An investigation of aerosol-monsoon interactions in CMIP6 models

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Introduction

- **Monsoon Low Pressure Systems (LPS)** are synoptic-scale systems that typically form over the Bay of Bengal.
- They have a lifetime of 3-7 days and propagate northwestwards (Mooley 1973, Sikka 1977).
- They can penetrate deep into the subcontinent and bring large amounts of rainfall along their path (Krishnamurthy and Ajayamohan, 2010).
- Thus, they are the major synoptic-scale variability during the monsoon and play a crucial role in determining the total monsoon rainfall and its distribution.
- Aerosol forcing is widely believed to have caused the weakening of the monsoon (Bollasina et al., 2011, Ganguly et al., 2012).
- However, impacts of aerosols on sub-seasonal variability, especially the monsoon LPSs are not as well understood.

Objective

This study explores the changes in the characteristics of monsoon low pressure systems (LPS) as a response to aerosol forcing and its absence.

Data and Methodology

Data:

- European Centre for Medium Range Weather Forecasts (ECMWF) ERA5 mean sea level pressure and precipitation data from 1950-2014.
- CMIP6 datasets from 4 expts – hist_all, hist_aer, hist_ghg and hist_nat.

LPS Tracking:

- Monsoon LPSs are tracked using the algorithm of Praveen et al. (2015).
- The algorithm searches for a local minimum and then identifies closed contours around it with an increment of 1-hPa.
- The minimum length for a system is taken as 3 days.
- Strength of a system is taken as the pressure difference between the local minimum and the outermost closed contours identified.
- Systems are tracked for the full monsoon season (JJAS – 122 days).
- Strength classification of systems based on strength:

1. Lows - ≤ 2hPa
2. Depressions - >2 and ≤ 4hPa
3. Deep Depressions - >4 and ≤ 10hPa
4. Cyclonic Storm - >10 and ≤ 16hPa
5. Severe Cyclonic Storms - >16hPa

Results and Discussion

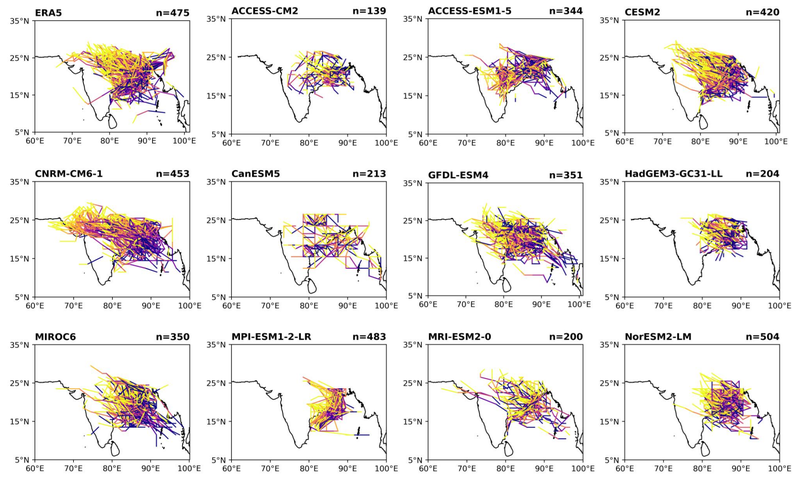

Figure 1. LPS tracks in ERA5 (top-left) and the CMIP6 hist_all (historical all forcing) experiment for the time period 1950-2014.

LPS precipitation shows maxima in southwest quadrant

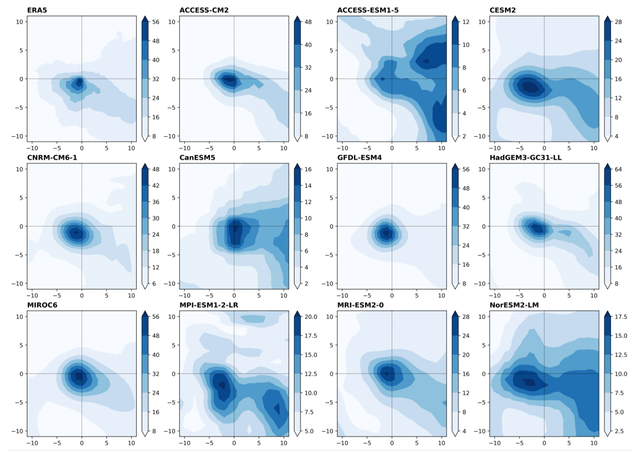

Figure 2. Storm centered composite of LPS precipitation (mm/day) for ERA5 tracks using ERA5 precipitation and the CMIP6 hist_all experiment from 1979-2014.

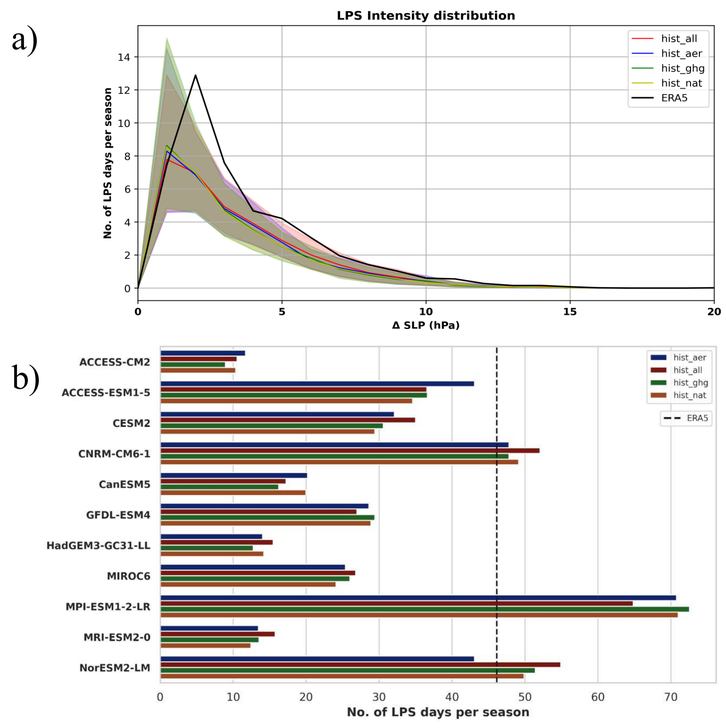

Figure 3. a) LPS intensity distribution, b) average no. of LPS days per season in CMIP6 models.

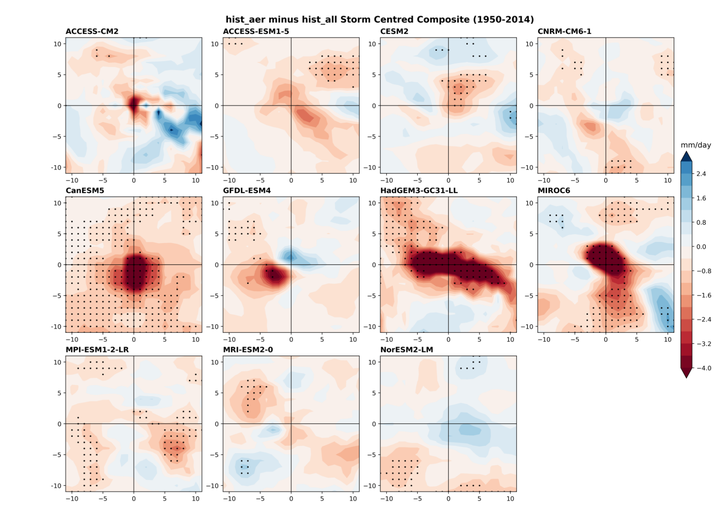

Figure 4. Difference between storm-centered composite of LPS precipitation between hist_aer and hist_all experiments. Most models show a decrease in the LPS precipitation due to aerosol forcing.

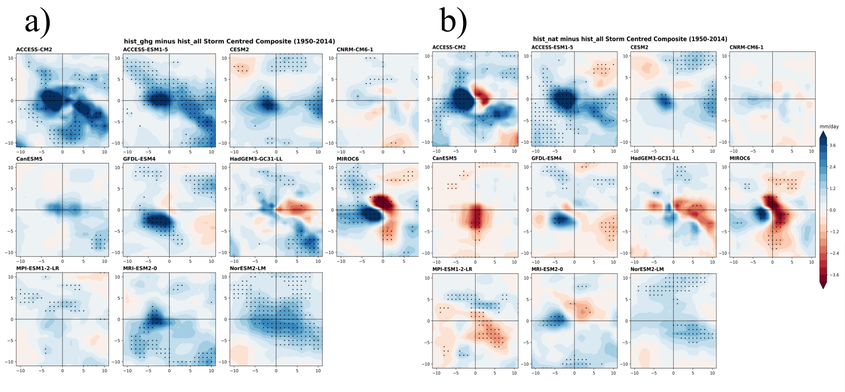

Figure 5. Difference between storm-centered composite of LPS precipitation between a) hist_ghg and hist_all experiments, and b) between hist_nat and hist_all experiments.

Conclusion

1. The monsoon LPSs are tracked in ERA5 and the different CMIP6 experiments.
2. Models under-estimate both the number of LPS days and their intensity.
3. While most models are able to capture the LPS precipitation structure (with the maxima in the SW quadrant), they underestimate the LPS-related precipitation.
4. There is no significant difference in the LPS intensity distributions amongst the different experiments.
5. The LPS-related precipitation changes in the different experiments show large inter-model variation. Excluding a few models, there is no significant difference observed.
6. Overall, aerosols reduce the LPS-precipitation and GHGs increase the LPS-precipitation.
7. We are interested in exploring the mechanisms that cause variations amongst the models.

References

Bollasina, M. A., Ming, Y., & Ramaswamy, V. (2011). Anthropogenic Aerosols and the Weakening of the South Asian Summer Monsoon. *Science*, *334*(6055), 502–505. https://doi.org/10.1126/science.1204994

Ganguly, D., Rasch, P. J., Wang, H., & Yoon, J. (2012). Climate response of the South Asian monsoon system to anthropogenic aerosols. *Journal of Geophysical Research: Atmospheres*, *117*(D13). https://doi.org/10.1029/2012JD017508

Krishnamurthy, V., & Ajayamohan, R. S. (2010). Composite Structure of Monsoon Low Pressure Systems and Its Relation to Indian Rainfall. *Journal of Climate*, *23*(16), 4285–4305. https://doi.org/10.1175/2010JCLI2953.1

MOOLEY, D. A. (1973). Some Aspects of Indian Monsoon Depressions and the Associated Rainfall. *Monthly Weather Review*, *101*(3), 271–280. https://doi.org/10.1175/1520-0493(1973)101<0271:SAOIMD>2.3.CO;2

Praveen, V., Sandeep, S., & Ajayamohan, R. S. (2015). On the Relationship between Mean Monsoon Precipitation and Low Pressure Systems in Climate Model Simulations. *Journal of Climate*, *28*(13), 5305–5324. https://doi.org/10.1175/JCLI-D-14-00415.1

Sikka, D. R. (1977). Some aspects of the life history, structure and movement of monsoon depressions. *Pure and Applied Geophysics*, *115*(5–6), 1501–1529. https://doi.org/10.1007/BF00874421

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