Modeling Radiative Impact of Aerosols over S Asia Constrained by Observation of Vertical Distribution

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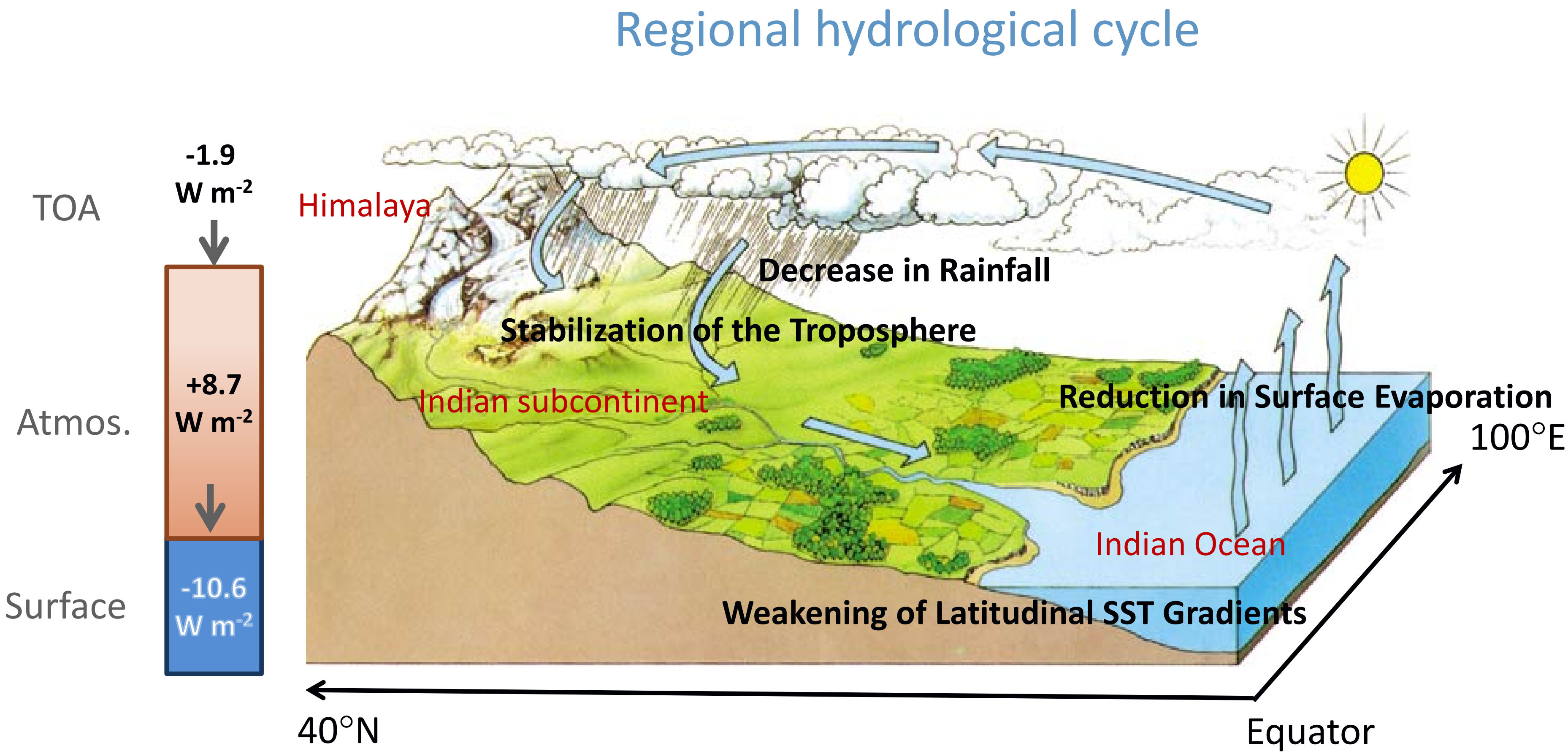
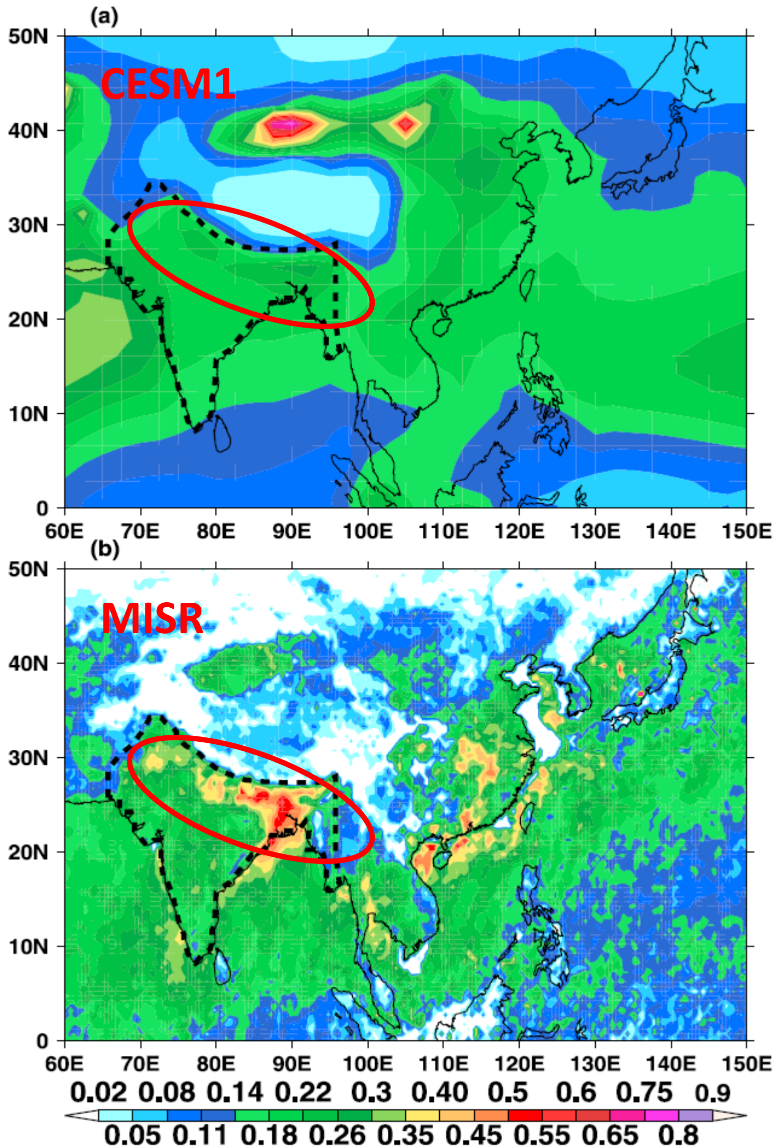
High aerosol loadings in S Asia influence the regional energy balance and hydrological cycle



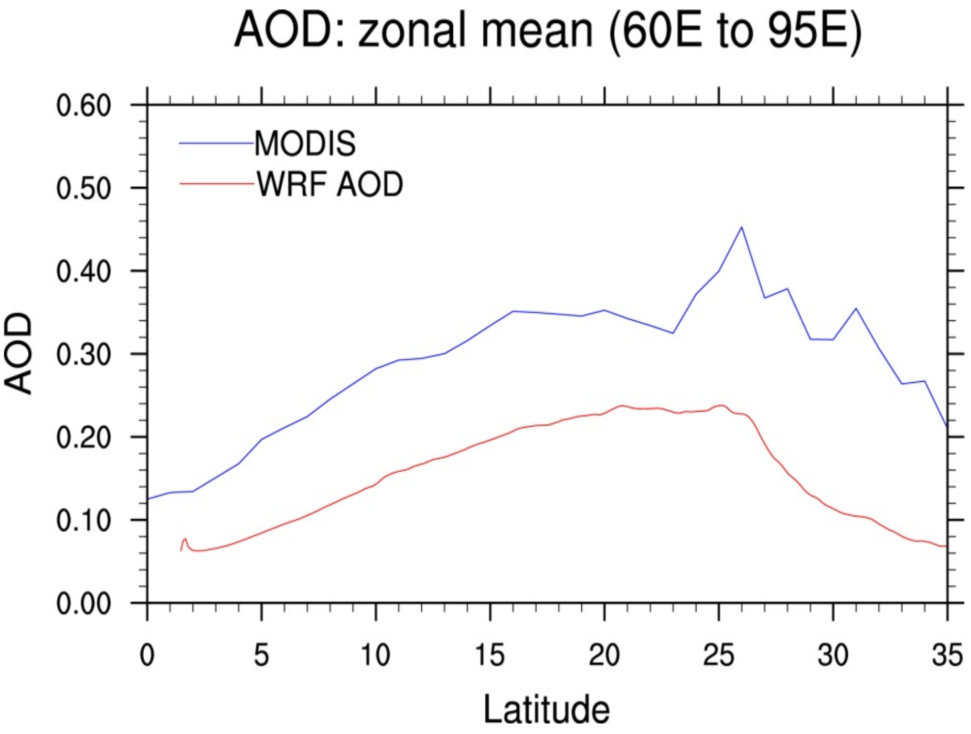
(e.g., Ramanathan et al., 2005; Lau et al. , 2006; Meehl et al., 2008; Bollasina et al., 2009)

Column aerosol optical depth (AOD) underestimated by models in comparison with satellite data



(Ganguly et al. 2012)

This study: similar underpredictions in the WRF-Chem simulations!



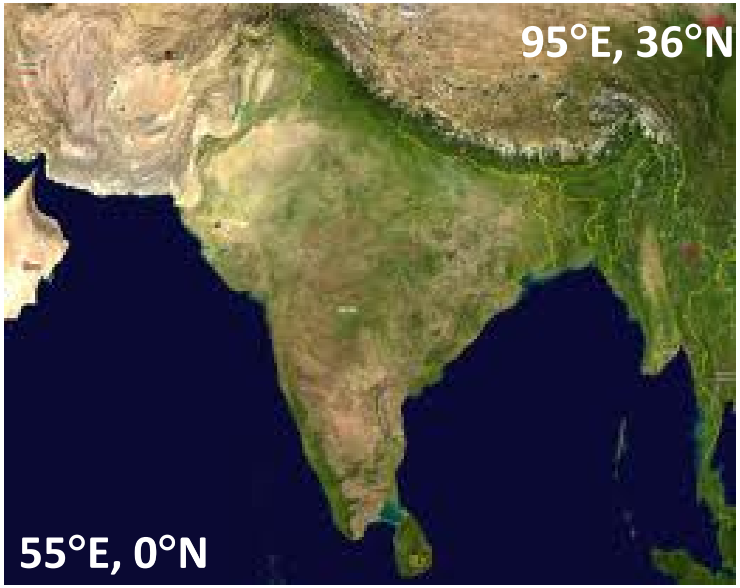
Questions

- How does the simulated aerosol extinction profile relate to the underestimated column AOD?
- How does the uncertainty in aerosol vertical distribution affect the simulated atmospheric heating and thermodynamics?

WRF-Chem Specification

- **WRF/Chem 3.3 with modifications**
- **Domain**: 55E ~ 95E and 0 ~ 36N
- **Grid size**:12km x 12km
- **Vertical layers**: 27
- **Chemistry**: MOZCART
  - MOZART gas-phase chemistry
  - GOCART aerosols:
    - Sulfate
    - BC and OC (hydrophilic and hydrophobic)
    - Dust (0.5, 1.4, 2.4, 4.5, and 8 μm in effective radius)
    - Sea salt (0.3, 1.0, 3.2, and 7.5 μm)
    - No SOA
  - Aerosols feedback to radiative transfer

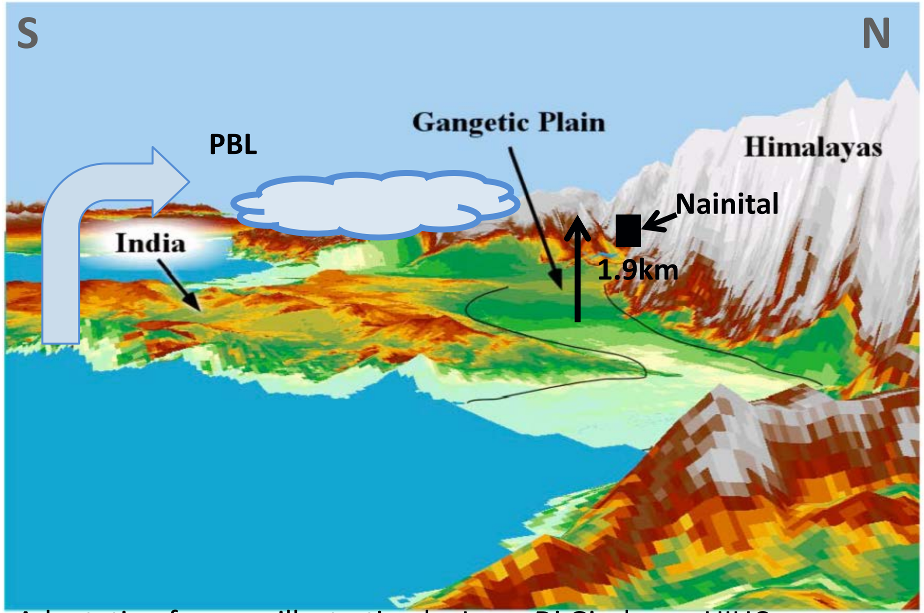
S Asia



- **Anthropogenic emissions:** SO_2, BC, and OC for year 2010 (Lu et al., 2011); others from EDGAR;
- **Physics/Dynamics**:
  - RRTMG for shortwave and longwave radiation
  - MYJ TKE PBL scheme
  - Thompson cloud microphysics
  - CAM5 cumulus parameterization

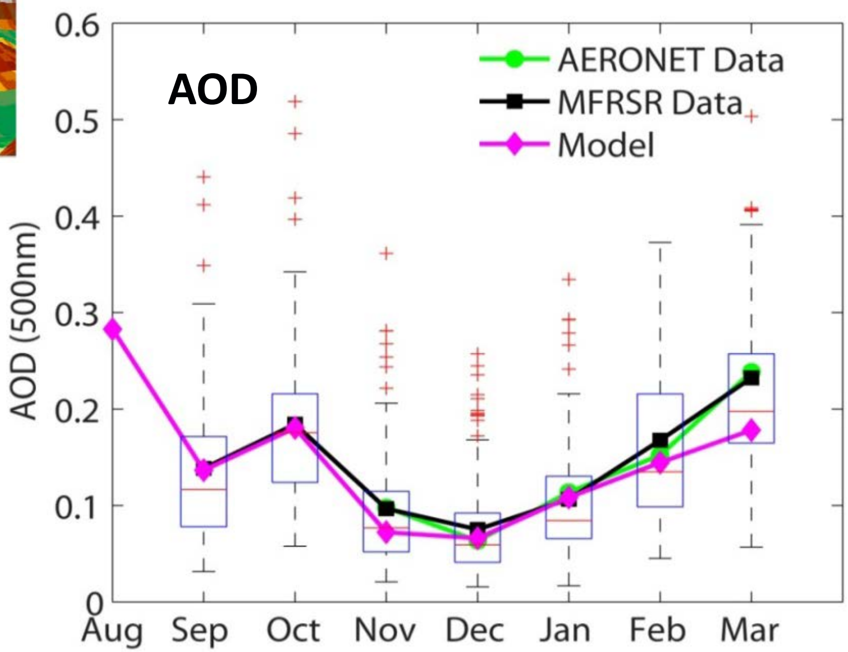
Ganges Valley Experiment (GVAX)

Surface measurements of aerosols were made from Aug, 2011 to Mar, 2012 at Nainital



Adaptation from an illustration by Larry Di Girolamo, UIUC

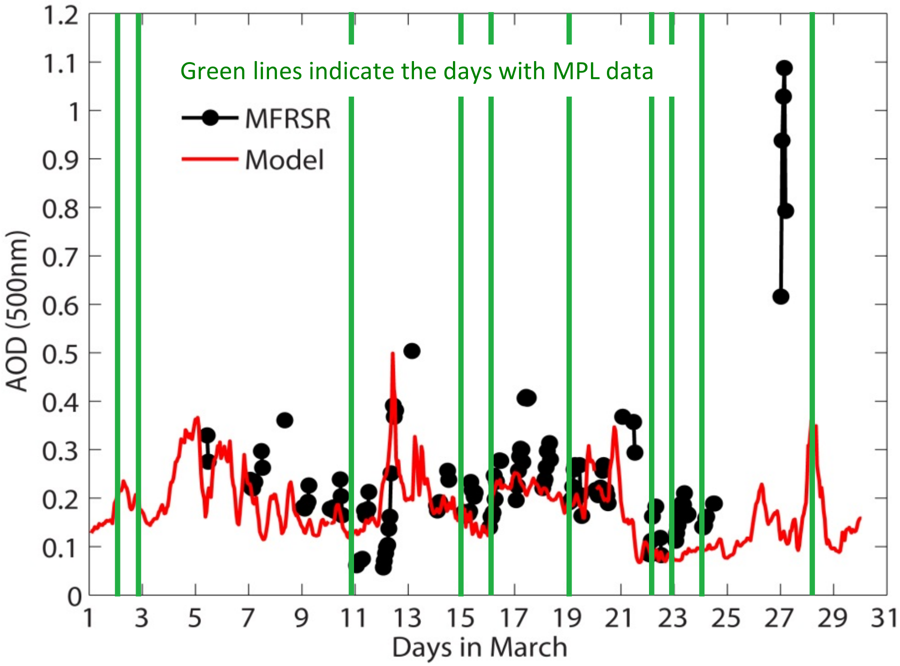
Situated at 1900 m above sea level, aerosols 'seen' at Nainital are mainly the portions being elevated above the PBL



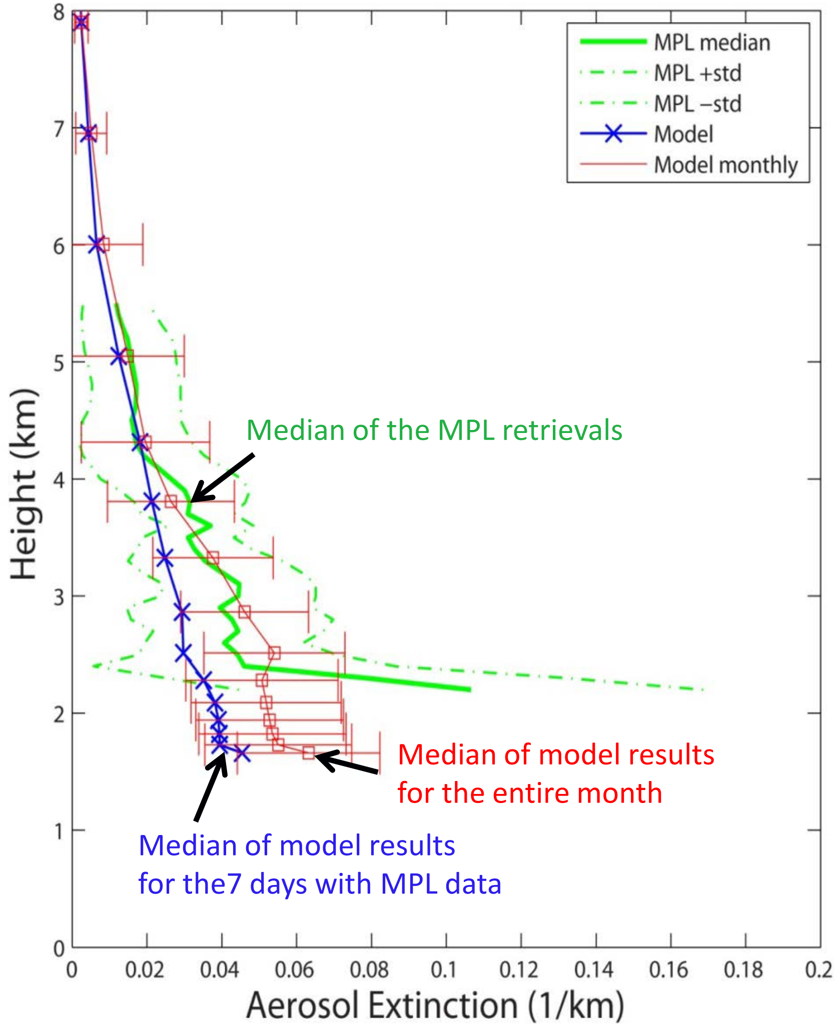
Nainital/GVAX: vertical profile of aerosol extinction

During Feb - Mar, 2012, there are total 16 days of MPL data available for retrieval of aerosol vertical distribution

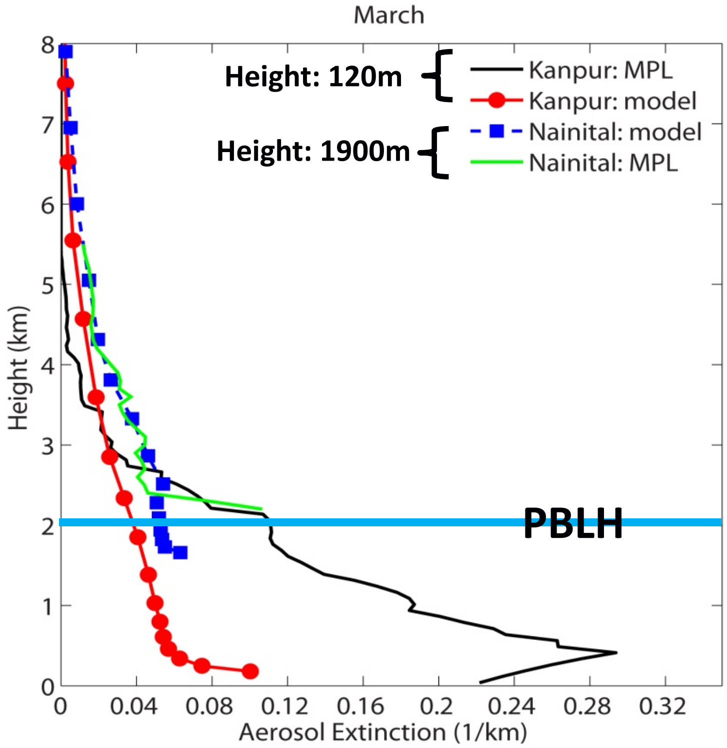
Daytime mean AOD in March 2012

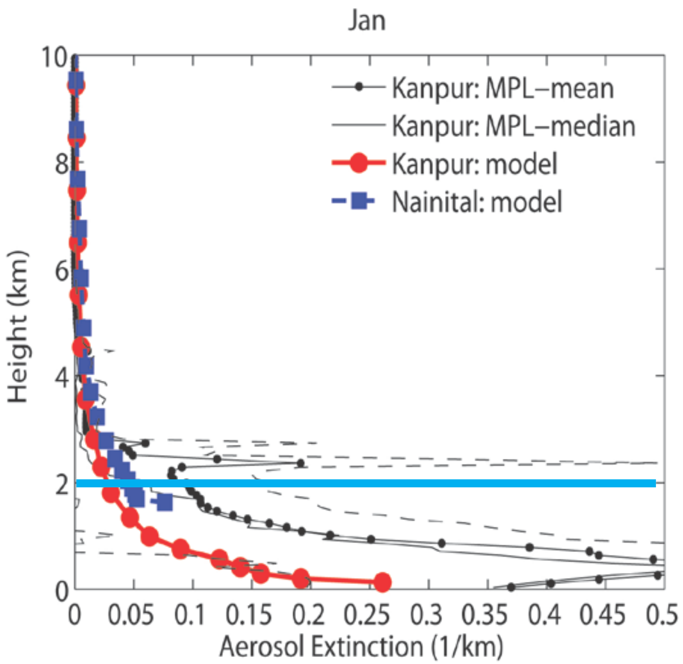


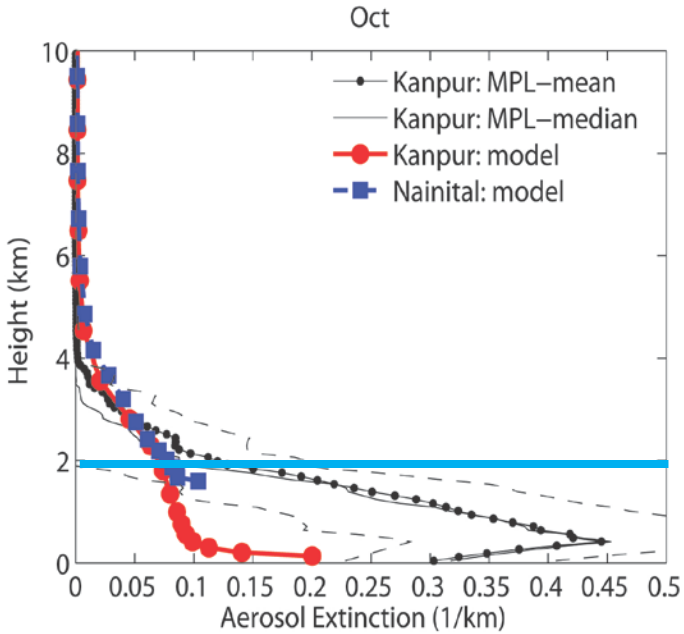
Vertical distribution of aerosol extinction



High-altitude vs. low- altitude locations



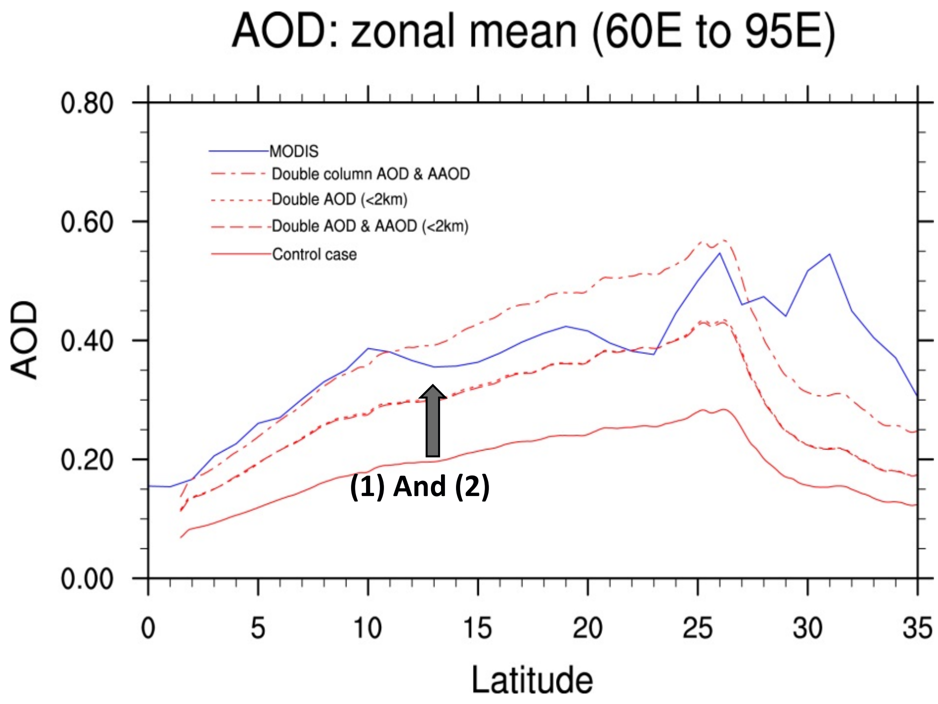




Underestimation of the column AOD is mainly due to the underestimation in the lower model levels, especially in the PBL

Sensitivity studies constrained by observations

- ✓ **Control run**
- ✓ **Sensitivity experiments:**
  1) **Double AOD below 2km; same SSA (increasing scattering and absorbing aerosols);**
  2) **Double AOD below 2km; larger SSA (increasing scattering aerosols only);**
  3) Double AOD and AAOD in the entire column (Included in the Poster)



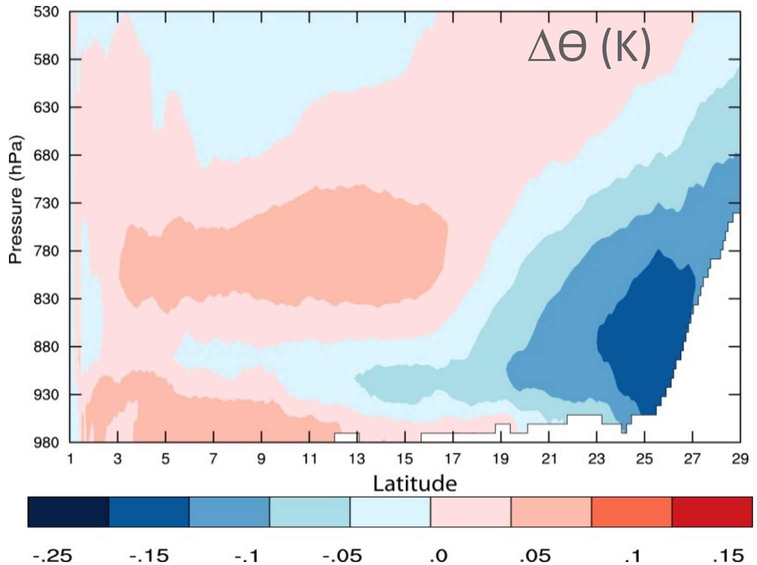
Aerosol direct radiative forcing

Regional mean (W m^{-2})	Control run	Double AOD (<2km), same SSA	Double AOD (<2km), larger SSA
TOA	-3.0	-4.9	**-5.4**
Atmosphere	+6.3	**+9.3**	+6.3
Surface	-9.3	**-14.2**	-11.7

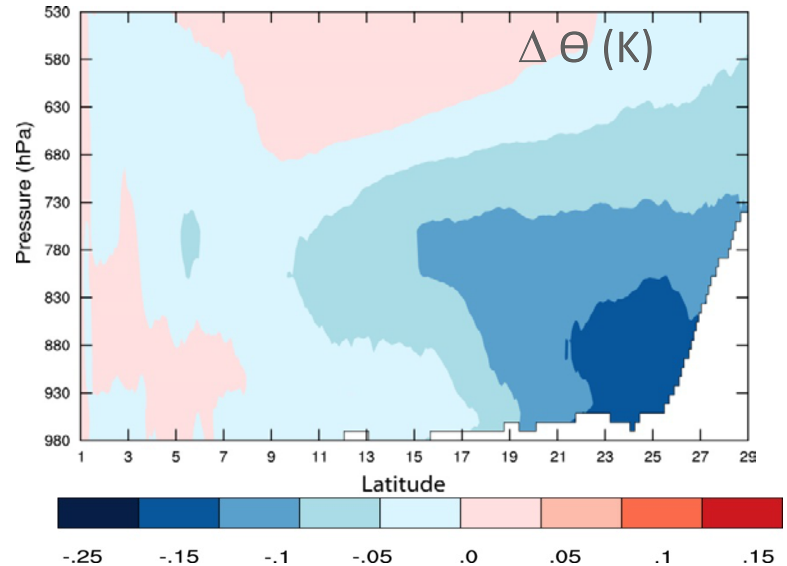
Changes in potential temperature

Tendency$_{\theta}$ = [radiation] +[microphysics]+ [pbl] +[cumulus] + [mixing,diffusion]

Control run: aerosol – no aerosol

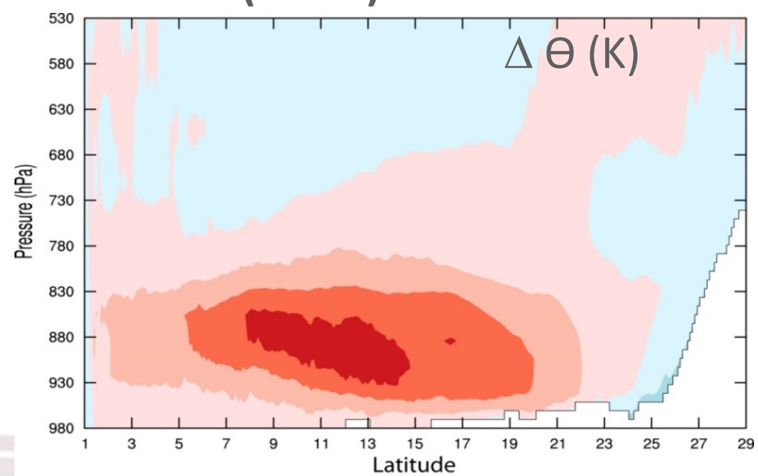


Double AOD (<2km) larger SSA - Control



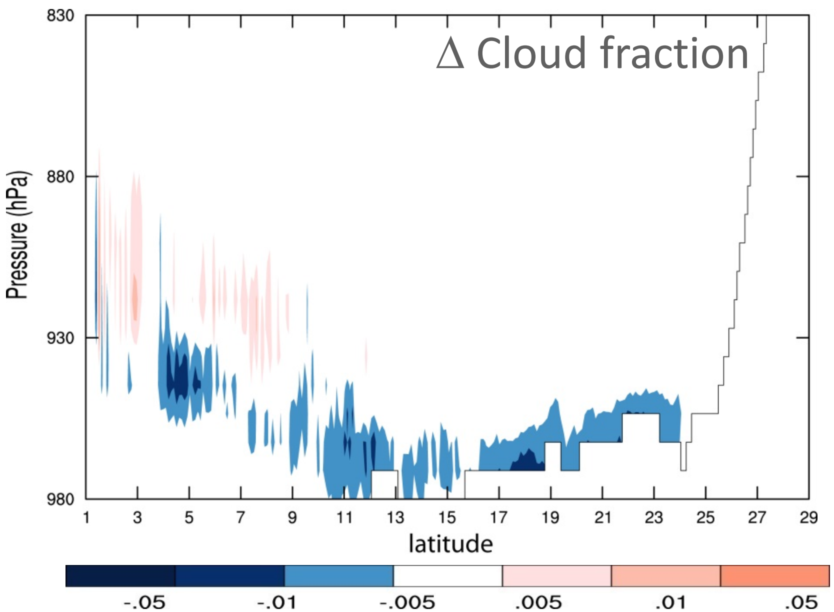
- Aerosol-radiation interactions lead to different responses in potential temperature over land and over the ocean
- With same increase in AOD, potential temperature is enhanced by increasing both scattering and absorption (same SSA), while reduced by increasing aerosol scattering only (larger SSA)

Double AOD (<2km) same SSA - Control

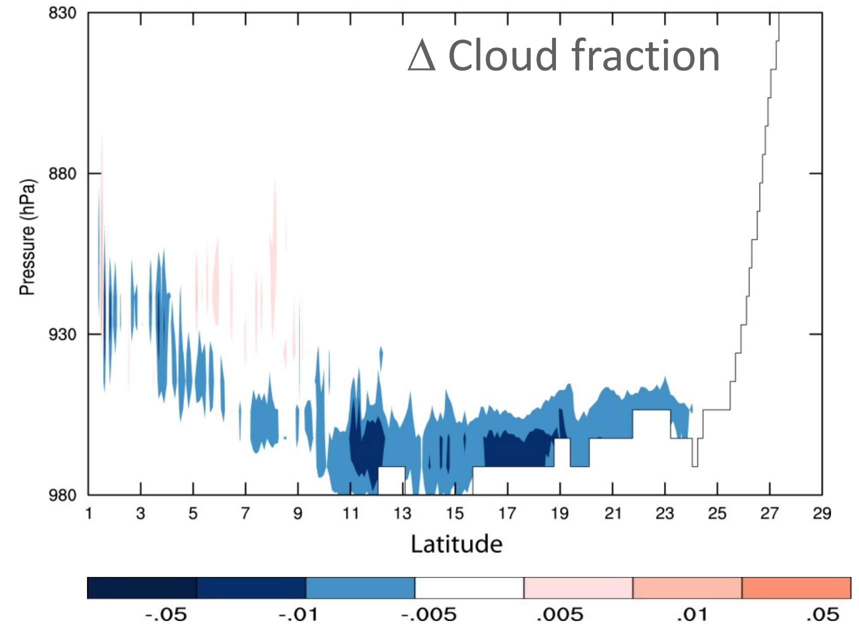


Impact on cloud cover

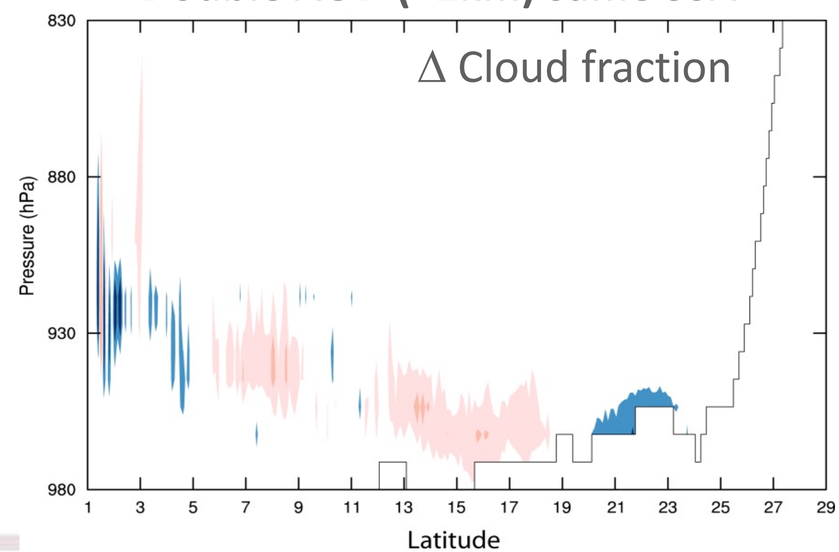
Control run



Double AOD (<2km) larger SSA



Double AOD (<2km) same SSA



- Aerosol-ratiation-cloud interactions lead to reductions in cloud cover
- With same increase in AOD, cloud cover is increased by increasing both scattering and absorption (same SSA), while reduced by increasing aerosol scattering only (larger SSA)

Conclusion

- Comparison with in surface aerosol measurements and extinction profiles suggest that underestimation of AOD in S Asia is mainly due to aerosol underpredictions in PBL

- The resulting responses in the potential temperature and cloud cover by constraining the aerosol extinction profiles suggest that increase of absorbing aerosols in PBL enhances convection (heating/more cloud cover), as scattering aerosols stabilize the lower atmosphere (cooling/less cloud cover).

- To understand aerosol-radiation-cloud interactions, we need more quality data to evaluate and improve vertical distribution of aerosol extinction and absorption simulated by models.