Modeling nitrate aerosols over East Asia using variable-resolution CESM2-MOSAIC

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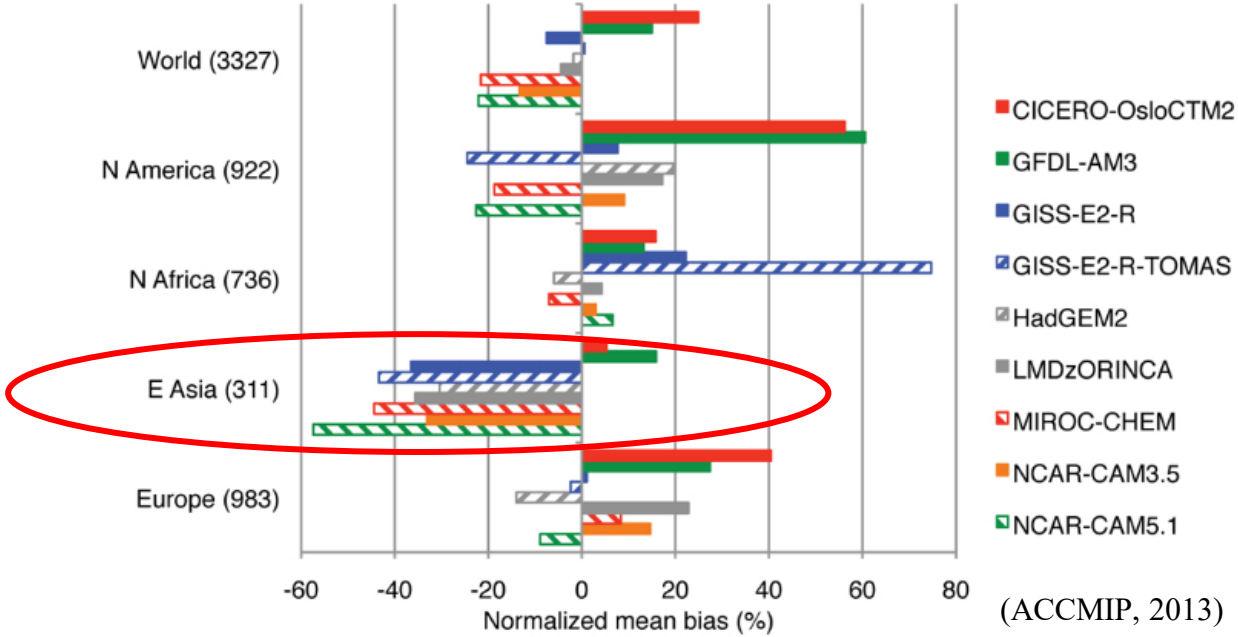
Background

- Nitrate precursor **emissions** are expected to increase and sulfate aerosols decrease in the future
- Hygroscopic nitrate and ammonium may enhance aerosol activation to **cloud** droplets and affect aerosol indirect forcing
- Only a minority of global climate **models** consider the formation and lifecycle of nitrate aerosols in the atmosphere

Background

Underestimation of aerosol optical depth (AOD) in East Asia



(ACCMIP, 2013)

Background

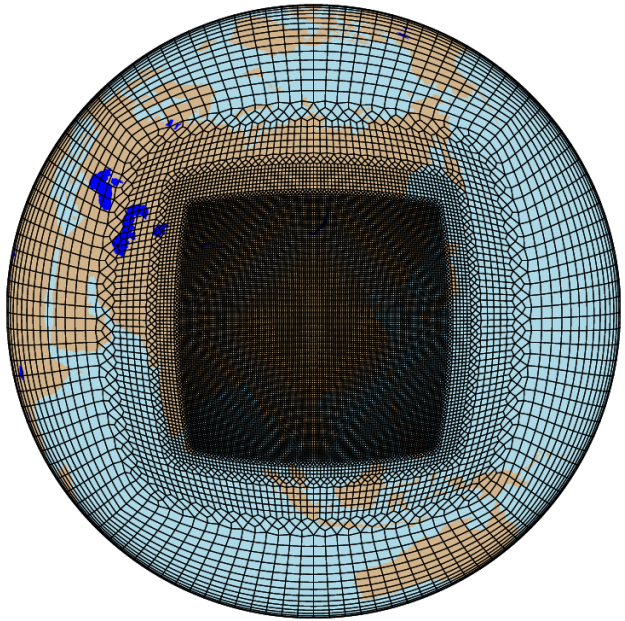
- Model resolution affects aerosol emission, transport, aerosol-cloud interactions, etc.

- Higher-resolution models with regional mesh refinement have been developed.

Evaluate the performance of variable-resolution CESM2-MOSAIC in modeling nitrate aerosols over East Asia

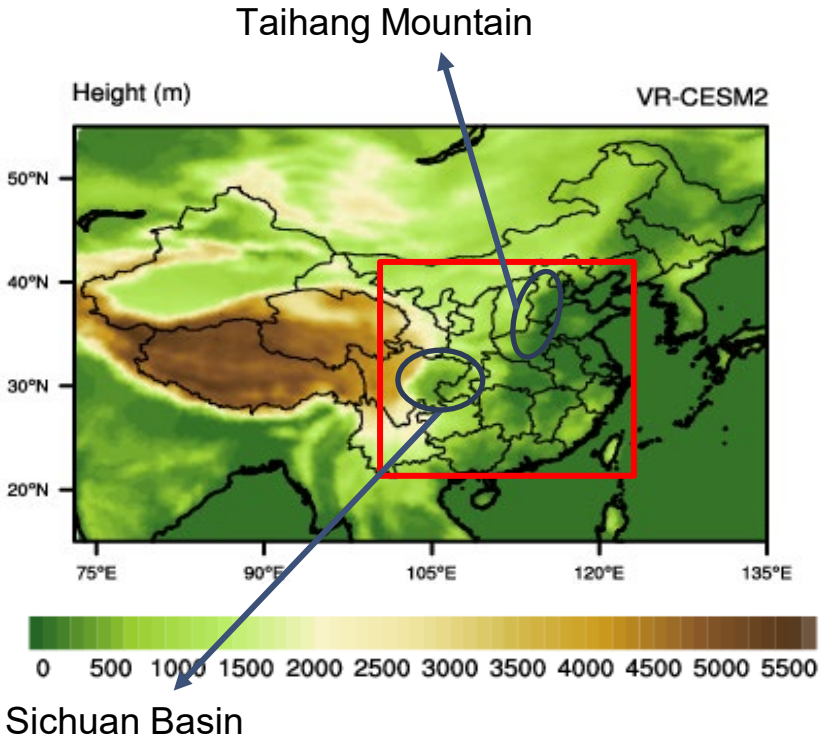
Experiment Design

Resolution	Chemistry	Aerosol
~1° → ~0.125°	CAM6-Chem	MAM4

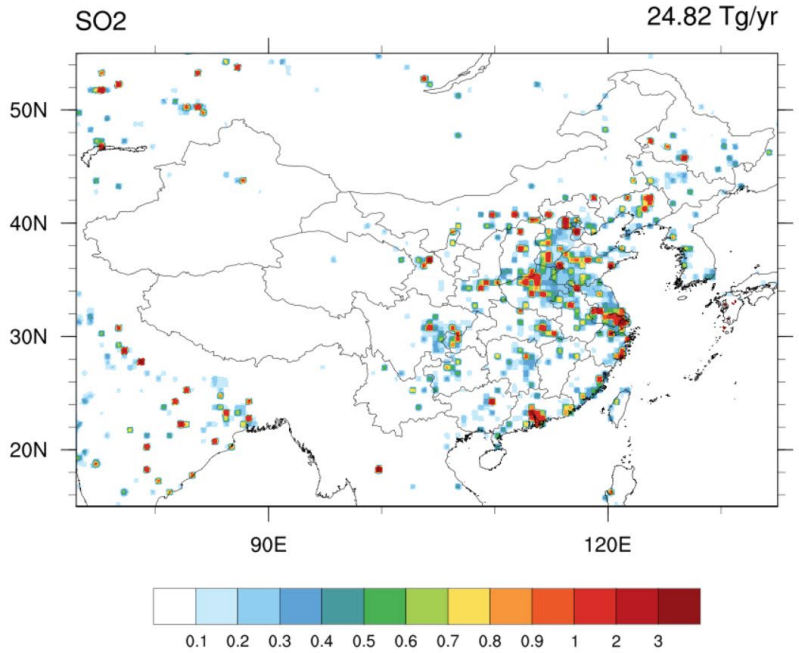


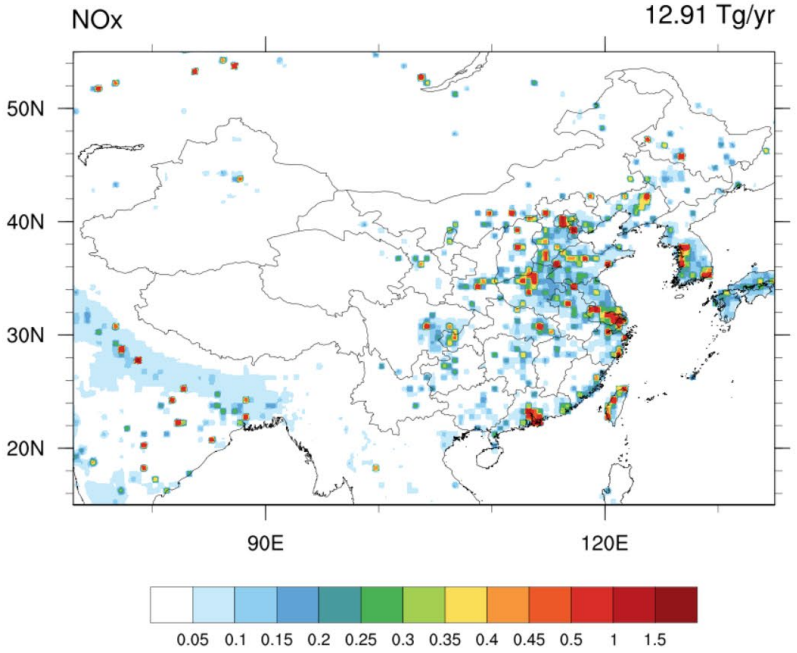
- Regional refinement over East Asia
- Gas/aerosol partitioning of nitrate (MOSAIC, Lu et al., 2021)
- Free-running for 4 years
- 2000 climatology

Study Area: eastern China



Emission





- **The distributions of anthropogenic emissions are inhomogeneous**
- **Point-like high emission values over northern China**

Regional budget of nitrate

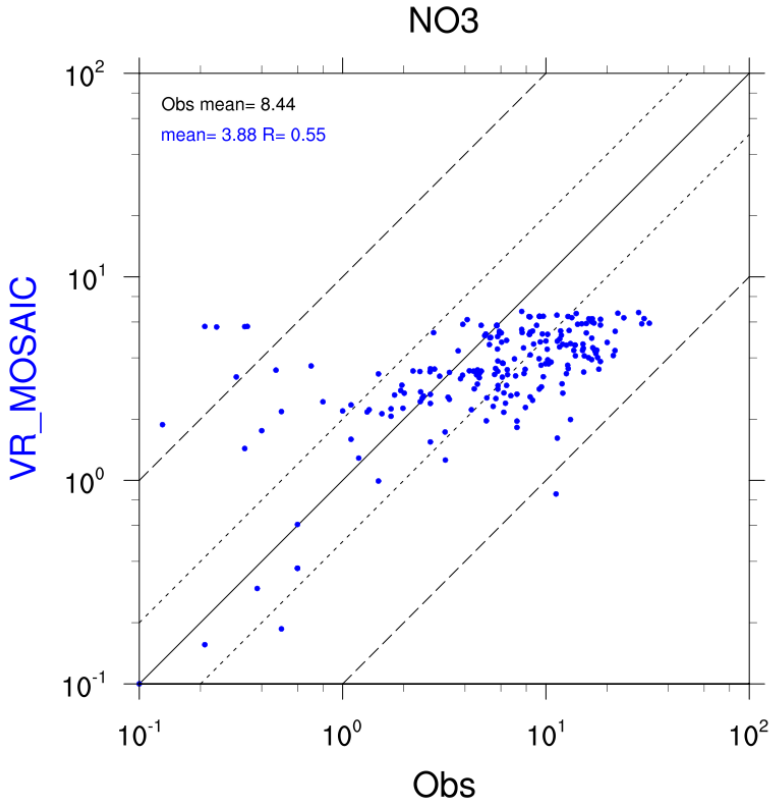
Total net production (5.00)			Deposition (-3.96)		Transport (-1.07)			
Evapo	Cond	Aqu	Dry	Wet	U_west	U_east	V_south	V_north
-19.01	8.07	15.94	-0.79	-3.17	0.38	-1.08	-0.25	-0.14

Unit: Tg/yr

- **Formation: gas-aerosol exchange loss (Evap) and production (Cond), and aqueous chemistry production (Aqu)**
- **Removal: dry and wet deposition, and transport across boundaries**

Surface concentration

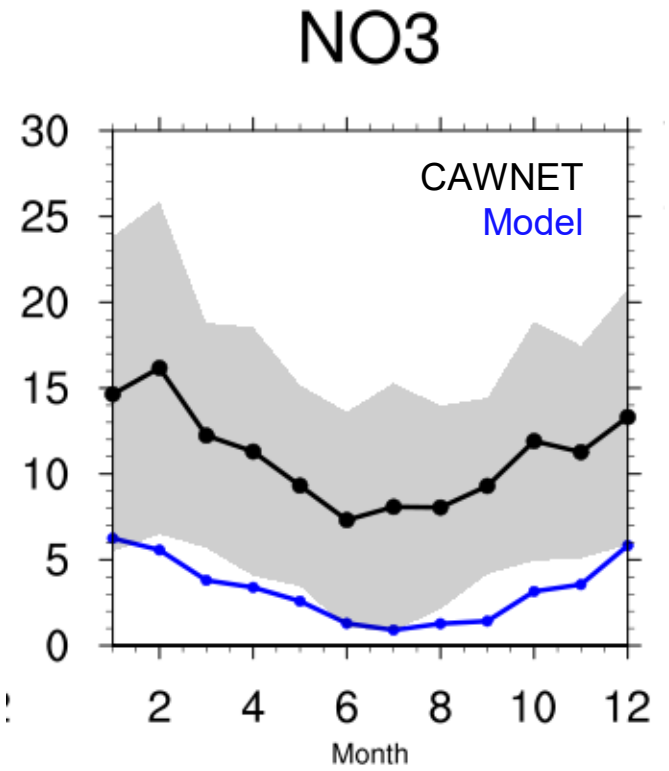
- **Model tends to underestimate nitrate aerosol concentrations at the surface over China**



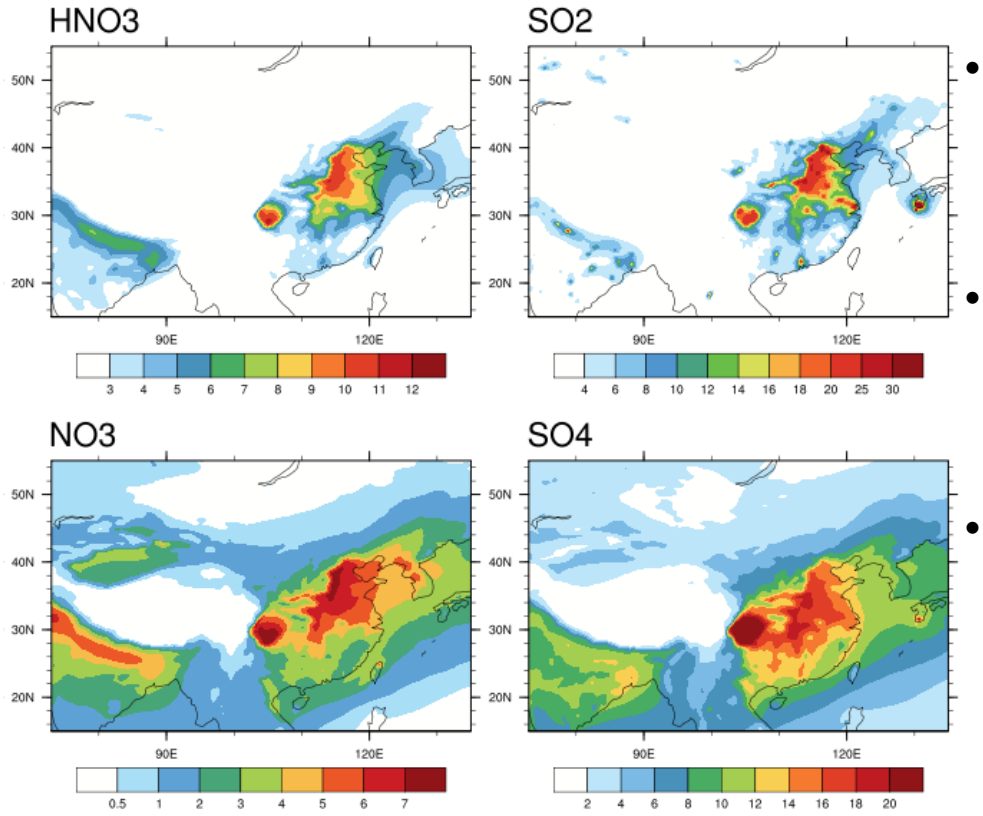
(Observations of NO3 concentrations from the literature)

Surface concentration

- **Model tends to underestimate nitrate aerosol concentrations at the surface over China**
- **Model capture the seasonal variation of nitrate aerosol, with active production at cold temperature**

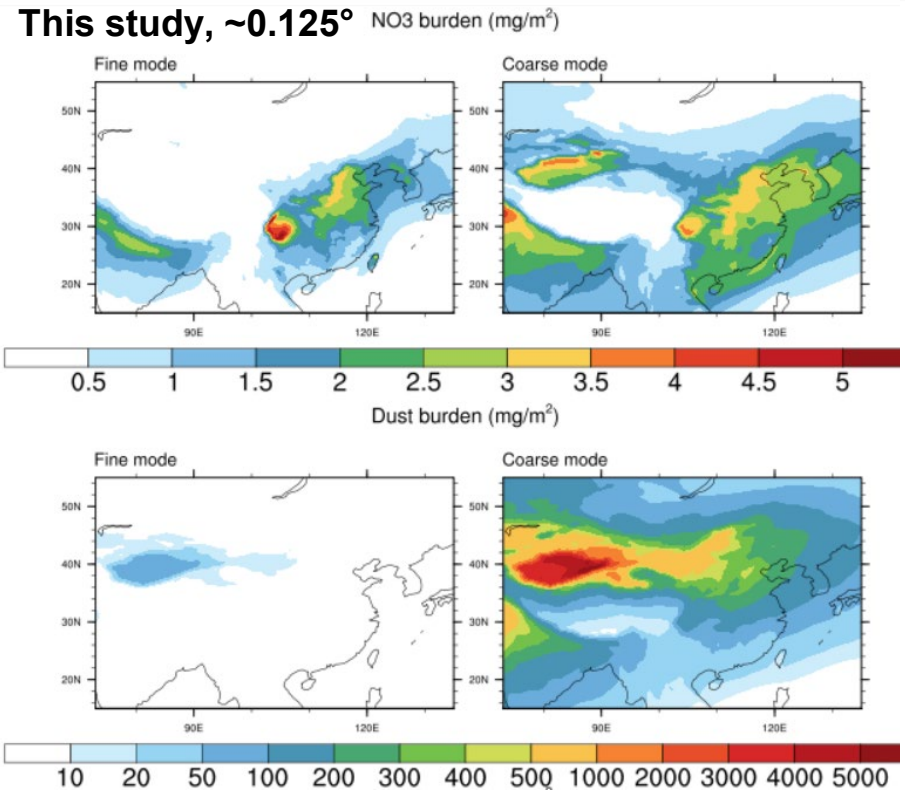


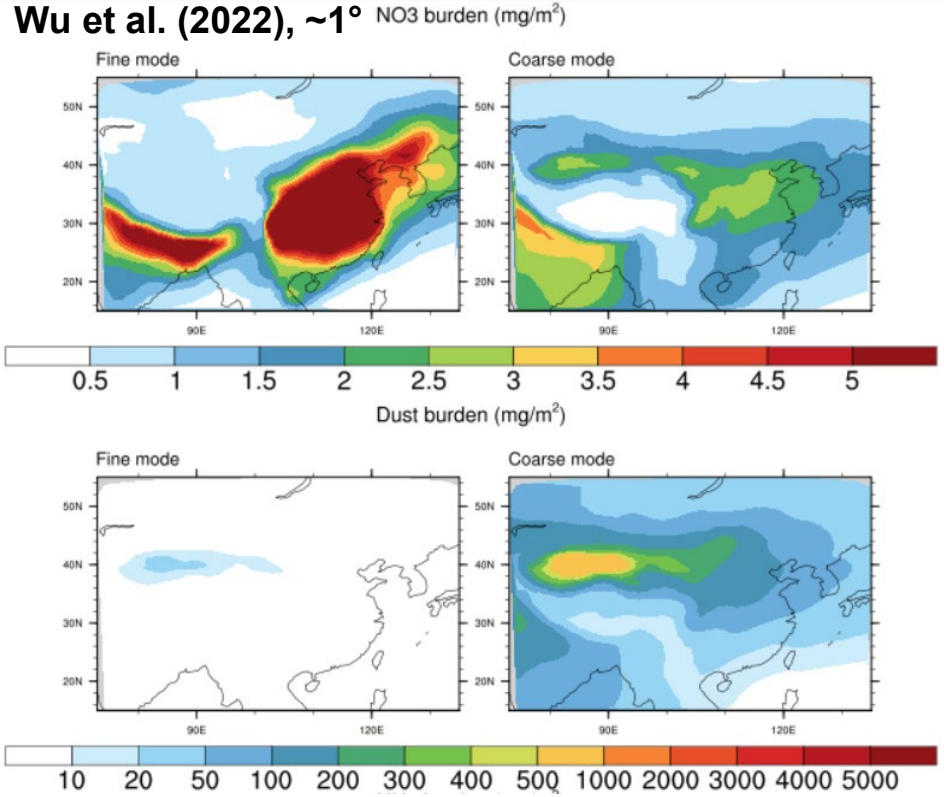
Burden



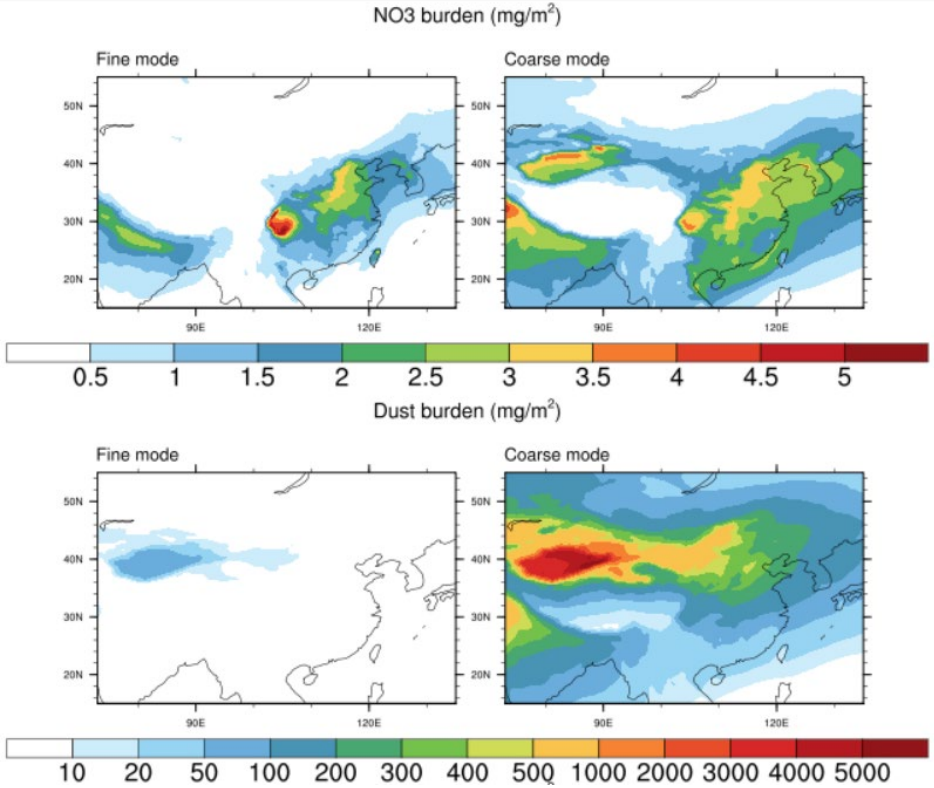
- Over eastern China, nitrate and sulfate burden are consistent with anthropogenic precursor gases
- Over remote regions, dust and heterogeneous reactions play an important role
- The complex chemistry and short lifetime of nitrate aerosols can lead to large gradients in concentrations in small areas, which can be represented within VR-CESM

Fine mode versus coarse mode



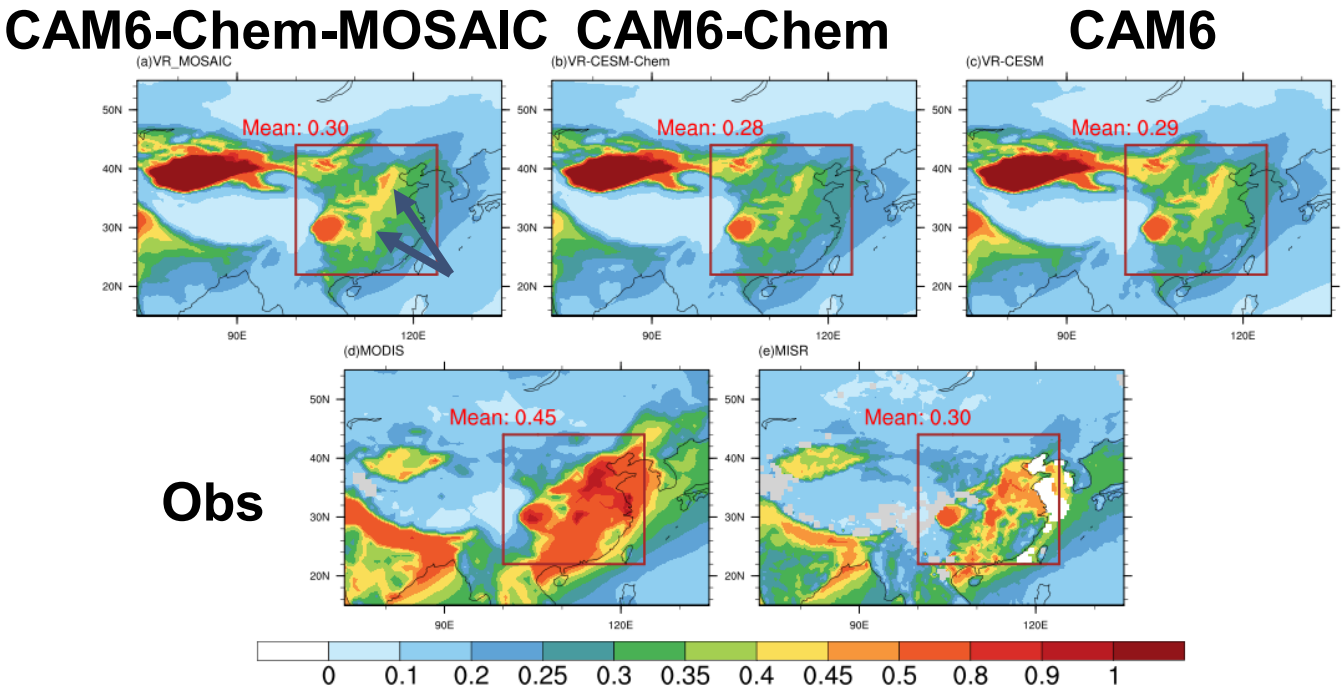


Fine mode versus coarse mode



- **Contribution of fine mode to nitrate burden is lower compared to previous study (>75%, Wu et al., 2022)**
- **Uncertainties in dust simulation affect heterogeneous reactions of nitrate aerosols**

AOD



- **Compared to CAM6-Chem, CAM6 overestimates organic aerosols concentration and thus AOD over northern China**
- **CAM6-Chem-MOSAIC better captures high values over northern and central China**

Conclusions

- **The performance of variable-resolution CESM2-MOSAIC in simulating nitrate aerosols over East Asia is evaluated.**
- **The model tends to underestimate nitrate aerosols concentrations, which may be related to uncertainties in emissions (e.g., NOx, SO2) and chemistry parameterizations (e.g., heterogeneous reactions).**
- **Low biases in AOD over northern and central China are reduced when nitrate aerosols are included.**
- **VR-CESM2 needs to be further tuned to reduce uncertainty in simulation, such as dust emission.**

Thanks