Diagnosing Cloud Feedbacks in CMIP5 Models

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Background

REVIEW ARTICLE

How Well Do We Understand and Evaluate Climate Change Feedback Processes?

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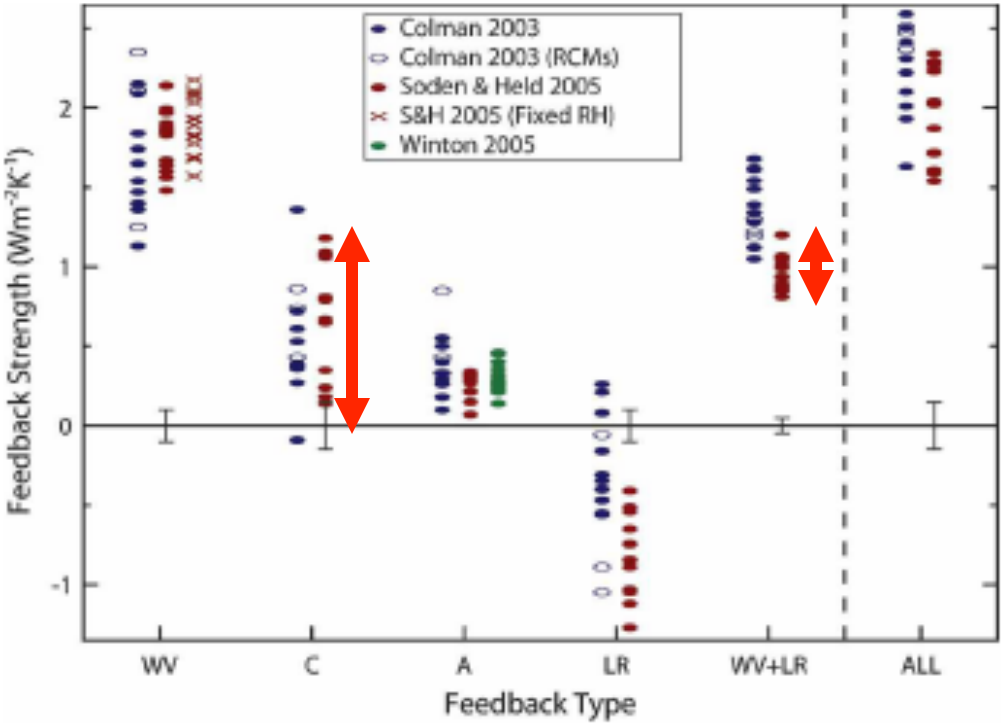
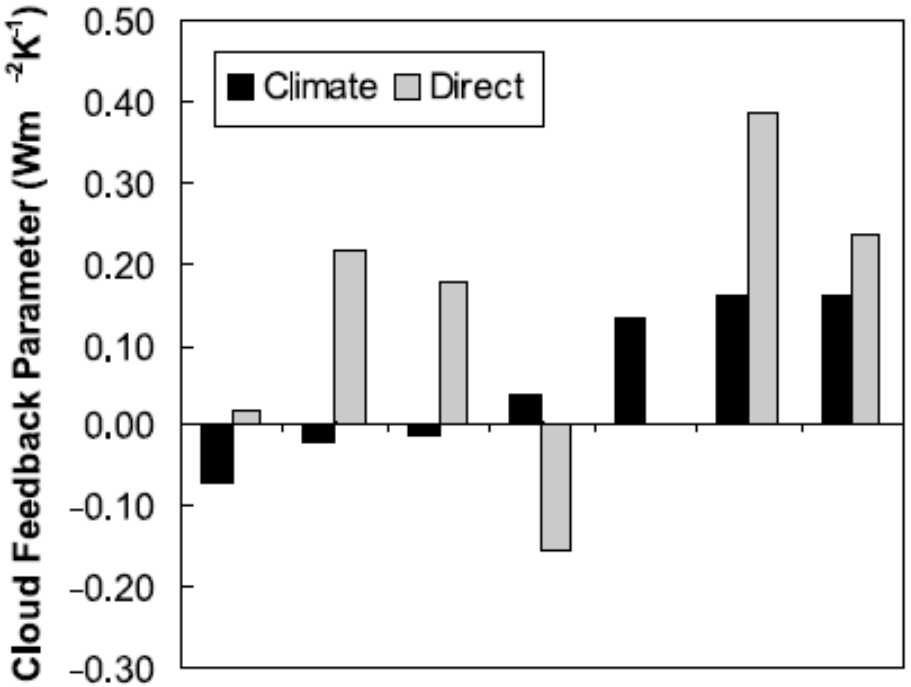


Cloud feedback is dominant source of uncertainty in models

Background

CO_2 forcing induces semi-direct effects with consequences for climate feedback interpretations

Timothy Andrews[1] and Piers M. Forster[1]

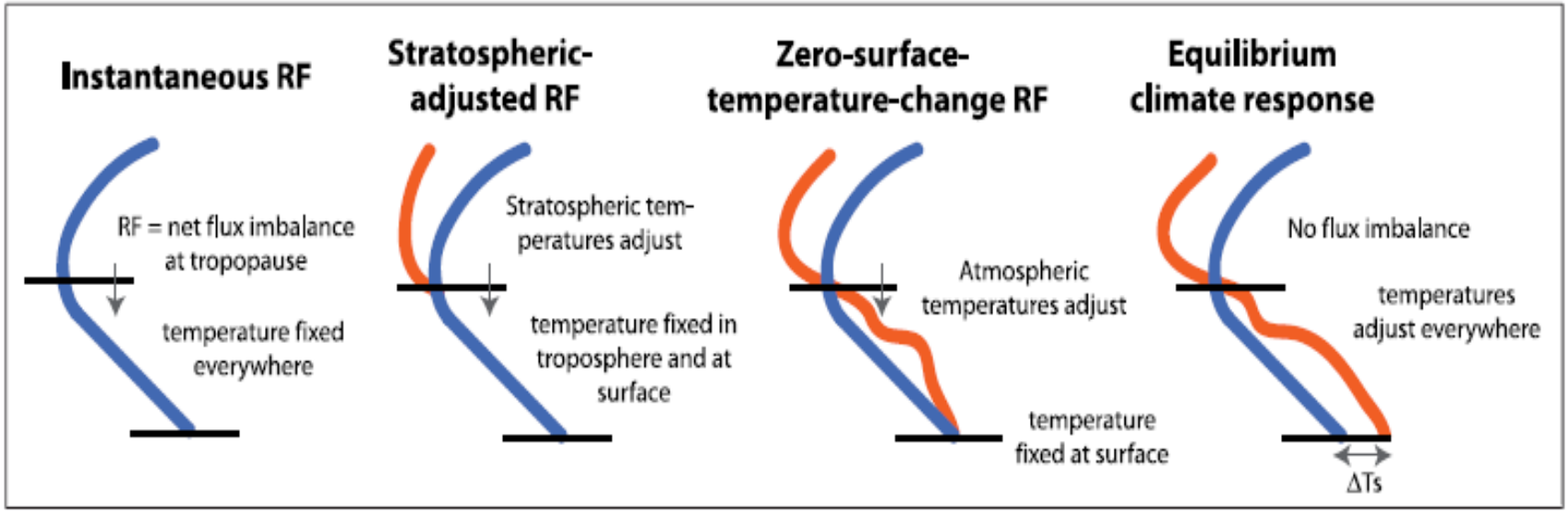


Most of cloud change is a "direct" response to CO2 forcing, not "climate" response to surface warming

Background

Changes in Atmospheric Constituents and in Radiative Forcing

Coordinating Lead Authors:
Piers Forster (UK), Venkatachalam Ramaswamy (USA)



Climate Feedbacks: Kernel Method

$$\lambda = \frac{\delta R}{\delta T}\frac{dT}{dT_s} + \frac{\delta R}{\delta W}\frac{dW}{dT_s} + \frac{\delta R}{\delta C}\frac{dC}{dT_s} + \frac{\delta R}{\delta \alpha}\frac{d\alpha}{dT_s}$$

Temperature Feedback | Water Vapor Feedback | Cloud Feedback | Sfc Albedo FeedbacK

Climate Feedback = $\delta R/\delta X$ X dX/dT_s

$\delta R/\delta X$: Radiative Transfer

dX/dT_s: Climate Response

Method 1: Finite Differencing

dX/dT_s

$dX=X_{2}$ `2000-2020

FALSE?

Assume all change is feedback

Climate Feedbacks: Kernel Method

$$\lambda = \frac{\delta R}{\delta T}\frac{dT}{dT_s} + \frac{\delta R}{\delta W}\frac{dW}{dT_s} + \frac{\delta R}{\delta C}\frac{dC}{dT_s} + \frac{\delta R}{\delta \alpha}\frac{d\alpha}{dT_s}$$

Temperature Feedback | Water Vapor Feedback | Cloud Feedback | Sfc Albedo FeedbacK

$dX/d\mathbf{T_s}$

Climate Response

Method 1: Finite Differencing

dX/dT_s

$dX=X_{2080\text{-}2100}-X_{2000\text{-}2020}$

Assume all change is feedback

Method 2: Linear Regression

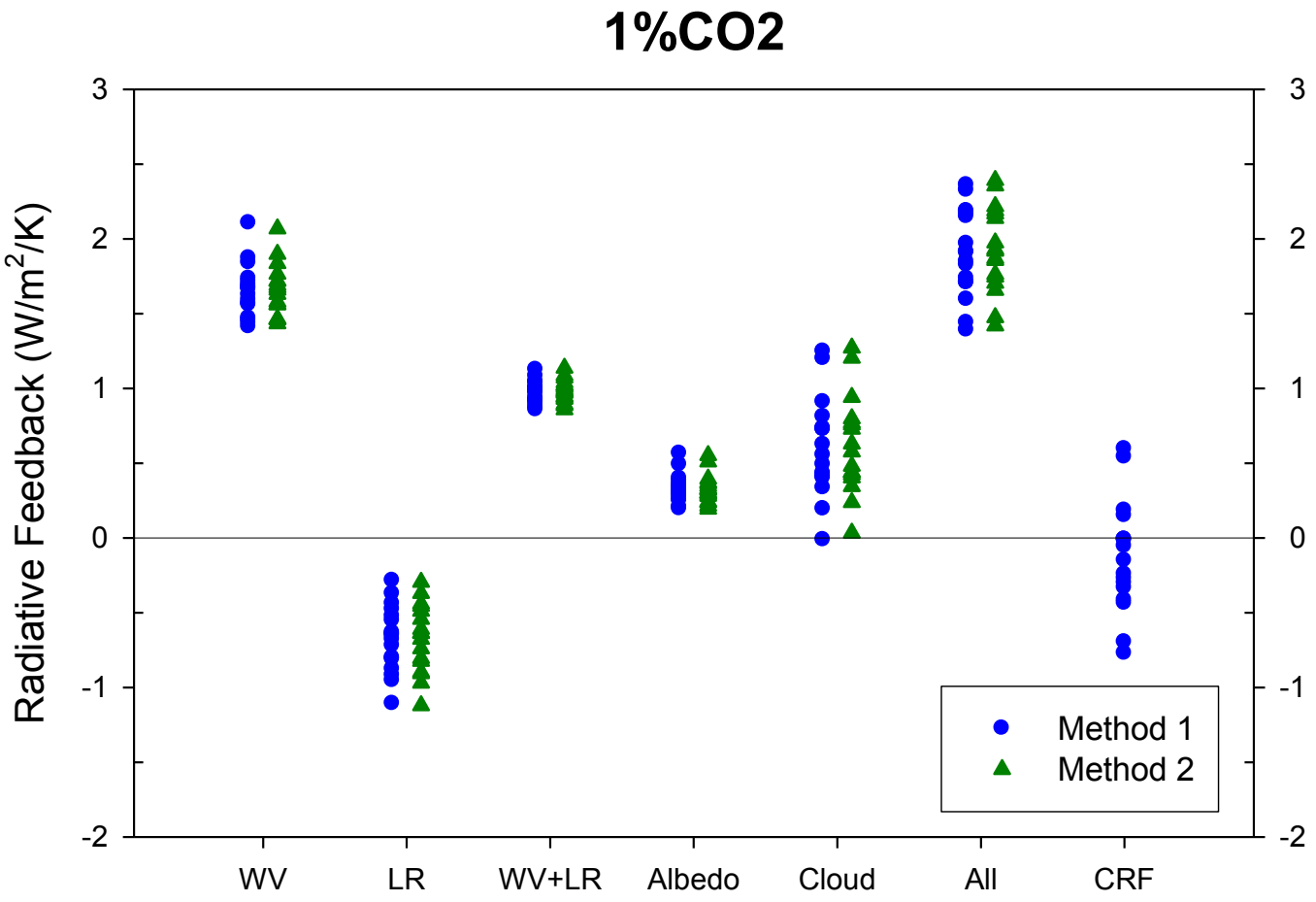
dX/dT_s

$X=a + b\ \mathbf{Ts}$

$dX/d\mathbf{Ts} = b$

Only use component correlated to dTs

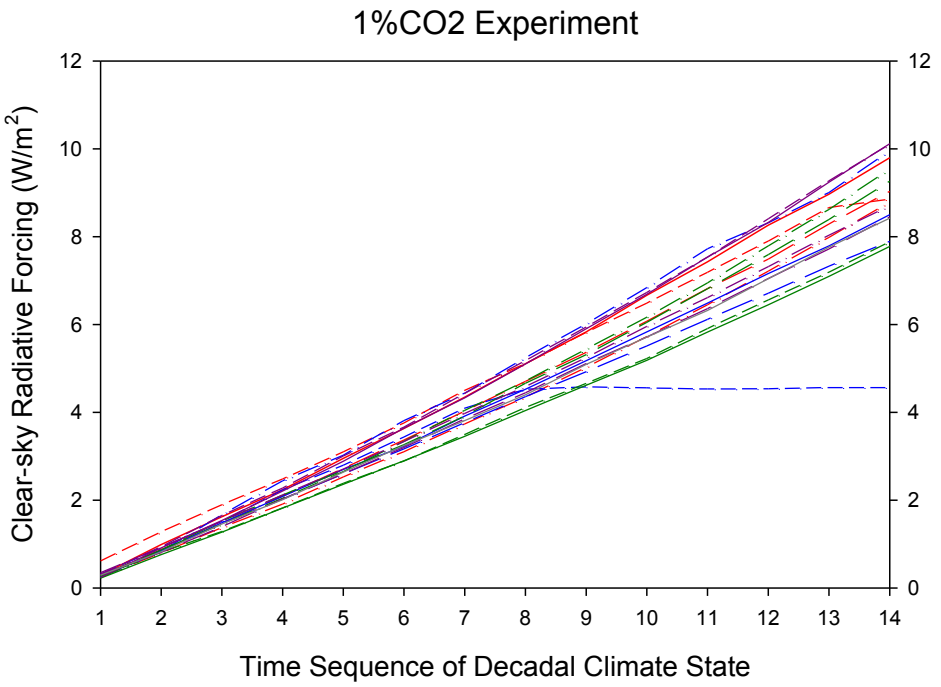
Climate Feedbacks in IPCC AR5 Models



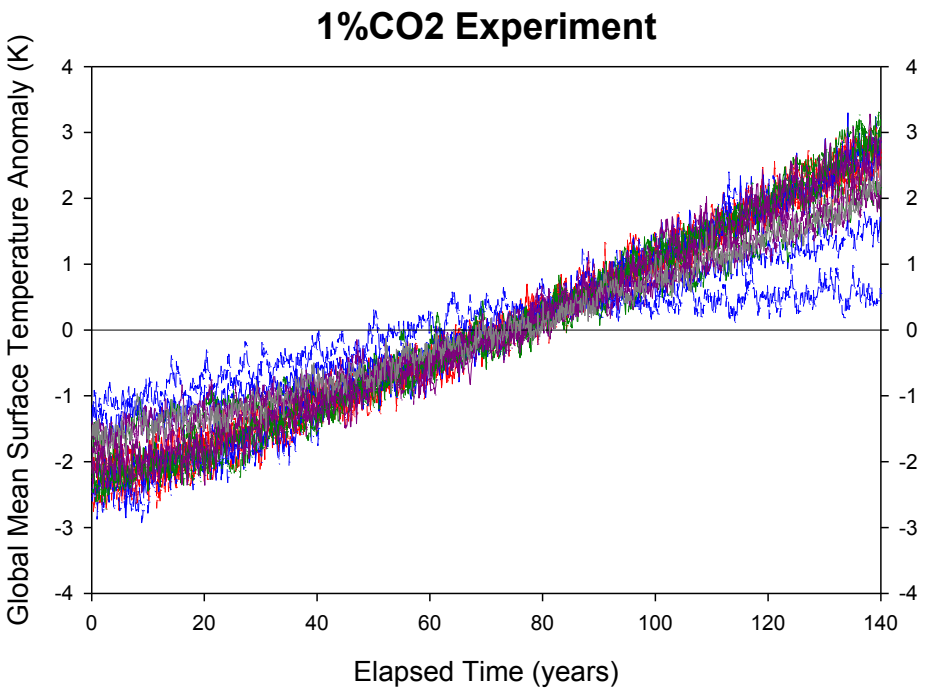
- **Very similar to AR4 :**
  - **Water vapor +lapse-rate uncertainty is small.**
  - **Cloud feedback is uncertain, but not negative.**
- **Method 1 and Method 2 are nearly identical.**

Climate Forcing in IPCC AR5 Models

Radiative Forcing

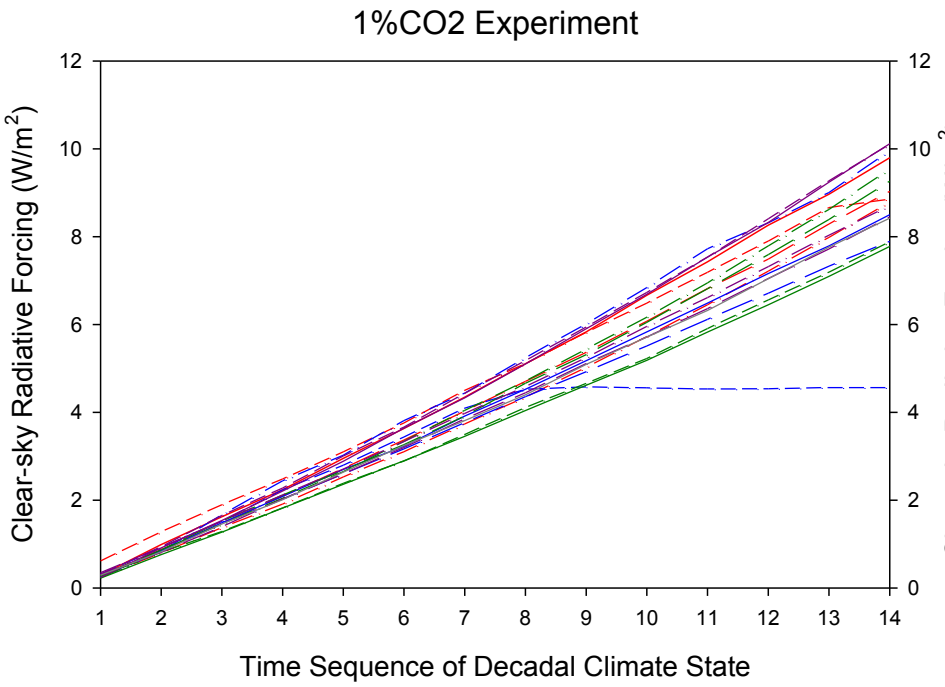


Global Mean dT_s

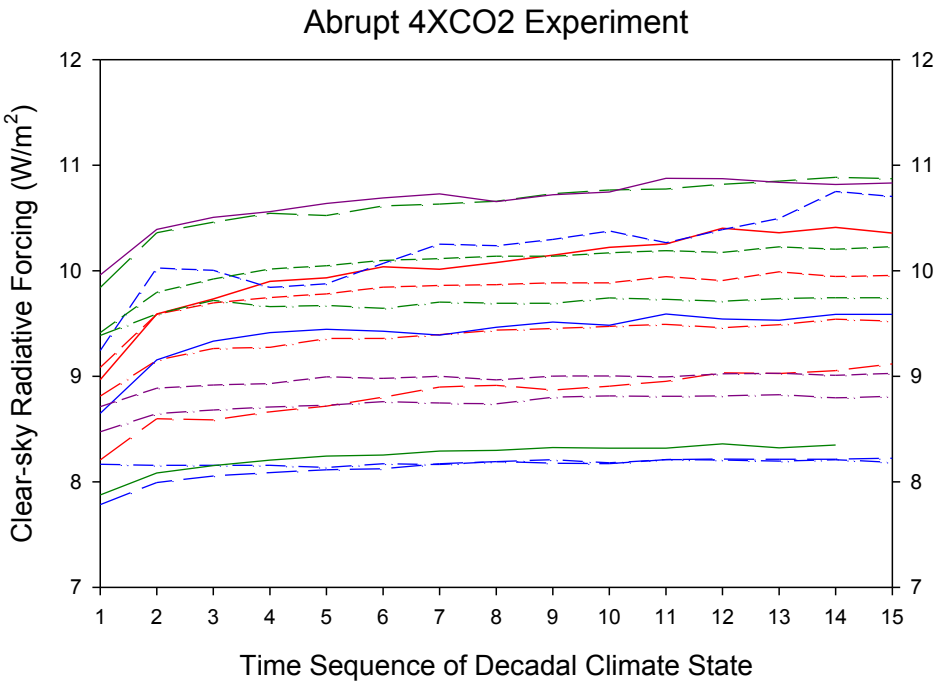


Climate Forcing in IPCC AR5 Models

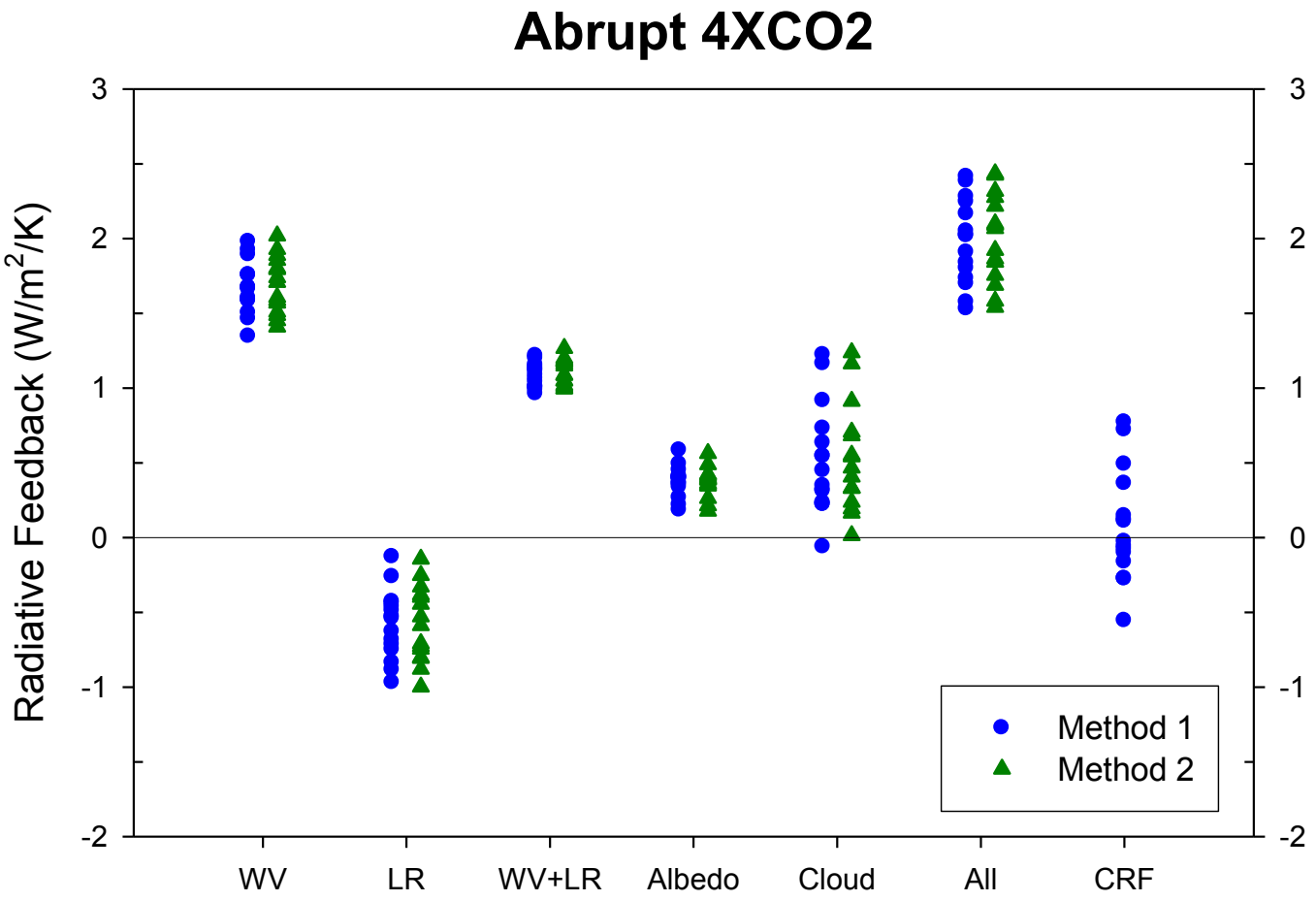
Radiative Forcing



Radiative Forcing

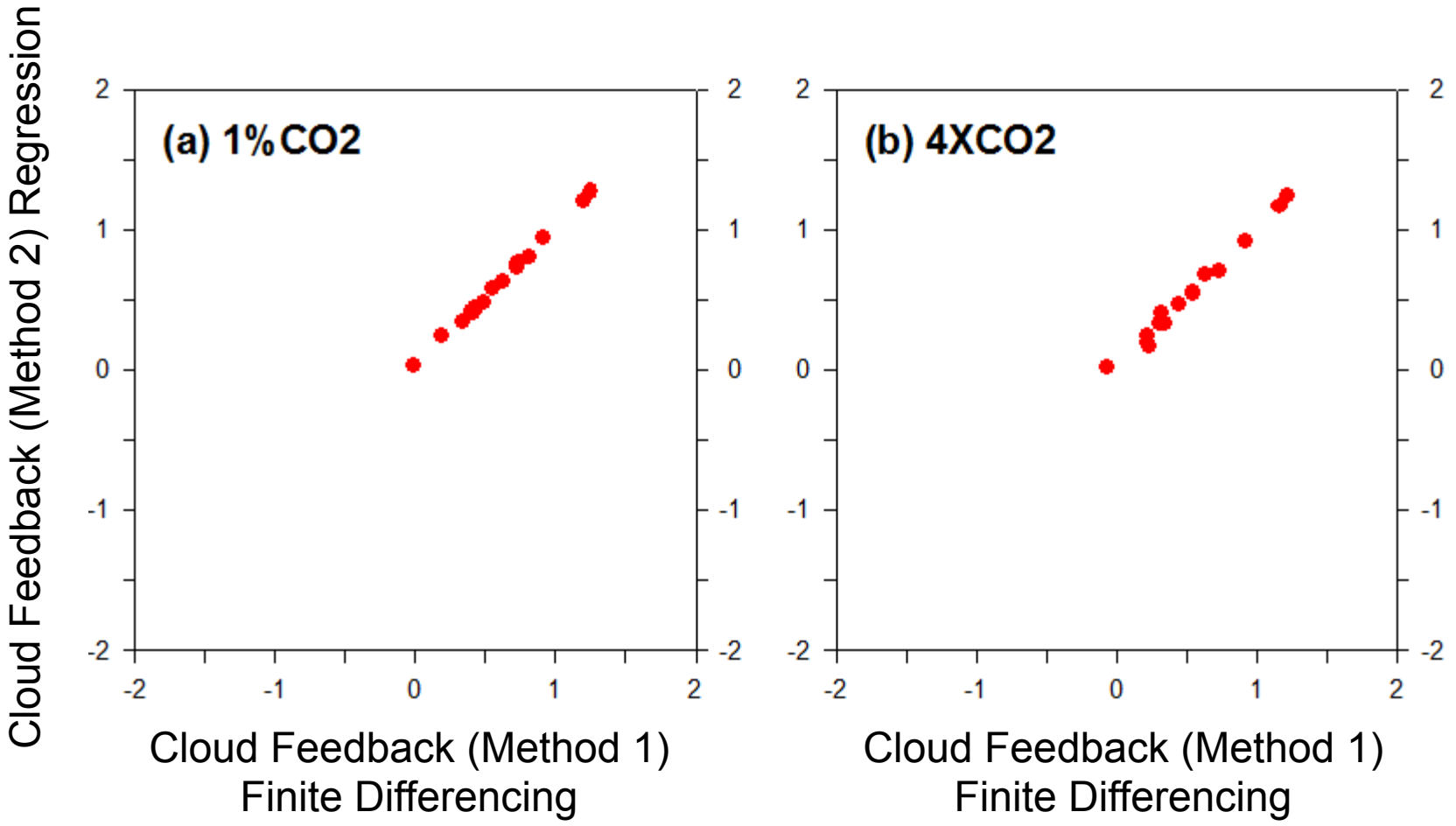


Climate Feedbacks in IPCC AR5 Models

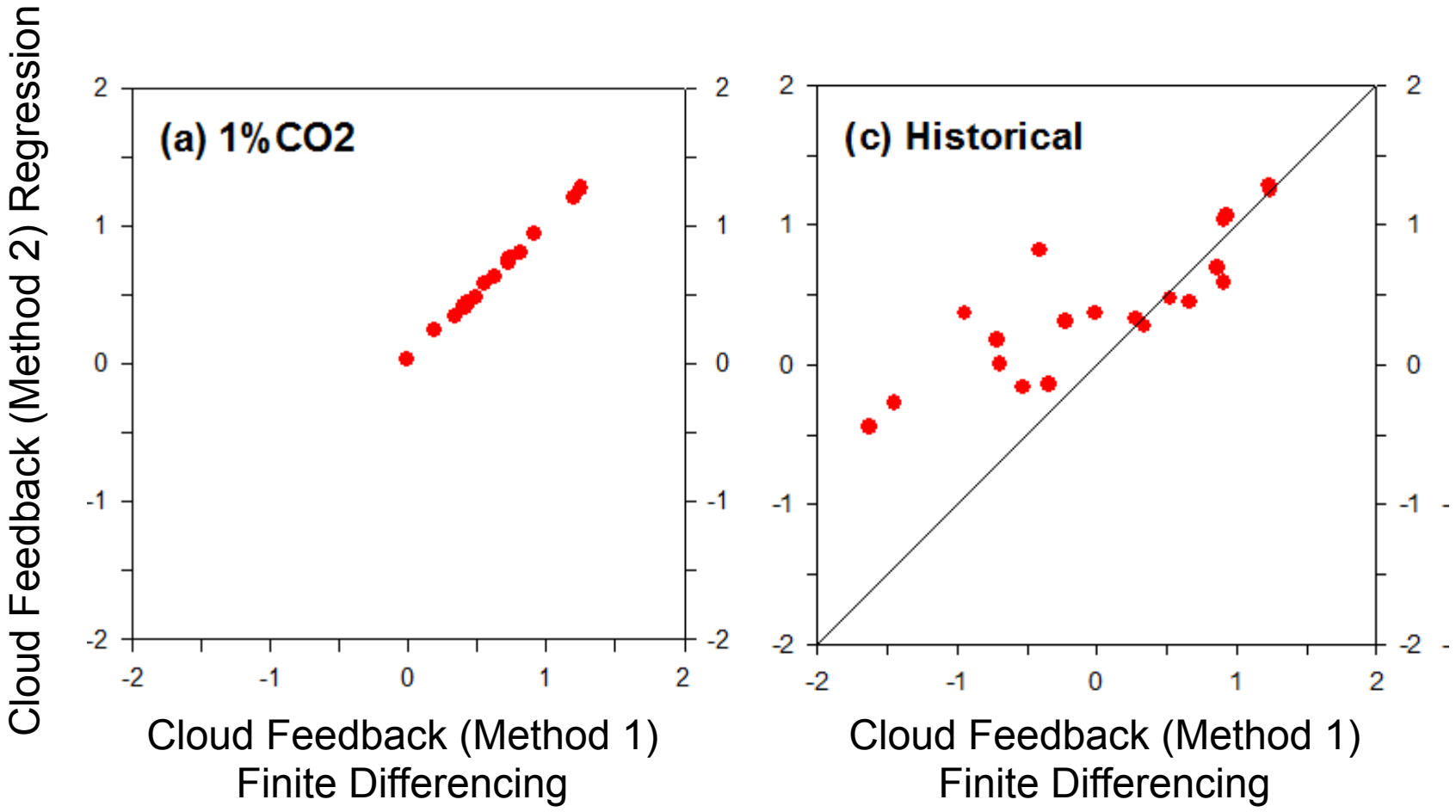


- **No evidence of a significant indirect forcing from CO_2.**
- **Climate feedbacks are robust across CO_2 scenarios.**

Cloud Feedbacks in IPCC AR5 Models



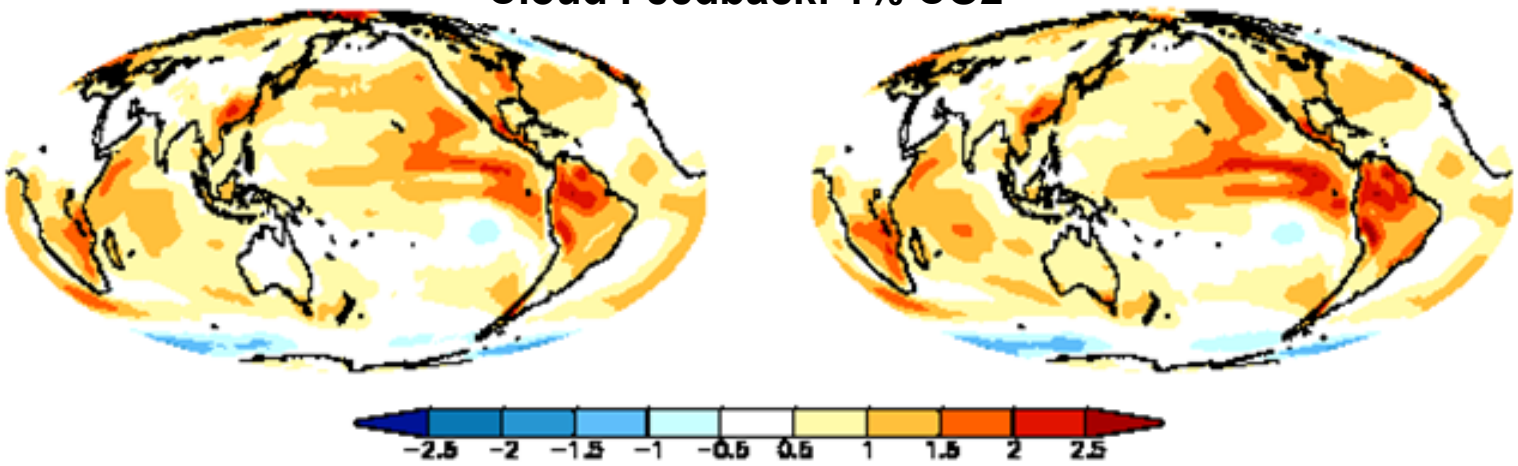
Cloud Feedbacks in IPCC AR5 Models



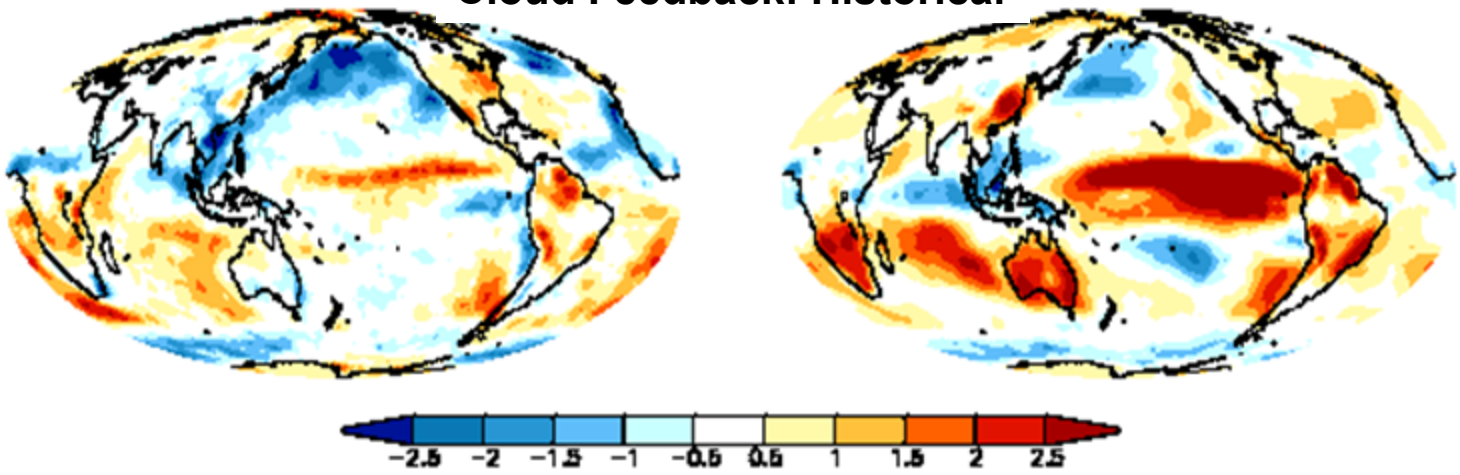
Cloud Feedbacks in IPCC AR5 Models

Differencing **Regression**

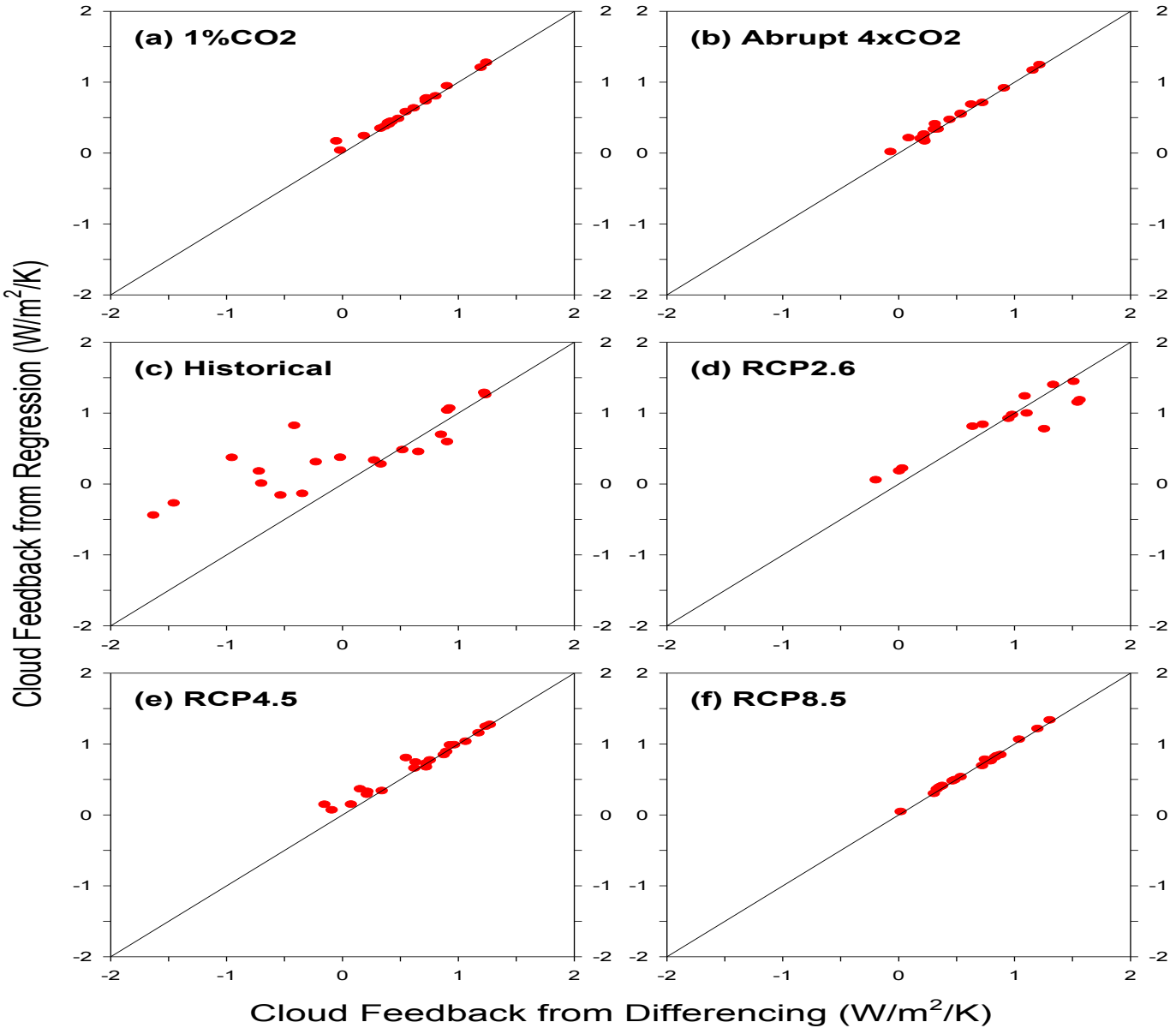
Cloud Feedback: 1% CO2



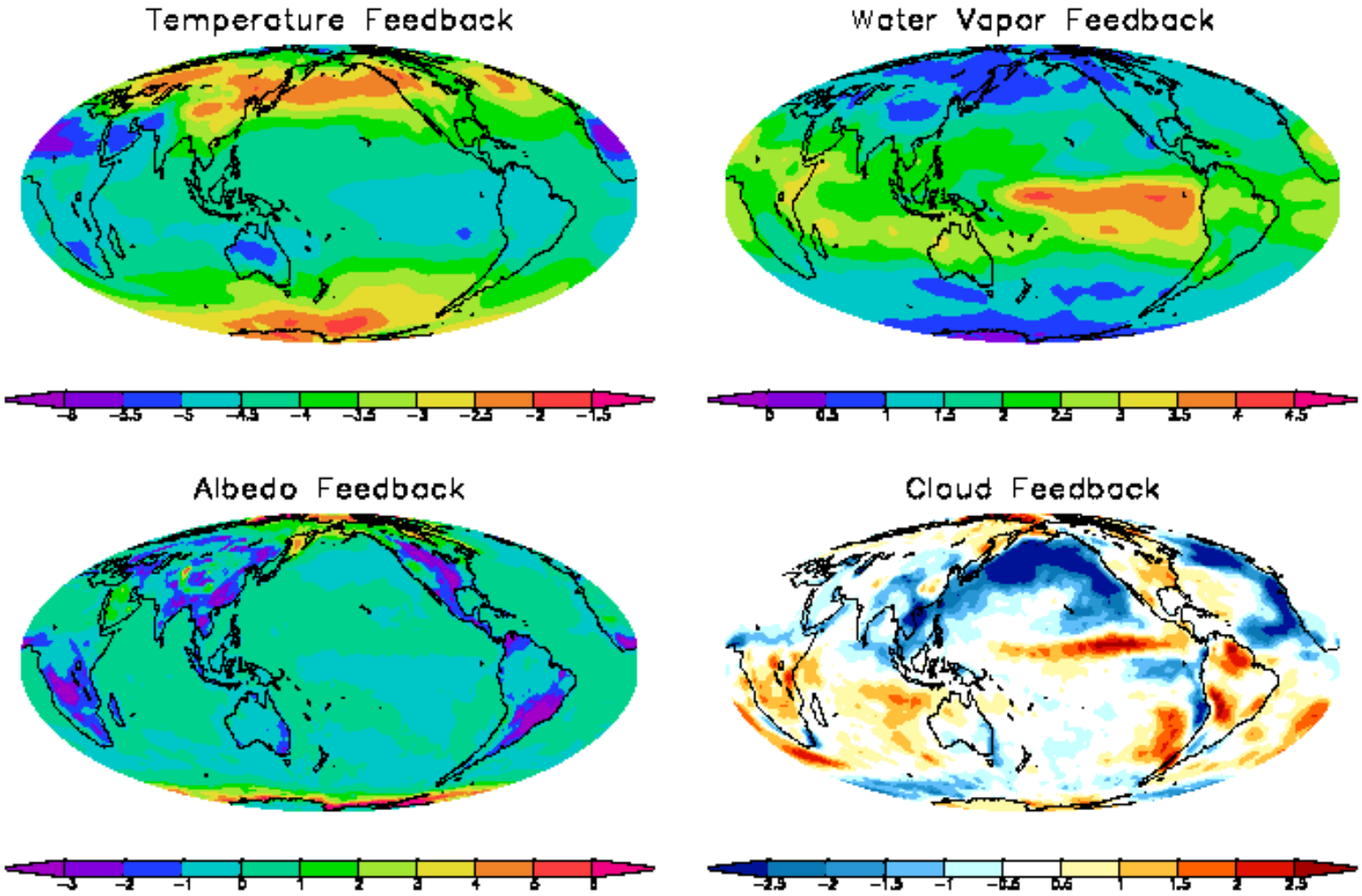
Cloud Feedback: Historical



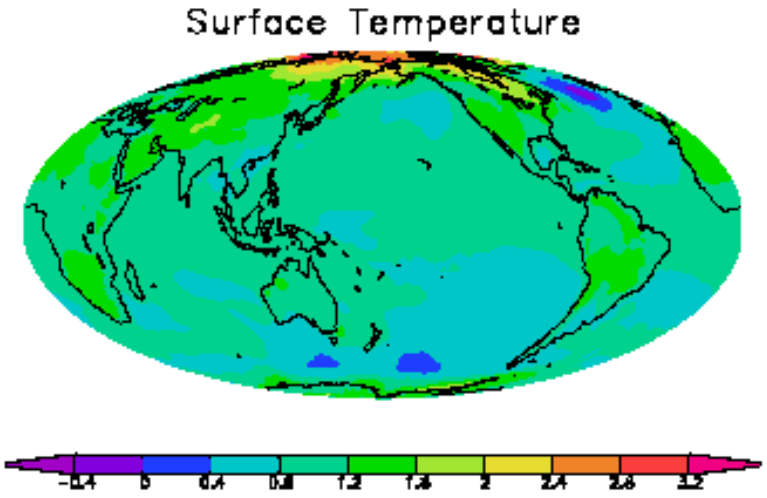
Cloud Feedbacks in IPCC AR5 Models

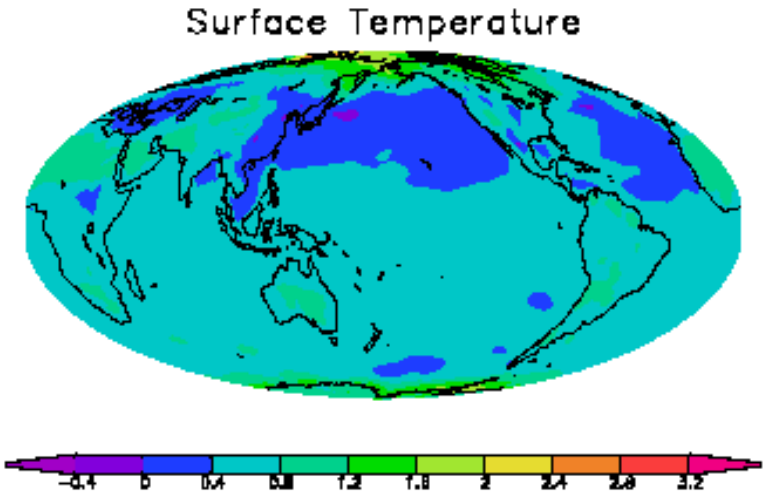


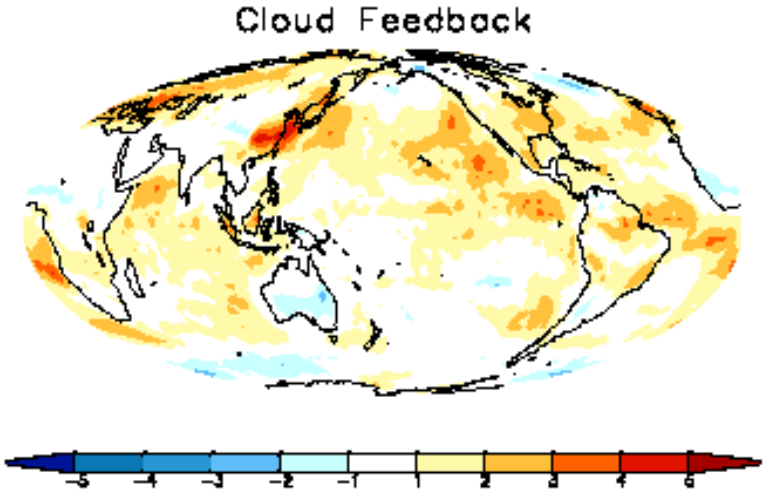
Ensemble Mean Feedbacks: IPCC AR5 Historical

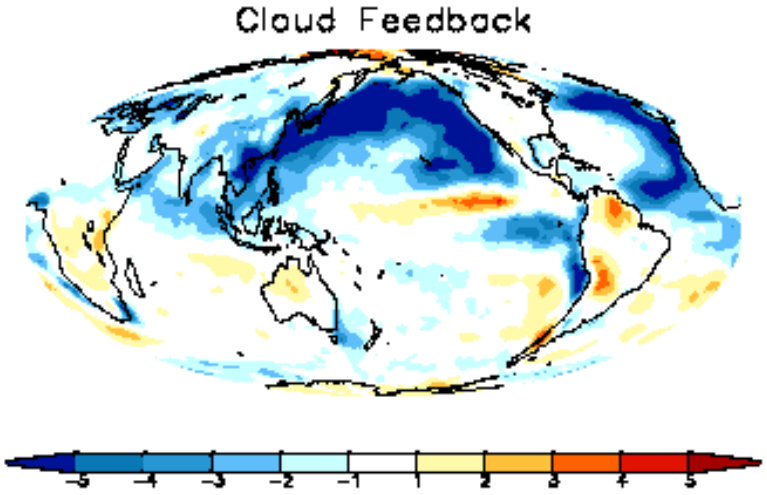


Ensemble Mean Cloud Feedback: IPCC AR5 Historical





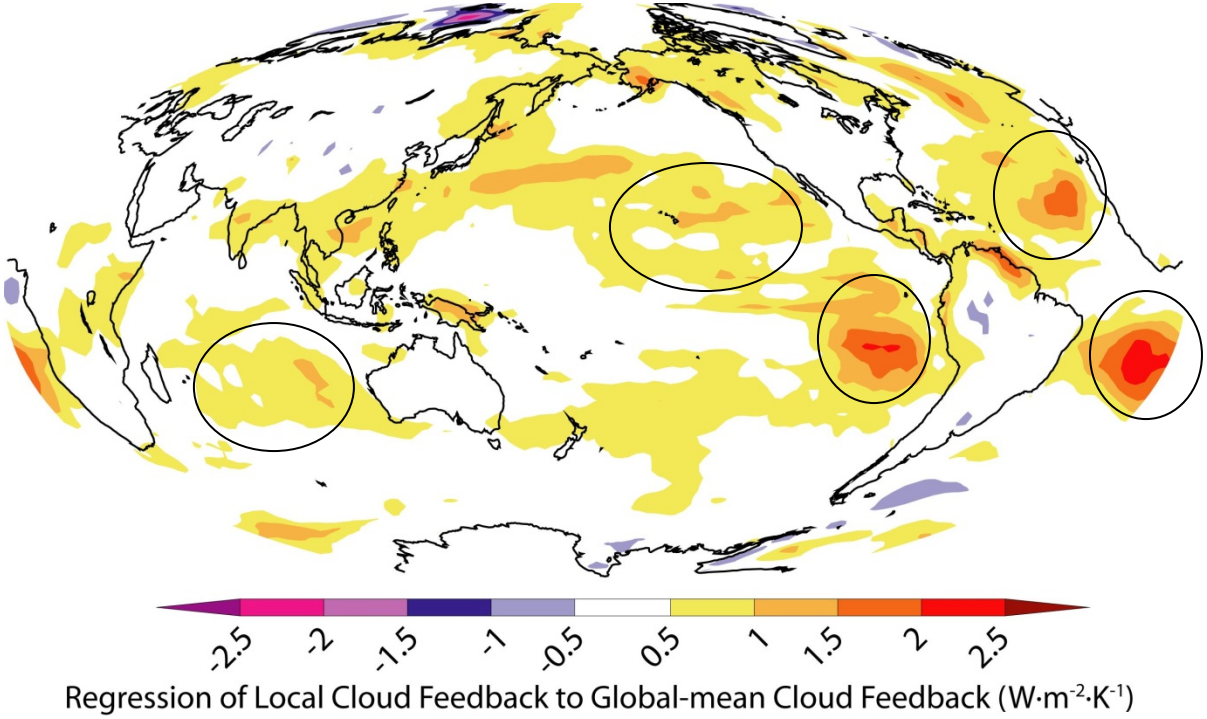




Positive Cloud Feedback (9 GCMs)

Negative Cloud Feedback (11 GCMs)

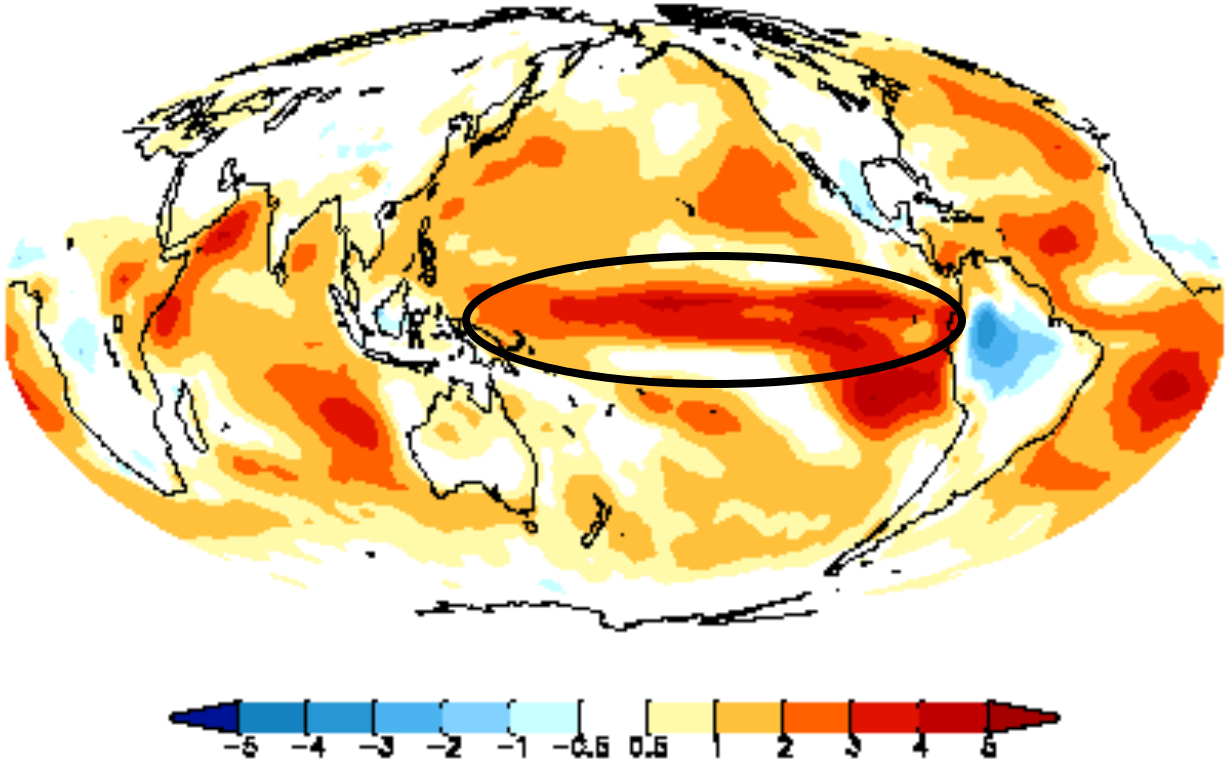
Local contribution to intermodel spread in cloud feedback: AR4



- **Most of intermodel spread arises from low stratocumulus/cumululs regions**

Soden and Vecchi (2011)

Local contribution to intermodel spread in cloud feedback: AR5



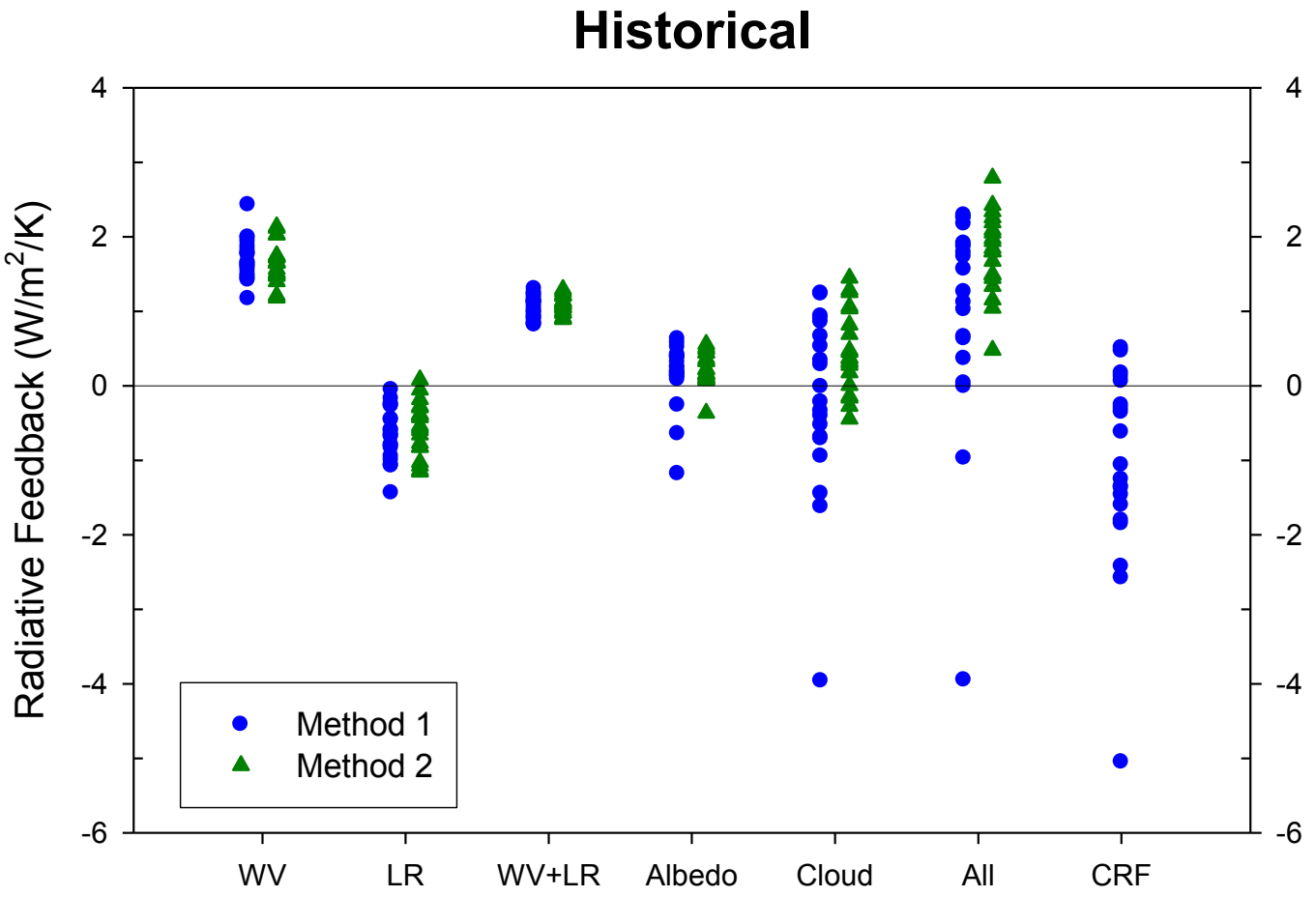
- Low subtropical clouds still uncertain.
- Large contribution from equatorial Pacific.

Summary

- No evidence for the indirect forcing of clouds by CO_2, but there is evidence for a strong indirect negative forcing by aerosols in historical runs.
- Feedbacks in AR5 (CMIP5) models are very similar to those simulated in AR4 (CMIP3) era models … but still no simple answer for why low cloud feedback is positive.
- Equatorial Pacific convective clouds **and** low marine subtropical clouds are biggest contributors to spread.

Extra Slides

Climate Feedbacks in IPCC AR5 Models



- **Some models indicate a negative cloud feedback …**
- **Cloud feedback differs between Method 1 (difference) & Method 2 (regression)**