On the Diagnosis of Radiative Feedback in the Presence of Unknown Radiative Forcing

-or-

Connecting the Dots:
Theoretical & Observational Evidence for Negative Cloud Feedbacks

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16 December 2009 AGU Meeting
San Francisco, CA
Radiative Flux vs. Temp. variations often show Strong Decorrelation…

WHAT AFFECTS THE REGRESSION SLOPE BESIDES FEEDBACK?


Radiative Flux Anomaly (W m\(^{-2}\))

Tropospheric T Anomaly (deg. C)

slope = 2.5 Wm\(^{-2}\)K\(^{-1}\)

\(r^2 = 0.22\)
…but PHASE SPACE plotting reveals linear striations with a common slope \( \sim 6 \text{ Wm}^{-2}\text{K}^{-1} \)

CONNECTING THE DOTS:
ARE LINEAR STRIATIONS FEEDBACK?
& low-pass filtering reveals Looping Patterns...

WHAT CAUSES LOOPING?

Radiative Flux Anomaly (W m\(^{-2}\))

Tropospheric T Anomaly (deg. C)

2007-08 cooling event

Monthly Running 3-Month Averages

slope 1.8
& older ERBS data shows similar looping pattern after 1991 Pinatubo eruption.

WHAT CAUSES LOOPING?

72-day “Seasons”, 60N-60S

Linear Patterns in Four IPCC AR4 Models (obvious in LW only)
Looping Patterns Seen in ALL 18 Models (especially in SW)

CNRM CM3 Model, SW
Linear & Looping Features Easily Explained with a Simple Model of Climate Variability:

(Spencer & Braswell, 2008 J. Climate [thanks to Isaac Held, pers. comm.])

\[ C_p \frac{d\Delta T}{dt} = f(t) + N(t) + S(t) - \lambda \Delta T \]

- **CERES MEASURES ALL RADIATIVE SOURCES** (NOT just feedback)
- **EXTERNAL RADIATIVE FORCINGS** (anthro.; volcanoes; solar)
- **INTERNAL RADIATIVE FORCINGS** (non-FB variations in clouds, mostly)
- **INTERNAL NON-RADIATIVE FORCINGS** (vars. in ocean => atmos. convective heat flux; variations in ocean upwelling)
- **FEEDBACK on T chg.**

Bulk heat Capacity (mixed layer depth)
SIMPLE MODEL: Clouds => Temperature (N term) causes LOOPING PATTERNS…

Model parameters
15 m mixed layer;
$\lambda = 6 \text{ W m}^{-2} \text{ K}^{-1}$;
1 month time step;
forced with low-pass filtered random cloud variations (“N” term)
SIMPLE MODEL: Temperature => Clouds (S term) causes LINEAR STRIATIONS.

Model parameters
15 m mixed layer;
$\lambda = 6 \text{ W m}^{-2} \text{ K}^{-1}$;
1 month time step;
forced with low-pass filtered random temp. variations ("S" term e.g. chgs. in convective heat flux)
Most Realistic: BOTH Forcings Combined
(internal radiative forcing + non-rad. forcing)

Model parameters
15 m mixed layer;
λ = 6 W m\(^{-2}\) K\(^{-1}\);
1 month time step;
forced with low-pass filtered random cloud & T variations
(“N” & “S” terms)

LINEAR & LOOPING PATTERNS
So, How Can We Better Extract Feedback “Signal” when it is Mixed in with Internal Radiative “Noise”?

- No single best method
- My current favorite: Compute month-to-month slopes (e.g. $\Delta [LW+SW] / \Delta T$) for LARGEST $\Delta T$’s & then average together (“Local Slopes Analysis”)
Local Slopes Analysis: CMIP Models vs. Satellite, evidence of neg. cloud feedback in satellite data?

Satellite vs. AR4 Model
Global LW feedback parameters

Satellite vs. AR4 Model
Global LW+SW feedback parameters

IPCC AR4 20th Century, (detrended)
Terra CERES vs. UAH MT

Avg. 1-Month Diagnosed Slope (from largest 40% of 1-month $\Delta T$'s)

Running Avg. 1-Month Diagnosed Slope (from largest 40% of 1-month $\Delta T$'s)
Implications for Satellite Diagnosis of Feedbacks

• Feedback diagnosis MUST account for “internal radiative forcing” (which decorrelates data)
  – Feedback can NOT be measured when it’s from time-varying radiative forcing of any kind (UNLESS known accurately and removed, e.g. CO2 forcing in a model)

• IGNORING internal radiative forcing leads to Feedback Parameter diagnosis errors which are variable and (usually) biased low
  – Spencer & Braswell 2008 J Climate

• Conceptually, this is a “cause vs. effect” issue:
  CLOUDS <=> TEMPERATURE
  – Previous feedback diagnoses have ignored the effect of causation in one direction: (clouds => temperature)
Backup Slides
WHY TROPOSPHERIC TEMPERATURE RATHER THAN SURFACE TEMPERATURE?

At ~1 month time resolution, Radiative Flux Anomalies (Aqua CERES LW+SW) are more closely correlated with Tropospheric Temperature (AMSU5) than with Sea Surface Temperature (AMSR-E).
IPCC CMIP Model Behavior vs. Satellite: evidence of negative cloud feedback?

Running Avg. Regression Slopes Sorted by abs(ΔT)

- Terra CERES LW+SW vs. UAH MT
  (9 years, global)

IPCC CMIP Models
(global, 20th Century)

<= largest ΔT’s  

smallest ΔT’s =>