Finite Cloud Effects at the ACRF TWP Site

Patrick Taylor and Robert G. Ellingson
Dept. of Meteorology, Florida State University, Tallahassee, FL 32306

Introduction:

- Most GCMs use a cloud amount weighted average to calculate upward and downward fluxes, Eq. (1).
  - Eq. (1) $F^{\uparrow\downarrow} = N F^{\uparrow\downarrow}_{cloud} + (N-1) F^{\uparrow\downarrow}_{clear}$
- Eq. (1) neglects (See Fig. 1):
  - Inhomogeneity of Cloud Microphysical Properties
  - 3D Cloud Field Bulk Geometry
  - Varying Cloud Thermodynamic Properties
- The difference in surface longwave forcing due to finite 3D clouds when compared to infinite clouds, referred to as (CSE) cloud side effect (i.e. (A) - (B) from Fig. 1), has been measured to be as much as 15 W m^{-2} (Heidinger and Cox 1996).

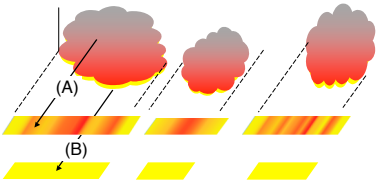


Fig 1. This schematic illustrates the contributions to the surface flux from (A) a realistic non-isothermal cloud field with inhomogeneous optical properties and 3D geometry and (B) considering a Plane Parallel cloud field with homogeneous optical properties.

Data:

- Observations are taken at the ACRF TWP Site from June 1999 through May 2003 and obtained from the ARM Data Archive.
- These instruments are used to extract cloud field parameters using the frozen turbulence approximation. The cloud parameters are used as input in to the PCLoS Models to determine N_e.

Instrument	Observations	Parameter(s) Extracted
Ceilometer	Cloud Base Height	Cloud Base Height, Cloud Base Length, N
ARSCL	Cloud Boundaries	Cloud Thickness
Radiosonde	Wind Speed	Cloud Base Length
Whole Sky Imager	Hemispheric Radiance	PCLoS, N, N_e
Pyrgeometer	Longwave Diffuse Downwelling Flux	N_e

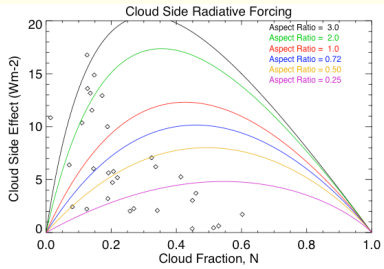
Summary and Conclusions:

62 two-hour intervals of single-layer cumulus clouds are studied at the ACRF TWP site.

The effective cloud fraction can be calculated using the PCLoS inferred from the Whole Sky Imager with some skill.

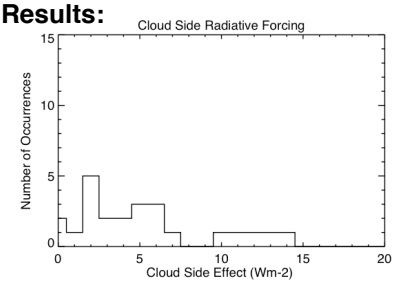
The mean cloud side effect (CSE) in the longwave at the surface is 7.15 W m^{-2} at Manus and 11.50 W m^{-2} at Nauru. The larger observed CSE at Nauru coincides with a larger mean aspect ratio. The mean CSE at the ACRF TWP considering all cases is 8.07 W m^{-2}.

The mean cloud side effect reported by Heidinger and Cox (1996) is very similar to the results presented here, despite the appearance of larger clouds at TWP. This is a result of two competing effects: (1) increased CSE with increased aspect ratio and (2) decreased CSE with smaller differences between clear and overcast downwelling fluxes.

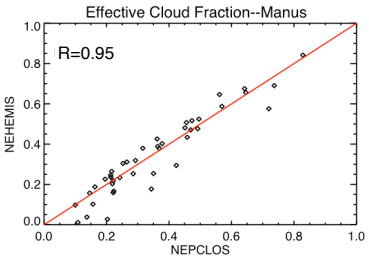


The cloud side effect (CSE) is plotted against cloud fraction N. The curves represent lines of equal aspect ratio. The CSE increases with increasing aspect ratio until mutual shading occurs. This graph presents a summary of the single-layer cumulus cloud field cases at TWP, representing the distributions of average cloud size, cloud fraction, and average CSE measured.

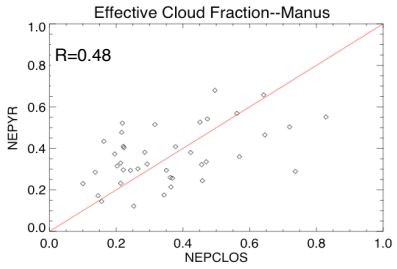
Results:



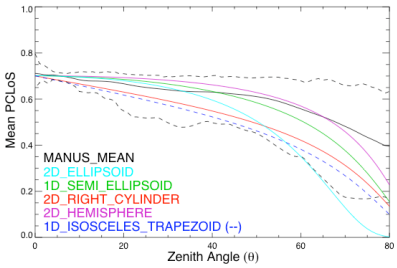
- Mean Flux from Cloud Side Emission:
  7.15 Wm^{-2} at Manus
  11.50 Wm^{-2} at Nauru



- The PCLoS Models are used to predict the effective cloud fraction. All of the models performed well despite a seemingly large error of approximately 0.1 in the model PCLoS values.



- The effective cloud fraction is determined using PCLoS from the WSI. Pyrgeometer data and MDTERP longwave radiative transfer model are used to validate the PCLoS effective cloud fractions.



- The PCLoS models are tested using the PCLoS inferred from the WSI. The Hemisphere and Semi-Ellipsoid model resulted in the least error at Manus and Nauru, respectively. The differences are a consequence of a larger mean cloud aspect ratio at Nauru.

Corresponding Author: Patrick Taylor
Email: ptaylor@met.fsu.edu
Phone: (850) 644-3340