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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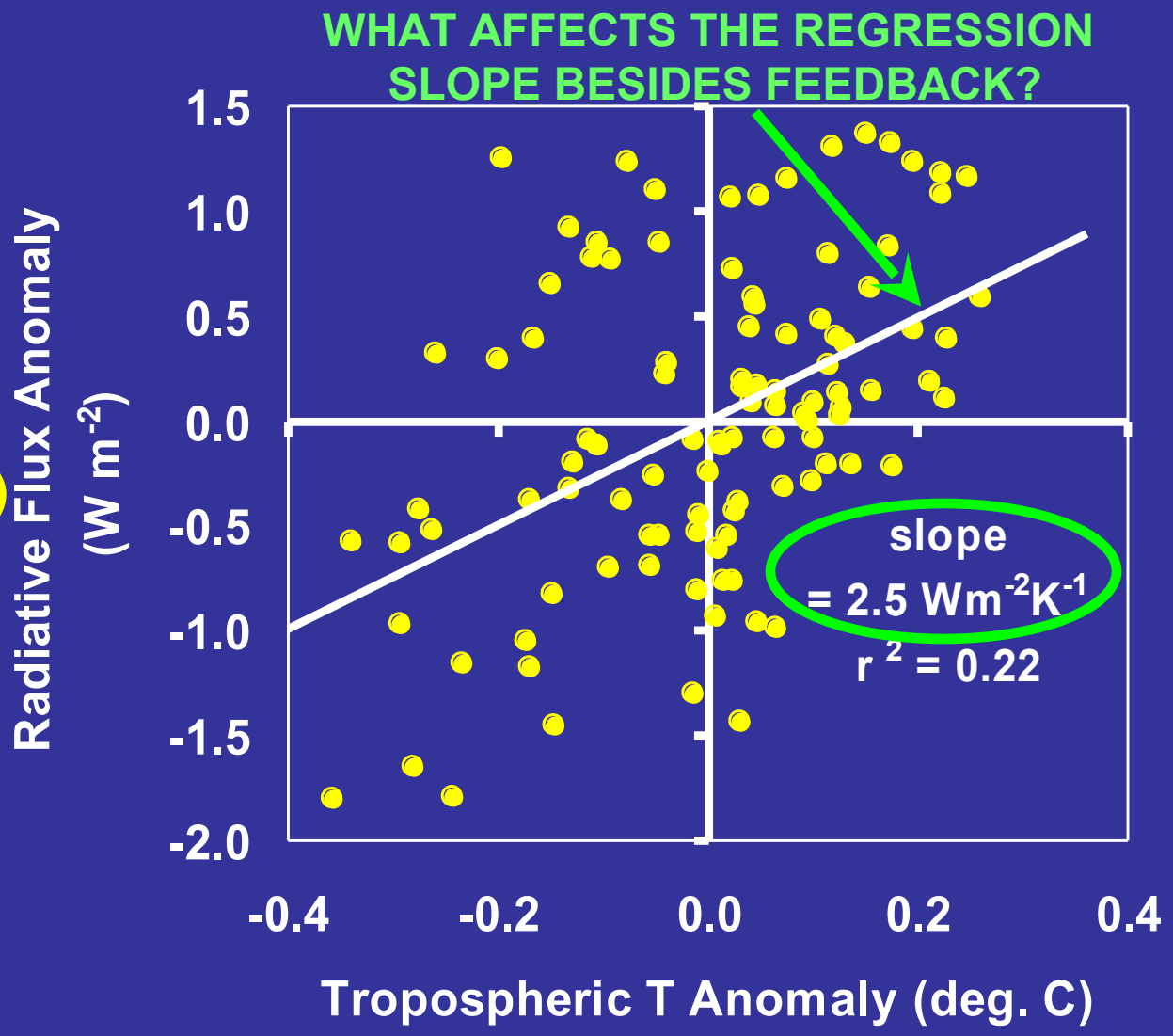
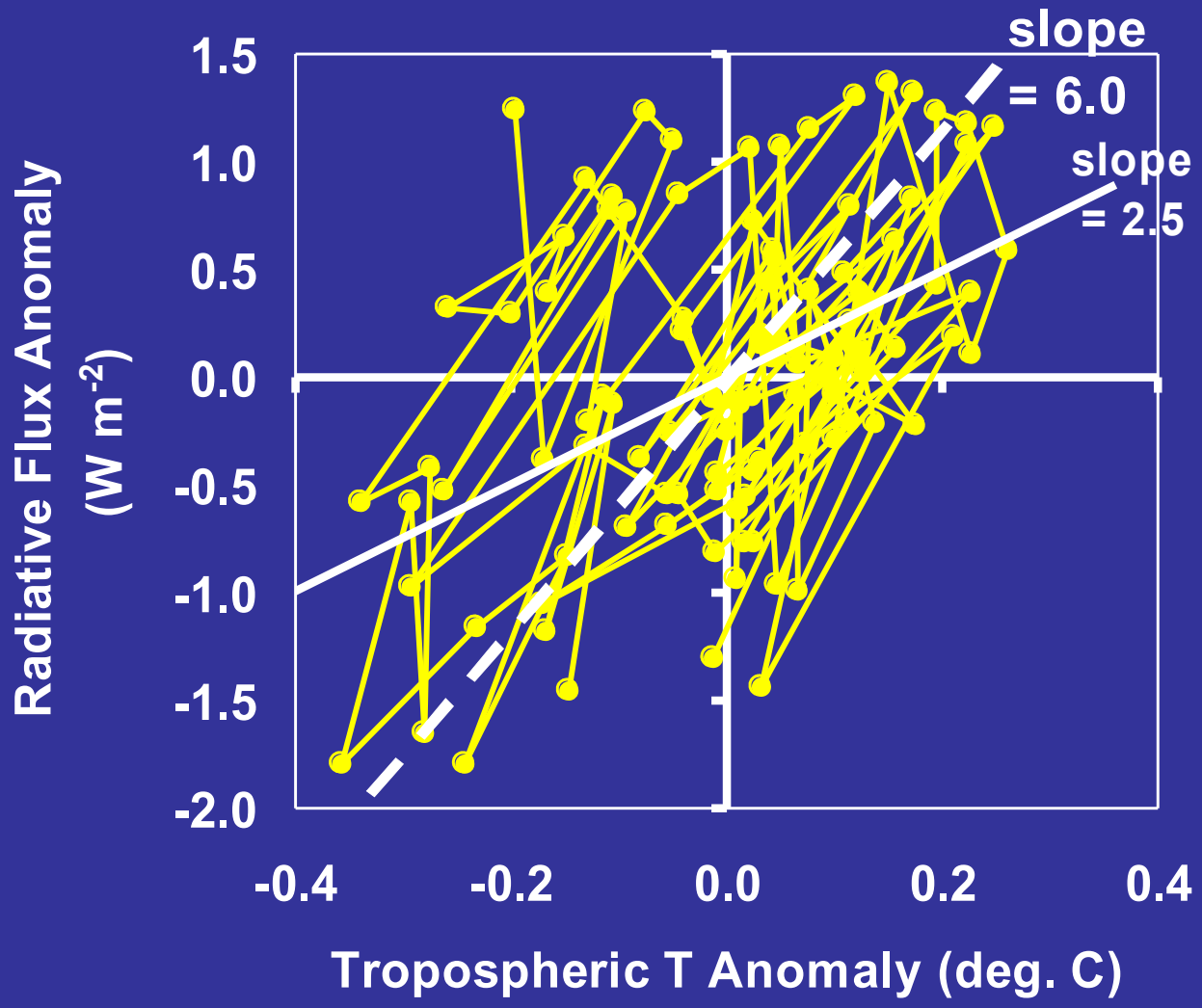
Radiative Flux vs. Temp. variations often show Strong Decorrelation…

Monthly Global
Terra Satellite
CERES ES-4 LW+SW
vs UAH MT (Aqua AMSU)
(Mar. 2000 – Dec. 2008)



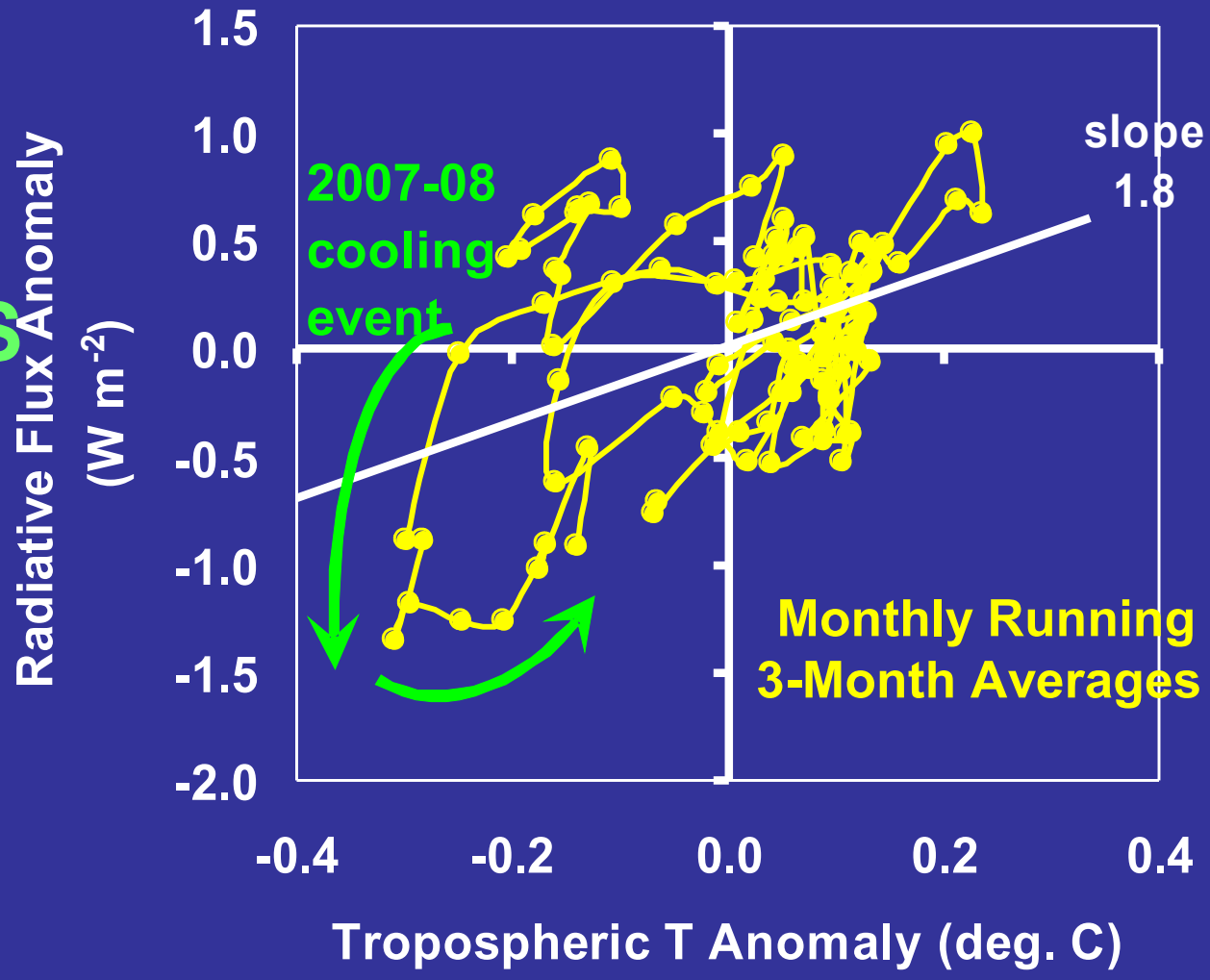
…but PHASE SPACE plotting reveals linear striations with a common slope ~6 $Wm^{-2}K^{-1}$

CONNECTING THE DOTS: ARE LINEAR STRIATIONS FEEDBACK?



…& low-pass filtering reveals Looping Patterns…

WHAT CAUSES LOOPING?

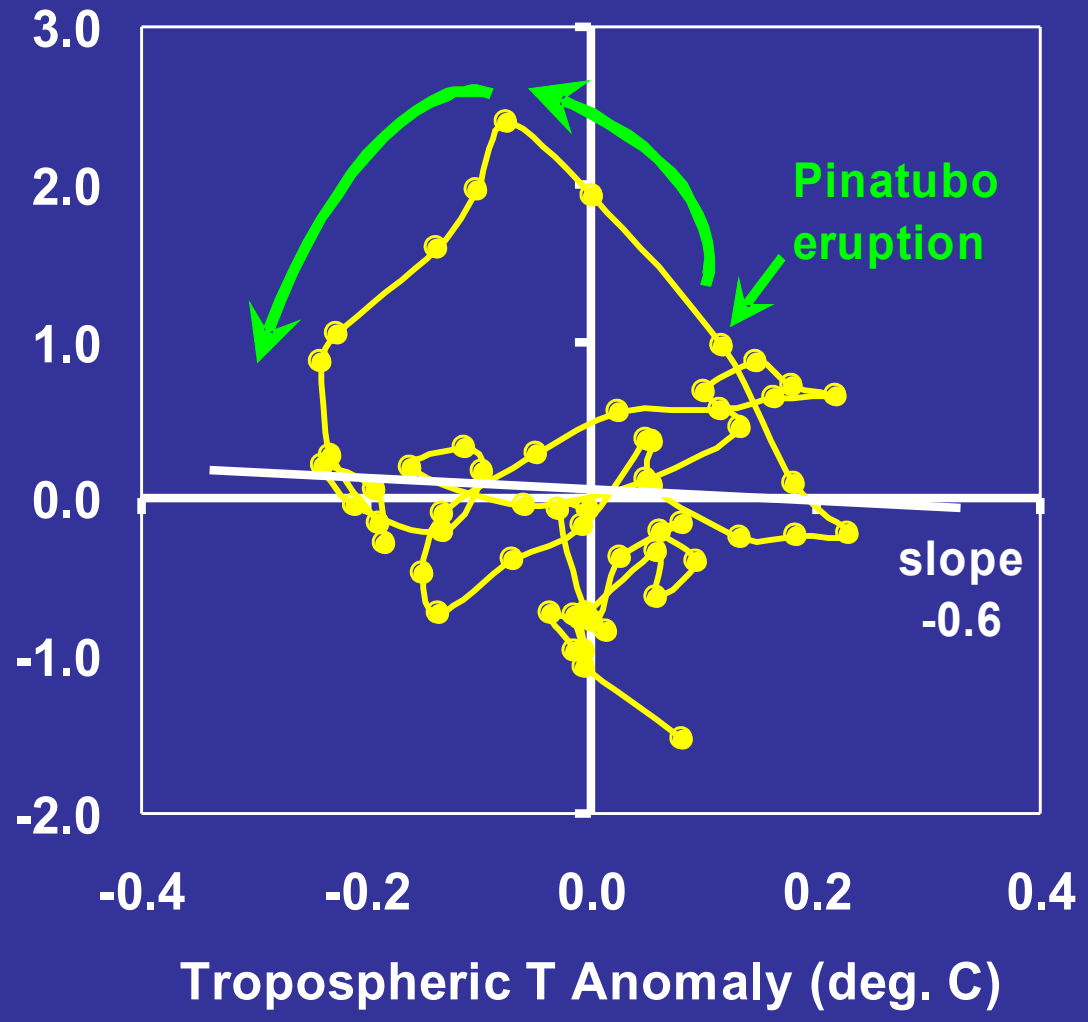


& older ERBS data shows similar looping pattern after 1991 Pinatubo eruption.

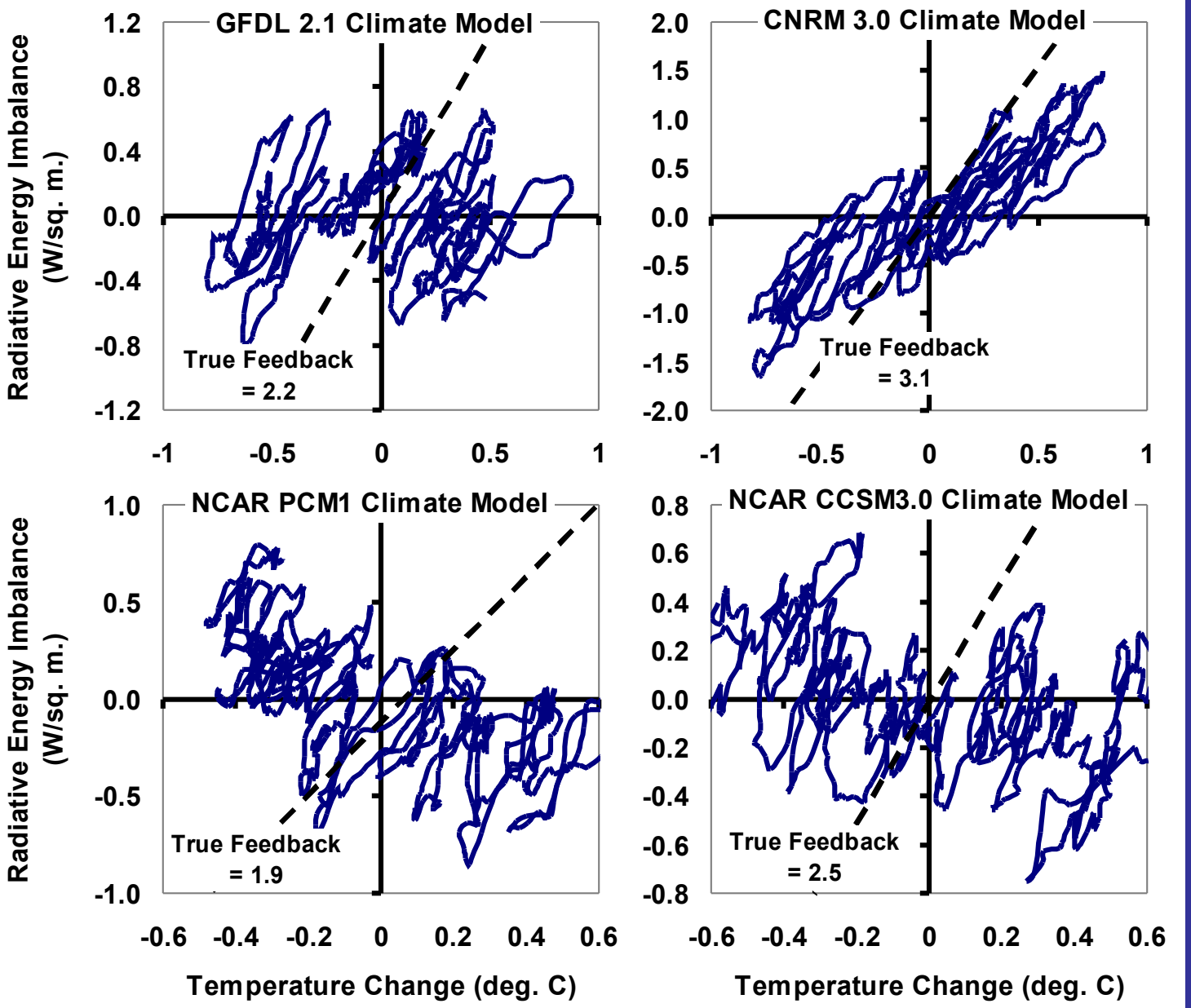
WHAT CAUSES LOOPING?

72-day "Seasons", 60N-60S

ERBS Satellite
ERBE LW+SW
vs UAH MT
(1985-1999)



Linear Patterns in Four IPCC AR4 Models (obvious in LW only)



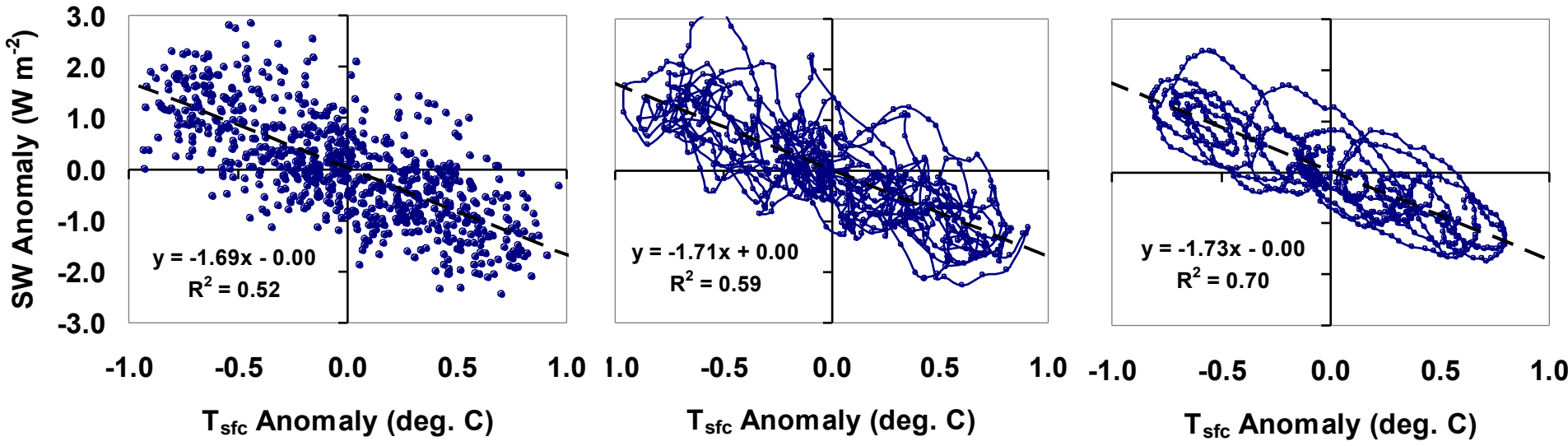
LW

Looping Patterns Seen in ALL 18 Models (especially in SW)

1 month averages

3 month averages

12 month averages



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.*])

Bulk heat Capacity (mixed layer depth)

CERES MEASURES ALL RADIATIVE SOURCES (NOT just feedback)

$$C_p(d\Delta T/dt) = f(t) + N(t) + S(t) - \lambda\Delta T$$

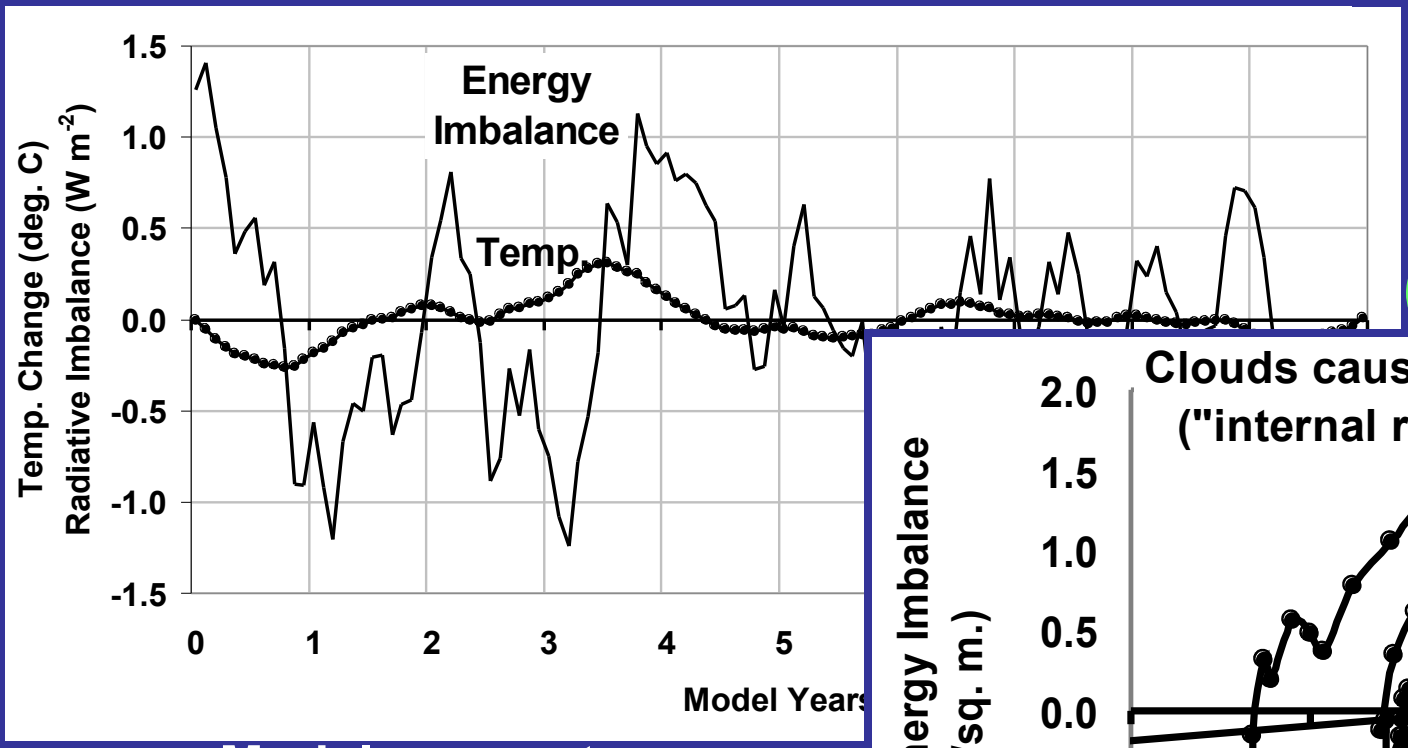
EXTERNAL RADIATIVE FORCINGS (anthro.; volcanoes; solar)

INTERNAL RADIATIVE FORCINGS (non-FB variations in clouds, mostly)

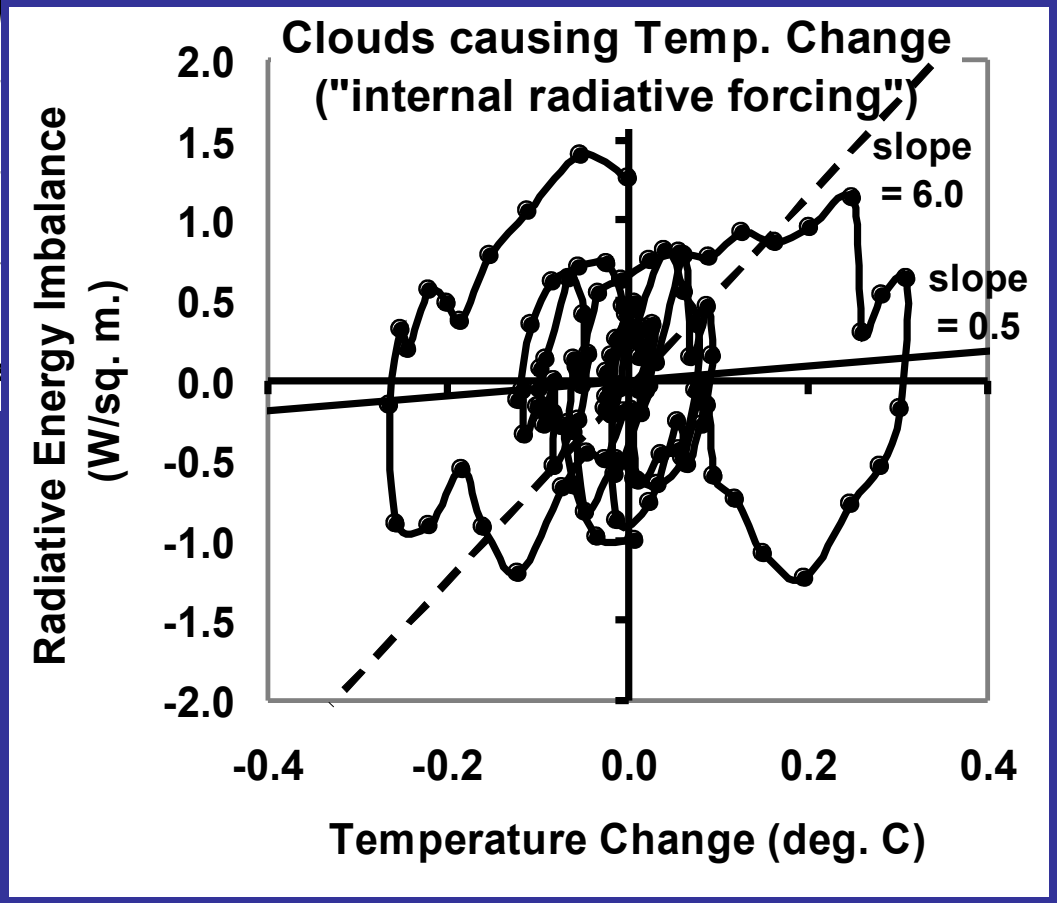
INTERNAL NON-RADIATIVE FORCINGS (vars. in ocean => atmos. convective heat flux; variations in ocean upwelling)

FEEDBACK on T chg.

SIMPLE MODEL: Clouds => Temperature (*N* term) causes LOOPING PATTERNS…



LOOPING PATTERN (uncorrelated)



Model parameters

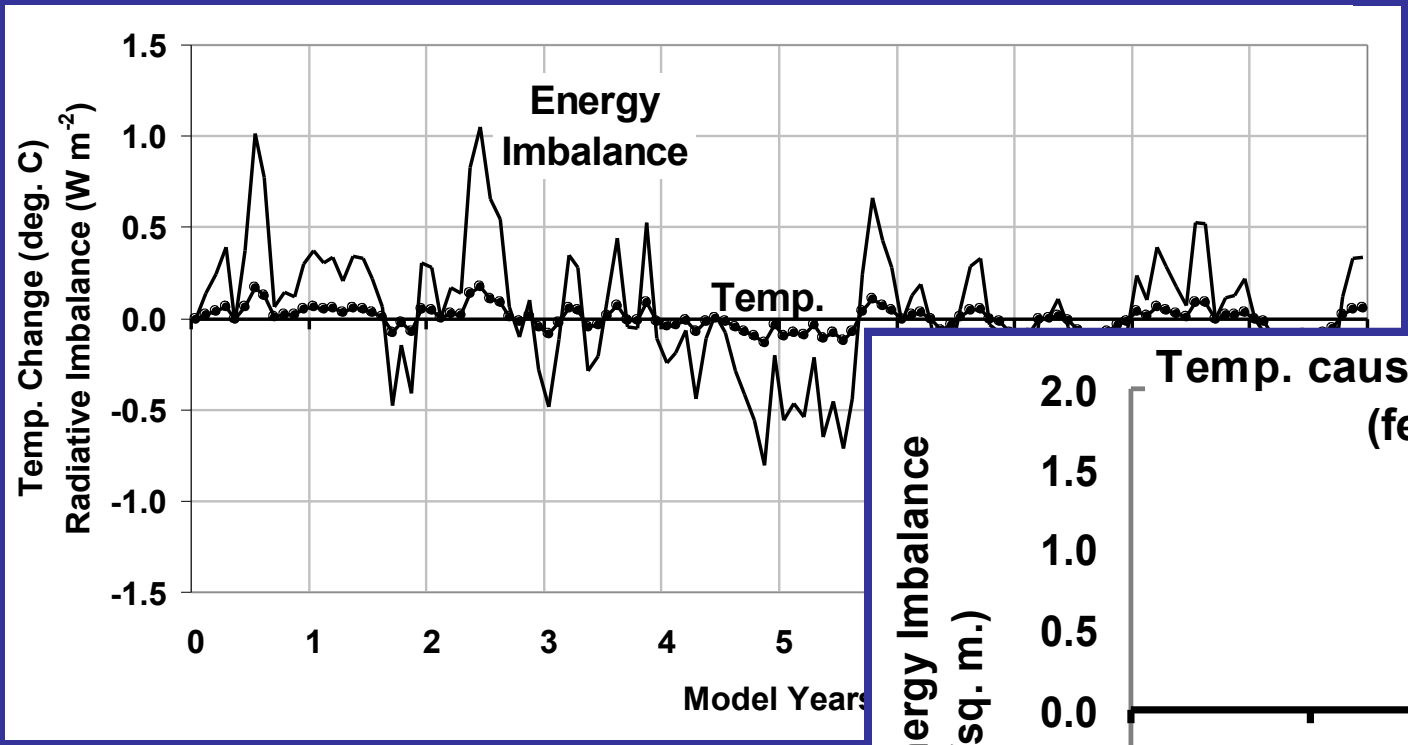
15 m mixed layer;

λ = 6 W m^{-2} K^{-1};

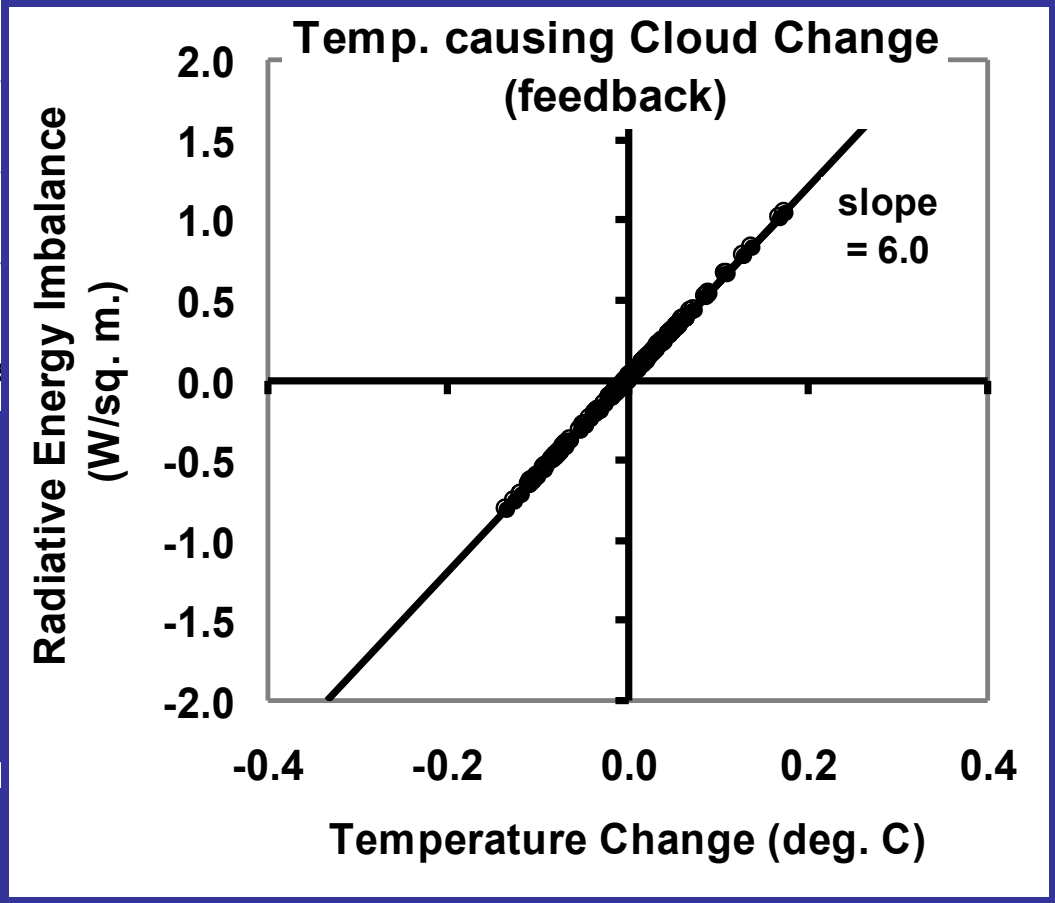
1 month time step;

forced with low-pass filtered random cloud variations ("N" term)

SIMPLE MODEL: Temperature => Clouds (*S* term) causes LINEAR STRIATIONS.



LINEAR PATTERN (correlated)



Model parameters

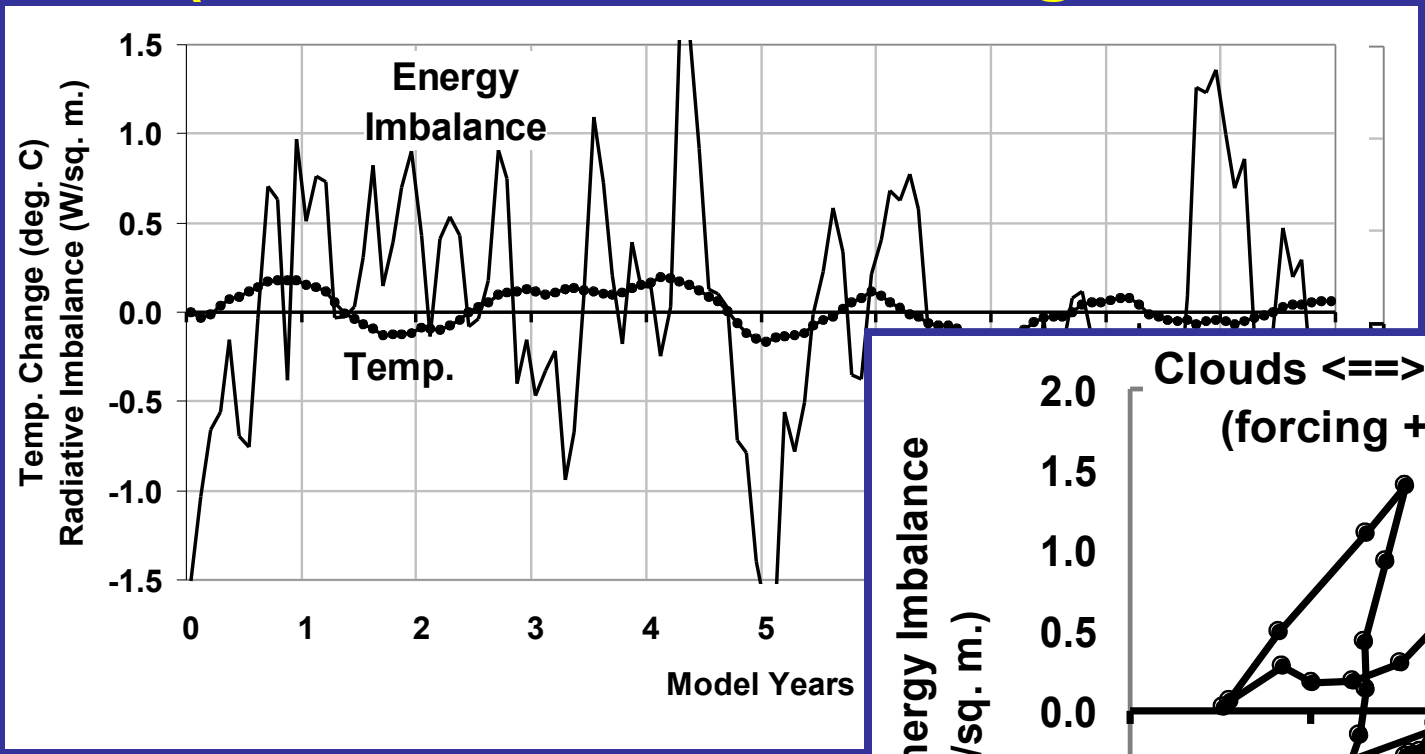
15 m mixed layer;

λ = 6 W m^{-2} K^{-1};

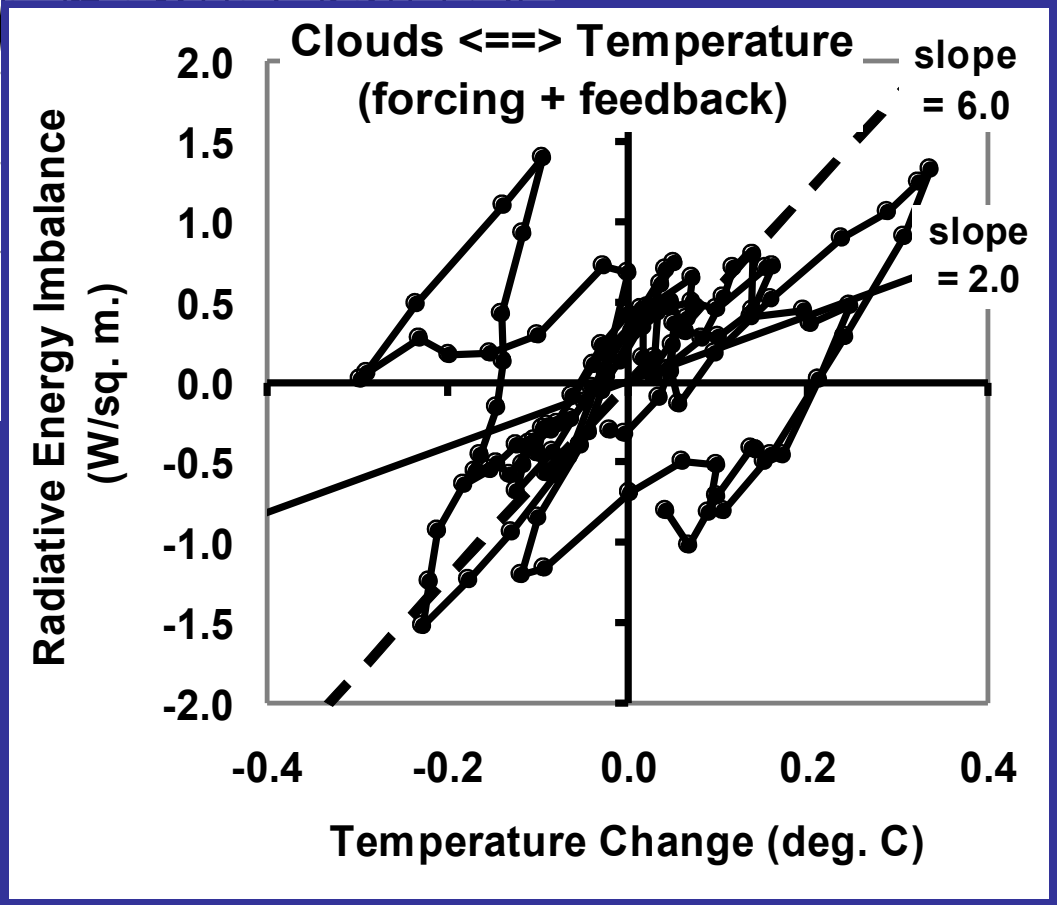
1 month time step;

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)



LINEAR & LOOPING PATTERNS



Model parameters

15 m mixed layer;

$\lambda = 6$ W m^{-2} K^{-1};

1 month time step;

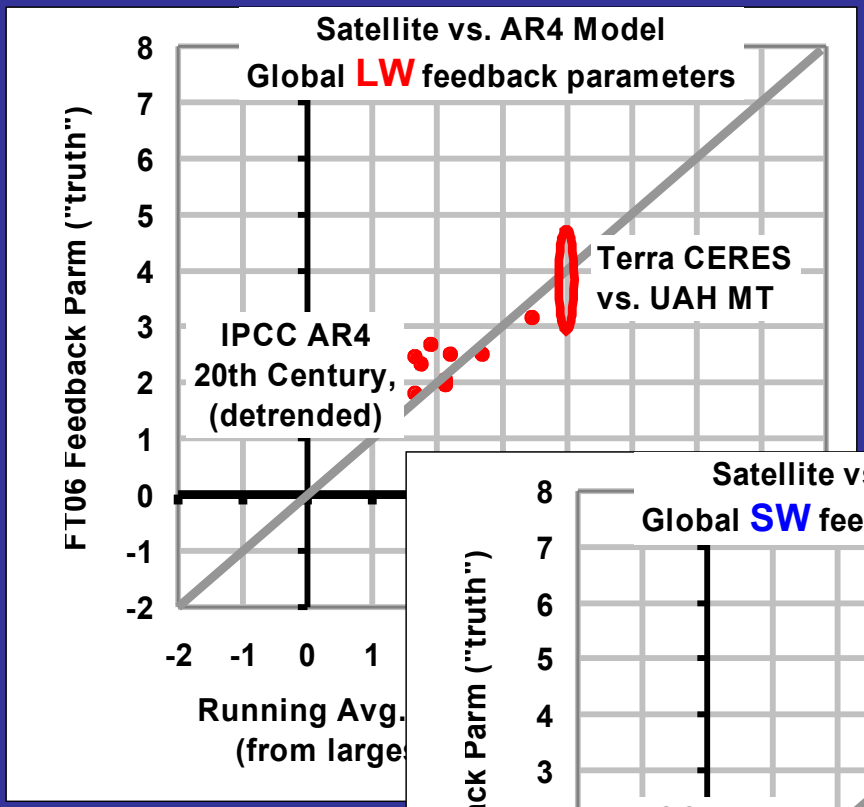
forced with low-pass filtered random cloud & T variations ("N" & "S" terms)

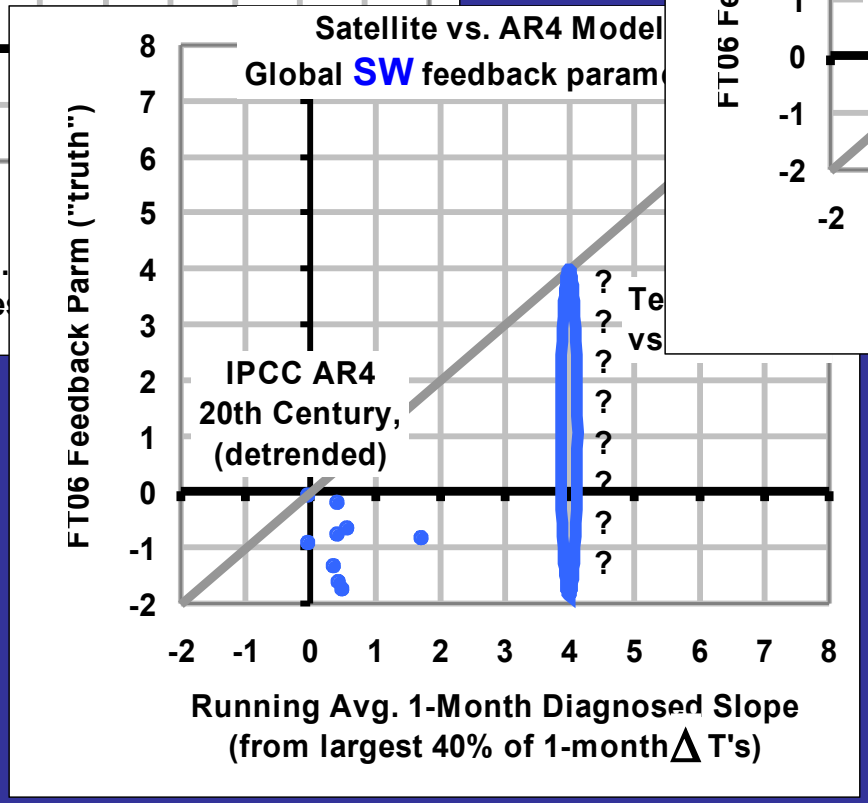
So, How Can We Better Extract Feedback "Signal" when it is Mixed in with Internal Radiative "Noise"?

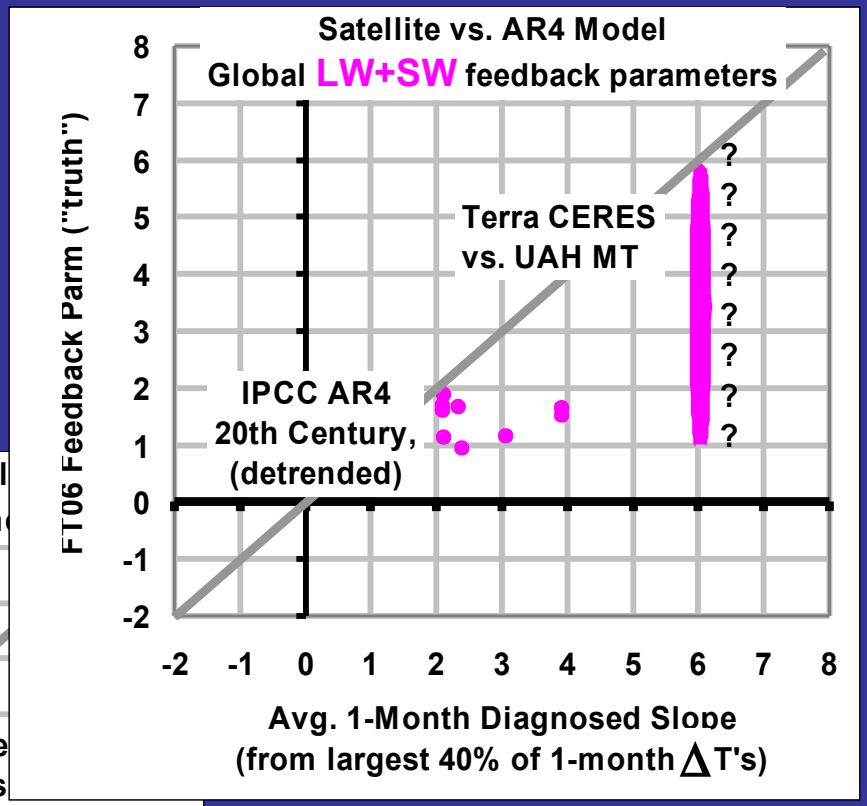
- No single best method
- My current favorite:

  Compute month-to-month slopes (e.g. Δ[LW+SW] / ΔT) for LARGEST ΔT's & then average together ("Local Slopes Analysis")

Local Slopes Analysis: CMIP Models vs. Satellite, evidence of neg. cloud feedback in satellite data?







Implications for Satellite Diagnosis of Feedbacks

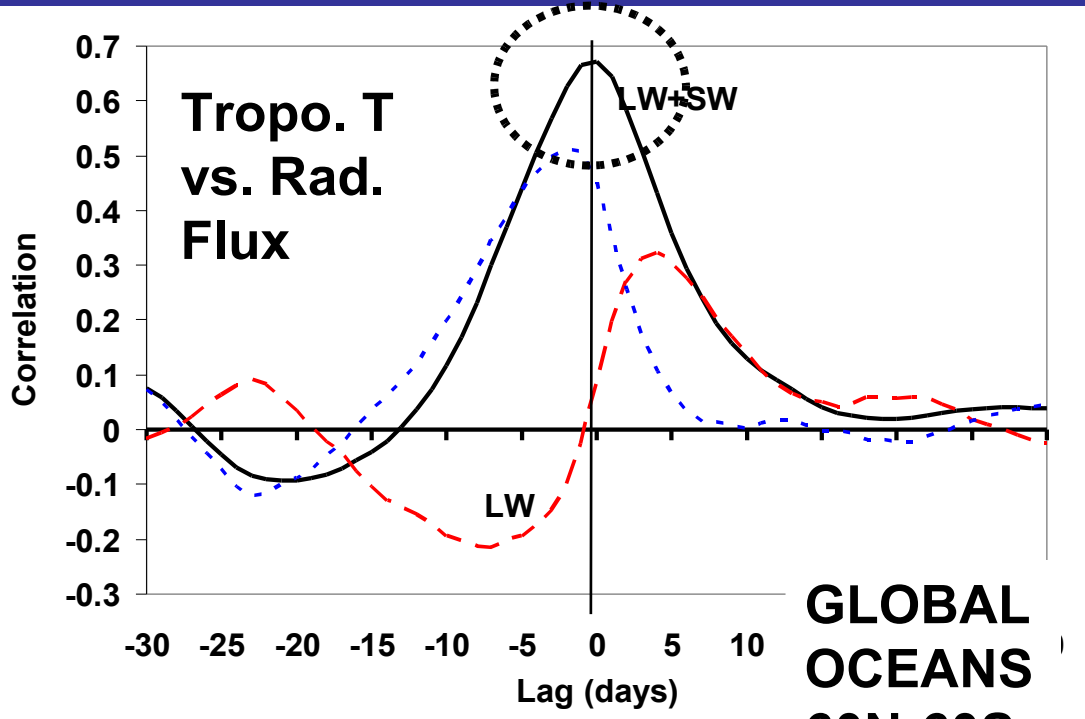
- **Feedback diagnosis MUST account for "internal radiative forcing" (which decorrelates data)**
  - **Feedback can NOT be measured when it's from time-varying radiative forcing of any kind (UNLESS known accurately and removed, e.g. CO2 forcing in a model)**
- **IGNORING internal radiative forcing leads 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:**

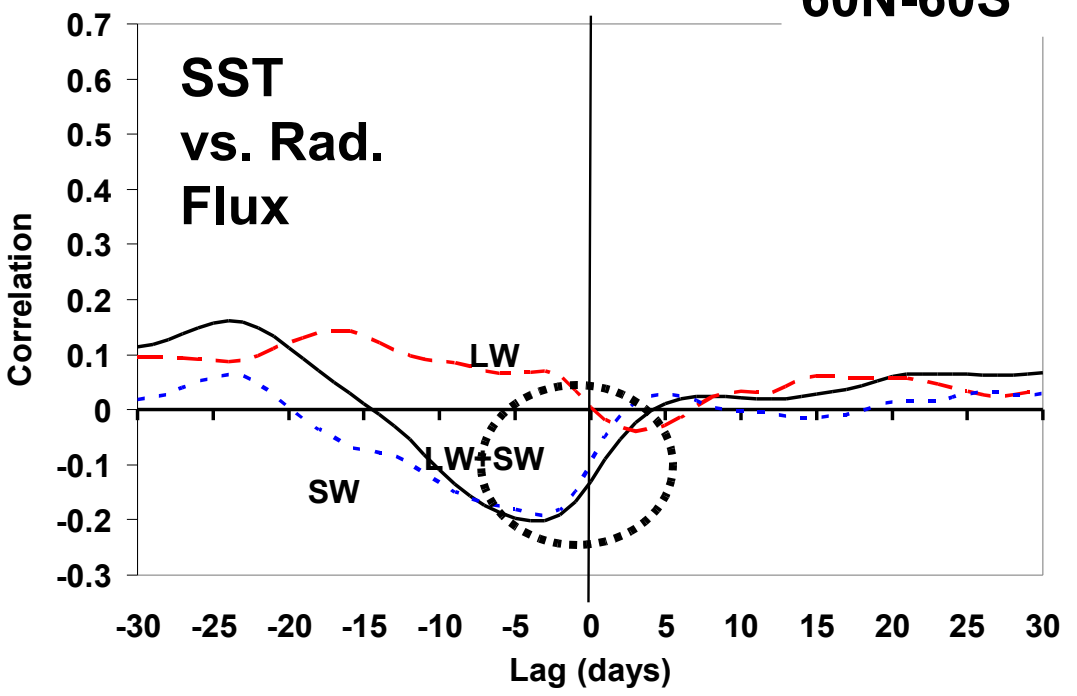
  CLOUDS <==> TEMPERATURE
  - **Previous feedback diagnoses have ignored the effect of causation in one direction: (clouds => temperature)**

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?