Impact of Aerosols and Clouds on Solar Energy Production over India

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Motivation & Methodology

The vast development, urbanization, industrialization, rapid population growth and growing energy demands in the region of India requires serious efforts from the Government of India in order to provide sustainable and viable development. In this context, the renewable energy is one of the best options compared to the other sources of energy due to the solar energy potential of the region and the available area for the installation of new solar projects. Recently, the Government of India, has a clear vision to promote the renewable/solar energy (Dumka et al., 2021, 2022 and references cited therein) and it becomes a fast-growing industry and trend over the India. At the same time, the attenuation of solar radiation reaching to the earth surface by aerosols, clouds, smoke as well as dust received significant attention as the change in amount of solar radiation have profound implication on the surface radiation budget and solar energy production. Therefore, the adequate knowledge about the effects of aerosols, clouds, smoke as well as dust is quite challenging task especially over the south Asia as the aerosol loading over the region is very complex. These aerosols and pollutants have significant impact on global horizontal irradiance (GHI) as well as beam horizontal irradiance (BHI) and the corresponding attenuation will reduce the efficiency of solar power plants by photovoltaics (PV) and Concentrated Solar Power (CSP) plants. With this background information, we study the impact of aerosols, clouds and smoke on the solar energy over India via using the remote sensing techniques described in detail in Dumka et al. (2021; 2022). In brief, we exploited the synergy of remote-sensed data in terms of satellite observations from the MODerate Resolution Imaging Spectroradiometer (MODIS), the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIPSO) and the Satellite Application Facility on support to Nowcasting/Very Short-Range Forecasting Meteosat Second Generation (SAFNWC/MSG) in conjunction with radiative transfer model (RTM) simulations and 1 day forecasts from the Copernicus Atmosphere Monitoring Service (CAMS). The results show that on an annual basis, the aerosol attenuation was 105 kWh m-2 for GHI and 266 kWh m-2 for BHI, respectively. The corresponding cloud effect is much larger with 245 and 271 kWh m-2. The energy production during the first quarter of 2021 was found to reach 650 kWh/m2 and the revenue generated was about INR (Indian rupee) 79.5 million. During the study period, the total attenuation due to aerosols and clouds was estimated to be 116 and 63 kWh/m2 for GHI and BHI, respectively. The financial loss due to the presence of aerosols was found to be INR 8 million, with the corresponding loss due to clouds reaching INR 14 million for the total Indian solar plant's capacity potential (40 GW). The findings of the present study will drastically increase the awareness among the decision makers in India about the indirect effects of aerosols and clouds on renewable energy production.

Results

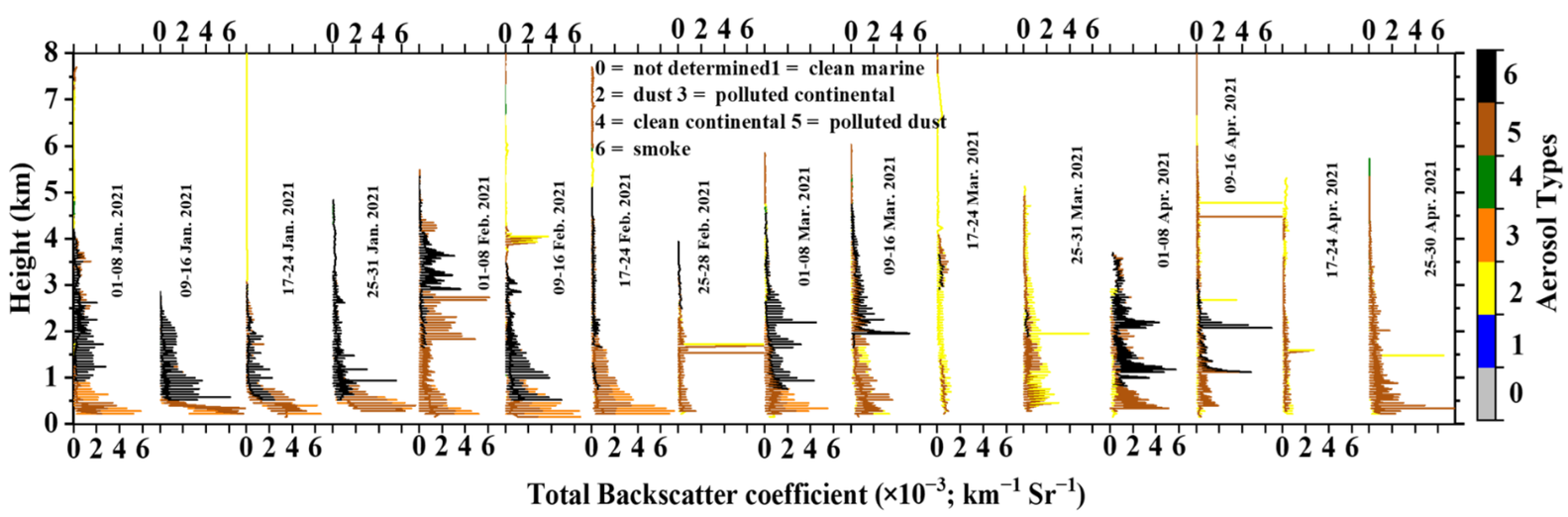


Figure A: Weekly mean vertical profiles of the total backscattering coefficient during January to April 2021. The color bars show the aerosol type.

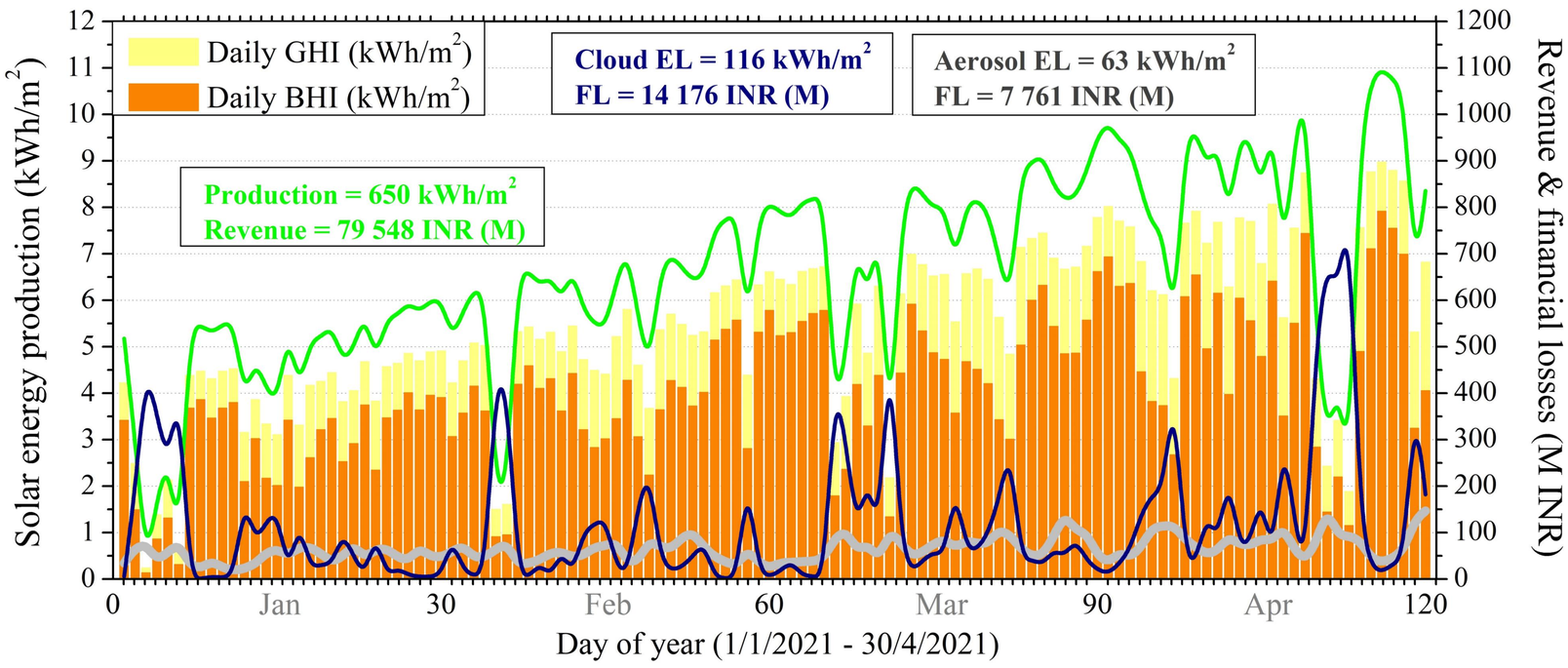
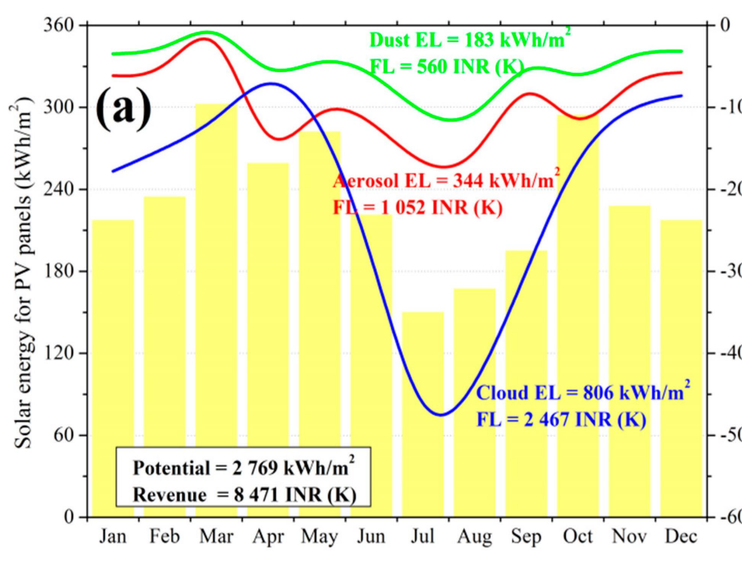


Figure C: Financial analysis of the aerosol & cloud impacts on the produced solar energy during Jan to Apr 2021. The impact was quantified in terms of daily mean and total energy losses, financial losses and solar energy potential.



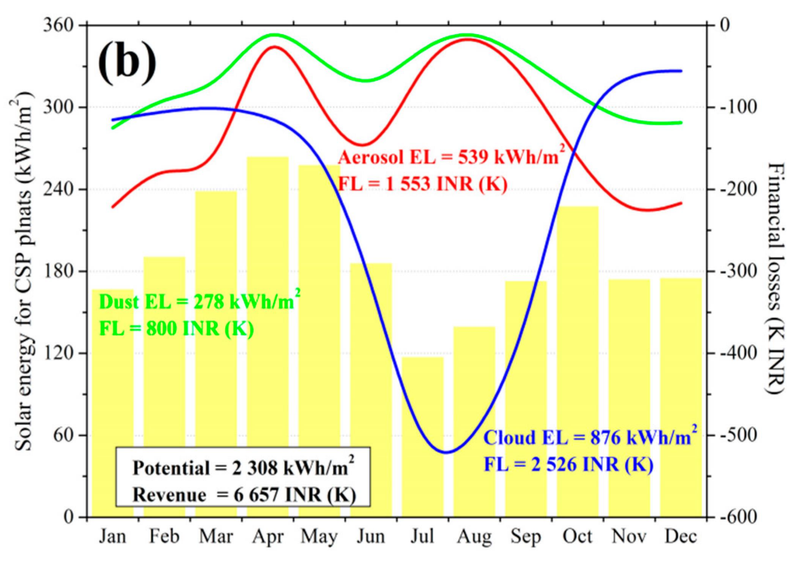


Figure D: Financial analysis of the aerosol, dust, and cloud impacts on the produced solar energy from PV (a) and CSP (b) installations with nominal power of 1 MW in the region of Nainital. The impact was quantified in terms of monthly mean and total energy losses, financial losses, and solar energy potential.

Northern India forest fires

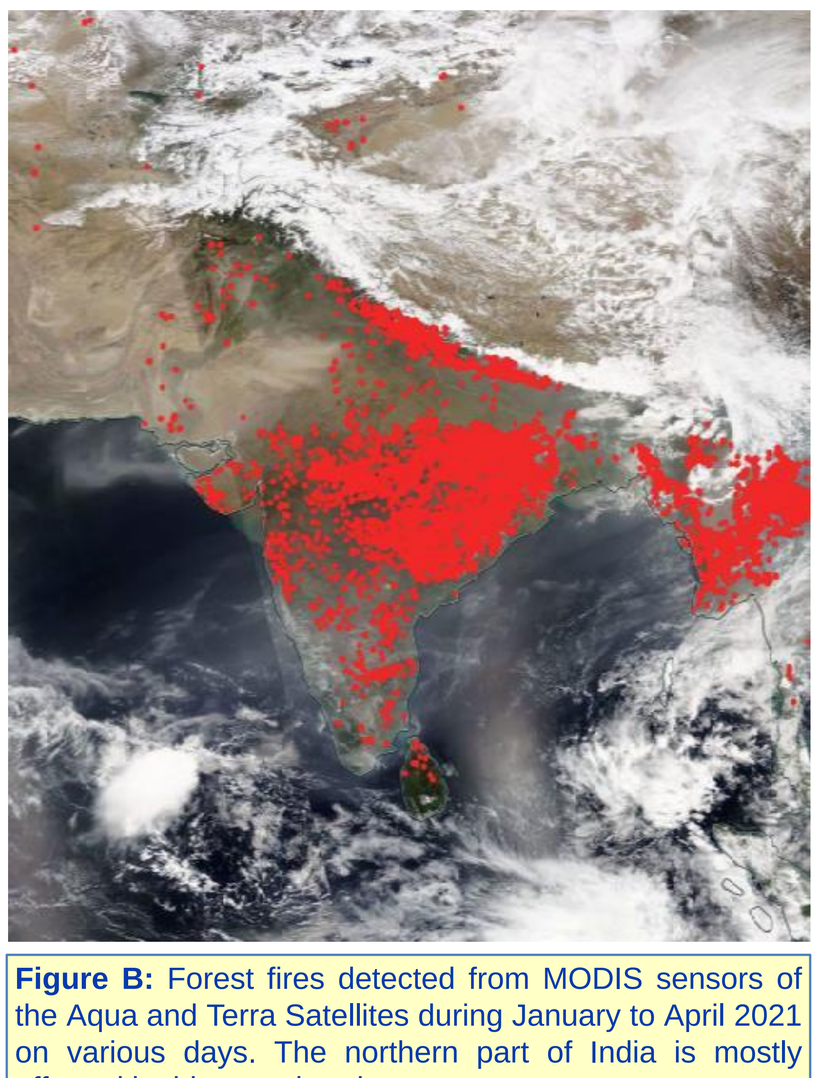


Figure B: Forest fires detected from MODIS sensors of the Aqua and Terra Satellites during January to April 2021 on various days. The northern part of India is mostly affected by biomass burning.

References

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