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Influence of PBL schemes on simulation of a heavy pollution episode in winter

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Outline

1. Introduction
2. Methodology
3. Results and discussion
4. Conclusion

Introduction

- Pollution background of Jiangsu province

Jiangsu province is an important component of Yangtze River Delta. Haze day in 2012-2013 exceeds 170 days, 30.4% of which are in winter.

It's meaningful to know impact of different set of model configuration on winter air pollution simulation.

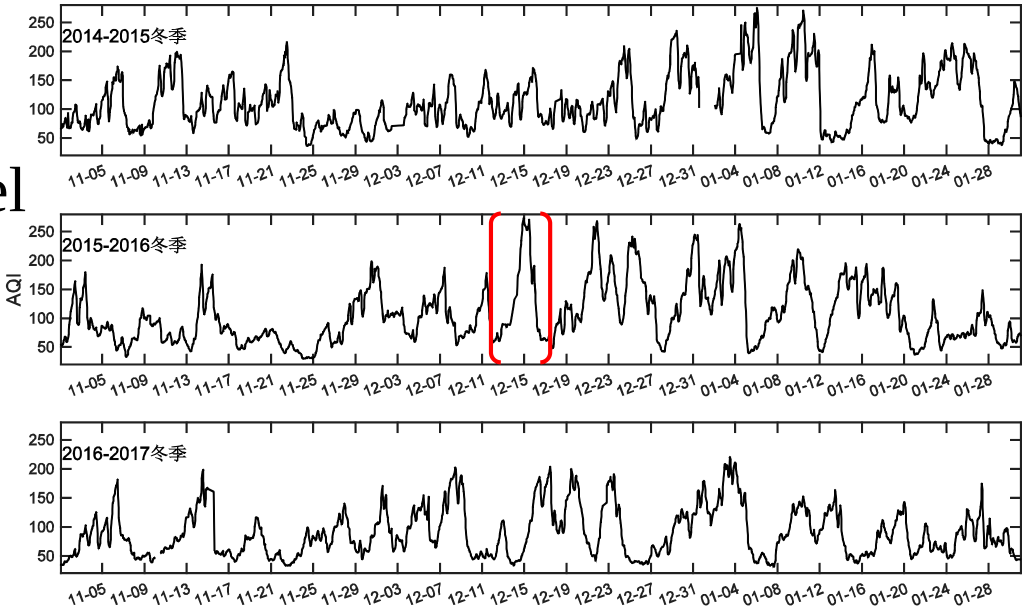


Fig.1 daily variation of AQI index during 2014-2016 winter
AQI exceed 250 is defined as heavy polluted.

●Impact of PBL schemes on air pollution simulation

Meteorological conditions, including horizontal and vertical wind components, temperature, water vapor mixing ratio, surface pressure, solar radiation, cloud fraction, precipitation, boundary layer height, and turbulence, are known to have direct impact on the simulation.

PBL schemes characterize the boundary layer structure in the lower atmosphere, where interchanges energy and matter.

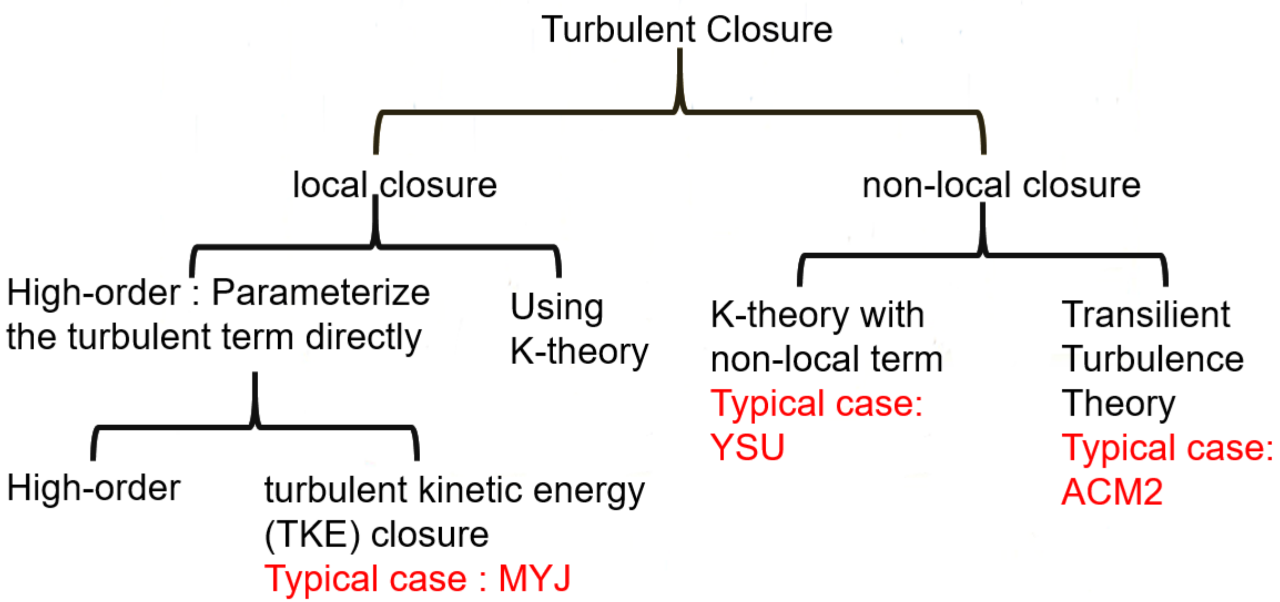


Fig2. Differences of PBL schemes

Uncertainly in emission inventory

Emission inventories are crucial ingredients to successful air quality modeling but are subject to great uncertainty. Tsinghua MEIC inventory(2012) is widely used in simulations for China, however due to comprehensive implementation of FGD and SCR/SNCR in Jiangsu Province, SO2 and NOx were not promptly captured in national inventory.

Table.1 The online power emission inventory, MEIC's power emission inventory and their ratio in total emission inventory over Jiangsu Province in 2012.(Zhang)

	Online power emission		MEIC power emission	
	Emission (tons $year^{-1}$)	Ratio in total (%)	Emission (tons $year^{-1}$)	Ratio in total (%)
SO_2	105579.2	10.4	367812.3	28.8
$PM_{2.5}$	21624.8	3.7	72171.6	11.3
PM_{10}	32641.2	4.0	103737.7	11.6
NO_x	277906.1	17.2	733814.4	35.4
CO	581950.5	6.2	343493.2	3.7
BC	3560.7	4.3	144.8	0.2
OC	2494.3	1.7	0.1573	0.0
NMVOCs	17328.6	0.9	7178.0	0.4

Methodology

Table.2 methodology table

Model input	Initial and boundary meteo. field	6h **FNL** reanalysis dataset at 1° resolution
	Landuse	MODIS 20
	Initial and boundary chem. field	Simulation **MOZART-4/GEOS-5** data
	Emission inventory	Modified MEIC inventory SO_2 reduced to 28% of orig. NO_x reduced to 38% of orig.
Model configuration	Simulation period	2015.12.09 00(UTC)—2015.12.18 00(UTC)
	Horizontal resolution	Domain1: 15km; Domain2: 5km
	PBL and sfclay schemes	Case1: YSU & Revised MM5 scheme
		Case2: ACM2 & Pleim-Xiu scheme
		Case3: MYJ & Monin-Obukhov scheme

Data used	Meteo	From national and base stations
	Pollute	From national stations

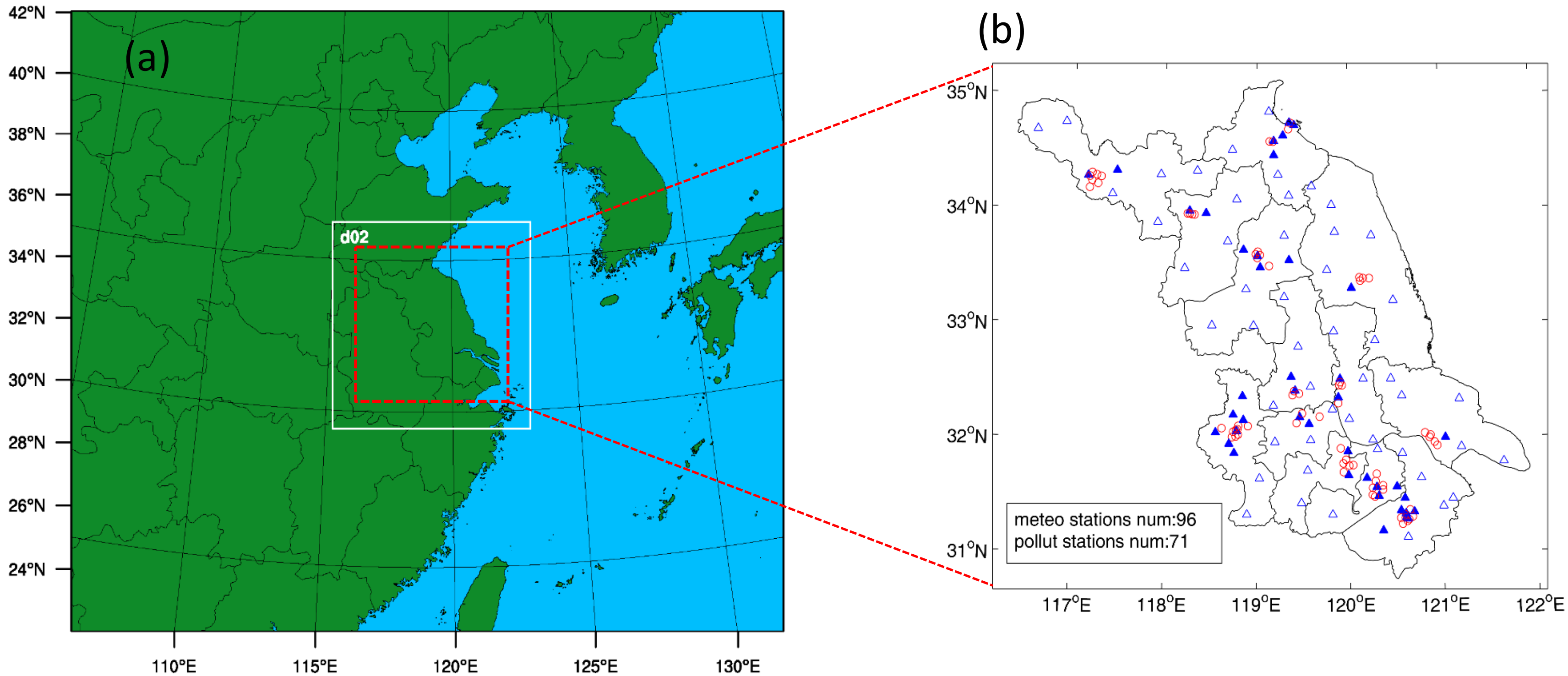


Fig.3 Nested modeling domains (a), the distribution of observation sites within domain 2 (b): circles: pollution observe sites; open triangles: rural meteo observe sites; filled triangles: urban meteo observe sites.

Meteorological situation of simulation period:

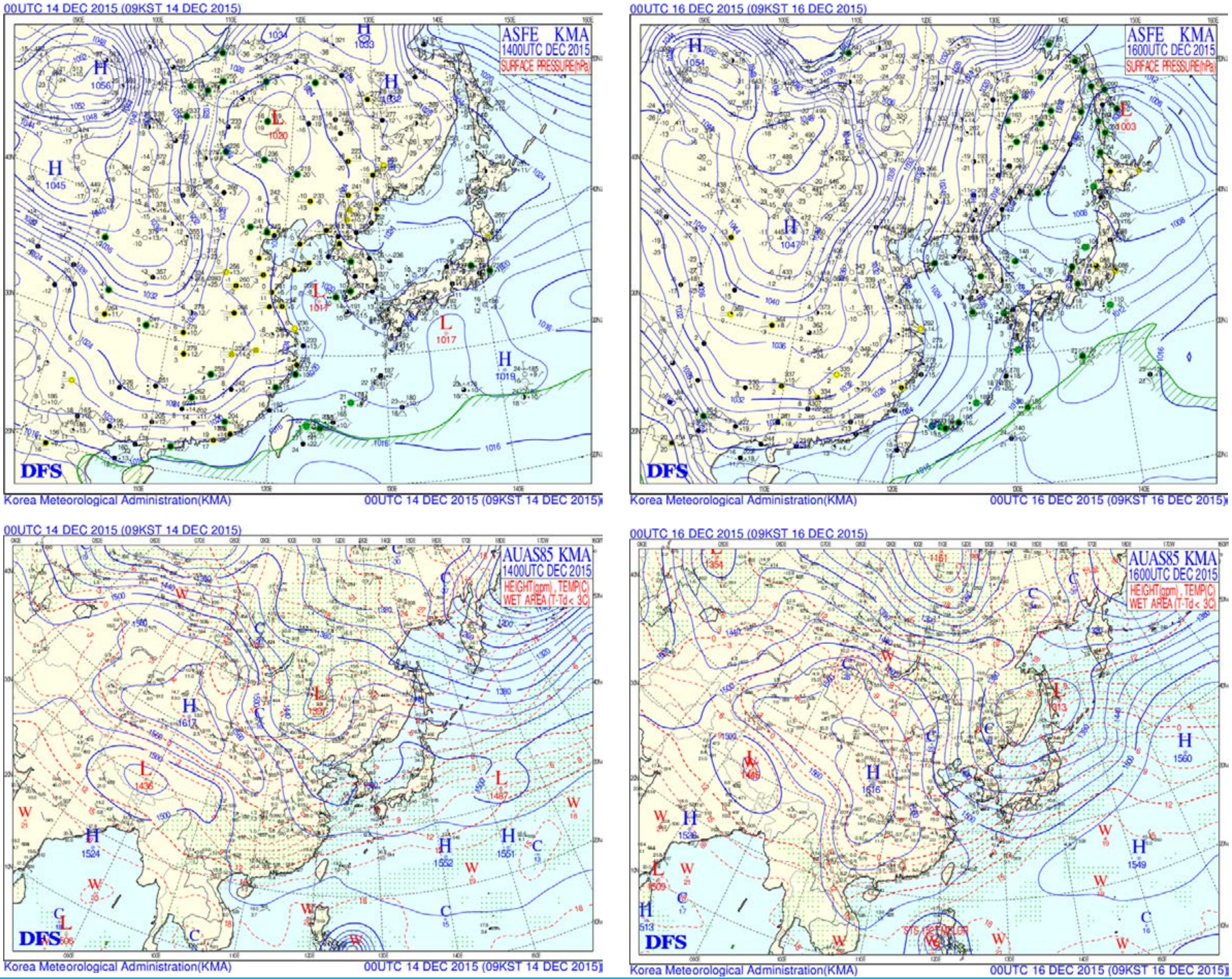
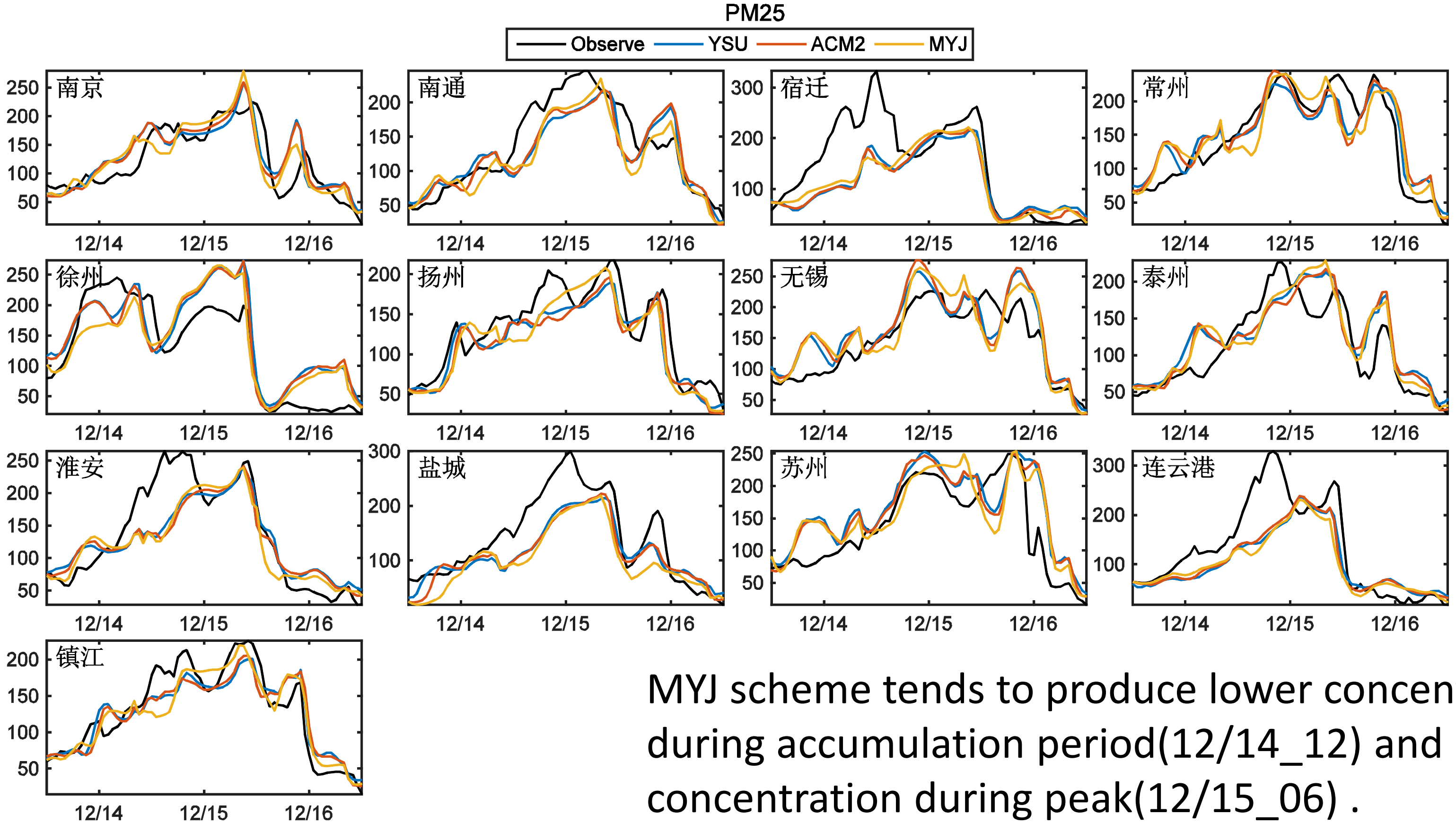


Fig.4 meteorological situation of simulation period(surface and 850hpa analysis map) from KMA

Results and discussion

PM2.5 data comparison:



MYJ scheme tends to produce lower concentration during accumulation period(12/14_12) and higher concentration during peak(12/15_06) .

Fig.5 hourly PM2.5 variation of 13 cities

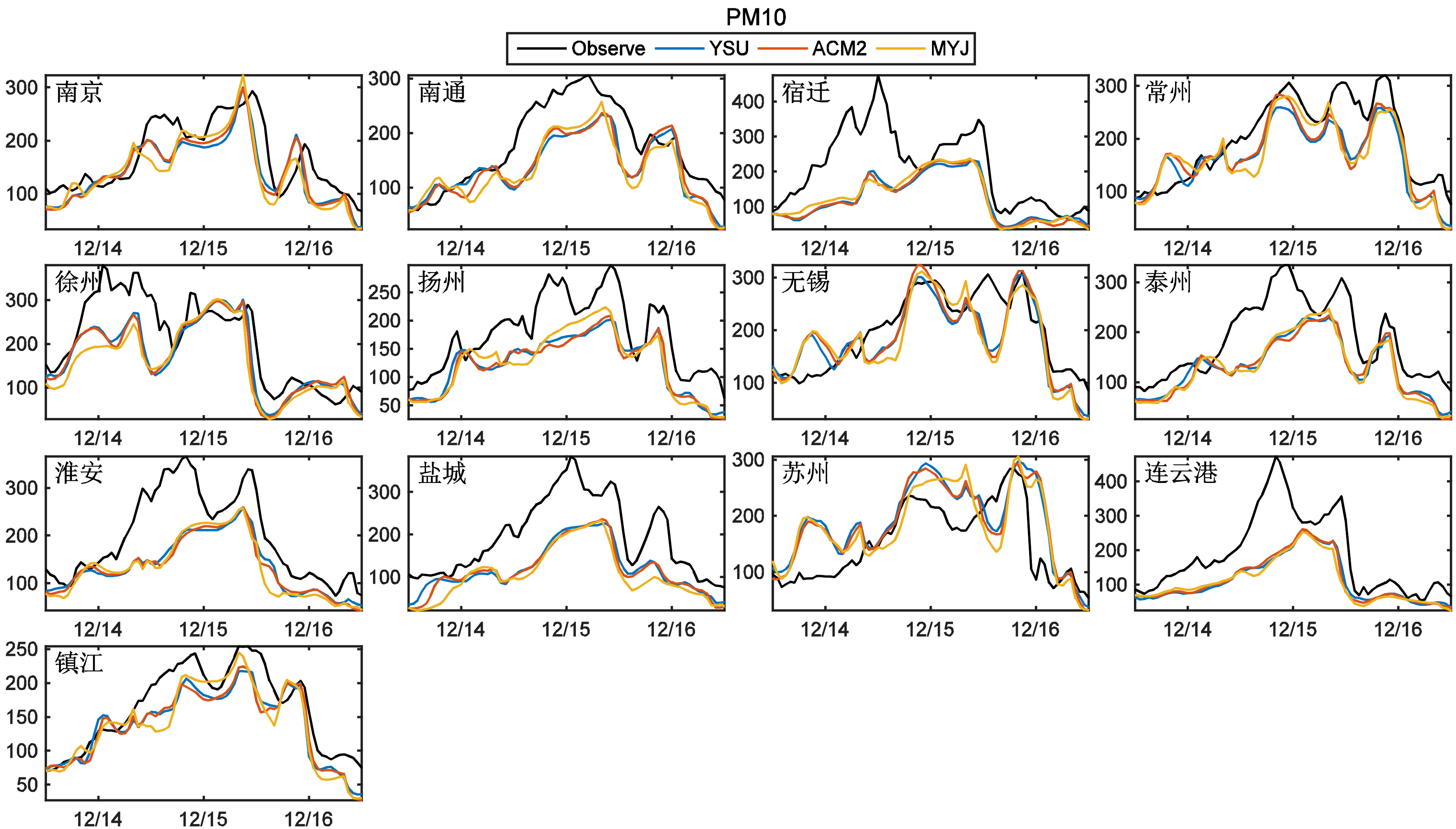


Fig.6 hourly PM10 variation of 13 cities

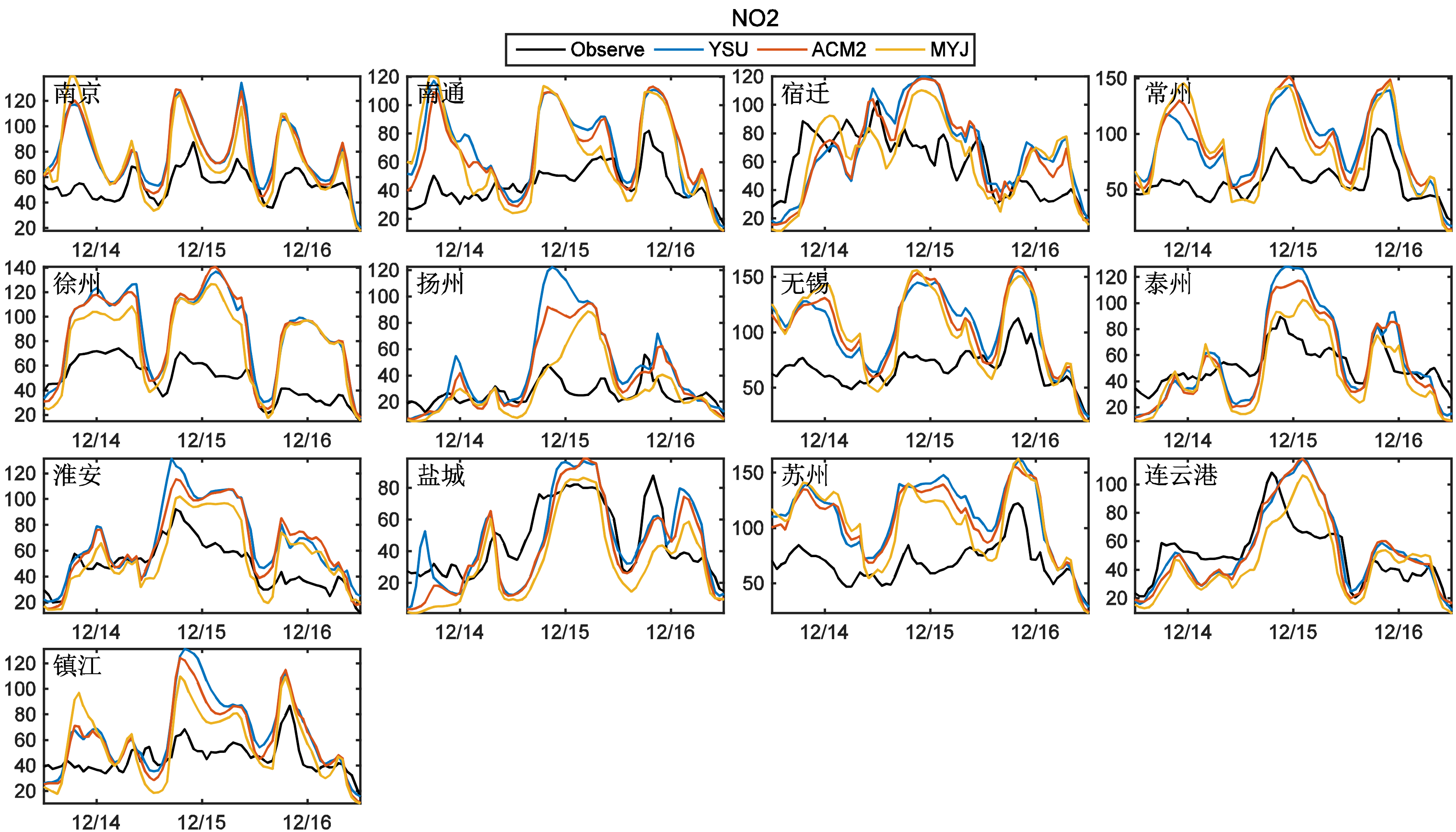


Fig.8 hourly PM10 variation of 13 cities

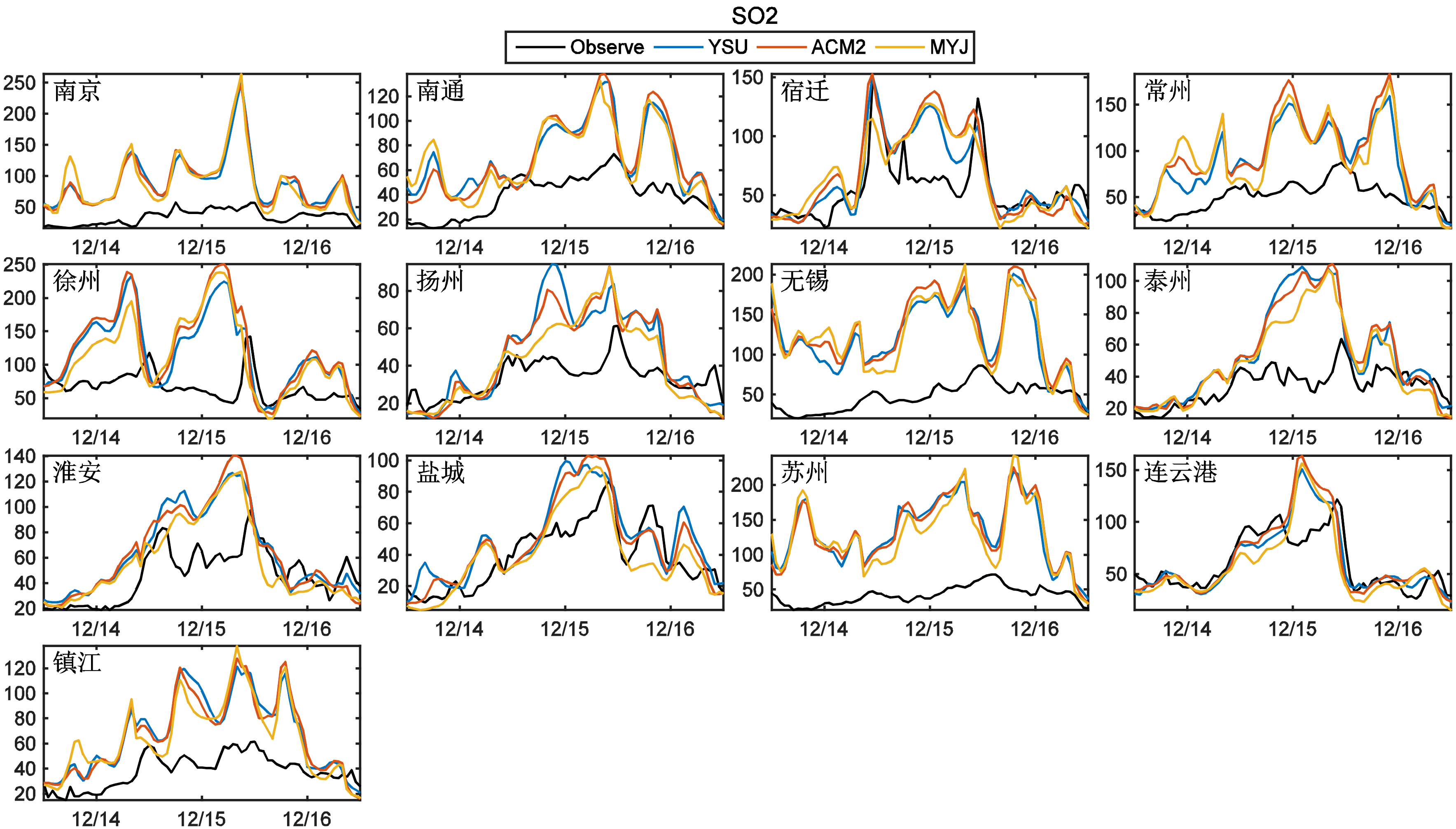


Fig.9 hourly PM10 variation of 13 cities

Select Yangzhou to analysis PM2.5, taylor diagram contains these statistics:

Centerd-RMS difference:

$$E'^2 = \frac{1}{N}\sum_{n=1}^{N}\left[\left(f_n - \bar{f}\right)^2 - (O_n - \bar{O})^2\right]$$

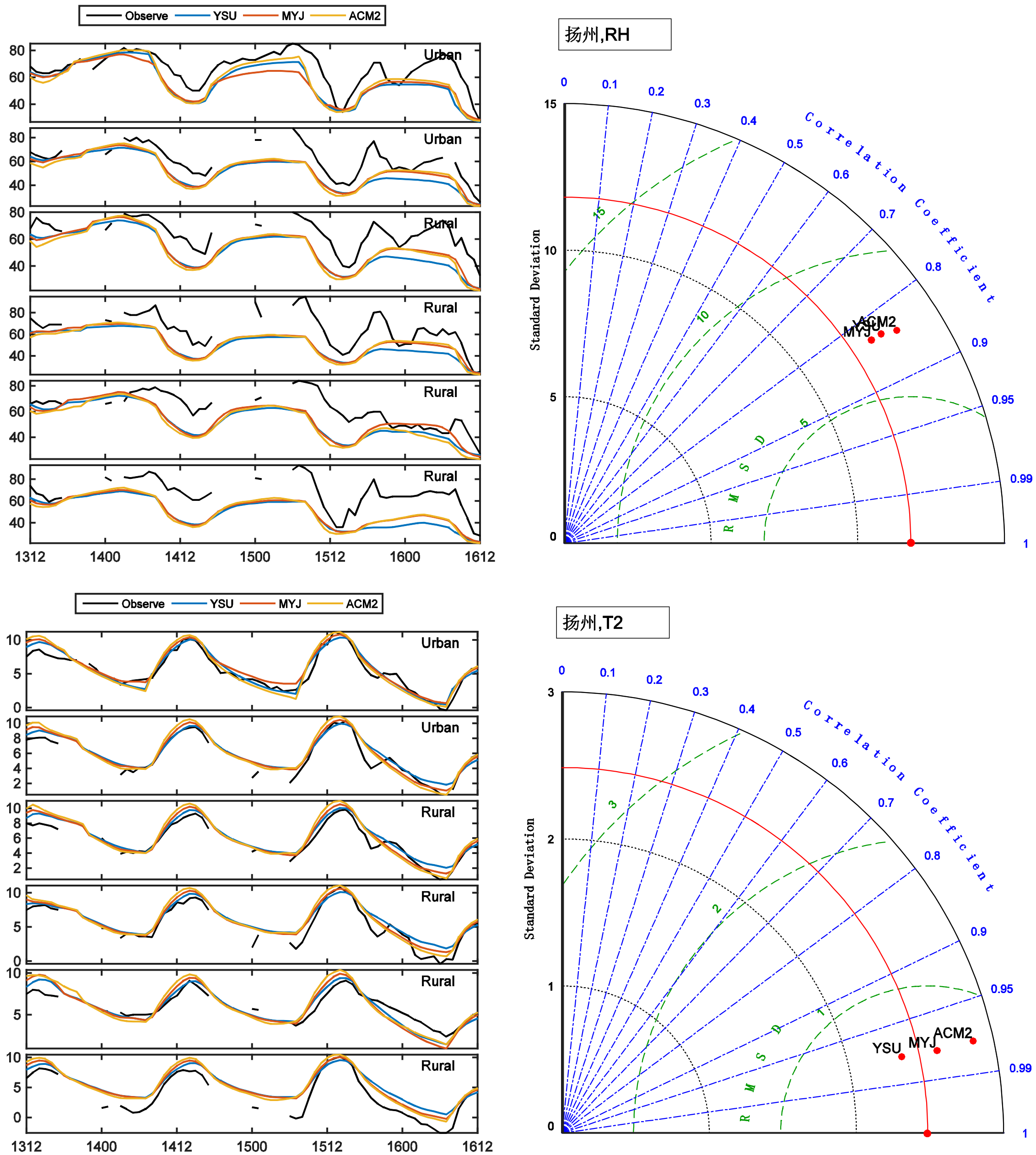
Correlation-coefficient:

$$R = \frac{\frac{1}{N}\sum_{n=1}^{N}\left(f_n - \bar{f}\right)(O_n - \bar{O})}{\sigma_f \sigma_O}$$

Standard deviation:

$$\sigma_f^2 = \frac{1}{\mathrm{N}}\sum_{n=1}^{N}\left(f_n - \bar{f}\right)^2$$

A good simulation result should have low centered-RMS difference, high correlation-coefficient and similar standard deviation to observation.



For RH and T2 all schemes produce well and no significant disparity among each other.

Fig.10 hourly variation of relative humidity and temperature in 2m in Yangzhou city and their taylor diagram.

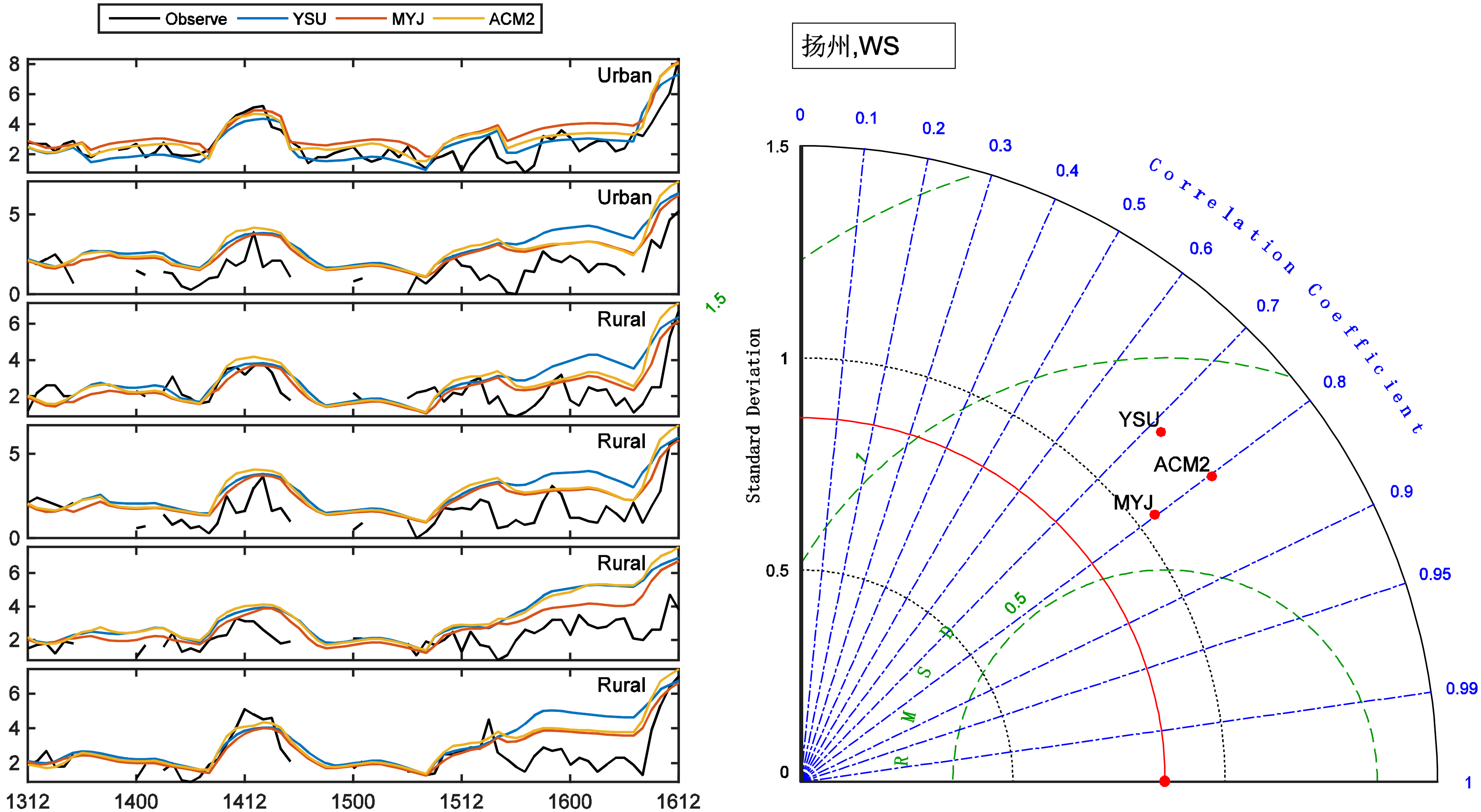


Fig.11 hourly variation of wind speed in Yangzhou city and its taylor diagram.

All schemes tend to produce higher wind speed
MYJ simulates wind best.

Spatial distribution of PM2.5 on 2015121500

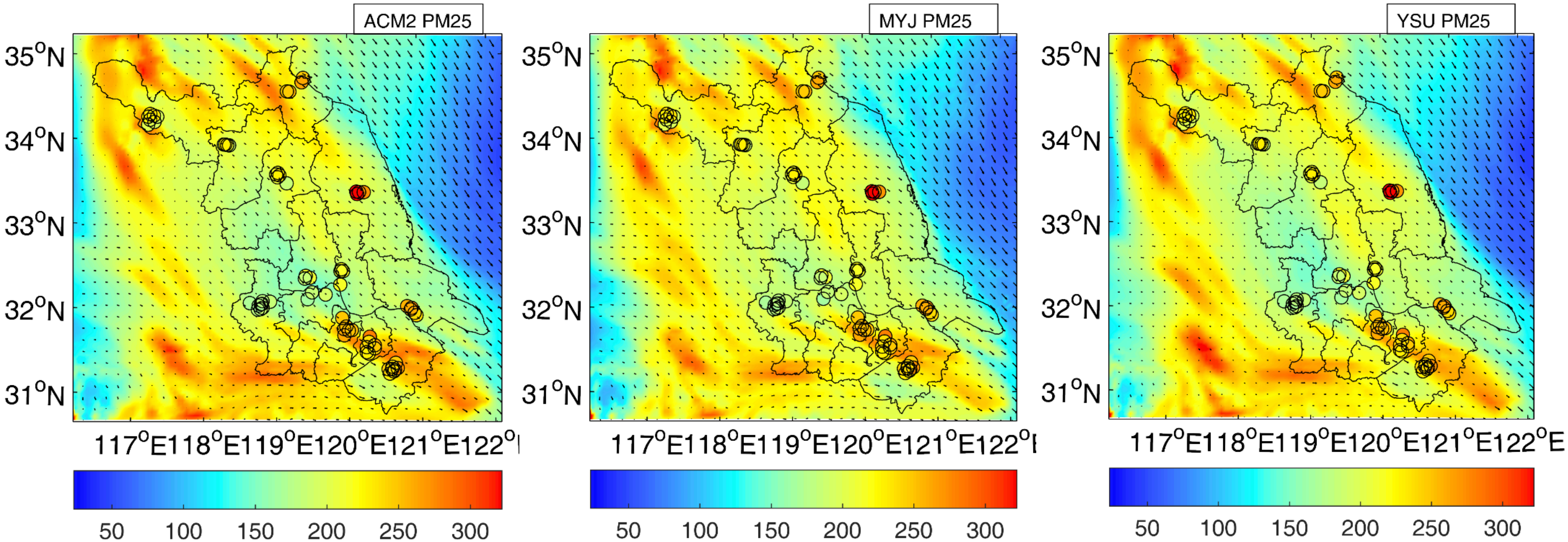


Fig.12 PM2.5 contour map with wind vectors and observe circles on 2015121500(Local time)

YSU has a relative clean Jiangsu province.

Since horizontal difference is not clear, it’s more likely that vertical diffusion plays an important role.

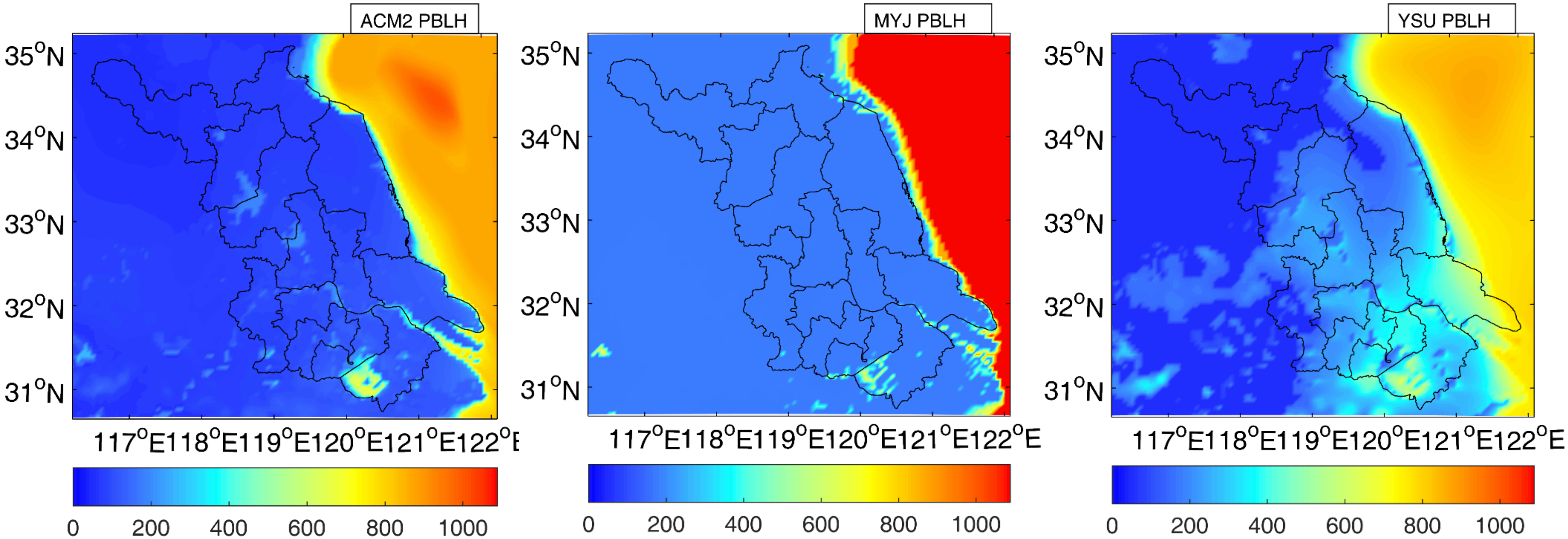


Fig.13 PBLH contour map on 2015121500(Local time)

MYJ and ACM2 produce lower and uniform PBLH in land and higher on sea,
YSU produces PBLH more related to landscape and higher in land,
These may interpret the difference of PM2.5

Spatial distribution of PM2.5 on 2015121514

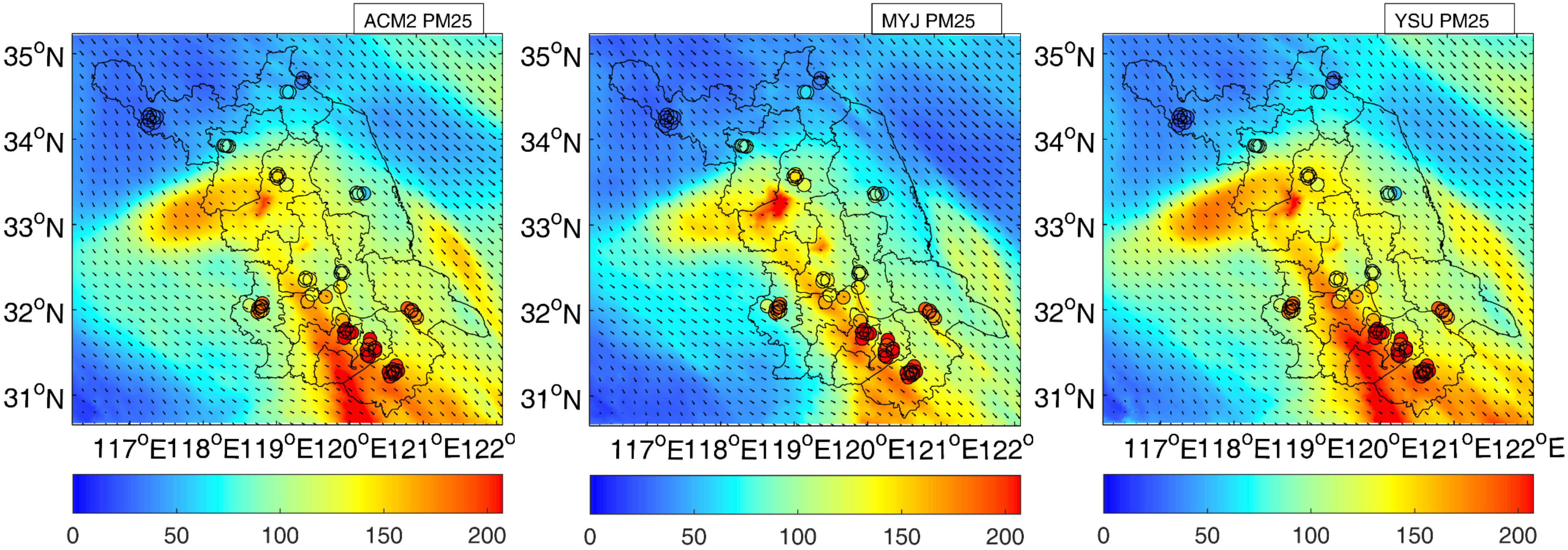


Fig.14 PM2.5 contour map with wind vectors and observe circles on 2015121514(Local time)

MYJ scheme produces relative clean area.

Notable difference occurs at daytime PBLH:

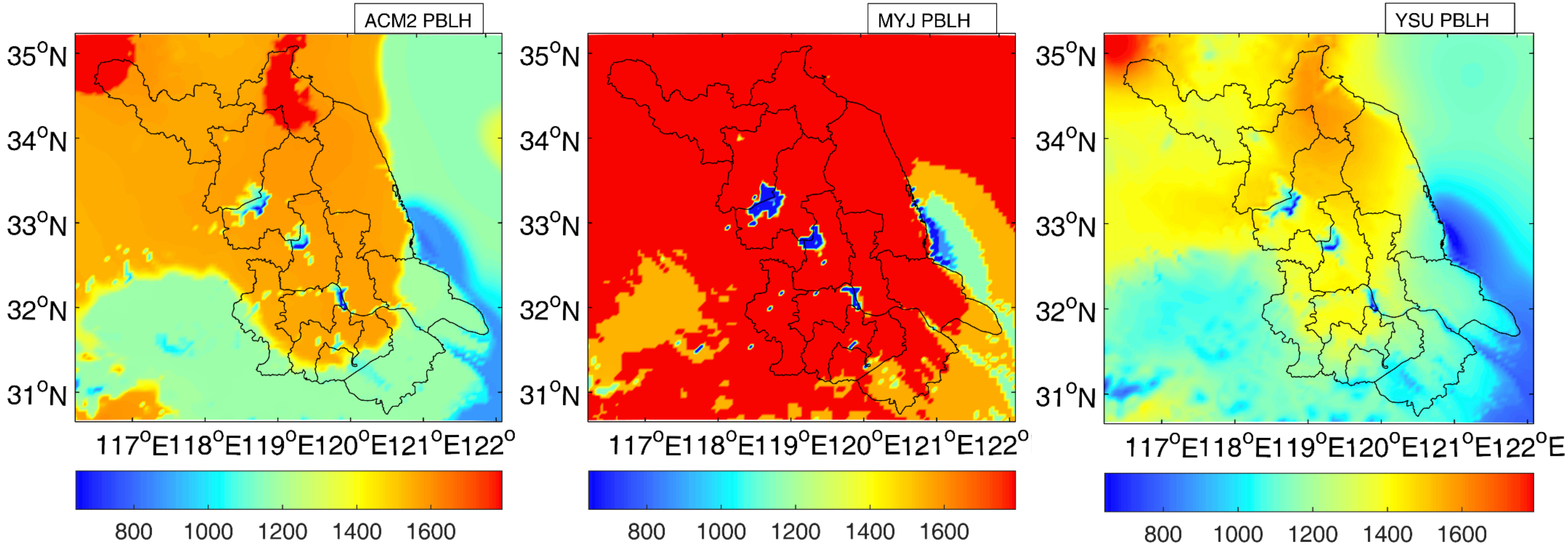


Fig.15 PBLH contour map on 2015121514(Local time)

MYJ produces much higher PBLH in most domain area,
ACM2 produces lower and uniform PBLH as MYJ,
YSU produces lowest and varied PBLH in domain area.

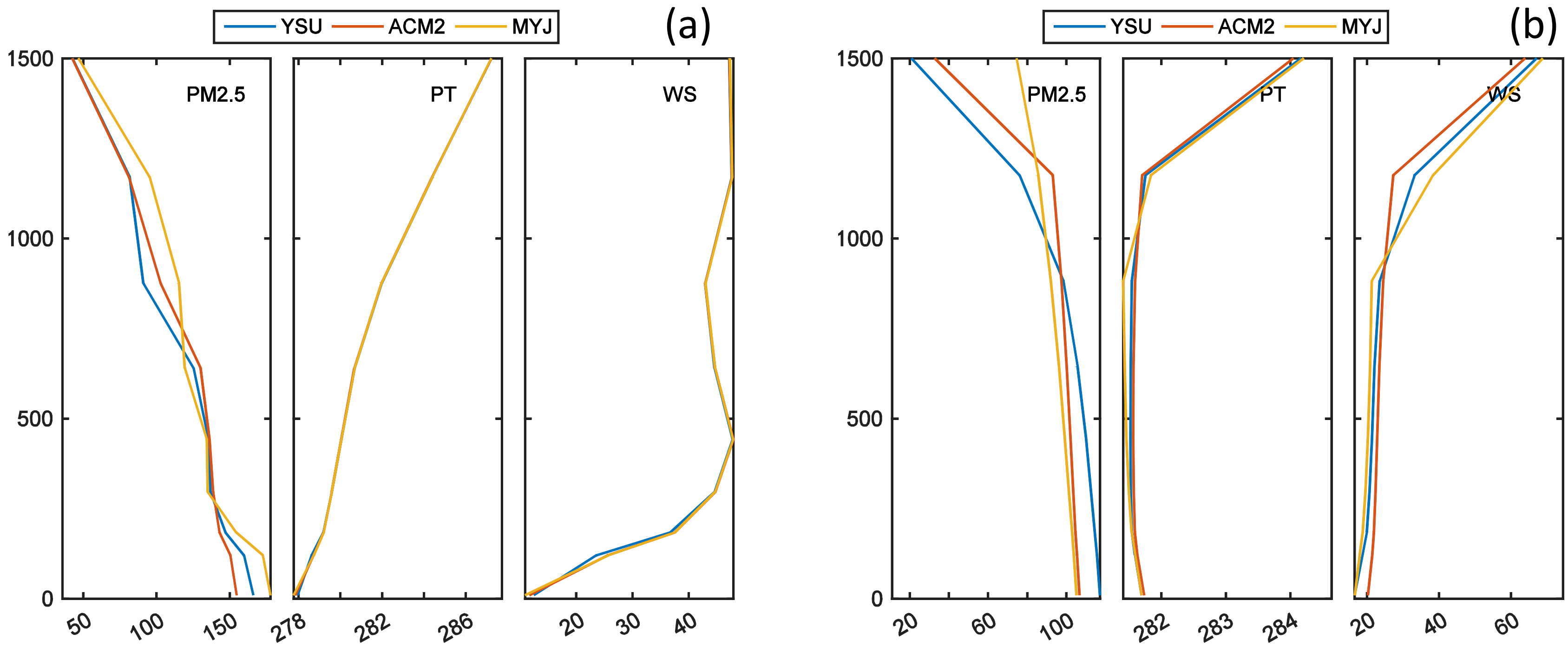


Fig.16 vertical profile of PM2.5, potential temperature and wind speed in Yangzhou city, (a) at 2015121500 and (b) at 2015121514

During Nighttime, PT(potential temperature) and WS(wind speed) have almost no difference among 3 schemes, however during daytime, due to different turbulent mechanisms of 3 schemes, PT and WS are varied by height.

Conclusion

- Turbulent diffusion typically dominates over mean vertical advection in vertical mixing. PBLH have most notable difference. PM2.5 distribution is more sensitive to vertical difference.
- Limited by one-way coupled WRF-CMAQ, different PBL schemes in WRF model may affect little on CMAQ, since CMAQ has its own vertical/horizontal advection/diffusion module. It’s more likely an input perturbation case of CMAQ model.

Thank you