3D effects in MODIS observations

Tamás Várnaí¹ and Alexander Marshak²

¹Univ. of Maryland, Baltimore County, ²NASA Goddard Space Flight Center
• Shadowy vs. illuminated cloud sides
• View-angle dependence
• 3D influence on effective radius retrievals
Shadowy vs. illuminated cloud slopes

Solar zenith angle: 20°-25°
- Slopes facing the sun (median \( \tau = 7.7 \))
- Slopes facing away from the sun (median \( \tau = 7.3 \))

Cumulative histogram value vs. Retrieved cloud optical thickness

Solar zenith angle: 50°-55°
- Slopes facing the sun (median \( \tau = 11 \))
- Slopes facing away from the sun (median \( \tau = 9 \))

Cumulative histogram value vs. Retrieved cloud optical thickness
MODIS granule
Ground track of satellite

MODIS observation geometry

Relative azimuth $\approx 60^\circ$ for oblique sun
Dataset

• Virtually all daytime granules for 11 months (8/2004-6/2005)
• About 7% of scan lines
• 11 µm BT and cloud products at 1 km resolution
• High-confidence retrievals
• Liquid cloud phase
High sun

Ocean

Land

Clouds over ocean, $\theta = 30^\circ-55^\circ$

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Clouds over land, $\theta = 30^\circ-55^\circ$

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Low sun

Ocean

Land

Clouds over ocean, $\theta = 55°-80°$

Clouds over land, $\theta = 55°-80°$
Solar zenith angle dependence
Is U-shape correct?
Could surface BRDF cause U-shape?

Thickest third of clouds

![Graph showing average optical thickness vs. viewing zenith angle for thickest third and all clouds]
Could uncertainties in cloud phase cause U-shape?

Warm pixels \( (T > 0^\circ C) \)

Clear-sky uncertainties (aerosol, gas absorption, Rayleigh scattering) unlikely
Could 3D effects cause U-shape?

Pixels far from cloud edges
Could shadowing/side illumination cause U-shape?

\[ \sigma = 20 \text{ km}^{-1} \quad 0 \leq \tau \leq 20 \]
Retrieved $\tau$-fields

Back

Nadir

Forward
1D look-up tables

\[
\theta_0 = 30^\circ
\]

\[
\theta_0 = 70^\circ
\]
3D effects in droplet size retrievals

- $r_{\text{eff}} > 25 \, \mu\text{m}$
Conclusions

MODIS allows statistical analysis 3D radiative effects.

For oblique sun, cloud heterogeneity influences view-angle dependence of MODIS cloud optical thickness.

1D framework appears insufficient to explain observations.

3D radiative effects appear consistent with observations.

3D effects likely influenced droplet size retrievals in Brazilian scene.