Examining state dependence of the cloud feedback using a perturbed parameter ensemble

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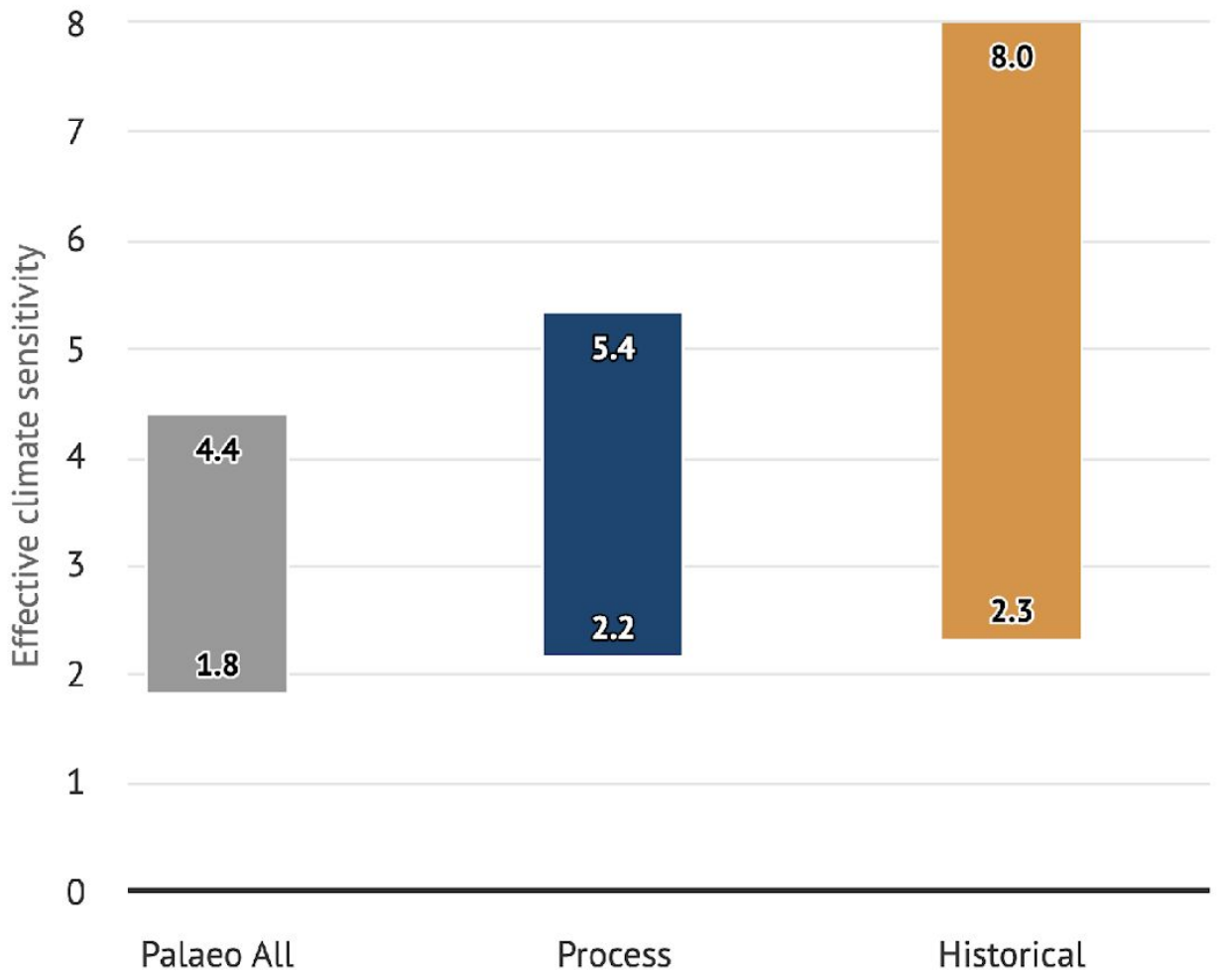
Paleoclimate provides the strongest constraints on climate sensitivity

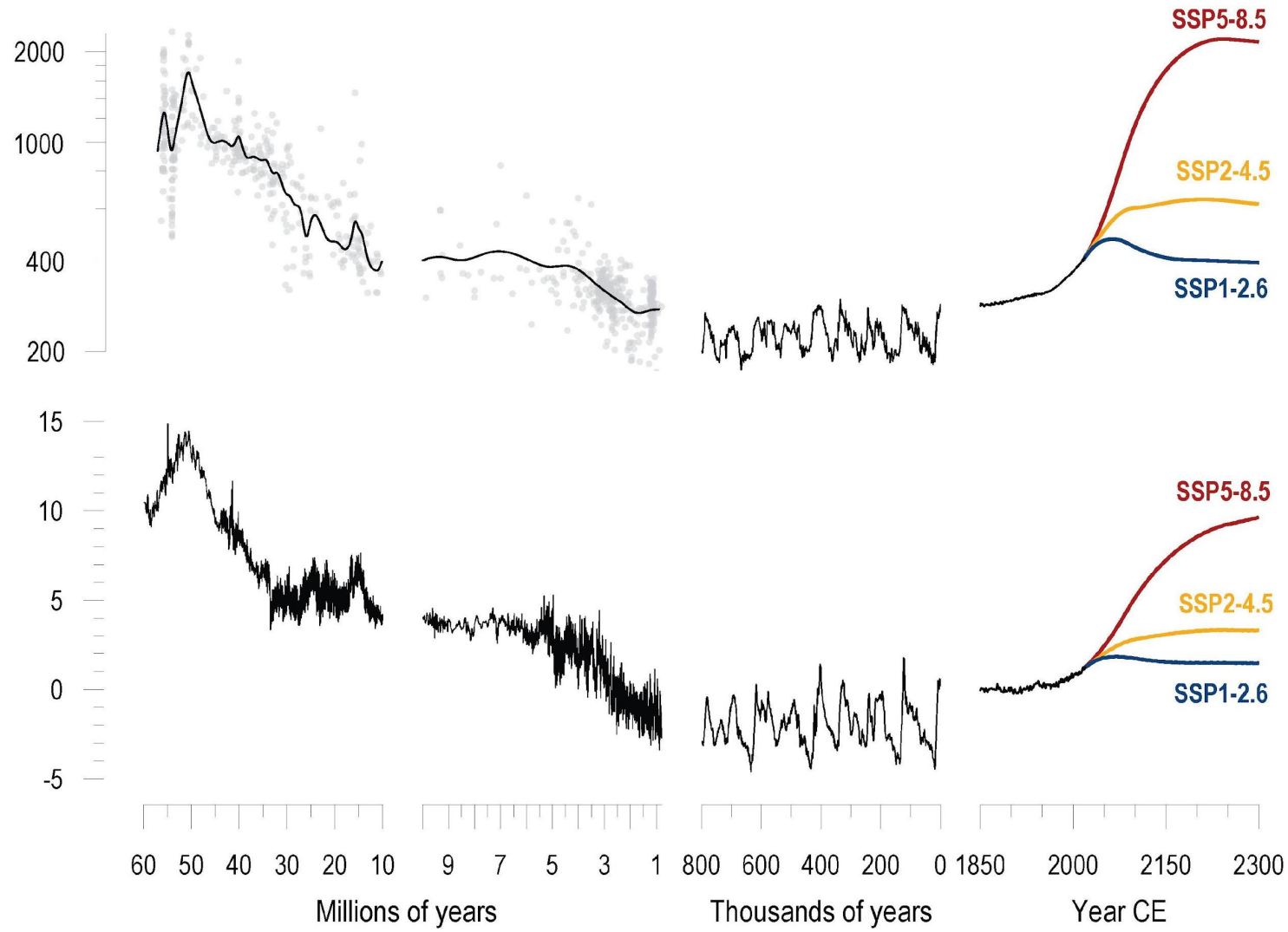


CarbonBrief & Sherwood et al. (2020)

State dependence is key for improving paleo-constraints

CO_2

Global surface temperature change



Modified after IPCC AR6

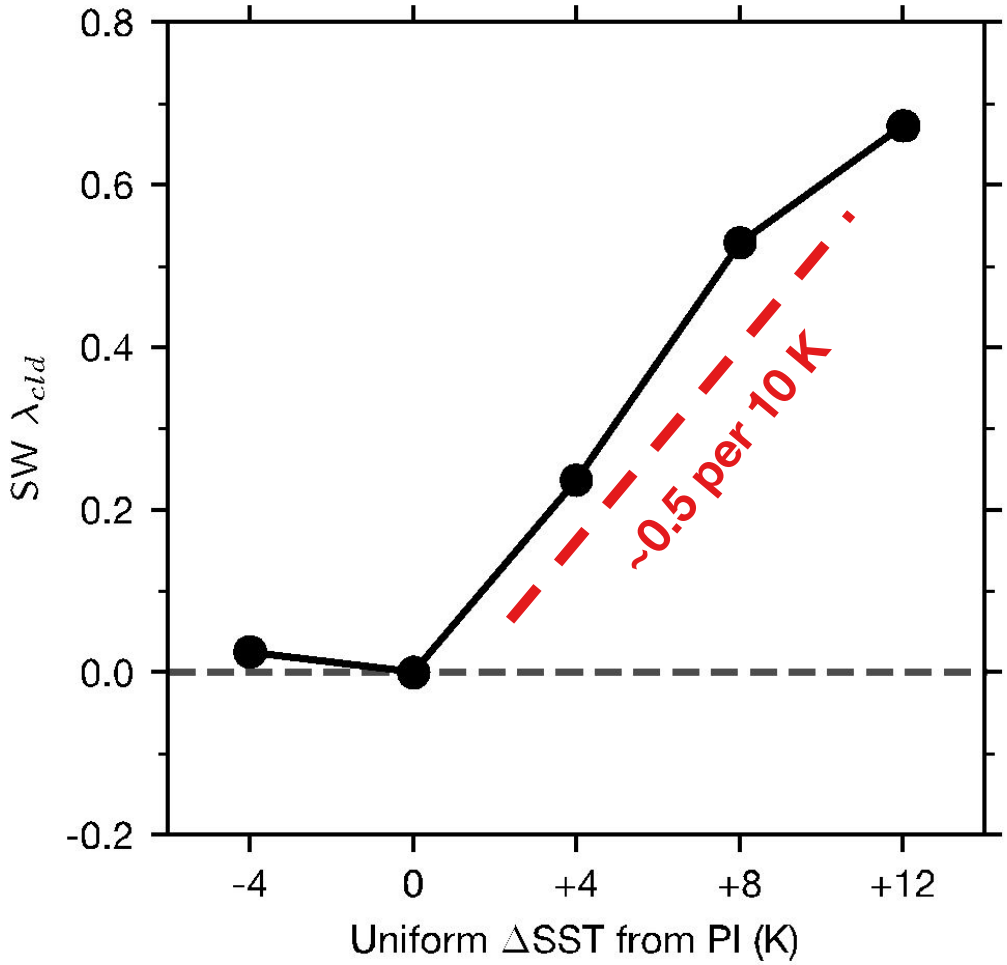
Does the cloud feedback increase with global warming?

CESM2-PaleoCalibr *(Zhu et al., 2022, JAMES)*

- *Match the present-day climate*
- *Realistic ice-age climate*
- *ECS = 4℃*

Fixed-SST simulations w/ uniform ΔT:

- m04k, prei, p04k, p08k, p12k, & p16k



Perturbed parameter ensemble (PPE) to explore *uncertainty & mechanism*

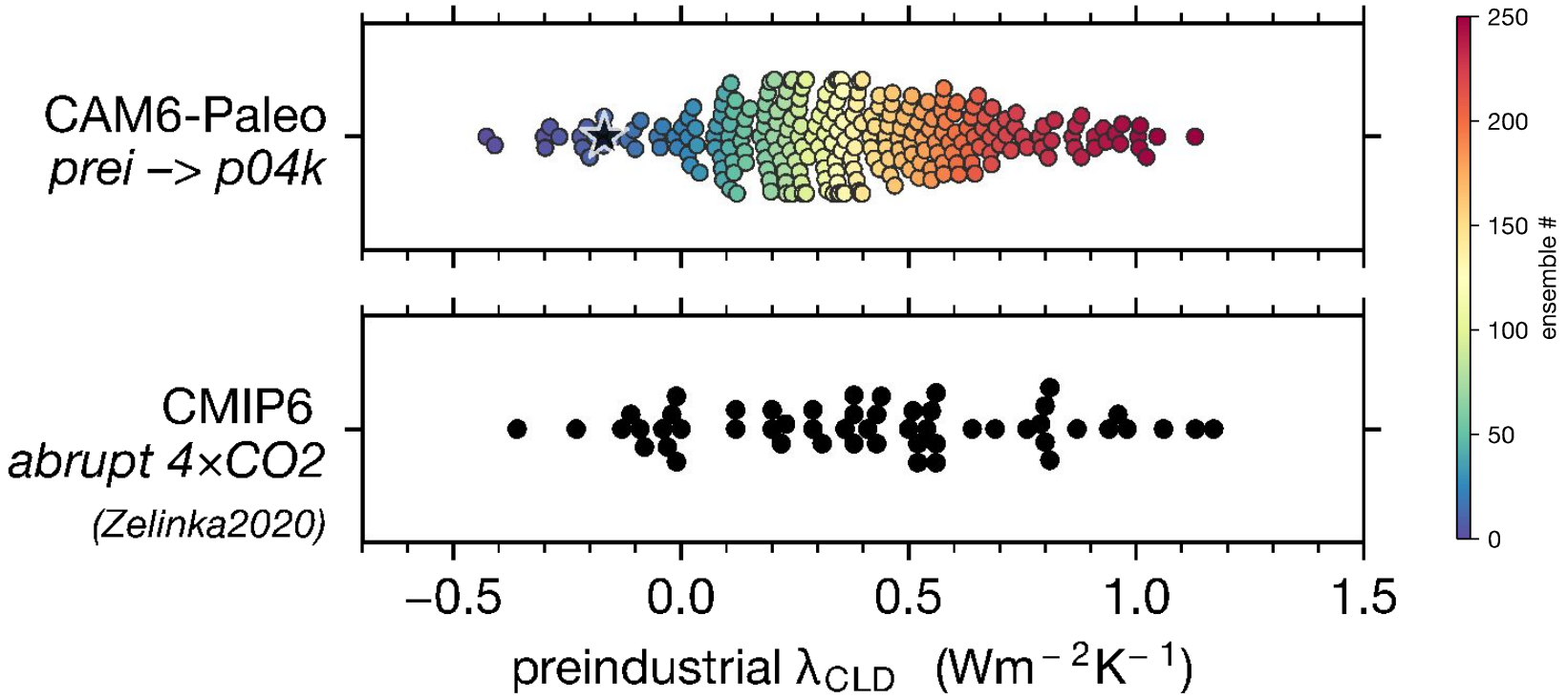
- *45 parameters* using *250 ensembles* of *5 years* each (using 2° CAM6-PaleoCalibr)
- 7 suites of fixed-SST PPEs: *m04k*, *prei*, *p04k*, *p08k*, *p12k*, & *p16k*

List of selected parameters

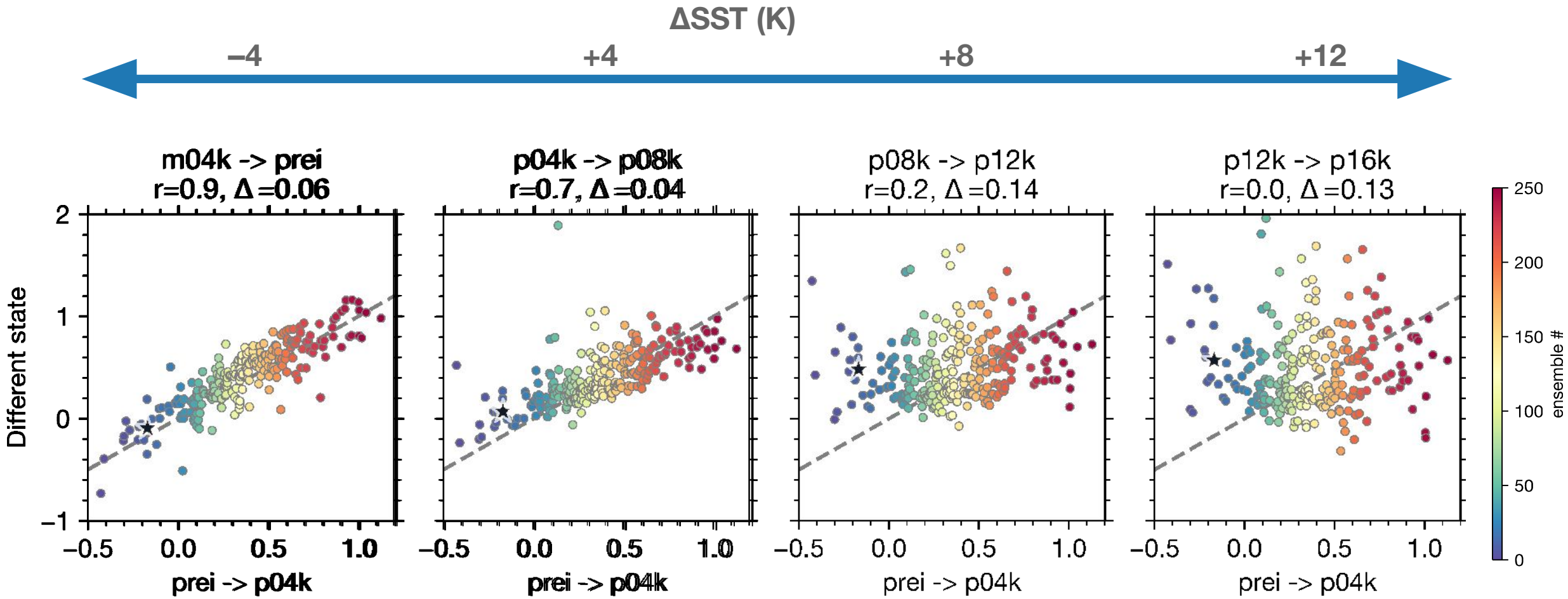
Eidhammer, Gettelman et al.

Physics	*Parameter Name*	*Description*	*Default*	*Min*	*Max*
CLUBB	clubb_c1	Low Skewness in C1 Skw.	1	0.4	3
	clubb_C2rt	Damping on scalar variances	1	0.2	2
	clubb_C8	Coef. #1 in C8 Skewness Equation	4.2	1	7
	clubb_c11b	High Skewness in C11 Skw	0.35	0.2	0.8
	clubb_c14	Constant for u'^2 and v'^2 terms	2.2	0.4	4
MG3	micro_mg_accre_enhan_fact	Accretion enhancing factor	1	0.1	10
	micro_mg_berg_eff_factor	Bergeron efficiency factor	1	0.1	1
	micro_mg_autocon_lwp_exp	KK2000 LWP exponent	2.47	2.1	3.3
	micro_mg_dcs	Autoconversion size threshold ice-snow	2.00E-04	5.00E-05	1.00E-03
	micro_mg_vtrmi_factor	Ice fall speed scaling	1	0.2	5
ZM	zmconv_dmpdz	Parcel fractional mass entrainment rate	-1.00E-03	-2.00E-03	-2.00E-04
	cldfrc_dp1	Parameter for deep convection cloud fraction	0.1	0.05	0.25
	zmconv_tiedke_add	Convective parcel temperature perturbation	0.5	0	2
	zmconv_capelmt	Triggering threshold for ZM convection	70	35	350
Aerosol	microp_aero_wsub_scale	Subgrid velocity for liquid activation scaling	1	0.1	5

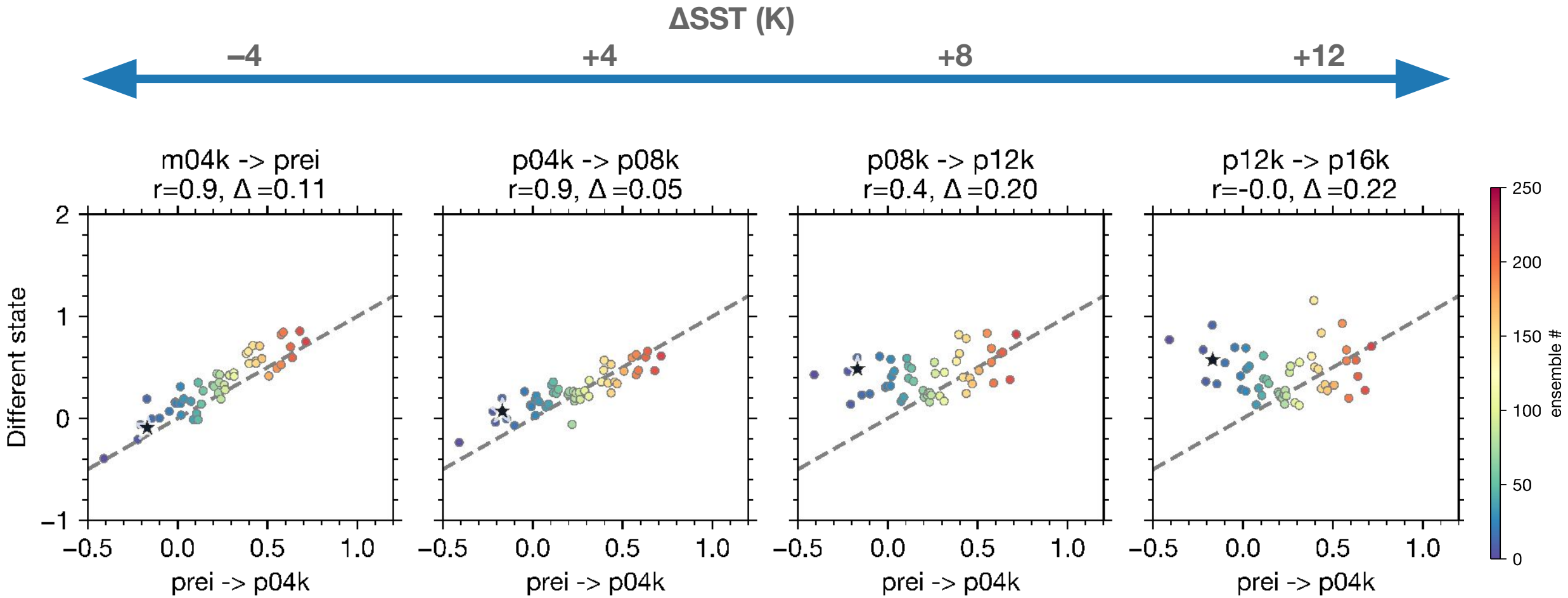
Preindustrial λ_{CLD}: PPE samples a wide range similar to CMIP6



State dependence of λ_{CLD}



Constrained state dependence of λ_{CLD}



Constraints: CERES-EBAF cloud forcing, ISCCP cloud fraction, & WCRP cloud feedback

Loeb et al., 2018; Pincus et al., 2012; Sherwood et al., 2020; Zelinka et al., 2022

Mechanisms?

High Lat.

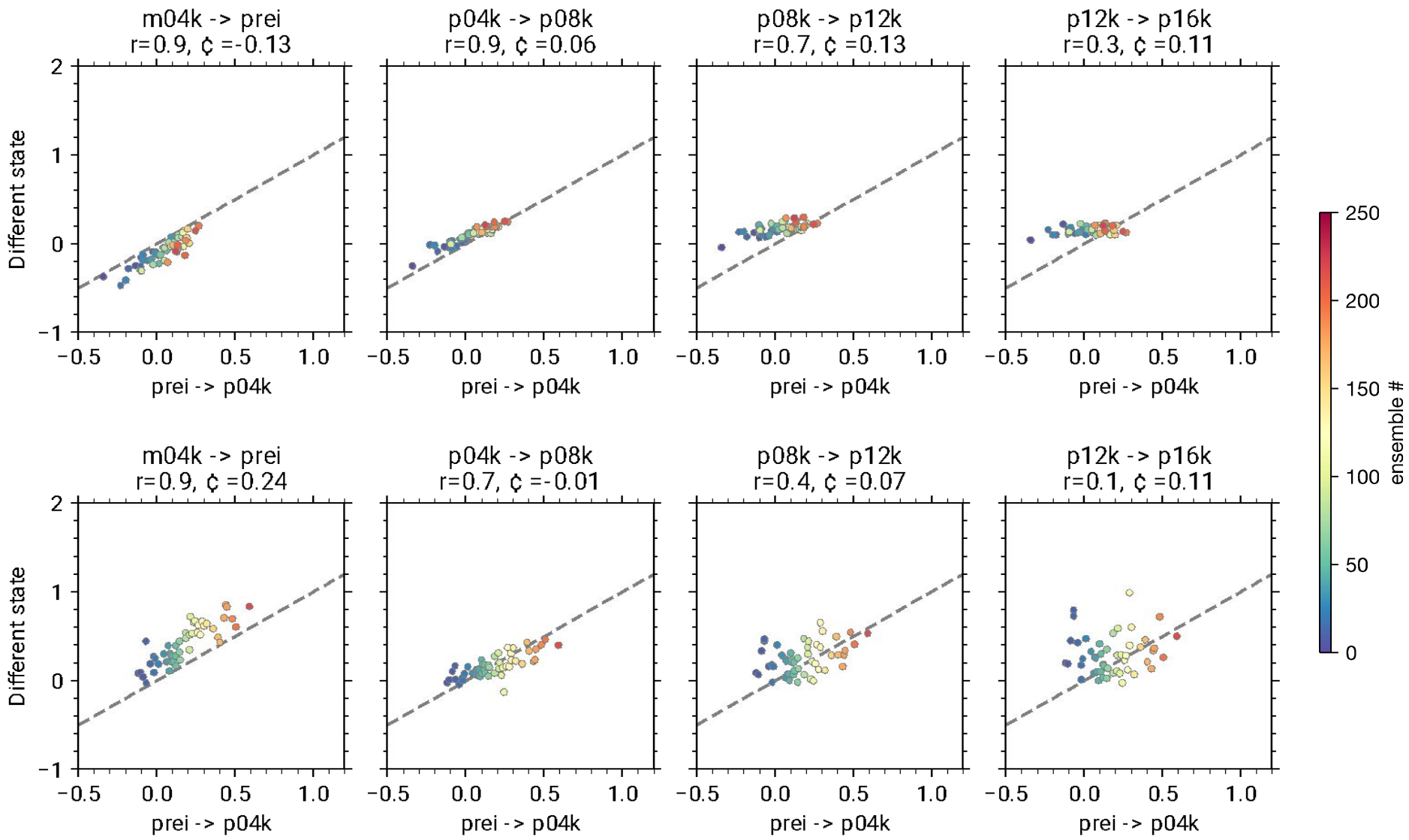
Monotonic & saturation □

mixed-phase clouds

Low Lat.

Nonmonotonic & complicated □

multiple processes



Take-home messages

- λ_{CLD} likely increases with warming: ~0.2 [–0.3, 0.8] $Wm^{-2}K^{-1}$ / 10K
  - High latitude: cloud ice decreases with warming
  - Low latitude: multiple processes & larger uncertainties (poor understandings from observational & modeling)

    e.g., latent heat increases nonlinearly with warming & dries low clouds *(e.g., Schneider et al., 2019)*

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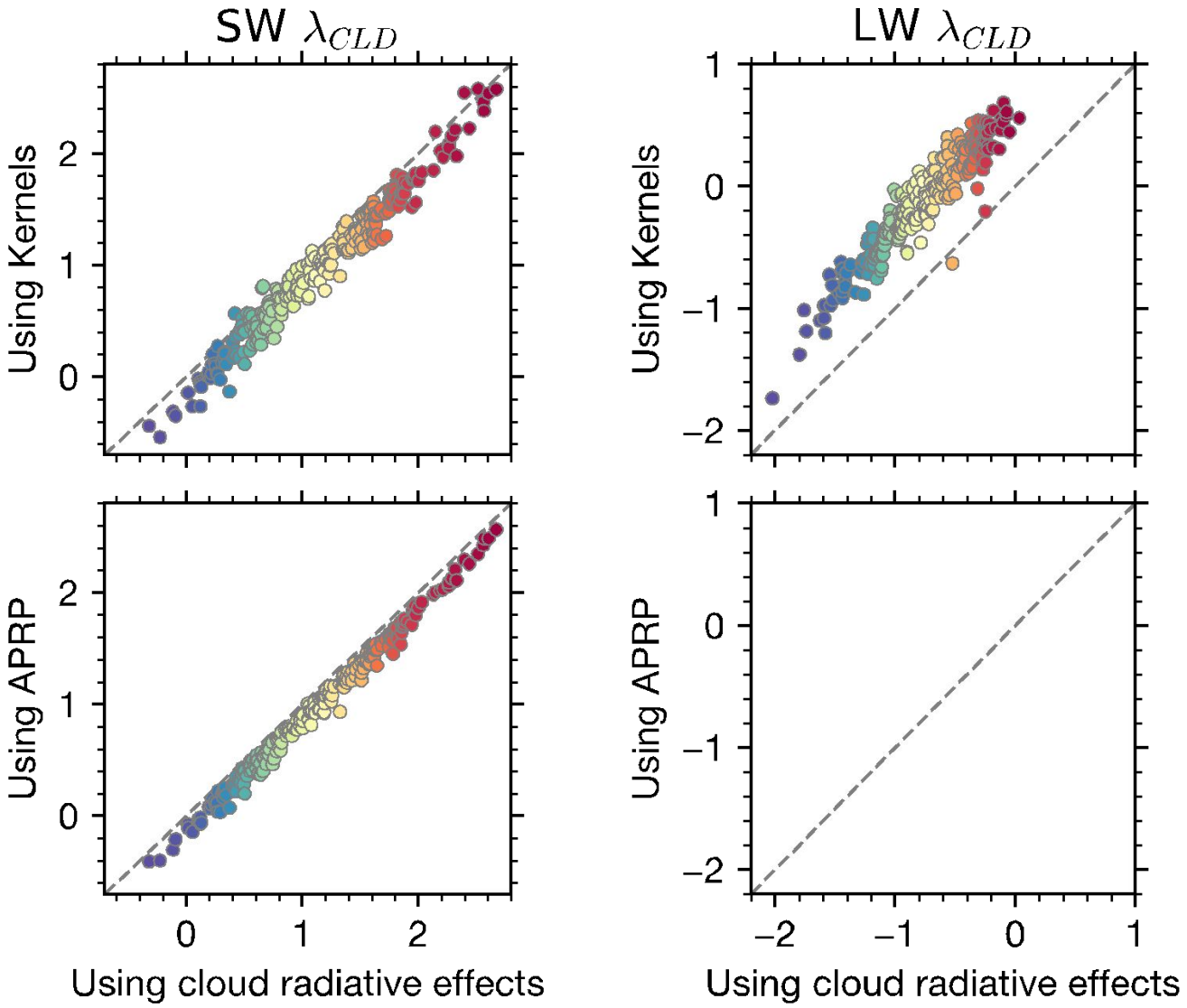
Thank you!

PPE samples a wide range of preindustrial λ_{CLD}



Cloud feedback