

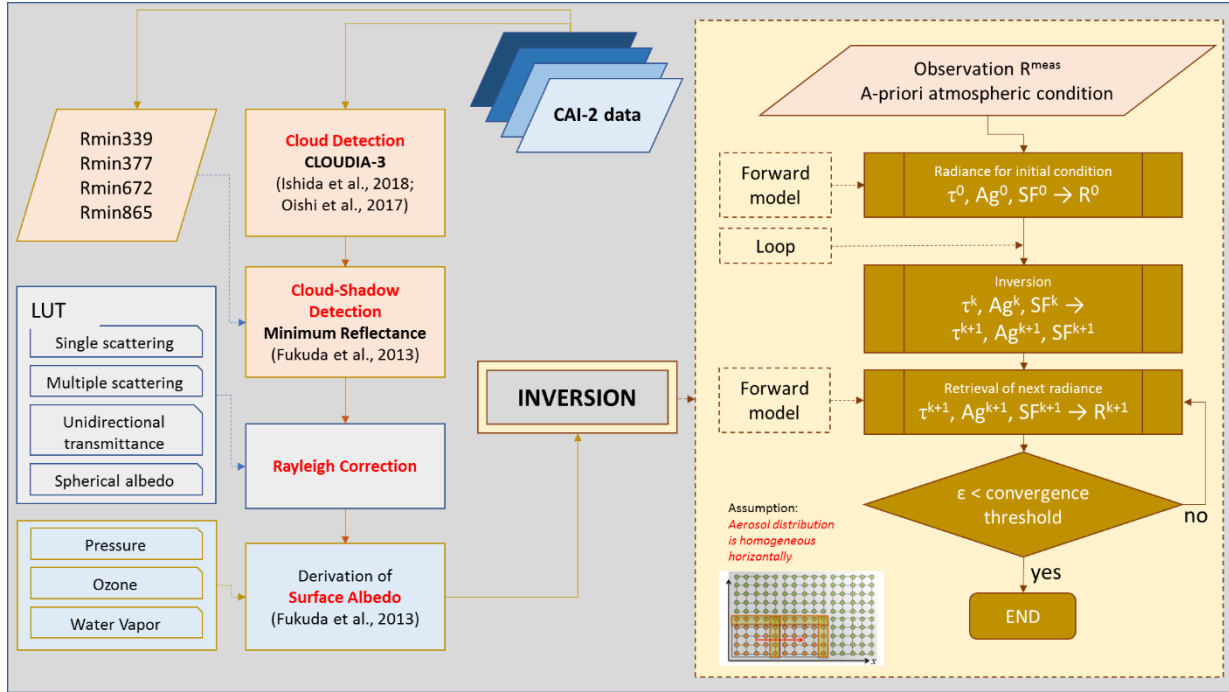
Supplementary Materials

Table T1: Network of aerosol observatories in the ARFINET and their regional classification.

| Region | Station Name | Station Code | Latitude | Longitude |
|--|--------------------|--------------|----------|-----------|
| IGP – Indo Gangetic Plains | Agra | AGR | 27.18 | 78.02 |
| | Delhi | DEL | 28.6 | 77.2 |
| | Gorakhpur | GKP | 26.75 | 83.38 |
| | Kanpur | KNP | 26.4 | 80.3 |
| | Patiala | PTL | 30.33 | 76.46 |
| | Ranchi | RNC | 23.23 | 85.23 |
| | Varanasi | VNS | 25.3 | 82.96 |
| NEI – North-Eastern India | Agartala | AGT | 23.5 | 91.25 |
| | Dibrugarh | DBR | 27.3 | 94.6 |
| | Imphal | IPH | 24.75 | 93.92 |
| | Kharagpur | KGP | 22.5 | 87.5 |
| | Kolkata | KKT | 22.57 | 88.37 |
| | Shillong | SHN | 25.6 | 91.91 |
| NWI – North-Western India | Ahmedabad | AHM | 23.1 | 72.6 |
| | Jaisalmer | JSL | 26.92 | 70.95 |
| | Naliya | NAL | 22.23 | 68.69 |
| | Rajkot | RJK | 22.3 | 70.73 |
| | Udaipur | UDP | 24.6 | 73.9 |
| HIM – Himalayan, sub-Himalayan and foot-hills of Himalayas | Dehradun | DDN | 30.34 | 78.04 |
| | Hanle | HNL | 32.78 | 78.95 |
| | Kullu | KLU | 31.9 | 77.1 |
| | Lachung | LCN | 27.4 | 88.74 |
| | Nainital | NTL | 29.2 | 79.3 |
| | Tawang | TWG | 27.59 | 91.87 |
| CI – Central India | Nagpur | NGP | 21.15 | 79.15 |
| | Bhubaneswar | BBR | 20.2 | 85.8 |
| PI – Peninsular India | Anantapur | ATP | 14.46 | 77.67 |
| | Bangalore | BLR | 12.97 | 77.59 |
| | Challakere | CHK | 14.32 | 76.65 |
| | Chennai | CHN | 12.7 | 79.92 |
| | Goa | GOA | 15.46 | 73.83 |
| | Hyderabad | HYD | 17.47 | 78.58 |
| | Kadappa | KDP | 14.46 | 78.81 |
| | Ooty | OTY | 11.4 | 76.7 |
| | Ponmudi | PMD | 8.8 | 77.1 |
| | Pune | PUN | 18.54 | 73.85 |
| | Thiruvananthapuram | TVM | 8.5 | 77 |
| | Vijayawada | VJD | 16.44 | 80.62 |
| | Visakhapatnam | VSK | 17.7 | 83.1 |
| IL – Island Location | Port-Blair | PBR | 11.64 | 92.71 |

5 **Table T2: Statistical fit parameters between satellite-retrieved (BC_{SAT} , 1 x 1-degree horizontal grid) and near-surface BC (BC_{SUR} , climatological monthly average values at different stations during 13:00 – 14:00 hrs. local time for the period 2015-2019) concentrations at different months.**

| | R | slope | intercept | N |
|-----|----------|-----------------|------------------|----------|
| Dec | 0.36 | 0.39 ± 0.22 | 2.36 ± 0.64 | 25 |
| Jan | 0.46 | 1.23 ± 0.53 | 0.49 ± 1.25 | 23 |
| Feb | 0.68 | 0.98 ± 0.21 | -0.43 ± 0.61 | 28 |
| Mar | 0.74 | 1.31 ± 0.23 | -0.97 ± 0.62 | 29 |
| Apr | 0.61 | 1.17 ± 0.30 | -0.97 ± 0.76 | 29 |
| May | 0.79 | 0.66 ± 0.12 | -0.04 ± 0.21 | 26 |
| Jun | 0.60 | 1.12 ± 0.34 | 0.22 ± 0.41 | 26 |
| Jul | 0.63 | 3.02 ± 0.77 | 0.29 ± 0.92 | 27 |
| Aug | 0.60 | 2.13 ± 0.63 | 1.22 ± 0.68 | 24 |



15 **Figure S1: Flowchart of CAI-2 L2 pre-processing algorithm (GOSAT-2 project: GOSAT-2/CAI-2 Level-2 Preprocessing Theoretical Basis Document - ATBD).**

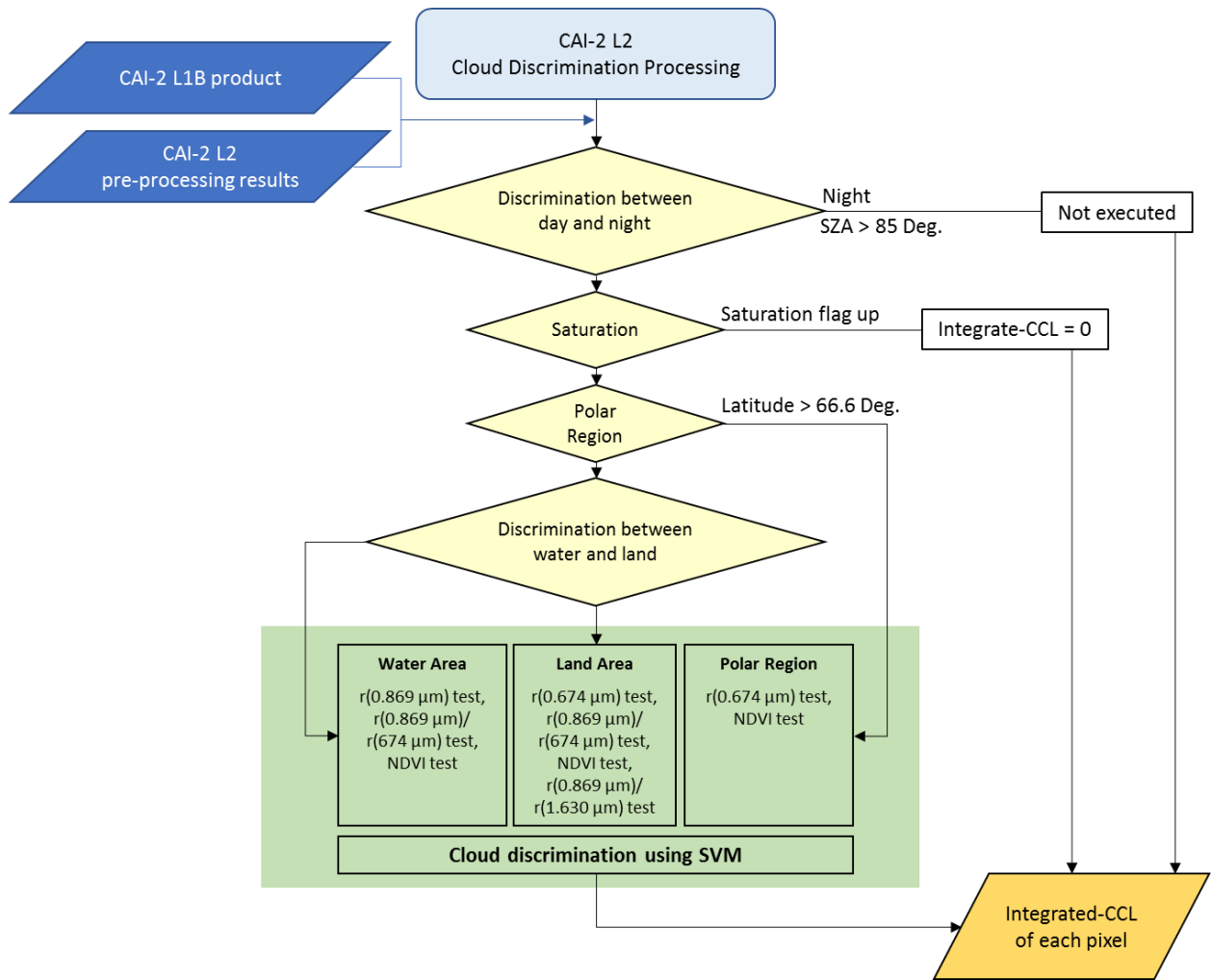
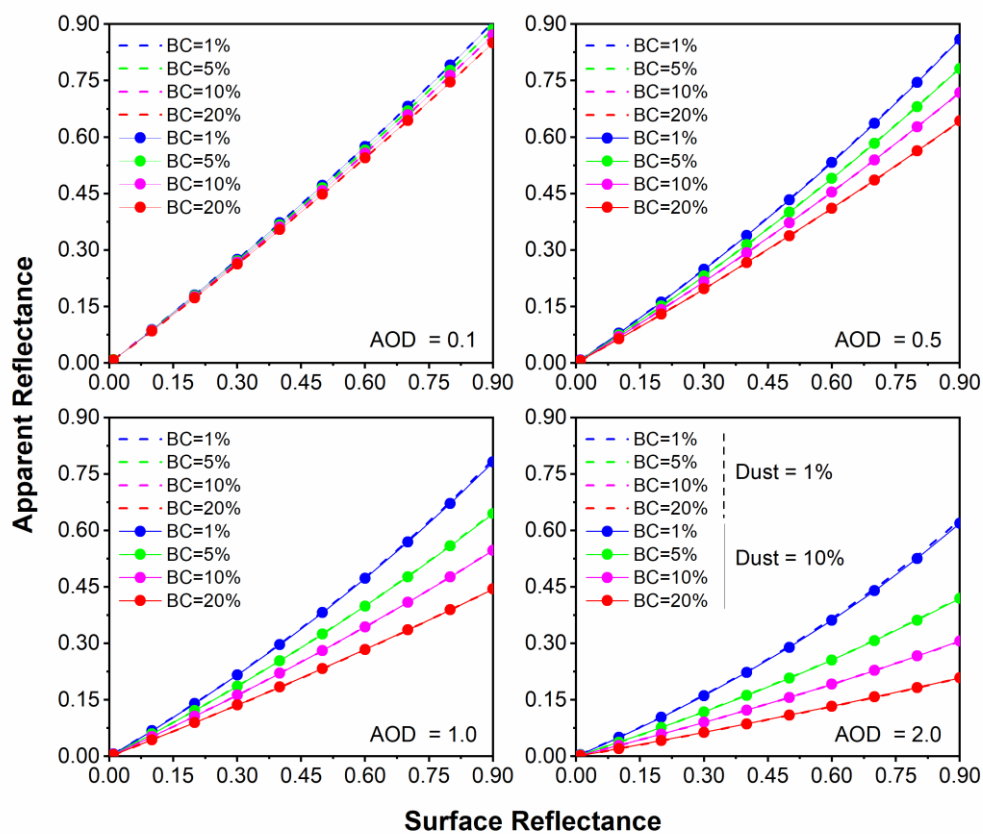


Figure-S2: The Flowchart of flow-chart of the Cloud and Aerosol Unbiased Decision Intellectual Algorithm (CLAUDIA3).



25 **Figure-S3:** Variability of apparent reflectance of satellite observation at 0.880 μm wavelength with surface reflectance for different fractions of BC (1%, 5%, 10% and 20%), dust (1% and 10%) under different conditions of AOD (0.1, 0.5, 1.0, 2.0). The fraction of water-soluble species is kept constant (50%). The solar zenith and azimuth angles are 40° and 100°, and satellite viewing angle and azimuth angle are 45° and 50° respectively. The surface reflectance is considered for homogeneous Lambertian surface.

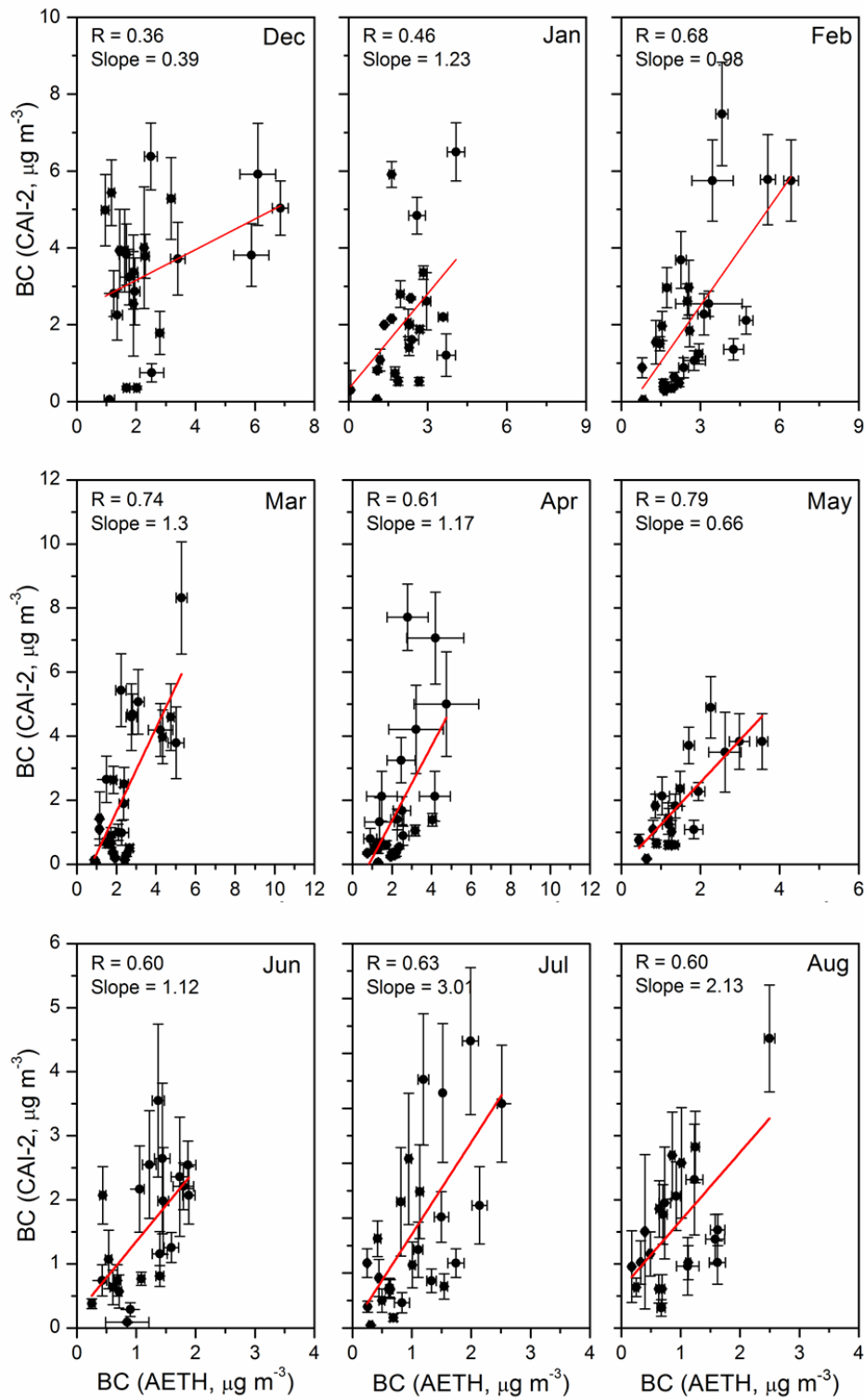
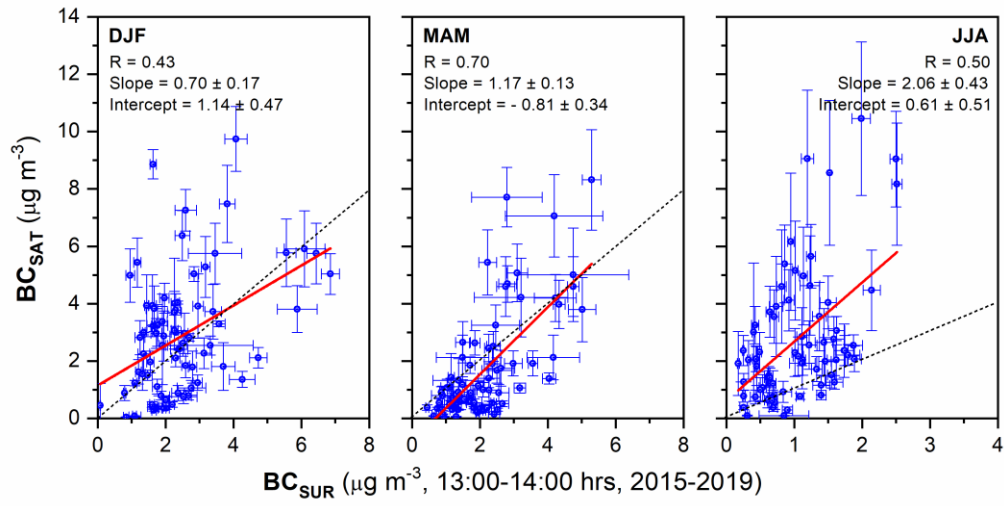


Figure S4: Comparison of monthly average BC from satellite (averaged over 1 x 1-degree area around each of the ARFINET sites) and surface measurements (during 13:00-14:00 hrs. local time for the period 2015-2019) at different locations during DJF, MAM and JJA. The solid red line is the linear fit of BC_{SAT} and BC_{SUR} .



40 Figure S5: Comparison of monthly average satellite BC (1 x 1-degree area average values around each of the point locations in the ARFINET) with surface BC (during 13:00-14:00 hrs. local time for the period 2015-2019) at different seasons, representing winter, pre-monsoon and monsoon. The solid red line is the linear fit, and the grey dash line is the one-to-one line of BC_{SAT} and BC_{SUR} .

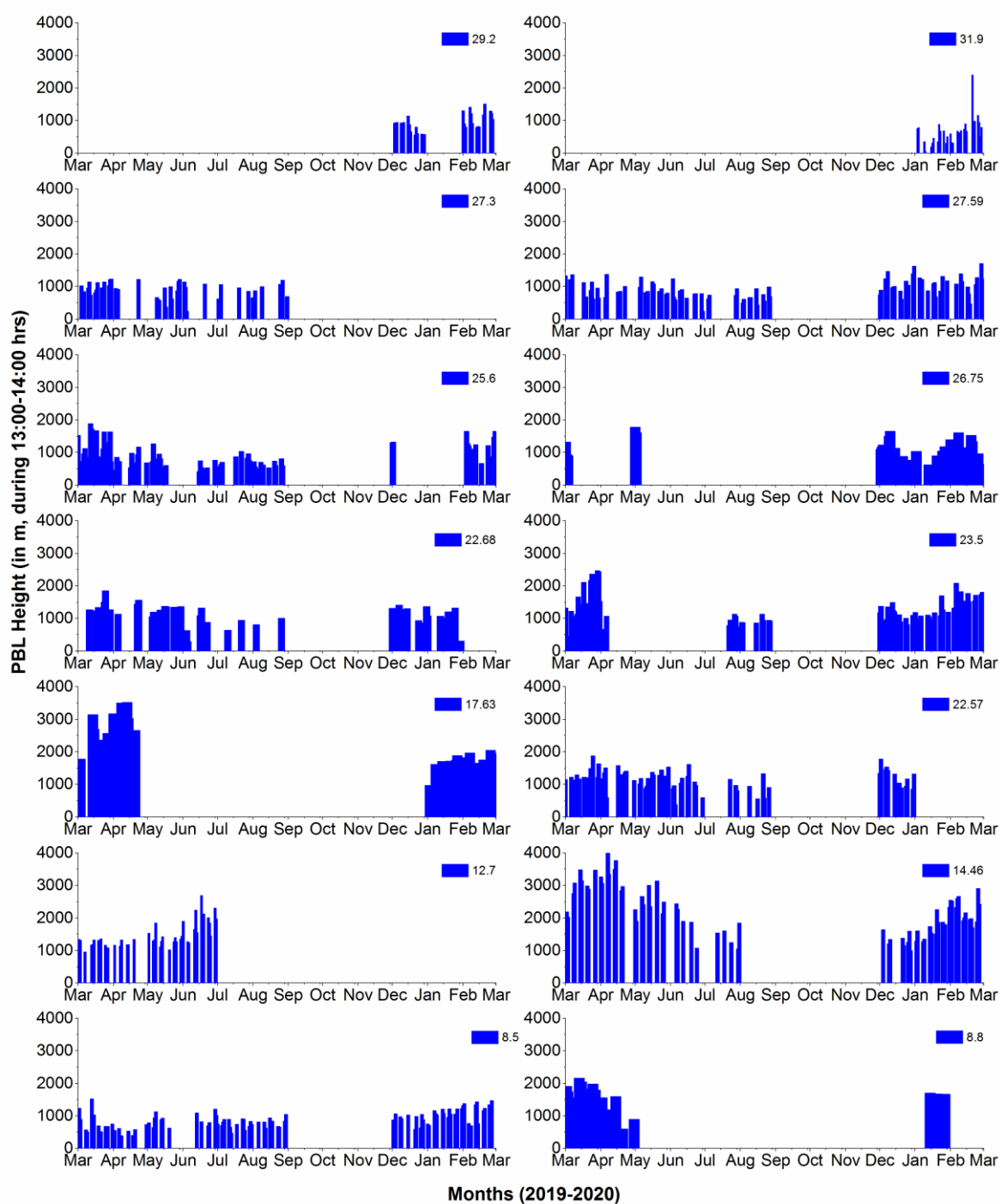


Figure S6: Day to day variability of planetary boundary layer (PBL) height (in m) over different locations of India. The days shown here correspond to the days of simultaneous measurements of BC from satellite and surface.

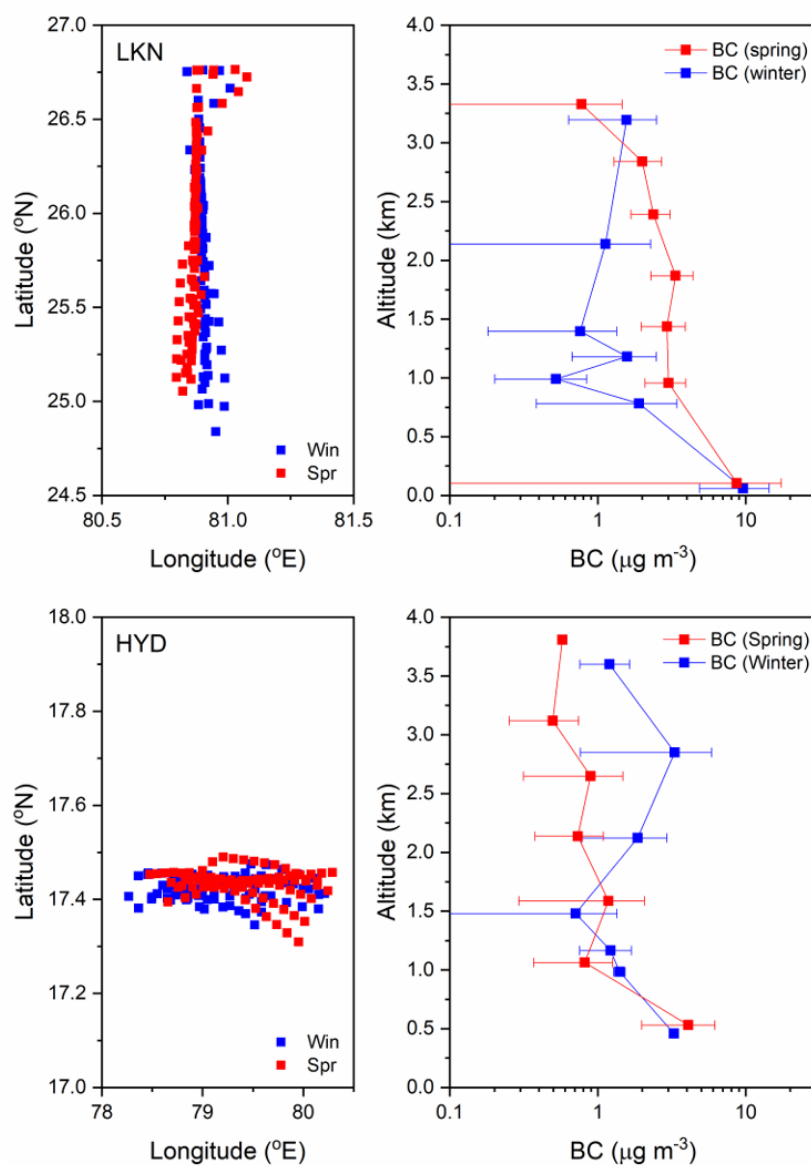


Figure-S7: Vertical profiles of BC (right panels) during two distinct periods of winter (December) and spring (May) over Hyderabad (central India) and Lucknow (Indo-Gangetic Plains). The horizontal bars show the standard deviations of the mean. The foot prints of the data acquisition along the flight tracks are also shown in the left panels.

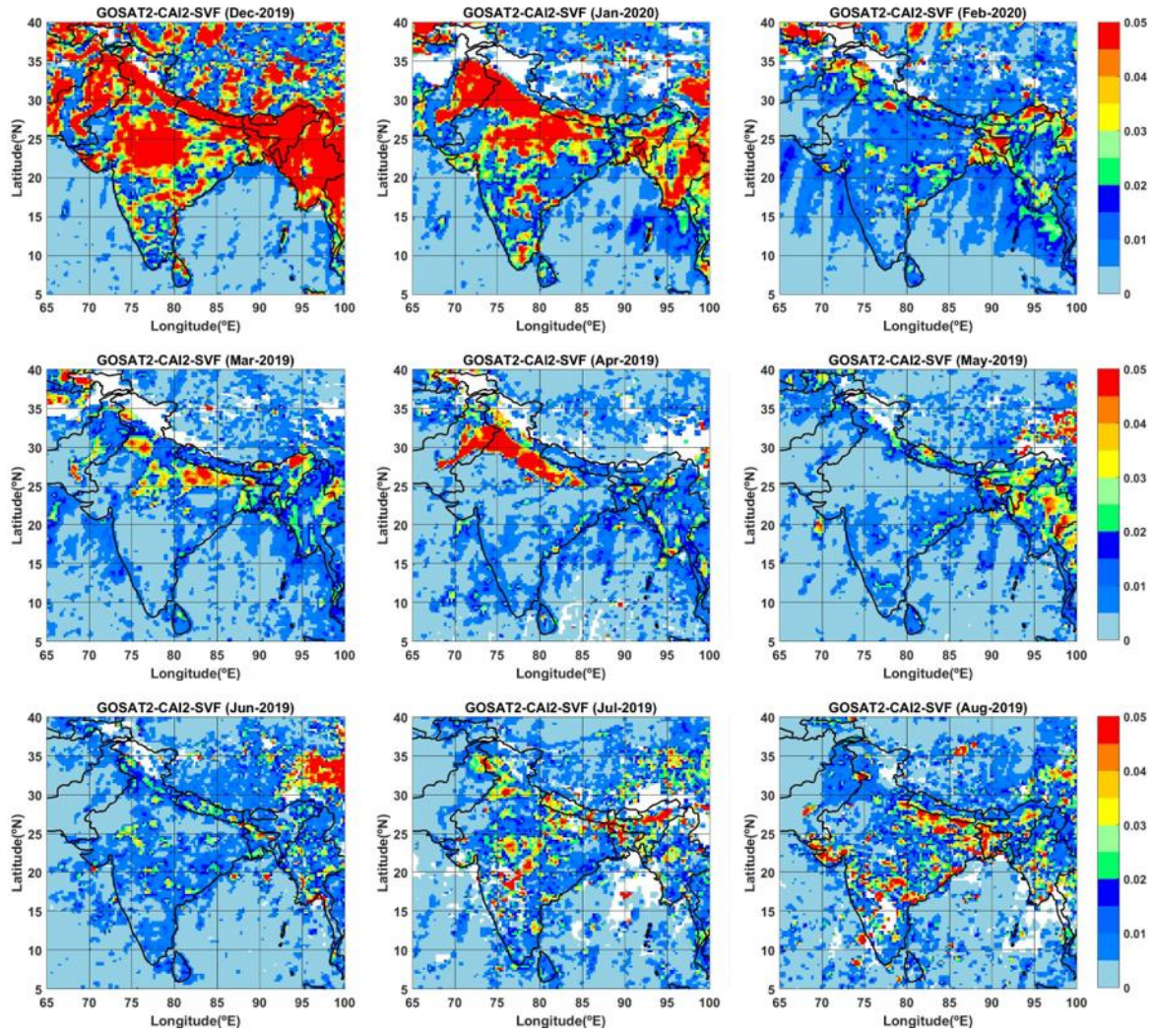
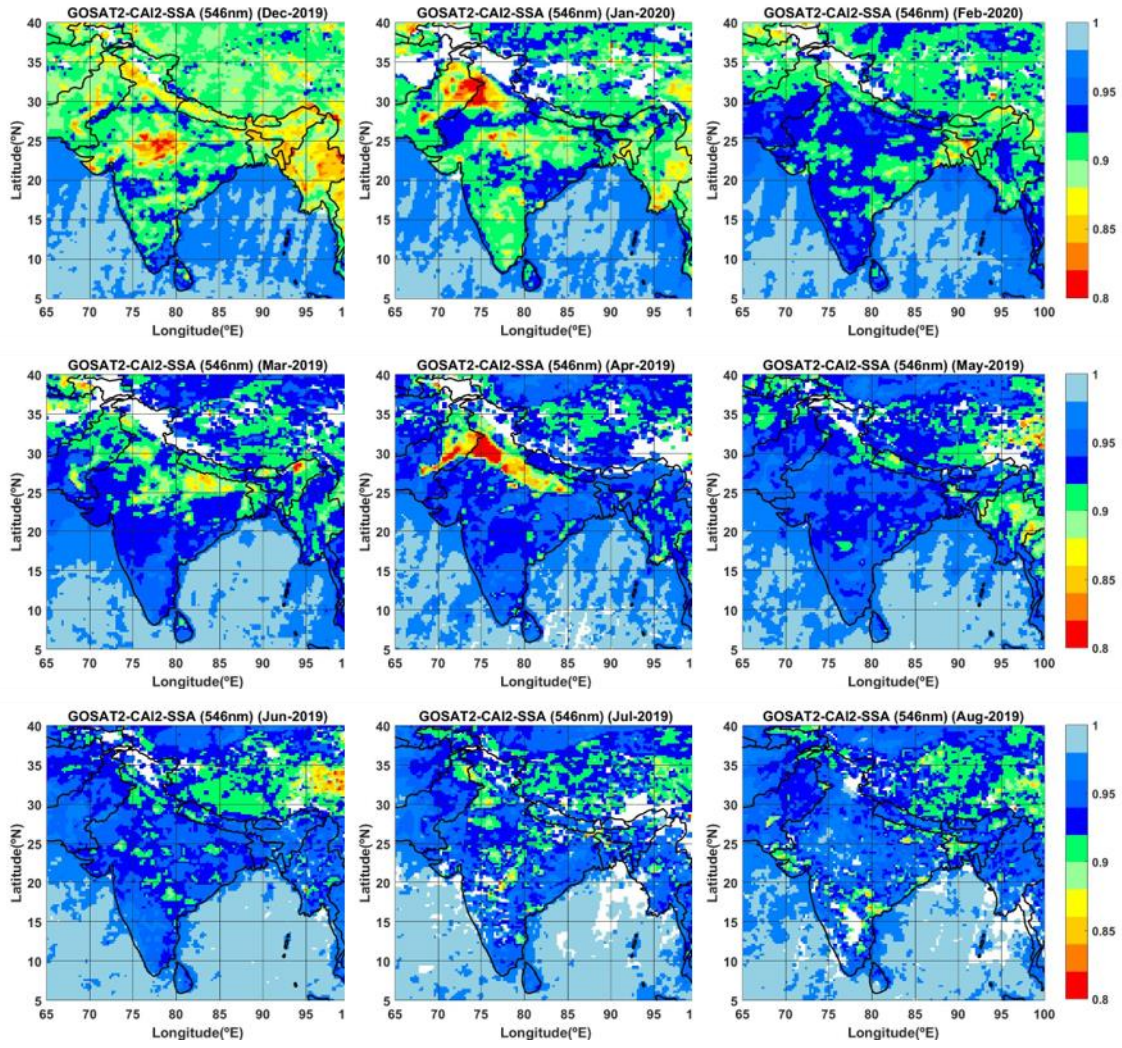


Figure S8: Regional distribution (monthly average) of soot volume fraction (SVF) during DJF, MAM and JJA.



60 Figure S9: Regional map (monthly average) of aerosol single scattering albedo (SSA) at 546 nm during DJF, JJA and MAM from CAI-2.

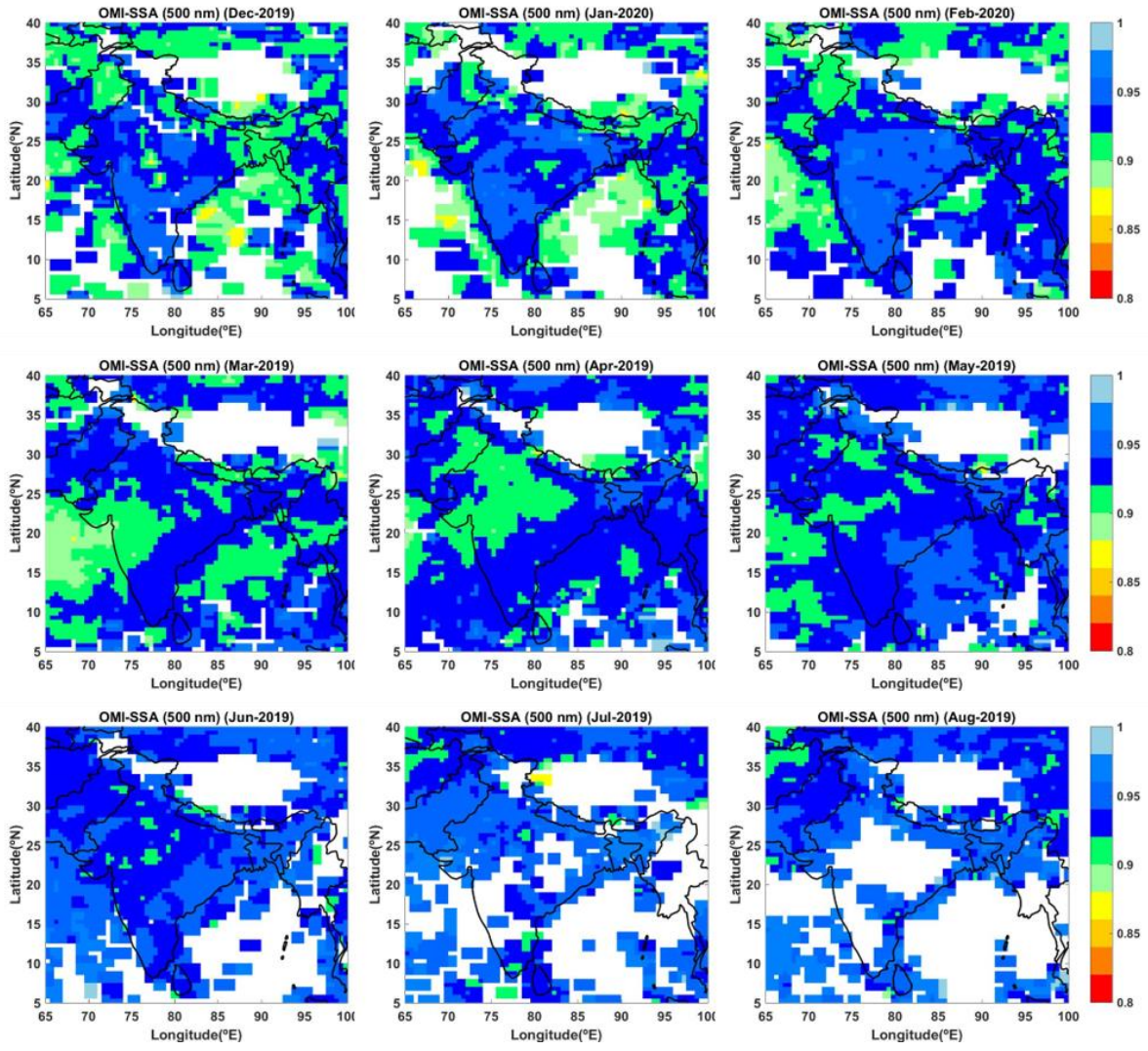


Fig.S10: Regional map (monthly average) of aerosol single scattering albedo (SSA) at 550 nm during DJF, JJA and MAM from OMEAUvd.

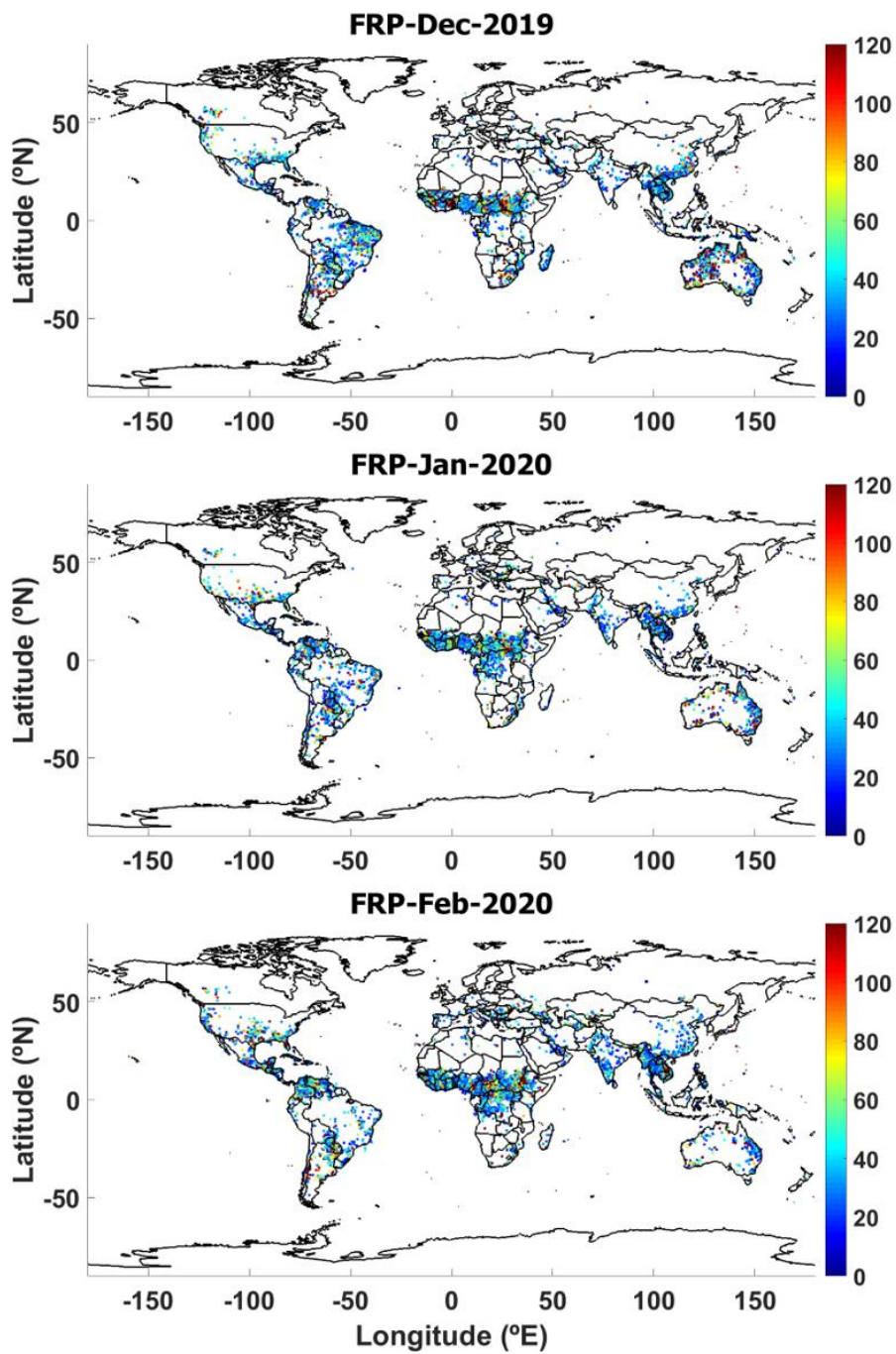
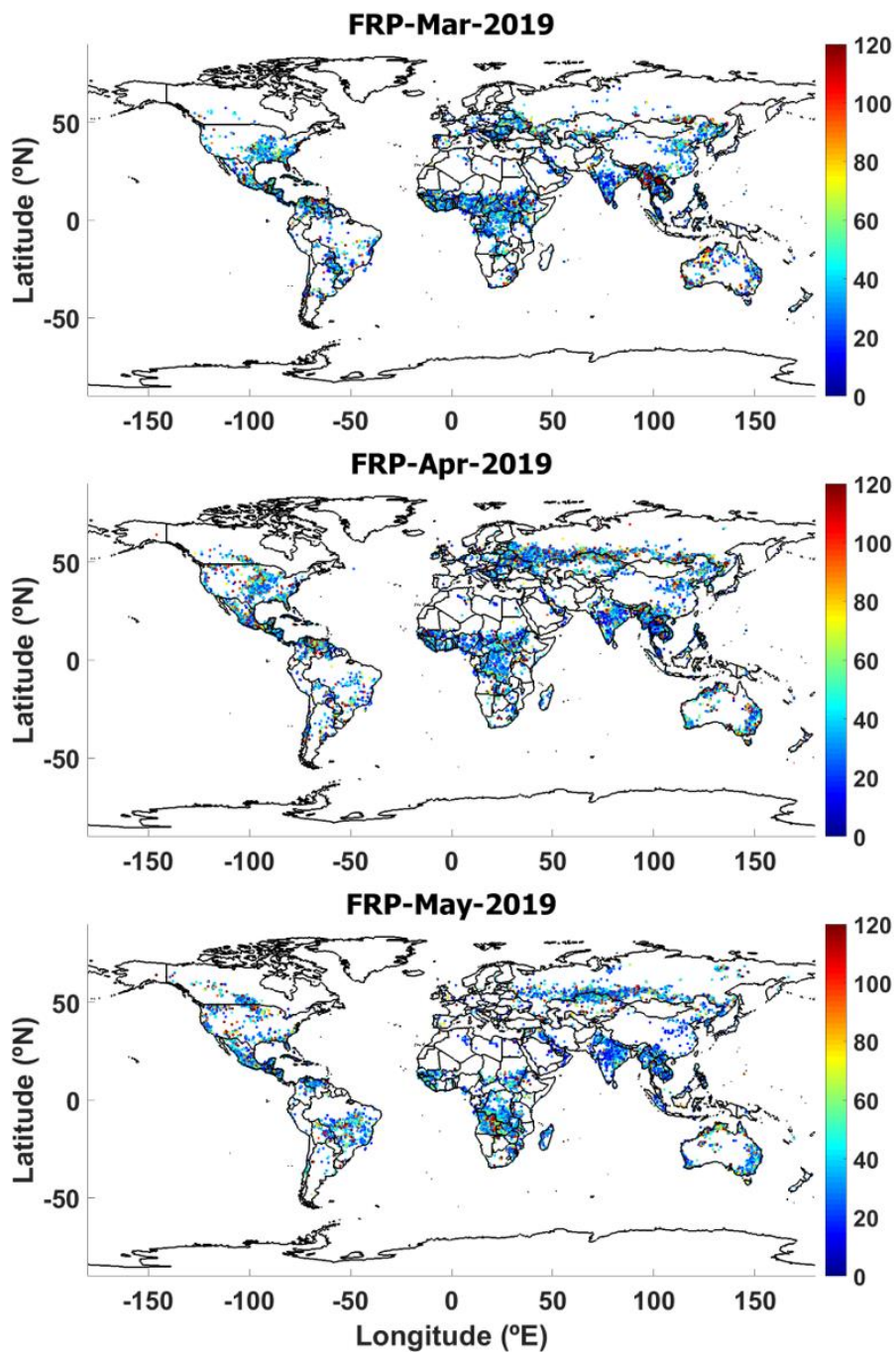


Figure S11: Fire radiative power (FRP, in MW) during DJF.



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Figure S12: Fire radiative power (FRP, in MW) during MAM.

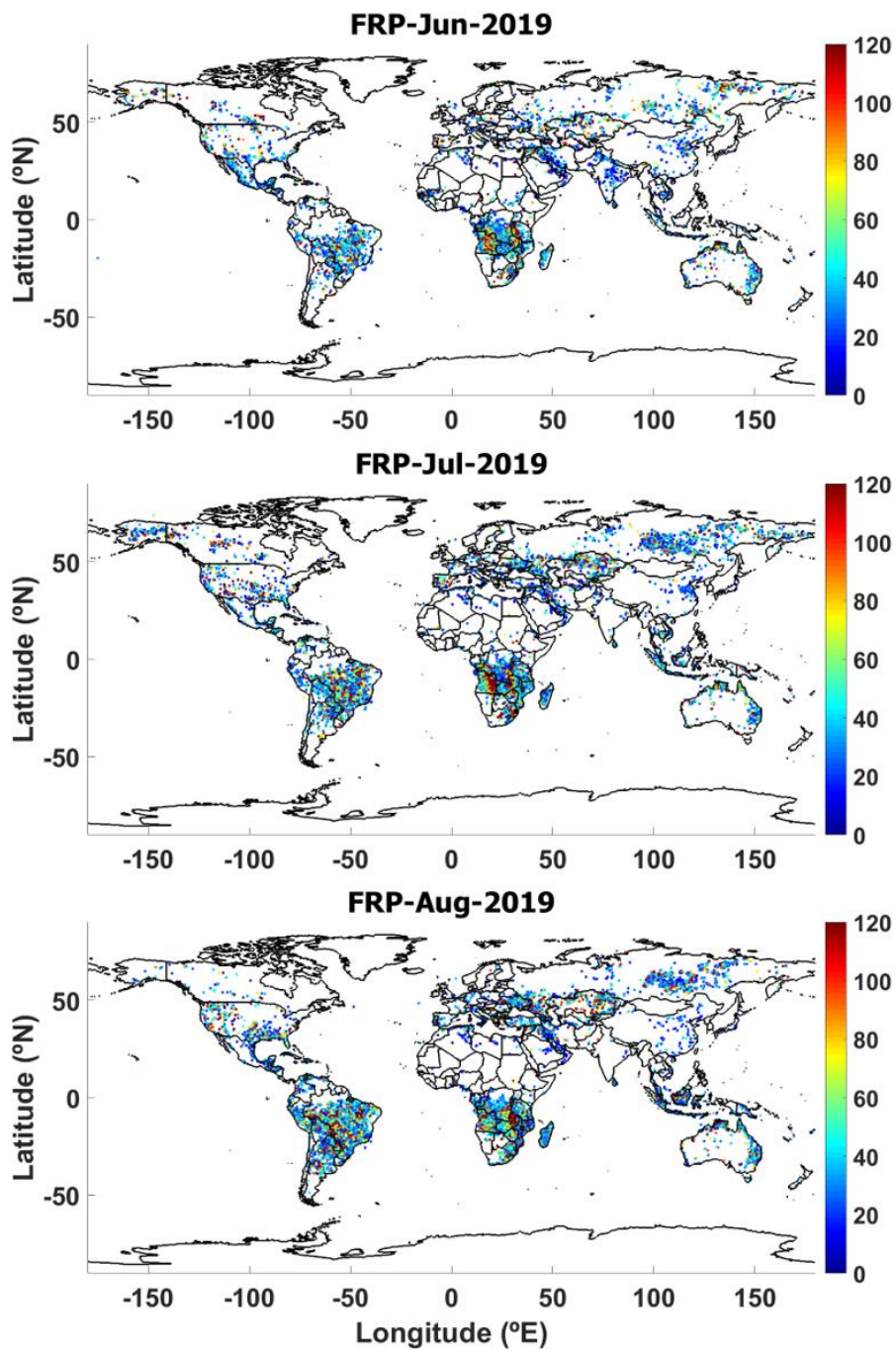


Figure S13: Fire radiative power (FRP, in MW) during JJA.

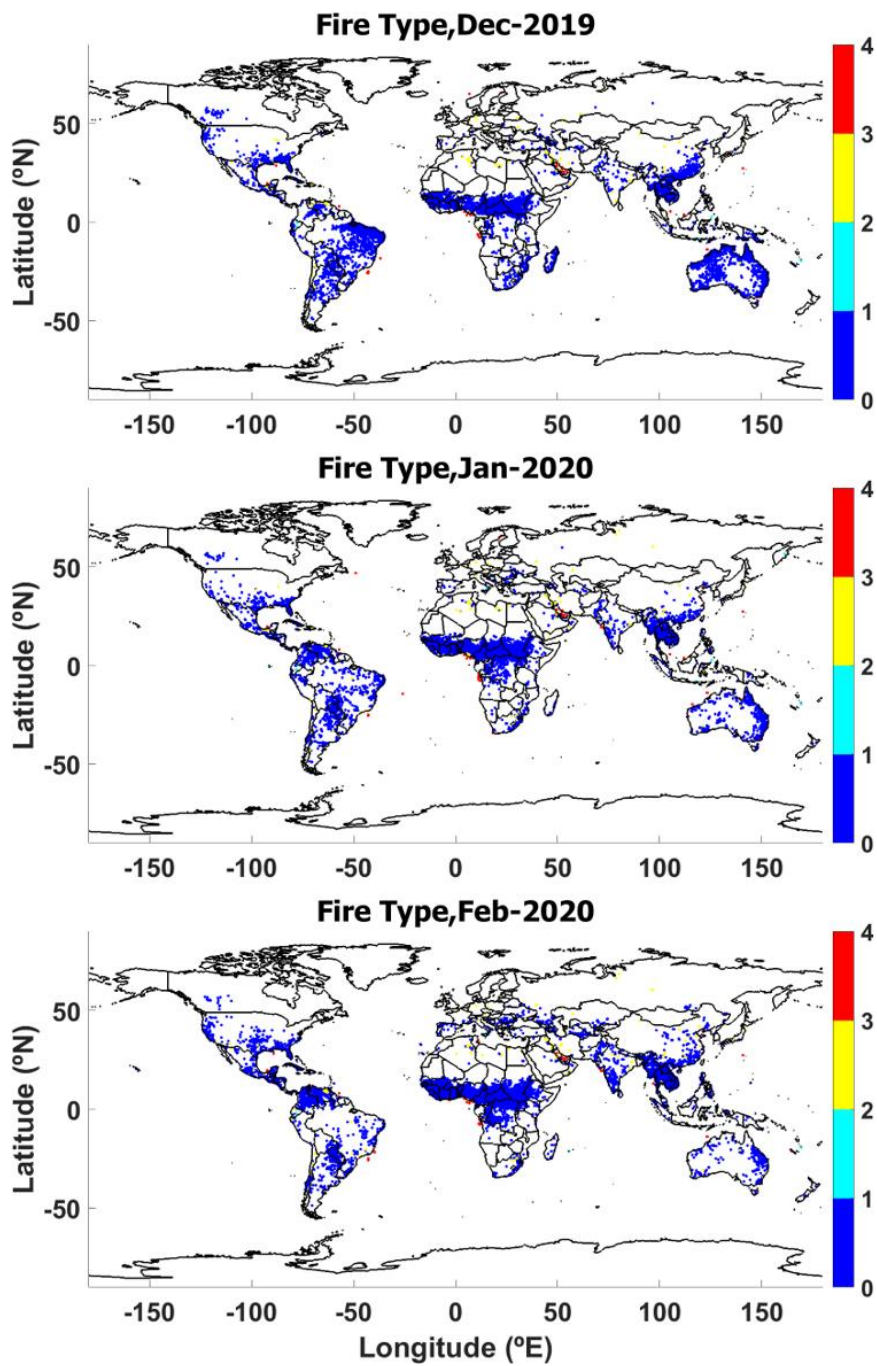


Figure S14: Fire type during DJF; 1 - vegetation fire, 2 - active volcano, 3 - static land shore and 4 - offshore.

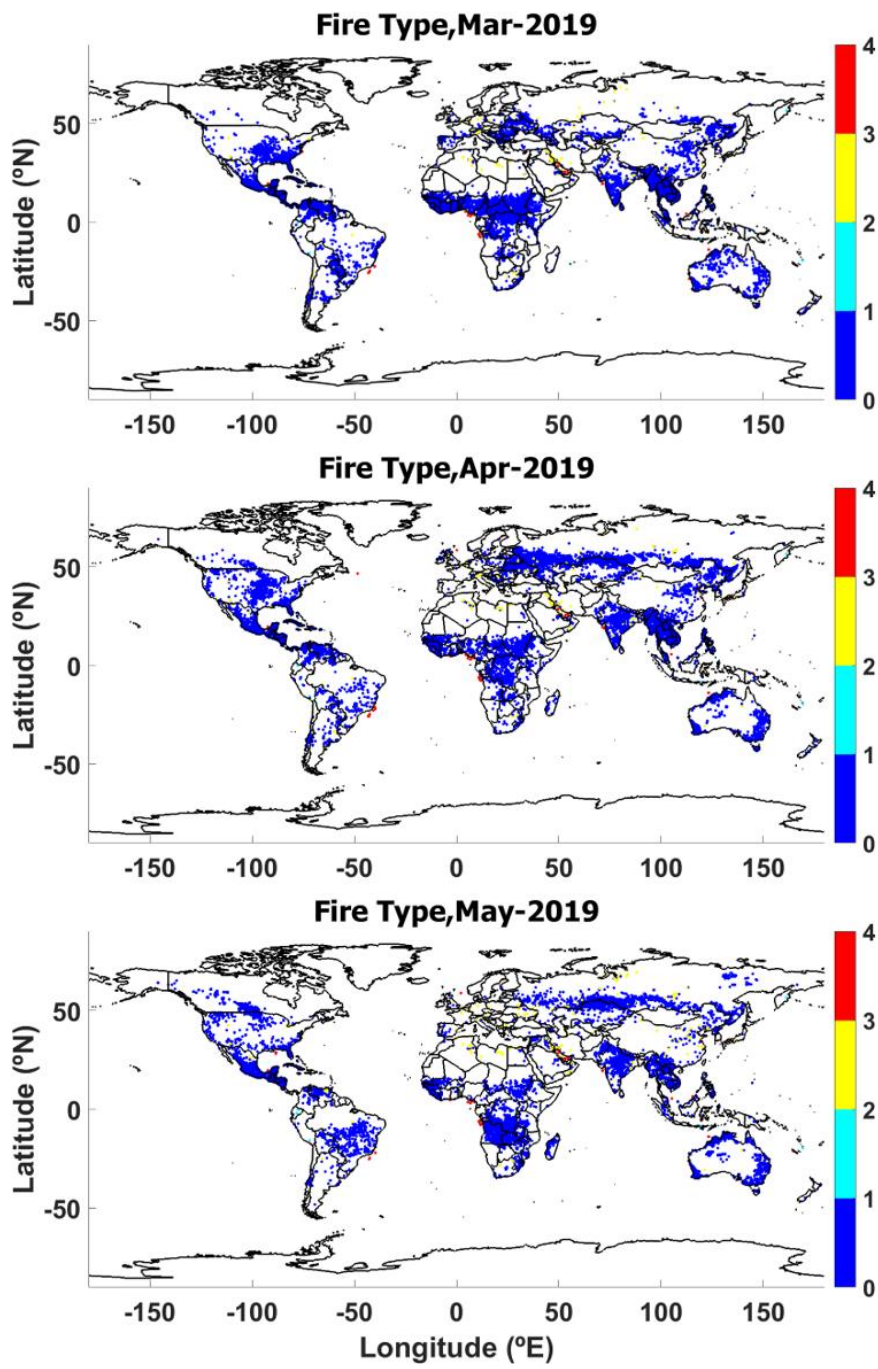


Figure S15: Fire type during MAM.

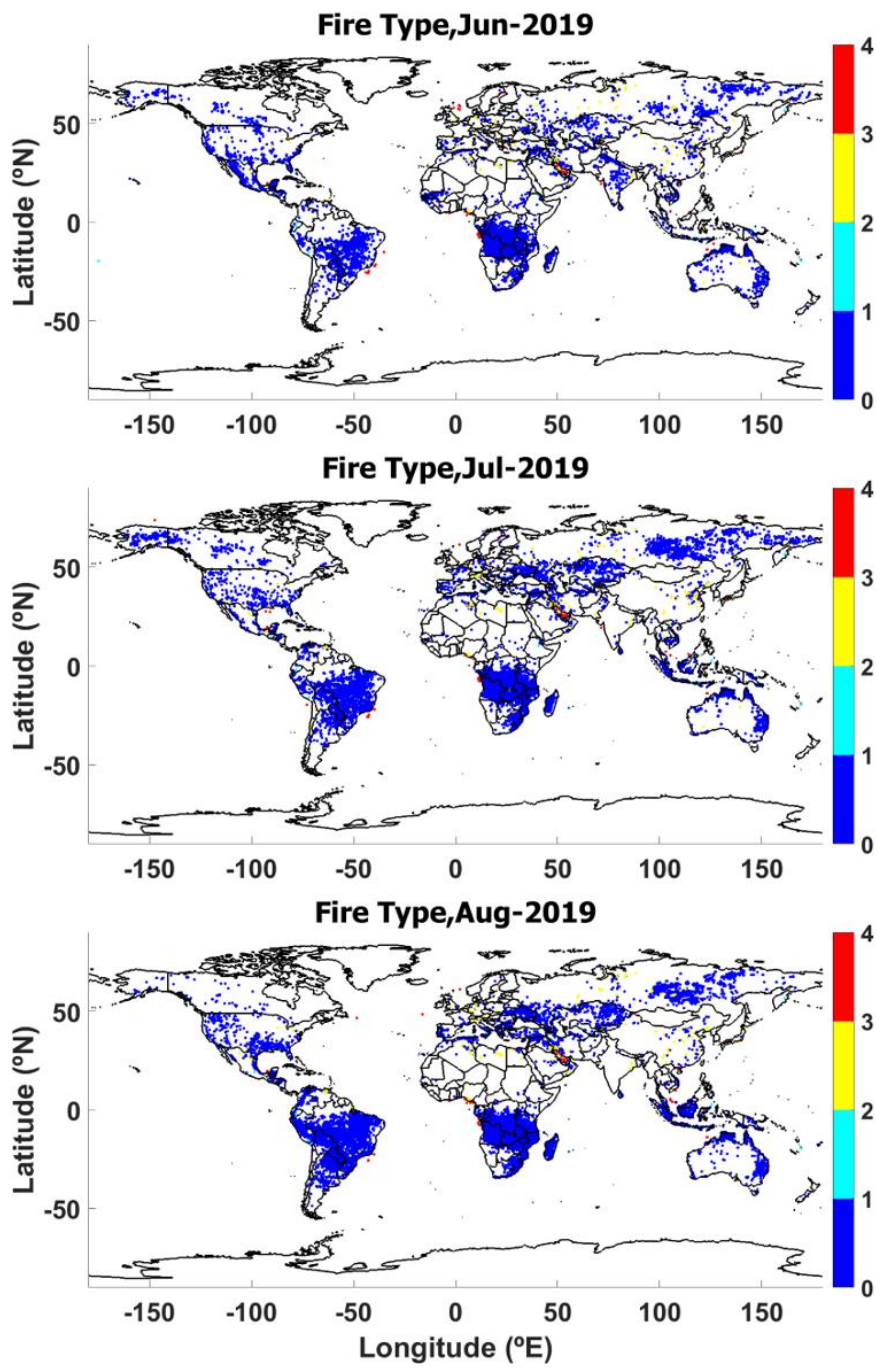


Figure S16: Fire type during JJA.