Evaluation of Four Different Warm Cloud Parameterization Schemes in Climate Model Simulations

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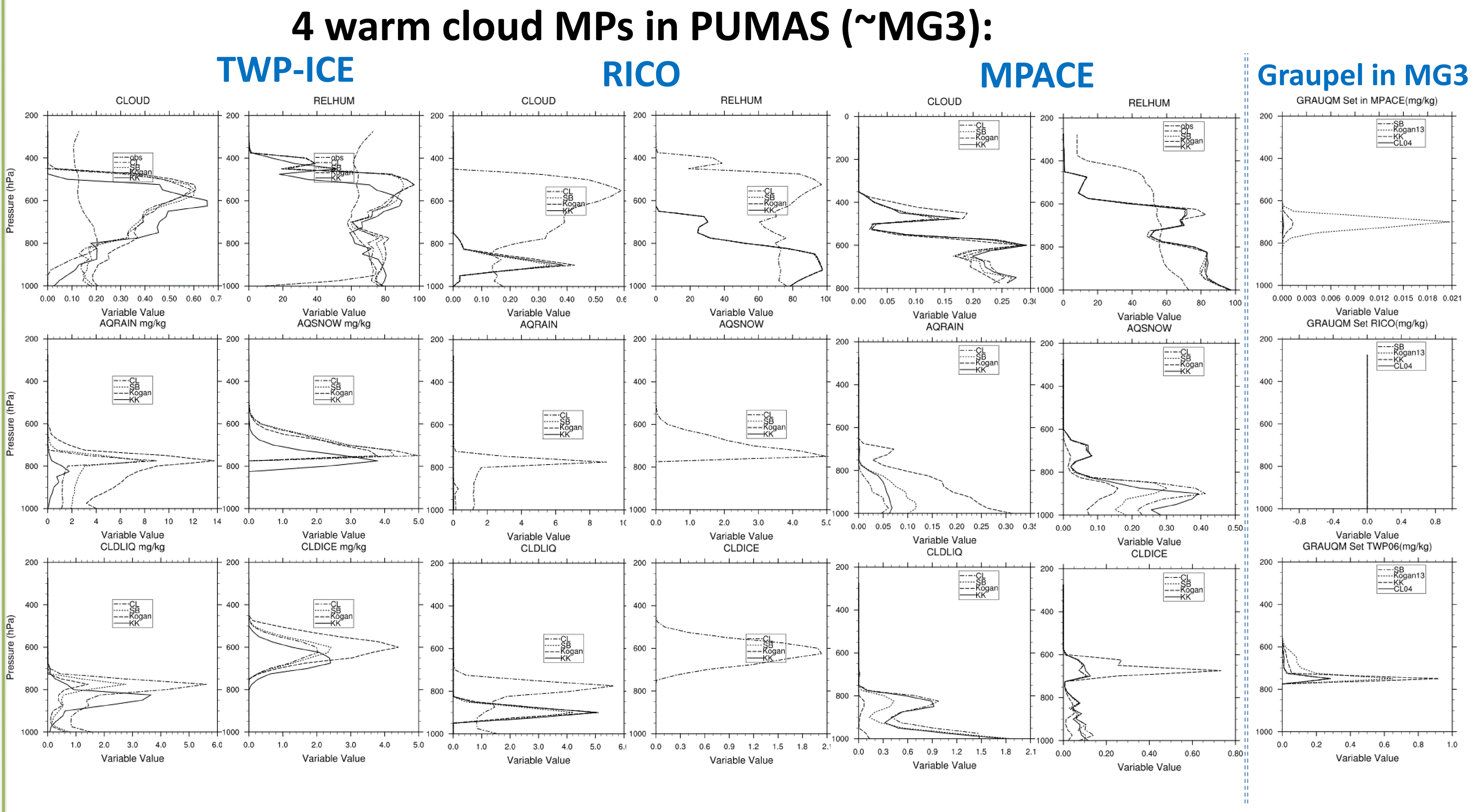
Abstract

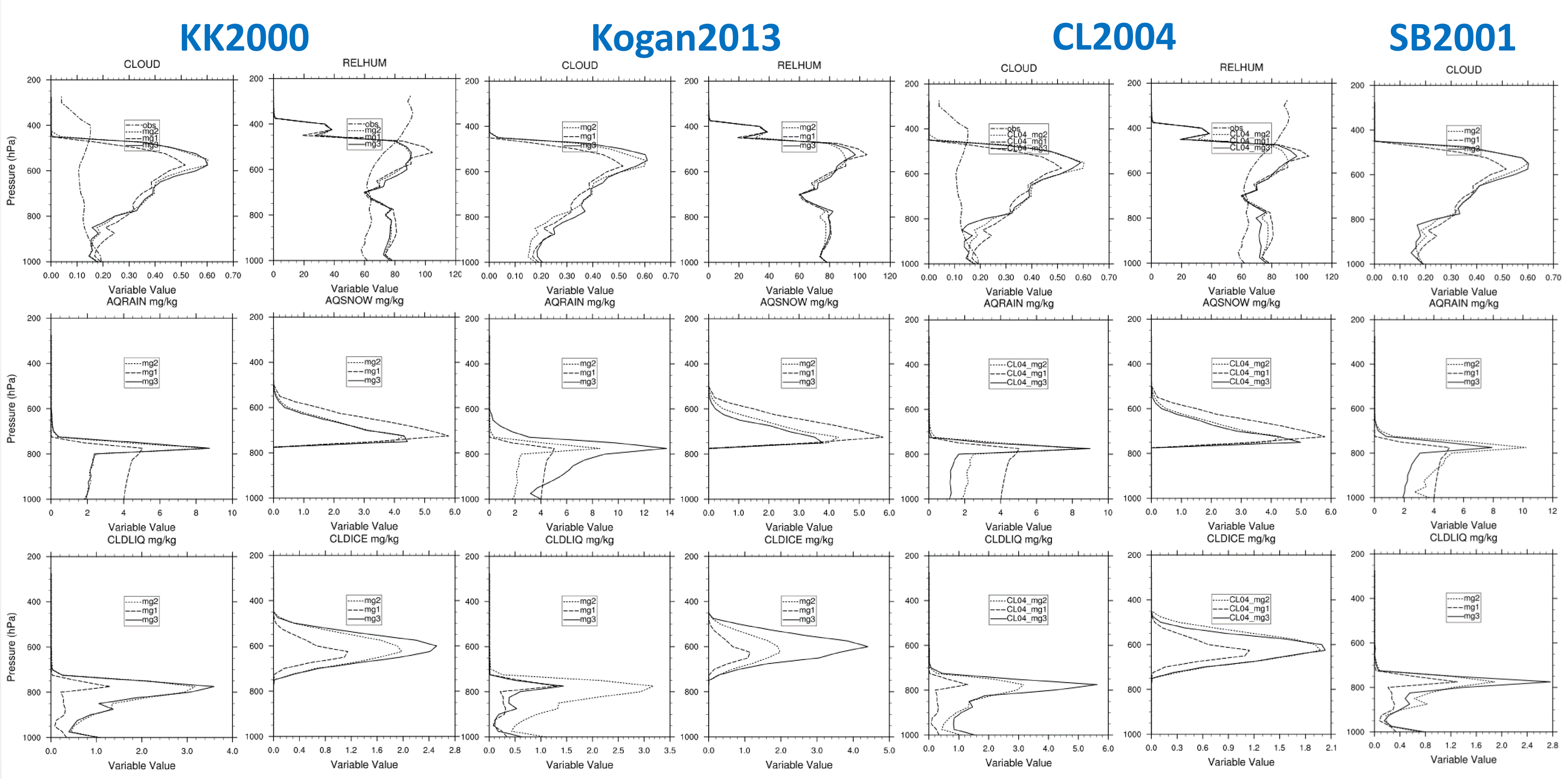
These numerical experiments are carried out with NCAR CESM version 2.3 beta 17. Quasi-CAM5 physic package is used including the Zhang-McFarlane scheme for deep convection, Park's cloud macrophysics scheme for large-scale condensation and cloud fraction, Morrison-Gettelman (i.e., PUMAS) stratiform cloud microphysics, MAM4 aerosol module, and the University of Washington's schemes for shallow convection and turbulent PBL. We evaluate the four different warm cloud MPs as listed below via using single column model (SCM) and global simulations.

Single column results

4 warm cloud MPs in PUMAS (~MG3):



3 MGs run with individual warm cloud MPs:



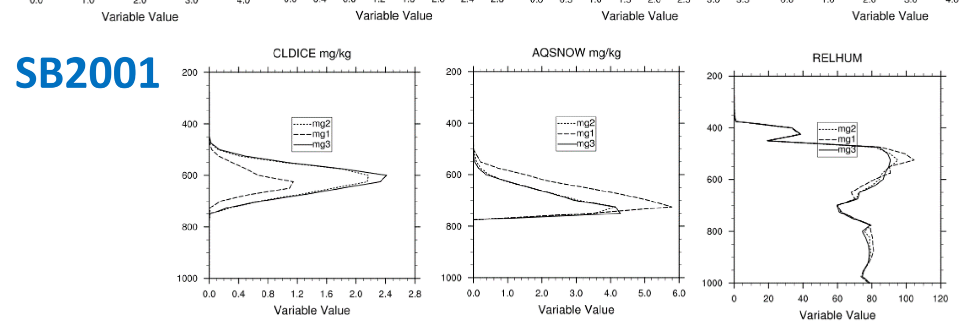


Fig.1 Time averaged variables in different MGs , and SCM simulations.

Methodology

Examples of parameterizing warm cloud processes:		
$R_{auto}(Z) = \left(\frac{\partial qr}{\partial t}\right) auto = A * qc(Z)^{a1} N_c^{a2}$		A=1350 ; a1=2.47 ; a2=-1.79
$R_{accr}(Z) = \left(\frac{\partial qr}{\partial t}\right) accr = B * \left(qc(Z) * qr(Z)\right)^b$		B,b = const.
Three IOPs for driving SCM simulations:		
TWP-ICE (TWP06)	$\frac{\partial w}{\partial t} = B(T, qv, qc) - Drag(w)$	w = Updraft velocity
	$R_{accr} = B(qc * qr)^b$	B = Buoyancy (water vapor and cloud water mixing ratio)
RICO	$\partial qr/\partial t = Autoconver(qc, Nc) - Accre(qc, qr)$	
	$R_{auto} = Aq_c^{a1} N_c^{a2}$	Nc = Cloud droplet number concentration
MPACE	$\frac{\partial qc}{\partial t} = condens/evapor(qv, T)$	qi = Ice crystal mixing ratio
	$\frac{\partial qi}{\partial t} = Ice\_Nucleation(T, qv, Ninp)$	Ninp = Ice particle number concentration

Four warm cloud MPs:			
SB2001	$R_{auto} = Aq_c^{\alpha} N_c^{\beta}$	$R_{accr} = Bq_c^{\gamma} q_r^{\delta}$	q_c = Cloud water mixing ratio
KK2000	$R_{auto} = Cq_c^{p} N_c^{q}$	$R_{accr} = Dq_c^{r} q_r^{s}$	q_a = Aerosol mixing ratio
CL2004	$R_{cloud} = Gq_a^{\zeta} q_c^{\eta}$	$F_{radiation} = Hq_c * optical\_depth(q_a)$	
Kogan2013	$R_{auto} = Eq_c^{\lambda} N_c^{\mu}$	$R_{accr} = Fq_c^{\kappa} q_r^{\zeta}$	q_r = Rainwater mixing ratio

Three versions of stratiform cloud MPs:

MG1/2/3: Cloud liquid and ice are prognostic while rain and snow are diagnostic in MG1. MG2 determines rain and snow in prognostic ways and MG3 further adds graupel or hail hydrometeor.

Table.1 The method to describe parameterizing warm cloud processes , three IOPs for driving SCM simulations , warm cloud MPs , and three versions of stratiform cloud MPs.

Global result

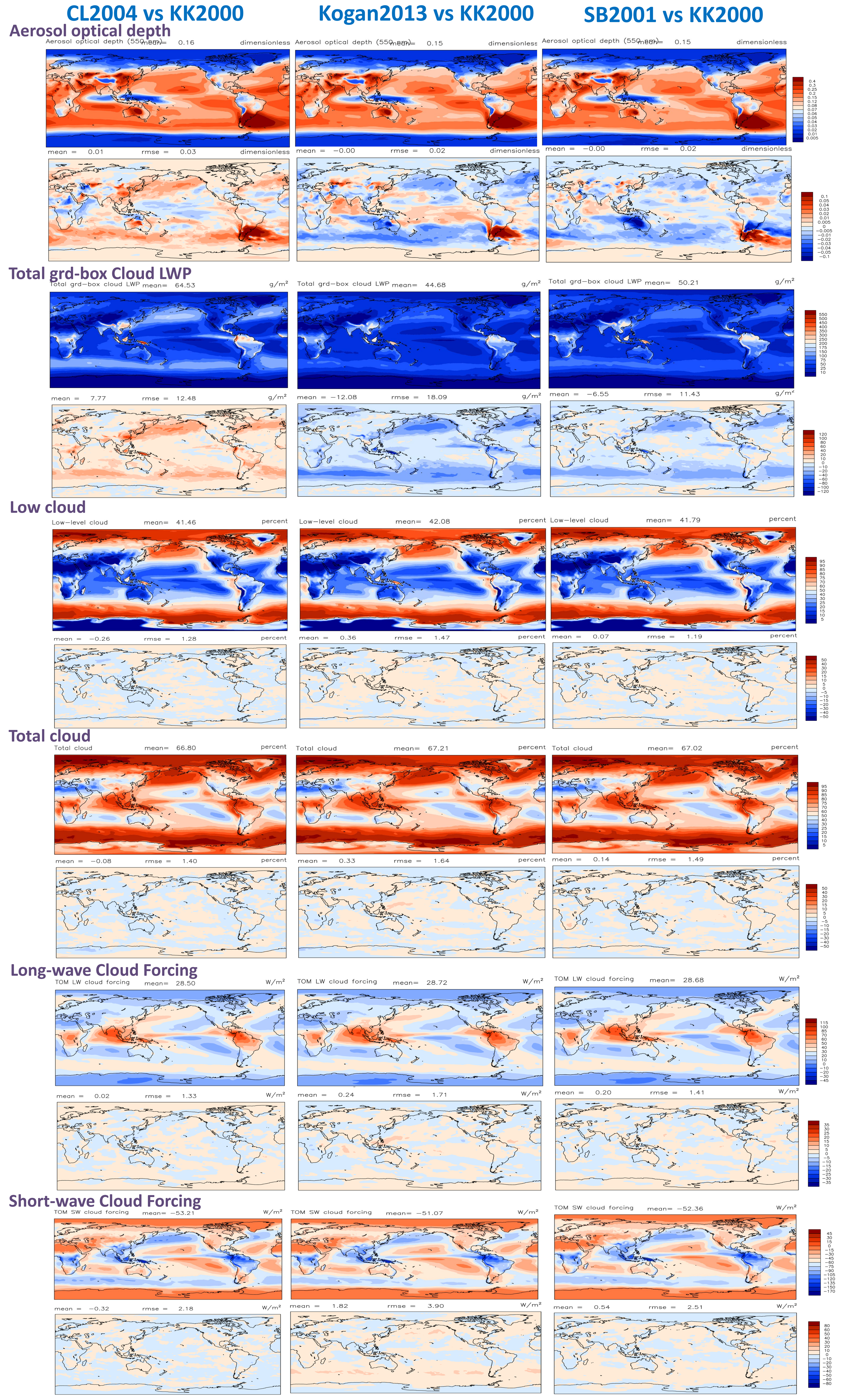


Fig.2 Global results in different simulations and different variations , minus KK2000's result.

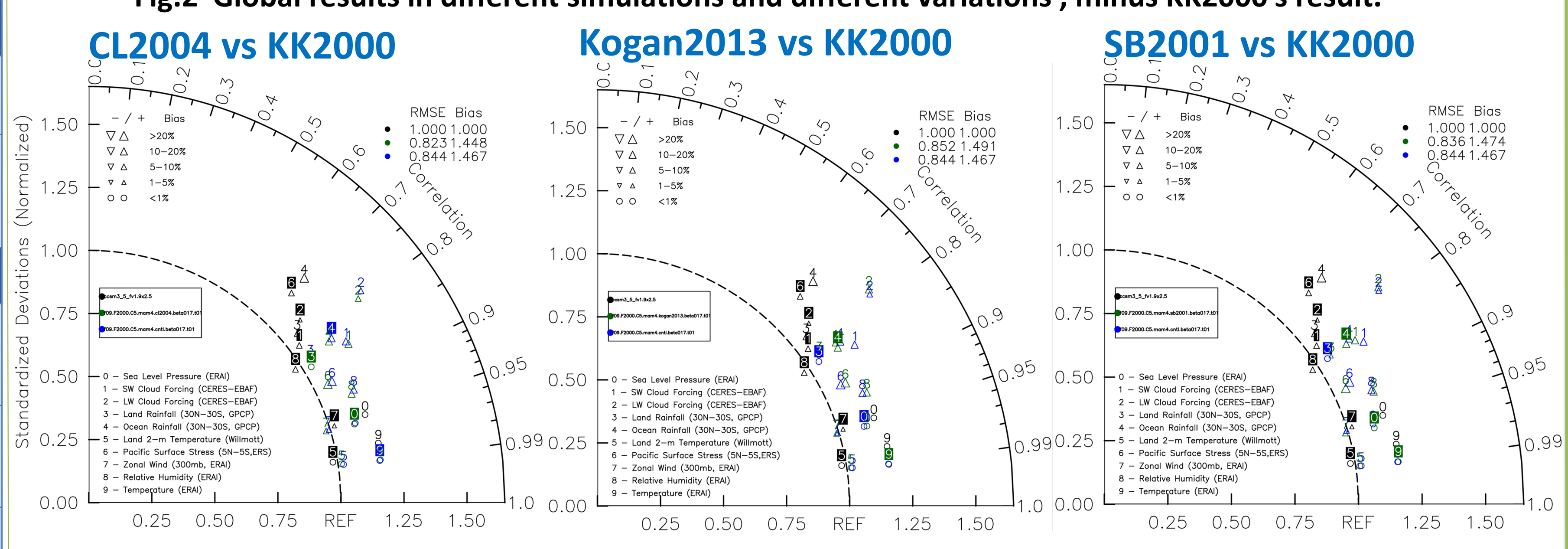


Fig.3 Taylor diagram.

R/bias	ccsm3_5	KK2000	CL2004	SB2001	Kogan13
Sea Level P	0.953/0.019	0.958/**0.011**	0.959/**0.011**	**0.962/0.011**	0.959/0.012
SWCF	0.801/5.601	0.847/12.132	0.853/12.802	0.837/10.991	**0.825/8.264**
LWCF	0.756/1.430	0.789/**9.274**	**0.797**/9.335	0.784/10.036	0.782/10.189
Land Rainfall	0.777/8.391	0.838/0.664	**0.854/0.309**	0.837/2.767	0.826/0.987
Ocean Rainfall	0.692/28.122	0.828/18.129	0.830/18.482	0.834/**17.493**	**0.835**/17.569
2-m T	0.987/0.006	**0.989/0.184**	**0.988**/0.217	**0.989**/0.232	**0.989**/0.263
PSS	0.695/7.828	0.895/25.767	0.896/**23.828**	**0.902**/25.432	0.895/30.815
ZW	0.954/1.718	0.957/6.158	0.957/6.168	**0.959**/5.820	0.957/**5.742**
RH	0.840/6.427	0.920/15.289	**0.924**/15.305	0.922/**15.250**	0.921/**15.250**
T	0.979/0.428	**0.990**/0.383	0.989/0.399	**0.990**/0.355	**0.990/0.315**

Table.2 The correlation coefficient , and bias between different simulations and ccsm3_5 in different variations.

Conclusion and Future Outlook

SCM results show that CL2004 tends to simulate more cloud liquid and less rain compared to the rest of three warm cloud MPs. It is also interesting to note that, according to the global simulations, the overall RMSE value simulated by CL2004 is the smallest among the four warm MPs suggesting the promising better performance associated with mean climate simulations. Notably, changes in aerosol-cloud interactions show opposite sign between CL2004 and the rest of three warm cloud MPs. More in-depth validations and evaluations from SCM simulations with ACE-ENA field campaign and global simulations with ESMAC Diags package can be devoted in the near future.