Explicit Aerosols corrections in Tropospheric NO_2 retrieval of OMI and Tropomi by using GEOS-Chem and satellite observations

Mengyao Liu, PKU ACM Group

in collaboration with

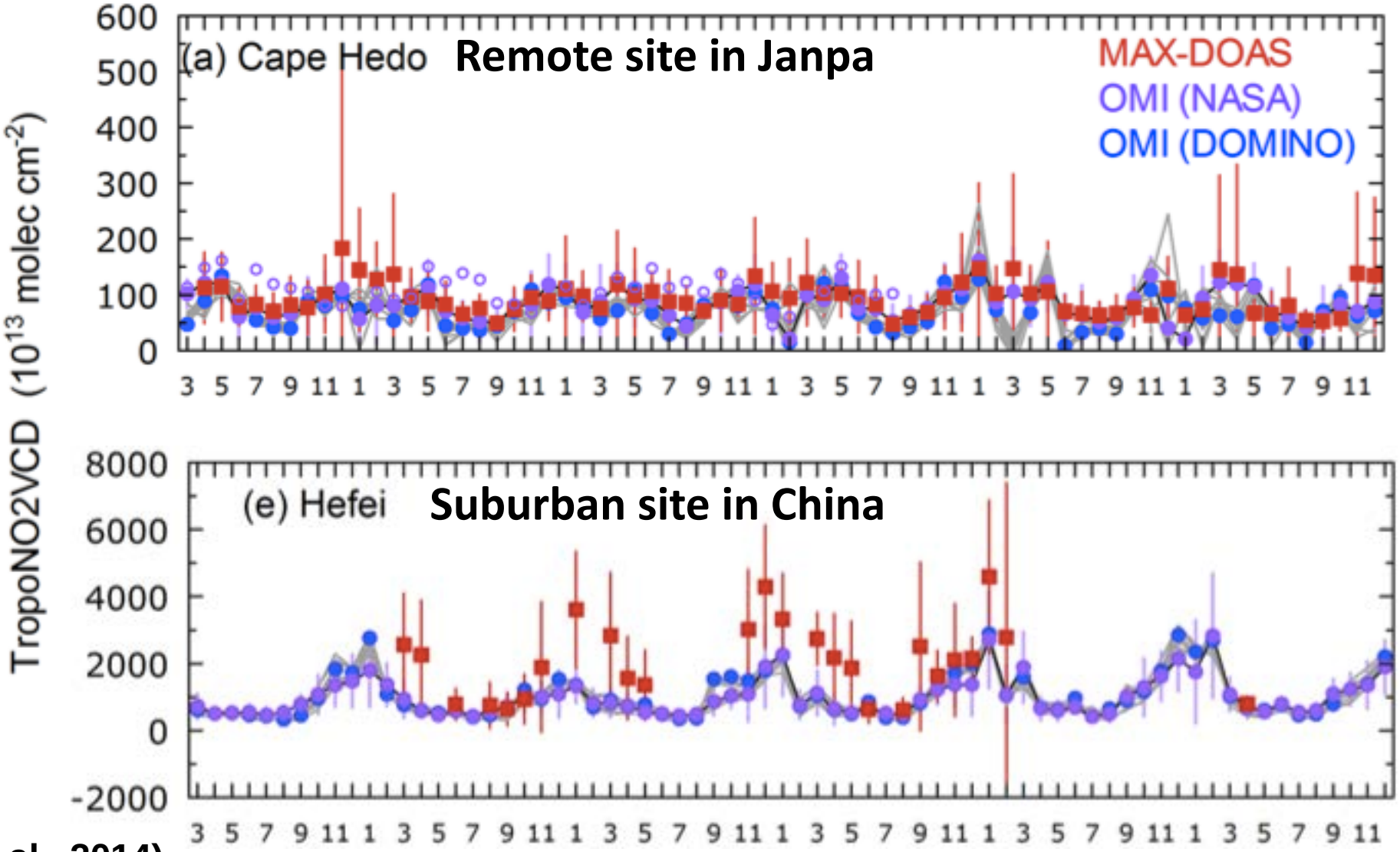
J.-T. Lin, K.F. Boersma, , H. Eskes G. Pinardi, Y. Wang, J. Chimot

Supported by NSFC, 973 program and FP7 QA4ECV project

Koninklijk Nederlands Meteorologisch Instituut
Ministerie van Infrastructuur en Milieu

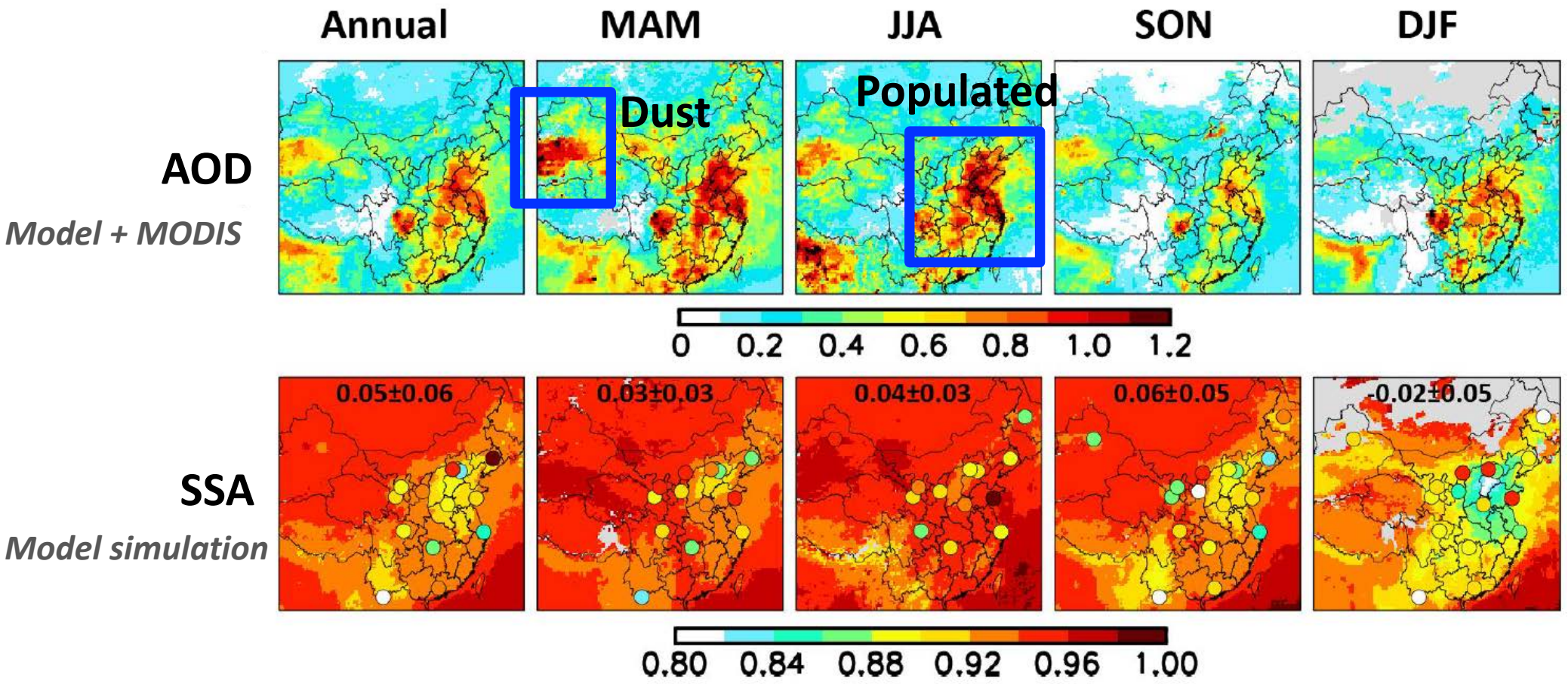
Satellite NO_2 VCD Have Bias in Aerosol-Polluted Areas

MAX-DOAS .vs. OMI NO_2 (2007–2012)



(Kanaya et al., 2014)

Aerosol Treatment is Critical over China



Characteristics of Chinese aerosols:

- Large amounts in key areas
- Highly absorbing in many areas
- Considerable spatiotemporal variability

(Lin and Liu et al., 2015, ACP)

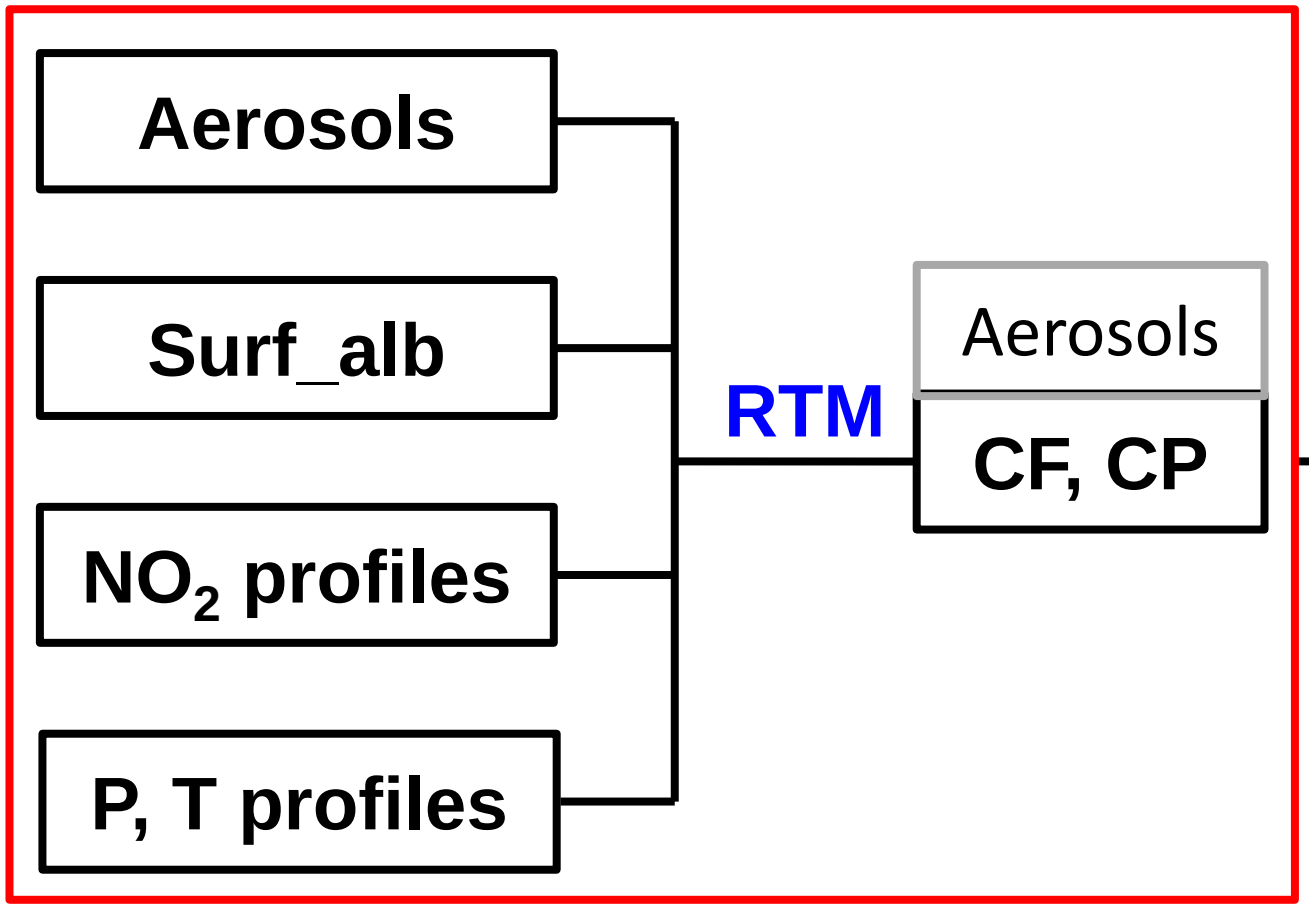
Retrieving Tropospheric NO_2 Vertical Column Density

Step 1: SCD from DOAS calc.

Step 2: Tropospheric and stratospheric SCD

Step 3: Tropospheric AMF – *error pool*

- SCD = F(radiance)
- SCD_T = SCD – SCD_S
- VCD_T = SCD_T / AMF



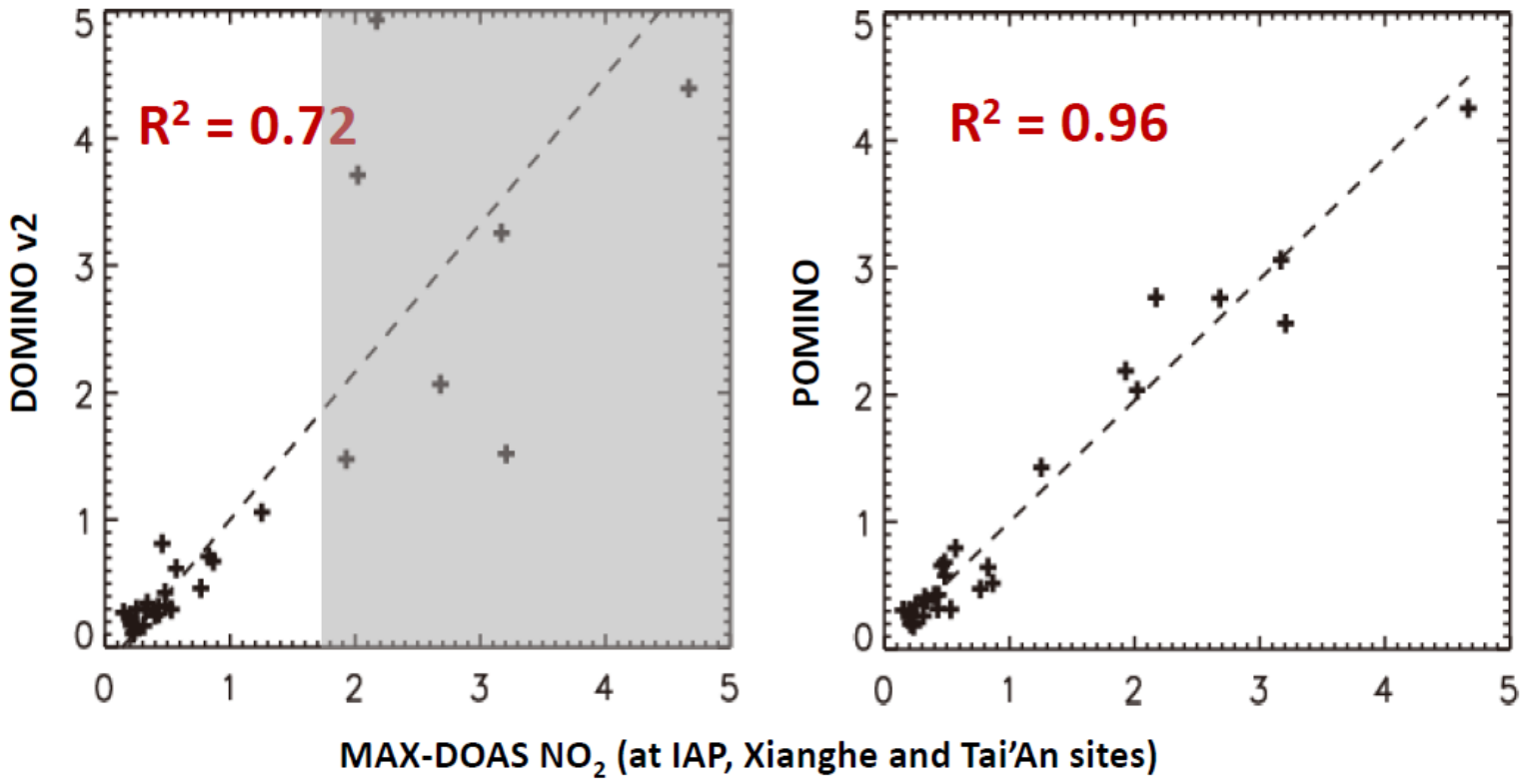
** " effective cloud" is Lambert reflector with albedo 0.8. cloud base starts from the ground。Effective Cloud fraction（CF）and effective cloud pressure（CP）are used to parameterize the cloud.

$$AMF = AMFcl \cdot CRF + AMFcr \cdot (1 - CRF)$$

Cloudy-sky Clear-sky

POMINO Better Captures NO_2 Day-to-day Variability

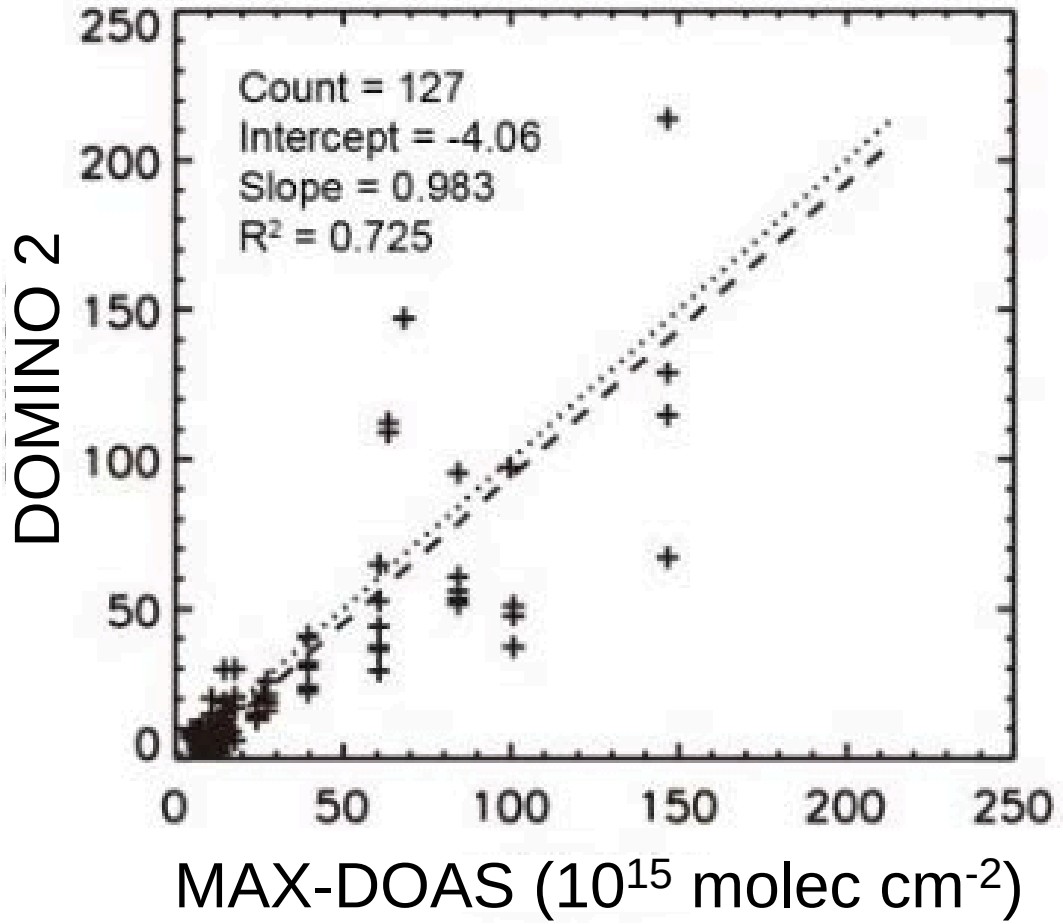
Evaluation of OMI NO_2 data using MAX-DOAS NO_2
(daily data; multiple years and seasons; data normalized to mean)

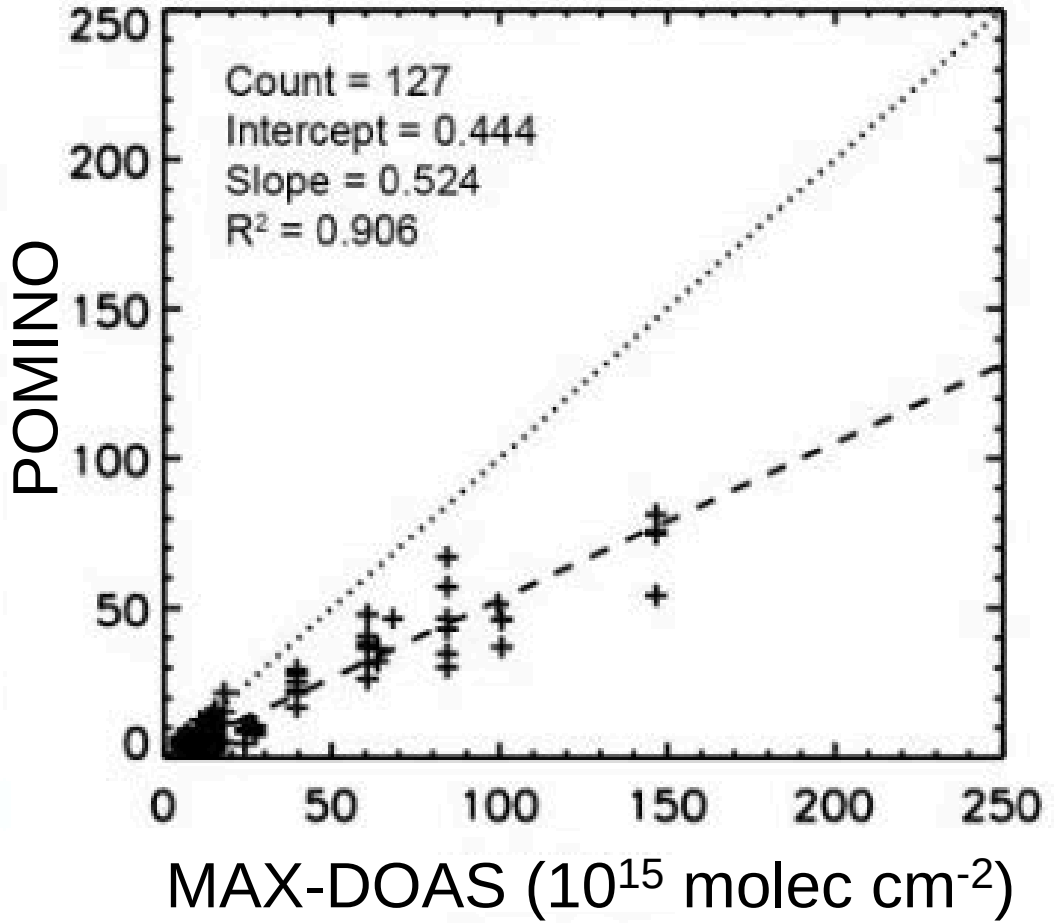


Lin et al., 2014 ACP

POMINO Underestimates MAX-DOAS

[At least 60% of underestimate is due to sampling difference]

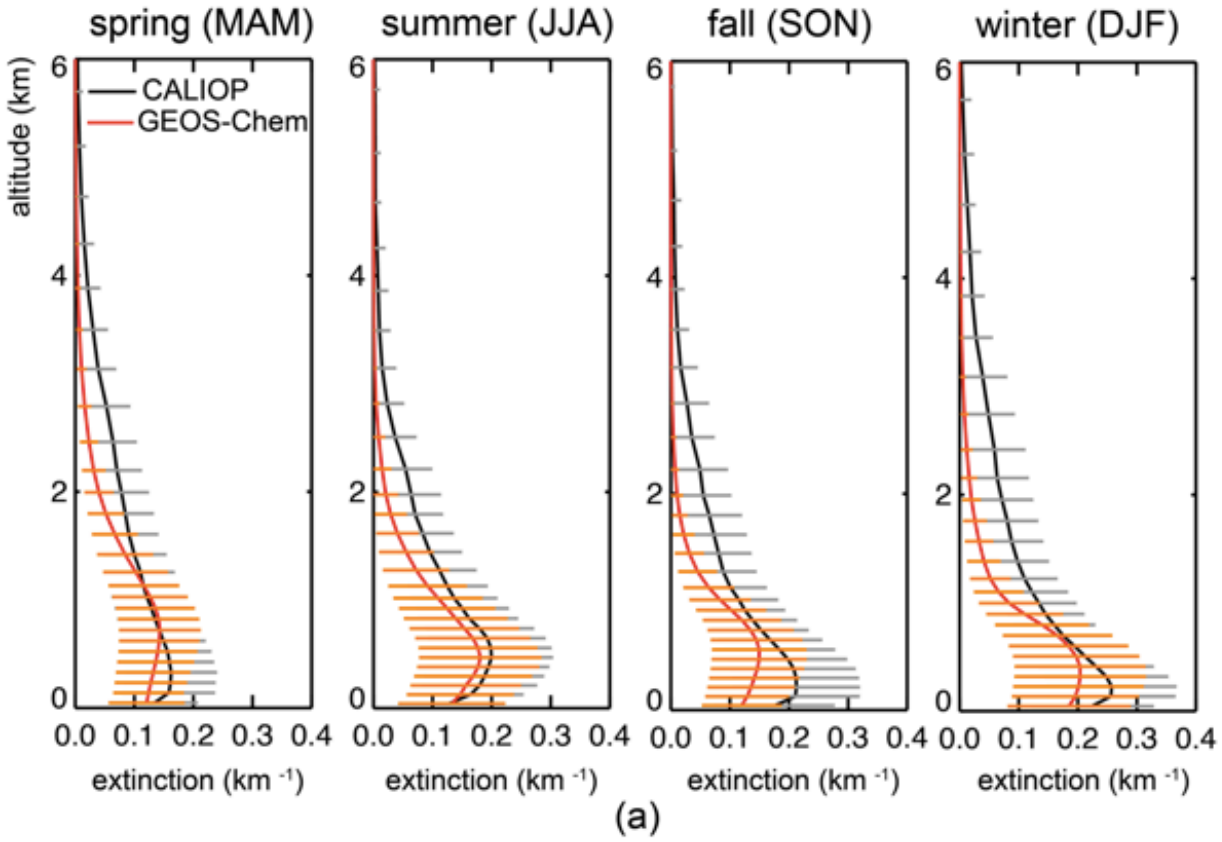




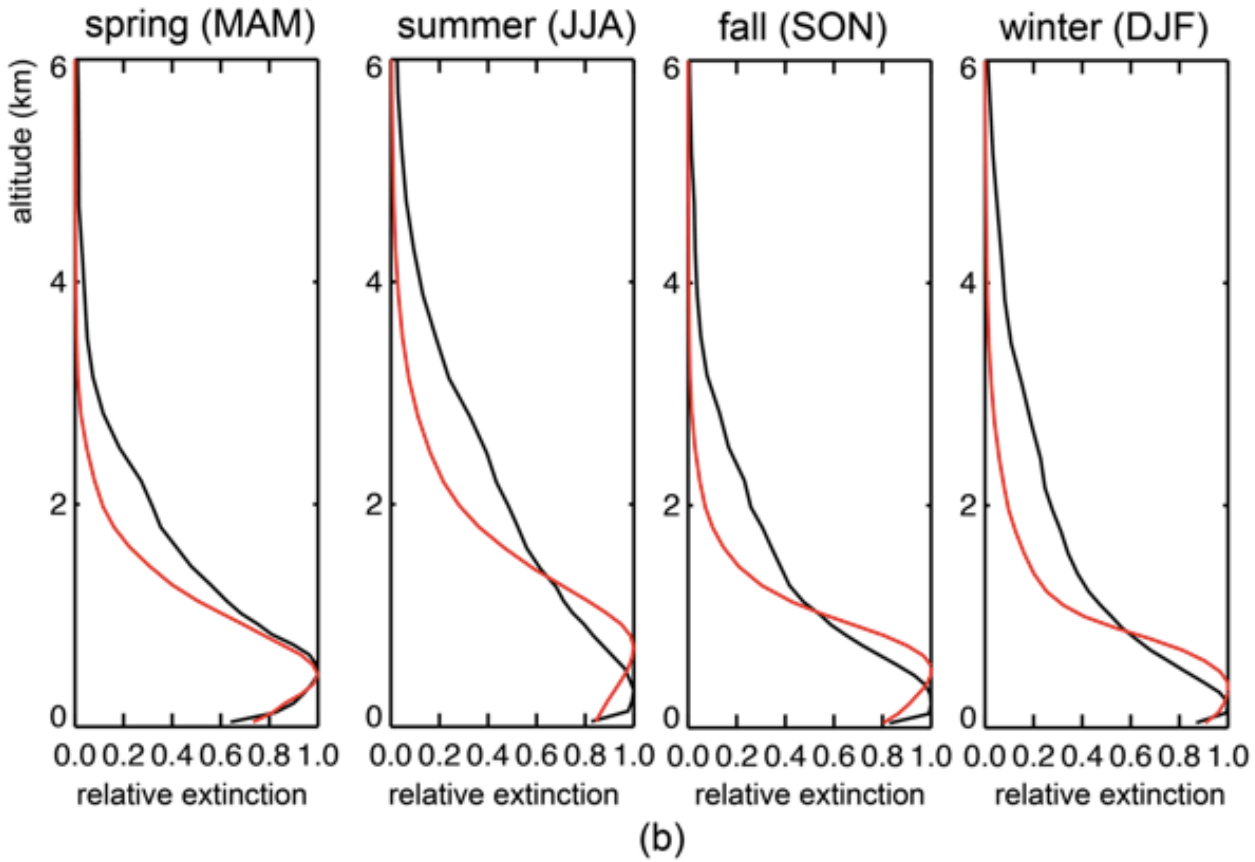
Lin et al., 2014 ACP

Negative (Positive) Bias in Aerosol Extinction Gradient Below (Above) 0.6 km

Absolute aerosol extinction profile over NEC



Aerosol extinction profile normalized by maxima of the profile



(Liu et al., AMTD, 2018)

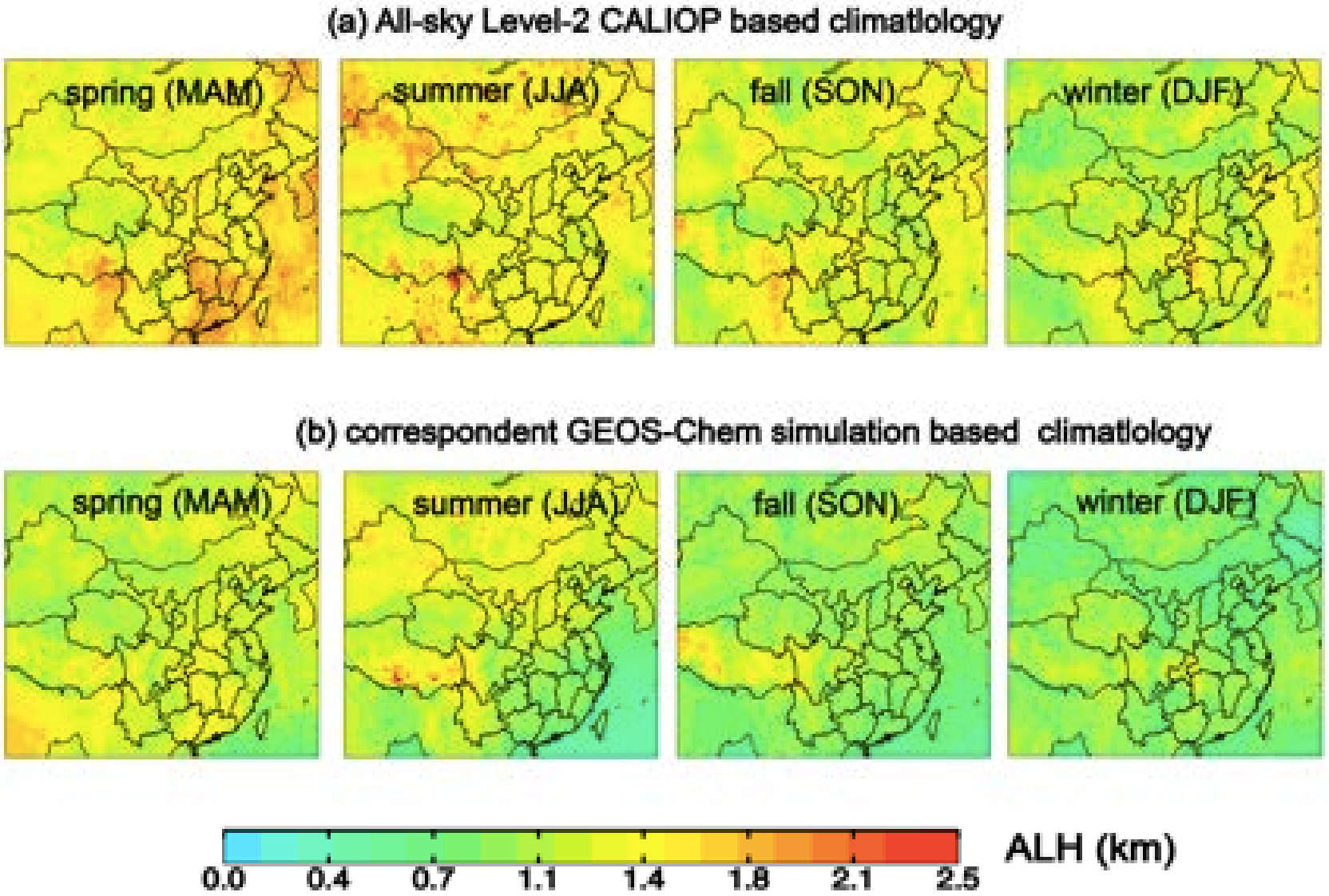
Model Captures Spatiotemporal Variation in Aerosol Layer Height

$$\mathrm{ALH} = \frac{\sum h(l)\sigma(l)}{\sum \sigma(l)}$$

$h(l)$-height above the ground
$\sigma(l)$-extinction of layer l

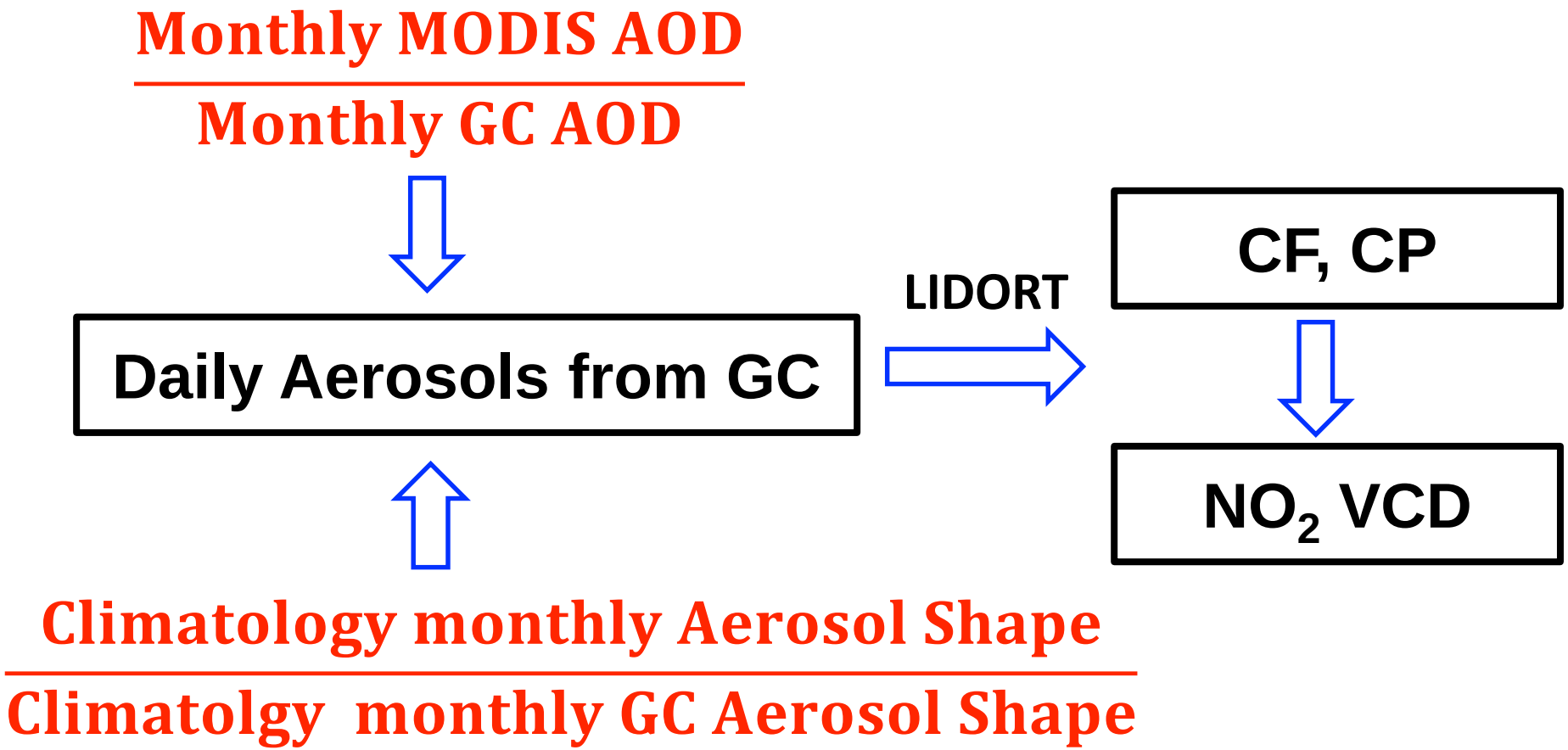
Horizontal res.:
0.5° lat. X 0.667 ° lon.

Vertical res:
36 layers in troposphere



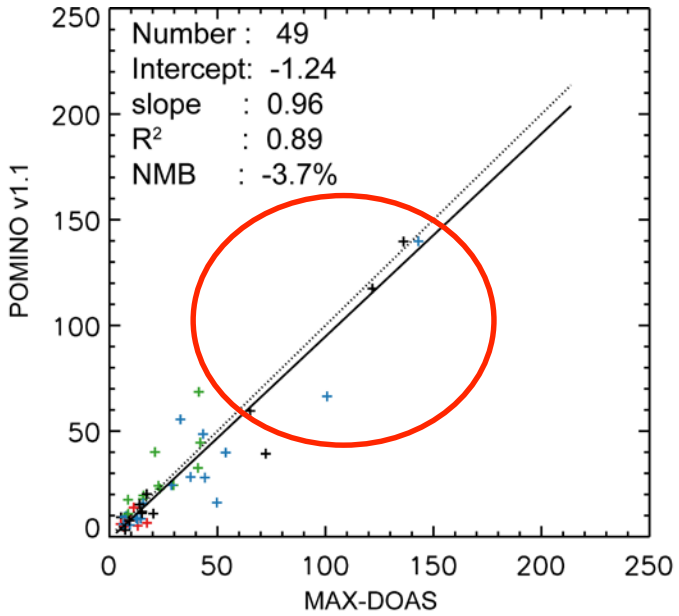
(Liu et al., AMTD, 2018)

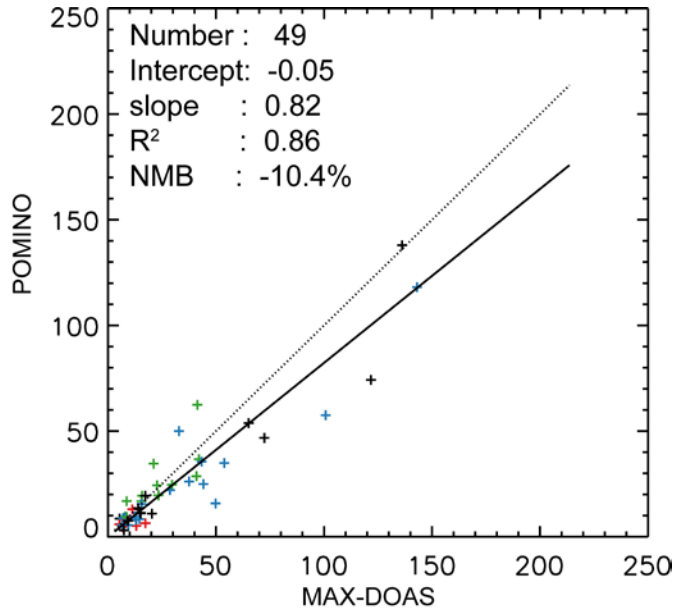
Use CALIOP Monthly Climatology (2007–2015) to Constrain Model



POMINO v1.1 improves NO_2 day-to-day variations

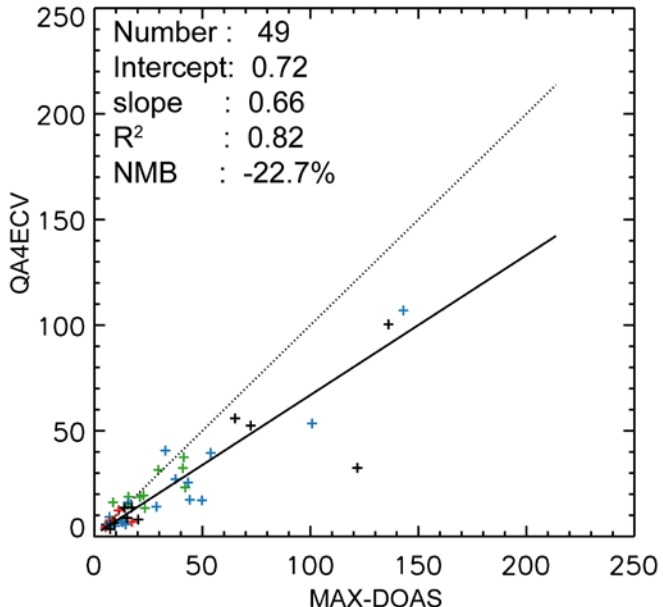
POMINO v1.1

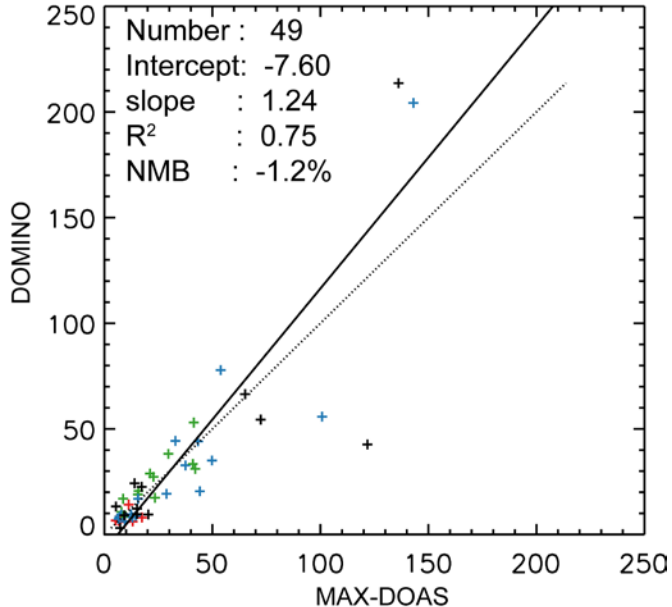




POMINO

QA4ECV





DOMINO v2

POMINO v1.1 performance better in Haze Days

OMI retrievals versus MAX-DOAS on haze days (27 samples)

Product	POMINO v1.1	POMINO	DOMINO	QA4ECV
slope	1.07	0.80	1.11	0.58
intercept	-3.58	1.76	-11.79	3.20
R^2	0.76	0.68	0.38	0.34
NMB (%)	4.4	-9.4	-5.0	-26.11

**haze day ---- selected by checking ground metrological weather records and corrected reflectance of MODIS/Aqua

OMI retrievals versus MAX-DOAS on clear-sky days (36 samples)

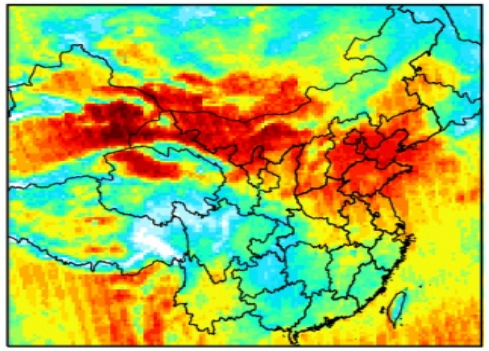
Product	POMINO v1.1	POMINO	DOMINO	QA4ECV
slope	1.29	1.13	0.92	0.79
intercept	-0.61	0.31	2.32	1.05
R^2	0.56	0.53	0.53	0.63
NMB (%)	20.76	20.40	21.91	-5.83

(Liu et al., AMTD, 2018)

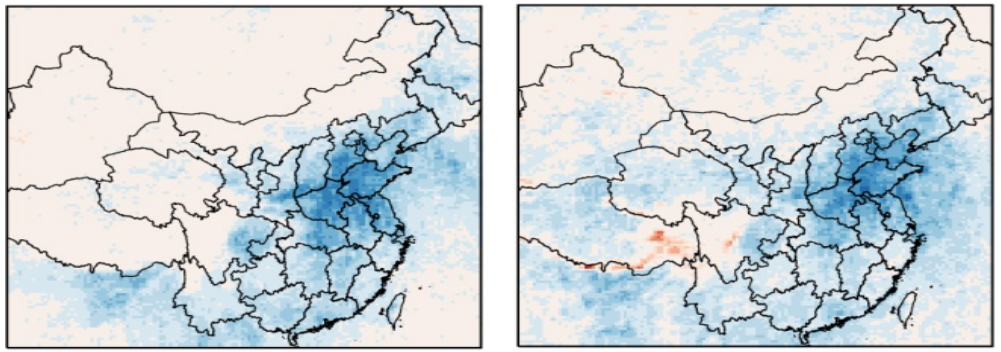
Open question: Explicit Aerosol Treatment Reduces Sampling Low Bias?

Valid pixels:
CRF ≤ 50%

Days per month w/ valid data in POMINO



noAER – POMINO **DOMINO – POMINO**

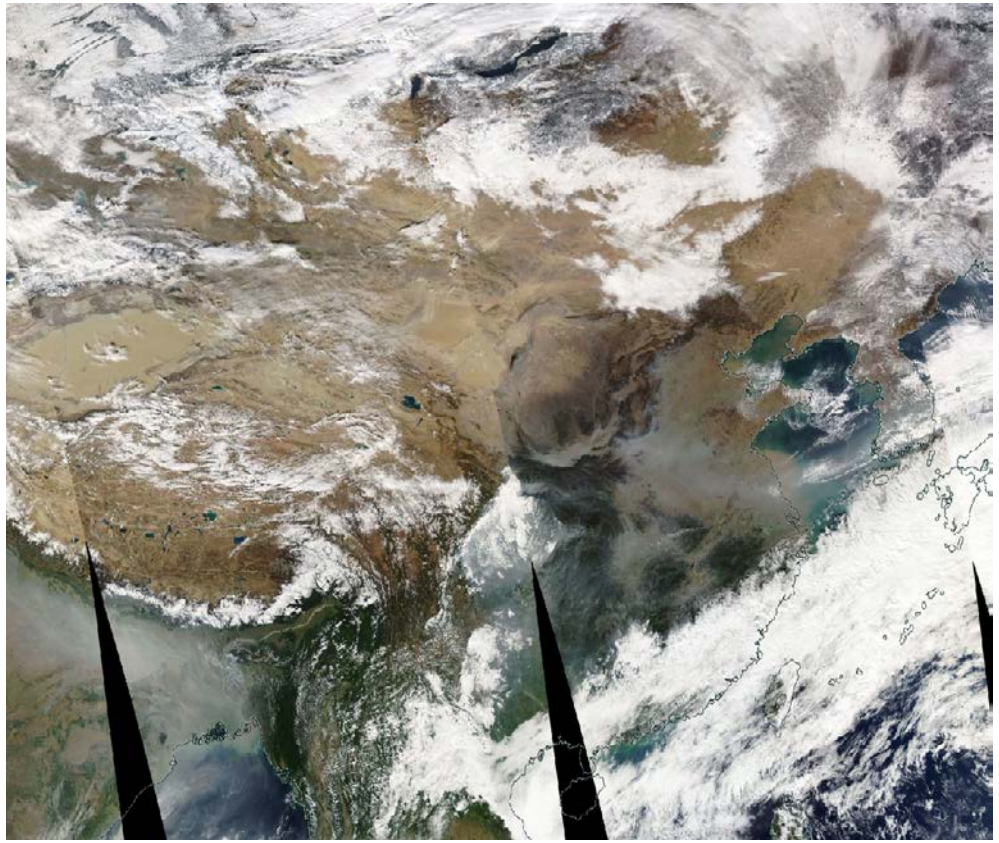


- **An explicit treatment better accounts for high-pollution days**

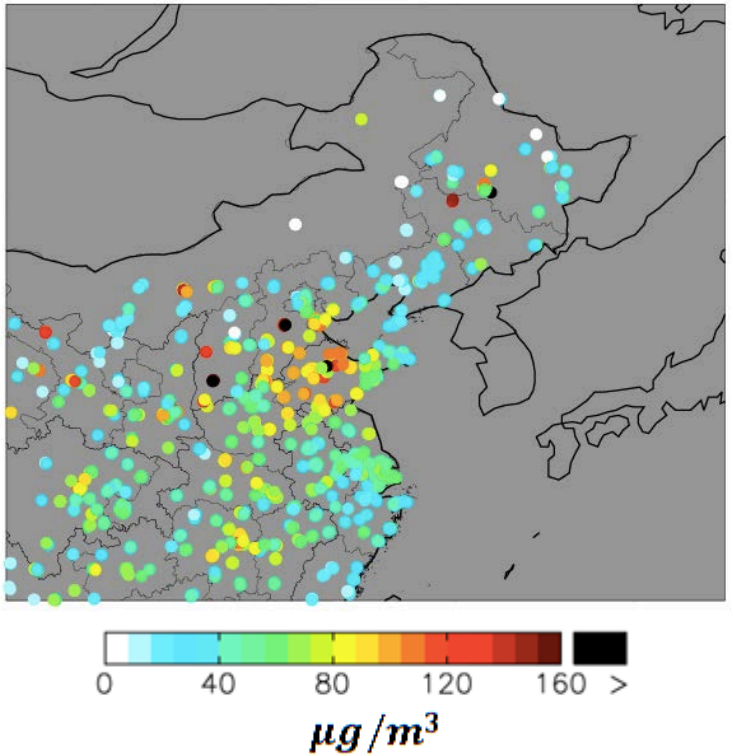
Lin and Liu et al., 2015, ACP

Case study: Influence of aerosols on Tropomi NO_2 VCD

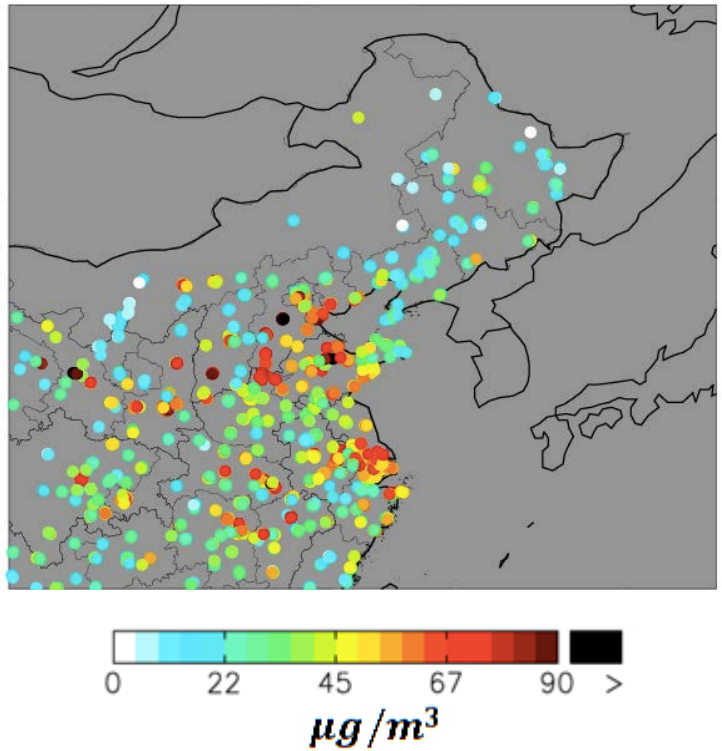
25th Nov 2017 clear & NOT clean



25/11 2017 $PM_{2.5}$

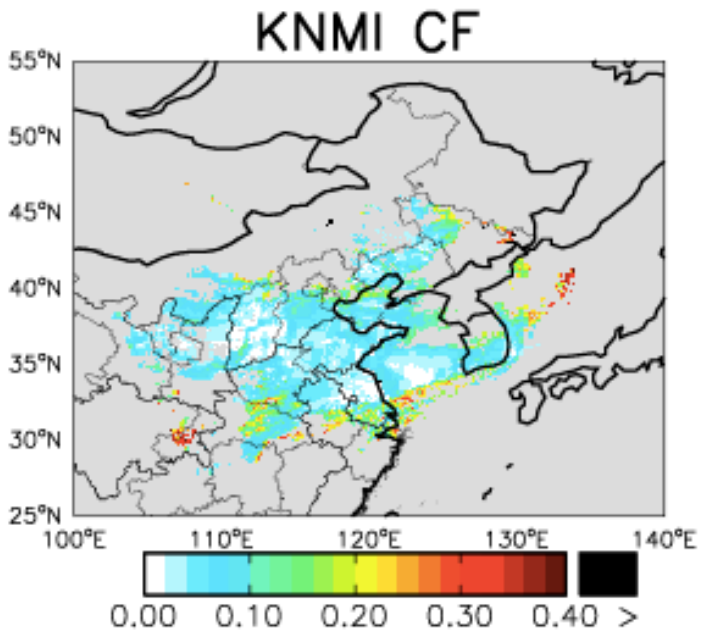


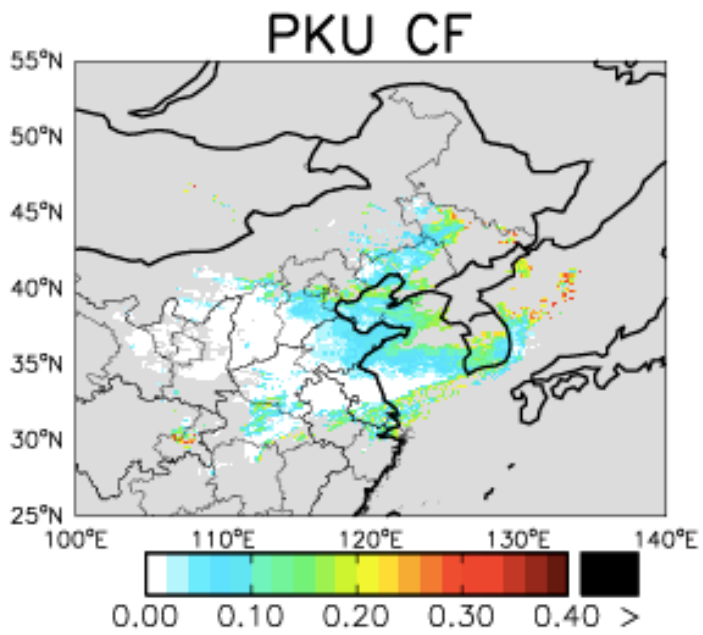
25/11 2017 NO_2

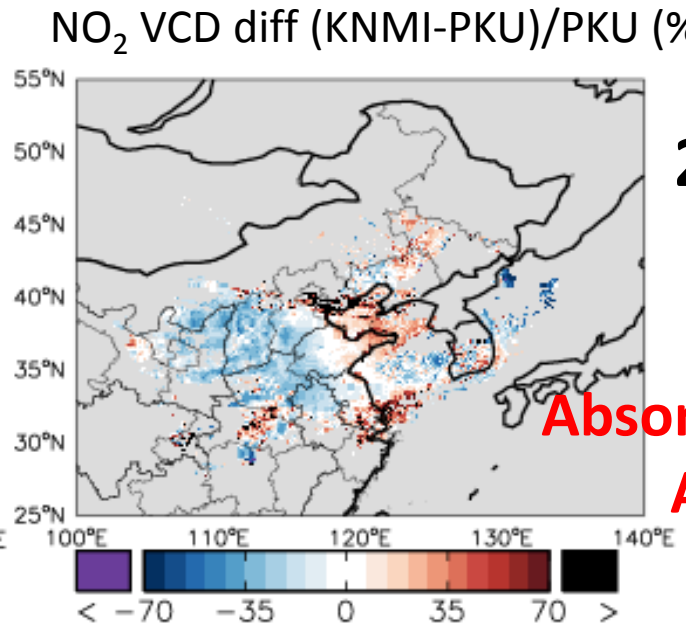


MODIS RGB

Neglect Absorbing Aerosols decrease NO_2 VCD

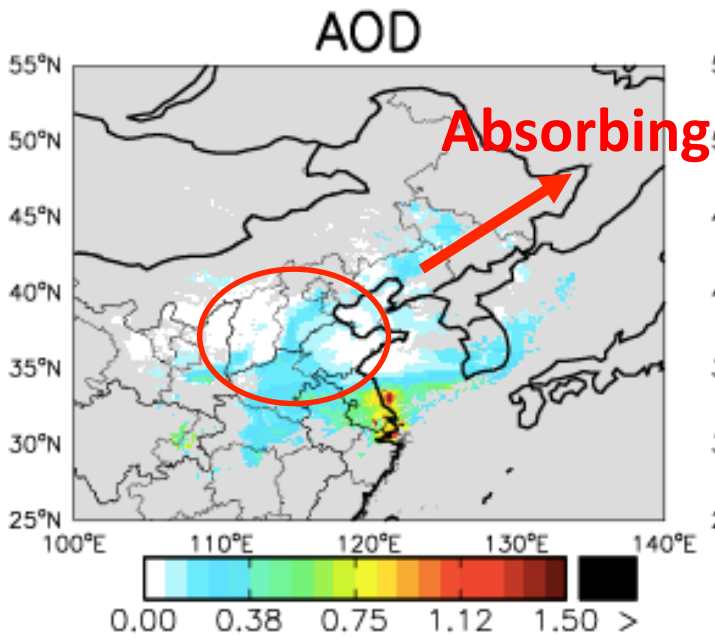


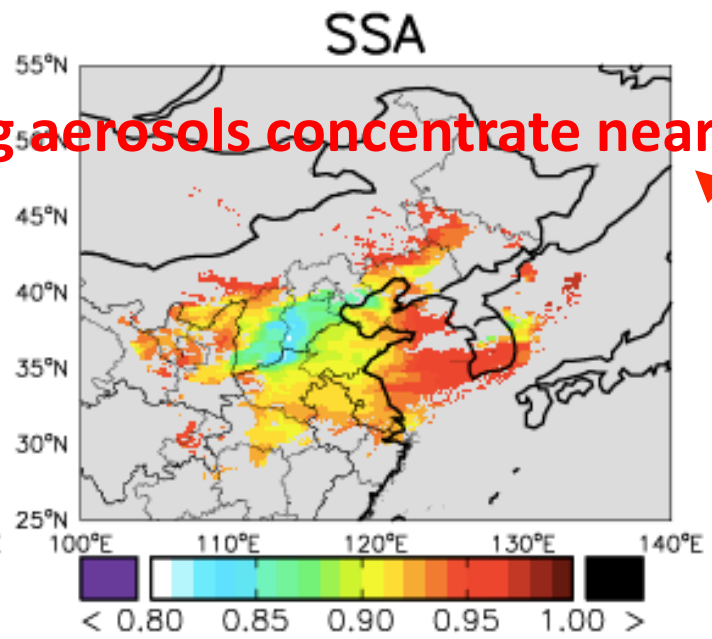




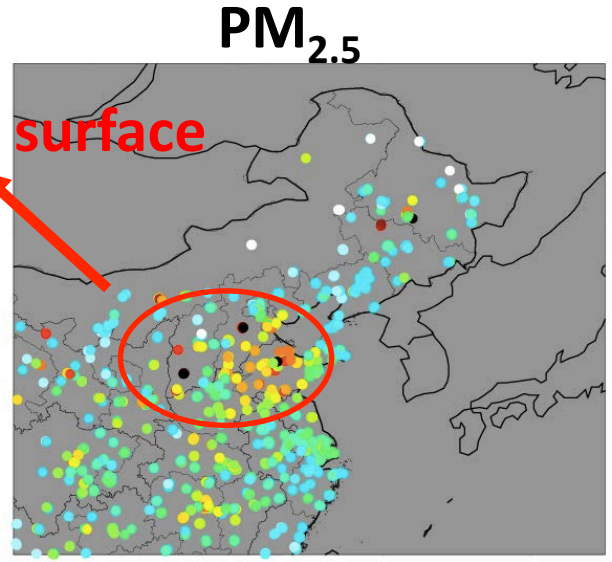
25/11 2017

Absorbing aerosols: AMF↓ VCD↑





Absorbing aerosols concentrate near surface



Summary

- Including daily aerosol information better captures day-to-day variation of NO_2 VCD, and decrease mean bias
- Explicit aerosol treatment provide a way to increases the number of valid days, reducing sampling bias, especially for high-res retrieval

You can get our NO_2 product from:

1, KNMI TEMIS official product website:
http://www.temis.nl/airpollution/no2.html

2, Our ACM group homepage:
http://www.phy.pku.edu.cn/~acm/acmProduct.php