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Evaluation of the Variation in Wind speed during Rainfall in a Tropical Location

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Abstract. This paper presents 6 years one-minute wind speed data obtained from Covenant University, Ota during the period 2012 to 2017. High rainfall accumulation and rain rate are the features experienced in the tropics. This eventually leads to high attenuation of microwave signals propagated at frequency above10 GHz. One factors amongst others that affect the accuracy of the measurement of rainfall is wind speed. Wind speed being one of the key parameters during rainfall, has significant effect on the accuracy of rainfall rate and the propagation of communication signals.For efficient and reliable access communication link there is need for adequate study to mitigate its effect on attenuation in any location of interest. As the wind speed increases during rainfallit induces error in the measurement of rain rate.Hence for adequate and reliable prediction of attenuation, the evaluation of the distribution of wind speed during rainfall is essentialin any locality.The results obtained showed that the average wind speed observed from 2012 to 2017 were 2.8 m/s, 2.7 m/s, 2.3 m/s, 1.4 m/s, 1.5 m/s and 1.5 m/s respectively. From the result obtained, the average wind speed is low.hence, no significant error in the measurement of rainfall accumulation and rain rate in the location of study.

1. Introduction

Rainfall rate is a fundamental parameter in the prediction of attenuation of microwave signals at frequency, 10 GHz and above [1-7]. Rainfall rate is the rain accumulation per unit time, measured in mm/hr. The accuracy in the measurement of precipitation data is particularly important as it is the major input parameter for some scientific applications especially in the prediction of attenuation of communication signals in any locality. Absorption and scattering are two phenomenon that causes reduction in the signal strength of incident microwave signals as it propagates through the troposphere from the transmitter to the receiver of the ground station [8-10]. This effect is observed both at the point-to-point link or earth to satellite link. These phenomena are severely observed during rainfall due to the spectral differences in the diameter of the wavelength of the microwave signal and rainfall distribution size. The arrival of raindrops at their terminal velocities on the earth surface depend on their sizes.

Thevertical wind speeds in cloudsdetermines the least possible size of raindrops dropping on the ground. The lower clouds generate drizzle type of rain with diameter of about 0.1 mm diameter [11-12]. During the fall, raindrops of about 7 mm in diameter breaks apart into smaller diameter.Raindrops which appear as almost perfect spheres with diameters less than 0.3 mm fall at terminal (falling) velocity [13, 12]. Rainfall rate can also be described as the depth of the layer of precipitation, as it falls for a period of one-hour and above especially when evaporation did not occur, not absorbed by the soil, and not affected by wind.

The rain gauge offers almost an accurate possible spatial and temporal measurement of rainfall at a point, although this might be prone to some likely errors depending on where it is installed. The environment or location of the rain gauge could change from calmness to turbulence (windy). Evaluation of the wind condition of the location of study is necessary to integrate its results as an additional cause of error for an adequate prediction of the total attenuation to radio waves signal propagated in the location of study.

These errors could be systematic and/or random errors which could be as a result of environmental condition that could affect reliable precipitation measurement and collection of accurate data such as wind-induced gauge measurement [14-15].Wind speed causes the terminal velocities and corresponding kinetic energy of raindrops to decrease/increase. This affects the inclination angle at which each raindrop falls. Any increase in wind speed causes a resultant rise in the inclination angle and kinetic energy of the raindrops as it approaches the ground [16].

These errors could be introduced into the rain gauge data measured and collected over time which could cause loss of rainfall accumulation and rain rate data. This data is very important for prediction of rain attenuation of communication signals hence the need to evaluate the wind speed observed during rainfall to ascertain its possible effect on the accuracy of the data collected and analysed [17-18]. Hence, the accurate information about the wind speed data in a targeted location for proper prediction of attenuation is very essential. It has been reported that in Nigeria, there is variation in the wind speed detected across the country. In the south, the wind speed ranges between 2 m/s and 9.5 m/s while a higher value is experienced in the north [19-20].

2. Methods and Data Analysis

The data used in the analysis was obtained at Covenant University, Ota, Southwest Nigeria. Figure 1 shows the Davis weather station-Vantage Vue2. The equipment is used in the measurement of weather data such as rainfall rate,temperature, humidity, wind speed, pressure, water vapour. It comprises of a group of devicesknown as Integrated Sensor Suite (ISS) for the measurements. In addition, itmeasures surface wind speed and directionusing an anemometer. It also measuressolar radiation and energywith the aid of solar sensors. Vantage Vue measures wind speeds as between 2 mph (3 km/h) and 150 mph (241 km/h). Davis' station also reports conditions in as little as 2.5-second intervals depending on what is being measured, which is of a great advantage. Davis gives a more accurate count over time. Davis' sensor measures wind speed and direction using the traditional cup and vane. The rain gauge used for collection of data is a tipping bucket rain gauge. It is a complete package called Integrated Sensor Suite connected to the weather station to acquire rainfall data. The data logger stores data every second to return an averaged value every 1- minute. The total number of data per day is 1,440 data which amounts to 44,640 per month. The time series plots were obtained to show the monthly variation of wind speed at the station of interest.

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Figure 1: Davis Weather Station Vantage Vue2

Source: http://www.eeprocess.com/Davis/vantage_vue_iss.html

The daily, monthly, and yearly wind speed data were measured, recorded and analysed for 6 years. The diurnal variation in the wind speed during rainfall were observed as the data used were obtained in one-minute interval. This is helpful in mitigating against loosing extremely low and/or high wind speed data. The monthly mean wind speed was analysed using excel package. Hence, the variation in the monthly mean wind speed data was monitored for the six years.

3. Results and Discussion

The monthly average wind speed observed for six years is presented in Figures 2 to 7. There was no result for January, February, and March 2012 because measurement started in April. The month of May was the month with the highest monthly average wind speed of 3.4 m/s in 2012 as shown in Figure 2. Figure 3 shows that February had the highest monthly average wind speed of 4.6 m/s in 2013 while the lowest was observed in three months i.e. June, July, and September, respectively. It was observed that, there was a decline in 2014 and 2015 while the highest monthly average wind speed of 3.7 m/s and 3.0 m/s were recorded respectively in April as shown in Figures 4 and 5, respectively. The lowest in 2014 was 1.3 m/s while in 2015, 0 m/s was observed. Also, in 2014, there was a constant wind speed was observed in May, June, and July. In 2016 and 2017, there was a further decline, the highest monthly average wind speed of 2.5 m/s and 2.4 m/s were recorded respectively in March as shown in Figures 6 and 7 respectively. The lowest in 2016 and 2017 is 0.7 m/s and 0 m/s respectively in January. The overall average was 2.0 m/s. Overall, it is observed that the highest wind speed occurred during the period when rainfall is about to kick off. This is the period when there is a shift from the dry season to rainy season and a drop in wind speed was observed during the rainy months in an average year (June, July, August, September, and October).

For a reliable access to communication signals along satellite communication link both on earth-space and point-to-point link requires a line-of-sight (LOS) link between the transmitter and the receiver. Along the LOS, weather parameters such as wind, if present above the threshold value would cause a false result in the estimation of rain accumulation and rain rate which would eventually affect the attenuation estimate for such locality. Ometan, et al.,2019 calculated the rain attenuation resultat 0.01 % to be 4.01 dB for this locality [21]. The variation in the wind speed obtained from the analysis shows that there was no effect of wind on the estimated rain attenuation. Therefore, the rain attenuation obtained in the study area would be used for the adequate calculation of receive power needed to mitigate its effect.

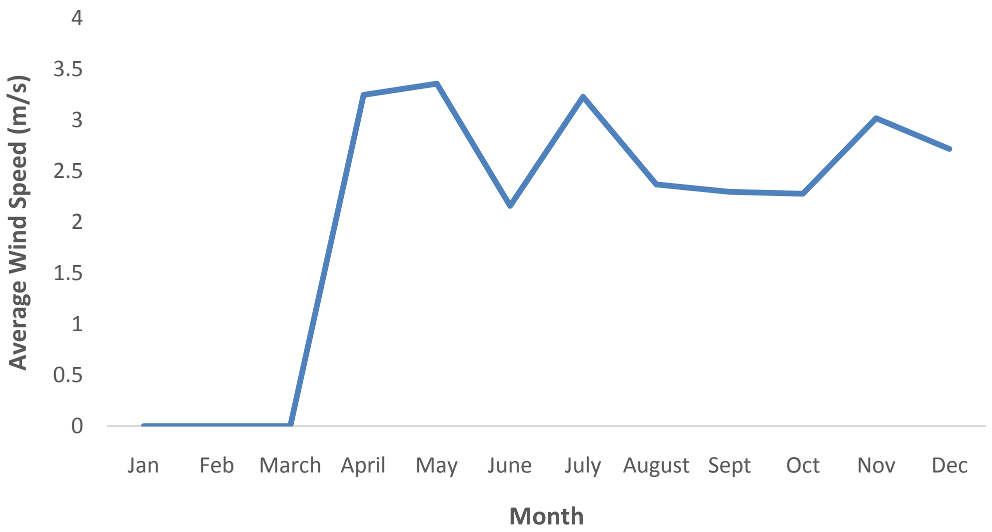

Figure 2: Average wind speed during rainfall in 2012

Figure 3: Average wind speed during rainfall in 2013

Figure 4: Average wind speed during rainfall in 2014

Figure 5: Average wind speed during rainfall in 2015

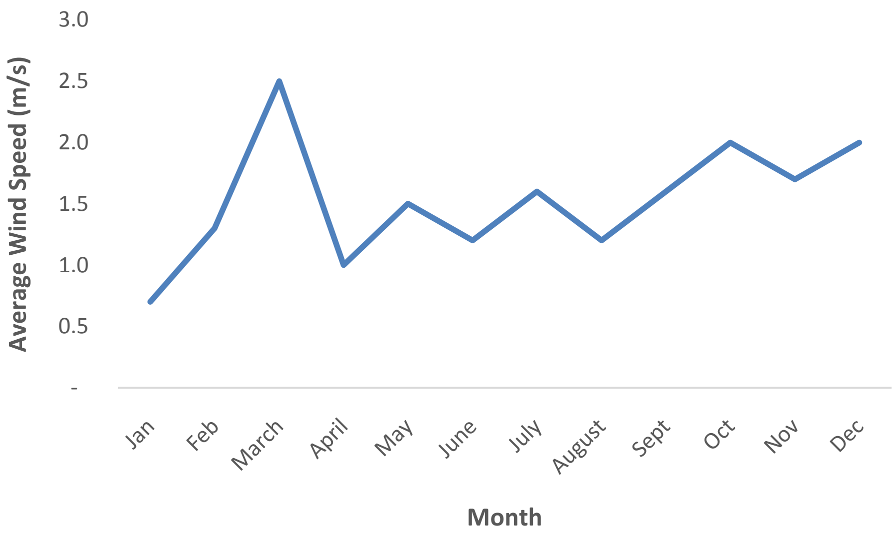

Figure 6: Average wind speed during rainfall in 2016

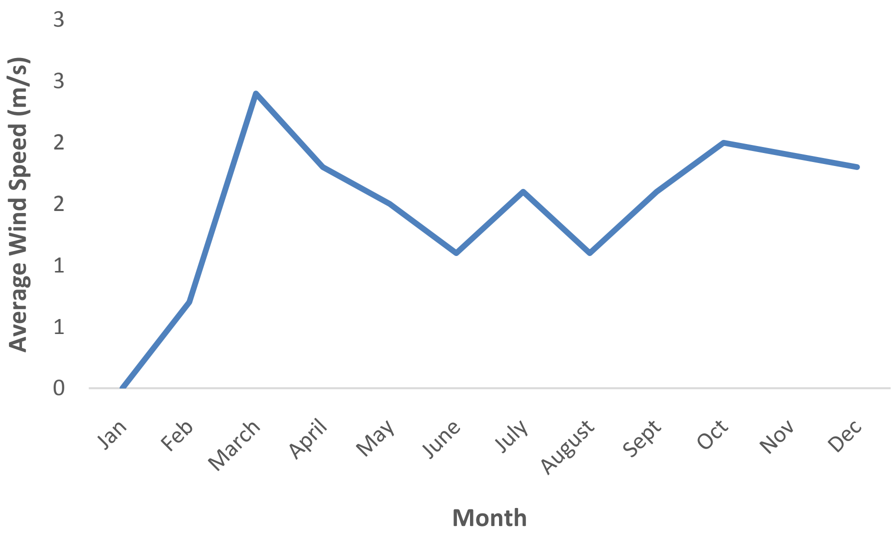

Figure 7: Average wind speed during rainfall in 2017

4. Conclusion

Wind speed being one of the key parameters in the troposphere, has significant effect in the propagation of communication signals for efficient and reliable access to information as technology advances. Hence the need for its adequate study to mitigate its effect in the evaluation of attenuation in any location of interest. Poor/inadequate knowledge of the wind intensity in a locality could result in inadequate prediction of rain attenuation in such a locality. This study, therefore, shows the analysis carried out on the monthly mean wind speed for the location of interest. The observed results show that the wind speed experienced in this location is low. It is found to be within the range such that it could not cause any error in the measurement of rainfall accumulation and rain rate, and hence the evaluation of rain attenuation. The analysis reveals that the received signal performance is not affected by wind, especially during rainfall. More analysis could still be carried out.

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