Geophysical Research Abstracts
Vol. 18, EGU2016-11439-1, 2016
EGU General Assembly 2016

Path-analysis based validation of aerosol-precipitation micro-scale interaction using observational evidences

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Aerosols can modulate variability of Indian summer monsoon by perturbing the radiative balance of the atmosphere, affecting the land-ocean processes and altering the cloud-microphysics at varying spatio-temporal scale, ranging from fast (less than a day) to slow (months) temporal effects. In the literature, overall interaction between AOD and Precipitation was quantified as correlation coefficients (*Ramchandran and Kedia, 2013; Gryspeerdt et al., 2012; Gryspeerdt et al., 2014)*, however the segregation of the interaction was required to better understand the presence/absence of pathway mediated through changes in cloud-microphysics and atmospheric stability. In this work, effects of aerosols on precipitation, mediated through changes in cloud-microphysics and atmospheric stability, on daily time-scales, are studied and quantified using coincident observational data of aerosols, clouds and rainfall, using *Path-analysis (Wright, 1969)*.

MODIS, ERA-interim and IMD data-sets for years 2000-2009 for Aerosol optical depth (AOD), Column water vapour (CWV), Cloud droplet effective radius (CDERL), Convective available potential energy (CAPE) and Precipitation, over Indian region were used for the analysis. Cause-effect model was built to validate and quantify the effects of AOD on precipitation, mediated through CDERL and CAPE. To contrast cause-effect mechanism in presence and absence of aerosol fields, high AOD-low Precipitation and low AOD-low Precipitation clusters were formed. Cluster-averaged time series were used to calculate the lagged correlation (AOD leading) and provided as input to *Path-analysis*.

“AOD-CDERL-Precipitation” and “AOD-CAPE-Precipitation” pathways were found to be statistically significant for high AOD-low Precipitation clusters while both were absent for low AOD-low Precipitation clusters, for years 2003 and 2004. For other years statistically significant pathway between AOD and Precipitation could not be found.

In “AOD-CDERL-Precipitation” pathway, path coefficient was found to be negative between aerosol abundance and cloud droplet, but positive between cloud droplet size and precipitation, indicating existence of high AOD-low CDERL-low Precipitation pathway. The sign of path coefficients were consistent with negative signs of AOD-CDERL correlation reported in literature (*Rosenfeld et al., 2008; Li et al., 2013; Gryspeerdt et al., 2012; Koren et al., 2008*).

In “AOD-CAPE-Precipitation” pathway, path coefficient sign between AOD-CAPE was positive for 2003 and negative for 2004. The path coefficient sign was found to be positive between CAPE-Precipitation for both 2003 and 2004, suggesting that the effect of AOD on Precipitation through CAPE was positive and negative for 2003 and 2004, respectively. The negative path coefficient between AOD and CAPE in 2004 supports the atmospheric stabilization hypothesis (*Cherian et al. 2013; Guo et al. 2013)*, with existence of high AOD-low CAPE-low Precipitation pathway. For 2003, both pathways were found to exert contrasting effect on precipitation rendering less reduction in precipitation as compared to 2004 in which both pathways were contributing to precipitation reduction. High AOD-low Precipitation clusters of 2003 and 2004 corresponded to slightly deficient and highly deficient regions reported by *Ramchandran and Kedia (2013*). The statistical significance of all the path coefficients were tested using α=0.05.

Using observational data with *Path-analysis*, overall effect of AOD on Precipitation was segregated and quantified into “AOD-CDERL-Precipitation” and “AOD-CAPE-Precipitation” pathways.

Keywords

Cloud-microphysics; aerosol; path analysis; lagged correlation.