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
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<td>CICE</td>
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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

CCSM3.5 – 2 deg

Track 1 – 2 deg

ANN: SPACE-TIME

Reference Grids Used

- / + Bias

△ >20%

△ 10-20%

△ 5-10%

△ 1-5%

○ <1%

0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0

Correlation

0.0 0.25 0.50 0.75 1.0

Standardized Deviations (Normalized)

0.0 0.25 0.50 0.75 1.0

RMSE Bias

1.000 1.000

0.844 1.091

0.853 0.851

- / + Bias

△ >20%

△ 10-20%

△ 5-10%

△ 1-5%

○ <1%

0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0

Correlation

0.0 0.25 0.50 0.75 1.0

Standardized Deviations (Normalized)

0.0 0.25 0.50 0.75 1.0

RMSE Bias

1.000 1.000

0.844 1.091

0.947 1.100

- / + Bias

△ >20%

△ 10-20%

△ 5-10%

△ 1-5%

○ <1%

0.0 0.25 0.50 0.75 1.0

Correlation

0.0 0.25 0.50 0.75 1.0

Standardized Deviations (Normalized)

0.0 0.25 0.50 0.75 1.0

- Sea Level Pressure (ERA40)

1 - SW Cloud Forcing (CERES2)

2 - LW Cloud Forcing (CERES2)

3 - Land Rainfall (30N-30S, GPCP)

4 - Ocean Rainfall (30N-30S, GPCP)

5 - Land 2-m Temperature (Willmott)

6 - Pacific Surface Stress (5N-5S,ERS)

7 - Zonal Wind (300mb, ERA40)

8 - Relative Humidity (ERA40)

9 - Temperature (ERA40)
Short wave cloud forcing (JJA - Wm\(^{-2}\)) – CERES-EBAF

Track 1 – 1 deg

Track 1 – 2 deg

Track 5 – 2 deg

CCSM3.5 – 2 deg

Community Climate System Model
Downward Surface Short-Wave (JJA - Wm\(^{-2}\)) - ISCCP

Track 1 – 1 deg

mean = 1.86
rmse = 21.96

W/m\(^2\)

Track 1 – 2 deg

mean = -4.71
rmse = 24.57

W/m\(^2\)

Track 5 – 2 deg

mean = -0.52
rmse = 21.50

W/m\(^2\)

CCSM3.5 – 2 deg

mean = -2.25
rmse = 23.53

W/m\(^2\)
Surface Temperature Bias (1850 model climate, JJA -Wm$^{-2}$) - Willmott

Track 1 – 1 deg
- mean = -0.13
- rmse = 2.73

Track 1 – 2 deg
- mean = 0.09
- rmse = 2.99

Track 5 – 2 deg
- mean = 0.15
- rmse = 3.92

CCSM3.5 – 2 deg
- mean = -1.09
- rmse = 3.09
Long wave cloud forcing (Wm$^{-2}$) – CERES-EBAF

Track 1 – 1 deg
- mean = -3.81
- rmse = 8.45

Track 1 – 2 deg
- mean = 0.11
- rmse = 8.60

Track 5 – 2 deg
- mean = -9.92
- rmse = 12.08

CCSM3.5 – 2 deg
- mean = -3.01
- rmse = 8.34
Precipitable Water (mm) - NVAP

Track 1 – 1 deg
mean = -0.49
rmse = 2.69

Track 1 – 2 deg
mean = 0.61
rmse = 3.28

Track 5 – 2 deg
mean = 1.09
rmse = 3.14

CCSM3.5 – 2 deg
mean = -0.23
rmse = 3.23

Community Climate System Model
Precipitation (mm/day) - CMAP

Track 1 – 1 deg
- mean = 0.25
- rmse = 1.06

Track 1 – 2 deg
- mean = 0.19
- rmse = 1.23

Track 5 – 2 deg
- mean = 0.36
- rmse = 1.15

CCSM3.5 – 2 deg
- mean = 0.26
- rmse = 1.24

Community Climate System Model
Track 1 – 1 deg

Anomalies + Wavelet Power (K²/unit freq.)

Δ SST (K)

Period (years)

Track 1 – 2 deg

Anomalies + Wavelet Power (K²/unit freq.)

Δ SST (K)

Period (years)

Track 5 – 2 deg

Anomalies + Wavelet Power (K²/unit freq.)

Δ SST (K)

Period (years)

Obs. HadISST-OI)

Anomalies + Wavelet Power (K²/unit freq.)

Δ SST (K)

Period (years)
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)

Global

land

Northern Hemisphere

Southern Hemisphere

Year

Year

TS anomaly (K)

TS anomaly (K)

0.884

0.793

0.894

0.777

0.859

0.623

0.827

0.842

Community Climate System Model
Surface Temp Change (1990-2004) (K)

Track 1 – 1 deg

mean = 0.91  rmse = 1.13

Track 5 – 2 deg

mean = 0.49  rmse = 0.68
Surface Temp Change (1990-2004) (K)

HadISST
1982-2001
minus
1870-1900

Track 1 – 1 deg
mean = 0.65
rmse = 0.68

Track 5 – 2 deg
mean = 0.29
rmse = 0.38
Latent Heat Flux (Wm$^{-2}$)

Global

Land

Year
Northern Hemisphere

Year
Southern Hemisphere

Flux anomaly (Wm$^{-2}$)

1860 1890 1920 1950 1980

Track 5 (2 deg)
Track 1 (1 deg)
HadCRU

1860 1890 1920 1950 1980

1860 1890 1920 1950 1980

1860 1890 1920 1950 1980

Community Climate System Model
Precipitation Changes (1990-2004, ANN)

Track 1

mean = 0.02  
rmse = 0.45  
mm/day

Min = -2.14  Max = 5.50

Track 5

mean = -0.05  
rmse = 0.30  
mm/day

Min = -1.51  Max = 0.96
TOA Energy Imbalance (Wm\(^{-2}\))

Global

Heating

Cooling

Land

Northern Hemisphere

Year

1860 1890 1920 1950 1980

Flux anomaly (Wm\(^{-2}\))

Year

Southern Hemisphere

1860 1890 1920 1950 1980

Flux anomaly (Wm\(^{-2}\))

Track 5 (2 deg)

Track 1 (1 deg)

HadCRU

Community Climate System Model
High Cloud (fraction)
Long Wave Cloud Forcing (Wm\(^{-2}\))

Global

Heating

Cooling

Land

Northern Hemisphere

Year

Southern Hemisphere

Year

Flux anomaly (Wm\(^{-2}\))

Track 5 (2 deg)

Track 1 (1 deg)

HadCRU

1860 1890 1920 1950 1980

1860 1890 1920 1950 1980

1860 1890 1920 1950 1980

1860 1890 1920 1950 1980

Year

Community Climate System Model
Clear Sky Short-Wave (Wm$^{-2}$)

Global

Land

Northern Hemisphere

Southern Hemisphere

Year

Flux anomaly (Wm$^{-2}$)

Krakatoa

Pinatubo

Track 5 (2 deg)

Track 1 (1 deg)

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

Global

Year
Northern Hemisphere

Land

Year
Southern Hemisphere

Flux anomaly (Wm$^{-2}$)

Year

Tracks:
- Blue: Track 5 (2 deg)
- Green: Track 1 (1 deg)
- Dashed: HadCRU
Low Cloud (fraction)

Global

Year: 1860-1980

Cloud anomaly (fraction)

-0.0080 to 0.0080

Land

Year: 1860-1980

Cloud anomaly (fraction)

-0.0080 to 0.0080

Northern Hemisphere

Year: 1860-1980

Cloud anomaly (fraction)

-0.0080 to 0.0080

Southern Hemisphere

Year: 1860-1980

Cloud anomaly (fraction)

-0.0080 to 0.0080

Legend:
- Track 5 (2 deg)
- Track 1 (1 deg)
- HadCRU

Community Climate System Model
Short Wave Cloud Forcing (Wm$^{-2}$)

Global

- Heating
- Cooling

Year

- Northern Hemisphere
- Southern Hemisphere

Track 5 (2 deg)
Track 1 (1 deg)
HadCRU

Land

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

**Aerosol Optical Depth (ANN)**

- **1960-1979**
  - mean = 0.02
  - rmse = 0.03
  - Dimensionless

- **1990-2004**
  - mean = 0.03
  - rmse = 0.04
  - Dimensionless

**Short Wave Cloud Forcing (JJA)**

- **1960-1979**
  - mean = -0.33
  - rmse = 3.51
  - $W/m^2$

- **1990-2004**
  - mean = -1.02
  - rmse = 4.34
  - $W/m^2$
20th Century Ocean Heat Content

Track 1 – 1 deg

Track 5 – 2 deg

Global Diagnostics Timeseries b40.20th.track1.1deg.006

Global Diagnostics Timeseries b40.20th.b36r2.58f
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 increases until 1970s
- Polar sea-ice volume shows significant decline in late 1990s (< track 1)