Projected Changes of East Asian Summer Monsoon in IAP coupled model FGOALS2-s

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Motivation

- The Asian summer monsoon (including SASM & EASM) is the strongest summer monsoon system in the world.
- The agriculture, economy and society across the EASM regions are critically influenced by the intensity, evolution and variation of the EASM.
- Updated scenarios in CMIP5 (Taylor et al., 2009).
Questions

What are the changes of EASM in future scenarios, respectively in its climatology, seasonality, interannual variations and its relationship with ENSO?
FGOALS

Flexible Global Ocean-Atmosphere-Land System
(Zhang et al., 2000; Zhou et al., 2005; Yu et al., 2008; Bao et al., 2010)
The milestones of LASG spectral coupled model

Flexible Global Ocean-Atmosphere-Land System
(Zhang et al., 2000; Zhou et al., 2005; Yu et al., 2008; Bao et al., 2010)
AGCM: SAMIL
(Spectral Atmospheric Model in IAP LASG)

- Resolutions: R42L26 (Spectral transform model with 26 atmospheric layers extending from the surface to 2.19 hPa, and its horizontal resolution is $2.81^\circ \times 1.66^\circ$),

- Physical processes

  - Radiative process: Edwards and Slingo, (1996), (Sun and Rikus, 1999a,b; Li et al., 2009);
  
  - Convective scheme: Tiedtke, 1989, Nordeng, 1994; Liu, 2009; Wang et al., 2010;
  
  - Vertical diffusion and PBL: Brinkop and Roeckner,(1995)
# OGCM: LICOM

<table>
<thead>
<tr>
<th></th>
<th>AR4 (LICOM1.1)</th>
<th>AR5 (LICOM2.0)</th>
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<tbody>
<tr>
<td><strong>Horizontal Resolution</strong></td>
<td>1°×1°</td>
<td>1°×(0.5°~1°)</td>
</tr>
<tr>
<td><strong>Vertical Resolution</strong></td>
<td>30 levels (25m in upper 300m)</td>
<td>30 levels (10m in upper 150m)</td>
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<td><strong>Advection Scheme</strong></td>
<td>2 order central difference</td>
<td>A shape-preserving (Yu, 1994)</td>
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<td><strong>Vertical Mixing</strong></td>
<td><em>Pacanowski and Philander, 1981</em></td>
<td><em>Canuto et al., 2001</em></td>
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<td><strong>Mesoscale eddy parameterization</strong></td>
<td>Gent and McWilliams, 1990</td>
<td>Gent and McWilliams, 1990; Large et al., 1997</td>
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<td><strong>Horizontal Viscosity</strong></td>
<td>2×10⁴ m²/s</td>
<td>3×10³ m²/s</td>
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<tr>
<td><strong>SW Radiation Penetration</strong></td>
<td>Constant (Paulson and Simpson, 1977)</td>
<td>Chlorophyll depended (Ohlmann, 2003)</td>
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## Experimental design

<table>
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<tr>
<th>Experiment</th>
<th>Notes</th>
<th># of years</th>
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<tr>
<td>Historical (1850-2005)</td>
<td>Impose changing conditions (consistent with observations), which may include:</td>
<td>156*3</td>
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<td>• atmospheric composition (including CO2), due to both anthropogenic and volcanic influences</td>
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<td></td>
<td>• solar forcing</td>
<td></td>
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<td>• emissions or concentrations of short-lived species and natural and anthropogenic aerosols or their precursors.</td>
<td></td>
</tr>
<tr>
<td>RCP4.5(2006-2100)</td>
<td>Radiative forcing stabilizes at ~4.5 W m(^{-2}) after 2100.</td>
<td>95*3</td>
</tr>
<tr>
<td>RCP8.5(2006-2100)</td>
<td>Radiative forcing reaches ~8.5 W m(^{-2}) near ~2100.</td>
<td>95*3</td>
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</table>
Projected Changes of EASM in IAP

FGOALS2-s
Climatological changes
Climatological annual cycle of zonal mean precipitation (110°E-120°E)

- Historical 1986-2005
- RCP4.5 2081-2100
- RCP8.5 2081-2100
- RCP8.5 - Historical

(a) (b) (c) (d) (e) (f)
The spatial patterns of the first MV-EOF mode of EASM. All panels are 850 hPa winds (vectors in units of m/s), precipitation (color shading in units of mm/day), and sea-level pressure (contours in units of hPa). (a) Observations, (b) CMIP5-Historical, (c) CMIP5-RCP4.5, (d) CMIP5-RCP8.5.

(Liu, Wang and Yang, 2008)
The correlation coefficients between the time series of EASM leading pattern and NINO3.4 index in CMIP5-Historical, CMIP5-RCP4.5, and CMIP5-RCP8.5.
Changes of SST in Winter

RCP4.5-Historical

RCP8.5-Historical
Leading pattern of tropical SST

Historical simulations 53.4%
RCP4.5 projection 51.3%
RCP8.5 projection 65.2%
The correlation coefficients between the time series of EASM leading pattern and NINO3.4 index in CMIP5-Historical, CMIP5-RCP4.5, and CMIP5-RCP8.5.
Summary

- EASM become clearly strengthened in term of monsoon precipitation and the monsoon lower-level westerly jet flow;
- The annual cycle of precipitation over EA becomes enhanced, which indicates more abrupt monsoon, while after EA monsoon onset, EASM march more northward;
- The leading pattern of EASM occurs more frequently in high emission scenario, and the reason can be explained by the changes of tropical SST in interannual timescale;
- The relationship between EASM interannual variations and ENSO will strengthen in future projections. It indicates the possible increase on the predictability of EASM interannual variations.
Thank you!
Equatorial Pacific Ocean (5S-5N)

Fgls2 (yrs 1601–1800)

Sea surface temperature

Month

Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

170E  170W  150W  130W  110W  90W

HadSST (1982–2001)

Sea surface temperature

Month

Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

170E  170W  150W  130W  110W  90W

Color scale:
2.1
1.8
1.5
1.2
0.9
0.6
0.3
0
-0.3
-0.6
-0.9
-1.2
-1.5
-1.8
-2.1
Global-average surface temperature

\[ y = -5 \times 10^{-5} x + 277.28 \]
CMIP5气候预估核心试验RCP8.5 & RCP4.5 试对全球气候变化的预估结果

RCP8.5 增温5.3K
RCP4.5 增温1.7K