



*Supplement of*

## **What caused record-breaking aerosol loading over the South China Sea in April 2023**

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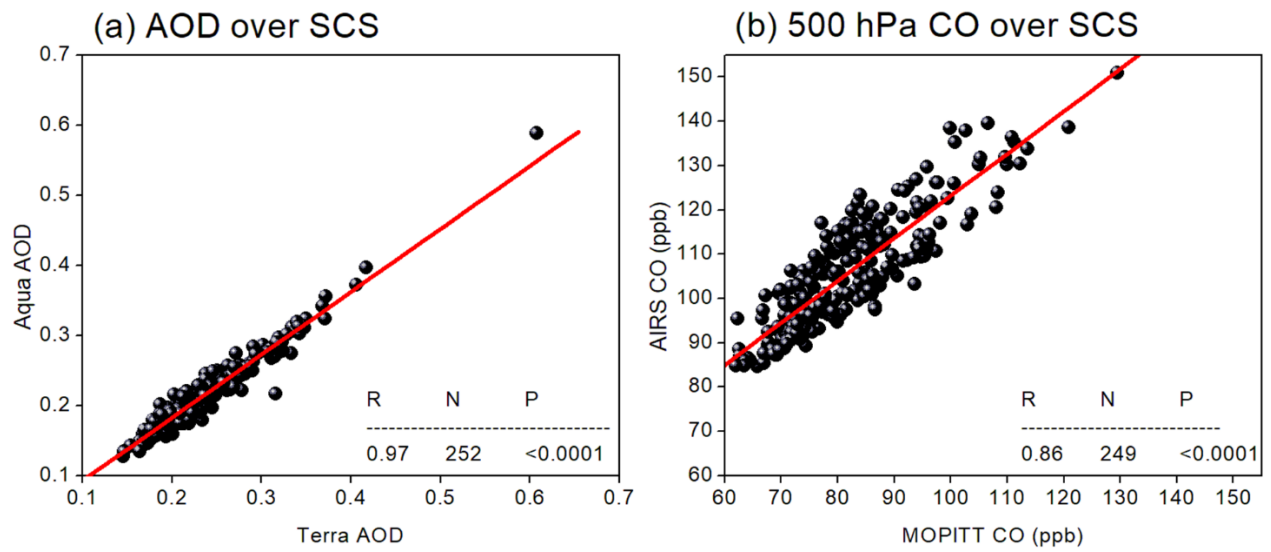


Figure S1. (a) Comparison between MODIS Terra AOD and MODIS Aqua AOD, (b) comparison between MOPITT and AIRS measured 500 hPa CO over the South China Sea during January 2003 to December 2023. (R is the correlation coefficient; N is the sample size; P is the significance value).

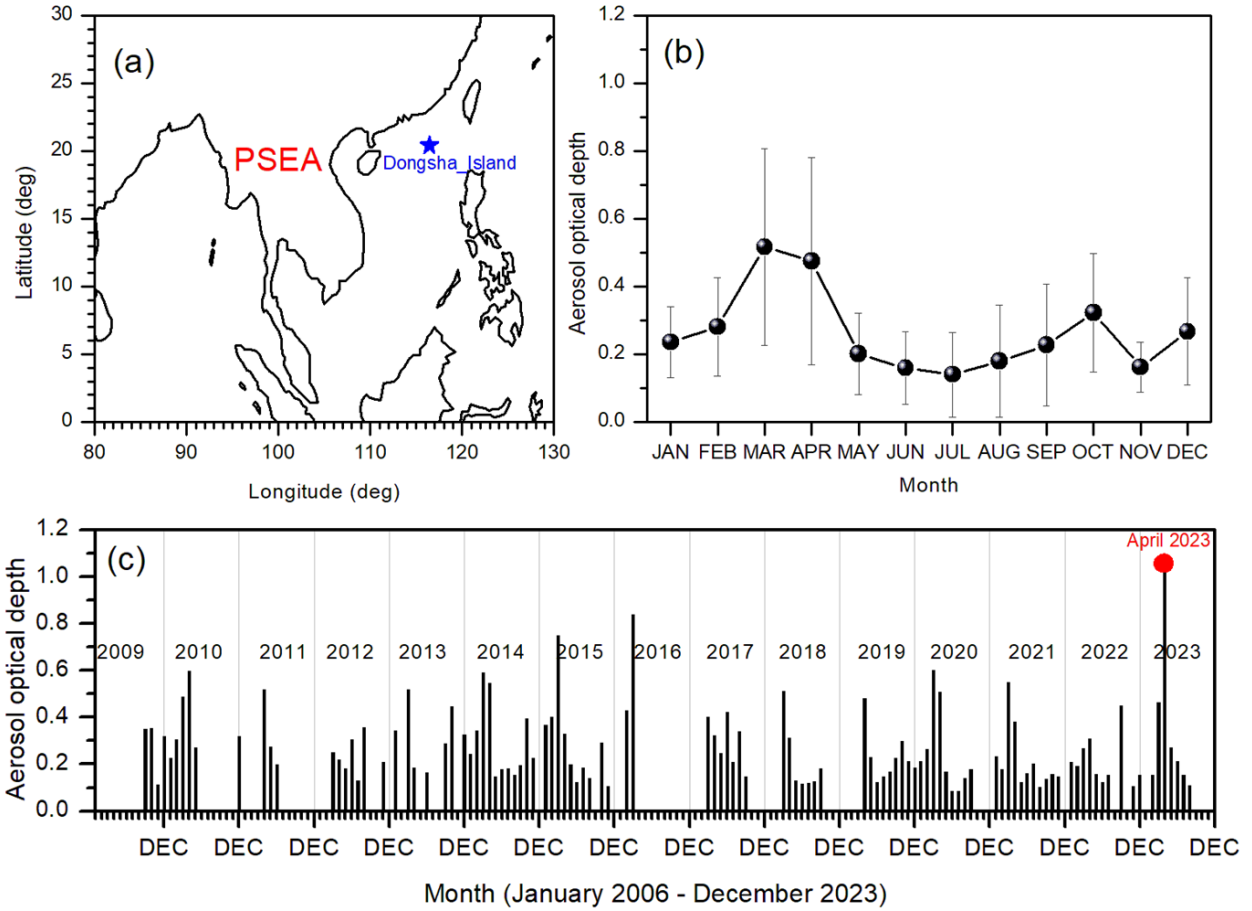


Figure S2. The location of the Dongsha\_Island ( $20.70^{\circ}\text{N}$ ,  $116.73^{\circ}\text{E}$ , 5 m a.s.l.) AERONET site (denoted by the blue star) in the South China Sea. (b) Monthly variations in aerosol optical depth (AOD) at Dongsha. Vertical error bars represent the standard deviation from the mean. (c) Time series of monthly AOD values from January 2009 to December 2023. The highest AOD occurred in April 2023, marking the peak of the entire data period.

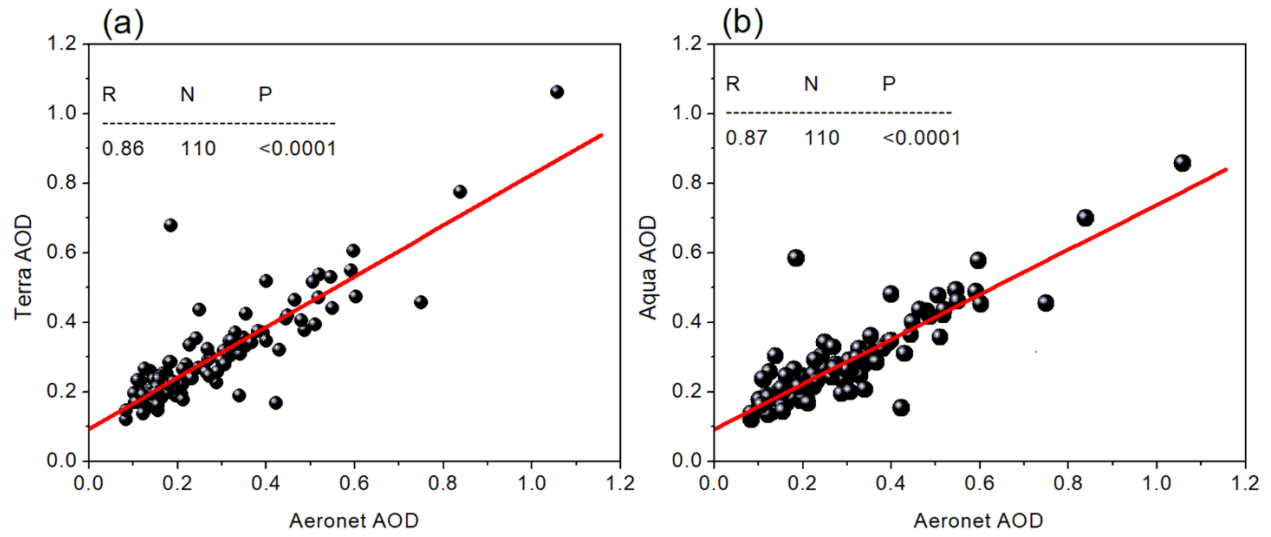


Figure S3. (a) Comparison between AERONET AOD and MODIS Terra AOD, (b) AERONET AOD and MODIS Aqua AOD over Dongsha Island during January 2009 to December 2023. (R is the correlation coefficient; N is the sample size; P is the significance value).

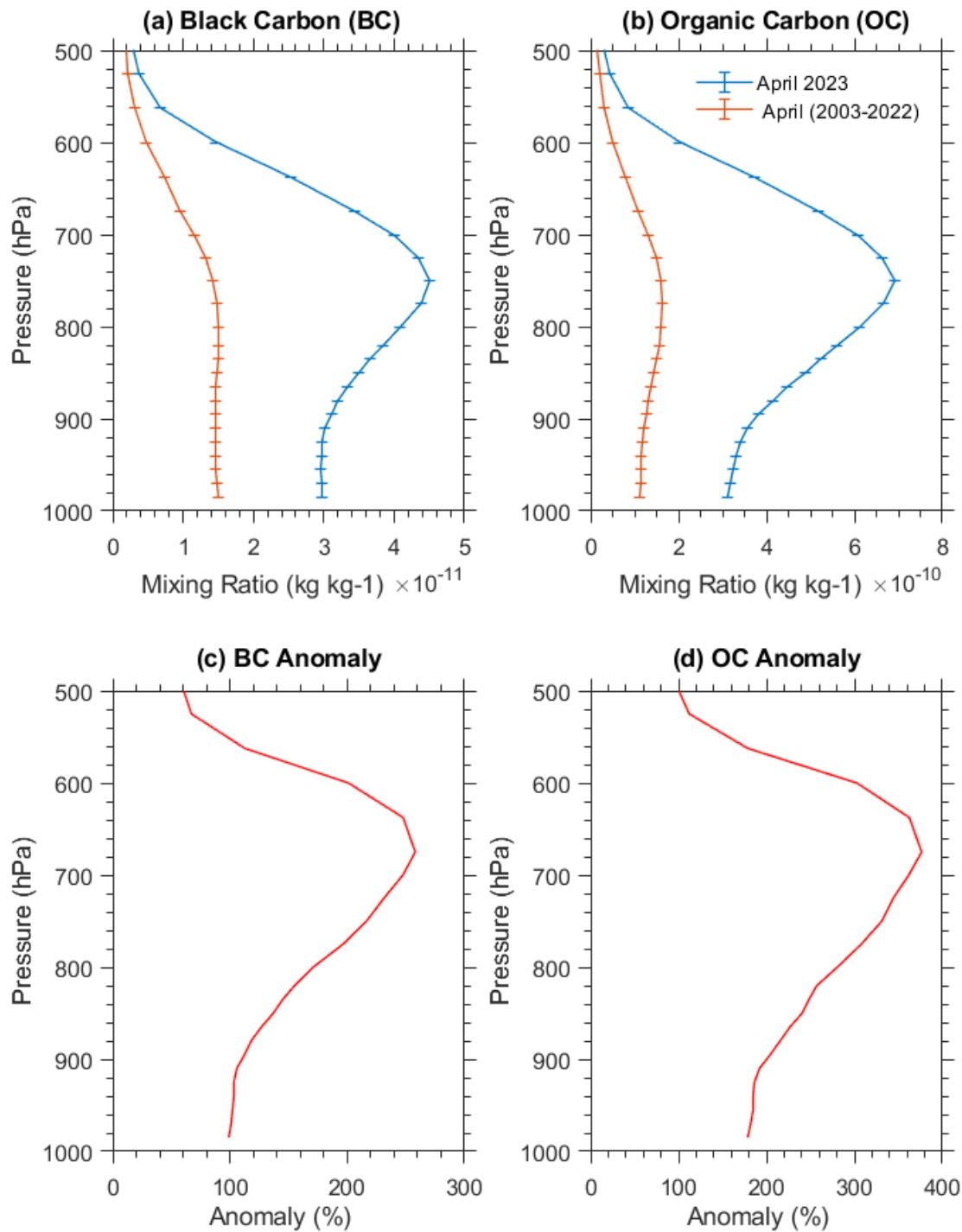


Figure S4. MERRA-2 reanalysis of the observed vertical distribution of (a) black carbon (BC) and (b) organic carbon (OC). The long-term April average is shown in brown, whereas April 2023 is shown in blue. The percentage change in April 2023 relative to the long-term average is shown for (c) BC and (d) OC.

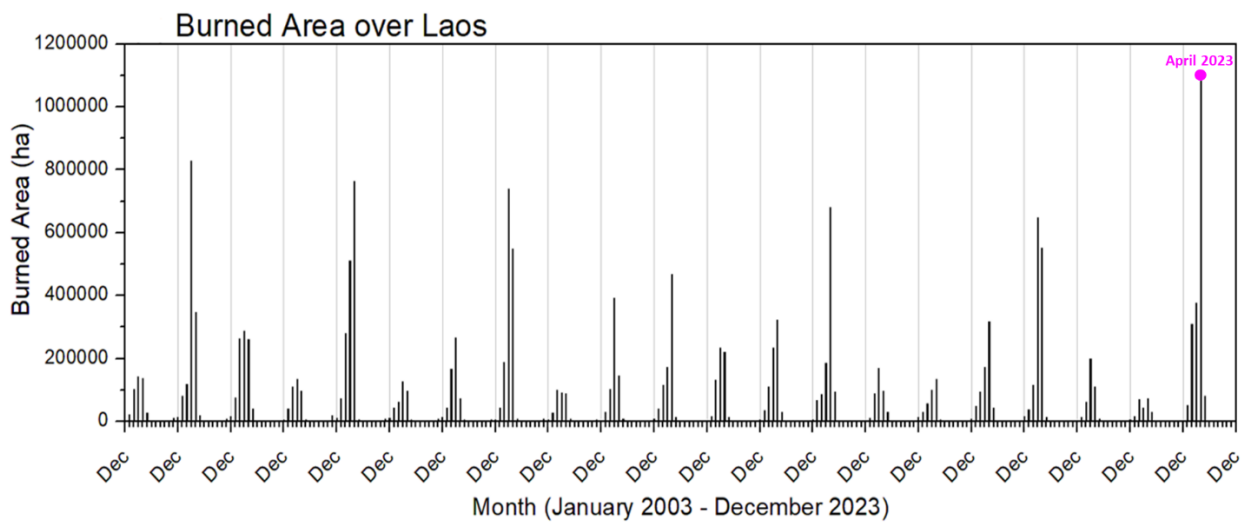


Figure S5. Time series of MODIS monthly total burned area (BA) values over Laos from January 2003 to December 2023. The most significant area burned in a single month in the recent record (2003-2023) occurred in April 2023 with 1.08 Mha burned.

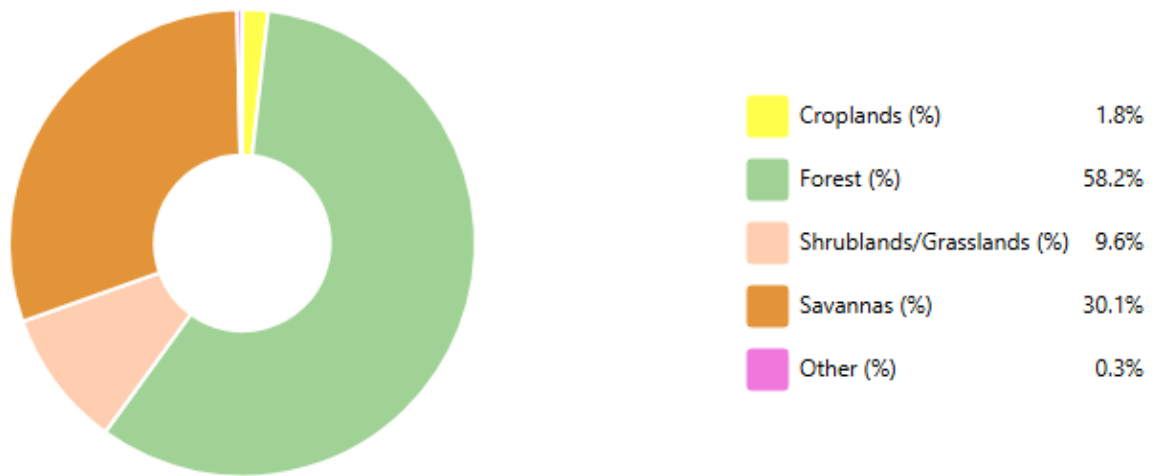


Figure S6. Distribution of land cover types over Laos. (Source: taken from <https://gwis.jrc.ec.europa.eu/apps/country.profile/>).

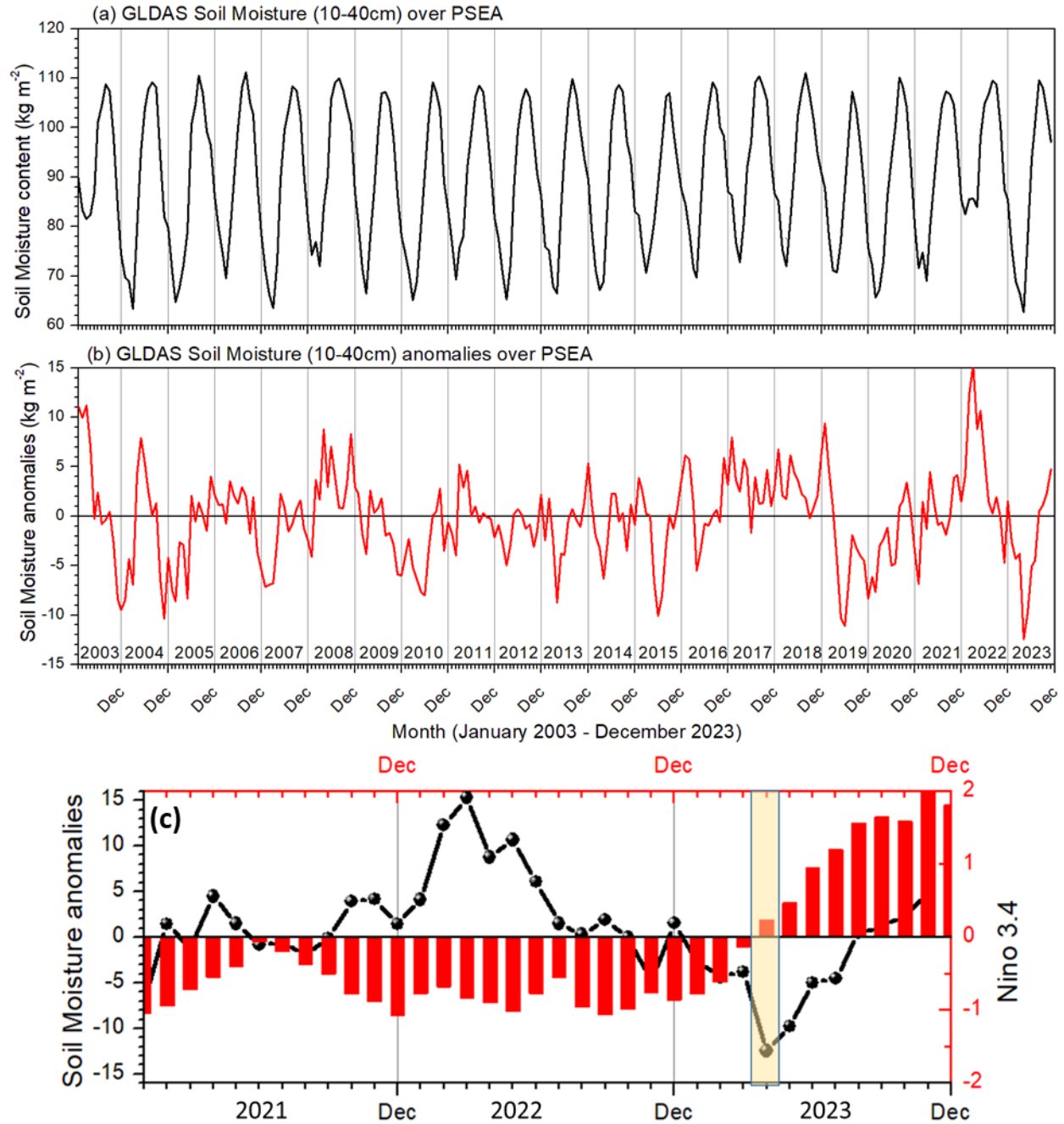


Figure S7. (a) Temporal variation of soil moisture (SM) content over northern Laos, (b) corresponding observed anomalies from January 2003 to December 2023. The evolution of SM anomalies (black) between January 2021 and December 2023, along with the evolution of Niño 3.4 Index (red bars). April 2023 was highlighted in sub plot (c).

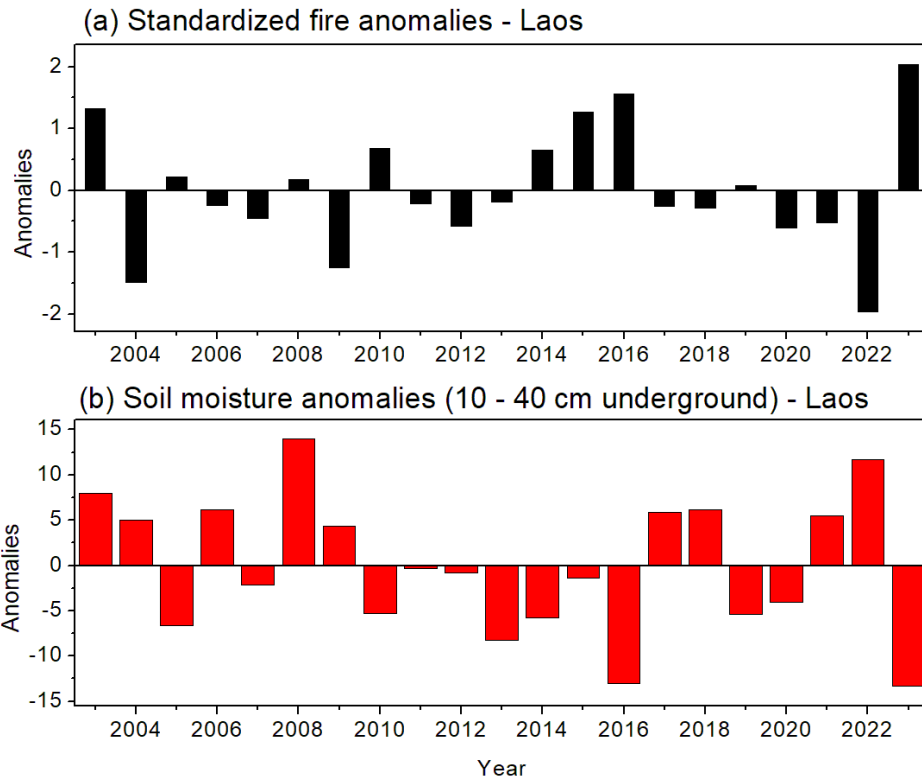


Figure S8. Inter-annual variability in (a) standardized fire anomalies, (b) soil moisture anomalies over Laos in April from 2003 to 2023.

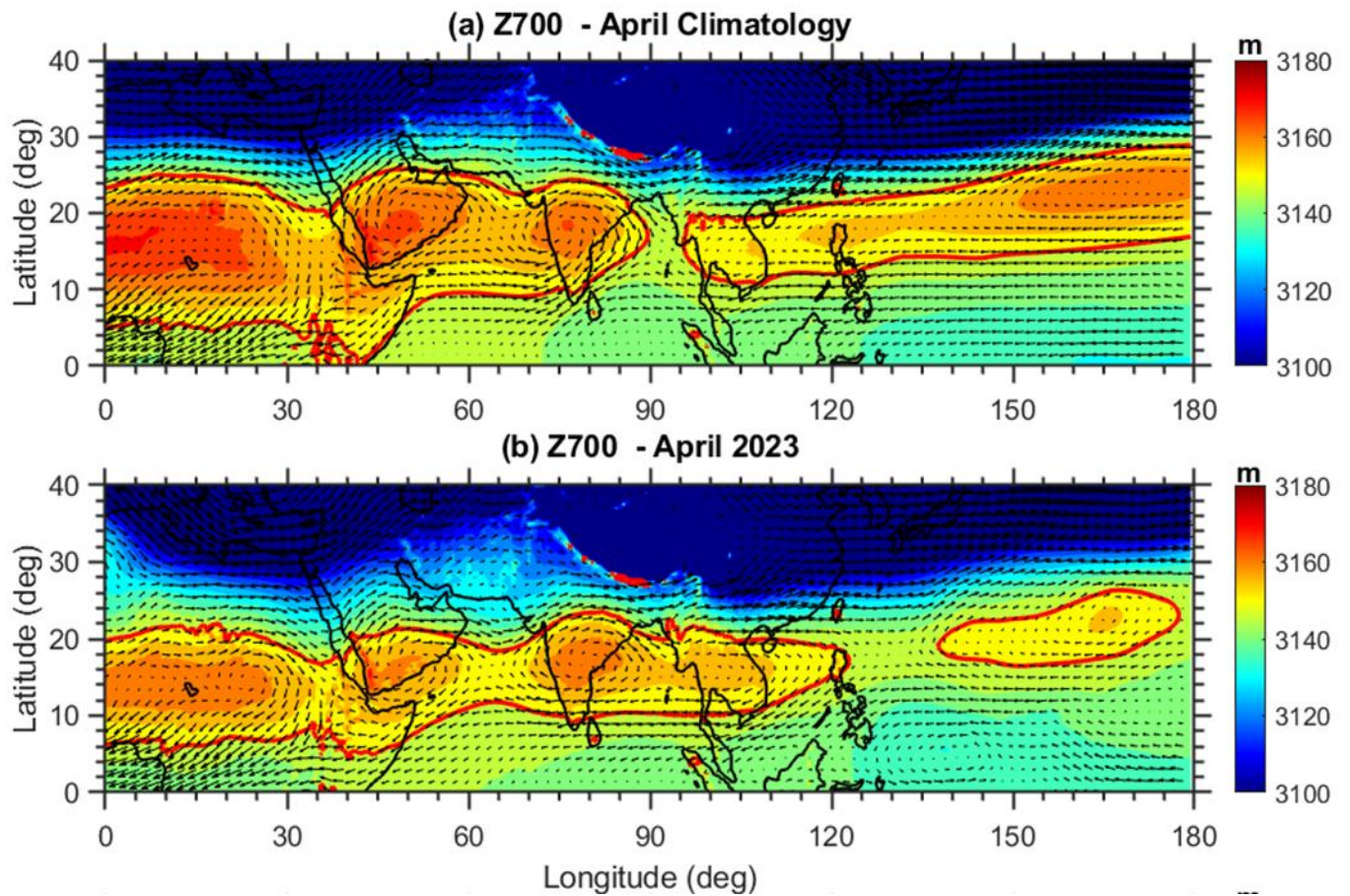


Figure S9. MERRA-2 reanalysis observed 700 hPa geopotential height (Z700) overlapped with the observed winds for (a) long-term April mean (2003-2023), (b) for April 2023.

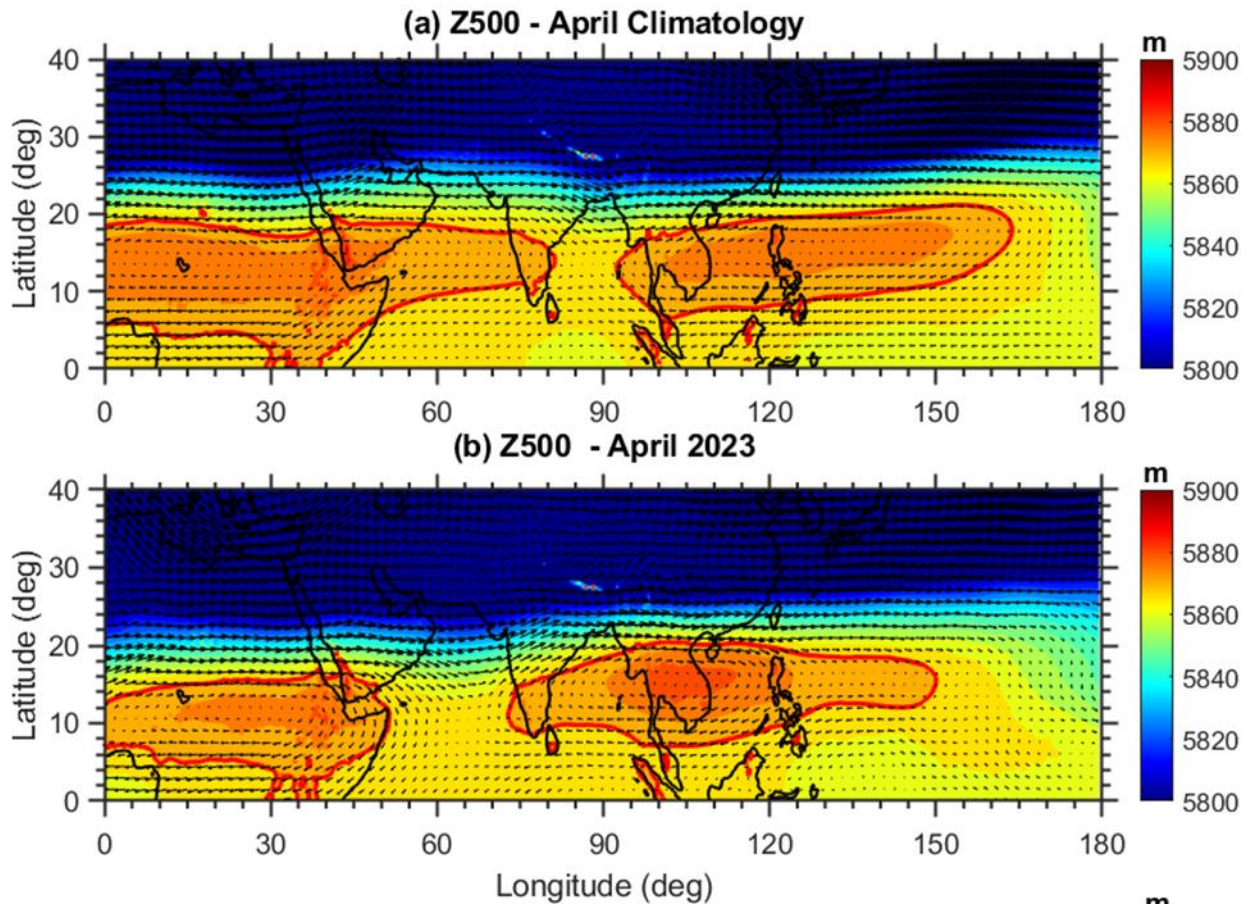


Figure S10. MERRA-2 reanalysis observed 500 hPa geopotential height (Z500) overlapped with the observed winds for (a) long-term April mean (2003-2023), (b) for April 2023.

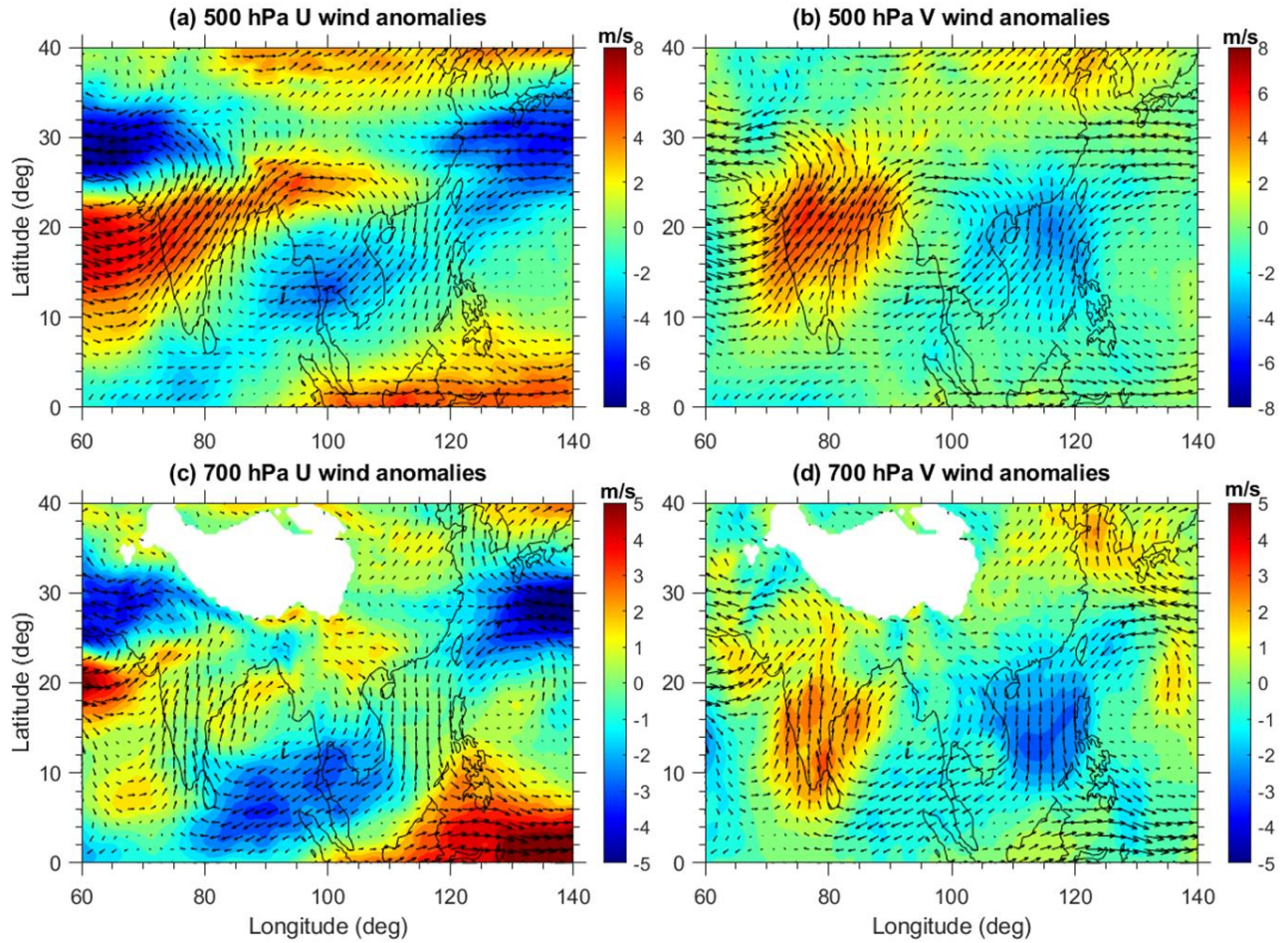


Figure S11. MERRA-2 reanalysis observed (a) 500 hPa zonal wind (U), (b) 500 hPa meridional wind (V) anomalies (color contours) overlapped with the observed wind vectors in April 2023. Subplots (c) and (d) are the same as (a) and (b), but observed at 700 hPa. The anomalies are calculated by subtracting the April 2023 monthly mean from the April climatology for the period 1991 to 2020.

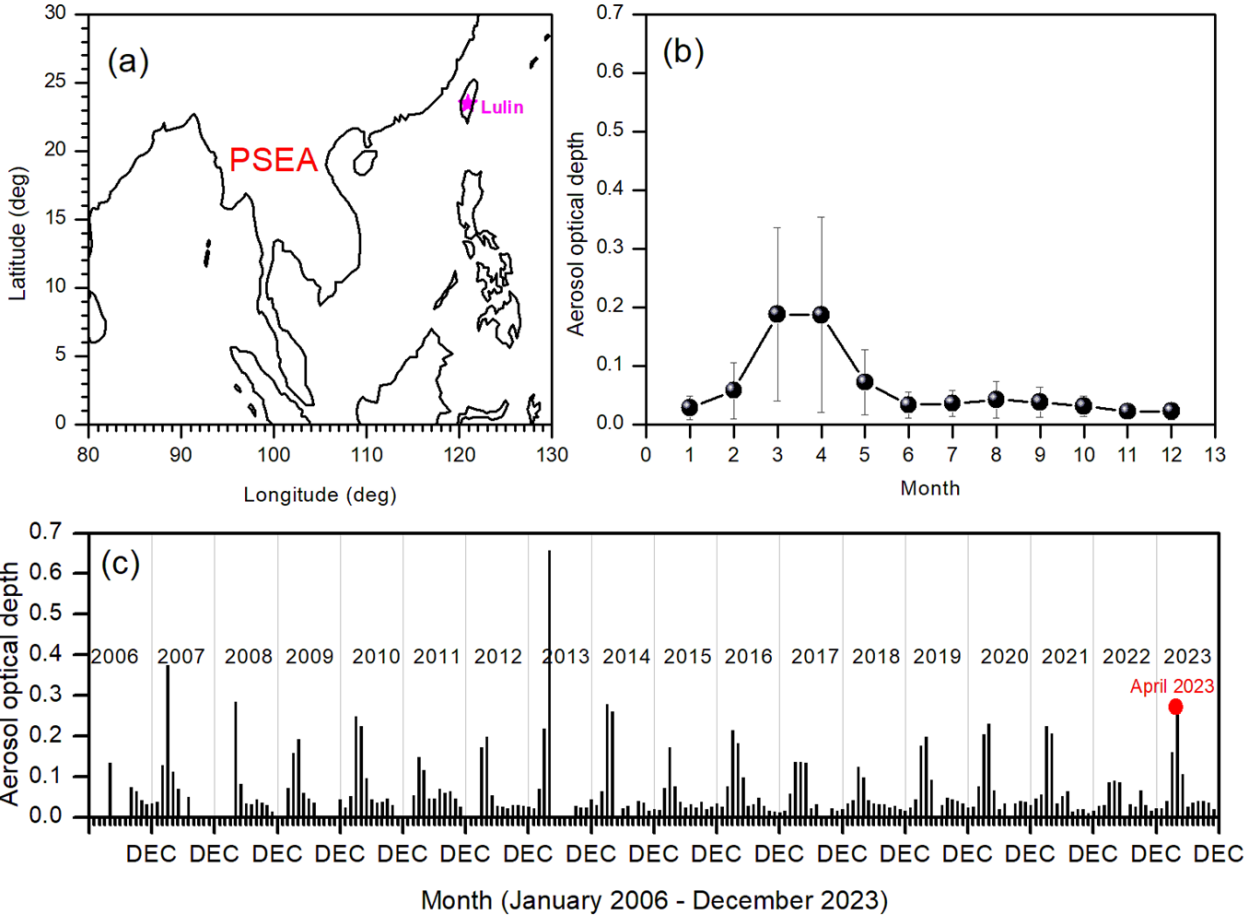


Figure S12. The location of the Lulin Atmospheric Background Station (LABS, 23°28'N, 120°52'E, 2,862 m) AERONET site (denoted by the purple star). (b) Monthly variations in aerosol optical depth (AOD) at Lulin. Vertical error bars represent the standard deviation from the mean. (c) Time series of monthly AOD values from January 2006 to December 2023.

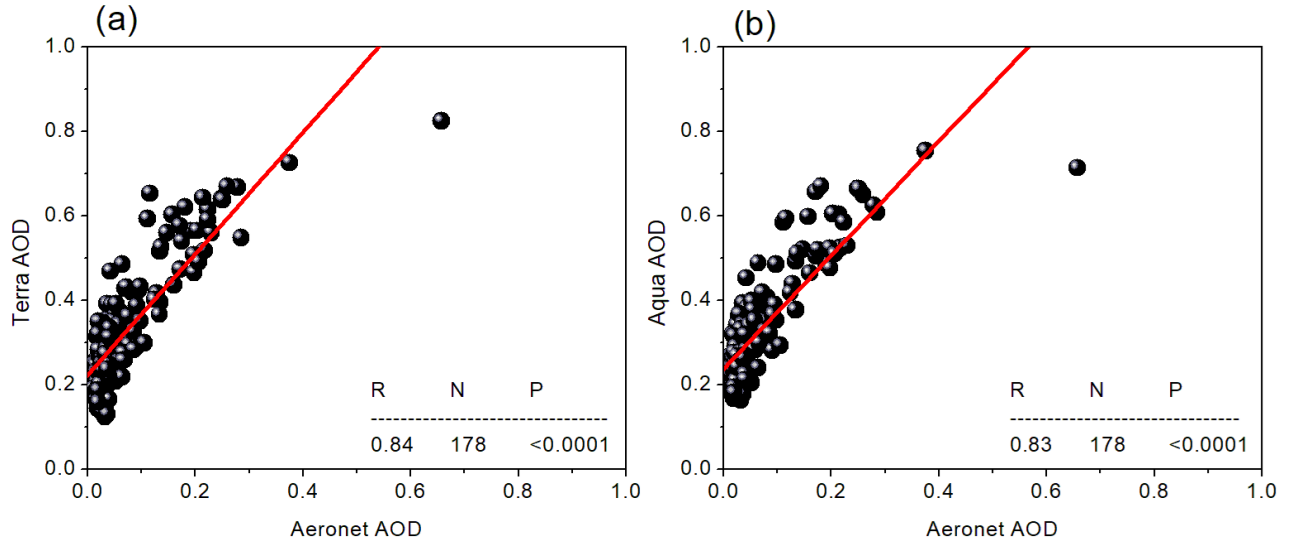


Figure S13. (a) Comparison between AERONET AOD and MODIS Terra AOD, (b) AERONET AOD and MODIS Aqua AOD over LABS during January 2006 to December 2023. (R is the correlation coefficient; N is the sample size; P is the significance value).

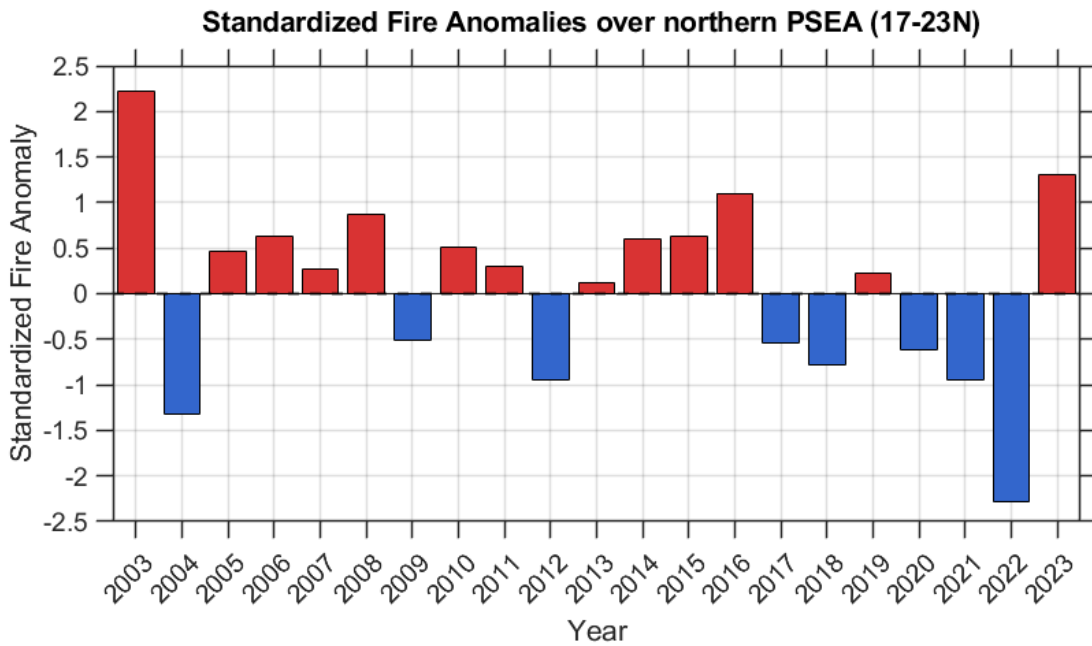


Figure S14. Inter-annual variability in standardized fire anomalies over northern PSEA in April from 2003 to 2023.

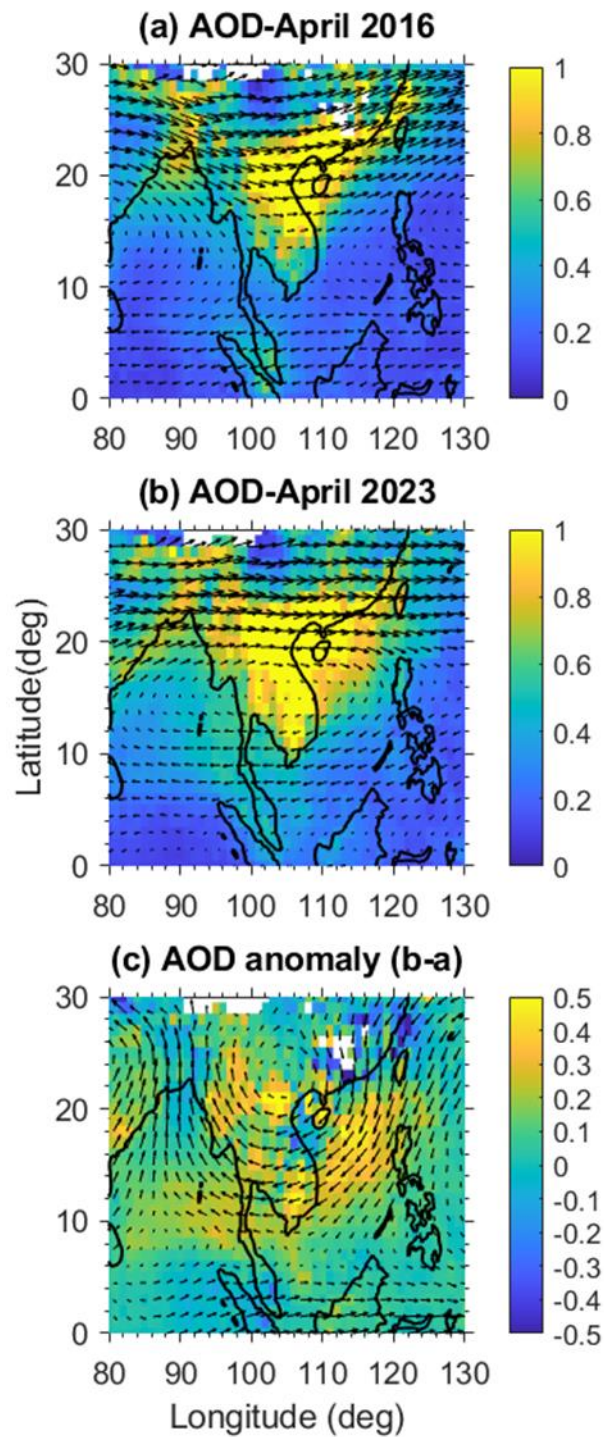


Figure S15. Spatial distribution of MODIS aerosol optical depth (AOD), MERRA-2 500-hPa wind vectors in (a) April 2016, (b) April 2023, and (c) AOD anomalies between April 2023 and April 2016.

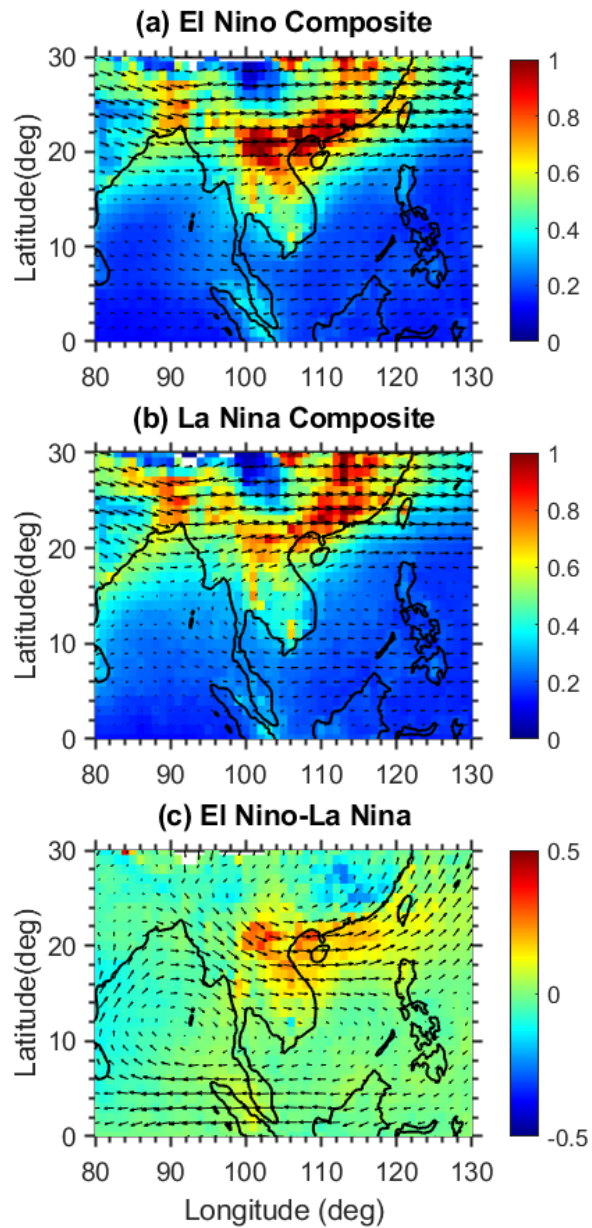


Figure S16. Composite fields of MODIS aerosol optical depth (AOD) and 500-hPa wind vectors for April: (a) El Niño years, (b) La Niña years, and (c) the difference between El Niño and La Niña composites.