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:

\[
N_e = 1 - 2 \left( 1 - N \right) \int \frac{P(\mu, \sigma)}{2} \mu d\mu
\]

\[
\mu = \cos \theta
\]

Surface Longwave Downwelling Flux:

Table 1. Mean model errors in \(N_e\) ranged from -0.08 to 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.

<table>
<thead>
<tr>
<th>Model</th>
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<tbody>
<tr>
<td>PCLoS</td>
<td>-0.12</td>
<td>-0.08</td>
<td>4.48</td>
<td>-3.44</td>
</tr>
<tr>
<td>Right Cylinder</td>
<td>0.10</td>
<td>0.03</td>
<td>4.06</td>
<td>1.48</td>
</tr>
<tr>
<td>Semi-Ellipsoid</td>
<td>0.04</td>
<td>-0.01</td>
<td>1.78</td>
<td>-0.57</td>
</tr>
<tr>
<td>Ellipsoid</td>
<td>0.03</td>
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<tr>
<td>Plane Parallel</td>
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