The GEWEX Radiative Flux Assessment Project

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Paul Stackhouse (NASA LaRC)

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GEWEX RFA TOA Radiation Overview

- GEWEX Radiative Flux Assessment (RFA) is a community based activity (first of its kind for TOA and surface radiative flux) commissioned by GEWEX Radiation Panel
- Assess our current understanding and capability to derive TOA radiative fluxes from analysis of satellite observations
  - Several workshops held => most recent in December 2010
  - Data sets developed and submitted to archive
  - Web site developed: http://gewex-rfa.larc.nasa.gov
  - Good working drafts of all chapters now exist
- Identify uncertainties and outstanding issues in flux estimation
  - Sources include satellite calibration, input data sources, spatial and temporal gap filling, and other assumptions
- GEWEX RFA report may be an useful reference for development of future climate system observation requirements for radiative fluxes as well as for understanding current data limitation and uncertainty for future IPCC report
  - GEWEX News Article published

RFA Report Status

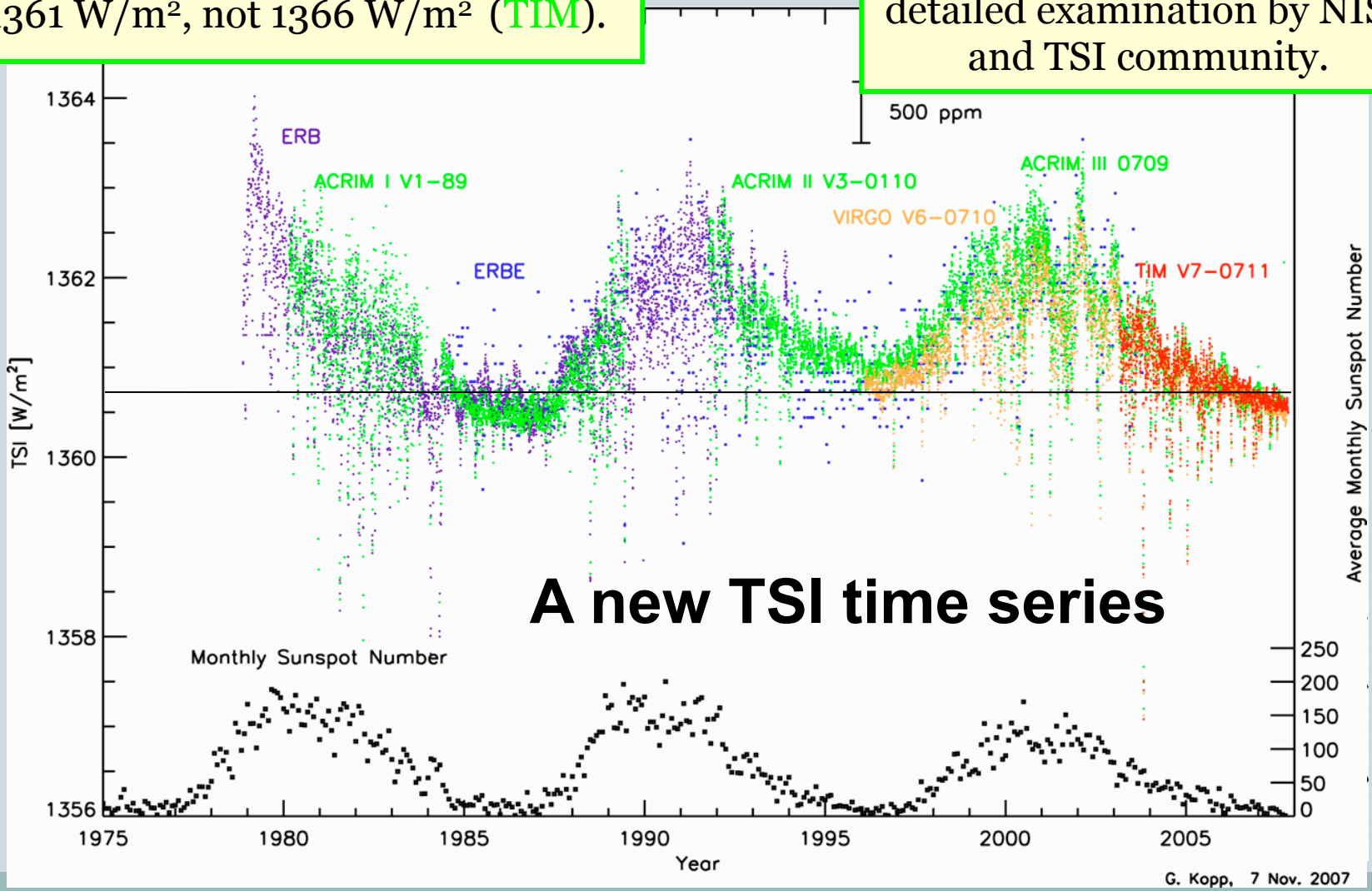
Section	Title	Responsible Author(s)	Status
0.0	Executive Summary	Raschke and all	Draft
1.0	Introduction	Raschke and all	Incomplete
2.0	Incoming Solar Irradiance	Kopp and Raschke	V3 Draft; reviews obtained
3.0	Long-Term TOA Flux Data Product Comparisons	Wong, Rossow and Zhang	Draft in revision
4.0	Long-Term Satellite Based Surface Flux Product Comparisons	Stackhouse, Kinne, Rashke, Hinkelman, Y. Zhang	Draft in revision
5.0	Long-Term In-Situ Surface Flux Data Product Comparisons	Dutton, Long, Leipert, Ohmura and Wild	Draft; ready for outside review
6.0	Satellite-Estimate Surface vs. In-Situ Measurement Comparisons	Hinkelman, T. Zhang, Stackhouse, Wild,	Draft in revision
7.0	Vertical Column Flux Divergence	Raschke and Kinne	Draft in revision
8.0	Global Radiation Budget Diagram	Loeb, Su	Draft in revision
9.0	Global Model Comparisons	Kinne, Raschke, Friedenreich, Hinkelman, T. Zhang	Draft in revision
A	Data Sets and Uncertainties	Hinkeman	Draft
B	Radiative Transfer Model Comparisons	Kato	Draft
C	Contributed Papers	Various	4 drafts
D	Lessons Learned	Co-Chairs	TBD

Chapter 2 Results: Total Solar Irradiance

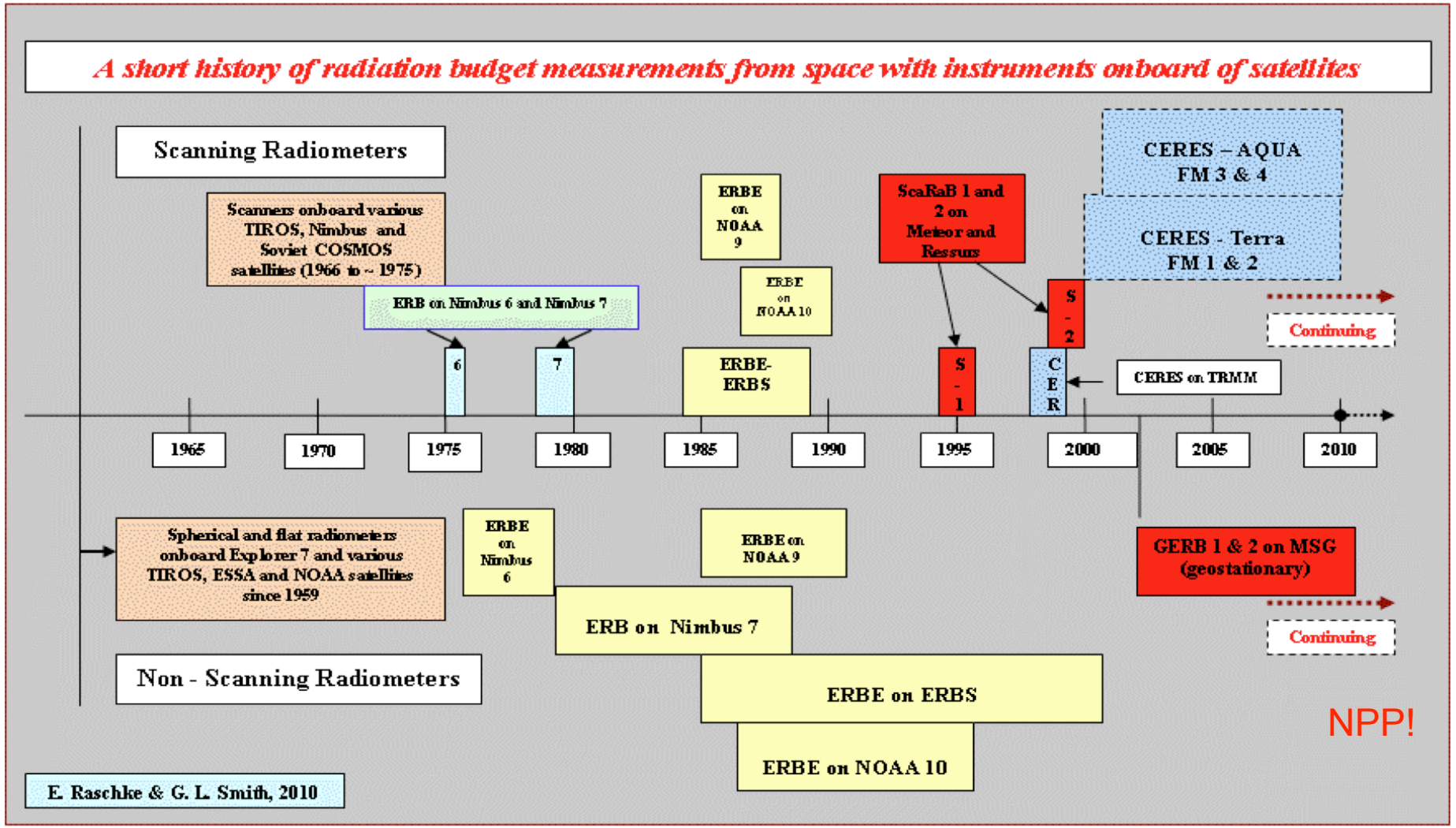
SORCE TIM Indicates Lower TSI Value

Fundamental discovery that the TSI is ~1361 W/m², not 1366 W/m² (TIM).

SORCE/TIM result motivated detailed examination by NIST and TSI community.



Chapter 3: Satellite TOA Radiation Measurements



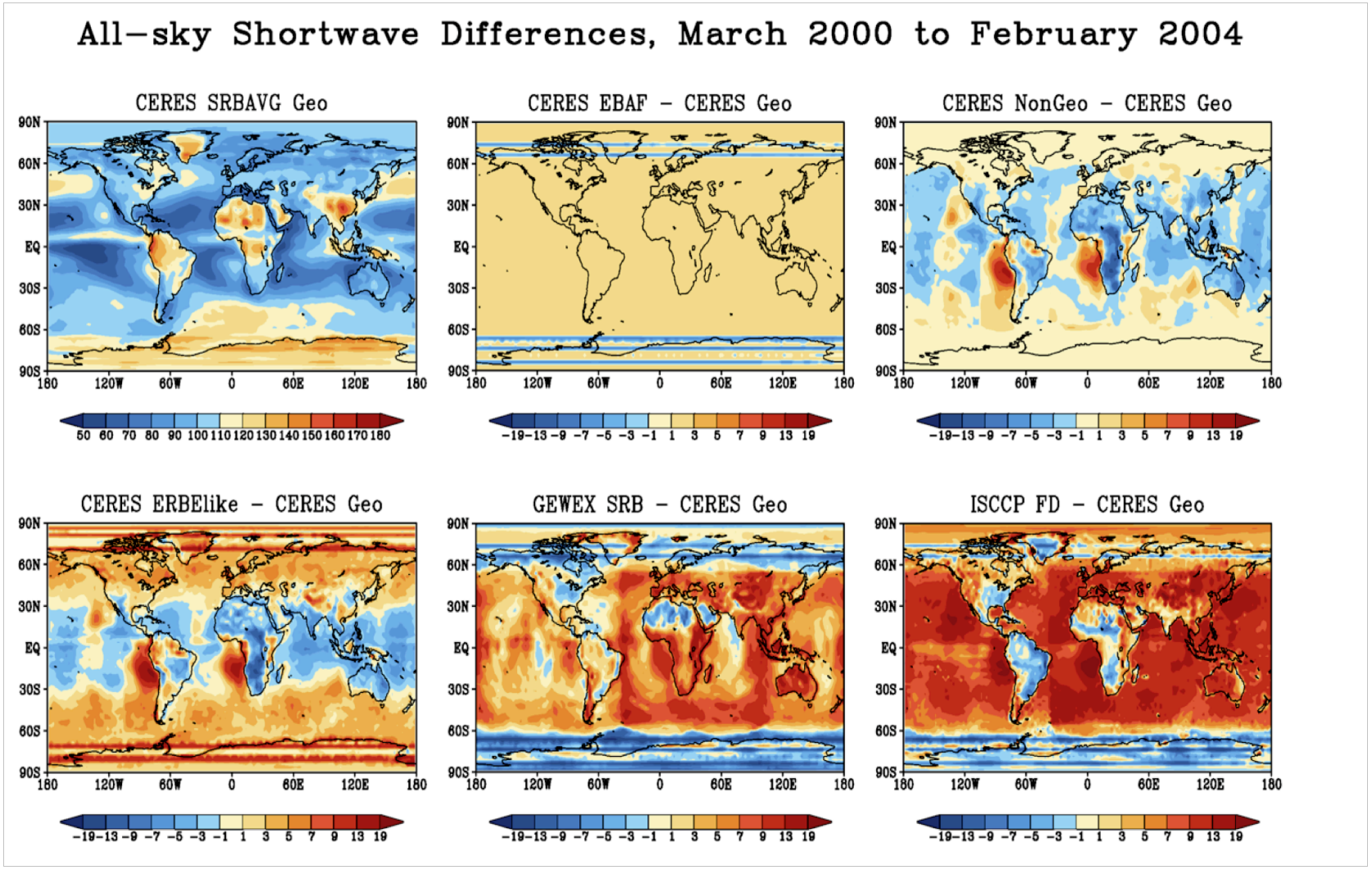
Chapter 3: TOA Radiation Datasets

Data Source	Satellite Source	Spatial Coverage	Temporal Coverage	
CERES*	Terra, Aqua	Global	03-2000 to 10-2005	2
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	
ERBE Scanner	ERBS, N9, N10	Global	02-1985 to 05-1989	1
ERBE NonScanner	ERBS	60N to 60S	1985 to 1999	
ScaRaB Scanner***	Meteor, Resurs	Global	1994-95, 1998-99	

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

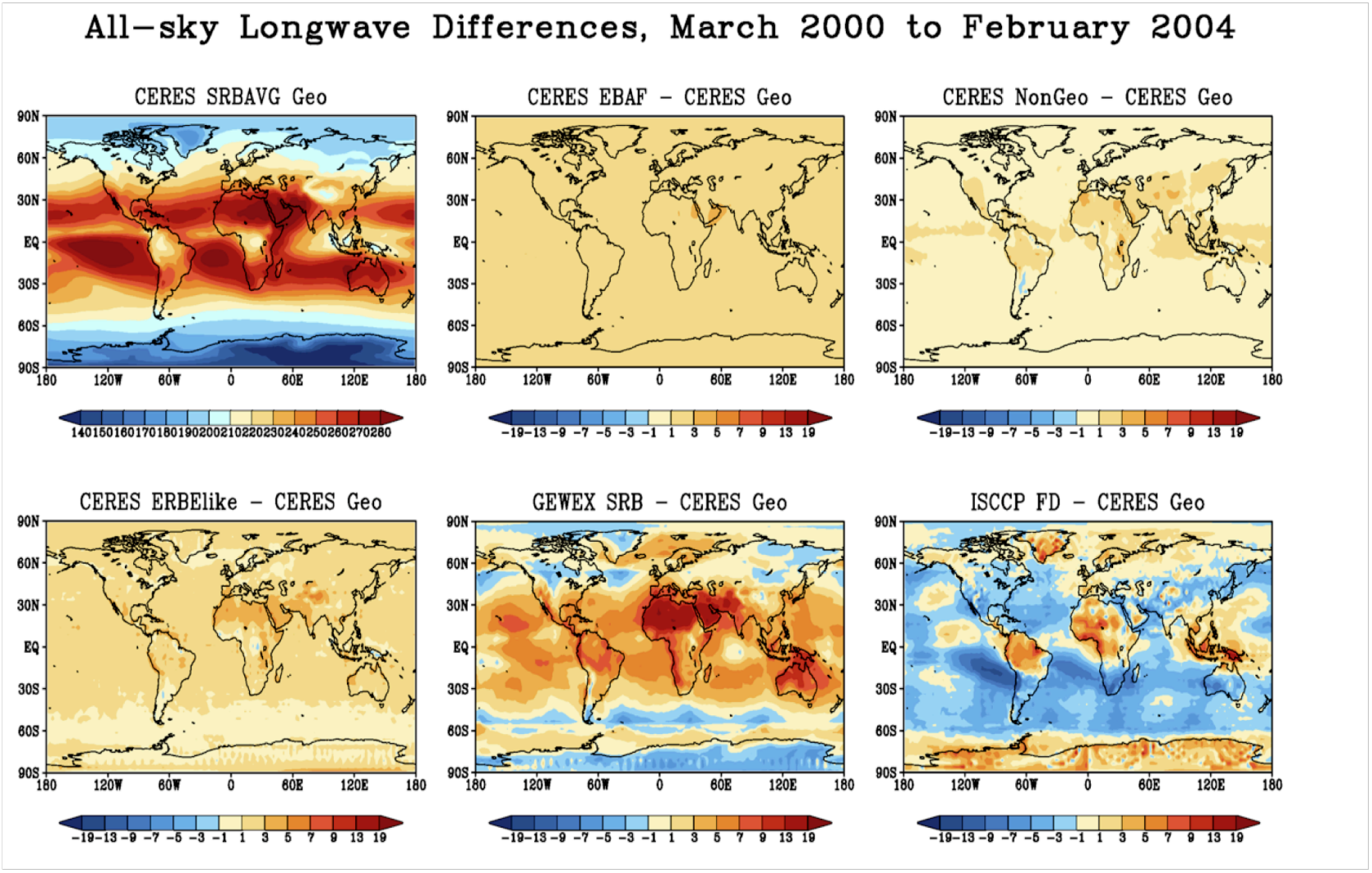
From Chapter 3; Contribution by Wong

Chapter 3: TOA Radiation Datasets



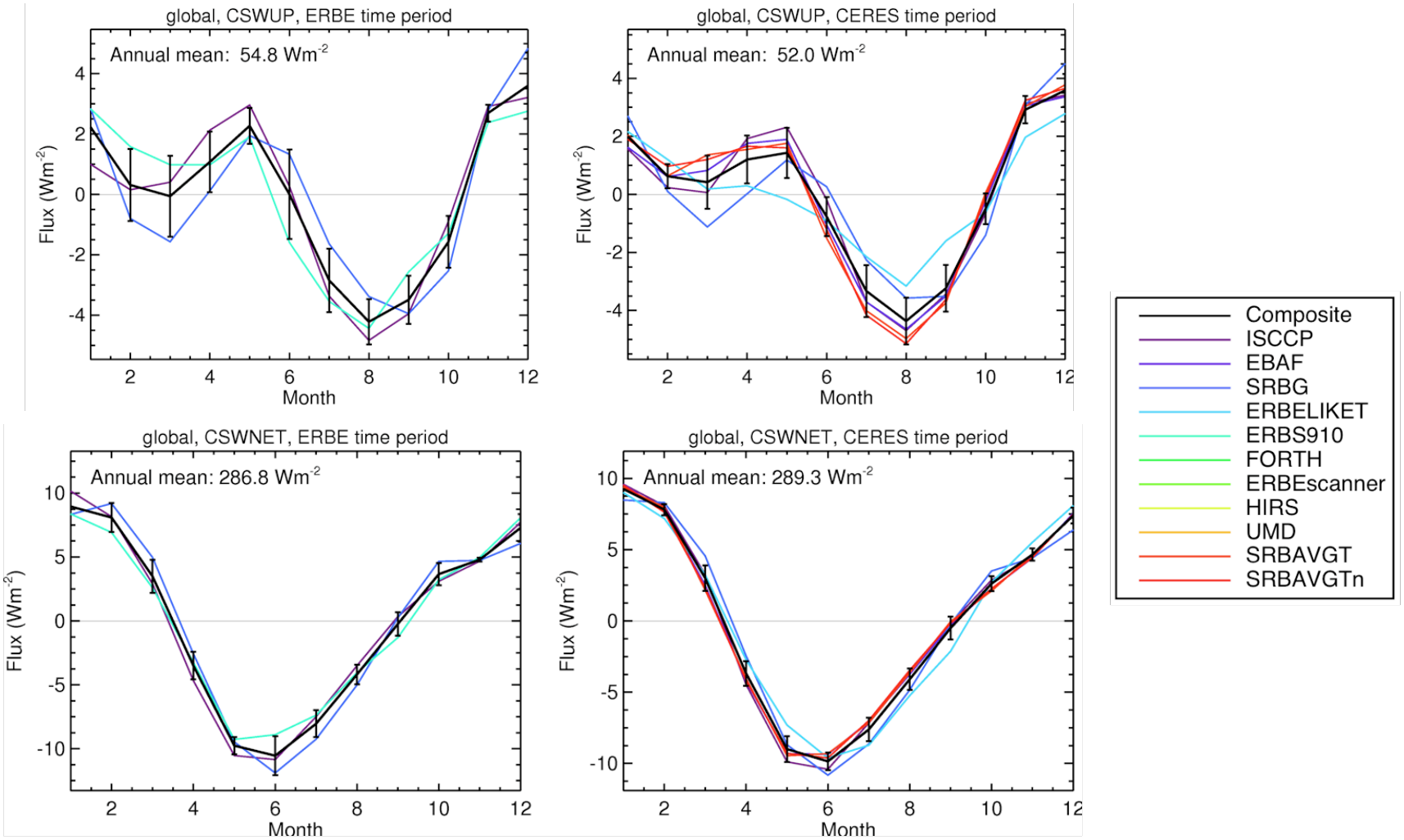
From Chapter 3; Contribution by Wong

Chapter 3: TOA Radiation Datasets



From Chapter 3; Contribution by Wong

Chapter 3: Annual Global Mean TOA Radiation Budget



From Chapter 3; Contribution by Hinkeman

Chapter 4: Surface Radiation Datasets

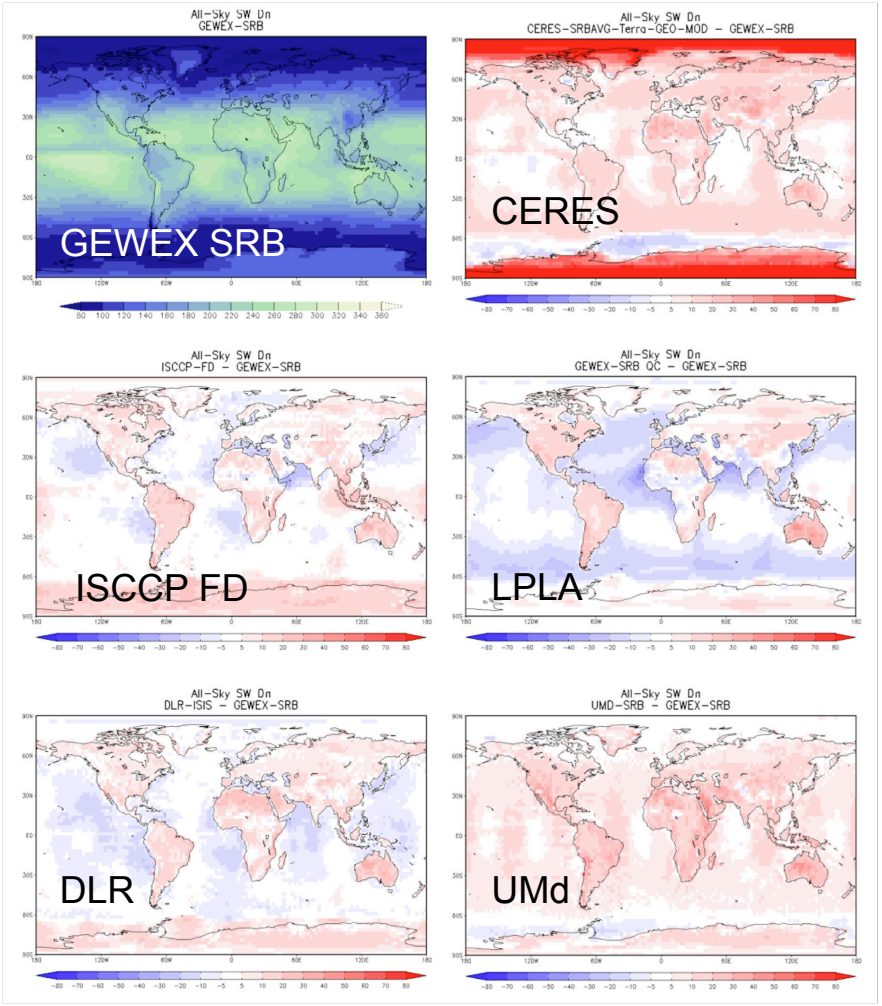
Data Source	Satellite Source	Spatial Coverage	Temporal Coverage	
CERES*	Terra, Aqua	Global	03-2000 to 10-2005	2
ISCCP-FD	ISCCP Geo + Polar	Global	07-1983 to 12-2004	3
LaRC GEWEX SRB	ISCCP Geo + Polar	Global	07-1983 to 06-2005	
FORTH	ISCCP Geo + Polar	Global	01-1984 to 12-2004	
Univ. Md. SW**	ISCCP Geo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

CERES: SRBAVG-GEO, SRBAVG-nonGEO, ERBE-like, and EBAF;

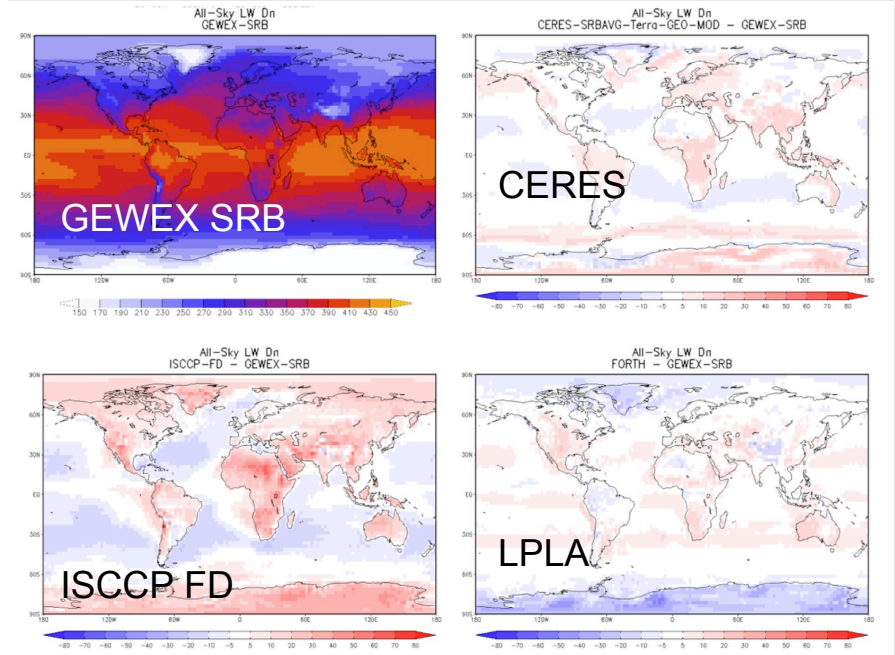
From Chapter 4: Contribution by Stackhouse, Cox, Mikovitz

Chapter 4: Comparison of Satellite Based Algorithms

SW Downward Fluxes



LW Downward Fluxes



Systematic differences noted and related to surface type and satellite view angle

From Chapter 4: Contribution by Stackhouse, Cox, Mikovitz

Chapter 5: Assessment of Surface Measurements & Uncertainties

Redundant measurements now provide estimates of operational uncertainties for in situ irradiance measurements

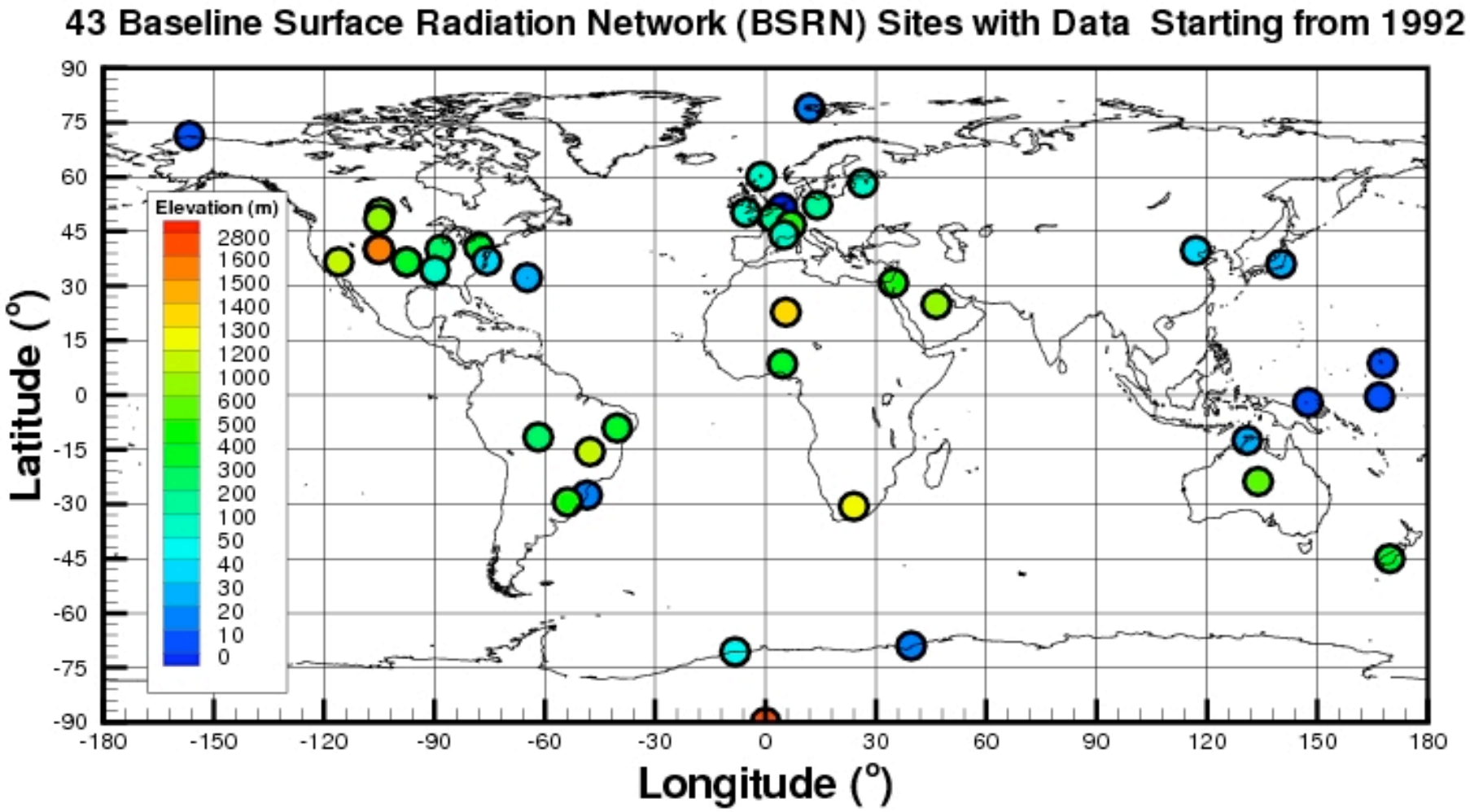
Quantity	1-3 min	1 Hr	1 Day	1 month	1 year	Figure #
SW Direct	± 16	± 14	± 8	± 5	± 4	5.1.2
SW Diffuse	± 14	±13	± 8	± 5	± 4	5.1.3
SW Global	± 25	± 24	± 11	± 8	± 6	5.1.4a
SW Total	± 21	± 19	± 11	± 7	± 6	
LW	± 6			± 4*		5.1.5

Table 5.1.10.1 The 95% inclusion ranges (W m^{-2}) of redundant measurement differences from operational network field sites for all zenith angles including nighttime. The values for the various parameters were obtained from the indicated or similar Figures with SW Total values were computed from square root sum of squares of the SW Direct and SW Diffuse.

* Averaging times vary between one and several weeks.

Chapter 5: Courtesy Ellsworth Dutton, NOAA

Chapter 6: Comparison of Satellite-based vs. In situ Surface Flux Measurements



From Chapter 6: Contribution by Hinkelman, T. Zhang & Stackhouse

Chapter 6: Comparison of Satellite-based vs. In situ Surface Flux Measurements

Statistics of GEWEX RFA *Satellite-based SW* Data Comparison with BSRN Data

Data Set	Bias (Wm^{-2})	RMS (Wm^{-2})	ρ	σ (Wm^{-2})	N
Sat_DLR_ISIS_Ed001	-1.9211	15.7730	0.9859	15.6596	1978
Sat_FORTH_Ed01a	-14.1678	24.2317	0.9703	19.6637	1811
Sat_GEWEX_SRBGSW_Ed281	-7.2823	20.7451	0.9771	19.4299	1978
Sat_GEWEX_SRBQSW_Ed025	-0.7686	16.8880	0.9830	16.8747	1978
Sat_ISCCP_FD_Ed000_010	-1.5877	16.5076	0.9842	16.4352	1978
Sat_UMD_SRB_Ed033	7.6642	21.6148	0.9791	20.2155	1978

From Chapter 6: Contribution by Hinkelman, T. Zhang & Stackhouse

Chapter 6: Uncertainties Using Reference Data Sets: Zonal Analysis

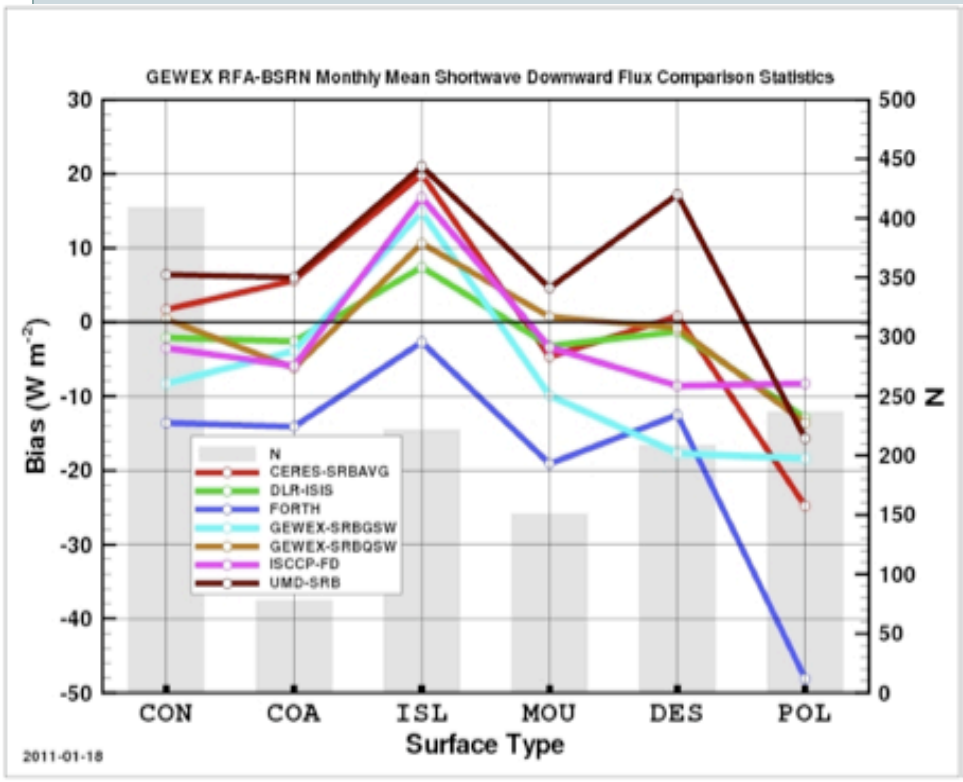
SW (CERES Time Period)

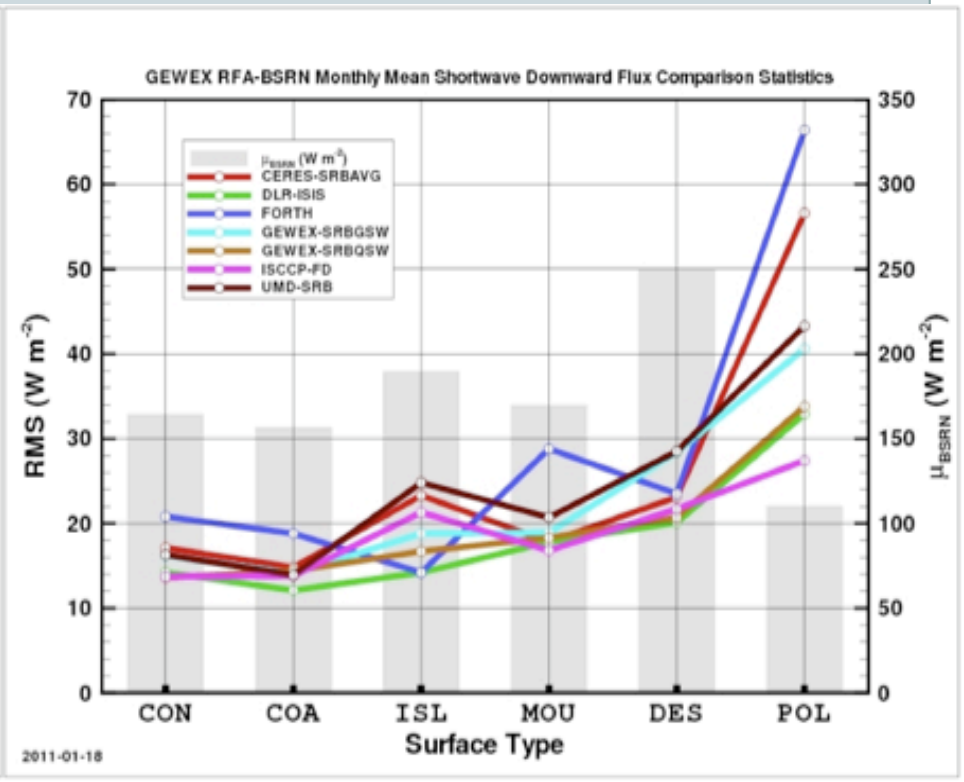
Red = tropics
Green = Mid-lats
Blue = polar

Data Set	Bias	RMS	ρ	σ	N
CERES_SRBAVG_Terra_GEO_MOD_Ed02d	0.4	28.3	0.950	28.3	1252
	18.2	20.0	0.953	8.4	140
	2.0	19.3	0.978	19.2	891
	-17.4	52.7	0.911	49.8	221
DLR_ISIS_Ed001	-2.6	20.3	0.977	20.2	1306
	5.0	11.2	0.952	10.1	140
	-1.3	16.8	0.980	16.7	891
	-10.7	31.5	0.972	29.7	275
FORTH_Ed01a	-15.9	29.7	0.954	25.2	1184
	-3.3	11.7	0.934	11.2	140
	-13.4	22.7	0.975	18.4	886
	-41.2	60.1	0.928	49.3	158
GEWEX_SRBGSW_Ed281	-7.6	25.0	0.968	23.8	1306
	14.0	17.0	0.948	9.7	140
	-8.8	20.5	0.974	18.6	891
	-14.7	38.0	0.961	35.2	275
GEWEX_SRBQSW_Ed025	-1.0	20.8	0.976	20.8	1306
	14.7	17.4	0.945	9.4	140
	0.2	16.6	0.979	16.6	891
	-12.8	31.7	0.973	31.7	275
ISCCP_FD_Ed000_010	-1.9	19.8	0.978	19.7	1306
	19.6	22.1	0.937	10.3	140
	-3.7	17.1	0.979	16.7	891
	-6.8	25.8	0.979	24.9	275

From Chapter 6: Contribution by Hinkelman, T. Zhang & Stackhouse

Chapter 6: Uncertainties Using Reference Data Sets: Surface Geographical Types

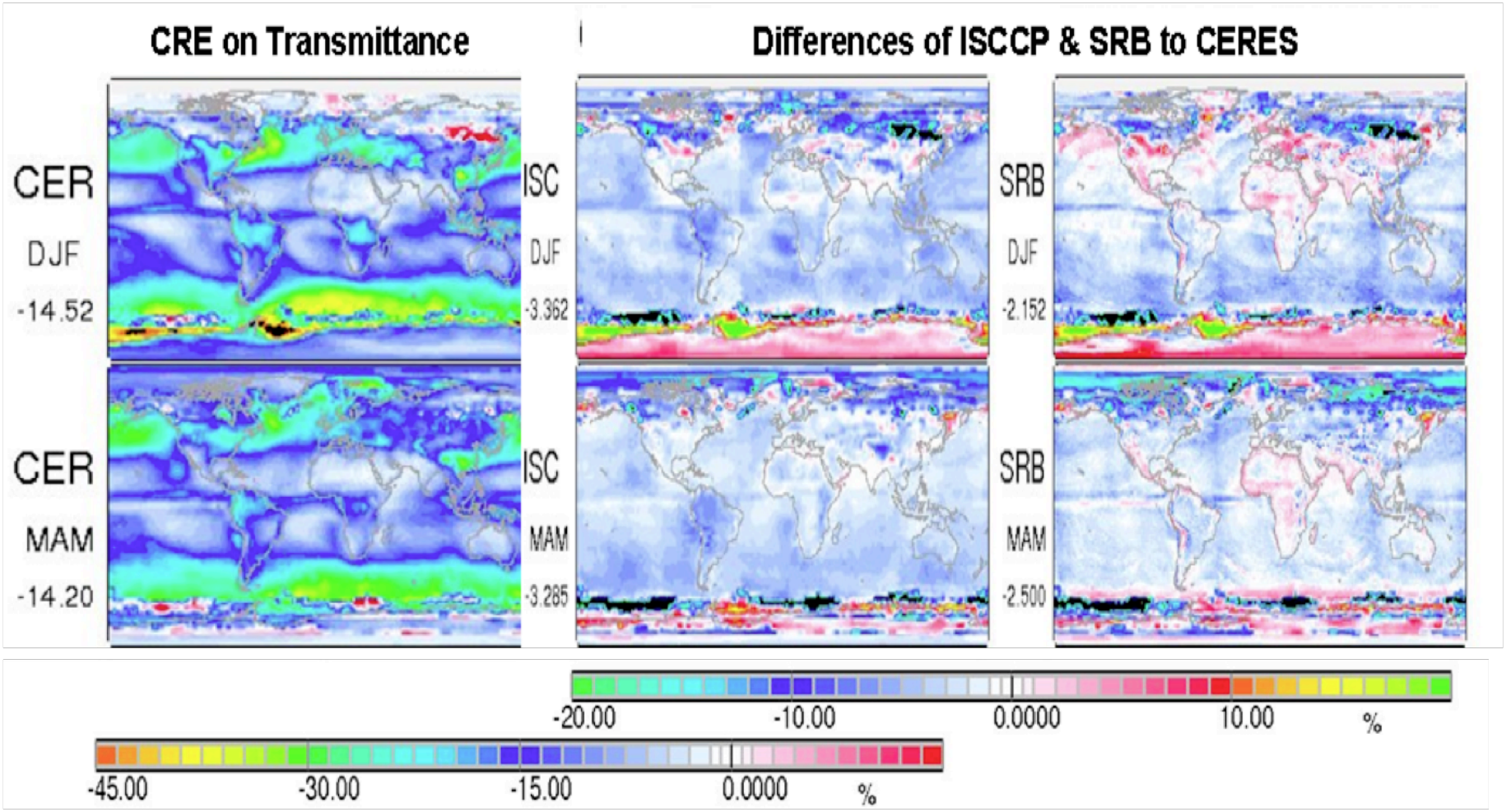




SW BSRN sites clustered by basic topographical surface type:
CON = continental, COA = coastal, ISL = island,
MOU = mountain, DES = desert, POL = polar

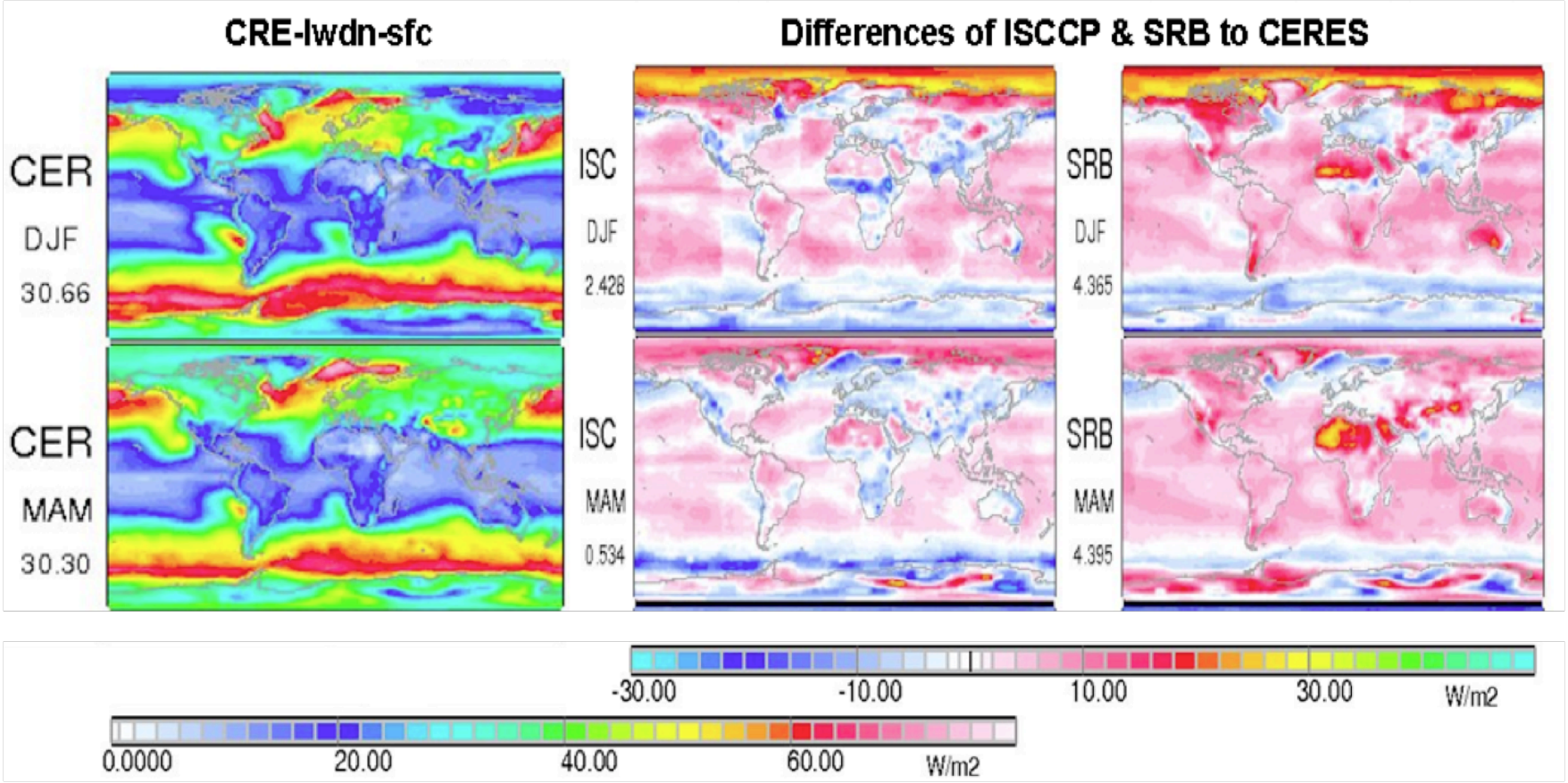
From Chapter 6; Contribution by Hinkelman, T. Zhang & Stackhouse

Chapter 7: Comparison of Satellite Based Algorithms



From Chapter 7: Contribution by Kinne, Raschke

Chapter 7: Comparison of Satellite Based Algorithms



From Chapter 7: Contribution by Kinne, Raschke

Chapter 8: Global Radiation Budget

Table 1. Global means and their 1 sigma uncertainties of various atmospheric properties considered for the surface flux uncertainty estimation.

Variables	Ocean	Land	Global	Reference
AOD	0.13±0.036	0.19±0.08		Remer et. al (2008)
SSA	0.97±0.02	0.95±0.04		Kinne (2008)
COD	3.9±0.5	3.9±0.5	3.9±0.5	ISCCP
Cloud Fraction (Fc)	0.73±0.05	0.59±0.07	0.70±0.05	Stubenrauch(2008)
Fc Diurnal	<1%	<1%	<1%	Wylie(2008)
Fc: High Cloud	0.26±0.07	0.27±0.04	----	Stubenrauch(2008)
Fc: Low Cloud	0.47±0.06	0.32±0.04	----	Stubenrauch(2008)
High Cloud Top Pres (hPa)	511±30	443±30	490±30	Wang (2000)
High Cloud Base Pres (hPa)	625±30	576±30	610±30	Wang(2000)
Low Cloud Top Pres (hPa)	866±30	811±30	850±30	Wang(2000)
Low Cloud Base Pres (hPa)	951±20	899±20	935±20	Wang(2000)
Re (μm)	15±2	13±2	-----	Riedi (2008)
De (μm)	50±5	45±5	-----	Kahn (2008)
Albedo	0.12±0.004	0.28±0.02	0.17±0.007	Zhang et al. (2007)
Skin Temp (k)	289.1±2.4	281.9±4.6	286.9±3.3	Zhang et al. (2007)
Near Surface Air Temp (K)	289.7±1.9	283.3±3.7	287.8±2.6	Zhang et al. (2006)
Precipitable Water (cm)	2.63 ± 0.34	1.86 ± 0.48	2.41 ± 0.39	Zhang et al. (2006)
Emissivity	0.924±0.037	0.971±0.039	0.938±0.038	Zhang et al. (2007)
Solar Constant (W m^{-2})	1365-4	1365-4	1365-4	

From Chapter 8; Contribution by Loeb & Su

Chapter 8: Global Radiation

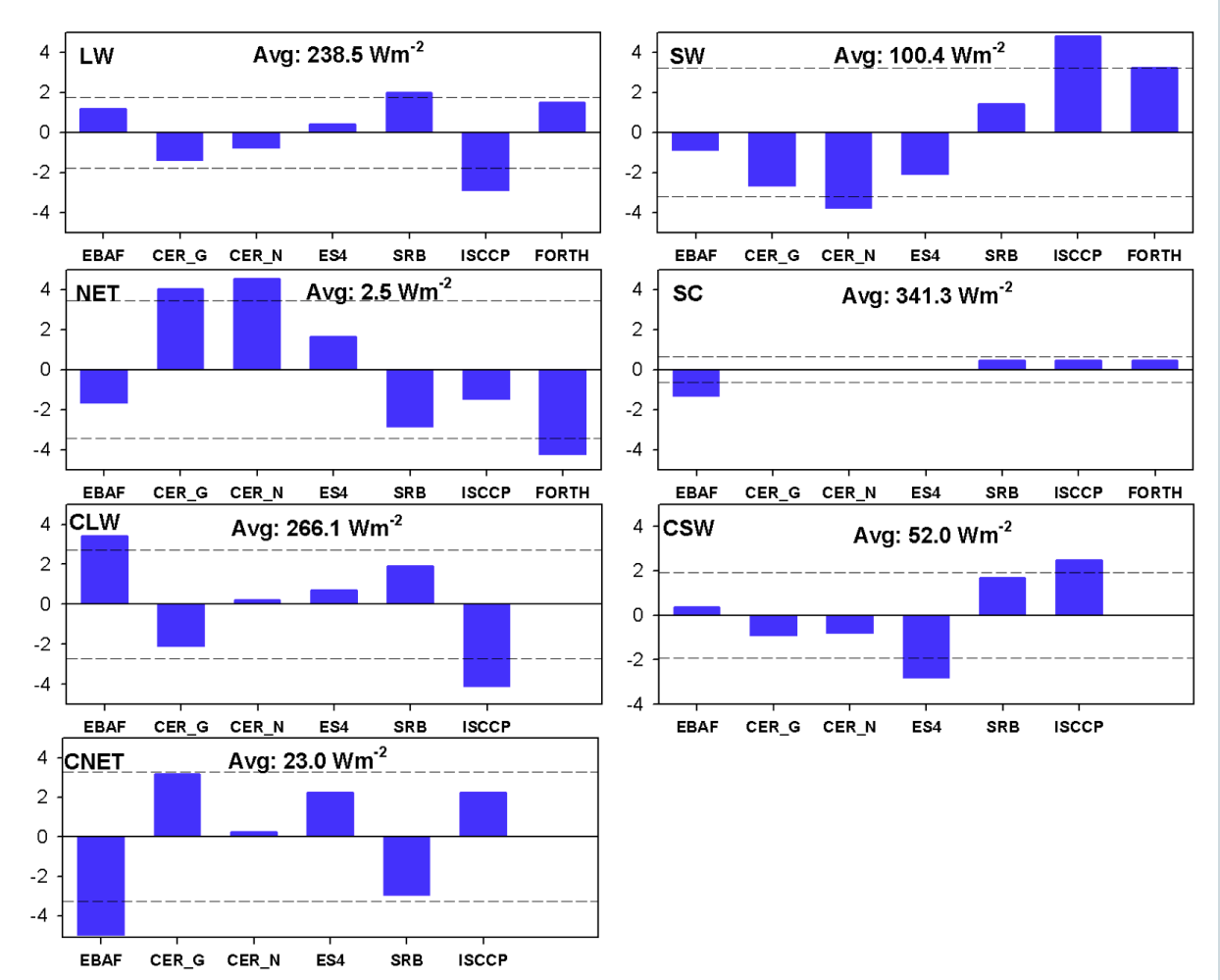
Table 3. Estimated uncertainty in global all-sky surface fluxes (1 sigma).

Variables	SWDN	SWUP	LWDN	LWUP	Net
Average State	186.0	22.7	340.3	398.0	105.6
AOD	2.0	0.2	0.3	0.0	1.7
SSA	0.8	0.1	0.4	0.1	1.0
Sfc albedo	0.4	1.1	0.0	0.0	0.7
Skin Temp. (K)	0.0	0.0	0.1	17.5	17.3
Air Temp. (K)	0.0	0.0	8.3	0.5	7.9
Precip. Water (cm)	2.1	0.2	5.2	0.4	3.4
Emissivity	0.1	0.0	0.1	1.0	1.0
High Cld Frac (%)	3.0	0.4	1.4	0.2	1.5
Low Cld Frac (%)	2.9	0.4	2.5	0.2	0.7
High COD	3.2	0.4	1.3	0.0	1.5
Low COD	5.4	0.6	3.1	0.3	2.4
High Cld Top Pres	0.0	0.0	0.1	0.0	0.1
High Cld Base Pres	0.0	0.0	0.2	0.0	0.2
Low Cld Top Pres	0.0	0.0	0.2	0.0	0.2
Low Cld Base Pres	0.0	0.0	0.2	0.0	0.2
High Cld De (μm)	0.1	0.0	0.1	0.0	0.1
Low Cld re (μm)	0.1	0.0	0.2	0.0	0.1
Solar Const. (wm^{-2})	-0.5	-0.1	0	0	-0.5
Overall Uncertainty	**7.7**	**1.4**	**10.8**	**17.5**	**19.3**

From Chapter 8; Contribution by Loeb & Su

Chapter 8: Global Radiation

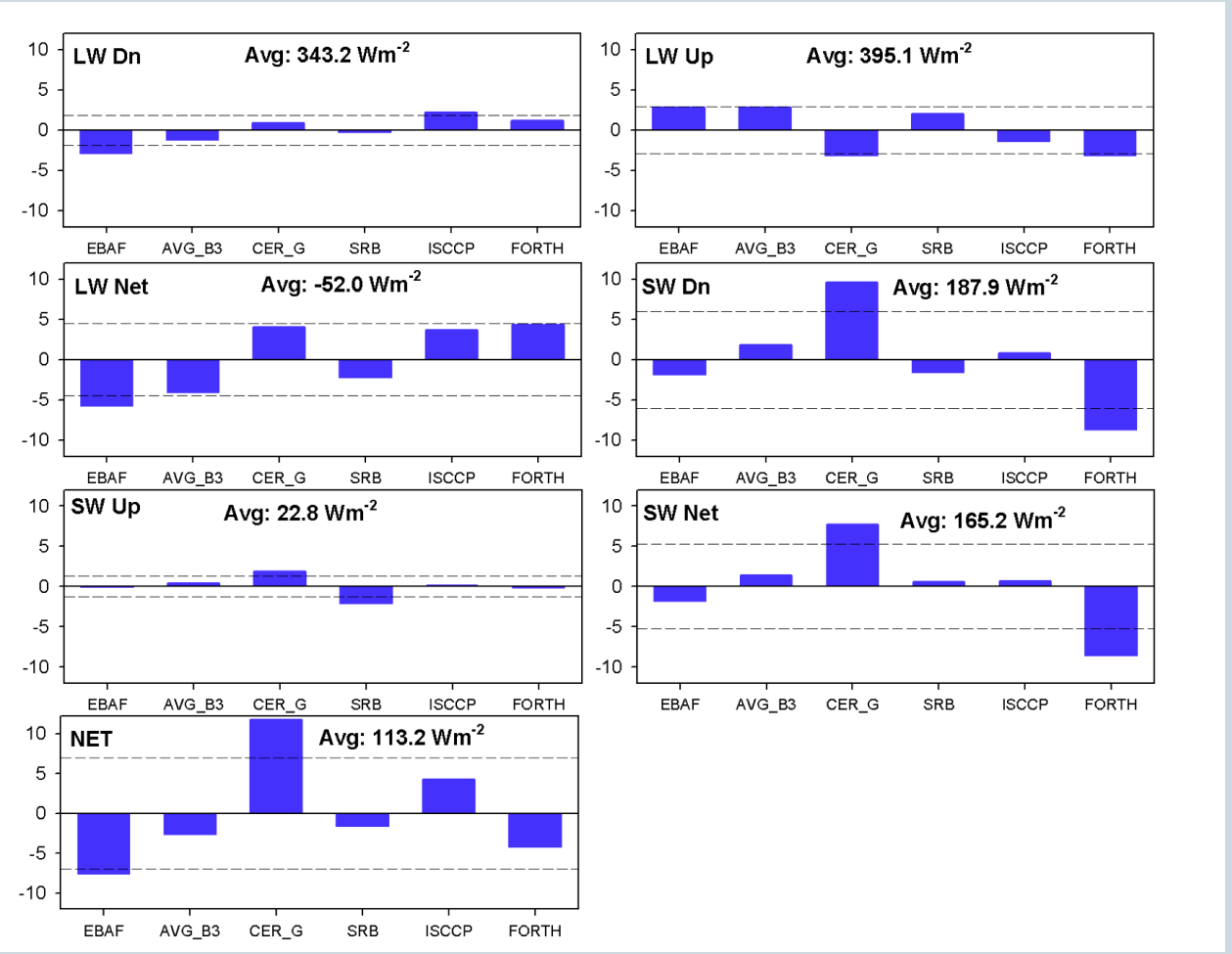
TOA Fluxes (During CERES Period)



From Chapter 8; Contribution by Loeb & Su

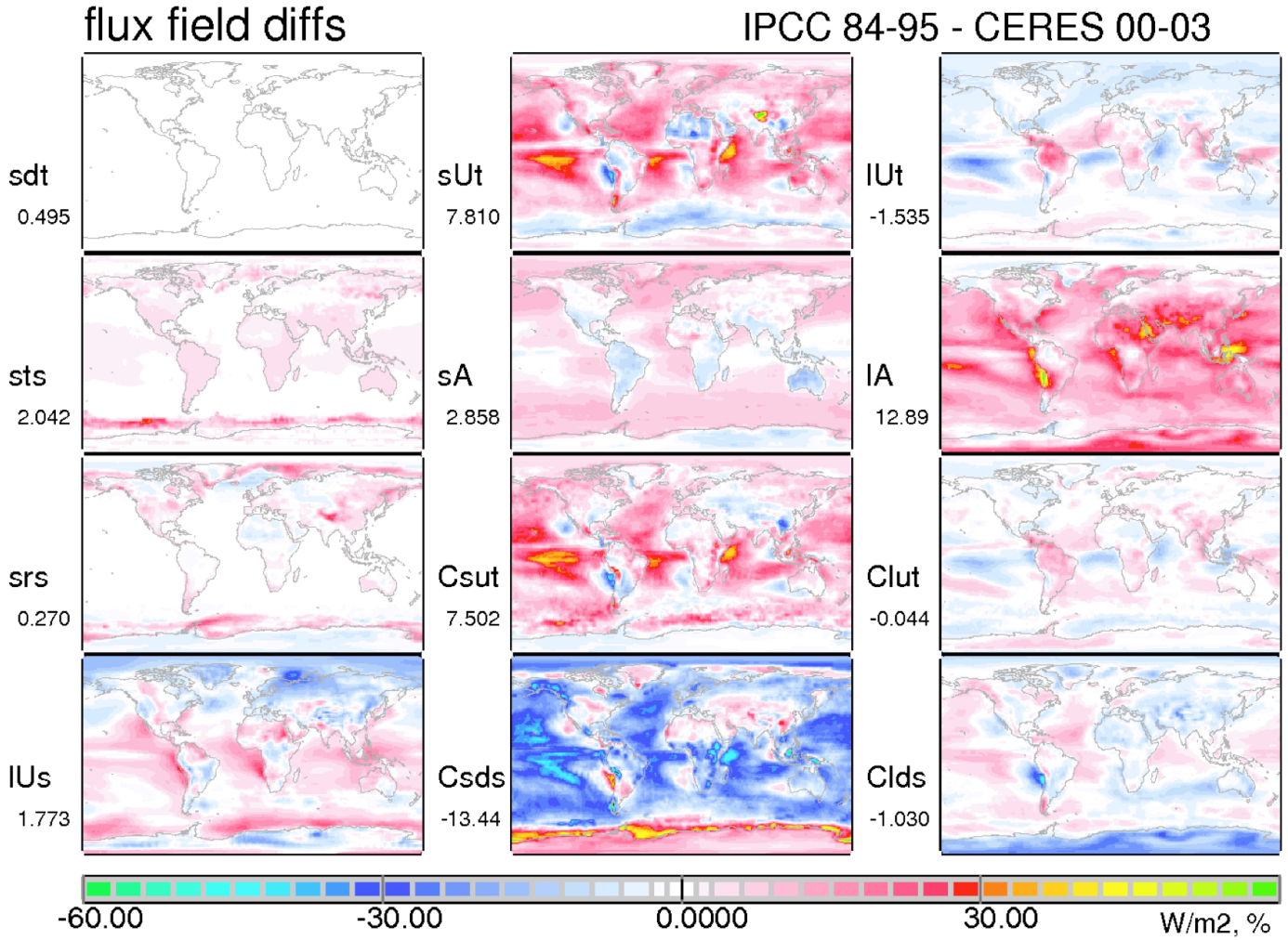
Chapter 8: Global Radiation

Surface Fluxes (During CERES Period)



From Chapter 8; Contribution by Loeb & Su

Chapter 9: Comparison to Models



From Chapter 9; Contribution by Kinne and Raschke

Radiative Flux Assessment Summary and Next Steps

- The GEWEX Radiative Flux assessment is making significant progress towards producing a community assessment of TOA and surface radiation flux estimates from satellite and model analysis.
  - New TOA solar irradiance measurements and discrepancies in computation of theoretical irradiance variability found and documented.
  - Surface measurement uncertainty being documented for surface error context.
  - Satellite-based radiative flux analysis being compared among algorithms and contrasted to reanalysis and model results. Large differences are being noted in time time and space.

- GEWEX-RFA lead authors and contributors are editing sections helping to assess radiative flux components.
  - Reviews will be sought for all chapters in the next 2 months
  - Suggested meeting in November

- Goal of producing a community-wide draft report for Dec 2011.

Extras