Macro-physical Properties of Shallow Cumulus from Integrated ARM Observations: Development of a New Data Product for Model Evaluation

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Motivation

- Information about cloud field inhomogeneity is needed to assess differences between cloud statistics obtained from model simulations and observations.
- *Can this information be obtained from Total Sky Imager (TSI) data with wide field of view (FOV)?*
- *Does level of agreement between cloud statistics obtained from **narrow**- and **wide**-FOV data depend on cloud field inhomogeneity?*

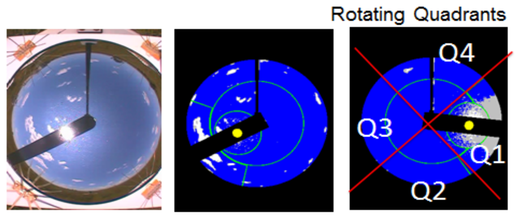


***Fig. 1** TSI image (left) and decision image (center) with clear-sky (blue) and cloudy (white) pixels and areas, which represent 100° (green circle) and 160° FOVs. For our study, the decision image is divided into rotating quadrants (right) with Q1 centered on the solar azimuth angle.*

***Fig. 2** Time series of ARSCL cloud fraction (CF), TSI fractional sky cover (SCV) with 100° and 160° FOVs (top), TSI SCV for three quadrants (middle), and the corresponding root-mean-squared difference (RMSD) (bottom) for a given day (05-15-2006).*

Data

- We apply data from (1) ***TSI***, (2) *Active Remote Sensing of Clouds* (***ARSCL***) and (3) 915 MHz Radar ***Wind Profiler***.
- The selected data represent **54** days (2005-2008) with *shallow cumulus* at the SGP site.
- We apply cloud classification from the ShallowCumulus evaluation VAP [**1**] for our data selection.
- In contrast to *wide*-FOV TSI data, ARSCL and Wind Profiler data represent *narrow-FOV* observations.

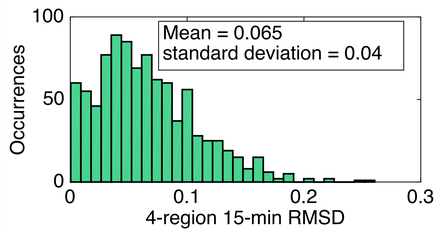


***Fig. 3**. Histogram of 15-min RMSD from days with "Small" and "Moderate" sky cover (**Table 1**). This distribution is used to categorize daily means as being within, above or below ½ standard deviation of the mean.*

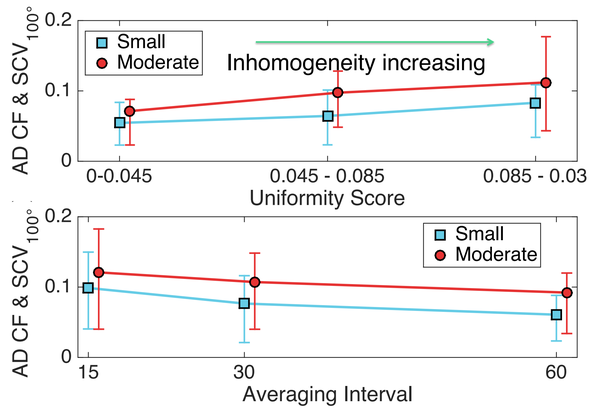


***Fig. 5**. Absolute difference (AD) between hourly ARSCL CF and TSI SCV (100°) for two groups with "Low" and "Moderate" sky cover (**Table 1**) as a function of hourly "uniformity" score (top) and AD between ARSCL CF and TSI SCV(100°) for different averaging periods (bottom). Error bars 25th and 75th percentiles.*

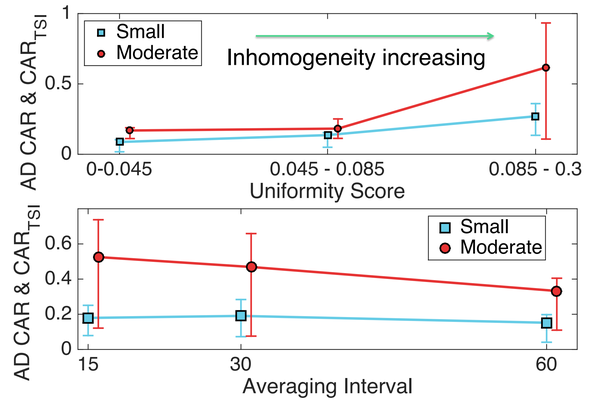
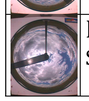


***Fig. 6**. The same as **Fig. 5** but for ARSCL and TSI CARs.*

***Table 1**. Day classification based on maximal hour of SCV(160°) and further classified with "uniformity" score. Number of days with shallow cumulus observed during HI-SCALE & LASSO is given in parentheses (magenta).*

	Sky Cover (160°)	Days/ 54 (14)	Description	Uniformity score		
				< 0.045	≈0.065	>0.085
	Sparse SCV ≤ 0.2	9 (0)	Sparse all day	Too sparse to assess uniformity		
	Small 0.2<SCV≤0.4	23 (2)	Sparse to low	5(1)	16(1)	2
	Moderate 0.4<SCV≤0.7	19 (11)	low to high	2(1)	10(10)	7
	Large SCV > 0.7	3 (1*)	Often not Sh. Cum.	Likely not shallow cumulus. *haze/smoke		

Summary

- We introduce a simple approach for acquiring information about cloud field inhomogeneity from high-resolution ground-based TSI images.
- We apply our approach to segregate days with cumulus clouds into three groups with different "uniformity" scores, which define cloud field inhomogeneity.
- We demonstrate that level of agreement between cloud statistics obtained from **narrow**- and **wide**-FOV data have a noticeable dependence on (1) cloud field inhomogeneity and (2) averaging period.

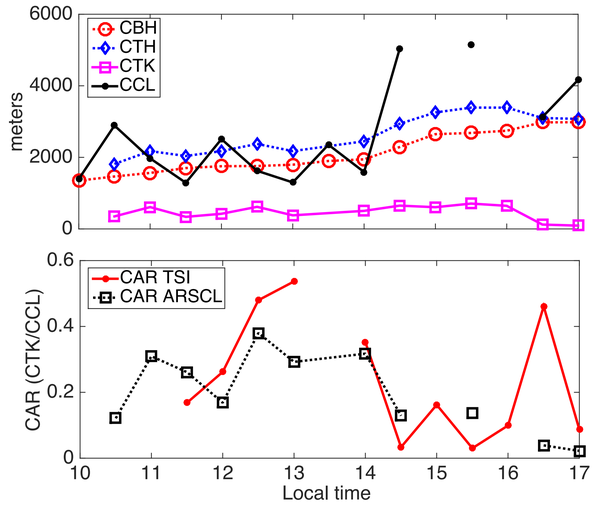


***Fig. 4**. Time series of ARSCL cloud base height (CBH), cloud top height (CTH), CTK and CCL (top); CAR from ARSCL and TSI [2] observations (bottom) for a given day (05-15-2006).*

Approach

- Analyze **TSI** data to examine *cloud field inhomogeneity*. Define SCV for three rotating quadrants (Q2-Q4; **Fig.1**). Calculate root-mean-squared difference (σ_{SCV}) between quadrant-mean SCV and SCV(100°) (**Figs.2,3**) for days with different "uniformity" score (**Table 1**).
- Analyze **ARSCL/Wind Profiler** data to obtain *cloud macro-physical properties*, such as cloud fraction (**CF**), chord length (**CCL**) , thickness (**CTK**) and cloud aspect ratio (**CAR**=CTK/CCL) (**Fig 4**).
- Compare **TSI**- and **ASCRL**-based cloud *macro-physical properties* for cases with different (1) "uniformity" score and (2) averaging periods (**Figs.5,6**).

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References:

1. https://www.arm.gov/data/data-sources/shallowcumulus-127
2. Kassianov, E. & Long, C. Cloud Aspect Ratios Derived from Total Sky Imagers Data: Case Studies. (2005).

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