Establishment of Cloud Regimes for Systematic Cloud Modeling

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Objectives

- Establish cloud regimes to enable regime-based evaluation of model fast physics.
- Use a multi-step procedure to achieve a continuous cloud classification in temporal space.
- Explore new use of vast amount of night-time cloud measurements that are underutilized in previous cloud classification study.
- Enrich cloud regimes with cloud system life cycle information.

Methodology and Data

- K-means clustering for objective classification
- 1999-2001 cold season (Nov. – March) data
- NASA ISCCP D1 cloud product -- base data for cloud classification.
- And data below to further establish a continuous cloud classification and the links between cloud regimes and dynamic/synoptic conditions,
  - DOE ARM ground-based ARSCL cloud product
  - DOE ARM continuous forcing data set
  - NOAA ABRFC hourly 4km x 4km precipitation data
  - NCEP reanalysis II 6-hourly sea level pressure for storm tracking

Classification

Step 1. Three approaches using cloud properties/statistics derived from daytime ISCCP D1 are explored.

— 3-parameters (cloud amount, cloud top, reflectivity, as in Gordon et al. 2005)
— 42-parameters (full D1 histogram, as in Jakob and Tselioudis 2003)
— 9-parameters (classical cloud types, this study)

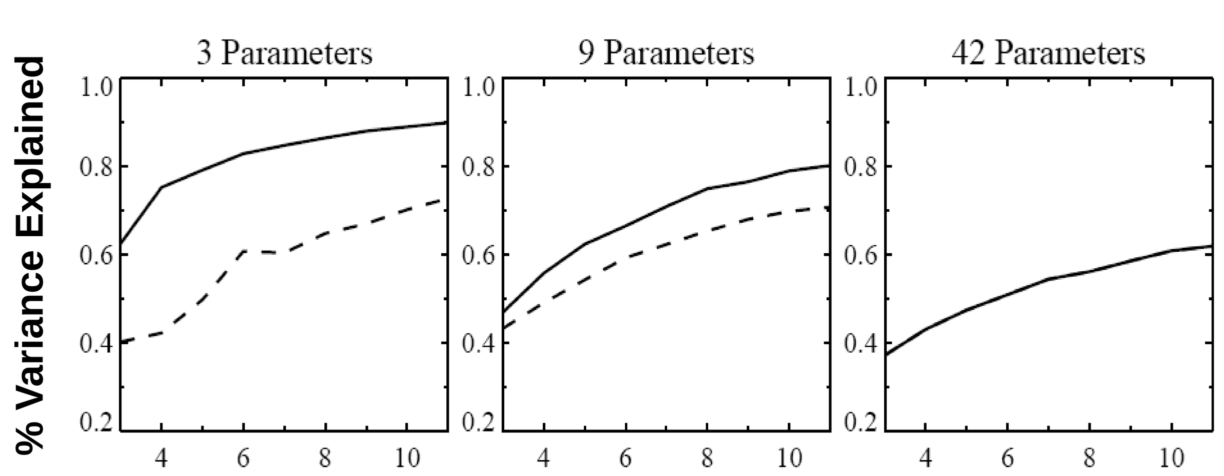


Fig. 1. Percentage variance explained by number of clusters from each classification. Solid line for variance of the classification data, dashed line for variance of corresponding D1 histogram.

Classification (continued)

Step 2. Clustering selection (6 clusters selected from 9 parameters)

— Variance starts to flatten after 6 clusters (Fig. 1)
— Similar regimes identified with different approaches (Fig. 2)
— Mean overall dispersion and intra-class dispersion for frontal and St/Sc classes smaller with 9 parameters (Table 1)
— Mean vertical velocity with 9 parameters more consistent with classical picture (e.g., for St/Sc regime highlighted in Fig. 2)

Table 1. Mean and Intra-Class Dispersion

	Extensive Ci	Patchy Ci	St/Sc	Frontal	Mean
3-Param Classes	0.26	0.10	0.33	0.31	0.234
9-Param Classes	0.27	0.13	0.29	0.30	0.230

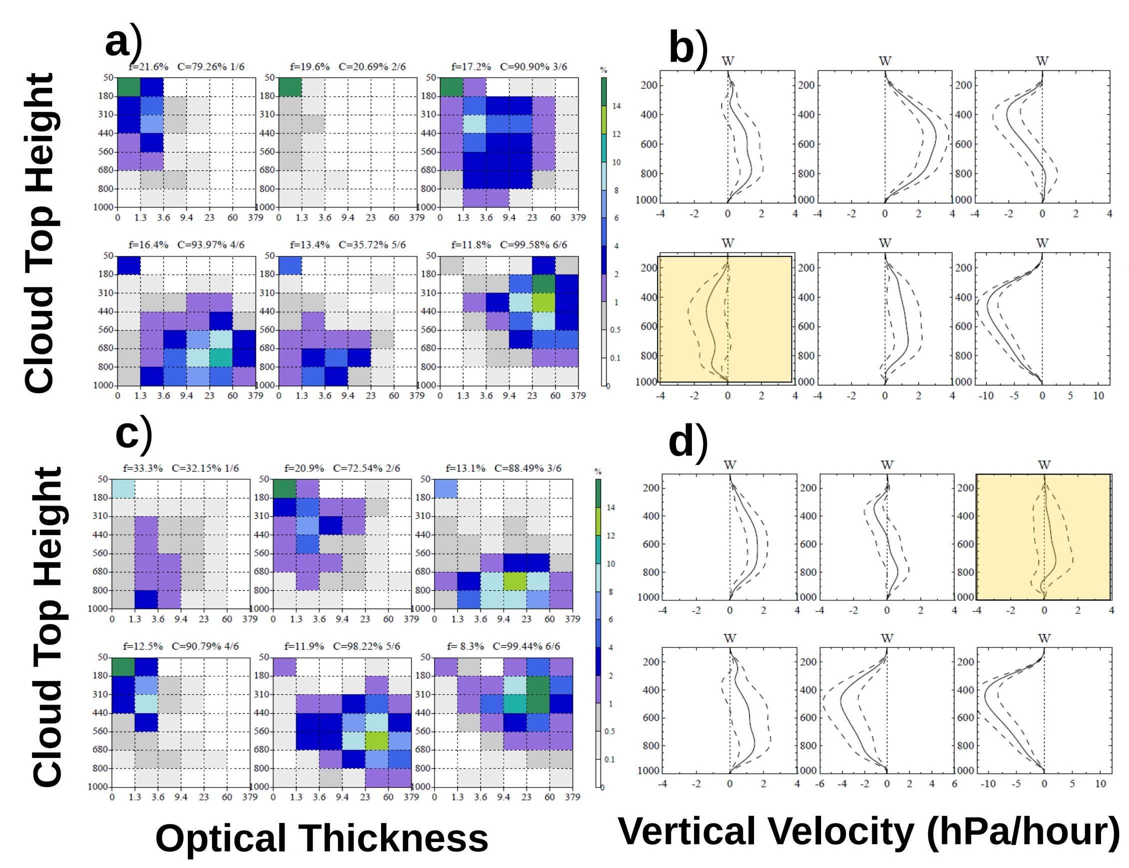


Fig. 2 Cloud histogram as a function of cloud top and optical thickness and the associated profile of vertical velocity for each cloud regime. a) and b for 3-parameter classification, c) and d) for 9 parameters. The numbers above each panel in a) and c) indicates frequency occurrence and mean total cloud amount. Note that the order of the classes differs in a) and c) due to different approaches.

Step 3. Classification of ARSCL profiles and extension to nighttime

— Derive the mean ARSCL profile associated with each regime (Fig. 3).
— Map all ARSCL data to the mean ARSCL profile to obtain a continuous cloud regime classification.
— Inclusion of the first 3 moments of ABRFC data improve the pattern correlation for frontal cloud regimes in Figure 2c.
— Inclusion of omega correlation improves the pattern correlation for stratus/stratocumulus regime.
— The final pattern correlations correspond to the D1 classes in Fig. 2c are 0.964, 0.985, 0.910,0.952,0.945, and 0.956,respectively.

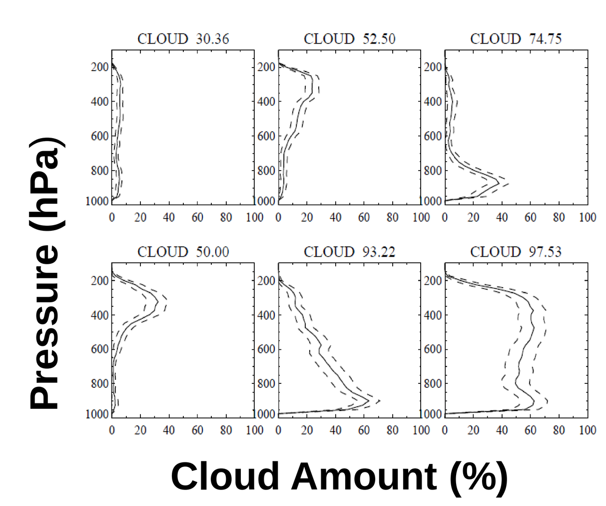


Fig. 3 Mean ARSCL profile for each ISCCP D1-based class in Figure 2c.

Cloud regime sequencing and statistics

— Large samples available for each class (Table 2)
— Intermittent and lasting events present for each class
— Dominant precussors/successors (outlined in Figure 4) are indications of cloud life cycle and regime transitions.

Table 2. Sample size and mean/max durations (in hours) for each class

Class	1	2	3	4	5	6
Samples	2763	594	850	1388	806	1012
durations	2.6 /22	1.6/12	3.2/26	3.8/35	2.9/28	4.6/32

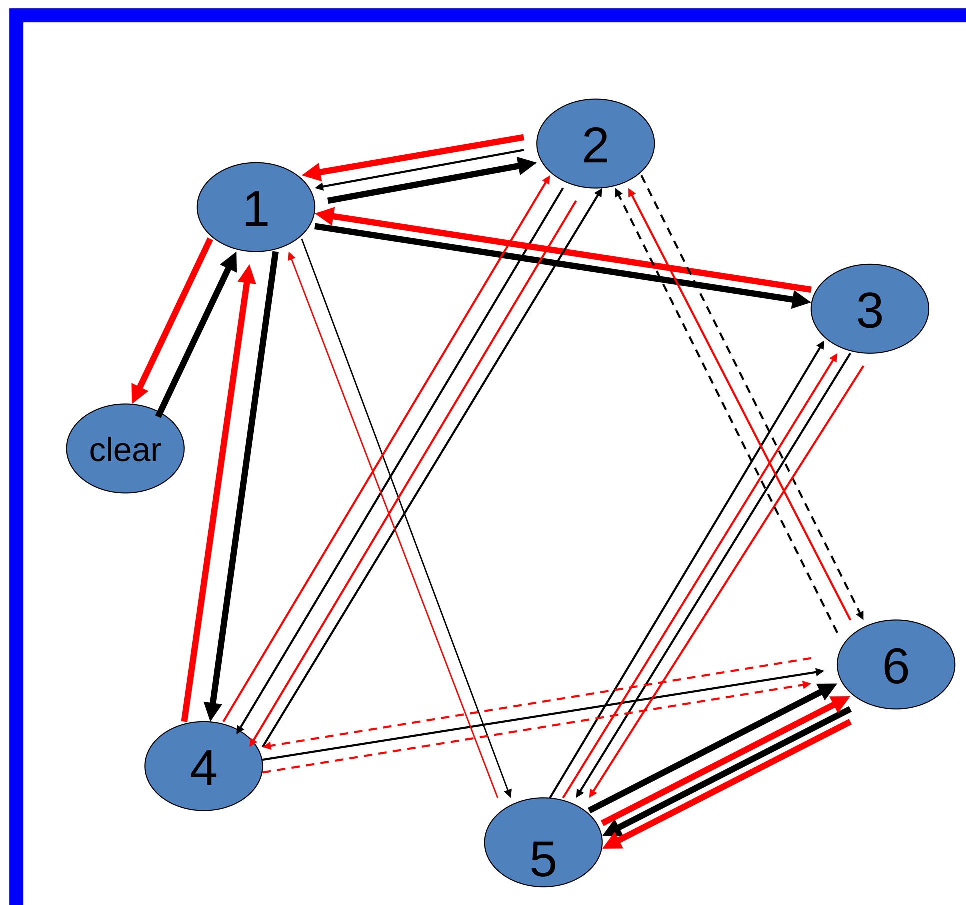
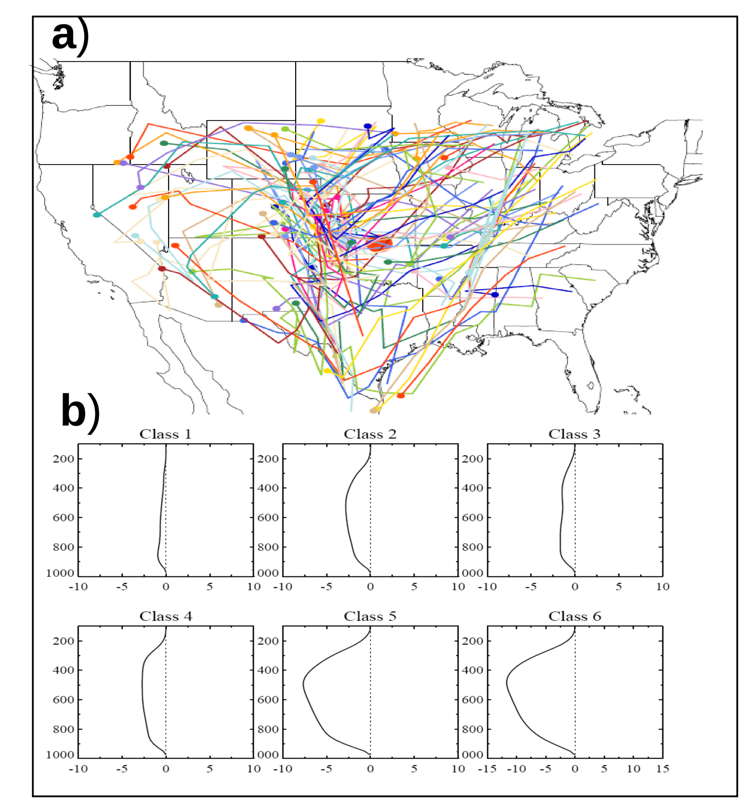


Figure 4. Top three precurssors (black) and successors (red) for each cloud regime identified in Figs 2c and 3. Arrows indicate the sequencing. Thick, thin, and thin-dashed lines correspond to the top three precurssors/successors, respectively. The thirds are shown only when accounting for over 10%. The sequencing depicts the succession of cloud classes moving over SGP. Selected sequencing may depict typical storm life cycle in Lagrangian view.

Cloud regimes under storm influences



Storm tracking using GISS' s MCMS.

Storm path with center w/i 1000 km of SGP CF considered.

High number of storms developed w/i SGP domain (indication of cyclogenesis).

Storms influence all cloud regimes (Table 2 vs 3).

Dynamic conditions can be very different w/ storm influence (Fig 2d, vs Fig. 5b, classes 1-4).

Fig. 5 a) Individual storm tracks that have influence on SGP domain, color dots indicate 1st detection of storm within the plot domain, **b)** associated vertical velocity profile for each cloud class with storm influence.

Table 3. Number of samples with storm influences

Class	1	2	3	4	5	6
Develop w/i domain	441	96	145	265	125	200
Move into domain	182	41	98	79	119	130
Total	623	137	243	344	244	330

Summary

- *Nine equivalent morphological cloud types derived from daytime ISCCP-D1 are used as classification data to define 6 cloud regimes.*
- *Associated mean ARSCL profiles used to categorize ARSCL data continuously.*
- *Cloud regime sequencing and life cycle can be derived from continuous classification.*
- *Cloud regimes under storm influences may experience drastically different dynamical conditions. Multi-step procedure is useful in sorting regimes of particular interest.*
- *Regime-based cloud modeling and evaluation may further consider short-lived vs long lasting, different transition paths, and varying dynamical conditions with storm influences.*

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