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Evaluation of nonlocal and local planetary boundary layer schemes in the WRF model

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outline

- Objectives
- Model Setup and Configurations
- Results

  Surface variables

  PBL structures

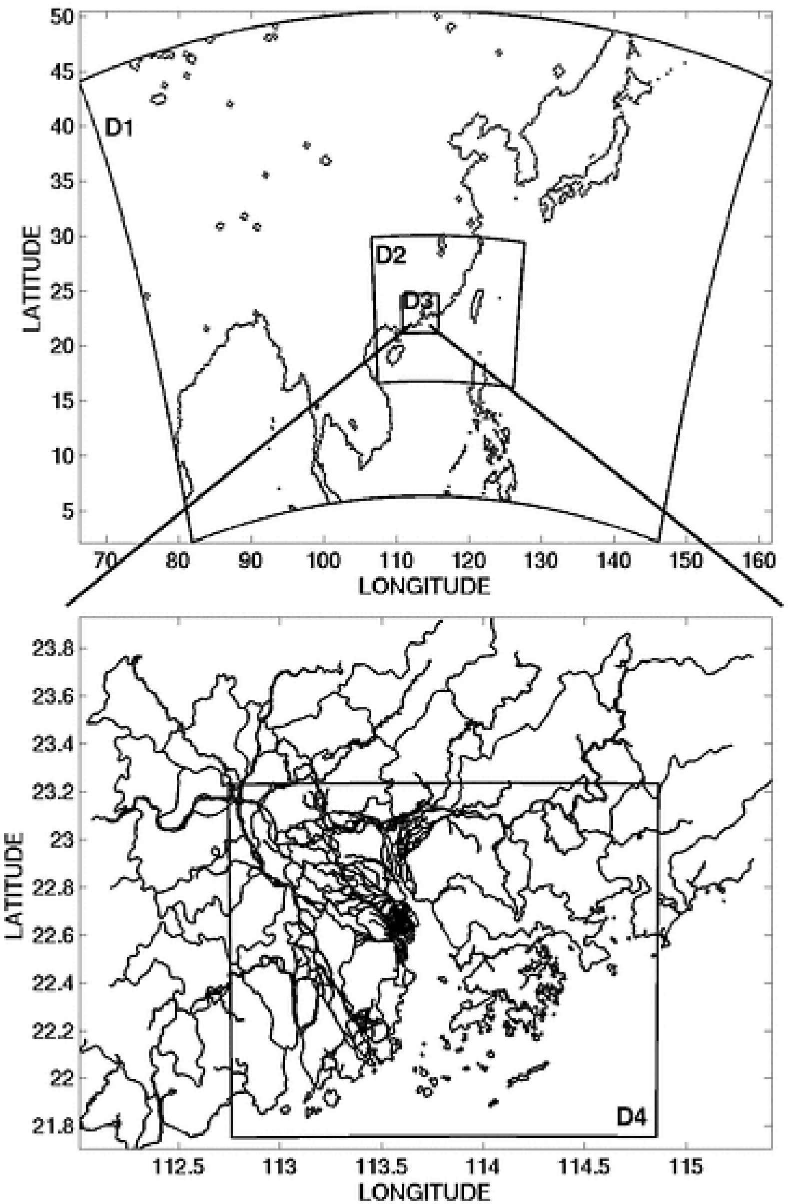
  PBL height
- Conclusion

Objectives

- **By using 10 meters wind speed,2m temperature and laser radar observation datas to assess the differences of four WRF PBL schemes.And find the preferred WRF PBL scheme for the Hong Kong region.**

- **In air quality modeling context, variation in vertical mixing intensity directly impacts pollutant dispersion characteristics. This was also have very heavy reference significance for our studied later.**

Model Setup and Configurations



	Hong Kong territory
time	**2006-6-1 08:00:00~2006-6-30 00:00:00** **2006-11-7 08:00:00~2006-11-30 00:00:00**
Center latitude	**28.5° N 114° E**
Domain resolution	**27km,9km,3km,1km**
vertical stratification	**21 sigma level**
Top pressure	**50hPa**
schemes	**Four PBL parameterization**

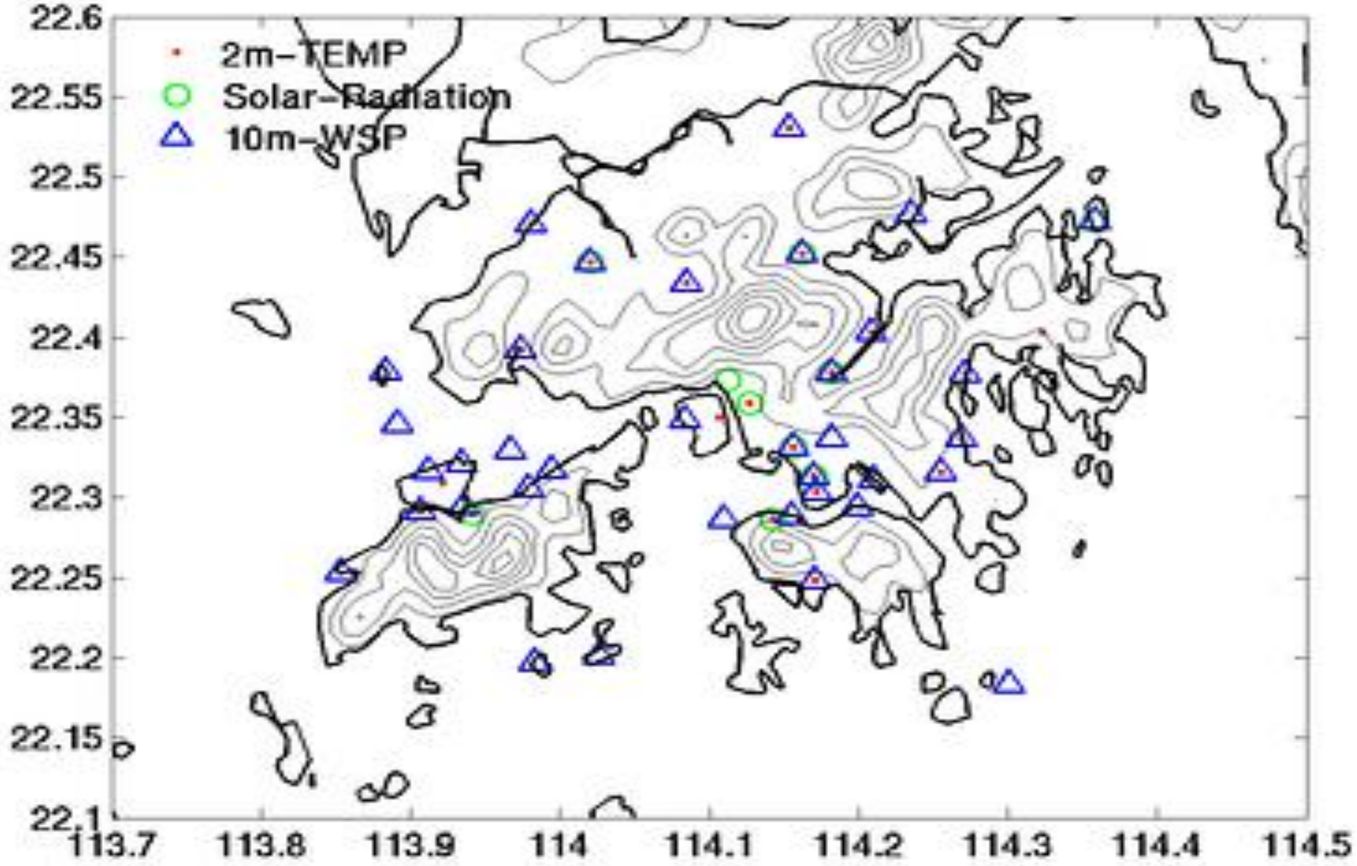


Figure 2. Spatial distribution of observation sites in Hong Kong.

Model Setup and Configurations

- Four PBL parameterizations in the WRF model

PBL schemes	Order of closure	Nonlocal mixing
YSU	1st order closure	Counter gradient terms for u, v, and θ
ACM2	Defined by empirical formula K_c	Explicit nonlocal fluxes for u, v, θ, and q
MYJ	TKE closure (1.5order) (One additional prognostic equation for TKE)	
BouLac	$K_c = S_c l e^{1/2}$	Counter gradient terms for θ

Model Setup and Configurations

To express effects of the divergence of turbulent fluxes to prognostic mean variables (C: u, v, θ, q) by vertical diffusion

$$-\frac{\partial}{\partial z}\overline{\omega' c'} = \frac{\partial}{\partial z}\left[K_c\left(\frac{\partial C}{\partial z}\right)\right]$$

- YSU PBL Scheme

$$\frac{\partial C}{\partial t} = \frac{\partial}{\partial z}\left[K_c\left(\frac{\partial C}{\partial z} - \gamma_c\right) - \overline{(\omega' c')}_h\left(\frac{z}{h}\right)^3\right]$$

Inverse gradient term

the flux at the inversion layer

- ACM2 PBL Scheme

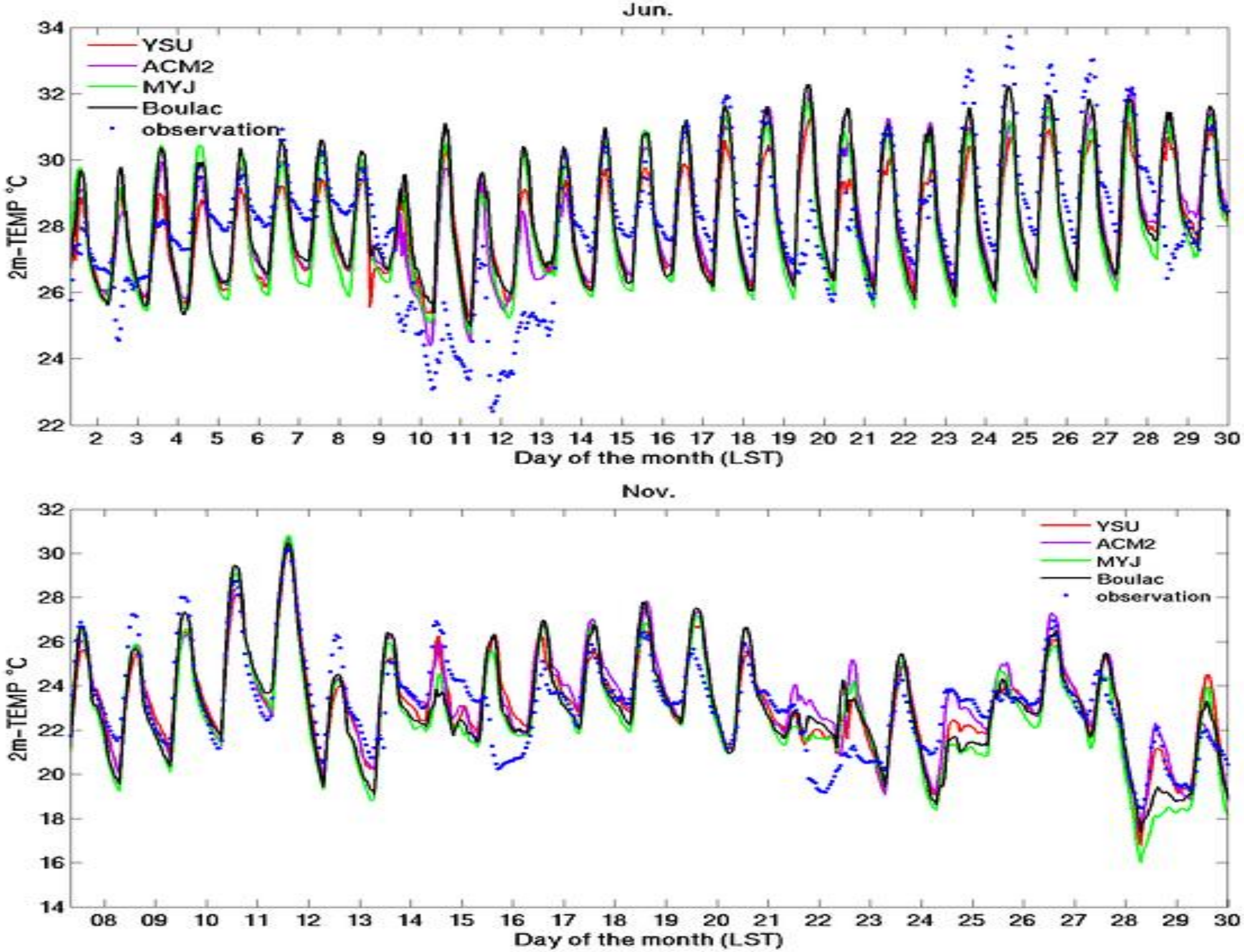
$$\frac{\partial C_i}{\partial t} = f_{conv}MuC_1 - f_{conv}Md_iC_i + f_{conv}Md_{i+1}C_{i+1}\frac{\Delta z_{i+1}}{\Delta z_i}$$

$$+\frac{\partial}{\partial z}\left[K_c(1 - f_{conv})\frac{\partial C_i}{\partial z}\right]$$

scalar adjustment

$$f_{conv} = \left[1 + \frac{k^{-2/3}}{0.1a}\left(-\frac{h}{L}\right)^{-1/3}\right]^{-1}$$

Results –Surface variables



Jun

Nov

Figure 3. Mean time series of 2 m temperature over 23 sites in Jun and Nov 2006.

Table 1. Model Performance in T2 for 1 km WRF Simulations Over the Period of 8 A.M., 1st Jun to 0 A.M., 30th Jun and the Period of 8 A.M., 07th Nov to 0 A.M., 30th Nov, 2006

	YSU	ACM2	MYJ	Boulac-Eta	Boulac-MM5
2 m Temperature (Celsius) in June					
Determination	0.51	0.51	0.47	0.51	0.53
Index of agreement	0.76	0.80	0.77	0.80	0.80
RMSE	1.54	1.47	1.68	1.53	1.46
NMB	-0.026	-0.013	-0.023	-0.012	-0.018
NME	0.044	0.040	0.048	0.042	0.041
2 m Temperature (Celsius) in November					
Determination	0.71	0.75	0.70	0.70	0.72
Index of agreement	0.90	0.91	0.88	0.89	0.91
RMSE	1.33	1.28	1.61	1.48	1.32
NMB	-0.008	0.000	-0.026	-0.014	-0.005
NME	0.045	0.043	0.056	0.050	0.044

a Rainy days are excluded; boldface indicates the best one among the different runs.

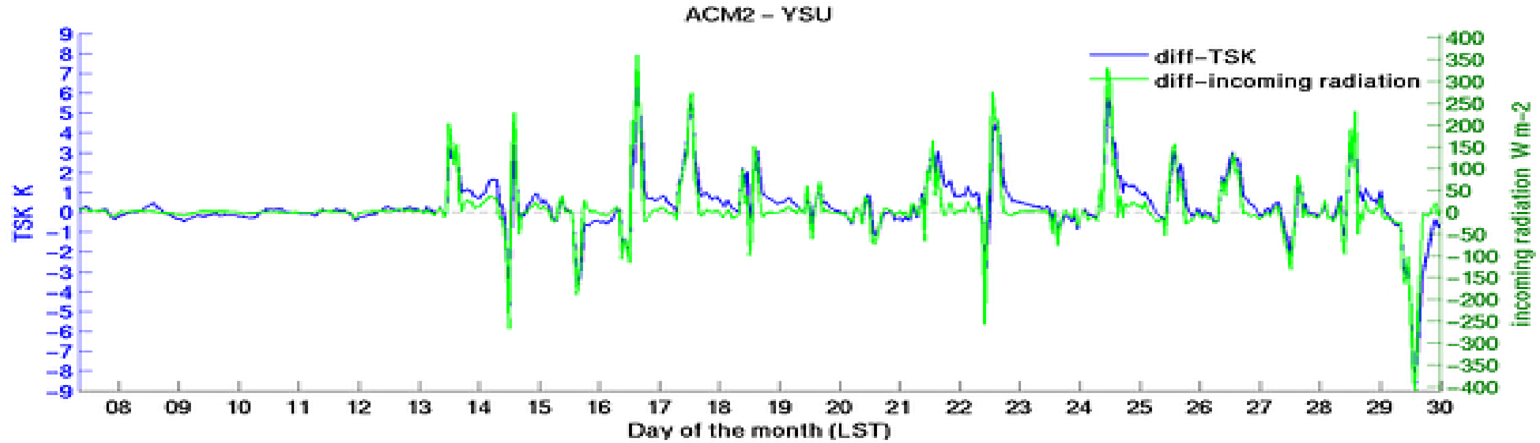


Figure 4. Mean time series of difference (ACM2-YSU) in surface skin temperature (TSK blue line) and difference (ACM2-YSU) in incoming radiation (green line) in November.

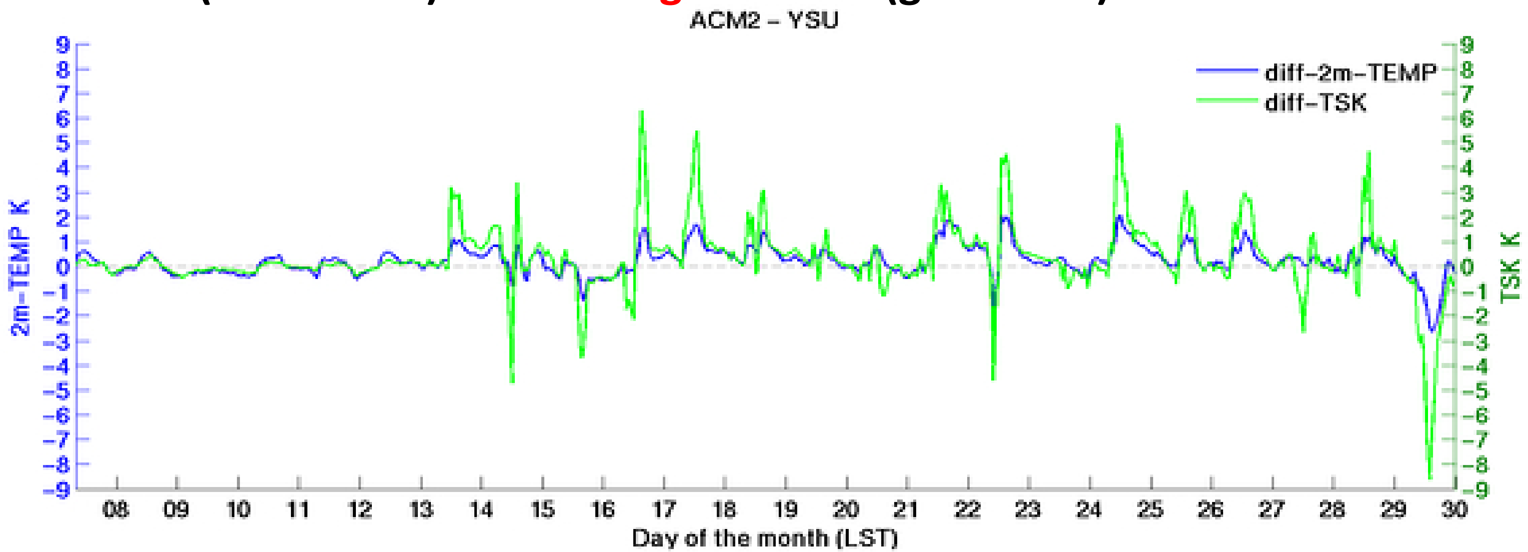


Figure 5. Mean time series of difference (ACM2-YSU) in 2 m temperature (blue line) and difference (ACM2-YSU) in surface skin temperature (TSK green line) in November.

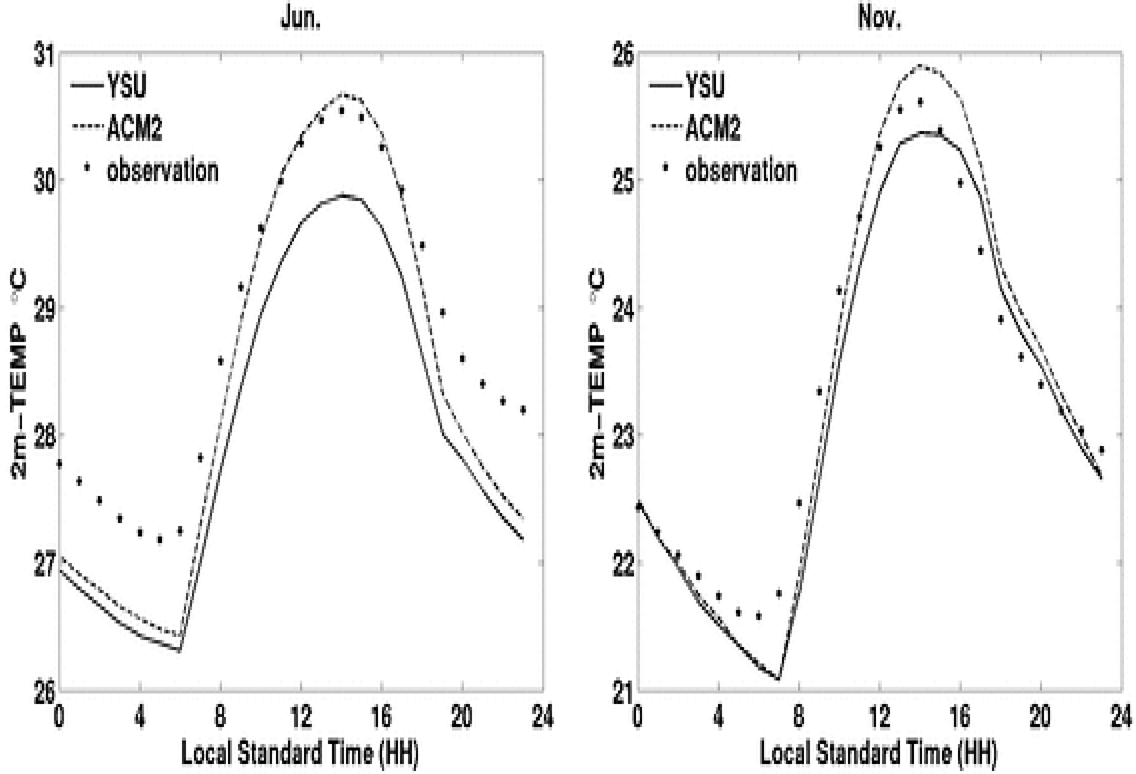


Figure 6. Diurnal mean time series of 2 m temperature over 23 stations in Jun and Nov 2006.

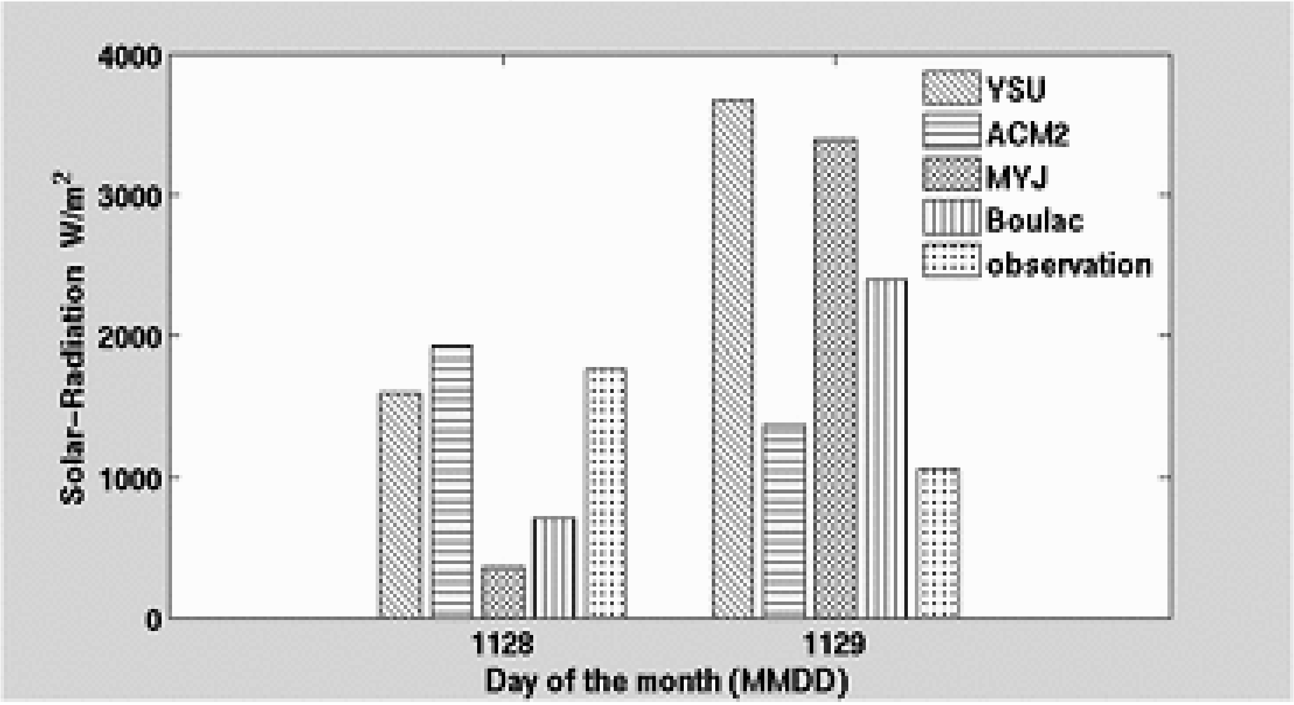


Figure 7. Mean bar chart of daily Solar-Radiation (from 8 A.M. to 6 P.M.) over 10 sites on Nov 28th and Nov 29th, 2006.

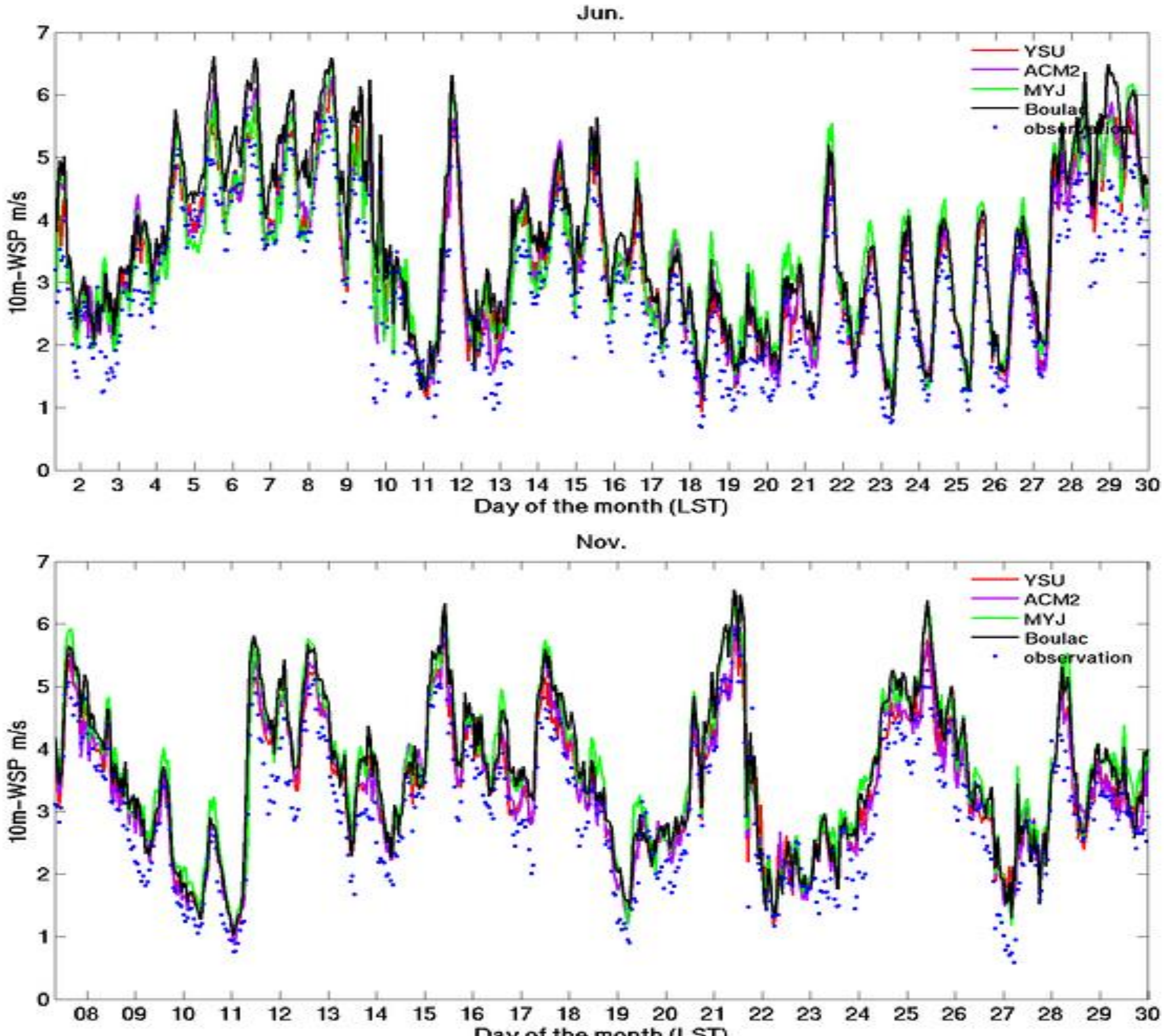


Figure 8. Mean time series of 10 m wind speed (WSP) over 40 sites in Jun and Nov 2006.

Table 2. Model Performance in 10 m Wind Speed for 1 km WRF Simulations Over the Period of 8 A.M., 1st Jun to 0 A.M., 30th Jun and the Period of 8 A.M., 07th Nov to 0 A.M., 30th Nov, 2006

	YSU	ACM2	MYJ	Boulac
	10 m Wind Speed (m/s) in June			
Determination	0.55	**0.58**	0.52	0.53
Index of agreement	0.78	**0.79**	0.74	0.74
RMSE	1.34	**1.32**	1.59	1.64
NMB	**0.22**	0.25	0.32	0.38
NME	**0.42**	**0.42**	0.52	0.54
	10 m wind speed (m/s) in November			
Determination	0.56	**0.57**	0.53	0.56
Index of agreement	0.79	**0.80**	0.74	0.76
RMSE	**1.27**	1.28	1.54	1.49
NMB	**0.20**	0.21	0.35	0.34
NME	**0.39**	**0.39**	0.51	0.49

[a]Rainy days are excluded; boldface indicates the best one among the different runs.

Results – PBL structures

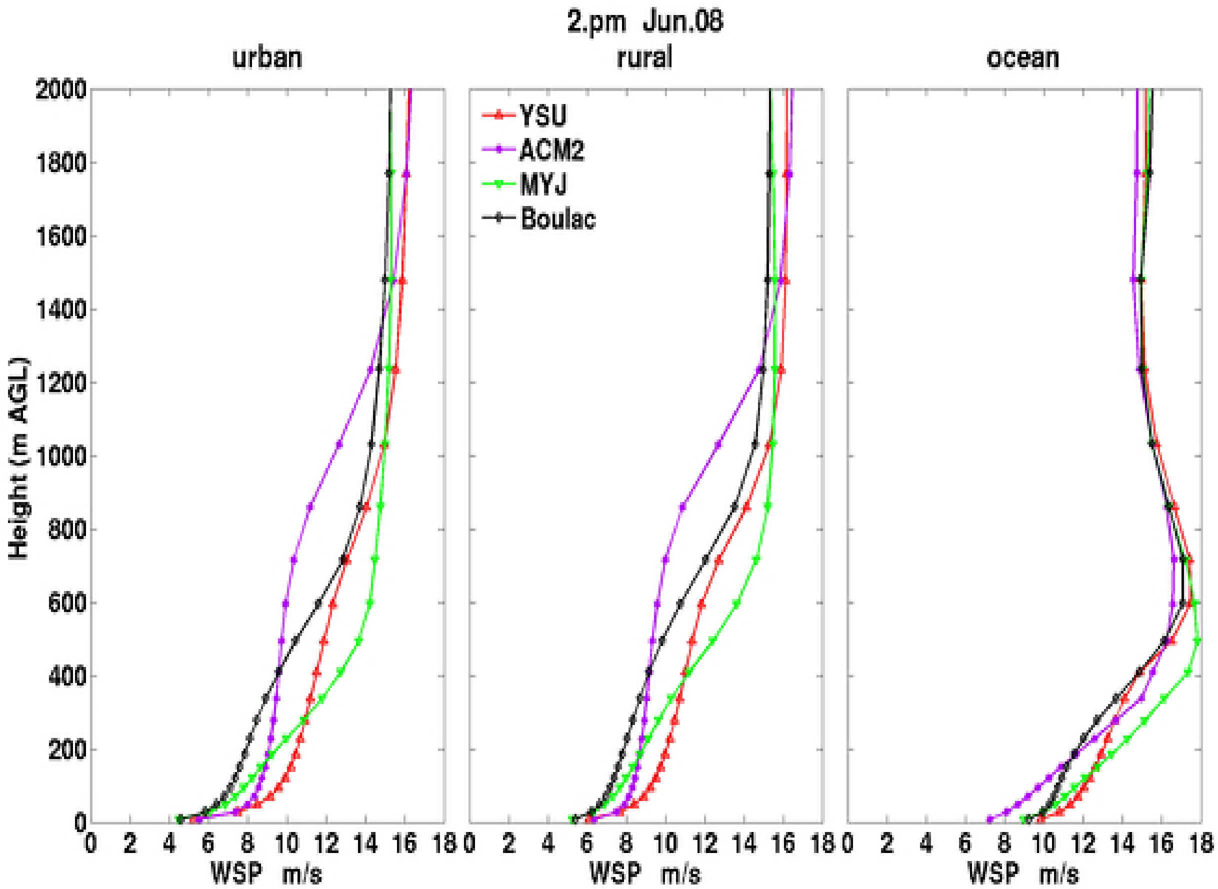


Figure 9. Spatially averaged vertical profiles of horizontal velocity in urban, rural and ocean regions at 2 P.M., June 8th, 2006.

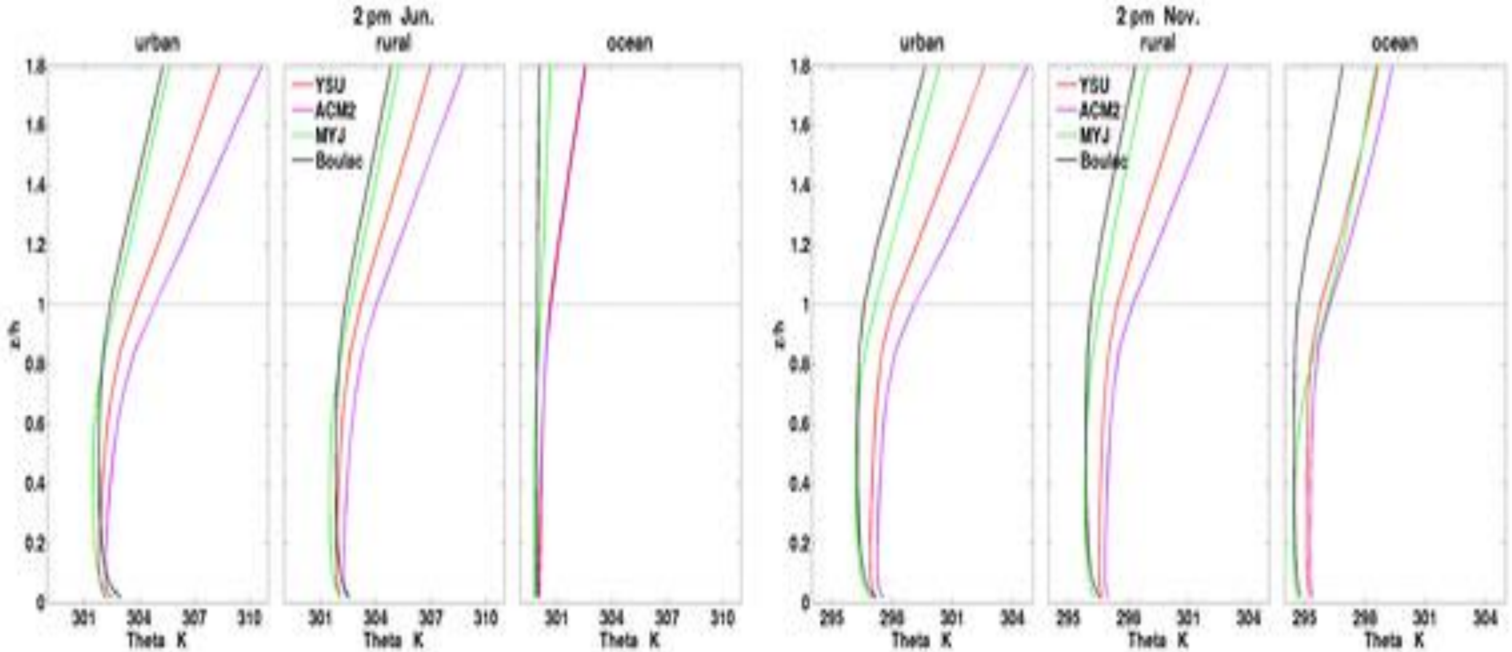


Figure 10. Spatially and hourly averaged vertical profiles of potential temperature as a function of normalized height in urban, rural and ocean regions at 2 P.M. over (left) Jun. and (right) Nov.

Results – PBL height

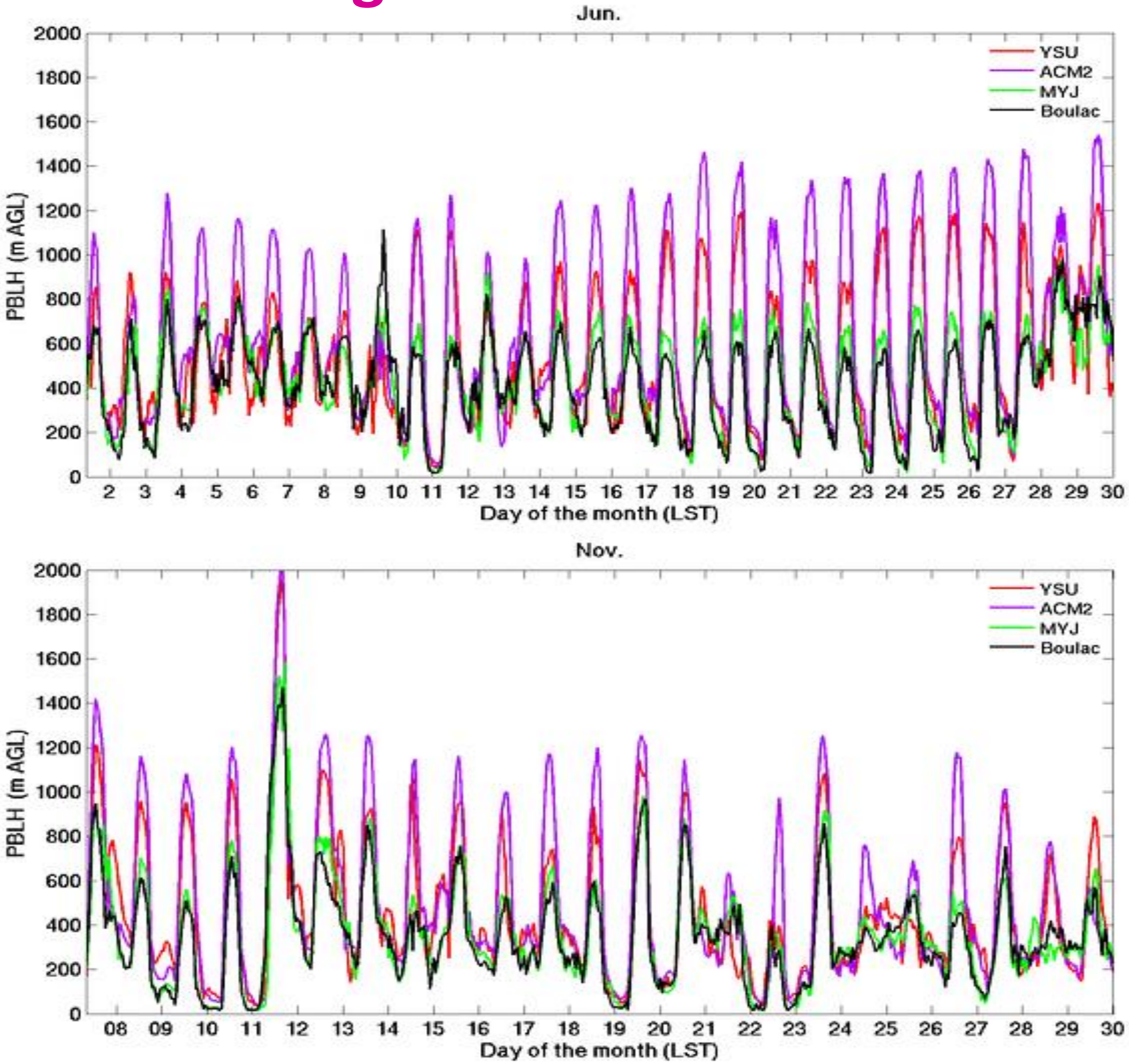


Figure 11. Mean time series of PBL height over 23 sites in Jun and Nov 2006.

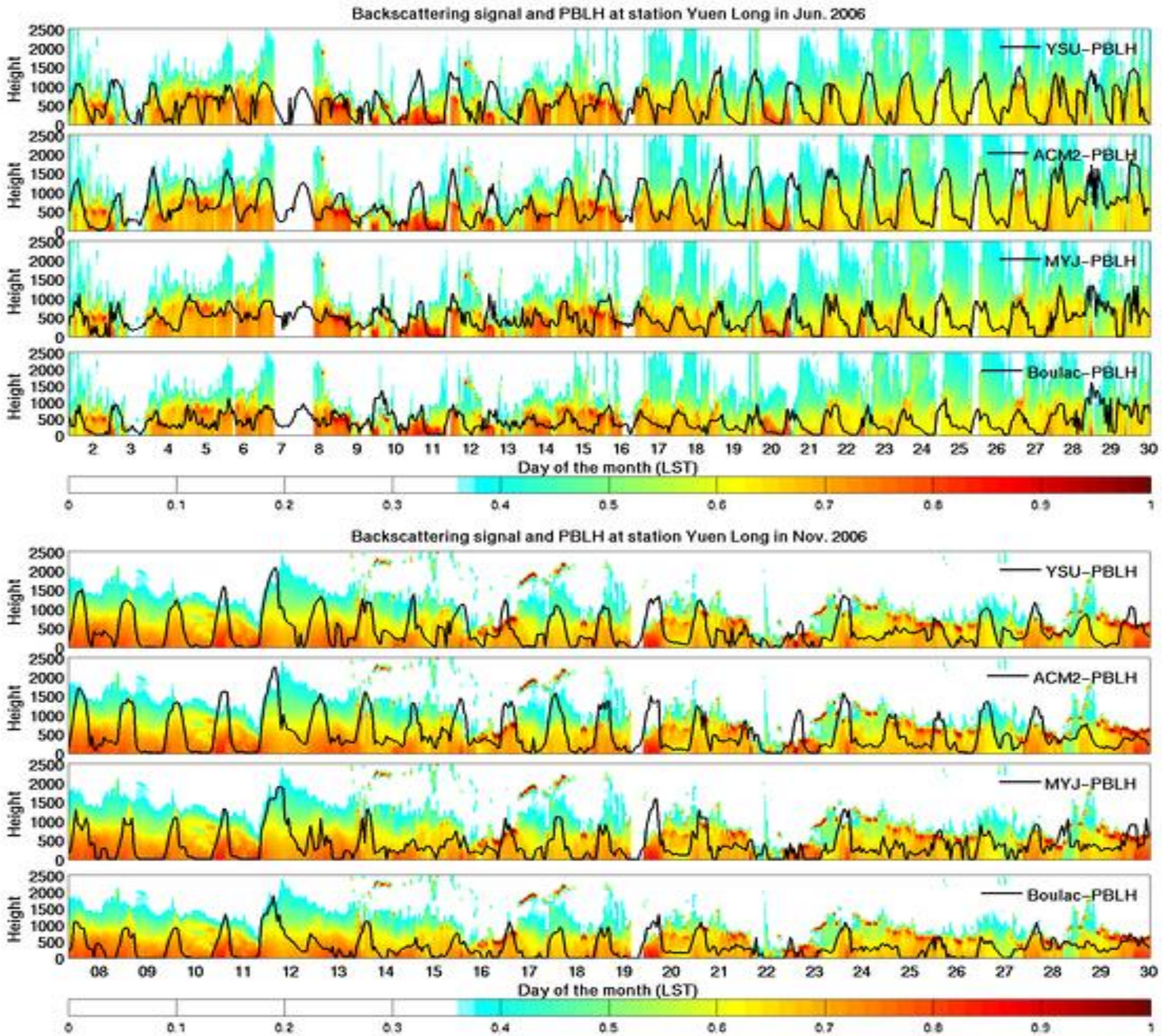


Figure 12. PBL Heights diagnosed by YSU, ACM2, MYJ, Boulac and lidar backscattering signals at Yuen Long station (note that 9th–12th, June and 21st–22nd, November are rainy days).

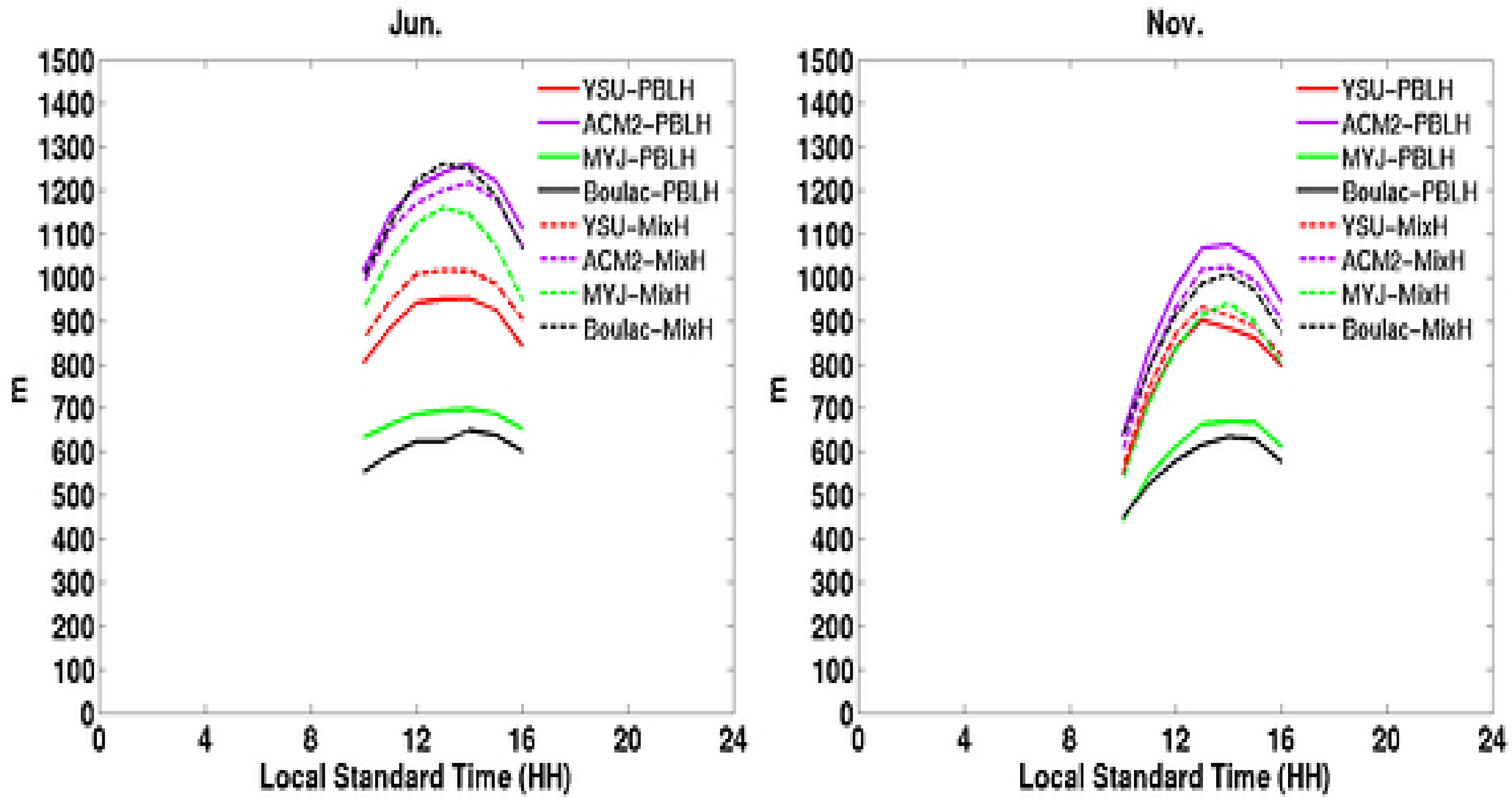


Figure 13. Diurnal mean time series of diagnosed PBL heights and mixed layer heights computed by a unified approach in (left) June and (right) November.

Conclusion

- By surface variables,ACM2 produces the best estimation of 2 m temperature and 10 m wind speed as compared with observations in the Hong Kong region over both simulation periods, June and November.
- Vertical profiles of horizontal velocity and potential temperature can exhibit significant variances among the PBL schemes across the entire PBL depth. This study shows that ACM2 is a suitable PBL scheme in WRF for air quality applications in the Hong Kong geographic region.
- The choice of PBL schemes has been shown to result in PBL height,and is useful for us to diagnosis.

Thank you