Evaluation of MERRA Radiative Fluxes using CERES EBAF data

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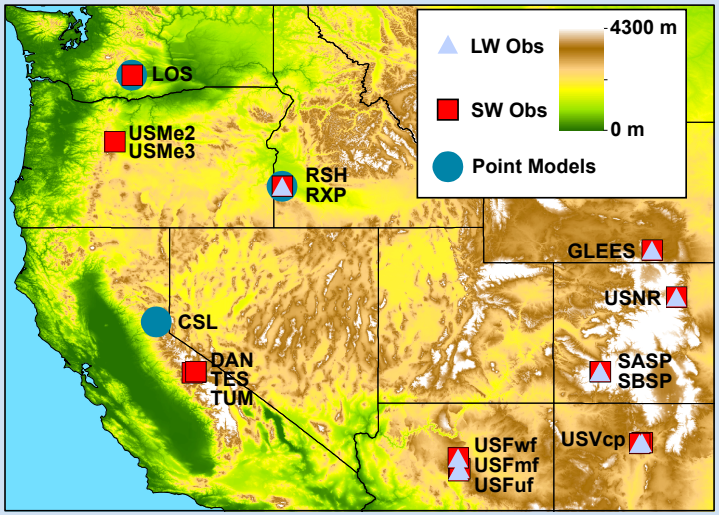
SYN Evaluation in Mountainous Areas



- Data as available 2000-2010
- Surface data avg'd to 3 hours
- Extensive QC applied to obs
  - Snow on dome detected
  - Shaded periods removed
- 10 Wm^{-2} lower limit (daytime <u>only</u> for SW)
- Elevation correction for LW

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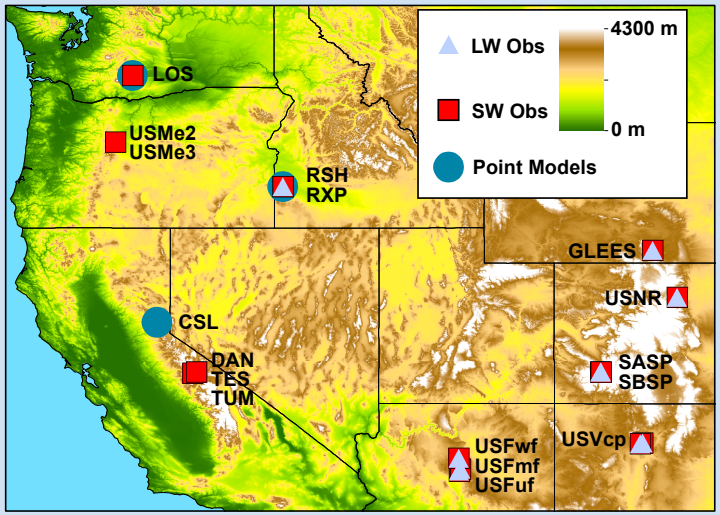

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SW

Site	N	Mean Meas.	Bias	St. Dev.	MAD	r
USFmf	3,948	520	-4 (-1)	128 (25)	84 (16)	0.90
USFuf	3,501	559	-13 (-2)	131 (23)	87 (16)	0.89
USFwf	4,147	500	2 (0)	127 (25)	81 (16)	0.90
CSL	1,244	403	47 (12)	115 (29)	71 (18)	0.91
DAN	5,452	461	-4 (-1)	116 (25)	78 (17)	0.94
TES	5,402	478	28 (6)	126 (26)	87 (18)	0.93
TUM	6,510	457	46 (10)	141 (31)	101 (22)	0.91
SASP	2,645	508	24 (5)	148 (29)	105 (21)	0.84
SBSP	3,374	495	3 (1)	140 (28)	97 (20)	0.85
USNR	5,308	436	40 (9)	157 (36)	115 (26)	0.85
RSH	6,108	482	21 (4)	101 (21)	70 (14)	0.92
RXP	7,389	444	7 (2)	94 (21)	64 (14)	0.94
USVcp	708	492	9 (2)	146 (30)	97 (20)	0.87
USMe2	4,813	413	13 (3)	95 (23)	62 (15)	0.94
USMe3	4,548	404	9 (2)	93 (23)	60 (15)	0.94
LOS	988	383	51 (13)	100 (26)	71 (19)	0.93
GLEES	4,803	429	-9 (-2)	122 (28)	82 (19)	0.91

LW

Site	N	Mean Meas.	Bias	Std. Dev.	MAD	r
USFmf	10,886	279	8 (3)	23 (8)	18 (7)	0.89
USFuf	10,723	265	18 (7)	25 (10)	20 (7)	0.87
USFwf	11,816	251	31 (12)	26 (10)	21 (8)	0.87
SASP	11,688	249	-4 (-2)	33 (13)	25 (10)	0.76
SBSP	12,493	230	0 (0)	33 (14)	25 (11)	0.79
USNR	10,628	261	1 (0)	25 (10)	19 (7)	0.85
RSH	15,542	282	-17 (-6)	24 (9)	20 (7)	0.85
USMe2	6,586	281	-1 (0)	26 (9)	20 (7)	0.75
USMe3	1,457	309	-8 (-3)	23 (8)	19 (6)	0.84
GLEES	11,894	243	6 (2)	30 (13)	24 (10)	0.78

SYN Evaluation over Snow

- Comparisons at SURFRAD stations
- Snow determined by measured albedo

Shortwave

All available measurements

Site	N	Mean Meas.	Bias	Std. Dev.	MAD	r
BON	10,041	361	-3 (-1)	88 (25)	58 (16)	0.94
DRA	10,774	474	-23 (-5)	81 (17)	54 (11)	0.96
FPK	10,537	327	13 (4)	76 (23)	50 (15)	0.95
GCR	10,218	377	9 (2)	110 (29)	70 (19)	0.91
PSU	10,329	319	22 (7)	124 (39)	84 (26)	0.87
SXF	9,050	342	10 (3)	108 (32)	68 (20)	0.90
TBL	10,679	384	17 (4)	105 (27)	69 (18)	0.92

High albedo (snow) conditions

Site	N	Mean Meas.	Bias	Std. Dev.	MAD	r
BON	663	225	-52 (-23)	77 (34)	56 (25)	0.91
DRA	Insufficient samples					
FPK	1,228	221	2 (1)	61 (27)	44 (20)	0.91
GCR	Insufficient samples					
PSU	1,139	217	18 (8)	92 (42)	65 (30)	0.85
SXF	1,034	236	-14 (-6)	81 (34)	56 (24)	0.88
TBL	717	295	-29 (-10)	101 (34)	73 (25)	0.83

Longwave

All available measurements

Site	N	Mean Meas.	Bias	Std. Dev.	MAD	r
BON	21,651	321	4 (1)	21 (7)	16 (5)	0.94
DRA	21,606	305	-6 (-2)	17 (6)	13 (4)	0.93
FPK	20,937	285	1 (1)	22 (8)	17 (6)	0.92
GCR	21,052	349	-1 (0)	21 (6)	16 (4)	0.94
PSU	21,673	316	0 (0)	26 (8)	20 (6)	0.91
SXF	18,456	302	2 (1)	25 (8)	19 (6)	0.92
TBL	21,636	288	-4 (-2)	21 (7)	16 (6)	0.91

High albedo (snow) conditions

Site	N	Mean Meas.	Bias	Std. Dev.	MAD	r
BON	663	245	19 (8)	27 (11)	22 (9)	0.81
DRA	Insufficient samples					
FPK	1,164	234	7 (3)	27 (12)	21 (9)	0.76
GCR	Insufficient samples					
PSU	1,138	256	-1 (0)	27 (11)	21 (8)	0.78
SXF	1,031	240	11 (5)	29 (12)	23 (9)	0.78
TBL	707	242	12 (5)	31 (13)	24 (10)	0.72

Data Sets

- MERRA Reanalysis v. 1, regridded to 1°x1°
- CERES TOA and Surface EBAF Ed. 2.8

Analyze 10 years of data: January 2001 – December 2010
Monthly time scale

CERES EBAF Uncertainty Estimates

TOA		
Scale	SW up	LW up
Monthly gridded	5	2.5
Annual global	1	1.75

(Wm^{-2})

Surface				
Scale	SW down	SW up	LW down	LW up
Monthly gridded	10	11	14	15
Monthly global	6	3	7	3
Annual global	4	3	7	3

Global Mean Energy Budget (Wm^{-2})

All-Sky TOA					
Data set	SW down	SW up	LW up	Total net	Albedo
CERES EBAF	339.8	99.6	239.6	0.6	0.293
MERRA	341.3	99.6	242.6	-0.8	0.292
Difference	1.5	0.0	3.0	-1.4	-0.001

All-sky Surface						
Data set	SW down	SW up	LW down	LW up	Total net	Albedo
CERES EBAF	186.3	24.1	345.2	398.1	162.2	0.129
MERRA	192.6	23.6	335.0	398.7	169.0	0.123
Difference	6.3	-0.5	-10.2	0.6	6.8	-0.007

- **TOA terms agree to within 3 Wm^{-2}**
- **Downwelling fluxes at surface agree worse: 6-10 Wm^{-2}**
- **These and TOA LW up exceed EBAF uncertainties**
- **MERRA TOA and surface albedo low**
- **TOA net fluxes agree to 1.4 Wm^{-2}, but surface net fluxes differ by 7 Wm^{-2}**

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(1.75)

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(4) (7)

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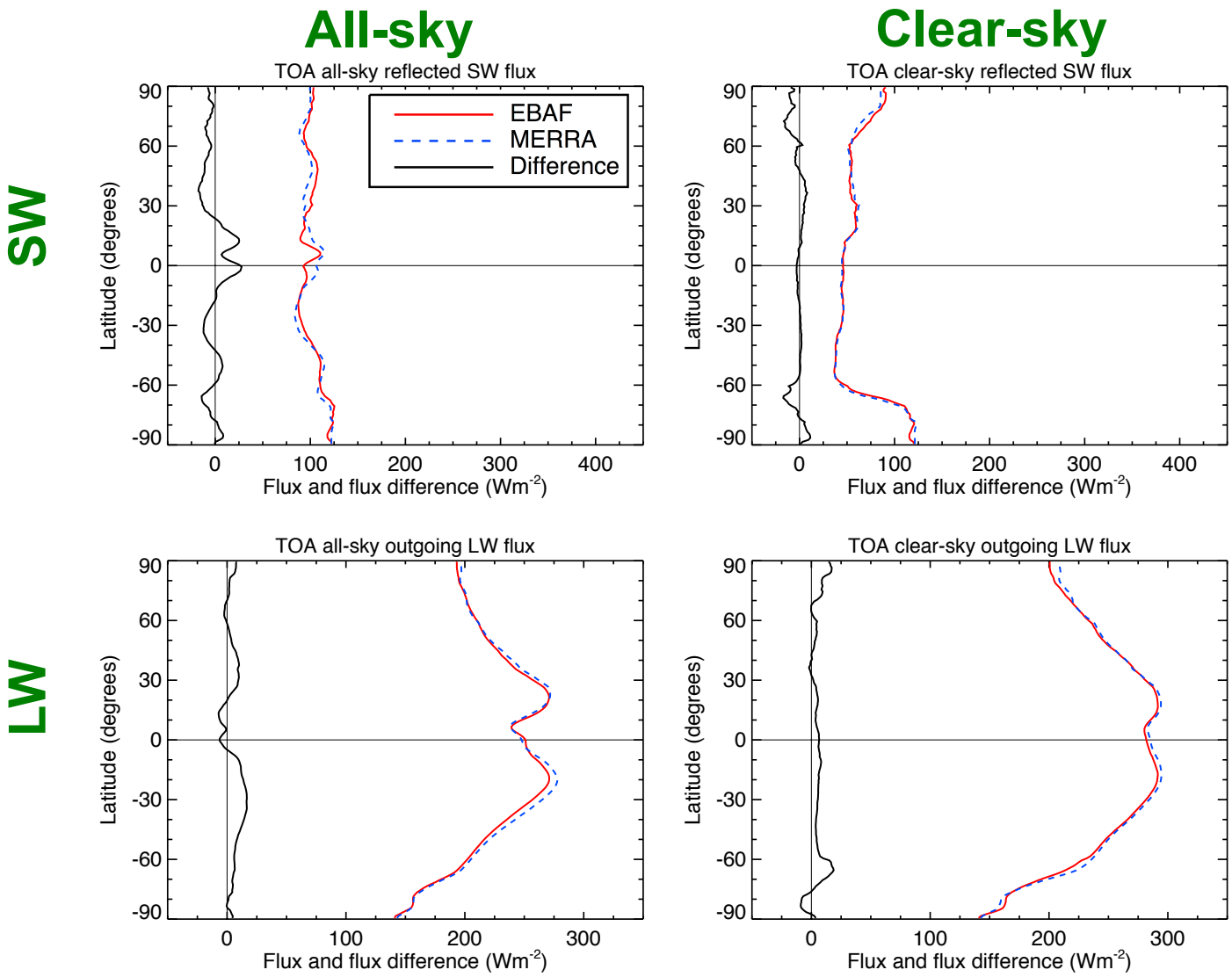
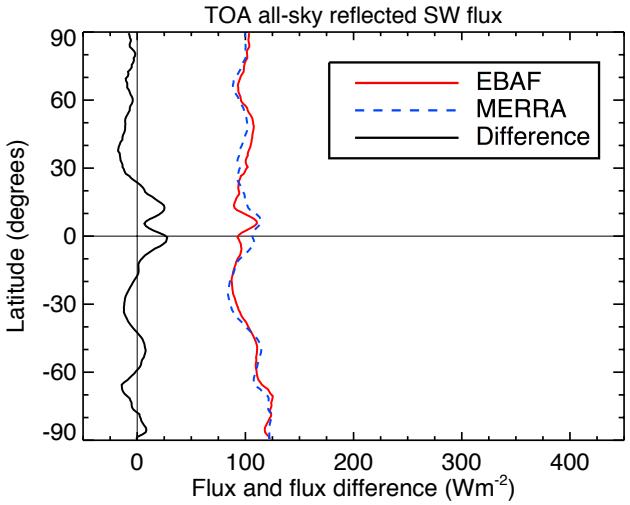
- These and TOA LW up exceed EBAF uncertainties
- MERRA TOA and surface albedo low
- TOA net fluxes agree to 1.4 Wm^{-2}, but surface net fluxes differ by 4 Wm^{-2}

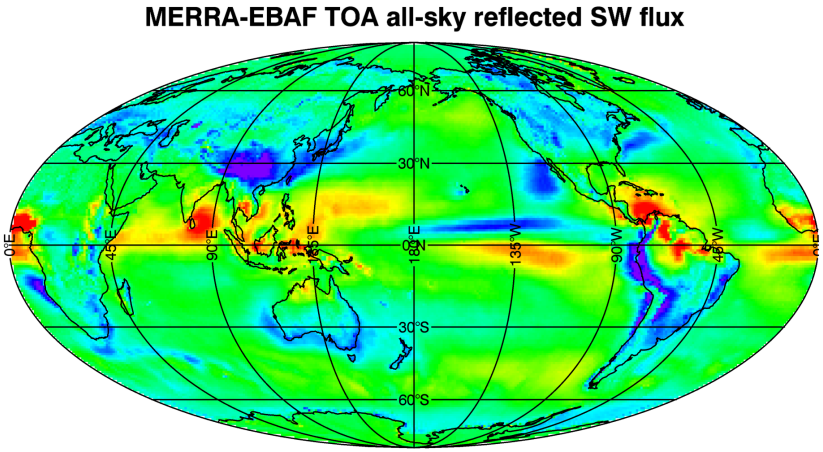
TOA Fluxes


All-sky
Clear-sky
SW
LW
TOA all-sky reflected SW flux
TOA clear-sky reflected SW flux
TOA all-sky outgoing LW flux
TOA clear-sky outgoing LW flux
EBAF
MERRA
Difference
Latitude (degrees)
Flux and flux difference (Wm-2)
90
60
30
0
-30
-60
-90
0
100
200
300
400

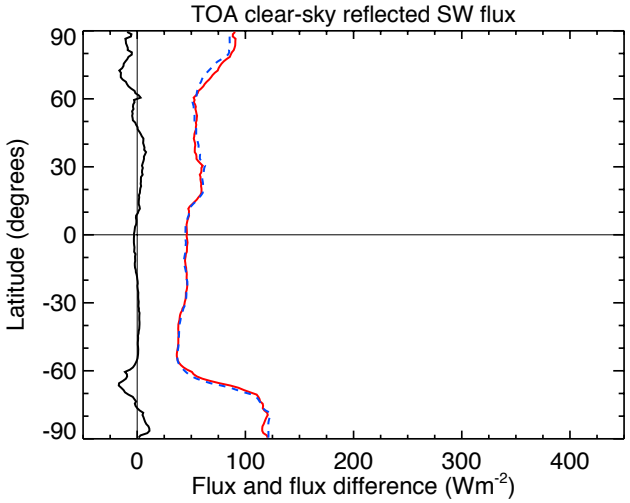
TOA Reflected SW

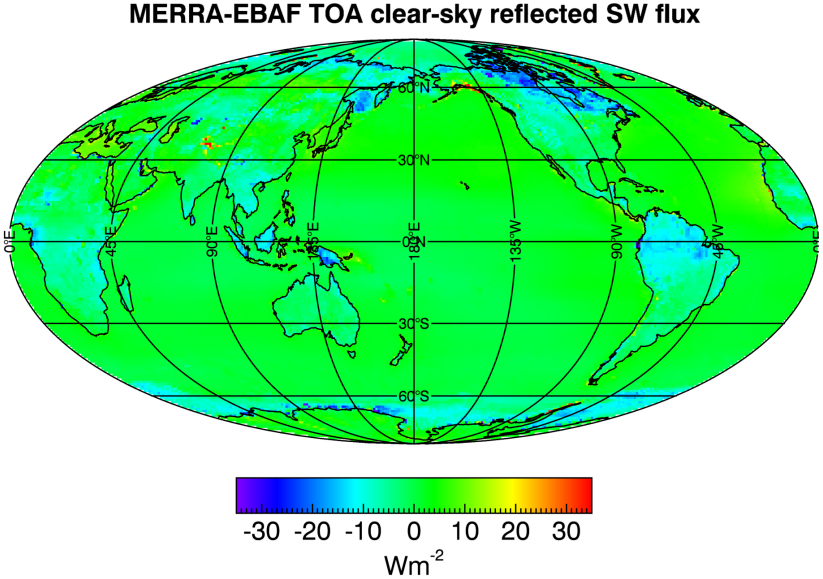
All-sky





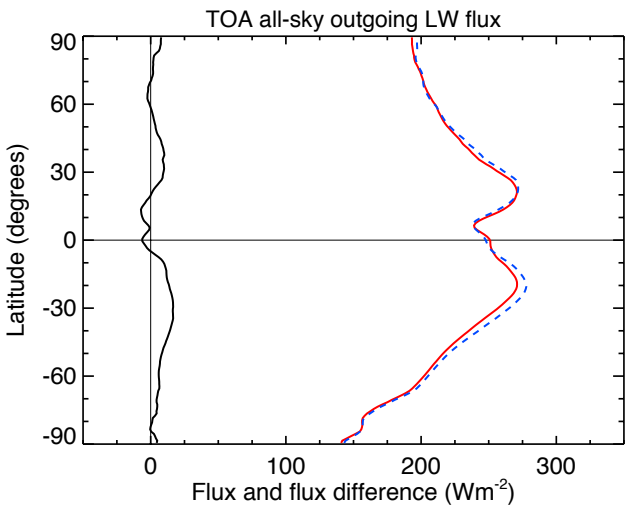
Clear-sky

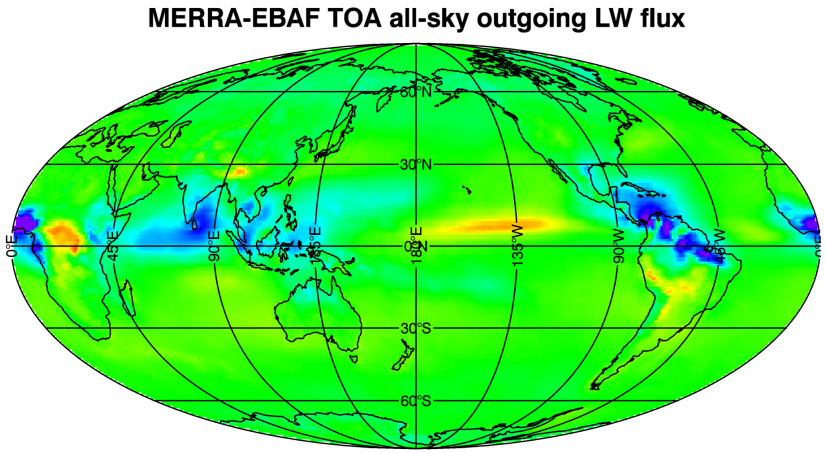




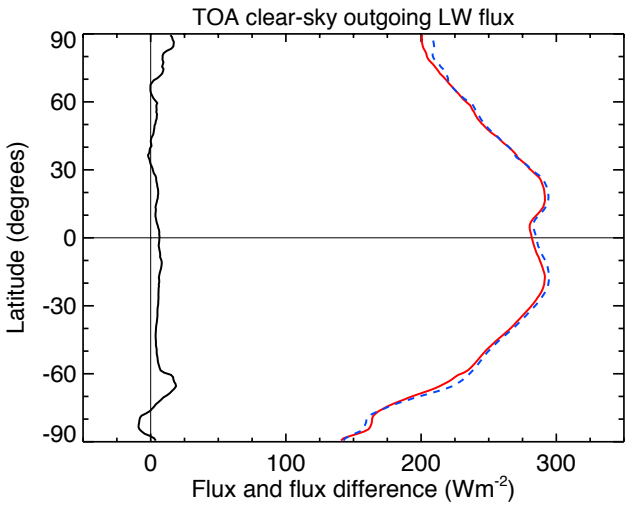
TOA Outgoing LW

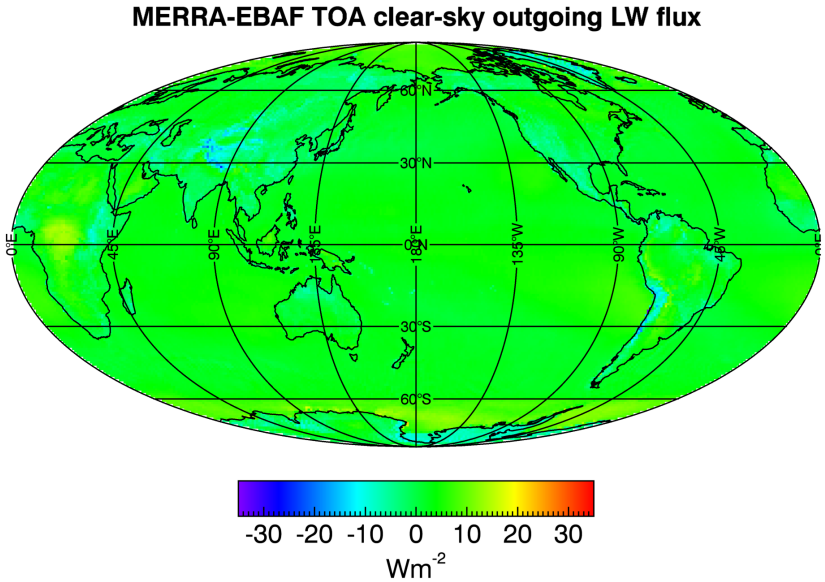
All-sky





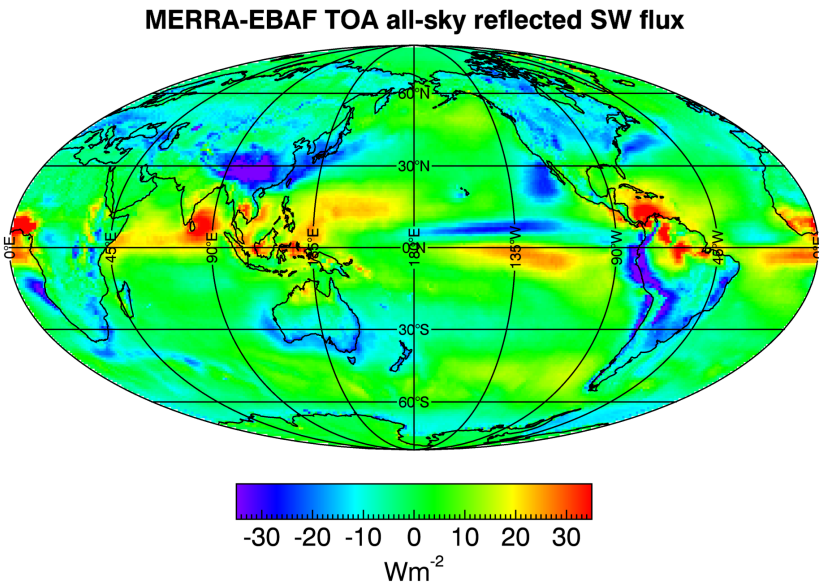
Clear-sky



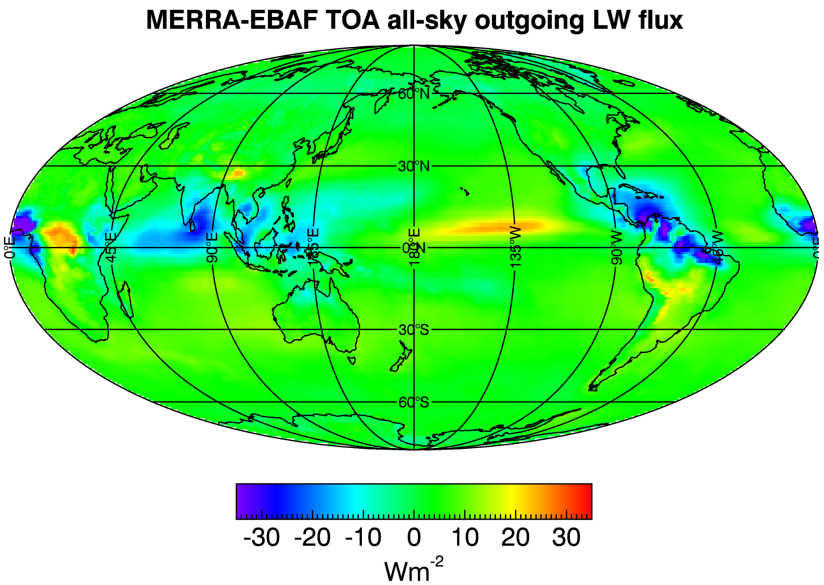


TOA Flux Difference Attribution

SW



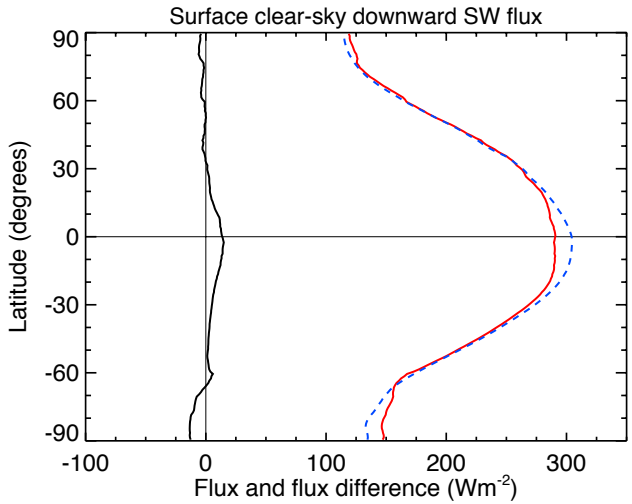
LW

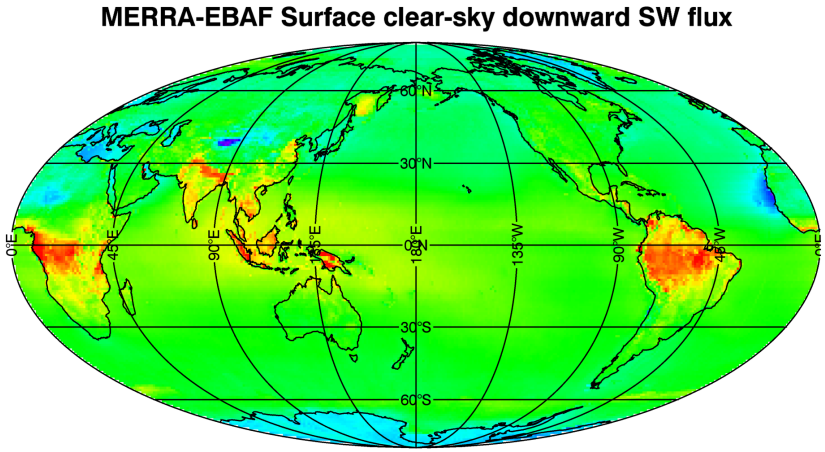


Many of the differences may be due to missing low cloud, mainly in midlatitudes.
High cloud problems found in the tropics, mainly excesses.

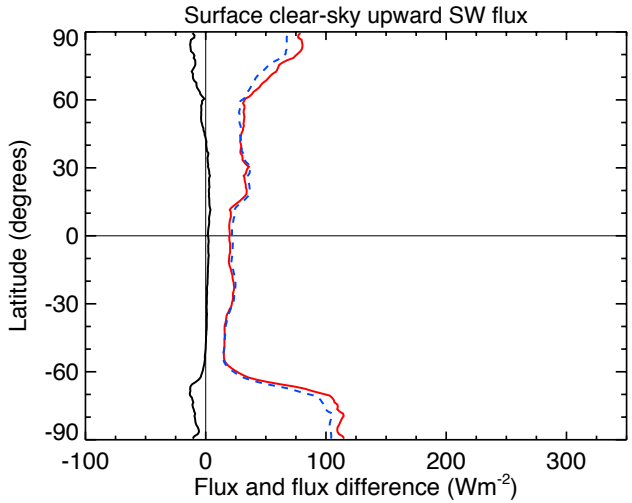
Surface Clear-sky SW Fluxes

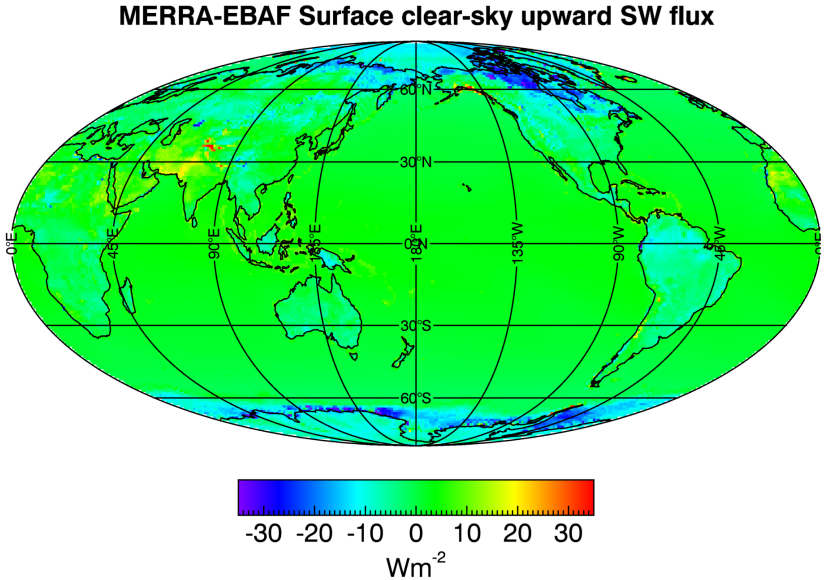
Downward





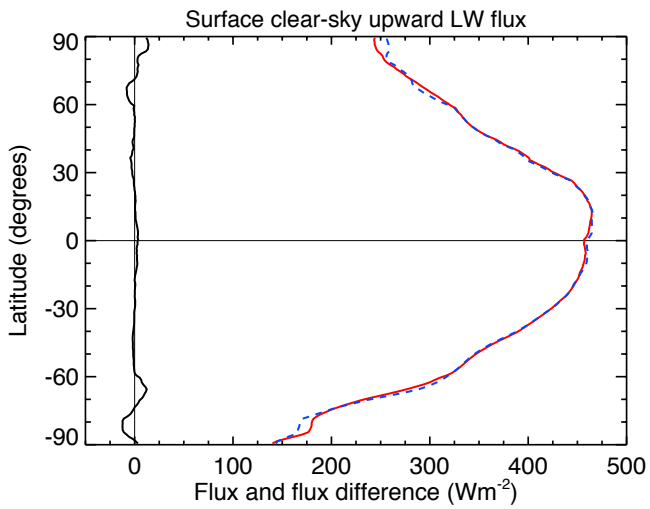
Upward

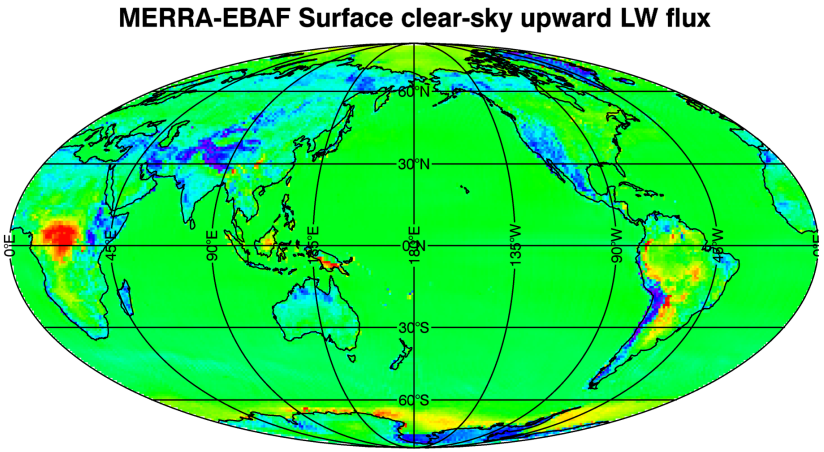




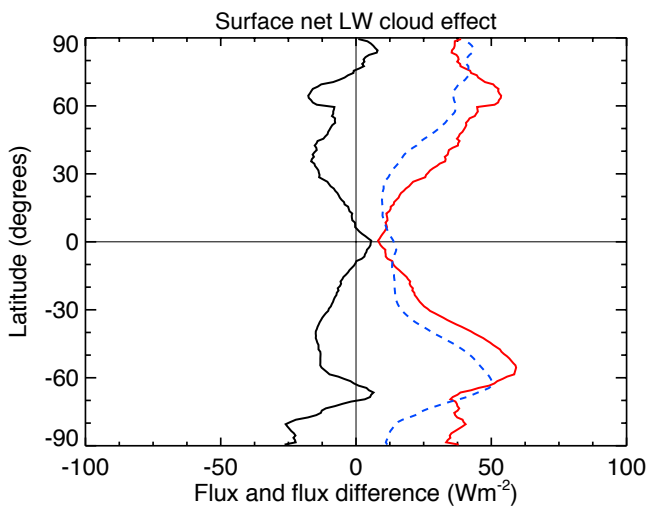
Surface LW Fluxes

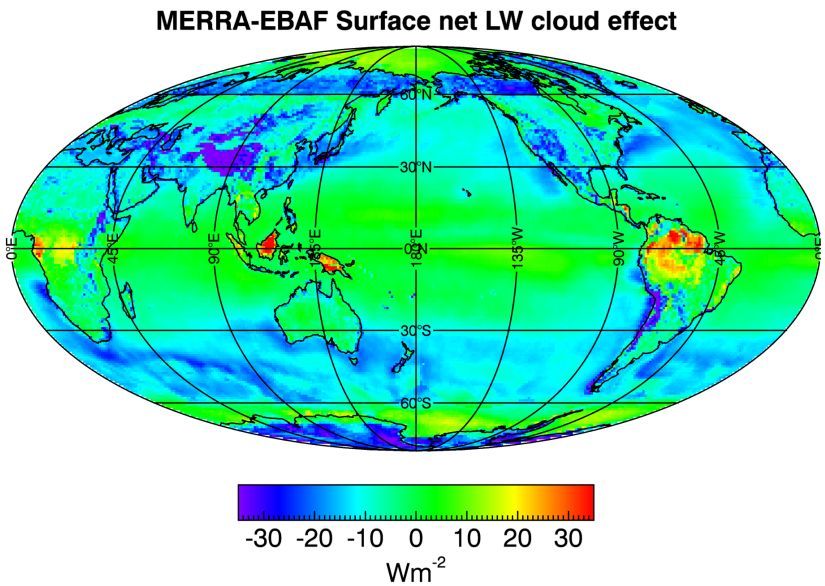
Clear-sky down



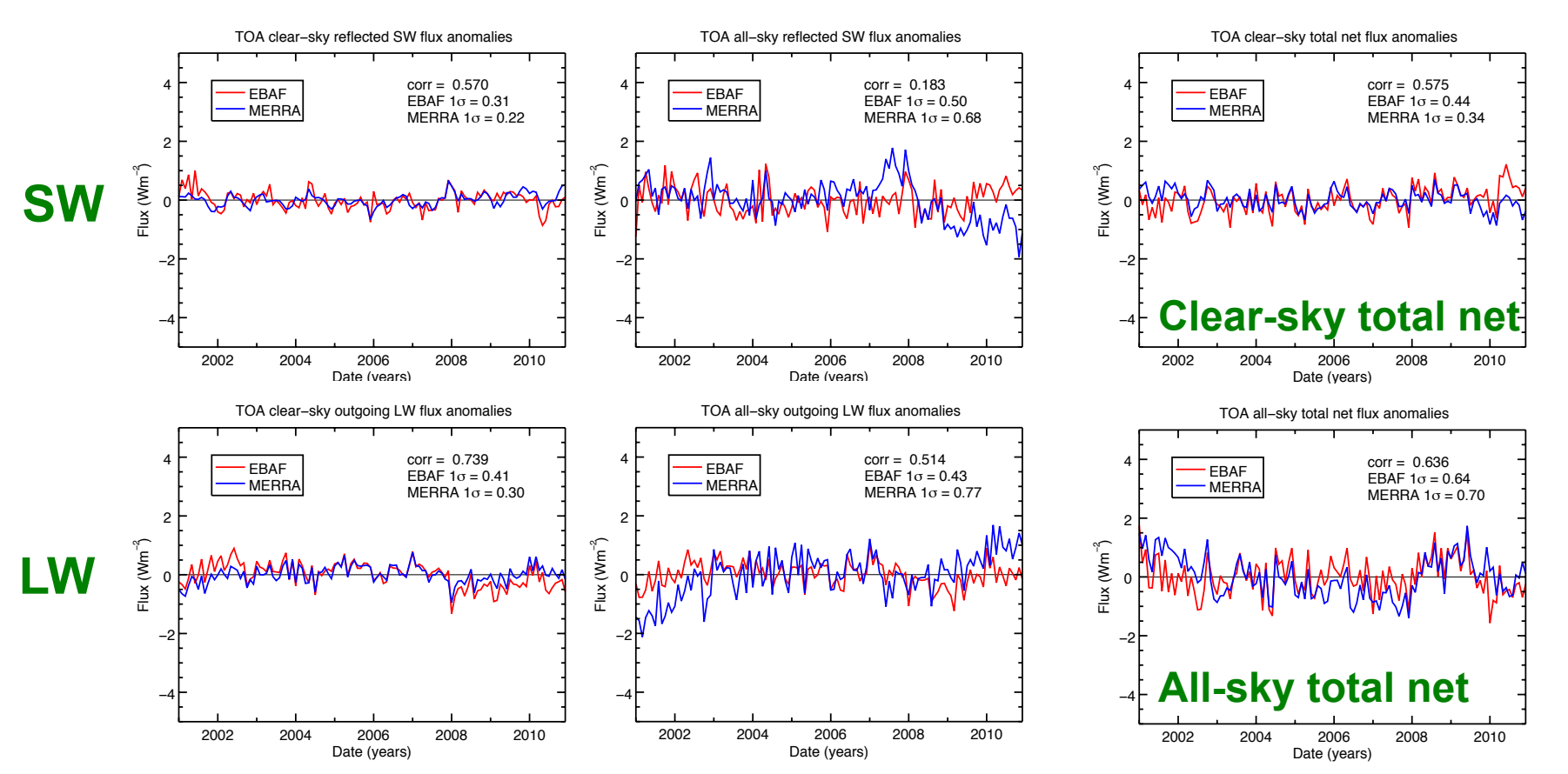


Net cloud effect



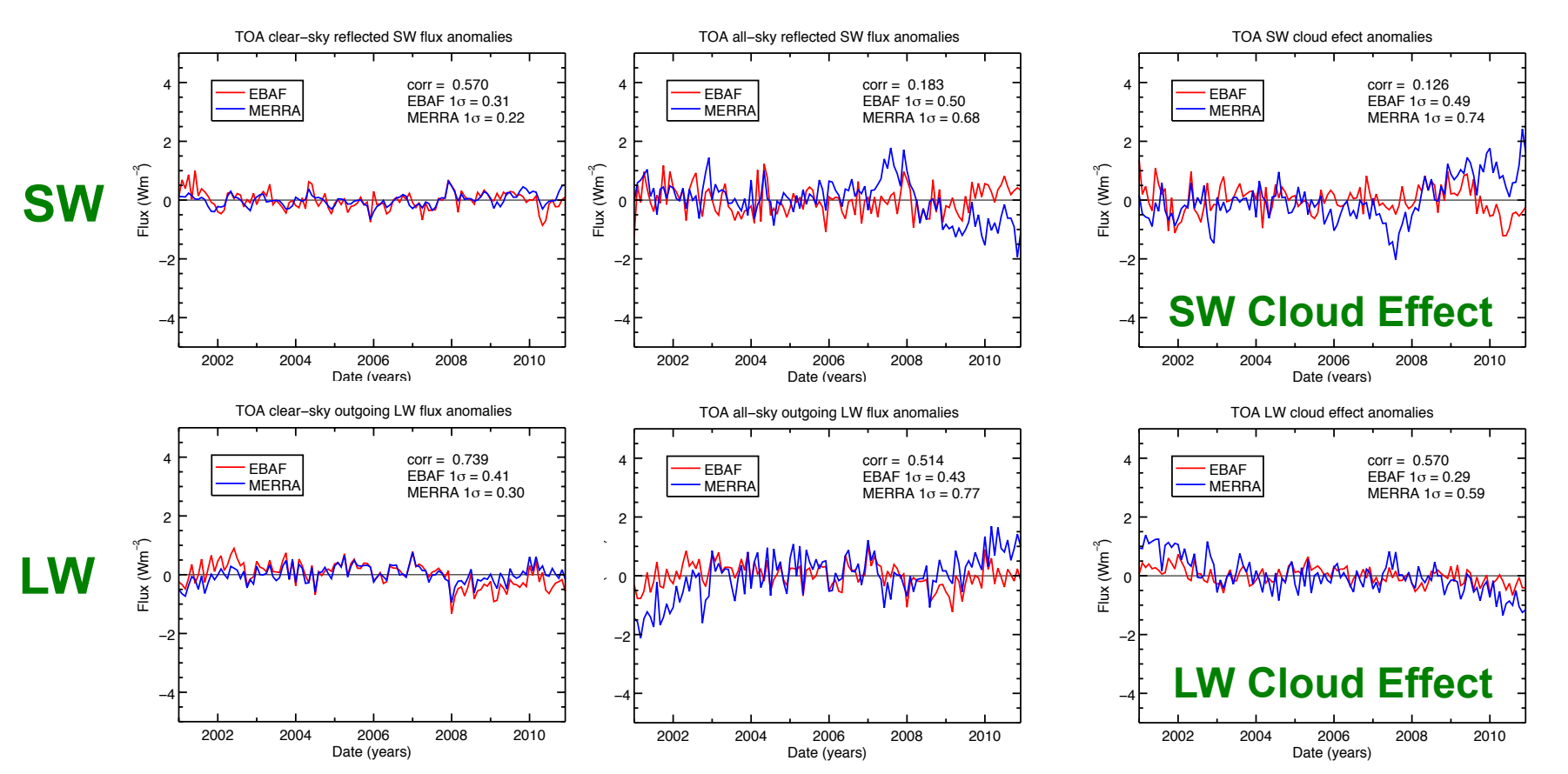


TOA Flux Anomaly Time Series



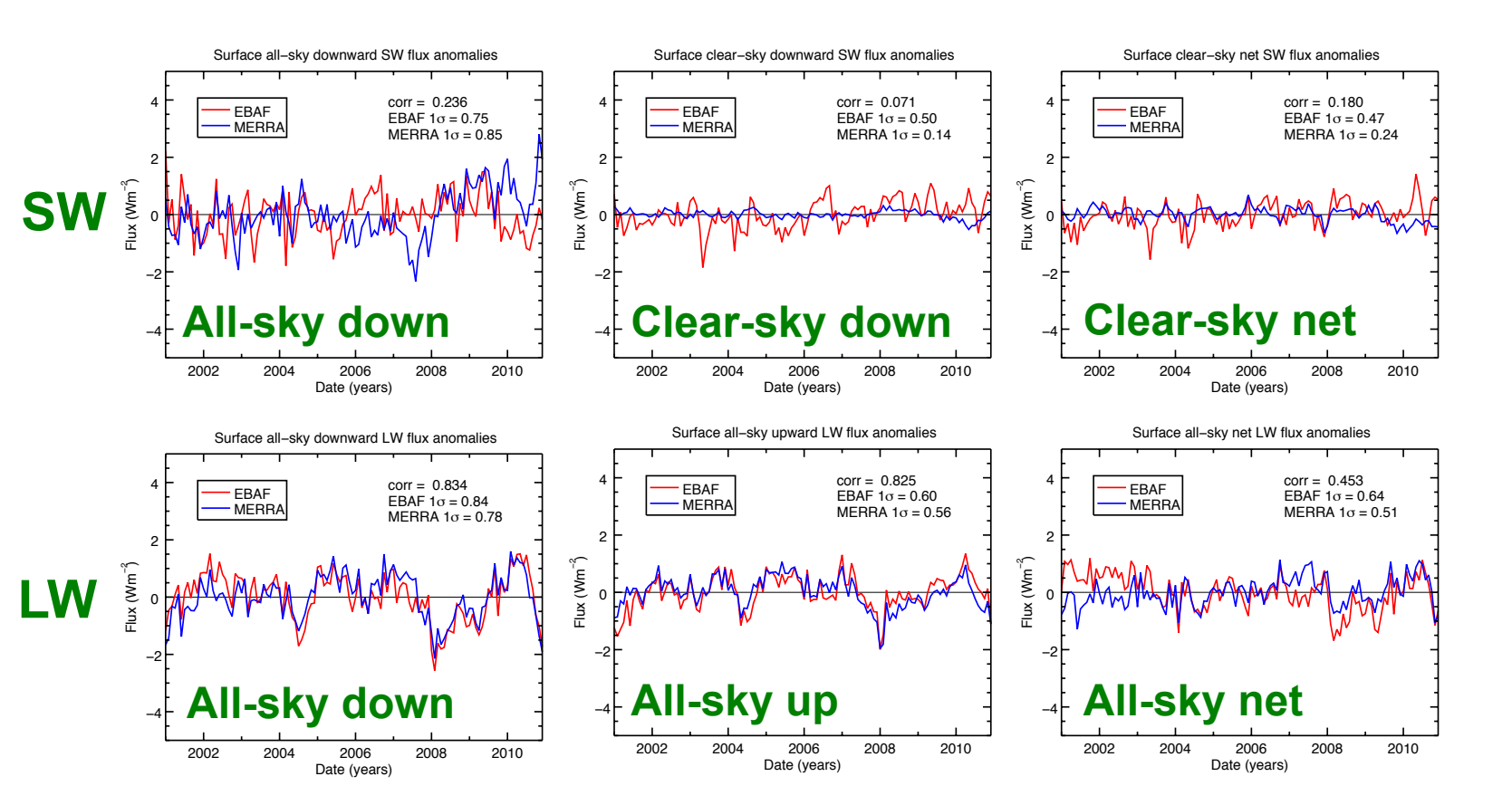
Magnitude of variability similar for clear sky, larger for all sky.
All-sky fluxes more poorly correlated.
Agreement is better in net fluxes.

TOA Flux Anomaly Time Series



LW cloud effect shows general downward trend in EBAF <u>and</u> MERRA.
SW cloud effect dominated by all-sky flux pattern.

Surface Flux Anomaly Time Series



Variability of SW downward fluxes much different for clear skies; improves in net.

LW agreement better for up- and downward terms than net.

Patterns in all-sky net fluxes ~opposite of TOA .

Conclusions

- MERRA v. 1 radiation budget was evaluated against CERES EBAF data over 2001-2010.
- Too much high cloud over tropics, insufficient low clouds in Sc areas and midlatitude continents.
- Possible aerosol deficiency in MERRA over tropical land.
- Polar/seasonal ice areas problematic.
- Cloud effect trends in TOA LW (EBAF and MERRA) and SW (MERRA after 2006).
- Time series correlation poor in SW, with smaller variability in MERRA clear-sky surface SW down.
- Overall energy budget matches to 1.4 Wm^{-2} at TOA, 4 Wm^{-2} at surface, net <u>loss</u> of energy.

Plans: Examine MERRA cloud structure using C^3M