Model Evaluation and Uncertainties: Study case for a Chinese haze event measured during KORUS-AQ

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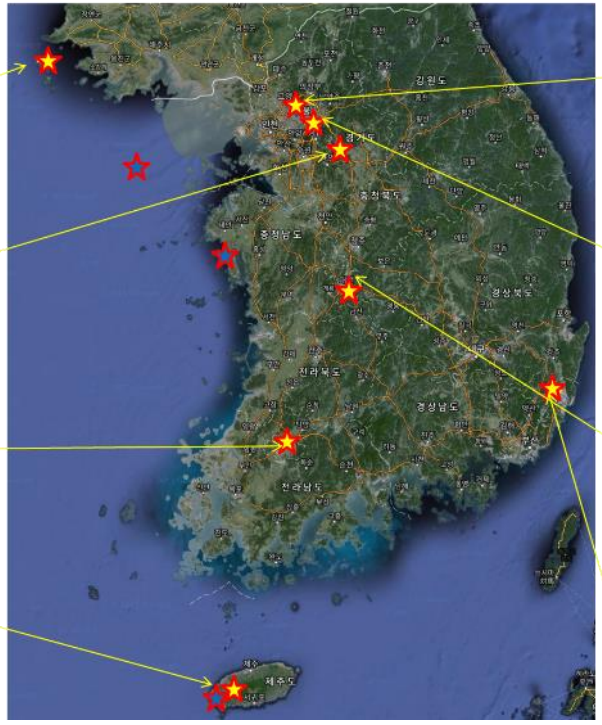
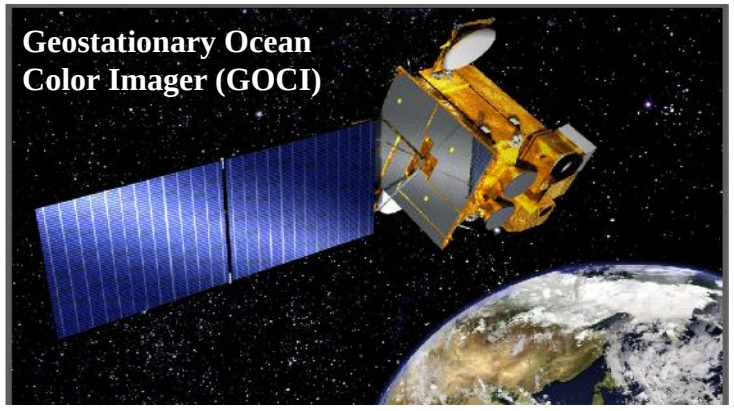
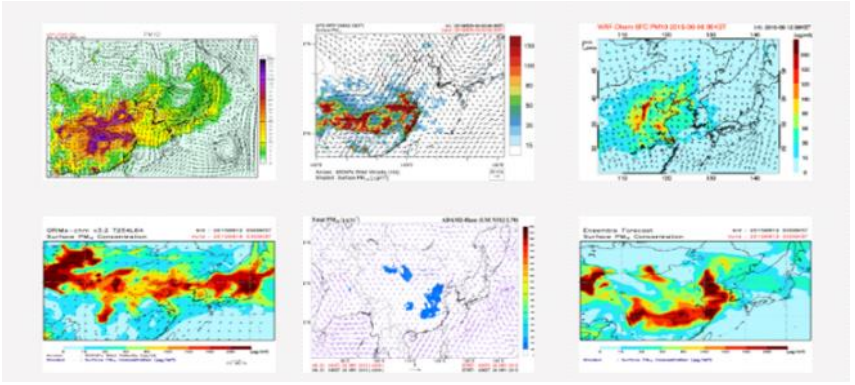
KORUS-AQ (May-June 2016)

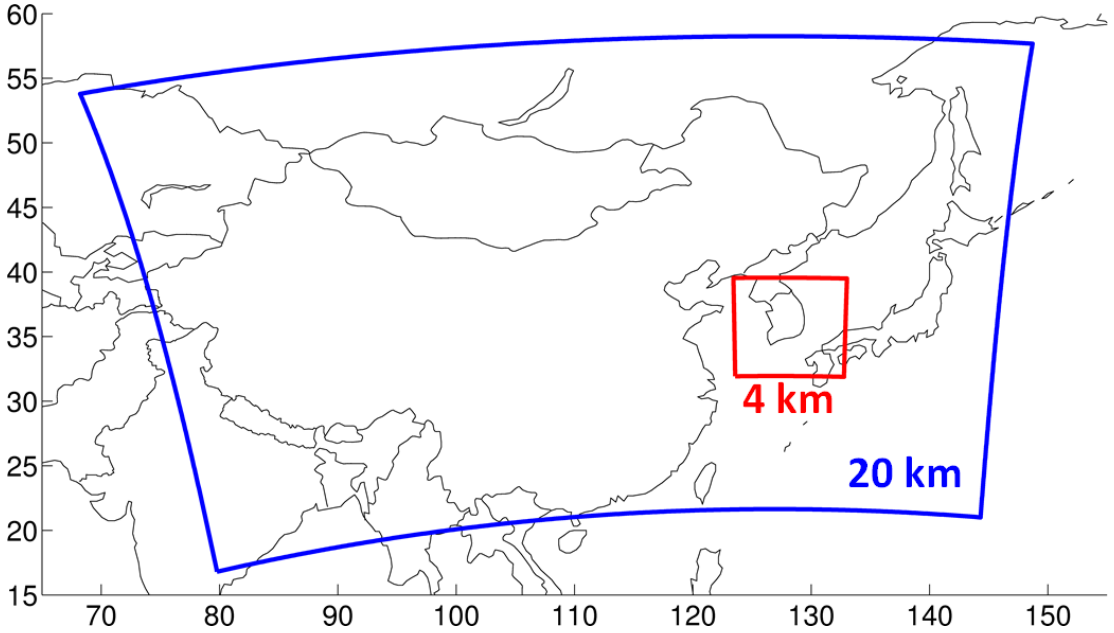




Korean and US Air Quality Model Forecasts



WRF-Chem forecasting system for KORUS-AQ

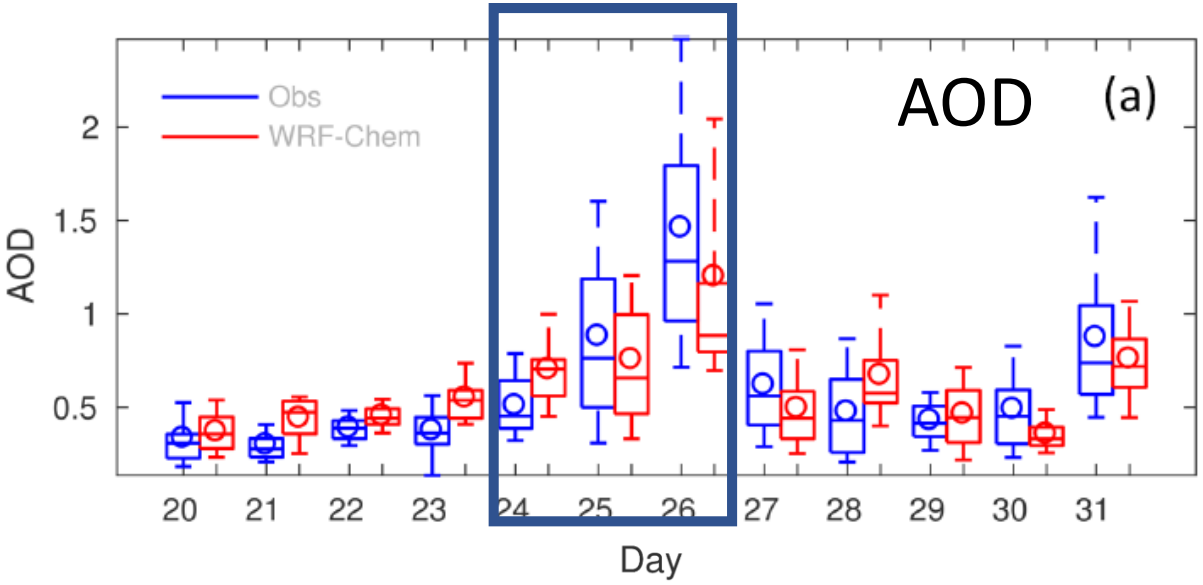


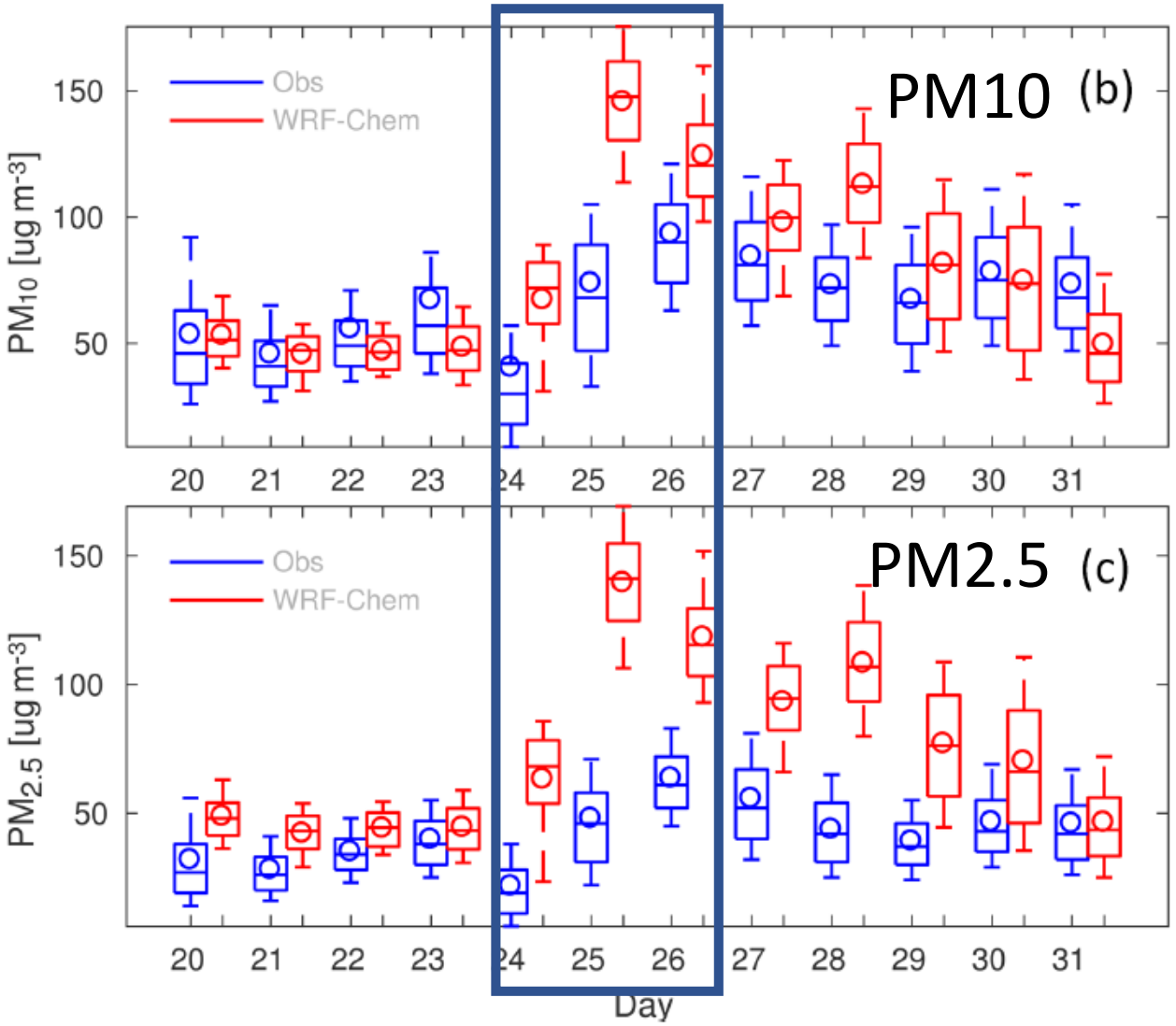
- WRF-Chem with MOSAIC aerosols (4 size bins) and a Reduced Hydrocarbon chemistry (Pfister et al. JGR 2014), including simplified SOA formation (Hodzic and Jimenez, GMD 2011)
- GFS and MACC meteorological and chemical boundary conditions
- KORUS-AQ anthro (Jung-Hun Woo) and QFED fire emissions
- AOD data assimilation using GSI (Saide et al., ACP 2013). MODIS and GOCI data were assimilated simultaneously every three hours (Saide et al., GRL 2014).
- Four days of forecasts were available for the outer domain, 2 days for the inner domain

Saide et al., ACP 2020

Evaluation against AERONET and surface PM

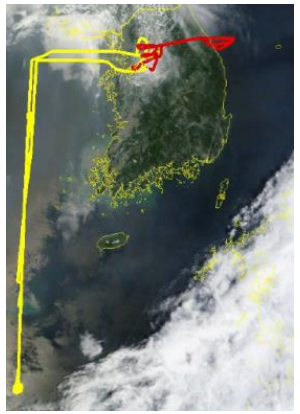
- AOD well captured over South Korea
- Over-predicted surface PM, especially PM2.5 often by a factor of 2 or larger

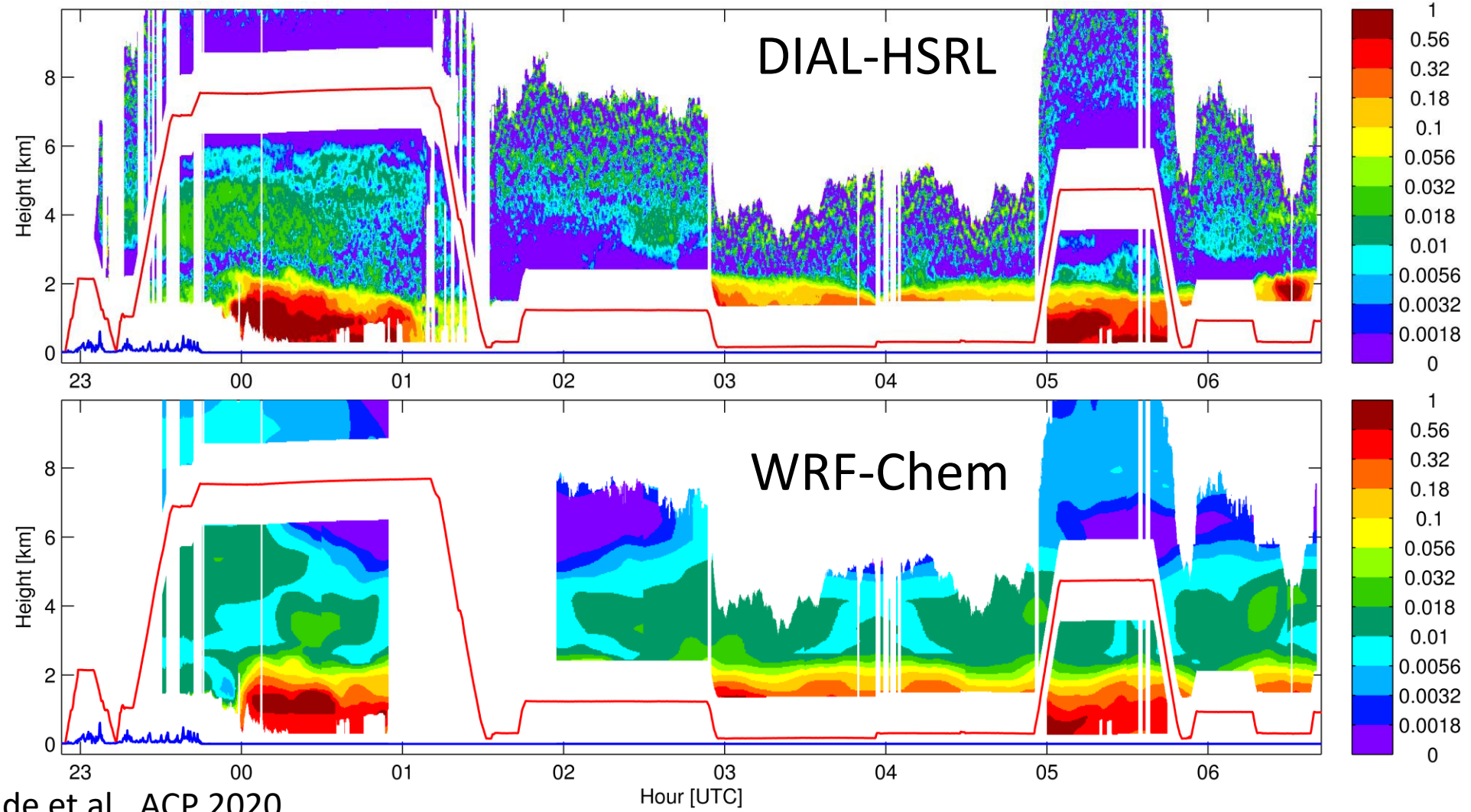


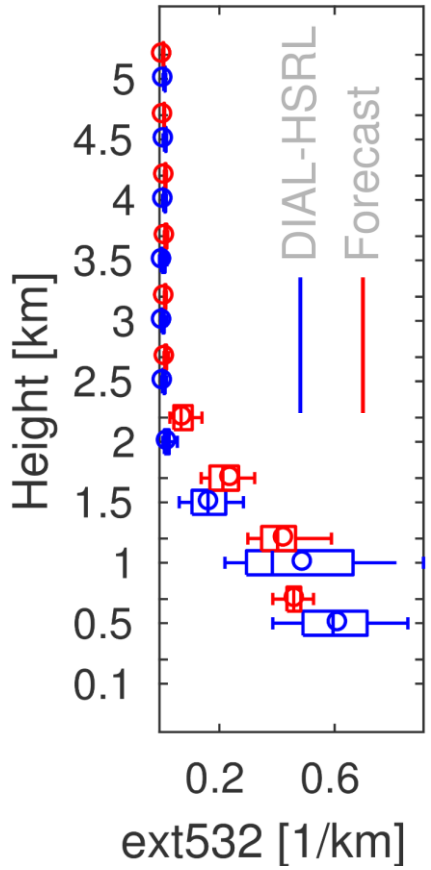


Saide et al., ACP 2020

DIAL-HSRL vs WRF-Chem May 24th (Extinction [1/km])







Saide et al., ACP 2020

Some definitions

- Mass Extinction efficiency (MEE) and Volume Extinction efficiency (VEE):

$$MEE = \frac{Dry\ extinction}{Mass\ concentration} \qquad VEE = \frac{Dry\ extinction}{Volume\ concentration}$$

Mass concentration: AMS (<1 µm), Volume concentration: size distributions (<5 µm), Extinction: nephelometer (<5 µm)

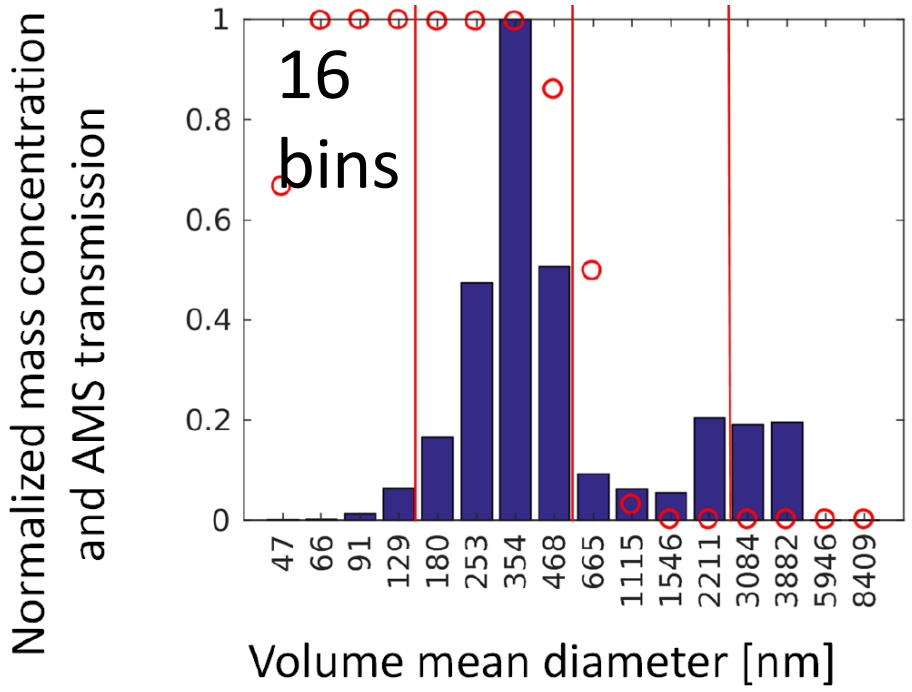
- Scattering enhancement factor due to aerosol hygroscopic growth: f(RH)

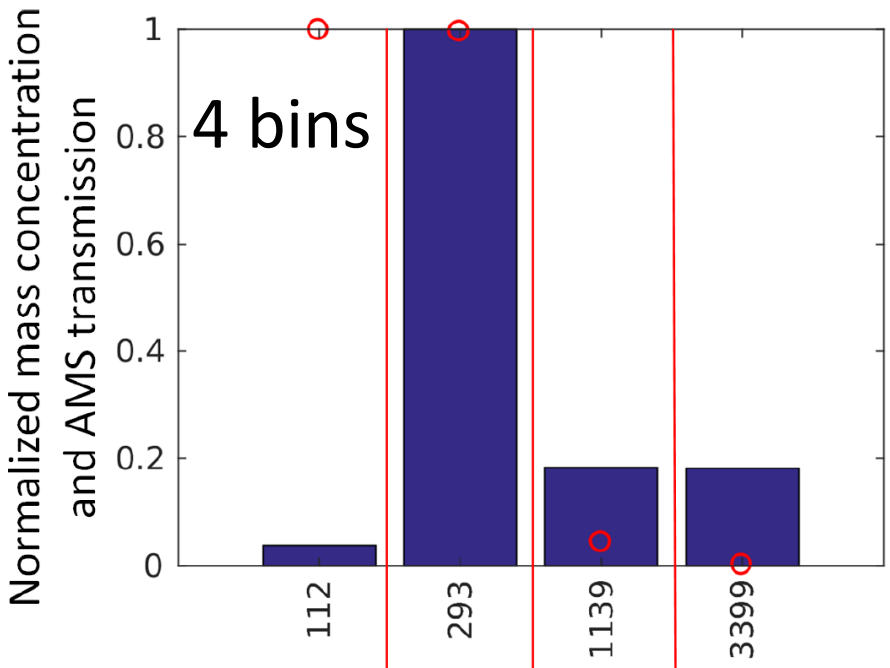
$$f(RH) = \frac{Scattering\ at\ 80\%\ RH}{Dry\ scattering\ (20\%\ RH)}$$

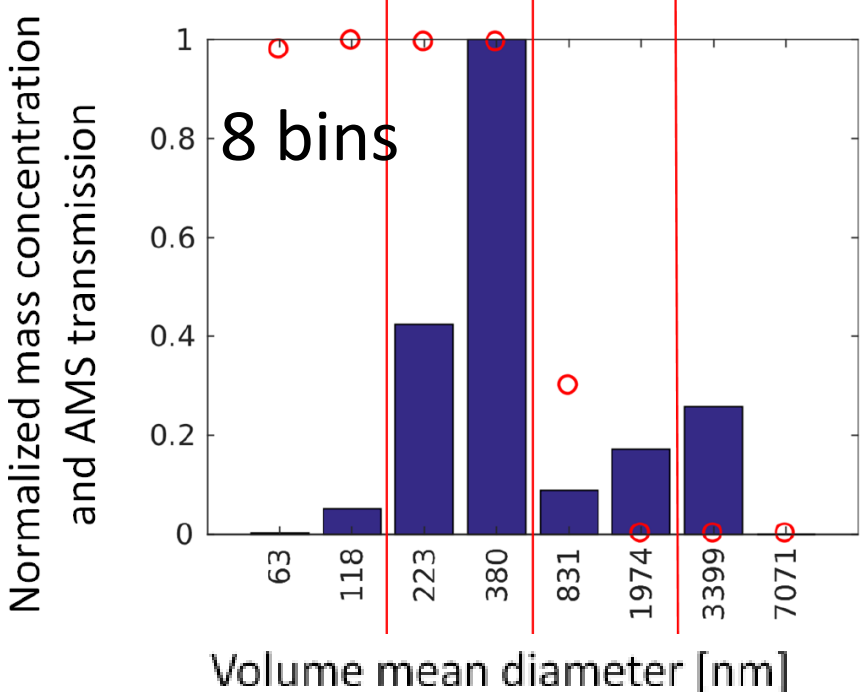
Saide et al., ACP 2020

Observed size distribution

- Forecast used 4 bins, more advanced configurations use 8
- Large heterogeneity within bins before aggregating







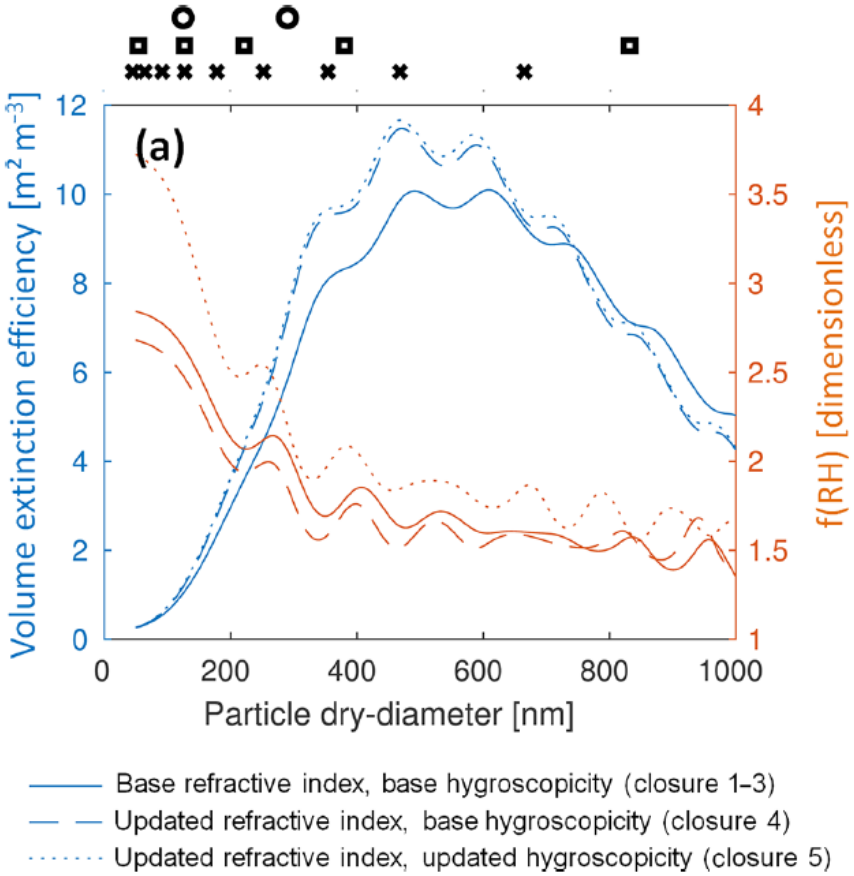
Saide et al., ACP 2020

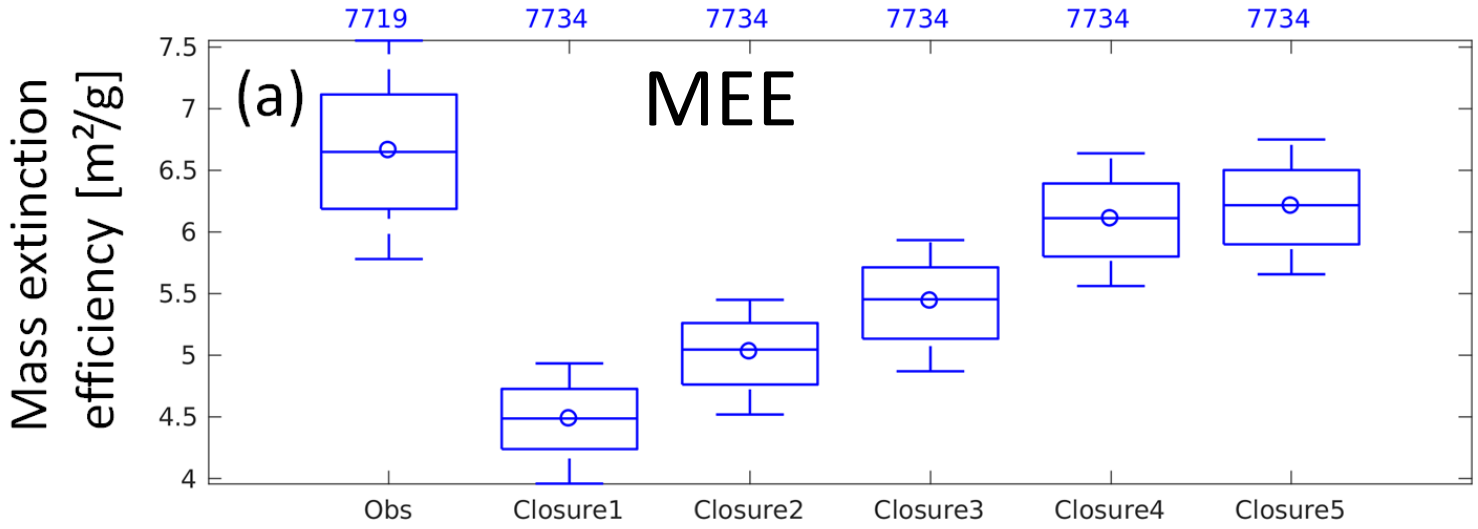
Closure study: MEE

Drive optical properties code with observed quantities (size distr. and chemical composition)

Name	# of size bins	Refractive index	Hygroscopicity
Closure1	4	Base	Base
Closure2	8	Base	Base
Closure3	16	Base	Base
Closure4	16	Updated	Base
Closure5	16	Updated	Updated

Saide et al., ACP 2020





Updated refractive index based on literature: Amonium-nitrate (1.5 to 1.55), Organic aerosol (1.45 to 1.55)

Closure study: f(RH)

Drive optical properties code with observed quantities (size distr. and chemical composition)

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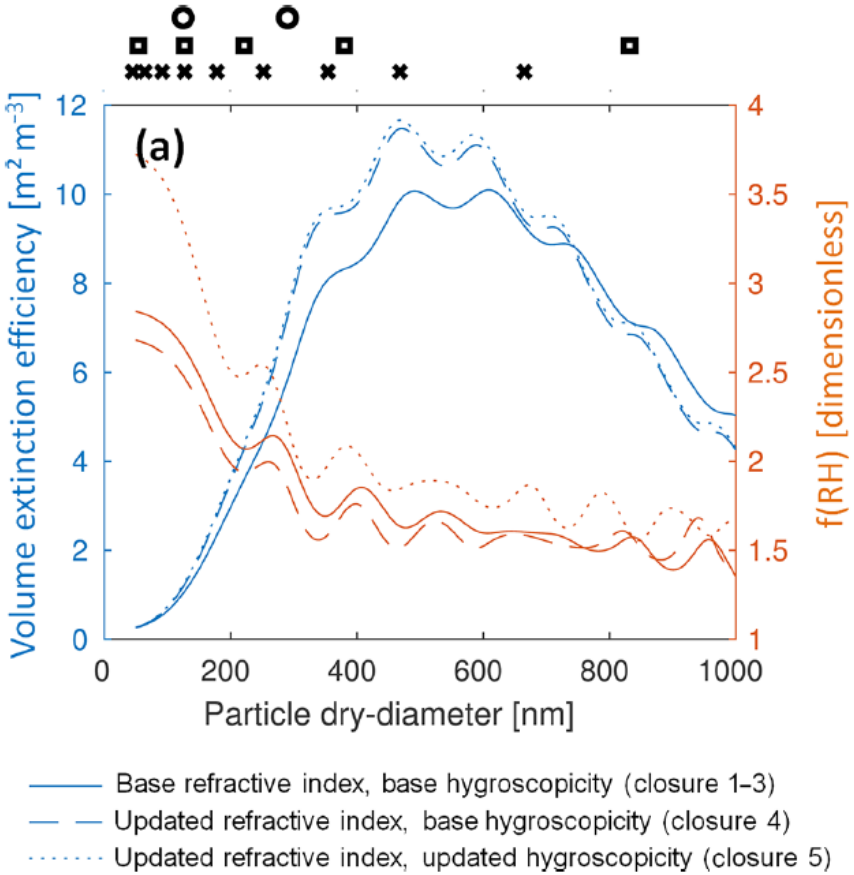
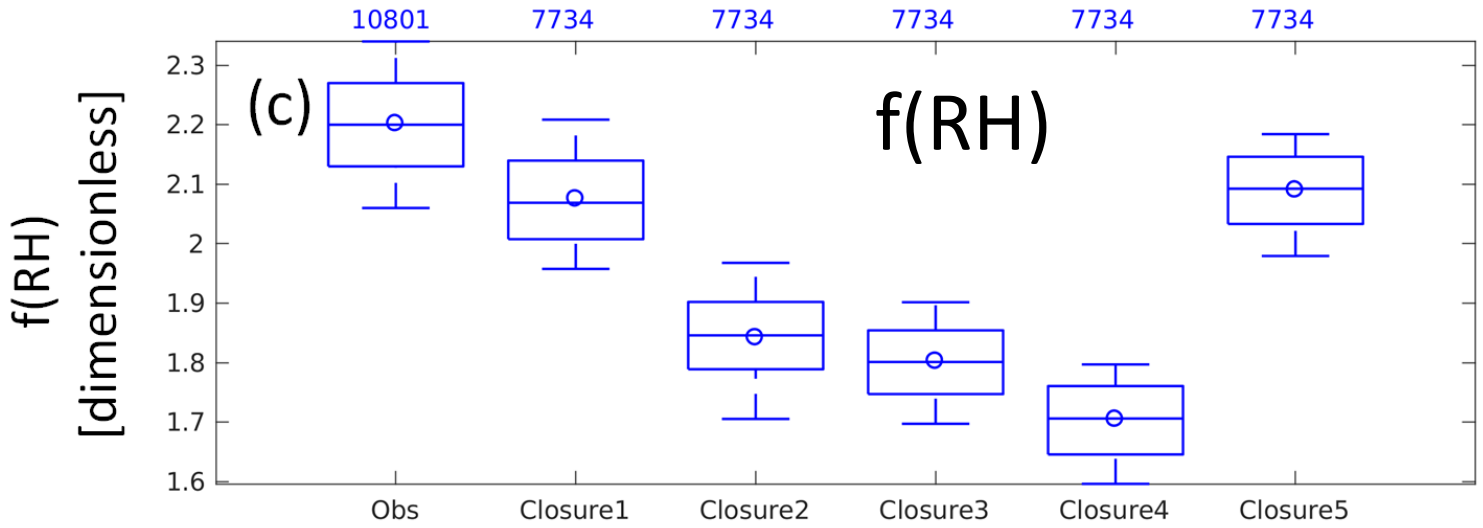
Saide et al., ACP 2020

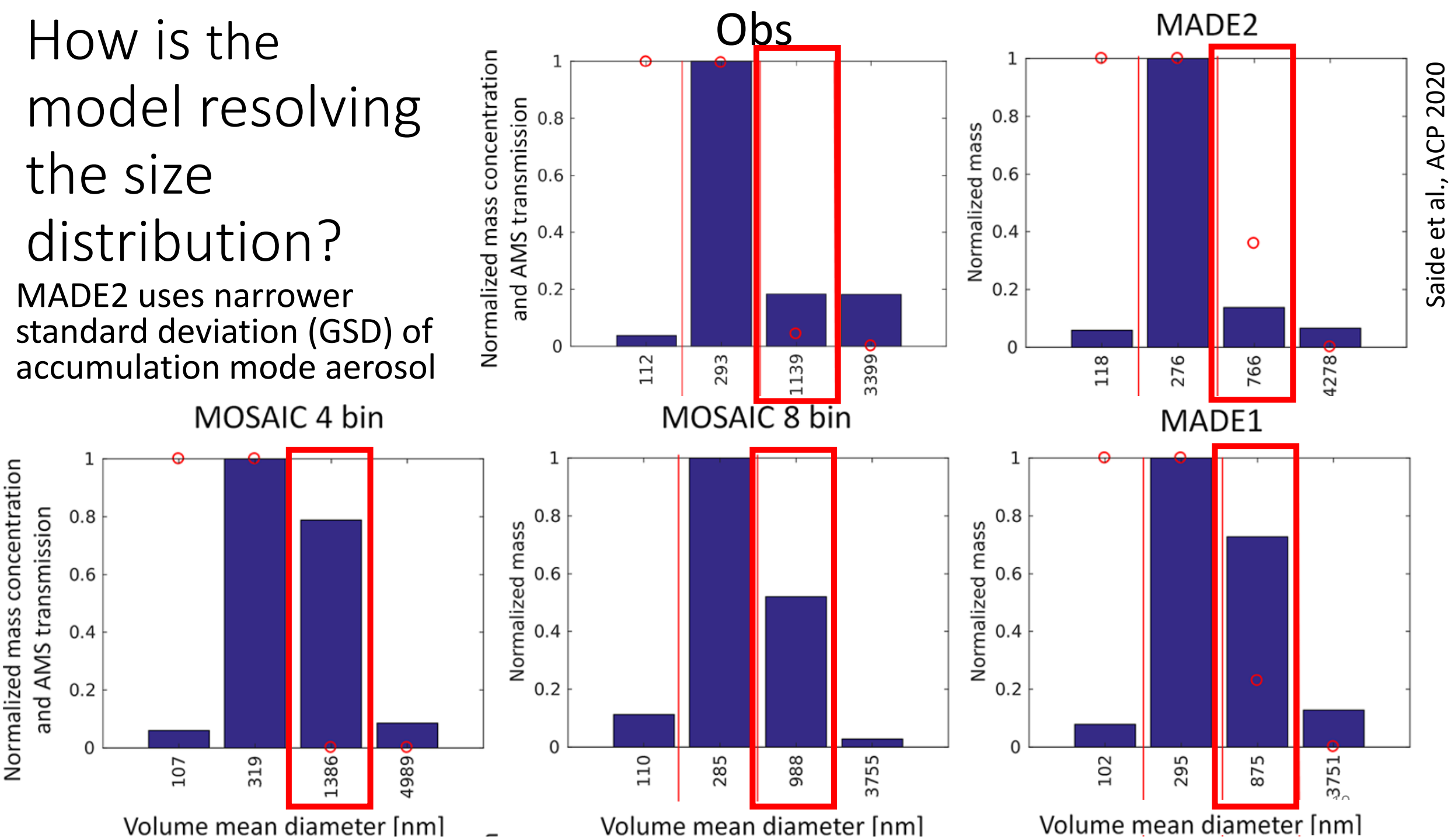




Updated hygroscopicity parameter based on literature: Ammonium-nitrate (0.5 to 0.67), Ammonium-sulfate (0.5 to 0.61) and organic aerosol and dust (0 to 0.14)

How is the model resolving the size distribution?

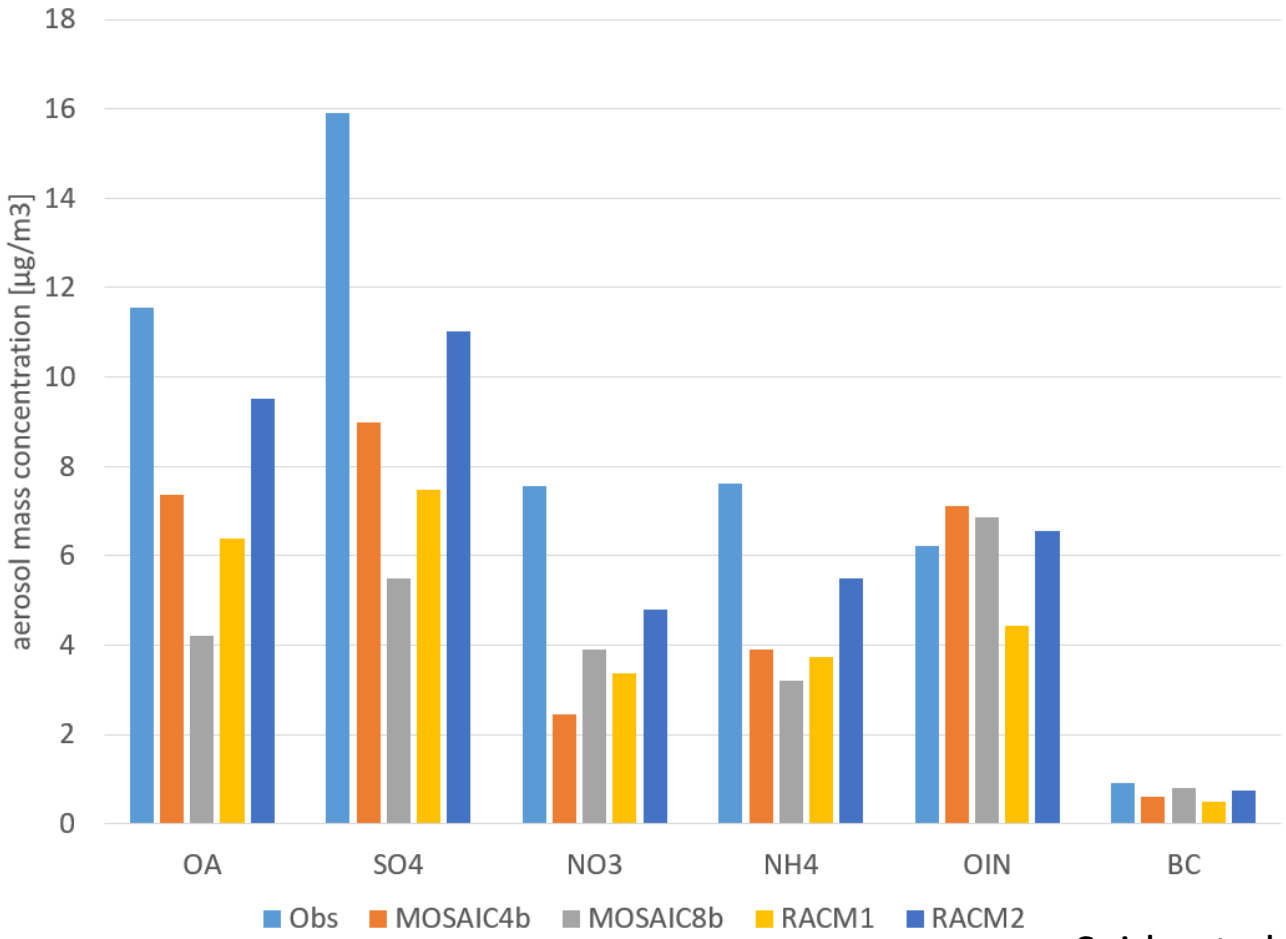
MADE2 uses narrower standard deviation (GSD) of accumulation mode aerosol

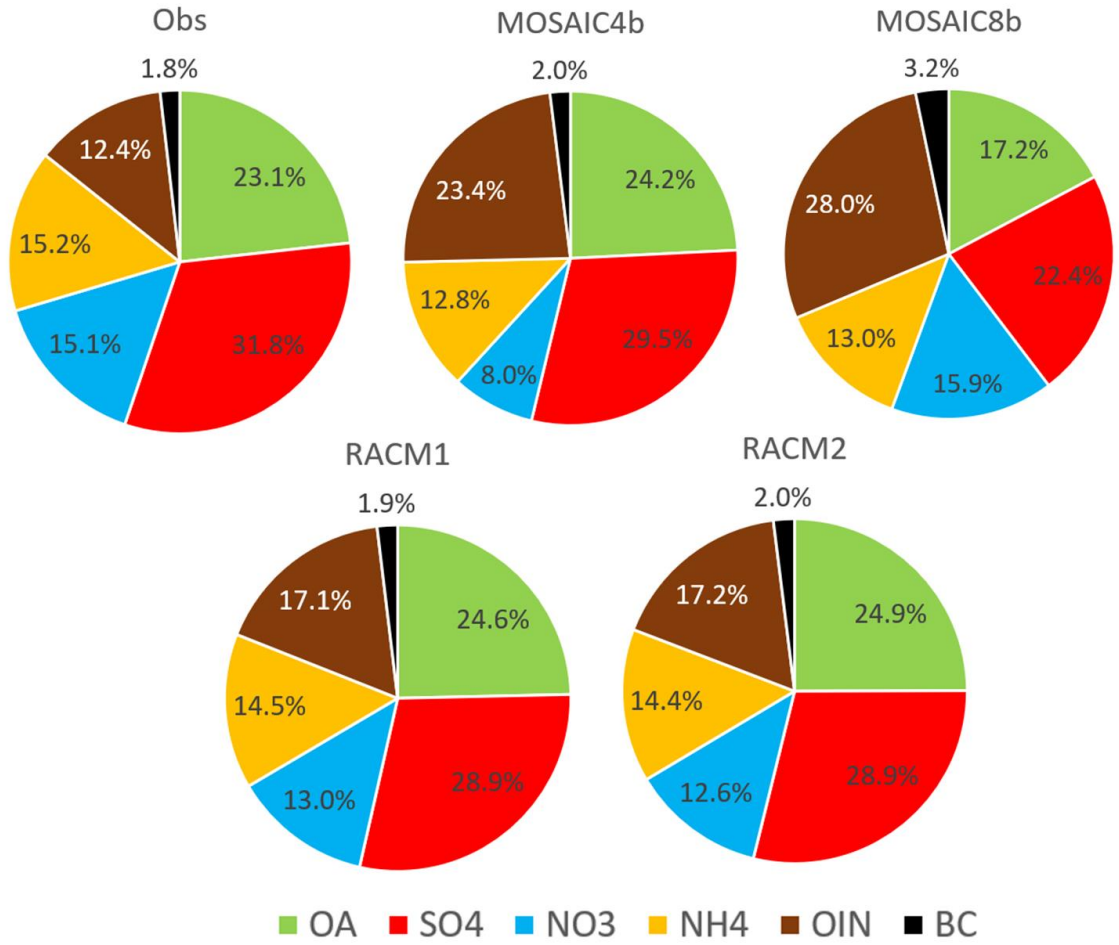


Saide et al., ACP 2020

How is the model resolving aerosol composition?

- Low concentrations of secondary aerosols
- Overpredict primary (less hygroscopic) fractions





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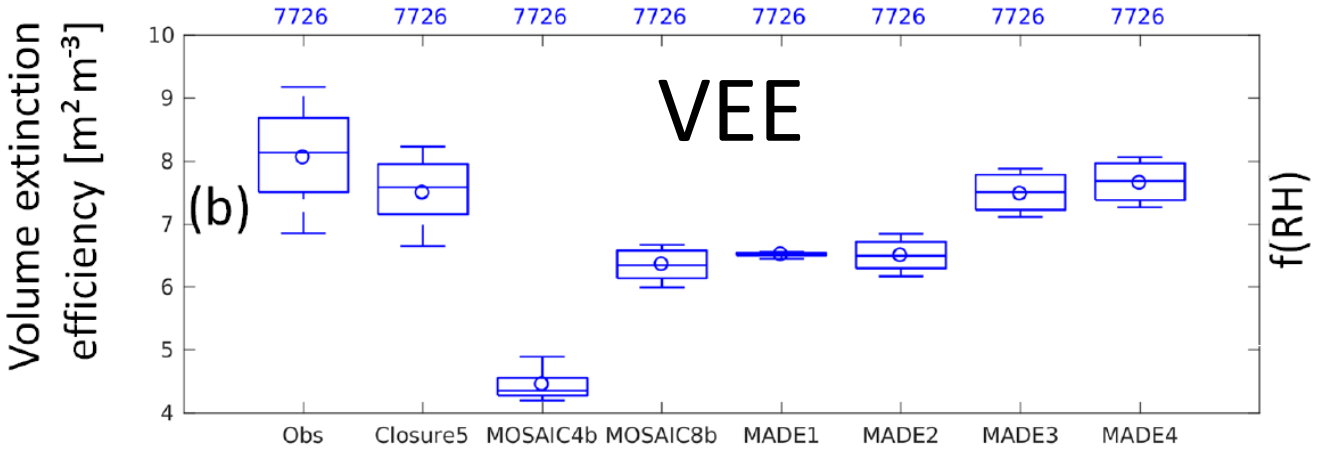
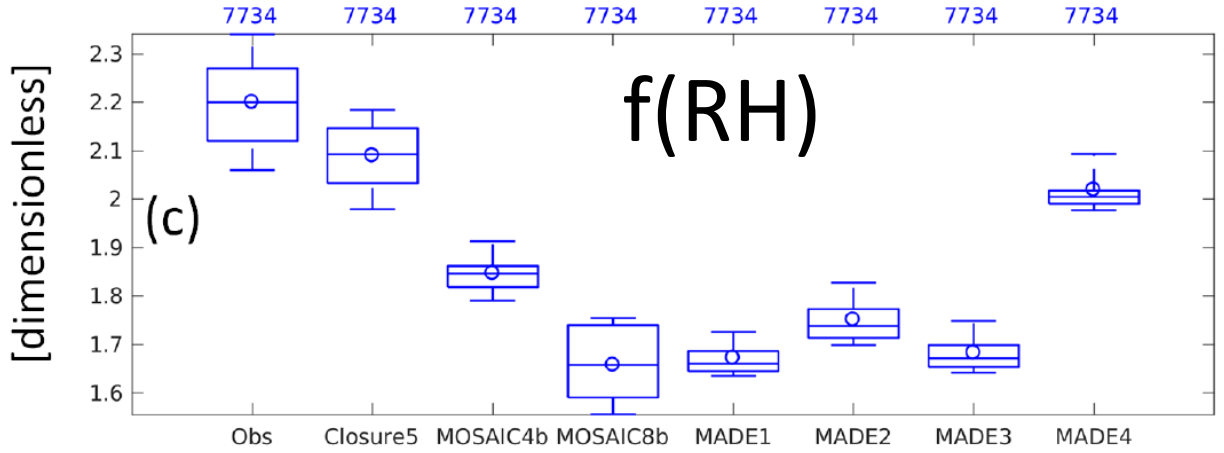
Testing WRF-Chem configurations

As in closure studies, agreement with observations can be obtained by refining bins, updating refractive indexes, and updated hygroscopicity

Name	Aerosol Scheme	Size bins used for OP	GSD of the modes	Refractive index	Hygroscopicity
MOSAIC4b	Sectional 4 bins	4 bins	-	Base	Base
MOSAIC8b	Sectional 8 bins	8 bins	-	Base	Base
MADE1	Modal	8 bins	Base	Base	Base
MADE2	Modal	8 bins	Updated	Base	Base
MADE3	Modal	8 bins	Updated	Updated	Base
MADE4	Modal	8 bins	Updated	Updated	Updated





Saide et al., ACP 2020

Conclusions

UCLA

- Multiple sources of model deficiency related to the calculation of optical properties explain discrepancies between AOD and PM2.5
- How to fix it?
  - Increase size bins resolution
  - Increase refractive indexes and hygroscopicity parameters
  - Improve secondary aerosol formation pathways
- **Implications** to as air quality forecasts, health-effect assessments, climate projections, solar-power forecasts

Thanks! Questions or comments?

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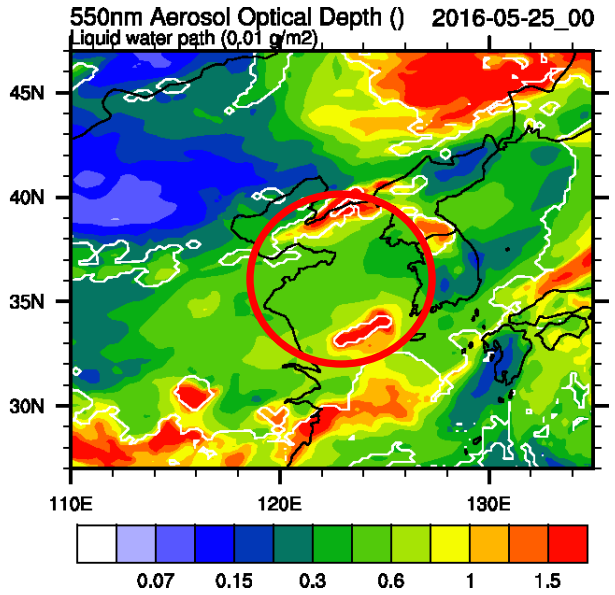
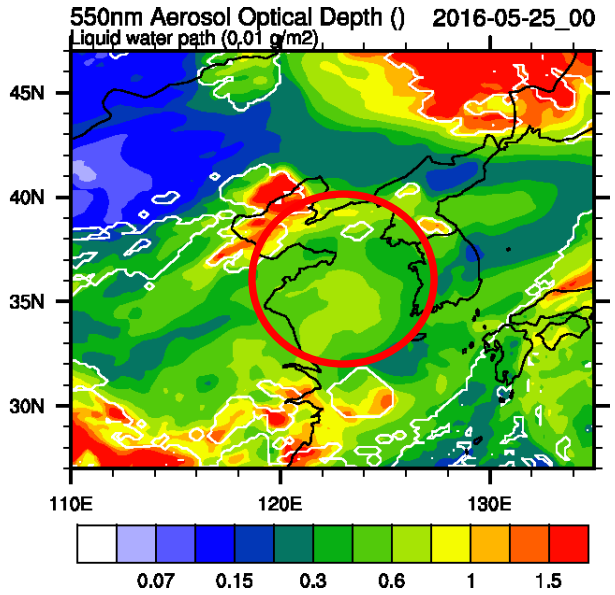
Supplemental slides

Example of AOD assimilation impact during KORUS-AQ (May 24th flight, Chinese haze over Yellow sea)

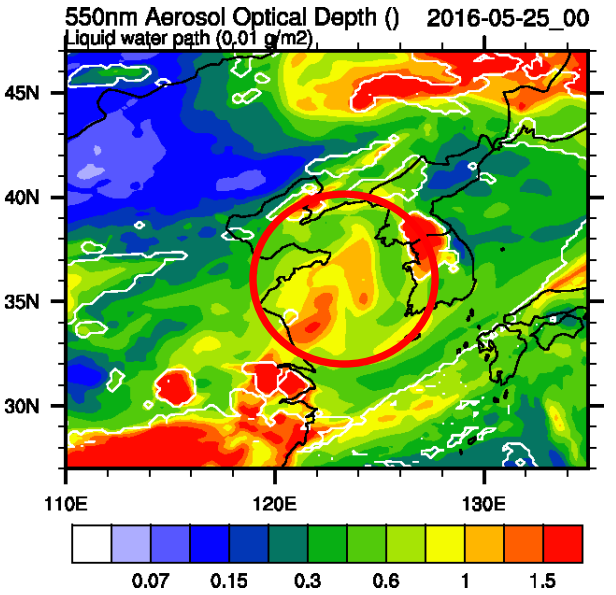
Day-3



Day-2

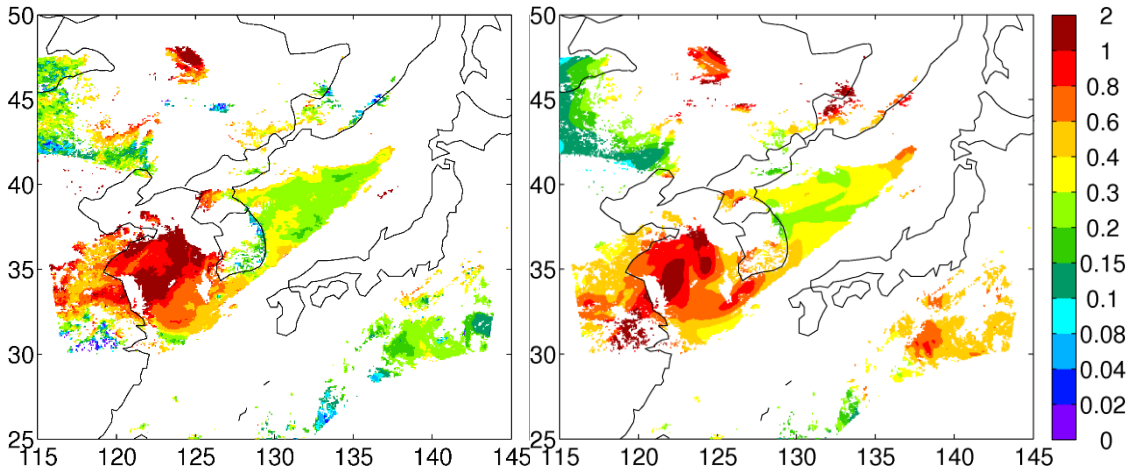


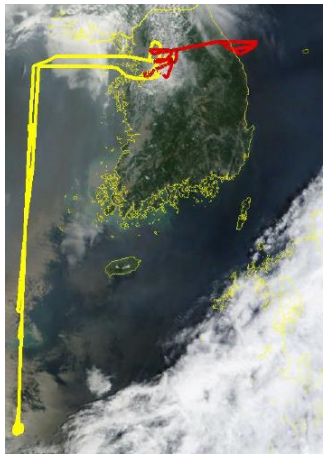
Day-1



Observed AOD (GOCI)

WRF-Chem Day-1





Saide et al., ACP 2020

Testing WRF-Chem configurations

Inconsistencies between MEE and VEE due to:

- Size distribution
- Speciation
- Organic aerosol density

Name	Aerosol Scheme	Size bins used for OP	GSD of the modes	Refractive index	Hygroscopicity
MOSAIC4b	Sectional 4 bins	4 bins	-	Base	Base
MOSAIC8b	Sectional 8 bins	8 bins	-	Base	Base
RACM1	Modal	8 bins	Base	Base	Base
RACM2	Modal	8 bins	Updated	Base	Base
RACM3	Modal	8 bins	Updated	Updated	Base
RACM4	Modal	8 bins	Updated	Updated	Updated