A 10-year climatology of cloud fraction and vertical distribution derived from both surface and GOES observations over the DOE ARM SGP Site

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Motivations

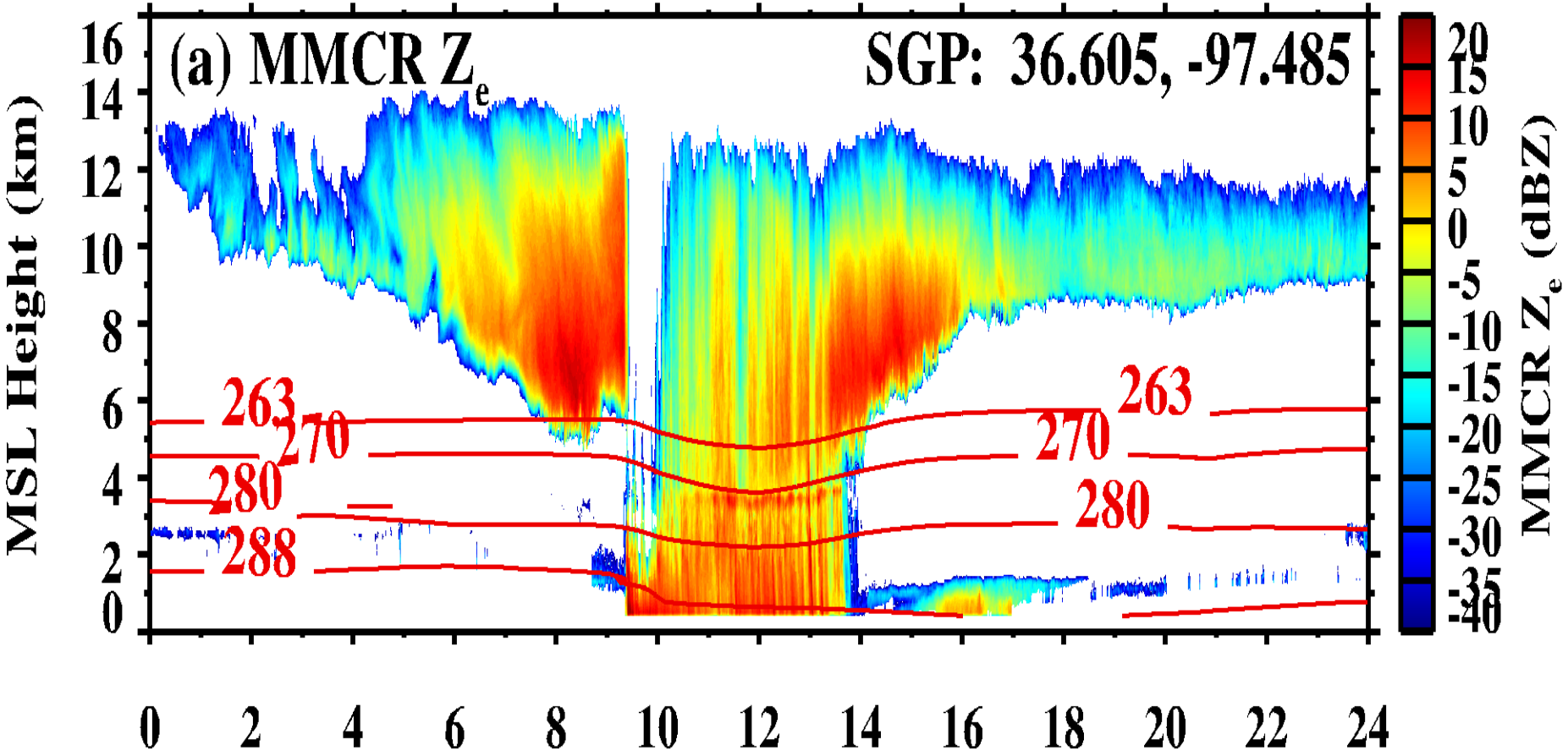
- How can temporal observations, like ARM measurements, compare to the areal observations or GCM grid box outputs?
- How can the ARM observations be used to evaluate the model simulations?

➔**point obs. VS areal obs. or grid box simulation**

Objectives

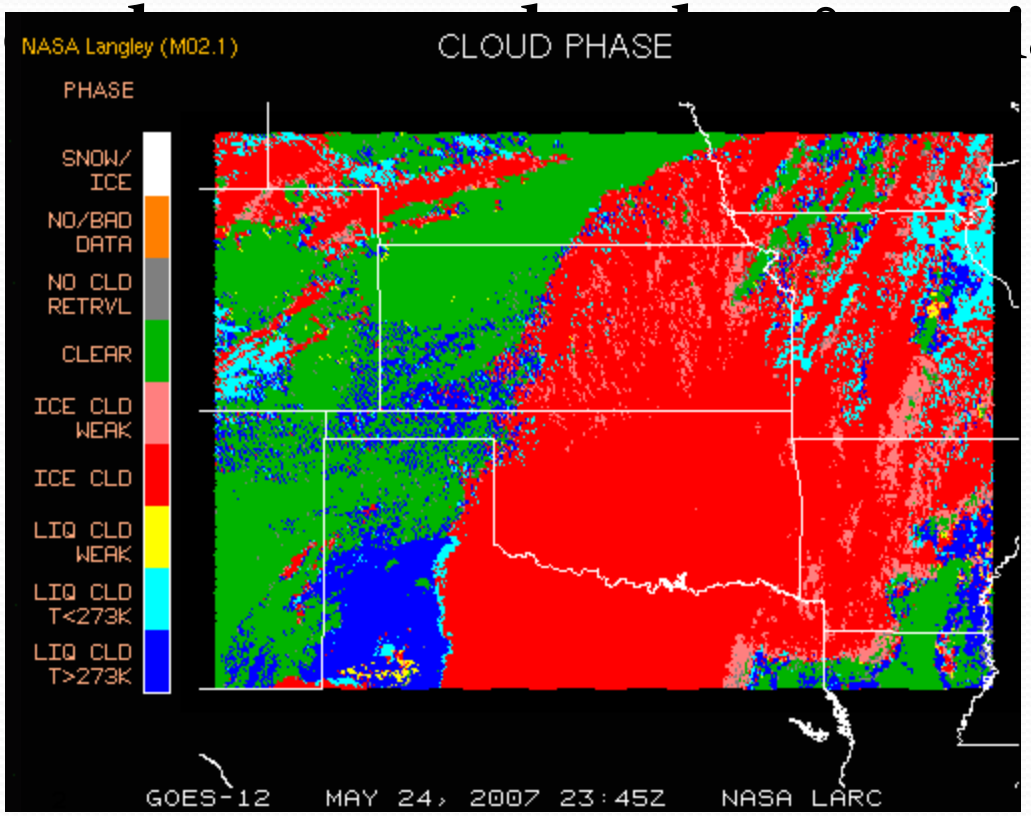
1. How well do the temporally averaged surface ARM data compare with the spatially averaged GOES data?
2. What point observations can be directly compared with areal observations?
3. How does cloud vertical distribution vary with different spatial resolutions, and seasons?
4. What about cloud fractions over ARM TWP sites and NSA site?

ARM Millimeter Wave Cloud Radar (MMCR)



GOES Satellite product:

- GOES satellite retrieved cloud and radiation properties by the NASA Langley (Minnis) group (1998-2007)
- al resolutions



Compatibilities

Area (SAT) vs. Area (MODEL) (Apples to Apples)	Point (MMCR) vs. Area (SAT/MODEL) (Apples to Oranges)
Cld. Amount = Cld. Amount Cld. Frequency = Cld. Frequency Cld. Fraction = Cld. Fraction	Cld. Amount ≠Cld. Amount Cld. Frequency ≠ Cld. Frequency Cld. Fraction = Cld. Fraction CF= AMT x FREQ

However:

$$\lim_{a \to 0} f_{area}(a) = f_{point} \qquad \lim_{t \to x} f_{point}(t) = f_{area}$$

Variables will become identical!

How do satellite frequency/amount compare with ARM results?

Point (ARM) vs. Areal (GOES)

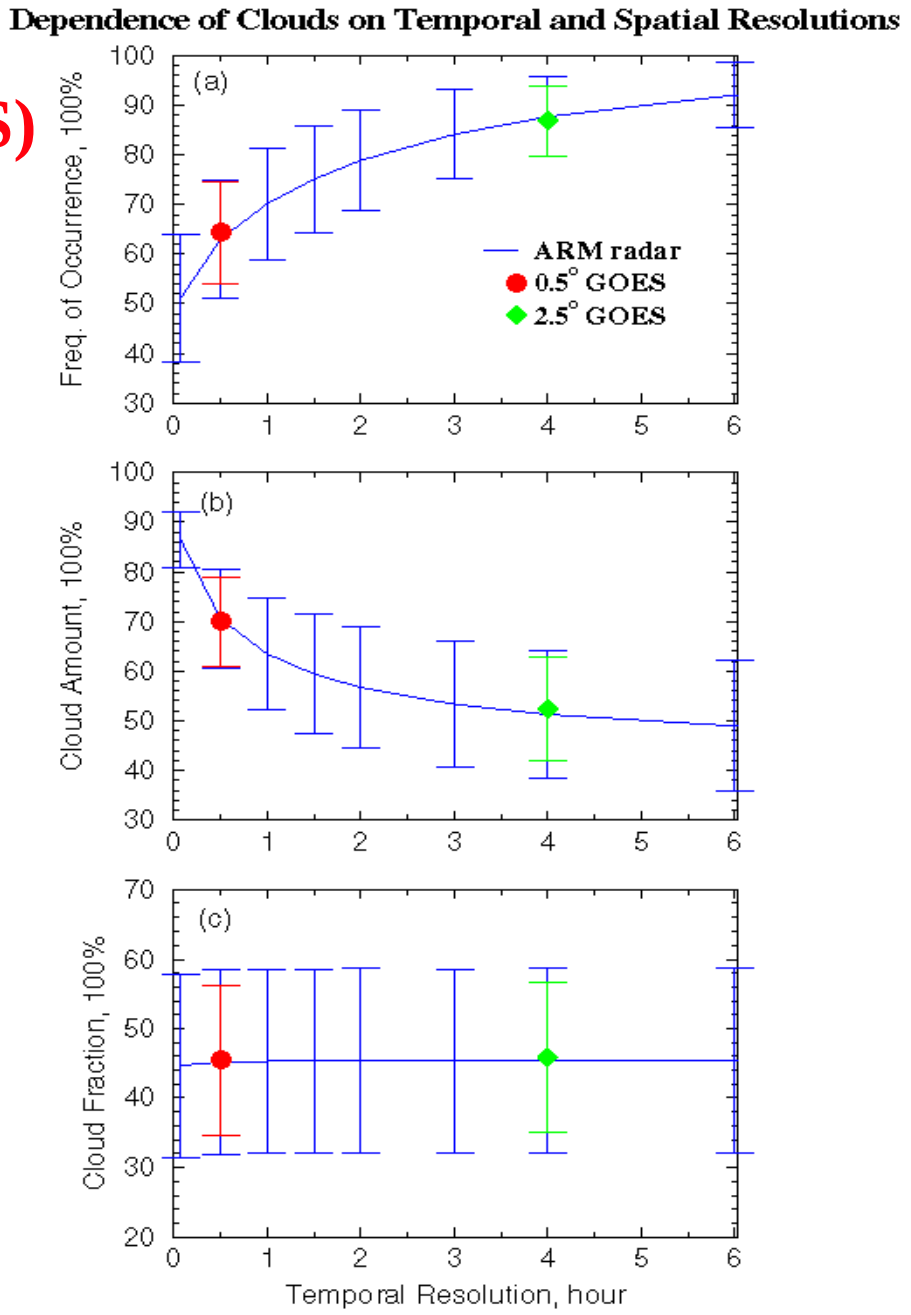
Cloud occurrence/amount

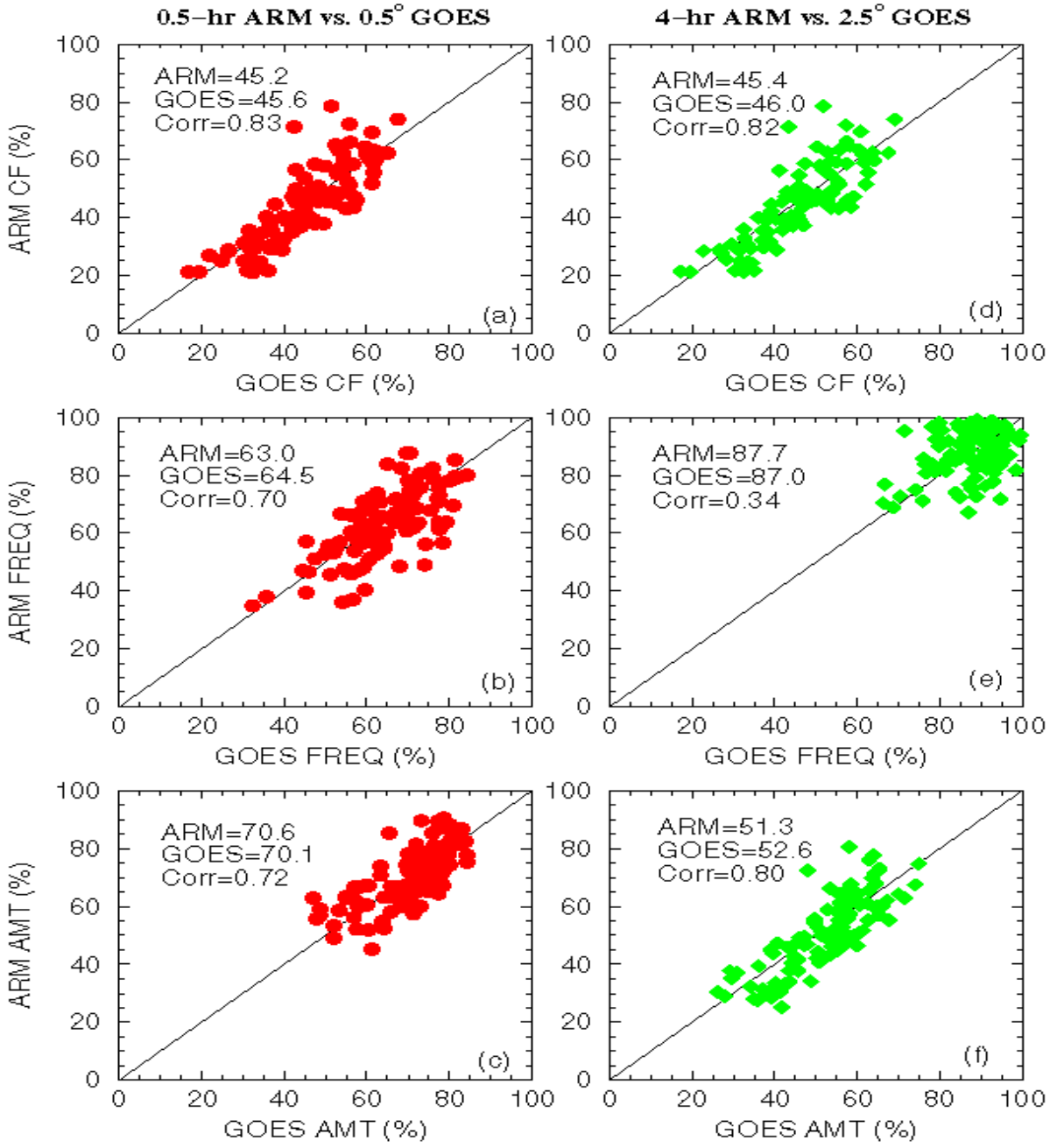
Cloud frequency increases and cloud amount decreases as the temporal and spatial averaging scales increase.

0.5-hr ARM ~ 0.5° GOES

4-hr ARM ~ 2.5° GOES

Cloud Fraction (AMT x FREQ) is independent of temporal and spatial resolutions.

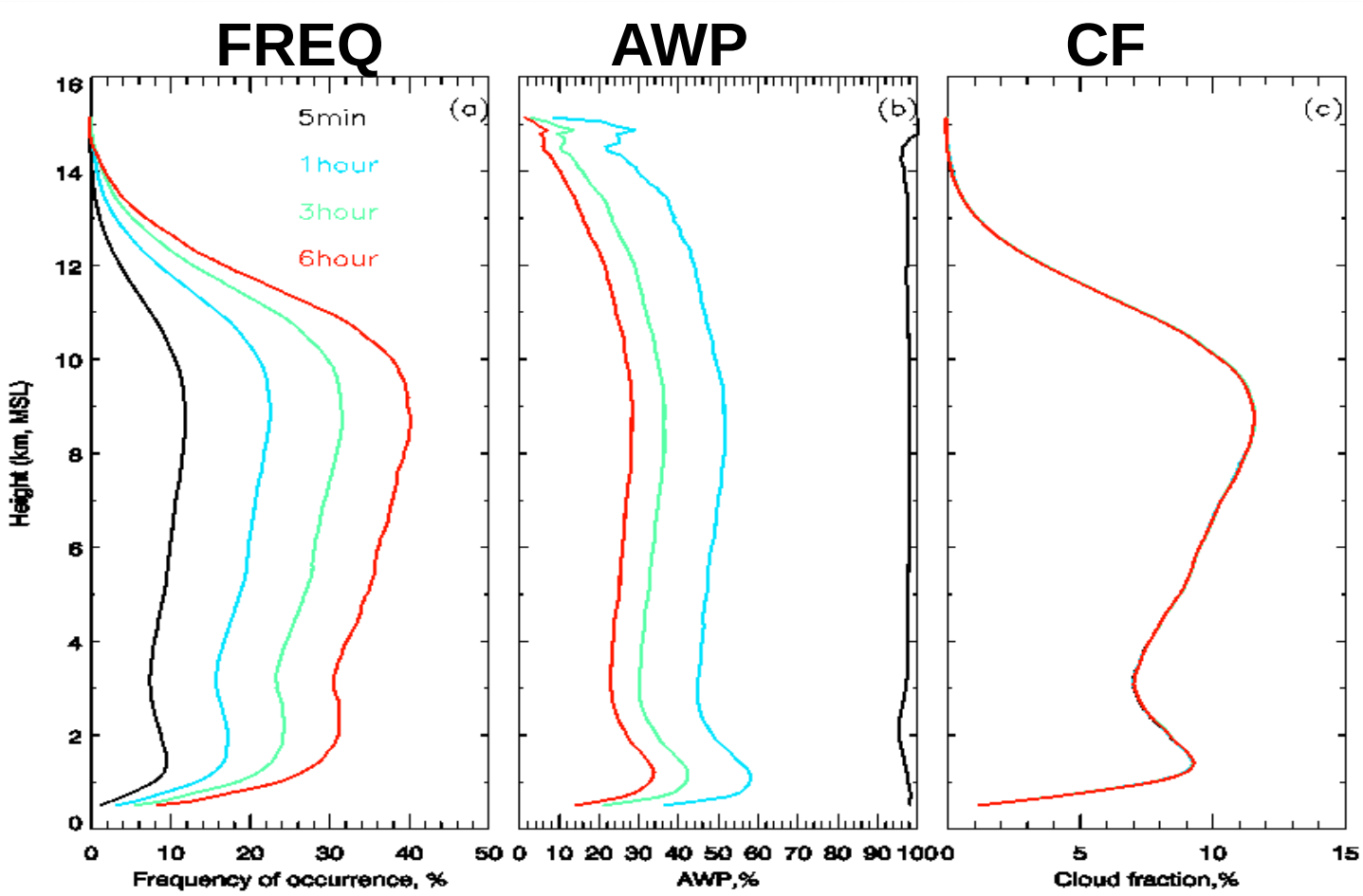




The long-term averaged surface and GOES cloud fractions agree to within 0.5%.

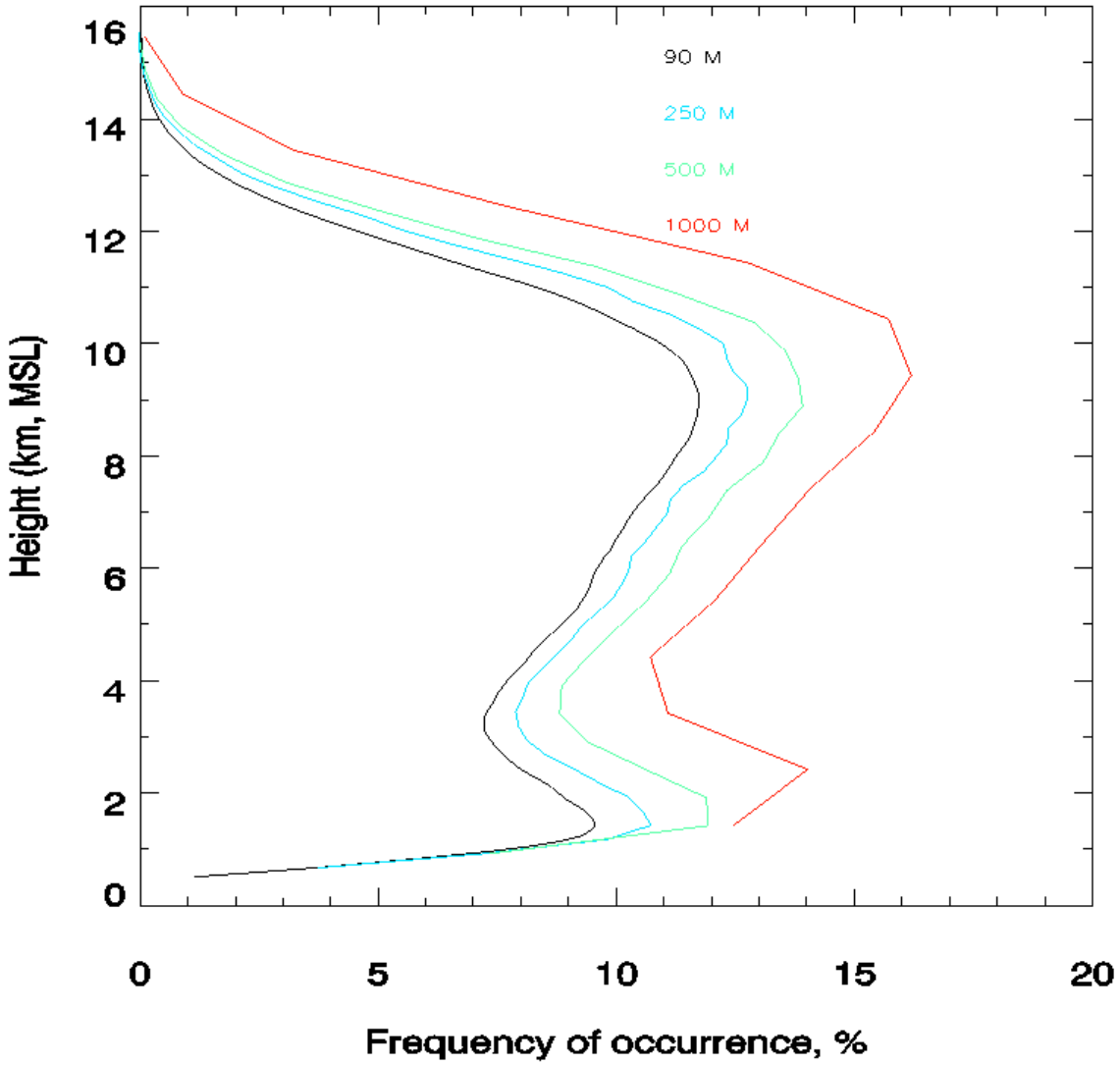
If we match the temporal and spatial resolutions, 0.5-hr vs. 0.5º, then the cloud frequency/amount between two data sets can agree to 0.7%

Cloud Vertical distributions (time)



Cloud FREQ increases, Amount decrease with increased temporal resolution. Again CF is independent.

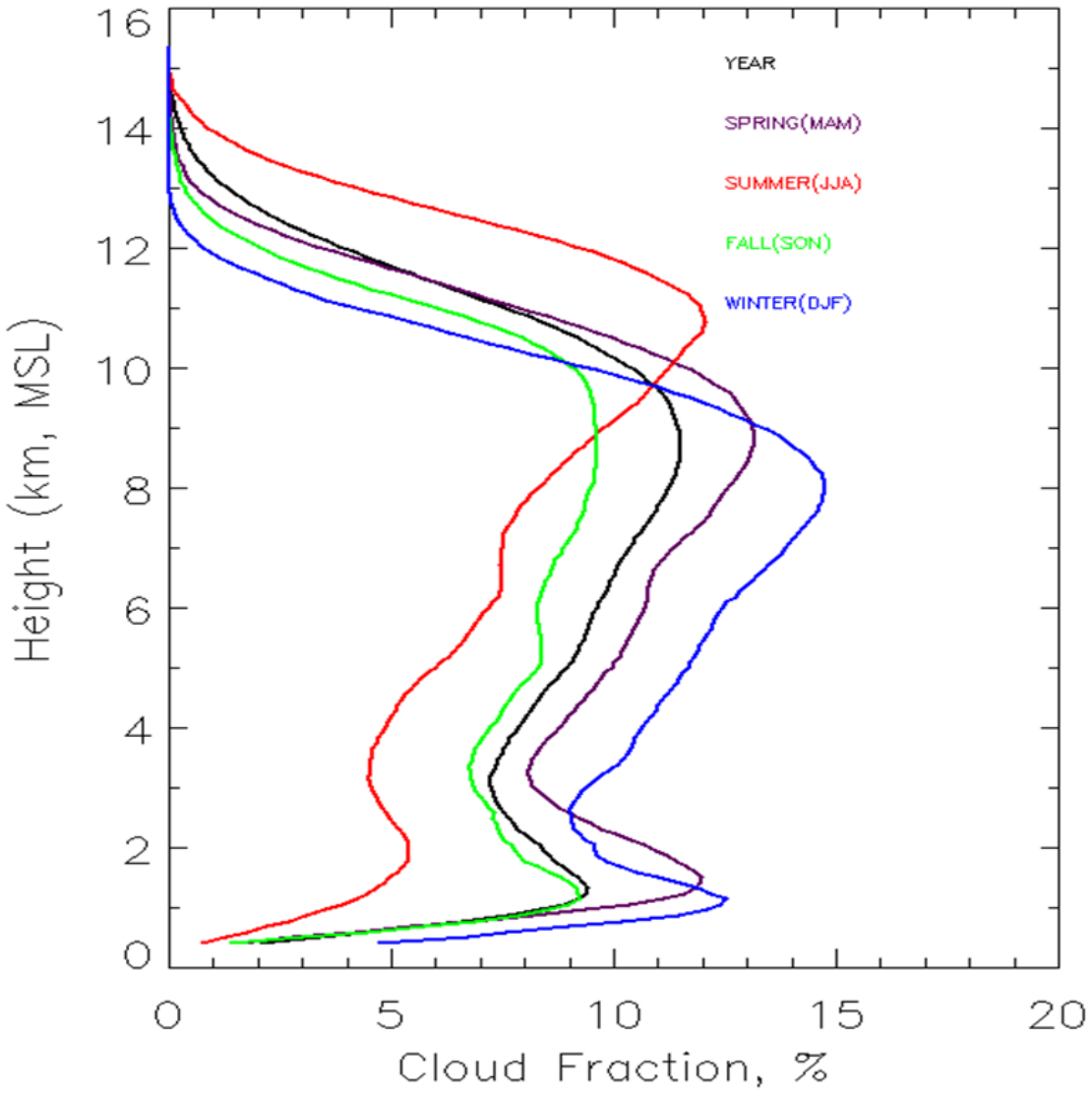
Cloud Vertical distributions (height)



1. The frequency of occurrence increases with the vertical resolution (so be careful when comparing with model results)

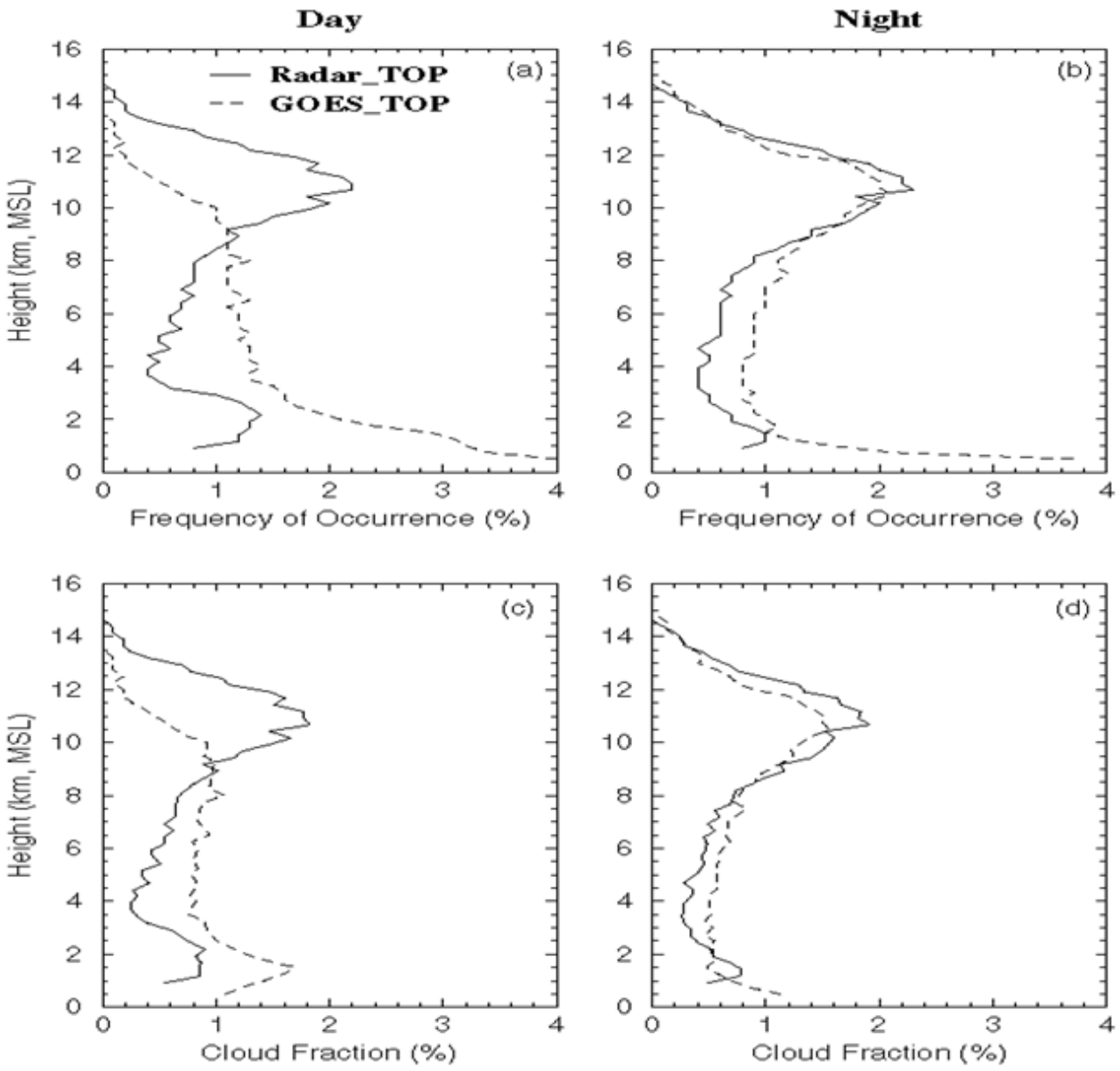
2. Though the vertical resolution varies from 90 m to 500 m, the bimodal distribution keep the similar shape with about 1-2% increasing in Freq.

Seasonal variation of cloud vertical distribution



- **Bimodal distribution for all the seasons;**
- **Lower peak locates between 1 and 2 km, and Higher peak locates between 8 and 11 km;**
- **The peaks of the Fall and Spring seasons have the similar altitude as those of annual distribution;**
- **More clouds in Winter and less in Summer.**

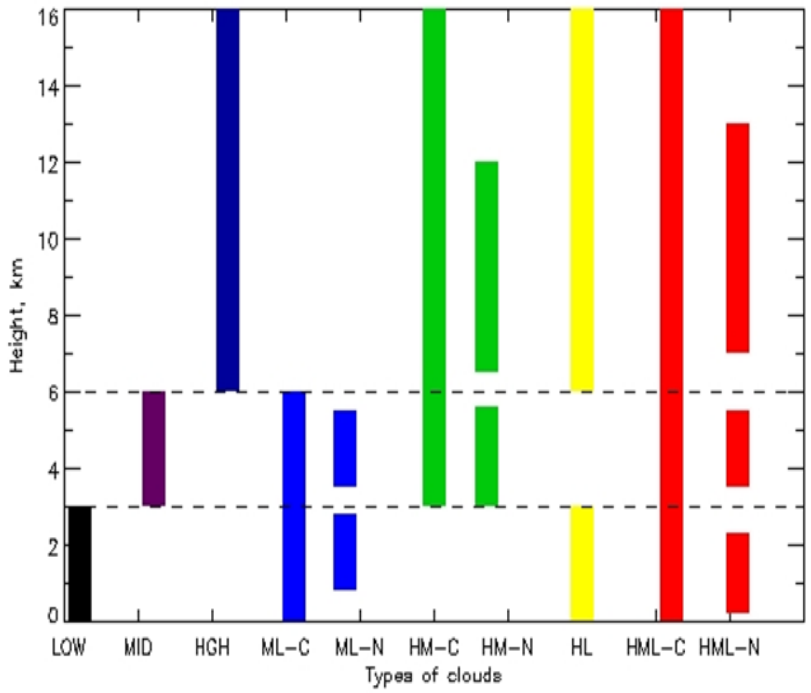
Comparison between MMCR and GOES

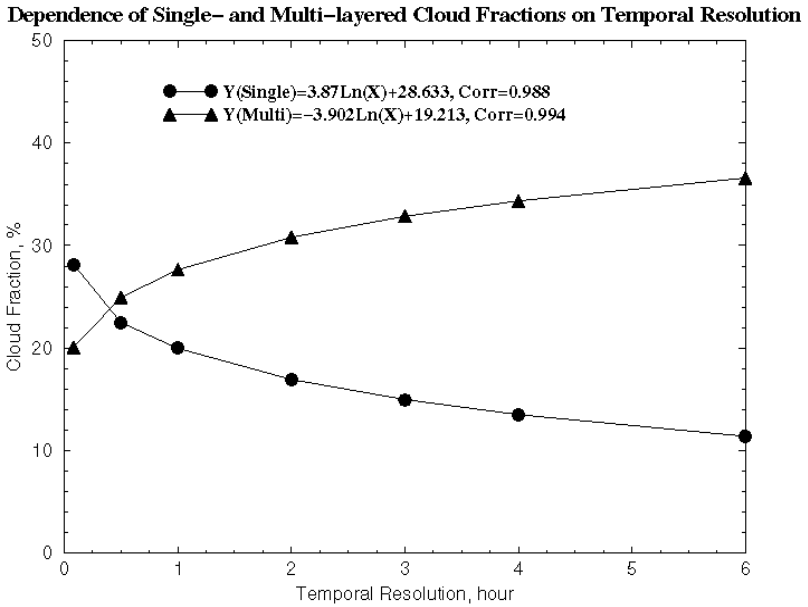


- The highest cloud-top height comparison
- GOES night-time derived cloud-top height agrees well with ARM radar observations.

Classification of clouds by their vertical structure

10 Categories of cloud classified by height



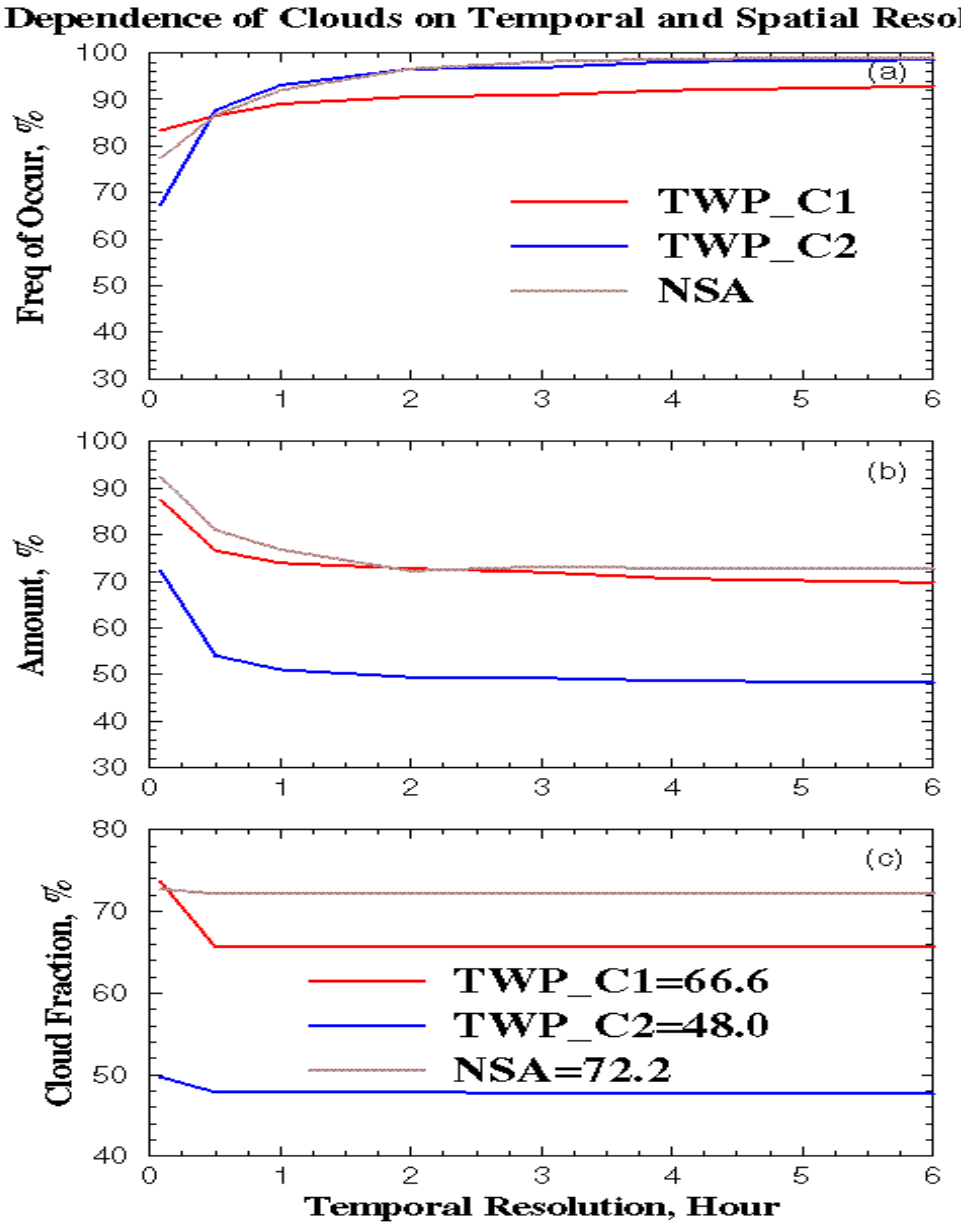


Single-layer cloud decreases And multilayer cloud increases With temporal resolution.

Cloud fractions for each category of clouds

Cloud type	Definition (km)	Annual (%)	Spring (%)	Summer (%)	Fall (%)	Winter (%)
1	Single low, < 3 km	9.3	10.4	5.0	10.2	11.9
2	Single middle, 3-6 km	2.8	3.3	2.1	2.9	2.8
3	Single high, > 6 km	16.7	16.4	19.9	13.7	16.7
4	Middle over low, contiguous	2.4	2.5	1.3	2.5	3.2
5	High over middle, contiguous	3.9	4.3	3.5	3.2	4.8
6	High over both mid and low, contiguous	2.6	2.9	1.8	2.4	3.5
7	Middle over low, non-contiguous	0.8	0.9	0.2	0.9	1.1
8	High over middle, non-contiguous	2.4	3.0	2.5	1.8	2.5
9	High over low, non-contiguous	3.7	4.1	2.1	3.4	5.2
10	High over mid and low, non-contiguous	2.3	2.7	1.3	2.3	3.0
Sum	Total CF	46.9	50.4	39.8	43.3	54.6

ARM TWP C1 and C2, and NSA sites



- The CF at TWP C2 is much less then those at TWP C1 and NSA sites.

Conclusion (Answers to four questions)

1) How well do the temporally averaged surface ARM data compare with the spatially averaged GOES data?

ARM and GOES derived CFs agree very well (0.7%), which further prove the ARM point observations can represent large areal observations.

2. What point observations can be directly compared with satellite observations?

In addition to CF, FREQ and AWP can be comparable if

0.5-hr ARM ~ 0.5° GOES

4-hr ARM ~ 2.5° GOES

Conclusion (Answers to four questions)

3. How does cloud vertical distribution vary with different spatial resolutions, as well as seasons?

➔**The cloud frequency of occurrence increases with the vertical resolutions from 90 m to 1000 m.**

➔**Bimodal distribution for all seasons; More clouds in Winter and less in Summer**

4. What about cloud fractions over ARM TWP and NSA?

The CF at TWP C2 is much less then those at TWP C1 and NSA sites.

Thank you for your attention!

Data Sets Over ARM sites

At SGP:

- MMCR/LIDAR: 199701-200612
- GOES: 199802-200712

At NSA:

MMCR/LIDAR: 199901-200412

At Manus=TWPC1

MMCR/LIDAR: 199901-200512

At Nauru=TWPC2

MMCR/LIDAR:199901-200212 and 200501-200612