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Quantifying the Influence of Agricultural Fires in Northwest India on Urban Air Pollution in Delhi, India

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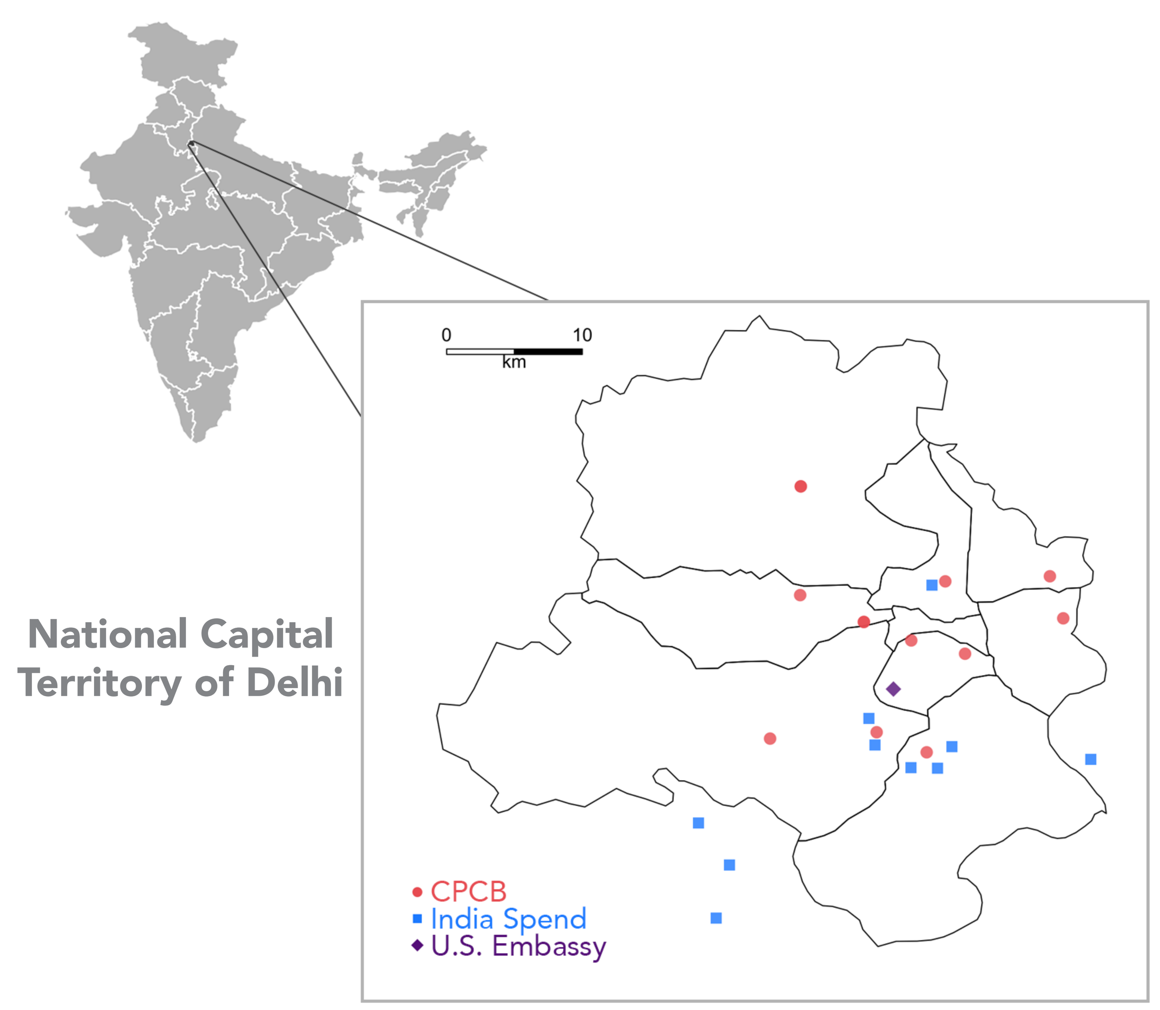
Post-monsoon agricultural fires during October-November in northwestern India are visible from space. Farmers burn rice crop residues to ready their fields for subsequent wheat crops. The city of Delhi sits just downwind of these agricultural fires. We compare surface $PM_{2.5}$ observations to model-derived $PM_{2.5}$ using the GFED4.1, GFAS, QFED, and FINN fire emission inventories coupled to the chemical transport model STILT. We find that we can reproduce the weekly variability of surface $PM_{2.5}$ and the magnitude of $PM_{2.5}$ during large pollution events predicted by the model. However, we find that often the modeling framework misses large pollution events. We suggest the coarse resolution of MODIS fire retrievals, local meteorology, and thick smoke interfering with surface thermal anomalies as reasons for these modeled pollution underestimates. As northwestern India is responsible for much of the food production in India, the influence of fires on urban pollution is critical in understanding the human health risks of these agricultural practices.

Surface Monitoring Network



Data cleaning to produce network average daily $PM_{2.5}$:

Step 1. Only retain sites whose $PM_{2.5}$ correlates with MODIS AOD ($R > 0.5$)

Step 2. Find the average difference between a site's $PM_{2.5}$ and the network averaged $PM_{2.5}$. Remove observations that deviate (2.5 stds) too much from this average difference.

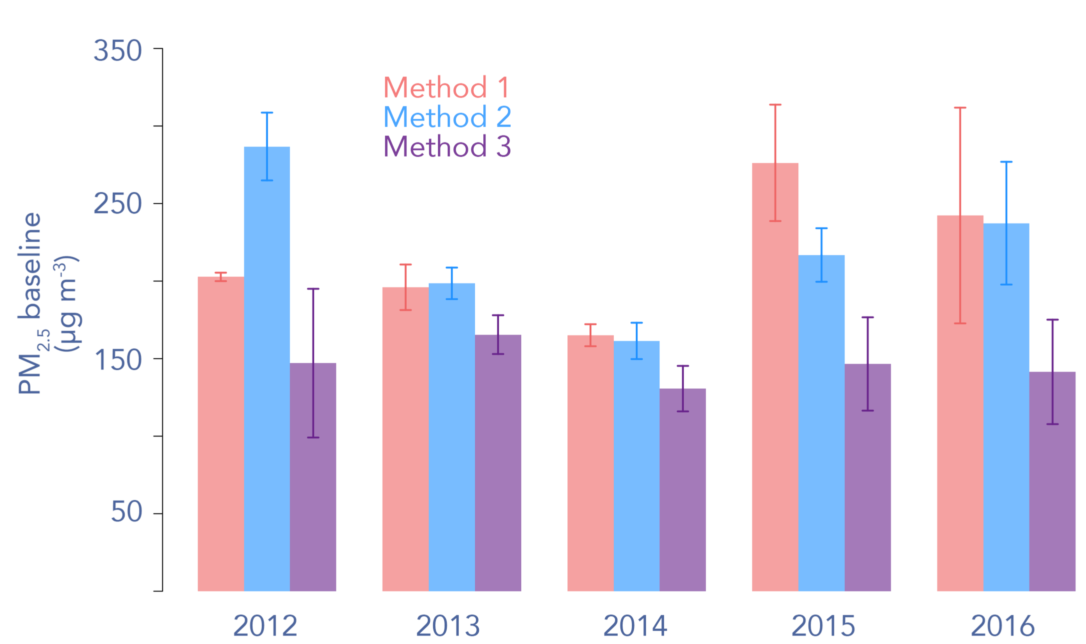
Anthropogenic Background

From observations, we establish an anthropogenic background each post-monsoon season that represents non-fire contributions to urban $PM_{2.5}$.

Method 1: mean of obs that occurred N days after a detected fire

Method 2: mean of obs, where (# overlapping fire & STILT cells) / (# fire cells) < threshold

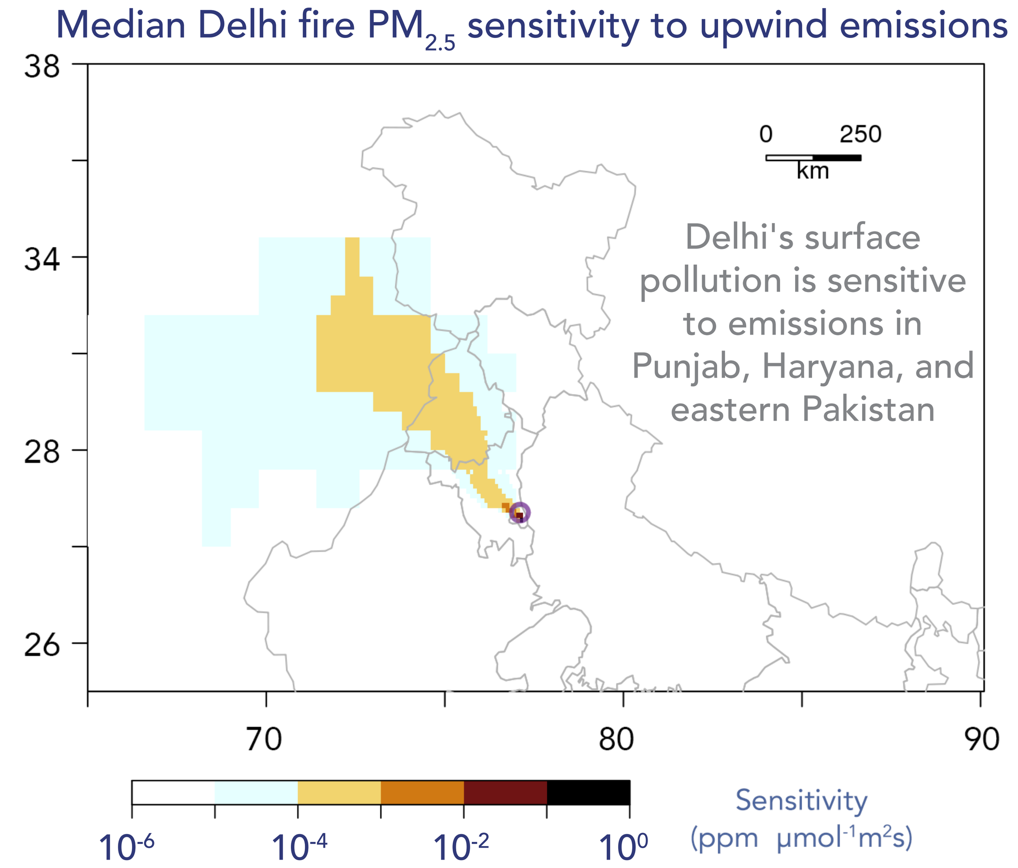
Method 3: mean of lowest M weekly averaged obs. during fire season



All backgrounds levels above the 60 μg m^{-3} standard imposed by the Central Pollution Control Board (CPCB).

Chemical transport: fire emissions → Delhi $PM_{2.5}$

Median Delhi fire $PM_{2.5}$ sensitivity to upwind emissions



STILT: Stochastic Time-Inverted Lagrangian Transport model

$$\underbrace{C(\mathbf{x}_r,t_r)}_{\text{Downwind observation}} = \int_{t_0}^{t_r} dt \int_V d^3x\, \underbrace{I(\mathbf{x}_r,t_r|\mathbf{x},t)}_{\text{Influence function}} \underbrace{S(\mathbf{x},t)}_{\text{Upwind emission}} + \int_V d^3x\, I(\mathbf{x}_r,t_r|\mathbf{x},t_0) \underbrace{C(\mathbf{x},t_0)}_{\text{Initial condition}}$$

STILT simulates $PM_{2.5}$ enhancements in space and time by letting "particles" flow backwards in time. The distribution of particles represents the influence of upwind emissions on the observation.

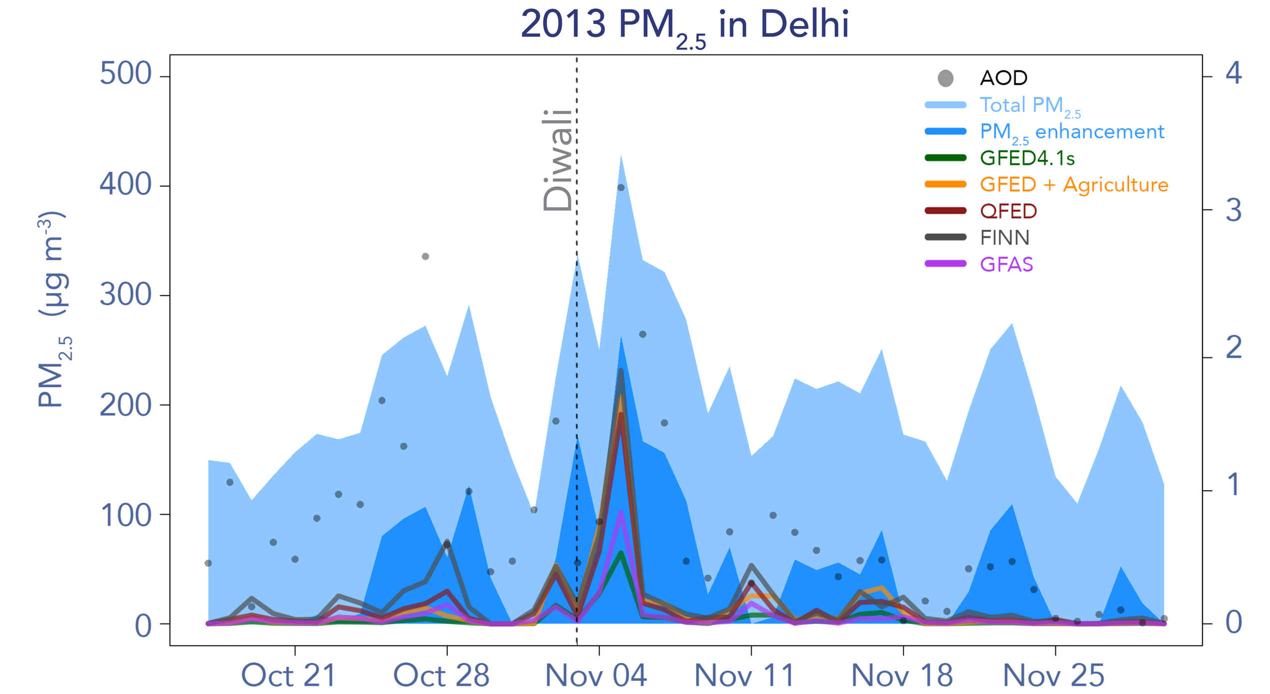
We use GDAS 0.5° meteorology and send 500 particles backwards in time for 5 days.

Sometimes good, sometimes bad agreement with observations.

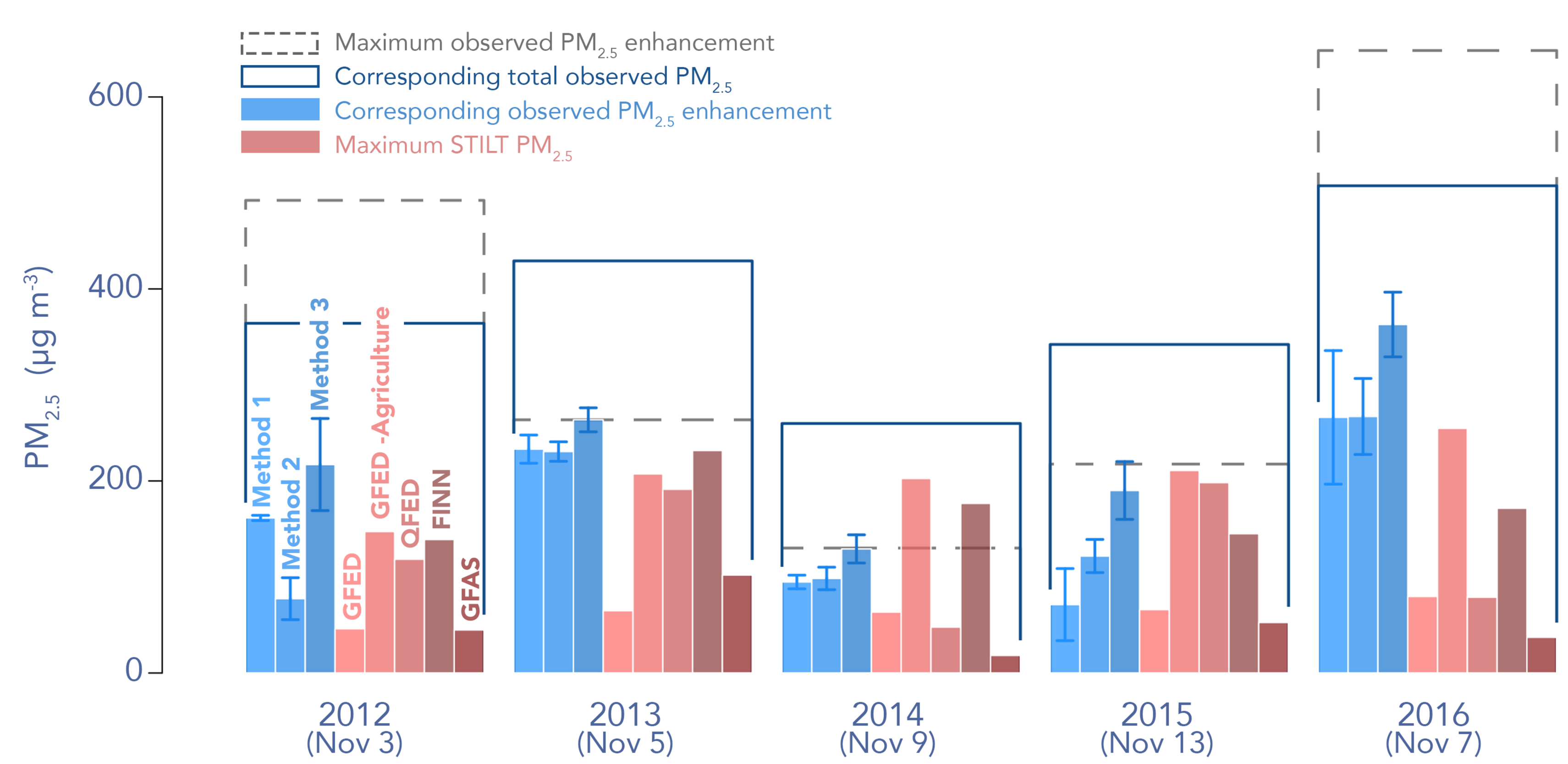
Mismatch before Nov. 5th peak
-Missing small fires not captured in fire emission inventories.
-Start of Diwali in Nov. 3rd.

Mismatch after Nov. 5th peak
-Stagnation feedback not captured in 0.5° GDAS meteorology.
-Thick smoke interfering with satellite fire retrieval.

2013 $PM_{2.5}$ in Delhi



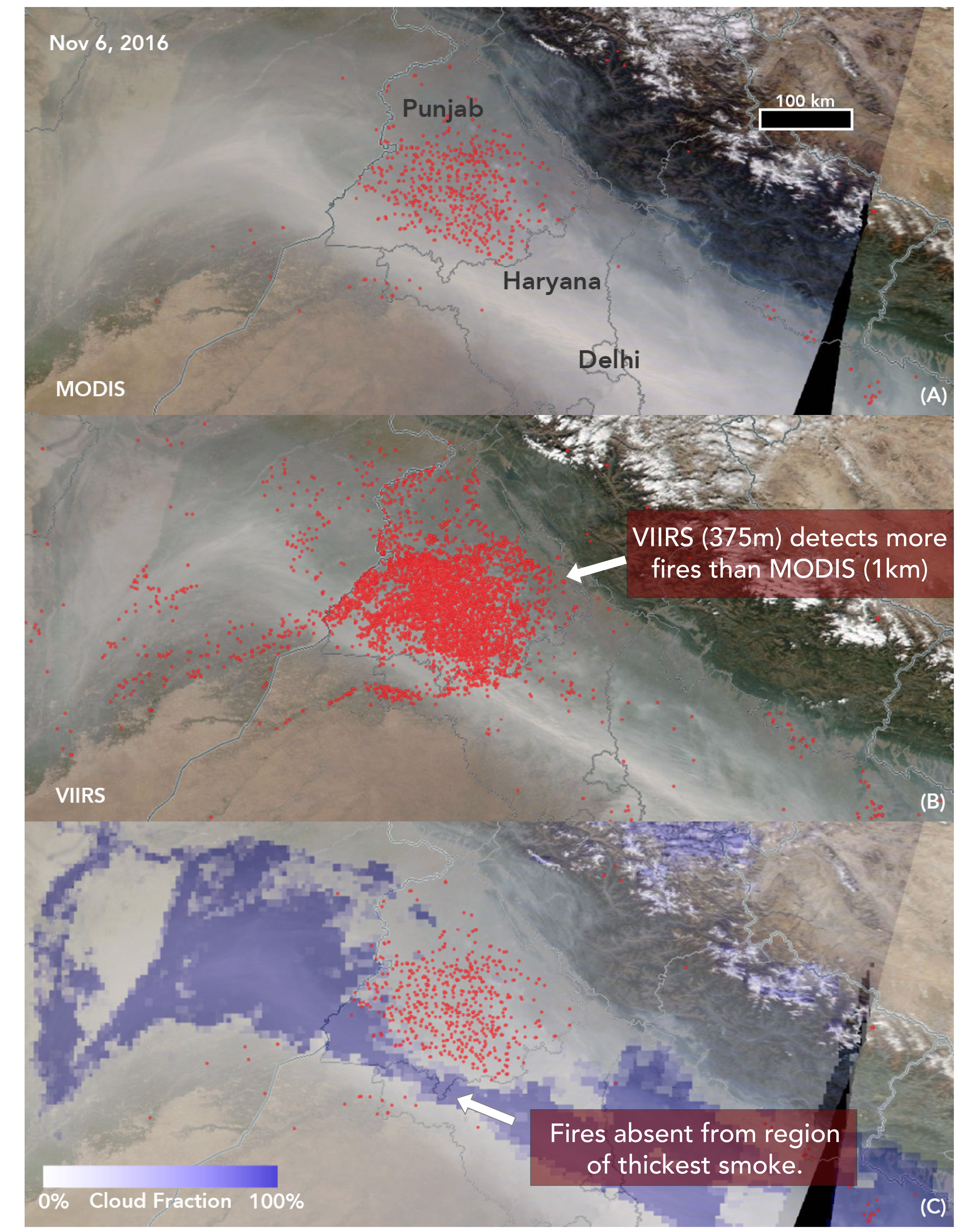
Simulated $PM_{2.5}$ from fires a major contributor to total observed $PM_{2.5}$ (when fires detected) during extreme events.



2012 & 2016
Maximum observed $PM_{2.5}$ does not occur on the day STILT predicts. Fire emission inventories missing large events altogether.

2013-2015
Largest events are picked up by fire emission inventories. FINN and QFED pick up the observed $PM_{2.5}$ enhancement the best (~50% of total obs. $PM_{2.5}$).

Fire Detection Retrievals



Conclusions

On days that STILT predicts the largest pollution events from fires, we can reproduce around 50% of the magnitude of observed $PM_{2.5}$, depending on which emission inventory is used.

We miss other pollution events during the post-monsoon burning season due to trouble with detecting small fires, local meteorology, or thick smoke interferring with the satellite retrieval.

Higher resolution fire retrievals (e.g., VIIRS) could provide an avenue to account for these "missing" fires.

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