Prediction of PM10 Concentrations using a Modular Neural Network System and Integration with an Online Air Quality Management System

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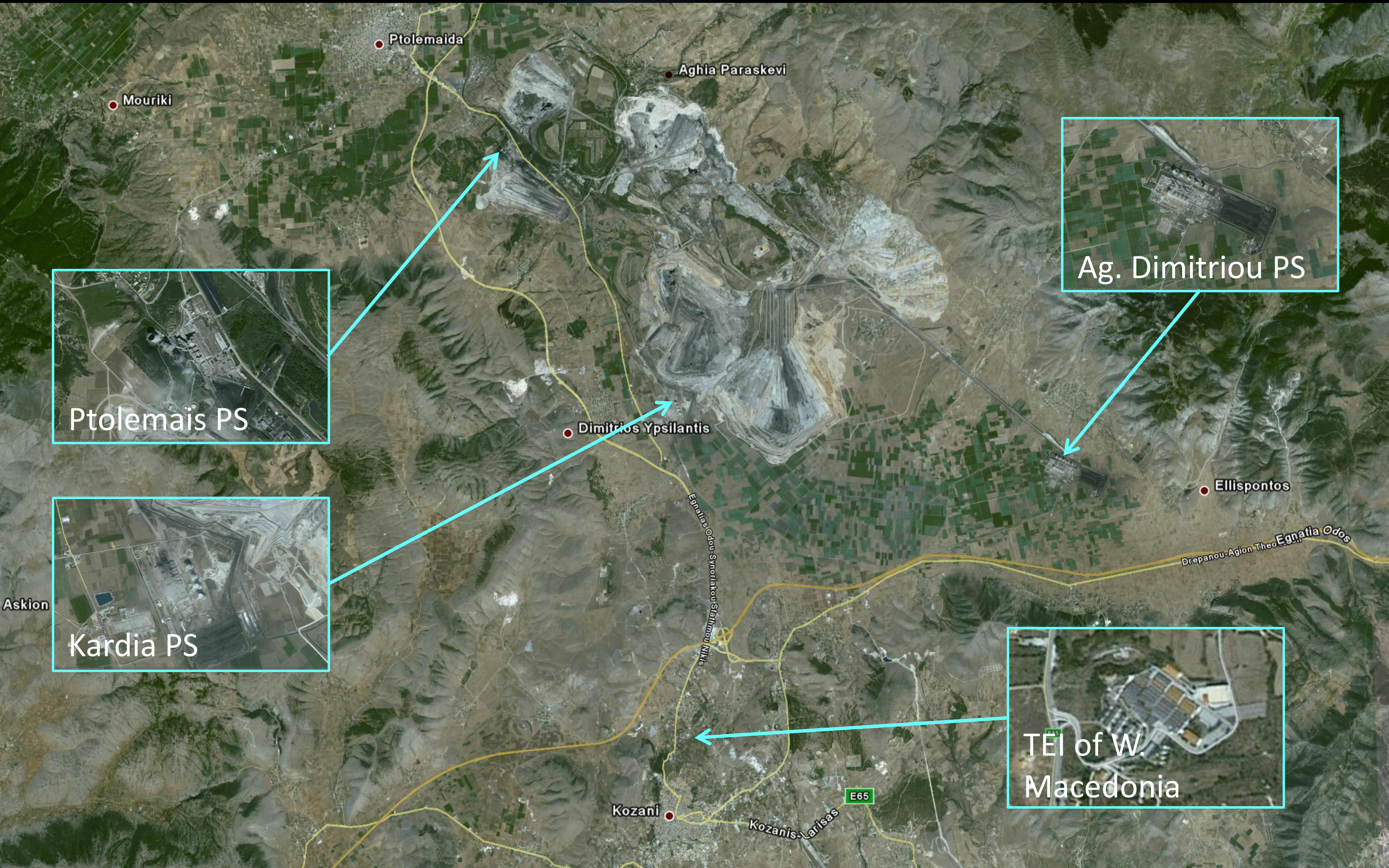
TEI
TECHNOLOGICAL EDUCATIONAL INSTITUTION
OF WESTERN MACEDONIA

Introduction

- The town of Kozani is located in the southern part of the Eordea basin and is the centre of significant industrial activity.
- A number of lignite power stations operate within the basin.
- It has been shown that under certain atmospheric conditions, pollutants emitted by these power stations reach the town of Kozani.
- Urban pollution sources also contribute to the problem of air quality in the town.

Problem Area Location



Ptolemaïs PS

Kardia PS

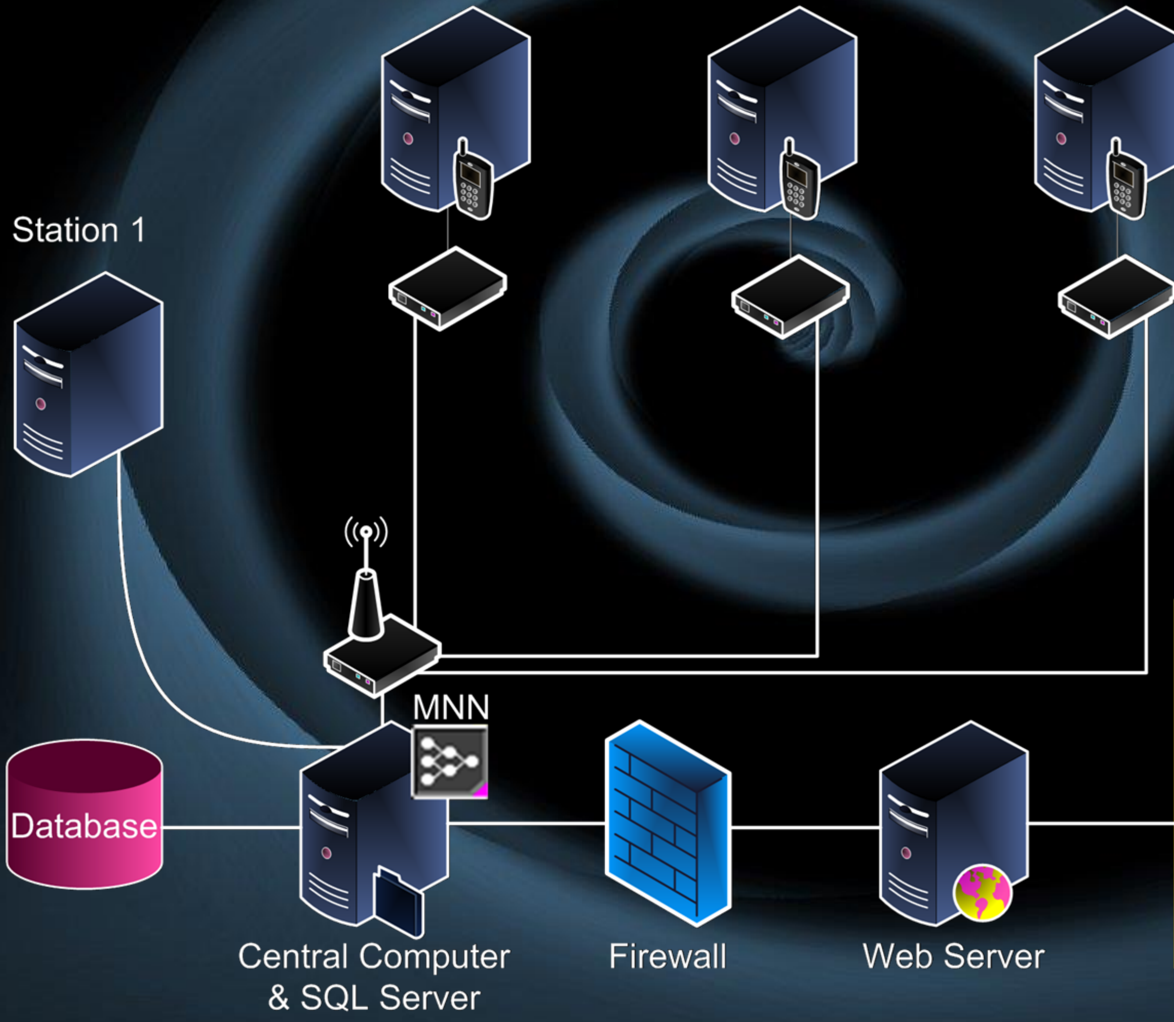
Ag. Dimitriou PS

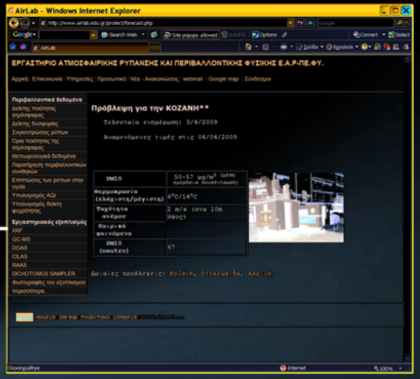
TEI of W. Macedonia

IAQMS and Modular Neural Network

- The air quality problem described above was the main motivation for the development of an Integrated Air Quality Management System (IAQMS) at the Laboratory of Air Pollution and Environmental Physics of the Technological Educational Institute (TEI) of Western Macedonia.
- In 2007, a modular neural network (MNN) system for the prediction of 24h average PM10 concentration was added to the IAQMS.

Structure of IAQMS





ΕΡΓΑΣΤΗΡΙΟ ΑΤΜΟΣΦΑΙΡΙΚΗΣ ΡΥΠΑΝΣΗΣ ΚΑΙ ΠΕΡΙΒΑΛΛΟΝΤΙΚΗΣ ΦΥΣΙΚΗΣ Ε.Α.Ρ-ΠΕ.ΦΥ.

Αρχική | Επικοινωνία | Υπηρεσίες | Προσωπικό | Νέα - Ανακοινώσεις | webmail | Google map | Σύνδεσμοι

Περιβαλλοντικά δεδομένα
- Δείκτης ποιότητας ατμόσφαιρας
- Δείκτης δυσφορίας
- Συγκεντρώσεις ρύπων
- Όρια ποιότητας της ατμόσφαιρας
- Μετεωρολογικά δεδομένα
- Παρατήρηση περιβαλλοντικών συνθηκών
- Επιπτώσεις των ρύπων στην υγεία
- Υπολογισμός AQI
- Υπολογισμός δείκτη ψυχρότητας

Εργαστηριακός εξοπλισμός
- XRF
- GC-MS
- DOAS
- CILAS
- RAAS
- DICHOTOMUS SAMPLER
- Φωτογραφίες του εξοπλισμού
- περισσότερα...

Πρόβλεψη για την ΚΟΖΑΝΗ**

Τελευταία ενημέρωση: 3/4/2009

Αναμενόμενες τιμές στις 04/04/2009

PM10	50-57 μg/m³ (μέση ημερήσια συγκέντρωση)
Θερμοκρασία (ελάχιστη/μέγιστη)	6°C/14°C
Ταχύτητα ανέμου	2 m/s (στα 10m ύψος)
Καιρικά φαινόμενα	
PM10 (neutro)	67

Ωριαίες προβλέψεις: Κοζάνη, Πτολεμαΐδα, Ακρινή

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Data Organisation

- For each day considered, eight hourly PM10 measurements are taken every three hours.
- The average PM10 concentration of the last 24 hours is also calculated.
- Meteorological parameters for the last 24 hours are taken into account including the minimum and maximum 1-h average relative humidity, the maximum temperature, the temperature range, the average wind direction and speed.
- Forecasted meteorological parameters for the following 24 hours are also considered, consisting of the minimum and maximum 1-h average of relative humidity, the forecasted maximum temperature, the difference between the maximum and minimum temperature, and the average wind speed.

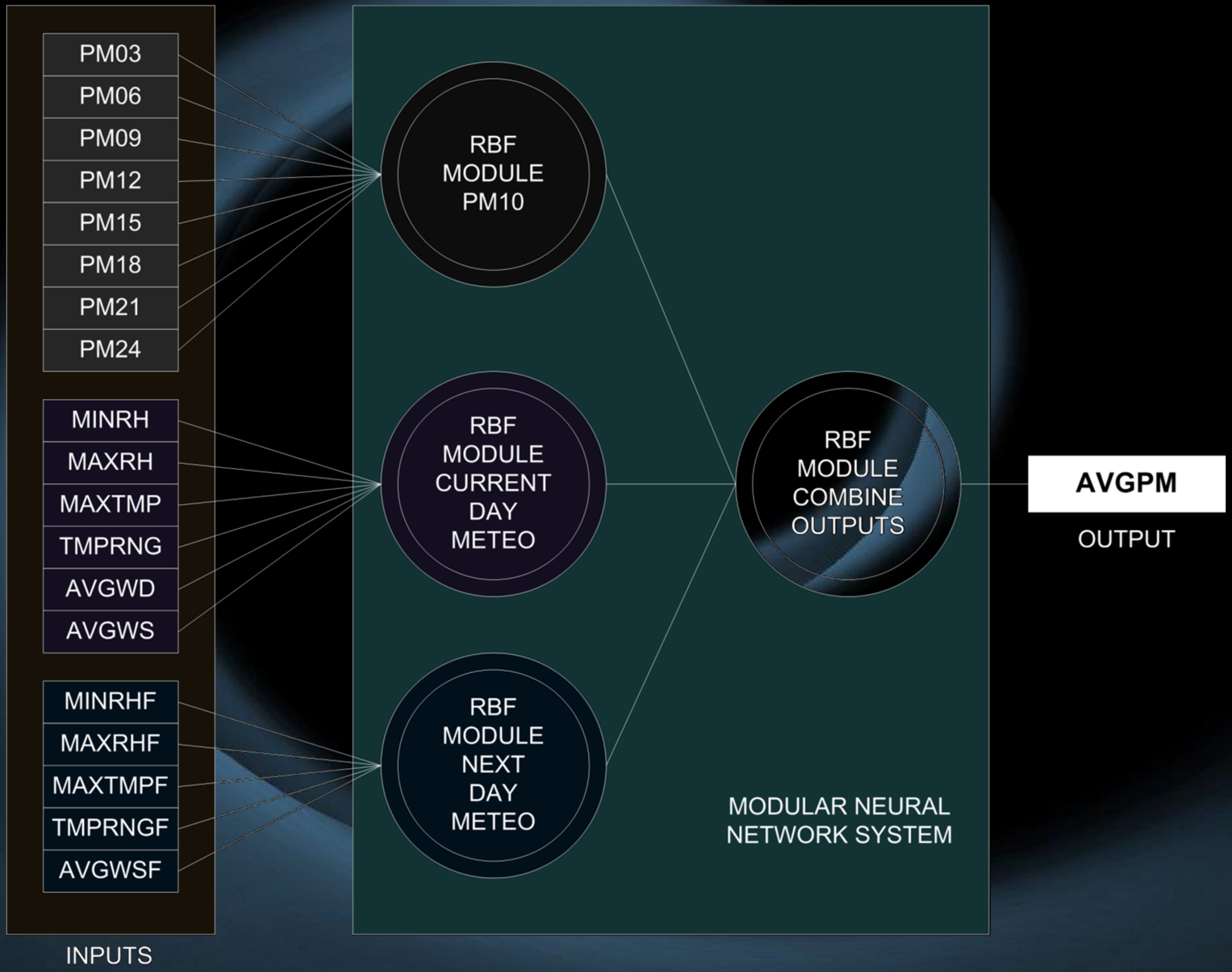
Modular Neural Network Structure

- The MNN system is based on Radial Basis Function (RBF) networks.
- The networks are arranged in two levels.
- The first level consists of three networks, each receiving different inputs and each producing a forecast of next day 24h average PM10 concentration.
- The first receives the eight PM10 hourly measurements, the second network receives meteorological inputs (observed values) regarding the last 24 hours, and the third network receives meteorological inputs (forecasts) regarding the following 24 hours.

Combining Multiple Outputs / Predictions

- The outputs from the three networks of the first level are directed as inputs to the single RBF network of the second level.
- This network combines the outputs from the three previous networks into one forecast of next day’s average PM10 concentration.

Modular Neural Network Structure



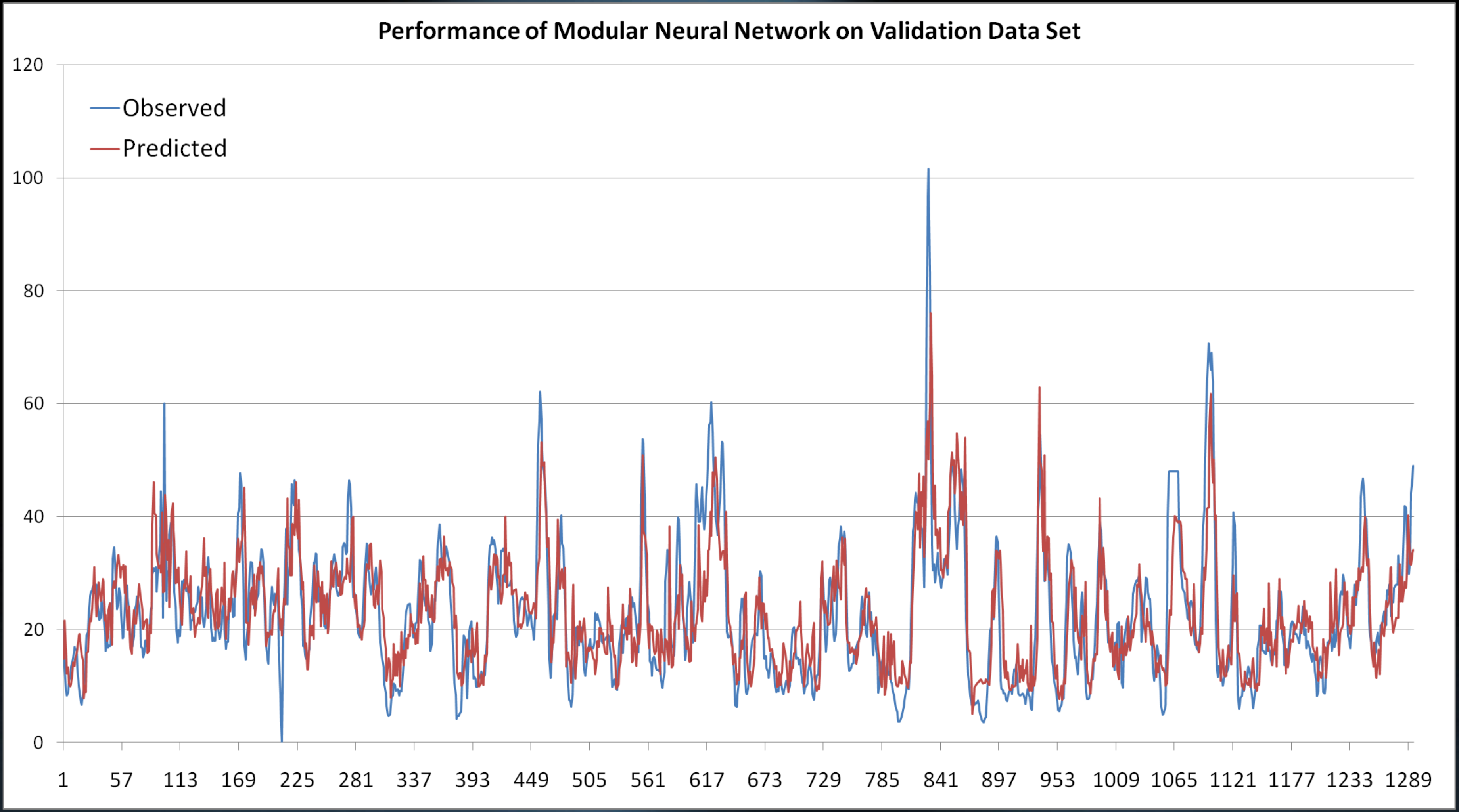
Why Modular?

- The philosophy of this structure is that by decomposing the prediction problem into three separate smaller problems, a better forecast may be obtained.
- The separate RBF networks can build a model between inputs and output easier and faster, requiring a smaller number of training patterns, as only a subset of the total inputs are used in each of them leading to a smaller number of network parameters to fix through training.
- The overall system is less dependant on each of the three different groups of inputs.
- It is also easier to examine the sensitivity of the system’s output to each of the inputs.
- In the future, this modular structure will allow prediction even when one of the RBF networks of the first level is unable to produce an output due to unavailability of one or more of the inputs for various reasons (lack of meteorological forecasts, measuring equipment breakdown, etc.)

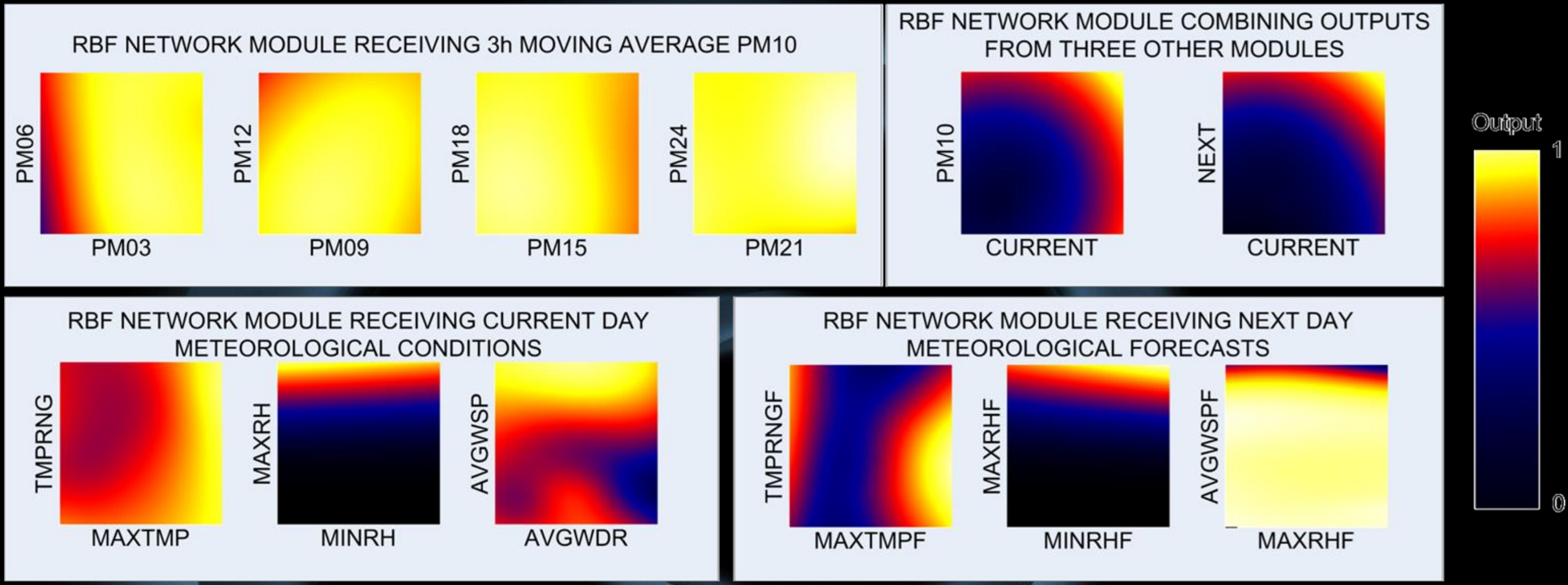
Modular Neural Network Development and Dataset

- The MNN was developed using data spanning over 12 months.
- This time period provided a total of 2603 patterns (approximately equal to 12 months x 30 days x 8 time periods) separated by 3 hours, i.e. complete sets of all 19 inputs and 1 output.
- These were split equally in two subsets, one used for training and one used for validation.
- The generation, training and testing of the modular neural network during development was achieved using a commercial package.
- Training of the network included fixing the number of radial basis functions, function centres, function widths, and output weights, for each of the sub-networks.

Performance during Development



Network Sensitivity Analysis

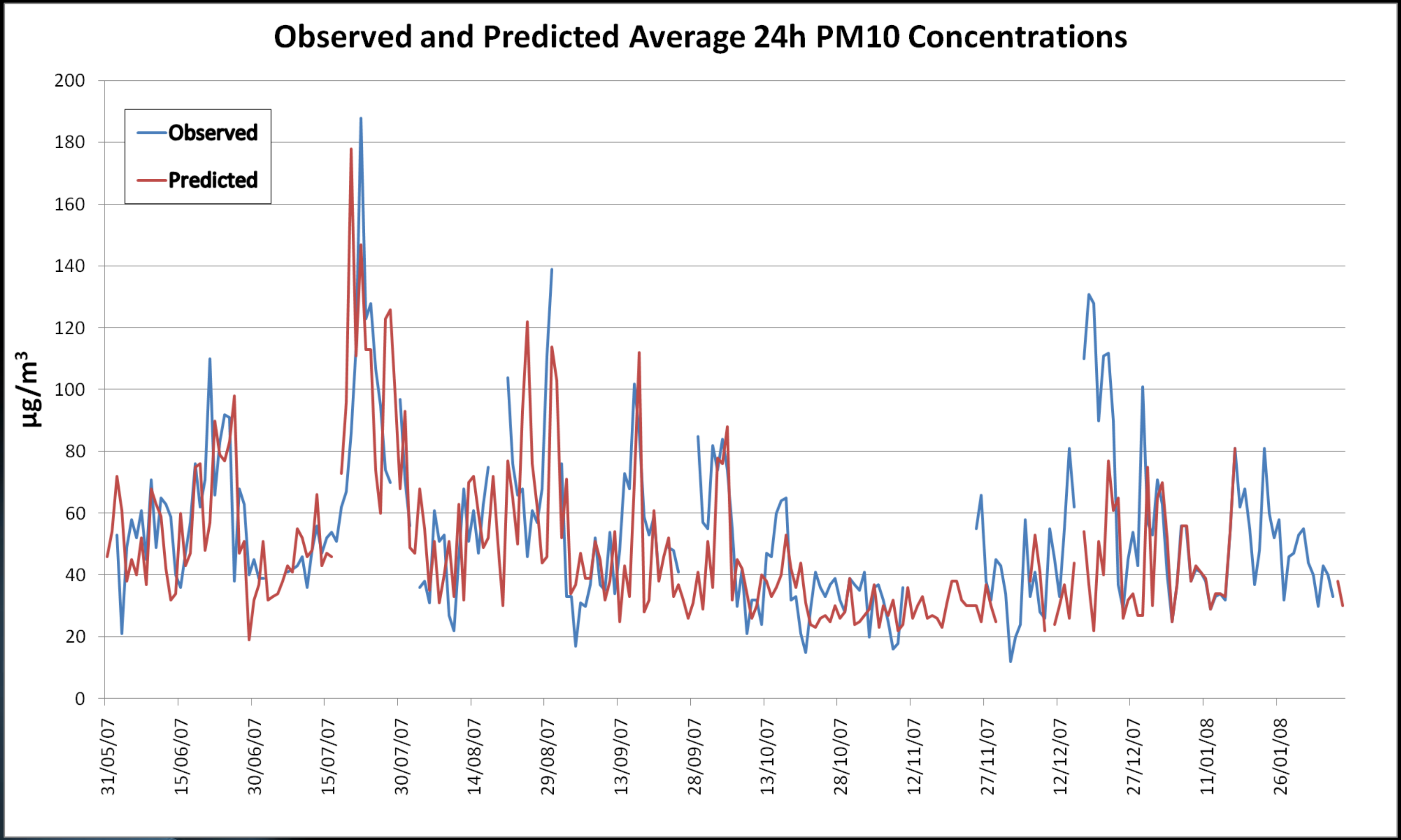


- The sensitivity of each network's output to each of the inputs was examined.
- The output of the second and third network is not affected by the measured and forecasted minimum relative humidity inputs (MINRH and MINRHF).
- Wind direction and speed seem to have a great influence on the output, as do the temperature related inputs.

Modular Neural Network Application

- The developed system was converted to computer code (a DLL application extension) that was integrated with the IAQMS in August 2007.
- Since then, it has been used to forecast the 24h average PM10 concentration in Kozani.
- The daily forecasts become available through the Laboratory’s website (http://www.airlab.edu.gr).

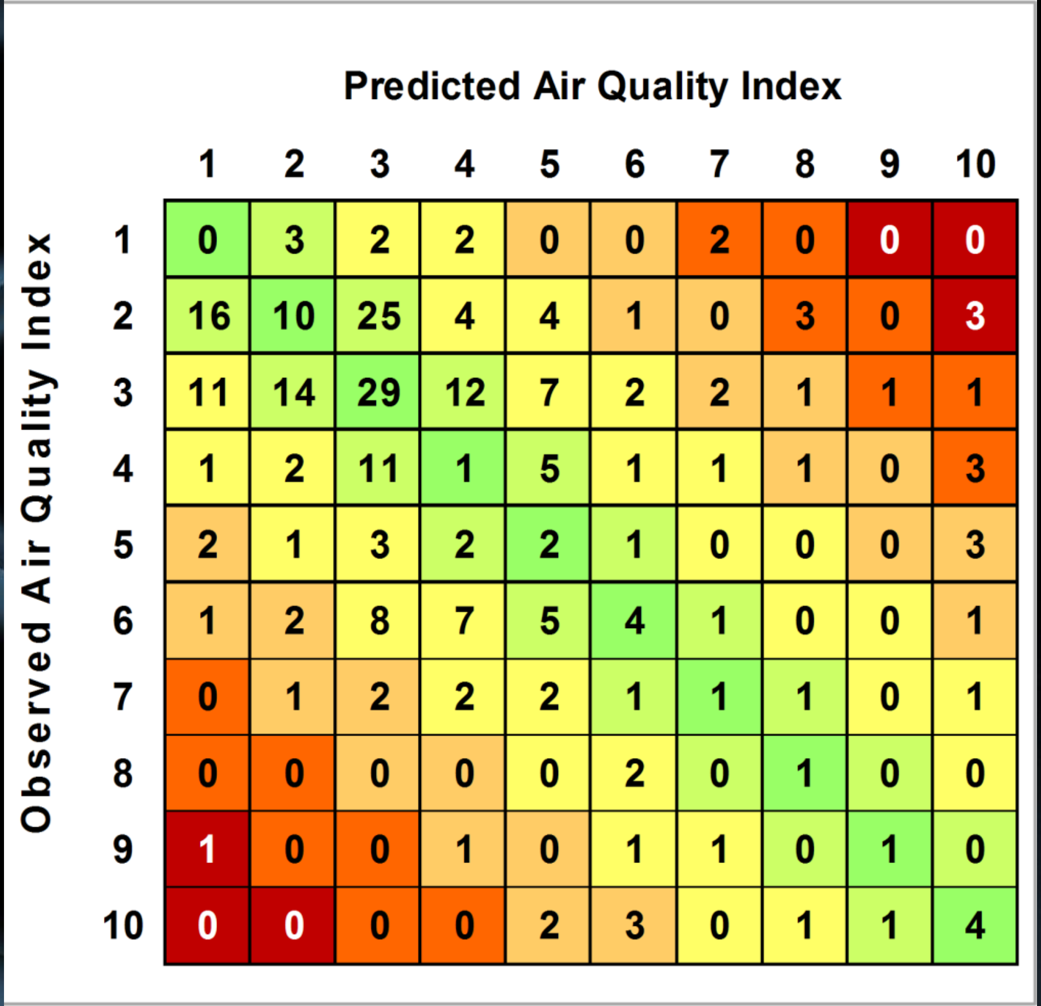
Performance during Application



- The coefficient of correlation between observed and predicted values is lower compared to the validation set used during training of the network.
- The validation data values were possibly easier to approach by the MNN as they were more uniform than the application data.
- The mean absolute error was 13.7% on the validation set and 26.3% during application.

Air Quality Index Predictions

Band	Index	PM10 Particles	
		24 hour mean	
		µgm^{-3}	µgm^{-3}
		(Grav. Equiv.)	(TEOM)
Low			
	1	0-21	0-16
	2	22-42	17-32
	3	43-64	33-49
Moderate			
	4	65-74	50-57
	5	75-86	58-66
	6	87-96	67-74
High			
	7	97-107	75-82
	8	108-118	83-91
	9	119-129	92-99
Very High			
	10	130 or more	100 or more



Predicted Air Quality Index

Observed Air Quality Index

	1	2	3	4	5	6	7	8	9	10
1	0	3	2	2	0	0	2	0	0	0
2	16	10	25	4	4	1	0	3	0	3
3	11	14	29	12	7	2	2	1	1	1
4	1	2	11	1	5	1	1	1	0	3
5	2	1	3	2	2	1	0	0	0	3
6	1	2	8	7	5	4	1	0	0	1
7	0	1	2	2	2	1	1	1	0	1
8	0	0	0	0	0	2	0	1	0	0
9	1	0	0	1	0	1	1	0	1	0
10	0	0	0	0	2	3	0	1	1	4

Conclusions

- This paper presented a modular neural network system based on RBF networks for the prediction of 24h average PM10 concentrations.
- The development of the system and its integration with an Air Quality Management System was explained.
- The predicting capacity of the presented system has been demonstrated using observed and predicted concentrations collected since it became operational as part of the IAQMS.

Further Tests and Research

- Further improvement of the system will include the development of

  - more representative and uniform training and application datasets

  - the capability to generate a forecast even when one the sub-networks cannot due to lack of input data.