New capability of Aerosols/Chemical DA for WRF-Chem

Wei Sun Zhiquan Liu

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National Center for Atmospheric Research
Boulder, CO

Chemical/Aerosol DA – Outline

- Background
- PM2.5 assimilation with GOCART scheme
- Chemical/Aerosol assimilation with MOSAIC scheme
- Conclusions and future works

Background

- To implement chemical assimilation in WRFDA
- To develop a flexible chemical assimilation system that can easily switch between different aerosol schemes
- To improve the forecast of PM2.5/PM10 and other gaseous pollutants.

Major modifications

- BE statistics and I/O for chemical species in GENBE2.0
- I/O of for chemical species in WRFDA
- add analysis variable
- obs I/O and operator
- diagnostics output

Chemical/Aerosol DA – Outline

- Background
- PM2.5 assimilation with GOCART scheme
- Chemical/Aerosol assimilation with MOSAIC scheme
- Conclusions

PM2.5 DA with GOCART

- WRFDA 4.0.3 3DVar
- PM2.5 Assimilation
- GENBE_2.0
  - analysis variable (univariate):

    p25, bc1, bc2, oc1, oc2, dust1, dust2, seas1, seas2, sulf
- GOCART Scheme
  - observation operator:

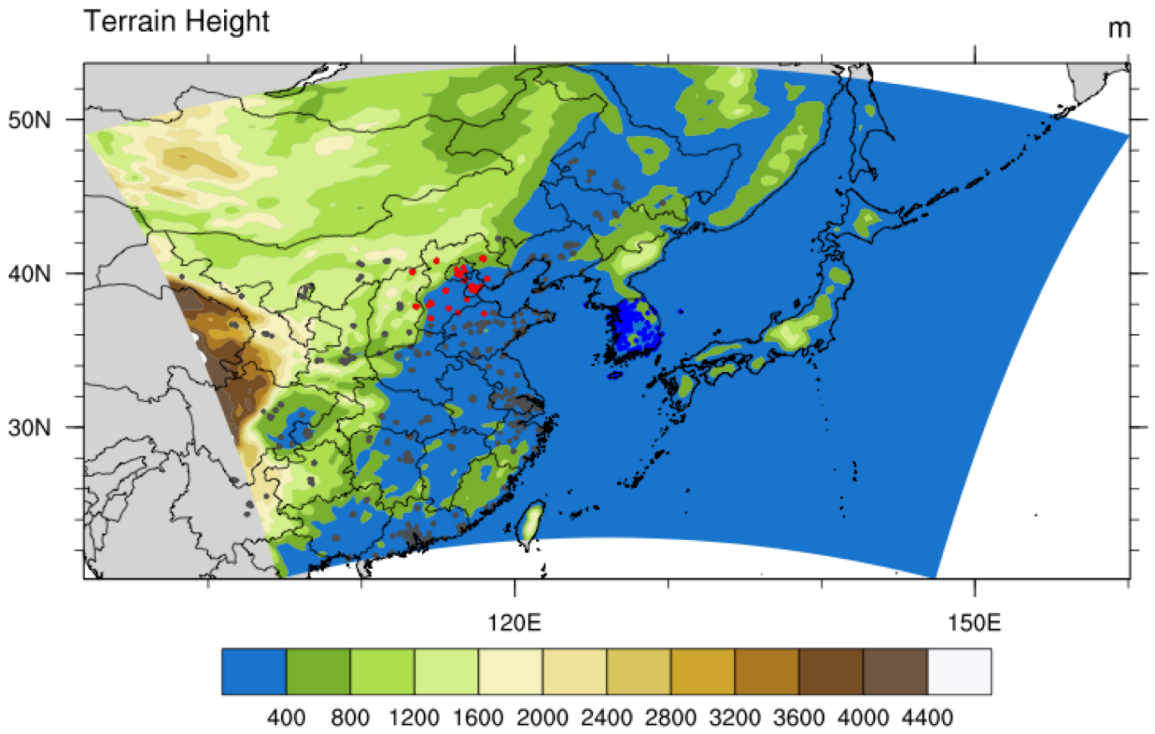
    $PM_{2.5} = \rho[p25 + bc1 + bc2 + 1.8(oc1 + oc2) + dust1 + 0.286*dust2 + seas1 + 0.942*seas2 + 1.375*sulf]$
  - observation error:

Chen, D., Liu, Z., Ban, J., Zhao, P., and Chen, M.: Retrospective analysis of 2015–2017 winter-time PM2.5 in China: response to emission regulations and the role of meteorology, Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2018-890, 2019.

$$\varepsilon_{PM2.5} = \sqrt{\varepsilon_0^2 + \varepsilon_r^2}, \qquad \varepsilon_r = \gamma\varepsilon_0\sqrt{\frac{\Delta x}{L}}, \qquad \varepsilon_0 = 1.0 + 0.0075 \times \prod_0$$

DA experiment

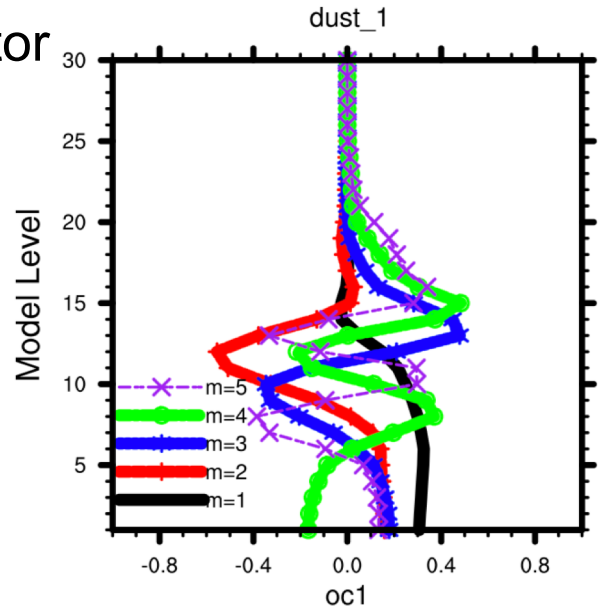
- 20160501—20160507
- 6hr cycling, 24hr forecast at 00UTC
- observation: $PM_{2.5}$ surface concentration over China and South Korea



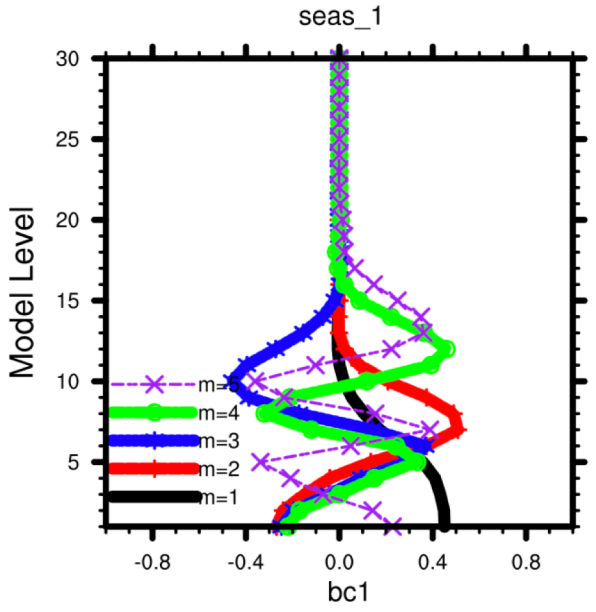
Get chemical statistics in GENBE_2.0

- Eigen Vector

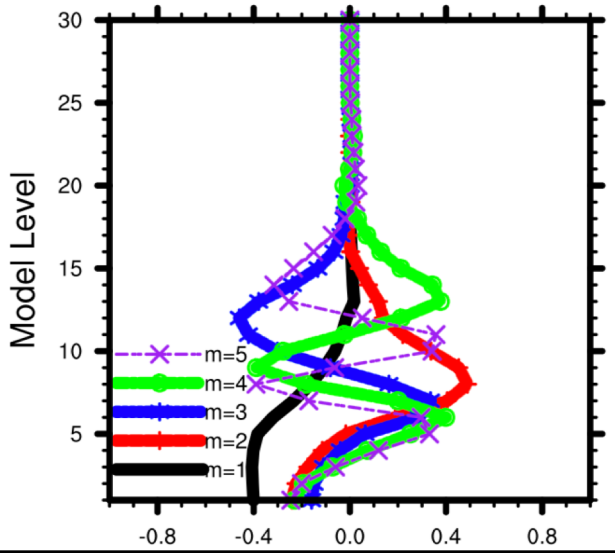
DUST_1



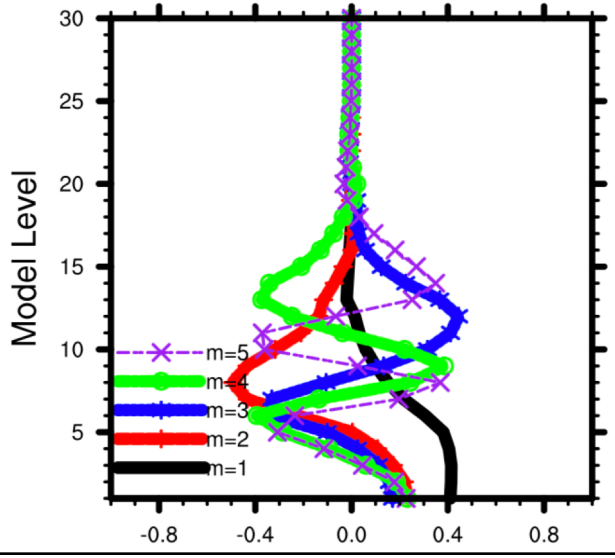
SEAS_1



OC1



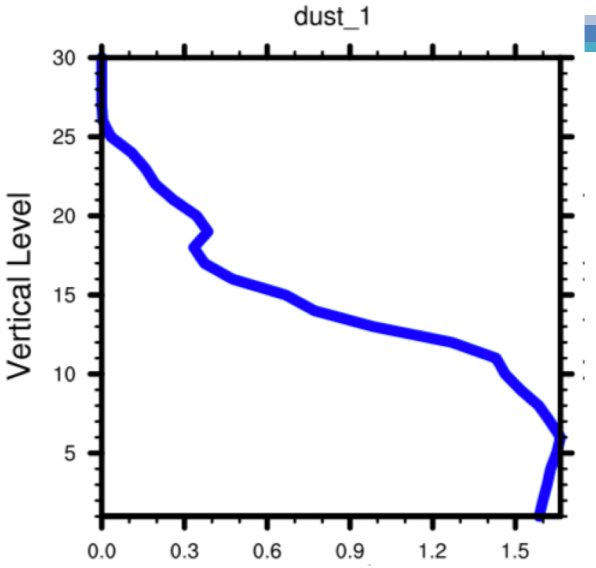
BC1

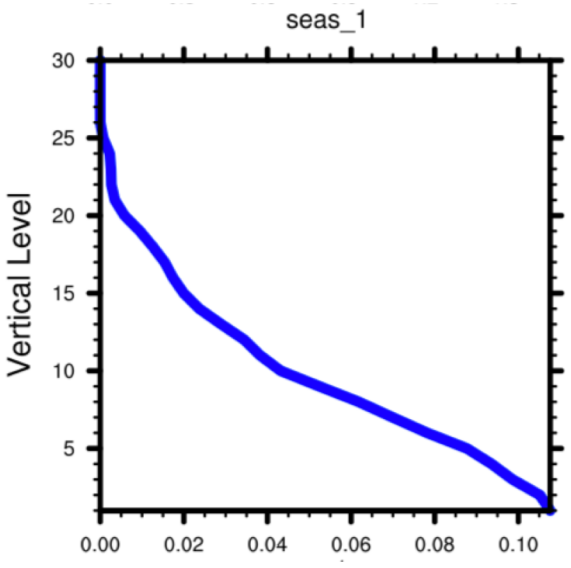


Get chemical statistics in GENBE_2.0

- Std Error

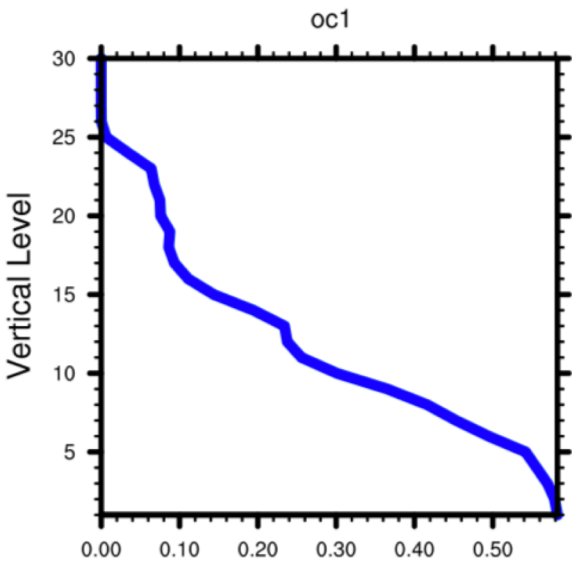
DUST_1

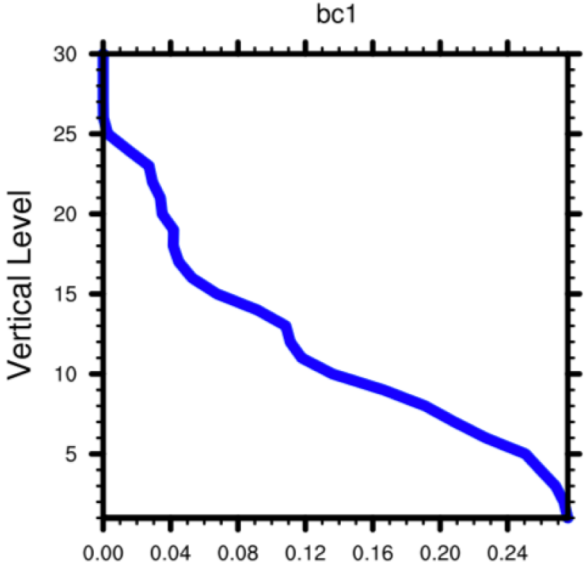




SEAS_1

OC1



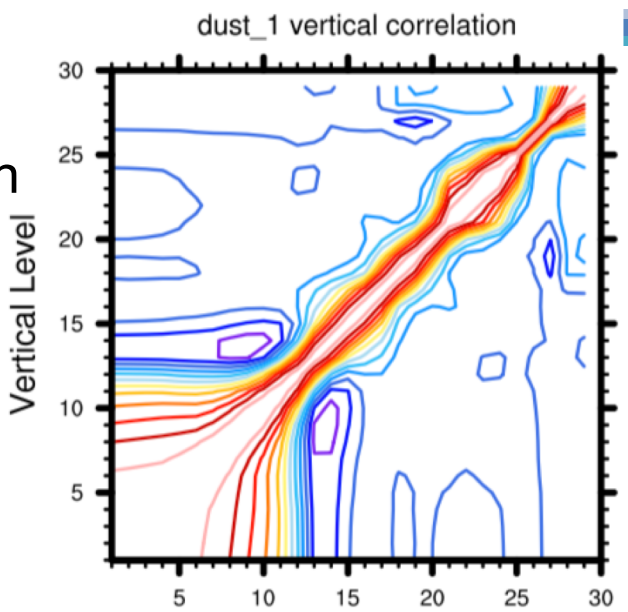


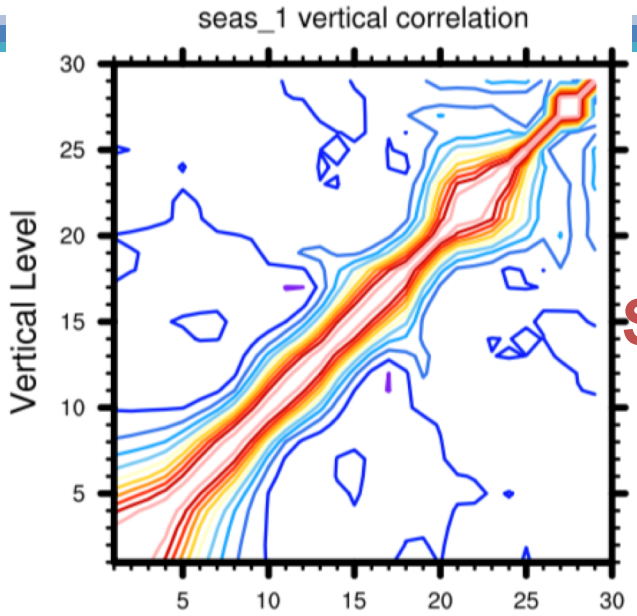
BC1

Chemical/Aerosol DA with GOCART

- Vertical Correlation

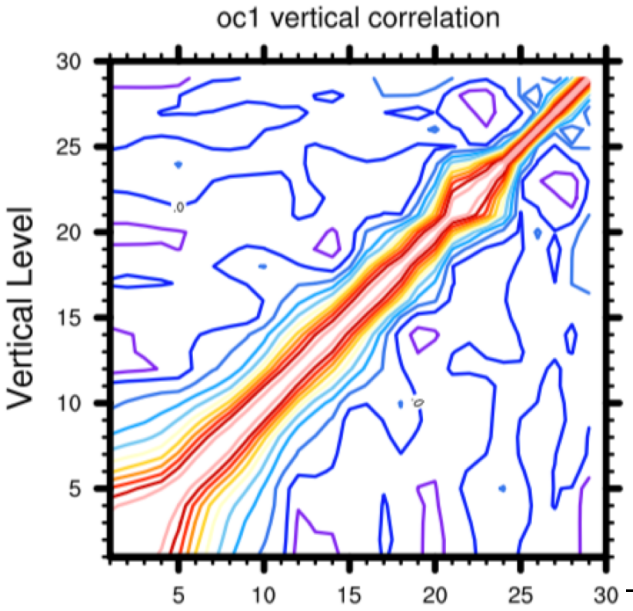
DUST_1

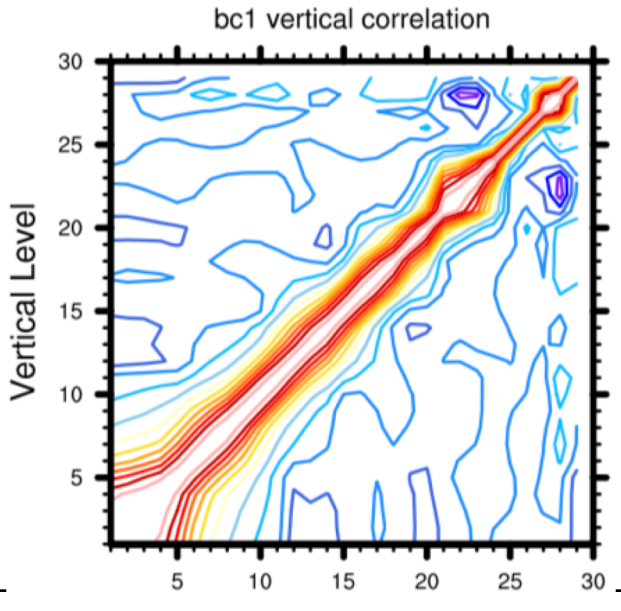




SEAS_1

OC1

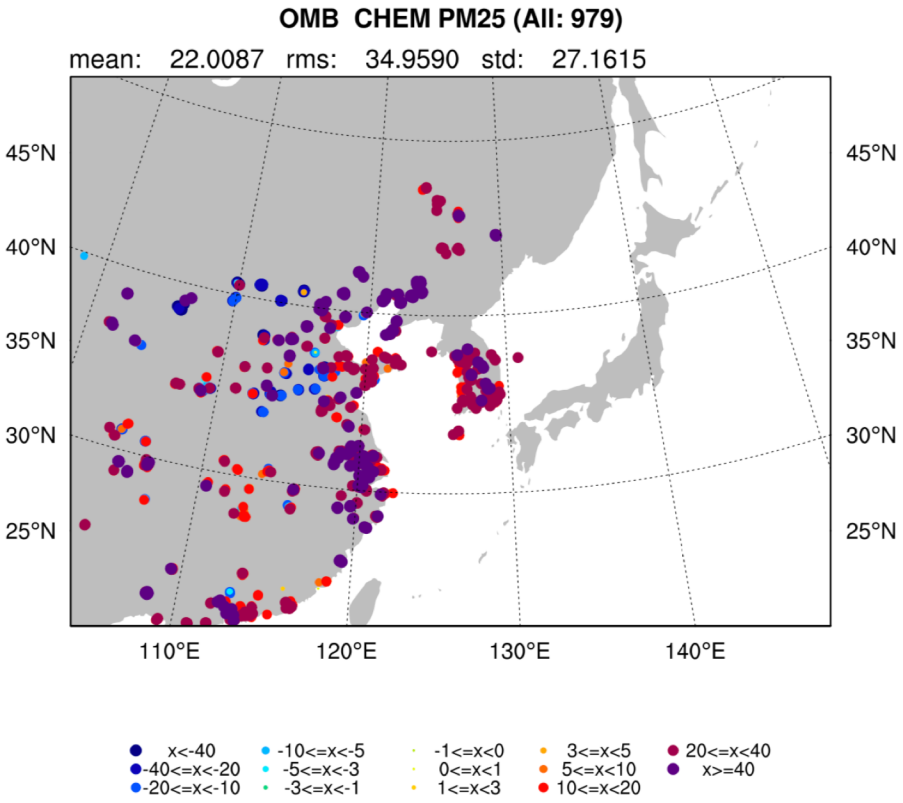


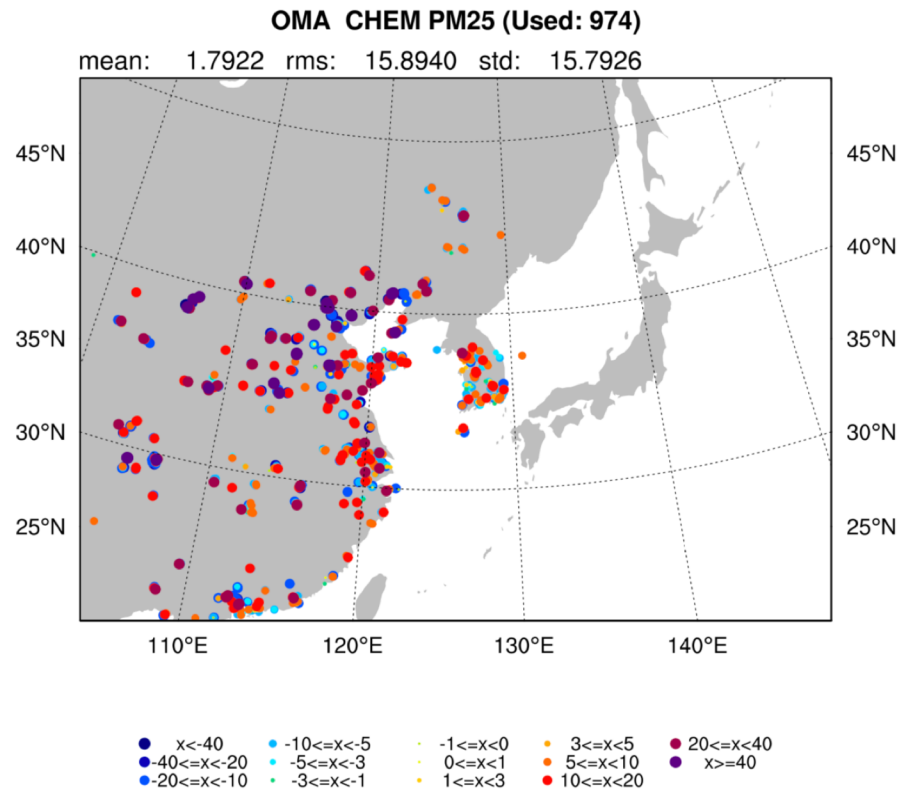


BC1

DA experiment

2016050100 UTC

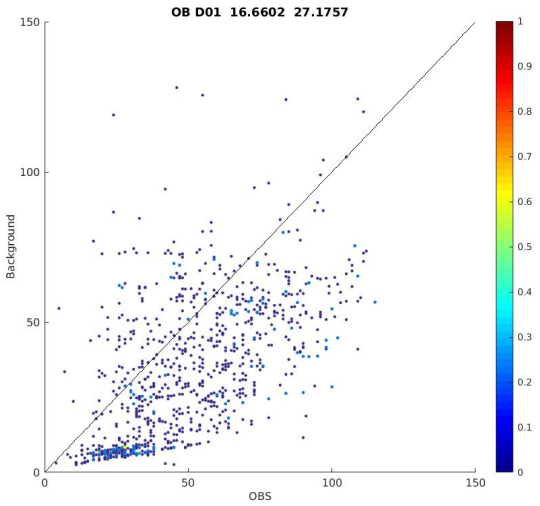


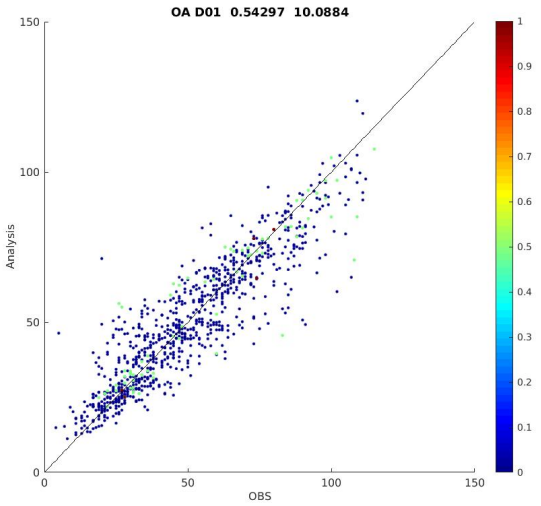


OMB **OMA**

DA experiment

GSI

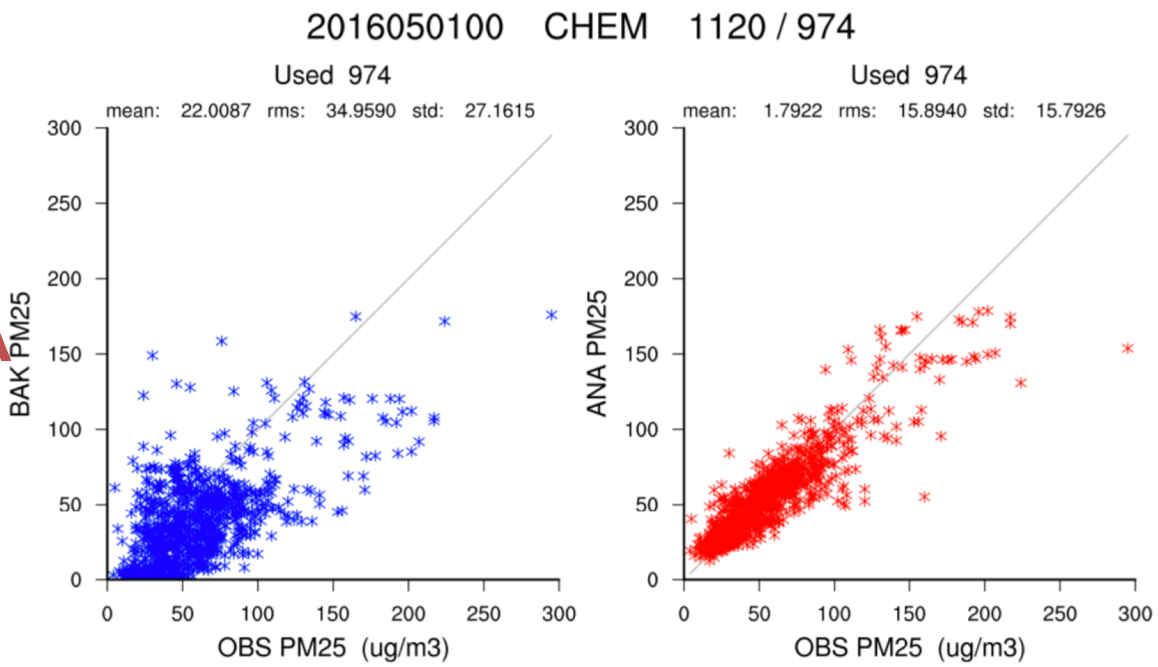




mean: 16.66—0.54

std: 27.18—10.09

WRFDA

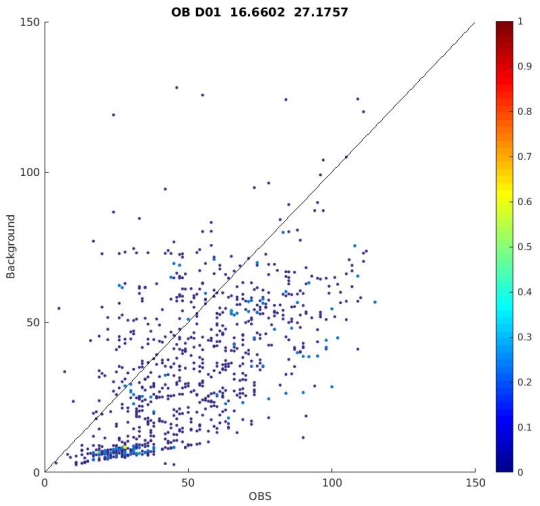


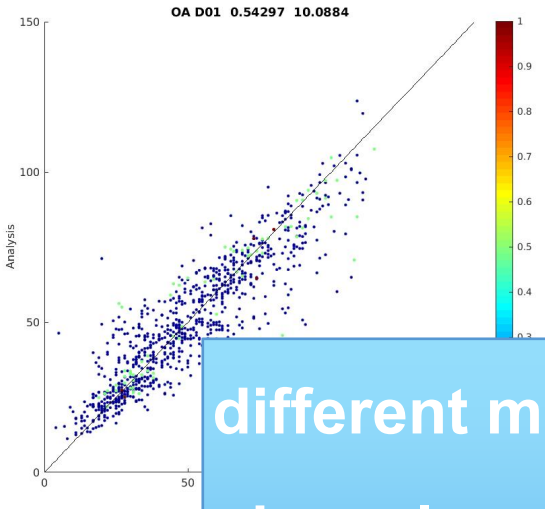
mean: 22.01—1.79

std: 27.16—15.79

DA experiment

GSI





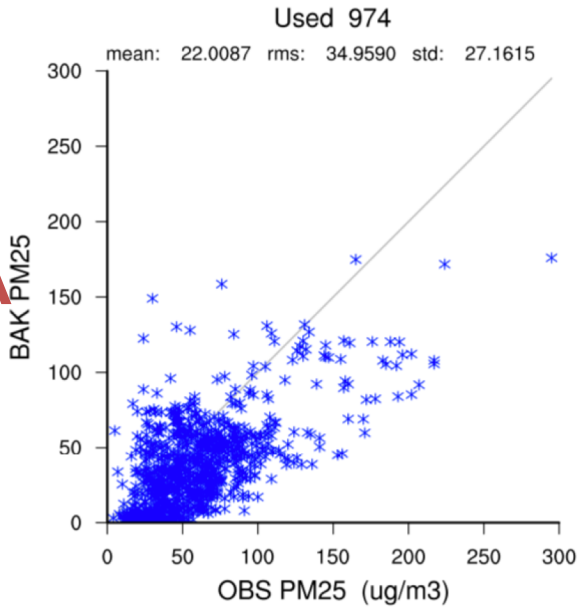
mean: 16.66—0.54

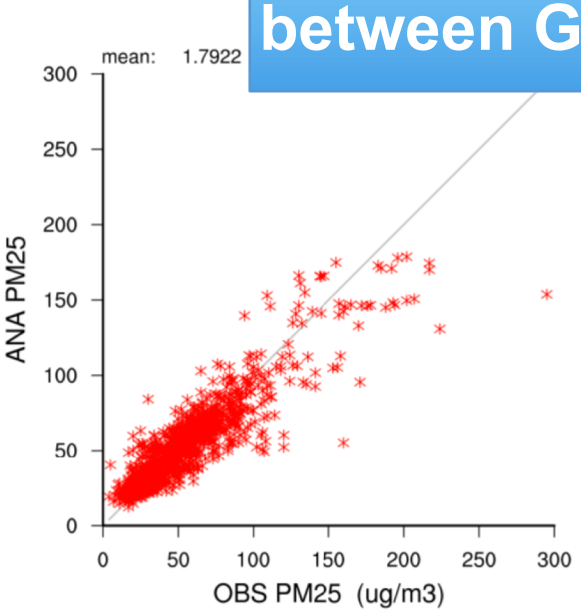
std: 27.18—10.09

different max realistic obs value and obs err between GSI and WRFDA

WRFDA

2016050100 CHEM 1120 / 97





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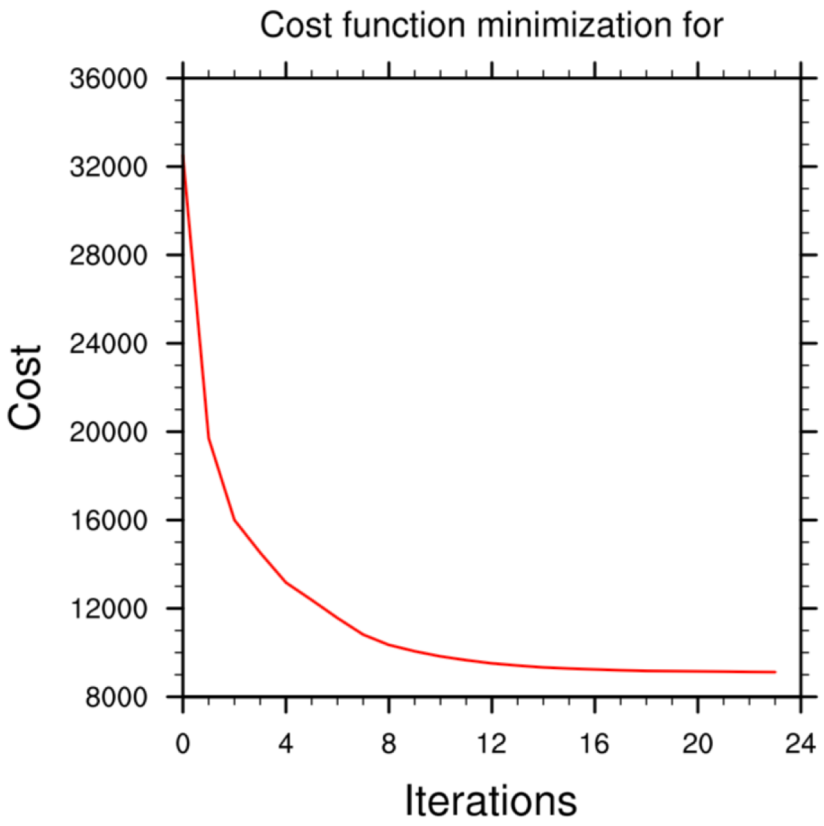
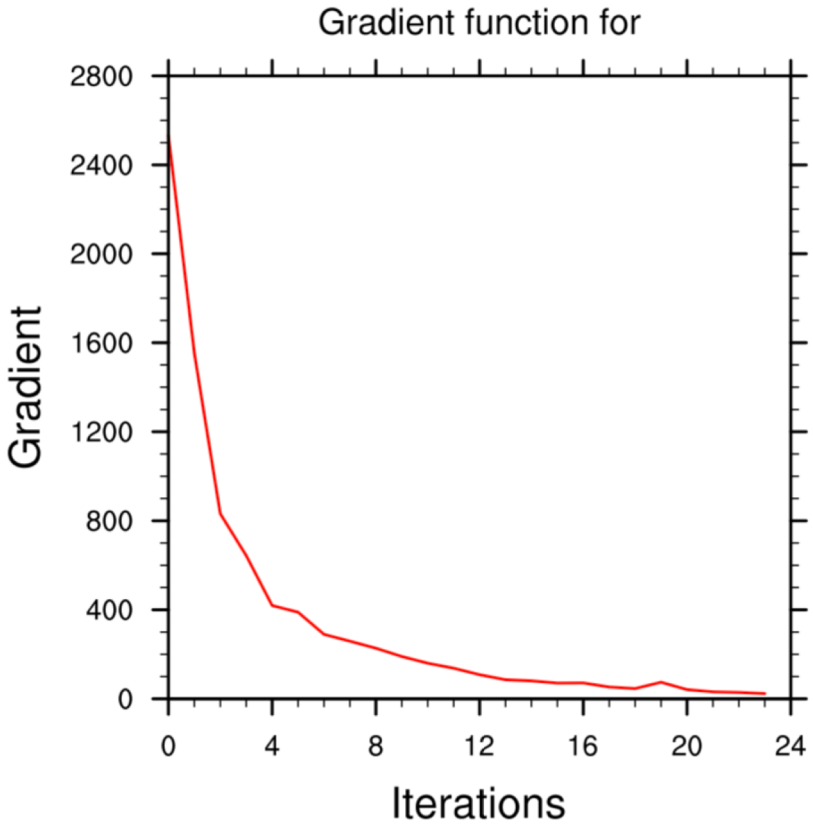
DA experiment

2016050100 UTC

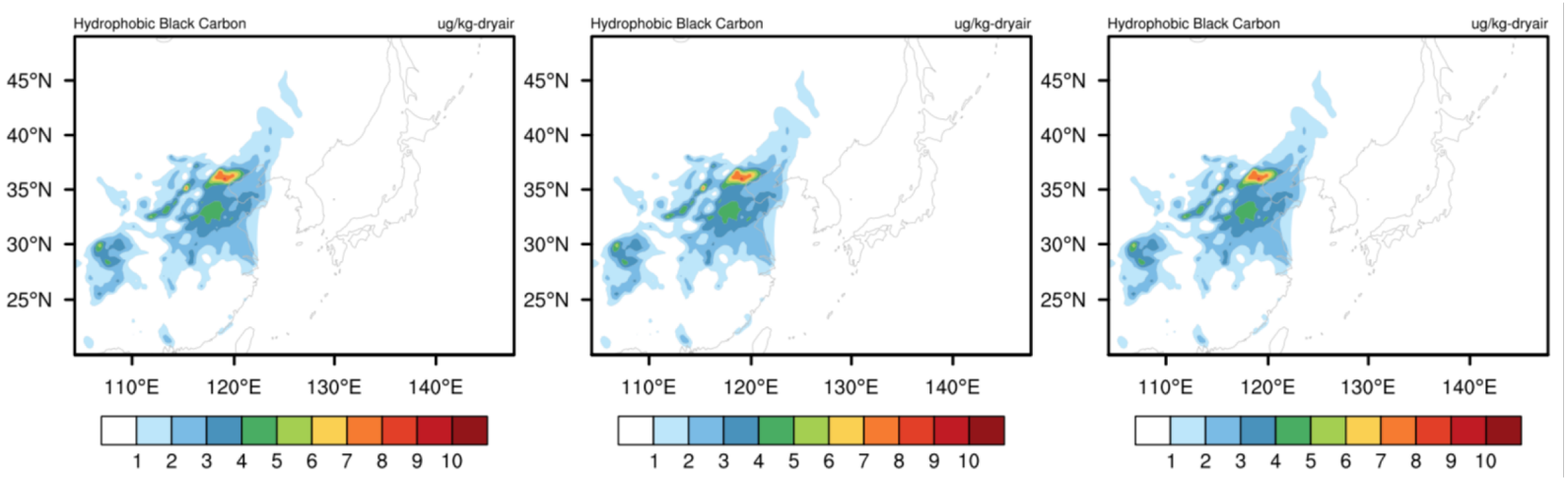




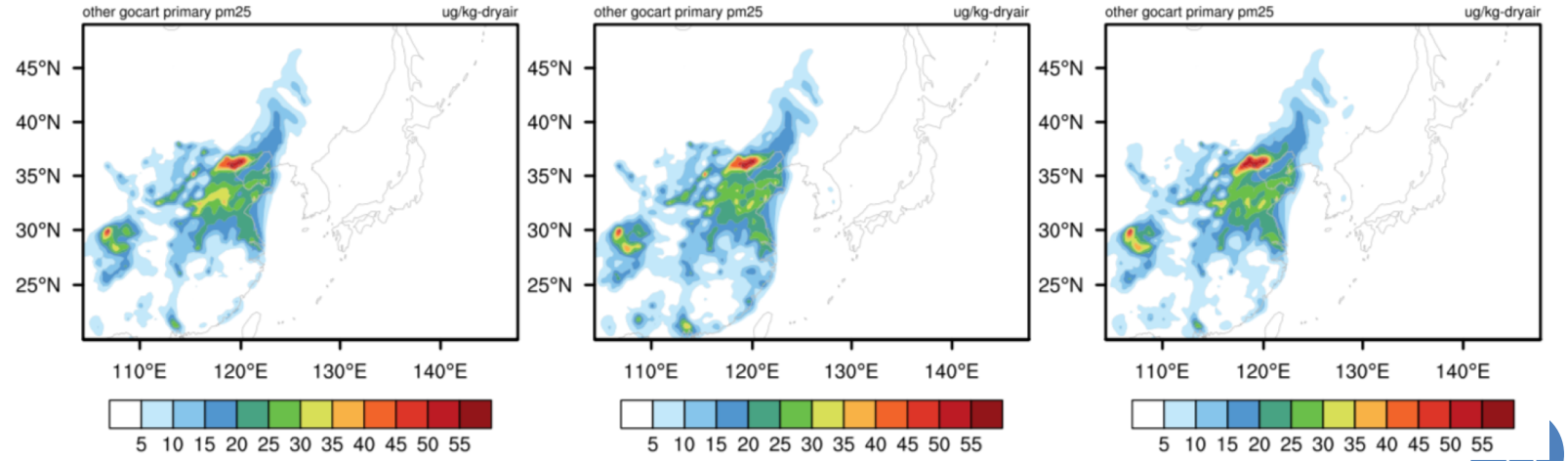
DA experiment

2016050100 UTC **W/O DA** **GSI** **WRFDA**

BC1

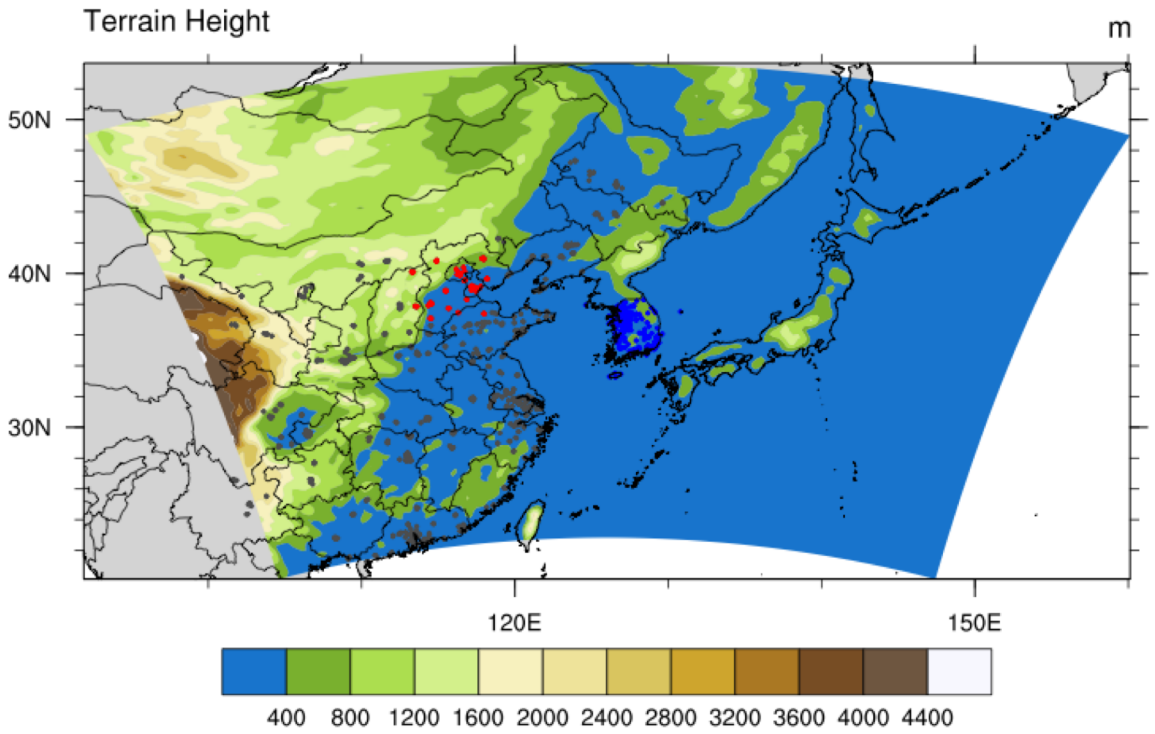


P25



Forecast Verification

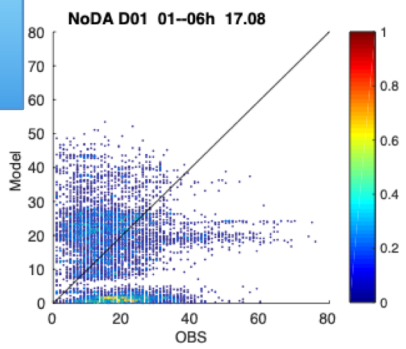
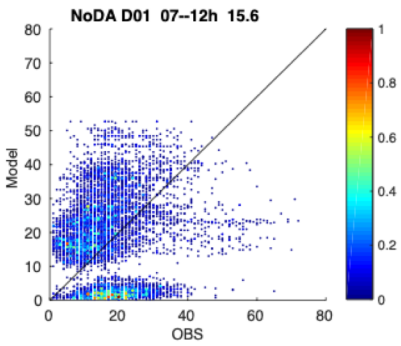
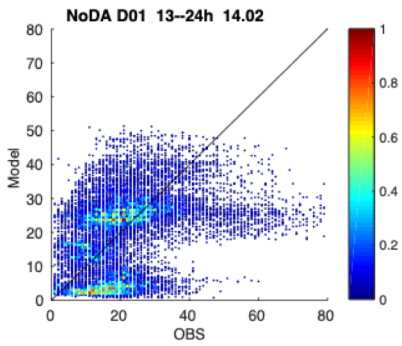
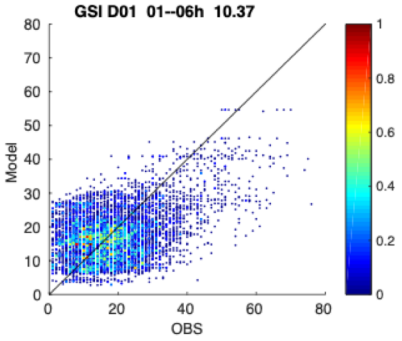
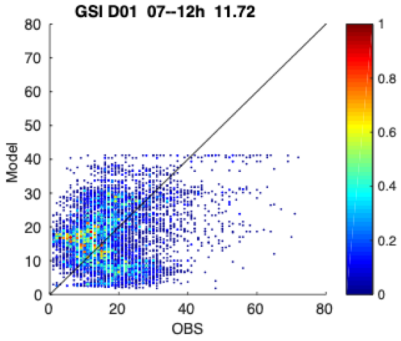
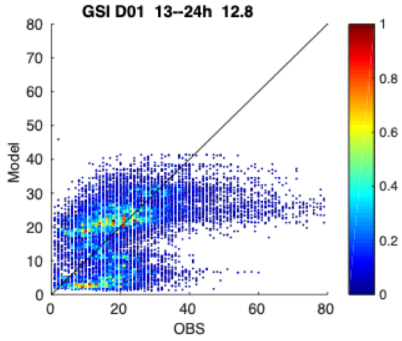
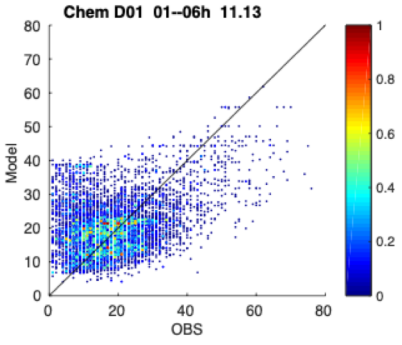
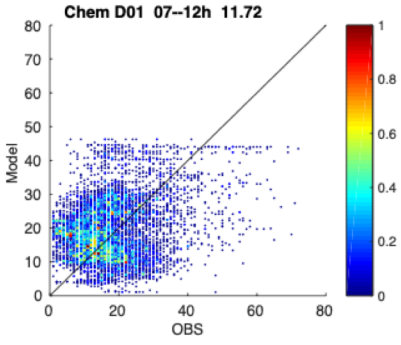
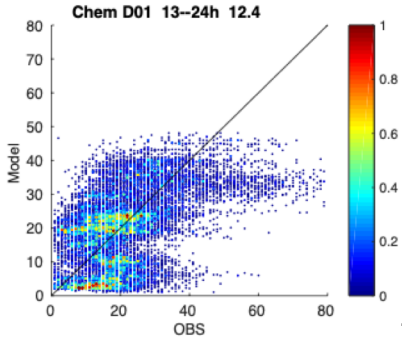
- 20160501—20160507
- 6hr cycling, 24hr forecast at 00UTC
- verification region: Polluted region over North China and South Korea



Forecast Verification

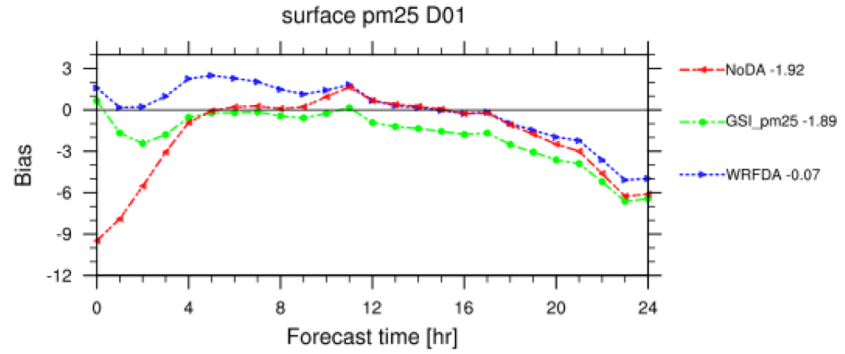
scatters for 01-24h forecast of all days

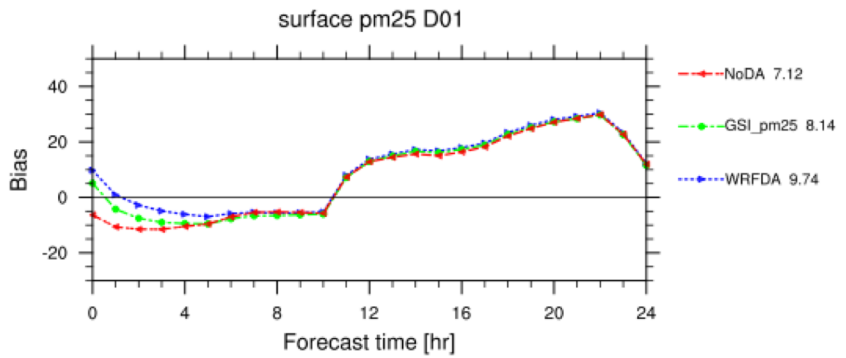
20160501—20160507

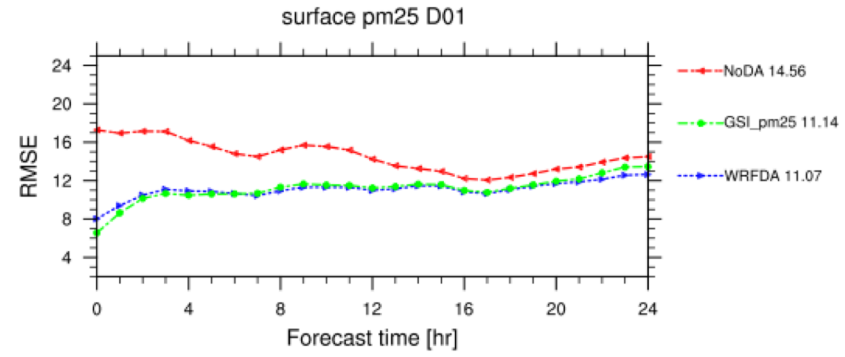
	01-06h	07-12h	13-24h
W/O DA			
GSI			
WRFDA			

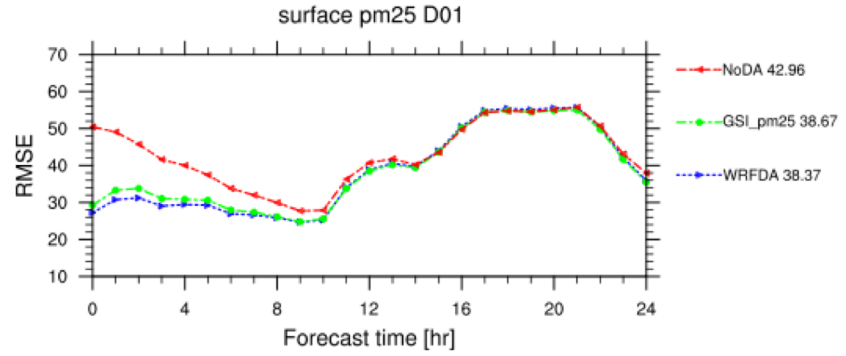
Forecast Verification

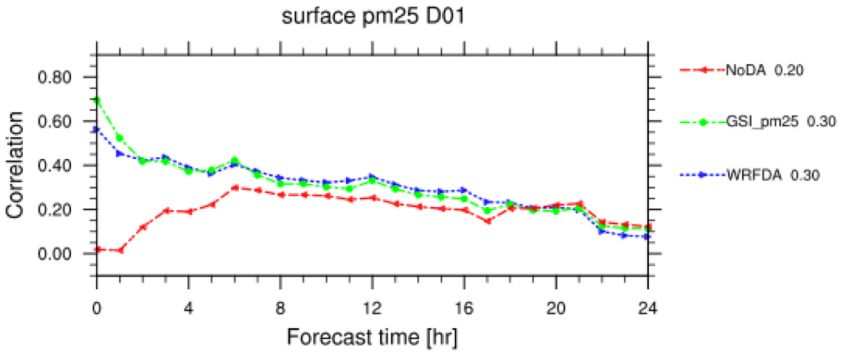
Korus (S. Korea) **20160501—20160507** Korus (N. China)

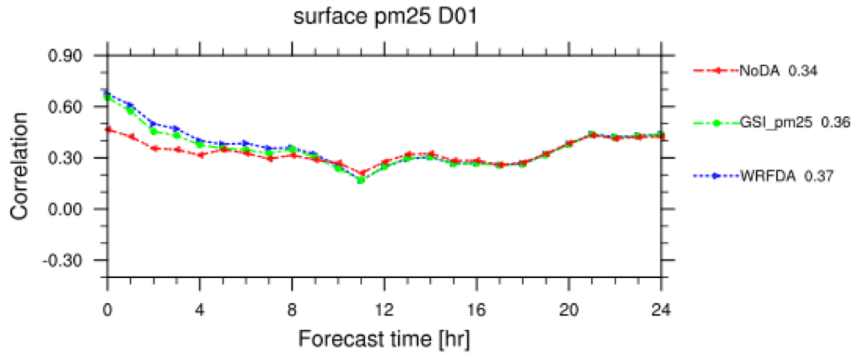






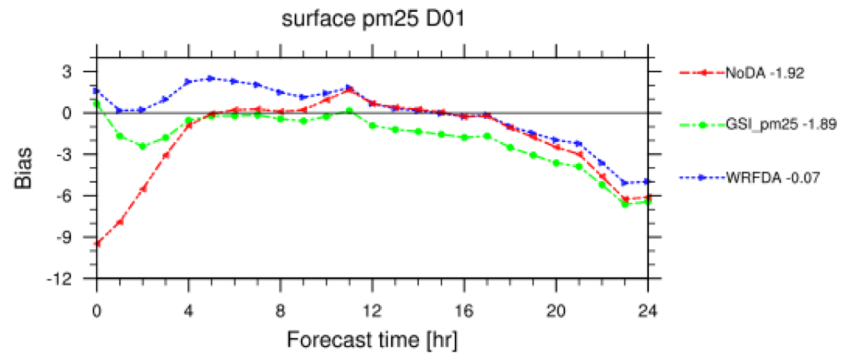


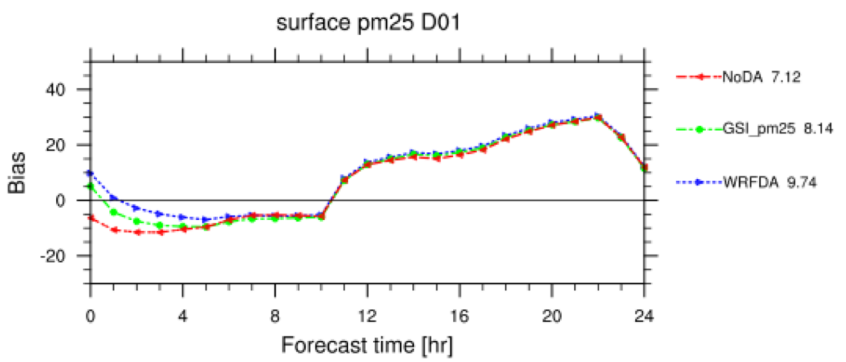


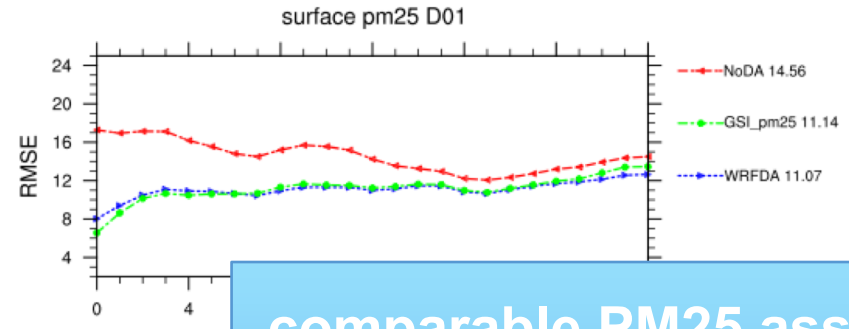


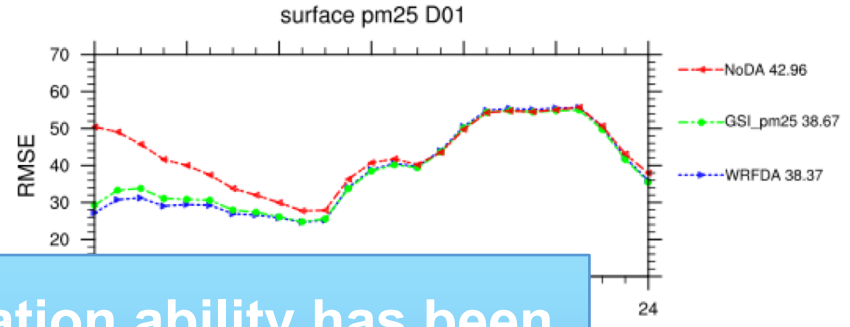
Forecast Verification

Korus (S. Korea) **20160501—20160507** Korus (N. China)

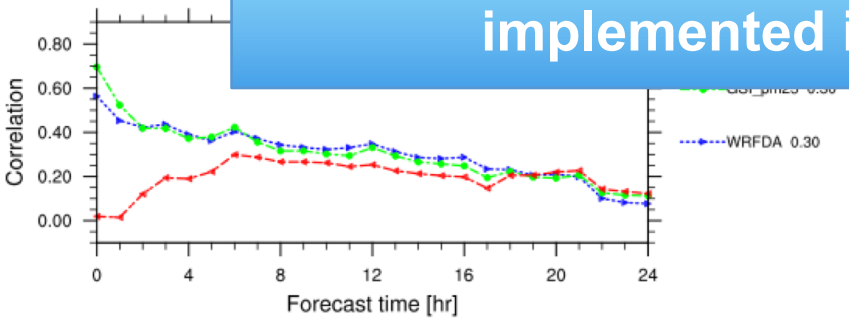


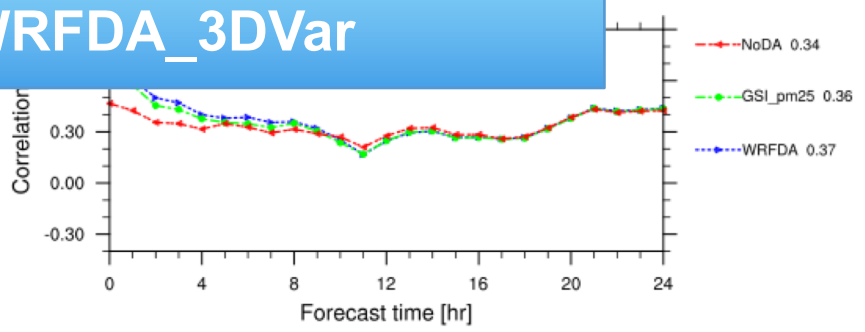






comparable PM25 assimilation ability has been implemented in WRFDA_3DVar





Chemical/Aerosol DA – Outline

- Background
- PM2.5 assimilation with GOCART scheme
- Chemical/Aerosol assimilation with MOSAIC scheme
  - PM25 assimilation
  - PM25 & PM10 assimilation
  - Gaseous pollutant assimilation
- Conclusions

PM2.5 DA with MOSAIC

- GENBE_2.0
  - analysis variable (univariate):

  bc, oc, so4, no3, nh4, cl, na, oin (bins 1-3)

easily switch between different aerosol schemes

- MOSAIC Scheme
  - observation operator:

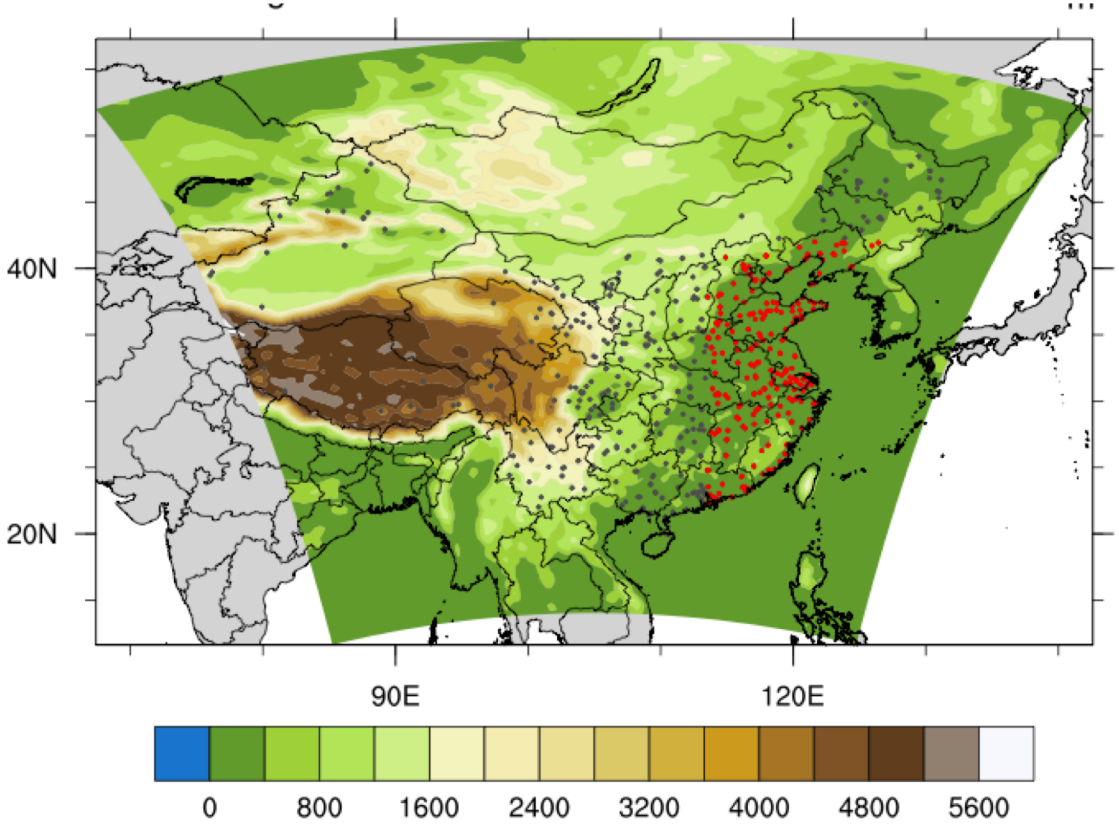
$$\mathrm{PM}_{2.5} = \rho \sum_{i=1}^{3} bc_i + oc_i + so_{4i} + no_{3i} + nh_{4i} + cl_i + na_i + oin_i$$

  - observation error:

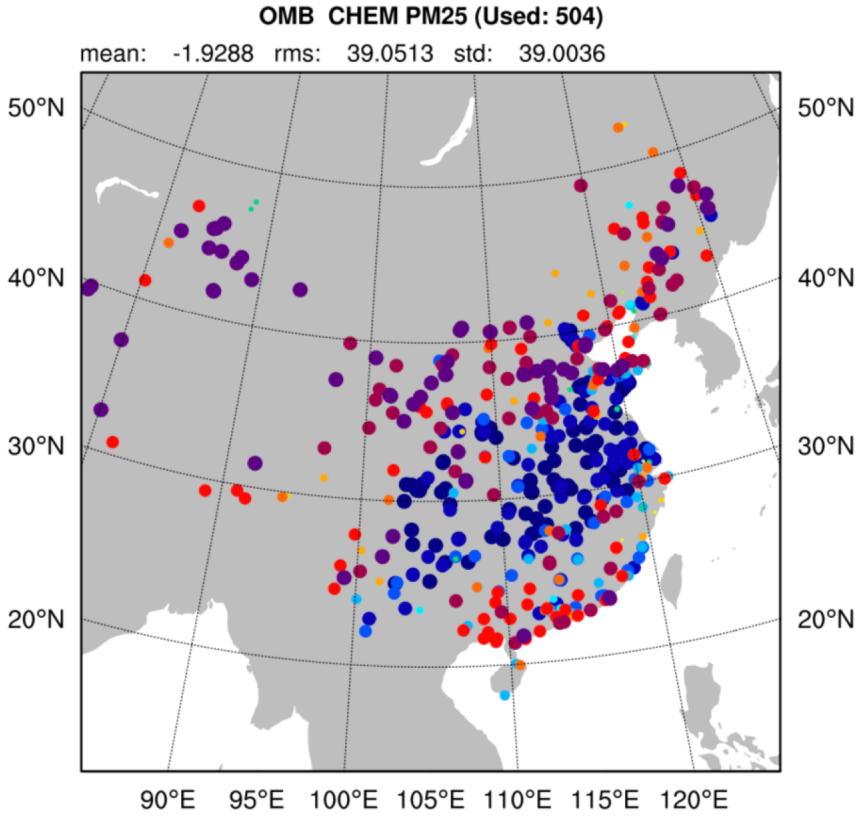
  same as GOCART scheme

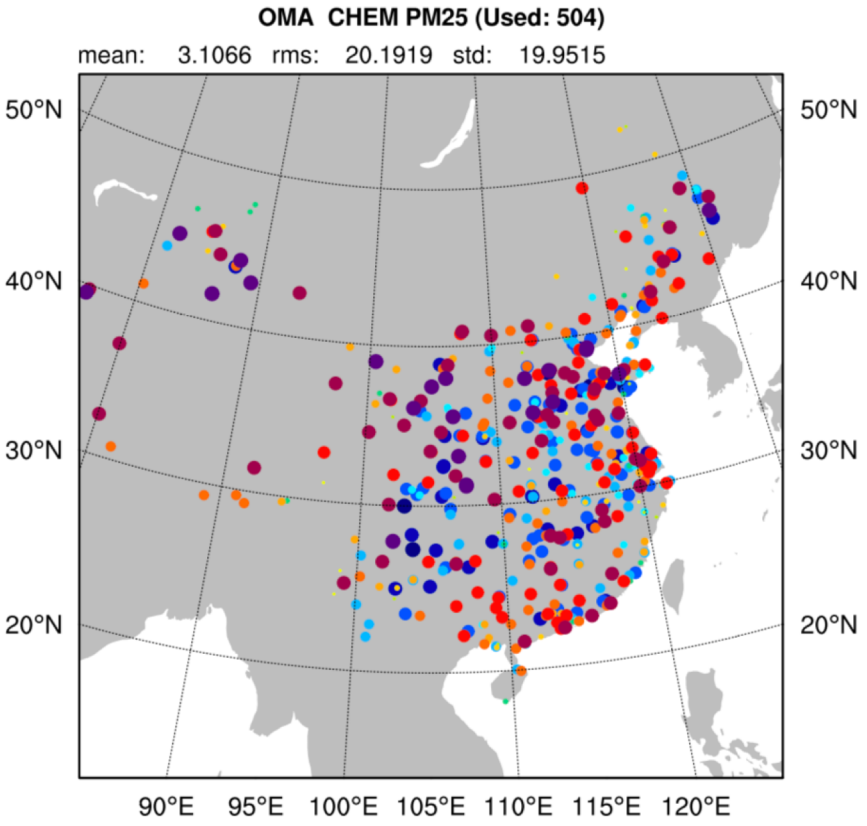
DA experiment

- 20150102—20150110
- 6hr cycling, 24hr forecast at 00UTC
- observation: PM2.5 surface concentrations over China



DA experiment



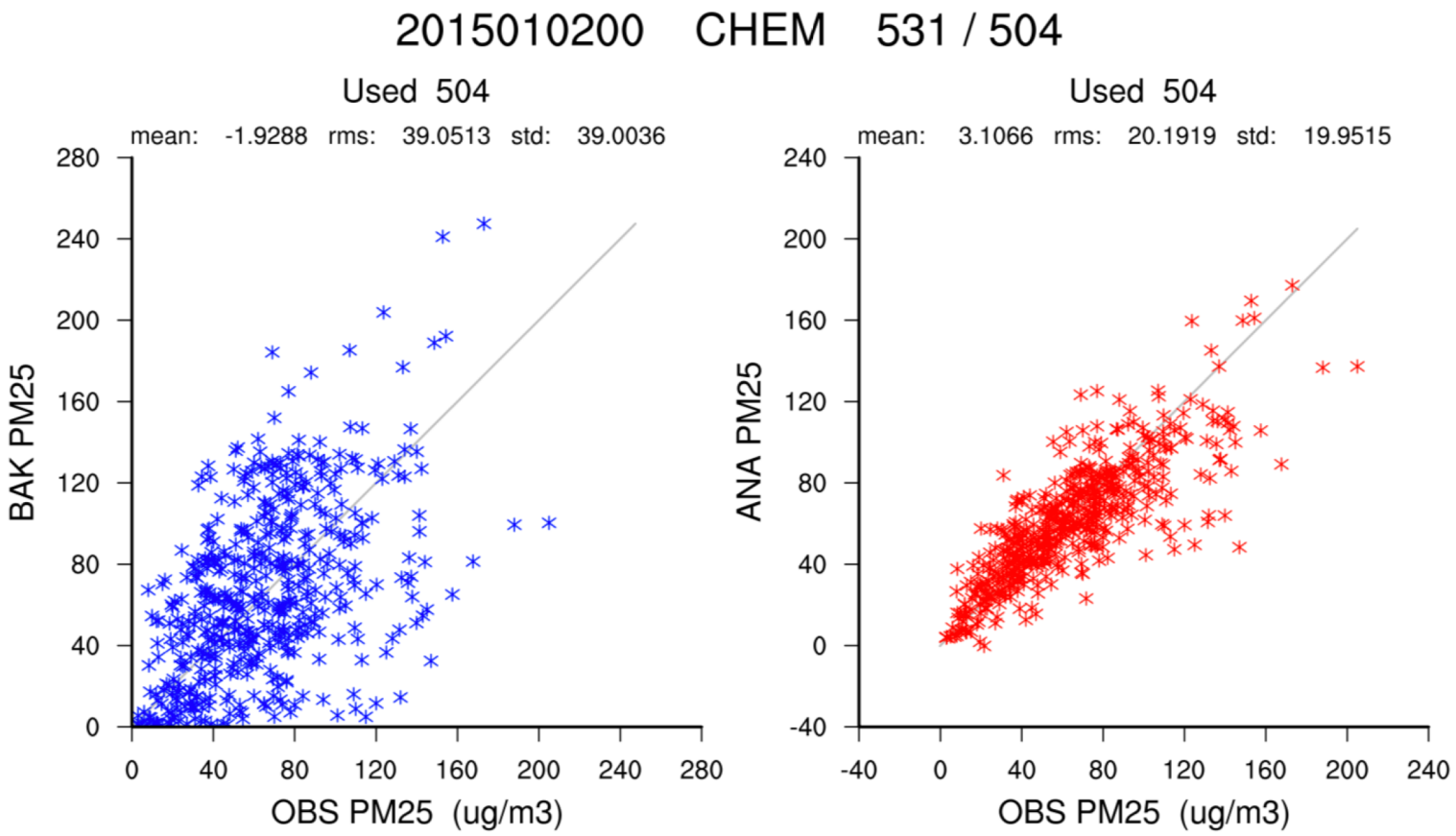


OMB

2015010200 UTC

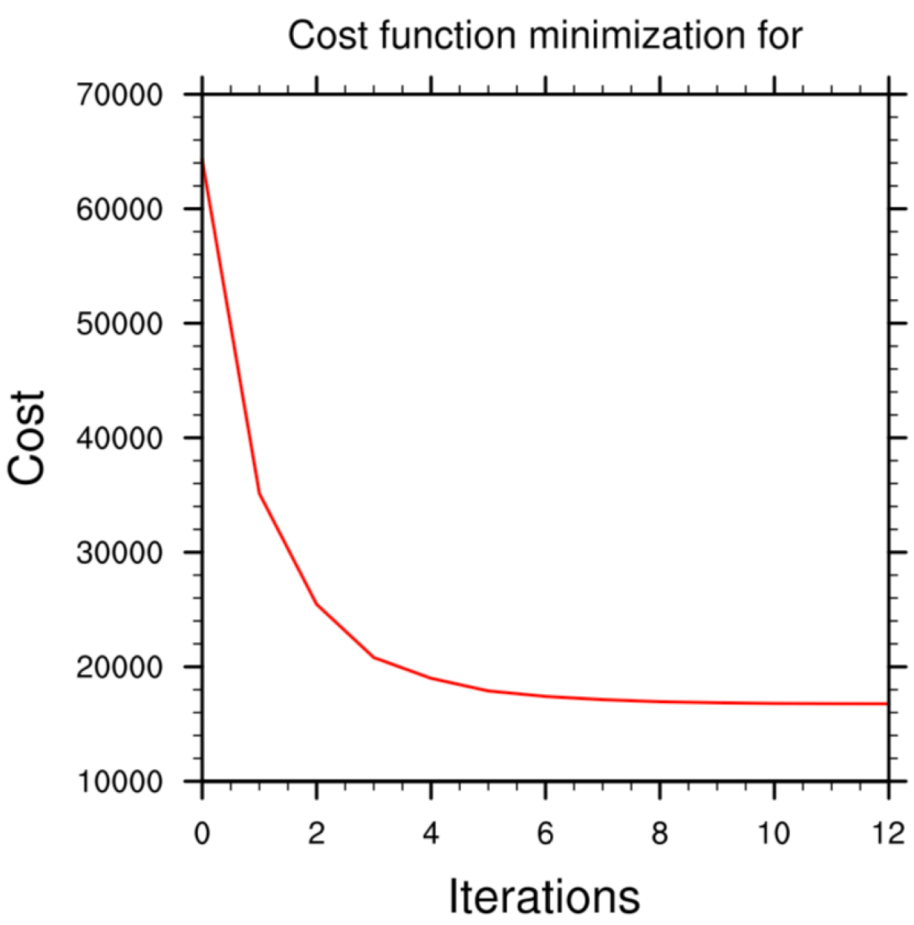
OMA

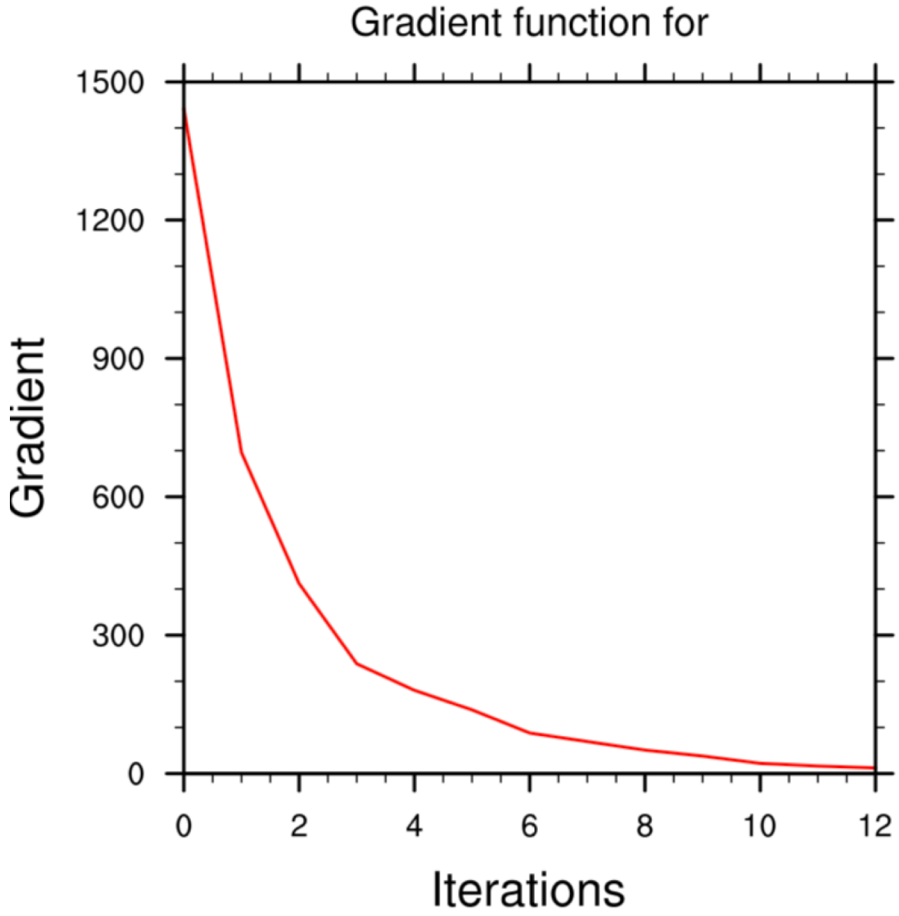
DA experiment



DA experiment

2015010200 UTC



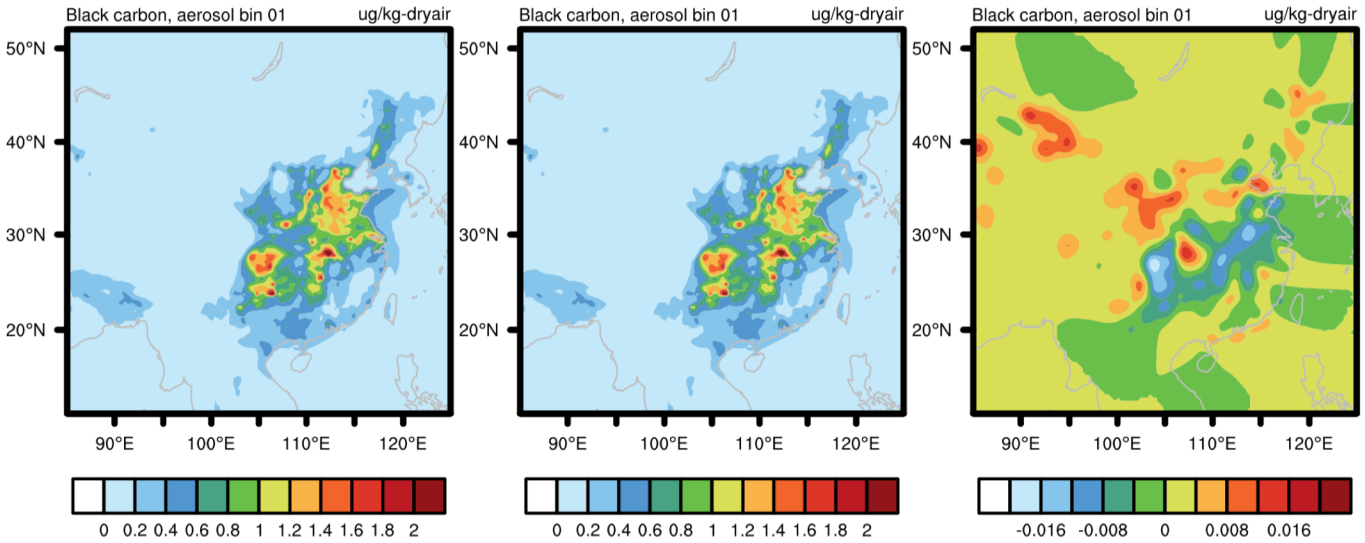


DA experiment

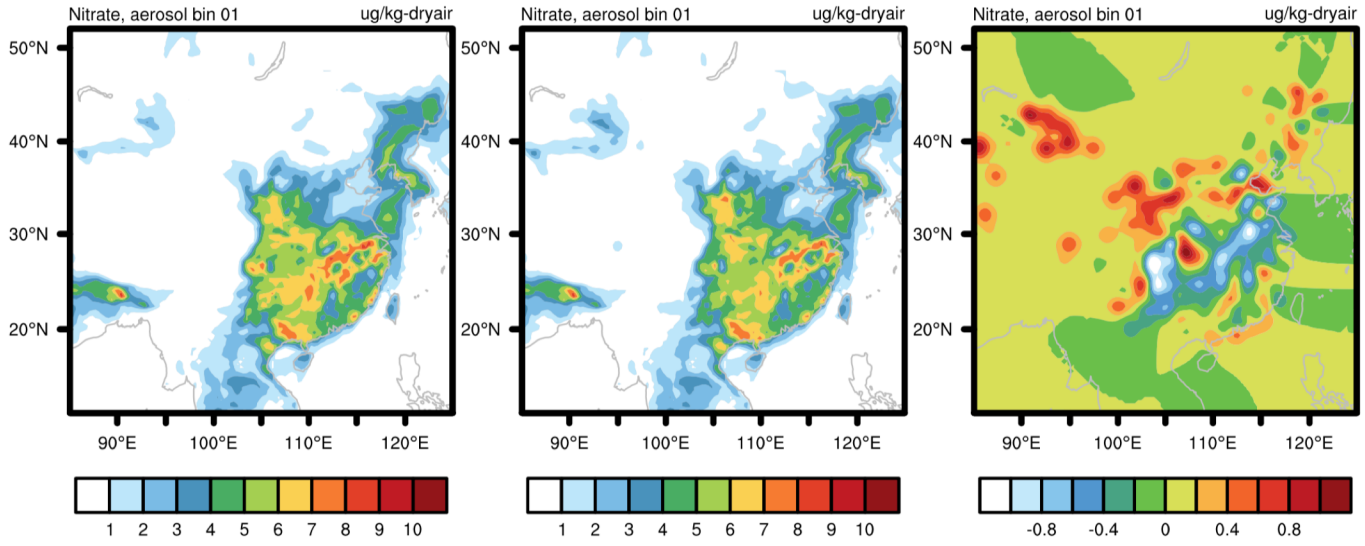
2015010200 UTC

W/O DA **WRFDA** **INCRE**

BC_1



NO3_1

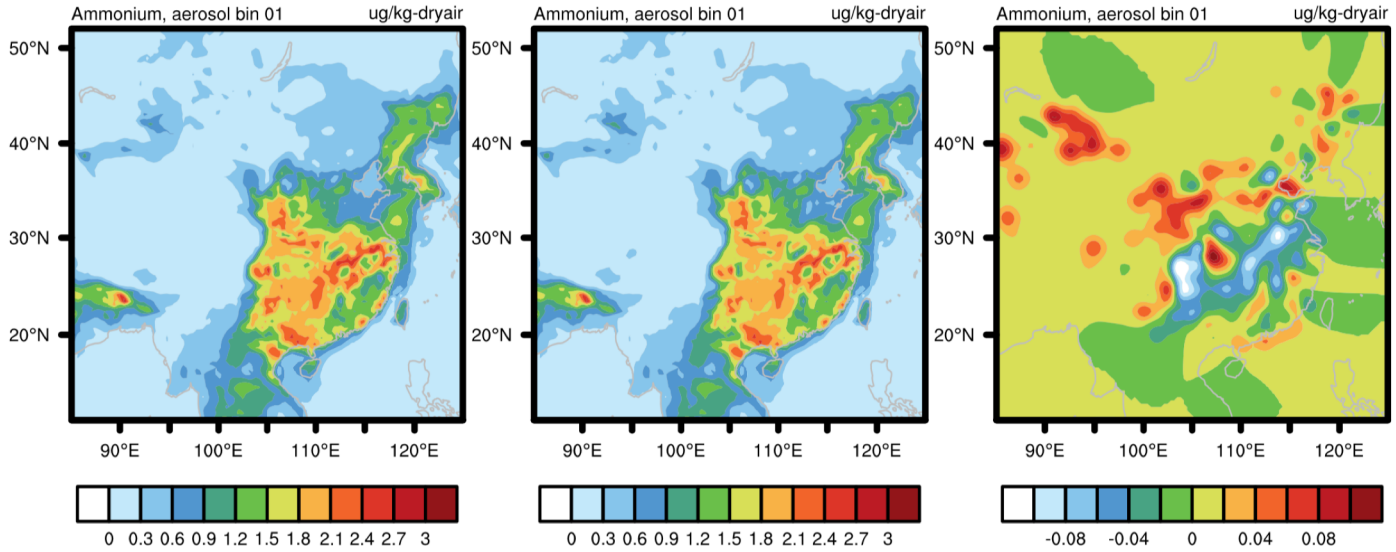


DA experiment

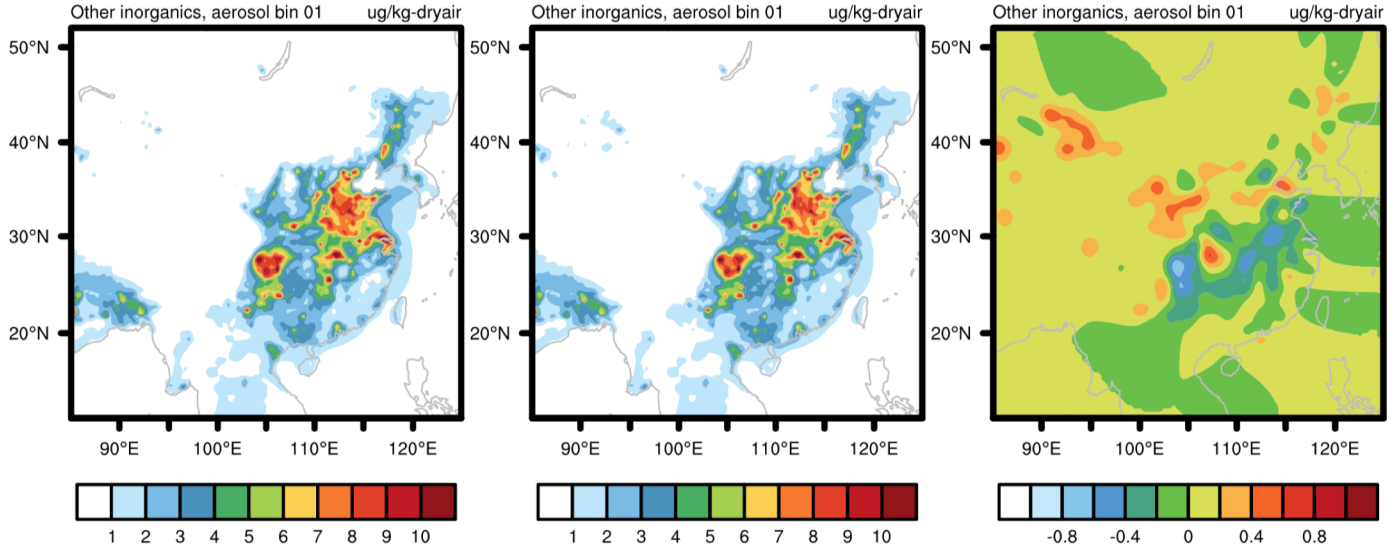
2015010200 UTC

W/O DA | **WRFDA** | **INCRE**

NH4_1

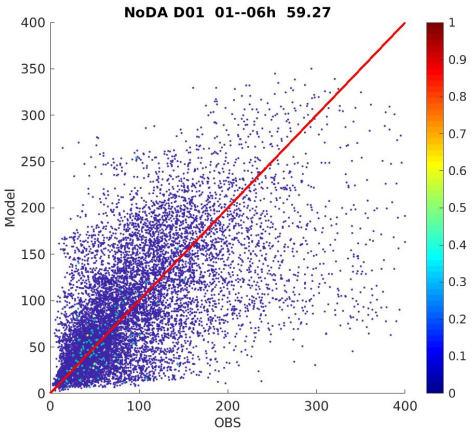
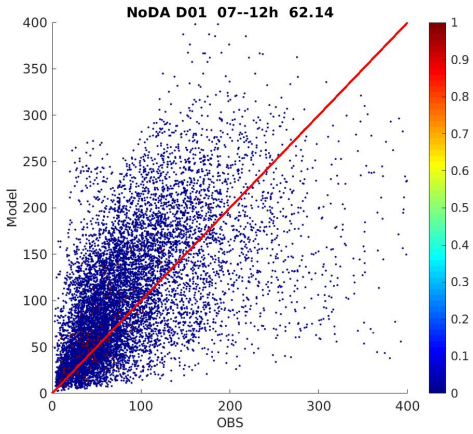
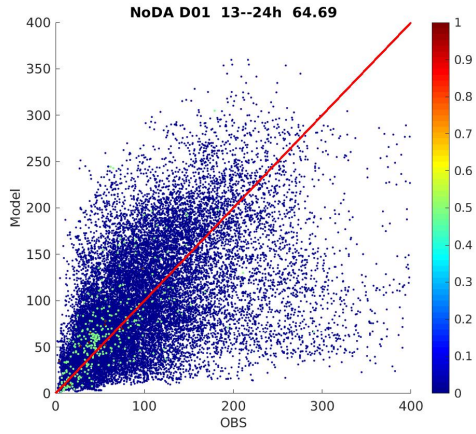
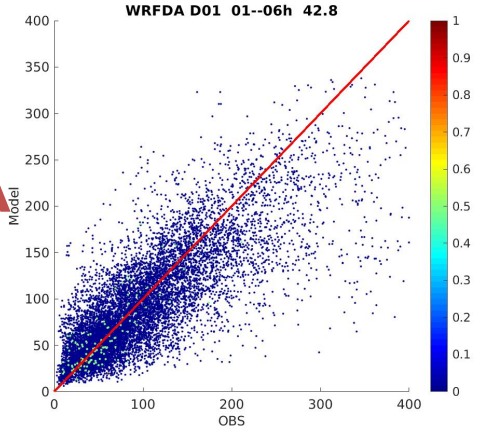
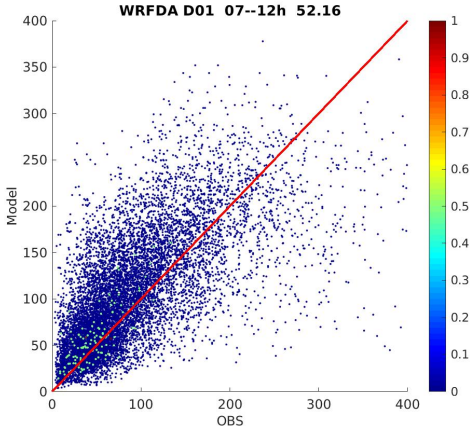
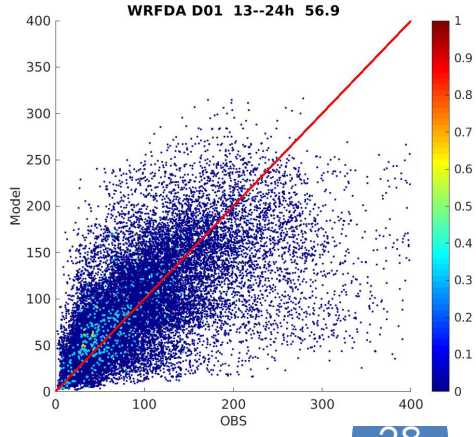


OIN_1



Forecast verification

20150102—20150110

	01-06h	07-12h	13-24h
W/O DA			
WRFDA			

DA experiment

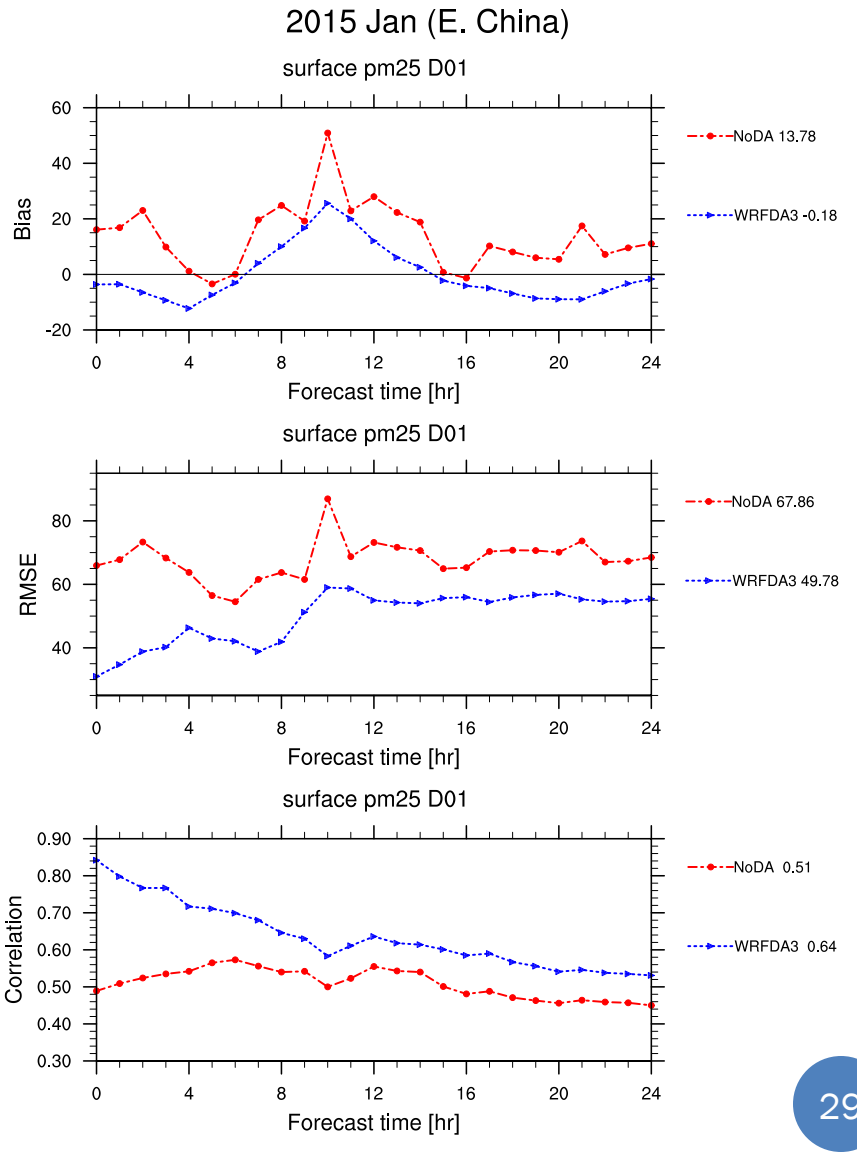
20150102—20150110

WRFDA works well with MOSAIC scheme

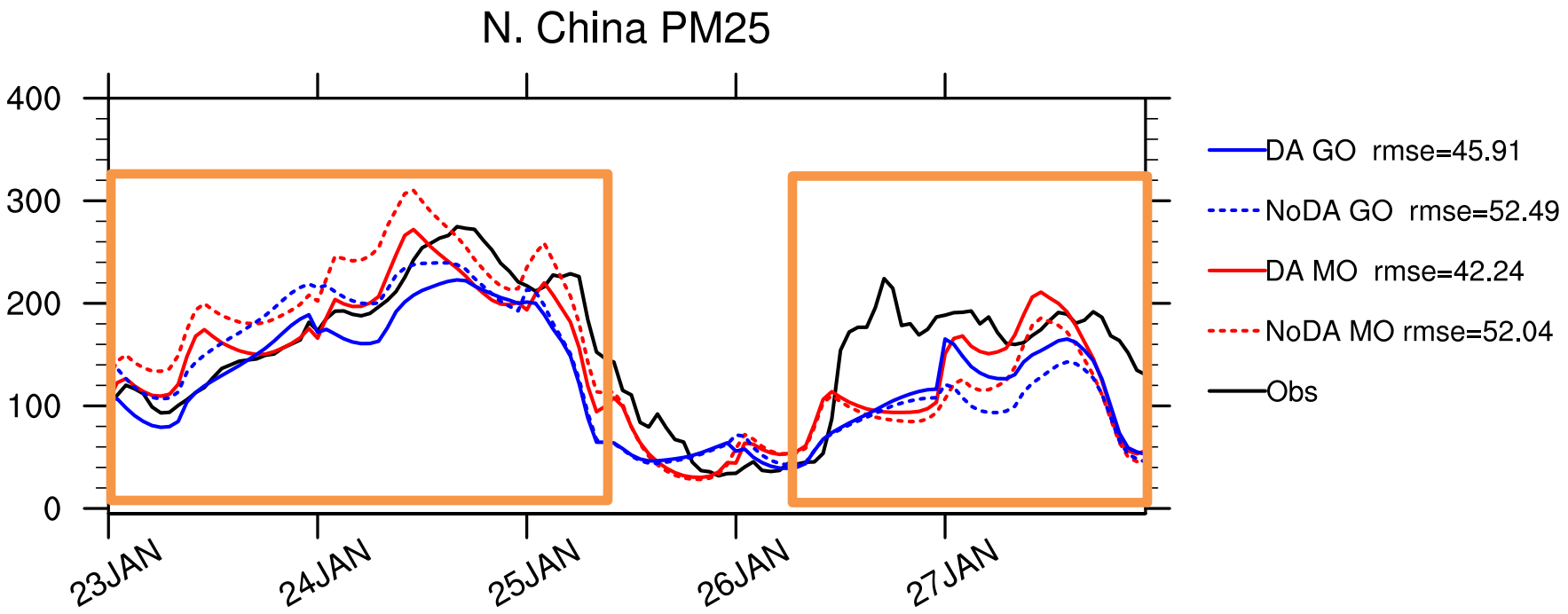
Developed Chemical DA system can easily switch between different aerosol schemes

26.6%

20.3%



PM25 forecast in GOCART and MOSAIC



Heavy Polluted Event on Jan 2017

PM2.5 & PM10 DA with MOSAIC

- MOSAIC Scheme
  - observation operator:

$$PM_{2.5} = \rho \sum_{i=1}^{3} bc_i + oc_i + so_{4i} + no_{3i} + nh_{4i} + cl_i + na_i + oin_i$$

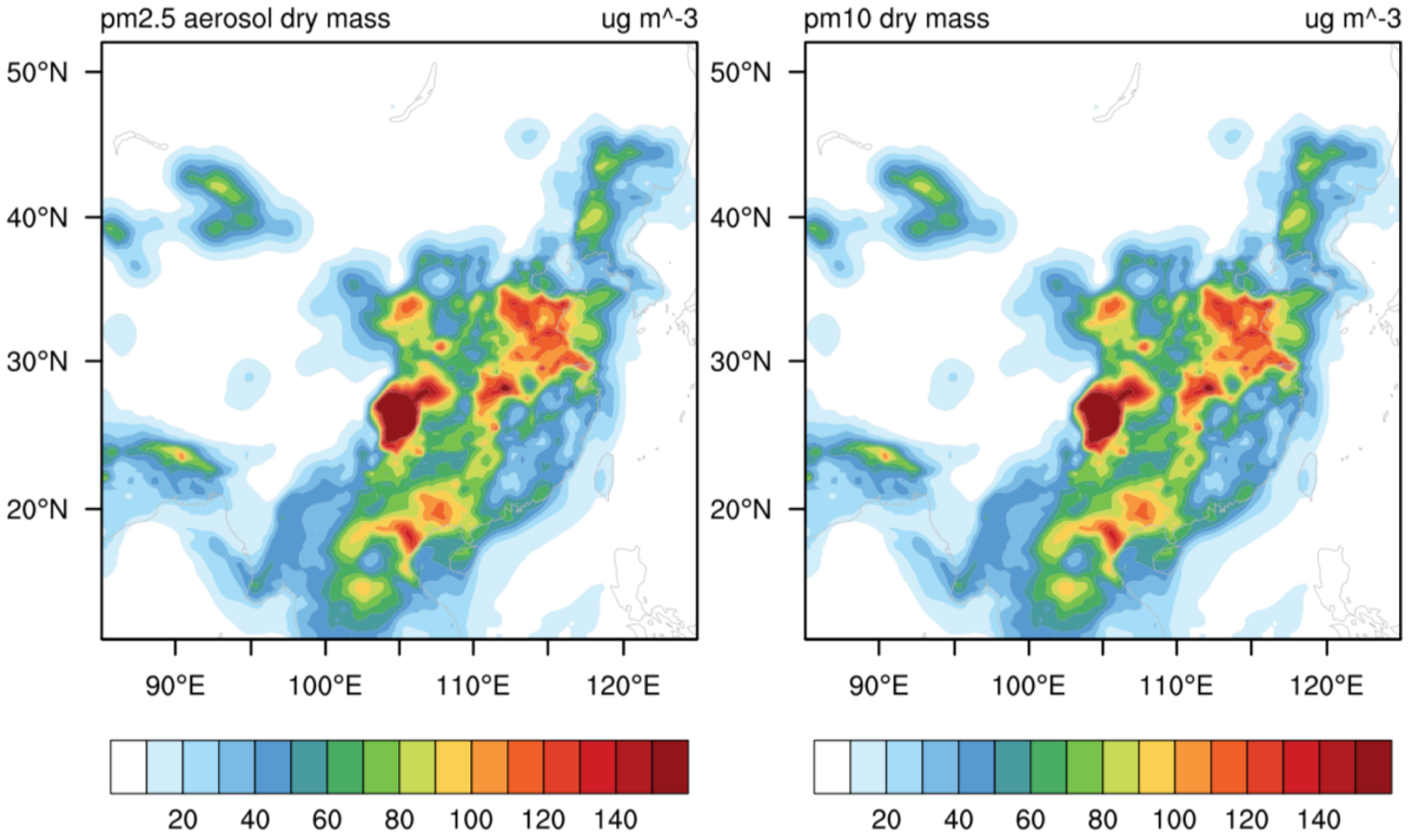
$$PM_{10} = \rho \sum_{i=1}^{4} bc_i + oc_i + so_{4i} + no_{3i} + nh_{4i} + cl_i + na_i + oin_i$$

(PM10-PM25) is used to control the 4th bin of the 8 type of species

Peng, Z., Lei, L., Liu, Z., Sun, J., Ding, A., Ban, J., ... & Chu, K. (2018). The impact of multi-species surface chemical observation assimilation on air quality forecasts in China. Atmospheric Chemistry and Physics, 18(23), 17387-17404.

PM2.5 & PM10 in WRF_Chem

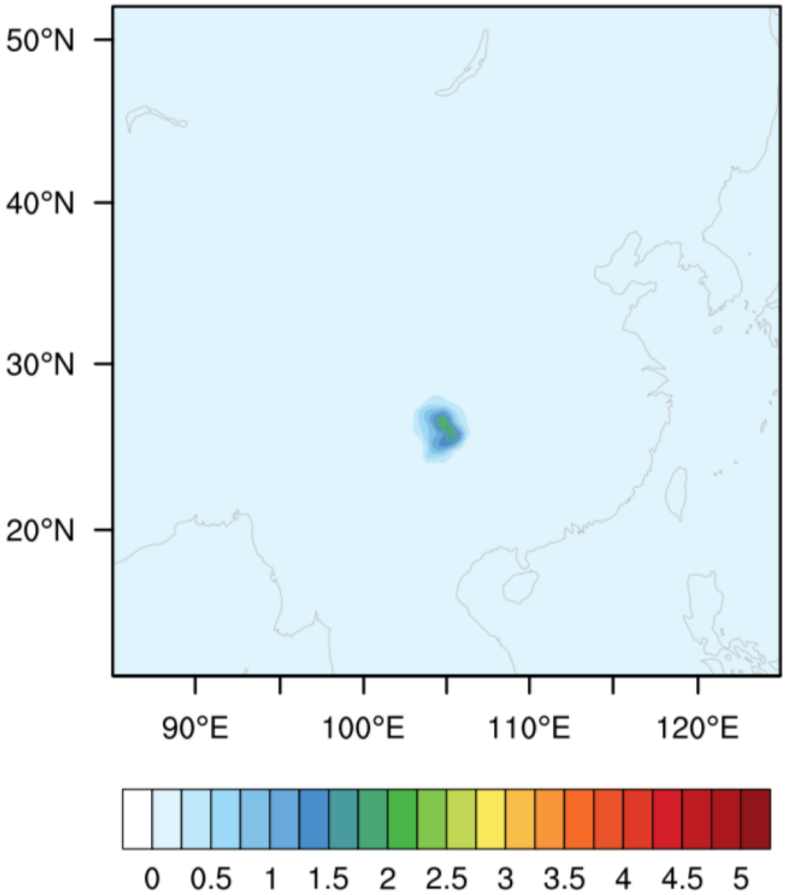
2015010200 UTC



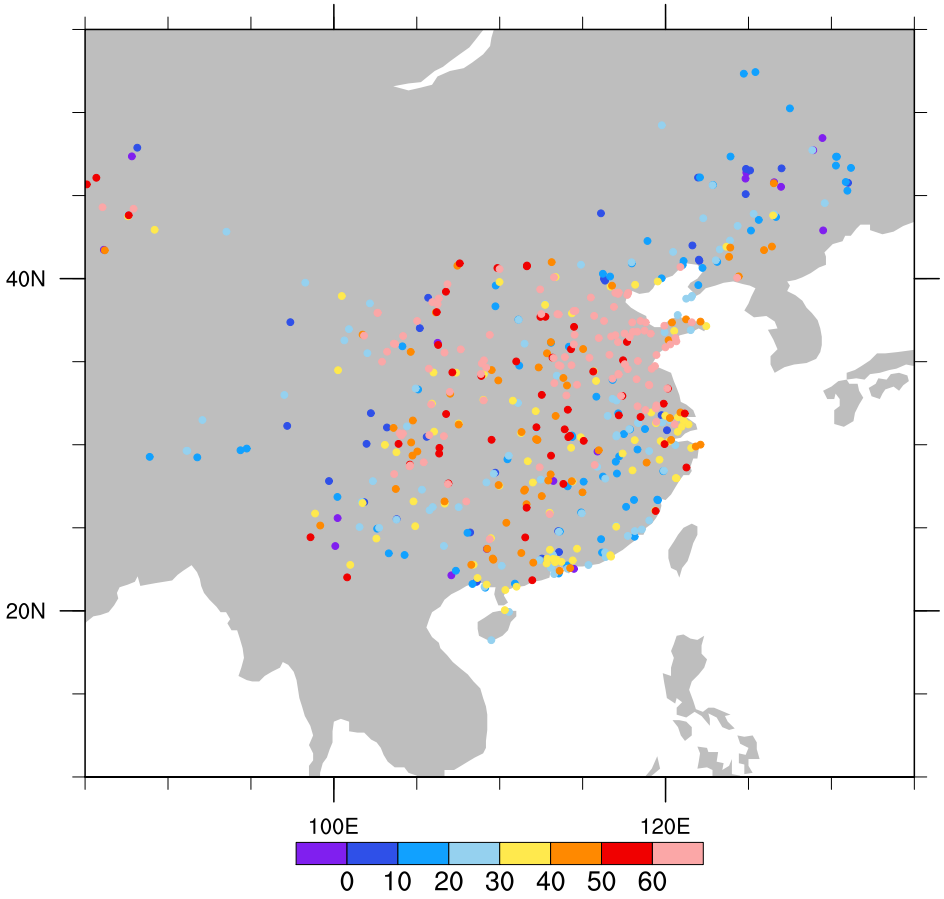
PM25 **PM10**

PM2.5 & PM10 in WRF_Chem

2015010200 UTC



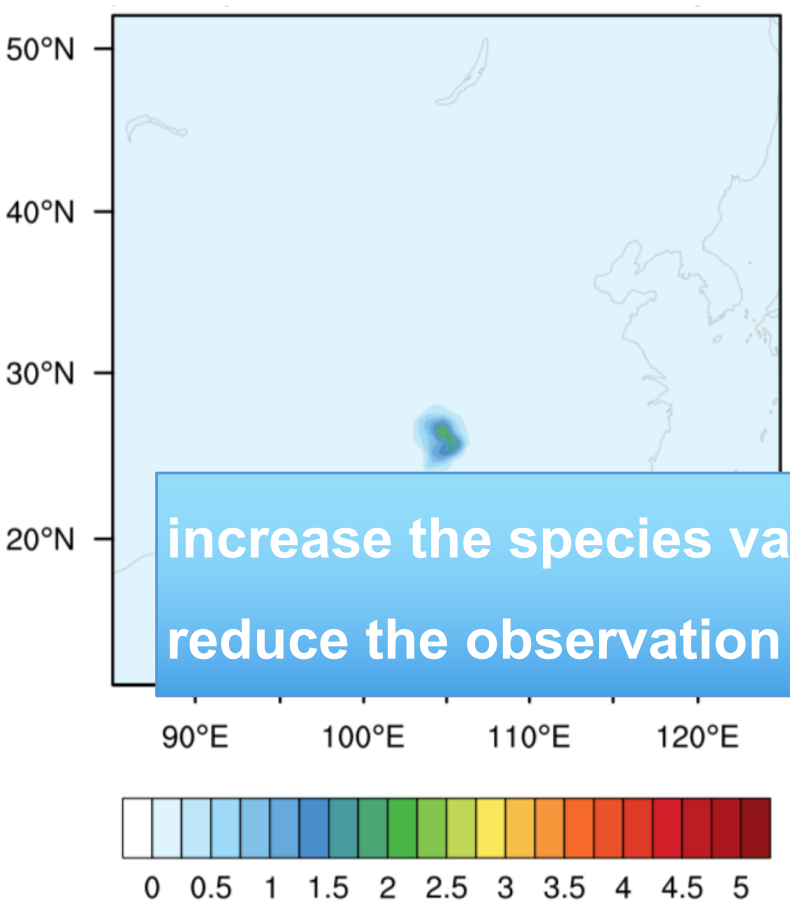
PM10-PM25 WRF



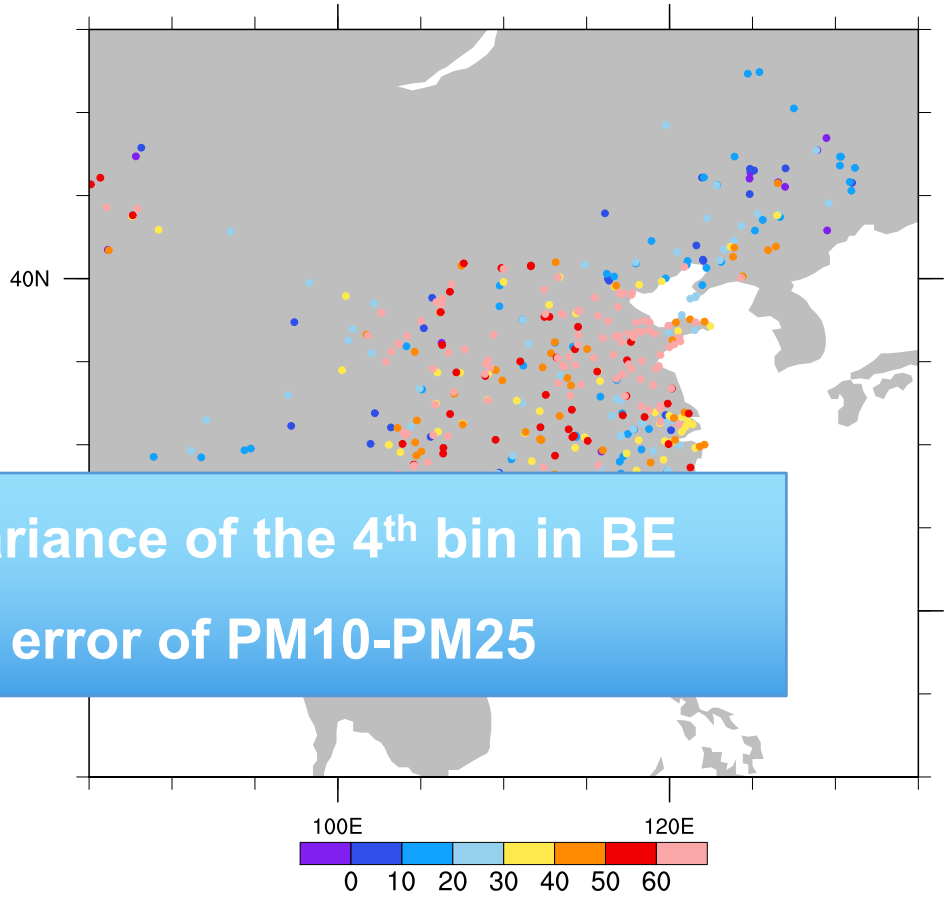
PM10-PM25 OBS

PM2.5 & PM10 in WRF_Chem

2015010200 UTC



PM10-PM25 WRF



PM10-PM25 OBS

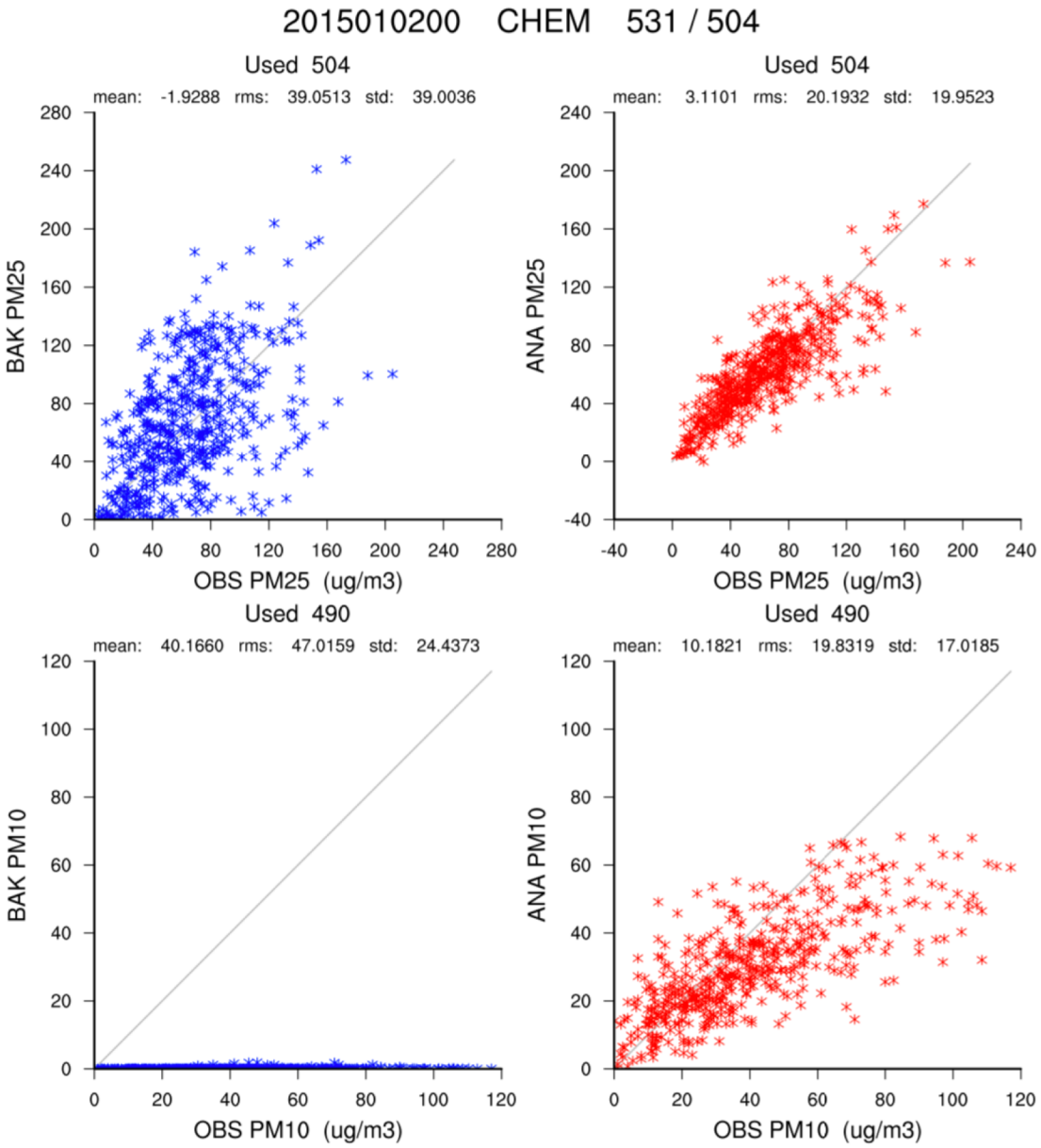
increase the species variance of the 4th bin in BE

reduce the observation error of PM10-PM25

PM2.5 & PM10 DA with MOSAIC

PM25

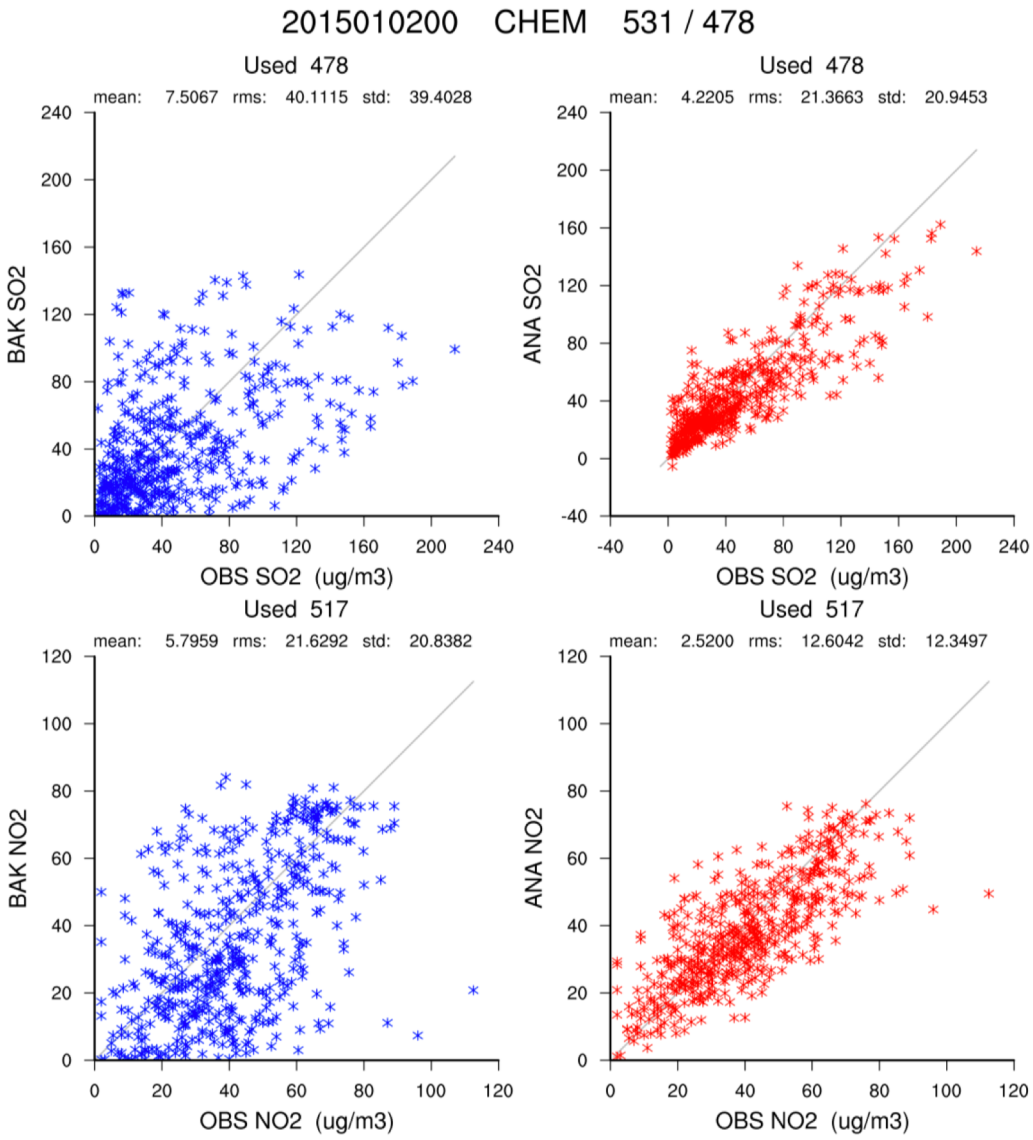
PM10-PM25



Gaseous Pollutant DA with MOSAIC

SO2

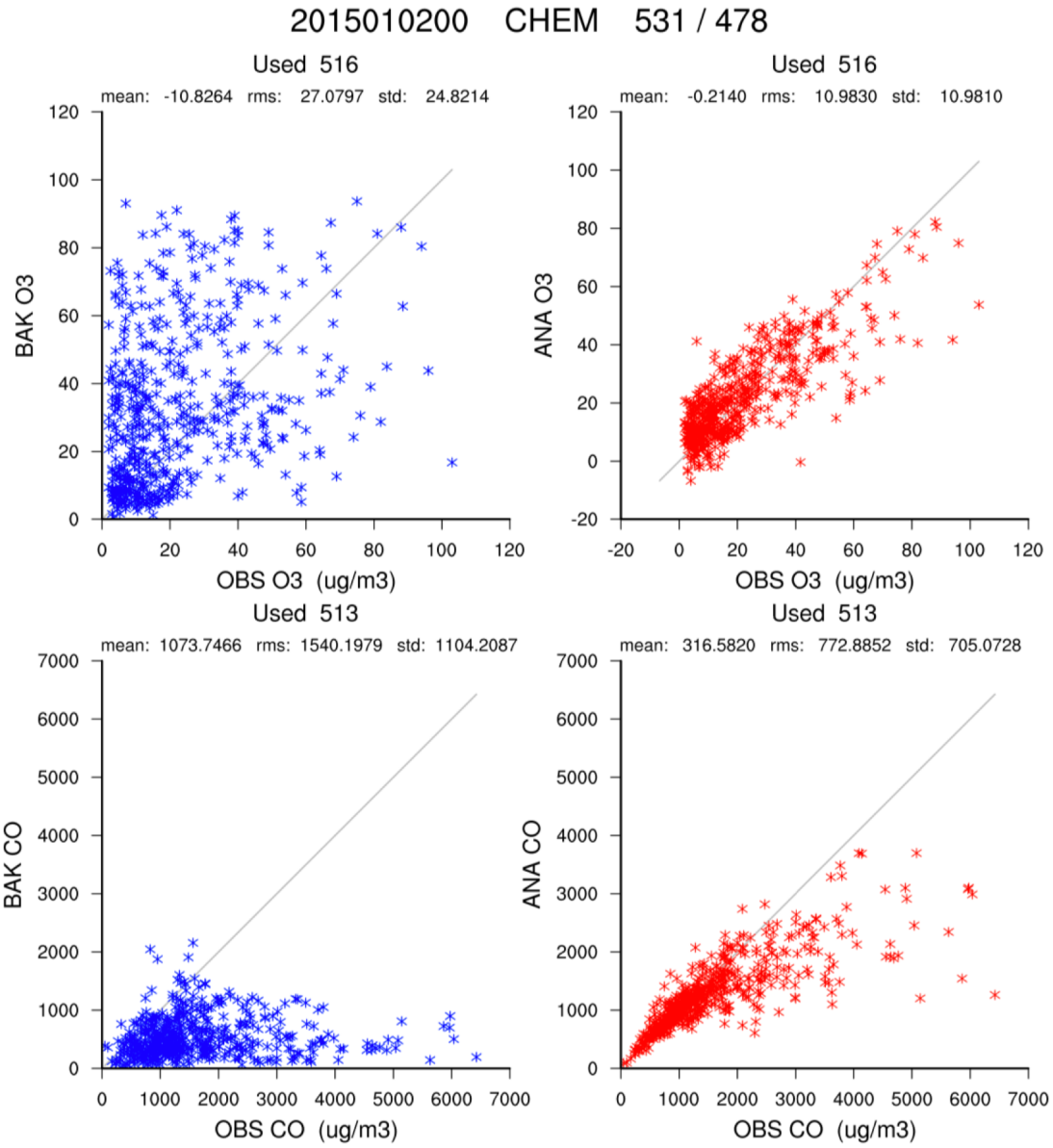
NO2



Gaseous Pollutant DA with MOSAIC

O3

CO



Conclusions and future works

- GENBE is developed to generate chemical statistics
- Chemical/Aerosol assimilation ability has been implemented in WRFDA-3DVar (PM2.5, PM10, SO2, NO2, O3, CO)
- Chemical/Aerosol DA system is designed with a flexible switch capability for different aerosol schemes
- Detailed analysis and further tuning
- Other chemical observation assimilation (satellite AOD)