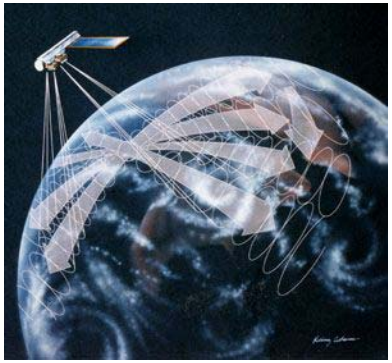


CERES SSF Angular Distribution Modeling

Norman G. Loeb[1], Natividad Manalo-Smith[2],
Konstantin Loukachine[3], Seiji Kato[1]

[1]Hampton University, [2]AS&M, [3]SAIC

Outline

- TOA Flux/ADM Production Schedule

- Recent Changes to SSF

- TOA Fluxes, ADMs and Spherical Earth Geometry

- CERES Azimuth Rate Comparisons

TOA Flux Production Schedule

1. August 2001

- Delivery of SSF Edition2A SW, LW & WN ADMs.
- Prepare SSF Edition 2A validation results.

2. September 2001

- Begin production of CERES/TRMM Edition 2A SSFs.
- Telecon on SSF Edition2A Validation Results.
- Complete SSF Edition2A Quality Summary.
- Archive SSF Edition 2A.

3. October 2001 – May 2002

- Preparation of 2-3 manuscripts for publication summarizing TRMM ADMs and validation results.
- Revised Edition2A ADMs to test sensitivity of neglecting off-Earth Earth Views ("Edition2B" ADMs).

TOA Flux Production Schedule (cont'd)

4. June 2002

- Process SSF Edition2B with updated ADMs.
- Fix bug in SSF aerosol optical depth retrievals. CERES relative azimuth angle were accidentally used.

5. February 2002 - September 2002

- Develop code for producing Terra ADMs. Initially use 8 months of Terra SSFs.

6. September 2002 – March 2003

- Develop and validate final Terra ADMs based on 2 years of Terra observations.

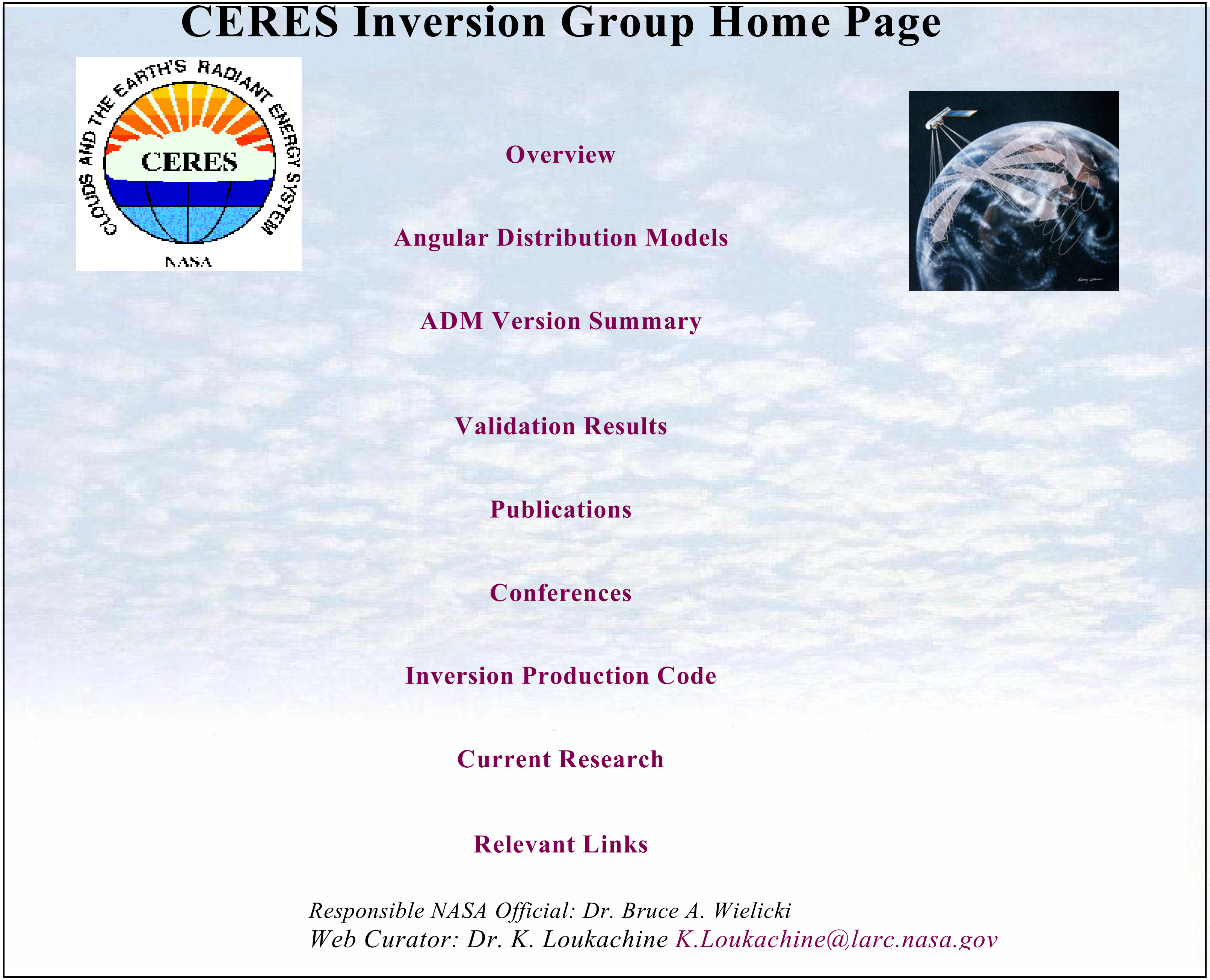
Recent Changes to SSF (to appear in SSF Edition2A)

- Include all CERES footprints that have at least 1 VIRS pixel coverage (independent of whether imager data is bad).
  =>User's should carefully check SSF parameters: "percent imager coverage (SSF-54)" and "cloud property extrapolation over cloudy area (SSF-63)".

- Retain clear scenes over "hot" desert and land with saturated VIRS channel 4 radiances.
  - Use CERES WN brightness temperature threshold to identify clear scenes over very hot surfaces.

- Changed units of window (WN) unfiltered radiance and TOA flux from W m^{-2} μm^{-1} to W m^{-2}.
  - WN unfiltered radiance & flux is defined over 8.1 - 11.8 μm wavelength interval.

http://asd-www.larc.nasa.gov/Inversion/



CERES Inversion Group Home Page

Overview

Angular Distribution Models

ADM Version Summary

Validation Results

Publications

Conferences

Inversion Production Code

Current Research

Relevant Links

Responsible NASA Official: Dr. Bruce A. Wielicki
Web Curator: Dr. K. Loukachine K.Loukachine@larc.nasa.gov

TOA Fluxes, ADMs and Spherical Earth Geometry

CERES ADM Definition:

The ADM anisotropic factors for a given scene type (*j*) are determined from the following:

$$R_j(\theta_{oi},\theta_k,\phi_l) = \frac{\pi \bar{I}_j(\theta_{oi},\theta_k,\phi_l)}{F_j(\theta_{oi})}$$

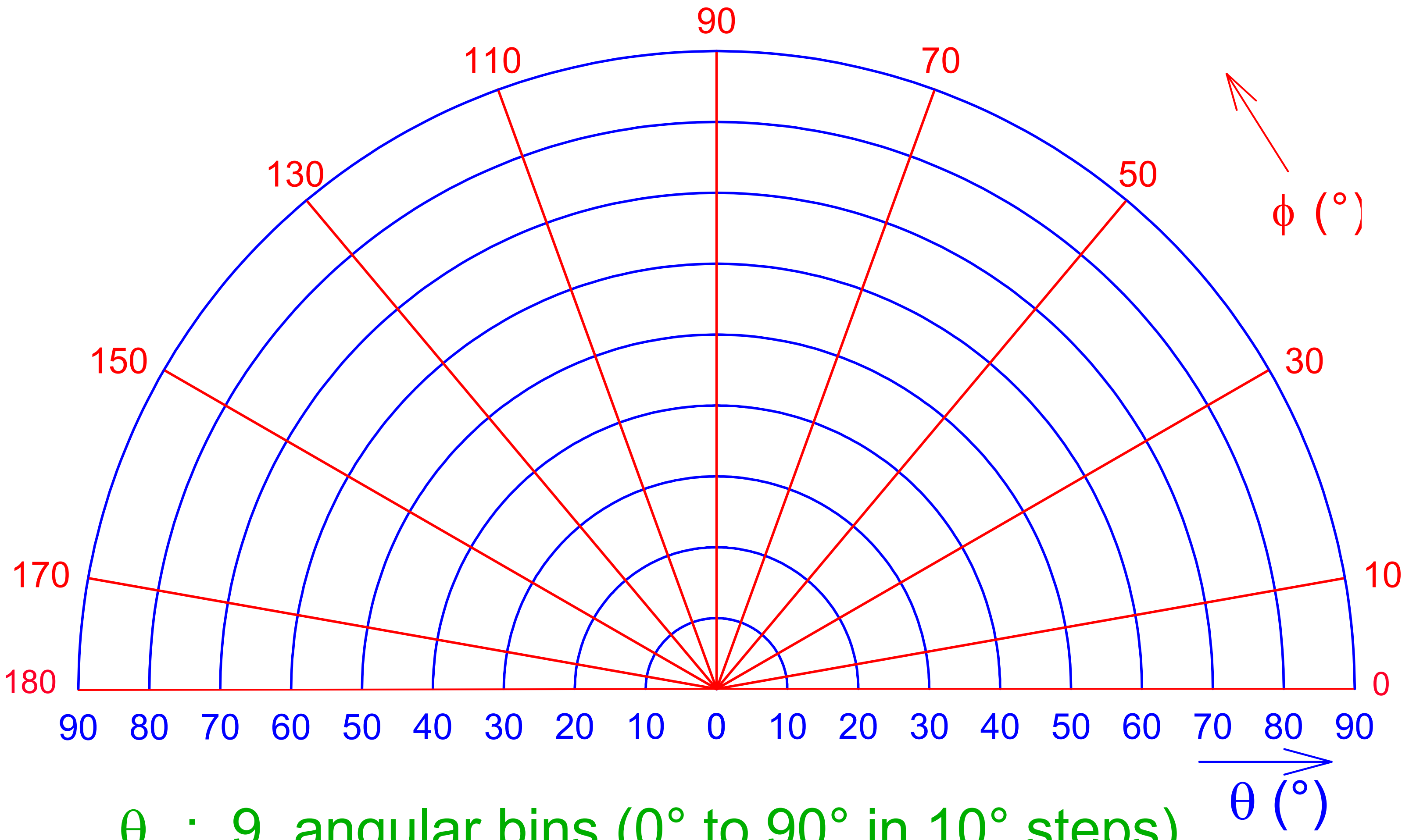
where

$$(\theta_{oi},\theta_k,\phi_l) \quad = \quad (\theta_{oi} \pm \frac{\Delta\theta_o}{2},\theta_k \pm \frac{\Delta\theta}{2},\phi_l \pm \frac{\Delta\phi}{2})$$

$\bar{I}_j(\theta_{oi},\theta_k,\phi_l)$ = Average radiance for scene type *j* in angular bin $(\theta_{oi}, \theta_k, \phi_l)$

$$F_j(\theta_{oi}) = \frac{1}{\pi}\sum_{q=1}^{N_q} w_q \left\{ \sum_{p=1}^{N_p} w_p \, \bar{I}_j(\theta_{oi},\theta_p,\phi_q)\cos\theta_p \right\}$$

CERES SW ADM Angular Bin Definitions



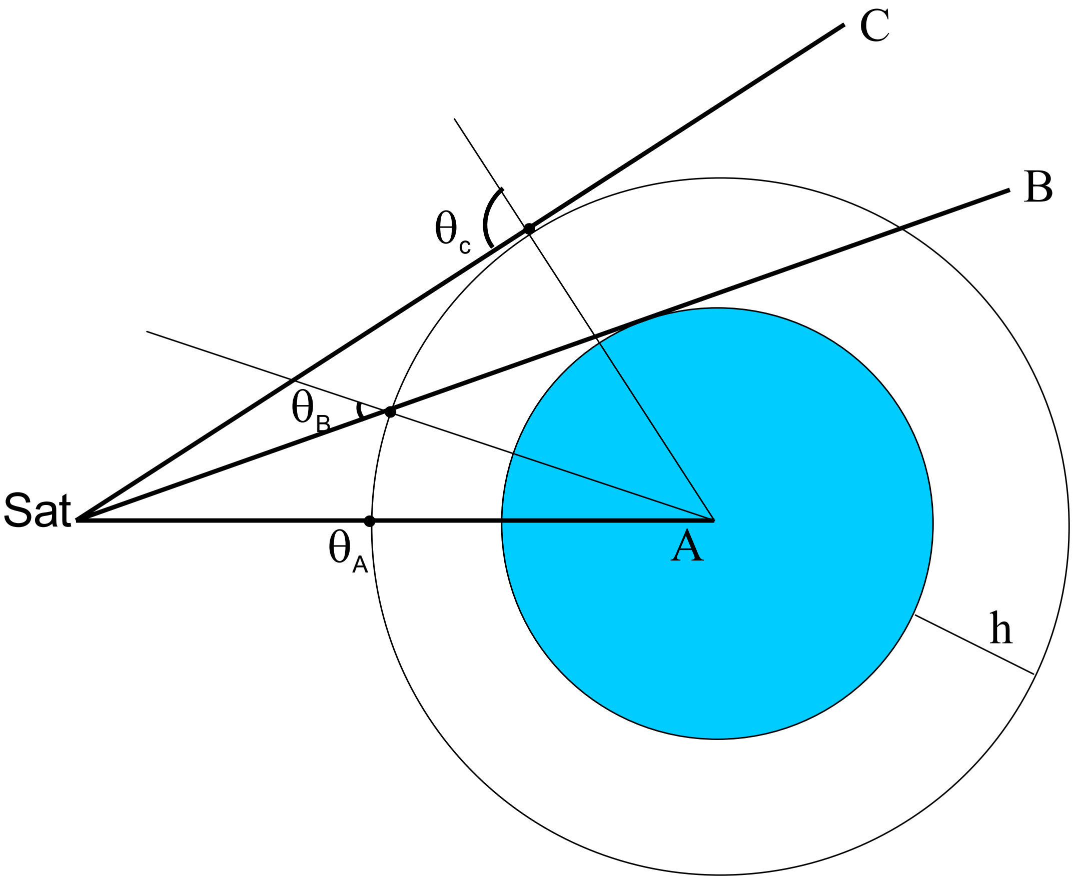
θ_o : 9 angular bins (0° to 90° in 10° steps)

θ : 9 angular bins (0° to 90° in 10° steps)

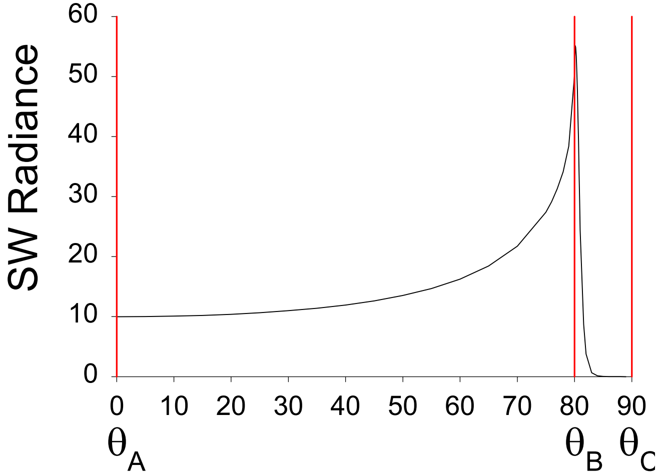
ϕ : 10 angular bins (0° to 180° in 10° or 20° steps)

SW & LW Radiances vs θ

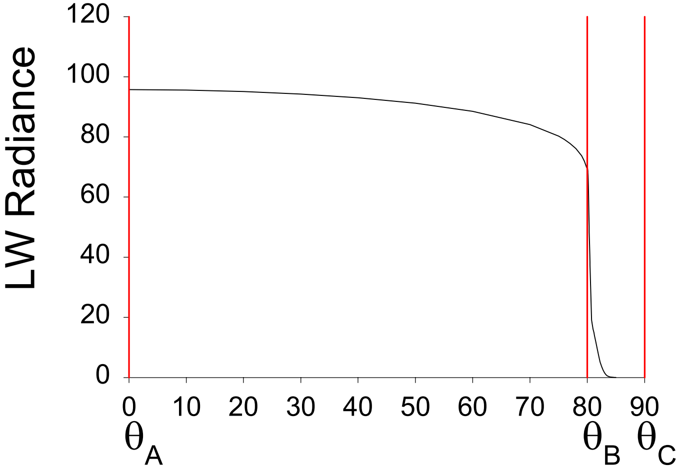
(Spherical Earth Geometry; MODTRAN; Rayleigh Atmosphere)



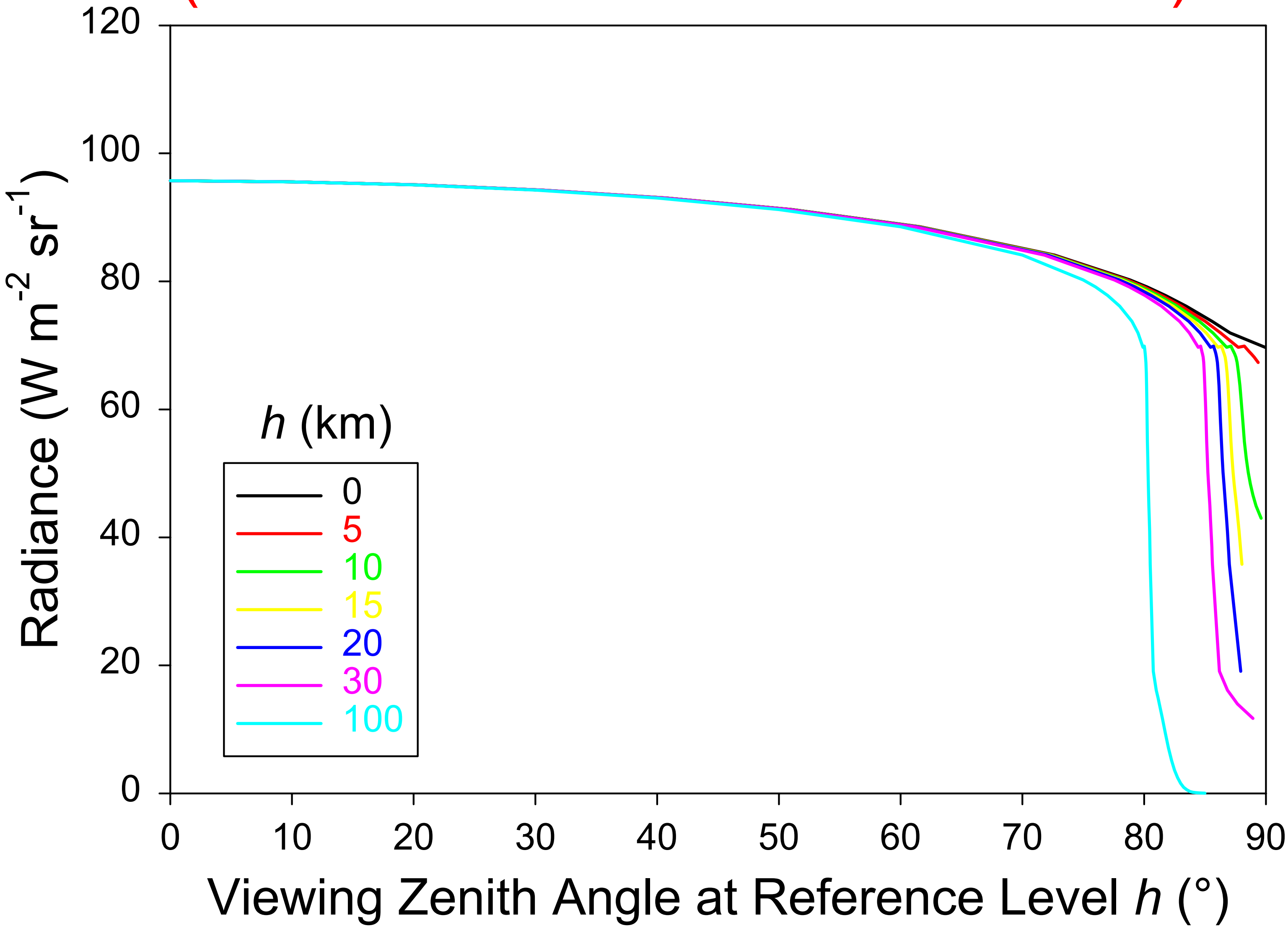
SW Radiance(h=100 km)



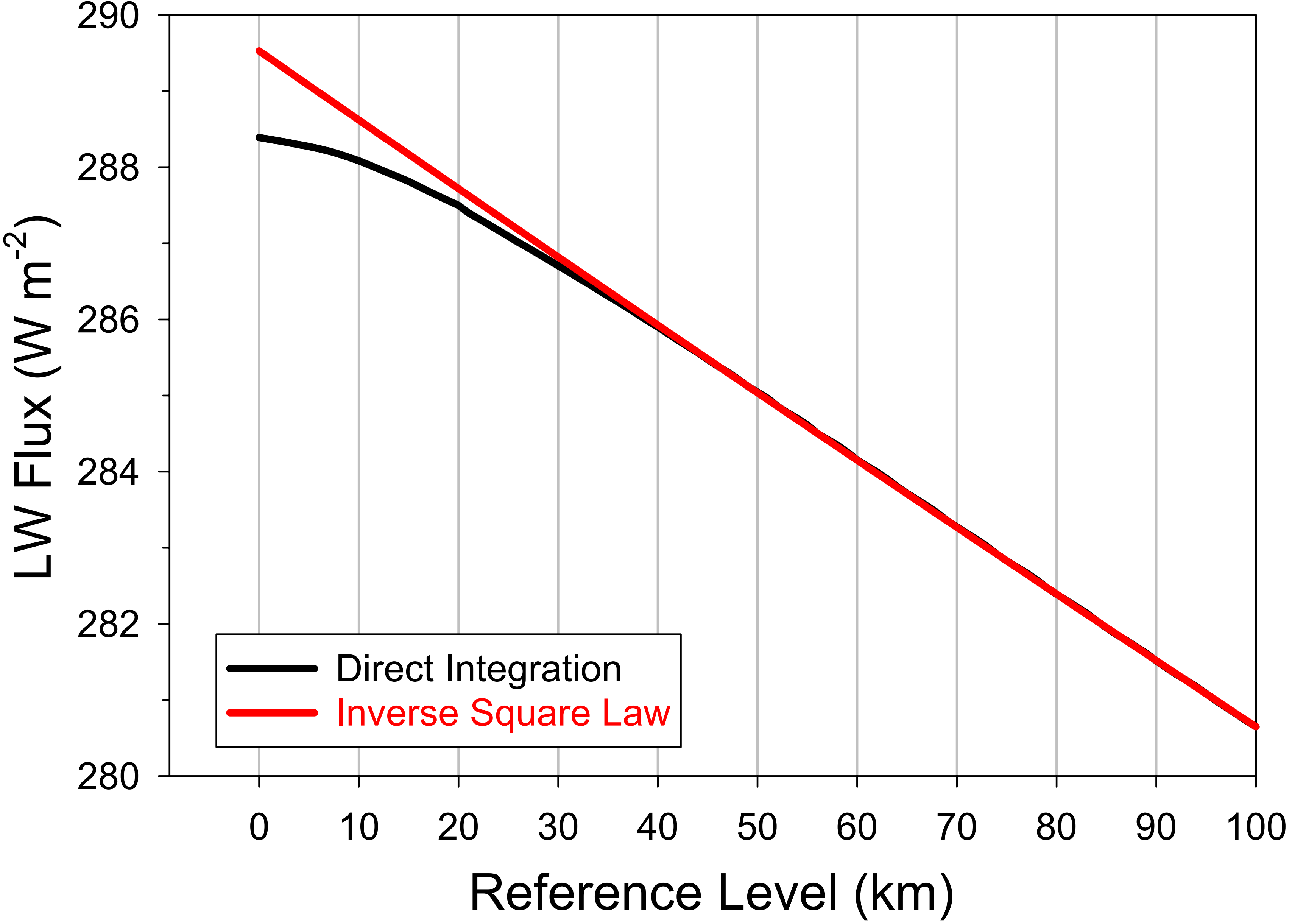
LW Radiance(h=100 km)



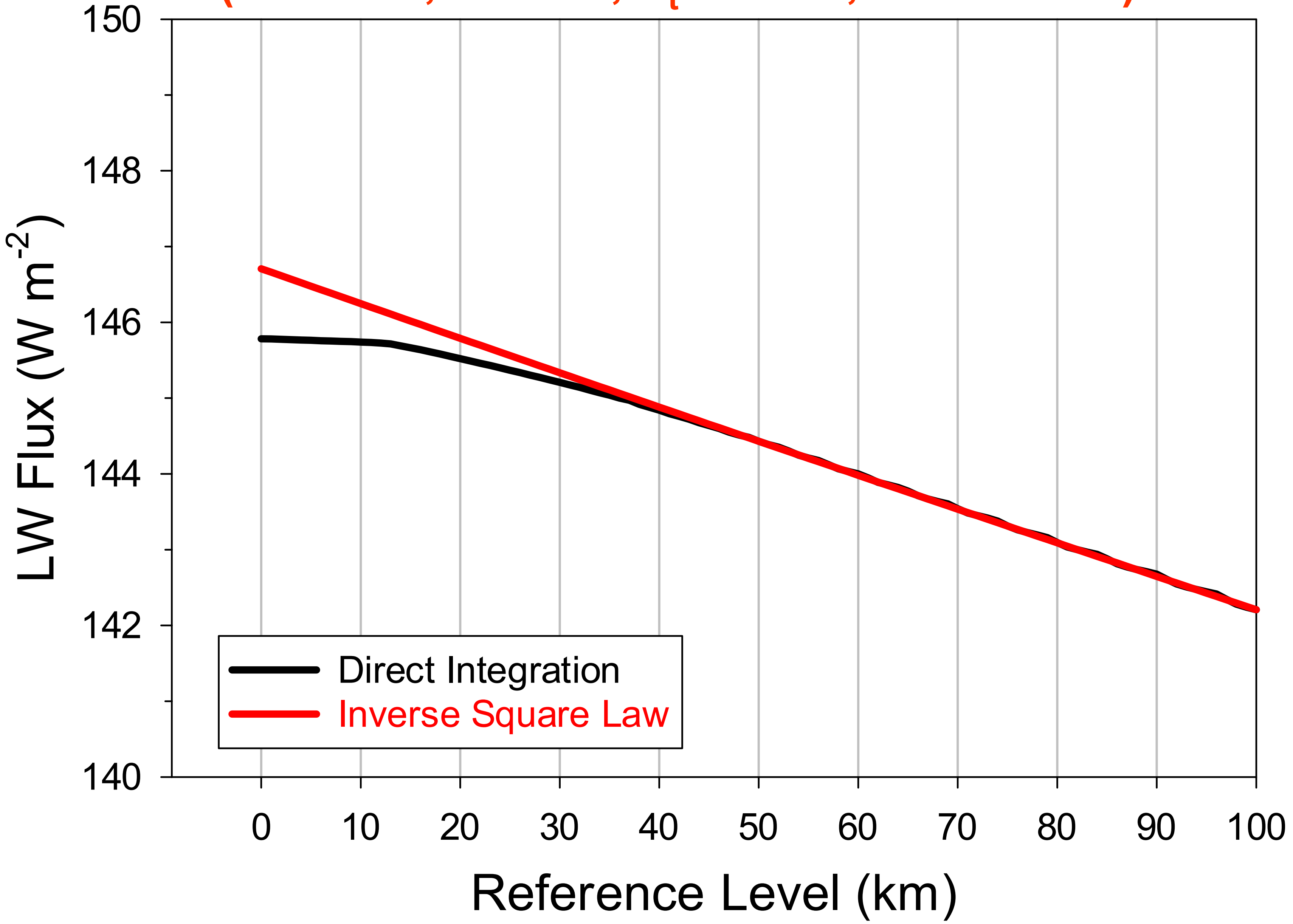
Clear Ocean LW Radiance vs Viewing Zenith Angle (As Function of Reference Level *h*)



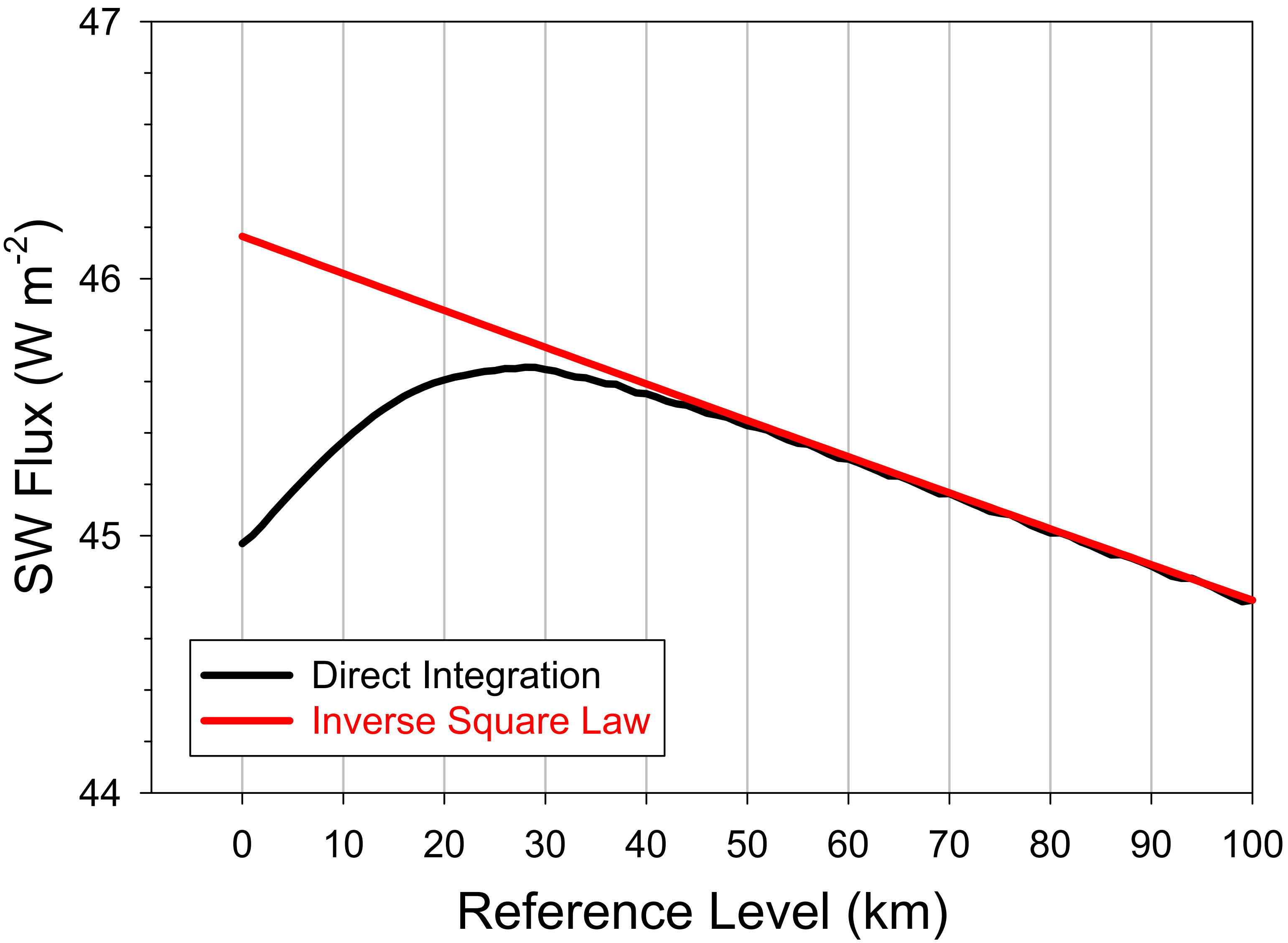
LW Flux vs Reference Level
(Clear Ocean; MODTRAN)



LW Flux vs Reference Level
(Thick Ci; τ=1000; Z_t=11 km; MODTRAN)

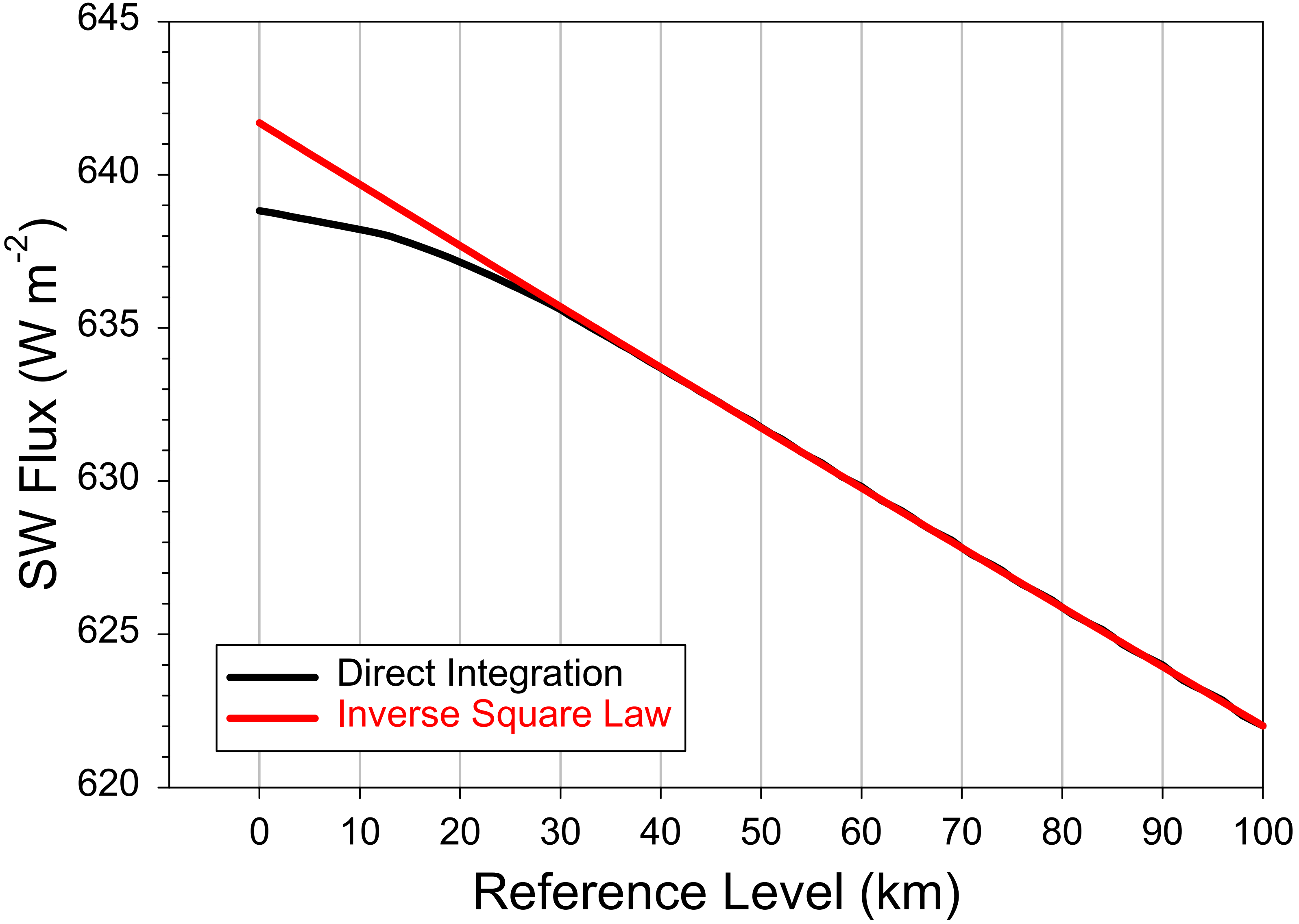


SW Flux vs Reference Level (Rayleigh Atm; θ_o=45; MODTRAN)

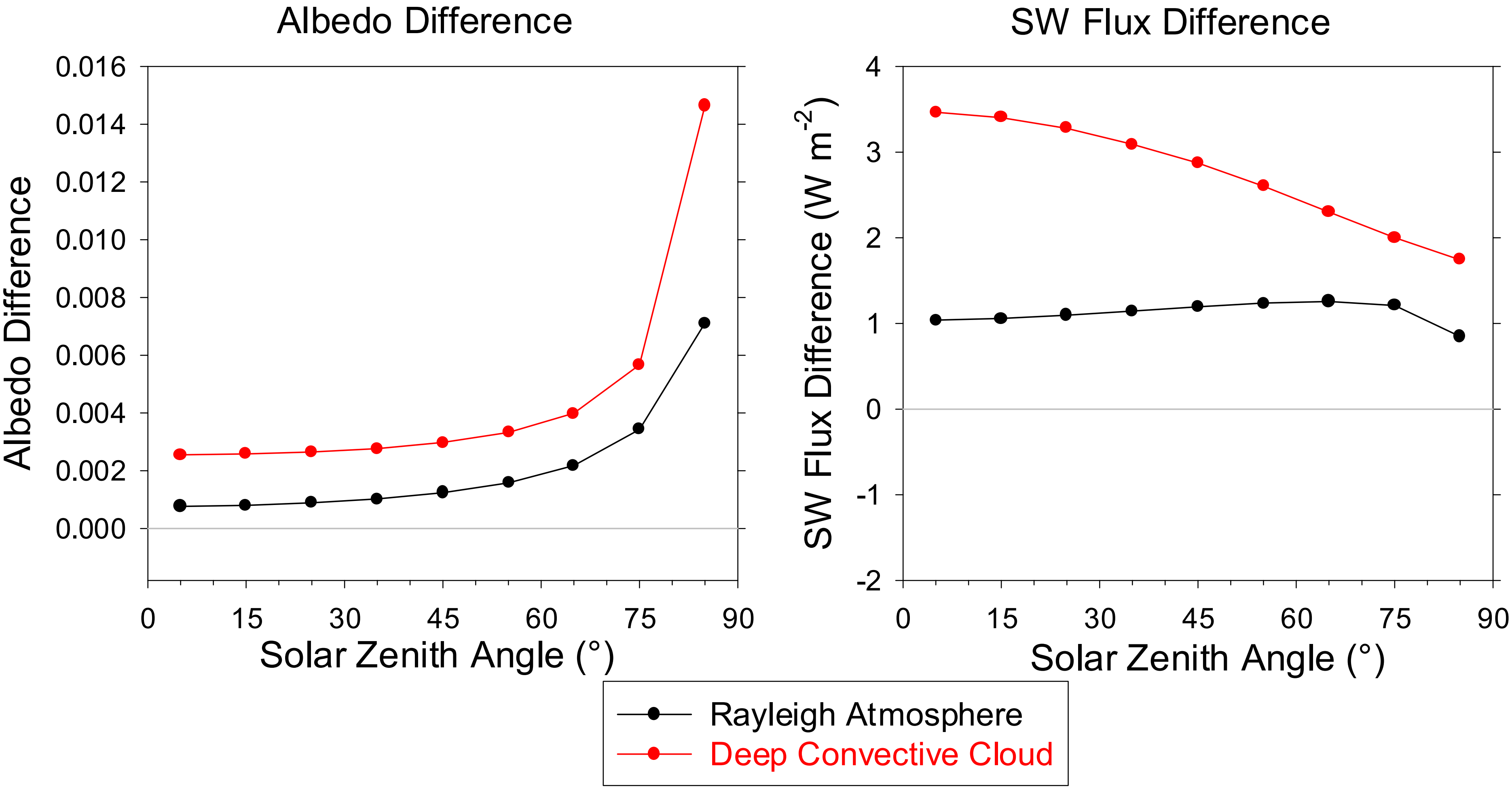


SW Flux vs Reference Level

(Thick Ci; τ=1000; Z_t=11 km; θ_o=45; MODTRAN)



Albedo & SW Flux Contribution From Off-Earth Views (MODTRAN; Surface Reference Level)



Edition2B ADMs

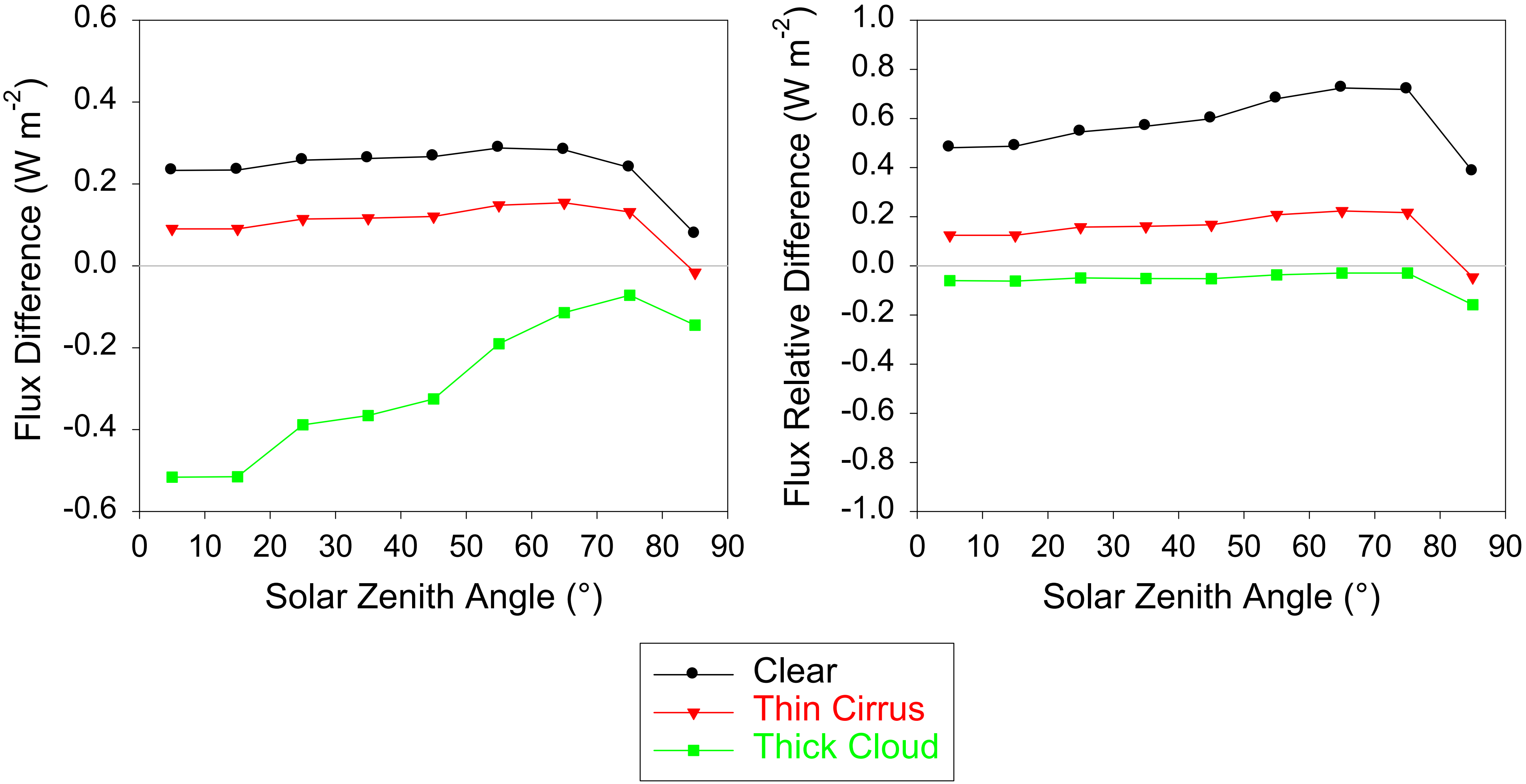
- Evaluate ADM TOA flux by direct integration at 100-km reference level. Use MODTRAN radiances to fill-in radiances at off-earth views.

- Define ADMs at the surface reference level via inverse square law:

$$R_j^{SW}(\theta_{oi},\theta_k,\phi_l;\ \mathrm{h_{sfc}}) = \frac{\pi \bar{I}_j^{SW}(\theta_{oi},\theta_k,\phi_l;\ \mathrm{h_{sfc}})}{F_j^{SW}(\theta_{oi};\mathrm{h_{100}})}\left(\frac{r_e}{r_e + h_{100}}\right)^2$$

$$R_j^{LW}(\theta_k;\ \mathrm{h_{sfc}}) = \frac{\pi \bar{I}_j^{LW}(\theta_k;\ \mathrm{h_{sfc}})}{F_j^{LW}(h_{100})}\left(\frac{r_e}{r_e + h_{100}}\right)^2$$

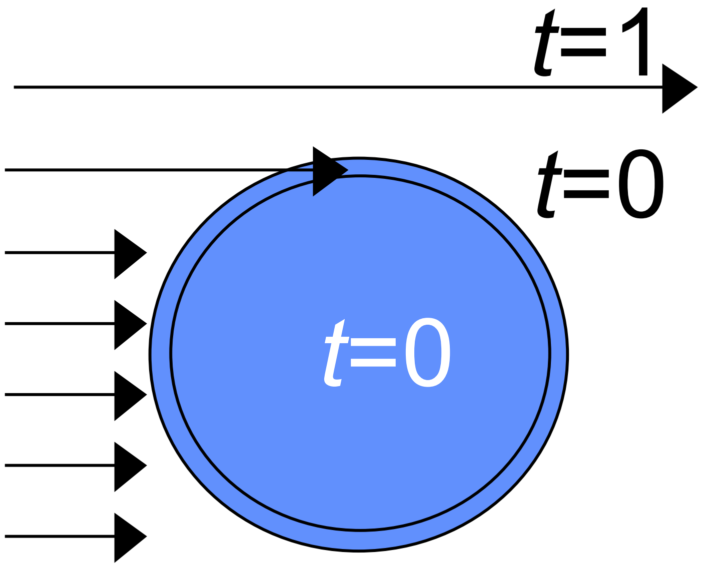
TOA SW Flux Error by Using MODTRAN to Fill-In Off-Earth Views
(Compared with ES8)



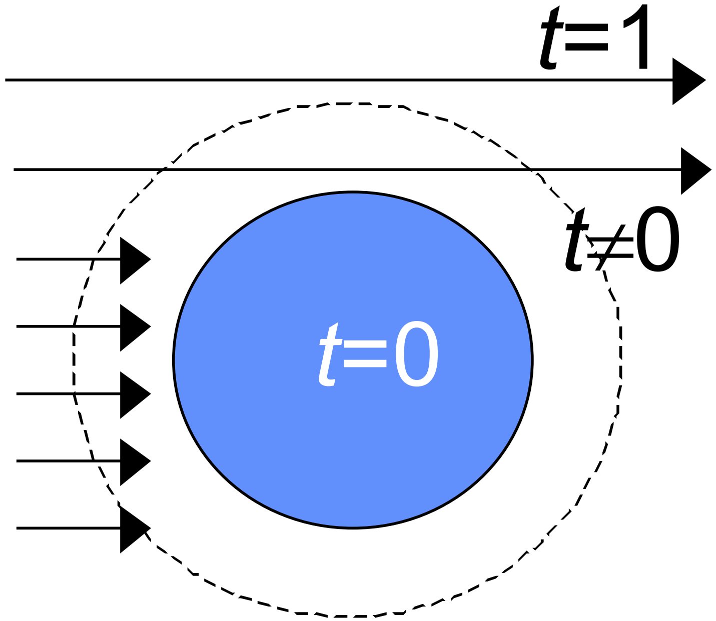
TOA Flux Reference Level (NOT AGAIN!)

Is there a reference level that is most appropriate for radiation budget studies?

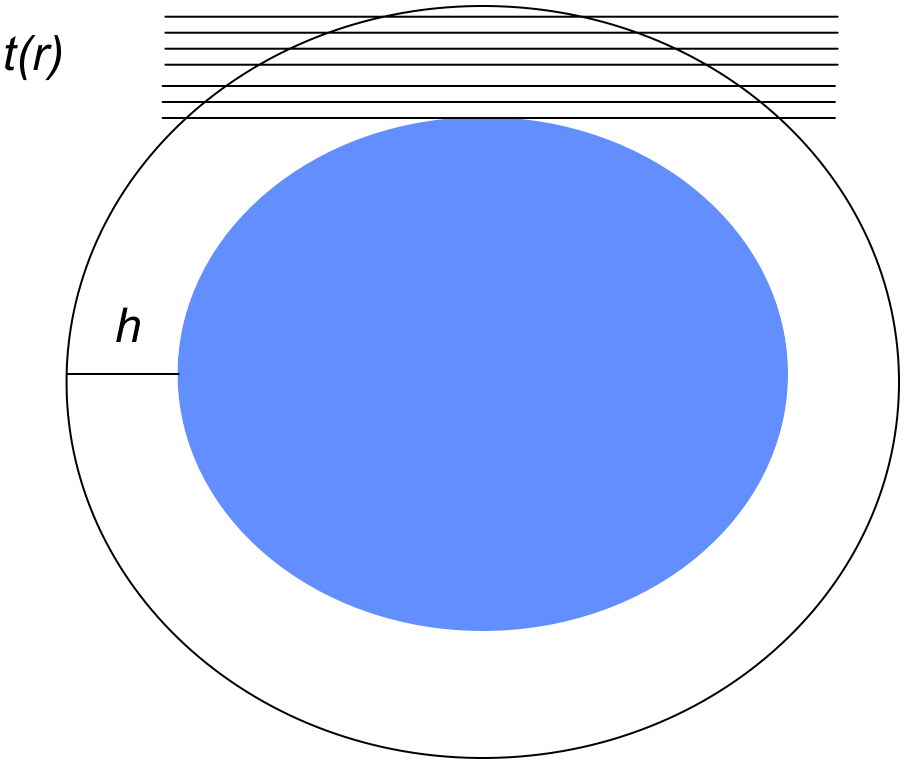
$$\frac{S_o}{4}(1-\alpha) = F^a$$



$$\frac{S_o}{4}(1-\alpha_h - t_h) = F_h^a$$



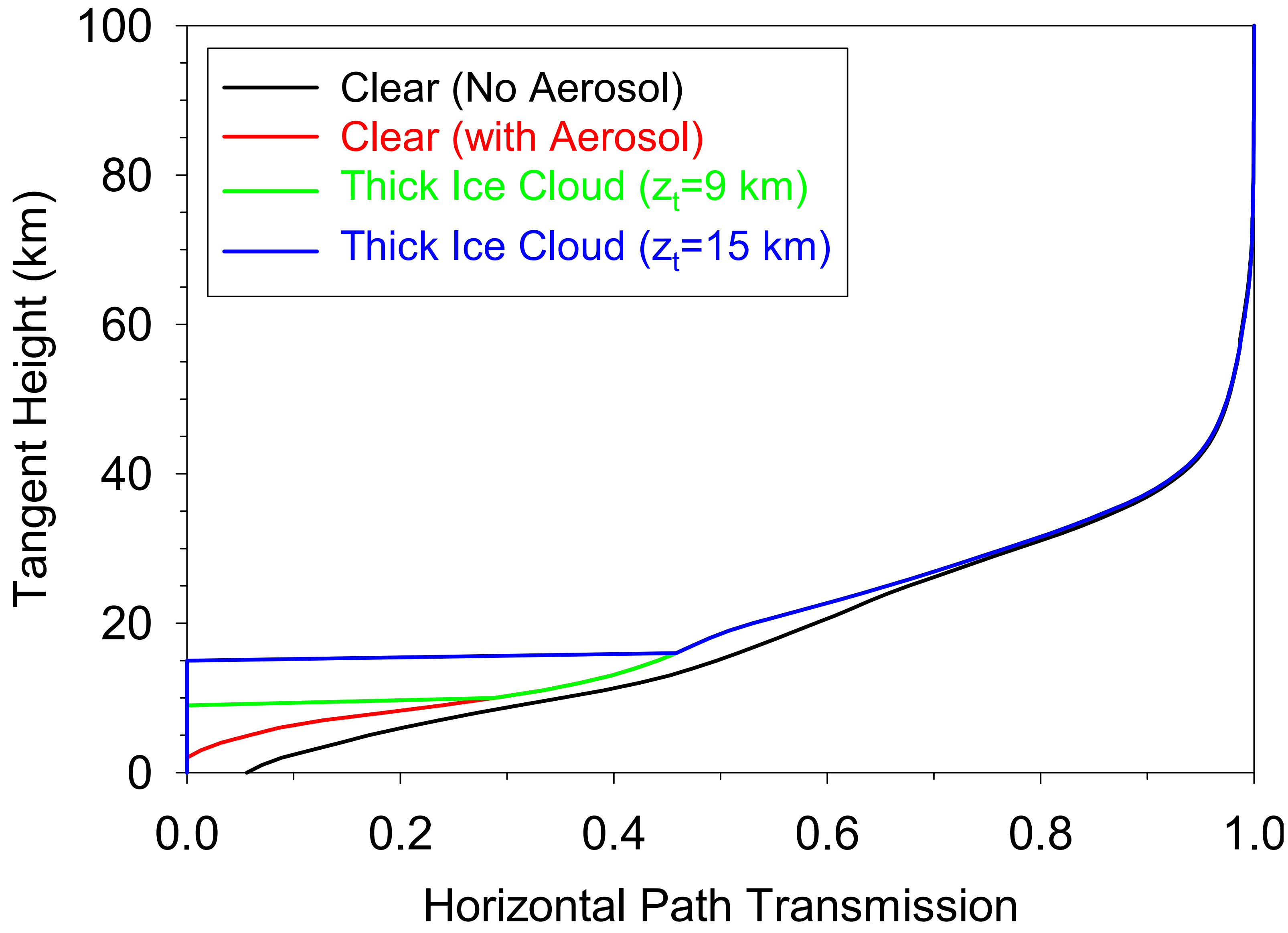
Effective Transmission t_h



$$t(r) = \frac{\int_0^\infty t_\lambda(r) S_{o\lambda} d\lambda}{\int_0^\infty S_{o\lambda} d\lambda}$$

$$t_h = \frac{\int_0^{r_e+h} 2\pi r t(r) dr}{\pi (r_e + h)^2}$$

MODTRAN Horizontal Path Transmission *t(r)*



t_h for Sample MODTRAN Cases (h=100 km)

Case	Profiles	Aerosol	Cloud	t_h ($\times 10^{-2}$)
1	Tropical	No	No	2.503
2	Tropical	Yes	No	2.446
3	Tropical	Yes	Thick Ice; z_t=9 km	2.423
4	Tropical	Yes	Thick Ice; z_t=15 km	2.354
5	Subarctic Winter	No	No	2.546
6	No Atmosphere			3.067

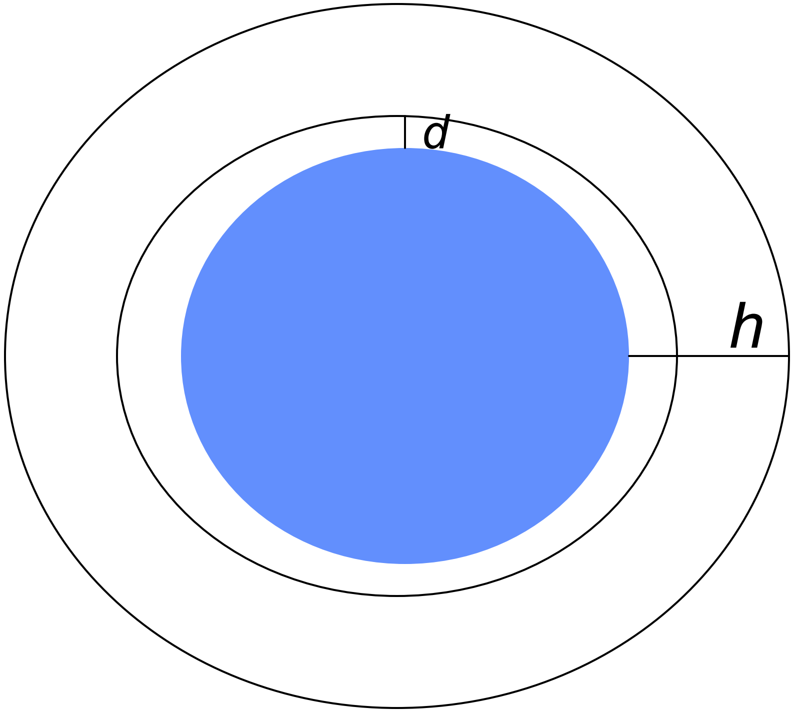
At an arbitrary reference level x:

$$\frac{S_o}{4} - \left(\frac{r_e + h}{r_e + x}\right)^2 (F_h^r + F_h^a) - t_x \frac{S_o}{4} = 0$$

$$t_x = 1 - \left(\frac{r_e + h}{r_e + x}\right)^2 (1 - t_h)$$

At x=d, t_x=0 :

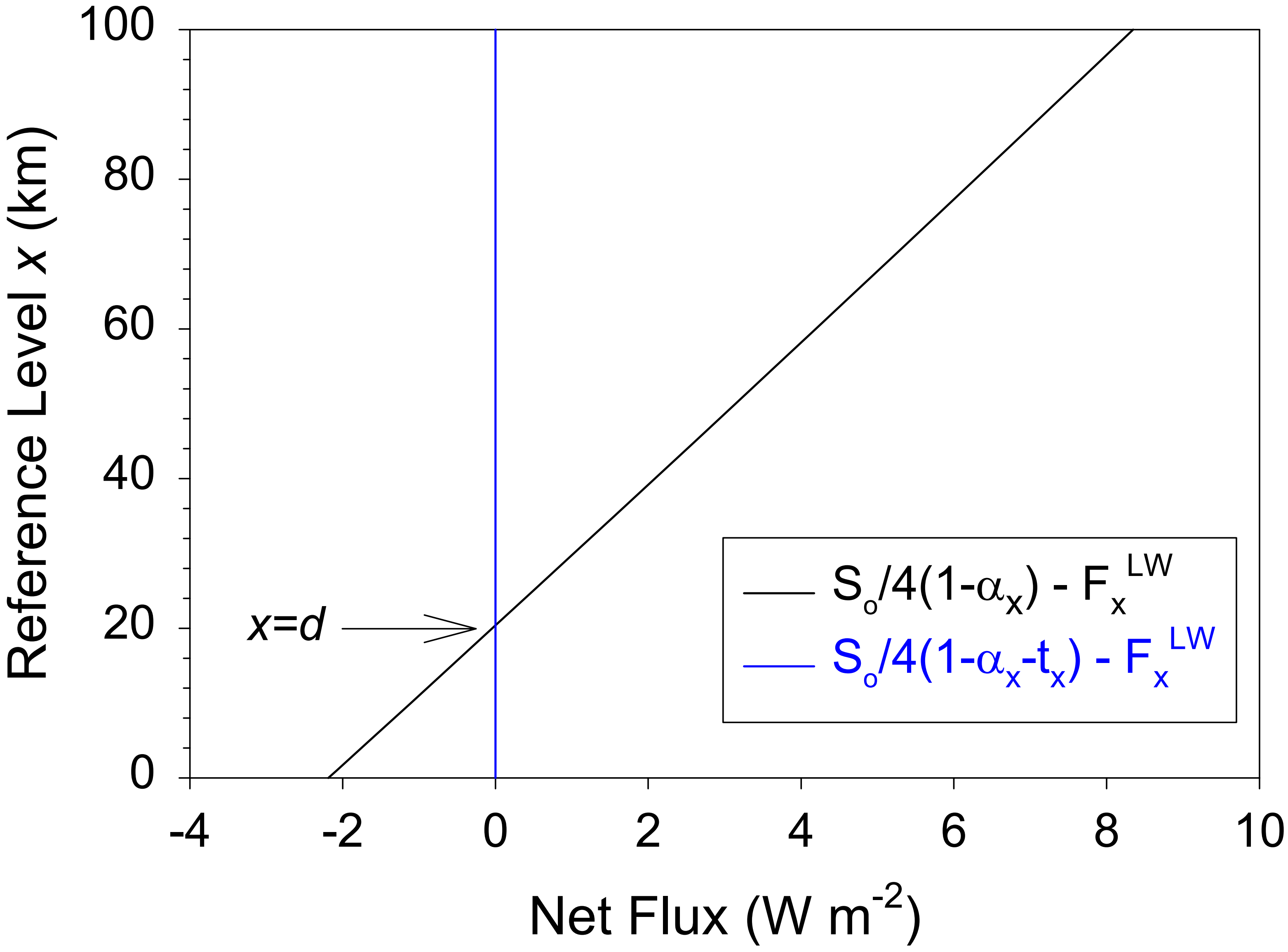
$$d = (r_e + h)\sqrt{1 - t_h} - r_e$$



t_h and *d* for Sample MODTRAN Cases (h=100 km)

Case	Profiles	Aerosol	Cloud	t_h ($\times10^{-2}$)	*d* (km)
1	Tropical	No	No	2.503	18.5
2	Tropical	Yes	No	2.446	20.5
3	Tropical	Yes	Thick Ice; z_t=9 km	2.423	21.1
4	Tropical	Yes	Thick Ice; z_t=15 km	2.354	23.4
5	Subarctic Winter	No	No	2.546	17.1
6	No Atmosphere			3.067	0

Net Flux vs Reference Level



Instantaneous TOA Flux Estimate

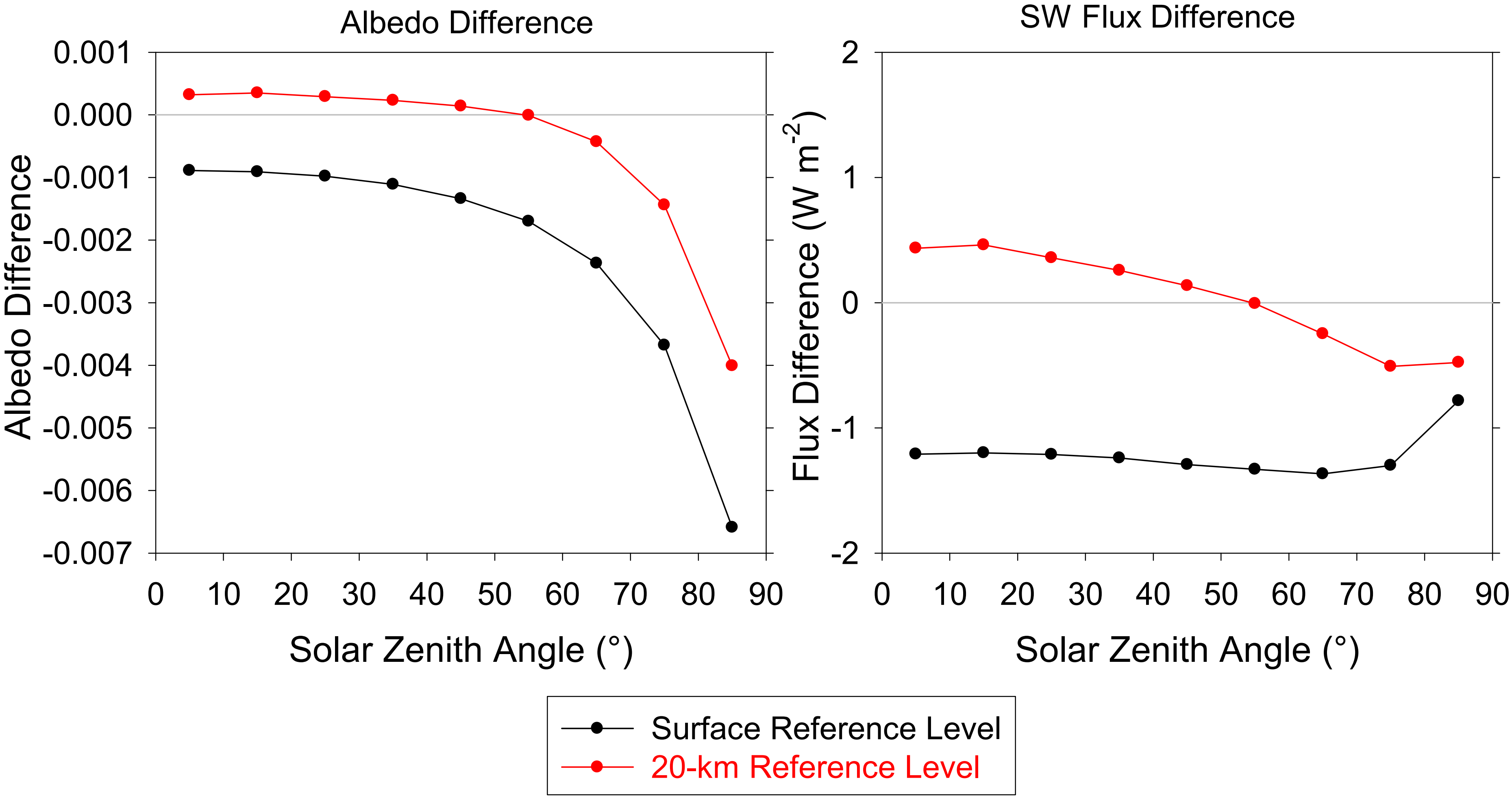
Instantaneous flux at 20-km reference level:

$$\hat{F}(\Omega; h_{20}) = \hat{F}(\Omega; h_{sfc})\left(\frac{r_e}{r_e + h_{20}}\right)^2$$

where,

$$\hat{F}(\Omega; \mathrm{h_{sfc}}) = \frac{\pi I(\Omega;\ \mathrm{h_{sfc}})}{R_j(\Omega;\ \mathrm{h_{sfc}})}$$

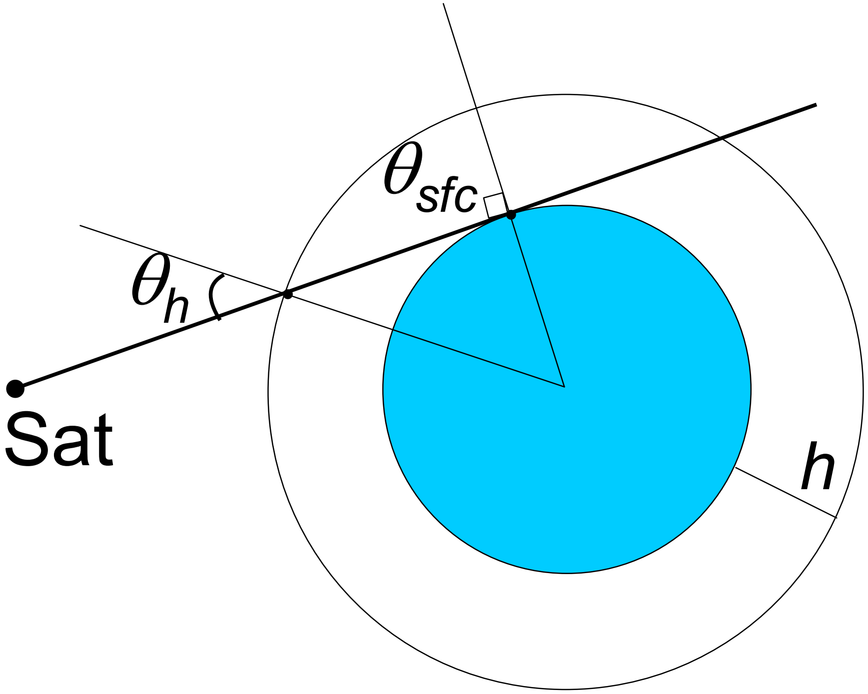
Tropical Average Albedo & SW Flux Difference
(SSF Ed2A - SSF Ed2B)



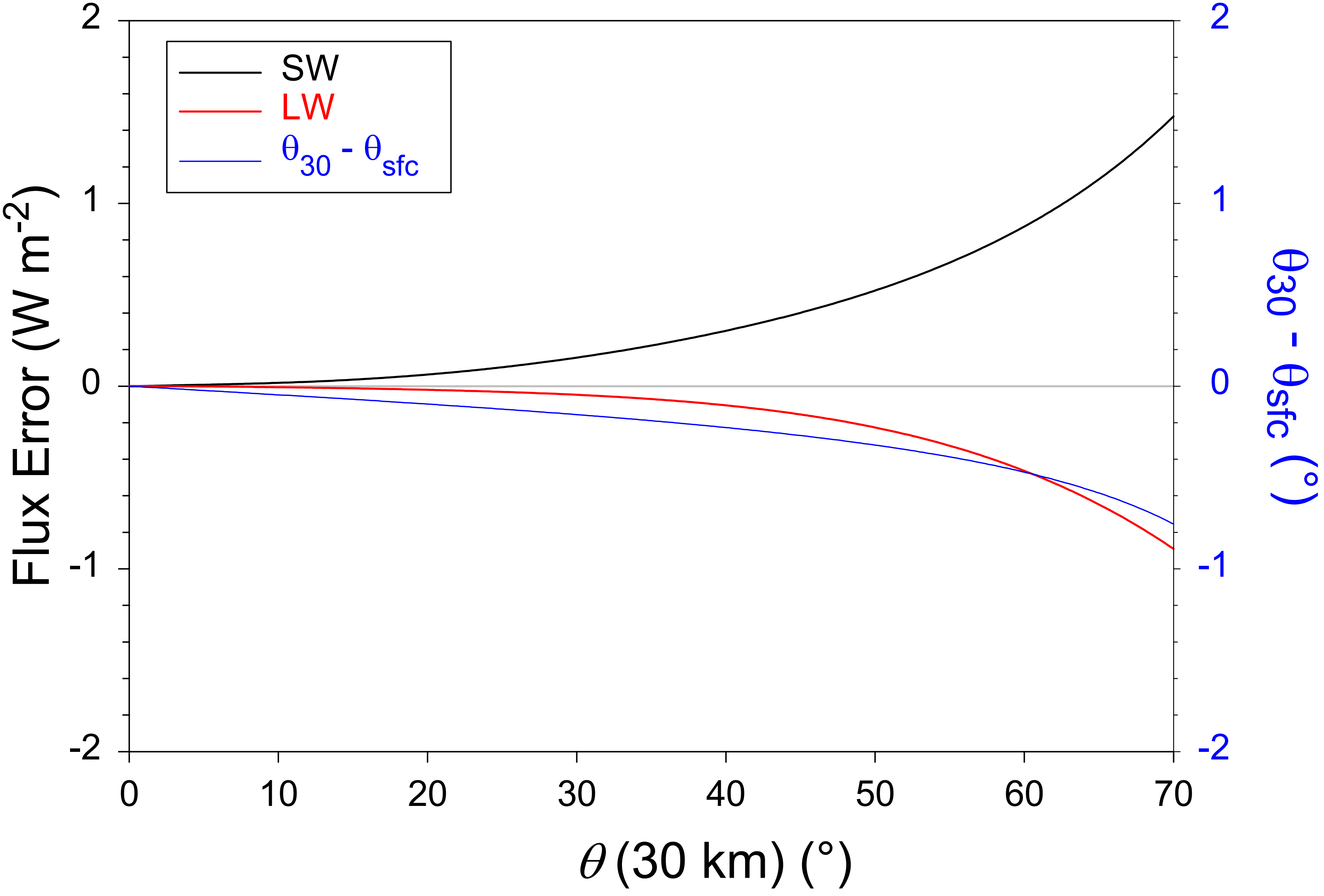
Comparison with ERBE Methodology

- ERBE ADMs constructed from Nimbus-7 using a surface reference level.
- On NOAA-9, 10 and ERBS, the ERBE ADMs were applied using viewing geometry defined at a 30-km reference level.

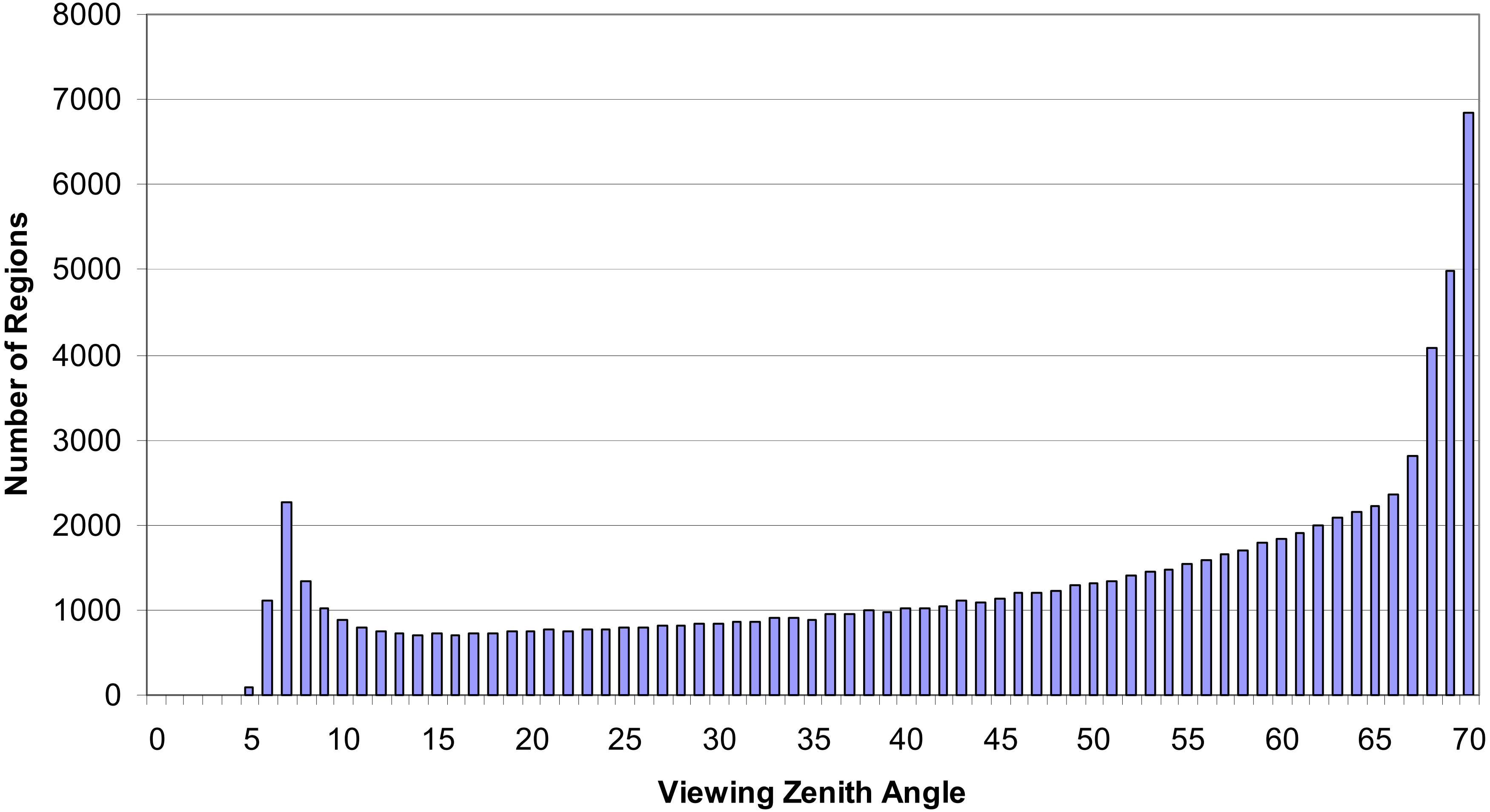
⇒ Viewing zenith used to estimate TOA flux is too small (inconsistent with how models were constructed).



Flux Error Due to Inconsistent Viewing Geometry



Crosstrack Incidence of Regional Mean VZAs
One Month of CERES Data



Equivalent Daily Mean Flux Bias (W m^{-2})

SW

Reference Level	Ed2B	Ed2A	ES8
Surface	-0.06	-0.67	-0.17
20 km	-0.06	-0.07	0.43

LW

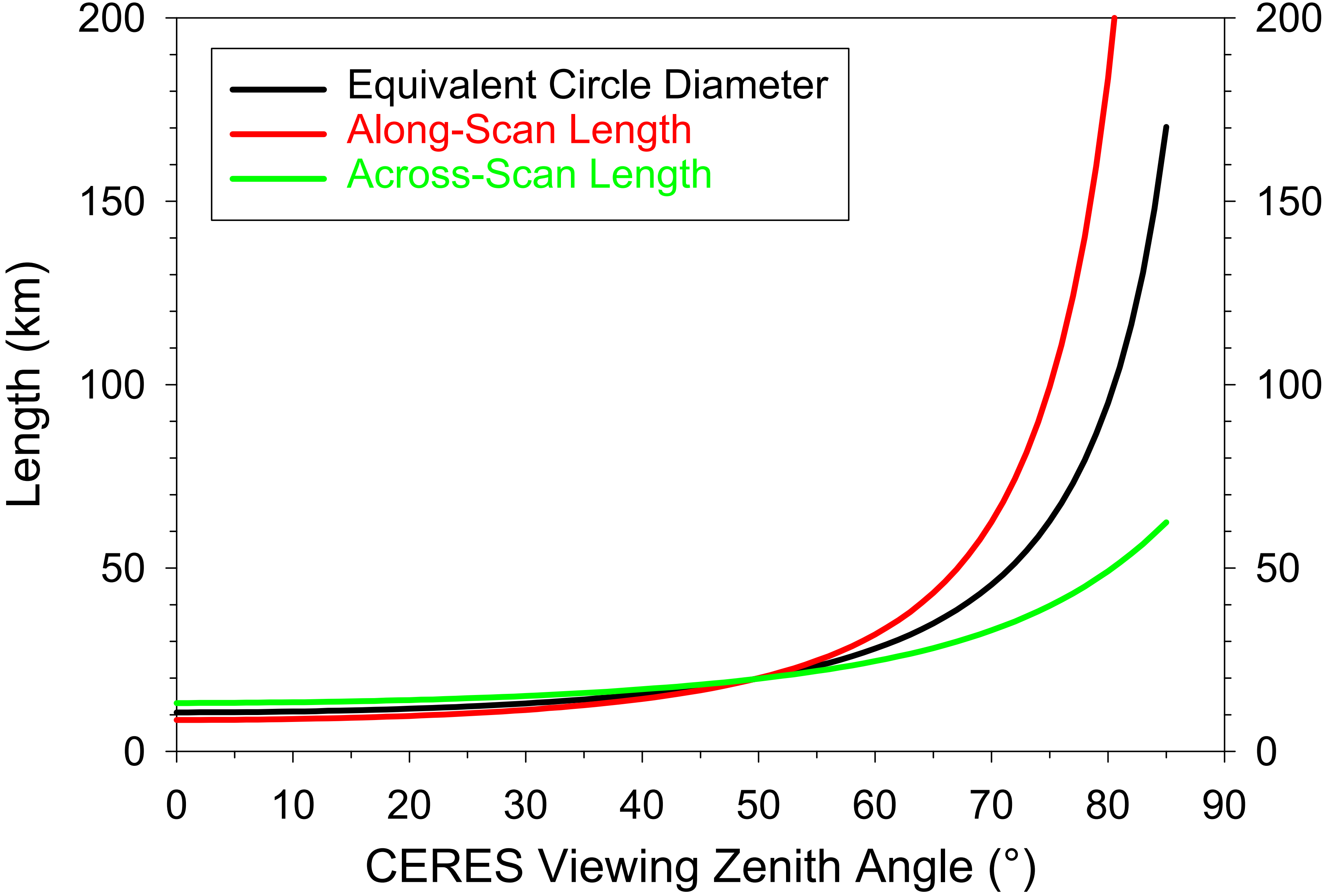
Reference Level	Ed2B	Ed2A	ES8
Surface	0.11	-0.94	-0.50
20 km	0.11	0.69	1.13

Changing CERES RAPS Azimuth Rate to Study the Effect of FOV Size on TOA Fluxes

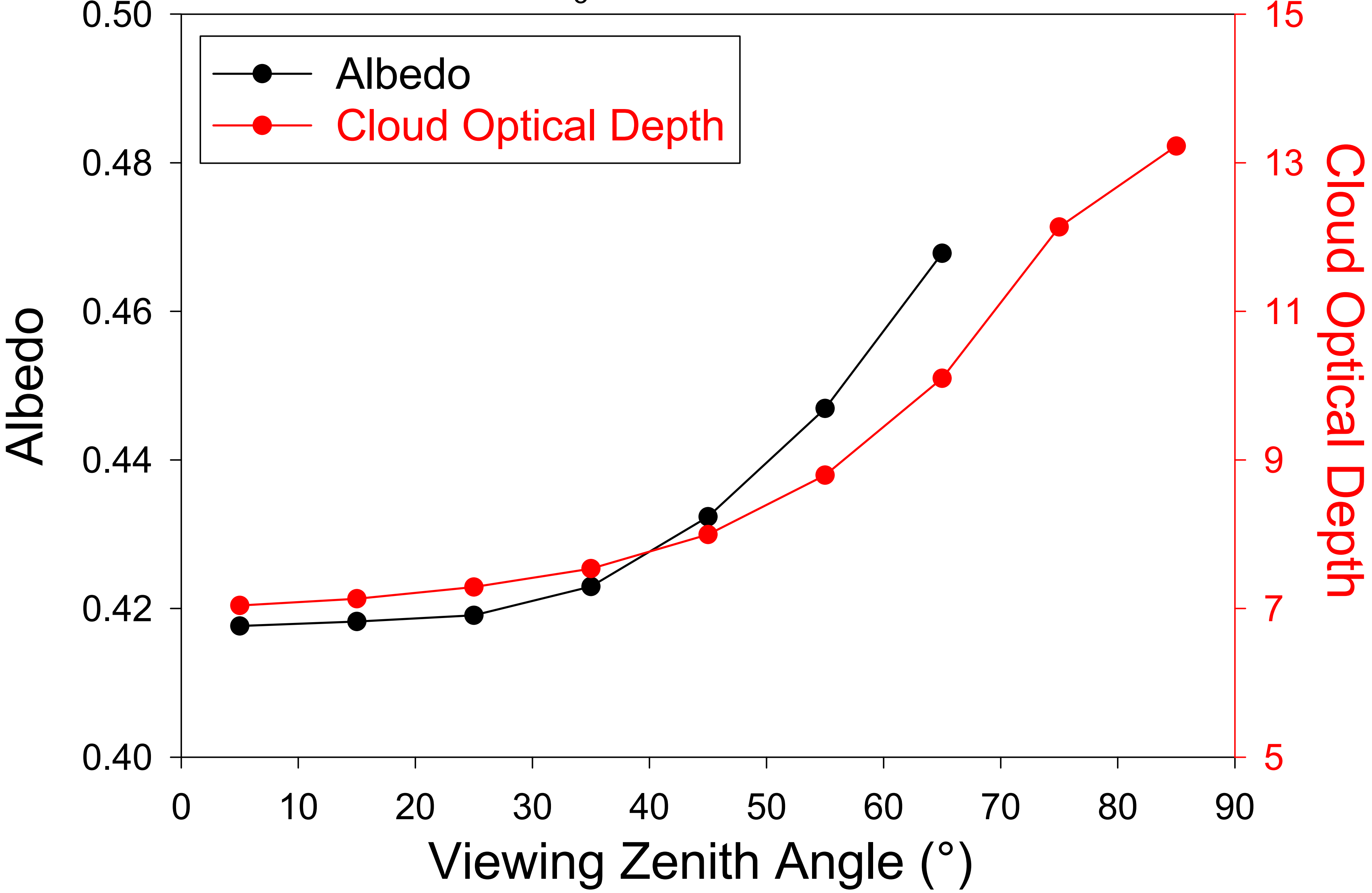
- FOV size depends on viewing zenith angle.
  - => How do TOA fluxes, ADMs and cloud properties change with FOV size?

- Can CERES/TRMM and CERES/Terra data be analyzed together without accounting for differences in FOV size?

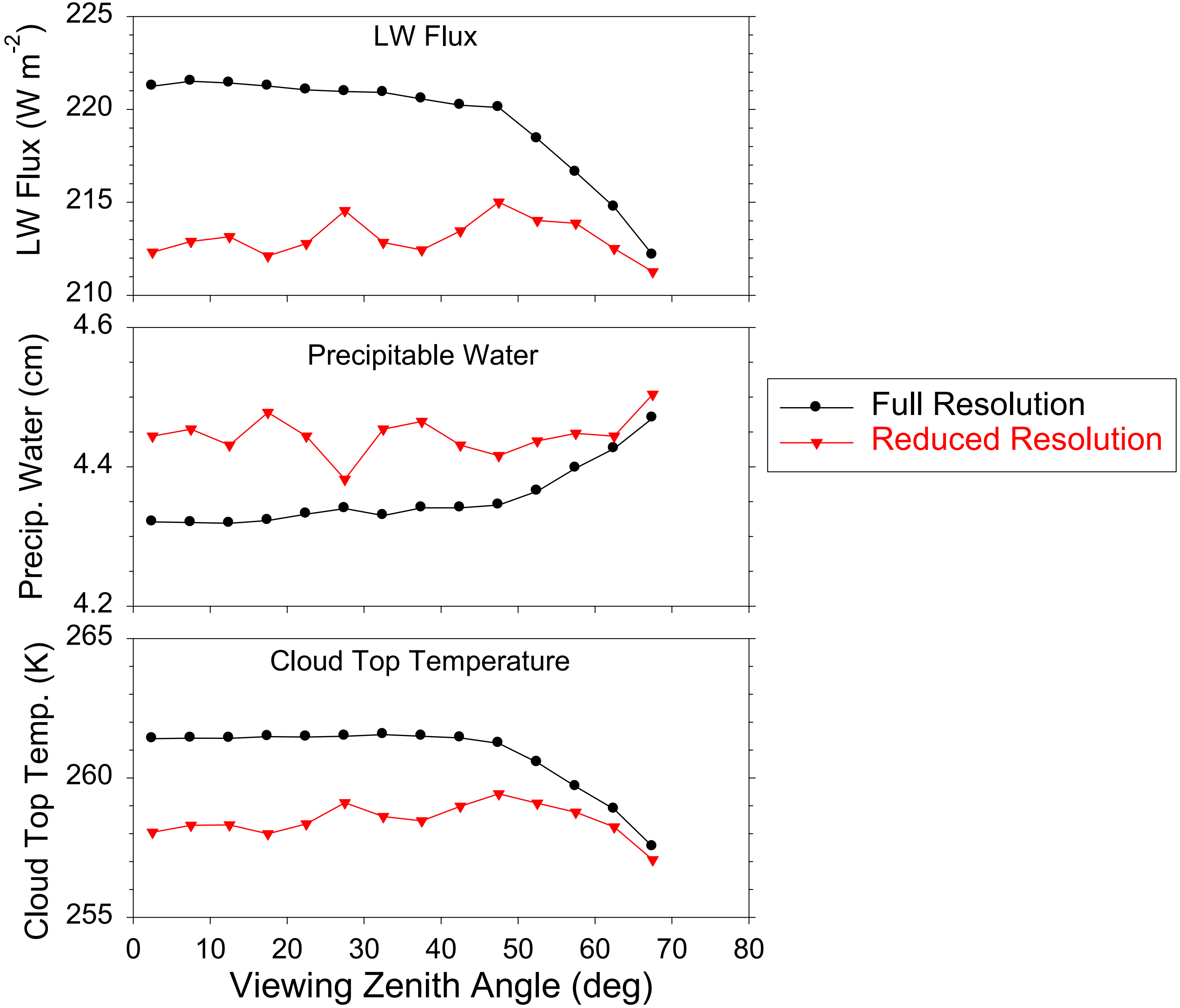
CERES-TRMM Footprint Size vs Viewing Zenith Angle (50% PSF Cutoff)



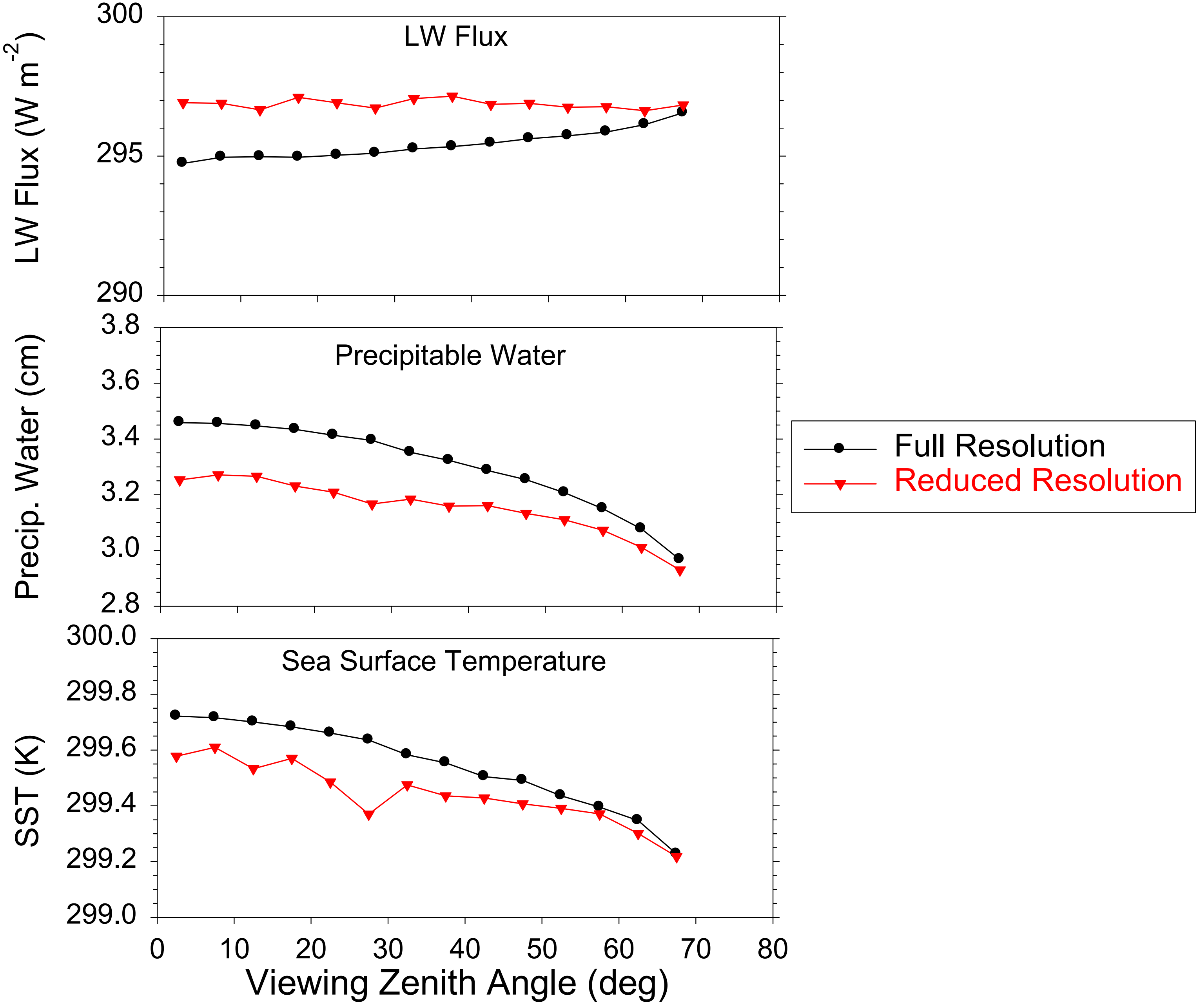
Albedo and Cloud Optical Depth vs Viewing Zenith Angle
(Overcast; θ_o=50-60; 9 Alongtrack Days)



Overcast Ocean

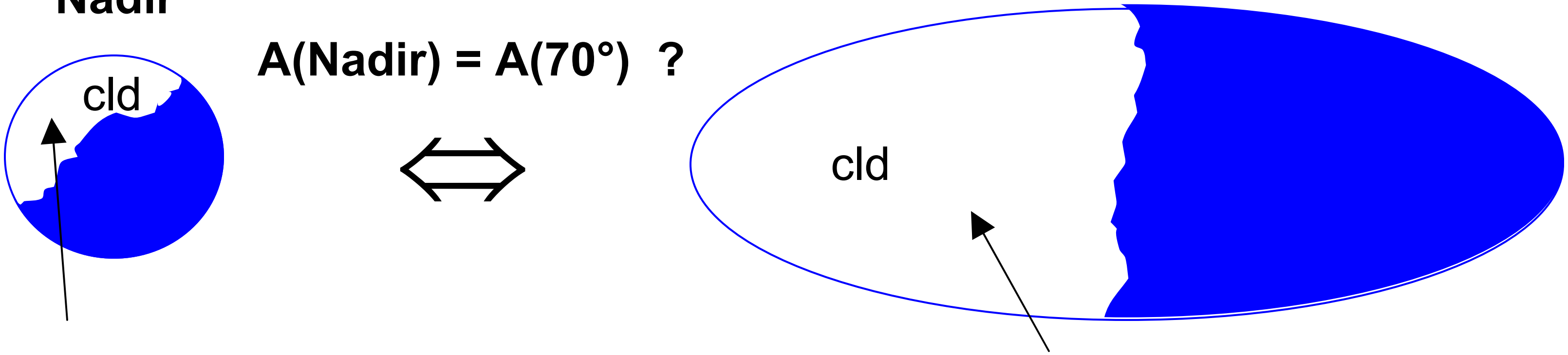


Clear Ocean


LW Flux
LW Flux (W m^{-2})
300
295
290
Precipitable Water
Precip. Water (cm)
3.8
3.6
3.4
3.2
3.0
2.8
Sea Surface Temperature
SST (K)
300.0
299.8
299.6
299.4
299.2
299.0
0
10
20
30
40
50
60
70
80
Viewing Zenith Angle (deg)
Full Resolution
Reduced Resolution

FOV Resolution and ADMs

- ADMs are determined from radiance populations stratified by viewing geometry and scene type (e.g. cloud phase, cloud fraction and log of cloud optical depth).
- Are the populations in every viewing zenith angle bin consistent for a given scene class? i.e. Do they likely have the same popl'n mean albedo? The same anisotropy?



θ = 70°

Nadir

A(Nadir) = A(70°) ?

***f*=40%-50%**

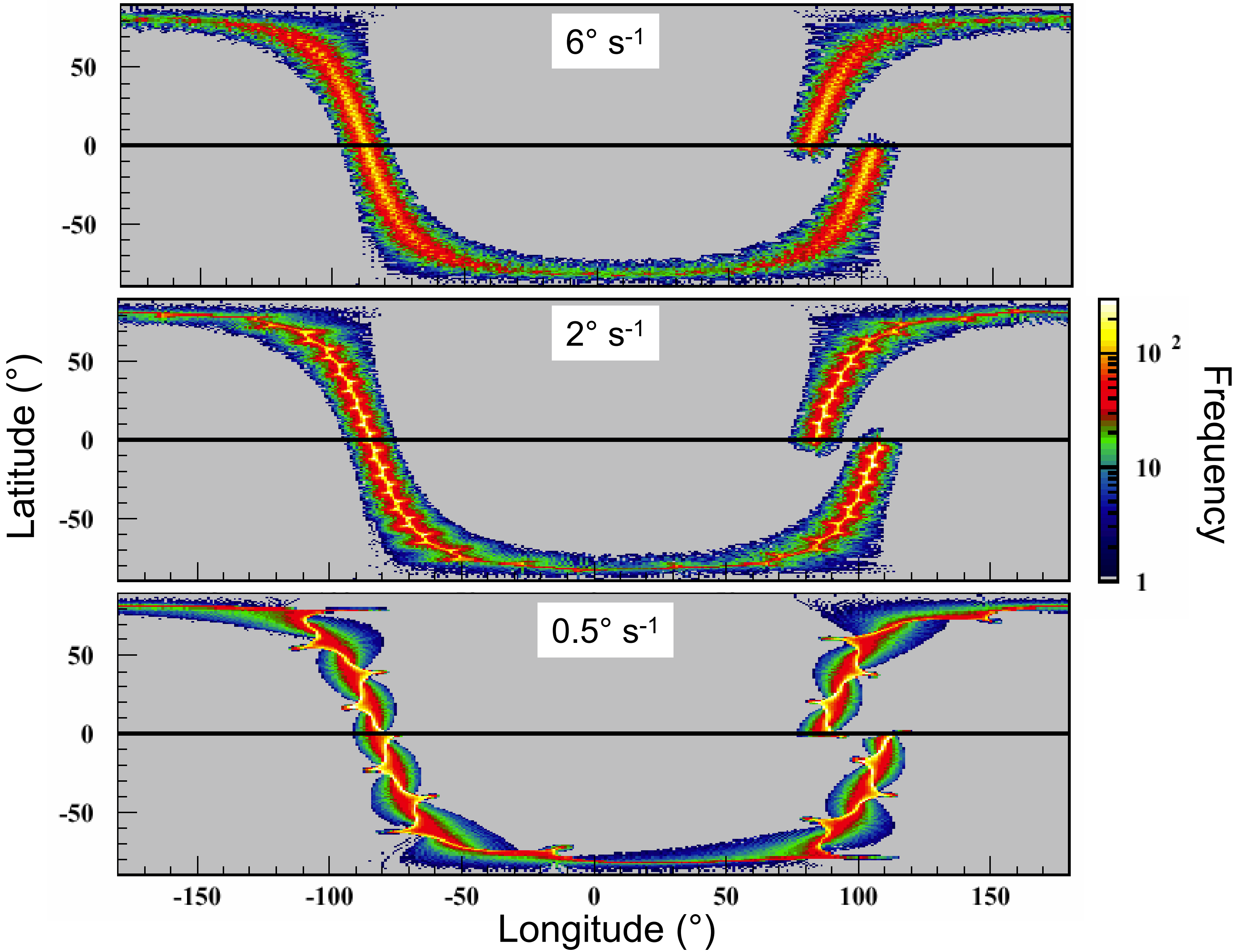
3 < exp(<log τ>) < 4

***f*=40%-50%**

3 < exp(<log τ>) < 4

Date	CERES Azimuth Rate ($^\circ$ s^{-1})
Oct 1, 2001	6
Oct 17, 2001	4
Oct 18, 2001	3
Oct 19, 2001	2
Oct 20, 2001	1
Oct 21, 2001	0.5

1 Terra Orbit with Different CERES RAPS Azimuth Rates



CERES RAPS Scan Pattern For Different Slew Rates