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Research Article

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Time-Frequency Fourier Transform Spectral Technique for Short Period Climatic Temperature Decomposition in Port-Harcourt, Nigeria

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ABSTRACT

Climate change is mainly due to anthropogenic factors that affect the level of comfort or health of people. Localized sources of atmospheric disturbances and air pollution (for example black soot) in some cities, like Port-Harcourt, may result in unusual changes in temperature and humidity. In this study, we investigate the changes in temperature and humidity around Port-Harcourt to understand the sudden weather changes noticeable in the city over very short periods. This study aims at improving and alleviating the long-term time limitations by observing the physical state of the Earth's lower atmosphere at 25m altitudes apart for variations of some weather forcing parameters which include pressure, temperature, and relative humidity (with the main focus on temperature for the study). The daily temperature data acquired for two years were averaged six (6) hours into four (4) quadrants of daytime and night-time events. The spectral behavior for regional climatic temperatures for all four (4) quadrants in Port-Harcourt for a short-term period was also investigated using Short Time Fourier Transformation, decomposition tech-nique, and a spectrogram to the discrete meteorological data. Temperature Spectrograms were generated and presented as 'spec-tral clouds' or yellow bands parallel to the time axis. The thermal mass of aerosols increased air temperatures and consequently reduced perturbations causing spectral clouds to appear bluish. These findings could help climatologists better understand the short-term mechanisms that could cause climate change.

Keywords: Aerosols, Fourier, Localized Sources, Perturbation, Spectral Clouds.

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Introduction

Weather forecasting is the application of science and engineering in whichto predict future time and placeatmospheric condition. The weather system on Earth is a chaotic system; as a result, small changes to one part of the system can evolve to have major effects on the whole system. Human attempts to control the climate have existed throughout history, and there is evidence that human activities, such as agriculture and industry, have altered weather patterns [1]. The atmosphere and in particular the At-mospheric Boundary Layer (ABL) are a complex dynamic system that cannot be predicted without the use of numerical models by the 20th Century [2]. Numerical weather prediction (NWP) models are computer codes based on simplified mathematical representations of physical processes. The output and results of limited area NWP models provide knowledge for daily weather forecasts as well as regional climate projections for future decades which become increasingly important for planning and adap-tation purposes. Variability in Temperature trends could be used as a factor to observe climate change. Sometimes, temperature records of up to 17 years may be required to identify human effects on global mean temperature [3]. It may not be sufficient to check temperature changes, only in the time domain. There may be some hidden information, hopefully, spectral analysis(Fou-rier transformation) will identify, periodic

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patterns and the strength of the component signals. 'Joint time-frequency analysis' will show both periodic patterns and when they occur using a spectrogram [4]. The interpretation of the spectrogram will be better appreciated in Figure 1 where a known time signal spectrogram helps to clarify the interpretation of any unknown. The quality of forecasts is highly dependent on reliable observational data. In situ, ground-based data acquired using a custom-built data logger will help to validate remote sensing radar or satellite-based data. This work presents the use of 'Spectral clouds' in Joint Time-Frequency space to remotely detect abnormalities and localize the sources of atmospheric disturbances in a short time frame. It determines and separates the components of anthropogenic disturbances both in time-frequency spread and their magnitudes. It also uniquely identifies seasonal variations early for short time/period to evaluate evolution/drift in climate change.

Weather can affect us in numerous ways, draught results in water shortage and significant effect on crops. The critical impact of weather on human lives led to the best-known applications of meteorology and weather forecasting [5,6]. Many studies have examined the applications of weather forecasting in many areas such as hazards of floods, desertification and urban planning settlement [7-9]. Meteorologists and climatologists are well aware of the fact that the weather systems that affects draught-prone areas are very complex and they are caused by fluctuations in the global atmosphere circulation [10]. Climate and its variability also affect many aspects of socio-economic development of the nation. Many researchers have projected global climate change due to greenhouse effect warming would be an unprecedented event in the history of human civilization [11].

Materials and Methods

This section is on the nature and source of data used for the research; the method used for short period climatic temperature decomposition from fast Fourier transforms spectral analysis.

Materials

The variations of weather forcing parameter of the Earth's lower atmosphere at two altitude 25m apart was observed and their averaged were computed using two custom built data loggers after a high precision calibration procedure. The device was powered with a 12V battery and communication with computer was through the ESP8266 Wifi module. The acquired Temperature data was cleaned to remove outliers and produced a timetable with unique time stamp. Data grouping was done by splitting data for each day into 4 quadrants accordingly; 0-6hrs./6-12hrs./12-18hrs./18-24hrs, representing $1^{st}/2^{nd}/3^{rd}/4^{th}$ quadrants. Daily temperature average of each quadrant for the year 2017/18 was used as raw timetable data for the 'Joint time-frequency analyses. Derived Timetable Data analysis was performed with Matlab (R2017b). It was used for the Digital Signal Processing works. Joint Time-Frequency Analysis Spectrograms were plotted and interpreted. Time-Frequency domain spectrogram appears like clouds of yellow colors on bluish background hereby named as 'Spectral Clouds'. The colours of the spectrogram encode frequency power levels. Deep Yellow colours indicate frequency content with higher power. Blue colours indicate frequency content with negligibly low or no power. A strong yellow horizontal line indicates the existence of an oscillatory signal at particular temperature frequency.

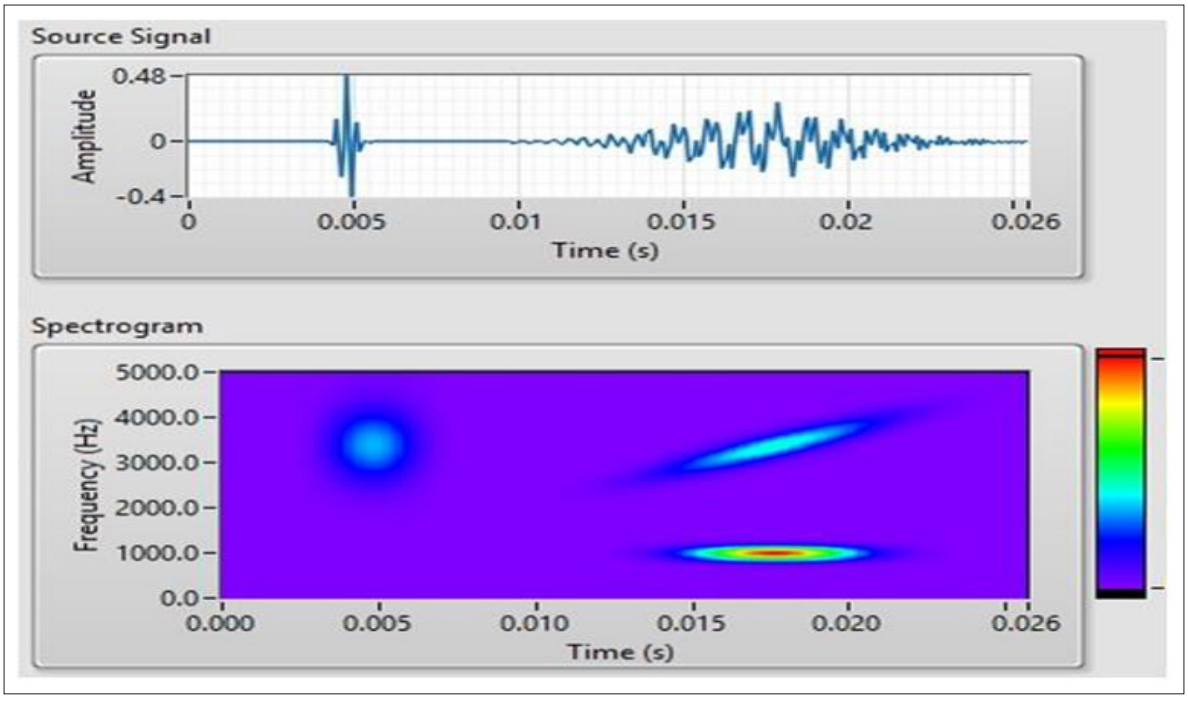

Figure 1: An example of decomposing a signal with three Gaussian waveforms to understand the Joint Time-Frequency Spectrogram.

Methods

The weather data stations were set up with the equipment at the premises of Rivers State University, Port Harcourt, Nigeria. The two weather station loggers were placed at different heights of 0m and 25m along the mast. Data acquisition was taken for a period of two years with the aim of covering both rainy and dry seasons. However, Data acquisition was done every minute with an average in every one hour. The equipment was mounted on a communication mast as shown in Figure 2.



Figure 2: The mast where the data logger was mounted is located on the premises of Rivers State University.

Results

The 3rd Quadrant refers to temperature readings taken between 12 p.m. and 6 p.m. daily. Figure 3 and Figure 4, illustrate the temperature histogram for the 3rd Quadrant (12 p.m. to 6 p.m.) for the years 2017 and 2018, respectively. Figure 5 provides a spectral cloud representation of the third quadrant temperatures for 2017, while Figure 6 presents the same data for 2018.

The temperature spectrogram has a sampling frequency of 0.25 cycles/day, which equals 2.8935185185E-6 Hz. Seasonal variations with strong low-frequency oscillations were detected, appearing as a band of graduated yellowish color, parallel and close to the horizontal axis in Figures 5 and 6. The most significant frequency band falls within the normalized frequency range of 0 to 0.10, which corresponds to oscillatory temperatures from DC up to 1.1 oscillations per month. The next prominent frequency band is in the range of 0.1 to 0.15, corresponding to oscillatory temperatures from 1.1 to 1.77 oscillations per month. Other events are distributed within the 0.6 to 1.0 Normalized Frequency range, corresponding to oscillatory temperatures from 7.01 to 11.78 oscillations per month. Table 1 can be used to convert the normalized frequency to cycles per month or cycles per year. The vertical yellow band indicates broadband signals, which have a spatial nature and are likely derived from anthropogenic sources.

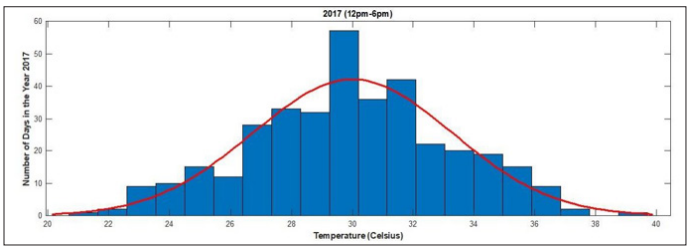

Figure 3: Histogram fit for the 3rd quadrant temperature distribution of 2017 and 2018 showing overshoots caused by activities of illegal refineries

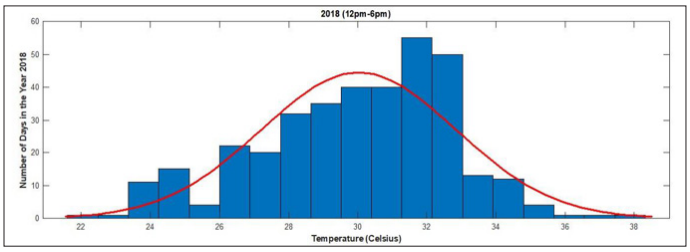

Figure 4: Histogram fit for the 3rd quadrant temperature distribution of 2017 and 2018 showing overshoots caused by activities of illegal refineries.

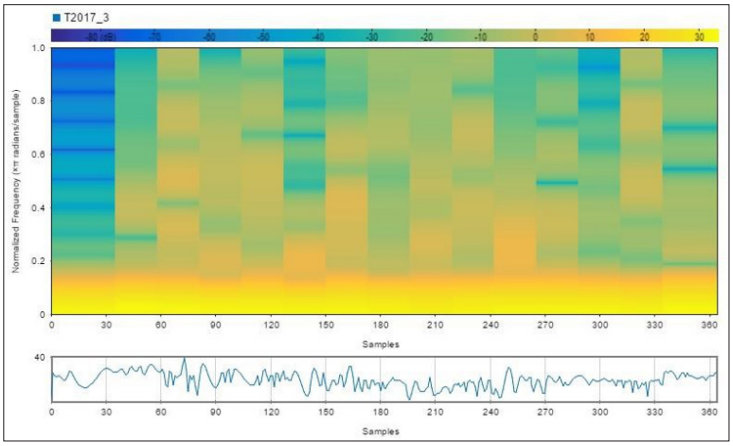

Figure 5: Joint Time-Frequency Spectrogram of the 3rd quadrant temperatures for 2017 and 2018, showing the distribu-tion of spectral clouds.

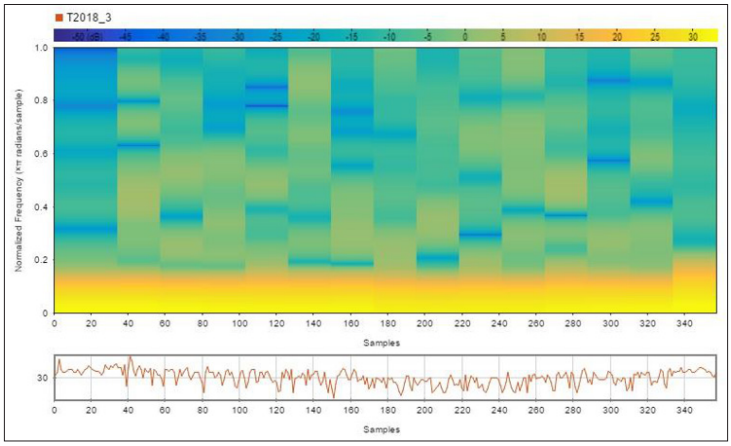

Figure 6: Joint Time-Frequency Spectrogram of the 3rd quadrant temperatures for 2017 and 2018, showing the distribu-tion of spectral clouds.

Table 1: Conversion scale to interpret the vertical position of spectral clouds as temperature oscillations in the Joint Time-Frequency Spectrogram

Normalized Freq	Osc./Yr.	Osc./Mth.
1.00	143	11.8
0.40	57.3	4.70
0.20	28.7	2.30
0.15	21.5	1.77
0.10	14.3	1.10

Discussion

The Advantage of splitting data into quadrants, every 6 hours of a day enabled us to identify/compare daytime and nighttime patterns throughout the years. It removed the gross effect of temperature depression or elevation caused by adjacent quadrants. The modal temperature of 2018 overshoots the fitted normal distribution curve (32 & 33 degrees Celsius) compared to 2017 (30 degrees Celsius) Figure 3 and Figure 4. These are likely due to air pollution from illegal refinery activities, causing black soot-suspended aerosols (about 25 microns) that have reached hazardous levels in Port-Harcourt City, Nigeria. The spectral clouds distribution in the Normalized Frequency range (0-0.15) represented oscillatory temperatures from DC up to 1.77 oscillations monthly are likely associated with tidal factors in Figure 5 and Figure 6. The spectral clouds distribution of quadrant Q3 for 2017/18 shows more temperature perturbations in the atmosphere of 2017 than in 2018, having a more yellowish distribution of spectral power (Figure 5). In the study of the variability of some climatology parameters in Nigeria [12,13], it was revealed that spectral analysis and Time-Frequency power characteristics served as tools for the prediction of weather variability. The demon-stration shows that there are times of strong tidal forcing, based on astronomical factors, which correlates with cool periods in the global temperature as recorded at 6- to 10-year intervals.

A broader spectral bandpass including nine oscillations and the combination of two or more harmonics of Low-Frequency Spectrum shows an additional relationship of temperature to tidal events [14,15]. The sun has set in quadrant 3 and it is expected that the temperature of the atmosphere will drop. Any reluctance to drop will be a result of thermal mass.

In Figure 3, the major outlier temperature in the year 2017 was 30 degrees Celsius. Unlike in Figure 4, two outliers temperatures 32 and 33 degrees Celsius as observed in Figure 4 represent the year 2018. The outliers are notably skewed to the right-hand side of the normal distribution curve.

Comparing the outliers in Figure 3 and Figure 4 confirms that, the year 2018 was warmer in the third quadrant than its preceding year 2017. Figure 5 shows the spectral cloud representation of the third quadrant temperatures for the year 2017 and Figure 6 represents that of the Year 2018. The temperature spectrum of 2018 appears to be more bluish than the temperature spectrum of the Year 2017. This may imply that the thermal mass effect of atmospheric pollution in the year 2018 was stronger than its previous year 2017.

Conclusion

The study helps to understand the weather relating to the safety of the skies around the site in Port-Harcourt. This air pollution may distort the thermodynamic state of the atmosphere. Moreover, the build-up of carbon dioxide in the atmosphere from human emissions reduces the amount of radiation released into space, which increases both the night-time and day-time temperatures. Temperature fluctuations were presented as spectral clouds. The Spectral Clouds distinguish; near seasonal oscillations (caused

by natural factors) and appear as yellow bands close to and parallel to the time axis. Disturbances (caused by anthropogenic factors) appeared as faint yellow patches distributed well above the time axis. The spatial distribution of spectral clouds serves as a non-subjective pointer to localize causes of temperature perturbations, in a short time frame to avert climate change. Any distortions in the low-frequency signals (Near seasonal oscillations) imply trouble for the planet (or climate change). The suc-cessful application of Short Time-Frequency Analysis as Spectral Clouds has created awareness of soot problems in Port-Har-court.

Abbreviations

None

Conflicts of Interest

None

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