MISR and Cloud Properties

aerosol indirect effect

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introduction

- MISR cloud capabilities
  - measurement characteristics
  - cloud products
- cloud heterogeneity examples
- cloud liquid water examples
- on the indirect effect

MISR measurement characteristics

- multi-angle (9 discrete angles, 0°–70°, pushbroom)
- high spatial resolution (≈275 m)
- narrowband spectral radiances
  - blue, green, red, near infrared
  - well-calibrated
  - 14 bit (good dynamic range)
- ≈5-year record
- sun-synchronous (≈10:30 am)

MISR cloud products

- co-registered cloud-top radiances
  - 2.2 km resolution
  - at level of maximum contrast
- stereo-derived products
  - cloud-top heights
  - cloud-tracked winds
  - geometrically based
    - no calibration drift

wind and height accuracy

- E-W wind component
  - ±1 m/s rms over 70.5 km
- N-S component
  - ± 2 m/s rms (to be confirmed)
- Height
  - ± 200 m rms (to be confirmed)
    - over 70.5 km (i.e. for wind)
  - ± 500 m rms
    - over 2.2 km

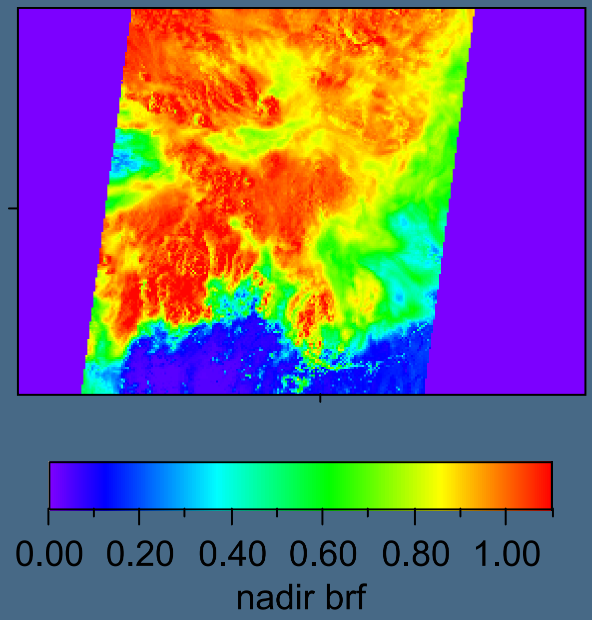
more products

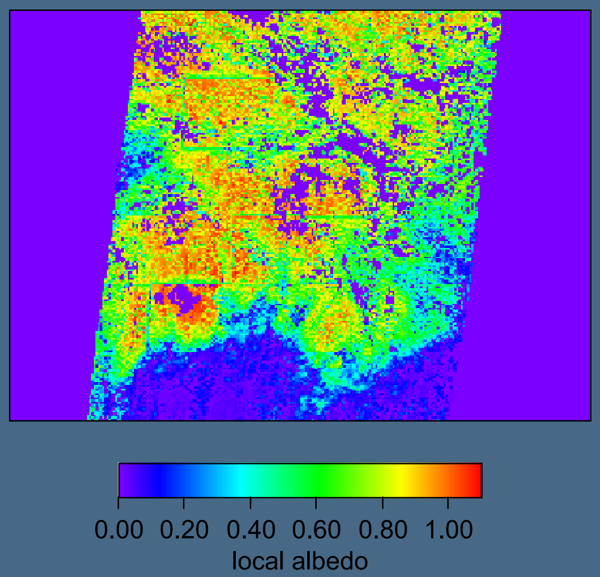
- consensus cloud classifiers
  - spatial signatures
  - angular signatures
  - radiometric thresholds
  - stereo heights
  - support vector machine assisted
- albedos
  - local (2.2 km)
  - regional (35.4 km)
    - expansive (toa), restrictive (top of cloud)
  - spectral and broadband

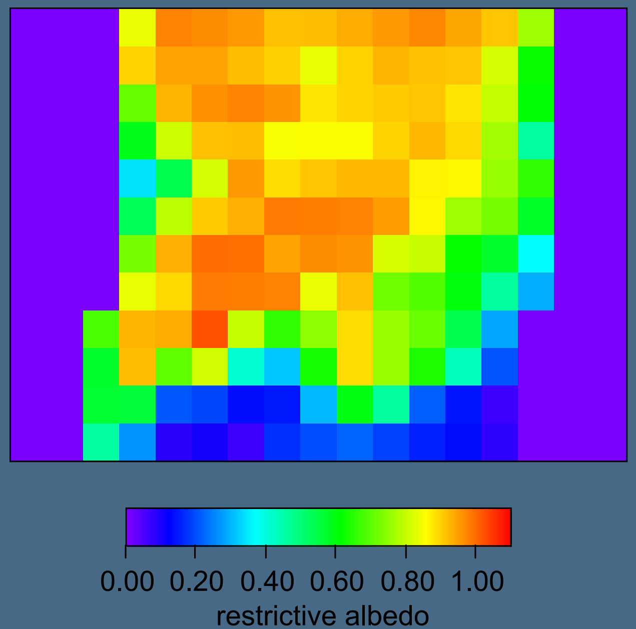
classifier example

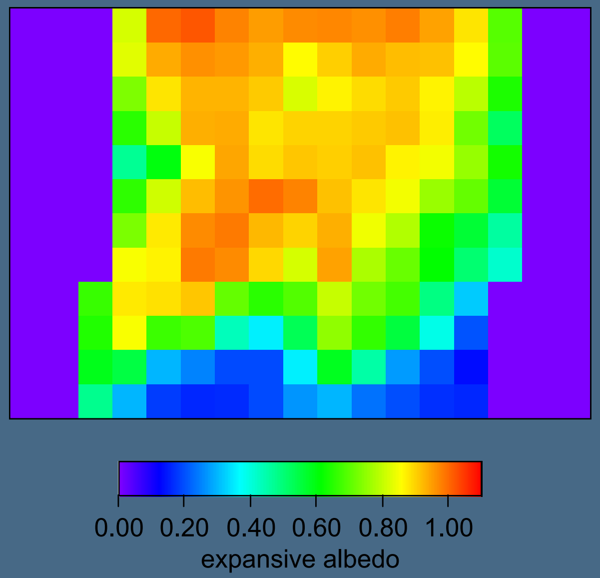
Garay et al.,
AMS 2005

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.


0.00 0.20 0.40 0.60 0.80 1.00
nadir brf


0.00 0.20 0.40 0.60 0.80 1.00
local albedo


0.00 0.20 0.40 0.60 0.80 1.00
restrictive albedo


0.00 0.20 0.40 0.60 0.80 1.00
expansive albedo

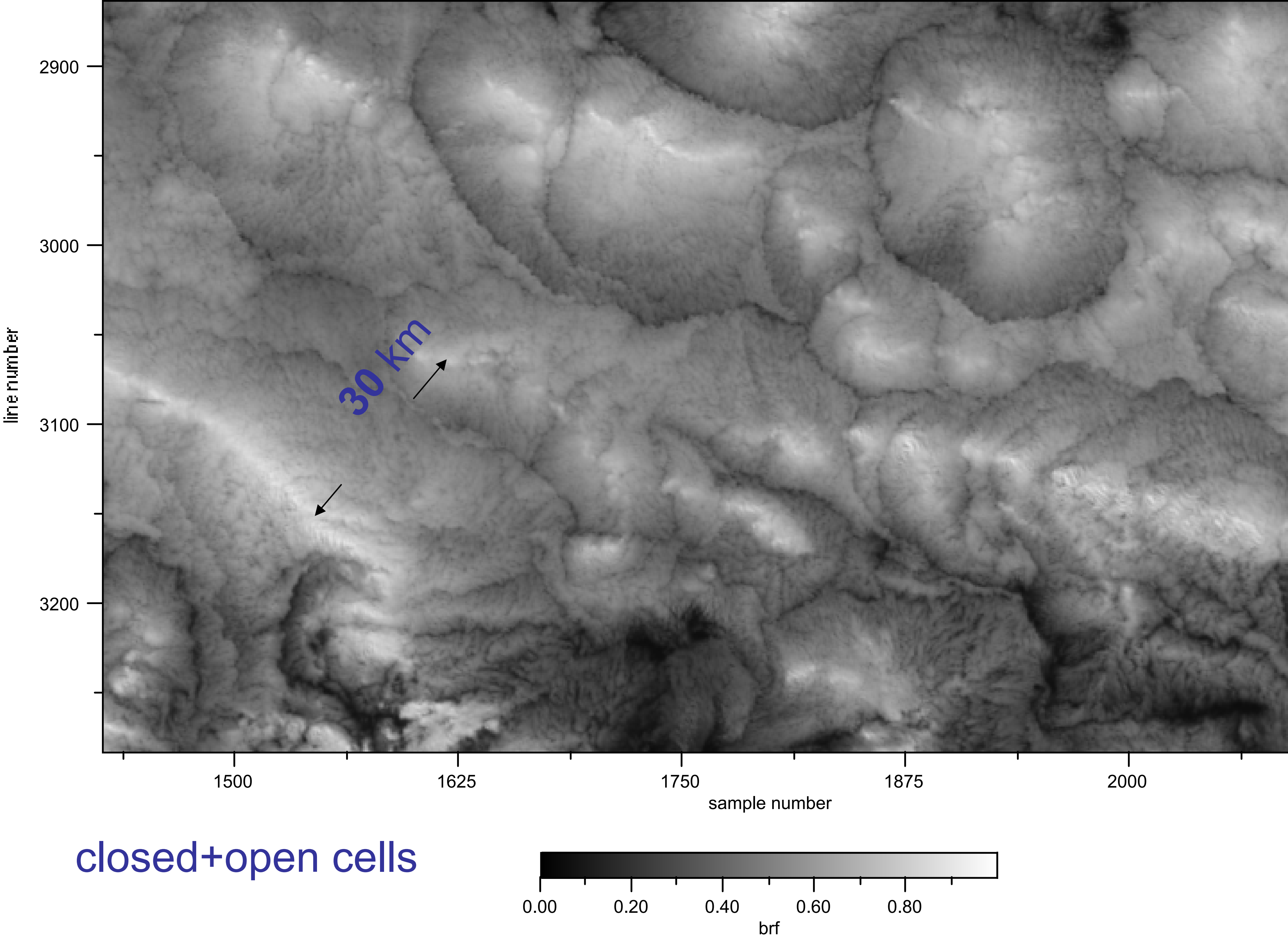
MISR albedo status

- spectral albedos
  - problems with anisotropy at high latitudes (low sun angle)
  - require improved stochastic weights
- broadband albedos
  - should get within ±3 W m^{-2}
- local albedos to be collated by cloud type (esp. height and phase)

more MISR cloud products

- cloud optical depth
- cloud effective radius
- cloud liquid water

…not


2900
3000
3100
3200
line number
1500
1625
1750
1875
2000
sample number
30 km
closed+open cells
0.00
0.20
0.40
0.60
0.80
brf

Hybrid Cell Scenario

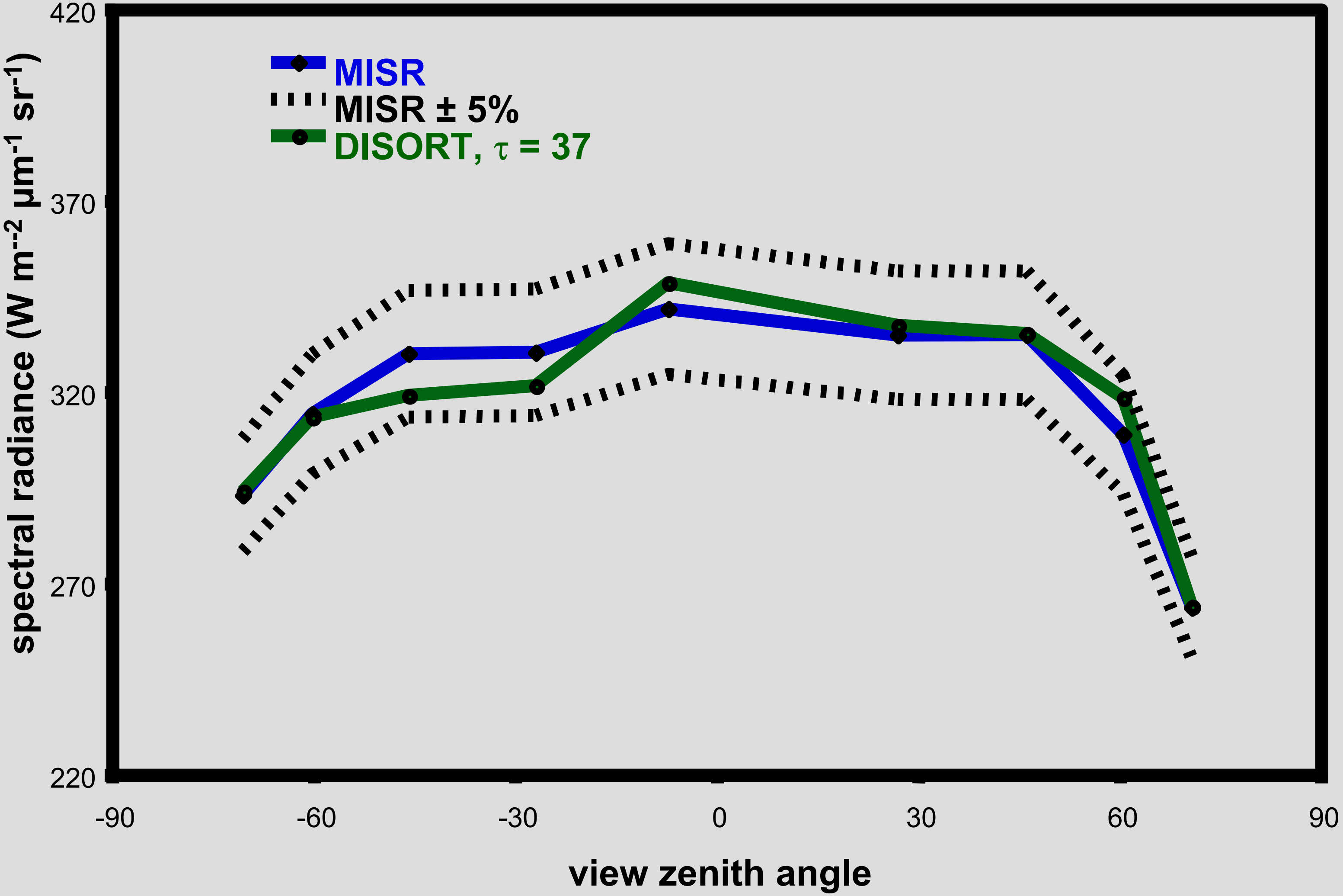
- brf: 0.25 — 0.85 in 15 km
- optical depth: 7 — 70
- cloud top height differential: < 500 m
- degrees of freedom: number density, droplet size, cloud thickness
- cannot be explained by a single dof

An explanation that works

	dark	bright
optical depth	7	70
effective radius	10 µm	15 µm
number density	50 cm^{-3}	100 cm^{-3}
thickness	250 m	500 m

single-angle approach to τ

- solar zenith angle bias
  - overestimate
- spatial heterogeneity bias
  - underestimate
- inconsistent anisotropy
  - overestimate
- saturation bias
  - underestimate



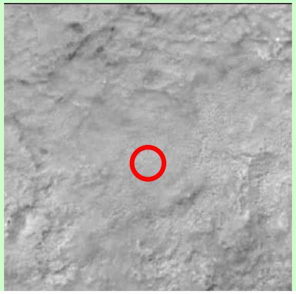
homogeneous cloud example

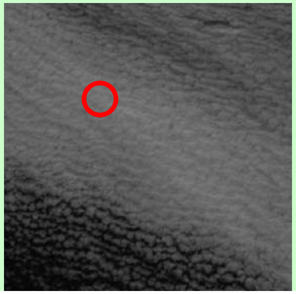
Horvath and Davies, GRL ‘04

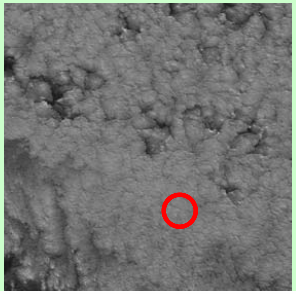
EXAMPLES-1

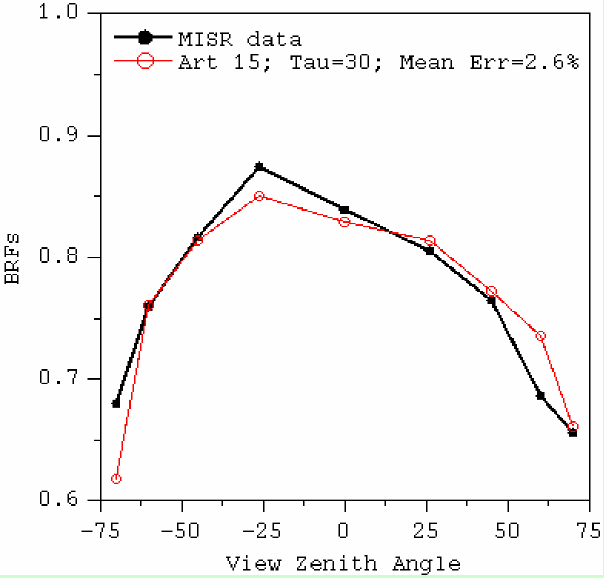
150 km

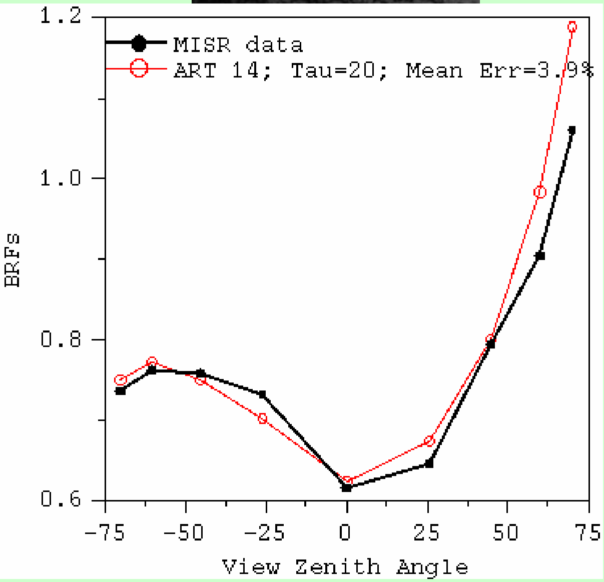
150 km

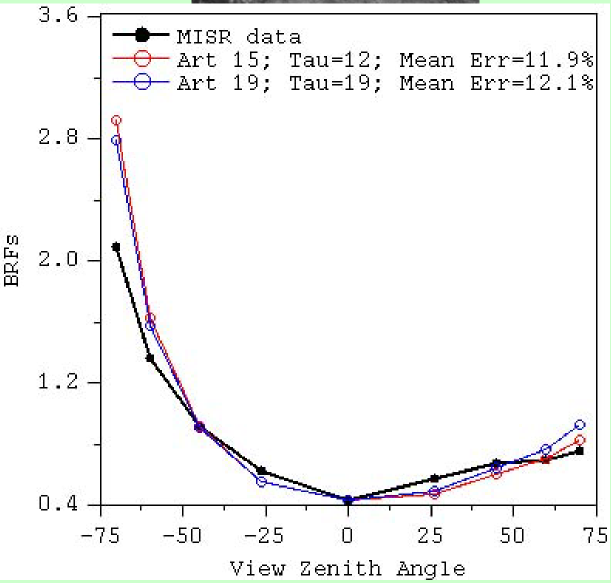










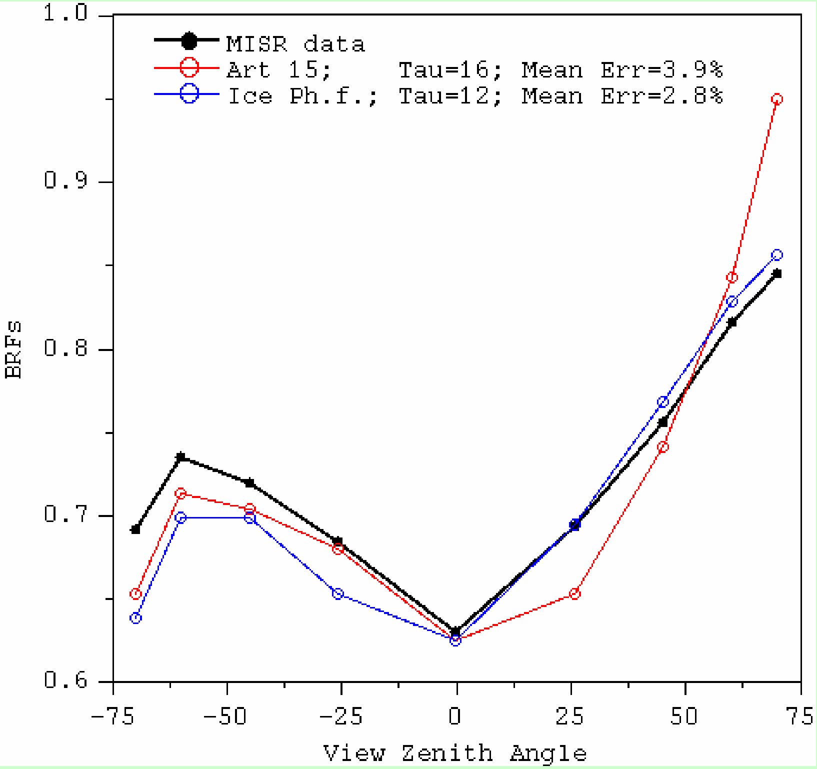


SZA=28°
Hc~5km

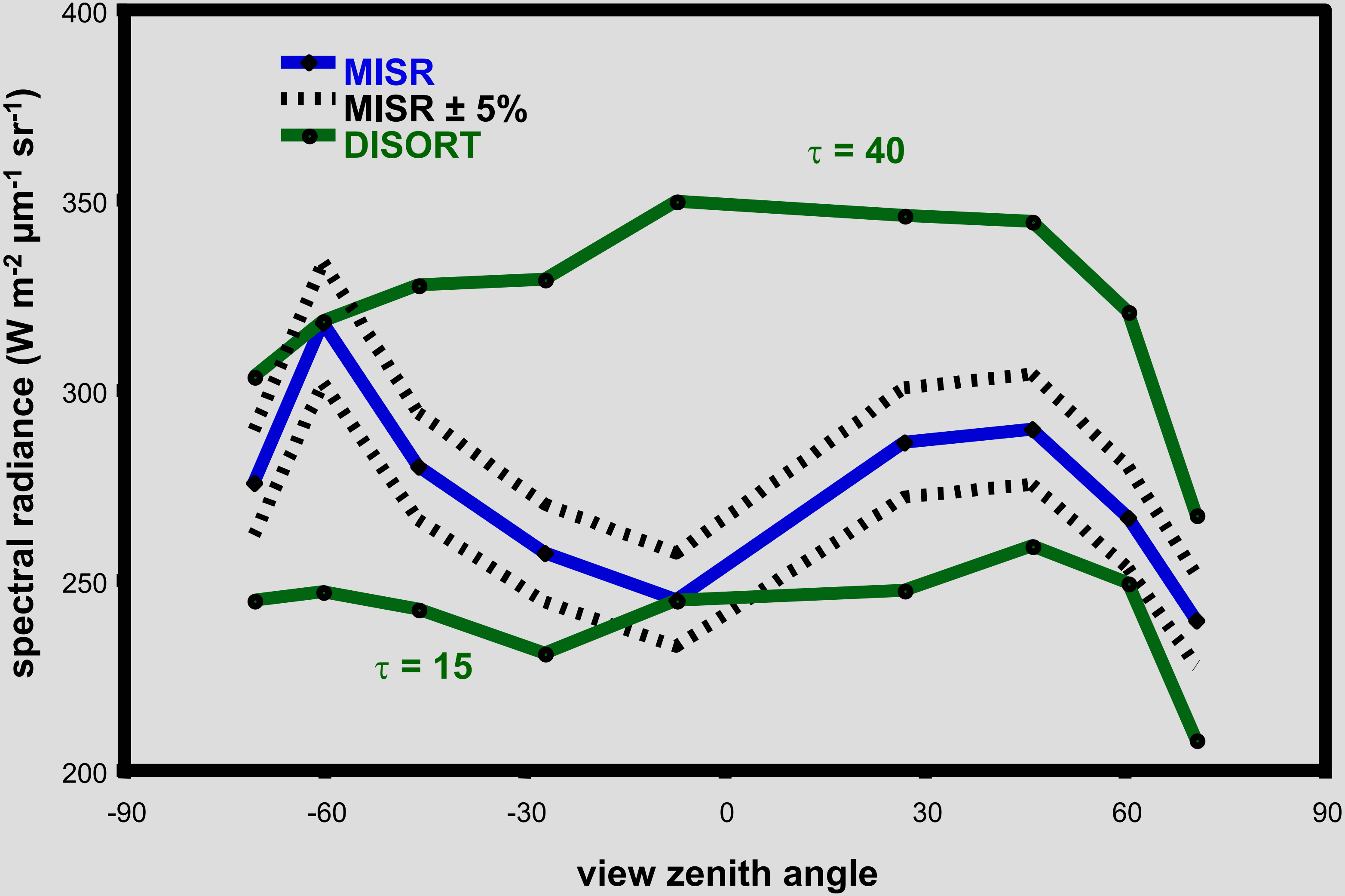
SZA=55°
Hc~2km

SZA=73°
Hc~2km

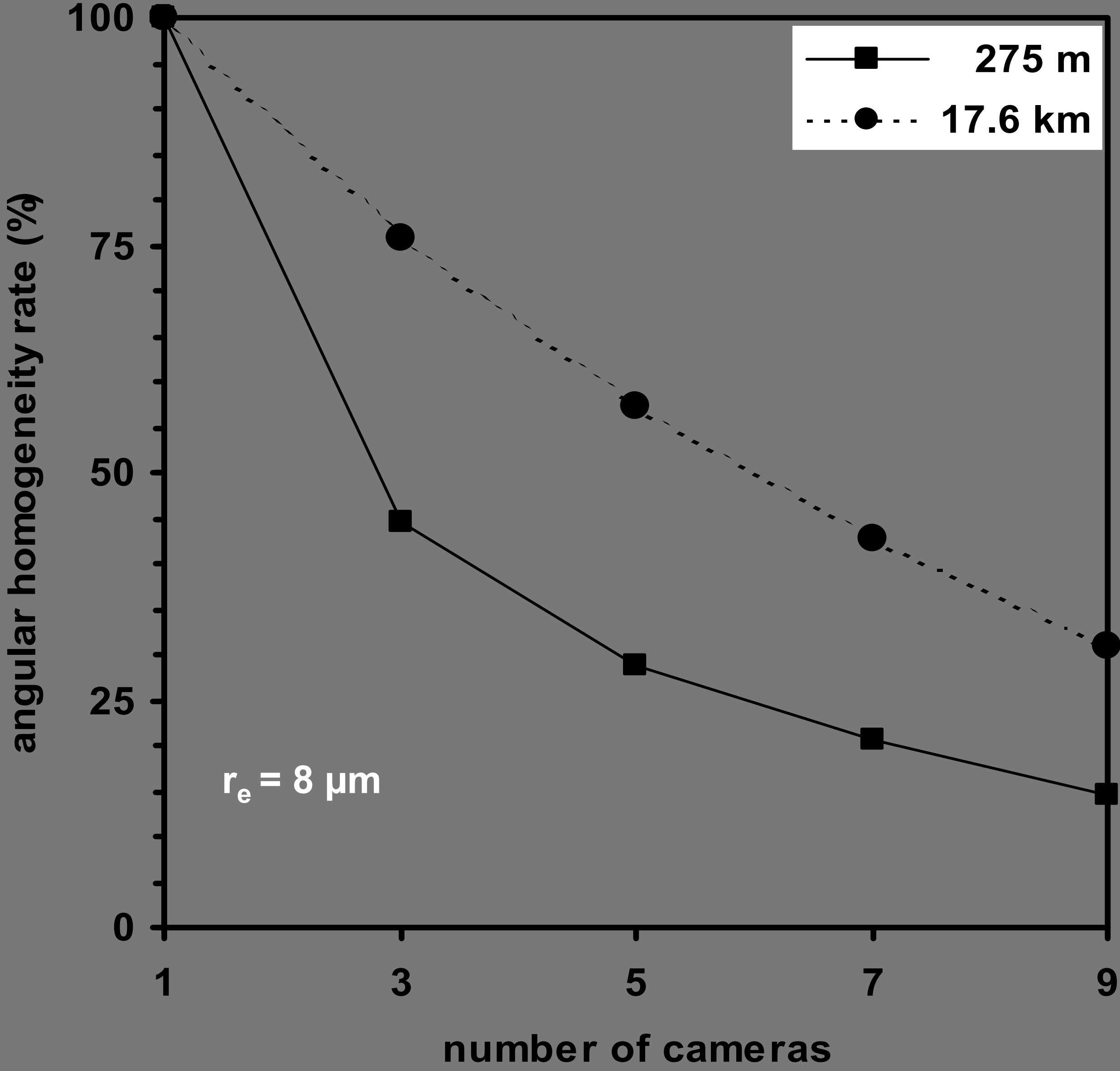
EXAMPLES-2



SZA=47°
Hc~12 km



heterogeneous cloud example

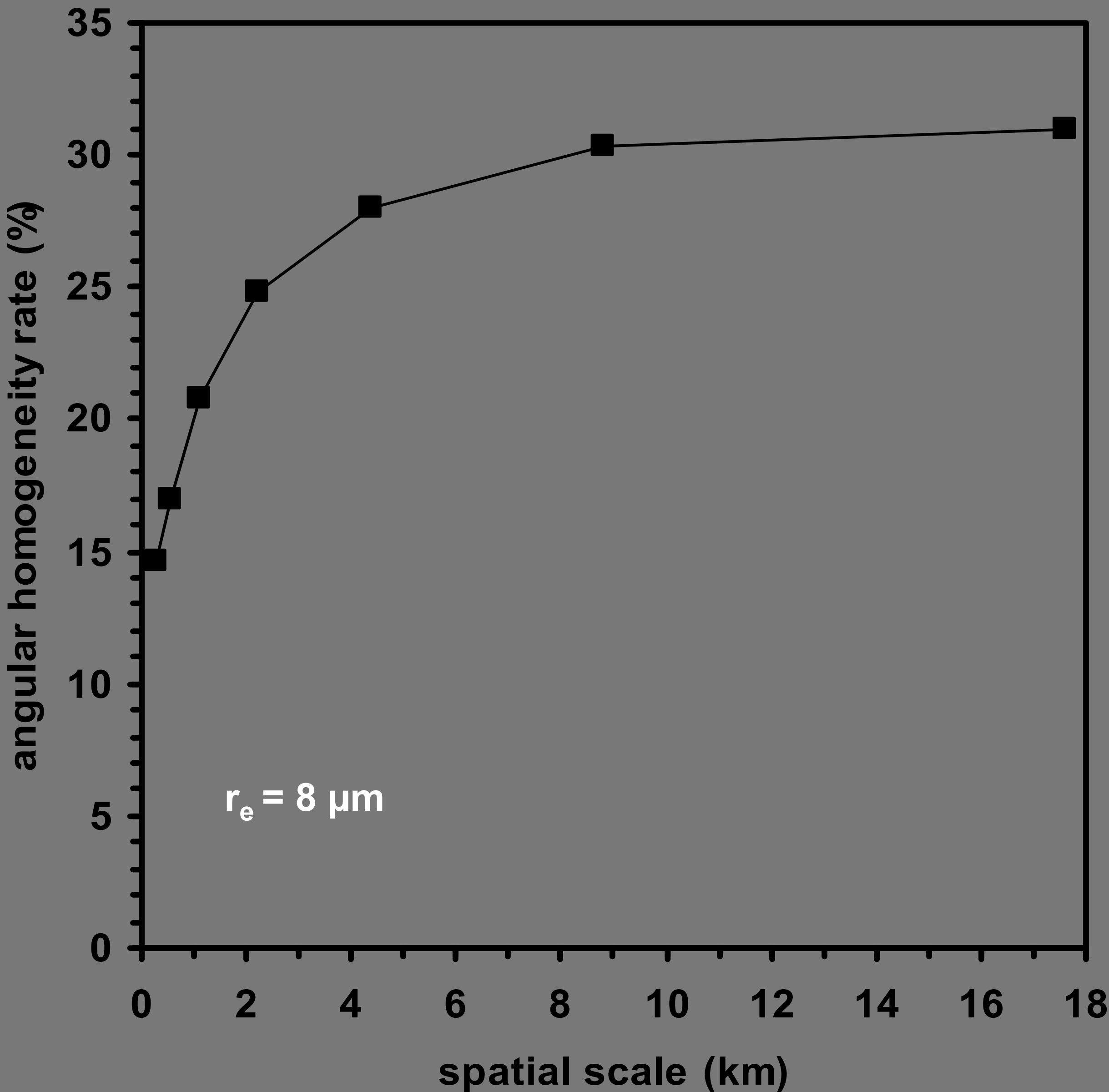


pass rate as number of cameras is increased

for two resolutions

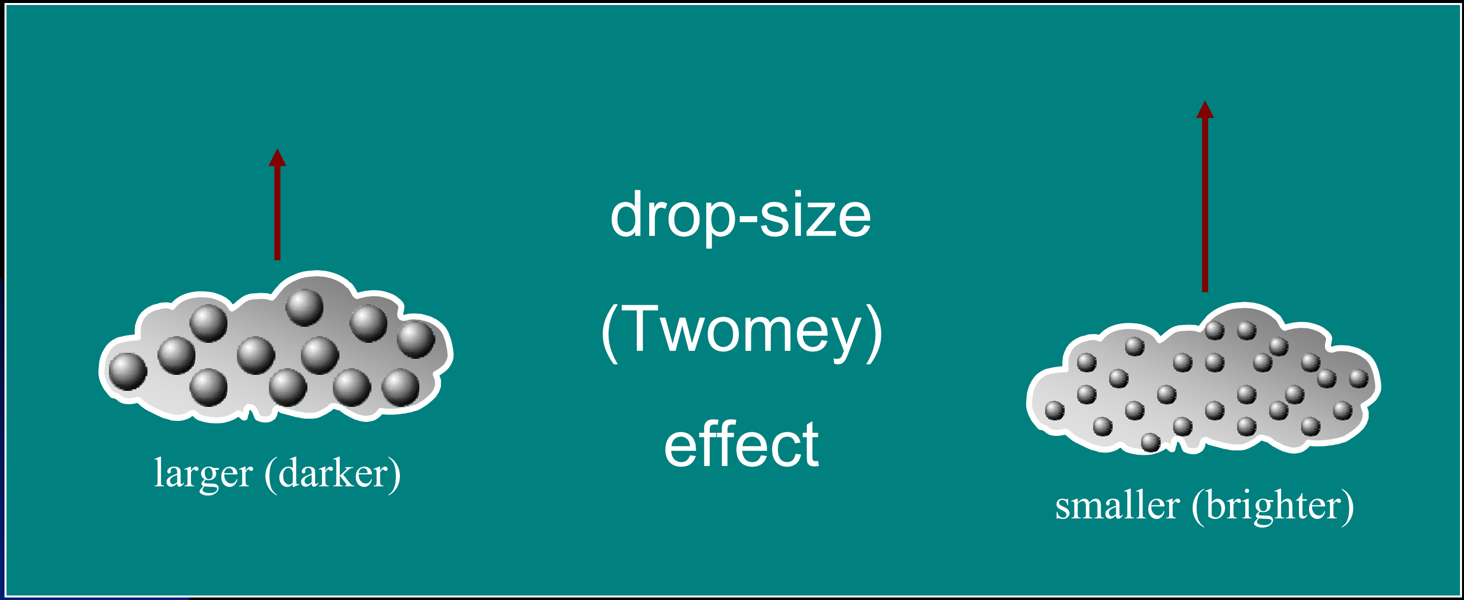
summary from 16 orbits

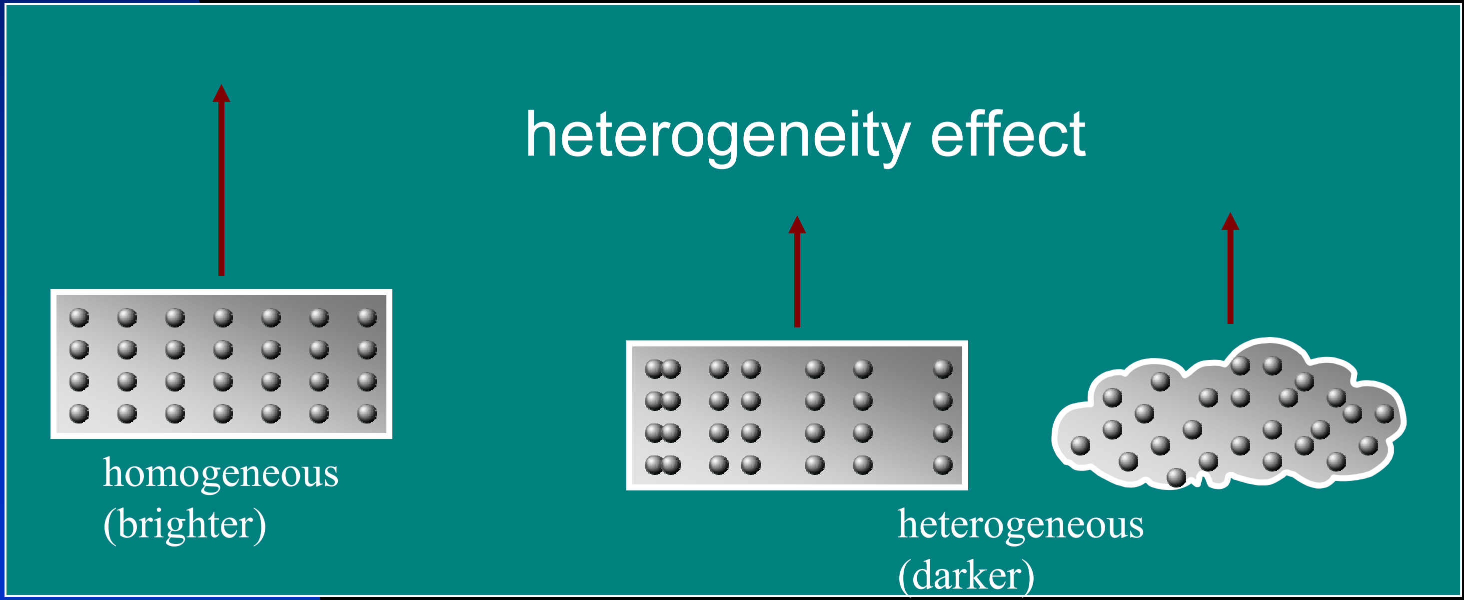
Horvath & Davies GRL'04



effect of resolution

Horvath & Davies GRL'04


drop-size
(Twomey)
effect
larger (darker)
smaller (brighter)

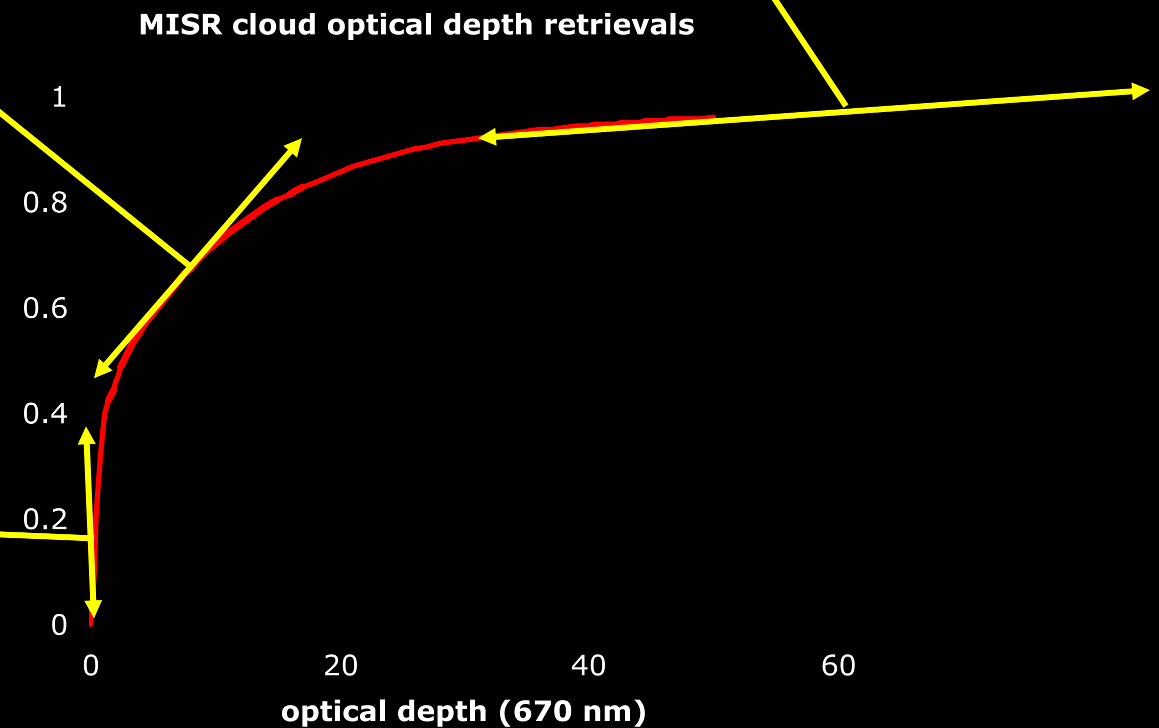

heterogeneity effect
homogeneous
(brighter)
heterogeneous
(darker)

single-angle 1D retrieval

truncated at τ = 50, from MISR nadir radiances, 14 Terra orbits

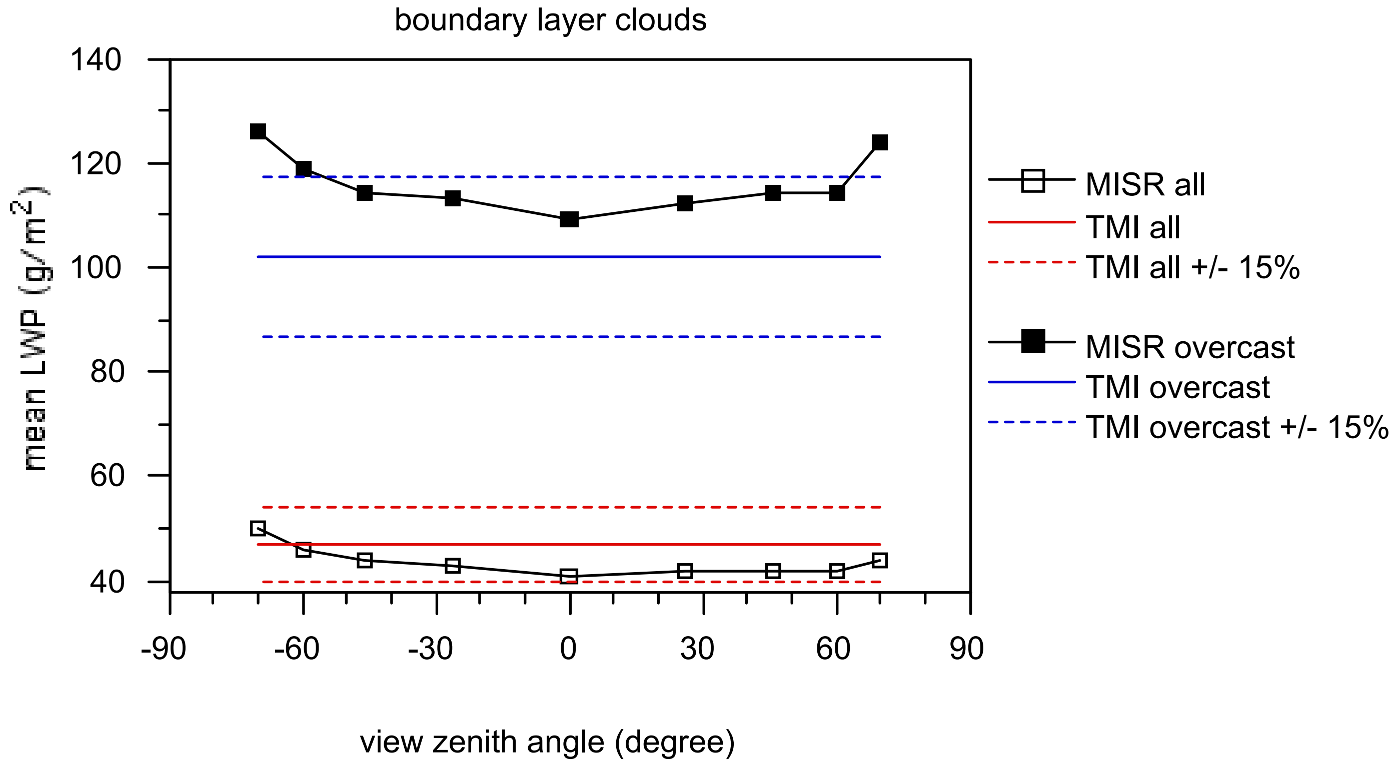
most radiatively important clouds are in this range

most hydrologically important clouds are in this range

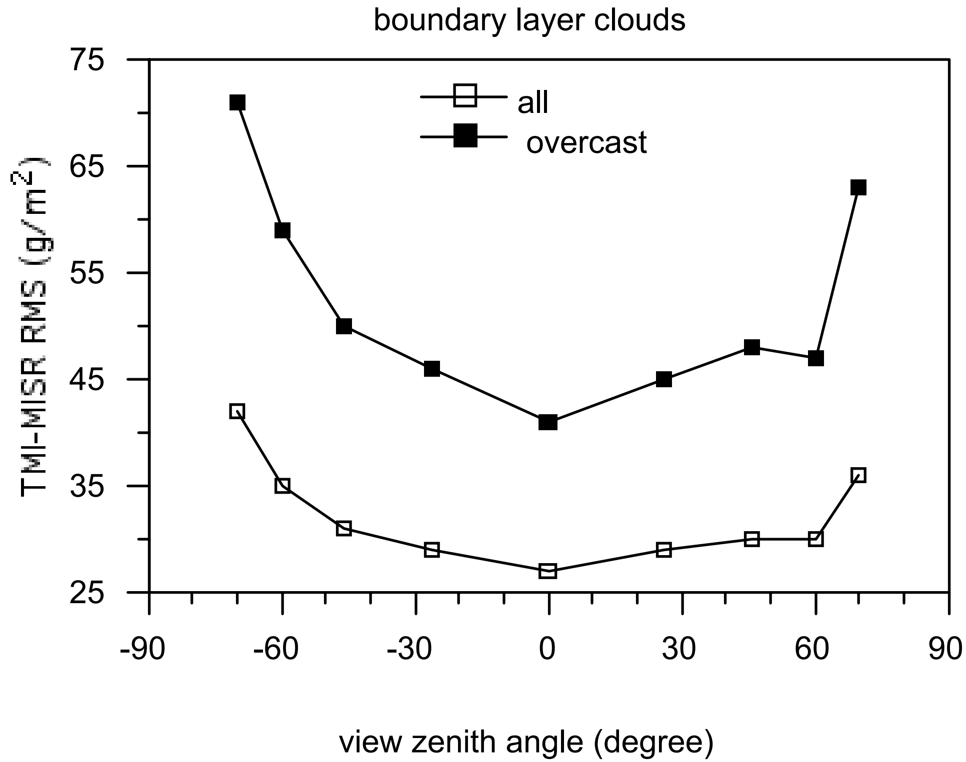


non-cloud

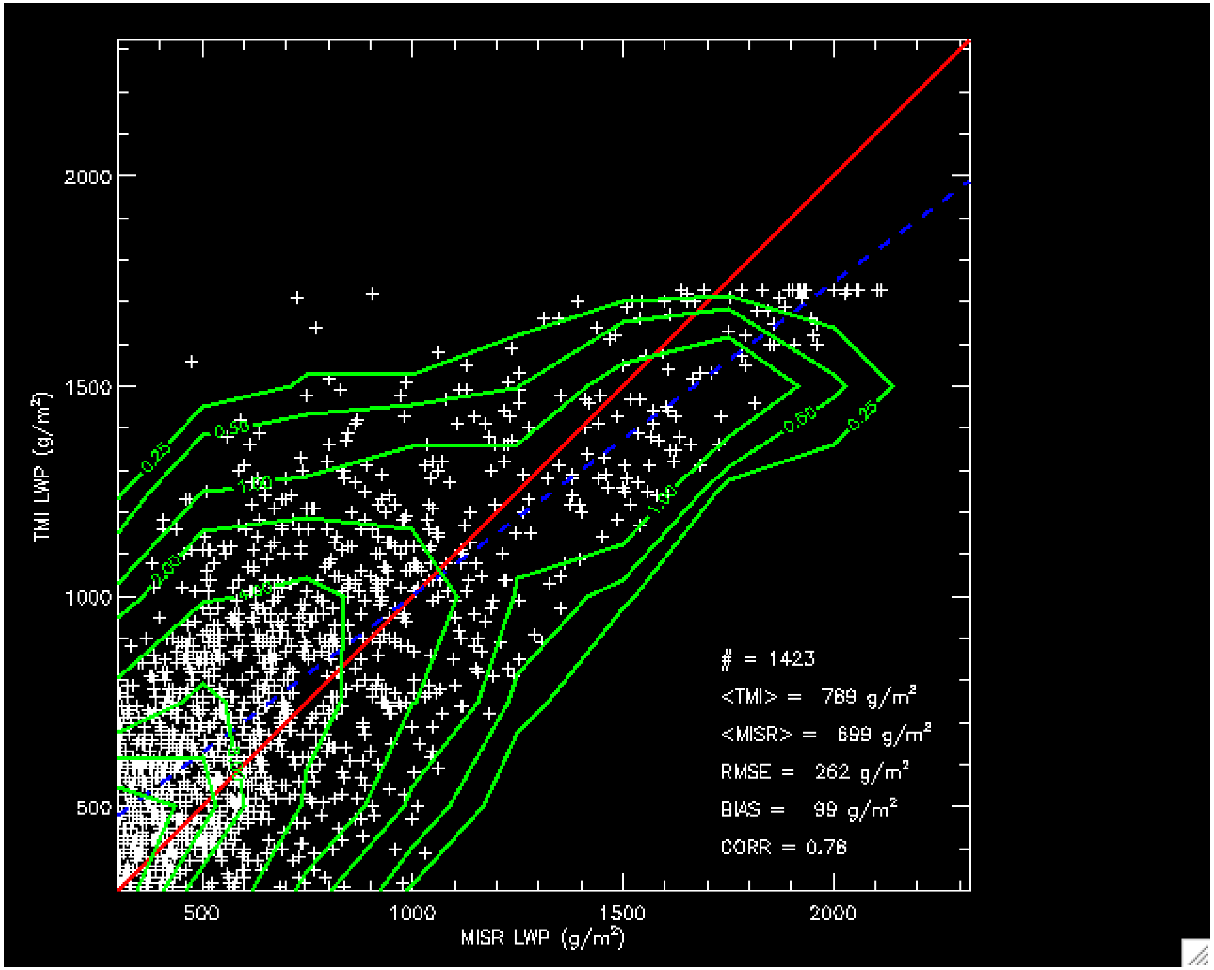
Boundary Layer Clouds
All 22 Cases (MISR, non-raining, water only, mean)



Boundary Layer Clouds
All 22 Cases (MISR, non-raining, water only, rms)



Deep Convective Clouds
All 22 Cases (MISR, WP>300 g/m^2, Re=Re(RR))

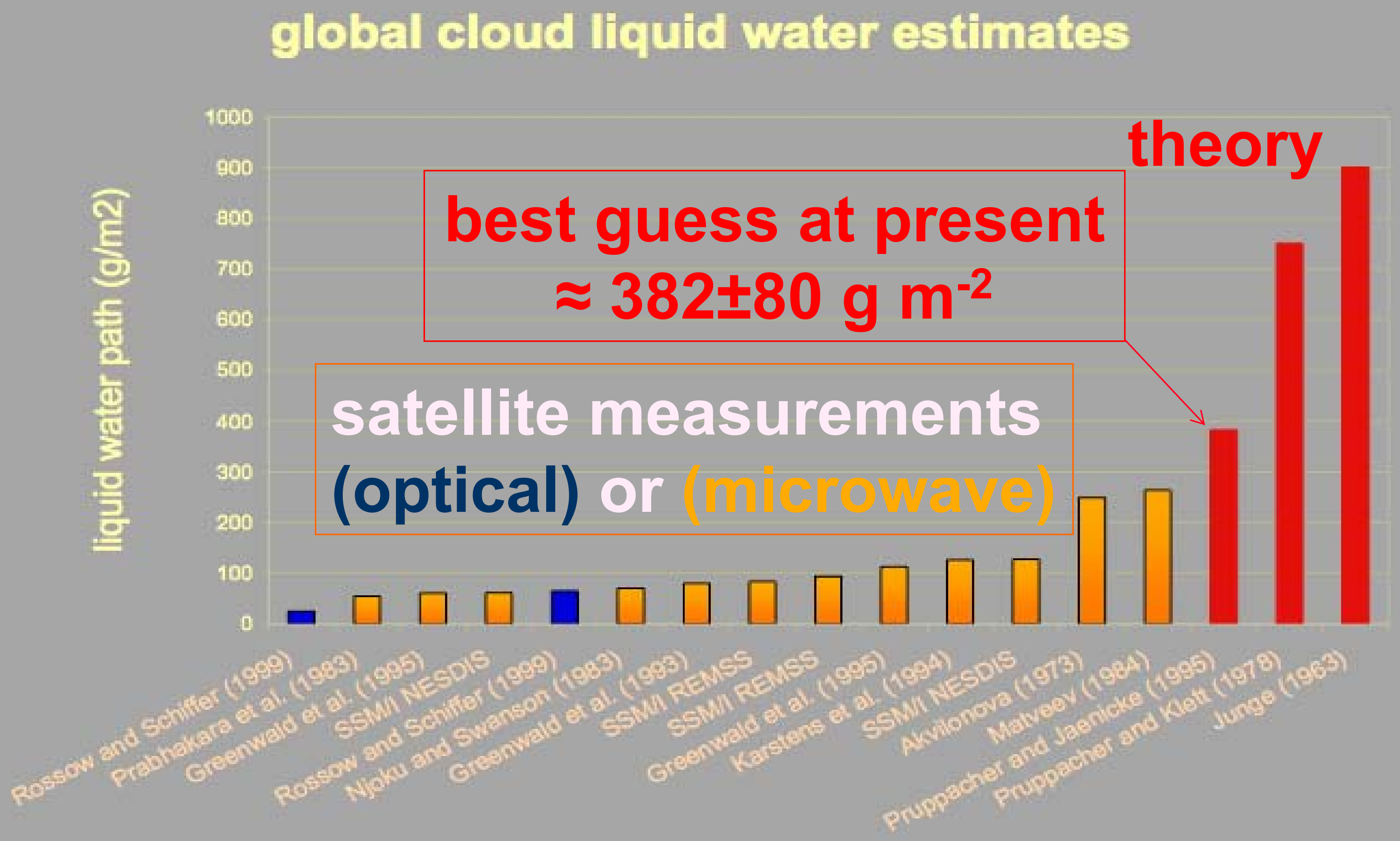


general thoughts

- toa radiances and albedos generally quite good
  - spectral and broadband
  - can be related to cloud types
- cloud heights and areas also quite good
- trends possible
  - radiometric calibration drift limits much of current record
  - geometric based trends more reliable

cont.

- global cloud properties appear quite problematic
  - thick clouds especially poor
  - heterogeneity effects dominate
- possible to cherry-pick
  - seek thinner clouds
  - seek homogeneous clouds

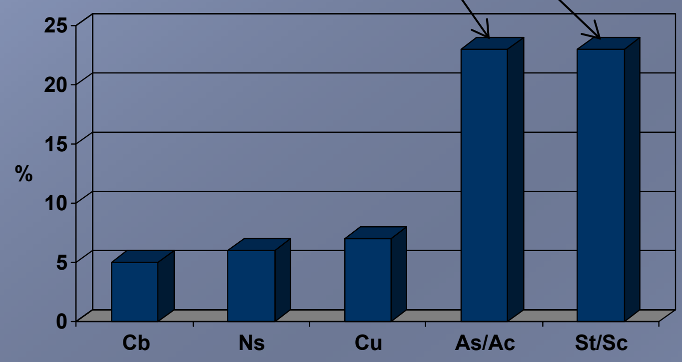

global cloud liquid water estimates
liquid water path (g/m2)
1000
900
800
700
600
500
400
300
200
100
0
Rossow and Schiffer (1999)
Prabhakara et al. (1983)
Greenwald et al. (1995)
SSM/I NESDIS
Rossow and Schiffer (1999)
Njoku and Swanson (1983)
Greenwald et al. (1993)
SSM/I REMSS
SSM/I REMSS
Greenwald et al. (1995)
Karstens et al. (1994)
SSM/I NESDIS
Akvilonova (1973)
Matveev (1984)
Pruppacher and Jaenicke (1995)
Pruppacher and Klett (1978)
Junge (1963)
theory
best guess at present
≈ 382±80 g m^{-2}
satellite measurements
(optical) or (microwave)

theoretical estimates of global cloud types

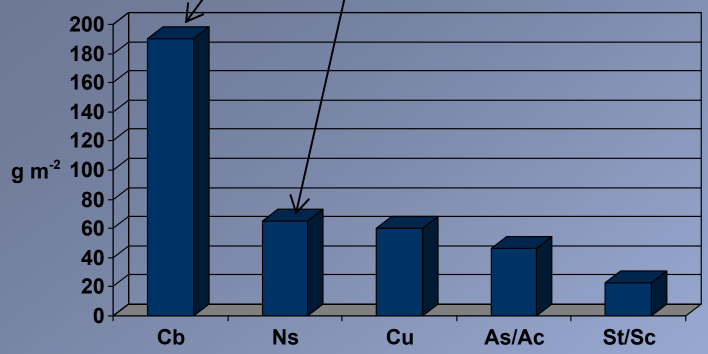
these dominate global albedo

these dominate global hydrology

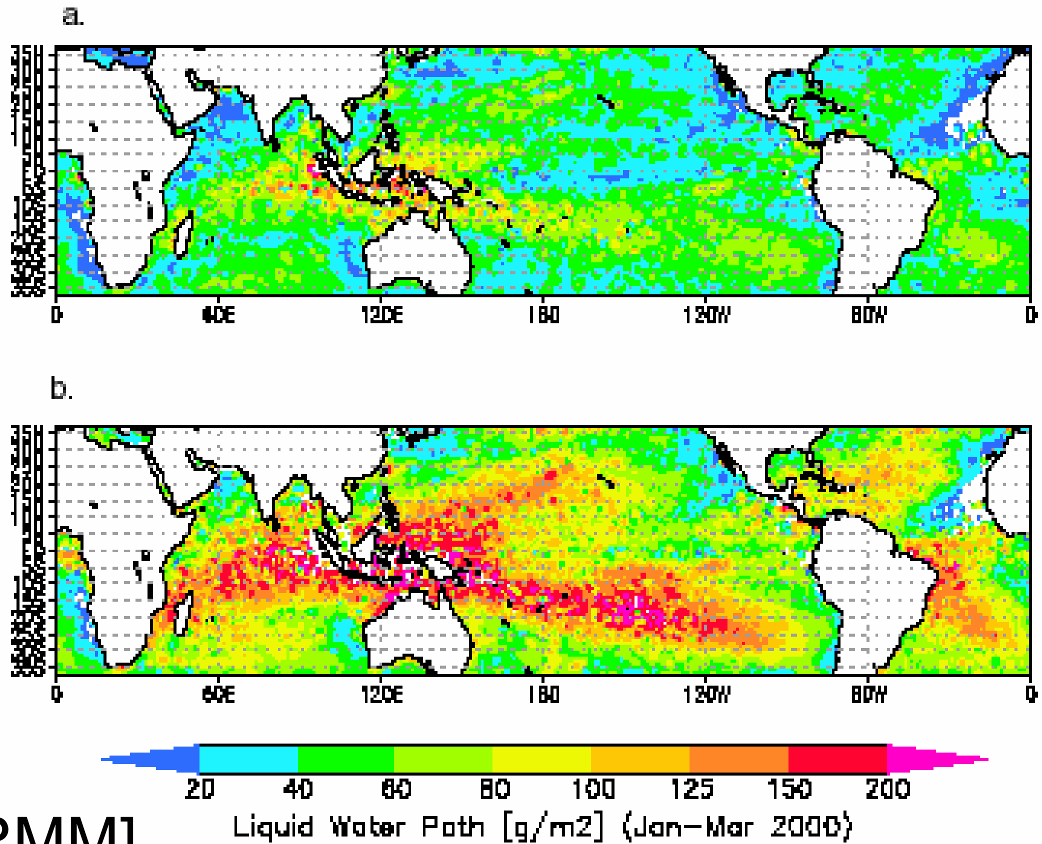
global cloud fractions



mean liquid water content



The problem with microwaves



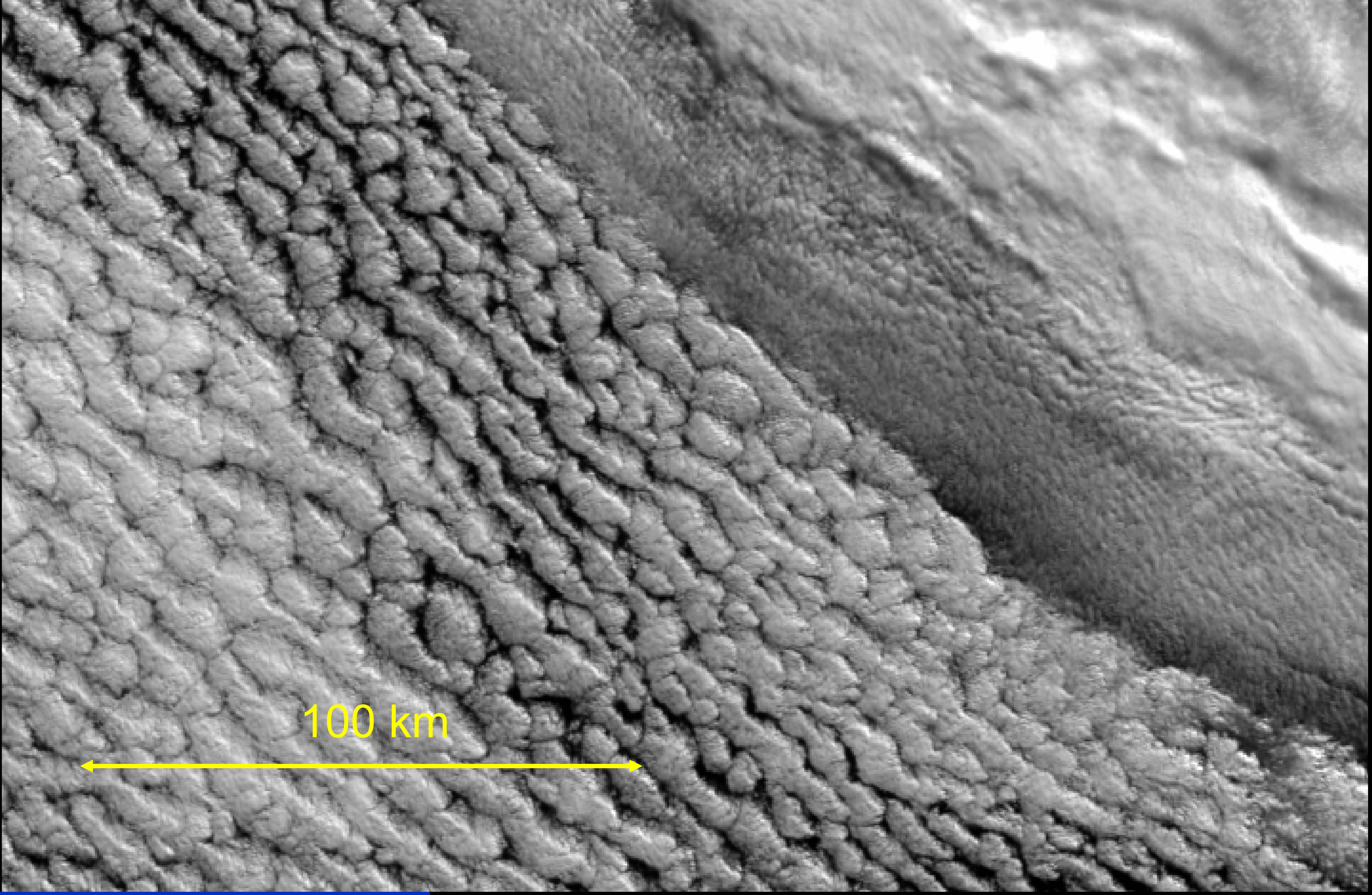
[TRMM]

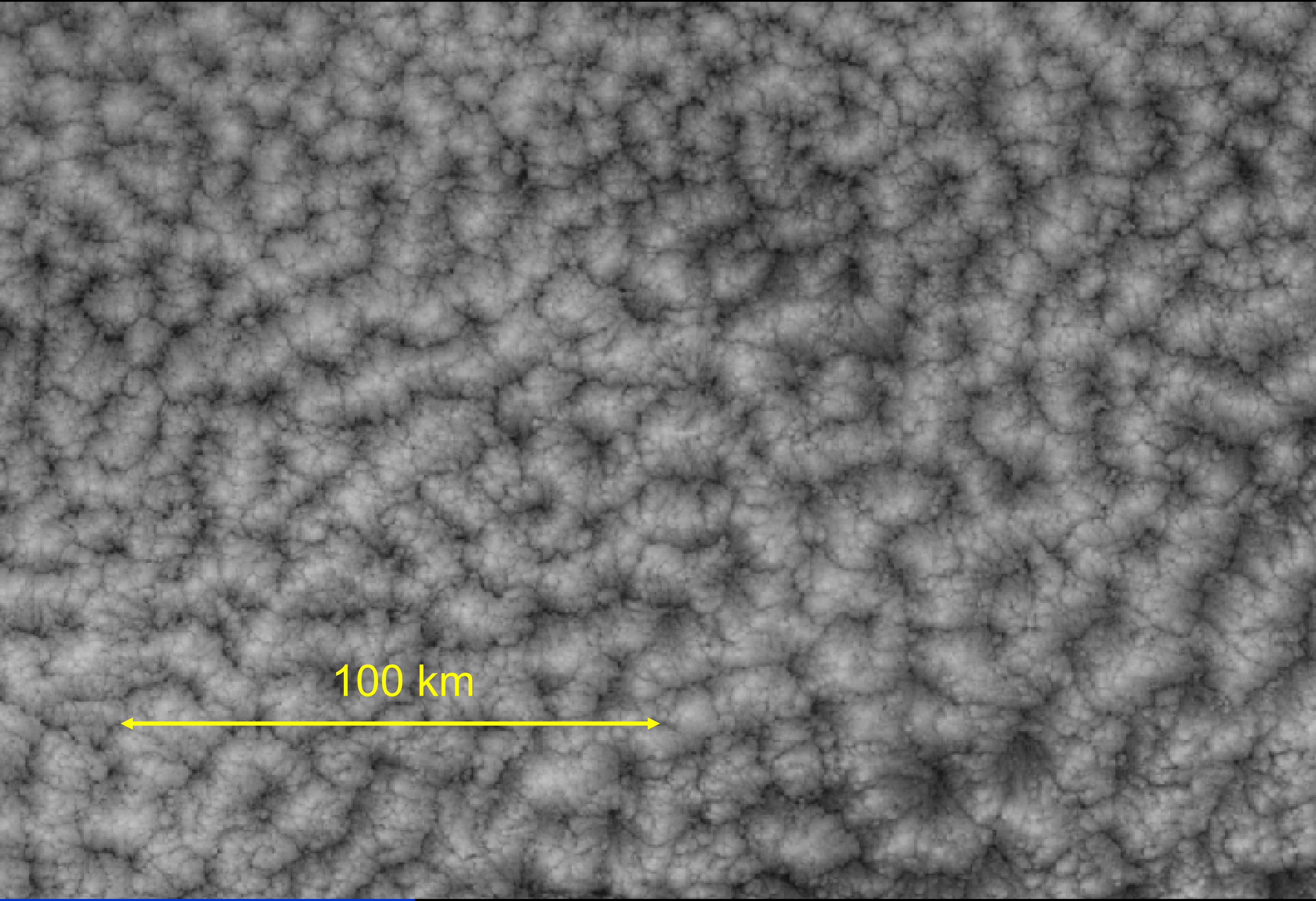
µwave only

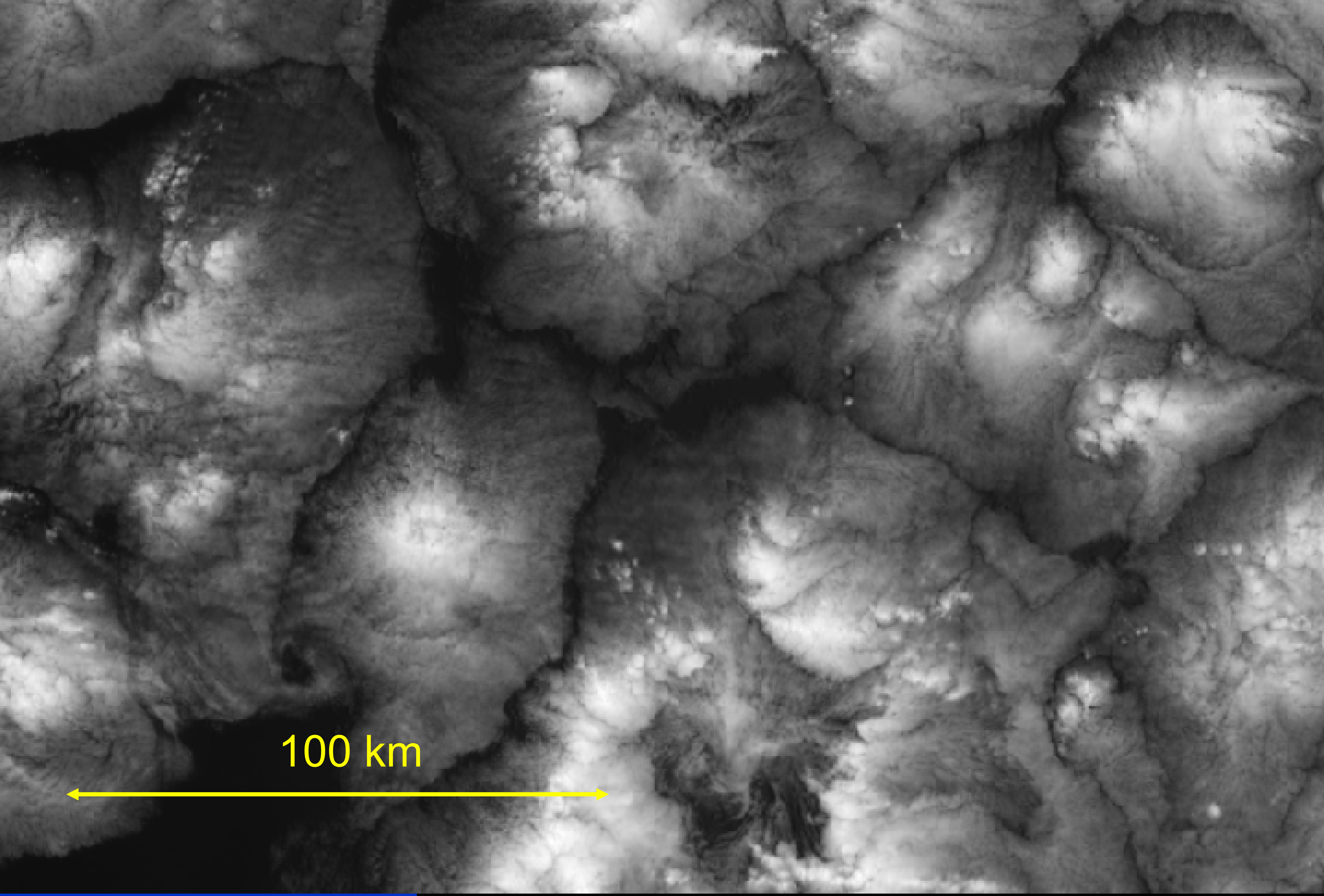
µwave + optical

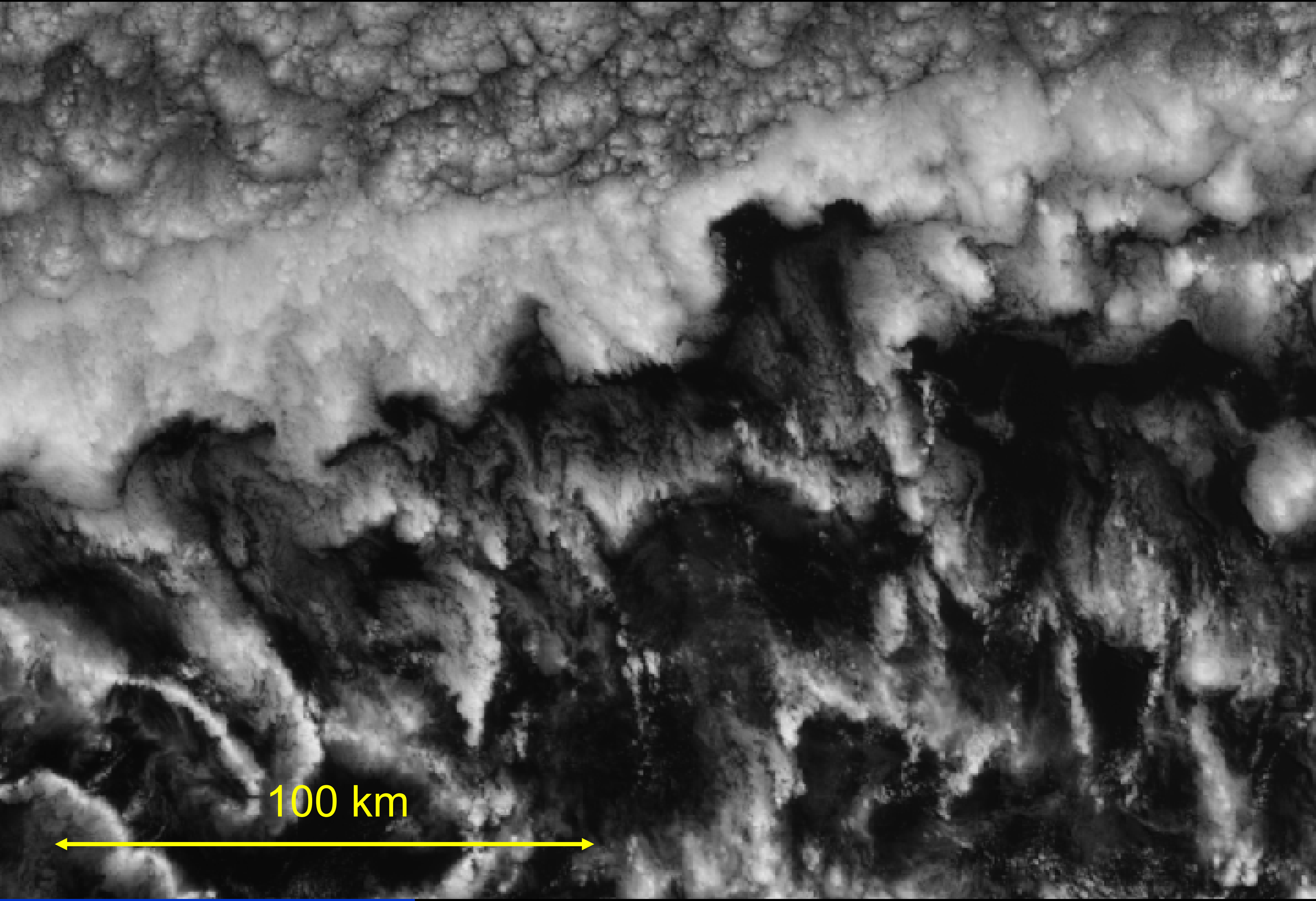
adapted from Masunaga et al., *J. Geophys. Res.*, 2002

Caution: do not attempt over land


100 km


100 km


100 km

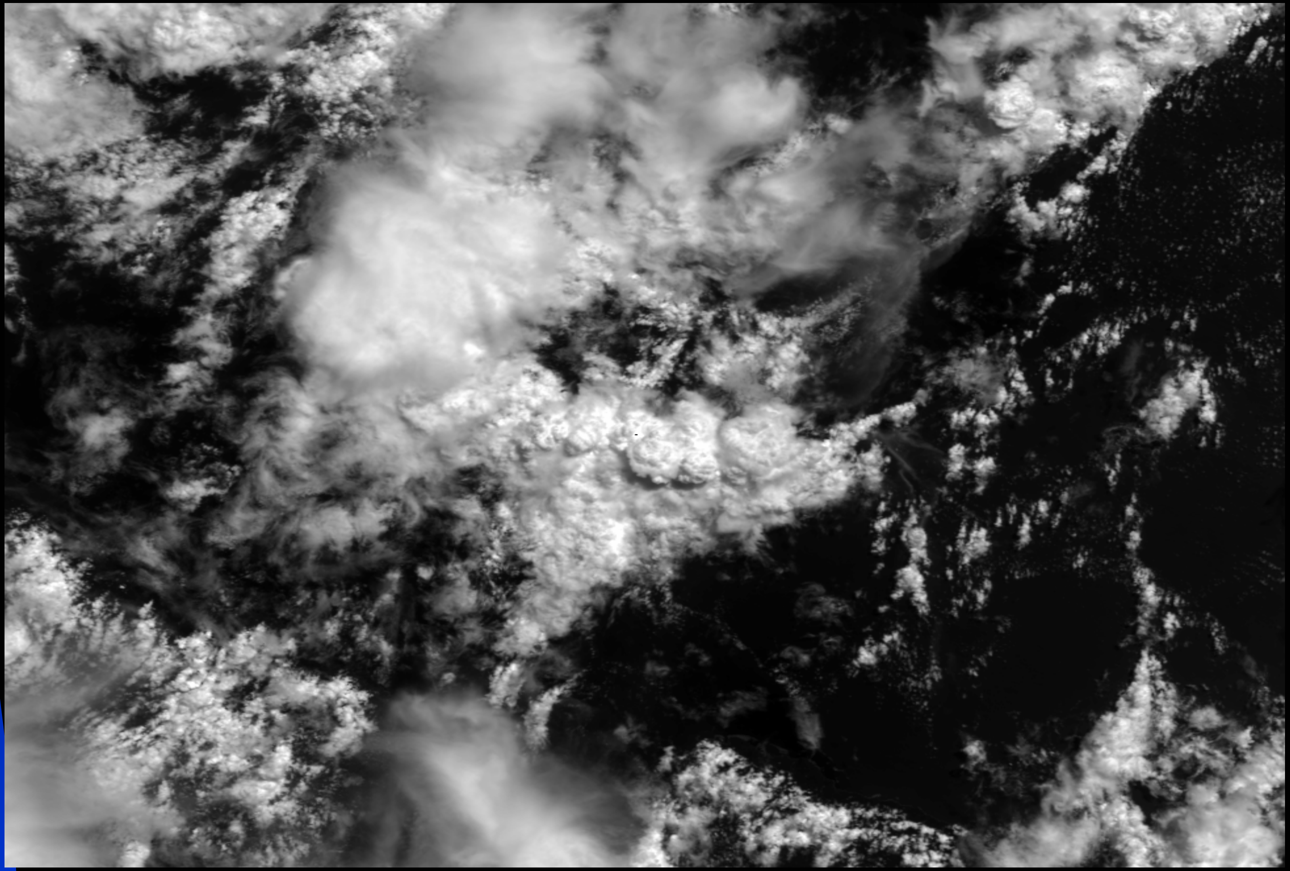

100 km

MISR high resolution imagery

270x230 km

Equatorial West Pacific

nadir image

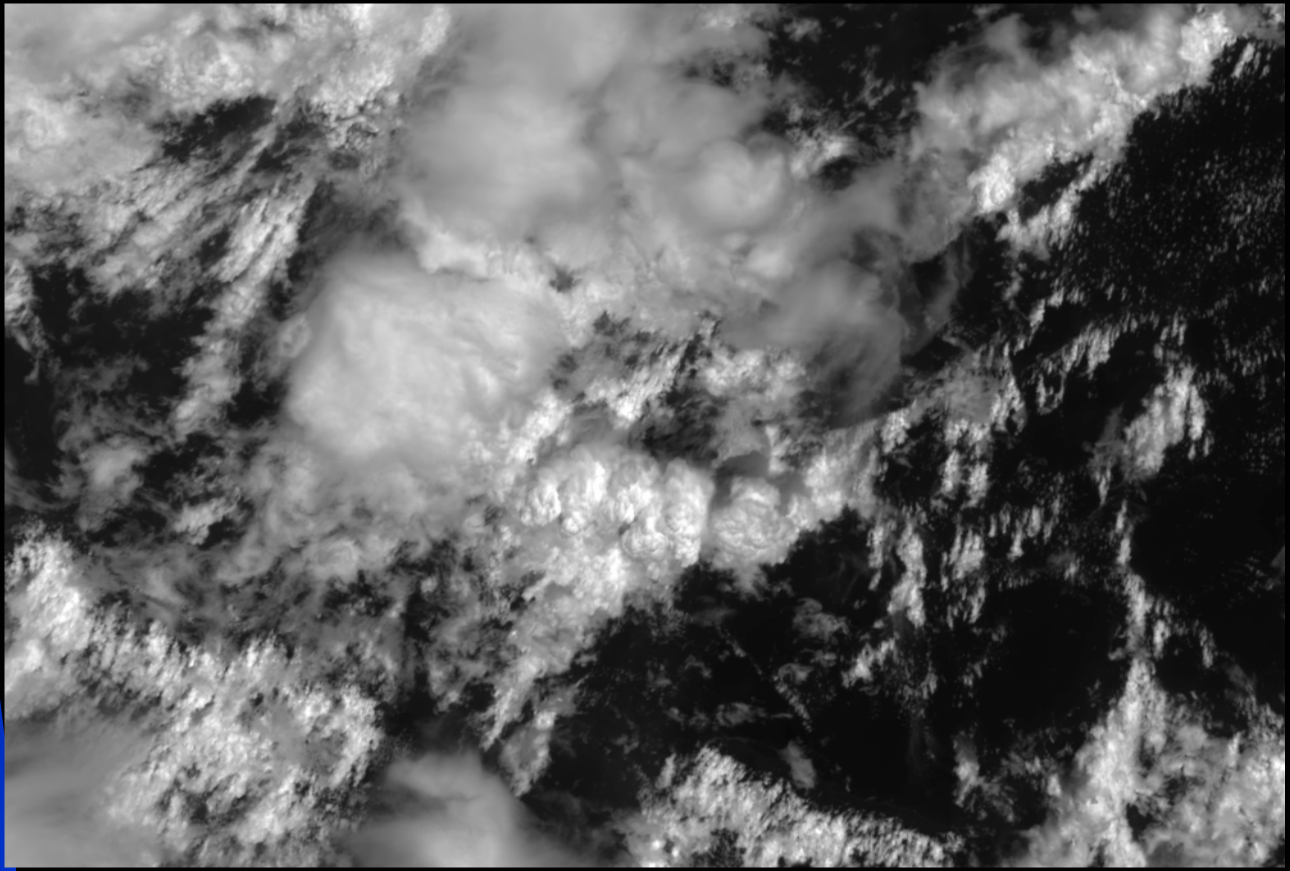


MISR high resolution imagery

270x230 km

Equatorial West Pacific

60° oblique image



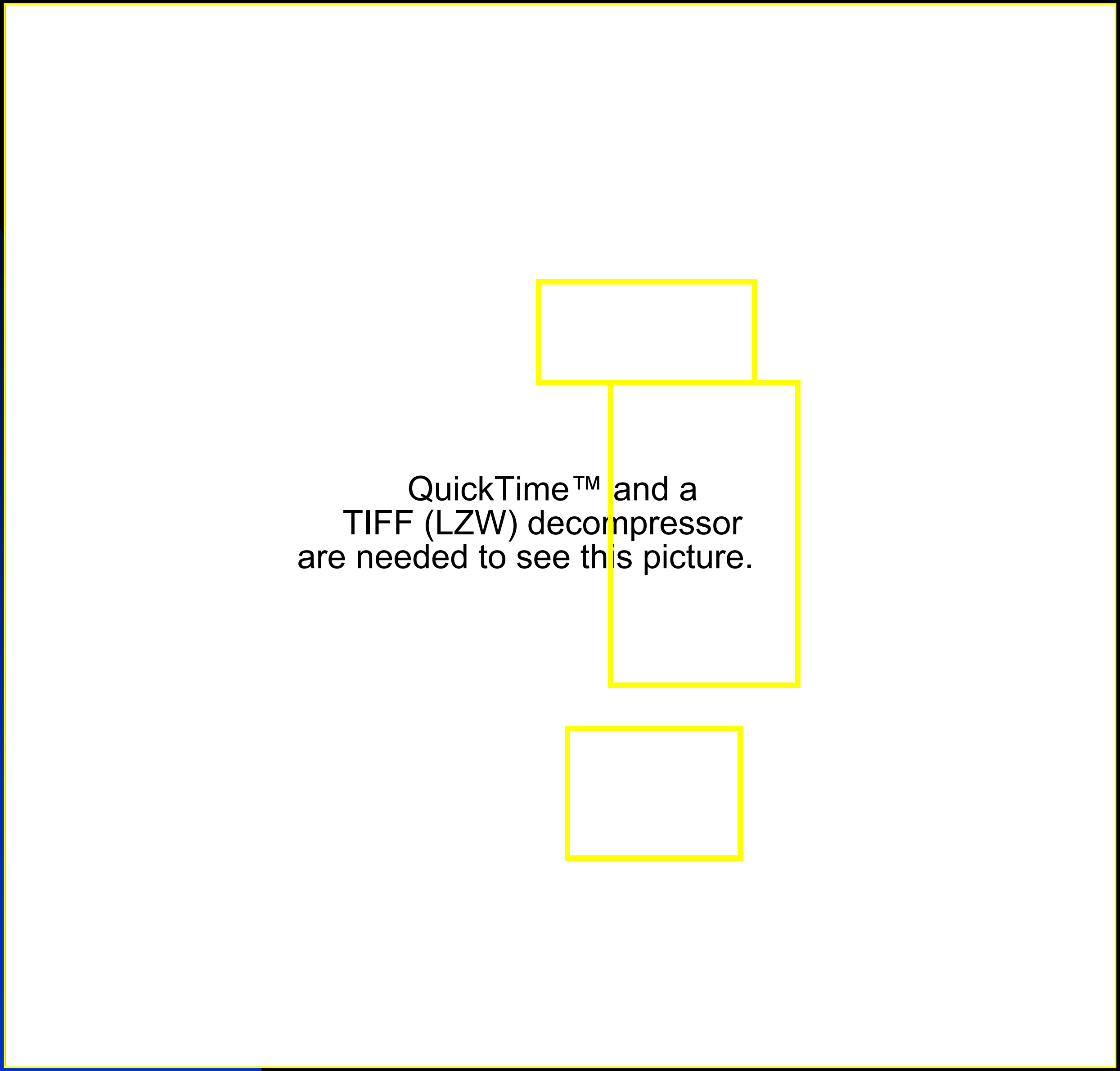
multi-angle approaches to τ

- using MISR for example
  - 9 pushbroom cameras
- nadir ± 26° views for stereo
  - cloud geometry (top and side)
- 45°–70° views of side reflectivity
- approach 1: match full 3D
- approach 2: gradient analysis using a reciprocal TIPA (tilted independent pixel approximation) approach

3D approach

- Zuidema et al., JGR '03
- use unsaturated nadir measurements + stereo geometry to initialize model
- compare MC output with observations
- iterate for consistency

MISR cloud top height field for the Zuidema et al 03 study



optical depths from the Zuidema et al. '03 study

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

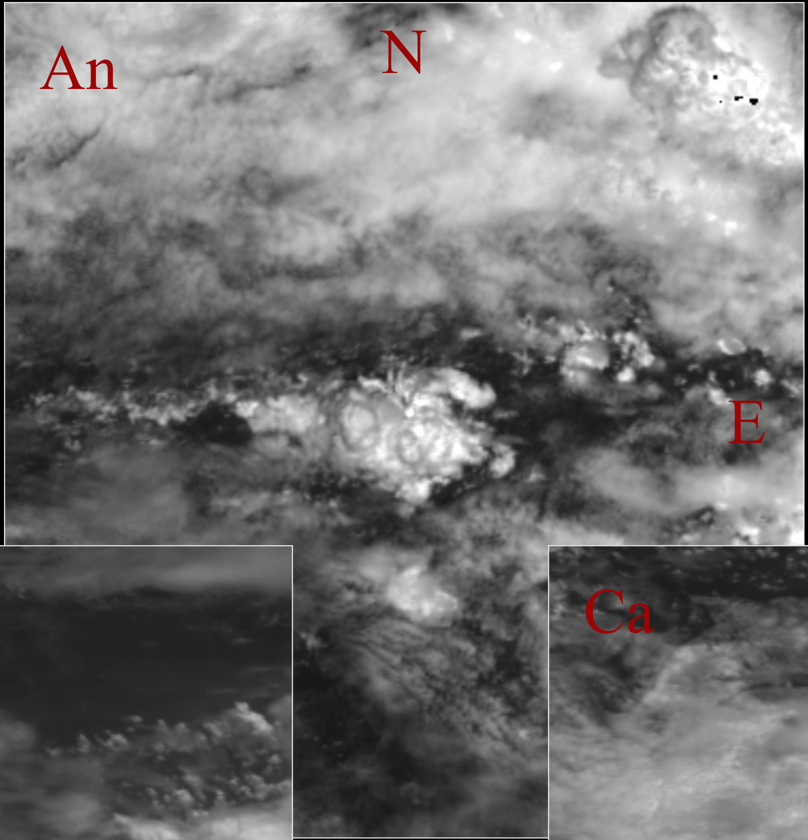
τ

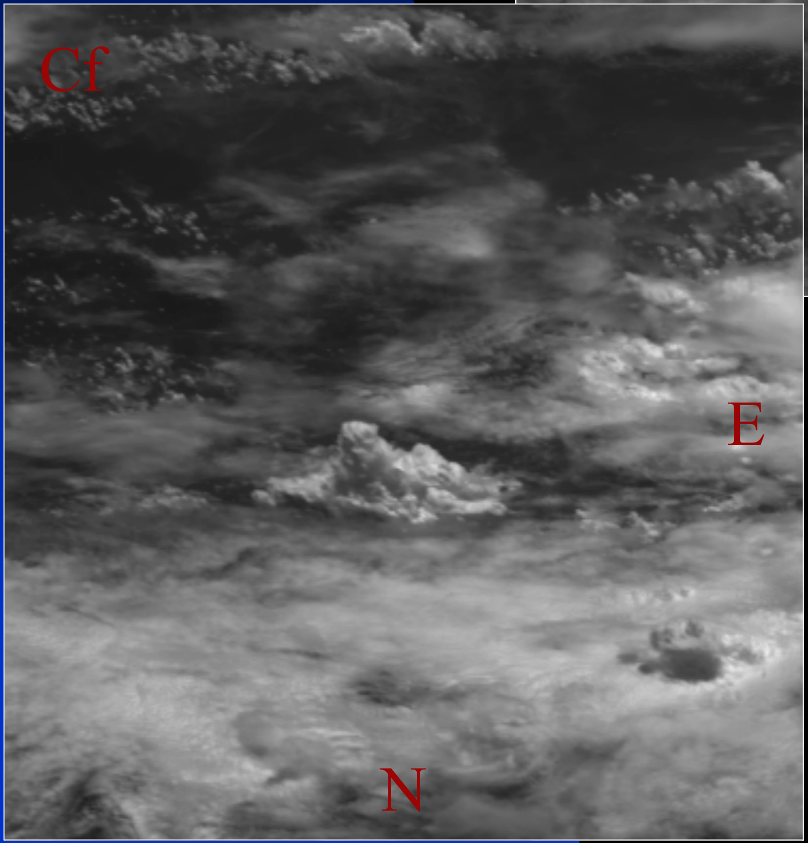
reciprocal-TIPA approach

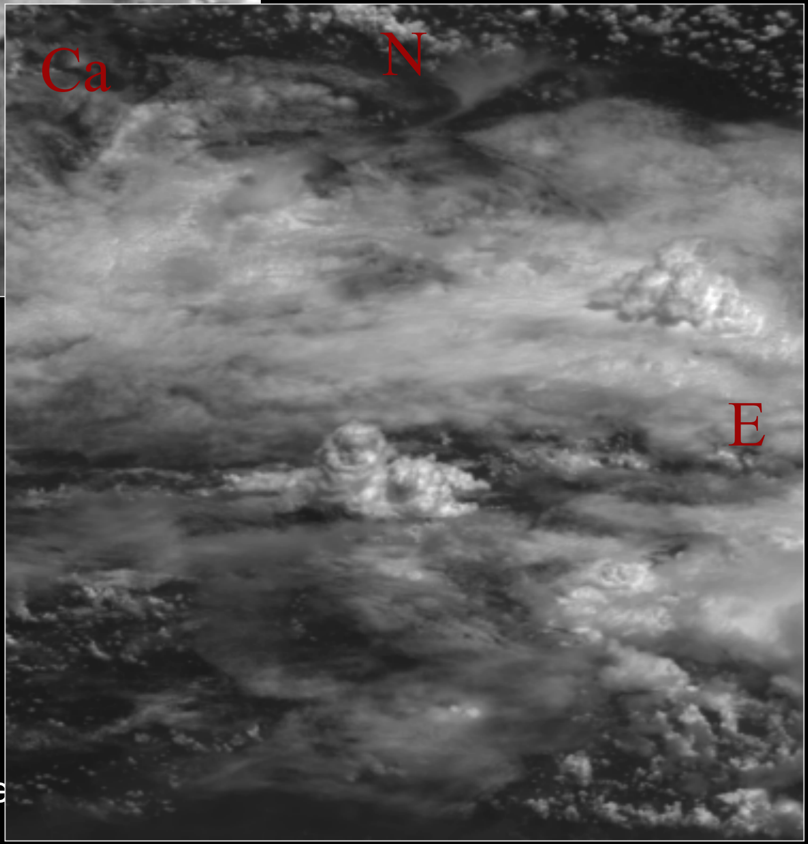
- much simpler than full 3D
- uses slant path in direction of viewing angle (reciprocal TIPA) (Várnai & Davies, JAS 99)
- adapts to the geometry of convective clouds
- relates gradient in radiance near cloud edges to slant path geometry
  - extinction coefficient, β vs height
  - integrate over height to get τ

static views from nadir and oblique cameras of the same cloud

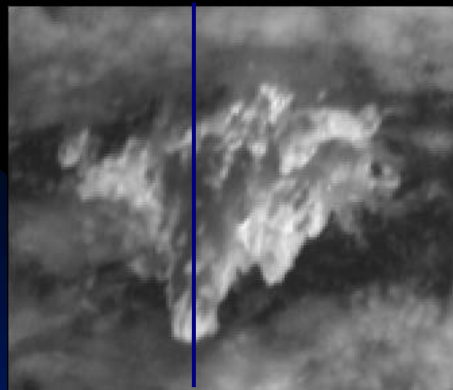
- Ca is the sunlit side
- 60° oblique view

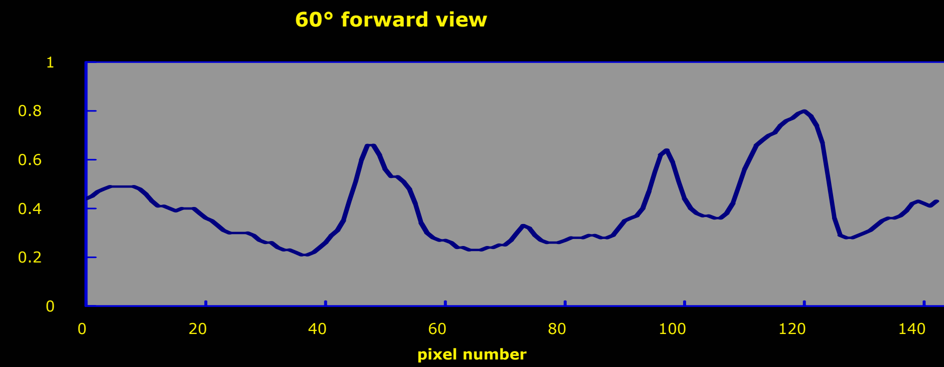


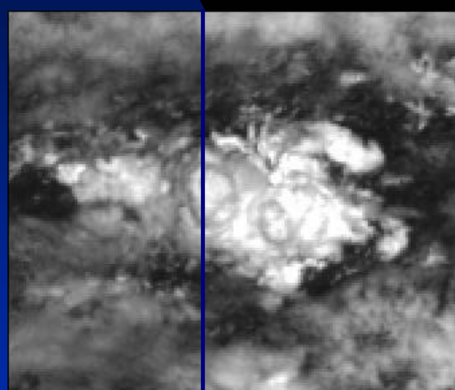


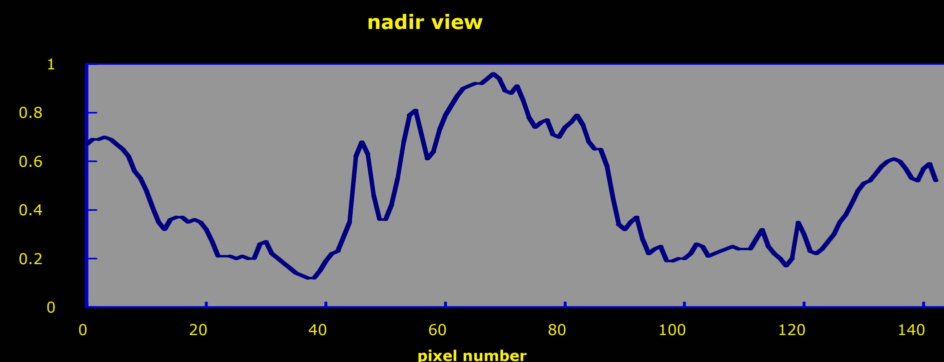


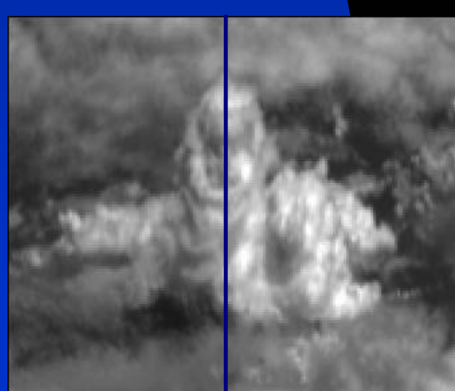
AEROCOM me

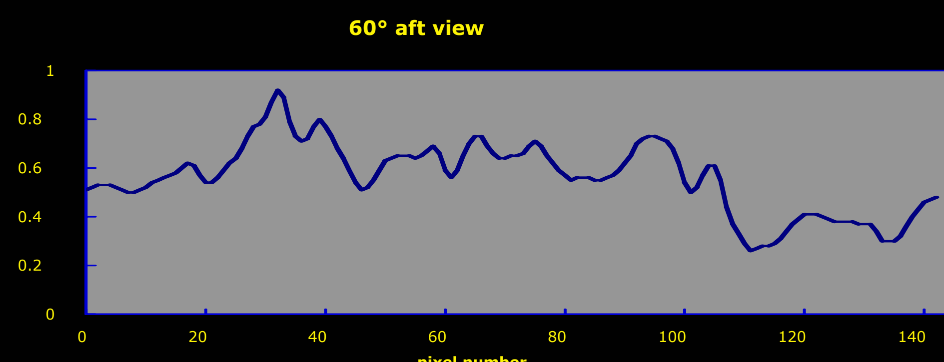



60° forward view
1
0.8
0.6
0.4
0.2
0
0
20
40
60
80
100
120
140
pixel number




nadir view
1
0.8
0.6
0.4
0.2
0
0
20
40
60
80
100
120
140
pixel number



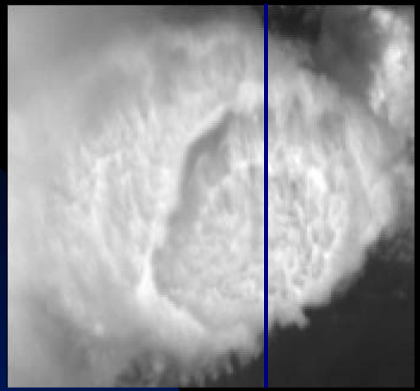

60° aft view
1
0.8
0.6
0.4
0.2
0
0
20
40
60
80
100
120
140
pixel number

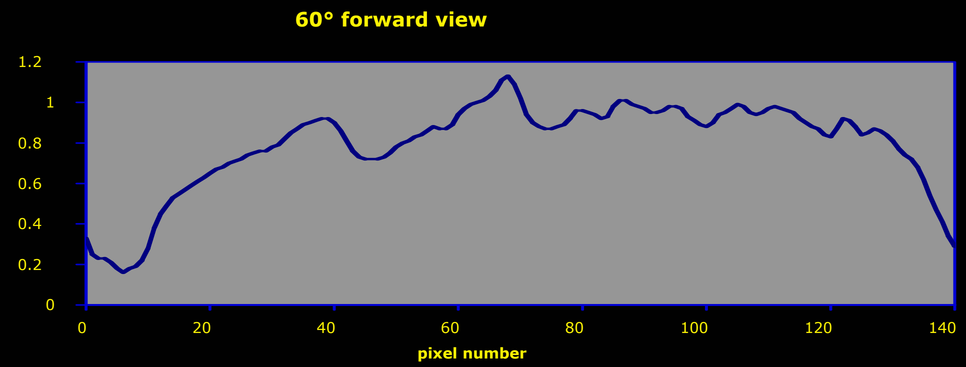
analysis

- cloud geometry
  - ≈ 5 km wide
  - ≈ 10 km deep
- reciprocal TIPA analysis:
  - $\tau_h > 25$, $\tau_v > 100$
  - β (ext. coeff.) > 5–10 km^{-1}
- gradient analysis of unsaturated τ
  - $\beta \approx 8\ km^{-1}$ at top, $\approx 22\ km^{-1}$ at base

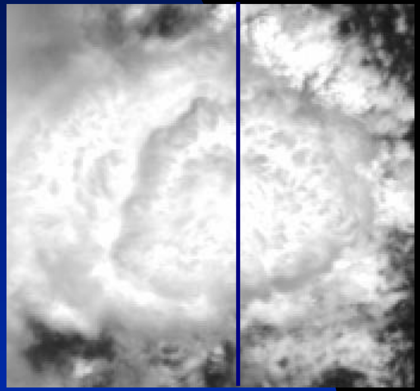
retrieval summary

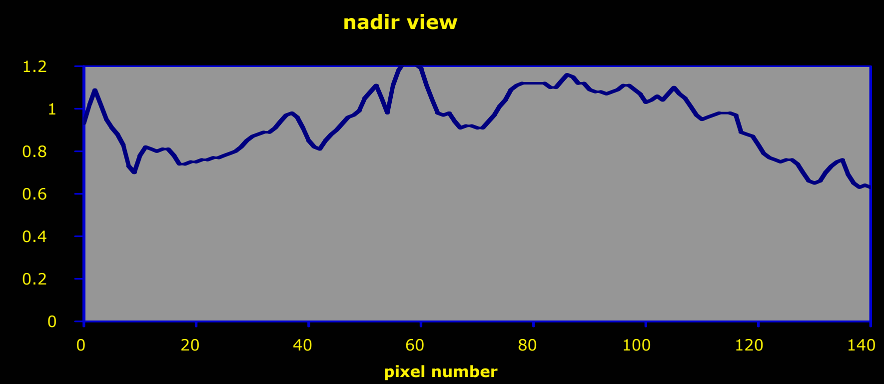
	nadir only	multi-angle
cloud vertical extent	no information	10.5±0.8 km
extinction coefficient	no information	8–22 km^{-1} (higher at base)
cloud optical depth	> 60	150±30



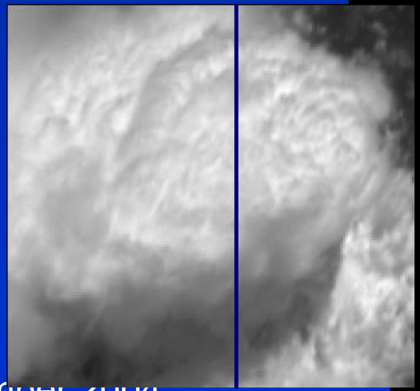


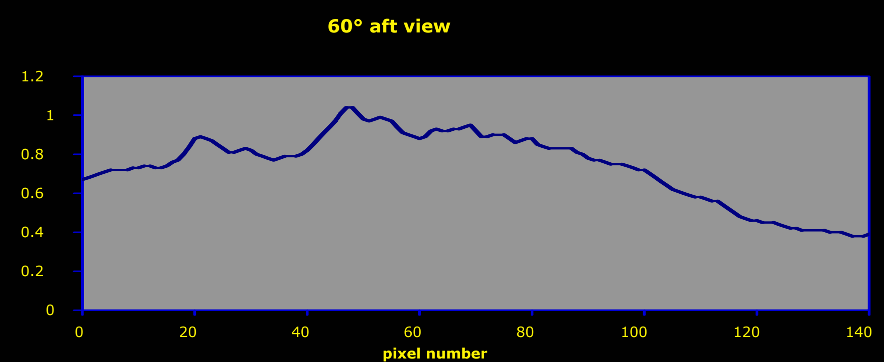
60° forward view
1.2
1
0.8
0.6
0.4
0.2
0
0
20
40
60
80
100
120
140
pixel number





nadir view
1.2
1
0.8
0.6
0.4
0.2
0
0
20
40
60
80
100
120
140
pixel number





60° aft view
1.2
1
0.8
0.6
0.4
0.2
0
0
20
40
60
80
100
120
140
pixel number

thicker cloud case

- vertical extent ≈ 11 km
- very bright
- nadir view alone
  - $\tau > 60$
- preliminary analysis indicates
  - $\tau > 300$