How well do AMIP models simulate the interannual and interdecadal variability of Asian monsoon: State of affairs and challenges

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In collaboration with B. Wu, H. Li, L. Li, J. Zhang, B. Wang
Outline

1. Background

2. Interannual variability of Asian monsoon

3. Global monsoon precipitation change

4. E. Asian monsoon circulation change

5. Summary
Target domain
JJA Precipitation

CAM T42

ERA40

observation

Topography

(Yu et al. 1999)
How about the performances of AGCMs in simulating the monsoon rainfall variability?

- AMIP models
- Interannual variability
- Interdecadal variability
Observational analysis has identified two leading modes of the AAM:

-- The first mode exhibits a prominent biennial tendency and concurs with El Niño

-- The second mode leads the Pacific warming by one year, providing a precursor for El Niño/La Niña development (Wang et al. 2007).

How well do AGCMs reproduce these leading modes?
### 11 AMIP AGCMs

<table>
<thead>
<tr>
<th>Institute</th>
<th>AGCM</th>
<th>Resolution</th>
<th>Name used in the discussion</th>
</tr>
</thead>
<tbody>
<tr>
<td>UKMO</td>
<td>HadGAM1</td>
<td>N96L38</td>
<td>HadGEM1</td>
</tr>
<tr>
<td>NCAR</td>
<td>CAM3</td>
<td>T85L26</td>
<td>CCSM3</td>
</tr>
<tr>
<td>MRI</td>
<td>-</td>
<td>T42L30</td>
<td>CGCM2_3_2a</td>
</tr>
<tr>
<td>MPI</td>
<td>ECHAM5</td>
<td>T63 L32</td>
<td>ECHAM5</td>
</tr>
<tr>
<td>CCSR</td>
<td>MIROC3_2(medres)</td>
<td>T42L20</td>
<td>MIROC3_2_medres</td>
</tr>
<tr>
<td>CCSR</td>
<td>MIROC3_2(hires)</td>
<td>T106 L56</td>
<td>MIROC3_2_hires</td>
</tr>
<tr>
<td>INM</td>
<td>-</td>
<td>4.0° lat x5.0° lon L21</td>
<td>INMCM3_0</td>
</tr>
<tr>
<td>IAP</td>
<td>GAMIL</td>
<td>2.8° lat x2.8° lon L26</td>
<td>FGOALS1_0_g</td>
</tr>
<tr>
<td>NASA/GISS</td>
<td>-</td>
<td>4.0° lat x5.0° lon L20</td>
<td>GISS_E_R</td>
</tr>
<tr>
<td>GFDL</td>
<td>-</td>
<td>2.0° lat x2.5° lon L24</td>
<td>GFDL_AM2</td>
</tr>
<tr>
<td>CNRM</td>
<td>-</td>
<td>T42 L45</td>
<td>CNRM_CM3</td>
</tr>
</tbody>
</table>

- Model outputs cover the period 1979-1999.

(Zhou et al. 2009a J. Climate)
S-EOF modes of MME precipitation and the associated 850hPa wind

(Seitler et al. 2009a J. Climate)
PC time series

(Zhou et al. 2009a J. Climate)
Comparison of AMIP against the observed dominant S-EOF modes of precipitation

Correlation coefficients between the observed and simulated anomalies (or PCs)

(Zhou et al. 2009a J. Climate)
Spatial pattern of correlation coefficients between the observed and AMIP MME rainfall anomalies.

- High skill in tropical region
- Nearly no skill in summertime WNP monsoon area.
- Better in winter

(Zhou et al. 2009a J. Climate)
Among the A-AM components, the EA summer monsoon shows the lowest reproducibility in interannual variability.
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Changes of JJA Rainfall

(Xin et al. 2006 J. Climate; Zhou et al. 2009, Meteorologische Zeitschrift)
An overall weakening tendency of global land monsoon precipitation intensity in the last 56 years (1948-2003) (Wang and Ding, 2006, GRL)

The EOF1 of normalized annual range anomalies (upper) and the corresponding PC (lower).

(Wang and Ding, 2006, GRL)
Global land monsoon precipitation change
(CAM2 T42, Global SST-driven, 15 realizations)

The first EOF of normalized annual range anomalies (upper) and the corresponding principle component (lower).

(Zhou et al. 2008a J. Climate)
SSTA congruent with the weakening trend of global land monsoon precipitation

(Zhou et al. 2008a J Climate)
Low skill in Asian-Australian monsoon rainfall

(Zhou et al. 2008a J Climate)
The specified SST forcing shows the lowest skill in reproducing the long-term variability of EA monsoon precipitation
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E. Asian Summer monsoon circulation index

NCEP/NCAR

GFDL AM2.1 GOGA

NCAR CAM3 GOGA

(T42+T85)

NCAR CAM3 TOGA

( Li et al. 2008 Clm Dyn )
Correlations of SSTA with EASM circulation index

(a) Observed SST, NCEP/NCAR EASMI

(b) Observed SST, CAM3 GOGA EASMI

(Li et al. 2008 Clm Dyn)
Precipitation: Mean State and Inter-decadal change

**GFDL AM2.1**
- 1950-1976 mean
- (e) AM2.1 GOGAI

**NCAR CAM3**
- 1950-1976 mean
- (d) CAM3 GOGAI
The monsoon rain band is controlled by the Western Pacific Subtropical High

Courtesy of Huang R. (2007)
Contour lines for 5870 gpm of 500 hPa geo-potential height for each summer

(Zhou et al. 2009b J Climate)
The warming tendency of Indian Ocean


SST averaged over the entire basin


(Casso et al. 2008)
# Description of 5 AGCMs

<table>
<thead>
<tr>
<th>Institute</th>
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<th>Resolution</th>
<th>Convection scheme</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPI</td>
<td>ECHAM5</td>
<td>T63 L31</td>
<td>Tiedtke (1989) with modifications for deep convection according to Nordeng (1994).</td>
<td>Hagemann et al. (2006)</td>
</tr>
<tr>
<td>UKMO</td>
<td>HadAM3</td>
<td>2.5° lat X 3.75° lon L19</td>
<td>Gregory and Rowntree (1990) with the addition of convective downdrafts (Gregory and Allen 1991)</td>
<td>Pope et al. (2000)</td>
</tr>
<tr>
<td>CNRM</td>
<td>ARPEGE</td>
<td>T63 L31</td>
<td>Deep convection is represented by a mass flux scheme with detrainment as proposed by Bougeault (1985). The stratiform and shallow convection cloud formation is evaluated via a statistical method described in Ricardand Royer (1993)</td>
<td>Cassou et al. (2001)</td>
</tr>
</tbody>
</table>
WPSH in IWP warming, cooling and *control* runs

(Zhou et al. 2009b J Climate)
JJA precipitation response to Indian Ocean warming: barely any significant signal over E. Asia

(Zhou et al. 2009b J Climate)
The specified SST forcing produces a reasonable responses in monsoon circulations, but barely any signal in monsoon rainfall.
Summary

1. The AMIP MME captures the leading modes of monsoon variability with a skill that is comparable to reanalysis in terms of the seasonally evolving spatial patterns and the corresponding temporal variations, as well as their relationships with ENSO.

2. The skill of AMIP simulation is season-dependent. The DJF (JJA) has the highest (lowest) skill. Over the East Asia, extra-tropical western North Pacific and South China Sea, the MME shows nearly no skill in JJA.

3. The topical Ocean warming is one mechanism for the weakening tendency of global land monsoon rainfall and E. Asian Monsoon Circulation. The decadal scale westward extension of WPSH is partly driven by the warming of Indian Ocean.

4. The AGCMs succeed in simulating the EA monsoon circulation change, but fail in simulating the EA monsoon rainfall change.
Issues call for further investigation

Can high resolution modeling improve the EA monsoon rainfall simulation in both mean state and multi-scale variabilities?
Expected collaborative efforts

◆ CCSR, MRI high resolution modeling
◆ GFDL C180 simulation, 1981-2005
◆ Met Office, N48, N96, N144, N216 , 25 years of AMIP2
◆ GEOS-5 simulation: C180-55km C360-27km **C720—14km C1440-6.9km C2880—3.4 km  C5760—1.7km**, case simulations for tropical cyclone to be used in monsoon studies
◆ COLA SP-CCSM
◆ SNUAGCM 25 km simulation
◆ Schubert Proposal: Data sharing in regional studies

as suggested by Dr. K.-M. Lau
Some further readings


Thank you 谢谢！

http://web.lasg.ac.cn/staff/ztj/index_e.htm
JJA Precipitation in 13 AMIP models
JJA precipitation in CMIP3
SSTA regressed upon PC of SEOF1
Land-Sea thermal contrast change

(105° -122° E average T and latitude –height cross-section)

NCEP/NCAR

AM2.1 GOGA

CAM3 GOGA

CAM3 TOGA

(Li et al. 2008 Clm Dyn)
Aerosol Forcing?

The prescribed aerosol forcing is the same as 20C3M.

(Li et al. 2008 Clm Dyn; consistent with Li et al. 2007 GRL)