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Evaluation of the MERRA-2 $PM_{2.5}$ mass and its constituent chemical species concentrations over a COALESCE network site in Bhopal, India

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Introduction

- $PM_{2.5}$ can cause respiratory diseases including asthma and lung cancer which may be the reason for shorter lifespan (Kim et al., 2015)
- About 3.4 ± 1.1 years of lifespan reduces because of $PM_{2.5}$ in India and this value is significantly high in Delhi alone viz. 6.3 ± 2.0 years (Ghude et al., 2016)
- Reanalysis data sets provides $PM_{2.5}$ data sets at high spatio-temporal resolutions.
- MERRA-2 $PM_{2.5}$ species have not been much evaluated over the Indian region

Objectives

- **Objective-1**: To evaluate MERRA2 $PM_{2.5}$ and $PM_{2.5}$ species over a regionally representative site in Bhopal, India

- **Objective-2**: To discuss the possible causes of disagreement between in-situ and MERRA2 $PM_{2.5}$ surface concentrations

Data and Methodology

Product	Spatial Resolution
MERRA 2 (BC, OC, Sulphate, Sea-salt, Dust), 2019	0.5° x 0.625°
In-situ measurements ($PM_{2.5}$, BC, OC, Sulphate, Nitrate, Sea-salt, Mineral Dust), 2019	In-situ measurements

Calculation of In-situ $PM_{2.5}$

$$PM_{2.5} = 1.6 * OC + BC + Sulphate + Nitrate + SeaSalt + Dust \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Calculation of in-situ dust (Chow et al., 1994)

$$\text{Dust} = 1.89 * Al + 2.14 * Si + 1.21 * K + 1.4 * Ca + 1.67 * Ti + 1.58 * Mn + 1.43 * Fe \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Calculation of MERRA2 $PM_{2.5}$ (Buchard et al., 2016)

$$PM_{2.5} = 1.6 * OC + BC + 1.375 * Sulphate + SeaSalt + Dust \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

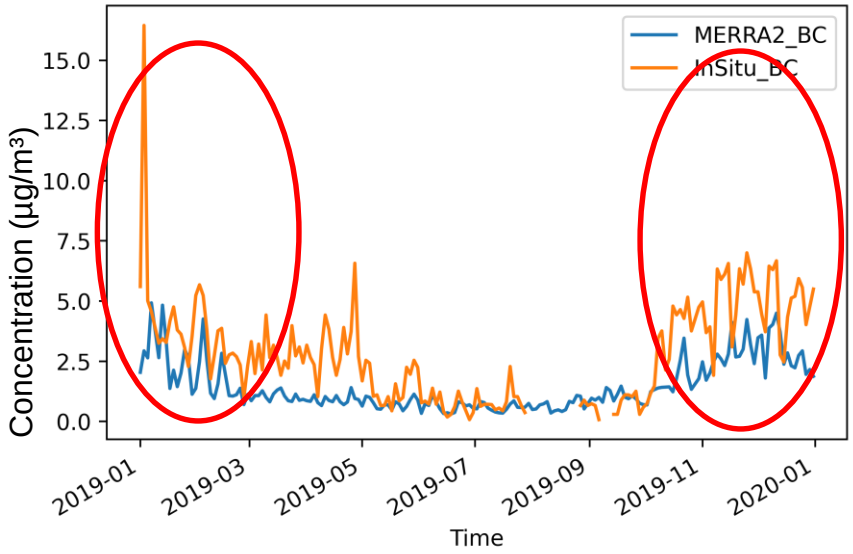
Evaluation methods

$$NMB = \frac{\sum_1^n (Mi - Oi)}{\sum_1^n O_i} * 100$$

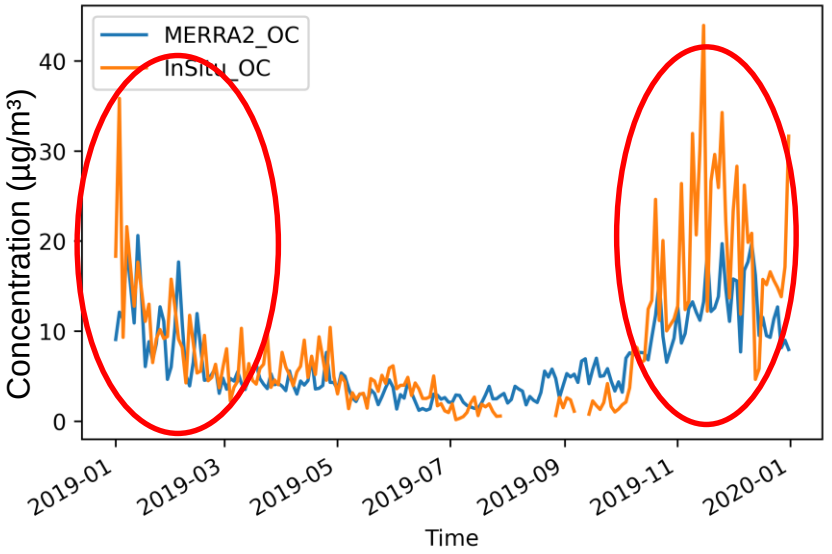
$$RMSE = \sqrt{\frac{1}{n}\sum_1^n (M_i - Oi)^2}$$

Where,
M: MERRA2 reanalysis parameter
O: Observed in-situ parameter
n: no of data points

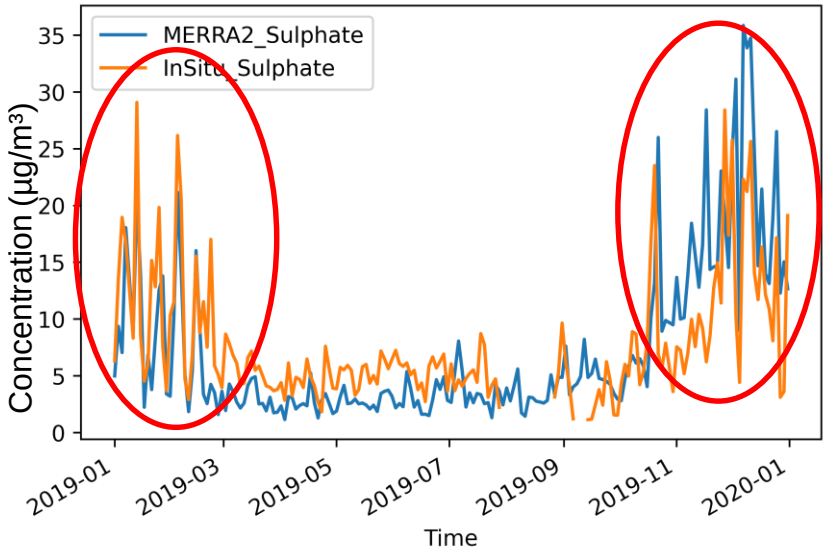
Results (Daily)



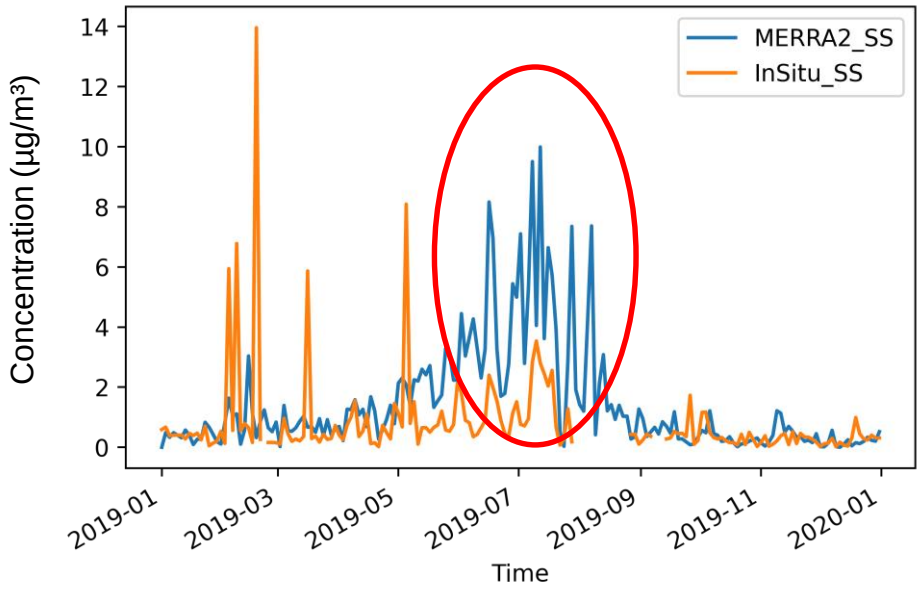
Black Carbon



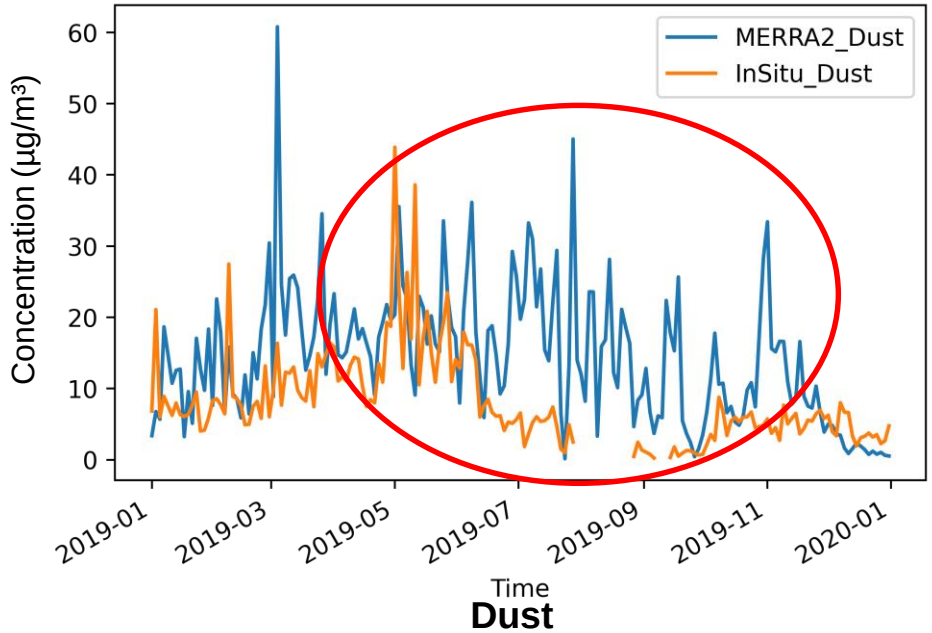
Organic Carbon



Sulphate

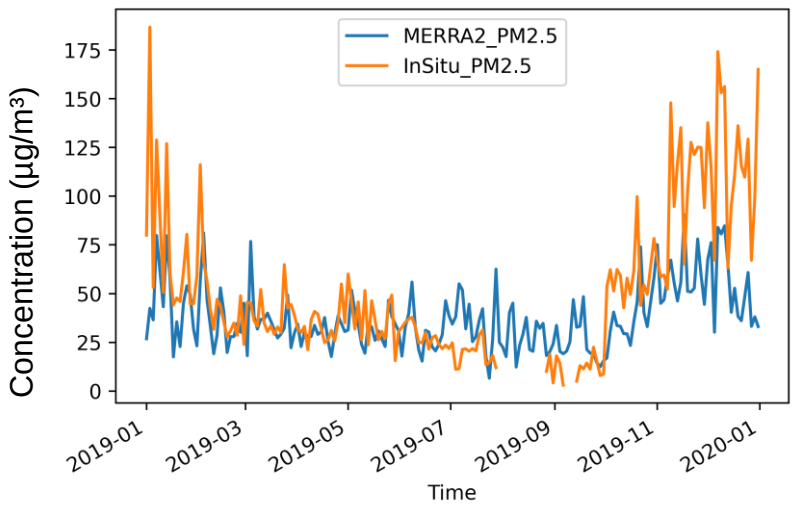


Sea-Salt

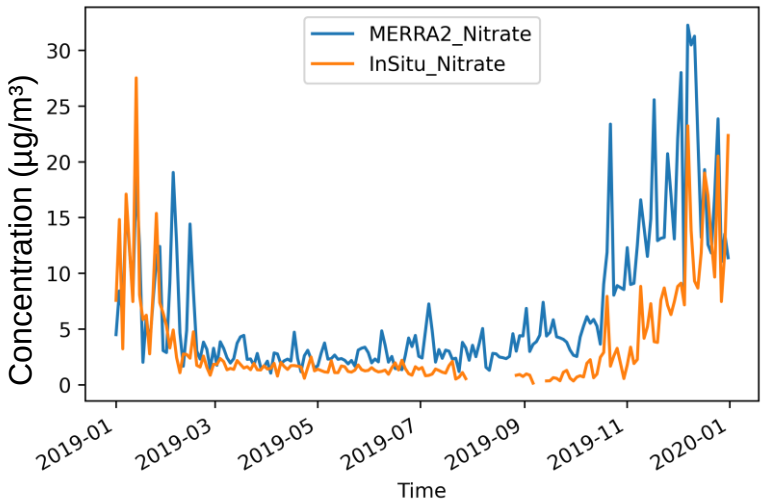


Dust

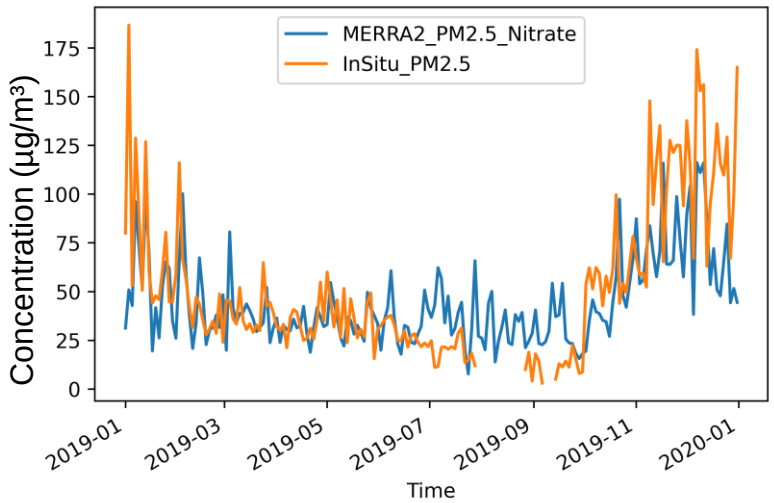
Results (Daily) Contd…



$PM_{2.5}$



Nitrate



$PM_{2.5}$ with Nitrate

A previous study (Kumar and Sunder Raman, 2020) over Bhopal observed a nitrate to sulphate ratio of ~0.9

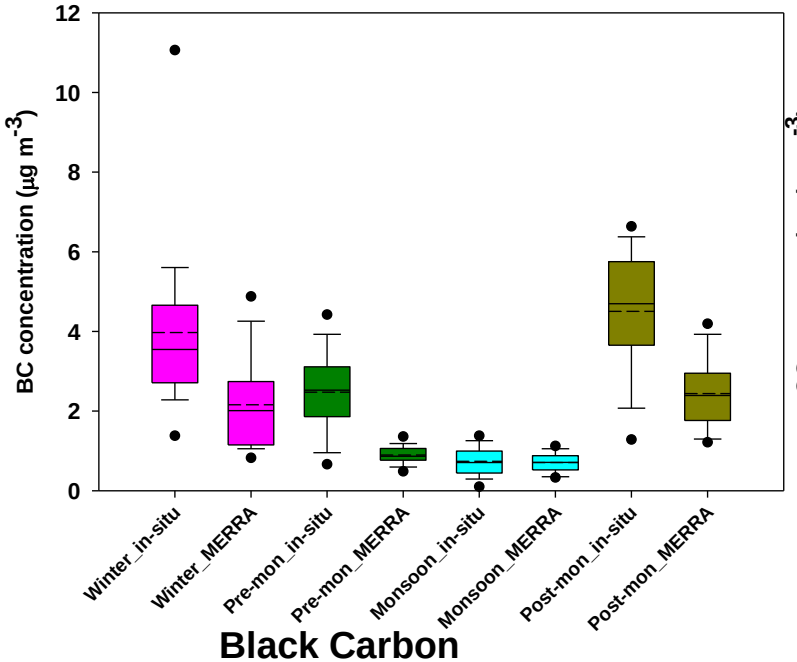
$$Nitrate = 0.9 * Sulphate$$

Calculation of MERRA2 $PM_{2.5}$(proposed)

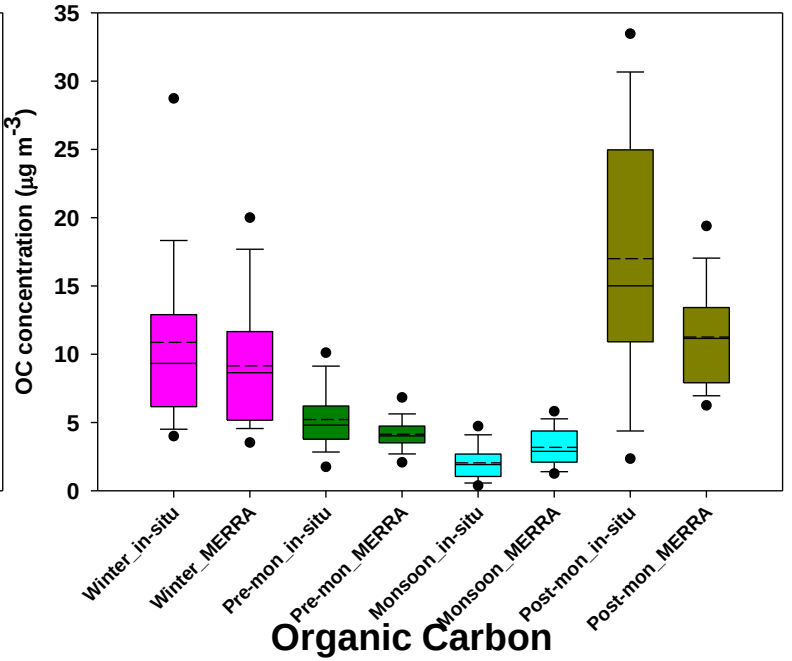
$$PM_{2.5} = 1.6 * OC + BC + 1.375 * Sulphate + SeaSalt + Dust + Nitrate$$

…… (4)

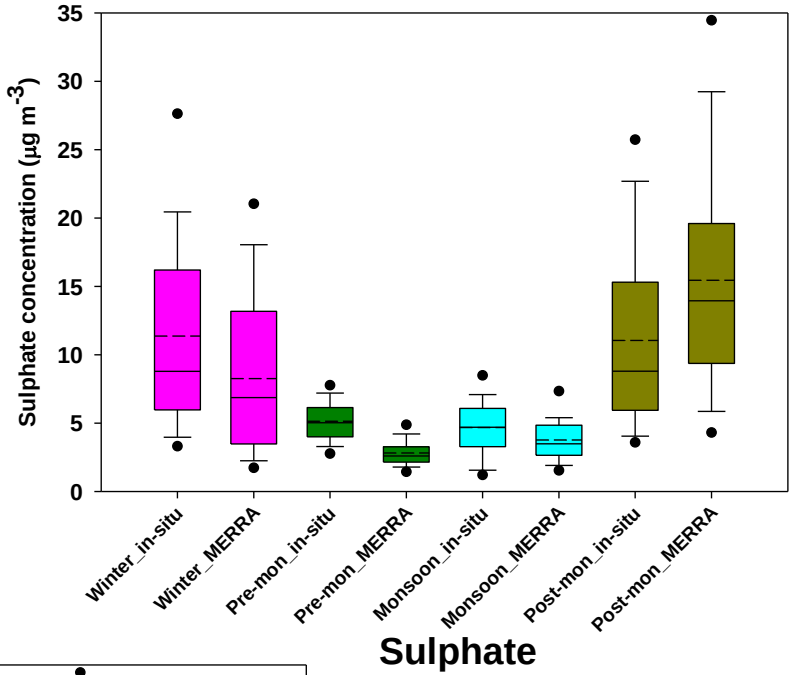
Results (Seasonal)



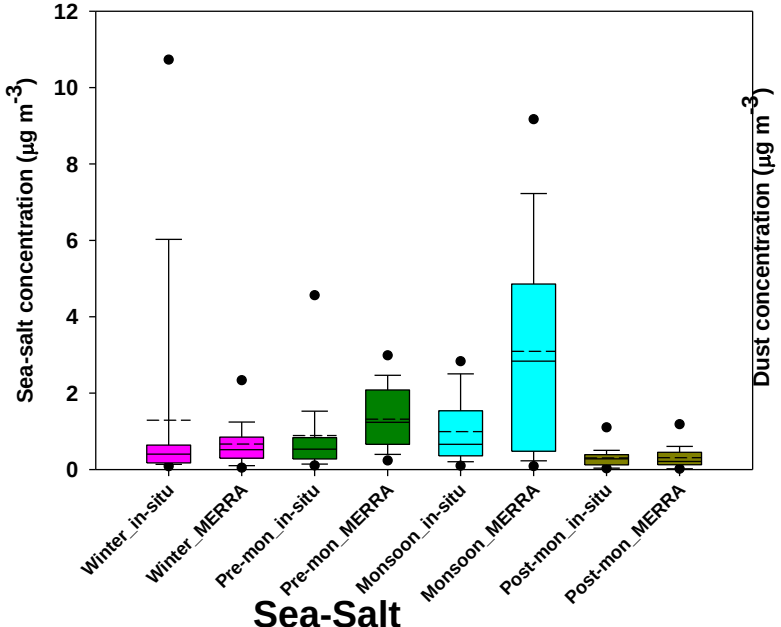
Black Carbon



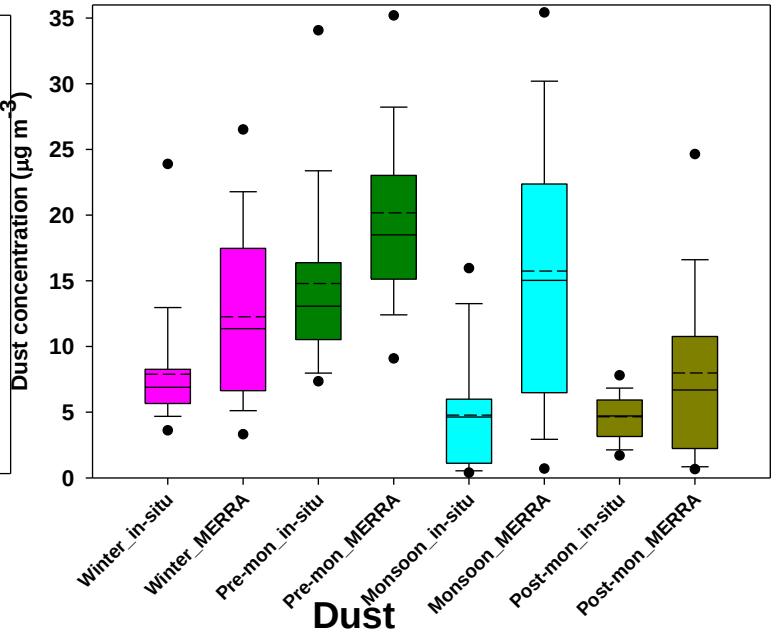
Organic Carbon



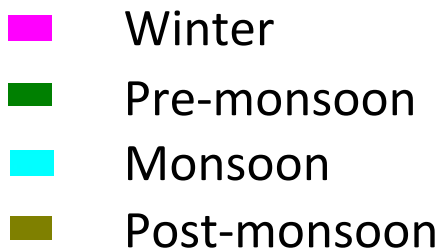
Sulphate



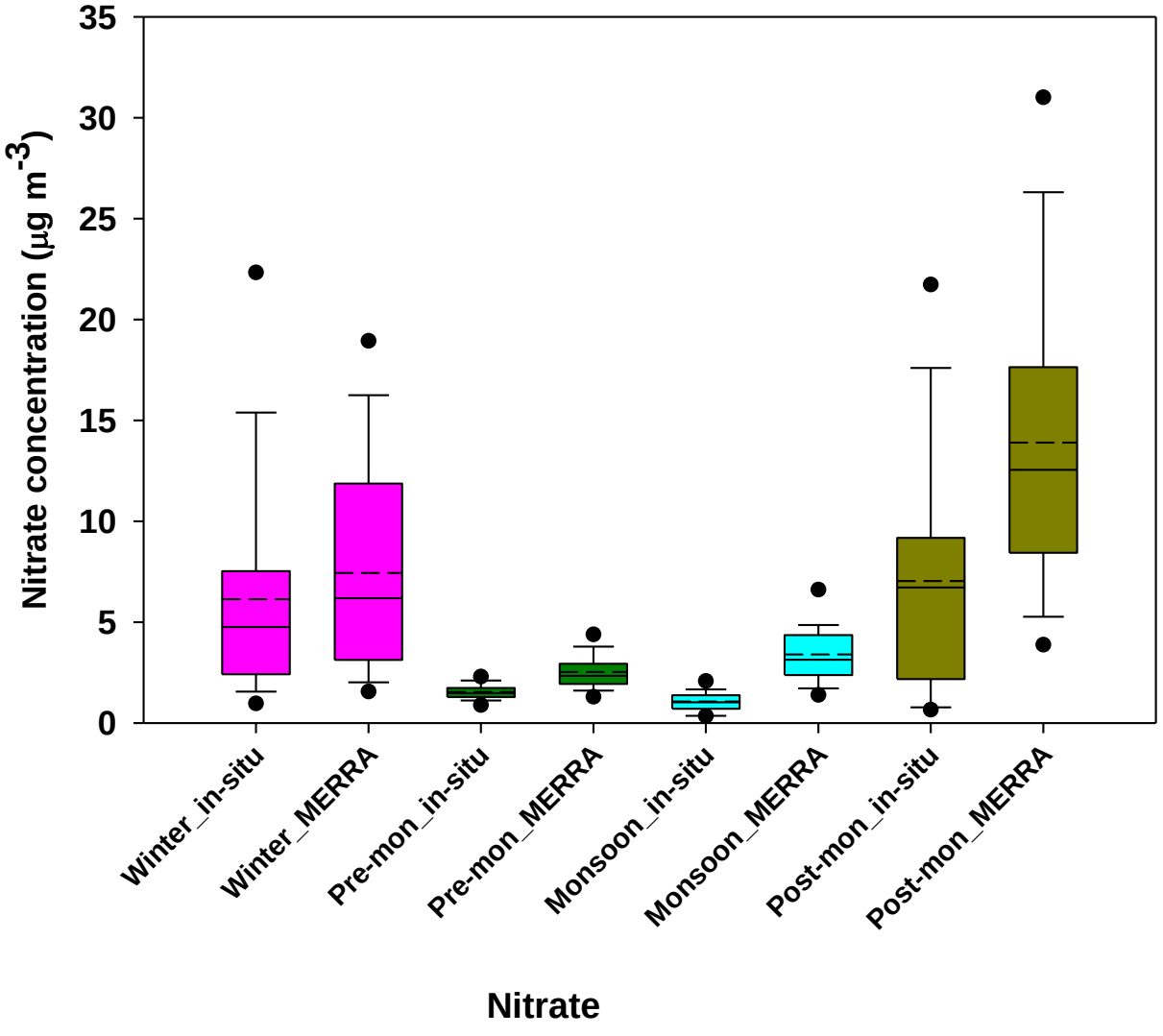
Sea-Salt

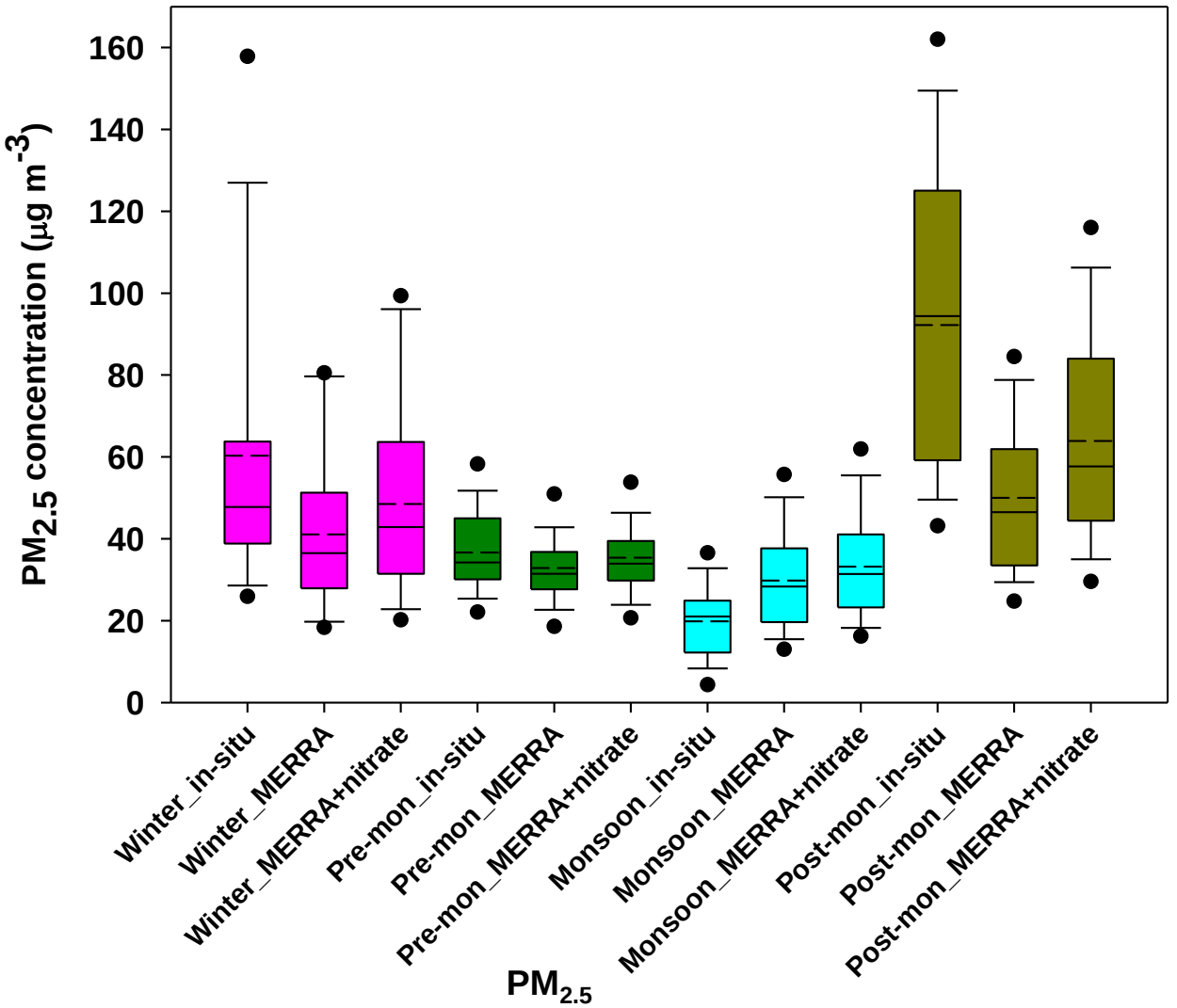


Dust



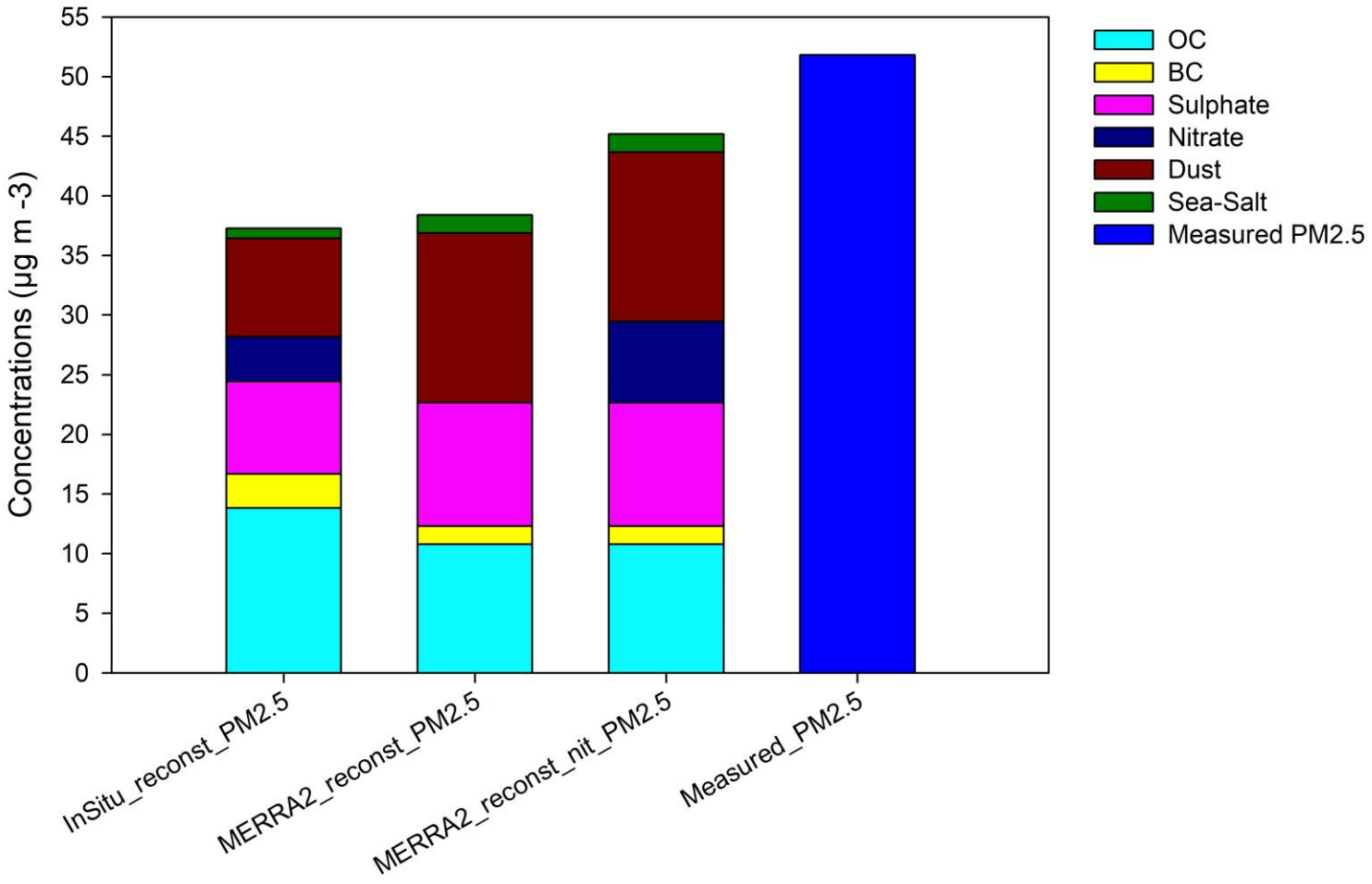
Results (Seasonal) Contd…





Inclusion of nitrate in MERRA2 $PM_{2.5}$ reconstruction helps in improving the agreement with the observations.

Results (Annual)



Species	NMB (%)	RMSE (µg/m³)
BC	-47.27	2.099
OC	-21.99	6.16
Sulphate	-2.71	5.35
Nitrate	81.17	5.64
Dust	72.02	11.09
Sea-Salt	87.83	2.17
PM2.5	-26.14	34.08
PM2.5 with Nitrate	-13.03	29.30

$PM_{2.5}$ underestimation was reduced by ~50 % by including nitrate in the MERRA2 products

Conclusions

- MERRA2 underestimated BC, OC and PM2.5 over Bhopal.
- High overestimation in Sulphate and Nitrate was found.
- Inclusion of nitrate in the MERRA2 products can improve agreement of MERRA2 $PM_{2.5}$ with in-situ measurements.

Acknowledgement

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References

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