Long-term Evaluation of Cloud Fraction Simulated by Seven SCMs Against the ARM Observation at the SGP Site

Hua Song[1](hsong@bnl.gov), Wuyin Lin[1], Yanluan Lin[2], Satoshi Endo[1], Leo Donner[2], Audrey Wolf[3], Anthony Del Genio[4], Roel Neggers[5], and Yangang Liu[1]

1 Atmospheric Science Division/BNL 2 NOAA/GFDL 3 Columbia University 4 NASA GISS 5 KNMI

1. Introduction

- Evaluation of the basic features (vertical profiles, mean cloud amounts and occurrences) of cloud fraction in 7 SCMs by comparison with ARM observations at the SGP site
- Statistical analyses with 3-year hourly data (Jan1999-Dec2001)
- Observation: CMBE ARSCL cloud fraction
- 7-SCM simulations driven by same surface and large-scale forcing plus a relaxation term, and run in FASTER SCM Testbed

Summary of Seven SCMs and Parameterizations of Cloud Fraction

Models	Resolution(SCM)	Parameterization of Cloud Fraction (a)		
ECWMF IFS	L91, 05min	**Prognostic** Tiedtke 1993; Gregory et al. 2000	$\frac{\partial a}{\partial t} = A(a) + S(a)_{conv} + S(a)_{strat} - E(a)$ (Tiedtke 1993)	
GFDL AM2	L24, 30min	**Prognostic** Tiedtke 1993; Anderson et al. 2004		
GFDL AM3	L24, 30min			
GISS ModelE2	L40, 30min	**Diagnostic** Del Geino et al. 1996	$a = sum(a_c, a_s)$	$a_c = f(M_u)$ $a_s = f(RH)$ $a_m = f(LTS)$
CAM3	L26, 20min	**Diagnostic** Slingo 1987; Rasch and Kristjansson 1998	$a = \max(a_m, a_c, a_s)$	
CAM4	L26, 20min	**Diagnostic** Slingo 1987; Varus and Waliser 2008		
CAM5	L30, 20min	**Diagnostic** Park/Gettelman et al. 2010	$a = sum(a_c, a_s)$	

2. Vertical Profiles of Cloud Fraction

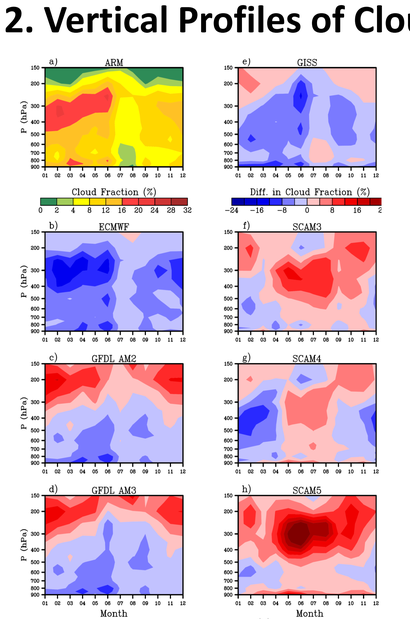


Fig1: Seasonal variation of cloud fraction in ARM observation (a), and differences of monthly mean cloud fraction between 7 SCMs and observation respectively (b-h).

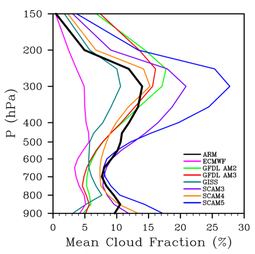


Fig3: Vertical profiles of 3-year mean cloud fraction

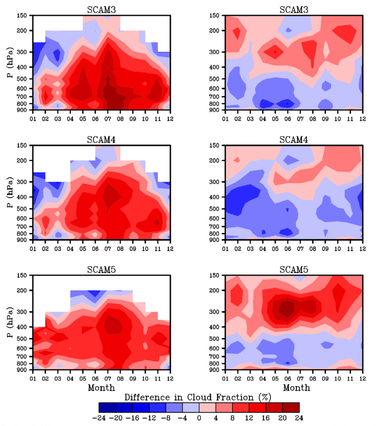


Fig2: Differences of monthly mean convective cloud fraction in three SCAMs and monthly mean cloud fraction in the observation (left panel), and differences of monthly mean stratiform cloud fraction in three SCAMs and monthly mean cloud fraction in observation (right panel).

- The ECMWF SCM underestimates all-level cloud fraction in all seasons.
- The two GFDL SCMs underestimate low-to-middle-level clouds and overestimate high-level clouds in most seasons.
- The GISS SCM underestimates cloud fraction below 300 hPa in all seasons and mildly overestimates cloud fraction above 300 hPa except in summer season.
- The SCAM3 and SCAM5 overestimate high-level cloud fraction in all seasons, while SCAM4 only overestimates high-level clouds in warm season.
- The three SCAMs underestimate low-level cloud fraction in cold seasons while mildly overestimate low-level cloud fraction in warm season.
- The three SCAMs have low-level (800 hPa to 600 hPa) cloud fraction similar to the observation, a result of overproduction of convective cloud fraction and underproduction of stratiform cloud fraction.

3. Frequency Distribution of Cloud Fraction

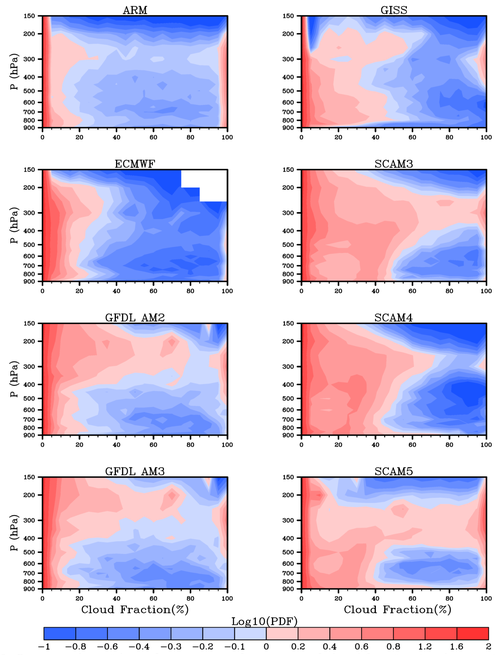


Fig4: Common logarithm of occurrence frequency of cloud fraction in observation and 7 SCMs binned by cloud fraction ranging from 0% to 100%.

- In the observation, it is a distinct U-shaped distribution of cloud occurrences, concentrating on CF<5% and CF>95% ranges.
- In 7 SCMs, cloud events occur much more frequently on moderately cloudy ranges at high levels or low levels.
- In ECMWF and GISS SCMs, the frequencies of cloudy events with CF>60% are much lower than the observation.

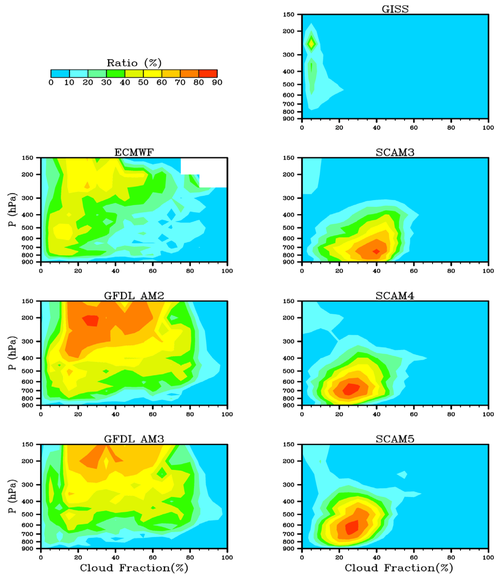


Fig5: Ratios of non-stratiform-cloud-source events (based on convective precipitation, RH and CF) to all the events for each cloud fraction bins in 7 SCMs.

- In ECMWF and two GFDL SCMs, the contribution of non-stratiform-cloud sources to cloud fraction is mainly above 400-hPa levels over the range 15%-70%.
- In GISS SCM, contribution of convection source is very small.
- In three SCAMs, cloud fractions below 400-hPa levels over range 10%-50% are mainly produced by convection process, while the cloud fractions below 400-hPa levels over range 60%-100% and above 300-hPa levels are mainly stratiform clouds.

4. Partitioning of Cloud Fraction

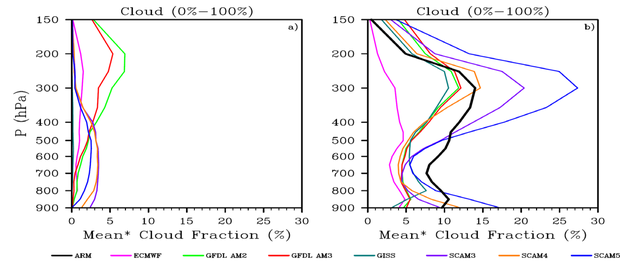
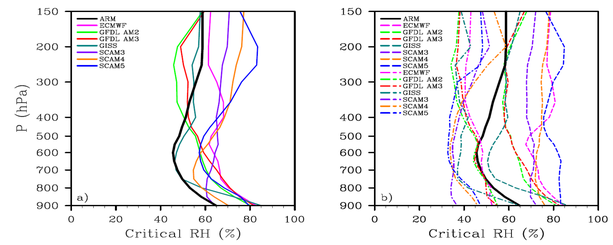


Fig6: a) 3-year mean cloud fraction for non-stratiform-cloud-source events in 7 SCMs; b) 3-year mean cloud fraction in observation for all events and in 7 SCMs for stratiform-cloud-source events.

- The contribution of non-stratiform-cloud-source events to the mean cloud fraction is mainly above 600-hPa in ECMWF and two GFDL SCMs and below 300-hPa in three SCAMs.
- The underestimation of low-level clouds in ECMWF and two GFDL SCMs and overestimation of high-level clouds in three SCAMs are mainly due to mean cloud fraction in the stratiform-cloud-source events.



$$RHc = 1 - \frac{1-RH}{(1-CF)^2}$$ (Quaas, 2012)

Fig 7: a) 3-year mean RHc (critical RH value for the occurrence of clouds) in observation and 7 SCMs for all events. b) 3-year mean RHc in observation for all events (black line) and 7 SCMs for non-stratiform-cloud-source events (dash-dotted lines) and stratiform-cloud-source events (dash lines).

- Larger critical RH in most SCMs than in the observation except for two GFDL SCMs at high levels.
- Critical RH for stratiform-cloud-source events are much larger than those for non-stratiform-cloud-source events in all SCMs, implying the lower sub-grid variability of humidity for stratiform-cloud source events.

5. Summary

- ✓Compared with observation, ECMWF SCM underestimates all-level clouds and GISS SCM underestimates clouds below 200 hPa.
- ✓The two GFDL SCMs overestimate high-level cloud fraction but underestimate low-level cloud fraction.
- ✓The three SCAMs overestimate high-level cloud fraction, but have low-level cloud fraction similar to the observation, due to the compensation between the overproduction of convective clouds and the underproduction of stratiform clouds.
- ✓The frequency distribution of cloud fraction shows a large discrepancy between the observation and SCMs.
- ✓The contribution of non-stratiform-cloud sources is mainly on the moderately cloudy range, at high levels for ECMWF and two GFDL SCMs and at low levels for three SCAMs.
- ✓Further analysis will be focused on relationship between cloud fraction (stratus) and relative humidity in SCMs and observation.

Acknowledgement

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