Efficacy of dust aerosol forecasts for East Asia using the adjoint of GEOS-Chem with ground-based observations

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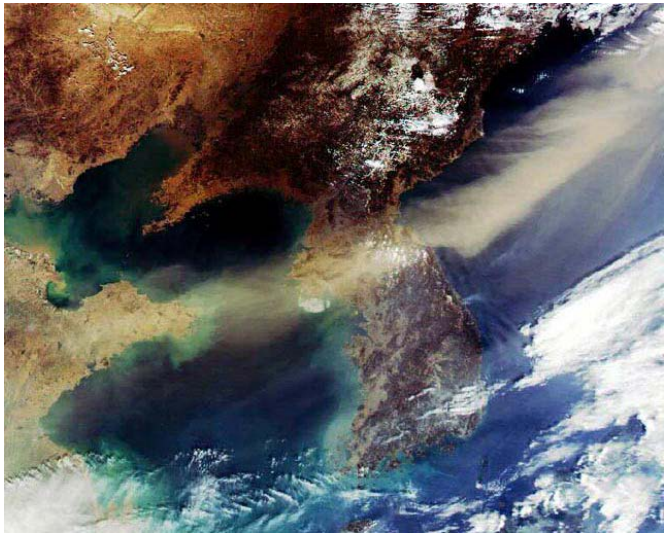
Objective and Methods

Examine the efficacy of the data assimilation (DA) system for daily dust storm forecasts based on the adjoint model and ground-based observations



GEOS-Chem Adjoint Model (v8-02-01)

- Driven by assimilated GEOS-5 meteorological fields from the NASA GMAO
- Spatial resolution of 2°x2.5°, 47 vertical levels

Case studies for dust forecast

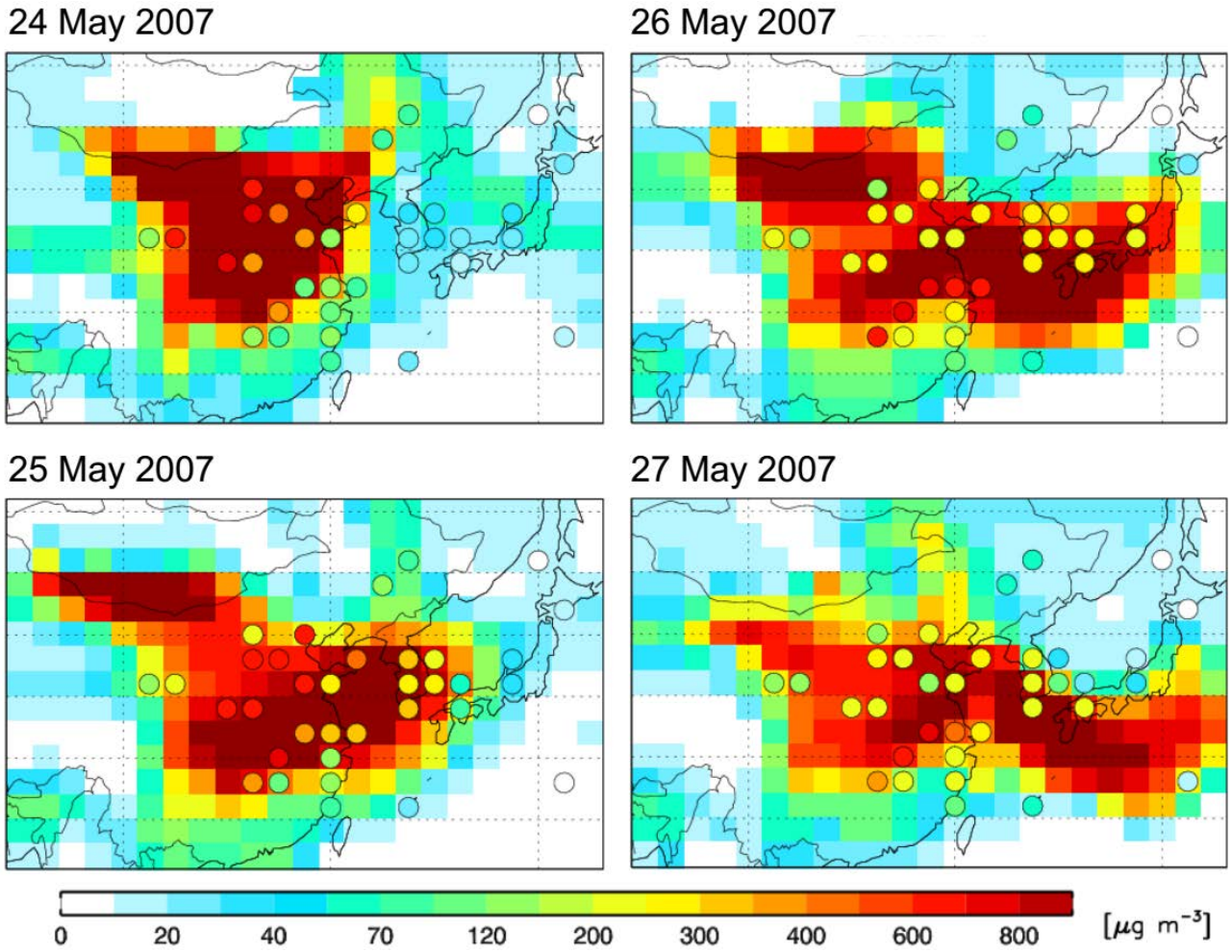
1. overestimation case (May 2007)
2. underestimation case (March 2011)

Observations

- Surface PM_{10}: API (China), NIER (Korea), EANET (Japan)

Simulated PM_{10} concentrations with a priori dust source in surface air

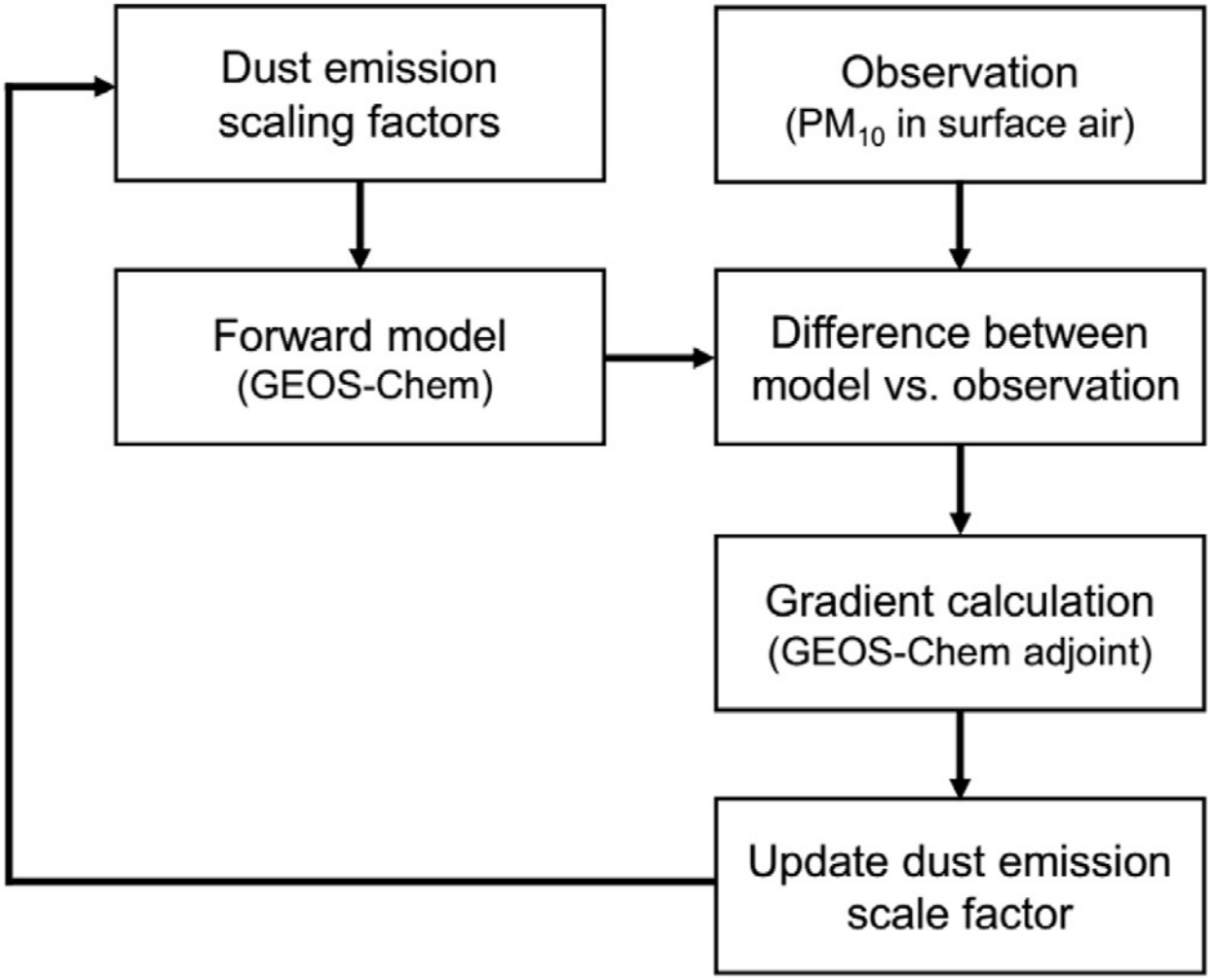
1. overestimation case (May 2007)



- ✓May 22-23, a severe dust storm occurred in the Gobi Desert.
- ✓The a priori model seems to capture the temporal evolution of dust aerosol transport.
- ✓But the model tends to overestimate the surface PM_{10} concentrations.

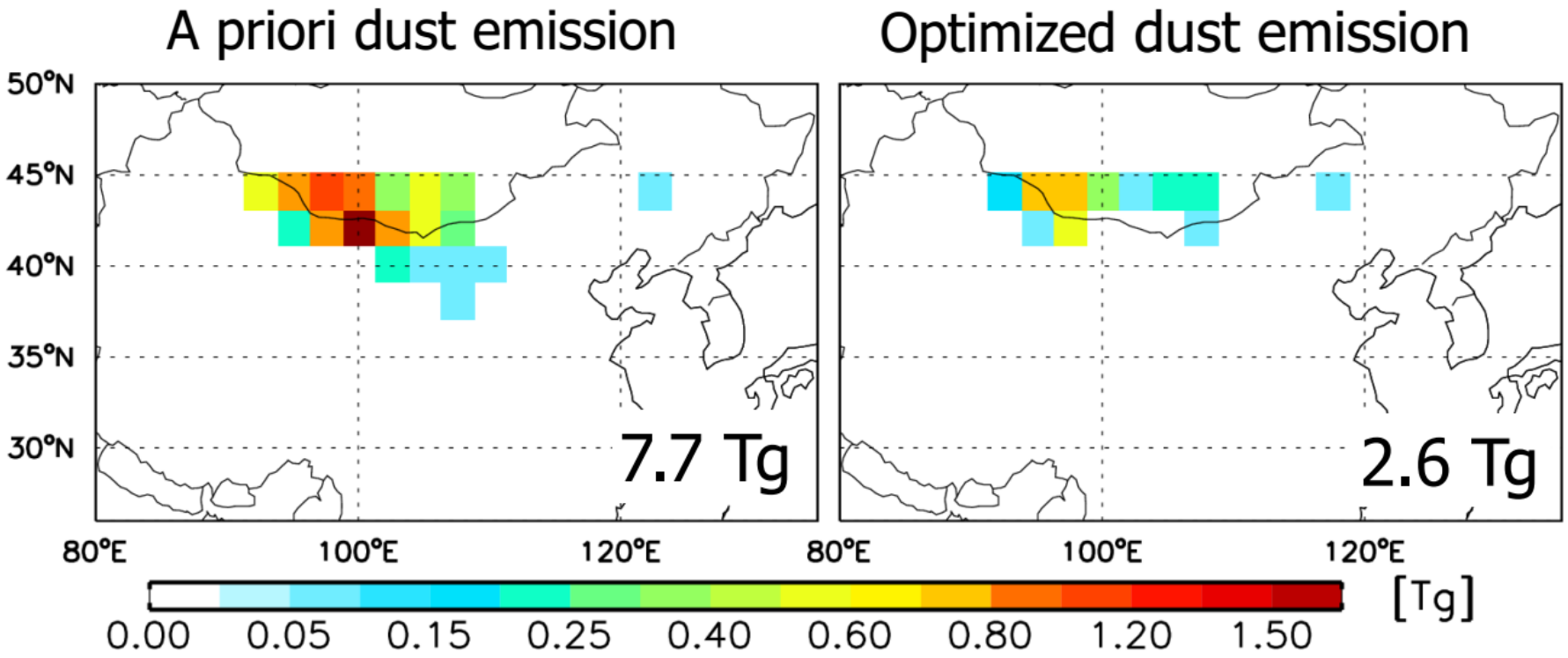
[Jeong and Park, 2018]

Flowchart of the proposed adjoint framework



Dust emissions simulated with a priori and optimized sources

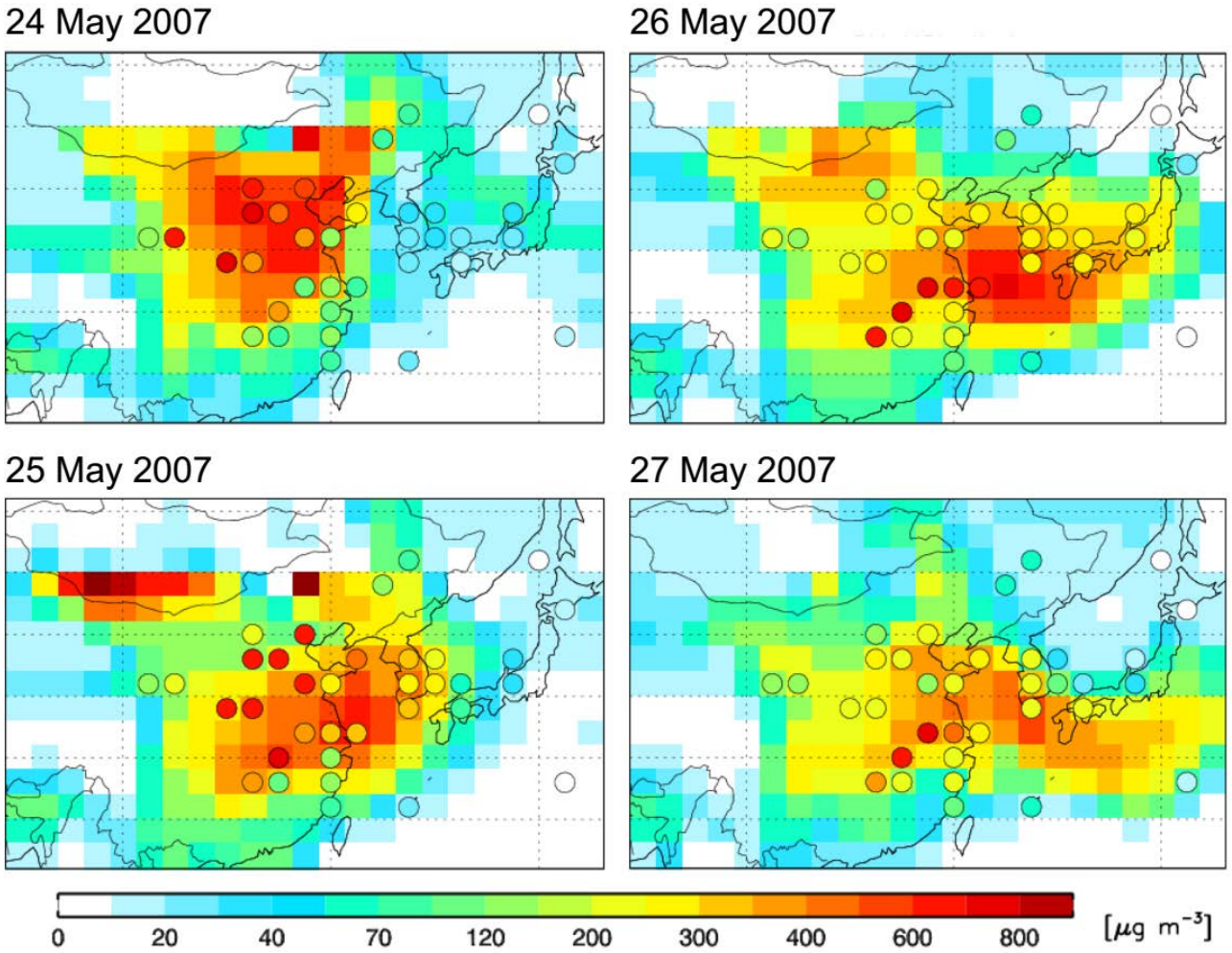
1. overestimation case (May 2007)



- ✓ To reduce the high bias of simulated dust concentrations, we applied the adjoint model with observed daily surface PM_{10} concentrations in East Asia.
- ✓ The a priori dust sources yield 7.7 Tg in the whole domain. However, the optimized dust emission based on the adjoint model calculation is 2.6 Tg.

Simulated PM_{10} concentrations with the optimized dust source in surface air

1. overestimation case (May 2007)

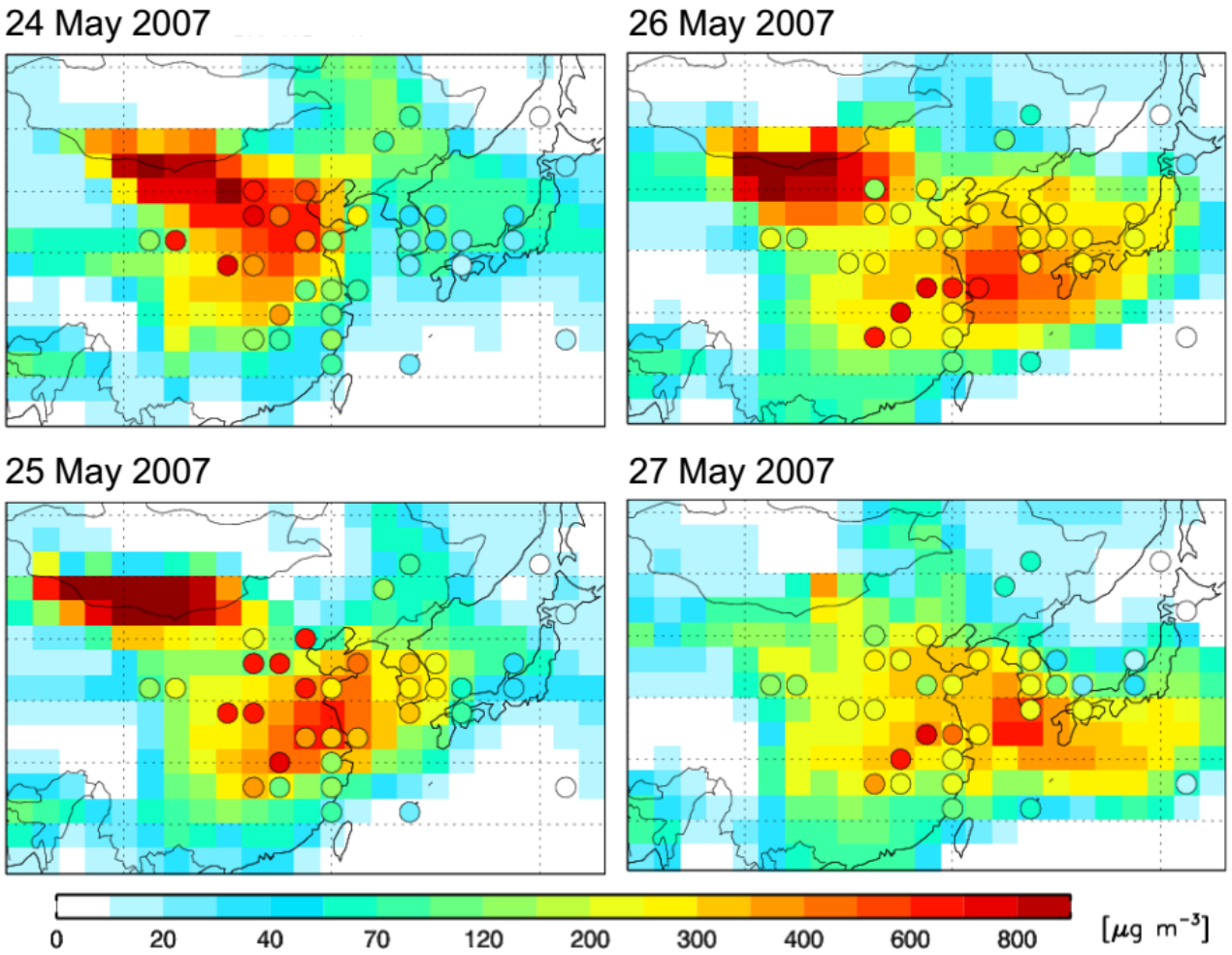


- ✓ The model with optimized dust sources better agrees with the observations, remarkably reducing the large bias.
- ✓ Successfully reproduces the spatial and temporal distributions of PM_{10} concentration observations, especially in downwind regions.

[Jeong and Park, 2018]

Surface PM_{10} concentrations forecasted with daily modified initial fields at 0000 UTC

1. overestimation case (May 2007)

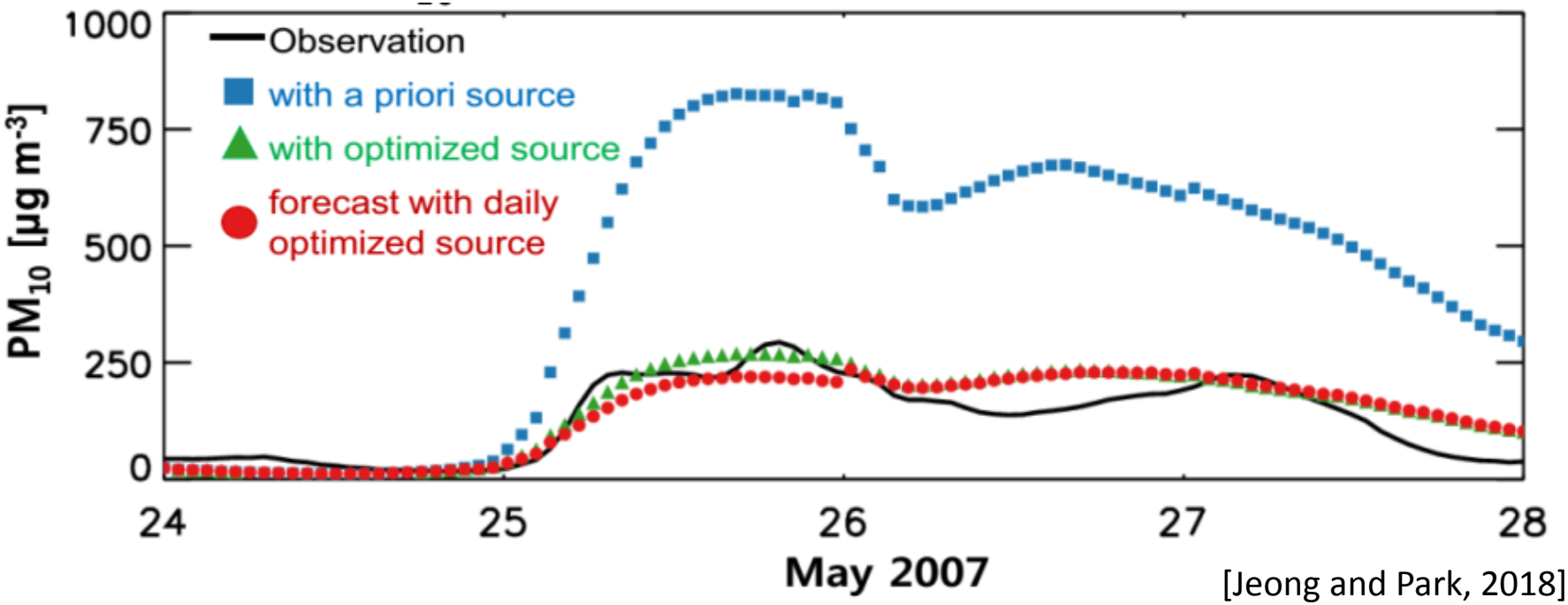


- The forecasts reproduce the high PM_{10} concentrations in downwind regions in Korea and Japan on May 25–27.
- The spatial pattern of the forecasted PM_{10} concentrations is similar to that of the observarions, even when based on the surface observations up to the previous day.

[Jeong and Park, 2018]

Observed and simulated hourly surface PM_{10} concentrations over South Korea

1. overestimation case (May 2007)



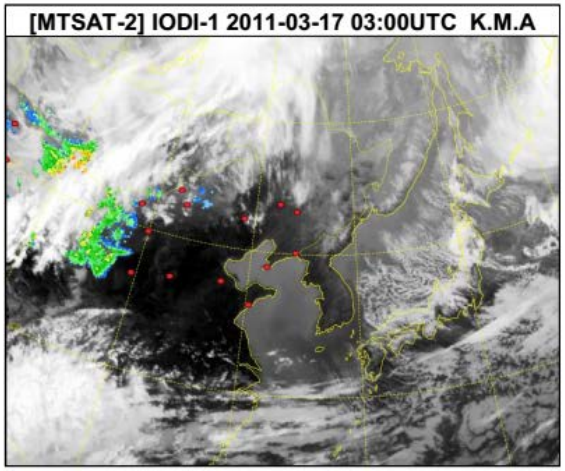
[Jeong and Park, 2018]

- Model with optimized dust sources significantly reduces the high bias.
- DA system successfully forecasts the time evolution of observed peak PM_{10} concentrations in Korea.

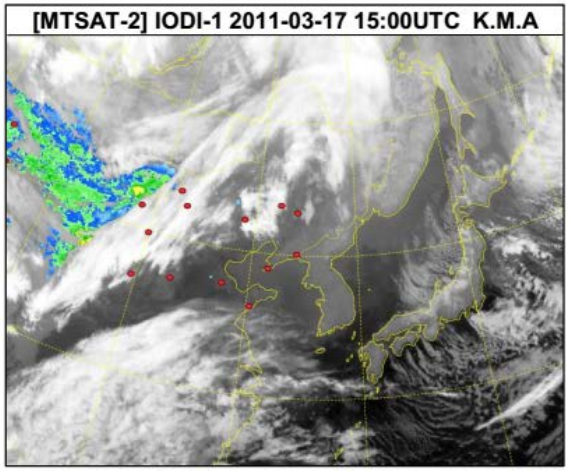
Satellite images of dust aerosol intensity on March 17-18, 2011

2. underestimation case (Mar 2011)

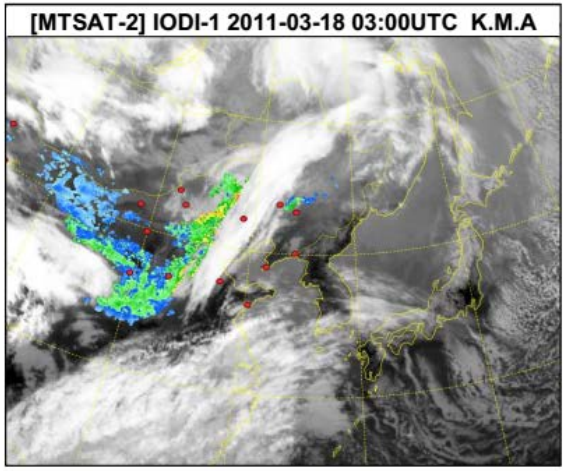
0300 UTC March 17, 2011



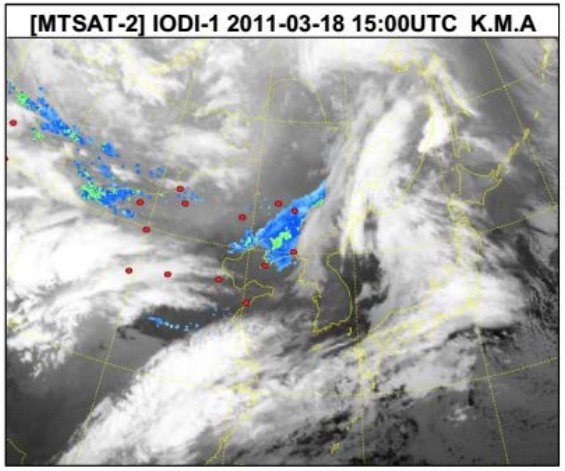
1500 UTC March 17, 2011



0300 UTC March 18, 2011



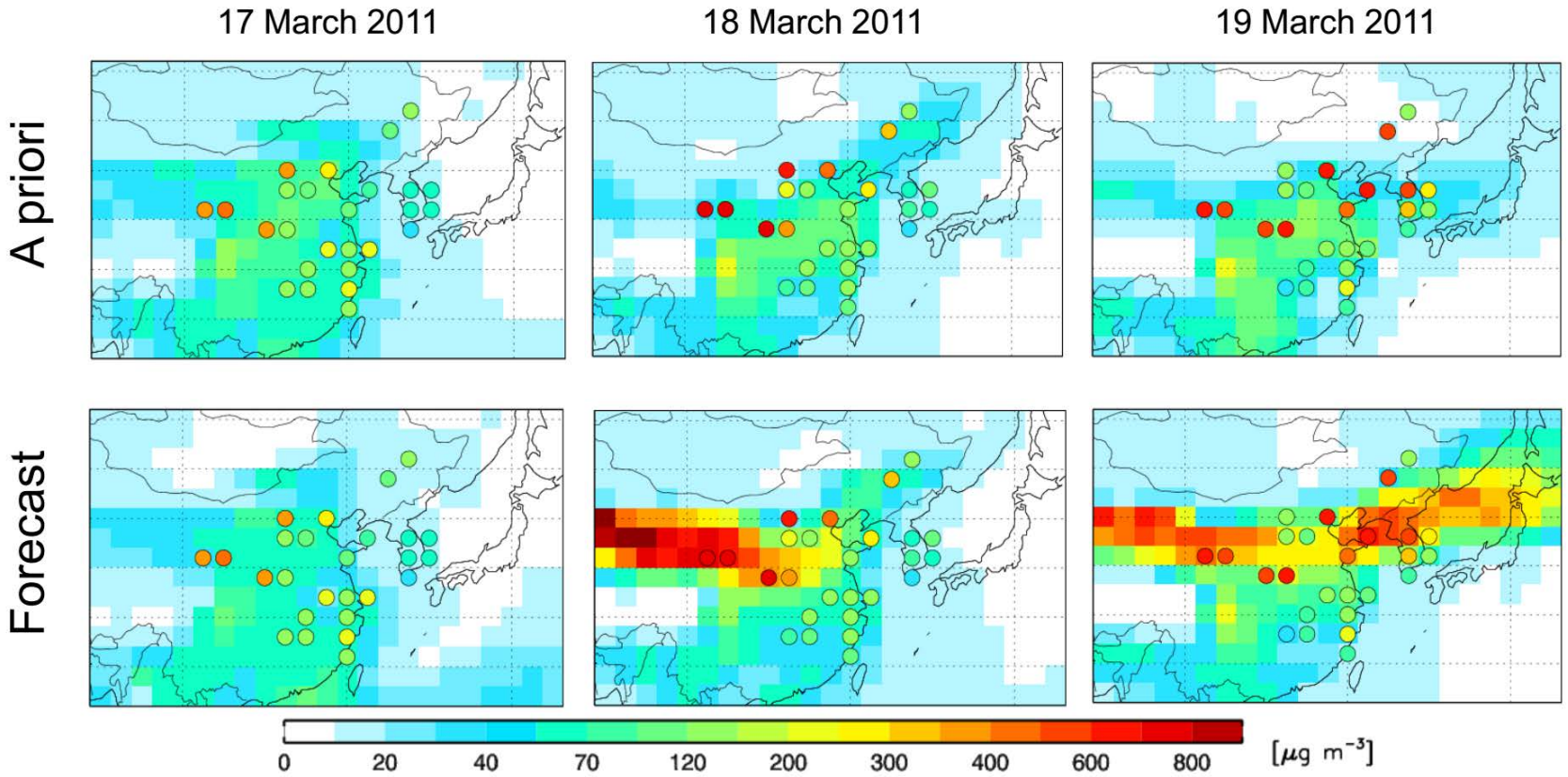
1500 UTC March 18, 2011



- A clear severe dust storm signal was observed in Northwest China on March 17; the dust storms moved southeastward following the low-pressure system.
- On March 18 a considerable dust signal was detected over eastern China approaching the western part of the Korean Peninsula.

PM_{10} concentrations simulated with a priori dust source and forecast in surface air

2. underestimation case (Mar 2011)

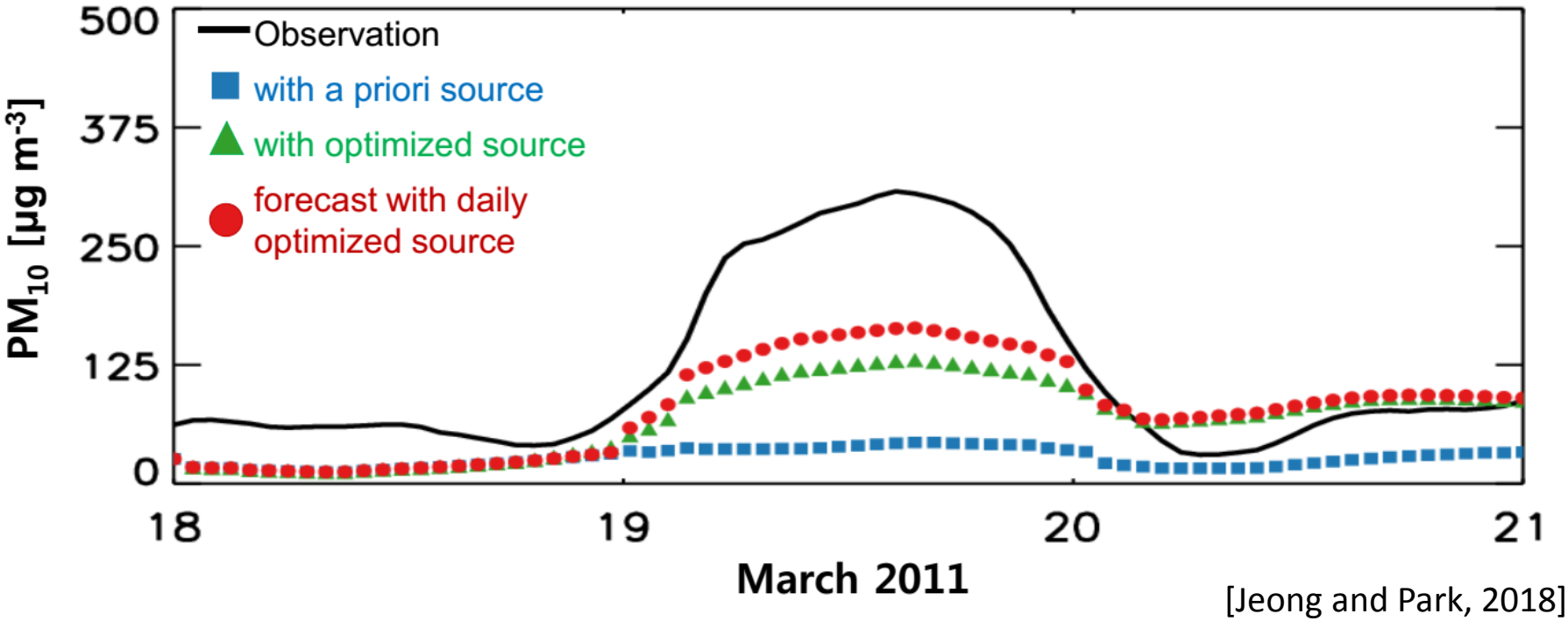


[Jeong and Park, 2018]

- The model with a priori dust sources does not show high concentrations at all.
- The forecast successfully reproduces the observed surface PM_{10} concentrations.

Observed and simulated hourly surface PM_{10} concentrations over South Korea

2. underestimation case (Mar 2011)



[Jeong and Park, 2018]

- The PM_{10} concentrations simulated with a priori sources are much lower than the observations (by a factor of 5), especially on March 19.
- The DA system generally captured the time evolution of observed PM_{10} concentrations including the core and tail of the severe dust storm.

Summary and discussion

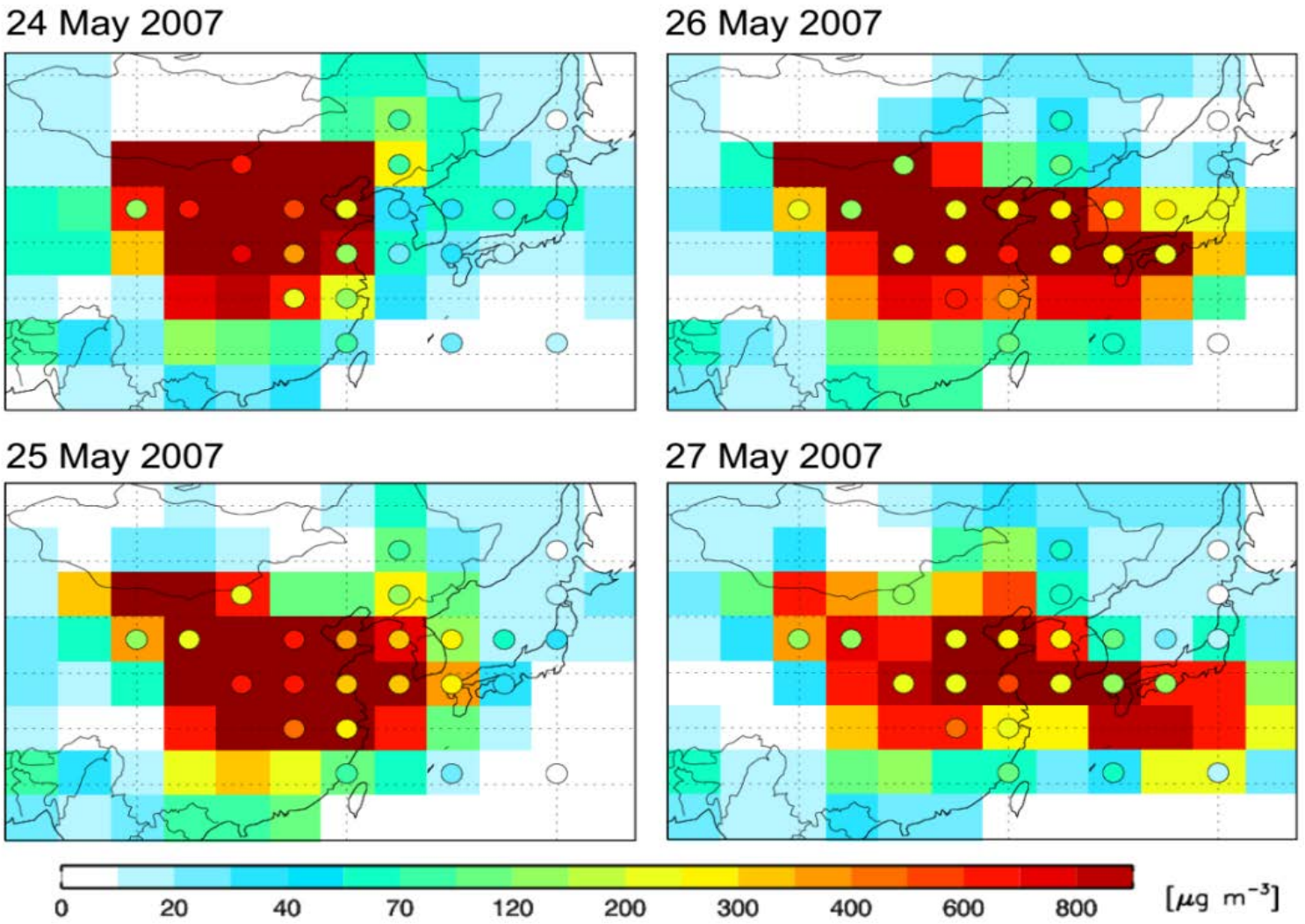
- The adjoint model constrained by observations showed better agreement with the spatial and temporal distributions of the observed PM_{10} concentrations through improved dust emissions in source regions.
- The forecast results successfully captured the spatial and temporal variations of ground-based observations in downwind regions, indicating that the data assimilation system with ground-based observations effectively forecasts dust storms, especially in downwind regions.
- Further work is necessary to improve the dust storm forecast by developing the DA system combining available hourly updated ground- and satellite-based aerosol data.

Thank You !

Sensitivity simulation for 4°x5° horizontal resolution on May 2007

1. overestimation case (May 2007)

❖ simulated with a priori dust sources

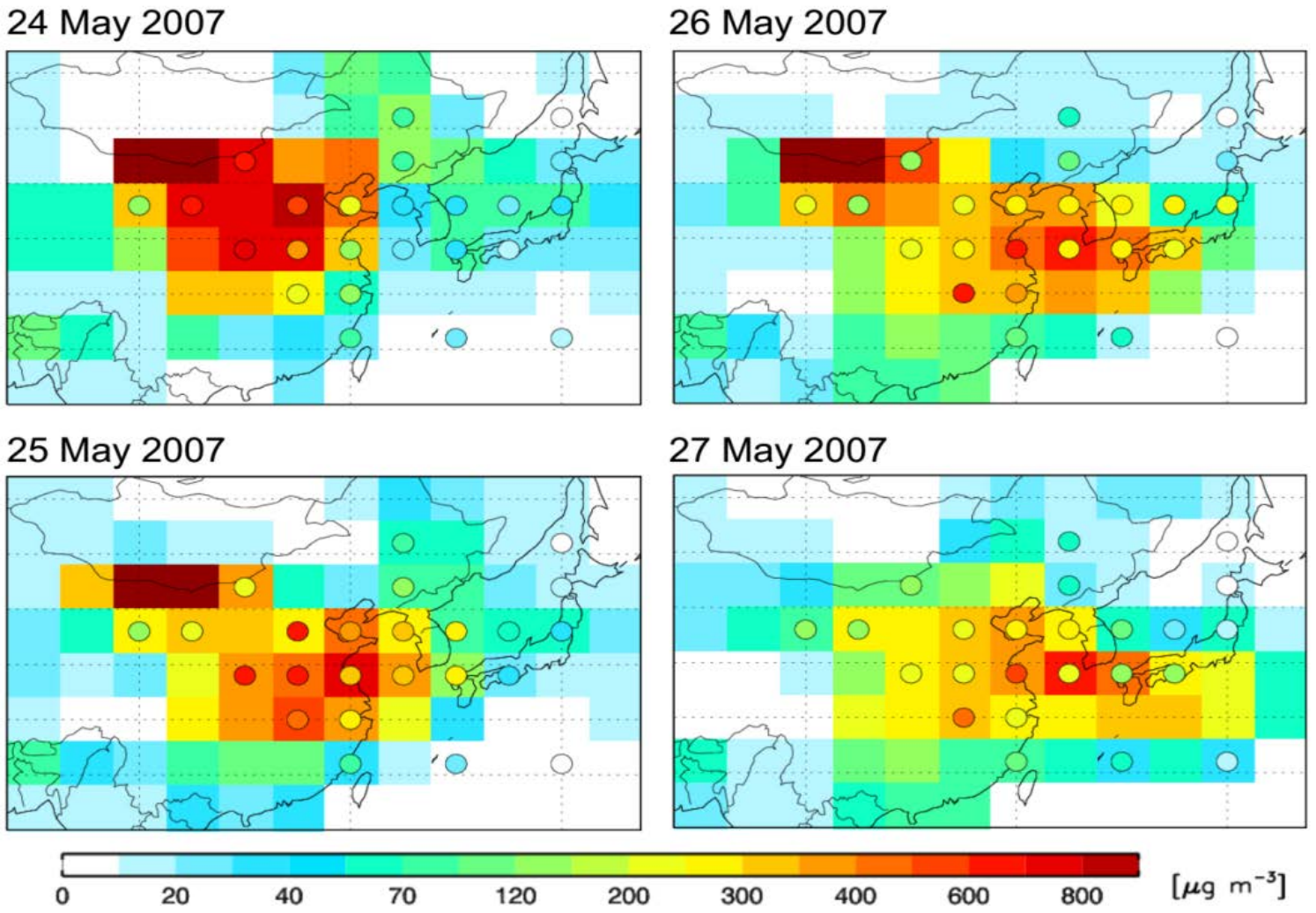


[Jeong and Park, 2018]

Sensitivity simulation for 4°x5° horizontal resolution on May 2007

1. overestimation case (May 2007)

❖ forecasted with daily modified initial fields at 0000 UTC



[Jeong and Park, 2018]

Statistics of the PM_{10} concentrations between model and observations in surface air

Case	Resolution	Simulation	R	regression slope	NMB (%)
May 2007	2°x2.5°	A priori	0.65	2.81	151
		A posteriori	0.63	0.85	1
		Forecast	0.62	0.77	-8
	4°x5°	A priori	0.78	4.06	242
		A posteriori	0.75	1.22	21
		Forecast	0.75	1.23	21
March 2011	2°x2.5°	A priori	0.19	0.15	-74
		A posteriori	0.61	1.02	-34
		Forecast	0.72	0.79	-51