Early Validation of New Angular Distribution Models For CERES-TRMM

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Outline

1. Preliminary SW, LW & WN ADMs for CERES-TRMM Edition 2: Status

2. Early Validation of new CERES-TRMM SSF ADMs

   i) Clear Ocean Fluxes: Aerosol optical depth dependence
   ii) New ADM fluxes vs Edition 1 Fluxes (VIRS12)
   iii) Viewing zenith angle dependence checks: Fluxes and Cloud properties
   iv) ADM Direct Integration tests

3. Future Work

TOA Flux Production Schedule

1. Prior to May 2001 CERES Science Team Meeting

- Finalize CERES-TRMM SW, LW and WN ADMs.
- Provide near-final version of ADM production code that uses CERES-TRMM ADMs.
- Make preliminary SSFs with new TOA fluxes available (e.g. full SSFs for one month; one or more months over validation regions).
- Continue validation of new TOA fluxes.

2. August 2001

- Complete SSF Edition 2 Quality Summary.
- Begin production of SSF Edition 2.

CERES-TRMM ADM Status

- Preliminary CERES-TRMM SW, LW and WN ADMs have been developed.

- Only invert fluxes for CERES footprints with known cloud properties.
  SW: Known cloud properties ≈98% of time.
  LW: Missing daytime IR cloud emissivities >1.0 (≈15% of total)
  Missing **ALL** nighttime IR cloud emissivities!

=>SOL'N: Need to develop "backup" ADMs that are dependent upon fewer cloud properties. Need to rerun clouds and redo all ADMs to account for any cloud algorithm changes and missing cloud IR emissivities.

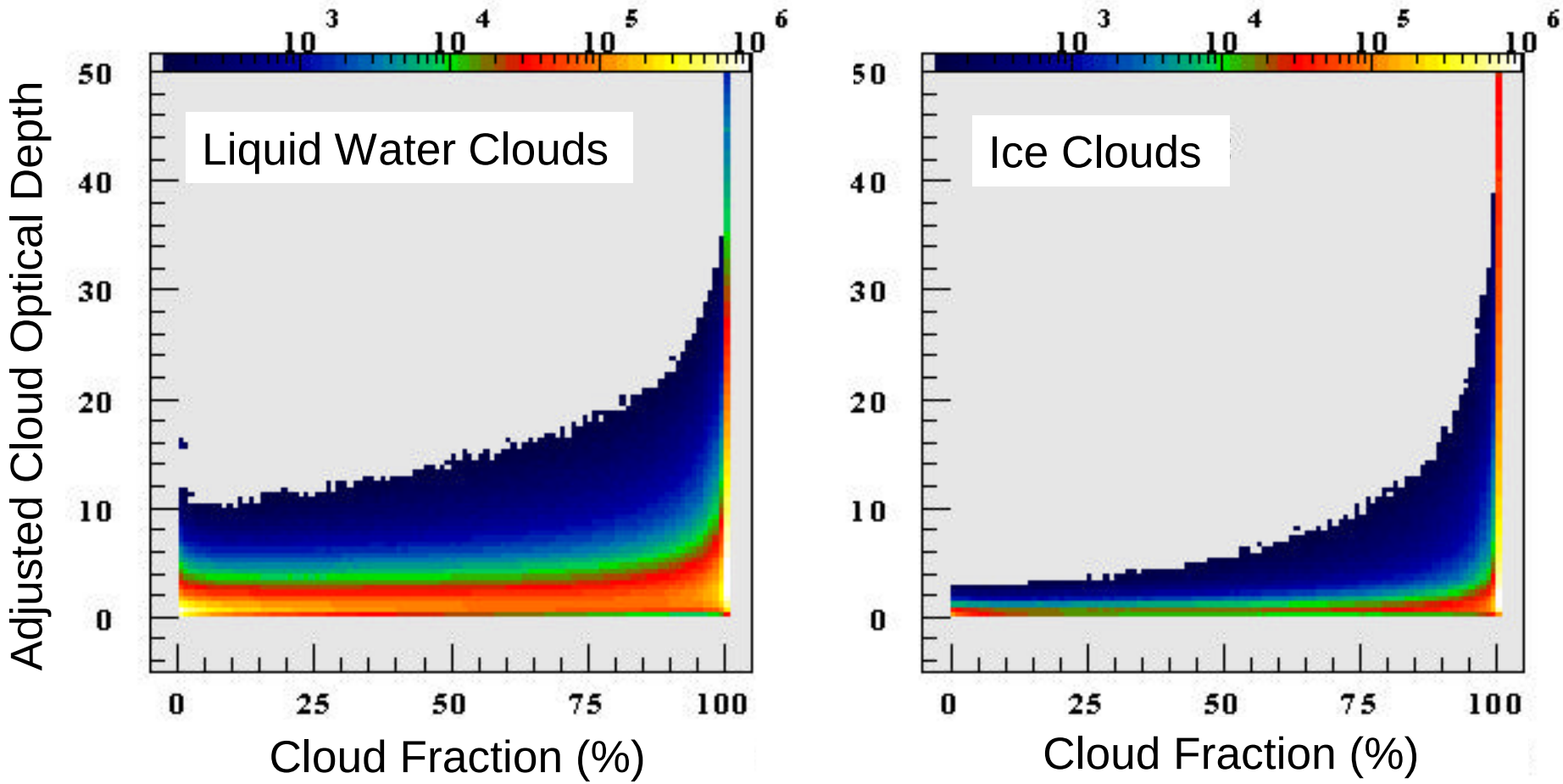
- Completed near-final version of TOA Flux code that applies the new ADMs.

- New ADM flux module made available to others for validation studies: SARB, Coakley, Hu

Preliminary Scene Types for CERES-TRMM SW ADMs

ADM Category		Scene Type Stratification	Actual Total
Clear	Ocean	- 4 Wind Speed Intervals	4
	Land	- 2 IGBP Type Groupings	2
	Desert	- Bright and Dark	2
	Snow	- Theoretical	1
Cloud	Ocean	- Liquid and Ice - 12 Cloud Fraction Intervals - 14 Optical Depth Intervals	62 (L) 53 (I)
	Land	- 2 IGBP Type Groupings - Liquid and Ice - 5 Cloud Fraction Intervals - 6 Optical Depth Intervals	45
	Desert	- Bright and Dark Deserts - Liquid and Ice - 5 Cloud Fraction Intervals - 6 Optical Depth Intervals	33
	Snow	- Theoretical	1
Total			203

SW ADM Frequency of Occurrence by Cloud Fraction & Adjusted Cloud Optical Depth (Ocean)



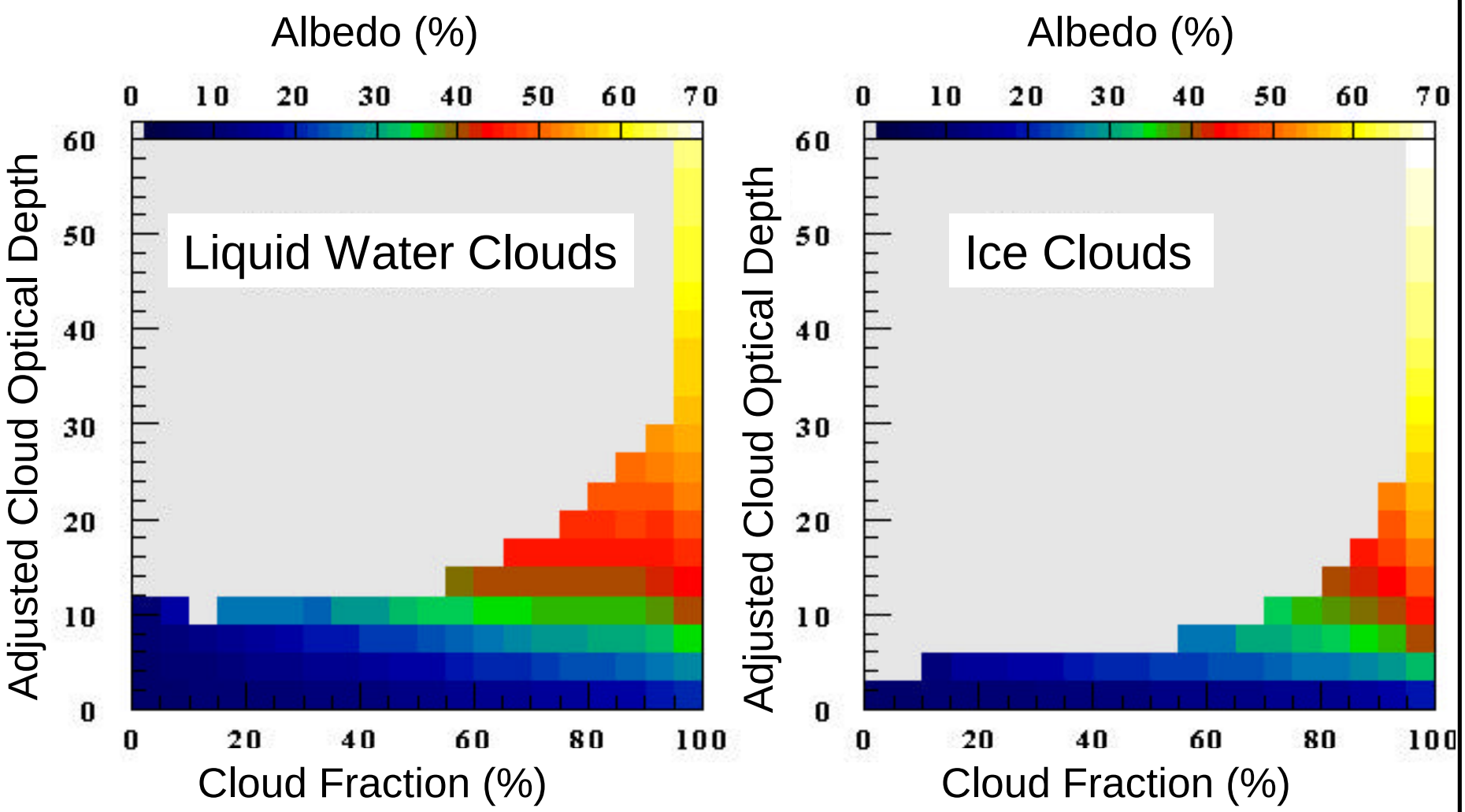
Adjusted Cloud Optical Depth

- "Correction" to 1D retrievals at VIRS pixel scale that forces ensemble cloud optical depth distributions to be self-consistent in all viewing geometries.
  => Assumes true optical depth does not depend on sun-earth-satellite viewing geometry.

- Requires knowledge of a reference cloud optical depth distribution representative of "truth" (e.g. from specific angle/other source).

- Plot τ-percentiles from each VIRS angular bin against τ-percentiles from the reference distribution. Use these curves to apply τ-correction at VIRS pixel scale (via footprint distribution).

SW Albedo by Cloud Fraction & Adjusted Cloud Optical Depth (Ocean)



Preliminary Scene Types for CERES-TRMM LW and Window ADMs

ADM Category		Parameter Stratification	Total
Clear	Ocean	3 Precipitable Water	12
		4 Vertical Temperature Change	
	Land	3 Precipitable Water	36
		4 Vertical Temperature Change	
		3 Surface Emissivity	
	Desert	3 Precipitable Water	36
		4 Vertical Temperature Change	
		3 Surface Emissivity	
Broken Cloud Field (4 intervals)	Ocean/Land	3 Precipitable Water	288 (O) 288 (L)
		6 DT (Sfc-Cloud)	
		4 IR Emissivity	
Overcast	Ocean + Land	3 Precipitable Water	108
		6 DT (Sfc-Cloud)	
		6 IR Emissivity	

Clear Ocean TOA Flux From CERES

- Define ADMs for 4 discrete wind speed intervals (m s^{-1}):
  < 3.5; 3.5 - 5.5; 5.5 - 7.5; > 7.5

- Estimate instantaneous flux/albedo using ADM:

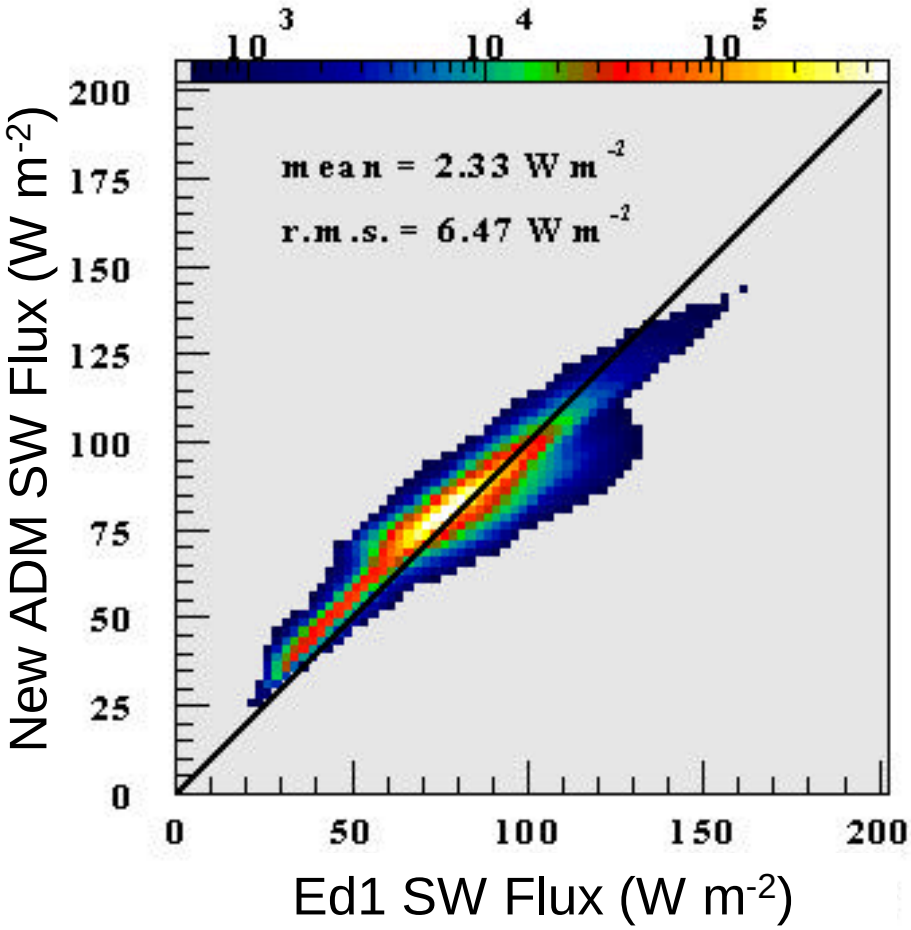
$$\hat{A} = \frac{r(\theta_o, \theta, \phi)}{R_j(w_k, \theta_o, \theta, \phi)}$$

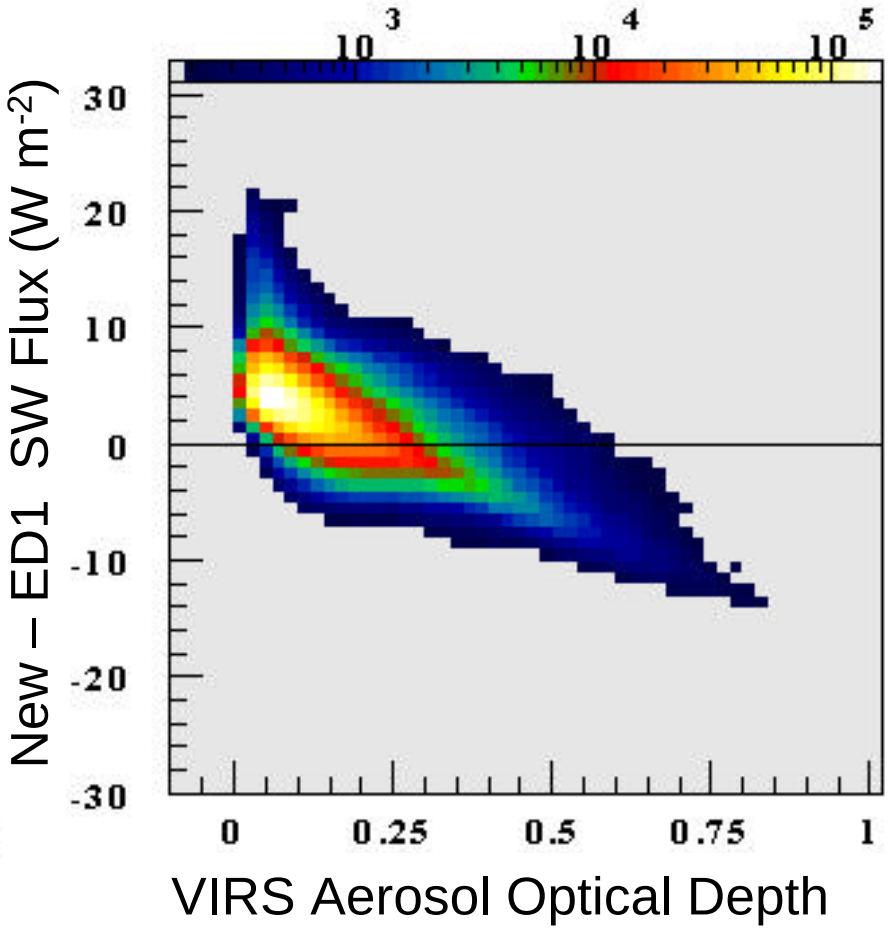
- Account for aerosol optical depth variations theoretically

$$\hat{A}' = \hat{A}\left\{\frac{R^{th}(w_k, I^{avg})}{R^{th}(w_k, I^{obs})}\right\}$$

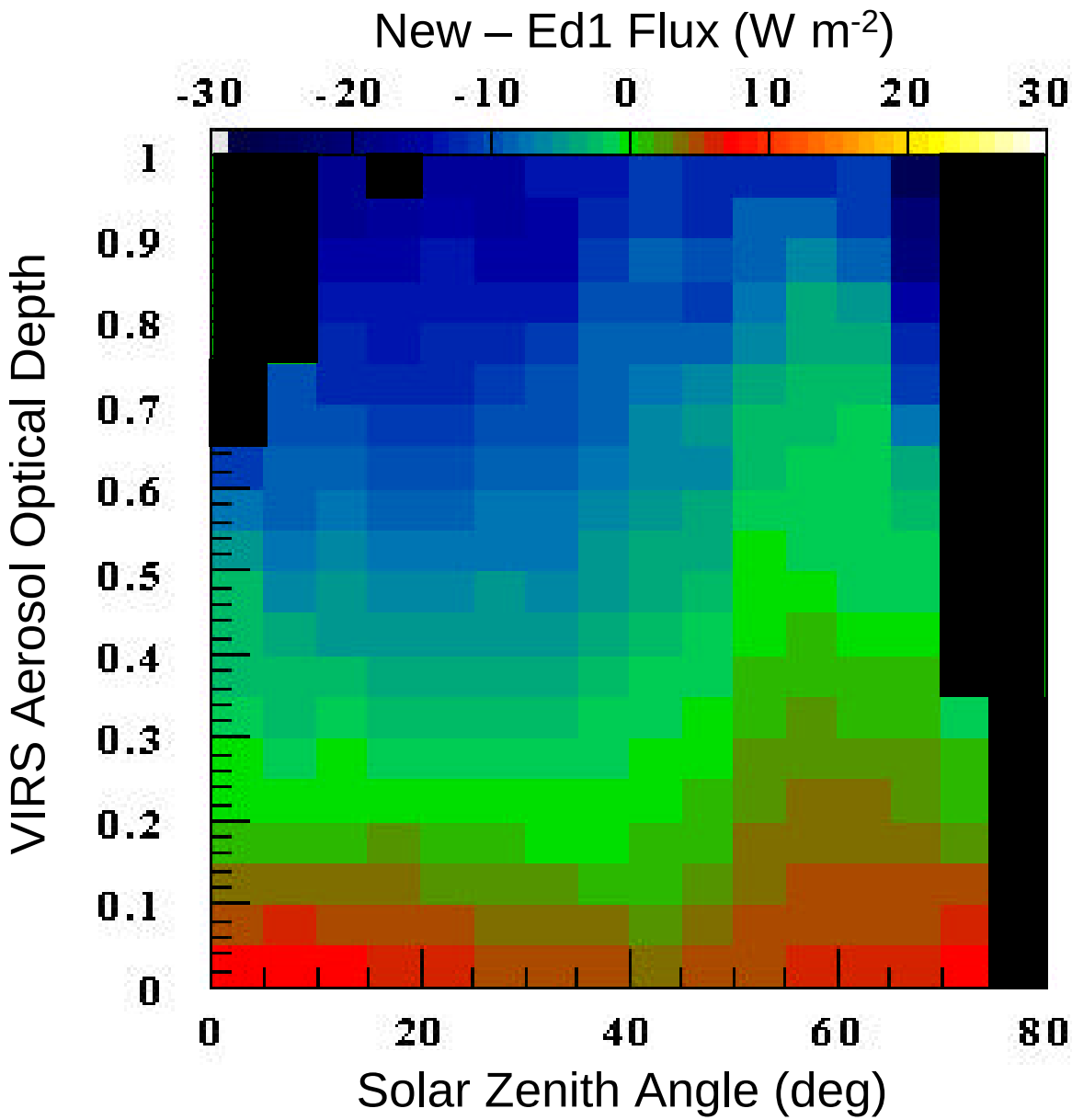
where $R^{th}(w_k, I^{obs})$ is a theoretical anisotropic factor inferred from an instantaneous observation and $R^{th}(w_k, I^{avg})$ is determined from the average radiance used to construct the ADM class.

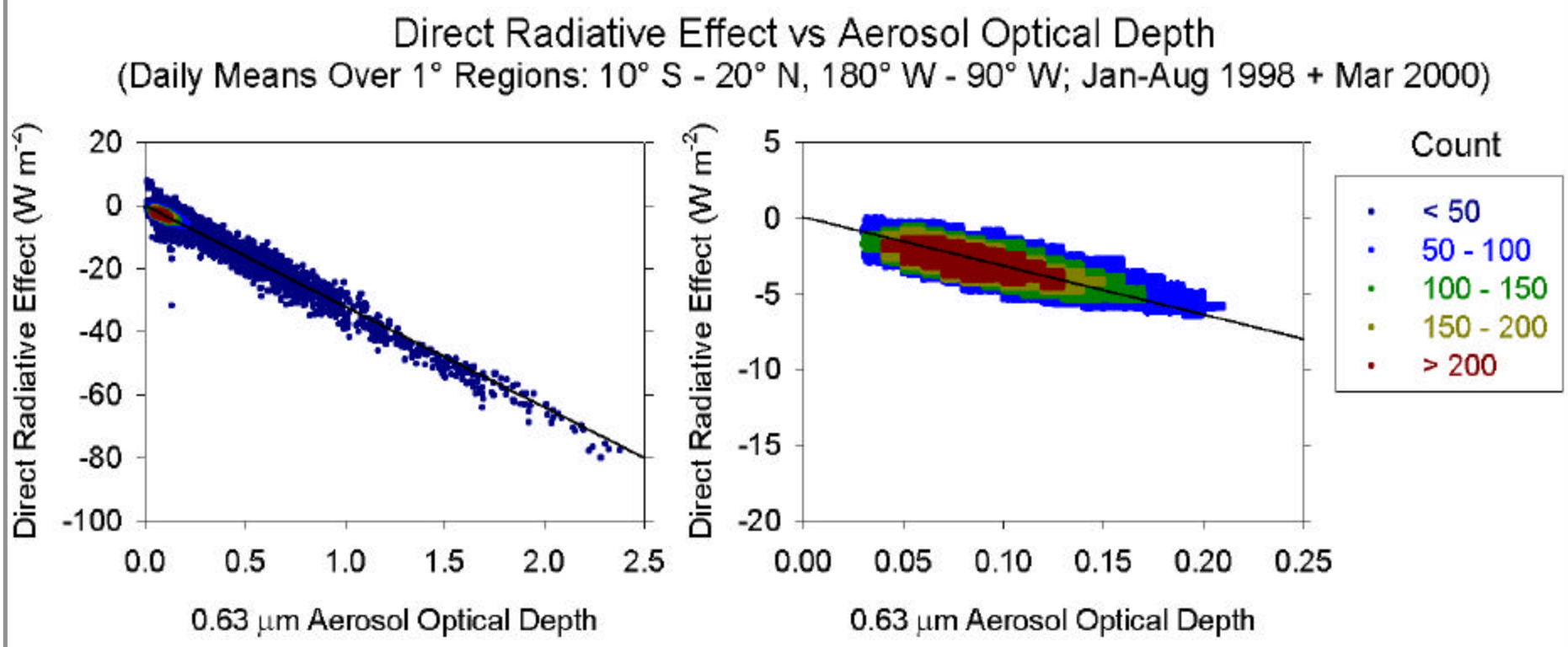
Clear Ocean Fluxes: New ADMs vs Edition 1 (9 Months; All Solar Zenith Angles)



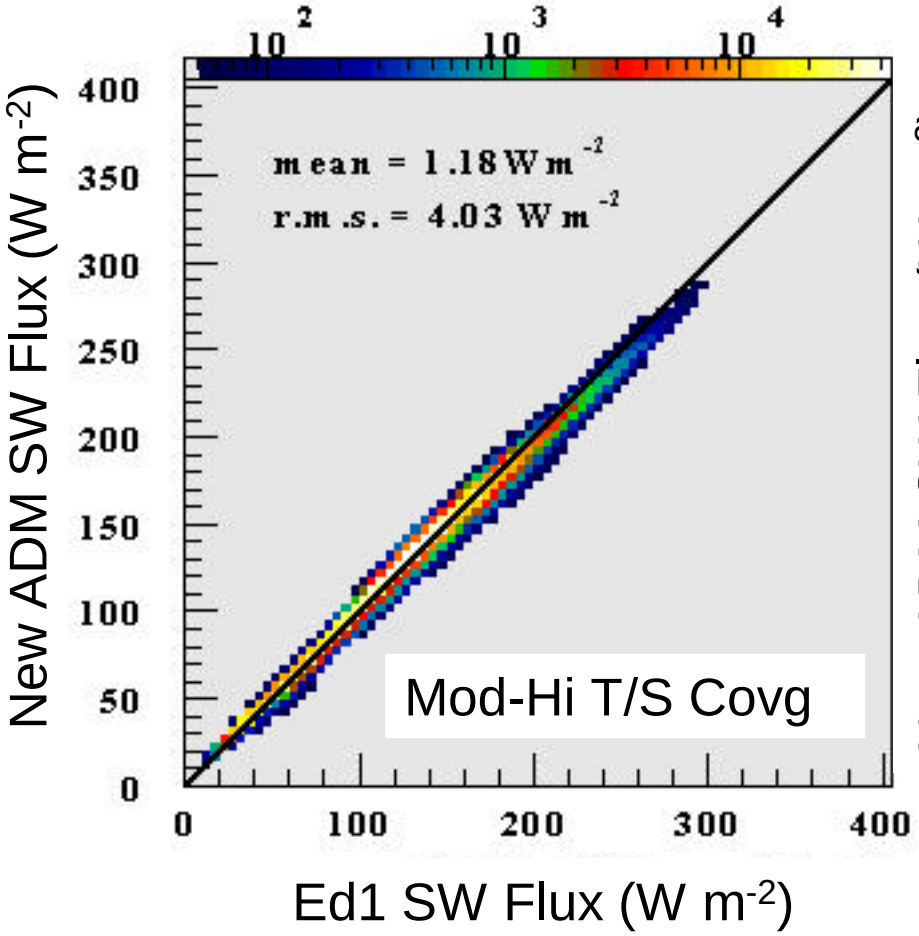


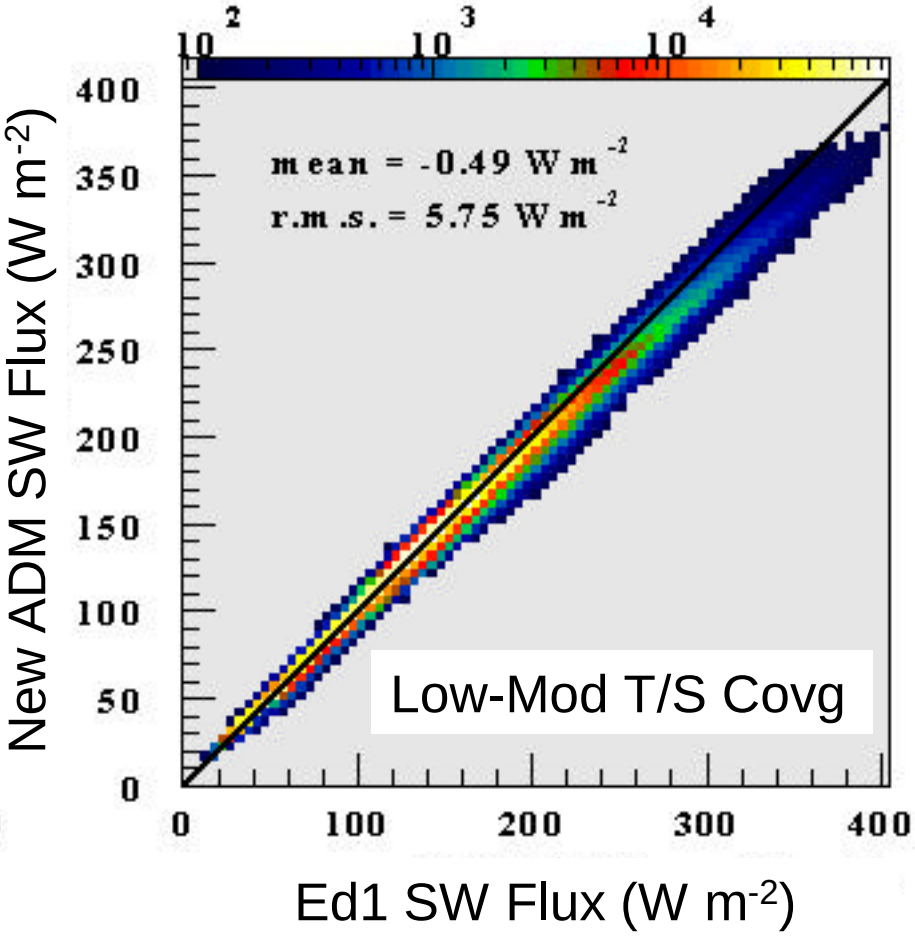
Clear Ocean Fluxes: New ADMs vs Edition 1 Flux



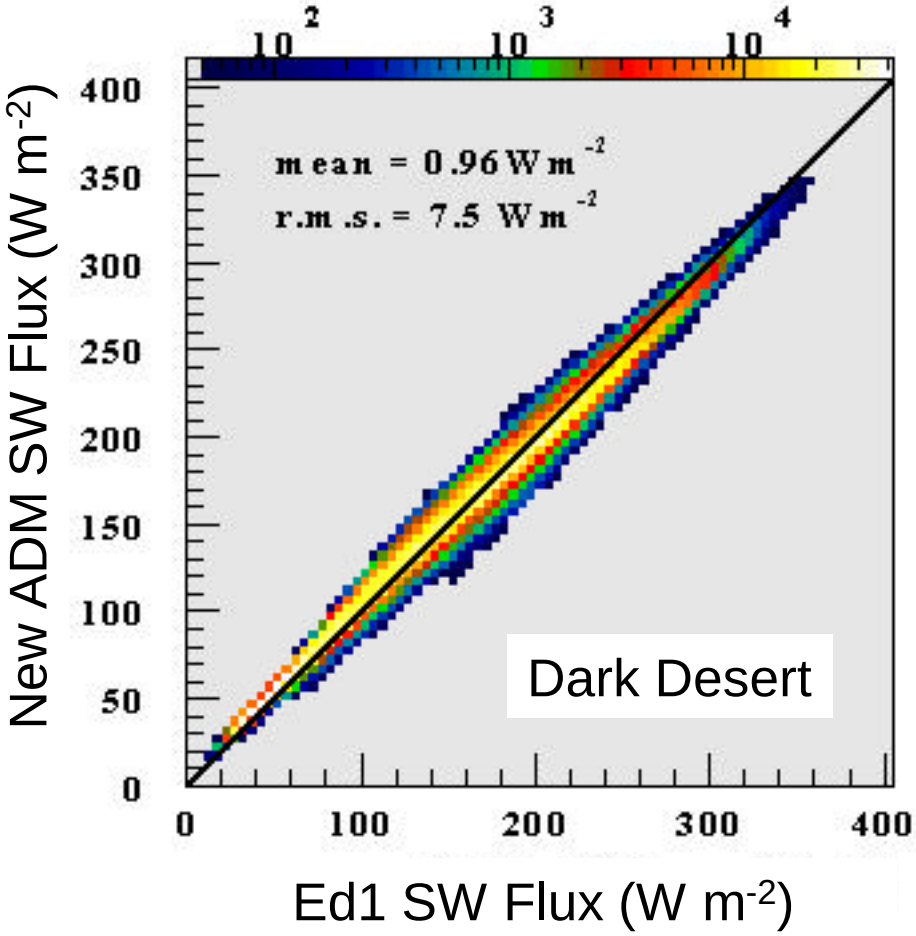

Direct Radiative Effect vs Aerosol Optical Depth
(Daily Means Over 1° Regions: 10° S - 20° N, 180° W - 90° W; Jan-Aug 1998 + Mar 2000)
Direct Radiative Effect (W m-2)
20
0
-20
-40
-60
-80
-100
0.0
0.5
1.0
1.5
2.0
2.5
0.63 μm Aerosol Optical Depth
Direct Radiative Effect (W m-2)
5
0
-5
-10
-15
-20
0.00
0.05
0.10
0.15
0.20
0.25
0.63 μm Aerosol Optical Depth
Count
< 50
50 - 100
100 - 150
150 - 200
> 200

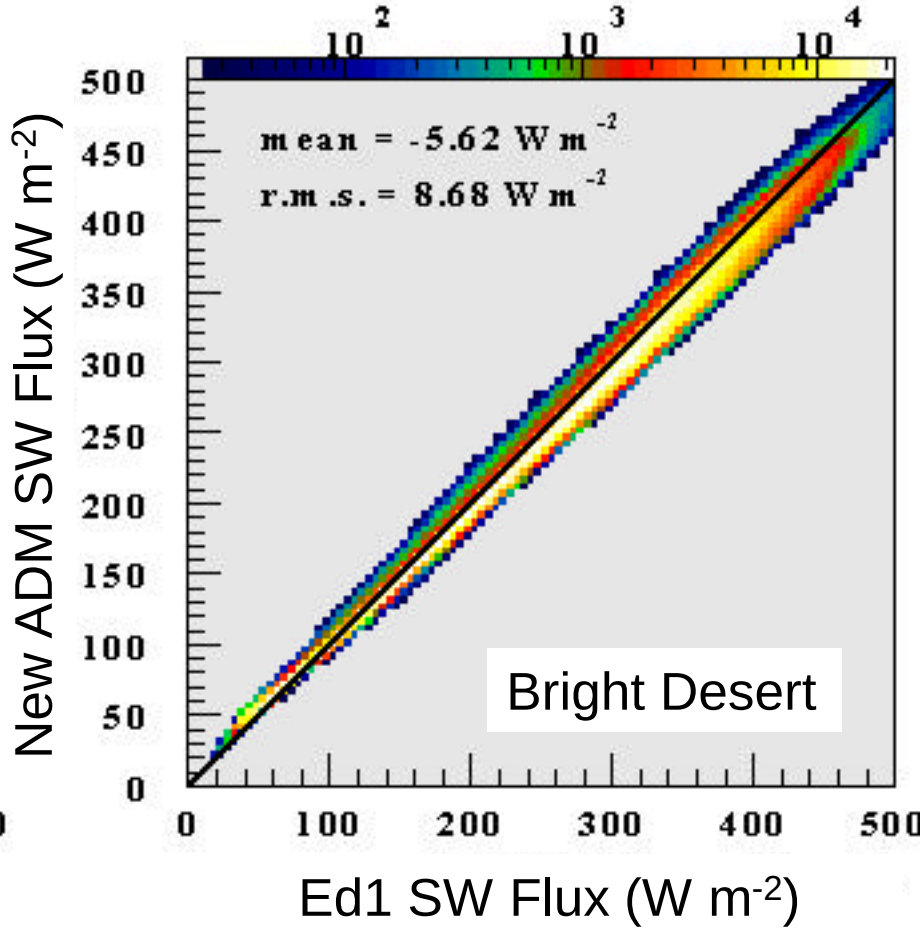
Clear Land Fluxes: New ADMs vs Edition 1 (9 Months; All Solar Zenith Angles)



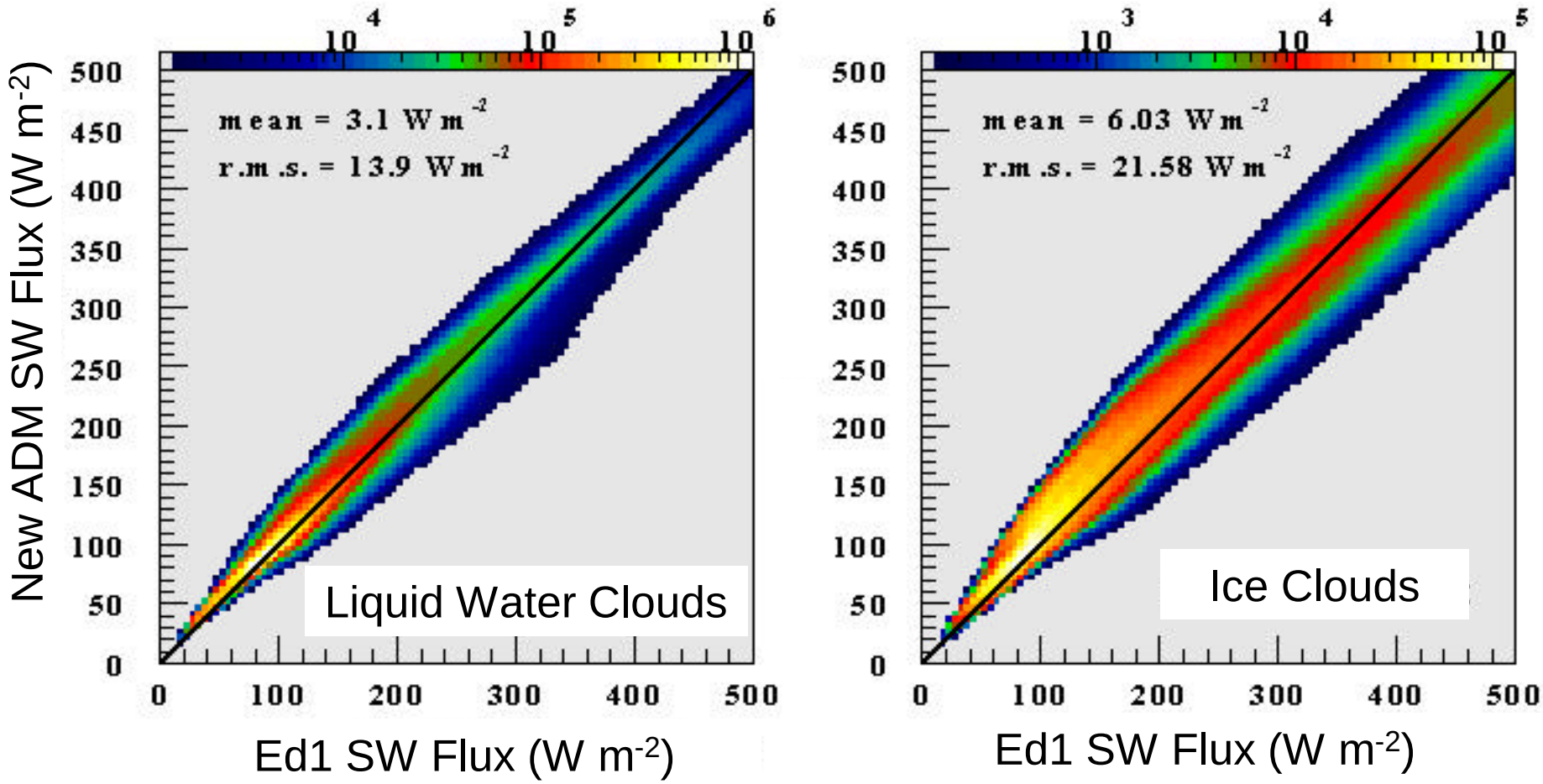


Clear Desert Fluxes: New ADMs vs Edition 1 (9 Months; All Solar Zenith Angles)

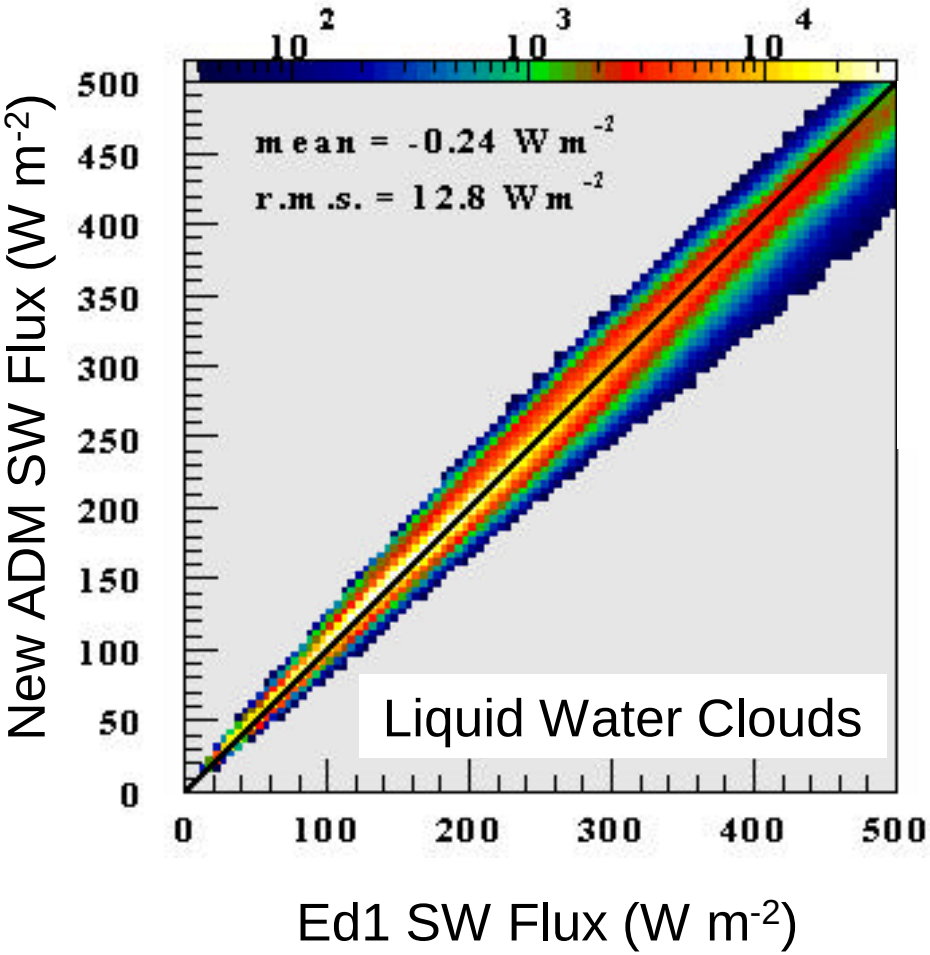


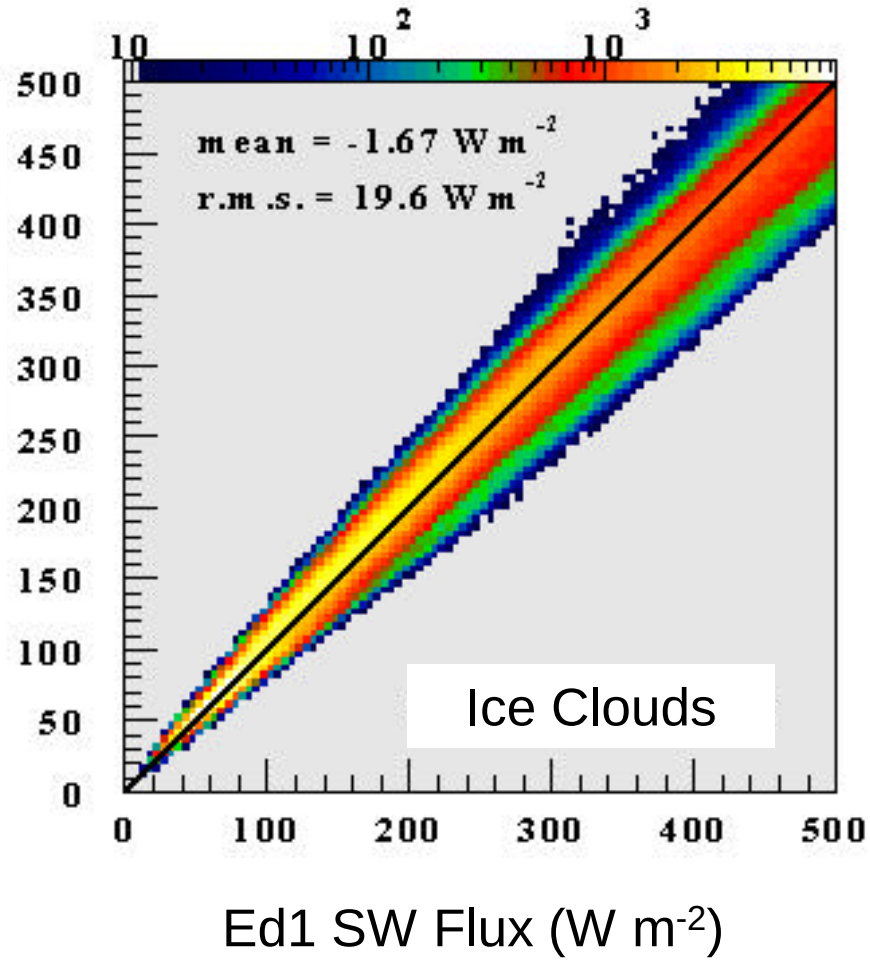


Clouds over Ocean: New ADMs vs Edition 1 (9 Months; All θ_o)

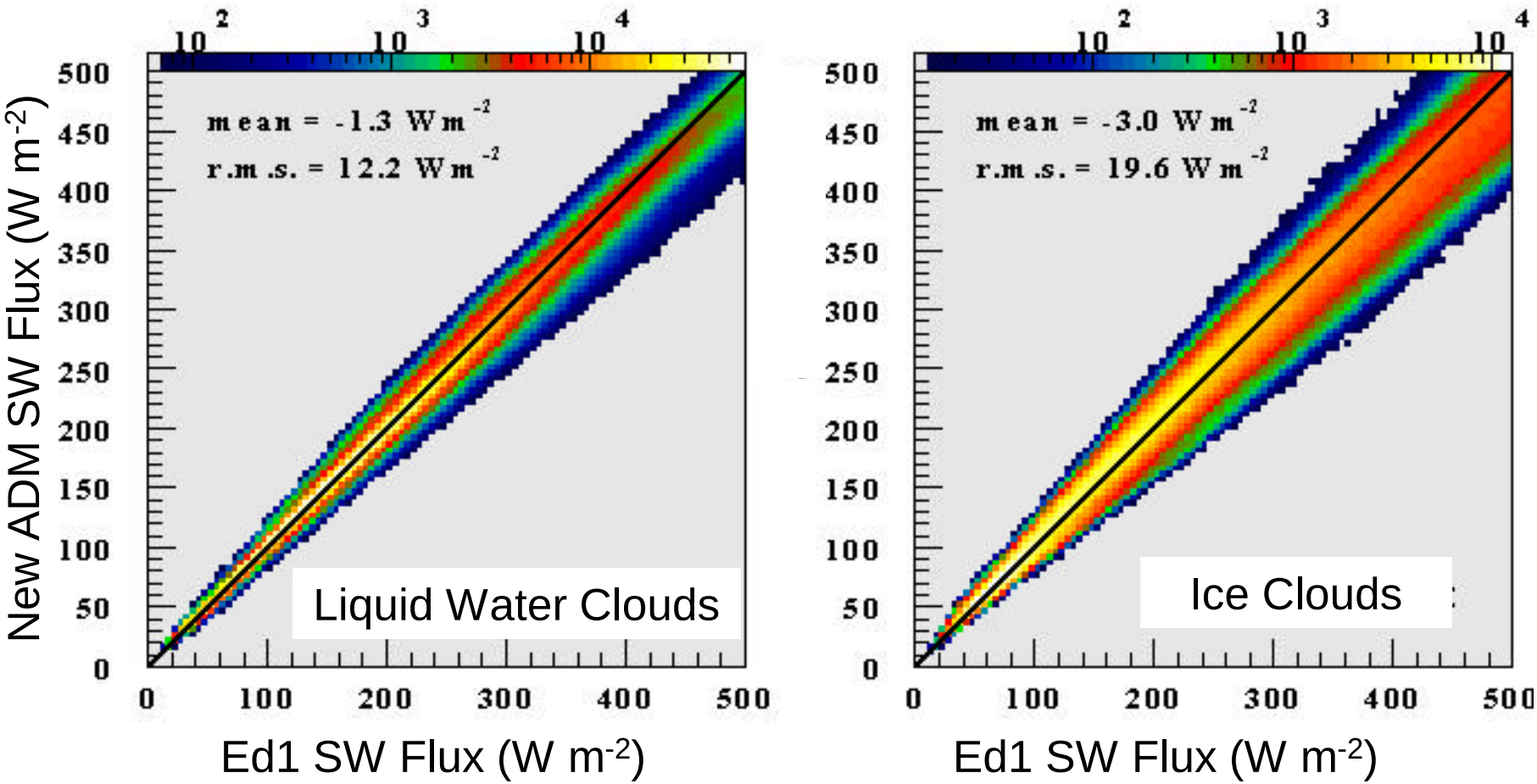


Clouds over Mod-High Tree/Shrub Land Covg:
New ADMs vs Edition 1(9 Months; All θ_o)



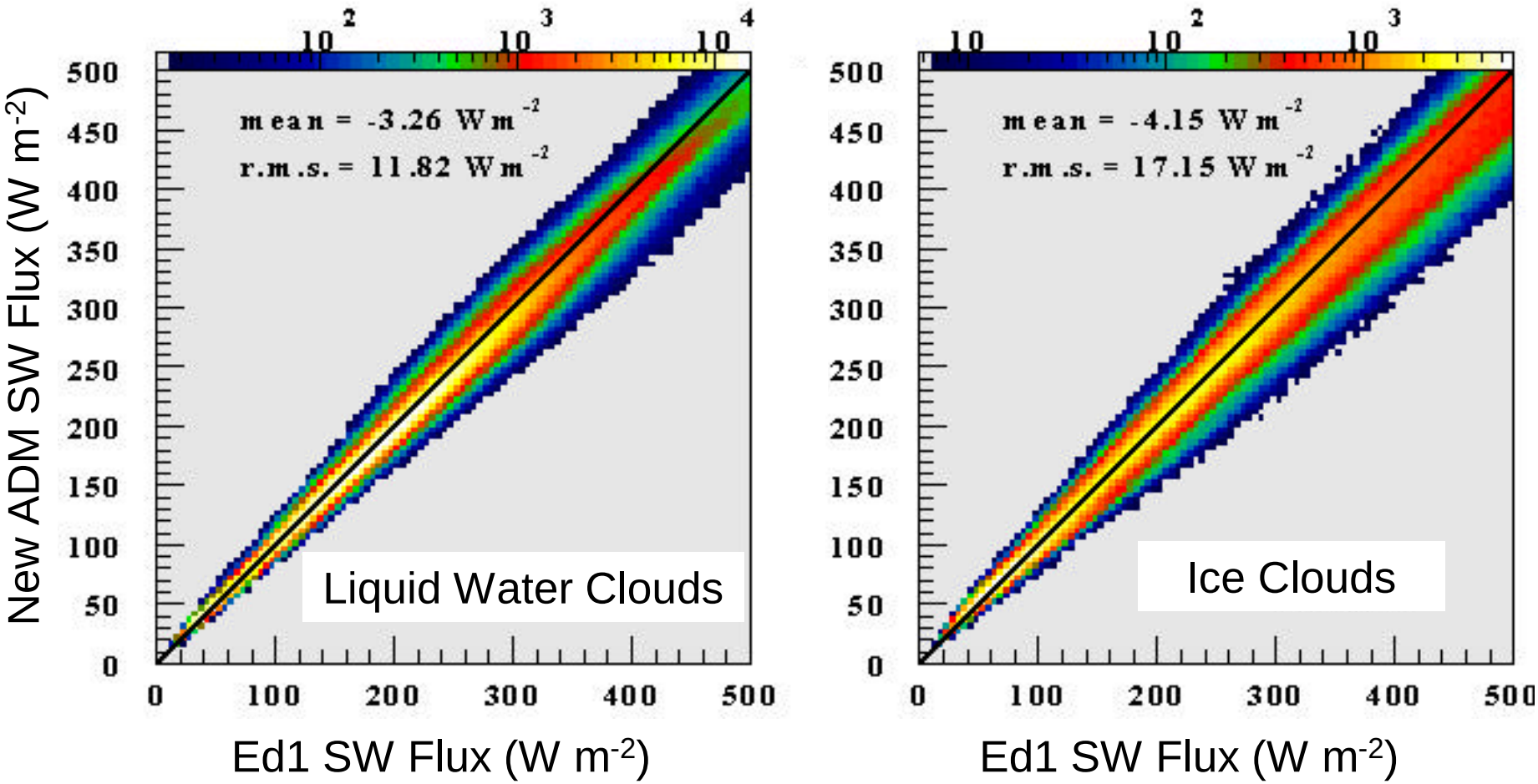


Clouds over Low-Mod Tree/Shrub Land Covg:
New ADMs vs Edition 1(9 Months; All θ_o)



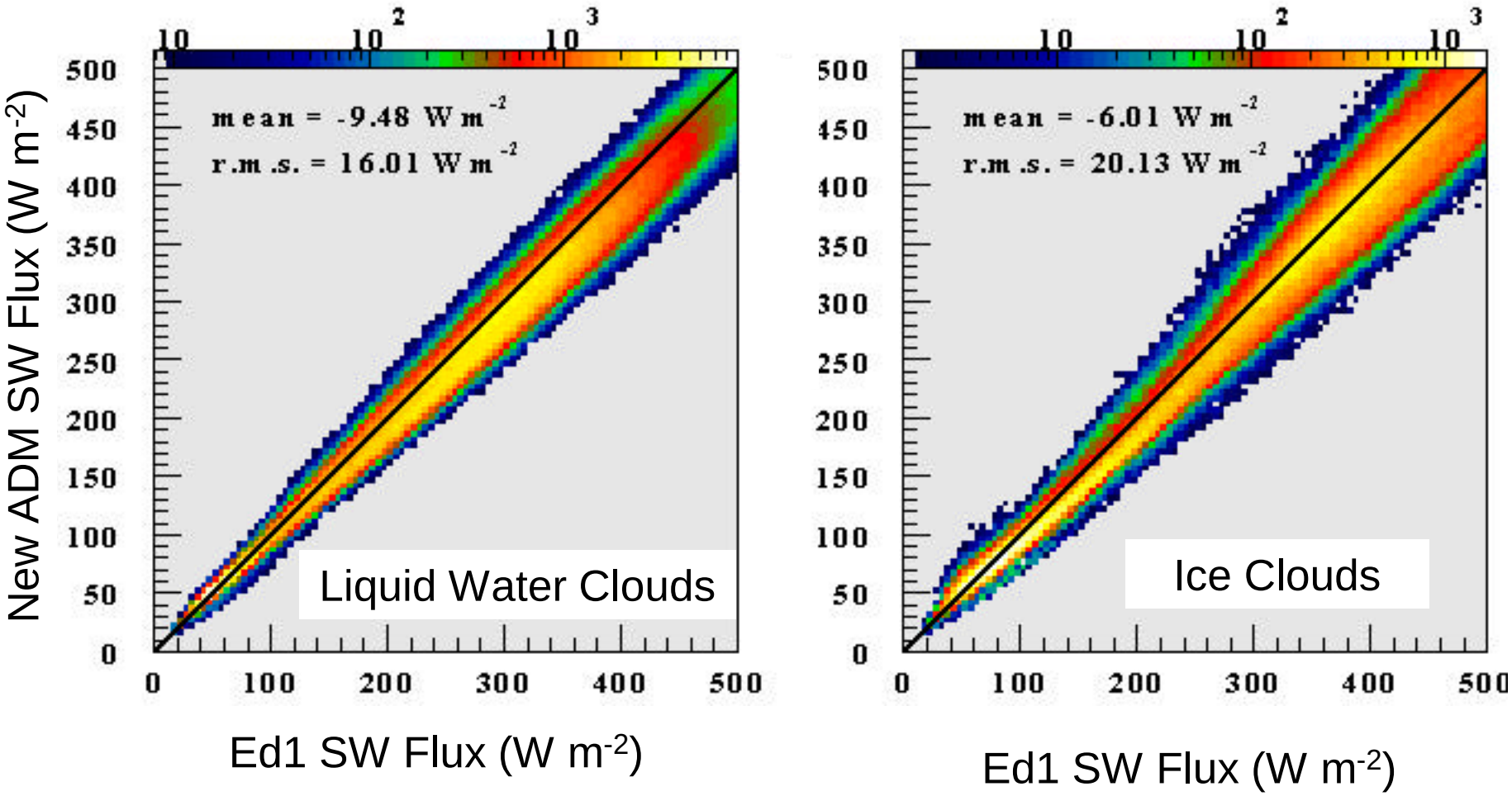
Clouds over Dark Desert :

New ADMs vs Edition 1(9 Months; All θ_o)

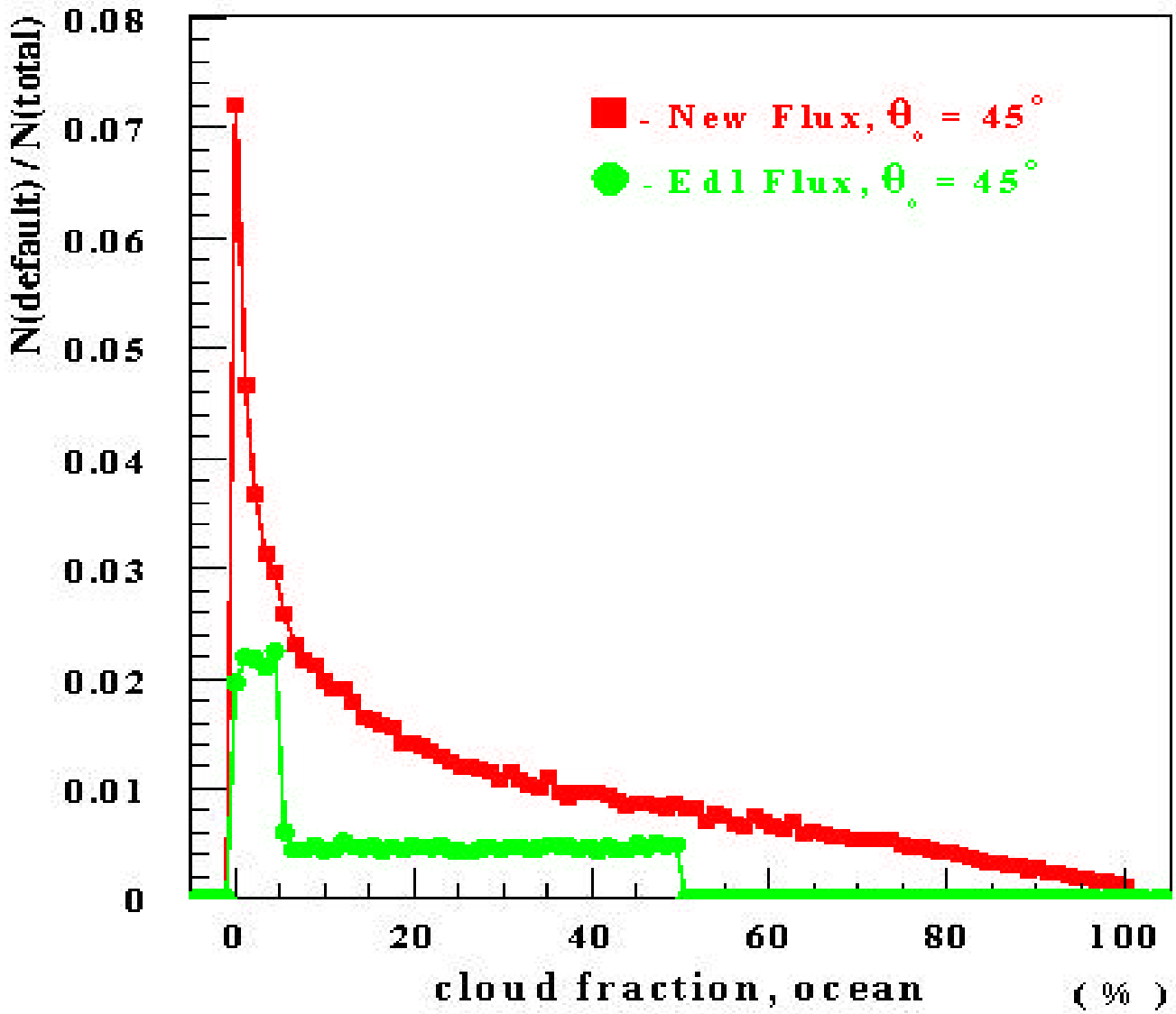


Clouds over Bright Desert :

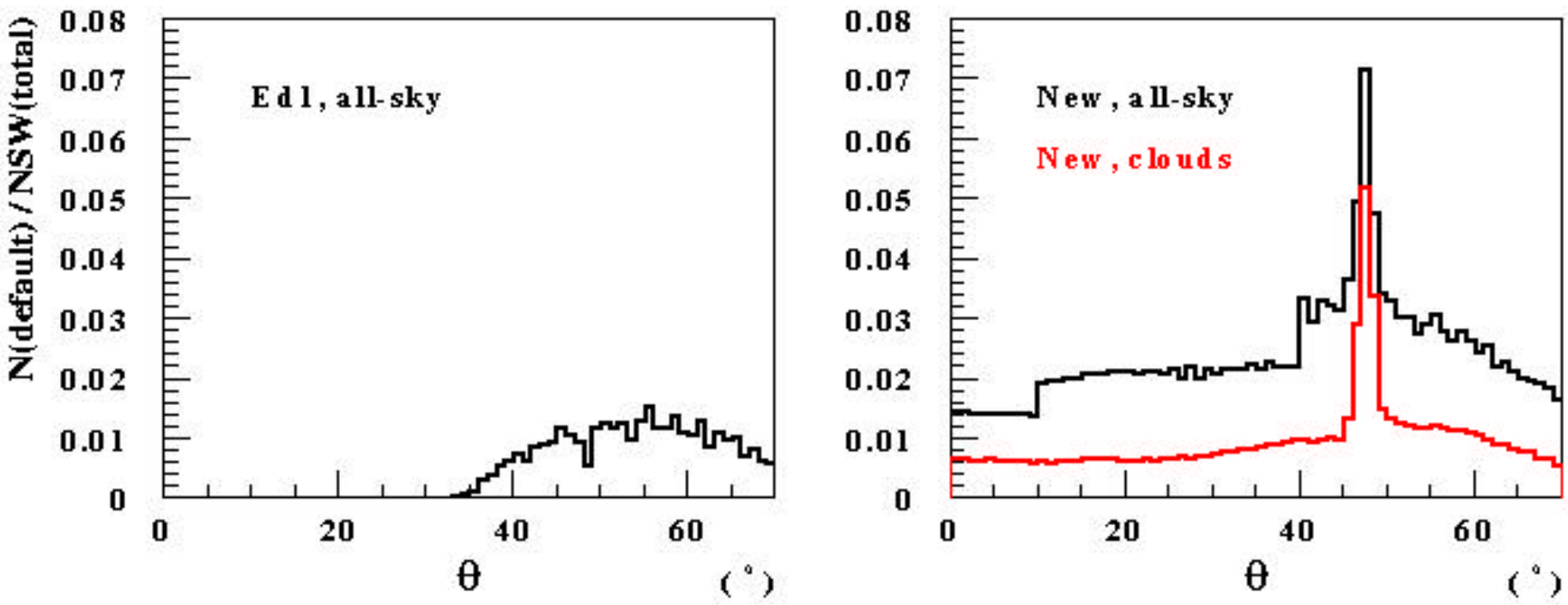
New ADMs vs Edition 1(9 Months; All θ_o)



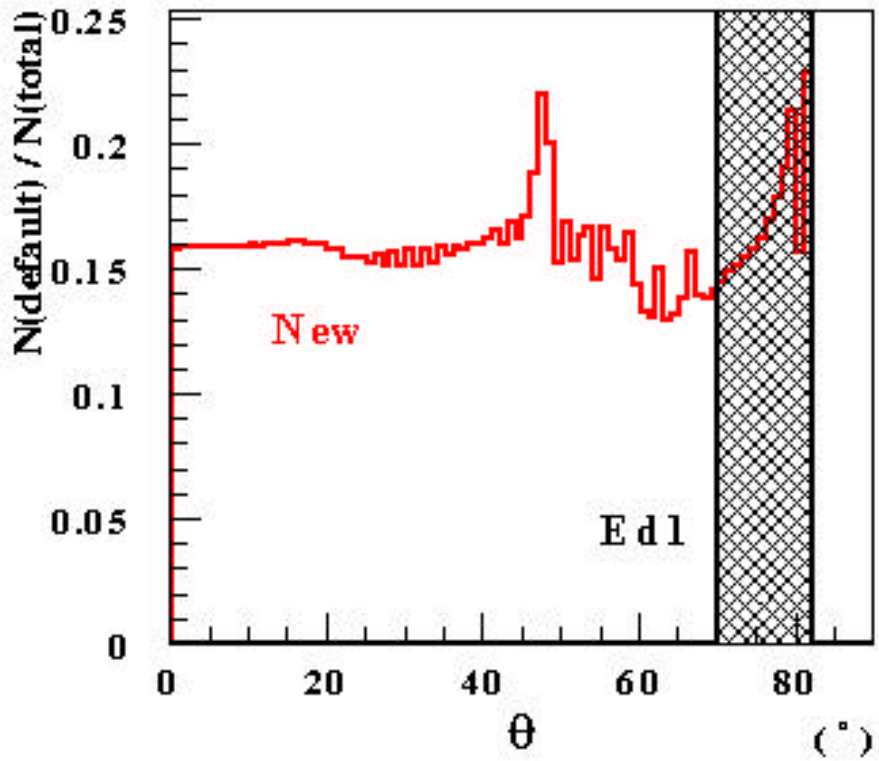
Relative Frequency of SW Flux Defaults by Cloud Fraction (θ_o=40°-50°)



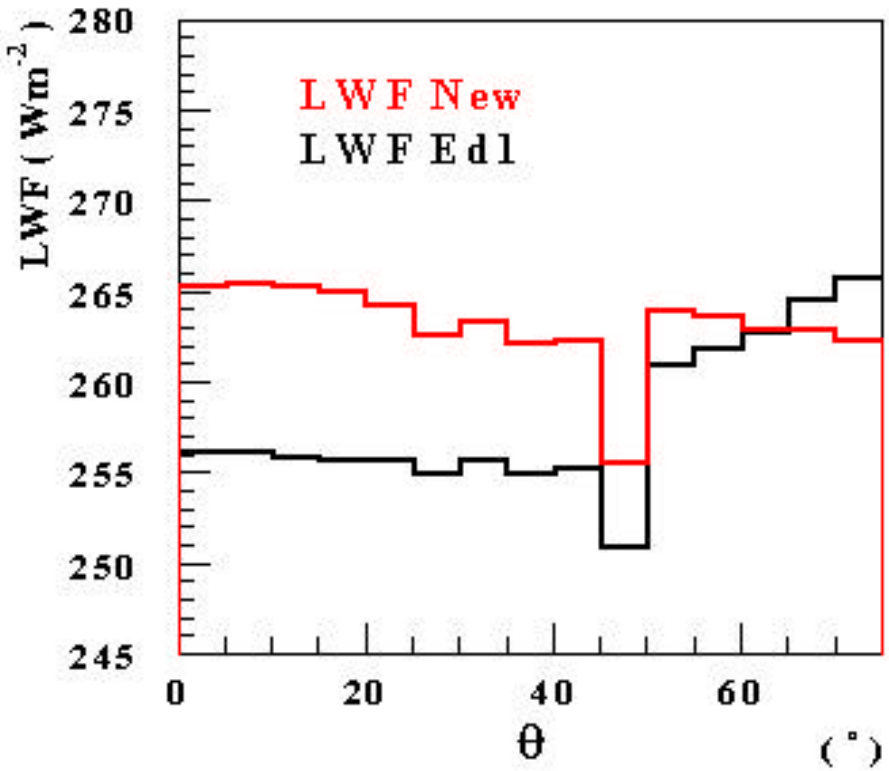
Relative Frequency of SW Flux Defaults by Viewing Zenith Angle (θ_o=40°-50°)



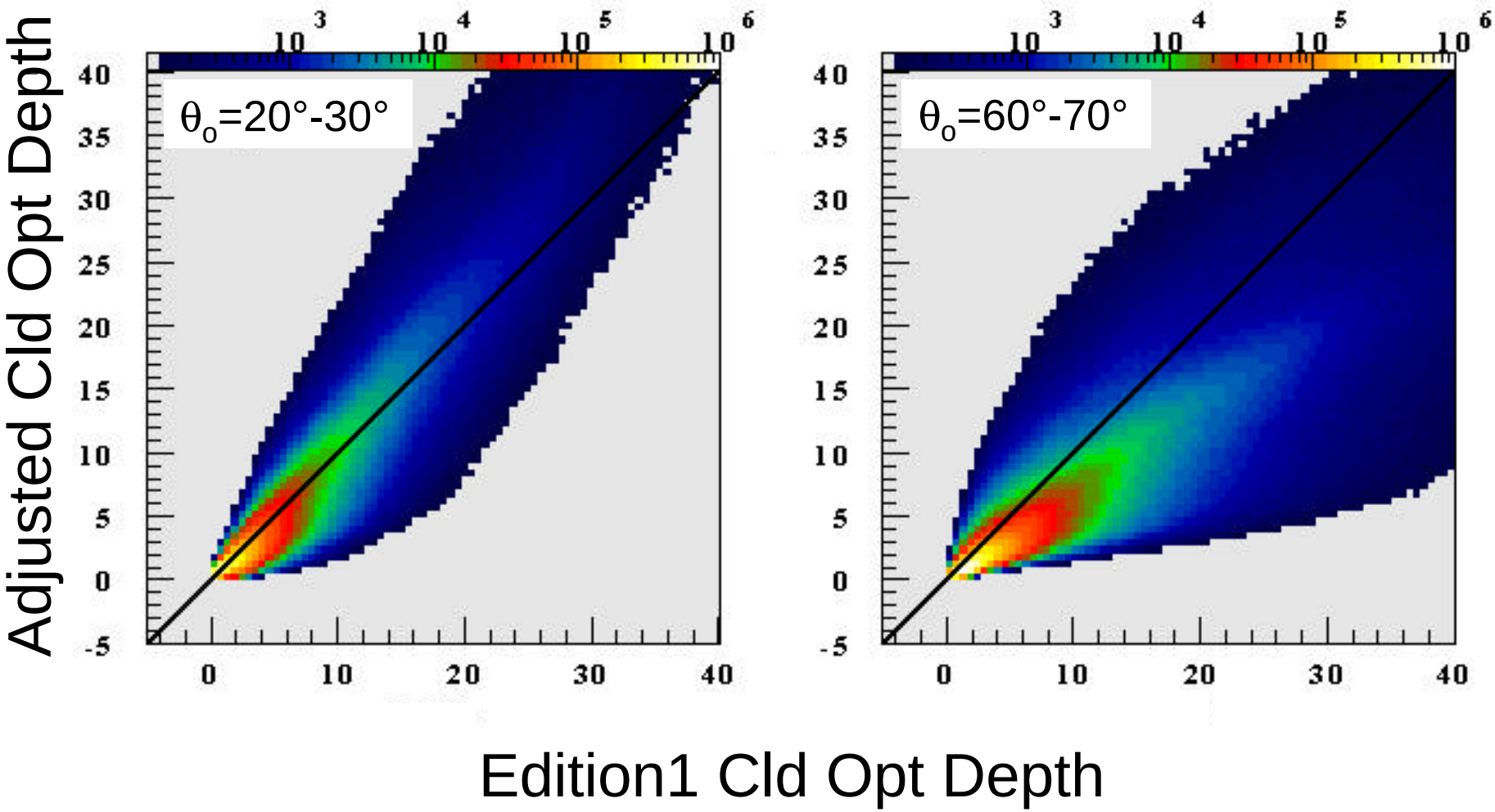
Relative Frequency of LW Flux Defaults by Viewing Zenith Angle

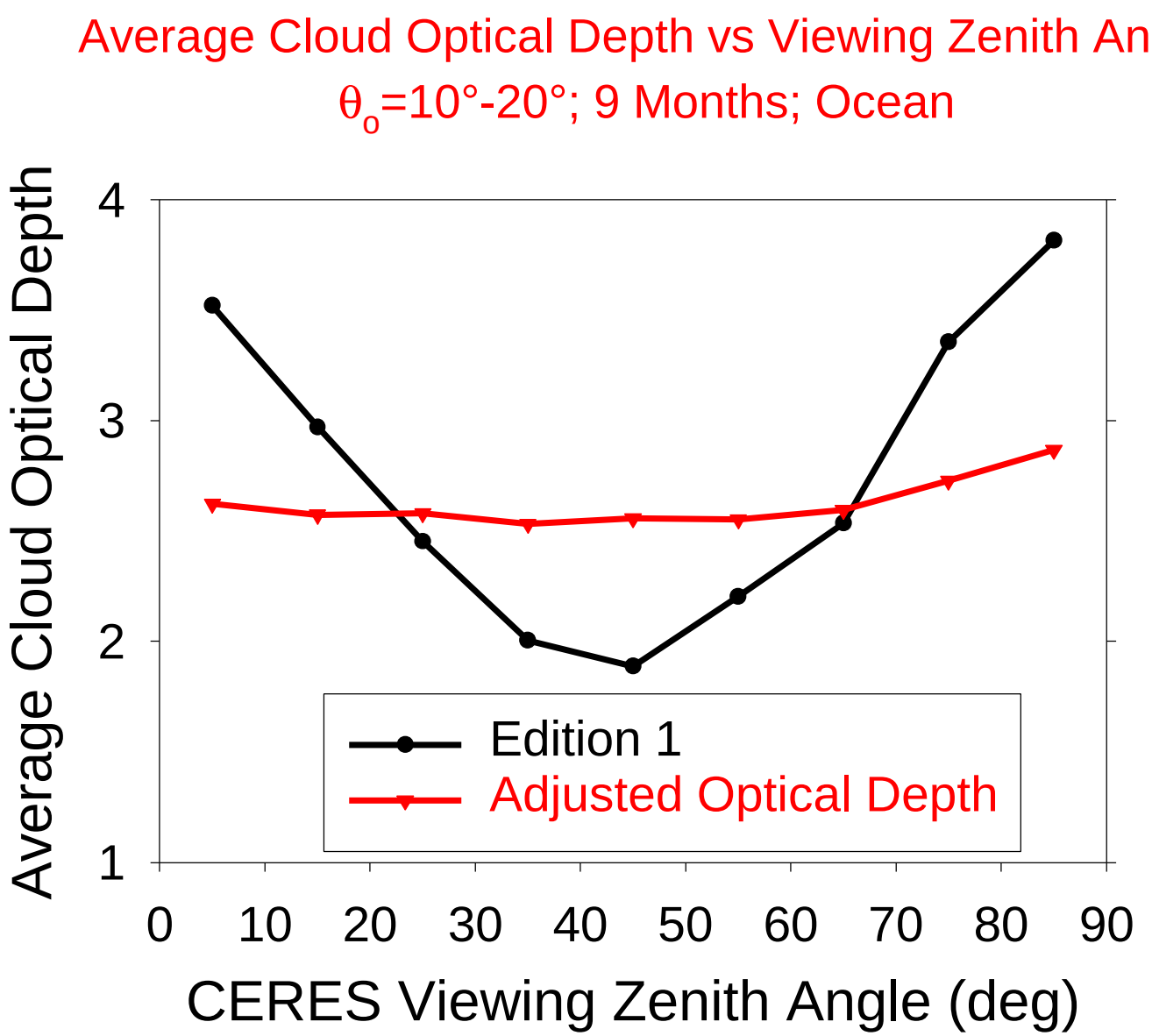


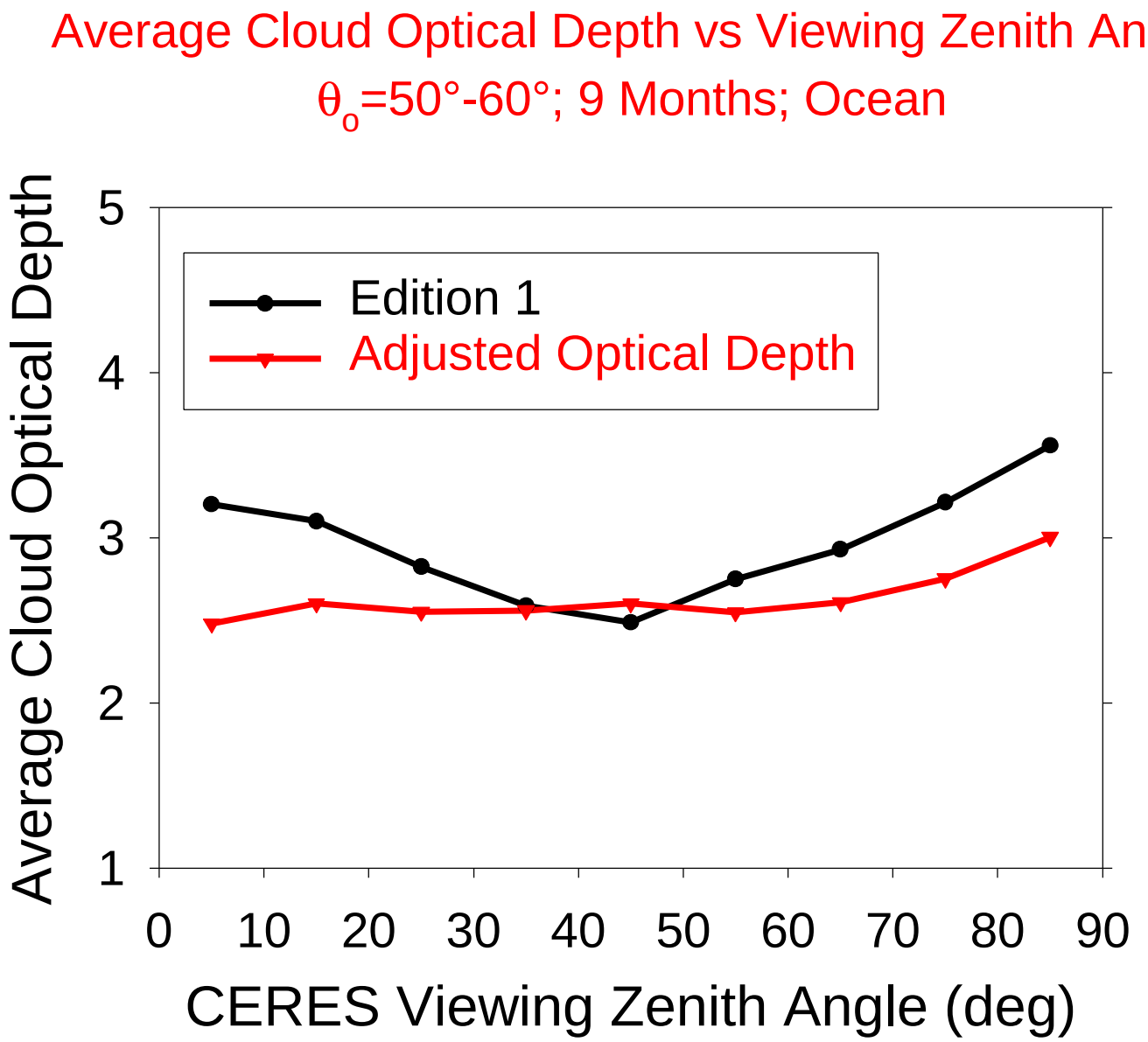
Avg LW Flux by Viewing Zenith Angle

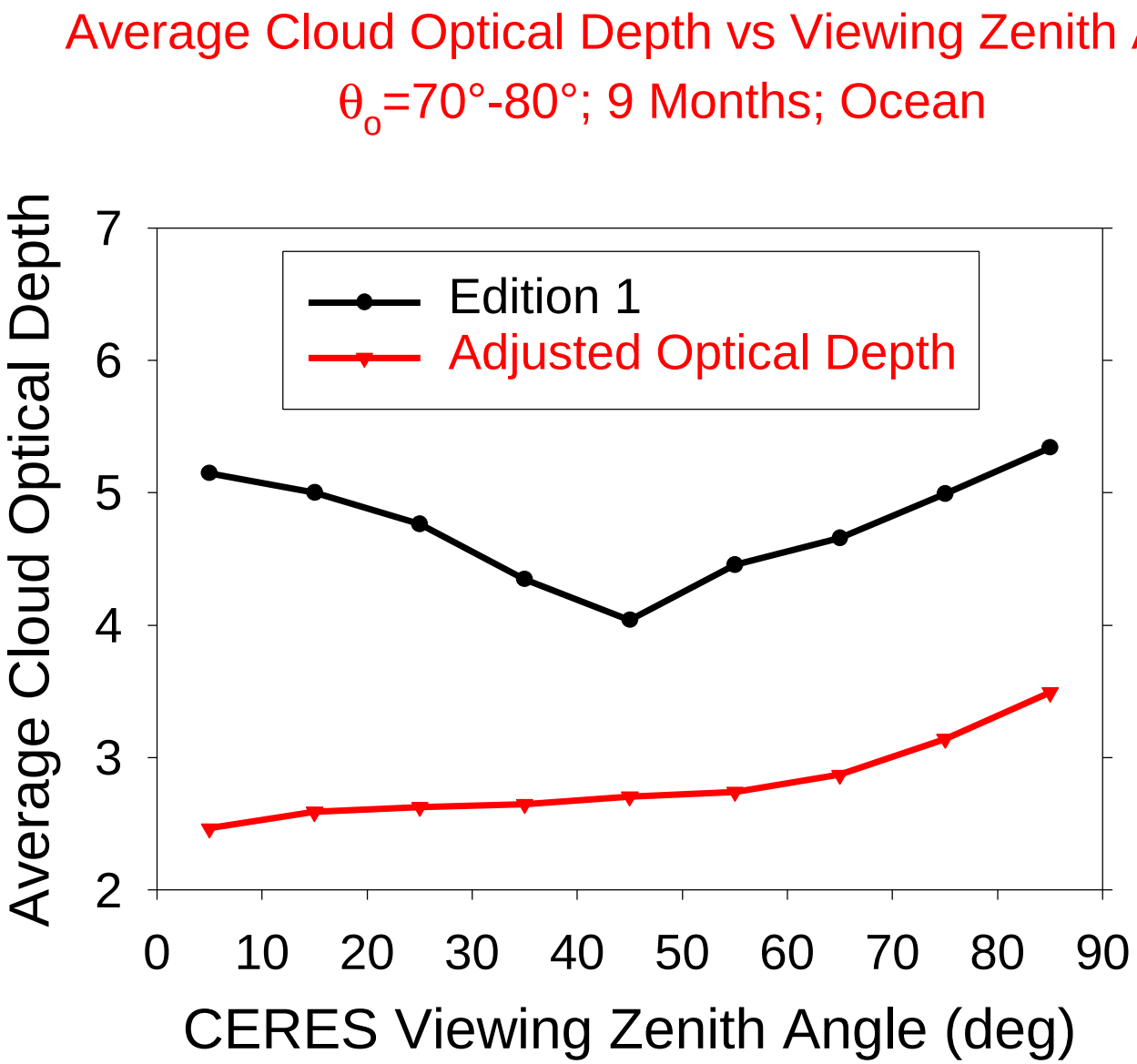


Adjusted vs Edition1 Cloud Optical Depth (9 Months)

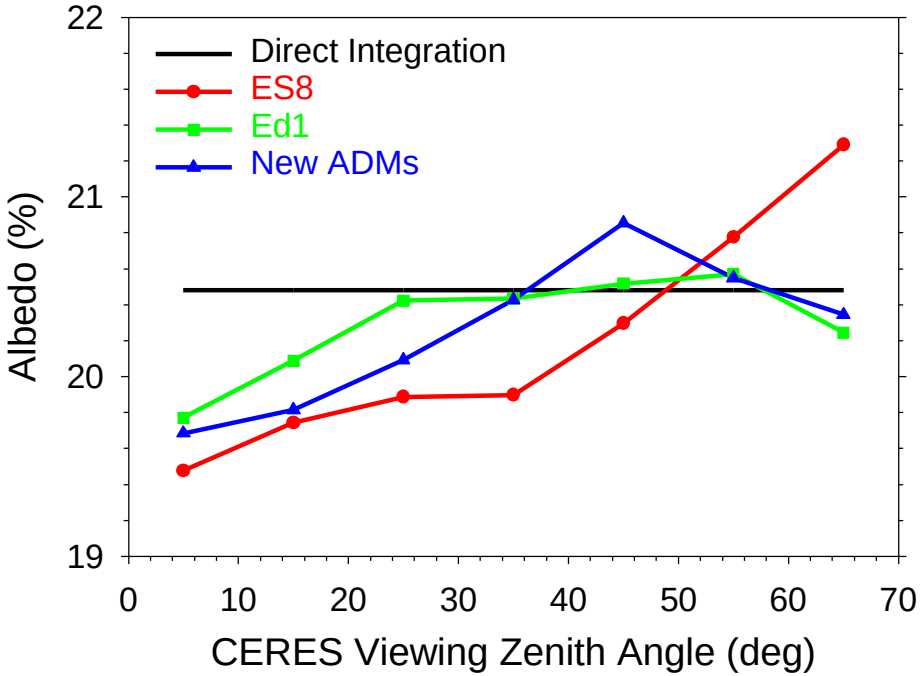


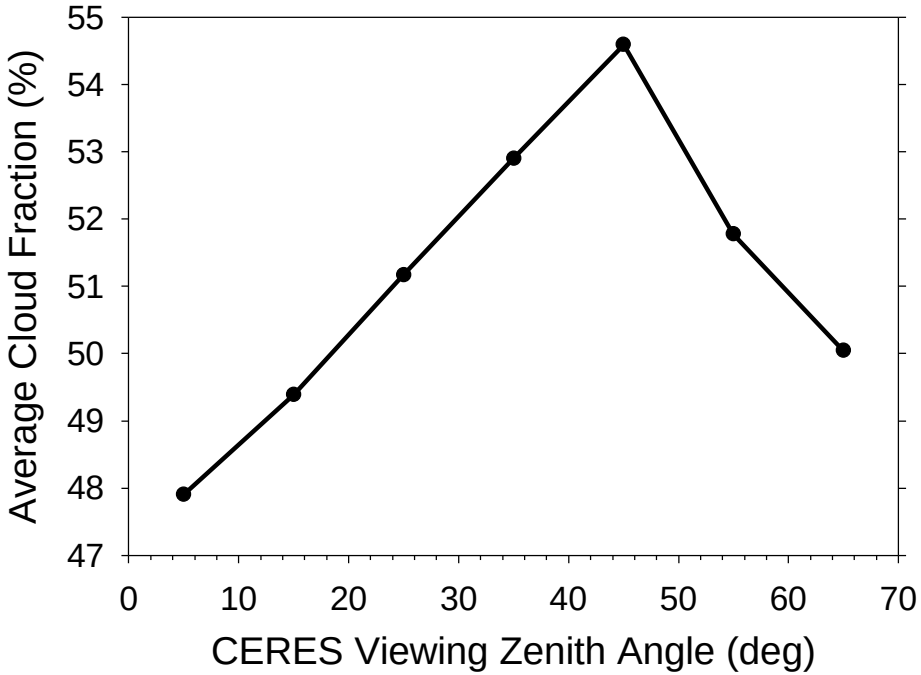

Average Cloud Optical Depth vs Viewing Zenith Angle
θ_o=10°-20°; 9 Months; Ocean
Average Cloud Optical Depth
4
3
2
1
0
10
20
30
40
50
60
70
80
90
CERES Viewing Zenith Angle (deg)
Edition 1
Adjusted Optical Depth


Average Cloud Optical Depth vs Viewing Zenith Angle
θ_o=50°-60°; 9 Months; Ocean
Edition 1
Adjusted Optical Depth
Average Cloud Optical Depth
5
4
3
2
1
0
10
20
30
40
50
60
70
80
90
CERES Viewing Zenith Angle (deg)

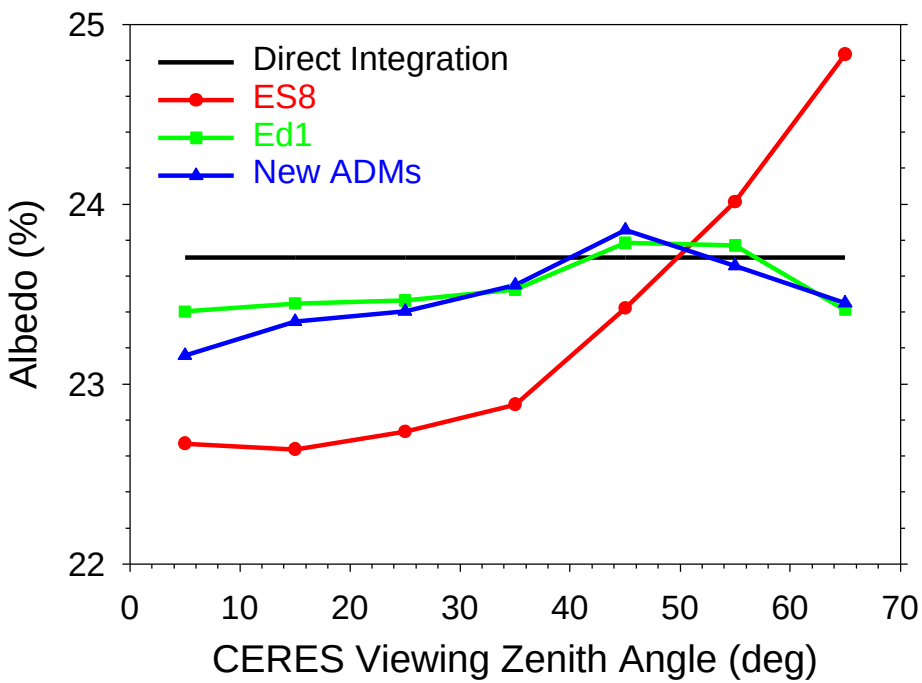

Average Cloud Optical Depth vs Viewing Zenith Angle
θ_o=70°-80°; 9 Months; Ocean
Edition 1
Adjusted Optical Depth
Average Cloud Optical Depth
7
6
5
4
3
2
0
10
20
30
40
50
60
70
80
90
CERES Viewing Zenith Angle (deg)

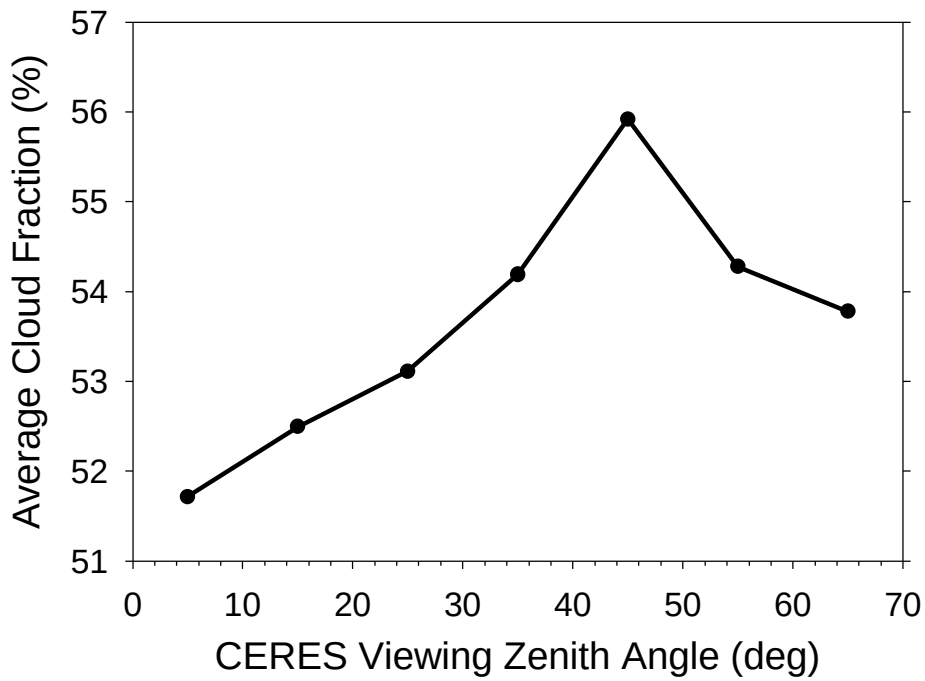
All-Sky Albedo Viewing Zenith Angle Consistency Tests
θ_o=20°-30°; 9 Months; FAPS+RAPS+Alongtrack; All Tropics



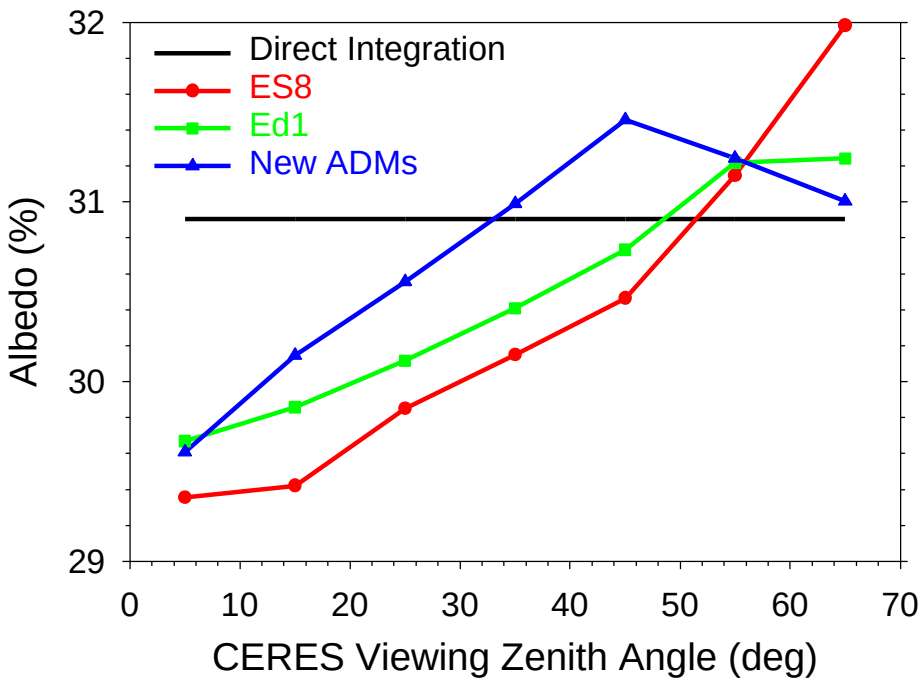


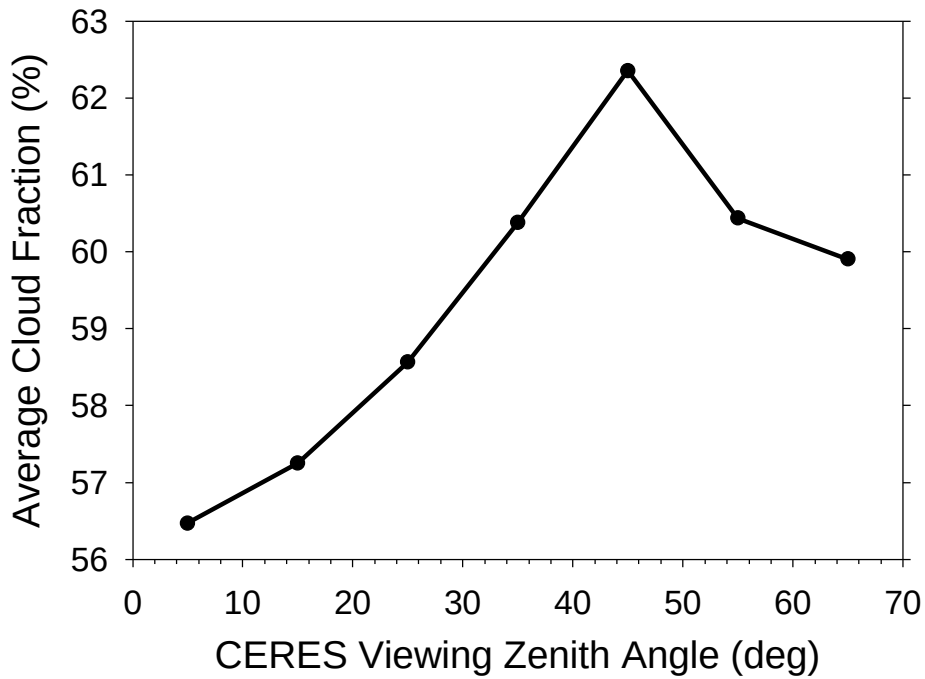
All-Sky Albedo Viewing Zenith Angle Consistency Tests
θ_o=40°-50°; 9 Months; FAPS+RAPS+Alongtrack; All Tropics





All-Sky Albedo Viewing Zenith Angle Consistency Tests
θ_o=60°-70°; 9 Months; FAPS+RAPS+Alongtrack; All Tropics



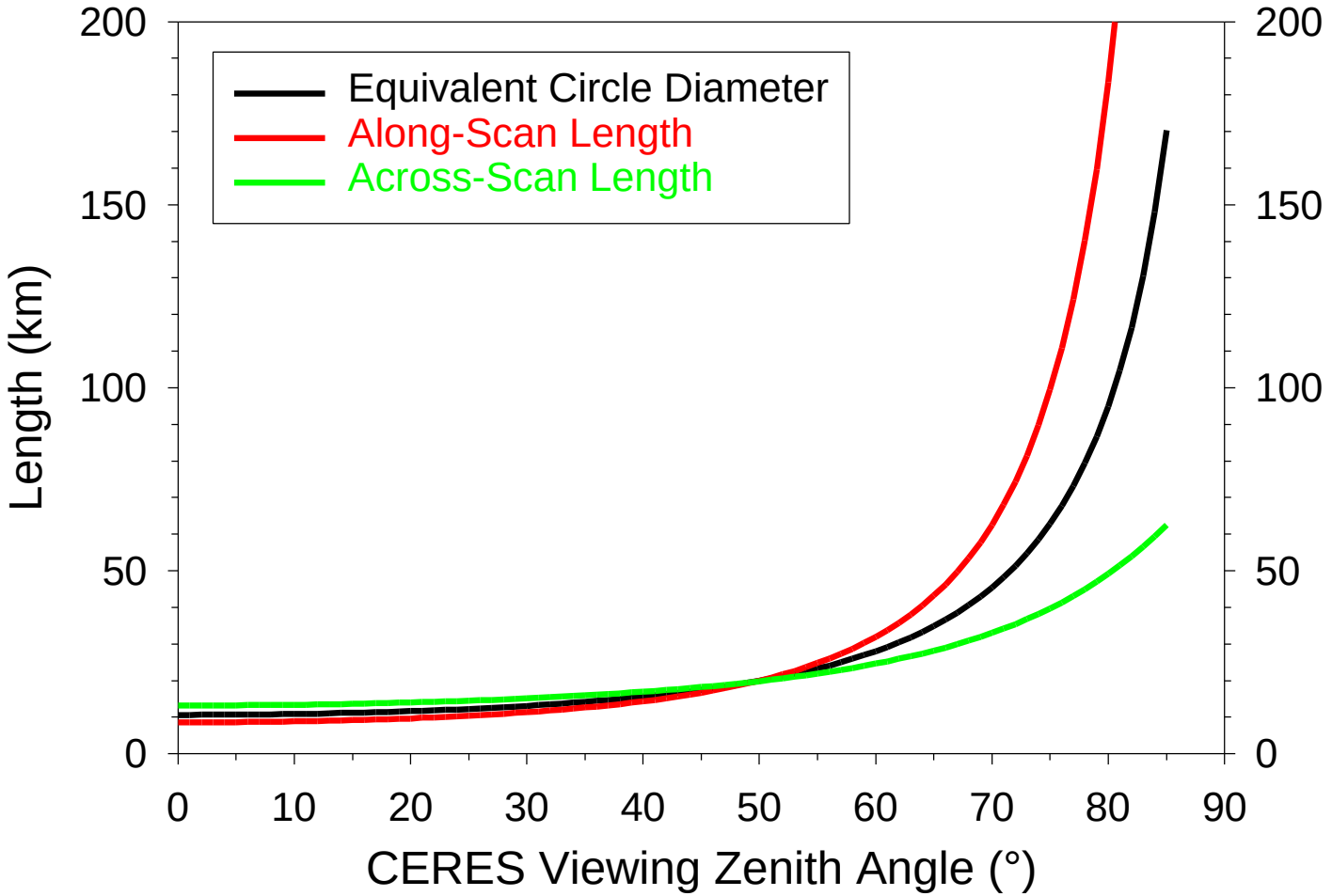


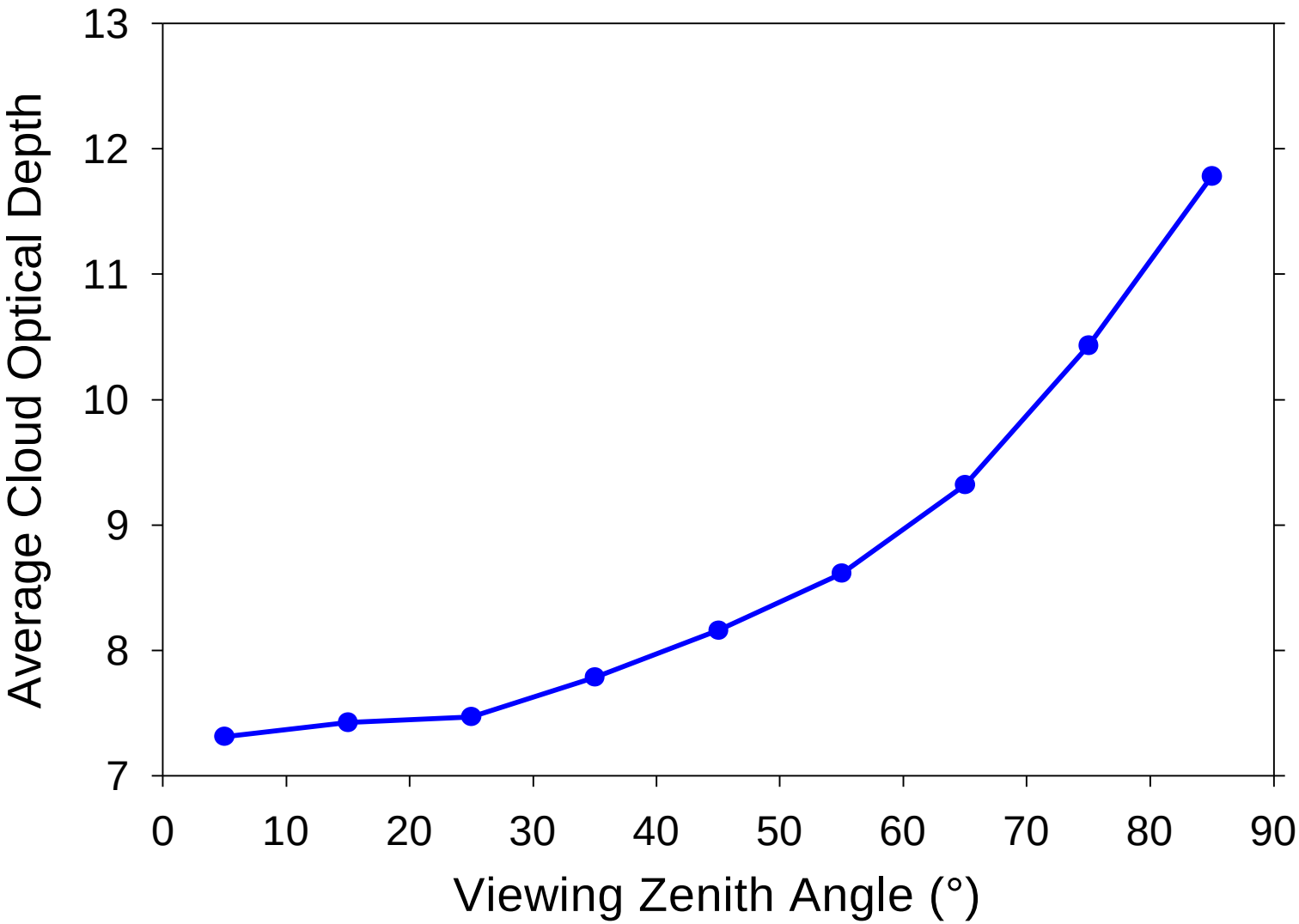
Likely Causes for Albedo Viewing Zenith Angle Dependence

- Change in CERES footprint size with viewing zenith angle.

- Viewing zenith angle dependence in cloud fraction.

CERES-TRMM Footprint Size vs Viewing Zenith Angle (50% PSF Cutoff)



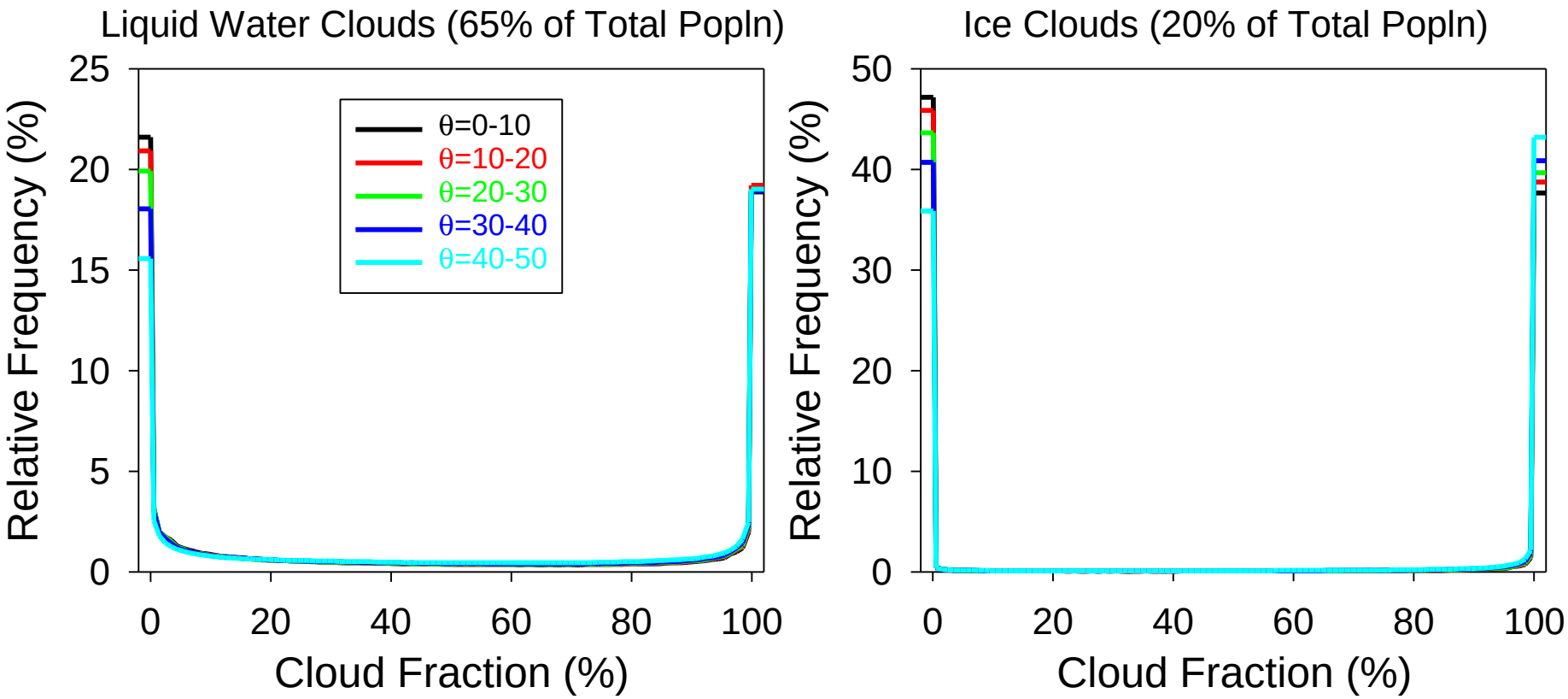

Ovc Cloud Optical Depth Against CERES Viewing Zenith Angle
(9 Alongtrack Days; θ_o=40°-50°)
Average Cloud Optical Depth
13
12
11
10
9
8
7
0
10
20
30
40
50
60
70
80
90
Viewing Zenith Angle (°)

Likely Causes for Albedo Viewing Zenith Angle Dependence

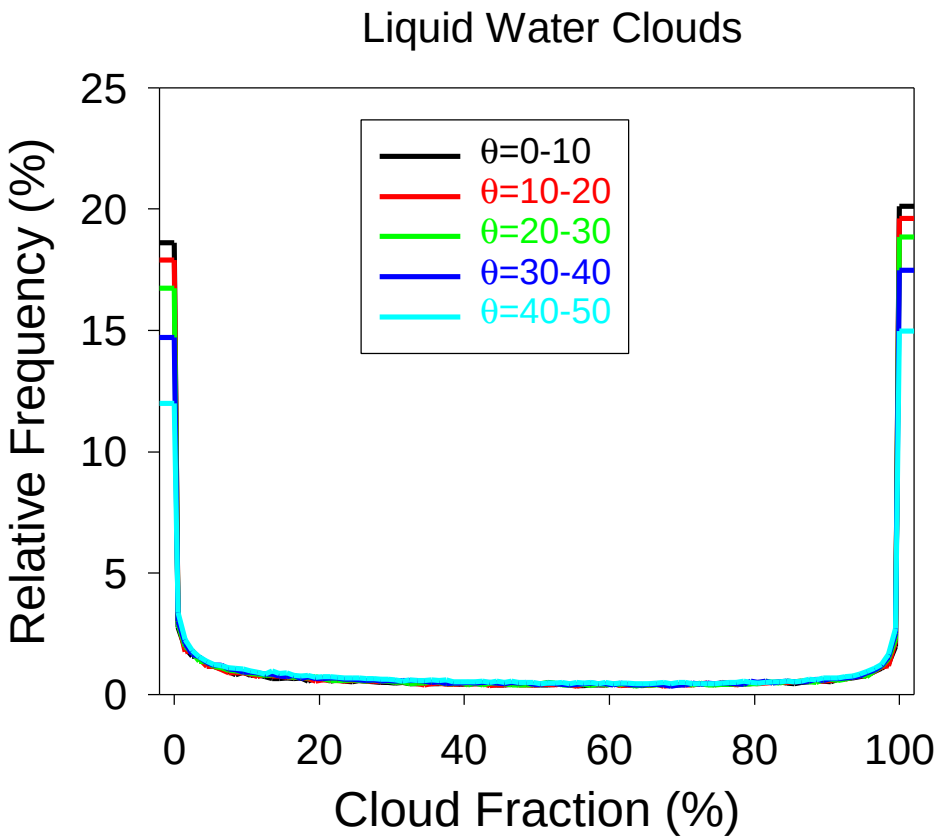
- Change in CERES footprint size with viewing zenith angle.

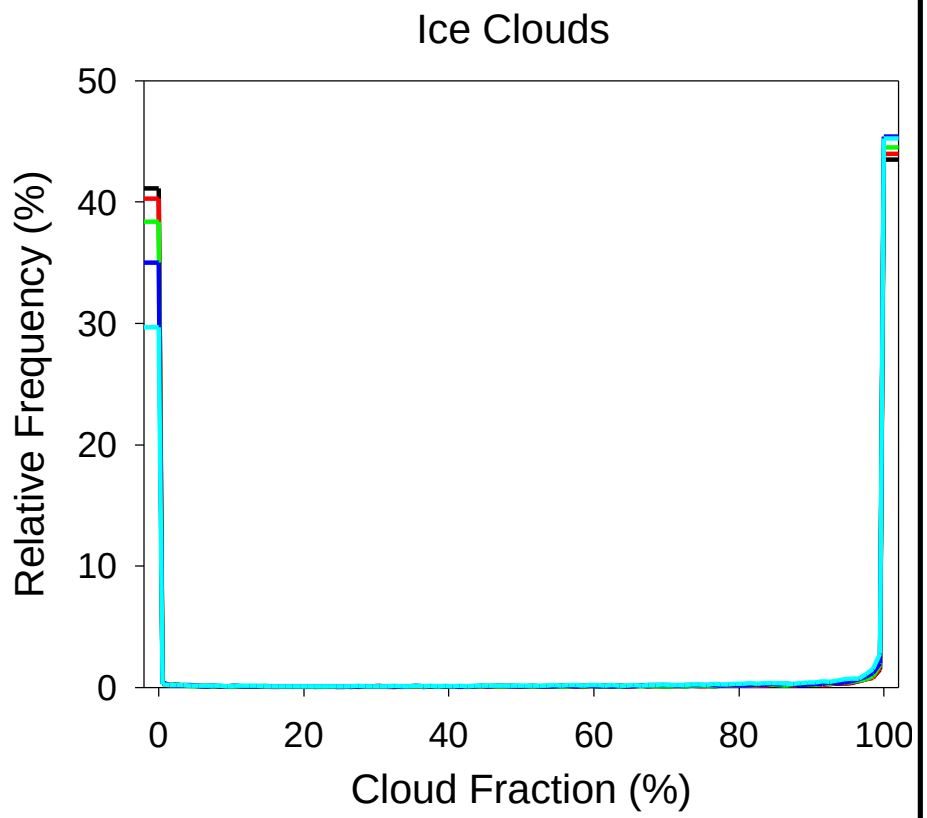
- Viewing zenith angle dependence in cloud fraction.

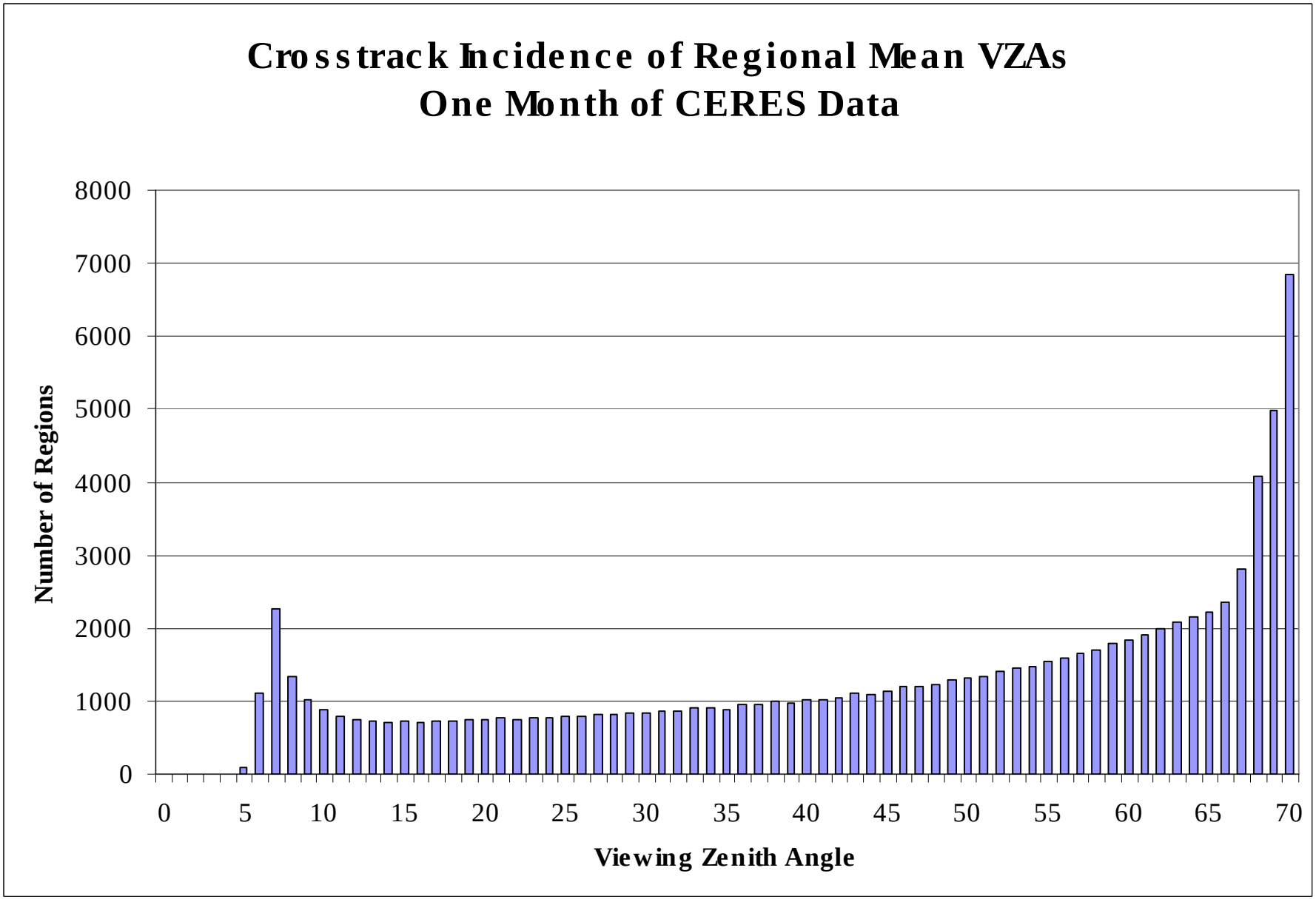
Cross-Track Cloud Fraction Frequency Distribution (q_o=40-50)



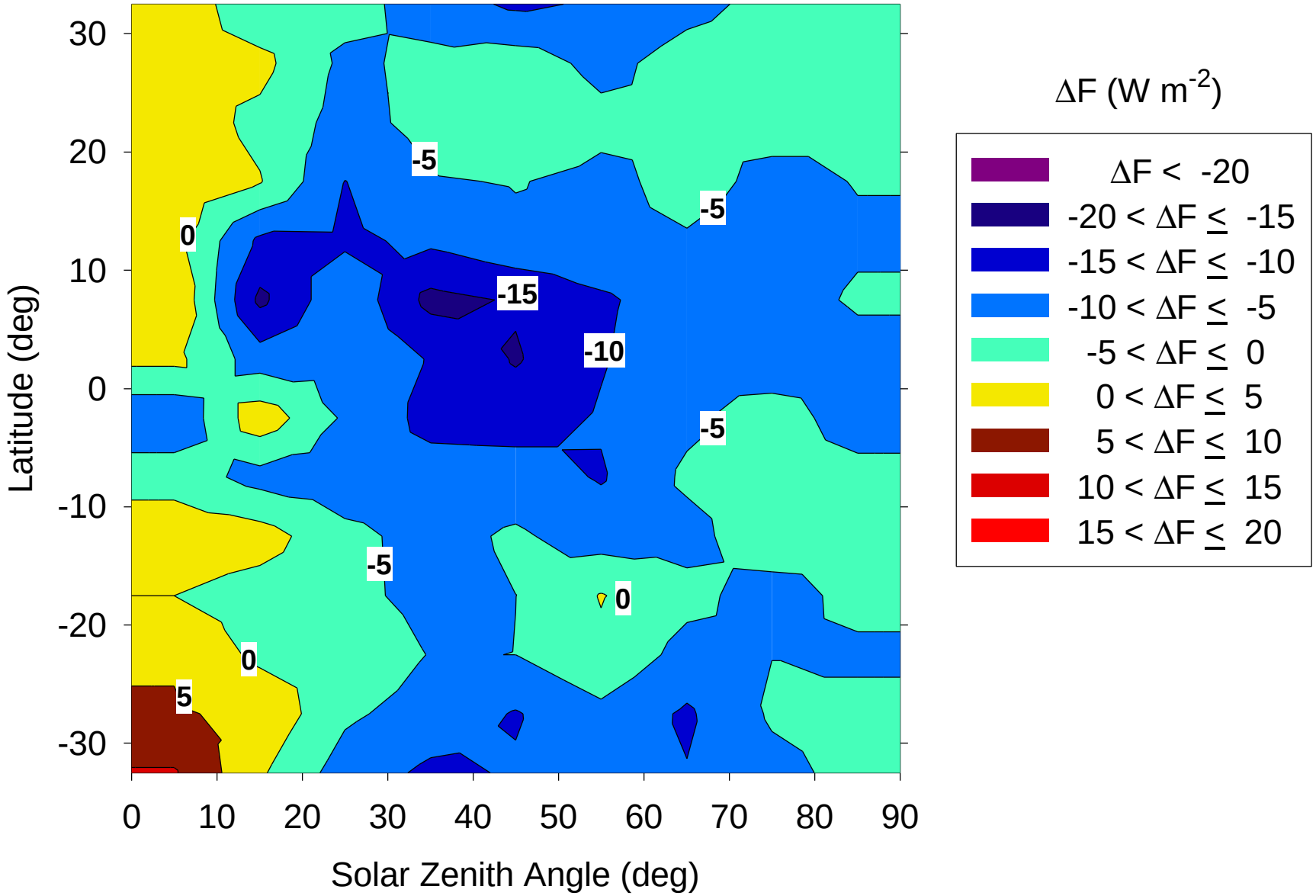
Along-Track Cloud Fraction Frequency Distribution (q_o=40-50)



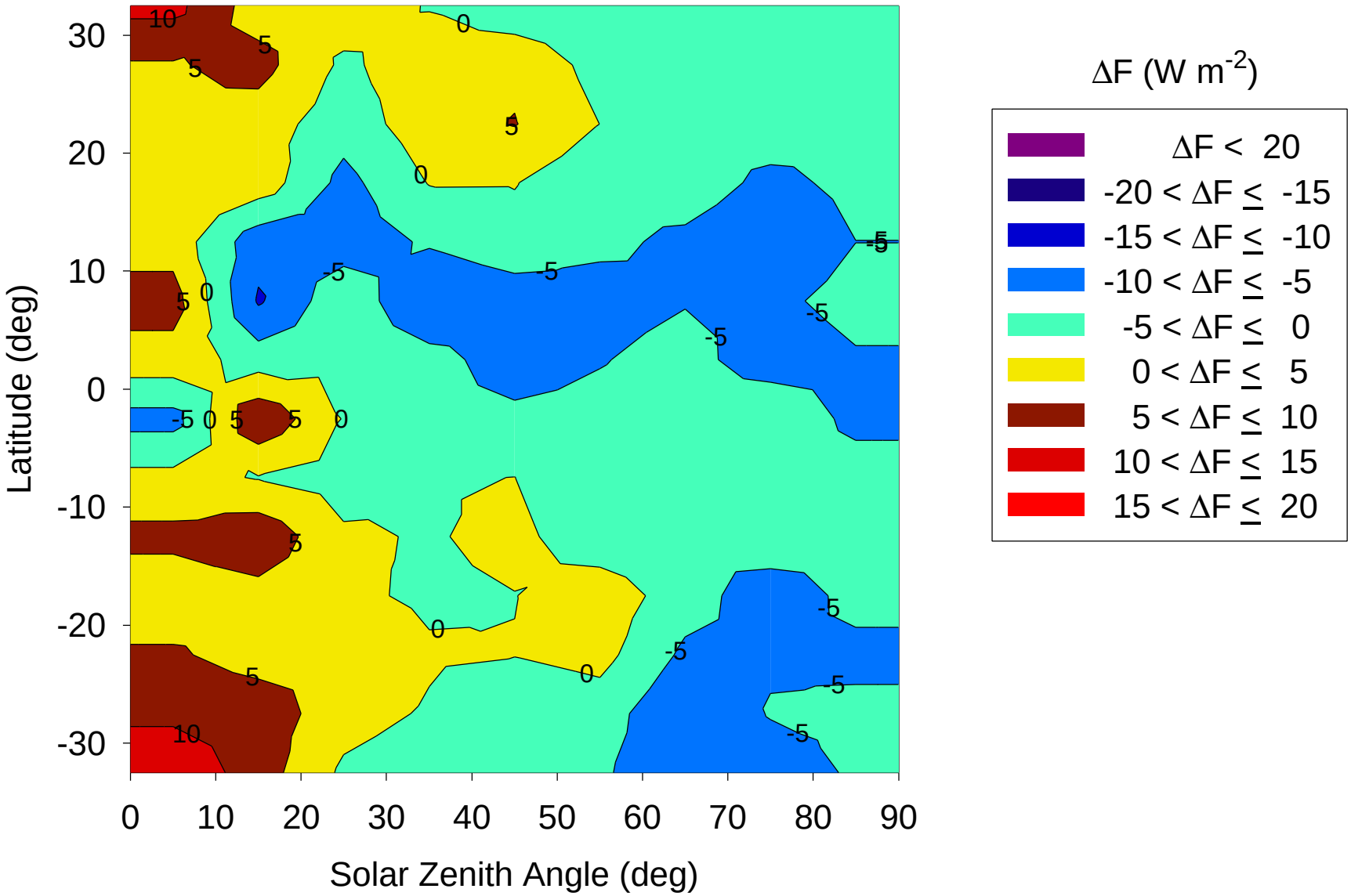



Crosstrack Incidence of Regional Mean VZAs
One Month of CERES Data
Number of Regions
8000
7000
6000
5000
4000
3000
2000
1000
0
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
Viewing Zenith Angle

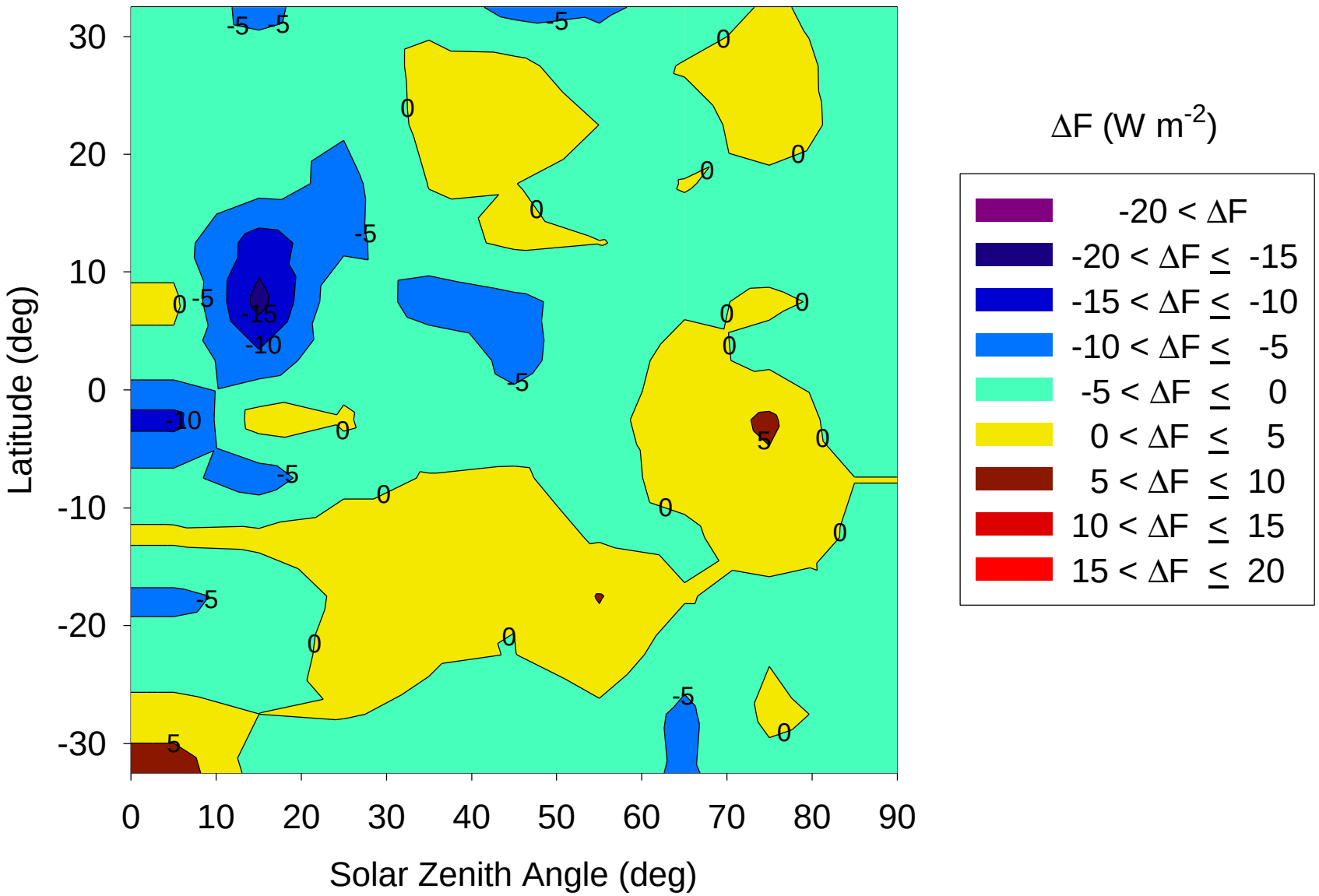
ES8 – Direct Integration All-Sky Flux by Latitude and θ_o
(9 Months; FAPS+RAPS+Alongtrack; **All Tropics**; $\theta < 50°$)



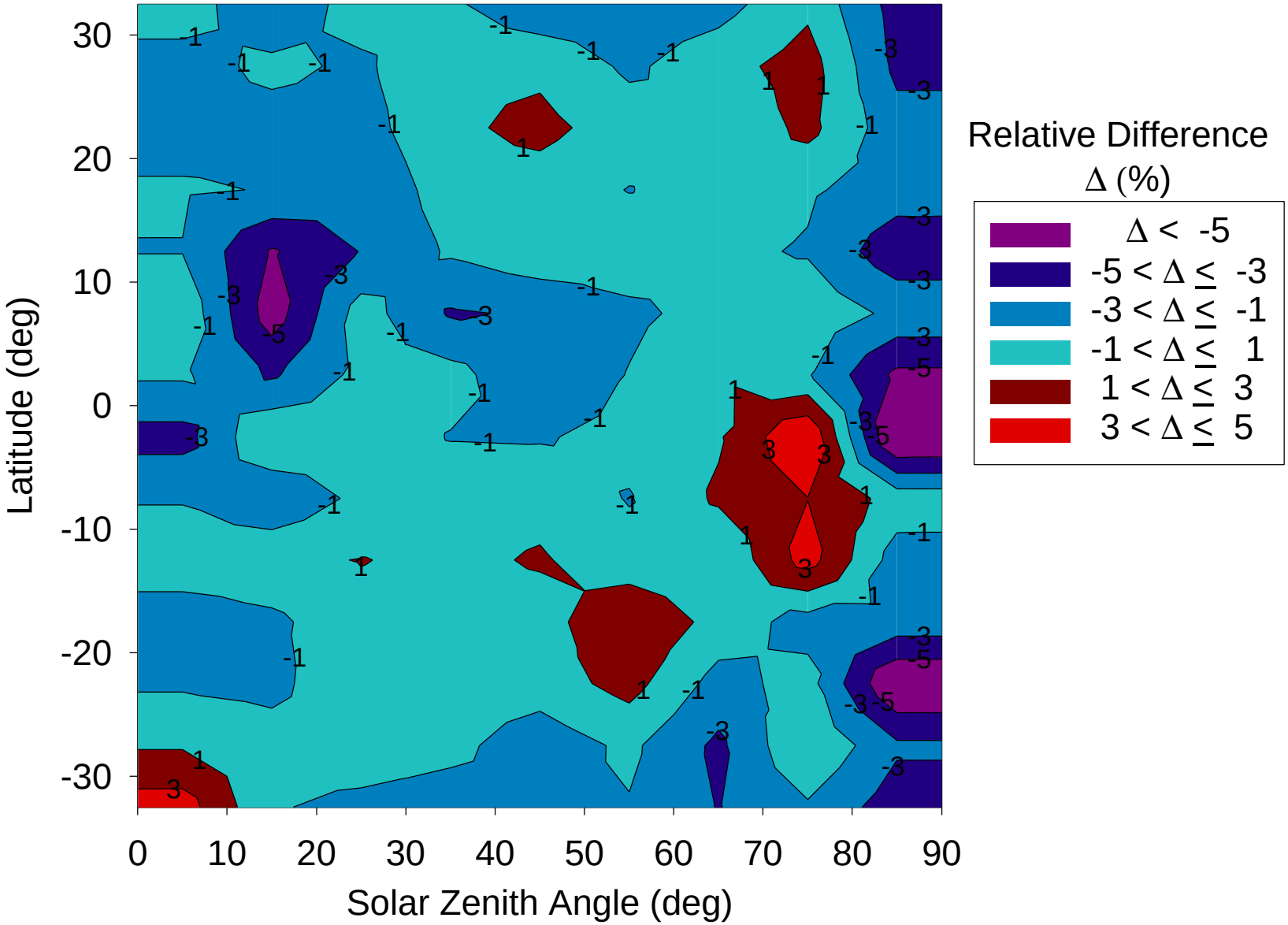
ED1 – Direct Integration All-Sky Flux by Latitude and θ_o
(9 Months; FAPS+RAPS+Alongtrack; **All Tropics**; $\theta < 50°$)



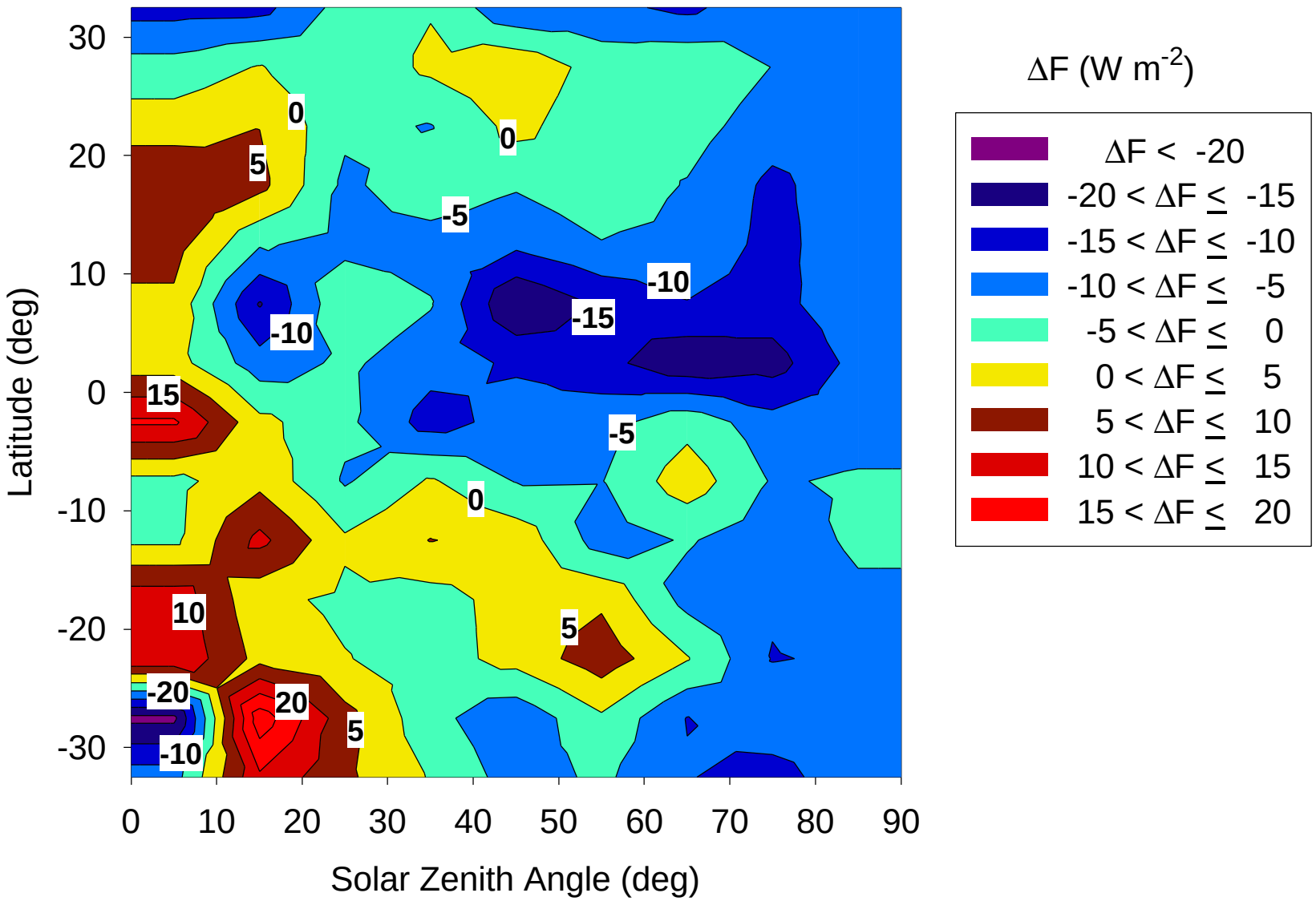
New ADMs – Direct Integration All-Sky Flux by Latitude and θ_o (9 Months; FAPS+RAPS+Alongtrack; **All Tropics**; $\theta < 50°$)



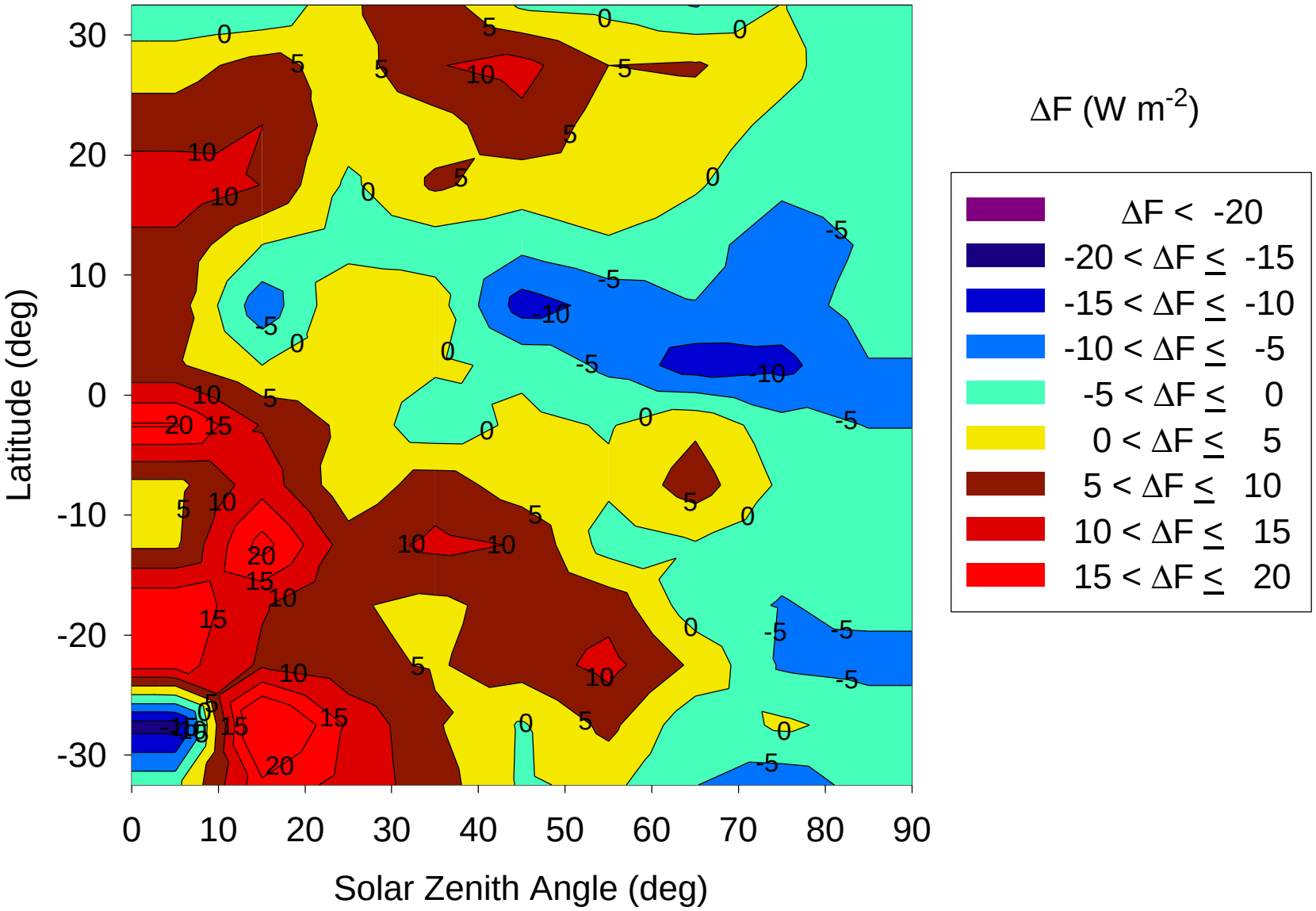
New ADMs – Direct Integration All-Sky Flux by Latitude and θ_o (9 Months; FAPS+RAPS+Alongtrack; **All Tropics**; $\theta < 50°$)



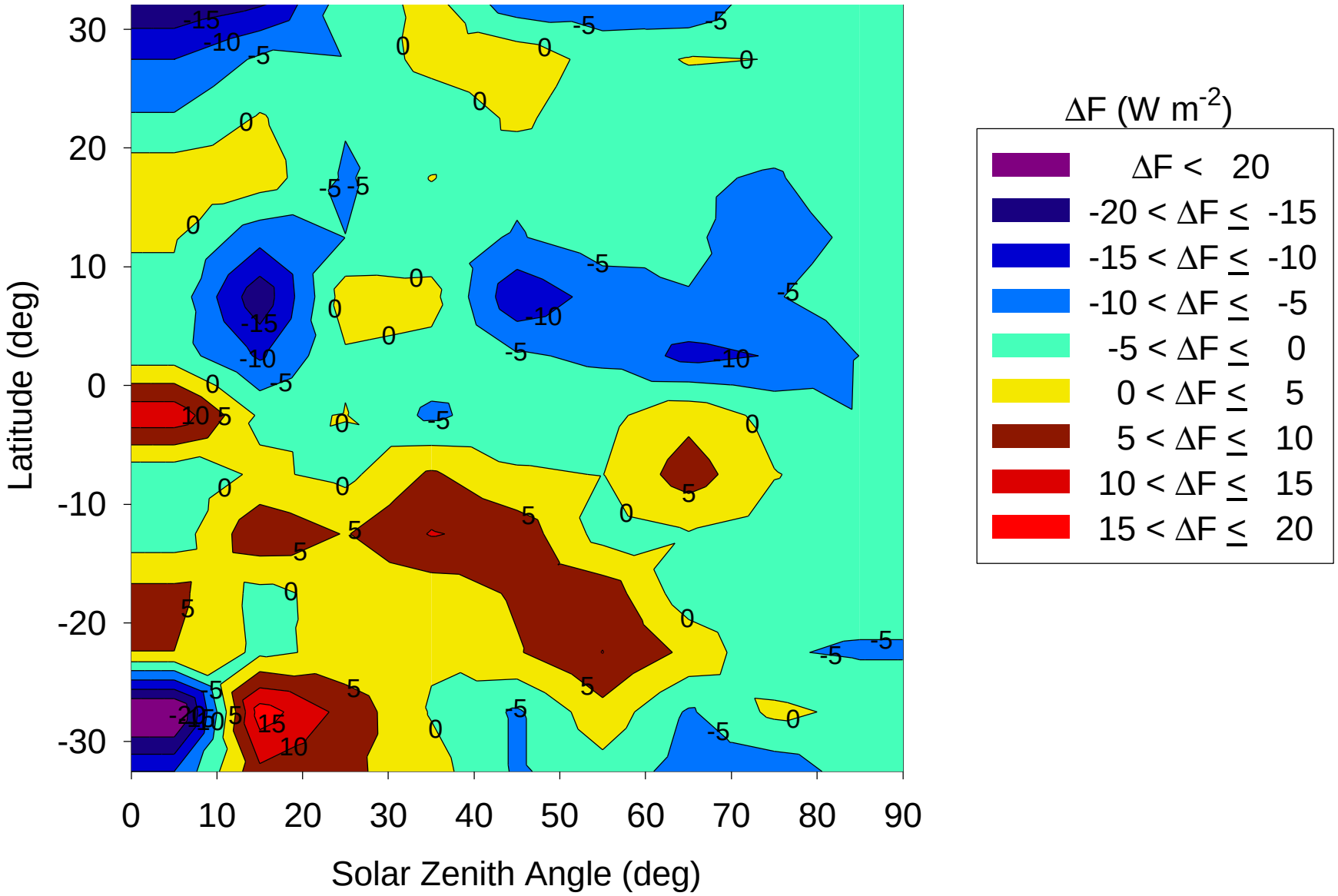
ES8 – Direct Integration All-Sky Flux by Latitude and θ_o
(9 Months; FAPS+RAPS+Alongtrack; **Land & Desert**; $\theta < 50°$)



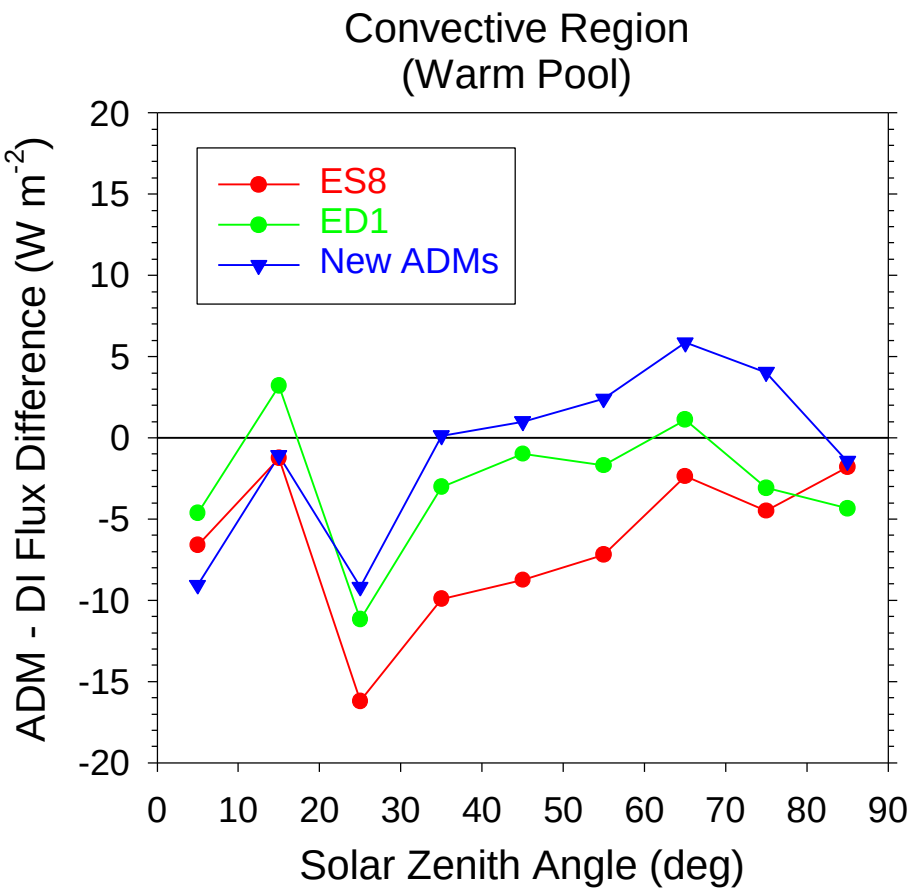
ED1 – Direct Integration All-Sky Flux by Latitude and θ_o
(9 Months; FAPS+RAPS+Alongtrack; **Land & Desert**; $\theta < 50°$)

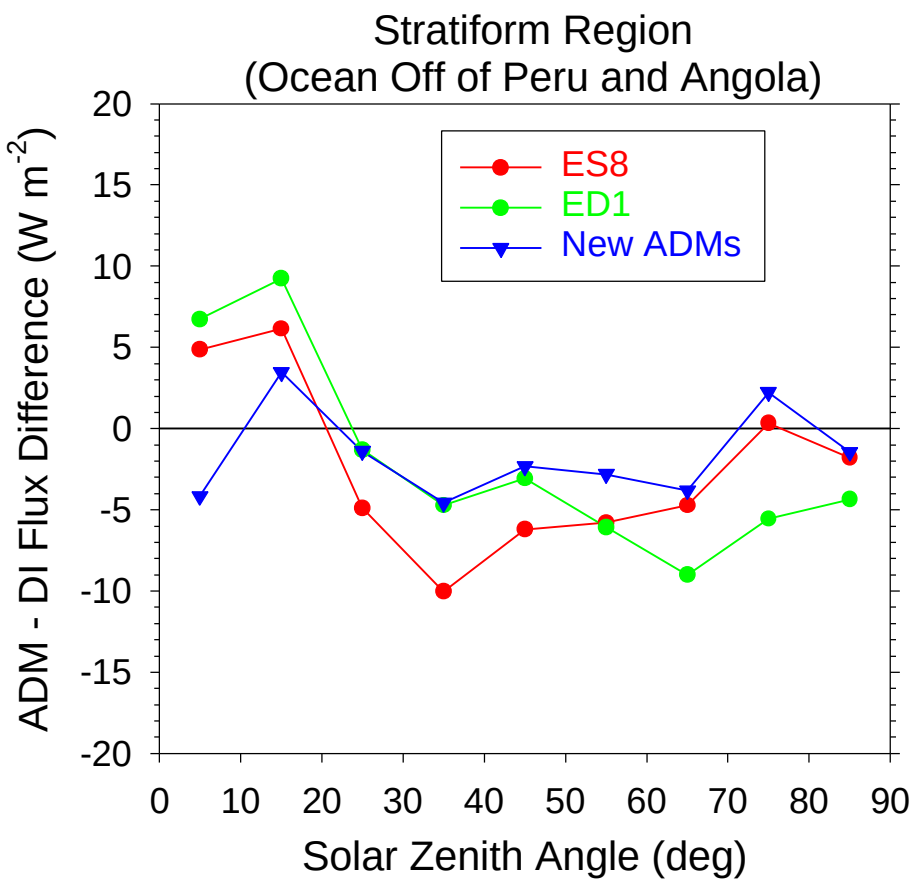


New ADMs – Direct Integration All-Sky Flux by Latitude and θ_o (9 Months; FAPS+RAPS+Alongtrack; **Land & Desert**; $\theta < 50°$)

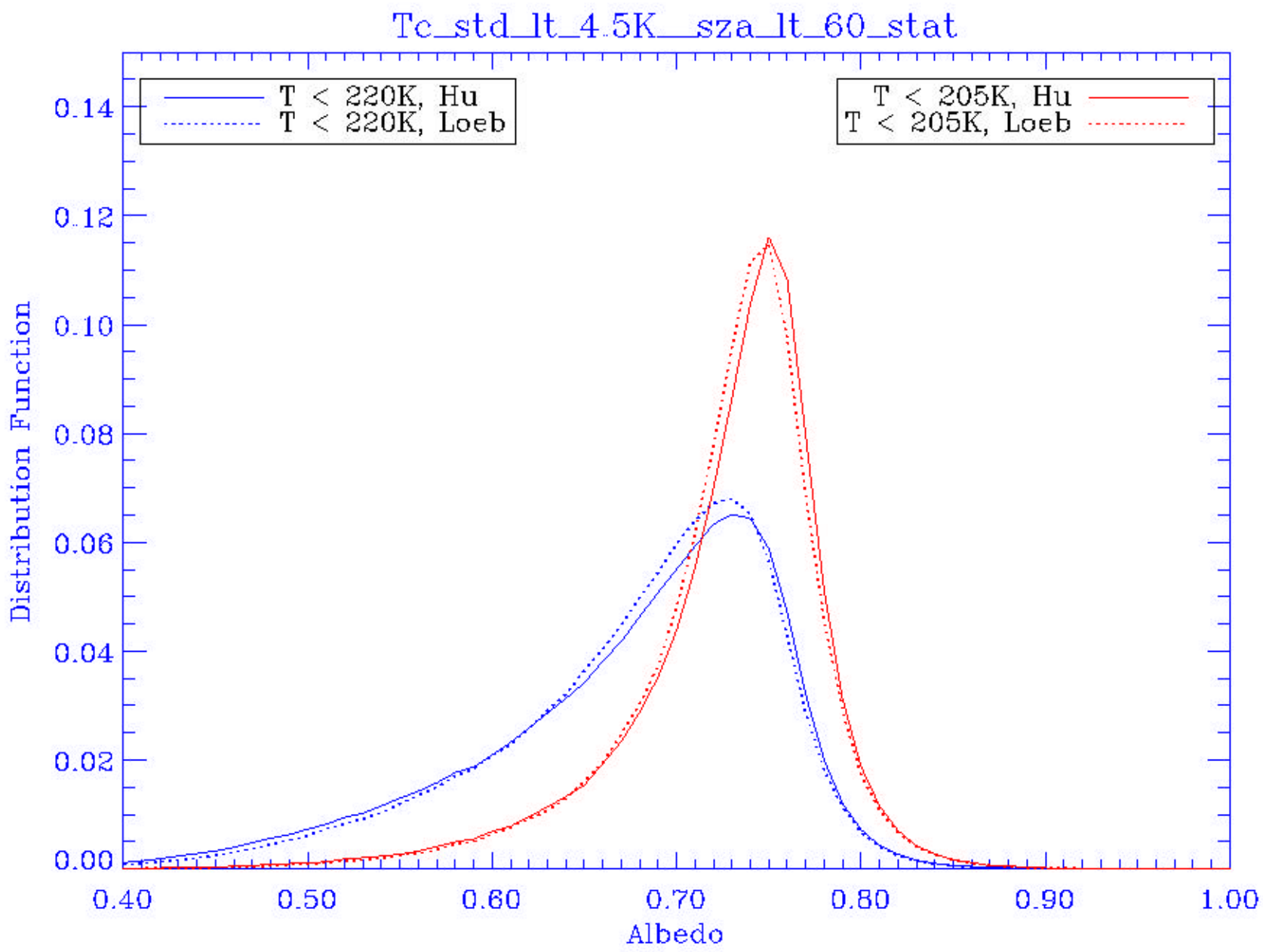


New ADMs – Direct Integration All-Sky Flux: Convective and Stratiform Regions





Albedos For Deep Convective Clouds: New ADMs vs Hu



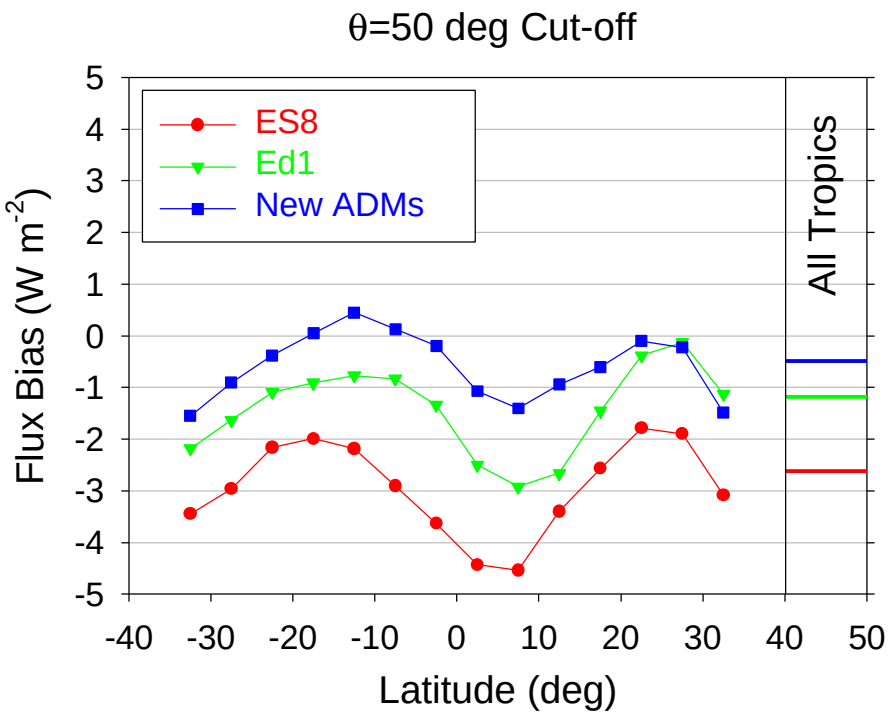
Equivalent (Spherical Albedo) Flux Bias

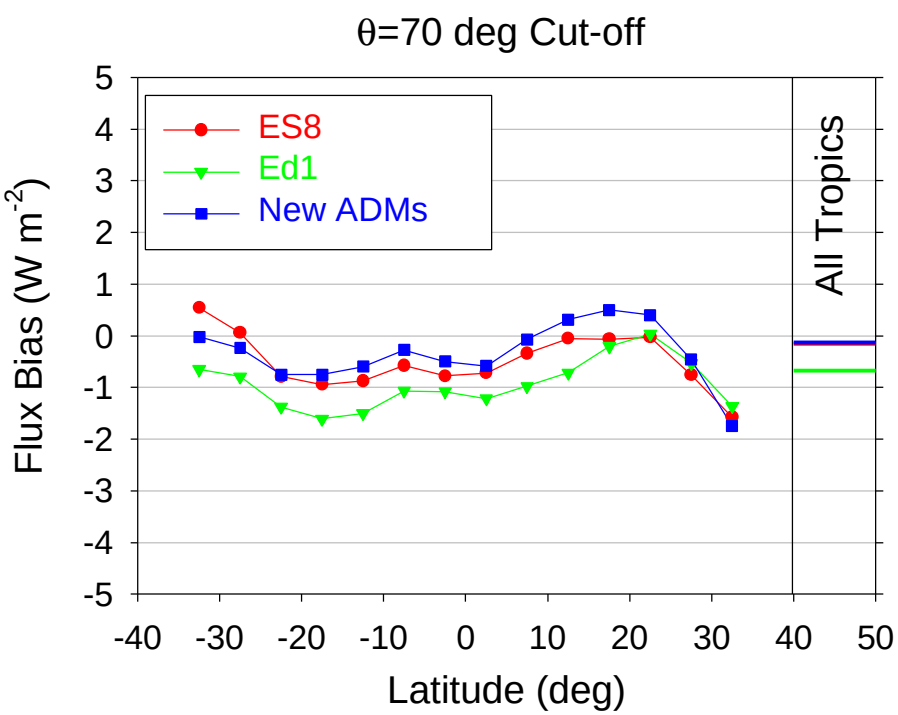
- Weight ADM albedos by TISA histograms of regional viewing zenith angle frequency of occurrence
- Determine “spherical albedo”
- Define equivalent flux bias over any region by:

$$\Delta F = (A_s^{ADM} - A_s^{DI}) \frac{E_o}{4}$$

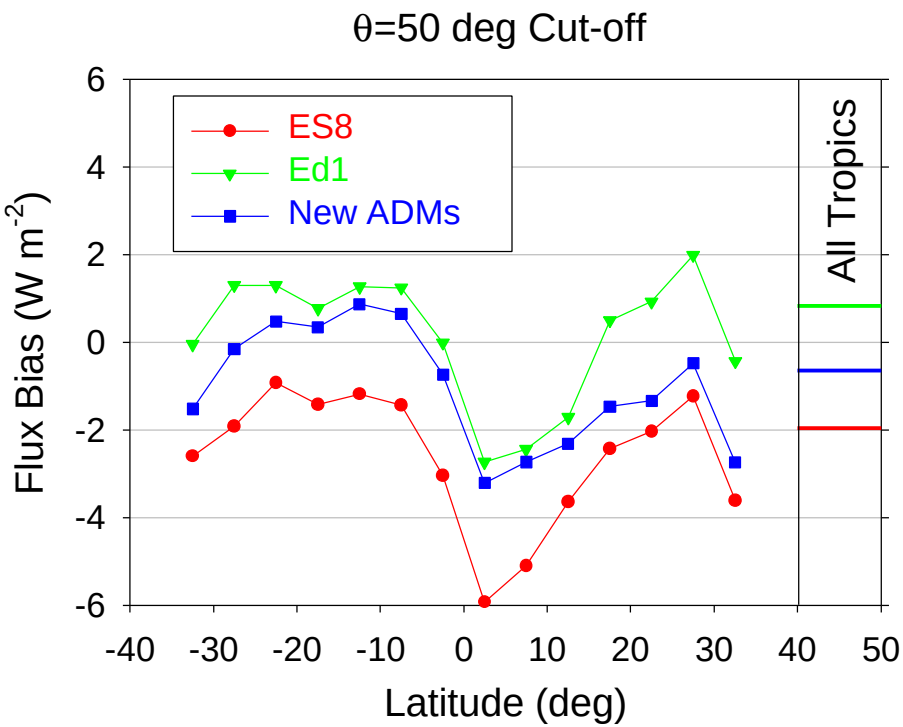
$$A_s = 2 \int_0^1 m_o A_p(m_o) dm_o$$

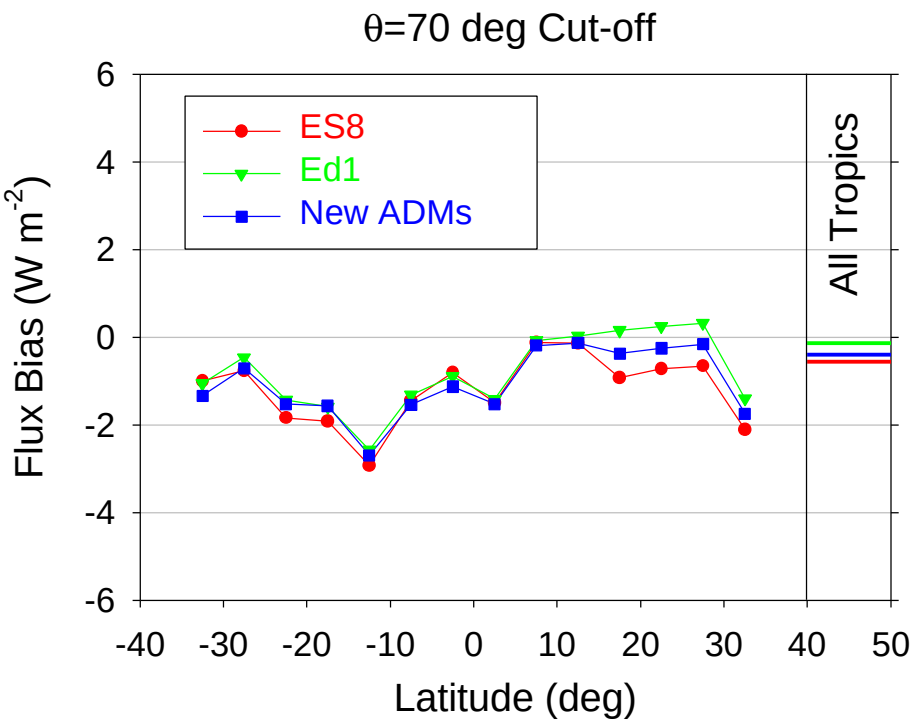
Equivalent (Spherical Albedo) Flux Biases - All Tropics





Equivalent (Spherical Albedo) Flux Biases - Land & Desert



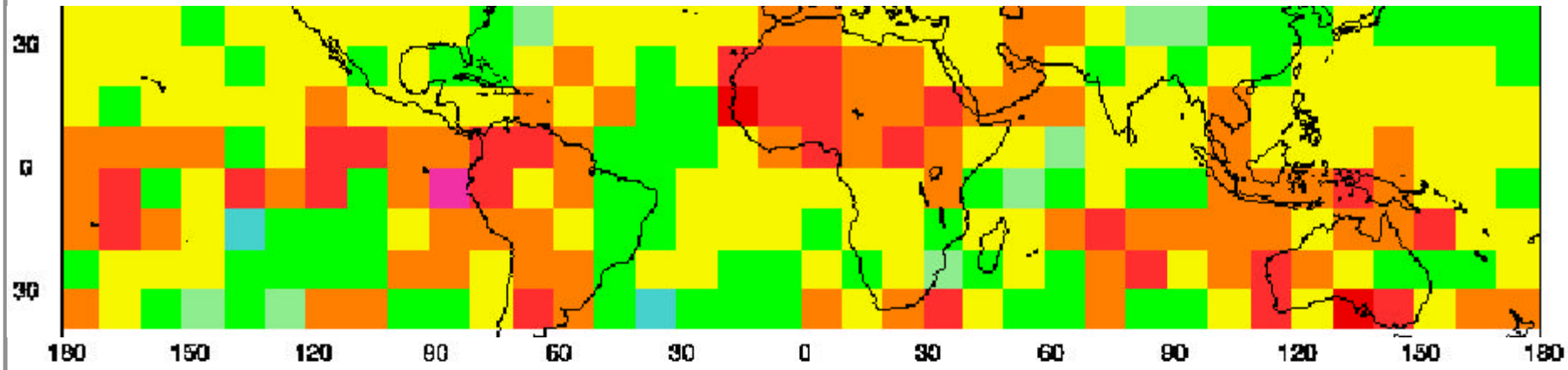


Equivalent (Spherical Albedo) Flux Bias (W m^{-2})

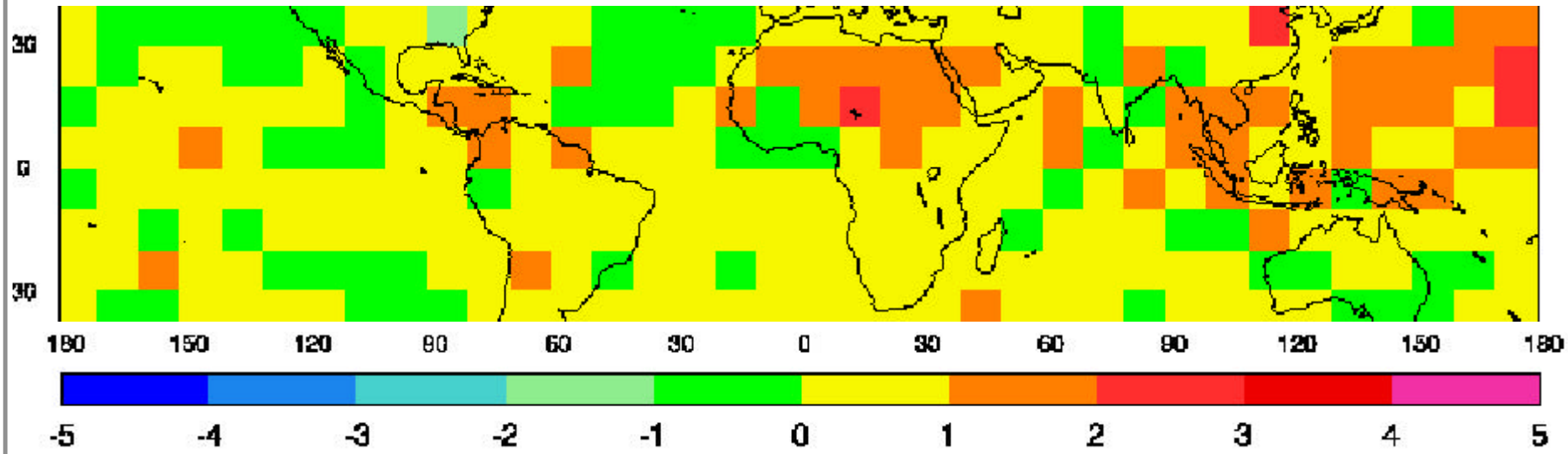
	ES8		Edition 1		New ADMs	
	q < 50°	q < 70°	q < 50°	q < 70°	q < 50°	q < 70°
All Tropics	-2.6	-0.15	-1.2	-0.67	-0.49	-0.13
Land+Desert	-2.0	-0.56	0.83	-0.14	-0.64	-0.40

New ADM – Direct Integration LW Flux Comparison

Jan-Mar 1998



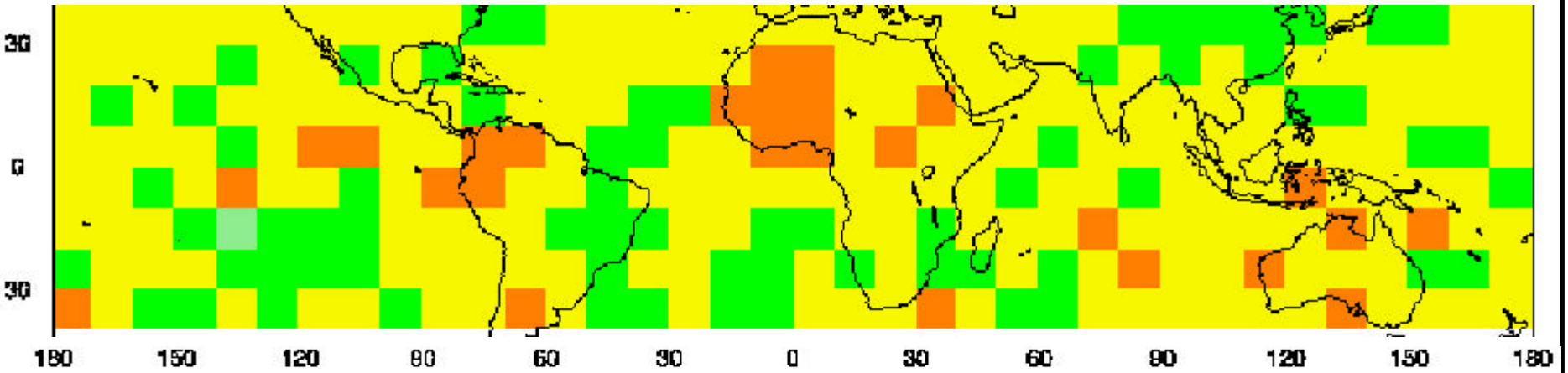
Jun-Aug 1998



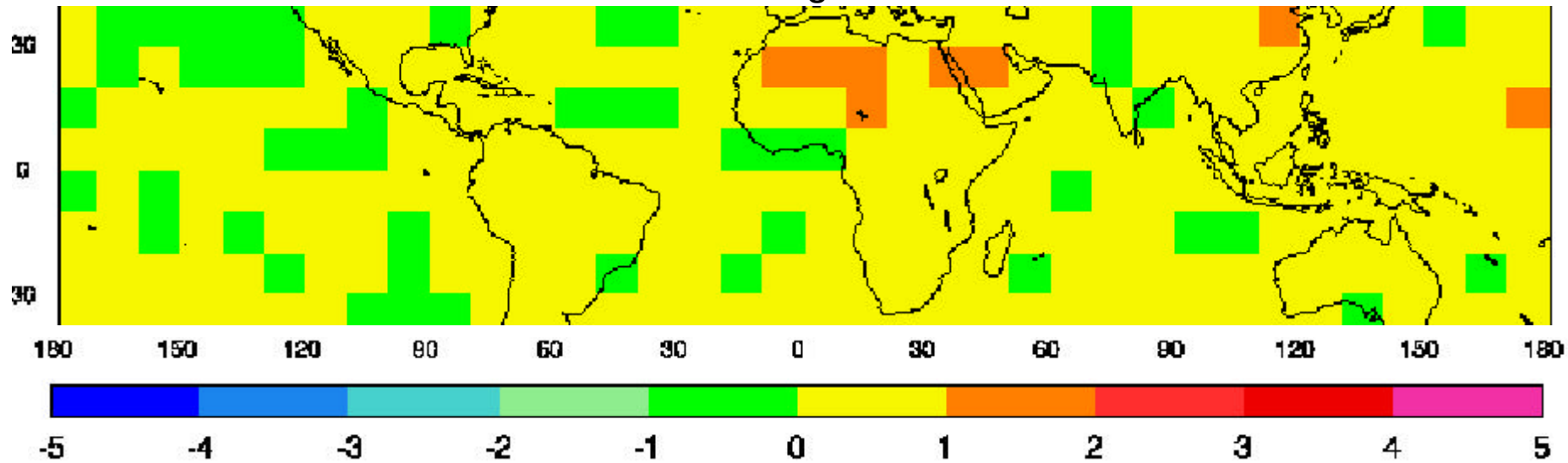
ΔF (W m-2)

New ADM – Direct Integration WN Flux Comparison

Jan-Mar 1998



Jun-Aug 1998



ΔF (W m-2)

All-Sky LW Flux Bias (W m^{-2})

	Edition 1		New ADMs	
Season	**Bias**	**RMS**	**Bias**	**RMS**
Jan, Feb, Mar	**0.09**	**1.2**	**0.6**	**1.15**
Jun, Jul, Aug	**0.04**	**1.2**	**0.43**	**0.74**

WN Flux Bias (W m^{-2})

	Edition 1		New ADMs	
Season	**Bias**	**RMS**	**Bias**	**RMS**
Jan, Feb, Mar	**0.05**	**0.58**	**0.31**	**0.55**
Jun, Jul, Aug	**0.03**	**0.56**	**0.25**	**0.39**

Summary

- Preliminary Ed2 ADMs show improvement over Ed1 (VIRS 12) and ERBE ADMs.
  - Can be improved further by identifying cause for ≈5-7% viewing zenith angle bias in albedo.
    => • 10% cloud fraction bias and/or
    • Variable CERES footprint size with viewing zenith angle.
  - Need to be updated to handle conditions when cloud properties are unavailable.

- Are the preliminary ADMs good enough for Beta Edition 2?

  - Edition 1 cloud properties + TOA fluxes based on preliminary Edition 2 ADMs.

Note: Would use Edition 1 fluxes when cloud properties are unavailable (2% SW; 15% daytime LW; 100% nighttime LW).