Evaluating clouds and radiation in the CCCma AGCM using CERES data

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Introduction

Evaluate clouds and radiation simulated by GCMs
Most AGCMs use TOA fluxes as part of model tuning
⇒ Makes evaluation of cloud radiative effects difficult
Are you getting the right answer for the right reasons?
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Break down cloud properties and radiative effect:
Cloud types (Webb, 2001; Chen, 2000)
Cloud objects (Xu, 2005)
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Cloud objects (Xu, 2005)

Evaluate properties as function of cloud top exposed to space
Cloud top exposed to space diagnostics

Computation of domain-mean flux using ICA

\[
\langle F_{ICA} \rangle = (1 - A_c)F^{clr} + A_c \int p(\tau)F_{1D}(\tau)d\tau
\]

\[
\langle F_{ICA} \rangle = (1 - A_c)F^{clr} + \sum_{i=1}^{i=M} A_{c,i} p_i(\tau)F_{1D,i}(\tau)d\tau
\]
Cloud top exposed to space diagnostics

Observable from passive instruments
Can infer $F_{1D,i}$ from CERES and MODIS
Diagnose easily from GCM (esp. using McICA)

Subgrid cloud structure

- McICA
  - Solar fluxes
  - Infrared fluxes
  - Heating rates
- Cloud props
  - Cloud amount
  - Optical thickness
  - Water contents
  - Particle sizes
Daily data and GCM output

Observations
CERES July 2001-2005
Daily means computed from TERRA SSF data
Cloud props for low, middle and high clouds exposed to space
Radiative fluxes at TOA derived from MODIS and CERES data
24-hour solar fluxes computed assuming constant meteorology
Daily data and GCM output

Observations
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AGCM simulations
Two developmental, tuned, versions of CCCma AGCM
T63, 35 levels
GCM15G $\rightarrow$ January 2008 (McICA implemented)
GCM15H $\rightarrow$ January 2009
GCM15G $\Rightarrow$ GCM15H several changes to clouds and radiation
Sampled along TERRA orbit
July climatology (GCM15H)

TOA all-sky albedo

TOA clear-sky albedo

Total cloud fraction

Cloud liquid water path

Solid line ⇒ obs, Dashed line ⇒ GCM15H
Sampling effects (Low cloud fraction July 2003)

Low cld frac all data

Low cld frac TERRA orbit

TERRA-ALL

AQUA-TERRA
Sampling effects (Low cloud fraction when present)

**Low cld. frac. (July 2003)**

- Solid line ⇒ obs
- Dashed red line ⇒ GCM15G
- Dashed black line ⇒ GCM15H

**Daily mean low cld. frac. (July 2001-2005)**

- Solid line ⇒ obs
- Dashed red line ⇒ GCM15G
- Dashed black line ⇒ GCM15H
Zonal means (July 2001-2005)

Computed using gridboxes with cld. frac. > 5%
Cloud inhomogeneity decreases as $\nu$ increases

$$p(\tau) = \frac{1}{\Gamma(\nu)} \left( \frac{\nu}{\bar{\tau}} \right)^\nu \tau^{\nu-1} e^{-\nu \tau / \bar{\tau}}, \; \nu = \left( \frac{\bar{\tau}}{\sigma} \right)^2$$

Solid line ⇒ obs
Dashed red line ⇒ GCM15G, Dashed black line ⇒ GCM15H
Need for consistency – $\nu$ parameter

GCM15G radiation code used minimum $\nu$ for “cloud blocks”

cloud blocks $\Rightarrow$ Adjacent cloudy layers

Necessary simplification for analytic solution
Need for consistency – \( \nu \) parameter

GCM15G radiation code used minimum \( \nu \) for “cloud blocks”

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Necessary simplification for analytic solution
Solar cloud radiative effect

TOA solar cloud radiative effect (JJA)

SWCF (W/m^2)

Latitude

CERES EBAF
block \( \nu \)
layer \( \nu \)
Binning by pressure and cloud $\tau$ ($20^\circ$S – $20^\circ$N)
Histograms of daily-means low clds (20°S – 20°N)

Black line ⇒ obs
Red line ⇒ GCM15G, Purple line ⇒ GCM15H
Summary

Diagnostic can highlight biases in GCM clouds and radiation
Direct link between cloud properties and radiation
⇒ Not inferred radiative effects

Straightforward to implement in GCMs with McICA
Couple with information from CloudSat/CALIPSO and COSP
⇒ Further analyse cloud vertical structure