Detection of Crop Residual Burning Area Using Satellite Data and Estimation of PM2.5 Emissions from North India

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Over the years, coarse-resolution satellite observations such as the Moderate Resolution Imaging Spectrometer (MODIS) and Visible Infrared Imaging Radiometer Suite (VIIRS) have been widely used to detect active fire hotspots (FHS) and burnt stubble areas which are the main sources of air pollution in India. This information is then utilized to construct global fire emission inventories which are essential to reconstruct and project the impacts of biomass burning on the air quality, public health, ecosystem dynamics, climate and land-atmosphere exchanges. The coarse resolution of these observations however, renders them ineffective to detect fire hotspots smaller than their grid cells. Moreover, active fires may occur outside the satellites' overpass periods which lead to underestimation of the total burnt area and erroneous simulation of the aerosol emissions over the target region. This study demonstrates the capabilities of Sentinel-2 observations to detect burnt stubble areas over north India for constructing PM2.5 emission inventory in higher resolution compared to MODIS or VIIRS. The monthly median of Sentinel-2 Multi Spectral Instrument observation was examined to detect burnt agricultural areas of northern India during 2018–2020. Burn severity of rice and wheat stubble was estimated using the delta Normalized Burnt Ratio (dNBR), which uses the difference between spectral responses of Sentinel-2 NIR and SWIR bands, before and after the burning event. The burnt areas detected by dNBR method on Sentinel-2 observations were then used to construct PM2.5 emission as one of the main inputs of Weather Research and Forecasting Model coupled with Chemistry (WRF-Chem) Version 3.9.1. Finally, the simulation results of the model were validated using ground-based in situ measurements over five locations in north India. Results revealed bimodal patterns of burning events over most northern Indian states, which peaked in April and November, with estimated total burnt areas exceeding 63.9 million hectares in April and 57.3 million ha in November, representing more than half of the total agricultural area in the region, which is in agreement with previous studies. Visual validation using Google Earth Very High Spatial Resolution images showed that dNBR method exhibits reasonable accuracy for detecting burnt area over the region. Comparison with EDGAR global emission database showed similar bimodal pattern of the burning event peaks albeit having large differences in emission values. The uncertainties generated from emission parameters as well as the differences of estimation approaches between EDGAR and dNBR method may account for this result. WRF-Chem simulation using emission inventory generated from Sentinel-2 observation in November 1-14, 2017 showed larger PM2.5 concentration which was in agreement with ground-based PM2.5 observations in north India compared to simulation with the "Default" inventory package of the model developed using MODIS (GFED Version 2). The model however, fell short to capture the striking diurnal variations of PM2.5 in each location which may be attributed to the uncertainties of parameterization schemes used for emission estimation. The comparison results also showed larger gap between simulated and ground observation of PM2.5 over urban and industrial regions compared to rural ones, indicating greater impact of other emission sources such as vehicle combustions and industrial waste over these regions.

This research was funded by Research Institute for Humanity and Nature (RIHN: a constituent member of NIHU) Project No. 14200133 (Aakash).

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Keywords: burnt area, dnbr, pm2.5, sentinel-2, stubble burning

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