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Linking changes in daily precipitation under warming to CIN and the DSE budget

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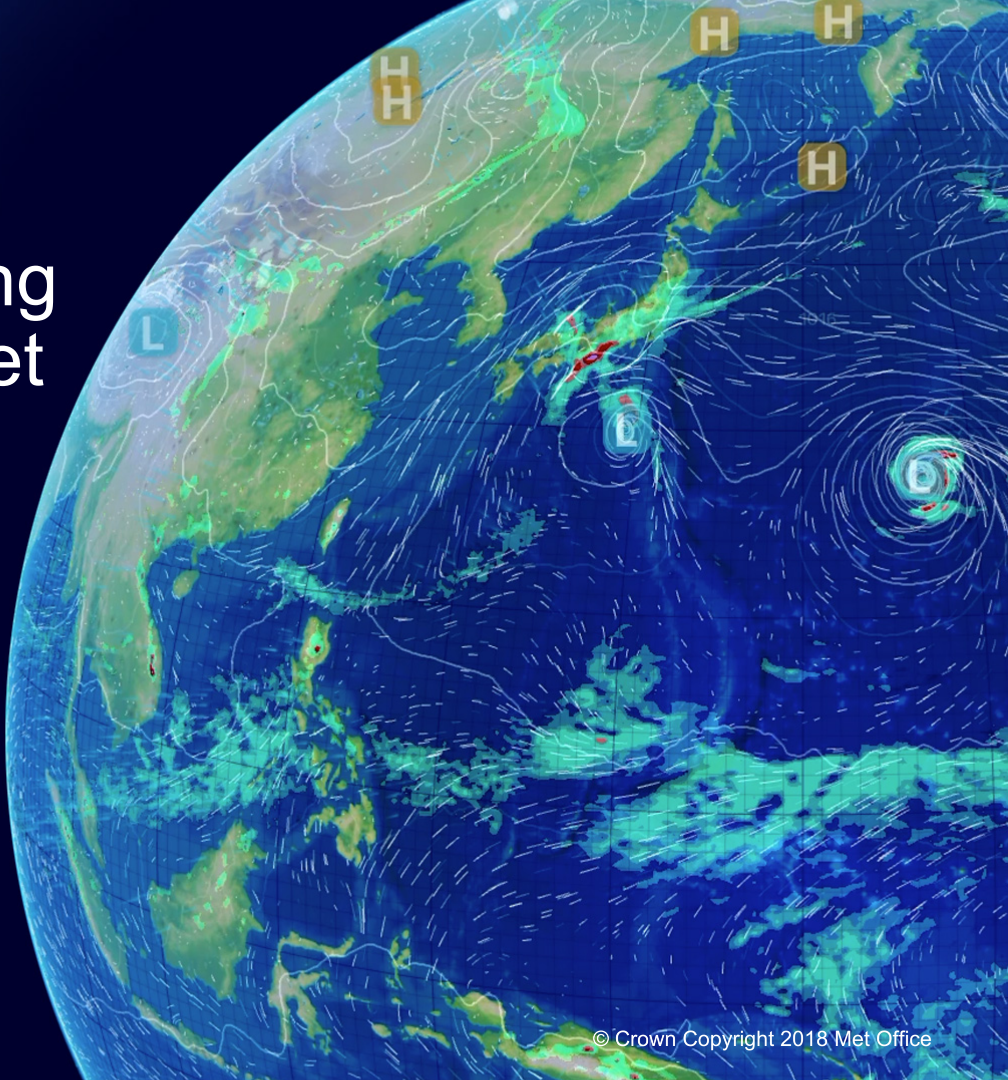
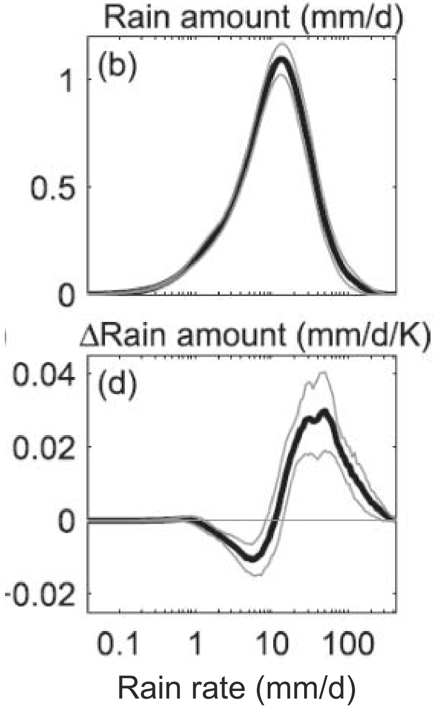
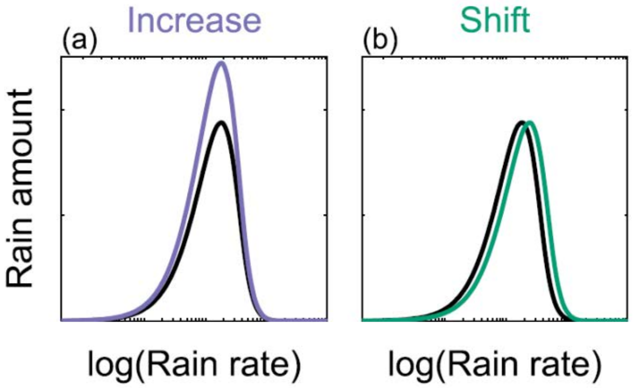
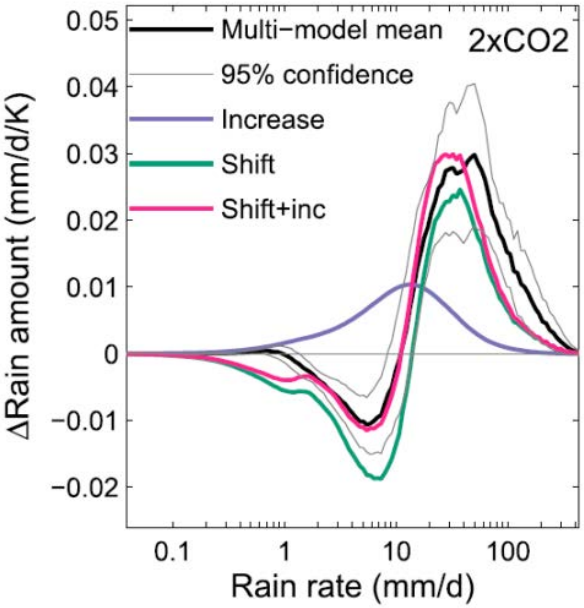


Two modes of daily precipitation change

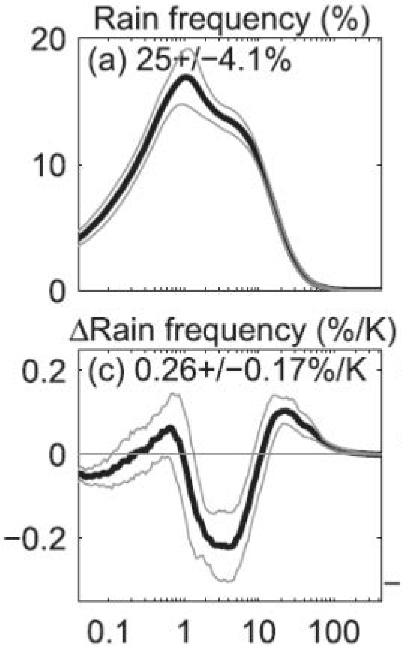


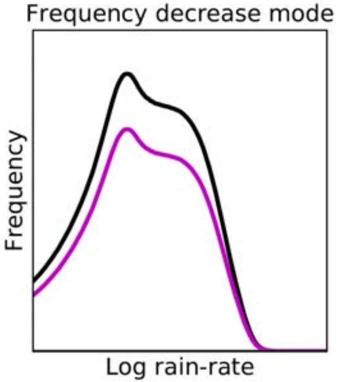




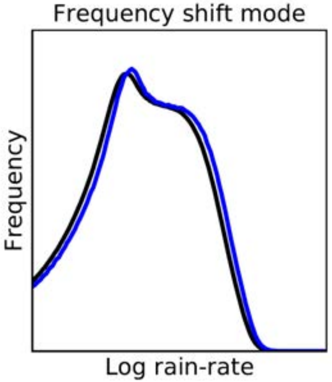
Pendergrass et al., 2014a,b, J. Climate

Changes in frequency

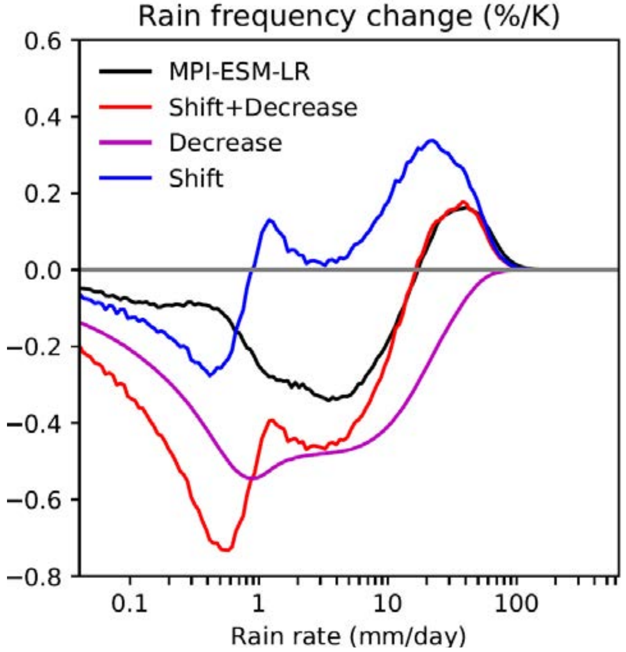




Decreased frequency of events



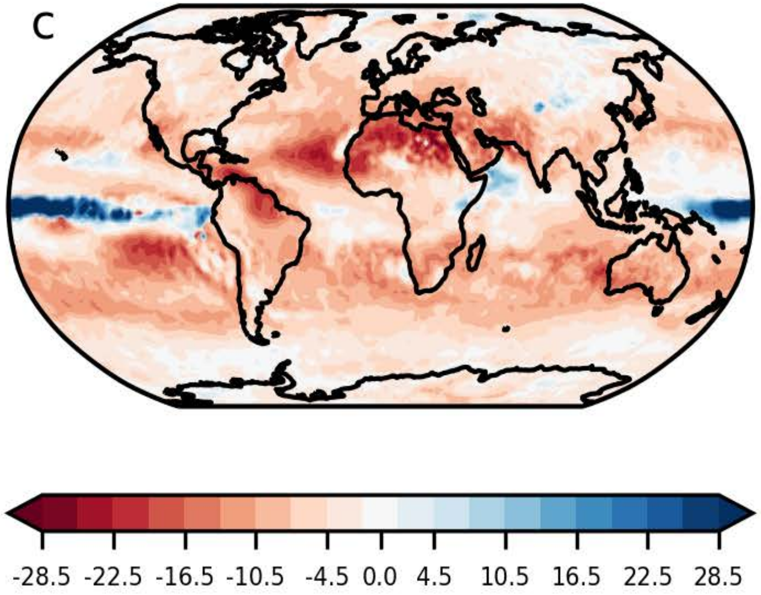
Increased intensity of events



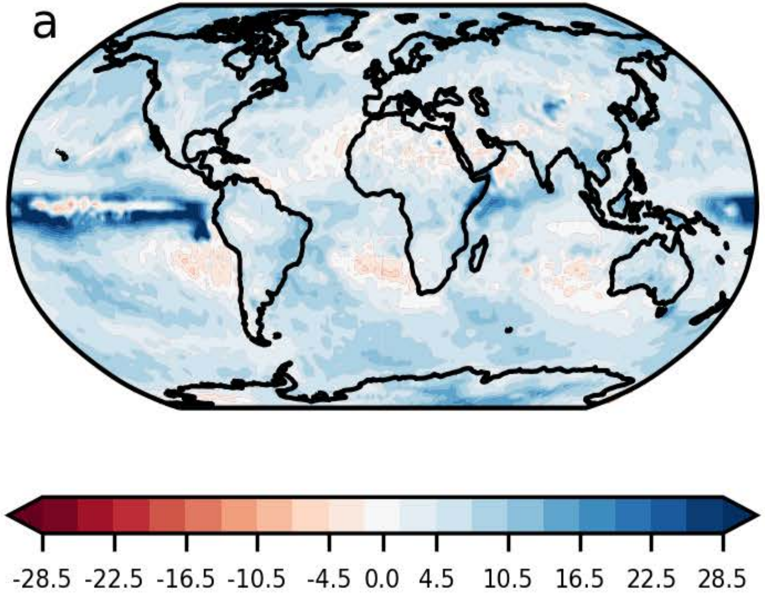
Pendergrass et al., 2014a,b, J. Climate

Regional modes of daily precipitation change

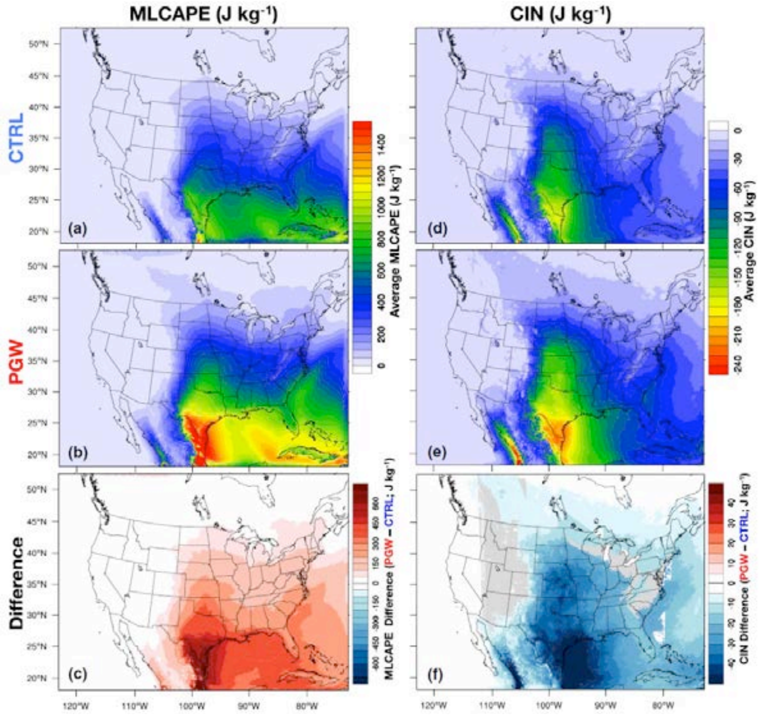
Frequency decrease mode (%)

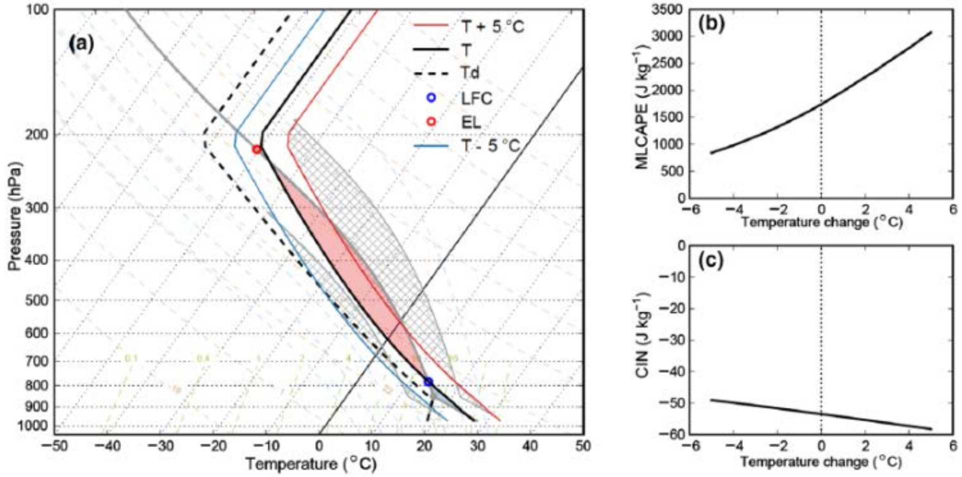


Frequency shift mode (%)



CIN and CAPE changes



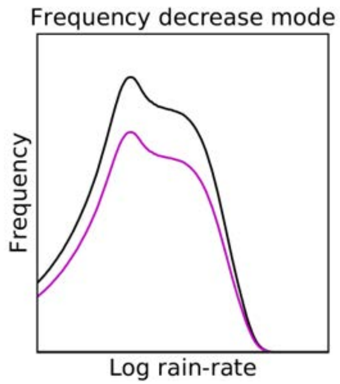


Rasmussen et al., 2017, Clim. Dyn.

CIN and frequency decrease mode

Assume that the frequency of deep convection scales under warming as a decreasing function of time-mean CIN:

$$f \propto g(\overline{CIN})$$

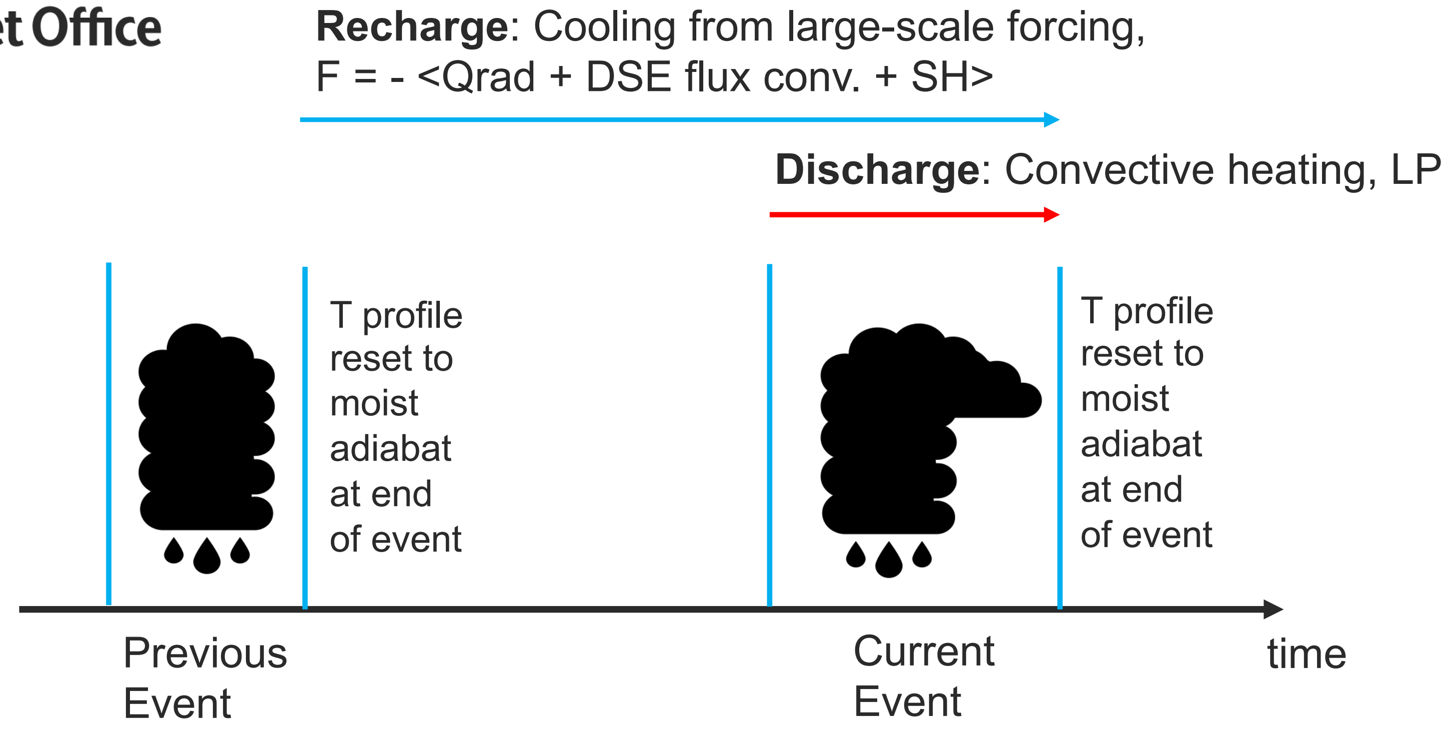


Now assume that this function holds for events at all rainfall intensities:

$$f(lnP) \propto g(\overline{CIN})$$

For increasing CIN, this gives a fractional decrease in frequency that is independent of rain-rate, i.e. a frequency decrease mode:

$$\frac{\Delta f(lnP)}{f(lnP)} = \frac{g(\overline{CIN'})}{g(\overline{CIN})} - 1$$



$$LP = \langle c_p(T(BLMSE_{current}) - T(BLMSE_{prev}))\rangle + \int_0^{\Delta t} F\,dt$$

Simple model predictions under warming

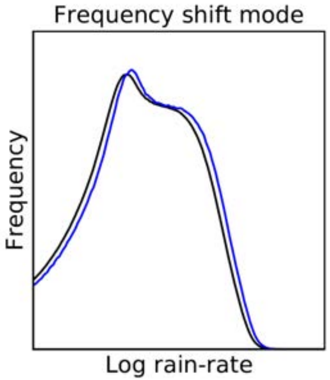
Primes denote future values under warming

For all events in the rainfall pdf, change in intensity is:

$$\frac{\Delta P}{P} = \frac{\overline{F'}}{\overline{F}} \times \frac{\overline{f}}{\overline{f'}} - 1$$

This produces a frequency shift mode:

$$f'(lnP) = f(lnP - \frac{\Delta P}{P})$$



Relating the frequency change back to CIN changes gives:

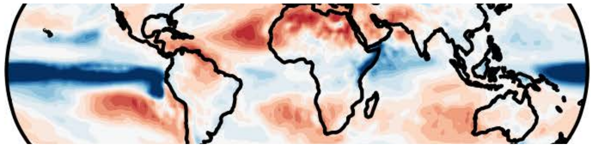
$$\frac{\Delta P}{P} = \frac{\overline{F'}}{\overline{F}} \times \frac{g(\overline{CIN})}{g(\overline{CIN'})} - 1$$

Estimated CIN and large-scale forcing changes

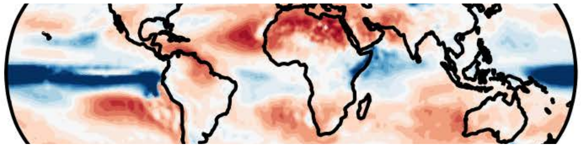
Frequency decrease mode: $$\frac{\Delta f(lnP)}{f(lnP)} = \frac{g(\overline{CIN'})}{g(\overline{CIN})} - 1$$

Frequency shift mode: $$\frac{\Delta P}{P} = \frac{\overline{F'}}{\overline{F}} \times \frac{g(\overline{CIN})}{g(\overline{CIN'})} - 1$$

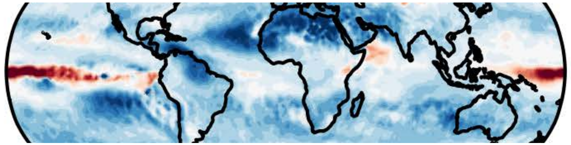
Mean Precipitation Change (%)



Large-scale forcing change (%)



CIN change (%)



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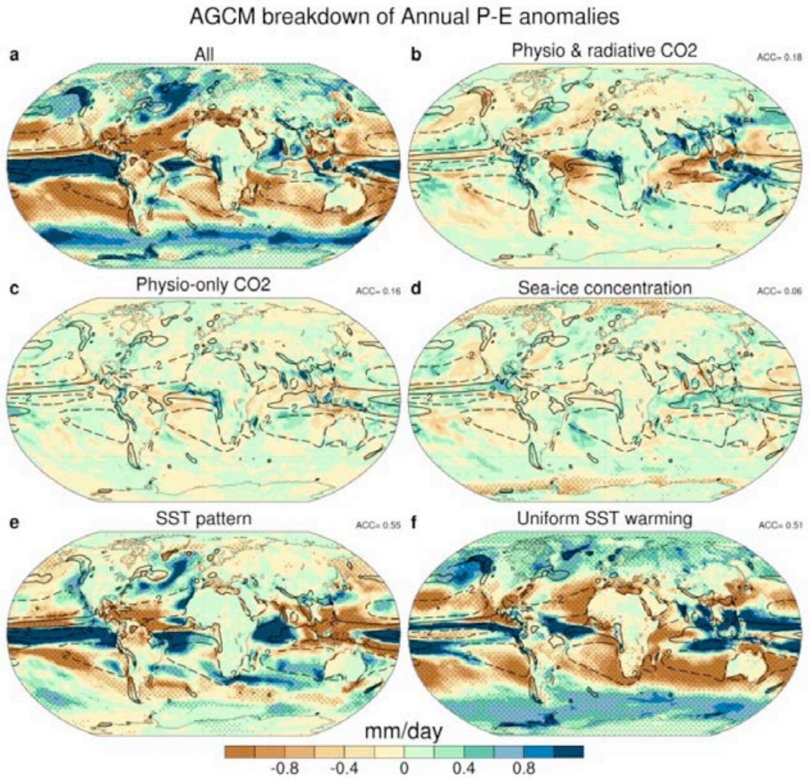
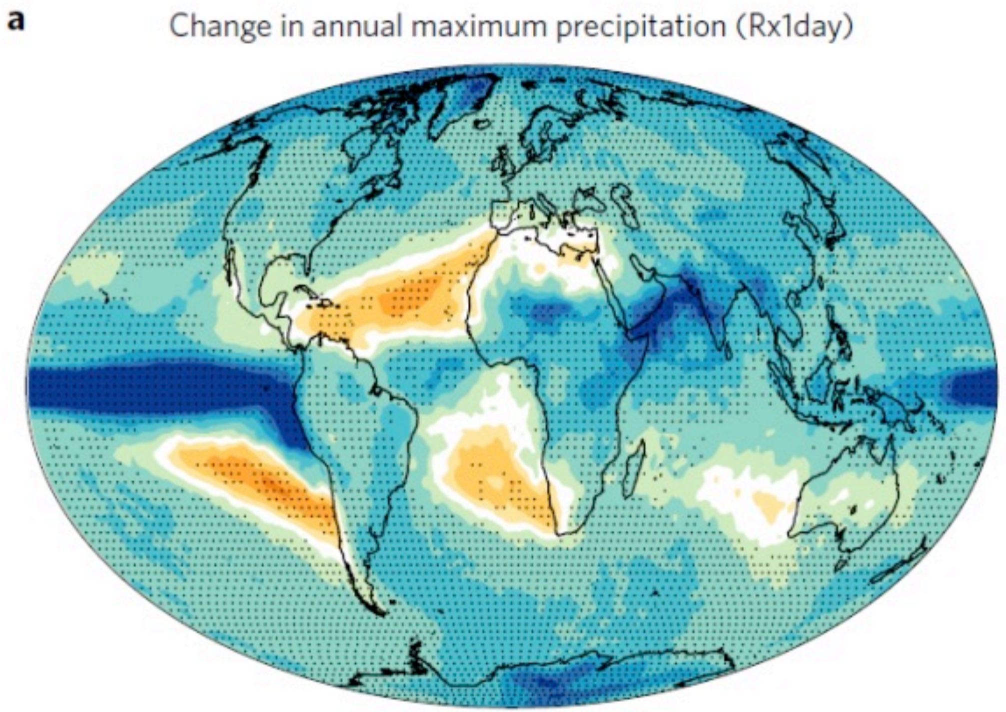
Conclusions

- Increased CIN under warming could lead to decreased frequency of convective events.
- Decreased frequency increases ‘recharge’ time between events, increasing ‘discharge’ precipitation intensity.
- Change in large-scale forcing also affects speed of ‘recharge’. This links long-term mean rainfall change to the daily pdf change, on both global and regional scales.

CFMIP time-slice experiments

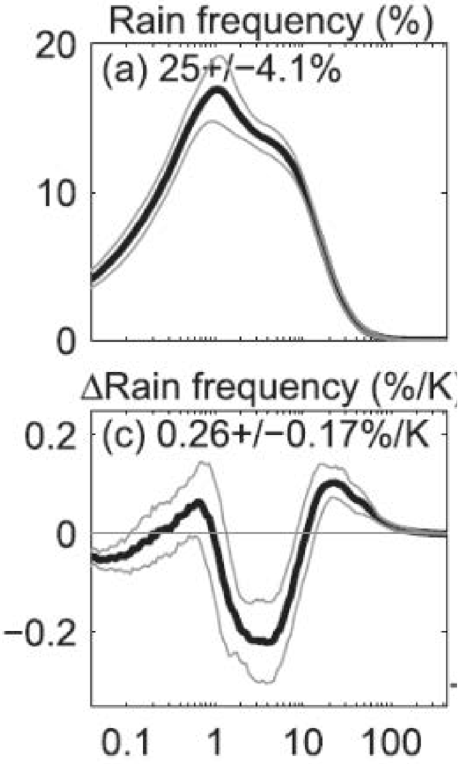


Link to precipitation extremes



Pfahl et al., 2017, Nature Clim. Change

Problem: Light precipitation doesn't decrease



- Because we're using daily data instead of 'event' data?
- Decrease mode manifests as a change from deep to shallow convective rainfall instead of to zero rainfall?
- CIN increase doesn't affect shallow convective rainfall in the same way as deep convection?

Consequence of MSE change

$$(BLMSE_{current} \widehat{-} BLMSE_{prev}) > 0$$

for large values of P in the rainfall pdf, and

$$(BLMSE_{current} \widehat{-} BLMSE_{prev}) < 0$$

for small values of P in the pdf.

$$\frac{\Delta P}{P} = \frac{\langle c_p(T(BLMSE'_{current}) \widehat{-} T(BLMSE'_{prev}))\rangle + \widehat{\tilde{F}'} \times \widehat{\Delta t'}}{\langle c_p(T(BLMSE_{current}) \widehat{-} T(BLMSE_{prev}))\rangle + \widehat{\tilde{F}} \times \widehat{\Delta t}} - 1$$