EXPECT

Cirrus Cloud Thinning

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Sedimentation scheme

- pkg_cld_sediment.F90
- Based on MATCH-MPIC version 2.0 (Lawrence and Crutzen, Tellus, 1998), adapted by Rasch and Boville, 1998 – 2003.
- Stoke's terminal velocity for < 40 microns.
- Cloud liquid and ice particles are allowed to sediment using independent settling velocities.

Sedimentation scheme

- Sedimenting particles evaporate if they fall into the cloud free portion of a layer.
- No bound is applied to prevent supersaturation of the layer. This will be accounted for in the subsequent cloud condensate tendency calculation.
- Maximum overlap is assumed for stratiform clouds, so particles only evaporate if the cloud fraction is larger in the layer above.

Ice sedimentation

- The ice velocity, v_i, is a function only of the effective radius, *Re*, which itself is a function only of *T*.
- For $Re < 40 \times 10^{-6}$ m, the Stokes terminal velocity equation for a falling sphere is used:

$$v_i = \frac{2}{9}\frac{\rho_w g R_e^2}{\eta}$$

- $Re > 40 \times 10^{-6}$ m, the Stokes formula is no longer valid and a linear dependence of v_i on $r = 10^{-6} \times Re$ is used:

$$v_i(r) = v_i(40) + (r - 40)\frac{v_{400} - v_i(40)}{400 - 40}$$

  - $v_{400} = 1.0$ m/s : the assumed velocity of a 400 micron sphere, after Locatelli and Hobbs [1974].

Ice effective radius and terminal velocity

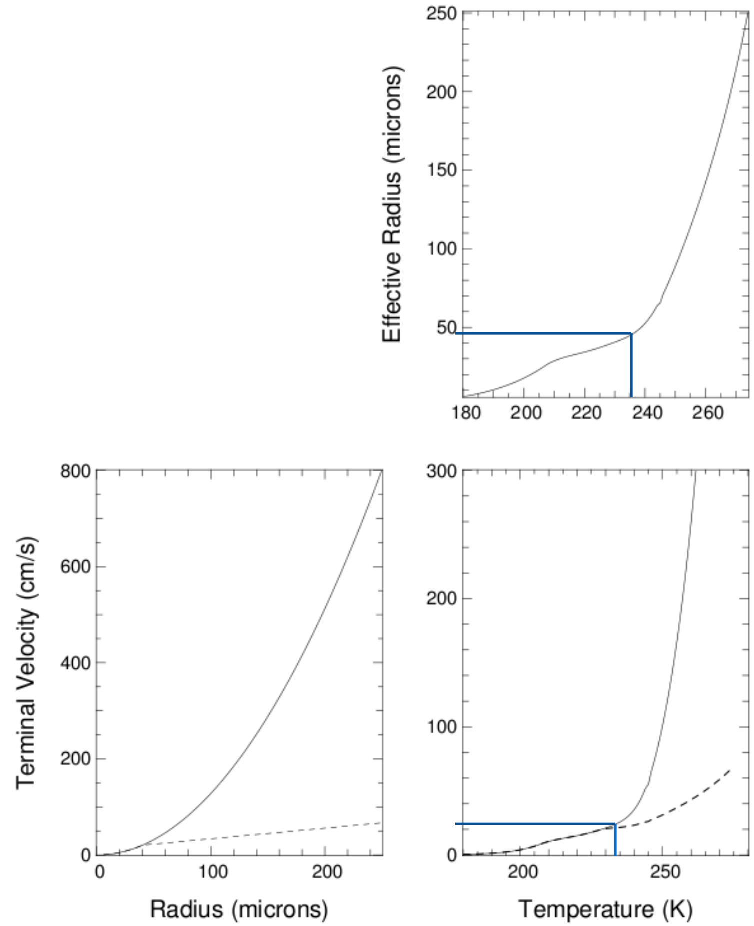
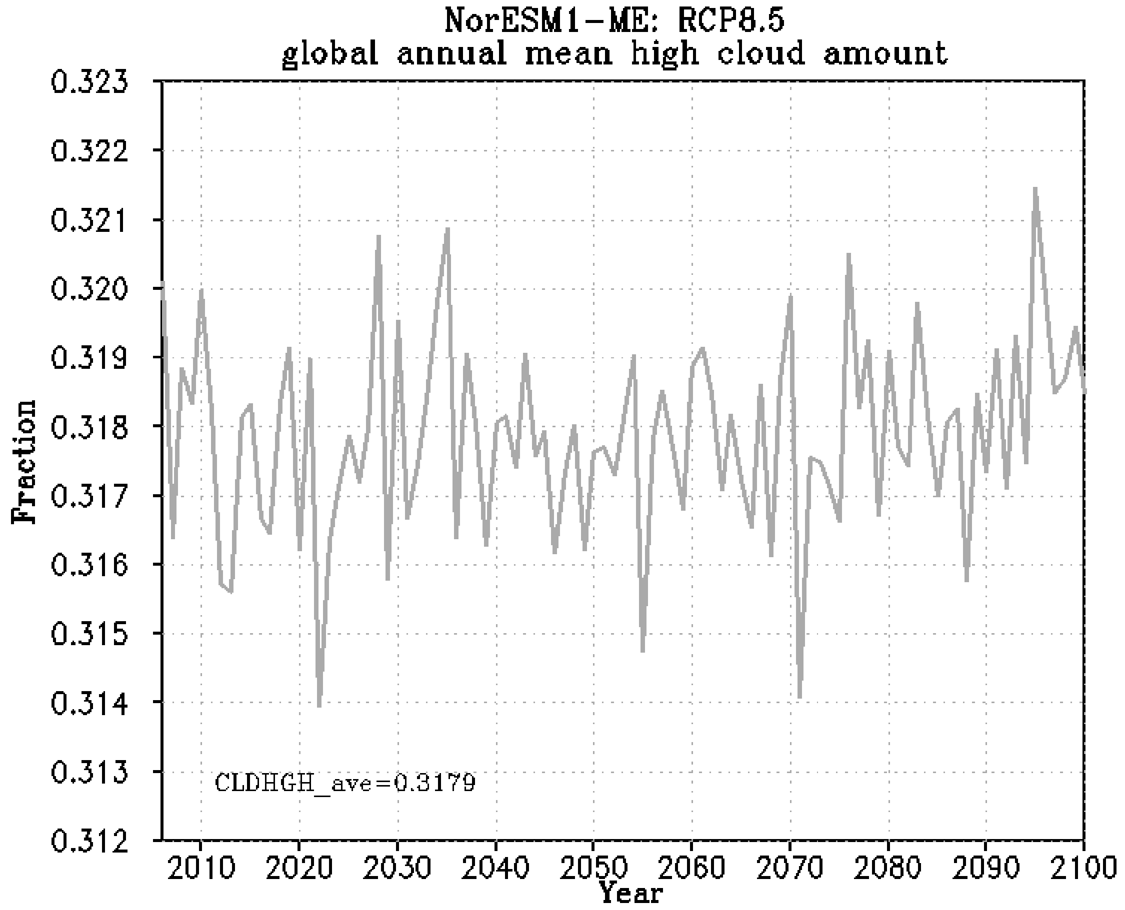
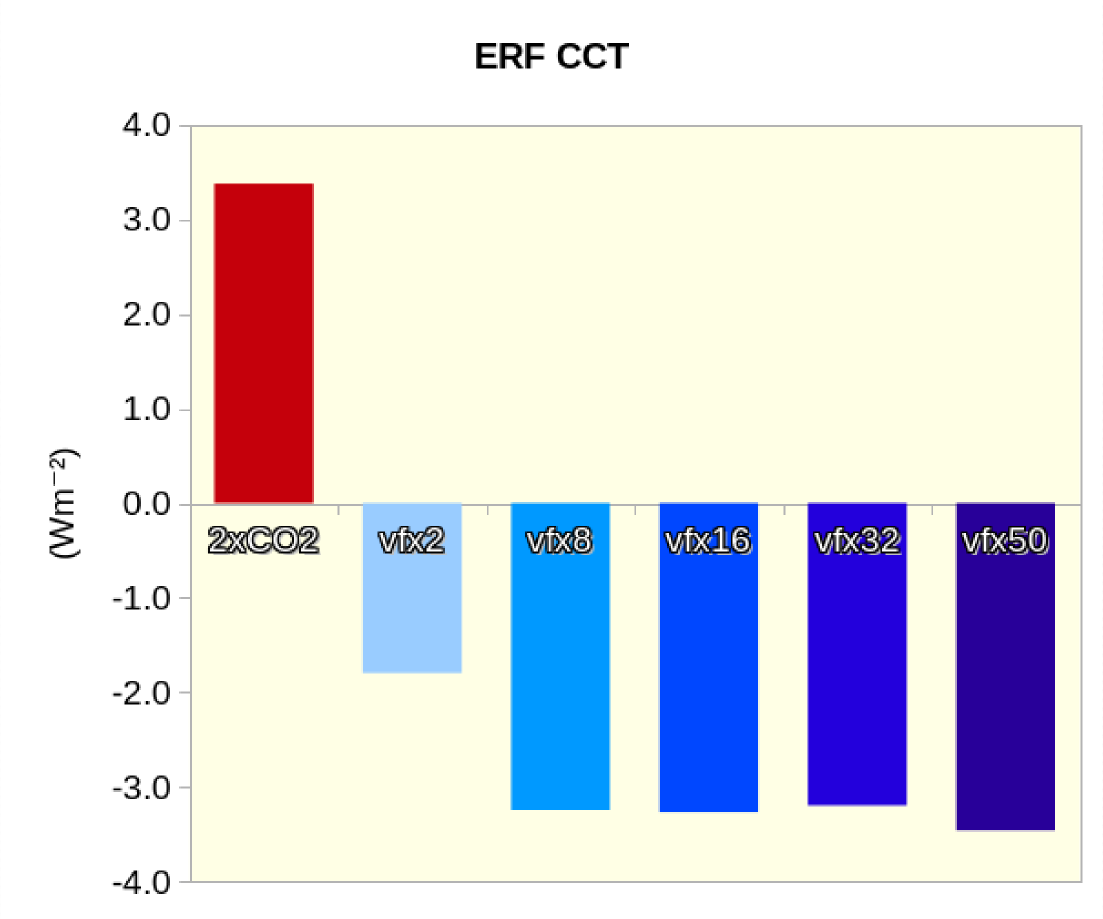


Figure 4.2: Ice effective radius and terminal velocity. Top, ice effective radius versus temperature. Bottom, ice velocity versus radius (left) and temperature (right); the Stokes terminal velocity is solid and the actual velocity is dashed.

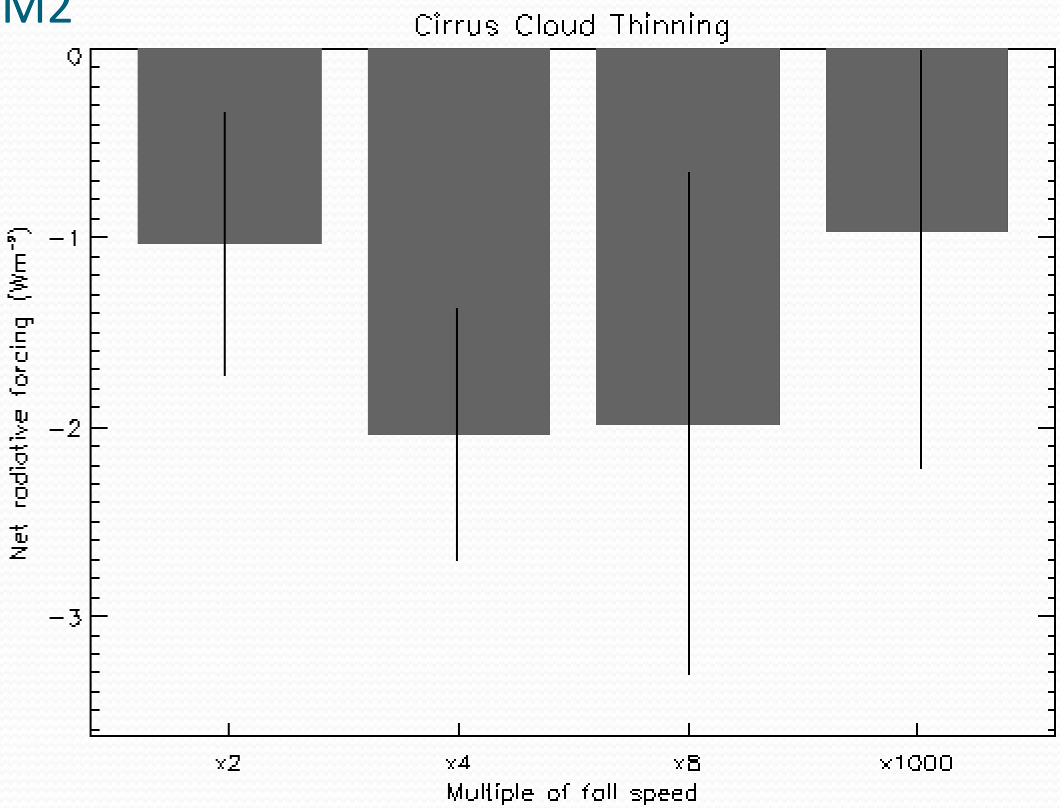
NorESM1-ME RCP8.5 vertically integrated high cloud amount



Fixed SST runs to estimate Effective radiative forcing:



Crook et al., 2015, Figure S3. Net radiative forcing at the top of atmosphere for the cirrus cloud thinning simulations for different rates of increase in ice particle fall speed. The error bars represent ±2 standard error for the estimated forcings. HadGEM2



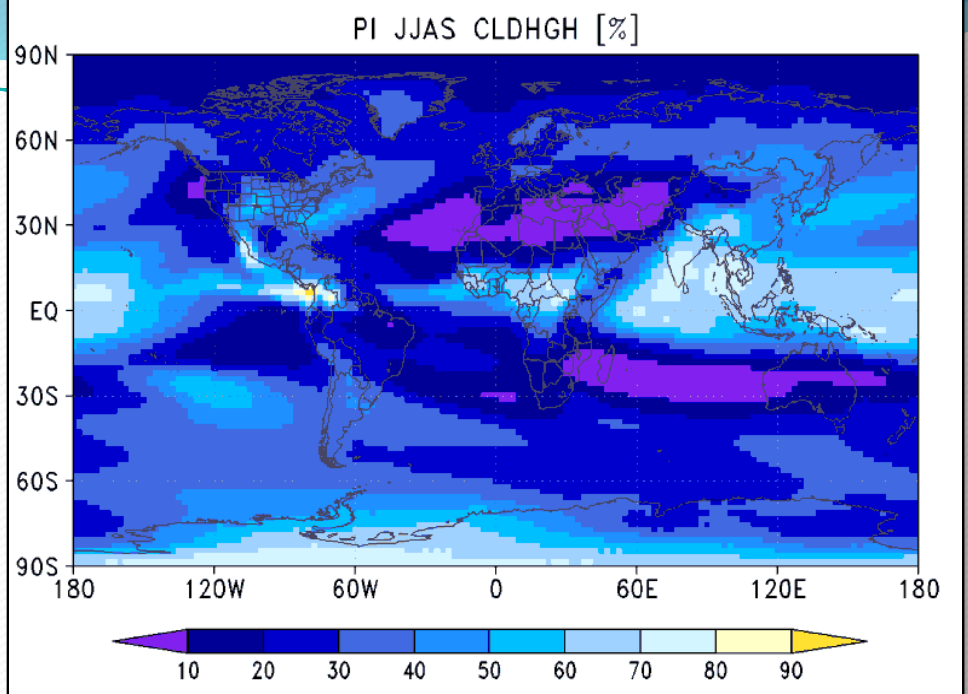
Some model results

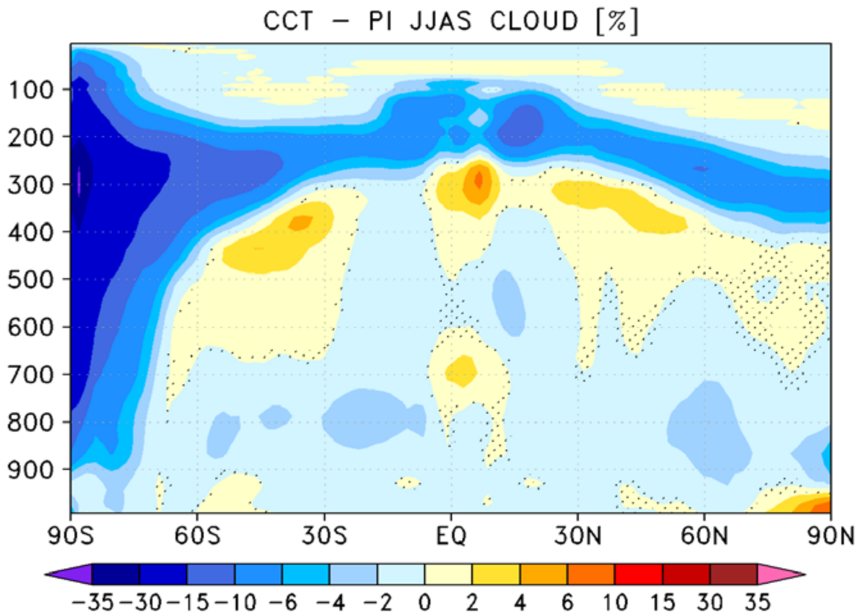
- NorESM1-M, coupled ocean.
- 50 year run.
- Mean over last 40 years shown.

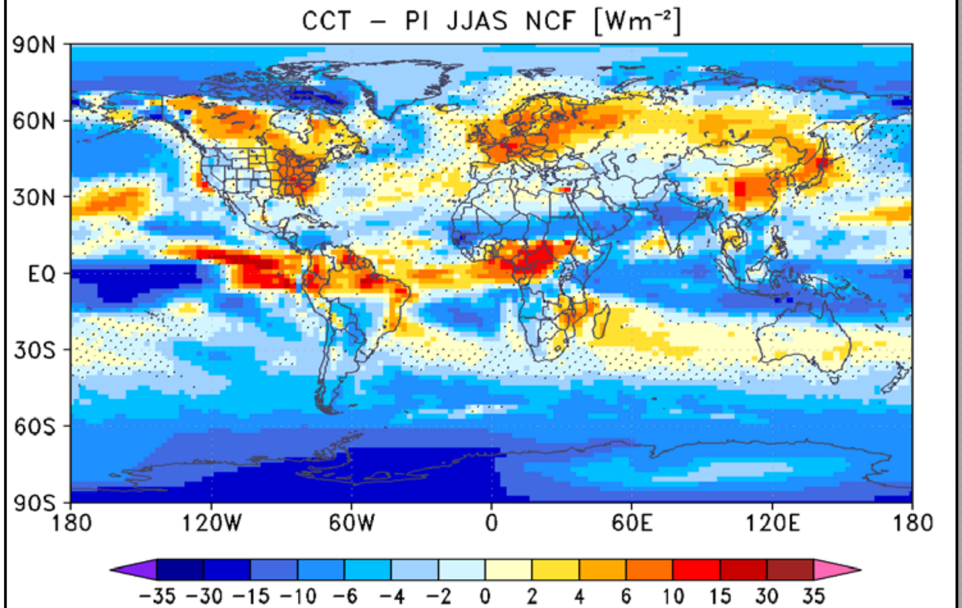
1. PI – pre-industrial control
2. CCT – climate engineering run with cirrus cloud thinning offsetting radiative forcing of 2xCO_2
   - Increase in ice crystal fall speeds for temperatures colder than -38ºC (after Muri *et al.*, 2014).
   - Simultaneously doubling CO_2.
   - Vf x 8 for T .lt. 235K + 2xCO2 => ERF ~ 0 Wm^{-2}.

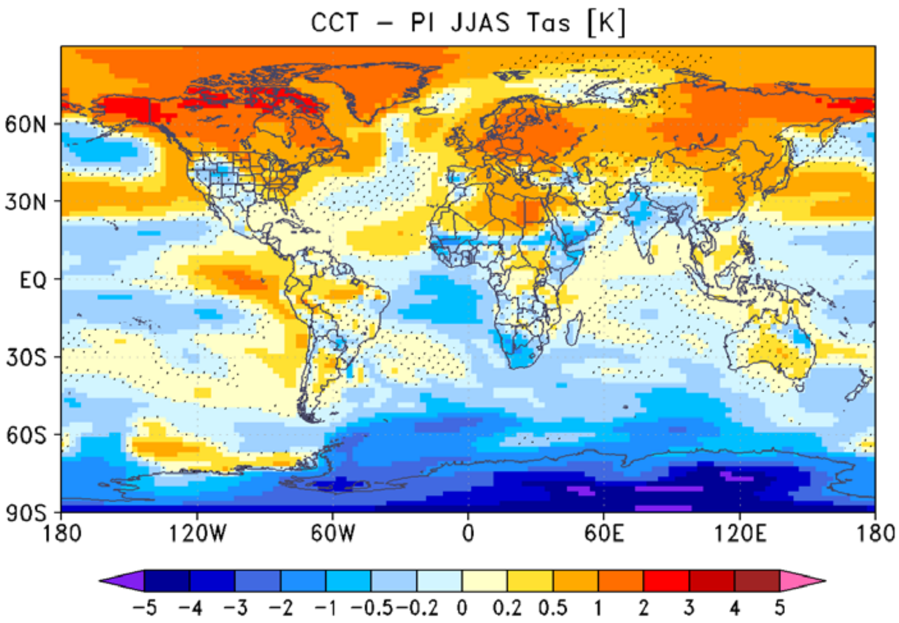
- Highest high cloud coverage in SH.

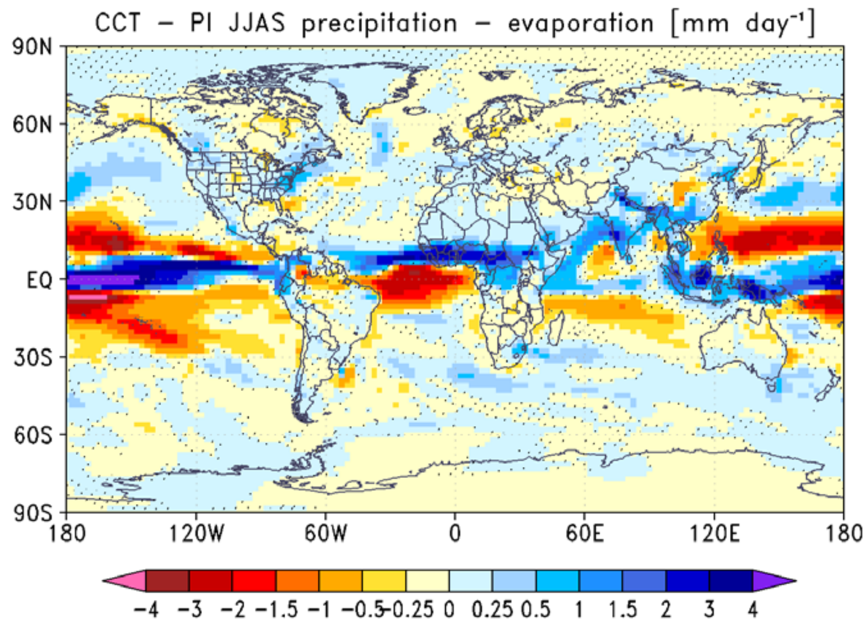
  Net cloud forcing largest south of 45°S.







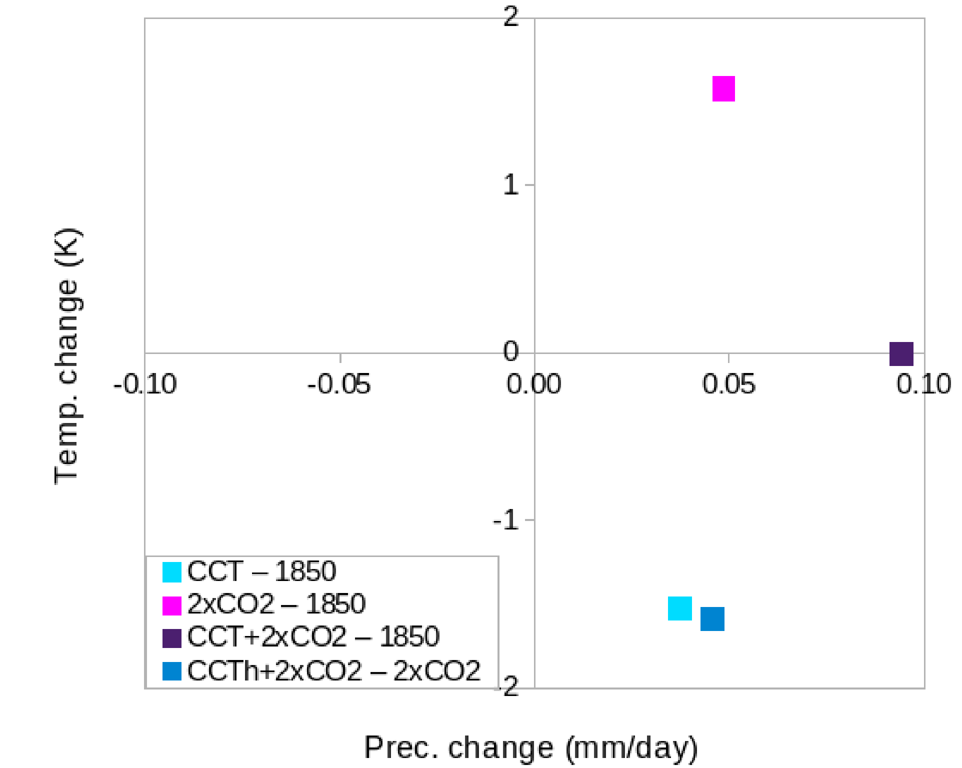


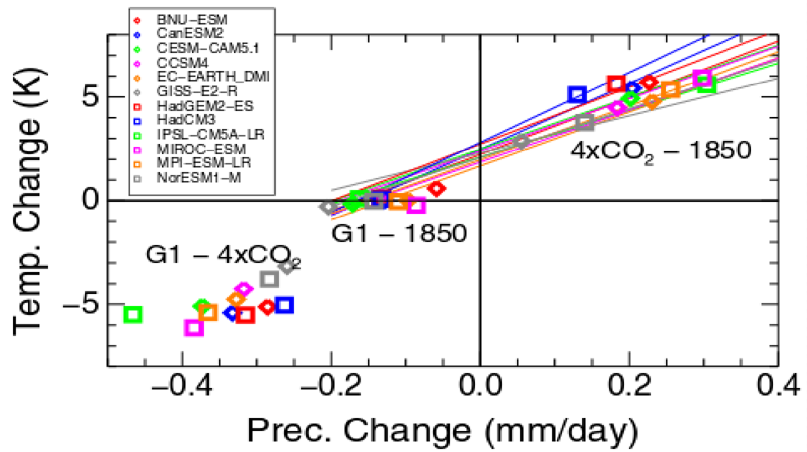


ΔTas CCT-PI = -0.04 K.

- Northwards shift of ITCZ away from cooler hemisphere.

Global annual mean precipitation response and change in temperature.





(Tilmes *et al.*, 2013)

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Summary

- Ice fall speed saturation effect at around 8 x fall speed.
- Max ERF ~ -3.3 Wm^{-2}.
- Largest forcing in SH,
  - Over-cooling, increasing thermal gradient between hemispheres,
  - northwards push of ITCZ.
- See Jón Egill's talk for more results.