Impact of Mixing States on Aerosol Direct Radiative Forcing and Heating Rate Based on GEOS-Chem-APM

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Introduction

- Mixing state of aerosol particles is an important factor influencing aerosol optical properties and direct radiative forcing (DRF), especially for black carbon (BC) particles (Bond et al., 2006; Ma et al., 2012). In fact, a core-shell configuration with BC particles serving as the core and other soluble particles functioning as the shell, is considered to be more realistic. However, most aerosol models, especially in regional scale, still use the assumptions of internal (all aerosol components are completely mixed, i.e. 100 % mixing) or external mixing (particles of different components totally separated, i.e. zero mixing) instead of core-shell mixing.
- In this study, the effects of aerosol mixing states on DRF and heating rate over China are explored by using nested GEOS-Chem-APM model.

Reference

Bond, T. C., Habib, G., and Bergstrom, R. W.: Limitations in the enhancement of visible light absorption due to mixing state, J. Geophys. Res., 111, D20211, doi:10.1029/2006JD007315, 2006.

Ma, X., Yu, F., and Luo, G.: Aerosol direct radiative forcing based on GEOS-Chem-APM and uncertainties, Atmos. Chem. Phys., 12, 5563–5581, doi:10.5194/acp-12-5563-2012, 2012.

Yu, F. and Luo, G.: Simulation of particle size distribution with a global aerosol model: contribution of nucleation to aerosol and CCN number concentrations, Atmos. Chem. Phys., 9, 7691–7710, doi:10.5194/acp-9-7691-2009, 2009.

Acknowledgments

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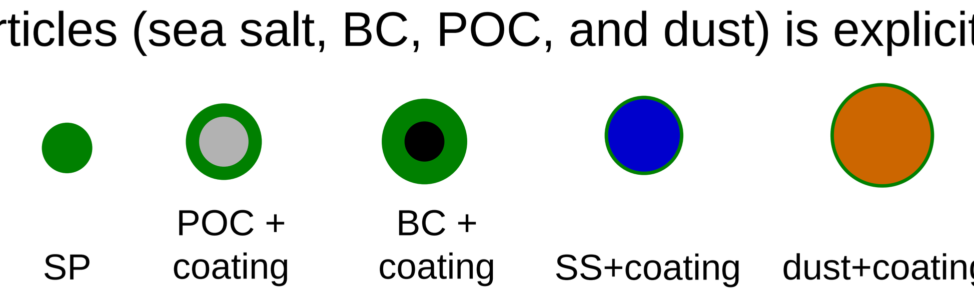
GEOS-Chem-APM Model

- GEOS-Chem-APM (Yu and Luo, 2009) is an advanced multi-type, multi-component, size-resolved global particle microphysics model. The microphysical processes include nucleation, condensation/evaporation, coagulation, equilibrium, and dry and wet deposition.
- Pre-calculated look-up tables are extensively used for nucleation rate and coagulation kernel calculations, which substantially reduce the computing time.
- Prognostic aerosol compositions include secondary particles (SP), BC, primary organic carbon (OC), sea salt, and mineral dust. The coating of secondary species on primary particles (sea salt, BC, POC, and dust) is explicitly simulated.



- Model version: Nested GEOS-Chem-APM v10-01
- Horizontal resolution: 0.25° x 0.3125°
- Simulated time: 2014.10.15 ~ 2014.10.25
- Nested domain : 15°S ~ 55°N, 70°E ~140°E

Results

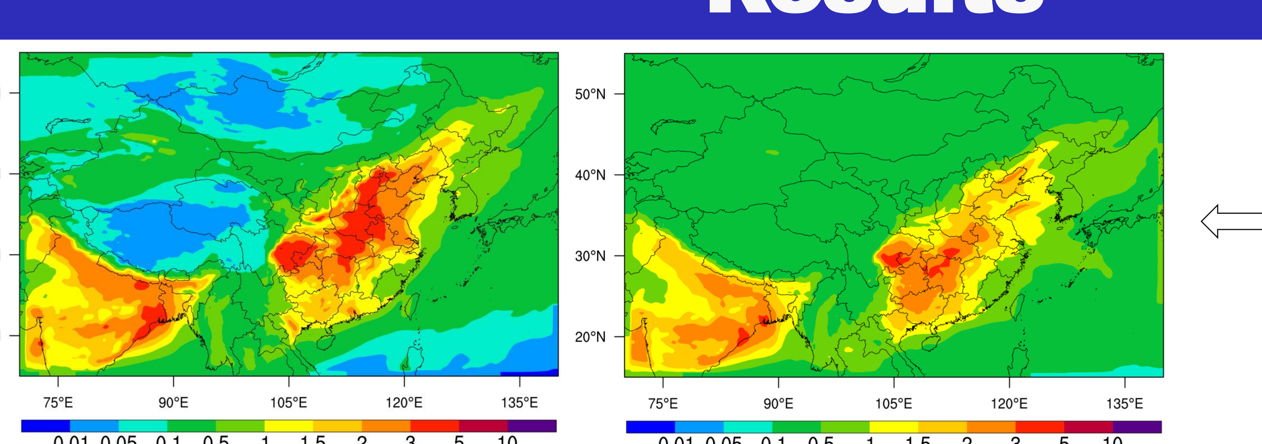


Fig. 1. The simulated 10-days mean burden of (left) BC and (right) secondary particles (SP) coated on BC over China.

Impact of aerosol mixing states on AAOD/SAOD/AOD

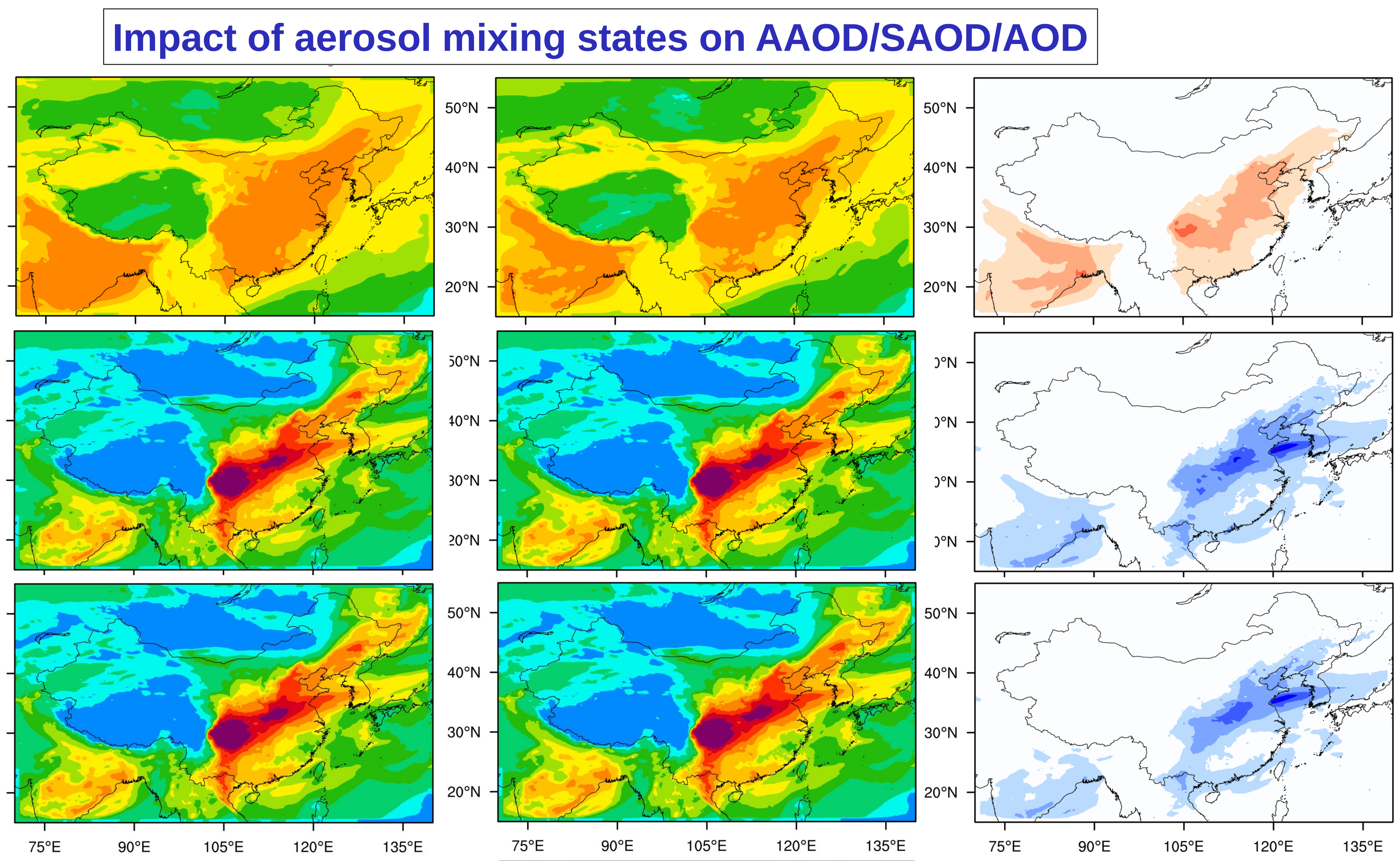


Fig. 2. The simulated 10-days mean AAOD (top), SAOD (middle), and total AOD (bottom). The left and middle column represent the AOD for core-shell and external mixing, respectively. The right column represents that change of AOD (coating experiment – No-coating experiment).

Results

Impact of aerosol mixing states on DRF – all sky

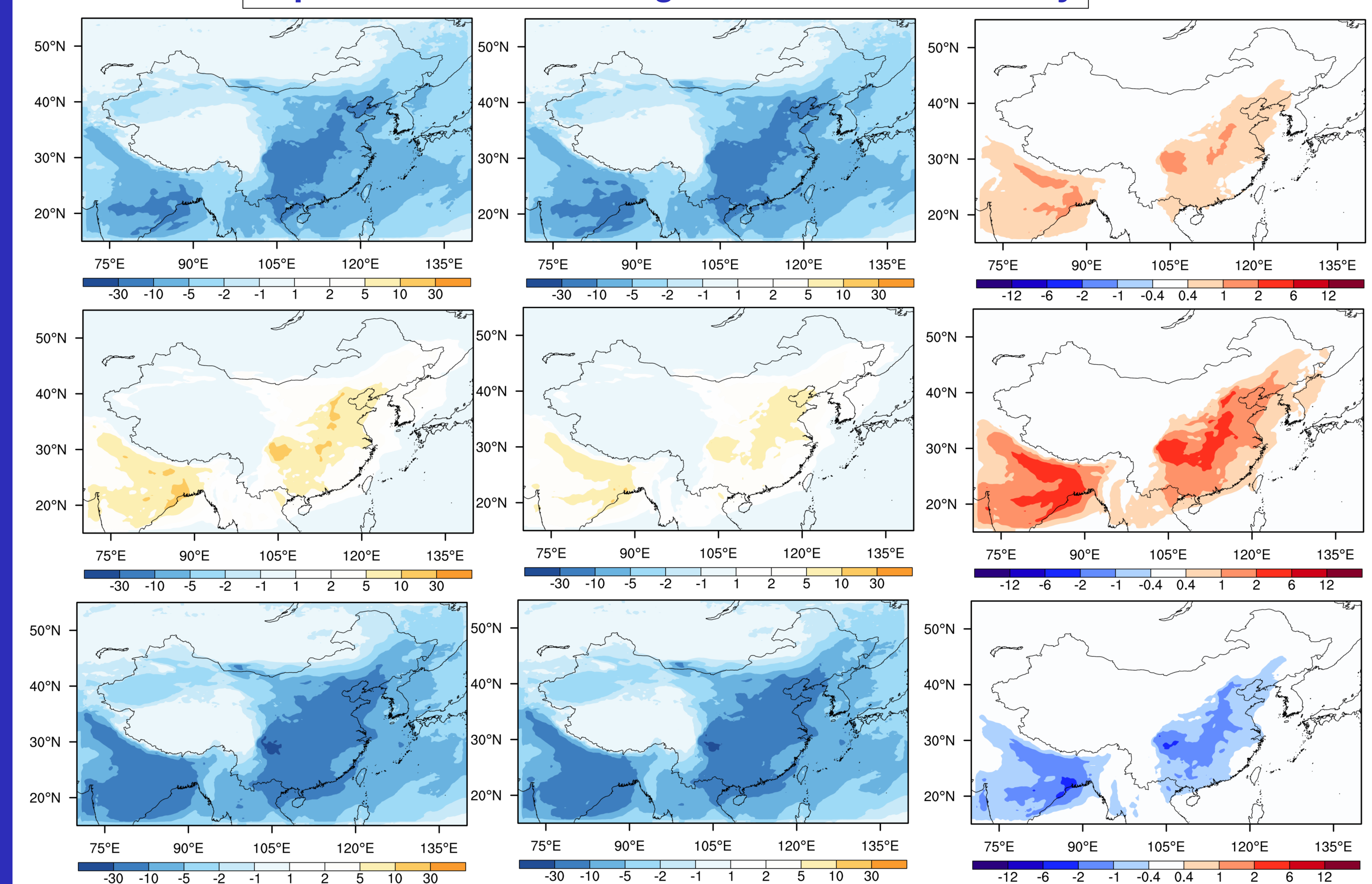


Fig. 3. The simulated 10-days mean DRF at TOA (top), atmosphere (middle) and surface (bottom) for all sky condition. The left and middle column represent the DRF for core-shell and external mixing, respectively. The right column represents that change of DRF (coating experiment – No-coating experiment). Unit: W m^{-2}

Impact of aerosol mixing states on DRF – clear sky

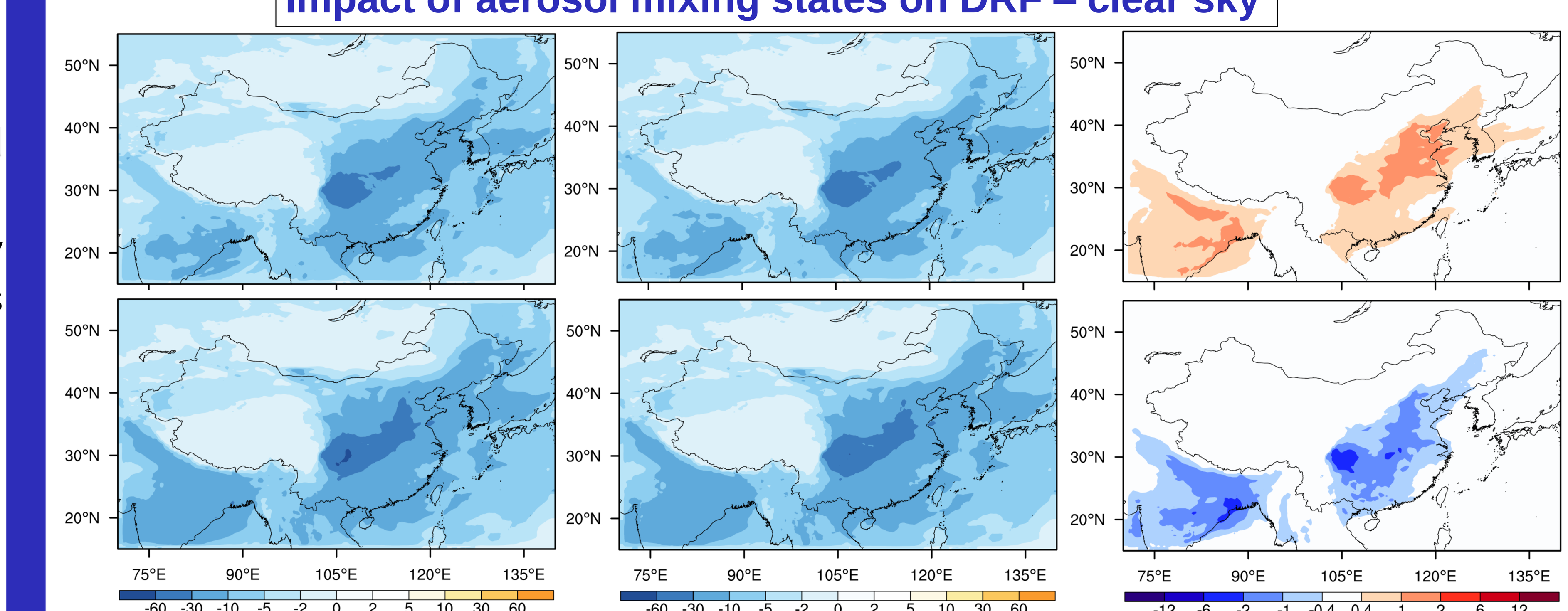


Fig. 4. The simulated 10-days mean DRF at TOA (top) and surface (bottom) for clear sky condition. The left and middle column represent the DRF for core-shell and external mixing, respectively. The right column represents that change of DRF (coating experiment – No-coating experiment). Unit: W m^{-2}

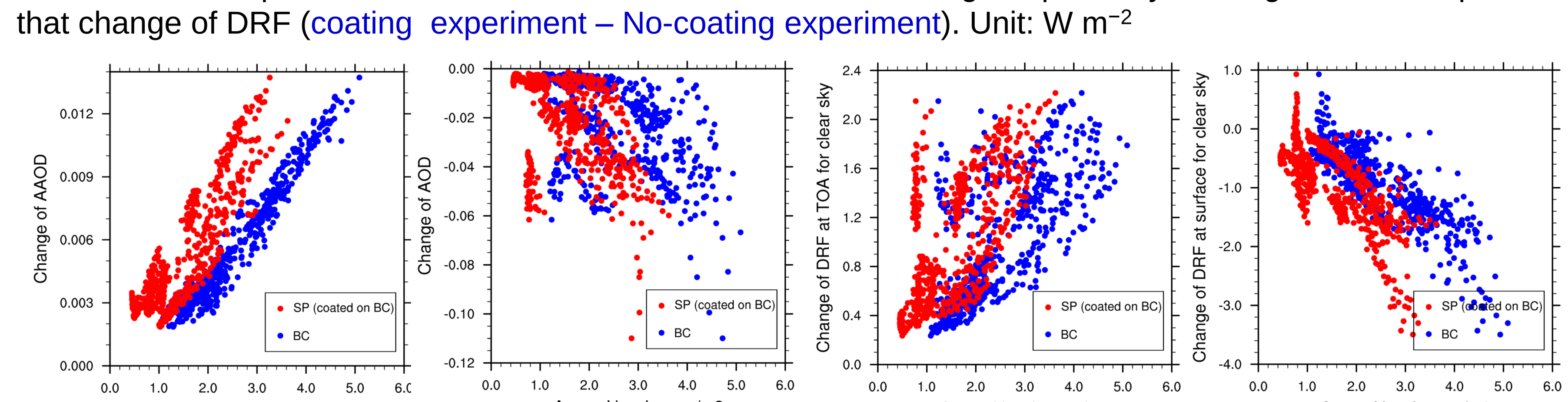


Fig. 5. Correlations between AOD and DRF change versus BC (blue) and SP(red) burden. Here, the change represents the value of coating experiment minus No-coating experiment.

Impact of aerosol mixing states on heating rate

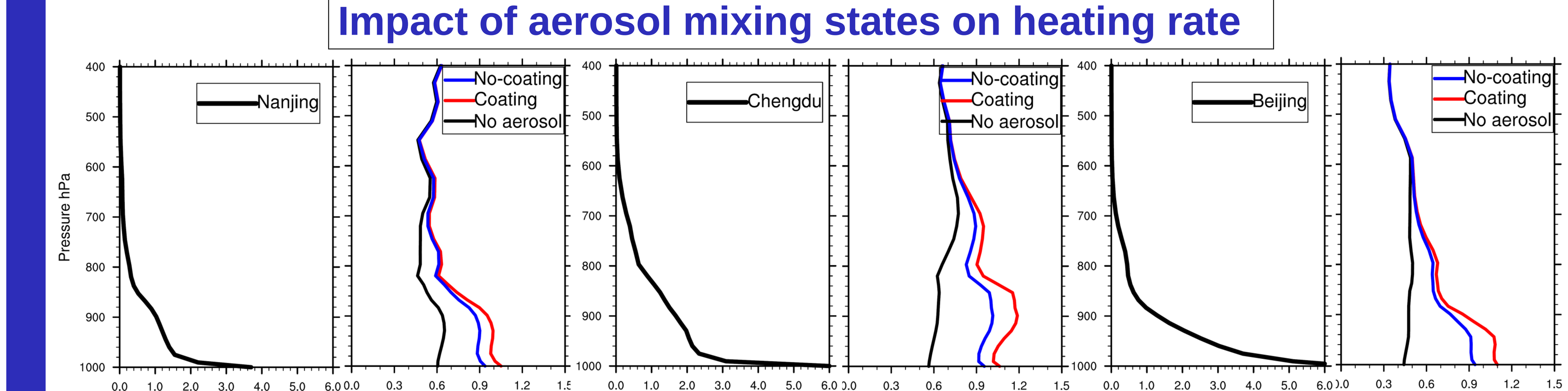


Fig. 6. Profiles of BC mass concentrations and heating rate in Nanjing (left), Chengdu (middle), and Beijing(right).

Conclusions

- ✓ Core-shell mixing enhances atmospheric absorption, but reduces atmospheric scattering and total extinction.
- ✓ DRF at atmosphere for all sky increases by up to 6 W m^{-2} in coating experiment, which implicates a strong atmospheric warming effect caused by core-shell mixing.
- ✓ DRF at TOA for all sky become less negative, while DRF at surface become more negative in coating experiment.
- ✓ Absolute value of AOD and DRF change are positively correlated to both BC and SP (coated on BC) burden.
- ✓ Heating rate of core-shell mixing is higher than that of external mixing, which is more evident at the height with high BC concentrations; e.g. at 950-1000 hPa.