The CAM5.1 release and coupled simulations

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The Community Atmospheric Model (CAM)

- Developed at the National Center for Atmospheric Research (NCAR)

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= New parameterization/dynamics
Let us introduce our new addition
CAM5.1 born on June 15, 2011
What’s in CAM5.1?

- **CAM5.1** = CAM5 + several **bug fixes**

- Changes: **small effect** except ...
  - bug fix for **size of snow** particles used in **radiation**
    - snow particles smaller -> more reflective -> large impact

- **SWCF, ANN**
  - Mean = -3.52 W/m²

- **LWCF, ANN**
  - Mean = 2.30 W/m²

- Change required **retuning**
Model versions and simulations

Models versions

• CCSM4: CAM4 – 1deg (released in April 2010)
• CESM1: CAM5.1 – 1deg (released in June 2011)

Simulations

• 1850 control
• 20th century
• Climate sensitivity
• Aerosol direct/indirect effect
Model versions and simulations

Models versions

• CCSM4: CAM4 – 1deg => “CAM4”
• CESM1: CAM5.1 – 1deg => “CAM5.1”

Simulations

• 1850 control
• 20\textsuperscript{th} century => “Late 20\textsuperscript{th} century” is a climo over 1981-2000
• Climate sensitivity
• Aerosol direct/indirect effect
1850 controls: SSTs versus Hurrell dataset

- **Temperature errors:** Model versus Hurrell (2008)
- RMSE reduced in CAM5.1
- Error in key regions (i.e. Eastern ocean)
Californian stratocumulus

Shortwave cloud forcing (W/m²)

Obs (CERES-EBAF)

CAM4

CAM5.1

Strong cooling effect on the ocean

Not enough cooling and cloud too close to the coast

Major improvement due to new PBL scheme in CAM5

=> better SSTs
20th century: Surface temperature

Global temperature anomalies from 1850-1899 average

- HADCRU
- CAM4
- CAM5.1
Warming over the 20th century

- Warming over 20th century: \( T_S(\text{present}) - T_S(\text{preindustrial}) \)
- Polar amplification
- Significant regional modulation of the global warming trend

Hurrell SSTs dataset

CAM4
Mean = 0.84

CAM5.1
Mean = 0.35
Warming over the 20th century

- Modulation of the warming is correlated to the change in aerosol over the 20th century
- Aerosol: **Cooling effect** on climate
- **CAM5**: aerosol indirect effect

**Aerosol Optical Depth (model)**

**CAM4**
Mean = 0.84

**CAM5.1**
Mean = 0.35
Late 20^{th} century: precipitation versus CMAP

- Precipitation errors: Model versus CMAP (Xie-Arkin)
- Local improvements but globally, no significant improvement with CAM5 (twin ITCZ still present)

CAM4

- Mean = 0.27
- RMSE = 1.09

CAM5.1

- Mean = 0.34
- RMSE = 1.06
Late 20th century: Sea-Level Pressure versus NCEP

CAM5.1 includes the Turbulent Mountain Stress (TMS) parameterization (~ take into account mountain roughness)

TMS improves the sea-level pressure
Late 20th century: Taylor diagrams

CAM3.5
Bias = 1.0
RMSE = 1.0

CAM4
Bias = 0.91
RMSE = 0.91

CAM5.1
Bias = 1.29
RMSE = 0.79
Pacific Variability: ENSO

Neale et al. (2008); Deser et al. (2011); Gent et al. (2011)
Nino3.4 over 20\textsuperscript{th} century

• CAM5.1 better than CAM4

But this result depends on ensemble member !!!
Let’s take another member

• CAM4 better than CAM5.1

But this result depends on ensemble member !!!
Climate sensitivity

• Equilibrium change in **surface temperature** due to a doubling of CO2 (from SOM simulations)

  - CAM4 = 3.17 K
  - CAM5.1 = 4.08 K

• Gettelman et al. (2011) show that:
  - Larger sensitivity in CAM5 is due: higher CO2 radiative forcing
  - larger shortwave cloud feedbacks

  Largest change due to shallow convection scheme:
  enhances positive cloud feedbacks in sub-tropics and mid-latitudes

**Adjusted shortwave cloud feedbacks**
Aerosol Direct Effect (ADE)
Aerosols scatter and absorb solar and infrared radiation

Aerosol Indirect Effect (AIE)
If aerosols increase
=> number of cloud droplets increases
=> droplet size decreases
=> for same LWP, clouds are brighter
Aerosol: direct and indirect effect

✧ **PNNL**: More accurate way of partitioning the aerosol radiative forcing.

**Aerosol Direct Effect (ADE)**
Aerosols **scatter** and **absorb** solar and infrared radiation
✧ *New way to compute ADE: include influence of clouds on ADE.*
*Ex*: Clouds can enhance warming by providing upwelling radiation that can be absorbed.

**Aerosol Indirect Effect (AIE)**
If aerosols **increase**
⇒ number of cloud droplets increases
⇒ droplet size decreases
⇒ for same LWP, **clouds are brighter**
✧ *New way to compute AIE as a residual*
Aerosol direct effect

**Cooling:** Sulfate aerosol accumulate over dark surface (Ex: Mediterranean)

**Warming:** black carbon accumulate over bright surface (Ex: Biomass burning in Africa)

Direct forcing: 0.01 W/m²

Small forcing because enhanced black carbon warming
Aerosol indirect effect

Solar AIE: -1.96 W/m²
- Strong indirect effect over South East Asia, Arctic, off the coast of Chili and North Pacific

Longwave AIE: 0.58 W/m²
- Effect stronger than other models
- Strongly correlated with changes in upper troposphere crystal number concentration
Summary

- Latest CESM simulations include: CAM5.1 at 1-degree resolution using CLM-CN (prognostic carbon and nitrogen cycle in the land).

- Overall, CAM5.1 produces better simulation than CAM4: More realistic surface temperatures, better scores (Taylor diagrams). But some biases remain (precipitation, double ITCZ).

- Climate variability: CAM4 and CAM5.1 reproduced nino3.4 reasonably well. ENSO strongly depends on ensemble member.

- Climate sensitivity is larger in CAM5 (~4K) than in CAM4 (~3.2K). Due to larger shortwave cloud feedbacks and higher CO2 radiative forcing. Changes dominated by shallow convection parameterization.

- We use a new method to assess aerosol direct and indirect effect. ADE: -0.011 W/m² (includes influence of cloud on aerosols). AIE: -1.96 W/m² (shortwave) and +0.58 W/m² (longwave).
Extra slides
Late 20th century: surface wind stress vs ERS

- Temperature errors: Model versus ERS

CAM4 – 1deg
Mean = 0.

CAM5.1 – 1deg
Mean = 0.
Stratocumulus

• Thin clouds that forms over cold oceans (Think “San Francisco”)

• Very reflective => strong cooling effect on the surface

• Very difficult to parameterize (very thin and maintained by a blend of complex processes)

Daily cycle of shortwave heating

entrainment at cloud top

Possible decoupling
drizzle
turbulence

Strong longwave cooling at cloud top

A few hundreds meters

CAM5 represents stratocumulus better
Sea-ice thickness: Loss over 20th century

CAM4-1deg  CAM5-2deg  CAM5.1-1deg

1850

Late 20th century
Late 20th century: 2-meter Temperature

- Temperature errors: Model versus CRU
  - CAM4: warming too much at mid-latitudes (no indirect effect)
  - CAM5.1: not enough polar amplification

CAM4 – 1deg
Mean = 0.02
RMSE = 2.13

CAM5 – 2deg
Mean = -0.29
RMSE = 2.36

CAM5.1 – 1deg
Mean = -0.81
RMSE = 2.05