remote sensing

Supplementary Materials for

Satellite-derived correlation of SO_2, NO_2, and aerosol optical depth with meteorological conditions over East Asia 2005-2015

Chin-An Lin [1,2], Yi-Chun Chen [1,*], Chian-Yi Liu [3], Wei-Ting Chen [4], John H. Seinfeld [5], and Charles C.-K. Chou[1]

1. The Modern-Era Retrospective analysis for Research and Applications, Version 2 (Merra-2) reanalysis data is used to investigate the aerosol composition over East Asia. Merra-2 reanalysis data starts from 1980 and is assimilated with modern hyperspectral radiance and microwave observations, along with GPS-Radio Occultation datasets. After 2004, NASA's ozone profile observation data is also used for Merra-2 data. The horizontal resolution of Merra-2 data is 0.5° × 0.625° and with 72 sigma model levels in vertical. We used the Merra-2 monthly AOD data from 2005 to 2015, which provides the information of AOD contributed by black carbon (BC), organic carbon (OC), sulfate aerosol (SO_4), dust, and sea salt, respectively. By applying the Merra-2 data, Fig. S1 show the 2005-2015 mean ratio of OC, BC, SO_4, and dust over total AOD, respectively. The results show that OC contributes about 10-20 % of total AOD over the focus regions in this study. SO_4 contributes over 60 % in all monitored regions, except the clean region South China Sea. BC and dust contribute less than 10% of total AOD individually.
   There may be some uncertainties because Merra-2 reanalysis does not consider nitrate. Based on this result, about 60 % of the change of AOD can be explained by analyzing the change of sulfate.

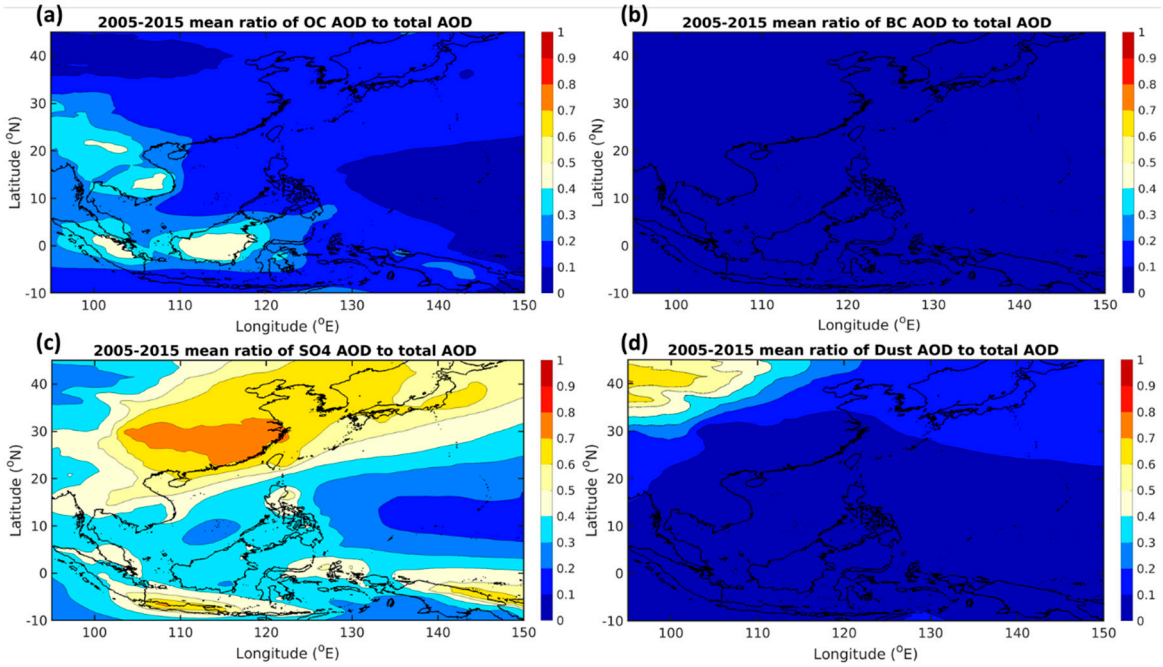

Figure S1. Spatial distribution of 2005-2015 averaged ratio of the extinction AOD of (a) organic carbon (OC), (b) black carbon (BC), (c) SO_4 (sulfate aerosol), and (d) dust over total extinction AOD. AOD data is from Modern-Era Retrospective analysis for Research and Applications, Version 2 (MERRA-2) reanalysis data.

2. Figures S2-S7 show the time series of yearly-mean SO_2, NO_2, AOD, and meteorological fields (850 hPa temperature, 850 hPa RH, and lower tropospheric stability (LTS)) over NCP, SB, SC, SCS, TW, and TWS. In NCP, SB, and SC, SO_2, NO_2, and AOD have clear increasing and decreasing trends during the period from 2005 to 2015. Compared with the annual variation of SO_2, NO_2, and AOD, the annual variations of meteorological fields are relatively small. Besides, the annual variations of meteorological fields are not closely related to the annual variations of SO_2, NO_2, and AOD. This is possibly because the impact of policy and environmental regulations on the annual change of SO_2, NO_2, and AOD overwhelms the impact of meteorology. Therefore, we focus more on the effect of policy and regulations on the long-term trend of SO_2, NO_2, and AOD in Sec. 3.2.2.

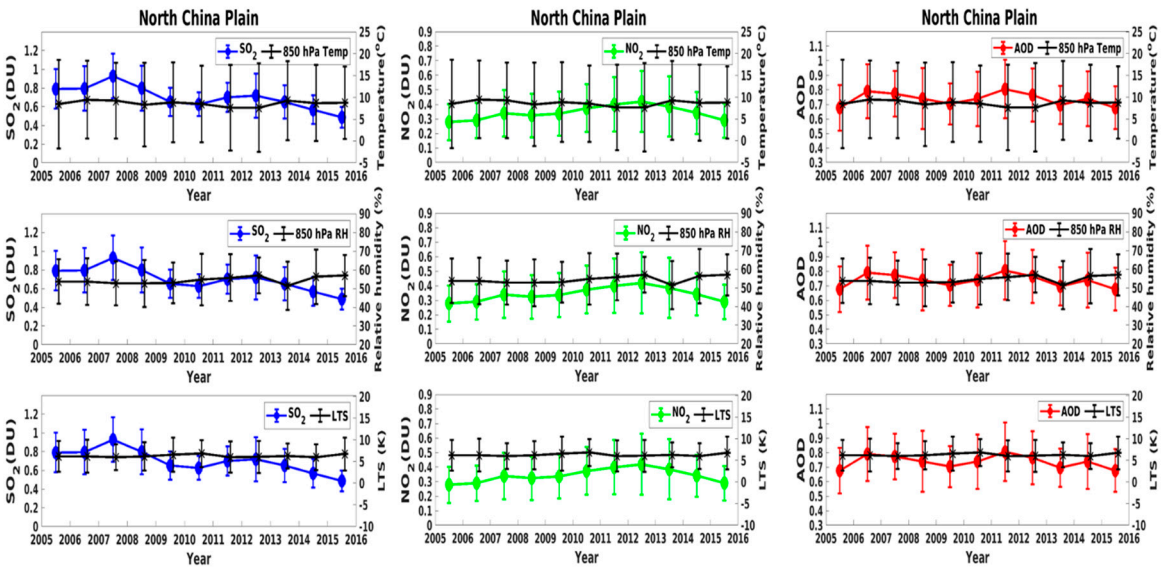

Figure S2. Time series of yearly-mean SO_2, NO_2, AOD, and meteorological fields (850 hPa temperature, 850 hPa RH, and lower tropospheric stability (LTS)) over North China Plain (NCP).

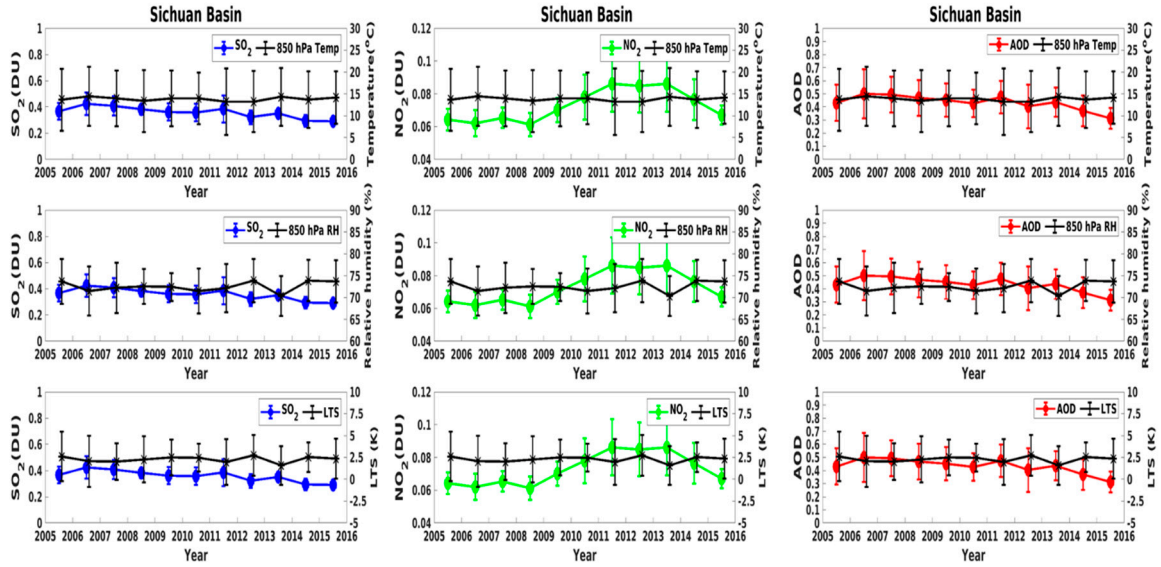

Figure S3. Time series of yearly-mean SO_2, NO_2, AOD, and meteorological fields (850 hPa temperature, 850 hPa RH, and lower tropospheric stability (LTS)) over Sichuan Basin (SB).

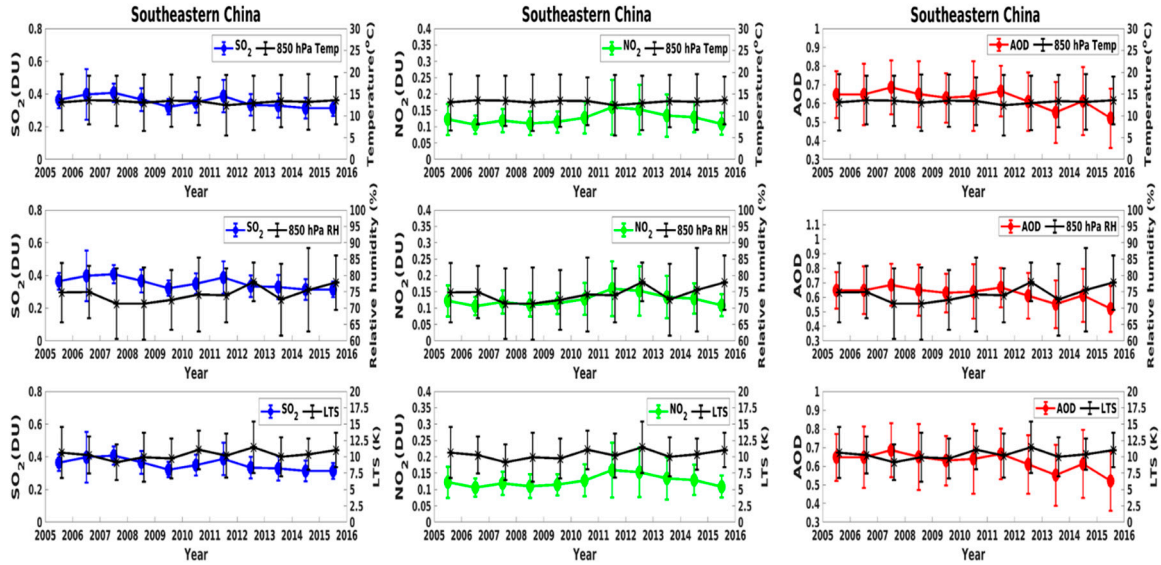

Figure S4. Time series of yearly-mean SO_2, NO_2, AOD, and meteorological fields (850 hPa temperature, 850 hPa RH, and lower tropospheric stability (LTS)) over Southeastern China (SC).

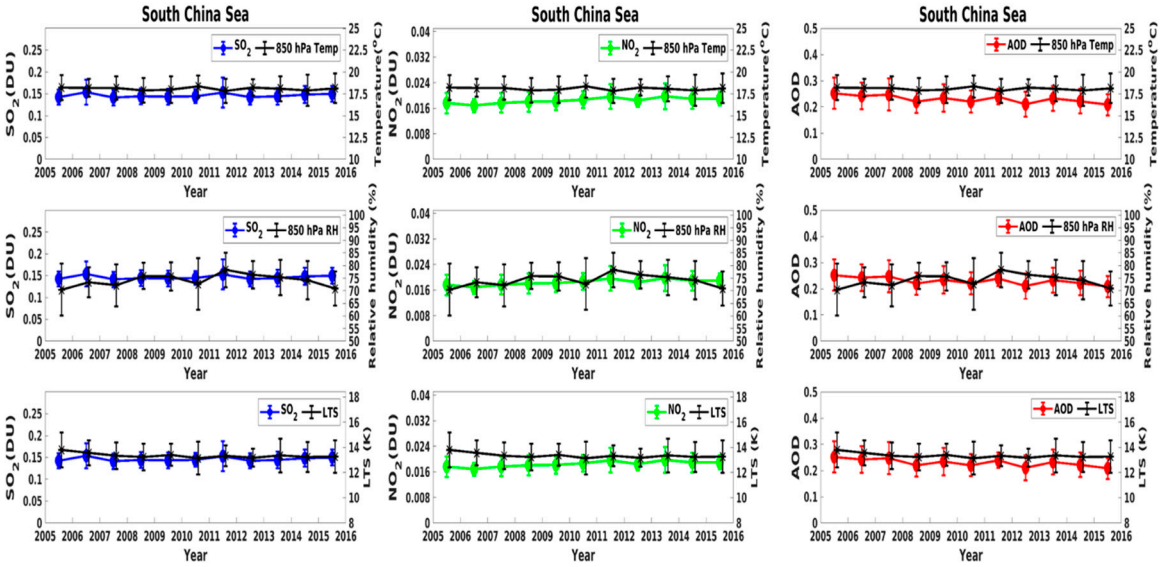

Figure S5. Time series of yearly-mean SO_2, NO_2, AOD, and meteorological fields (850 hPa temperature, 850 hPa RH, and lower tropospheric stability (LTS)) over South China Sea (SCS).

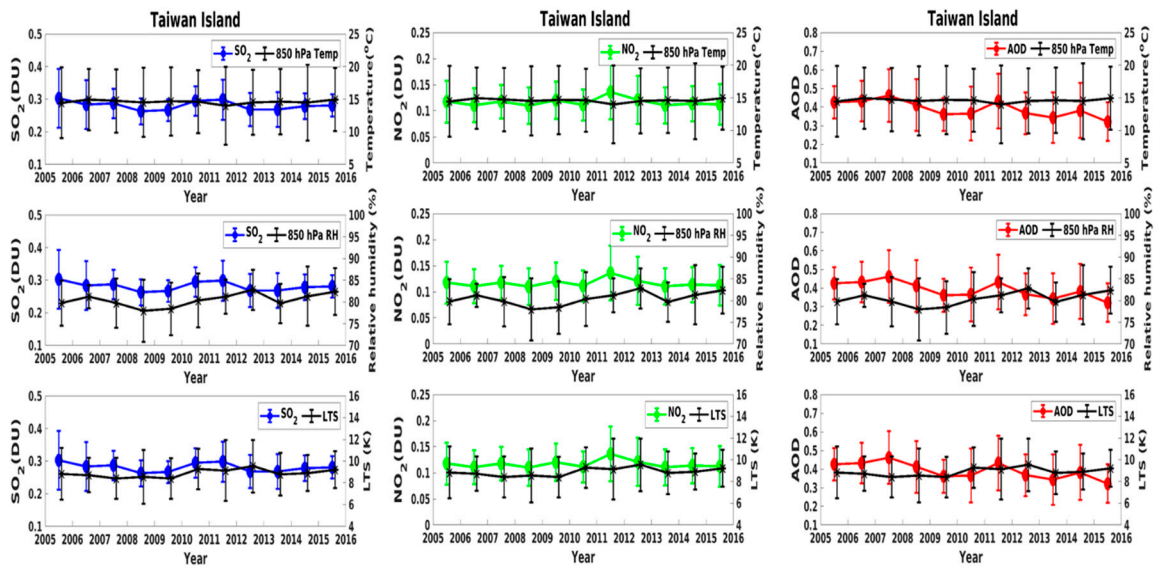

Figure S6. Time series of yearly-mean SO_2, NO_2, AOD, and meteorological fields (850 hPa temperature, 850 hPa RH, and lower tropospheric stability (LTS)) Taiwan Island (TW).

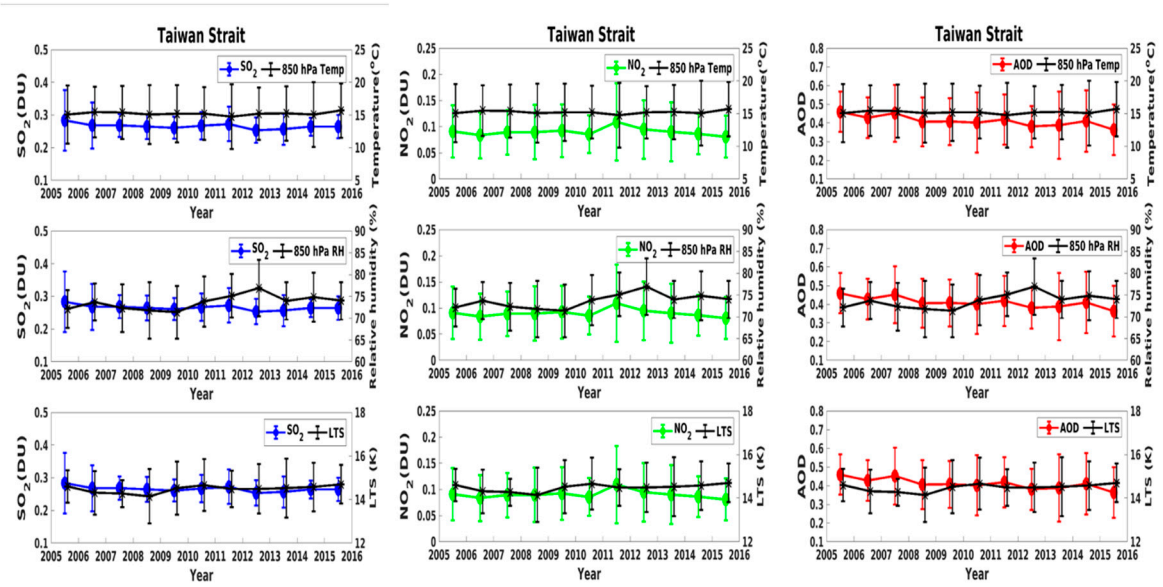

Figure S7. Time series of yearly-mean SO_2, NO_2, AOD, and meteorological fields (850 hPa temperature, 850 hPa RH, and lower tropospheric stability (LTS)) Taiwan Strait (TWS).

3. Figures S8-S13 show the 2005-2015 seasonal mean SO_2, NO_2, AOD, and meteorological fields (850 hPa temperature, 850 hPa RH, and lower tropospheric stability (LTS)) over NCP, SC, SB, SCS, TW, and TWS. Figures S8-S13 exhibit similar information with Table. 1. We have described the relationship between SO_2, NO_2, AOD, and meteorology in Sec. 3.3.1.

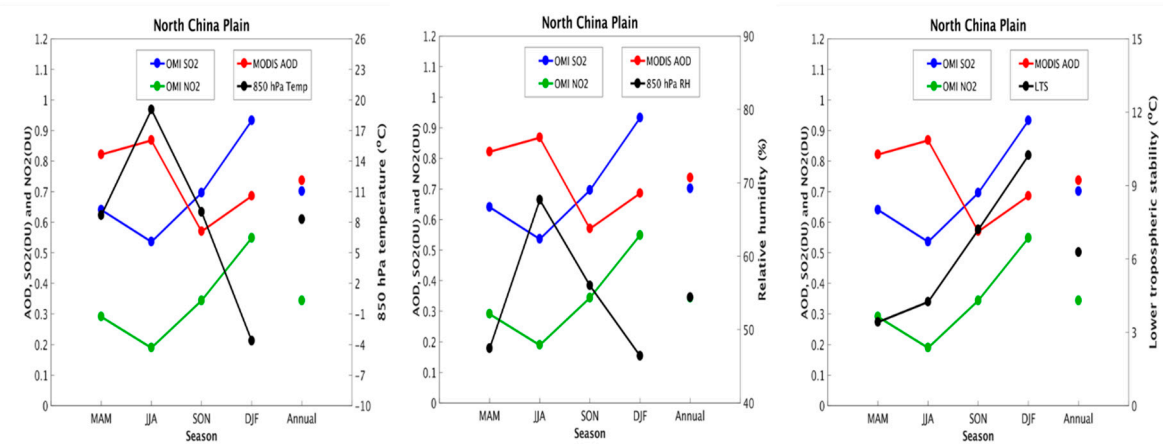

Figure S8. Seasonal cycle of 2005-2015 mean SO_2, NO_2, AOD, and meteorological fields (850 hPa temperature, 850 hPa RH, and lower tropospheric stability (LTS)) over NCP.

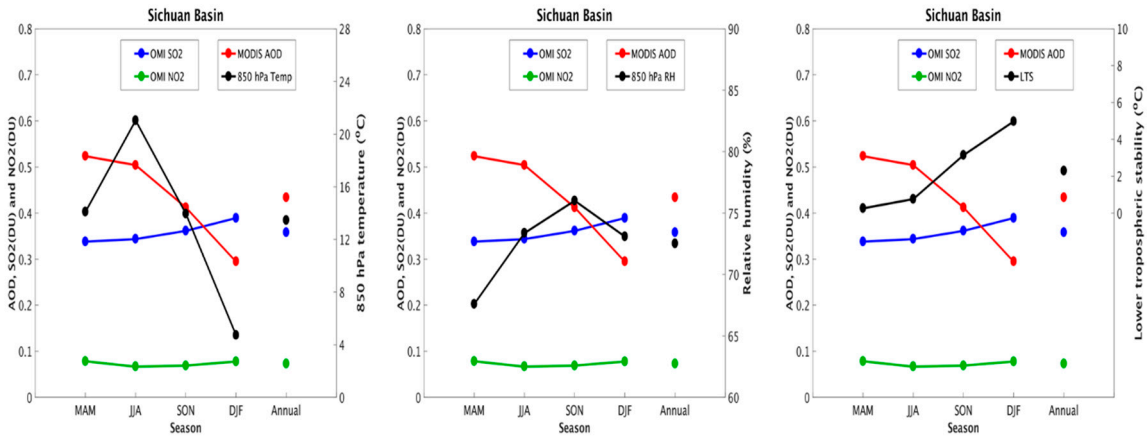

Figure S9. Seasonal cycle of 2005-2015 mean SO_2, NO_2, AOD, and meteorological fields (850 hPa temperature, 850 hPa RH, and lower tropospheric stability (LTS)) over SB.

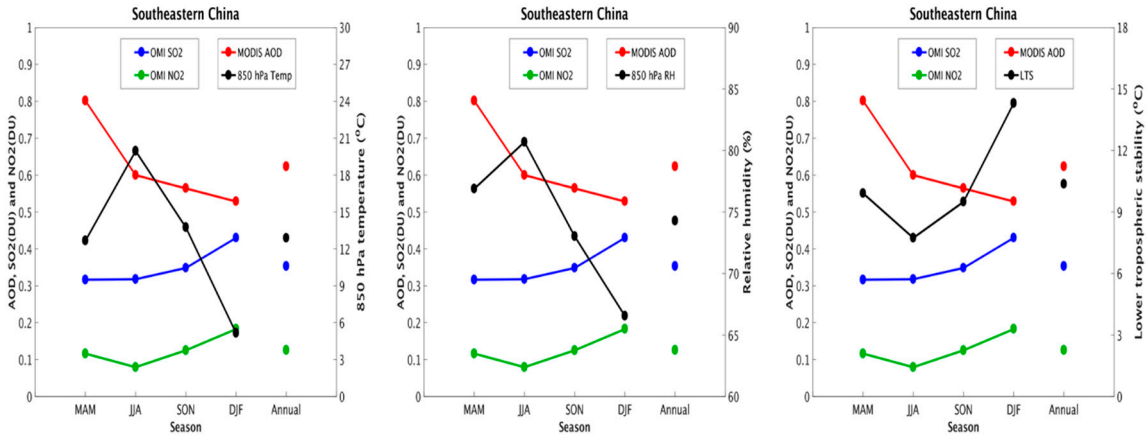

Figure S10. Seasonal cycle of 2005-2015 mean SO_2, NO_2, AOD, and meteorological fields (850 hPa temperature, 850 hPa RH, and lower tropospheric stability (LTS)) over SC.

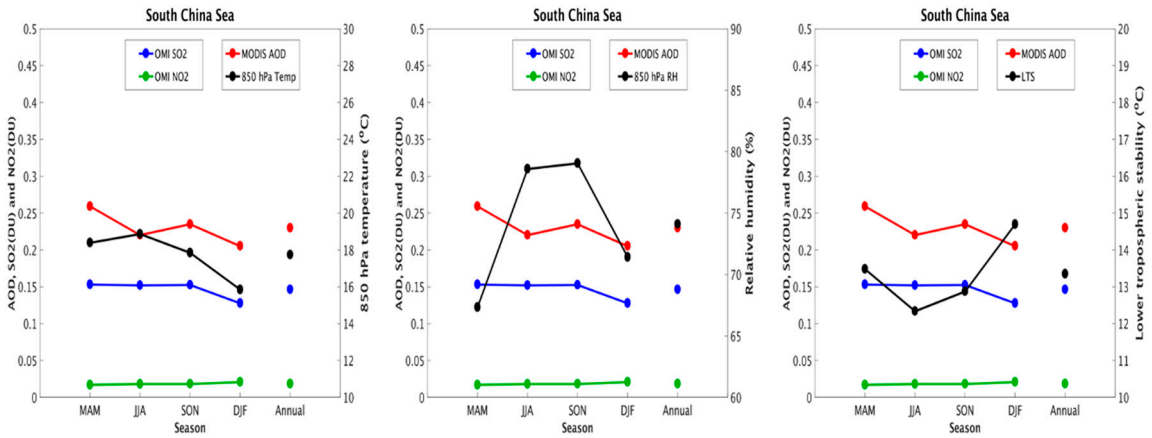

Figure S101. Seasonal cycle of 2005-2015 mean SO_2, NO_2, AOD, and meteorological fields (850 hPa temperature, 850 hPa RH, and lower tropospheric stability (LTS)) over SCS.

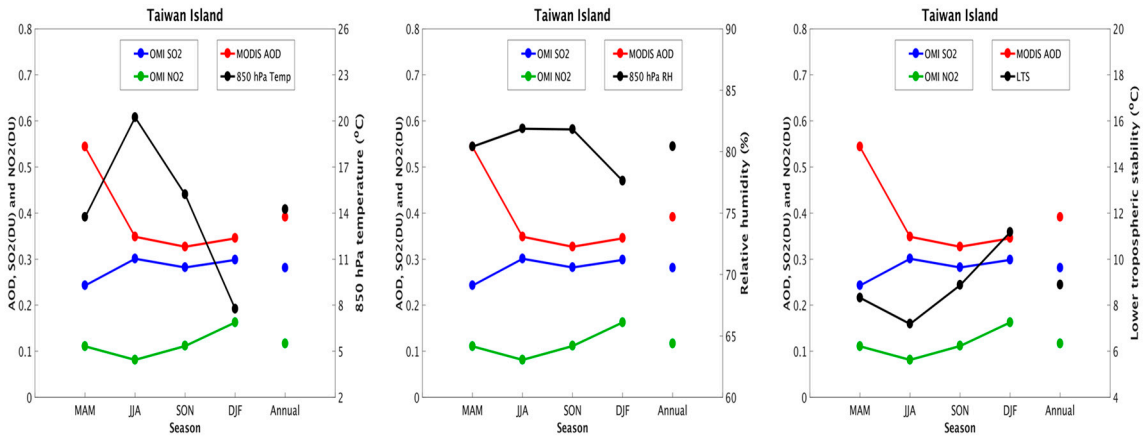

Figure 112. Seasonal cycle of 2005-2015 mean SO_2, NO_2, AOD, and meteorological fields (850 hPa temperature, 850 hPa RH, and lower tropospheric stability (LTS)) over TW.

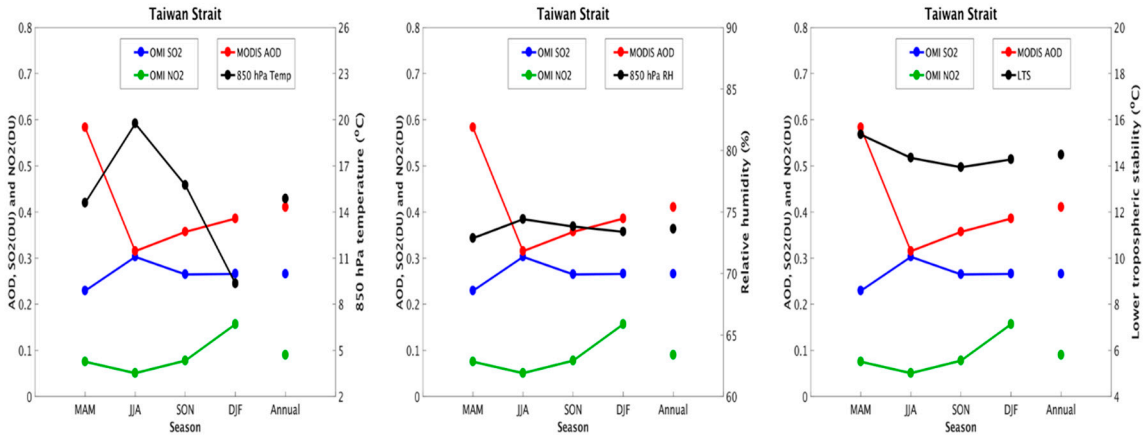

Figure S13. Seasonal cycle of 2005-2015 mean SO_2, NO_2, AOD, and meteorological fields (850 hPa temperature, 850 hPa RH, and lower tropospheric stability (LTS)) over TWS.