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## Seasonal surface refractivity patterns in the part of Lagos-Nigeria

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**Abstract:** The surface refractivity(SF) is essential in estimating the performance of terrestrial radio links. In the troposphere, there are lots of meteorological updraft and downdraft that influence the refractive index. In this study, we examine the seasonal variation of an emerging community in Lagos to design a reliable and efficient radio communication system based on the meteorological parameters. Thirty-nine years dataset between 1980-2018 was used to examine both the surface refractivity and the meteorological drivers that determine the SF patterns. It was observed that early wet season and late dry season were seen to have higher SF values, i.e., 262.03 N-unit and 262.07 N-unit respectively, while early dry and late wet had lower SF, i.e., 261.71 and 261.76 respectively. It is now possible to use the weather forecast to predict the likely SF pattern over the tropics.

### 1. Introduction

Surface refractivity refers to the refractive index of the earth's atmosphere and is generally estimated using the earth's surface temperature, humidity, and pressure. The refractive index of the earth's atmosphere is somewhat dynamic as various meteorological factors drive it. Hence, it varies from one geographical location to another. However, its variation in the troposphere is observed to be small but plays an important role in radio wave propagation. Hence, salient parameters in radio wave propagation attenuation such as scintillation, fading, and ducting depend on the refractive index [1]. The refractive index is essential in estimating the performance of terrestrial radio links. In the troposphere, there are lots of meteorological updraft and downdraft that influence the refractive index. Some scientists had related it to the molecular constituents of nitrogen, oxygen, carbon dioxide, and water vapour [2-3]. The quantum mechanical molecular resonance of the nitrogen, oxygen, carbon dioxide, and water vapour is unique in an open system as it varies diurnally and seasonally.

The troposphere is quite important in the determination of the refractive index because the formation of weather, i.e., wind dynamics, cloud formation, rain, snow, and thermal variations, occur within this part of the atmosphere [4]. Based on the above, some scientists have observed that the refractive index's estimation can not be solely calculated based on temperature, humidity, and pressure. For example, Emetere et al. [5] postulated that since aerosol loading over West Africa is significantly based on satellite imagery, the determination of surface refractivity would not depend on the quantum mechanical molecular resonance of the nitrogen, oxygen, carbon dioxide and water vapour but the aerosol influx. Based on the above, they developed a model that was more sensitive to tropospheric perturbations. Amajama et al. [6] postulated that radio signals and refractivity could be negatively impacted by wind direction. This postulation may be strange, but when compared to the postulation of Babatunde and Israel [7] that showed that north-south movement of the Inter-tropical discontinuity (ITD) influences the variation of surface refractivity, it is clear that the agents that drive weather variability are potent to determine the variations in surface refractivity. Hall [8] reported that all these activities in the troposphere influence radio waves at frequencies above 30MHz and non-different to frequencies greater than 100MHz. Bean

and Dutton [9] postulated that since the molecular resonance is dependent on frequency, there is the possibility that the refractive index tends to be dispersive above  $\sim 50$  GHz. This postulation is quite interesting as it juxtaposes the assertions of Emetere et al. [5] on what parameters should influence the quantum mechanical molecular resonance of air constituents. Research works have been reported on the surface refractivity over parts of Nigeria. Ayantunji et al. [10] that there is the possibility of a significant horizontal variation of refractive index over Nigeria due to its extreme climatic conditions. Bawa et al. [2] reported the surface refractivity values in central northern (Anyigba) and southwest (Lagos) to be 242 N- units and 384 N-units, respectively. Akinwumi et al. [3] reported that refractivity value in the northeast and southwest Nigeria is 262.5 N units and 392.84 N units, respectively. Also, Ayantunji et al. [10] reported that the seasonal refractivity value is higher in the rainy season than the dry season. The refractivity values presented by Bawa et al. [2] and Akinwumi et al. [3] for Lagos are significantly different because of the high convective nature of different parts of Lagos. In this study, we examine the seasonal variation of an emerging community in Lagos to design a reliable and efficient radio communication system based on the meteorological parameters. Early wet season and late dry season were seen to have higher SF values, i.e., 262.03 N-unit and 262.07 N-unit respectively, while early dry and late wet had lower SF i.e., 261.71 and 261.76 respectively.

## 2. Methodology

The surface refractivity was calculated using a dataset of temperature, humidity, and pressure. The dataset of temperature, humidity, pressure, wind direction, and shortwave UV radiation was downloaded from Modern-Era Retrospective analysis for Research and Applications (MERRA). All measurement was taken at 10 m above ground. Datasets on MERRA are obtained at  $0.5^\circ \times 0.66^\circ$  grid with 72 layers. MERRA dataset is the combination of the land surface (MERRA-Land) and atmospheric aerosols (MERRAero) [11].

The dataset was measured at intervals of a minute; hence, the dataset's size is about 19,699,200 cells each for the wind speed and wind direction parameters. The averages of each parameter were first calculated into months of the year. The averages for a group of ten years were calculated e.g. 1980-1989, 1990-1999, 2000-2009, and 2010-2018. The surface refractivity was plotted and compared to the trends of other parameters. The datasets were divided into four seasons, i.e., early dry-DJF, late dry-MAM, early wet-JJA, and late rain-SON. The wind direction has been reported to be the meteorological driver for SF [6]. In this research, the shortwave UV radiation was selected as the second meteorological driver that determines SF trend because of the shortwave radiation influences temperature and relative humidity.

The study location, i.e., Agege is closer to the Gulf of Guinea. The Gulf of Guinea is the northeasternmost part of the tropical Atlantic Ocean. It is a populated location because of its proximity to the capital of Lagos. The occupants in the study site are mainly residential with scattered medium industries such as Lapdap Nigeria Enterprises. Dumil Industries Limited. Bibitosh Nigeria Limited. Mos-Plastic Industries Ltd. Vk Plastics Ltd. Lydoline Paints Limited. Power Systems. Swiss Pharma Nigeria Limited (Swipha).

The surface refractivity over Agege-Lagos was estimated using the to ITU-R [12]. The atmospheric radio refractive index ( $n$ ) are estimated by:

$$n = 1 + N \times 10^{-6}$$

where  $N$  is the radio refractivity which is estimated using:

$$N = \frac{77.6}{T} \left( P + 4810 \frac{e}{T} \right) = N_{\text{dry}} + N_{\text{wet}}$$

Where  $N_{\text{dry}}$  is the dry term of the radio refractivity and  $N_{\text{wet}}$  is the wet term of the radio refractivity,  $N_{\text{wet}}$ ,  $P$  is the total atmospheric pressure (hPa),  $e$  is the water vapour pressure (hPa),  $T$  is the absolute temperature (K). The relationship between water vapour pressure and relative humidity is given by:

$$e = \frac{H \cdot e_s}{100}$$

$H$  is the relative humidity (%),  $e_s$  is the saturation vapour pressure (hPa) that can be estimated using:

$$e_s = 6.1121 \exp\left(\frac{17.502t}{t + 240.97}\right)$$

where  $t$  is the temperature ( $^{\circ}\text{C}$ ).

### 3. Results and Discussion

The surface refractivity was plotted in Figure 1, while the respective drivers were displayed in Figures 2-5. The surface refractivity (SF) shows that the seasonal surface refractivity differs for all seasons. Early wet season and late dry season were seen to have higher SF values, i.e., 262.03 N-unit and 262.07 N-unit respectively, while early dry and late wet had lower SF, i.e., 261.71 and 261.76 respectively. It is observed that the SF pattern for early dry and early wet are inversely proportional. Also, the SF pattern for late dry and late wet is inversely proportional.

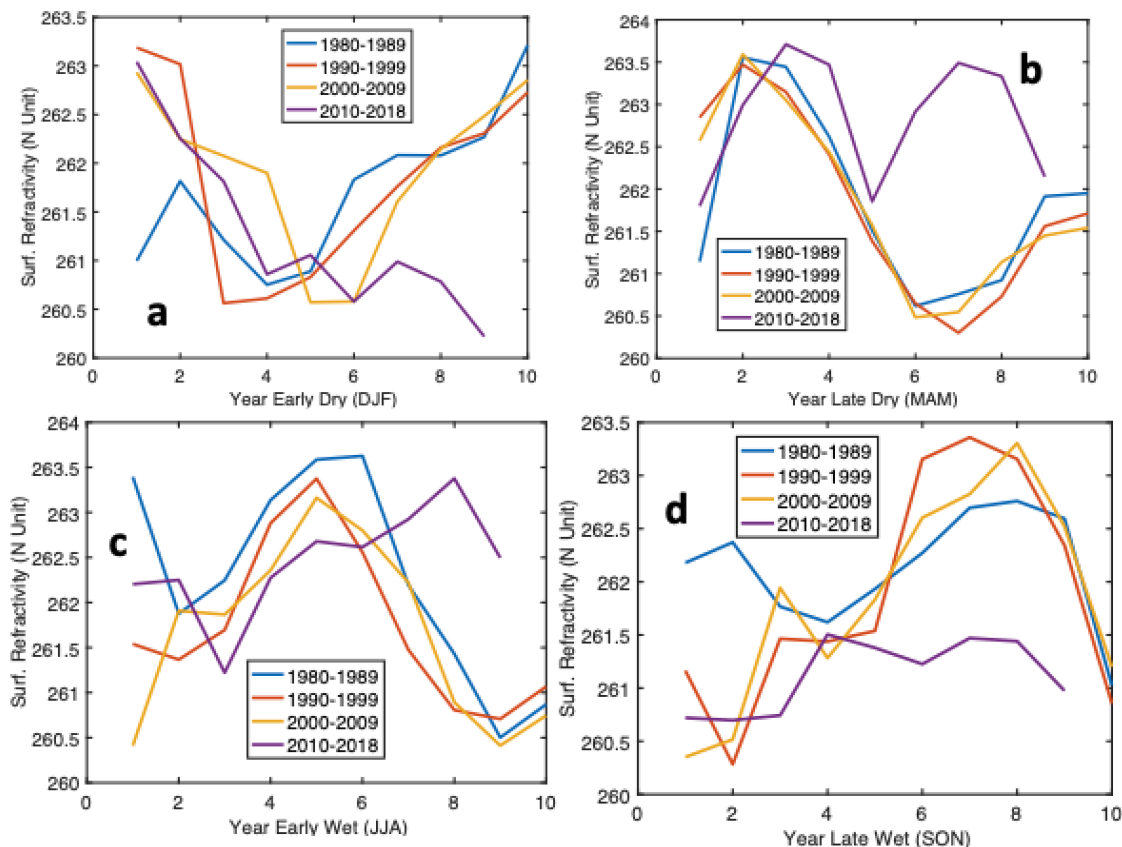


Figure 1: Refractive index for all four seasons

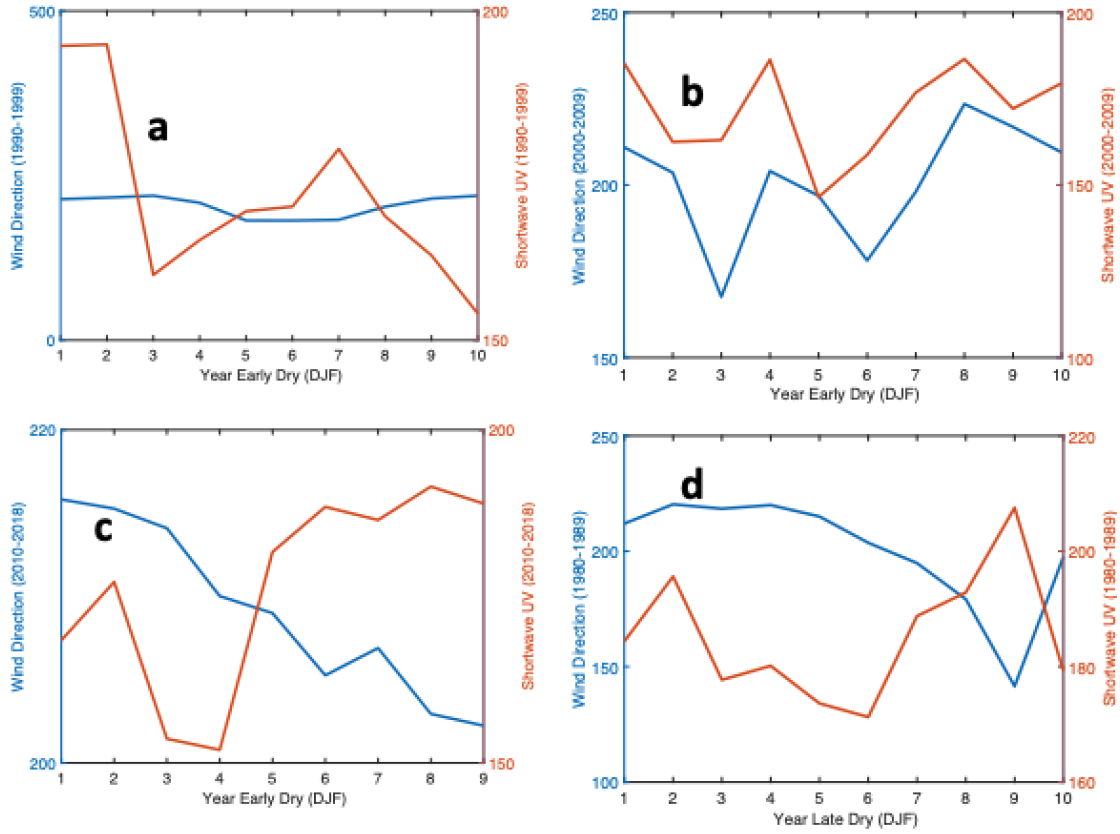


Figure 2: Meteorology drivers of surface refractivity (Early dry)

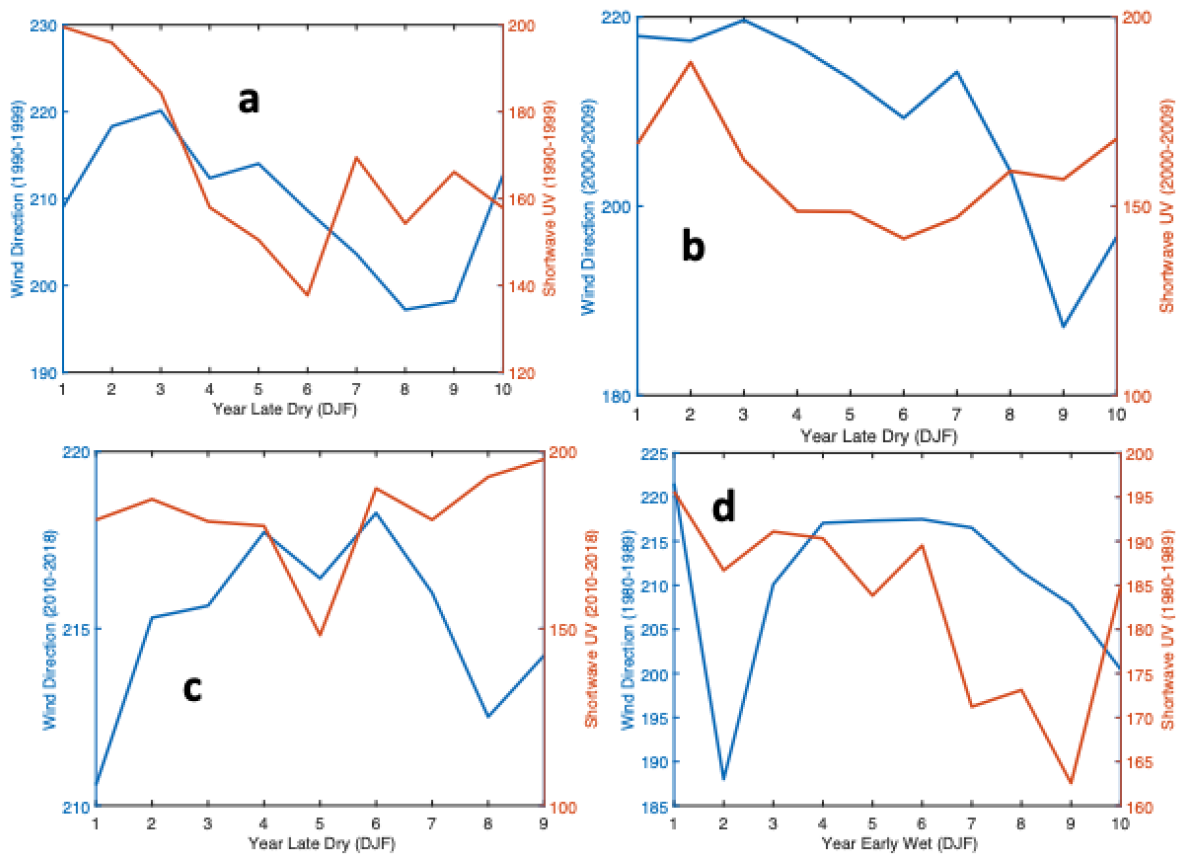


Figure 3: Meteorology drivers of surface refractivity (late dry)

1

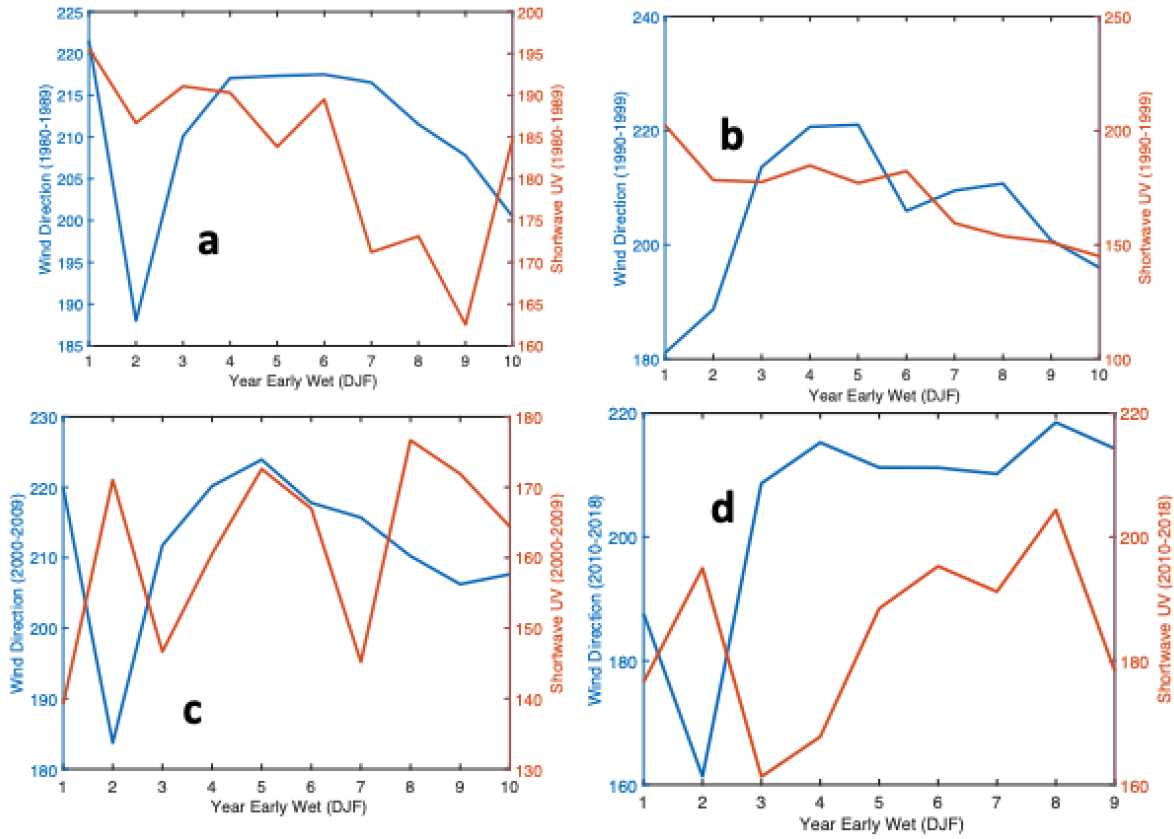


Figure 4: Meteorology drivers of surface refractivity (Early wet)

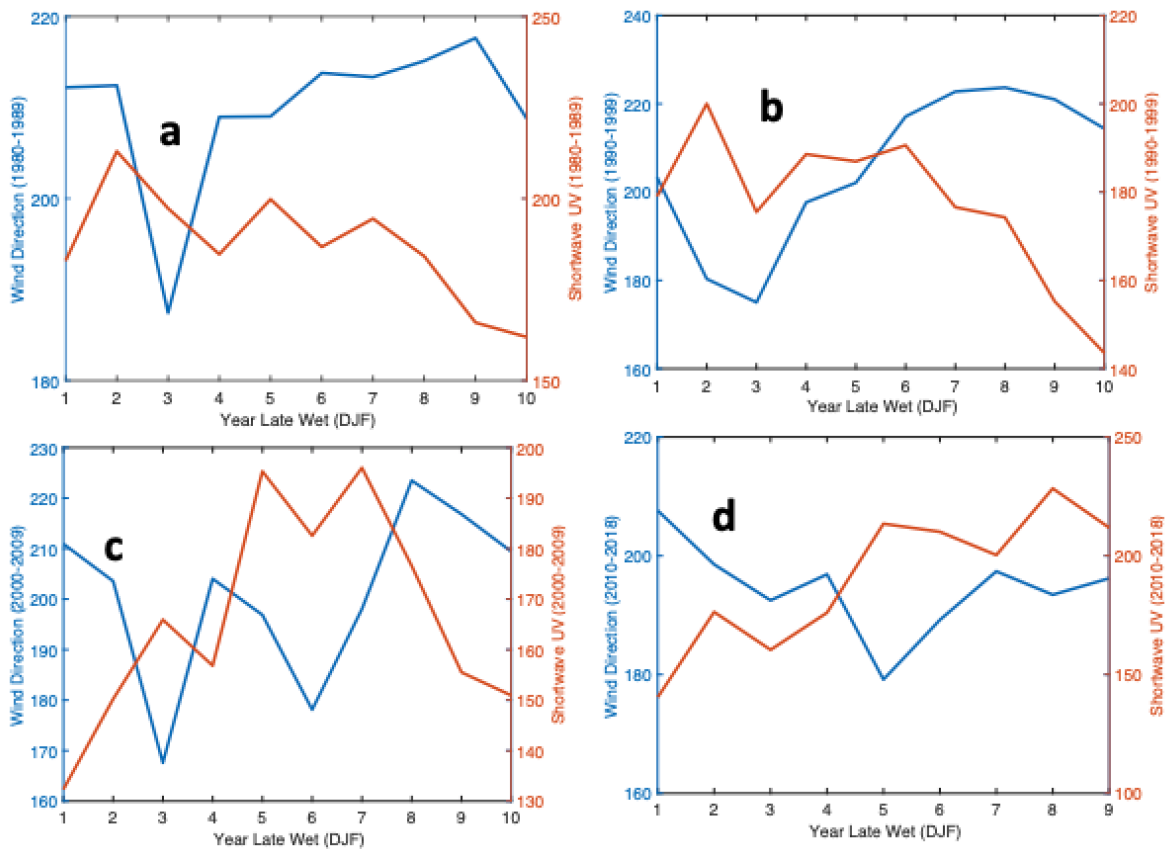


Figure 5: Meteorology drivers of surface refractivity (Late dry)

Early dry slightly confirms that the short wave radiation is most likely one of the meteorological drivers that control SF (Figure 2). The late dry season shows that the wind direction and shortwave driver had almost similar experience between 1980 and 1989 (Figure 3a). Other years did not depict that these drivers were significant (via pattern analysis) to have influenced the SF values. In early wet, the wind direction is the only meteorological drivers that influence the SF variations. In the late wet season, it was observed that both the wind and shortwave radiation had influence over the between 1990-1999. These results show that the main drivers for early wet and dry seasons are wind direction and shortwave radiation. These drivers were observed to have relative influence in the late seasons.

#### 4. Conclusion

The research has shown the professionals on the reasons for varying telecommunication challenges in parts of Lagos, Nigeria. The telecommunication budget link design should consider switching algorithm that would naturally alternate each of the seasons as it has been established that the SF between early dry and early wet seasons are inversely proportional, as well as the late dry and late wet. It was also proven that some meteorological drivers determine the SF at certain seasons. It is now possible to use the weather forecast to predict the likely SF pattern over the tropics.

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