Weather Related Health Impacts

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It has been known that there is an association between Weather and Human Health especially mortality and morbidity. It is interesting to see the combination of meteorological and air pollution parameters on Human mortality

- We are seeking the association between
- 1. Weather parameters
- 2. Pollution parameters

- Human Health

Motivation

- Atmospheric Circulation Types and daily Mortality in Athens, Greece (EHP,2001, 591-595, IJB, 2007, 315-322)
- Assessment and Prediction of short term hospital admissions (AE, 2008, 7078-7086).
- The effect of Meteorological and Pollution parameters on the Frequency of Hospital Admissions for cardiovascular and Respiratory problems (IBE, 2004)
- The effect of ambient benzene concentrations in the vicinity of petrol stations (AE, 2007, 1889-1902)

- The effect of Circulation types on Daily Mortality
- The effect of a combination of parameters on Daily Morbidity
- The effect of benzene on cancer risk
- The effect of pollutants on Daily Morbidity

Atmospheric Circulation Types

- Synoptic Types
- Mesoscale Types

Synoptic Types-Methodology

- P-mode principal components analysis
- Varimax rotation
- Non-hierarchical K-means clustering analysis
- Application to two sub-periods of the year, cold period (16 Oct-15 Apr), warm period (16 Apr-15 Oct)

Synoptic Types Cold Period/1

1W	Weak easterly flow;high humidity, extensive cloudiness, low radiation levels	12.3
2W	Relatively strong, dry N-NW flow;extensive cloudiness	11
3W	Strong relatively dry NE flow	12.1
4W	High humidity levels;SW flow;extensive cloudiness	9.2

Synoptic Types Cold Period/2

5W	Weak SW flow; local circulations, relatively high radiation levels,relative humidity low,diurnal temperature range high	11.5
6W	S-SE flow; warm humid air masses, relatively high temperature range	13.4
7W	Atmospheric pressure highest, diurnal temperature range high, N weak winds	17.6
8W	Weak pressure gradient over Aegean; high, air temperature, diurnal temperature range and solar radiation	12.9

Synoptic Types Warm period/1

1S	Relatively weak SW flow all day; air masses warm and humid, low total radiation	14.4
2S	NE strong winds, relatively low solar radiation, air temperature and humidity	9.2
3S	Relatively low wind speed, high temperature range	20.4

Synoptic Types Warm period/2

4S	Strong northerly wind flow; water vapor pressure and relative humidity generally low	20.0
5S	Wind light without constant direction, total radiation low	17.9
6S	Local circulations with SW direction during daytime; air masses humid and relatively warm	18.1

Data Used

- Mortality Data 10 years
- Synoptic Types
- Mesoscale Types
- Pollution Data (Black smoke)

Statistical Tools Used

- Generalized Additive Methods
- Extensive Poisson regression to model the non-linear effects of the covariates
- We used LOESS smoother to control for seasonal patterns and long term trends and allowed for overdispersion
- Lags for 1 and 2 days before

Relative risks (95% cfl) for total daily mortality for the cold period

AMT	Lag0	Lag1	Lag2
5W	Reference	Category	
1W	1.03	1.01	1.00
2W	1.03	0.96	0.92
3W	0.99	0.96	0.95
4W	1.09	1.04	0.98
6W	1.04	1.03	1.02
7W	1.00	1.00	1.01
6W	1.00	1.00	1.01

Relative risks (95% cfl) for total daily mortality for the warm period

AMT	Lag0	Lag1	Lag2
2S	Reference	Category	
1S	1.06	1.07	1.04
3S	1.02	1.01	0.98
4S	1.01	1.01	0.96
5S	1.00	1.01	1.01
6S	1.07	1.05	1.05

The 1987 heatwave associated with more than 8000 deaths in excess, is associated with air mass types 1S (5 days) and 6S (4 days)

Positive relative risks for mortality were associated with exposures to black smoke.

Increase of 10 µg/m3 was associated with about a 0.5% increase in the daily number of deaths

Relative risks (95% cfl) for total daily mortality for the cold period (adjusting for BS)

AMT	Lag0	Lag1	Lag2
5W	Reference	Category	
1W	1.04 (100)	1.02	1.01
2W	1.07 (76)	1.03	1.01
3W	1.00 (54)	1.00	1.01
4W	1.08 (93)	1.04	0.99
6W	1.02 (120)	1.01	0.99
7W	1.03 (122)	1.04	1.05
6W	1.02 (98)	1.03	1.04

Relative risks (95% cfl) for total daily mortality for the warm period (adjusting for BS)

AMT	Lag0	Lag1	Lag2
2S	Reference	Category	
1S	1.04 (72)	1.04	1.01
3S	1.07 (80.4)	1.04	1.02
4S	1.07 (60.4)	1.07	1.03
5S	0.98 (88.8)	0.99	0.98
6S	1.05 (69.1)	1.02	1.02

Mesoscale Types/1

Westerly flow (a)	Winds medium intensity, reduced humidity/moderate temperature
Easterly flow (b)	Very low temperatures, rather weak winds/snow
Strong northerly flow, cold period (c1)	Strong/cold dry northern winds
Weak northerly flow, cold period (c2)	Moderate and cold dry winds from the north
Strong northerly flow, warm period (c3)	Strong and cool almost dry winds from the north
Weak northerly flow, warm period (c4)	Moderate and cool, almost dry winds from the north

Mesoscale Types/2

Strong southerly flow (d1)	Increased temperature and moist air masses
Pure sea breeze (d2)	Increase RH and moderate winds from the south
Weak sea breeze (d3)	Increased RH and weak winds from the south
Very weak southerly flow (d4)	Humid very weak winds from the south
Flow without main component (f)	Moderate temperature and humidity, very weak winds from various directions

Mesoscale categories

Mes cat	Cold-base	Cold-BS	Warm-base	Warm-BS
f	Reference		Category	
a	1.007	1.025	0.994	1.006
b	**1.094**	**1.111**		
C1,2	1.004	1.017		
C3,4			0.993	1.009
d1	1.039	1.053	1.085	**1.094**
d2			1.036	1.039
d3			**1.109**	1.023
d4	1.020	1.020		

Concluding Remarks/1

- High relative risk for mortality was detected during the cold period is affected by air masses associated with SW flow, followed by days characterized by stagnant conditions
- During the warm period, days with air masses characterized by SW flow (with humid and warm conditions) again have the highest mortality rates.

Concluding Remarks/2

- The effects of air mass types on mortality are observed mainly on the same day during the cold period, but persist on the next day during the warm period
- The effects of air mass types and black smoke are not so clearly dependent

Concluding Remarks/ 3

- Given the high predictability of the air mass types(2-3 days before with high accuracy) a well developed air mass type classification could be a valuable tool for the authorities to use in predicting future unhealthy conditions for humans and the impact on public health.

Concluding Remarks/ 4

- The highest relative risks for mortality is type b in winter (easterly winds) associated with cold outbreaks
- The second highest is d4 associated with southerly flow in winter
- D1 and d2 weather patterns are associated with southerly flow during summer and present elevated relative risks for mortality

Concluding Remarks/5

- The mesoscale categorisation do not appear to improve our understanding of the association between the weather types and mortality
- The relative risks for mortality seems to improve when we adjust PM concentrations.

Effect of meteorological and Pollution Parameters on the frequency of Hospital Admissions

- Aim: Examination the relationship between hospital admissions for cardiovascular (cardiac in general including heart attacks) and/or respiratory diseases (asthma)

Data/1

- 8-y period
- Admissions due to cardiovascular and/or respiratory diseases
- Meteorological parameters (mean Temperature, maximum and minimum temperature, diurnal temperature range, atmospheric pressure, water vapor pressure, relative humidity, irradiance, wind speed, u and v components of the wind, black smoke concentrations)

Data/2

- Changes from 10-days interval to 10 days interval of the meteorological parameters were estimated (ΔTmean…ΔS) 12 parameters
- The average day to day absolute change was estimated (DTmean…DS) 12 parameters

Methodology/1

- Simple linear correlation
- Stepwise Regression Analysis multiple linear correlation coefficients were estimated

Methodology/2

- The Meteorological/pollution factors were transformed to 3-(10 day interval) moving averages with binomial coefficient weights (1, 2, 1).
- With this transformation, cumulative effects can appear clearer and intra-monthly “noise” is removed.
- Stepwise Regression analysis was employed with depended variable the number of admissions and independent variables the 36 meteorological/pollution factors

Methodology/3

- The analysis was applied twice.
- (i) on the time series of the 10-days values (36 cases/year X8 years=288 cases)
- (ii) on the smoothed ones (286 cases)
- The process was employed for two sub periods (warm, cold) to seek possible seasonal dependence.

Results

Year (r=30%, 9% of variance explained, 1.7 admissions/10-days)

Admissions=0.04RH+0.22 Δrange-0.16DRH+3.73

Summer (r=28%, 8% of variance explained, 1.6 adm/10-days)

Admissions=-0.15Δmin+49.34

Winter (r=41%, 16% of variance explained, 1.7 admissions/10-days)

Admissions=0.19Δv+49.34-0.34DRH+7.85

Results on Smoothed variables

Year (r=45%, 20% of variance explained, 1.0 admissions/10-days)

Admissions=0.06RH+0.37V+0.01S+0.25Δrange-0.12DRH-0.38DP+1.07

Summer (r=62%, 38% of variance explained, 0.9 adm/10-days)

Admissions=0.55V+0.02S-0.99DTmax+0.43DI+1.4

Winter (r=53%, 28% of variance explained, 0.9 admissions/10-days)

Admissions=0.19Δrange+0.59Δu+0.90DV -0.32DRH+6.30

Concluding Remarks/1

- There is a statistically significant influence of weather on cardiovascular and respiratory diseases.
- Black Smoke concentrations, humidity and temperature are the factors mainly affecting the diseases
- Stepwise Regression analysis involving more factors leads to higher linear correlation coefficients, higher percentages of the total variance

Concluding Remarks/2

- There are two shortcomings in the methodologies applied.
- 1. They do not involve all the weather and pollution parameters
- 2. The proper use of the equations requires a very precise and reliable weather forecast for at least 10-days, which is not considered possible yet.

- Estimation of the health risk due to the ambient benzene concentrations in the vicinity of petrol stations

Why benzene

- Benzene is rapidly but incompletely absorbed by humans following inhalation exposure
- Is classified as class 1 carcinogen (International Association on the Risks of Cancer)

Aim

- We evaluate the net benzene contribution of petrol stations in their vicinity
- We estimate the cancer risk, due to petrol stations, for the people living and working around it.

Data

- Three petrol stations (urban, suburban, rural)
- Benzene concentrations measured with the aid of passive and active samplers
- Traffic data
- Meteorological data

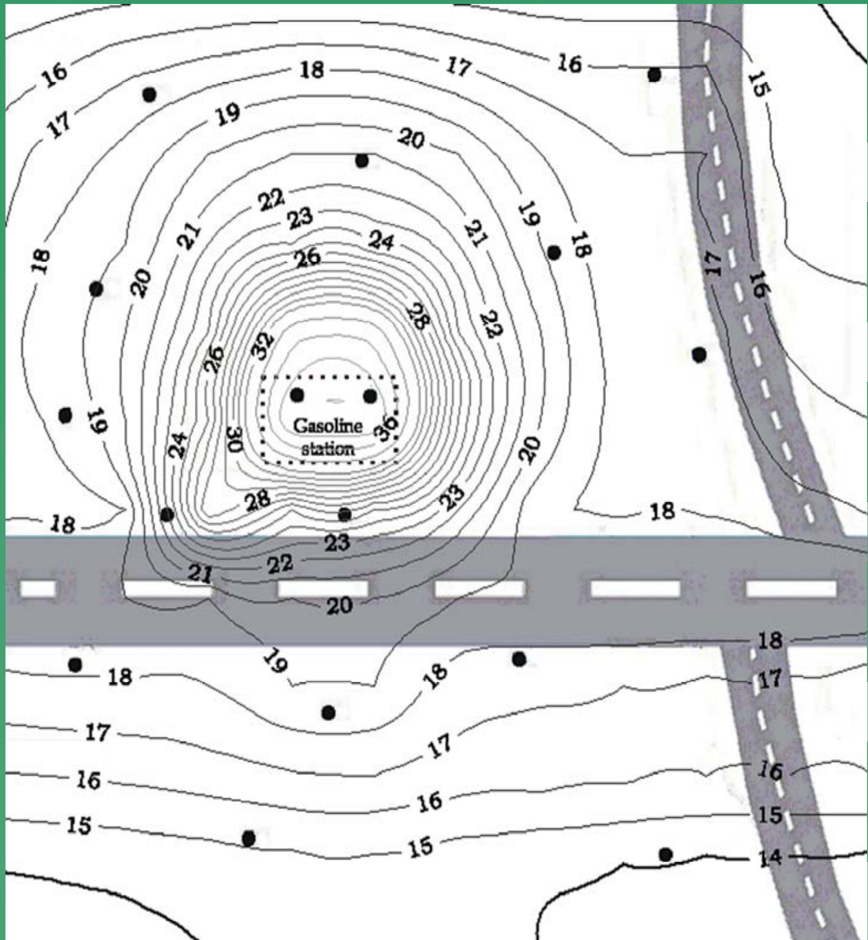
Methodology

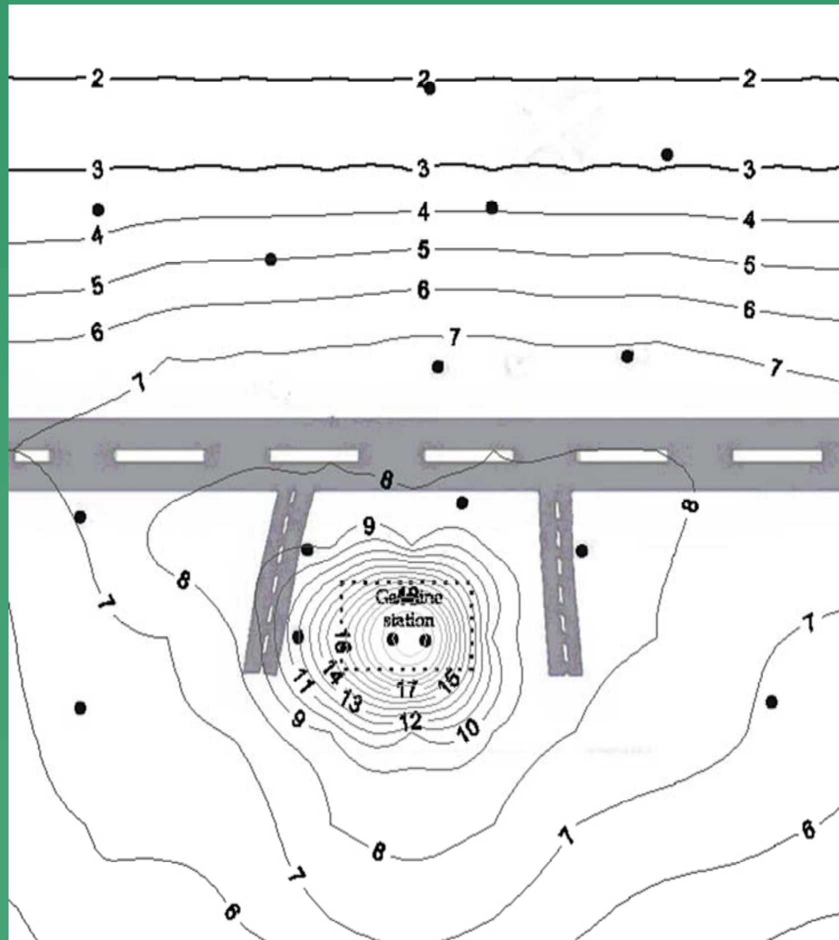
- Collection of experimental data (benzene, traffic, met)
- COPERT model
- CALINE 4 model
- Health Risk evaluation

Percentage distribution of vehicle categories in each study location

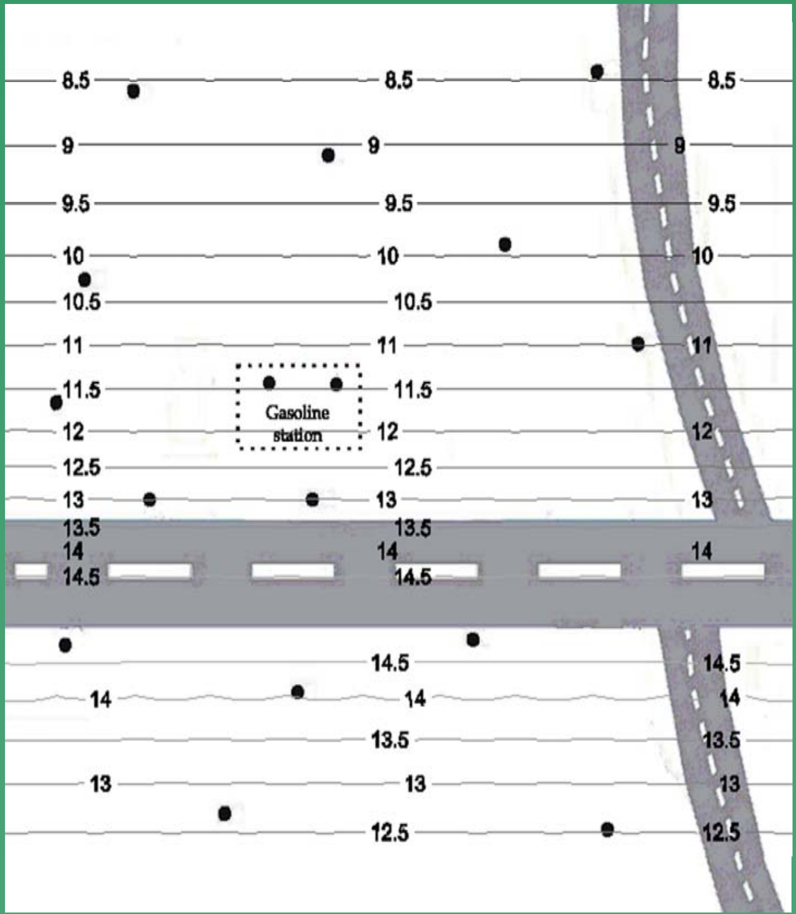
	Urban	Suburban	Rural
Catalytic	70	64	42
Non-catalytic	8	9	11
Diesel Vehicles	5	11	8
Light Duty	7	8	23
Heavy Duty	2	1	9
Buses	1	3	5
Motorcycles	7	4	2

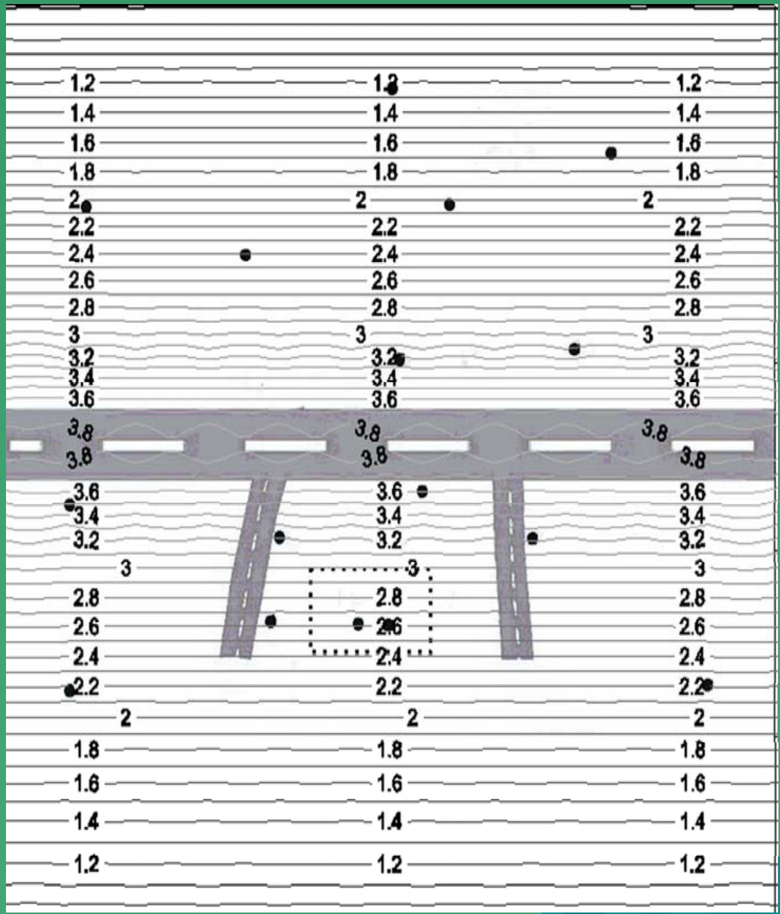
Benzene conc in urban and Suburban locations

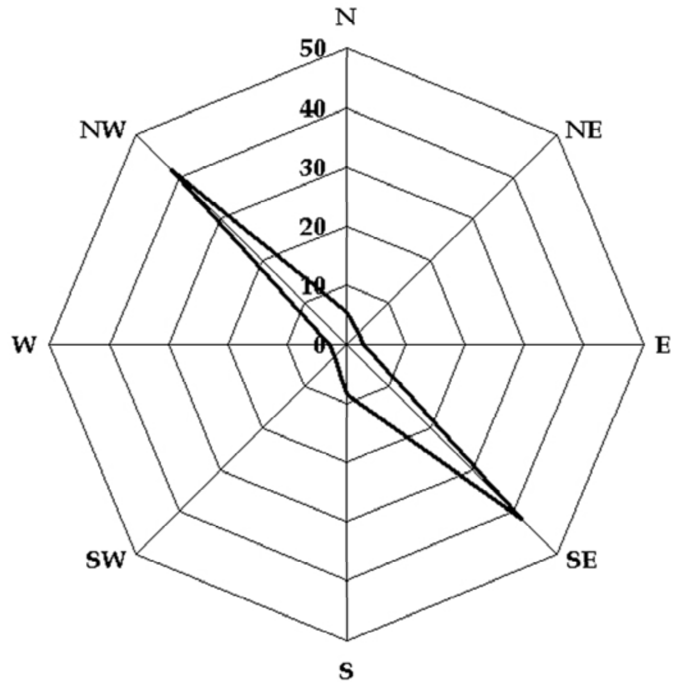




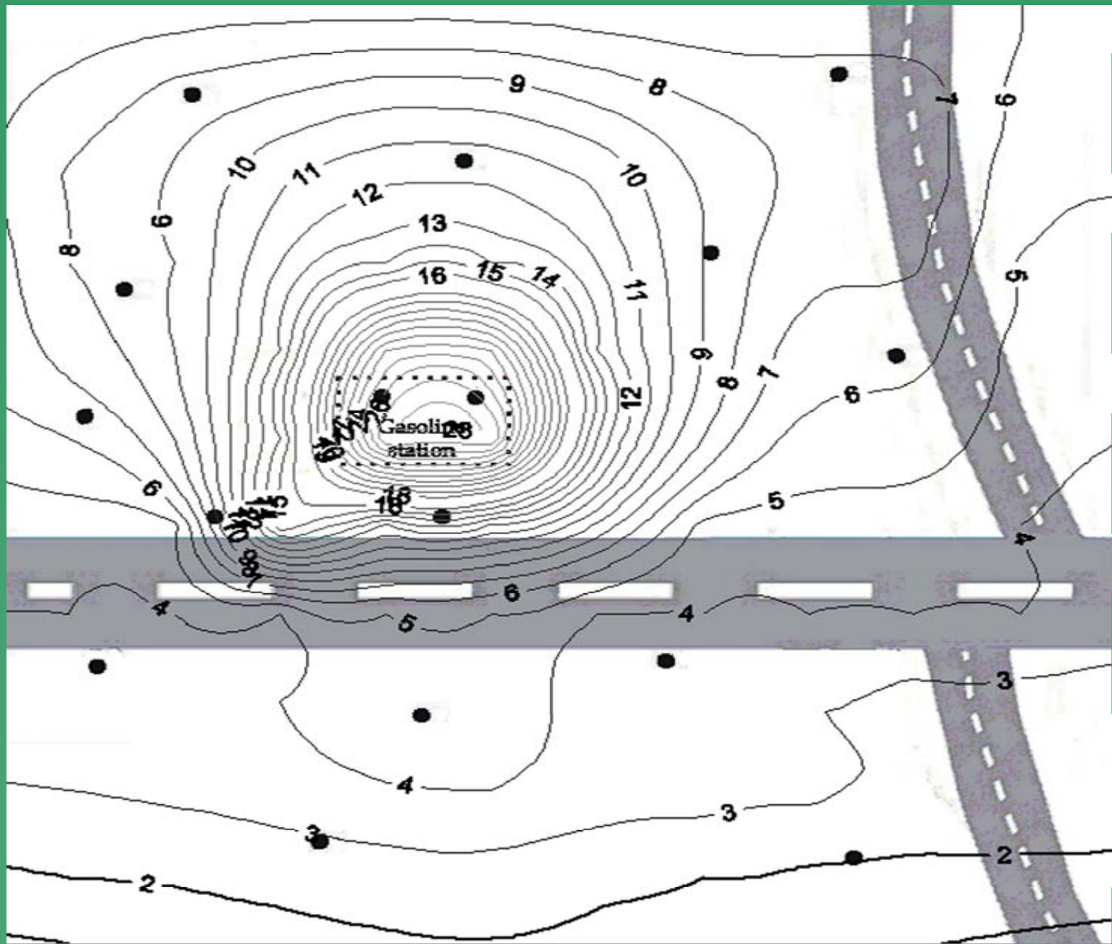
Benzene concentrations caused without the presence of petrol stations






N
NE
E
SE
S
SW
W
NW
50
40
30
20
10
0

Benzene conc caused by the petrol station in urban location

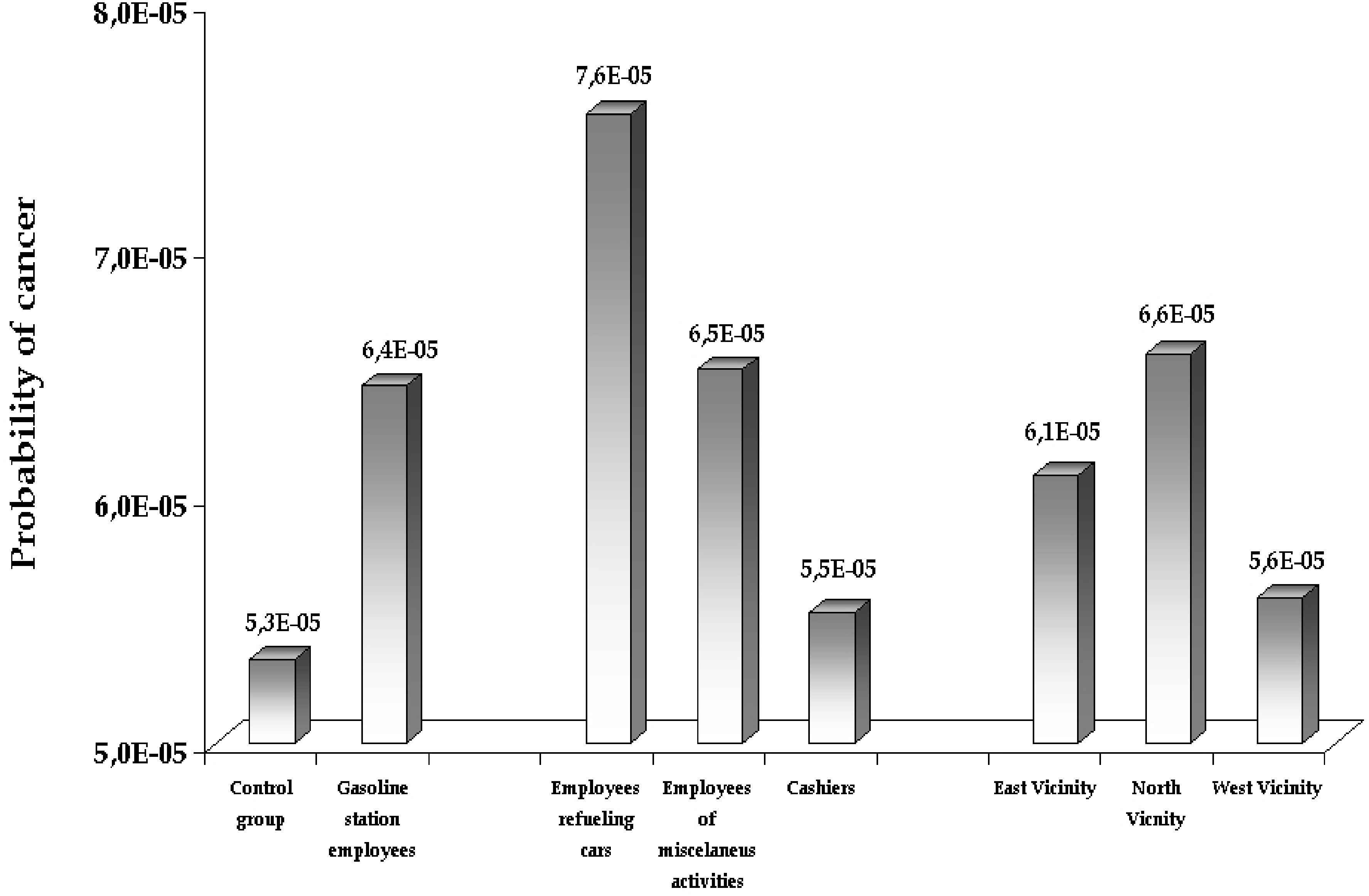


Hearth-Risk Evaluation

- Estimation of the Cancer Risk for benzene
- *R*=C(IUR)
- C benzene concentration (µg/m3)
- IUR inhalation unit risk estimate (probability of cancer for a 70-year exposure to 1 µg/m3)

Results

- Urban Station 72 people/million
- Suburban St 15 people/million
- Rural Station 2 people/million
- The risk of leukemia is increased by 21% in the north-west side of the petrol station
- The similar risk for the west side is increased by 3%


Probability of cancer
8,0E-05
7,0E-05
6,0E-05
5,0E-05
5,3E-05
6,4E-05
7,6E-05
6,5E-05
5,5E-05
6,1E-05
6,6E-05
5,6E-05
Control group
Gasoline station employees
Employees refueling cars
Employees of miscelaneus activities
Cashiers
East Vicinity
North Vicnity
West Vicinity

Concluding Remarks/1

- The contribution of the petrol stations to the formation of the total benzene concentrations observed is significant in all the examined environments (urban, rural, suburban)
- The population living at the vicinity is exposed to an additive concentration ranging from 3-6 μg/m3

Concluding Remarks/2

- The risk of leukemia caused by benzene alone is increasing from 3-21% depending on exposure times
- It is another risk (air, water and food chain) that is added to the other risks and should be addressed.

- Assessment and Prediction of short term hospital admissions

General concepts

Although the number of daily hospital admissions is a valid metric for assessing urban air pollution effects to public health, several shortcomings are raised related to:

- ***The net contribution of the meteorological parameters***
- ***Several forms of misclassification bias***
- ***Co-linearity among different air pollutants***
- ***The degree that ambient air monitoring represents human exposure***
- ***Harvesting resistance of health effects to air pollution***

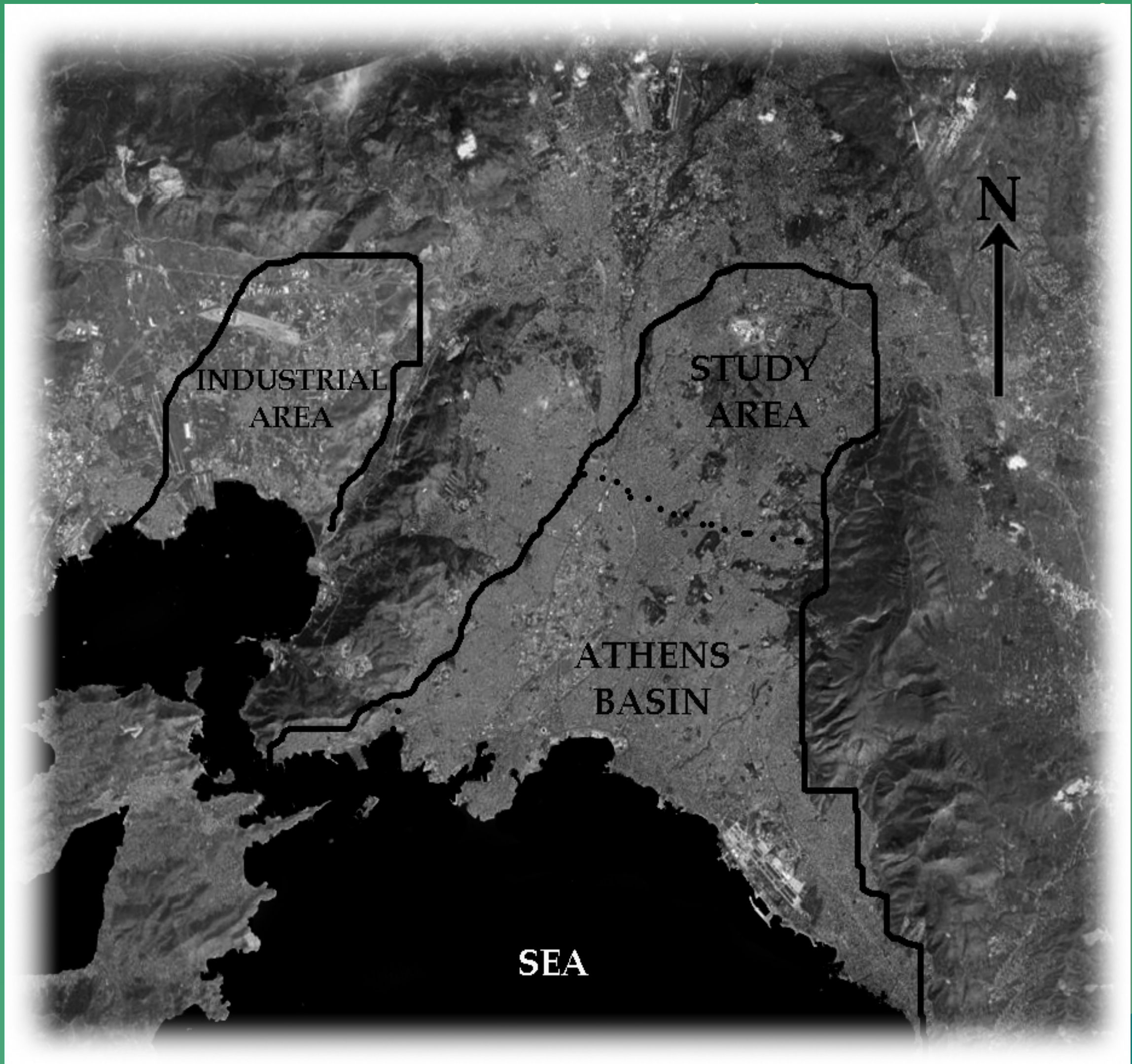
Methodological Approaches

✓Till now, the problem of hospital admissions was tackled by several forms of linear regression techniques

✓ Considering that the link among air pollution-meteorology –hospital admissions is governed by several non linear parameters, a methodology implementing more “flexible” and “adaptive” formulas should be welcomed

✓A new methodological approach is utilized in the hospital admissions issue that implements Artificial Neural Networks, and the obtained results are compared to them provided by a stepwise regression technique

Area under study – Athens



- Hospital admission data of the area related to **cardio-respiratory diseases**
- Air pollution data related to:
  - ✓ **CO**
  - ✓ **NO_2**
  - ✓ **SO_2**
  - ✓ **O_3**
  - ✓ **PM_X**
- Meteorological data related to
  - ✓ **Temperature**
  - ✓ **Humidity**
  - ✓ **Wind speed**
  - ✓ **Wind direction**

Results

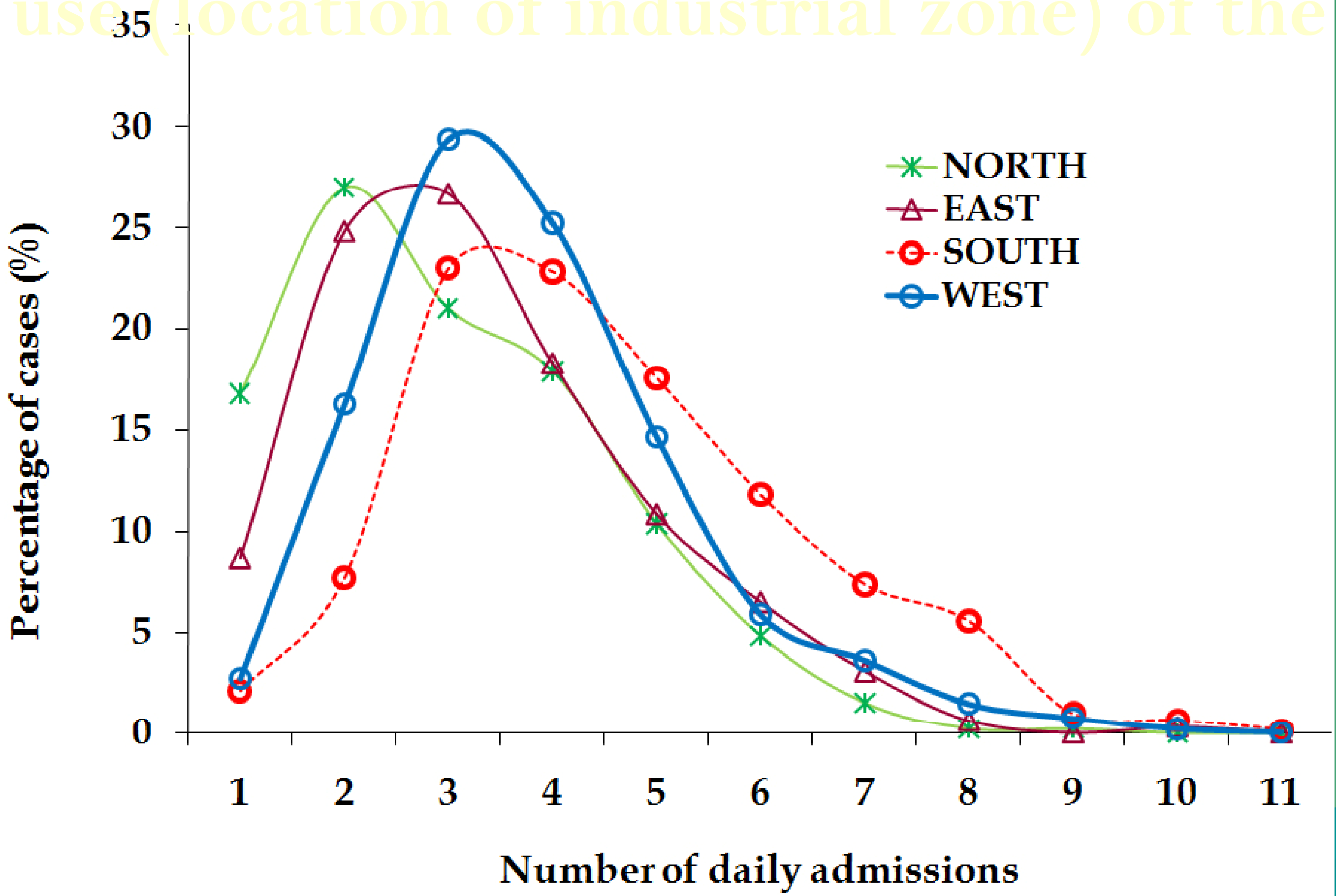
- **PM** keep a dominant role among the air quality parameters; a 10μg/m^3 concentration increase leads to a 10% increase of the number of daily hospital admissions

- **O_3** is also a pollutant with significant effect to public health and a 10μg/m^3 concentration increase leads to a 7.2% increase of the number of daily hospital admissions

- **SO_2**, NO_2 and CO are presenting a significant cross-correlation degree and a clear quantification of the their contribution although is also important (but less than PM and O_3)

Results

• The effect of wind direction to the number of daily hospital admissions is more than substantial and related to the topography (urban basin) and the land use (location of industrial zone) of the area



Days with more than more than **5 admissions**:

- **2%** of the days with **Northern** winds
- **15%** of the days with **Southern** winds

Results

• Temperature and humidity have a non linear influence; Very high and very low levels seem to increase the feeling of discomfort with an consequent increase in the number of hospital admissions

• In summer the combination of:

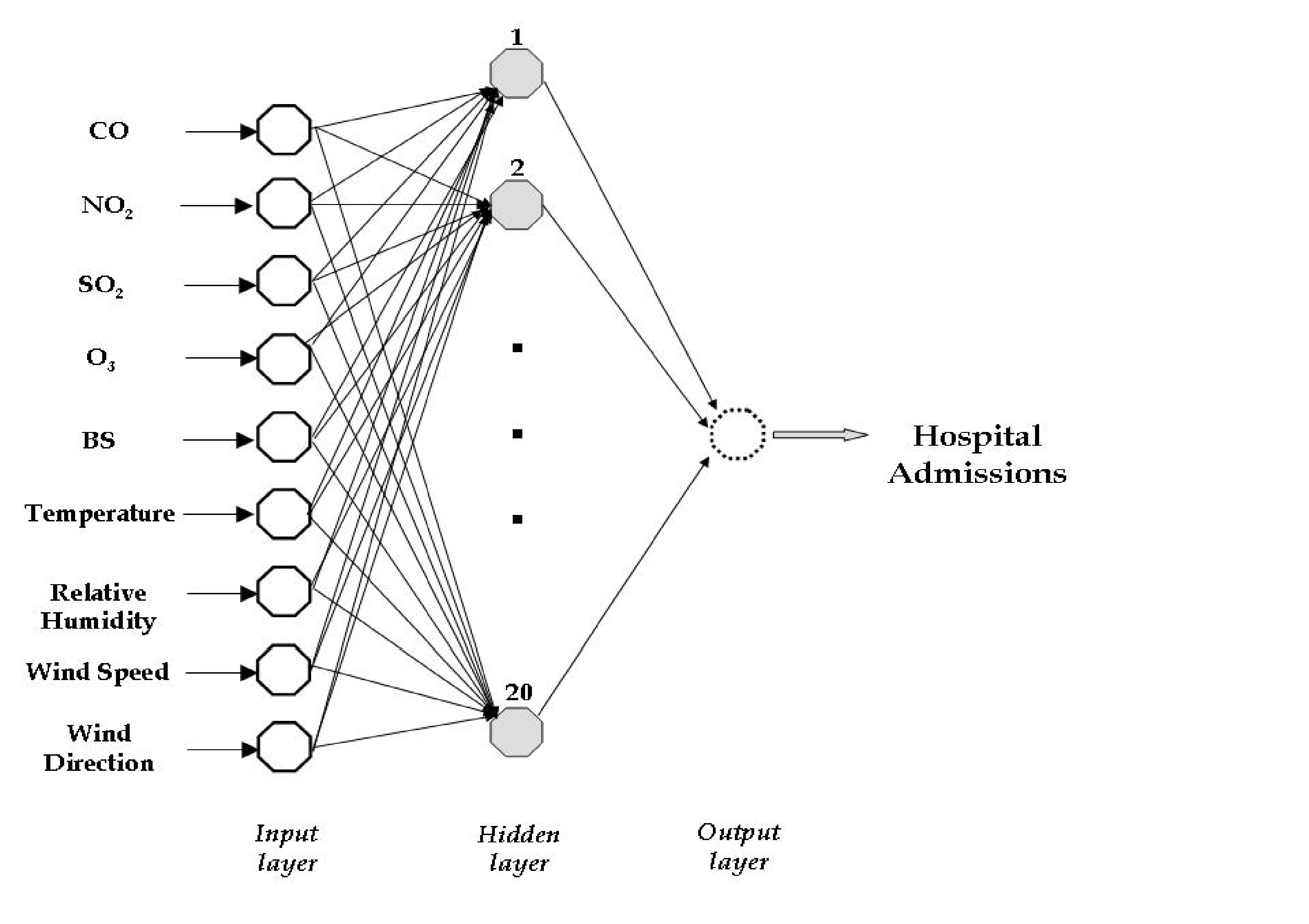
- *High temperatures*
- *Elevated humidity*
- *South-western winds which tend to accumulate pollutants*

Elevated number of hospital admissions

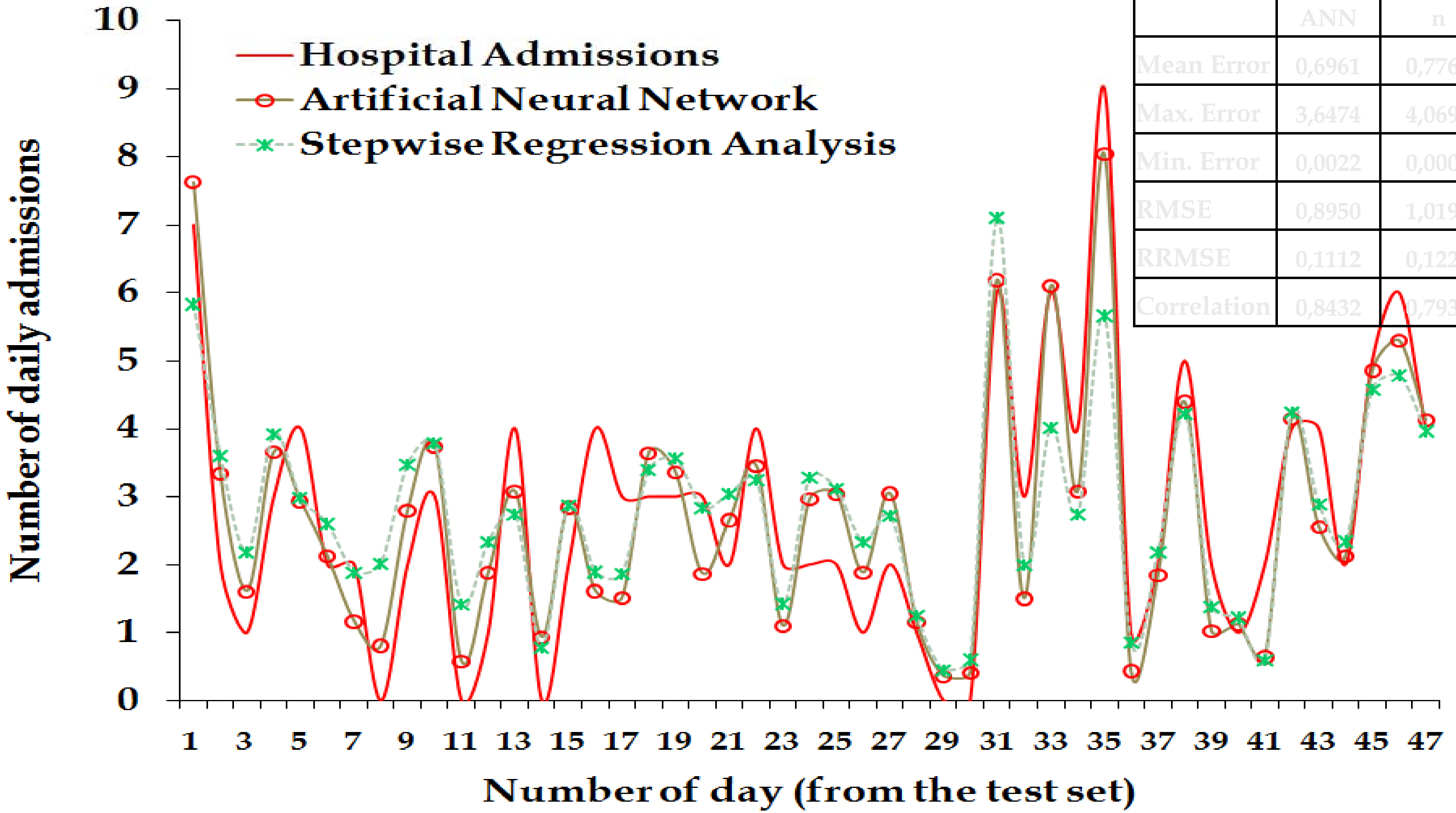
• Wind speed do not have a clarified role because is also depended in the direction, thus:

- *In North and Eastern direction winds that do not promote pollutants accumulation, the greater the speed, the less the hospital admissions*
- *South and Western winds that transfer pollution from the industrial zone do not have a clear influence based on the wind speed because the effect of pollution transfer is in contradiction to the increased degree of dispersion in the urban area*

Proposed ANN



Number of daily admissions vs ANN and stepwise regression predictions



	ANN	Regression
Mean Error	0,6961	0,7763
Max. Error	3,6474	4,0690
Min. Error	0,0022	0,0005
RMSE	0,8950	1,0198
RRMSE	0,1112	0,1225
Correlation	0,8432	0,7930

Relative Importance of the affecting parameters

• For the stepwise regression analysis, the standardized coefficient B was used as the indicator of relative importance among the parameters

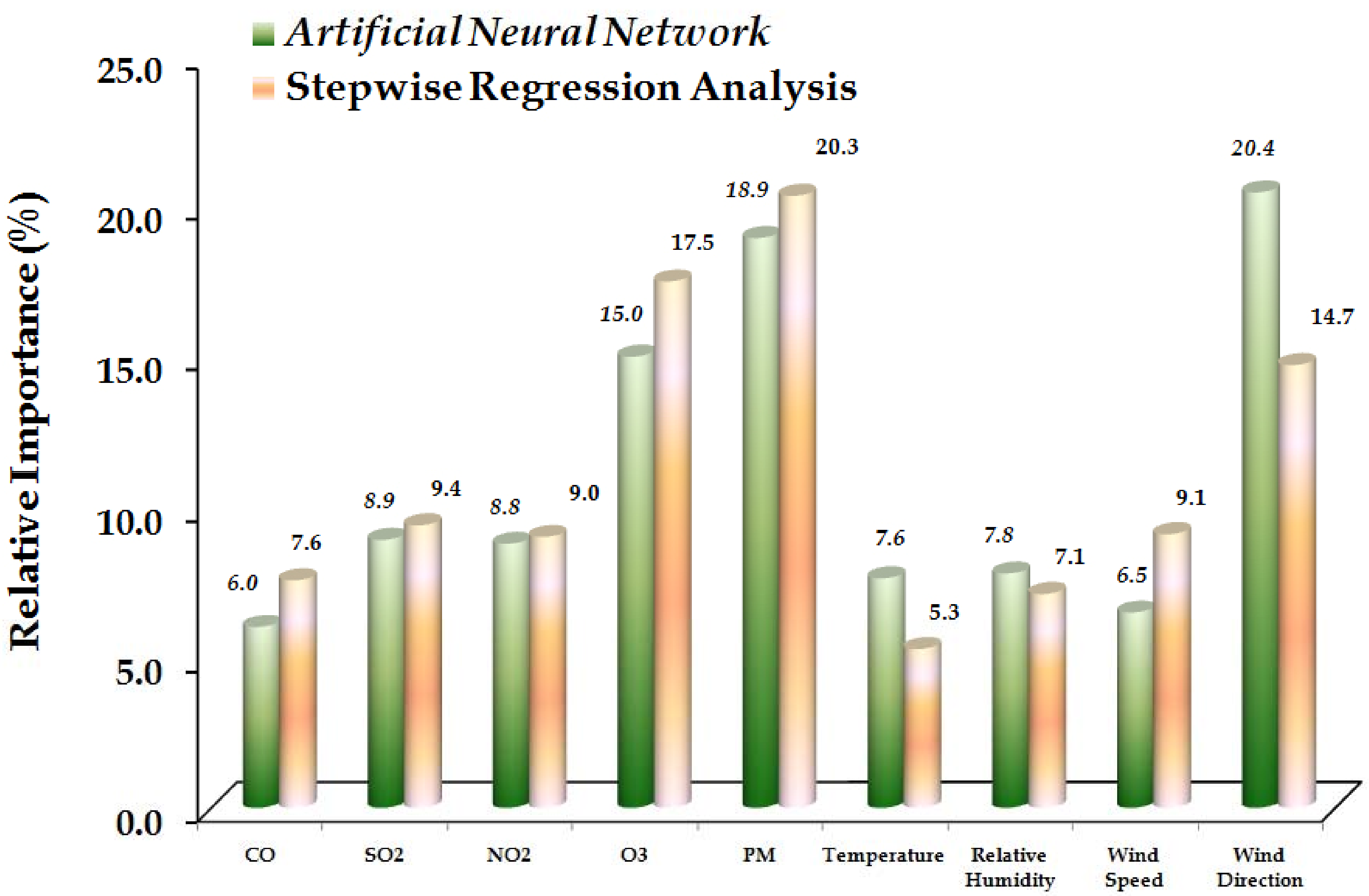
• For the ANN, the weights assigned to the connections between the layers of the ANN can provide information on the relative importance of each parameter

• The technique involves partitioning the hidden–output connection weights of each neuron into components associated with each input neuron

• The comparison of the results indicated that the ANN attributes a more significant role to the meteorology than the regression model

• Based on the fact that the overall performance of the ANN is better, the values attributed to the relative importance by that technique are considered as more reliable

Relative Importance of the affecting parameters



Concluding Remarks

• Events of increasing daily hospital admissions number is observed when a combination of air pollution and meteorological parameters concur

• The role of meteorology is dual:

- *Pollutants accumulation*
- *Increasing discomfort under very high and low values of temperature and humidity*

• Regression models tend to underestimate the role of meteorology due to:

- *Autocorrelation to pollutants concentration*
- *Non linear direct effects on human health*

• ANNs seem to be a promising technique in that kind of applications due to the multiple functions enabled for connecting the affecting parameters and adaptation in non-linear systems. Relative importance attributed to meteorology is a characteristic example

General Conclusions

- There is a correlation between weather types or parameters on mortality and morbidity due to cardiac diseases
- Particulate Matter plays a role when is associated with weather parameters and possibly increases the relative risk for mortality
- Benzene in association with met variables increases the possibility of cancer appearance especially in the vicinity in petrol stations
- Pollutant concentrations increase the hospital admissions due to respiratory and heart diseases

Thank you for your Attention