Understanding the Long-term Changes of E. Asian Summer Monsoon from a Global Monsoon Perspective

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Eleventh Meeting of the CLIVAR/Asian-Australian Monsoon Panel (AAMP11) & the 7th FOCRA II
Beijing, CHINA, 6-10 April 2011
Changes of EASM: Local Pattern


EASM index

Rainfall anomalies
Southern Flood and Northern Drought:
Part of a sandwich pattern
Tropospheric Cooling over EA:
the land-sea thermal contrast reduced

Motivation

• Possible mechanisms:
  Aerosol forcing, PDO, Tibetan Plateau thermal forcing, internal variability, global warming, ect.

• Up to now:
  Still there is no consensus in this regard.
Motivation

To understand the mechanisms of long-term or interdecadal changes of EASM from a Global Monsoon perspective.
Outline

1. Monsoon changes in the past 50 yrs
2. Monsoon changes in the 20\textsuperscript{th} century
3. Future changes
The weakening tendency of EASM during 1950-99 is a local manifestation of global monsoon change.

Both changes are driven by the interdecadal changes of Tropical Ocean.

Evidences: Historical SST-driven AGCM simulations
EASM in the model
**Model and Experiments**

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<thead>
<tr>
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<th>CAM3 (T85)</th>
<th>CAM3 (T42)</th>
<th>AM2.1 (FV)</th>
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<tbody>
<tr>
<td>GOGA</td>
<td>5</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>TOGA</td>
<td>5</td>
<td>5</td>
<td>N/A</td>
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<tr>
<td>ATM</td>
<td>N/A</td>
<td>10</td>
<td>N/A</td>
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**Definition of EASM Index:**

Normalized zonal wind shear between 850 and 200 hPa averaged within (20-40N,110-140E) (After Han and Wang, 2007)

Correlations between SSTA and EASM index

Global Monsoon in the model
The observed and simulated Global Land monsoon index

SST-driven AGCM ensemble simulation, with 12 realizations

Zhou et al. 2008 Ocean forcing to changes in global monsoon precipitation over the recent half century, *Journal of Climate, 21* (15), 3833–3852
SSTA congruent with the weakening trend of global land monsoon precipitation

Zhou et al. 2008  Ocean forcing to changes in global monsoon precipitation over the recent half century, Journal of Climate, 21 (15), 3833–3852
Is the weakening tendency of EASM & Global Monsoon during 1950-99 a phenomenon of the whole 20th century?

NO!
Outline

1. Monsoon changes in the past 50 yrs
2. Monsoon changes in the 20th century
3. Future changes?
Rain-gauge datasets for 1901-2002

1. Global Precipitation Climatology Centre (GPCC)
   Full Data Reanalysis Version 4;

2. Climate Research Unit (CRU)

3. NCAR Precipitation anomaly data (Dai-dataset)
   Compiled by Dr. Aiguo Dai and covers 1901-1995

4. Global Historical Climatology Network v2 (GHCN2)

Changes of global land monsoon precipitation

Global and NH land monsoon PRCP:
1) upward trend during 1901-1950s (95% confidence)
2) downward trend from 1950s to 1980s (95% confidence)
3) Recovering in recent decades

SH land monsoon precipitation:
No significant trend

Note: above-normal anomalies during 1950-1960

Majority of global land monsoon precipitation show coherent change.

PC: increasing trend during 1901-1955, decreasing trend since the 1950s, and followed by a recovery since the Late 1980s.

Precipitation changes for regional monsoons

- Recovering since late 1980s: N&S. African, E. Aian, and Australian monsoon

Decadal change of JJA rainfall

1951-1978

1979-1992

1993-2004

Normal: 1971-2000 average

(After Ding et al. 2009)
• **Models**

  - GFDL AM2 (2.0° * 2.5° L24)
  - HadAM3 (2.75° * 3.75° L18)

• **Time:** 1901-2002

• **Ensemble members**

  - GFDL AM2: 10
  - HadAM3: 4
Normalized time series of (a) NHMI, (b) SHMI, (c) GMI
(Bars are based on OBS)

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<tr>
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<th>NHMI</th>
<th>SHMI</th>
<th>GMI</th>
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<tbody>
<tr>
<td>GFDL</td>
<td>0.39</td>
<td>0.33</td>
<td>0.37</td>
</tr>
<tr>
<td>HadAM3</td>
<td>0.41</td>
<td>0.26</td>
<td>0.44</td>
</tr>
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The observed major features are well reproduced in the simulations.
Also evidenced by the high correlations.
Correlation between monsoon index and tropospheric mean temperature (T200-500)

In the observation:
Warmer land – colder ocean.

What has happened in the model world?
Colder ocean better simulated;
A stronger land-sea thermal contrast and thus a stronger monsoon.
Outline

1. Monsoon changes in the past 50 yrs
2. Monsoon changes in the 20\textsuperscript{th} century
3. Future changes?
Global Monsoon domain in CMIP3 Models

Low resolution 5°

Medium resolution 3°

High resolution 1.8°

Multi-model ensemble of 23 AR4 models
Normalized N. H. Land monsoon changes under A1B

Low resolution 5°

Medium resolution 3°

High resolution 1.8°
Projected Rainfall over different regions of China

Sun and Ding, 2009
CORE EXP of CMIP5 for IPCC AR5
HadGAM2 (N96/L38)

HadGOM2 (0.5-2.0/L31)

Starting from Nov. 1960, 1965, ..., 2005, make 10-yrs prediction

Weishenme, A et al. (2007) ECMWF Technical Report
Decadal Hind-cast of N. Hemisphere monsoon index

NHI Decadal Hindcast

Precip (mm/day)

Year


Prediction

Observation
Summary

• The weakening tendency of EASM in the past 50 years is a local manifestation of global monsoon change, which was driven by interdecadal changes of Tropical Ocean.

• The weakening tendency of monsoon is only evident in the late half of the 20th century (not evident in the whole 20th century), suggesting it was not purely a response to global warming.

• Scenario projection of future change of global monsoon exhibits an increasing tendency, which is purely driven by the increasing GHGs. But the decadal prediction Exp tells us a different tendency.
THANKS
Some further readings


Trend of monsoon rainfall coverage, intensity, and amount (1948-2003) (Zhou et al. 2008 GRL)
Global Monsoon in the past 1000 yrs: LASG/IAP versus ECHO-G models

Lasg/Iap (Zhou et al. 2011)

ECHO-G (Liu et al. 2009)