Evaluation, application and development of ESM in China

Bin Wang¹,²

Contributors:

1. LASG, Institute of Atmospheric Physics, CAS
2. CESS, Tsinghua University
3. Beijing Normal University
4. Beijing Climate Center
5. First Institute of Oceanography

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Outline

◆ Preliminary evaluations on CMIP5
◆ Important applications
◆ Progress in coupling techniques
◆ Future development for AR6
# CMIP5 models in China

<table>
<thead>
<tr>
<th>Group Name</th>
<th>Institution</th>
<th>Model Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>LASG-CESS</td>
<td>Institute of Atmospheric Physics, Chinese Academy of Sciences; Tsinghua University</td>
<td>FGOALS-g2</td>
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<td>LASG</td>
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<tr>
<td>BNU</td>
<td>Beijing Normal University</td>
<td>BNU-ESM</td>
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<tr>
<td>BCC</td>
<td>Beijing Climate Center</td>
<td>BCC-CSM 1.1</td>
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<tr>
<td>FIO</td>
<td>First Institute of Oceanography</td>
<td>FIO-ESM1.0</td>
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</tbody>
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# Main Variables Evaluated

<table>
<thead>
<tr>
<th>Variable name</th>
<th>Component</th>
<th>Evaluation Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation</td>
<td>Globe</td>
<td>Root Mean Square Error</td>
</tr>
<tr>
<td>Global mean SAT anomaly (SATA)</td>
<td>Detrend of SATA</td>
<td>Taylor skill (Taylor, 2001)</td>
</tr>
<tr>
<td>Tropic SSTA annual cycle</td>
<td>Pacific</td>
<td>Pattern Correlation</td>
</tr>
<tr>
<td>Warm extremes</td>
<td>1980-1999, 21 regions</td>
<td>Relative RMS</td>
</tr>
<tr>
<td>Asian Monsoon</td>
<td>JJAS mean, annual cycle index</td>
<td>Pattern Correlation</td>
</tr>
<tr>
<td>ENSO</td>
<td>SD, variance annual cycle, amplitude, zonal wind stress</td>
<td>Direct comparison or correlation with observation</td>
</tr>
</tbody>
</table>
Global area-weighted mean RMSE of Precipitation (1980-2005) (OBS: GPCP)

Mean: 1.31; Max: 1.72; Min: 1.09 (unit: mm/day)
20th Century SAT Variation (1870-2005)

[Bar chart showing Taylor Skill with HADCUT3 for various models, with Mean: 0.52; Max: 0.64; Min: 0.39]
Tropic Pacific Annual Cycle

$(2^\circ S-2^\circ N, 120^\circ E-80^\circ W)$

Mean: 0.63; Max: 0.82; Min: 0.26
Performance of AR5 models on presenting warm extremes for 1980-1999 at 21 regions

(Zhao et al, 2012)
Skills of CMIP Models on JJAS Asian Precipitation and Wind

(Zhou et al. 2012; Sperber et al. 2012)

(OBS: ERA40)

(OBS: GPCP)
Relative rainfall rate in the Bengal Bay region

Onset

Duration

Withdraw

5 mm/day

Peak

Summer monsoon annual cycle index

(Sperber et al. 2012)
1) Comparing with CMIP3 models, CMIP5 models improve the Asian summer monsoon significantly;

2) China MMM performs better than CMIP3 MMM on onset and duration, but worse on withdraw and peak;

3) FGOALS-g2 presents better onset and duration but worse withdraw and peak than both CMIP3 MMM and CMIP5 MMM;

4) FGOALS-g2 presents better onset, withdraw and duration but worse peak than China MMM.

(OBS: GPCP)
Other models: CNRM-CM5, INMCM4.0, MIROC5, MIROC-ESM, MPI-ESM-LR, NorESM1-M

(Huang et al, 2012)
Other models: CNRM-CM5, HadGEM2-ES, IPSL-CM5A-LR, IPSL-CM5A-MR, MIROC-ESM, MPI-ESM-LR

(Huang et al, 2012)
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Modeling scheme courtesy of Dong, 2010
http://114.255.218.74/index.jsp
Developed and developing world responsibilities for historical climate change

ALL = All countries’ emission = AX1 + NX1
AX1 = developed countries’ emissions;
NX1 = developing countries’ emissions;

- CO₂ concentration:
  Developed: 61% and 71%;
  Developing: 39% and 29%;

- CO₂ radiative forcing:
  Developed: 53% and 62%;
  Developing: 47% and 38%;

- Air temperature:
  Developed: 60% and 64%
  Developing: 40% and 36%

Wei et al., 2012, PNAS
Developed and developing world responsibilities for CO₂ mitigation

- Contributions to reduction of global warming:
  - Developed: 33% and 35%
  - Developing: 67% and 65%

- Mitigation goal:
  - Current mitigation cannot control rising temperature within 2°C in 2100. It is necessary to fill the gap with more ambitious mitigation efforts.

Wei et al., 2012, PNAS
Surface Air Temperature Anomalies by FGOALS-g2 (2nd sample of historical run)

Surface air temperature anomalies (SATA)

FGOALS-g2

Cor: 0.84

HadCRUT3

1900 1920 1940 1960 1980 2000 2020

0.60 0.30 0.00 -0.30 -0.60

1966-1990

FGOALS-g2 (Cor=0.678)

HadCRUT3

1986-2005

FGOALS-g2 (Cor=0.786)

HadCRUT3
30-year predictions of SATA by FGOALS-g2

After detrend

1966-1990

Hindcast

1986-2005

2011-2035 (Forecast)
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Lack of direct flux exchange in available couplers

NCAR Coupler

Centralized flux coupler without direct flux exchange

(Oiu et al, 2011)

OASIS Coupler

Decentralized non-flux coupler without direct flux exchange
C-Coupler: to overcome the imperfection
(the first coupler developed by Chinese scientists)

- Centralized flux coupler for modularization and standardization
- Direct flux exchange for better parallel efficiency of high-resolution models

(Liu et al, 2011)
Ensemble coupling software framework

Online ensemble tool for coupled climate model

ATM1  ATM2  ...  ATMn

Ensemble + Coupling

OCN

Motivation
How weather noise / atmospheric model uncertainty impacts the climate response?

(Xue et al, 2011)
Online
Multi-initial condition ensemble

Single initial condition

Online Multi-model ensemble

Offline Multi-model ensemble

(Xue et al, 2011)

(Xue et al, 2012)
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Future Plan for AR6

- Further evaluation of China CMIP5 models and other CMIP5 models for understanding of uncertainties in these models;
- Development of high-resolution AGCM and OGCM (0.5°-0.1° in horizontal and 50 layers in vertical within 5 years);
- Development of earth system model based on our own coupler: C-Coupler;
- Improvements of online ensemble coupling framework and ensemble coupling strategies;
- Improvements of dynamical cores, physical parameterizations, and carbon cycle processes.
Thank you