Clouds-SST relationship and interannual variability modes of Indian summer monsoon in the context of clouds and SSTs: Observational and CFSv2 studies

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Introduction

- This study examines the relationship between clouds and Sea Surface Temperature (SST) during Indian Summer Monsoon (ISM).

- Cloud-rainfall and cloud-SST relationships are studied using grid point correlation and further investigated by PCA and MCA.

- Along with that, dominant modes of interannual variability of rainfall, SST and clouds are also investigated.

- Relationship of ENSO and IOD with clouds and rainfall are also examined in this study.
Datasets Used

- Observation datasets (January 2003 - December 2011)
  - Clouds - MODIS (Moderate Resolution Imaging Spectrometer)
  - Rainfall - GPCP (Global Precipitation Climatology Project)
  - SST - OISST (Optimum Interpolation Sea Surface Temperature)

- CFSv2 model free run data (January 2019 - December 2039)
  - In case of model data we have performed long coupled runs of CFSv2 for 30 years from 12th December 2009 to 31st December 2039 on the Prithvi High Performance Computing at IITM.
  - Data from last 20 years out of 30 years of model simulation are considered and the first 10 years are excluded for the spin-up purpose.
JJAS Mean Pattern (Clouds)
JJAS Mean Pattern (Rainfall)

(a) GPCP Rainfall

(b) CFSv2 Rainfall

(c) Model Rainfall Bias (CFSv2–GPCP)
JJAS Mean Pattern (SST)

(a) Observation

(b) CFSv2

(c) Model Bias (CFSv2−Observation)
Cloud-Rainfall Relationship
Cloud-SST Relationship

Observation

(a) High level Clouds & SST
(b) Mid level Clouds & SST
(c) Low level clouds & SST
(d) Total Clouds & SST

CFSv2

(e) High level Clouds & SST
(f) Mid level Clouds & SST
(g) Low level clouds & SST
(h) Total Clouds & SST
Principal Component Analysis (PCA)

- The main purpose of the PCA is to identify dominant patterns and to reduce dimensions of the data with minimal loss of information.

- This method is an explanatory tool, which allows a time display and space display. PCA is also called as Empirical Orthogonal Function (EOF).

- PCA gives the patterns where most variance are present.

- Principal components are orthogonal to each other.
PCA (Rainfall)

**Observation**

(a) EOF1 (35.53)
(b) PC1

(c) EOF2 (18.63)
(d) PC2

**CFSv2**

(e) CFSv2 EOF1 (12.93)
(f) CFSv2 PC1

(g) CFSv2 EOF2 (10.25)
(h) CFSv2 PC2
PCA (High-Level Clouds)

Rainfall and High level clouds Correlations

Spatial Correlation

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<thead>
<tr>
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<th>Observation</th>
<th>CFSv2</th>
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<tbody>
<tr>
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<td>EOF 2</td>
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Time Series correlation

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<tr>
<td>PC2</td>
<td>0.92</td>
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PCA (SST)

Clouds and SST Time Series Correlations

Observation

<table>
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<tr>
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<th>High-level clouds</th>
<th>Mid-level clouds</th>
<th>Low-level clouds</th>
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<tbody>
<tr>
<td>PC1</td>
<td>0.52</td>
<td>0.63</td>
<td>—</td>
</tr>
<tr>
<td>PC2</td>
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<td>0.56</td>
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CFSv2

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<td>0.43</td>
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Maximum Covariance Analysis (MCA)

- Correlation analysis and PCA may not give the complete structure of actual relationship among two meteorological variables.

- PCA is a covariance matrix based on a single spatio-temporal field, while MCA is based on the decomposition of a “Cross-covariance” matrix derived from two fields.

- So, A better way of exploring inter-relation between two fields can be done by performing MCA.
MCA (High-level clouds and Rainfall)

Observation (MCA for High level Clouds & Rainfall)
(a) MCA First mode (48.81)  (b) MCA Second Mode (18.00)

CFSv2 (MCA for High level Clouds & Rainfall)
(c) MCA First mode (26.72)  (d) MCA Second mode (14.48)
MCA (High-level clouds and SST)

Observation (MCA for High level Clouds & SST)

(a) MCA First mode (43.12)  (b) MCA Second Mode (24.05)

CFSv2 (MCA for High level Clouds & SST)

(c) MCA First mode (34.28)  (d) MCA Second mode (24.25)
## Relationship of Clouds with ENSO and IOD

### Observation

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### CFSv2

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<td>0.67</td>
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Conclusion

- Observation reveals the dominance of high-level clouds in monsoon regime and CFSv2 is able to replicate the cloud fraction pattern but it underestimates the amount of high-level clouds.

- Cloud-Rainfall relationship shows high-level clouds are highly correlated with rainfall.

- First mode of high-level clouds is associated with ENSO pattern and Second mode of high-level clouds is associated with IOD pattern. CFSv2 fails to show IOD pattern for second mode.

- CFSv2 have good ENSO skills but limited ability to represent IOD.
Thank You