ESTIMATING THE ANNUAL AND SEASONAL DIURNAL CYCLE OF PRECIPITATION OVER CENTRAL FLORIDA USING WSR-88D RADAR AND TIPPING BUCKET RAIN GAUGE DATA

Jason L. Pippitt, David B. Wolff, and David A. Marks

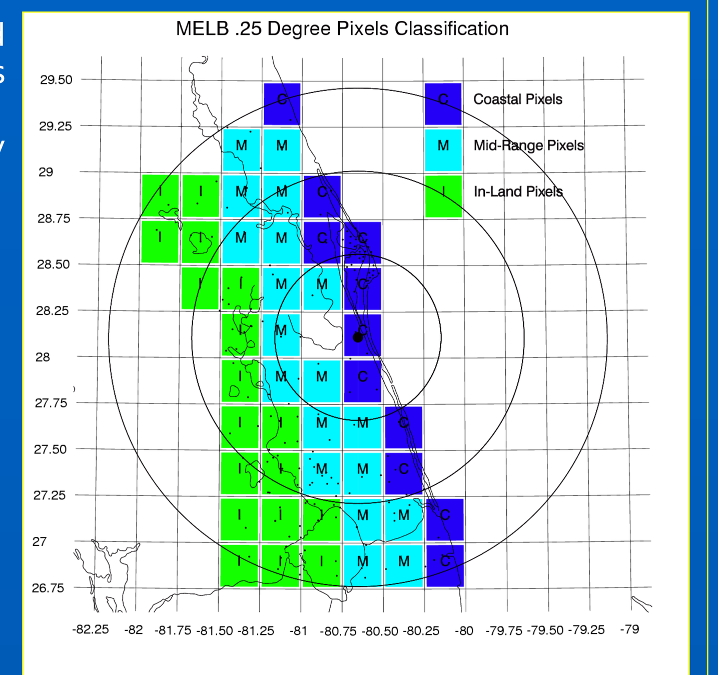
NASA Goddard Space Flight Center, Greenbelt, MD and Science Systems & Applications, Inc, Lanham, MD

91st AMS Annual Meeting
Seattle, WA January 23-27 2011

Introduction

Several recent diurnal rainfall studies such as Sorooshian et al. (2002) have focused on the large scale diurnal cycle, as estimated by satellites such as NASA's Tropical Rainfall Measuring Mission (TRMM). However, our approach is focused over smaller areas (0.25° x 0.25°), with near round-the-clock sampling via ground-based radars and several networks of tipping bucket rain gauges. We observed the decade-long (2000-2009) annual and seasonal diurnal cycles of rainfall over quarter degree pixels using quality controlled gauge and radar data from the TRMM Ground Validation (GV) radar site at Melbourne, Florida (MELB).

- Two data sets, radar data and gauge data, were evaluated and compared to assess the annual and seasonal diurnal cycle of precipitation.
- Instantaneous radar rain rates were obtained from the TRMM Satellite Validation Office (TSVO) 2A-53 product, gauge rain rates were obtained from the 2A-56 product. Wolff et al. (2005) provide a detailed description of all TSVO products.
- Our method is limited to quarter degree pixels that contain gauges. Pixels were grouped into three specific geographical regions: coastal, mid-range, and inland. The diurnal cycle of each region was determined by calculating the mean of all the pixels within that group.
- We analyzed each regions time of maximum and minimum rain intensity tmax and tmin, their corresponding rain rate intensity rmax and rmin, and other significant secondary modes.



Annual Diurnal Rainfall Cycle

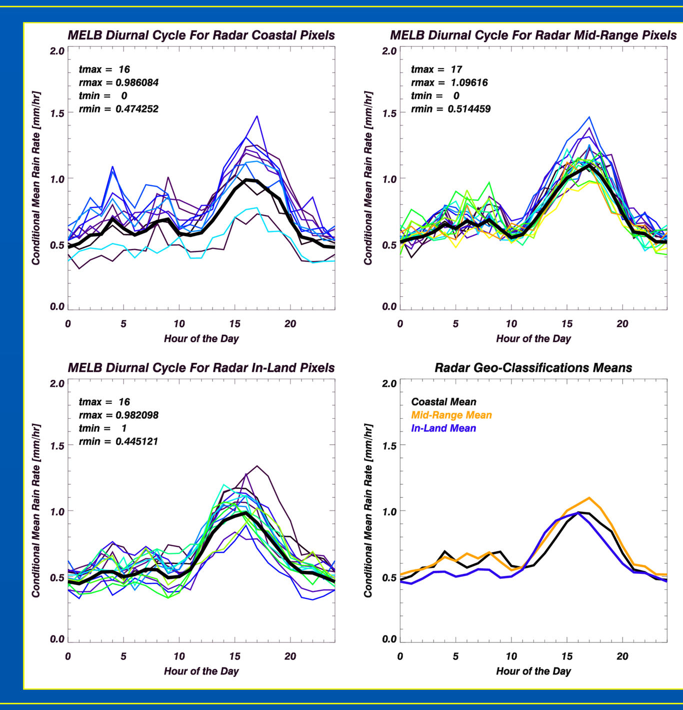
- Tmax for all regions, and both data sets, occurs in the afternoon. Coastal pixels have the earliest tmax, thus precipitation starts near the coast and moves west. Similar landward phase propagation has been noted for coastal regimes most recently by Kikuchi et al. (2007).
- For both data sets mid-range pixels have the highest rmax values, suggesting the convergence zone is prevalent there.
- Maritime convection develops after midnight due to gravity waves emitted by land heating (Mapes et al. 2002). These showers move toward the coast and contribute to a small early morning mode.

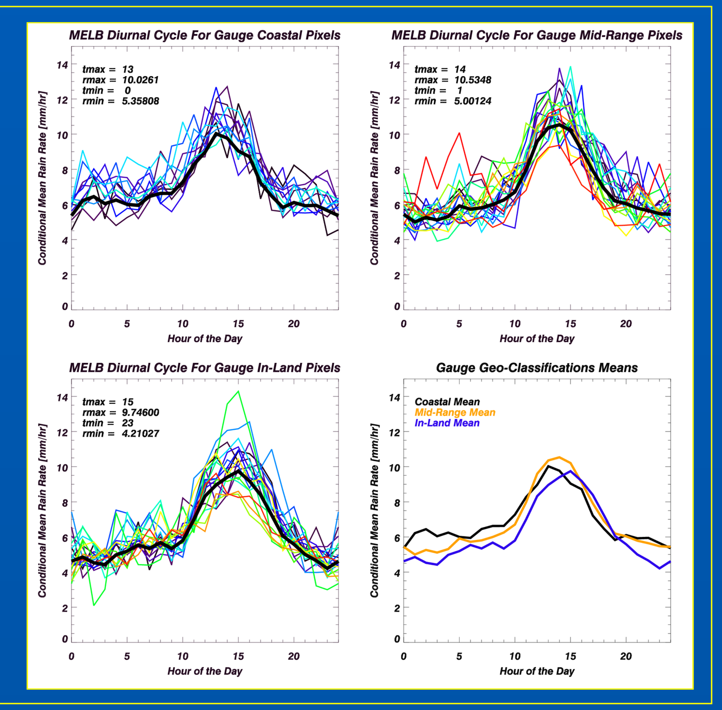
Radar Data

comparison of rmax	mid-range > coastal	mid-range > inland	coastal > inland
percent difference	10.6%	11.0%	0.4%

Gauge Data

comparison of rmax	mid-range > coastal	mid-range > inland	coastal > inland
percent difference	4.9%	7.8%	2.8%





Summer Diurnal Rainfall Cycle

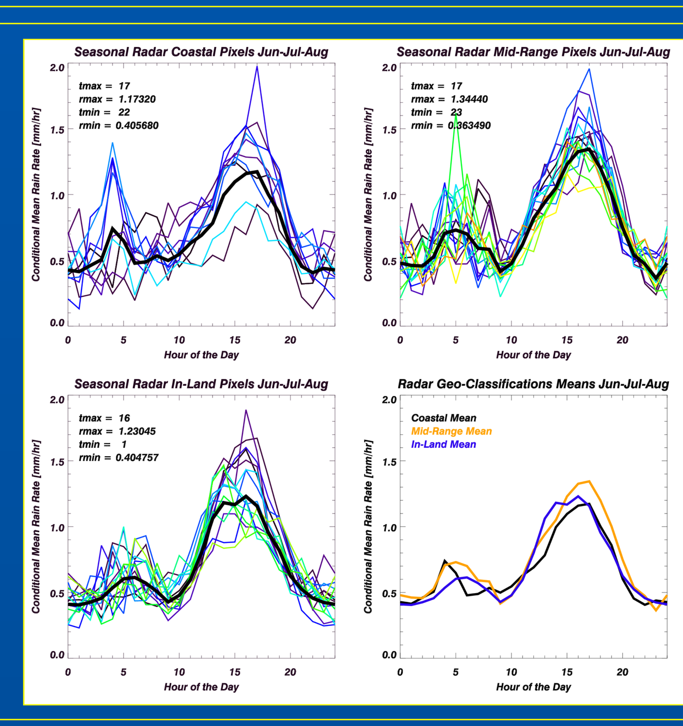
- During the summer months (June – August), for all regions and all data sets tmax occurs in the afternoon.
- Coastal pixels have the highest rmax for gauge data whereas rmax for radar data is highest for mid-range pixels. Climatology and radar data suggest that the convergence zone establishes itself between mid-range and inland pixels.
- A secondary mode is evident in the morning hours. The data suggests that showers initiate over the ocean and move inland during the overnight to morning hours.

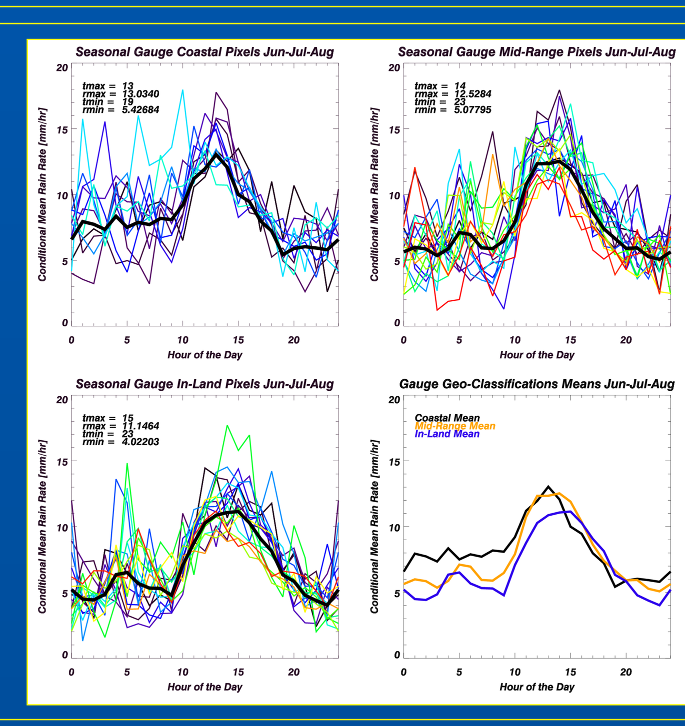
Radar Data

comparison of rmax	mid-range > coastal	mid-range > inland	inland > coastal
percent difference	13.6%	8.9%	4.8%

Gauge Data

comparison of rmax	coastal > mid-range	mid-range > inland	coastal > inland
percent difference	4.0%	11.7%	15.6%





Autumn Diurnal Rainfall Cycle

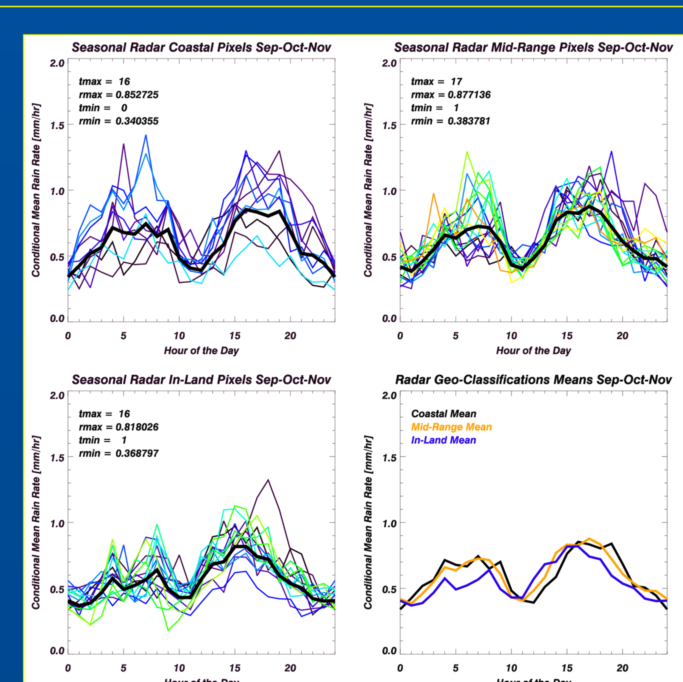
- During the autumn months (September – November), tmax occurs in the afternoon for all regions and all data sets.
- Mid-range pixels have the highest rmax values, suggesting the convergence zone is prevalent in this region. During autumn radar data and climatology suggest the convergence zone moves closer to the coast.
- A secondary mode occurs during the overnight to morning hours and is caused by maritime convection that moves inland. We found the secondary mode to be most pronounced during autumn, similar to findings of Yang et al. (2006).

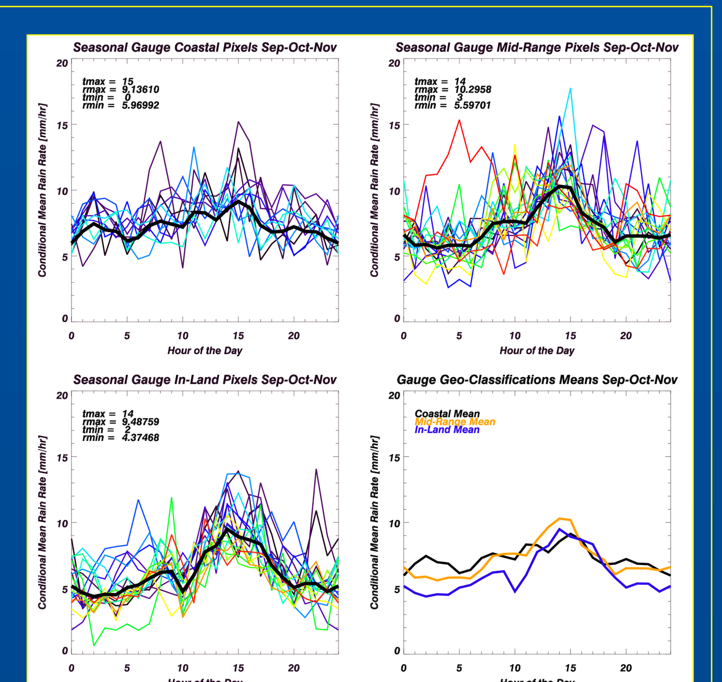
Radar Data

comparison of rmax	mid-range > coastal	mid-range > inland	coastal > inland
percent difference	2.8%	7.0%	4.2%

Gauge Data

comparison of rmax	mid-range > coastal	mid-range > inland	inland > coastal
percent difference	11.9%	8.2%	3.8%





Winter Diurnal Rainfall Cycle

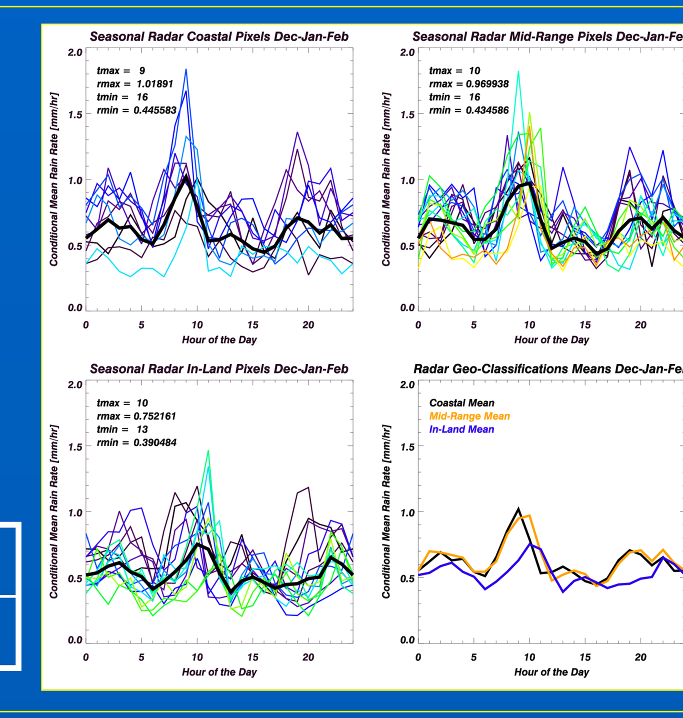
- Gauge data is extremely noisy during the winter months (December – February). For gauge data tmax is in the afternoon and tmin occurs around midnight.
- Radar data conveys a different pattern, showing a morning rmax with coastal pixels having the highest values. Schwartz et al. (1979) conveys the source of the morning maximum to be a winter quasi-stationary front that routinely sets up within this area.
- Two addition modes occur within the radar data, an evening mode (approximately 1900LT) and an overnight mode (approximately 0200 LT).

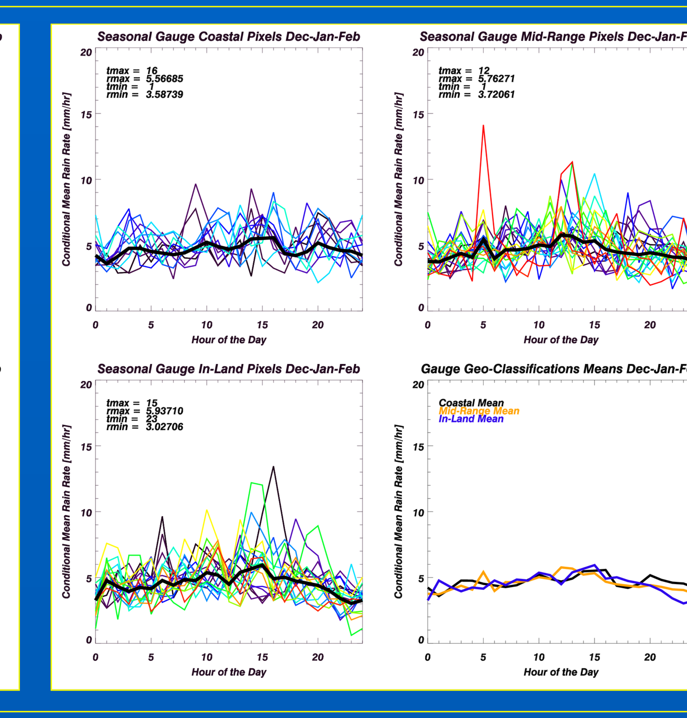
Radar Data

comparison of rmax	coastal > mid-range	mid-range > inland	coastal > inland
percent difference	4.9%	25.3%	30.1%

Gauge Data

comparison of rmax	mid-range > coastal	inland > mid-range	inland > coastal
percent difference	3.5%	3.0%	6.4%





Spring Diurnal Rainfall Cycle

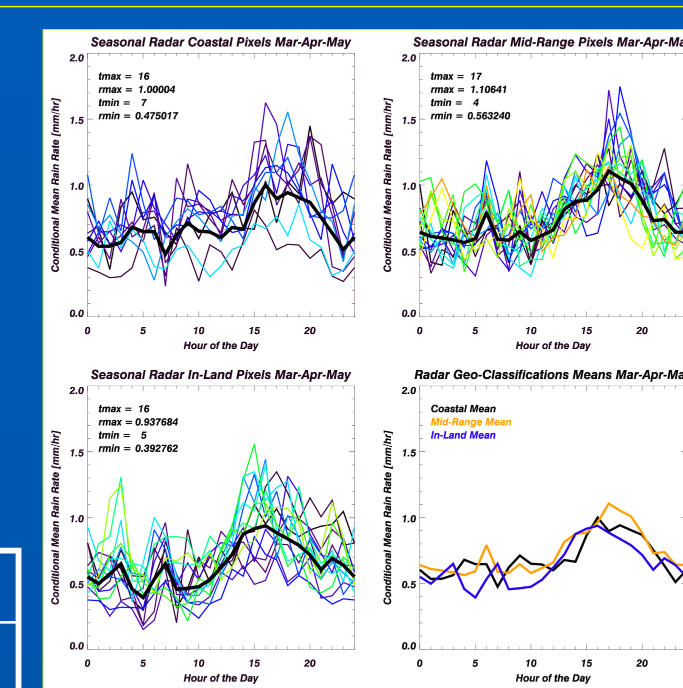
- An afternoon tmax occurs for all regions and all data sets during the spring months (March – May).
- Gauge data suggests that rainfall is uniform over the region during the spring, radar data suggests mid-range pixels have a substantially higher rmax. The convergence zone during the spring sets up over mid-range and coastal pixels.
- A small morning mode is evident in the radar data. This mode shows precipitation beginning to the east, increasing over mid-range pixels, and then dissipating over inland pixels. Nighttime inversions over this area may contribute to the enhanced rain rates (Schwartz et al. 1979).

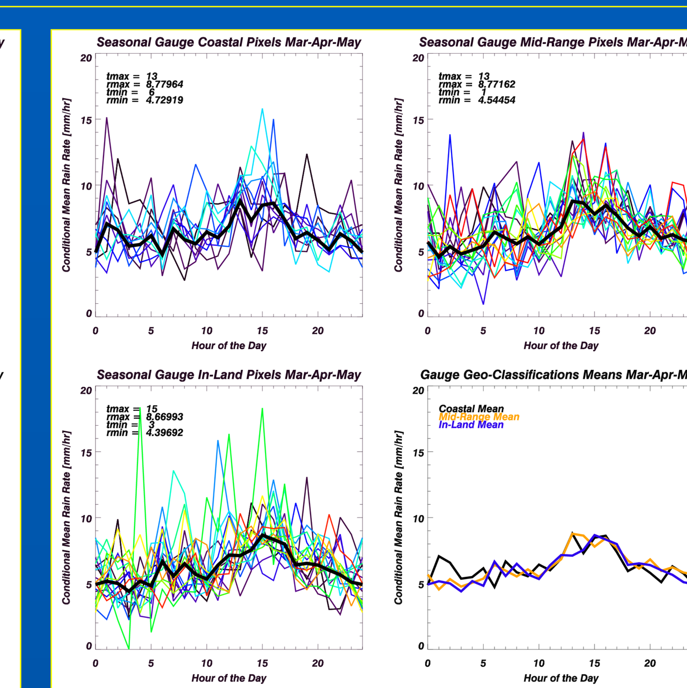
Radar Data

comparison of rmax	mid-range > coastal	mid-range > inland	coastal > inland
percent difference	10.1%	16.5%	6.4%

Gauge Data

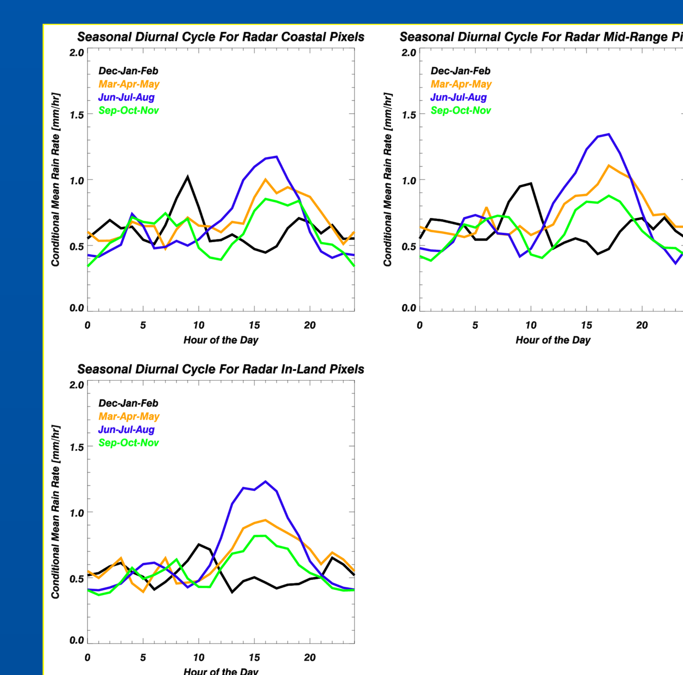
comparison of rmax	coastal > mid-range	mid-range > inland	coastal > inland
percent difference	0.1%	1.2%	1.3%

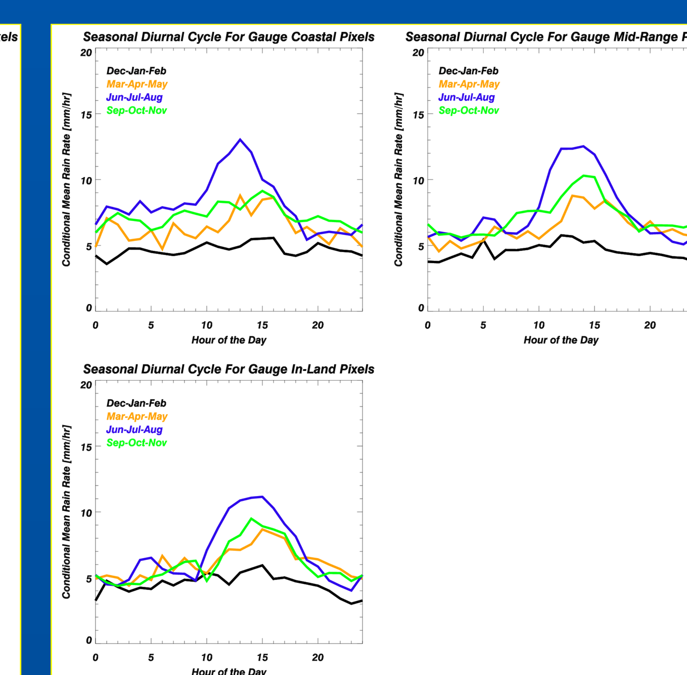




Summary

- Spring, summer, and autumn have similar phases as the annual cycle with an afternoon maximum and a nighttime minimum. Winter has a different phase, with a maximum occurring in the late morning hours and a minimum occurring during the afternoon.
- We found the area of maximum rainfall is closest to the coast during the winter when the sea breeze and daytime heating is the weakest, and furthest inland during the summer months when these factors are the strongest.
- Summer has the highest amplitude followed by spring, autumn, and winter, thus summer months have the greatest influence on the annual cycle, and indeed on the annual rainfall budget. The relatively high amplitude of the radar data winter maximum suggests that it is a strong influence on the annual cycle's late morning mode. The autumn morning mode affects the annual morning modes. The most influential aspect of spring on the annual cycle is its afternoon maximum.
- Gauge and radar data both have similar findings though the radar data conveys a more robust result. Radar data samples the entire 27 km² grid versus point measurements within that grid for gauge data. The sparseness of gauge data as you move inland also causes a discrepancy with the radar data. A dense inland rain gauge network would provide results, possibility more consistent with radar data findings.





References

Kikuchi, K., B. Wang, 2007: Diurnal Precipitation Regimes in the Global Tropics. J. Climate, **21**, 2680-2696.

Mapes, B.E., T.T. Warner, M. Xu, 2002: Diurnal Patterns of Rainfall in Northwestern South America. Part III: Diurnal Gravity Waves and Nocturnal Convection Offshore. Mon. Wea. Rev., **131**, 830-844.

Sorooshian, S., X. Gao, K. Hsu, R. A. Maddox, Y. Hong, H. V. Gupta, B. Imam, 2002: Diurnal Variability of Tropical Rainfall Retrieved from Combined GOES and TRMM Satellite Information. *J. Climate*, **15**, 983– 1001.

Schwartz, B.E., L.F. Bosart, 1979: The Diurnal Variability of Florida Rainfall. Mon. Wea. Rev., **107**, 1535-1545.

Wolff, D.B., D.A. Marks, E. Amitai, D.S. Silberstein, B.L. Fisher, A. Tokay, J. Wang, and J.L. Pippitt, 2005: Ground Validation for the Tropical Rainfall Measuring Mission (TRMM). J. Atmos. Oceanic Technol., **22**, 365-379.

Yang, S., and E.A. Smith, 2006: Mechanisms for Diurnal Variability of Global Tropical Rainfall Observed from TRMM. *J. Climate*, **19**, 5190–5226.

Acknowledgements

Dr. Ramesh Kakar (NASA HQ), Dr. Scott Braun (TRMM Project Scientist), Dr. Mathew Schwaller (NASA/GSFC), and TRMM Precipitation Office Support: Jianxin Wang, David Makofski, Bart Kelley and Lynne Shupp