Carbonaceous aerosols from Indo-Gangetic Plain & Central Himalaya: Sources & Impact

M.M. Sarin

C4 Workshop – IITM (Pune) **1 – 3 May, 2013**

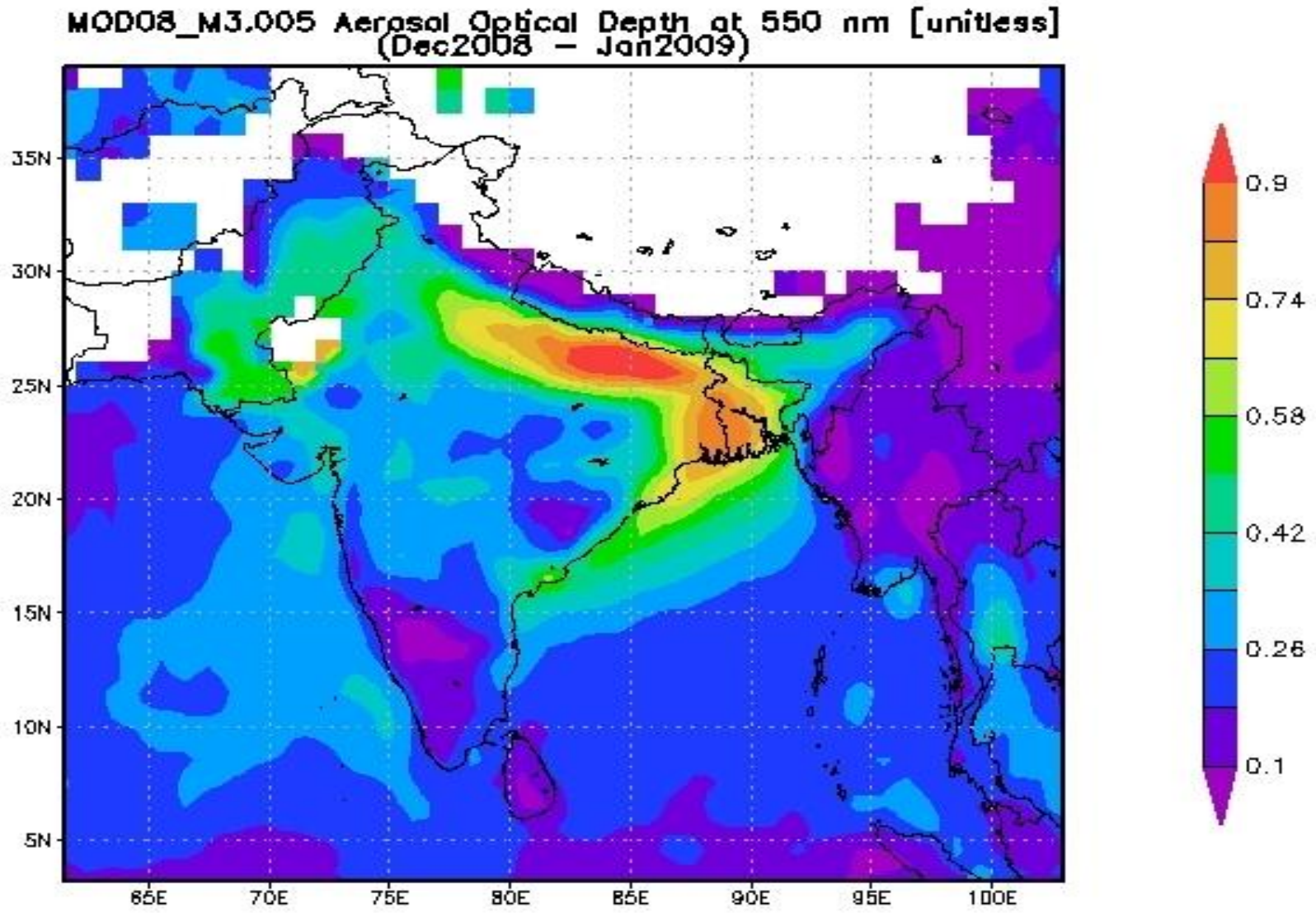
Interactions between climate-physical-chemical processes are intricate:

- Nonlinear
- Involve feedbacks
- Need to understand:

Climate-Physics-Chemistry system

Example: Effect of chemistry on climate due to anthropogenic aerosols

(as important as greenhouse gases)


MOD08_M3.005 Aerosol Optical Depth at 550 nm [unitless]
(Dec2008 – Jan2009)
35N
30N
25N
20N
15N
10N
5N
65E
70E
75E
80E
85E
90E
95E
100E
0.9
0.74
0.58
0.42
0.26
0.1

During wintertime, emissions from post-harvest agricultural-waste burning, fossil-fuel combustion and wood-fuel for domestic heating

☞ ***result in enormous amount of organic carbon (OC) and elemental carbon (EC) that modify the total particulate carbon content of the atmosphere***

Atmospheric radiative Forcing

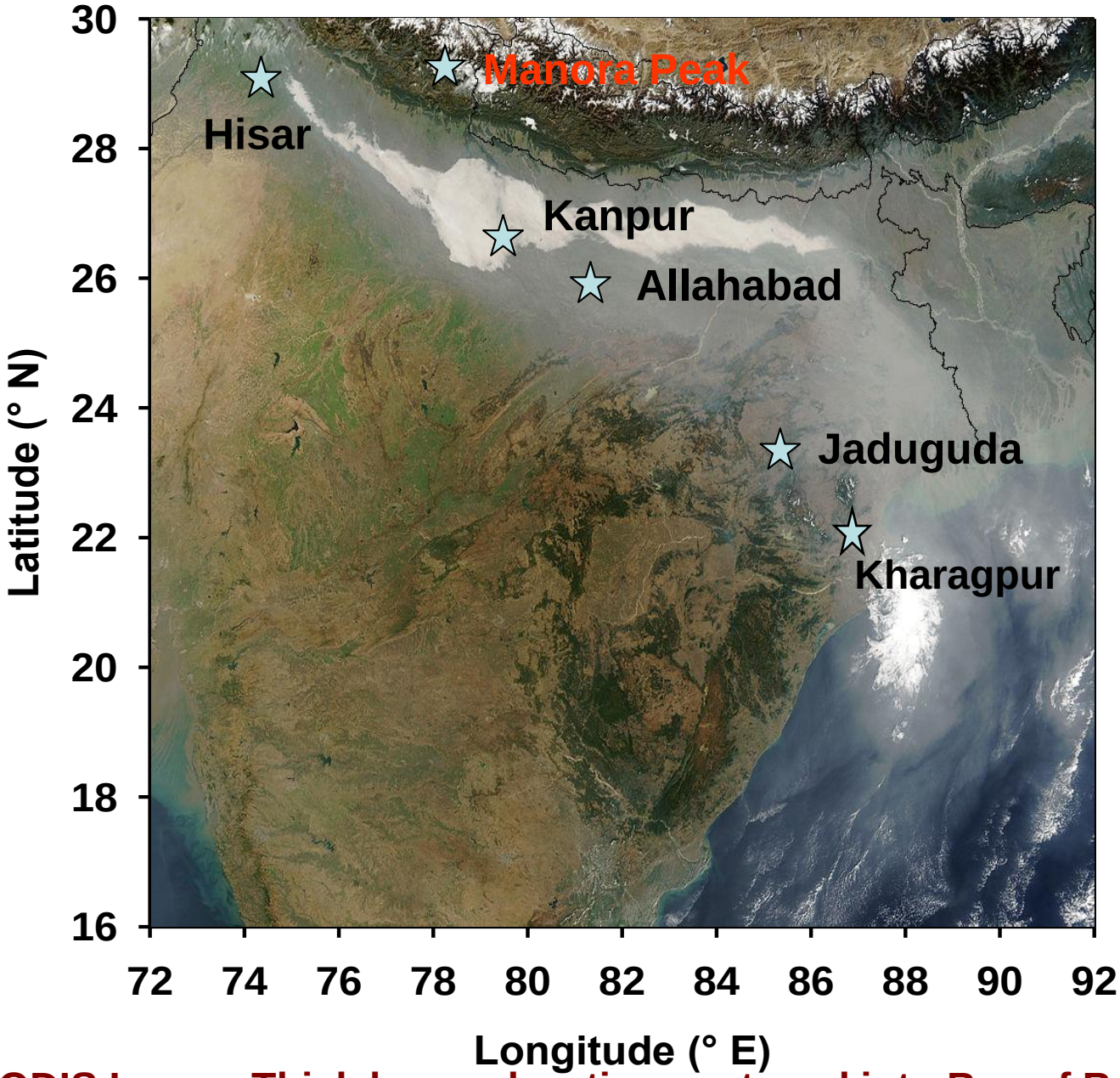
(Modeling Studies):

✷ **Predicted OC/EC : Based on Emission sources**

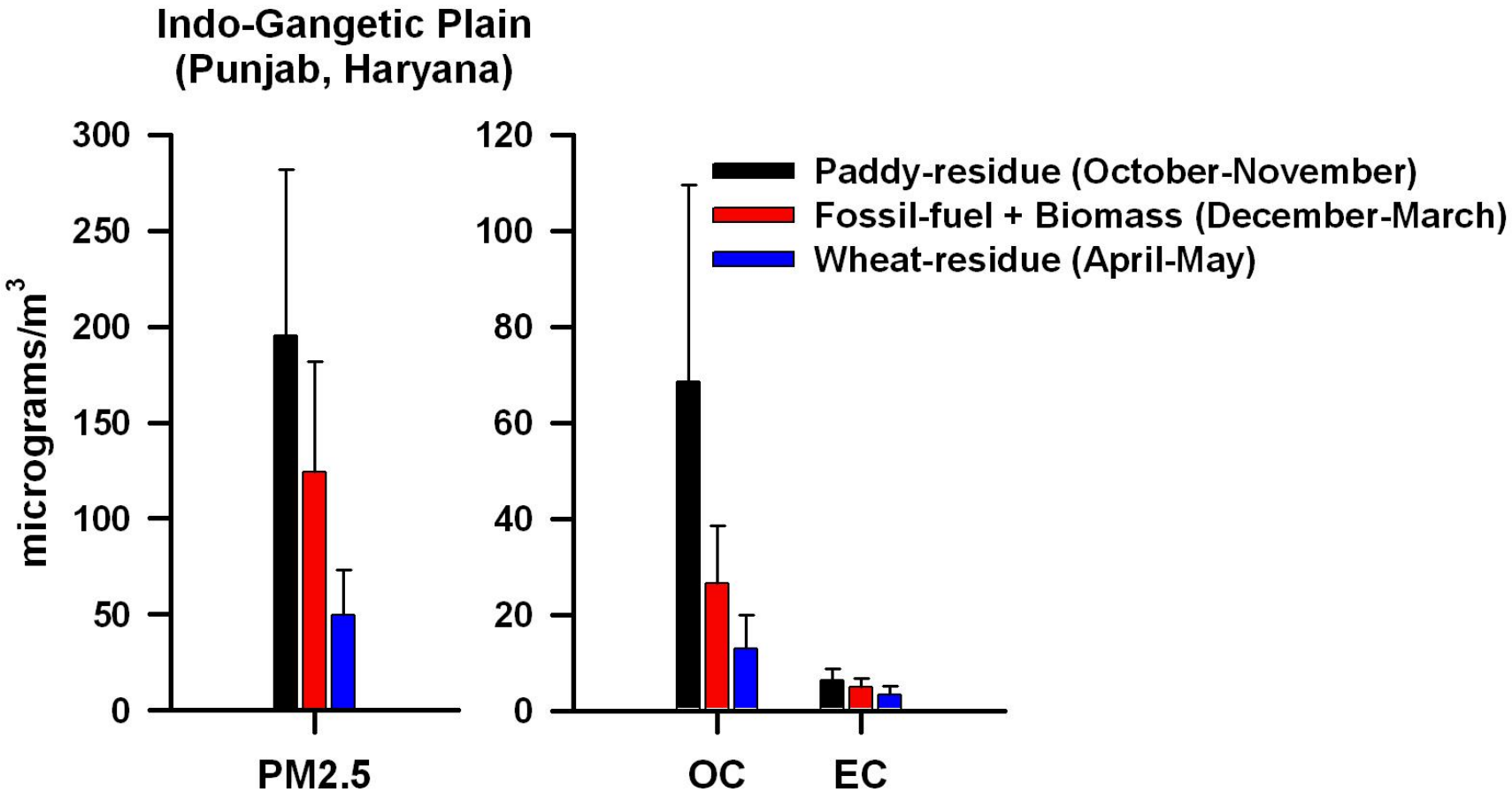
(fuel consumptions & relevant emission factors)

✷ **Subject to significant uncertainties**

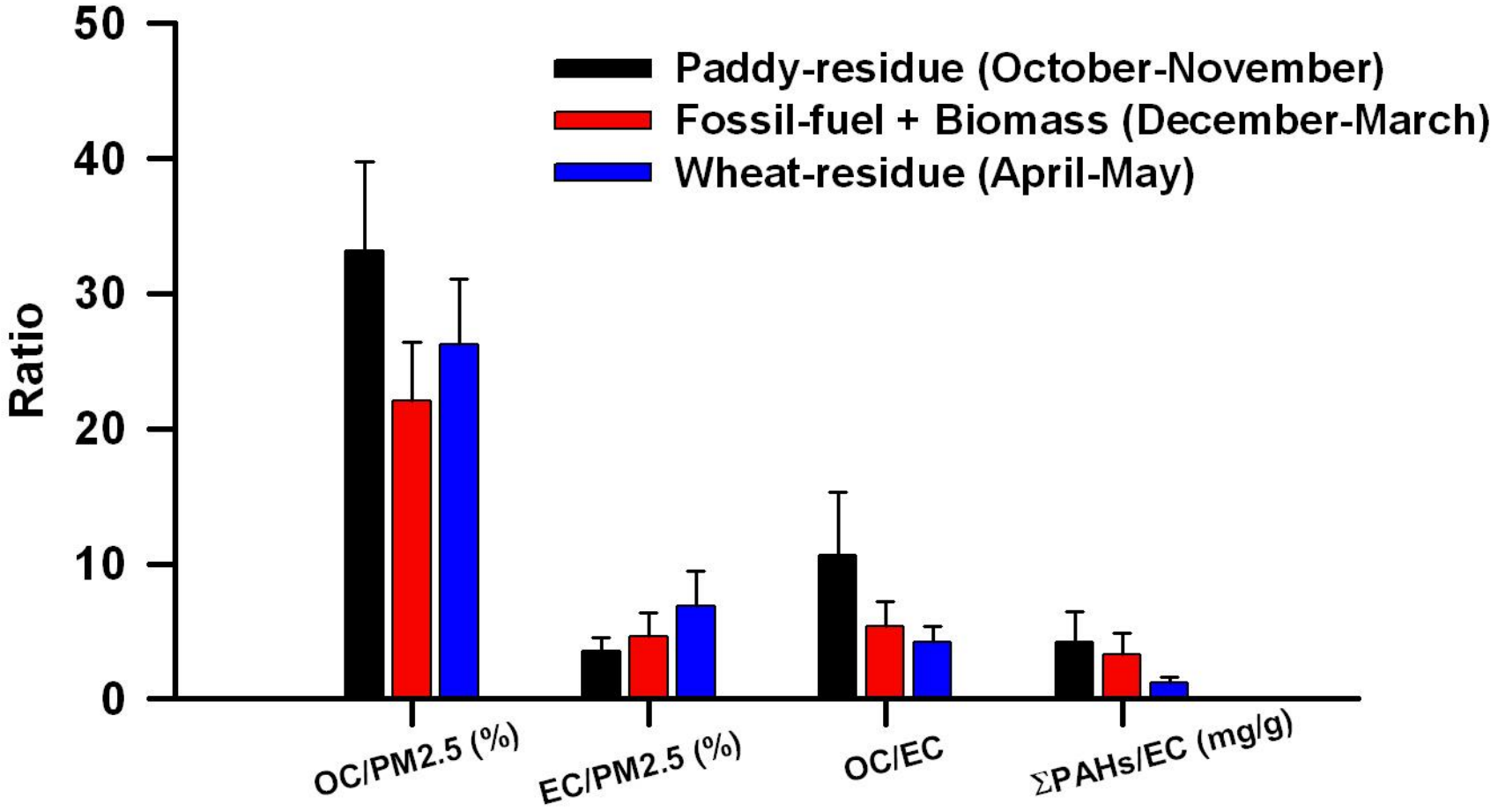
☞**Thus need for direct measurements through network of stations**



MODIS Image: Thick haze advecting eastward into Bay of Bengal.

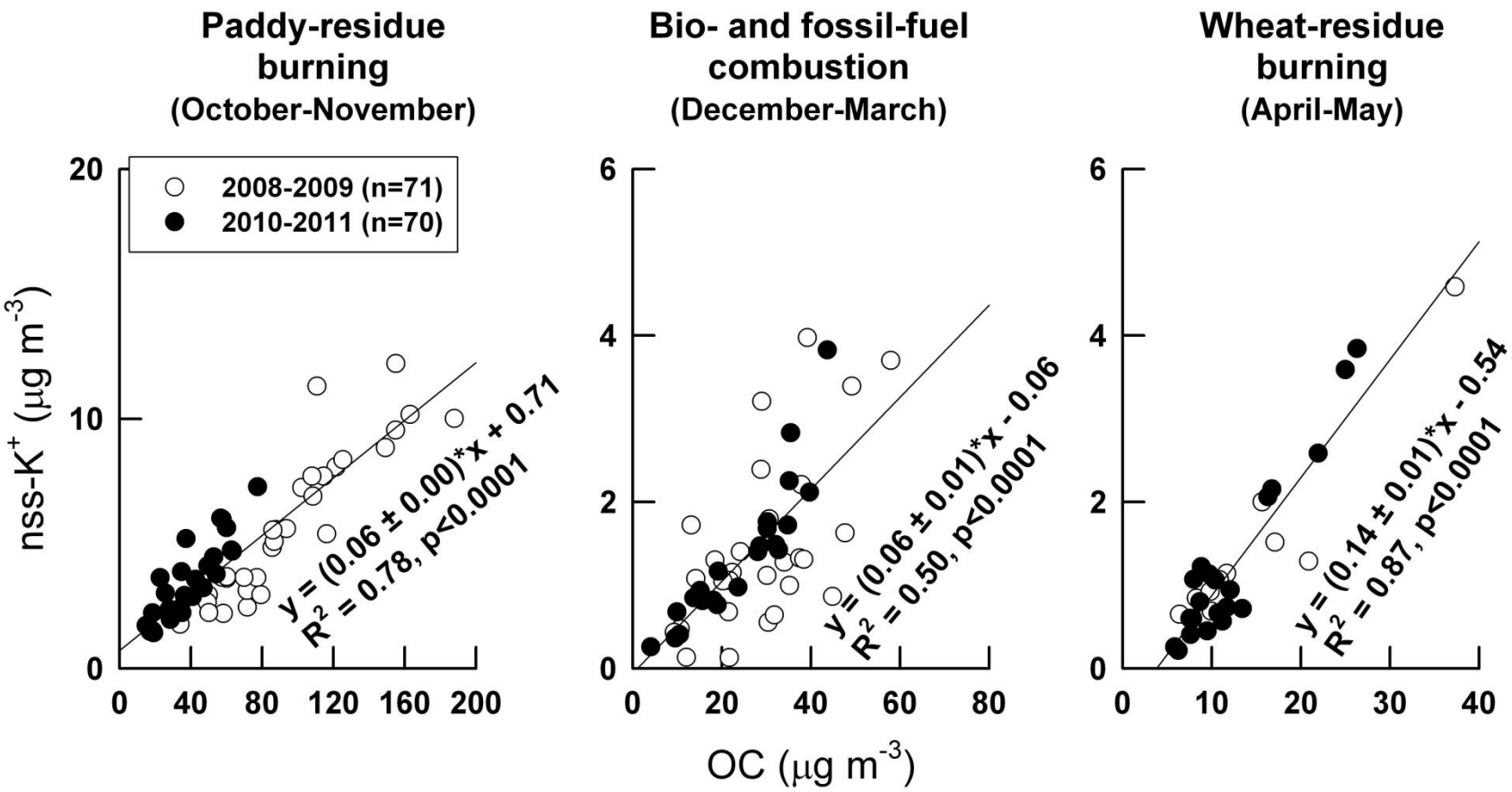


Emissions from post-harvest agricultural-waste burning in Northern India

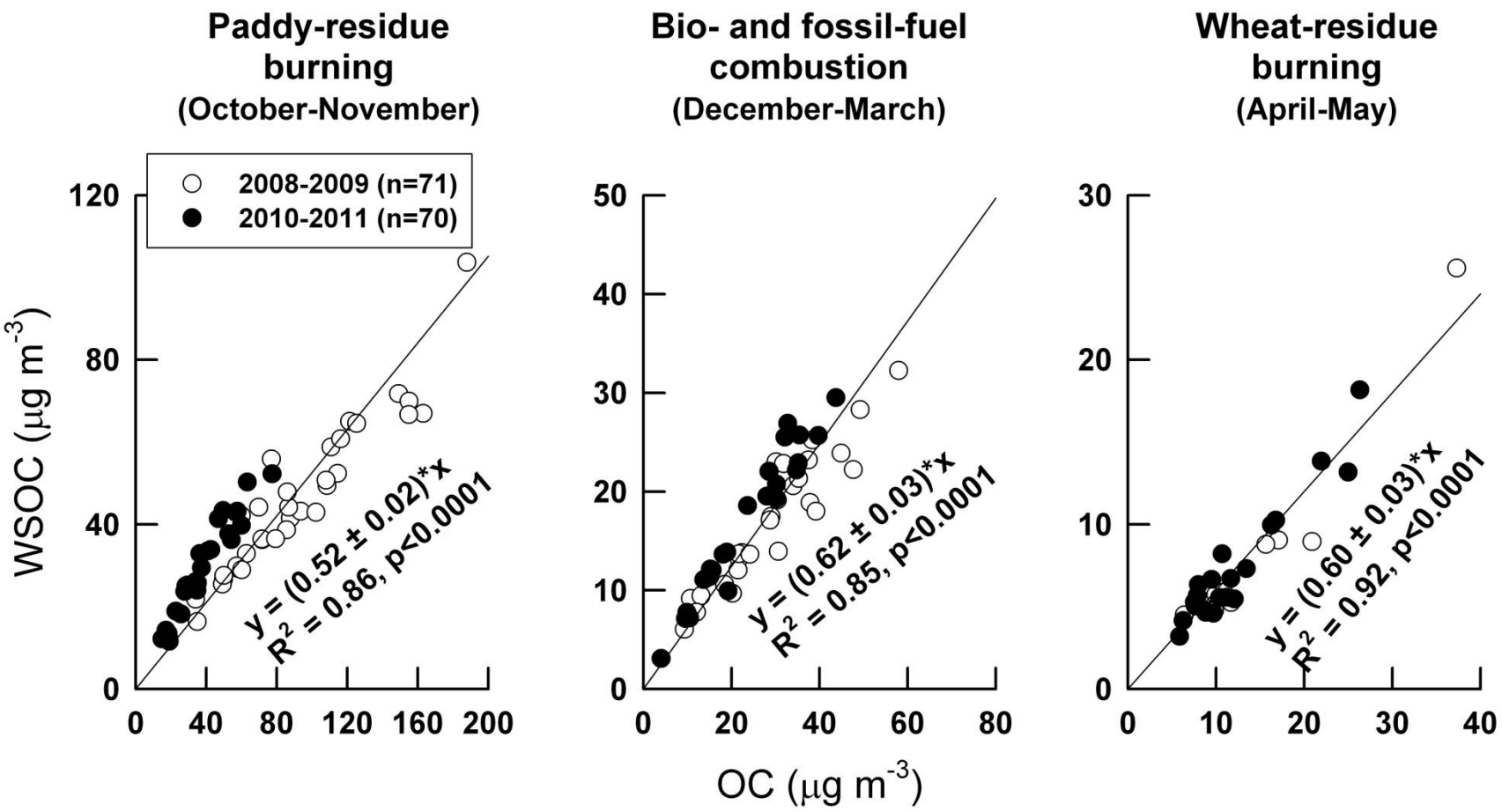


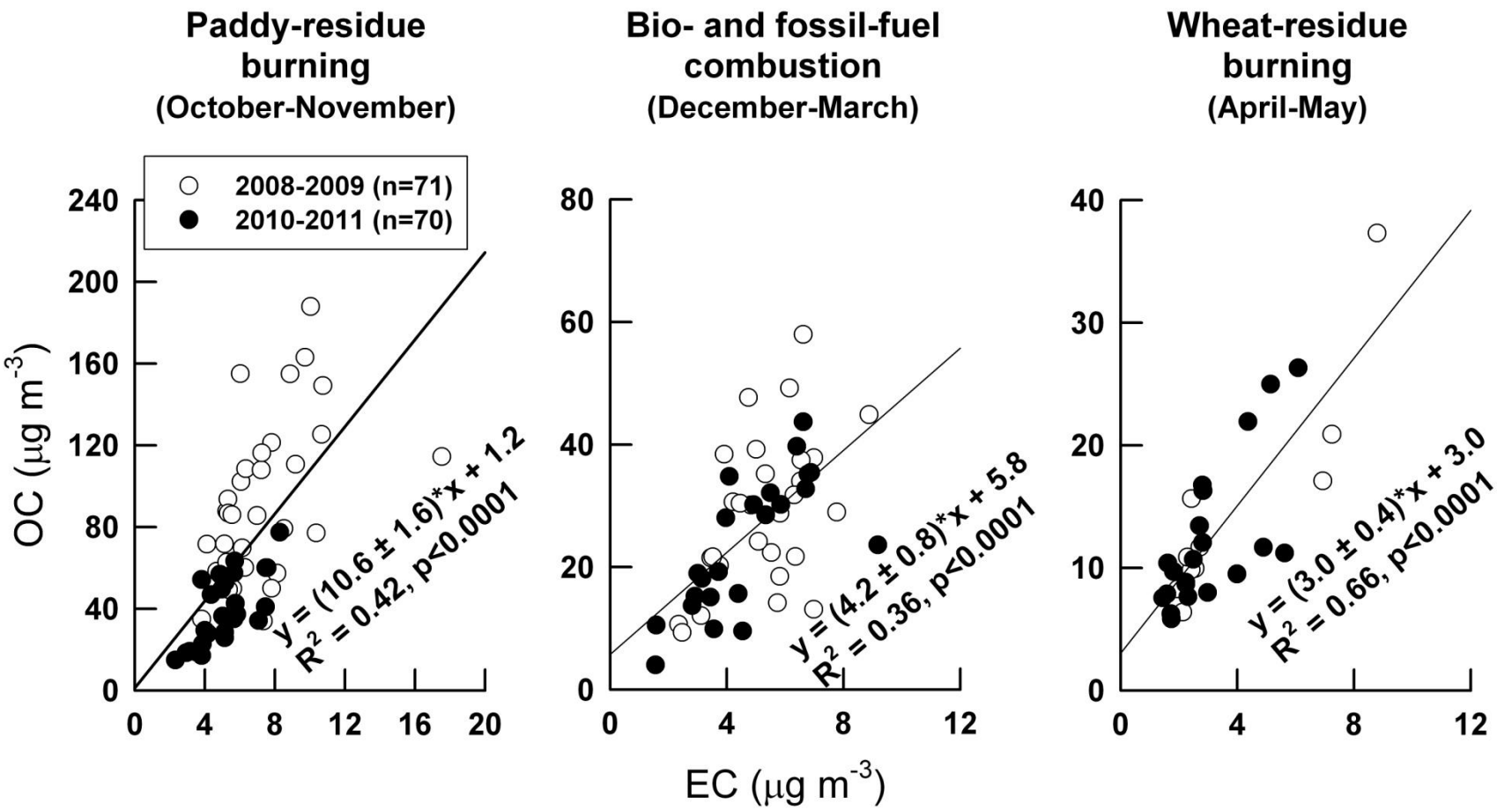
IGP upwind sources: Chemical characteristics

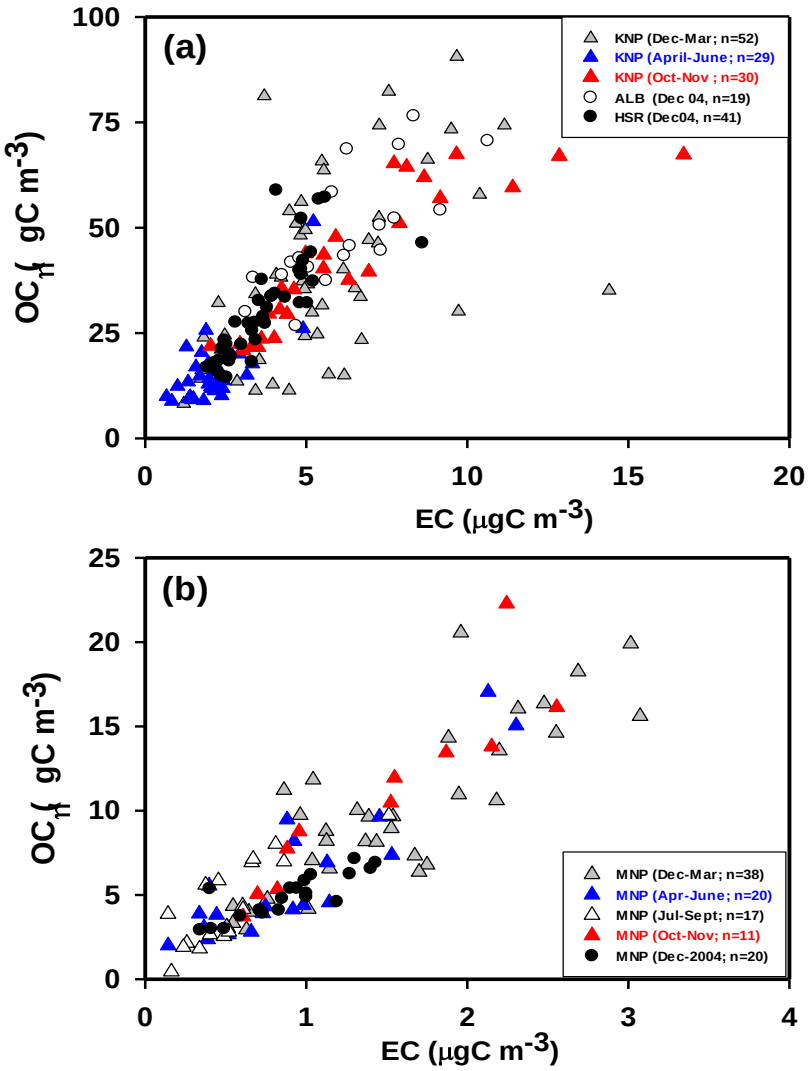
Rajput, Sarin et al., AE (2011) 45: 6732-6740



Chemical characterization of post-harvest agricultural residue burning in the upwind Indo-Gangetic Plain


Paddy-residue burning
(October-November)
2008-2009 (n=71)
2010-2011 (n=70)
y = (0.52 ± 0.02)*x
R² = 0.86, p<0.0001
Bio- and fossil-fuel combustion
(December-March)
y = (0.62 ± 0.03)*x
R² = 0.85, p<0.0001
Wheat-residue burning
(April-May)
y = (0.60 ± 0.03)*x
R² = 0.92, p<0.0001
WSOC (μg m-3)
OC (μg m-3)


Paddy-residue burning
(October-November)
Bio- and fossil-fuel combustion
(December-March)
Wheat-residue burning
(April-May)
2008-2009 (n=71)
2010-2011 (n=70)
OC (μg m-3)
EC (μg m-3)
y = (10.6 ± 1.6)*x + 1.2
R2 = 0.42, p<0.0001
y = (4.2 ± 0.8)*x + 5.8
R2 = 0.36, p<0.0001
y = (3.0 ± 0.4)*x + 3.0
R2 = 0.66, p<0.0001



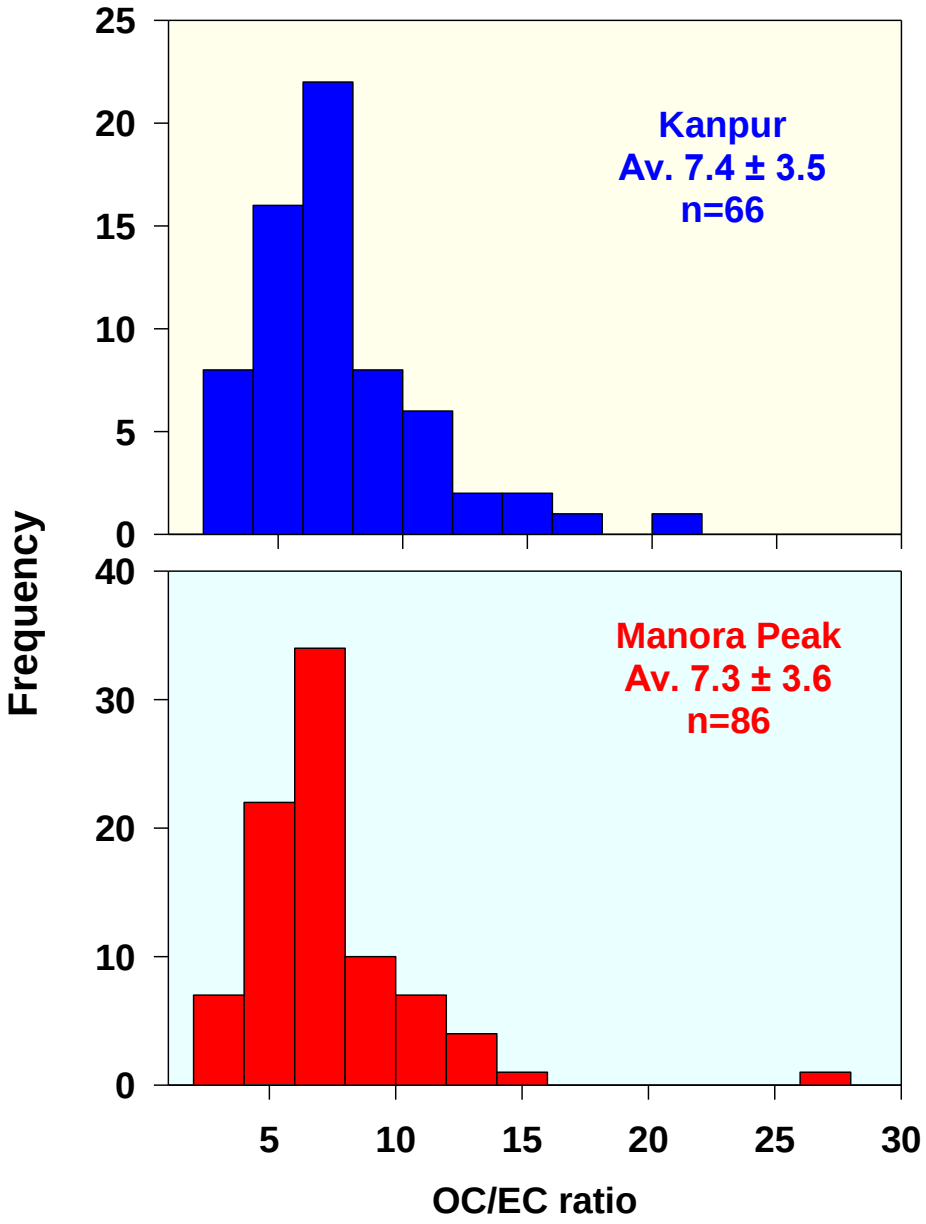
Indo-Gangetic Plain

High-altitude site (Manora Peak)

Characteristic and significant linear relationship for EC and OC documenting high OC/EC ratio

Ram & Sarin et al; ACP (2010) 10: 11791-11803

OC/EC ratios at urban (Kanpur) and high-altitude (Manora Peak) sites

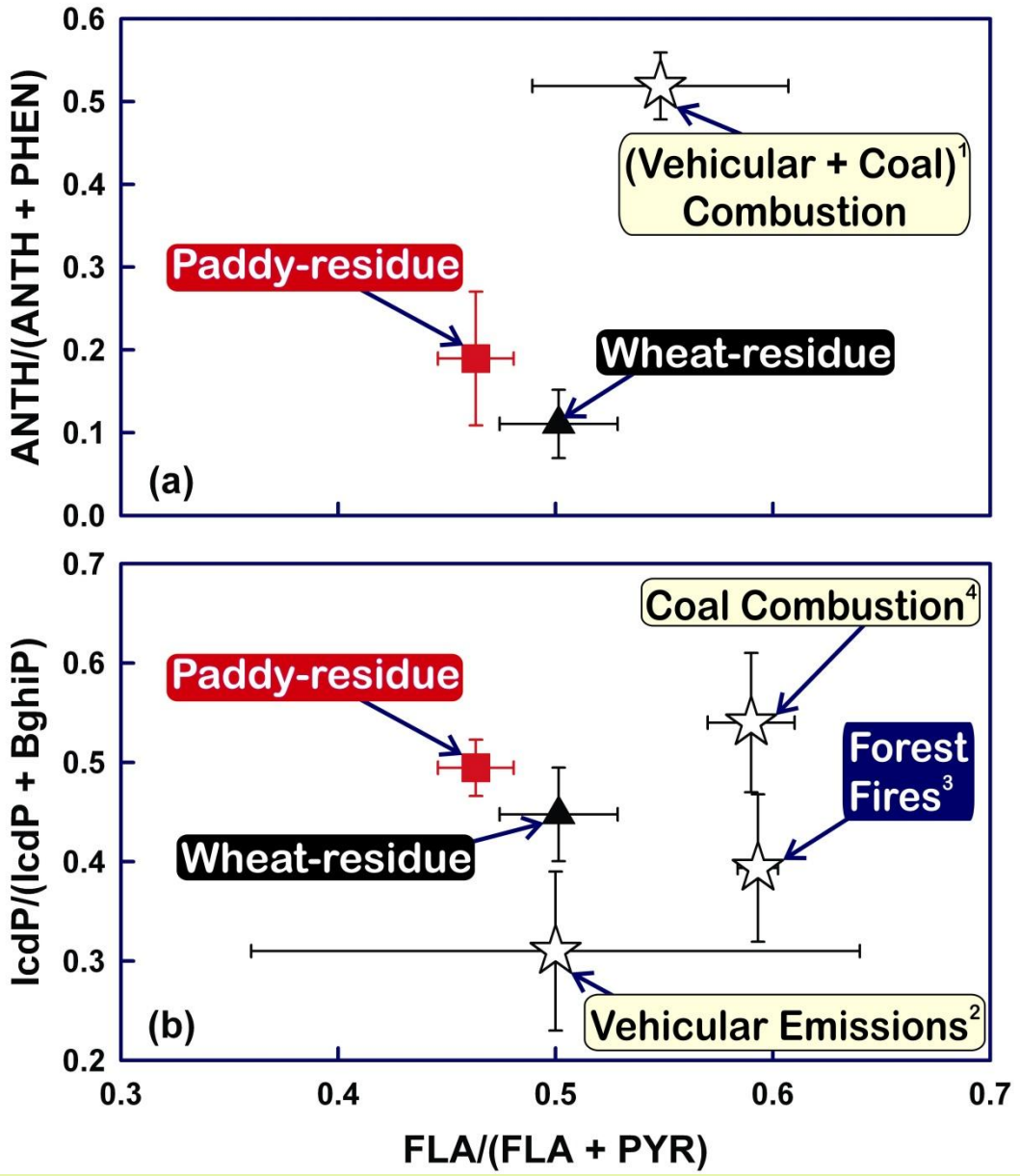


Inferences:

Higher OC/EC ratios suggest dominance of scattering OC than absorbing EC.

The scattering coefficient of OC need to be considered in regional scale climate models.

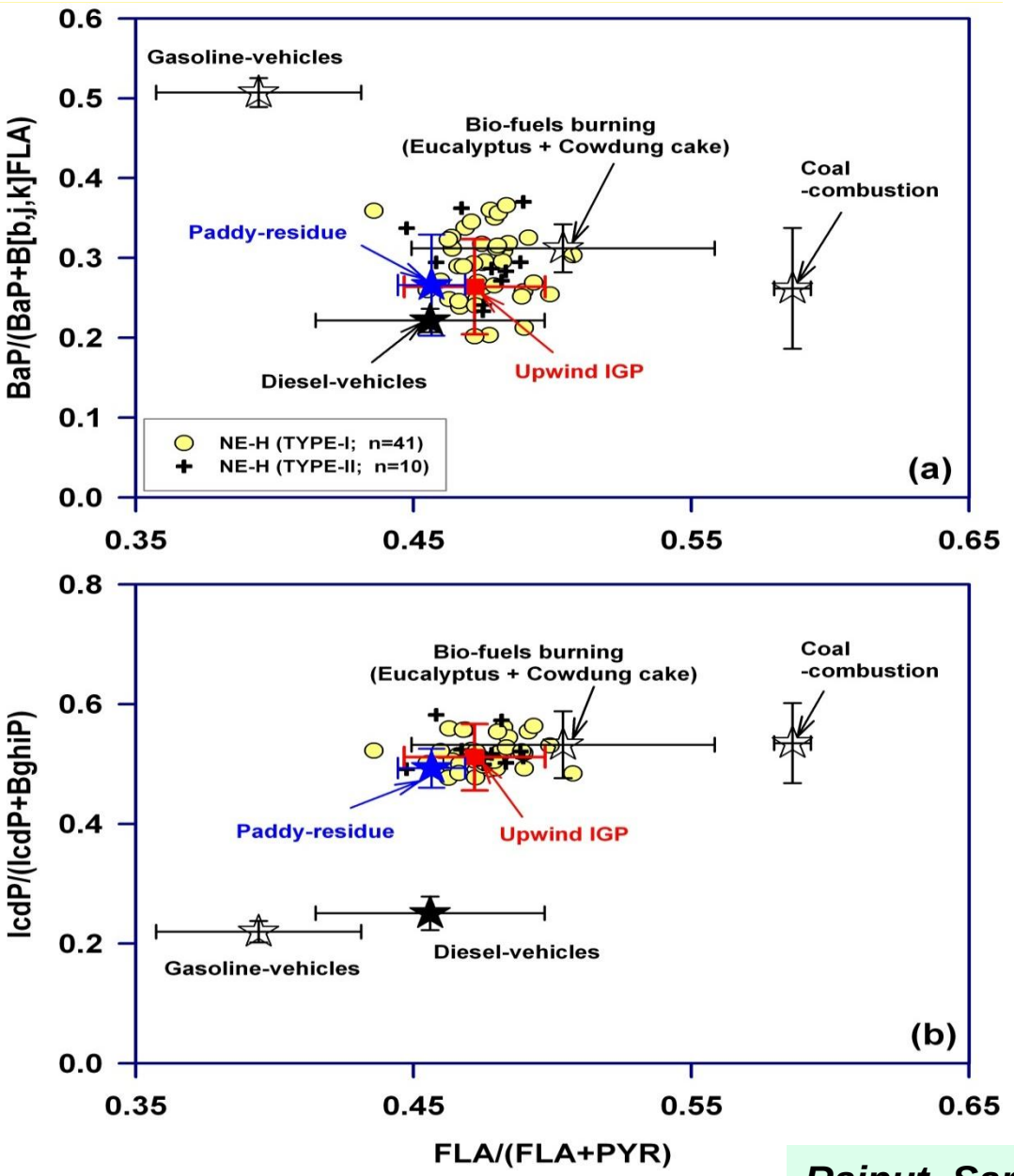
Ram, Sarin et al; ACP 2010, JGR 2010



Cross-plots: Use of PAH isomers as diagnostic tracers

Rajput, Sarin et al., AE (2011) 45: 6732-6740

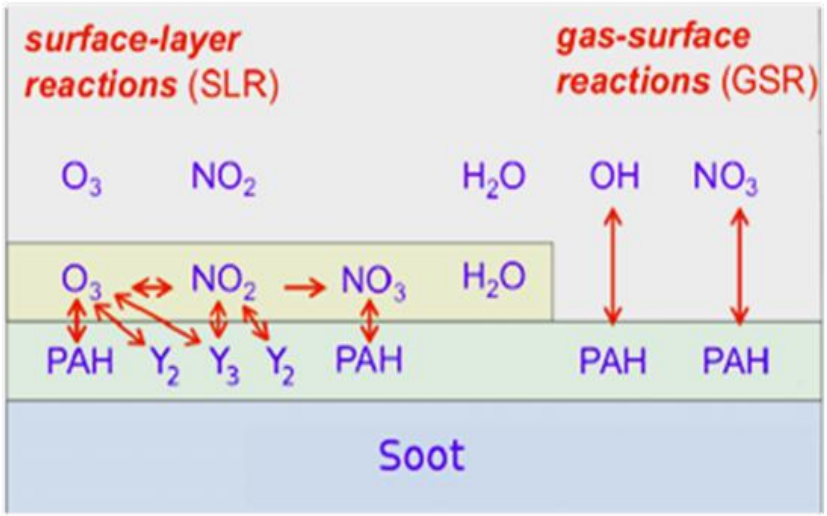
Atmospheric PM2.5, EC, OC, WSOC and PAHs from NE-Himalaya



Rajput, Sarin et al., 2013 (APR)

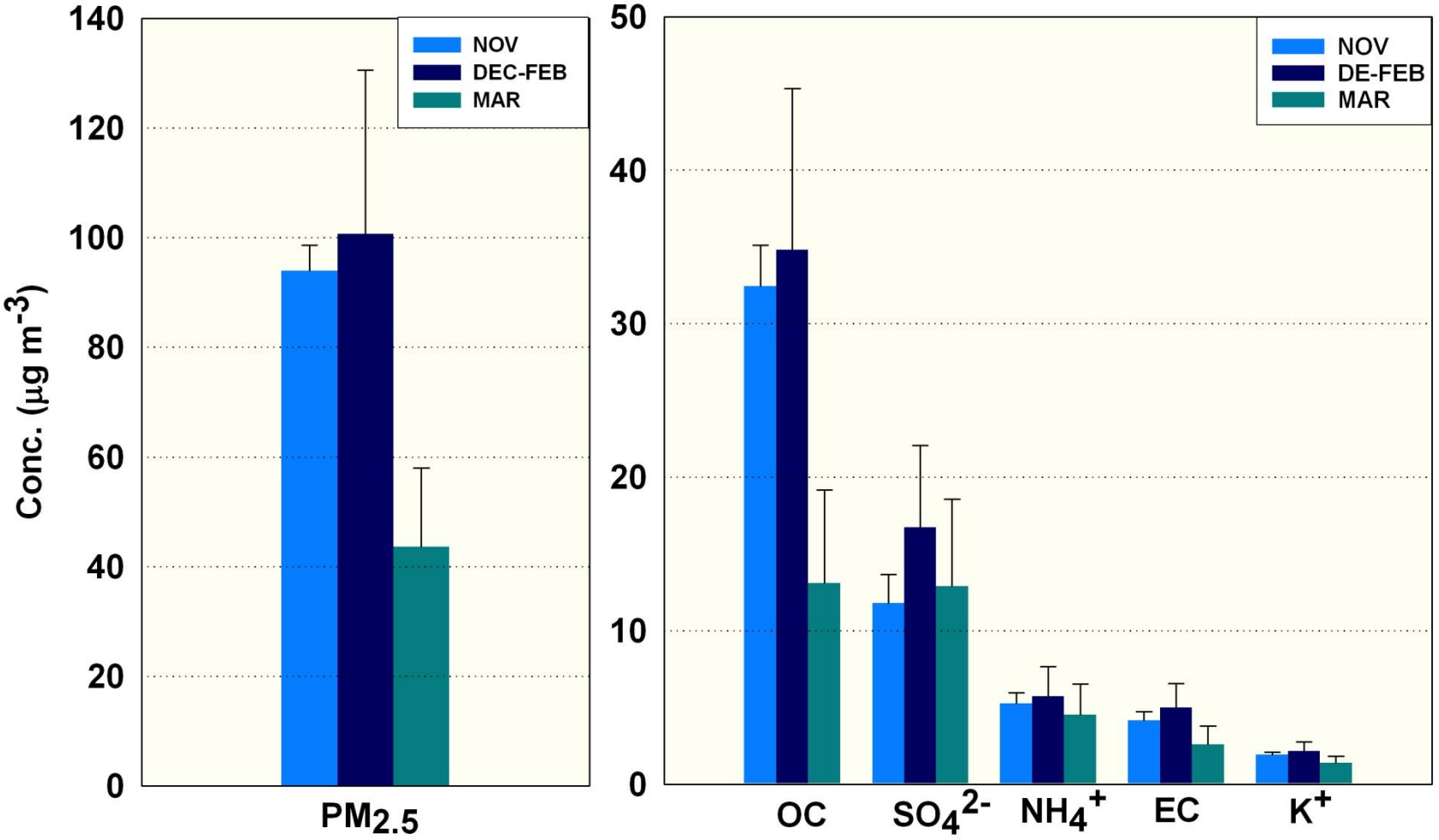
Significance: Polycyclic Aromatic Hydrocarbons (PAHs)

- Potentially participate in **heterogeneous-phase reactions** with O_3, NO_X and OH radical.



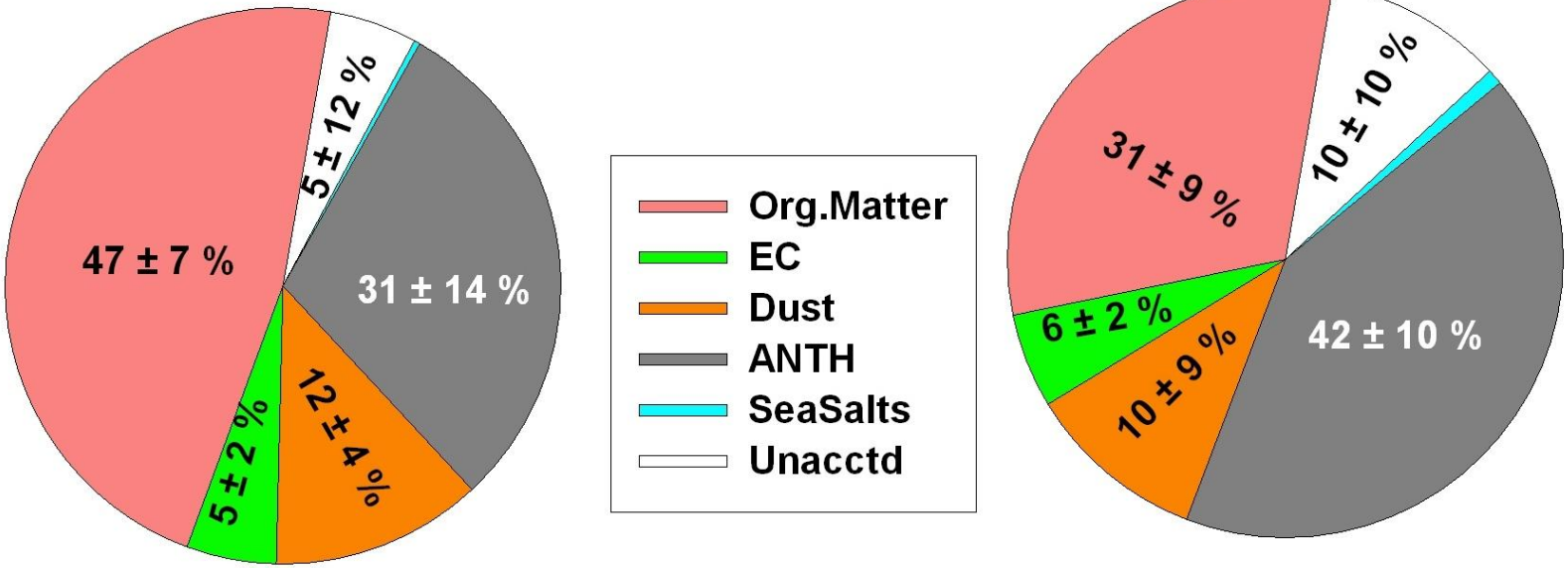
Atmospheric outflow from Indo-Gangetic-Plain

(January – April)



IGP Outflow: Chemical composition suggests dominance of OC and SO_4^{2-}

Mass closure of Particulate matter: IGP-Outflow vis-à-vis Bay of Bengal



(a) Kharagpur
(IGP-outflow: Source)

$PM_{2.5}$: 90 μg m^{-3}

OM/OC ~ 1.5

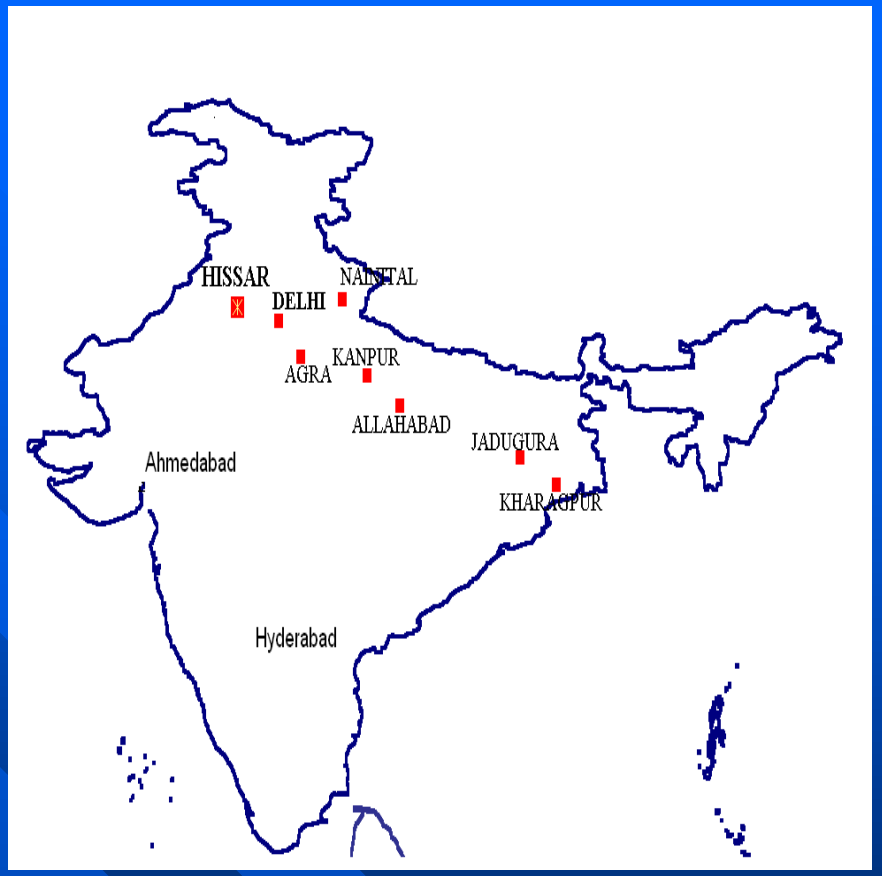
(b) Bay of Bengal
(IGP-outflow:Sink)

$PM_{2.5}$: 38 μg m^{-3}

OM/OC ~ 2.0

Srinivas & Sarin et al.; 2013 (AE Under Review)


EC (BC), OC, IC, K^+,
NO_3^- and SO_4^{2-}


HISSAR
DELHI
NAINITAL
KANPUR
AGRA
ALLAHABAD
JADUGURA
Ahmedabad
KHARAGPUR
Hyderabad

Impact of pollution sources on MABL:

* **Large Chloride depletion:** **Oxidation of DMS & hydrocarbons (tropospheric sink)** *J. Atmos. Chem. (2011)*

* ***Chemical processing of mineral dust during long-range transport*** *Marine Chem. (2010); Tellus (2012)*

Biogeochemistry (2012)

* **Atmospheric N-deposition:**

Role of N_{org} vis-à-vis N_{Inorg} *Marine Chem. (2011)*

* ***Enrichment of toxic trace metals*** *J. Mar. Syst. (2012)*

Chloride depletion in MBL

Complete degassing of HCl from NaCl

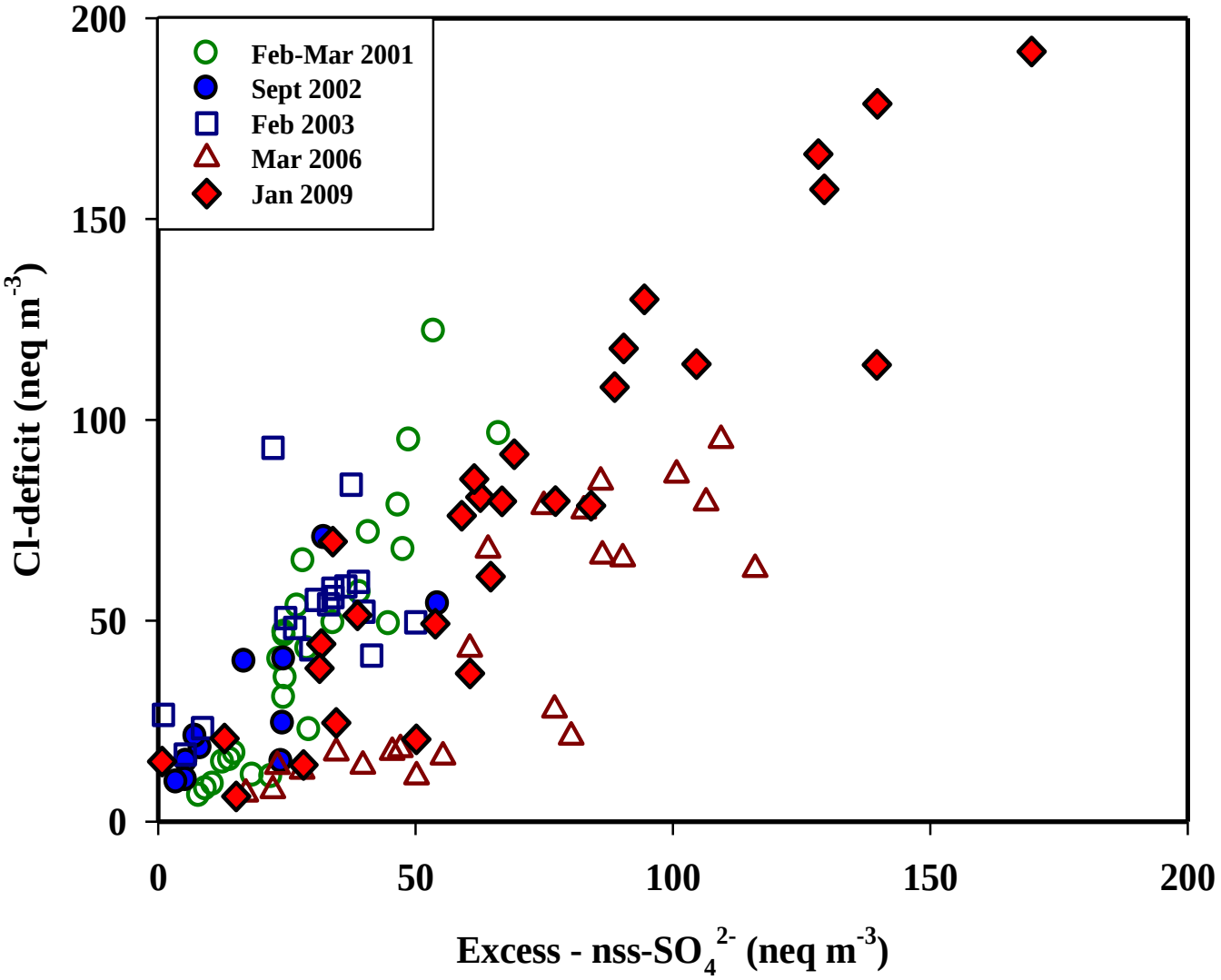
(Deliquescent sea-salt aerosols)

- **97--100% RH, buffered pH ~8**

$$\text{nss-}SO_4^{2-} \Longrightarrow \underset{\text{----------oxi.----------}}{SO_2\ (S\ +4) \longrightarrow SO_4^{2-}\ (S\ +6)}$$

- $2NaCl + H_2SO_4 \longrightarrow 2HCl\uparrow + Na_2SO_4$
- $NaCl + HNO_3 \longrightarrow HCl\uparrow + NaNO_3$

- **Consequence of decreasing aerosol pH as droplets evaporate**
- **HCl(aq.) reaches saturation**
- **HCl (g) Aqueous phase ⟶ gas phase**



Increase in Cl-deficit with aerosol nss-SO_4^{2-} over Bay of Bengal.

Sarin, Kumar, Srinivas, Sudheer and Rastogi

Jour. Atmos. Chem 66(2010)1-10

Implications :

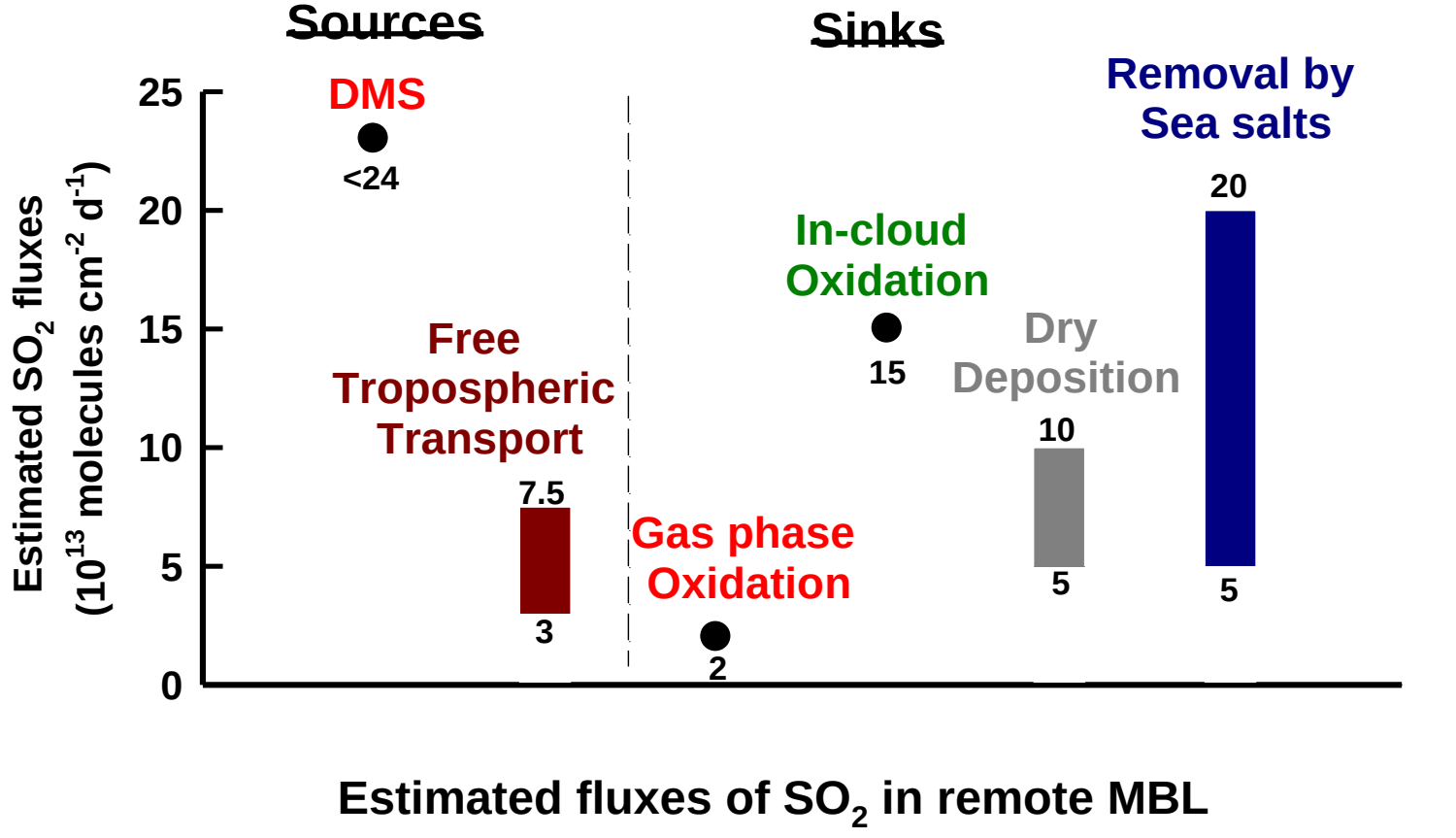
- (SO_2) SO_4^{2-} —*Sea-salt*→ **limit CCN**
- **Anthropogenic** (SO_2) SO_4^{2-} —*Sink*→ **change to coarse**

Increase Ozone loss :

1. $O_3 + S_{iv}\ (SO_2) \xrightarrow{oxi.} SO_4^{2-} + O_2$ **[major O_3 sink]**
   (at pH : ~6-8 , Rate constant 4 x 10^{11})

2. $O_3 + Cl^- \xrightarrow{oxi.} ClO^- + O_2$ **[slow rate]**
   (Unaccounted O_3 sink !)

HCl degassing from sea-salt



Estimated fluxes of SO_2 in remote MBL

Concluding thoughts (Regional issues):

**** Export fluxes of aerosols and their precursors from continents (mega-cities, biomass burning emissions, desert dust)?***

*** Atmospheric aging of BC & role as CCN?**

*** What models need:** ***OC/EC ratios and Org. matter-to-Org C ratio***

Atmospheric processing (aging !) of soot aerosols:

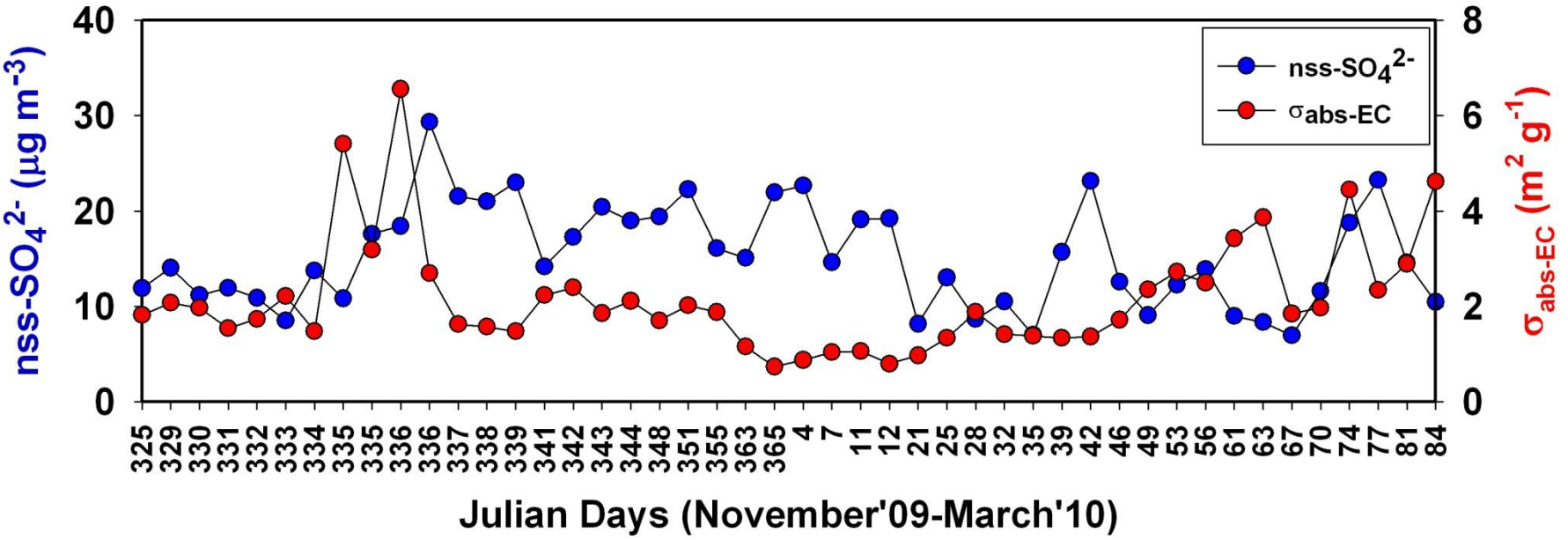
— *when exposed to sub-saturated sulphuric acid, may exhibit marked change in morphology (decreased mobility-based diameter & increased effective density)*

— **experience large hygroscopic size & mass growth and act efficiently as CCN**

— *changes optical properties (scattering & absorption)*

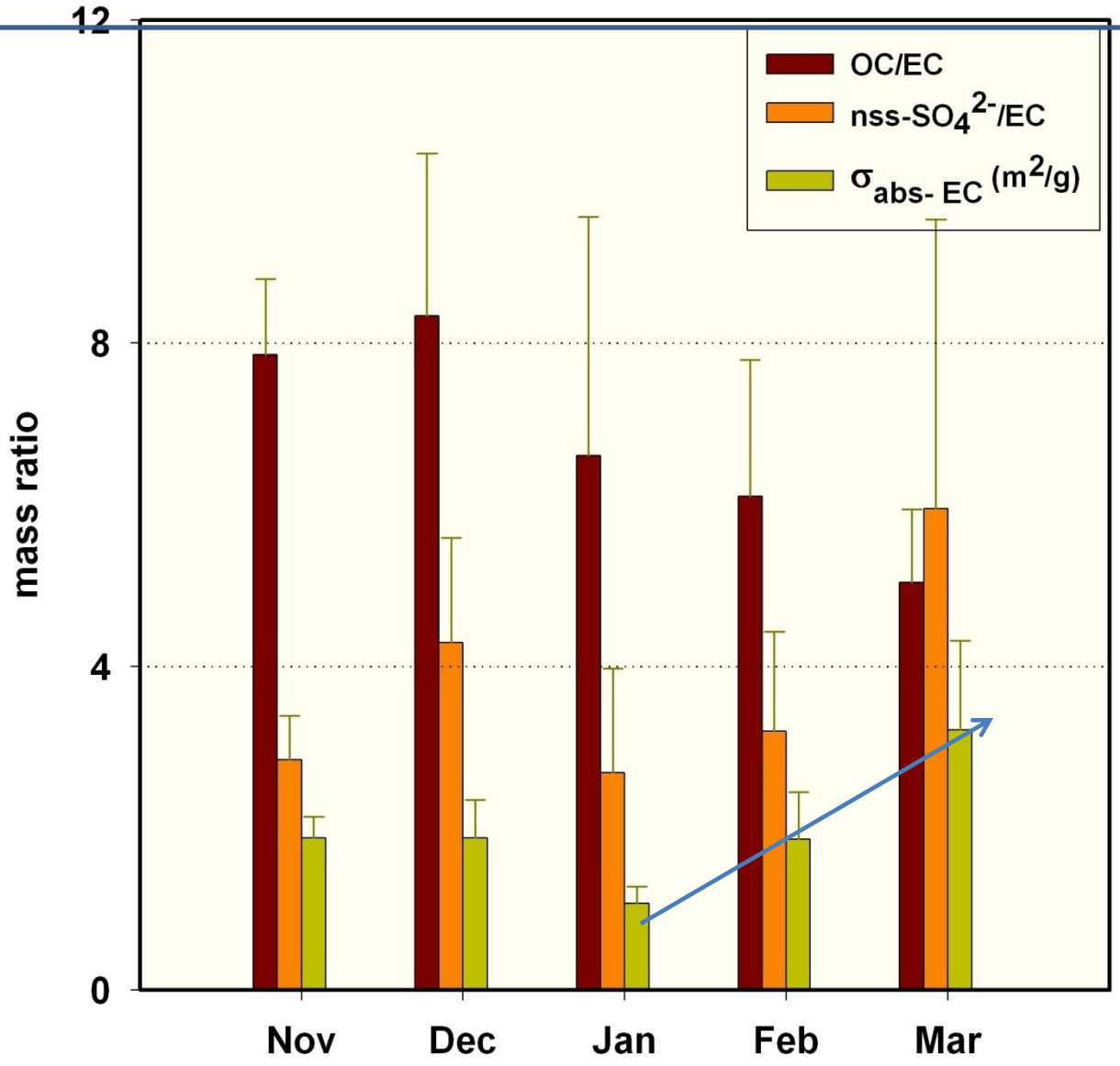
K.Ram, Sarin & Tripathi (JGR 2010)

Temporal variability of mass absorption efficiency of EC (σ_{abs-EC}) & nss-SO_4^{2-}



Atmospheric outflow from the Indo-Gangetic Plain

Temporal variability of mass absorption efficiency of EC ($\sigma_{abs\text{-}EC}$) & nss-SO_4^{2-}



Atmospheric Soot Particles:

Much attention on reactions with nitrogen oxides:

(NO & NO_2)

NO_2 + Soot $\rightarrow\rightarrow$ HONO + NO

"Current models underestimate production of HONO"

HONO $\rightarrow$ photolytic source of OH^- radical

✷ **Soot + (O_3) $\longrightarrow$ OH, R–C=0 & R–C–0**

Make Soot-particles more polar

↓

Increases their efficiency as CCN