Forcing & feedbacks in a transient CO_2 reversibility scenario

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Conceptual framework for steadily increasing forcing (global mean)

e.g. 1% per year to 4×CO_2

$N = F - \alpha \cdot \Delta T$ F, *forcing; α, feedback*

$F = \rho \cdot \Delta T$ *ρ, climate resistance*

$N = \kappa \cdot \Delta T$ κ, *ocean heat uptake efficiency*

$\rho = \kappa + \alpha$

- *Does this still apply when the CO_2 change is reversed?*
- *Does it apply at the regional scale?*

Coupled simulations with HadGEM2-ES
1% to 4×CO_2 then -1% to 1× CO_2

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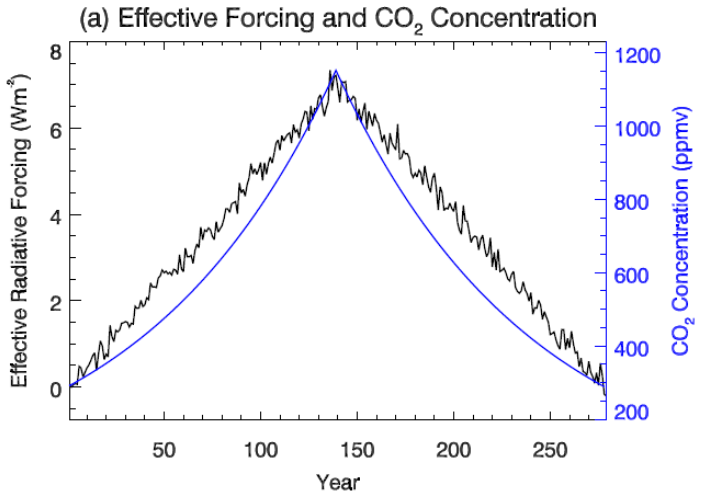
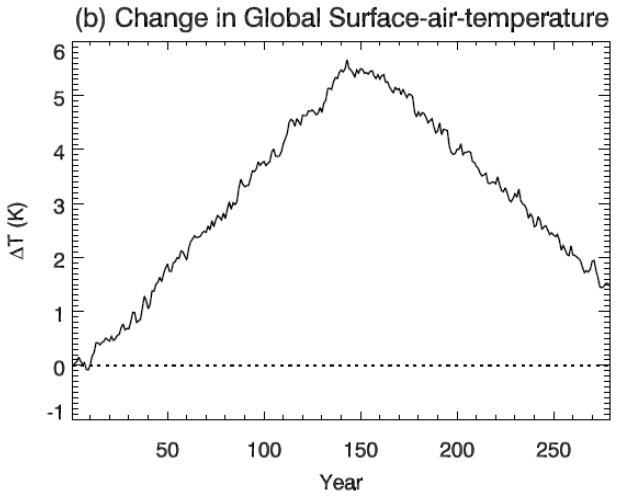
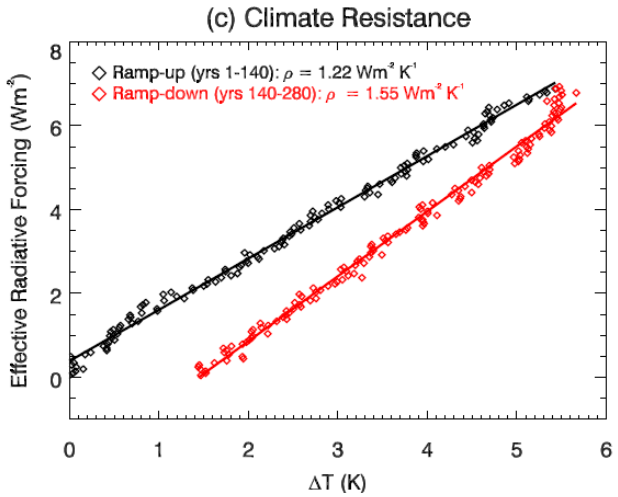
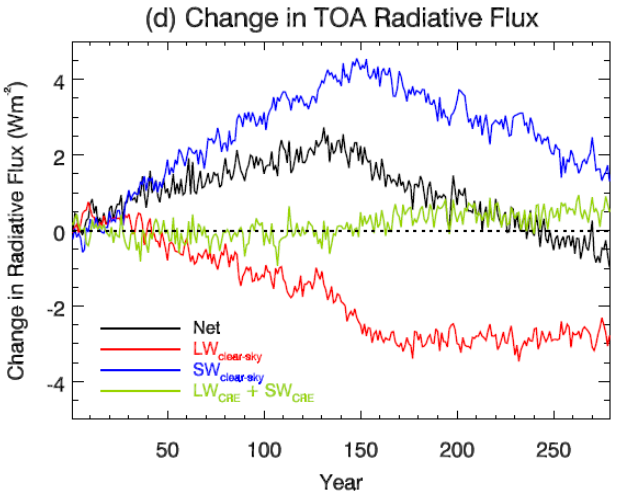




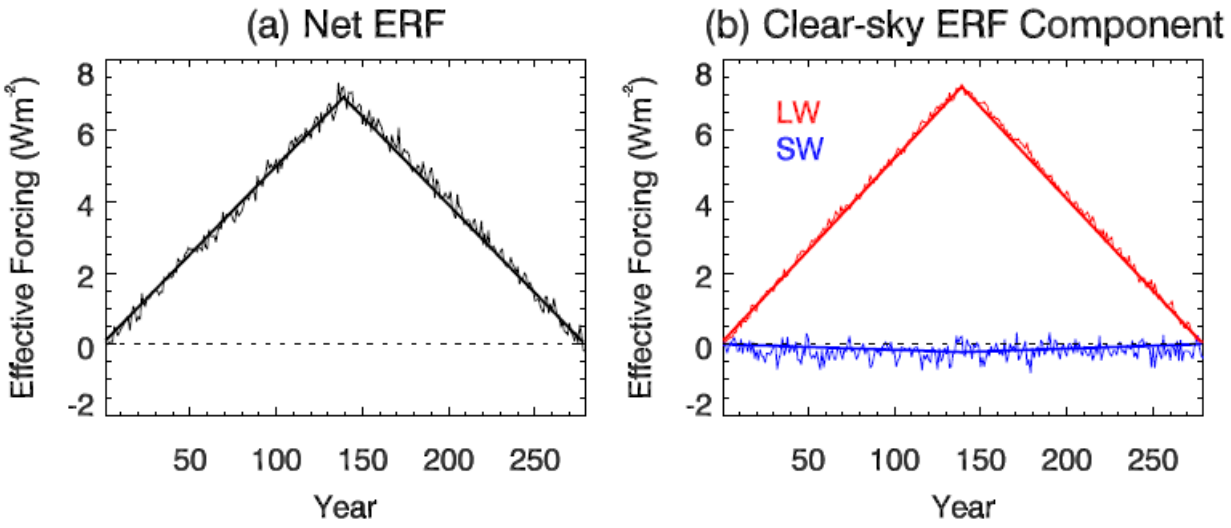
Ramp up:
ρ = 1.22

Ramp down:
ρ = 1.55





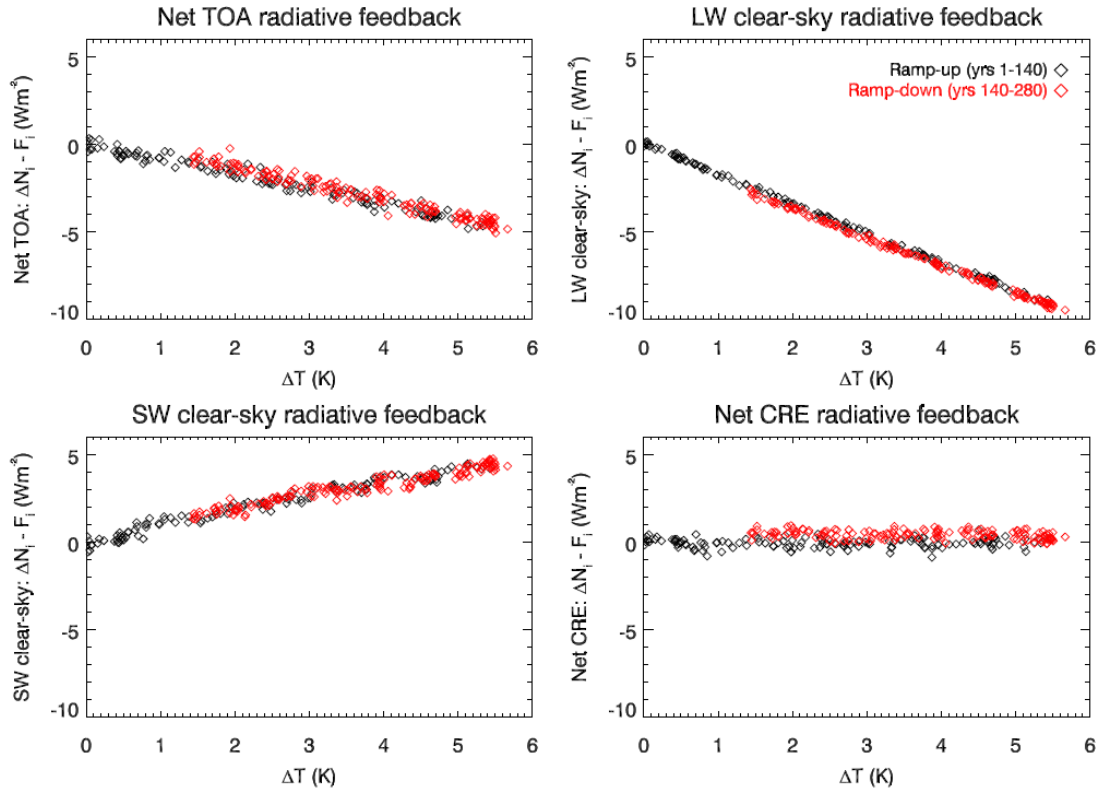
Atmosphere-only simulations with fixed SSTs (Hansen experiments): Effective forcing & rapid adjustments



$$\Delta X_{F/B} = \Delta X - \Delta X_{ADJ}$$

Ramp up : $\Delta X_{ADJ} = \Delta X(\text{Hansen}) \bullet (t/140)$

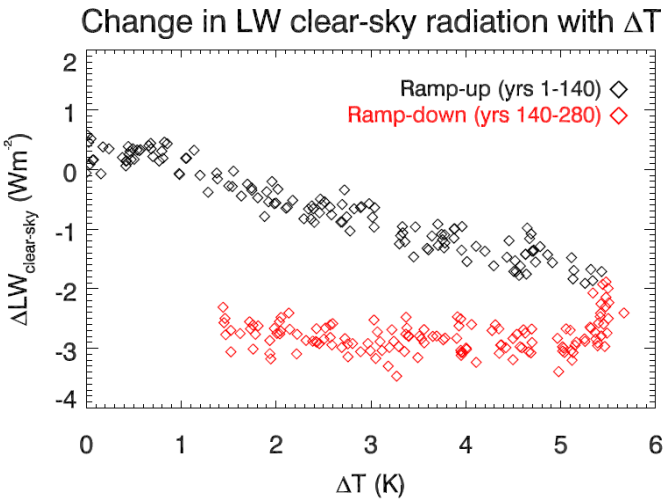
Separates adjustment (ADJ) and temperature mediated response (F/B) in a transient scenario



Estimate the feedbacks from regressions of $\Delta X_{F/B}$ against ΔT

Ramp up

Ramp down



Apparent ‘hysteresis’ is removed when forcing is correctly accounted for

High- and low-level cloud adjustments: Radiative & plant physiological forcing

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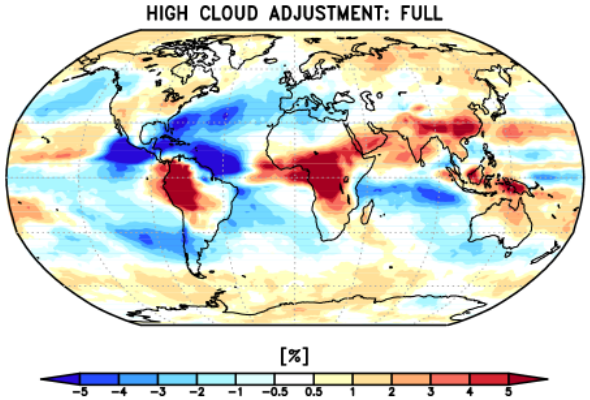
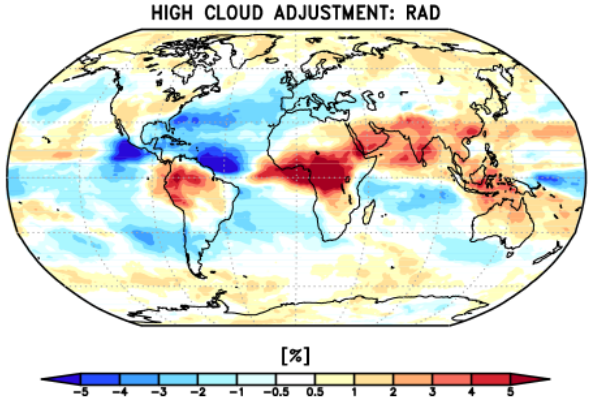
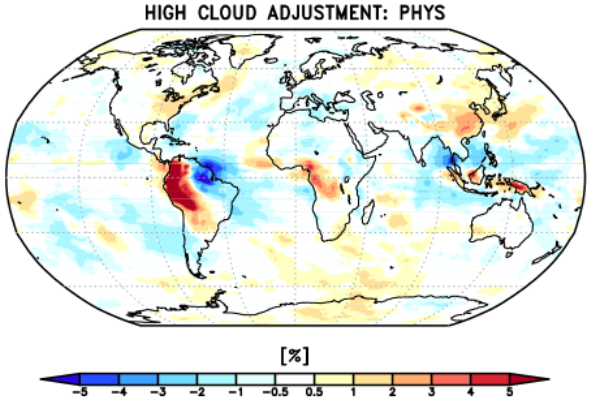
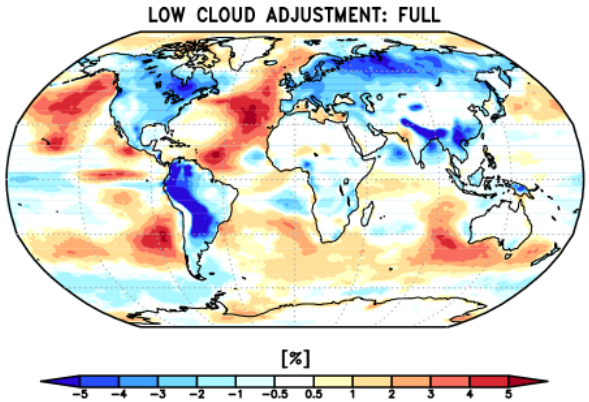
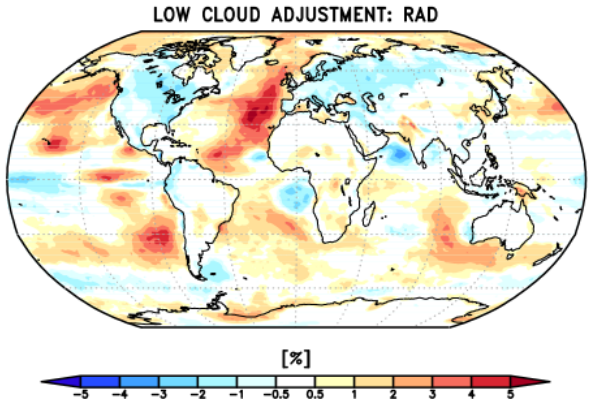
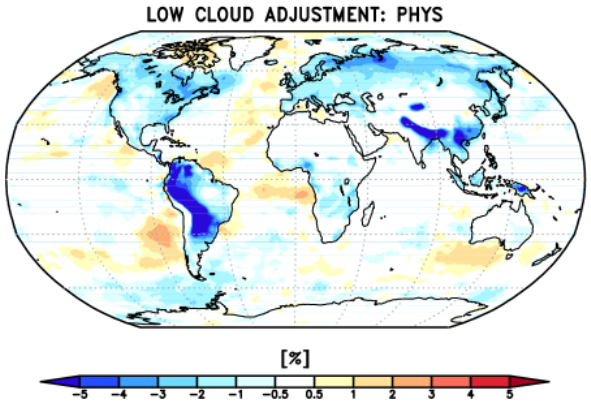








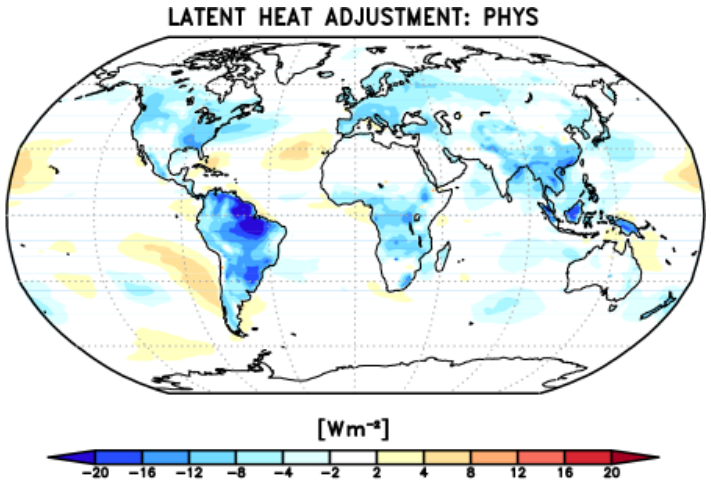


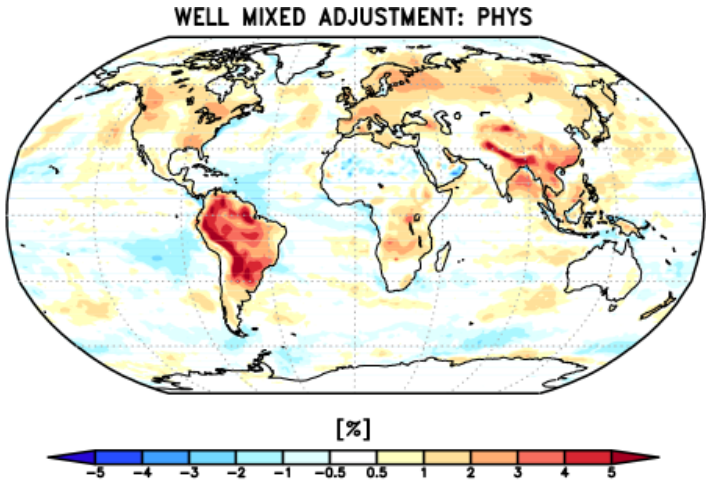


“FULL” “RAD” “PHYS”

Adjustments to latent & sensible heat and boundary layer types

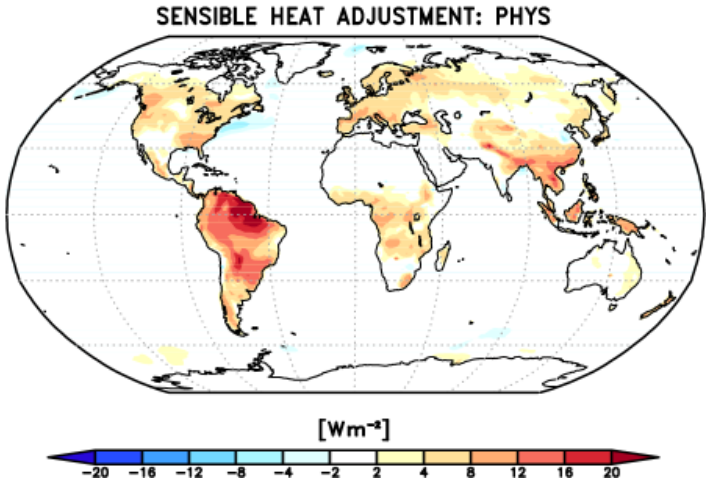
LH

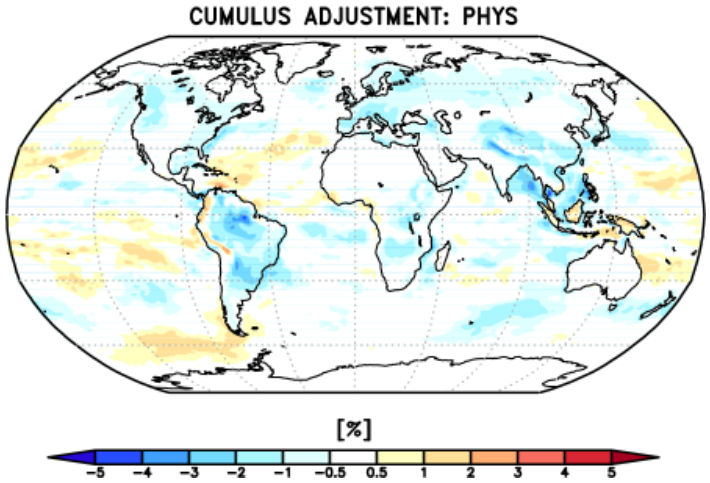




Well mixed

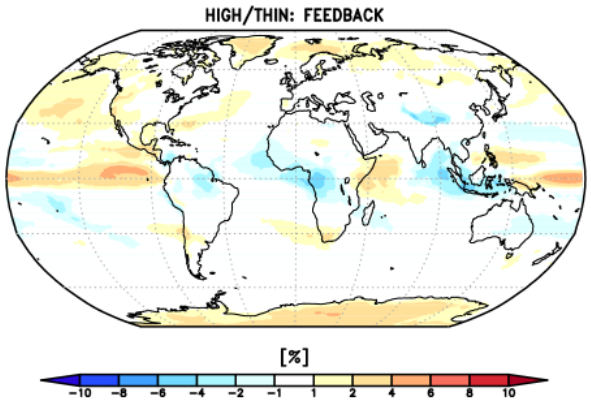
SH

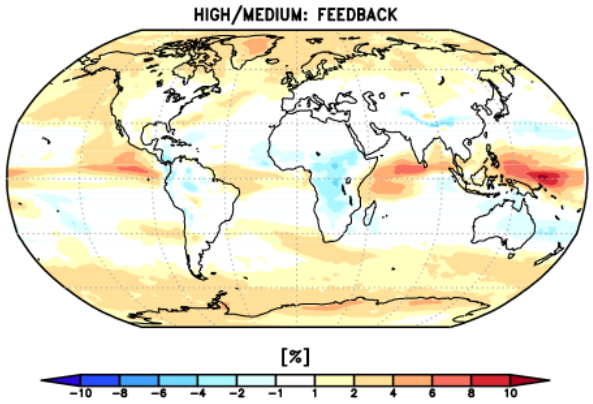


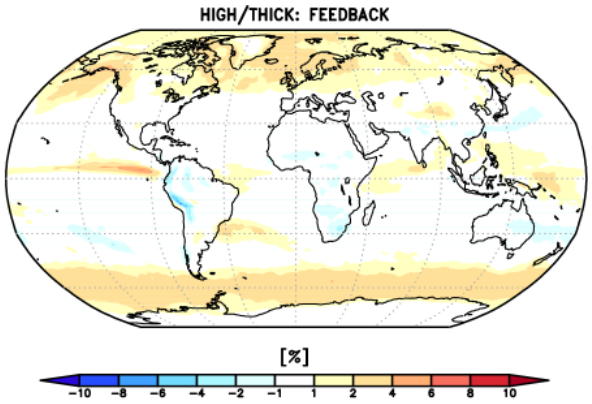


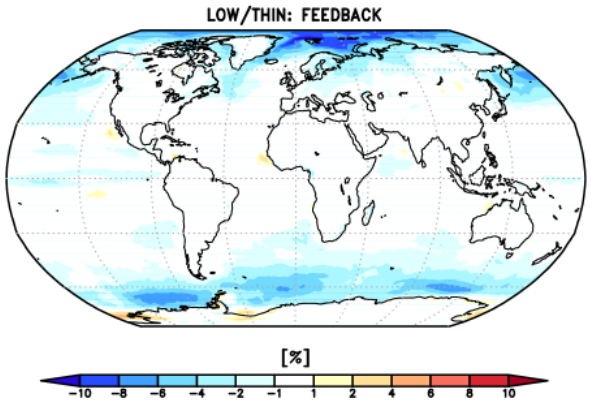
Cumulus

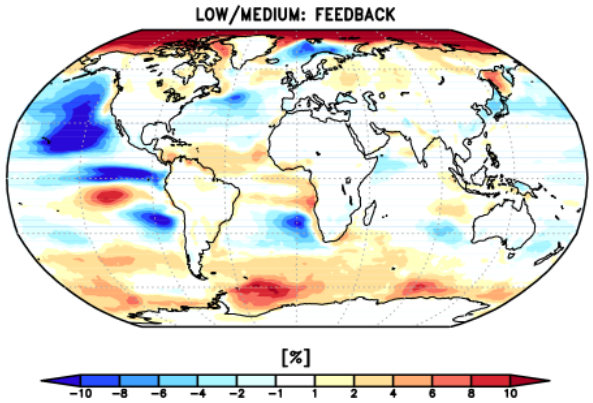
High- and low-level cloud feedbacks: $\Delta X_{F/B} = \Delta X - \Delta X_{ADJ}$ (Years 125-140)

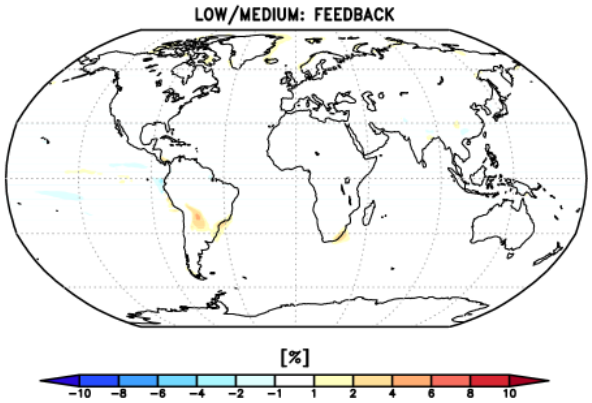












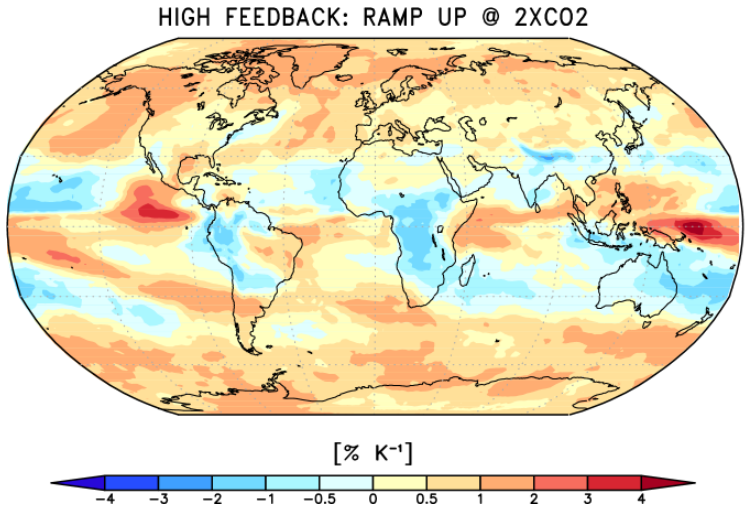
“Thin” “Medium” “Thick”

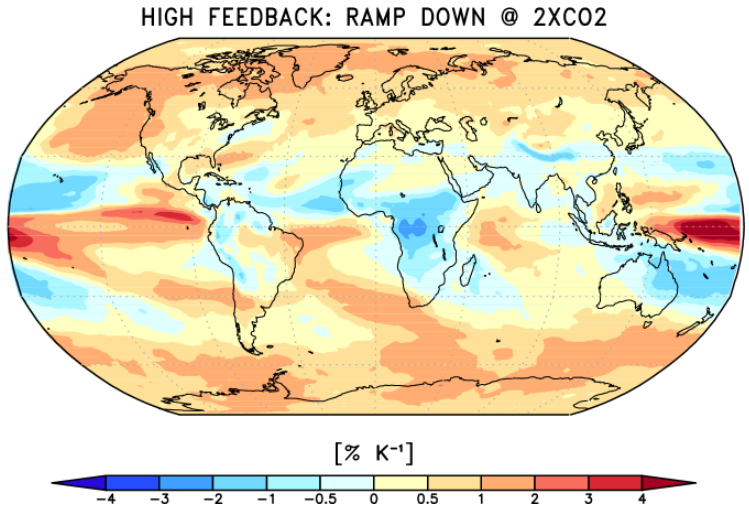
Forcing-feedback framework applied locally: $(\Delta X - \Delta X_{ADJ})/\langle \Delta Ts \rangle$

Ramp up @ 2×CO_2

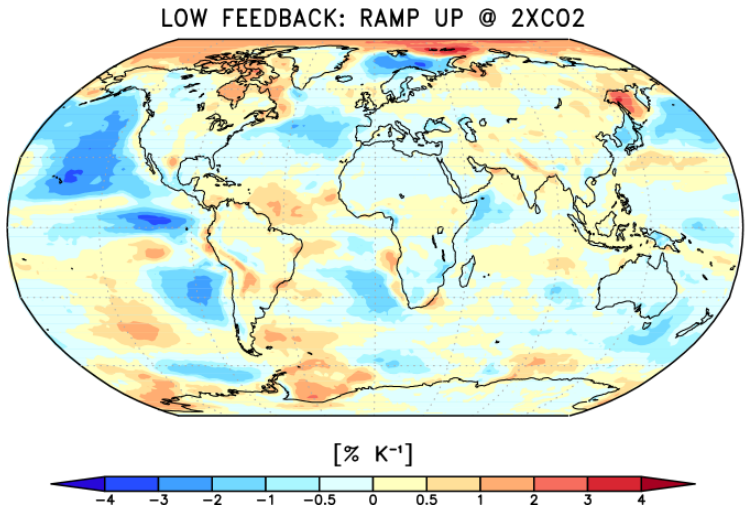
Ramp down @ 2×CO_2

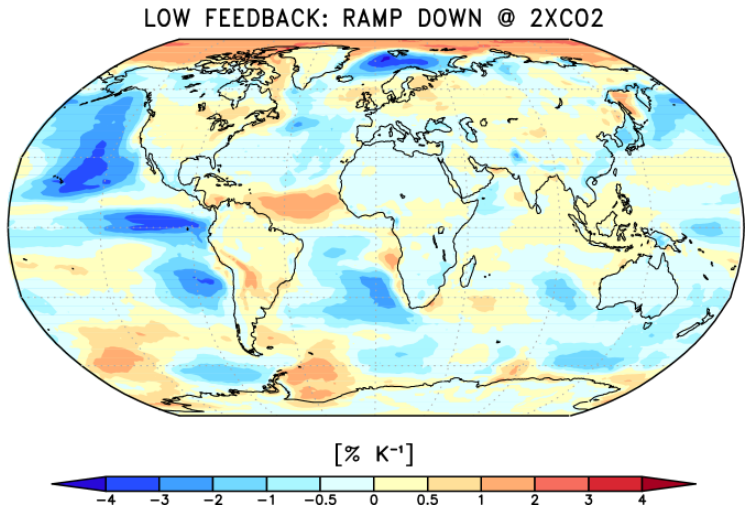
High





Low





Evolution of surface warming during ramp down: dT(local) / dT(global)

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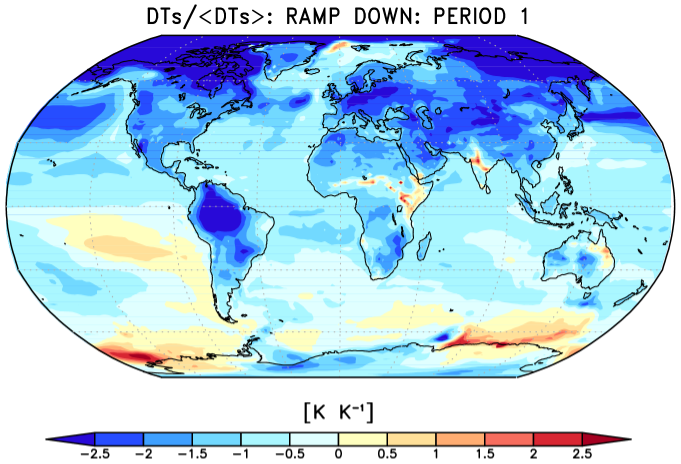
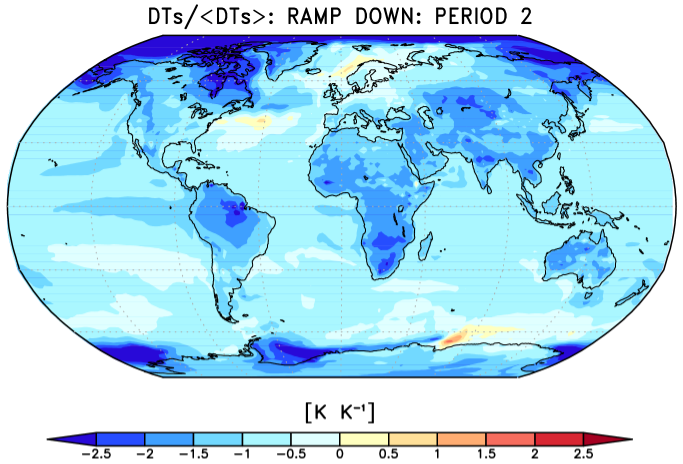
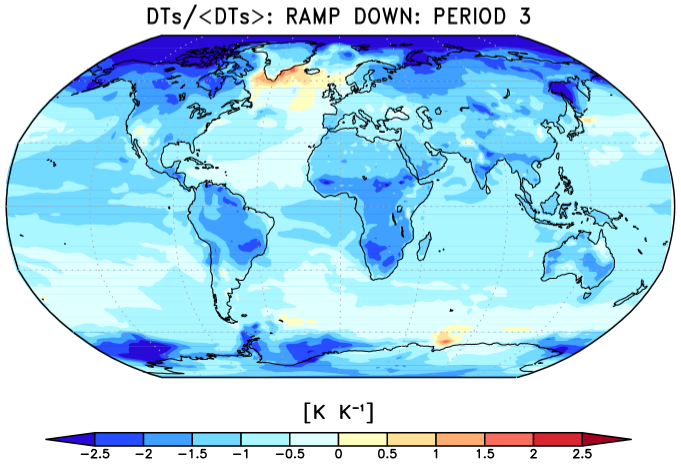
Period 1

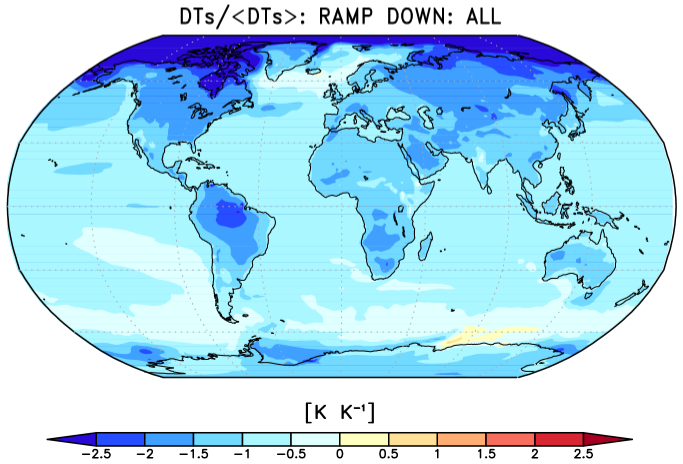




Period 2

Period 3





ALL

Clear-sky absorbed solar over Southern Hemisphere: dSW(local) / dT(global)

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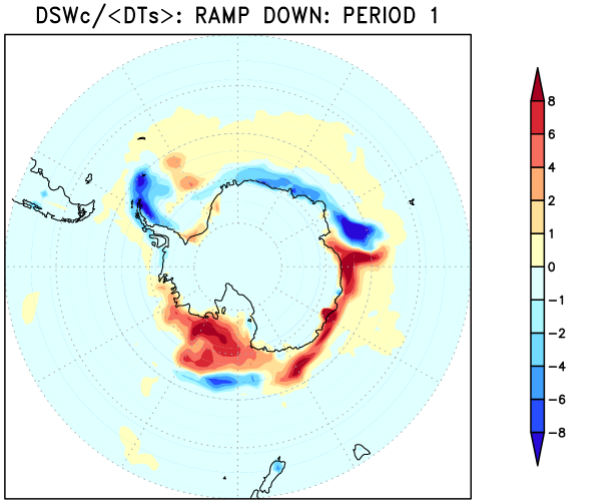
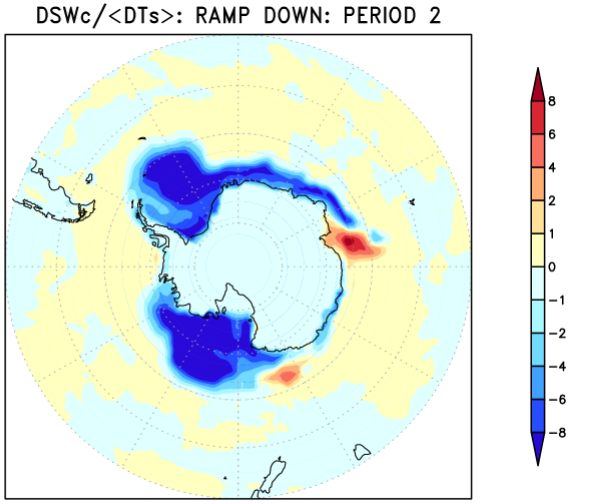
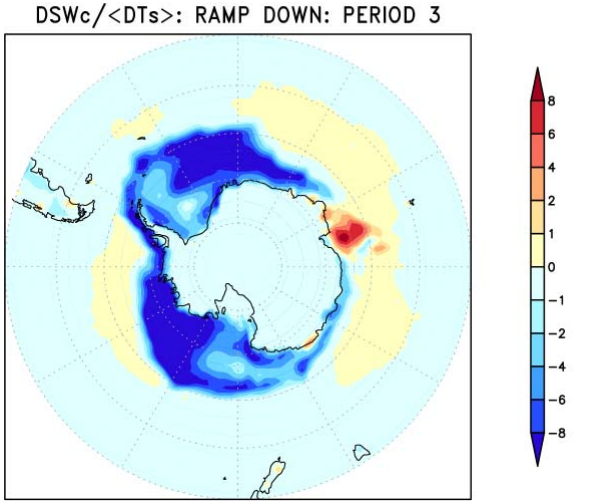
Period 1

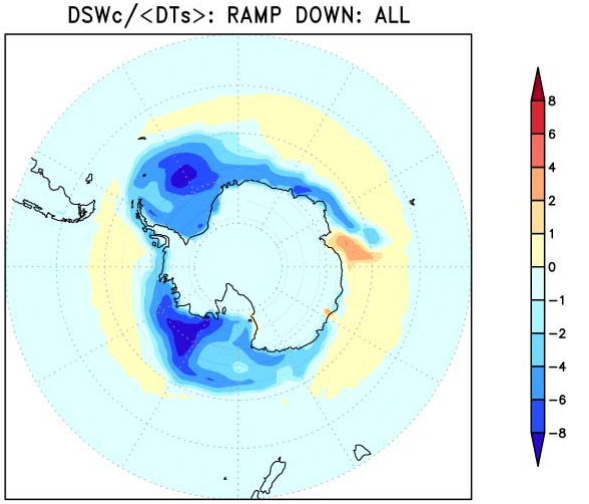




Period 2

Period 3





ALL

Summary

- A general method to separate forcing/adjustments and feedbacks in transient experiments
- Feedbacks entirely reversible under this idealized mitigation scenario – no evidence for “hysteresis”
- Conceptual framework applies to regional feedbacks – at least to 1st order
- “Unusual” behaviour can be considered as deviations from this framework
- But…care needed, especially with a non-constant warming pattern