Viewing Geometry Effect on Retrievals of Cloud Droplet Size

(Why the effective radius of CERES water cloud product is several microns larger than that of ISCCP?)

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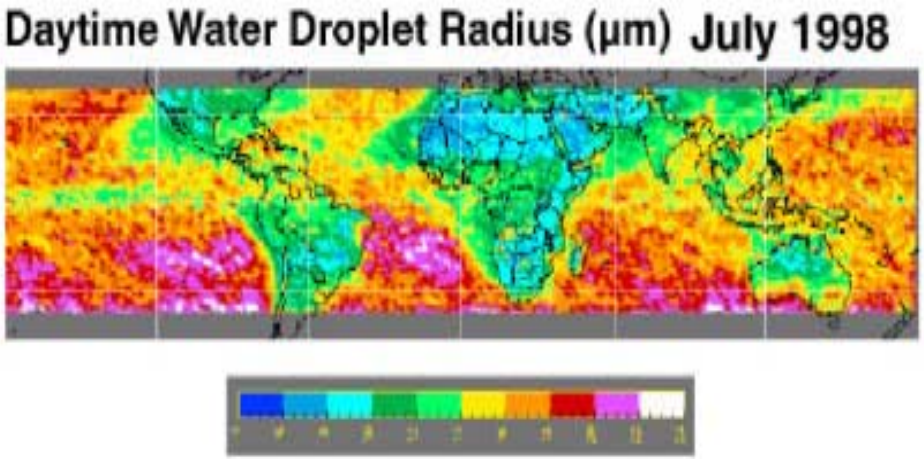
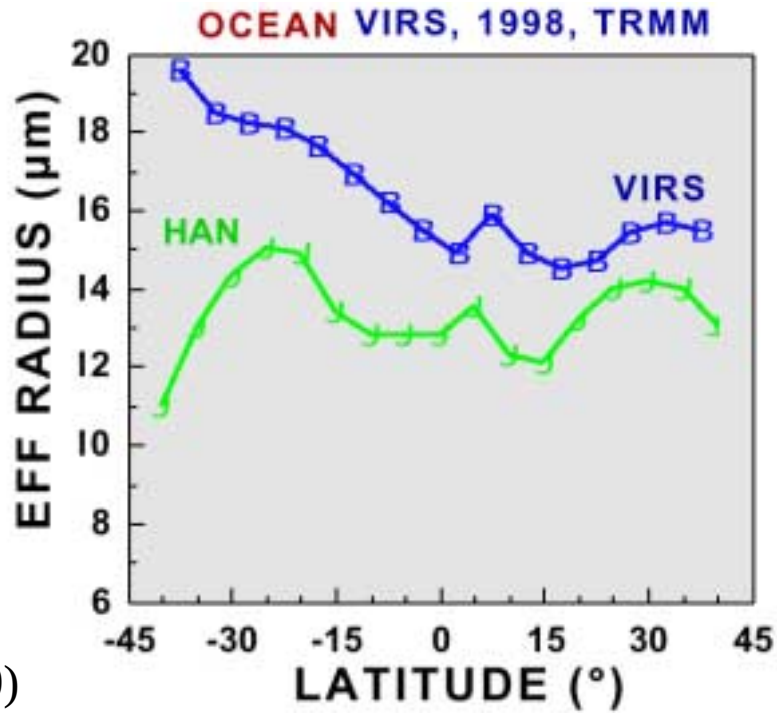
Comparison of retrieved water cloud effective droplet radius





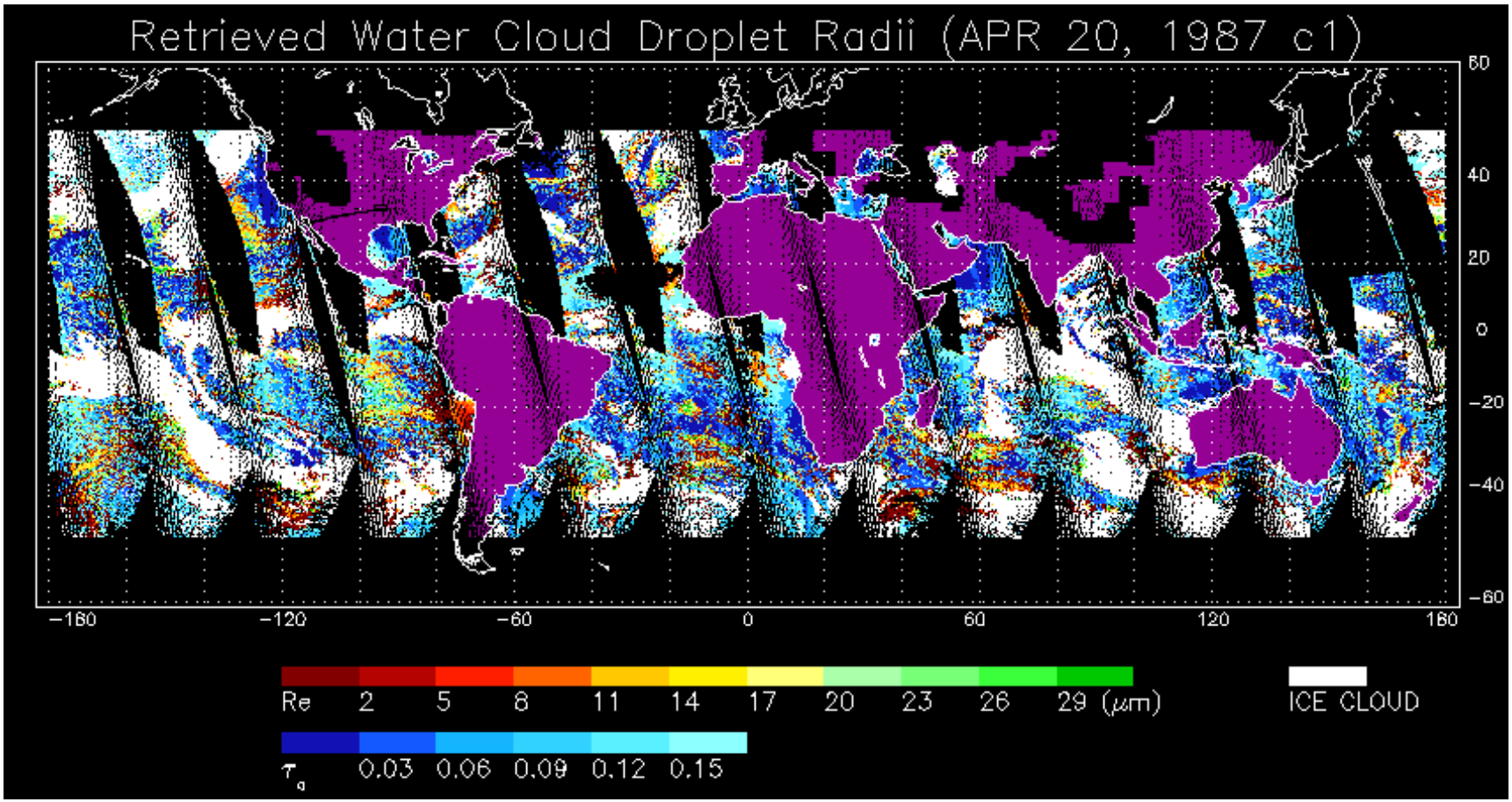
From Minnis et al., (2000)

Differences of several microns exist between retrieved r_e by CERES and ISCCP

What caused the difference?

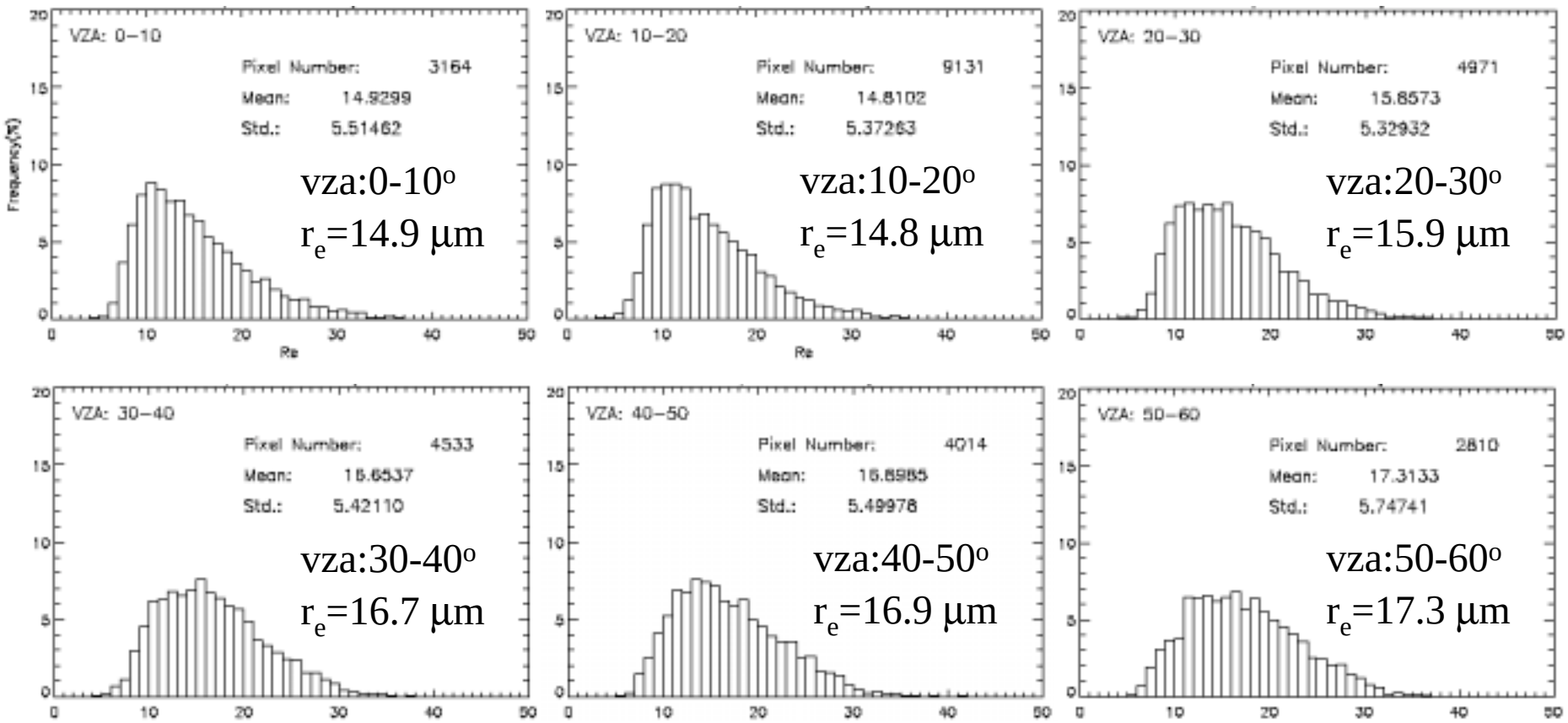
- Model comparisons of reflection functions (thick clouds)
- More detailed pixel level comparisons for specific scenes (examine details of model outputs for individual pixels)
- Could there be some viewing geometry effect?
  - CERES: All viewing angles
  - ISCCP: Near-nadir viewing (μ>0.90) only (Han et al., 1994)

Is there any signature of viewing geometry dependency?



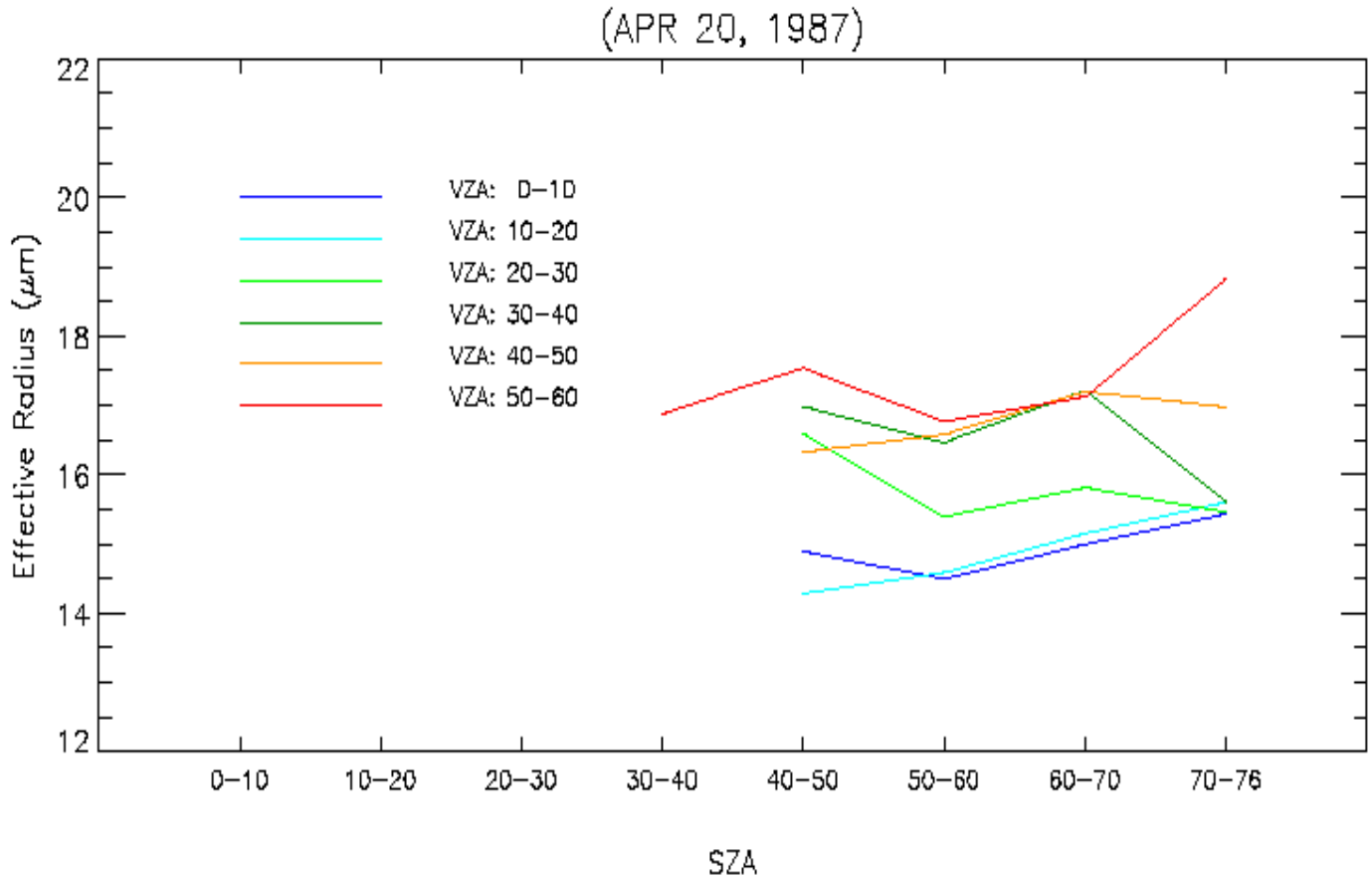
No apparent stripes of forward and backward scattering angle pattern in results of one day retrieval

Finding evidence of viewing geometry dependency



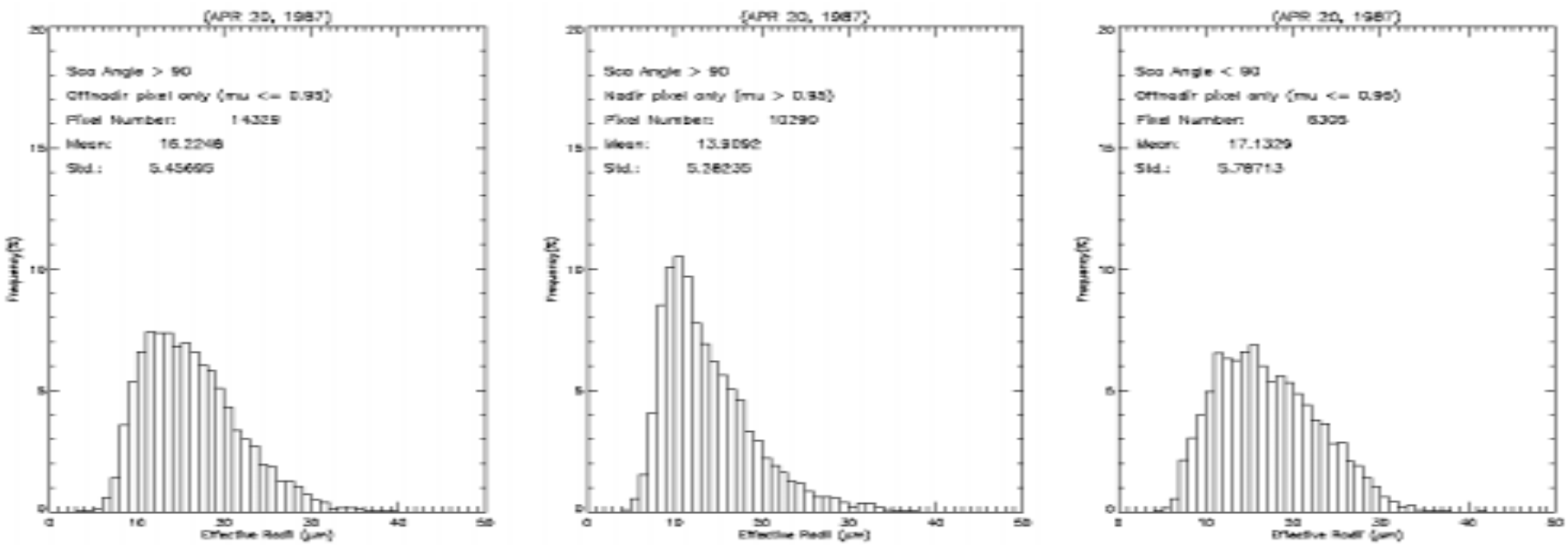
A gradual increase of r_e with increasing view zenith angle is found when vza>20°

Solar Zenith Angle Dependence?



Solar zenith angle dependence does not show a consistent trend

Is there difference of retrieved r_e between forward and backward scattering?



Backward Scattering
r_e=16.2 μm

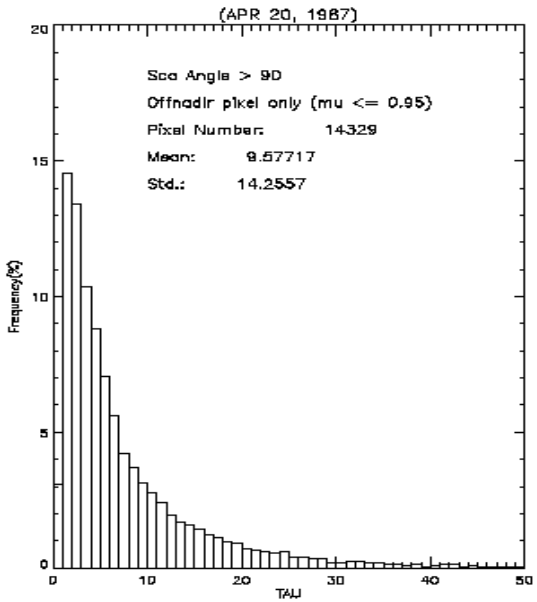
Nadir (μ>0.95)
r_e=13.9 μm

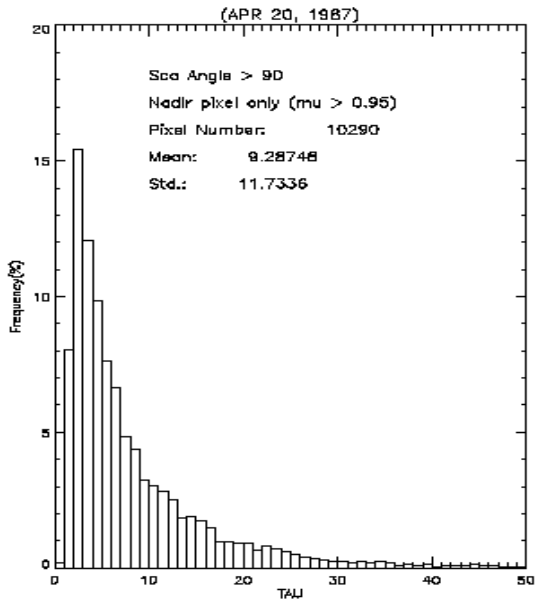
Forward Scattering
r_e=17.1 μm

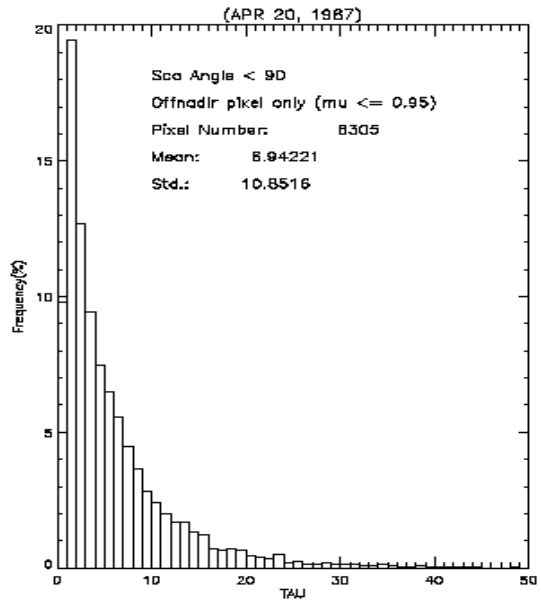
r_e is larger at off-nadir for both forward and backward scattering

r_e is slightly smaller at backward scattering than that at forward scattering

What is the behavior of optical thickness for forward and backward scattering







Backward Scattering
τ=9.6

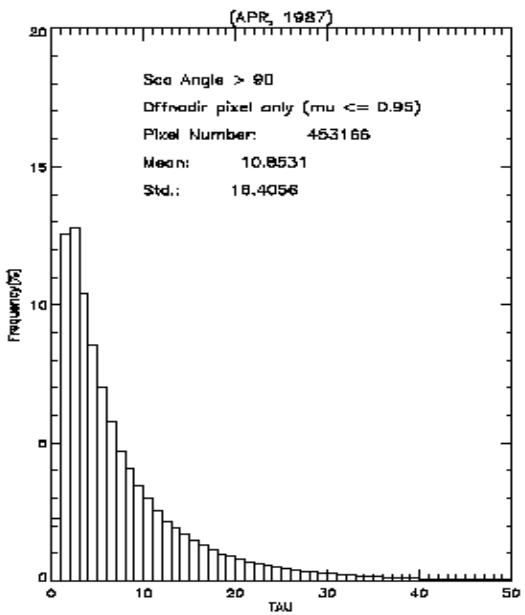
Nadir (μ>0.95)
τ=9.3

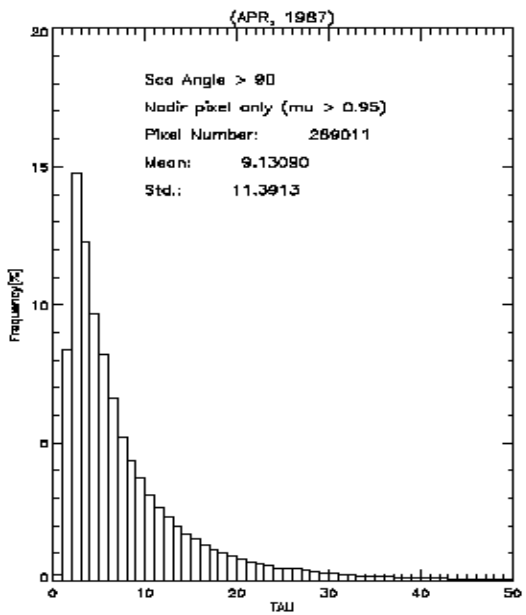
Forward Scattering
τ=6.9

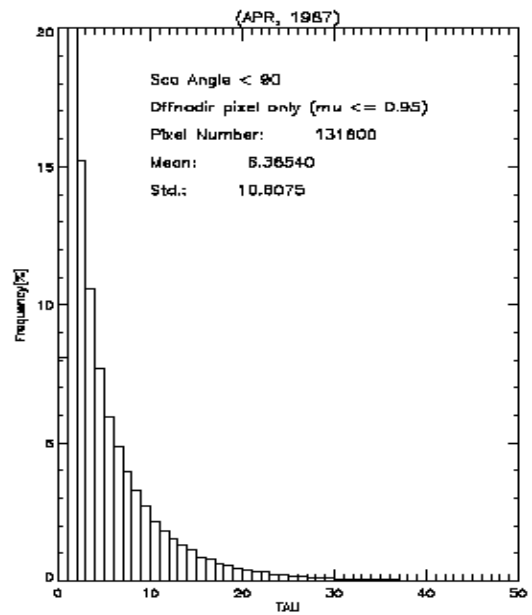
Optical thickness is larger at directions of backward scattering

consistent with expectations based on cloud top morphology or 3-D effect

3-D effect of optical thickness for forward and backward scattering also shown in monthly data





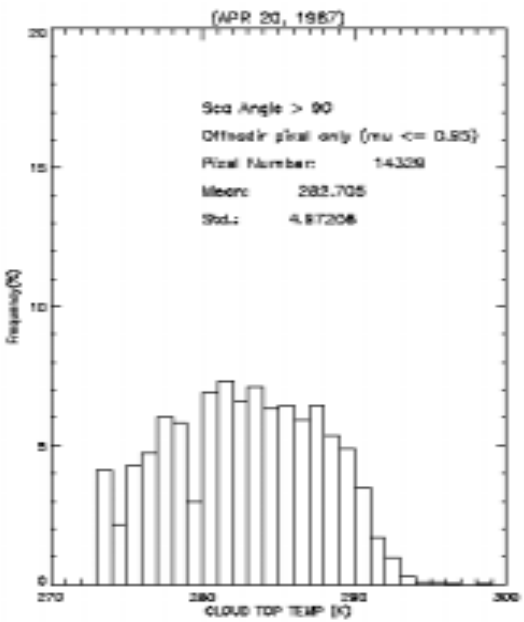


Backward Scattering
τ=10.9

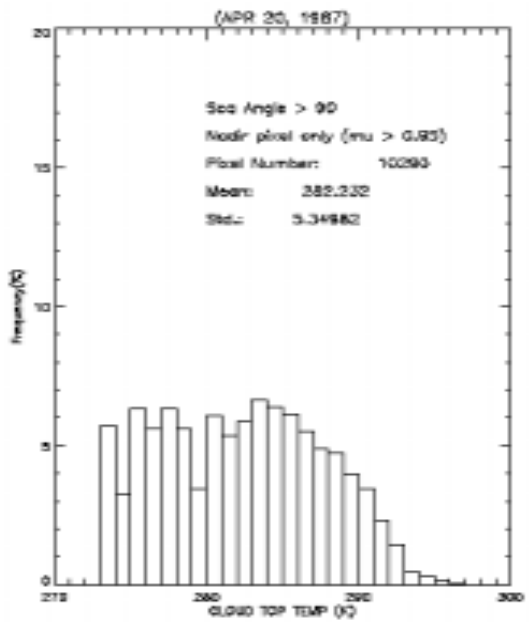
Nadir (μ>0.95)
τ=9.1

Forward Scattering
τ=6.4

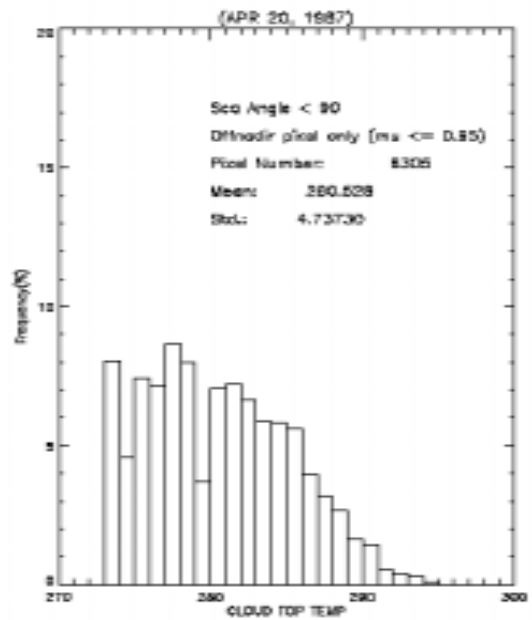
What is the pattern of channel 4 brightness temperature for forward and backward scattering



Backward Scattering
T_b=282.7 K



Nadir (μ>0.95)
T_b=282.2 K

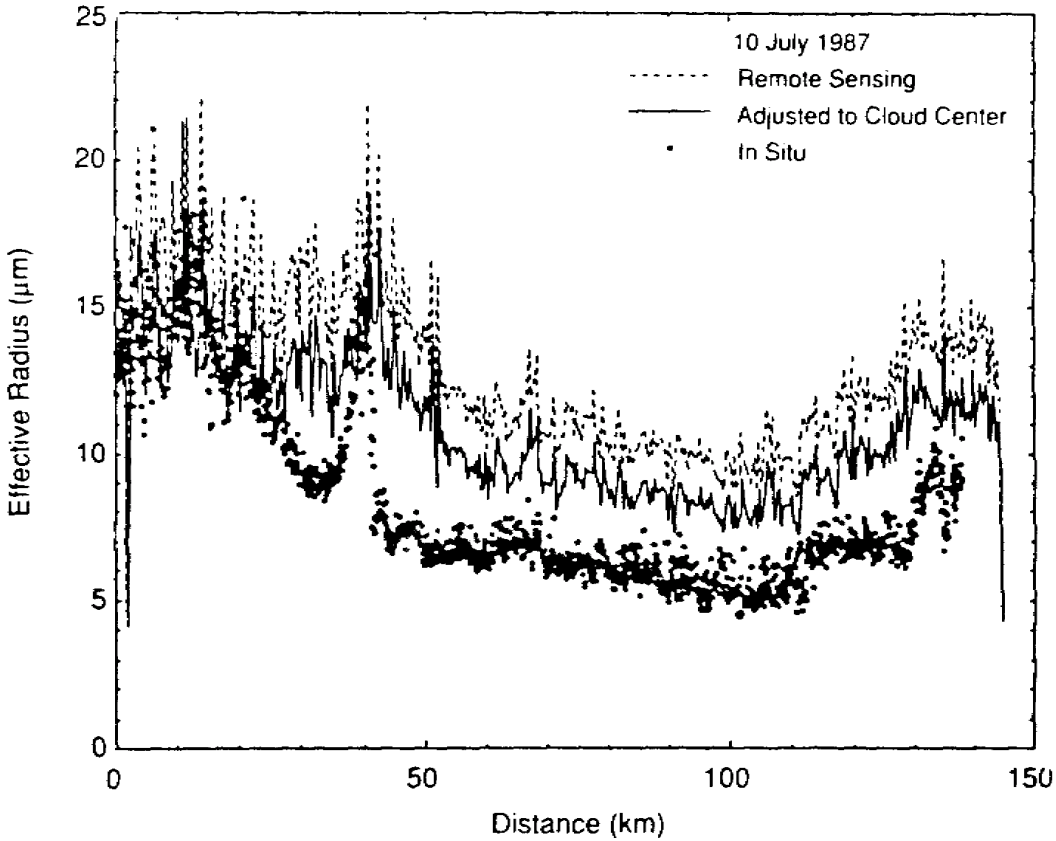


Forward Scattering
T_b=280.5 K

T_b is lowest at directions of forward scattering, may be caused by shadow

This pattern cannot explain the viewing geometry dependence of r_e

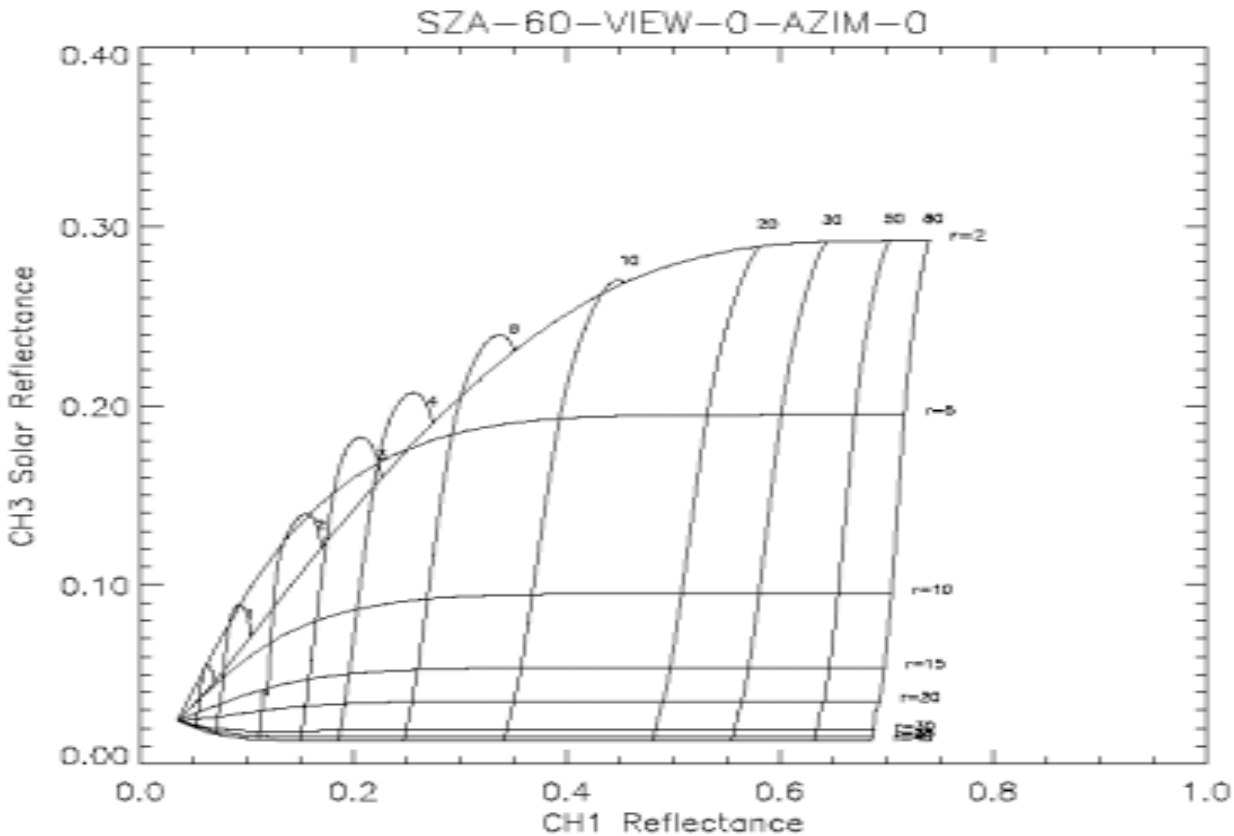
Another candidate: vertical inhomogeneity of r_e?



From Nakajima et al. (1991), p734, Fig. 3

Seeing lower part of clouds should make retrieved r_e smaller, not larger

What is the effect of an overestimated optical thickness on retrievals of r_e?

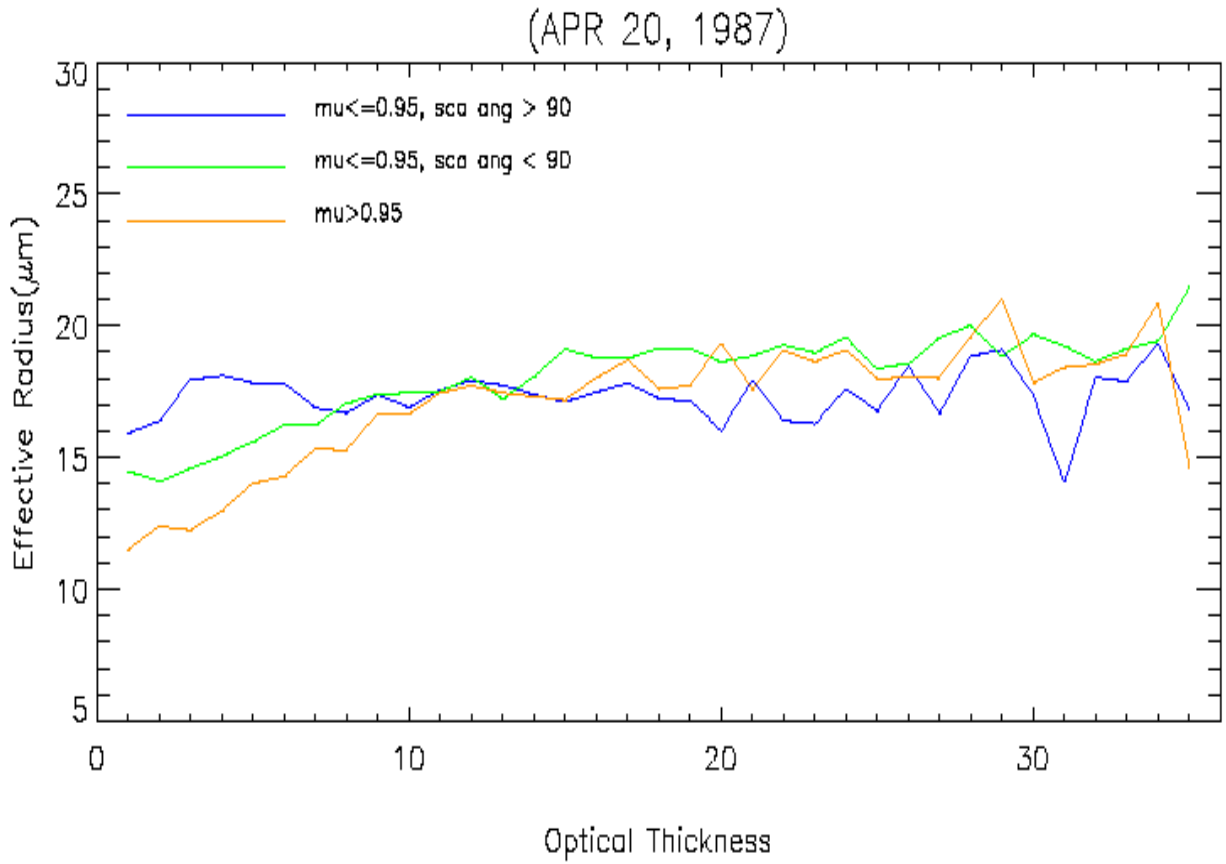


For large τ (τ >6), the effect on retrieval of r_e is negligible

For small τ, an overestimated τ may lead to overestimation of r_e

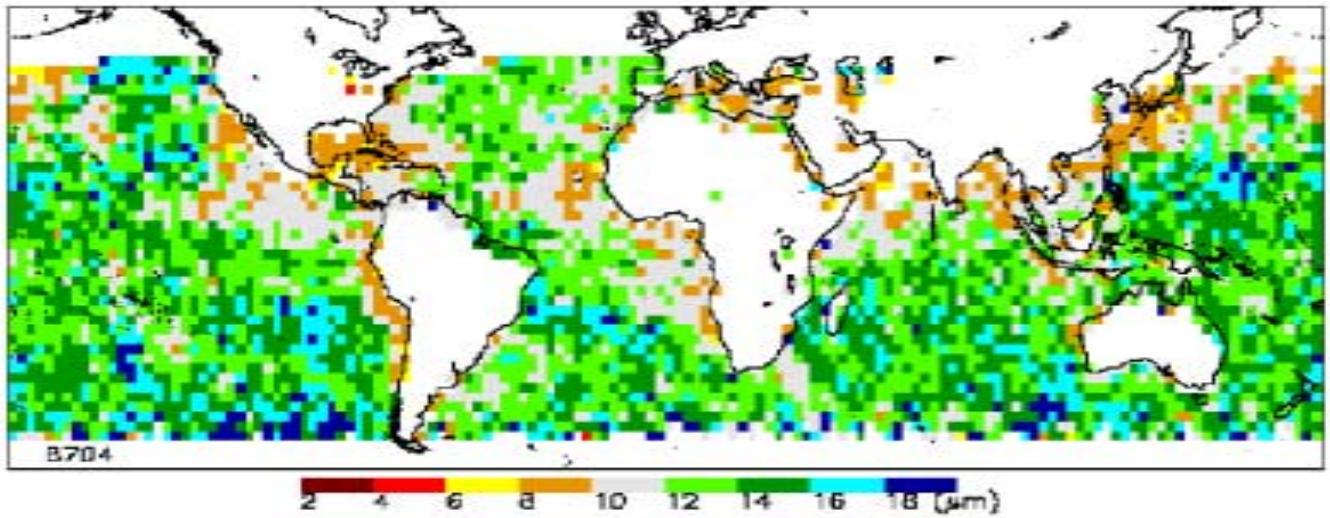
Implies significant overestimation of r_e for small τ. Do we see it?

Examine r_e- τ relations for different viewing geometries



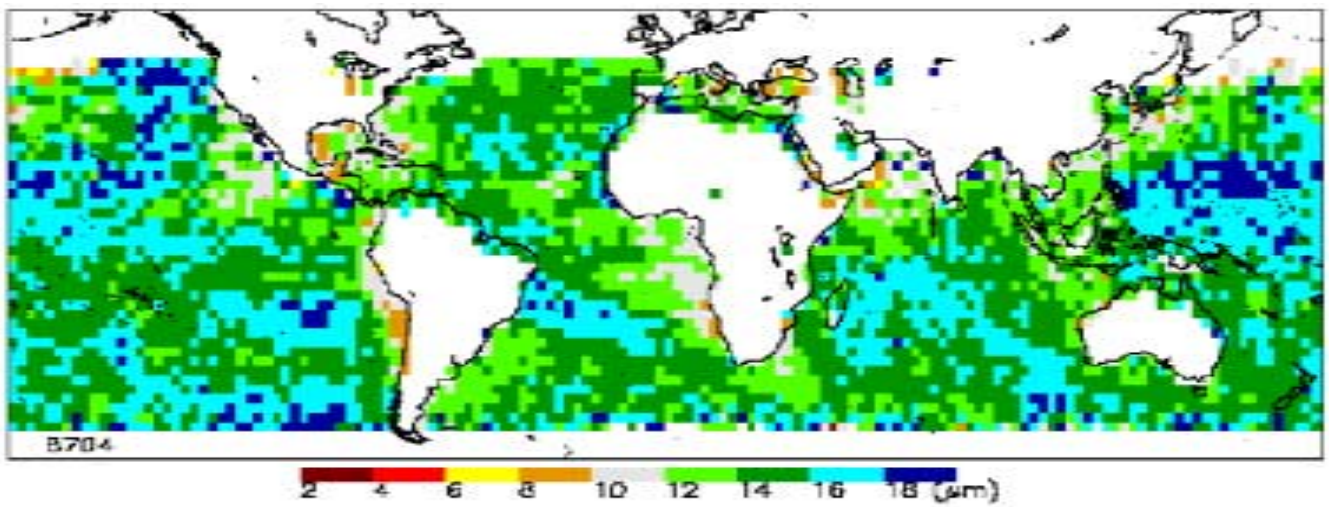
- For backward scattering, overestimation of τ dominates for small τ; but more backscattering in channel 3 dominates for large τ.
- For forward scattering, the shadow effect of channel 3 dominates.

Results of Global Surveys of r_e (8704)



Nadir viewing only

r_e=13.7 μm



All viewing angles

r_e=15.2 μm

Conclusions

- **Larger r_e values are associated with off-nadir viewing geometries in both forward and backward scattering directions due to cloud top morphology**
- **In forward scattering directions, larger r_e is due to the dominating shadow effect**
- **In backward scattering geometry**
  - **smaller r_e is shown only for clouds with relatively large optical thickness (τ>10) due to enhanced ch.3 reflectance**
  - **larger r_e is associated with clouds with smaller τ (τ<10) due to the positive bias of optical thickness**