GEWEX Radiation Panel

Frascati, Italy, 9-13 October 2006

CERES Overview

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Outline

- NPOESS & NPP Update
- CERES, SeaWIFS, ISCCP, Earthshine, Ocean Heat Storage Comparisons
- TOA and Surface Flux Error Estimates
- Cloud Radiative Forcing by Dynamic State
- CERES Data Products Update

CERES NPP & NPOESS Update

NPOESS:

- Recent review of NPOESS resulted in significant scale-back of climate capabilities due to cost and schedule problems (e.g., OMPS Limb, TSIS, ERBS, ALT, APS).
- Current plan is to fly CERES FM-5 on NPOESS C1 in 2014. Budget has yet to be determined.
- CERES gap risk with Terra/Aqua transition to NPOESS (2014 launch of CERES FM-5) is 60% or more through 2025. Climate goal is 10% (Ohring et al., 2005).

NPP:

- No technical or schedule challenges to putting CERES FM-5 back on NPP for a launch in late 2009.
- CERES gap risk is reduced by a factor of 2 with FM-5 on NPP and ERB sensor on NPOESS in 2014 and 2021. More engineering work is needed to quantify gap risks beyond 7 years.
- Recommendation: The remaining CERES instrument (FM-5) should be moved from C1 to NPP to provide for the necessary overlap with the present CERES instruments and to ensure data continuity of this measurement.

Current Status: NASA submitted a white paper for the Office of Science and Technology Policy (OSTP) to assess the impacts of the review.

The scientific challenge of understanding and documenting climate variability and change

- **Anticipating climate sensitivity in response to anthropogenic radiative forcing well in advance of the actual trend requires an observing system that measures the most relevant climate variables with a high degree of precision.**

- **The largest uncertainty in global climate sensitivity over the next century is cloud feedback.**

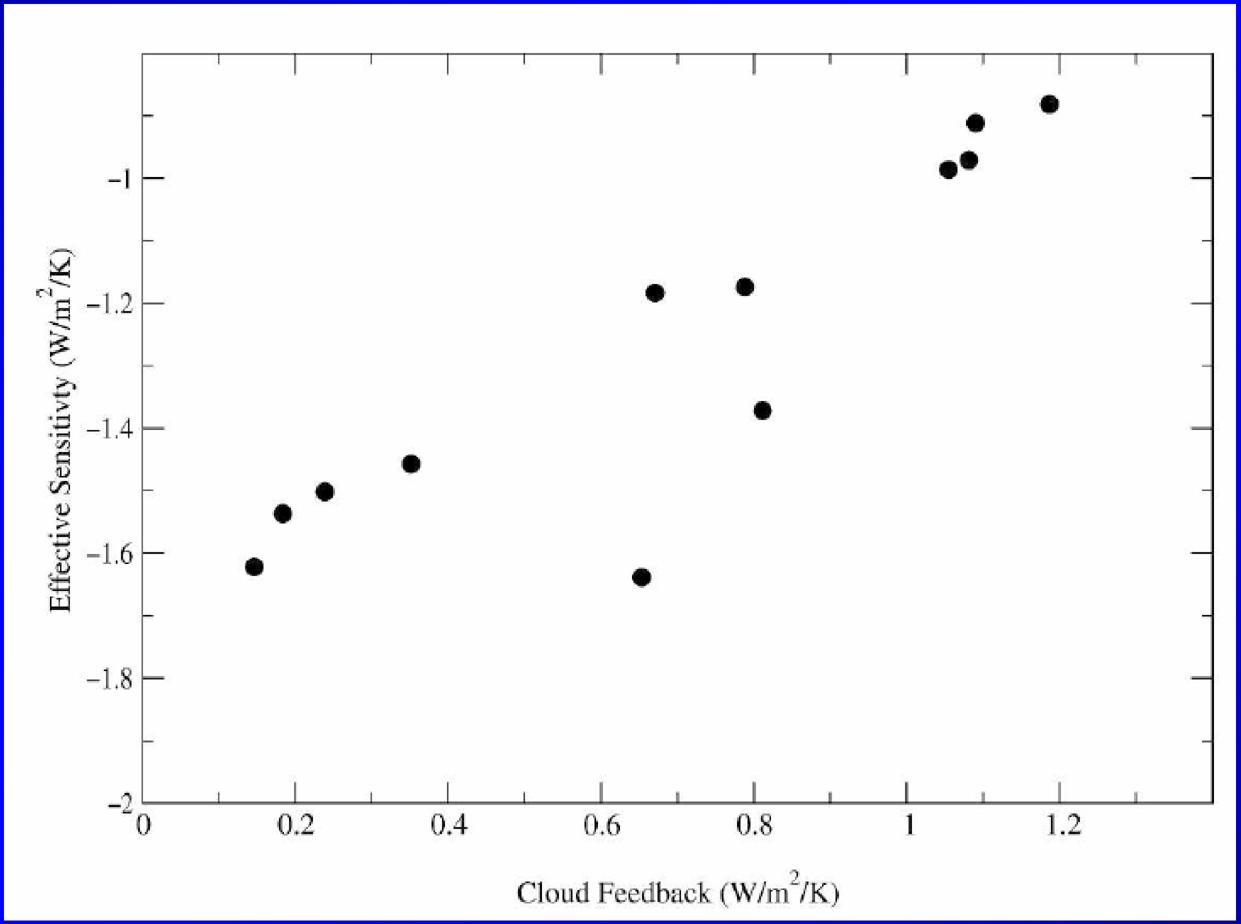
  - **A global cloud feedback of 25% would amplify or dampen global warming by 25%.**

  - **Global cloud feedback is linear in changing cloud radiative forcing (CRF) (Soden and Held, 2006).**

  - **This implies that changes in net CRF are directly related to climate sensitivity.**

  - **A global cloud feedback of 25% translates into a 0.3% per decade requirement in SW broadband calibration stability (Ohring et al., 2005).**

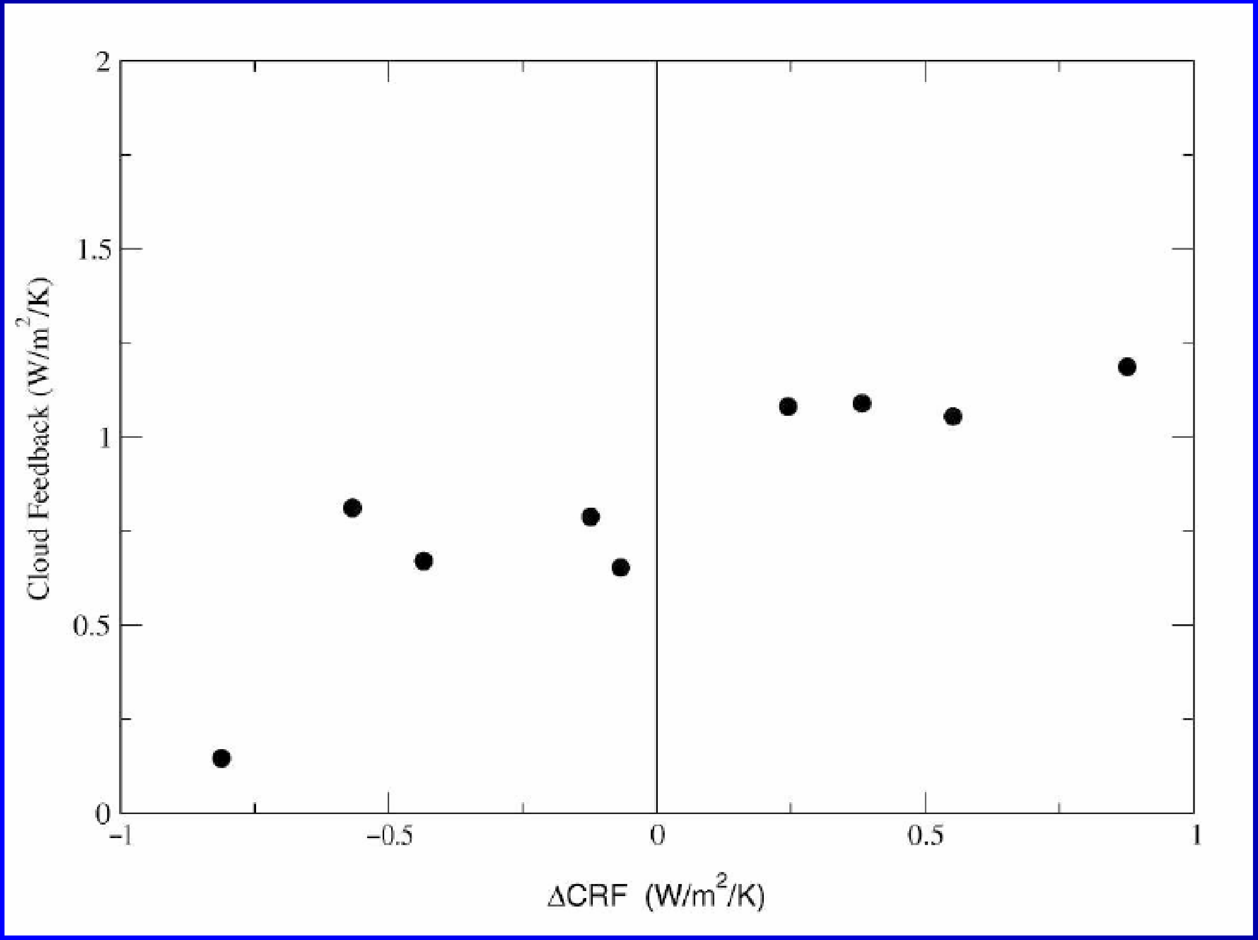
Climate Sensitivity vs Cloud Feedback
IPCC AR4 Models



Climate sensitivity is essentially linear in cloud feedback

Soden et al. 2006
J.Climate

Cloud Feedback vs Cloud Radiative Forcing
IPCC AR4 Models

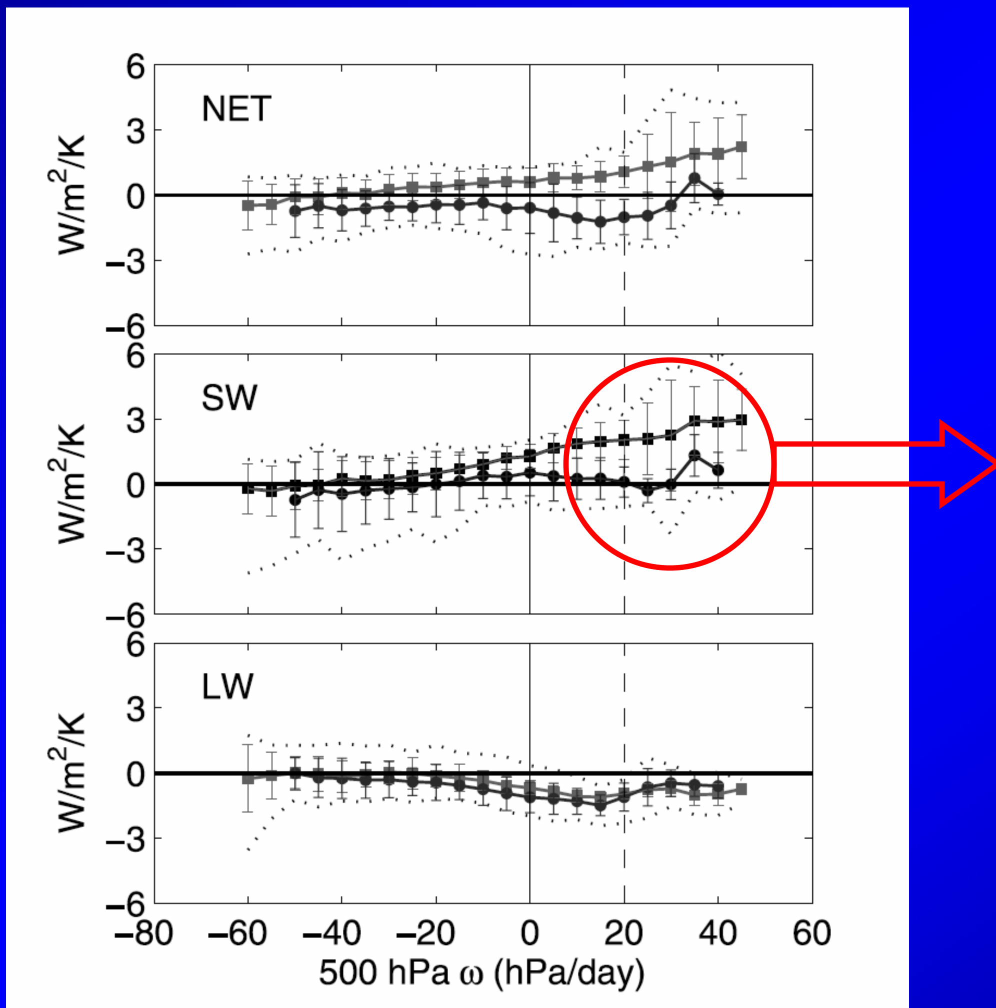


Cloud Feedback is essentially linear in cloud radiative forcing change

Soden et al. 2006
J.Climate

Sensitivity in CRF–SST changes by Dynamical Regime (15 IPCC AR4 Ocean-Atmos GCMs: 30S to 30N Ocean)

ΔCRF / ΔSST (Wm^{-2}/K)



Vertical Velocity (+ = downward motion)

- Increase CO2 by 1% per year for 80 years

Low Clouds Dominate Cloud Radiative Forcing Changes (SW reflected flux) and Cloud Feedback uncertainty

Bony and Dufresne
GRL, 2005

The scientific challenge of understanding and documenting climate variability and change

- The difficulty in documenting climate variability and change lies in the calibration stability requirements.

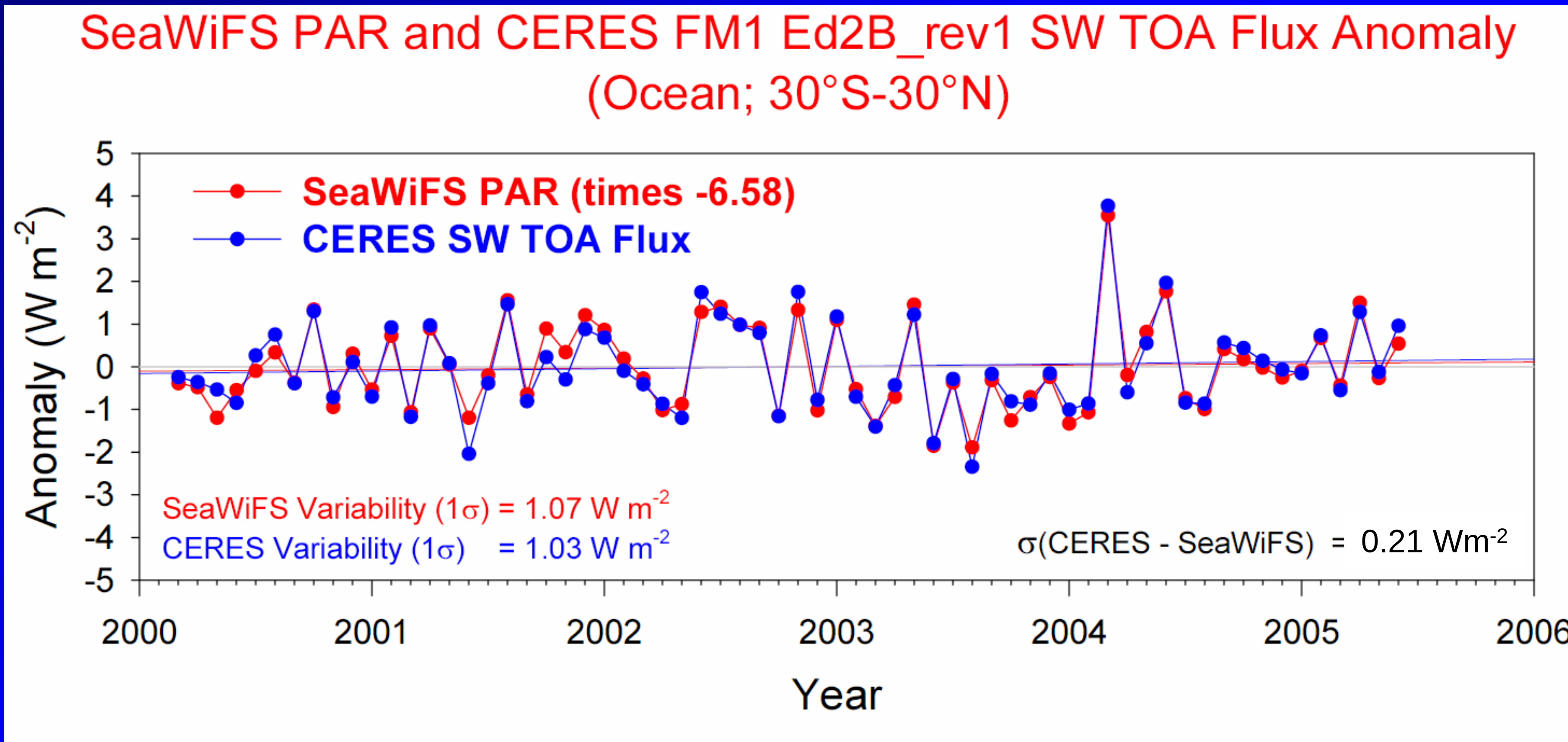
- A global cloud feedback of 25% translates into a 0.3% per decade requirement in SW broadband calibration stability (Ohring et al., 2005).

- While unprecedented, the 1% absolute accuracy in CERES SW radiance is still a factor of 4 too low to assure better than 0.3% per decade consistency between non-overlapped observations of cloud radiative forcing.

- The CERES record does however appear sufficiently stable to meet the climate requirement if given at least several months overlap with a mission in the same orbit (Loeb et al., 2006).

- The lack of data record continuity significantly degrades our ability to constrain cloud feedback.

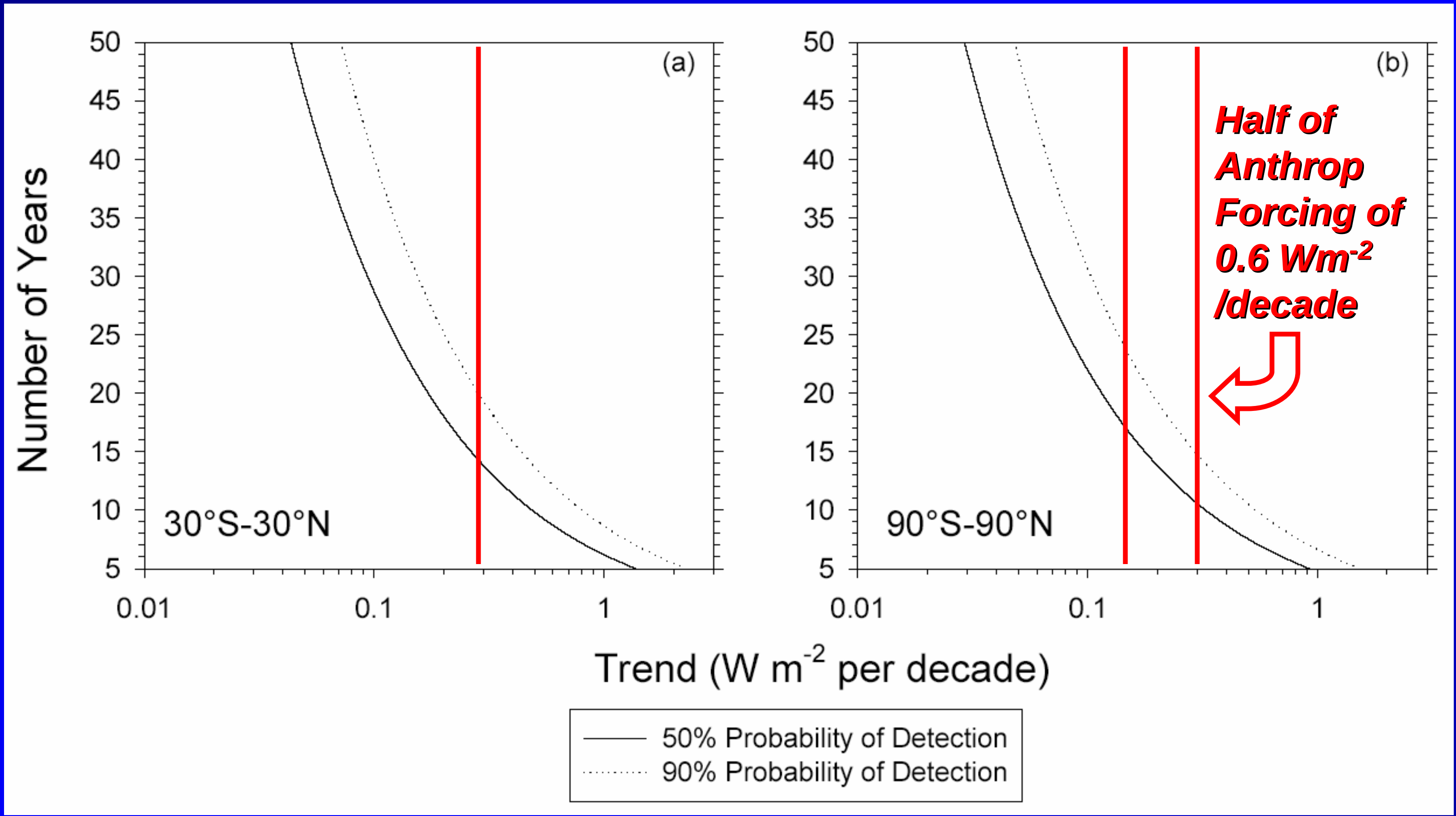
SW TOA Flux Interannual Variability: Tropical Ocean



Shows consistent calibration stability at < 0.3 Wm^{-2} per decade (95% conf)
Unfortunately only works for tropical mean ocean (nband vs bband issues)
Regional trends differ by +2 to -5 Wm^{-2}/decade SeaWiFS vs CERES

Loeb et al. 2006
J. Climate, in press

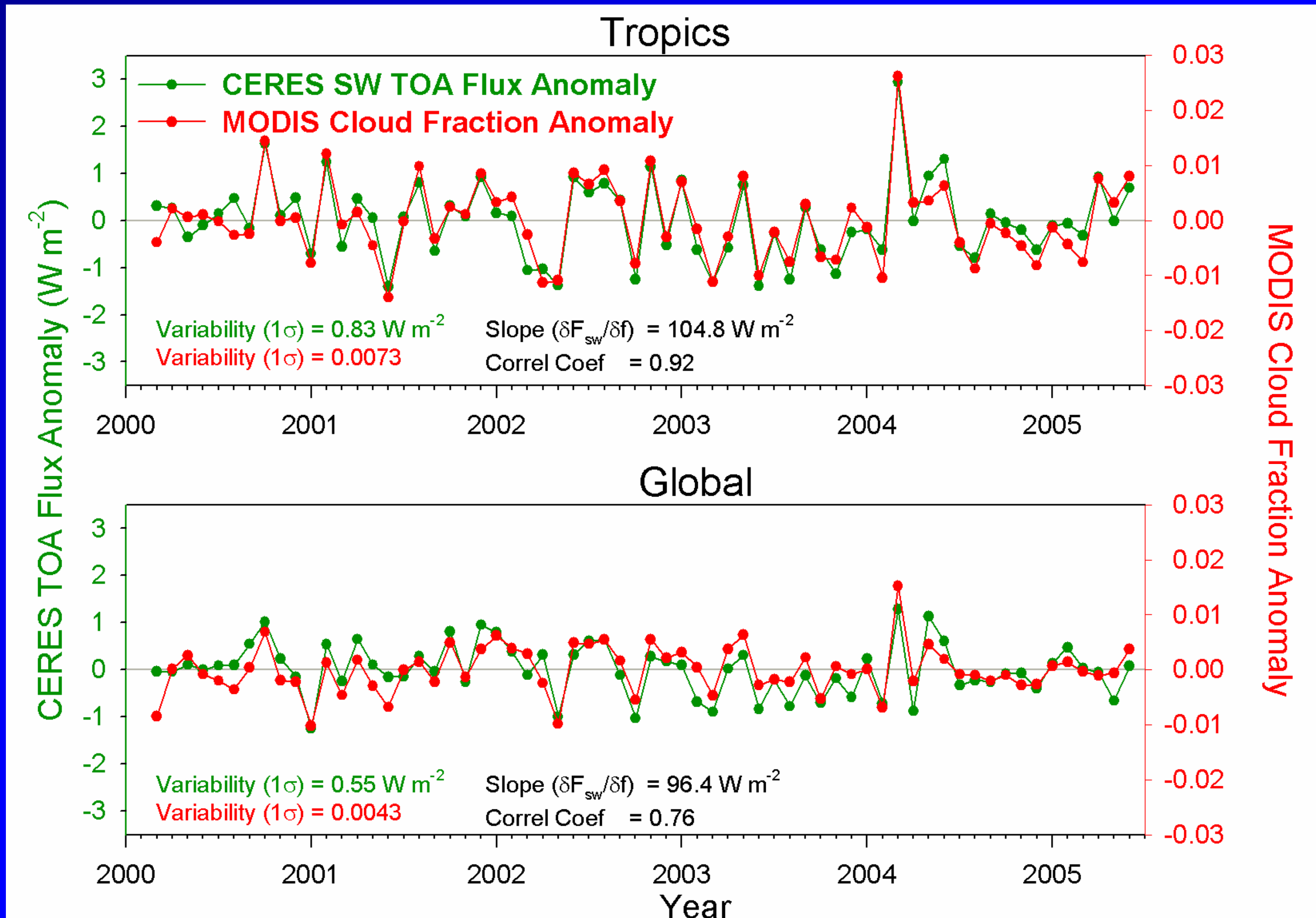
Using CERES to Determine Length of Climate Data Record Needed to Constrain Cloud Feedback



Given climate variability, 15 to 20 years is required to first detect climate trends at cloud feedback level with 90% confidence, and 18 to 25 years to constrain to +/- 25% in climate sensitivity

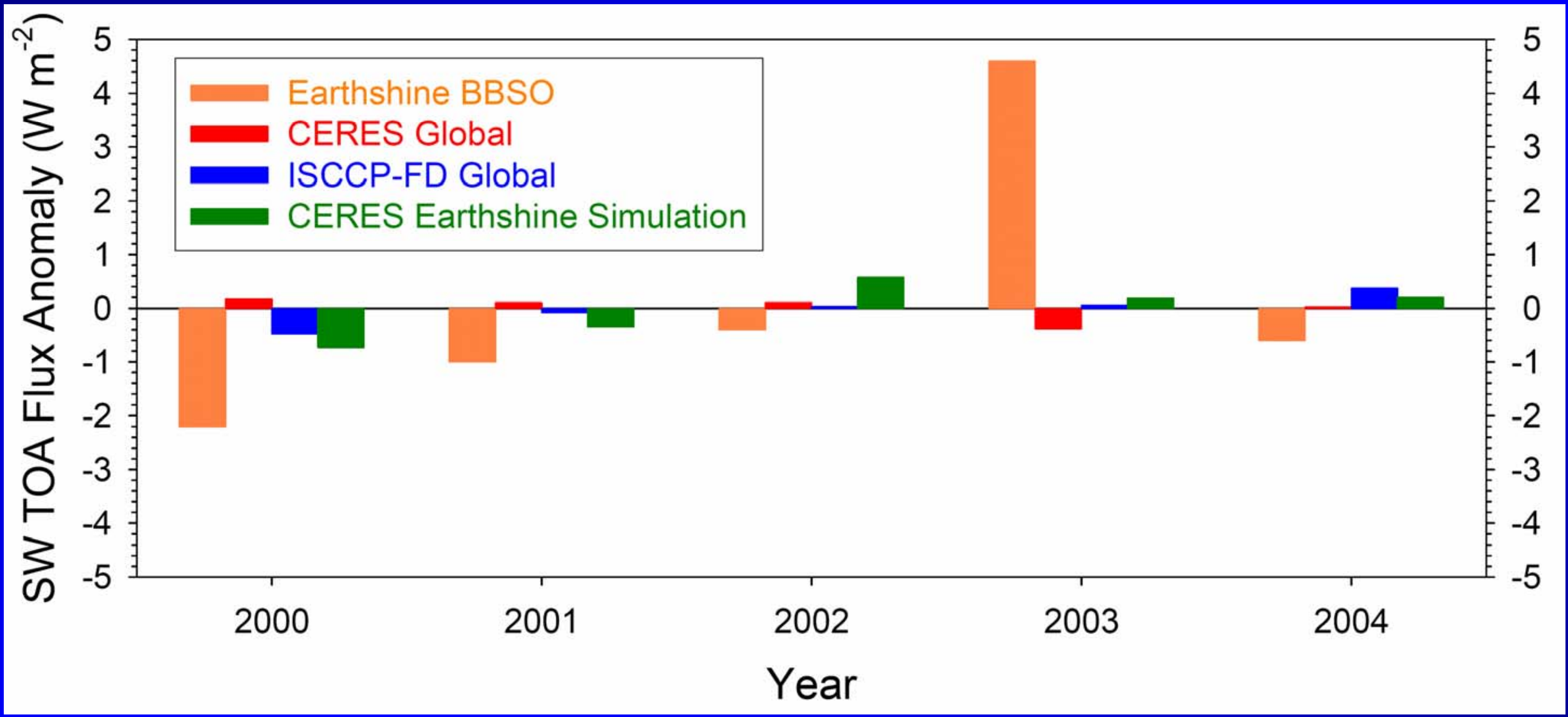
Loeb et al. 2006
J. Climate, in press

CERES Shortwave TOA Reflected Flux Changes: Ties to Changing Cloud Fraction



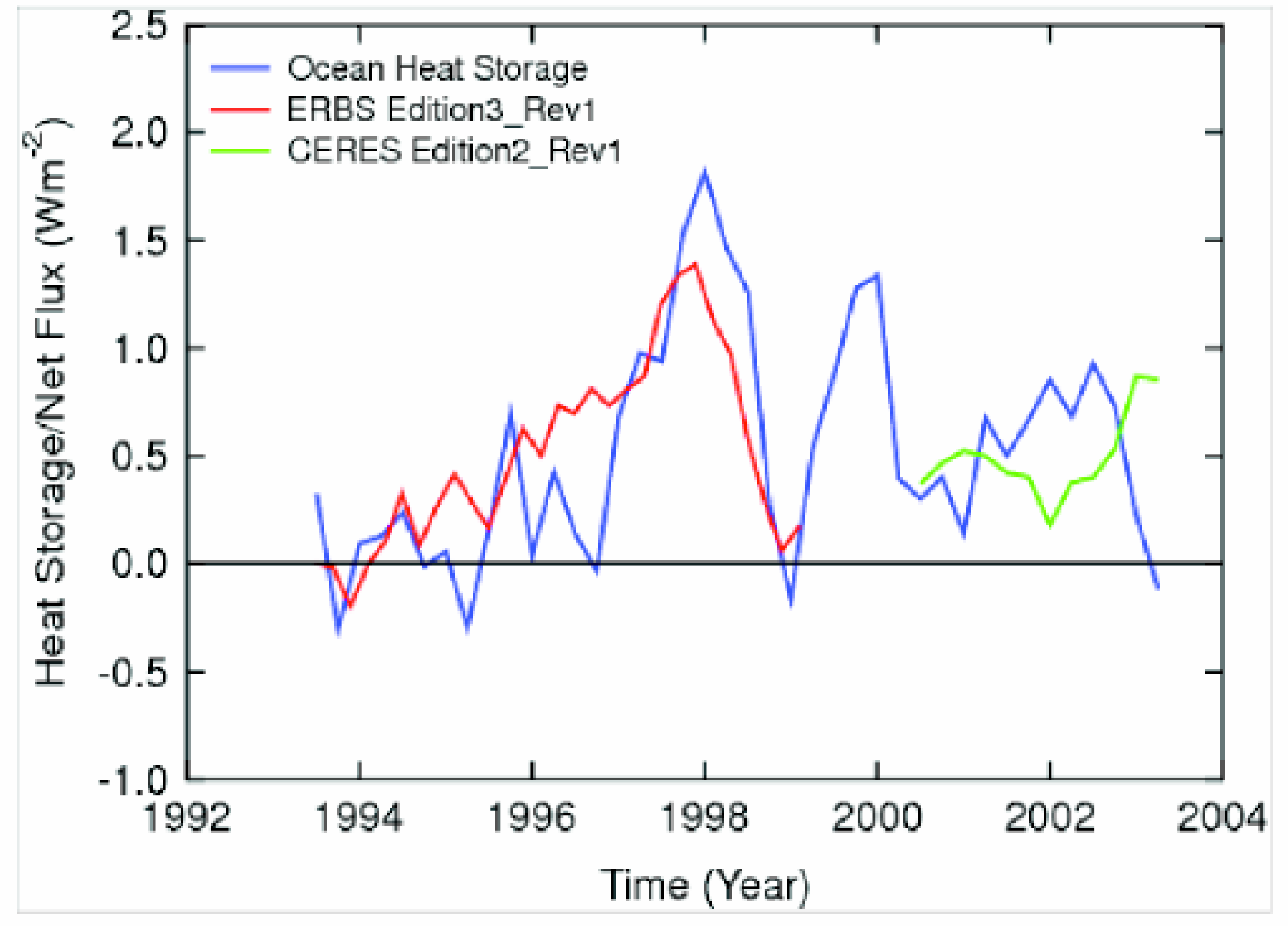
Unscrambling climate signal cause and effect requires complete parameter set at climate accuracy. For e.g. for forcing/response energetics: radiation, aerosol, cloud, land, snow/ice, temperature, humidity, precipitation

Annual Mean Global SW TOA Flux Anomaly



Loeb et al. 2006
GRL, submitted

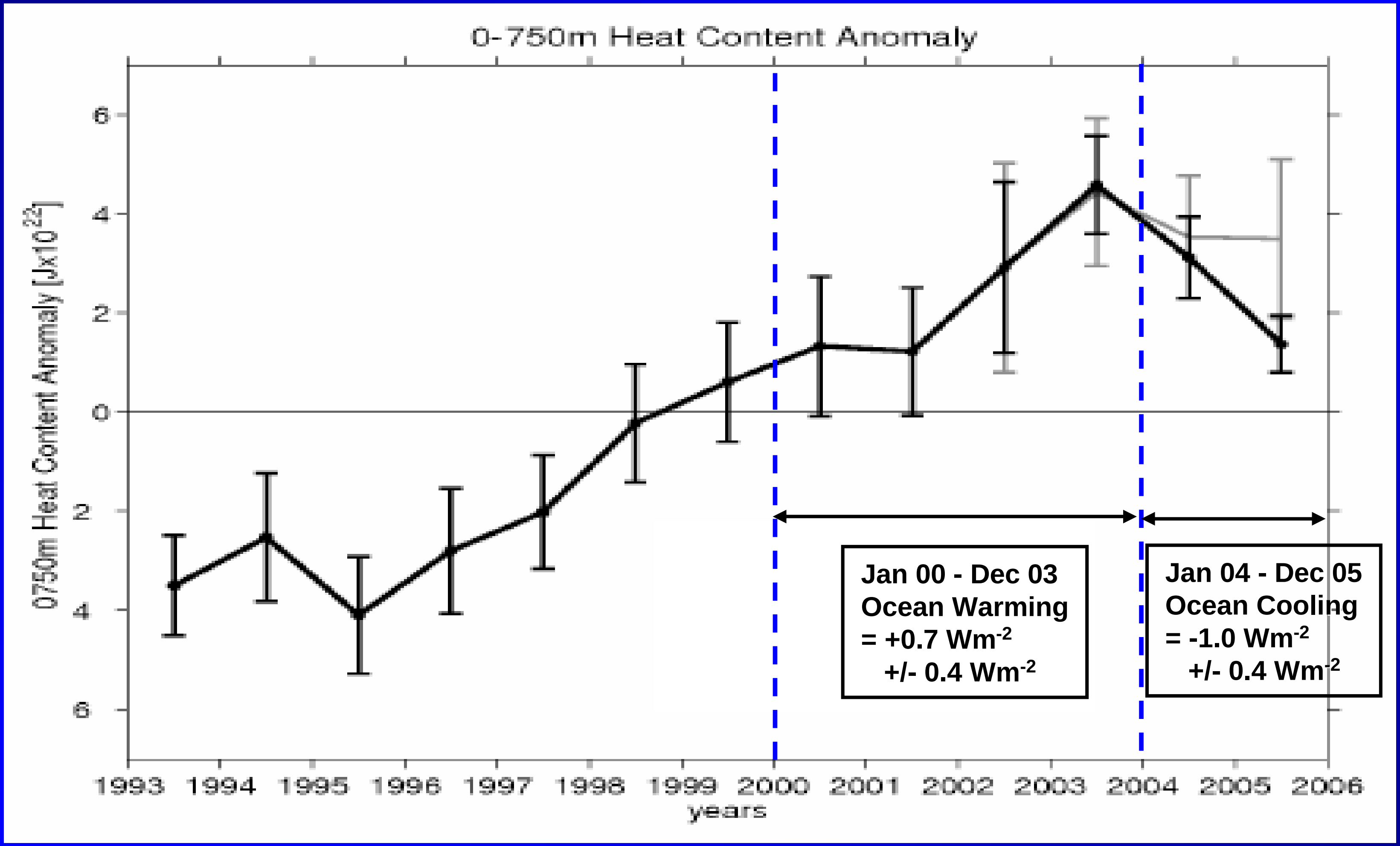
CERES Net Radiation vs Global Ocean Heat Storage



We will need to carefully unscramble cloud feedback and natural variability in ocean heat storage: a fusion of ocean/atmosphere data

Wong et al. 2006
J.Climate, in press

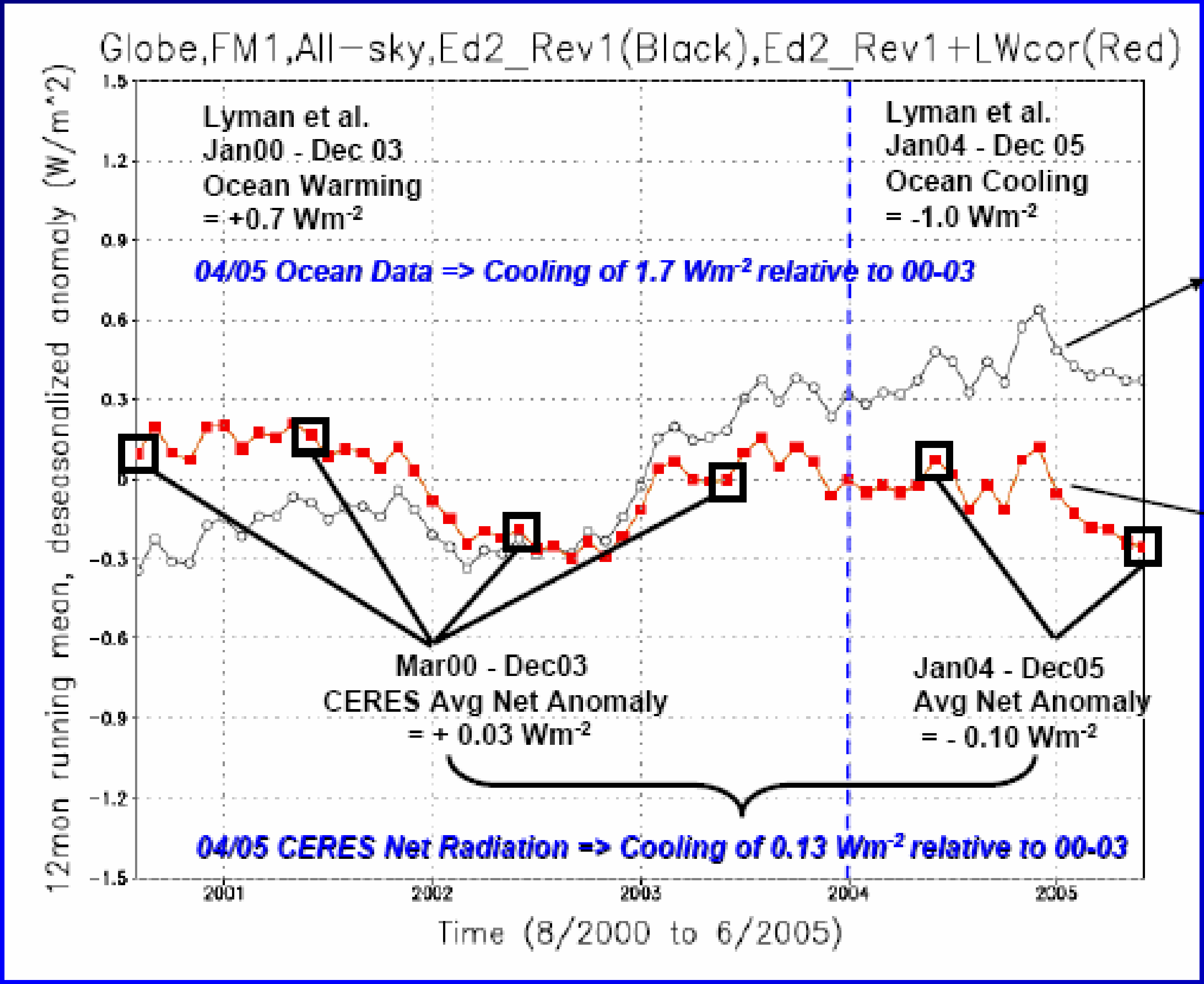
Lyman et al., 2006 Ocean Cooling in 2004/2005



Note: Change in OHCA of 1×10^{22} J per year = 0.6 Wm^{-2}

Lyman et al., GRL, Aug 2006

Does CERES Net Radiation Indicate Recent Ocean Cooling?



Global Net CERES Terra FM1 Instrument ES-8 All-Sky TOA Flux Edition 2, Rev1 12 mo running means (June = year center) current data (Wong)

Same as above, but showing the level of changes expected in Edition 3 calibration improvements, primarily in daytime LW fluxes (Wong, Charlock, Mathews, Priestley, Loeb)

Estimates of total sea level (Leuliette et al., 2004) show continued sea-level rise during the past 3 years.

Ocean Heat Content Anomaly
2004-2005 vs 2000-2003
-1.7 Wm^{-2}

CERES TOA Net Radiation
2004-2005 vs 2000-2003
-0.3 Wm-2

Sea-level rise must due to:

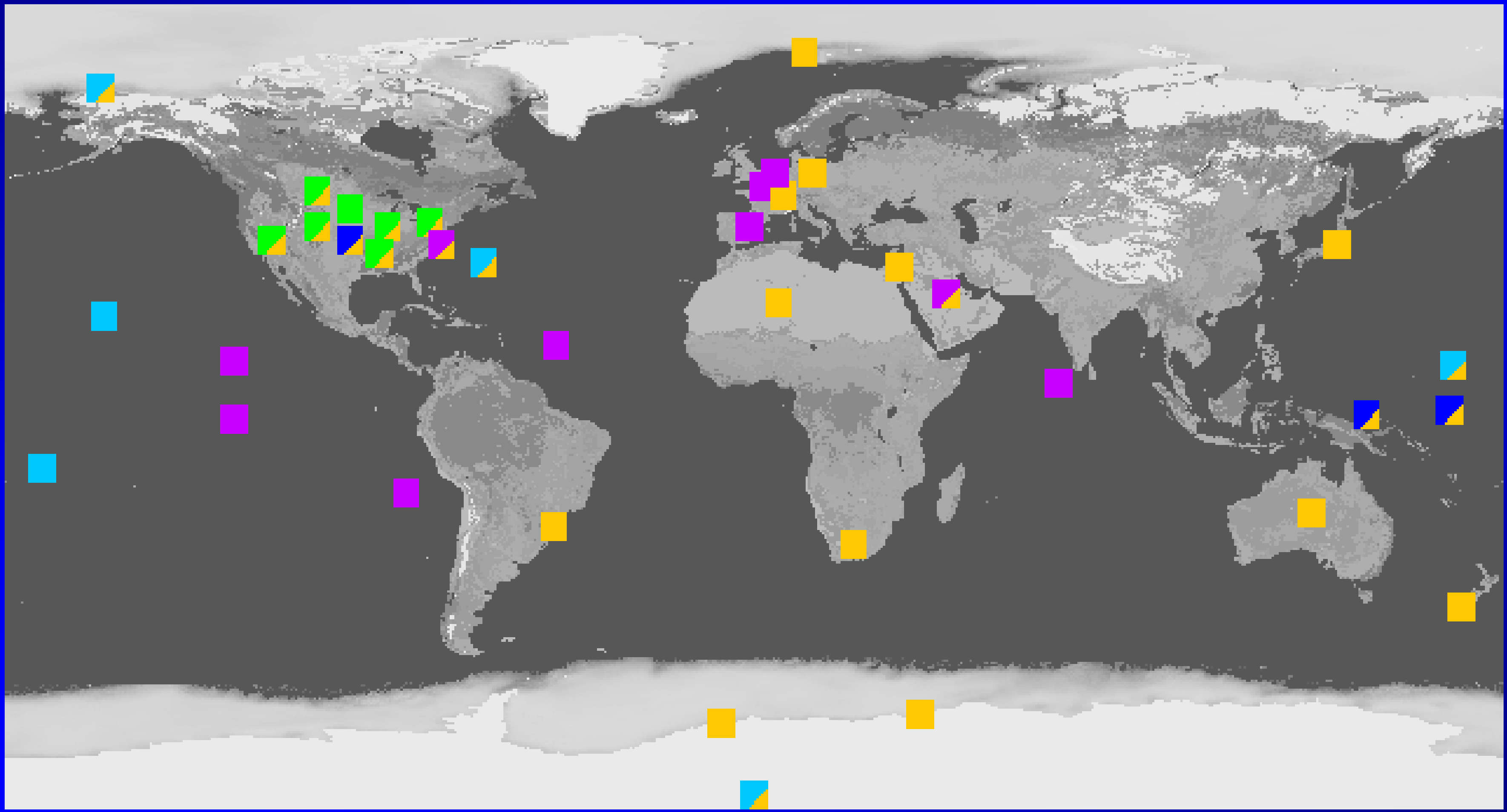
Acceleration of melting of land-bound ice?
- Recent GRACE observations of Greenland and Antarctica mass balance show that 2004-2005 sea-level rise contributions were similar to 2000-2003.

Deep ocean warming (below 750m) and warming below sea ice regions dominate over upper 750-m contribution?

TOA Flux Errors

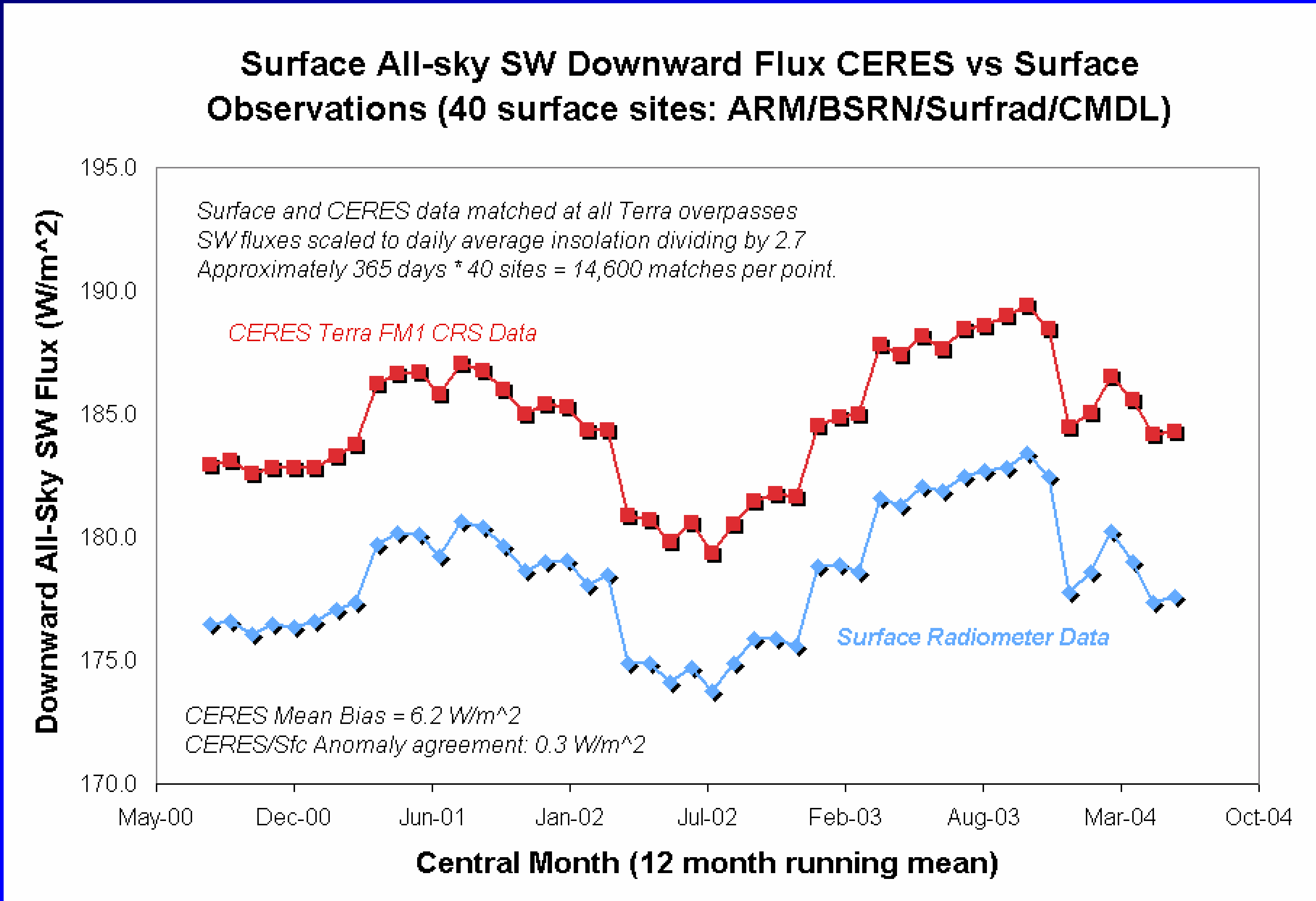
	Global Interannual Cld Rad Fcing Trend/decade	Zonal Eqtr - Pole Gradient Monthly	1 deg region Monthly (1 σ)	20km fov Instantaneous (1 σ) (S_0 = 1000)
Dominant Error Sources	Calibration Stability	Angle Sampling Twilight	Calibration Time Sampling	Angle Sampling
TOA SW Flux	0.3 Wm^{-2} Terra Rev1	3.5 Wm^{-2}	3.0 Wm^{-2}	10 Wm^{-2}
TOA LW Flux	0.5 Wm^{-2} Terra Rev1	2.0 Wm^{-2}	1.5 Wm^{-2}	5 Wm^{-2}
TOA Net Flux	0.6 Wm^{-2} Terra Rev1	4.0 Wm^{-2}	3.5 Wm^{-2}	11 Wm^{-2}
Science Rqmt	0.15 Wm^{-2} 25% feedback	1 - 3 Wm^{-2}	2 - 5 Wm^{-2}	10 Wm^{-2}

ARM/BSRN/CMDL/Surfrad Surface Radiation Sites

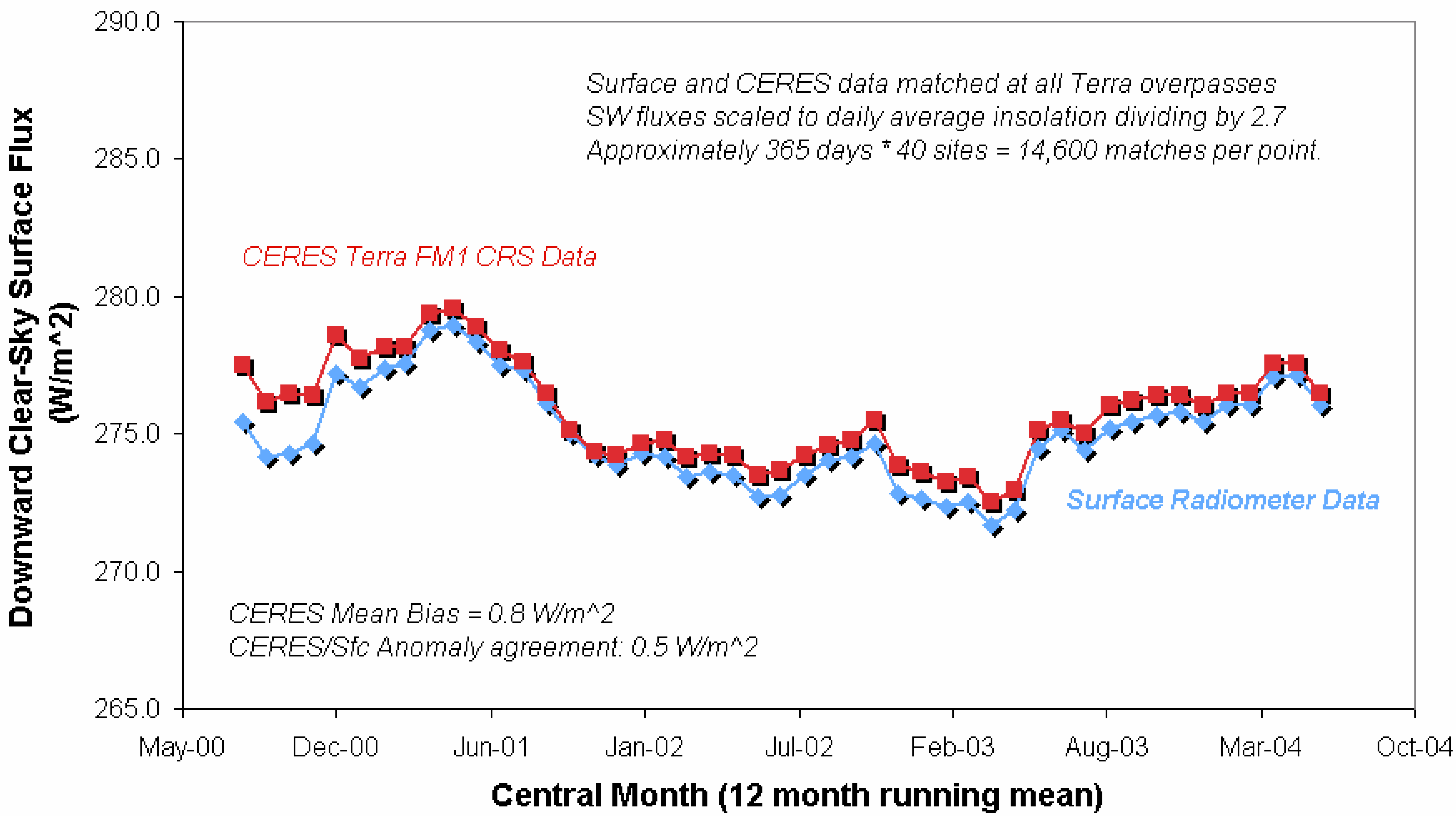


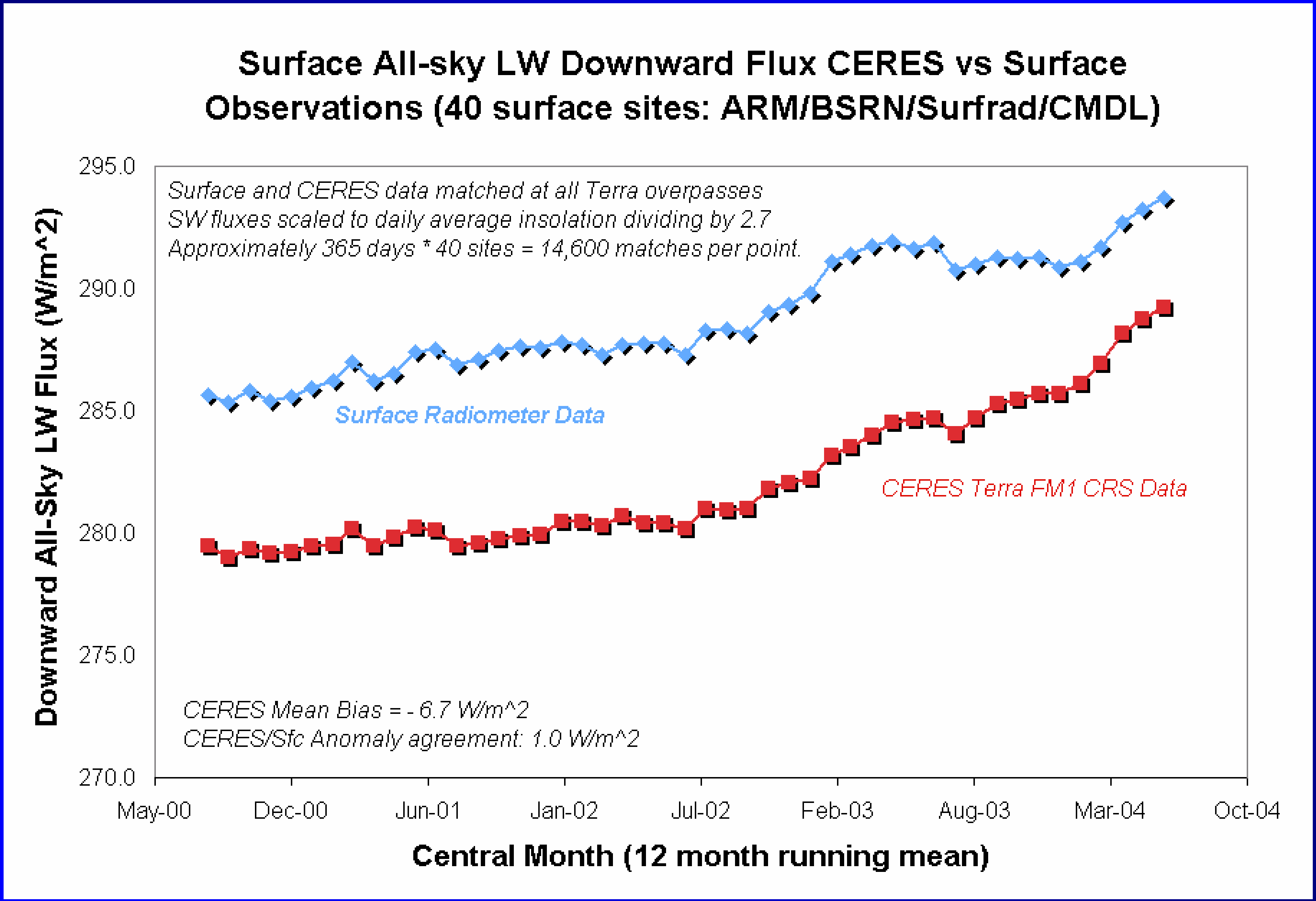
Surface Downward Flux Errors: 20 - 40 Surface Sites

	Global Interannual Cld Rad Fcing Variability	SYN/AVG (est) Month, 1-deg Bias, Clr/All (1 σ)	SRBAVG Month, 1-deg Bias All (1σ)	CRS 20km fov Instantaneous 1 σ, Clr/All Sky (S_o = 900)
Dominant Error Sources	TBD	Aerosol, Tair, Polar sfc/cld Site Inhom.	Aerosol, Tair, Param. Site Inhom.	Angle Samp, Water Vapor Aerosol, Tair
Surface Down SW Flux	0.5 Wm^{-2} (40 sites)	0 / +5 Wm^{-2} (σ = 6)	3 Wm^{-2} (σ = 20)	23 / 20 Wm^{-2}
Surface Down LW Flux	1.0 Wm^{-2} (40 Sites)	-7 / -6 Wm^{-2} (σ = 8)	< 1 Wm^{-2} (σ = 10)	12 / 17 Wm^{-2}
Surface Down Total Net Flux	1.1 Wm^{-2} (40 Sites)	-7 / -1 Wm^{-2} (σ = 9)	4 Wm^{-2} (σ = 22)	26 / 26 Wm^{-2}
Science Rqmt	TBD	< 5-10 Wm^{-2}	< 5-10 Wm^{-2}	< 25 Wm^{-2}
BSRN Acc.	TBD	5 SW?, 10 LW?	5 SW, 10 LW	15 SW, 10 LW

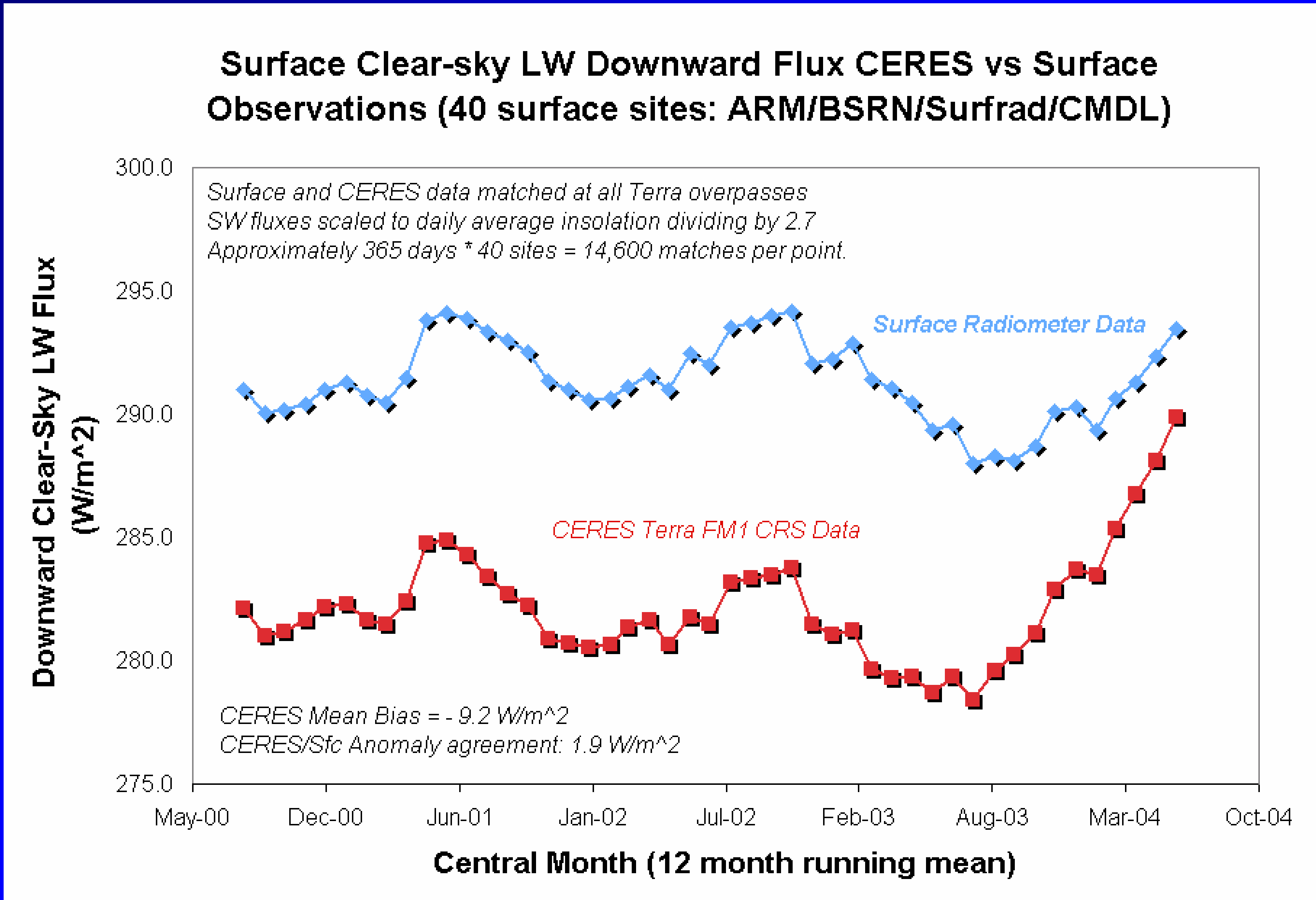

Surface All-sky SW Downward Flux CERES vs Surface Observations (40 surface sites: ARM/BSRN/Surfrad/CMDL)
Surface and CERES data matched at all Terra overpasses
SW fluxes scaled to daily average insolation dividing by 2.7
Approximately 365 days * 40 sites = 14,600 matches per point.
CERES Terra FM1 CRS Data
Surface Radiometer Data
CERES Mean Bias = 6.2 W/m^2
CERES/Sfc Anomaly agreement: 0.3 W/m^2
Downward All-Sky SW Flux (W/m^2)
195.0
190.0
185.0
180.0
175.0
170.0
May-00
Dec-00
Jun-01
Jan-02
Jul-02
Feb-03
Aug-03
Mar-04
Oct-04
Central Month (12 month running mean)

Surface Clear-sky SW Downward Flux CERES vs Surface Observations (40 surface sites: ARM/BSRN/Surfrad/CMDL)

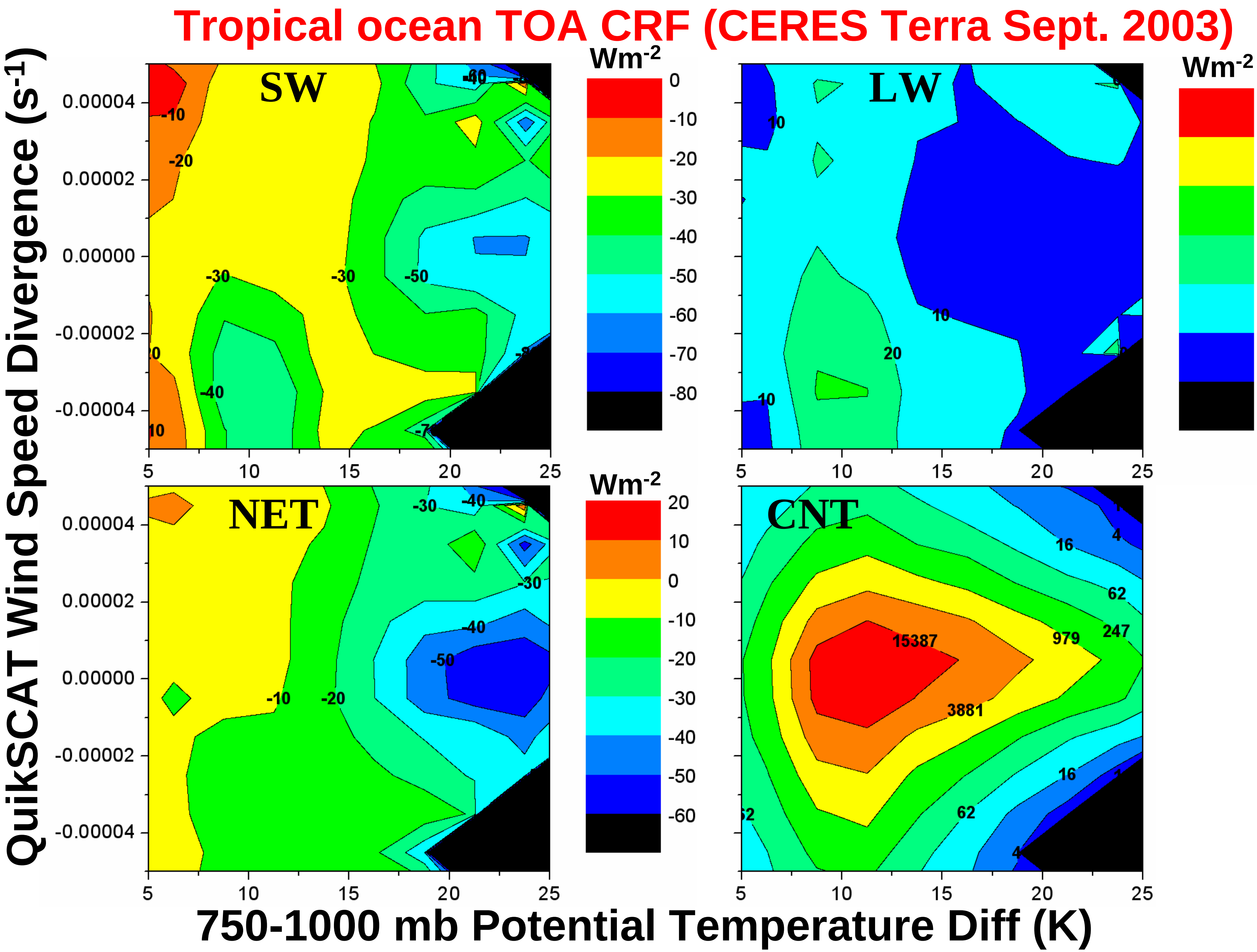




Surface All-sky LW Downward Flux CERES vs Surface Observations (40 surface sites: ARM/BSRN/Surfrad/CMDL)
Surface and CERES data matched at all Terra overpasses
SW fluxes scaled to daily average insolation dividing by 2.7
Approximately 365 days * 40 sites = 14,600 matches per point.
Surface Radiometer Data
CERES Terra FM1 CRS Data
CERES Mean Bias = - 6.7 W/m^2
CERES/Sfc Anomaly agreement: 1.0 W/m^2
Downward All-Sky LW Flux (W/m^2)
295.0
290.0
285.0
280.0
275.0
270.0
May-00
Dec-00
Jun-01
Jan-02
Jul-02
Feb-03
Aug-03
Mar-04
Oct-04
Central Month (12 month running mean)

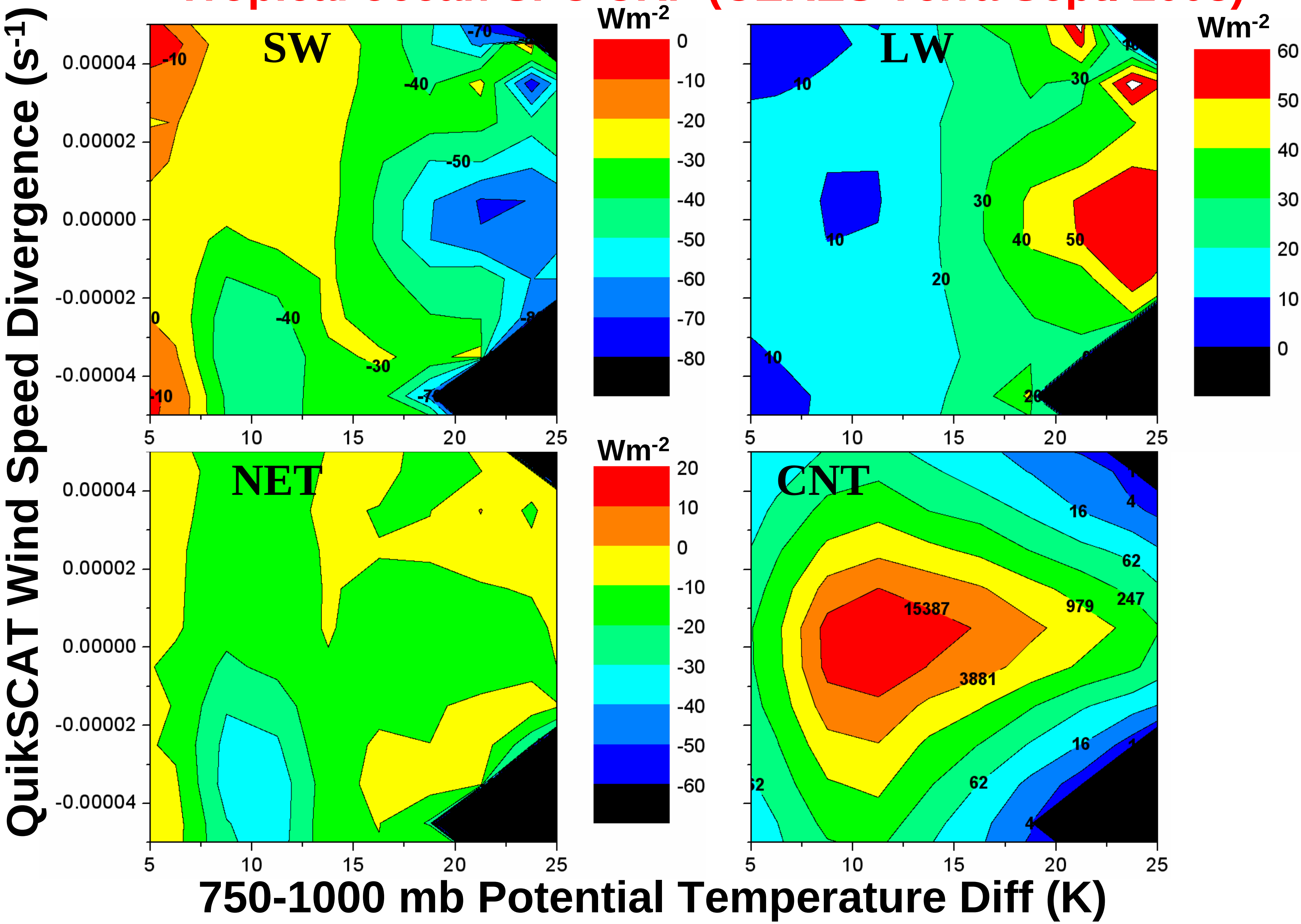


Surface Clear-sky LW Downward Flux CERES vs Surface Observations (40 surface sites: ARM/BSRN/Surfrad/CMDL)
Surface and CERES data matched at all Terra overpasses
SW fluxes scaled to daily average insolation dividing by 2.7
Approximately 365 days * 40 sites = 14,600 matches per point.
Surface Radiometer Data
CERES Terra FM1 CRS Data
CERES Mean Bias = - 9.2 W/m^2
CERES/Sfc Anomaly agreement: 1.9 W/m^2
Downward Clear-Sky LW Flux (W/m^2)
300.0
295.0
290.0
285.0
280.0
275.0
May-00
Dec-00
Jun-01
Jan-02
Jul-02
Feb-03
Aug-03
Mar-04
Oct-04
Central Month (12 month running mean)



Tropical ocean TOA CRF (CERES Terra Sept. 2003)
SW
LW
NET
CNT
Wm-2
0
-10
-20
-30
-40
-50
-60
-70
-80
60
50
40
30
20
10
0
20
10
0
-10
-20
-30
-40
-50
-60
15387
3881
979
247
62
16
4
QuikSCAT Wind Speed Divergence (s-1)
0.00004
0.00002
0.00000
-0.00002
-0.00004
5
10
15
20
25
750-1000 mb Potential Temperature Diff (K)

Tropical ocean SFC CRF (CERES Terra Sept. 2003)



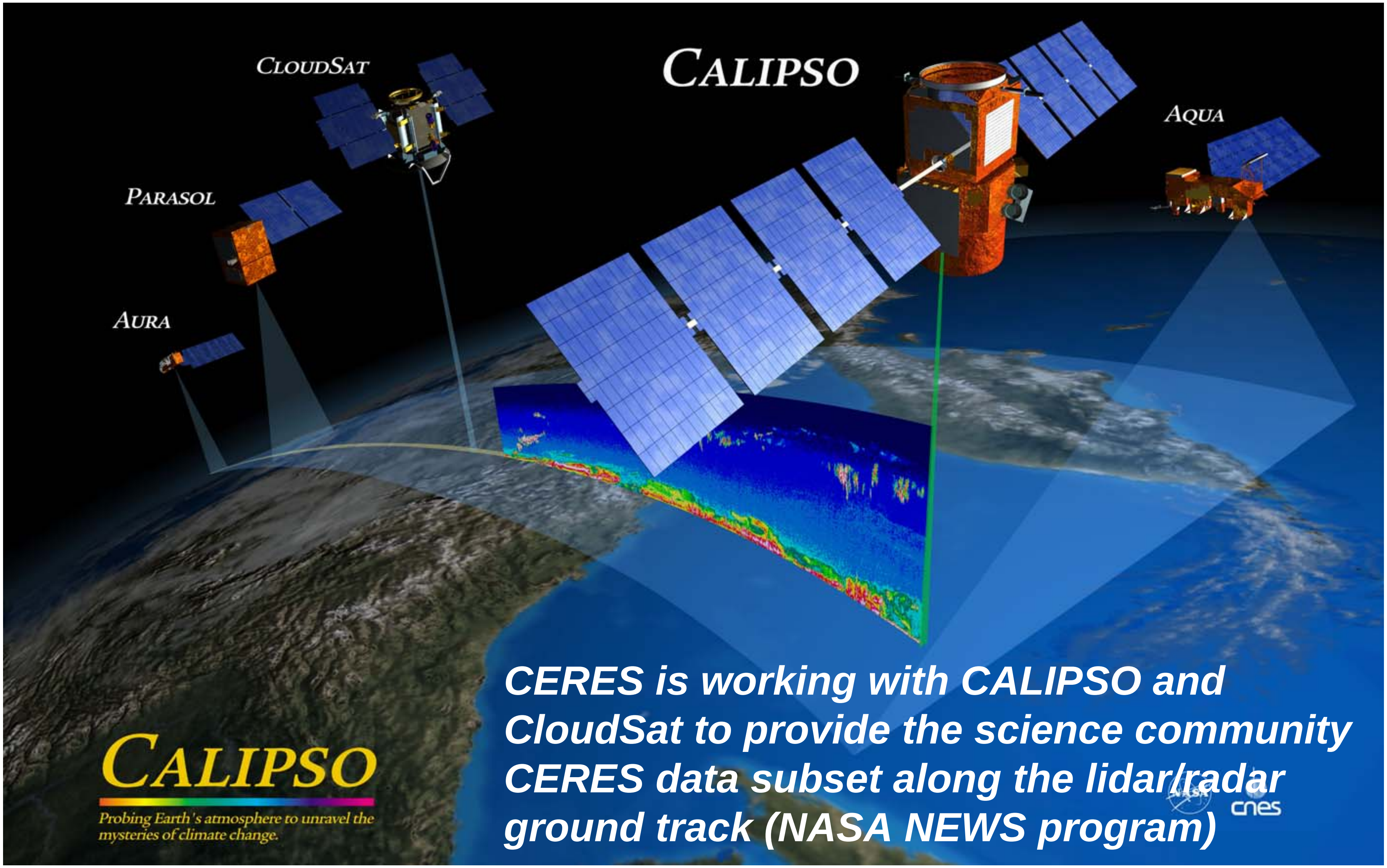
CERES Data Product Status

- Data available free from the LaRC Atmospheric Sciences Data Center at: http://eosweb.larc.nasa.gov/PRODOCS/ceres/table_ceres.html
- Rev1 SW flux correction tables for all months to 2005 (~ 1% changes) available in simple on-line tables in Data Quality Summaries: all products.
- Rev1 is a user applied correction and primarily affects trend studies.
- ERBE-Like TOA fluxes: Ed2 Terra 3/00 - 12/05, Aqua 7/02 - 12/05
- SSF merged cloud/radiation: Ed2B Terra to 12/05, Aqua Ed2A to 12/05
- CRS Sfc/Atm/TOA/cloud/aerosol: Ed2B Terra to 12/05, Ed2A Aqua to 12/05
- SFC and FSW gridded 1-degree instantaneous: similar to SSF/CRS

CERES Data Product Status

- SRBAVG new geo SW fluxes: Terra Edition2D SRBAVG complete for 3/00 - 5/04. Expect to process through 12/05 by Spring 07.
- Synoptic (SYN) and AVG products still beta. Focus will move to these now that the SRBAVG SW tie of geo diurnal to CERES is working.
- Aqua products more advanced than Terra especially for polar clouds.
- Products have frozen algorithms within a satellite/Edition: e.g. Terra Ed2B.
- Edition 3 improvement. Anticipate production in early 2007. *GRP is welcome to suggest desired Edition 3 changes.*
- Working with GEWEX Radiative Flux Assessment and NASA NEWS to make highly subsetted versions of CERES gridded data available.

"A-Train" Formation for Aerosol and Cloud Vertical Profiles
Atmospheric State => Aerosol/Cloud => Radiative Heating



Next Steps, Future Issues

- Joint meeting with GERB at UKMO in Exeter Oct 23-27
- GERB Edition 1 coming out for validation of diurnal cycles
- CALIPSO and CloudSat in test: A-train begins!
- Edition 3 will correct SW contamination by spectral scene type (improve Rev1 ocean and all-sky approximation).
- *NPOESS has eliminated ERBS sensor.*
- *Last CERES FM-5 sensor currently scheduled on NPOESS C1 in 2014: but gap risk large: much better on NPP in 2010.*

There would now appear to be a narrowing set of next look possibilities:

- deep ocean warming (below 750m) and warming below sea ice regions dominating the upper 750m warming

- transition from XBT to ARGO dominated ocean heat storage data causing a subtle but significant change in apparent ocean heat content.

- both CERES as well as one of the altimeter and GRACE data sets are screwed up. But neither of these three data sets has undergone any major changes in the last several years, so this seems a less likely scenario.