A Study of the Probability of Clear Line of Sight (PCLoS) through Single-Layer Cumulus Cloud Fields in the Tropical Western Pacific

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Motivation:

Cloud parameterizations within Global Climate Models (GCMs) account for the largest uncertainty in current climate change predictions. One reason for this is that current methods for including sub-grid scale cloudiness invoke unrealistic assumptions about cloud field statistical properties. Specifically, the plane parallel horizontal (PPH) cloud assumption used in parameterizing longwave radiation under broken cloudiness unrealistically neglects three-dimensional cloud radiative effects. While there is currently no broadly accepted solution to this problem, any solution must be physically realistic and tested using a wide array of observations.

Objectives:

- Test various simple Probability of Clear Line of Sight (PCLoS) models at ARM Tropical West Pacific Sites
- Quantify model errors in parameterizing effective cloud fraction N_e and surface longwave downwelling flux F↓ using ARM observations
- Make recommendation of usefulness in GCMs
- Add a new perspective to parameterizing marine boundary layer clouds

Conclusions:

• N_e model agrees with WSI within 0.01 assuming the hemisphere and semi-ellipsoid cloud shape.
• F^{-} calculations are improved by ~2–3 Wm–2 relative to observations using hemispherical and semi-ellipsoidal shaped clouds instead of PPH, at Manus and Nauru respectively.
• Simple, analytical models of the probability of clear line of sight provide an effective means of parameterizing 3D cumulus cloud radiative effects in GCMs.
• Observed cloud side effect was ~ 2–4 Wm–2 on average.

Effective Cloud Fraction:

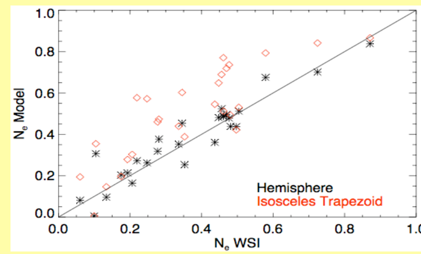


Figure 2 (Above). This scatterplot of N_e WSI versus N_e Model shows the results for the hemisphere and isosceles trapezoid cloud shape. The hemisphere cloud shape resulted in the best results at Manus.

- Effective cloud fraction is determined by integrating,

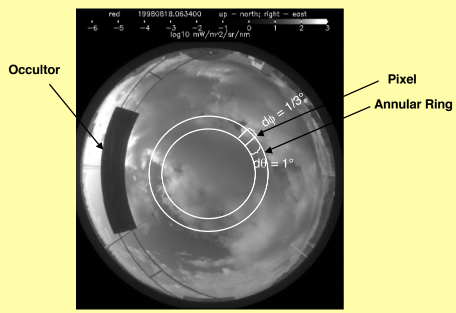
$$N_e = 1 - 2(1-N)\int_0^{\frac{\pi}{2}} P(\mu, s)\mu d\mu$$

from Ellingson (1982), where s refers to assumed cloud shape and μ= cosθ.

- Observed effective cloud fraction is also determined using longwave radiometric flux data showing similar results to WSI.

Observed PCLoS:

Retrieval of PCLoS from WSI

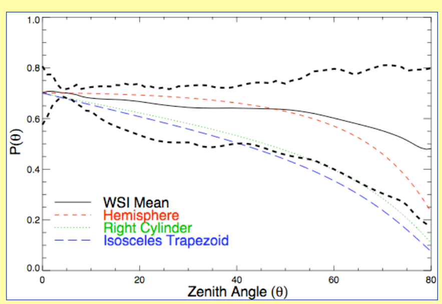


- Find average cloud fraction in each pixel over a 2-hour interval, 13 total images
- Average cloud fraction around an 1° wide annular ring
- PCLoS(θ)=1-N(θ)

Figure 1 (Right). Mean PCLoS at Manus Island for 29 single-layer cumulus cases. The heavy dashed lines represent the 10th and 90th percentile of the observations. The hemisphere cloud shape model resulted in the least error in PCLoS at Manus Island.

Model Calculation of PCLoS

- Necessary information: average cloud aspect ratio β and absolute cloud fraction N.
- Cloud field averaged β and N are found using a combination of ARSCL and Ceilometer data assuming frozen turbulence.
- General form for Poisson distributed PCLoS models: $PCLoS(\theta)=(1-N)^{f(\theta)}$
- Assumed shapes include hemisphere, right cylinder, isosceles trapezoid, semi-ellipse and ellipse.



Surface Longwave Downwelling Flux:

Table 1. Mean model errors in N_e ranged from -0.08-0.12, resulting in downwelling surface flux errors ranging from -4 to 4.5 Wm^{-2}. The surface longwave flux errors are less than 1 Wm^{-2} for the hemisphere and semi-ellipsoid models.

	$N_{e,model} - N_{e,obsPCLoS}$		$F_{model} - F_{ObsPCLoS}$	
PCLoS Model	Manus	Nauru	Manus (Wm^{-2})	Nauru (Wm^{-2})
Right Cylinder	0.10	0.03	4.06	1.48
Isosceles Trapezoid	0.12	-0.08	4.48	-3.44
Hemisphere	0.001	-0.03	0.14	-1.61
Semi-Ellipsoid	0.04	-0.01	1.78	-0.57
Ellipsoid	0.08	0.03	3.24	1.13
Plane Parallel Horizontal	-0.05	-0.07	-1.77	-3.41

- F↓ at the surface is determined using cloud amount weighted average.

$$F^{\uparrow\downarrow} = N_e F^{\uparrow\downarrow}_{cloud} + (1-N_e)F^{\uparrow\downarrow}_{clear}$$

- F↓cloud and F↓clear are determined using radiosonde observations as input into MDTERP (MarylanD Terrestrial Radiation Package.

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