The GEWEX Radiative Flux Assessment Project

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~75 participants (TOA, surface, and both)

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Radiative Flux Assessment: Overview

A community-based activity commissioned by the GEWEX Radiation Panel.

Goals:

- **Assess our current understanding of and capability to derive TOA and surface radiative fluxes from satellite observations.**
- **Assess uncertainties and outstanding issues in flux estimation.**
  - **Sources include satellite calibration, input data, spatial and temporal gap filling, and other assumptions.**

Purposes:

- **Increase understanding of data limitations and uncertainties for future IPCC reports and climate community in general.**
- **To determine areas requiring further improvement.**
- **Development of climate system observation requirements for radiative fluxes.**
- **To assemble a simplified satellite database.**

Data and Analysis Methods

All satellite products supplied as monthly means on 2.5° x 2.5° global grid over their entire temporal range.

Both top-of-atmosphere (TOA) and surface fluxes included.

Many parameters for each product: SW up, SW down, LW up, total net, LW down, net SW, net LW.

Surface in-situ data also collected.

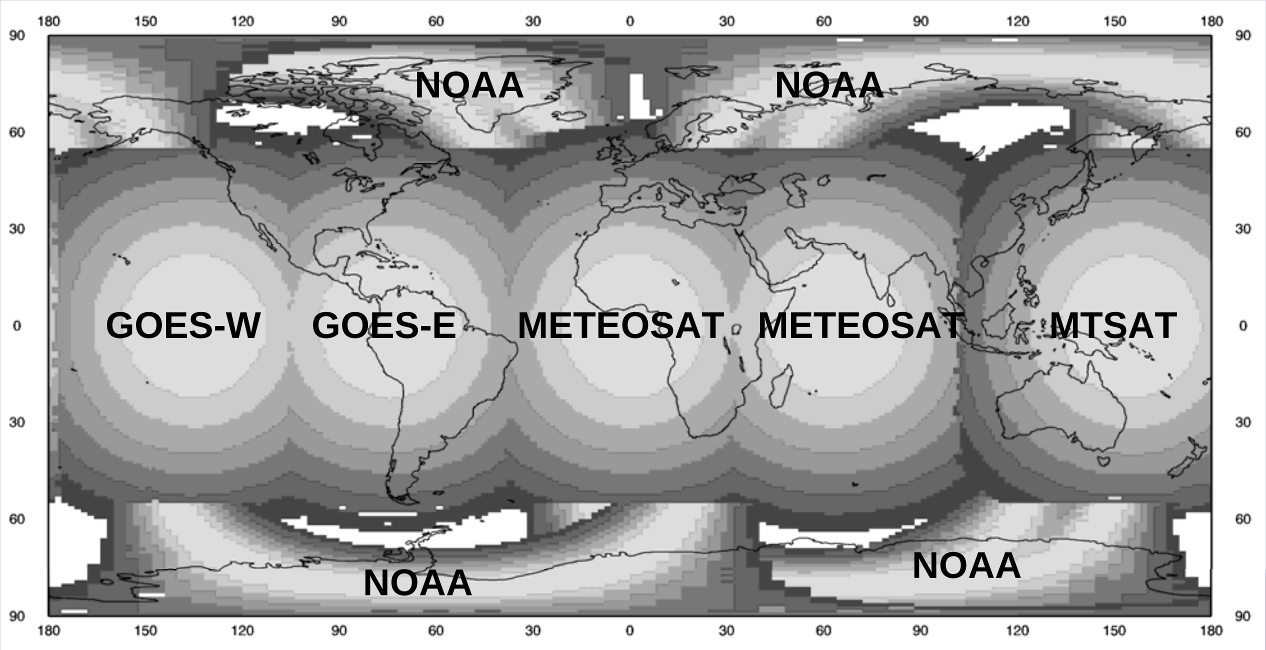
Analysis types:

- Global climatologies
- Annual cycles
- Time series analysis
- Comparisons to surface measurements

“ISCCP Cloud Amount Artifact”

- Rings apparent in cloud and radiation products.
- Related to position and view zenith angles of geostationary satellites.

Current global meteorological satellite coverage

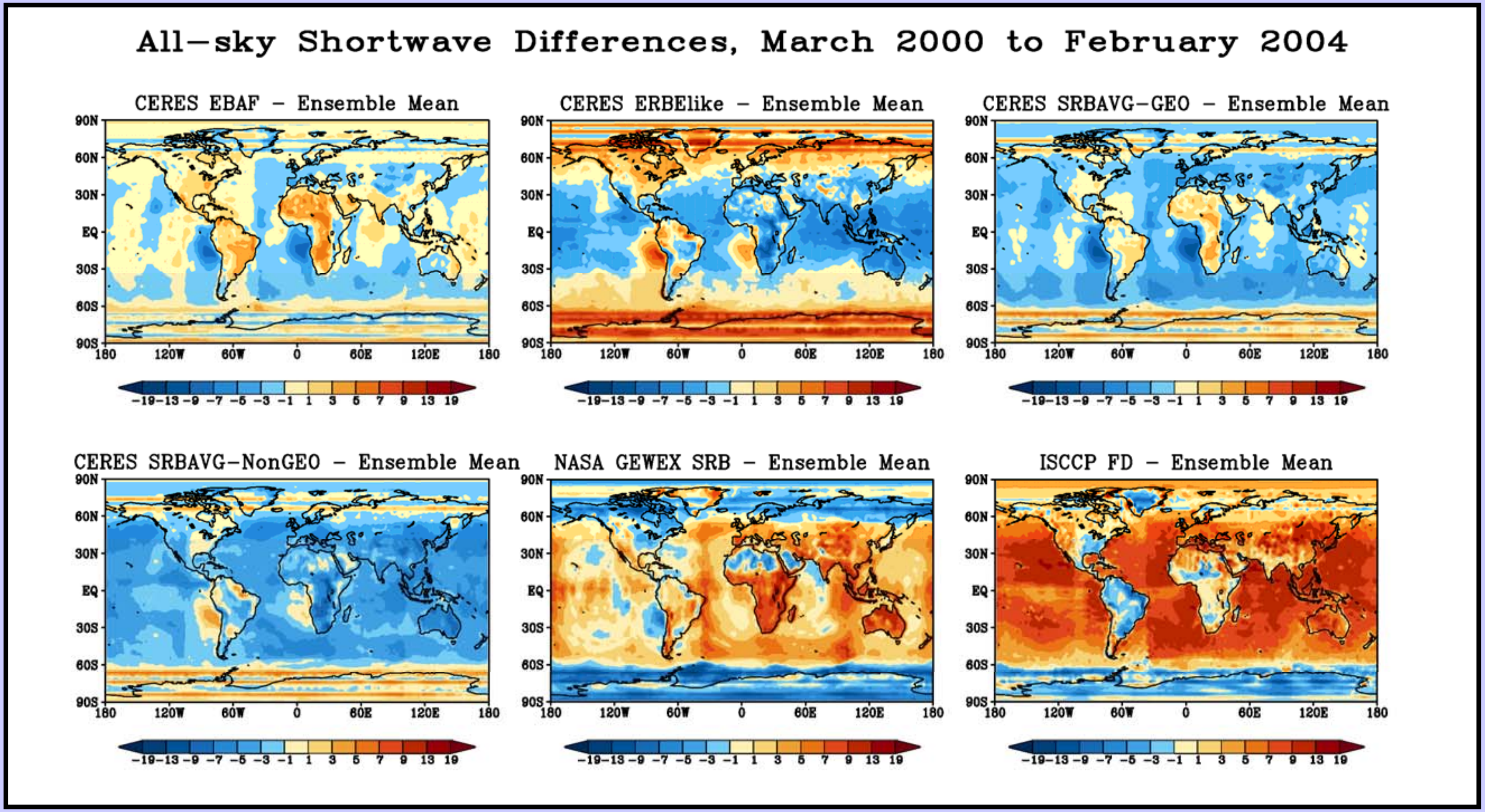


TOA Satellite Radiation Data Sets

Data Set	Satellite Source	Spatial Coverage	Temporal Coverage	
ERBE Scanner	ERBS, N9, N10	Global	02-1985 to 05-1989	1
ERBE NonScanner	ERBS	60°N to 60°S	1985 to 1999	
ScaRaB Scanner***	Meteor, Resurs	Global	1994-95, 1998-99	
ISCCP-FD	ISCCP Geo + Polar	Global	07-1983 to 12-2004	3
LaRC GEWEX SRB	ISCCP Geo + Polar	Global	07-1983 to 06-2005	
FORTH	ISCCP Geo + Polar	Global	01-1984 to 12-2004	
Univ. Md. SW**	ISCCP Geo + Polar	Global	07-1983 to 12-2004	
Univ. Md. HIRS/OLR**	NOAA Polar	Global	01-1979 to 09-2003	
CERES*	Terra, Aqua	Global	03-2000 to 10-2005	2

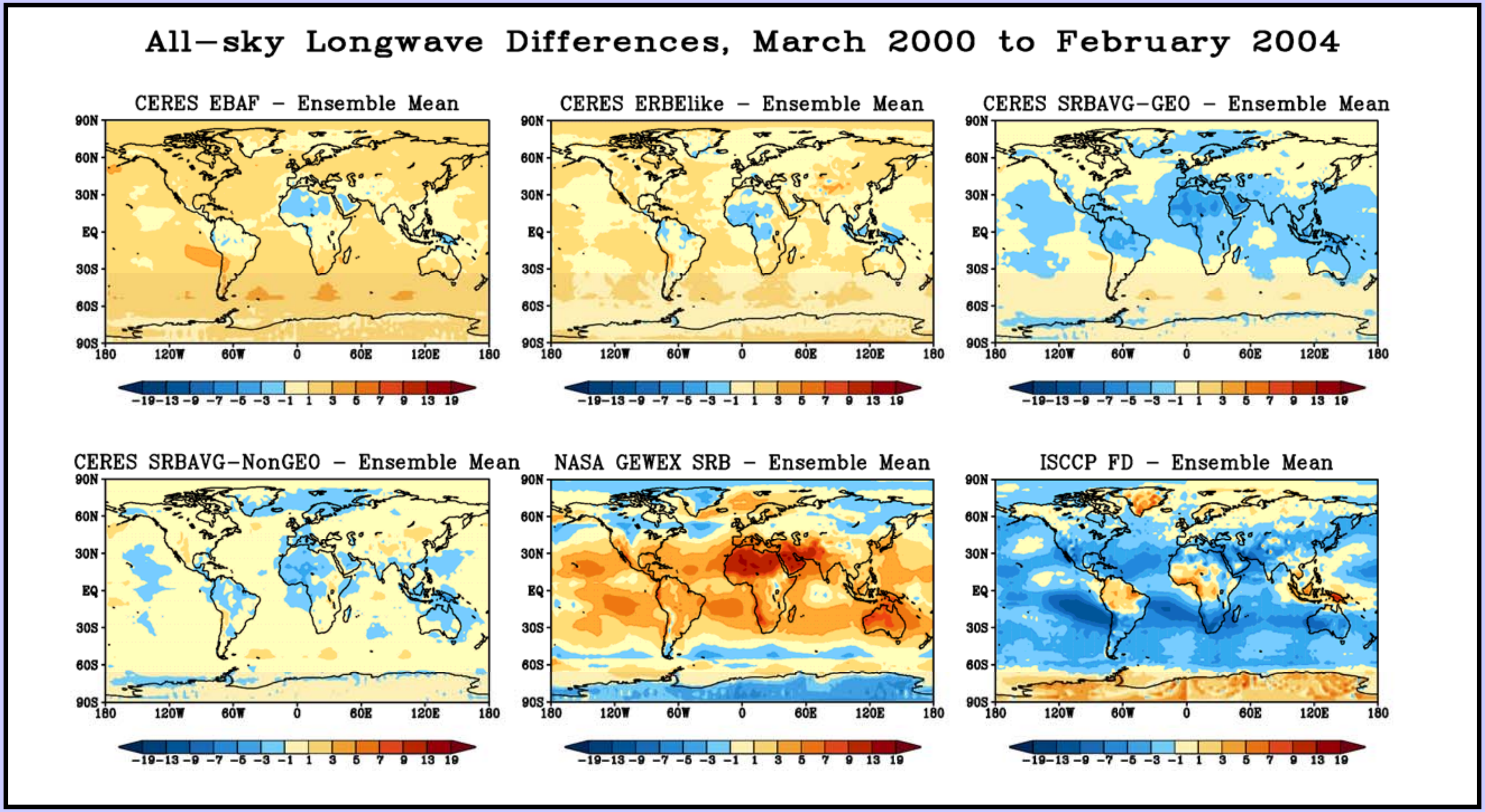
*** CERES: SRBAVG-GEO, SRBAVG-nonGEO, ERBE-like, and EBAF**
**** UM SW, UM HIRS/OLR: single component data**
***** ScaRaB: a few months within these two periods**

TOA Shortwave Flux Differences



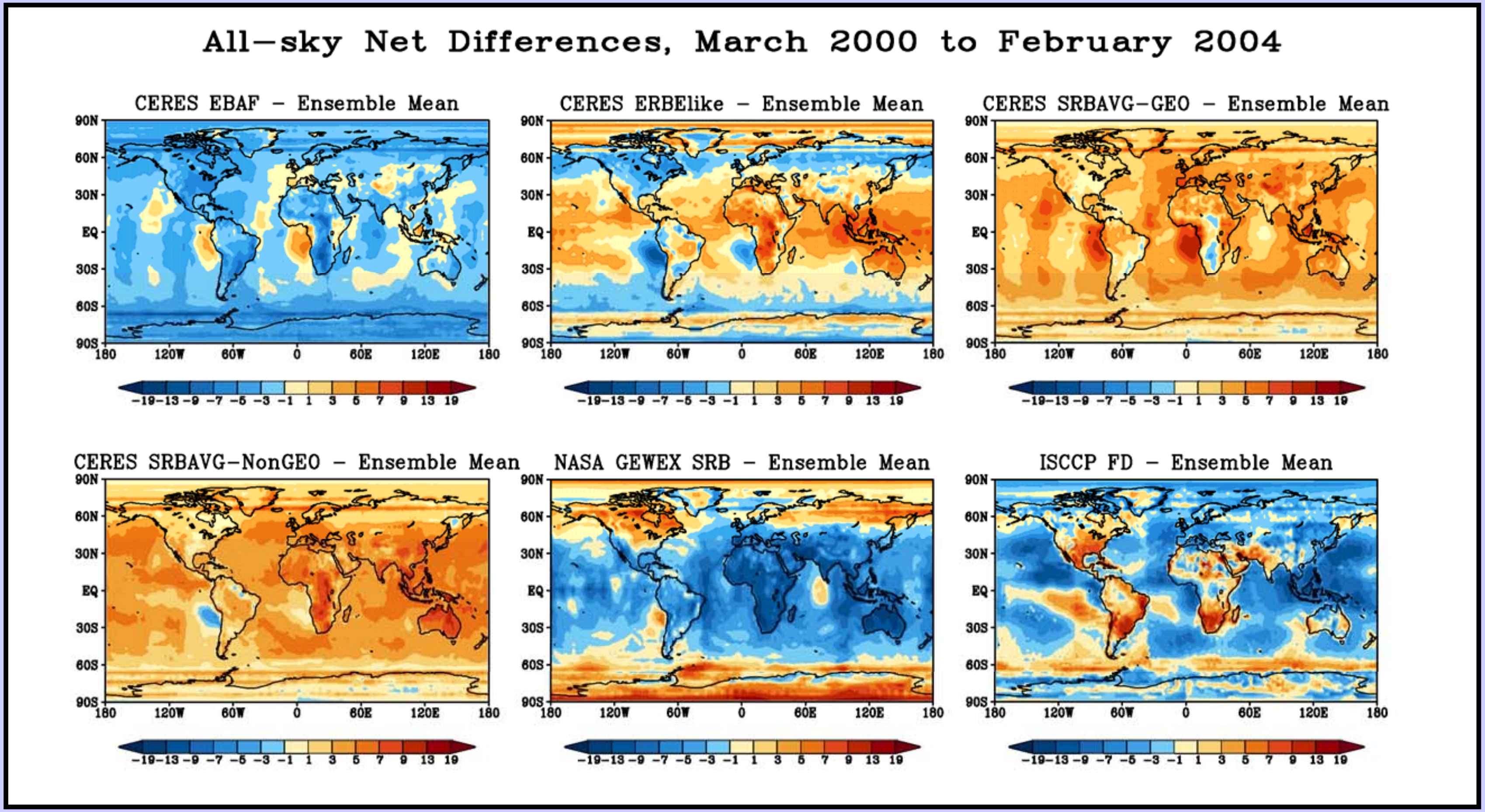
- CERES products have smaller SW fluxes than ISCCP-based products.
- Horizontal artifacts in polar areas are introduced mainly by CERES ERBElike and SRBAVG products.
- Orbital patterns are visible; ensemble mean is contaminated with geo-stationary satellite artifacts.

TOA Longwave Flux Differences



- Regional differences are small for CERES-based products but large for ISCCP-based products.
- Geo artifacts (ISCCP-FD and GEWEX SRB) are reduced, but still noticeable over Southern Hemisphere.

Overall Net Flux Differences



- Complicated regional patterns are produced by combination of longwave and shortwave differences.
- Some data products show mostly negative differences; others mostly positive.
- Difference between EBAF and other CERES products due to forced TOA energy balance.

Annual Global Mean TOA Radiation Budget

Parameters (Wm^{-2})	Ensemble Mean	σ	Relative σ	Range
Incoming solar	341.3	0.7	0.2%	340.0, 341.8
Clear-sky LW out	266.1	2.7	1.0%	262.0, 268.0
Clear-sky SW out	52.0	1.9	3.6%	49.2, 54.5
Clear-sky net	23.1	3.3	14.3%	18.1, 26.2
All-sky LW out	238.3	1.8	0.8%	235.6, 240.5
All-sky SW out	99.9	3.2	3.2%	96.6, 105.2
All-sky net	3.2	3.2	100.0%	-0.4, 7.0

- **Agreement: LW within 1%, SW within 4% of the ensemble mean.**
- **Disagreement: Largest relative σ for net due to small net value, smallest for solar incoming.**
- **LW agrees better when clouds are included, SW worse (but their overall magnitudes change as well.)**

Satellite Surface Radiation Data Sets

Data Set	Satellite Source	Spatial Coverage	Temporal Coverage	
ISCCP-FD	ISCCP Geo + Polar	Global	07-1983 to 12-2004	
LaRC GEWEX SRB	ISCCP Geo + Polar	Global	07-1983 to 06-2005	3
FORTH*	ISCCP Geo + Polar	Global	01-1984 to 12-2004	
Univ. Md. SW**	ISCCP Geo + Polar	Global	07-1983 to 12-2004	
DLR ISIS SW**	ISCCP Geo + Polar	Global	07-1983 to 06-2000	
Univ. Md. Net SW**	ERBS, N9, N10	Global	02-1985 to 05-1989	1
CERES***	Terra, Aqua + Geo	Global	03-2000 to 10-2005	2

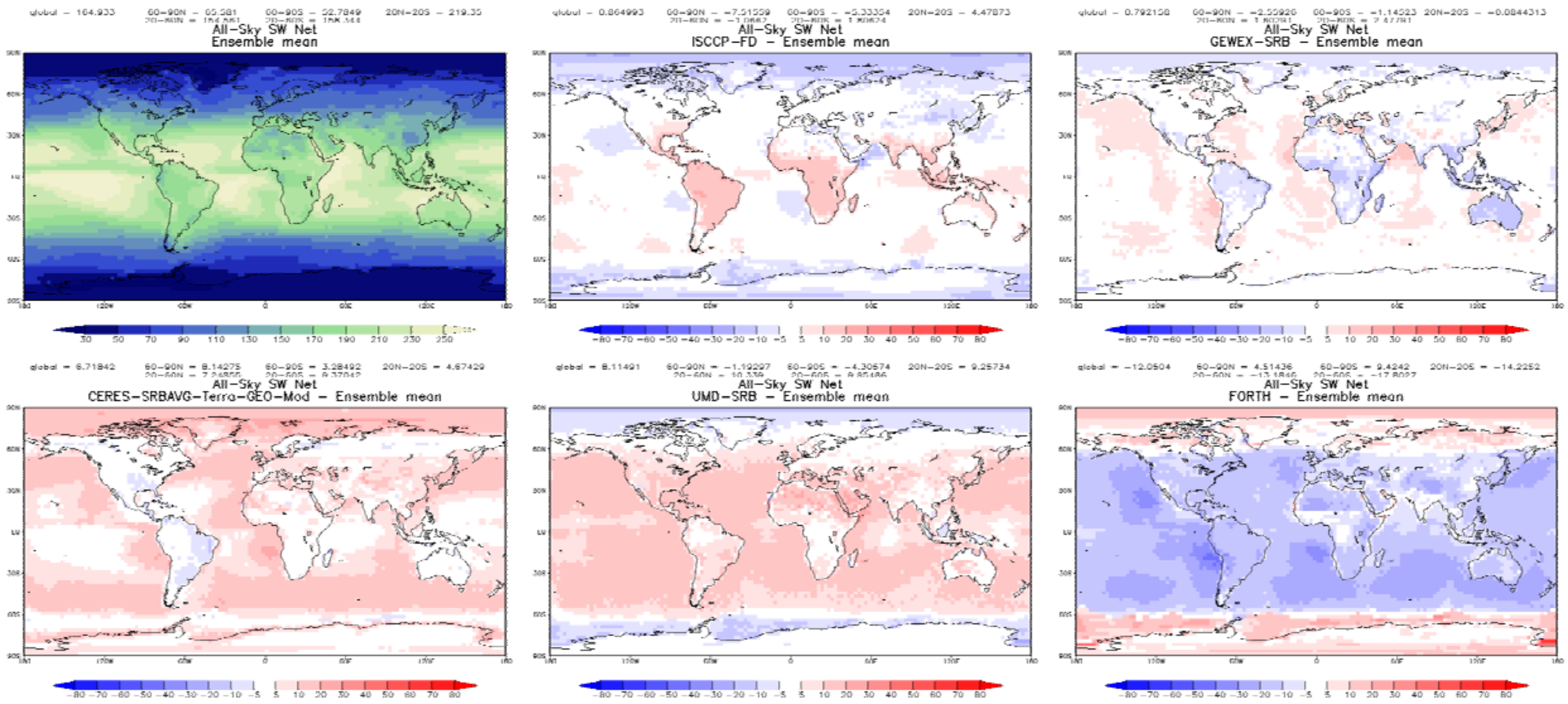
*** Incomplete in polar areas**

**** UM SW, UM Net SW, DLR ISIS: single component data**

***** CERES: SRBAVG-GEO**

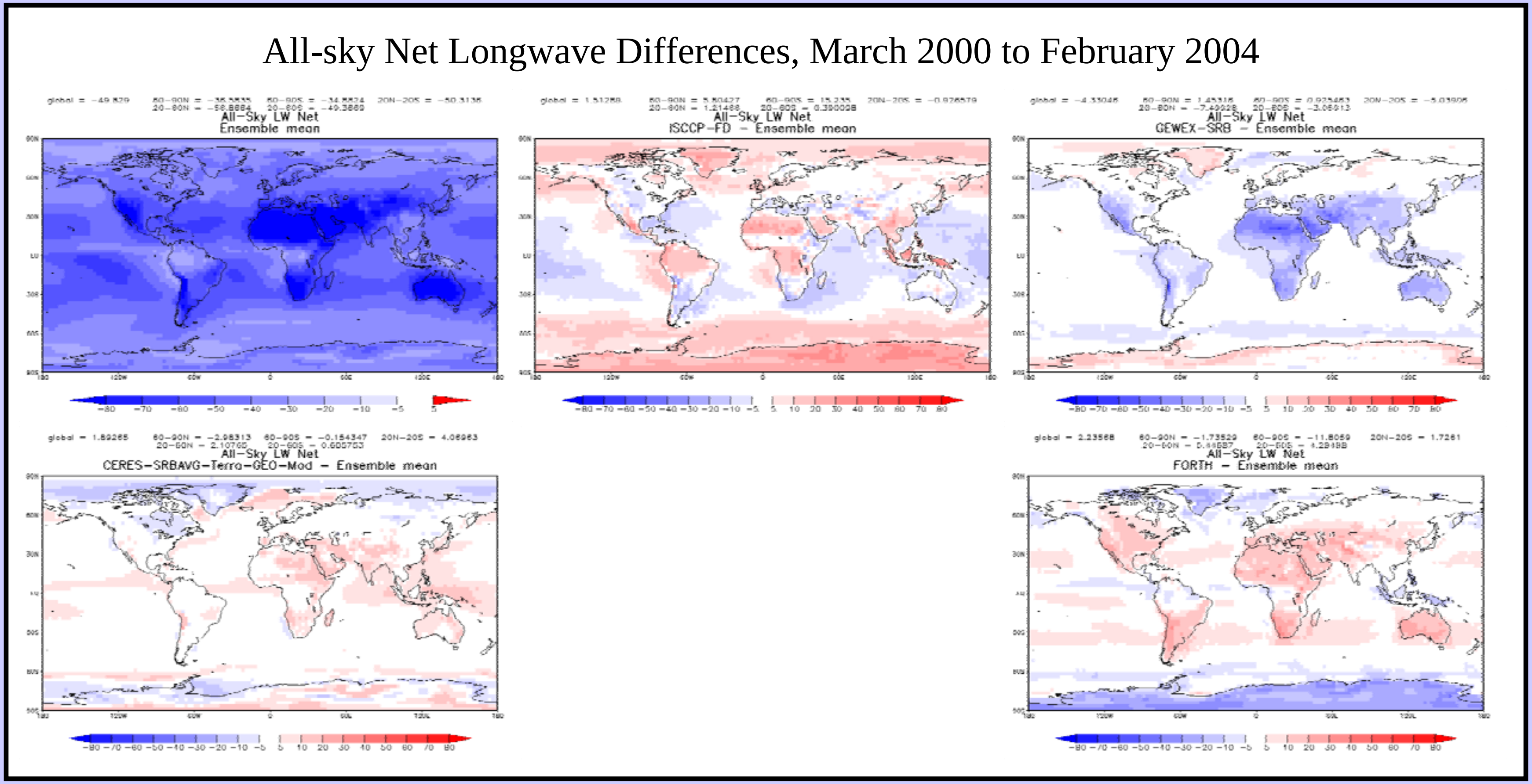
Surface Shortwave Flux Differences

All-sky Net Shortwave Differences, March 2000 to February 2004



- CERES SRBAVG-GEO has larger net SW flux than ISCCP-based products.
- Biases in ISCCP-based products vary; contrast often between polar and non-polar regions or land vs. ocean.

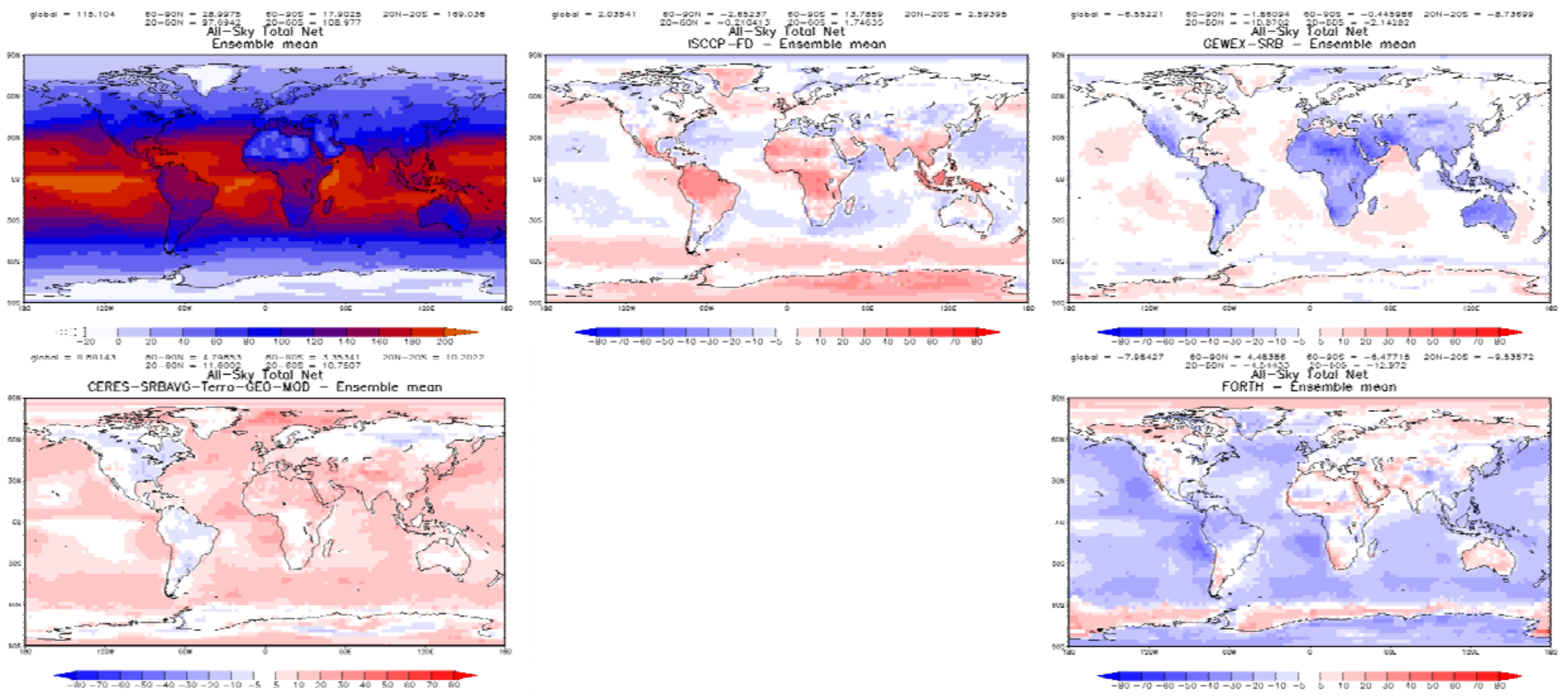
Surface Longwave Flux Differences



- **CERES SRBAVG-GEO is close to ensemble mean; biases in ISCCP-based products vary.**

Surface Net Flux Differences

All-sky Total Net Flux Differences, March 2000 to February 2004



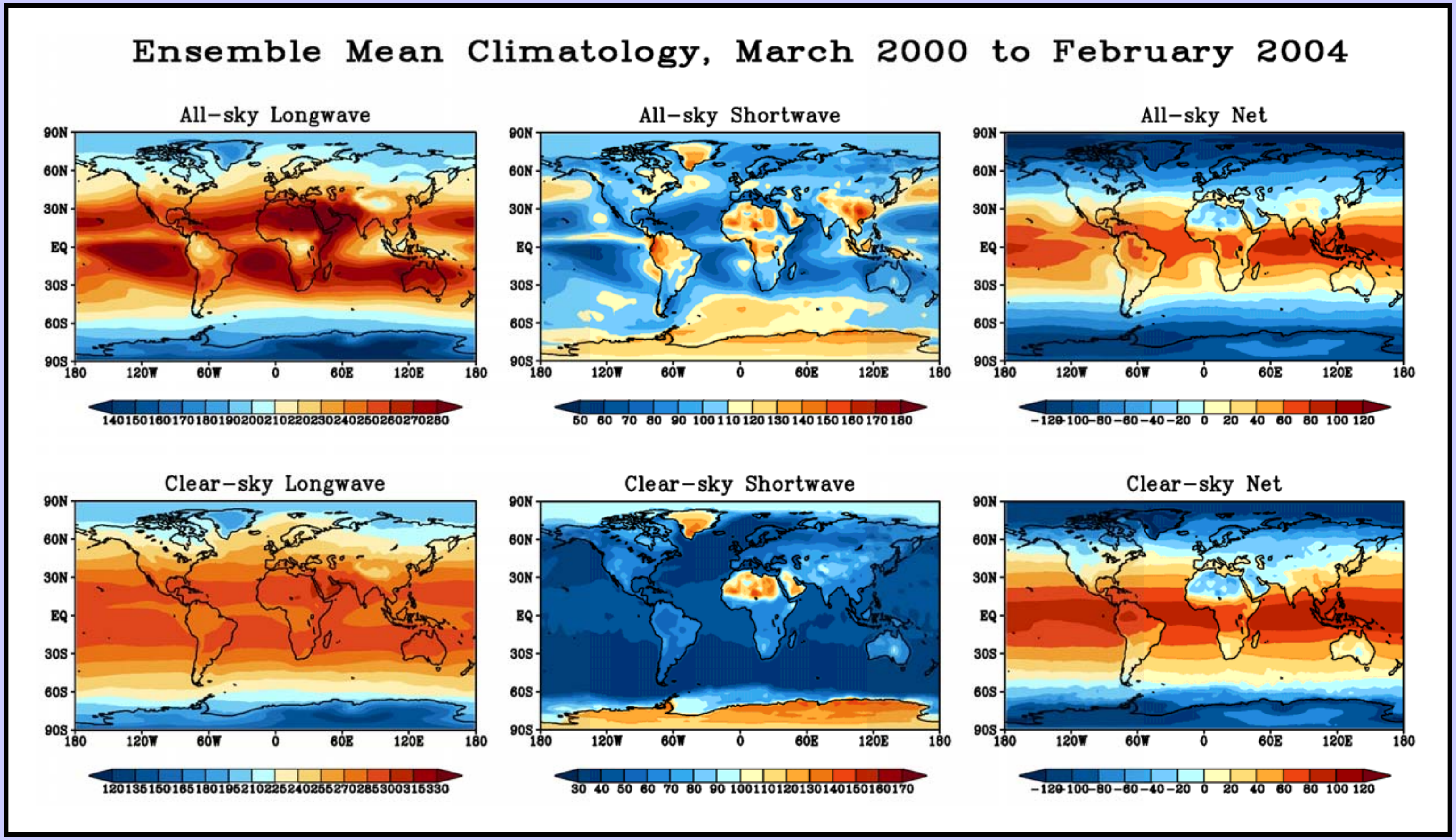
- **CERES SRBAVG-GEO net fluxes are high relative to ISCCP-based products; biases in ISCCP-based products vary.**

Annual Global Mean Surface Radiation Budget

Parameter (Wm^{-2})	Ensemble Mean	σ	Relative σ	Range
All-sky SW Down	188.0	6.3	3.3%	[178.4, 197.6]
All-sky SW Up	23.9	2.2	9.3%	[20.6, 26.8]
All-sky Net SW	164.9	6.9	4.2%	[152.9, 173.0]
All-sky LW Down	344.9	2.5	0.7%	[342.9, 347.9]
All-sky LW Up	394.8	3.1	0.8%	[391.9, 399.1]
All-sky Net LW	-49.8	3.9	7.8%	[-57.0, -47.6]
All-sky Total Net	115.1	7.5	6.5%	[104.2, 123.7]

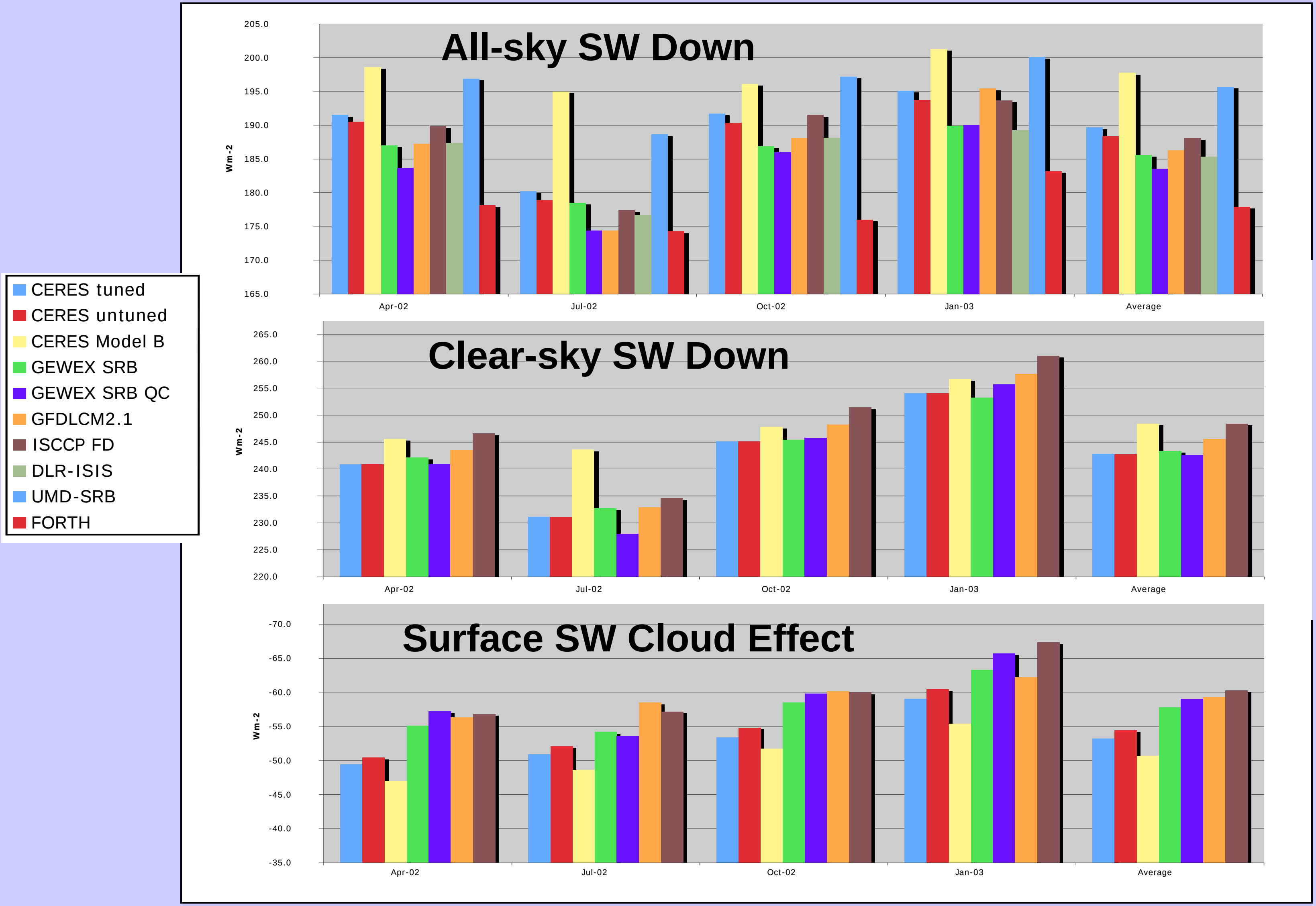
- **Agreement: LW within 4 Wm^{-2} SW within 7 Wm^{-2} of ensemble mean.**
- **Disagreement: Largest relative σ for SW up due to small net value, smallest for LW up and down.**
- **LW agrees better when clouds are included, SW worse (but their overall magnitudes change as well.)**

TOA All-sky vs. Clear-sky Fluxes



- All-sky fluxes are strongly affected by clouds.
- Largest differences are in tropics and for SW in the south Atlantic ocean.

SW Surface Cloud Effect Comparisons



- **All-sky flux range 15-20 Wm^{-2}, clear-sky 5-10 Wm^{-2}, cloud effect range ~10 Wm^{-2}.**
- **CERES-based cloud effect smaller than ISCCP-based; ISCCP-based and GFDL model values all similar (tuning?).**

Cloud Data Treatment Effects

ISCCP vs. GEWEX-SRB:

Both based on ISCCP cloud data, but…

ISCCP:

- **Uses retrieved cloud properties -- e.g., cloud amount, optical depth -- as input streams.**
- **Fluxes from 2-stream computation.**

SRB:

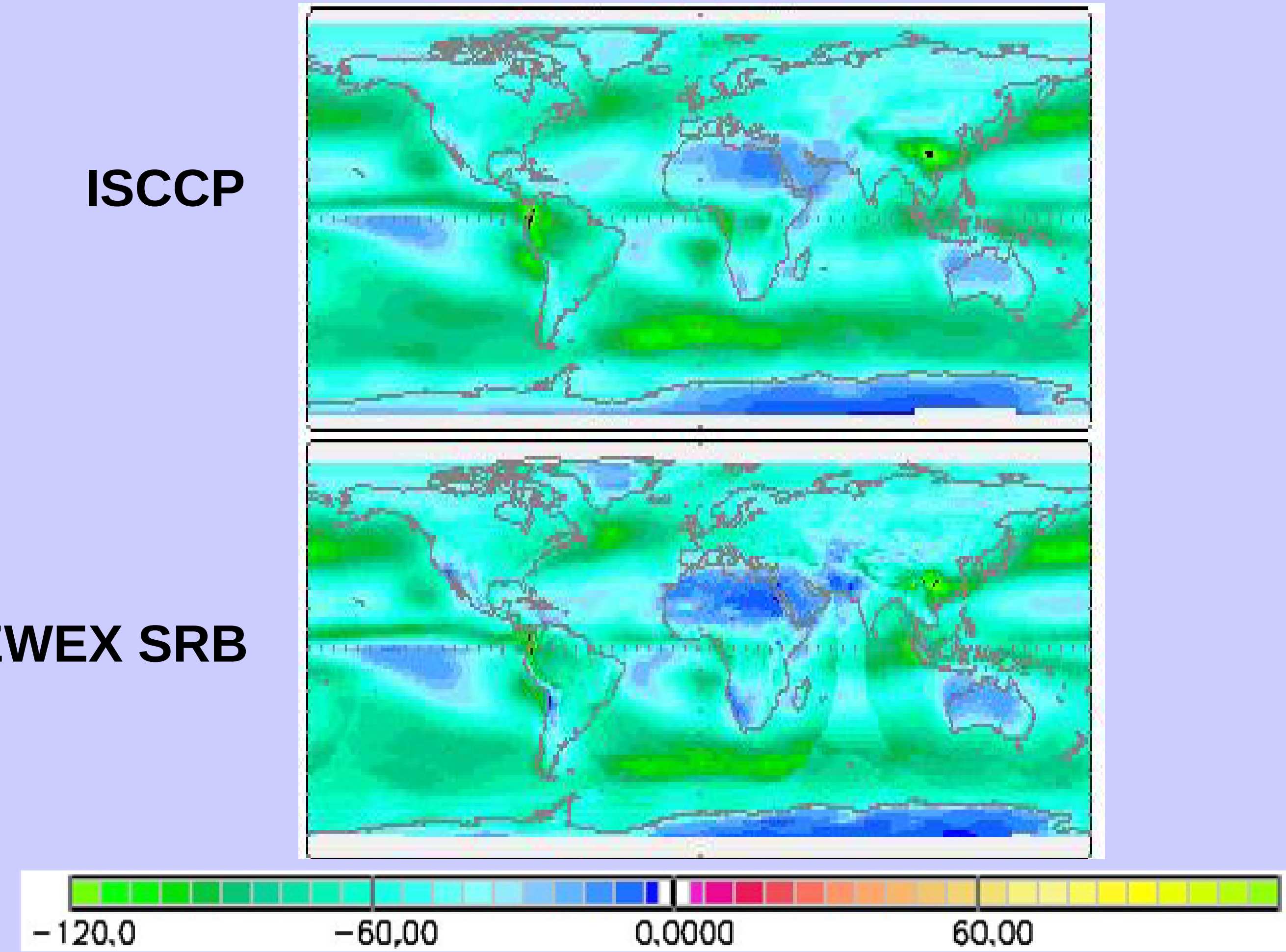
- **Uses ISCCP radiances and cloud amount.**
- **Fluxes from parameterization tied to TOA radiances.**

Cloud Treatment Effects

Surface SW Cloud Effect

ISCCP

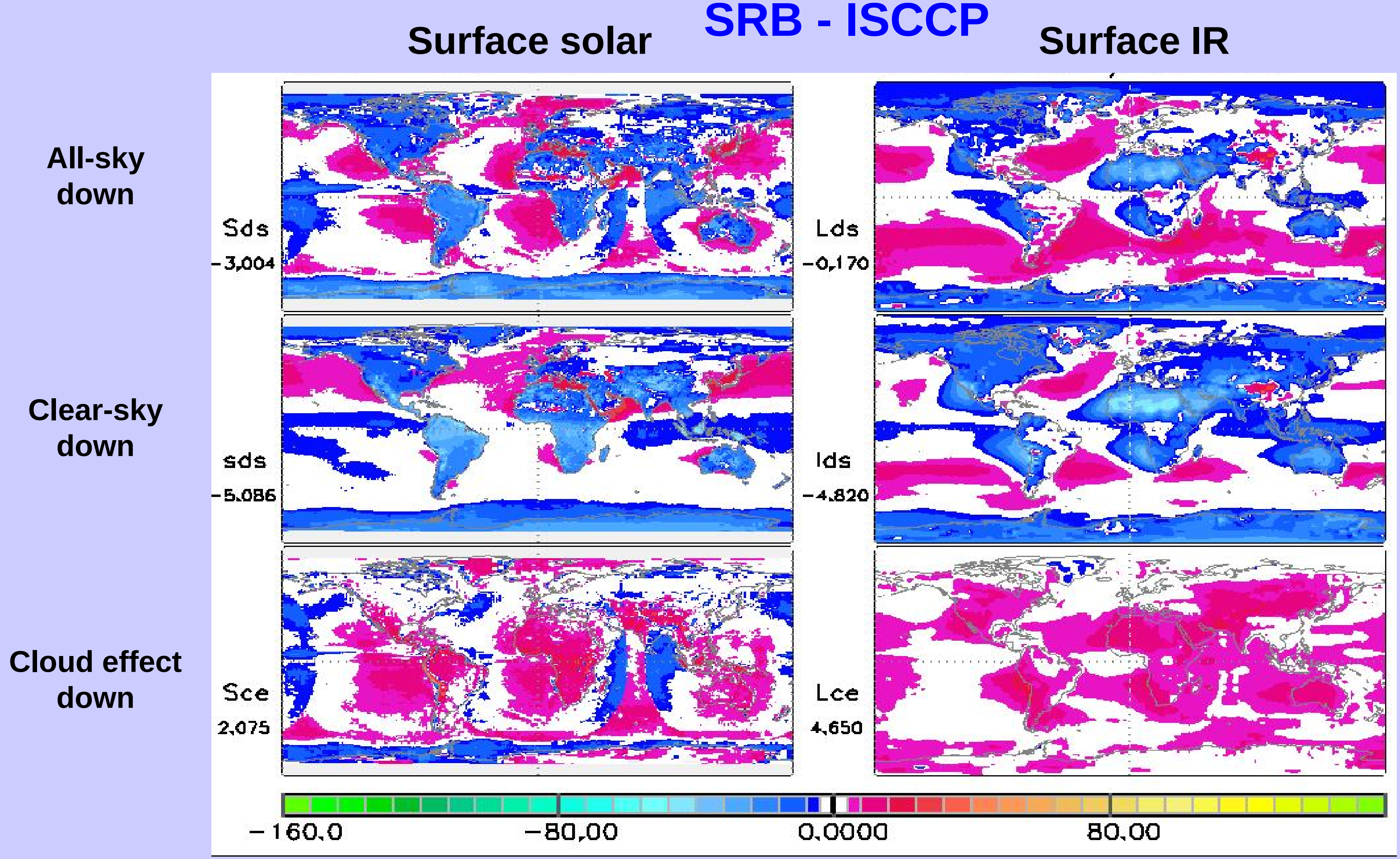
GEWEX SRB



- Rings visible in SRB fluxes, faint in ISCCP image.
- Optical depth error compensates for additional cloud amount for ISCCP.

Cloud Property Effects

SRB - ISCCP



- SRB solar cloud effect less negative than ISCCP by 2 Wm^{-2} -- optically thinner clouds.
- SRB IR cloud effect larger than ISCCP by 5 Wm^{-2} -- lower altitude or greater LWP.

Assessment Challenges

Assessment Challenges

- **Data format**
  - **needs to be uniform, simple:**

  ASCII global 2.5° gridded values, time series
  - **needs to be easily available:**

  Archive at NASA Atmospheric Science Data Center
- **Extent of analysis**
  - **must be achievable in reasonable time frame**

  Limited to

  1. **Global climatologies**
  2. **Annual cycles**
  3. **Time series analysis**
  4. **Comparisons to surface measurements**

Assessment Challenges

- **Analysis uniformity**
  - central process or coordinated among multiple groups?

    Main analysis by a few researchers

    Contributed chapters from individual groups
- **Editing and approval process**
  - requires community involvement:

    Rely on data providers and GEWEX Radiation Panel
- **Motivation**
  - volunteer activity:

    No clear solution.

GEWEX RFA: Status

- Several workshops held.
- Data archive established (NASA LaRC ASDC).
- Data sets developed and submitted to archive. (Archive closed 2007.)
- Analysis underway.
- Report being written and edited.

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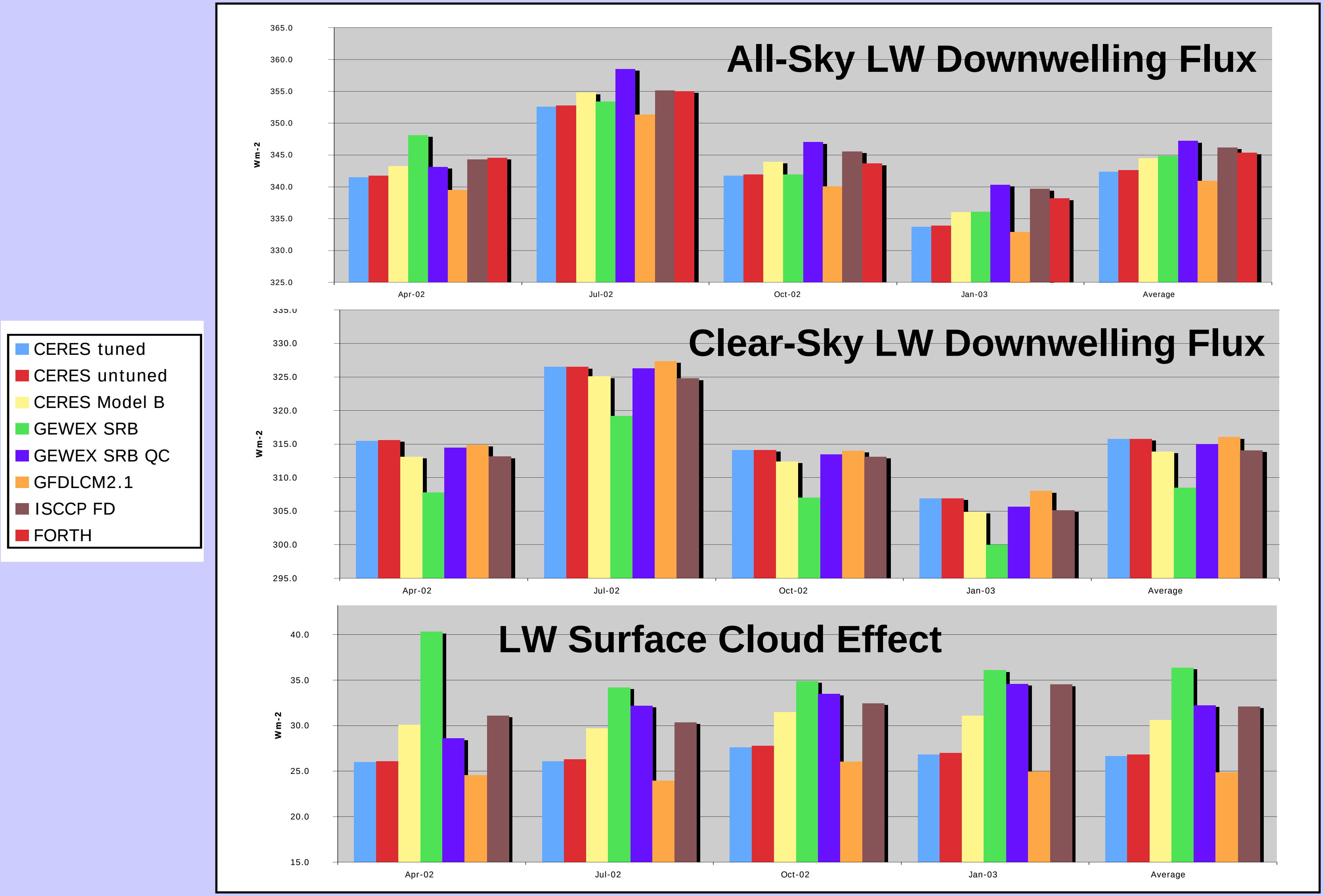
Goal: Report complete in 2010!

Web site:

http://gewex-rfa.larc.nasa.gov

(or google “GEWEX-RFA”)

LW Surface Cloud Effect Comparisons



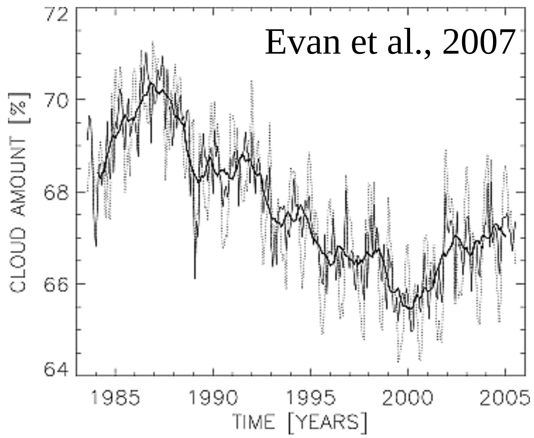
- **All-sky flux range 5-10 Wm^{-2}, clear-sky <10 Wm^{-2}, cloud effect range 10-15 Wm^{-2}.**
- **CERES-based cloud effect smaller than ISCCP-based.**
- **GFDL model has smallest cloud effect, GEWEX-SRB largest.**

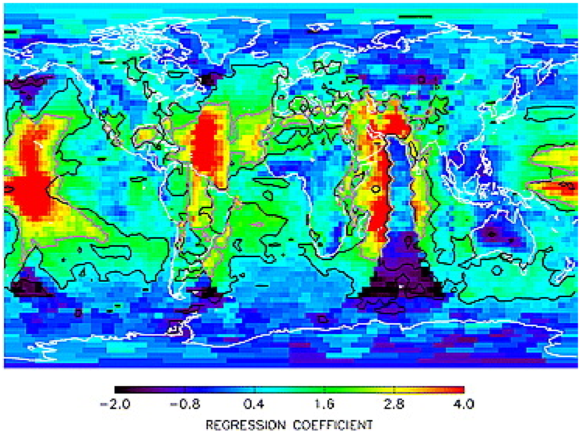
In-situ Surface Radiation Data Sets

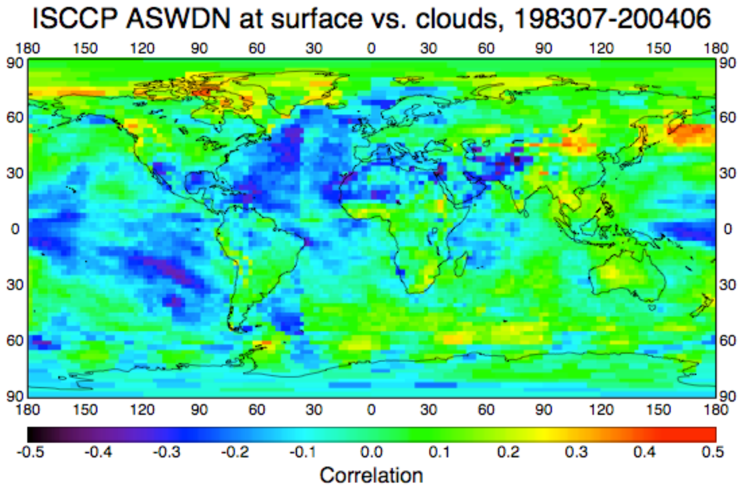
Data Set	No. Sites	Location	Sample Frequency	Temporal Coverage
GEBA	30	Global	Monthly	Various, 1983-2008
BSRN	34	Global	Monthly 15-min	Various,1992-2006
Univ. Oregon	3	Oregon	Monthly 15-min	Various, 1979-2006 01-2004 to 12-2004
ASRN	6	Switzerland	15-min	01-2004 to 12-2004
LaRC CAVE	22	Global	15-min	01-2004 to 12-2004
C. Long Derived Products*	30	Global	Monthly 15-min	Various,1992-2006 01-2004 to 12-2004

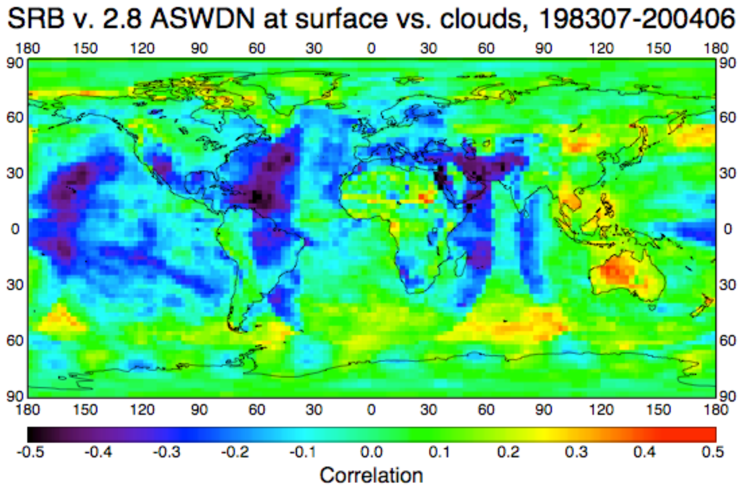
*** In addition to fluxes, contains many variables derived from them (sky cover, cloud optical depth, effective cloud transmissivity, etc.)**

Cloud Treatment Effects









- **Artifact now evident in ISCCP data, but more obvious in GEWEX-SRB.**
- **Optical depth error compensates for additional cloud amount for ISCCP.**

RFA Report Outline

Section	Title
0.0	Executive Summary
1.0	Introduction
2.0	Incoming Solar Irradiance
3.0	Long-Term TOA Flux Product Comparisons
4.0	Long-Term Satellite-Based Surface Flux Product Comparisons
5.0	Long-Term In-Situ Surface Flux Data Product Comparisons
6.0	Satellite-Estimated vs. In-Situ Measured Surface Flux Comparisons
7.0	Vertical Column Flux Divergence
8.0	Global Radiation Budget Summary
Appendix A	Data Sets and Uncertainties
Appendix B	Radiative Transfer Model Comparisons
Appendix C	Contributed Papers
Appendix D	Lessons Learned