Appendix A

To better understand the relationships between the AOD/rainfall (here combined product of DEEPBLUE AOD discussed in Query 2 (missing data issue) of Other Comments is used) and COD/rainfall, standardized anomaly of the EC components was created as follows:

$$x' = \frac{x - x_{month\_mean}}{x_{month\_std}}$$

where x_{month_mean} and x_{month_std} are the monthly mean and standard deviation for the monthly in question of data x. Due to the limited duration of the observational record as mentioned in reply to Query 1, the analysis of the intra-annual cycle of the anomalies does not produce statistically significant results. However, because of strong seasonality in aerosols, clouds and rainfall, it is possible to interpret positive phase and negative phase anomalies in the context of regional climate. Below, we present the monthly histogram plots obtained by comparing standardized anomalies of MODIS AOD with TRMM rainfall and MODIS AOD with MODIS COD.

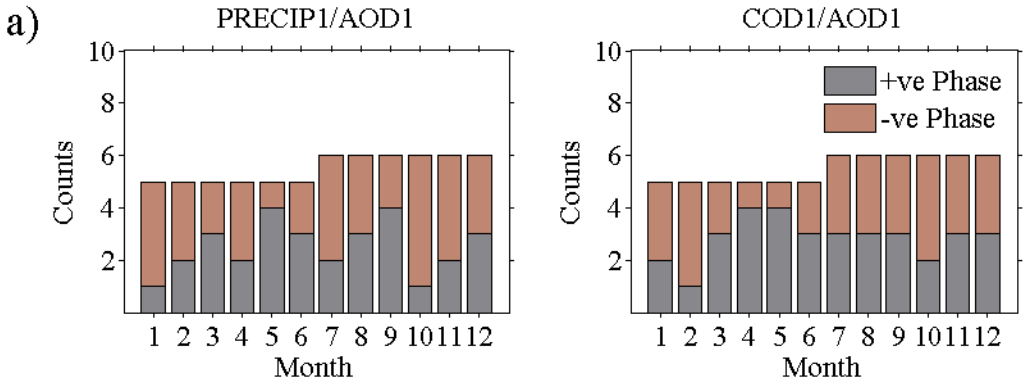

Figure A1: *Standardized anomalies of the first EC component of MODIS AOD and TRMM rainfall/MODIS COD.*

During the period of 66 months considered above, 30 occasions showed positive phase relationship, i.e., PRECIP1 (first EC component of TRMM rainfall) anomaly is negative (positive) when AOD1 (first EC component of MODIS AOD) anomaly is negative (positive). The month of May had highest in phase relationship, which is a pre-monsoon season. On the other hand, 36 occasions showed negative phase relationship, i.e, PRECIP1 anomaly is negative (positive) when AOD1 anomaly is positive (negative). The month of January and October showed highest negative relationship and these periods consistent with low precipitation in the winter and fall (post-monsoon) respectively.

For COD1 (first EC component of MODIS COD) and AOD1 anomalies, 34 out of 66 occasion showed in phase relationship. The month of April and May had highest in phase relationship, again during the pre-monsoon season. And, 32 of 66 occasions showed

negative phase relationship as described earlier with a maximum during the month of February and October i.e winter and post-monsoon season.

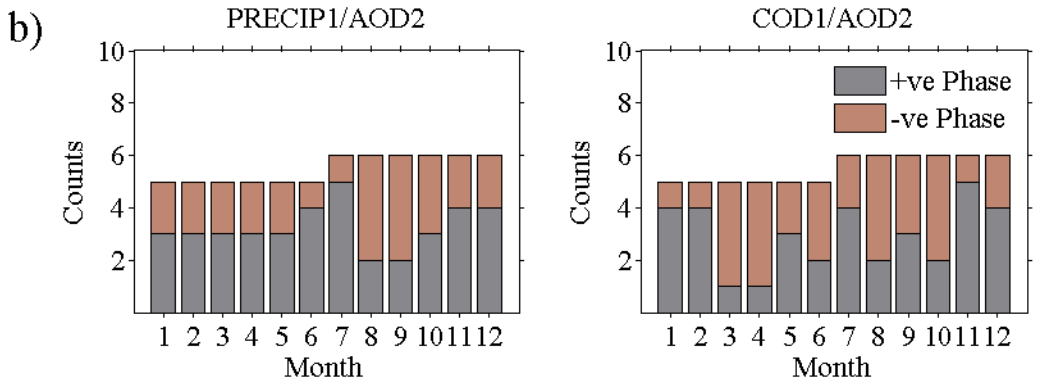

Figure A2: *Standardized anomalies of the second EC component of MODIS AOD and first EC component of TRMM rainfall/MODIS COD.*

In the above case for PRECIP1 and AOD2 (second EC component of MODIS AOD) anomalies, 39 out of 66 occasions where in phase, with maximum in phase relationship present during the month of June, July i.e. during the first half of the monsoon season. This does indicate that an increase in the precipitation during the monsoon season does have a positive impact on the increase in second mode of AOD.

Similarly, 35/66 occasions showed in phase relationship between COD1 and AOD1 anomalies, with a maximum during the months of January, February and November, i,e the winter periods. And, 31 out of 66 occasions showed negative phase relationship with a maximum during the month of March and April i.e. the pre-monsoon season.

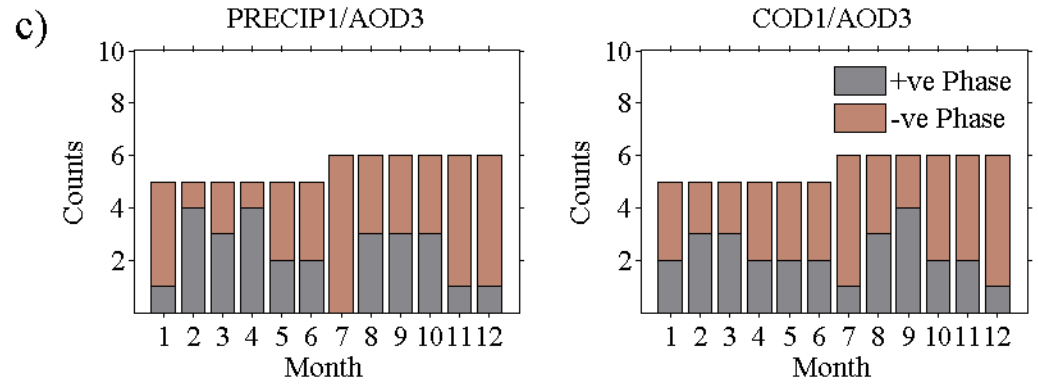

Figure A3: *Standardized anomalies of third EC component of MODIS AOD and first EC component of TRMM rainfall/MODIS COD.*

For PRECIP1 and AOD3 (third EC component of MODIS AOD), 27 out of 66 occasions showed in phase relationship with maximum for the month of February and April i.e the pre-monsoon season. And, 39 out of 66 occasions showed negative phase relationship, with maximum for the month of July (6 out of 6 years) suggesting increase in AOD anomaly for weaker monsoon rainfall in July.

For COD1 and AOD3 anomalies, 27 of 66 occasions showed in phase relationship with 70% of maximum analyzed period for the month of September. Negative phase was observed for 39 out of 66 months with maximum for the month of July i.e during monsoon and again in December (winter month) as well.

So a consistent strong negative phase relationship was observed between the AOD3 and PRECIP1/COD1 for the month of July suggesting increase in the AOD of this mode with weaker monsoon rainfall in July.

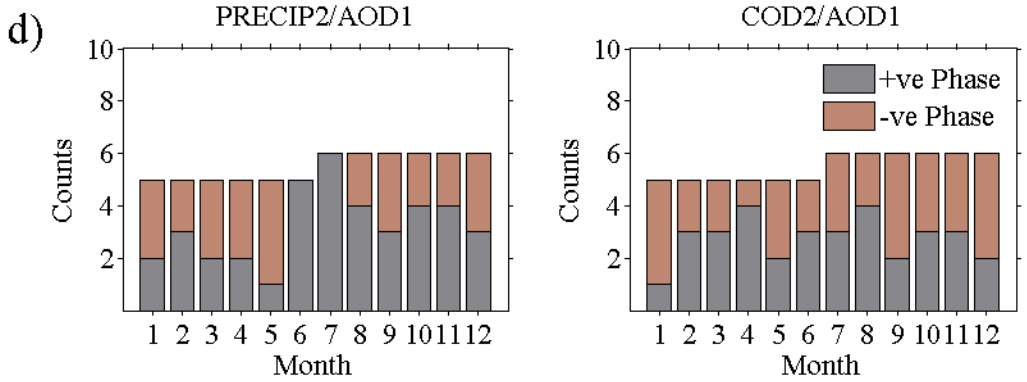

Figure A4: *Standardized anomalies of third EC component of MODIS AOD and first EC component of TRMM rainfall/MODIS COD.*

For PRECIP2 (second EC component of TRMM precipitation) and AOD1 anomalies, 39 of 66 occasions showed in phase relationship, with month of June and July having strongest relationship. This suggests that increase in monsoon rainfall over Central India and southern slopes of Himalayas, correlates with the increase in AOD over NW of Aravalli range. And, 27 of 66 occasions had negative phase relationship with a maximum for the month of May.

For COD2 (second EC component of MODIS COD) and AOD1 anomalies, 33 of 66 occasions showed in phase relationship with a maximum for month of April, during pre monsoon season. And, 33 of 66 occasions exhibited negative phase relationship with a maximum for the month of January i.e the winter period.

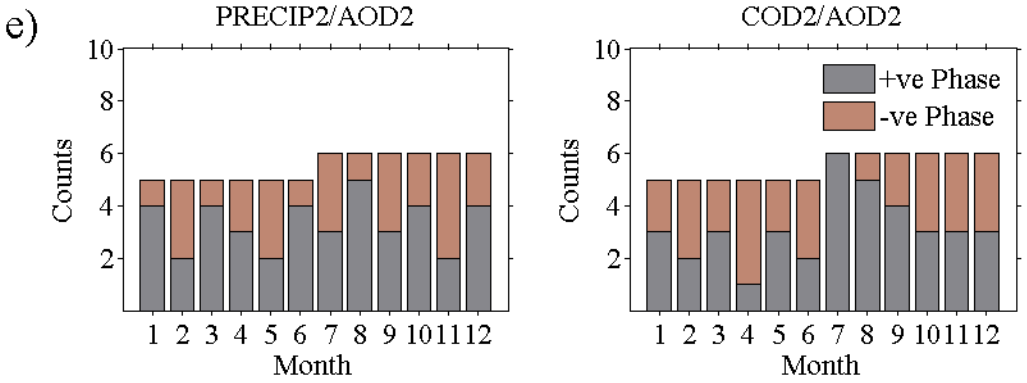

Figure A5: *Standardized anomalies of second EC component of MODIS AOD and second EC component of TRMM rainfall/MODIS COD.*

For PRECIP2 and AOD2 anomalies, 40 of 66 occasions showed in phase relationship. This is the highest in phase relationship observed between different modes of PRECIP and AOD. And, 26 of 66 occasions showed negative phase relationship with a maximum of around 70% for the month of November.

Similarly, 38 of 66 occasions showed in phase relationship with a maximum for the month of July, during monsoon. And, 28 of 66 occasions showed negative phase relationship with a maximum for the month of April, during pre-monsoon season. This mode shows a strong positive relationship between the increase in AOD and the COD.

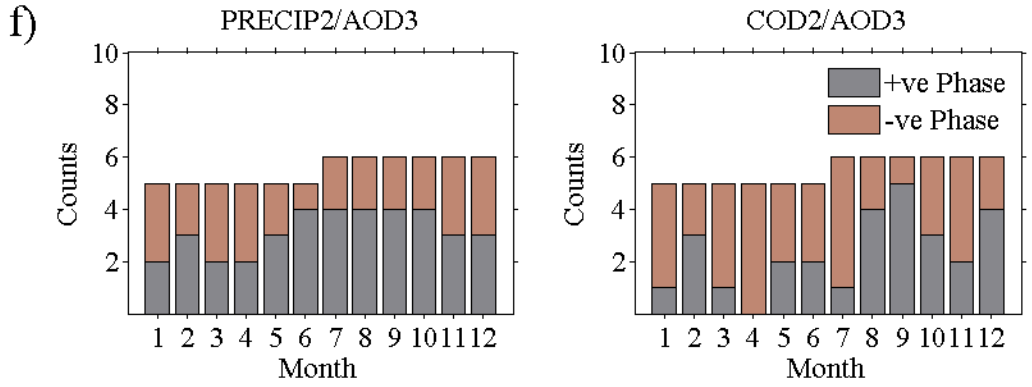

Figure A6: *Standardized anomalies of third EC component of MODIS AOD and second EC component of TRMM rainfall/MODIS COD.*

For PRECIP2 and AOD3 anomalies, 38 of 66 occasions showed in phase relationship with a maximum during the summer monsoon period (JJAS). And, 28 of 66 occasions showed negative phase relationship.

For COD2 and AOD3, 28 of 66 occasions showed in phase relationship with a maximum of for the month of September. And, 38 of 66 occasions showed negative phase relationship with maximum for the month of April and July.