Effects of Planetary Boundary Layer Parameterizations on High Resolution Regional Climate Simulation over Tibetan Plateau

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Outline

➢ Motivation

➢ Sensitivity of PBL parameterizations

➢ Evaluation of high resolution simulation

➢ Summary

Motivation

Planetary Boundary Layer: part of the troposphere that is directly influenced by the presence of the earth's surface

Tibetan Plateau :Complex topography an average altitude of over 4000m

Free Atmosphere

Shallow conection

Land-Atmospere Interactions

**Planetary Boundary Layer**
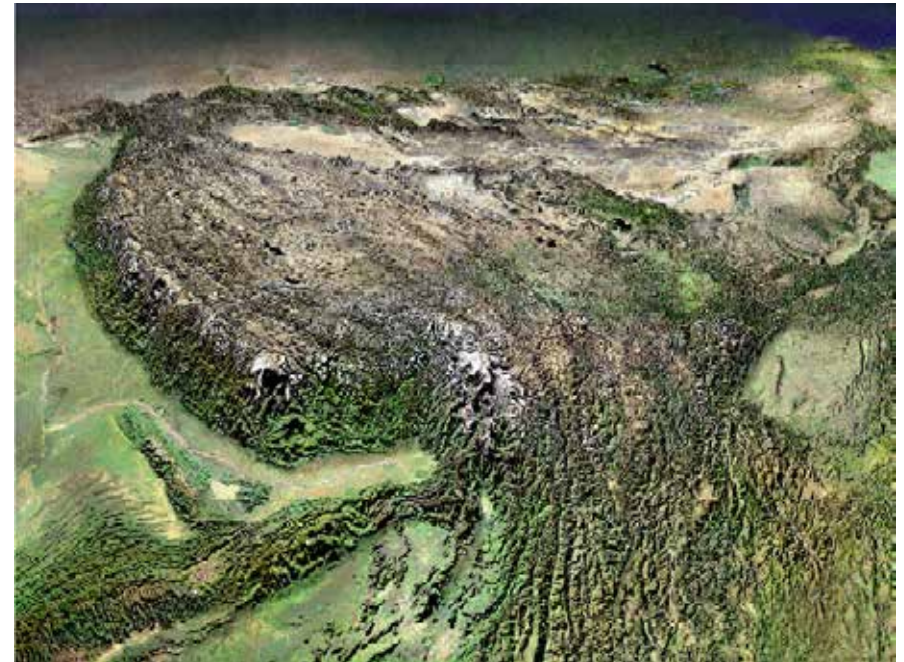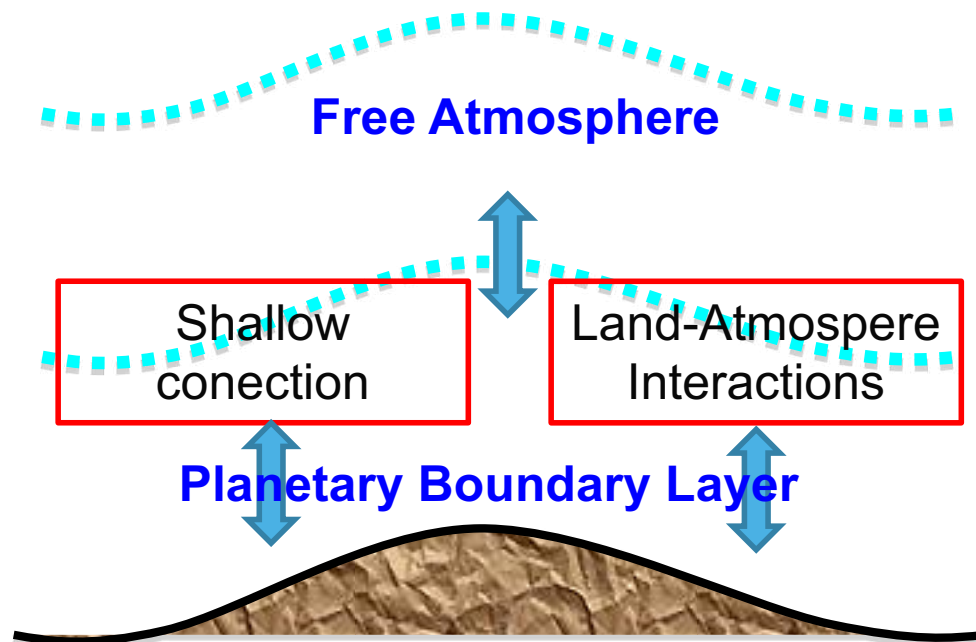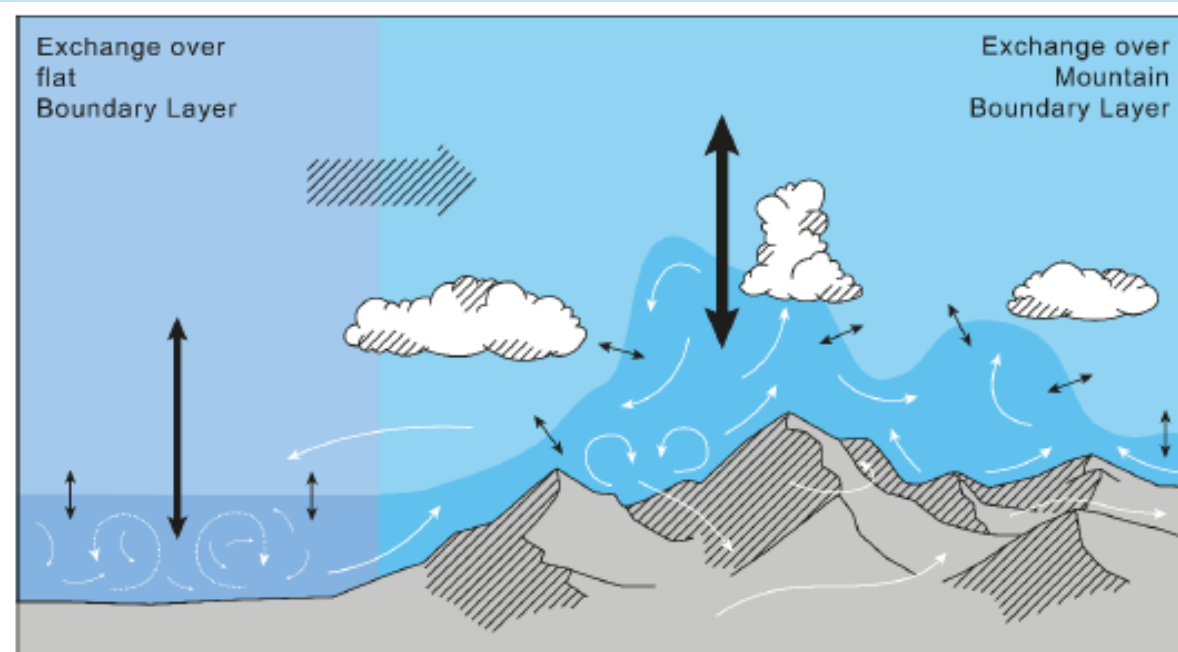
(Serafin et al., 2019, TEAMx)

➢ Over mountainous terrain, exchange processes include turbulent mixing, breeze systems, gravity wave propagation and moist convection.

➢ Vertical transport towards the free atmosphere is conjectured to be on average more intense over mountains

➢ The high altitude complex terrain influence of TP on the atmosphere is closely related to its PBL

Sensitivity of PBL parameterizations on regional climate simulations over TP

What are the performances of RCM simulations over TP with different PBLs ?
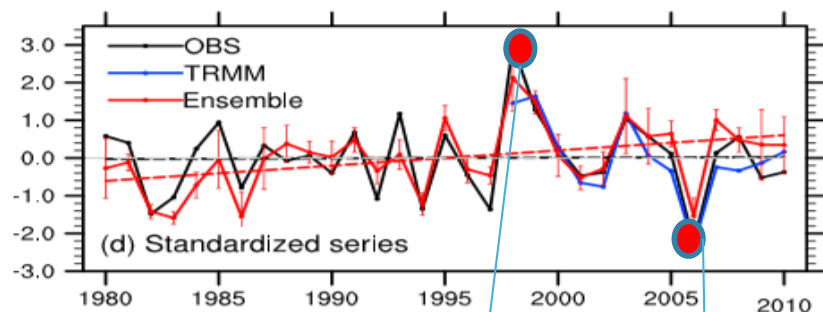
Model Domain and Experiments Design

Model Domain
（9km resolution）
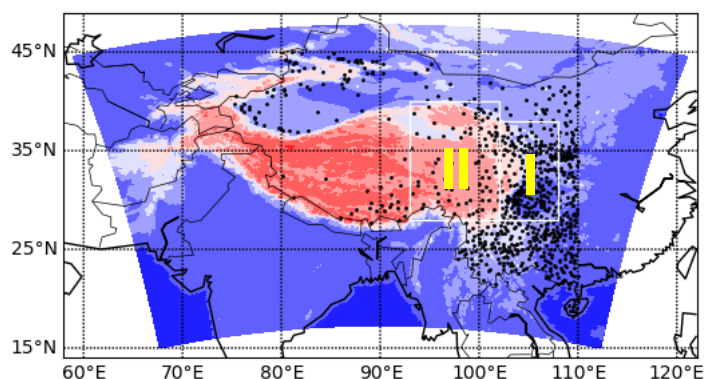
I:
East of
TP

II:
Central
East TP

Normalized time series of stations' average summer precipitation of TP(Wang et al. 2017)

**Simulation periods : May 16- Sep 1**
1998 (Wet), 2006 (Dry)

Model Configuration	
Model prototype	WRF 4.0
Governing equations	Nonhydrostatic
Grids and resolution	531x361, 9km
Vertical Layers (top)	40 P-Sigma layers (50hPa)
Cumulus convection	Grell 3D ensemble
Explicit moisture	Thompson
Radiation	RRTMG
Land Surface	NOAH-MP LSM

PBL Schemes

(1) YSU (CTL)
(2) Mellor-Yamada-Janjic TKE
(3) MYNN 2.5 level TKE
(4) Bougeault and Lacarrere PBL
(5) UW PBL from CAM5
(6) Shin-Hong 'scale-aware' PBL
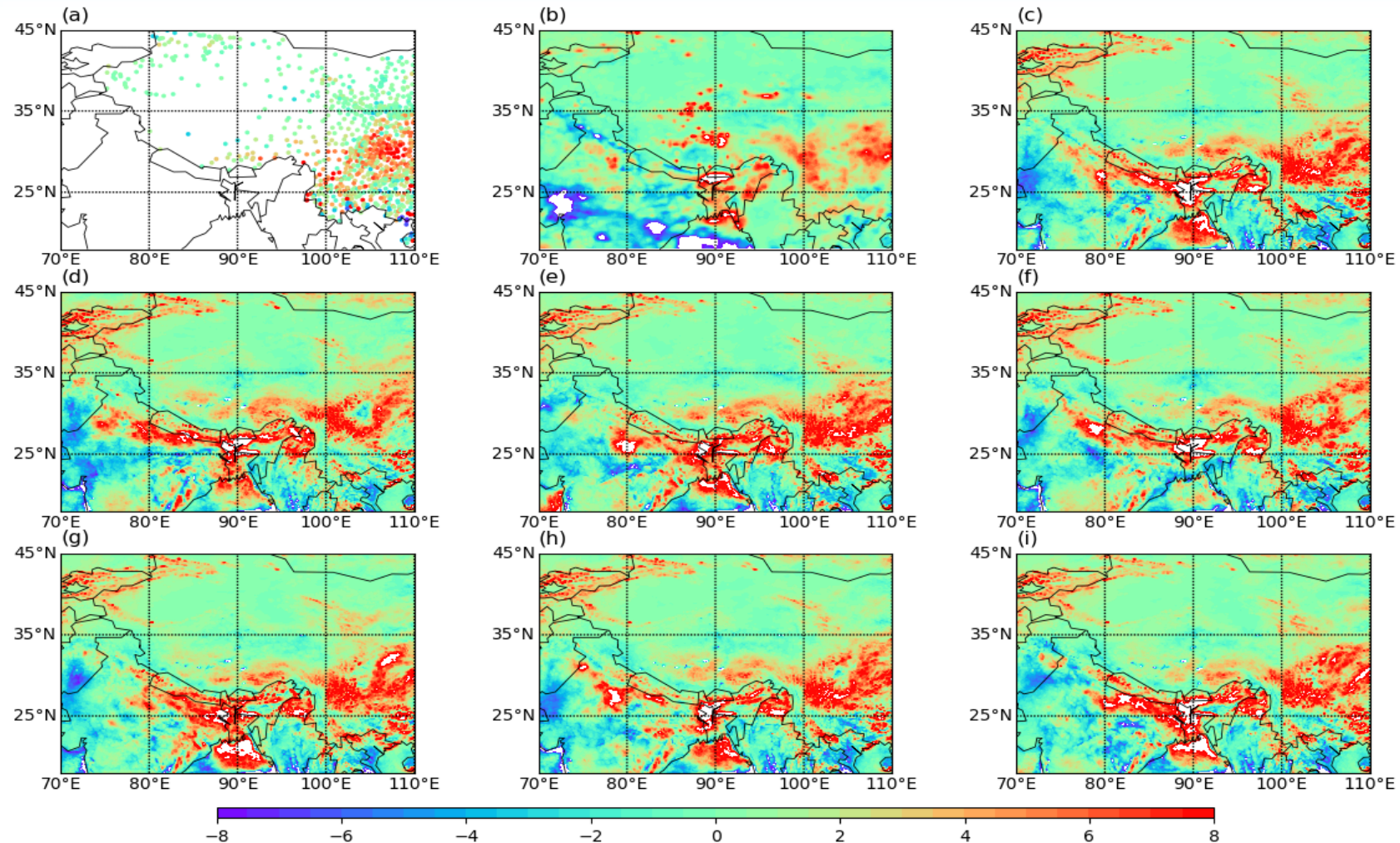(7) Grenier-Bretherton-McCaa

1998 JJA precipitation
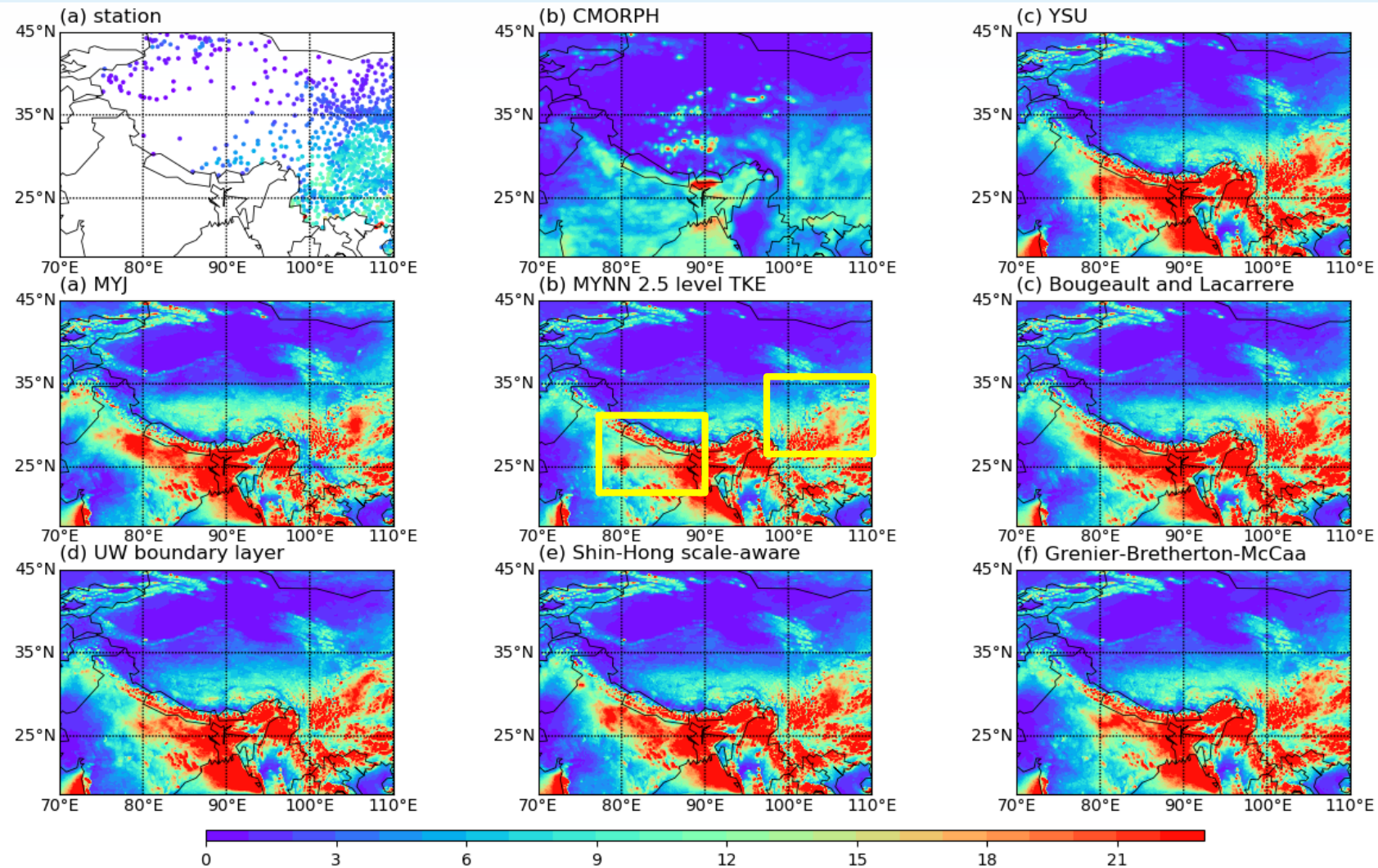
WRF clearly overestimate JJA precipitation, differences exist between different PBL experiments.
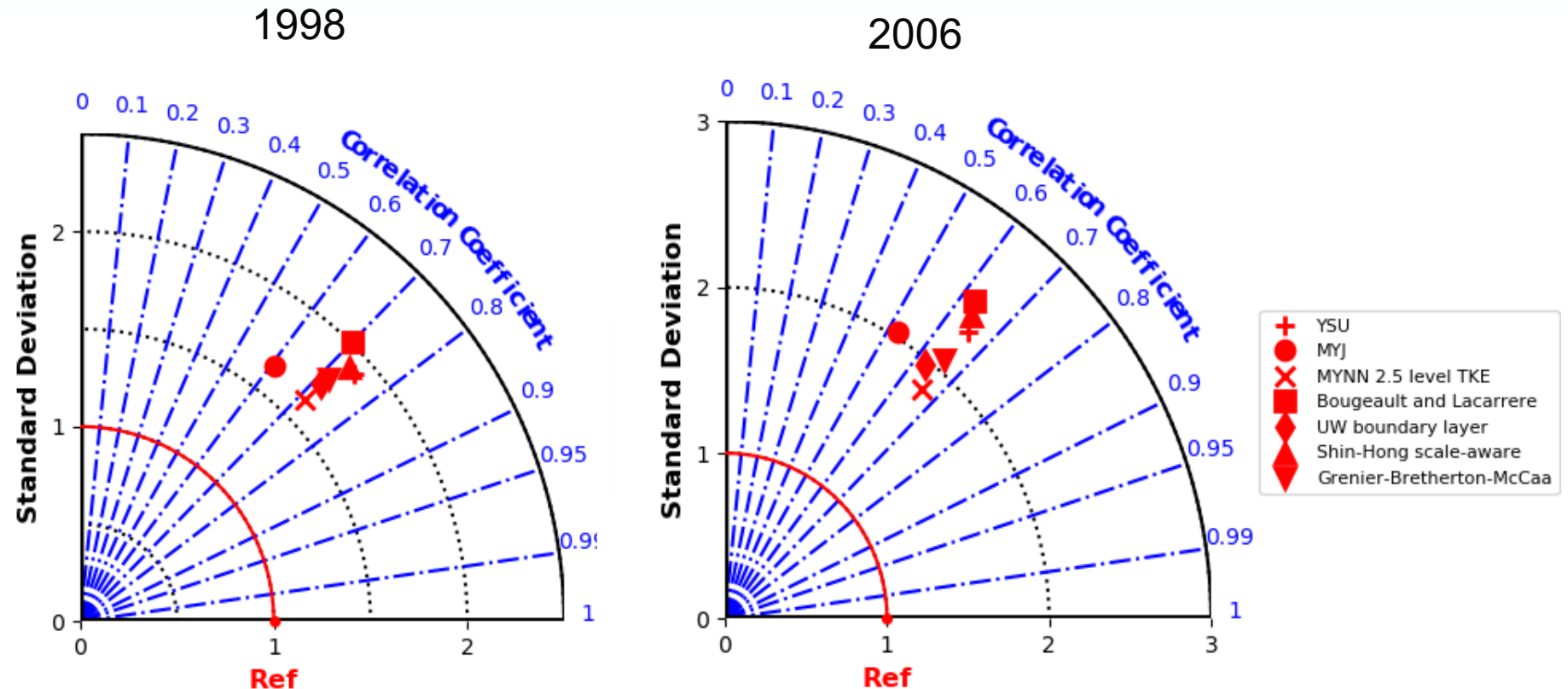
2006 JJA precipitation
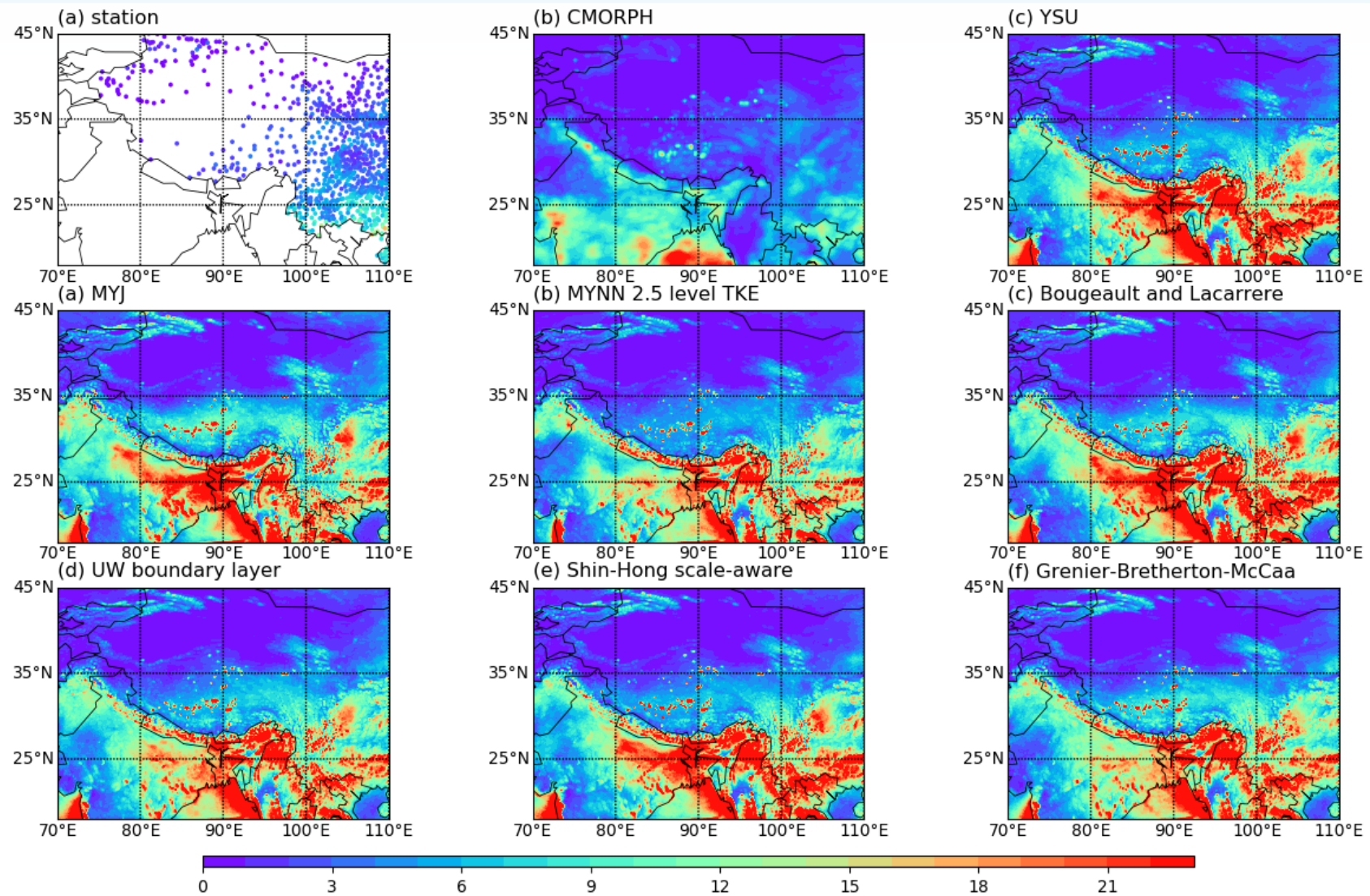
The difference of JJA precipitation between 1998 and 2006


WRF reproduced the differences of JJA precipitation between wet and dry year

Taylor diagram of spatial patterns of JJA precipitation

➤ All experiments simulate the distributions of JJA precipitation with Corr at about 0.6-0.7, but obviously enlarge the spatial variability

➤ MYNN2.5 shows best performance compare to the other PBLs

Variations of daily precipitation and surface air temperature
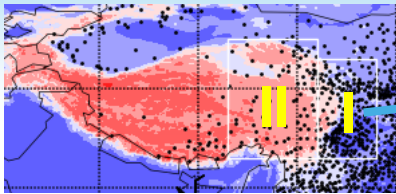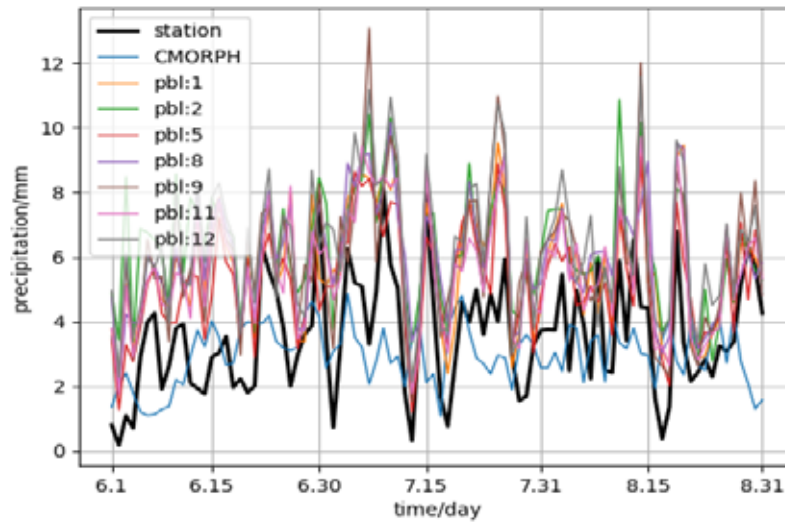
Region I : East of TP

1998

2006

Pr
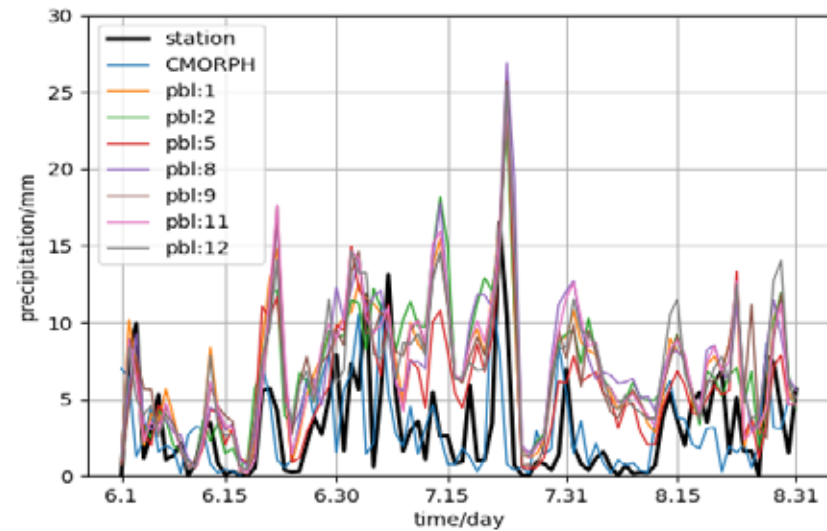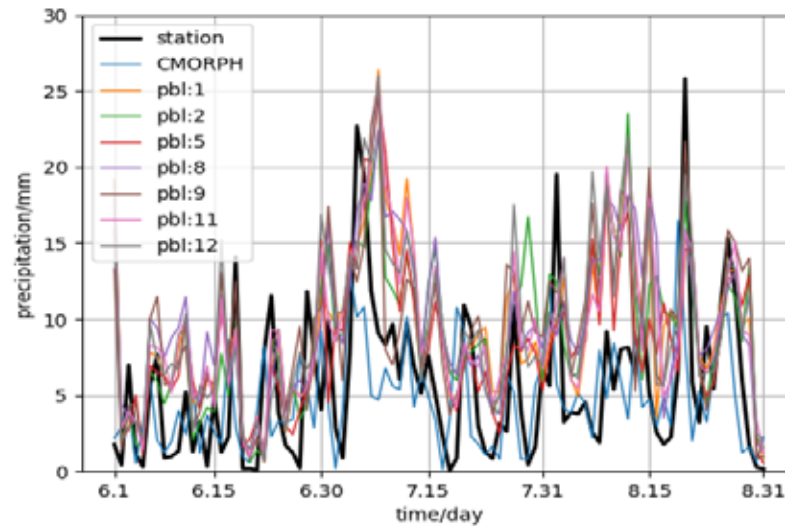
T2m
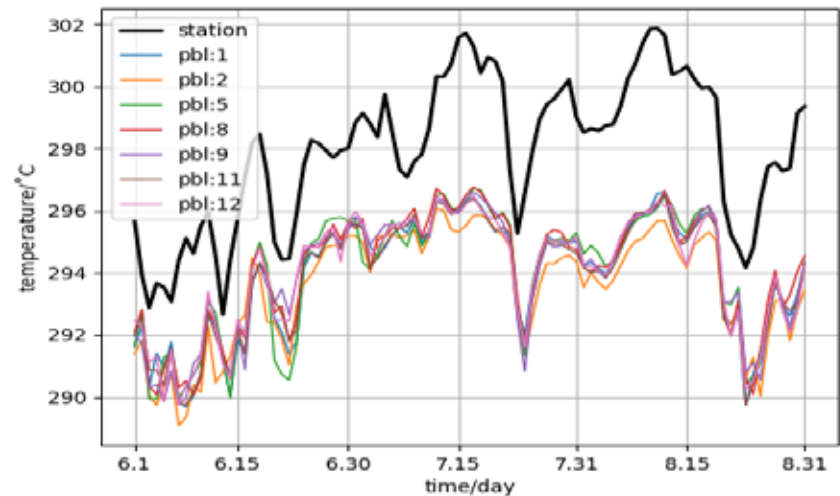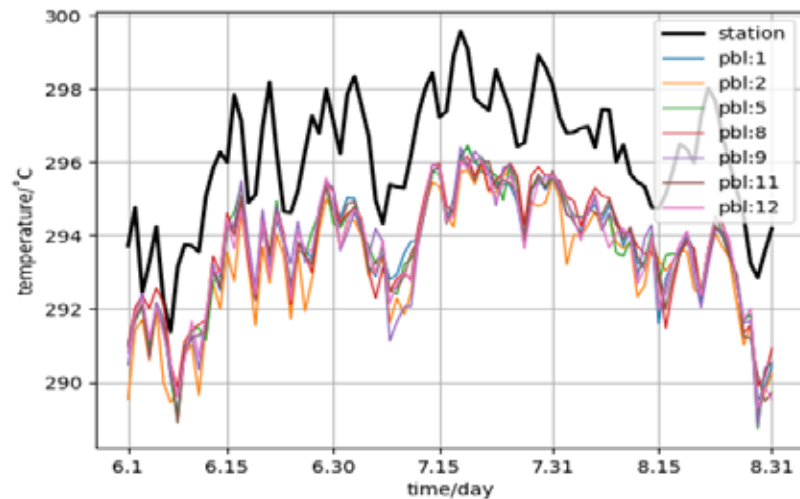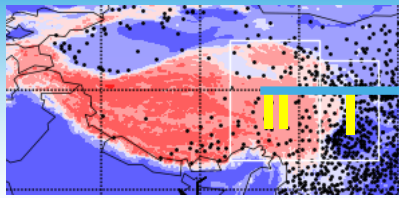
Region II : Central East of TP

1998   2006

Pr
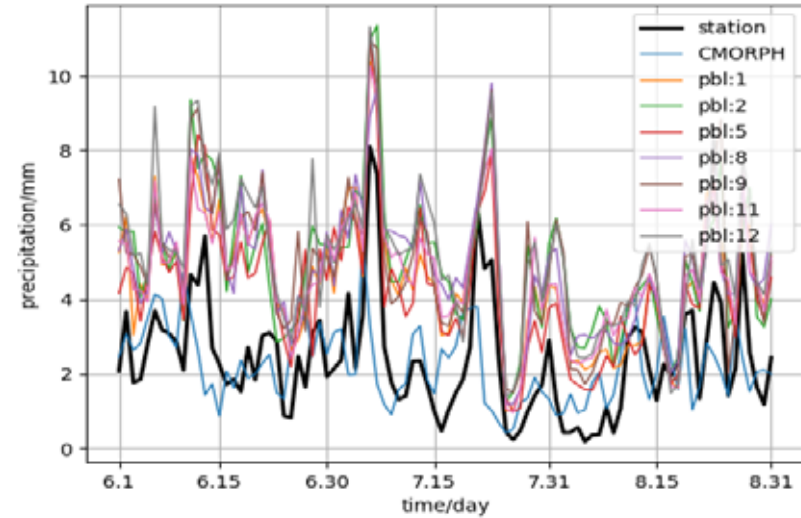
T2m
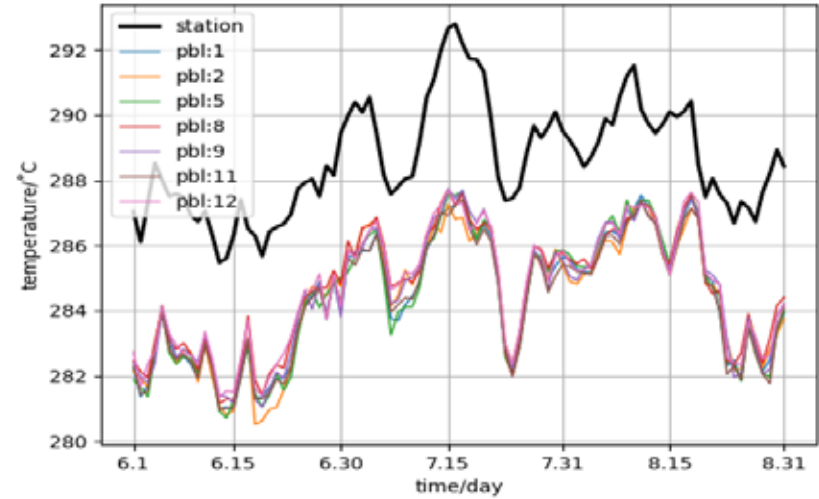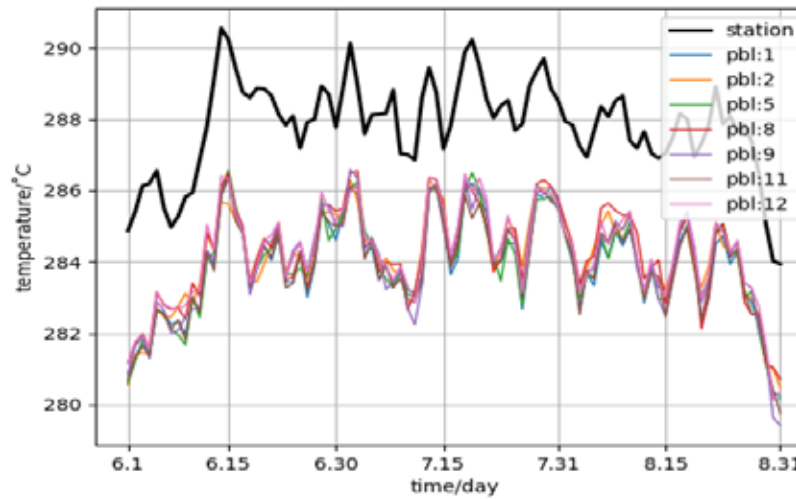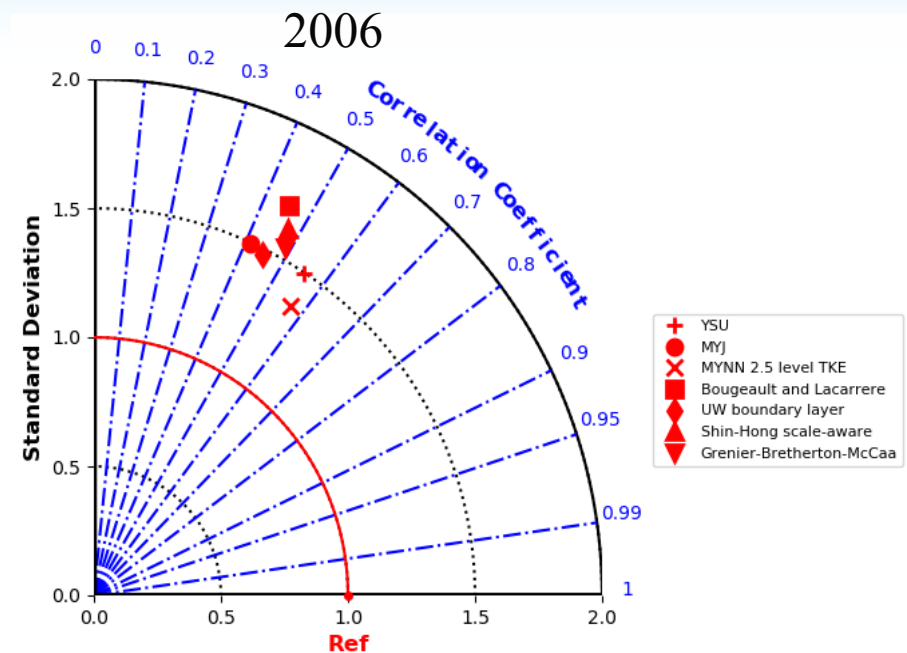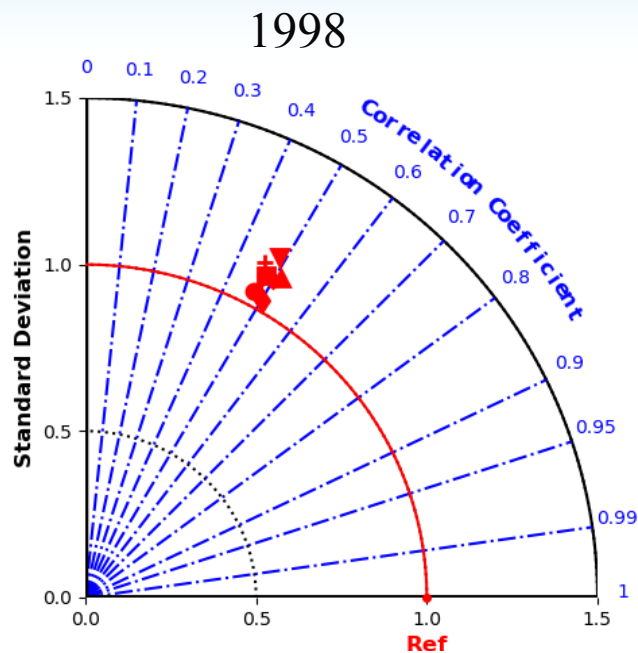
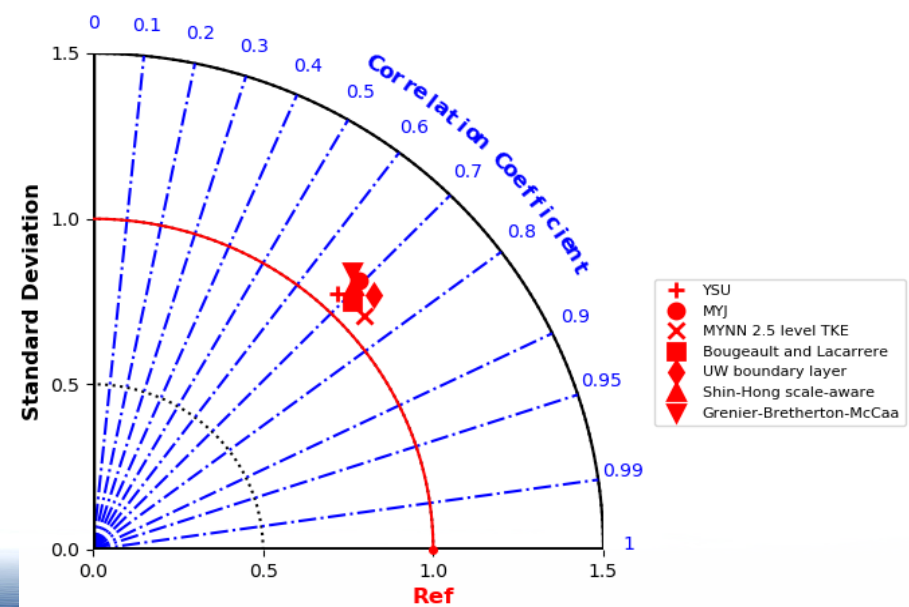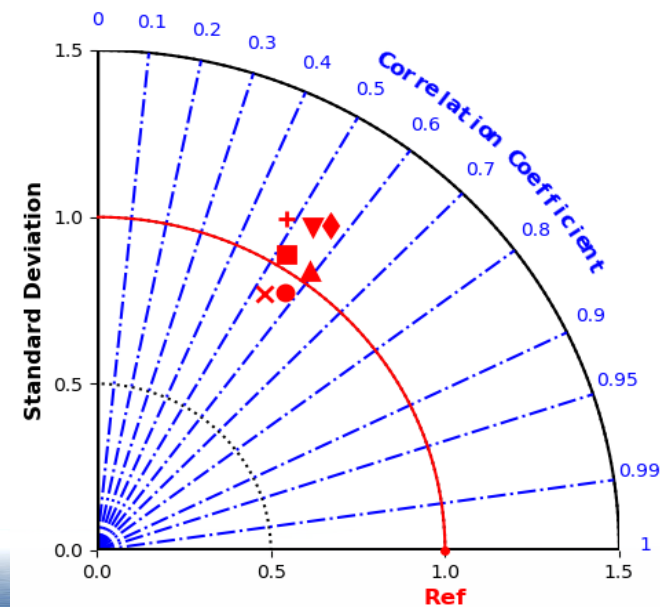Wet and cold biases exist over central east of TP

Taylor diagram of temporal variation of daily precipitation

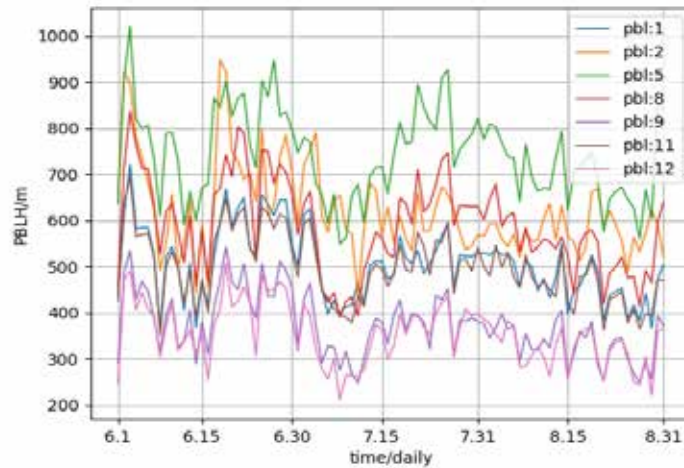# Variations of daily PBL height
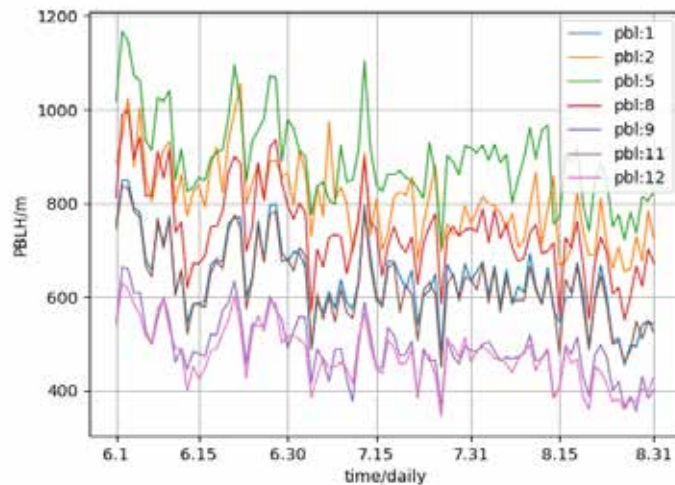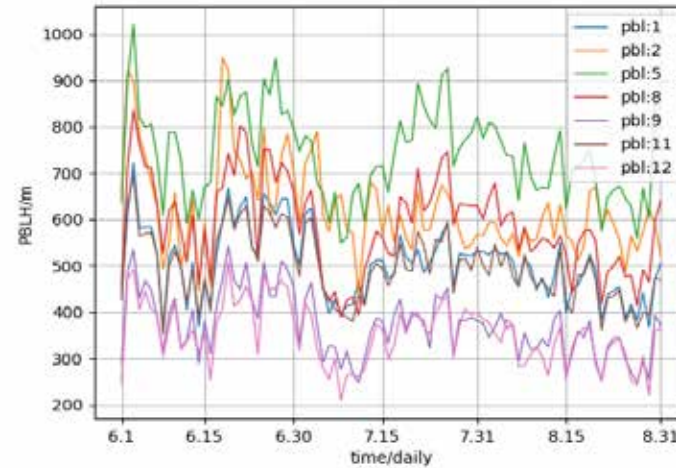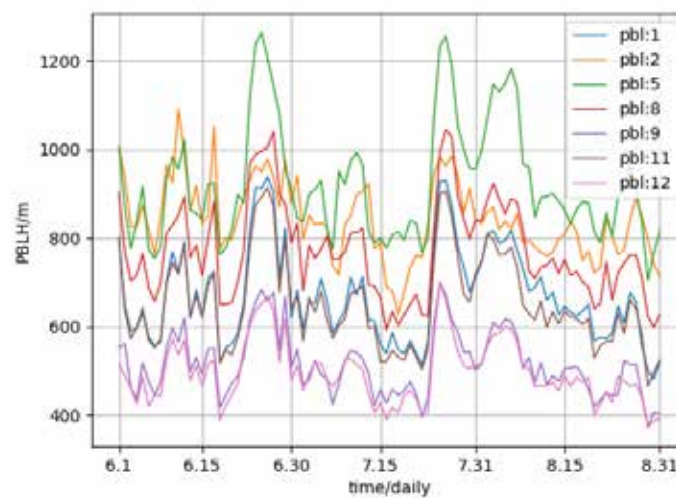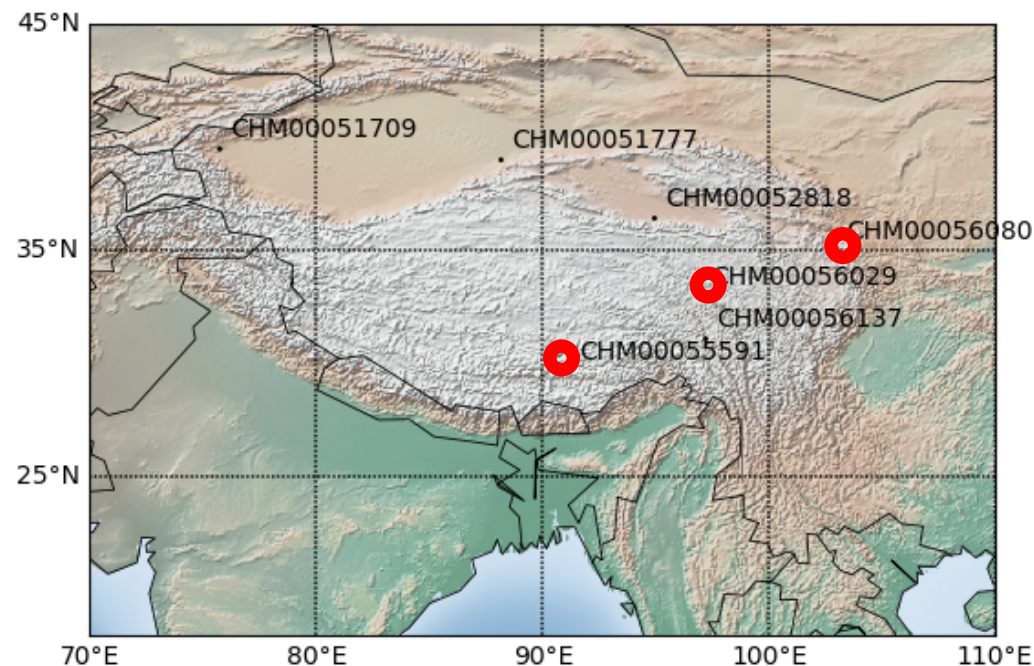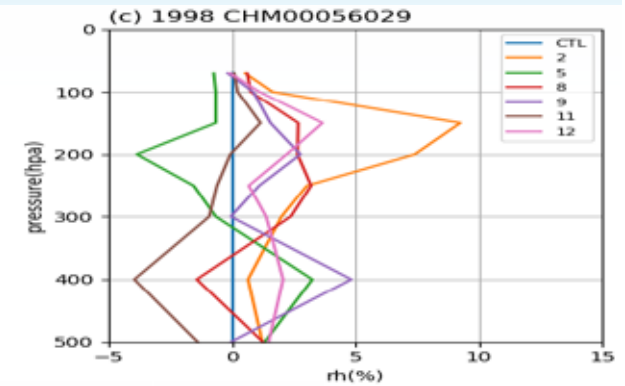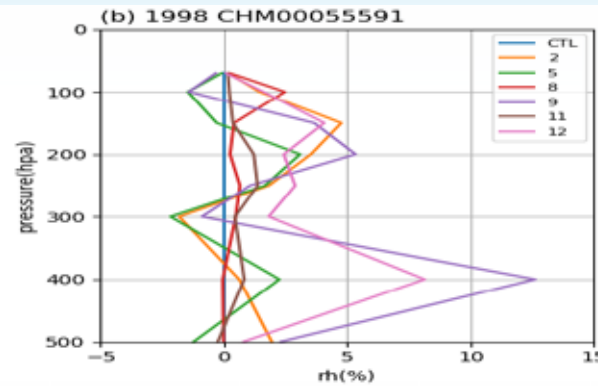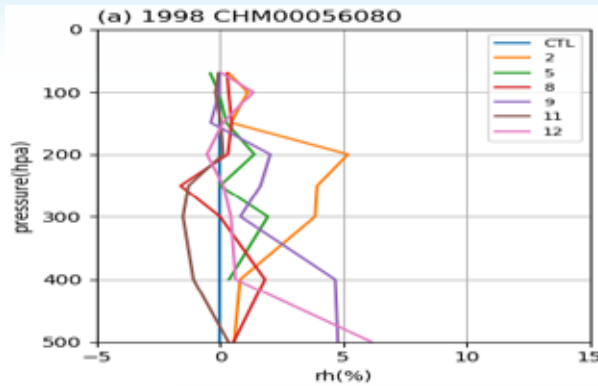

The variations of PBLH are quite similar, MYNN2.5 shows highest PBLH

➢Evaluate the profiles of relative humidity to see the influence of PBLs
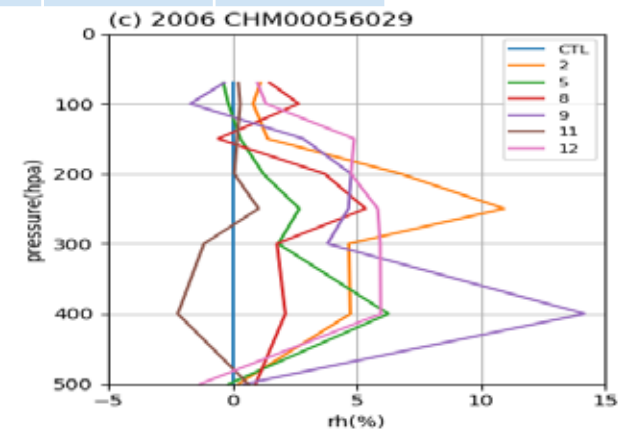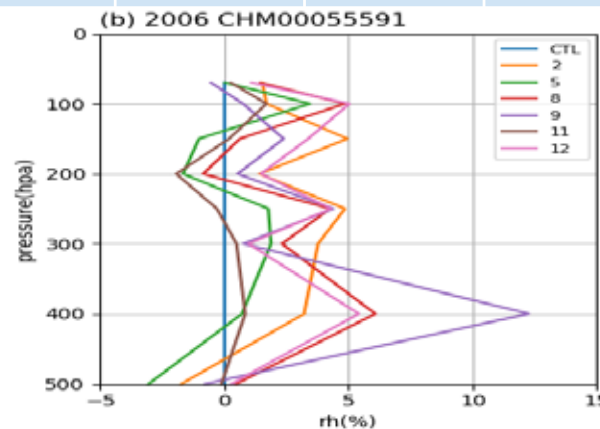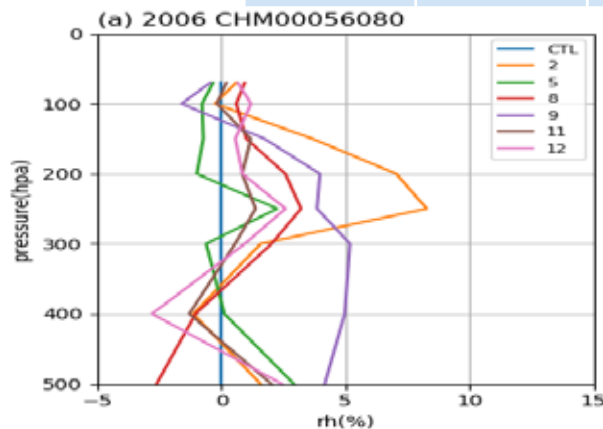
➢The three stations are chosen over TP region

	lat	lon	height
56080	35.0	102.9	3500.0
56029	33.0	96.95	3301.0
55591	29.67	91.13	2940.0

Vertical profile (relative humidity)

Stn.	YSU ctl	MYJ 2	MYNN 5	BL 8	UW 9	SH 11	GBM 12
56080	4.60	4.33	4.75	4.36	5.41	4.82	5.44
55591	3.30	3.94	3.18	3.56	5.97	3.99	4.82
56029	5.55	6.19	5.17	5.69	5.09	4.52	5.50

| Stn.	YSU	MYJ	MYNN	BL	UW	SH	GBM
56080	3.27	3.24	2.74	3.06	3.44	3.34	3.58
55591	2.70	4.87	2.61	3.13	3.23	2.74	4.01
56029	5.50	6.04	4.68	5.55	6.54	4.96	6.01

Conclusion

➢ WRF can simulate the difference of JJA precipitation between 1998 and 2006, but it clearly overestimate the JJA precipitation especially in dry year over TP.

➢ Obvious differences of PBL height can be found in WRF simulations with different PBL schemes.

➢ The overestimation of low level moisture is associated with the overestimation of precipitation.

Evaluation of high resolution decadal regional climate simulation over TP

Experiment Design

Model Doamin

height(m)
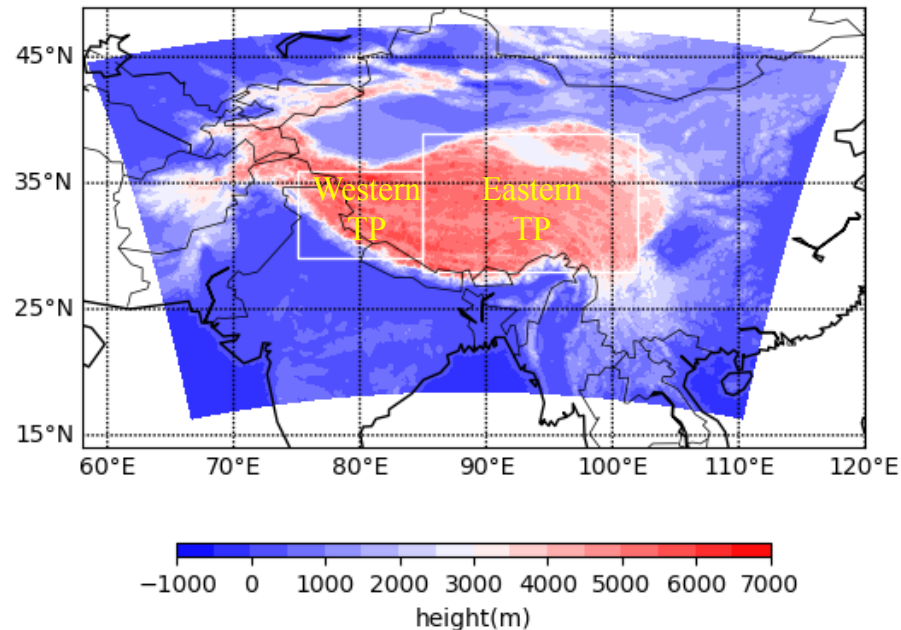
Validation Dataset:
  Daily precipitation and surface air temperature from APHRODITE
aphrodite.st.hirosaki-u.ac.jp

| Model Configuration	
Model prototype	WRF 4.1.1
Governing equations	Nonhydrostatic
Grids and resolution	531x361, 9km
Vertical Layers (top)	40 P-Sigma layers (50hPa)
Cumulus convection	NONE
Explicit moisture	Thompson
Planetary Boundary Layer	MYNN 2.5 level
Radiation	RRTMG
Land Surface	NOAH-MP LSM
Spectral Nudging	Yes
Driving	ERA5 3hr
Simulation Period	2000-2009 Continue Run

Mean Precipitation

WRF
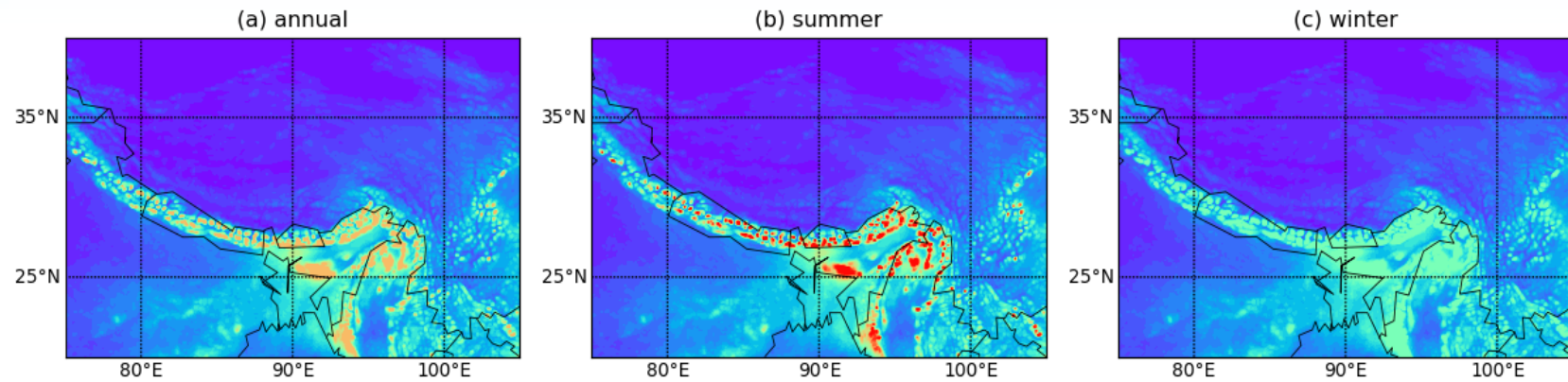
APHRO

Wet bias
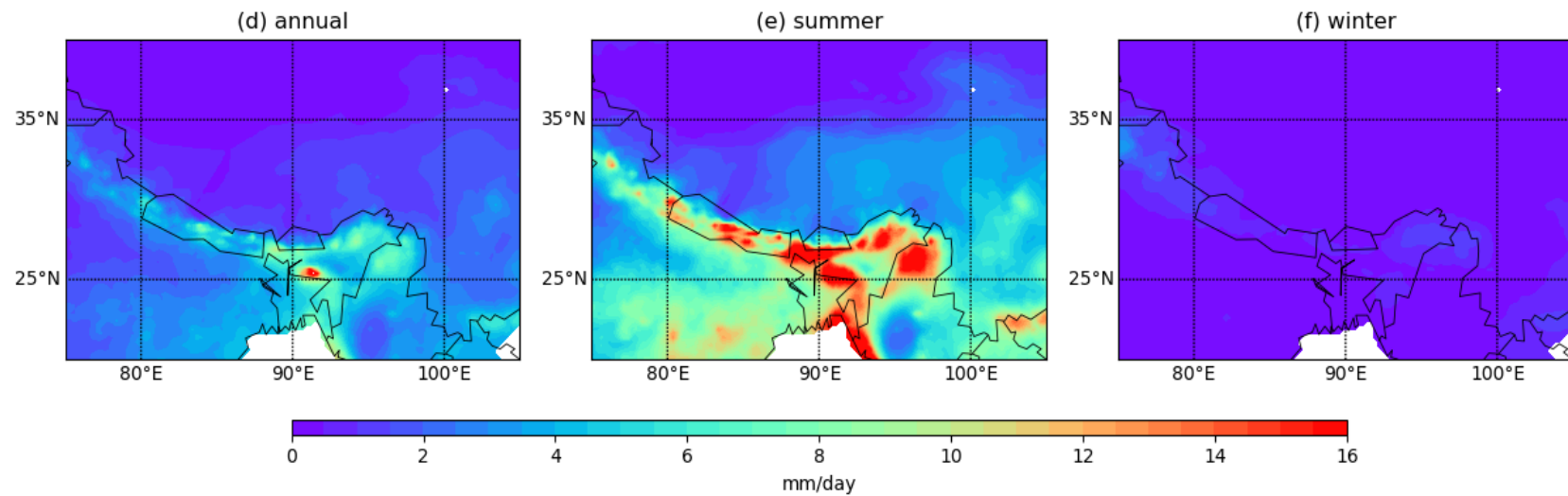
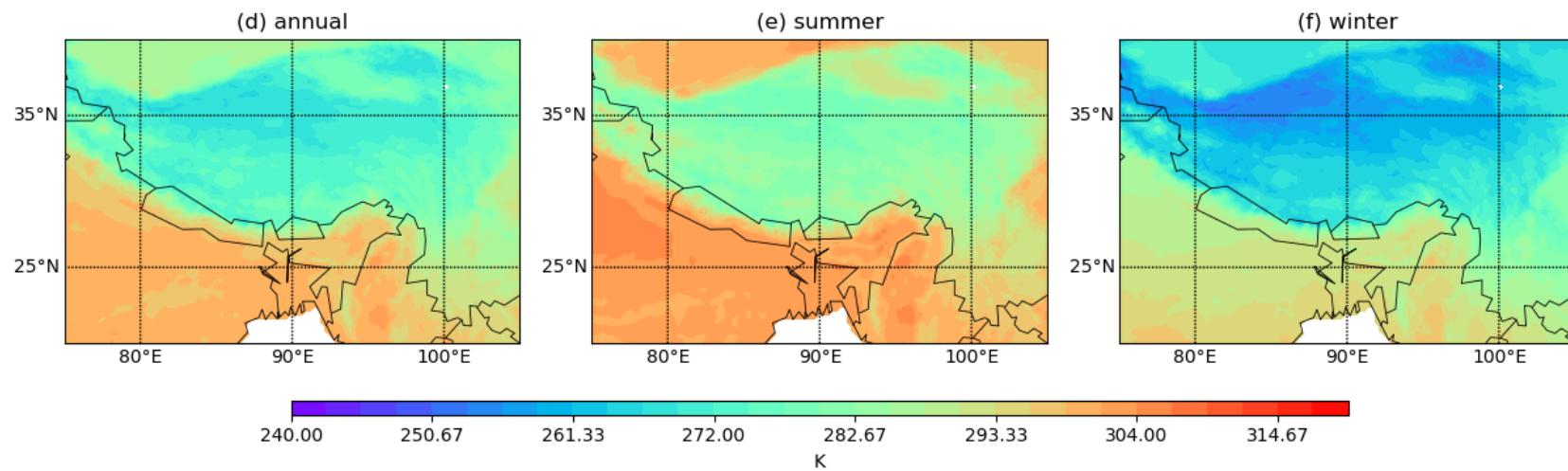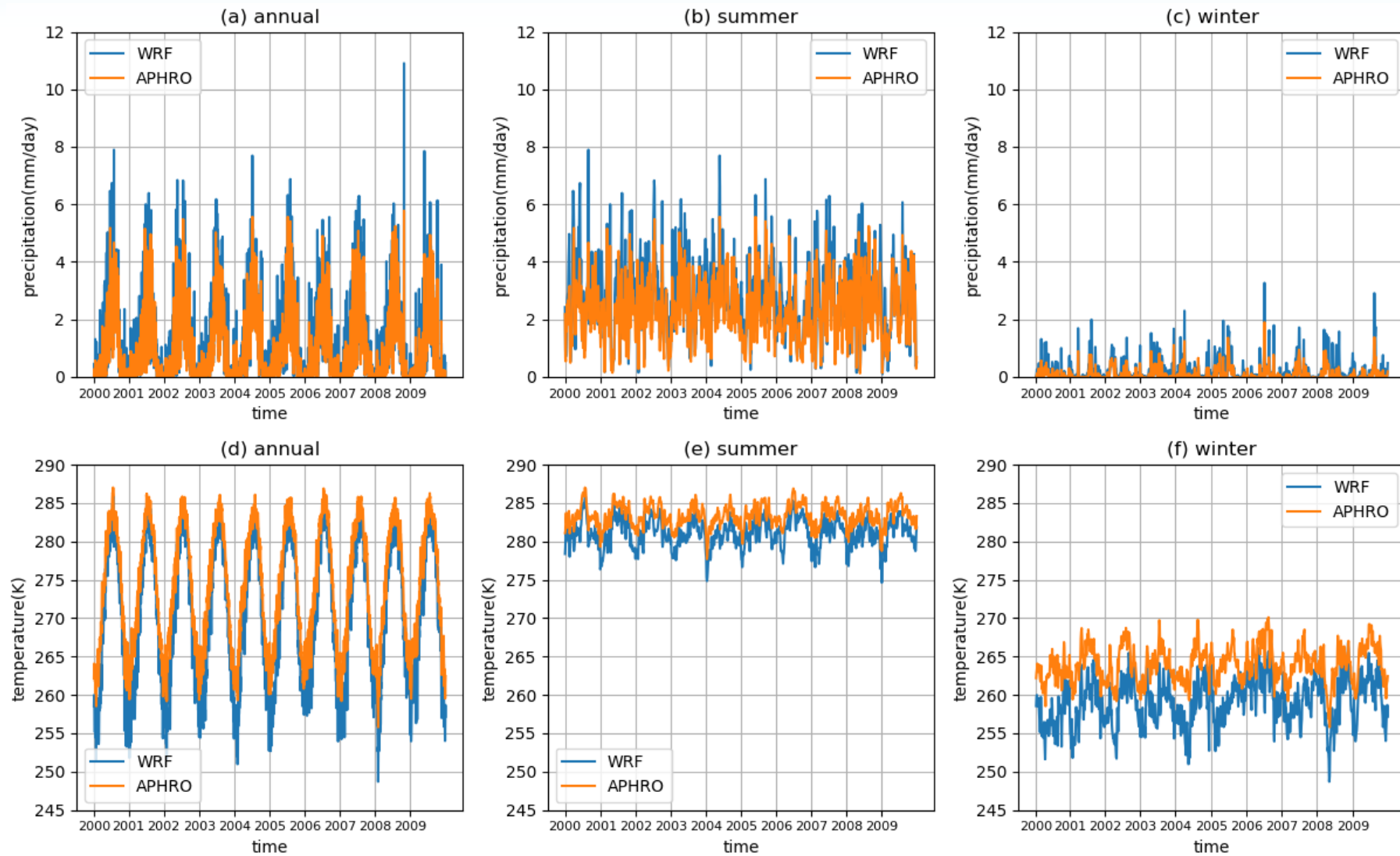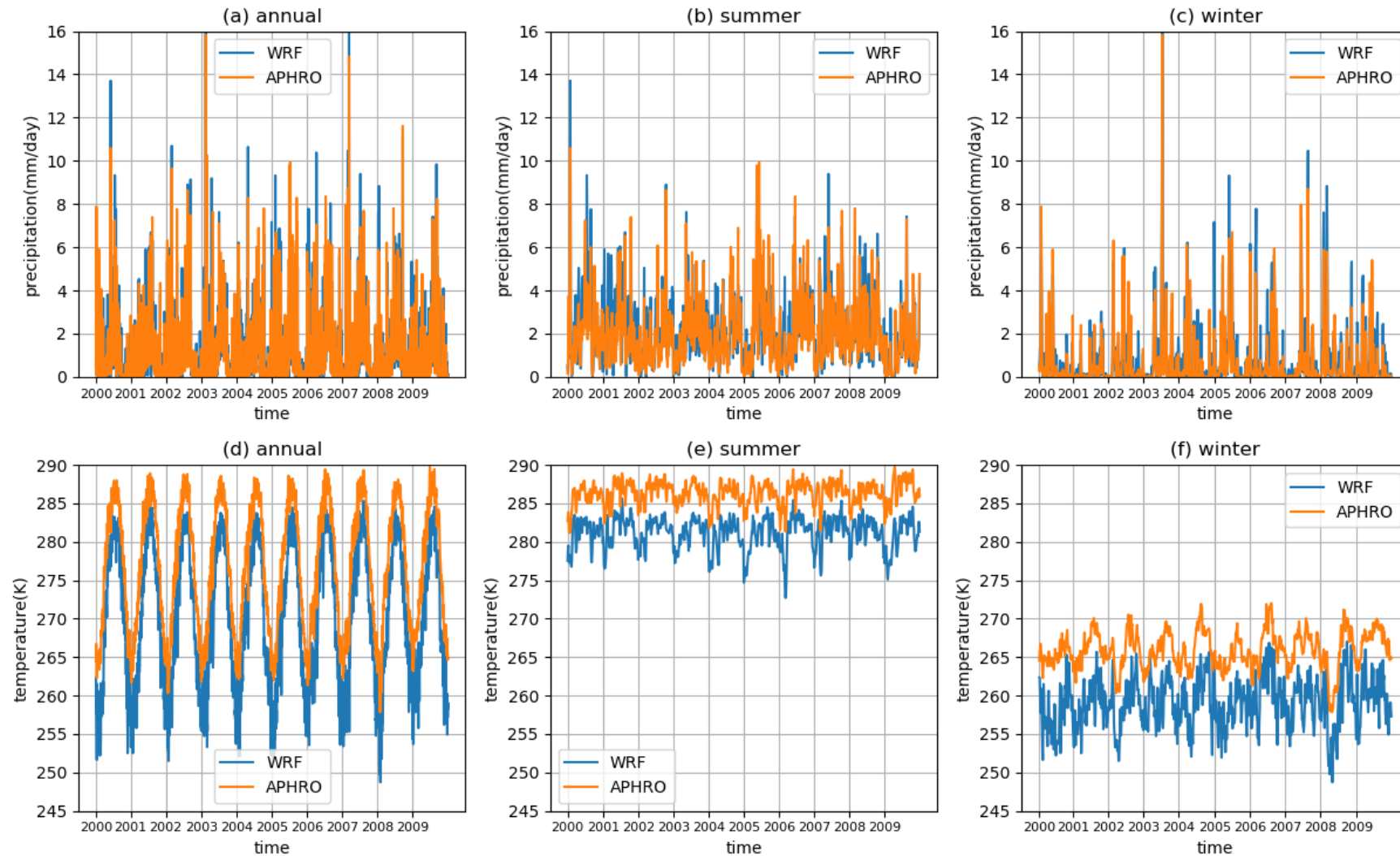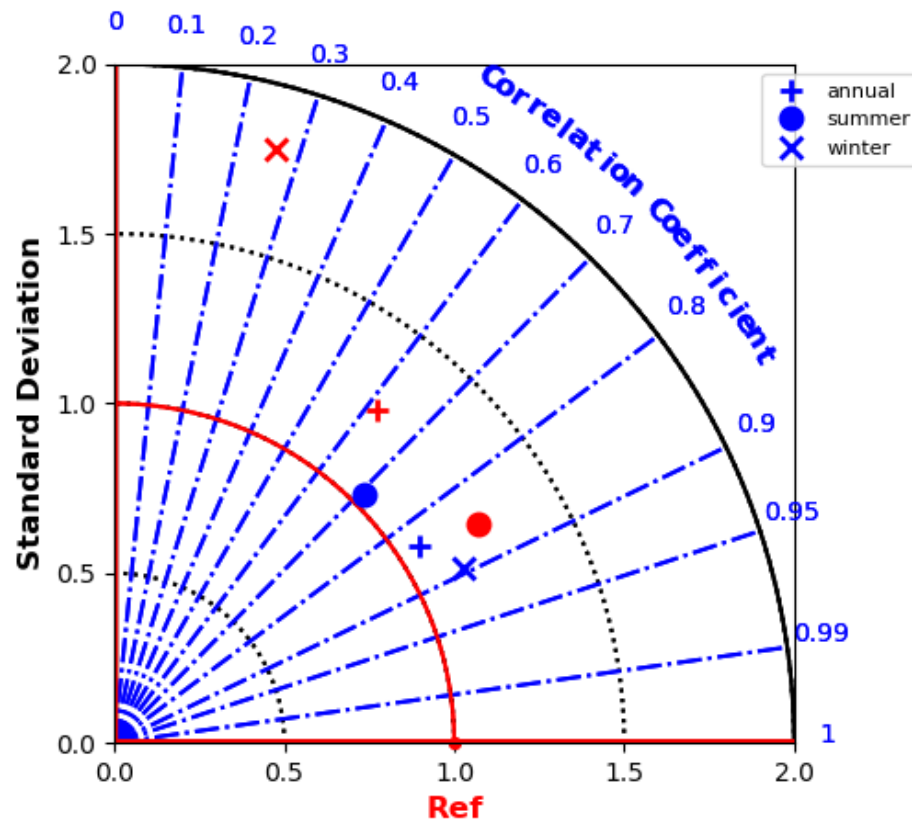# Mean Surface Air Temperature

WRF
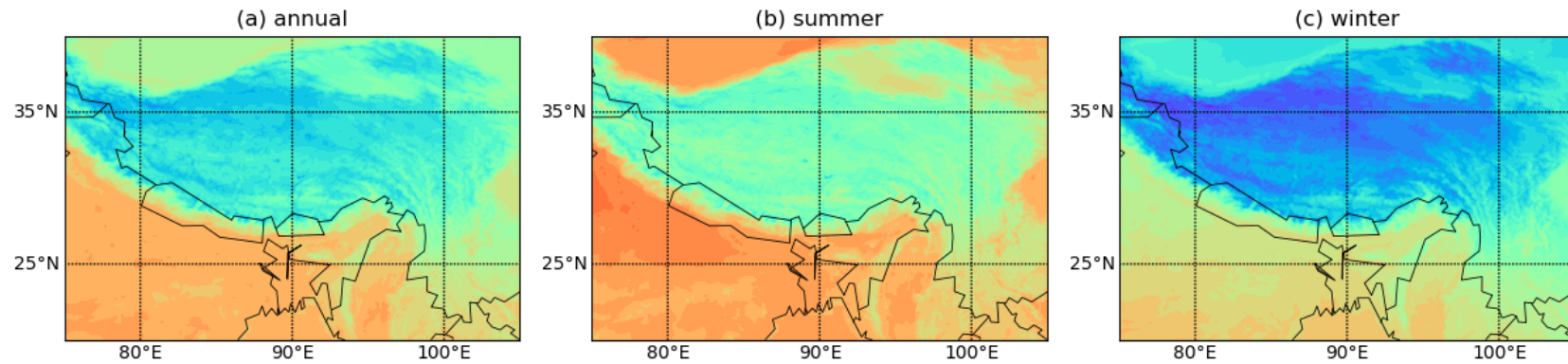
APHRO

Cold Bias

Variation of Pr and T2m over Eastern TP

Variation of Pr and T2m over Western TP

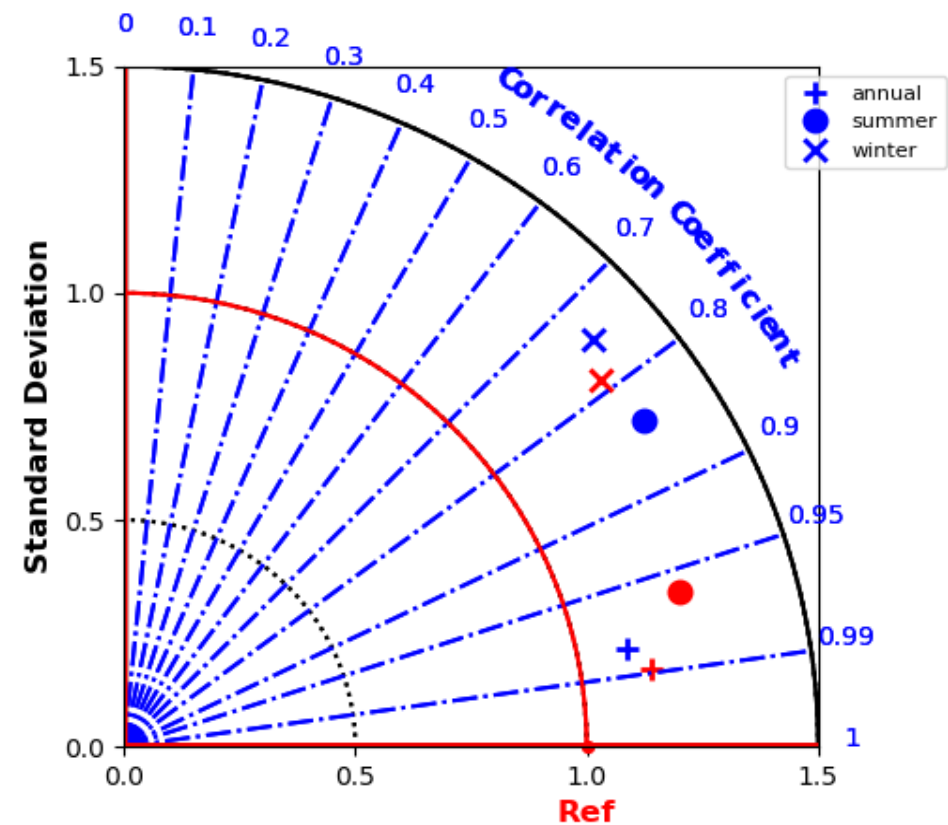# Taylor Diagram of temporal variations of precipitation and surface air temperature
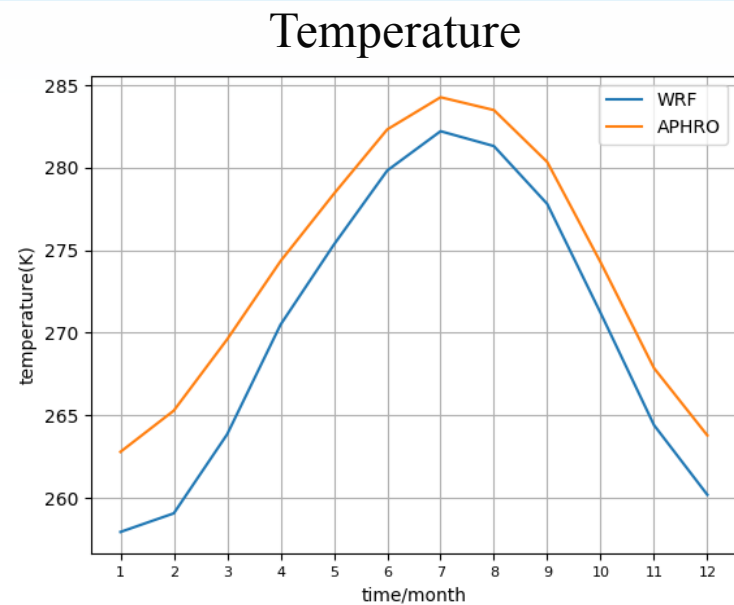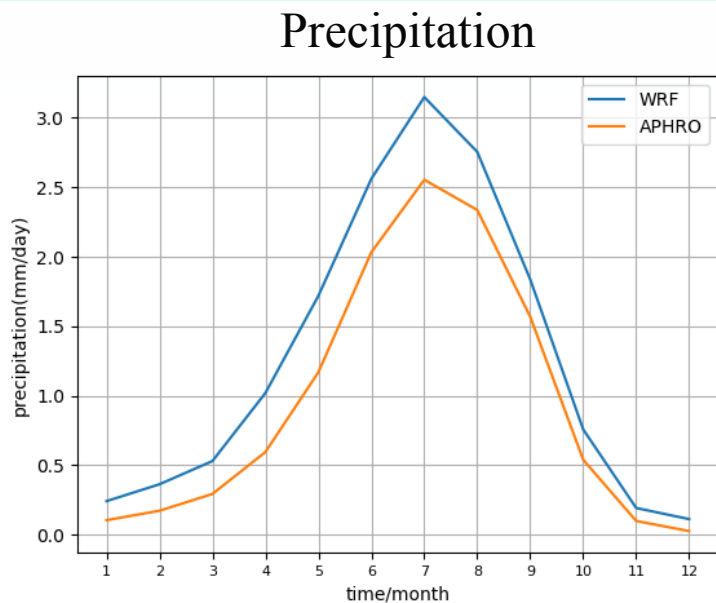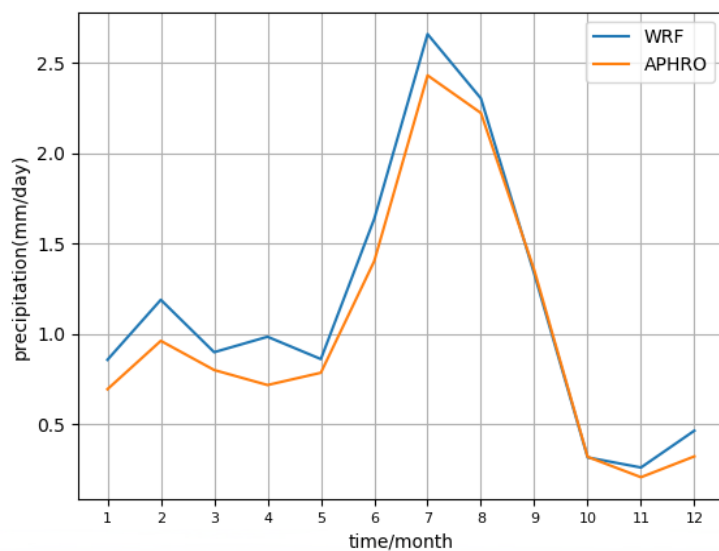

Precpitation

Temperature

Red: Eastern TP   Blue : Western TP

Seasonal Cycle

Precipitation

Temperature

Eastern TP

Western TP
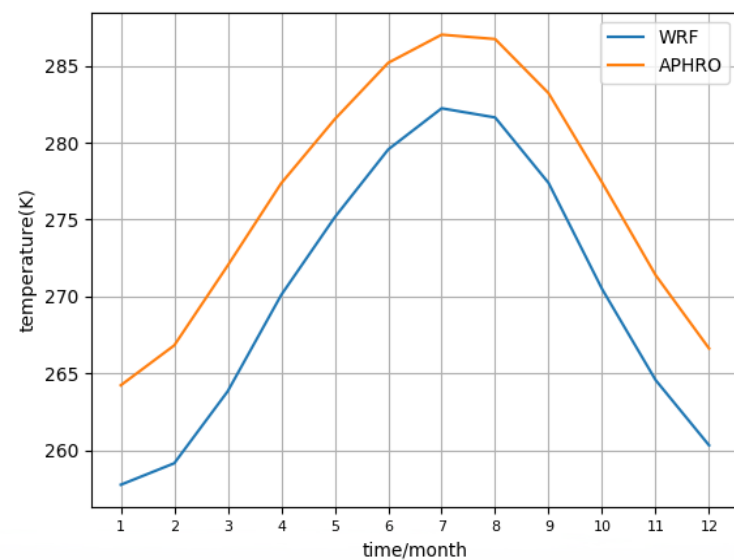
Surface wind over complex terrain

(a) annual   (b) summer   (b) winter
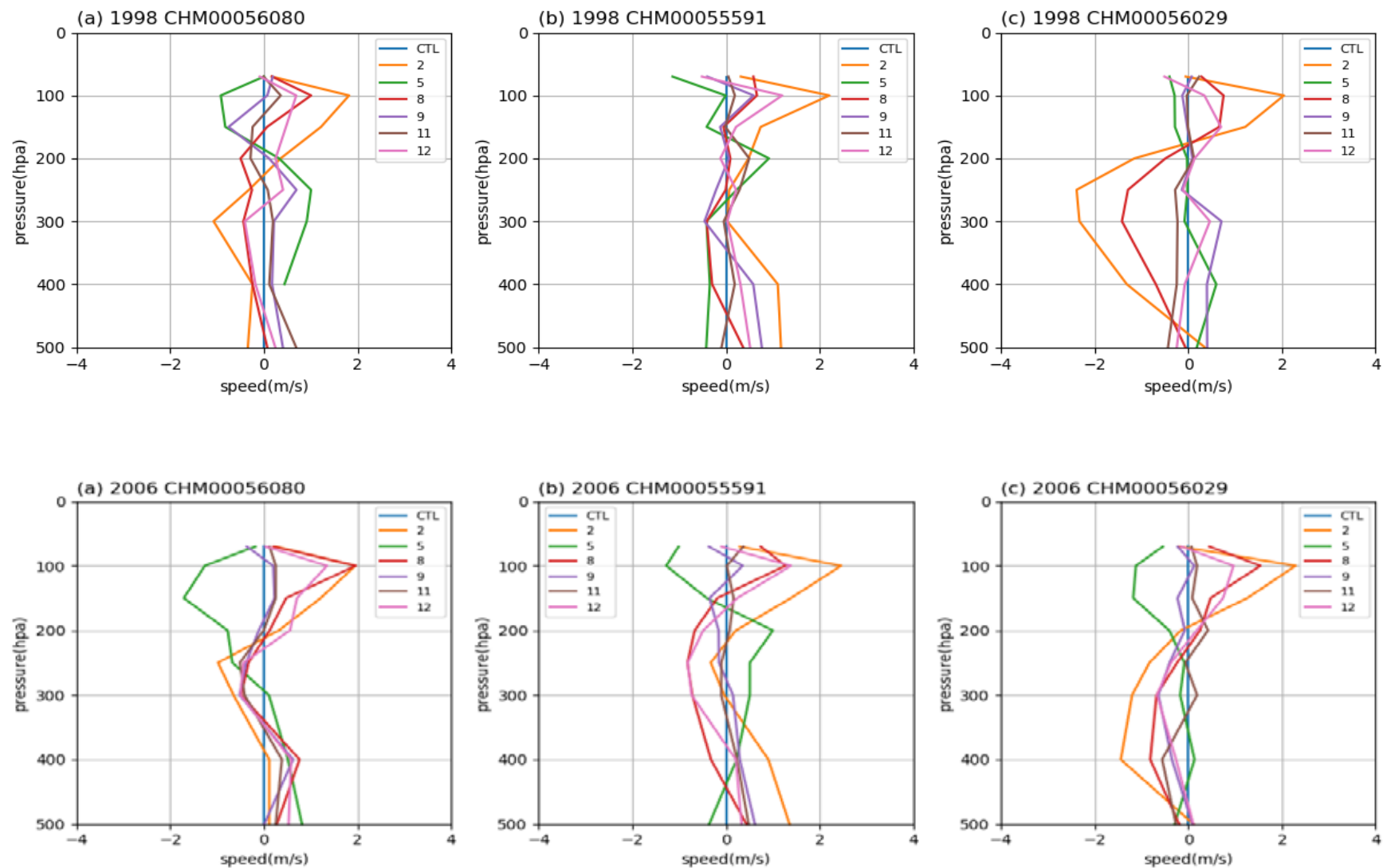
Wind speed (m/s)
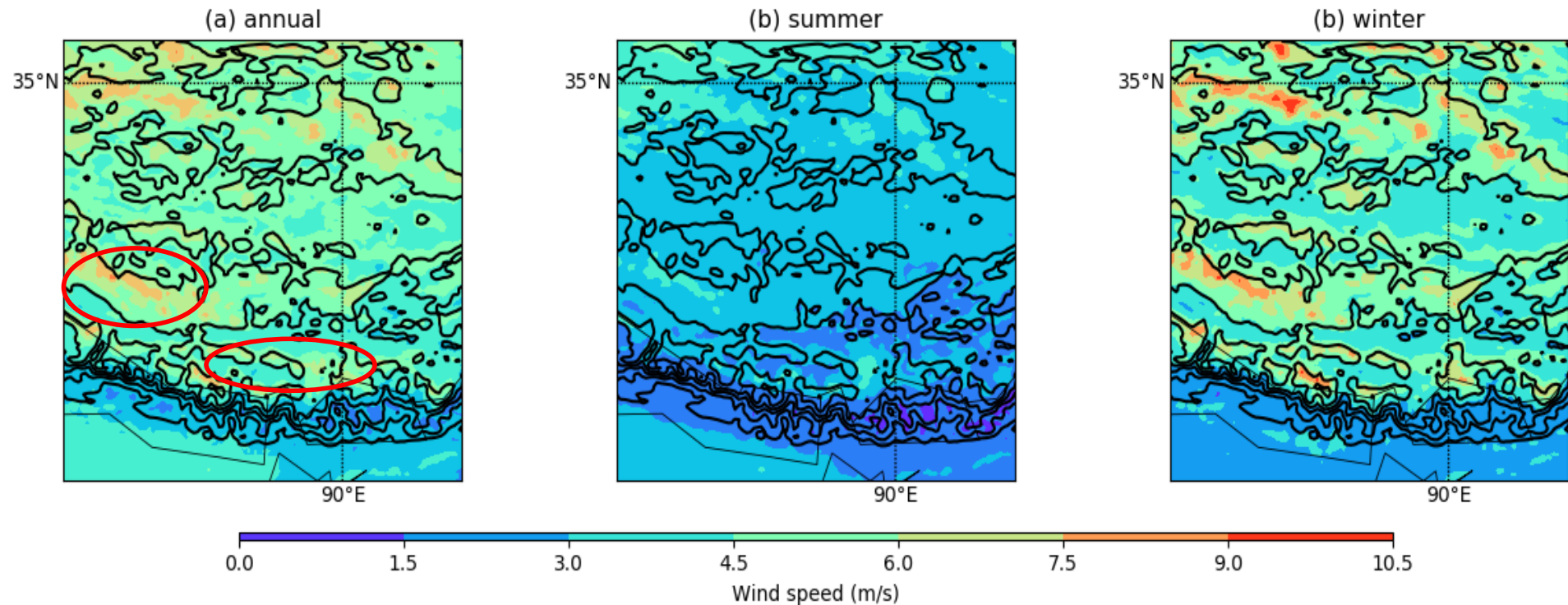
WRF with high resolution can reproduce the surface wind induced by complex topography

Summary

➢ The WRF simulation without convection scheme at gray-zone grid can well reproduce the spatiotemporal variations of annual mean precipitation and surface air temperature over Tibetan Plateau.

➢ Compare to the APHRO grid datasets, WRF tend to overestimate the precipitation and underestimate the temperature in winter.

➢ Larger positive biases of precipitation exist over eastern TP, while larger colder biases of temperature exist over western TP.

Thank you !

Vertical profile (wind speed)
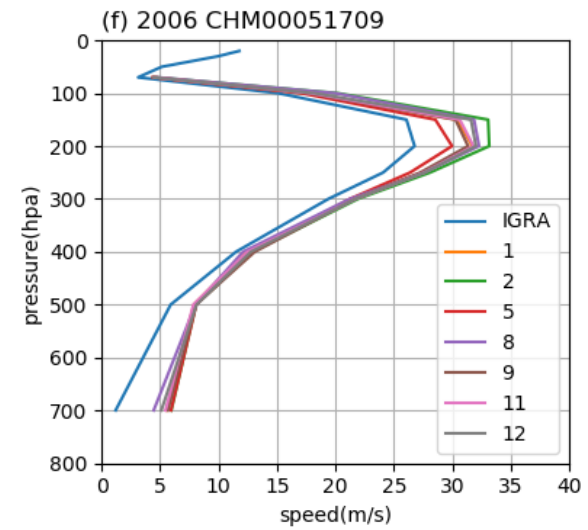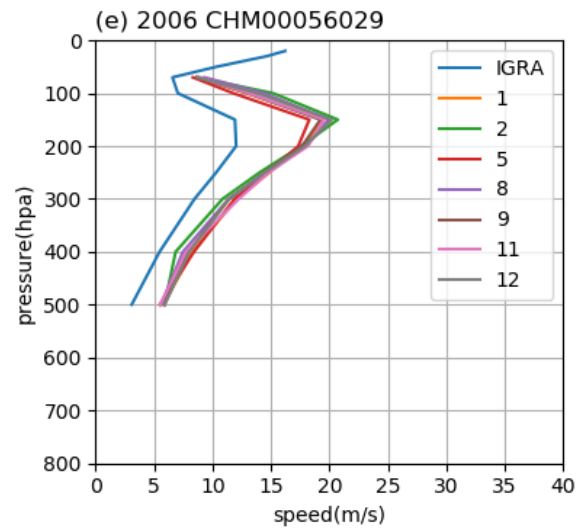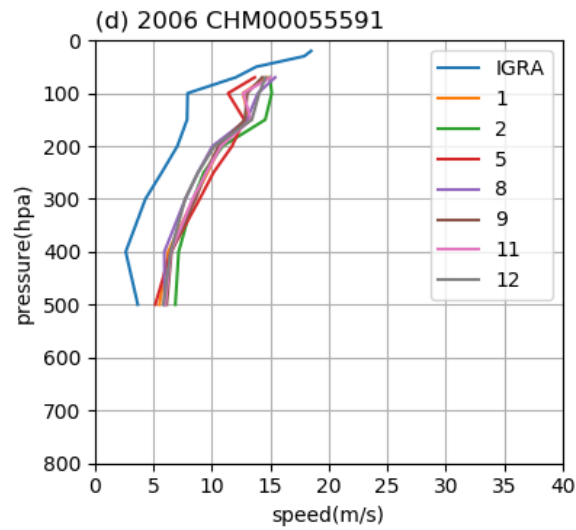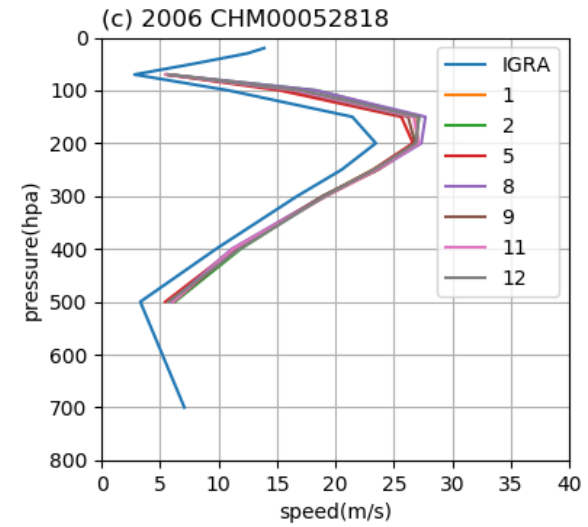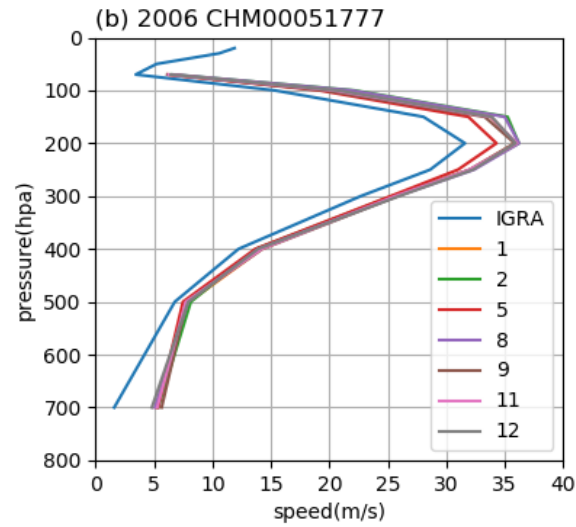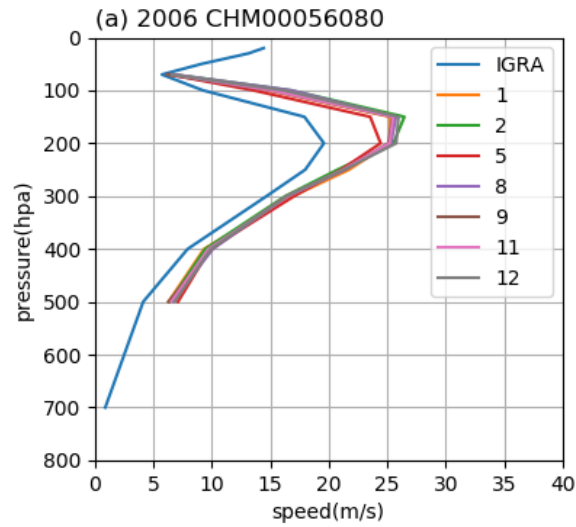
Total Wind Speed(year 1998)
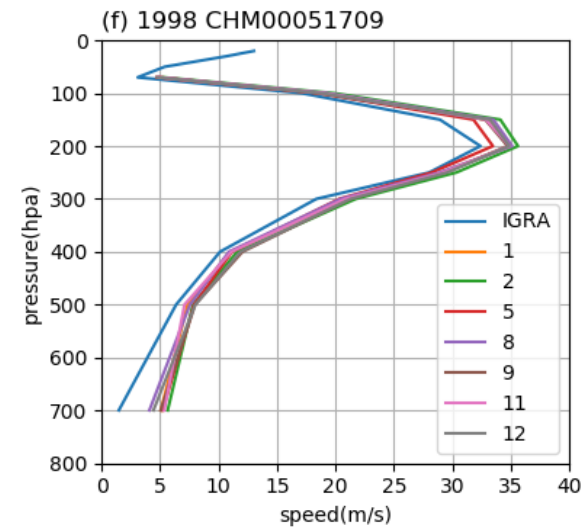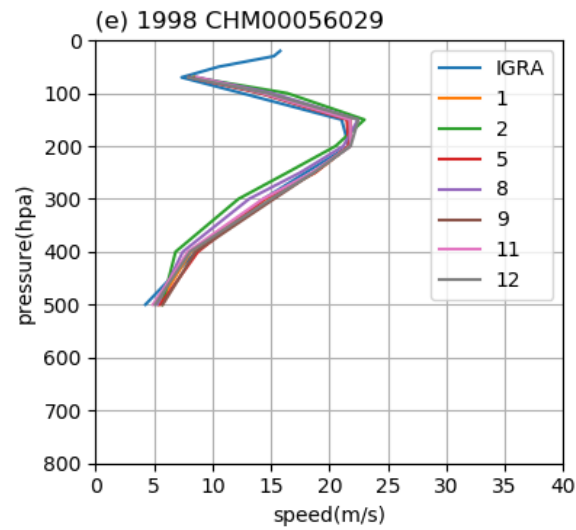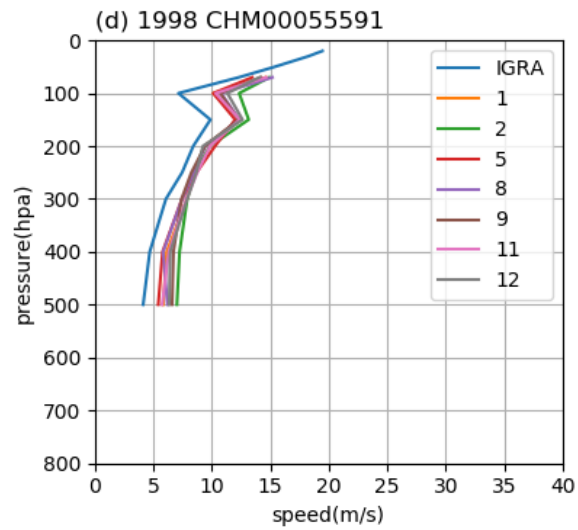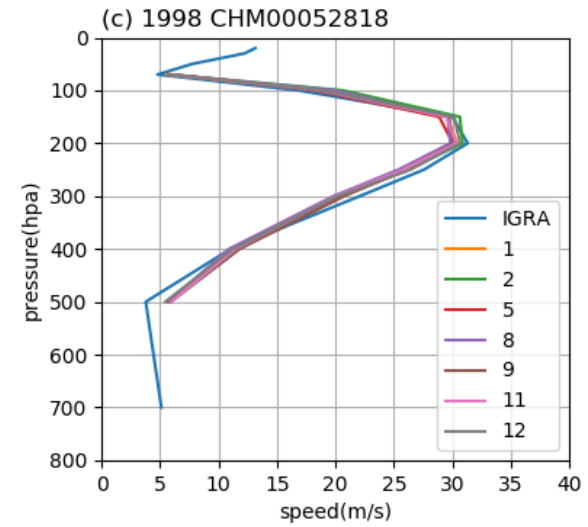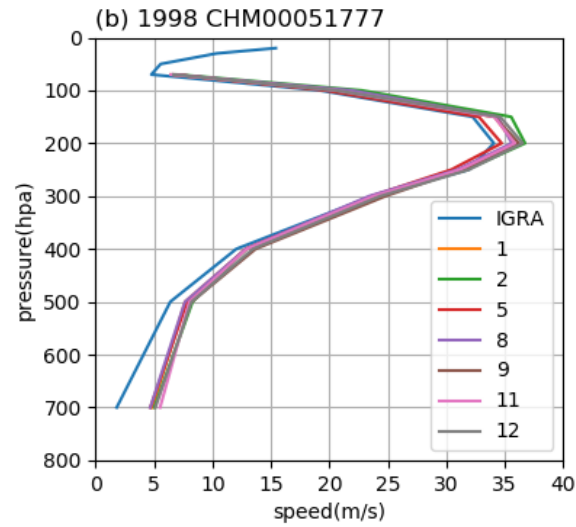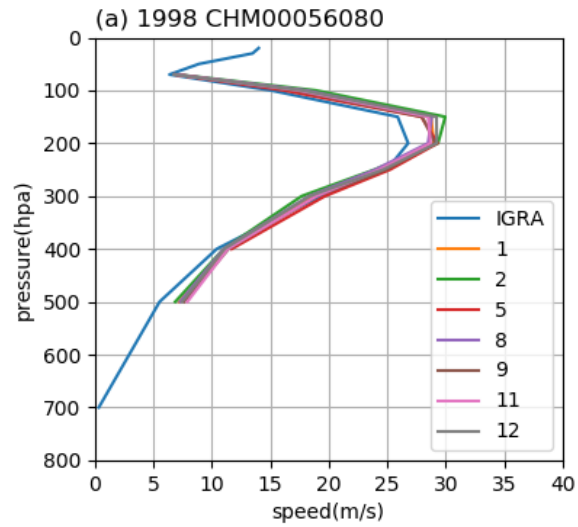
Total Wind Speed(year 2006)

Table 2

Overview of the PBL parameterization schemes used in this study.

Scheme	Closure type	Boundary layer height definition
YSU (Hong et al., 2006)	1.0 order nonlocal	R_{ib} method (0 for stable, 0.25 for unstable)
MYJ (Janjić, 2002)	1.5 order local	TKE threshold $(0.2\,m^2\,s^{-2})$
MYNN3 (Nakanishi and Niino, 2004)	2 order local	TKE threshold $(1.0 \times 10^{-6}\,m^2\,s^{-2})$
BouLac (Bougeault and Lacarrère, 1989)	1.5 order local	TKE threshold $(5.0 \times 10^{-3}\,m^2\,s^{-2})$
GBM (Grenier and Bretherton, 2001)	1.5 order local	Prognosed from three entrainment closure approach
ACM2 (Pleim, 2007)	1.0 order nonlocal	R_{ib} method (0.25)
UW (Bretherton and Park, 2009)	1.5 order local	R_{ib} method (0.25)
SHIN-HONG (Shin and Hong, 2011)	1.0 order nonlocal	R_{ib} method (0)

(Xu et al., 2019)