

Validation of Terra/SSF Surface-only Fluxes

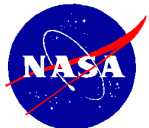
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Hampton, Virginia

28th CERES Science Team Meeting
Norfolk, Virginia
6 - 8 May 2003



Validation of Terra/SSF Surface-only Fluxes (CERES Subsystem 4.6)

- Downwelling clear-sky and all-sky SW and LW surface fluxes derived from relationships with TOA fluxes and atmospheric data.

- Each component currently computed from two models

LPSA/LPLA:

Langley Parameterized
SW/LW Algorithm

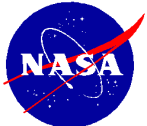
		Model A	Model B
SW	Clear	Li et al.	LPSA
	All-sky	-	LPSA
LW	Clear	Inamdar and Ramanathan	LPLA
	All-sky	-	LPLA

- Validation criteria:
 $\pm 20 \text{ Wm}^{-2}$ for instantaneous CERES FOV
- Validation data sources: ARM/SGP, BSRN, and CMDL sites
- FM1 and FM2 results almost identical; only FM1 results shown



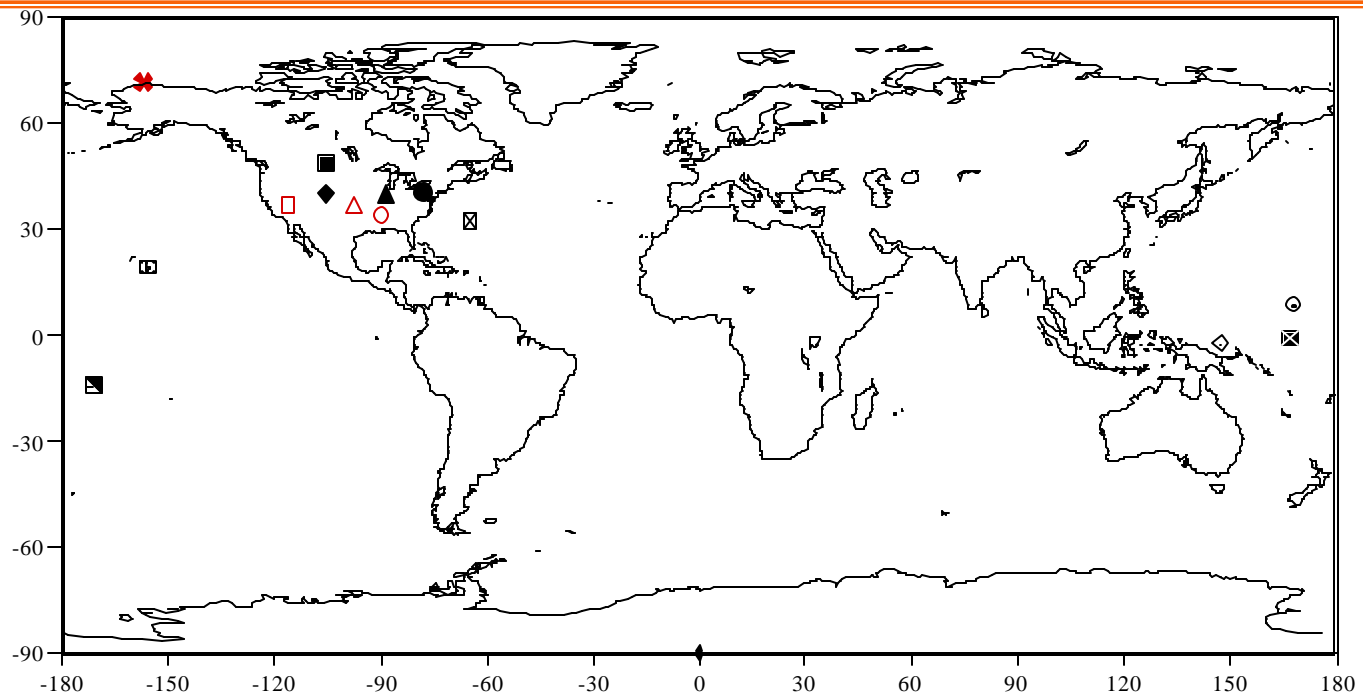
Algorithms

- SW Model A:
Li *et al.* (1993): *J. Climate*, **6**, 1764-1772.
- SW Model B (LPSA/Staylor Algorithm):
Darnell *et al.* (1988): *J. Climate*, **1**, 820-835.
Darnell *et al.* (1992): *J. Geophys. Res.*, **97**, 15741-15760.
Gupta *et al.* (2001): *NASA/TP-2001-211272*, 31 pp.
- LW Model A:
Inamdar and Ramanathan (1997): *Tellus*, **49B**, 216-230.
- LW Model B (LPLA):
Gupta (1989): *J. Climate*, **2**, 305-320.
Gupta *et al.* (1992): *J. Appl. Meteor.*, **31**, 1361-1367.

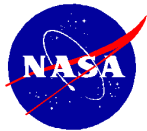


Surface -only Fluxes

Sites Used



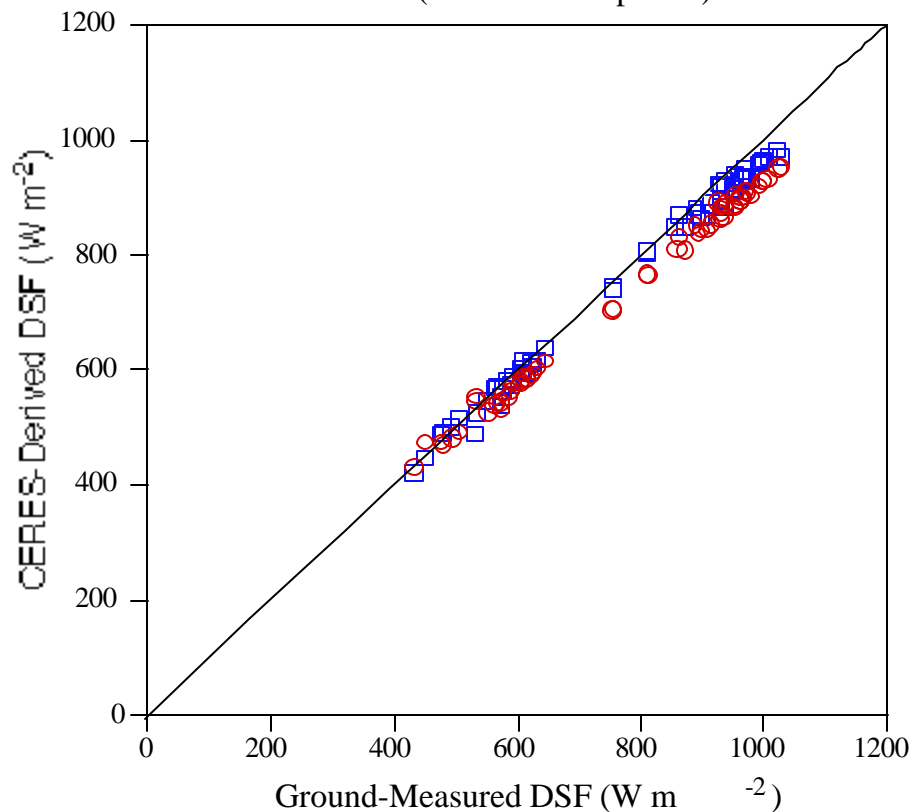
- | | | |
|-----------------------------------|------------------------------------|----------------------------------|
| ■ 48.31N, 105.10W Fort Peck, MT | ○ 34.25N, 89.87W Goodwin Creek, MS | ⊙ 8.72N, 167.72E Kwajalein |
| ● 40.72N, 77.93W Penn State, PA | △ 36.60N, 97.48W SGP ARM | □ 19.54N, 155.58W Mauna Loa, HI |
| ▲ 40.05N, 88.37W Bondville, IL | ◇ 2.06S, 147.43E Manus | ◼ 14.23S, 170.56W American Samoa |
| ◆ 40.13N, 105.24W Boulder, CO | ⊠ 0.52S, 166.92E Nauru Island | ✱ 71.32N, 156.61W Barrow, AK |
| ◻ 36.63N, 116.02W Desert Rock, NV | ⊠ 32.30N, 64.77W Bermuda | ⬇ 90.00S, 0.00 South Pole |



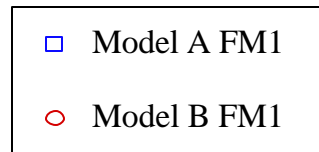
Clear-Sky SW Flux Validation

ARM/SGP Central Facility
Terra Ed. 1A (Nov2000 - Sep2001)

Ground Data Source:
Unshaded Pyranometer



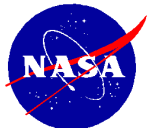
Clear-Sky/1-Minute



Number of Points = 61

Model A:
Mean Bias = -19.9
RMSD = 26.0
Random Error = 12.9

Model B:
Mean Bias = -43.2
RMSD = 49.7
Random Error = 10.7

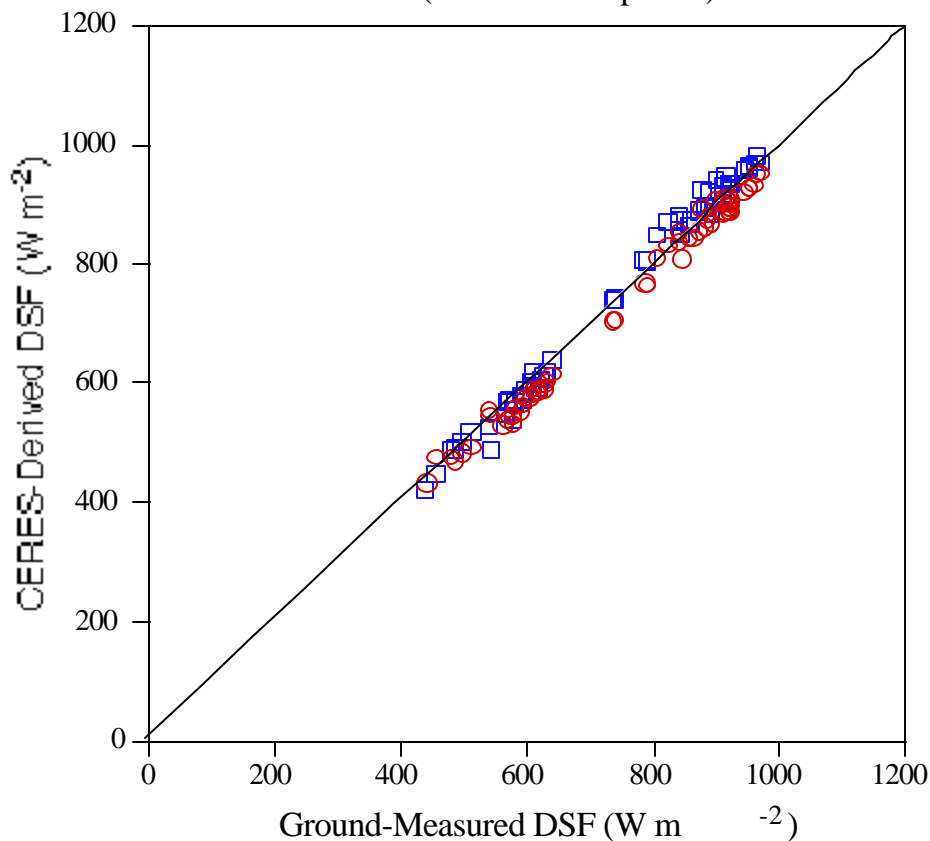


Clear-Sky SW Flux Validation

ARM/SGP Central Facility
Terra Ed. 1A (Nov2000 - Sep2001)

Ground Data Source:
Direct + Diffuse

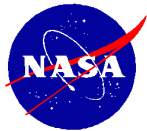
Clear-Sky/1-Minute



Number of Points = 61

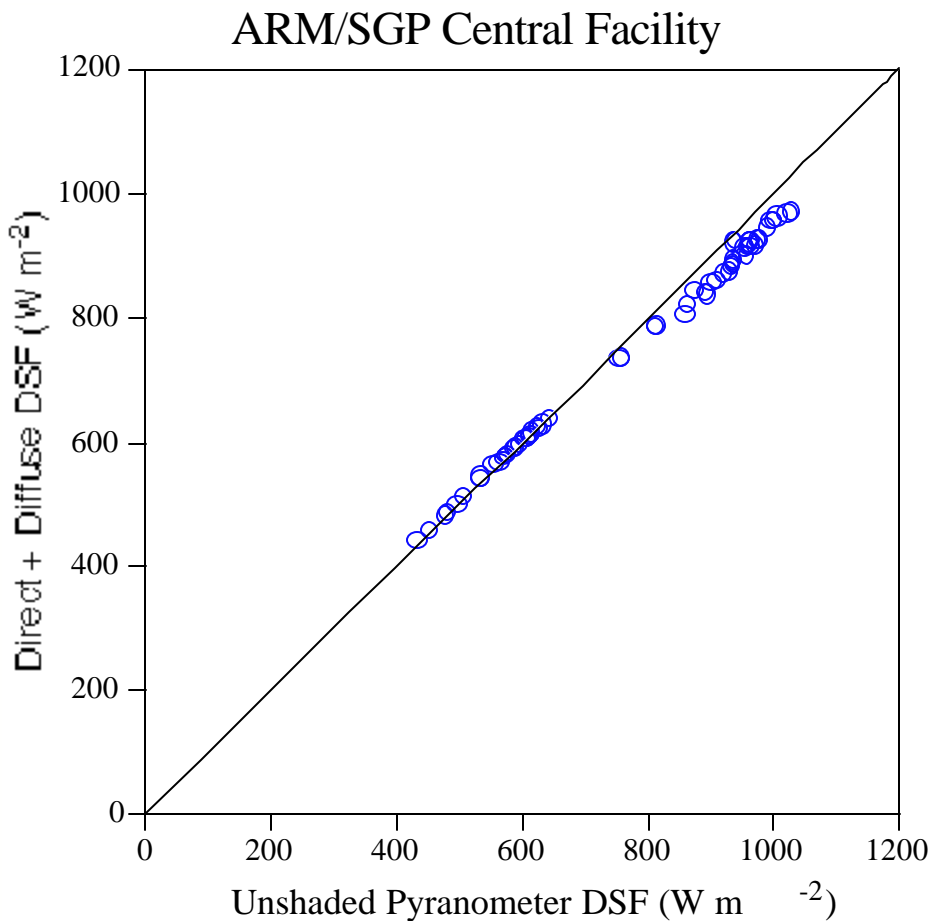
Model A:
Mean Bias = 2.8
RMSD = 20.3
Random Error = 16.0

Model B:
Mean Bias = -20.5
RMSD = 25.4
Random Error = 14.9



Surface
-only
Fluxes

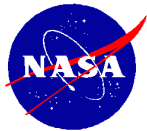
Clear-Sky SW Flux Validation



Unshaded Pyranometer
vs.
Direct + Diffuse
Clear-Sky/1-Minute

Footprints Matched With FM1

Number of Points = 61
Mean Bias = -22.7
RMSD = 33.6
Random Error = 8.5

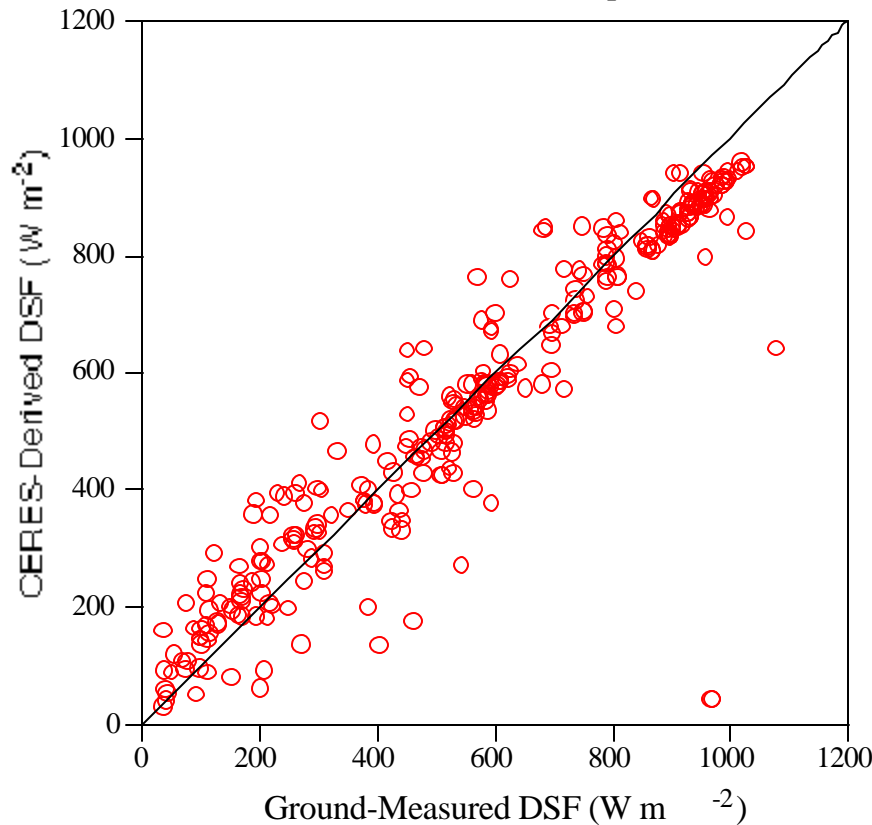


Surface
-only
Fluxes

All-Sky SW Flux Validation

ARM/SGP Central Facility
Terra Ed. 1A (Nov2000 - Sep2001)

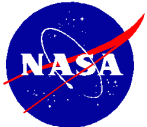
Ground Data Source:
Unshaded Pyranometer



All-Sky/1-Hour

○ Model B FM1

Model B:
Number of Points = 316
Mean Bias = -16.2
RMSD = 107.6
Random Error = 96.4



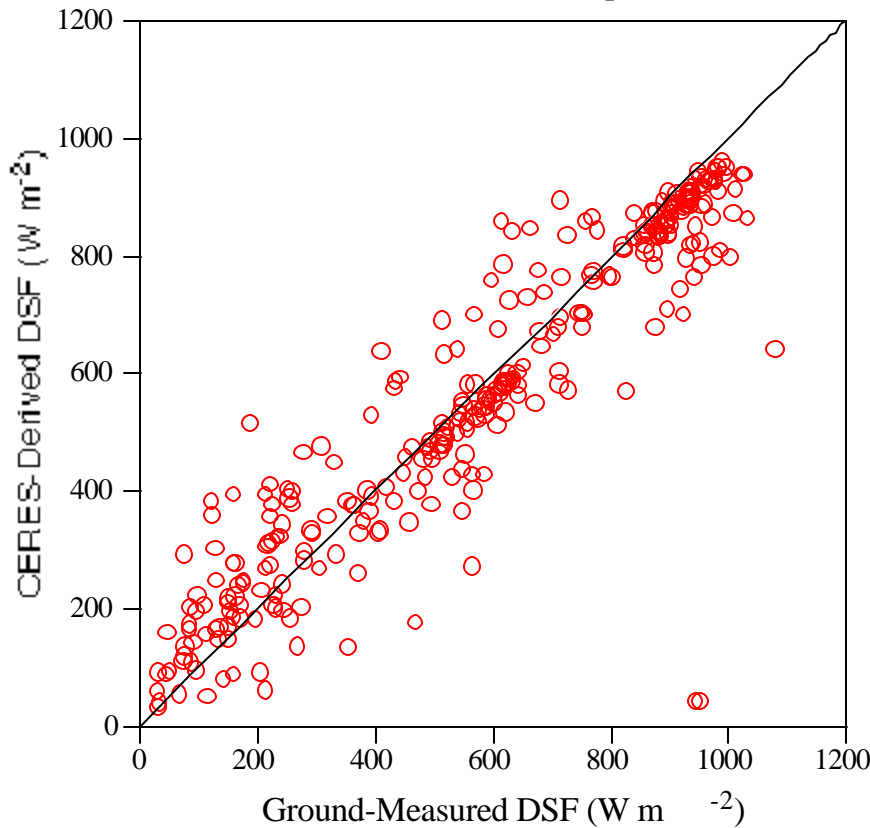
Surface
-only
Fluxes

All-Sky SW Flux Validation

ARM/SGP Central Facility
Terra Ed. 1A (Nov2000 - Sep2001)

Ground Data Source:
Direct + Diffuse

All-Sky/1-Hour



○ Model B FM1

Model B:
Number of Points = 316
Mean Bias = -15.7
RMSD = 119.9
Random Error = 106.6



Surface
-only
Fluxes

All-Sky SW Flux Validation

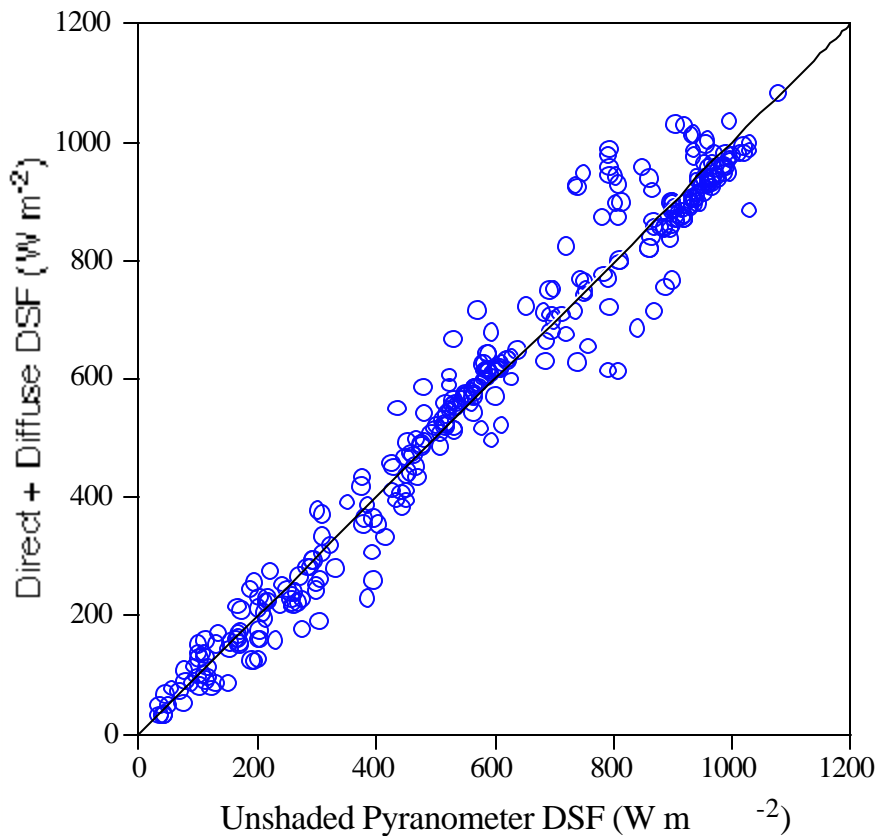
ARM/SGP Central Facility

Unshaded Pyranometer
vs.

Direct + Diffuse

All-Sky/1-Hour

Footprints Matched With FM1



Number of Points = 316

Mean Bias = -0.5

RMSD = 56.6

Random Error = 56.6



Surface
-only
Fluxes

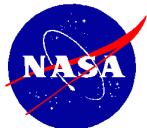
Summary Statistics - ARM/SGP Central Facility

Comparison Between	Number of Points	Bias $W m^{-2}$ (%)	RMSD $W m^{-2}$ (%)	Random Error $W m^{-2}$ (%)
Clear-Sky Shortwave Comparisons				
Model A GUnP Model B - UnP	61	-19.8 (-2.56) -43.2 (-5.59)	26.0 (3.36) 49.7 (6.43)	12.9 (1.67) 10.7 (1.38)
Model A GDaD Model B - DaD	61	2.8 (0.30) -20.5 (-2.73)	20.3 (2.71) 25.4 (3.39)	16.0 (2.13) 14.9 (1.99)
DaD - UnP	61	-22.7 (-2.94)	33.6 (4.35)	8.5 (1.10)
All-Sky Shortwave Comparisons				
Model B - UnP	316	-16.2 (-2.78)	107.6 (18.53)	96.4 (16.60)
Model B - DaD	316	-15.7 (-2.70)	119.9 (20.65)	106.6 (18.36)
DaD - UnP	316	-0.5 (-0.08)	56.6 (9.75)	56.6 (9.75)

UnP GUnshaded Pyranometer

DaD GDirect + Diffuse

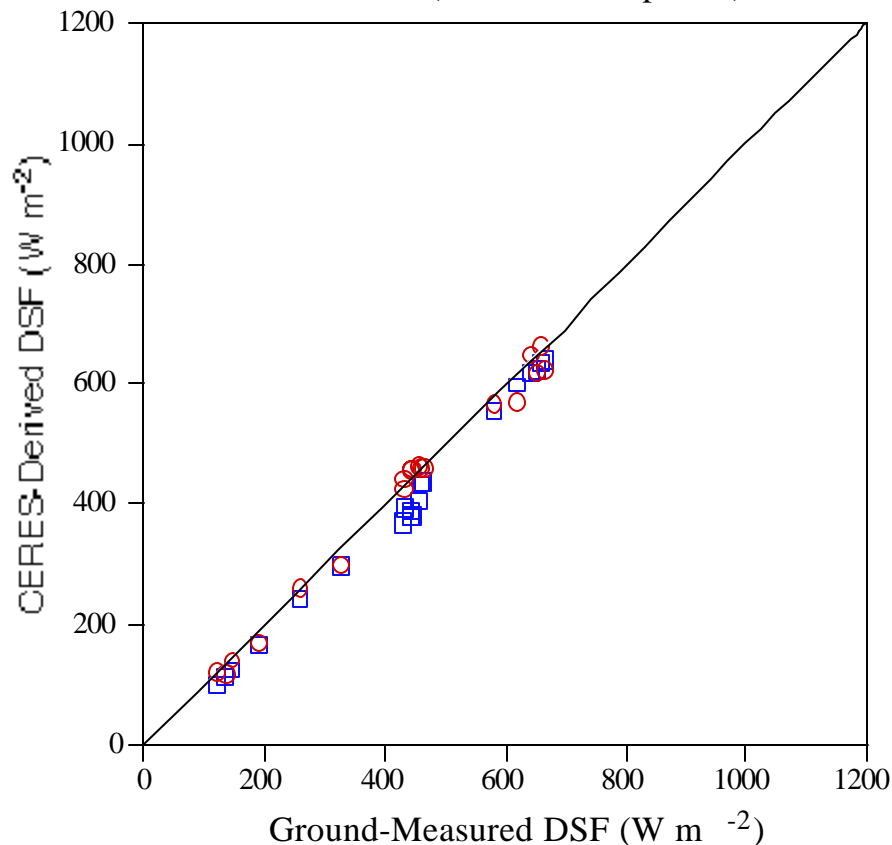
- Clear-Sky errors lower for comparisons with Direct+Diffuse; All-Sky errors comparable
- Comparisons for other sites will be made with Direct+Diffuse only



Clear-Sky SW Flux Validation

Barrow, Alaska/CMDL
Terra Ed. 1A (Nov2000 - Sep2001)

Ground Data Source:
Direct + Diffuse



Clear-Sky/1-Minute

- Model A FM1
- Model B FM1

Number of Points = 20

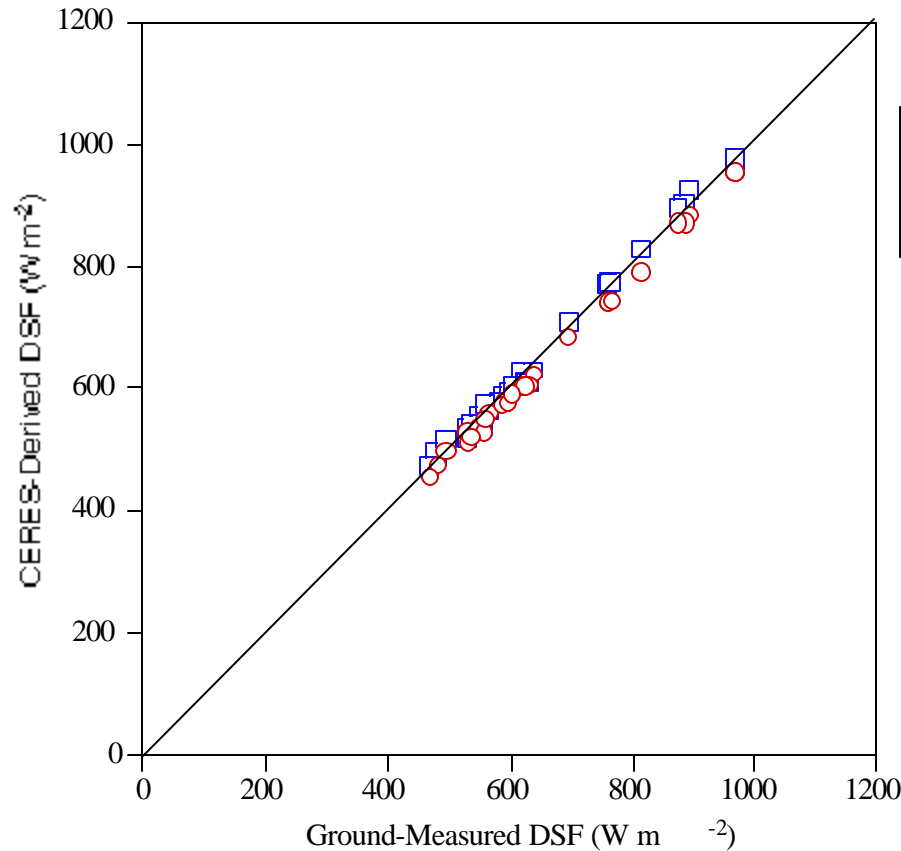
Model A:
Mean Bias = -35.2
RMSD = 38.8
Random Error = 16.2

Model B:
Mean Bias = -9.4
RMSD = 20.3
Random Error = 17.8



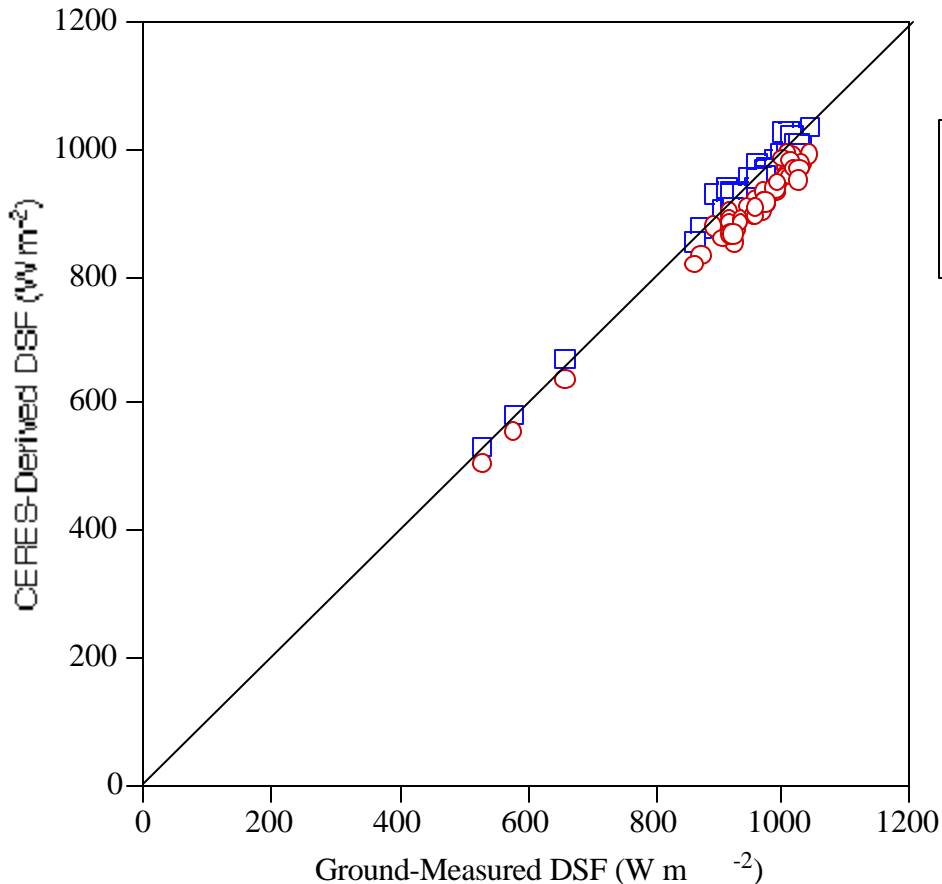
Clear-Sky SW Flux Validation

Goodwin Creek /SURFRAD
Nov 2000 - Sep 2001/Terra ED1A

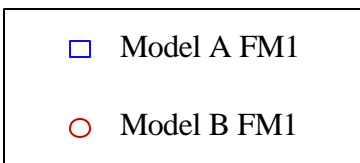


Clear-Sky SW Flux Validation

Desert Rock /SURFRAD
Nov 2000 - Sep 2001/Terra ED1A



Clear Sky I minute
Direct + Diffuse



Npoints = 55

Model A

Bias = -5.09 W m^{-2}

RMSD = 15.55 W m^{-2}

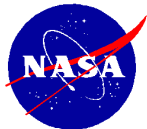
Random Error = 13.96 W m^{-2}

Model B

Bias = -45.51 W m^{-2}

RMSD = 48.16 W m^{-2}

Random Error = 14.10 W m^{-2}

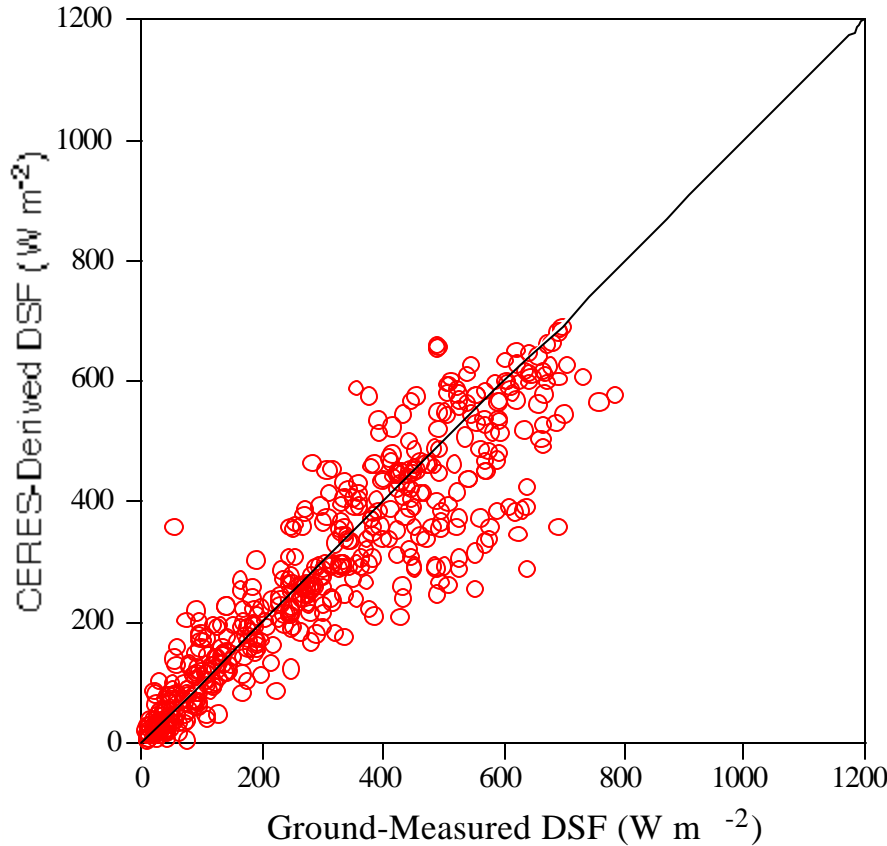


All-Sky SW Flux Validation

Barrow, Alaska/CMDL
Terra Ed. 1A (Nov2000 - Sep2001)

Ground Data Source:
Direct + Diffuse

All-Sky/1-Hour



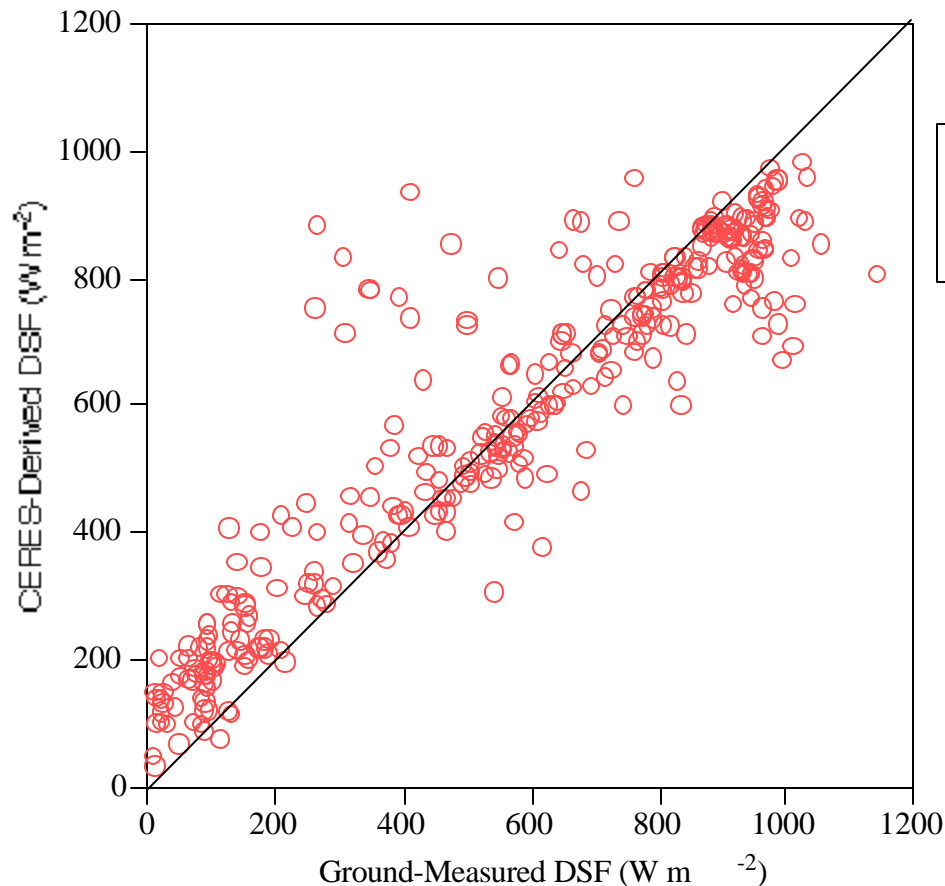
○ Model B FM1

Model B:
Number of Points = 501
Mean Bias = -19.3
RMSD = 84.1
Random Error = 74.8

Surface
-only
Fluxes

All-Sky SW Flux Validation

Goodwin Creek /SURFRAD
Nov 2000 - Sep 2001/Terra ED1A



All Sky hour
Direct + Diffuse

○ Model B FM1

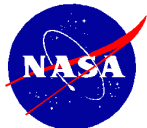
Npoints = 343

Model B

Bias = 17.63 W m^{-2}

RMSD = 126.76 W m^{-2}

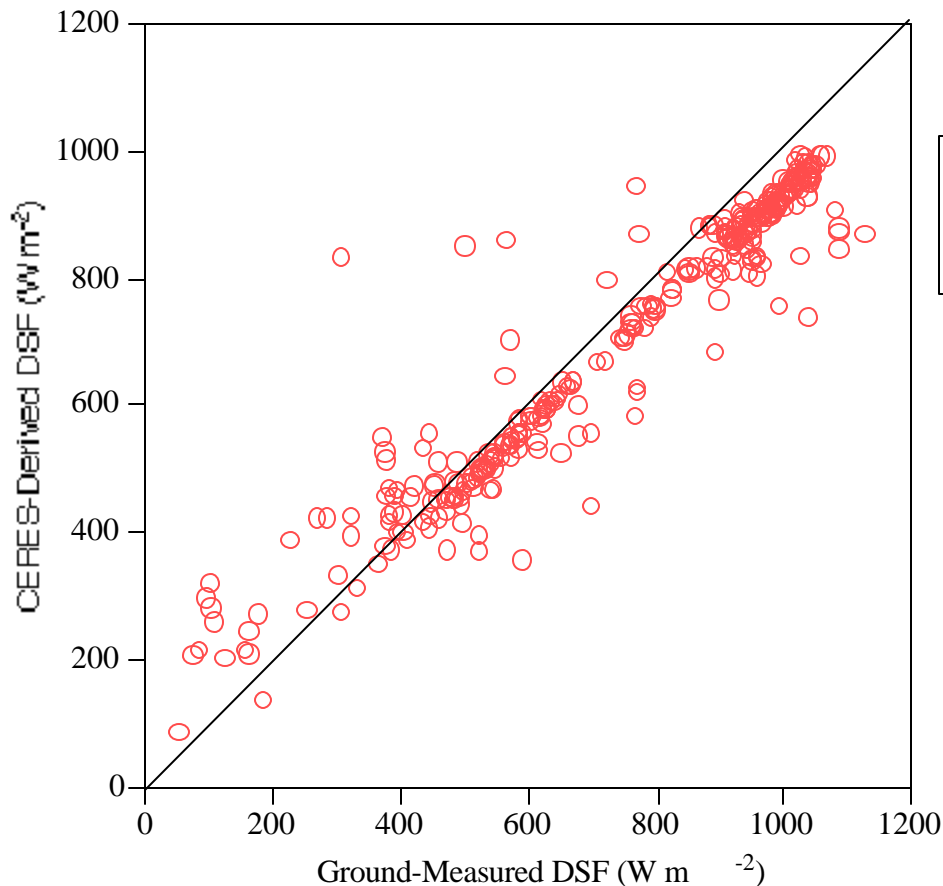
Random Error = 100.51 W m^{-2}



Surface
-only
Fluxes

All-Sky SW Flux Validation

Desert Rock /SURFRAD
Nov 2000 - Sep 2001/Terra ED1A



All Sky hour
Direct + Diffuse

○ Model B FM1

Npoints = 346

Model B

Bias = -38.01 W m^{-2}

RMSD = 88.67 W m^{-2}

Random Error = 62.85 W m^{-2}



Summary Statistics - CMDL and SURFRAD Sites

(All comparisons with Direct+Diffuse measurements)

Location (Model)	Number of Points	Bias $W m^{-2}$ (%)	RMSD $W m^{-2}$ (%)	Random Error $W m^{-2}$ (%)
Clear-Sky Shortwave Comparisons				
BAR (Model A)	20	-35.2 (-8.20)	38.8 (9.03)	16.2 (3.77)
BAR (Model B)		-9.4 (-2.19)	20.3 (4.73)	17.8 (4.15)
GWN (Model A)	29	4.2 (0.64)	13.6 (2.06)	11.6 (1.75)
GWN (Model B)		-14.7 (-2.23)	16.3 (2.47)	7.1 (1.07)
DRA (Model A)	55	-5.1 (-0.54)	15.6 (1.64)	14.0 (1.47)
DRA (Model B)		-45.5 (-4.80)	48.2 (5.08)	14.1 (1.49)
All-Sky Shortwave Comparisons				
BAR (Model B)	501	-19.3 (-6.48)	84.1 (28.22)	74.8 (25.10)
GWN (Model B)	343	17.6 (3.15)	126.8 (22.62)	100.5 (17.93)
DRA (Model B)	346	-38.0 (-5.08)	88.7 (11.86)	62.9 (8.40)

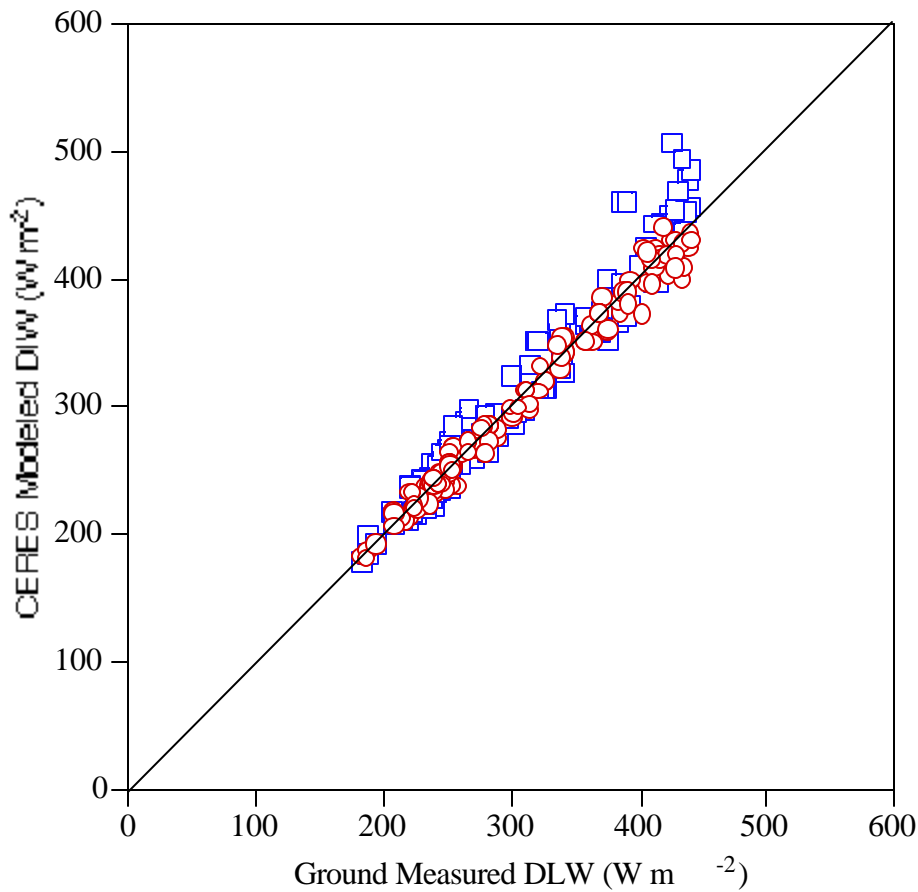
BAR GBarrow/CMDL; GWN GGoodwin Creek/SURFRAD ; DRA GDesert Rock/SURFRAD

- Bias varies greatly between different comparisons
- Random error consistently large for all-sky comparisons



Longwave Clear-sky Comparison

Central Facility
Nov 2000- Sep 2001 Terra1A



Clear Sky I minute

- Model A FM1
- Model B FM1

Npoints = 147

Model A

Bias = 4.29 W m^{-2}

RMSD = 19.38 W m^{-2}

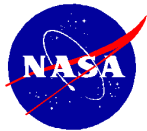
Random Error = 18.07 W m^{-2}

Model B

Bias = -1.41 W m^{-2}

RMSD = 9.06 W m^{-2}

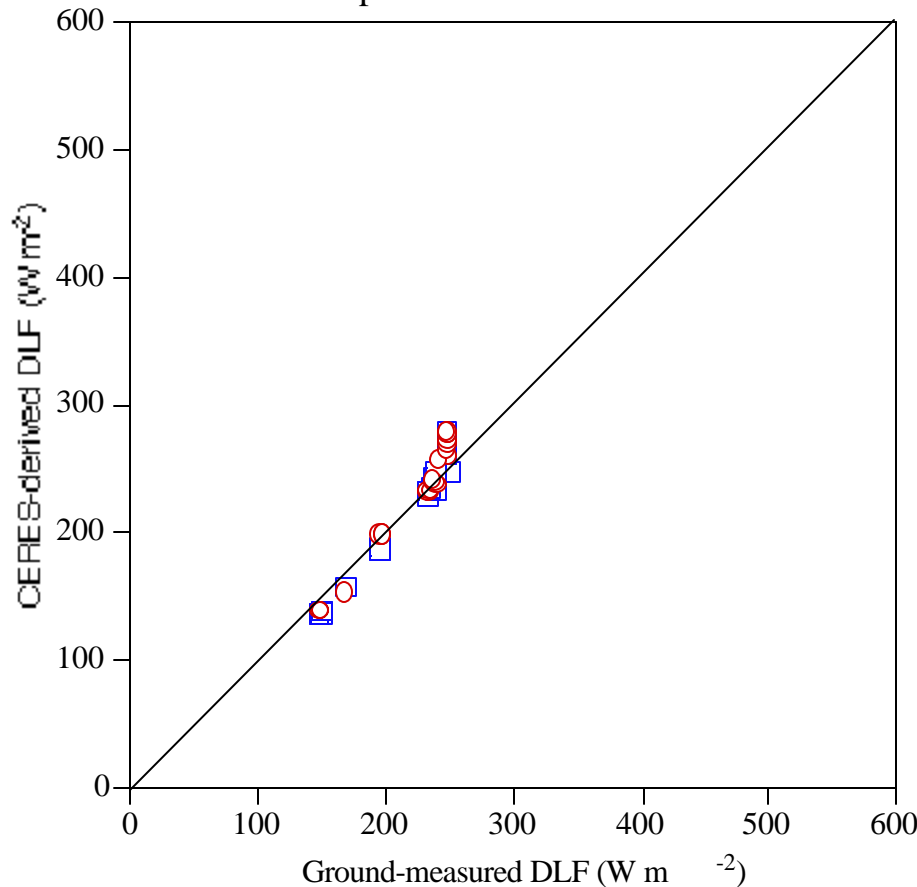
Random Error = 8.93 W m^{-2}



Surface
-only
Fluxes

Longwave Clear-sky Comparison

Barrow, AK/ CMDL
Nov 2000 - Sep 2001/Terra ED1A



Clear Sky I minute
Day

- Model A FM1
- Model B FM1

Npoints = 23

Model A

Bias = 0.04 W m⁻²

RMSD = 12.39 W m⁻²

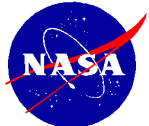
Random Error = 8.06 W m⁻²

Model B

Bias = 5.24 W m⁻²

RMSD = 14.83 W m⁻²

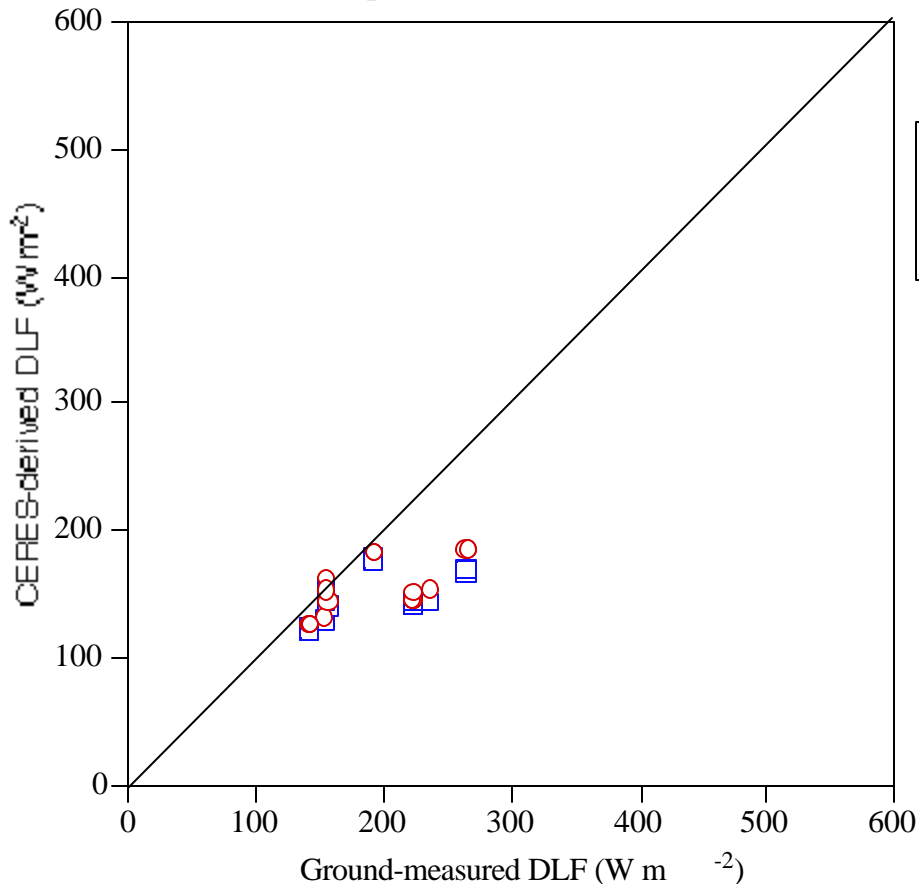
Random Error = 8.61 W m⁻²



Surface
-only
Fluxes

Longwave Clear-sky Comparison

Barrow, AK/ CMDL
Nov 2000 - Sep 2001/Terra ED1A



Clear Sky I minute
Night

- Model A FM1
- Model B FM1

Npoints = 18

Model A

Bias = $50.64 W m^{-2}$

RMSD = $61.58 W m^{-2}$

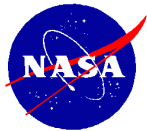
Random Error = $13.66 W m^{-2}$

Model B

Bias = $-44.05 W m^{-2}$

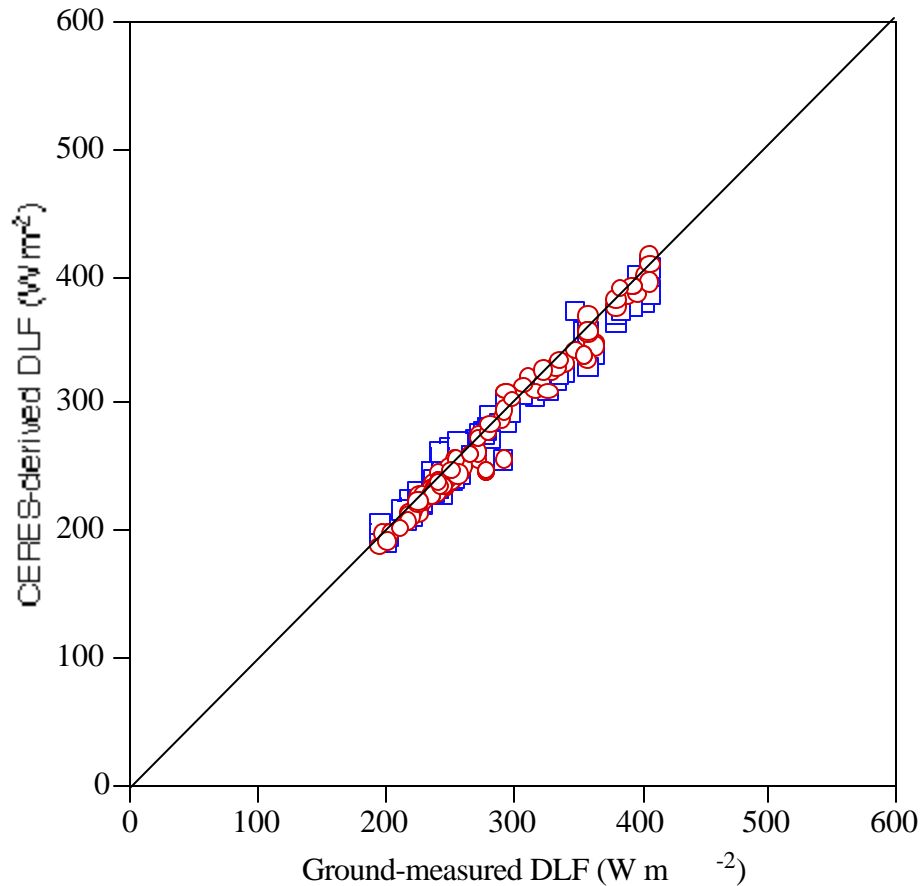
RMSD = $55.67 W m^{-2}$

Random Error = $15.68 W m^{-2}$



Longwave Clear-sky Comparison

Goodwin Creek/ SURFRAD
Nov 2000- Sep 2001 Terra1A



Clear Sky I minute

□ Model A FM1

○ Model B FM1

Npoints = 99

Model A

Bias = -4.17 W m^{-2}

RMSD = 10.91 W m^{-2}

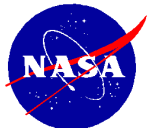
Random Error = 9.59 W m^{-2}

Model B

Bias = -6.27 W m^{-2}

RMSD = 11.61 W m^{-2}

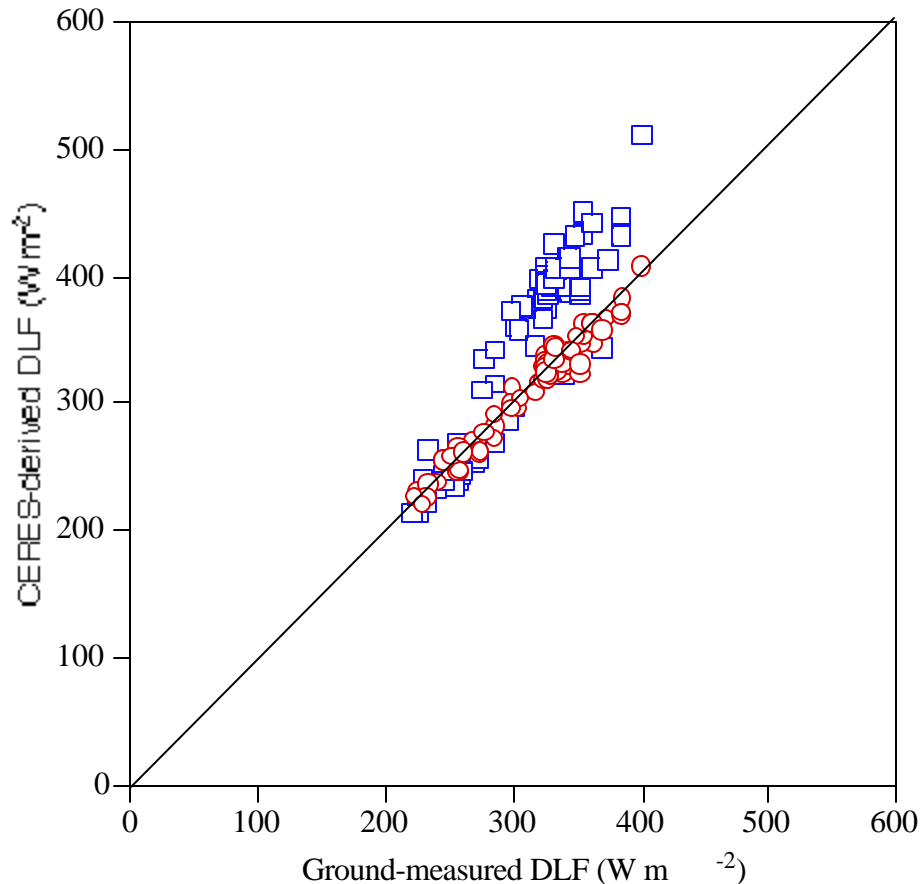
Random Error = 9.65 W m^{-2}



Longwave Clear-sky Comparison

Desert Rock/ SURFRAD

Nov 2000- Sep 2001 Terra1A



Clear Sky I minute

□ Model A FM1

○ Model B FM1

Npoints = 77

Model A

Bias = 39.63 $W m^{-2}$

RMSD = 53.67 $W m^{-2}$

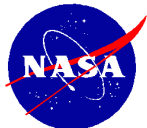
Random Error = 27.41 $W m^{-2}$

Model B

Bias = -1.18 $W m^{-2}$

RMSD = 8.10 $W m^{-2}$

Random Error = 7.96 $W m^{-2}$



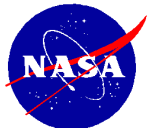
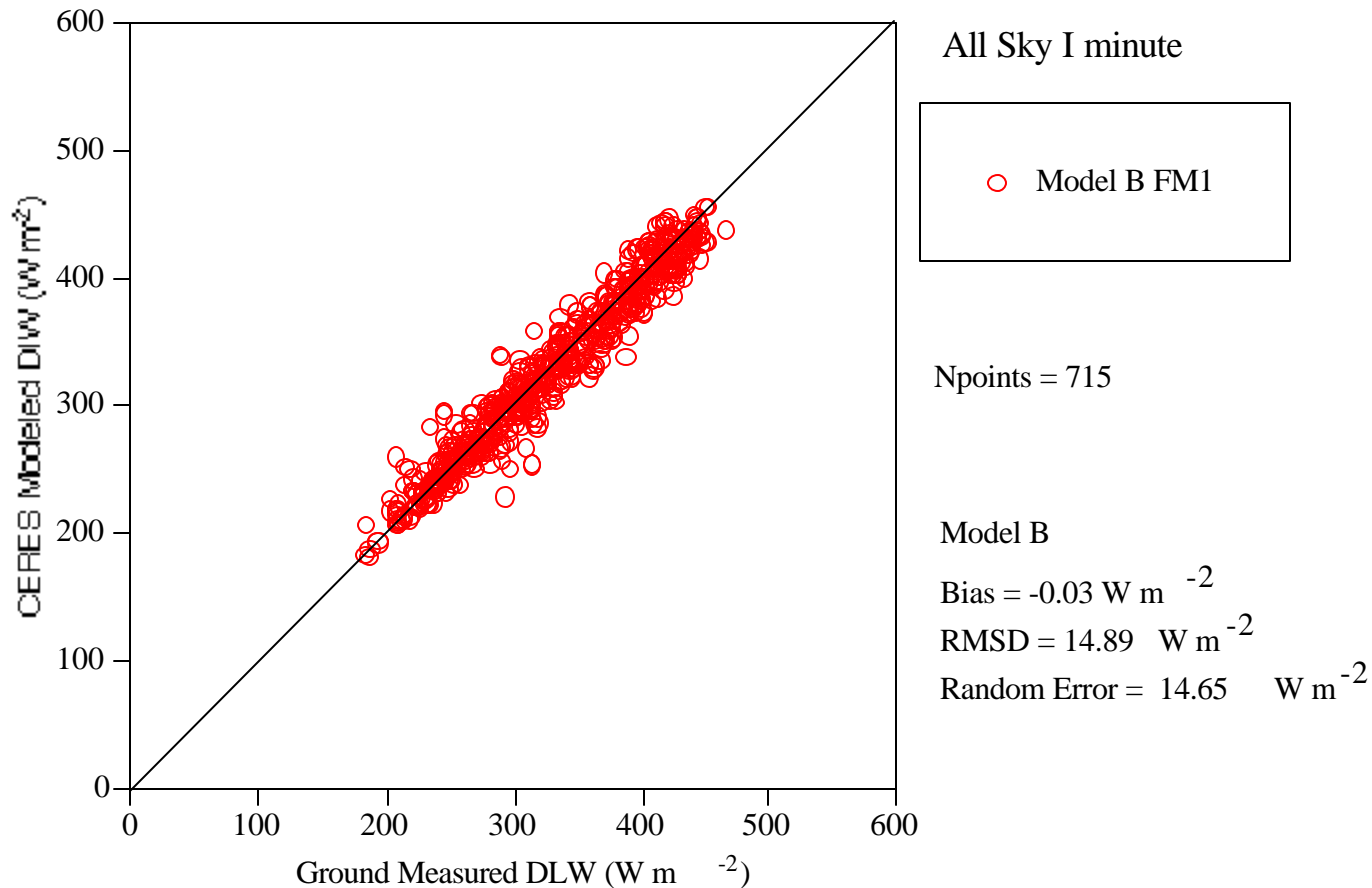
Summary Statistics - Clear-Sky LW Fluxes

Location		Number of Points	Bias W m ⁻² (%)	RMSD W m ⁻² (%)	Random Error W m ⁻² (%)	
Central Facility (SGP)	A	T	147	4.29 (1.44)	19.38 (6.50)	18.07 (6.06)
		D	62	20.99 (6.87)	27.28 (8.93)	14.28 (4.67)
		N	85	-7.89 (-2.69)	10.32 (3.52)	6.66 (2.27)
	B	T	147	-1.41 (-0.47)	9.06 (3.04)	8.93 (2.99)
		D	62	-4.79 (-1.57)	10.70 (3.50)	8.51 (2.79)
		N	85	1.05 (0.36)	7.65 (2.61)	6.98 (2.38)
Barrow (CMDL)	A	T	41	-22.21 (-10.82)	41.85 (20.39)	35.21 (17.16)
		D	23	0.04 (0.02)	12.39 (5.83)	8.06 (3.79)
		N	18	-50.64 (-25.83)	61.58 (31.41)	13.66 (6.97)
	B	T	41	-16.40 (-7.99)	35.82 (18.77)	34.75 (16.94)
		D	23	5.24 (2.47)	14.83 (6.99)	8.61 (4.06)
		N	18	-44.05 (-22.47)	55.67 (28.39)	15.68 (8.00)
Goodwin Creek (SURF)	A	T	99	-4.17 (-1.49)	10.91 (3.89)	9.59 (3.42)
		D	34	5.61 (2.15)	8.71 (3.34)	6.65 (2.55)
		N	65	-9.29 (-3.19)	11.89 (4.09)	7.12 (2.45)
	B	T	99	-6.27 (-2.23)	11.61 (4.14)	9.65 (3.44)
		D	34	-12.47 (-4.78)	15.49 (5.94)	8.87 (3.40)
		N	65	-3.02 (-1.04)	8.93 (3.07)	8.27 (2.84)
Desert Rock (SURF)	A	T	77	39.63 (12.71)	53.67 (17.21)	27.41 (8.79)
		D	55	59.85 (18.23)	62.98 (19.18)	17.33 (5.28)
		N	22	-10.94 (-4.04)	12.77 (4.72)	6.40 (2.37)
	B	T	77	-1.18 (-0.38)	8.10 (2.60)	7.96 (2.55)
		D	55	-1.95 (-0.59)	8.49 (2.59)	8.26 (2.52)
		N	22	0.74 (0.27)	7.03 (2.60)	6.94 (2.56)

Surface
-only
Fluxes

Longwave All-sky Comparison

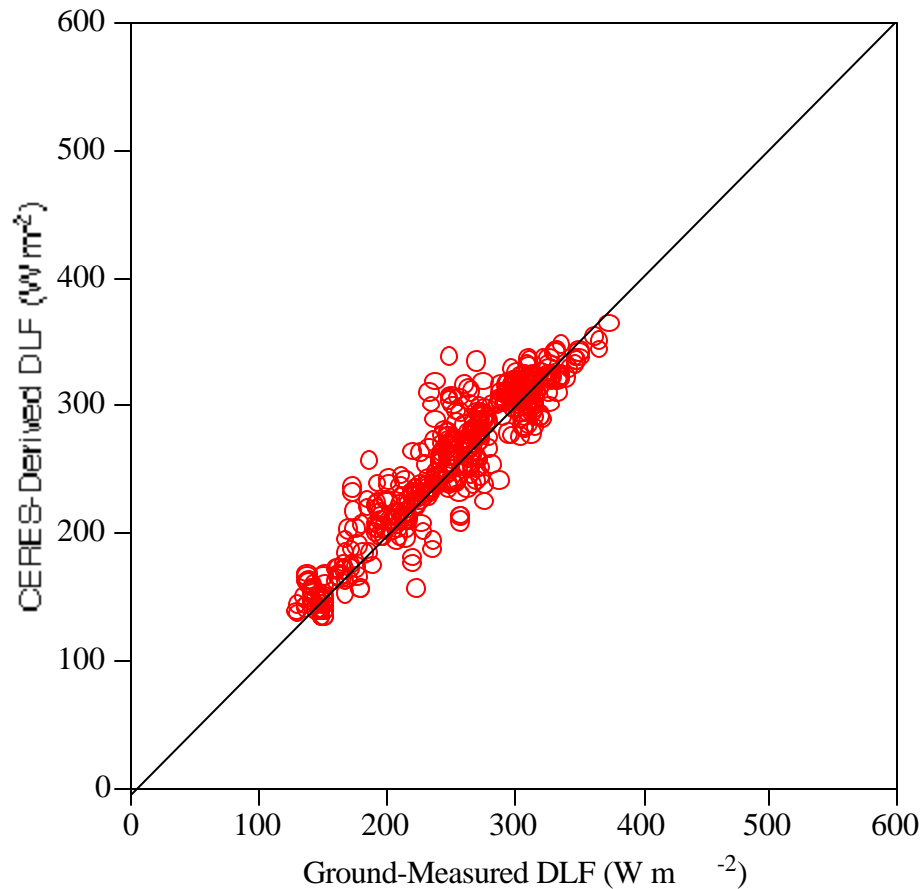
Central Facility
Nov 2000- Sep 2001 Terra1A



Surface
-only
Fluxes

Longwave All-sky Comparison

Barrow, AK/ CMDL
Nov 2000 - Sep 2001/Terra ED1A



All Sky 1 minute
Day

○ Model B FM1

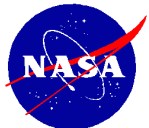
Npoints = 523

Model B

Bias = 6.17 W m⁻²

RMSD = 20.53 W m⁻²

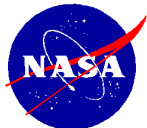
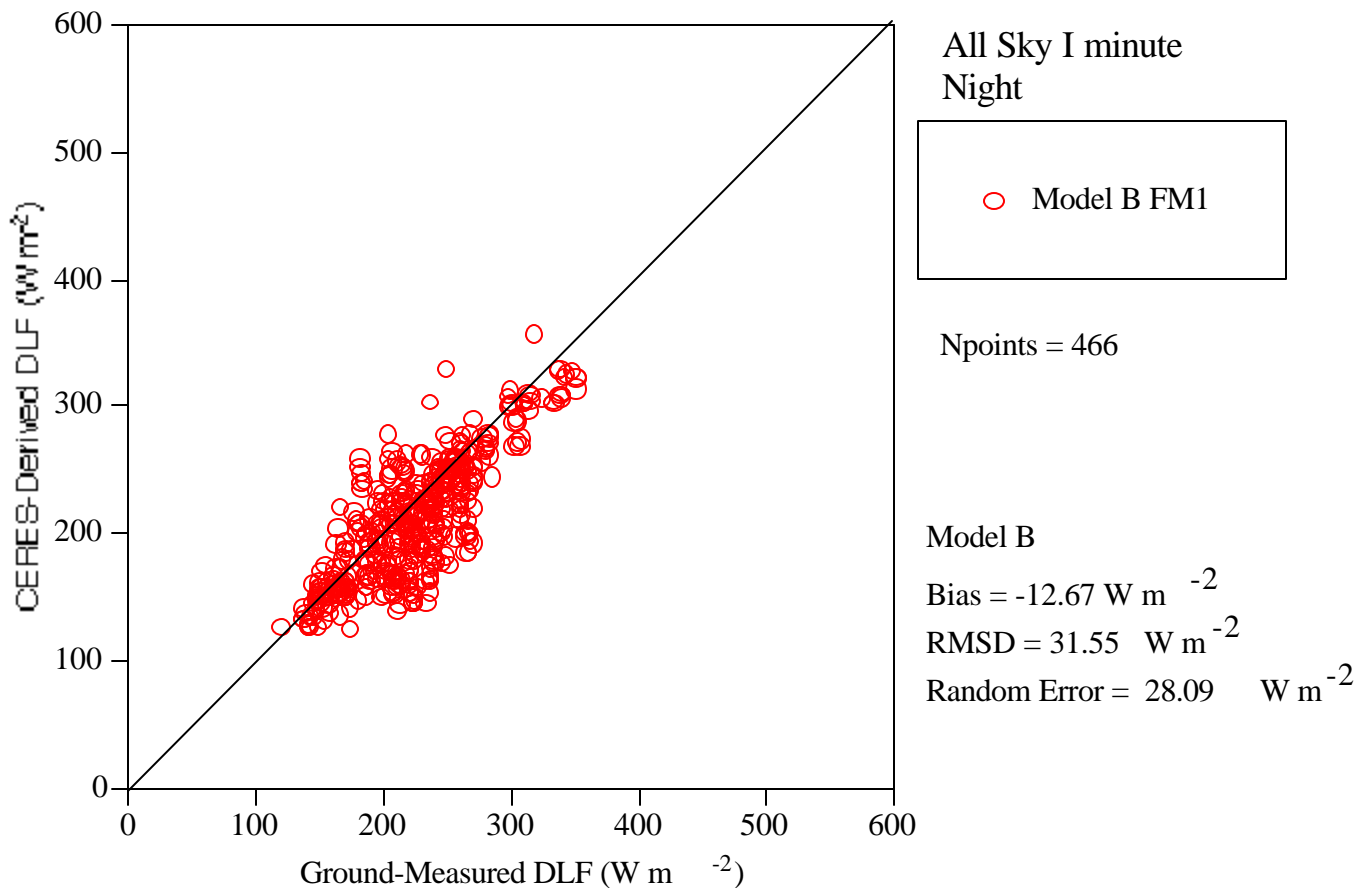
Random Error = 19.42 W m⁻²



Surface
-only
Fluxes

Longwave All-sky Comparison

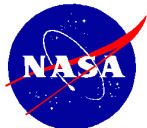
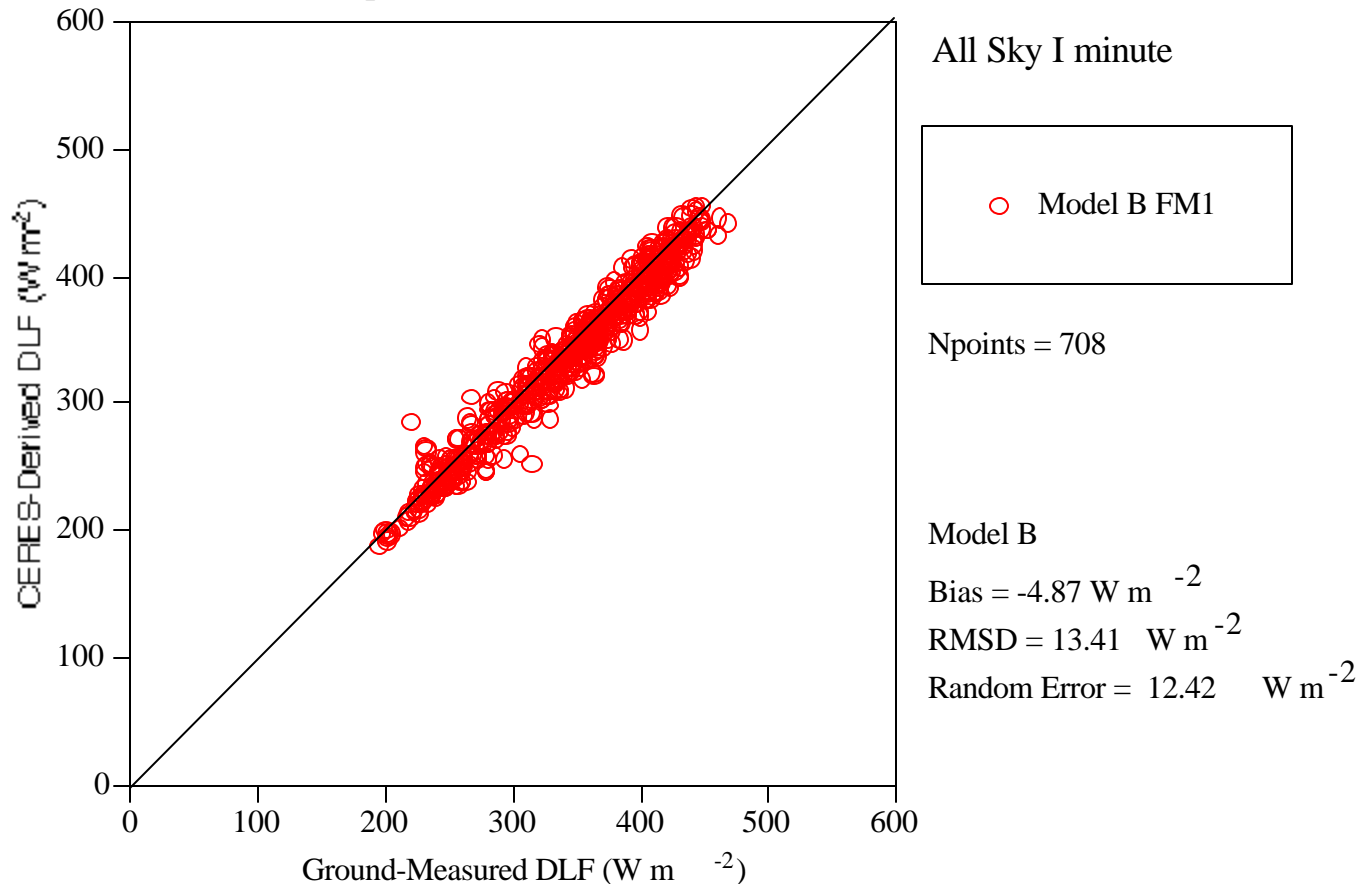
Barrow, AK/ CMDL
Nov 2000 - Sep 2001/Terra ED1A



Surface
-only
Fluxes

Longwave All-sky Comparison

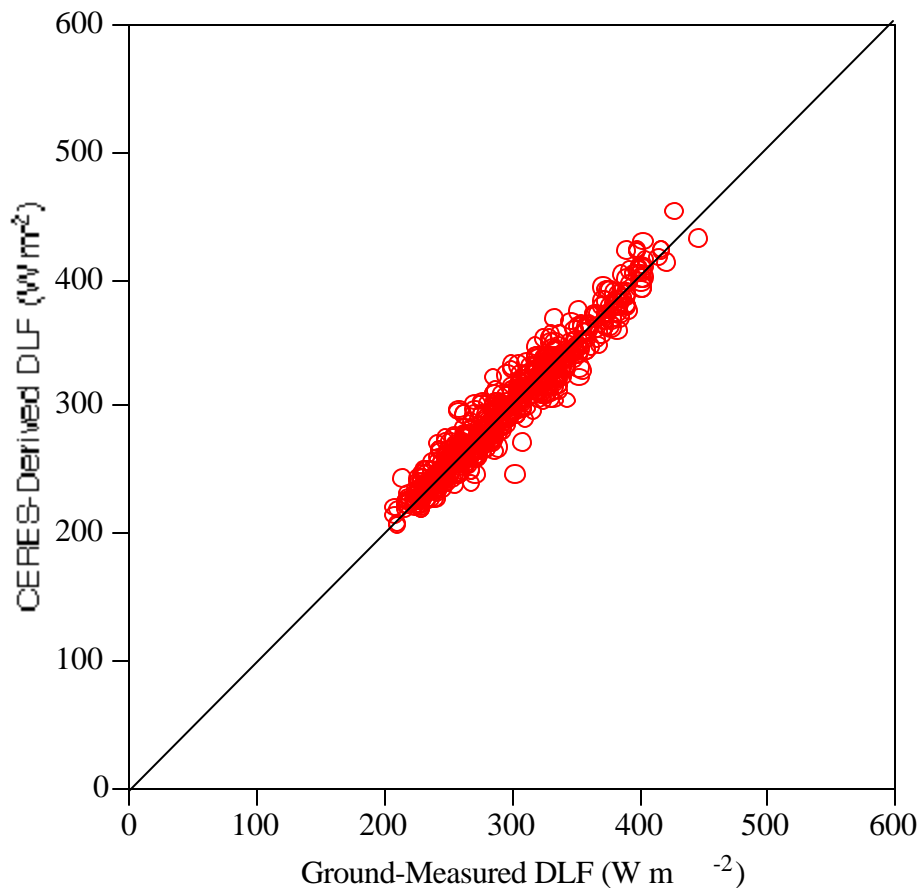
Goodwin Creek /SURFRAD
Nov 2000- Sep 2001 Terra1A



Surface
-only
Fluxes

Longwave All-sky Comparison

Desert Rock/SURFRAD
Nov 2000- Sep 2001 Terra1A



All Sky 1 minute

○ Model B FM1

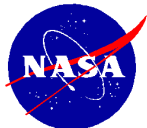
Npoints = 707

Model B

Bias = 2.70 W m^{-2}

RMSD = 11.69 W m^{-2}

Random Error = 11.36 W m^{-2}



Surface
-only
Fluxes

Summary Statistics - All-Sky LW Fluxes

Separated Into Day and Night

Location		Number of Points	Bias $W m^{-2}$ (%)	RMSD $W m^{-2}$ (%)	Random Error $W m^{-2}$ (%)
Central Facility (SGP)	T	715	-0.03 (-0.01)	14.89 (4.56)	14.65 (4.48)
	D	370	-0.88 (-0.26)	14.96 (4.48)	13.83 (4.15)
	N	345	0.87 (0.27)	14.79 (4.65)	14.72 (4.62)
Barrow (CMDL)	T	988	-2.71 (-1.13)	26.32 (10.99)	26.14 (10.92)
	D	522	6.17 (2.43)	20.53 (8.09)	19.42 (7.65)
	N	466	-12.67 (-5.69)	31.55 (14.17)	28.09 (12.62)
Goodwin Creek (SURF)	T	708	-4.87 (-1.43)	13.41 (3.94)	12.42 (3.65)
	D	366	-5.40 (-1.53)	12.63 (3.59)	11.41 (3.24)
	N	342	-4.31 (-1.31)	14.19 (4.32)	13.35 (4.07)
Desert Rock (SURF)	T	707	2.70 (0.91)	11.69 (3.93)	11.36 (3.82)
	D	363	0.95 (0.31)	10.77 (3.55)	10.71 (3.53)
	N	344	4.42 (1.52)	12.75 (4.38)	11.95 (4.11)

