Estimating the Contribution of Brick Kiln Industry to PM2.5 Emission over Northern India

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Abstract

This study examines the effects of Indian brick kiln (BK) industry, which is the second-largest in the world, to PM2.5 emission over the northern part of the country. We analyze MODIS LAI/FPAR and global land cover products, as well as NASA's LDAS vegetation and soil datasets with 3887 BK plantation locations over the region for determining the contribution of brick kiln industry to fine particulates emission, especially during its highest concentration period in December to February. Our preliminary results show more than 60% of BK plantations are located in silt-rich areas for making brick kiln with more than 80% plantations are situated over croplands on the outskirts of urban areas (Figure 1), indicating proxies for the increase of PM2.5 emission over Northern India.

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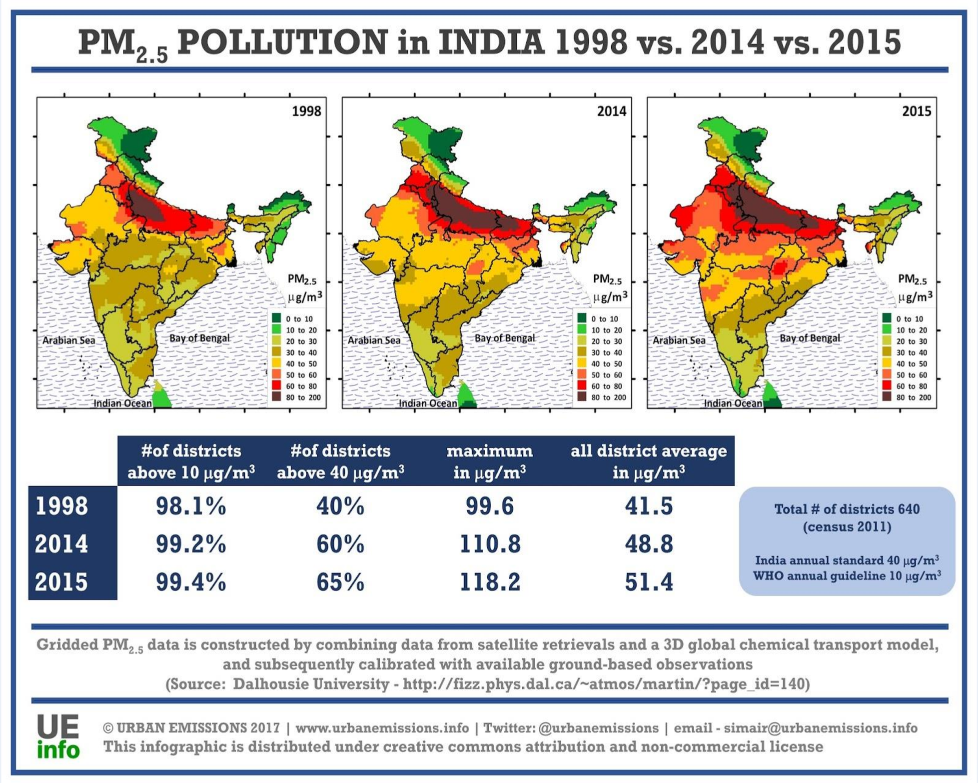
1. BACKGROUND

1-1 Introduction



$PM_{2.5}$ or fine particulate matters are tiny aerosols with diameter of 2.5μm or less, which are typically generated from incomplete combustion of fossil fuel in vehicles, biomass In stoves for cooking and heating, coal in small industrial operations and agricultural waste in post-harvest fields. It's also the $PM_{2.5}$ which plays the role of major component of air pollution which is now choking India.

Brick kiln and $PM_{2.5}$ emission

India is the second largest brick producer in the world. Brick kiln (BK) emits fine particles of coal, dust particles, organic matters and gases such as SO2, NOx, H2S, CO etc.

Estimated annual $PM_{2.5}$ emission: 23,300t for Great Dhaka region alone (Schmidt, 2013)

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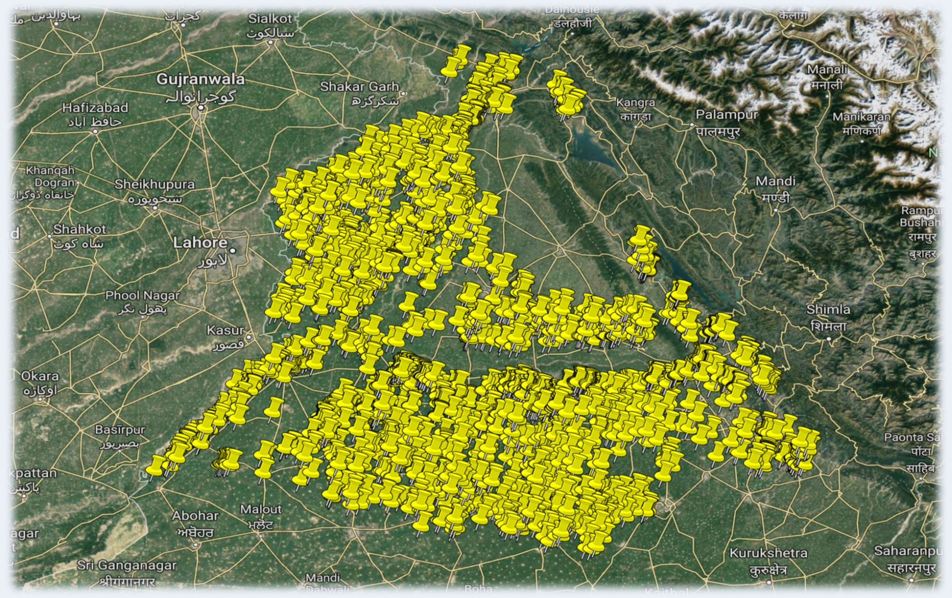
1-2 Key problems



- Limited inventory for PM2.5 emission originated from BK.
- In-situ observations using aerial photo, UAV or drone are difficult due to air-space regulations.
- Lack of remote sensing products for identifying BK locations.

1-3 Study objectives

- Develop a novel technique to estimate regional $PM_{2.5}$ emission from BK over Northern India using numerical model simulation and remote sensing data
- Evaluate the effectiveness of countermeasure in reducing $PM_{2.5}$ emission from brick industry in India

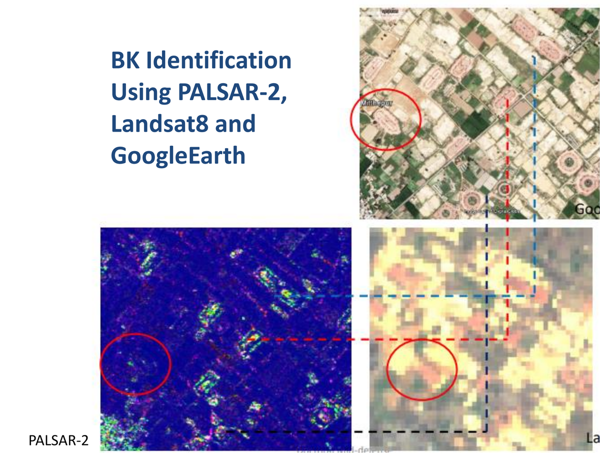
2. METHODOLOGY

2-1 Model design

STEP 1

$PM_{2.5}$ Emission Quantification

- **In-situ Observation**
- **Plume Digital Imaging** (MacFarland et al., 2004; Du et al., 2007; Smith et al., 2017)
- **BK Location Identification** using **Google Earth Engine** Cloud Platform (Developed by Dr. Prakhar Misra of IIS UTokyo)



Emission amounts : $E_{i,,} = A_{j,k} \times EF_i$

$$A_{j,k} = \left[\sum_{c=0}^{n}\left(P_{c,j,k} \times R1_c\right)\right] \times F1 \times \left(R2_{j,k} \times F2_{j,k}\right)$$

Residue/grain ratios of crops

Burning efficiency

Ratio of crop residue

Factor for yearly changes of $R2_{j,k}$

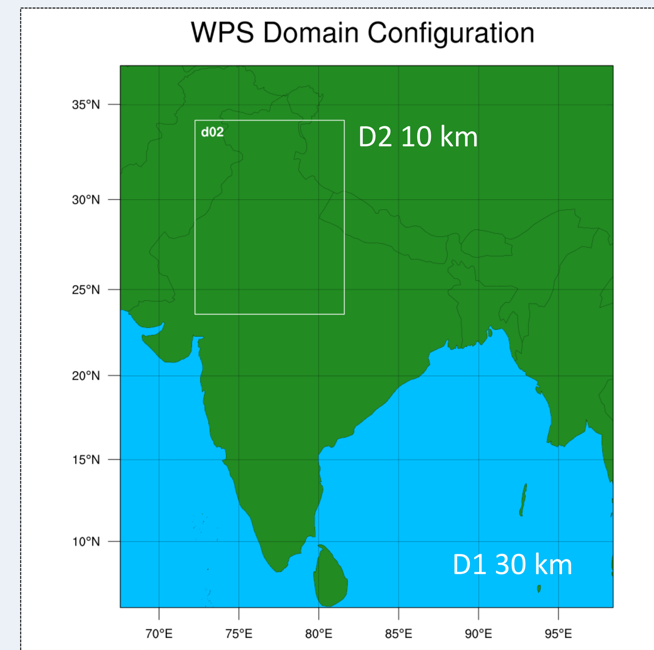
STEP 2

Meteorological Field

- Reanalysis Data

Regional Model

- WRF-Chem ver. 3.9.1



Aerosol microphysical process : scavenging, wash out, dry/wet deposition

STEP 3

Result Verification

- **In-situ Observation**
- **Model Sensitivity Test**
- **Data Assimilation (EnTKF) using remote sensing observation (MODIS/CAI)**

  Emission inventory could be updated by comparing model results and observation

Final Output

- Regional PM2.5 Emission Model for Analysis and Prediction

2-2 Data used

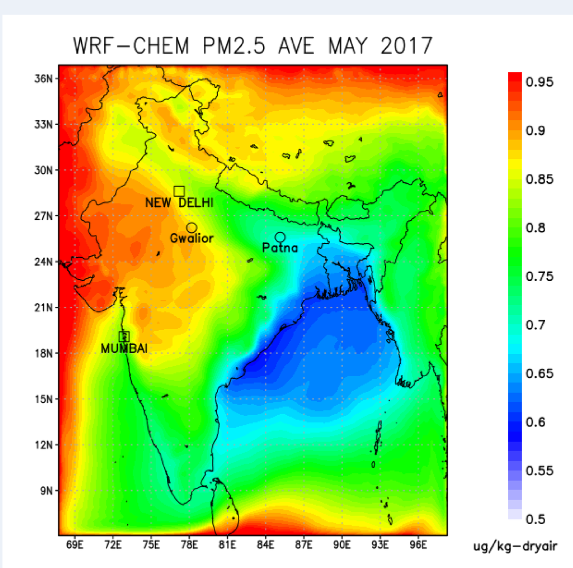
- ECMWF ERA-Interim (2017-2018, 6-hourly,~80km spatial res.)
- MOZART/WACCM chemistry boundary dataset (2017-2018)
- MODIS LAI/FPAR dataset (2017-2018, 8-daily, 500m spatial res.)
- MODIS annual land cover products (Jan 2018, 500m spatial res.)
- MODIS AOD (2017-2018, daily, 1km spatial res.)
- BK locations (2016, 3887 points from Google map)
- BK locations based on LANDSAT8 and PALSAR2 data identification using GEE cloud platform

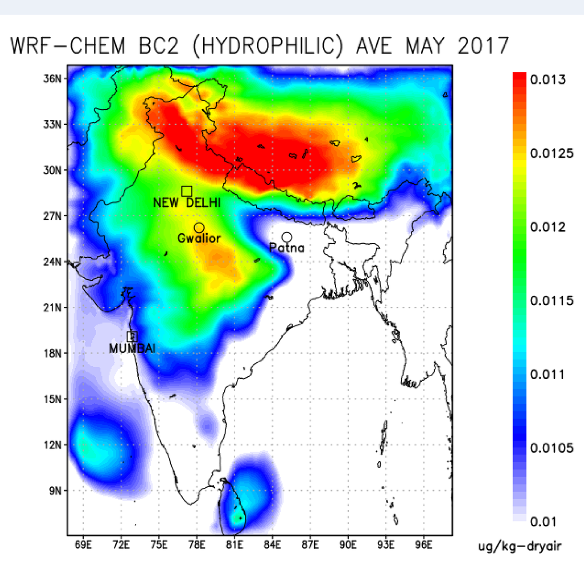
2-3 Model parameterization

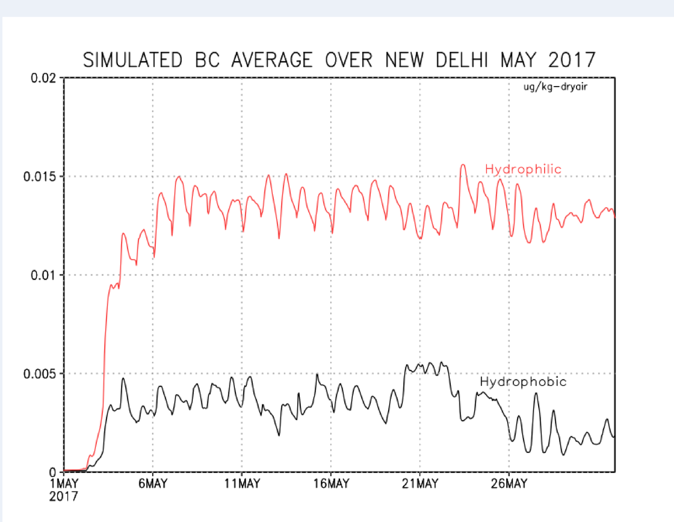
Configuration	Scheme	Namelist Value	References
Longwave radiation	RRTMG	ra_lw_physics=4	Iacono et. al (2008)
Shortwave radiation	RRTMG	ra_sw_physics=4	Iacono et. al (2008)
Microphysics	Lin et. al	mp_physics=2	Lin et. al (1983)
Cumulus	Grell3D	cu_physics=5	Grell (1993), Grell and Devenyi (2002)
Planetary Boundary Layer	YSU	Bl_bl_physics=1	Hong et. al (2006)
Land surface	NOAH LSM	sf_surface_physics= 2	Niu et. al (2011), Yang et. al (2011)
Surface layer	5-layer Thermal Difussion	sf_sfclay_physics=1	Dudhia (1996)

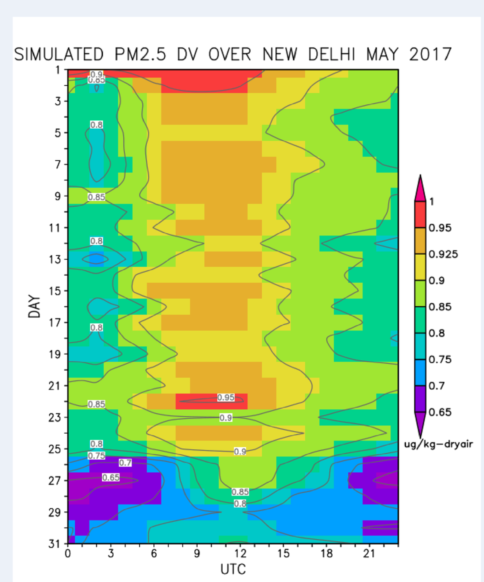
3. RESULTS

3-1 $PM_{2.5}$ simulation



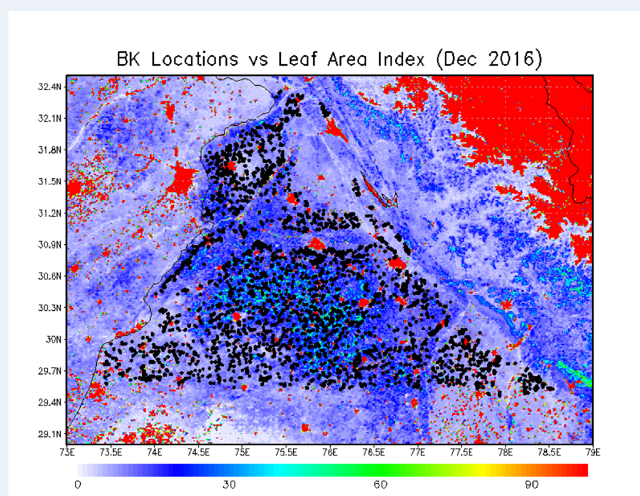


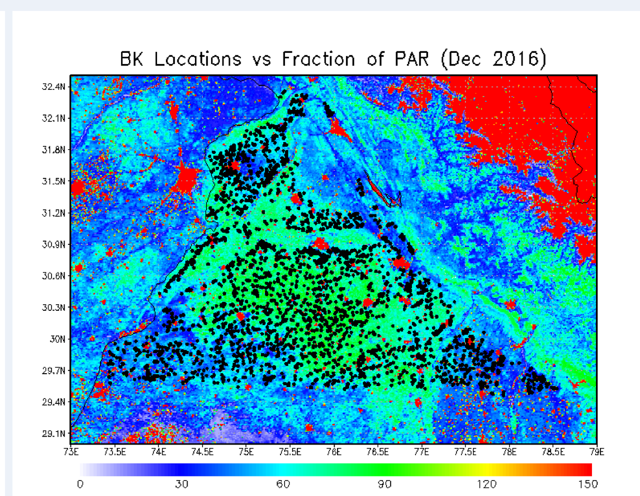


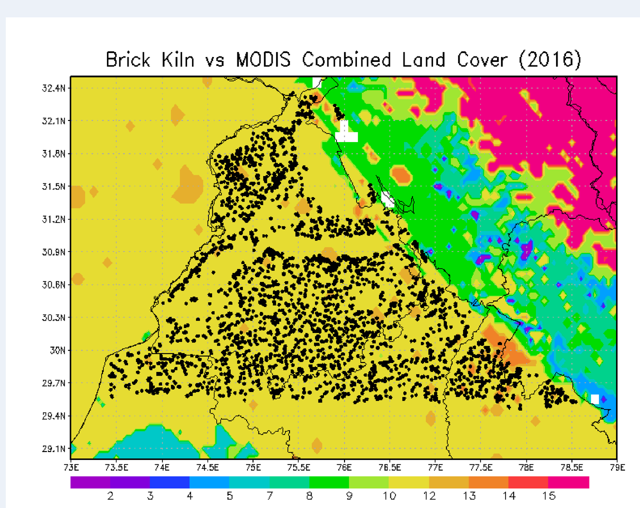


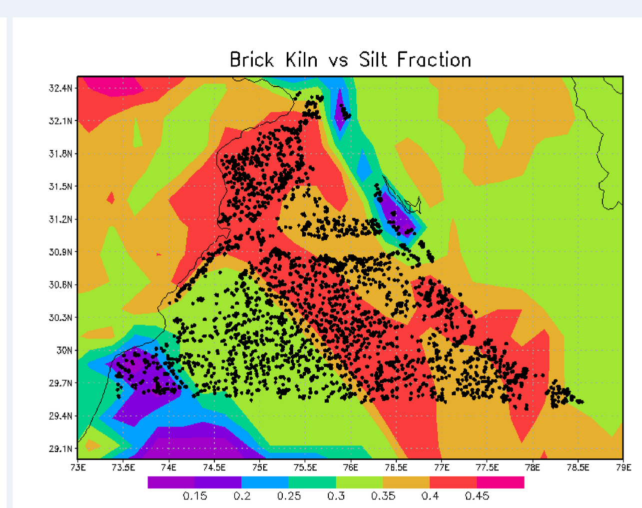
Model was run with 1 month spin-up

3-2 MODIS land products analysis









MODIS data analyzed during the period of December 2017 – January 2018

4. CONCLUSIONS AND FUTURE WORKS

4-1 Conclusions

- More than 60% of BK plantations are located in the silt-rich areas for making brick kiln with more than 80% plantations are situated over cropland regions in the outskirts of urban areas in India.
- Simulated $PM_{2.5}$ emission shows diurnal variations over the locations of BK plantations

4-2 Future works

- $PM_{2.5}$ simulations using BK location generated by GEE cloud platform
- In-situ observations using digital imaging to estimate the emission of BK plumes

Acknowledgement

- Brick kiln locations using GEE cloud platform were provided by Dr. Prakhar Misra and Prof. Wataru Takeuchi of Institute of Industrial Science, The University of Tokyo

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