

CERES Climate Data Records

Role in Climate Research, Why on NPP?

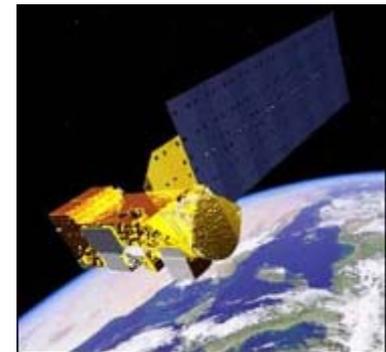


Bruce Wielicki
Feb 28, 2007

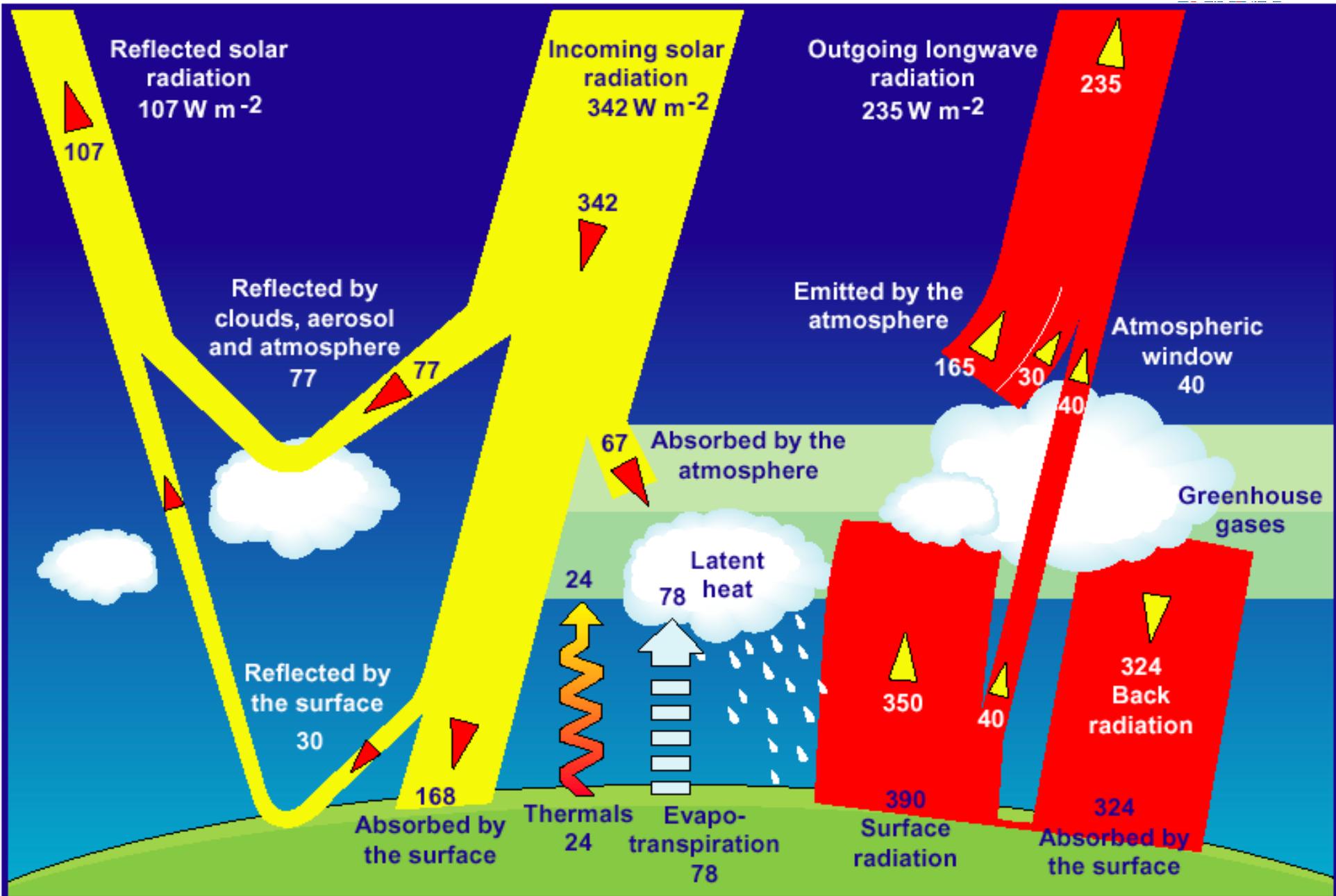


Radiation Budget

- LaRC provides critical science knowledge and Earth radiation balance data for the characterization of global climate change.
- Past ERBE and current CERES instruments on TRMM (1), Terra (2), and Aqua (2) have provided 23 years of sustained radiation budget measurements (1984 to current).
- LaRC involved in the development of the CLARREO mission concept for new solar and infrared spectral radiance climate benchmarks and for a “Climate Calibration Observatory” to raise to climate accuracy a wide range of solar and infrared spaceborne instruments.



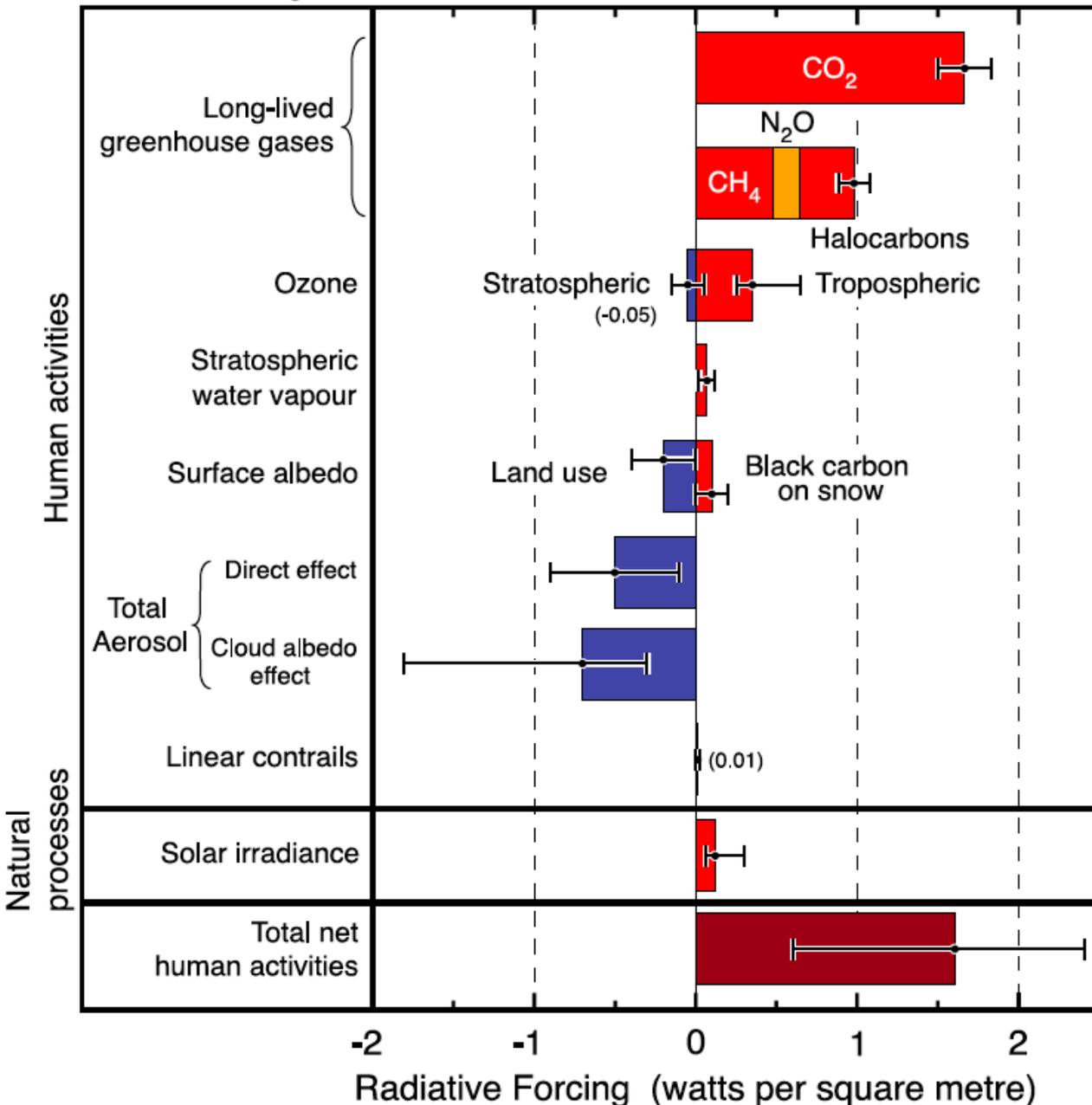
Climate System Energy Balance



Radiative forcing of climate between 1750 and 2005

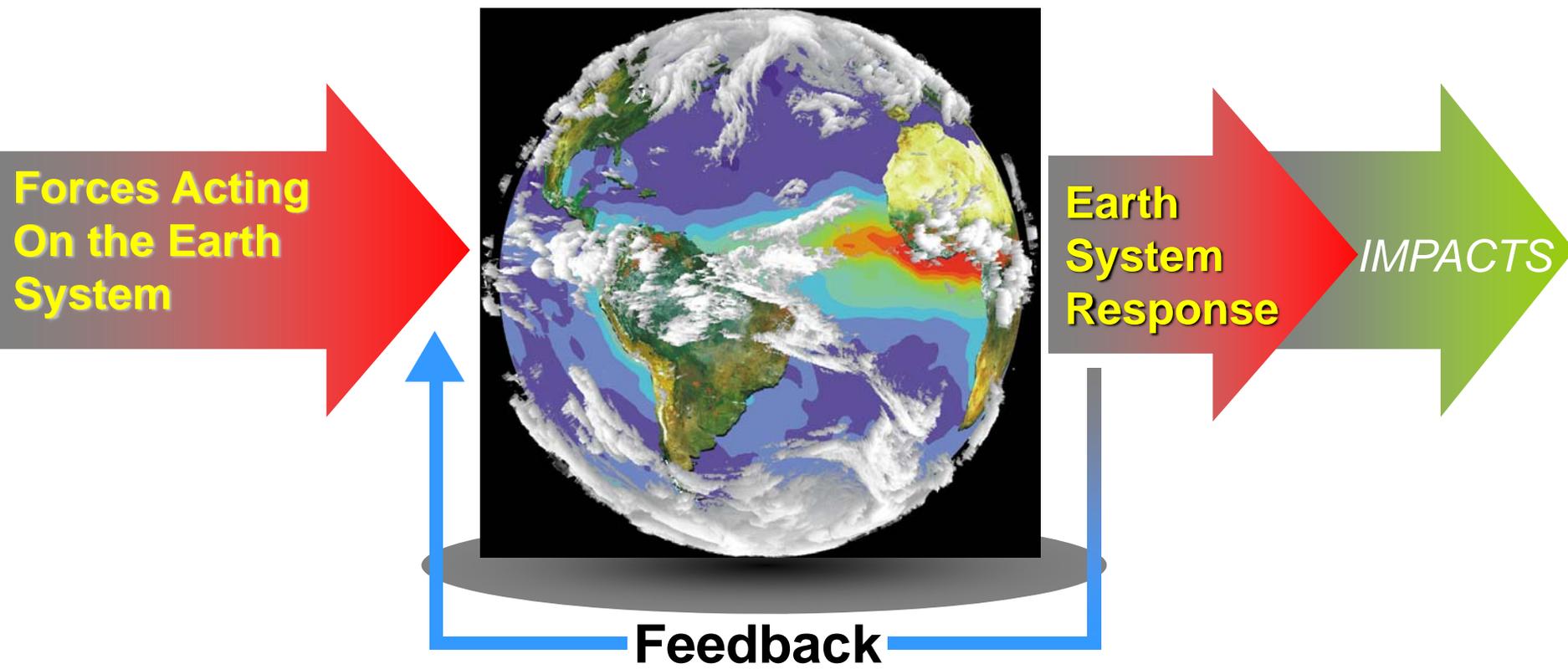


Radiative Forcing Terms



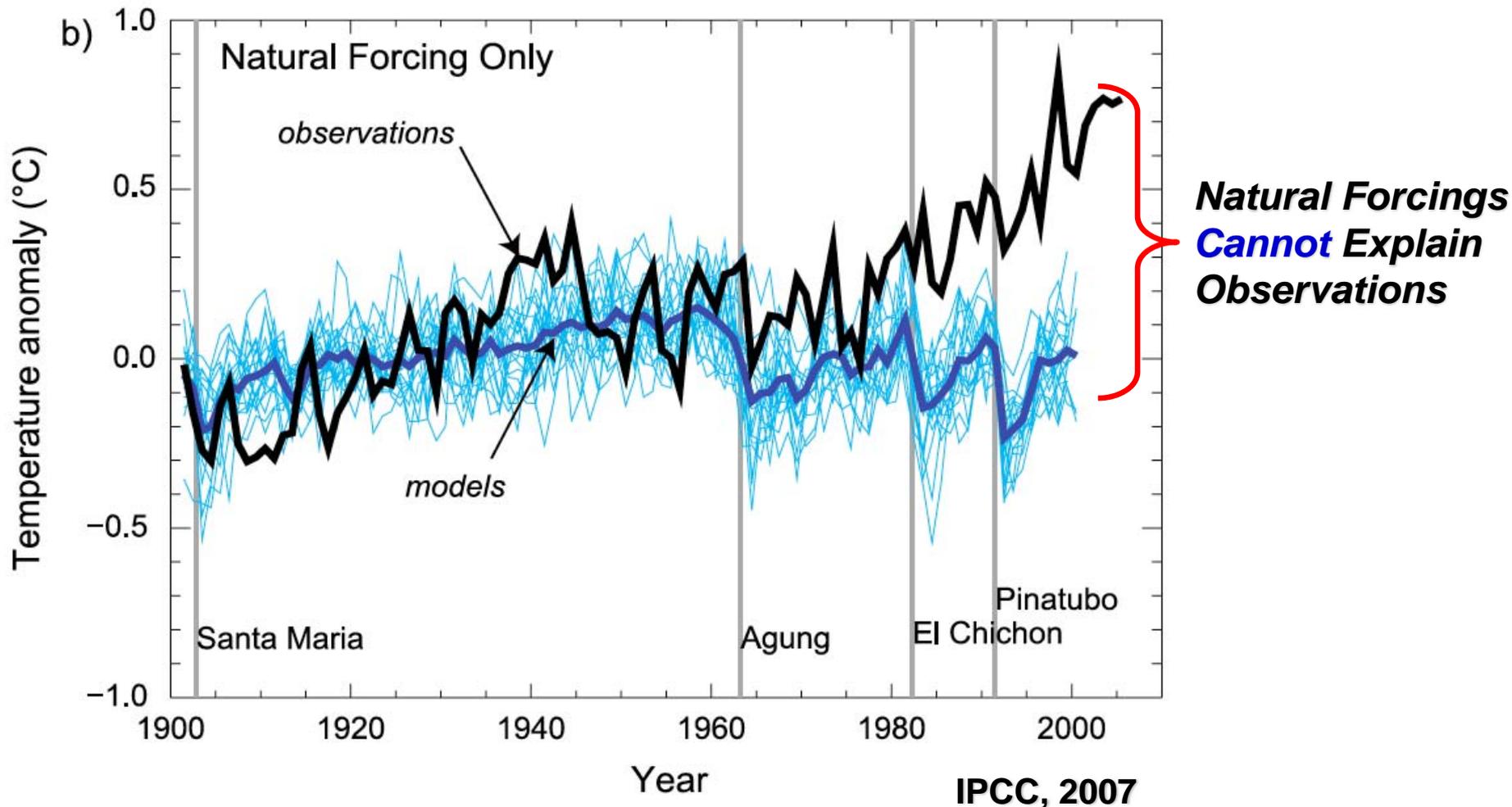
Human Radiative Forcing of Earth's Energy Balance & Climate 1750-2005

How does the Earth Respond?



Of the total forcing of the climate system, 40% is due to the direct effect of greenhouse gases and aerosols, and 60% is from feedback effects, such as increasing concentrations of water vapor as temperature rises.

What do physical climate models predict the change should be?



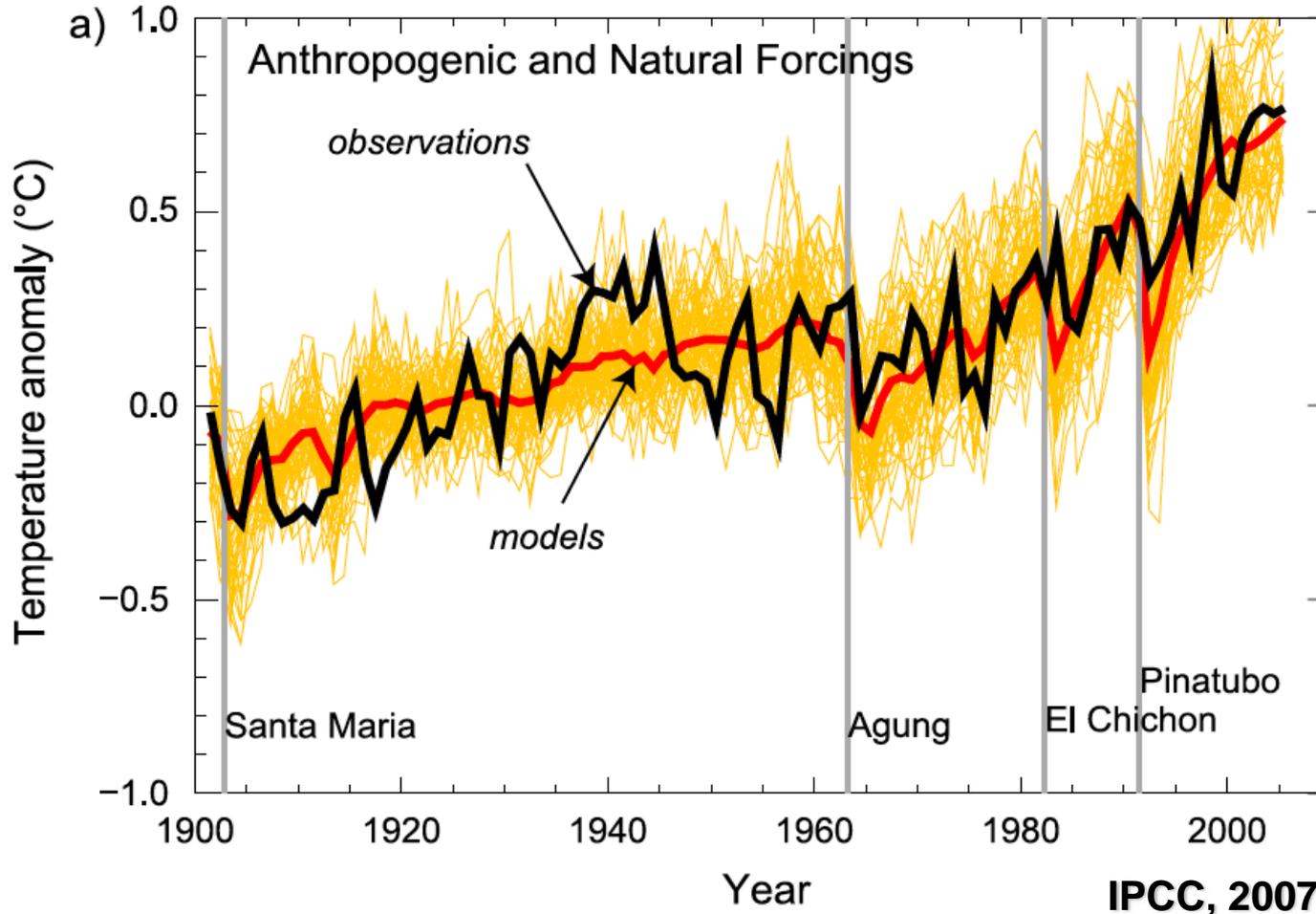
Natural Forcings: Solar, Volcanic Eruptions

Human Forcings: CO₂, Methane, Aerosols, Ozone, Land change

Climate Model Predictions: Add Human Forcing



GLOBAL MEAN SURFACE TEMPERATURE ANOMALIES

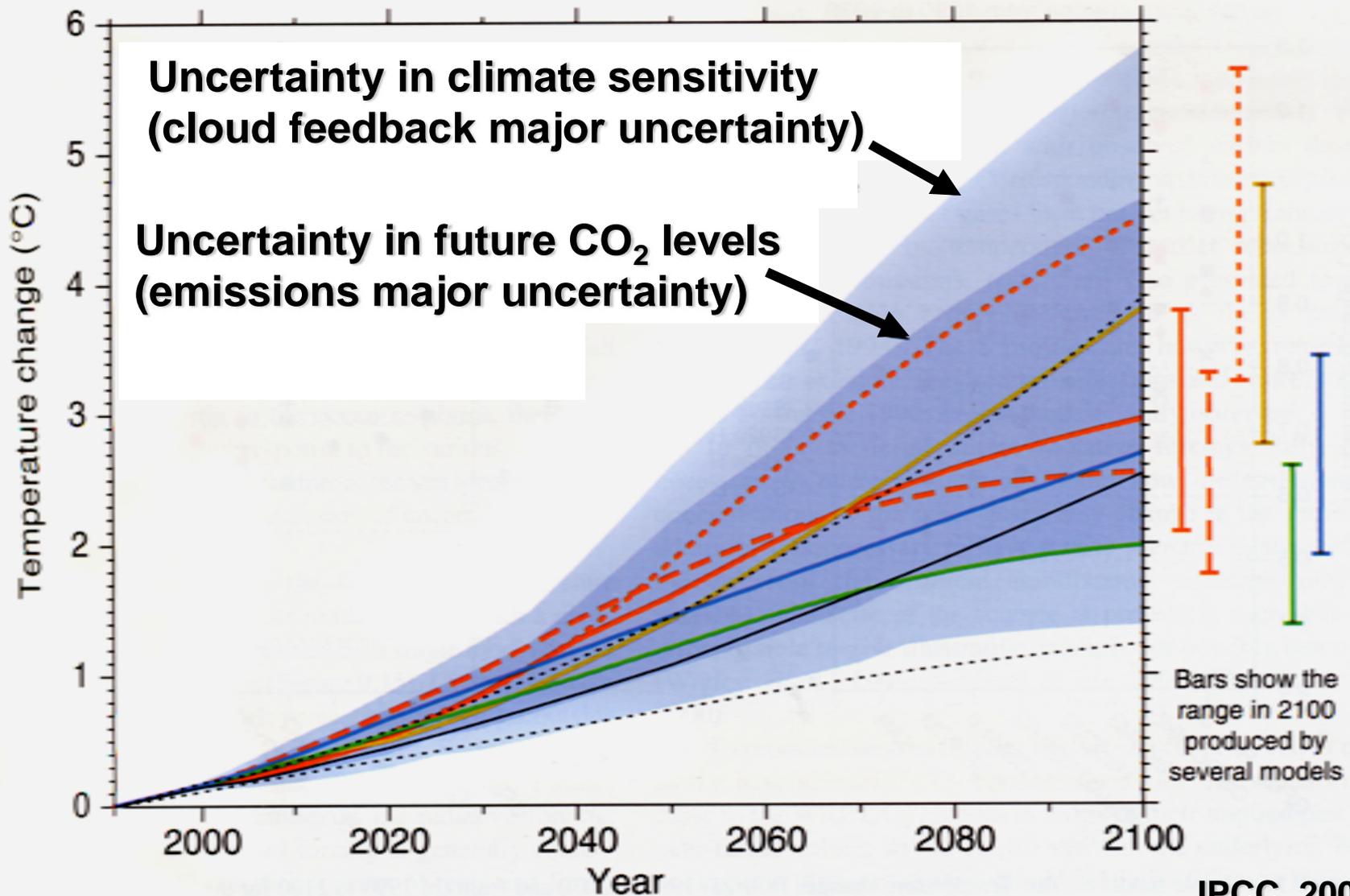


**Natural Forcings
And
Human Forcings
Do Explain
Observations**

Natural Forcings: Solar, Volcanic Eruptions

Human Forcings: CO_2 , Methane, Aerosols, Ozone, Land change

Global Temperature Predictions



IPCC, 2001

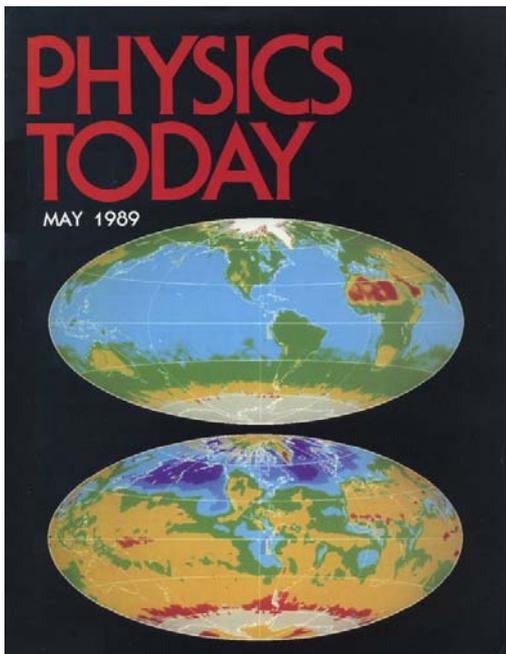
Langley Climate Data Records

Past



Climate Model "Rosetta Stone"

ERBE Cloud Radiative Forcing



Ramanathan et al., 1989

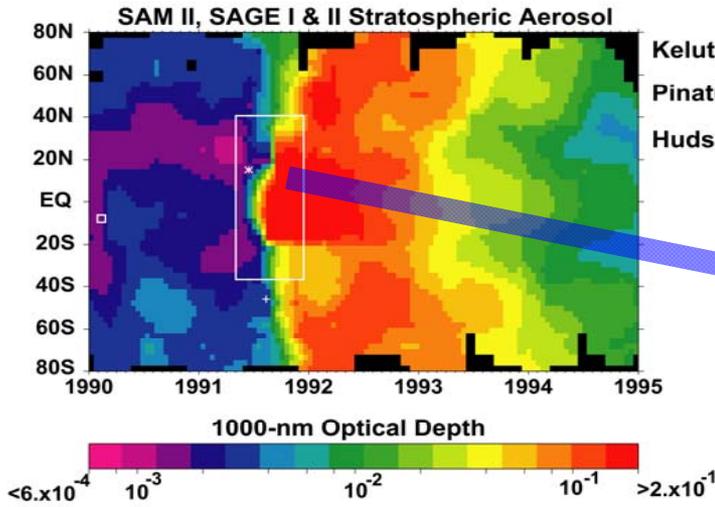


Ramanathan et al., 1989
Harrison et al., 1990

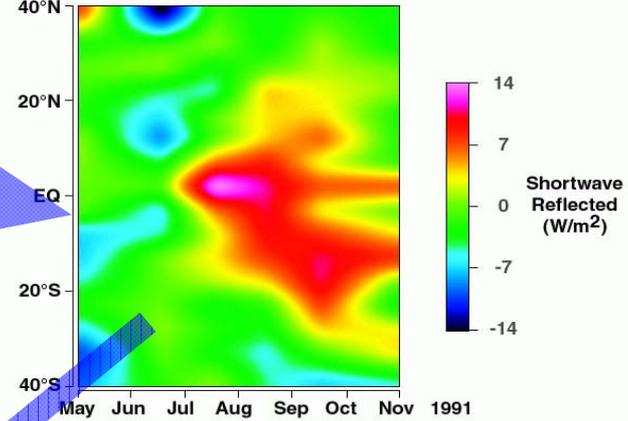
- First separation of planetary energy budget to isolate effects of clouds
- Change in cloud radiative forcing with global temperature = cloud feedback
- Demonstrated cloud feedback uncertainty in climate models



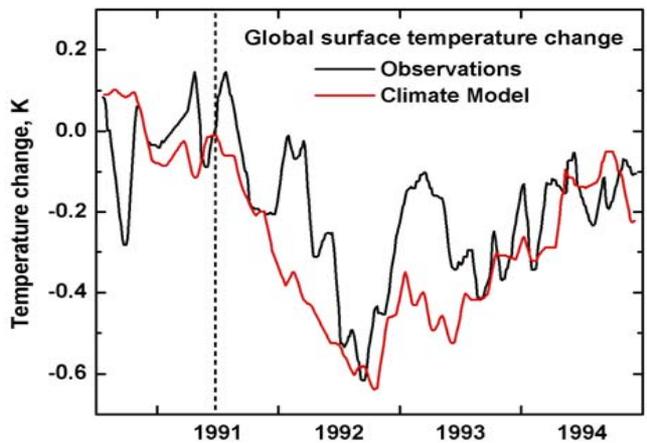
How did the Mt. Pinatubo Eruption Affect Climate?



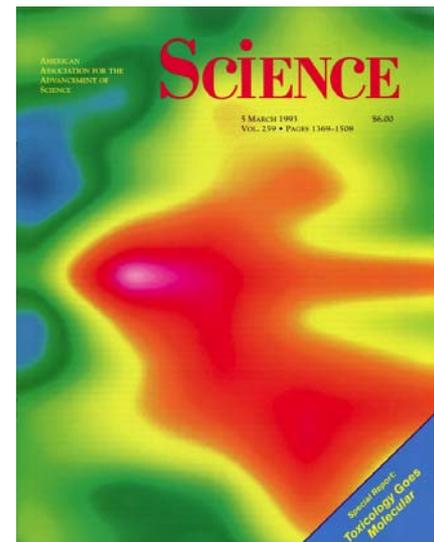
ERBE Observed That Mt. Pinatubo Aerosols Increased Solar Reflected Radiation



Radiative Cooling

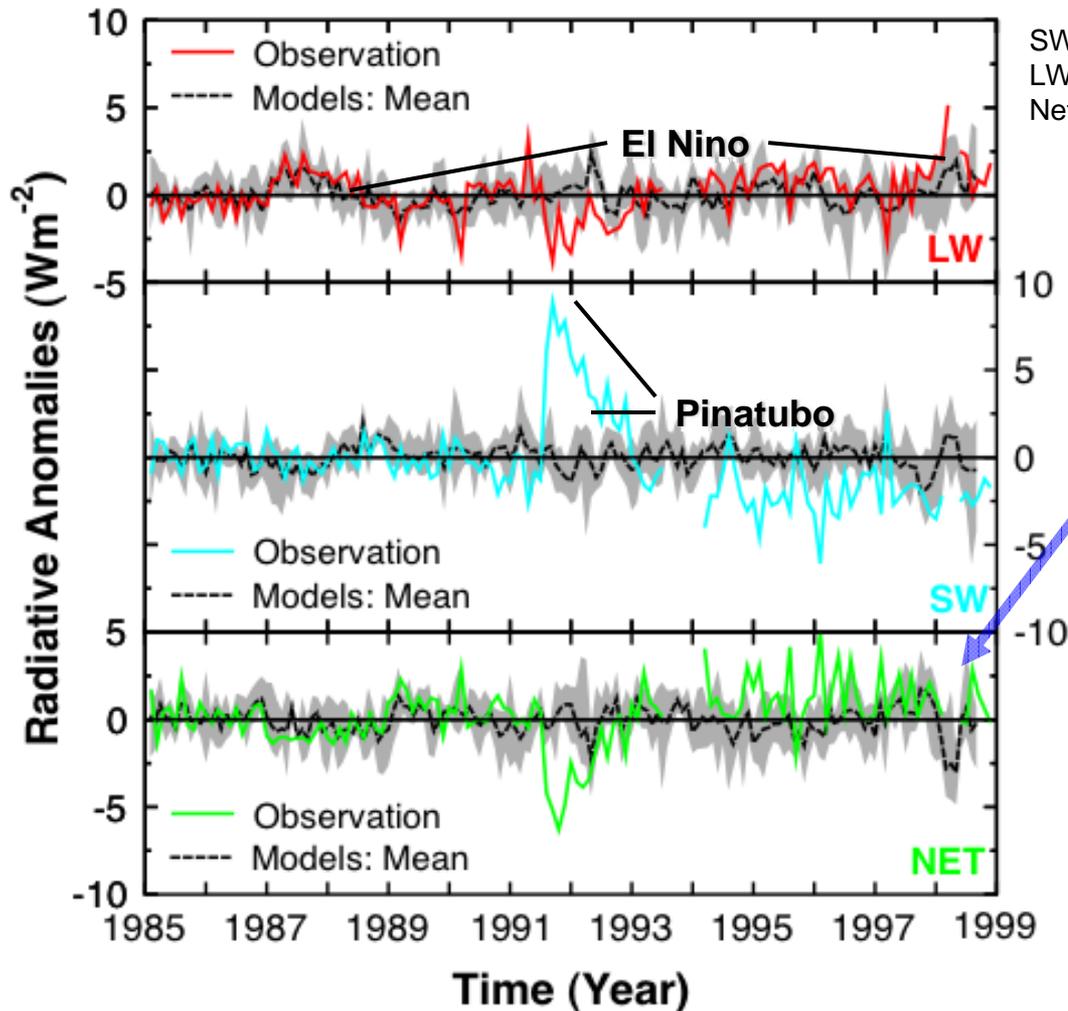


Hansen et al., 1993



Minnis et al., 1993

Surprising Findings: Tropical Earth Radiation Anomalies



SW = solar energy reflected to space
 LW = Earth thermal energy emitted to space
 Net = solar insolation - solar reflected - thermal emitted

Net heating of the tropics in the 90s versus the 80s was $\sim 1.5 Wm^{-2}$. Why?

- ocean heating?
- poleward transport?
- still a mystery... not clear ocean heating & transport data sufficiently accurate.



Wielicki et al., Science 2002
 Wong et al., J. Climate 2006

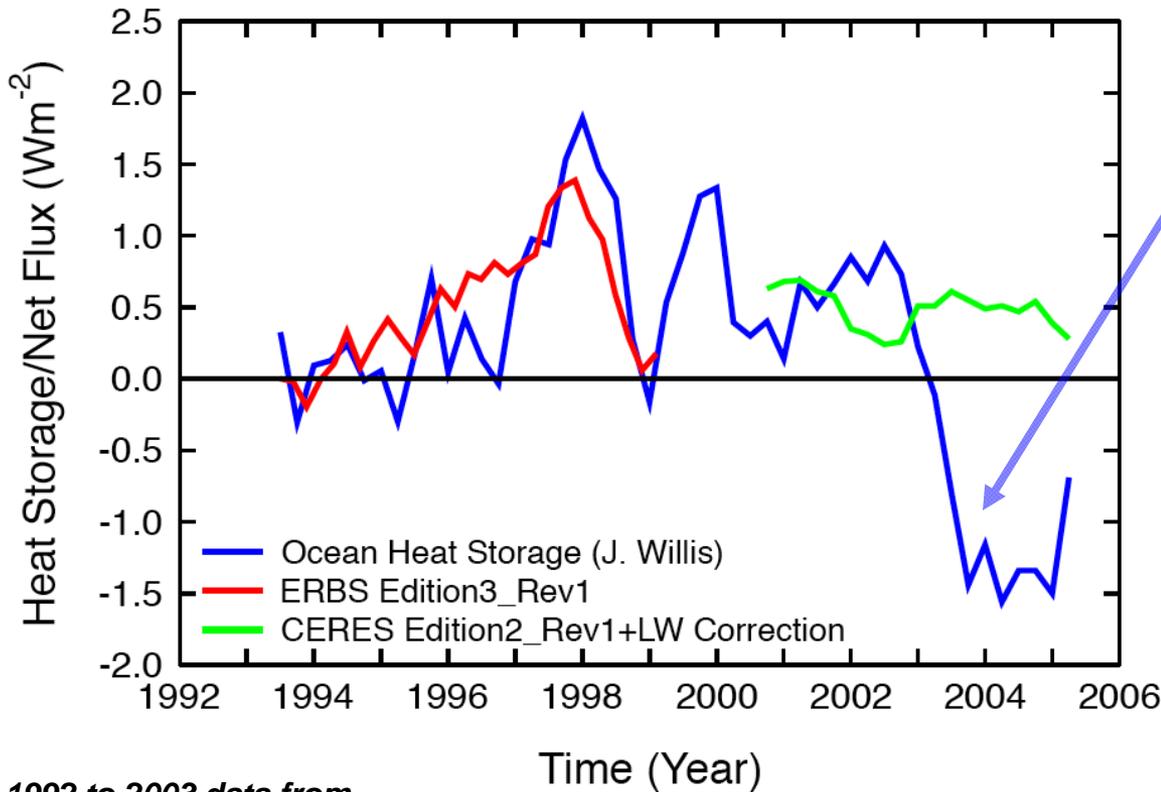
Langley Climate Data Records



Current



Does recent global ocean cooling mean NO global warming?



Recent Ocean Cooling?
Lyman et al., Science 2006



1992 to 2003 data from
Wong et al. J. Climate 2006

Net Radiation (CERES): No
Altimeter Sea Level: No
GRACE Ice Sheet: No



Does recent ocean cooling mean NO global warming?

Answer: No. Results came from small biases in ocean in-situ data between old observation system (XBT) and transition to new system (ARGO) after 2002, biases of only ~ 0.01 deg C.

Willis et al., 2007 GRL

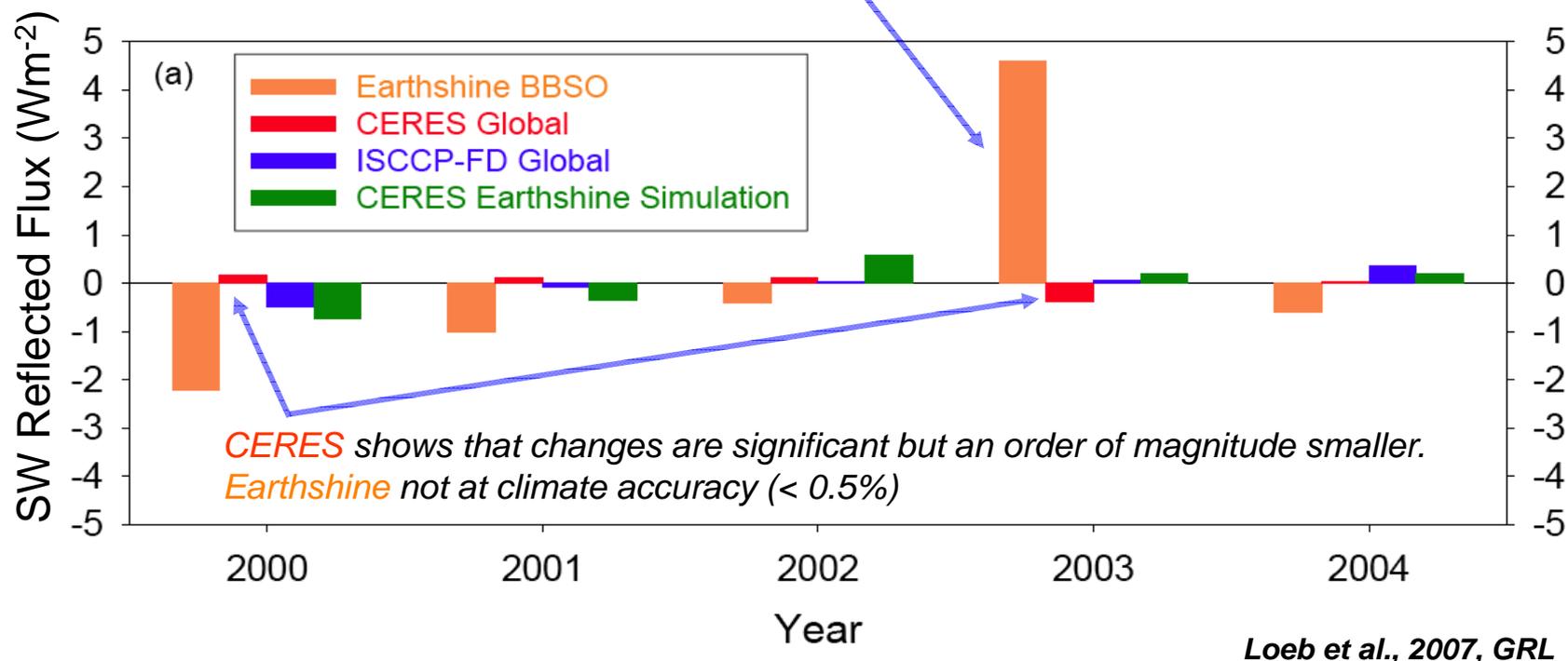
- *Ocean Warming in 2003-2005 similar to average warming over 1993-2003.*
- *Remains consistent with ocean heating predicted by IPCC climate models.*

***We must have independent observations
at climate accuracy.***



Earthshine: High Accuracy is Critical

Earthshine data implies a huge change of 6 Wm^{-2} in global reflected SW flux:
is the Earth's albedo changing? *Palle et al., Science, 2004*



Anthropogenic radiative forcing = 0.6 Wm^{-2} / decade, global average SW flux = 100 Wm^{-2} .

Extremely high accuracy is critical.



Data Fusion for Climate Data

CERES is Leading the Way

Input Data

CERES Cross-track Broadband

CERES Hemispheric Scan ADMs

MODIS Cloud/Aerosol/Snow and Ice

Microwave Sea Ice

MATCH Aerosol Assimilation

GEOS 4-D Assimilation Weather
(fixed climate assimilation system)

Geostationary 3-hourly Cloud

Consistent Intercalibration

Output Data

ERBE-Like TOA Fluxes (20km fov, 2.5 deg grid)

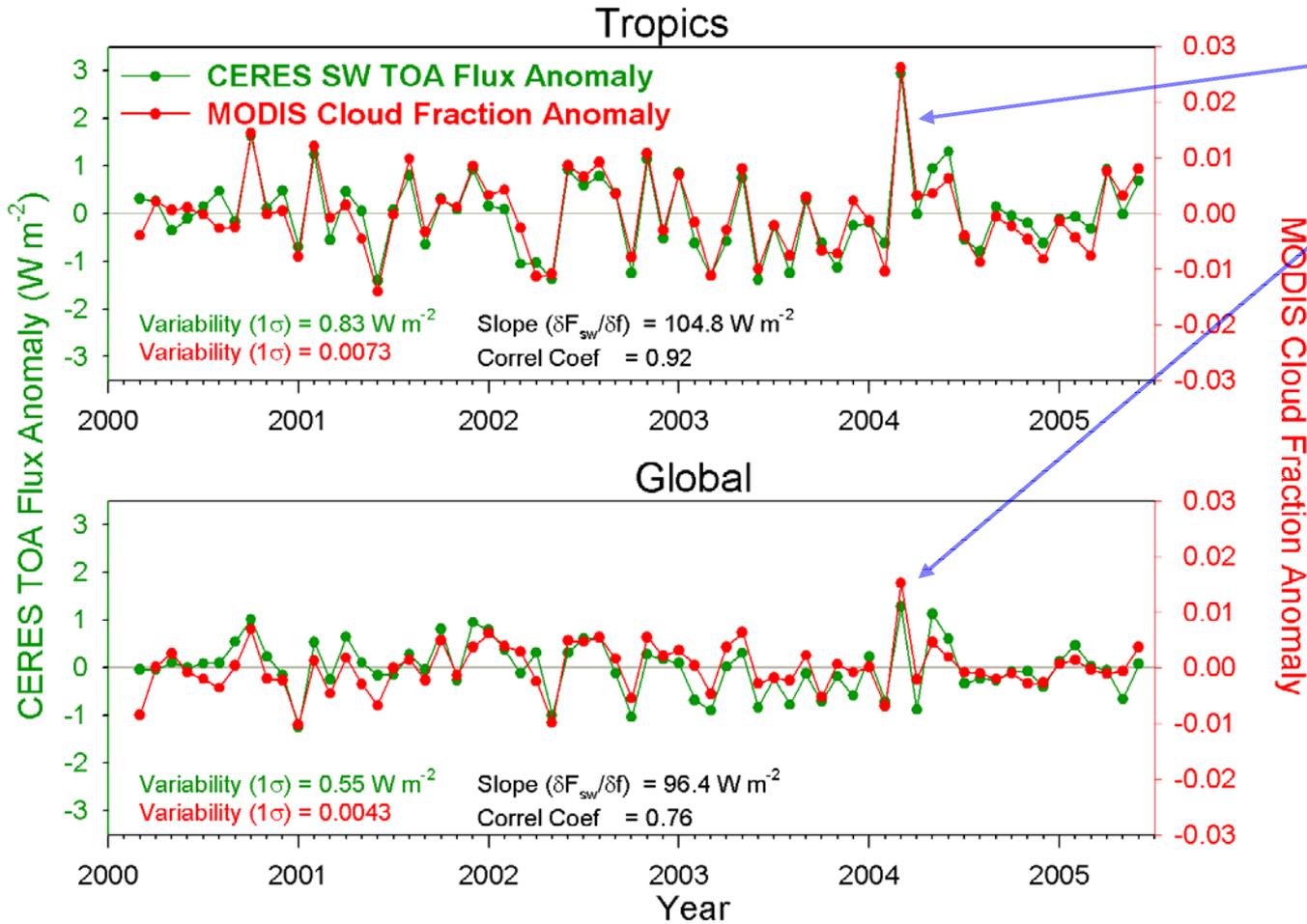
CERES Instantaneous TOA/Sfc/Atmosphere Flux

- 20 km fov (SSF, CRS products)
- 1 degree grid (SFC, FSW products)
- Fluxes, cloud and aerosol properties

CERES Time Averaged TOA/Sfc/Atmosphere

- 3-hourly, daily, monthly
- 1 degree grid (SRBAVG, AVG, ZAVG products)
- Fluxes, cloud and aerosol properties

What drives changes in global albedo?

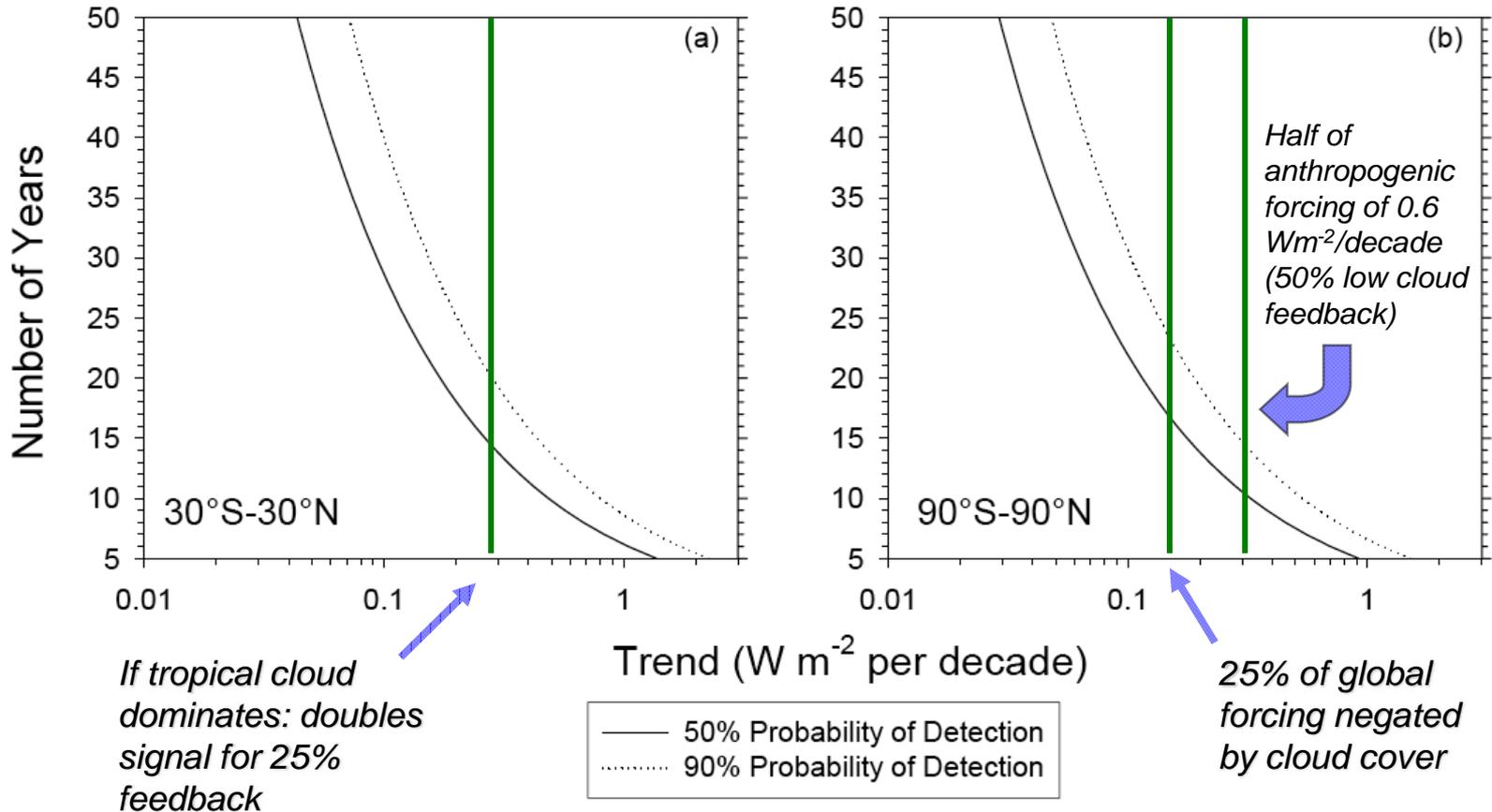


The Tropics drive global albedo variations: global is in phase with tropics and half the magnitude

Cloud fraction variations are the cause, not cloud thickness



Cloudiness Trends Changing Earth's Energy Balance: How long will it take to observe a 25% cloud feedback? *i.e. change in clouds amplifies or negates 25% of anthropogenic forcing*



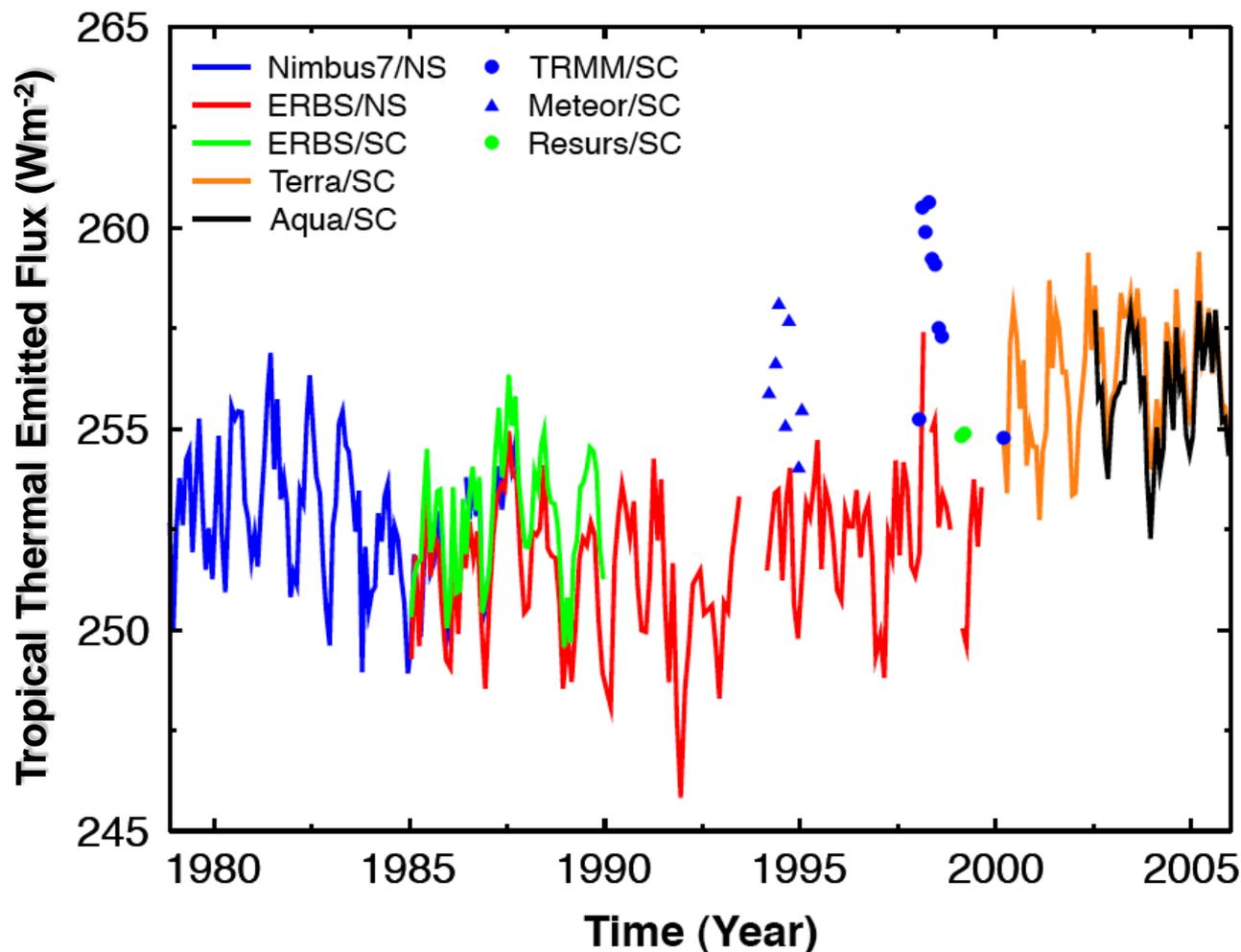
Given climate variability, 15 to 20 years is required to first detect climate trends at 25% cloud feedback level with 90% confidence.

Why Overlapping Climate Data Records?

Absolute Accuracy Inadequate!



Overlapping Climate Data Records is Critical



Anthropogenic radiative forcing of climate is $\sim 0.6 \text{ Wm}^{-2}$ per decade



Goal $\sim 0.15 \text{ Wm}^{-2}$ per decade



1.2 Wm^{-2} calibration accuracy: current best capability (e.g. CERES)

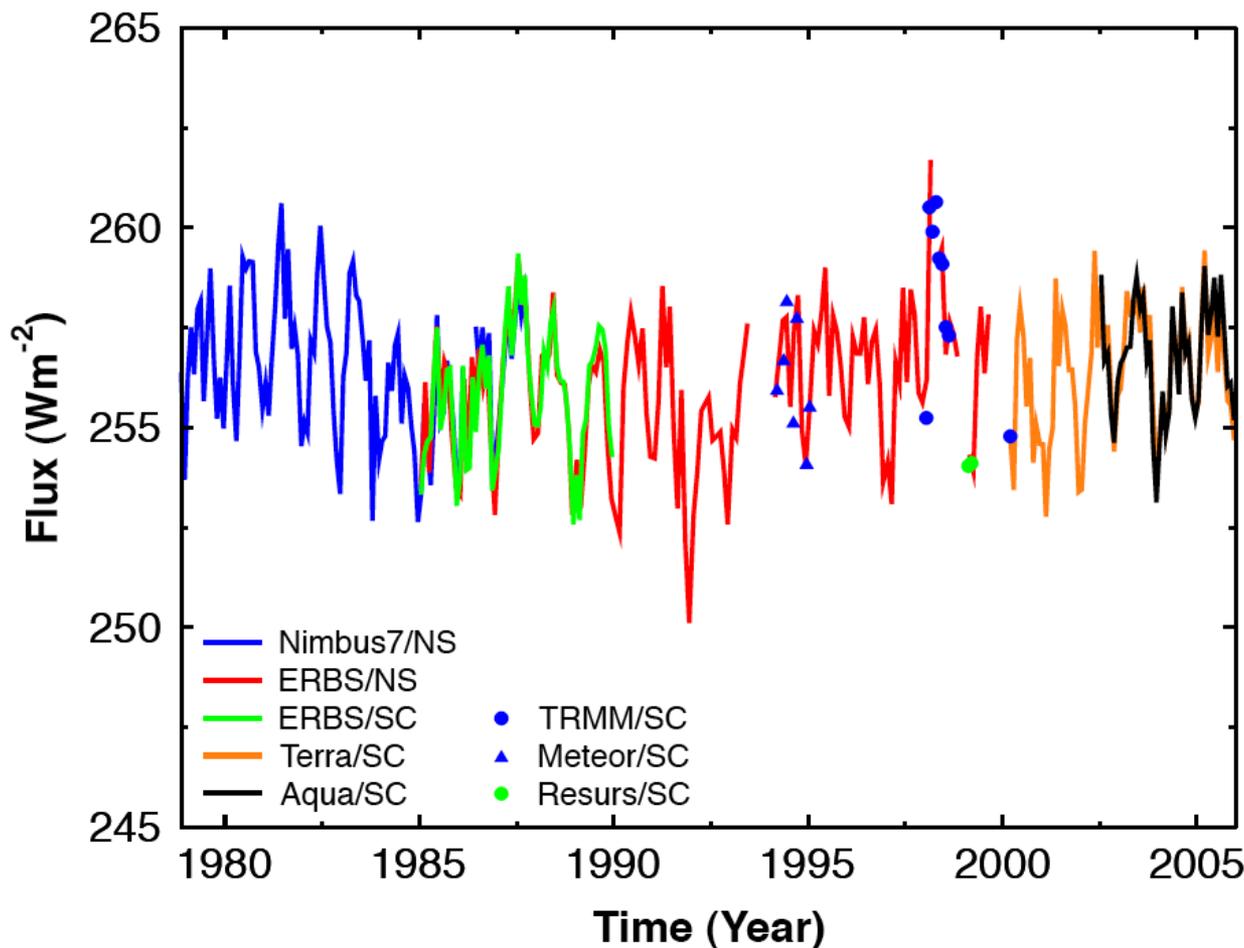


Why Overlapping Climate Data Records?

*The overlapped intercalibrated climate data record:
allows reliance on stability, not absolute accuracy*



Tropical Mean (20N to 20S) Outgoing Longwave Radiation
with Overlap Adjustment



**Anthropogenic
radiative forcing of
climate is $\sim 0.6 \text{ Wm}^{-2}$
per decade**



**Goal $\sim 0.15 \text{ Wm}^{-2}$
per decade**



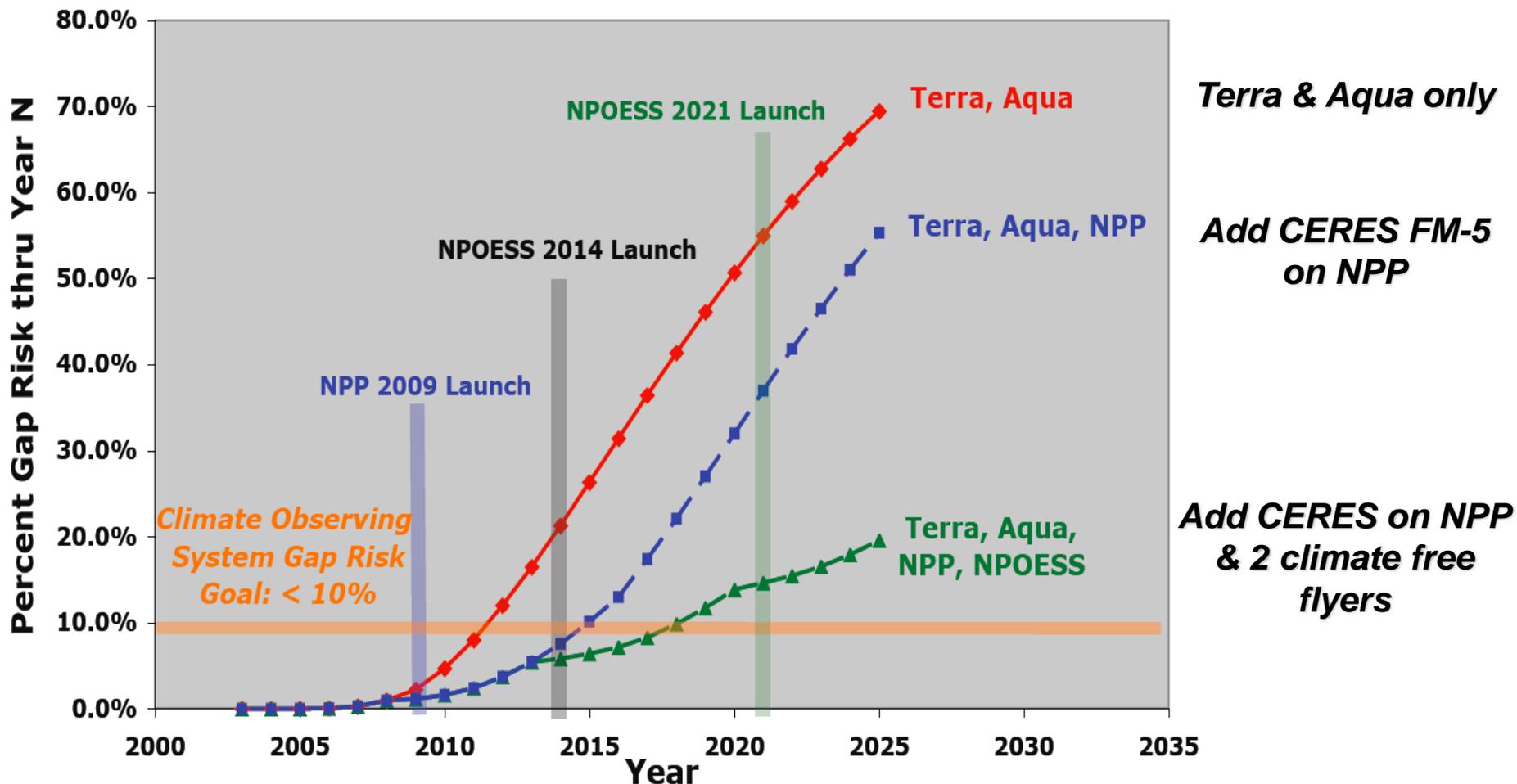
**1.2 Wm^{-2} calibration
accuracy: current
best capability
(e.g. CERES)**





What is the Radiation Budget Gap Risk?

3 future scenarios: NPP and Climate Free-flyers



Gaps start the climate data record back at zero.

Langley Climate Data Records



Future





Summary

- Langley has a long history of leading climate data records
- 8 - dimensional sampling "universe" for climate radiative energy balance
- Fusion of multiple satellite instruments key to 8-D sampling, cause/effect
- 15 to 20 year climate data records to exceed climate "noise"
- Decadal change is the key "prediction" of climate models
- Cloud Radiative Forcing change (CERES) = cloud feedback, the largest IPCC climate sensitivity uncertainty
- Absolute accuracy decadal change is 0.1 to 0.2%
- Currently use stability/overlap because absolute accuracy of current satellite instruments insufficient (0.5 to 5%). For example: CERES reflected SW: 1% or 1 Wm^{-2} , emitted LW: 0.5% or 1.2 Wm^{-2} of flux.
- Independent multiple observations are key to resolve surprises
- Cannot go back in time to "re-measure and verify" as in laboratory experiments
- ***Flying CERES FM-5 copy on NPP key to continuing climate data record: eliminate data gap. CERES-II long term.***
- ***CLARREO calibration of climate observations key to reduce future sensitivity to data gaps but likely 2015 to 2017 launch.***



Summary, con't

- U.S. public climate epiphany is reaching the tipping point: beyond 50%
- Congress passed the tipping point a year ago
- All 3 next president candidates: McClain, Obama, Clinton strongly endorse climate change action
- NASA likely to focus more on earth science and climate in the next administration/congress
- NPP is currently caught in the old vision of EOS to NPOESS and has not yet stepped up to full support for a full suite of climate data records.
 - Likely to change in 1 to 3 years (before or near launch).
 - LaRC, GSFC, and NOAA collaboration will increase as will funding levels for climate observations, modeling and general research.
 - We need to be aware that NPP's value to the climate observation system will grow over time, as will efforts to improve the accuracy, quality, and completeness of its climate data records.
 - Adding CERES to NPP is the first step in this direction.
- Looking forward to a growing collaboration of LaRC, GSFC, and NOAA (e.g. CLASS) on NPP, realizing that NPOESS and current budget limits drive many short term challenges
- We want to thank GSFC for their strong support of the increasing climate focus of NPP.