OMI Observations of Interannual Increases in SO_2 Emissions from Indian Coal-Fired Power Plants: 2005–2012

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Background & Objective

Background

- India has surpassed the U.S. to be the world's second largest SO_2 emitting country, after China, since 2010 [Lu et al., 2011; Xing et al., 2013]
  - *the rapid economic development & the absence of regulations*
- Coal-fired powers are the biggest SO_2 emission sources in India
  - *~50% of the national SO_2 emissions*
  - *~70% of the emission increment during 1996–2010*
- Inconsistency in Indian SO_2 trends:
  - *Bottom-up emissions: increased dramatically since the mid-1990s* [Lu et al., 2011]
  - *National mean SO_2 concentrations from the official monitoring network: declined since 2000* [CPCB, 2012]
- Therefore, an independent data source is needed to verify the real SO_2 situation in India. For example,
  - *Satellite remote sensing from the Ozone Monitoring Instrument (OMI)*

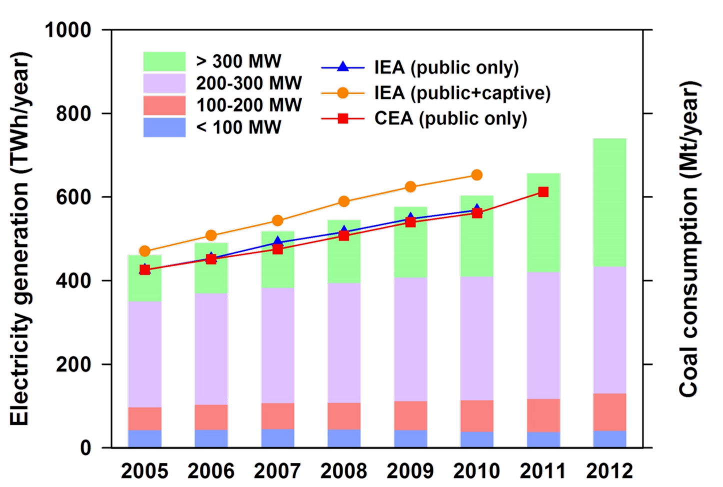
Objective

- Use a unit-based methodology to develop the SO_2 emission inventory for the Indian coal-fired power sector
- Apply the oversampling technique and improved OMI retrievals to study the relationship between OMI SO_2 observations and SO_2 emissions over Indian coal-fired power plants
- Study the interannual trend of SO_2 emissions from the space during the OMI era of 2005–2012

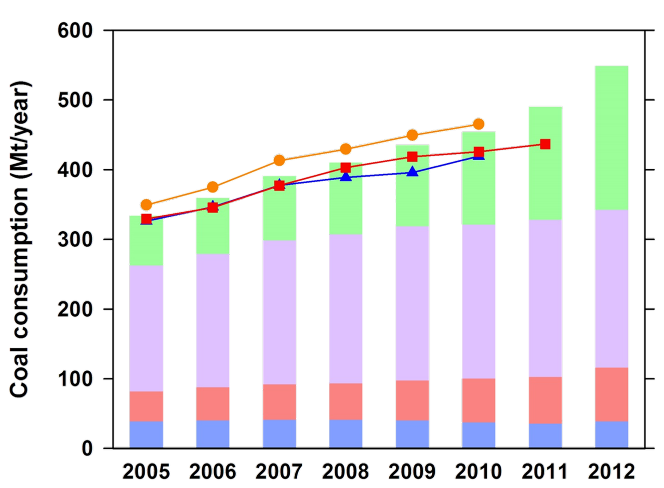
Methods & Data Sets

Bottom-Up, Unit-Based SO_2 Emission Inventory

- Indian coal-fired power units with capacity >20 MW are included
  - *165 plants, > 720 units* [CEA, 2006-2013]
  - *Unit-level information is collected: geographical location, boiler size and type, coal type and sulfur content, electricity generation, specific coal consumption, SO_2 control technology, exact time when the unit came into operation and/or retired, etc.*



Power generation: 61% increase



Coal consumption: 64% increase

- Total SO_2 emission (E) from coal-fired power plants for year i:

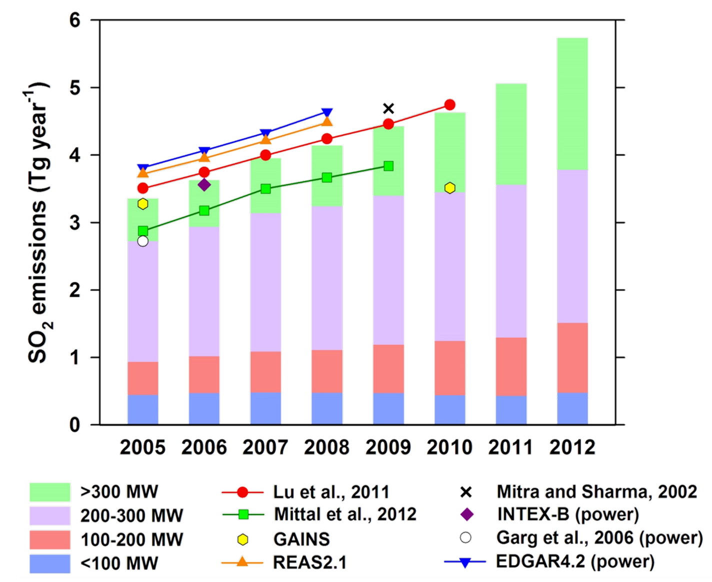
$$E_i = \sum_j \sum_k \sum_l 2 \times G_{i,j,k} \times SCC_{i,j,k} \times S_{j,k} \times (1 - SR_j) \times (1 - \eta_l)$$

(j: coal type; k: unit; l: control technology; G: electricity generation; SCC: specific coal consumption; S: sulfur content; SR: sulfur retention in ash; η: removal efficiency)

OMI SO_2 Retrievals

- Data source [Krotkov et al., 2006]
  - *Planetary boundary layer daily SO_2 data in the NASA OMSO2 Level-2 product*
- Filters
  - *Remove pixels with large solar zenith angle, high radiative cloud fraction and terrain height, at swath edges, or affected by row anomalies*
- Corrections
  - *Pacific sector correction, local AMF correction, and local bias correction*
- Oversample the valid pixels with corrected vertical columns at a 2 km × 2 km grid for the whole domain of India

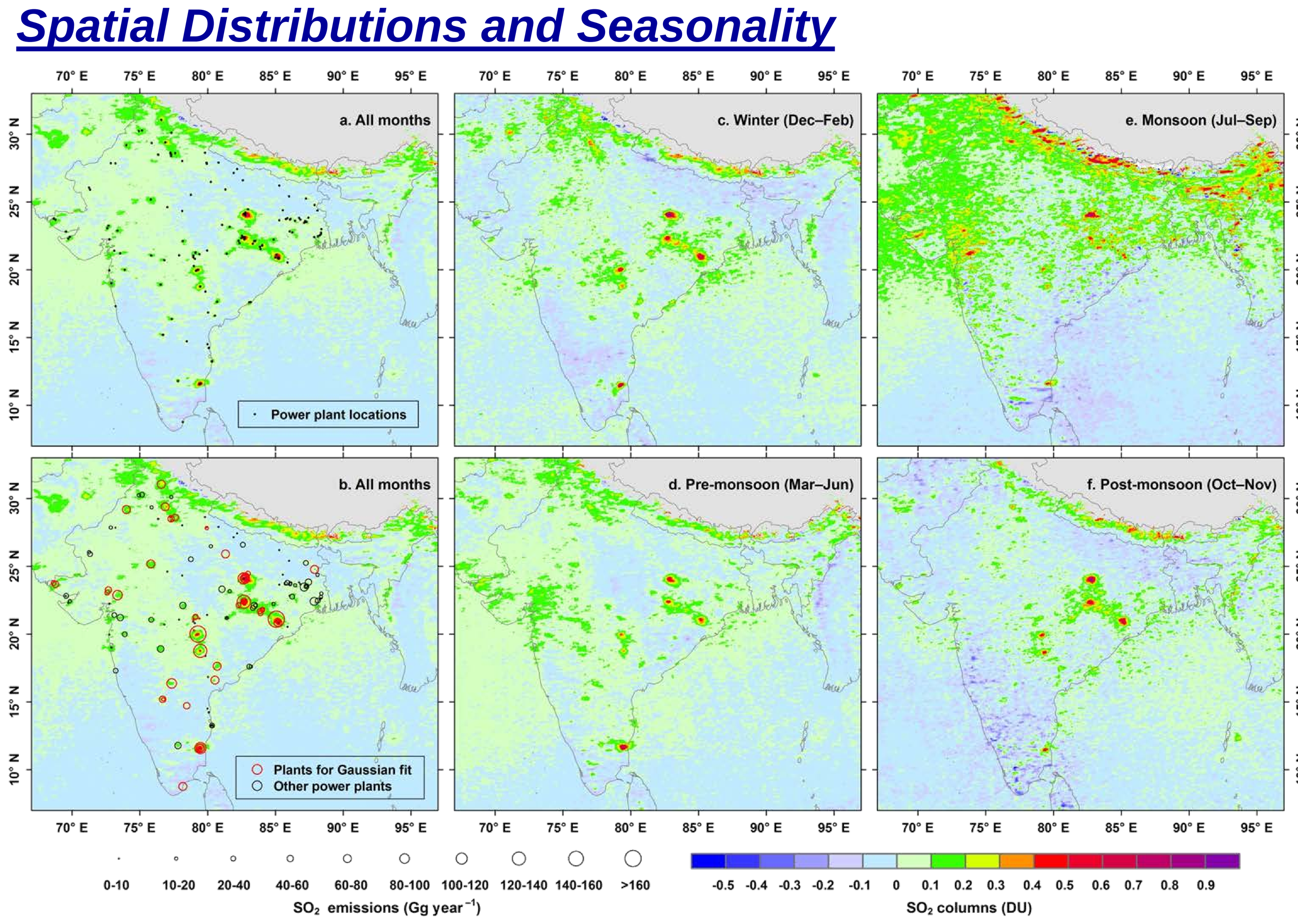
SO_2 Emissions from Power Plants



- **SO_2 emissions 2005–2012 71% increase, 8.0%/year**
- By boiler size ~73% from units with capacity >200 MW
- Emission uncertainties ±13%

SO_2 Emissions Observed by OMI

Spatial Distributions and Seasonality



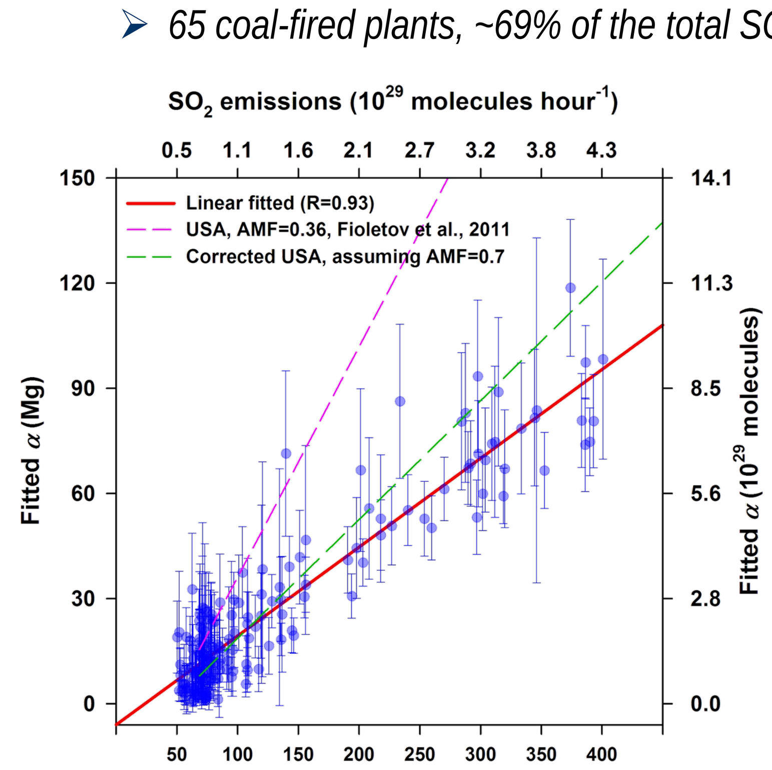
- A number of satellite SO_2 hot spots are observed over India, and they match the locations and the amounts of SO_2 emissions of large coal-fired power plants reasonably well
- Seasonality
  - *No significant seasonal variations in OMI SO_2 over India, different from OMI NO_2*
  - *Monsoon is the worst period to observe SO_2 from OMI, similar to OMI NO_2*

Fitting Hot Spots with 2-D Gaussian Function

$$OMI_{SO_2} = \alpha f(x,y) = \frac{\alpha}{2\pi\sigma_x\sigma_y\sqrt{1-\rho^2}} \exp\left(-\frac{1}{2(1-\rho^2)}\left[\frac{(x-\mu_x)^2}{\sigma_x^2} + \frac{(y-\mu_y)^2}{\sigma_y^2} - \frac{2\rho(x-\mu_x)(y-\mu_y)}{\sigma_x\sigma_y}\right]\right)$$

[Fioletov et al., 2011]

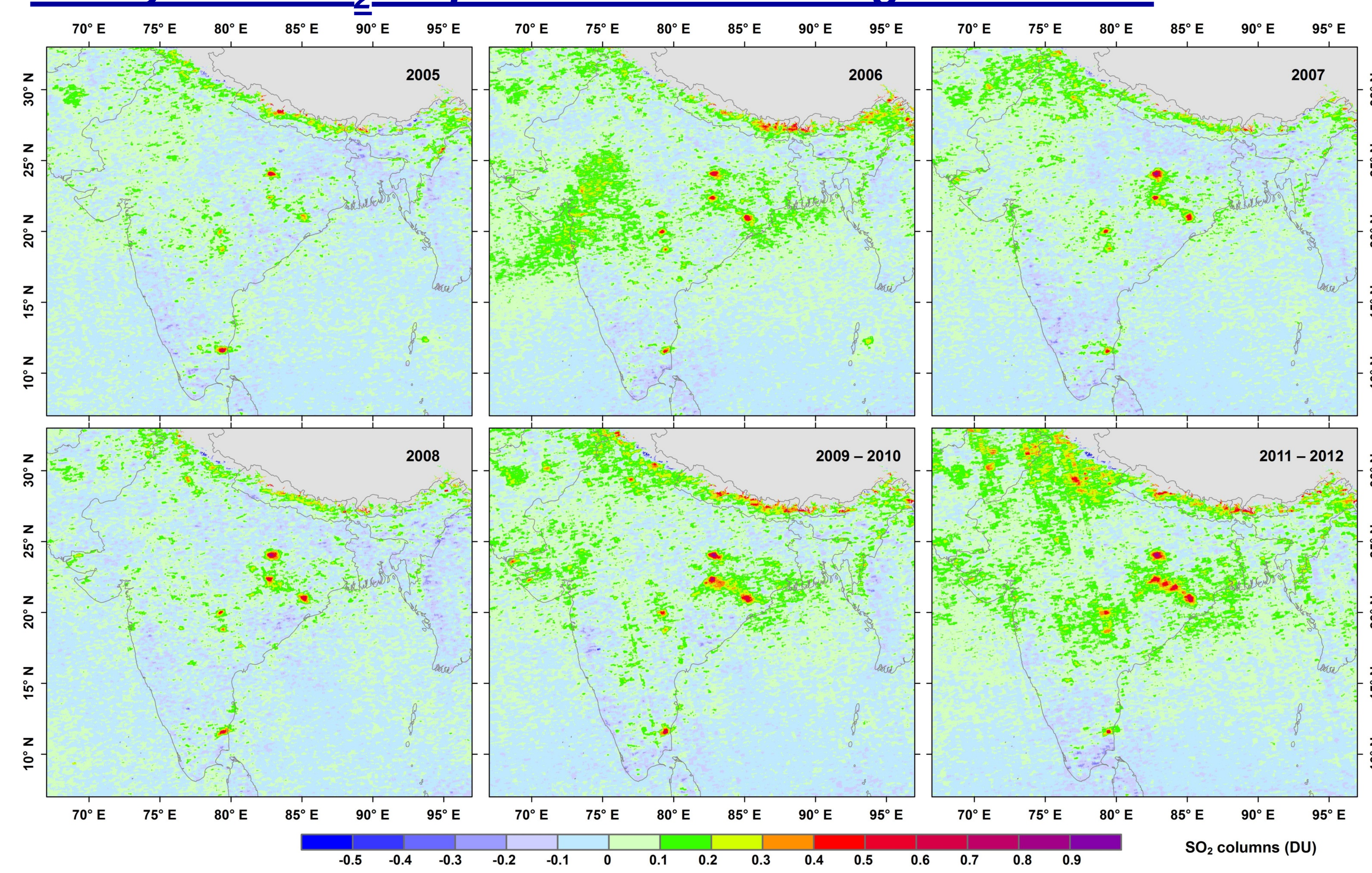
- Since $\iint f(x,y)dxdy = 1$, α physically means the total number of SO_2 molecules observed (or SO_2 burden) near the source
- 23 power plant areas are studied
  - *65 coal-fired plants, ~69% of the total SO_2 emissions*



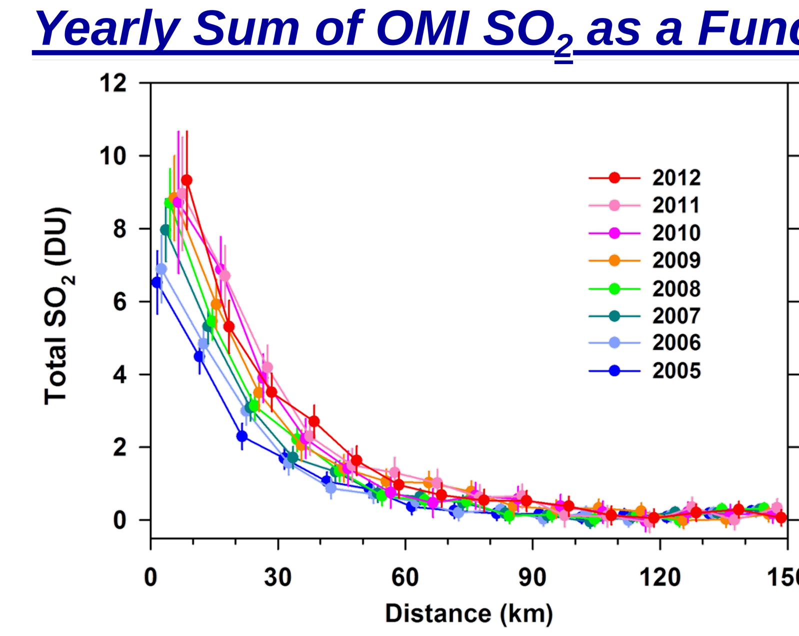
- **Good agreement between SO_2 emissions and OMI-observed SO_2 burden over power pant areas**
- Regions with annual SO_2 emissions >50 Gg/year produce statistically significant α values
- Effective OMI-observed SO_2 dispersion time: 2.2 h

SO_2 Trends over Power Plant Areas

Yearly OMI SO_2 Maps over India during 2005−2012

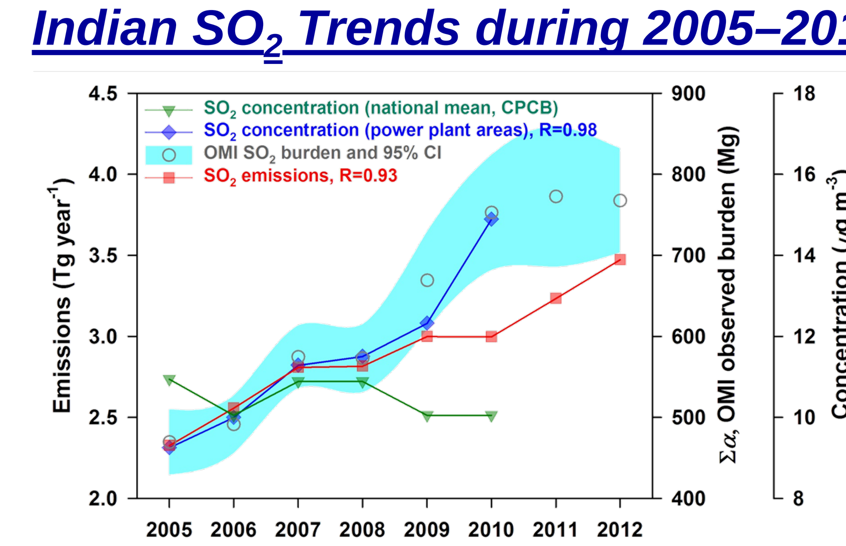


Yearly Sum of OMI SO_2 as a Function of the Distance



- The sum of OMI signals over the hotspot centers was continuously increasing during 2005–2012
- **Total amount of SO_2 observed by the OMI increased by 63% from 2005 to 2012**

Indian SO_2 Trends during 2005–2012



- The declining national mean SO_2 concentration trend reported by the Indian Government differs markedly from the trends of both OMI SO_2 observations and national SO_2 emissions
- **The official air quality monitoring network needs to be optimized to reflect the true SO_2 situation in India**
  - *too many monitors in city centers, too few monitors in emission-increasing areas*

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