Diurnal cycle of water vapor and clouds profiles observed from space, comparison with one GCM

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The cloud and water vapor diurnal cycles


Zhao, W., et al. The diurnal cycle of clouds and precipitation at the ARM SGP site: Cloud radar observations and simulations from the multi-scale modeling framework (2017).
The global view of the cloud diurnal cycle has changed recently

1) Observe how the Relative Humidity profiles and Cloud profiles respond to the solar diurnal forcing across the Tropics

2) Test the model physic
1) Observe how the Relative Humidity profiles and Cloud profiles respond to the solar diurnal forcing across the Tropics

2) Test the model physics

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Observations collected recently by low-orbiting satellites => diurnal cycle
- Relative Humidity Profiles from SAPHIR on-board the Megha-Tropiques (Brogniez et al. 2011)
- OLR from ScaRaB instrument on-board the Megha-Tropiques satellite (Roca et al. 2015)
- Cloud profiles from CATS Lidar on-board the International Space Station (York et al. 2019)

Simulations with the LMDz6 GCM with COSPv2/lidar, AMIP type run, high frequency outputs

Time Period: June- July-August 2015-2016-2017
Observations of the diurnal cycles

Relative Humidity

Opaque Clouds Fraction

Thin Clouds Fraction

OCEAN

LAND

Local Time (hrs)

Local Time (hrs)

Local Time (hrs)

Local Time (hrs)

Chepfer et al., under review
Oceanic Ascent: Obs in relative anomaly wrt. daily mean

- RH relative anomaly is max in the mid-troposphere at night (15%)
- Cloud relative anomaly is small: max 1%
- Opaque cloud relative anomaly in the mid troposphere in early afternoon (drives the OLR)
- Thin cloud positive relative anomaly in the boundary layer 0-6am and tied to RH in free troposphere
Oceanic Ascent: focus on the upper troposphere (> 5 km)

Storm resolving model simulation by Ruppert and Klocke, 2019
suggest the late afternoon ice clouds are produced by a second diurnal mode of the tropical upward motions due to local SW radiative warming.
Oceanic Ascent: focus on the lower troposphere (< 5 km)

The observations show an enhancement of the condensed water (thin clouds) very close to the surface (<1km) at late night (LW slight surface warming)

Ruppert and Klocke, 2019
Oceanic Ascent: comparison with GCM

Relative Humidity

Opaque Clouds Fraction

Thin Clouds Fraction

16 km

0 km

Ocean Asc

LMDz + COSPv2

OLR

SST

0.4K

Red

0 km

16 km

0 km

Local Time (hrs)

Local Time (hrs)

15% 15% 15%

-1% -1% -1%

0 W/m2 4 W/m2

Red

Red

0.15K

-0.2K
Land Ascent: Obs in relative anomaly with respect to daily mean.
Land Ascending air regions: comparison with GCM

![Graphs and charts showing relative humidity, opaque clouds fraction, thin clouds fraction, OLR, and SST variations over time for continental and oceanic regions with different w500 conditions.](image)
Almost no cloud diurnal cycle in the model (<1%) compared to observations

NB: the model daily mean state is wrong (not shown here)
Summary

• Recent space-borne instruments observe the diurnal cycle of cloud profile and relative humidity profile across the Tropics.

• The LMDZ model does not reproduce the observed diurnal cycles. The daily mean clouds profile and relative humidity profile are biased in the model (not shown); these biases influence the diurnal cycle biases.

• Does that matter if the diurnal cycle is biased in the model?
  “some fast processes shape the long term response… based on intuition (cloud changes are fast) and based on examples in the literature”
Supplementary
Daily mean Profiles of HR, Thin Clouds, Opaque Clouds: Obs & Models

Relative Humidity daily mean profiles
LMDZ-AMIP JJA_2006-2014 30S-30N

Thin CF [%]
a) Thin cloud fraction daily mean profile
LMDZ-AMIP JJA_2006-2014 30S-30N

Opaque CF [%]
b) Opaque cloud fraction daily mean profile
LMDZ-AMIP JJA_2006-2014 30S-30N

Obs
Model+
COSPv2/
lidar
Table 1: Daily mean values over the four tropical areas (30°S-30°N) for 9 years of the LMDZ-AMIP+COSPv2 run.
Oceanic subsidence air regions: comparison with GCM

- **Opaque Clouds**:
  - 60% in the model
  - 60% in observations

- **Thin Clouds**:
  - 1% in the model
  - 1% in observations

**Model +CSPv2**

- Ocean Moderate Subs:
  - Relative Humidity
  - 15%

- Ocean Strong Subs:
  - Relative Humidity
  - 15%

**OBS**

- Ocean Moderate Subs:
  - Relative Humidity
  - 15%

- Ocean Strong Subs:
  - Relative Humidity
  - 15%
Oceanic Strong subsidence air regions

OBS

Model +COSP/ lidar

Relative Humidity

Opaque Clouds

Thin Clouds

Cloud anomaly profiles diurnal cycle from LMDZ-AMIP JJA_2006-2014 30S-30N ocean_w500strong_sub

Opacity Cloud relative anomaly profile diurnal cycle (%)

Thin Cloud relative anomaly profile diurnal cycle (%)

RH diurnal cycle relative anomaly profile (%)
Land Subsiding air regions: in Relative Daily anomalies (equation)

OBS

Model +COSP/ lidar
Figure 3. Composites for the selected regions marked by rectangles in Figure 2b, with line thickness and color pigment proportional to magnitude of IWP (or SW; Figure 1). (a) Mean vertical pressure velocity $\omega$ (gray-black; hPa/hr) and SW* averaged from 11–13 L (reds; K/day), and $\omega'$ (deviation from daily mean) averaged over (b) 00–06 and (c) 12–18 L. (d) As in (b) and (c) except for the diagnostic motion due to SW $\omega_{SW}$. (e–g) As in (a)–(c) except with cloud liquid water ($q_c$; red) and cloud ice ($q_i$; blue; mg/kg). Profiles of $q_c$ and $q_i (=0)$ for CTL are only included in panel (d), with the daily mean (thick dashed) and means for 00–06 and 12–18 L (thin dashed) as labeled. Lastly, time series of (h) rainfall (mm/hr), (i) liquid water path (LWP; $10^{-2}$ mm), and (j) IWP ($10^{-3}$ mm = g/m$^2$) with time means subtracted.

ATL = Atlantic; CTL = control; EPAC = East Pacific; IO = Indian Ocean; IWP = ice water path; LWP = liquid water path; SPCZ = South Pacific Convergence Zone.
Maps of Grid Box Number of Occurrence in the MTCC Dataset

$\omega_{500} < -20 \text{ hPa/day}$

$-20 < \omega_{500} < 20 \text{ hPa/day}$

$\omega_{500} > 20 \text{ hPa/day}$

Number of Occurrences (within each $1^\circ \times 1^\circ$ Grid Box)