

# 3D Radiative Effects in Bi-spectral and Polarimetric Cloud Property Retrievals: Theoretical study using a LES-satellite retrieval simulator

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## What are 3D effects?



Most remote sensing algorithms are based on 1D Radiative Transfer (RT) simulations instead of realistic 3D RT

- Cloud field within each pixel is homogeneous (Homogeneous Pixel Approximation)
- No mutual photon transport among pixels (Independent Pixel Approximation, IPA)

When the clouds deviate from these approximations, we can expect discrepancies in the retrievals

## **Bi-spectral retrievals**

Simultaneously retrieve Cloud Optical Thickness (COT,  $\tau$ ) and Cloud Effective Radias (CER, r<sub>e</sub>) from two spectral reflectances [Nakajima and King 1990],

Water non-absorbing (less-absorbing) band for COT 2. Water absorbing band for CER



Figure 1: Illuminating and shadowing effects in bi-spectral (Nakajima-King) retrievals illustrated using an idealized 1D cloud field named "step cloud".

## Polarimetric retrievals

Uses the angular pattern of the polarized reflectance to retrieve CER and Cloud Effective Variance (CEV) simultaneously [Breon and Goloub, 1998]



Figure 2: Polarized phase function P12( $\Theta_s$ ) as a function of scattering angles for different wave lengths (a), CEV values (b) and CER values (c).



Figure 3: (a) Simulated polarized reflectances for the step cloud case in Figure 1(a) based on 3D and 1D RT simulations in blue and red respectively at VZA = 0 for VNIR band. Corresponding polarimetric retrievals are shown in blue dashed and red dotted lines based on 3D and 1D RT simulations respectively. (b) Angular pattern of the polarized reflectance at the selected locations (2.11, 6.01, 11.95 km) in (a).





2 4 6 8 10 12 14

•	Simulated cloud fields from DHARMA LES
	model [Ackerman et. al. 2004, Zhang et. al
	2012]

Marine Stratocumulus [Stevens et. Al. 2003] RICO: Rain in Cumulus over the Ocean [Rauber et. al. 2007]

• *a* : Scales the optical

•  $\mu, \mu_o$  : Cosines of

scattering

directions

of  $w(\tau)$ 

thickness for multiple

• *b* : Determines the peak

viewing and incident

)	Case	Cloud Fraction (%)	Mean LWP	Mean COT	S.D. COT	Mean CER	Mean CEV
	DYCOMS-II	99	166.0	17.9	6.2	15.8	0.066
	RICO	35	58.1	3.3	9.0	28.4	0.252

Vertically weighted pseudo retrievals

Two variable parametric vertical weighting function for  $\tau$ ,  $w(\tau) = c\tau^{b} \exp[-a\tau(1/\mu + 1/\mu_{o})]$  where c is the normalization constant





$$N_{vw}(r) = \int_0^{\tau_{tot}} N(r,\tau) w(\tau) d\tau$$

Vertically weighted CER and CEV can be obtained using  $N(r, \tau)$ 

[Platnick 2000, Alexandrov et. Al. 2012, Zhang et. al. 2017, Miller et. al. 2017]

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Solar Zenith Angle, SZA = 40° for all simulations and vertically weighted results with "Sun" to the West. Viewing Zenith Angle, VZA = 0 for both vertically weighted and bispectral retrievals.



spectral retrievals.

### Polarimetric retrievals