Validation of CERES Aqua & Terra SSF Surface-only Fluxes

David P. Kratz
Climate Science Branch, NASA Langley Research Center
Hampton, Virginia

Anne C. Wilber & Shashi K. Gupta
Analytical Services and Materials, Inc.
Hampton, Virginia

4th CERES-II Science Team Meeting
Hampton, Virginia
November 1, 2005

Aqua 1B / Terra 2B

Validation of CERES Aqua & Terra SSF Surface-only Fluxes

- Down-welling 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

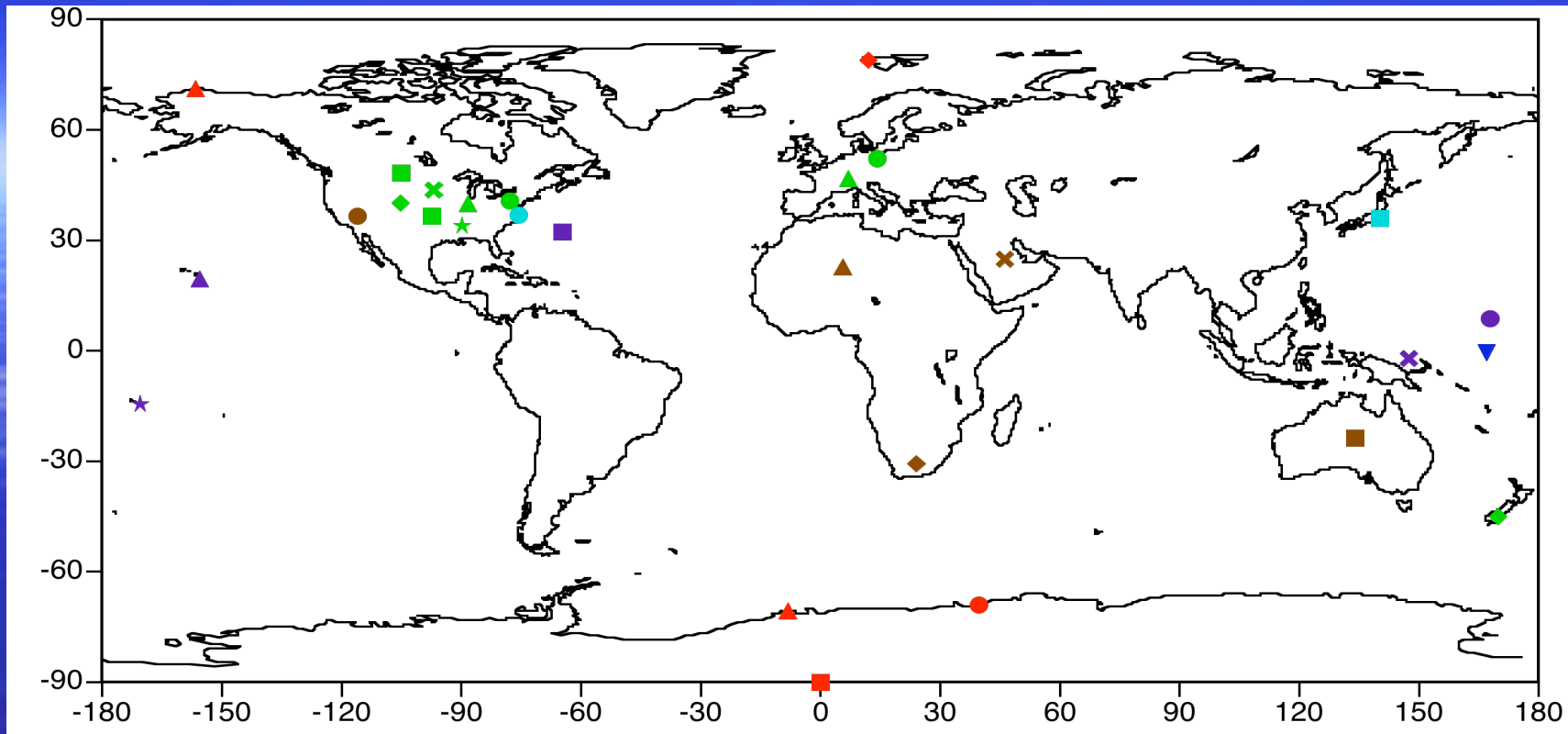
- Validation criteria:
  ±20 Wm^{-2} for instantaneous CERES FOV
- Validation data sources: SURFRAD, ARM/SGP, BSRN, & CMDL
- CERES date sources: Terra FM1 and FM2; Aqua FM3 and FM4

Algorithms/References

- 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.
- SW & LW Model B Validation
  Gupta *et al.* (2004): *J. Atmos. Ocean Tech.*, **21**, 742-752.

CERES Aqua & Terra Data Timeframes

- Data acquisition frozen 1-October-2005 to allow sufficient time for processing and comparison.
- Aqua 1B: July 2002 through March 2005.
- Terra 2B: March 2000 through May 2005.

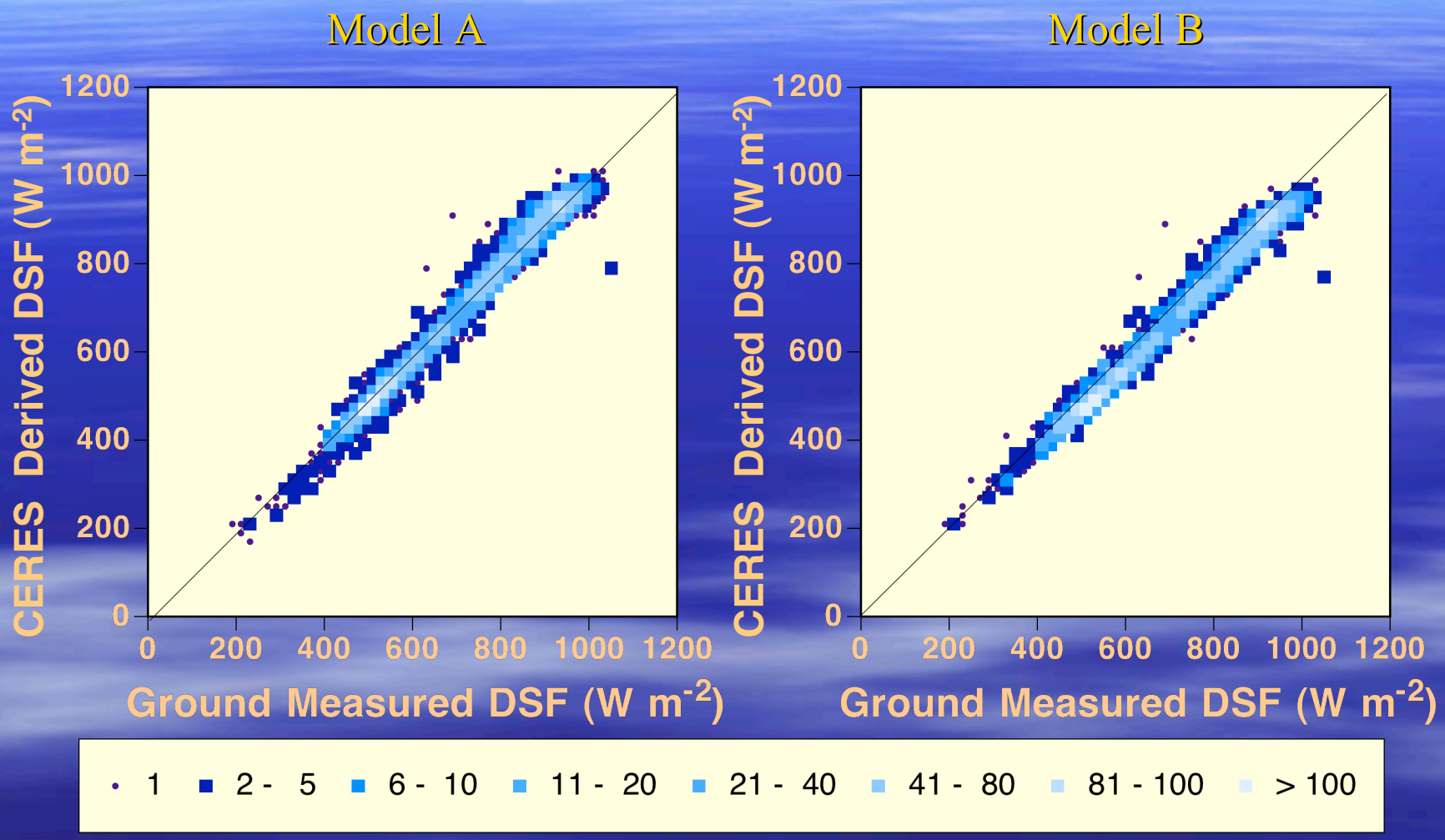


- 48.31N, 105.10W Fort Peck, MT
- 40.72N, 77.93W Penn State, PA
- 40.05N, 88.37W Bondville, IL
- 40.13N, 105.24W Boulder, CO
- 34.25N, 89.87W Goodwin Creek, MS
- 43.73N, 96.92W Sioux Falls, SD
- 36.60N, 97.48W SGP ARM
- 52.22N, 14.12E Lindenberg
- 46.82N, 6.95E Payerne
- 45.03S, 169.7E New Zealand
- 32.30N, 64.77W Bermuda
- 8.72N, 167.72E Kwajalein
- 19.54N, 155.58W Mauna Loa, HI
- 14.23S, 170.56W American Samoa
- 2.06S, 147.42 E Manus
- 0.52S, 166.9 E, Nauru
- 36.05N, 140.13E Tatano
- 36.9N, 75.71W COVE
- 71.32N, 156.61W Barrow, AK
- 90.00S, 0.00 South Pole
- 69.00S, 39.58E Syowa
- 70.65S, 8.25W Georg von Neumayer
- 78.9N, 11.95E Ny Alesund
- 24.91N, 46.41E Saudi Solar Village
- 23.70S, 133.87E Alice Springs
- 36.63N, 116.02W Desert Rock, NV
- 22.78N, 5.52E Algeria
- 30.67S, 24.0E De Aar

Aqua 1B

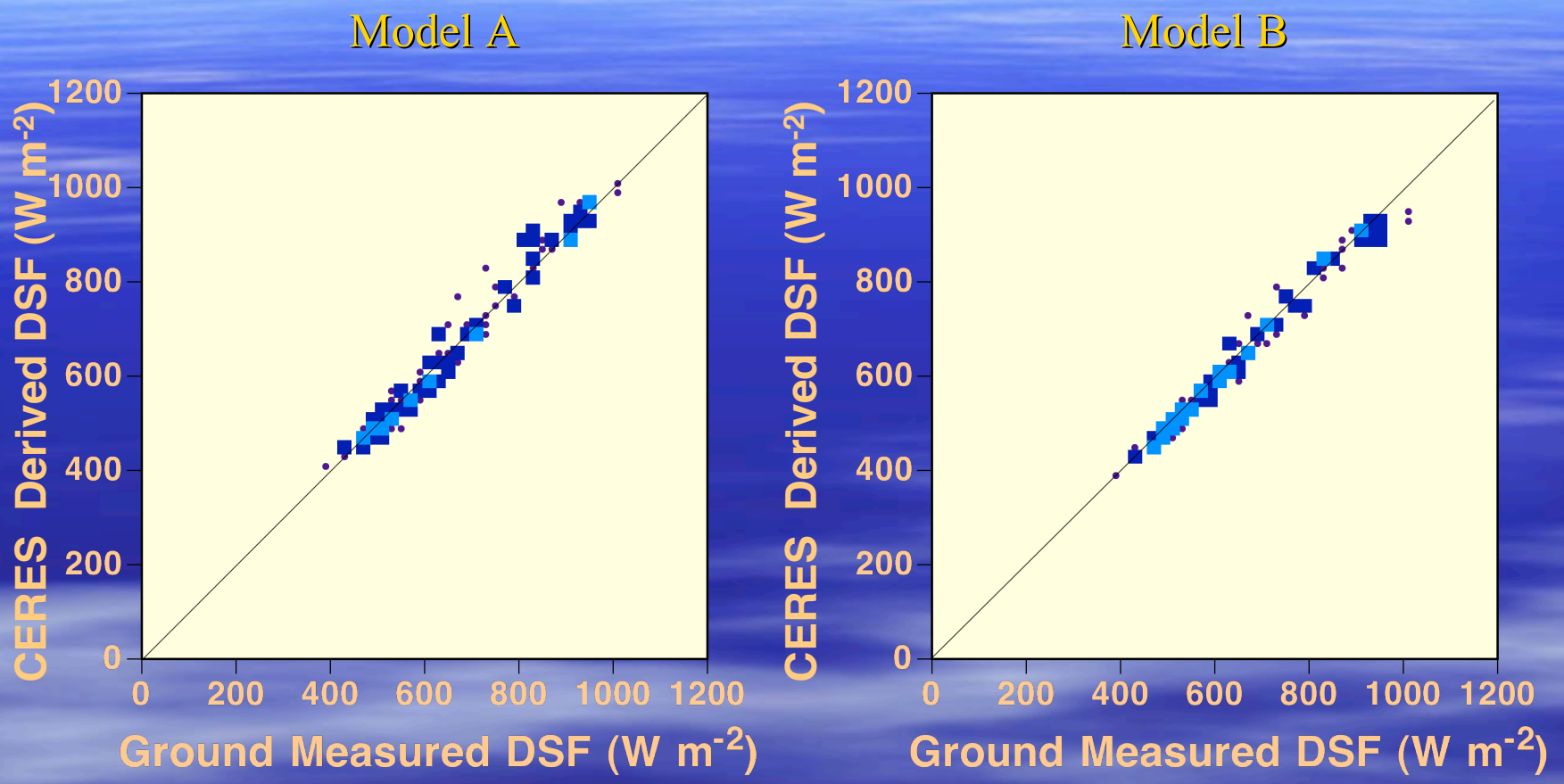
Shortwave Clear-Sky
July 2002 through March 2005

Aqua Shortwave Clear-Sky Continental



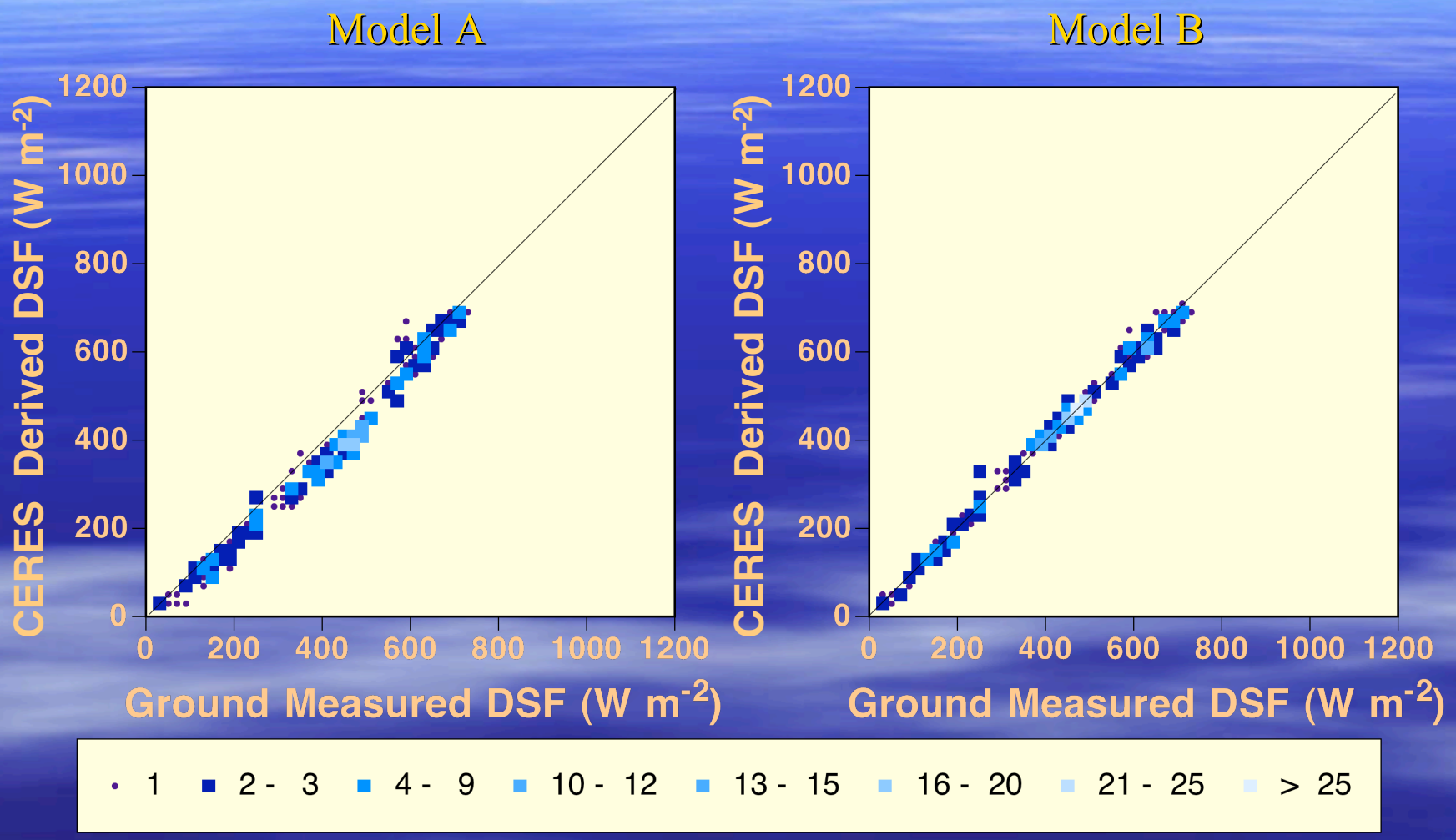
Aqua 1B

Aqua Shortwave Clear-Sky Coastal



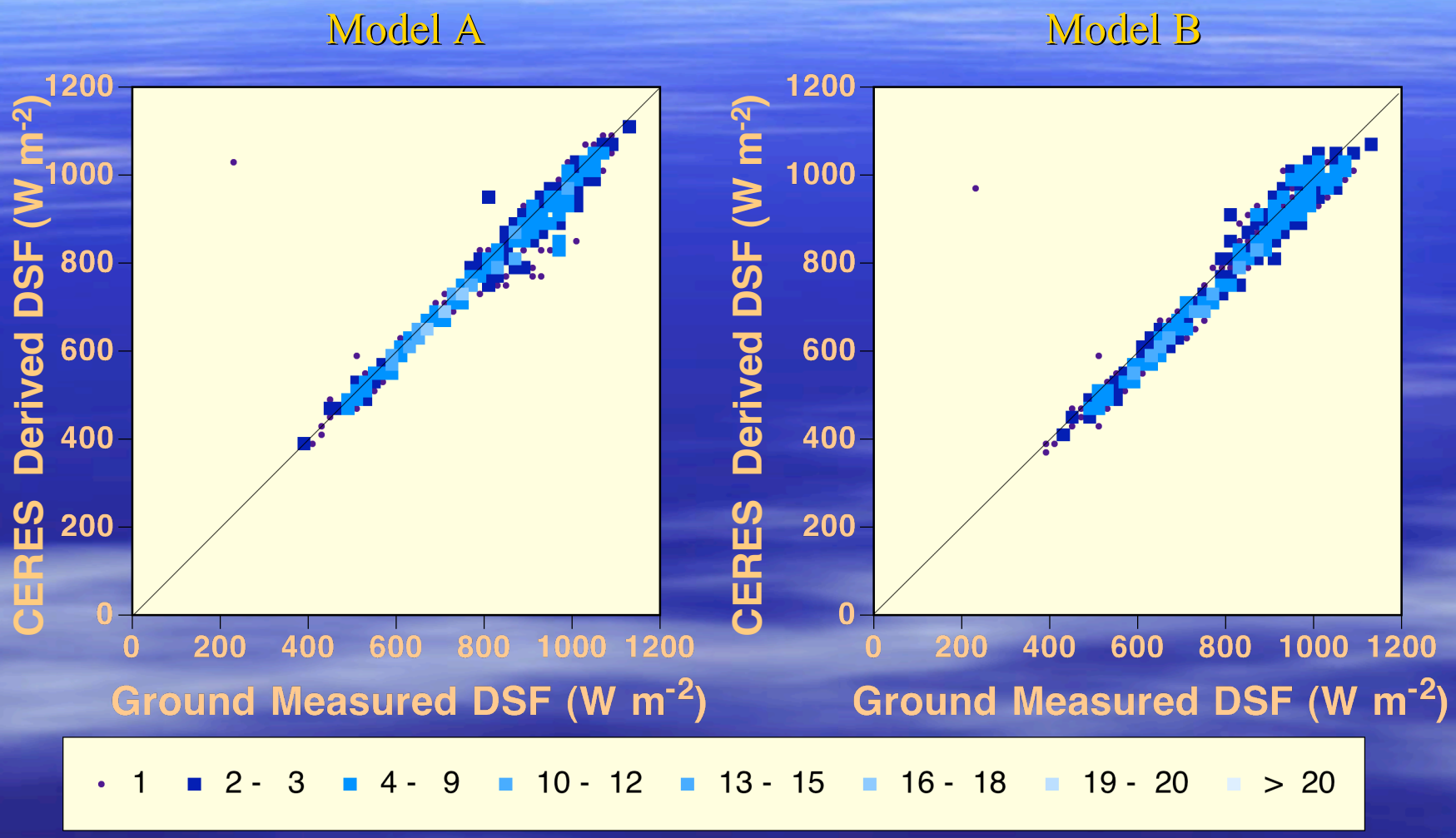
Aqua 1B

Aqua Shortwave Clear-Sky Ant-arctic



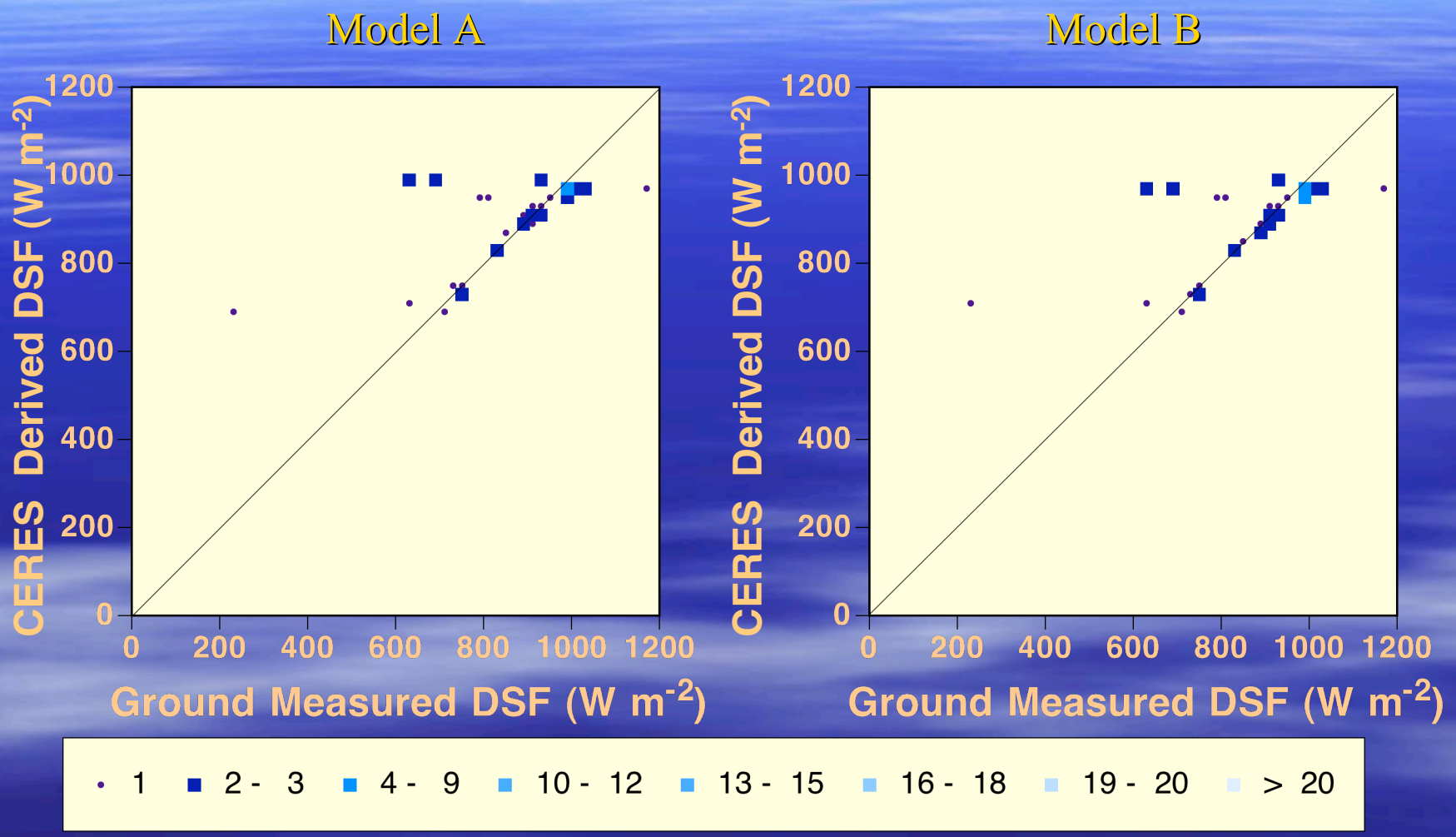
Aqua 1B

Aqua Shortwave Clear-Sky Desert



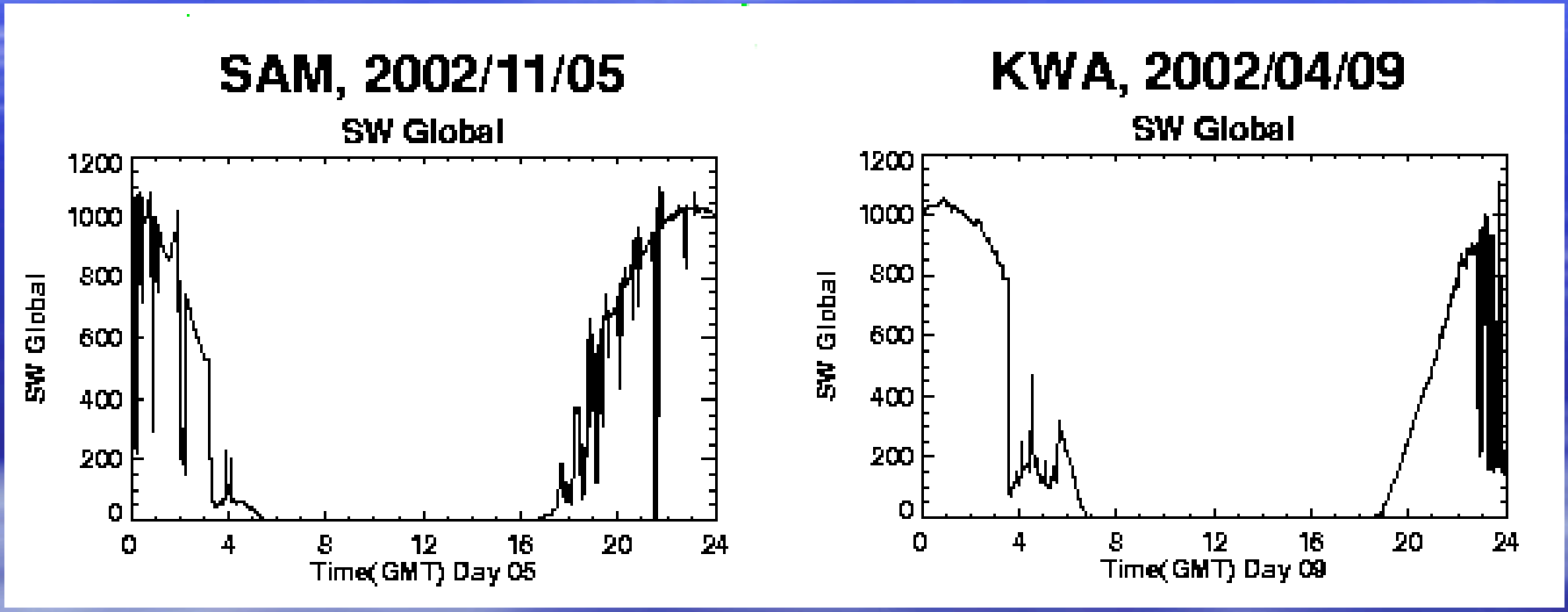
Aqua 1B

Aqua Shortwave Clear-Sky Island



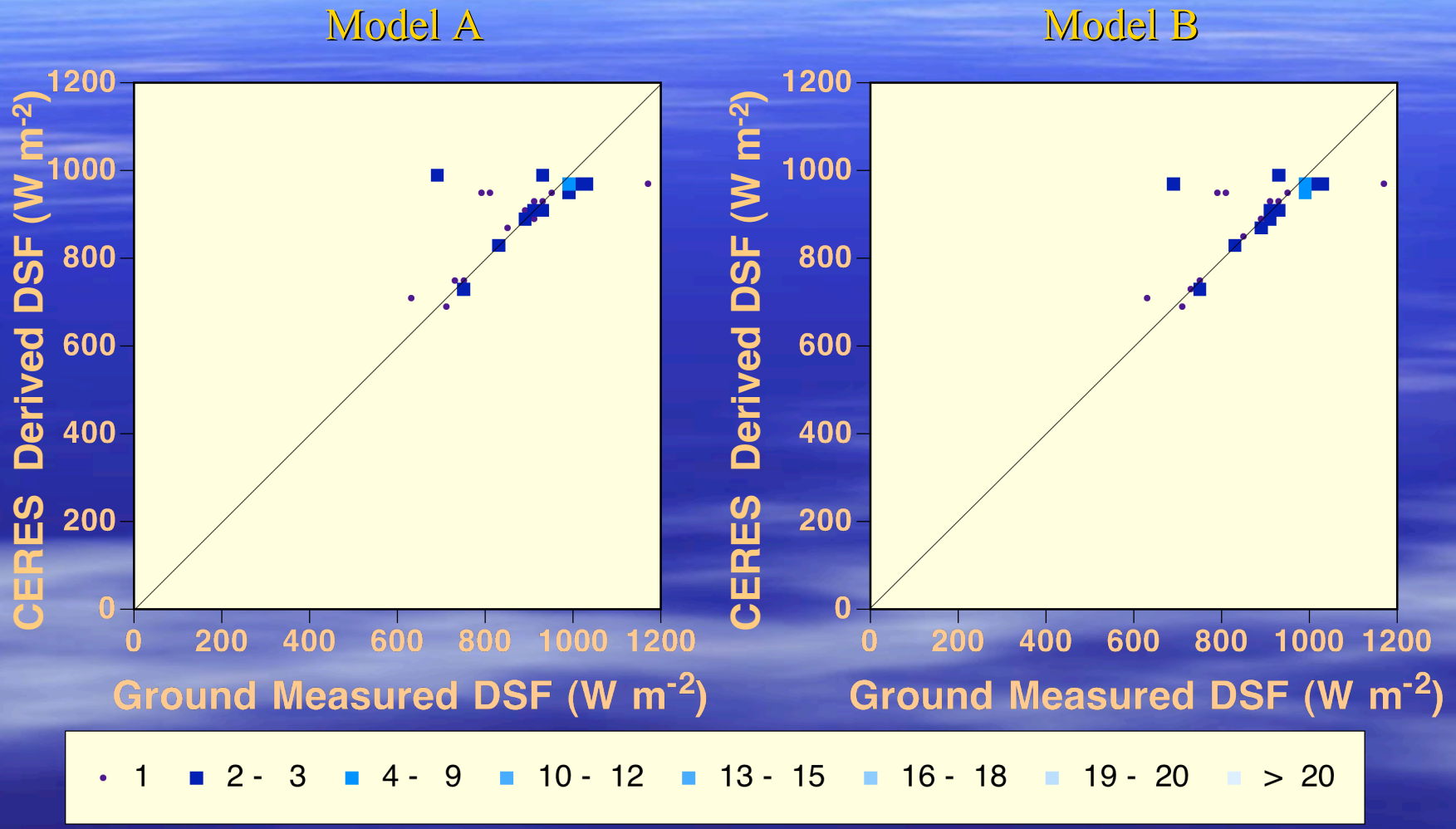
Aqua 1B

Shortwave Clear-Sky Island

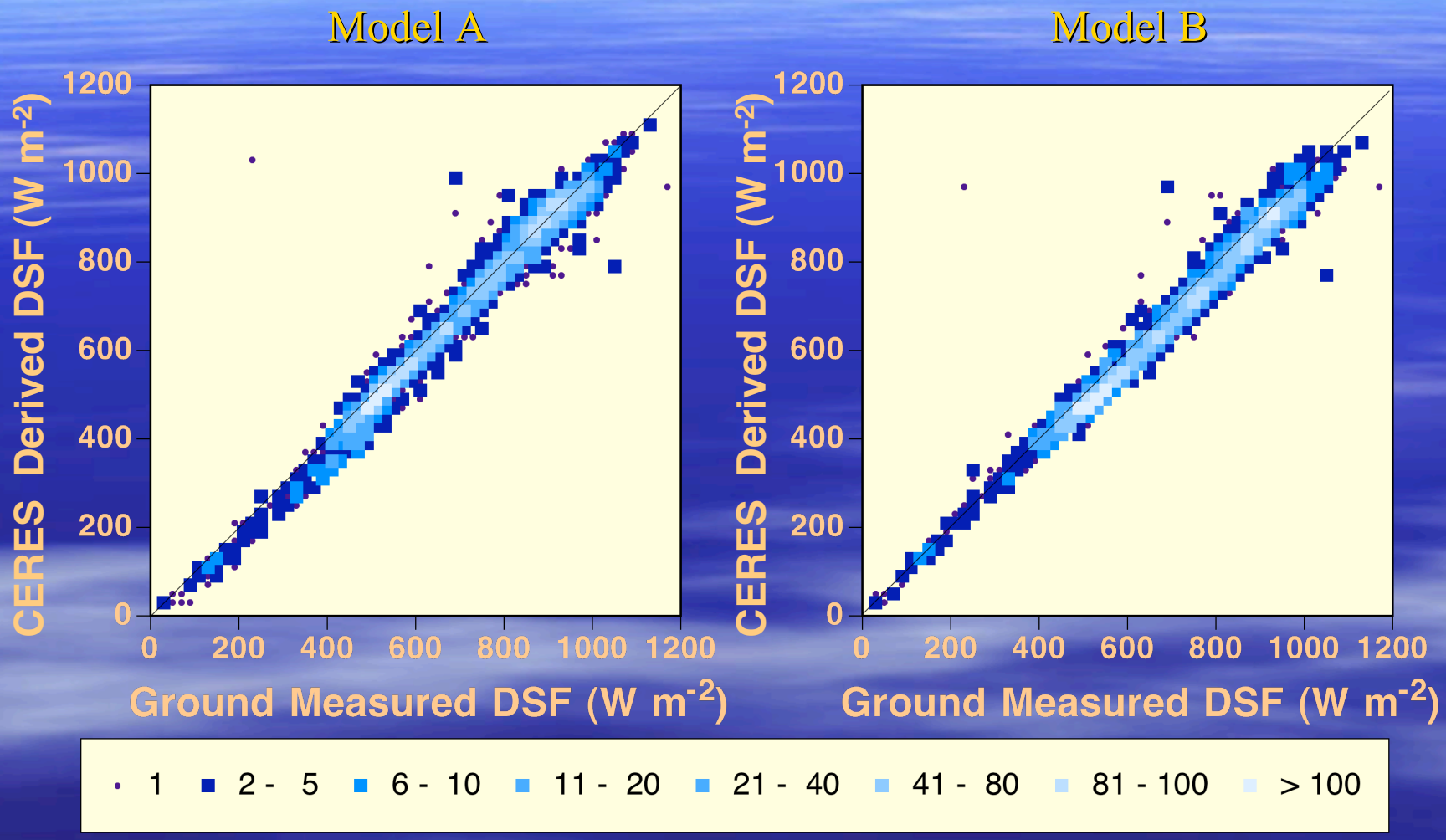


Surface Site

Aqua Shortwave Clear-Sky Island (filtered)



Aqua Shortwave Clear-Sky Global (with island filter)



Aqua 1B

Aqua Shortwave Clear-Sky

Sites # of Points		SWA	SWB
Continental	Bias Wm^{-2} (%)	-11.60 (-1.62)	-30.32 (-4.24)
4147	σ Wm^{-2} (%)	22.8 (3.2)	19.9 (2.8)
Coastal	Bias Wm^{-2} (%)	0.66 (0.10)	-7.95 (-1.20)
164	σ Wm^{-2} (%)	26.9 (4.1)	19.4 (2.9)
Ant-Arctic	Bias Wm^{-2} (%)	-43.71 (-10.34)	-1.71 (-0.41)
309	σ Wm^{-2} (%)	27.7 (6.5)	15.1 (3.6)
Desert	Bias Wm^{-2} (%)	-18.68 (-2.34)	-26.43 (-3.31)
620	σ Wm^{-2} (%)	42.0 (5.3)	43.2 (5.4)
Island	Bias Wm^{-2} (%)	34.67 (3.99)	28.89 (3.32)
46	σ Wm^{-2} (%)	74.9 (8.6)	70.4 (8.1)
Global	Bias Wm^{-2} (%)	-13.52 (-1.91)	-26.98 (-3.82)
5286	σ Wm^{-2} (%)	30.5 (4.3)	27.6 (3.9)

Aqua 1B

Aqua Shortwave Clear-Sky

Sites # of Points		SWA	SWB
Continental 4147	Bias Wm^{-2} (%) σ Wm^{-2} (%)	-11.60 (-1.62) 22.8 (3.2)	-30.32 (-4.24) 19.9 (2.8)
Coastal 164	Bias Wm^{-2} (%) σ Wm^{-2} (%)	0.66 (0.10) 26.9 (4.1)	-7.95 (-1.20) 19.4 (2.9)
Ant-Arctic 309	Bias Wm^{-2} (%) σ Wm^{-2} (%)	-43.71 (-10.34) 27.7 (6.5)	-1.71 (-0.41) 15.1 (3.6)
Desert 620	Bias Wm^{-2} (%) σ Wm^{-2} (%)	-18.68 (-2.34) 42.0 (5.3)	-26.43 (-3.31) 43.2 (5.4)
Island 43	Bias Wm^{-2} (%) Bias Wm^{-2} (%)	9.06 (1.01) 64.3 (7.2)	3.32 (0.37) 60.1 (6.7)
Global 5119	σ Wm^{-2} (%) Bias Wm^{-2} (%)	-14.22 (-2.01) 28.6 (4.0)	-27.84 (-3.93) 25.6 (3.6)

Aqua 1B

Terra Shortwave Clear-Sky

Sites # of Points		SWA	SWB
Continental 10822	Bias Wm^{-2} (%) σ Wm^{-2} (%)	-3.59 (-0.48) 28.7 (3.8)	-22.76 (-3.04) 26.4 (3.5)
Coastal 388	Bias Wm^{-2} (%) σ Wm^{-2} (%)	7.42 (1.11) 32.2 (4.8)	-14.50 (-2.17) 28.0 (4.2)
Ant-Arctic 628	Bias Wm^{-2} (%) σ Wm^{-2} (%)	-49.46 (12.05) 23.5 (5.7)	-0.89 (-0.22) 15.9 (3.9)
Desert 2287	Bias Wm^{-2} (%) σ Wm^{-2} (%)	-24.58 (-2.89) 41.5 (4.9)	-18.81 (-2.21) 39.7 (4.7)
Island 126	Bias Wm^{-2} (%) σ Wm^{-2} (%)	32.98 (3.68) 61.4 (6.9)	15.82 (1.77) 58.0 (6.5)
Global 14251	Bias Wm^{-2} (%) σ Wm^{-2} (%)	-8.35 (-1.11) 36.1 (4.8)	-20.60 (-2.75) 31.8 (4.2)

Terra 2B

Terra Shortwave Clear-Sky

Sites # of Points		SWA	SWB
Continental 10822	Bias Wm^{-2} (%) σ Wm^{-2} (%)	-3.59 (-0.48) 28.7 (3.8)	-22.76 (-3.04) 26.4 (3.5)
Coastal 388	Bias Wm^{-2} (%) σ Wm^{-2} (%)	7.42 (1.11) 32.2 (4.8)	-14.50 (-2.17) 28.0 (4.2)
Ant-Arctic 628	Bias Wm^{-2} (%) σ Wm^{-2} (%)	-49.46 (-12.05) 23.5 (5.7)	-0.89 (-0.22) 15.9 (3.9)
Desert 2287	Bias Wm^{-2} (%) σ Wm^{-2} (%)	-24.58 (-2.89) 41.5 (4.9)	-18.81 (-2.21) 39.7 (4.7)
Island 74	Bias Wm^{-2} (%) Bias Wm^{-2} (%)	-6.79 (-0.73) 41.1 (4.4)	-20.89 (-2.25) 40.3 (4.4)
Global 13811	σ Wm^{-2} (%) Bias Wm^{-2} (%)	-9.16 (-1.22) 33.7 (4.5)	-21.10 (-2.81) 29.4 (3.9)

Terra 2B

Conclusions: Shortwave Clear-sky

CERES derived SW surface fluxes are generally within the desired accuracies (biases) for models A and B. Nevertheless, model A severely underestimates the surface fluxes for cases involving low water vapor amounts (e,g, (ant)arctic cases), while model B tends to underestimate the surface fluxes to a greater extent with increasing surface flux.

A potential source of error for both models appears to be the aerosol maps. We are in the process of replacing them by the climatological aerosol maps based upon 60 months of the Model for Atmospheric Transport and Chemistry (MATCH) data.

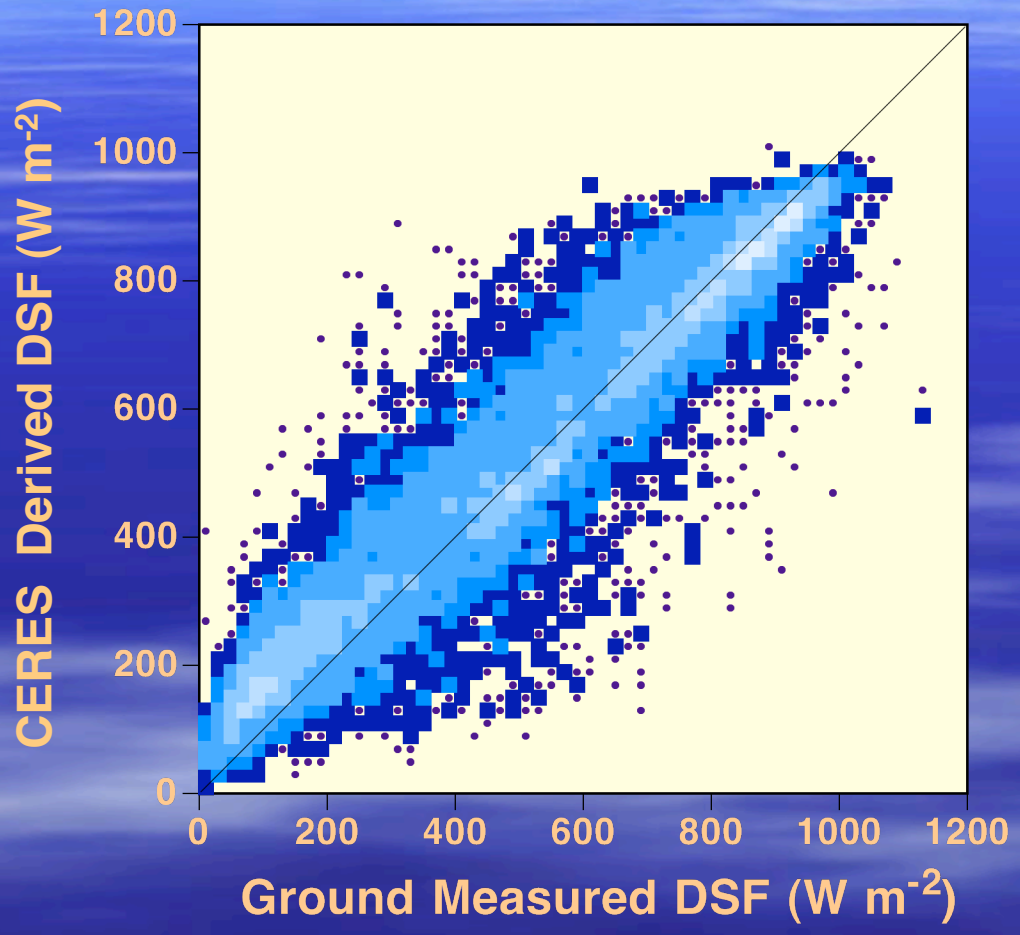
Precision still requires substantial improvement, with mismatches in scene identification being a major source of error.

Terra 2B & Aqua 1B produce similar results for clear-sky conditions.

Aqua 1B

Shortwave B Cloudy-Sky
July 2002 through March 2005

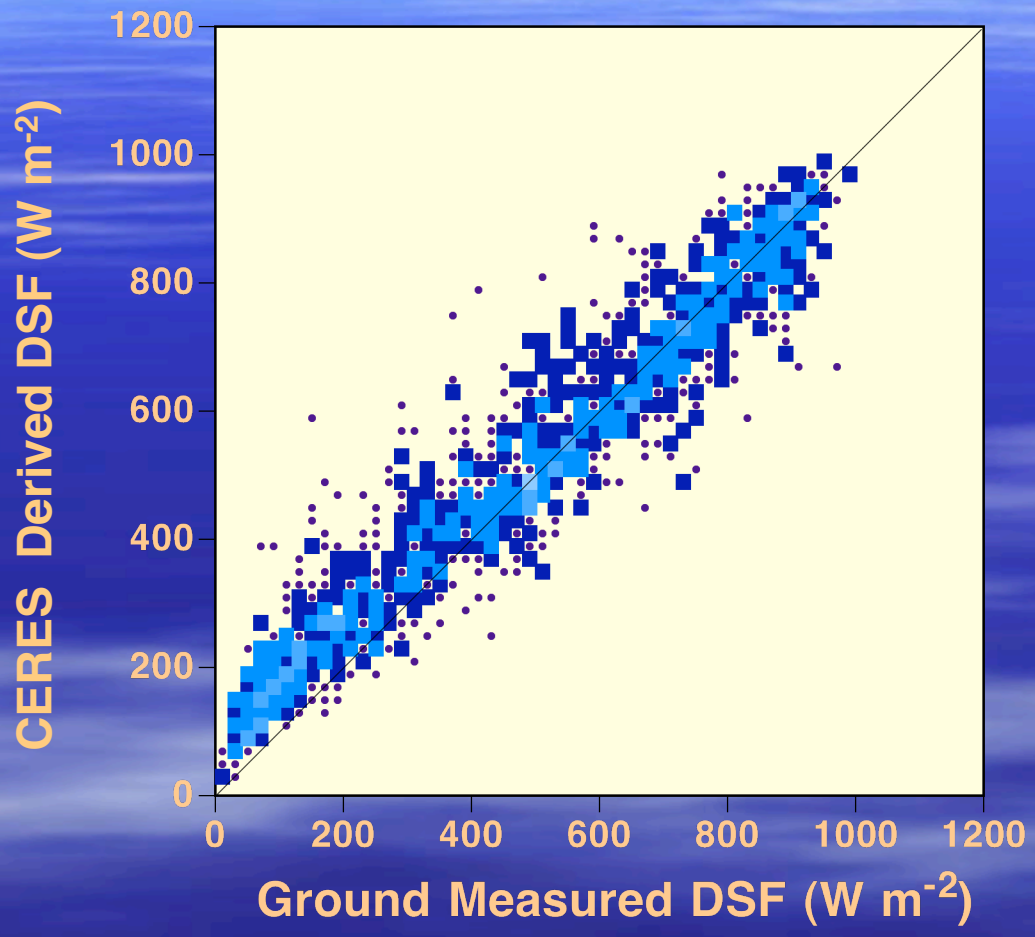
Aqua Shortwave B Cloudy-Sky Continental



1 2 - 5 6 - 10 11 - 20 21 - 40 41 - 80 81 - 100 > 100

Aqua 1B

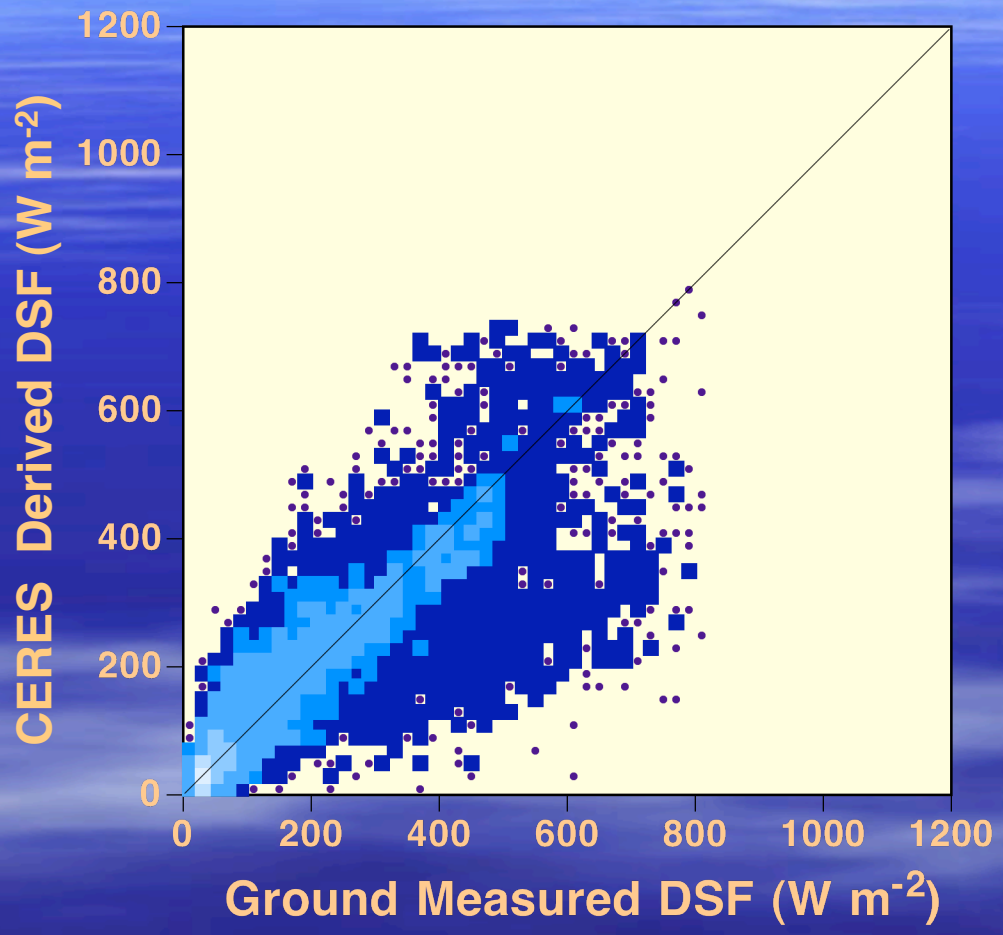
Aqua Shortwave B Cloudy-Sky Coastal



• 1 ■ 2 - 3 ■ 4 - 9 ■ 10 - 12 ■ 13 - 15 ■ 16 - 18 ■ 19 - 20 ■ > 20

Aqua 1B

Aqua Shortwave B Cloudy-Sky Ant-arctic

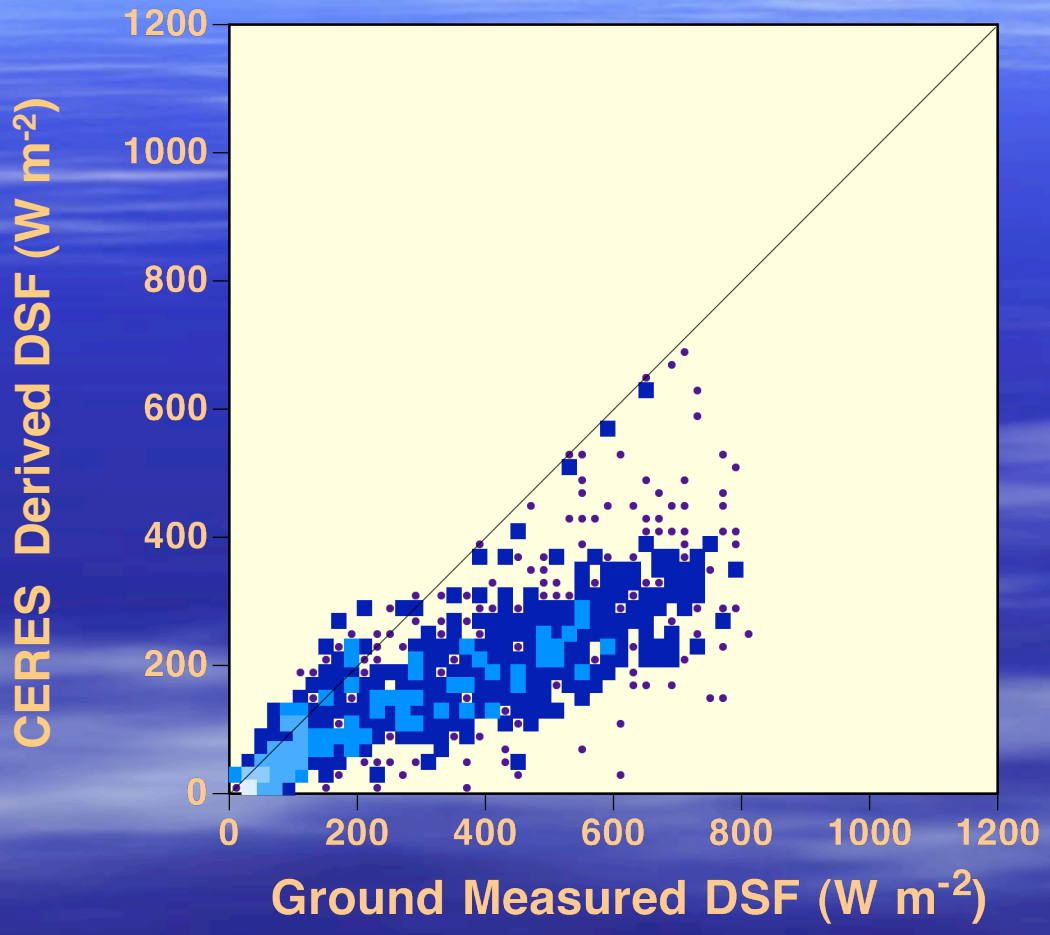


1 2 - 10 11 - 20 21 - 50 51 - 100 101 - 150 151 - 200 > 200

Aqua 1B

Aqua Shortwave B Cloudy-Sky

Georg Van Neumeyer

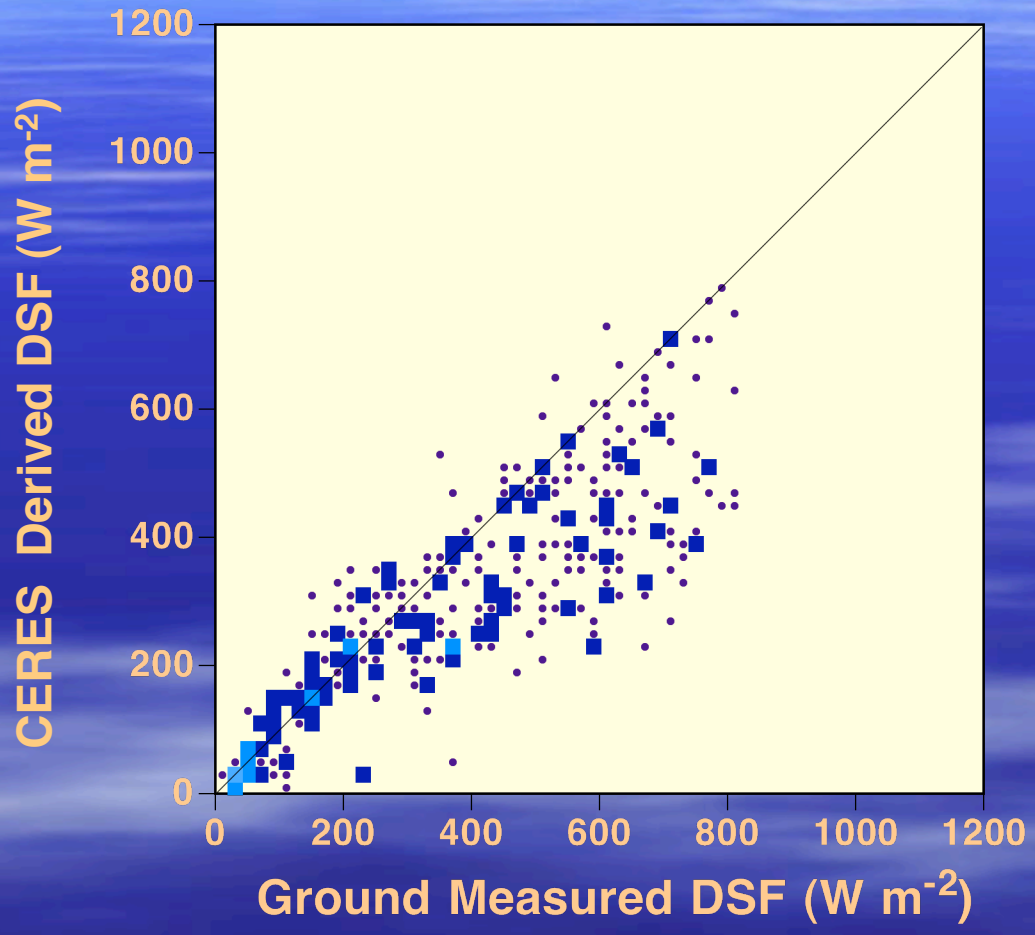


• 1 ■ 2 - 5 ■ 6 - 10 ■ 11 - 20 ■ 21 - 40 ■ 41 - 60 ■ 61 - 80 ■ > 80

Aqua 1B

Aqua Shortwave B Cloudy-Sky

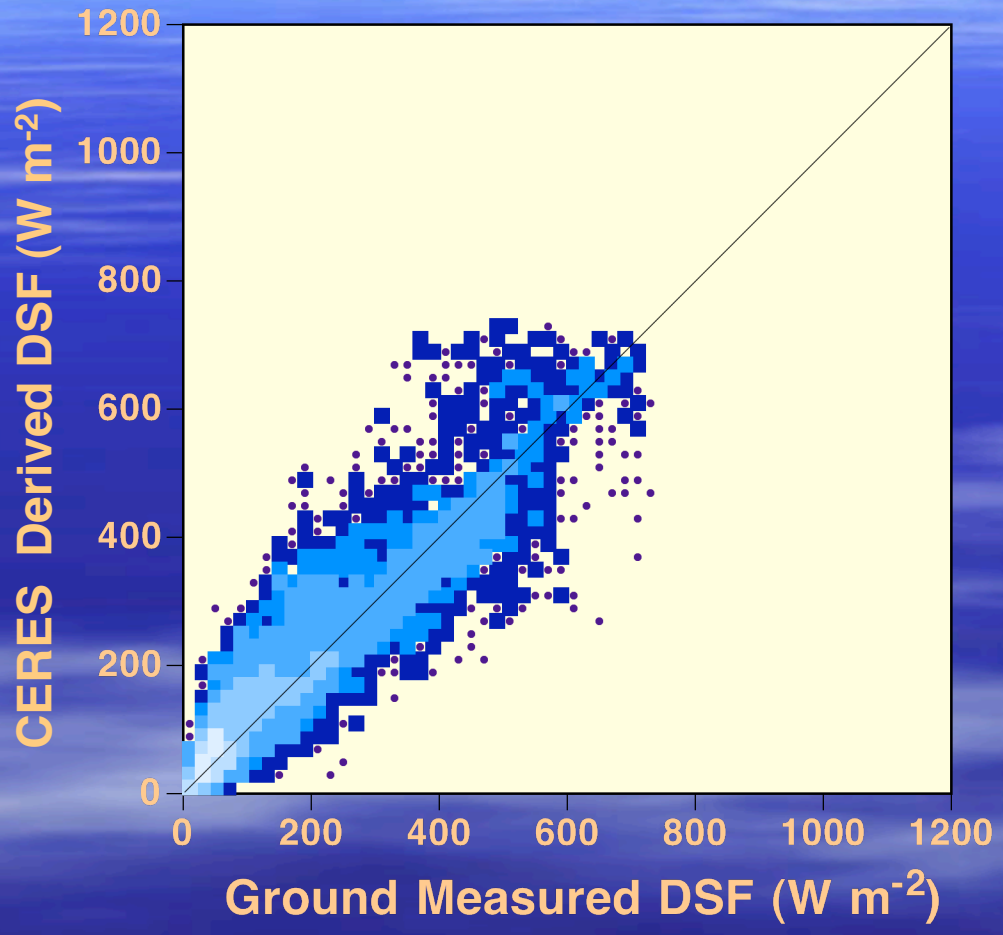
Syowa



• 1 ■ 2 - 3 ■ 4 - 9 ■ 10 - 12 ■ 13 - 15 ■ 16 - 18 ■ 19 - 20 ■ > 20

Aqua 1B

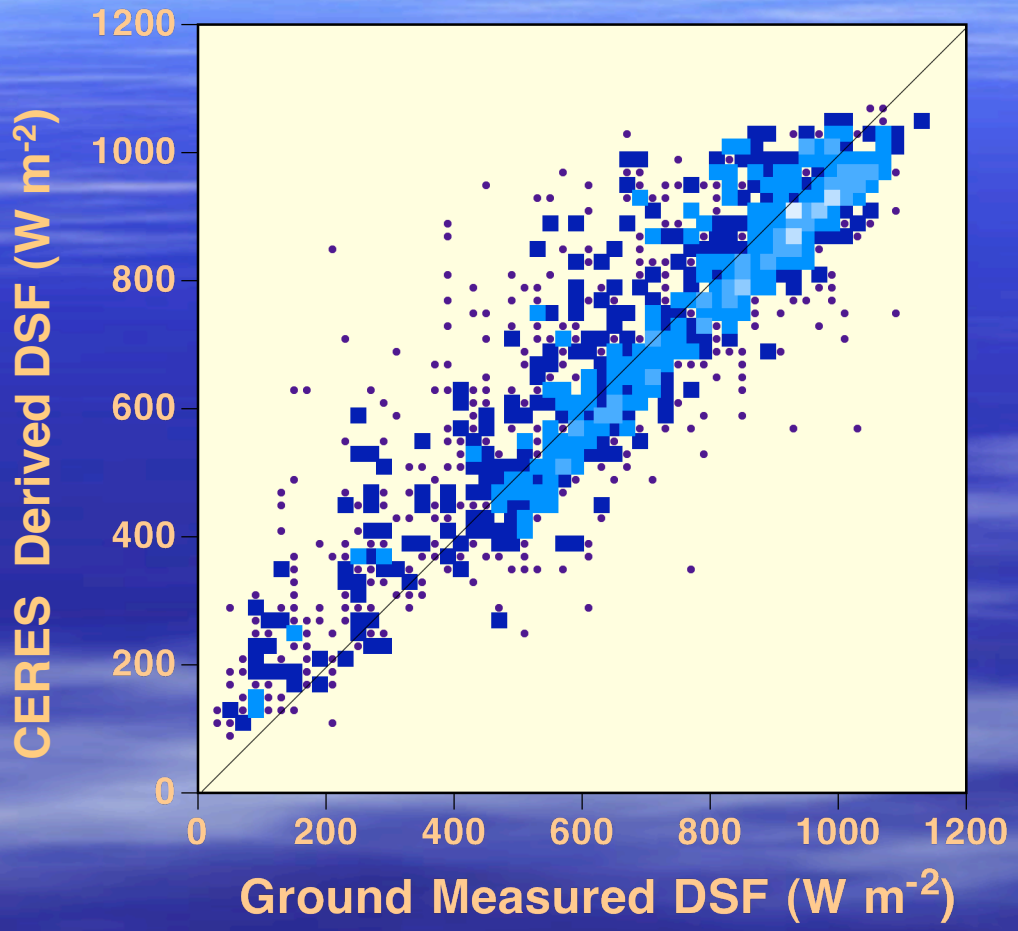
Aqua Shortwave B Cloudy-Sky Ant-arctic (no GVN & SYO)



1 2 - 5 6 - 10 11 - 20 21 - 40 41 - 80 81 - 100 > 100

Aqua 1B

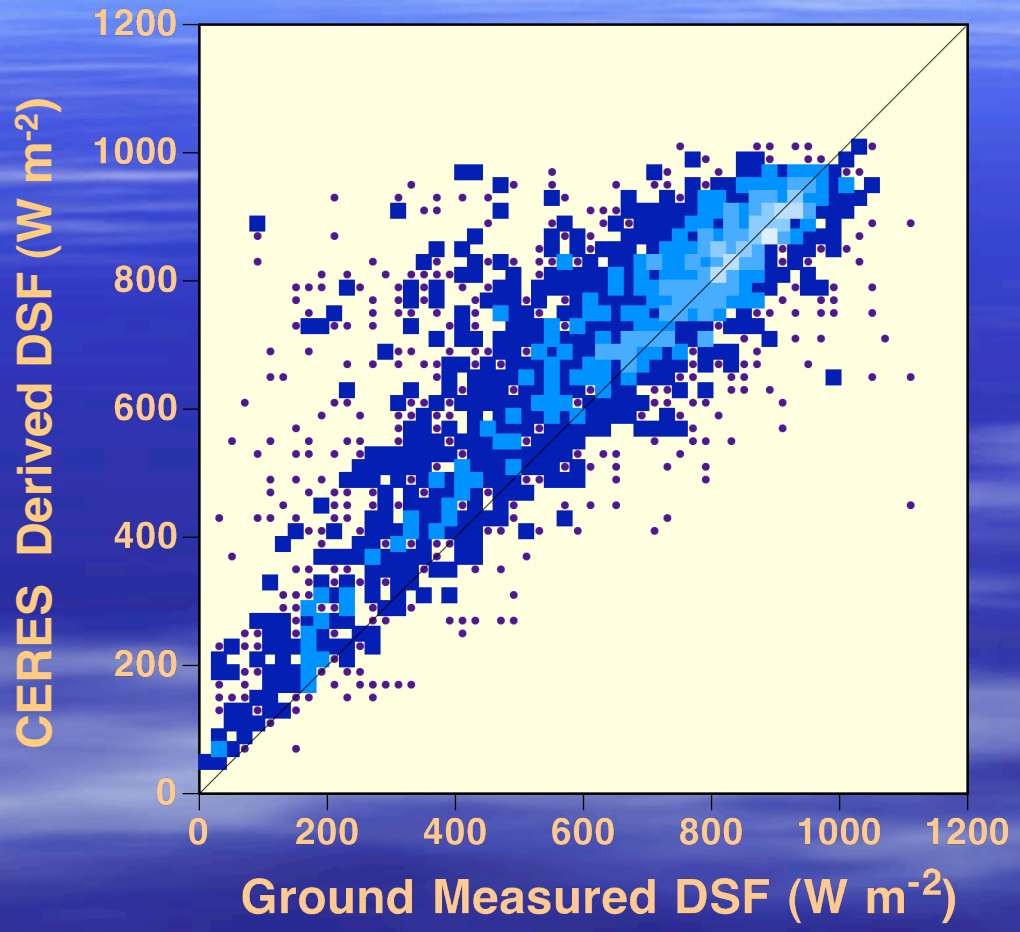
Aqua Shortwave B Cloudy-Sky Desert



• 1 ■ 2 - 3 ■ 4 - 9 ■ 10 - 12 ■ 13 - 15 ■ 16 - 18 ■ 19 - 20 ■ > 20

Aqua 1B

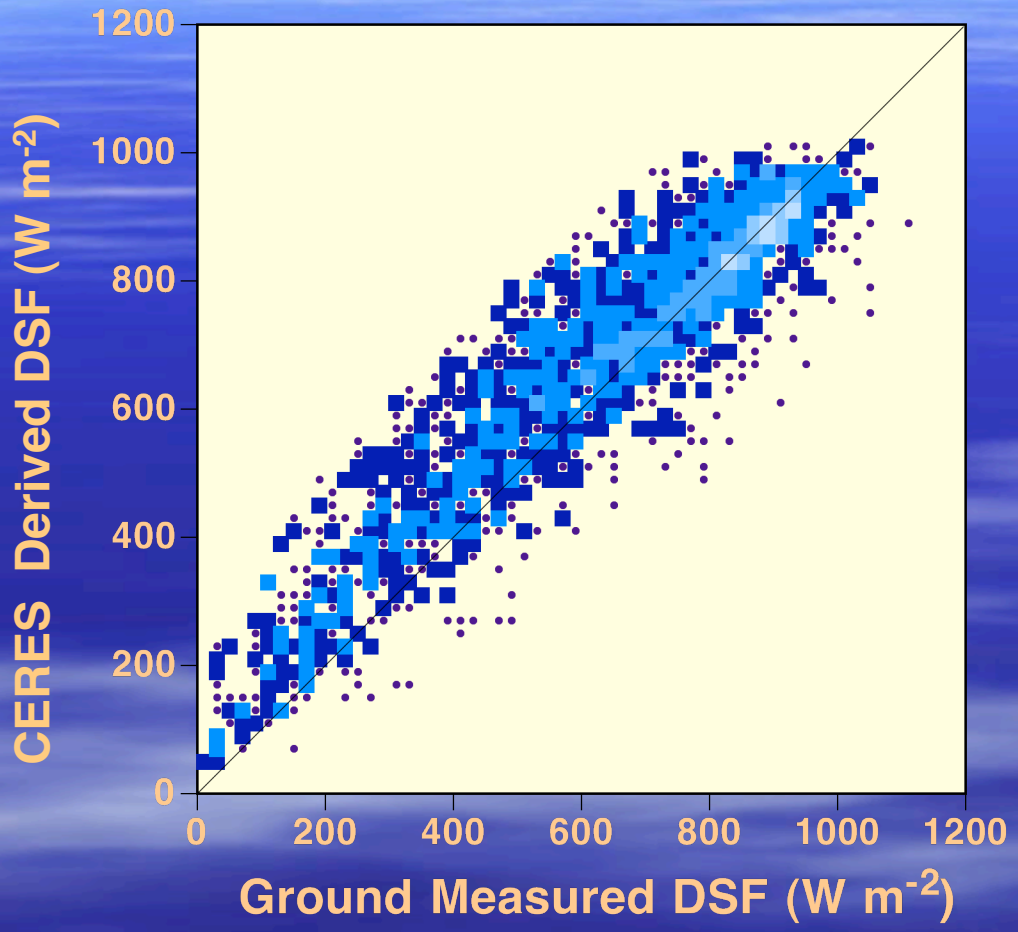
Aqua Shortwave B Cloudy-Sky Island



• 1 ■ 2 - 5 ■ 6 - 10 ■ 11 - 15 ■ 16 - 20 ■ 21 - 25 ■ 26 - 30 ■ > 30

Aqua 1B

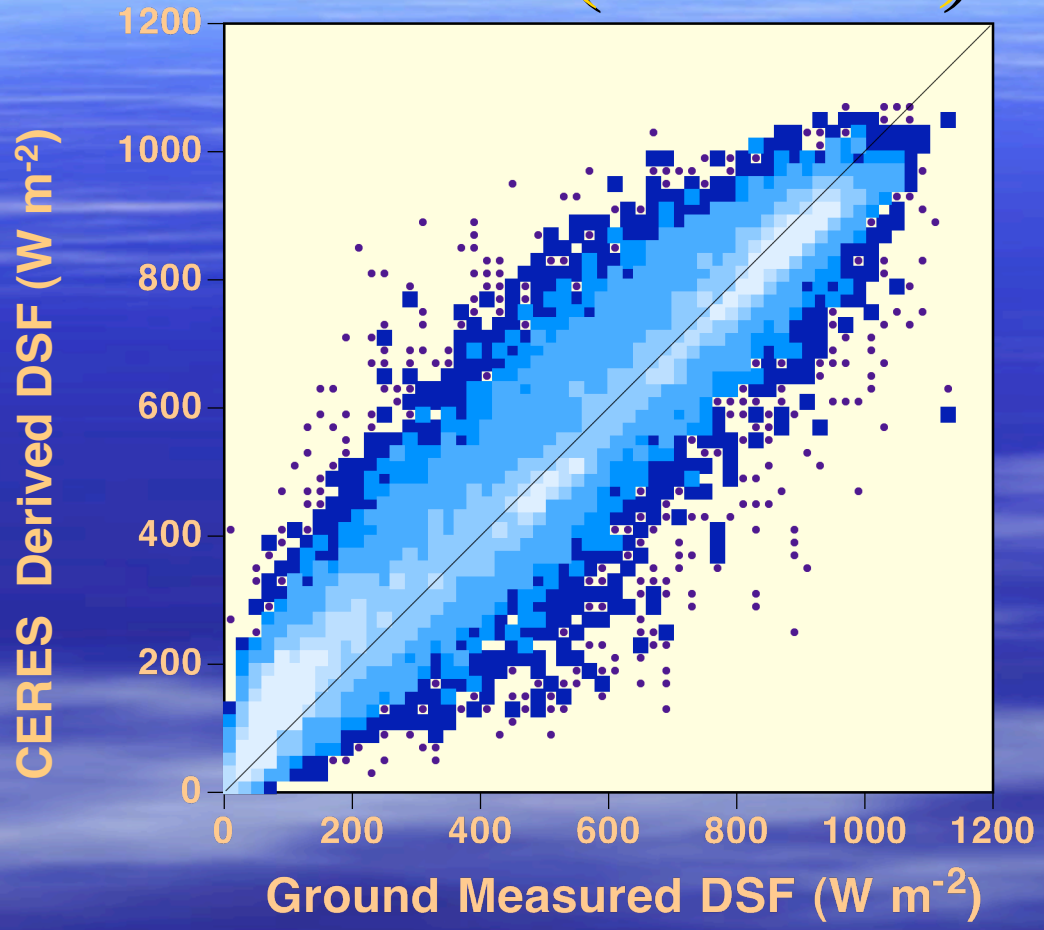
Aqua Shortwave B Cloudy-Sky Island (filtered)



• 1 ■ 2 - 3 ■ 4 - 9 ■ 10 - 12 ■ 13 - 15 ■ 16 - 20 ■ 21 - 25 ■ > 25

Aqua 1B

Aqua Shortwave B Cloudy Global (filtered)



1 | 2 - 5 | 6 - 10 | 11 - 20 | 21 - 40 | 41 - 80 | 81 - 100 | > 100

Aqua 1B

Aqua Shortwave B Cloudy-Sky

Sites # of Points		SWB
Continental 19439	Bias Wm^{-2} (%) σ Wm^{-2} (%)	19.85 (3.92) 85.4 (16.9)
Coastal 1678	Bias Wm^{-2} (%) σ Wm^{-2} (%)	32.95 (6.77) 69.6 (14.3)
Ant-Arctic 9414	Bias Wm^{-2} (%) σ Wm^{-2} (%)	-12.72 (-5.47) 91.1 (39.1)
Desert 1968	Bias Wm^{-2} (%) σ Wm^{-2} (%)	7.45 (1.05) 94.7 (13.4)
Island 2627	Bias Wm^{-2} (%) σ Wm^{-2} (%)	63.29 (10.36) 108.0 (17.7)
Global 35126	Bias Wm^{-2} (%) σ Wm^{-2} (%)	14.30 (3.17) 97.3 (21.6)

Aqua Shortwave B Cloudy-Sky

Sites # of Points		SWB
Continental 19844	Bias Wm^{-2} (%) σ Wm^{-2} (%)	19.00 (3.72) 84.9 (16.6)
Coastal 1724	Bias Wm^{-2} (%) σ Wm^{-2} (%)	32.31 (6.52) 69.1 (13.9)
Ant-Arctic 7531	Bias Wm^{-2} (%) σ Wm^{-2} (%)	17.82 (8.30) 65.9 (30.7)
Desert 2100	Bias Wm^{-2} (%) σ Wm^{-2} (%)	6.90 (0.96) 93.0 (12.9)
Island 2490	Bias Wm^{-2} (%) σ Wm^{-2} (%)	46.39 (7.43) 81.9 (13.1)
Global 33689	Bias Wm^{-2} (%) σ Wm^{-2} (%)	20.69 (4.45) 83.4 (17.9)

Terra Shortwave B Cloudy-Sky

Sites # of Points		SWB
Continental 29461	Bias Wm^{-2} (%) σ Wm^{-2} (%)	27.41 (5.39) 82.3 (16.2)
Coastal 2522	Bias Wm^{-2} (%) σ Wm^{-2} (%)	33.15 (6.68) 66.9 (13.5)
Ant-Arctic 18863	Bias Wm^{-2} (%) σ Wm^{-2} (%)	-17.51 (-7.37) 95.2 (40.1)
Desert 1932	Bias Wm^{-2} (%) σ Wm^{-2} (%)	22.63 (3.35) 90.8 (13.4)
Island 5155	Bias Wm^{-2} (%) σ Wm^{-2} (%)	49.94 (7.63) 104.4 (16.0)
Global 57933	Bias Wm^{-2} (%) σ Wm^{-2} (%)	14.88 (3.39) 99.3 (22.6)

Terra Shortwave B Cloudy-Sky

Sites # of Points		SWB
Continental 29694	Bias Wm^{-2} (%) σ Wm^{-2} (%)	27.09 (5.32) 82.4 (16.2)
Coastal 2608	Bias Wm^{-2} (%) σ Wm^{-2} (%)	32.44 (6.39) 66.1 (13.0)
Ant-Arctic 14664	Bias Wm^{-2} (%) σ Wm^{-2} (%)	15.74 (7.19) 68.5 (31.3)
Desert 1983	Bias Wm^{-2} (%) σ Wm^{-2} (%)	22.00 (3.23) 90.2 (13.2)
Island 4958	Bias Wm^{-2} (%) σ Wm^{-2} (%)	43.01 (6.50) 78.8 (11.9)
Global 53907	Bias Wm^{-2} (%) σ Wm^{-2} (%)	25.54 (5.67) 81.5 (18.1)

Aqua & Terra Shortwave All-Sky

Sites # of Points		SWB
Aqua Global 38940	Bias Wm^{-2} (%) _ Wm^{-2} (%)	14.58 (2.93) 78.5 (15.8)
Terra Global 68246	Bias Wm^{-2} (%) _ Wm^{-2} (%)	17.05 (3.33) 77.1 (15.0)

Conclusions: Shortwave Cloudy-Sky

CERES cloudy-sky SW surface fluxes derived with model B provide results close to the desired accuracies (biases) for most cases, but accurate results remain challenging for the coastal and island cases.

There is a serious error in either the derived or measured fluxes for coastal Antarctic sites: Georg Van Neumeyer and Syowa.

Precision still requires substantial improvement, with mismatches in scene identification being a major source of error.

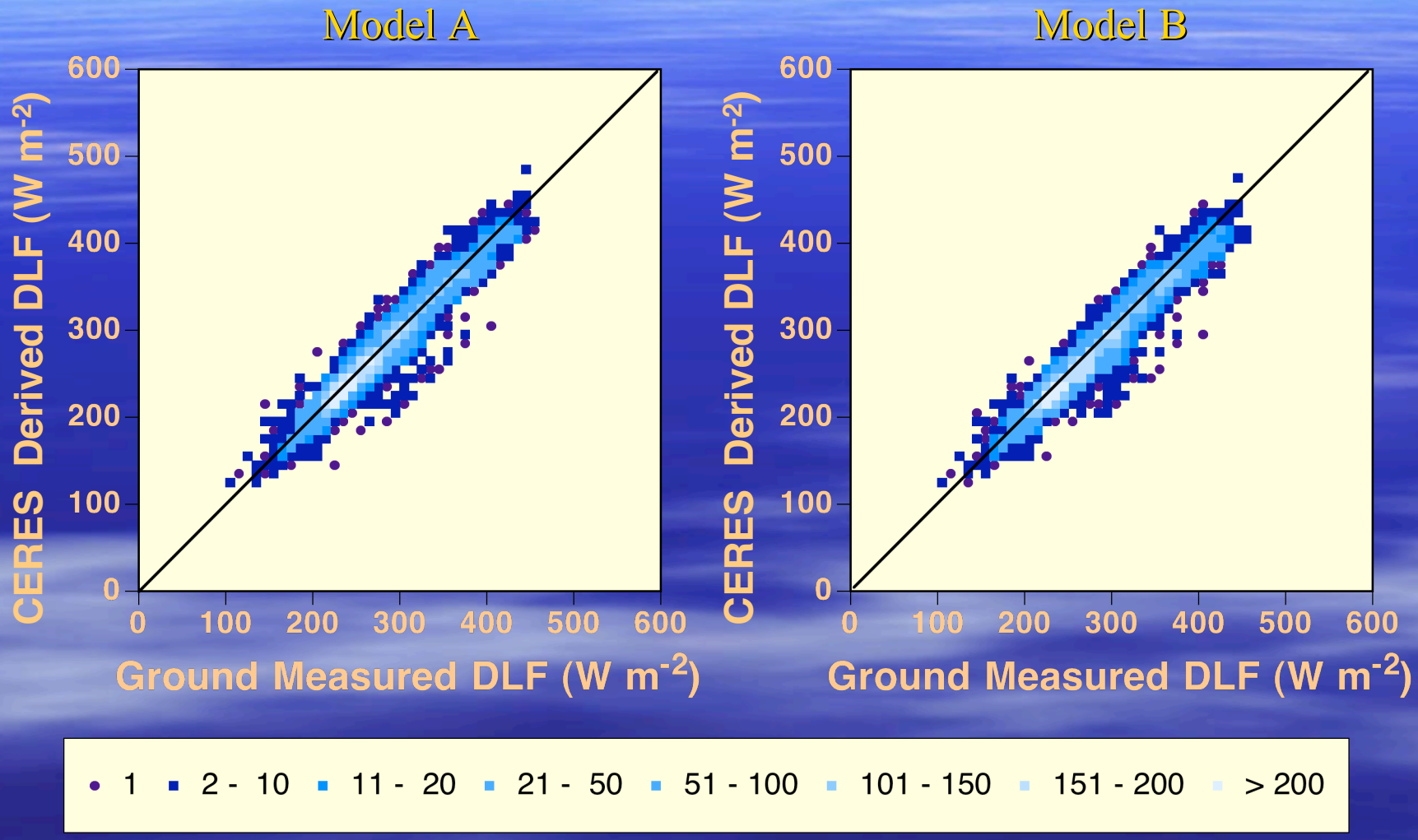
Large scatter implies that we need to examine the relationship between surface and satellite retrievals of cloud properties.

Terra 2B & Aqua 1B produce similar results for cloudy-sky conditions.

Aqua 1B

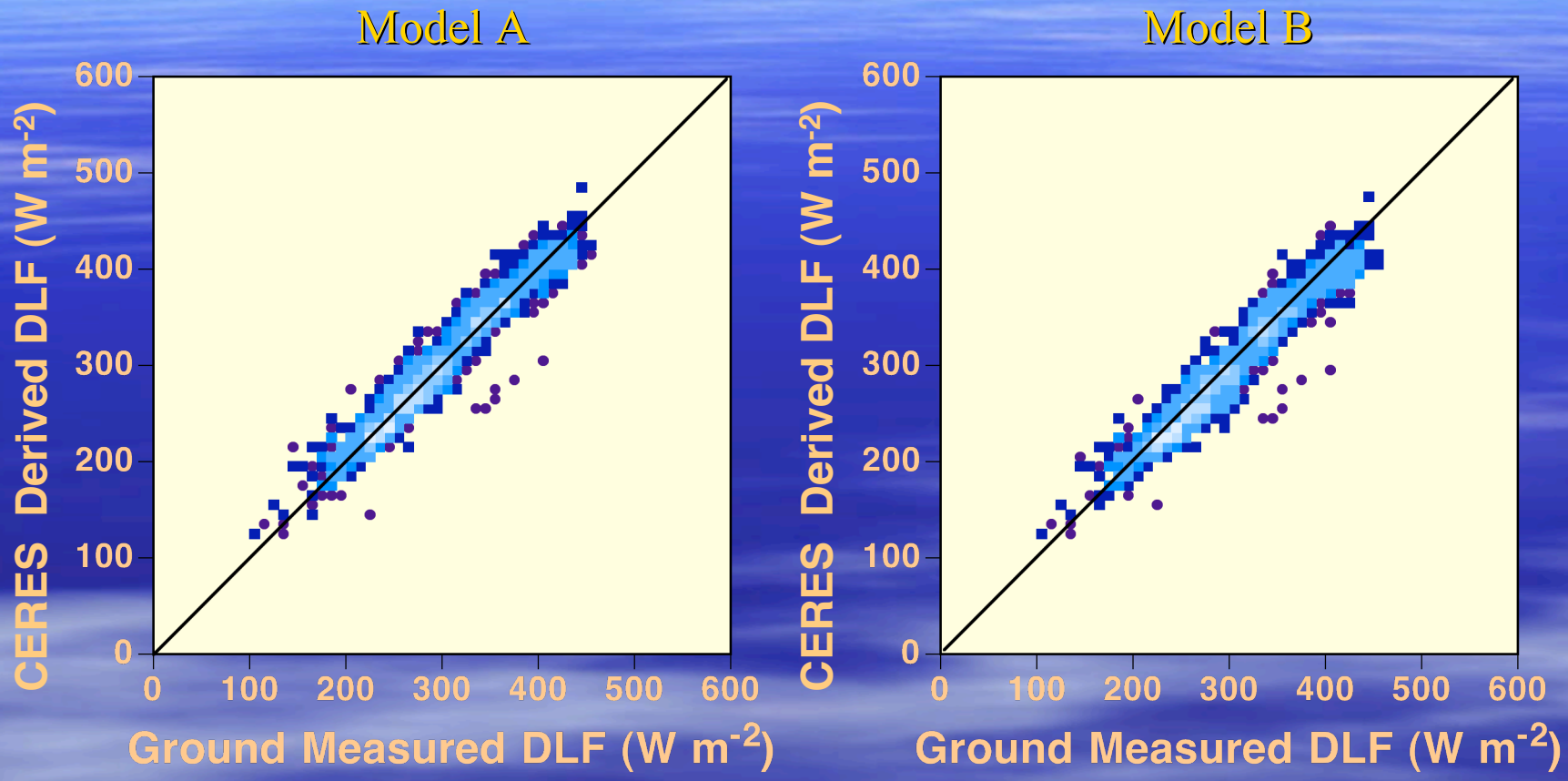
Longwave Clear-Sky
July 2002 through March 2005

Aqua Longwave Clear-Sky Continental



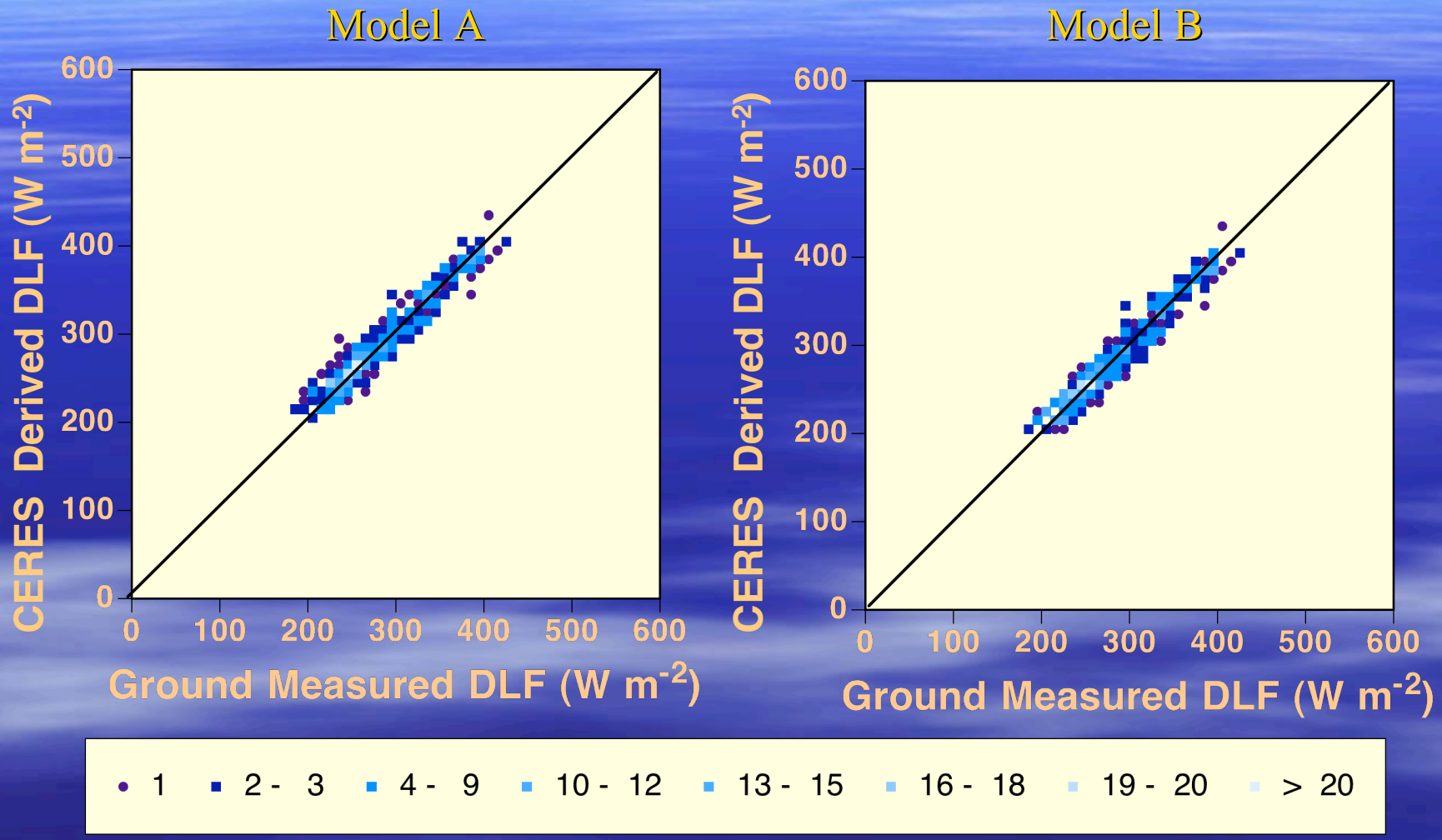
Aqua 1B

Aqua Longwave Clear-Sky Daytime Continental

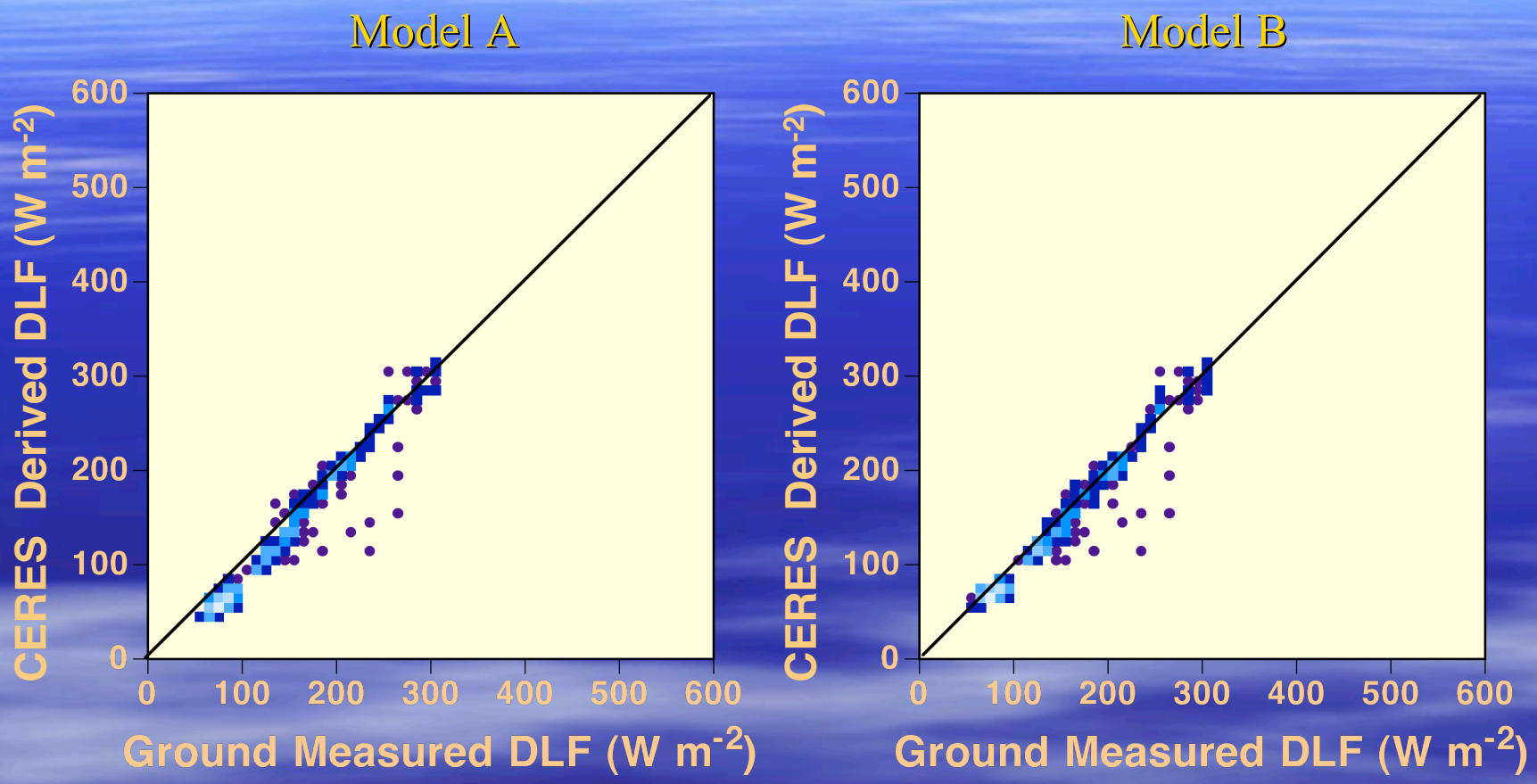


Aqua 1B

Aqua Longwave Clear-Sky Coastal

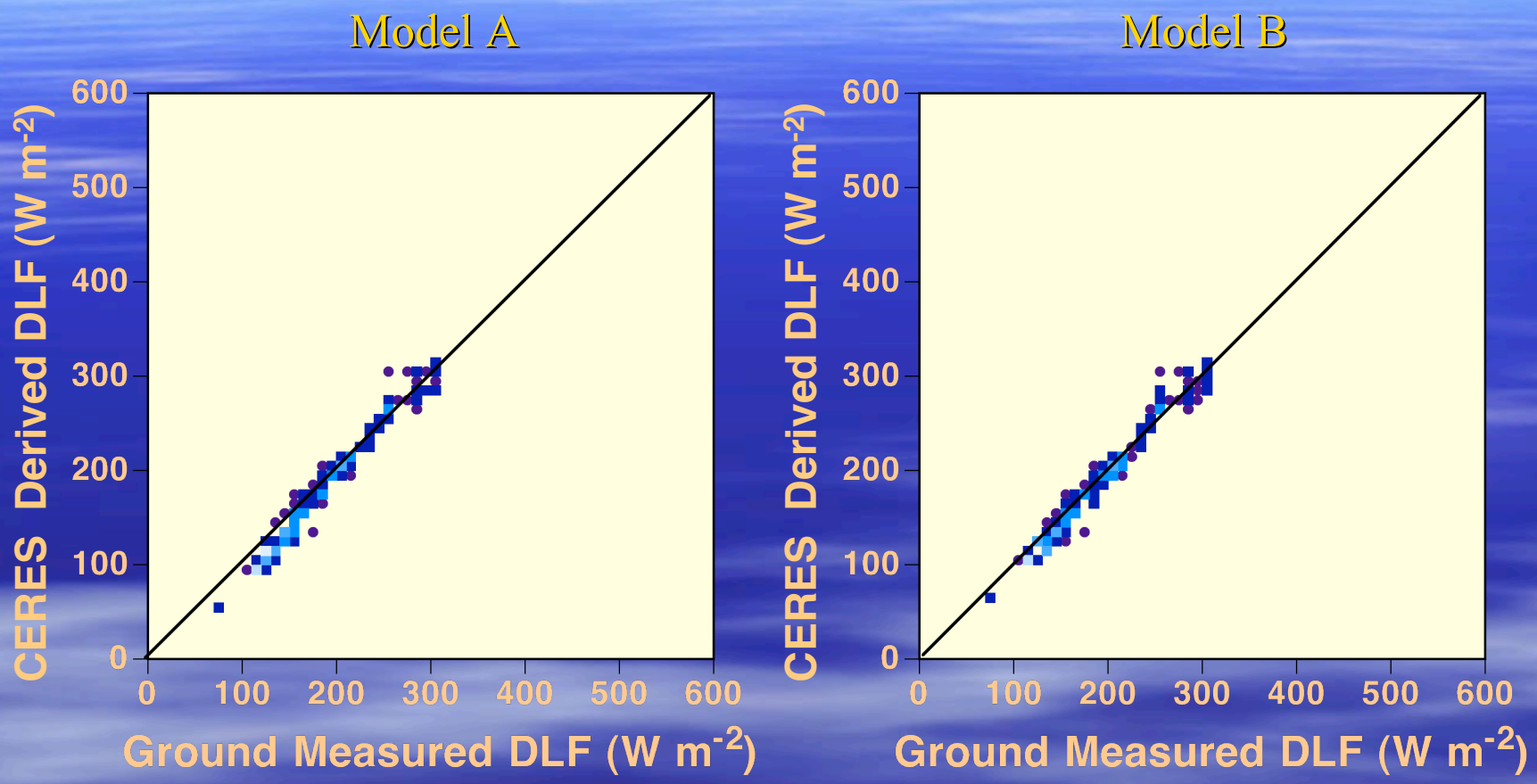


Aqua Longwave Clear-Sky Ant-arctic



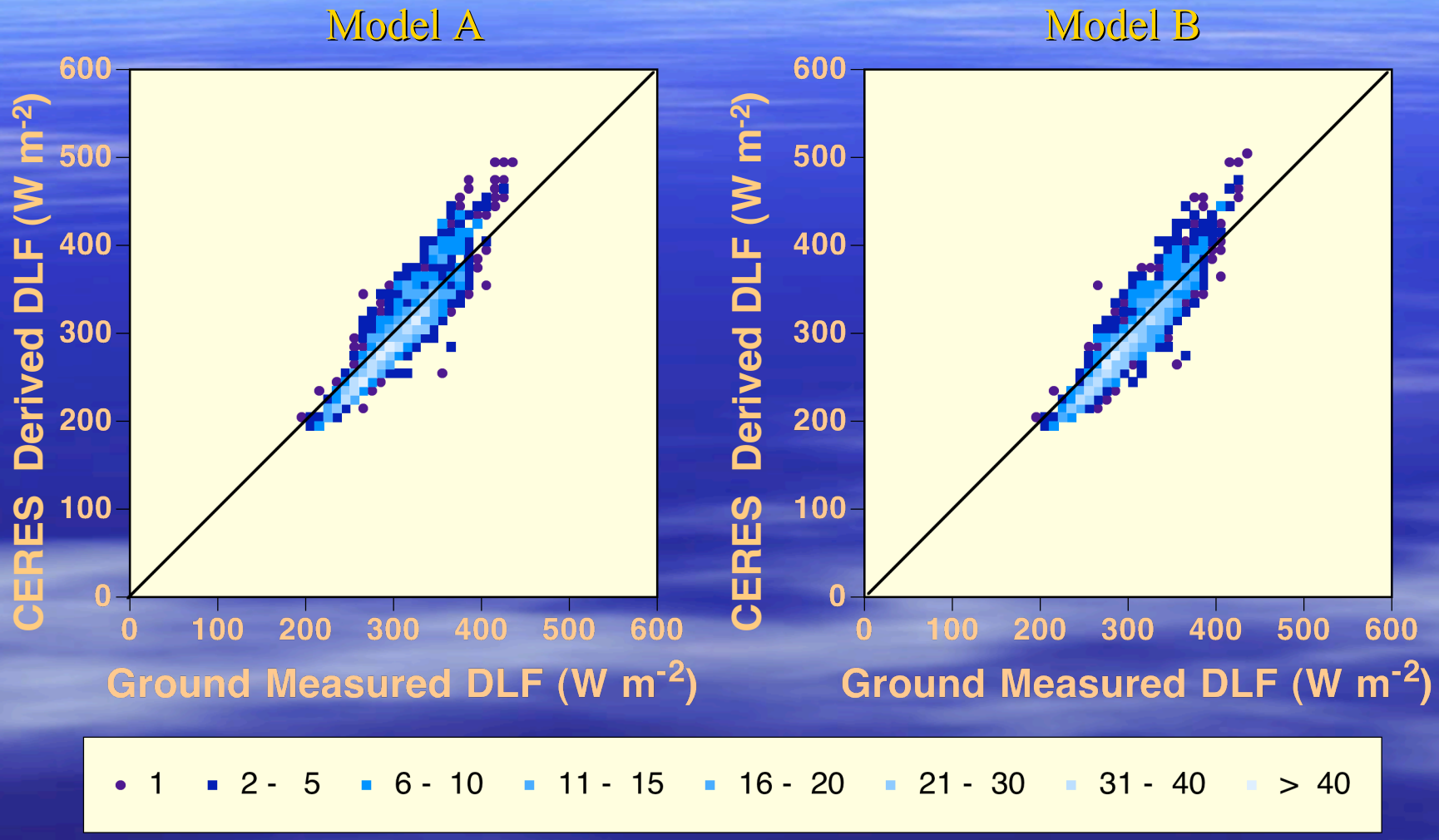
Aqua 1B

Longwave Clear-Sky Daytime Ant-arctic



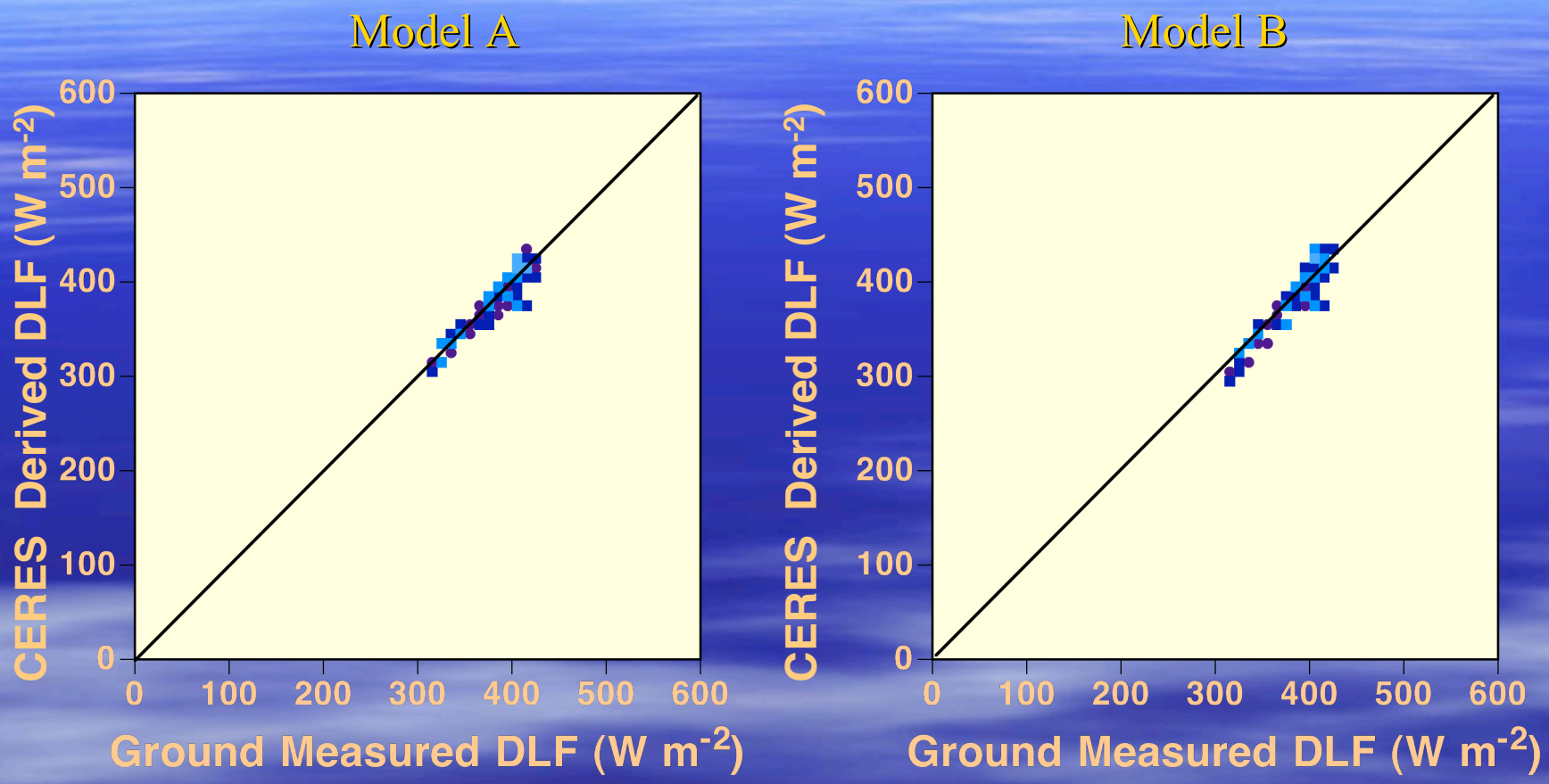
Aqua 1B

Aqua Longwave Clear-Sky Desert



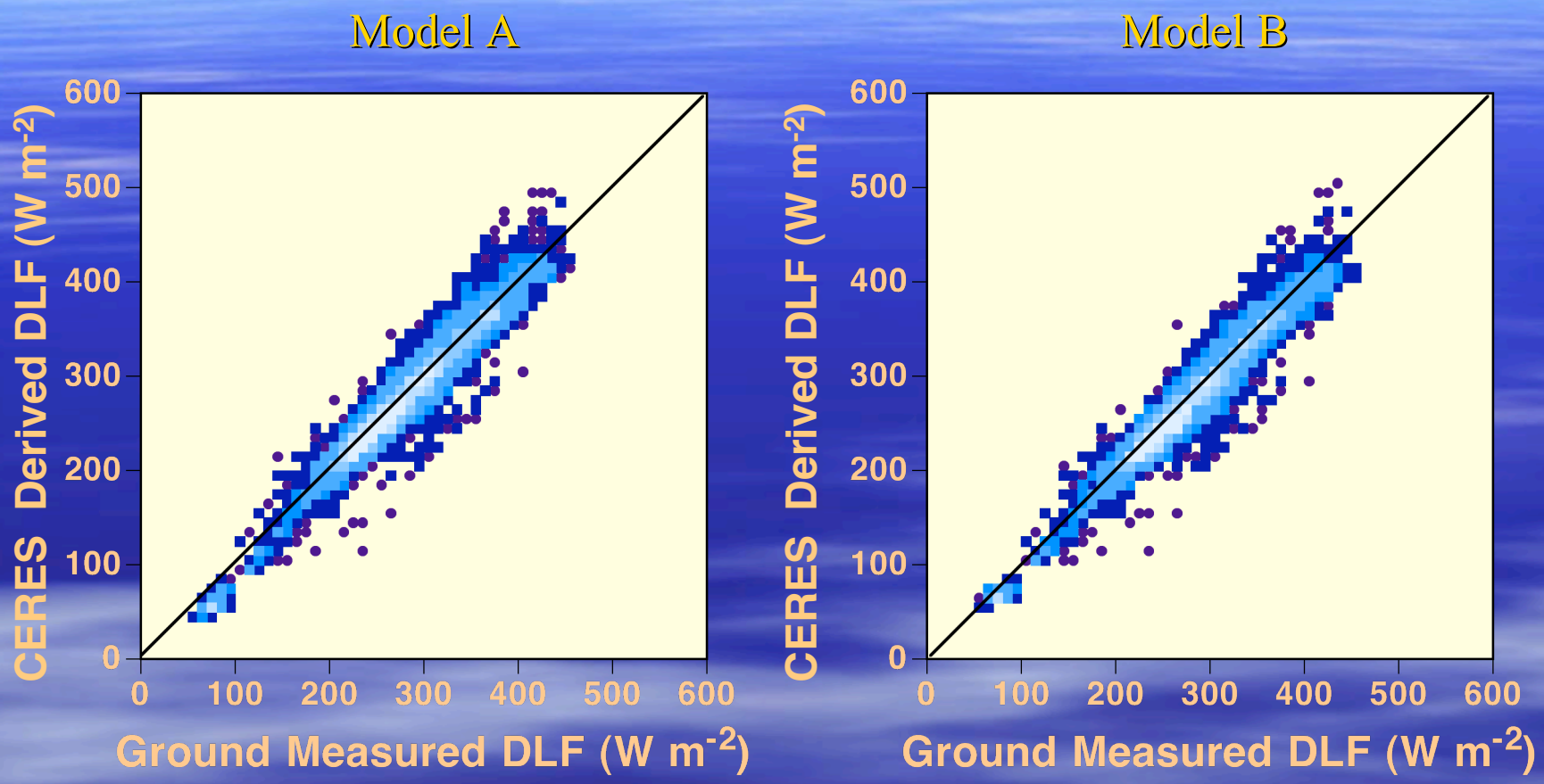
Aqua 1B

Aqua Longwave Clear-Sky Island



Aqua 1B

Aqua Longwave Clear-Sky Global



Aqua 1B

Aqua Longwave Clear-Sky

Sites # of Points		LWA	LWB
Continental 11288	Bias Wm^{-2} (%) σ Wm^{-2} (%)	-2.52 (-0.88) 14.9 (5.2)	-5.60 (-1.96) 14.8 (5.2)
Coastal 511	Bias Wm^{-2} (%) σ Wm^{-2} (%)	6.61 (2.29) 12.5 (4.3)	1.88 (0.65) 12.5 (4.3)
Ant-arctic 848	Bias Wm^{-2} (%) σ Wm^{-2} (%)	-14.33 (-11.96) 10.8 (9.0)	-8.05 (-6.72) 10.7 (8.9)
Desert 1792	Bias Wm^{-2} (%) σ Wm^{-2} (%)	-2.47 (-0.80) 22.6 (7.3)	-6.43 (-2.09) 20.7 (6.7)
Island 142	Bias Wm^{-2} (%) σ Wm^{-2} (%)	-0.76 (-0.20) 11.9 (3.1)	0.09 (0.02) 13.6 (3.5)
Global 14581	Bias Wm^{-2} (%) σ Wm^{-2} (%)	-2.87 (-1.02) 16.5 (5.9)	-5.53 (-1.98) 15.9 (5.7)

Aqua 1B

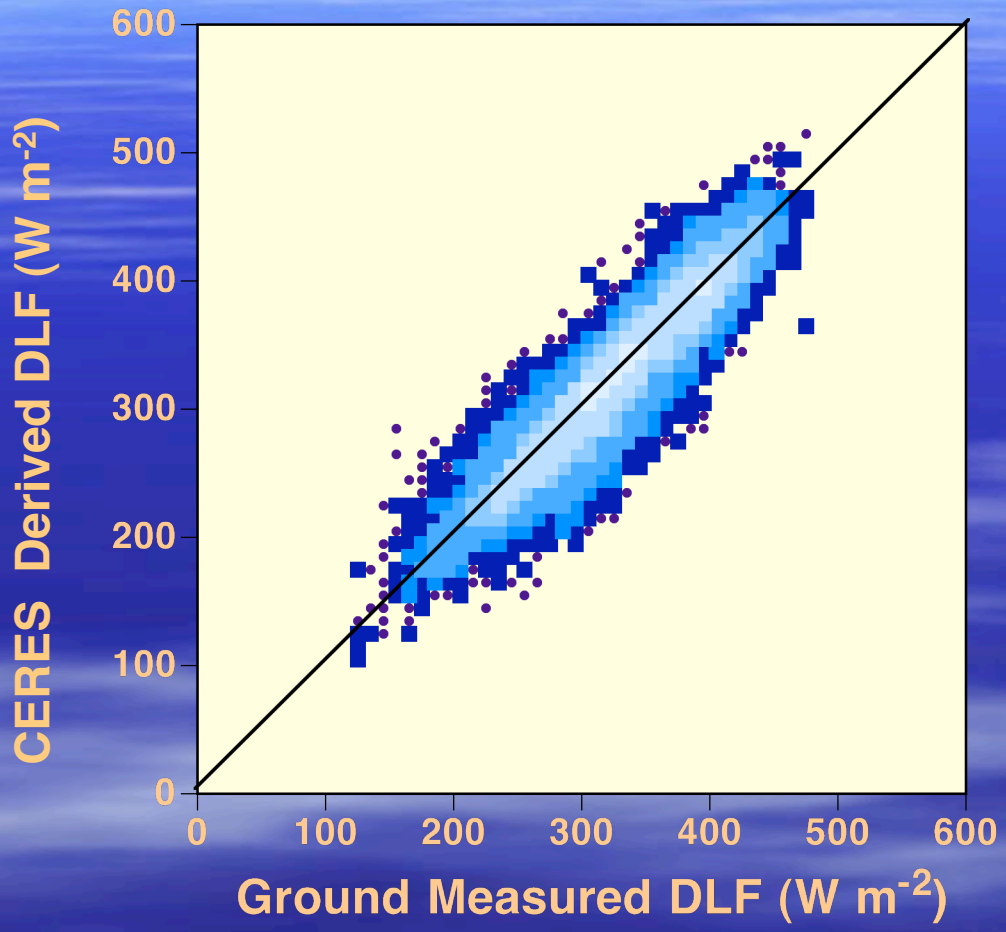
Terra Longwave Clear-Sky

Sites # of Points		LWA	LWB
Continental	Bias Wm^{-2} (%)	-2.35 (-0.79)	-5.11 (-1.71)
22956	σ Wm^{-2} (%)	14.1 (4.7)	14.1 (4.7)
Coastal	Bias Wm^{-2} (%)	2.54 (0.90)	-3.65 (-1.30)
910	σ Wm^{-2} (%)	12.7 (4.5)	13.1 (4.7)
Ant-arctic	Bias Wm^{-2} (%)	-9.17 (-5.96)	-6.68 (-4.34)
848	σ Wm^{-2} (%)	15.1 (9.8)	14.5 (9.4)
Desert	Bias Wm^{-2} (%)	2.61 (0.81)	-1.73 (-0.54)
3856	σ Wm^{-2} (%)	20.3 (6.3)	19.5 (6.0)
Island	Bias Wm^{-2} (%)	-0.31 (-0.08)	3.03 (0.77)
329	σ Wm^{-2} (%)	10.6 (2.7)	11.8 (3.0)
Global	Bias Wm^{-2} (%)	-1.68 (-0.56)	-4.53 (-1.52)
28955	σ Wm^{-2} (%)	15.6 (5.2)	15.4 (5.2)

Aqua 1B

Longwave B Cloudy-Sky
July 2002 through March 2005

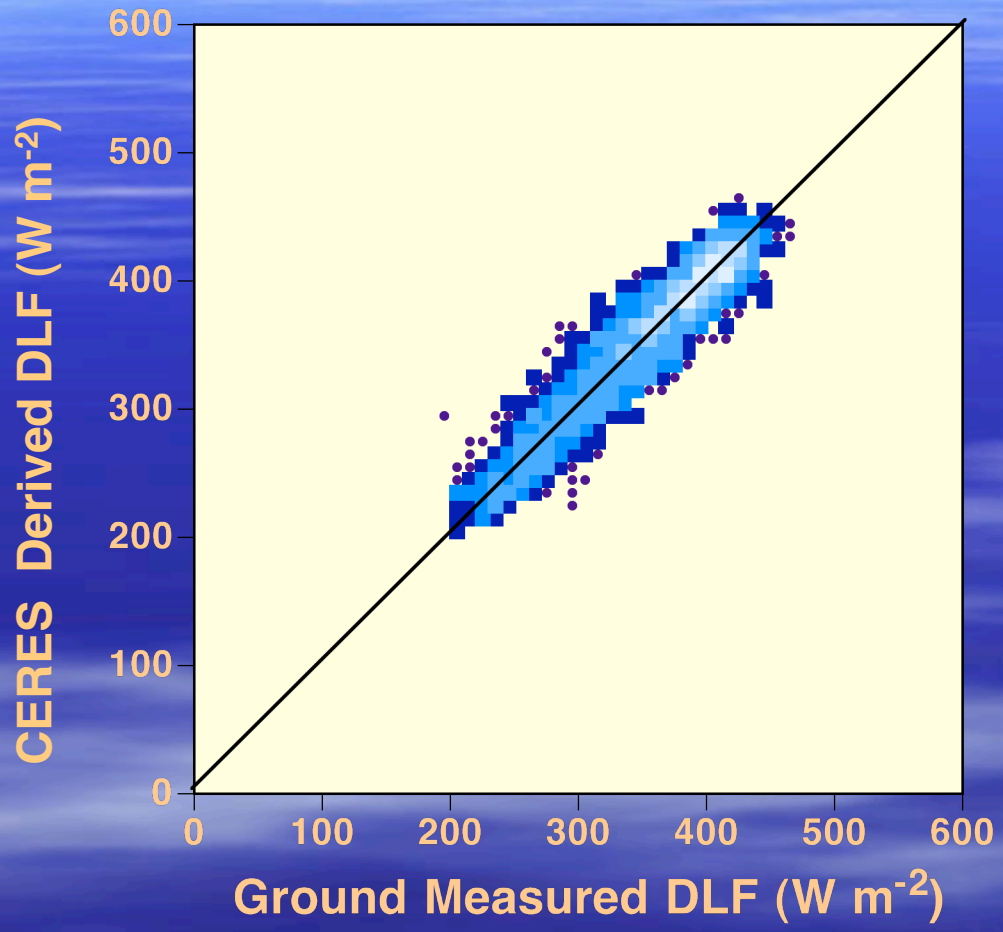
Aqua Longwave B Cloudy-Sky Continental



• 1 ■ 2 - 10 ■ 11 - 20 ■ 21 - 50 ■ 51 - 100 ■ 101 - 200 ■ 201 - 400 ■ > 400

Aqua 1B

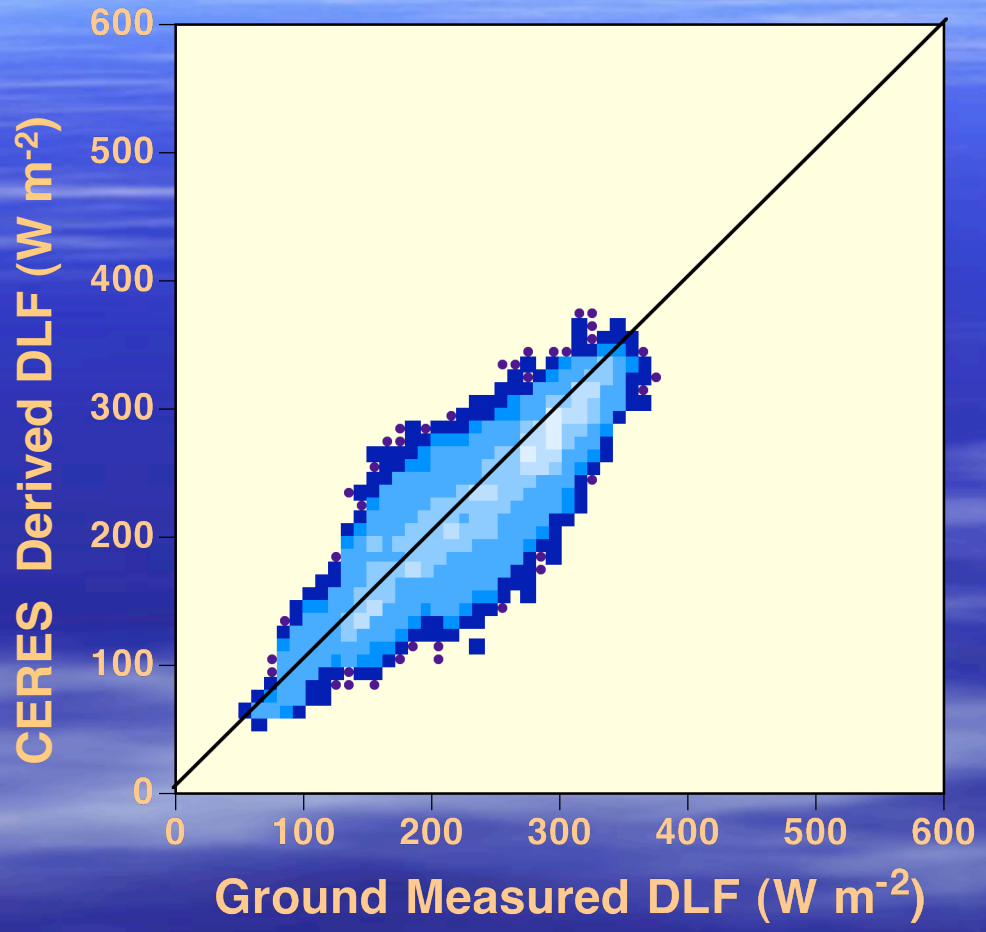
Aqua Longwave B Cloudy-Sky Coastal



• 1 ■ 2 - 5 ■ 6 - 10 ■ 11 - 20 ■ 21 - 30 ■ 31 - 40 ■ 41 - 50 ■ > 50

Aqua 1B

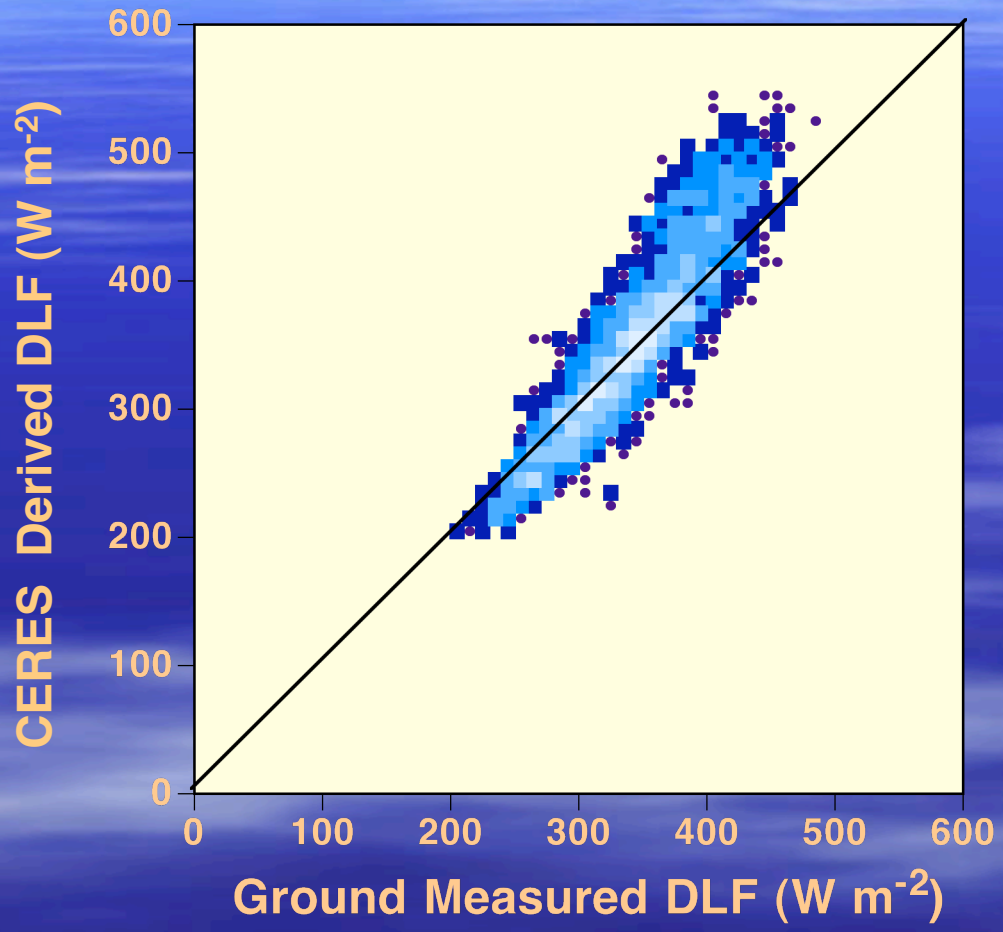
Aqua Longwave B Cloudy-Sky Ant-arctic



• 1 ■ 2 - 10 ■ 11 - 20 ■ 21 - 50 ■ 51 - 100 ■ 101 - 150 ■ 151 - 200 ■ > 200

Aqua 1B

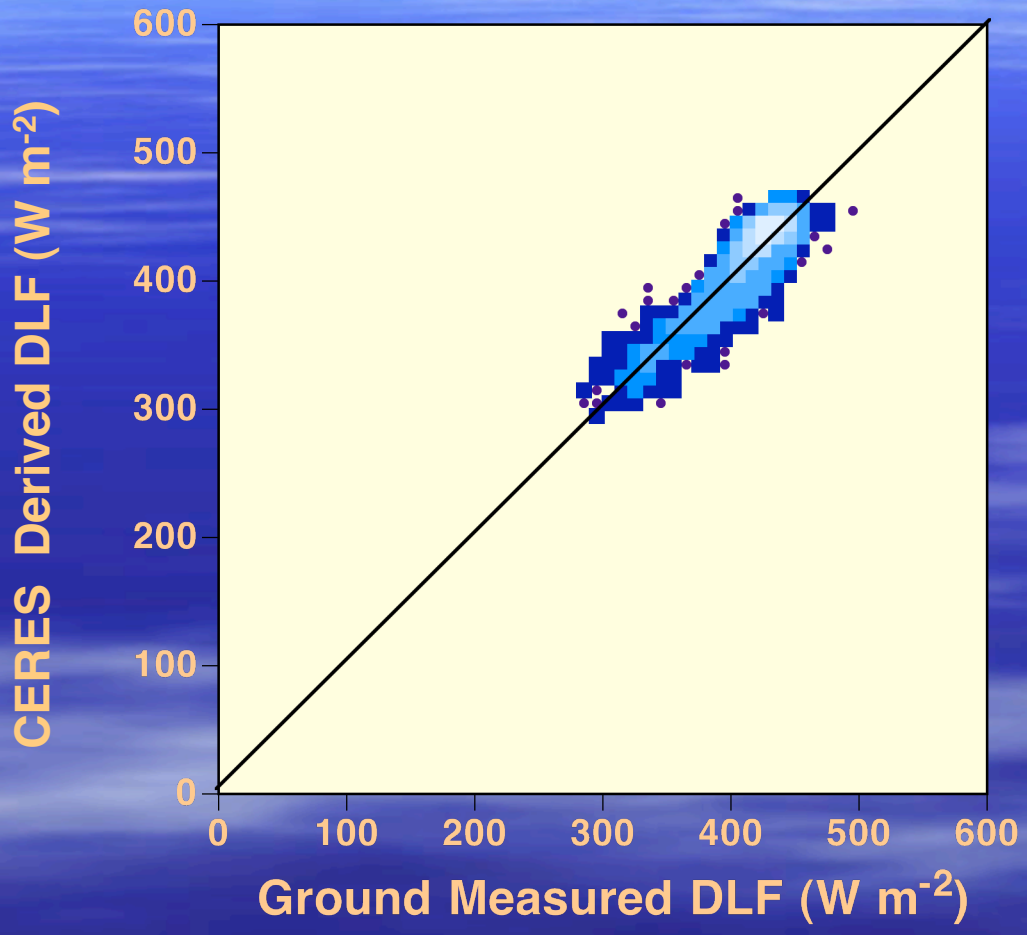
Aqua Longwave B Cloudy-Sky Desert



• 1 ■ 2 - 5 ■ 6 - 10 ■ 11 - 15 ■ 16 - 20 ■ 21 - 30 ■ 31 - 40 ■ > 40

Aqua 1B

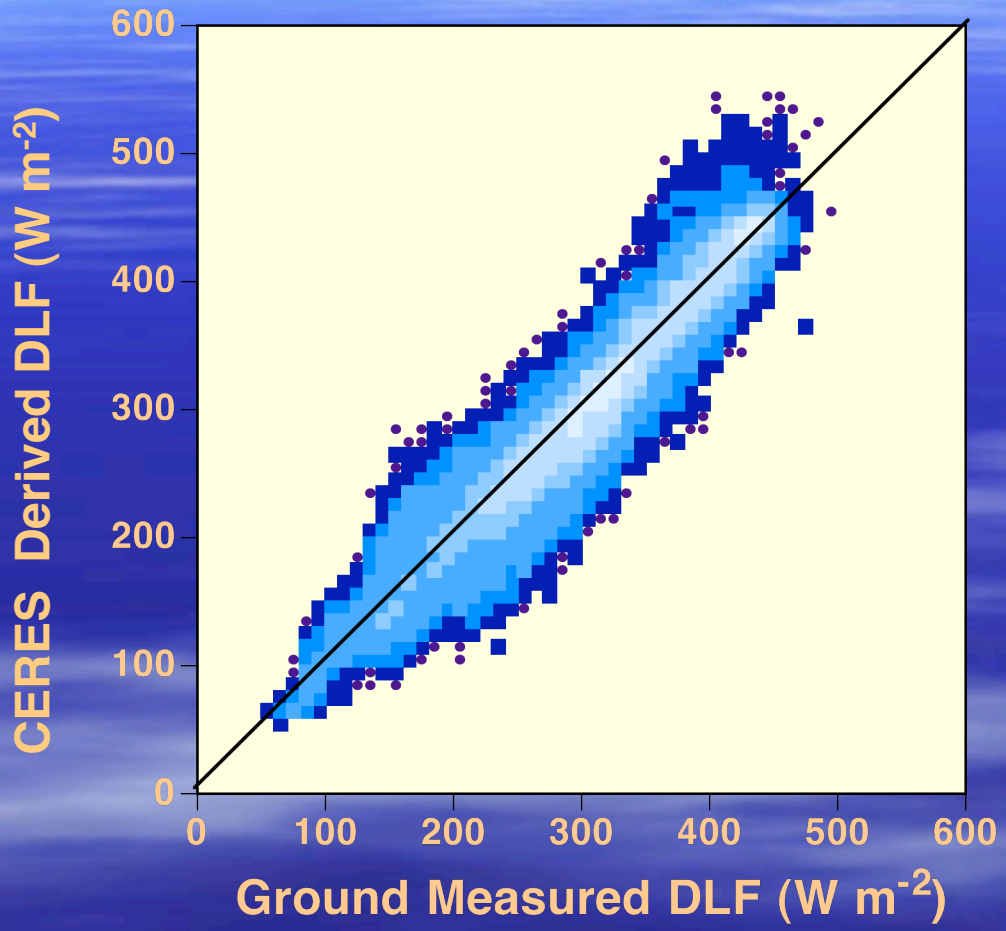
Aqua Longwave B Cloudy-Sky Island



1 2 - 10 11 - 20 21 - 50 51 - 100 101 - 200 201 - 400 > 400

Aqua 1B

Aqua Longwave B Cloudy-Sky Global



1 2 - 10 11 - 30 31 - 100 101 - 150 151 - 300 301 - 600 > 600

Aqua 1B

Aqua Longwave B Cloudy-Sky

Sites # of Points		LWB
Continental 38278	Bias Wm^{-2} (%) σ Wm^{-2} (%)	-1.76 (-0.54) 21.9 (6.7)
Coastal 2930	Bias Wm^{-2} (%) σ Wm^{-2} (%)	3.84 (1.09) 18.8 (5.4)
Ant-arctic 21807	Bias Wm^{-2} (%) σ Wm^{-2} (%)	-7.67 (-3.35) 27.0 (11.8)
Desert 3446	Bias Wm^{-2} (%) σ Wm^{-2} (%)	11.49 (3.35) 28.8 (8.4)
Island 6100	Bias Wm^{-2} (%) σ Wm^{-2} (%)	5.70 (1.38) 14.1 (3.4)
Global 72561	Bias Wm^{-2} (%) σ Wm^{-2} (%)	-2.05 (-0.67) 24.7 (8.0)

Terra Longwave B Cloudy-Sky

Sites # of Points		LWB
Continental 60536	Bias Wm^{-2} (%) σ Wm^{-2} (%)	-0.38 (-0.11) 20.6 (6.2)
Coastal 4451	Bias Wm^{-2} (%) σ Wm^{-2} (%)	4.20 (1.21) 19.8 (5.7)
Ant-Arctic 42061	Bias Wm^{-2} (%) σ Wm^{-2} (%)	-5.00 (-2.23) 27.7 (12.3)
Desert 4318	Bias Wm^{-2} (%) σ Wm^{-2} (%)	2.47 (0.73) 21.5 (6.4)
Island 13479	Bias Wm^{-2} (%) σ Wm^{-2} (%)	5.96 (1.44) 14.4 (3.5)
Global 124917	Bias Wm^{-2} (%) σ Wm^{-2} (%)	-0.98 (-0.32) 23.8 (7.8)

Aqua & Terra Longwave All-Sky

Sites # of Points		LWB
Aqua Global 88089	Bias Wm^{-2} (%) _ Wm^{-2} (%)	-2.67 (-0.88) 23.5 (7.8)
Terra Global 155038	Bias Wm^{-2} (%) _ Wm^{-2} (%)	-1.68 (-0.56) 22.5 (7.4)

Conclusions: Longwave

In general, CERES derived LW surface fluxes are within desired accuracies (biases) for both clear-sky (models A & B) & cloudy-sky (model B) cases.

Exceptions: Model A tends to underestimate the surface fluxes for low water vapor amounts, while both model tend to overestimate the surface fluxes for the very high flux cases (Hypothesis: mismatch in surface temperatures).

Precision is within desired limits for clear-sky cases.

Precision is close to desired limits for cloudy-sky cases, with the increased scatter between TOA & surface measurements being attributed to mismatches in derived cloud properties (scene identification).

Terra 2B & Aqua 1B results are very similar.