

# Development and Validation of Wind Direction Codes for Meteorological Data Analysis

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**ABSTRACT**

Qualitative research makes use of non-numerical data for example words, phrases symbols, images or directional descriptors, which require systematic coding before performing any analysis. In meteorological studies, wind direction data are recorded in qualitative form, and that is a challenge for statistical analysis. This study is aimed at the development and validation of a coding scheme for wind directions data, obtained from weather station of CGG Toro. The researchers came developed codes for the wind directions, after the review of some related literature. The researchers used the developed codes to run descriptive statistics, after which the results were compared with those of the weather link software where the results appeared to be the same. The result appeared to be similar with those produced by weather link software. The study, therefore, demonstrates that the proposed coding scheme is reliable, and suitable for researches involving wind directions data. It is recommended that researchers adopt the developed codes for future studies requiring statistical analysis of wind directions.

**Keywords:** Wind Speed, Coordinates and Codes.

**1. INTRODUCTION**

Wind direction is an integral part of meteorological parameter, that has a significant effect on environmental processes, atmospheric studies, the accuracy of GNSS and Radio Signal measurements. Understanding and analysing wind direction patterns over time allows researchers to model climatic behaviour, predict weather phenomena, and assess the impact on signal propagation.

Previous studies show that wind speed and wind directions can influence GNSS signal delays, turbulence and over all the reliability of satellite-based measurements. Therefore, accurate coding, categorization and analysis of wind direction data is a vital step in meteorological and geospatial data analysis involving wind direction.

Coding of wind directions' data refers to the process of transforming collected information or observations into a set of meaningful, cohesive categories. Qualitative data refers to non-numeric data, that is, data that are not quantitative. Wind direction generally means the direction from which it originates. Wind directions have greater effects on the atmospheric water vapour, which affects GNSS signals in the following ways:

- i. It reduces their propagation velocity and
- ii. It delays the required time for GNSS signals to reach the ground.
- iii. Wind directions also affect the air flow and pollutants dispersion.

The directions of wind are divided into four categories, but this paper is restricted to only three of the categories, viz:

1. Cardinal Wind Directions: these are the North(N), South(S), East(E), and West(W);
2. Intermediate or Ordinal Wind Directions: these are the North-East (NE), North-West (NW), South-East (SE), and South-West Wind Directions;
3. Secondary or Inter-Cardinal Wind Directions: these are the North-North-East (NNE), East North-East (ENE), East South-East (ESE), South South-East (SSE), South South-West (SSW), West South-West (WSW), West North-West and North- North-West Wind Directions. If we combine the cardinal, ordinal and the secondary wind directions we will have 16 wind directions.

### Objectives of the work

The main objectives of this study are:

1. To identify and categorize wind directions at the weather station.
2. To assign angular cut-off points for wind directions.
3. To code wind directions for statistical analysis.
4. To analyse data and validate the result.
5. To interpret findings and make conclusions.

## 2. REVIEW OF RELATED LITERATURE

### Literature Review on The Effect of Wind Directions on GNSS And Radio Signals

Guan et al., (2018), in their work “wind directions signature in GNSS- R observations from space, the feasibility of retrieving wind directions from the systemic Delay Doppler Map DDM is analysed with the use of a simulation tool ( $p^2EPs$ ) to generate the DDMs under different geometry configurations, wind speed, and wind directions. The researchers investigated DDM changes caused by the wind directions and proposed two metrics to retrieve the wind directions from the DDM shape changes. Simulation results show that the DDM changes caused by the wind directions can be detected.

Joseph (2016) in his work “Wind versus UHF Radio signal, studied wind within the earth’s troposphere and its effect on the radio signal. Experiments have been carried out in a residential area (Etta-Agbor) in the Calabar metropolises, Nigeria, with the UHF (35 dB, 519.25 MHz), radio signal transmitted from Cross River Broadcasting Cooperation Television (CRBC-TV) measured with a Cable TV-analyser, and simultaneous measurements of the atmospheric components: Temperature, Pressure, Humidity and Wind (speed and direction) by relevant apparatus. The Research show a uniform atmospheric temperature, pressure and humidity, wind has a marked effect on radio signal. The signal transmits better if they propagate in a similar direction with the wind, while it has poor transmission if they it propagates in a contrary direction with the wind. The Researchers have done an excellent job, most especially by proving that the Delay Doppler Map changes caused by wind directions, are investigated. This shows the impact of Wind Directions on DDM. The research conducted by Joseph also shows the effect of wind directions on radio Signals. But the two studies did not show any method of coding of Wind Directions that will convince the reader on how they dealt with the string nature of Wind Directions.

### Literature Review on The Effect of Wind Direction on The Speed of a Ship

Li (2018), conducted research on a decision support system for Vessel speed decision in maritime logistics using weather archive big data. The paper used weather archive big data to estimate the real fuel consumption for speed optimization problems, where the wind direction was studied as a factor that has a significant effect on the speed of a ship.

### Literature Review on The Effect of Wind Directions On-Air Pollutants and Others

Wooten (2011), in his work “statistical analysis, for the relationship between wind speed, pressure and temperature” used actual readings from a Buoy in the Gulf near French and the reading estimated using Doppler within a Hurricane. The study aimed at identifying the relationship between wind speed and pressure, using both regression analysis, and non-response analysis to detect interaction and higher order terms. The non-response test was further used in order to obtain a helpful information about the

relationship between pressure, wind speed and temperature. The methods were practical in both univariate and multivariate analysis using real-world data. In the study, five storms that had reached hurricane status category were used, which has the support of the Saffir-Simpson scale (1973 – 1974)

For the description of data and concept for comparison, a standard multiple regression analysis for the statistical model of water and dew point and Wooten's augmented matrix was employed to determine the relationship that exists among the variables including the interactions between wind speed and pressure. The relationship between wind speed and pressure was found using the equation :  $\hat{\beta} = [XX]^{-1}X'Y$ , applied to the first data set, and developed the model  $\hat{P} = 101296.96 - 0.312669w - 0.00285818w^2$ .

The result also shows that the non-response analysis provides alternative parameter estimates for standard multiple regression and allows the analysis to go beyond functional analysis of dependent and independent variables to that of co-dependent variables. It also shows that temperature is related to wind speed and pressure when there are no storms, therefore, it is necessary to observe temperature in order to understand when low pressure results to higher wind speed like those found within a hurricane. The researchers concluded that using statistical regression and non-response analysis, pressure can be explained by using wind speed. However, simple correlation analysis shows that wind speed and the surface is highly correlated with the temperature, while dew point is related to the relative humidity and air density. Pressure is also highly correlated on atmospheric temperature. In fact, the pressure appeared to be co-dependent with wind speed and temperature. There are two solutions for pressure, depending on the temperature and wind speed. Similarly, there are two solutions for wind speed depending on pressure and temperature.

Mohammed and Ahmed (2021) conducted a research on the Temporal variation of wind speed for different climatic seasons Northern in Sudan. The objectives of the work were:

A – to generate broad – base quantitative data on wind speed, wind direction and inter-relationship between air temperature and wind speed in the northern state that may help in designing wind erosion control project.

B – to investigate the monthly and diurnal variation of wind speed and wind directions within different climatic seasons. The study was undertaken at Karima area, which is part of the Northern state of Sudan which lies between Latitude  $17^{\circ} 45' - 19^{\circ} 15' N$  and Longitude  $30^{\circ} 15' - 32^{\circ} 00' E$ . They used three meteorological stations in the Northern state, located at Wadi, Halfa, Dongolla and Karima. The area of the state is approximately  $338,697km^2$

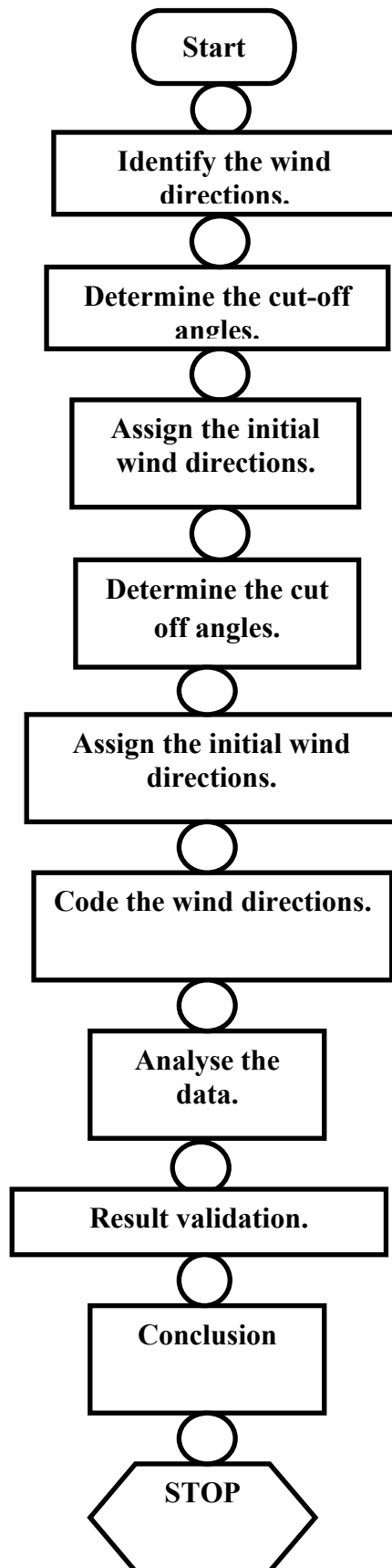
### Climatic Type

The type of climate in the state was characterized as desert (hyper – arid), with two seasons, a hot summer from April to September and a cold winter from October to March.

## 3. METHODOLOGY

An opportunity sampling technique was used to collect monthly temperature and wind speed data from the Karim station. They used data for the period of ten years (i.e. 2001 – 2011). The climatic data were monthly and daily averages for wind velocity, air temperature and wind direction. Three-month meteorological data, one from each climatic season (April for summer, August for autumn, and December for winter), were selected to represent their respective seasons in the research. The methods for data analysis were mean, standard deviation (STD), coefficient of variation (CV) and simple regression analysis. The result showed that the wind speed varied widely in frequency and direction during each month and day, even within the same climatic seasons.

In two seasons, the diurnal variation for different climatic seasons April, August and December were much than the monthly variation, due to the high monthly variability of wind speed. The result shows that the predominant direction was North. Significantly, negative and cubic wind speed – temperature correlations in the two seasons for August and December were found. The result shows that the regression technique is effective to show the relationship between climatic variables. Huang et al., (2019), investigated the effects of Wind Directions on the airflow and pollutant dispersion inside a long street Canyon using computational fluid dynamics (CFD). It is concluded that, to investigate the effects of the ambient wind direction on the flow and pollutant dispersion inside a long street Canyon the data must be in a numerical form. Kim et al., (2015), in their study, the influence of wind direction and speed on the transport of vehicular air pollutants was investigated using mobile laboratory in an urban area. It is concluded that this analysis, over three spatial scales, will clarify the effect of wind on air pollution in a roadway environment in urban areas. In conclusion, all the papers reviewed have done their best in the study of the effect of Wind Speed and Wind Directions on different variables, still, none of them displayed a guide on how to analyse wind direction by researchers with the aid of any codes. That was the reason for the researchers to develop codes for Wind Directions, Wind Directions data obtained from GNSS meteorological station.



**Figure 1.** Flowchart Representing the Process of This Work

**Data source:** Meteorological station of CGG Toro, Bauchi State, Nigeria.

**Period Covered:** 1 FEBRUARY; 2 MARCH; 3 APRIL; 4 MAY; 5 JUNE; 6 JULY; 7 AUGUST; 8 SEPTEMBER; 9 OCTOBER; 10 NOVEMBER; 11 DECEMBER. 2022.

**Parameters:** Only Wind Directions

#### Identification of Wind Directions

- Examine raw data from the meteorological station.
  - Extract Wind Direction for the period of study.
- Determination of the cut-off angles
- Define angular boundaries for wind directions (e. g. N, NE, E, SE etc.)
  - Ensure that all possible wind directions were assigned to a sector.

#### Coding Algorithm

A dynamic programming algorithm which employs remembering the result of the past and then applying it, to find the result of the present.

The algorithm was divided into seven (7) different steps using the idea of the Fibonacci Sequence as:

Step 1: Identify the ordinal, cardinal and inter-cardinal wind directions.

Step 2: Determine their cut-off angles (in degrees) of each wind direction.

Step 3: Assign the initial code to the First wind direction (i.e., the direction with 0 degrees)

Step 4: Code the wind directions into statistical software (SPSS is used in this work).

Step 5: Analyse the data using descriptive statistics in SPSS

Step 6: Validate the result, using a comparison between the result obtained and the existing summary in the weather link software.

Step 7: Draw conclusions, based on the result of the analysis.

#### Type of Coding Used

An inductive (or open) coding was used where the coding started from scratch and created codes based on the qualitative data itself. You don't have a set or codebook: all codes arise directly from the survey responses.

#### Representation of the in a Flow Chart

The process of this work is represented using a flow chart, from the beginning to the end. See figure 1.

## 4. RESULTS & DISCUSSION

#### Coding, Analysis, and Validations of the Wind Directions

The wind directions were coded from north(N) which has 0.1 up to the north-north-west which ended with 1.6. they also have degrees where north(N) has 0 degrees at the starting and 360 degrees when it completes the circle. See table 1:

**Table 1:** Codes and degrees of The Wind Directions

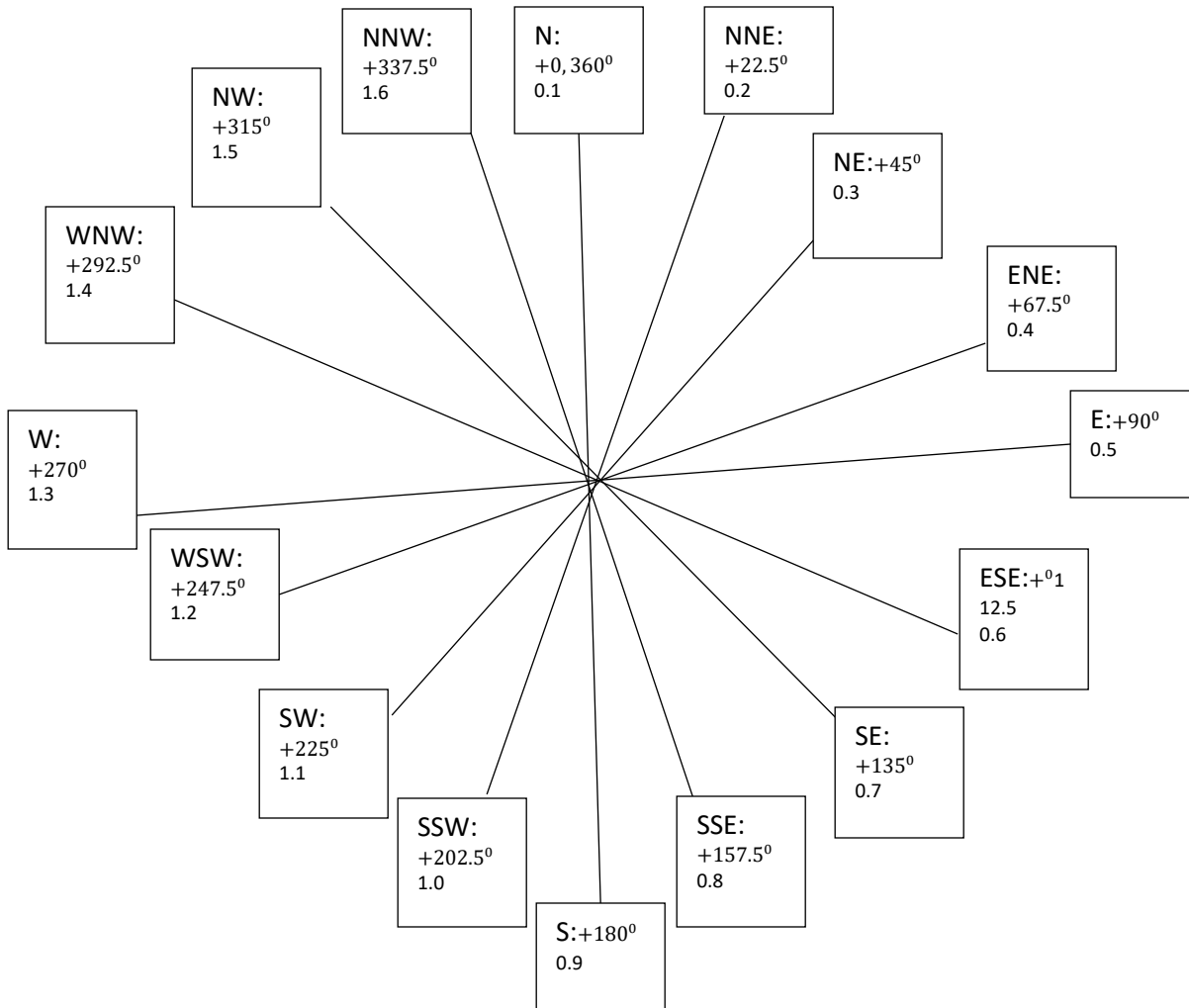
S/number	Wind directions	Abbreviations	Degrees	Code
1	North	N	+0, 360 <sup>0</sup>	0.1
2	North North-East	NNE	+22.5 <sup>0</sup>	0.2
3	North-East	NE	+45 <sup>0</sup>	0.3
4	East North-East	ENE	+67.5 <sup>0</sup>	0.4
5	East	E	+90 <sup>0</sup>	0.5
6	East South-East	ESE	+112.5 <sup>0</sup>	0.6
7	South-East	SE	+135 <sup>0</sup>	0.7
8	South South-East	SSE	+157.5 <sup>0</sup>	0.8

9	South	S	+180 <sup>0</sup>	0.9
10	South South-West	SSW	+202.5 <sup>0</sup>	1.0
11	South-West	SW	+225 <sup>0</sup>	1.1
12	West South-West	WSW	+247.5 <sup>0</sup>	1.2
13	West	W	+270 <sup>0</sup>	1.3
14	West North-West	WNW	+292.5 <sup>0</sup>	1.4
15	North-West	NW	+315 <sup>0</sup>	1.5
16	North North-West	NNW	+337.5 <sup>0</sup>	1.6

Table 1 shows the distribution of wind directions, their cut-off degrees and their codes. The angles started from +0<sup>0</sup> which corresponds to North Direction, and terminates at +337.5<sup>0</sup> which corresponds to North-North-West. The codes also started from 0.1 which is for the North direction and ends at 1.6 which is for the North-North-West.

**Representation of wind directions and their degrees using picture**

The coded wind directions and their cut-off degrees are represented in a pictural form. See figure 2:



**Figure 2.** the coordinates of the wind directions their codes and degrees

**Calculation of the dominant (mode), mean, and standard deviation of the wind directions**

We calculated the mode which in other word means the dominant wind direction, the mean, and the standard deviation of the wind directions with the aid of SPSS22 so that we can be able to validate our result. See table 2:

**Table 2.** Presentation of Results From SPSS

S/NO	MONTH	MEAN	DIR	MODE	DIR	STD	STD ERROR
1	FEBRUARY	(0.7)	SE	(0.1)	N	0.6	0.01233
2	MARCH	(0.8)	SSE	(0.1)	N	0.5	0.01058
3	APRIL	(0.9)	S	(1.1)	SW	0.3	0.00683
4	MAY	(0.9)	S	(1.1)	SW	0.8	0.00709
5	JUNE	(0.9)	S	(1.1)	SW	0.3	0.00753
6	JULY	(0.9)	S	(1.1)	SW	0.3	0.00725
7	AUGUST	(0.9)	S	(1.1)	SW	0.4	0.00907

Source: SPSS 22

Table 2 shows the result obtained from SPSS with the aid of the coded wind directions. It displays the mean, mode, and the standard error. The means and modes of the directions are also displayed. The modes in order word are called the dominant wind directions. We can understand from the table above that the dominant wind direction for the month of February and March was North direction having South-East and South-South-East as the mean respectively. While wind directions for the months of April, May, June, July and August, we got South-West direction as dominant and South direction as means throughout.

**Dominant wind directions from weather link**

Dominant wind directions for February, March, April, May, June, July, and August 2022 were represented in table 3:

**Table 3:** Presentation of result from Weather Link

S/NO	MONTH	MODE
1	FEBRUARY	N
2	MARCH	N
3	APRIL	SW
4	MAY	SW
5	JUNE	SW
6	JULY	SW
7	AUGUST	SW

Source: CGG Toro, weather station.

The results in table 3 show that the modal or in other word the dominant wind directions as computed by the weather Link software, where, February and March have North direction as dominant while April to August have South-East as the dominant. The results Obtained from our work are similar with those recorded by the Weather Link Software. This means, the codes generated from our work are quite okay and can be used as a way of simplifying further scientific analysis that may involve the use of wind directions.

**5. CONCLUSION**

The work is intended to simplify the use of Wind Directions in scientific research that might come up. After reviewing some previous literatures, a coding algorithm is set. A code and cut-off angle were assigned for each of the wind directions using inductive coding method. The codes were used to calculate mean, mode, standard deviation and standard error for each of the wind directions in order to determine dominant direction for each of the months from February to August 2022. The result was further compared with the result generated by weather Link Software and found out that they are similar. Based on the result from our work and one generated from the Weather Link Software

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### Author Contributions

The Authors contributed to this work in the following ways:

1. Adamu Ibrahim – contributed with the development of the work, data analysis and interpretation.
2. Adamu Ubaidullahi Usman – contributed with downloading and organization of meteorological data.
3. Yohanna Stephen Adams – Assisted in the analysis and validation of the data.

### Informed consent

Not applicable.

### Conflicts of interests

The author declare that they have no conflicts of interest, competing financial interests or personal relationships that could have influenced the work reported in this paper.

### Ethical approval & declaration

Not applicable. This article does not contain any studies with human participants or animals performed by any of the authors. Ethical guides were followed in accessing Meteorological data used in the study.

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### Data and materials availability

All data associated with this study will be available based on the reasonable request to the corresponding Author.

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