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Research Article

Selçuk weather station and web-mobile applications

Fatih Basciftci [a], ***Erdem Agbahca*** [a], ***Kubra Uyar*** [a], ***Zuleyha Yilmaz Acar*** [a], ***Burak Tezcan*** *,[a]

[a]*Selçuk University, Faculty of Technology, Konya/Turkey*

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ABSTRACT

In this paper, a system for reading meteorological data like temperature, humidity, air pressure, wind speed, wind direction, and rainfall at regular intervals, deployed in Selçuk University Alaeddin Keykubat Campus. The system also provides real-time images and video time-lapses of the campus sky. These data are made available to university people via a website and mobile applications for both iOS and Android. The website and mobile applications provide a clear experience for the users, also explaining the icons and terms used on the website. Users can access the system archive in graphical ways.

1. Introduction

Meteorology is the study of changes and developments in weather events in relation to their causes. Meteorological systems provide information to forecast the effects of these events on daily life. Weather changes on daily basis have a great impact on mood [1] and human activities like agriculture, tourism, or entertainment [2]. Changes in weather events became more unpredictable after the twentieth century due to high population growth, global warming, etc. Modern weather stations include many sensors for reading temperature, humidity, air pressure, wind speed, wind direction, and rainfall. Ground-based meteorological data are considered the golden standard in the field [3].

In this study, meteorological data is collected using sensors at one-minute intervals and presented to the user with ten minutes update cycles.

Although there is no universally accepted definition, heat waves are unusually hot-dry or hot-humid weather events that have subtle onset, are intermittent, last 2-3 days, and have visible effects on humans and the environment [4]. Therefore question of which temperatures cause heatwaves depends on the region's climate: the same meteorological situation may cause heatwaves in one region and not in another region [4]. In the last decade, the frequency, intensity, and duration of weather events raised significantly. Heatwaves are extreme weather events that affect society, ecology, and the economy [5]. The frequency of heatwaves has increased in much of Asia, Australia, and Europe [6]. Data collected in this study can be used to detect climate conditions that cause heatwaves in Konya which is an agriculturally important place in Turkey.

Dursun [7] studied machine learning performance on the classification of meteorological data. Temperature, humidity, air pressure, and dew point of Elazığ province were gathered and classification performance of some fuzzy logic and neural networks were compared. He also forecasted weather conditions using meteorological data of Elazığ province. Ünal Çalargün [8] analyzed real meteorological data for Turkey recorded between 1970 and 2007. It is aimed to find fuzzy relationship rules from spatial and temporal data. Smith and Lakshmanan [9] created a system reporting important weather changes. Williams and Cornford [10] argued that meteorological data such as real-time temperature and rain rate can be accessed free over the internet, but they should be made more understandable for users. They also developed forecast methods using interpolation. Tural and Samet [11] studied collecting, analyzing, and mapping real-time meteorological data. The system enables access to real-time meteorological data and analysis over the web. It gathers real-time data from meteorological stations and after some preprocessing creates

* Corresponding author. E-mail address: *btezcan@selcuk.edu.tr*
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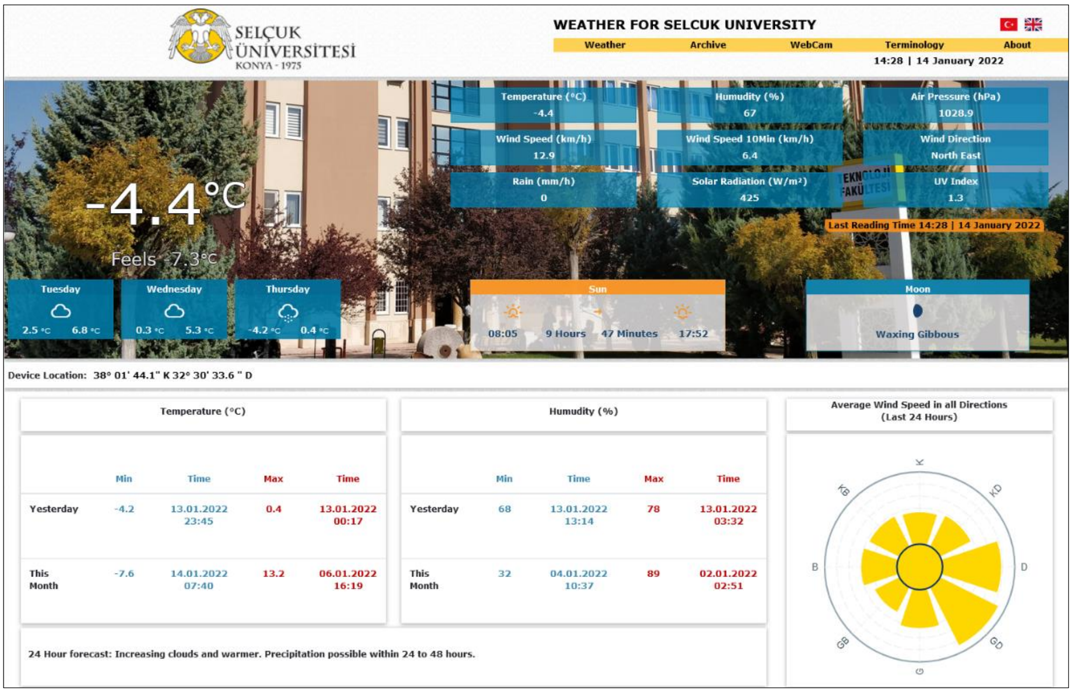

Figure 1. Homepage - Weather Interface

instances in a geographical database. Developed system published as a web service and users can access from a desktop, mobile or web apps. Altan [12] studied wavelet transform to diagnose and fix errors in agricultural meteorological data. He compared wavelet transform results with a regression model created using meteorological data from nearby stations. Gökrem and Durgun [13] developed a dynamic graphical system for collecting and analyzing data. Users can access the data in real-time. Arroyo and Herrero [14] analyzed different clustering methods using Spain Meteorological Agency's data from 4 different stations between 2004-2010. Chu and Zheng [15] studied on an image collection of rich weather events and graphical dynamics. Also, using geography-labeled image collection, they detected some correlations between weather properties and metadata, and statistical results associating human behavior and weather conditions were given.

Since the first release of smartphones, mobile application usage has grown significantly and some of the applications became ubiquitous in our daily life. The number of available applications in the Google Play store has reached 2.8 million as of 2021 [16]. The popularity of weather applications has increased each year [17] and the Google Play store has 8985 weather applications with an average rating of 4.07 as of 2021 [16].

Real-time weather data is required in various fields such as plant water requirements estimation [18], energy and mass balance measurements over glaciers [19], or for discovering wind energy-potential areas in Oman [20]. Accessing weather data provided from weather stations should be made available through mobile applications. Because especially for students, convenience is the dominant factor when choosing a source of information [21].

In this study, a website and mobile applications for a weather tracking system is developed. According to [22], weather apps use three kinds of main screen presentation styles: Essential/Nowcast, Table Shaped, and Map-centered. Our mobile app follows the Essential style because providing essential information without exhausting the user is provided convenience. Also, people tend to stay away from complex menus or secrets when using weather apps [23].

The next section explains the materials and the workings of the weather station and its applications.

2. Material and Methods

In this study, meteorological data of a weather station (Figure 2) is presented to users around Selçuk University Campus on a user-friendly website (Figure 1). It also shares images of the campus sky and a forecast for the next 24 hours (Table 1).

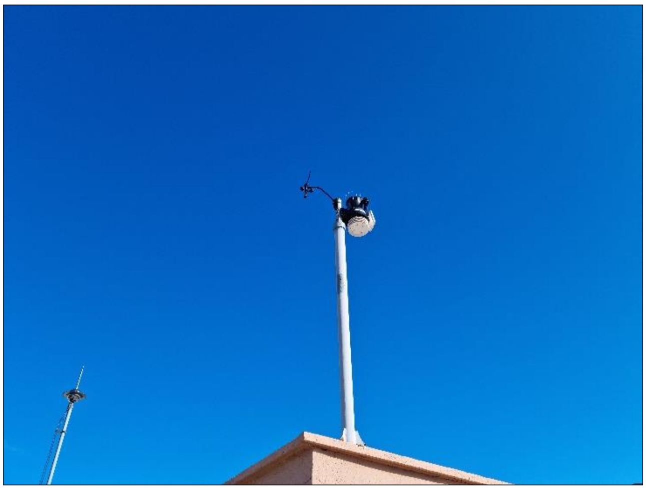

Figure 2. Placement of the meteorological station

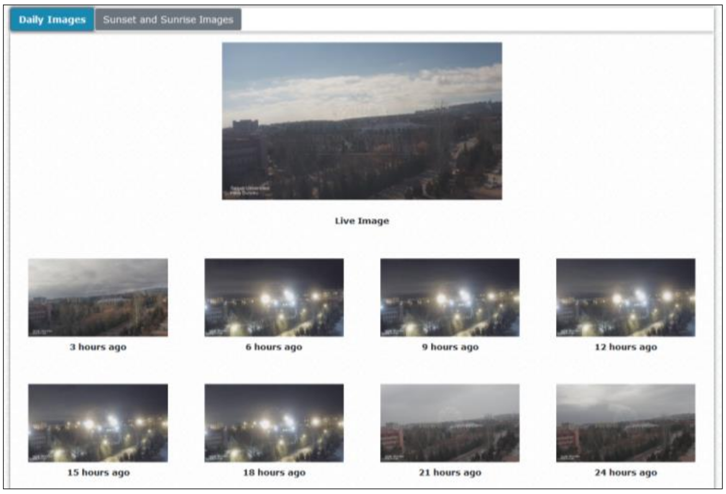

Figure 3. Images Interface

Table 1. Sample Forecast Messages

Forecast Messages
Mostly clear
Increasing clouds. Precipitation is possible within 12 to 24 hours. Windy
Partly cloudy with little temperature change
Mostly cloudy and cooler
Mostly cloudy and cooler. Windy with a possible wind shift to the NW
Clearing and cooler. Precipitation ending within 6 hours

2.1. Materials

Materials used in the collection and presentation of weather data are explained below. The example sensor images are illustrated in Figure 4. Also, the fully deployed weather station can be seen in Figure 5.

Wind Speed/Direction Sensor: The wind direction sensor has a sensitivity range of (0°-360°), resolution (1°) and maximum error margin of (+3°). Wind speed sensor has sensitivity of (1-80 m/s), resolution of (0,1 m/s).

Rain Rate Sensor: This sensor can measure both rain rate and rainfall intensity. It has a sensitivity of (0-6550 mm) and a resolution of (0,2 mm).

Temperature/Humidity Sensor: Due to high sensitivity and long lifetime, a capacitive sensor has been chosen. Temperature-wise, it has a sensitivity in the range of (-40°, +65°) and an error margin of (+0,3°C). Humidity-wise, it has a sensitivity in the range of (%1 - %100) and a maximum +%2 error margin.

Atmospheric Pressure Sensor: The pressure sensor has a sensitivity in the range of (540mb - 1100mb) and an error margin of +1 mb.

Solar Radiation Sensor: Solar radiation is the calculated heat of light. This sensor has a sensitivity of (0 W/m2 - 1800 W/m2) and an error margin of maximum ±%5.

Ultraviolet (UV) Sensor: This sensor has a sensitivity of %5 and (0 MED) - (199 MEDs) range. UV index has %5 sensitivity and (0)-(16) range.

Wireless Data Transmitter: Communication with the weather station is being done via wireless data transmitter. It generates its energy via a solar panel.

Wireless Receiver Module: It can collect, display and transfer data coming from the transmitter. Live data transfer can be done to a computer via a wired connection.

IP Camera: IP cameras are suitable for outdoor conditions and are used for collecting images of the campus sky.

Server and Power Source: All processing and saving jobs of the meteorological data are being done on this system. The server is supported by an uninterruptible power supply.

Figure 4. Sensor Examples

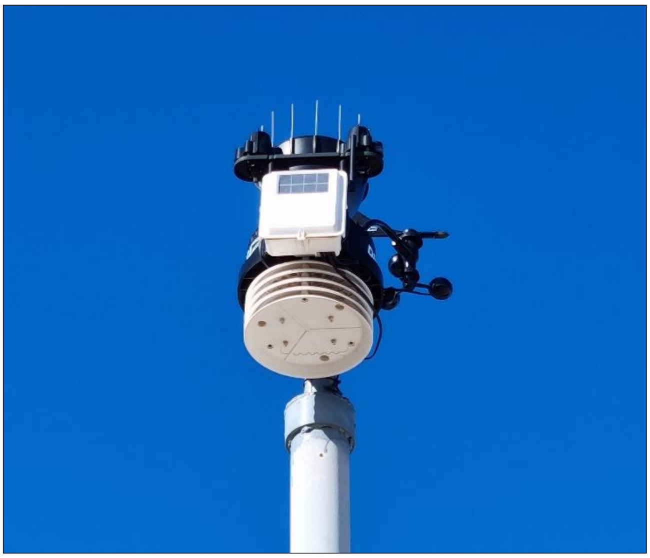

Figure 5. Close-up of Weather Station

2.2. Web Elements and Interfaces

Mainly, the website's back-end programming has been done using ExpressJS [24], and front-end programming using React [25]. React is a fast, scalable, and simple web framework. React component logic provides an easy and fast structure to present frequently changing data to users. React solves the expensive DOM manipulation problem using virtual DOM. All operations related to DOM are first done on virtual DOM and react detects the differences on this virtual DOM. This way, only the different parts are manipulated on actual DOM, and DOM manipulations are minimalized.

The system includes five interfaces which are developed to be user-friendly and functional. These are Weather, Archive, Camera Images, Terminology, and About.

2.2.1. Weather

The weather interface is also the homepage of the website (Figure 1). Weather station data presented on this screen is updated every minute. The weather interface consists of five parts. The top left of the screen includes the current temperature and feels like temperature with big font and appropriate icon. Also, recorded minimums and maximums for the last three days are given. The top right gives the current values for the temperature, humidity, air pressure, wind speed, wind direction, rain rate, solar radiation, and UV. Sunrise, sunset times, and moon cycles are given below this part. The below part includes yesterday and this month's values for temperature and humidity which are most relevant for the people. Also, approximate wind direction for each direction throughout 24h is given as a chart.

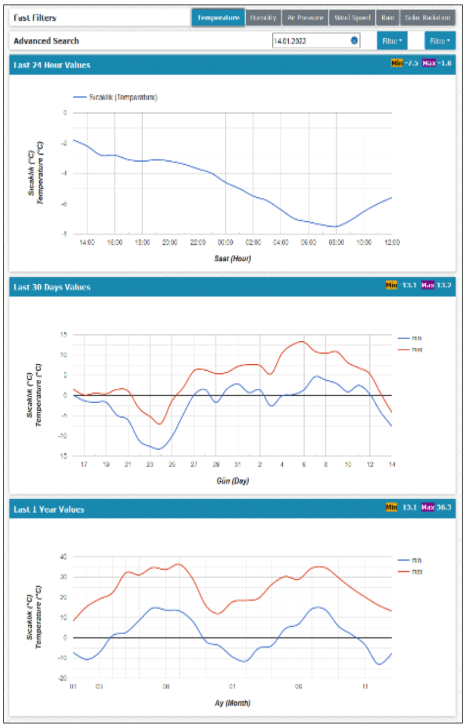

Figure 6. Archive Interface for Temperature

2.2.2. Archive

The archive interface provides daily, monthly, and yearly data. The graphic examples of temperature and rain are illustrated in Figure 6 and Figure 7, respectively. The archive includes data starting from 01.01.2020. Advanced filtering can be done for 24 hours, 1 month, or 1-year basis for temperature, humidity, air pressure, wind speed, rain rate, and solar radiation. Also provides quick filtering for the last 24 hours, the last month or the last year.

2.2.3. Images

Images interface provides images of the campus sky for the last 24h with three-hour intervals (Figure 3). Also, daily sunrise and sunset time-lapses are available.

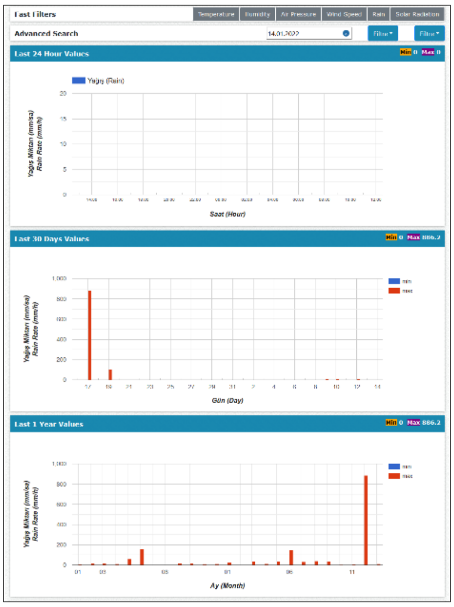

Figure 7. Archive Interface for Rain

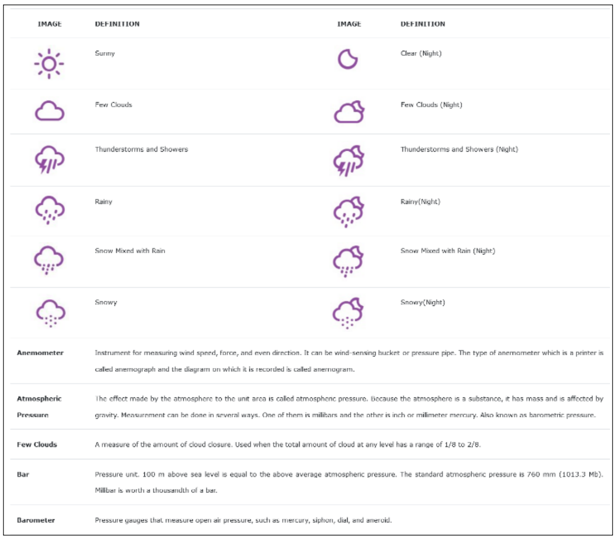

Figure 8. Terminology Interface Sample

2.2.4. Terminology

The terminology interface provides the user with the necessary knowledge of the meteorological concepts used on the website (Figure 8).

2.2.5. About

About interface provides information about the website, developers, and mobile versions of the website.

2.3. Mobile Elements

There are many platforms for developing mobile applications. For these platforms to be used in the project, it is considered that they are compatible with Android or iOS operating systems. Android Studio is used to develop Android applications, and XCode programs are used to develop iOS applications. Developing mobile applications for both Android and iOS can be provided on many platforms today. These platforms are in two forms as native and hybrid mobile application platforms.

Native applications are developed directly for a mobile operating system and that can provide direct access to software and hardware facilities. They are disadvantaged in terms of time and efficiency [26, 27].

Hybrid applications can adapt to all platforms. While the design is usually created for a single operating system in native applications, it is a highly preferred application type in hybrid applications due to its ability to adapt to both Android and iOS operating systems [27].

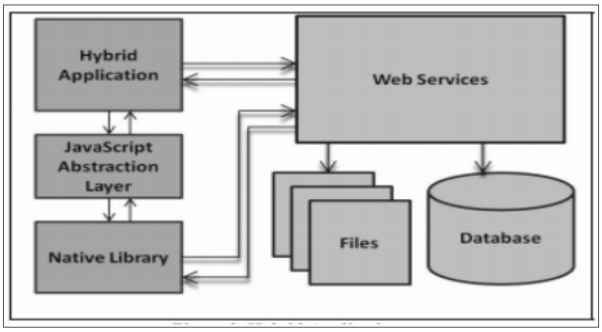

Figure 9. Hybrid mobile application process [27]

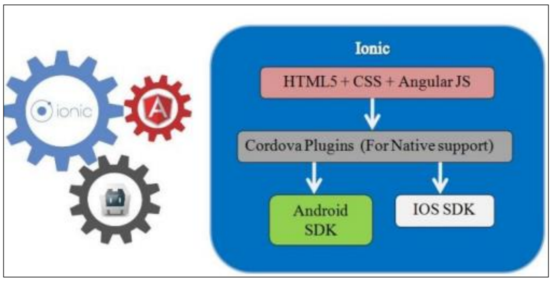

Figure 10. Ionic framework architecture [28]

The hybrid mobile application process is shown in Figure 9. Some hybrid application platforms are listed as React Native, Flutter, and Ionic Framework. Considering the features of the project, the plugins to be used and the usefulness of the environment, we chose Ionic Framework as the most appropriate choice compared to other alternatives.

Ionic framework is a kind of open-source framework that uses HTML5, CSS, and Javascript. While the framework offers a typescript option with AngularJS, it can be built on both Android and iOS with Cordova Plugins [28]. The architecture is shown in Figure 10.

While developing the Selçuk University meteorology mobile application, the stages of establishing the preferred environments, making the configuration settings, realizing the graphical designs, and creating the algorithms were carried out.

2.3.1. The splash screen and mobile application icon

When the application is opened, a picture is shown to the user during the installation of the components. The content of the picture is an advertisement of the application, in short, with the logo, application name, and background design. The designed splash screen is illustrated in Figure 11(a).

The application icon is the image of the application that appears in the phone menu. With a simple and striking design, a design that can appeal to every user has been made. The application icon is illustrated in Figure 11(b).

2.3.2. The home page of the mobile application

The home page is designed as five panels: the top panel, the historical temperature information panel, the panel with the solar information, the panel with the moon phases, and the forecast panel.

Since the top panel of the home page is the first part that catches the eye of the user, the design in this section is designed remarkably and understandably. It is the screen where the user receives instant information such as air temperature, pressure, wind strength and direction, humidity. It is also the part where the user will interact the most. The panel is intended to have animations shaped by the weather. Depending on the weather conditions, graphical designs that inform the user better, such as snowy, rainy, foggy, and sunny, are dynamically programmed on the panel. Weather conditions are symbolized by an icon so that the user can learn the weather more simply and clearly.

(a) The splash screen (b) The mobile application icon

Figure 11. The screen and icon images of the mobile application

Depending on the time, the current day or night situation is also visualized with a background image.

The historical temperature information panel is aimed to display the current weather conditions on a panel at certain time intervals during the day. The user can learn the weather conditions a few hours ago from this panel. In addition, the lowest and highest temperature of the air for the past three days can be accessed on this panel. When the user touches on any line on this panel, he can get detailed information about the humidity and wind for that day.

The sunrise and sunset times of the day are displayed on the panel with the sun information. In addition, the current position of the sun is calculated mathematically. Mathematical calculations have been added for a more precise and realistic sun movement near sunrise and sunset times. Visually, a more effective interface has been prepared for the user.

On the other hand, the panel with the moon information is designed as a panel that shows the phase of the moon for the day. The data sent under the name of the day, month, year parameters are found with an algorithm in which phase the moon is. This data is displayed to the user in the form of icons.

Finally, a section has been added in the forecast panel that allows users to be informed about the forecasts of the 24-hour weather conditions on the home page. The home page image of the application is shown in Figure 12.

Figure 12. The home page screen

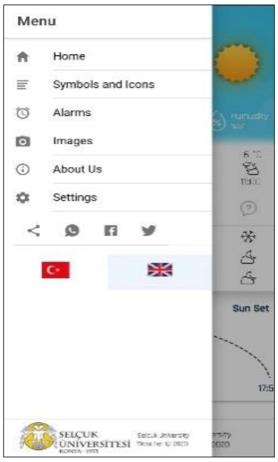

Figure 13. The Side Menu

2.3.3. The side menu

It is the panel that comes in front of the user as a result of swiping from the icon in the upper left on the main page or by swiping from left to right with his finger. From here, the user can access different pages with one touch.

This menu contains symbols and icons, warnings, images, about, settings, sharing options, and language options. The image of the application side menu is given in Figure 13.

The Symbols and icons option is aimed to convey to the user what the symbols and icons in the application mean on this page. Symbols and icons in the application are in Figure 14.

On the settings page, there is a section that allows the user to turn the application notifications on or off and to select the update frequency of the data on the main page in minutes. Application notifications are sent to the user's phone morning and evening at 07:15 and 20:15. If the weather conditions of the day are unusual, a warning message is sent to the user. This notification is listed in the alerts option in the side menu. When extraordinary weather conditions occur, there are some criteria determined to be included in both notification and warnings on the page.
These are listed below.

- High temperature,
- The possibility of icing,
- Strong wind,
- The dominant wind from the southeastern direction,
- Dangerous ultraviolet levels,
- Heavy rain

Certain mathematical calculations are made for the above-mentioned criteria. According to these, the system sends a warning message when a result matching these criteria is found. Thus, information is transferred to the user both in the form of a notification and in the form of a table. In addition, if there is an ongoing criterion, it is shown on the table with the phrase "Continuing". If it does not continue, the last seen date and time information are presented within 24 hours.

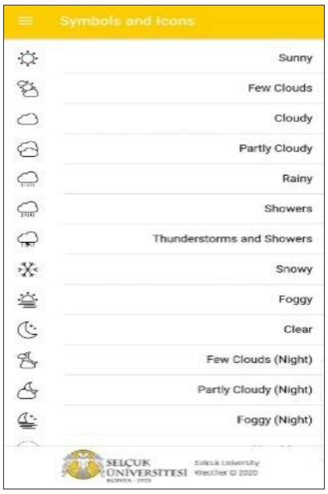

Figure 14. The Symbols

With the camera in the Selçuk University weather tracking system, the images are obtained from the campus at certain intervals. An accelerated short video was obtained by combining images at a certain interval from these images at sunrise and sunset times. These short videos are integrated into the developed mobile application. Thus, the sunset and sunrise short videos of the campus area lasting six seconds can be accessed via the mobile application. The images page is illustrated in Figure 15.

The about page, information about the Selçuk University weather tracking system project, to which the data used by the mobile application belongs, and the information of the developers are given.

Finally, there is a section on the side menu where users can switch different language options with one click. Users can choose the language they want in this section and use it in their preferred language without closing the application or restarting it.

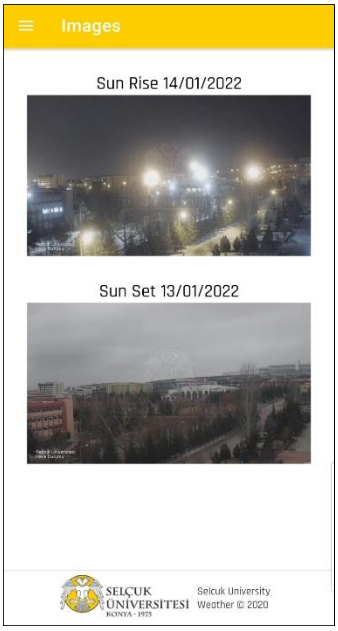

Figure 15. The Images Page

3. Comparison of the meteorological data with Turkish State Meteorological Service

In order to confirm the accuracy of the data received by the Selçuk University weather tracking system, the meteorological data for some days were noted on the website of the Turkish State Meteorological Service (TSMS) for the Selçuklu district of Konya province (https://www.mgm.gov.tr/). The TSMS obtains meteorological data of Konya province Selçuklu district from the Konya airport station. The direct comparison with our data is show in Table 2. You can also view graphical comparisons in the Appendix A.

Although obtained data are close to each other, the reason for the differences is that our system is located in the Selçuk University Alaeddin Keykubat Campus. In other words, while the TSMS data is obtained from the Konya airport, our system obtains data from the Selçuk University campus. The distance between the campus and the Konya airport is approximately 8 kms and there is an altitude difference between them. Standard Deviation and RMSE values are given in Table 3. Standard deviation of our data is mostly similar -sometimes better- to standard deviation of TSMS data. RMSEs of the normalized difference between our data and TSMS data are around 0.5 which is the psychological limit for a good RMSE in the literature. Temperature RMSE is a bit higher. It may be because temperature is the most affected value from the altitude difference.

Thus, it is seen that our system shows the campus weather information with very accurate results for both the academic and administrative staff working on the campus, the students, and also the guests.

4. Conclusions

In this paper, we have developed a system to collect meteorological data of Selçuk University Alaeddin Keykubat Campus. The main meteorological data system collects are temperature, humidity, air pressure, rain rate, wind speed, wind direction, solar radiation, and UV. The collected data is shared with people living around the campus via a website. This website is designed to provide people with necessary information about the weather around them. Users can better understand the weather situation with live images and time-lapses from the sky around the meteorological system. These data will also be provided via mobile applications both for Android and IOS. After a few years, collected data may be used in climate change studies. The mobile application was developed by a hybrid application method with an Ionic framework and designed as a user-friendly interface. With the developed mobile application, the users can access instant weather information, historical weather information of Selçuk University Alaeddin Keykubat Campus. In addition, an alarm system that warns the users of extreme weather conditions has been integrated into the application. The proposed mobile application appeals to both campus staff and students as well as residents of the neighborhood.

Table 2. The comparison of obtained meteorological data with Turkish State Meteorological Service

Date	Temperature (°C)		Weather Condition		Rain Rate (mm)		Humidity (%)		Wind Speed (km/h)		Atmospheric Pressure (hPa)	
	TSMS	Ours	TSMS	Ours	TSMS	Ours	TSMS	Ours	TSMS	Ours	TSMS	Ours
29.12.2021	0.1	3.7	Foggy	Cloudly	0.0	0.0	98	79	7	9.7	1014.2	1020.8
30.12.2021	5.1	5.3	Cloudly	Cloudly	0.0	0.0	79	80	7	16.1	1013.6	1020.0
31.12.2021	4.4	6.9	Cloudly	Cloudly	0.0	0.0	81	76	9	0.0	1019.1	1025.2
1.01.2022	2.5	5.3	Cloudly	Cloudly	0.0	0.0	90	82	4	0.0	1017.2	1023.8
2.01.2022	7	6.1	Cloudly	Cloudly	0.0	0.0	69	72	28	27.4	1019.6	1025.6
3.01.2022	3.1	2.6	Partly Cloudy	Cloudly	0.0	0.0	66	73	7	0.0	1018.8	1026.5
5.01.2022	12.8	11.6	Clear	Clear	0.0	0.0	55	49	15	14.5	1017.5	1024.2
7.01.2022	12.1	10.8	Partly cloudy	Cloudly	0.0	0.0	57	61	6	9.7	1018.2	1022.7
8.01.2022	12.2	10.1	Cloudly	Cloudly	0.0	0.0	48	51	26	22.5	1015.2	1020.1
9.01.2022	12	10.3	Partly Cloudy	Partly Cloudy	0.0	0.0	47	46	22	25.7	1007.7	1012.8
10.01.2022	8.9	7.9	Cloudly	Cloudly	0.0	0.0	59	57	13	16.1	1005.1	1011.2
11.01.2022	7.5	5.9	Rain Showers	Rain	0.0	0.0	80	73	22	19.3	1011	1016.9
12.01.2022	5.9	4.2	Cloudly	Cloudly	0.0	0.0	78	78	9	11.3	1011	1017.5

Table 3. The comparison of standard deviations and RMSEs

Value	Standard Deviation of TSMS	Standard Deviation of Ours	RMSE of Normalized Difference
Temperature	4.18	2.93	0.744942938
Humidity	16.06	12.88	0.43735977
Wind Speed	8.3	9.36	0.578276095
Atmospheric Pressure	4.62	4.85	0.565961571

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APPENDIX A: Graphical Comparisons

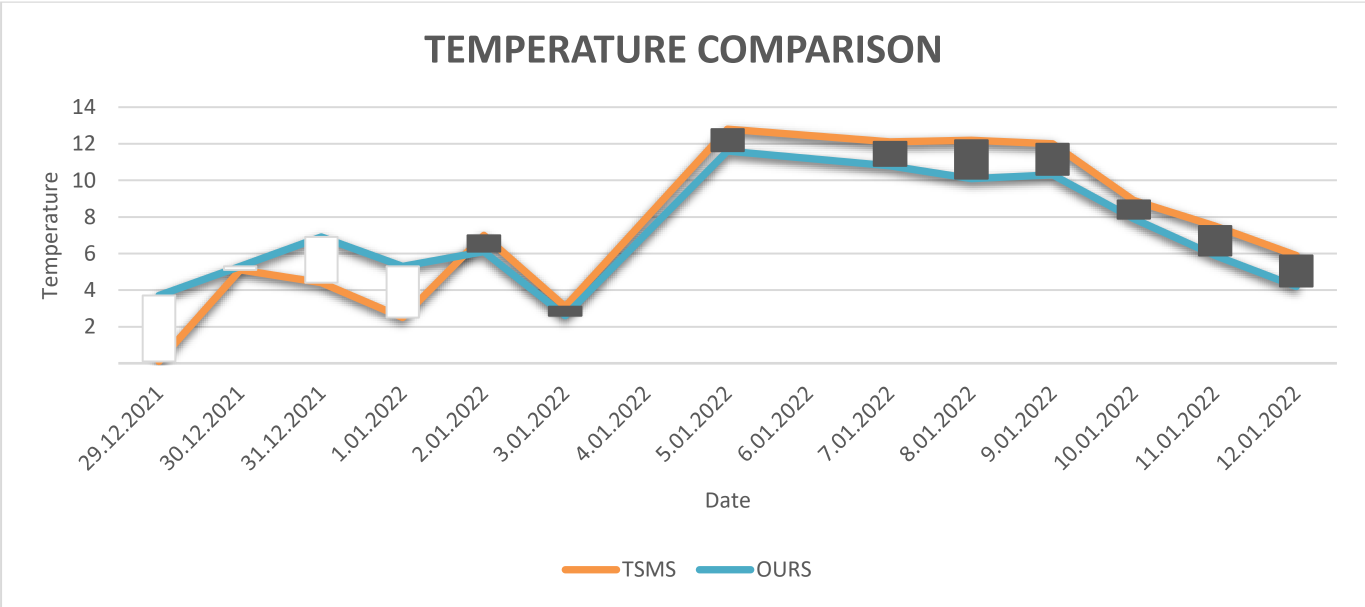

Figure 16. Temperature Comparison

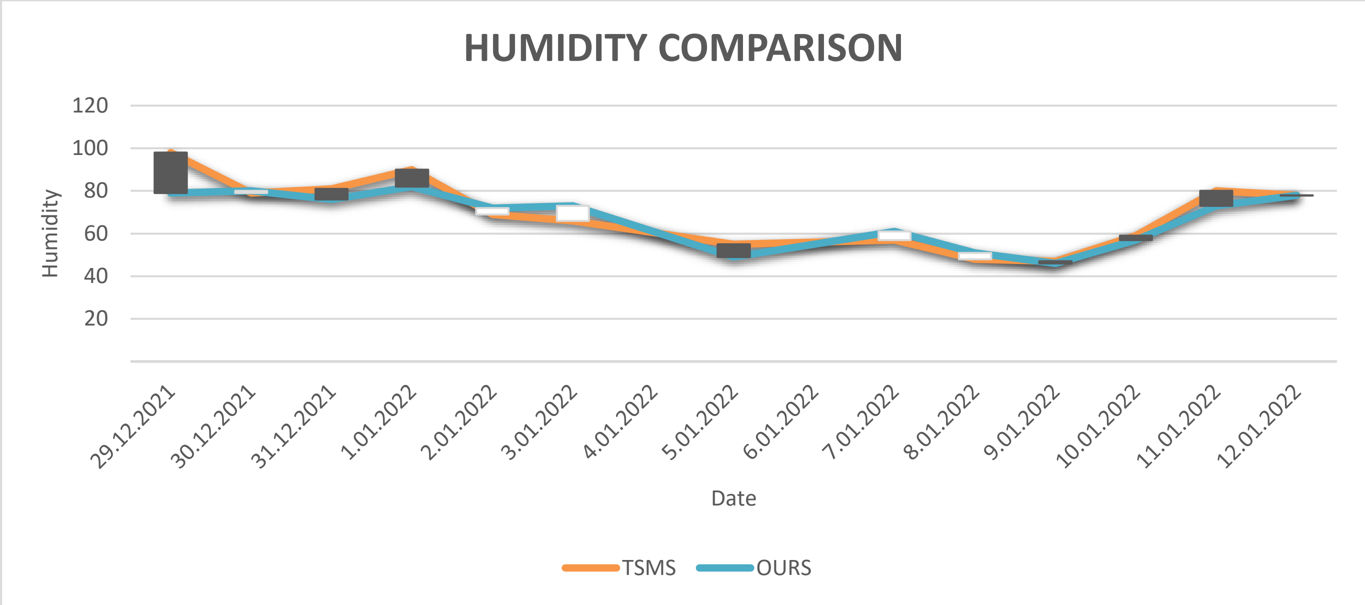

Figure 17. Humidity Comparison

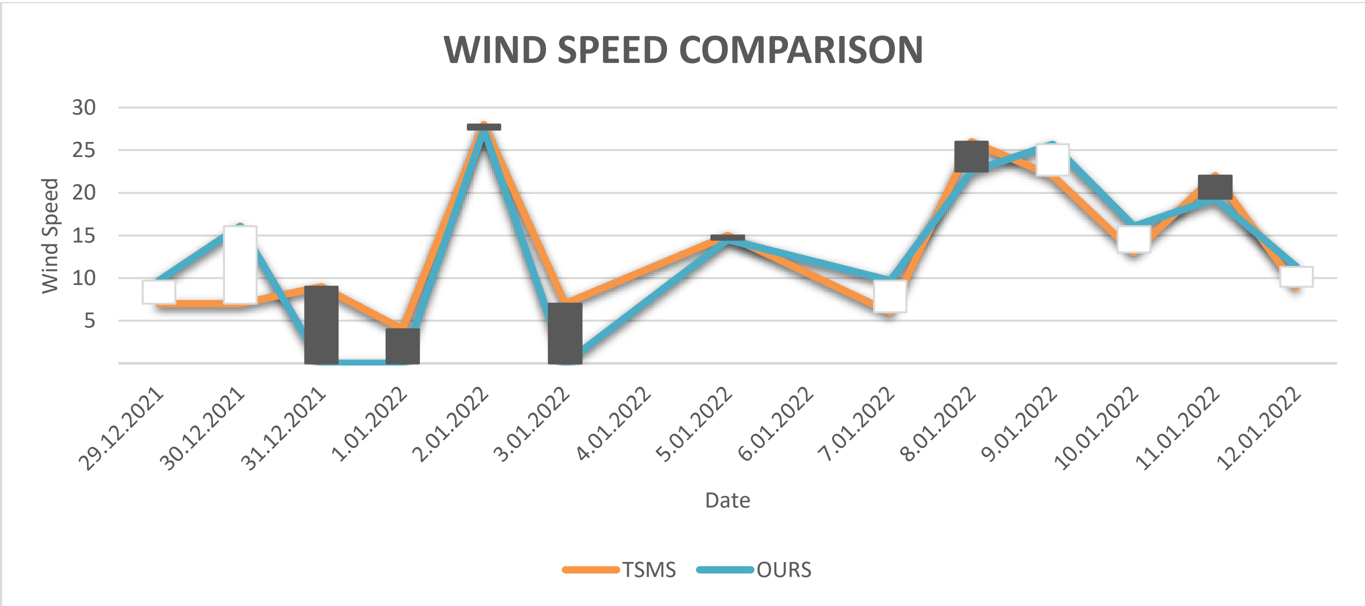

Figure 18. Wind Speed Comparison

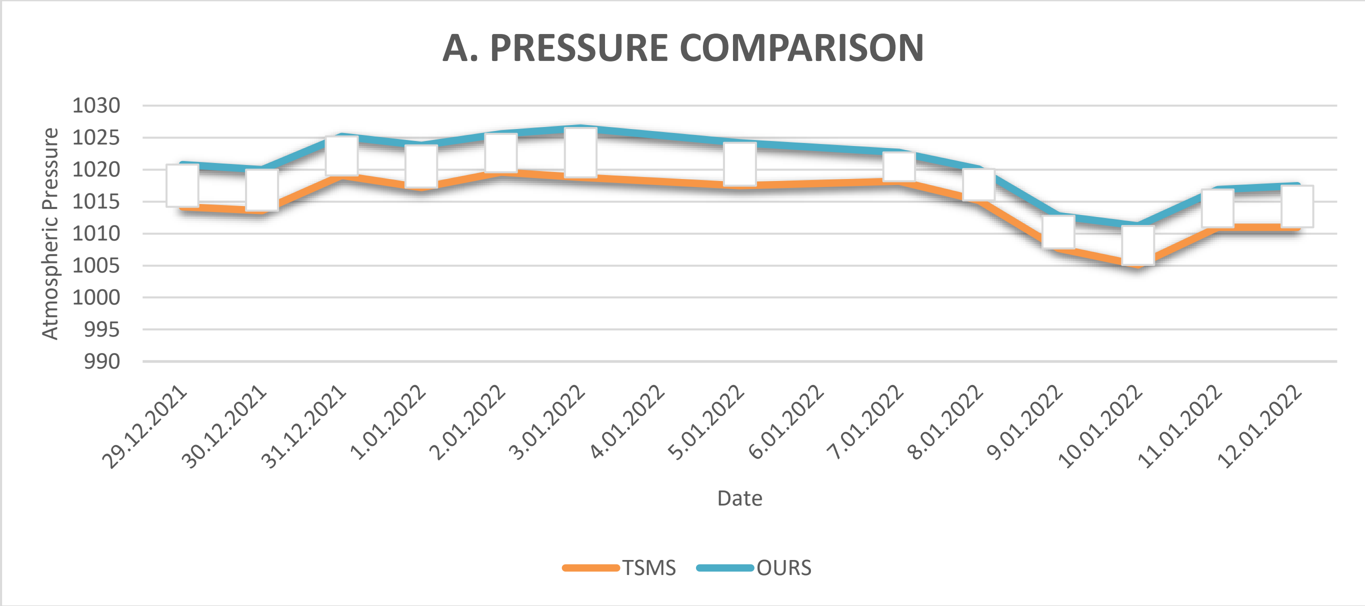

Figure 19. Atmospheric Pressure Comparison