Modelling aerosol-boundary layer interactions over Northern India- Case study of 2016 haze episode using WRF-Chem

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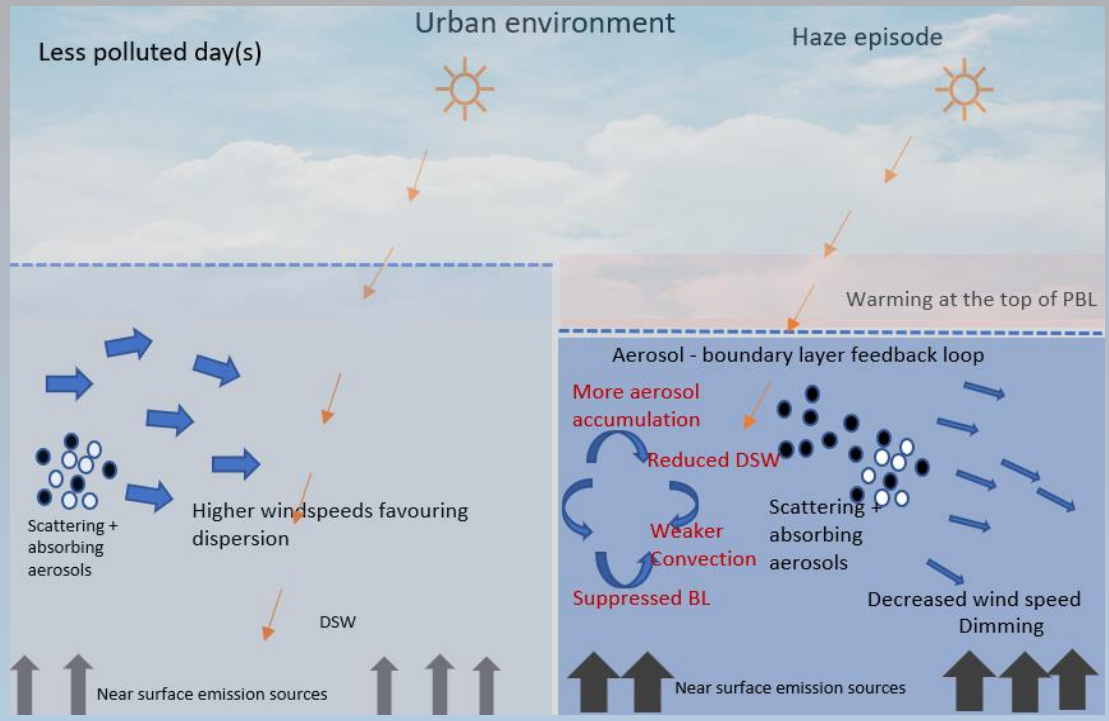
Motivation

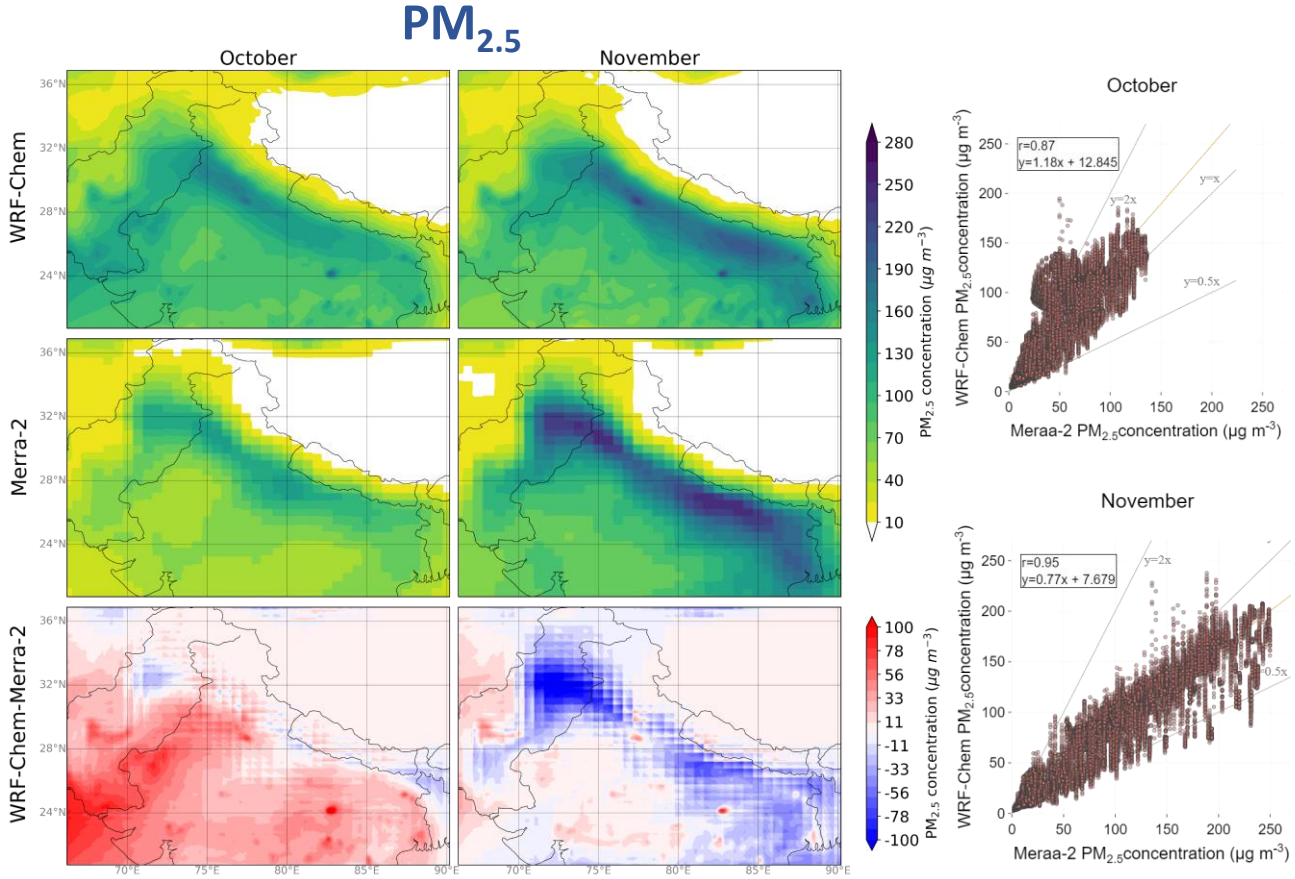
- 100% of population in India is exposed to $PM_{2.5}$ levels above latest WHO guidelines.
- Every year the Indo-Gangetic plains (IGP) witnesses seasonal spikes in $PM_{2.5}$ levels.
- In 2016 IGP region experienced a severe haze episode lasting a week (1-7th Nov).
- Significant aerosol-planetary boundary layer (PBL) feedbacks have been reported to enhance pollution over East Asia during haze.
- Modelling results: WRF-Chem v4.2 (12km x 12km horizontal resolution) using MOZART-MOSAIC aerosol scheme.



Mechanism under question-

- Aerosol-radiation feedback loop
- Near surface cooling & upper PBL heating
- Decreased mixing & more accumulation of pollutants

Results: WRF-Chem comparison with Merra-2 reanalysis dataset for North India



Monthly mean comparison: $PM_{2.5}$(left)

- Model simulates $PM_{2.5}$ and BC spatial variation reasonably well.
- Better spatial correlation for Nov month for both BC and $PM_{2.5}$.
- Model generally underestimates $PM_{2.5}$ by -10% and BC by -30% over North West India for Nov.

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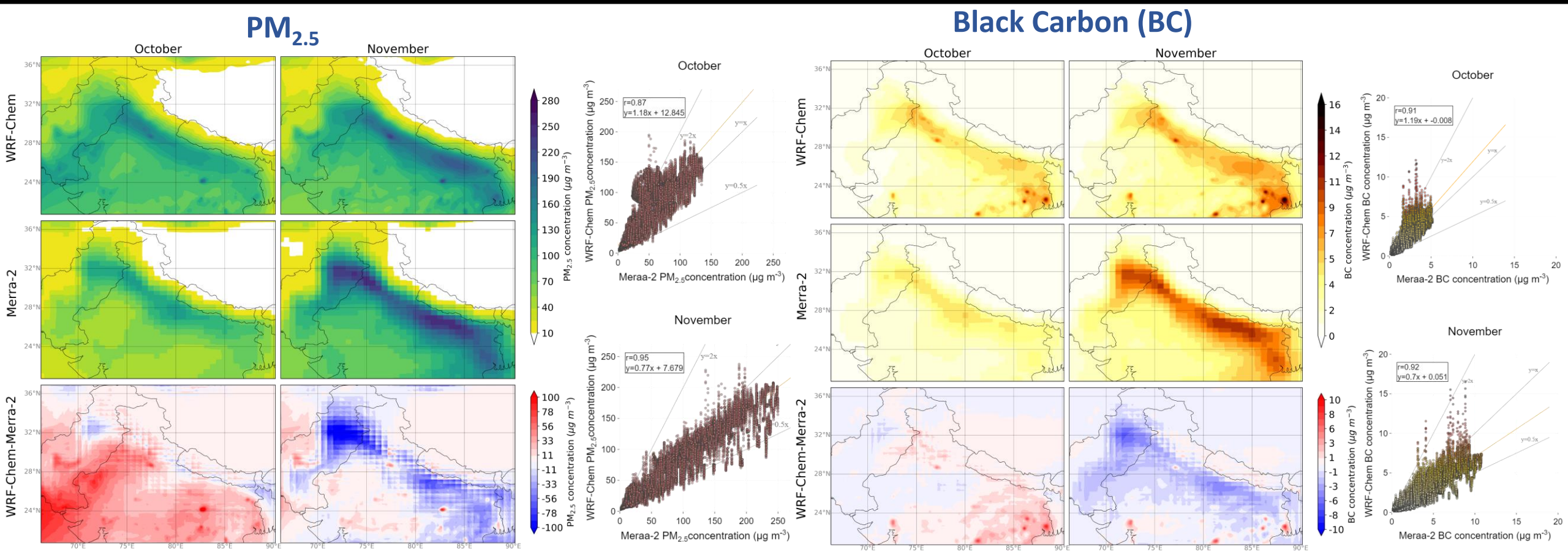

Monthly mean comparison: $PM_{2.5}$(left) and Black Carbon (right)

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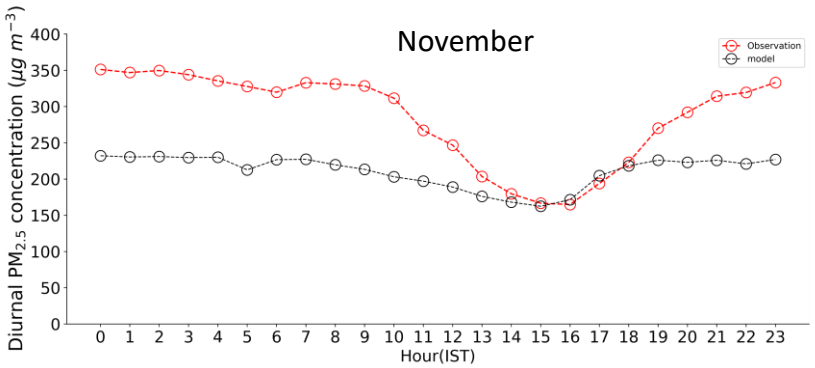
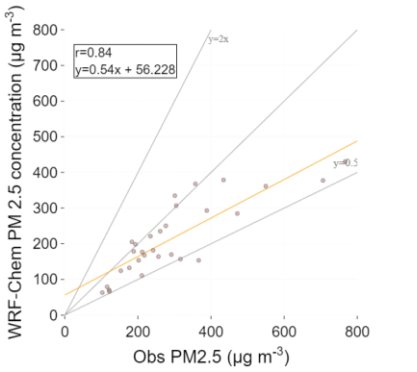
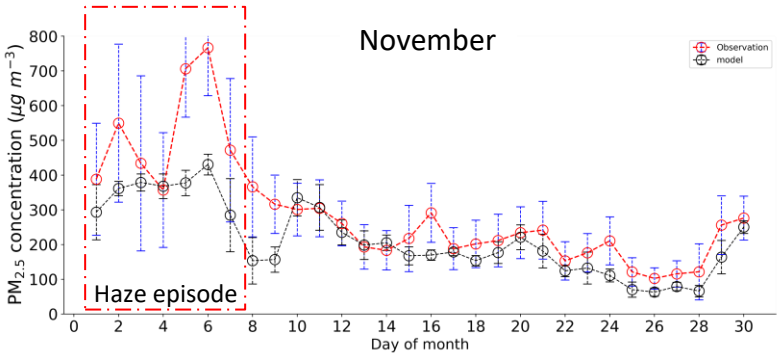
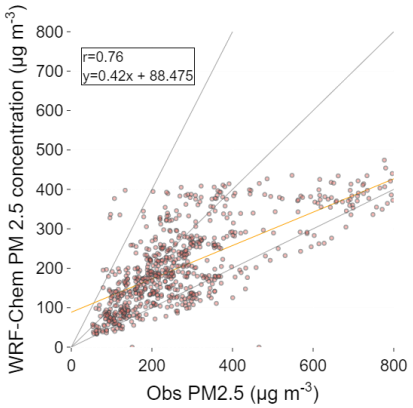
Results: WRF-Chem-Measurement comparison over Delhi

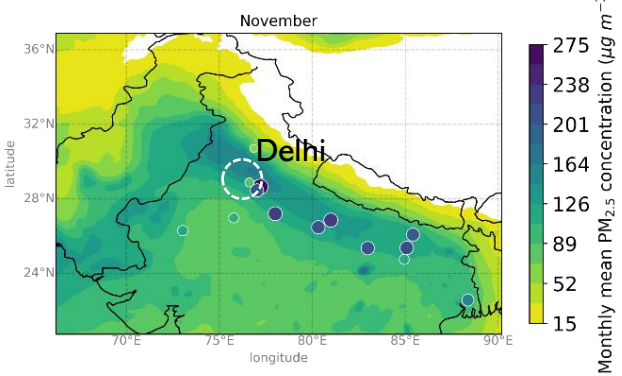
$PM_{2.5}$







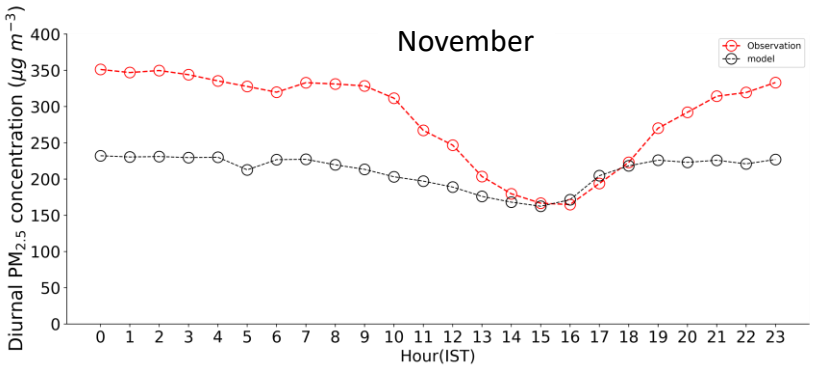


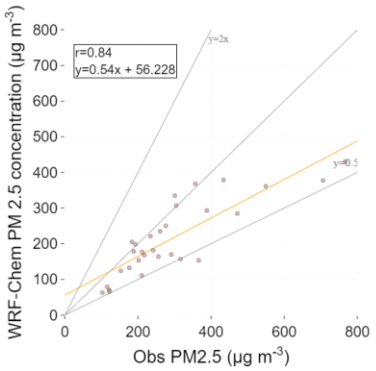


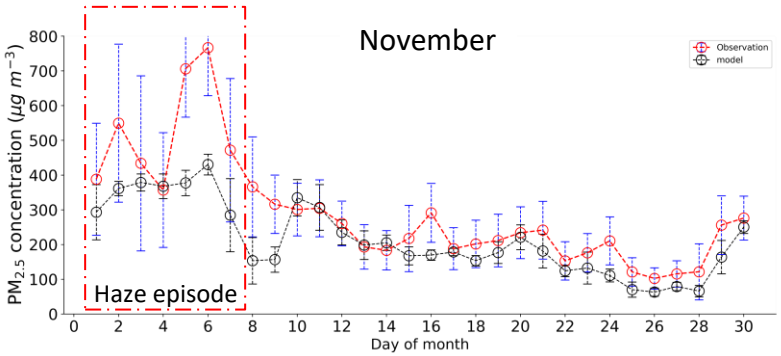
Model shows overall good performance for daily $PM_{2.5}$ towards end of Haze episode (r =0.8) in Nov.

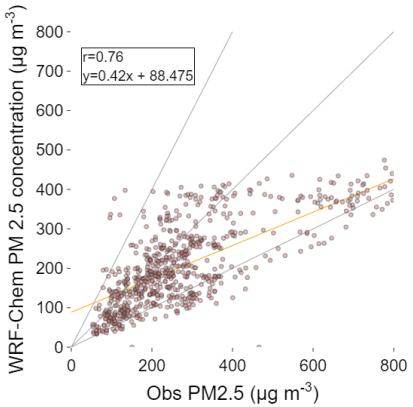
Results: WRF-Chem-Measurement comparison over Delhi

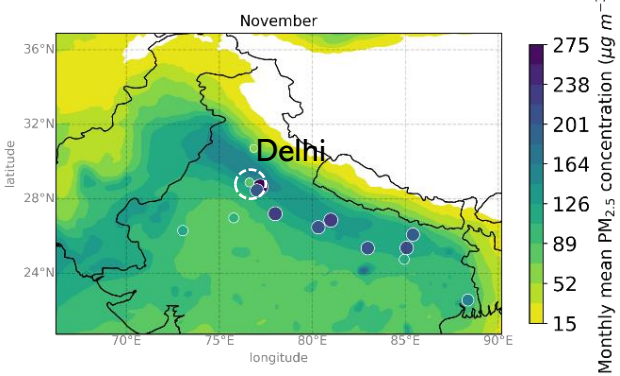
$PM_{2.5}$





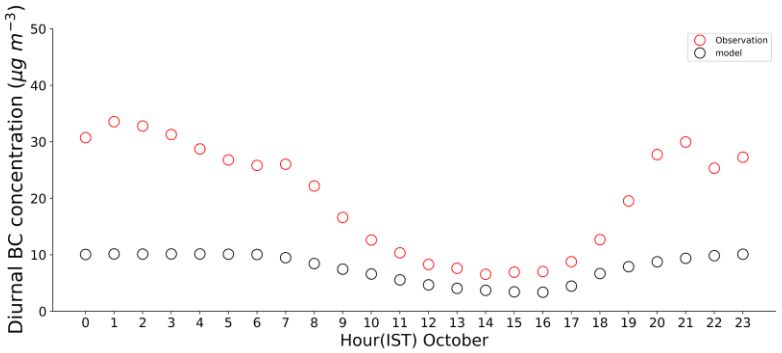


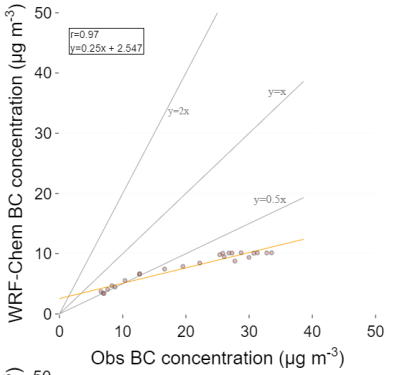


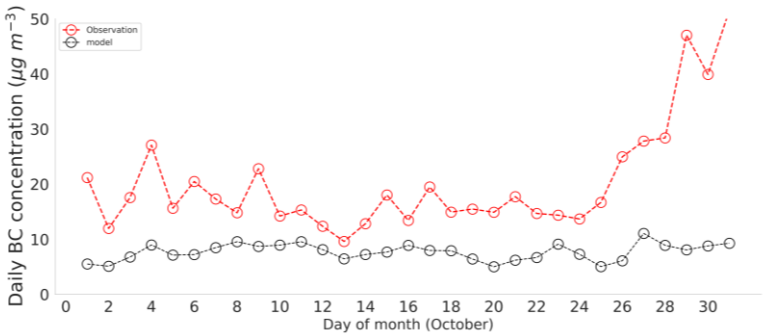


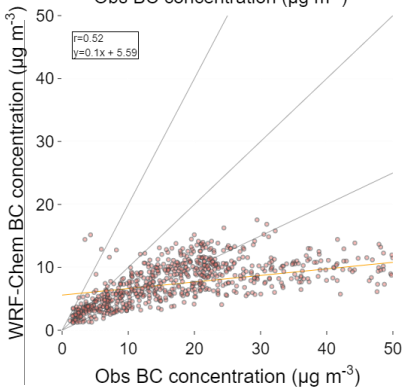
Model shows overall good performance for daily $PM_{2.5}$ towards end of Haze episode (r =0.8) in Nov.

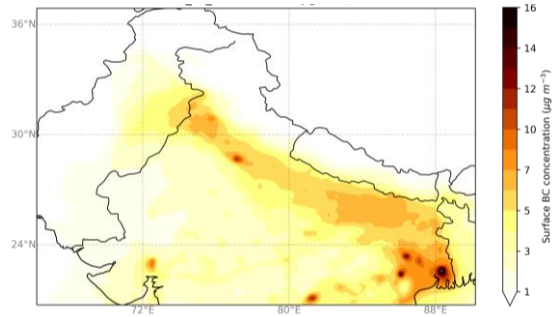
Black Carbon (BC)











Model underestimates observed daily averaged BC by ~5-6 times and follows diurnal pattern with a good agreement.

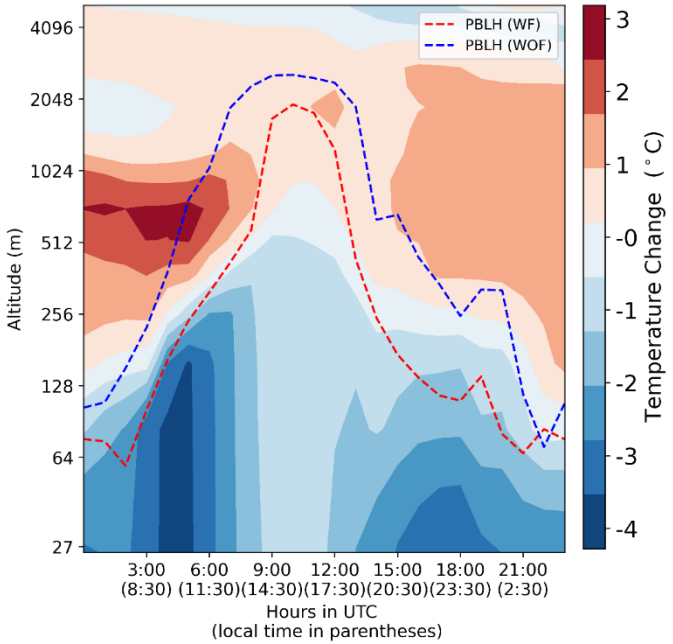
Aerosol impact on Vertical temperature profile and Inversion over Delhi

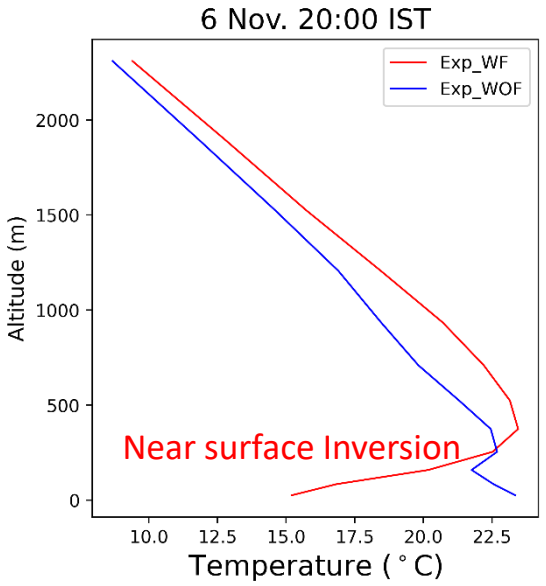
Control - Experiment

WF: With full aerosol-meteorology feedbacks

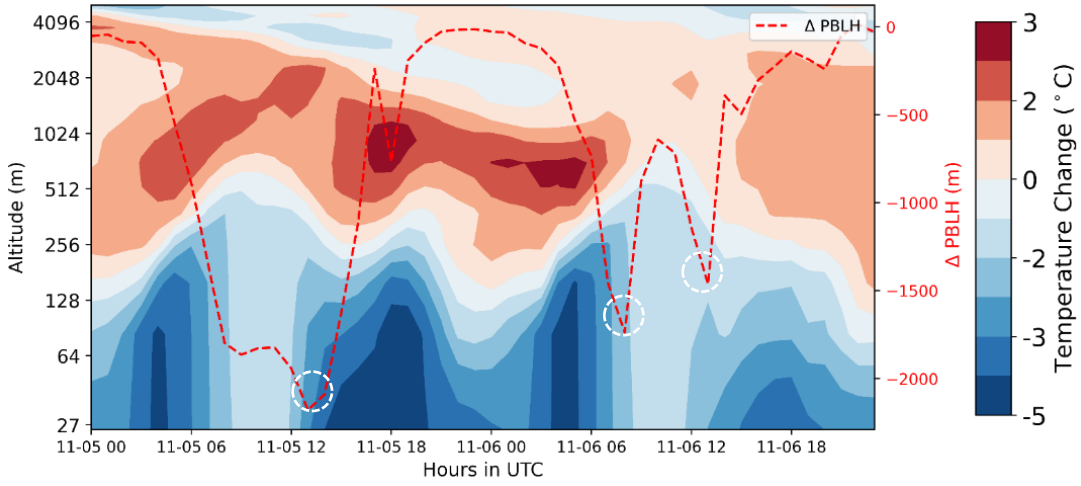
WOF: Aerosols -meteorology feedbacks switched off

6th Nov





Haze days : 5-6th Nov



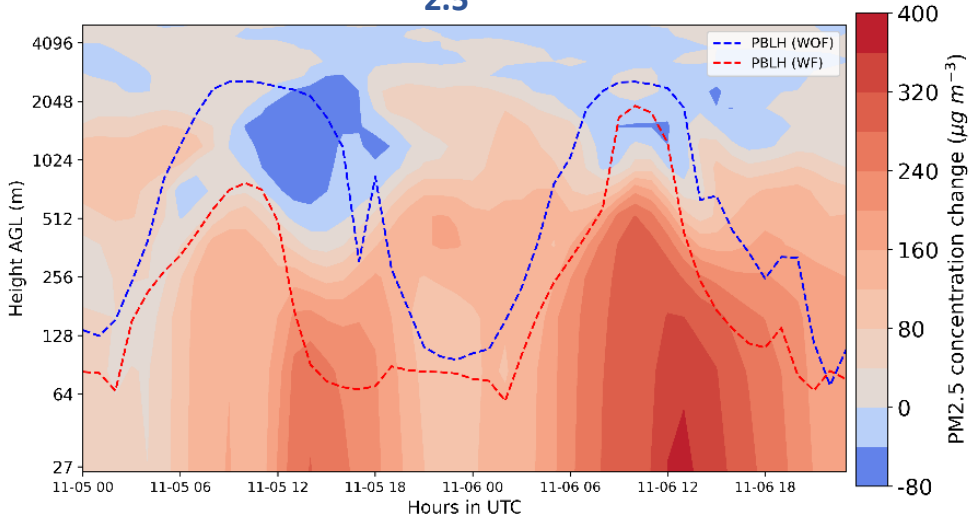
Aerosol impact on Planetary boundary layer height (PBL) and temperature:

- During severe haze episode aerosols show a net cooling effect near the surface and warming above 300-500m.
- Largest PBL reductions occur at 18:00 and 20:00 IST (1.5 – 2km).

Aerosol impact on pollutant concentrations

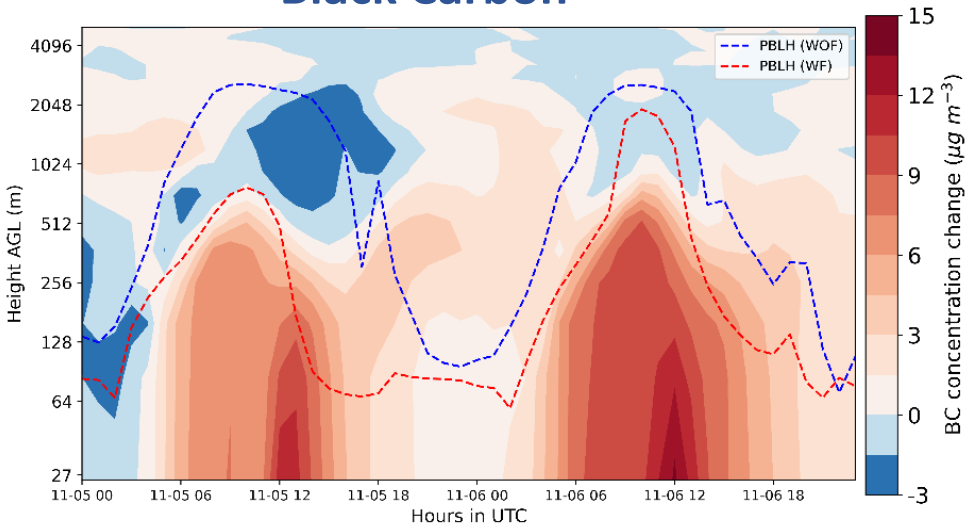
Control - Experiment

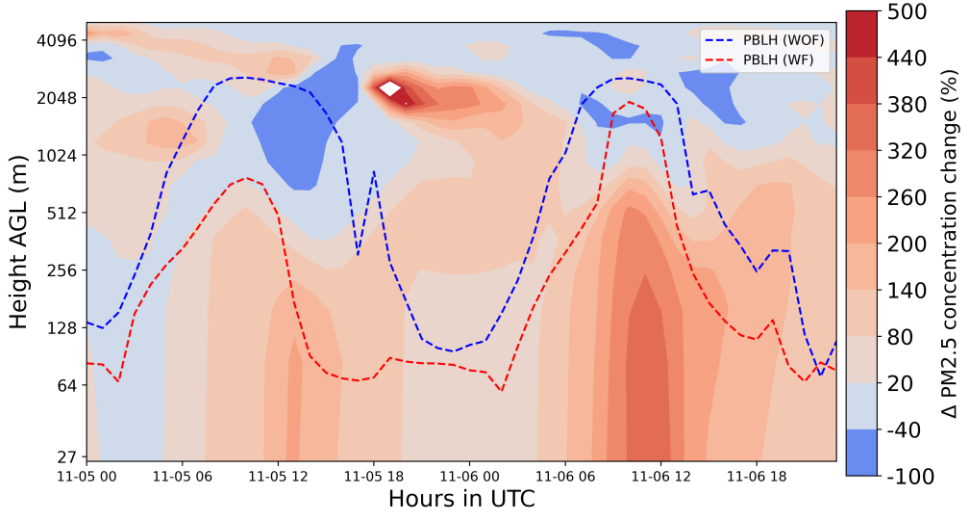
$PM_{2.5}$



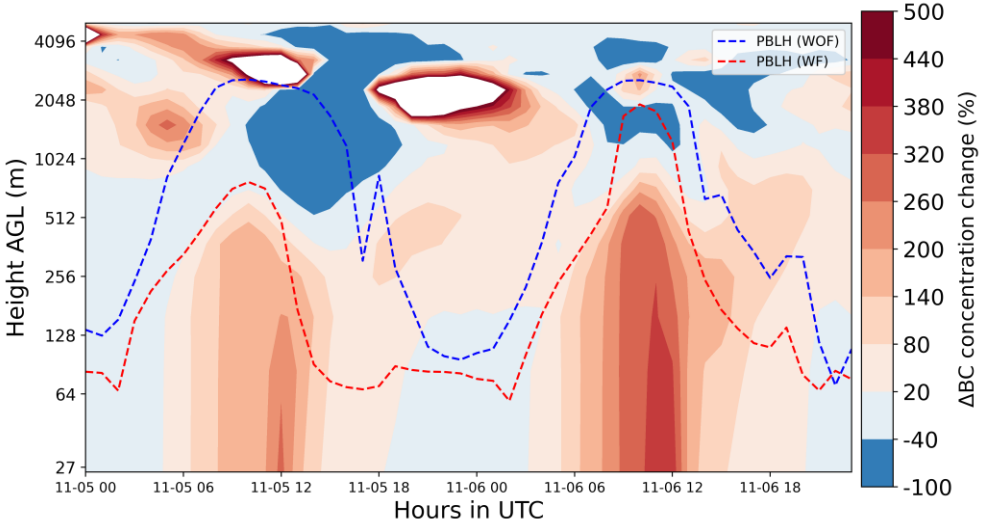
Absolute changes

Black Carbon





Percentage changes



In absence of feedbacks on meteorology hourly $PM_{2.5}$ and BC concentrations dramatically increase near surface by ~100%.

Outlook

- **WRF-Chem tends to miss the pollutant peaks during haze episode but reproduces spatial heterogeneity over Northern India well.**

- **Aerosol impacts on vertical temperature vary with altitude: cooling near the surface and warming above 300 – 500m.**

- **Vertical structure of aerosol species and meteorology is crucial in understanding temperature inversions and diurnal peaks in near surface pollution.**

Thank you!

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