Cloud drop effective radius as seen from aircraft, MODIS and MISR

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Acknowledgements

Bob Rauber

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Lusheng Liang

Steve Platnick

Conor Haney

The breakdown of the 1-D radiative transfer assumption for horizontally heterogeneous clouds leads to systematic errors in the retrieval of τ and r_e

These systematic errors co-vary with the underlying cloud heterogeneity and sun-view geometry

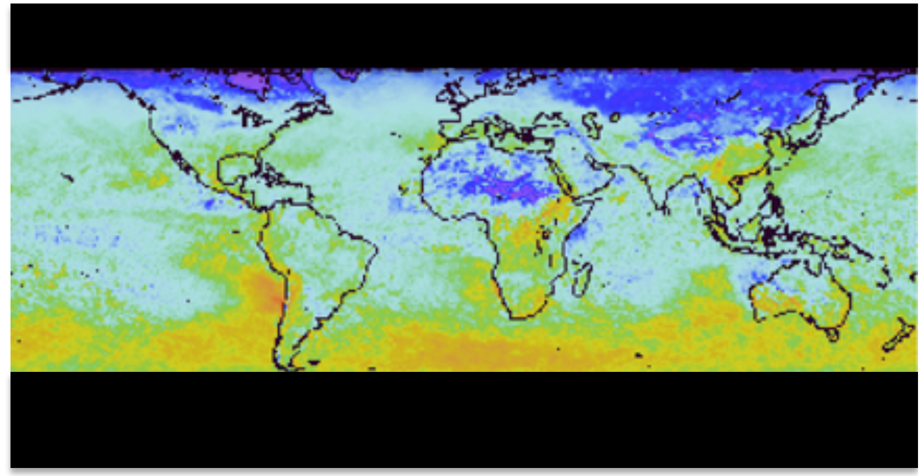
If systematic errors are not quantified under a wide range of conditions, then we cannot decouple true space-time variability found in nature from artificial space-time variability introduced through the breakdown of the 1-D radiative transfer assumption.

Oreopoulos and Platnick (2008)

Relative cloud albedo susceptibility:

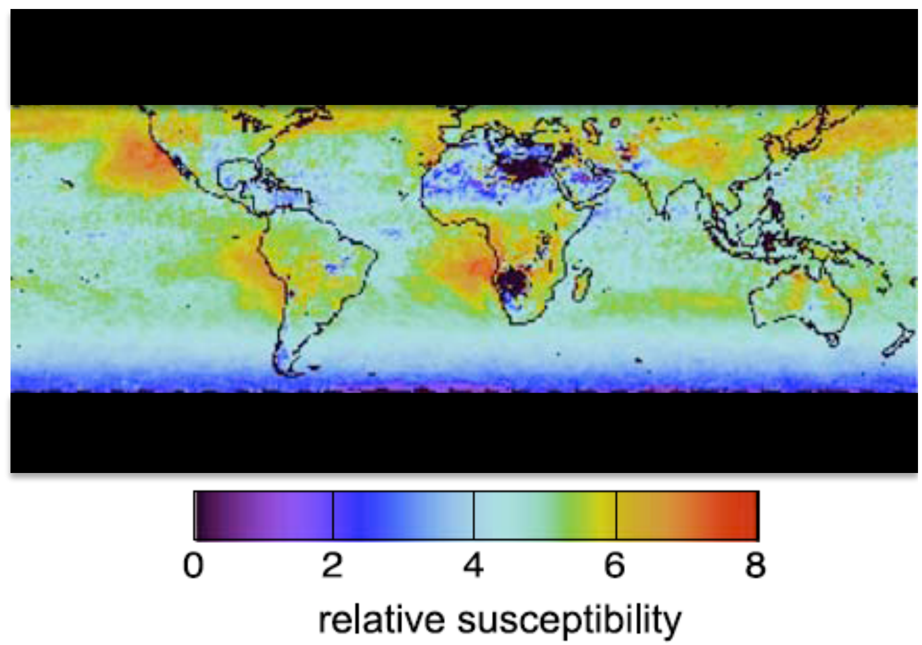
$$S = \frac{dA}{dN/N} = N\frac{dA}{dN}$$

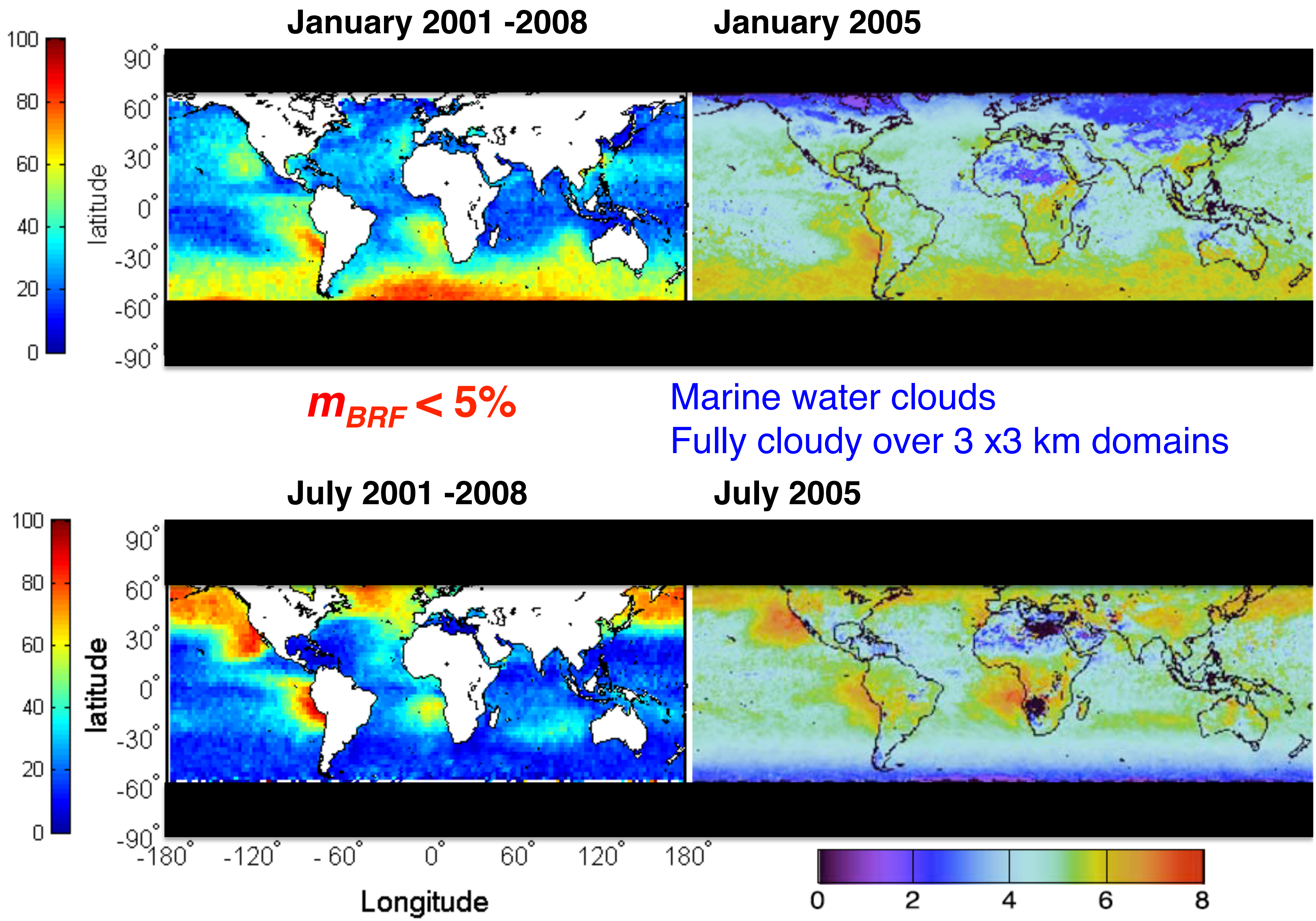
January 2005



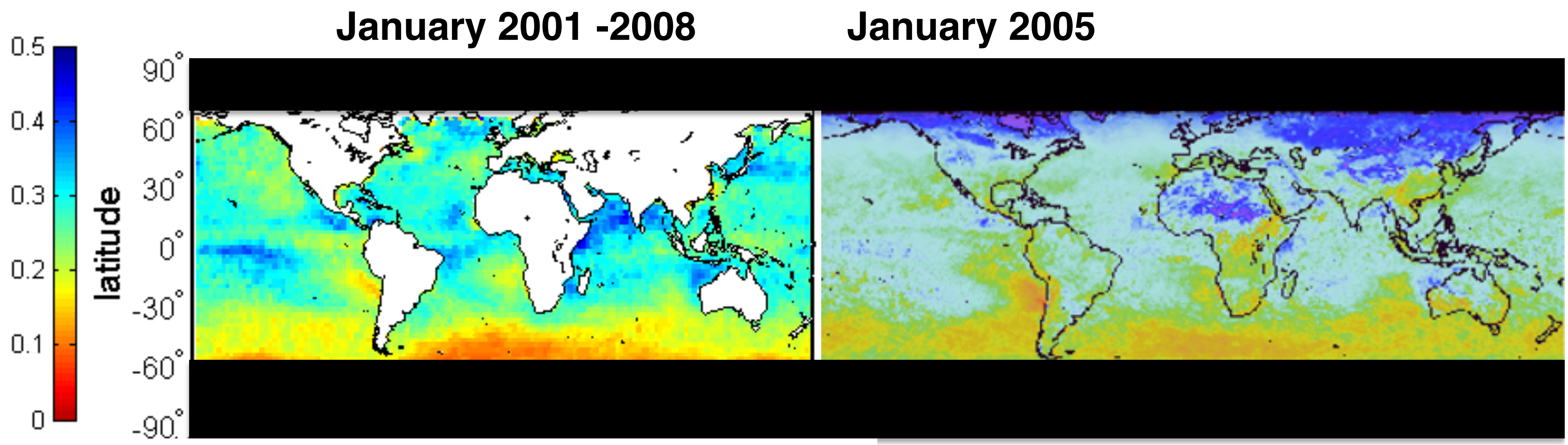
Marine water clouds

July 2005



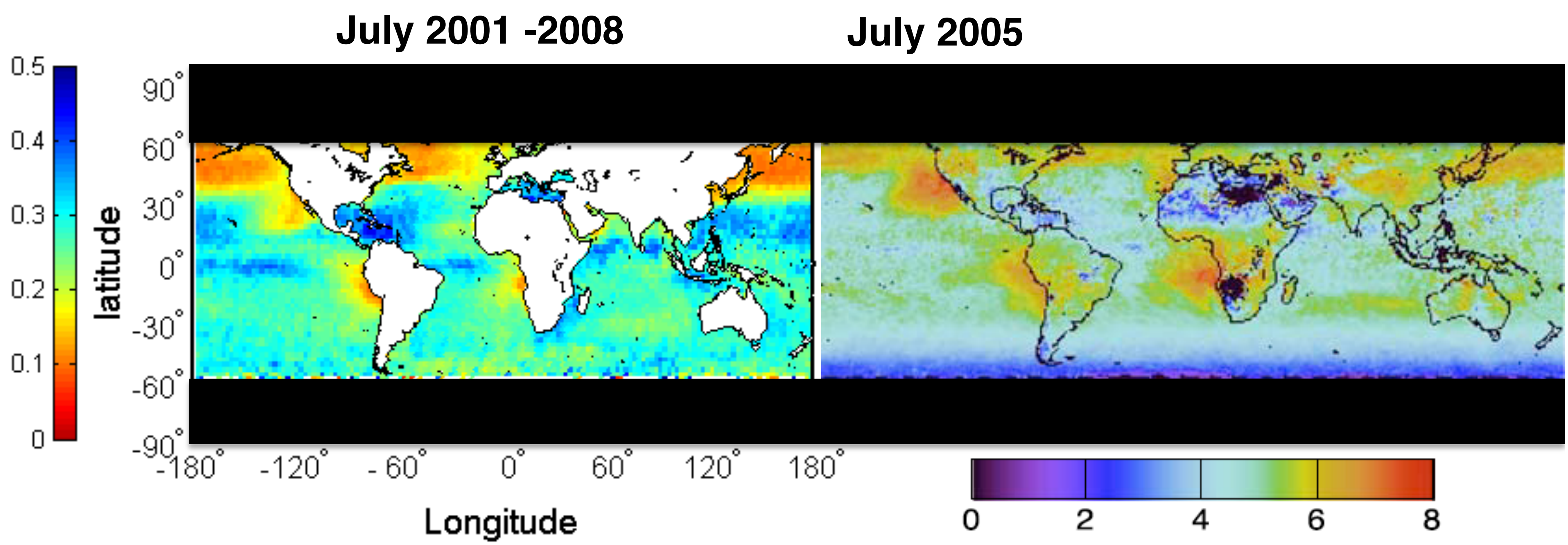


Di Girolamo, Liang, Platnick (GRL 2010)



H_σ

Marine water clouds
Fully cloudy over 3 x3 km domains



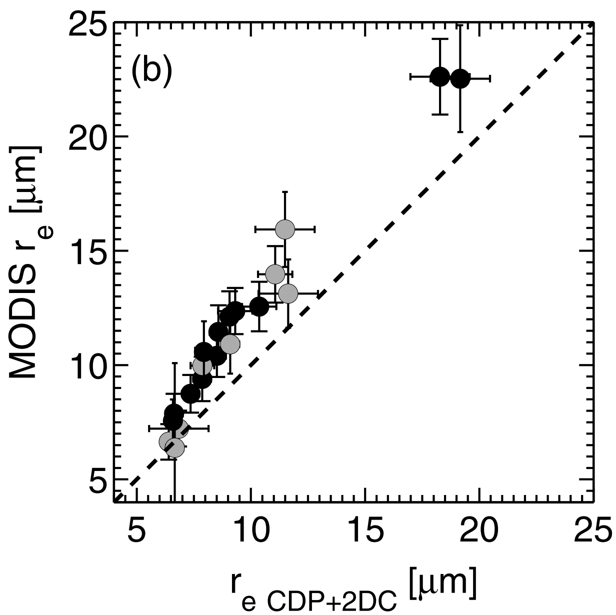
Di Girolamo, Liang, Platnick (GRL 2010)

Field campaigns used in evaluating VIS/NIR cloud optical depths and effective radii for warm marine clouds…

APEX, ASTEX, COSAT, FIRE, SOCEX II, VOCALS, WENPEX

Field campaigns used in evaluating VIS/NIR cloud optical depths and effective radii for warm marine clouds…

APEX, ASTEX, COSAT, FIRE, SOCEX II, **VOCALS**, WENPEX

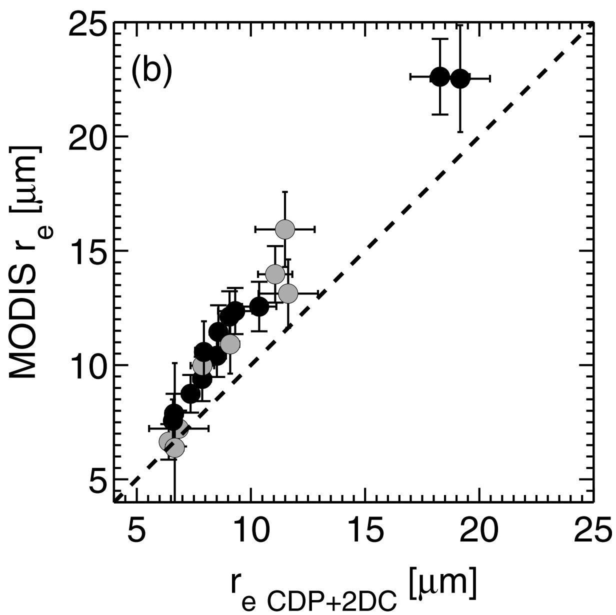


Painemal and Zuidema (2011)

~ 1 – 2 *μ*m high bias in MODIS r_e

Field campaigns used in evaluating VIS/NIR cloud optical depths and effective radii for warm marine clouds…

APEX, ASTEX, COSAT, FIRE, SOCEX II, VOCALS, WENPEX



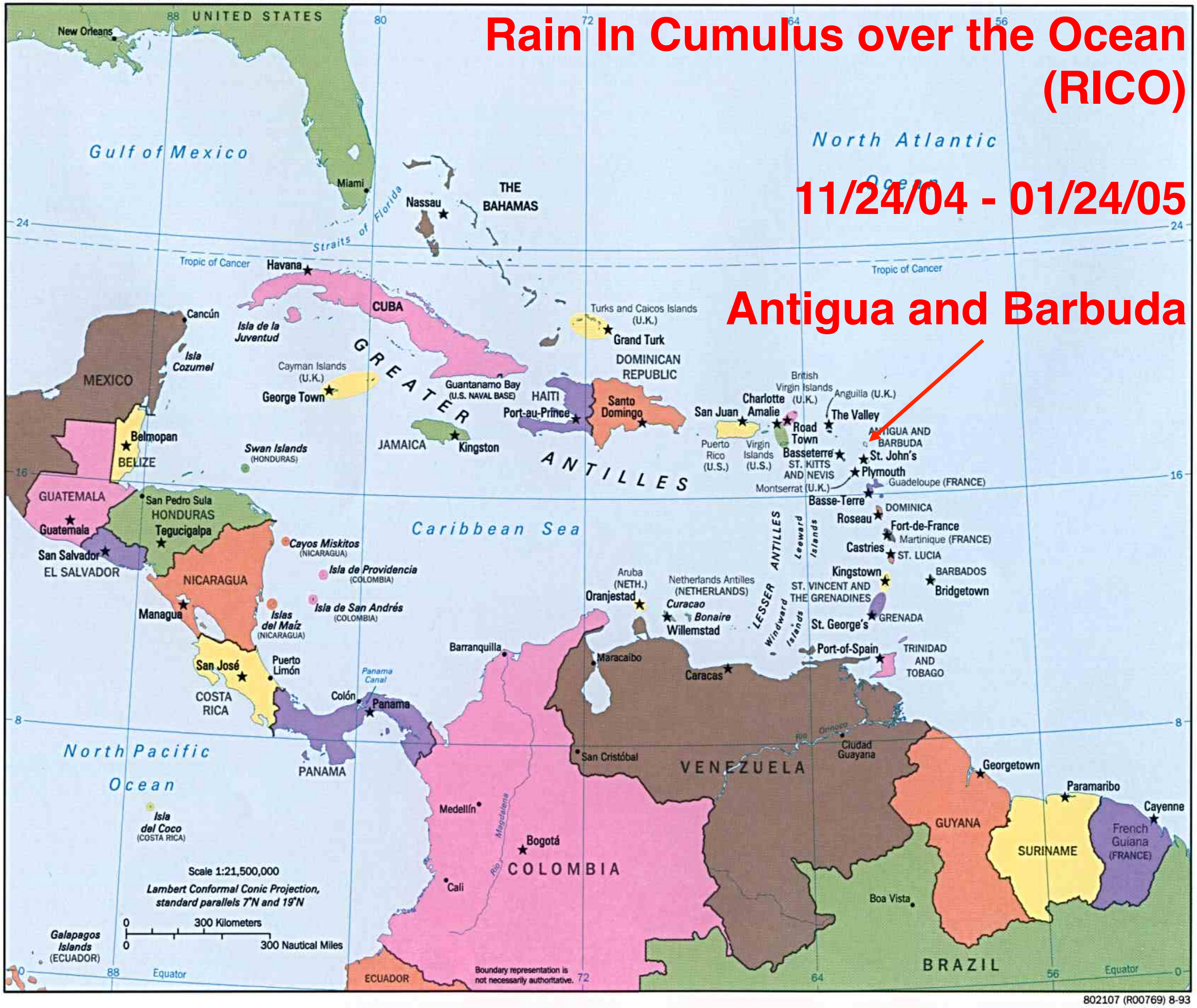
Painemal and Zuidema (2011)

~ 1 – 2 μm high bias in MODIS r_e

… all for marine stratiform clouds under high sun conditions

Rain In Cumulus over the Ocean (RICO)

11/24/04 - 01/24/05

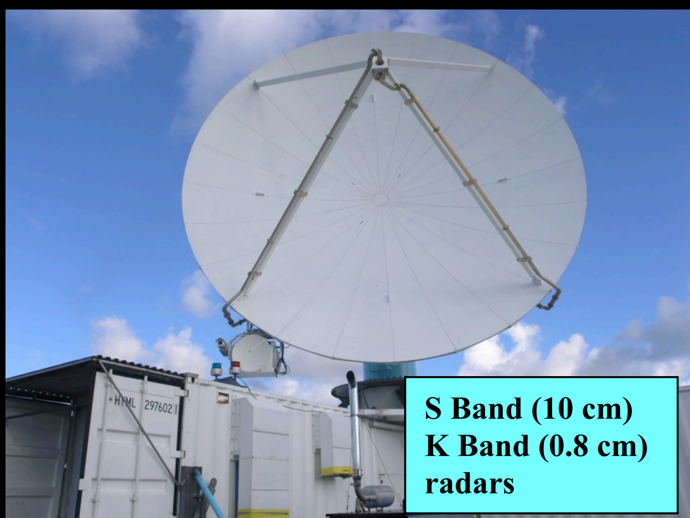


RICO Instrumentation Platforms

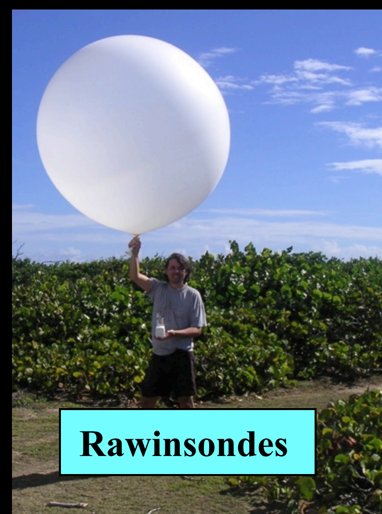
NCAR C-130

University of Wyoming King Air

UK Met Office BAE-146

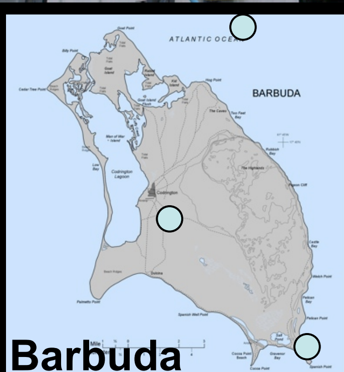


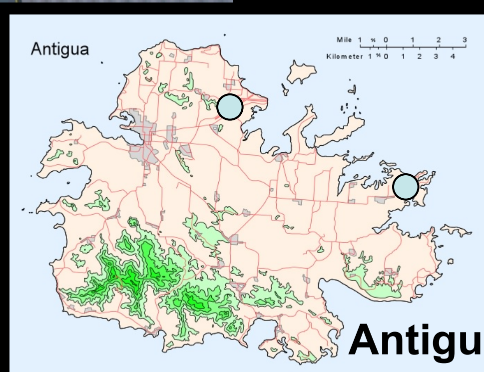
S Band (10 cm)
K Band (0.8 cm)
radars



Rawinsondes

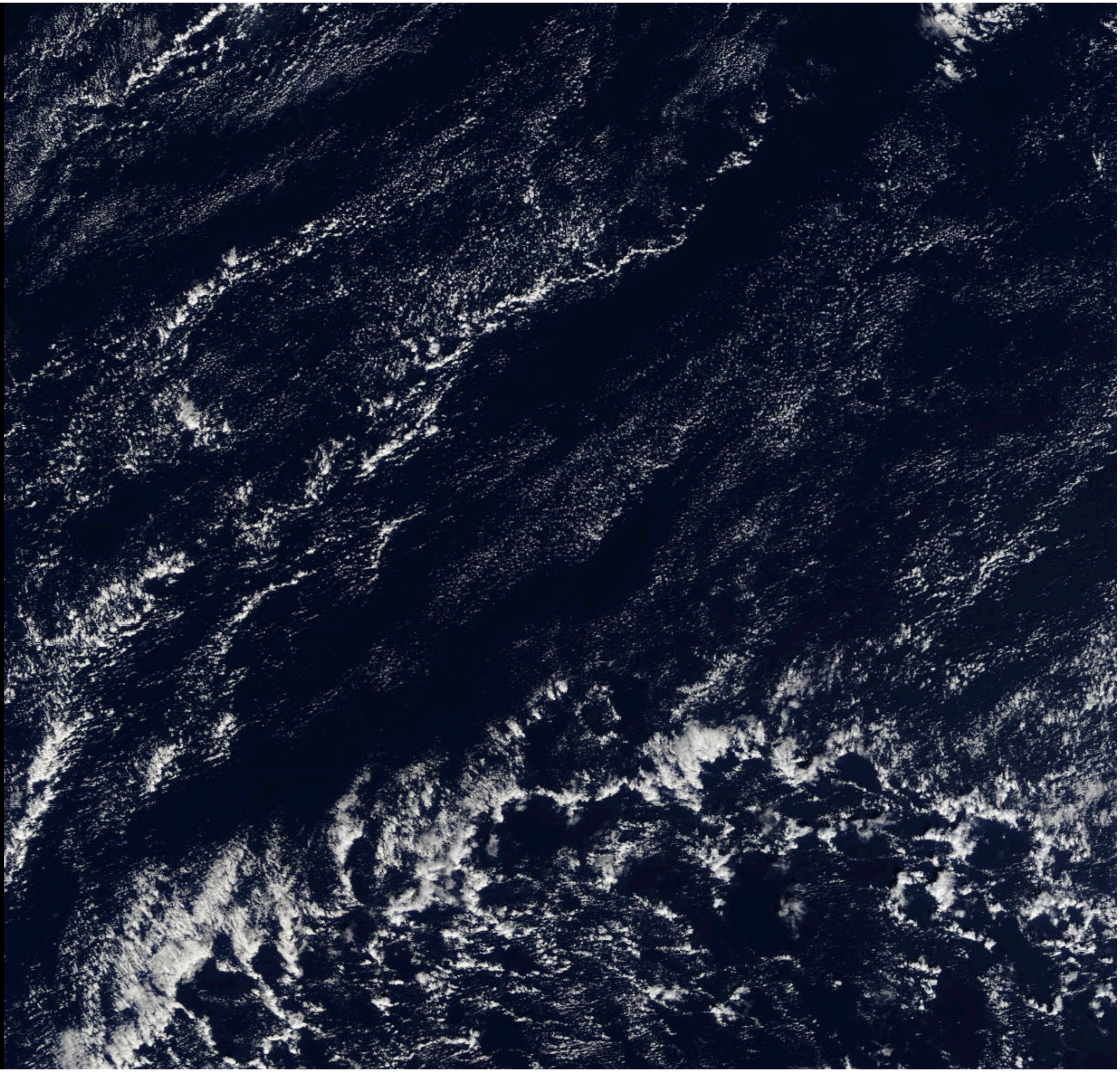
Research Ship Seward Johnson



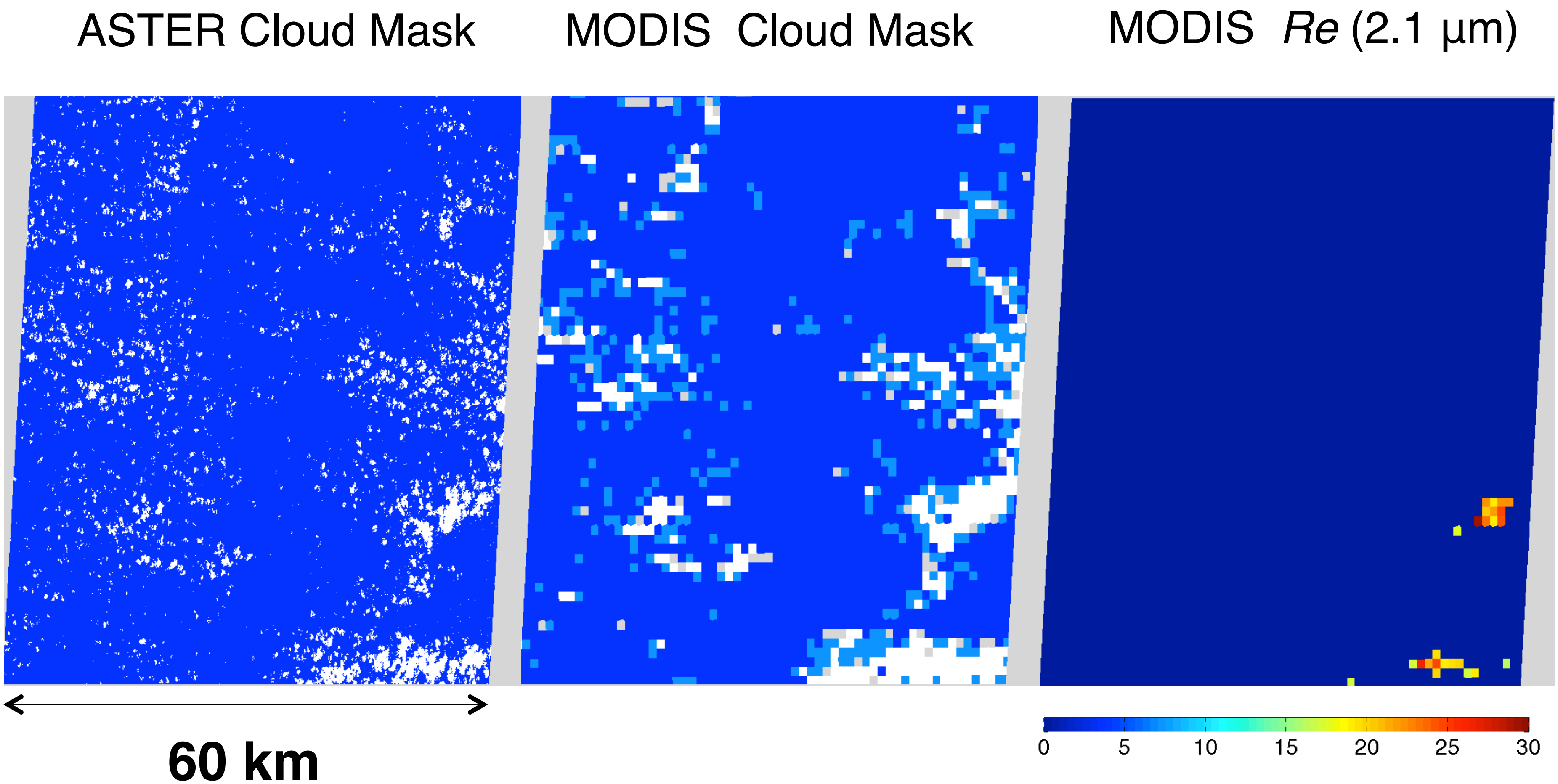


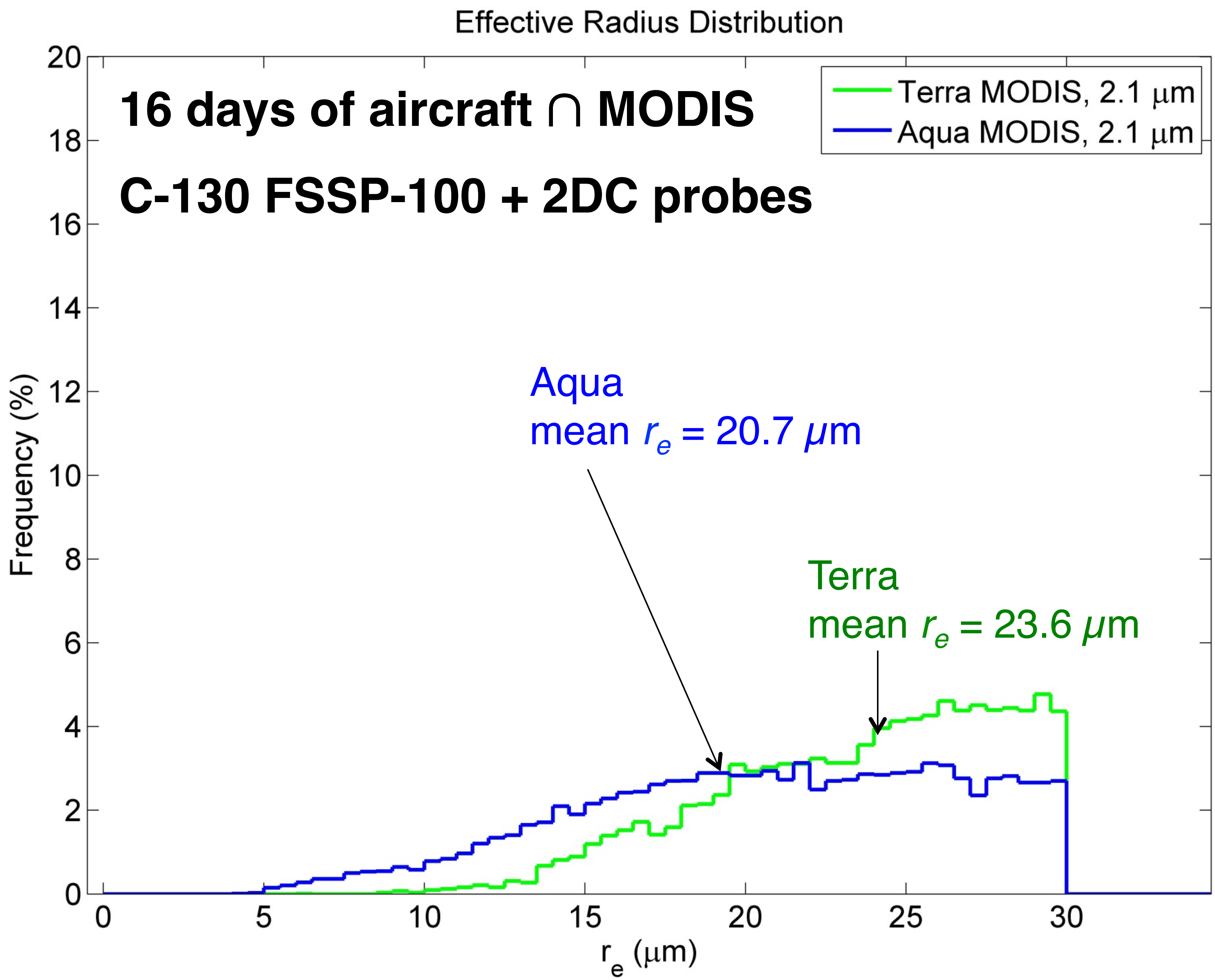
17 “Golden days” of flight data and 62 days of continuous coverage from S and K band radars

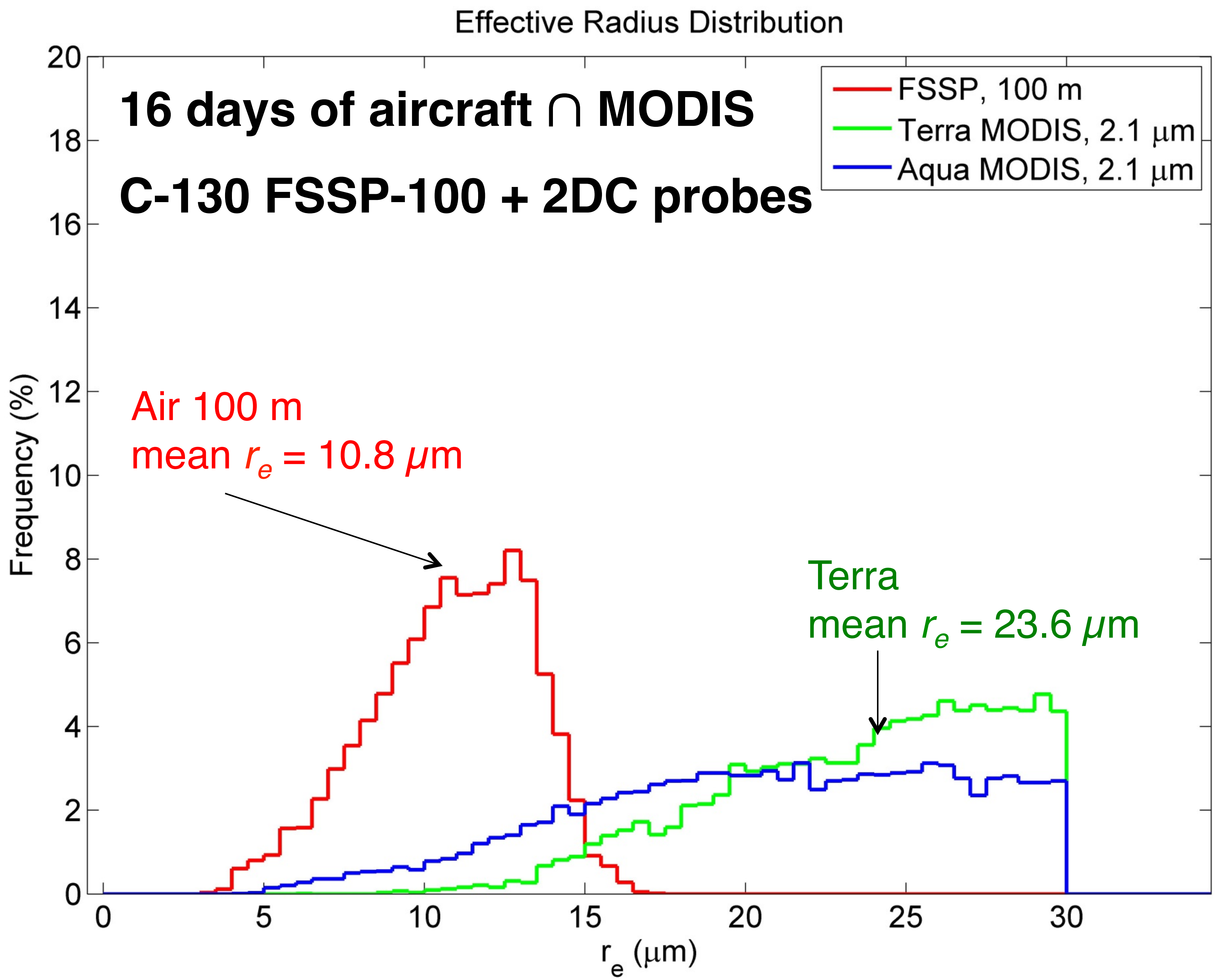
MODIS
1 km

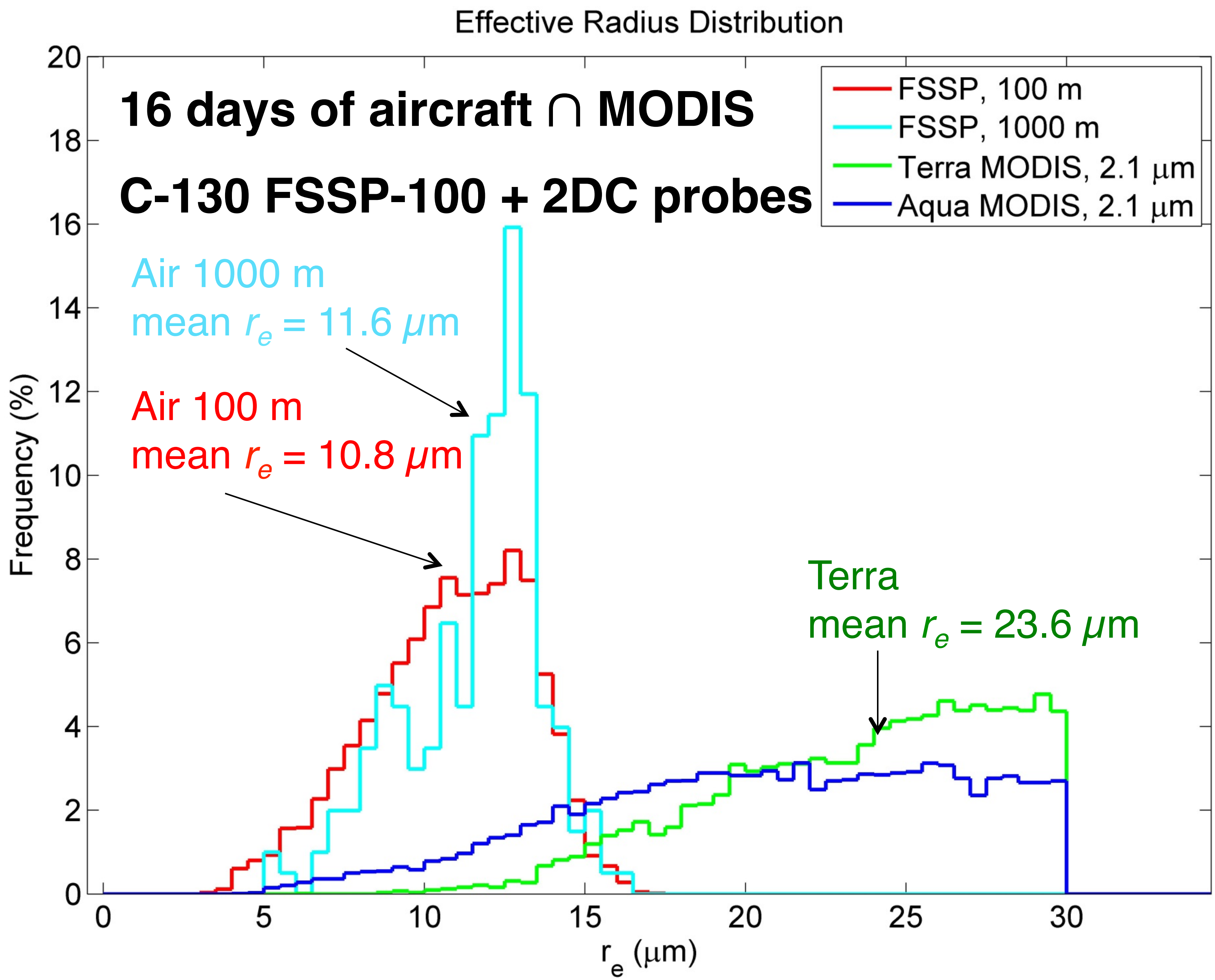


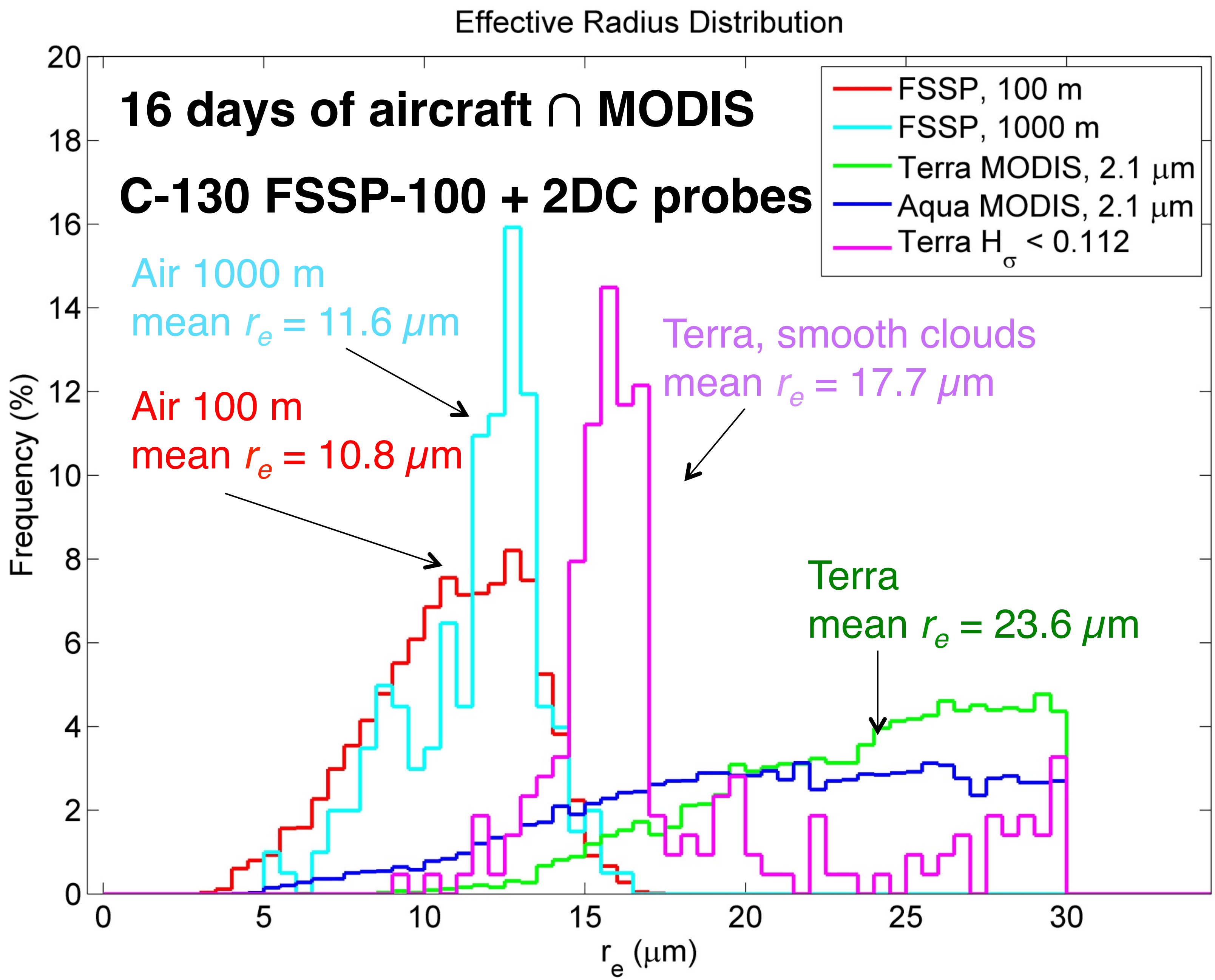
AST_L1B_00309152004140606_09282004120827.hdf

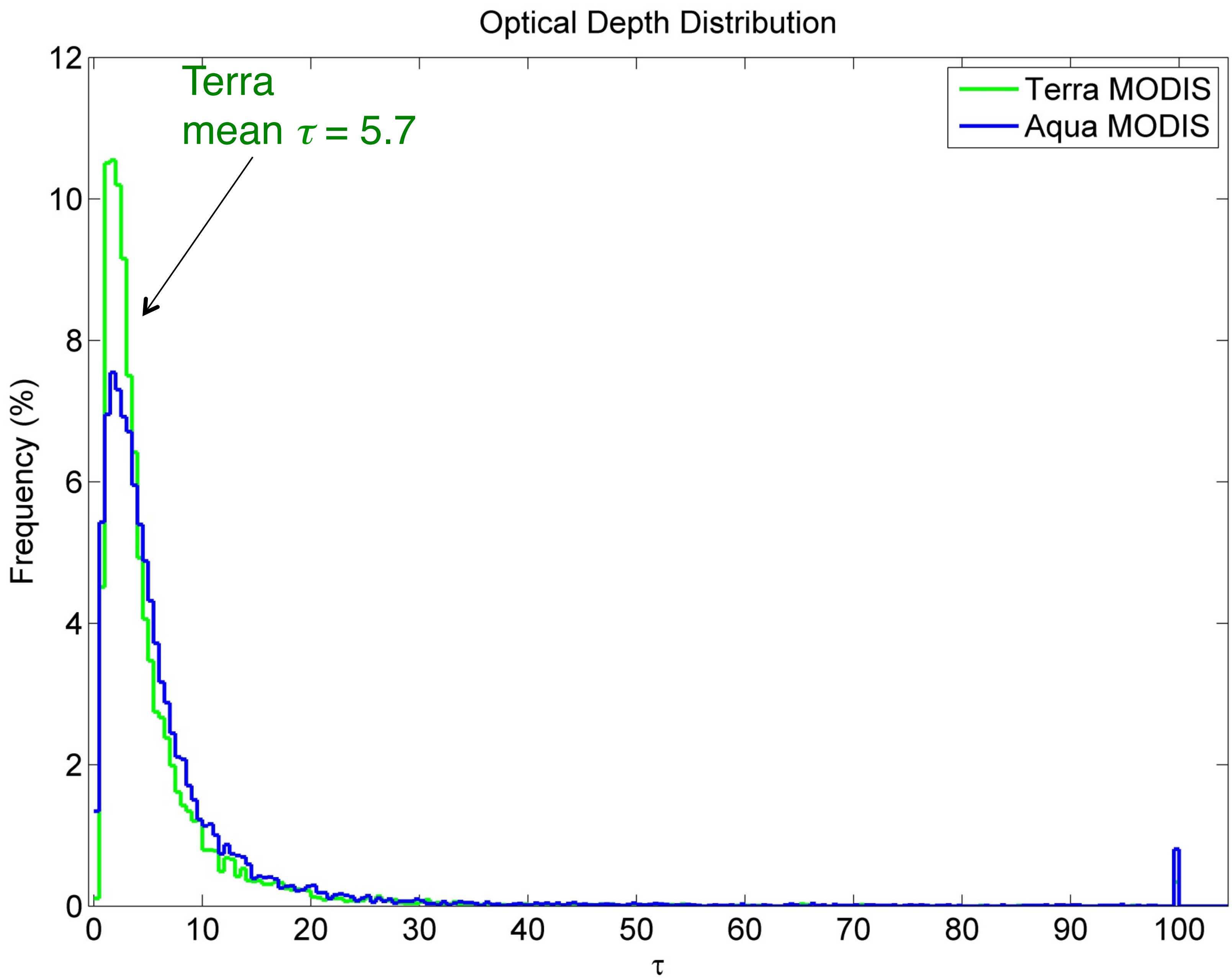


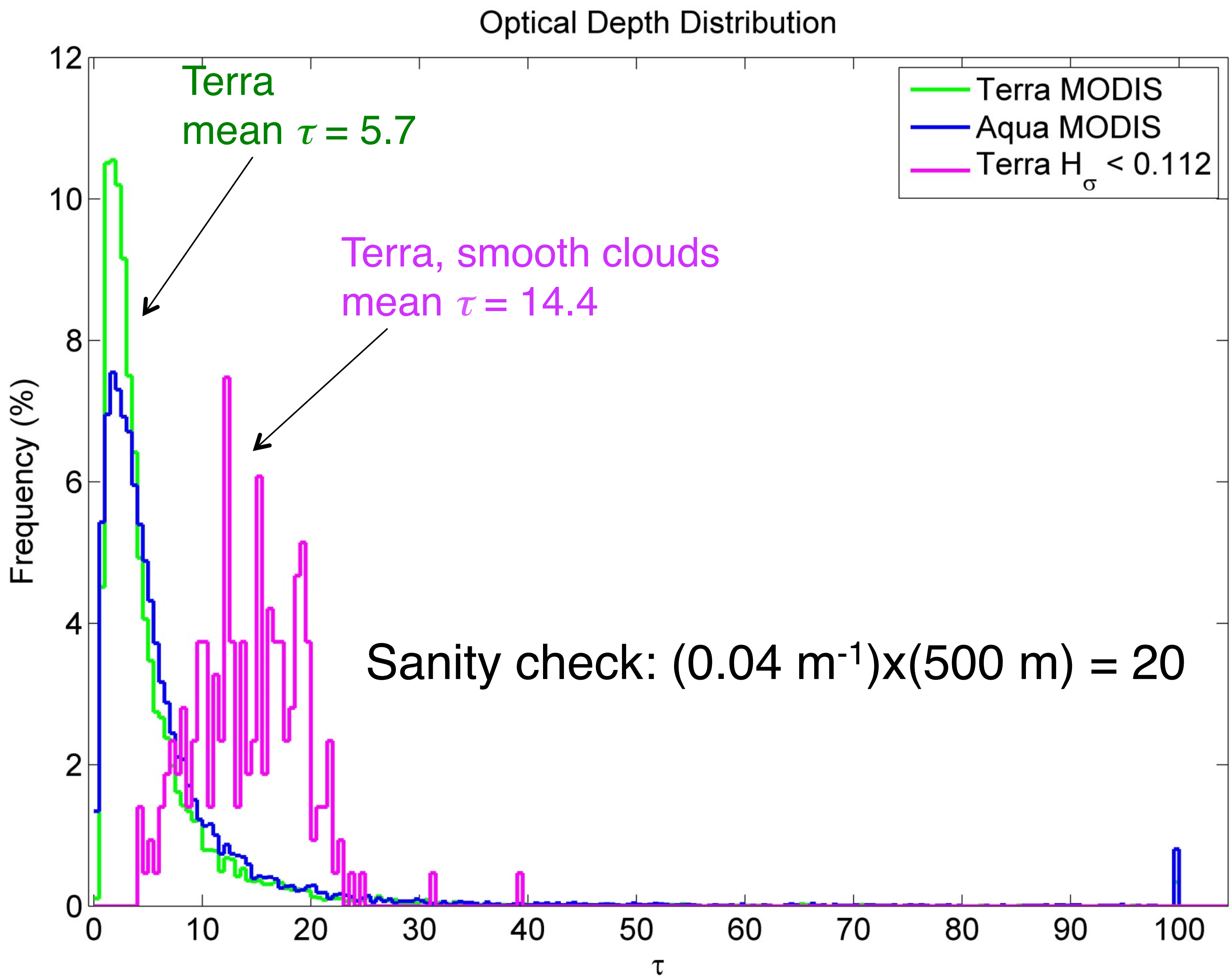

Effective Radius Distribution
16 days of aircraft ∩ MODIS
C-130 FSSP-100 + 2DC probes
Terra MODIS, 2.1 μm
Aqua MODIS, 2.1 μm
Aqua
mean r_e = 20.7 μm
Terra
mean r_e = 23.6 μm
Frequency (%)
r_e (μm)
0
2
4
6
8
10
12
14
16
18
20
0
5
10
15
20
25
30


Effective Radius Distribution
16 days of aircraft ∩ MODIS
C-130 FSSP-100 + 2DC probes
FSSP, 100 m
Terra MODIS, 2.1 μm
Aqua MODIS, 2.1 μm
Air 100 m
mean r_e = 10.8 μm
Terra
mean r_e = 23.6 μm
Frequency (%)
r_e (μm)
0
2
4
6
8
10
12
14
16
18
20
0
5
10
15
20
25
30

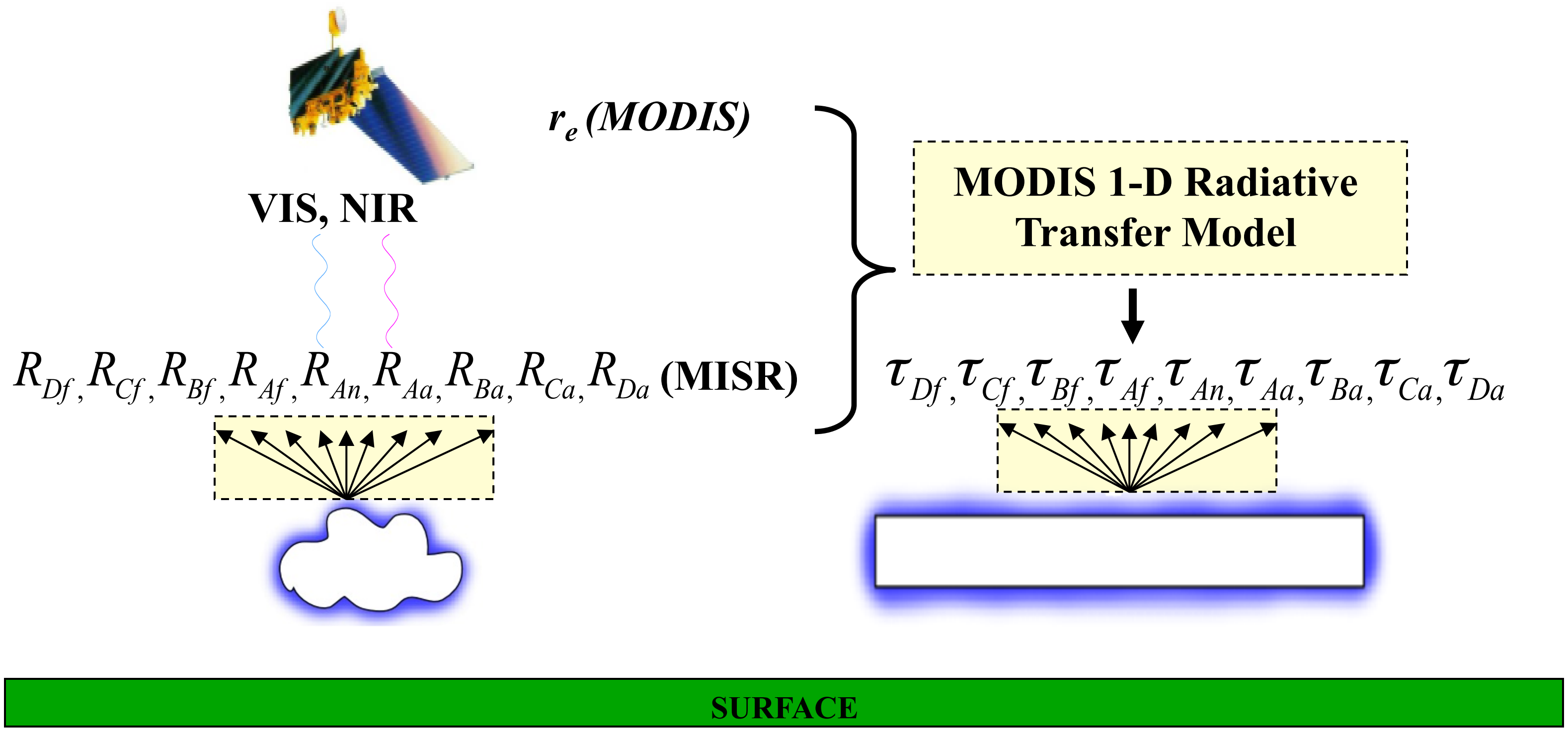

Effective Radius Distribution
16 days of aircraft ∩ MODIS
C-130 FSSP-100 + 2DC probes
FSSP, 100 m
FSSP, 1000 m
Terra MODIS, 2.1 µm
Aqua MODIS, 2.1 µm
Air 1000 m
mean r_e = 11.6 µm
Air 100 m
mean r_e = 10.8 µm
Terra
mean r_e = 23.6 µm
Frequency (%)
r_e (µm)
0
2
4
6
8
10
12
14
16
18
20
0
5
10
15
20
25
30


Effective Radius Distribution
16 days of aircraft ∩ MODIS
C-130 FSSP-100 + 2DC probes
FSSP, 100 m
FSSP, 1000 m
Terra MODIS, 2.1 μm
Aqua MODIS, 2.1 μm
Terra H_σ < 0.112
Air 1000 m
mean r_e = 11.6 μm
Air 100 m
mean r_e = 10.8 μm
Terra, smooth clouds
mean r_e = 17.7 μm
Terra
mean r_e = 23.6 μm
Frequency (%)
r_e (μm)
0
2
4
6
8
10
12
14
16
18
20
0
5
10
15
20
25
30

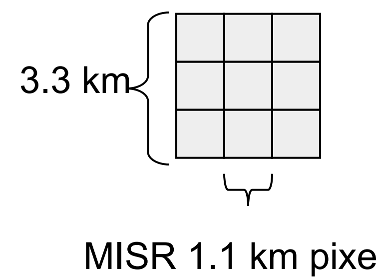

Optical Depth Distribution
Terra
mean τ = 5.7
Terra MODIS
Aqua MODIS
Frequency (%)
τ
0
2
4
6
8
10
12
0
10
20
30
40
50
60
70
80
90
100



Optical Depth Distribution
Terra
mean τ = 5.7
Terra, smooth clouds
mean τ = 14.4
Terra MODIS
Aqua MODIS
Terra H_σ < 0.112
Sanity check: $(0.04\ m^{-1})$x(500 m) = 20
Frequency (%)
τ
0
2
4
6
8
10
12
0
10
20
30
40
50
60
70
80
90
100

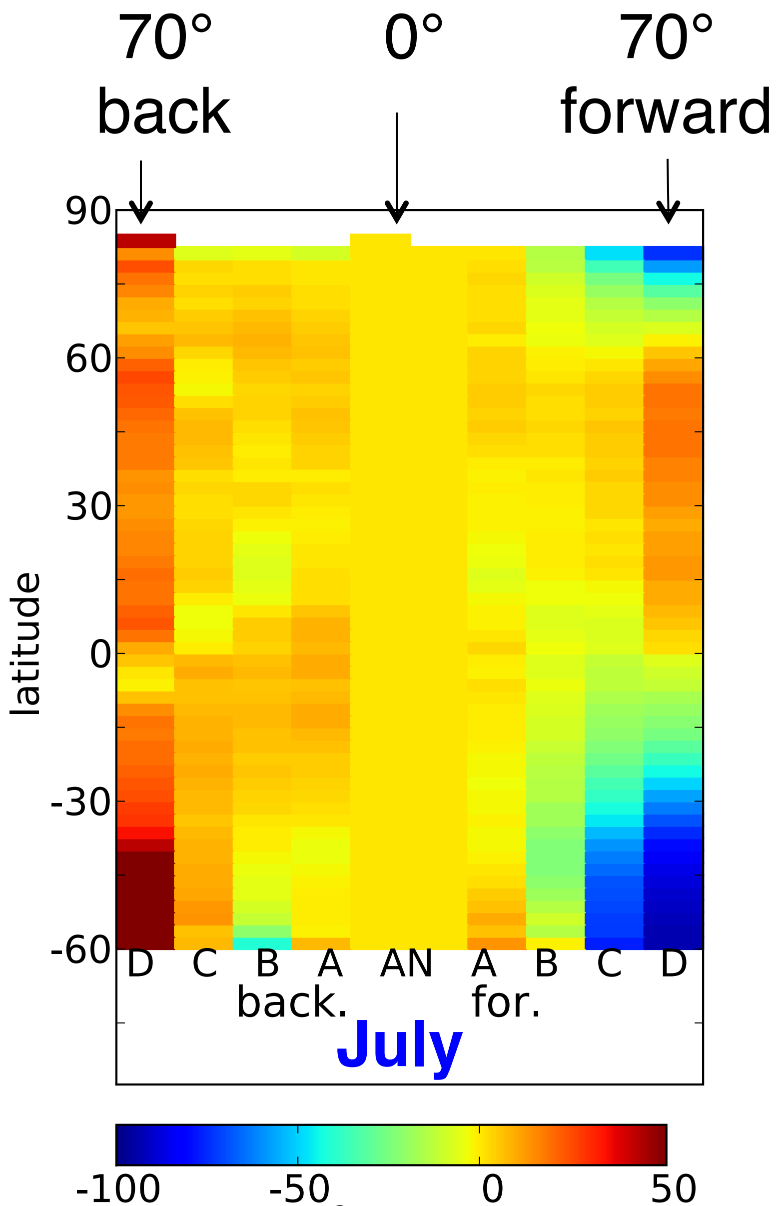


- MODIS-MISR fusion for January and July 2001 – 2008
- Oceanic water clouds
- Fusion done at cloud tops at ~ 1km resolution
- Only fully cloudy 3 km x 3 km regions are registered in MODIS and MISR multiple views

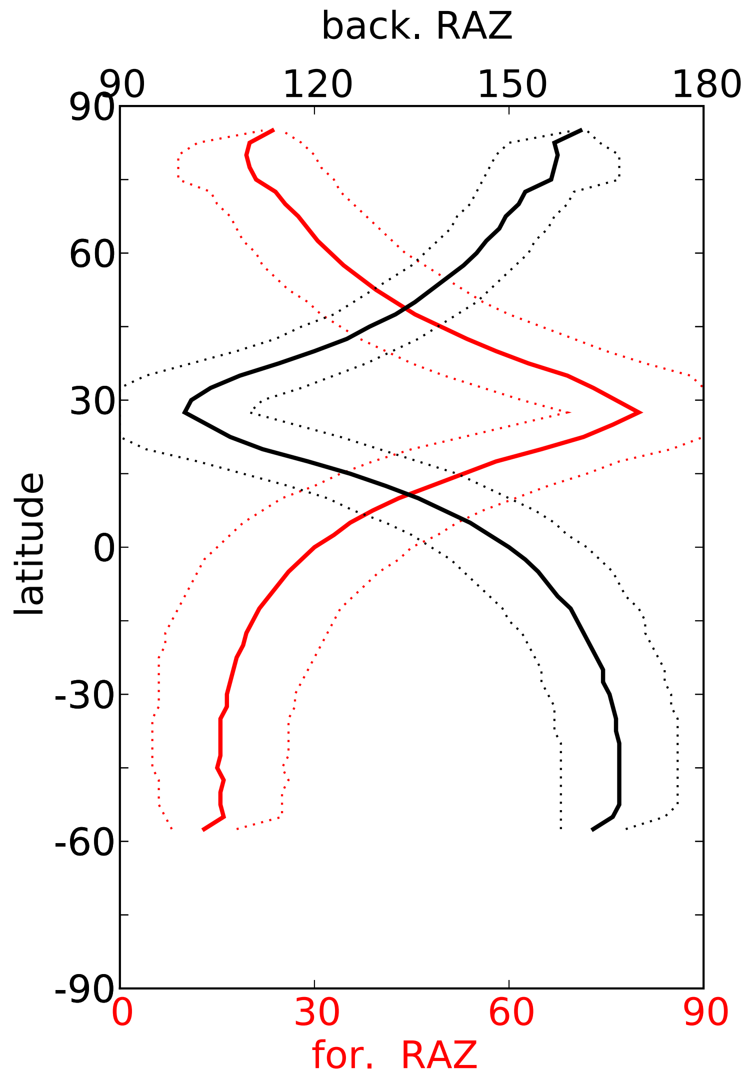


Liang et al. (2009) , Di Girolamo et al. (2010), Liang and Di Girolamo (2013)

Zonal mean τ vs MISR view angles

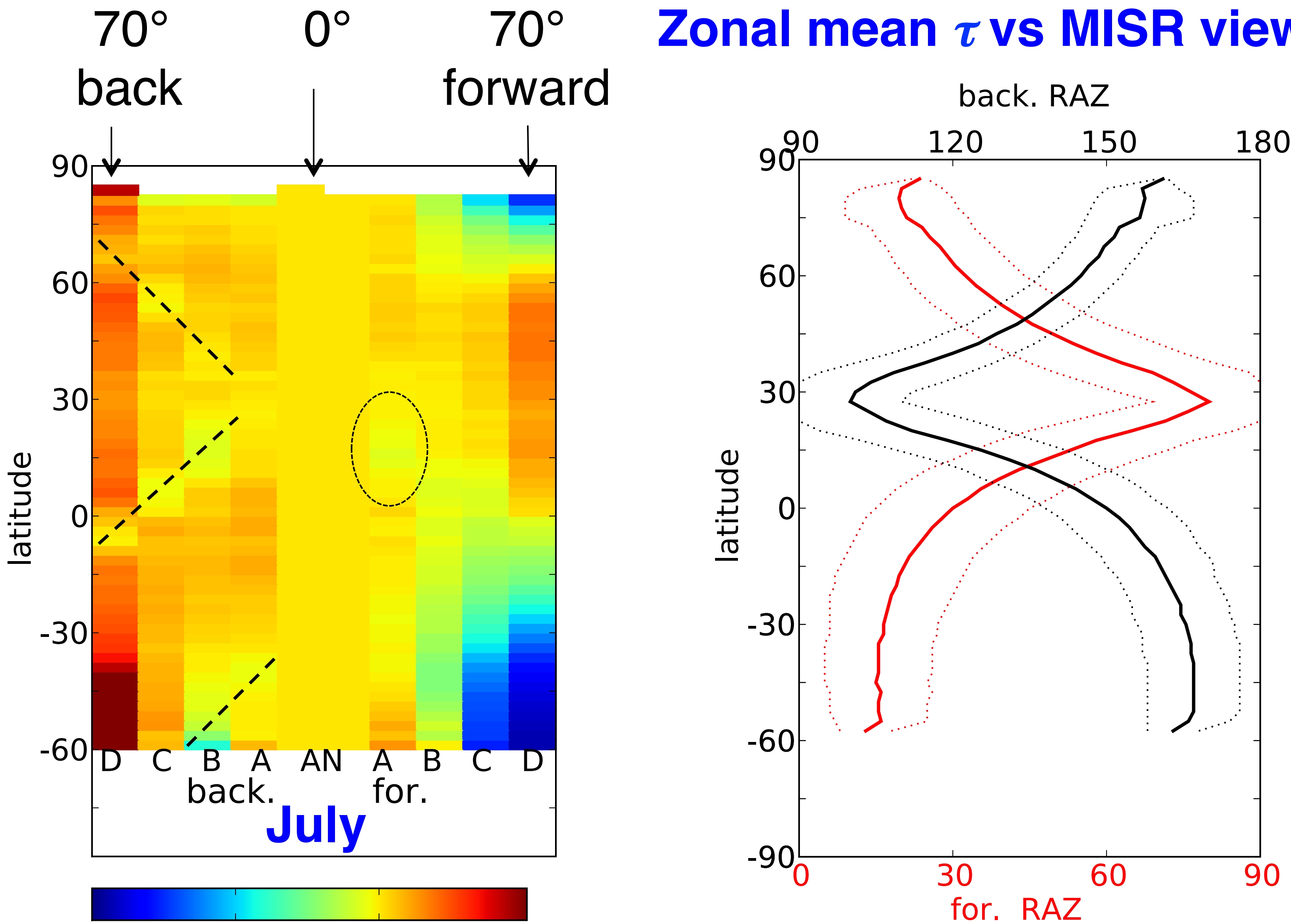


$$\delta^{c}_{mean} = \frac{\tau^{c} - \tau_{AN}}{\tau_{AN}} \times 100\%$$



Liang and Di Girolamo (2013 JGR)

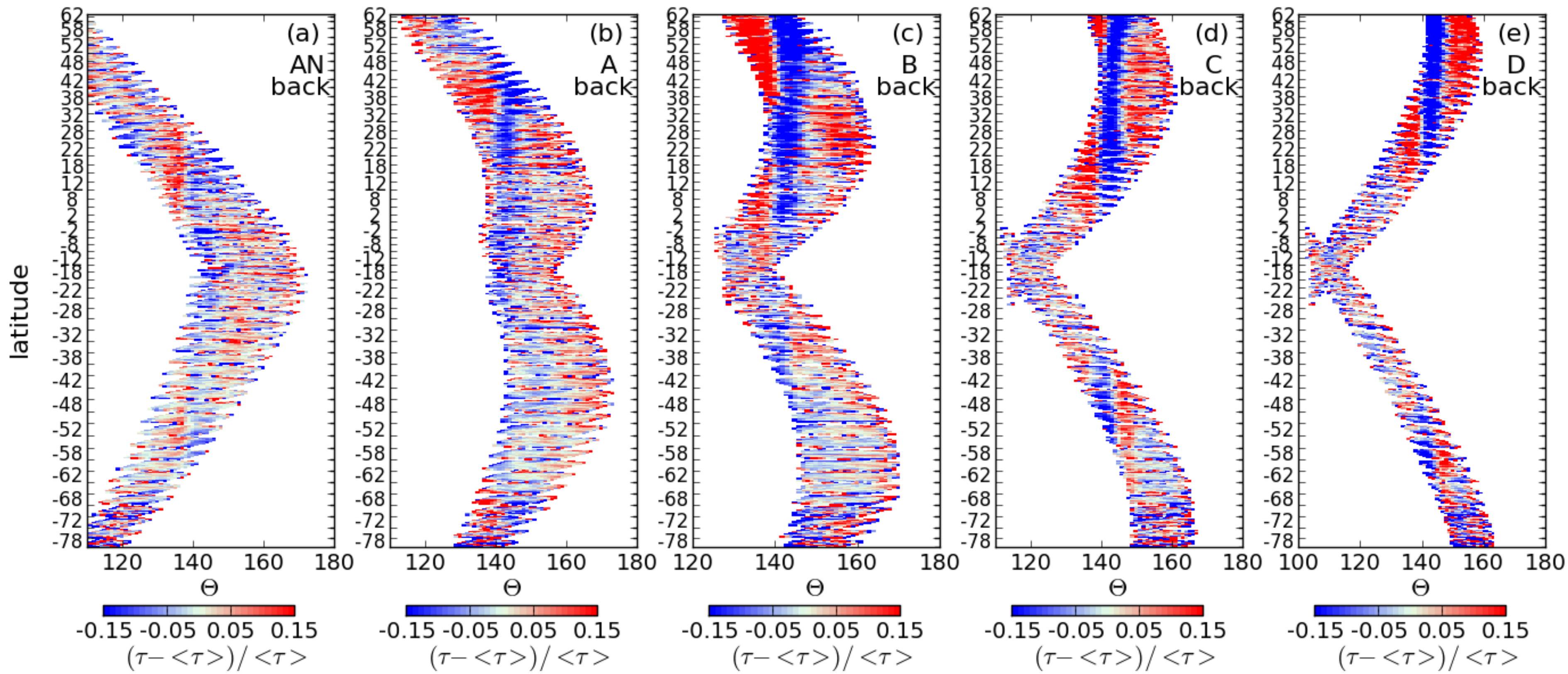
Zonal mean τ vs MISR view angles



$$\delta^{c}_{mean} = \frac{\tau^{c} - \tau_{AN}}{\tau_{AN}} \times 100\%$$

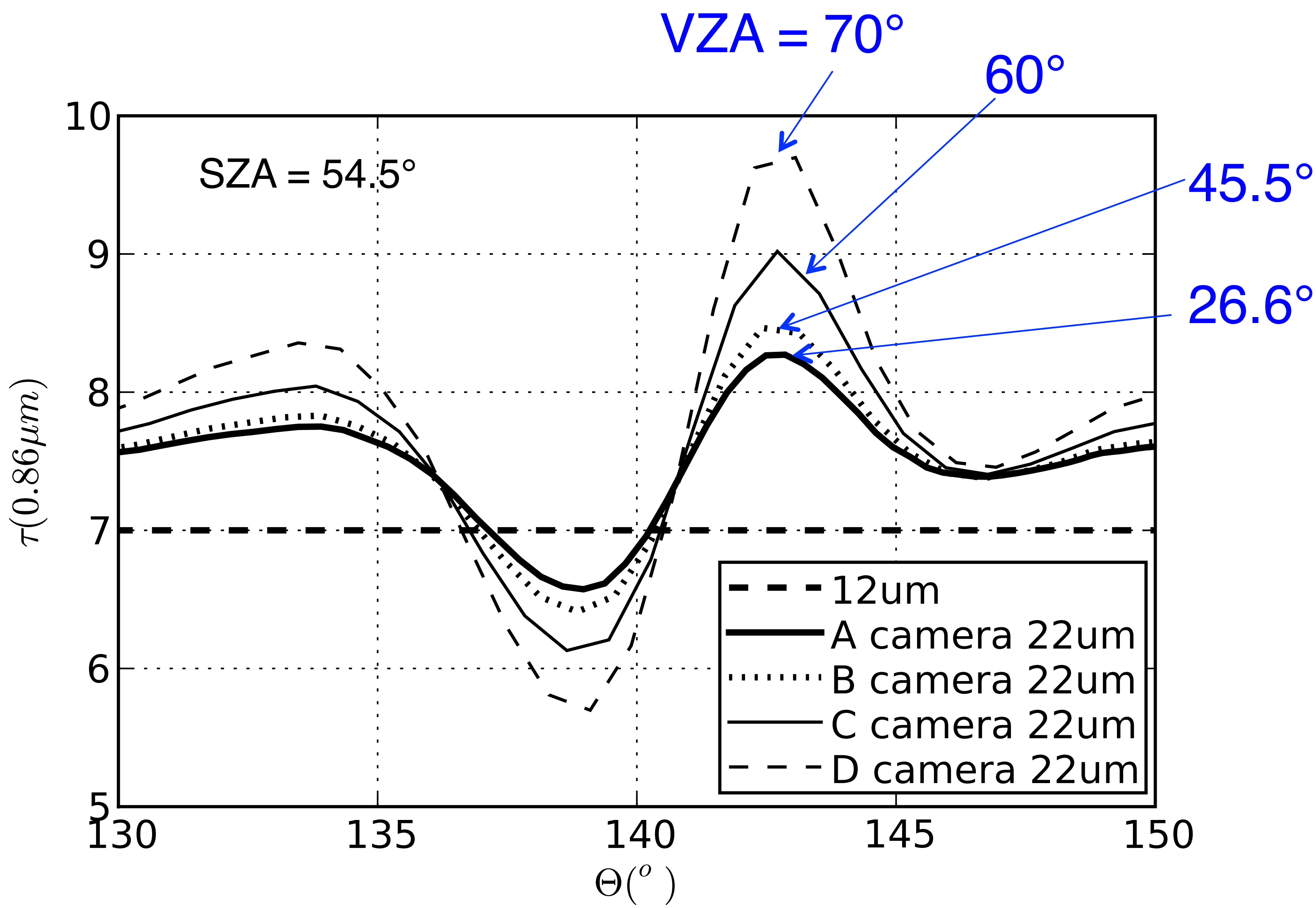
Liang and Di Girolamo (2013 JGR)

January

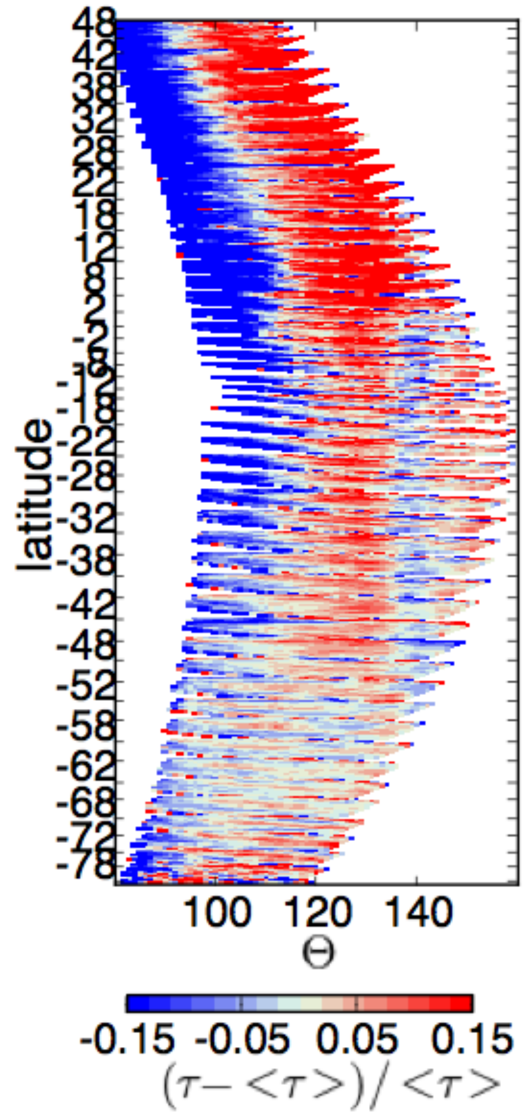


Relative optical depth bias at a particular latitude and scattering angle relative to the average optical depth over all scattering angles at that latitude

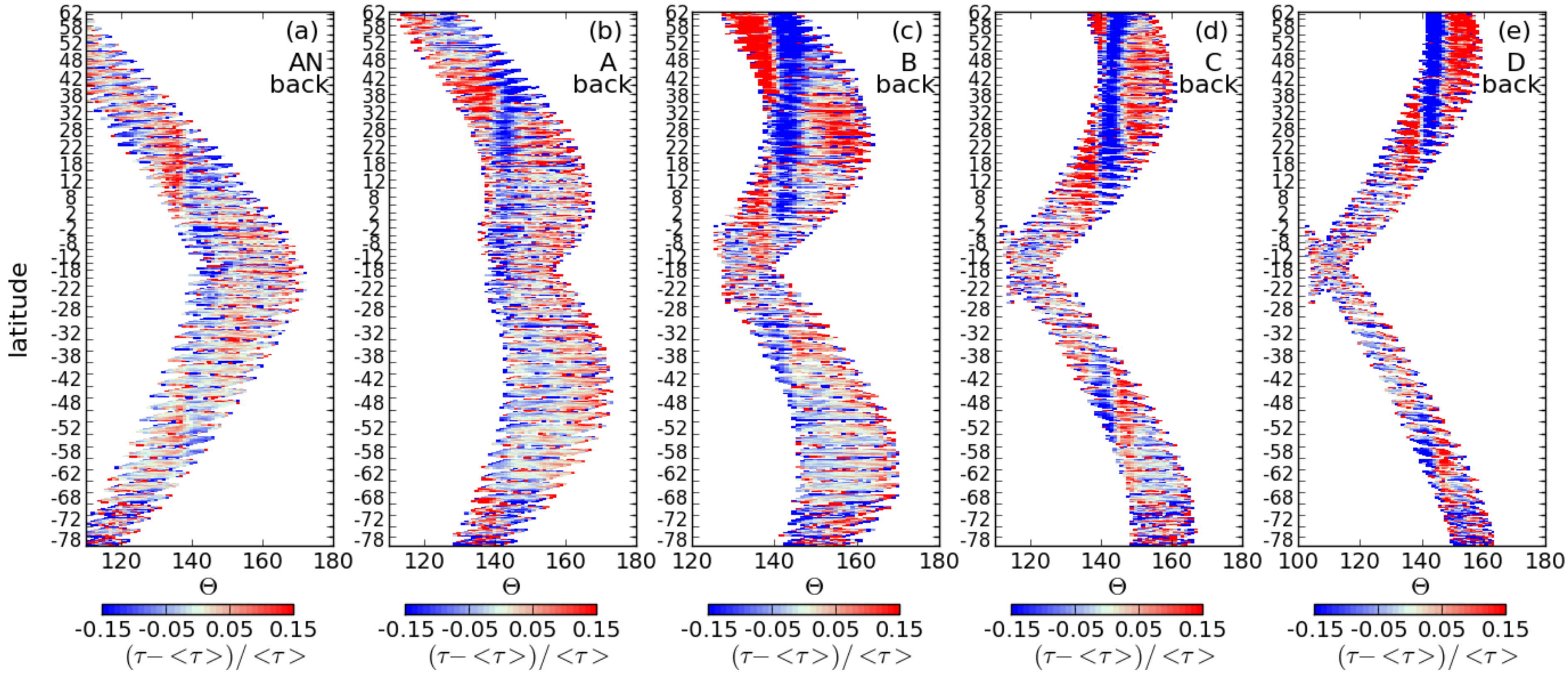
Example of τ 1-D retrieval sensitivity to systematic error in r_e at scattering angles in the backward direction for the different MISR view angles.



MODIS τ–bias vs scattering anglein January



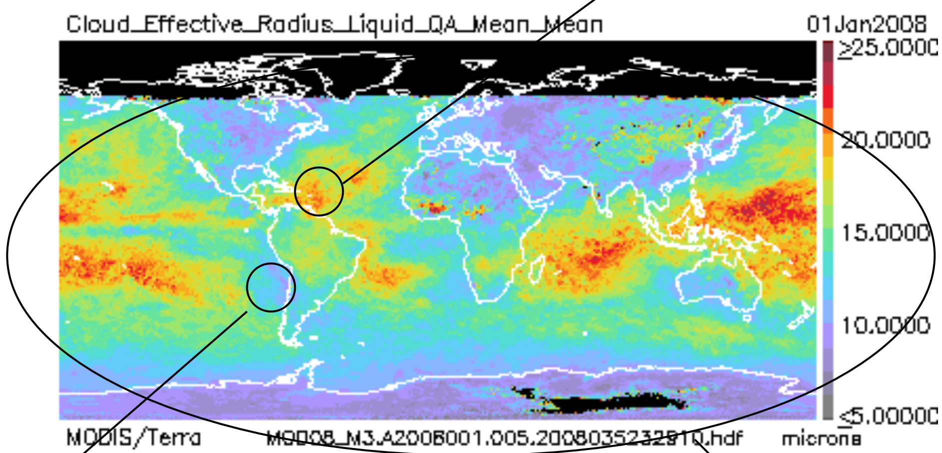
January



Preliminary calculations indicate that the cloud bow dip can be explained with *a* ~ 4 to 6 *μ*m overestimate of MODIS-retrieved r_e in the global mean

Summary

High bias of 7 – 12 μm
Based on Aircraft
Marine cumuliform
High Sun



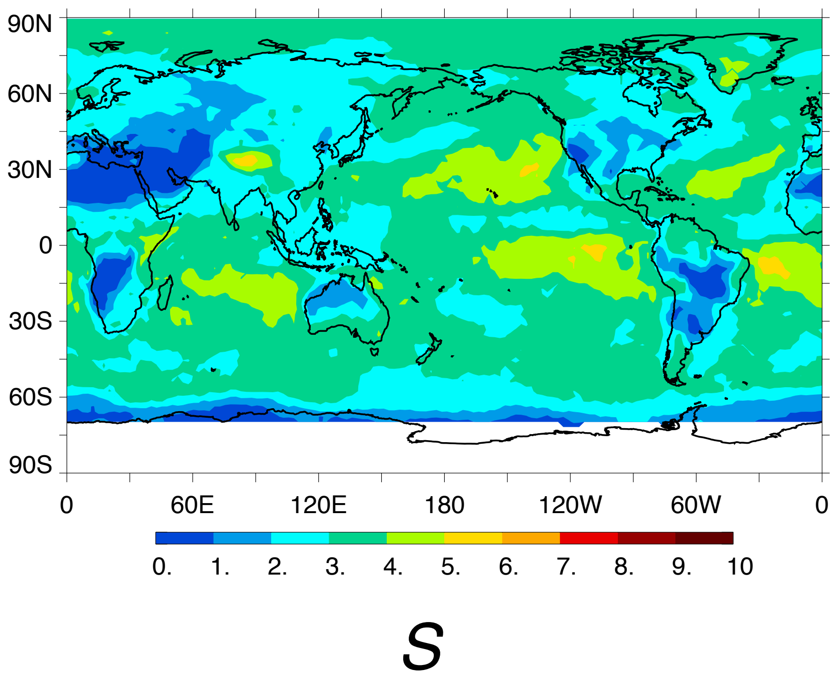
High bias of 1 – 2 μm
Based on Aircraft
Marine stratiform cloud
High Sun

High bias of 4 – 6 μm
Global mean
Based on MISR

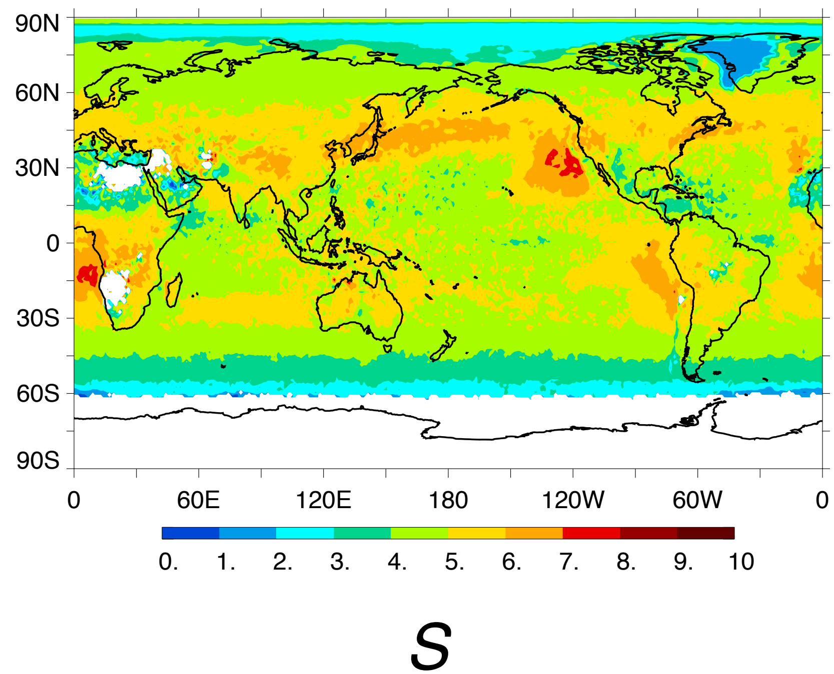
Relative cloud albedo susceptibility to droplet number concentration:

$$S = \frac{dA}{dN/N} = N\frac{dA}{dN}$$

AM3



MODIS



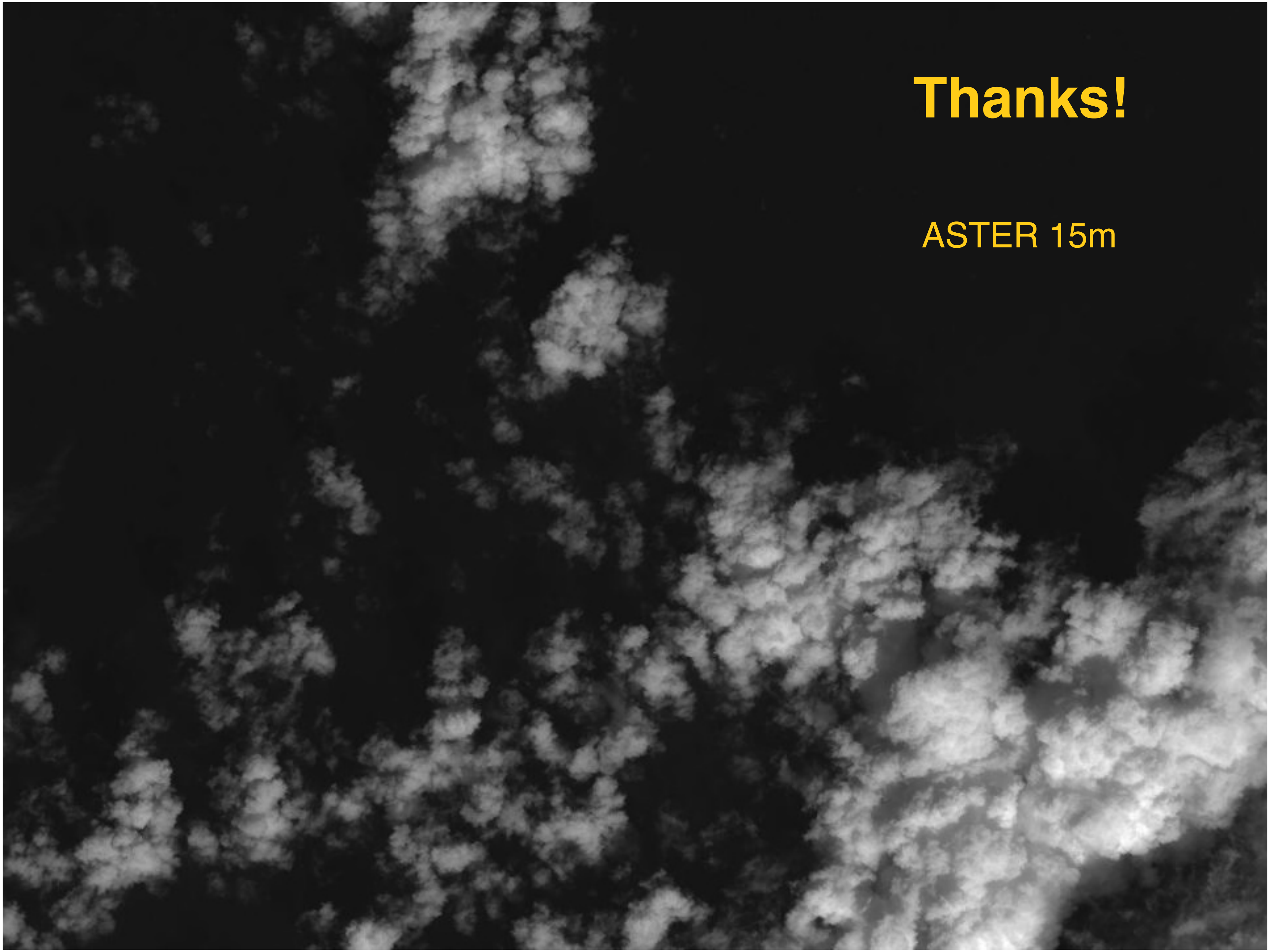
Courtesy of Yi Ming (GFDL)

Oreopoulos & Platnick (2008)

If we are to increase the scientific utility of the data…

- We need to develop and implement a bias correction procedure for MODIS r_e and τ that depends on H_σ, sun-view geometry, etc.

- Path forward using MODIS and MISR fusion


Thanks!
ASTER 15m