CERES Aqua Angular Distribution Models

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Aqua ADM Development

- Developed using Aqua Edition1B SSFs from August 2002 – June 2004 (23 months).
- Same approach as was used to develop and apply Terra ADMs.

  => Main difference between Terra and Aqua approach is in scene identification (clouds).

Uncertainty in Regional Mean SW TOA Flux

APPROACH

i) Construct 10°x10° latitude-longitude regional ADMs by season (e.g., DJF, JJA) from:

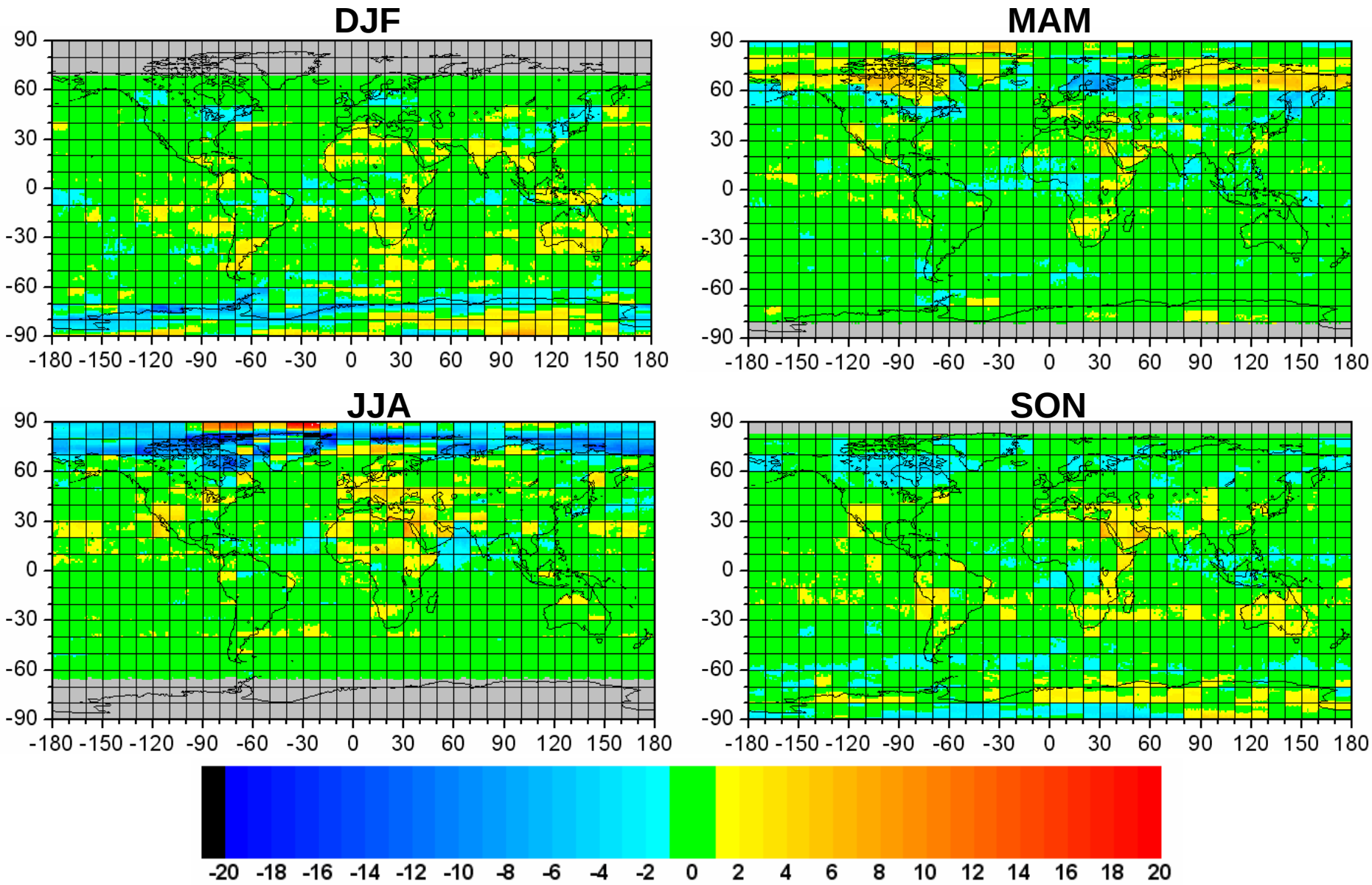
- **i) Measured CERES radiances**
- **ii) Radiance predicted by CERES ADMs**

ii) Apply regional ADMs to determine fluxes from the same data using one month of crosstrack measurements.

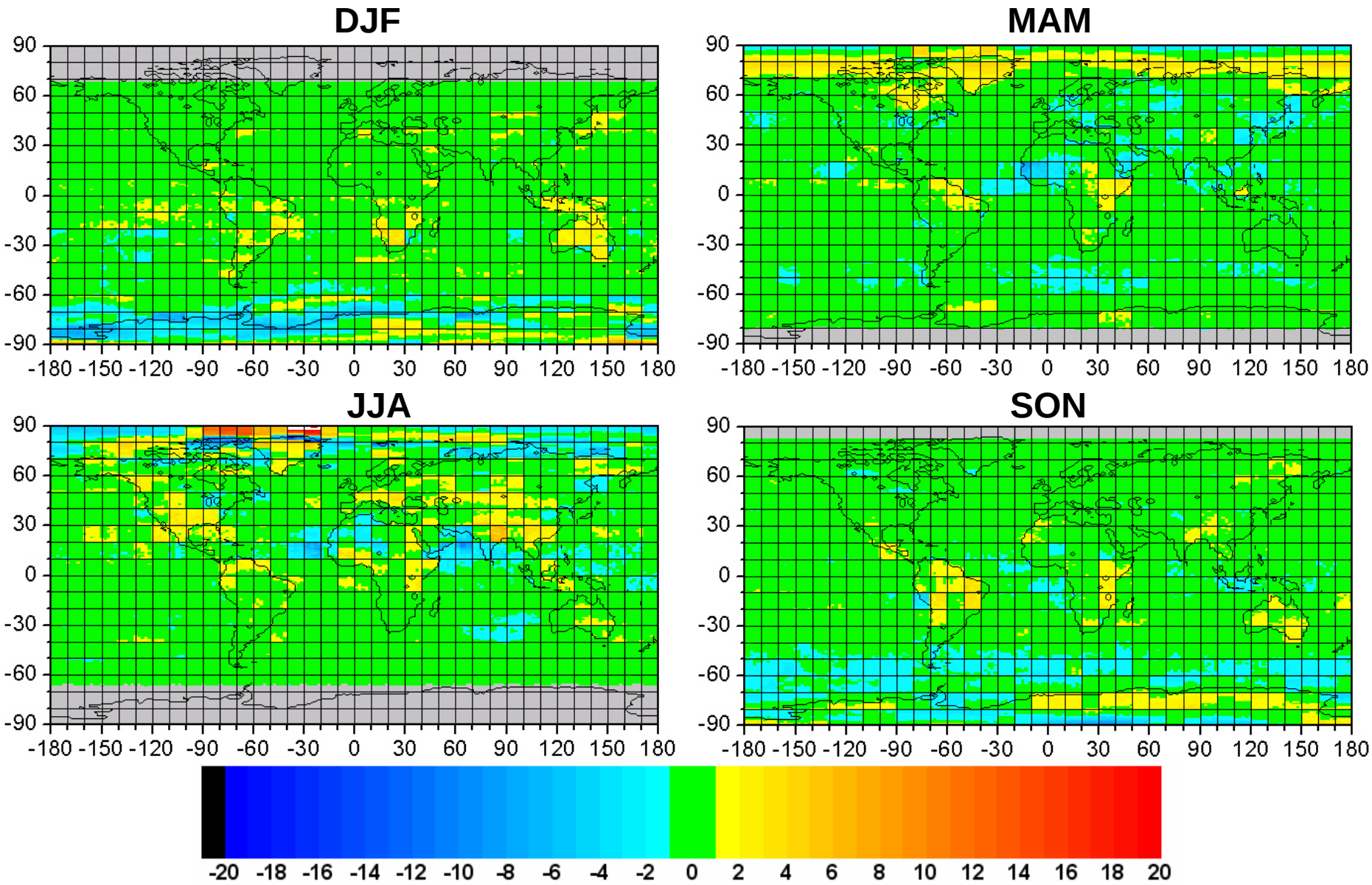
iii) Determine regional mean error in SW TOA flux.

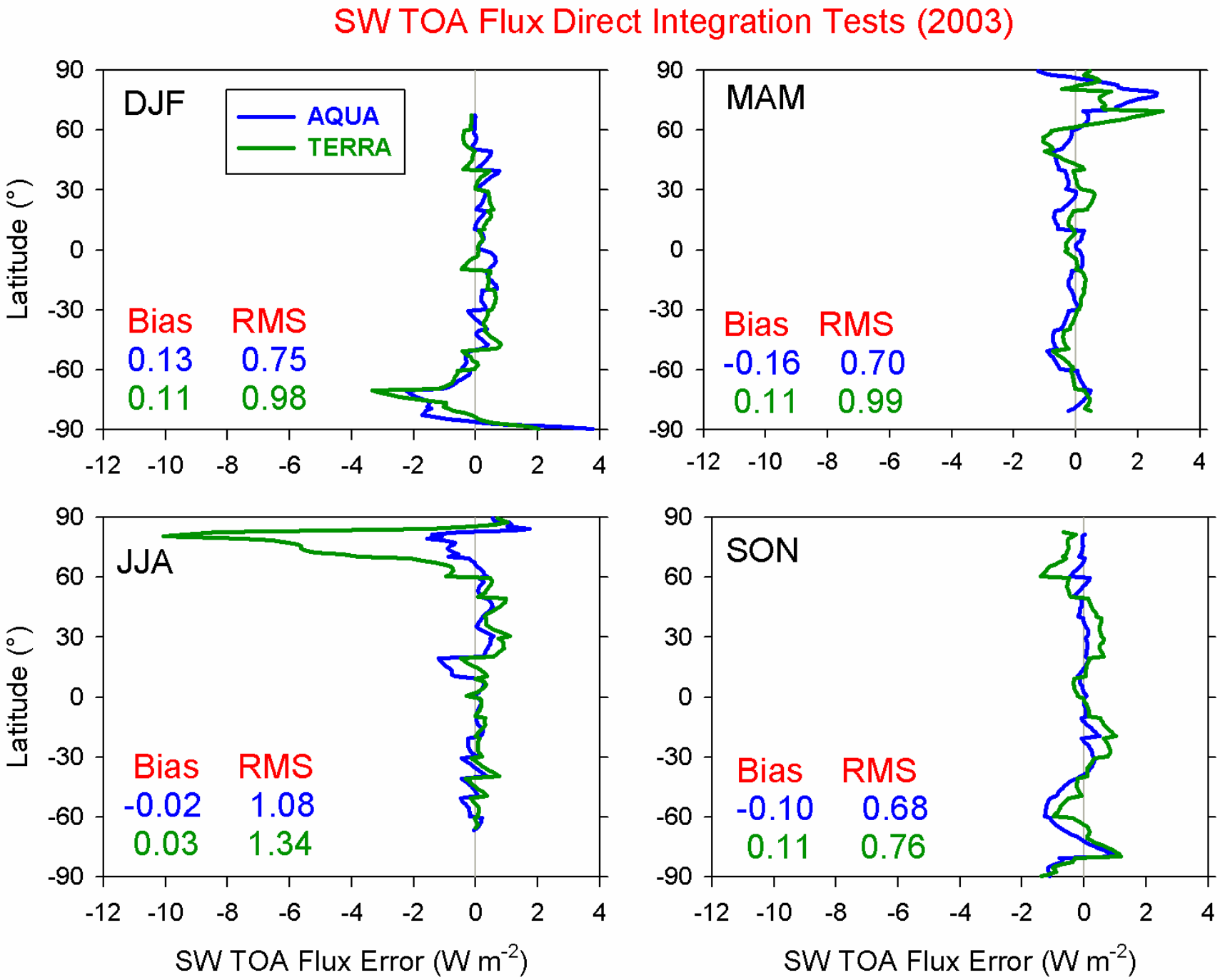
Note: This approach considers only footprints with non-default cloud properties.

Regional Mean SW TOA Flux Errors due to ADM Uncertainties (Terra)

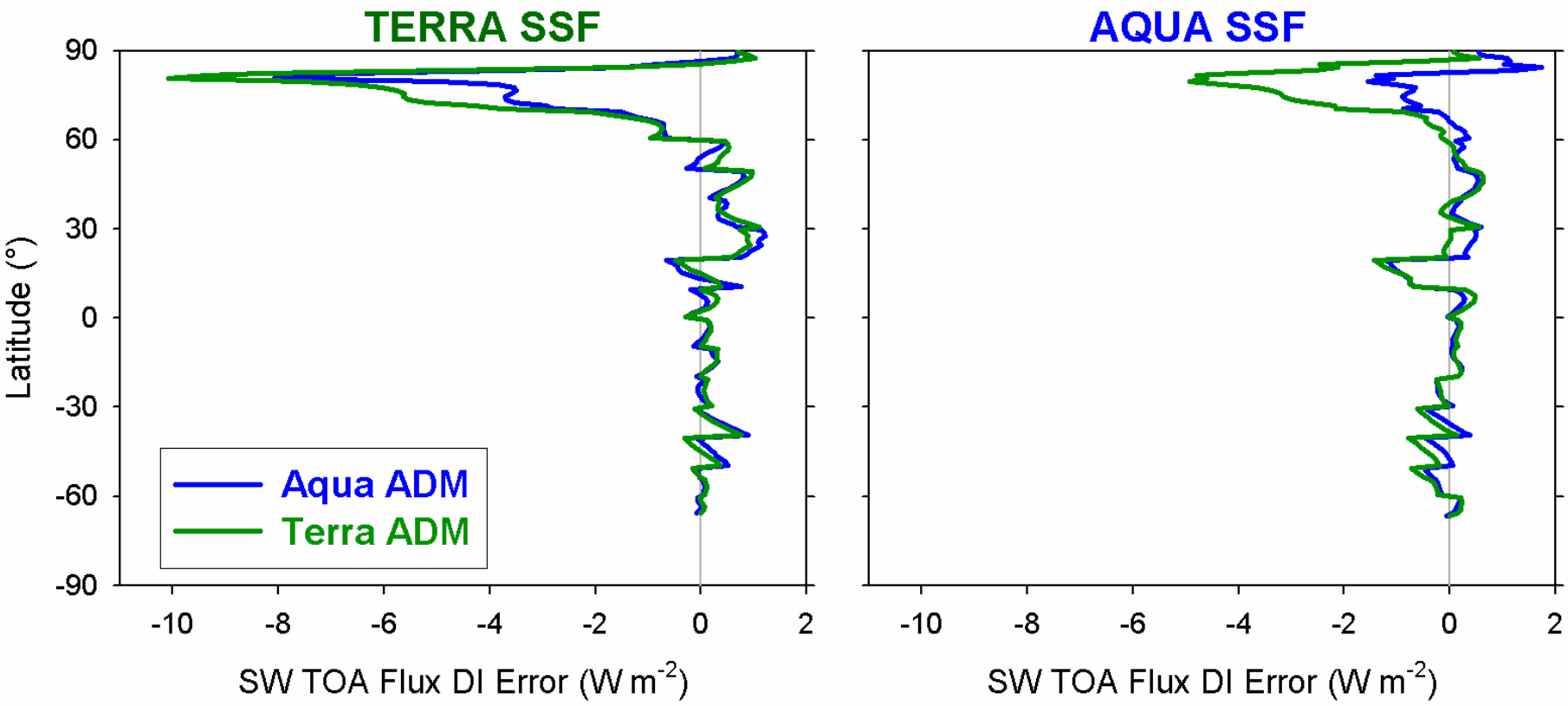


Regional Mean SW TOA Flux Errors due to ADM Uncertainties (Aqua)




SW TOA Flux Direct Integration Tests (2003)
DJF
AQUA
TERRA
Bias RMS
0.13 0.75
0.11 0.98
MAM
Bias RMS
-0.16 0.70
0.11 0.99
JJA
Bias RMS
-0.02 1.08
0.03 1.34
SON
Bias RMS
-0.10 0.68
0.11 0.76
Latitude (°)
SW TOA Flux Error (W m-2)
90
60
30
0
-30
-60
-90
-12 -10 -8 -6 -4 -2 0 2 4

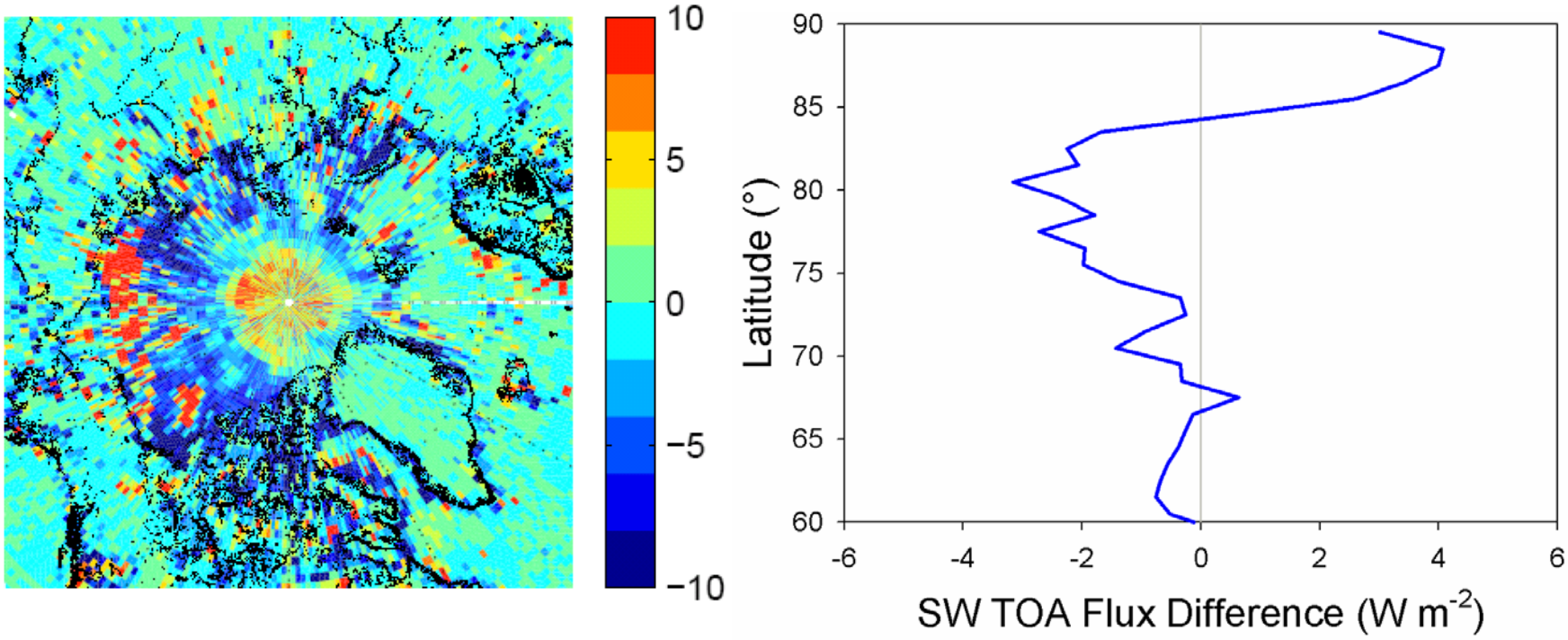
SW TOA Flux Error (JJA, 2003)



Differences between Terra Ed2 and Aqua Ed1 Daytime Polar Cloud Mask

- Aqua tests use 2.1 μm channel, Terra tests use 1.6 μm.
- In Aqua Ed1, thresholds of snow and cloud detection were changed in most of branches:
  -> the clear land and open ocean detection uses T11 instead of Tskin.
- The mini-mask for classifying TBD pixels changed. More of these are being retrieved on Aqua.
- Added Twilight MODIS Polar Tests in Aqua Ed1 that separates super cold plateau and non-super cold polar regions.
- Thin Ci tests remained the same. For daytime polar, the thin Ci tests (based on T11-T12) were in Terra Ed2 already.

Terra SSF_Ed2B minus Terra SSF_Ed2_Test (July 1, 2003)

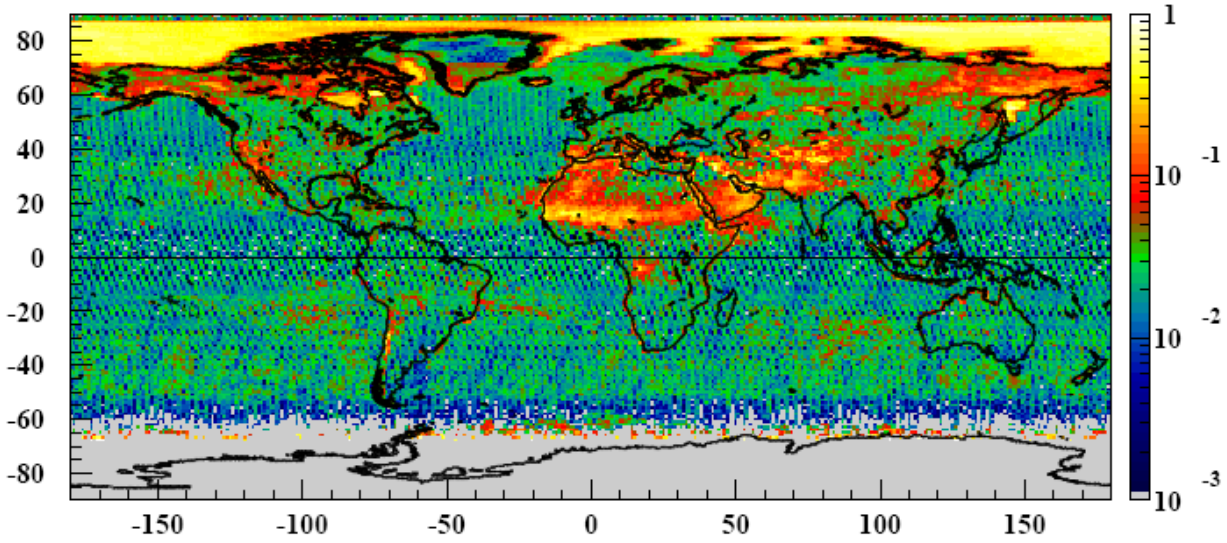


Terra SSF_Ed2B: Uses Terra sea-ice ADMs

Terra SSF_Ed2_Test: Uses Aqua sea-ice ADMs

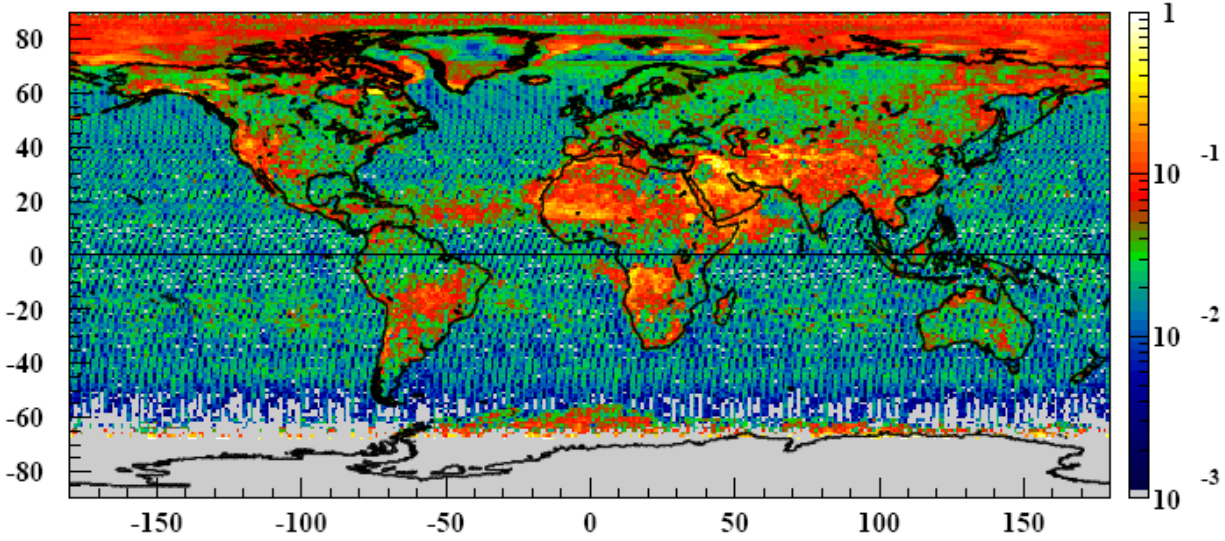
Fraction of CERES Fluxes Estimated using Neural Network ADMs

Terra, July 2003, FAPS



Terra: significant fraction of "cloud no retrievals" over Arctic sea-ice.

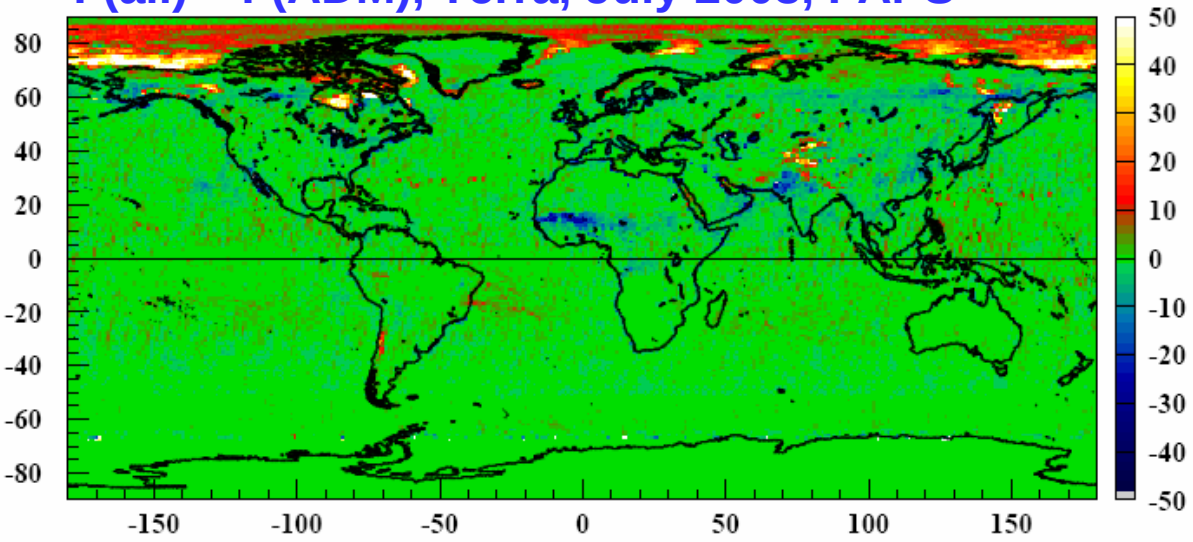
Aqua, July 2003, FAPS



Aqua: fewer "cloud no retrievals" than Terra over Arctic sea-ice, but more elsewhere.

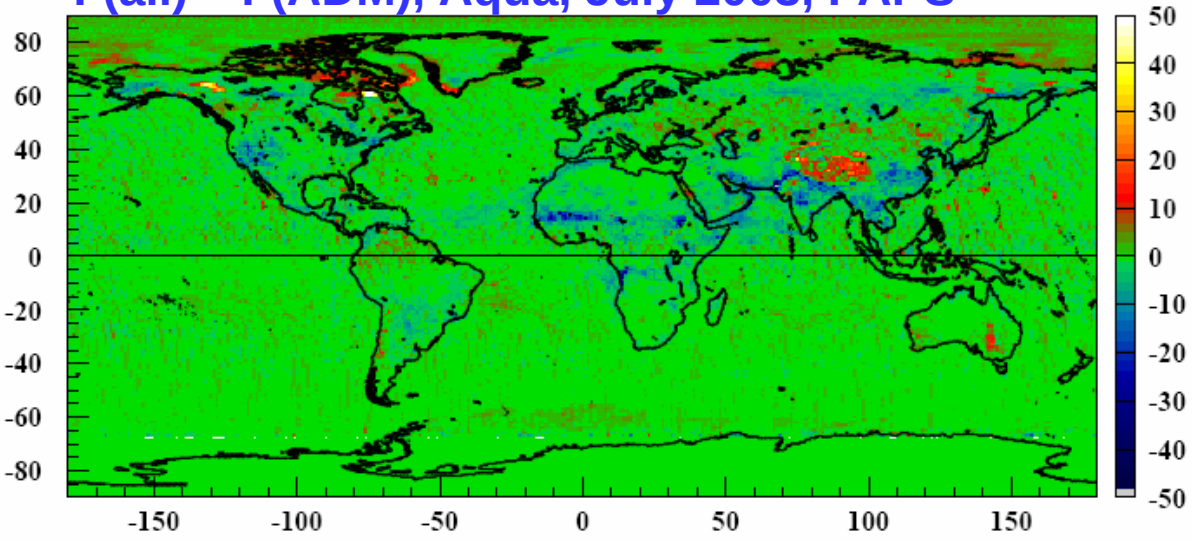
TOA SW Radiative Effect of "Cloud No Retrievals" Footprints (No Diurnal Averaging)

F(all) – F(ADM), Terra, July 2003, FAPS

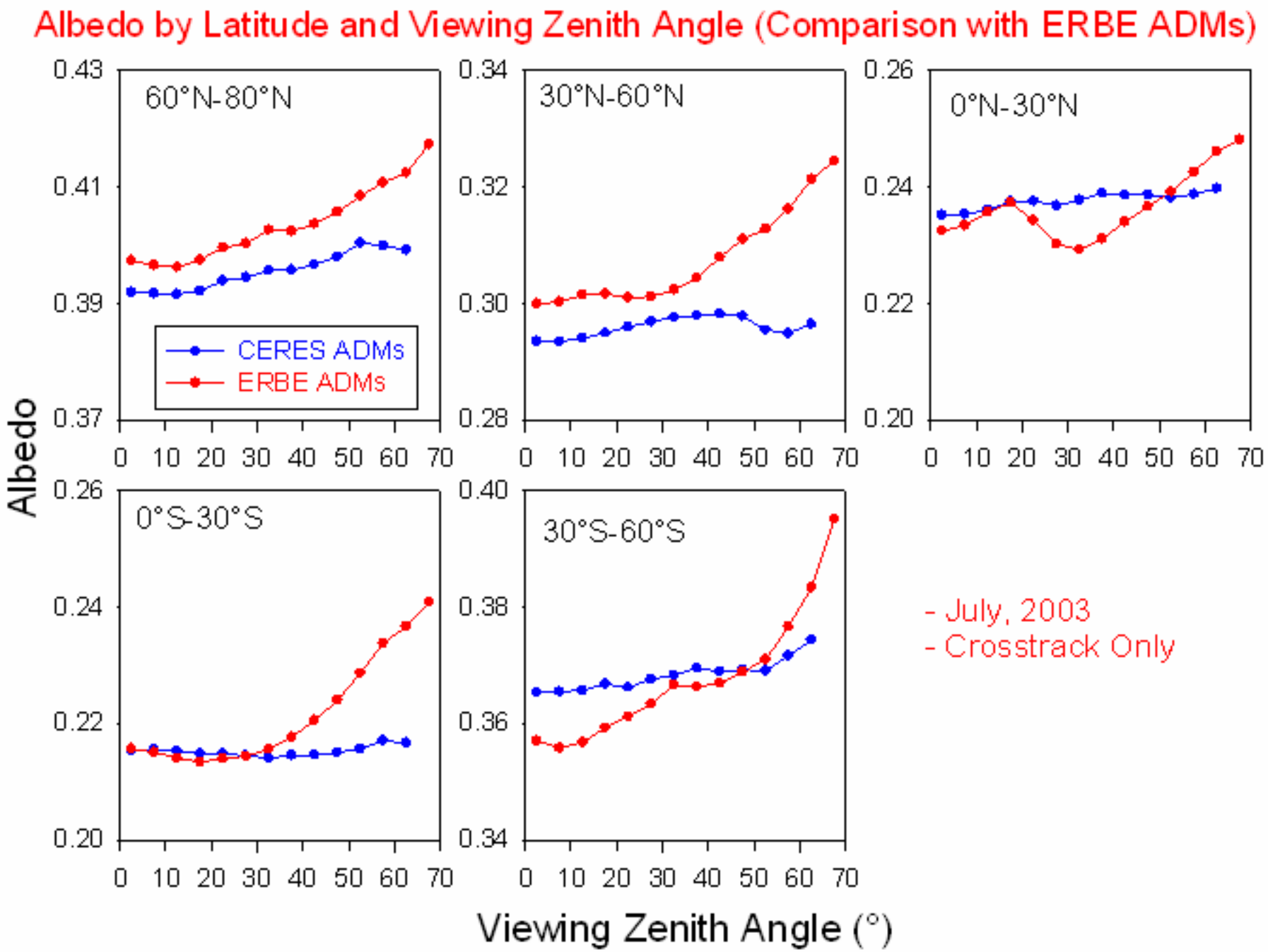


Terra: "cloud no retrievals" footprints increase SW TOA flux over Arctic sea-ice.
⇒ Strong dependence upon Neural Network ADMs

F(all) – F(ADM), Aqua, July 2003, FAPS

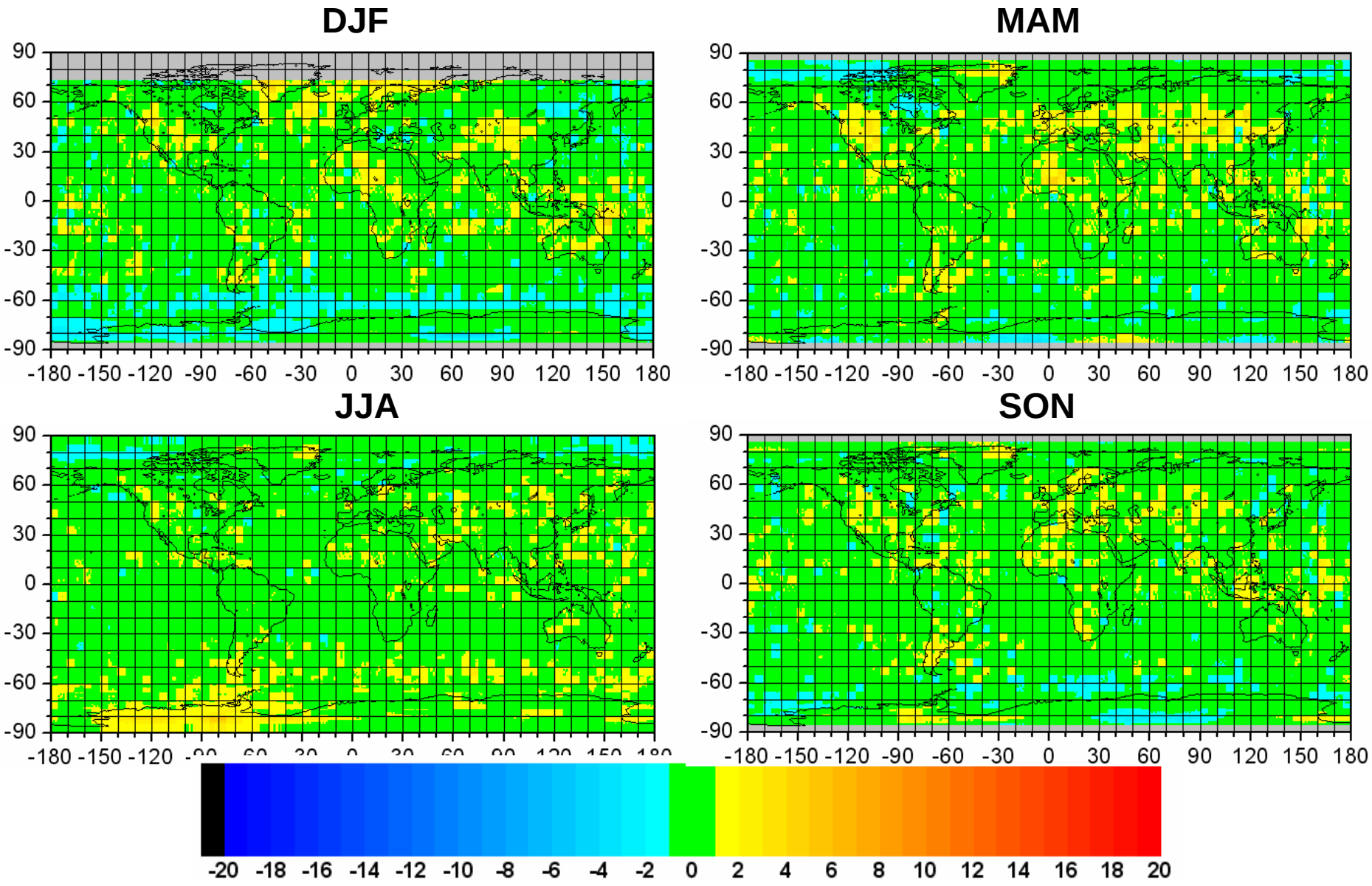


Aqua: Weak dependence up Neural Network ADMs.

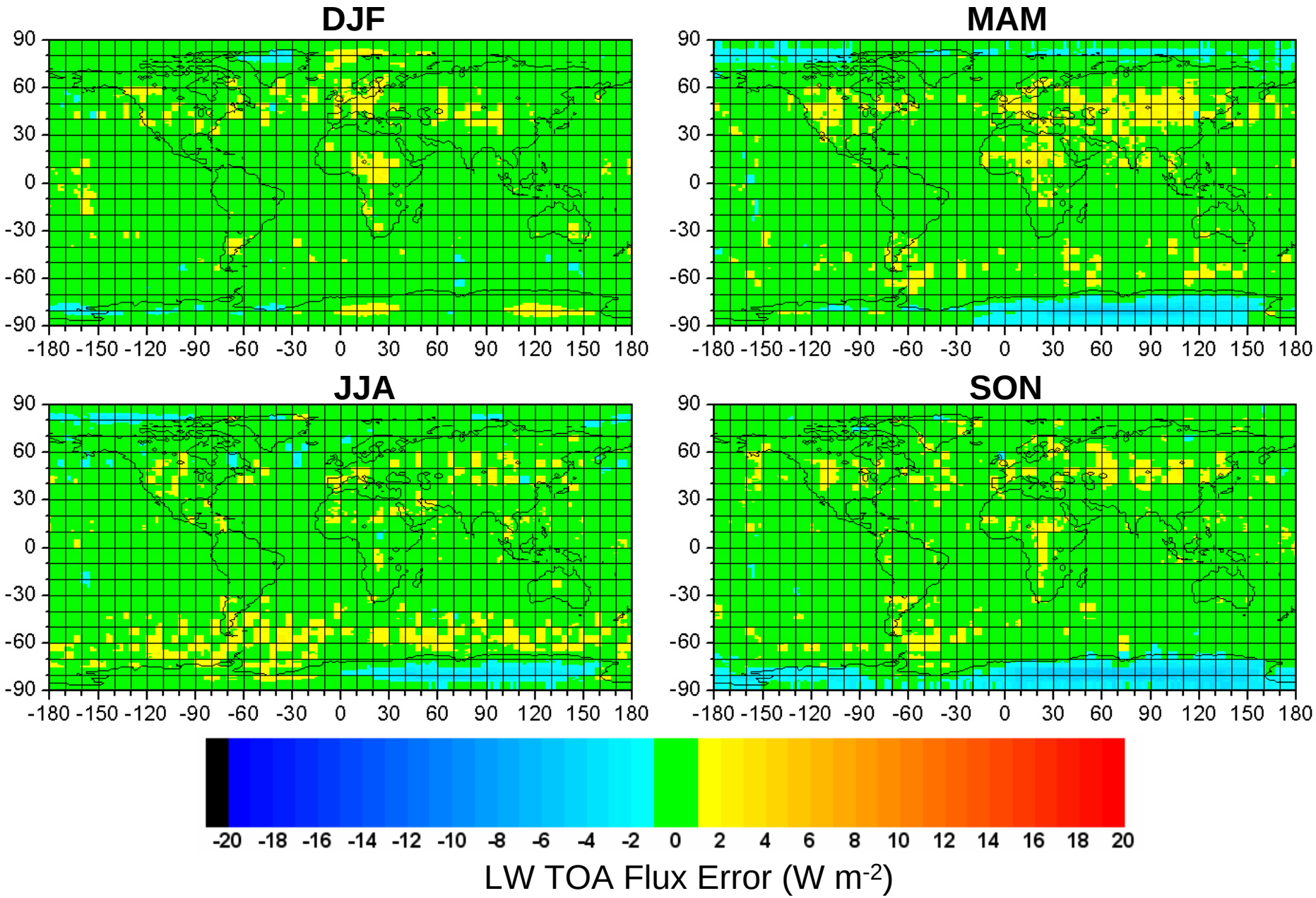

Albedo by Latitude and Viewing Zenith Angle (Comparison with ERBE ADMs)
60°N-80°N
30°N-60°N
0°N-30°N
0°S-30°S
30°S-60°S
CERES ADMs
ERBE ADMs
Albedo
Viewing Zenith Angle (°)
- July, 2003
- Crosstrack Only

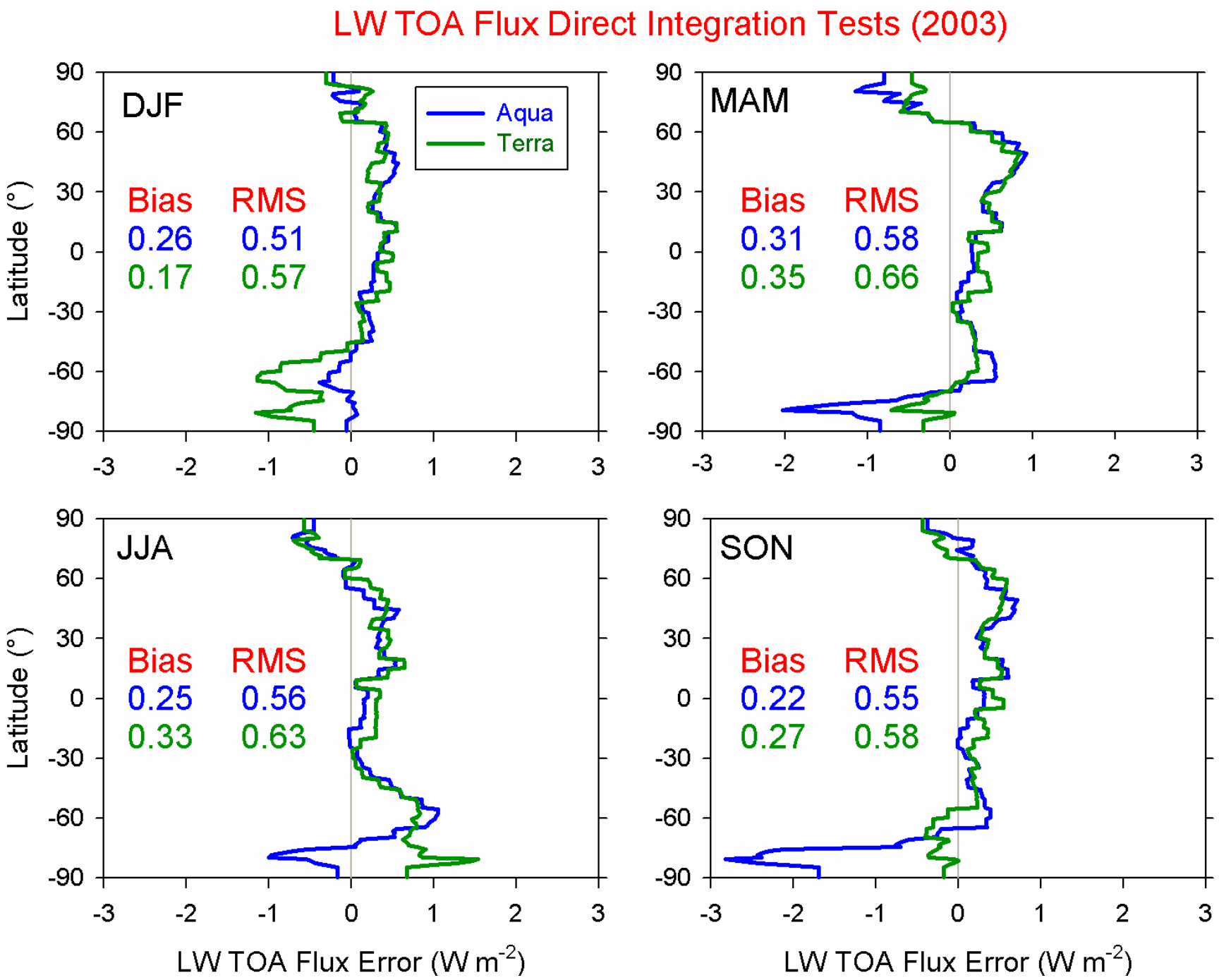
Uncertainty in Regional Mean LW TOA Flux

Regional Mean LW TOA Flux Errors due to ADM Uncertainties (Terra)

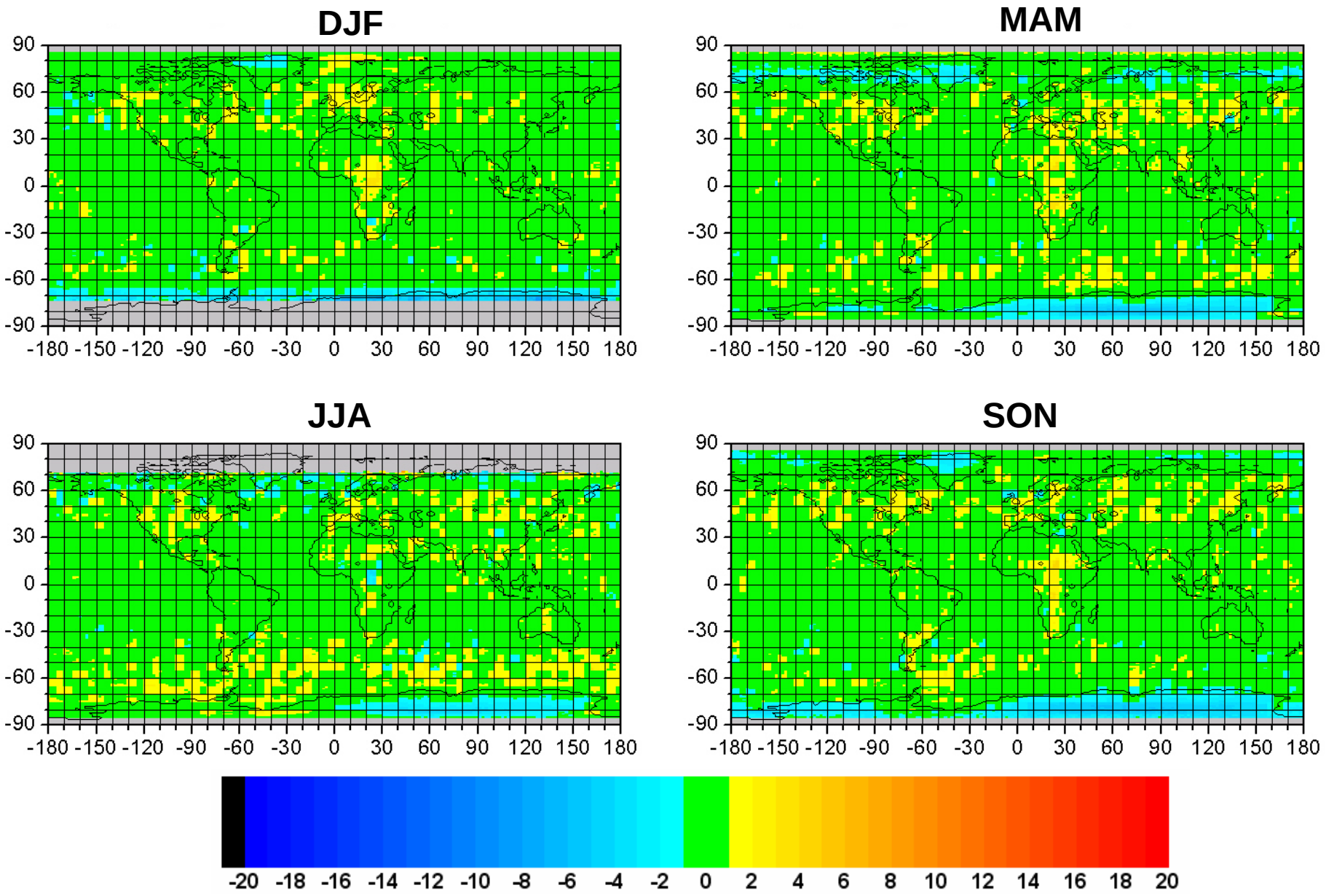


Regional Mean LW TOA Flux Errors due to ADM Uncertainties (Aqua)

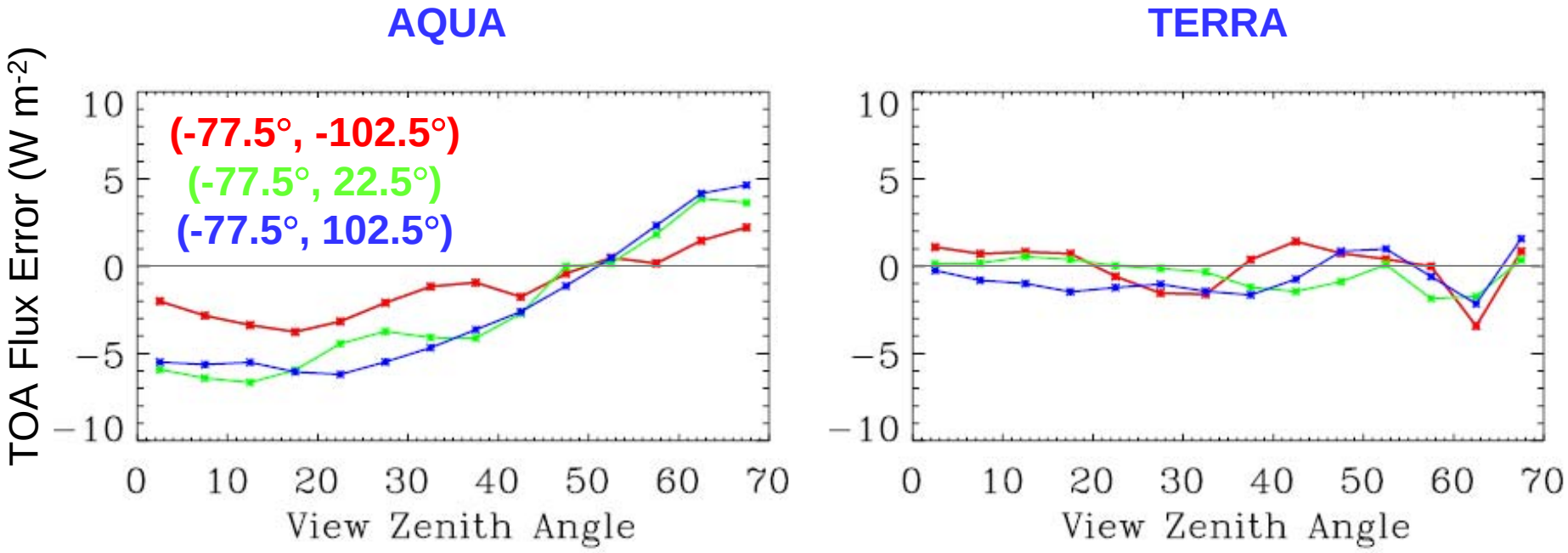



LW TOA Flux Direct Integration Tests (2003)
DJF
Aqua
Terra
Bias RMS
0.26 0.51
0.17 0.57
MAM
Bias RMS
0.31 0.58
0.35 0.66
JJA
Bias RMS
0.25 0.56
0.33 0.63
SON
Bias RMS
0.22 0.55
0.27 0.58
Latitude (°)
90
60
30
0
-30
-60
-90
-3 -2 -1 0 1 2 3
LW TOA Flux Error (W m-2)

Regional Mean Nighttime LW TOA Flux Errors due to ADMs (Aqua)



Nighttime LW TOA Flux Error Against Viewing Zenith Angle (5° x 5° latitude-longitude regions; SON, 2003)



Nighttime Polar Cloud Mask Changes between Terra Ed2 and Aqua Ed1

- In Aqua Ed1, over the super Cold Plateau regions, the snow/ice tests were changed so as to slightly reduce cloud cover compared to Terra Ed2.

  -> In Terra Ed2, Antarctic ice caps were sometimes misidentified as clouds.

Note: super cold ice cap definition:

Tskin < 230 K, T11 < 230 K, elevation > 1000 m and IceMap > 0

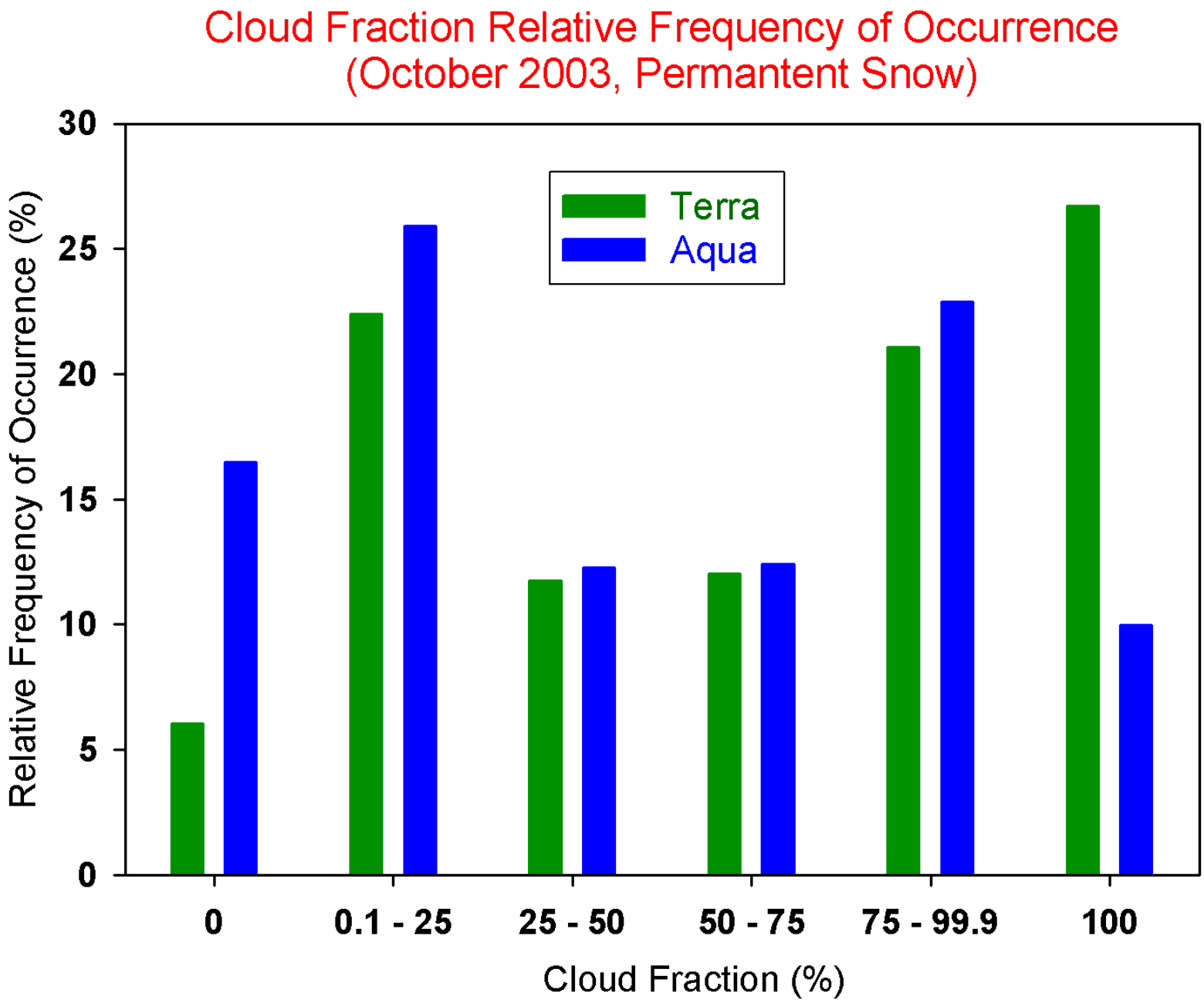
Cloud mask changes:

Clouds: Tskin > 230 and T11 < 240 and **Tcs - T11 > 15** and T3.7-T12 > 4 (Aqua)

Tskin > 230 and T11 < 240 and **Tcs - T11 > 12** and T3.7-T12 > 4 (Terra)

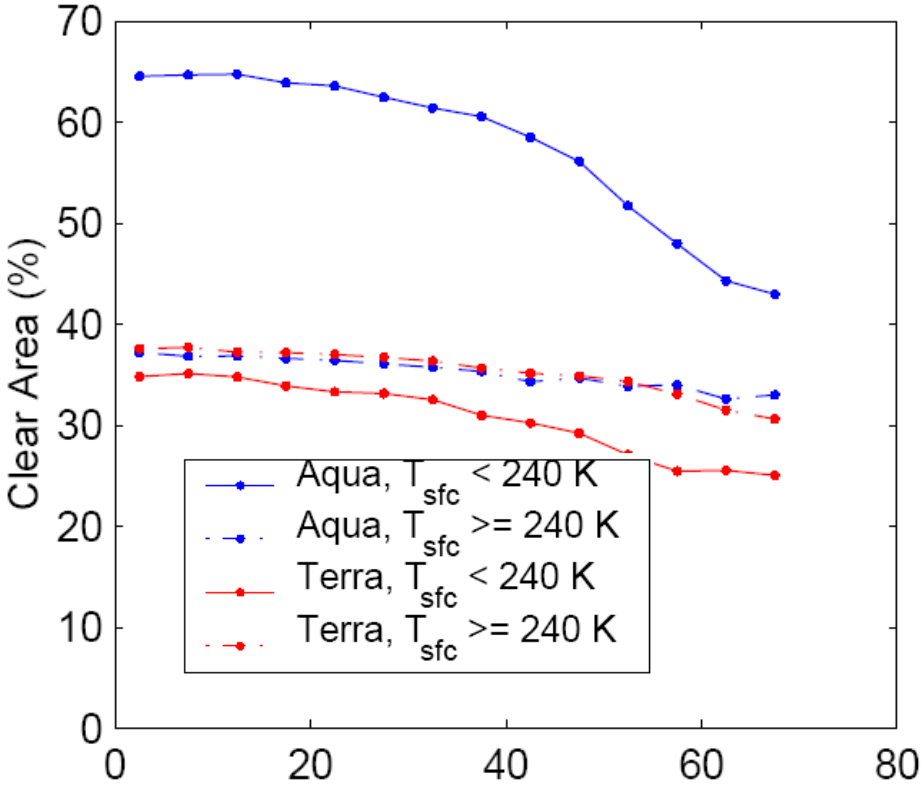
Ice: **T11 < 220** and **T67 - T 11 > 5** and T11 - T12 < 0.7 (Aqua)

T11 < 210 and **T67 - T 11 > 9** and T11 - T12 < 0.7 (Terra)

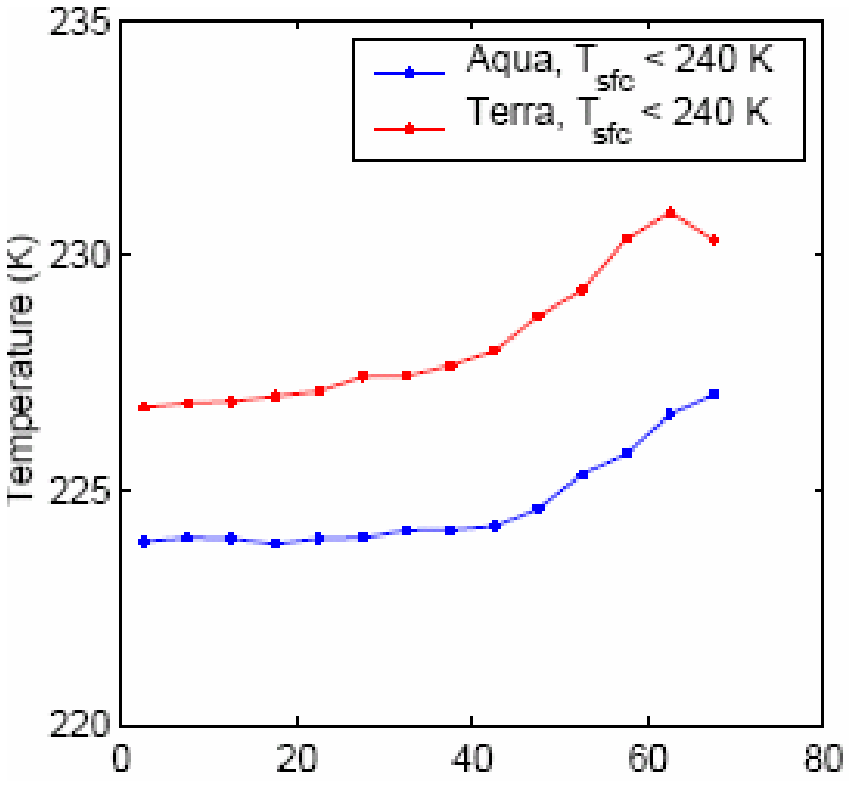

Cloud Fraction Relative Frequency of Occurrence
(October 2003, Permantent Snow)
Relative Frequency of Occurrence (%)
30
25
20
15
10
5
0
Terra
Aqua
0
0.1 - 25
25 - 50
50 - 75
75 - 99.9
100
Cloud Fraction (%)

Nighttime Clear Area Coverage and Surface Skin Temperature over Permanent Snow (October 2003)

Clear Area Coverage

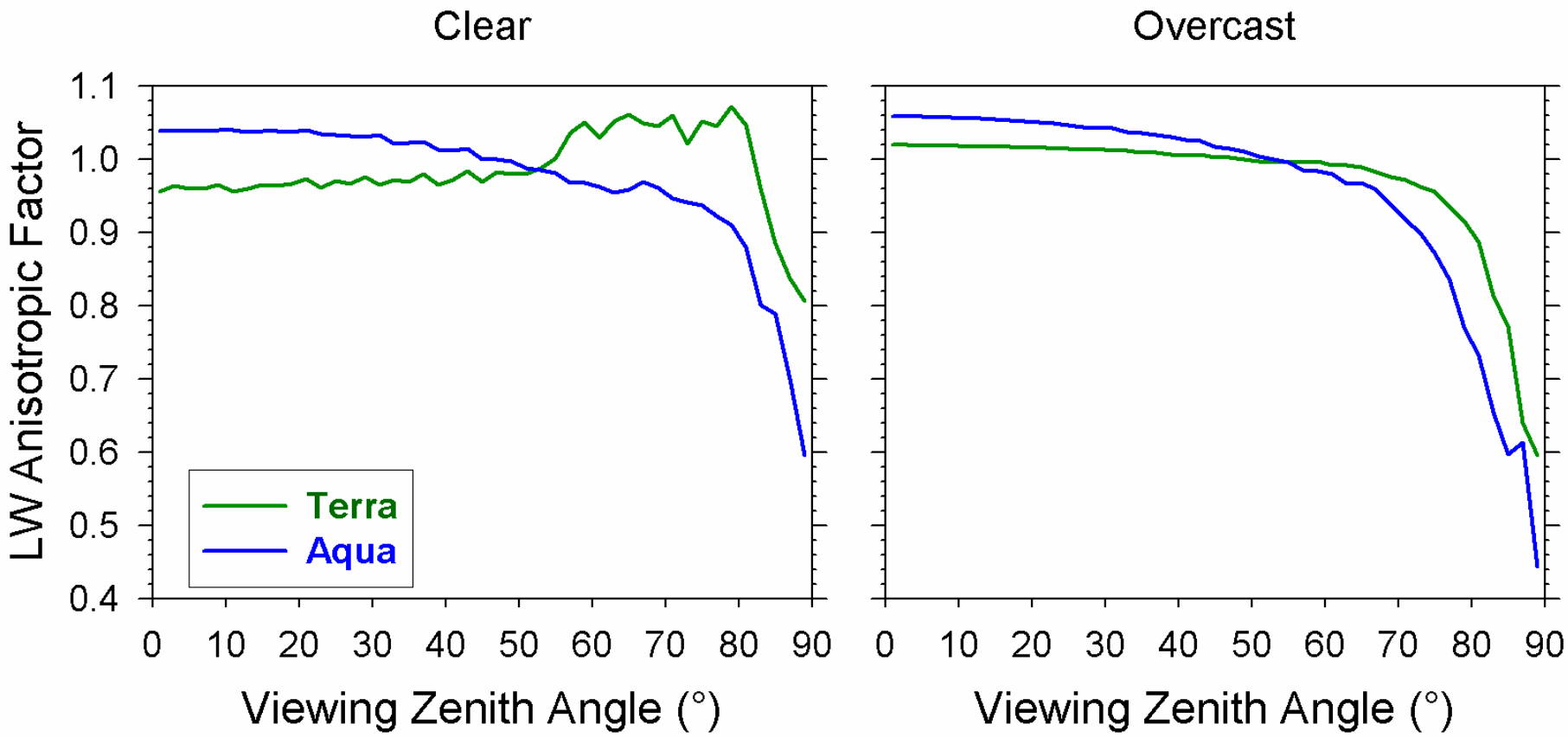


Surface Skin Temperature (Clear)

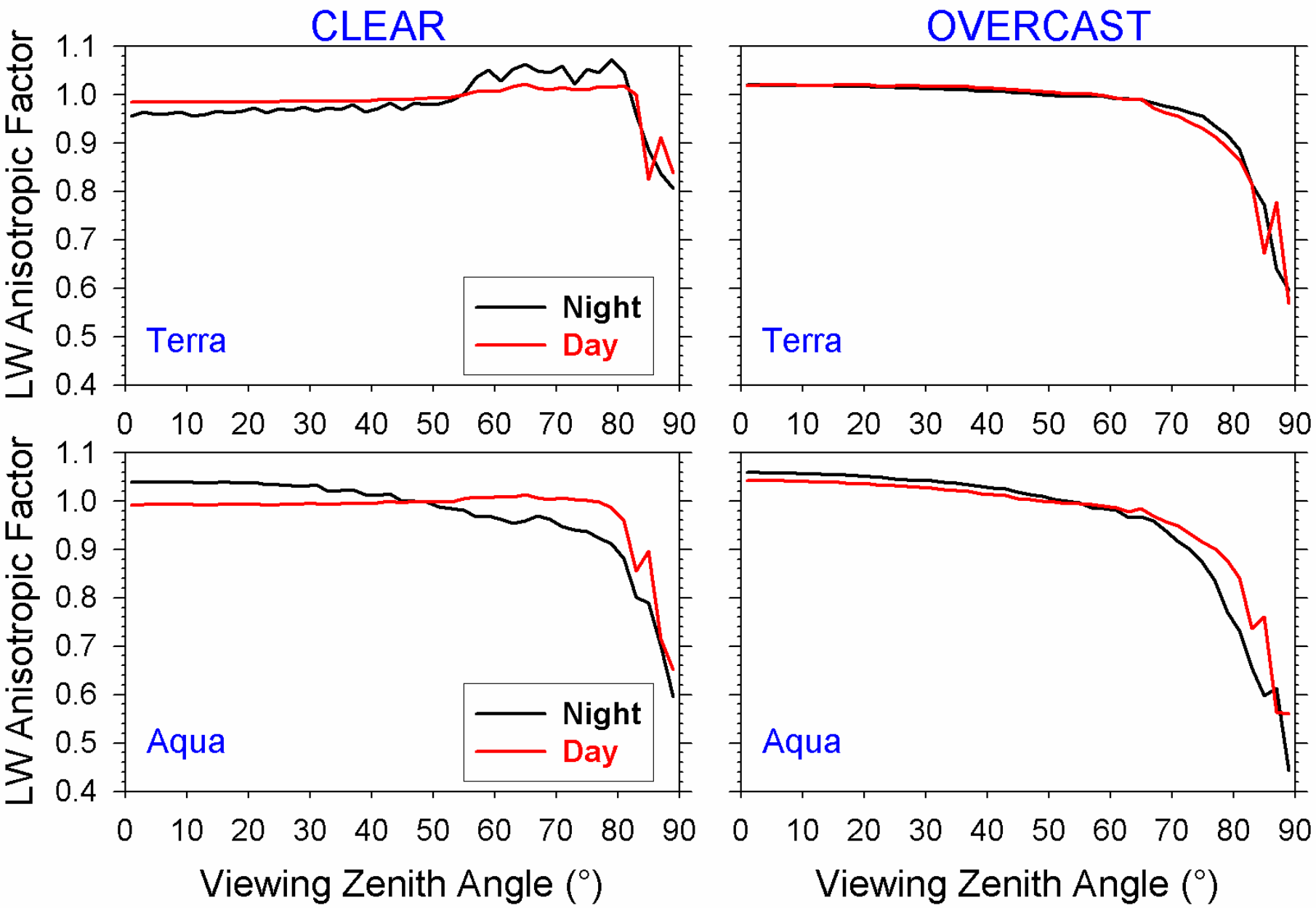


Viewing Zenith Angle (°)

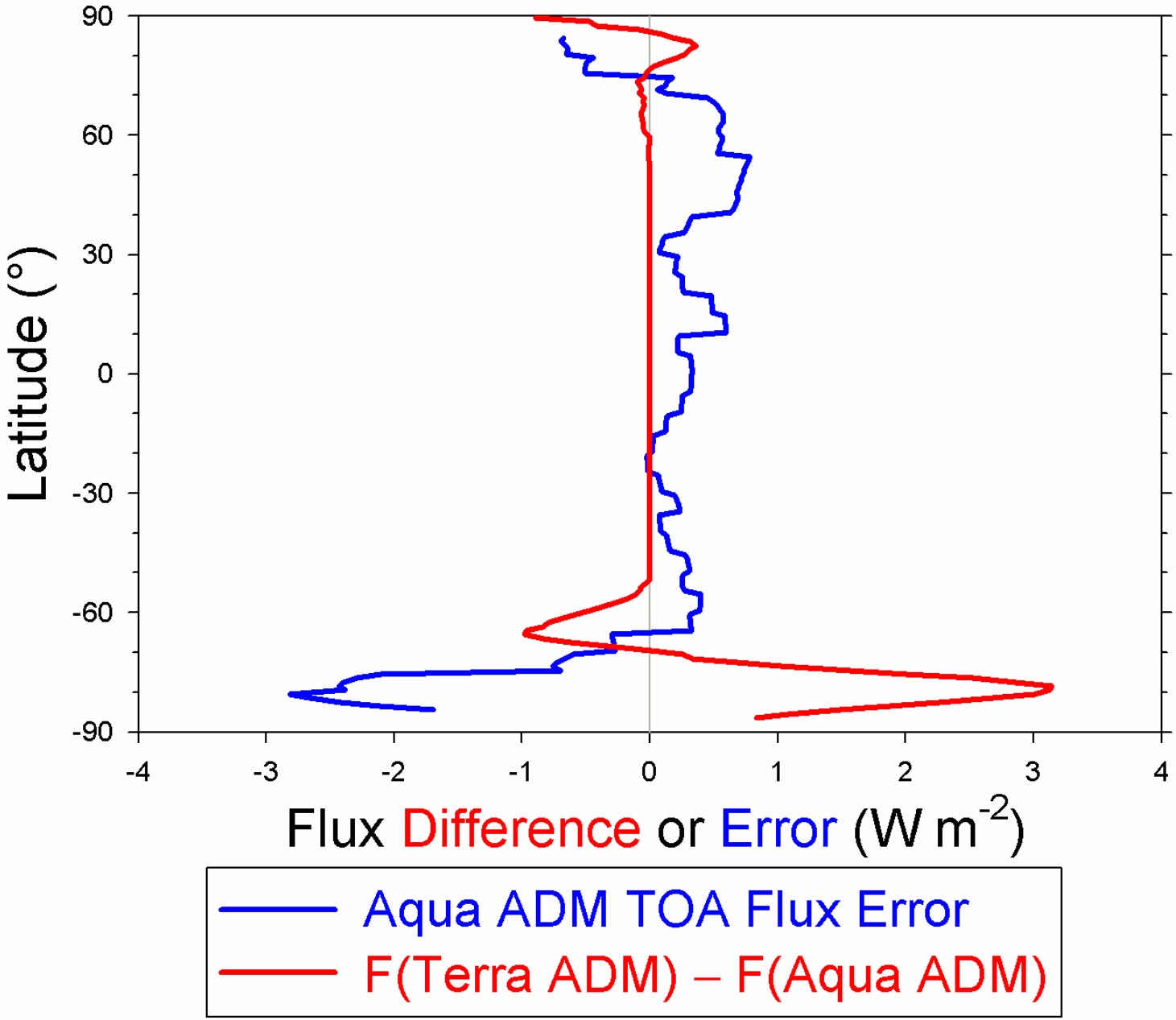
Terra and Aqua LW Nighttime ADMs for Permanent Snow



Clear and Overcast Terra and Aqua LW ADMs

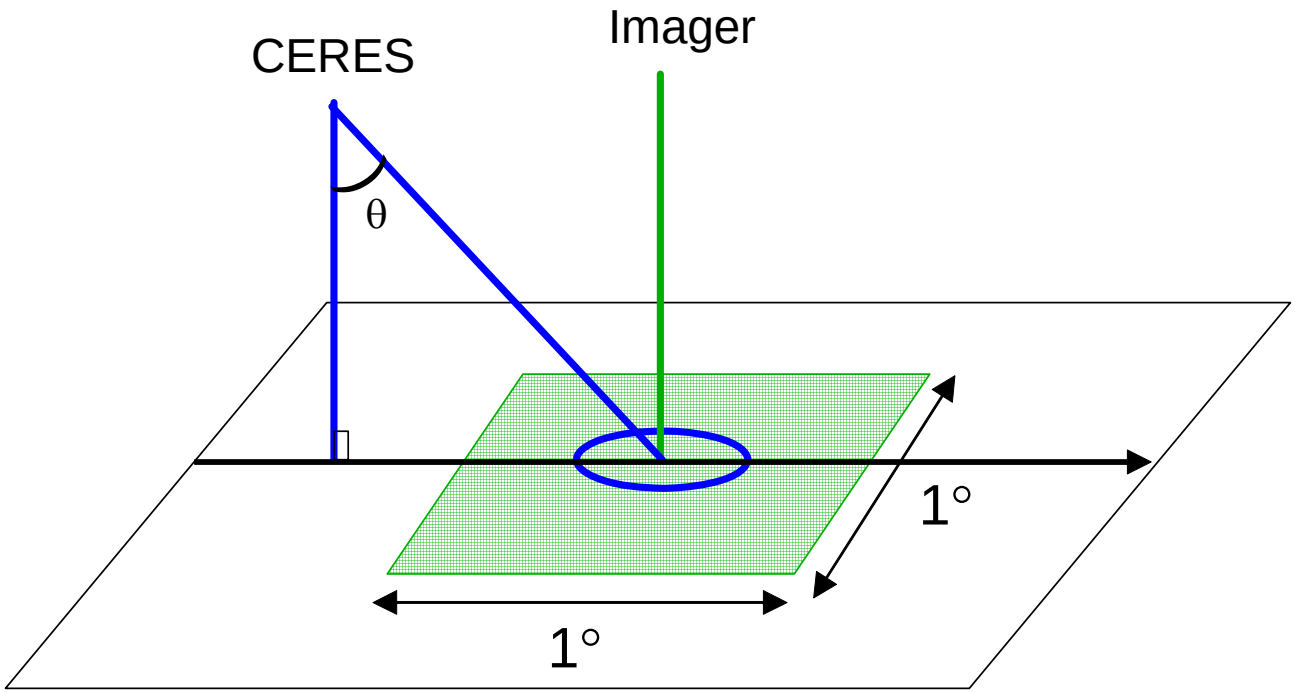


Effect of Replacing Aqua Nightime LW Permanent Snow ADMs with Terra ADMs (Aqua SSF October 2003)



Instantaneous TOA Flux Uncertainty

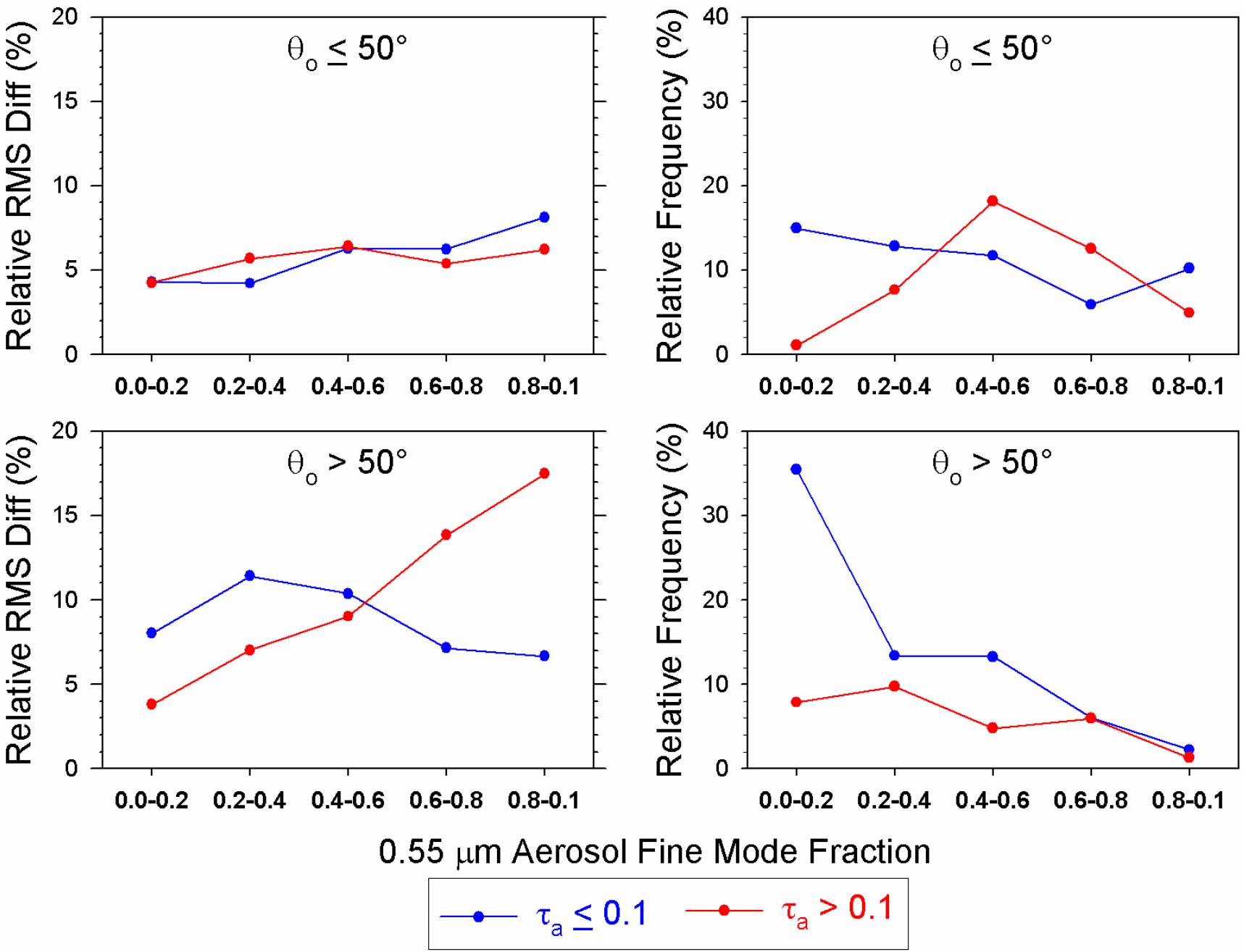
Instantaneous TOA Flux Consistency Tests



- Convert imager nadir visible radiance to broadband flux
- Compare off-nadir CERES flux with nadir flux inferred from imager visible radiance.

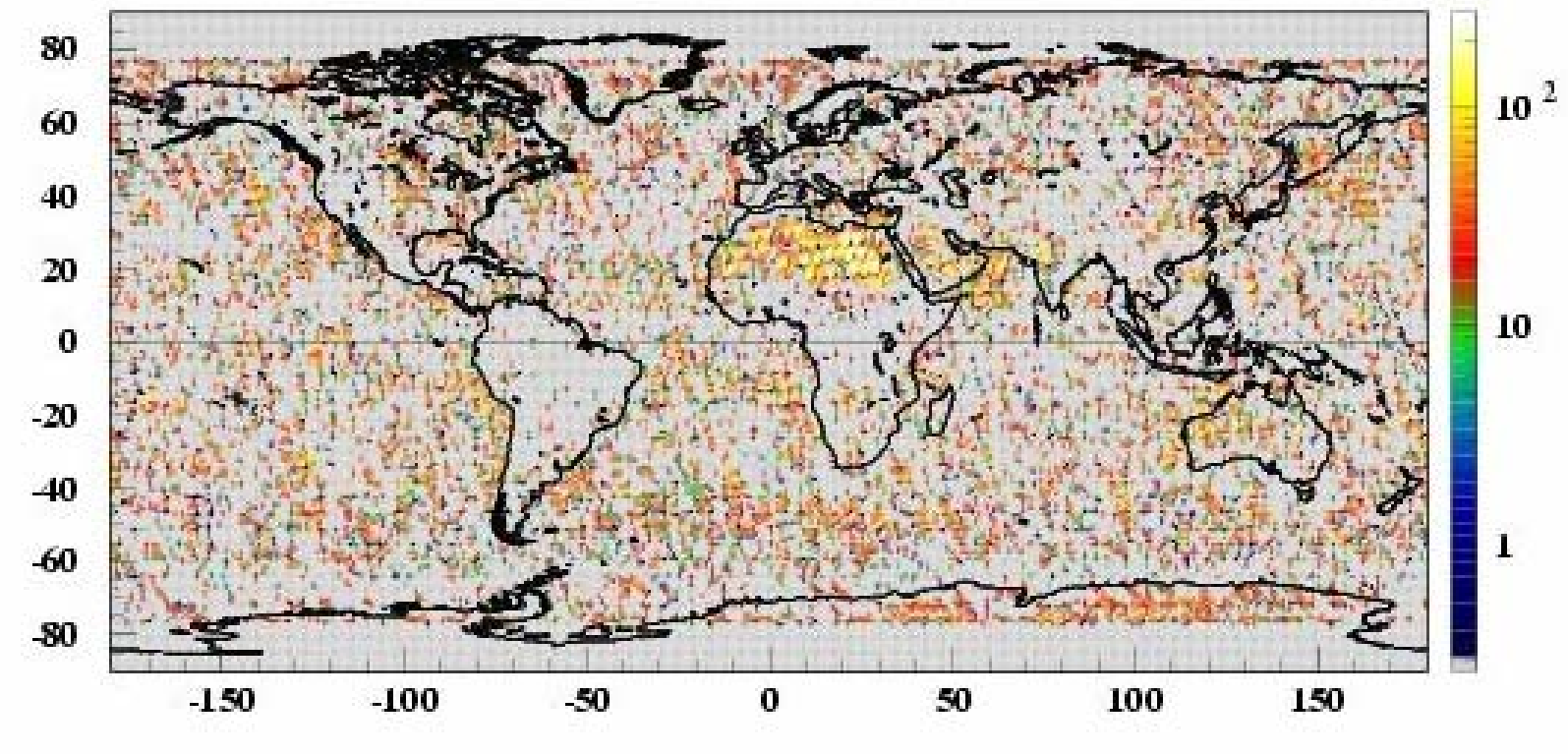
Consistency = [F(θ=50°-60°) - F (Nadir)] / F (Nadir)] x 100%

Clear Ocean SW TOA Flux Consistency vs Aerosol Fine Mode Fraction



Aqua: 47 Days, N FOV = 401,239

Terra: 48 days, N FOV = 545,018



SSF Cloud Classification
(Each Cloud Layer)

	PCL			MCL			OVC		
High	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**
Mid	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Low	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
	Thin	**Mod**	**Thick**	**Thin**	**Mod**	**Thick**	**Thin**	**Mod**	**Thick**

PCL: CF = 0.1 - 40%	**High: EP < 440 mb**	**Thin: τ < 3.35**
MCL: CF = 40 – 99%	**Mid: EP = 440 – 680 mb**	**Mod: τ = 3.35 – 22.63**
OVC: CF = 99 – 100%	**Low: EP > 680 mb**	**Thick: t > 22.63**

No-Glint Ocean Scene Type SW TOA Flux RMS (%)

Aqua Ocean: All-sky RMS = 4.23% (6.04%)

CLR		PCL			MCL			OVC		
5.28	High							10.21	6.70	3.99
	Mid	16.01							5.62	4.20
	Low	8.33	10.06		10.63	6.13		25.50	3.78	3.61
		Thin	Mod	Thick	Thin	Mod	Thick	Thin	Mod	Thick

Terra Ocean: All-sky RMS = 4.07% (5.21%)

CLR		PCL			MCL			OVC		
6.27	High							11.64	6.84	3.72
	Mid					10.73			5.65	4.15
	Low	7.77	9.68		7.31	5.28		28.51	3.06	3.56
		Thin	Mod	Thick	Thin	Mod	Thick	Thin	Mod	Thick

Land SW TOA Flux RMS (%)

Aqua Land: All-sky RMS = 6.58% (5.03%)

CLR		PCL			MCL			OVC		
3.05	High	3.01						9.79	8.11	4.65
	Mid	4.63				7.85			4.77	3.06
	Low	10.59	7.65			10.81			4.83	4.43
		Thin	Mod	Thick	Thin	Mod	Thick	Thin	Mod	Thick

Terra Land: All-sky RMS = 5.77% (4.90%)

CLR		PCL			MCL			OVC		
4.12	High	4.09						23.27	6.01	3.92
	Mid	5.30	16.38			7.36			5.04	4.11
	Low	8.65	8.10		16.53	5.97			6.43	4.36
		Thin	Mod	Thick	Thin	Mod	Thick	Thin	Mod	Thick

Snow/Ice SW TOA Flux RMS (%)

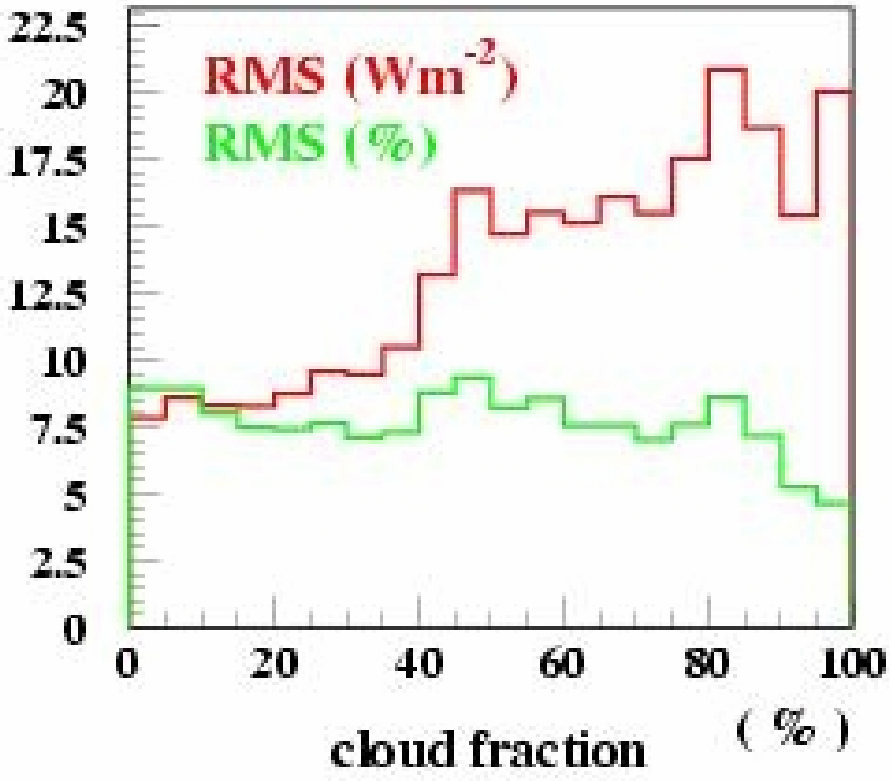
Aqua Snow/Ice: All-sky RMS = 8.23% (7.40%)

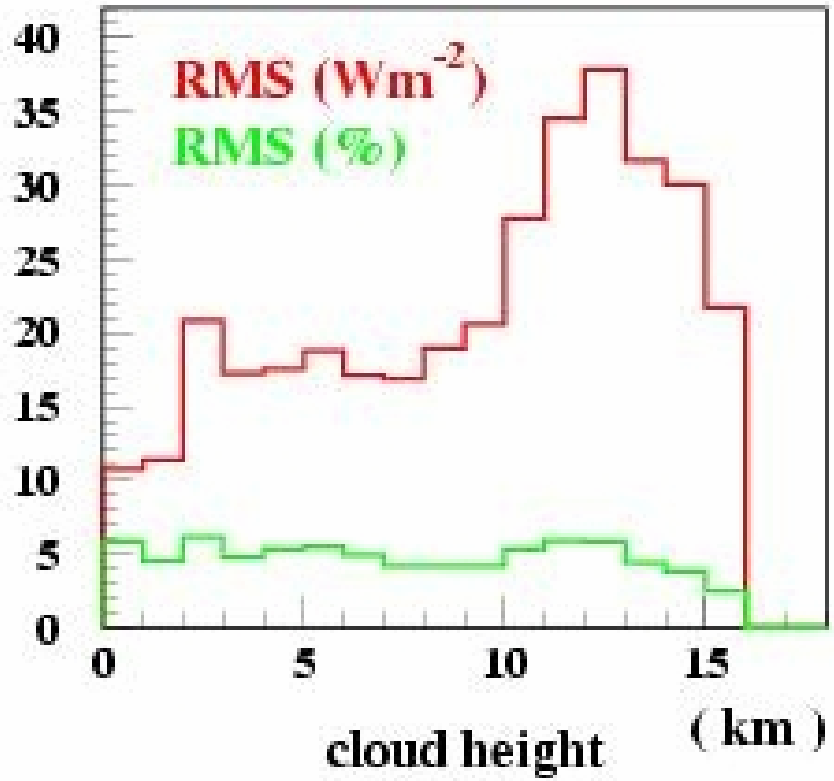
CLR		PCL			MCL			OVC		
5.02	High	6.04						8.65	8.79	
	Mid	5.37	10.12		6.19	10.16		7.35	6.97	
	Low	9.79	17.50		11.54	14.18		8.85	5.17	
		Thin	Mod	Thick	Thin	Mod	Thick	Thin	Mod	Thick

Terra Snow/Ice: All-sky RMS = 8.50% (8.17%)

CLR		PCL			MCL			OVC		
7.22	High				11.26			9.97	6.19	9.40
	Mid	6.21	12.42		7.08	9.54		10.28	4.87	15.27
	Low	10.05	17.01		9.04	10.77		8.50	5.98	6.47
		Thin	Mod	Thick	Thin	Mod	Thick	Thin	Mod	Thick

SW TOA Flux Consistency by Cloud Fraction and Cloud Height (Ocean)





Ocean LW TOA Flux RMS (%)

Aqua Ocean: All-sky RMS = 2.39% (2.30%)

CLR		PCL			MCL			OVC		
1.06	High	1.05						6.04	7.69	5.97
	Mid	1.02							4.72	2.28
	Low	0.73	0.71		1.05	0.99			1.52	1.96
		Thin	Mod	Thick	Thin	Mod	Thick	Thin	Mod	Thick

Terra Ocean: All-sky RMS = 2.66% (2.63%)

CLR		PCL			MCL			OVC		
0.97	High	1.95						6.35	7.79	7.31
	Mid					5.13			4.47	4.84
	Low	0.96	1.08		1.06	2.42		2.51	2.24	2.42
		Thin	Mod	Thick	Thin	Mod	Thick	Thin	Mod	Thick

Land LW TOA Flux RMS (%)

Aqua Land: All-sky RMS = 2.94% (1.97%)

CLR		PCL			MCL			OVC		
1.60	High	2.42						2.41	6.75	5.90
	Mid	2.15				3.42			3.77	3.35
	Low	1.57	1.53			1.18			1.35	1.64
		Thin	Mod	Thick	Thin	Mod	Thick	Thin	Mod	Thick

Terra Land: All-sky RMS = 3.41% (2.09%)

CLR		PCL			MCL			OVC		
1.85	High	2.65						5.62	8.51	7.58
	Mid	2.00	1.88			3.69			3.94	2.07
	Low	2.00	1.96		3.26	1.43			1.27	2.25
		Thin	Mod	Thick	Thin	Mod	Thick	Thin	Mod	Thick

Snow/Ice LW TOA Flux RMS (%)

Aqua Snow/Ice: All-sky RMS = 2.13% (2.26%)

CLR		PCL			MCL			OVC		
2.27	High	2.20						5.01	7.46	
	Mid	2.96	1.52		2.05	2.50		1.84	3.40	
	Low	2.19	1.37		1.96	1.61		2.43	1.61	
		Thin	Mod	Thick	Thin	Mod	Thick	Thin	Mod	Thick

Terra Snow/Ice: All-sky RMS = 2.78% (2.87%)

CLR		PCL			MCL			OVC		
2.85	High	2.58			2.3 9			5.15	5.16	4.10
	Mid	2.35	5.59		2.36	2.23		4.00	4.85	3.84
	Low	2.12	2.34		2.45	2.22		5.48	2.19	5.54
		Thin	Mod	Thick	Thin	Mod	Thick	Thin	Mod	Thick

Summary

- CERES TOA flux uncertainties from new CERES ADMs:
  - => 1σ regional mean TOA flux : < 1 W m^{-2}
  - => Instantaneous SW TOA flux: 10 -15 W m^{-2}
  - => Instantaneous LW TOA flux : 5 -10 W m^{-2}

- Significant reduction in albedo dependence on viewing zenith angle compared to ERBE ADMs.

- Large bias in Terra SW TOA flux for Arctic sea-ice. Important changes in cloud mask lead to improvements for Aqua.
  => Suggest using Aqua sea-ice ADMs in Terra Ed3 processing.

- Large bias in Aqua nighttime LW fluxes over permanent snow. Important changes in cloud mask resulted in large biases for Aqua.
  => Suggest using Terra nighttime LW permanent snow ADMs in Aqua Ed2A processing.

- Evidence for a dependence in clear ocean instantaneous uncertainty on aerosol fine-mode fraction.
  => Suggest incorporating fine-mode fraction for Terra and Aqua Ed3 processing.