# CERES Angular Distribution Model Analyses


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# OUTLINE

i) CERES SSF Edition3: ADM-related Issues

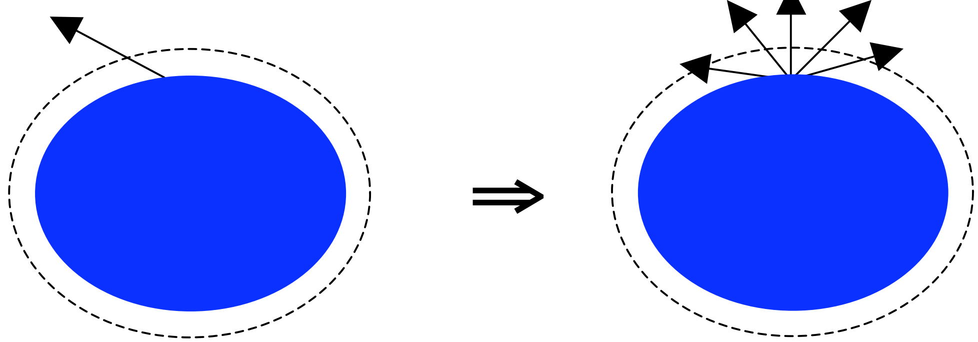
ii) Instantaneous TOA Flux Uncertainties

iii) MISR vs CERES TOA Albedo Comparison

# Instantaneous Fluxes at TOA
# and Angular Distribution Models

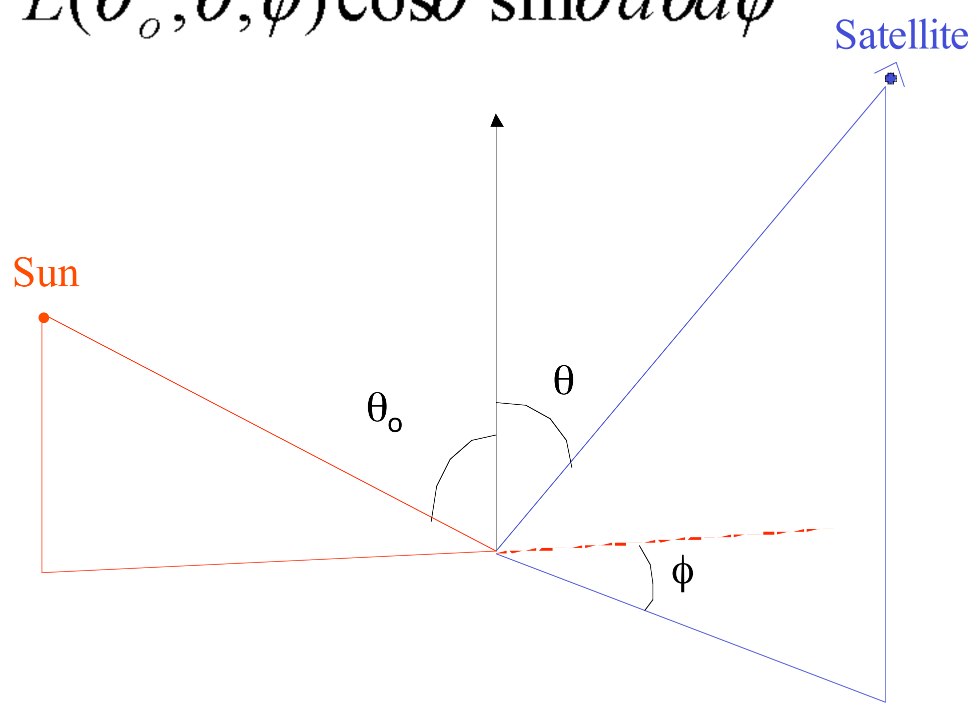
CERES Radiance Measurement

TOA Flux Estimate



SW
LW
WN

$$F(\theta_o) = \int_0^{2\pi} \int_0^{\frac{\pi}{2}} L(\theta_o, \theta, \phi) \cos\theta \sin\theta \, d\theta \, d\phi$$



# Instantaneous Fluxes at TOA and Angular Distribution Models

TOA flux estimate from CERES radiance:

$$\hat{F}(\theta_o,\theta,\phi) = \frac{\pi L(\theta_o,\theta,\phi)}{R_j(\theta_o,\theta,\phi)}$$

where,

$$R_j(\theta_o,\theta,\phi) = \frac{\pi L_j(\theta_o,\theta,\phi)}{\int_0^{2\pi}\int_0^{\frac{\pi}{2}} L_j(\theta_o,\theta,\phi)\cos\theta\sin\theta d\theta d\phi}$$

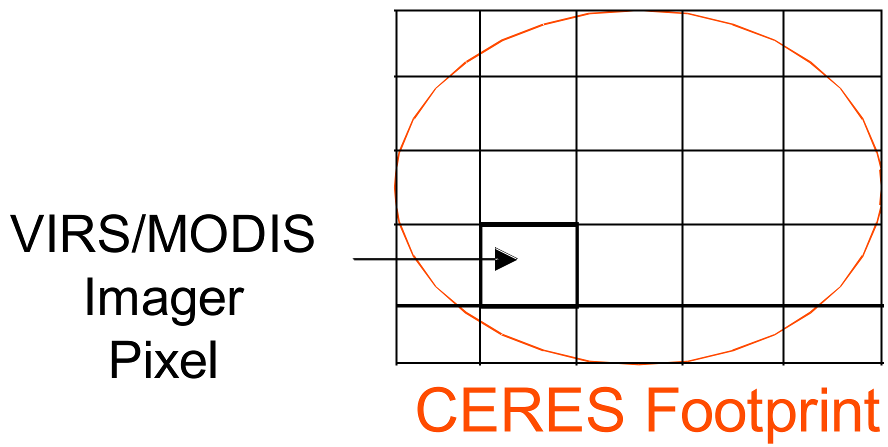
$R_j(\theta_o,\theta,\phi)$ is the Angular Distribution Model (ADM) for the "j$^{th}$" scene type.

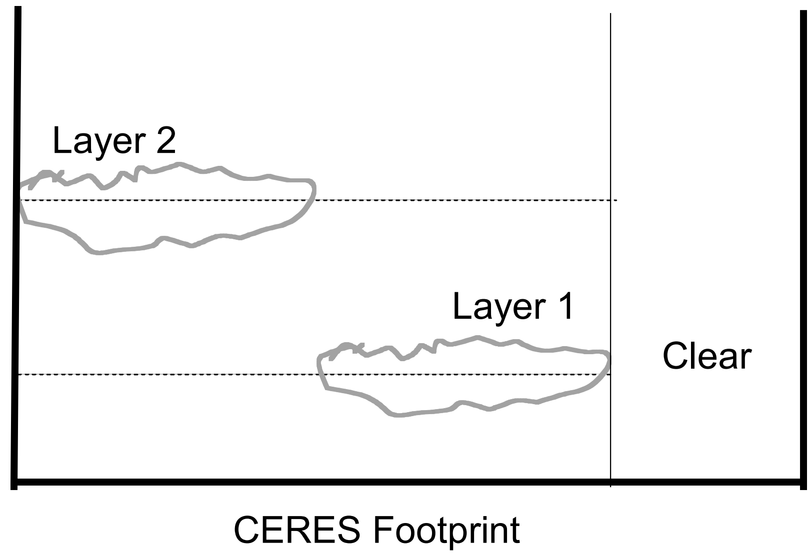
# CERES Single Scanner Footprint (SSF) Product

- Coincident CERES radiances and imager-based cloud and aerosol properties.

- Use VIRS (TRMM) or MODIS (Terra, Aqua) to determine following parameters in up to 2 cloud layers over every CERES FOV:

Macrophysical: Fractional coverage, Height, Radiating Temperature, Pressure
Microphysical : Phase, Optical Depth, Particle Size, Water Path
Clear Area : Albedo, Skin Temperature, Aerosol optical depth, Emissivity



# CERES/Terra Shortwave ADMs for Different Scene Types

| Scene Type | Description |
|---|---|
| Clear Ocean | Function of wind speed; Correction for aerosol optical depth included. |
| Cloud Ocean | Function of cloud phase; Continuous function of cloud fraction and cloud optical depth (5-parameter sigmoid). |
| Land & Desert Clear | 1° regional monthly ADMs using Analytical Function of TOA BRDF (Ahmad and Deering, 1992). |
| Land & Desert Cloud | Function of cloud phase; continuous function of cloud cover and cloud optical depth; uses 1°-regional clear-sky BRDFs to account for background albedo. |
| Permanent Snow | Cloud Fraction, Surface Brightness, cloud optical depth |
| Fresh Snow | Cloud Fraction, Surface Brightness, Snow Fraction, cloud optical depth |
| Sea-Ice | Cloud Fraction, Surface Brightness, Ice Fraction, cloud optical depth |

# CERES/Terra Longwave & Window ADMs for Different Scene Types

| Scene Type | Description |
|---|---|
| Clear Ocean, Land, Desert | Ocean, Forest, Cropland/Grass, Savanna, Bright Desert, Dark Desert, precip. water, lapse rate, skin temperature |
| Clouds Over Ocean, Land, Desert | Function of precip. water, skin temp., sfc-cloud temp. diff; continuous function of parameterization involving cloud fraction, cloud and sfc emissivity, sfc and cloud temp. |
| Permanent Snow<br>Fresh Snow<br>Sea-Ice | Each a function of cloud fraction, sfc temp, sfc-cld temp diff |

# CERES ADMs

| Satellite | Data Used | Reference | Data Products |
|---|---|---|---|
| TRMM | SSF Ed1<br>(01/98-08/98; 03/00) | Loeb et al.<br>2003<br>(JAM) | SSF Ed2B |
| Terra | SSF Ed1A<br>(03/00 – 02/02) | Loeb et al.<br>2004<br>(JAOTECH) | SSF Ed2B |
| Aqua | SSF Ed1B<br>(08/02 – 06/04) | Same as Terra | SSF Ed2A |

## Terra Edition3 TOA Flux/ADMs

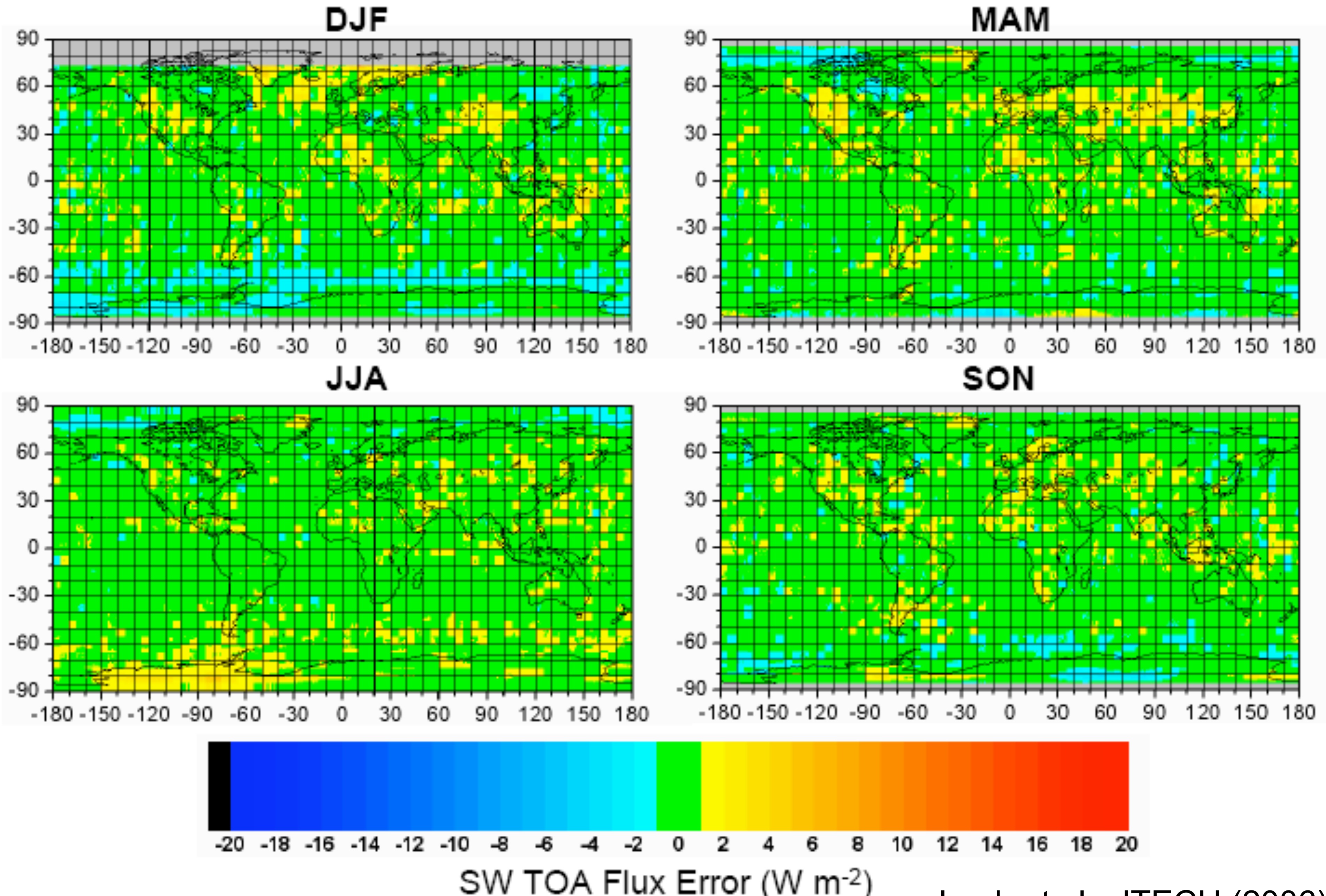
Use the same ADMs as in Edition2B with the following modifications:

- Aqua sea-ice SW ADMs for Terra.

- Terra permanent snow nighttime LW ADMs for Aqua Ed3.

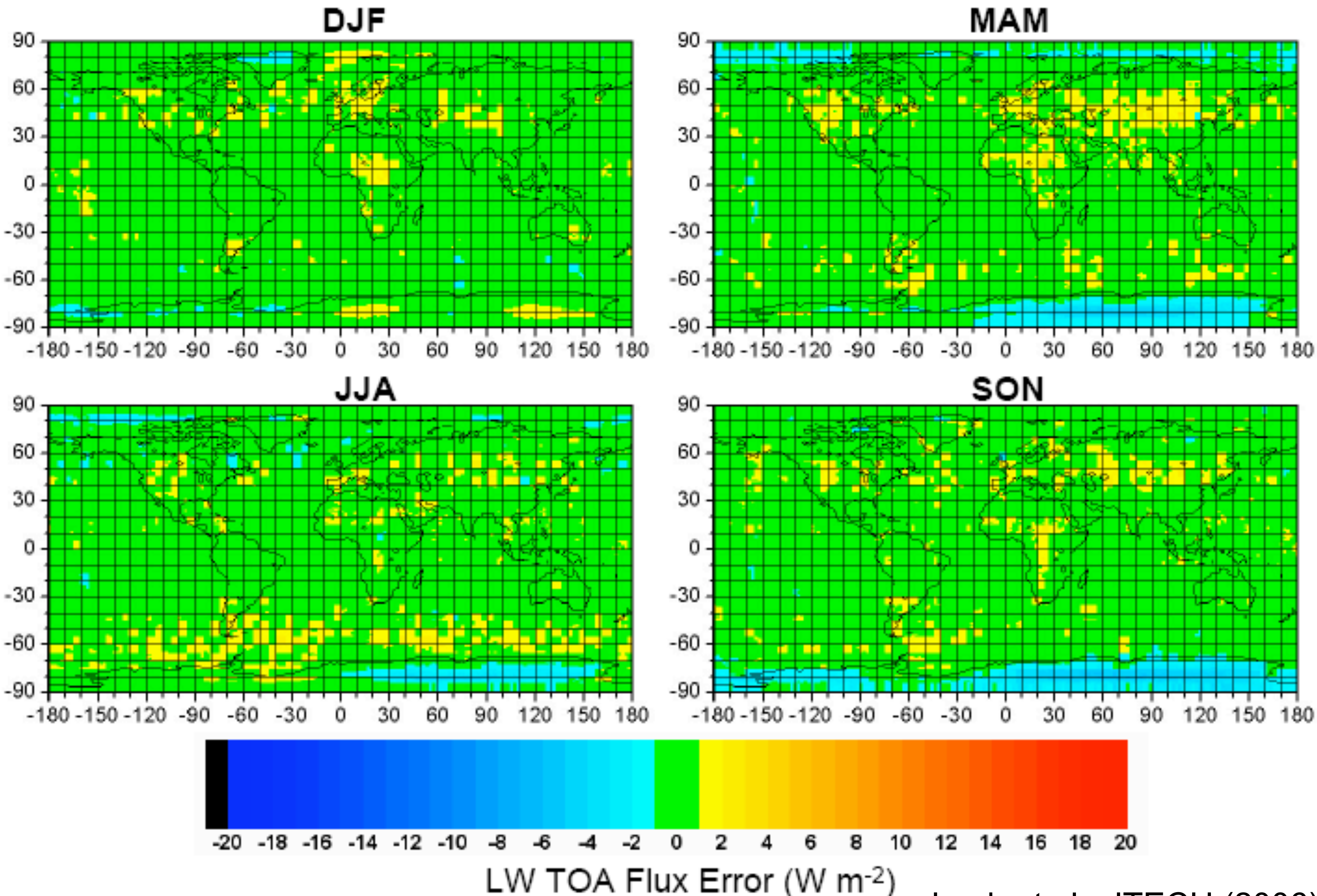
- Evaluate use of Ed2 ADMs applied to Ed3 scene identification using Ed3_beta files that will be generated prior to running official Ed3 SSFs.

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



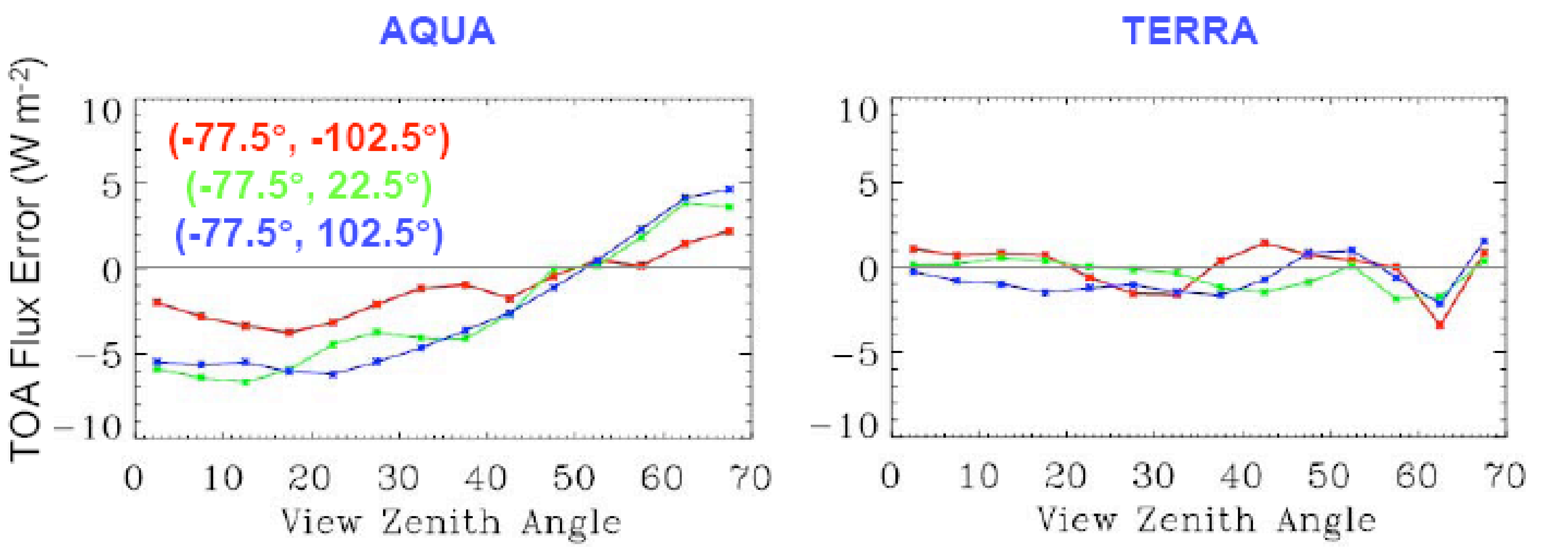

Loeb et al. JTECH (2006)

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



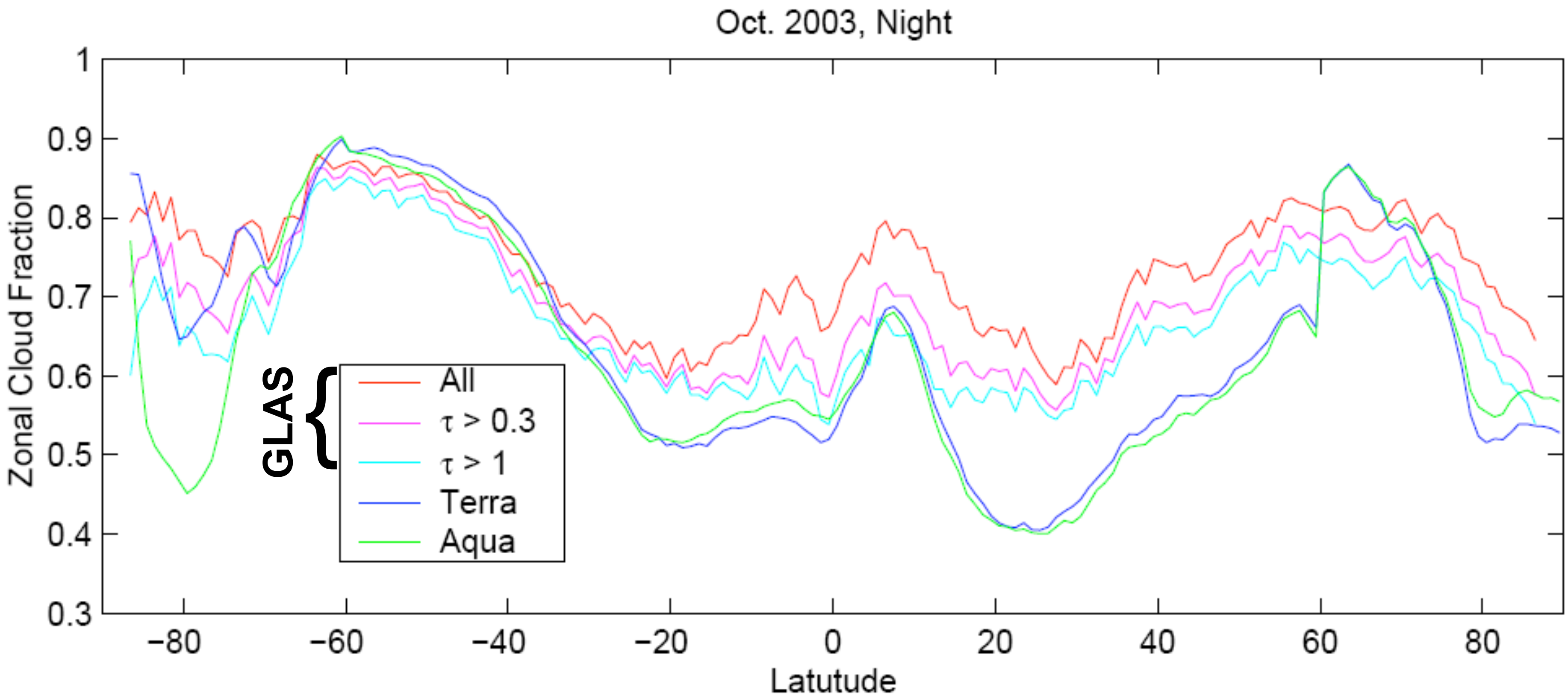

Loeb et al. JTECH (2006)

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




Loeb et al. JTECH (2006)

# CERES Cloud Fraction Comparison with GLAS



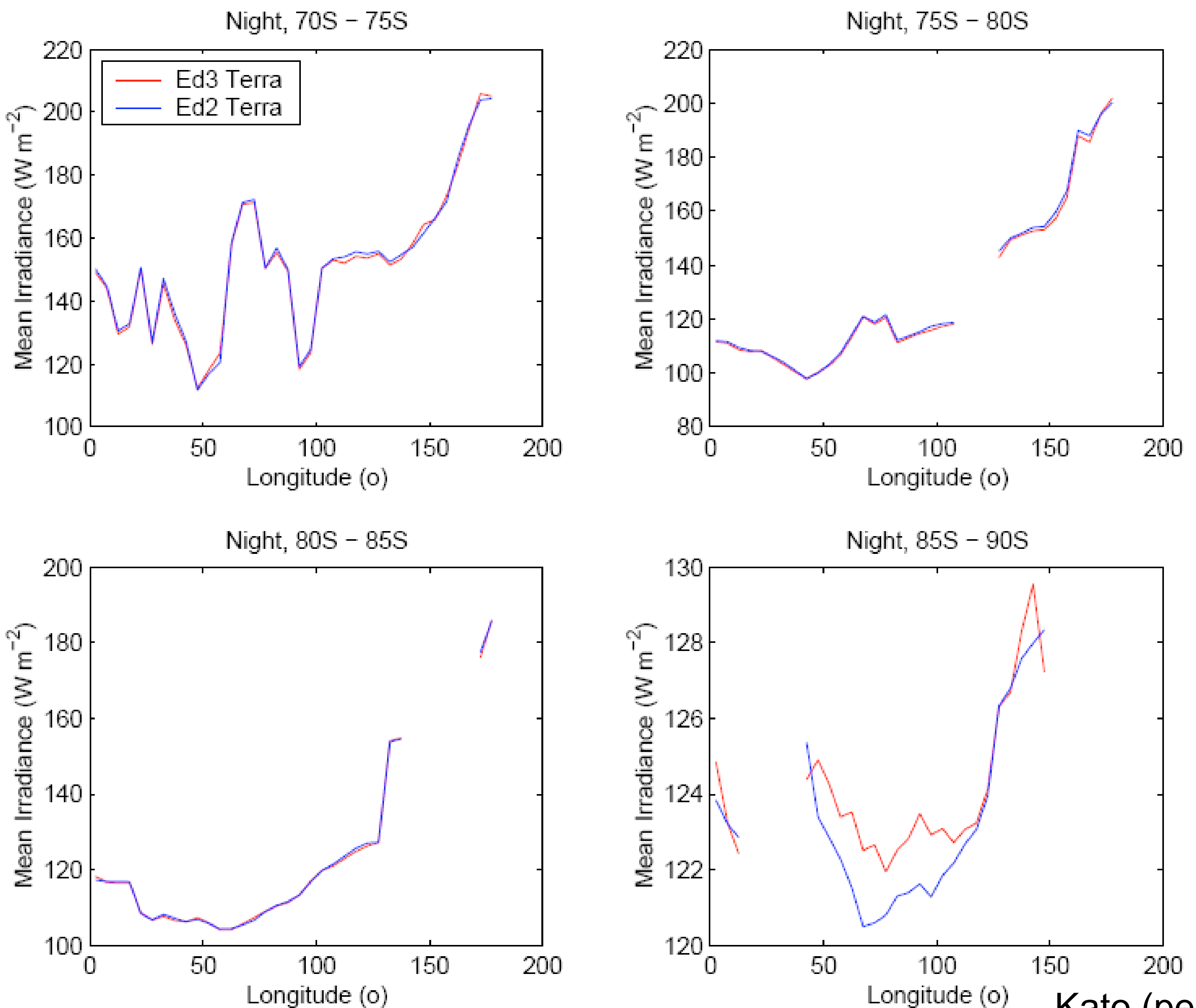

Seiji Kato (pers. comm.)

- Both ADM DI tests and direct comparisons of cloud fraction with GLAS show that original Terra cloud mask for nighttime Antarctic is better than Aqua cloud mask.

- Are preliminary Terra Ed3 permanent snow nighttime LW TOA fluxes consistent with Terra Ed2?

- Consider one day of Ed3_beta for Oct 1, 2005.

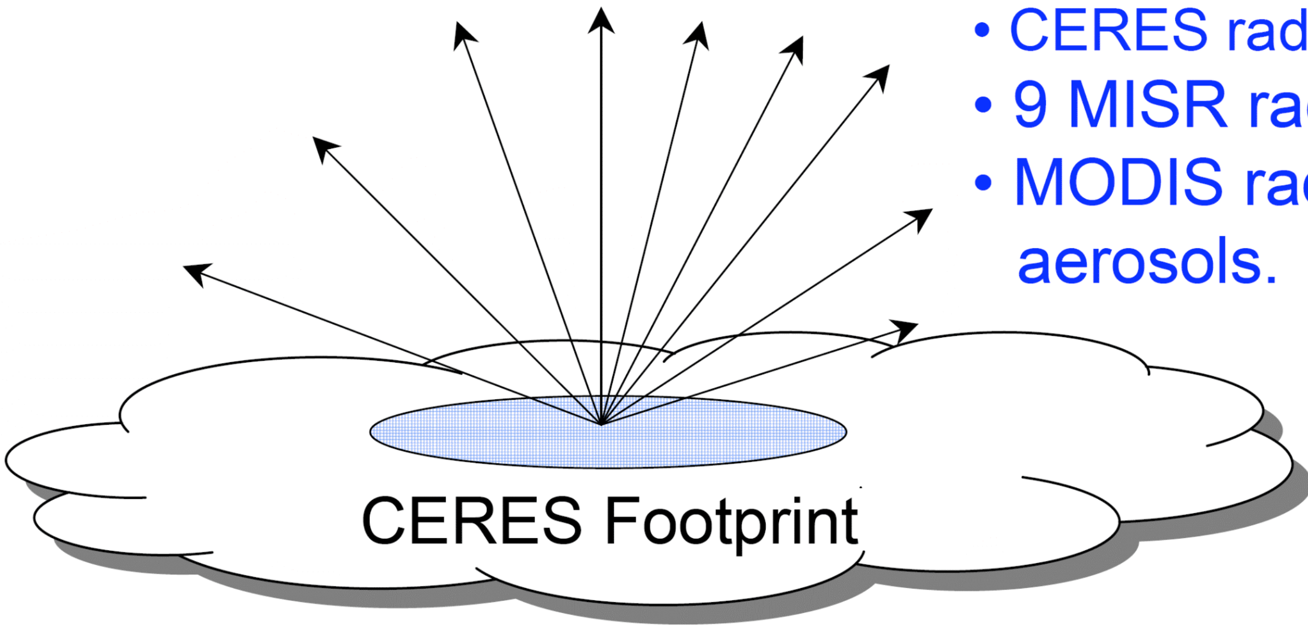
# Preliminary Terra Ed3_beta Result for One Day (October 1, 2005)




Kato (pers. comm.)

# TOA Albedo Comparison between CERES & MISR

# New Merged CERES-MODIS-MISR Dataset




- CERES radiances and fluxes
- 9 MISR radiances (4 channels)
- MODIS radiances, clouds and aerosols.

Available at the NASA Langley Research Center Atmospheric Sciences Data Center

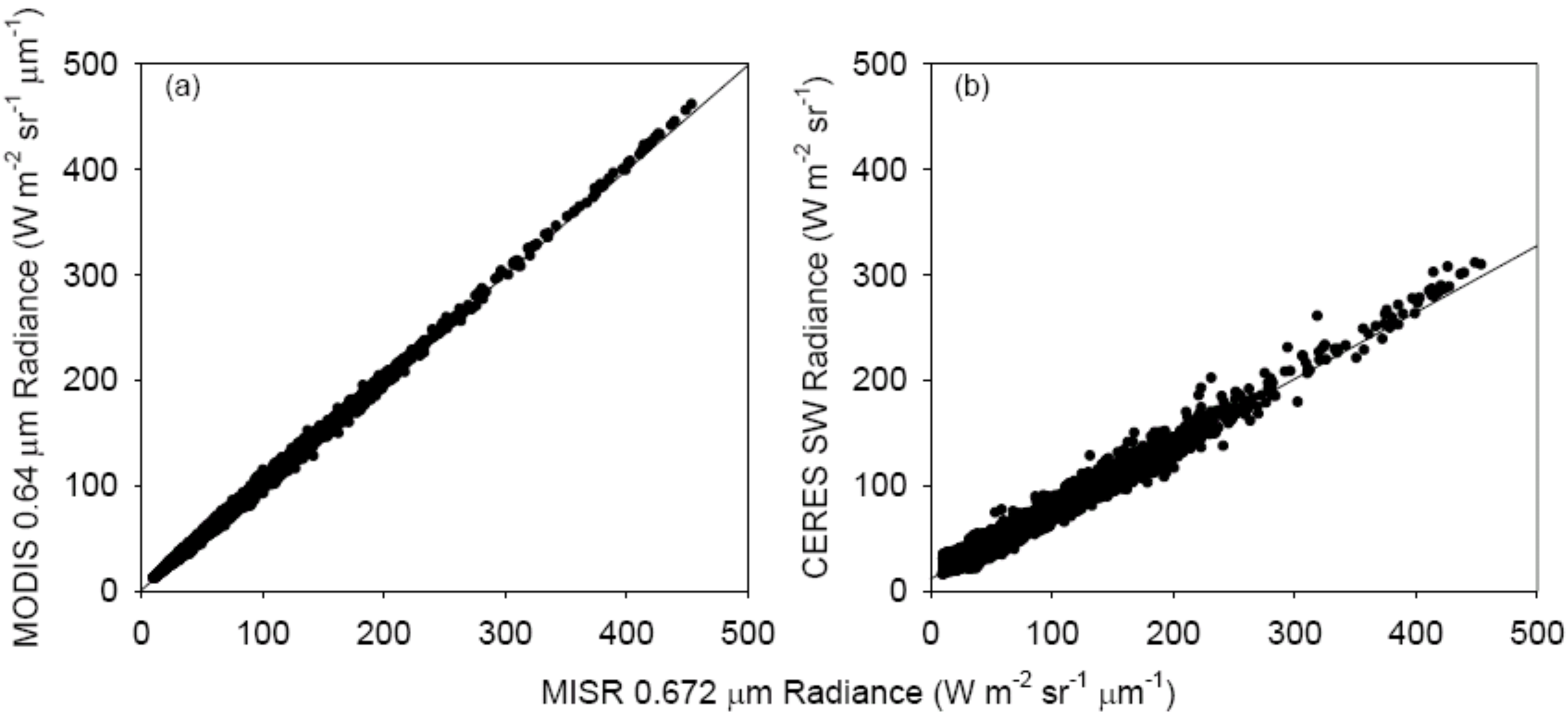



Figure 1 (a) MODIS and MISR nadir radiances in the red band averaged over CERES footprints for all-sky conditions on September 12, 2000. Only footprints in which the CERES viewing geometry lies within 0.5° of the MISR AN camera are shown. (b) CERES SW and MISR red channel radiances for the same footprints as in (a). Solid line is the regression fit.

Loeb et al. JGR (2006)

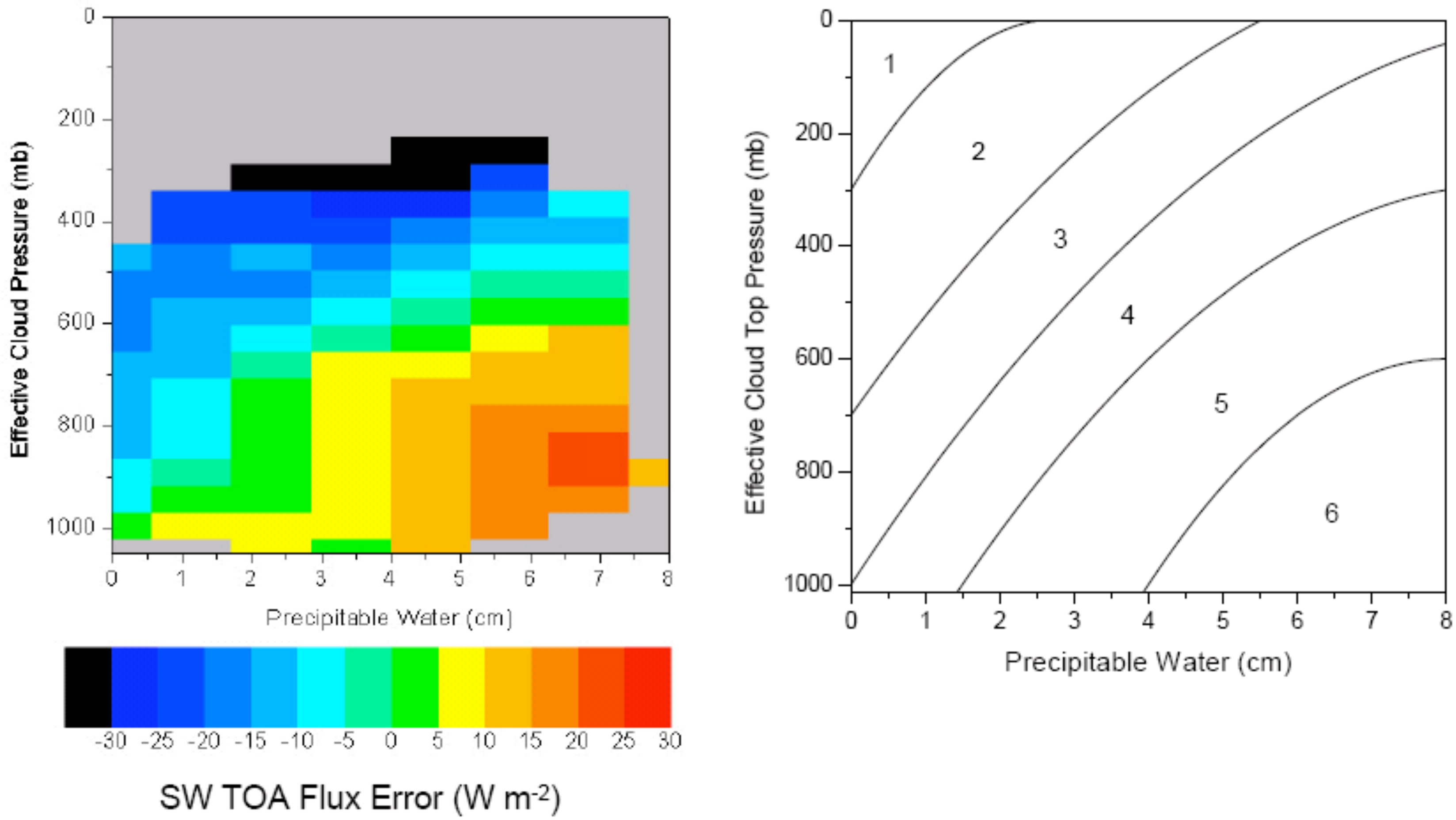



Figure 2 (a) Error in instantaneous SW TOA flux for tropical ocean overcast liquid water clouds inferred from the errors in radiances estimated from a narrow-to-broadband regression analysis that does not explicitly account for effective pressure and precipitable water variations. CERES anisotropic factors are used to convert from a radiance error to a flux error. (b) Empirically derived contours defining effective pressure and precipitable water domains in Fig. 2a.

Loeb et al. JGR (2006)

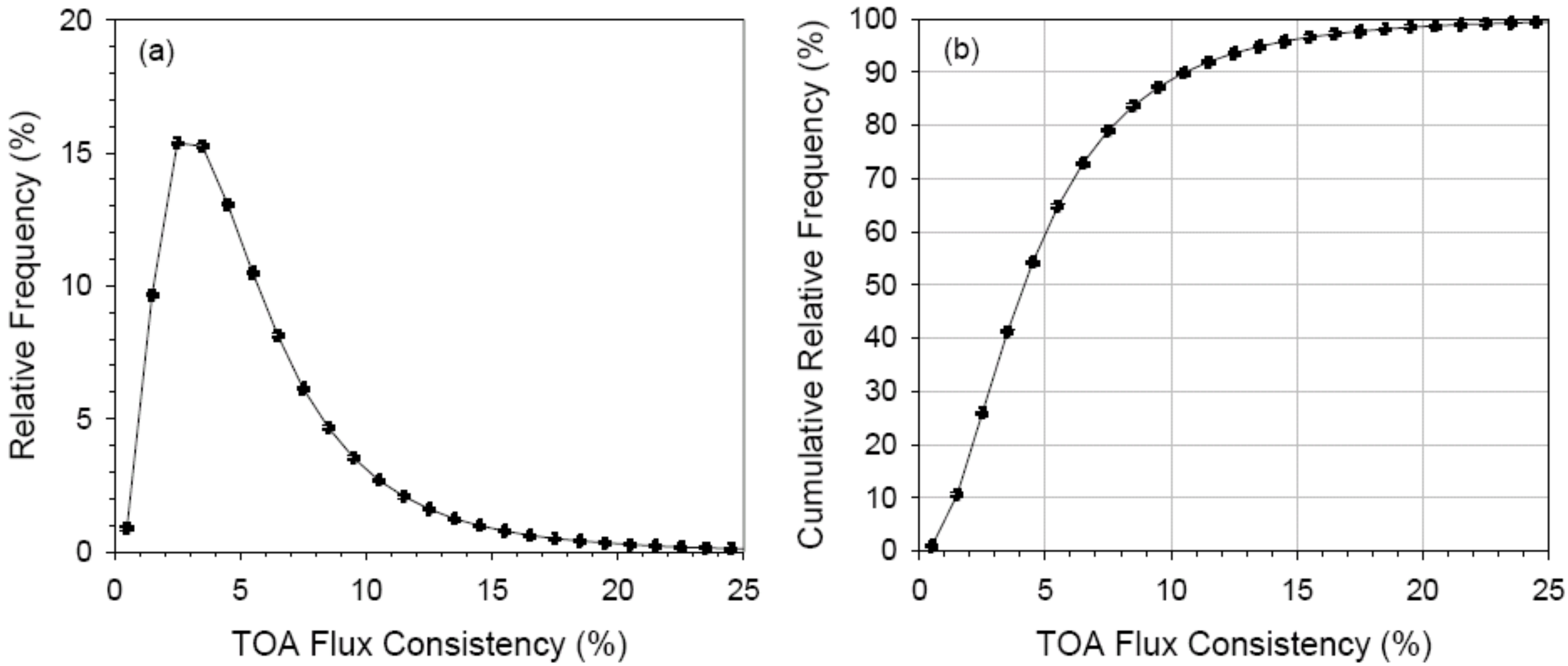



Figure 3 (a) Relative frequency and (b) cumulative relative frequency of SW TOA flux consistency for global all-sky conditions over ice-free ocean.

Loeb et al. JGR (2006)

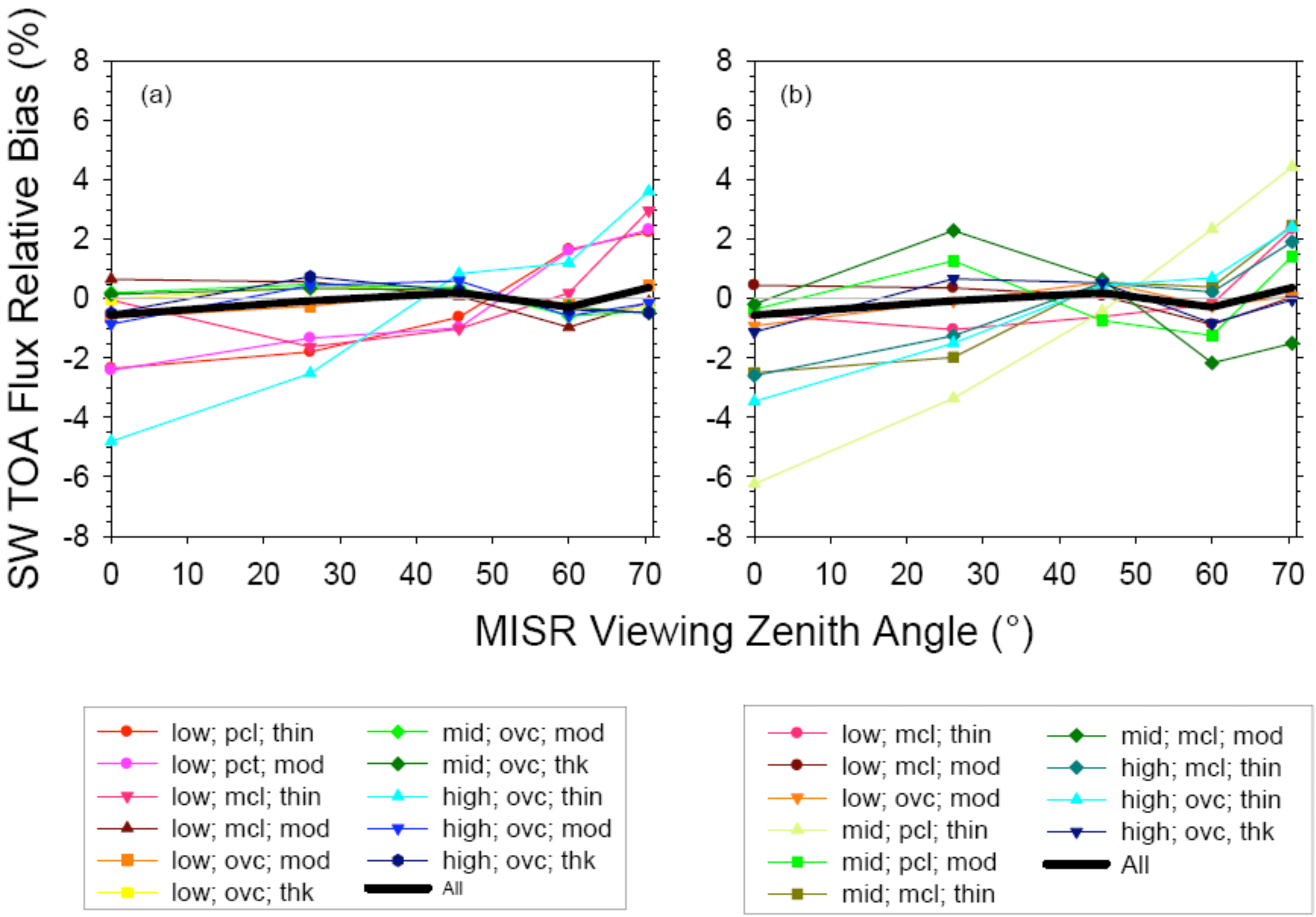
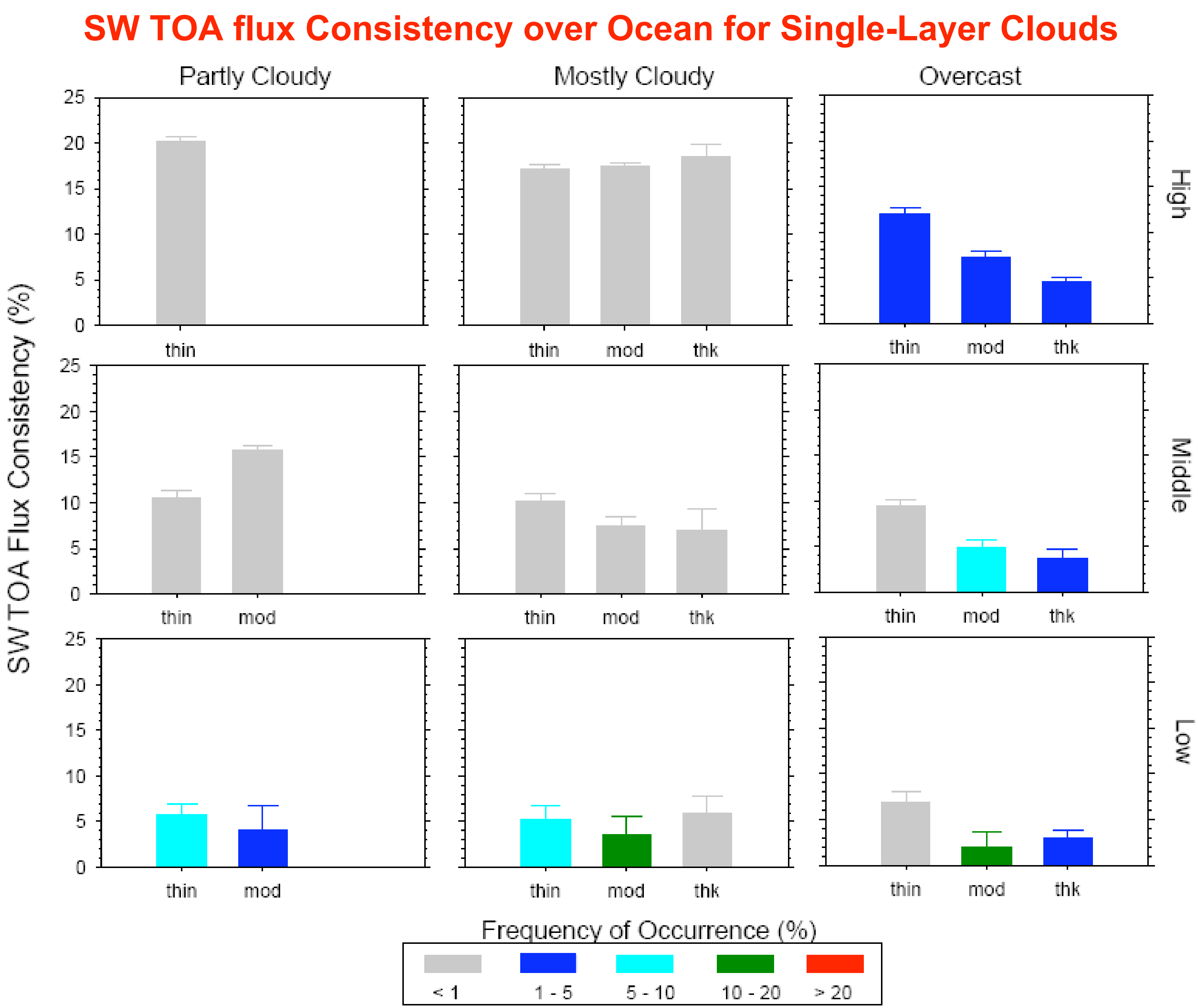
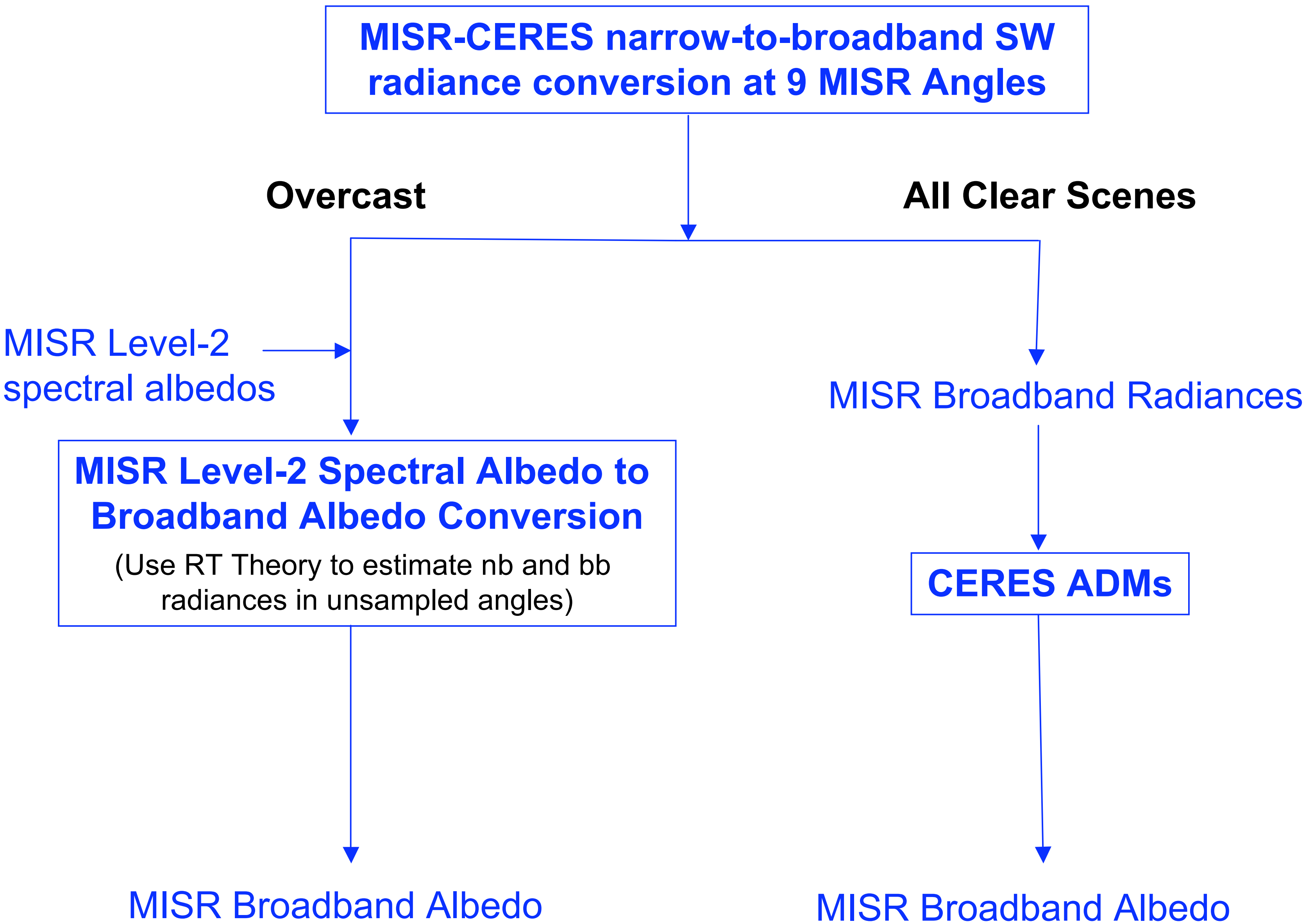



Figure 6 SW TOA flux relative bias against MISR viewing zenith angle by cloud type for (a) single-layer clouds and (b) multi-level clouds. The solid black line in each plot corresponds to the all-sky case (single+multilayer).

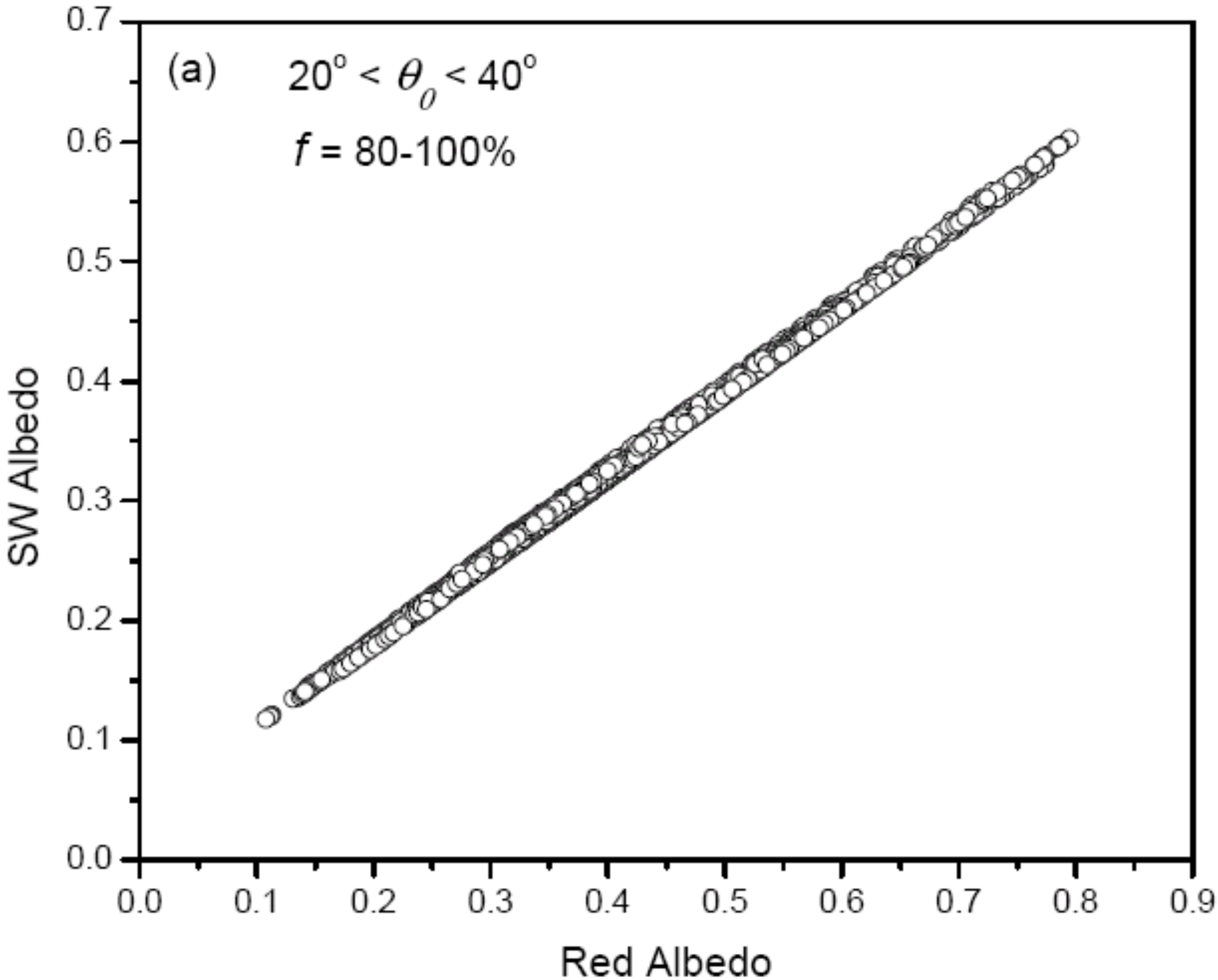
Loeb et al. JGR (2006)


SW TOA flux Consistency over Ocean for Single-Layer Clouds
Partly Cloudy
Mostly Cloudy
Overcast
High
Middle
Low
SW TOA Flux Consistency (%)
0
5
10
15
20
25
thin
mod
thk
Frequency of Occurrence (%)
< 1
1 - 5
5 - 10
10 - 20
> 20

# Algorithm for Estimating Broadband Albedo from MISR

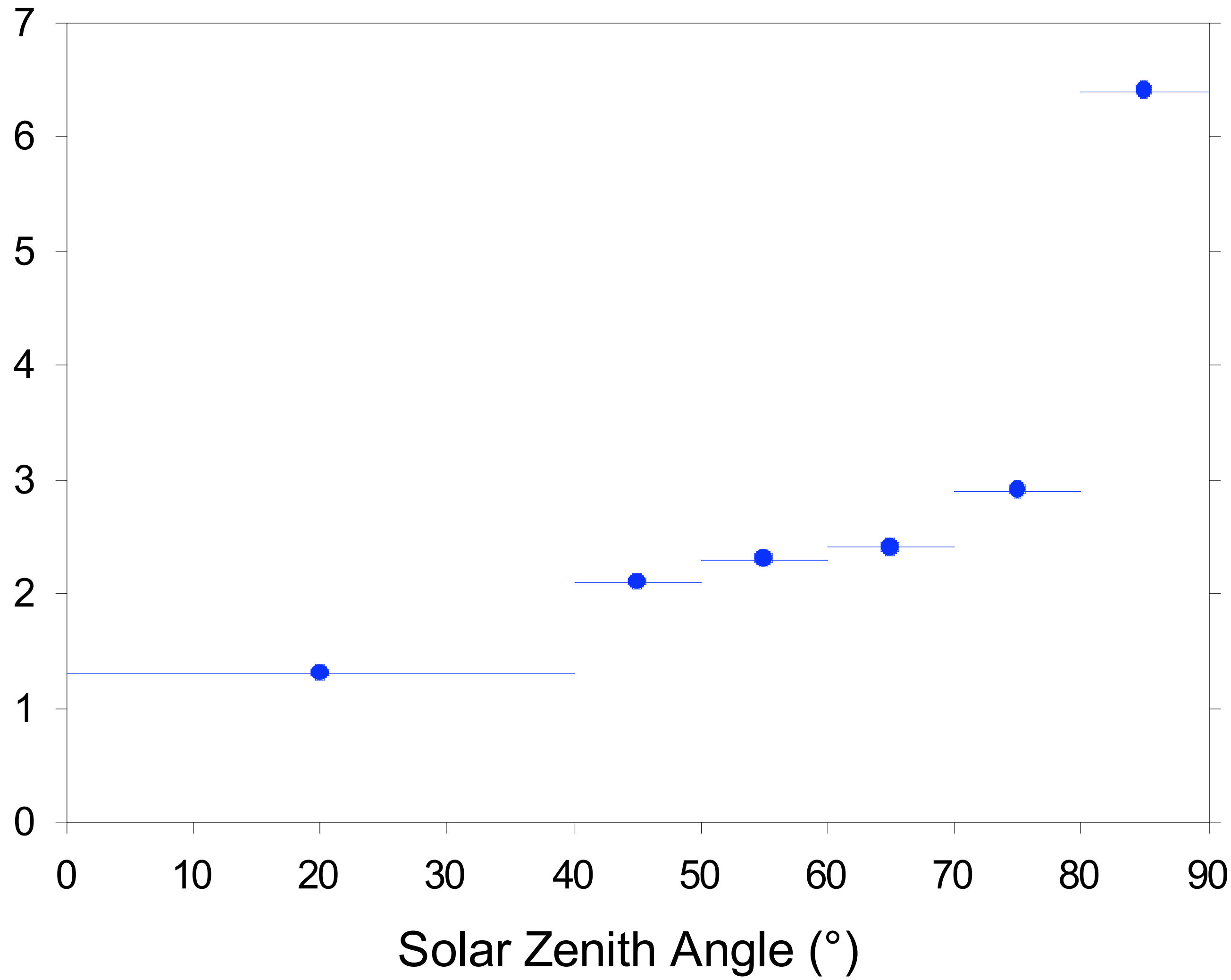


# MISR Red Band Albedo vs CERES SW Albedo

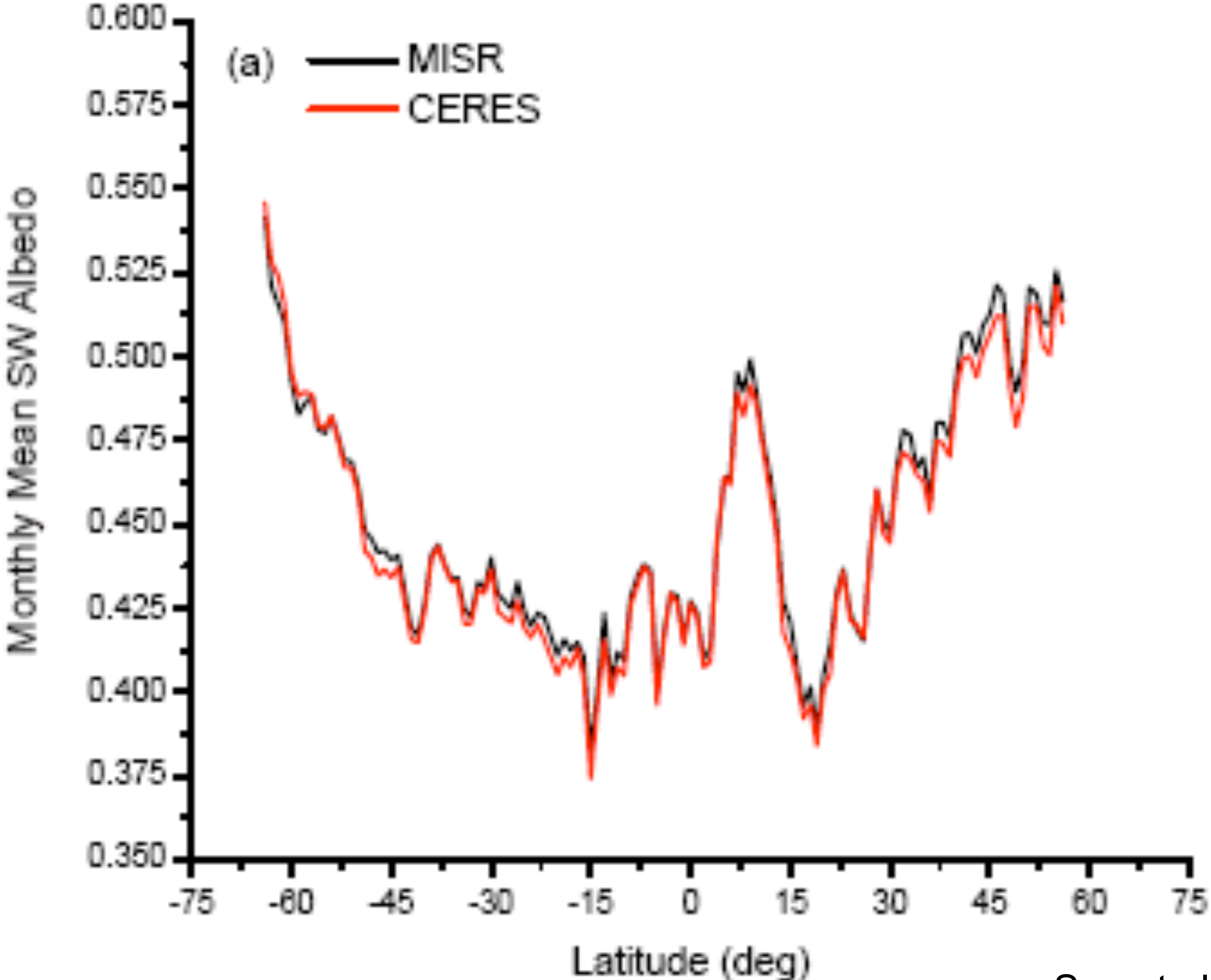



Sun et al., GRL (2006)

## Relative Error in MISR-CERES Narrow-to-Broadband Albedo Conversion

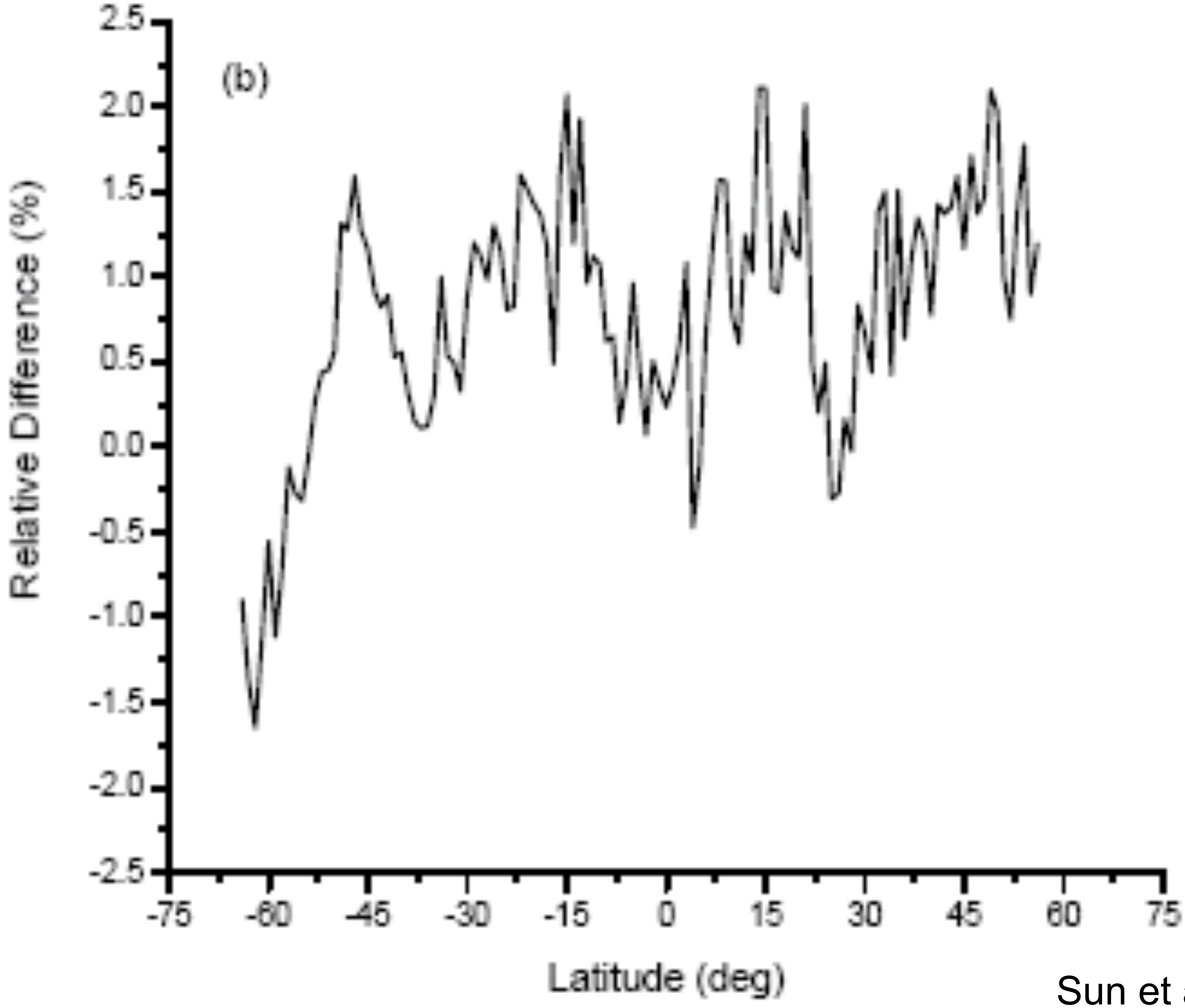


# Overcast Ocean – Monthly Mean Broadband Albedo



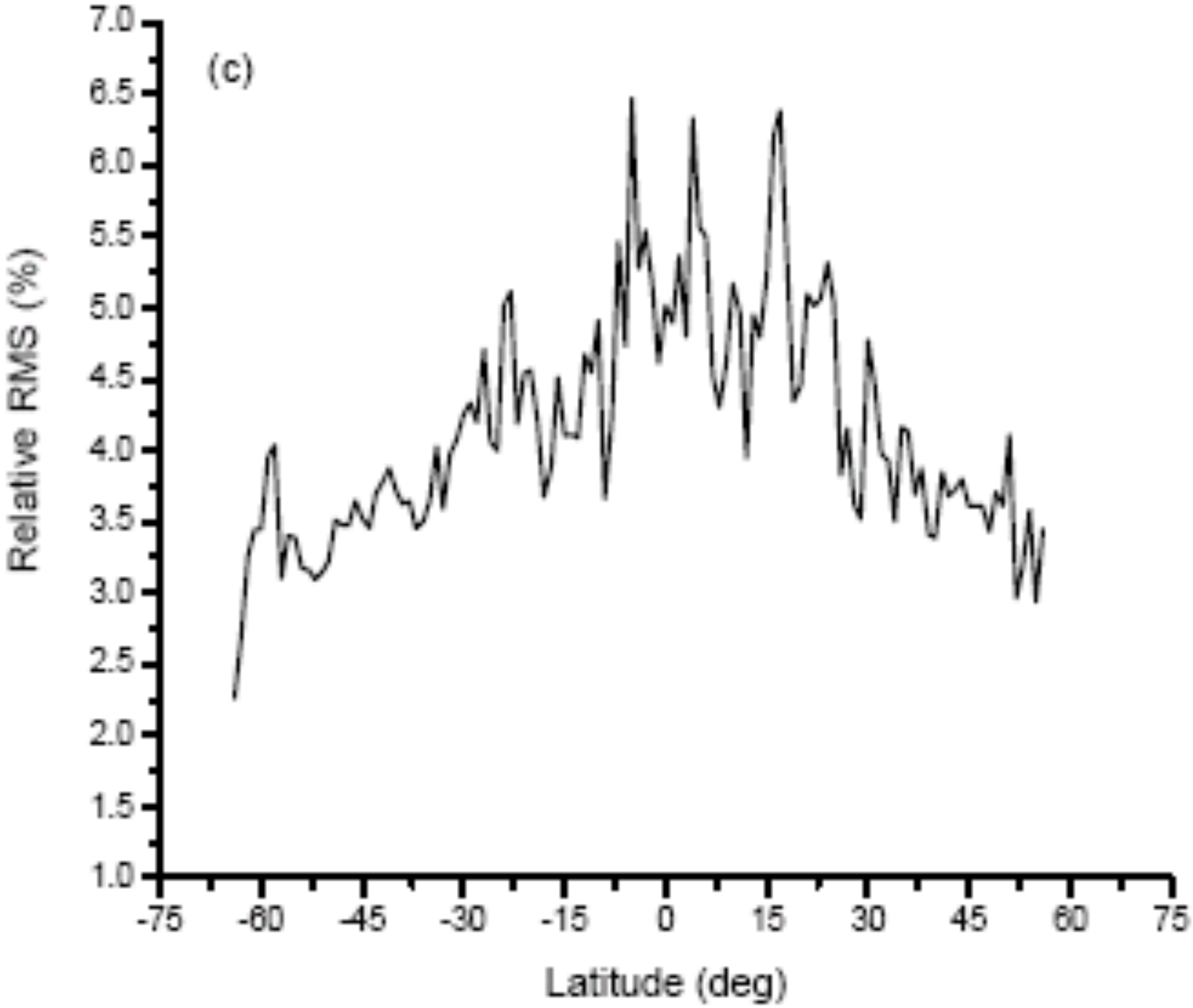

Sun et al., GRL (2006)

# MISR minus CERES Relative Difference



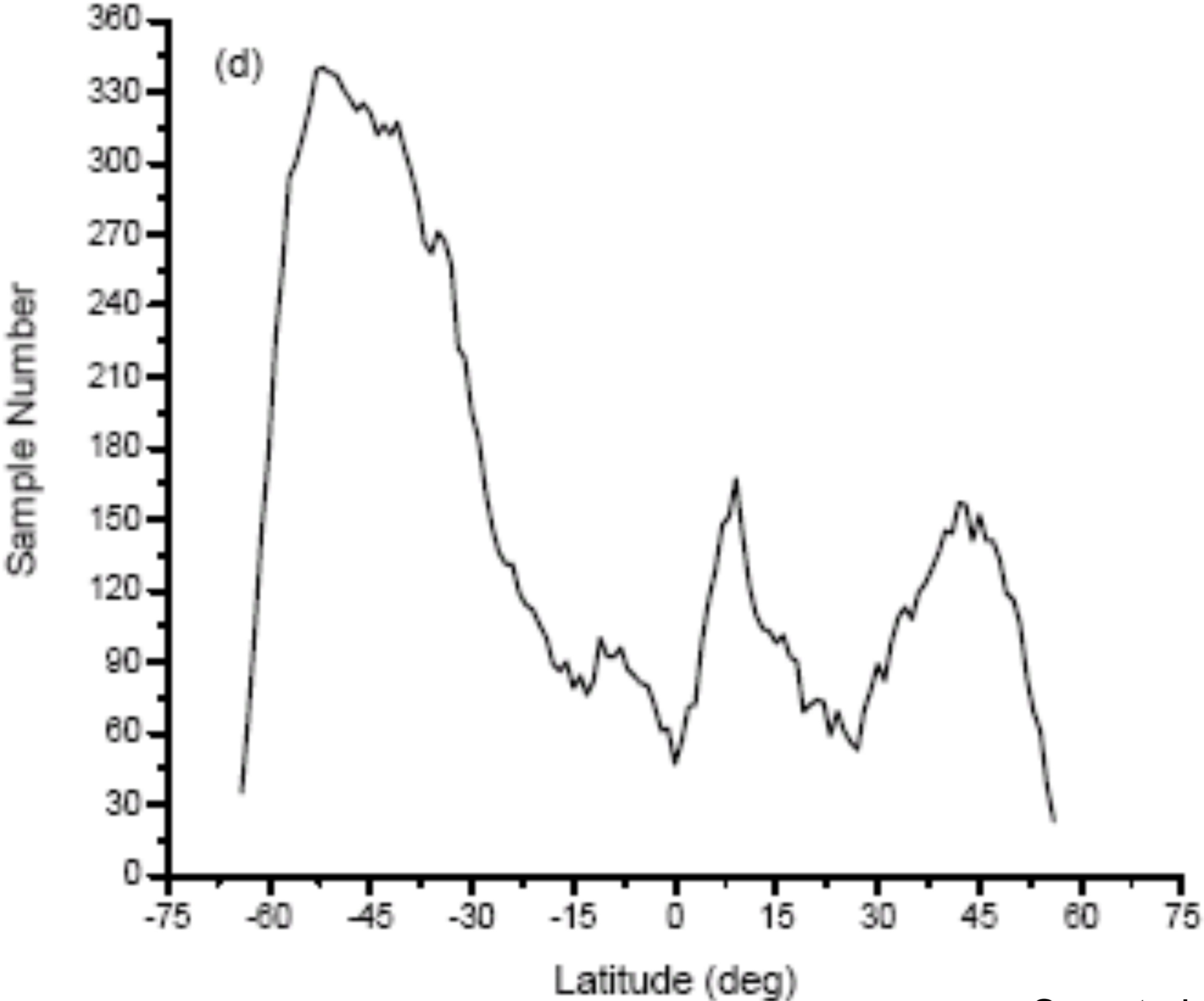

Sun et al., GRL (2006)

# MISR - CERES Relative RMS Difference




Sun et al., GRL (2006)

# Comparison Sampling by Latitude



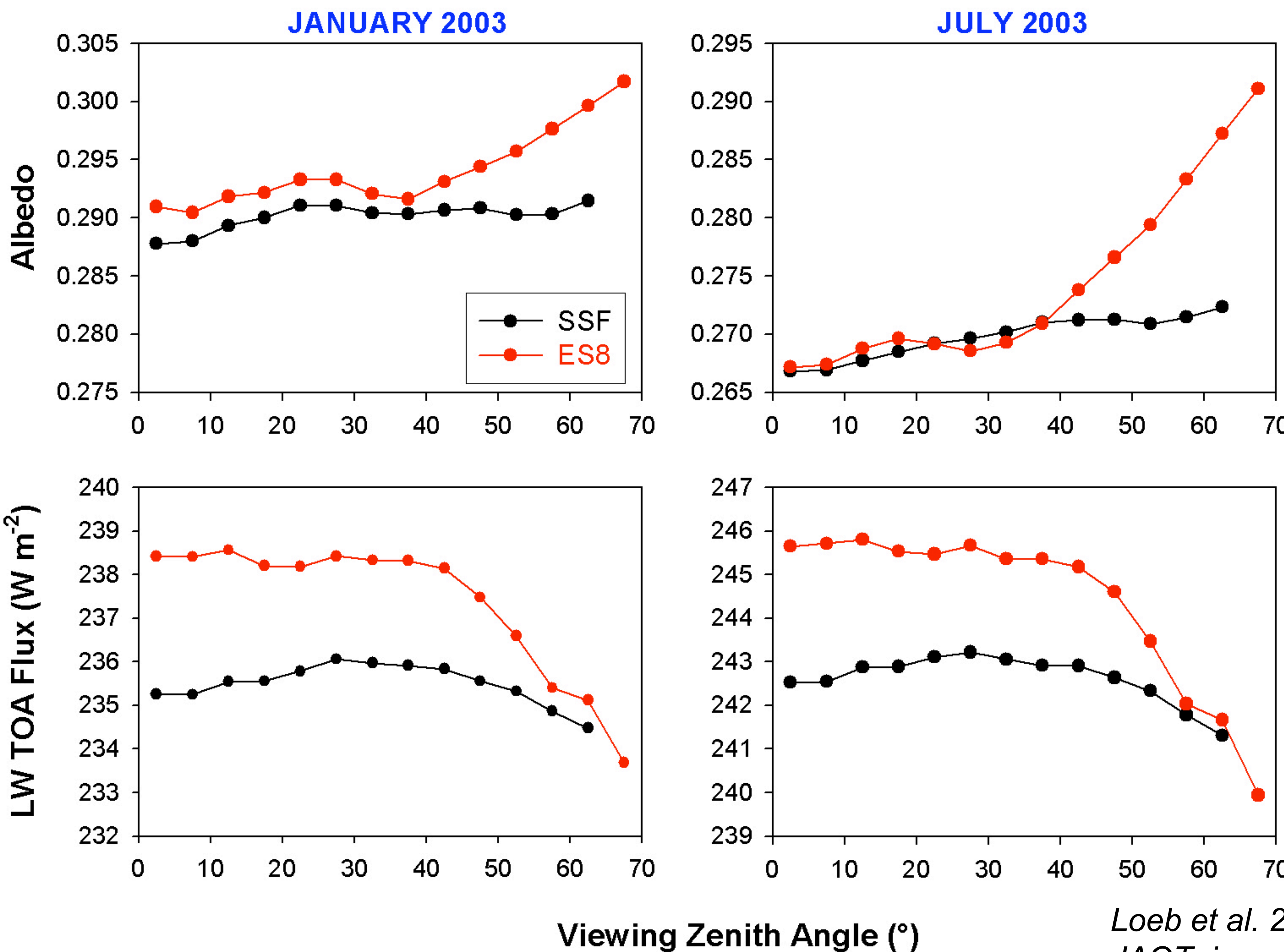

Sun et al., GRL (2006)

# MISR-CERES TOA Albedo Comparison

- For overcast 1°×1° ocean regions with coincident MISR Level-2 35.2-km regions and CERES footprints, the relative difference and RMS difference between MISR and CERES albedos are ~0.8% and ~4.3%, respectively.
- Accounting for a ~2.0% error in MISR albedos due to narrow-to-broadband conversion errors, the RMS difference between MISR and CERES albedos due to ADM differences alone is estimated to be ~3.8%.

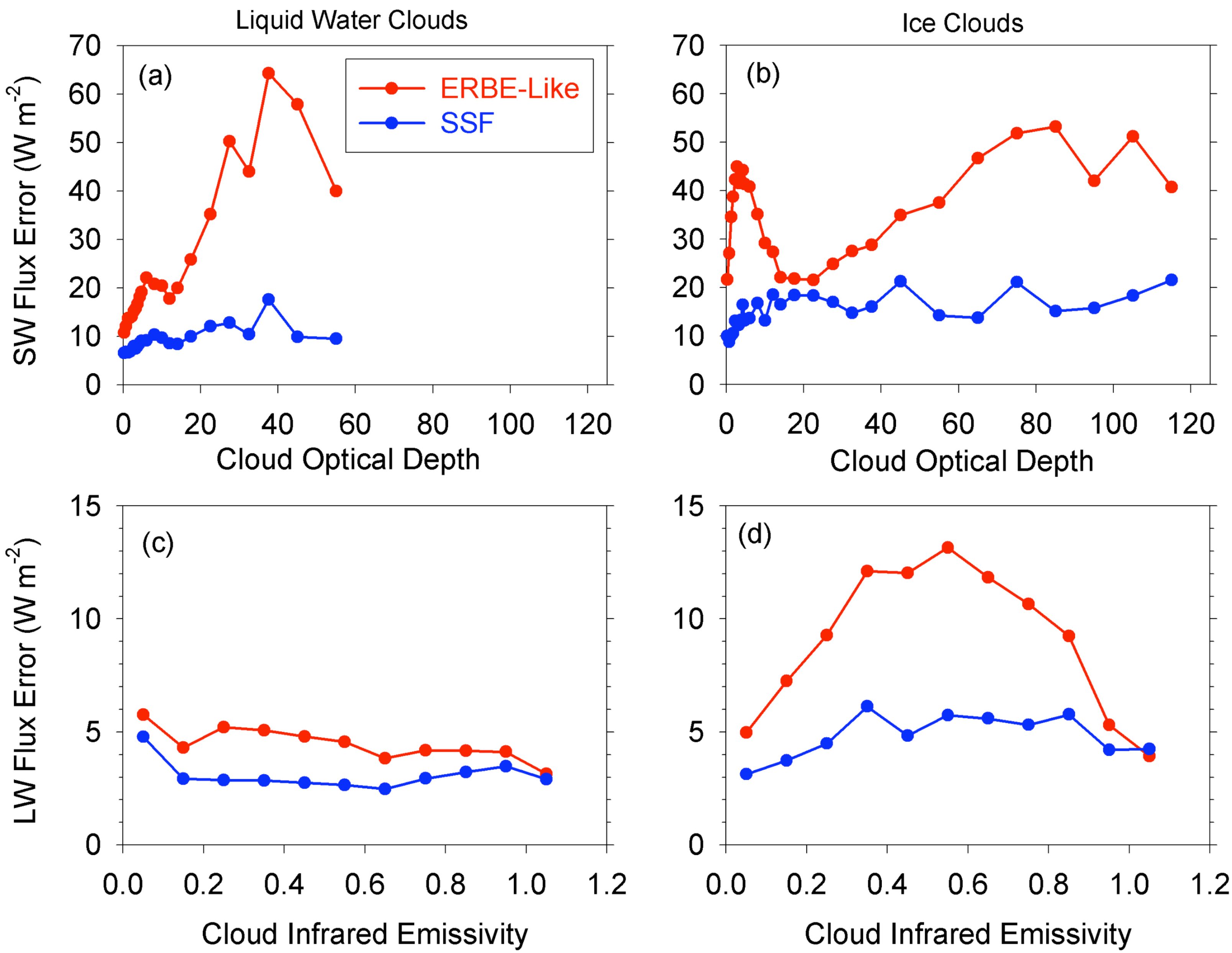
Sun et al., GRL (2006)

# SSF & ERBE-Like Global Albedo & LW TOA Flux vs Viewing Zenith Angle




*Loeb et al. 2006*
*JAOT, in press*

# Instantaneous TOA Flux Error by Cloud Property



# Summary

- CERES SSF Edition3: ADM-related Issues
  => Will use Ed2 ADMs for Edition3.
  => Need to assess how this impacts TOA flux accuracy.
  => Preliminary Terra Ed3 permanent snow nighttime LW TOA fluxes appear to be consistent with Terra Ed2.

- Overcast albedo comparisons with MISR (60°S-60°N):
  => Relative difference and RMS difference between MISR and CERES albedos are ~0.8% and ~4.3%, respectively.

- CERES TOA fluxes: new CERES ADMs vs ERBE
  => Significant reduction in bias with viewing geometry from new CERES ADMs for both all-sky and by cloud type.