Climate Implications of the Moist-convective Diurnal Cycle

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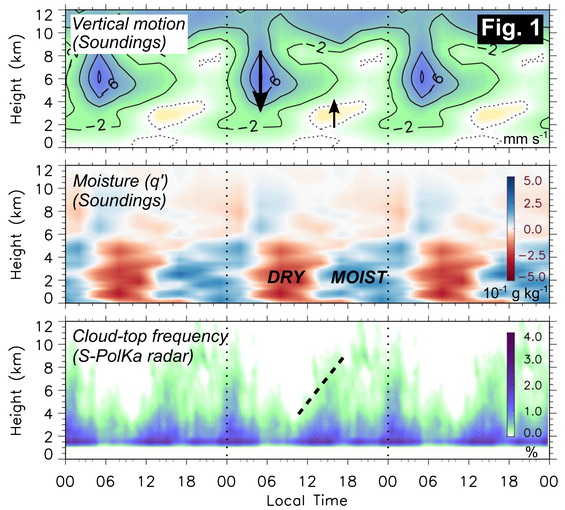
INTRODUCTION

A pronounced large-scale diurnal cycle of clouds, humidity, and vertical motion (*w*) can be noted in suppressed regimes over the tropical oceans (Fig. 1), as was observed during initiation of the Madden–Julian oscillation (MJO) in the DYNAMO (Dynamics of the MJO) field experiment.

Diurnal Cycle in Tropical Suppressed Regimes (DYNAMO)



Of interest is if and how this diurnal cycle feeds back onto the climate system at longer timescales through timescale interaction:

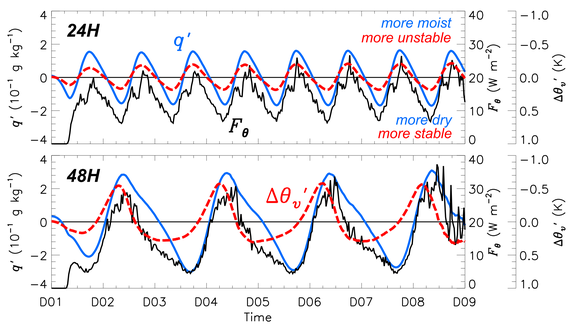
What role does the diurnal cycle play in cloud-deepening and upscale growth in the tropics – namely, in MJO initiation?

An idealized study is conducted with a cloud model (CM1)[1] at 200 m *x,y* spacing to test this question. Large-scale forcing is parameterized using the Weak Temperature Gradient (WTG) approximation,[2] whereby a balanced vertical motion is diagnosed that offsets (via adiabatic motion) simulated diabatic heat sources. This diagnosed large-scale vertical motion is then used to advect *T* and *q*. The diurnal cycle is simulated for 16 days, *varying only diurnal period to isolate nonlinear feedbacks*: **12H**, **24H**, and **48H**; with one case with solar forcing fixed to the daily mean (**NODC**).

ANALYSIS

Even though the magnitude of the diurnal solar cycle is the same in all simulations, a longer diurnal cycle leads to higher-amplitude diurnal cycles in cloud-layer humidity and convective instability. More moist and unstable conditions each afternoon lead to ***stronger diurnal and daily-mean convective cloud activity*** (Fig. 2) (i.e., deeper clouds, greater rainfall; not shown). Stronger cloud activity is associated with greater low-level diabatic heating (via enhanced condensation).

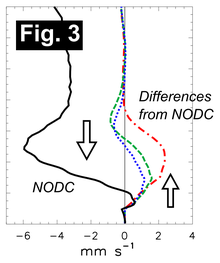
Diurnal Cycle in Moisture and Instability



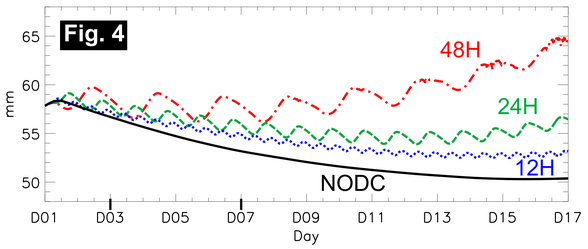
*Quantities averaged over the cloud layer: specific humidity (**q'**), lapse rate of virtual potential temp. (**$\Delta\theta_v'$**), and convective cloud activity, as quantified by vertical eddy θ_v flux (**F_θ**) in 24H ad 48H. Primes indicate anomaly from the daily mean.*

Greater large-scale diabatic heating, in turn, increases large-scale upward motion in accordance with WTG balance (Fig. 3). Greater large-scale upward motion causes stronger moistening (Fig. 4), which causes a ***more rapid large-scale transition from shallow to deep clouds***.

Large-scale w



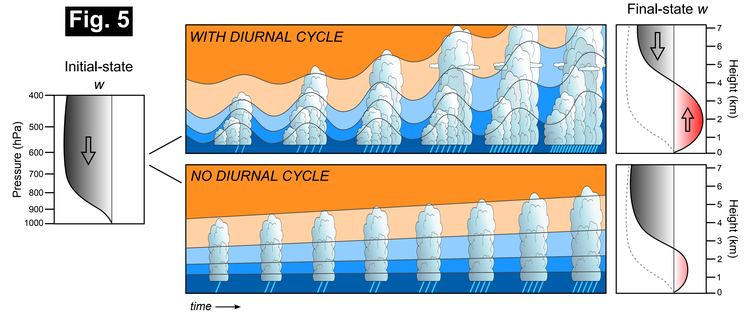
Precipitable Water



CONCLUSIONS

In summary, the diurnal cycle causes stronger moist convection (e.g., deeper clouds), which leads to more rapid large-scale day-to-day moistening under WTG balance. Greater moistening leads to a more rapid transition from large-scale suppressed to active (deep-convective) conditions. This ***diurnal time-scale feedback*** (summarized in Fig. 5) implies that the diurnal cycle is a potentially important forcing mechanism to the climate system. Specifically, the diurnal cycle of moist convection may accelerate MJO initiation in the tropical Indian Ocean where diurnal variability is often pronounced.

The Diurnal Timescale Feedback



Important questions remain, which will likely require both climate and cloud models to fully answer:

1. How does this diurnal timescale feedback manifest in nature?

2. What other diurnal timescale feedbacks might exist in the climate system?

References:

Bryan, G., and J. M. Fritsch, 2002: A benchmark simulation for moist nonhydrostatic numerical models. *Mon. Wea. Rev.*, **130,** 2917--2928.

Herman, M. J., and D. J. Raymond, 2014: WTG cloud modeling with spectral decomposition of heating. *J. Adv. Model. Earth Syst.*, **6,** 1121–1140.

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Ruppert, J. H., and R. H. Johnson, 2016: On the cumulus diurnal cycle over the tropical warm pool. *J. Adv. Model. Earth Syst.,* in press.

Ruppert, J. H., 2016: Climate forcing by the diurnal cycle of convective clouds. Submitted.

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