Unexpected 10-Hour Oscillation in Convectively Aggregated State in Cloud-Resolving Model

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Motivation

The precipitation rate, which is directly tied to latent heat release, is approximately balanced by the ARC rate in equilibrium; this relationship suggests a positive correlation between ARC and precipitation. In contrast, on the regional scale, high clouds cause the precipitation rate and the ARC rate to be negatively correlated in both space and time. The radiative warming associated with the high clouds promotes regional-scale rising motion and so feeds back to enhance the regional precipitation rate. This incongruence is cause for a closer investigation of this relationship.

Abstract

While investigating the relationship between atmospheric radiative cooling and latent heating—specifically how convective self-aggregation impacts this relationship—in a cloud-resolving model, an unexpected process was observed: a strong 10-hour periodic oscillation. The simulations were performed using the System for Atmospheric Modeling for a period of 100+ days over a 768 km square domain with no large-scale forcing and no rotation. Once convection aggregates and precipitation reaches a sustained increased level, the precipitation rate fades in and out so that the minimum is approximately 20% of the maximum within each period. The same pattern is observed in moisture and energy fields, though the strongest fluctuations occur in the precipitation rate. These simulations were run using both single and double-moment microphysics and this trend is insensitive to the microphysics.

Globally

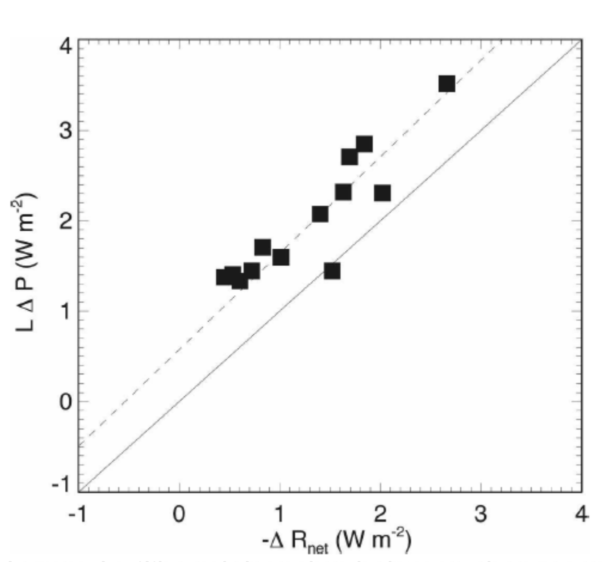


Figure 1a. The relationship between changes in latent heating vs changes in atmospheric column cooling for the AR4 models (Stephens and Ellis, 2008)[1].

Regionally

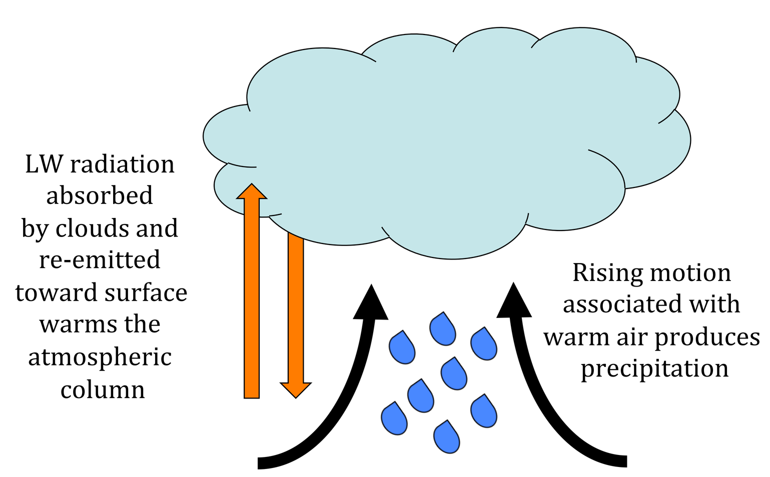
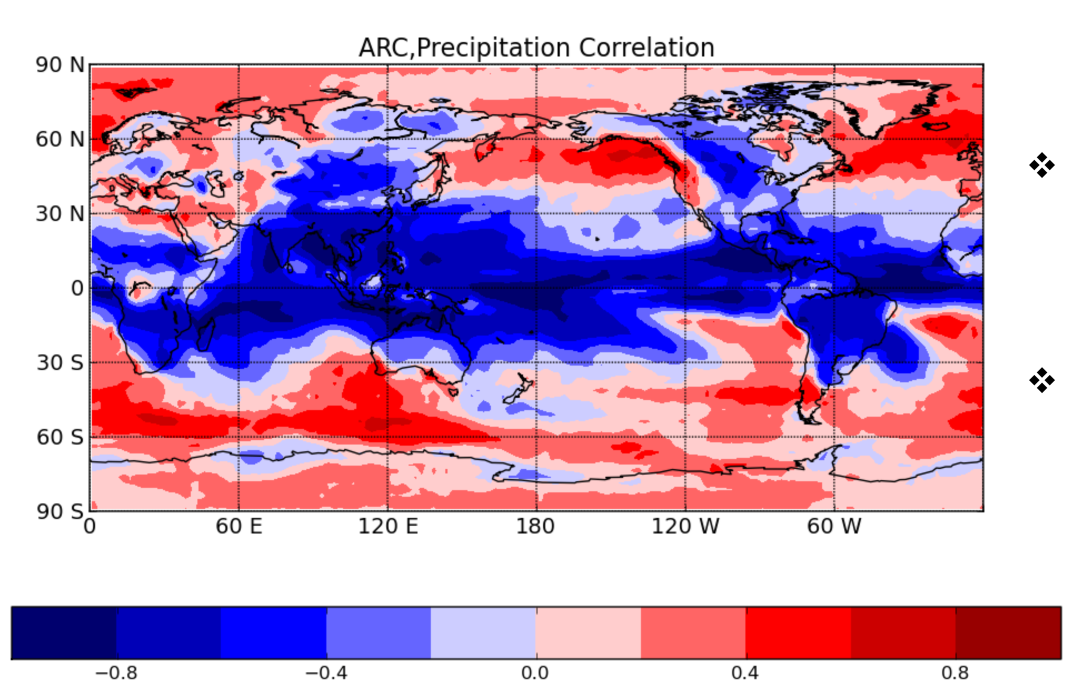


Figure 1b. A depiction of the regional-scale relationship between ARC and precipitation.

Temporal (Seasonal) Correlation



- ARC and precipitation are strongly anti-correlated in the tropics (between 30° S and 30° N).
- ARC and precipitation are positively correlated at middle and high latitudes.

Figure 2. The temporal (seasonal) correlation between ARC and precipitation rates calculated from monthly observations[2,3] (2000-2014).

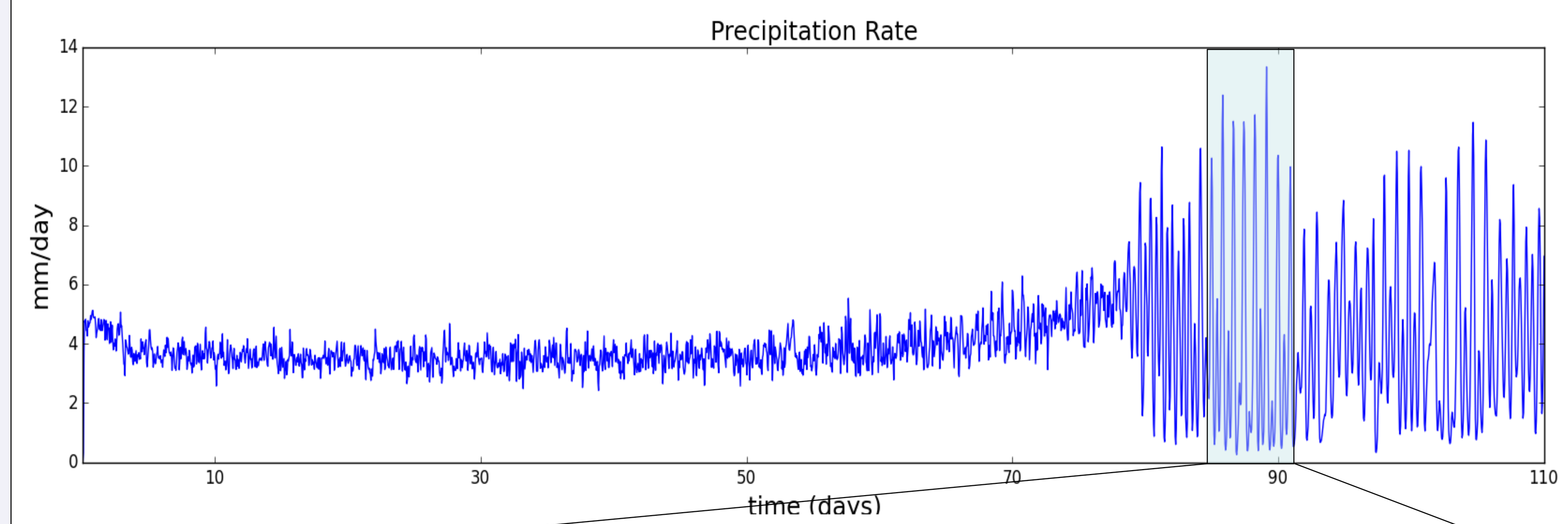
Simulation Specifications

System for Atmospheric Modeling, version 6.10.6[4]

- 768 km by 768 km domain.
- 3 km resolution.
- No diurnal cycle. Constant solar insolation of 413.98 W/m^2.
- No rotation.
- No large-scale forcing.

Recent Results

Domain Averaged Precipitation



- A closer look shows a two-step oscillation with low peaks and high peaks.

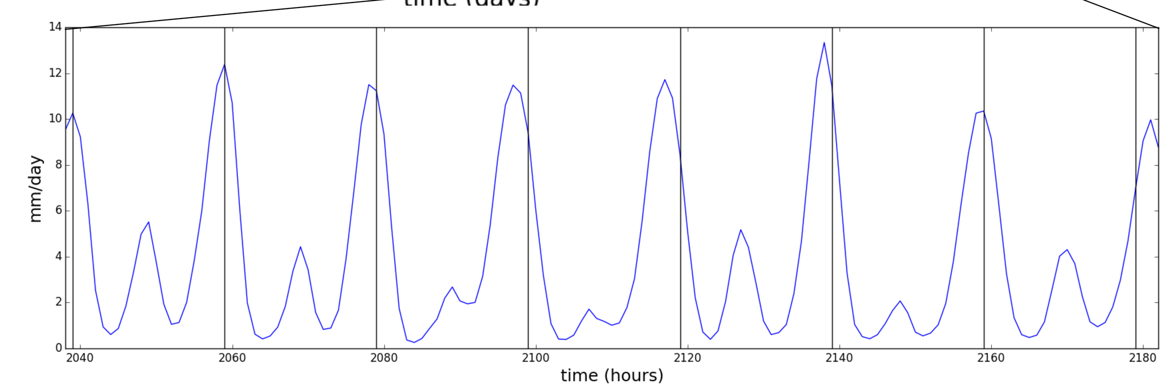


Figure 3a (top). Domain averaged precipitation rate over the 110-day simulation. Double-moment microphysics used. Figure 3b (above). A closer look at the precipitation rate from day 85 (2040 hours) to day 91 (2184 hours). Vertical lines mark 20-hour intervals (starting at hour 2039).

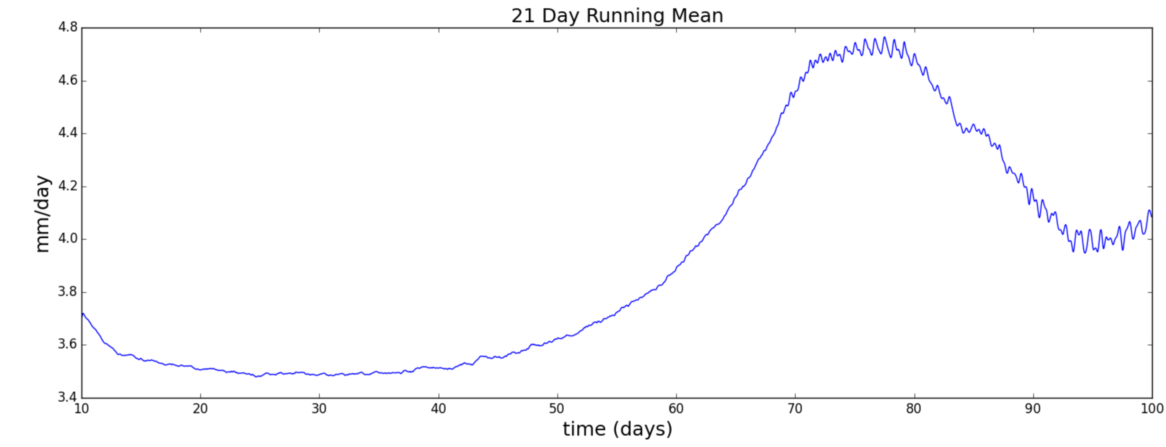


Figure 4 (left). The 21-day running mean of the precipitation rate shows an increase during the aggregation process.

Domain Snapshots

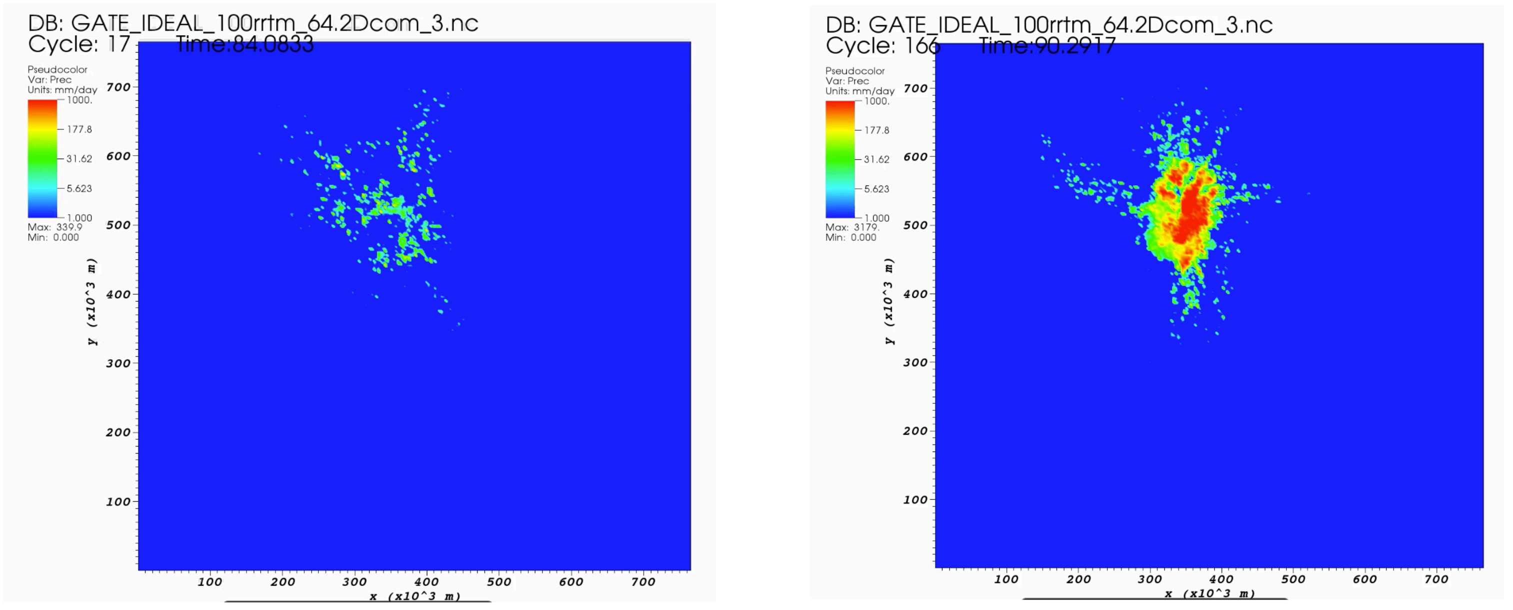


Figure 5. Snapshots of the domain in the aggregated state. The two panels show examples of the minima (left) and maxima (right) of the precipitation rate.

Comparison of Microphysics Schemes

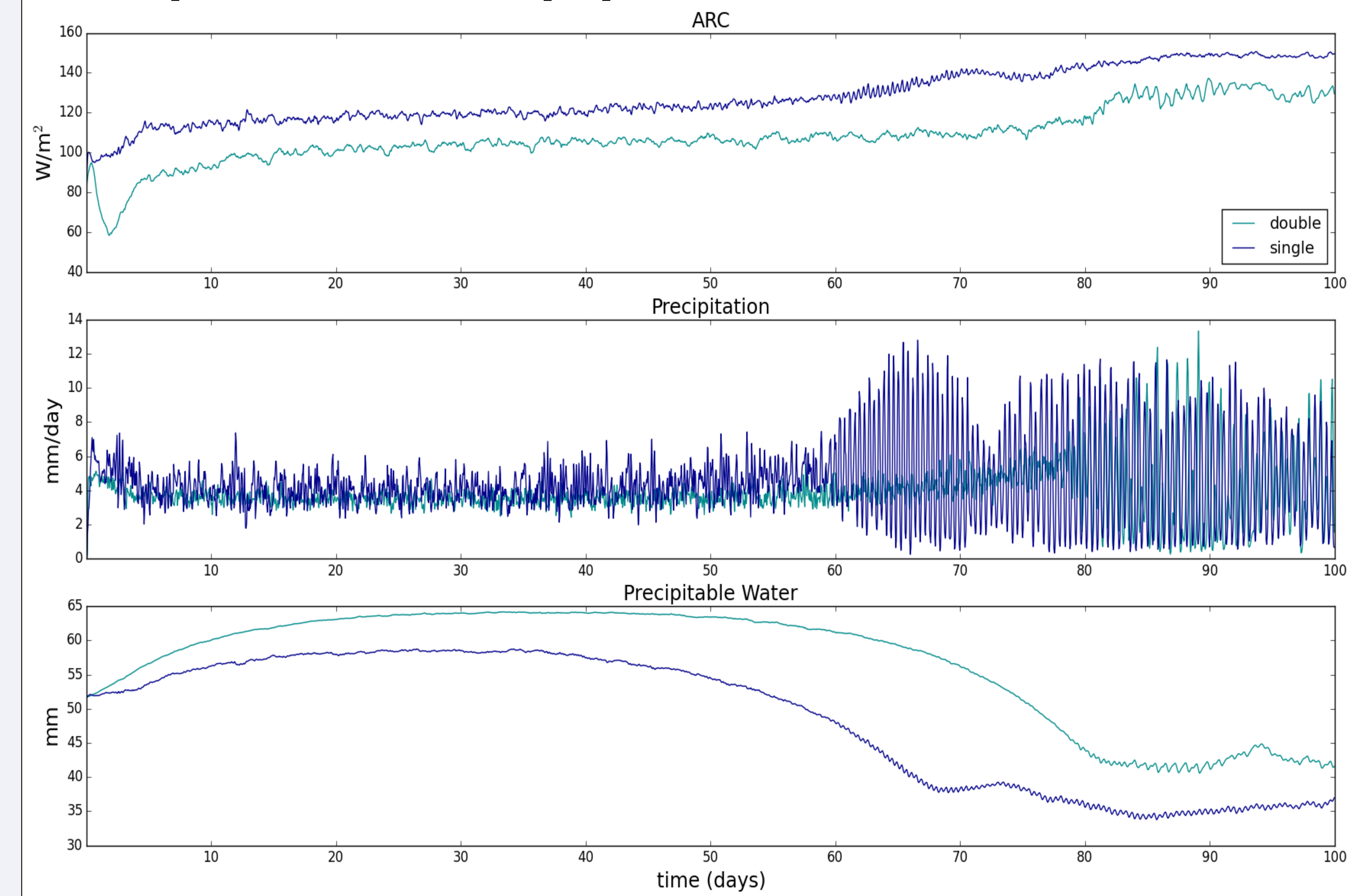


Figure 6. Comparison of the domain-averaged atmospheric radiative cooling rate (top), precipitation rate (middle), and precipitable water (bottom) using single-moment and double-moment microphysics schemes.

Key Points

- A consistent 10-hour oscillation is present in the aggregated state.
- The oscillation is observed in all moisture and energy fields, but the fluctuation is strongest in the precipitation rate and has two steps.
- The oscillation is insensitive to microphysics.

Future Work

Future simulations in SAM will test for sensitivities of the oscillation to domain size, resolution, and sea surface temperature.

References and Acknowledgements

[1]Stephens, G.L., Ellis, T.D., 2008. Controls of Global-Mean Precipitation Increases in Global Warming GCM Experiments. J. Clim., 21: 6141.
[2]GPCP Precipitation data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA,
[3]CERES Radiation data provided by the CERES Science, Data Management, Data Processing and Stewardship Teams at NASA Langley Science Directorate, Hampton, Virginia, USA.
[4]Khairoutdinov, M., Randall, D., 2003. Cloud resolving modeling of the ARM summer 1997 IOP: Model formulation, results, uncertainties, and sensitivities, J. Atmos. Sci., 60.

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