Evaluating parameterized variables in the Community Atmospheric Model along the GCSS Pacific cross-section

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The GCCS Pacific Cross-section

Several cloud regimes: stratocumulus, transition, deep convection

- EUROCS project  
  JJA 1998

- GCSS intercomparison  
  JJA 1998/2003

- This study  
  YOTC: JJA 2008

- Observations  
  ISCCP data
  SSM/I product
  CloudSat + Calipso
  GPCP and TRMM precip
  Flash Flux data

- Reanalyses  
  ERA-Interim, Merra
Observations along the cross-section

- **Low-level cloud**
- **Cloud fraction**
- **Precipitation**
- **SWCF**
- **LWCF**

- **TRMM**
- **GPCP**

- **CERES-EBAF**
Methodology for the forecasts

**Forecast**

- **Strategy**
  If the atmosphere is initialized **realistically**, the error comes from the parameterizations deficiencies.

- **Advantages**
  - Evaluate the forecast against observations on a particular day and location
  - Evaluate the nature of moist processes parameterization errors before longer-time scale feedbacks develop.

- **Limitations**
  Accuracy of the atmospheric state?

**Evaluation**

- AIRS, ISCCP, TRMM, GPCP, SSMI, CloudSat, Flash-Flux, ECWMF analyzes
Ensemble mean forecast and timeseries forecast

**Ensemble mean forecast**: average data at the same “forecast time”

**Timeseries forecast**: concatenate data at the same “forecast time” (hours 0-24) from individual forecasts
# Model versions

## 3 versions of CAM

<table>
<thead>
<tr>
<th>CAM3</th>
<th>Release 2004</th>
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</thead>
<tbody>
<tr>
<td><strong>CAM4</strong></td>
<td><strong>Release April 2010</strong></td>
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<tr>
<td>“track1”</td>
<td><strong>New physics:</strong></td>
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<td></td>
<td>- Deep convection (Neale and Richter, 2008)</td>
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<tr>
<td><strong>CAM5</strong></td>
<td><strong>Release June 2010</strong></td>
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<tr>
<td>“track5”</td>
<td><strong>New Physics:</strong></td>
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<tr>
<td></td>
<td>- Cloud microphysics (Morrison, Gettelman)</td>
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<td></td>
<td>- Radiative Transfer (Iacono, Collins, Conley)</td>
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<td></td>
<td>- PBL and Shallow convection (Bretherton and Park)</td>
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<td></td>
<td>- Macrophysics (Park, Bretherton, Rasch)</td>
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<td></td>
<td>- Aerosol formulation (Ghan, Liu, Easter)</td>
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<td></td>
<td>- Ice clouds (Gettelman, Liu, Park, Mitchell)</td>
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</tbody>
</table>
Highlights of the results

• Climate bias appears very quickly
  - where deep convection is active, error is set within 1 day
  - 5-day errors are comparable to the mean climate errors

• CAM3
  - ITCZ: warm/wet bias of the upper troposphere
    too much precipitation and high level cloud
  - StCu: cloud too close to the coast and PBL too shallow

• CAM4/Track 1
  - ITCZ: CAM4 reduces warm/wet bias of the upper troposphere
    dramatic improvement of precipitation
    … but too little high-level cloud compared to observations

• CAM5/Track 5
  - ITCZ: same improvements as with CAM4
  - StCu: better PBL height and low-level cloud fraction
    … but underestimates high-level cloud and LWP
Precipitation: Monthly means, June 2008

• CAM3: overestimates the precipitation in the ITCZ
• CAM4/5: reduction in the ITCZ precipitation at day 1
  precipitation intensity increases later in the forecast
Precipitation timeseries, JJA 2008

At the ITCZ:

- **CAM3**: overestimates the precipitation in the ITCZ, rains all the time

- **CAM4/5**: reduction in the ITCZ precipitation, better correlation with observed precipitation, underestimates strong events

**Forecast at day 1**

**Correlation with TRMM**

- TRMM
  - CAM3 (0.50)
  - CAM4 (0.70)
  - CAM5 (0.66)

**Mixing parcel ⇔ env**

- No mixing
- Allows mixing
Precipitation timeseries, JJA 2008

Forecast at day 1

TRMM
CAM3 (0.50)
CAM4 (0.70)
CAM5 (0.66)

Correlation with TRMM

Relative humidity

CAM4/5: precipitation better connected to mid-troposphere
Precipitation timeseries, JJA 2008

Correlation with TRMM

CAM3 (0.50)
CAM4 (0.70)
CAM5 (0.66)

Forecasts at day 1 and day 5 show decreasing correlation with observations for CAM4 and CAM5 in 5-day forecasts.
Moisture profile in the stratocumulus regime

**Moisture in CAM4**

- **Day 0**
- **Day 1**
- **Day 3**
- **Day 5**

**CAM4: PBL collapses**

Dry and surface-driven PBL scheme

**Moisture in CAM5**

**CAM5: PBL height is maintained**

scheme based on prognostic TKE w/ explicit entrainment at top of PBL
Water vapor budget in the stratocumulus regime

\[
\frac{\partial q}{\partial t} = -V \cdot \nabla q - \omega \frac{\partial q}{\partial p} + Q_{PBL} + Q_{\text{shallow}} + Q_{\text{cloud-water}}
\]

Advective tendencies

Total physics tendency: \( Q_{\text{phys}} \)

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**Q_{\text{phys}} \text{ in CAM4}**

- Total
- PBL
- shallow conv.
- cloud-water

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**Q_{\text{phys}} \text{ in CAM5}**

- Pressure (hPa)
- Moisture tendency (g/kg/day)
Conclusion

- **CAM forecasts** allows for diagnosing parameterization errors in different cloud regimes

- **CAM3**
  - too much precipitation near ITCZ (deep convection scheme: no mixing between the parcel and its environment)
  - PBL too shallow in StCu (dry and surface-driven PBL scheme)

- **CAM4**
  - dramatic improvement of precipitation in the early forecast with the new convection scheme (entrainment of environment)

- **CAM5**
  - new PBL scheme produces deeper and better mixed PBLs (PBL scheme: prognostic TKE with explicit entrainment at top of PBL)