Angular Distribution Modeling (ADM) Group

Activity Since Last Science Team Meeting:

- Spectral correction paper accepted in *J. Appl. Meteor.* (Loeb et al.).
- Development of longwave ADMs for clear and overcast scenes stratified by cloud properties (Manalo-Smith and Loeb).
- Validation of cloud property averaging over CERES footprints (Loeb, Miller and Geier).
- Development of a new method for reducing angle-dependent biases in satellite cloud optical depth retrievals (Loeb).
- Theoretical studies in support of CERES ADM development (Chambers).

CERES SSF Average Cloud Property Validation

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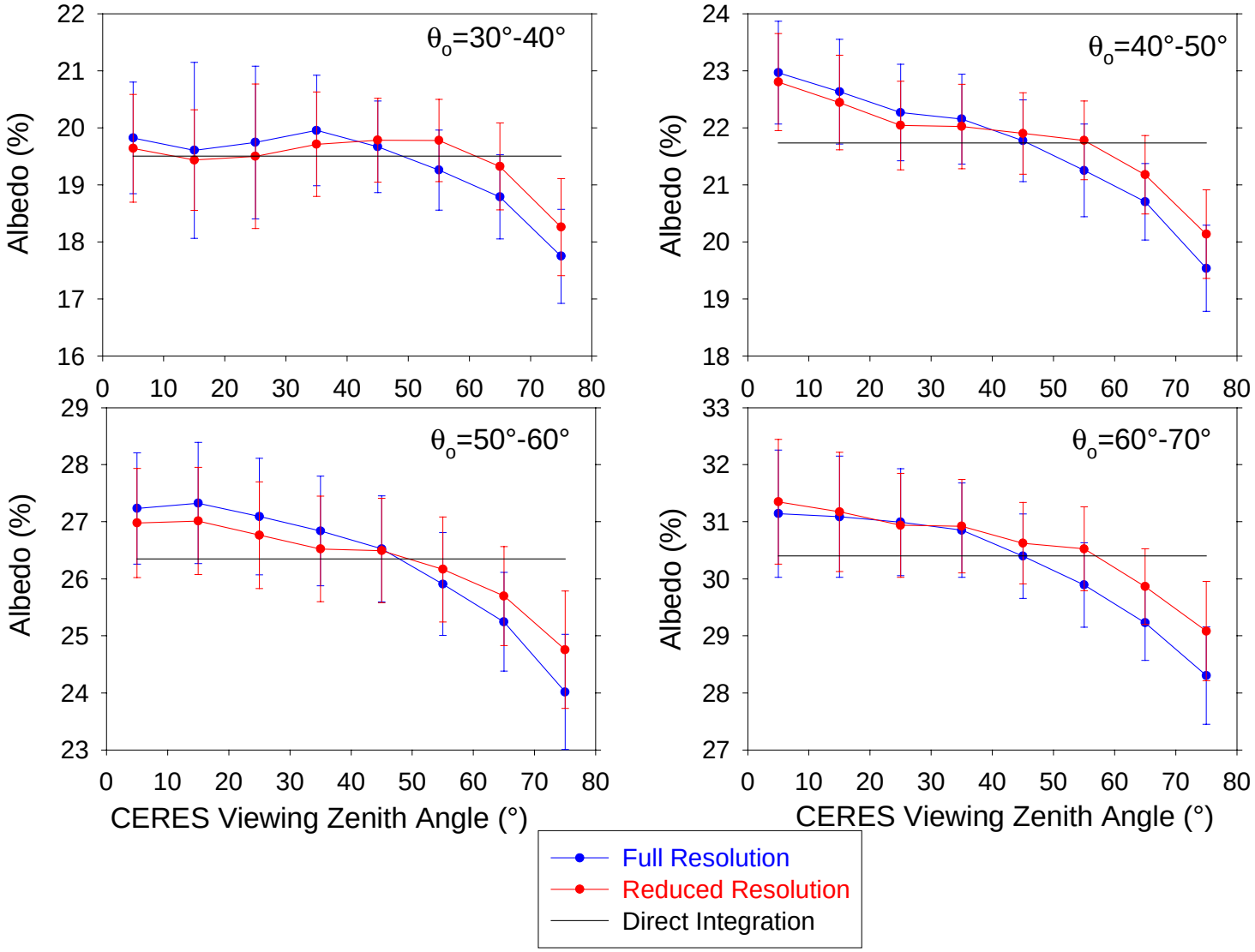
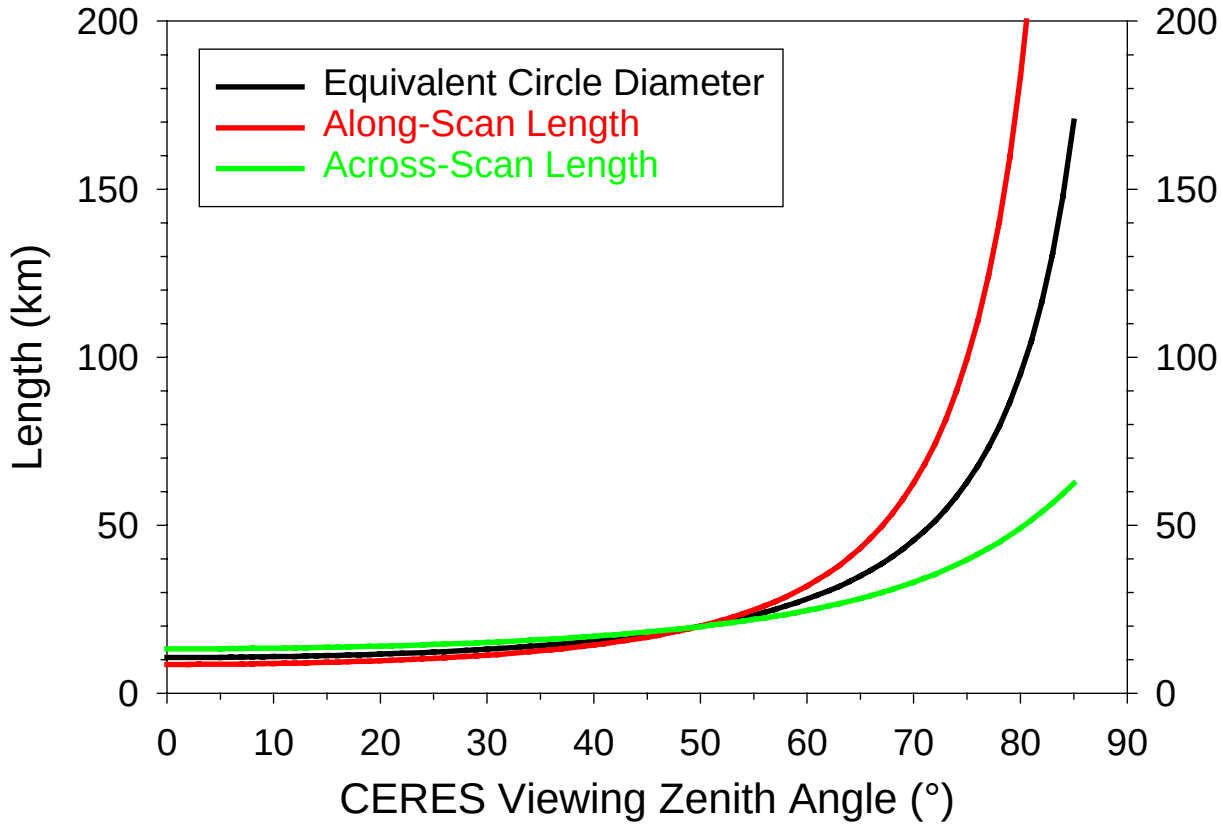
NASA Langley Research Center

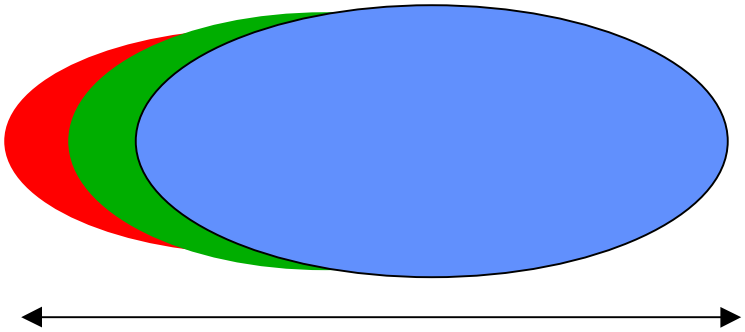
All-Sky Mean Albedo vs CERES Viewing Zenith Angle (80 RAPS Days)



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



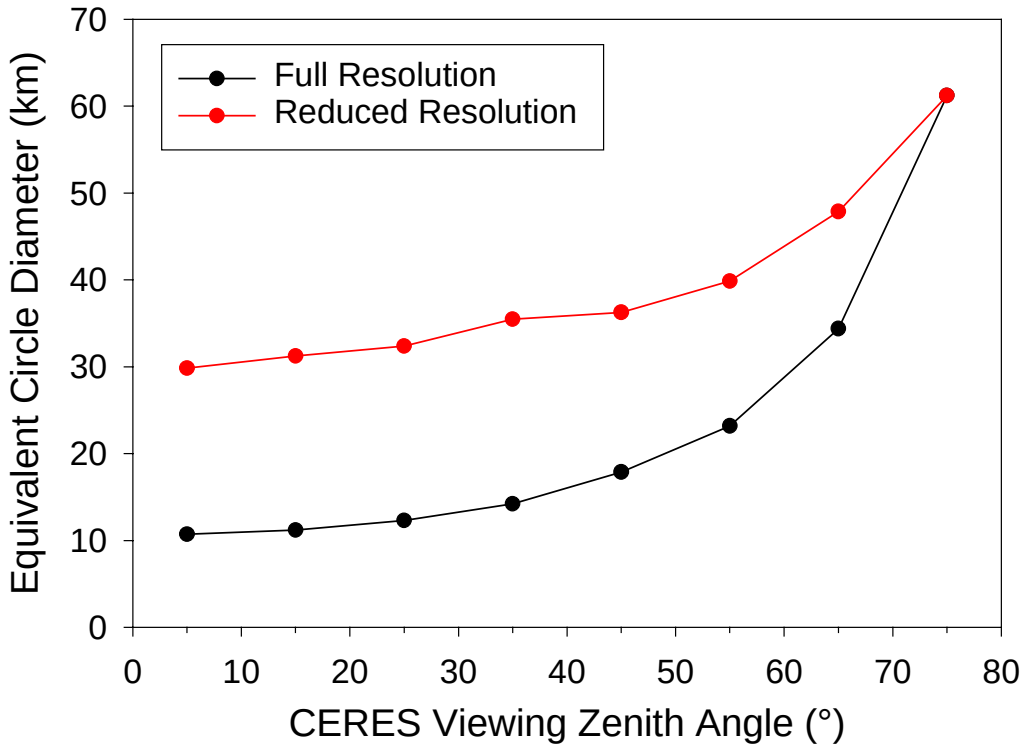
Footprint Averaging



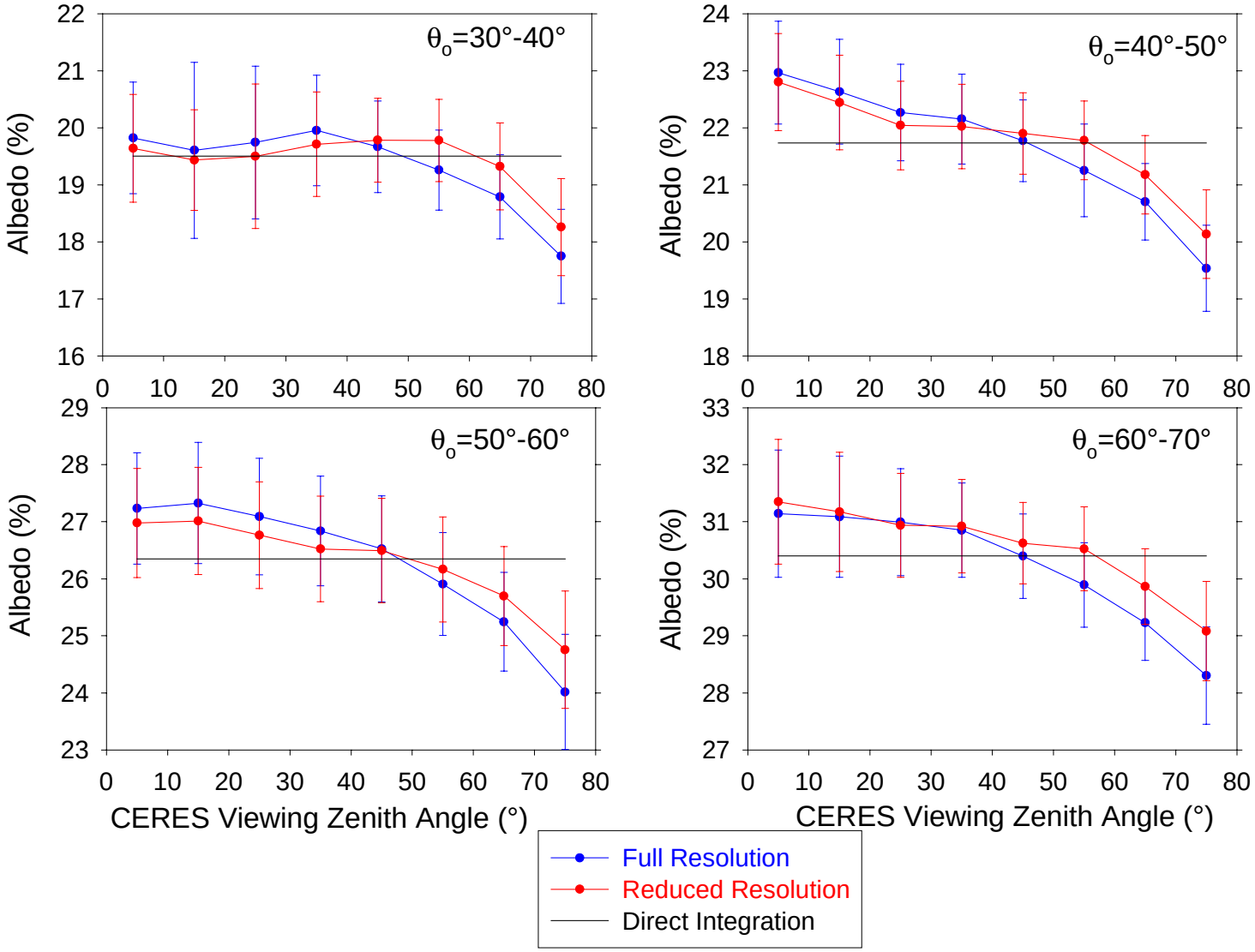
Along-Track 60 km

$$\bar{I} = \frac{1}{N}\sum_{i=1}^{N} I_i$$

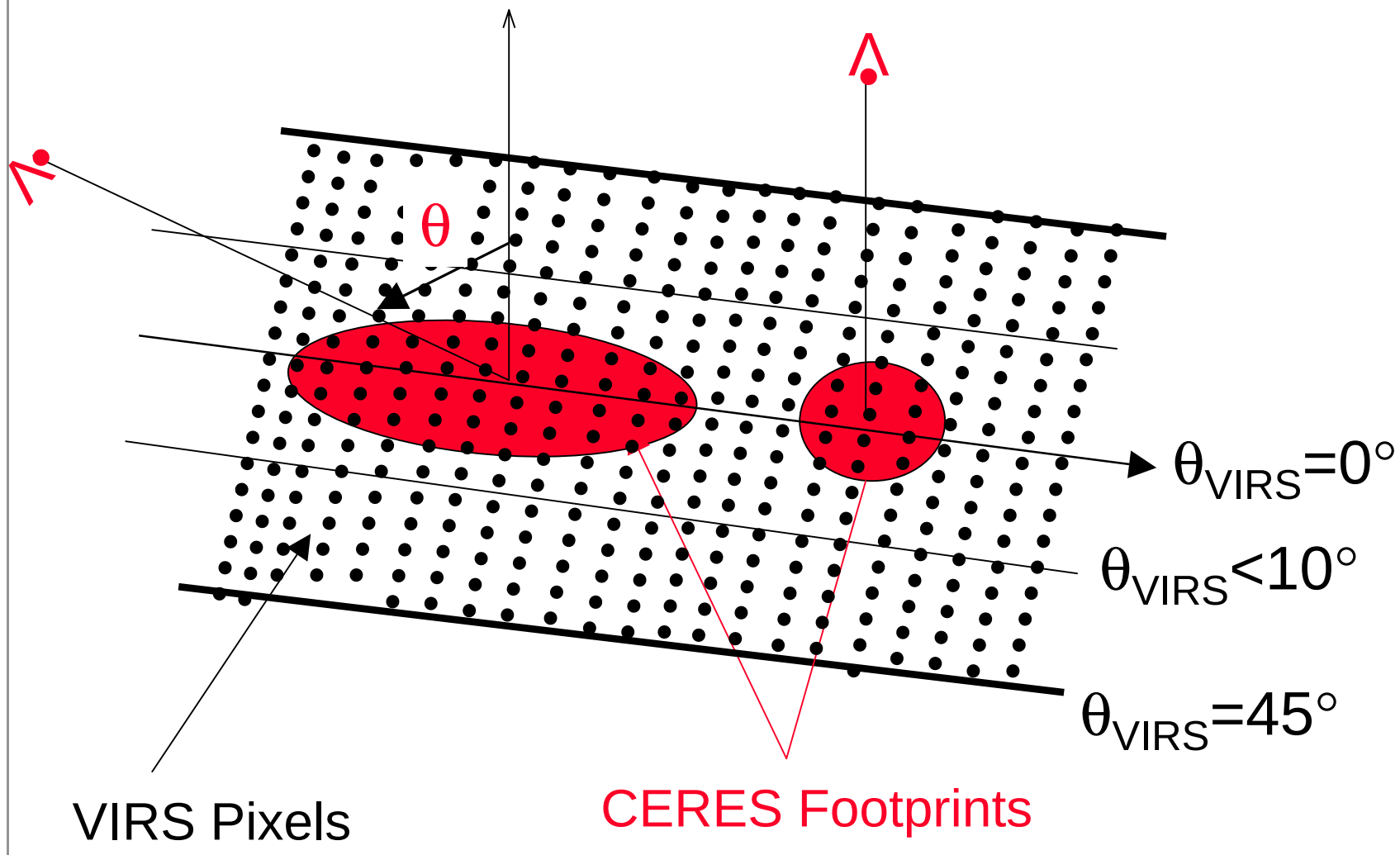
$$\bar{f} = \frac{1}{N}\sum_{i=1}^{N} f_i$$

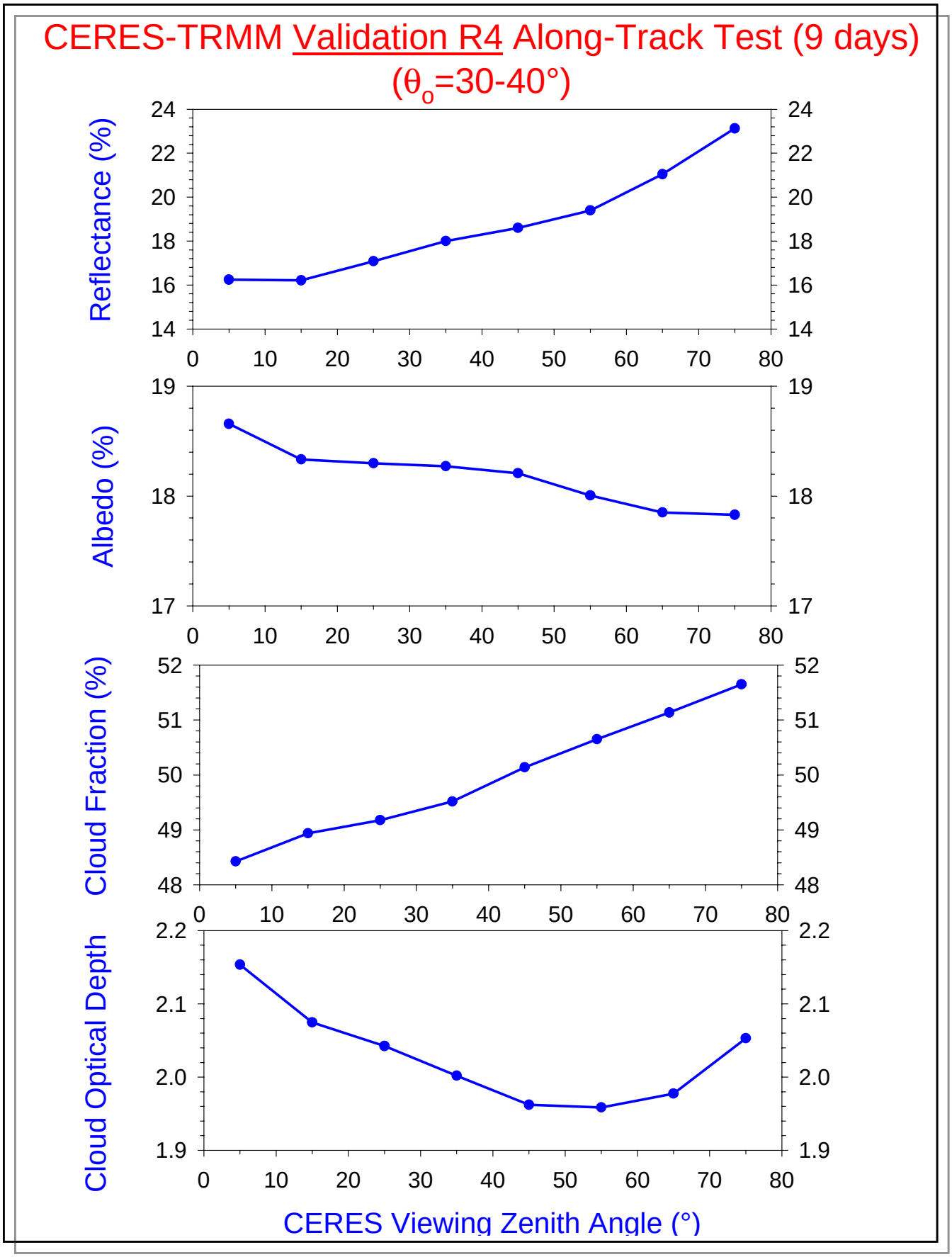


All-Sky Mean Albedo vs CERES Viewing Zenith Angle (80 RAPS Days)

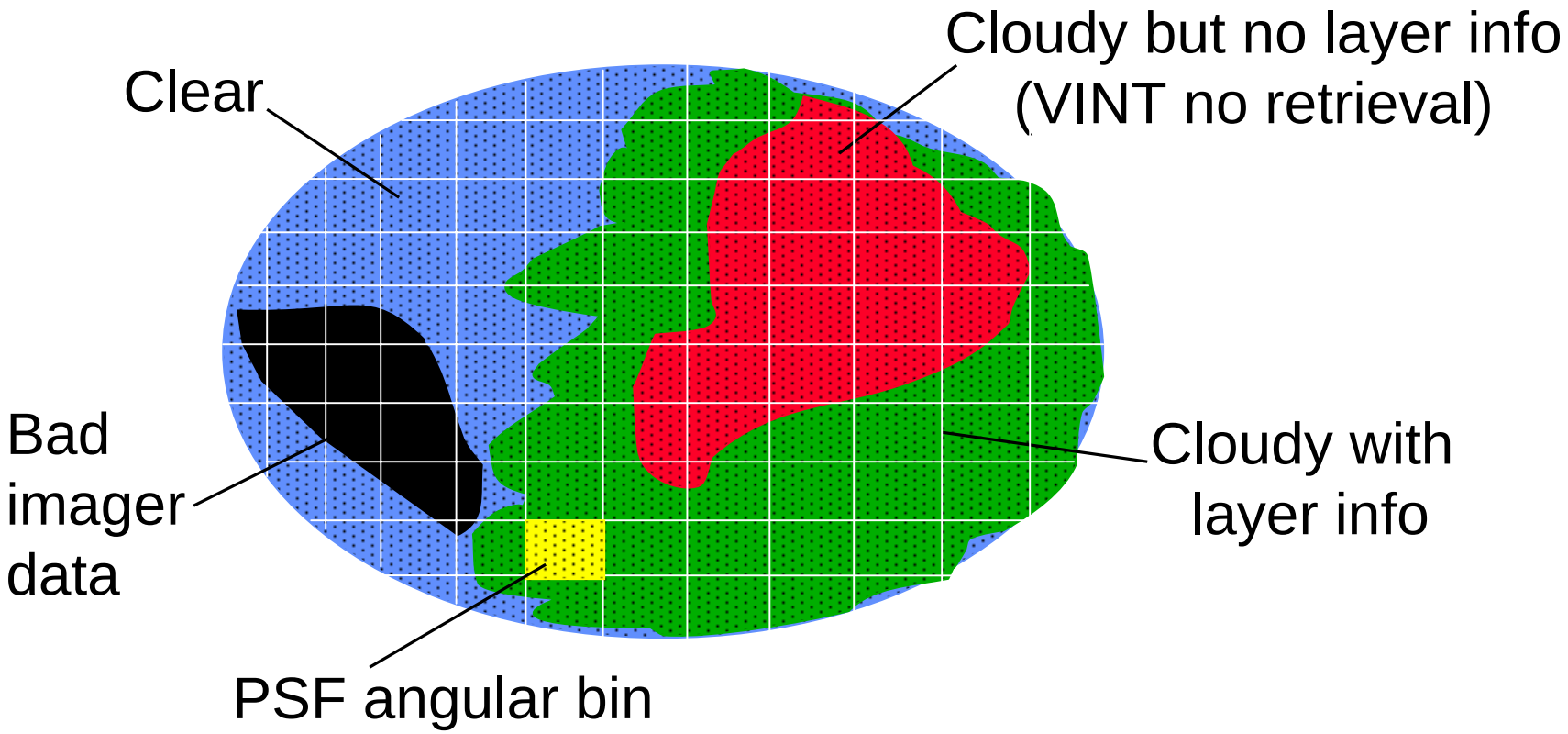


Along-Track Viewing Geometry




CERES-TRMM Validation R4 Along-Track Test (9 days)
(θo=30-40°)
Reflectance (%)
Albedo (%)
Cloud Fraction (%)
Cloud Optical Depth
CERES Viewing Zenith Angle (°)

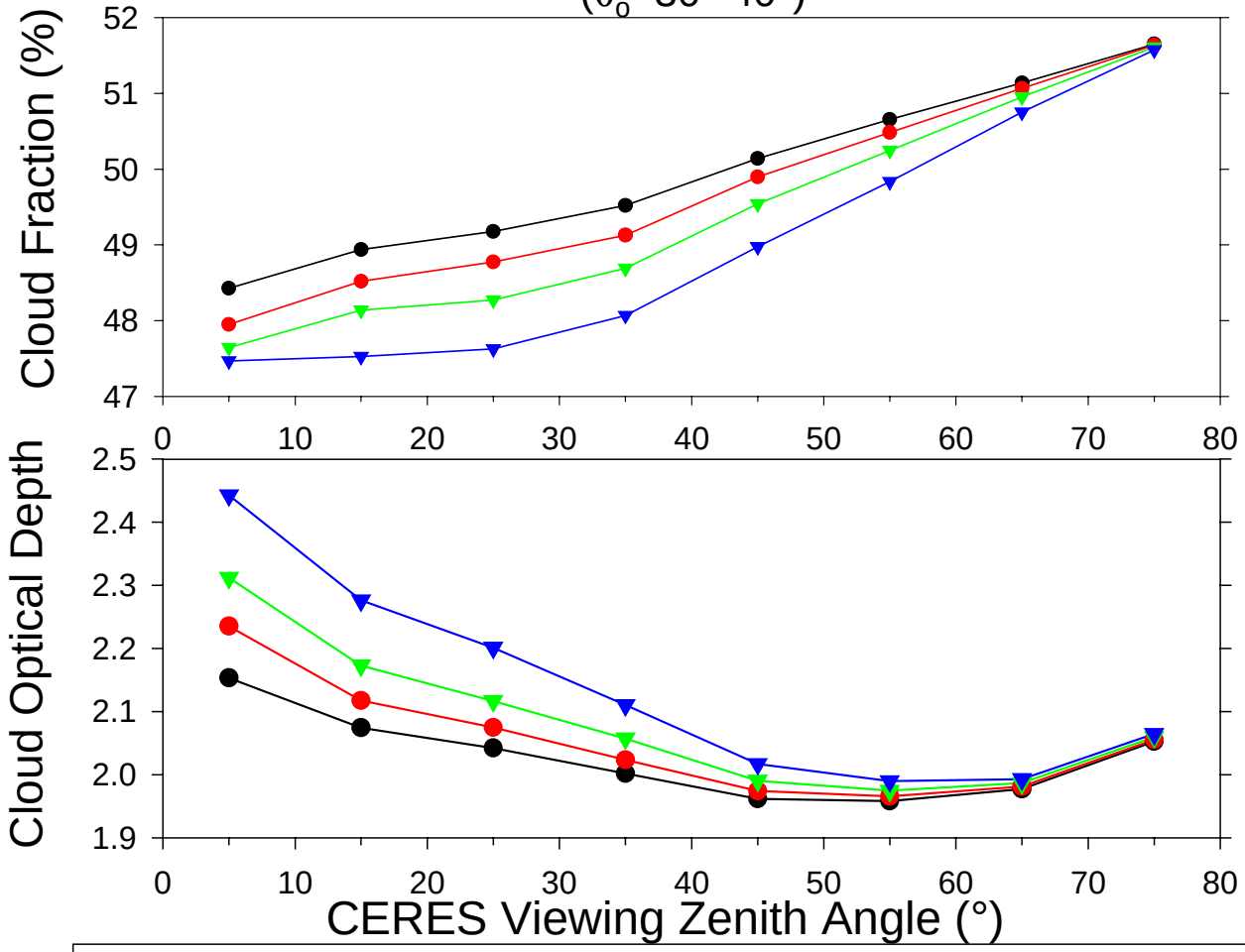
ValidationR4 Footprint Rejection/Acceptance Criteria



If PSF-weighted percent coverage of
"Bad data"+"VINT no retrieval"
over CERES Footprint > 25%:
REJECT FOOTPRINT

Validation R4 Avg Cloud Fraction and Cloud Optical depth vs Viewing Zenith Angle

(θ_o=30°-40°)



Explanation of ValidationR4 Biases

i) VINT no retrievals tend to occur more frequently for thin cloud layers.

ii) Footprint rejection occurs more frequently for CERES near nadir angles since the smaller footprint size means there are fewer imager pixels to begin with, so just a few "no retrievals" can cause these footprints to be rejected.

iii) VINT no retrievals occur ~10-15% of the time, whereas "bad imager data" occurs <1% of the time (for CERES along-track).

Bottom Line:

- By throwing away footprints with too much “VINT no retrieval” we essentially define our climatology according to how well the data conforms to our retrieval algorithm!!!

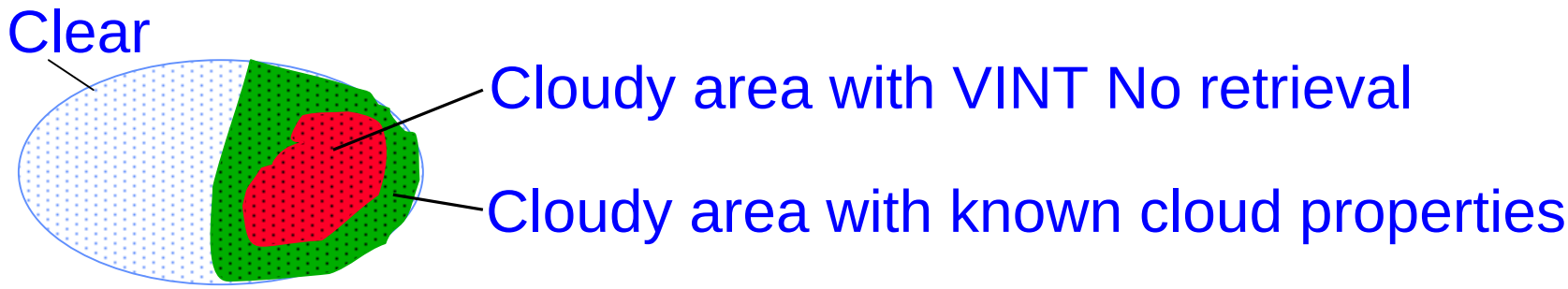
=> possibly bias global means (e.g. excluding certain cloud types, thicknesses etc...).

Edition 1 Footprint Rejection/Acceptance Criteria

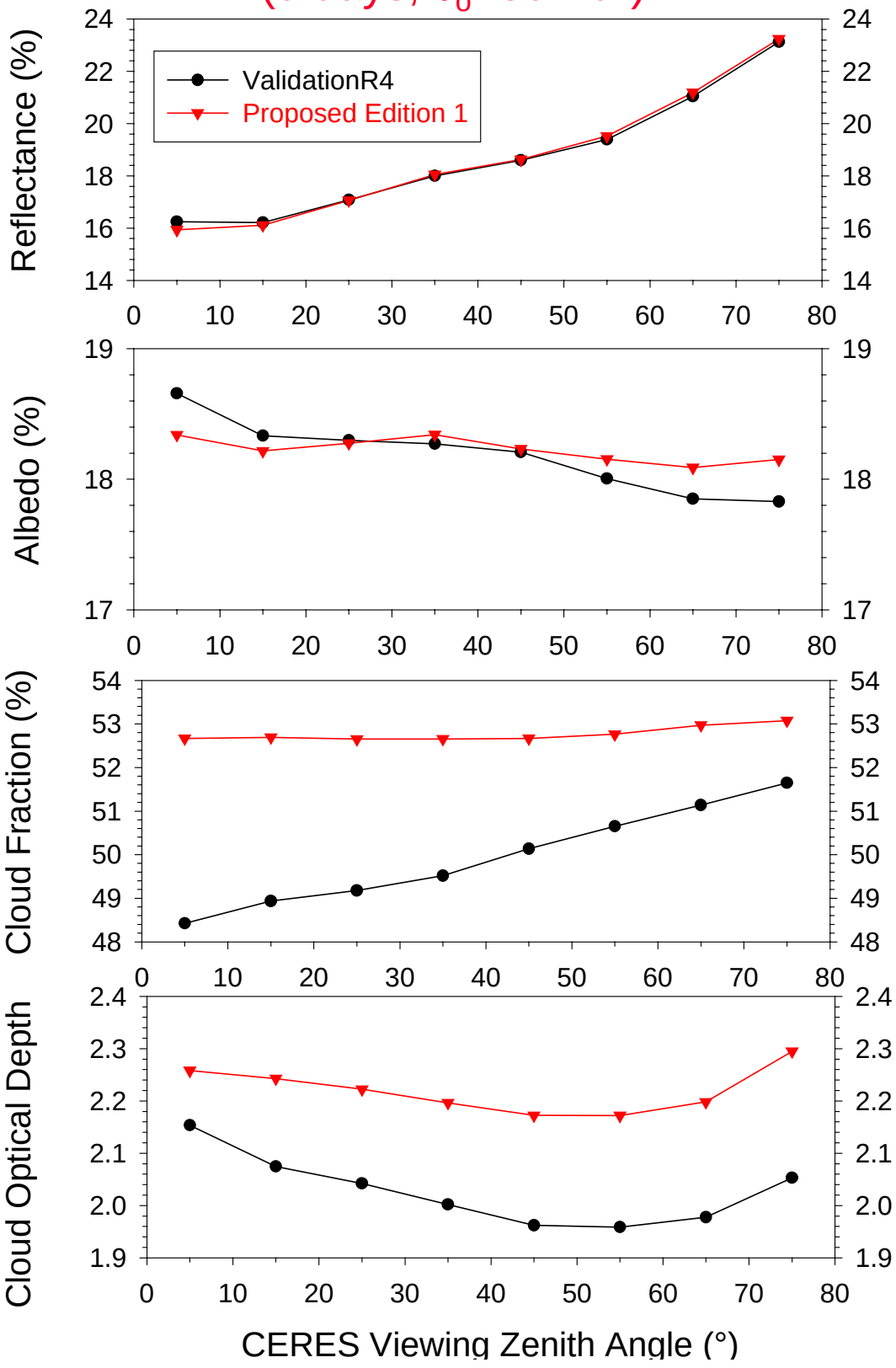
i) "Bad data"> 40%: REJECT FOOTPRINT.

ii) Otherwise keep footprint regardless of VINT no retrieval coverage.

iii) Assume average cloud properties over known cloudy area are representative of unknown cloudy area (i.e. over area with VINT no retrievals).



CERES-TRMM ValR4 & Edition1 Along-Track Test
(9 days; θ_o=30-40°)

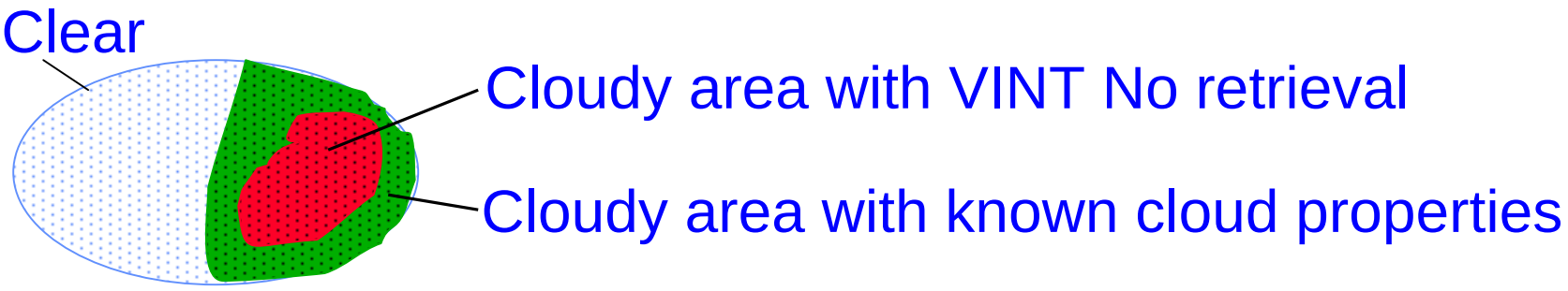


Define new diagnostic parameter that provides user with info on what fraction of total cloudy area had VINT no retrievals:

$$\% \text{ Extrap over cloudy area} = f^{VNR} / A_c \times 100\%$$

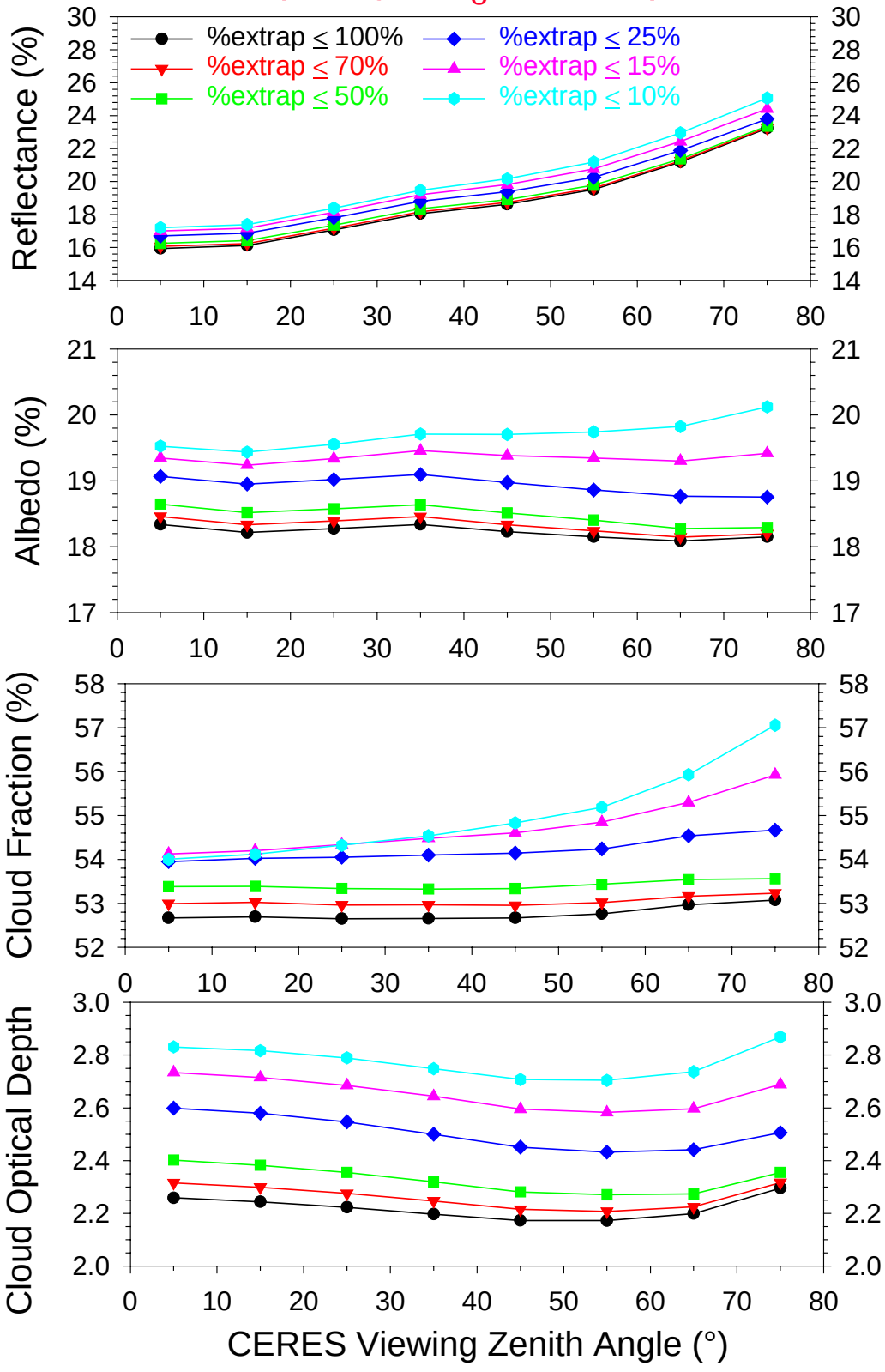
f^{VNR} =fraction of CERES footprint with VINT no retrievals

A_c =cloud fraction over CERES footprint

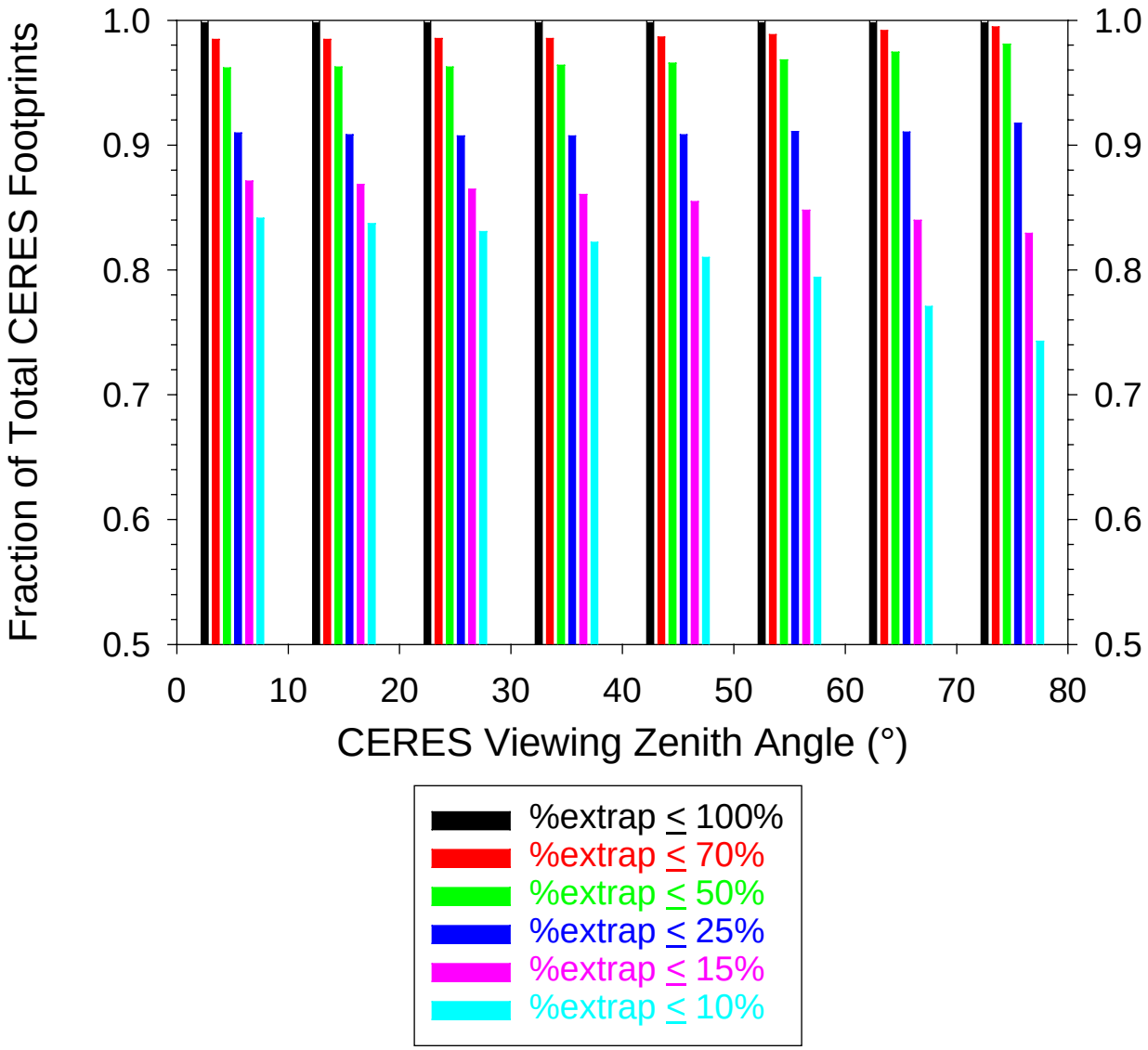


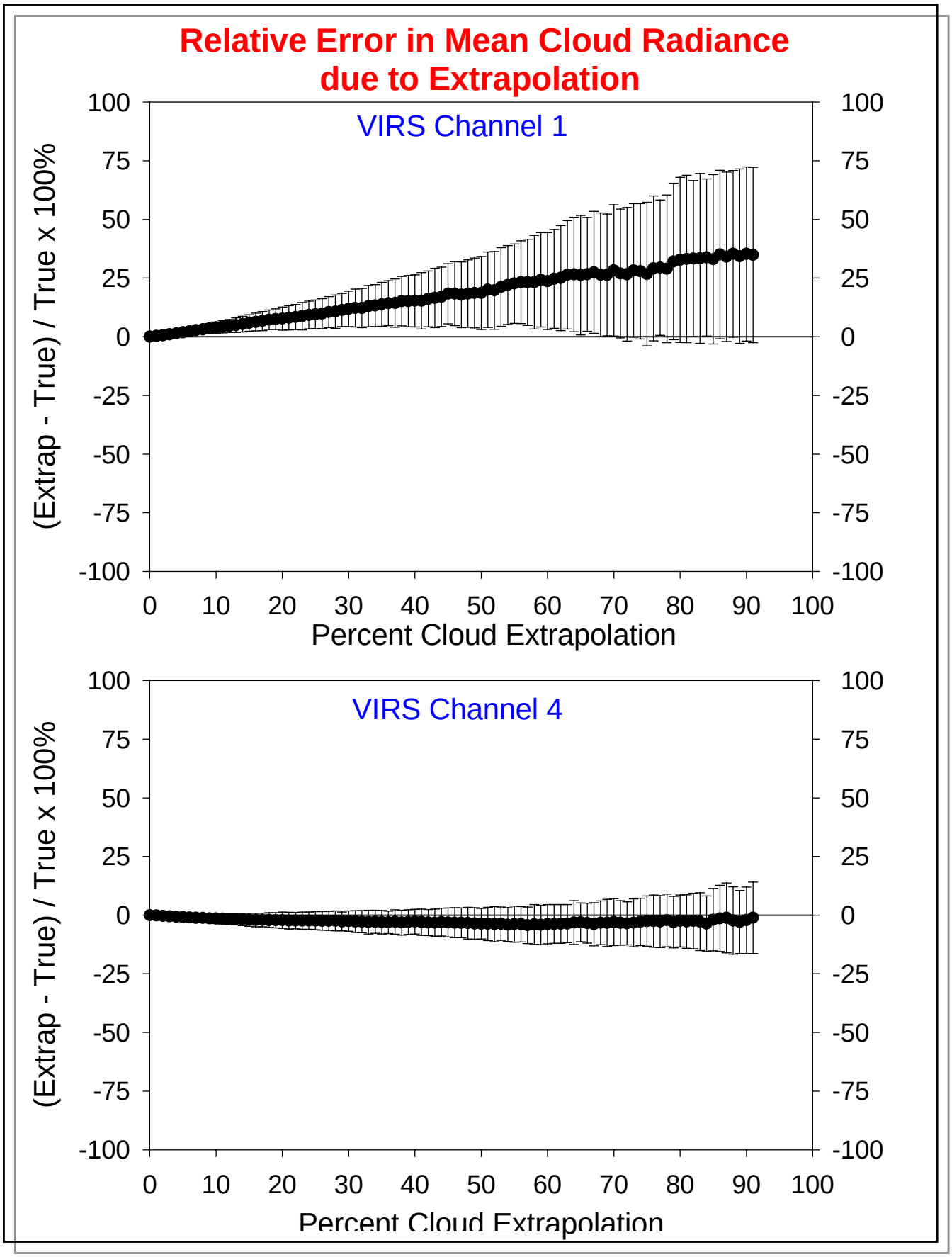
CERES-TRMM Edition1 Along-Track Test

(9 days; θ_o=30-40°)



Fraction of Total Available CERES Footprints (θ_o=30-40°)




Relative Error in Mean Cloud Radiance due to Extrapolation
VIRS Channel 1
(Extrap - True) / True x 100%
100
75
50
25
0
-25
-50
-75
-100
0
10
20
30
40
50
60
70
80
90
100
Percent Cloud Extrapolation
VIRS Channel 4
(Extrap - True) / True x 100%
Percent Cloud Extrapolation

Summary

i) VINT no retrievals occur ~10-15% of the time. More prevalent for thin cloud layers.

ii) By rejecting CERES footprints with a given fraction of VINT no retrieval pixels, a bias in mean cloud optical properties is introduced.

iii) In SSF Edition 1, CERES footprint selection/rejection criterion has been modified so that all eligible footprints are retained. Cloud properties in VINT no retrieval regions are estimated from those in regions where cloud properties are known.

USERS CAN CHECK DEGREE OF EXTRAPOLATION OVER CLOUDY REGION FOR EACH FOOTPRINT FROM THE "CLOUD PROPERTY EXTRAPOLATION OVER CLOUDY AREA" PARAMETER ON SSF.

A New Method for Reducing Angle-Dependent Biases in Satellite Cloud Optical Depth Retrievals

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Hampton University

Background

Previous studies have demonstrated that:

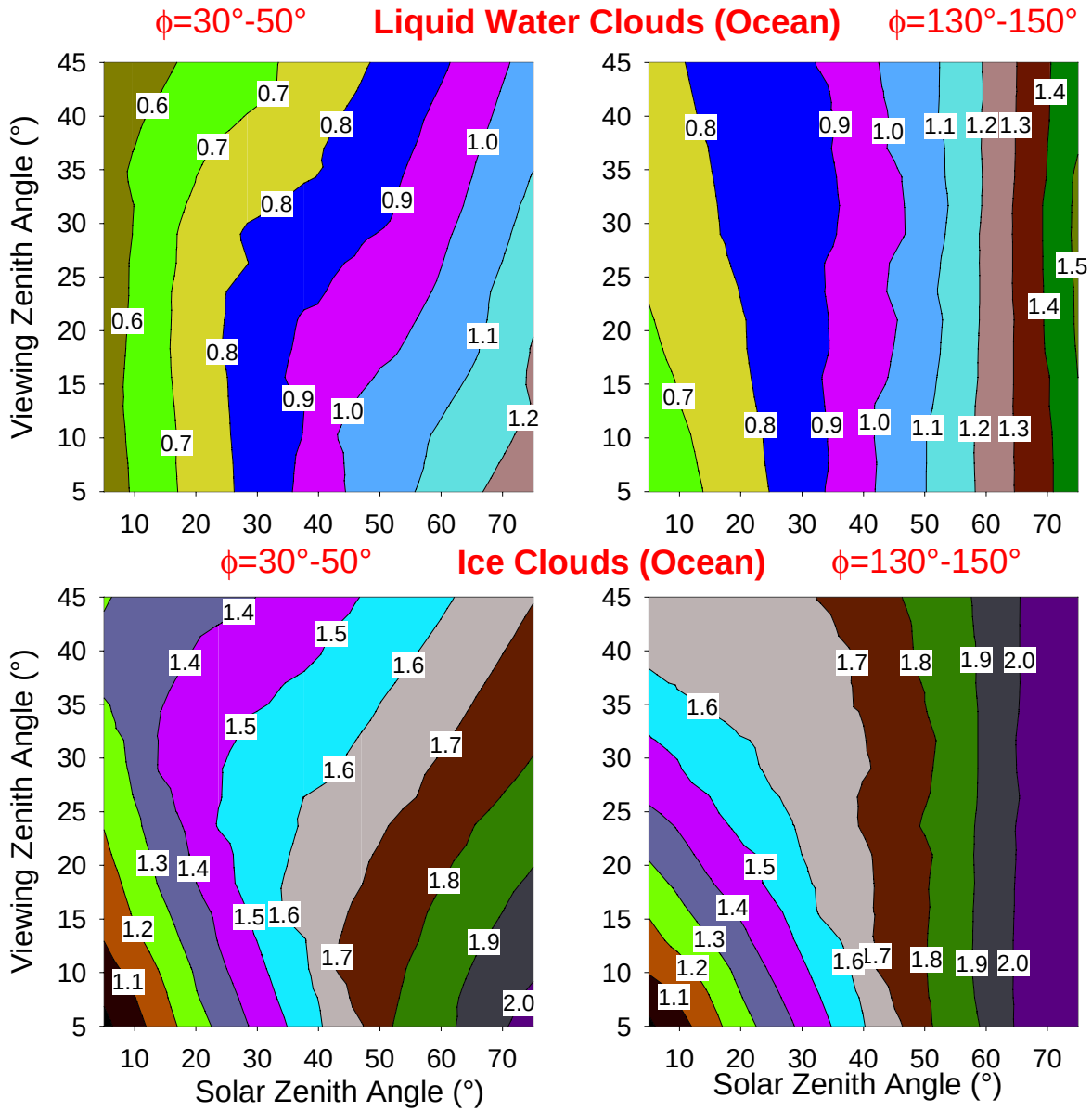
i) Existing 1D radiative transfer methods for inferring cloud optical depth from satellite measurements suffer from systematic angle-dependent biases.

ii) Angular distribution models (ADMs) constructed using a biased scene identification lead to biased albedos and fluxes.

iii) ADM scene classes defined using percentiles of cloud optical depth significantly reduce albedo & flux errors.

iv) However, percentile approach requires fixed spatial resolution at all viewing angles—not available from CERES SSFs.

8-Month Mean ln τ vs Viewing Geometry (Validation R4)



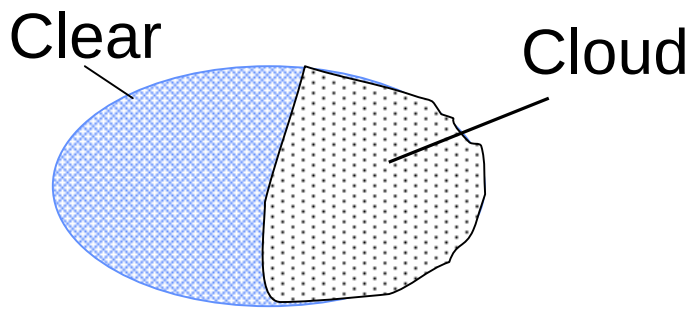
Approach

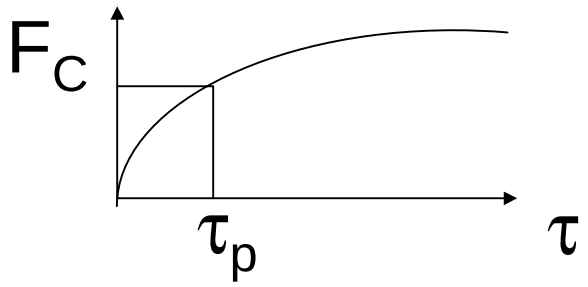
- Develop a “correction” to 1D retrievals at VIRS pixel scale that forces ensemble cloud optical depth distributions to be self-consistent in all viewing geometries.
  => Assumes true optical depth does not depend on sun-earth-satellite viewing geometry.

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

- Attempts to “correct” for potential biases in retrieval scheme only—i.e. it does not account for possible biases due to variable imager/CERES spatial resolution with angle.

Imager Pixel-Level Cloud Optical Depth Distributions from SSFs



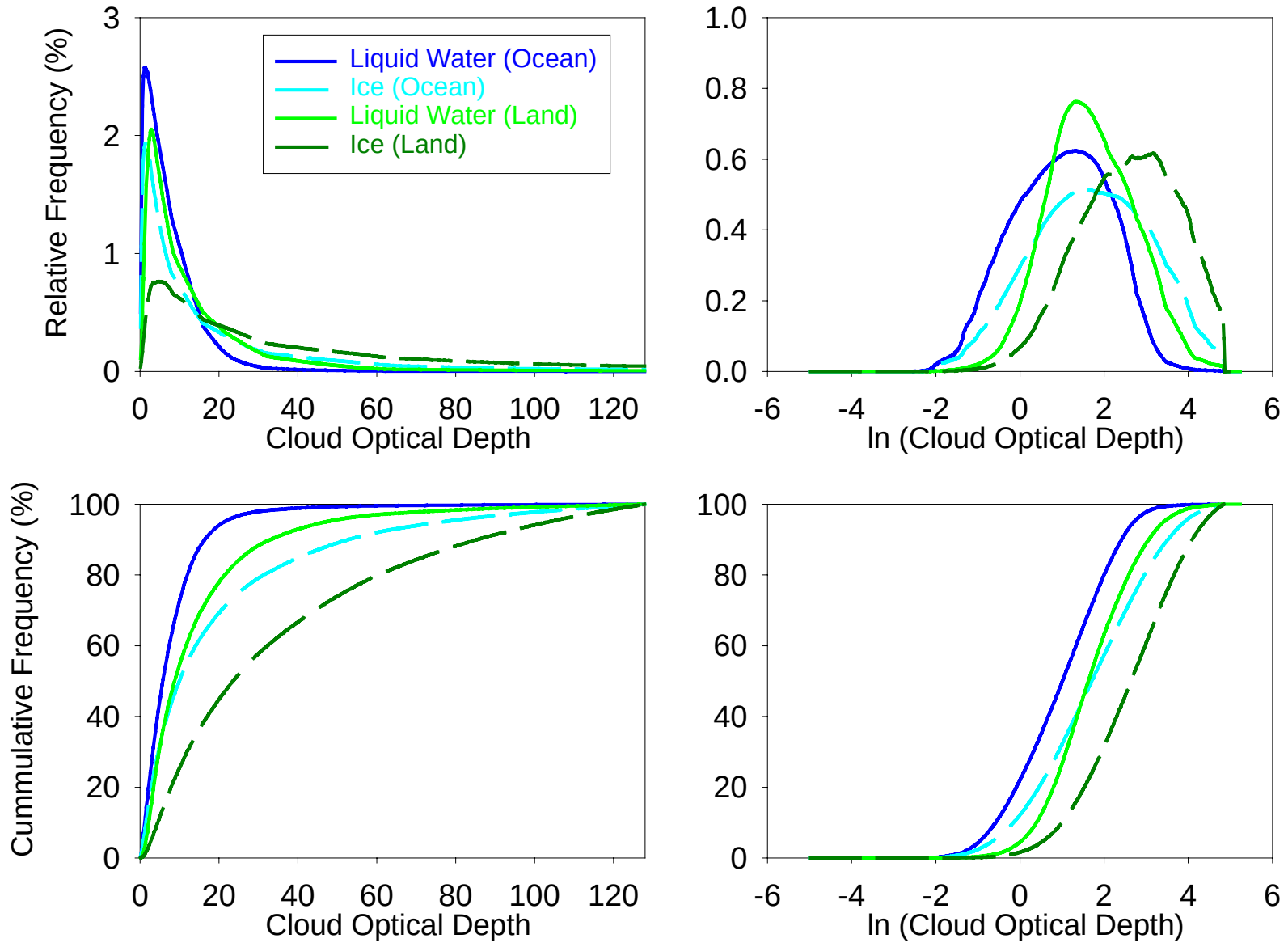


τ_p for p=1, 5, 10,..., 90, 95, 99

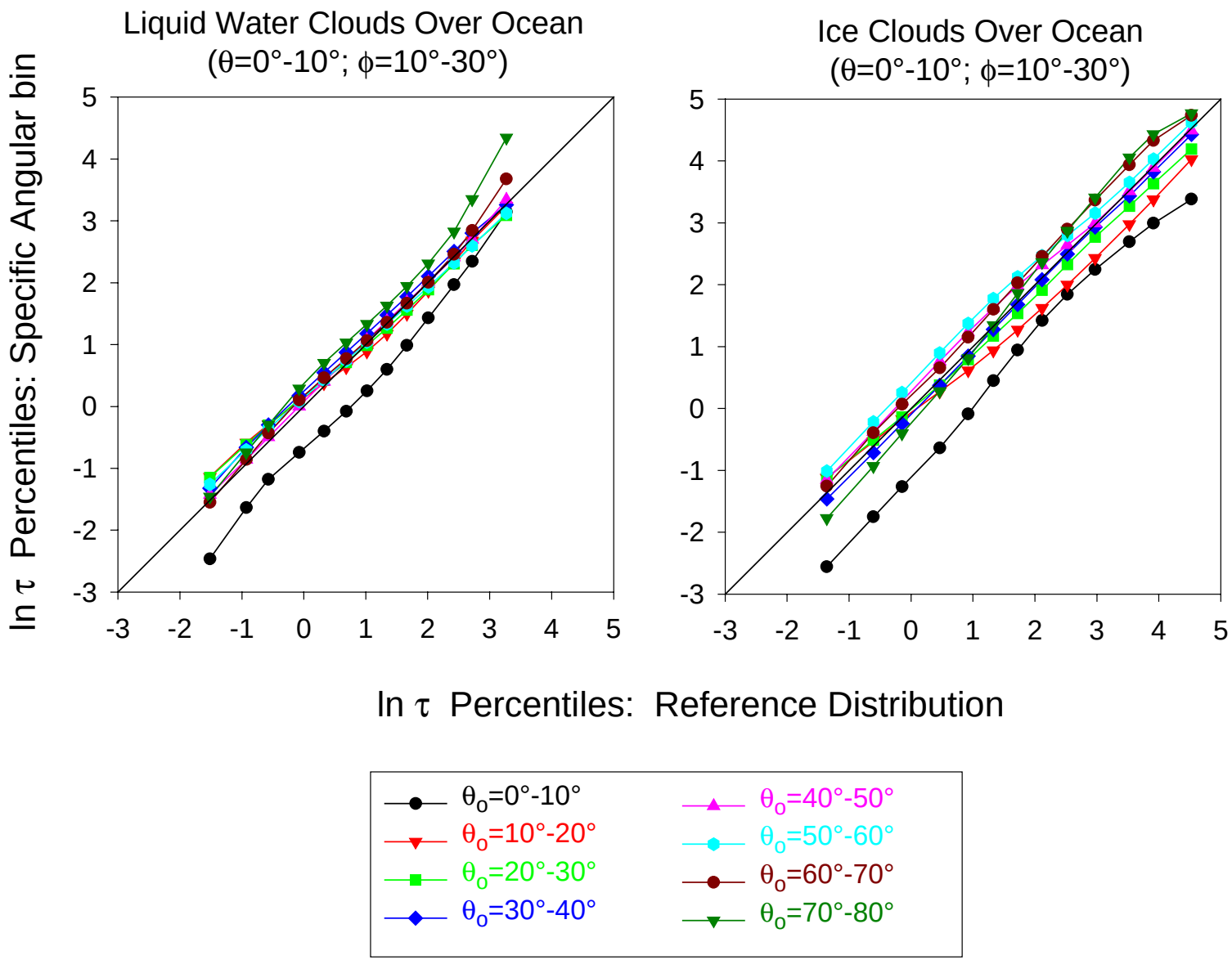
Imager τ distribution over CERES footprint

- Determine τ frequency distributions from 8 months of imager retrievals stratified by VIRS viewing geometry.
- Define reference cloud optical depth distribution (e.g. for a specific angle or from other sources). Here we use VIRS retrievals for θ_o=40°-50°; θ=0°-10°.
- Plot τ-percentiles from each VIRS angular bin against τ-percentiles from the reference distribution. Use these curves to apply τ-correction.

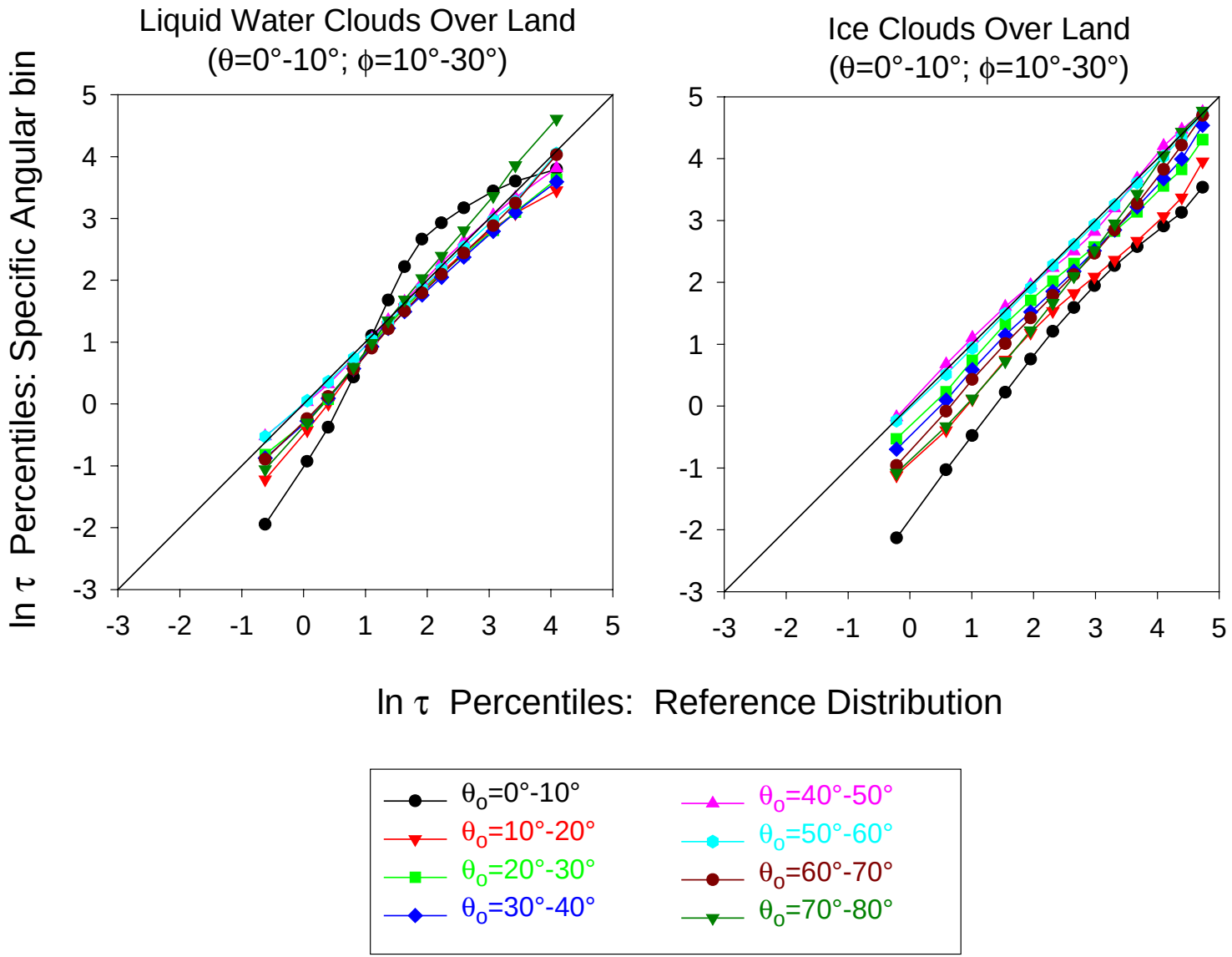
Reference Cloud Optical Depth Distributions



ln τ Correction Curves: Ocean



ln τ Correction Curves: Land



Cloud Optical Depth "Correction" Applied to Individual Footprint

footprint ln τ_p values; viewing geometry;
phase index (1-2); ocean/land

↓

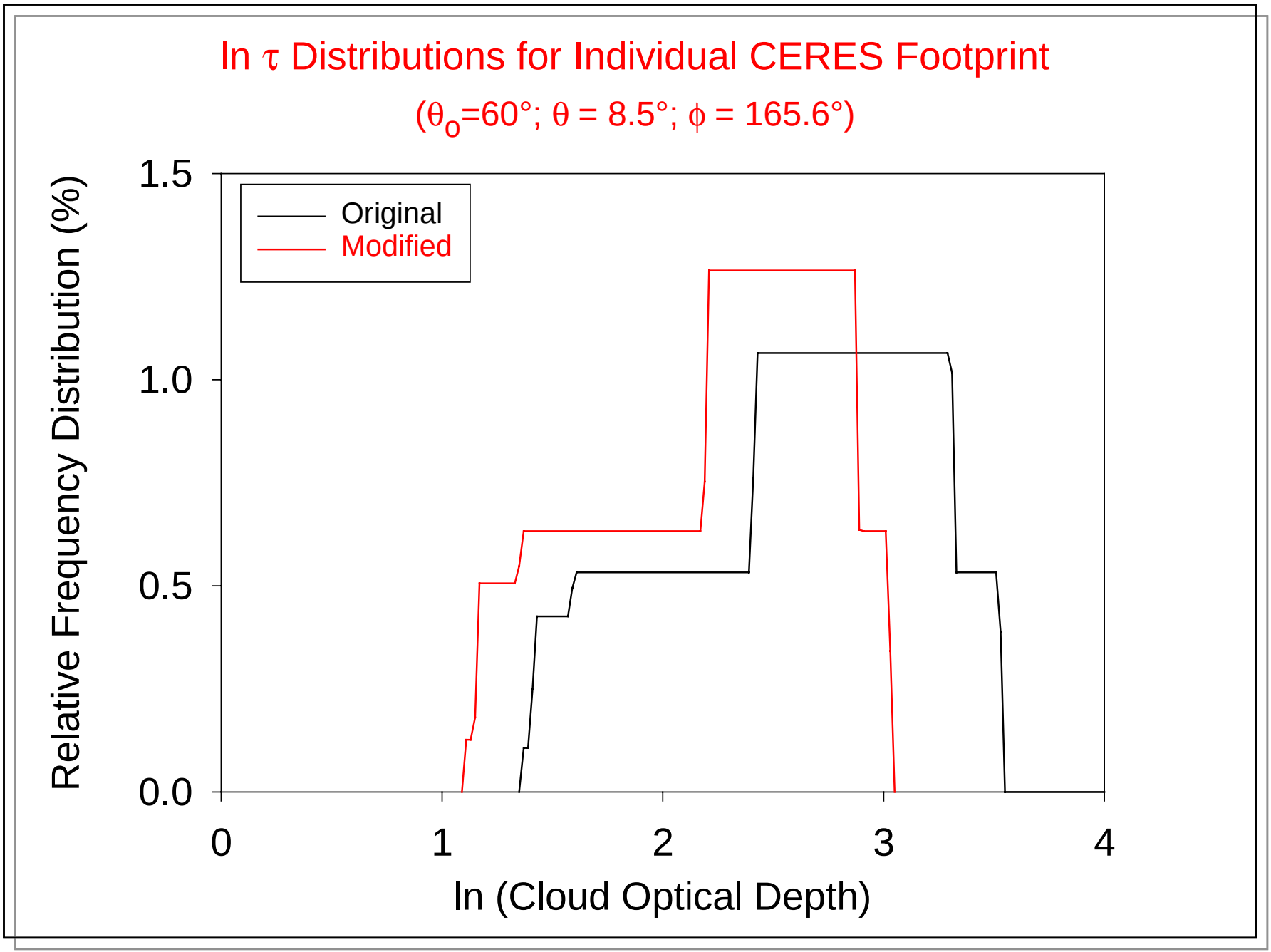
Apply τ-correction curve to each ln τ_p value (13)

↓

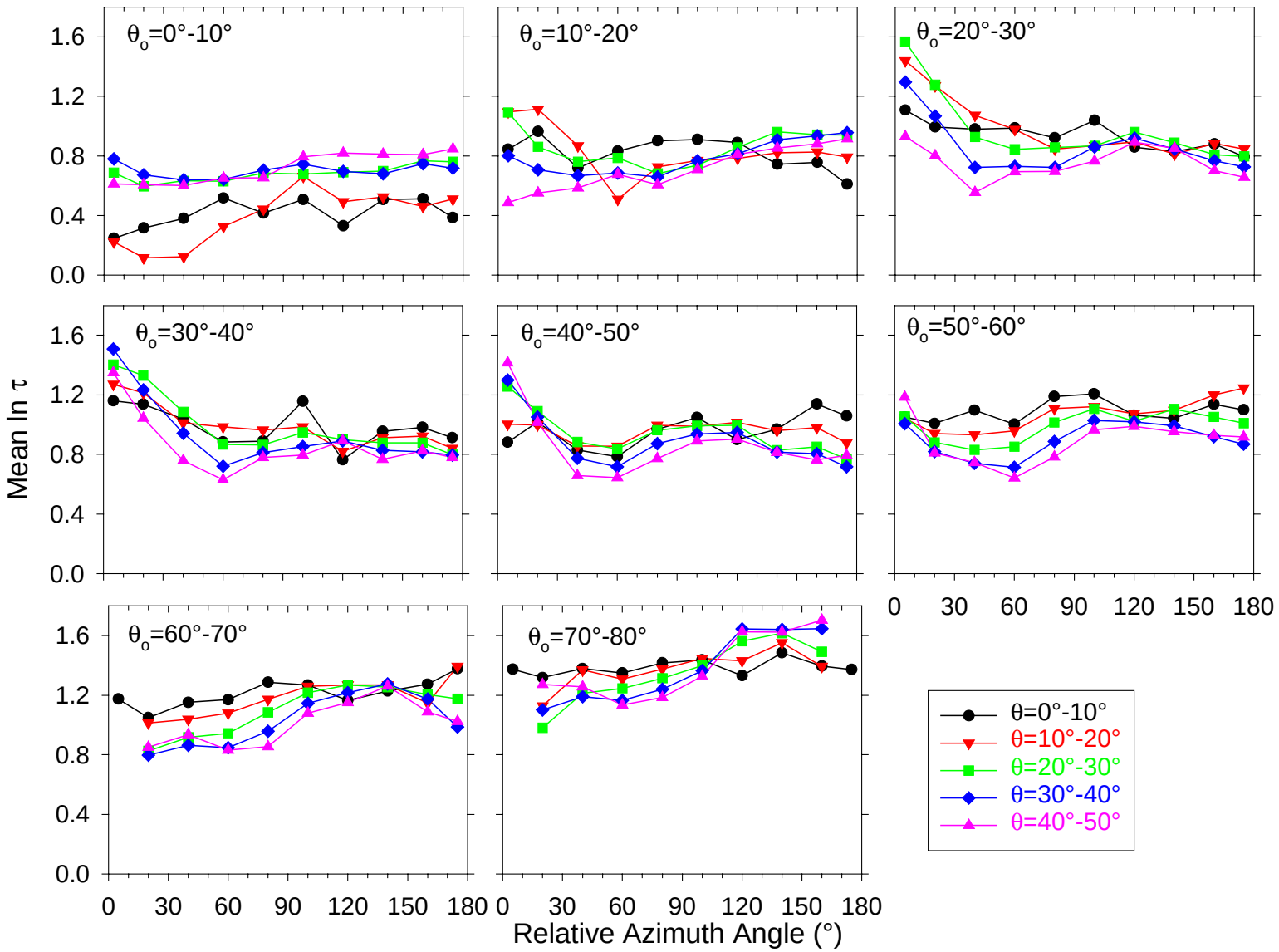
ln τ'_p values

↓

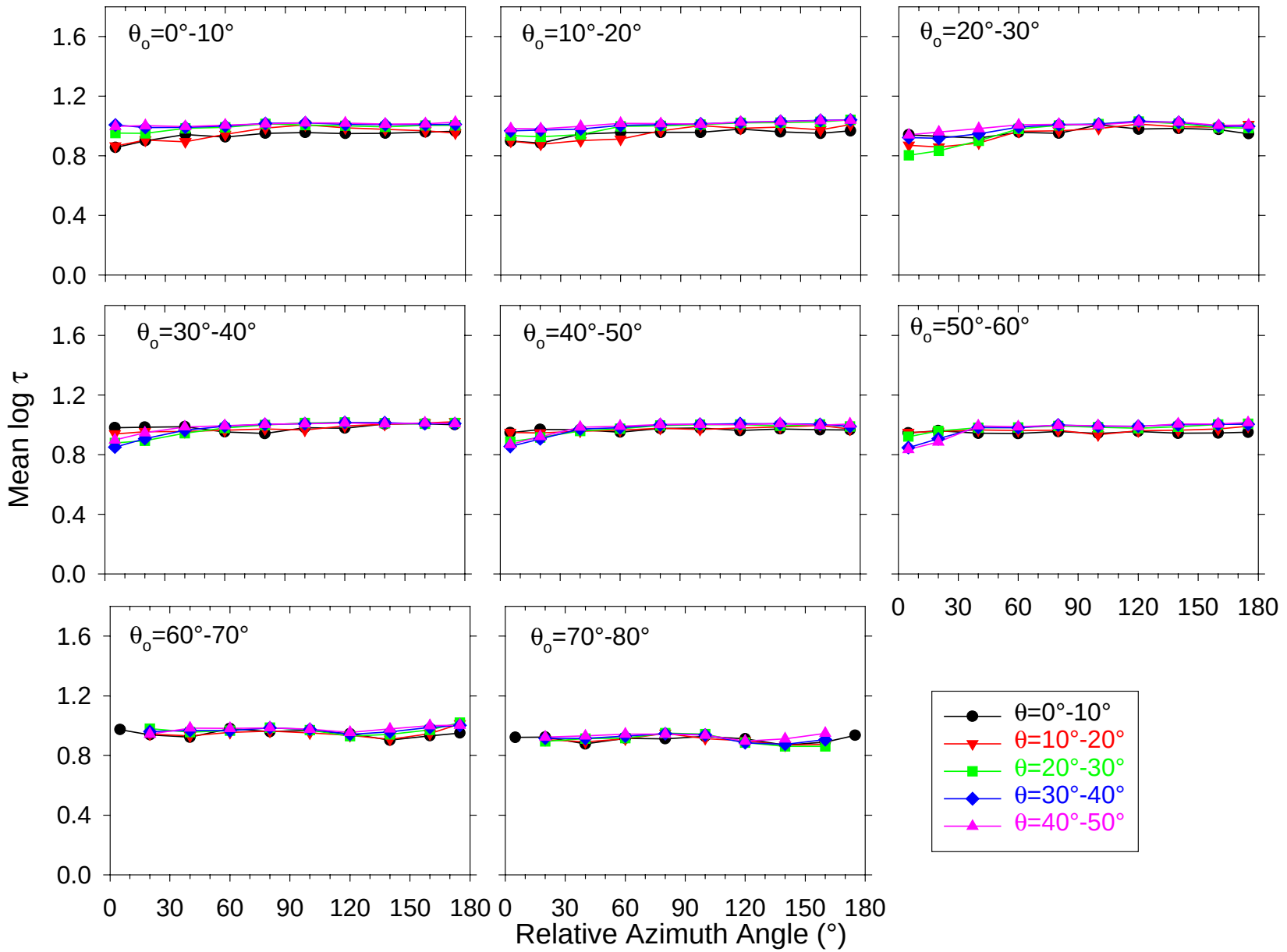
Modified
footprint mean
ln τ


ln τ Distributions for Individual CERES Footprint
(θo=60°; θ = 8.5°; ϕ = 165.6°)
Original
Modified
Relative Frequency Distribution (%)
1.5
1.0
0.5
0.0
0
1
2
3
4
ln (Cloud Optical Depth)

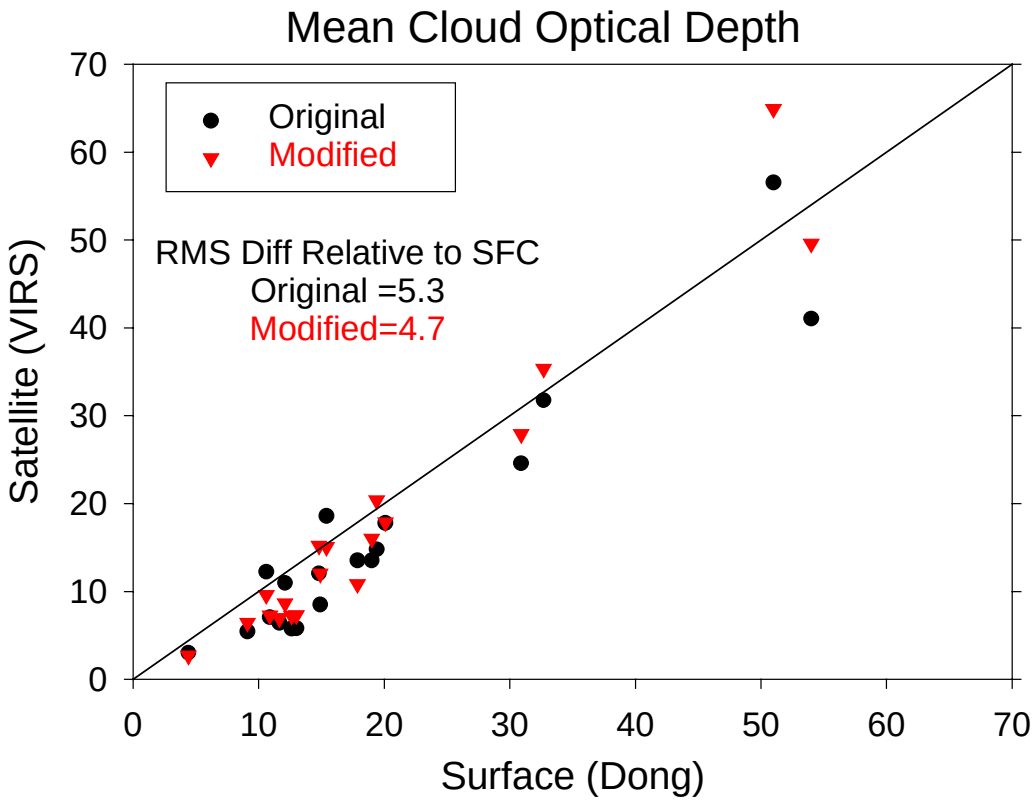
Liquid Water Clouds Over Ocean (ValidationR4)

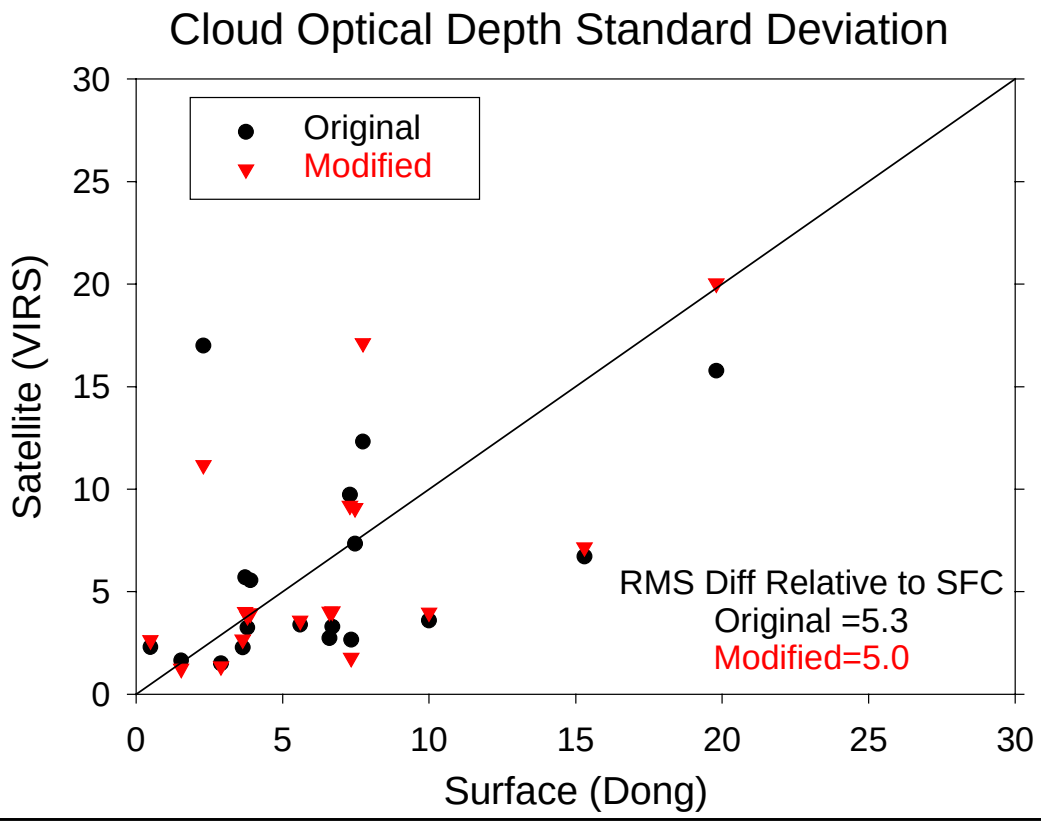


Liquid Water Clouds Over Ocean (Modified Retrievals)

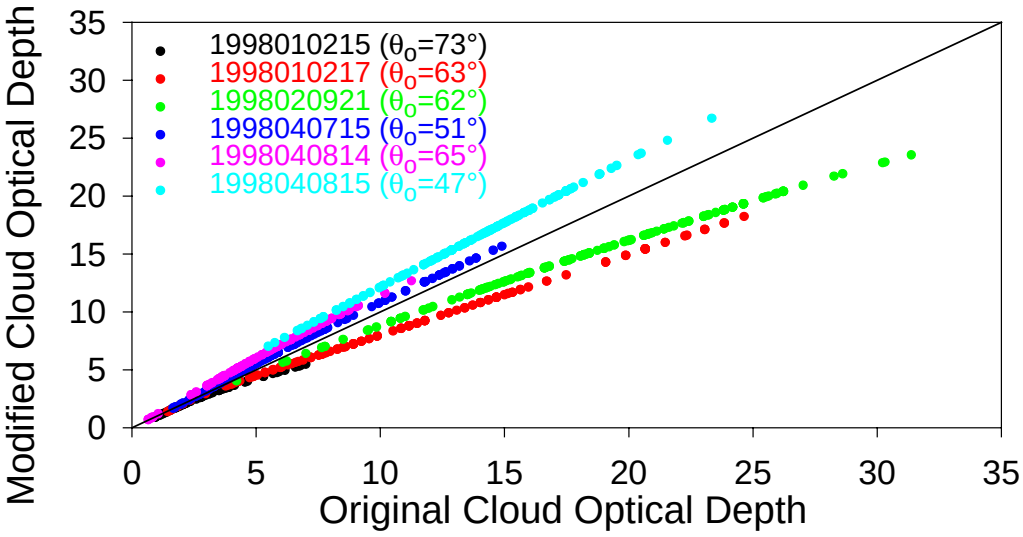


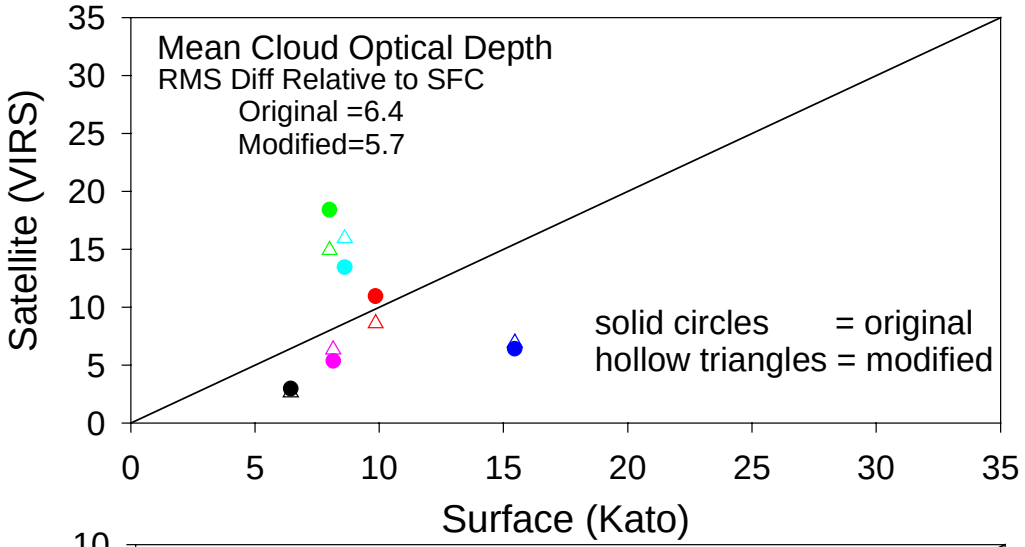
Stratus SGP Cloud Optical Depth Comparisons

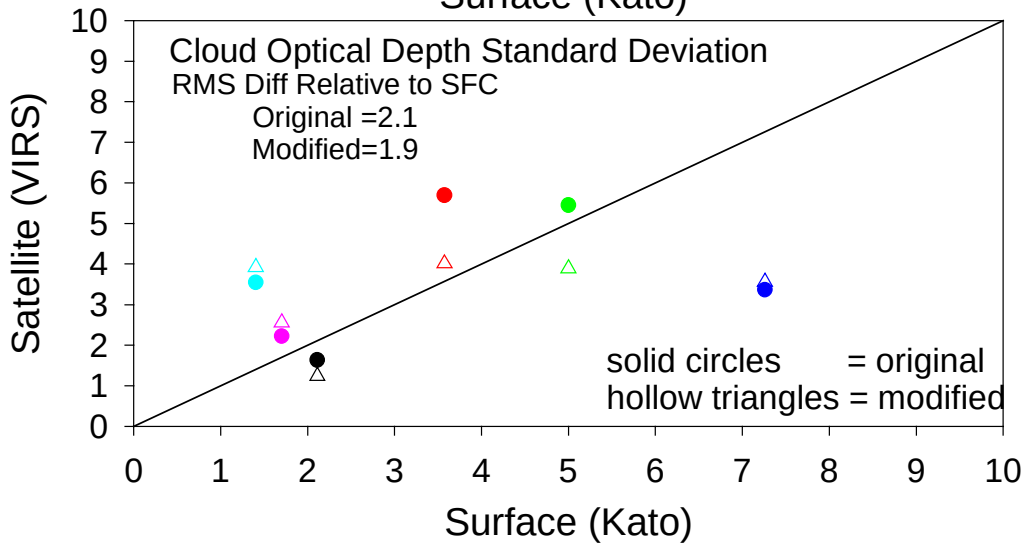




Stratus SGP Cloud Optical Depth Comparisons







Summary

i) A new method for removing angle-dependent biases in satellite cloud optical depth retrievals has been developed.

ii) Largest corrections occur for thick clouds at large solar zenith angles.

iii) Main strength of method is that it removes optical depth dependence on satellite viewing geometry.

iv) Main weakness is that reference optical depth distribution does not account for diurnal variations.

v) This approach will be used to develop CERES ADM optical depth classes.

- Will require more than 8 months of VIRS data.

=> “VIRS-only” SSFs need to extend the 8-month TRMM record.