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Design Implementation of Integrated Sensors for Weather Detection and Monitoring Systems

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Abstract

Data of weather are important to obtain as it yields some benefits from knowing it. One of them being evacuation from disasters. For example, if there is a typhoon, we know the direction where it is heading. Another one being helping the work of weather forecasts. Data taken can be used to forecast if temperature in the next days will increase or decrease, and if the weather changes. To obtain those data, we need sensors. Most sensors cannot measure all weather data individually, which means that to measure more of those data, those sensors must be combined. This work aims to assemble sensors and integrate them into a prototype that can obtain weather data parameters. The prototype is then used to get data through data obtaining process, so that it may be used to analyze the weather. This study created an integrated sensor prototype with Arduino as its microcontroller. Sensors such as DHT-11, wind speed sensor, and wind direction sensor are integrated so that they may capture parameters at the same time. To make the prototype easier to use, LCD display is used to show the data when the prototype is in use, and the data is also stored in SD card for analysis purposes. Parameters were taken in 2 locations, analyzed with tables and graph, and also compared with results of another study to see if the data makes sense. The prototype was successfully built and easy to use. The temperature difference is only 3.6-4.1 C, humidity difference being 1%, and the wind direction difference being 1.01 m/s. Considering weather-atlas taking data for the whole day as opposed to this prototype, the provided data makes sense.

Keywords: Weather Detection, Disasters, Integrated Sensors, Monitoring Systems.

Introduction

Environmental situation and the needs of weather sensor

Environmental problems exist in this world. One of them being air pollution. Air pollution is the entry of compounds or chemical elements (gas / particulates) with concentrations that exceed the threshold into the atmosphere which can cause disturbance to the activity and health of living things and plants [1-4]. Natural occurence or human activities can create air pollution. As of human activities, examples such as industrial activities, waste removals through fire, and vehicle works may cause air pollution. Factors such as temperature, humidity, and rainfall can help us know athmospheric chemical reactions that creates pollution, thus it is important to measure those factors [5]. By measuring wind direction, we can know where air emmission migrates. Temperature is related to chemical reactions formation that contribute to forming pollutants. Humidity is also important. Other substances can be binded if humid air particles concentrates. Pollution and pollutants can also be cleaned and dissolved with rainfall.

Green energy can be developed and researched to contribute to ending environmental problems. Instead of using fossil fuel, wind force is one of the choices that can be used to power technologies. Wind force being used means a huge development in moving towards using green energy. Many countries have reached the advanced technique in applying wind force in technologies. Indonesia has many renewable energy source that can be used, wind energy being one of them. Wind force being used for energy source is promising as it is sustainable, inexpensive, and does not do environmental damage. Wind force being used as energy source has become more popular due to its low cost and clean resources [6]. Because of this, there is a need to monitor wind sources and wind speed from afar. This can be done by making a device that can monitor those things. To know the wind speed, a device called anemometer can be used to obtain the data. It is a device that is used by station weather forecasts to measure the wind speeds with its catcher cups.

Obtaining weather data is also important as President University is located in an industrial area, where there is obviously air pollution from factories and vehicles. It is also important for weather mitigation in which parameters such as wind direction can help people know where cyclones are heading so that evacuation can be done sooner before the disaster hits.

To monitor weather condition and to measure the wind speed, an integrated sensor that can measure those measurements is needed. It can include temperature, humidity, wind speed, and wind direction sensors. Thus, this research will revolve along creating a weather station prototype that can obtain data which can be used to analyze the weather condition.

Development of Weather Monitoring System

Weather sensors have various history depending on the individual sensors. This is because in the past, one device is used to only measure one parameter, not combined parameters that can be detected by just one or two devices of weather sensor nowadays. Due to the context of this thesis, development of sensors that will be explained is the development of wind speed detection, wind direction detection, humidity detection, and rainfall detection.

Wind Speed Detection Development.

Wind sensor was developed by many people in the past. A version of anemometer was developed in 1846 using four hemispherical cups and mechanical wheels [7]. The cups are attached to horizontal arms with a vertical rod at the center. The wind is caught by these cups as it moves the arms and spins the rod. Thus the conclusion can be taken in which when the rod spins faster, the wind blowing is also faster.

Other improvements were also done when electric generators were installed at the base of the anemometer. Electric current was generated when the wind spins the rod which is located at the center. The device could read and record the wind speeds from the anemometer when the amount of current is produced for certain wind speeds. This way of measuring wind speed can also be done to measure wind speed from various places at the same time. This is why weather forecasting and monitoring also depends on anemometers, as they give people the ability to study weather patterns from wind measurements of many locations.

More different improvements were also made to make wind measurements more accurate. To measure lower wind speeds with better accuracy, another anemometer (hot wire anemometer) was created in which low wind speed can be measured by how the air cools a heated wire in the anemometer.

Development of Weather Vane.

Weather vanes are devices that are used to show the direction of the blowing wind. In the past, they were placed on high places such as the top of houses or barns to capture the information of where the wind blows clearly and better. Wind vanes have pointers or arrows that are tapered at one end to catch even the directions of lightest winds. A wind vane works as the larger end of the pointer acts as a sort of scoop that catches the wind [8]. When the pointer turns, balance will be found by larger end and line up with the wind source.

In further times, roosters were used as wind vanes proved to be good at it as they have tails that work good to capture the blowing wind due to their perfect shapes to do the job. As time passes by, roosters are replaced with wind vanes to show the direction where the wind is from. Modern weather vanes are now less ornamental as the instrument is usually placed on remote reading stations, only being in the form of simple arrows. Combining a weather vane with an anemometer at the same axis (a vertical rod may be used) can give coordinated readout [9].

Development of Humidity Measurements.

Humidity was already measured in the past using prototype hygrometers [10]. In ancient China of during the Shang dynasty, weather was studied. A charcoal bar and a lump of Earth was used and had its dry weight measured. Then it was to be compared with its damp weight after it was placed in open air. The weight difference were used to measure the humidity. Another technique was also used in which the lump of earth and the bar of charcoal were hanged separately on a stick.

A string on the middle point was also added to make it horizontal in dry air condition. When the air was dry, the charcoal would be light, it would be heavy at humid air condition. This was an ancient hygrometer. Now a modern hygrometer is already created. It can measure humidity by the changes of electrical resistance [11]. It uses a thin piece of semiconductive materials such as lithium chloride. Its resistance is to be measured, as it is affected by humidity.

The application of a weather integrated sensor.

Crop growth is affected by two factors, external and internal. Internal factors mean factors that are affected by genetic of the plants. And external factors includes climatic and soil factors. Climatic factors consist of precipitation, humidity, temperature, solar radiation, wind speed, and atmospheric gases. While soil factors include soil moisture, soil air, soil temperature, soil matter, and soil reaction [12, 13].

There were bigger challenges to get the good quality weather data in agriculture farm to make weather predictions. Many crops have lost due to unpredicted rains, floods, critical wind and temperatures. Without weather station as in the past, farmers would helplessly accept losses of crops without anything that could be done to prevent it. But now weather stations are placed at farms that help people monitor weather fluctuations and make predictions [141].

Weather data such as rainfall, temperature, humidity, wind velocity, and wind direction can be used to help people do certain farm operations like irrigation scheduling, harvesting crops, and to find the right time to apply sprays for the plants. Precautionary measures can also be taken when there is to be heavy rain or wind blows, or incoming severe temperatures. With the weather stations, farmers do not need to go to their farms to find out the weather data. Data can be sent to them using data transferring methods such as IoT and etc.

In Industrial sites, weather stations are placed to do monitoring for infrastructures, monitoring areas where there may be spills, and for rapid response tool when there are release of hazardous materials [15]. For oil & gas platform, they are used for weather reporting and aid in helicopter operations. Weather stations can also be used for railways as railroads are required to nicely deal with high wind hazards and hazardous material response. The weather stations are used to monitor high wind hazards, facilitate hump yard operations, and emergency response.

Research Methodology

System Components

DHT-11.

The DHT11 is a basic, ultra low-cost digital temperature and humidity sensor. It uses a capacitive humidity sensor and a thermistor to measure the surrounding air and spits out a digital signal on the data pin [16]. It is simple to use but requires careful timing to grab data. Compared to the DHT22, DHT11 is much cheaper with less accuracy with smaller range of detection which makes this equipment is suitable for simple research project. This sensor is depicted in Fig. 1.

Fig. 1. DHT11 Temperature and Humidity Sensor

Arduino Uno R3.

Arduino Uno is a type of microcontroller that has 14 digital input/output pins, 6 pins for analog inputs, a USB connection, a reset button, and a 16 MHz ceramic resonator. It is shown in Fig. 2. It has a power jack and ICSP header [17]. This microcontroller is simpler to use compared to other microcontrollers, enable you to use both analog and digital type of sensor, and is suitable for beginners.

Fig. 2. Arduino Uno

Wind Speed Sensor.

This sensor is used to determine the speed of the wind [18]. The cup like structures capture the wind blows, revolves, and output analog values based on the speed of the rotation, so a formula in the programming is needed to convert that output into wind speed data. This sensor requires 12 Volt of voltage input to run properly and gives voltage output in the range of 0-5 V. The device is shown in Fig. 3.

Fig. 3. Wind Speed Sensor

Wind Direction Sensor.

This wind direction sensor as shown in Fig. 4 tells us where the wind direction is [18]. The flattened vane end is blown by the wind till it stops spinning and becomes steady, with the vane pointing into the wind direction. This sensor gives voltage output through one of the wires which is the data pin to Arduino. Every angle would give different voltage output, giving 0 Volt at 0-degree angle, and around 4.8 Volt at maximum angle, in which when it returns to 0 angle position, the output voltage will return to 0 Volt. The output voltage is made on scale with 360-degree angle as they are directly proportional. Thus, it enables us to tell the degree of direction at a certain voltage. This sensor requires 12 Volt as the input voltage for it to run.

Fig. 4. Wind Direction Sensor

LCD Panel.
LCD or Liquid Crystal Display is a type of display which uses liquid crystal to function as it is shown in Fig. 5. It displays the ASCII characters with fixed size. These characters are the ones that form the texts.

Fig. 5. LCD Panel Display

RTC DS 1307.
RTC or Real Time Clock is a module that can maintain hours, minutes, seconds, date, month, and year. This module can work both with the input of 3.3 V, or 5V. A 3V battery power source is also needed for this module to maintain information. I2C communication protocol is used by this module as shown in Fig. 6.

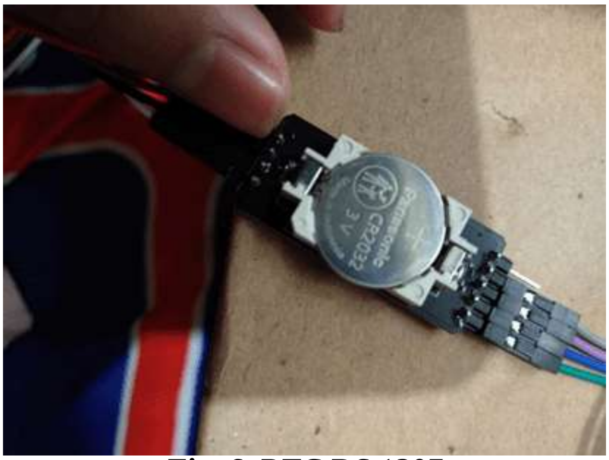

Fig. 6. RTC DS 1307

SD Card Module.
This SD card module lets the Arduino communicate with the SD card in order to write the obtained data into a file in the card and save it. In the case of this project, it helps Arduino to save the data as a Wordpad file into the SD card through the module. It is shown in Fig. 7.

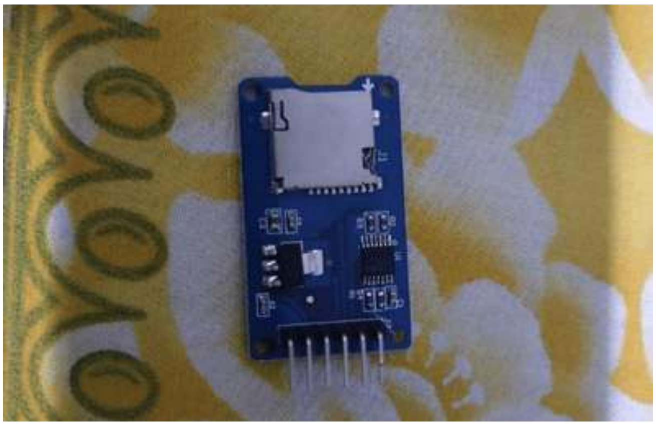

Fig. 7. SD Card Module

Hardware Implementation

The initial step is to integrate sensors into one prototype. This is the purpose of our research. How to integrate those sensors and make them working well each other and as a one integrated system? Wind direction sensor, wind speed sensor, and DHT-11 sensor are connected to the Arduino Uno. They are connected in either analog or digital pin depending on the sensor. The coding in the Arduino application will process the data that are obtained from the sensor into measured data of parameters of the respective sensors. After that, the data will be displayed in LCD display, and stored into an SD card through the SD card module. A block diagram for the system is made and shown in Figure 8.

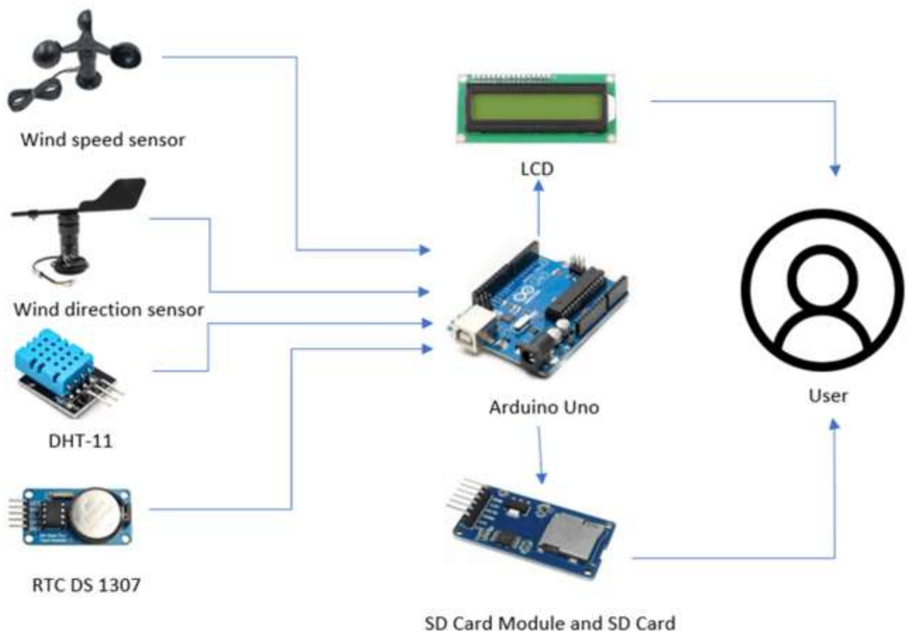

Fig. 8. Block Diagram of the Integrated Sensor for Weather Monitoring System

The prototype has steps to run in the process. First, when the prototype is started, it also starts Arduino. It starts the RTC and file in the SD card where data is going to be saved. It proceeds with reading and writing the data obtained from the DHT-11 sensor, which are temperature and humidity data. Next, the wind speed sensor is the one that reads data, which is processed and written after the complete data is obtained. After that, the wind direction sensor reads the data that it can obtain, and it is then processed to be wind direction data. As all the desired data are obtained at this point, LCD panel displays the data. Next, the data is stored in a file in an SD card. Finally, the process loops or it can be ended by the user. The flowchart of the system is shown in Figure 9.

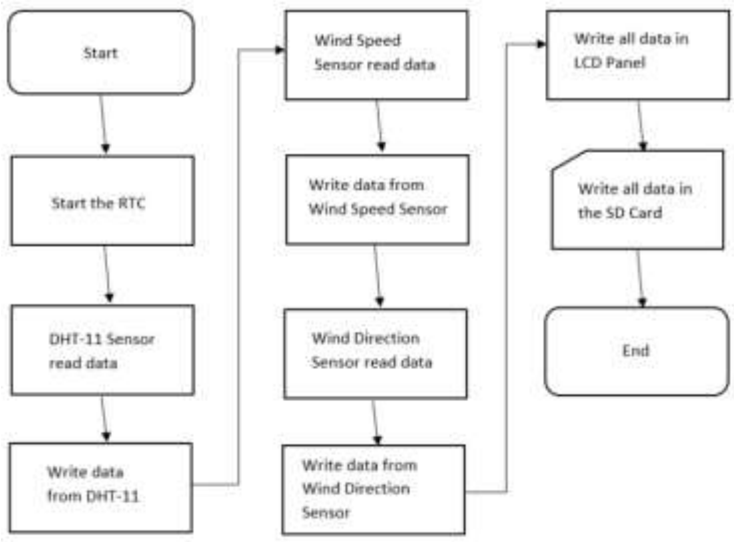

Fig. 9. Flowchart of the Integrated Sensor for Weather Monitoring System

The sensors are also wired in a way that they can work alongside each other. The data wire of DHT-11 is connected to pin D3, while its VCC and GND are connected to the VCC and GND of the Arduino, as is the case of the other sensors. Meanwhile for wind speed sensor, it is connected to pin A2, and for wind direction sensor, it is connected to pin A0. Wind direction sensor is also connected to external voltage source of 10 V so it can work properly. Figure 10 shows how the sensors are wired to create the prototype.

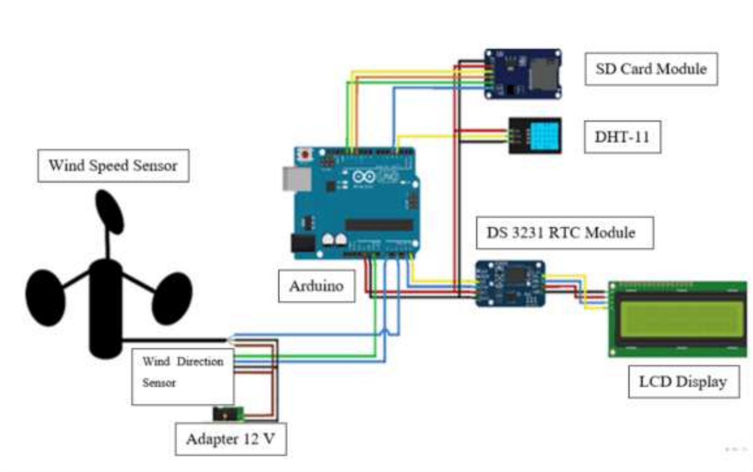

Fig. 10. Wiring Diagram of the Integrated Sensor for Weather Detection & Monitoring System

Software Implementation

The prototype is implemented into Arduino software in which it is the place where the coding is done, but the data displayed is through an LCD Panel as shown in Figure 3. Configuring RTC is also essential so the data is displayed alongside a timestamp in which the data is obtained. The temperature and humidity are shown first, then it proceeds to showing wind speed and the direction of the wind. After the data is obtained, it is plotted inside a table before it is charted in linear graph or radar chart (for wind direction). As for radar chart, the direction of the wind is plotted depending on their appearance frequency throughout the time period of data measurements.

The data that is obtained is put into an SD Card which is attached to an SD Card module, to send the data to the card. The data is put in the form of texts in Wordpad file which in this case its name is "DATA", as shown in Figure 3.6. The data also has timestamps for each period. All of this is permanently stored without further actions to manually save the data in the SD card every time the data is obtained. The file containing the data can also be used directly to plot the data inside tables, using Workspace Spreadsheet, by simply importing the data file to the application. It is an important task to be done (can't be skipped).

Results and Discussion

After combining, assembling, and implementing those small and big components of sensors, actuators and microcontroller (hardware and software), then the final device prototype was well finished. It is ready to be used for some measurement tests and so able to do its purpose. The final device prototype has been made and running successfully, where the system can receive the data from the sensors, then processing the data, and display the results. The overall system is depicted in Figure 11 (all connections is closed by the brown box, so it is neat and tidy).

Fig. 11. Integrated sensor for weather detection & monitoring system prototype (finished well)

The author used some sensors such as wind speed sensor, wind direction sensor, rain sensor, and DHT-11 to measure 4 parameters which are wind speed, wind direction, temperature, and humidity in this project. The wind direction sensor needs to have its 0-degree output point aligned with the direction of the North. To do this, the author marks the direction of 0-degree output of the wind direction sensor and uses compass to align it.

The measurements were done in 8 days. The time for the measurements was from 3:00 – 3:20 pm. The place of the measurements was in front of marketing office where there are less buildings to block the wind and more trucks passing by as there are more trucks entering the area to travel to a factory. This place will be referred as area 1. Table 1 shows the measurements on the last day of the first area.

Table 1. Eighth Day Results of Weather Monitoring System in Area 1

Minute	Wind Speed (mps)	Wind Direction (degree)	Wind Direction	Temperature (°C)	Humidity (%)
2	0.30	232	South West	26	69
4	0.40	221	South West	27	68
6	0.40	219	South West	27	71

8	0.30	62	North East	26	72
10	0.60	301	West	26	69
12	0.30	307	West	26	69
14	0.30	322	West	26	66
16	0.40	304	West	26	69
18	0.30	46	North East	26	71
20	0.30	39	North East	26	72

On eighth day, the wind speed increases, decreases, and fluctuates at the end. 0.0 mps is the minimum wind speed while the maximum wind speed is 0.6 mps. The direction of the wind points to West in most time interval taken, which is 4. There are minor wind directions such as pointing to North East and South West both 3 times. The minimum temperature is 26 °C, while the maximum temperature is 27 °C. The minimum amount of humidity is 68%, while the maximum is 72%. Another measurement was made in Area 2. Area 2 is in front of housing complex.

The measurements were done in 8 days with the timeframe lasting from 3:40pm – 4:00pm. The measurement on its last day is shown in Table 2. The measurements are made in many parameters, including minute, wind speed (mps), wind direction (degree), wind direction, temperature (Celcius degree) and humidity (%). Those parameters are important and relevant, so then we will know the environmental situation before we can make the correct decision and policy in the future. And of course, the detection and monitoring must be continued in a certain period of time.

Table 2. Eighth Day Results of Weather Monitoring System in Area 2

Minute	Wind Speed (mps)	Wind Direction (degree)	Wind Direction	Temperature (°C)	Humidity (%)
2	0.60	272	West	29	72
4	0.00	210	South	28	71
6	0.40	179	South	28	73
8	0.70	310	North West	28	71
10	0.00	323	North West	27	72
12	0.40	122	South East	28	71
14	0.60	65	North East	28	71
16	0.30	93	East	27	71
18	0.40	353	North	27	71
20	0.30	321	North West	27	73

On the eighth day, the wind speed fluctuates, where 0.0 mps is the minimum wind speed while the maximum wind speed is 0.6 mps. The direction of the wind points to North West in most time interval taken, which is 3. There are minor wind directions such as pointing to the North East and East both 1 time. The minimum temperature is 27 °C, while the maximum temperature is 29 °C. Temperature

also fluctuates a bit but not by much. The minimum amount of humidity is 71%, while the maximum is 73%. The results of 8 days measurements for 20 minutes are shown from Table 2. The wind speed hits 0.00 mps more often than area 1 in which it does 1.7x more. And the temperature is moderate (does not hit 35 °C and above on average).
Here are the explanations:

- There are less winds that can be caught in this area as it is more surrounded by houses
- The measurements were done from 3 :40 pm until 4:00 pm, which means that the temperature is not too high.

The data is then averaged and compared with data from Weather-atlas.com with the condition of comparing with the same data of city the prototype taking the data in, which is Bogor.

Table 3. Comparison of average temperature and humidity with Weather-atlas.com

	Temperature (°C)		Humidity (%)	Wind Speed (mps)
	Average High	Average Low		
Average data from Weather-atlas.com [15]	31,3	22,3	72	1,38
Average obtained from this research in area 2 (on the last day)	27,7	26,2	71	0,37

The temperature data taken in both areas are still in the range of average high and average low of temperature in that month according to weather-atlas. Area 2 average temperature has 3.6 ^{o}C difference compared to its average high, and 5.4 difference with its average low. The humidity only differs by 1%, which is small. As for average wind speed when compared to weather-atlas data, area 2 has 1.01 mps difference with the average data in Weather Atlas for the whole day [15]. Considering weather-atlas taking data for the whole day as opposed to this prototype, this prototype provided data that makes sense.

Conclusions

The study shows that the integrated sensor prototype is successfully built and manages to capture 4 parameters, which are wind direction, wind speed, temperature, and humidity. LCD display is also used to show the data to the users, and the data is stored into an SD card as well to make them usable for analysis. The data obtained are compared with data from weather-atlas and they only have small differences which tell that the data measured by the prototype make sense. The temperature difference is only 3.6-4.1 C, which is small and fair considering that the weather-atlas average the data for the whole day, humidity difference being 1% which is small, and the wind direction difference being 1.01 m/s.

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