An improved aerosol wet removal parameterization coupled with an explicit convective cloud scheme in CAM6

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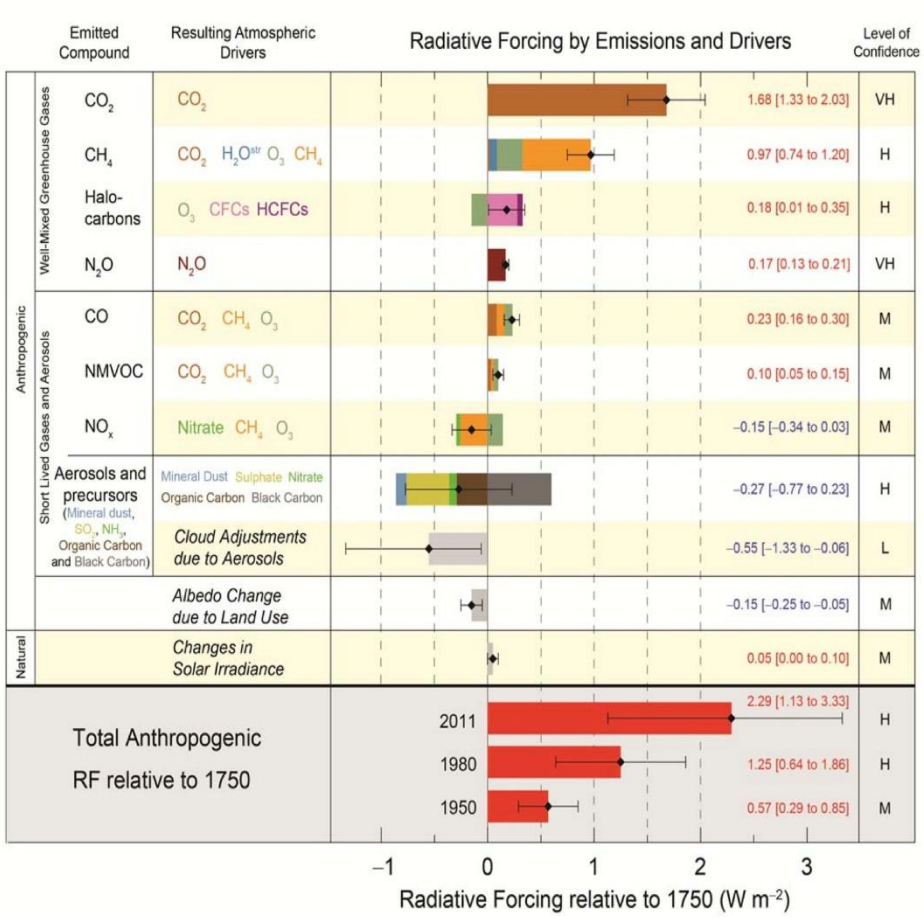
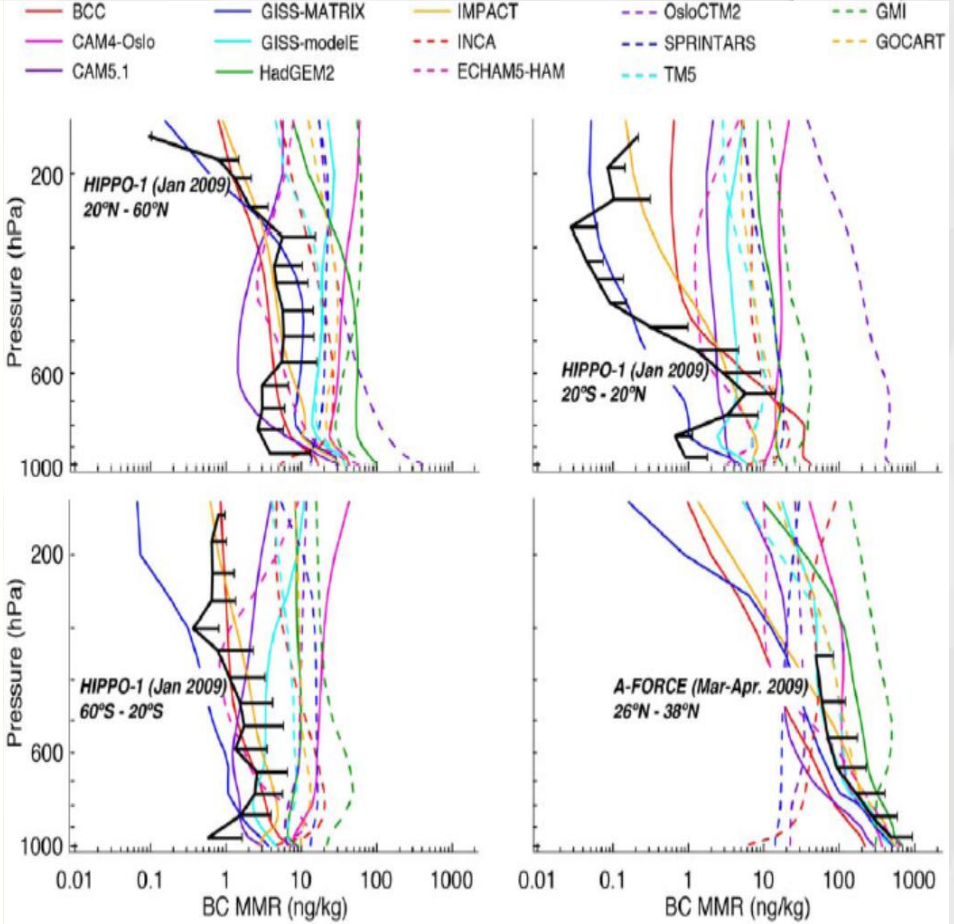
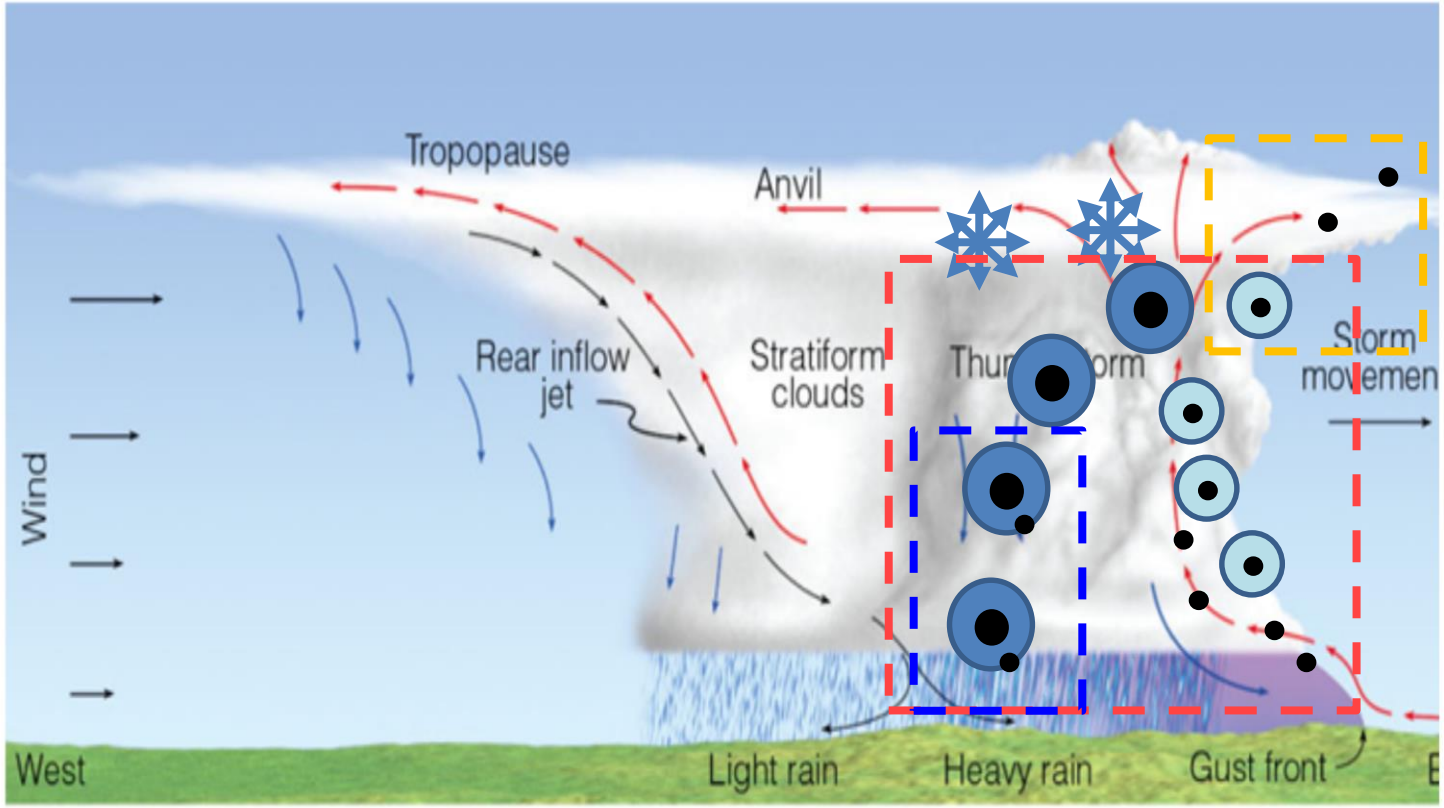
Importance of Aerosol and its Vertical Distribution





(IPCC5, 2013)

Classifications of Aerosol Wet Scavenge



Snow/Graupel Crystal

Rain Droplet

Cloud Droplet

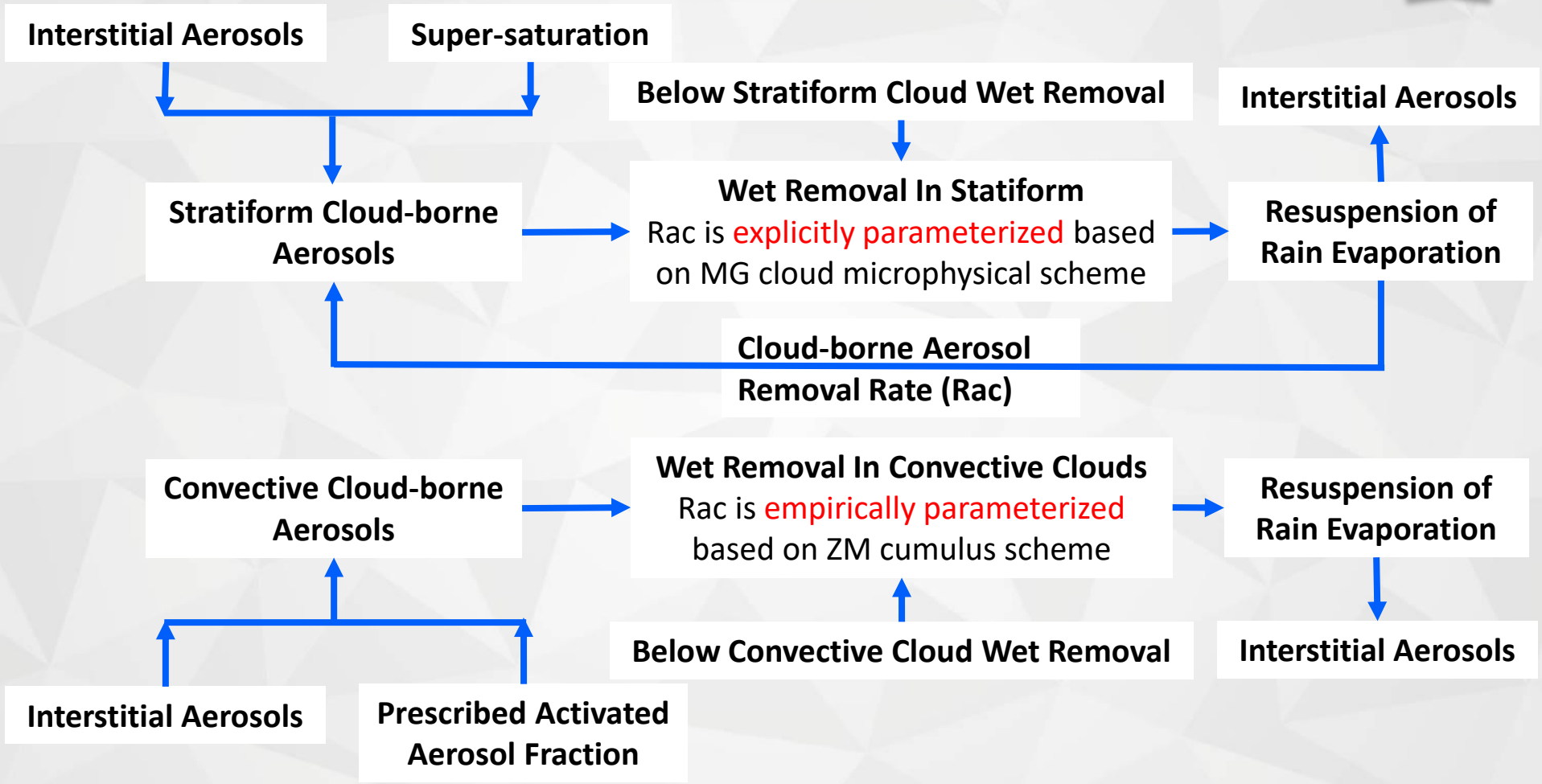
Aerosol

Aerosol In-Cloud Wet Removal

Aerosol Below-Cloud Wet Removal

Resuspension of Wet Removal

Aerosol Wet Removal Parameterizations in CAM



Part 2

Scheme Improvement and Experiment Setup

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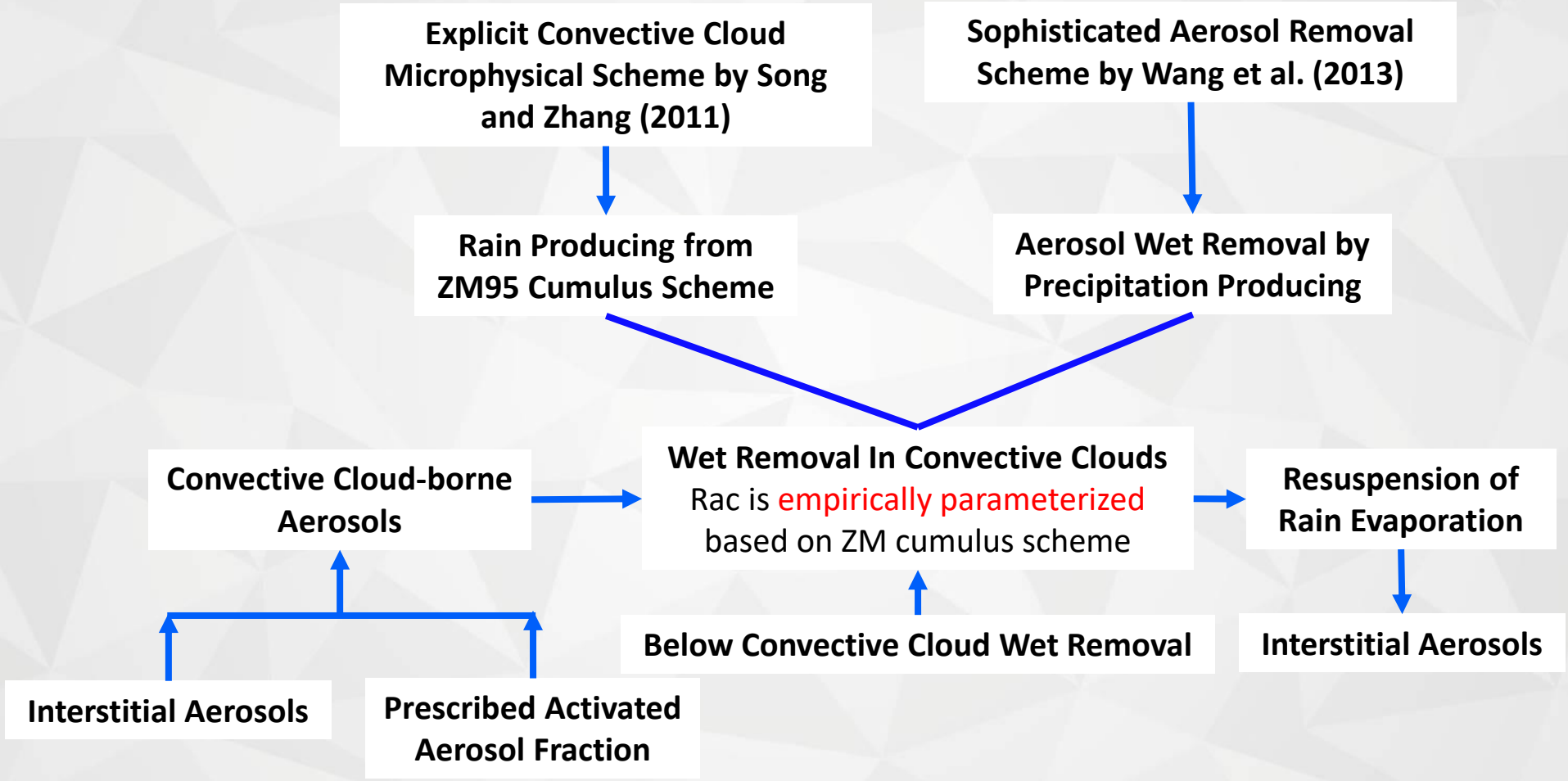
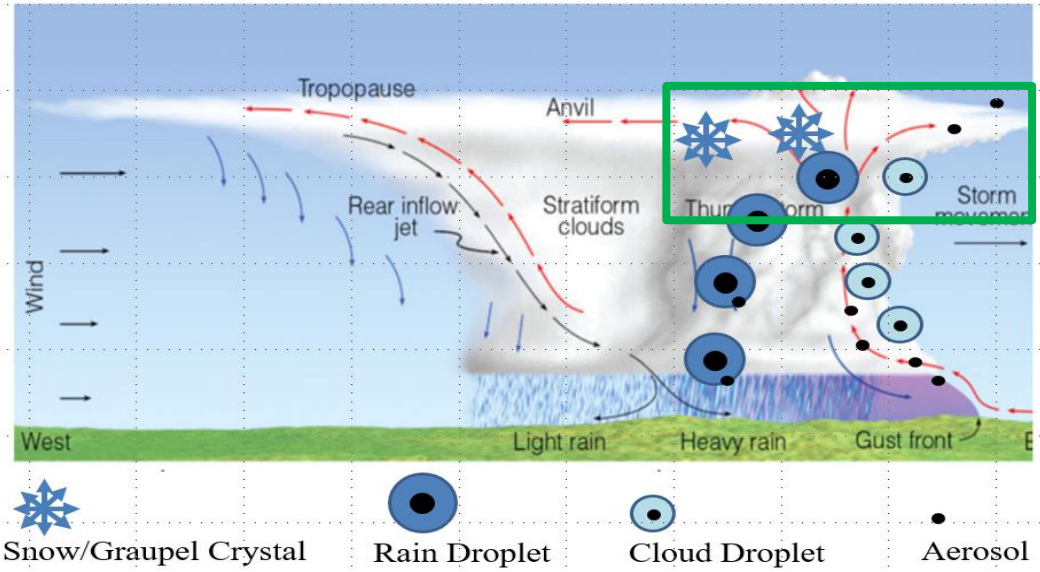
Introducing New Schemes



Scheme Improvement -1



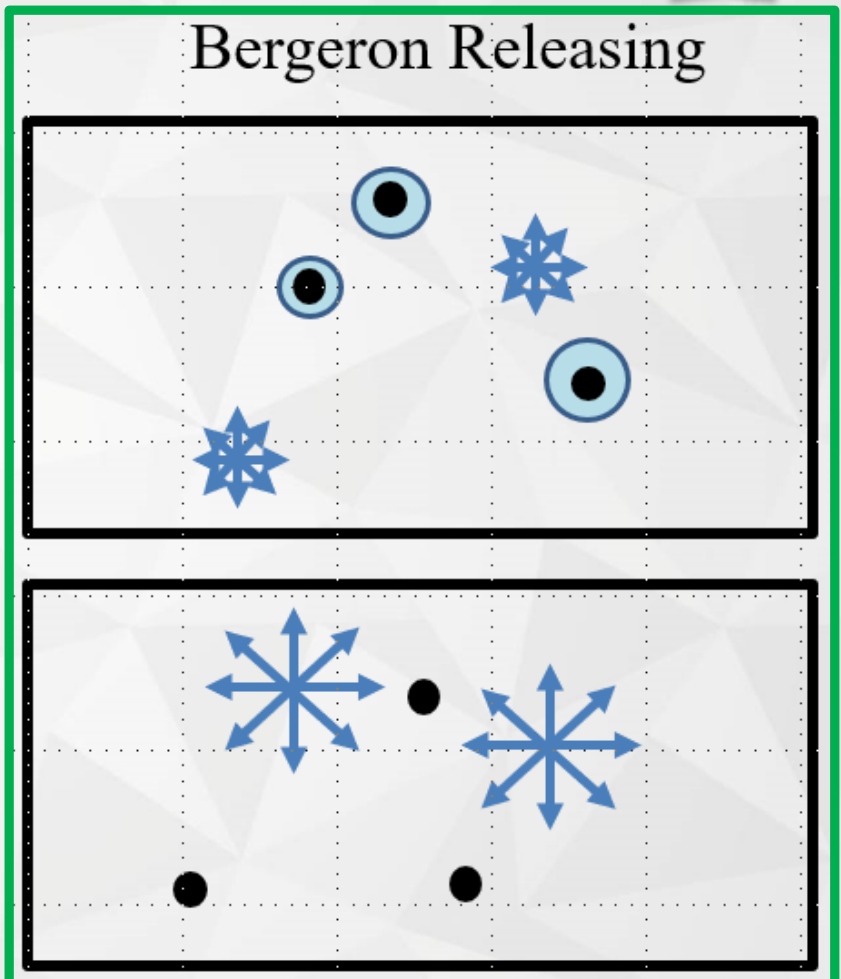
$$\left(\frac{\partial q_{ec}}{\partial t}\right)_{up} = \frac{\partial (M_u q_{uc})}{\partial p} - \frac{\partial (M_u q_{ec})}{\partial p} + Act \cdot q_{uI} - Wet \cdot q_{uc} + \mathrm{Re}\, s \cdot q_{uc}$$

Explicitly Parameterized Rain Producing Rate

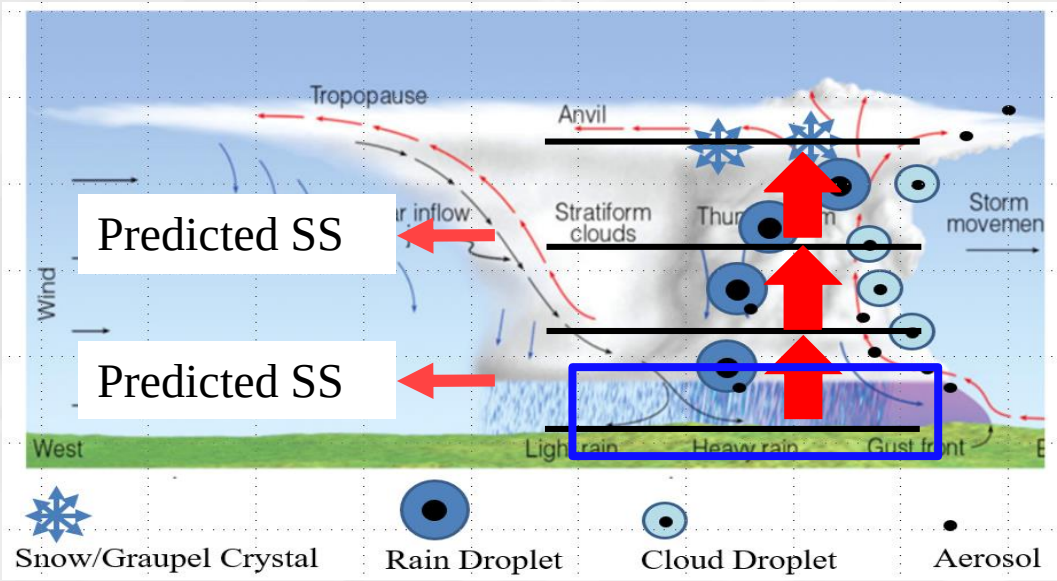
$$Wet = \frac{\mathrm{Pr}\, ec}{\mathrm{Pr}\, ec + cldm}$$

Aerosol Releasing by Bergeron Process

$$Wet = \frac{\mathrm{Pr}\, ec - P_{Berg}}{\mathrm{Pr}\, ec + cldm}$$



Scheme Improvement -2

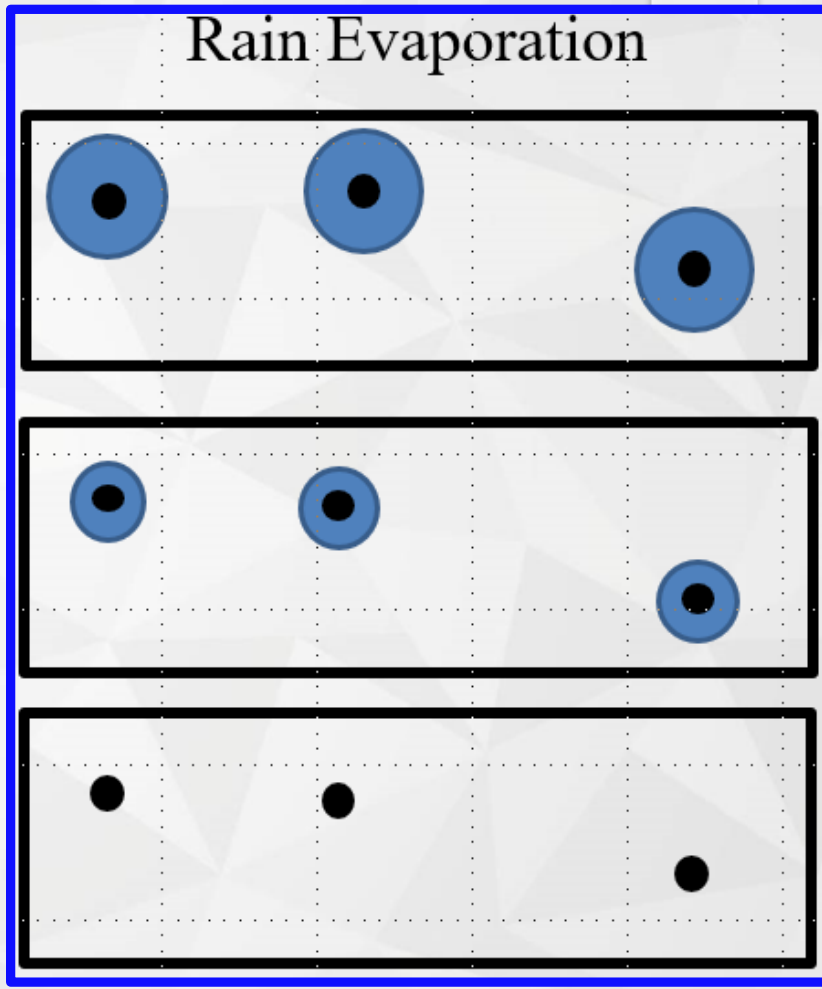


$$\left(\frac{\partial q_{ec}}{\partial t}\right)_{up} = \frac{\partial (M_u q_{uc})}{\partial p} - \frac{\partial (M_u q_{ec})}{\partial p} + Act \cdot q_{uI} - Wet \cdot q_{uc} - \mathrm{Re}\, s \cdot q_{uc}$$

Aerosol Releasing by Rain droplet Entire Evaporation

Aerosol Secondary Nucleation in Cumulus

$$\mathrm{Re}\, s = \frac{\mathrm{P}\, eva}{\mathrm{Pr}\, ec + cldm}$$



Model Configuration and Experiment Setup

	Convective removal		Bergeron Releasing		Rain Evaporation		Secondary Nucleation	
	St	Conv	St	Conv	St	Conv	St	Conv
CTL	-	-	-	-	-	-	-	-
CONV	-	X	-	-	-	-	-	-
WBF	-	X	X	X	-	-	-	-
SN	-	X	-	-	-	-	-	X
EE	-	X	-	-	X	X	-	-
ToMod	-	X	X	X	X	X	-	X

Runtime period: 18 month free run (first 6 months are spin-up time)
CESM2 configuration: 30 levels, MG2, MAM4, CLUBB
Modified schemes: SZ11 Convective Cloud Microphysics (Song and Zhang, 2011)
WH13 Convective In-cloud Aerosol Wet Removal (Wang et al., 2013)

Part 3

Results and Discussions

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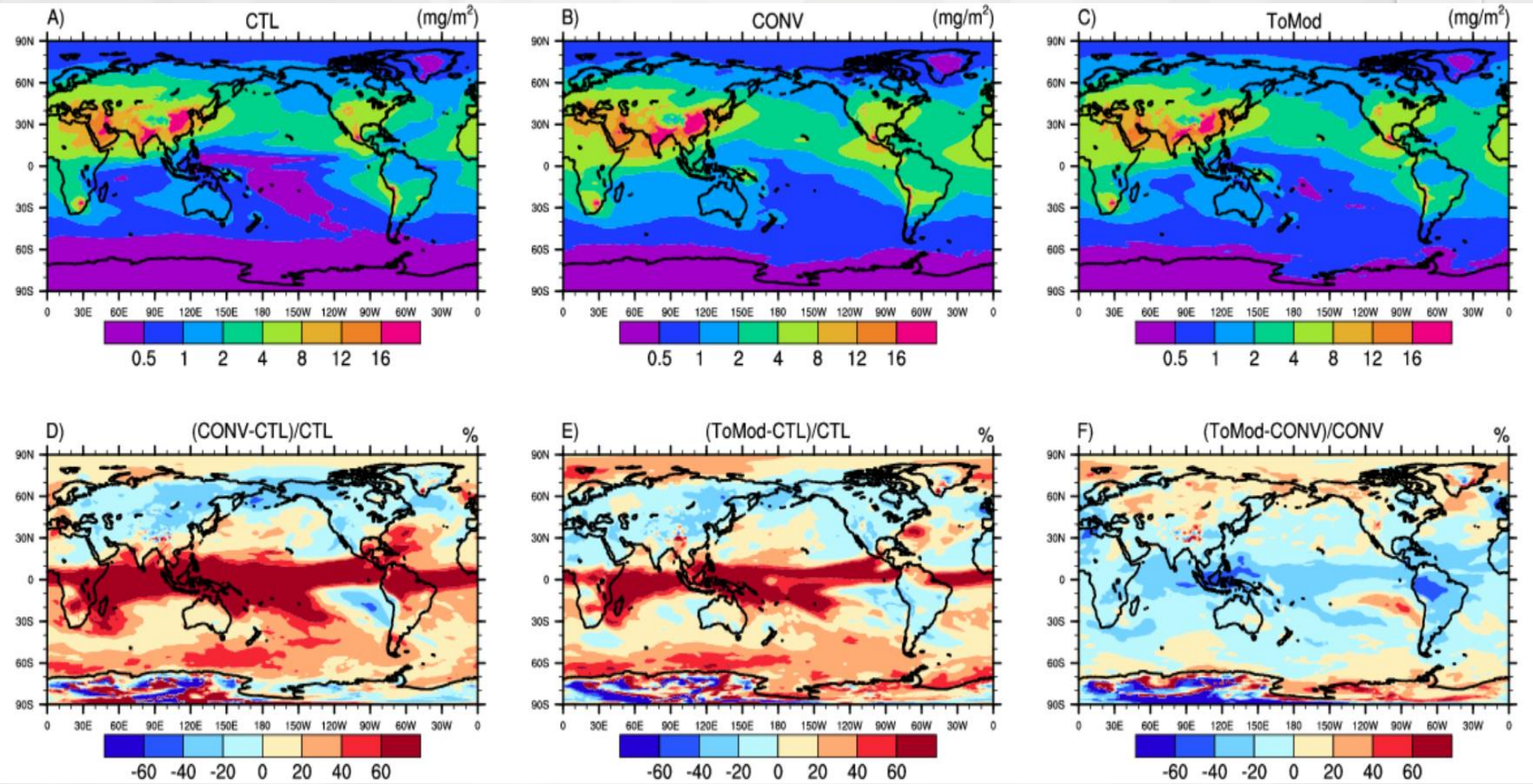
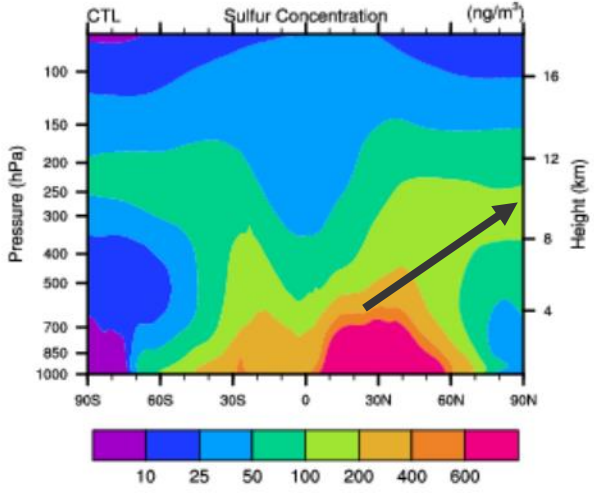
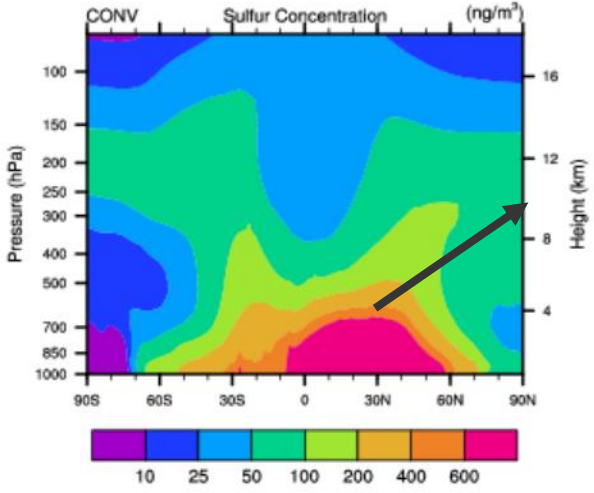
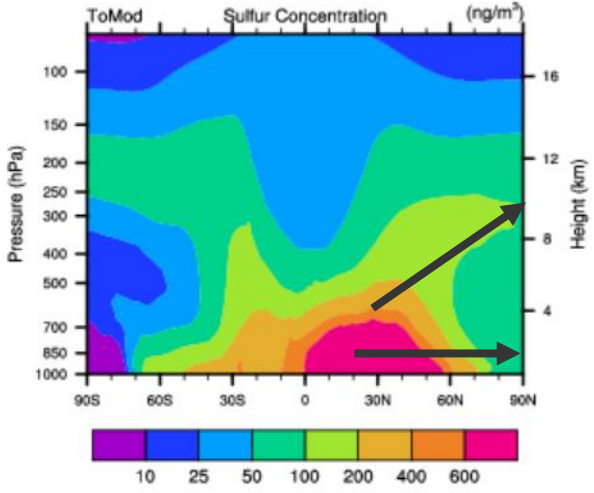
Sensitivities of Sulfate Aerosol Distribution

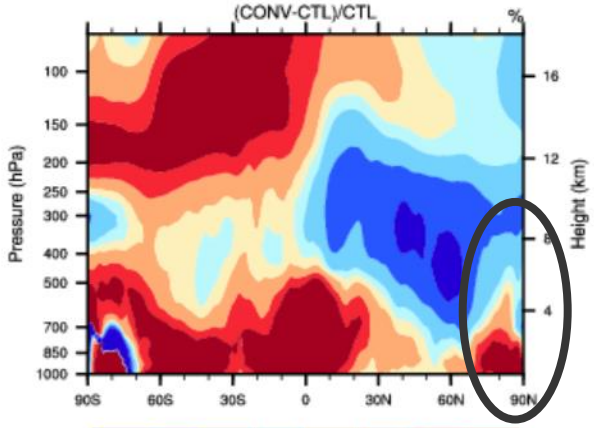


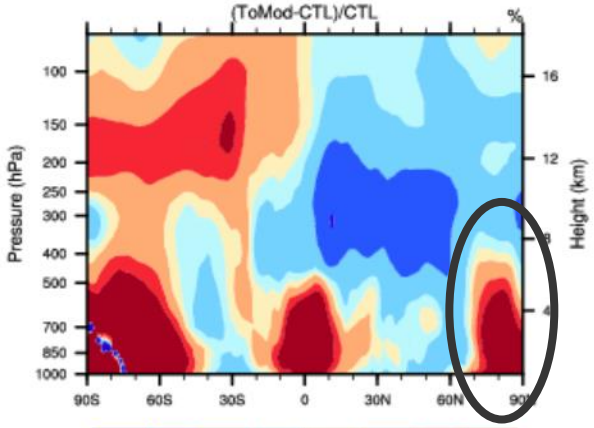
Sulfate Aerosol Transports

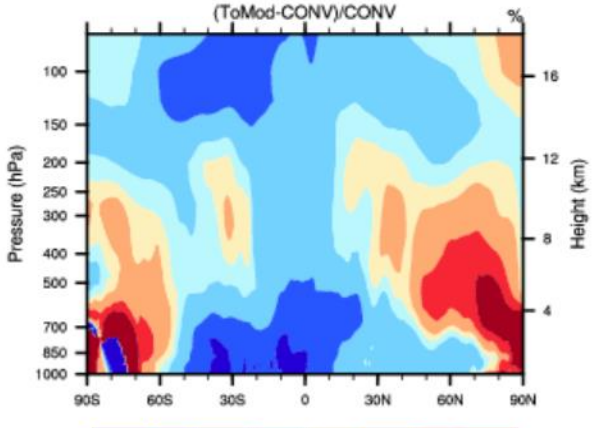




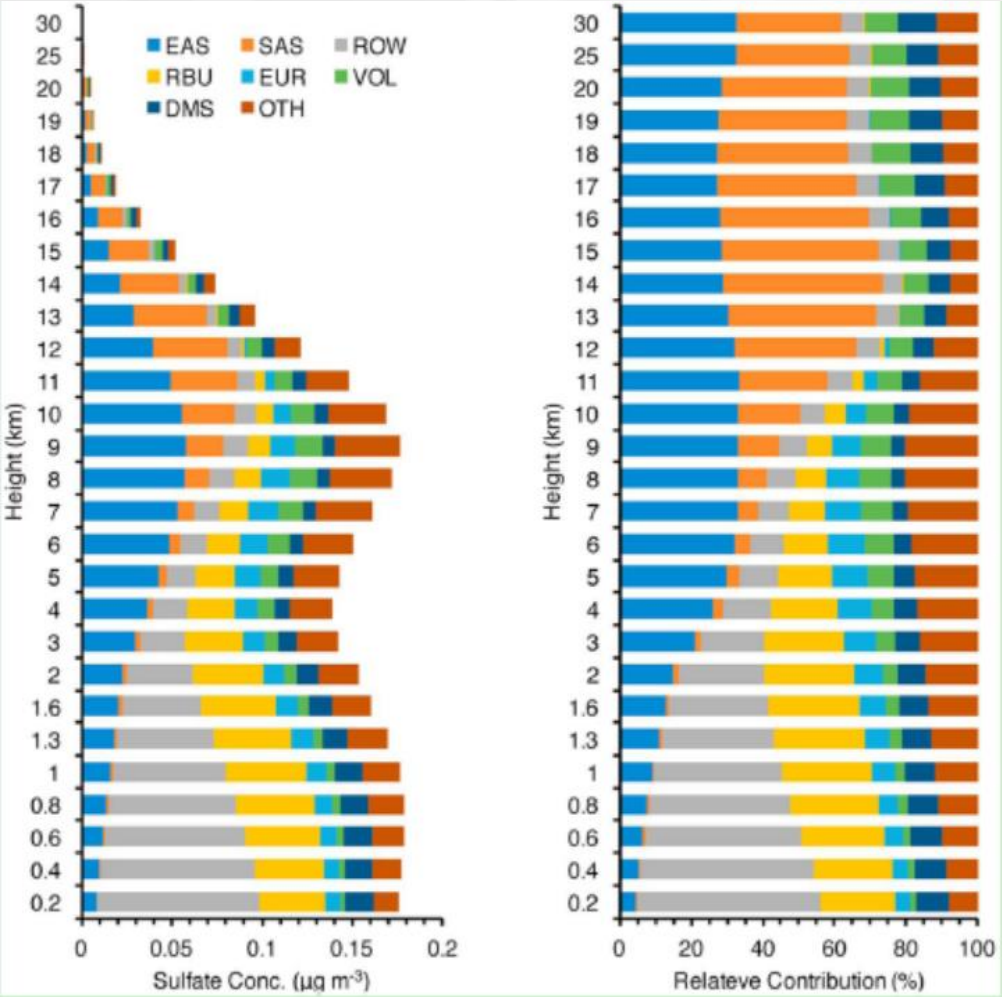


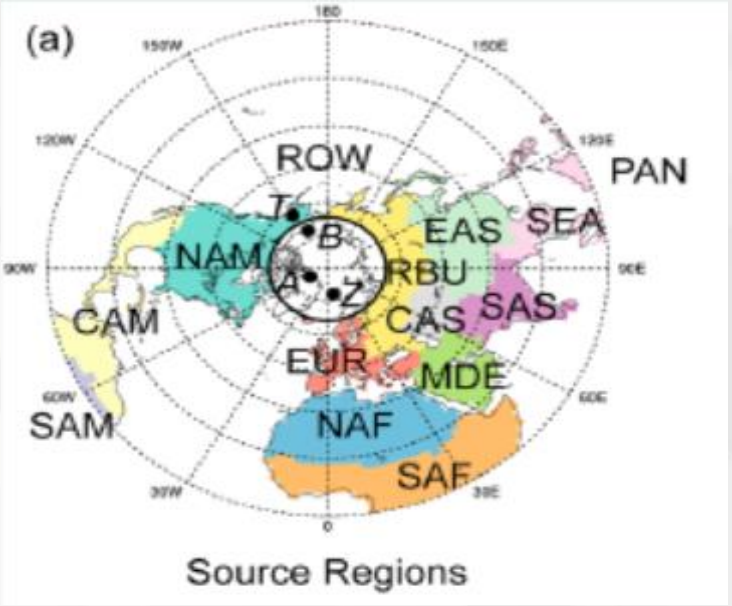






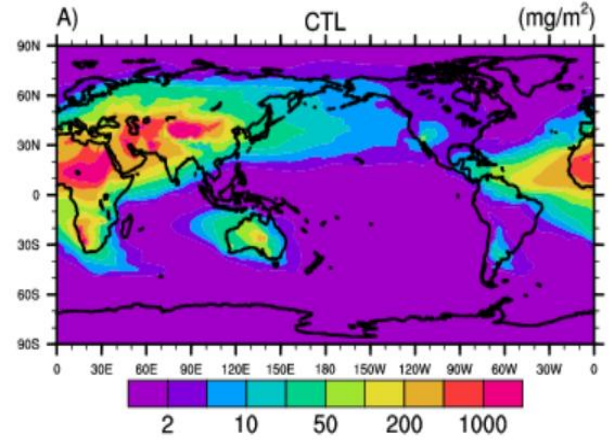
Elevations of Sulfate Aerosol Transport Path

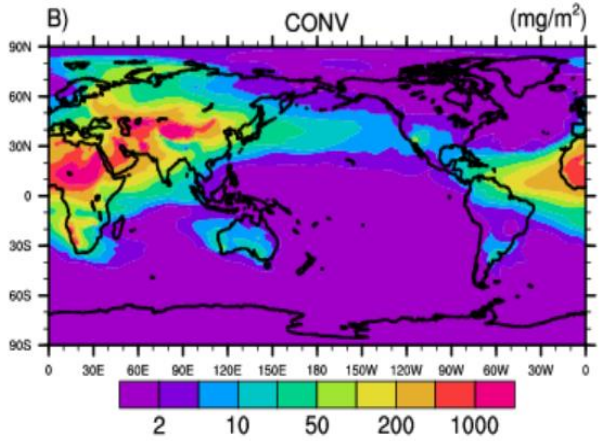


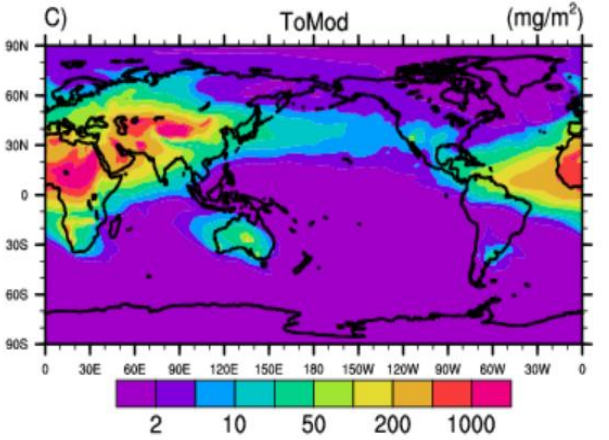


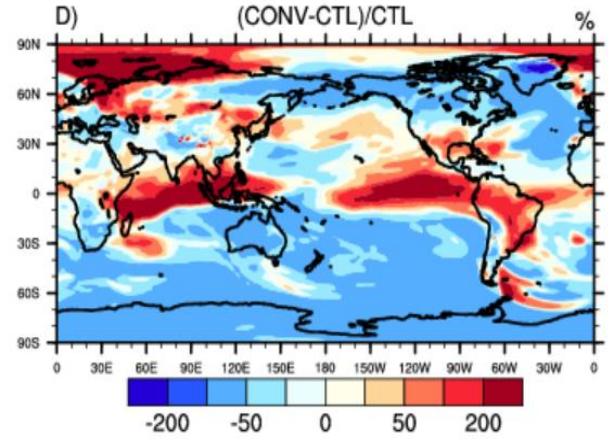
(Yang et al., 2018)

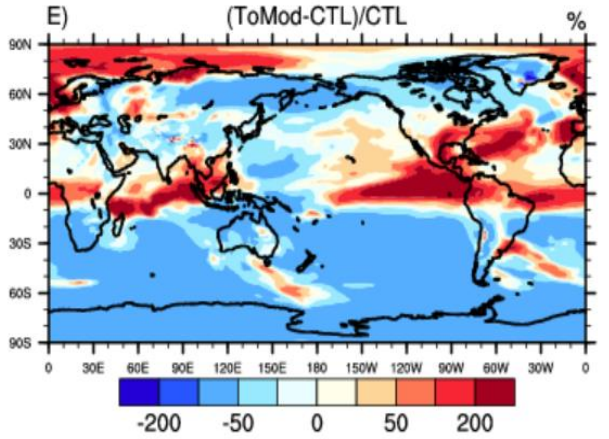
Sensitivities of Dust Aerosol Distribution

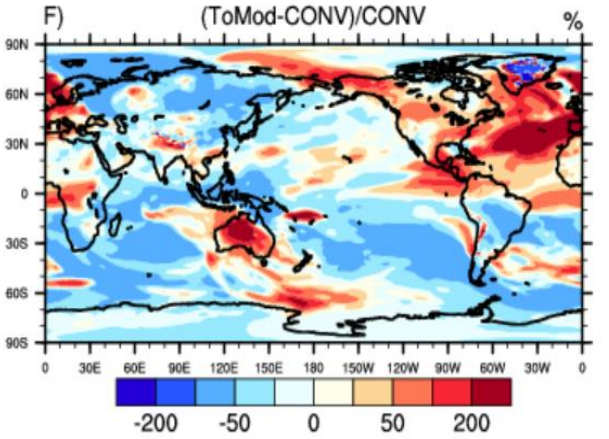




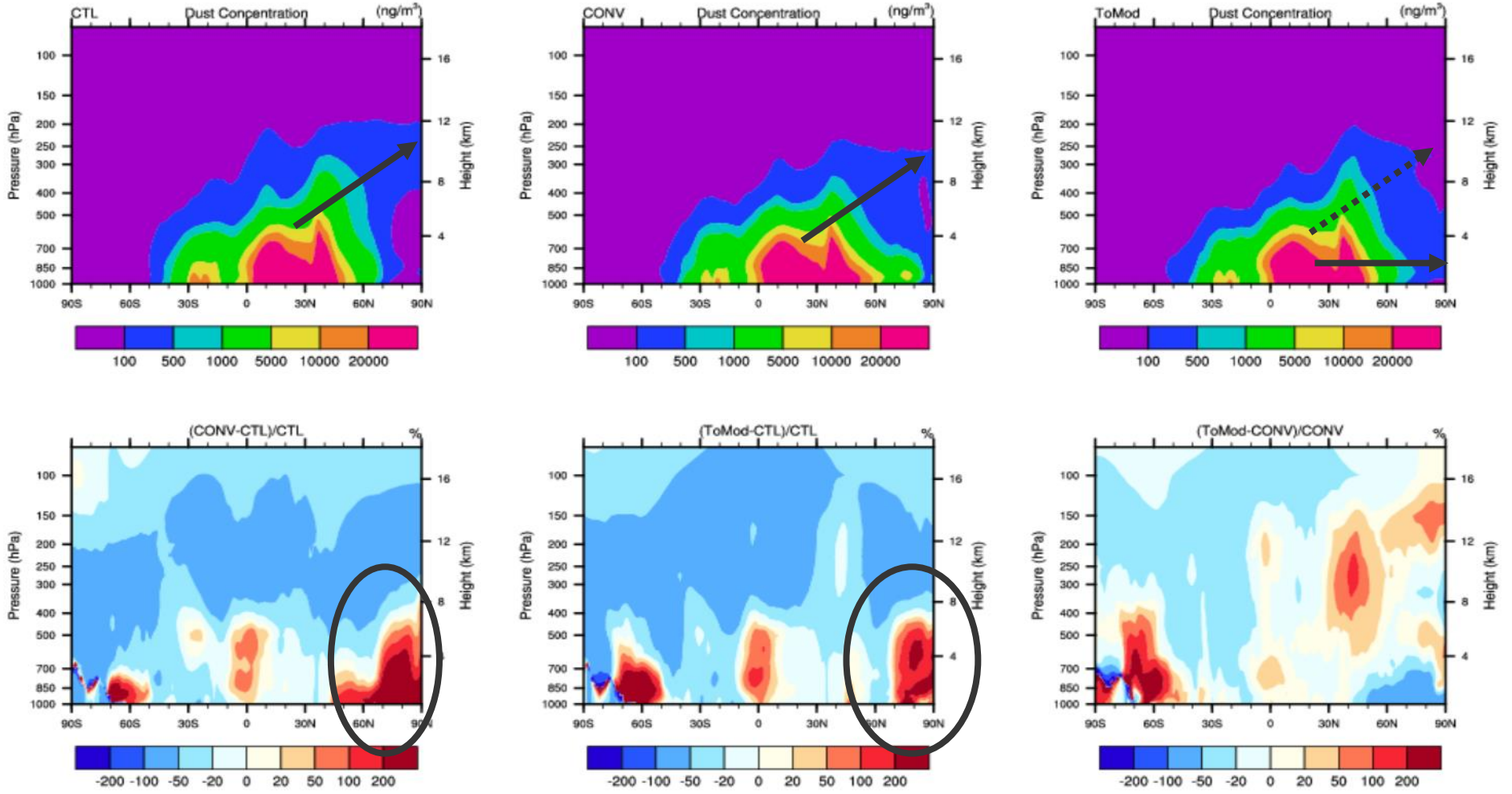






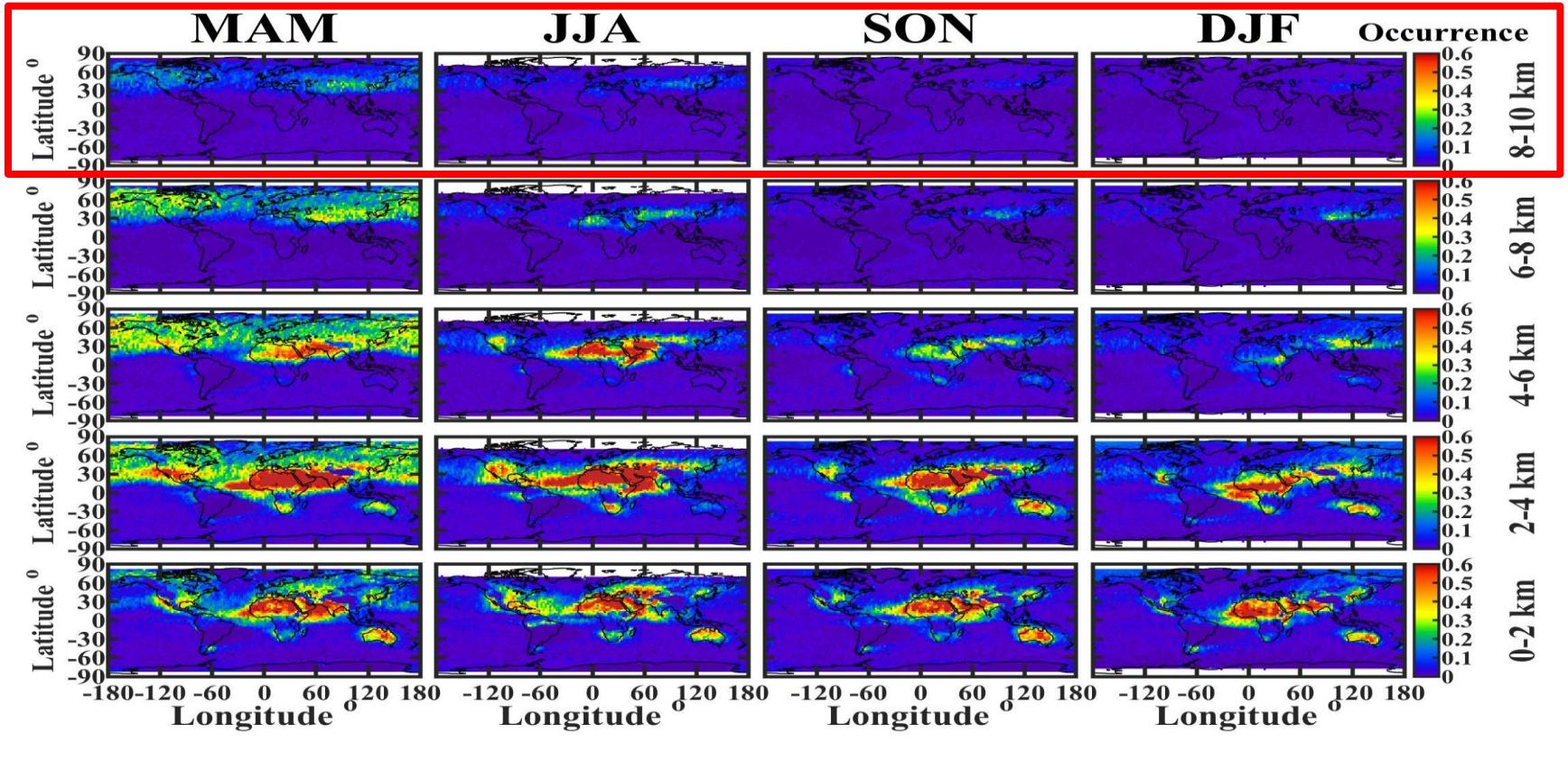


Dust Aerosol Transports



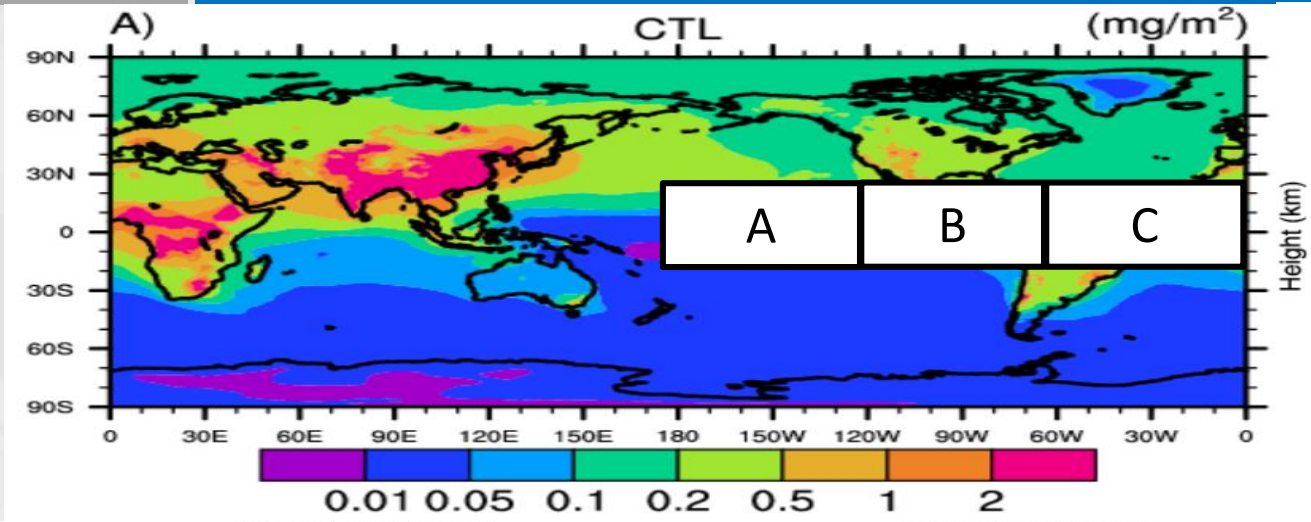
Observed Dust Transport

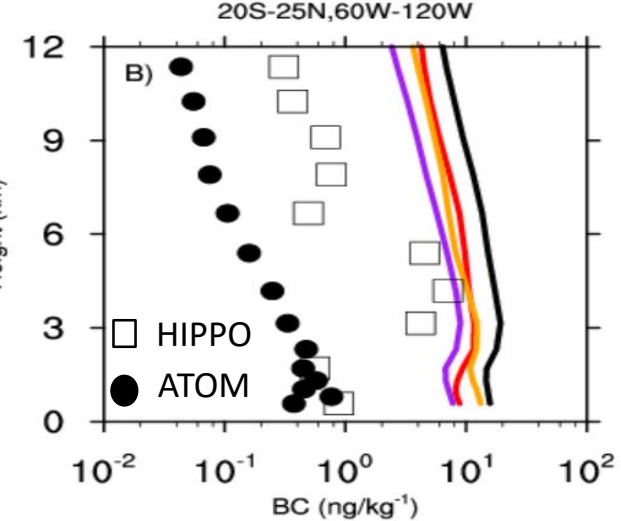
Averaged dust occurrence from CALIPSO observation (2007-2009)

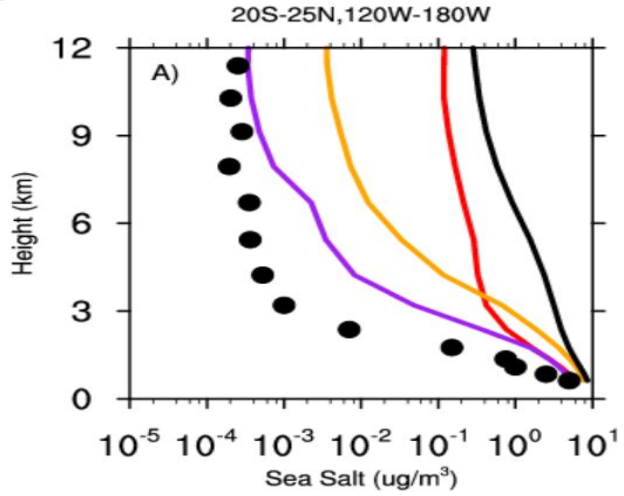


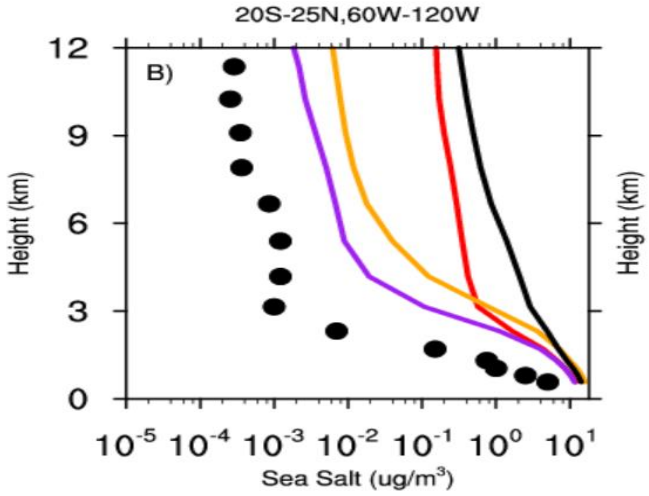
(Yang et al., 2019)

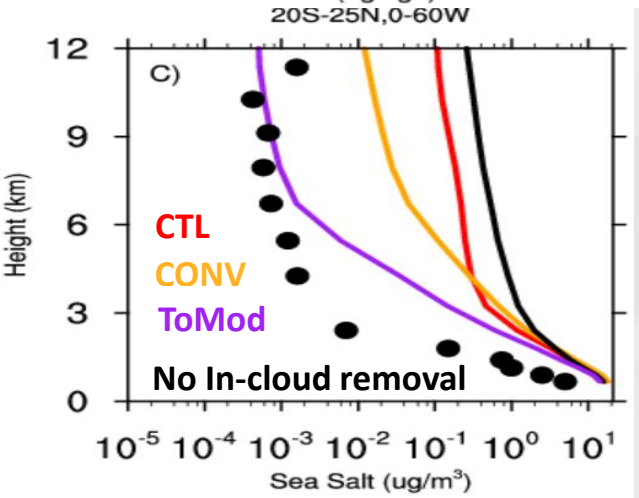
Evaluation of Aerosol Vertical Profile Simulations



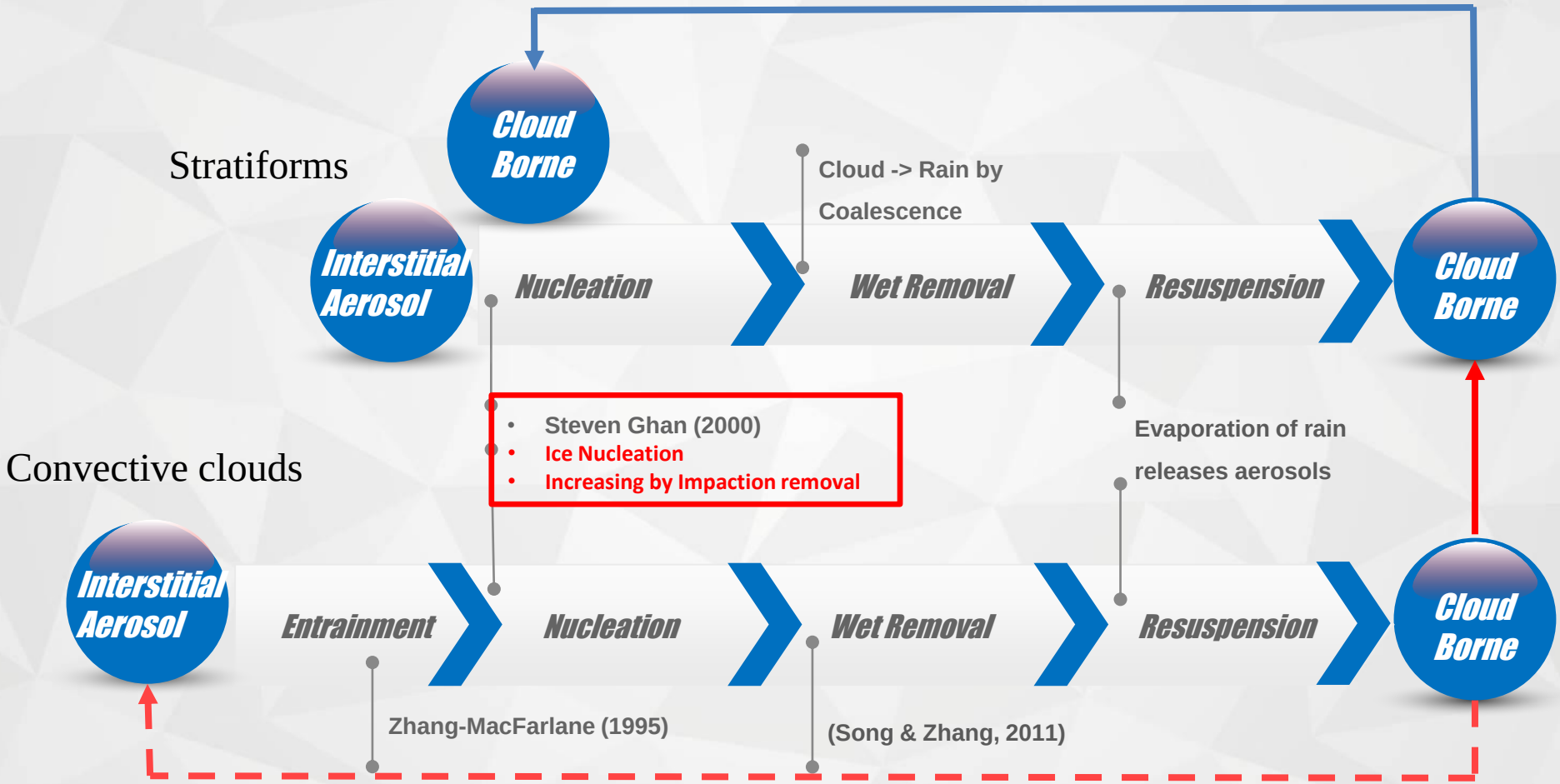








Toward a Uniform Representation of Cloud-borne Aerosol



Part 4

Conclusions

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Conclusions

Sensitivities of the Aerosol Distributions

- Both aerosols in remote areas are sensitive to scheme changes.
- Aerosol transport to Artic should be at lower layers.

Evaluations of Simulated Aerosol Profiles

- Profiles of sea salt aerosols with high hydrophilia are improved.
- Improvement of BC vertical distribution may need to IN scavenge.

Uniform Representations of Cloud-borne Aerosols

- Detrainment should transport convective cloud-borne aerosols into Stratiform.
- A comprehensive cloud-borne aerosol resources are required.

Questions?

Thank you for your attention