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Simulation with WRF of anomalous East Asia summer monsoon in 1993: Sensitivity to shortwave radiation schemes and ozone absorption

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1. Introduction

❑ Previous regional climate modeling studies

- **Most of WRF regional climate studies have used the simple shortwave radiation scheme of Dudhia (1989) instead of the more realistic spectral scheme of Chou and Suarez (1999) which has been available since 2000 (Chen and Dudhia 2000).**

- **In a large number of regional climate model (RCM) studies, the prescribed vertical limit in a model has been much lower than the observed maximum height of ozone (10~5 hPa).**

❑ Assumption

- **The use of the Goddard scheme (Chou and Suarez 1999) and the inclusion of maximum ozone height in the WRF model might give better results in reproduced temperature.**

- **The improved temperature would result in more realistic simulation of the East Asia summer monsoon (EASM) because…**

1. Introduction

❑ Large-scale circulations and EASM

- Intensity and location of **upper and low level flows** can significantly affect the **frontal activity and displacement** of the subtropical front (Meiyu, Changma and Baiu).

- Upper level jet over central/southern China, Korea and Japan
  - northward shift of suppressed jet : anomalous drought
  - southward shift of enhanced jet : anomalous flooding

- 850 hPa wind: strengthened (weakened) southerly (or southwesterly) resulted in the increase (decrease) of precipitation

- Of note here is that both the high and low level **large-scale circulations** are closely related to the **large-scale temperature structure**.
  - Upper level jet: northward temperature gradient (thermal wind relationship)
  - (Low-level) monsoon flows: land-sea thermal contrast

2. Numerical Experiments

❑ Configuration (Version 2.1.1)

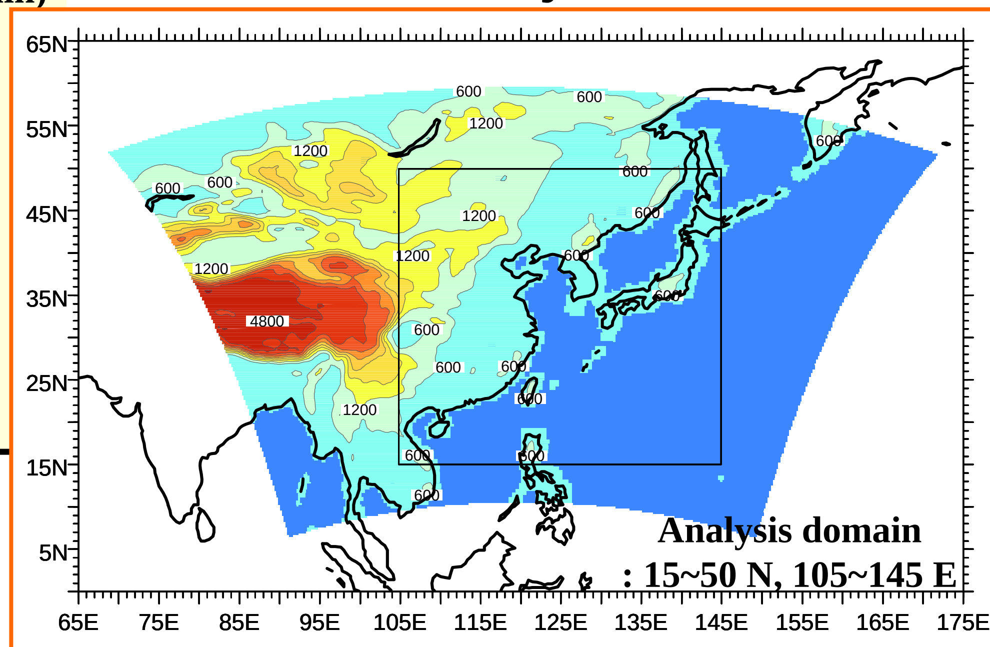
Features	Selected value/option
Integration time step	180 s
Horizontal resolution	50 km (145 X 115)
Simulation period*	1 May 1993 - 31 August 1993
Analysis period	1 June 1993 - 31 August 1993
Surface B. C. & SST	Reanalysis-2 (1.875° X ~2 °, 6 h)
Lateral B. C.	ERA (2.5° X 2.5 °, 6 h)
Cumulus convection	Betts-Miller-Janjic (cudt=30 min)
Cloud microphysics	Lin et al.
Surface layer	Monin-Obukhov
PBL	YSU (bldt=180 s)
Land surface	Noah
Longwave radiation	RRTM (radt=30 min)
Solar constant	1365 W m^{-2}
WRF SI for terrain	SILAVWT=0
	TOPTWVL=2

* EASM in 1993: Southward migration of intensified jet and anomalous wet condition over central China, South Korea & Japan

❑ Numerical experiments

	CTL	*SWG*	*SWT*
Shortwave radiation	*Dudhia*	*Goddard*	*Goddard*
Vertical limit	*50 hPa*	*50 hPa*	*5 hPa*
Vertical levels	*31*	*31*	*35*

❑ Model & analysis domain



2. Numerical Experiments

❑ Dudhia scheme (Dudhia 1989)

- **No spectral bands : do not consider the rapidly varying SW absorption with WN.**
- **Absorption of H_2O and cloud**
- **Implicit treatment of absorption of O_3 and trace gases**
- **Scattering : cloud and Rayleigh scattering**

❑ Goddard scheme (Chou & Suarez 1999)

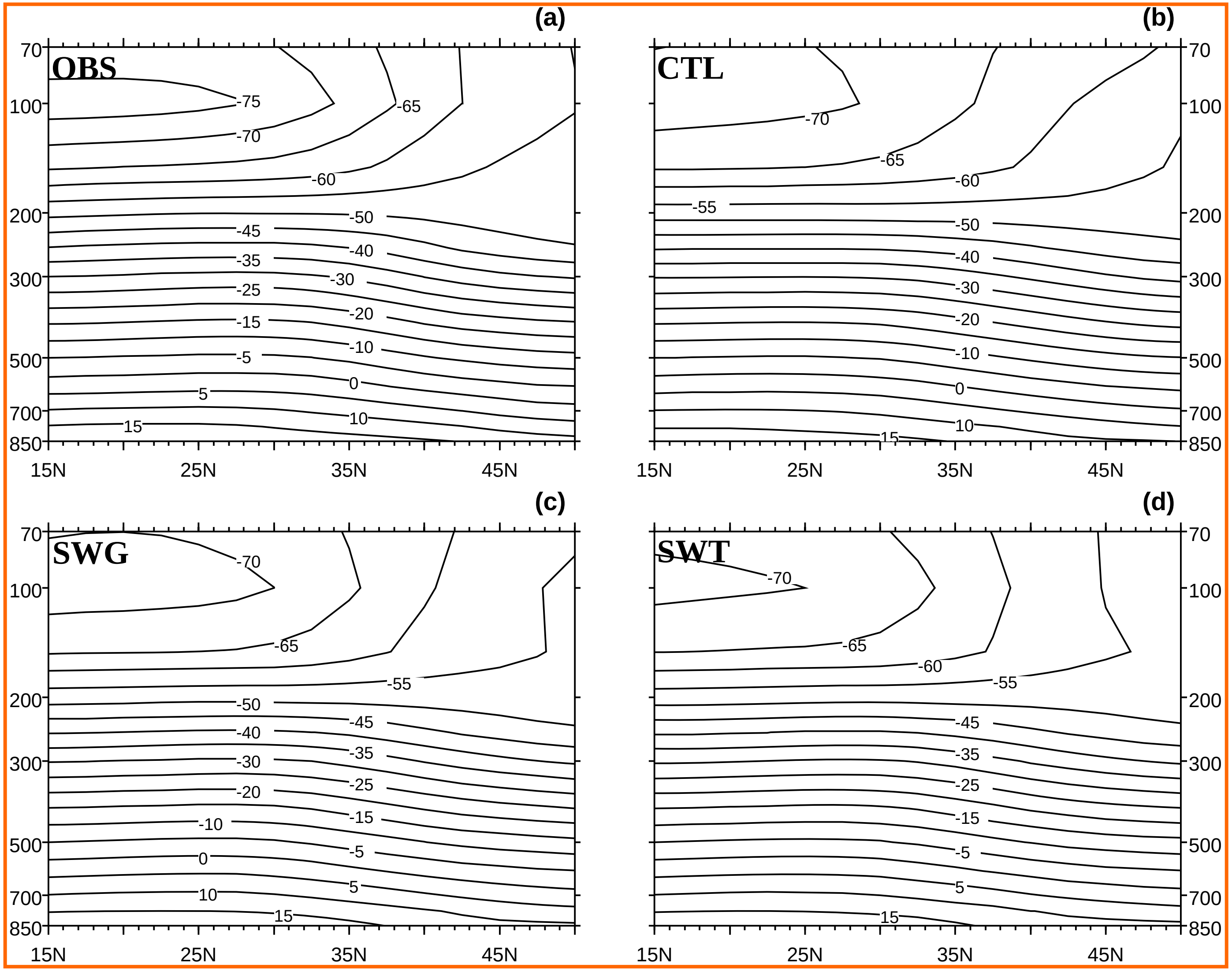
- **11 bands (UV & VIS : 8, NIR : 3)**
- **Explicit and detailed computation of gaseous absorption (H_2O, O_3, O_2, CO_2) and cloud**
- **Scattering : cloud and Rayleigh scattering**
- **Atmospheric heating rate (SFC~0.01 hPa) is accurate to within 5 % compared with high-spectral resolution (line-by-line) calculation under clear-sky condition**

(number of vertical layer = 75)

Band	Spectral Range (μm)	Absorber (A) /Scatter (S)
1	0.174~0.225	O_3 (A)/Rayleigh (S)
2	0.225~0.245 0.260~0.280	O_3 (A)/Rayleigh (S)
3	0.245~0.260	O_3 (A)/Rayleigh (S)
4	0.280~0.295	O_3 (A)/Rayleigh (S)
5	0.295~0.310	O_3 (A)/Rayleigh (S)
6	0.310~0.320	O_3 (A)/Rayleigh (S)
7	0.320~0.400	O_3 (A)/Rayleigh (S)
8	0.400~0.700	O_3, H_2O (A)/Rayleigh (S)
9	0.70~1.22	O_3, H_2O (A)/Rayleigh (S)
10	1.22~2.27	H_2O (A)/Rayleigh (S)
11	2.27~10.0	H_2O (A)
Total spectrum		O_2 (A), CO_2 (A)

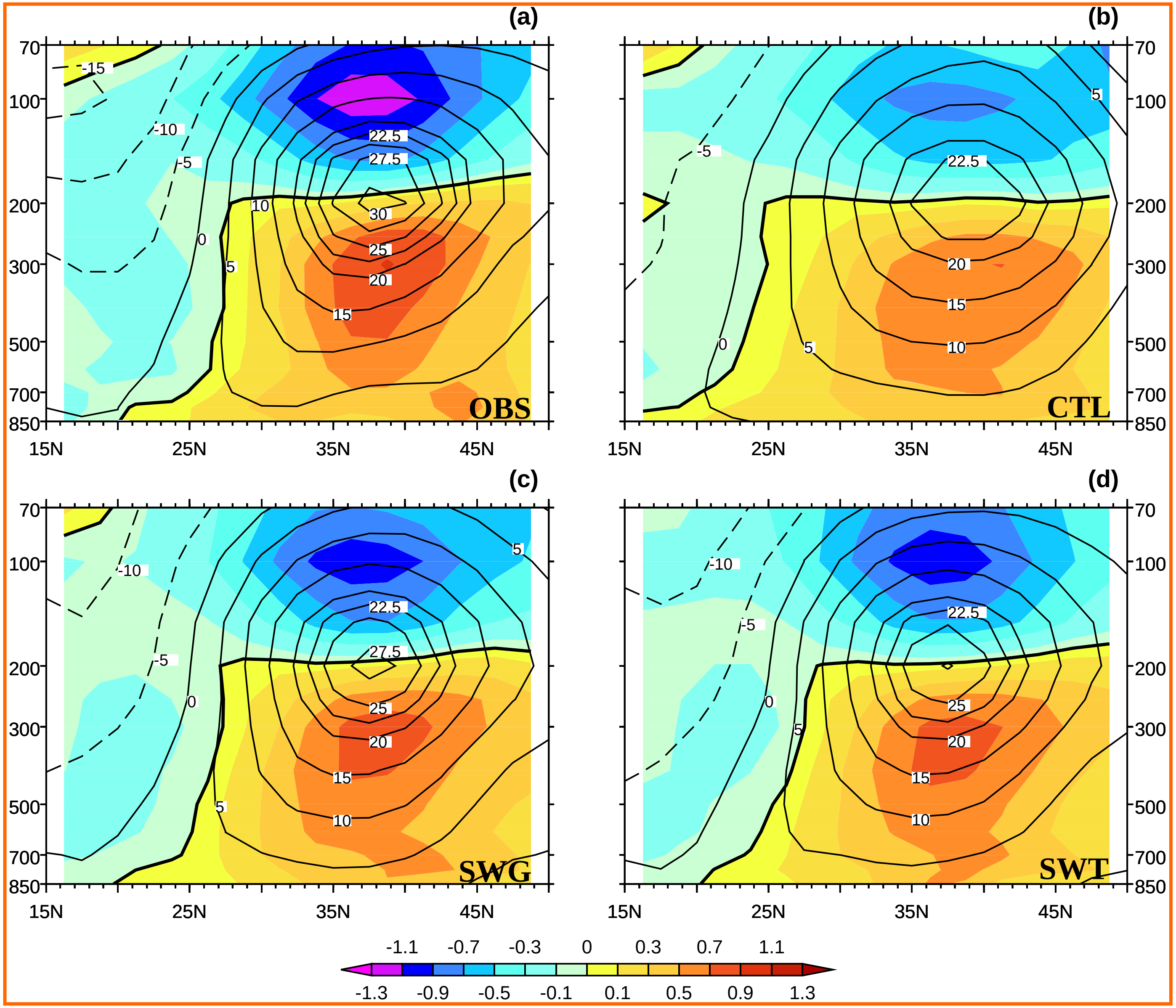
3. Simulation Results

❑ JJA Temperature



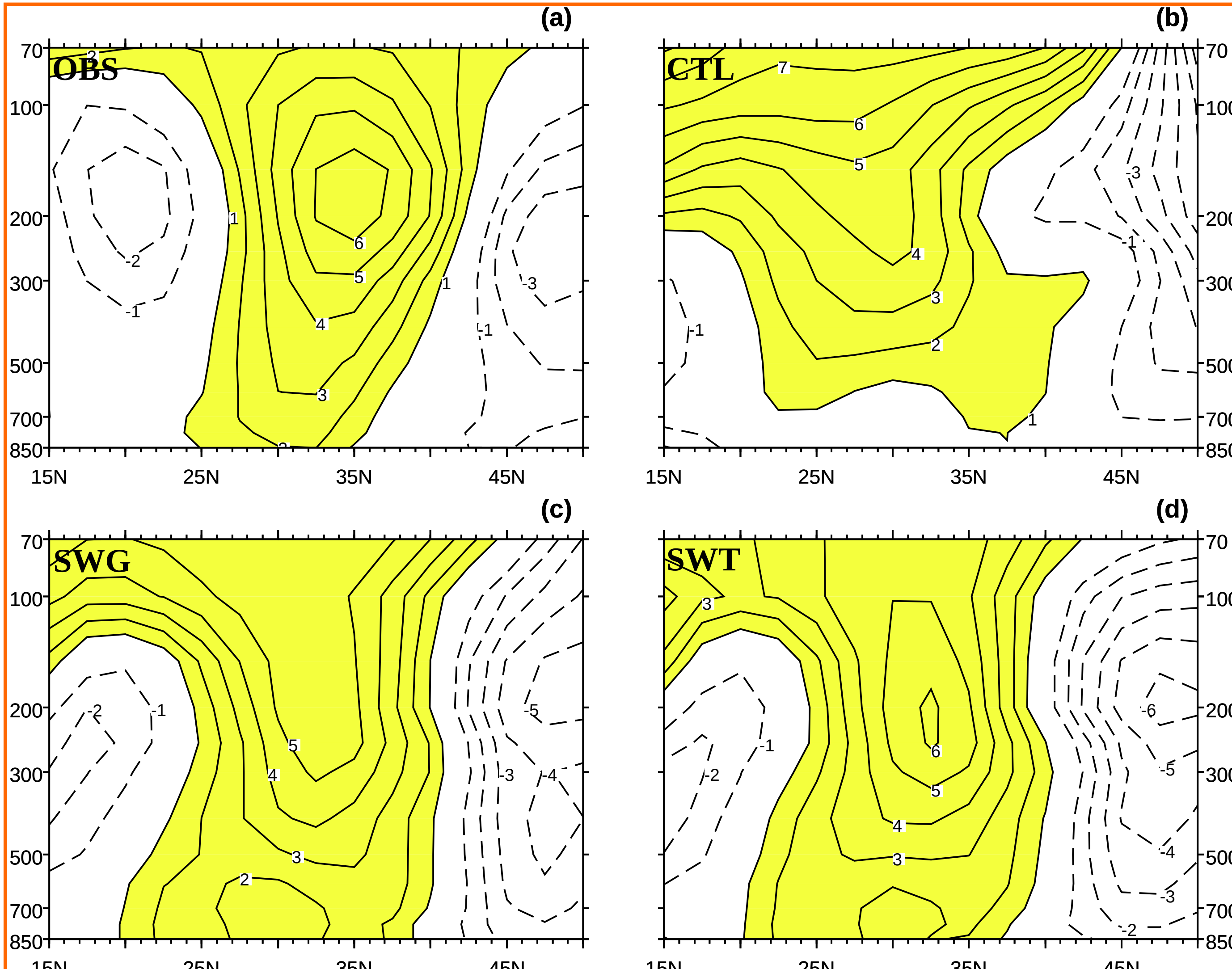
3. Simulation Results

- **JJA ΔT & U**



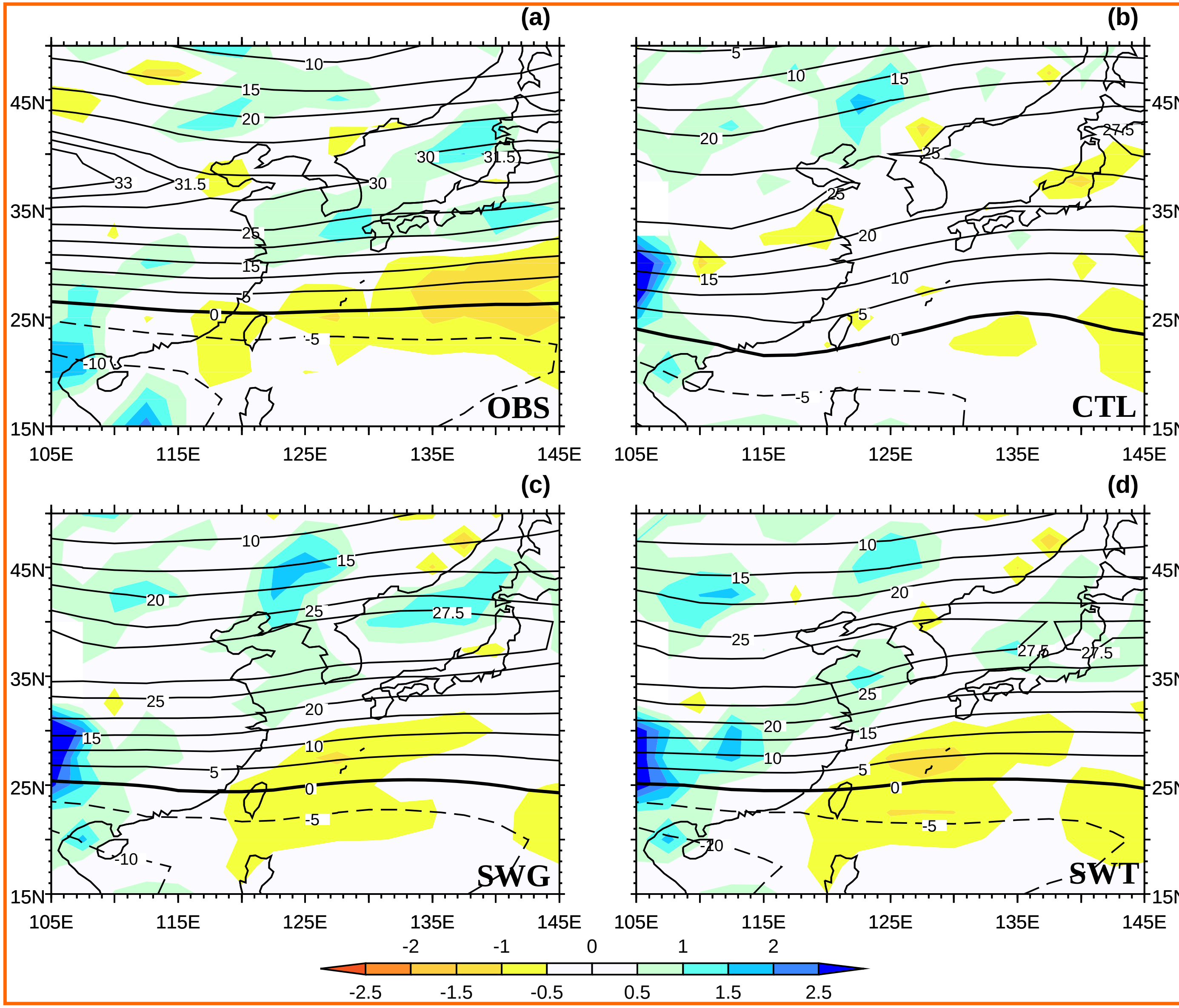
3. Simulation Results

❑ **JJA anomaly of U**

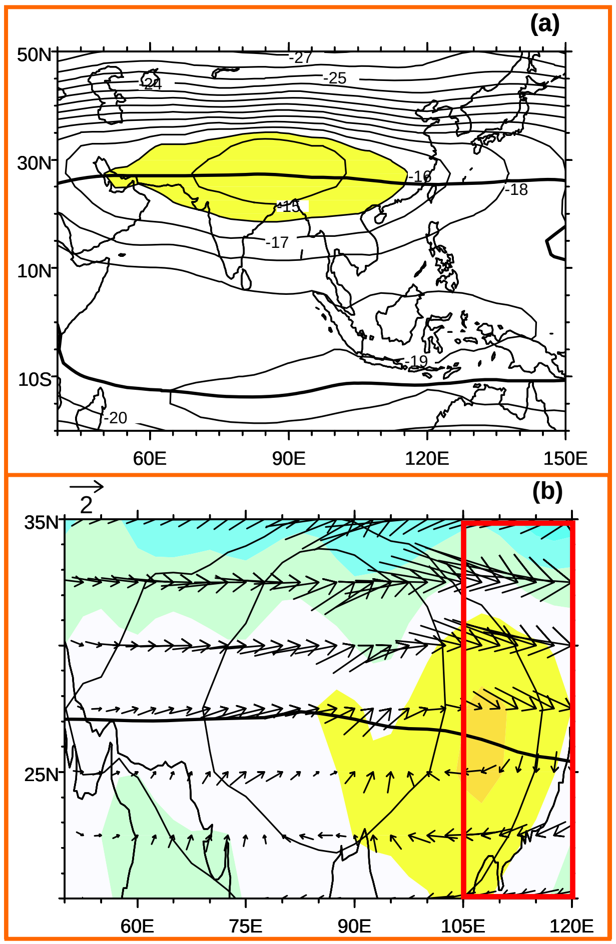


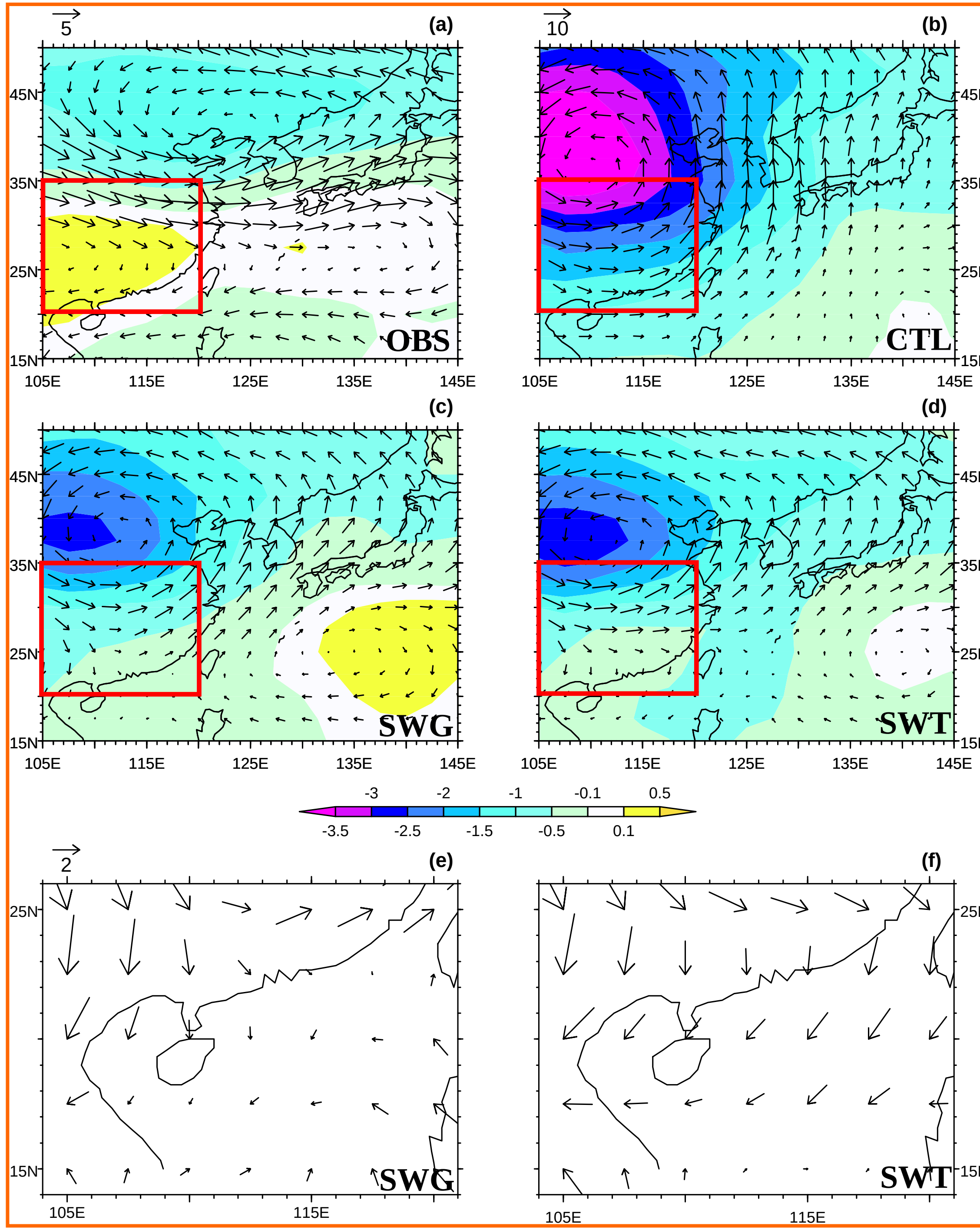
3. Simulation Results

- JJA U200 and RV850



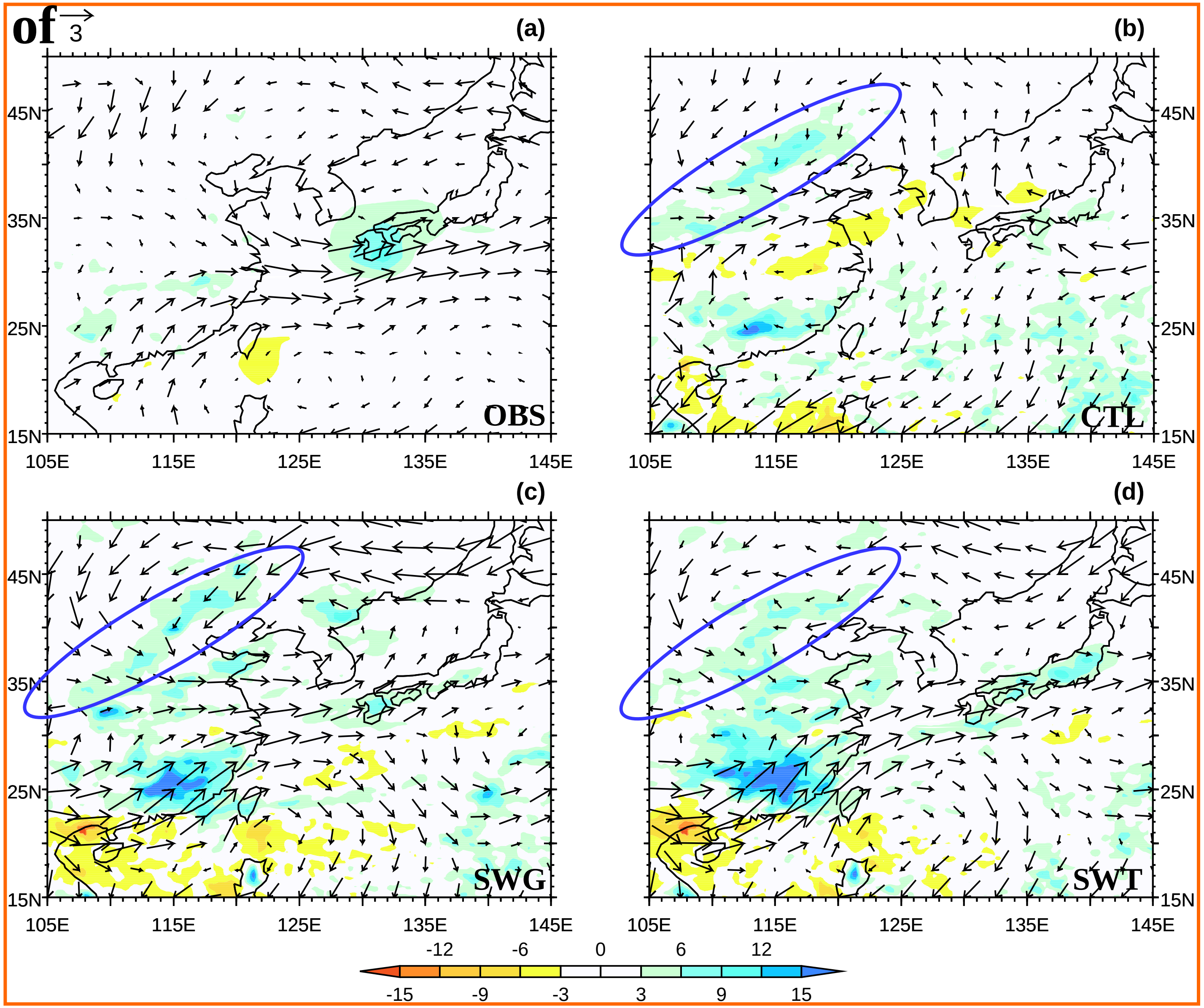
❑ JJA anomaly of vertically integrated temperature (600~200 hPa) & W200





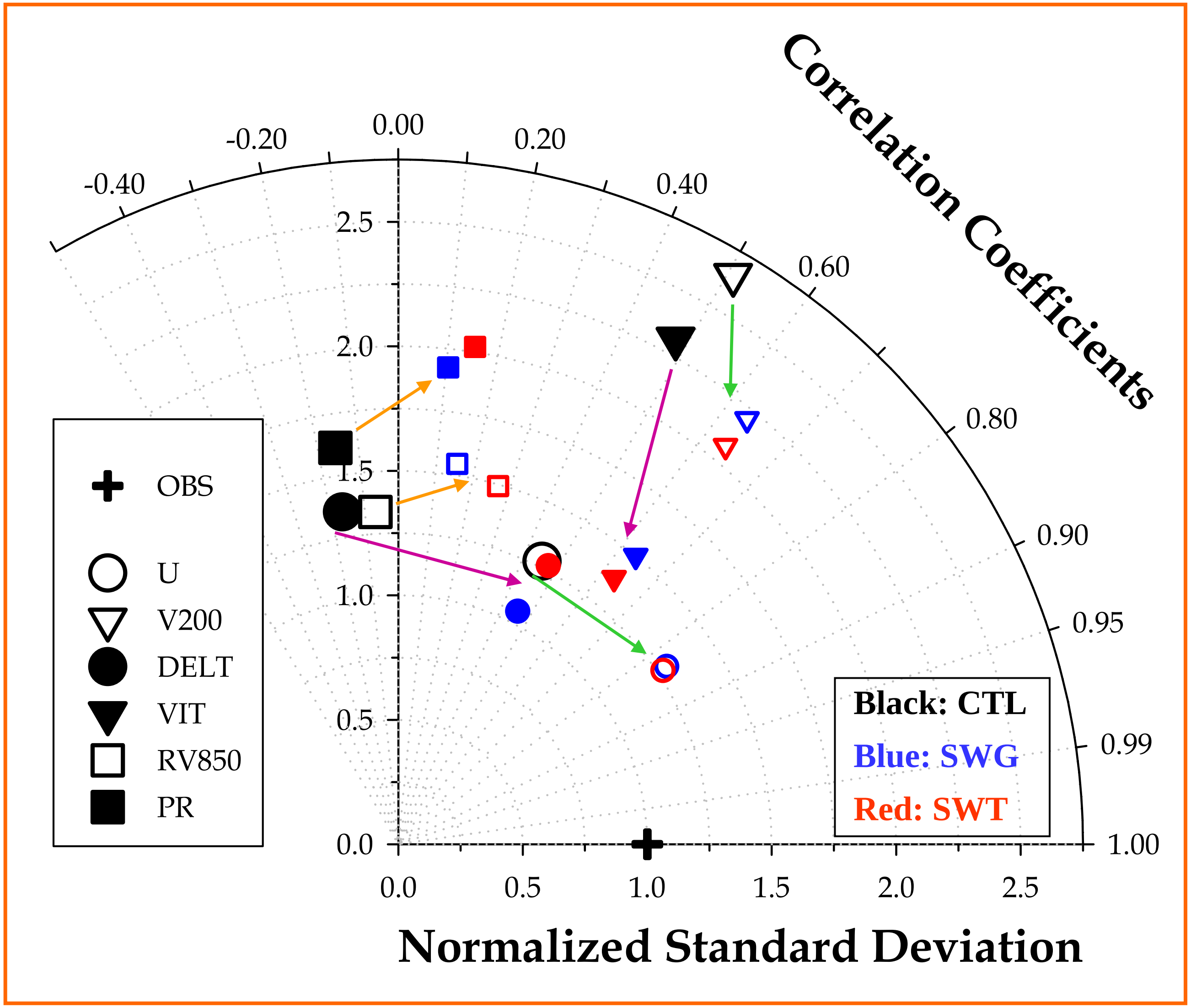
3. Simulation Results

- ❑ JJA anomaly of W850 & PR



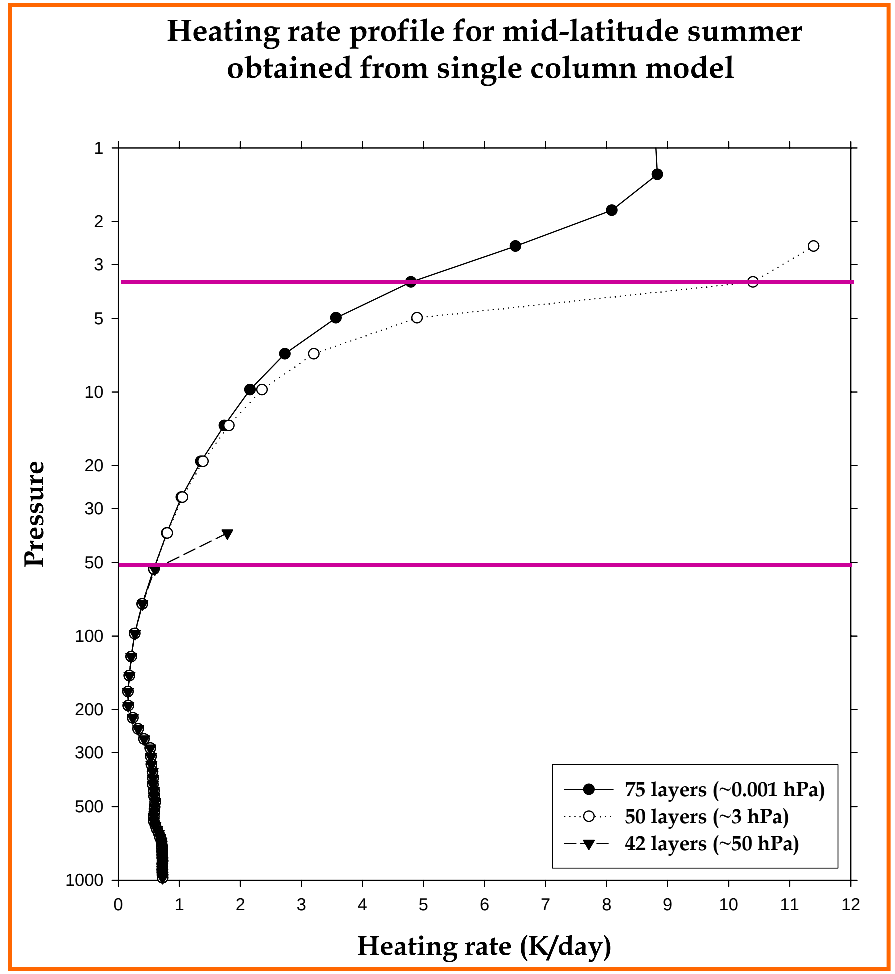
3. Simulation Results

❑ Taylor diagram



Level index	CTL & SWG			SWT		
	σ level	pressure (p_s=1000)	pressure (p_s=900)	σ level	pressure (p_s=1000)	pressure (p_s=900)
1	1.000	1000.0	900.0	1.000	1000.0	900.0
2	0.993	993.4	894.0	0.993	993.0	893.7
3	0.980	981.0	883.0	0.980	980.1	882.1
4	0.966	967.7	871.1	0.966	966.2	869.6
5	0.950	952.5	857.5	0.950	950.3	855.3
6	0.933	936.4	843.1	0.933	933.3	840.0
7	0.913	917.3	826.0	0.913	913.4	822.1
8	0.892	897.4	808.2	0.892	892.5	803.3
9	0.869	875.5	788.7	0.869	869.7	782.8
10	0.844	851.8	767.4	0.844	844.8	760.4
11	0.816	825.2	743.6	0.816	816.9	735.3
12	0.786	796.7	718.1	0.786	787.1	708.5
13	0.753	765.4	690.0	0.753	754.2	678.9
14	0.718	732.1	660.3	0.718	719.4	647.6
15	0.680	696.0	628.0	0.680	681.6	613.6
16	0.639	657.0	593.2	0.639	640.8	576.9
17	0.596	616.2	556.6	0.596	598.0	538.4
18	0.550	572.5	517.5	0.550	552.3	497.3
19	0.501	525.9	475.8	0.501	503.5	453.4
20	0.451	478.5	433.4	0.451	453.7	408.6
21	0.398	428.1	388.3	0.398	401.0	361.2
22	0.345	377.8	343.3	0.345	348.3	313.8
23	0.290	325.5	296.5	0.290	293.5	264.5
24	0.236	274.2	250.6	0.236	239.8	216.2
25	0.188	228.6	209.8	0.188	192.1	173.3
26	0.145	187.8	173.3	0.145	149.3	134.8
27	0.108	152.6	141.8	0.108	112.5	101.7
28	0.075	121.3	113.8	0.064	68.7	62.3
29	0.046	93.7	89.1	0.042	46.8	42.6
30	0.021	69.9	67.8	0.028	32.9	30.1
31	0.000	50.0	50.0	0.017	21.9	20.2
32				0.010	14.9	13.9
33				0.006	11.0	10.4
34				0.002	7.0	6.8
35				0.000	5.0	5.0

$$\frac{\partial T}{\partial t} = -\frac{1}{\rho C_p}\frac{\partial F(z)}{\partial z} = \frac{g}{C_p}\frac{\partial F(p)}{\partial p}$$



4. Summary

1. Sensitivity of the simulated regional summer monsoon climate to solar radiation parameterizations is investigated. Also examined are the effects of model top layers which describe the effects of ozone absorption and associated solar heating rate on the simulation of regional climate.

2. The results show that the **meridional gradient of the zonal mean air temperature could be significantly improved** when the **Goddard scheme** is utilized compare with the CTL, leading to better agreements in balanced zonal winds.

3. Moreover, the **SWT** has best performance in capturing the observed anomaly of westerly flows, vertically-integrated temperature and 200-hPa winds, suggesting that **ozone absorption and associated heating rate may play a contributing role**.

4. Summary

4. Accompanying the improved upper air flows, better results are obtained in the simulation of 850-hPa circulation structures. In the SWG and the SWT, the modeled relative vorticity becomes quite comparable to the observation and the southwesterlie are able to be reproduced; while both are not the case in the CTL.

5. However, the estimated rainfall does not show a superior prediction in the results using the Goddard scheme compared to those in the CTL. Rather, all simulations display rarely explainable overprediction in the northeastern parts of the Asian continent, which seems to be intrinsic feature of the WRF model, and in the northwestern Pacific Oceans, which, on the other hand, has been more often reported in other regional climate modeling studies.

Thank you…