Air quality meteorological and environmental information system in Western Macedonia, Hellas

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Abstract: This paper aims to present the development of an operational, monitoring, as well as high-resolution local-scale meteorological and air quality forecasting information system for West Macedonia region, Hellas, in a dynamic, easily accessible and user-friendly way. The system, having been operated by the Laboratory of Atmospheric Pollution and Environmental Physics since 2002, has been in a continuous process of improvement. It consists of a structured system fully accessible and manipulable by users, as well as a system for accessing and managing measurement results in a direct and dynamic way. Thus, updates of the weather and air pollution forecast for the West Macedonia region are provided for the next seven days based on current day information. The forecasts are displayed through dynamic-interactive web charts, whereas there is also a visual illustration of the atmospheric pollution of the region in a map, using images and animation images. The application has been developed using state of the art web technologies (Ajax, Google Maps, etc.) and under an open-source software philosophy, allowing users to update the code according to their needs.

Keywords: air quality information system; environmental data; dissemination practices; web-based applications; open-source software; Hellas.

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1 Introduction

Web applications constitute valuable up-to-date tools in a number of different cases. A typical case is their use in managing environmental problems with an aim to protect people from any unfortunate consequences, these problems can cause. Their development is therefore of particular interest in many cases, such as the development of integrated air quality (AQ) management systems (Triantafyllou et al., 2004). At European level, the right of access to environmental information has been enacted through appropriate legislation, incorporated into the relevant Greek legislation as well [Council Directive 90/313/EC, Council4 (1996) – Council Directive 96/62/EC, Council5 (1998)]. Nowadays, the combination of telecommunications and new technologies has created a framework for such systems development that are increasingly sophisticated (Karatzas and Kukkonen, 2009). The EAP system, acronym of the Atmospheric Pollution Laboratory in Greek (Schimak, 2003) (Ergastirio Atmspospherikis Ripansis), but also corresponding to the ancient Greek word 'EAP' meaning 'Spring' , was first developed in West Macedonia in 2002 in an attempt to diffuse environmental information about AQ by providing access to the public (http://www.airlab.edu.gr, 2018). For this reason four atmospheric measurement stations were installed in the four West Macedonia region prefectures capitals, i.e., Kozani, Florina, Kastoria, and Grevena. AQ was recorded through an appropriate website, with the ability to provide measurement history, as well as the extension of stations (Triantafyllou et al., 2006). For every station, a previous and current index of pollution appeared, in a scale of 1–10, with an appropriate colour scale (Triantafyllou et al., 2004). The system was expanded and upgraded in May 2010, regarding data transfer, the way of presentation, as well as the amount of information provided. Specifically, it was recommended:

a the combined use of different methods to transmit terminal stations measurement data to a central base station in real or almost real-time

b the promotion of environmental information to the internet, with a properly designed dynamic website providing navigation in the Google Maps application (Triantafyllou et al., 2011a; Skordas et al., 2017; http://www.airlab.edu.gr, 2018).

In this paper, there is an update of the EAP system, developed as more dynamic, easily accessible, user-friendly and under an open-source software philosophy. The application consists of a structured information system fully accessible and manipulable by users, as well as a system for accessing and managing measurement results in a direct and dynamic way. Weather and air pollution forecast updates for the West Macedonia region, are provided for the next seven days based on current day information. The forecasts are displayed through dynamic-interactive web charts, whereas there is also a visual illustration of the atmospheric pollution of the region in a map using images and animation images. There is also an option to view history, while a new function has been added regarding the use of online reports for monitoring, analysing, controlling and processing measurements, historical data, and statistics of each station in real-time over the internet. Finally, the administrator can use the measurement stations management system in order to dynamically create, modify and delete objects, points and information of each station on the Google Maps. In this way, the points processing (updating, deleting, adding) becomes easier. The proposed AQ measurement information system application has been developed using open-source software tools such as HTML, JavaScript, PHP, and MySQL. HTML is the language for the internet interface design. HTML can create a platform-independent language for constructing hypertext documents to communicate multimedia information easily over the internet (Duckett, 2008). Javascript is a client-side scripting language providing powerful extensions to the HTML used to compose web pages. It is mainly used for checking and validating web form input values to make sure no invalid data are submitted to the server (http://www.w3schools.com/js, 2018). PHP is the most popular server-side programming language for use on web servers. Any PHP code in a requested file is executed by the PHP runtime, usually to create dynamic web page content. It can also be used for command-line scripting and client-side GUI applications. PHP is a cross-platform programming language and can be used with many relational database management systems (RDBMS) (Atkinson and Suraski, 2004). MySQL is a high-performance, multithread, multi-user RDBMS built around a client-server architecture. Also, MySQL uses the structured query language standard giving a great deal of control over this relational database system (Vaswani, 2004). Finally, the Apache server is responsible for expecting requests from various programs – users and then serving the pages, according to the standards set by the protocol hypertext transfer protocol (HTTP) (Laurie and Laurie, 2003). There has been a growing interest over the past decade in open-source software applications in several areas of technology, such as e-learning, distance learning, web applications, internet of things, etc. (Lazaridis et al., 2016; Skordas et al., 2017; Fragulis et al., 2018).

2 Characteristics of the proposed web platform

2.1 Advantages of using web technologies in the AQ measurement and information system

The proposed web-based environmental application is accessible anytime, anywhere and through any personal computer or smart phone/tablet with an internet connection. Therefore, the user could retrieve the needed information from the online platform easily and quickly (Mendes, 2014; Shaffi and Al-Obaidy, 2013). The user interface of web-based applications is easier to customise than in the case of other types of applications. Therefore, the administrator could update the application GUI, or could customise the presentation of information to different user groups (Caudill, 2007). Moreover, the administrator can achieve a greater level of interoperability between web applications. For example, it is easier to integrate a web-based meteorological system with a web-based AQ package than to get two proprietary systems to communicate with each other (Chung et al., 2003). Installation and maintenance become less complicated too. Once a new version or upgrade is installed on the host server, all users can access it immediately. In addition, as the upgrades are performed by an experienced administrator the results are rather reliable. Finally, if an application requires more power to perform tasks, only the server hardware needs to be upgraded (Murugesan and Deshpande, 2016).

2.2 Analysis of various issues during the development phase

The n-tier architecture was selected for system design (Manuel and AlGhamdi, 2003), whereas the system development was based on the WebML methodology (Ceri et al., 2000, 2002; Granada et al., 2017). Specifically, in the requirements analysis, a group of users was formed to interact with the application. In the next phase, we have developed the basic functions the application is expected to provide to users. Finally, a different front-end was created for each user group, to test the functions available to the user needs and then the application entities were designed and developed accordingly. In order to evaluate the usability, functionality, and effectiveness of the web application, the following steps were performed:

- First, the application was uploaded to a web server and the test data was imported. Secondly, we tested the application speed/response. The results were very satisfactory, as the application worked rather fast.
- Next, we created an account for every user type (simple users/authorised users). We tested the application with a number of users from different backgrounds (system developers, computer analysts, environmental researchers, environmental engineering students, and finally a group of newspaper/web-journalists), trying to have a representative sample of citizens with differences in age, level of education, occupation and concerns about the daily problems of the urban environment.

- The users' test results (feedback) were taken into account and helped us improve several parts of the application.
- Specifically, during the alpha and beta test, users pointed out that the functionality of the site, such as Google Maps, charts, and animation images should be improved.
- When the final version of the web system was developed, most test users were satisfied with the changes of the front-end of the application, as well as the variety of information provided through maps and charts or tables.
- More than 75% of participants stated that the most favourite categories of the information presented were the weather forecast, air pollution and air pollution indices using dynamic Google Maps presentations/images/animation images and news.
- It should be noted that we chose to provide test users with little or no information about the application in order to test, whether it is functional and easy to use. The comments, we received, were quite satisfactory and encouraging. The majority of comments were positive, and test-users considered the application easy to handle and use.

2.3 Community implications

It is generally accepted that well informed communities on environmental issues are aware of the negative effects environmental pollution might have on their health and can support plans for the protection of the environment. AQ is among the most significant and thoroughly studied environmental quality concepts. People, especially if they belong to the so-called high-risk population groups, are willing to be aware of the possible effects of atmospheric pollution on their health (Karatzas and Kukkonen, 2009; Bosh et al., 2006). At European level, the right to gain access to environmental information has also been institutionalised through appropriate legislation. Focusing on the atmosphere, constant and immediate citizens' awareness of AQ is one of the cornerstones of modern European environmental legal framework and is clearly reflected in relevant legislative directives (Directive 1996/62/EC, 1996; Directive 2003/4/EC, 2003; Directive 2008/50/EC, 2008). There are several institutes and organisations, i.e., national environmental agencies, ministries or national, regional, local authorities, universities, research centres that are responsible for operating AQ monitoring networks, analysing pollutant concentrations data and providing AQ assessments at national level. They inform the community on current, as well as on forecast AQ situation and take measures in case there is an excess in AQ standards (http://www.epa.gov, 2019; https://uk-air.defra.gov.uk, 2019; https://airnow.gov, 2019; Duyzer et al., 2015).

2.4 Benefits of the proposed system

The main benefit of the system, when compared to other platforms, is the setup of a fully operating environmental information system with the following capabilities:

- Easy access to environmental and related pollution data at different levels of information.

- Improved near real-time environment monitoring.
- Presentation of near-real-time environmental parameters that allow prefecture/municipality managers to decide, whether there is a state of emergency in the event of an air pollution incident.
- Enhanced visualisation, using static or near-real-time information
- Access to AQ information in areas throughout North Greece (Central, West, East Macedonia and Thrace), where the public does not currently have this opportunity.
- The data-sharing capabilities the system provides can be of tremendous use to the AQ research community in Greece, as well as in European countries. As scientists from different countries begin to share AQ information, new discoveries can be made about the behaviour and causes of regional air pollution.
- After setting up and agreeing-upon data sharing standards, the system could interface with existing systems, while allowing for AQ data sharing worldwide. This worldwide availability of data will no doubt benefit AQ research, as well as giving public access to an important health resource. Thus, information will not only be used for further research, but more importantly, for public health protection. (https://airnow.gov, 2019).

2.5 Limitations

The limitations of our proposed system are similar to those of any other air pollution information platform. More particularly, air pollution forecasts are inherently uncertain and their accuracy is not guaranteed. In addition, air pollution is not the only cause of health problems. Local authorities accept no liability, either for public health, or any action taken by citizens based on forecasts and alerts, as well as the consequences of their actions. The AQMEIS air pollution forecasts and health advice are clearly indicative.

2.6 Novelties

The development and implementation of such a forecasting system in operational mode is in many cases a site-specific problem, especially in areas with uneven ground. In the case of West Macedonia Hellas, the operation of lignite power plants and open lignite mines, has local environmental impacts. The area, where the above mentioned industrial activities take place, is a broad, relatively flat-bottom basin surrounded by tall mountains with heights ranging from 800 to more than 2,000 m above mean sea level (MSL). The ground unevenness, as well as the variety of different pollution sources, including urban and industrial ones, render the development and operational implementation of such a forecasting system for the specific area of special scientific interest.

The system consists of three levels.

- First level-data collection: For each station, there is a special software for automatic data storage from a database sensor on a PC. An automated check is performed before the values are stored in the database (gaps, recursive values). The physical connection between the sensor and the computer is the RS-232 and IP connection.

The administrator can easily specify the time base measurement (five minutes average, hourly average) of the sensor.

- Second-level data transfer: Data are transferred from each station to the central base station. Each station database communicates directly with the central database. Various methods are used to connect the terminals to the central base station, based on the characteristics and specificities of each terminal. The system supports various methods of communication, such as local area network (LAN), internet, and GPRS. GPRS-VPN communication, i.e., tunnelling method, IPsec and GRE protocols, are used at some stations, due to their geographical location. Specifically, each station is connected to a GPRS Cisco router, and data transmission is performed wirelessly to the host via APN. Data is collected at the central station, where it is processed and stored, while the desired information is created, i.e., colour scale, measurements, environmental indicators, etc. as well. Finally the XML files are generated.
- Third level-web development software: All modules of the dynamic web software, i.e., online web station reports, dynamic web charts, atmospheric pollution forecast, stations management using Google Maps, were created from scratch. The tools used are HTML, PHP, JavaScript, and Flash. A back-end application was created for managing stations and Google Maps API. The system has no limitation on the number of interconnected regional stations.

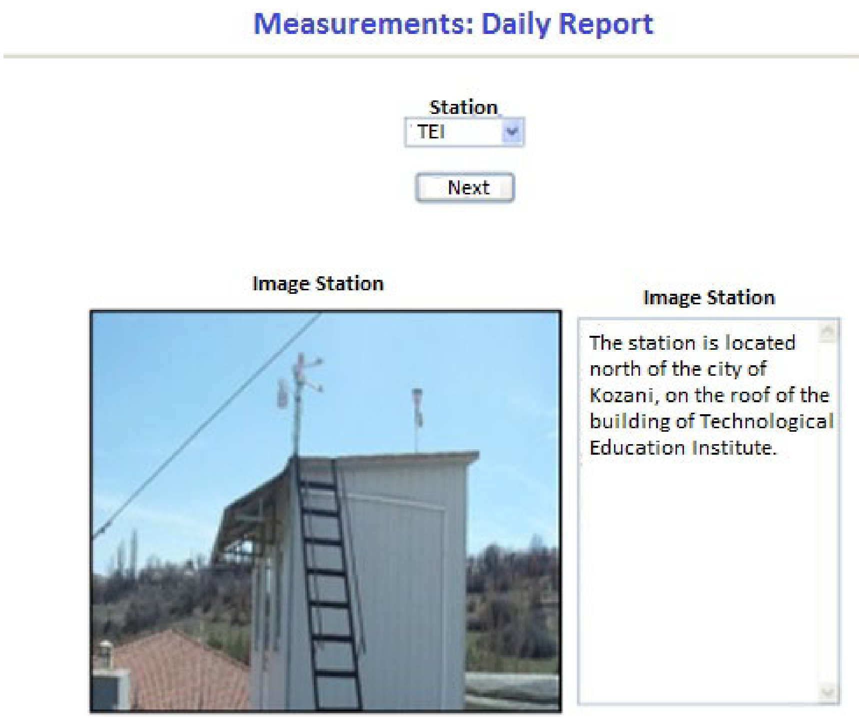
3 User interface

In this section, the user interface and the application functions are described. There are three levels of user access (groups of users). At first level, the user has the ability to be informed in real-time about weather conditions, air pollution and air pollution indices in an area of interest using Google Maps. The second level is for authorised users only, who can be analytically informed through reports about measurements of a specific time period. The third level is for the administrator, who has access to all information and also inserts, updates or deletes data from the database. The administrator can also dynamically interfere or interface and manage all the information on the Google Maps.

3.1 Online web station reports

The 'online web station reports' is a new online web feature that allows approved application members to monitor, analyse, check and process measurements, using the statistics of each station in real-time. Furthermore, the ability of pumping previous measurements is given; a function that did not exist in the web application until a short time ago. The login is achieved through a special personal password given to the members by the web application support team. The users input the password and after validation, they can perform a number of available functions in a secure and user-friendly online web environment. More specifically the feature offers the following functions to its members: presentation of daily, weekly and monthly values, according to the user's choice, either for a selected station all measured data, or for specifically selected measured parameters (sensors), with simultaneous calculation and presentation of maximum, minimum, average values, sum, number and percentage of measurements in a table or the ability to output data in MS Excel. The functions of the new web features are described in detail. There are four categories of online web station reports, i.e., daily, weekly, monthly and periodic. Each report is displayed in three parts (forms). In the first form, by selecting a station, the image is displayed, as well as various information about the specific station (Figure 1).

Figure 1 Station image (see online version for colours)



Notes: Station located on the University of Western Macedonia building roof, North of Kozani. Daily report management.

If the user does not choose a station, an error report appears. By clicking on 'next', the second form of the report appears in which the user can choose which measurement fields to be shown, as well as the measured time interval (5 min or 60 min) and the specific date, those measurements were taken (Figure 2).

The dates differentiate according to the report category the user will choose; more specifically, there are:

a Daily report: The current date appears.

b Weekly: The first day of the current week is set, as the starting date.

c Monthly: The first day of the current month is set, as the starting date.

d Periodic: The current dates are set as dates (from–to) with the ability by the user to change spaces (from–to).

If the user does not choose any measurement fields or chooses a date on which there are no figures reported, then the system will display an error message. By clicking on 'report' the algorithm moves to the last tab of the report, where a table of contents appears in a dynamic way with information about the hour, the measurement fields, measurement results, as well as other statistical data (Figure 3).

Figure 2 Selecting a day for measurement report (see online version for colours)

Also, the algorithm calculates and displays the number of measurements (e.g., ‘100 measurements found’), the current page and the total number of pages (e.g., ‘page 1 from 12’). Depending on the number of records, an equal number of pages is created. The application can display 25 measurements per page. Also, the users can move to any page they wish, in order to access any measurement of interest. Every form of measurement also has a status field (numbers 0, 1 or 2). This table is used to check the validity of a field measurement. In this way, if there are no results for a specific date in one field, then the indication ‘NODATA’ is displayed. All checks are made based on the status field. If, however, the measurements in a field are incorrect for a specific date, due to various factors, then the ‘off scan’ indication is displayed. Similarly, checks rely on field status. For every field measurement at a particular moment, the following statistics are taken into account:

a average value

b minimum value

c date and time the minimum value was found

d the number of records of the minimum value

e maximum value

g date and time of record of maximum value

h total number of measurements

i percentage per 100.

By pressing 'Excel' the station measurements can be displayed on an Excel form, which the user is able to open at once or save for later use (Figure 4).

3.2 Stations management using Google Maps

The dynamic management of each station measurements in a simple way, i.e., using an online geographical web interface, constitutes another innovation of the web application. The administrator, using this specific feature, i.e., management of the Measurement Stations using Google Maps, can insert, delete and modify data easily and simply aiming at a dynamic update on the Google Maps application.

Figure 3 Statistical data report (see online version for colours)

found 288 Measurements (Page 1 of 32)

1 2 3 4 5 6 > >>

	DATE	PM10	TOUT	SR	PRES	RH	WD	WS	TEST	UVB	MASS2	TIN	PM10E
1	00:05	OffScan	2	0	952	86	182	2	OffScan	OffScan	NoData	17	NoData
2	00:10	OffScan	2	0	952	86	182	2	OffScan	OffScan	NoData	17	NoData
3	00:15	OffScan	2	0	952	86	191	2	OffScan	OffScan	NoData	17	NoData
4	00:20	OffScan	2	0	952	86	179	2	OffScan	OffScan	NoData	17	NoData
5	00:25	OffScan	2	0	952	87	183	2	OffScan	OffScan	NoData	17	NoData
6	00:30	OffScan	2	0	952	87	180	2	OffScan	OffScan	NoData	17	NoData
7	00:35	OffScan	2	0	952	87	187	2	OffScan	OffScan	NoData	17	NoData
8	00:40	OffScan	2	0	952	87	195	2	OffScan	OffScan	NoData	17	NoData
9	00:45	OffScan	2	0	952	87	189	2	OffScan	OffScan	NoData	17	NoData
10	00:50	OffScan	2	0	952	87	192	2	OffScan	OffScan	NoData	17	NoData
11	00:55	OffScan	2	0	952	88	198	2	OffScan	OffScan	NoData	17	NoData
12	01:00	OffScan	2	0	952	87	200	1	OffScan	OffScan	NoData	17	NoData
13	01:05	OffScan	2	0	952	88	197	2	OffScan	OffScan	NoData	17	NoData
14	01:10	OffScan	2	0	952	88	198	2	OffScan	OffScan	NoData	17	NoData
		PM10	TOUT	SR	PRES	RH	WD	WS	TEST	UVB	MASS2	TIN	PM10E
1	AVG	*	1	25	951	91	202	1	*	*	*	17	*
2	Min	*	-30	0	912	0	0	0	*	*	*	15	*
3	Date	*	19:55	00:05	19:55	19:55	19:55	02:25	*	*	*	20:10	*
4	Num	*	239	1	239	239	239	29	*	*	*	242	*
5	Max	*	4	263	952	100	248	3	*	*	*	18	*
6	Time	*	13:00	12:15	00:05	20:30	11:00	06:00	*	*	*	13:10	*
7	Num	*	156	147	1	246	132	72	*	*	*	158	*
8	Data	*	288	288	288	288	288	288	*	*	*	288	*
9	Data[%]	*	100.00	100.00	100.00	100.00	100.00	100.00	*	*	*	100.00	*

Thus, the administrator can use the specific feature as a platform to visualise information without having to write even a code line. Moreover, an important element of the feature is the easy expansion and integration N (N = count) of the stations measurements on the interactive Google Maps. Station management is made through the interactive Google Maps interface; the application administrator can insert, delete and modify dynamically a certain point, i.e., station in an area, according to geographical latitude and longitude. To insert a specific station in the map, the following actions are required:

a the insertion of the chosen municipality: the user chooses from a list the one the station belongs to

b the insertion of the type of station measurement, i.e., meteorological, measuring pollution, both.

All the data is stored in the MySQL database application. Then, the administrator sets the name of the station, the latitude and longitude, municipality, address, description, type of station and the image of the station (Figure 5). Finally, all information is stored in the database and can be retrieved and displayed dynamically, both points and information, on Google Maps.

Figure 4 Data of a chosen measurement station (see online version for colours)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	**Station:**	TEI												
2	**Date:**	6/27/2016												
3	**Report Type:**	Mean												
4	**Time Base:**	5 Min												
5														
6														
7	**Date**	**Time**	**PM10**	**Tout**	**SR**	**Pres**	**RH**	**WD**	**WS**	**Test**	**UVB**	**mass2**	**Tin**	**PM10_E**
8			ug/m3	oC	w/m2	mbar	%	deg	m/s	m/s	w/m2	ug	oC	ug/m3
9	6/27/2016	00:05	NoData	16,2	0	950	85	73	0,1	OffScan	OffScan	NoData	14	NoData
10	6/27/2016	00:10	NoData	16,2	0	950	85	76	0,6	OffScan	OffScan	NoData	14	NoData
11	6/27/2016	00:15	NoData	16,3	0	950	84	84	1,4	OffScan	OffScan	NoData	14	NoData
12	6/27/2016	00:20	NoData	16,2	0	950	84	84	0,6	OffScan	OffScan	NoData	14	NoData
13	6/27/2016	00:25	NoData	16,3	0	950	83	84	1,1	OffScan	OffScan	NoData	14	NoData
14	6/27/2016	00:30	NoData	16,7	0	950	81	84	0,9	OffScan	OffScan	NoData	14	NoData
15	6/27/2016	00:35	NoData	16,6	0	950	80	83	1	OffScan	OffScan	NoData	14	NoData
16	6/27/2016	00:40	NoData	16,5	0	950	81	82	0,6	OffScan	OffScan	NoData	14	NoData
17	6/27/2016	00:45	NoData	16,3	0	950	82	82	0,4	OffScan	OffScan	NoData	14	NoData
18	6/27/2016	00:50	NoData	16	0	950	84	83	1	OffScan	OffScan	NoData	14	NoData
19	6/27/2016	00:55	NoData	16,1	0	950	83	83	1	OffScan	OffScan	NoData	14	NoData
20	6/27/2016	01:00	NoData	16,3	0	950	82	83	0,6	OffScan	OffScan	NoData	14	NoData
21	6/27/2016	01:05	NoData	16,3	0	950	82	83	0,8	OffScan	OffScan	NoData	14	NoData
22	6/27/2016	01:10	NoData	16,4	0	950	82	83	1,1	OffScan	OffScan	NoData	14	NoData
23	6/27/2016	01:15	NoData	16,5	0	950	81	83	0,9	OffScan	OffScan	NoData	14	NoData
24	6/27/2016	01:20	NoData	16,5	0	950	82	82	0,7	OffScan	OffScan	NoData	14	NoData
25	6/27/2016	01:25	NoData	16,3	0	950	83	81	0,2	OffScan	OffScan	NoData	14	NoData
26	6/27/2016	01:30	NoData	16,1	0	950	84	81	0,1	OffScan	OffScan	NoData	14	NoData
27	6/27/2016	01:35	NoData	16	0	950	85	83	0,4	OffScan	OffScan	NoData	14	NoData
28	6/27/2016	01:40	NoData	16	0	950	85	84	1,4	OffScan	OffScan	NoData	14	NoData
29	6/27/2016	01:45	NoData	16,1	0	950	84	84	1,6	OffScan	OffScan	NoData	14	NoData
30	6/27/2016	01:50	NoData	16,1	0	950	84	83	1,4	OffScan	OffScan	NoData	14	NoData
31	6/27/2016	01:55	NoData	16	0	950	84	84	1,2	OffScan	OffScan	NoData	14	NoData
32	6/27/2016	02:00	NoData	16,2	0	950	82	84	1	OffScan	OffScan	NoData	14	NoData
33	6/27/2016	02:05	NoData	16,5	0	950	79	84	0,9	OffScan	OffScan	NoData	14	NoData
34	6/27/2016	02:10	NoData	16,7	0	950	78	84	0,1	OffScan	OffScan	NoData	14	NoData
35	6/27/2016	02:15	NoData	16,7	0	950	78	82	0,1	OffScan	OffScan	NoData	14	NoData
36	6/27/2016	02:20	NoData	16,5	0	950	80	81	0,3	OffScan	OffScan	NoData	14	NoData
212	6/27/2016	17:00	NoData	31	457	949	25	323	5,2	OffScan	OffScan	NoData	18	NoData
213	6/27/2016	17:05	NoData	31,1	434	949	25	308	4,2	OffScan	OffScan	NoData	18	NoData
214	6/27/2016	17:10	NoData	31,1	417	949	26	311	3,9	OffScan	OffScan	NoData	18	NoData
215	6/27/2016	17:15	NoData	31,1	402	949	27	339	4	OffScan	OffScan	NoData	18	NoData
216	6/27/2016	17:20	NoData	30,8	381	949	28	329	4,4	OffScan	OffScan	NoData	18	NoData
217	6/27/2016	17:25	NoData	30,7	368	949	29	345	4,1	OffScan	OffScan	NoData	18	NoData
218	6/27/2016	17:30	NoData	30,7	348	949	28	341	3,8	OffScan	OffScan	NoData	18	NoData
219	_													
220	**Min**			15.1	0	949	25	3	0.1				13	
221	**Time**			03:40	00:05	16:30	17:00	14:55	02:30				05:20	
222	**Max**			31.7	993	950	86	357	5.2				18	
223	**Time**			15:45	12:55	07:55	03:45	13:10	17:00				09:10	
224	**AVG**			23.2	435	950	58	119	1.7				16	
225	**Num**		* 0	* 210	* 210	* 210	* 210	* 210	* 210	* 0	* 0	* 0	* 210	* 0
226	**Data[%]**		* 0	* 72.9	* 72.9	* 72.9	* 72.9	* 72.9	* 72.9	* 0	* 0	* 0	* 72.9	* 0

On the map, users can see meteorological information, as well as information about pollution from various stations and areas. For every station, a previous and current pollution index of 1–10 appears with an appropriate corresponding colour scale. By clicking on each point of the station information, i.e., online measurements, previous and current day air pollution indices, general information about the station, is displayed. The user may also activate or deactivate one or more points on the map (Triantafyllou et al., 2011a).

Figure 5 Station management (see online version for colours)

To achieve dynamic updating of the stations measurements on Google Maps, the file airlab_markers.php is employed, catering for the creation and updating of the XML file. More specifically, the application data, i.e., the name and station measurements, their geographical position, general information, as well as a representative photograph of each station and the representation symbol, are retrieved in the XML structure, submitting the appropriate preset SQL query to the database, via the corresponding code of the PHP page. TheXMLfile has an element, i.e., root-top level element, and especially the ‘markers’, while the remaining elements are nested. For the appropriate structure of the XML file, there is an additional code in the airlab_markers.php file. Then, all the necessary data validity checks take place. The algorithm is realised by PHP scripts and the specific feature developed, is supported by Internet Explorer, Firefox, Opera and Google Chrome browsers.

3.3 Forecast

An additional new feature is the weather and air pollution forecast. This module presents the results of a high resolution, local-scale meteorological and AQ forecasting system performed and operated at the Atmospheric Pollution and Environmental Physics Lab, Department of Environmental Engineering, University of West Macedonia, which can be used as a decision support system tool in the industrialised area of West Macedonia in NW Greece. The system combines two prognostic models, i.e., the conformal-cubic atmospheric model and the air pollution model (TAPM). Moreover, one global atmospheric model to produce synopticscale forecasts and one limited area model for local-scale meteorological and air pollution forecasting (Thatcher and Hurley, 2010). An analytical description and evaluation of the system can be found in Triantafyllou et al. (2011b) and Matthaios et al. (2017).

3.3.1 Weather forecast in West Macedonia with dynamic web charts

Weather forecasting through dynamic web charts is another new feature catering for delivering the most reliable, accurate weather information possible. It provides web users with free, real-time and online weather information in the West Macedonia region for the next few days, using state-of-the-art monitoring and forecasting technology (Figure 6).

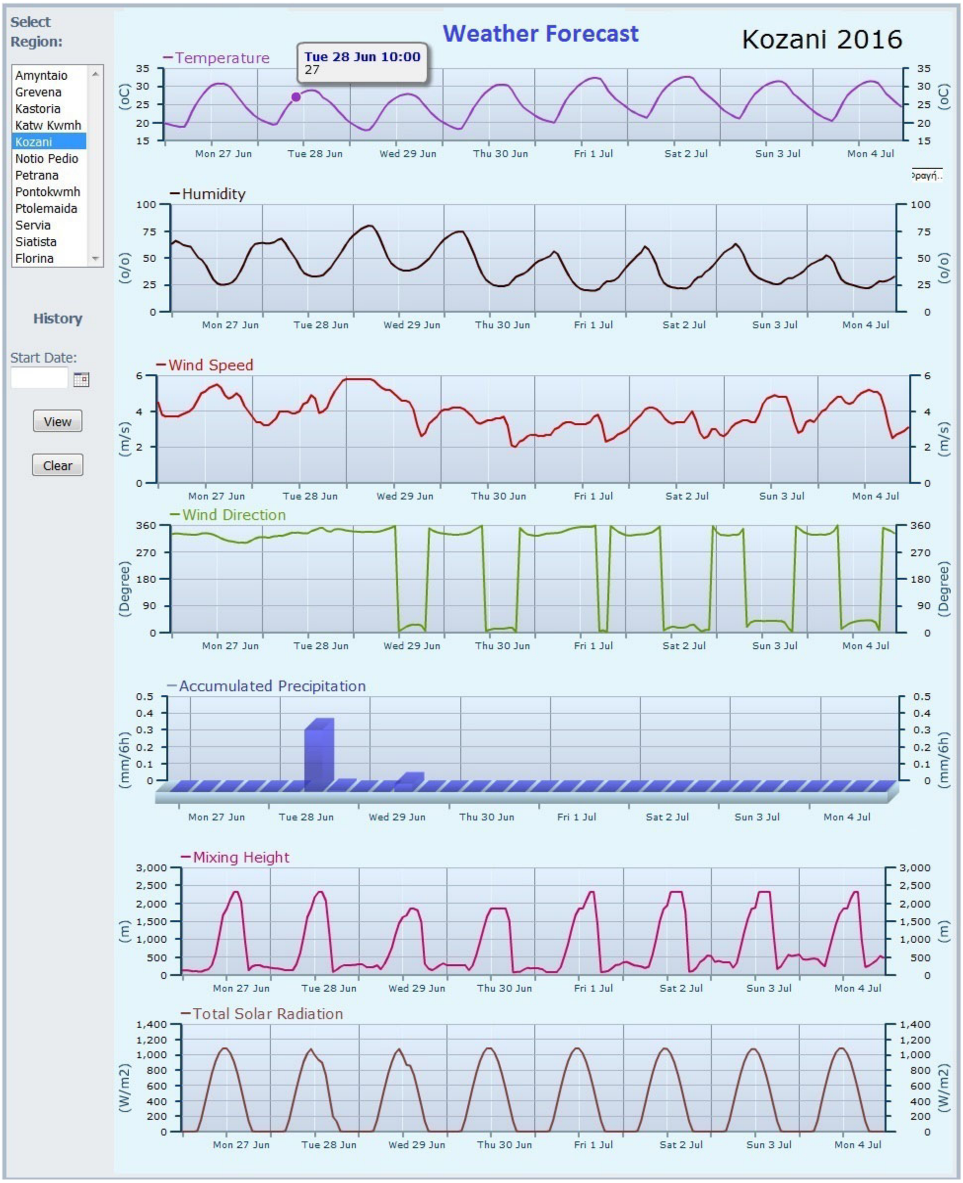
The information is produced on a high-end server (Triantafyllou et al., 2011b) stored in a database and presented to the public in the form of dynamic web graphs (Figure 7).

Meteorological parameters are temperature, humidity, wind speed, wind direction, accumulated precipitation, mixing height and total solar radiation. PHP scripts retrieve from the MySQL database the 24 hour average values for each meteorological parameter (except for the accumulated precipitation, for which a total of six hours is taken into account) at each location in West Macedonia. Next, the information is displayed in a graph. The user can then choose a location to see the weather forecast. By choosing ‘history’, the previous meteorological measurements and figures are displayed in graphs.

3.3.2 Air pollution forecast in West Macedonia

Another important part of the application is atmospheric pollution forecast of the PM10 (particulate matter) over the next few days in West Macedonia (Figure 8). The application dynamically displays these regions in a map using images; according to the pollution percentages in a certain region, the corresponding colour scale is presented denoting the levels of pollution. Choosing ‘region’, ‘pollutant agent’, ‘source of emission’ and ‘date’, pollution percentages for previous and current dates, as well as those for the next three days, are displayed. This part of the application uses JavaScript, while a very small part of the code was written in PHP (date management).

Figure 6 Weather forecast (see online version for colours)



TAPM generates image files (xxx.jpg) in the hard disc of the server in which JavaScript searches and then displays. When not enough environmental data is available for a certain date, an image appears entitled ‘pollution image display unavailable’. The necessary validation integrity checks of the dates are also made (from–to). Finally, choosing ‘history’ the user can see older images of pollution rates in a certain region of West Macedonia. Choosing ‘movement’, a JavaScript algorithm is executed, animating the pollution illustrations in the area of interest (Figure 9).

Figure 7 Flowchart scheme of the application (see online version for colours)

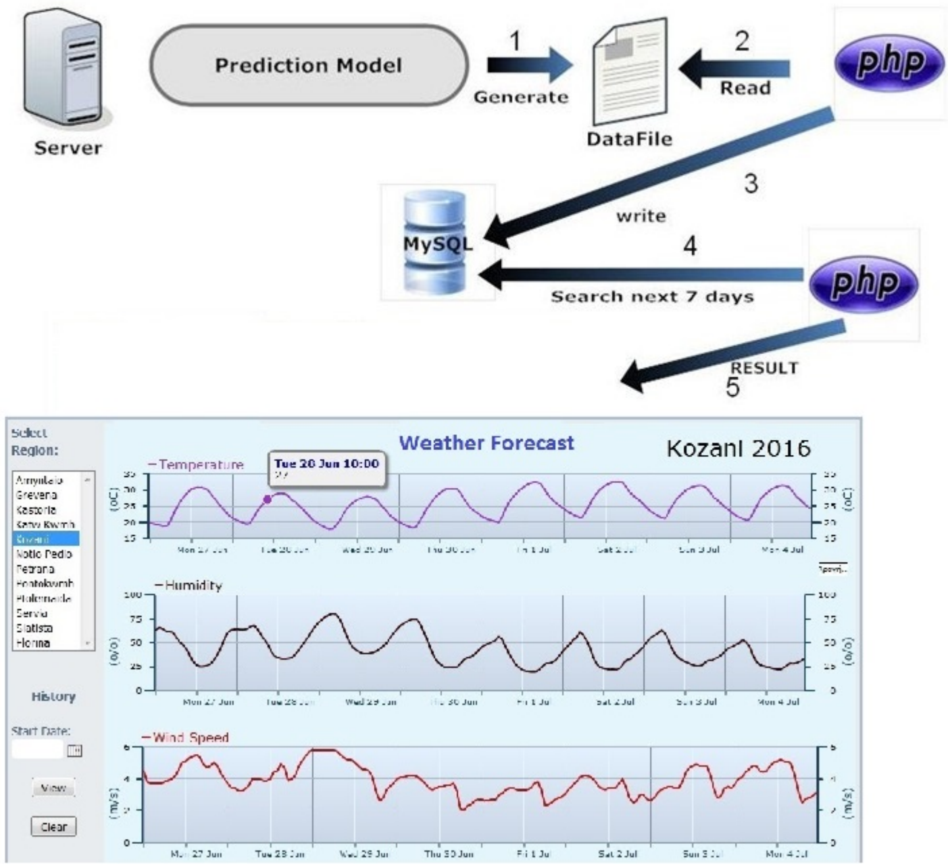


Figure 8 Atmospheric pollution forecast (see online version for colours)

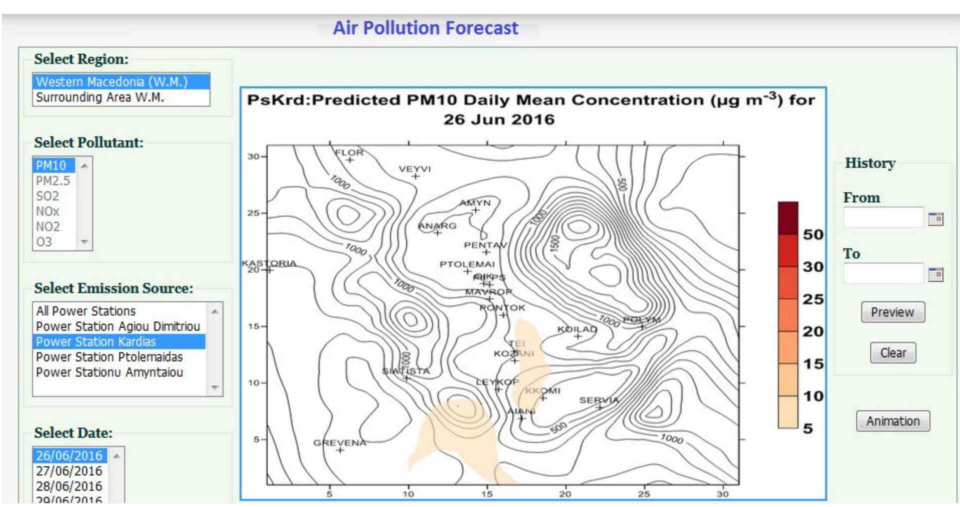


Figure 9 Forecast animated illustration (see online version for colours)

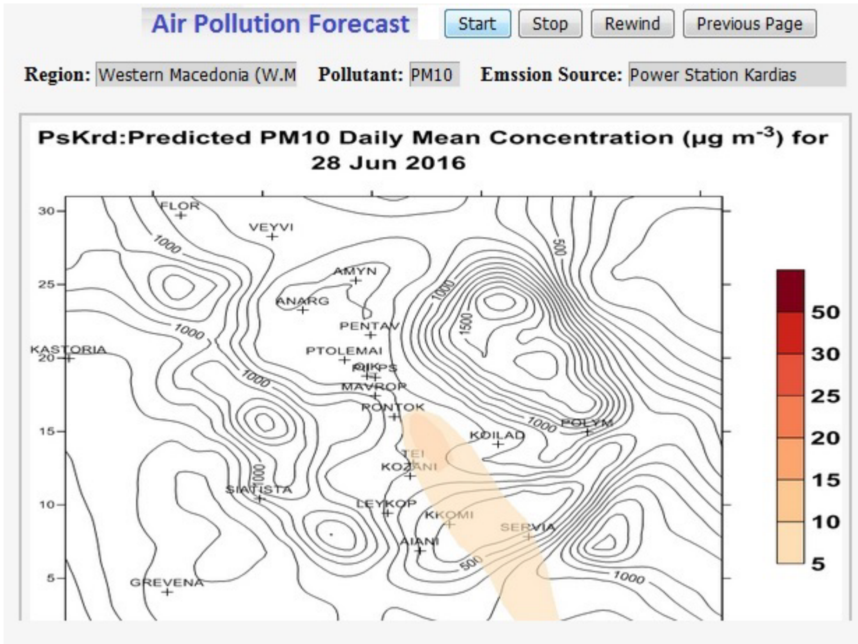
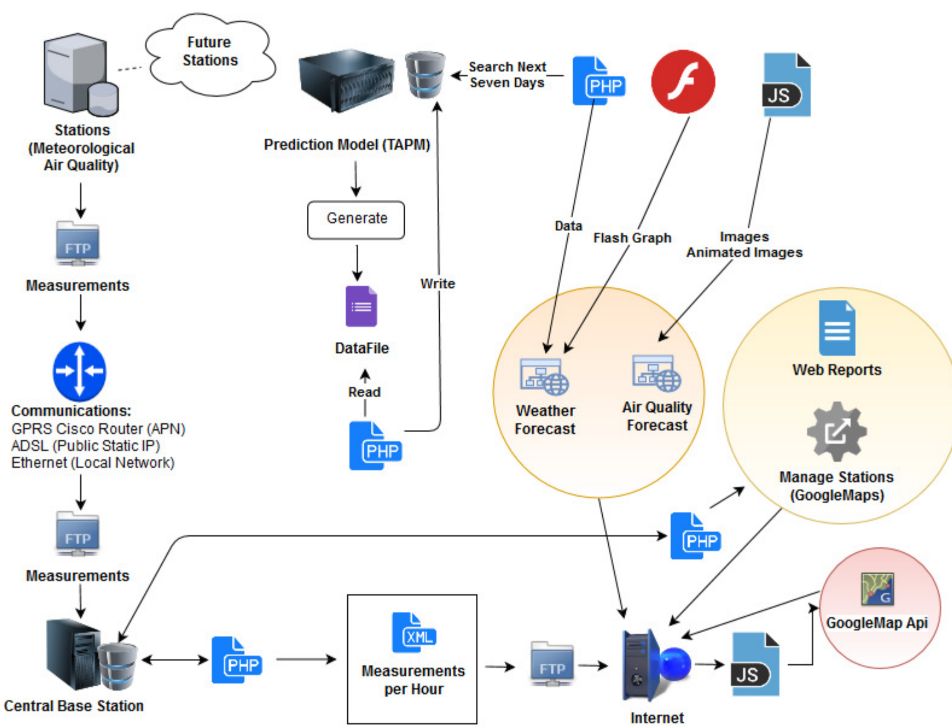


Figure 10 Complete diagram of the system (see online version for colours)



4 Technical information and description of the internal engine of the proposed platform

The complete diagram of the system is shown in Figure 10. It shows the relations between terminal stations and the central base station, different types of network communications based on the features and characteristics of the stations, such as:

- router and static public IP address via internet service provider (ISP)
- GPRS router for data to be sent wirelessly via APN
- LAN usage.

Each station stores measurements from its sensors (atmospheric pollution, meteorological data) in a local database and then the data is sent hourly via FTP to an ASCII file. These data are then analysed and stored in a central database at the main/central station. Then, using an algorithm (written in PHP), an XML file is created with the necessary information, such as measurements, yesterday's/today's environmental indicators (Ott and Thom, 1976; Thom and Ott, 1976). This particular file (XML) is sent via FTP every hour to the web server and a sub module written in JavaScript reads the XML file and links these measurements from the various stations to the Google Map API. Also, two algorithms written in PHP retrieve data from the database in order to manage the measurement stations and their connection to Google Maps (administrator access only), and online web station reports with statistics of each station (normal/authoritative user access). For the meteorological forecast of the next seven days, there is a dedicated server of the EAP – PEF (Triantafyllou et al., 2011b) running TAPM. This system model generates a file every four hours with meteorological forecasts of the coming seven days for the regions of West Macedonia. Then, running an algorithm written in PHP, the values of the file are read and stored in the main database. Another PHP script file is used to visualise the prediction values in a flash graph format at the front-end of the application. With the air pollution forecast over the next three days, TAPM produces and stores images/animated images on the server. This module on the website is only accessible to authorised users.

For database access, MySQL is used because it is a very fast and powerful database management system allowing the user to store, search, sort and recall data efficiently. All information stored in the MySQL database can be retrieved dynamically every time it is needed. The architecture of this database consists of a total of 20 tables. Eight tables are used for measurements collected from the stations; more specifically, in reports and in the dynamic system for air pollution monitoring through an interactive chart. Finally, 12 tables are used for weather forecast information storage. Each table represents a certain location in West Macedonia. The proposed application is part of an AQ monitoring network system for West Macedonia region, with industrial focus on the Ptolemais – Kozani basin region, developed at the Laboratory of Atmospheric Pollution and Environmental Physics of the Technological Education Institute of West Macedonia. The system was co-funded by the TEIWM, the West Macedonia Regional Operational Programme 2000–2006, and by the municipality of Kozani. The architecture of this system consists of four terminal stations, collecting environmental information, a central station, and a web server. Different technologies (ADSL, GPRS, and Ethernet) are used to transfer data to the central station. The data is sent to the main station every half an hour. The complete set of collected data is transmitted to the web server every 60 minutes, where the proposed application provides meteorological, environmental, weather and air pollution forecast data for West Macedonia region.

Table 1 Measurement equipment technical details

Measured magnitudes	*Principle of operation*
Temperature	Platinum resistance thermometer Max. error: 0.25%
Relative humidity	Measuring the relative humidity is based on the fact that hydroscopic materials will change their dimensions depending on the ambient humidity. Accuracy: +2.5%
Wind speed	Cup anemometer. The sensor serves for transmission of electrically measured values of the wind speed. Accuracy: +/–0.5m/s
Wind direction	A wind vane system (sensor) kept parallel to the wind direction though the occurring wind pressure. The position of the direction sensor is transmitted to a ring potentiometer. Initial deflection: 15 deg
Solar radiation	Star-shaped pyranometer, the principle of operation is based on thermoelectric effect.
PM10 (particulate matter which pass through a size – selective inlet with a 50% efficiency cut-off at 10μ aerodynamic diameter)	The particulate monitoring instrument utilise the radiometric principle of beta attenuation by a two – beam compensation method

Further details on the design of the above-mentioned AQ monitoring network can be obtained from Triantafyllou (2004), Triantafyllou et al. (2011a) and Skordas et al. (2011).

5 Discussion

5.1 Similar platforms

There are several institutes, universities, research centres and organisations in charge of operating AQ monitoring networks, managing concentration data and providing AQ assessments. They are also responsible for informing the public of current data, warning about the anticipated air pollution situation, as well as taking further measures in the event of extreme values. There are currently several local, regional and continental scale automatic forecast information systems (AQFIS) worldwide. Some examples are the following:

- The PREVAIR consortium was implemented in France, in 2003 upon an initiative by the Ministry for Ecology, Sustainable Development and Spatial Planning (MEDAD) with the aim of generating and publishing daily AQ forecasts and maps resulting from numerical simulations on different spatial scales. The system also supplies observation maps based on measurements carried out in situ (Menut et al., 2005) (http://www.prevair.org/en/index.html).

- The 'airText' system in England and Wales, is a free service to the public providing AQ alerts by SMS text messages, emails, voicemails and three-day forecasts of AQ, pollen, UV and temperature for Greater London and the South East. The 'airText' is an independent service, operated by Cambridge (Stidworthy et al., 2017) (http://www.airtext.info/).
- The AQ and emergency modelling system SILAM is a global-to-mesoscale dispersion model developed for atmospheric composition, AQ, and emergency decision support applications, as well as for inverse dispersion problem solution (Sofiev et al., 2006) (http://silam.fmi.fi).
- The MM5-CHIMERE AQ forecasting and simulation system is a limited-area, non-hydrostatic, terrain-following, sigma-coordinate model, designed to simulate or predict mesoscale atmospheric circulation (Vautard et al., 2005) (http://www.mmm.ucar.edu/mm5/).
- The European Air Pollution Dispersion model in Germany, EURAD, and EURAD-IM (inverse model) AQ studies are performed and analysed on local, as well as Europe wide scales (Elbern et al., 2007) (http://www.eurad.uni-koeln.de/7224.html?&L=1).
- AirNow is the official AQI site, which protects public health by providing forecast and real-time AQ information across the USA, Canada, and Mexico. The system receives real-time AQ observations from over 2,000 monitoring stations and collects forecasts for more than 300 cities, providing information via the internet and emails. The web services provide
  - a current or historical forecasted AQI values and categories for a reporting area by zip code or latitude and longitude
  - b current or historical PM2.5, ozone, beta version of contour maps in KML
  - c AQI values or data concentrations for a specified date and time range and set of parameters within a geographic area of interest
  - d current AQI values and categories for a reporting area by zip code or latitude and longitude (White, 2010) (https://www.airnow.gov/).
- AQ in Cyprus is monitored and accessed with the assistance of a network of nine fully automatic monitoring stations, located all over Cyprus. The acquired measurement results are presented to the general public online, along with other useful information on AQ issues, through public indoor/outdoor panels and a specially designed web-based AQ information portal. Specifically, the AQI Cyprus website is accessible to the public through a set of web pages such as
  - a daily AQ forecast maps
  - b graphs for domains of interest and prescribed pollutants
  - c information on expected health impacts of the forecasted AQ situation, thus allowing them to manage their activities accordingly (Moussiopoulos et al., 2012) (https://www.airquality.dli.mlsi.gov.cy/).

5.2 Comparison to other platforms

Regarding the similarities, as well as the differences between the above mentioned platforms and the current proposed environmental system, these are:

1 Similarities
   - Built on an open source philosophy.
   - Client-server technology providing information via the internet. The measurement results are presented to the general public online.
   - Forecast and real-time observed AQ information. Current or historical forecasted AQI values. AQI values or data concentrations for a specified date and time range and set of parameters within a geographic area of interest.
   - Daily AQ forecast maps. Three-day AQ forecasts. Graphs for the domains of interest and the prescribed pollutants.

2 Differences
   - The (normal) user has the ability to dynamically view previous measurements in Google Maps, weather and air pollution forecasts, in a friendly and easy way.
   - A number of back-end web applications have been developed, allowing the authorised user to view statistics, process, and store meteorological-AQ measurements for each station and to dynamically manage the measuring stations (create, edit, delete) on the Google Maps.

5.3 New features of the proposed system

Back in 2002, the EAP (acronym of the Greek words Atmospheric Pollution Laboratory) system was developed and applied for the first time in the West Macedonia region by the Atmospheric Pollution and Environmental Physics Laboratory. Through a well designed website it provided direct public awareness on AQ, measured at four stations located in the West Macedonia region. Each station was connected via modem technology and sent data to the central base station. There was a 'clickable' static map of the West Macedonia region from which the user could select one of the four stations, in order to display the city station name, and the results of the measurements (Triantafyllou, 2004). Eight years later (May 2010), the system was upgraded. The connectivity of the terminal stations to the central base station was selected and applied in different ways, depending on the characteristics and features of each terminal, as follows:

a one station was connected with a router and with internet access of one ISP, it was sending data to the central base station

b three stations were connected to a GPRS router, where data transmission to the server was received wirelessly via APN

c the last computer station was connected via a LAN network and was sending data to the central base station.

Nowadays, the proposed system has several new additions. The stations on the site are presented in a Google Maps format. On the website (http://www.airlab.edu.gr) a Google format map of the region of interest is illustrated, from which the user can navigate to the stations. A separate window-balloon is created with information and characteristics for each station. The Google Maps window-balloon shows the current values of the station, the air quality index (AQI) of the previous-current day and it also shows general information related to the specific station. The system has the ability to dynamically display previous meteorological and AQ data for each station through Google Maps.

Figure 11 Dynamic Google Maps presentation (see online version for colours)

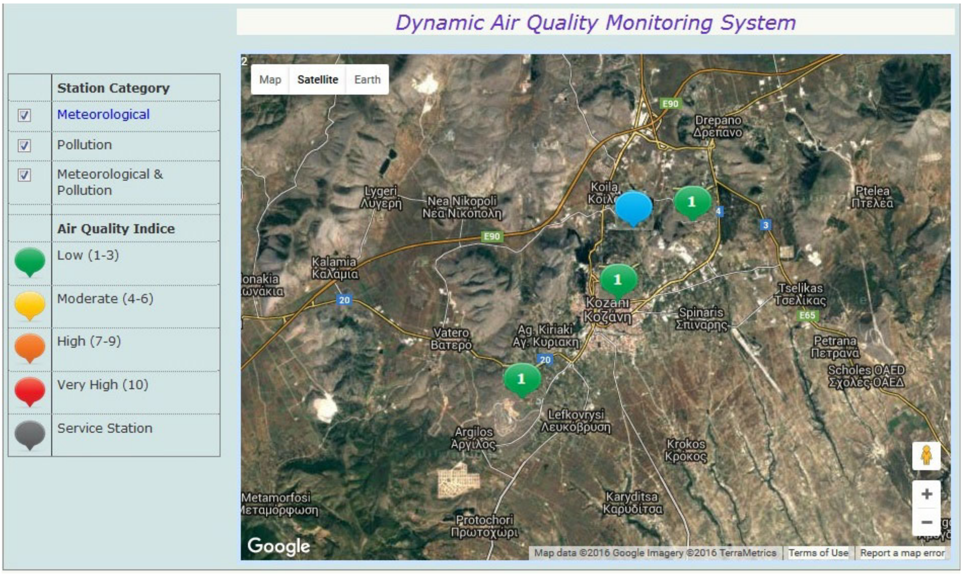
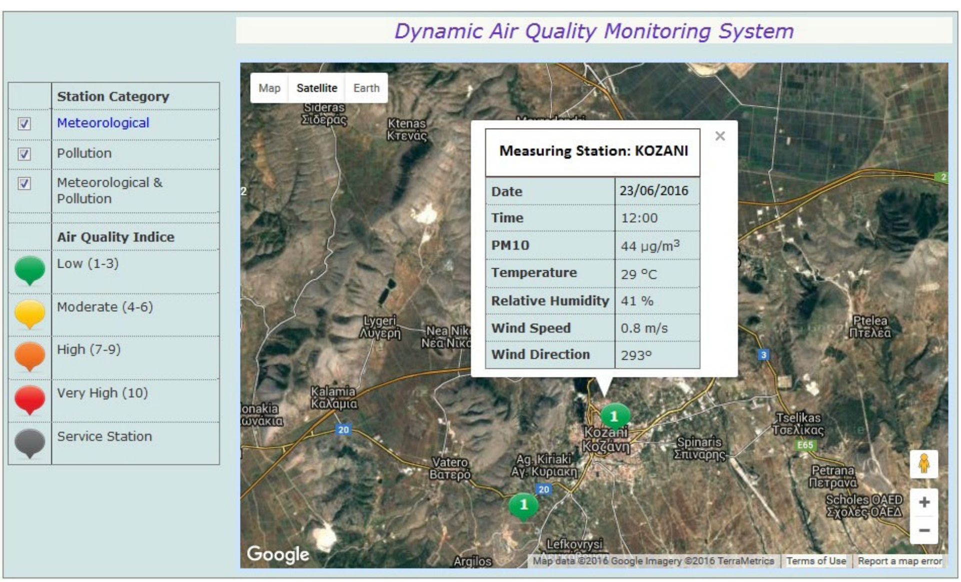


Figure 12 Measurement details in a Google Maps format (see online version for colours)



The second feature is the meteorological forecast information for the upcoming seven days. This information is generated by using a high-end server with high processing power and memory from data stored in a large database using PHP programming code with the results appearing in graph form. Each site visitor can be informed by selecting the area of interest and then through a number of charts providing the forecast for the next seven days regarding temperature, humidity, wind speed, wind direction, total solar radiation and accumulated precipitation (sum/six hours). Also the system has the ability to dynamically display past meteorological data.

The third feature is air pollution prediction of (PM10) for the next few days. This time the user must be authorised with a username and password. The website dynamically displays regions in a map using images; according to the pollution percentages in a certain region, the corresponding colour scale is presented denoting the levels of pollution. Also, the system provides dynamically previous air pollution data and the user has the option to choose up to one month before the current date.

Another feature is 'online web station reports' where, authorised users of the backend application have the ability to view, check, analyse, export measurements and produce statistics for each station. Also, with the feature – manage stations using Google Maps – the user has the ability to create, delete, modify points and information for each station on the map.

Finally, an additional new feature is a weather and air pollution forecast. This module presents the results of a high-resolution local-scale meteorological and AQ forecasting system carried out and operated by the Lab of Atmospheric Pollution and Environmental Physics, Department of Environmental Engineering, West Macedonia University of Applied Sciences, for use as a decision support tool in the West Macedonia industrial area in NW Greece. The system combines two prognostic models: one global atmospheric model to produce synoptic-scale forecasts and one limited area model for local–scale meteorological and air pollution forecasting. More specifically, the conformal cubic atmospheric model (CCAM) (McGregor, 2005; McGregor and Dix, 2008) and TAPM (Hurley, 2007a; Hurley et al., 2001, 2005; Hurley, 2007b) are combined to give a downscaling approach for local scale meteorological and air pollution forecasting in the area under study. The two models are combined in such a way that CCAM forecasts lateral boundary conditions (LBCs) by creating synoptic data files that are used as input for TAPM (Thatcher and Hurley, 2010). TAPM was configured with three (nested) grids of 63 × 69 horizontal points with 18 km, 6 km, and 2 km grid spacing, and 25 vertical levels at 10 m, 25 m, 50 m, 100 m, 150 m, 200 m, 250 m, 300 m, 400 m, 500 m, 600 m, 750 m, 1 km, 1.25 km, 1.5 km, 1.75 km, 2 km, 2.5 km, 3 km, 3.5 km, 4 km, 5 km, 6 km, 7 km, and 8 km. Seven-day forecasts of synoptic data are automatically downloaded to a PC hard drive from CCAM modelling system (four analysis downloads/day) and stored on the TAPM synoptic file format at 6 h intervals. TAPM itself runs to produce a seven-day forecast. After the model run, batch files upload the results to a server. The data are stored on a data basis at 1 h intervals. An analytical description and evaluation of the system can be found in Triantafyllou et al. (2011b) and Matthaios et al. (2017).

6 Conclusions

The operational, monitoring, as well as high-resolution, local-scale meteorological and AQ forecasting information system for the West Macedonia region, Hellas, has been developed and operated by the Lab of Atmospheric Pollution and Environmental Physics, Department of Environmental Engineering West Macedonia University of Applied Sciences. The information system is presented, in a dynamic, easily accessible and user-friendly way. The application has been developed using state of the art web technologies (Ajax, Google Maps, etc.) and on an open-source software philosophy that enables users/authors to update/enrich the code according to their needs. Extending the abilities of the system is under development by our research team. Specifically, we work to add, among others, the following:

- expansion of the system with stations installed in Central and East Macedonia/ Thrace.
- creating a mobile application for iPad and Android users.
- addition of a number of modules using Python programming language.

References

Atkinson, L. and Suraski, Z. (2004) *PCore PHP Programming*, 3rd ed., Pearson Education, Inc., Publishing as Prentice Hall Professional Technical Reference, New Jersey.

Bosh, A., Karagiannis, G., Stamatopoulos, V. and Kotis, T. (2006) 'Public perception of realtime information services for environmental monitoring and management of asthma', *Journal of Telemedicine and Telecare*, Vol. 12, No. 1, pp.11–13.

Caudill, J.G. (2007) 'The growth of m-learning and the growth of mobile computing: parallel developments', *International Review of Research in Open and Distance Learning*, Vol. 8, No. 2, ISSN: 1492-3831.

Ceri, S., Fraternali, P. and Bongio, A. (2000) 'Web modeling language (WebML): a modeling language for designing web sites', *Computer Networks*, Vol. 3, Nos. 1–6, pp.137–157.

Ceri, S., Fraternali, P., Bongio, A., Brambilla, M., Comai, S. and Matera, M. (2002) *Designing Data-Intensive Web Applications*, Morgan Kaufmann, San Francisco.

Chung, J.Y., Lin, K.J. and Mathieu, R.G. (2003) 'Web services computing: advancing software interoperability', *Computer*, Vol. 36, No. 10, pp.35–37.

Council Directive 96/62/EC of 27 September 1996 on Ambient Air Quality Assessment and Management.

Directive 1996/62/EC: Council Directive 96/62/EC of 27 September 1996 on Ambient Air Quality Assessment and Management.

Directive 2003/4/EC of the European Parliament and of the Council of 28 January 2003 on Public Access to Environmental Information and Repealing Council Directive 90/313/EEC.

Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008, on Ambient Air Quality and Cleaner Air for Europe.

Duckett, J. (2008) *Beginning Web Programming with HTML, XHTML, and CSS*, Wiley Publishing, Indianapolis.

Elbern, H., Strunk, A., Schmidt, H. and Talagrand, O. (2007) 'Emission rate and chemical state estimation by 4-dimensional variational inversion', *Atmos. Chem. Phys. Discuss*., Vol. 7, pp.1725–1783.

Fragulis, G.F., Lazaridis, L., Papatsimouli, M. and Skordas, I. (2018) 'O.D.E.S: an online dynamic examination system based on a CMS Wordpress plugin', *Proceedings of the 3rd South-East Europe Design Automation, Computer Engineering, Computer Networks, and Social Media Conference (SEEDA-CECNSM 2018)*, Kastoria, Hellas, 22–24 September.

Granada, D., Vara, J.M., Brambilla, M., Bollati, V. and Marcos, E. (2017) 'Analysing the cognitive effectiveness of the WebML visual notation', *Software & Systems Modeling*, Vol. 16, No. 1, pp.195–227.

Hurley, P. (2007a) 'Development and verification of TAPM', in *Proceedings of the 29th NATO/SPS ITM on Air Pollution Modelling and its Application*, Aveiro, Portugal, 24–28 September.

Hurley, P. (2007b) 'Modelling mean and turbulence fields in the dry convective boundary layer using the EDMF approach', *Boundary-Layer Meteorol.*, Vol. 125, No. 3, pp.525–536.

Hurley, P., Blockley, A. and Rayner, K. (2001) 'Verification of a prognostic meteorological and air pollution model for year-long predictions in the Kwinana region of Western Australia', *Atmos. Environ.*, Vol. 35, No. 10, pp.1871–1880.

Hurley, P., Physick, W. and Luhar, A. (2005) 'TAPM – a practical approach to prognostic meteorological and air pollution modeling', *Environ. Modell. & Software*, Vol. 20, No. 6, pp.737–752.

Duyzer, J., van den Hout, D., Zandveld, P. and van Ratingen, S. (2015) 'Representativeness of air quality monitoring networks', *Atmospheric Environment*, Vol. 104, pp.88–101.

Karatzas, K. and Kukkonen, J. (2009) 'Quality of life information services towards a sustainable society for the atmospheric environment', in *COST Action ES0602 Workshop Proceedings*.

Laurie, B. and Laurie, P. (2003) *Apache: The Definitive Guide*, O'Reilly Media, Inc., Sebastopol.

Lazaridis, L., Papatsimouli, M. and Fragulis, G.F. (2016) 'S.A.T.E.P: synchronous-asynchronous tele-education platform', *Proceedings of the South-East Europe Design Automation, Computer Engineering, Computer Networks and Social Media Conference SEEDA-CECNSM 2016*, Kastoria, Hellas, 23–25 December.

Manuel, P.D. and AlGhamdi, J. (2003) 'A data-centric design for n-tier architecture', *Information Sciences*, Vol. 150, Nos. 3–4, pp.195–206.

Matthaios, V.N., Triantafyllou, A.G., Triantafyllos, A.A., Sakkas, V. and Garas, S. (2017) 'Performance and evaluation of a coupled prognostic model TAPM over a mountainous complex terrain industrial area', *Theoretical and Applied Climatology*, DOI: 10.1007/s00704-017-2122-9.

McGregor, J. and Dix, M. (2008) 'An updated description of the conformal cubic atmospheric model', in Hamilton, K. and Ohfuchi, W. (Eds.): *High-Resolution Simulation of the Atmosphere and Ocean*, pp.51–76, Springer, New York.

McGregor, J.L. (2005) 'C-CAM: geometric aspects and dynamic formulation', *CSIRO Marine and Atmospheric Research Technical Report*, Vol. 70 [online] http://www.cmar.csiro.au/eprint/open/mcgregor_2005a.pdf.

Mendes, E. (2014) 'Web development versus software development', *Practitioner's Knowledge Representation: A Pathway to Improve Software Effort Estimation*, pp.13–25, Springer-Verlag Berlin, Heidelberg, ISBN: 978-3-642-54156-8.

Menut, L., Honore, C., Rouil, L., Beekmann, M., Vautard, R., Poisson, N., Peuch, V.H. and Rico, M. (2005) 'PREV'AIR, a modeling platform for the air quality predictability study', *Geophysical Research Abstracts*, Vol. 7, p.4449.

Moussiopoulos, N., Douros, I., Tsegas, G., Kleanthous, S. and Chourdakis, E. (2012) 'An air quality management system for policy support in Cyprus', *Advances in Meteorology*, DOI: 10.1155/2012/959280.

Murugesan, S. and Deshpande, Y. (2016) *Web Engineering: Managing Diversity and Complexity of Web Application Development*, Springer, ISBN: 3-540-42130-0.

Ott, W.R. and Thom, G.C. (1976) `A critical review of air pollution index systems in the United States and Canada', *Journal of Air Pollution Control Association*, Vol. 26, No. 5, pp.460–470.

Schimak, G. (2003) 'Environmental data management and monitoring system UWEDAT', *Environmental Modelling and Software*, Vol. 18, pp.573–580.

Shaffi, A.S. and Al-Obaidy, M. (2013) 'Analysis and comparative study of traditional and web information systems development methodology (WISDM) towards web development applications', *International Journal of Emerging Technology and Advanced Engineering*, Vol. 3, No. 11, ISSN: 2250-2459.

Skordas, I., Fragulis, G.F. and Triantafyllou, A.G. (2011) 'e-AirQuality: a dynamic web application for evaluating the air quality index for the City of Kozani, Hellas', *PCI 2011 15th, Panhellenic Conference on Informatics*, Kastoria, Greece, 30 September–2 October.

Skordas, I., Tsirekas, N., Kolovos, N., Fragulis, G.F., Triantafyllou, A.G. and Bouliou, M.G. (2017) 'e-SEM: dynamic seminar management system for primary, secondary and tertiary education', *Proceedings of the South-East Europe Design Automation, Computer Engineering, Computer Networks and Social Media Conference SEEDA-CECNSM 2017*, Kastoria, Hellas, September.

Sofiev, M., Siljamo, P., Valkama, I., Ilvonen, M. and Kukkonen, J. (2006) 'A dispersion modelling system SILAM and its evaluation against ETEX data', *Atmospheric Environment*, Vol. 40, No. 4, pp.674–685.

Stidworthy, A., Jackson, M., Johnson, K., Carruthers, D. and Stocker, J. (2017) 'Evaluation of local and regional air quality forecast for London', *18th International Conference on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes*, Bologna, Italy, 9–12 October.

Thatcher, M. and Hurley, P. (2010) 'A customisable downscaling approach for local-scale meteorological and air pollution forecasting: performance evaluation for a year of urban meteorological forecasts', *Environmental Modeling & Software*, Vol. 25, No. 1, pp.82–92.

Thom, G.C. and Ott, W.R. (1976) 'A proposed uniform air pollution index', *Atmospheric Environment*, Vol. 10, No. 3, pp.261–264.

Triantafyllou, A.G. (2004) 'Atmospheric pollution – atmospheric boundary layer', *Advances in Measurements Technologies*, Edited by TEI of Western Macedonia, Kozani, p.256.

Triantafyllou, A.G., Evagelopoulos, V. and Zoras, S. (2006) 'Design of a webbased information system for ambient air quality data', *Journal of Environmental Management*, Vol. 80, No. 3, pp.230–236.

Triantafyllou, A.G., Evagelopoulos, V., Kiros, E.S. and Diamantopoulos, C. (2004) 'Design of a webbased information system for ambient air quality data in west Macedonia, Greece', *7th Panhellenic (International) Conference of Meteorology, Climatology and Atmospheric Physics*, Nicosia, 28–30 September.

Triantafyllou, A.G., Skordas, J., Diamantopoulos, C. and Topalis, E. (2011a) 'The new dynamic air quality information system and its application in West Macedonia, Greece', *4th Macedonian Environmental Conference*, Thessaloníki, Greece, March, p.4.

Triantafyllou, A.G., Krestou, A., Hurley, P. and Thatcher, M. (2011b) 'An operational high resolution local scale meteorological and air quality forecasting system for Western Macedonia, Greece: some first results', *Proceedings of the 12th International Conference on Environmental Science and Technology (CEST2011)*, 8–10 September, p.A-1904:1911.

Vaswani, V. (2004) *MySQL: The Complete Reference*, Brandon A. Nordin, McGraw-Hill, New York.

Vautard, R., Bessagnet, B., Chin, M. and Menut, L. (2005) 'On the contribution of natural Aeolian sources to particulate matter concentrations in Europe: testing hypotheses with a modeling approach', *Atmospheric Environment*, Vol. 39, No. 18, pp.3291–3303.

White, J.E. (2010) *AIRNow-International: The Future of the United States Real-time Air Quality Reporting and Forecasting Program AND GEOSS Participation* [online] https://earthzine.org/airnow-international-the-future-of-the-united-states-real-time-air-quality-reporting-and-forecasting-program-with-geoss-participation-2/ (accessed 20 March 2019).

Websites

http://comeap.org.uk/
http://www.airlab.edu.gr/ (accessed 2018).
http://www.w3schools.com/js/ (accessed 2018).
http://www.airlab.edu.gr/arlb/Anakoinwseis/6_dt02_zwntanes_metrhseis.pdf (accessed 2018).
http://www.epa.gov/outdoor-air-quality-data/interactive-map-air-quality-monitors (accessed 2019).
https://uk-air.defra.gov.uk/air-pollution/daqi (accessed 2019).
https://airnow.gov/ (accessed 2019).