Using PPE simulations and parametric sensitivity analysis to better understand cloud physics and parameterization in EAM over different regions and cloud regimes

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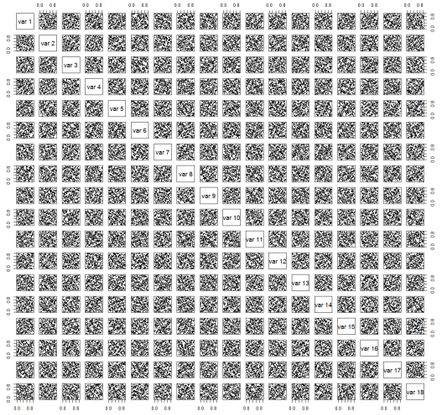
Experiment Design



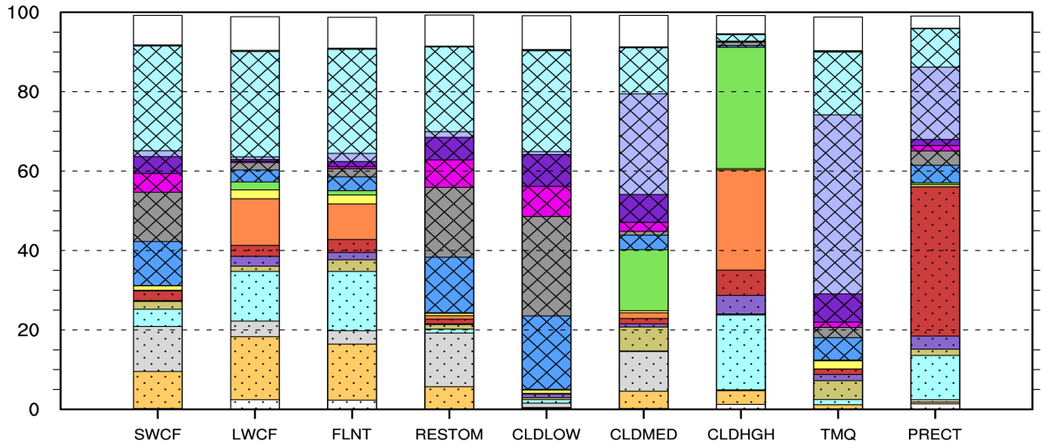
Configuration

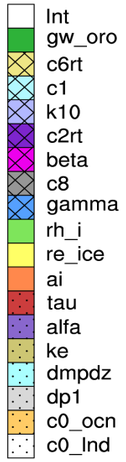
- 18 perturbed parameters.
- 256 sampling points from the parameter space.
- Latin Hypercube sampling method.
- 12 ensemble members corresponding to 12 months for each sampling point.
- 5-day long simulation and all days' results analyzed.
- Two 256x12 ensemble simulations at a rather modest cost and within 5 days of wall clock time.

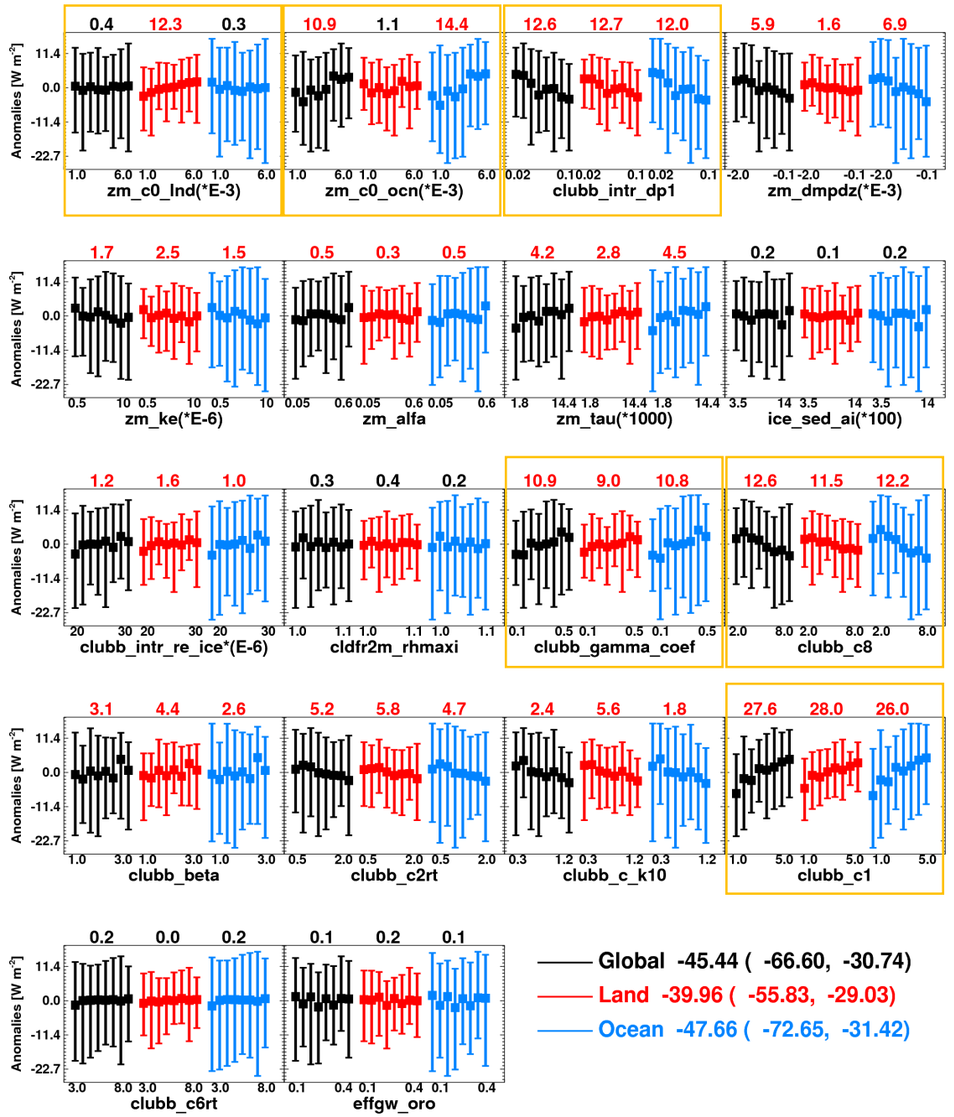
18 perturbed parameters in EAM-v1 PPE simulations

#	Parameter Name	Low	Default	High	Description	Namelist Prefix	File Name (.F90)	Reference
1	**c0_lnd**	0.001	0.002	0.006	*Deep* convection precipitation efficiency over land	zmconv_	zm_conv	Qian15/Ma
2	**c0_ocn**	0.001	0.002	0.006	*Deep* convection precipitation efficiency over ocean	zmconv_	zm_conv	Qian15/Ma
3	**dp1**	0.02	0.1	0.1	Deep convection cloud fraction parameter	_	clubb_intr	Ma
4	**dmpdz**	-2.0e-3	-0.5e-3	-0.1e-3	Parcel fractional mass entrainment rate	zmconv_	zm_conv	Qian15/Neale
5	**ke**	0.5e-6	1.0e-6	10.0e-6	Evaporation efficiency of precipitation	zmconv_	zm_conv	Qian15
6	**alfa**	0.05	0.10	0.60	Maximum cloud downdraft mass flux fraction	zmconv_	zm_conv	Qian15
7	**tau**	1800.0	3600.0	14400.0	Time scale for consumption rate deep CAPE	zmconv_	zm_conv	Qian15/Neale
8	**ai**	350.0	700.0	1400.0	Fall speed parameter for cloud ice	cloud_ai	micro_mg_utils	Ma/Zhang
9	**re_ice**	20	25	30	Effective radius of detrained ice crystals from deep convective clouds	cloud_reffi_zmdetr	clubb_intr	Ma/Zhang
10	**rhmaxi**	1.00	1.0	1.10	Max relative humidity threshold for ice cloud	cldfrc2m_	cldfrc2m	Ma/Zhang
11	**gamma_coef**	0.1	0.32	0.5	Constant of the width of PDF in w-coordinate	Clubb_	parameters_tunable	Guo15/Ma
12	**c8**	2.0	4.2	8.0	Constant associated with Newtonian damping of $\overline{w'^3}$	Clubb_	parameters_tunable	Guo15/Ma
13	**beta**	1.0	2.4	3.0	Constant related to skewness of θ_l and qt	Clubb_	parameters_tunable	Guo15/Ma
14	**c2rt**	0.5	1.0	2.0	Constant with dissipation of variance of total water $\overline{q_t'^2}$	Clubb_	parameters_tunable	Guo15/Ma
15	**c_k10**	0.3	0.6	1.2	Momentum diffusion factor	Clubb_	parameters_tunable	Ma
16	**c1**	1.0	1.0	5.0	Constant associated with dissipation of variance of $\overline{w'^2}$	Clubb_	parameters_tunable	Ma
17	**c6rt**	3.0	4.0	8.0	Low skewness of Newtonian damping of water flux	Clubb_	parameters_tunable	Qian
18	**effgw_oro**	0.1	0.3	0.4	Gravity wave drag intensity	-	gw_drag.F90	Ma

Parametric sensitivity at global scale (Qian et al., 2018)



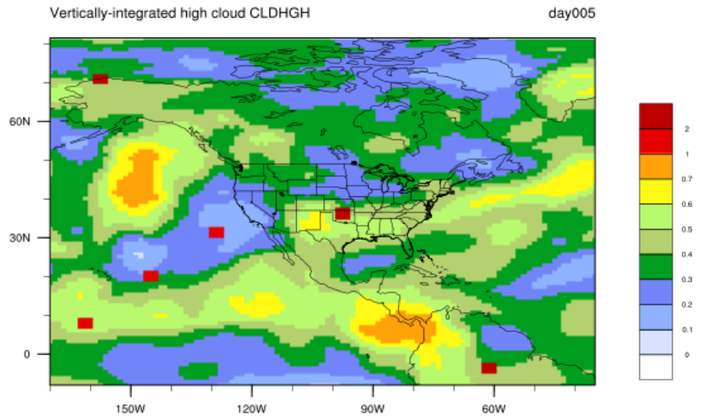




(Top) Relative importance of 18 parameters for nine interest variables

(Right) Responses of global SWCF to 18 parameters

Parametric sensitivity and relative importance vary with regions and cloud regimes



Ocean_deep (197.5-200E, 7.07-8.95N)

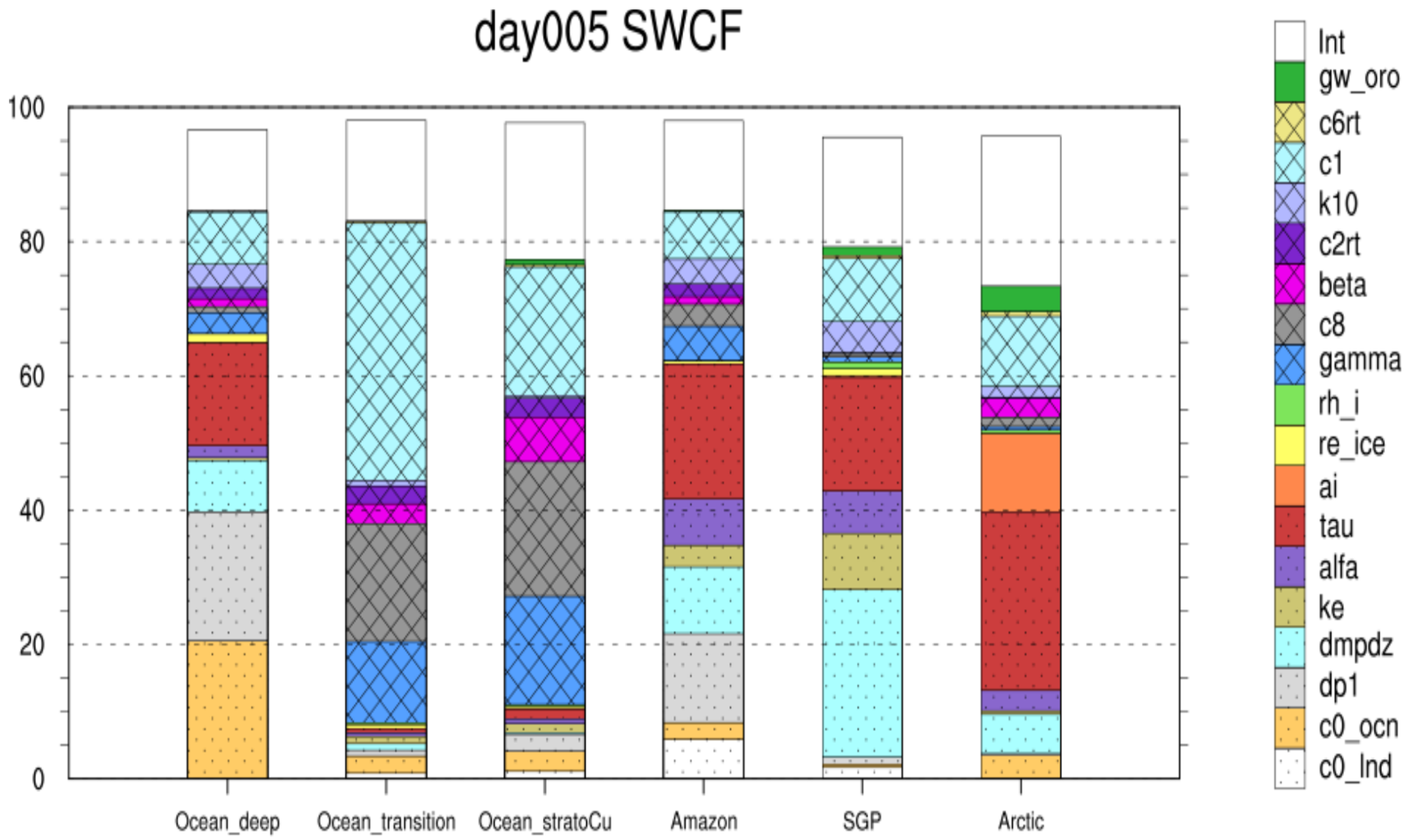
Ocean_transition (213.75-216.25E,19.32-21.20N)

Ocean_stratocu (230E-232.5E, 30.63-32.51N

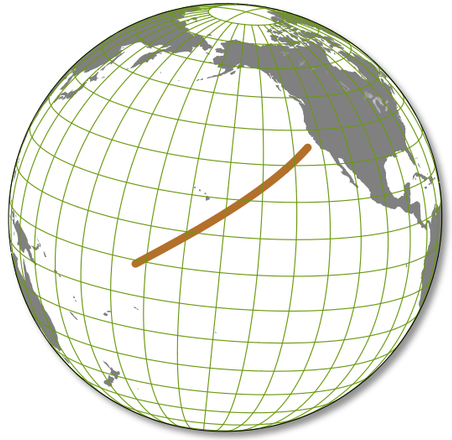
Amazon (297.5-300E, -4.24- -2.36S)

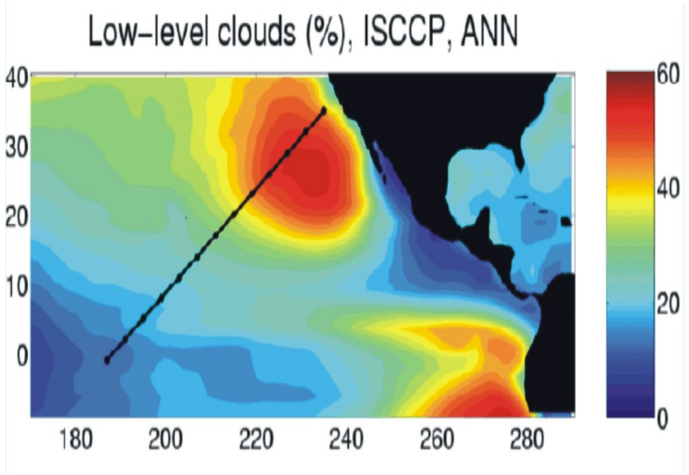
SGP (261.25-263.75E, 35.34-37.22N)

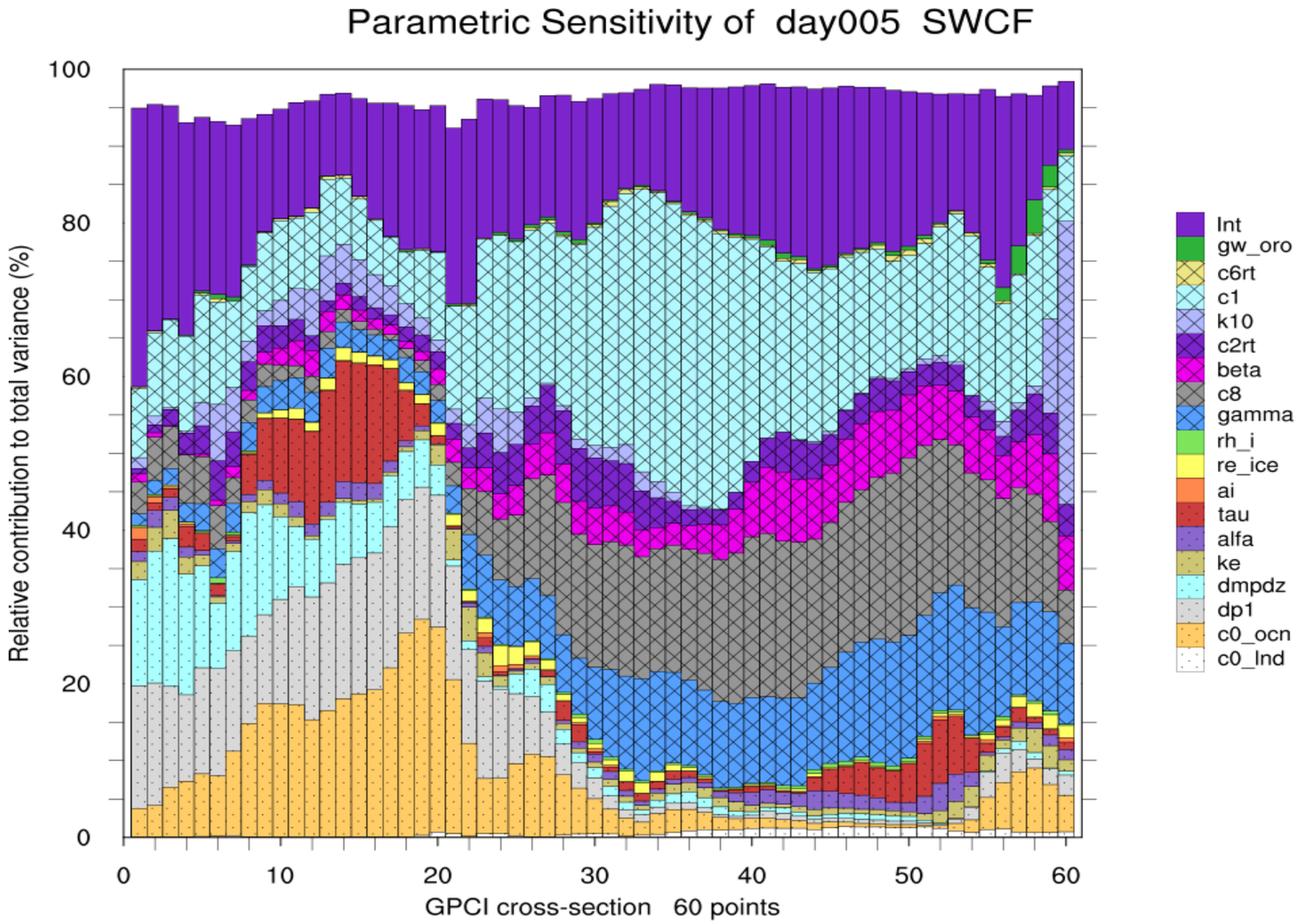
Arctic (201.25-203.75E, 70.2-72.09N)



Parametric sensitivity along GPCI transect from deep convection to stratocumulus-to-cumulus transition to marine boundary layer clouds







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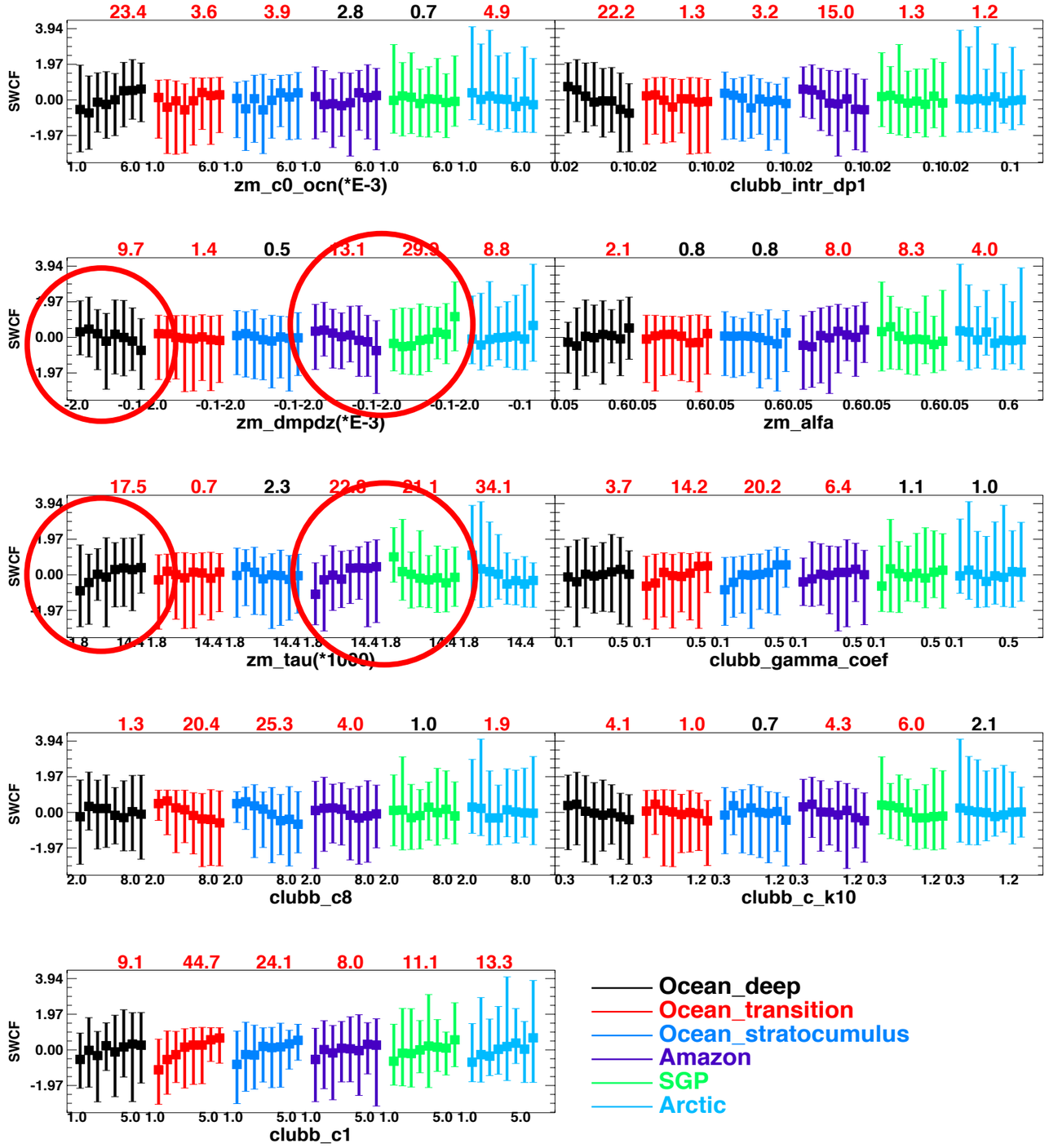
Responses of SWCF to key parameters vary with regions and cloud regimes

e.g. Tropics vs. SGP



Convective parameter influences clouds over Tropics vs. SGP differently through thermodynamic process

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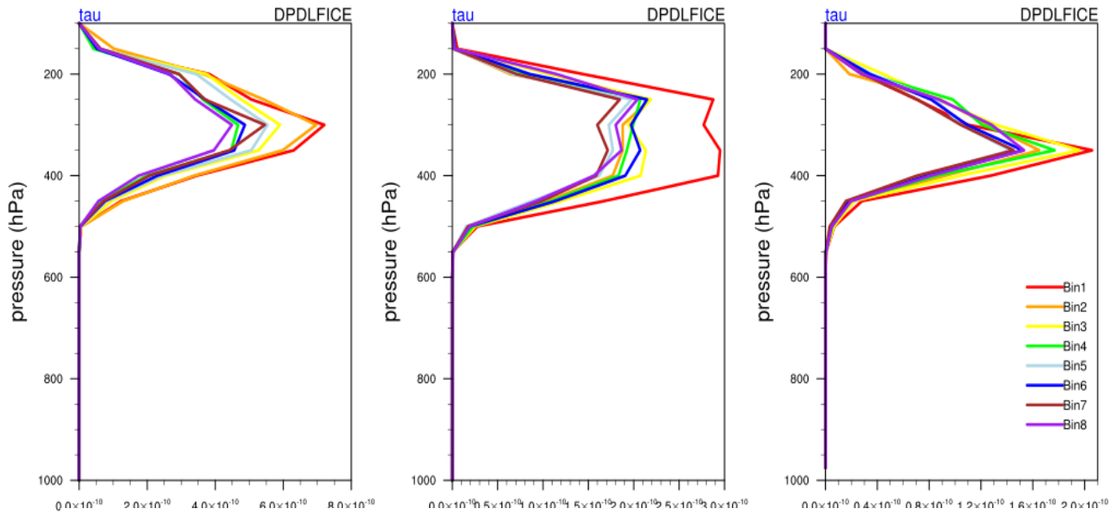
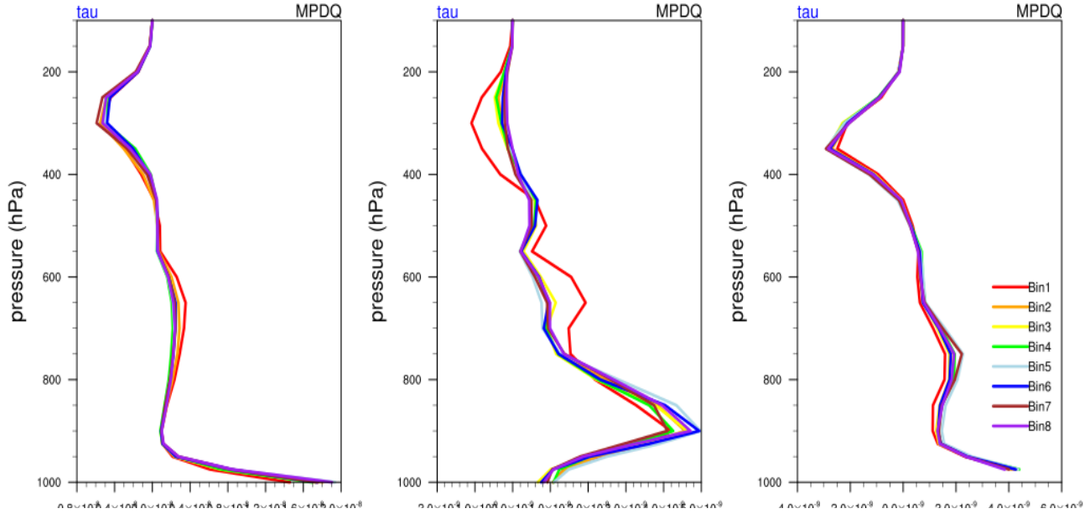
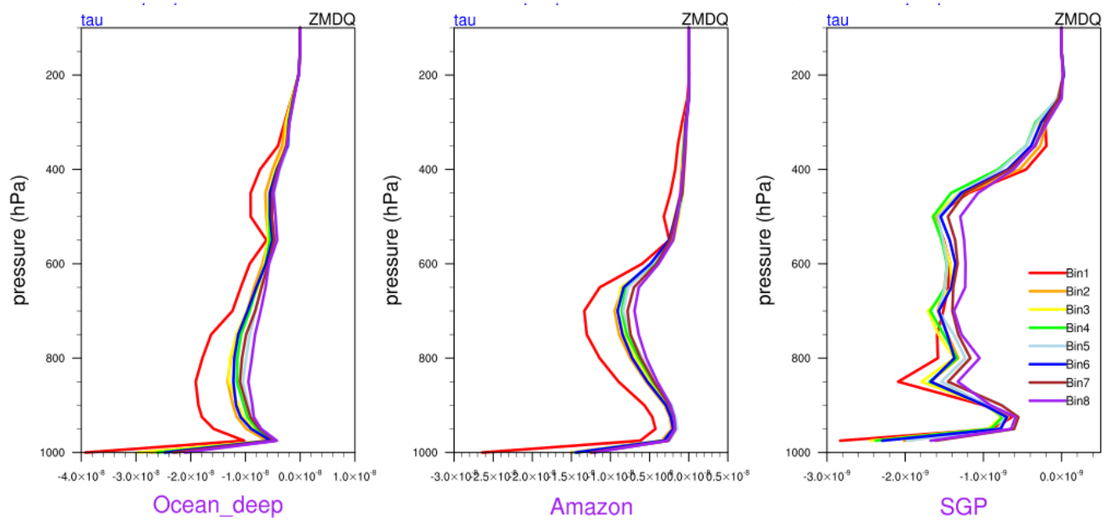
Detrained ice from deep convection (kg/kg/s)



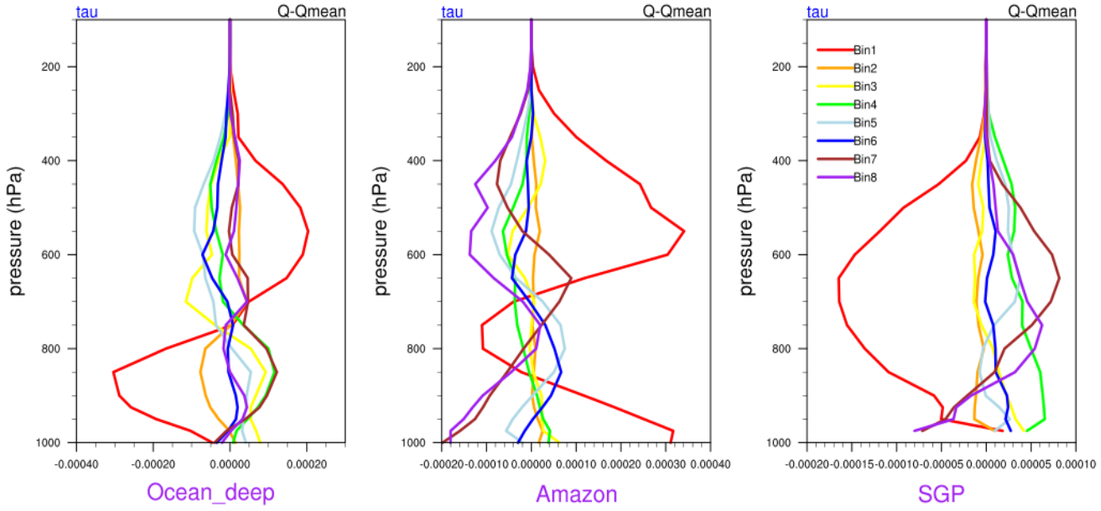
Q tendency - Morrison microphysics (kg/kg/s)



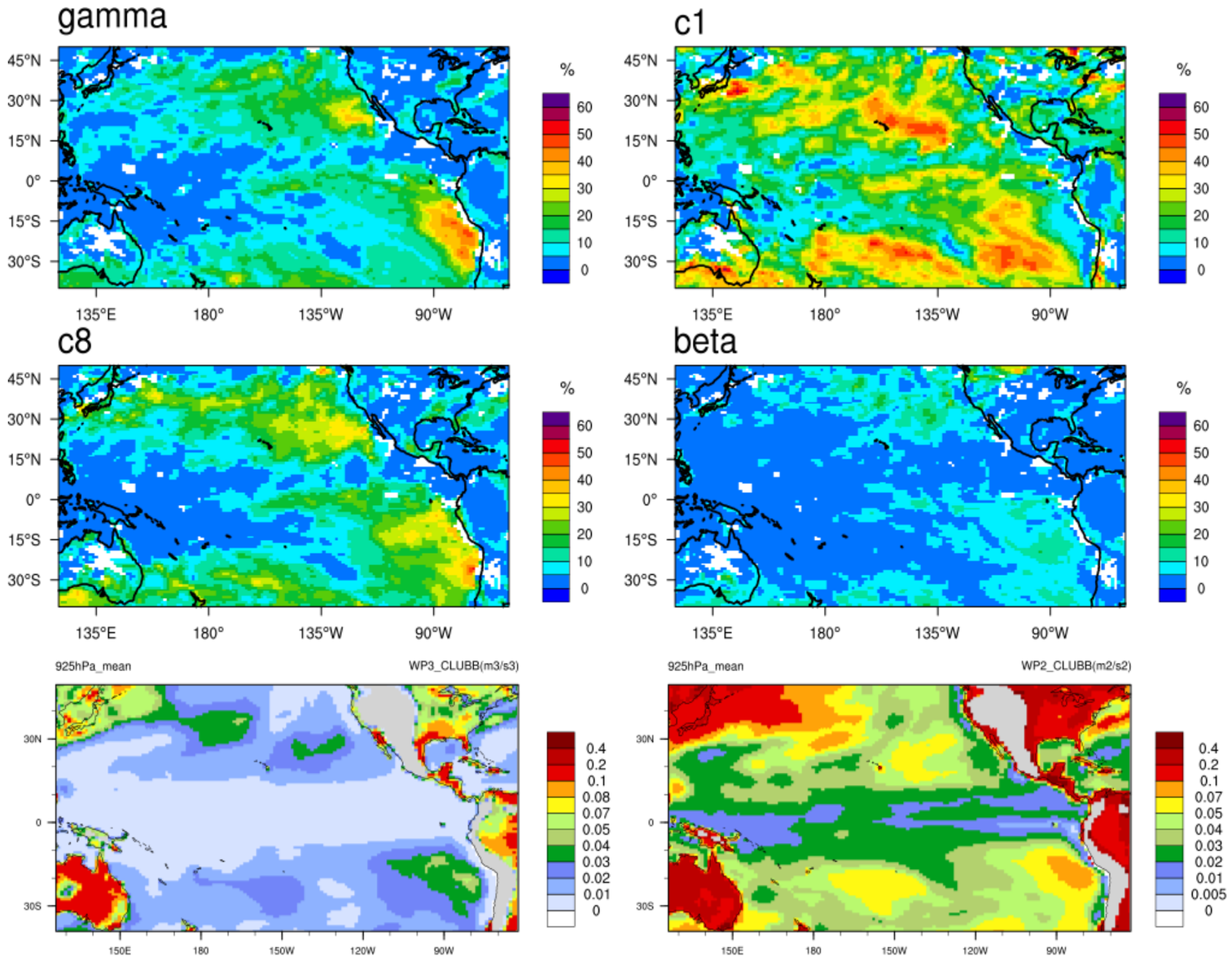
Q tendency - Zhang-McFarlane moist convection (kg/kg/s)



Specific humidity (kg/kg)



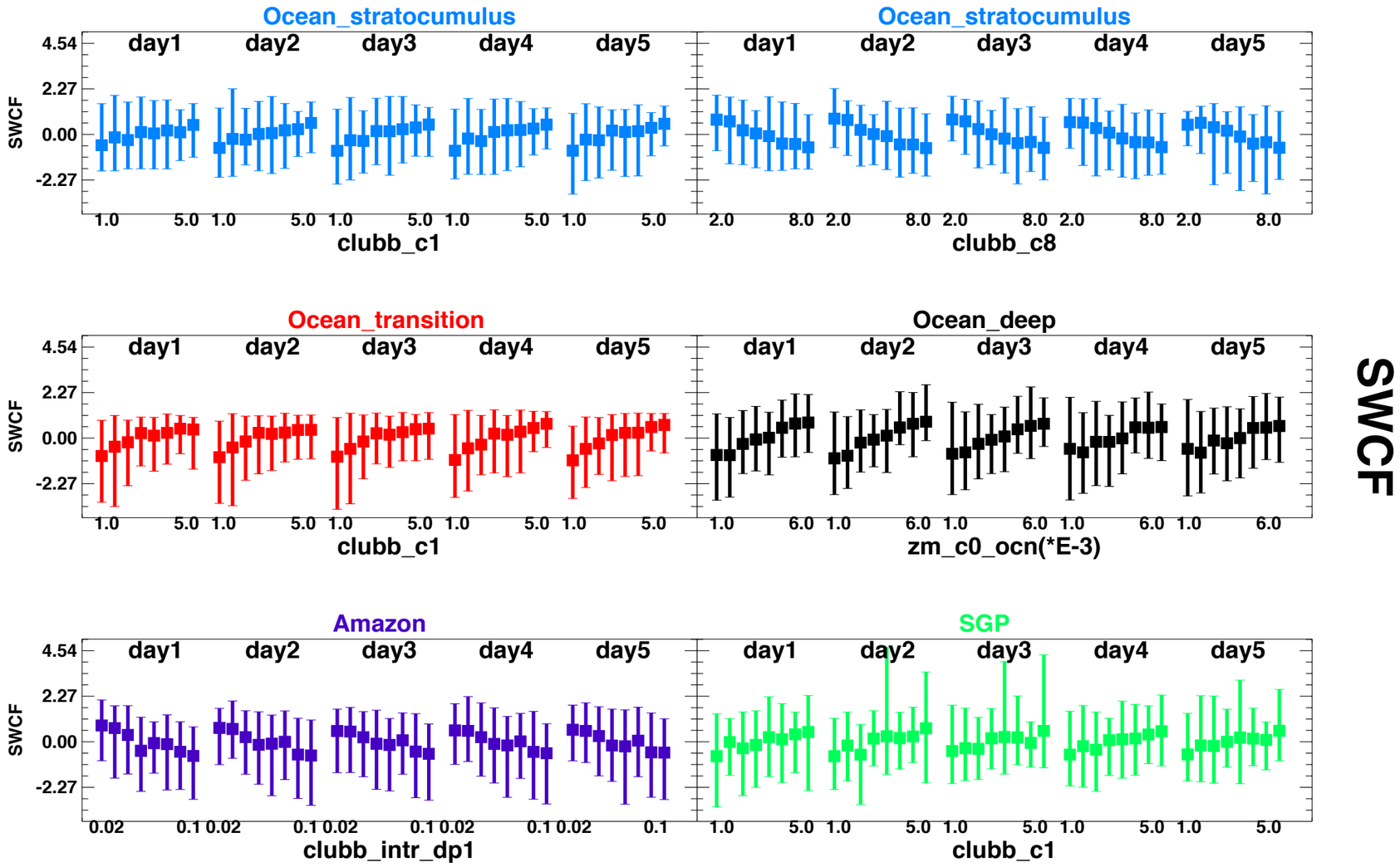
Spatial distribution of contribution of CLUBB parameters to the total variance of SWCF and association with second and third moment of vertical velocity



WP3: Third moment of Vertical Velocity

WP2: Vertical Velocity Variance

Parametric sensitivity evolving with prediction length differently in different cloud regimes



SWCF

Summary

- Parametric sensitivity and relative importance vary with regions and cloud regimes.
- Cloud forcing has opposite response to some convective parameters over mid-latitude vs. tropical land through competing thermodynamic process.
- The sensitivity of low cloud and SWCF to key CLUBB parameters shows a large spatial variability in the subtropical eastern Pacific, in association with second and third moment of vertical velocity.
- Parametric sensitivity evolving with prediction length differently in different cloud regimes (e.g. more stable in MBL cloud than cumulus cloud).
- This study improves our process-level understanding on cloud physics and parameterization and provides insights for developing more advanced space-awareness parameterization schemes.