CAM4/CCSM4
Overview and Simulations

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# CAM Evolution

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CAM3 -> CAM4: Physics Changes

Convection Dilution
✓ Reduced sensitivity to surface temp
✓ Increase sensitivity to atmos. humidity
Neale et al. (2008)

Convective Momentum Transports
✓ Reduce excessive surface trades
Richter and Rasch (2008)

Polar Cloud Freeze Drying
✓ Reduce excessive winter-time polar low cloud
Vavrus and Waliser (2008)

\[
f = f \times \left[ \max(0.15, \min(1.0, \frac{q}{0.003})) \right].
\]
CAM3 -> CAM4: Dynamics Changes

Default: Finite Volume (FV)
- Lat-lon grid
- Scaling limitations
- Conserves mass and total energy
- Conservative and monotonic 2D transport scheme

Option: HOMME-Spectral Element
Mark Taylor, DOE, NCAR-CISL
- Unstructured grid (cubed sphere)
- Highly scalable
- Locally conserves mass and moist energy
- Tracer advection modeled on FV core
- Advection modeled on Eulerian core
Annual Precipitation


Observed (CMAP, average 1979-1998)
Annual Precipitation Biases

Observed (CMAP, average 1979-1998)
Indian/Asian Monsoon

1970-1999
JJAS Average Rainfall
JJAS 850-mb winds
✓ Break phase improved
✓ North east Indian cycle improved
✓ Higher resolution better captures orographic features (inc Indian rain shadow)
Daily rainfall averages
-20N-20S land regions
-All interpolated to 2 deg
-Model (1990-1999)
-Obs. (1998-2007)
-Reduction in moderate rainfall events
-Mean return period events of ~6 months (>25 mm/day) and greater are better reproduced
-Implications for future extreme event changes
Global Surface Stress Improvements

Direction (vectors) strength (colors)
✓ Reduced trade-wind biases (CMT)
✓ Reduced Atlantic low strength (CCSM4, 1deg)
✓ Greatest improvements come from including turbulent mountain drag (TMS) formulation

ERS

CCSM4 (1 deg)

CCSM4 (2 deg)

CCSM3 (T85)
Polar Low-Cloud Improvements
Late 20th Century

Warren

CCSM3 (T85)

Annual Polar Cloud Fraction (%)

CloudSat

Freeze-drying

CCSM4 (1 deg)

Community Earth System Model
Composite Madden Julian Oscillation (MJO)


Eight phase composite of PC1 and PC2 from combined EOFs.
20th Century coupled experiments
Composite Madden Julian Oscillation (MJO)


Eight phase composite of PC1 and PC2 from combined EOFs.
20th Century coupled experiments
Zero-lag correlation of nino3 SST anomalies (white box) with global SST anomalies. 20th Century simulations (1900-1999)

Global ENSO Response
20\textsuperscript{th} Century Climate Change

Surface temperature changes over the 20\textsuperscript{th} Century (1970-1999 minus 1850)
CCSM3 and CCSM4: warming somewhat strong
CESM1-CAM5: warming somewhat weak
Short wave cloud forcing over the 20th Century (1970-1999 minus 1850)
CCSM3 and CCSM4: low-cloud feedbacks are positive (warming)
Amplified signals at 1 deg. compared to 2 deg.
Cubed-sphere grid overcomes dynamical core scalability problems inherent with lat/lon grid

Work of Mark Taylor (SciDAC), Jim Edwards (IBM), Brian Eaton (CSEG)

CCSM4 (cam,clm,cice,docn)

CAM/HOMME Dycore

Simulated Years/Day

10^{-1}

10^{0}

10^{1}

NCORES

10^{3}

10^{4}

10^{5}

ORNL–PF APE 0.25°

ANL–BGP APE 0.25°

ORNL–PF APE 0.125°

ORNL–PF CCSM 0.125°

ANL–BGP CCSM 0.25°

CAM4-HOMME (1 deg)

CAM4-FV (1 deg)
CAM4/CCSM4 Summary

✓ CAM4 major component changes
   a. Convective momentum transports
   b. Convective buoyant parcel dilution
   c. ‘Freeze drying’ of polar low-cloud
   d. Finite volume dynamical core
   e. Option of HOMME spectral-element dynamical core

✓ Translates to mostly tropical atmosphere climate improvements
   ✓ Reduced strong bias in surface stresses (sub-tropical, mid-latitude)
   ✓ Improved mean precipitation simulation and local feature
   ✓ More frequent extreme precipitation events over land
   ✓ Stronger modes of tropical variability (esp. MJO)
   ✓ Reduced winter-time polar cloud excess
   ✓ Improved transport properties (WACCM, CAM-chem)

✓ More realistic coupled modes of variability
   ✓ El Nino period 2->3-5 years
   ✓ Realistic global teleconnection patterns
Lag correlation of 20-100 day band pass filtered precipitation and 850-mb zonal wind with 90E region (top) and equator (bottom)