The Role of Radiative Interactions in Tropical Cyclone Development under Realistic Boundary Conditions

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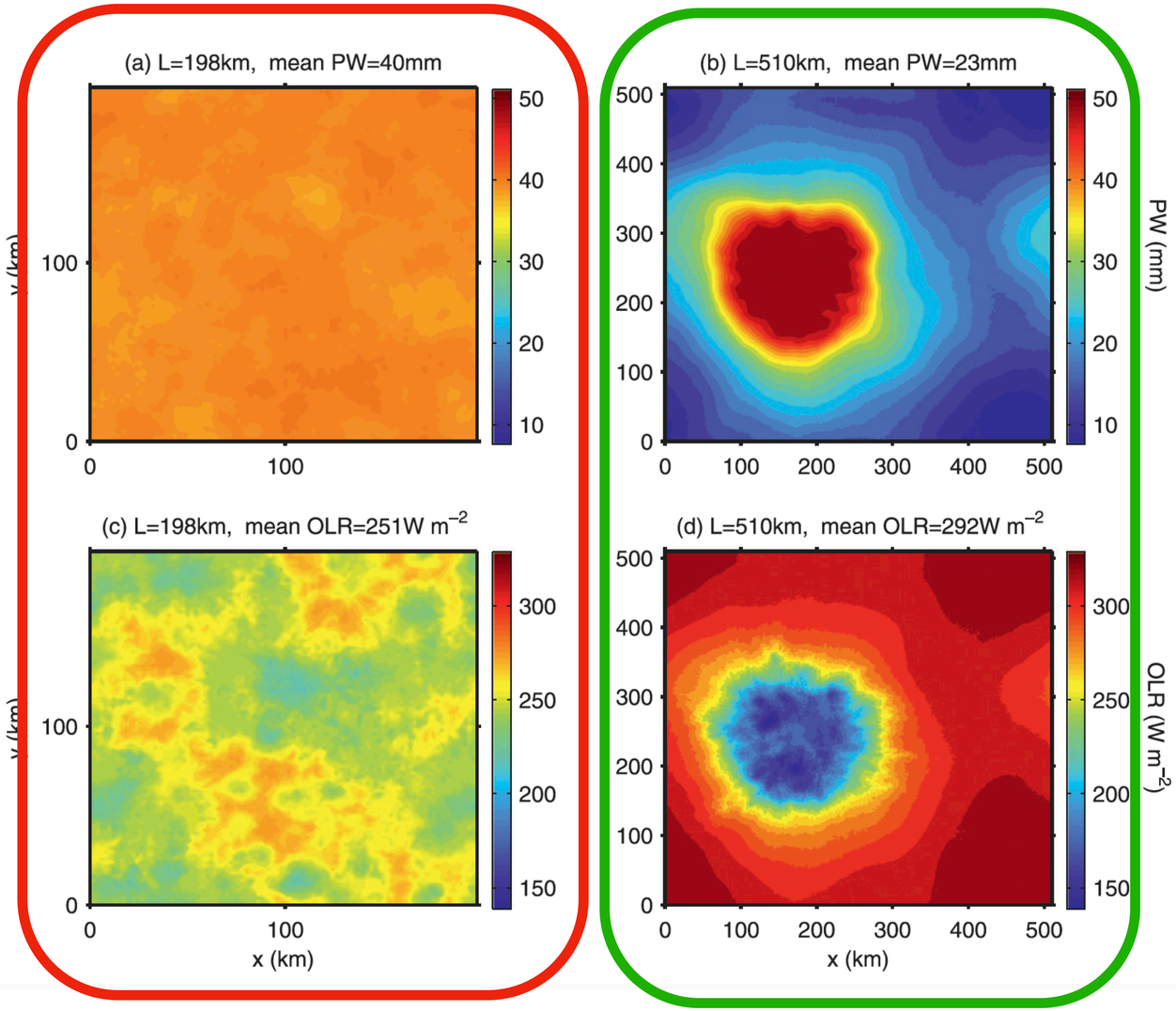
For TC Seed Theory see: Hsieh, T.-L., G.A. Vecchi, W. Yang, I.M. Held, and S.T. Garner (2020): Large-scale control on the frequency of tropical cyclones and seeds: a consistent relationship across a hierarchy of global atmospheric models. *Clim. Dyn.*, doi:10.1038/s41467-019-08471-z

What is convective aggregation?



Disorganized convection → **Aggregation (isolated cluster)**

Convective aggregation in a cloud-resolving model

Muller and Held (2012)

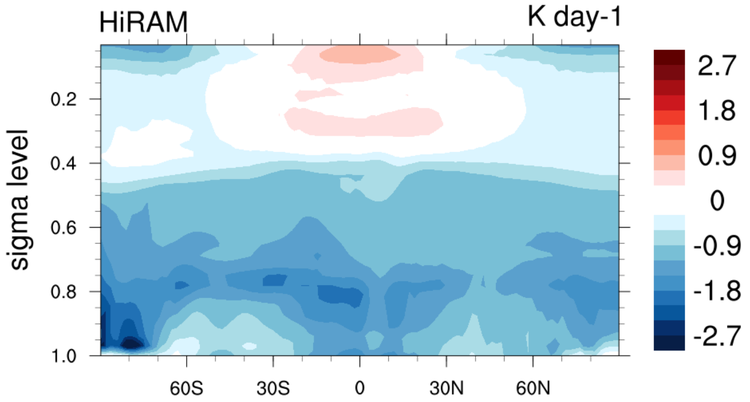
We use HiRAM, a TC-permitting AGCM, to investigate the role of radiative interactions in TC development

- Horizontal resolution: ~50 km; Vertical levels: 32 levels
- Prescribed with observed SST and sea ice

Experiment name	SST forcing	CO_2 forcing	Radiation
Control	1986-2005 Average	Fixed	Fully Interactive
ClimRad	1986-2005 Average	Fixed	Prescribed Climatology
Control_plus4K	Add 4K warming	Fixed	Fully Interactive
ClimRad_plus4K	Add 4K warming	Fixed	Prescribed Climatology
Control_plus2K_2CO_2	Add 2K warming	2CO_2	Fully Interactive
ClimRad_plus2K_2CO_2	Add 2K warming	2CO_2	Prescribed Climatology
Control_2CO_2	1986-2005 Average	2CO_2	Fully Interactive
ClimRad_2CO_2	1986-2005 Average	2CO_2	Prescribed Climatology

Present-day climate

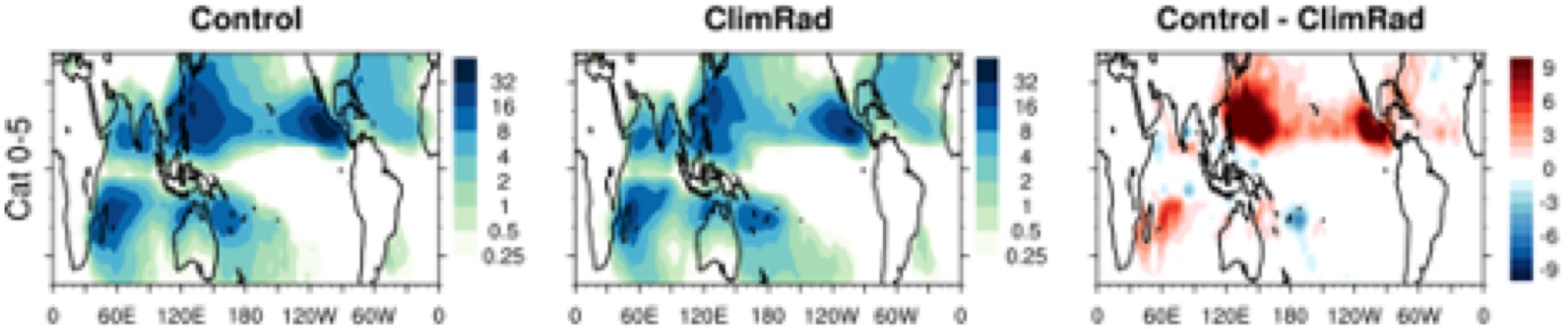
Different global forcing scenarios

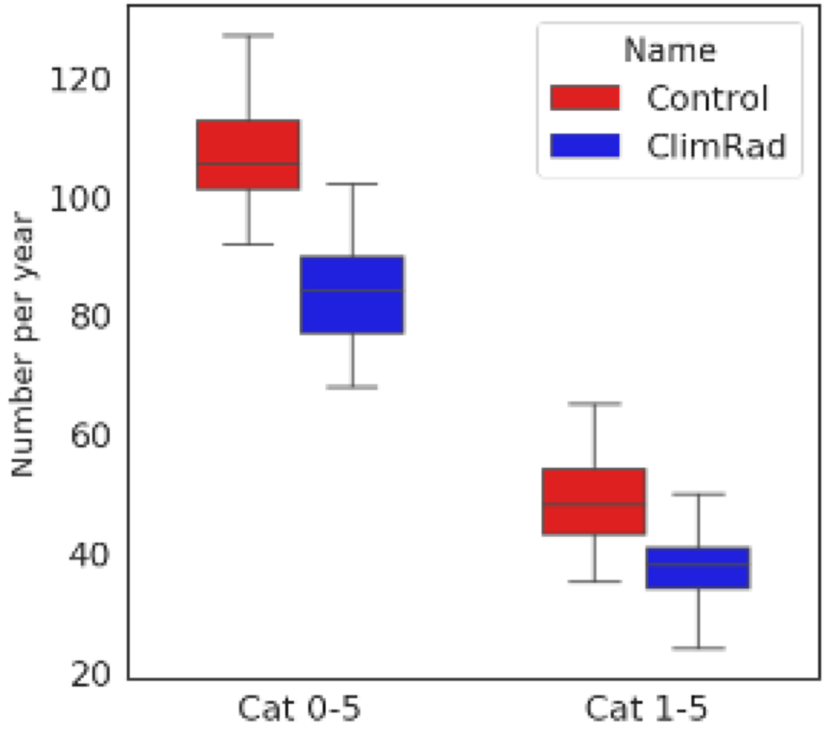


Control radiative cooling in HiRAM

Interactive radiation increases TC activity

TC Density





Climatological radiation reduces TC frequency by ~20%

TC frequency can be understood in terms of:

Seed frequency (depends on large-scale ascent and vorticity)

Genesis probability (depends on Tang and Emanuel ventilation index)

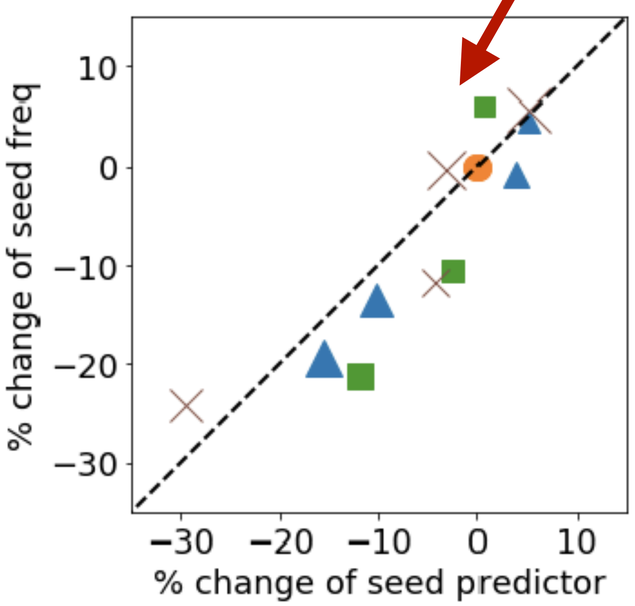
Convection x **Probability** x **Probability'**

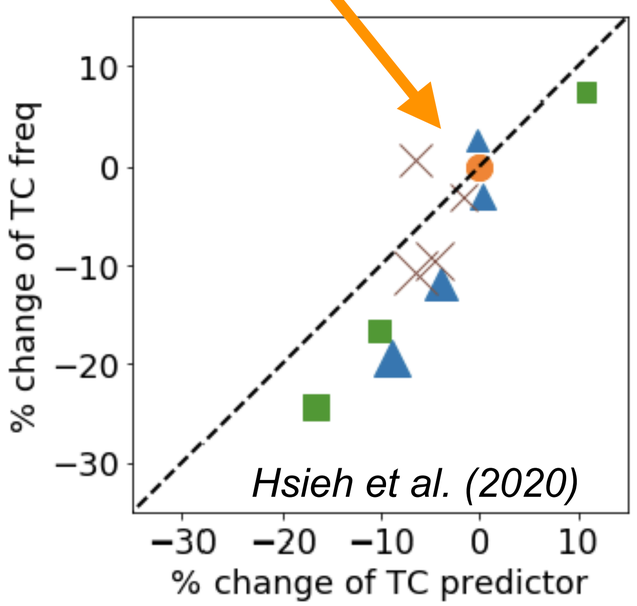
$\propto -\overline{\omega}_{500}$ $\propto (f+\overline{\zeta})$ $\frac{\text{potential intensity}}{(\text{vertical shear}) \cdot (\text{moisture deficit})}$

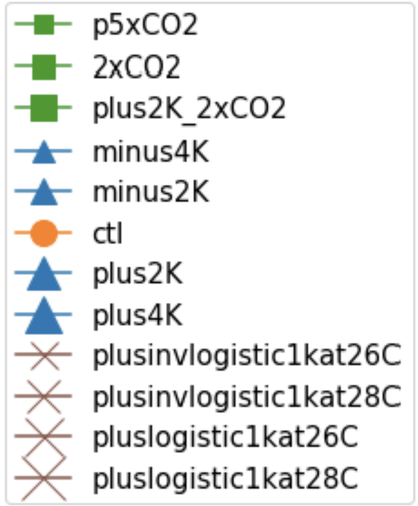
Seeds

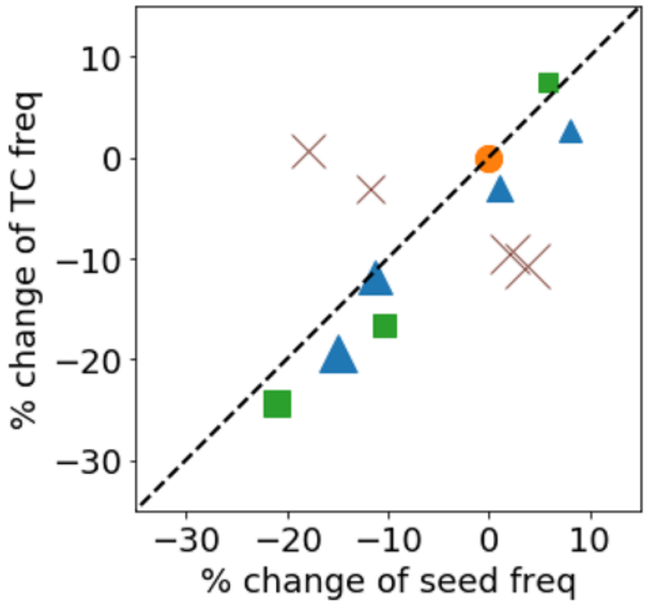
Tropical cyclones

Seeds ≠ TCs





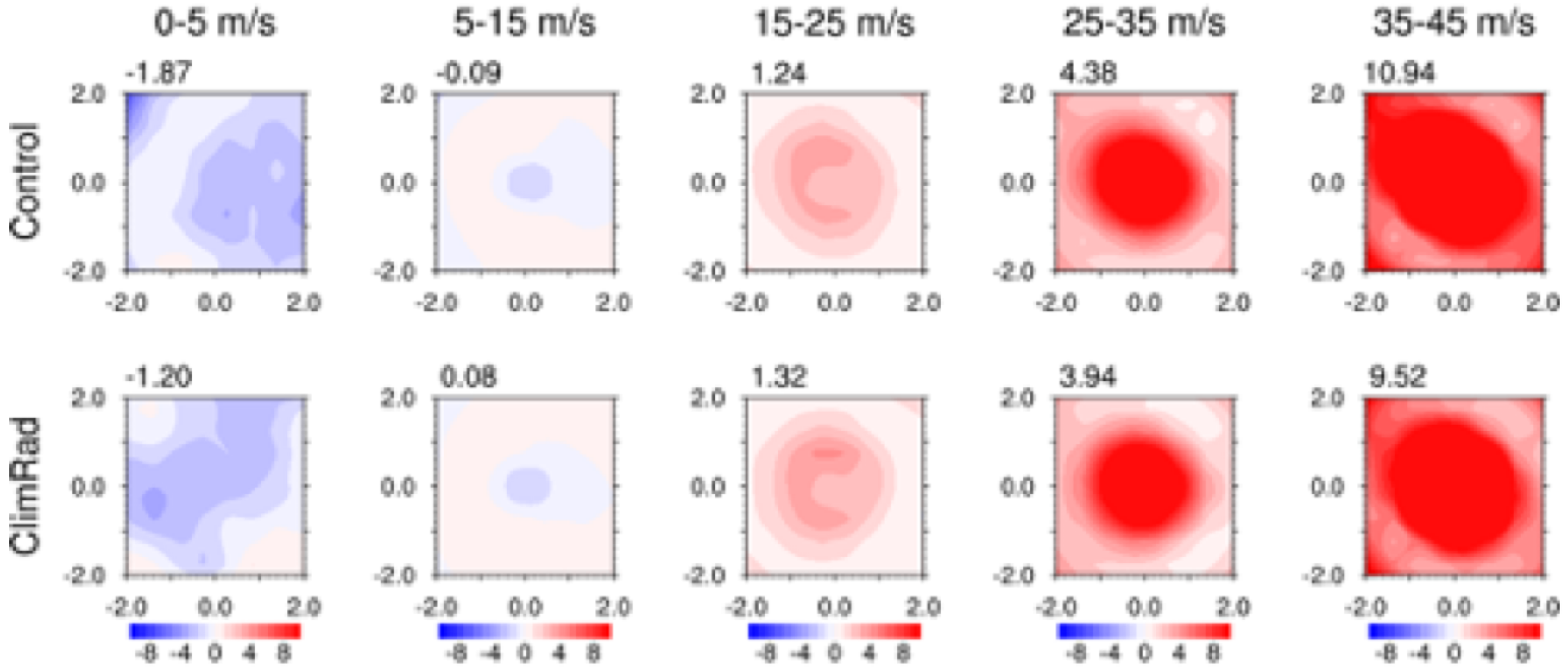




Suppressing radiative feedbacks reduces seeds

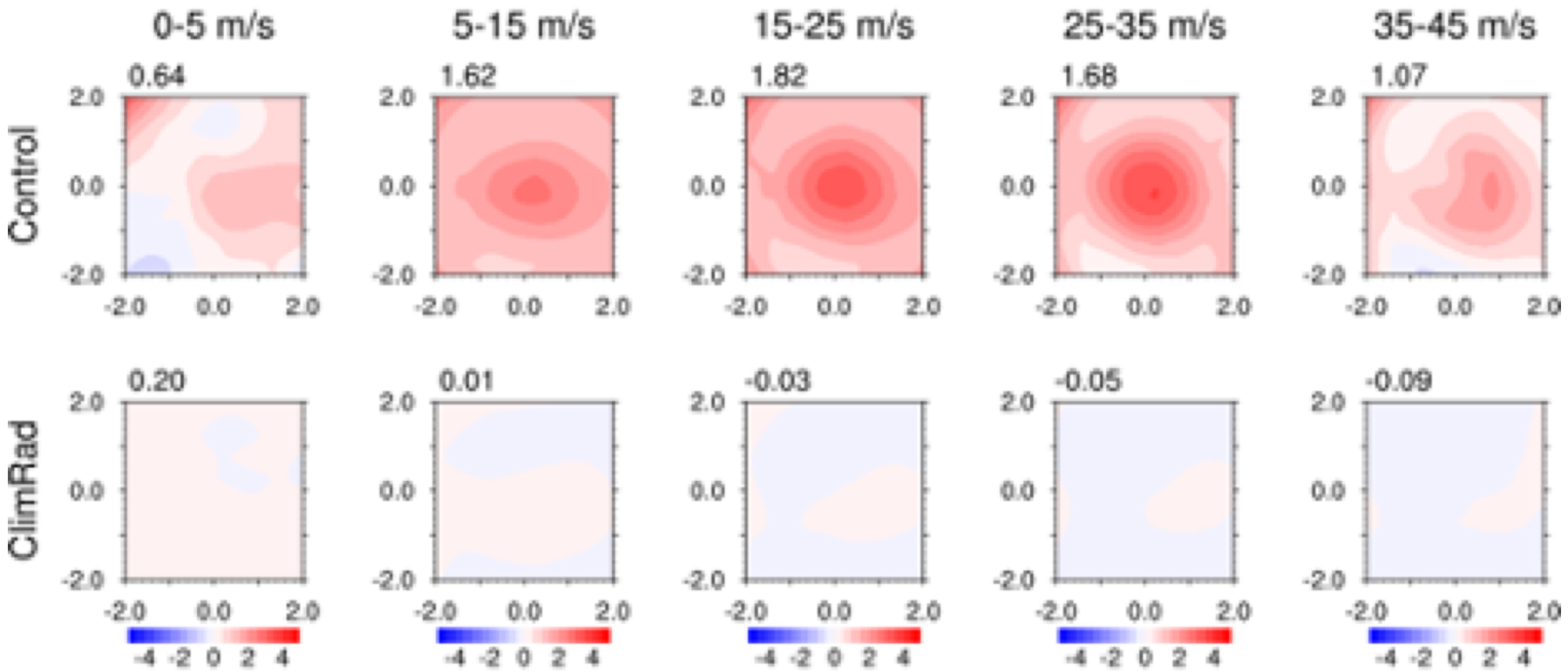
Following Wing and Emanuel (2014) we diagnose MSE variance budget

$$\frac{1}{2}\frac{\partial h'^2}{\partial t} \sim L_v q' \cdot THF' + L_v q' \cdot R'$$



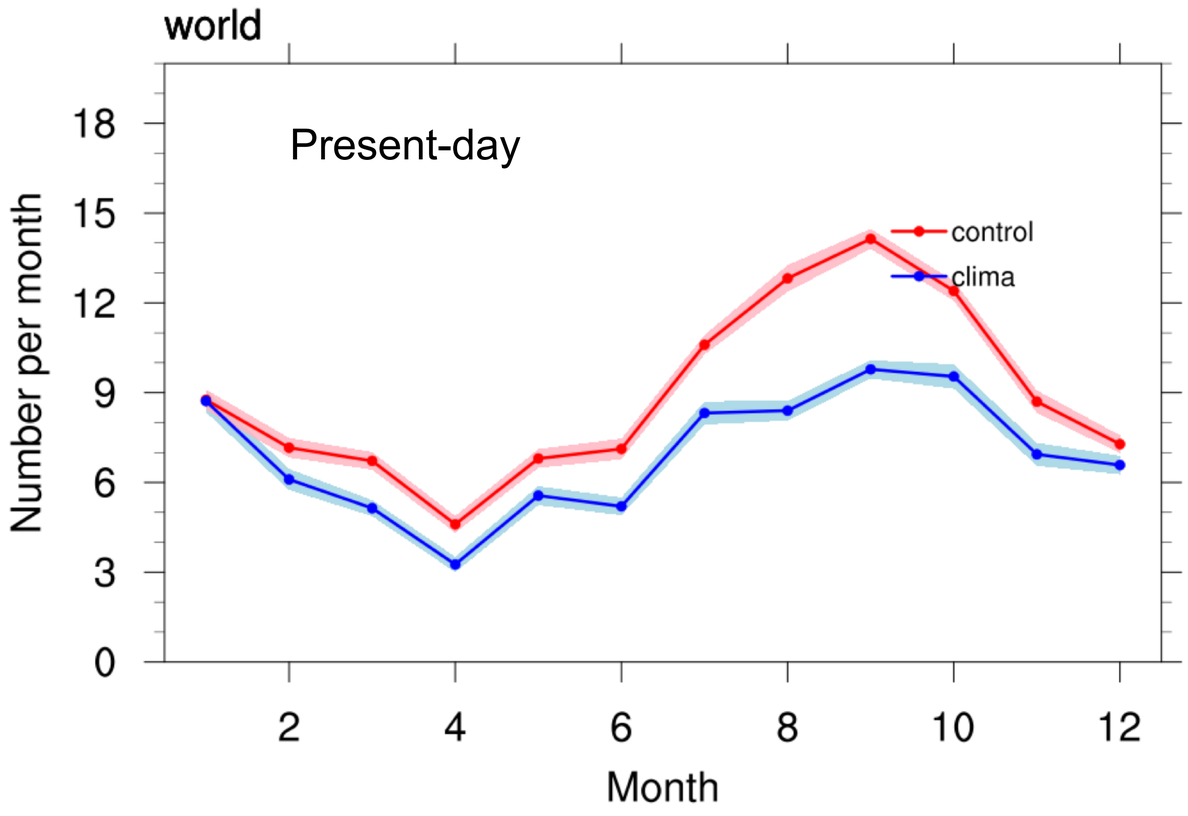
The surface turbulent flux feedback is similar between the Control and ClimRad, for weak winds it is negative.

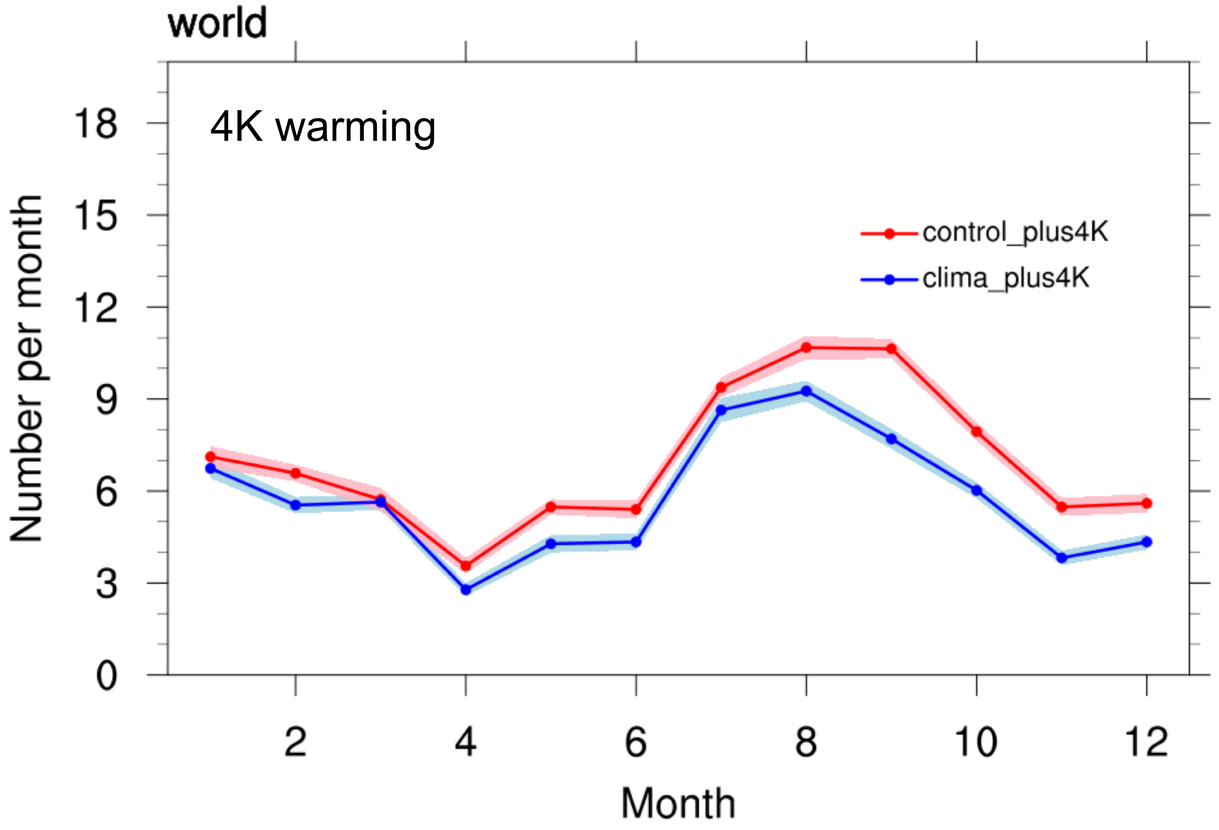
$$\frac{1}{2}\frac{\partial h'^2}{\partial t} \sim L_v q' \cdot THF' + L_v q' \cdot R'$$



The radiative feedback is very different
With interactive radiation it is positive even for weak winds

In a warmer world, radiative feedbacks impact global TC frequency less.





A quick summary of the response in TC frequency

1. Radiative interaction enhance global TC frequency

2. Primarily due to impact on pre-TC synoptic disturbances (“seeds”)

3. MSE budget: for weak vortices surface flux feedback negative, while positive the radiative feedback becomes requires radiative interactions

4. TC impact of radiative interactions is diminished in a warmer climate:
   More moisture: larger positive contribution from latent heat release for genesis?

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