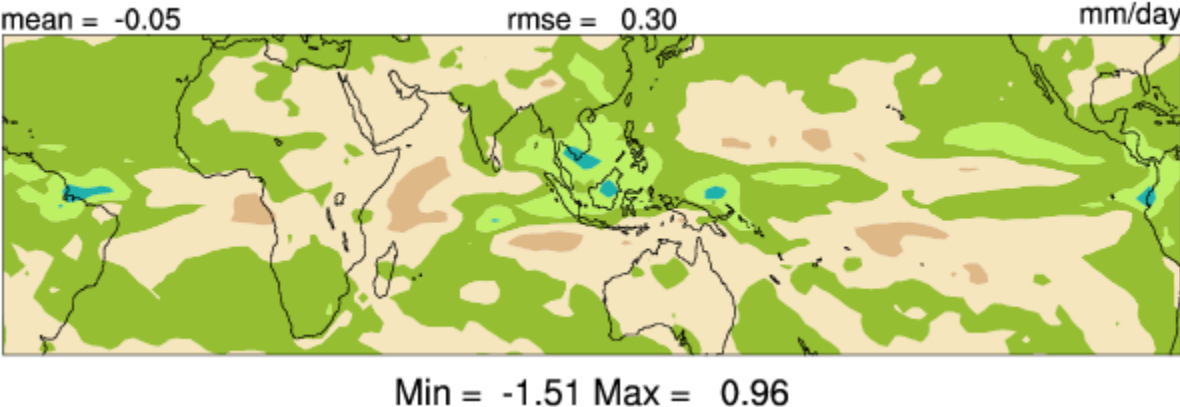


Precipitation Changes (1990-2004, ANN)

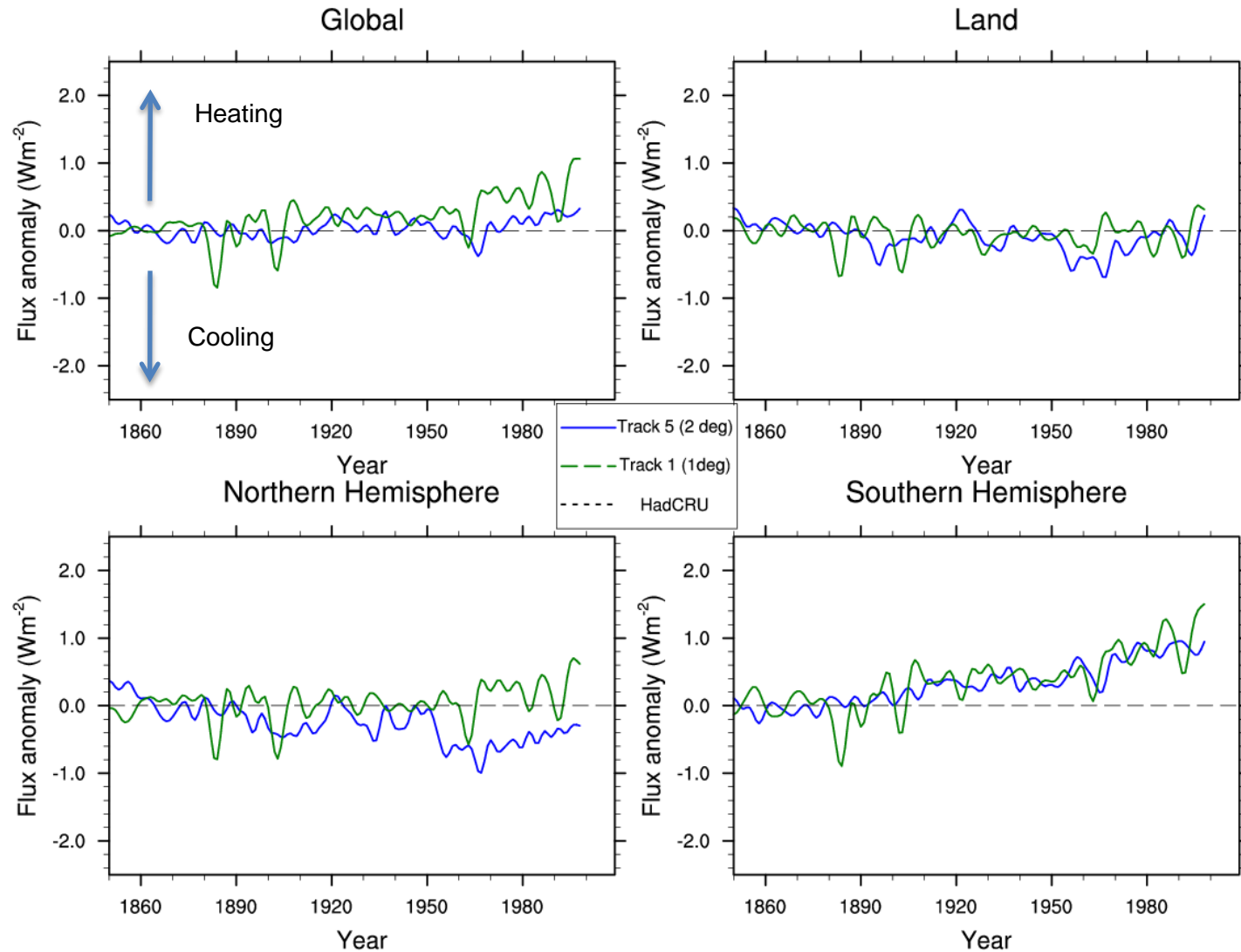
Track 1



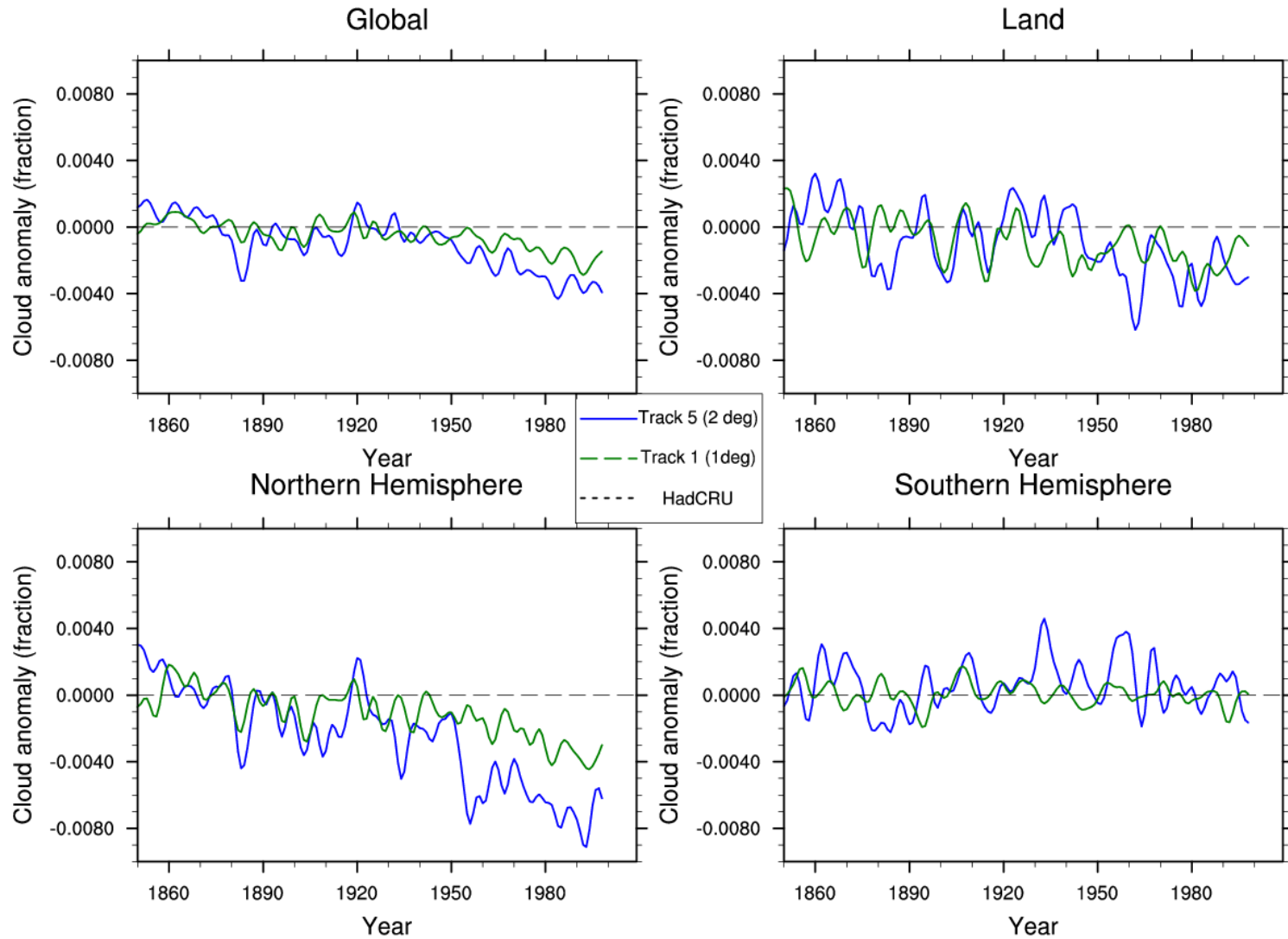
Track 5



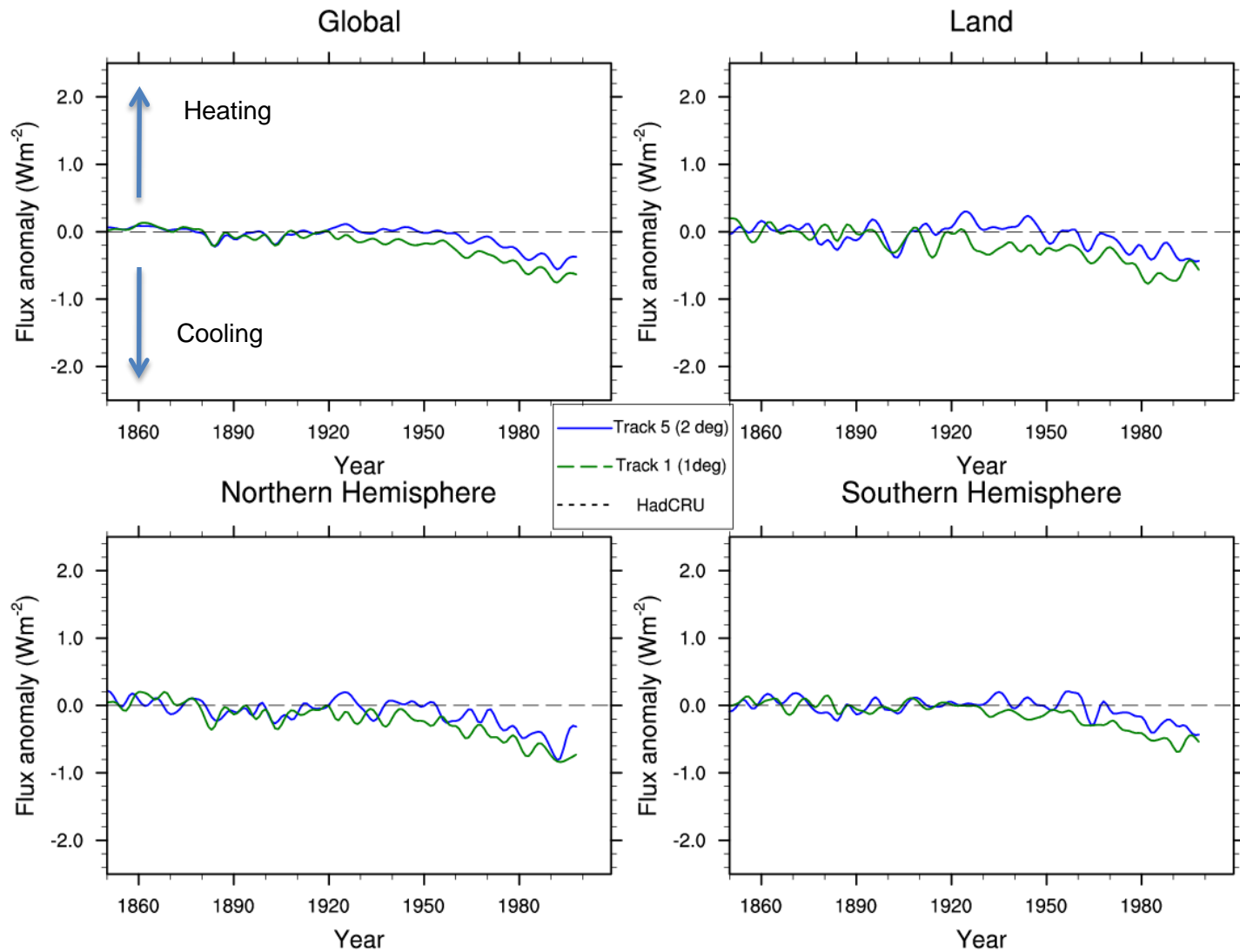
TOA Energy Imbalance (Wm^{-2})



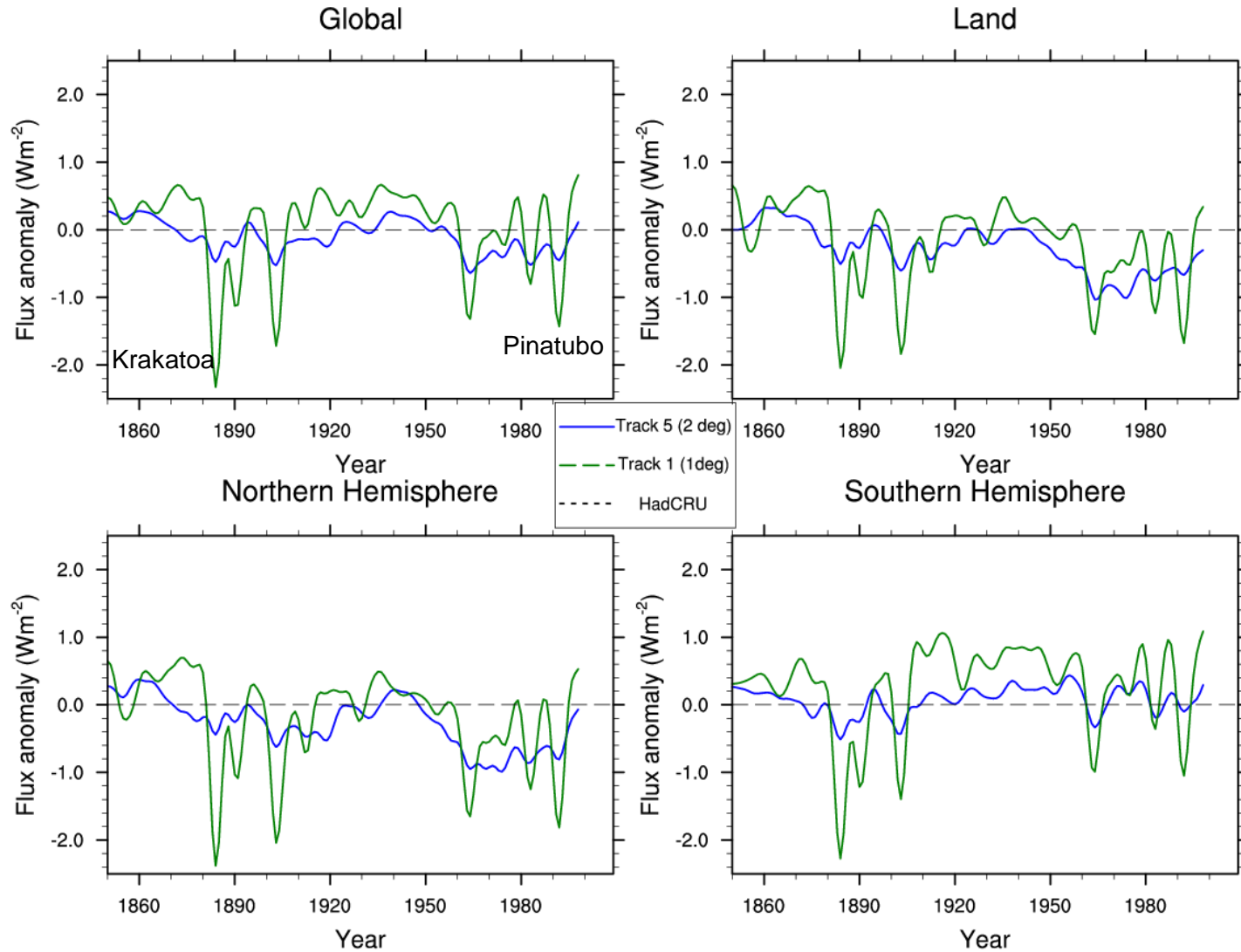
High Cloud (fraction)



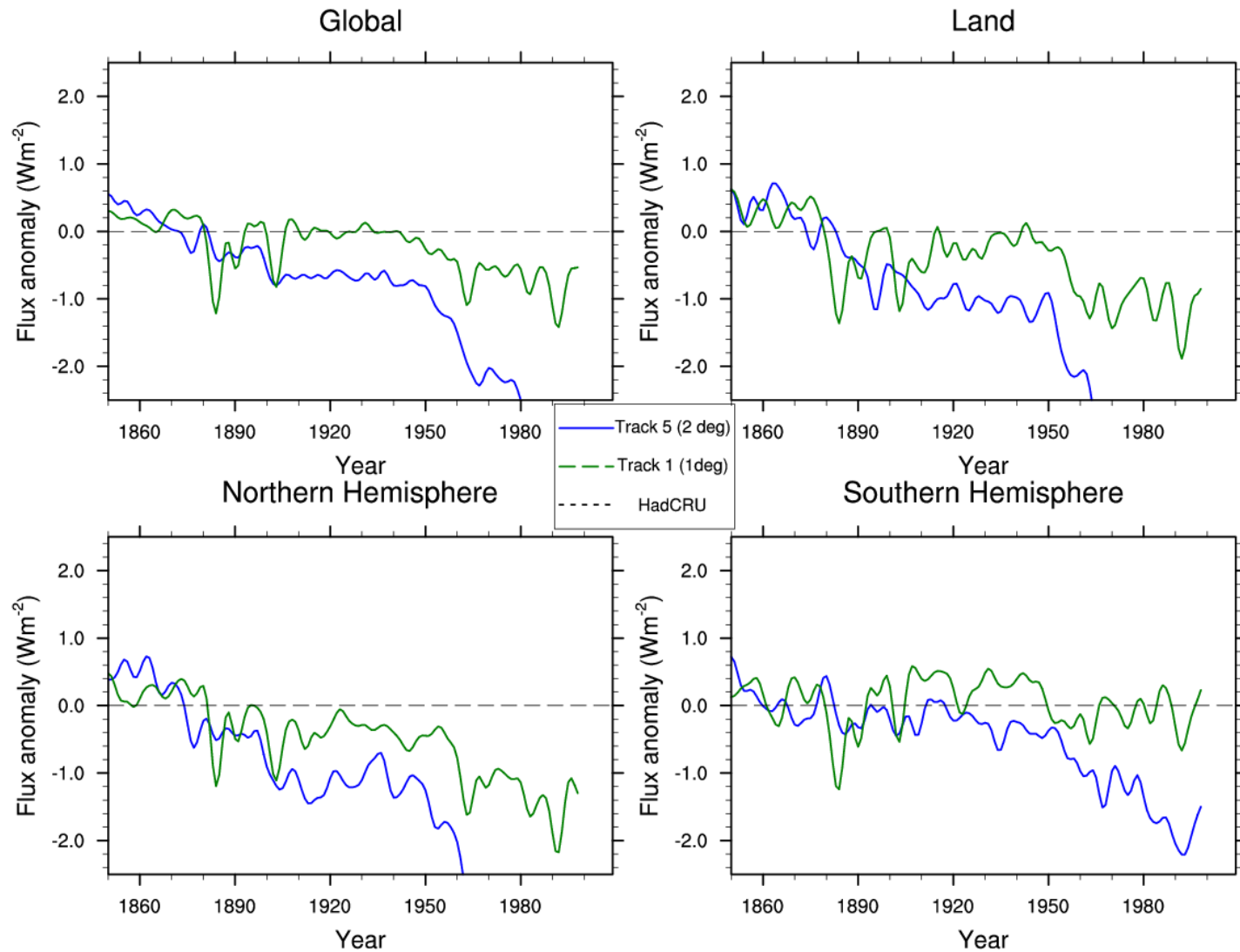
Long Wave Cloud Forcing (Wm^{-2})



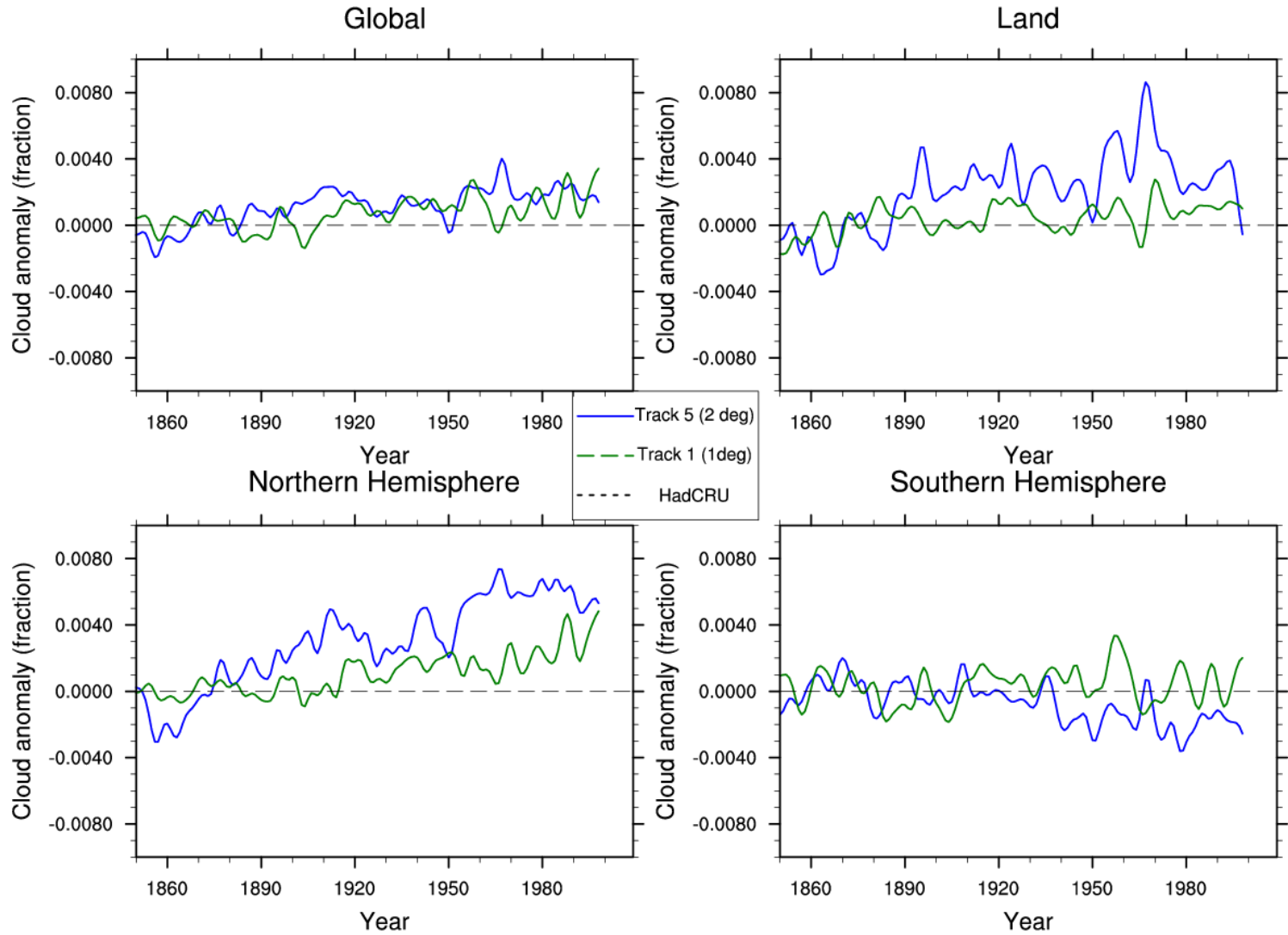
Clear Sky Short-Wave (Wm^{-2})



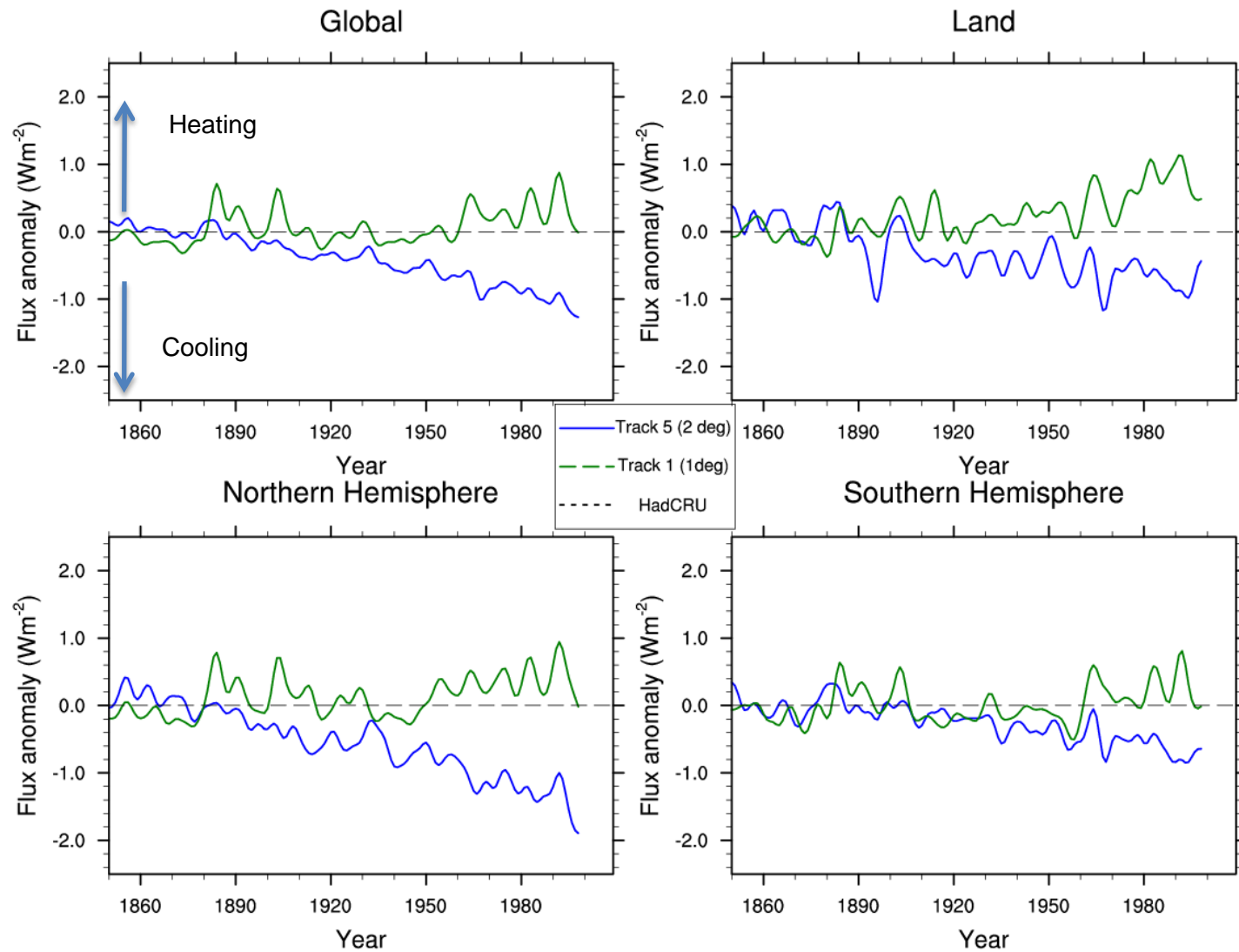
Surface Clear Sky Short-Wave Down(Wm^{-2})



Low Cloud (fraction)



Short Wave Cloud Forcing (Wm^{-2})



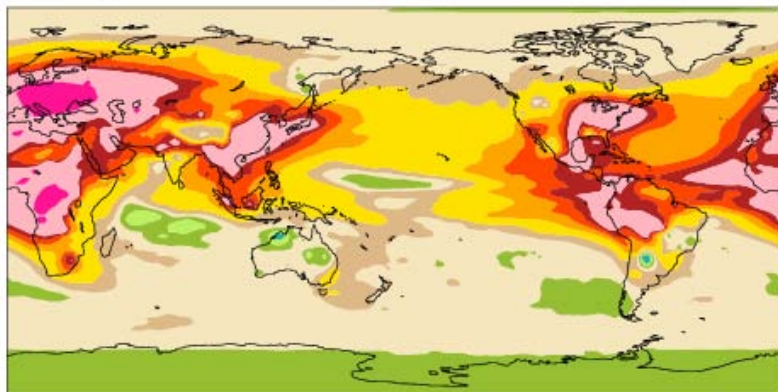
Aerosols and short-wave cloud forcing changes (Track 5)

1960-1979

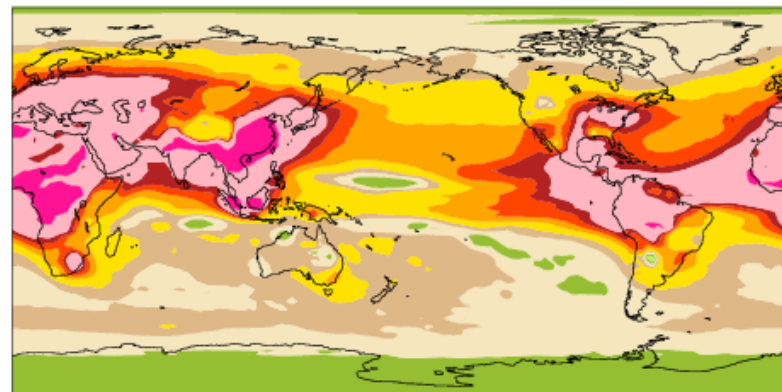
Aerosol Optical
Depth
(ANN)

1990-2004

mean = 0.02 rmse = 0.03 dimensionless

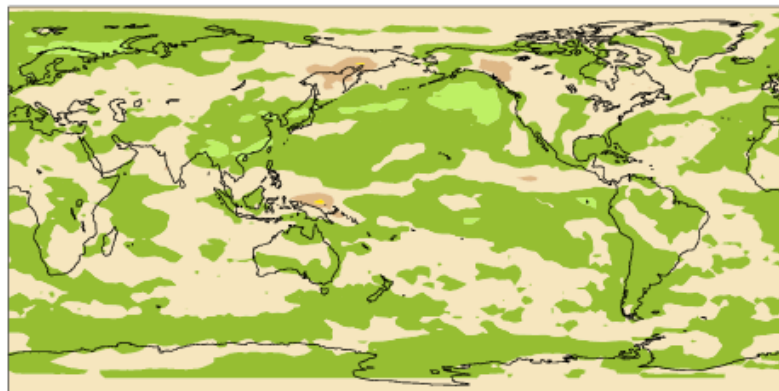


mean = 0.03 rmse = 0.04 dimensionless

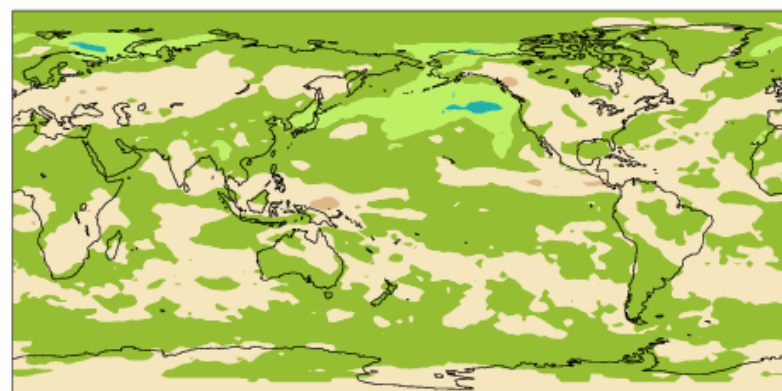


Short Wave Cloud Forcing
(JJA)

mean = -0.33 rmse = 3.51 W/m²



mean = -1.02 rmse = 4.34 W/m²



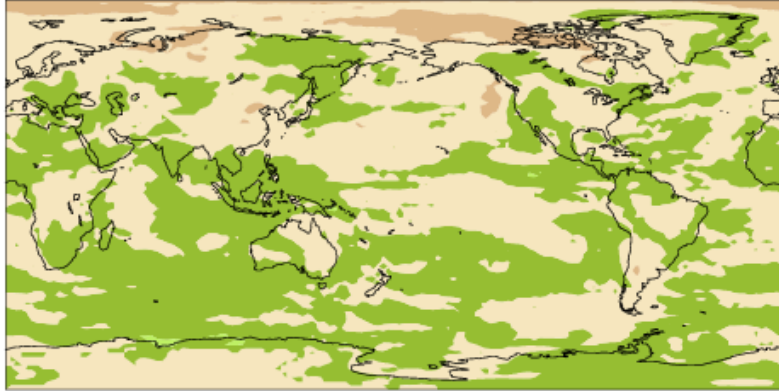
Low Cloud and Cloud Water Changes (Track 5)

1960-1979

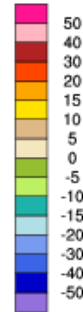
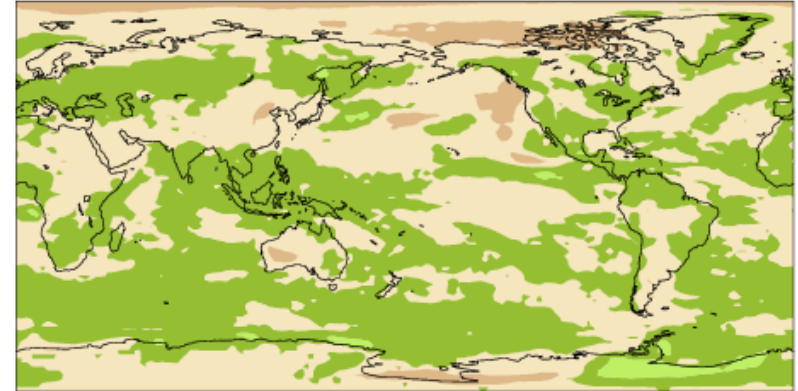
Low Cloud
Fraction
(JJA)

1990-2004

mean = 0.05 rmse = 1.67 percent

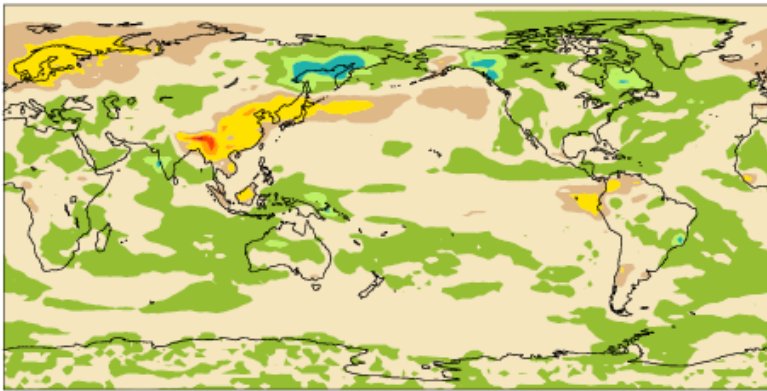


mean = 0.03 rmse = 1.95 percent

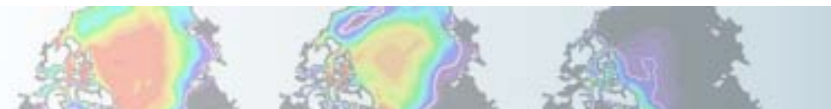
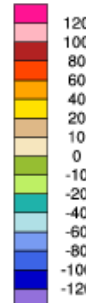
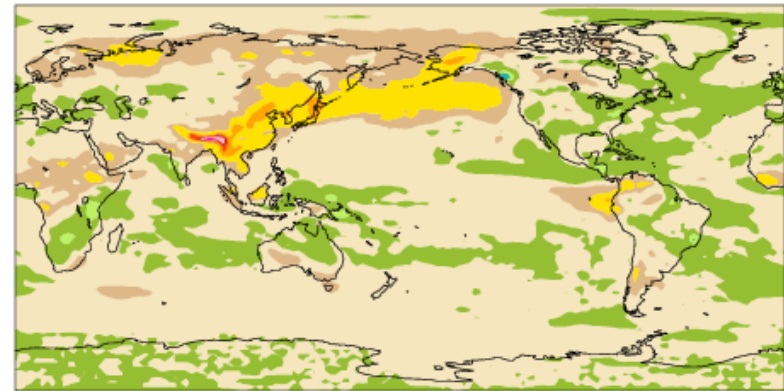


Total Grid Ave. Water Path
(JJA)

mean = 2.12 rmse = 7.32 g/m²

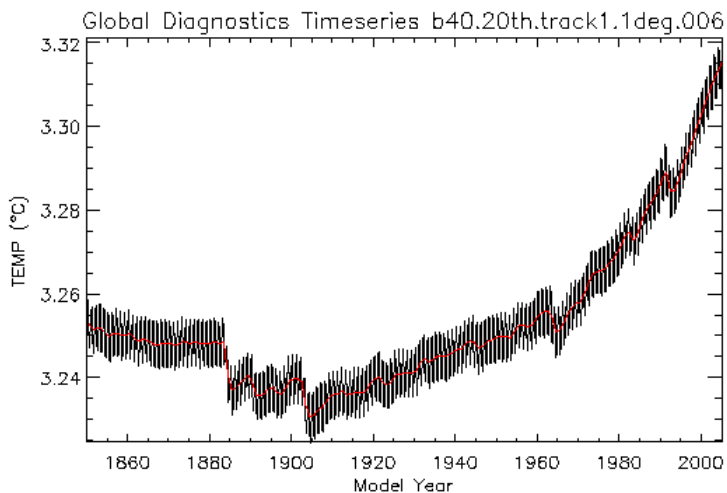


mean = 4.18 rmse = 9.56 g/m²

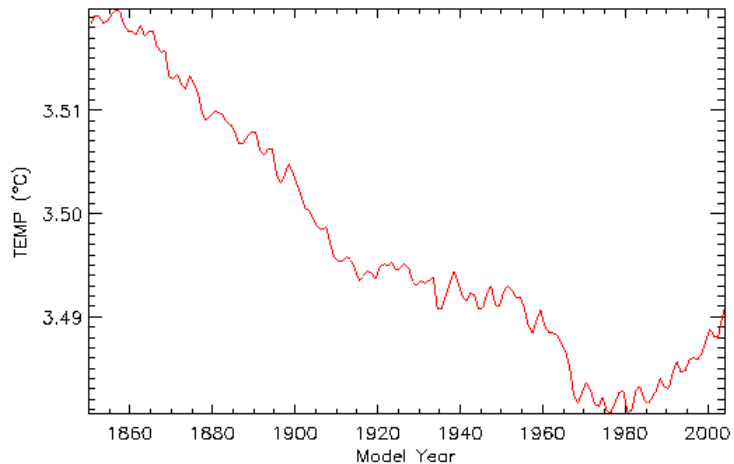
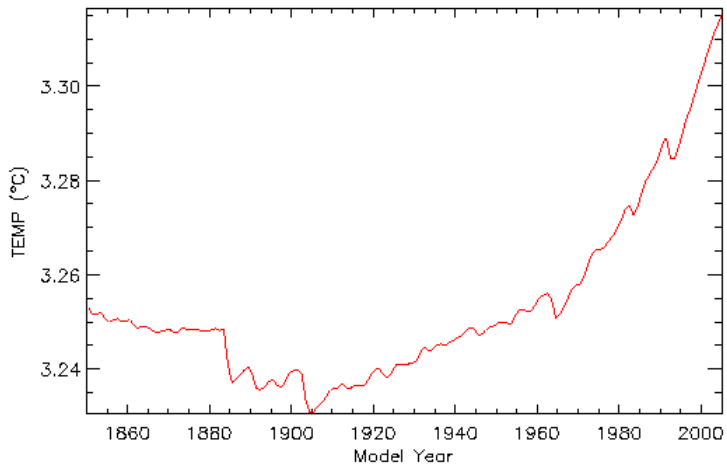
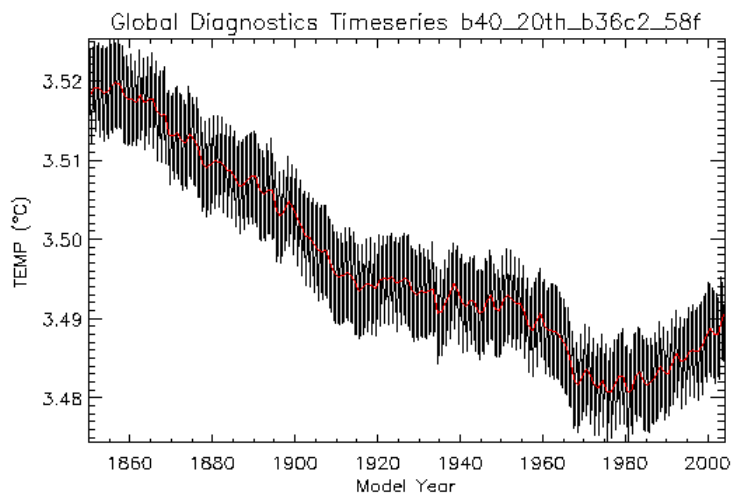


20th Century Ocean Heat Content

Track 1 – 1 deg

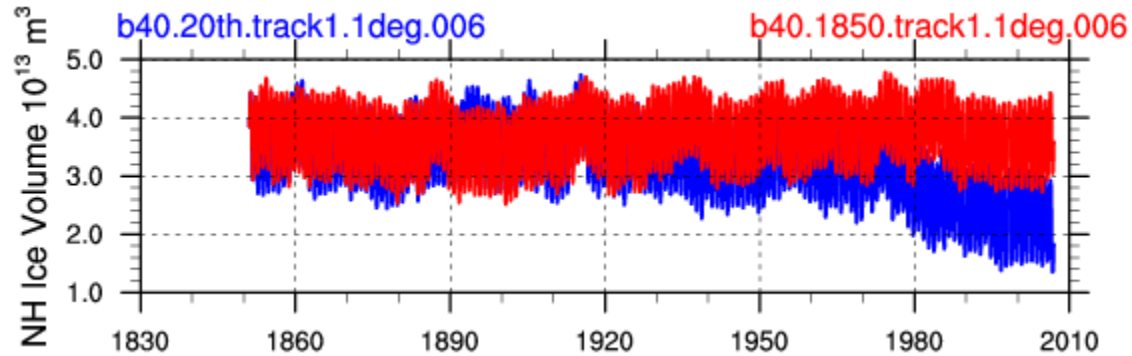


Track 5 – 2 deg

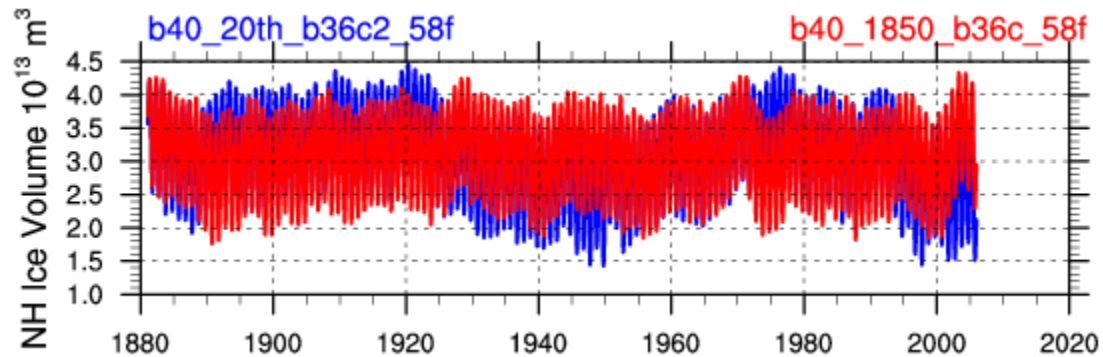


20th Century Arctic Ice Volume

Track 1 – 1 deg



Track 5 – 2 deg



Summary

- Track 5 coupled climate is competitive with Track 1 (1deg/2deg)
- SST errors are similar in magnitude, but different in nature
- Short wave cloud forcing shows significant improvements (low cloud)
- Long wave forcings remain a problem in mid-latitudes (clear sky v. cloud)
- ENSO characteristics are maintained across configurations (high amp.)
- 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)
- Ocean heat content does not increase until 1970s
- Polar sea-ice volume shows significant decline in late 1990s (< track 1)

