Constraining the Pattern Effect using Hierarchical Machine Learning and PPEs

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DOE EESM PI Meeting
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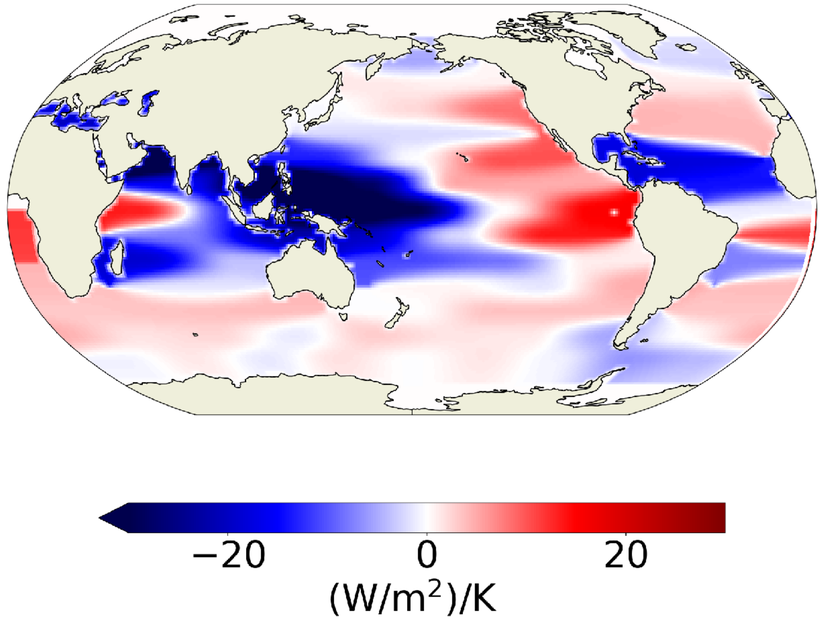
Radiative Response depends on pattern of warming: Greens Functions

$$\frac{\partial \overline{R}}{\partial T(x)}$$



Warming warm SSTs
→ negative feedback

Warming cold SSTs
→ positive feedback

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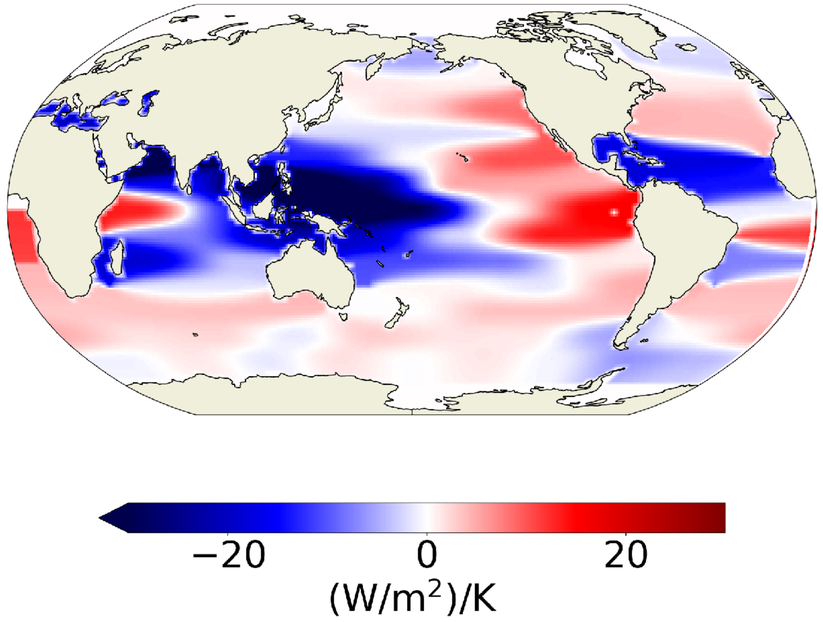

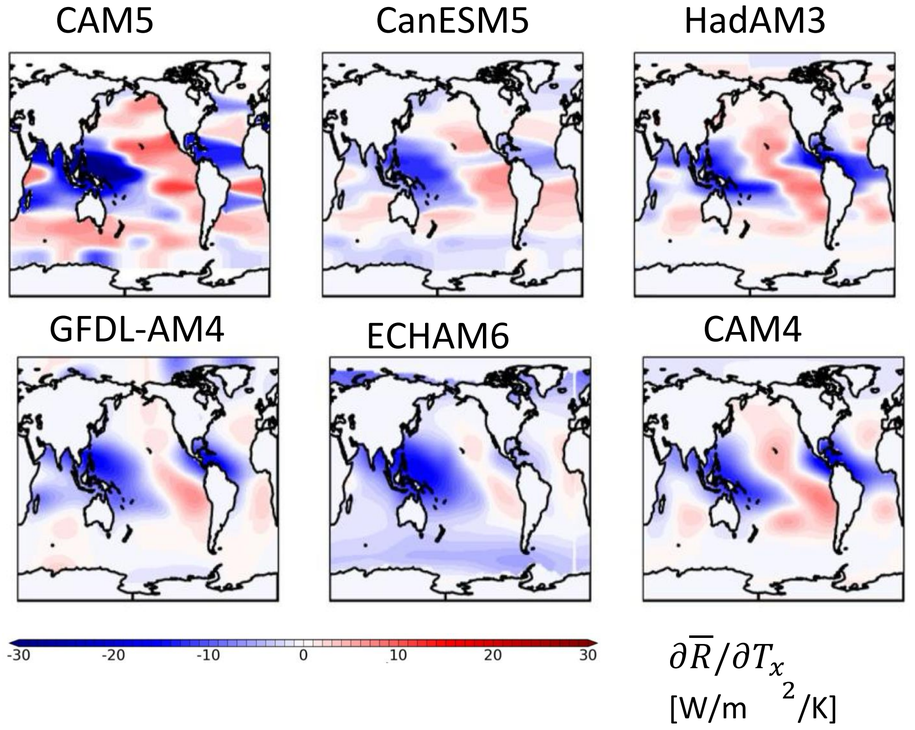

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Warming cold SSTs
→ positive feedback

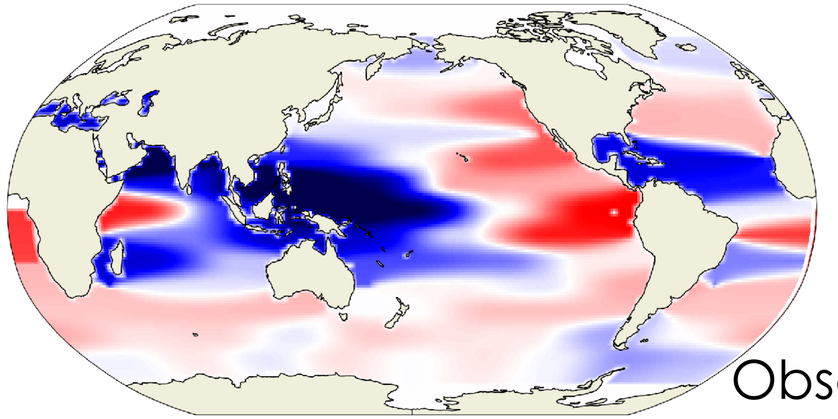
GreensFunction MIP (GFMIP)

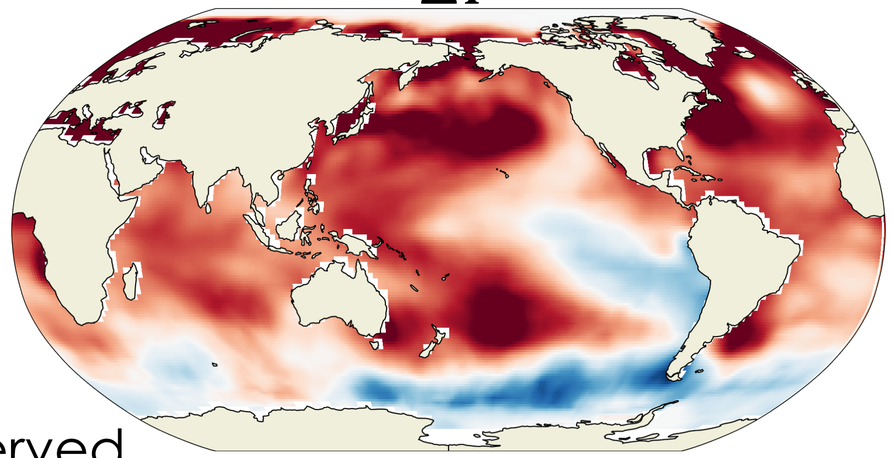
GCM Greens function agree on pattern
~10 models

Bloch-Johnson et al, 2024, JAMES

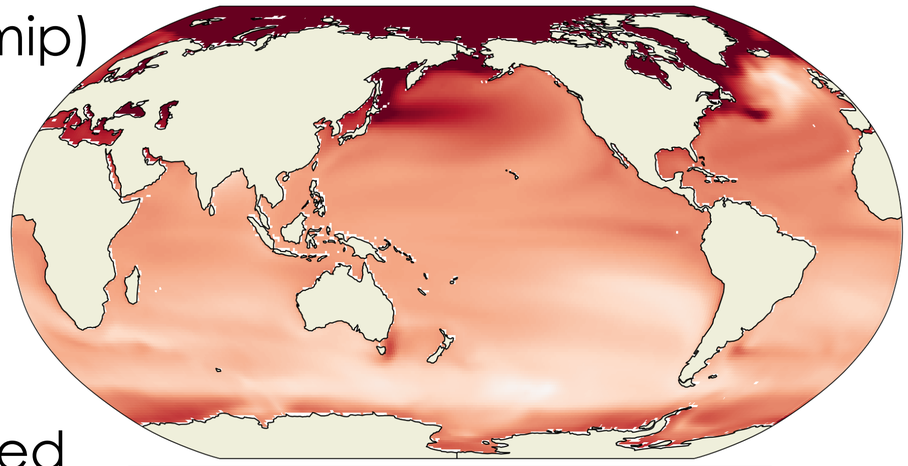
Observed patterns drive very negative feedbacks

$$\lambda = \sum \frac{\partial \overline{R}}{\partial T(x)} \times \frac{\Delta T(x)}{\Delta \overline{T}}$$

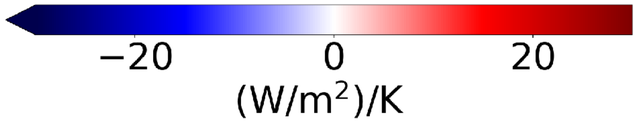




Observed (amip)



Coupled (cmip)



Warming warm SSTs
→ negative feedback

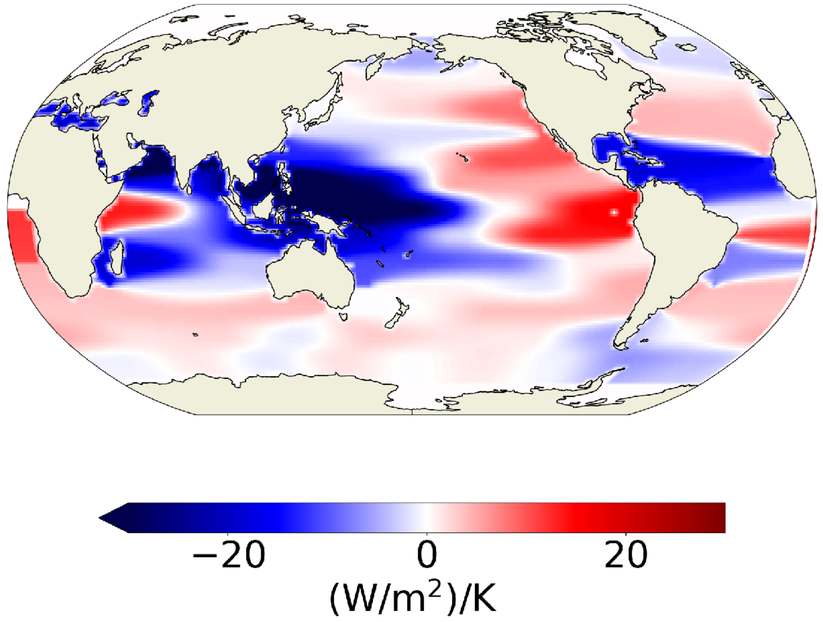
Warming cold SSTs
→ positive feedback

The pattern of model-simulated warming since 1979 diverges from observations

Observed warming drives more negative feedbacks , slowed down warming, weakens ECS constraints
Armour, Proistosescu, et al 2024

How do we constrain the pattern effect?

$$\frac{\partial \overline{R}}{\partial T(x)}$$



Problem: GCM Green's Function require

- 1000 year simulations
- 50 degrees of freedom
- We only have 24 years of obs of global radiation

Solution: Hierarchical Machine Learning & Regularization

Hierarchical Machine Learning

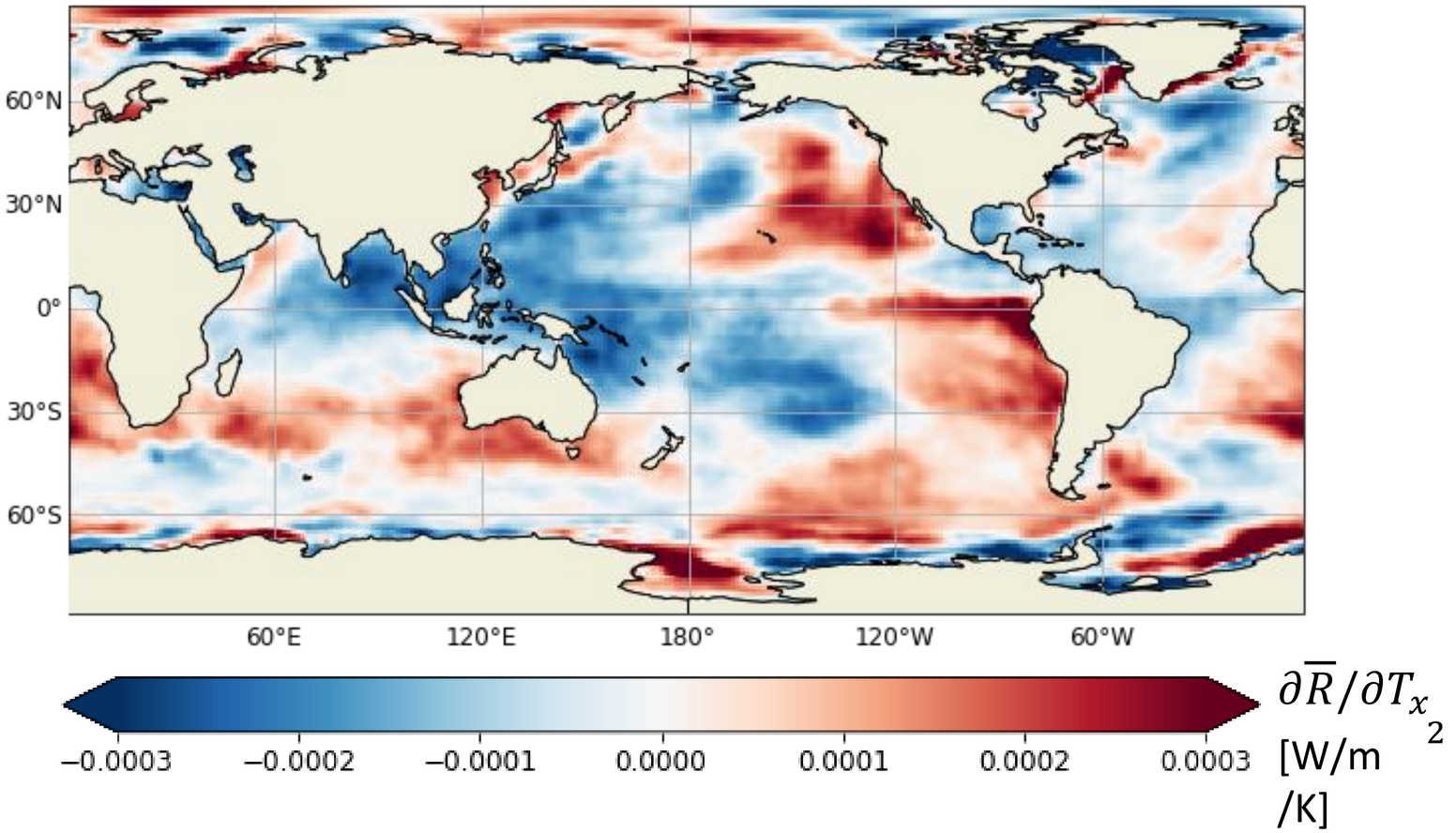
Green's Functions are linear response functions

$$\overline{R}_t = \sum_x (\partial \overline{R} / \partial T_x) \cdot T_{xt} = \sum_x \beta_x \cdot T_{xt}$$

Hierarchical Gaussian Process

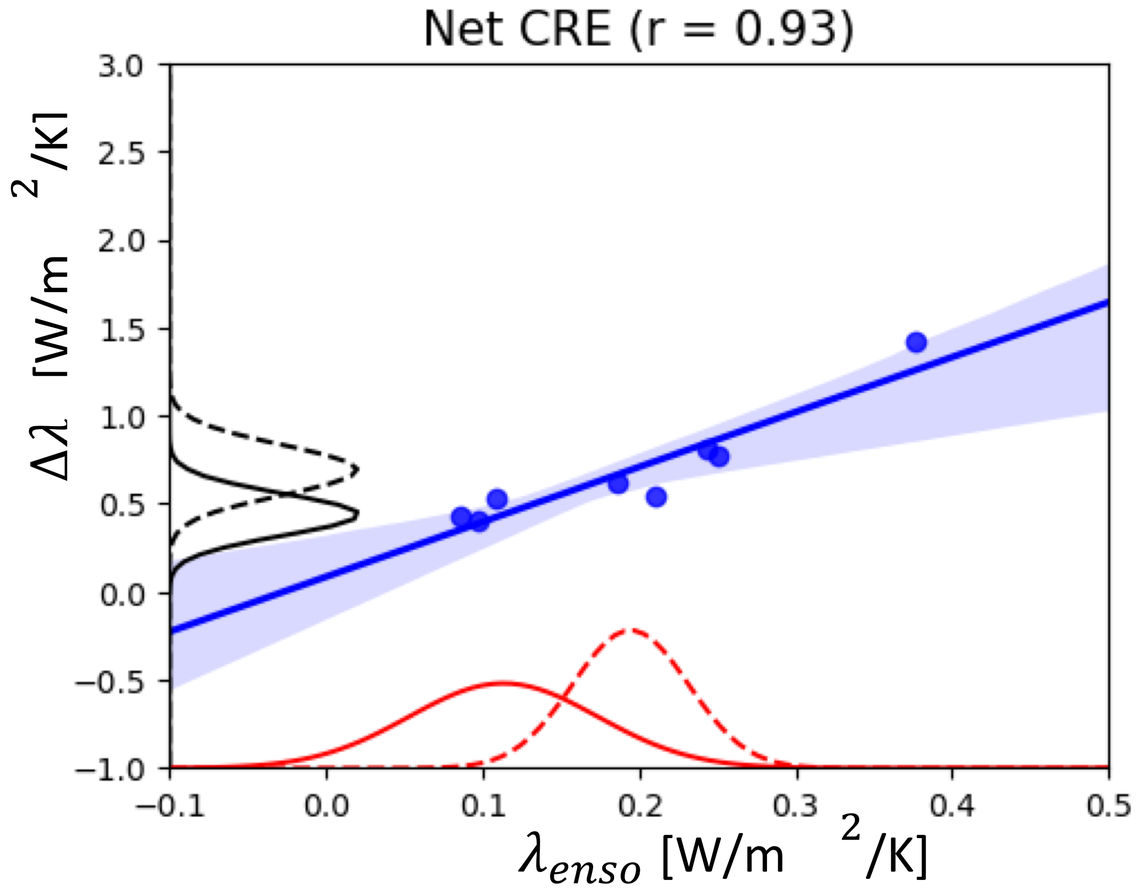
$$\beta \sim \mathcal{N}(\mu_{\beta_{GCM}}, \sigma_{\beta_{GCMs}})$$

E3SM



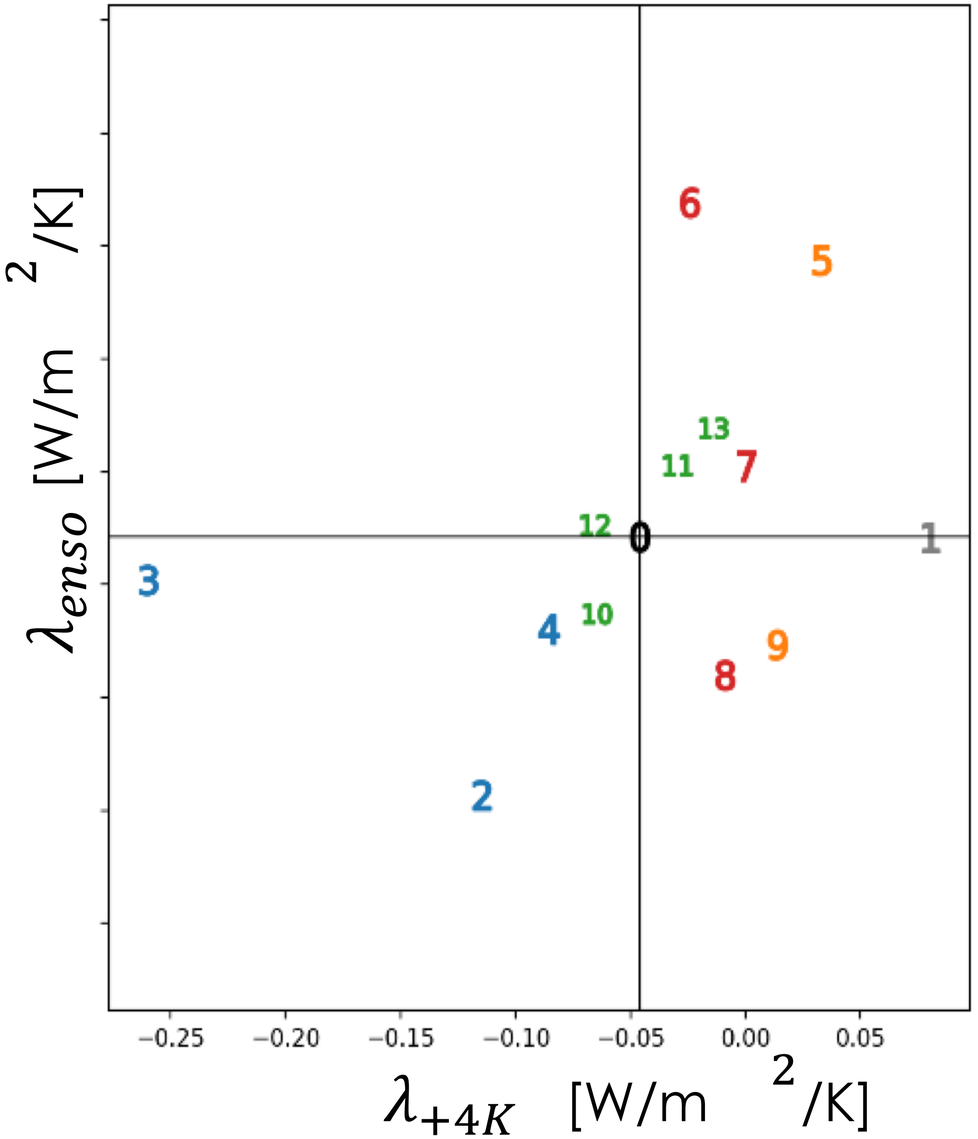
Model physics of the pattern effect

ENSO is a good proxy for the pattern effect.



Hanke et al (in prep)

Model physics of the pattern effect



E3SMv2 PPE

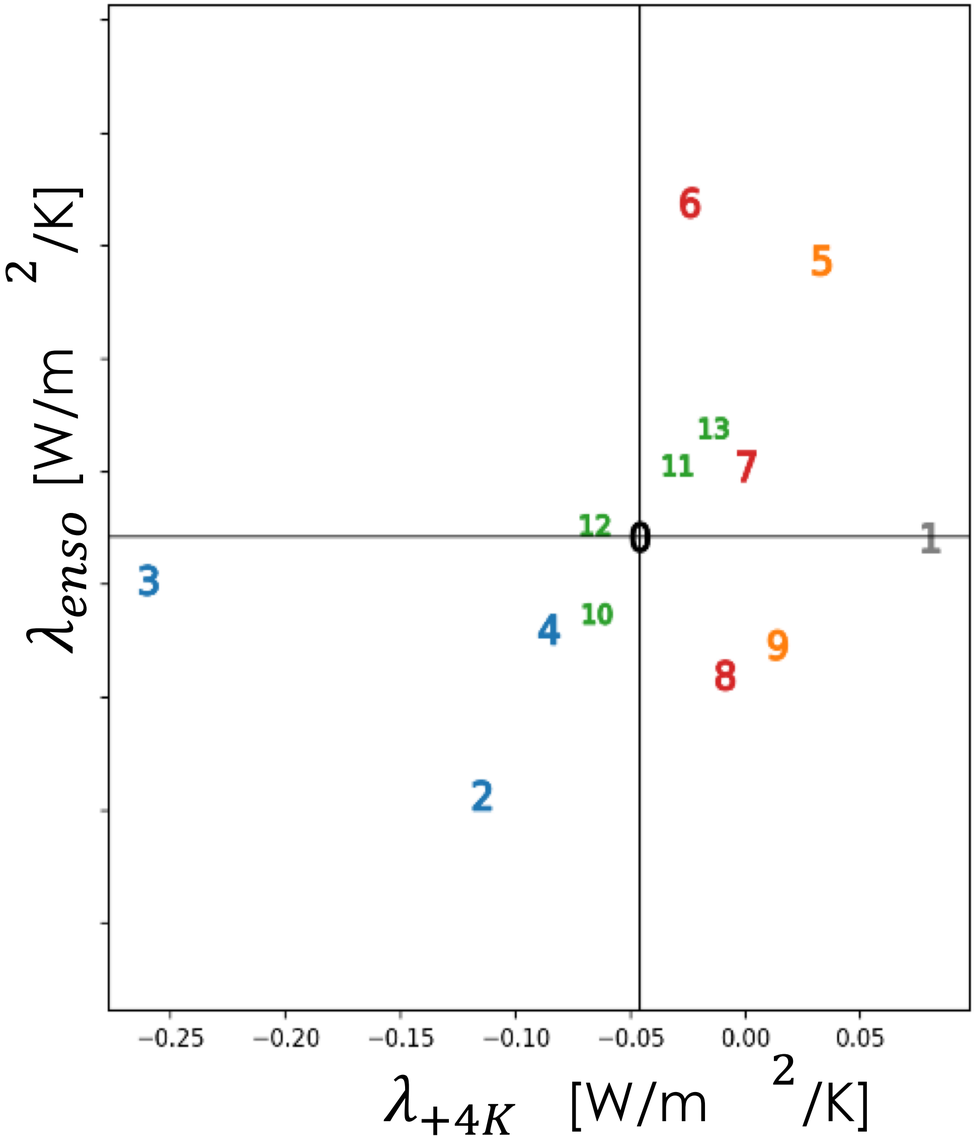
13 parameters, one at a time.

- Present day
- +4K
- ENSO pattern

default
nomincdnc
warm rain
mixed phase
turbulence
convection

0	default	**3**	prccoef1	**6**	clubbc1	**9**	clubbtk1	**12**	so4sz
1	nomincdnc	**4**	accre_enhan	**7**	gammacoef	**10**	icedeep	**13**	dp1
2	prcexp1	**5**	berg	**8**	clubbc8	**11**	icesedai		

Model physics of the pattern effect



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The CESS cloud feedback and ENSO cloud feedbacks are not strongly correlated (they are more sensitive to different parameters).

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nomincdnc
warm rain
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turbulence
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