Three-dimensional radiative transfer considerations in the remote sensing of cloud properties

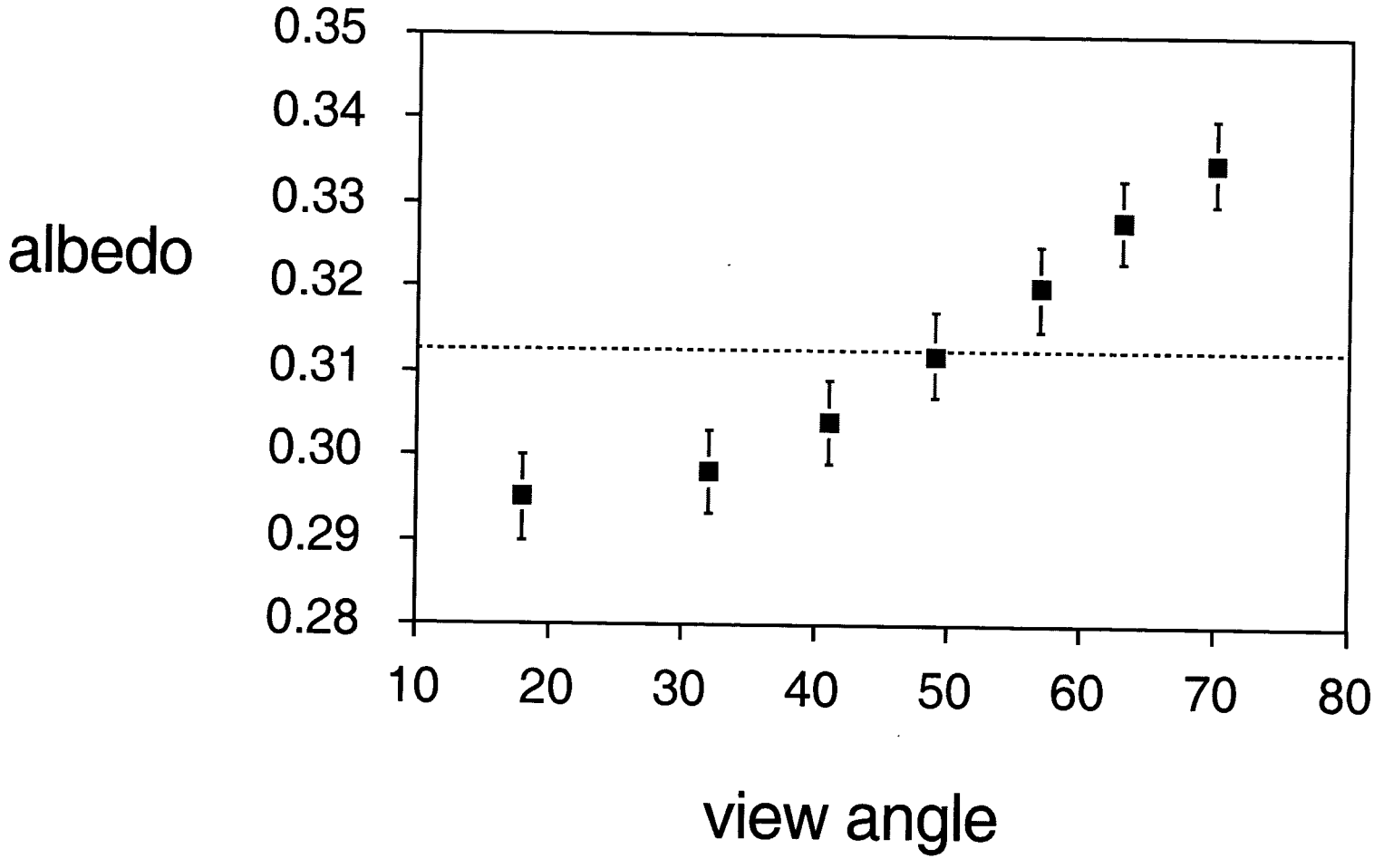
Roger Davies, Jet Propulsion Laboratory
Ákos Horváth, UCLA
Paquita Zuidema, NOAA ETL

overview

- review of past problems
- issues with albedos
- issues with optical depths
- measured heterogeneity
- multi-angle (MISR) solution approaches

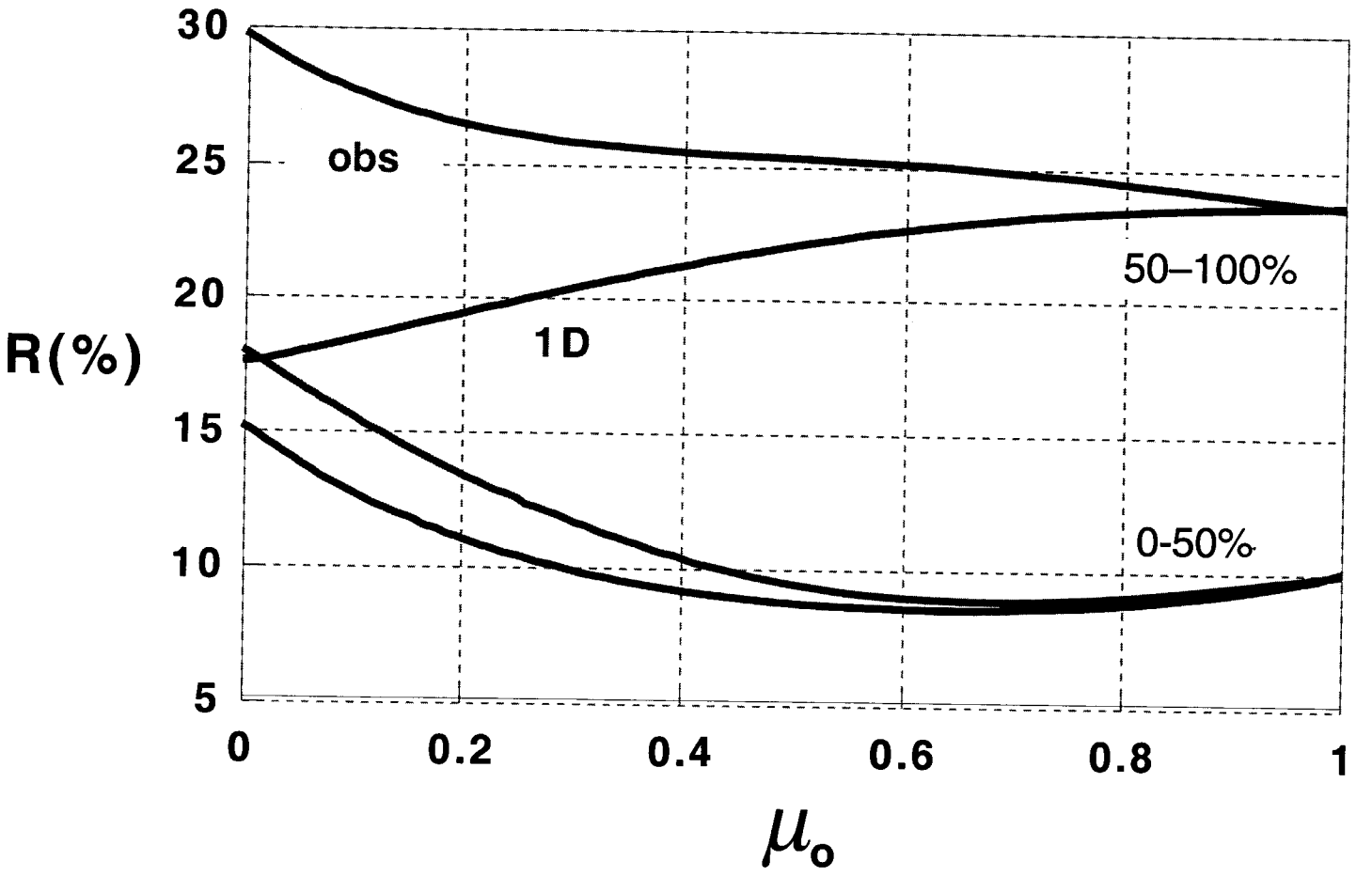
ERBS albedo vs view angle

April 1985



Global oceanic, from Earth Radiation Budget Experiment

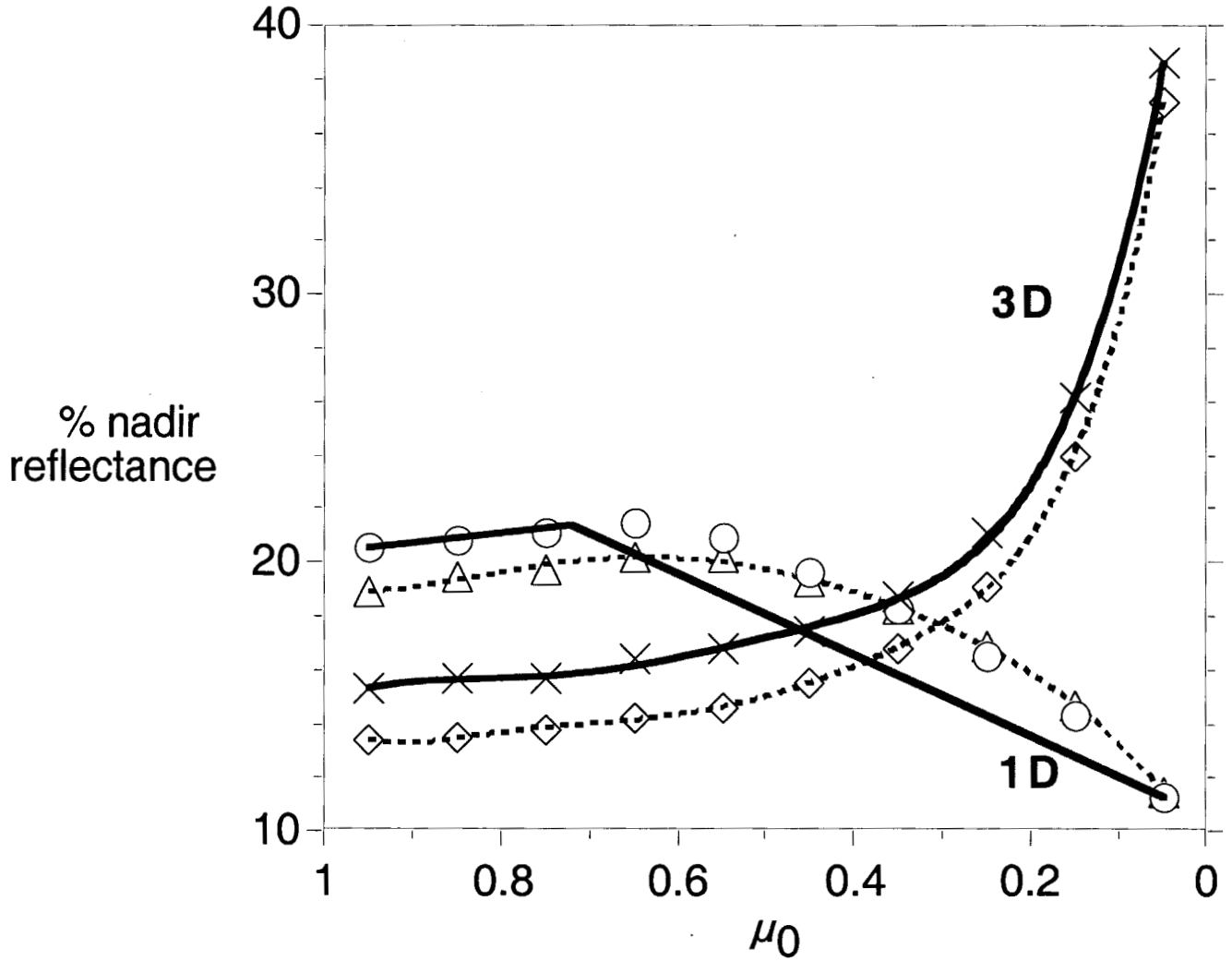
Observed & 1D Nadir Reflectance



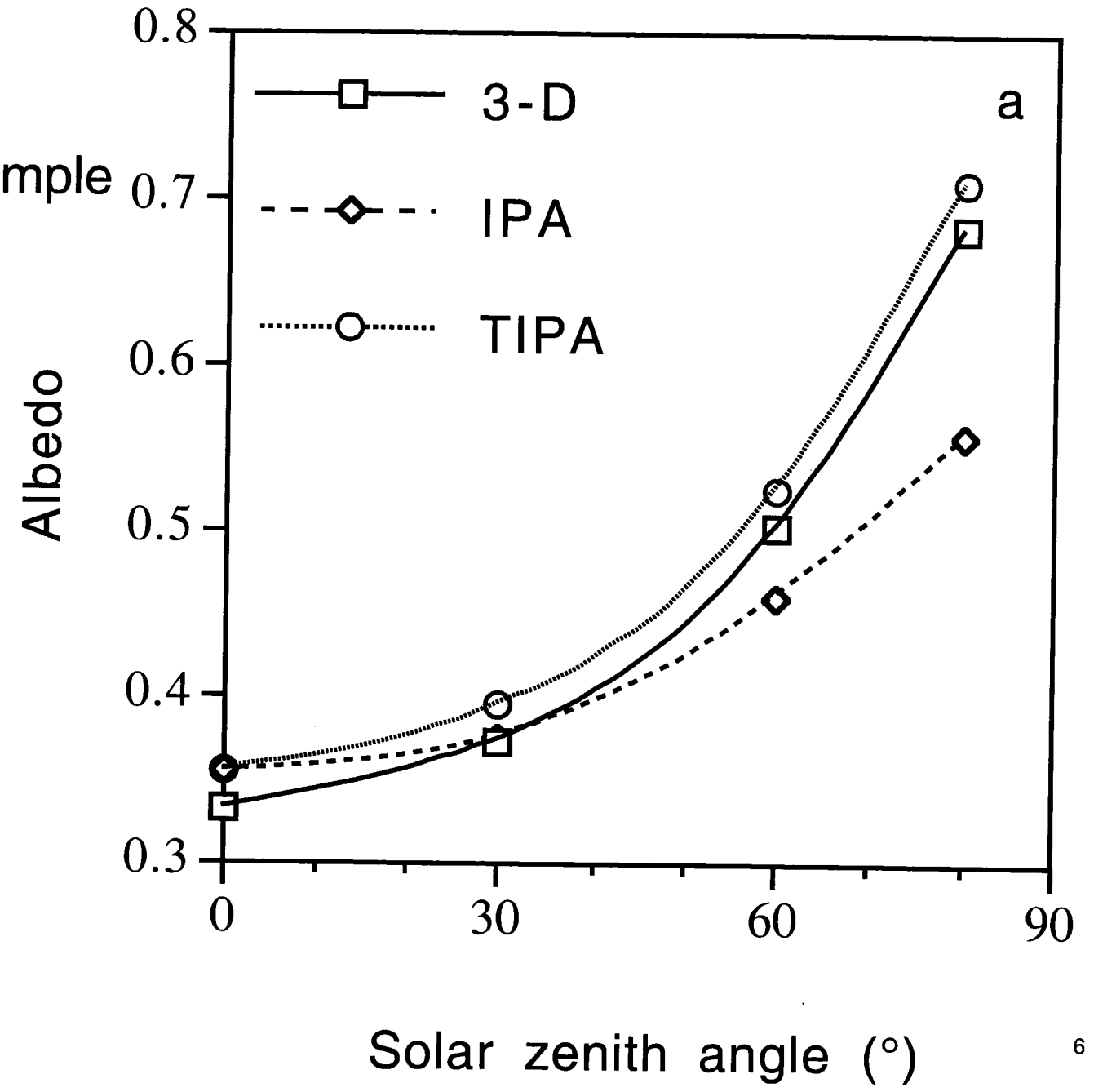
observations are tuned to measurements at $\mu_0 = 1$ (overhead sun)

Loeb and Davies, JGR '95

Comparison of 1D vs 3D and external (solid) vs internal (dashed) heterogeneities. [Loeb, Várnai and Davies, JGR '97]



Case study example from AVHRR

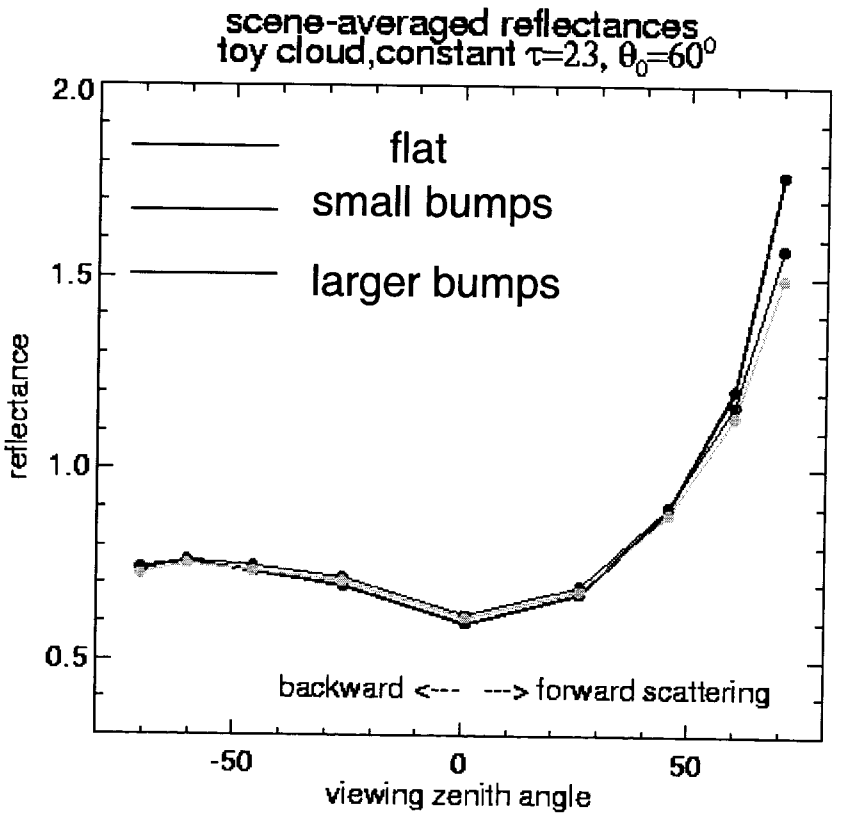


Sub-pixel height variability may also be important

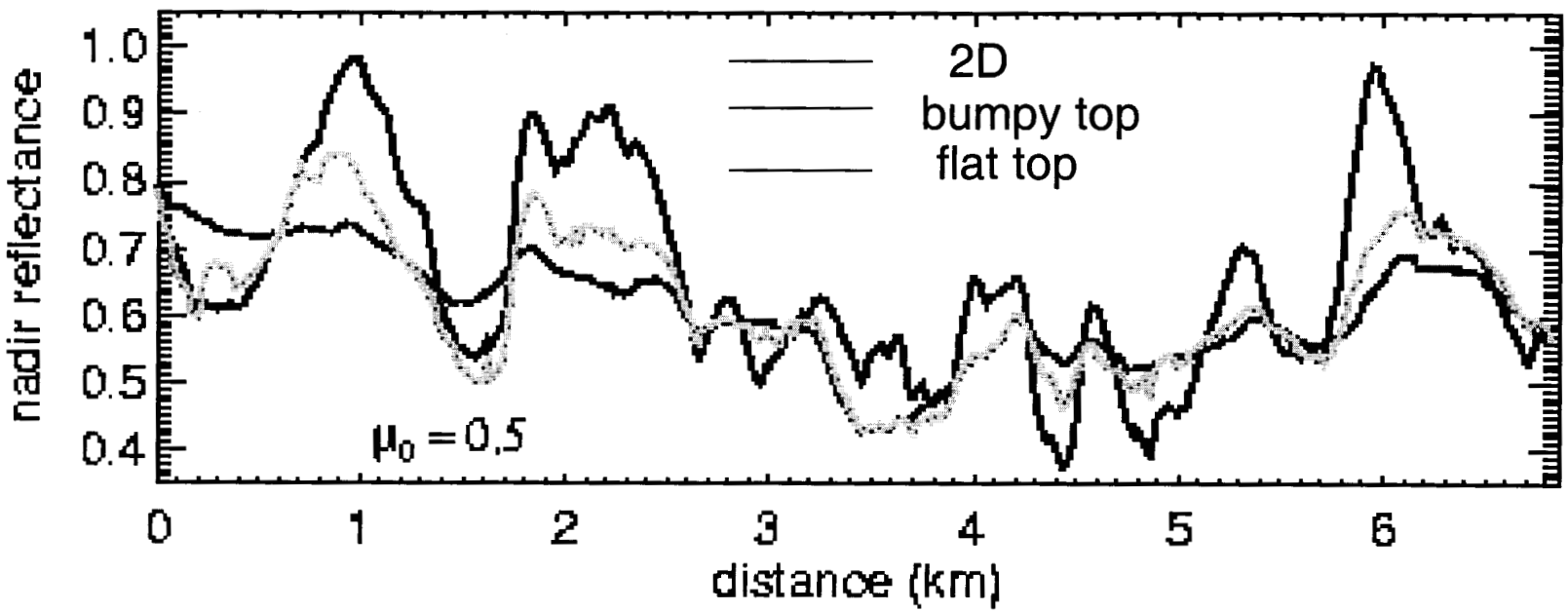
Loeb, Varnai, Winker, 1998: "plane-parallel models significantly overestimate the reflectance dependence on view angle in the forward-scattering direction" (for overcast clouds)

Why? cloud top bumps

(recall MISR heights good to 500 m and are considered flat over the 275 m pixel)



Cloud top bumps have a large influence on nadir reflectances at oblique sun angles



extends Loeb and Davies, 1996

from Zuidema

Spatial homogeneity test

(Genkova and Davies, GRL)

- 16 orbits on April 9, 2001
- 8.8 km nadir radiance within ± 5%
- exclude ice sheets (65°N, 55°S)
- exclude clear ocean
- homogeneity pass rate

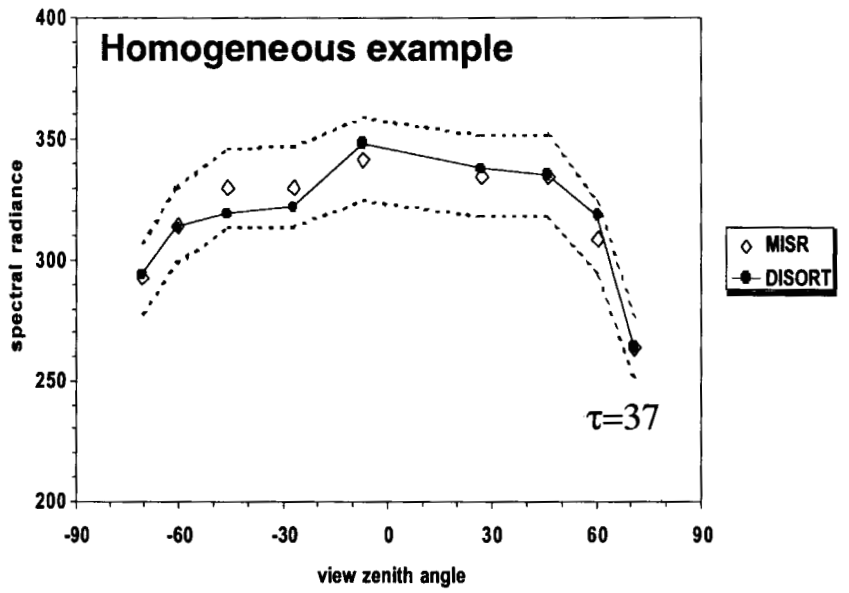
  1.3 (±0.3) %

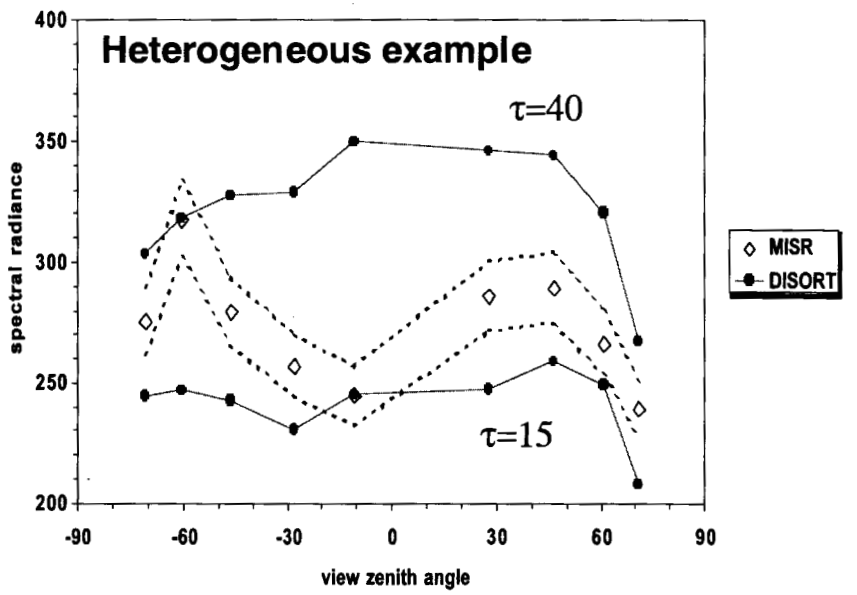
Angular Homogeneity Test

(Horváth and Davies, GRL)

- use IPA optical depth retrievals
- independently camera-by-camera
- tolerance of ± 5% in optical depth implies homogeneous
- apply to entire orbit
  - avoid sun glint views
  - avoid other uncertain surface reflectivity (thin clouds)

Exploring the effect of cloud 3-dimensional structure on retrieval of cloud properties



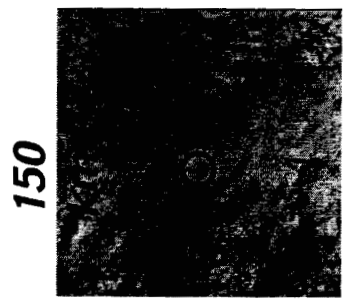


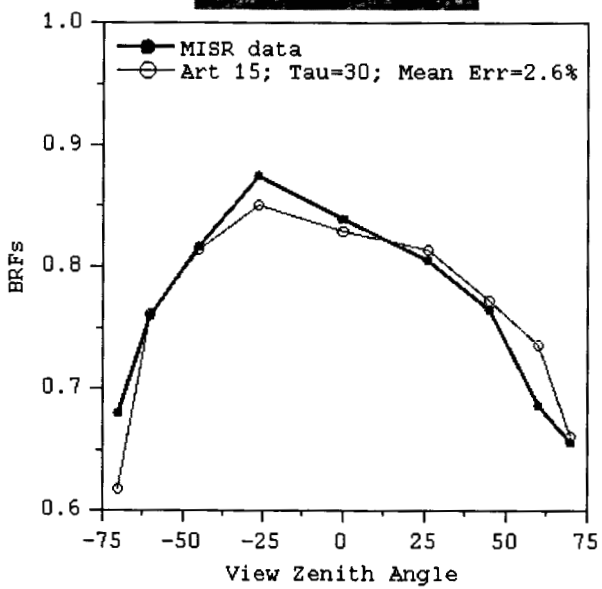
The combination of MISR's spatial resolution and multi-angle data permits testing conventional assumptions used in satellite retrieval of cloud properties.

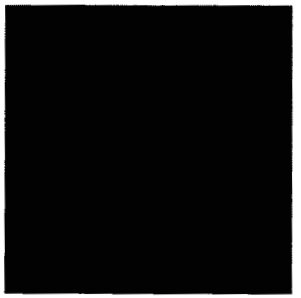
Significance: Conventional 1-dimensional radiative transfer theory assumes cloud horizontal homogeneity. MISR data indicate that this situation occurs < 10% of the time.

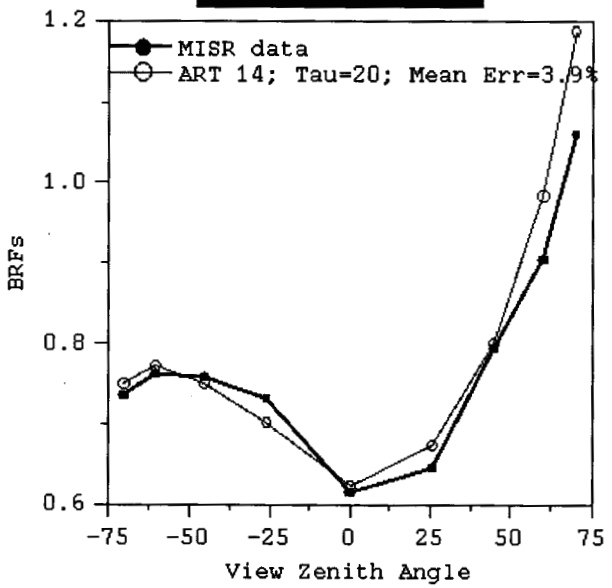
Acknowledgment:
A. Horvath, UofA
I. Genkova, PNNL

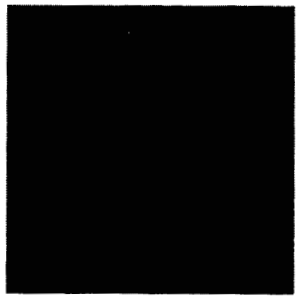
Good agreement with 1D theory for homogenous scenes — can retrieve microphysical properties

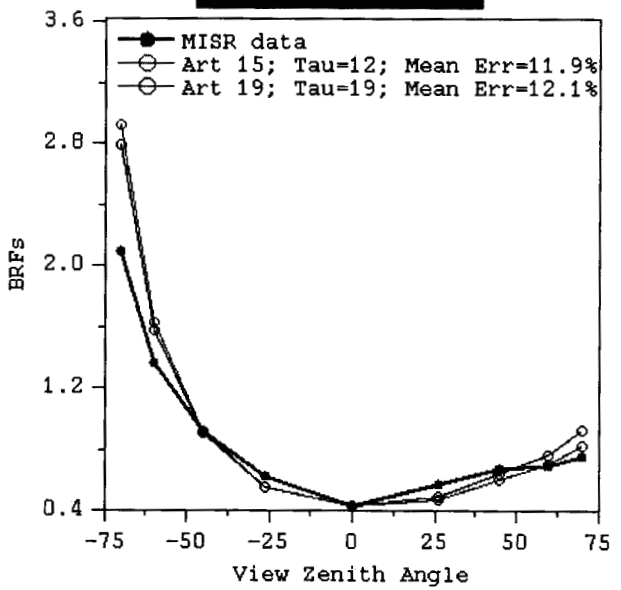












SZA=28°
Hc~5km

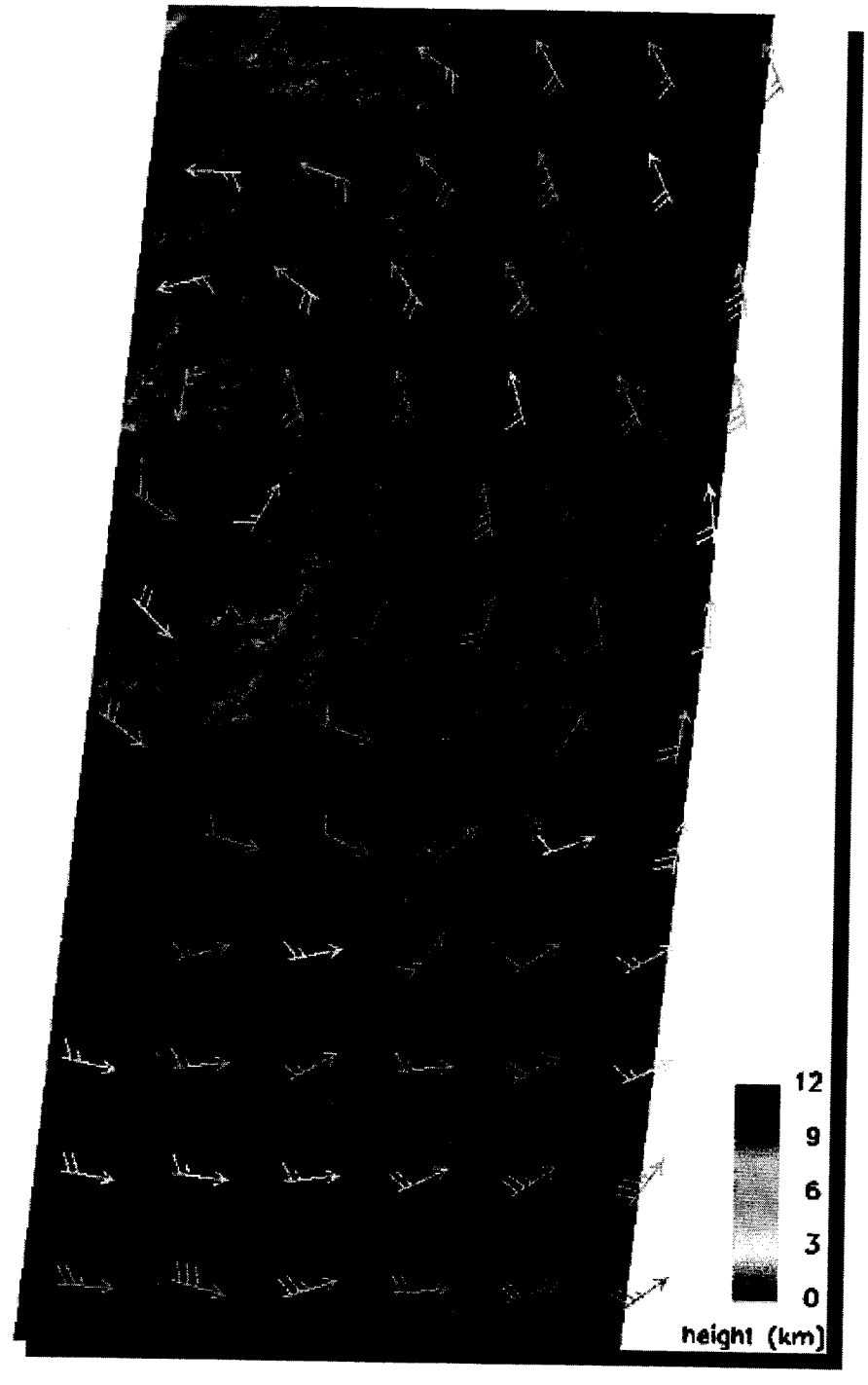
SZA=55°
Hc~2km

SZA=73°
Hc~2km

High density winds

Path 227
Orbit 6964
Block 55-60

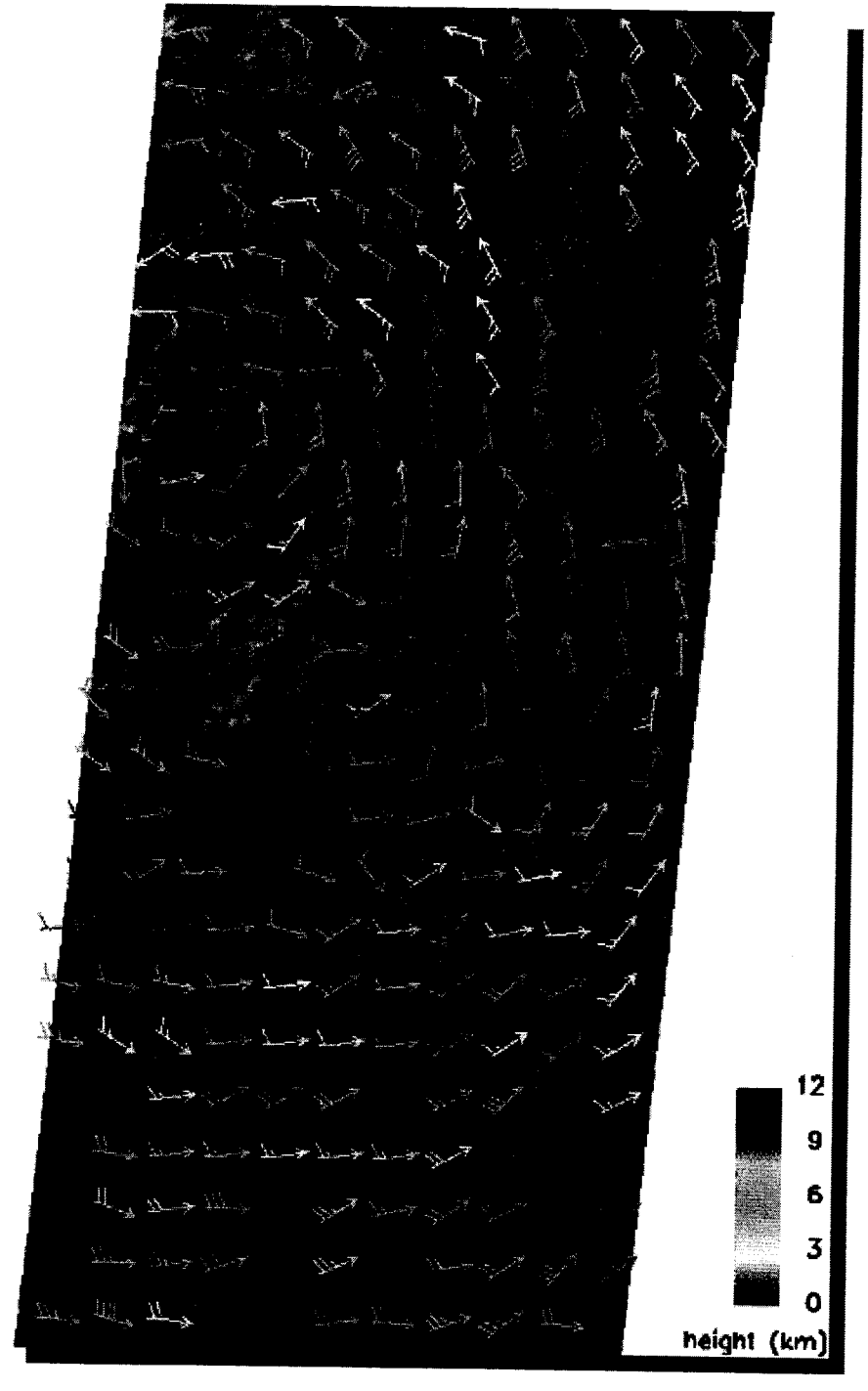
Standard: 70.4 km



High density winds

Path 227
Orbit 6964
Block 55-60

Standard: 35.2 km

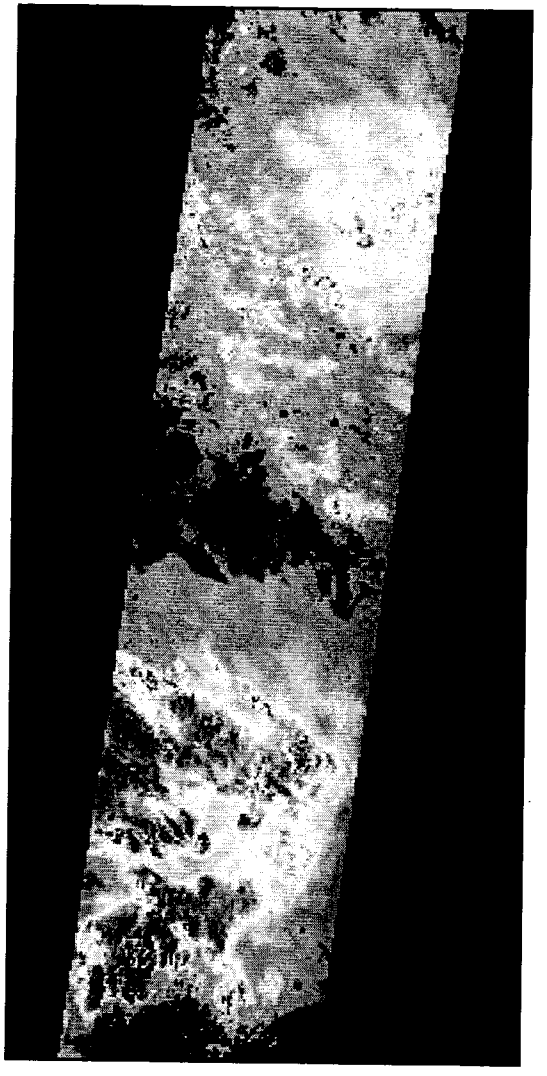


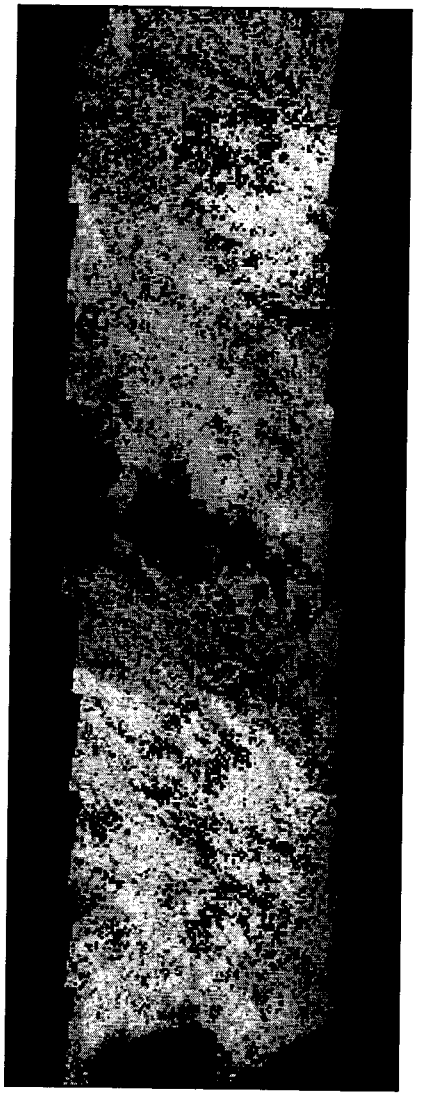
Albedo Improvements

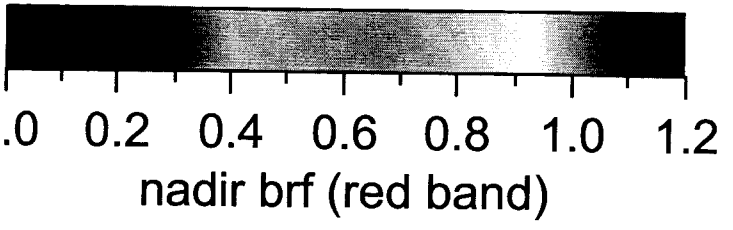
- Deterministic, stochastic and solid angle local albedos
- Expansive albedo
- Restrictive albedo

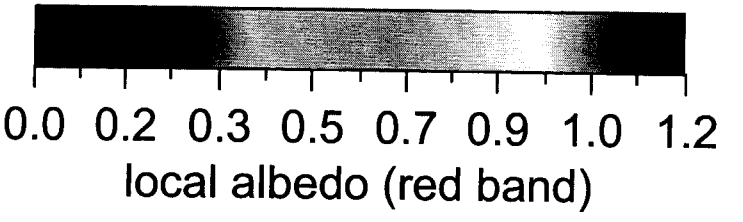
orbit 11268, blocks 91-101

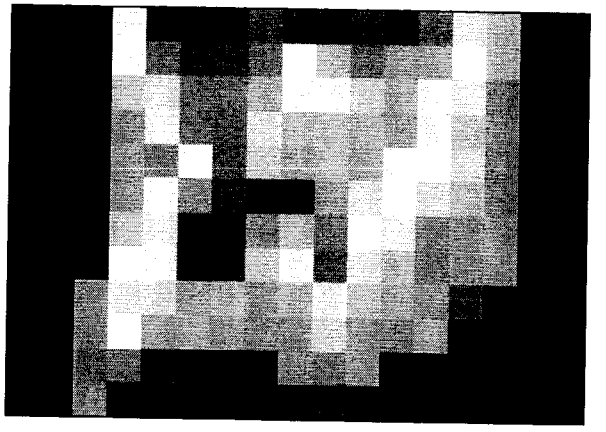
≈1500 km

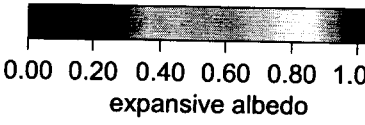




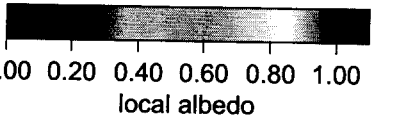




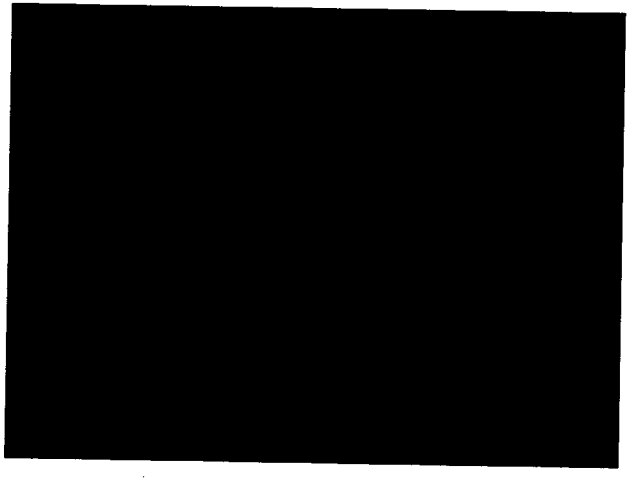




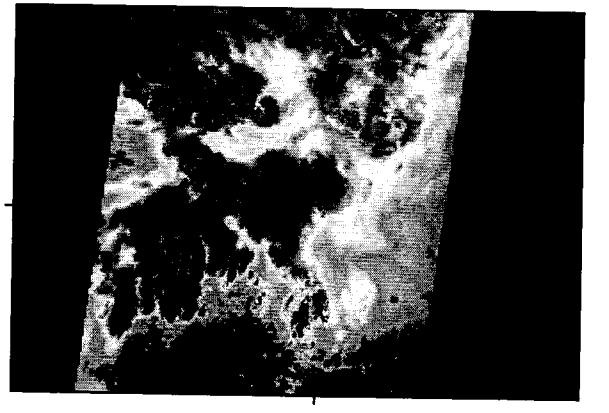
expansive albedo



local albedo



restrictive albedo



nadir brf