The Quest Is On

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Purpose

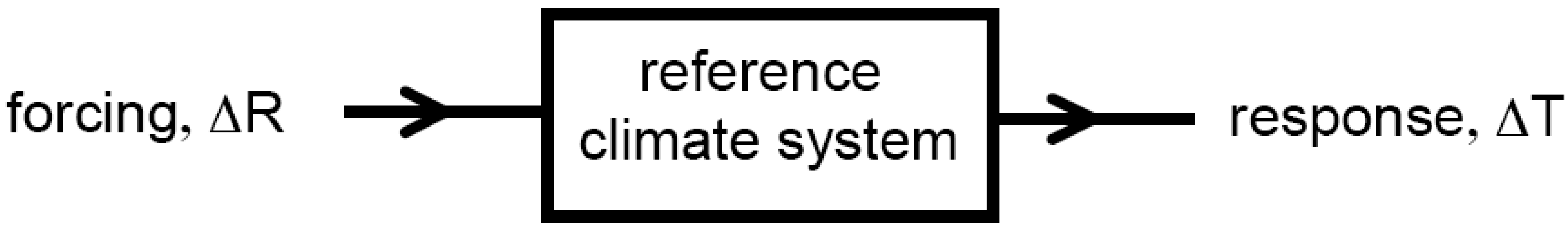
- Response to the papers in Science, October 2007
  - ***Why Is Climate Sensitivity So Unpredictable?*** by Gerard Roe and Marcia Baker
  - ***Call Off the Quest*** by Myles Allen and David J. Frame

- Demonstrate how the framework presented in this paper can be used to <u>define</u> observation requirements for cloud and other feedbacks.

From Roe and Baker (2007):

- Uncertainties in projections of future climate change have not lessened substantially in past decades.
- Both models and observations yield broad probability distributions for long-term increases in global mean temperature expected from the doubling of atmospheric carbon dioxide, with small but finite probabilities of very large increases.
- The shape of these probability distributions is an inevitable and general consequence of the nature of the climate system.
- A simple analytic form for the shape can be derived that fits recent published distributions very well.
- The breadth of the distribution and, in particular, the probability of large temperature increases are relatively insensitive to decreases in uncertainties associated with the underlying climate processes.

Feedback analysis: basics



Climate sensitivity defined by: $\Delta T_0 = \lambda_0 \, \Delta R$

Reference climate system:

- Blackbody (i.e., no atmosphere).
- Terrestrial flux $= \sigma T^4$ (Stefan-Boltzmann)
- $\lambda_0 = (4\sigma T^3)^{-1} = 0.26 \text{ K } (\text{Wm}^{-2})^{-1}$

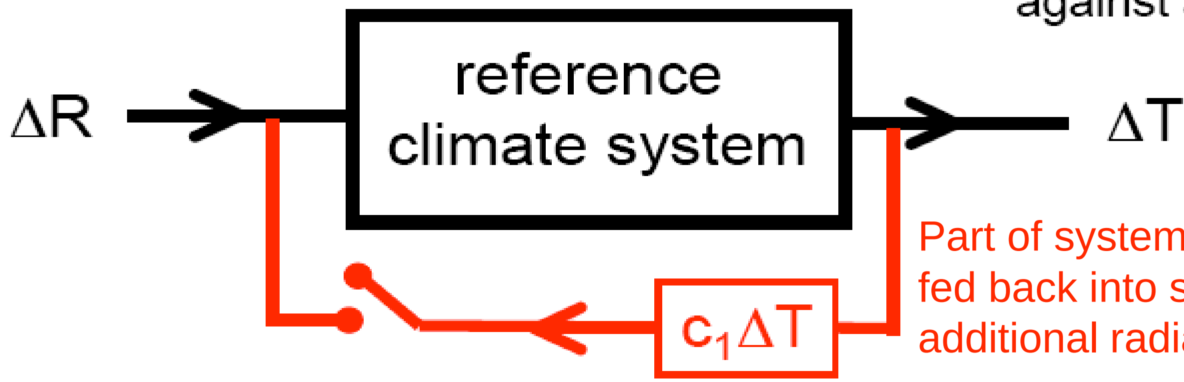
$\Rightarrow \Delta T_0 = 1.2\ ^oC$ for a doubling of CO_2

Roe, 2007

Feedback analysis: basics

- defn: input is a function of the output

(n.b. Feedbacks are only meaningful when defined against a reference state.)



Part of system's response is fed back into system as additional radiative forcing

$$\Delta T = \lambda_0(\Delta R + \boxed{c_1\Delta T})$$

$$\Rightarrow \quad \Delta T = \frac{\lambda_0 \Delta R}{1 - c_1\lambda_0} = \frac{\Delta T_0}{1-f} = G\Delta T_0$$

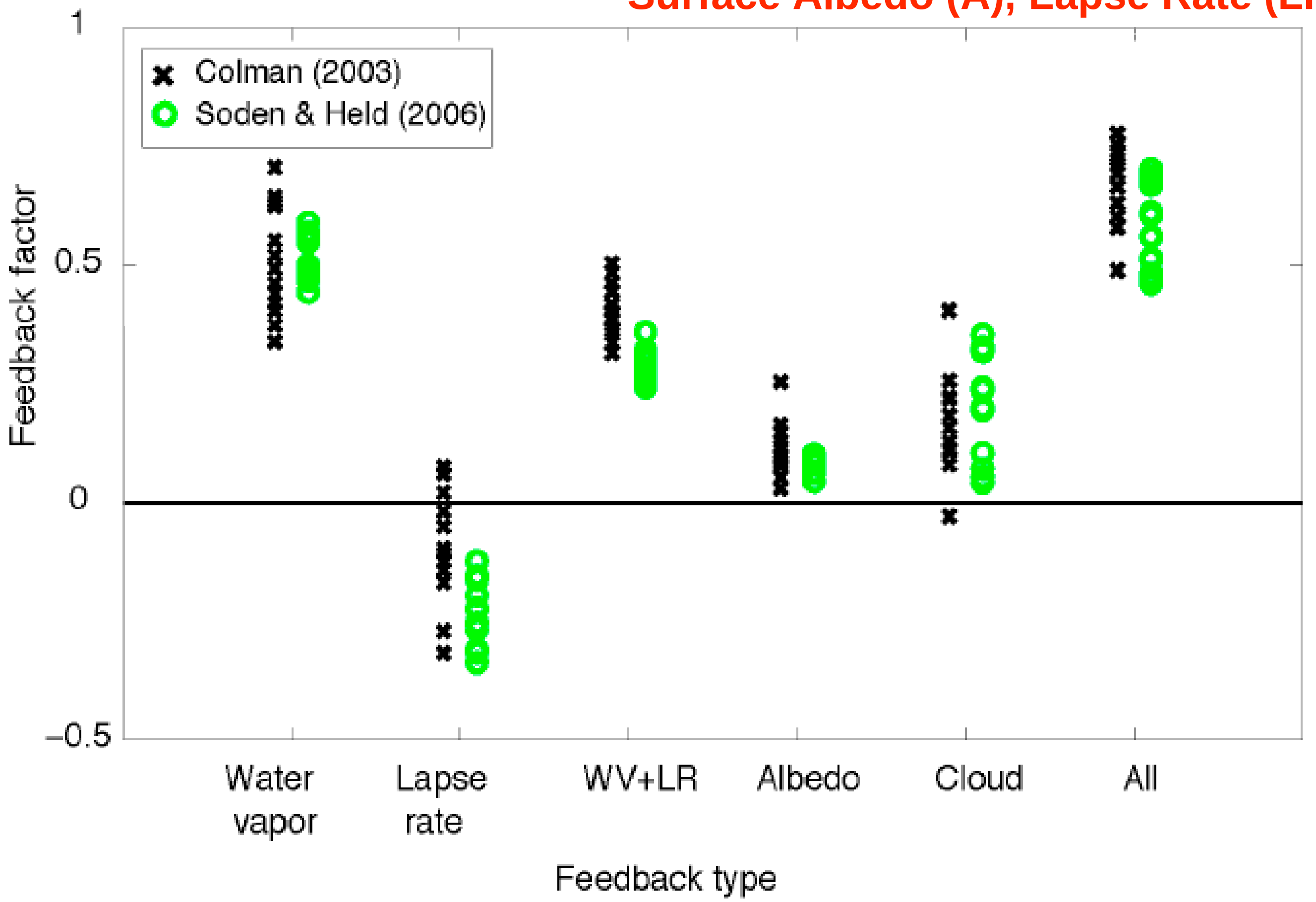
f = Total feedback factor; G = Gain = $\Delta T/\Delta T_o$= 1/(1-f)

+ve feedback: f > 0 => Gain > 1; $\Delta T > 1.2^oC$

-ve feedback: f < 0 => Gain < 1; $\Delta T < 1.2^oC$

Feedback factors add linearly: $f = f_{cloud} + f_{wv,lapse\ rate} + f_{sfc\ albedo} + ...$ Roe, 2007

GCM Climate Feedback Factors for Water Vapour (WV), Cloud (C), Surface Albedo (A), Lapse Rate (LR)



Individual feedbacks uncorrelated among models, so can be simply combined:

Soden & Held (2006):

$\bar{f} = 0.62; \sigma_f = 0.13$

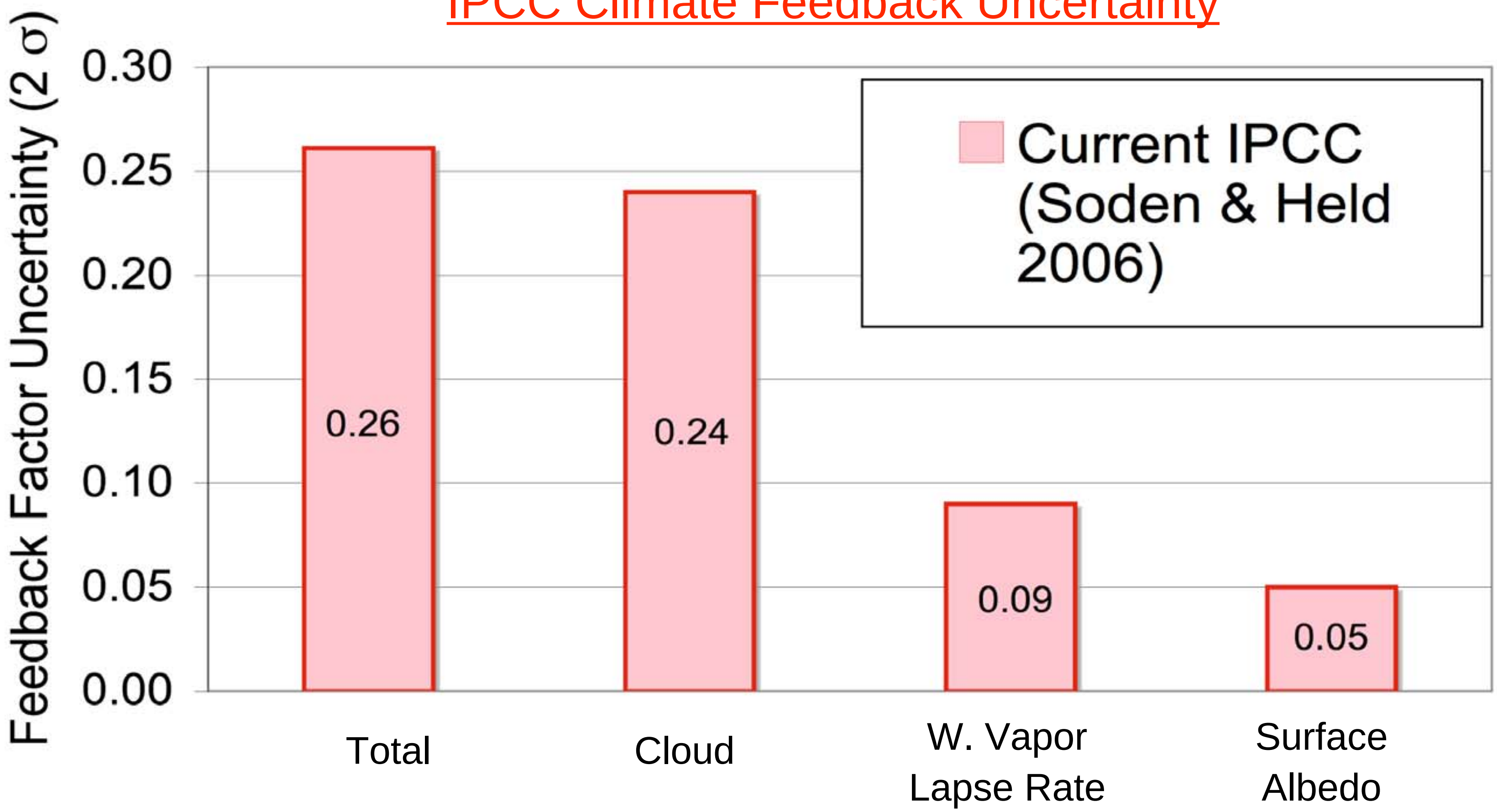
Colman (2003):

$\bar{f} = 0.70; \sigma_f = 0.14$

- In the presence of water vapour, lapse rate and surface albedo feedbacks, but no cloud feedbacks, GCMs predict climate sensitivity ($\pm 1\sigma$) ≈ 1.9°C ± 0.15°C.
- With cloud feedbacks the mean & stdev are larger (3.2°C ± 0.7°C) because the GCMs all predict a positive cloud feedback but strongly disagree on its magnitude.
- f=0.62 corresponds to G=2.6 and ΔT=3.2°C

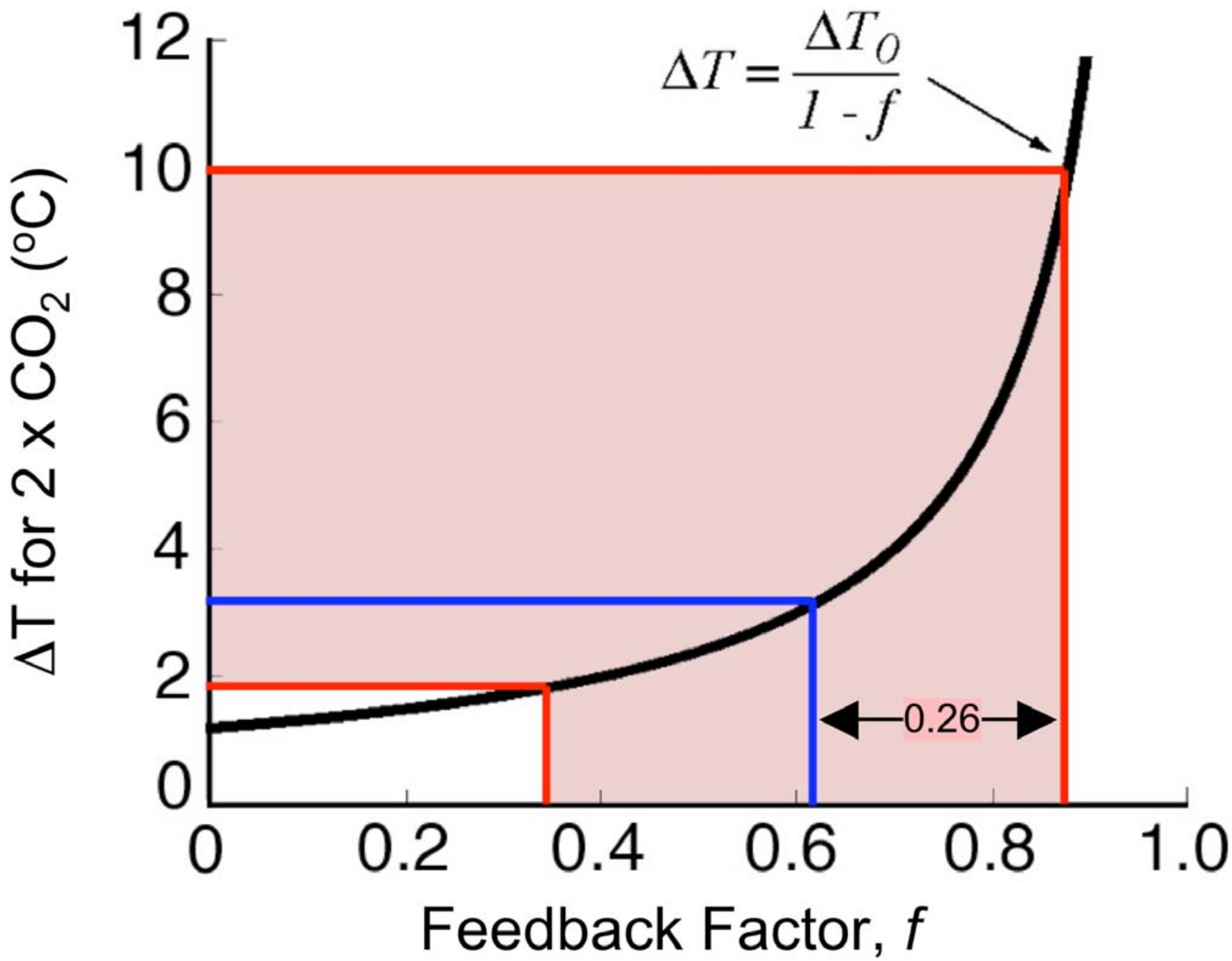
IPCC 2007

IPCC Climate Feedback Uncertainty



The uncertainty in climate feedback is driven by these three components. The feedback for the climate system is $f = 0.62 \pm 0.26\ (2\sigma)$

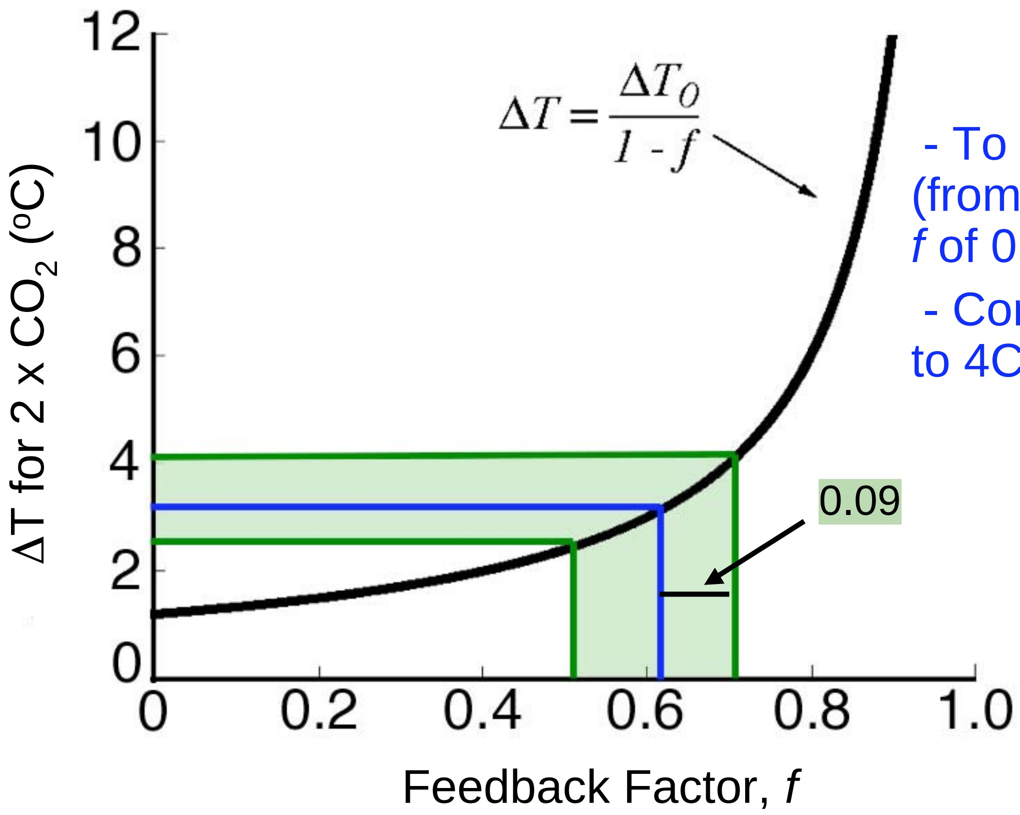
Current Climate Uncertainty (2σ)



Current measured feedback uncertainties result in large uncertainties in predicted ΔT (Roe and Baker, 2007). ΔTo = the Earth's temperature as a simple blackbody.

IPCC 2007: 2ºC < ΔT < 10ºC (2-σ range)

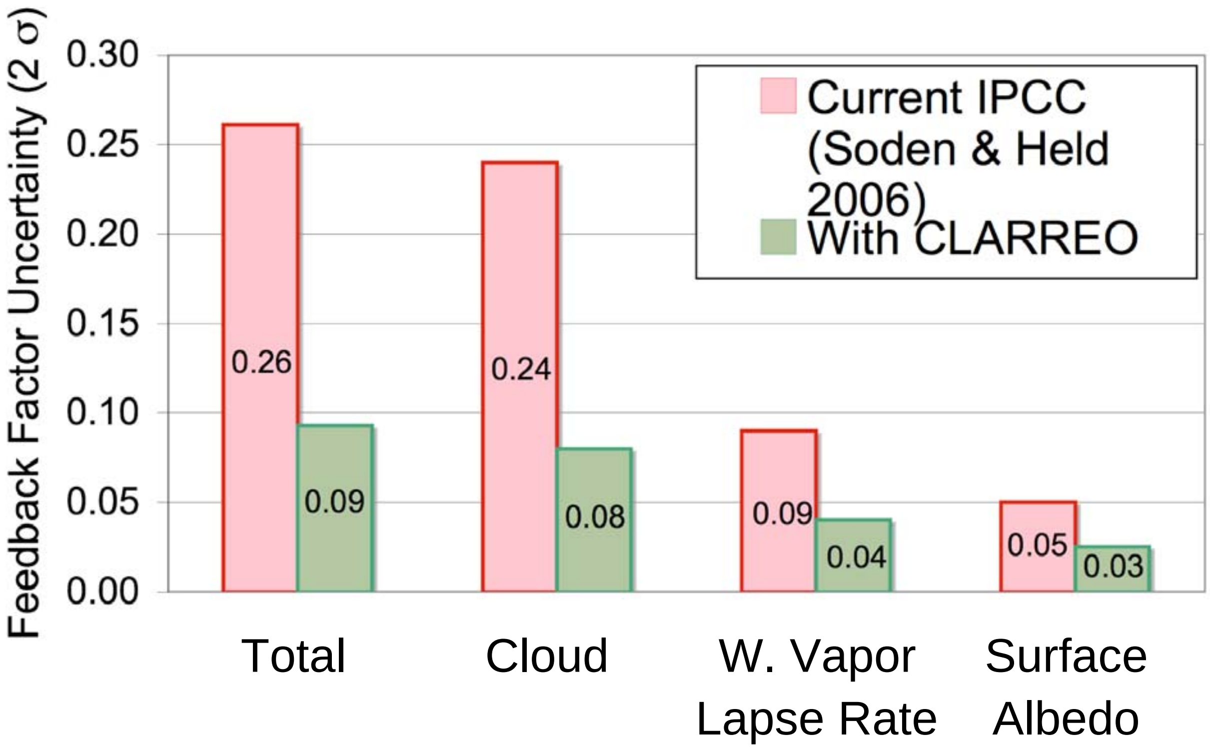
Reducing Climate Uncertainty Requires a More Accurate Measurement of Feedback



- To reduce the range by a factor of 5 (from 8C to 1.5C), need an uncertainty in *f* of 0.09.
- Corresponds to a range in ΔT of 2.5C to 4C.

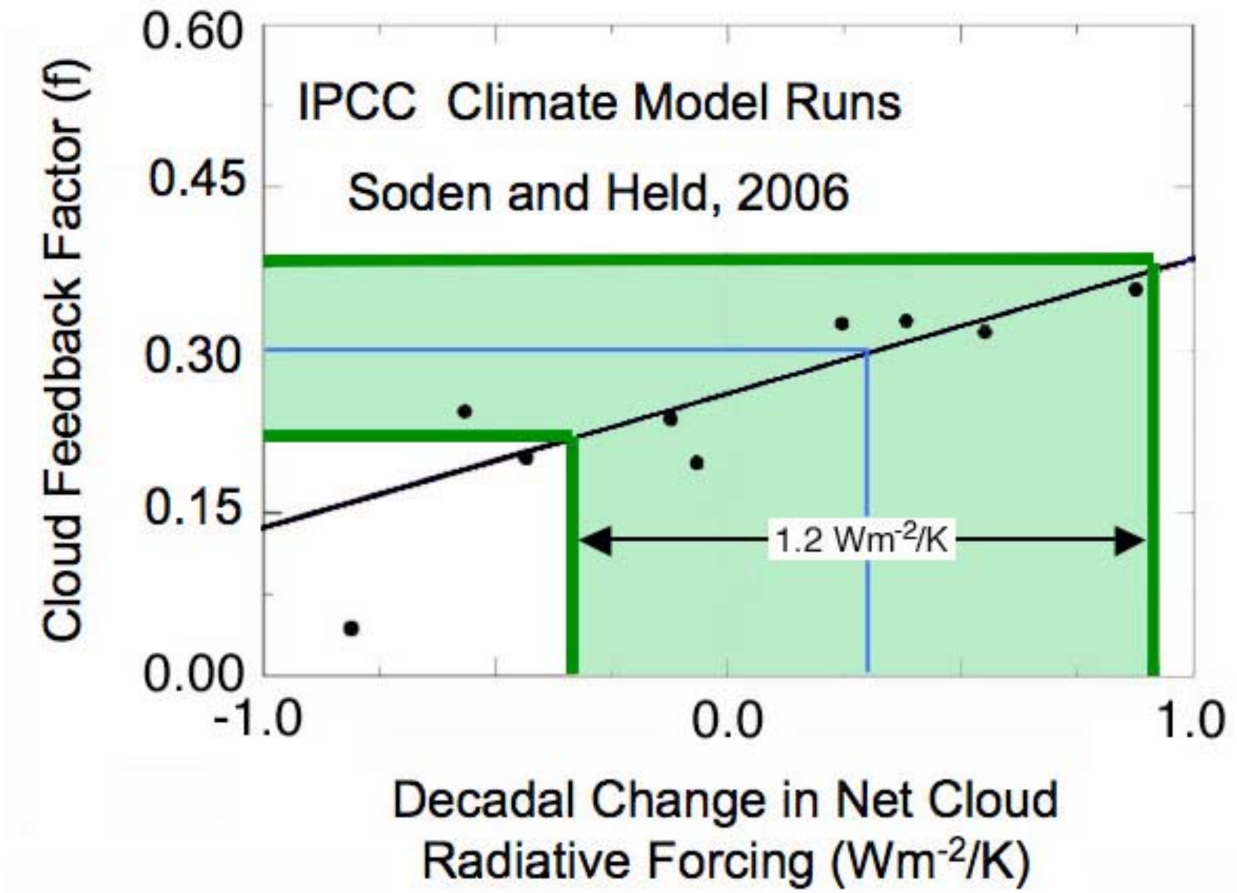
CLARREO Requirements Based on Reducing Feedback Uncertainty: Cloud Feedback Example

CLARREO Reduces Climate Uncertainty



These feedback uncertainty goals define the observation requirements

Cloud Feedback Uncertainty Goal Defines the Observation Requirement



Decadal Trend Observation Requirement

- The uncertainty goal for feedback factor *f* sets the observation goal for Net Cloud Radiative Forcing (CRF) at 1.2 Wm^{-2}/K

- IPCC models predict a 0.2 K / decade warming in the next few decades independent of sensitivity. (because the warming is controlled by the slow ocean response time)

Therefore, the Net CRF observation goal is:
$(1.2\ Wm^{-2}/K) * (0.2K/decade) = 0.24\ Wm^{-2}/decade$

CLARREO Calibration Requirement For Measuring Cloud Feedback

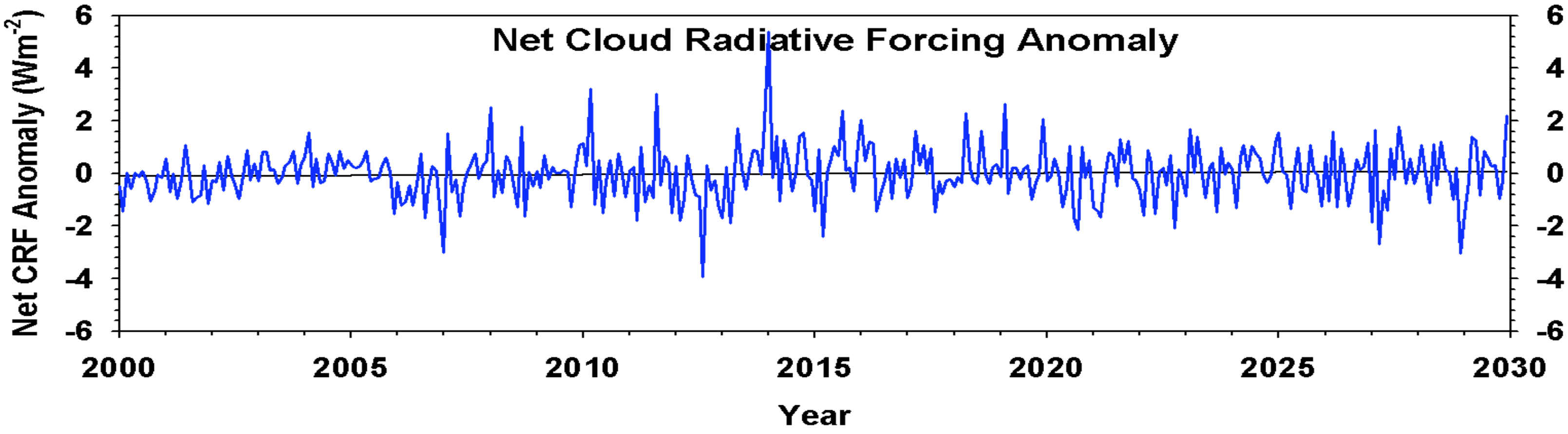
The Net CRF observation goal
sets the decadal calibration goal:

Net CRF = SW CRF + LW CRF
CRF = Clear minus All-Sky TOA Flux

Shortwave (SW): 0.24/50 = 0.5% (2σ)
Longwave (LW): 0.24/30 = 0.8% (2σ)

This requirement is four times more accurate than the current SW broadband channel absolute accuracy:
Requires overlap for current observations (no gap)
and/or
Requires CLARREO for future observations (gap OK)

CLARREO Sampling Requirement



The Net CRF observation goal also sets the sampling requirements

- 20+ year record for trend to exceed natural variability
- Full swath sampling for low observation sampling noise
- 20km FOV or smaller to separate clear and cloud scenes

Solution: CLARREO required to calibrate broadband observations to needed absolute accuracy. CERES provides sampling of the Net CRF decadal change.

Additional Climate Feedbacks:

Similar climate model and data sampling analyses could be performed for other climate feedbacks

- Water vapor/lapse rate feedback will require latitude profile and height profile requirements for temperature and humidity. Can be extended to spectral fingerprinting.
- Surface albedo (e.g. snow/ice) will require latitude dependent requirements.
- Other feedbacks could also be considered in this framework.
- Climateprediction.net perturbed physics modeling provides an ideal framework to explore the relationships.

The Quest Has Just Begun

A new era of climate Observing System Simulation Experiments (OSSEs), a new era of calibration.

- A new methodology for linking climate model uncertainties to observation requirements has been highlighted.
- The current large uncertainties in climate feedbacks are not inevitable, nor is large uncertainty in climate sensitivity. CLARREO will likely play a key role.
- The example of cloud feedback linked to Net CRF does NOT eliminate the need to separately determine aerosol indirect effect. This remains the largest radiative forcing uncertainty and must be subtracted from the observed decadal change in SW CRF.