CLOUD FRACTION: CAN IT BE DEFINED AND MEASURED?

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MOTIVATION

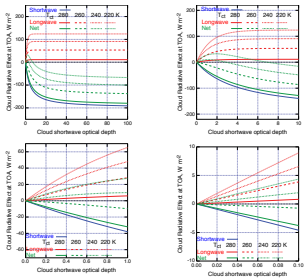
- Clouds are the most uncertain component of GCMs.
- Climate sensitivity in GCMs depends strongly on the representation of clouds.
- GCMs must be evaluated on the basis of their representation of clouds.
- Cloud fraction is the zeroth order measure of clouds in models and observations.

Surprisingly, and in spite of the fact that we deal with clouds on a daily basis, to date there is no universal definition of a cloud. . . . Ultimately, the definition of a cloud depends on the threshold sensitivity of the instruments used in cloud studies.

Clothiaux, Barker & Korolev (2005)

Cloud influences are not all the same

CLOUD RADIATIVE EFFECT – DEPENDENCE ON OPTICAL DEPTH AND CLOUD-TOP HEIGHT

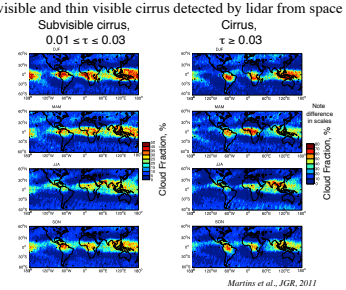


Shortwave TOA CRE is 24-hour average at equinox for latitude of ARM SGP site. Surface temperature, 285K; surface albedo, 0.15.

Even for thin cirrus clouds, τ_{SW} ~0.01, the radiative effects are substantial, -0.5 W m^{-2} in the shortwave and as great as 1.8 W m^{-2} in the longwave.

OPTICALLY THIN CLOUDS CAN BE PREVALENT, ESPECIALLY IN TROPICS

Subvisible and thin visible cirrus detected by lidar from space

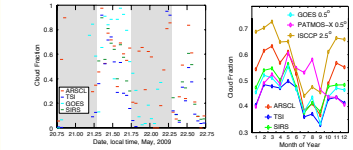


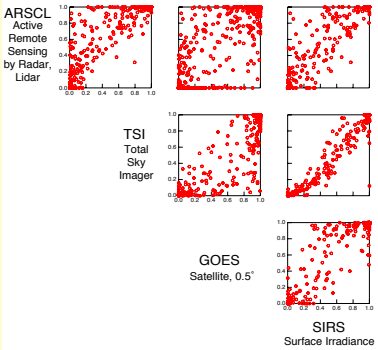
Martins et al., JGR, 2011

THE CHALLENGE

DIFFERENT MEASURES YIELD VERY DIFFERENT CLOUD FRACTION

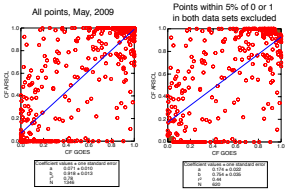
Cloud fraction at SGP by multiple methods



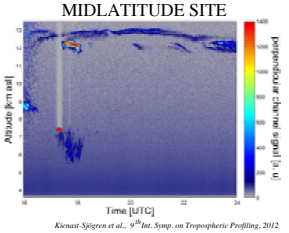


CORRELATION IS DOMINATED BY ONES AND ZEROES

Cloud fraction at SGP by ARSCL AND GOES, May, 2009



PERSISTENT VERY THIN CIRRUS AT MIDLATITUDE SITE

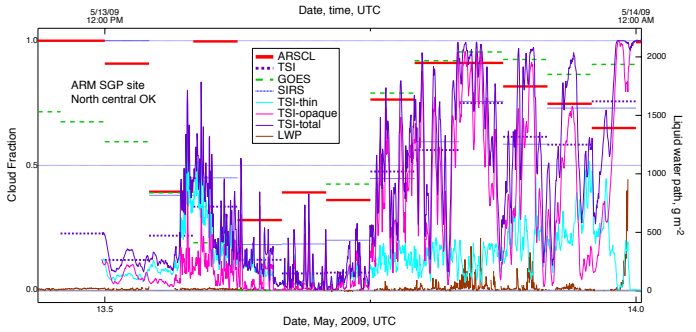


Kienast-Sjögren et al., 9th Int. Symp. on Tropospheric Profiling, 2012

Optical depth of cirrus layer estimated as 0.003 to 0.004.

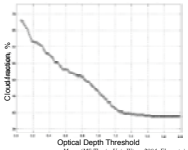
SOME ISSUES

Cloudiness is highly variable



THRESHOLD DEPENDENCE

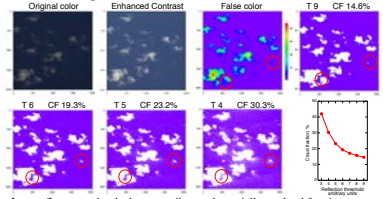
In lidar retrievals of cirrus



Moves (MS Thesis, Univ Wisc., 2004, Elevanta)

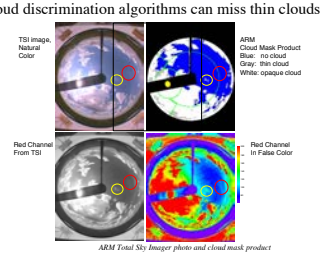
Fraction of time cloud detected by lidar as function of optical depth threshold during a single night of observations.
Cloud fraction increases strongly with decreasing threshold.

In images of clouds above dark (ocean) scene



Low reflectance cloud edges contribute substantially to cloud fraction.
Difficult to find threshold that avoids false positives and false negatives.

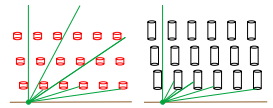
Cloud discrimination algorithms can miss thin clouds



ARM Total Sky Imager photo and cloud mask product

CLOUD SIDEWALL EFFECT

Both cloud fields have same cloud area fraction



Vertical view angle yields same cloud fraction.

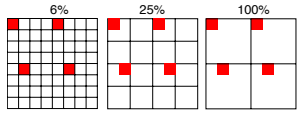
Slant view angle yields artifact high cloud fraction because of cloud sidewalls, more so for tall clouds.

Pertains to cloud fraction from surface and satellite.

The effect can be minimized by restricting viewing zenith (or nadir) angle to within ± 50°.

RESOLUTION EFFECT

Fraction of pixels containing some cloud



BOTTOM LINES

- Cloud fraction is inherently binary and cannot account for highly variable cloud properties.
- Cloud fraction alone is thus not very informative.
- Measured cloud fraction depends on threshold, resolution, measurement technique, etc.
- Evaluation of model representation of clouds might better focus on continuous properties such as liquid (ice) water path or optical depth.