iJRASET
International Journal For Research in
Applied Science and Engineering Technology

# INTERNATIONAL JOURNAL FOR RESEARCH
## IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

**Volume:** 5 **Issue:** XI **Month of publication:** November 2017

**DOI:**

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue XI November 2017- Available at www.ijraset.com

# Wind Profiler Observations of Shallow Convection over Palau in Tropical Western Pacific

G. Mahboob Basha[1], U.V. Murali Krishna[2], Mohammed Waaiz[1], K. Krishna Reddy[3], Ryuichi Shirooka[4]
[1]*Department of Physics, Rayalaseema University, Kurnool*
[2]*Indian Institute of Tropical Meteorology, Pune, Maharastra, India*
[3]*Department of Physics, Yogi Vemana University, Kadapa, Andhra Pradesh, India*
[4]*Department of Coupled Ocean-Atmosphere-Land Processes Research, Japan Agency for Marine-Earth Science and Technology, Yokosuka, Japan*

***Abstract: The radar reflectivity factor of wind profiler radar is used to study diurnal and seasonal variability in shallow convection over Palau islands (7°20' N, 134°28' E) in Western Tropical Pacific ocean. Diurnal variability indicates it's highest in the afternoon over Palau. Seasonal variability shows a larger occurrence in westerly monsoon (WM) compared to easterly monsoon (EM). However extra extreme shallow convection occurs throughout EM compared to WM. It is found that a more humid environment at the surface and relatively higher vertical velocities are responsible for higher occurrence of shallow convection during WM season. In this paper, an attempt is made to explore diurnal variability in the shallow convection over Palau islands and does the shallow cumulus convection differ in easterly and westerly regimes?***
***Keywords: Shallow convection, Wind Profiler Radar, Monsoon, Radar Reflectivity***

## I. INTRODUCTION

Shallow cumulus clouds play a pivotal role in the tropical oceans, and can have considerable importance from the perspective of climate dynamics. Precipitation from shallow clouds over the tropical and subtropical oceans generally occurs in the form of light rain/drizzle from stratocumulus/stratus [1]. Past tropical field campaigns [2-4] and also trade wind boundary layer during the Atlantic Trade wind Experiment (ATEX), the Barbados Oceanographic and Meteorological Experiment (BOMEX), the GARP Atlantic Tropical Experiment (GATE), the Tropical Ocean–Global Atmosphere Coupled Ocean–Atmosphere Response Experiment (TOGA COARE) and the Indian Ocean Experiment (INDOEX) as well as from Large Eddy Simulation (LES) and theoretical studies[5-10] revealed about shallow convection and quantify the impact of shallow cumulus convection on large-scale tropical circulations. The representation of shallow cumulus convection in climate models has practical consequences in determining climate sensitivity. The simulation of the diurnal cycle of convection is an important measure of a climate model's performance [11],[12] . However, the climate models usually cannot produce the observed diurnal variation in rainfall pattern [12].The relationships between the overall statistics of shallow cumuli and a varying large scale environment remain to be understood in more detail. This has become particularly evident as global climate models (GCM's) indicate different responses of these clouds to a warming climate contributing to the uncertainty in estimating climate sensitivity [13],[14]. To improve the representation of shallow clouds in climate models a better understanding of processes on a range of scales is required. Particularly, it is important to evaluate, how and to what extent processes on smaller scales affect those on larger scales and vice versa. Part of the water vapor collected in the trade-wind boundary layer through shallow cumulus convection is subsequently transported to the Inter-tropical Convergence Zone (ITCZ) by trade winds, feeding deep convection that drives large-scale circulations [15-17]. Their importance in weather and climate has been documented [15] yet our understanding of their role in global water and energy cycles and their treatment in climate models are poorly understood [18],[19].

Most of the previous observational and modeling studies focused on deep convective cumulus clouds or stratus clouds [12], [20]. However, little attention has been paid to the shallow cumulus convection which is abundant over much of the tropical oceans. Shallow cumuli not only affect the Earth's radiation budget, but also impact the heat, moisture and momentum budget in the boundary layer and hence the feedback on deep convection that drives large-scale circulations. Detailed estimate of the frequency and intensity of shallow convection, in particular over larger areas and longer time periods, are very rare. As these clouds cover small area, and hence the area covered by precipitation, are hard to measure using visible, microwave and infrared sensors aboard operational satellites. Also the sensor footprints are often too coarse and clouds and precipitation at higher levels can easily obscure low-level clouds and precipitation near the surface. Several researchers studied the shallow cumulus convection from the space-born

Tropical Rainfall Measuring Mission (TRMM) Precipitation Radar (PR) and revealed that the shallow precipitation contributes about 20% of the total precipitation in the tropics [21-23]. However, these estimates are based on TRMM data for which the majority of radar echoes (that span at least 750 m in depth) have tops below 3 km. Although the TRMM PR has high vertical resolution and low rain-rate detection (a minimum of 0.4-0.5 mm/h), it is yet unclear how much precipitation is actually observed from shallow clouds by TRMM. Sensitivity and resolution effects can lead to an under sampling of radar echoes at low levels, in particular at off-nadir scanning angles due to radar main-lobe contamination[24]. Hence, it is necessary for continuous monitoring of shallow cumulus convection with high temporal resolution. Among all spaced and ground-based instruments, wind profiler radar is well suited for monitoring of shallow cumulus convection with ~200-m height and 180s temporal resolution.

Hence, in the present study, an attempt is made to explore the variability in shallow cumulus convection during easterly and westerly monsoon seasons over Palau Islands. The remaining parts of the paper are as follows: the data and methodologies are presented in section II. The observational results of shallow cumulus convection during easterly and westerly monsoon periods are given in section III; the influence of environmental parameters on the occurrence of shallow convection is provided in section IV; and summary of the present study is provided in section V.

## II. DATA AND METHODOLOGY

Japan Agency for Marine-Earth Science and Technology (JAMSTEC) is carrying out research at Palau Islands($7^o$ 20' N, $134^o$ 28' E) focusing on the Pacific Area Long-term Atmospheric observation for Understanding of climate change (PALAU) project to understand the mechanism of cloud-precipitation processes and air-sea interactions over the warm water pool, focusing on seasonal and intra-seasonal variations [25]. JAMSTEC installed ground based sensors viz., a Lower Atmospheric Wind Profiler (LAWP), Micro Rain Radar, Ceilometer, Microwave Radiometer, Impact Disdrometer and Automatic Weather Station at Aimeliik observatory ($7.3^o$N, $134.3^o$E). However, for the present study, lower atmospheric Wind Profiler Radar (WPR), Joss-Waldvogel Disdrometer (JWD) data is utilized.

Wind profiler radar is a versatile instrument to investigate the vertical structure of shallow cumulus convection with high temporal and vertical resolution [26]. Several researchers studied the deep convective cumulus clouds or stratus clouds using WPR [27],[28]. Observations with the WPR were carried out fairly continuously from 01 April, 2003 to 31 March, 2007. A total of 1140 days of wind profiler data are available until March 2007 for analysis. Non-availability of the WPR data is mainly due to the power failure at the observational site and also due to the malfunctioning of the instrument. Precipitation data was collected using JWD for the above mentioned period. For the present study rainfall rate less than 0.1 mm/h are excluded for the analysis. In addition, the vertical wind velocity and relative humidity data for the above mentioned period are collected from ERA-Interim reanalysis. The ERA-Interim is the largest global atmospheric reanalysis produced by the European Center for Medium-Range Weather Forecast (ECMWF). The monthly mean data are available at different pressure and at a grid resolution of $0.25^o$ latitude $\times 0.25^o$ longitude. A comprehensive documentation on the accuracy, bias correction and limitations of the ERA-Interim reanalysis are discussed in[29].

WPR isused to classify precipitation into three categories namely stratiform, deep convection and shallow convection by examining the vertical structure of radar reflectivity based on the algorithm proposed by [30].If there is a clear signature of bright band (the region just below zero degree isotherms having enhanced reflectivity which is produced by liquid coated ice particles) is observed by WPR then the corresponding rainfall at the ground is considered as stratiform. If there is an enhanced turbulence above the zero degree isotherms with the absence of bright band then the corresponding rain at ground is considered as deep convection. Rainfall at the ground level is considered as shallow convection if the clouds are not extended beyond zero degree isotherm level with turbulence within the cloud system. The only difference between the present rainfall classification and classification by [30] is that they classified rain into stratiform, mixed, shallow, and deep convection but in the present study we have classified them into three types only (stratiform, shallow, and deep convection).To study the seasonal variation in shallow convection, the precipitation datasets are classified into WM and EM seasons as defined in [31] .Onset of westerly monsoon occurred during May and withdrawal occurred during November in the year 2003. However, onset of westerly monsoon occurred in June for 2004, 2005 and 2006 and withdrawal occurred during November for 2004 and October for 2005 and 2006.

## III. RESULTS

Four years of WPR data is analyzed to study the variability in shallow convection over Palau Islands. To summarize the radar reflectivity factor profiles in 2D histograms contour frequency by altitude diagram (CFAD) of radar reflectivity has been used. Figure 1 shows the CFAD of radar reflectivity derived during all the rainy periods. The highest frequencies of radar reflectivity are present above 20 dB and at altitudes above 5 km, which corresponds to higher occurrence of deep convection over Palau. The

CFAD also show that the radar reflectivity increases with decreasing altitude and reaches its maximum between 4 and 5 km. At high altitude, the ice particles form, which further grow larger due to the dynamical and microphysical process and fall down to the lower altitudes. As the radar reflectivity is a six power of the size, there is an increase in radar reflectivity with decreasing height. In the region between 4 and 5 km an enhanced reflectivity is observed which is due to melting layer. Further the frequency is more above 20 dB below 4 km height which corresponds to the presence of shallow convection over Palau.

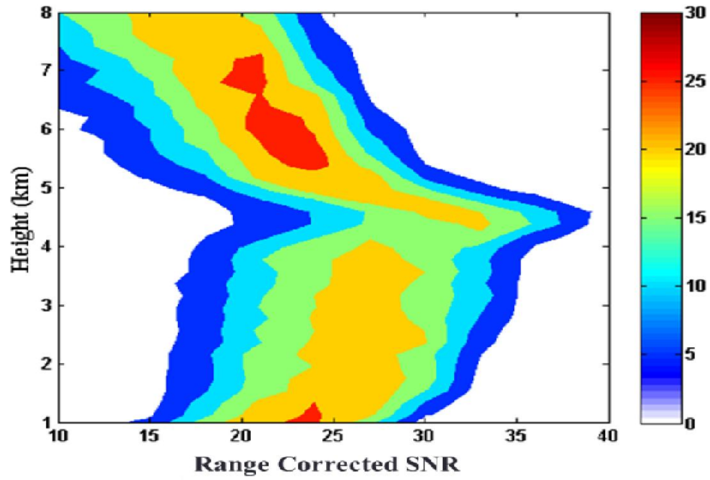



Fig. 1: Contour frequency by altitude diagram of the radar reflectivity over Palau. Horizontal bin dimension is 3 dB. Color bar indicates the percentage of the corresponding radar reflectivity at different heights to the overall radar reflectivity

Figure 2 shows the histograms of accumulated rainfall collected from JWD during stratiform, deep convective and shallow convective precipitation during EM and WM periods. From the figure, it is clear that the total rainfall is more in WM season compared to EM season for all types of precipitation. Further, the JWD data reveal that deep convective precipitation is more prevalent contributing about 70% of the total rainfall and warm rain showers from shallow cumuli contributes about 19% (14.4%) of the total rainfall during EM (WM) periods over Palau region. Hence, shallow clouds contributes significant amount to the total precipitation over Palau Islands. The diurnal variability in the occurrence of shallow cumulus convection during EM and WM period is shown in Figure 3.The occurrence of shallow cumulus convection is maximum during afternoon hours and minimum in the late evening/night. [32]Kikuchi and Uyeda, (1996)reported a peak in the occurrence of radar reflectivity values during the afternoon hours from Doppler radar observations of evolution of tropical storm over the Manus, Papua New Guinea during the TOGA-COARE. [33] Shirooka and Uyeda, (1991)also reported from the radar observations that the cloud reaches the developing stage during the afternoon hours over Japan.

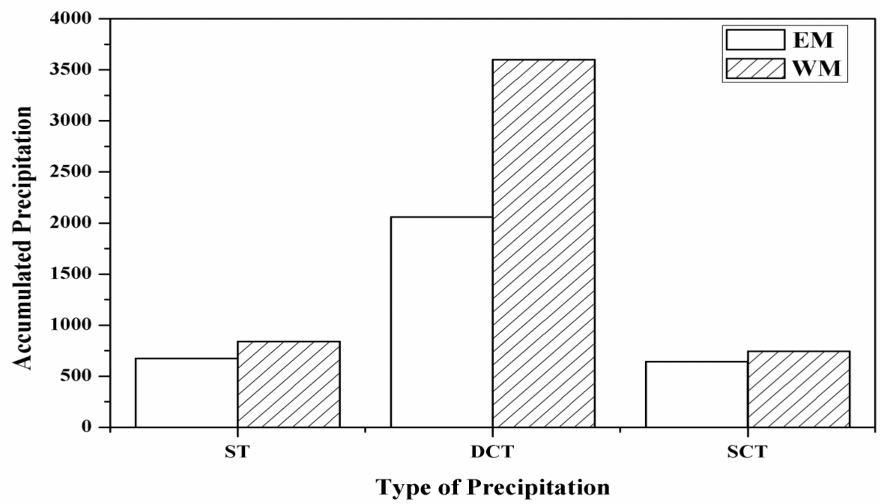



Fig. 2: Total accumulated rainfall measured using Joss-Waldvogel Disdrometer during Easterly and Westerly monsoon seasons. Here ST, DCT and SCT represent stratiform, deep convection and shallow convection respectively.

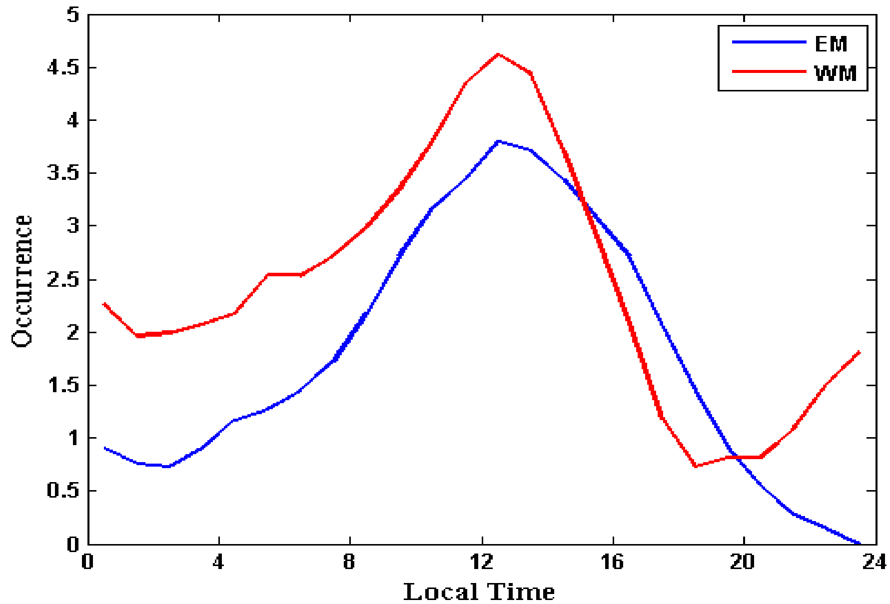



Fig. 3: Diurnal variation in the occurrence of shallow convection during Easterly and Westerly monsoon seasons.

The occurrence of shallow convection shows a bimodal distribution over Palau during WM season with its primary peak in the afternoon hours (1300hrs)in association with the solar heating. In addition, a secondary peak is also observed in the mid-night (0000hrs) during WM season. During EM season, the shallow convection shows its maximum in the mid-afternoon (1300hrs) time. Further, the occurrence of shallow convection is higher during WM season compared to EM season.

Rain rate statistics for EM and WM shallow convection are shown as box and whiskers in Figure 4. In this plot boxes represent data between the 25th and 75th percentile and the whiskers show data from the 5 to 95 percentiles. The horizontal red lines and square with in the box represents the median value and mean values of rain rate respectively. Mean value of rain rate is 4.3 (3.9) mm/h during easterly (westerly) regime. During the easterly (westerly) regime the 5thand 95thpercentile of shallow convective rain rates are found, respectively, at 0.1 and 19 (0.1 and 16) mm/h. Moreover, the99 percentile of rain rate is found at 42.8 and 34.2 mm/h during EM and WM seasons respectively. This indicates that the most intense rain rates are observed during EM season. This is further evidenced from Figure 5 which shows the diurnal variation of maximum rain rate in EM and WM seasons shallow convection.

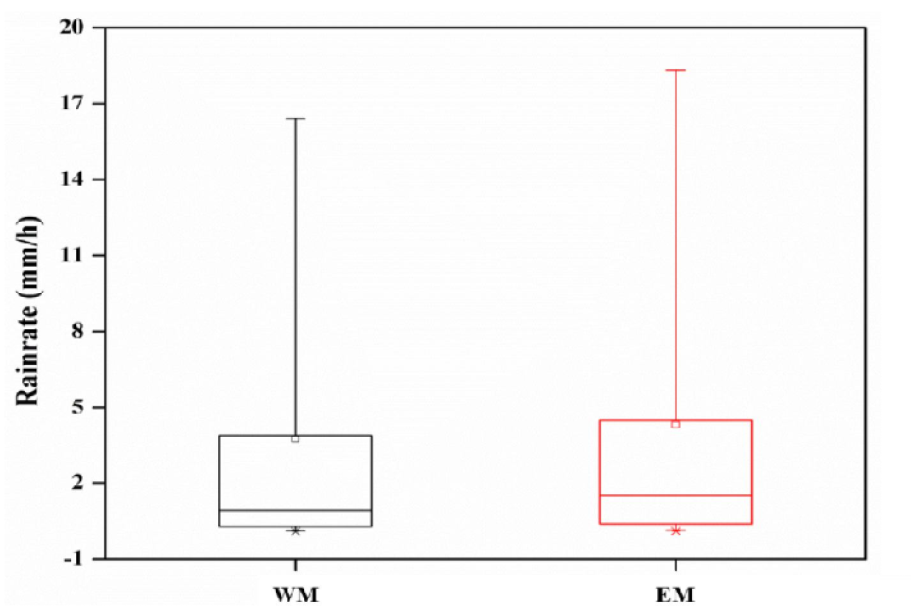



Fig. 4: Box and whisker plot of shallow convection rainrate during Easterly and Westerly monsoon seasons.

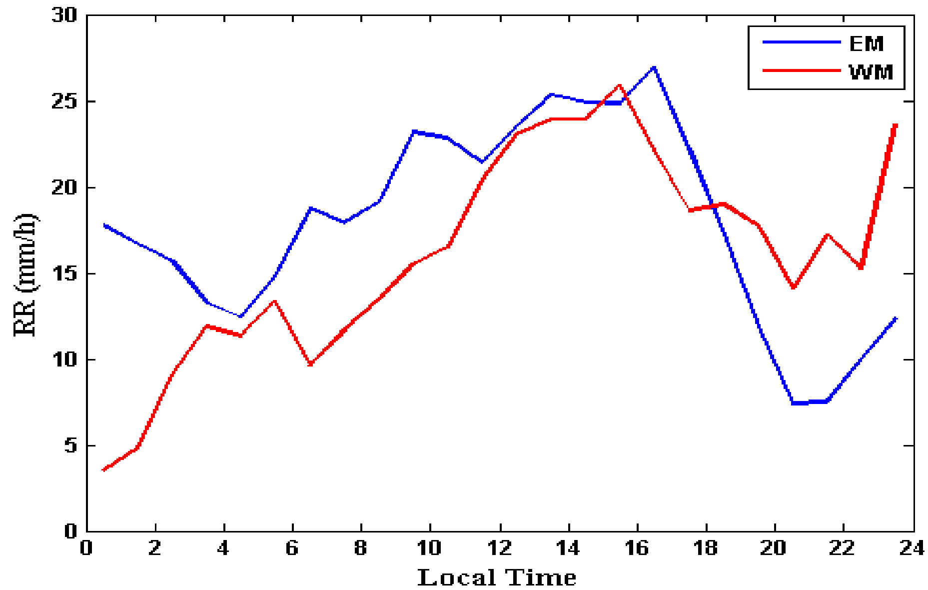



Fig. 5: Diurnal variation in the maximum surface rain rates observed during Easterly and Westerly monsoon seasons shallow convective precipitation.

The diurnal variation in rain rate followed the diurnal occurrence of shallow convection over Palau with comparable higher rain rates during EM season. However the maximum in the rain rate lags behind the occurrence i.e. higher rain rates are found ~2 hours after the maximum occurrence. So, higher convective rain rates are found in shallow convective echoes in the easterly regime compared to their westerly regime counterparts.

To estimate the magnitude of rainfall proportions during EM and WM seasons, rainfall volume fractions are analyzed in Figure 6. A prominent diurnal cycle is observed with the greatest shallow convective rainfall fractions observed around 1400-1600hrs (1300 hrs) at which time shallow convective rainfall contributes nearly 65% (80%) of the total rain in the EM (WM) period. In addition Figure 7 also shows a secondary maximum in convective fractions at 0000 LT during the WM period. This secondary maximum is absent in EM period. The smallest shallow convective rainfall fractions are observed in the mid-night, when the fraction of rainfall associated with shallow convective rainfall is around 10% in the both monsoon seasons.

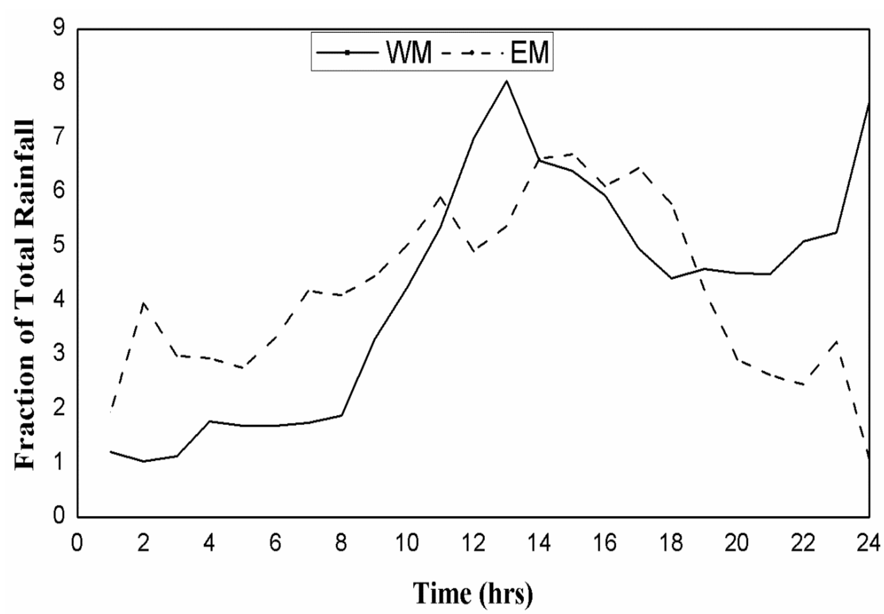



Fig. 6: Hourly average of rainfall fractions measured using Joss-Waldvogel Disdrometer in shallow convection during Easterly and Westerly monsoon seasons.

## IV. DISCUSSION

Clouds with different dimensions may produce different amounts of rain at the ground, for instance, deeper clouds may rain more intensely. Deeper clouds with a higher (cloud-top) liquid water content may rain more, as shown in early studies of precipitating shallow cumulus radar and LES studies [35,36] . In general, clouds are formed by the phase transition between vapor and liquid, when the humid air moves upwards due to ascending currents. The ascending currents are represented by the vertical velocity. Figure 7 shows the height monthly variability of the vertical velocity obtained from ERA-Interim reanalysis. The color bar with positive (negative) values signifies the upward (downward) motion. If the updrafts are strong, there will be a huge vertical development of deep convective clouds and if weak results in shallow clouds. Moderate up drafts are observed above 4 km during WM season. As the updrafts are moderate, shallow clouds as well as deep clouds are possible over Palau Islands.
Further, the monthly mean relative humidity obtained from ERA-Interim reanalysis has been investigated. Figure 8 shows the vertical variations in the monthly mean relative humidity over Palau. It is observed that the humidity is high extending from surface to 4 km during August and September of WM season. In addition, the relative humidity is comparable high (from surface to 10 km) during WM season. The moderate updrafts along with high humidity resulted in the formation of shallow as well as deep clouds over this region.

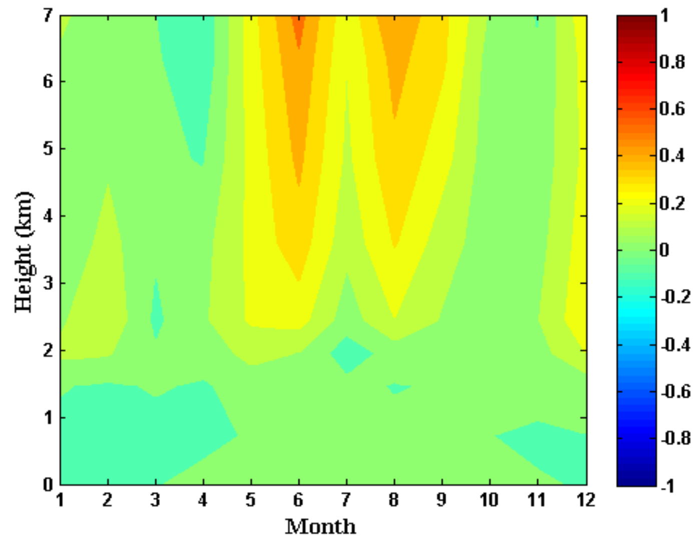



Fig. 7: Vertical variations in the monthly mean vertical velocity (cm/s) derived from ERA-Interim reanalysis.

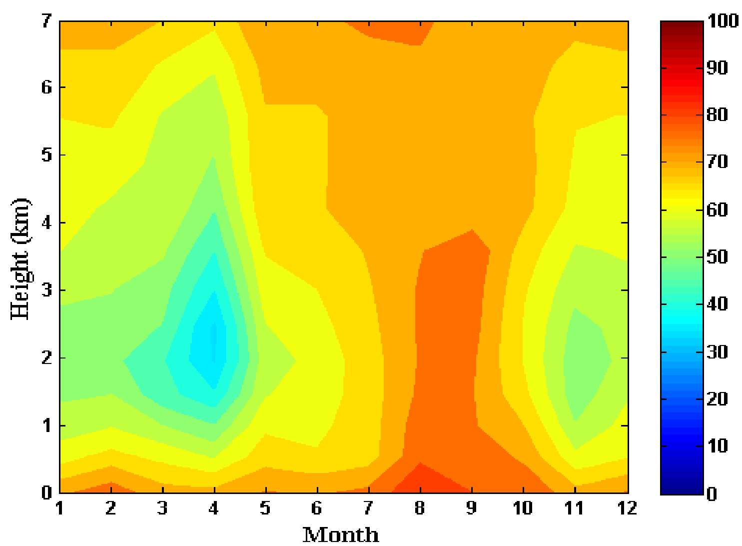



Fig. 8: Vertical variations in the monthly mean vertical velocity (cm/s) derived from ERA-Interim reanalysis.

## V. SUMMARY

Four years of Wind profiler radar data along with JWD and ERA-Interim reanalysis are analyzed to study the occurrence of shallow convection over Palau Islands. The observations reveal that the occurrence of shallow cumulus convection shows a prominent diurnal variation with higher occurrence during afternoon. Further the occurrence is higher during westerly monsoon compared to easterly monsoon season. Rain-rate statistics shows that the rain rates are higher in easterly monsoon compared to westerly monsoon. This intense shallow convection tends to occur in the mid-afternoon in westerly and easterly monsoon season at which time the rainfall contribution is about 65% in easterly monsoon and 80% in westerly monsoon total rainfall. Also a secondary maximum in the occurrence of shallow convection is observed at mid-night during westerly monsoon season. The moderate updrafts along with high humidity resulted in the higher occurrence of shallow clouds over this region.

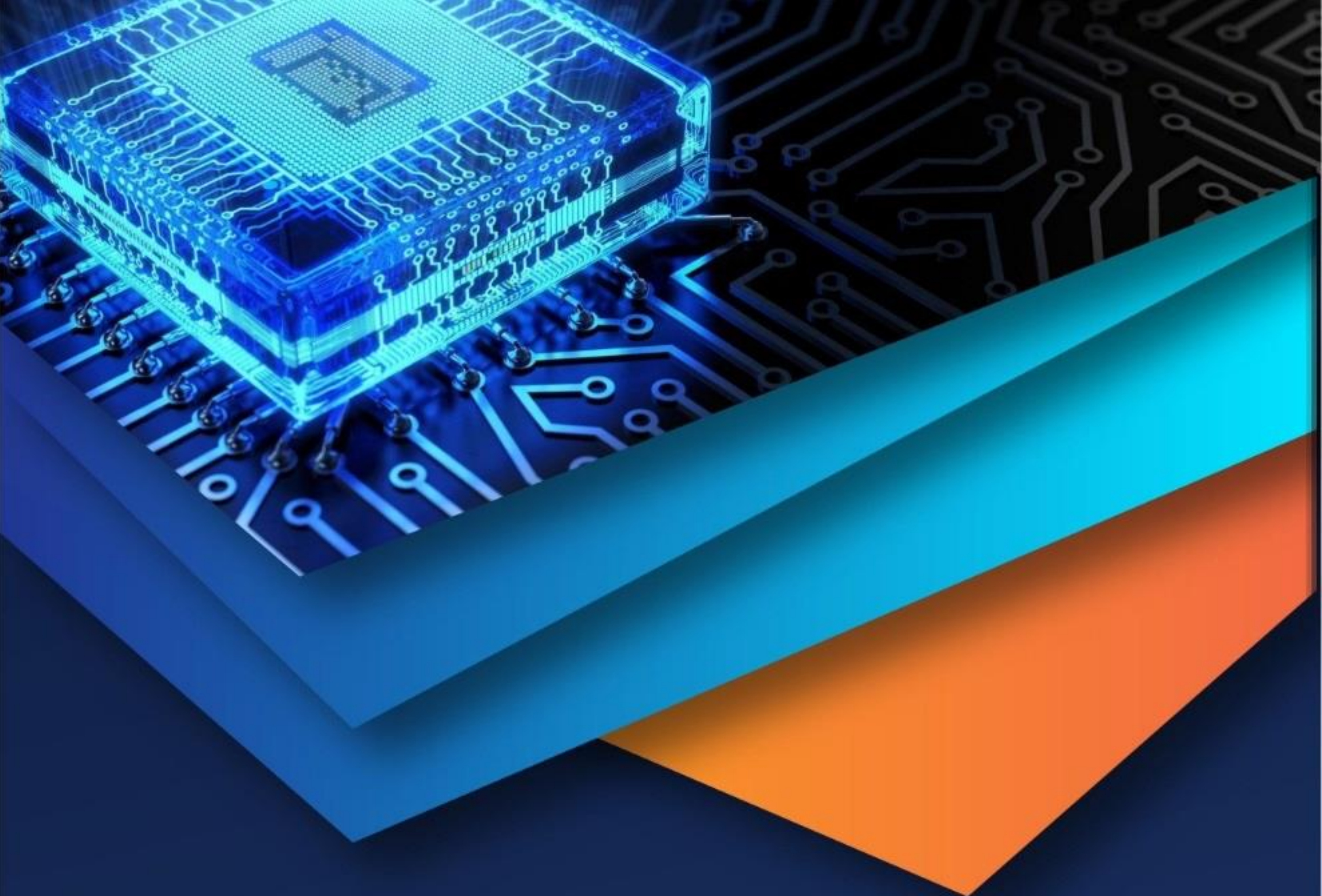
## VI. ACKNOWLEDGEMENTS

We appreciate receiving the vertical velocity and relative humidity data from ERA-Interim reanalysis of ECMWF at http://apps.ecmwf.int/datasets/.

## REFERENCES

[1] Austin, P. M., R. M. Rauber, H. T. Ochs III, and L. J. Miller, 1996: Trade wind clouds and Hawaiian rain bands. Mon. Wea. Rev., 124, 2126–2151.
[2] Austin, J., 1948: A note on cumulus growth in a nonsaturated environment. J. Meteor., 5, 103–107.
[3] Byers, H. R., and R. K. Hall, 1955: A census of cumulus-cloud height versus precipitation in the vicinity of Puerto Rico during the winter and spring of 1953–1954. J. Meteor., 12, 176–178.
[4] LeMone, M. A., and W. T. Pennell, The relationship of trade wind cumulus distribution to sub cloud layer fluxes and structure, Mon. Weather Rev., 101,524-539, 1976.
[5] Arakawa, A., and W. H. Schubert, 1974: Interaction of a cumulus cloud ensemble with the large-scale environment, Part I. J. Atmos. Sci., 31, 674–701.
[6] Betts, A., and W. Ridgway, 1989: Climatic equilibrium of the atmospheric convective boundary layer over a tropical ocean. J. Atmos. Sci., 46, 2621–2641.
[7] Siebesma, A. P., C. S. B. A. Brown, A. Chlond, J. Cuxart, P. Duynkerke, H. Jiang, M. Khairoutdinov, D. Lewellen, C.-H. Moeng, E. Sanchez, B.
[8] Stevens, and D. E. Steven, 2003: A large-eddy simulation study of shallow cumulus convection. J. Atmos. Sci., 60, 1201–1219.
[9] Stevens, B., 2006: Bulk boundary layer concepts for simplified models of tropical dynamics. Theoretical and Computational Fluid Dyn.,20, 279-304.
[10] Stevens, B., 2007: On the Growth of Layers of Non-precipitating Cumulus Convection. J. Atmos. Sci., 64, 2916-2931.
[11] Stevens, B., et al. (2001), Simulations of tradewind cumuli under a strong inversion, J. Atmos. Sci., 58(14), 1870–1891.
[12] Randall, D. A., Harshvardhan, and D. A. Dazlich, 1991: Diurnal variability of the hydrologic cycle in a general circulation model. J. Atmos. Sci., 48, 40–62.
[13] Yang, G.-Y., and J. Slingo, 2001: The diurnal cycle in the Tropics. Mon. Wea. Rev., 129, 784–801.
[14] Bony, S., J. L. Dufresne, H. L. Treut, J. J. Morcrette, and C. Senior (2004), On dynamic and thermodynamic components of cloud changes, Clim. Dyn.,22, 71–86.
[15] Medeiros, B., B. Stevens, I. M. Held, M. Zhao, D. L. Williamson, J. G. Olson, and C. S. Bretherton (2008), Aquaplanets, climate sensitivity, and low clouds, J. Clim., 21(19), 4974–4991.
[16] Riehl, H., T. C. Yeh, J. S. Malkus, and N. E. La Seur, 1951: The north-east trade of the Pacific Ocean. Q. J. Roy. Meteor. Soc., 77, 598–626.
[17] Tiedtke, M., W. A. Heckley, and J. Slingo, 1988: Tropical forecasting at ECMWF: The influence of physical parameterization on the mean structure of forecasts and analyses. Q. J. Roy. Meteor. Soc., 114, 639–644.
[18] Tiedtke, M., 1989: A comprehensive mass flux scheme for cumulus parameterization in large-scale models. Mon. Wea. Rev., 117, 1779–1800.
[19] Lenderink, G., Siebesma, A. P., Cheneit, S., Ihrons, S., Jones, C. G., Marquet, P., Muller, F., Olmera, D., Calvo, J., S´anchez, E., and Soares, P. M. M., 2004: The diurnal cycle of shallow cumulus clouds over land: a single-column model inter comparison study, Q. J. Roy MeteorolSoc, 130, 3339–3364.
[20] Boville B. A., Rasch P. J., Hack J. J., McCaa J. R. 2006. Representation of clouds and precipitation processes in the Community Atmosphere Model Version 3 (CAM3). J. Climate 19: 2184–2198.
[21] Liu C., Moncrieff M. W. 1998. A numerical study of the diurnal cycle of tropical oceanic convection.J. Atmos. Sci. 55: 2329–2344.
[22] Short, D. A., and K. Nakamura, 2000: TRMM radar observations of shallow precipitation over the tropical oceans. J. Climate, 13, 4107–4124.
[23] Schumacher, C., and R. A. Houze Jr., 2003a: Stratiform rain in the Tropics as seen by the TRMM precipitation radar. J. Climate, 16, 1739–1756
[24] Schumacher, C., and R. A. Houze Jr., 2003b: The TRMM precipitation radar's view of shallow, isolated rain. J. Appl. Meteor., 42, 1519–1524.
[25] Lau, K., and H. Wu, 2003: Warm rain processes over tropical oceans and climate implications. Geophys. Res. Lett., 30(24), 2290, doi: 10.1029/2003GL018567.
[26] Nuijens, L., B. Stevens, and A. Siebesma, 2009: The environment of precipitating shallow cumulus convection. J. Atmos. Sci., 66, 1962{1979.
[27] Ushiyama, T., Reddy, K. K., Kubota, H., Yasunaga, K. and Shirooka, R, 2009: Diurnal to interannual variation in the raindrop size distribution over Palau in the western tropical Pacific. Geophys. Res. Lett., 36, L02810, doi: 10.1029/2008GL036242.
[28] Gage, K. S., C. R. Williams, and W. L. Ecklund, 1994: UHF wind profilers: A new tool for diagnosing tropical convective cloud systems. Bull. Amer. Meteor. Soc., 75, 2289–2294.
[29] Atlas, D., C. W. Ulbrich, F. D. Marks Jr., E. Amitai, and C. R. Williams, 1999: Systematic variation of drop size and radar-rainfall relations. J. Geophys. Res., 104(D6), 6155-6169.
[30] Reddy, K. K., Kozu, T., Ohno, Y., Nakamura, K., Higuchi, A., Reddy, K. M. C., Anandan, V. K., Srinivasulu, P., Jain, A. R., Rao, P. B., Rao, R. R., Viswanathan, G., Rao, D. N., 2002: Planetary boundary layer and precipitation studies using lower atmospheric wind profiler over tropical India. Radio Sci.,37(4), 14-1-14-17.
[31] Dee, D. P., et al., 2011: The ERA-Interim reanalysis: configuration and performance of the data assimilation system. Q. J. R. Meteorol. Soc. 137, 553-597.

[32] Williams, C.R., Ecklund, W.L., Gage, K.S., 1995: Classification of precipitating clouds in the tropics using 915-MHz wind profilers. J. Atmos. Oceanic Technol., 12, 996–1011.
[33] Kubota, H., Shirooka, R., Ushiyama, T., Chuda, T., Iwasaki, S., Takeuchi, K., 2005: Seasonal variations of precipitation properties associated with the monsoon over Palau in the western Pacific, J. Hydrometeor., 6, 518–531.
[34] Kikuchi, O., Uyeda, H., 1996. Doppler radar observations on the structure and characteristics of tropical clouds during the TOGA-COARE IOP in Manus, Papua New Guinea-Characteristics of cloud clusters analyzed with Doppler radar and GMS-IR Data. J. Fac. Sci. Hokkaido University Ser VII (Geophysics) 10, 107–133.
[35] Shirooka, R., Uyeda, H., 1991. Morphological structure of evolving cumuli asseenby a radar and stereographic photographs. J. Fac. Sci. Hokkaido University Ser.7 (Geophysics) 9(1), 41–50.
[36] Gray, W. M., and R. W. Jacobson Jr., 1977: Diurnal variation of deep cumulus convection. Mon. Wea. Rev., 105, 1171–1188.
[37] Austin, J., 1948: A note on cumulus growth in a nonsaturated environment. J. Meteor., 5, 103–107.
[38] Byers, H. R., and R. K. Hall, 1955: A census of cumulus-cloud height versus precipitation in the vicinity of Puerto Rico during the winter and spring of 1953–1954. J. Meteor., 12, 176–178.



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

# INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY