UNIVERSITY OF WESTERN MACEDONIA

Department of Mechanical Engineering

Environmental Technology Laboratory

Weather clustering approaches and air quality climatic trends in urban environments

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- The present study is in the frame of European founded H2020, ICARUS Project.

The ICARUS project's main objective is to develop integrated tools and strategies for urban impact assessment in support of air quality and climate change governance in EU Member States leading to the design and implementation of appropriate abatement strategies to improve the air quality and reduce the carbon footprint in European cities.

More information could be found in https://icarus2020.eu/

ICARUS

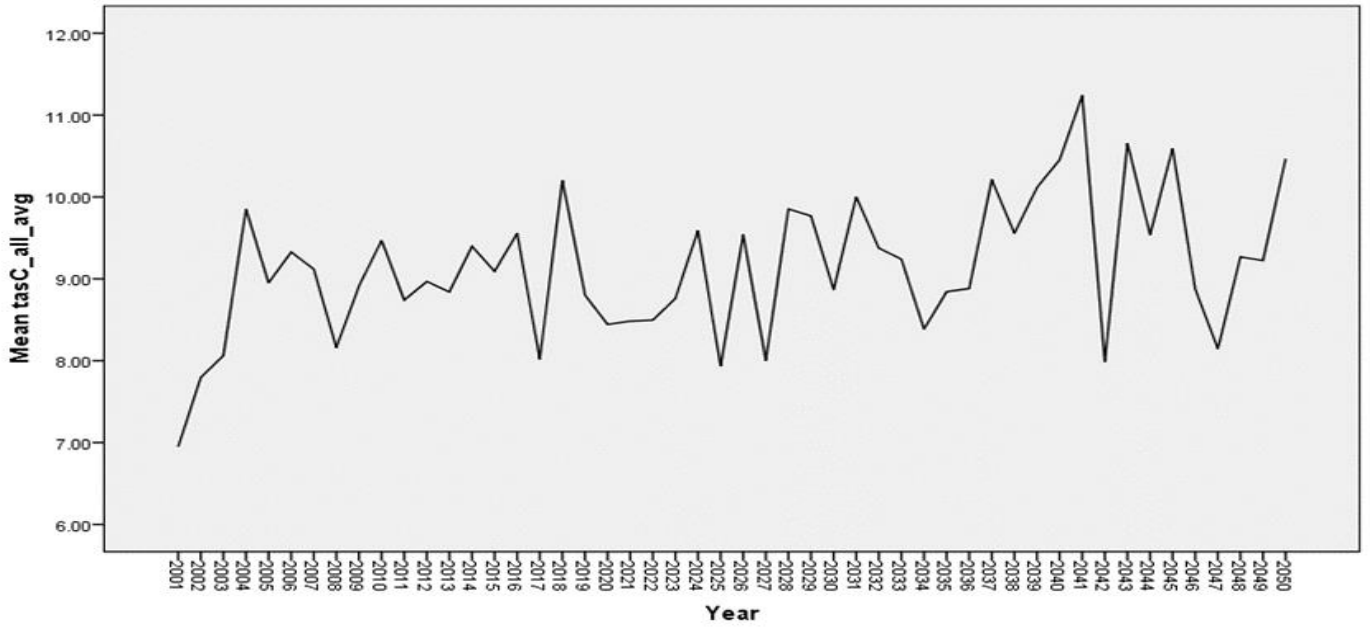
Motivation - I

- Climatic changes are expected to have a direct influence on local and urban air quality.
- Air Quality changes depend mainly on:
  - Weather patterns changes
  - Emissions patterns changes

Note: Weather pattern change studies have to take into consideration its **highly irregular temporal variation**.

Motivation -II

Example: A numerical prediction of yearly average temperature in the city of Stuttgart for the period 2001-2050



A logical approach → **Weather Clustering**

Aim of the study

- Use existing regional weather numerical data for 50 years (i.e. 2001-2050) to perform weather cluster analysis.
  - **EURO-CORDEX** Database
  - IPCC Fifth Assessment Report (AR5) climatic scenarios (**RCP4.5**)
- Identify weather trends with respect to time in terms, of the generated clusters 'frequency of occurrence'.
- Identify the clusters behavior with respect to air quality in terms of major hazardous pollutants concentrations (O_3, NO_2, PM) based on the existing data in the past period (2001-2015).

CASE STUDY: Stuttgart wider urban area.

Methodology

Following the climatic scenario RCP4.5 and using the set of the **CORDEX daily data (spatial resolution ~10km)** produced by **INERIS-WRF331F model** for the period **2001-2050**, specific weather patterns have been identified called **weather clusters** for the city of Stuttgart focusing on a 50km x 50km area around the city centre.

Step 1 - Data Selection and Collection

Step 2 – Principal Component Analysis(PCA)

Step 3 – K means Cluster Analysis

Cluster Identification

Step 1- Data Selection and Collection

The selected Weather parameters:

1. 2-meter temperature
2. daily temperature range
3. 2-meter relative humidity (%)
4. surface pressure
5. precipitation
6. 10- meter U-component wind velocity
7. 10-meter V-component wind velocity
8. downward short-wave surface radiation
9. atmospheric boundary layer thickness

Each of the above parameters has been averaged over the selected 50km x 50km city domain.

Step 2- PCA

Principal component analysis (PCA) enables us to transform a number of (possibly) correlated parameters (such as the abovementioned weather parameters into a (smaller) number of uncorrelated variables called principal components

Step 3- k-means Cluster Analysis

- Cluster analysis is a statistical method able to identify, from a large dataset, subgroups with some degree of homogeneity.

- **k-means method** seems to perform well through various methods in the field of weather pattern identification.

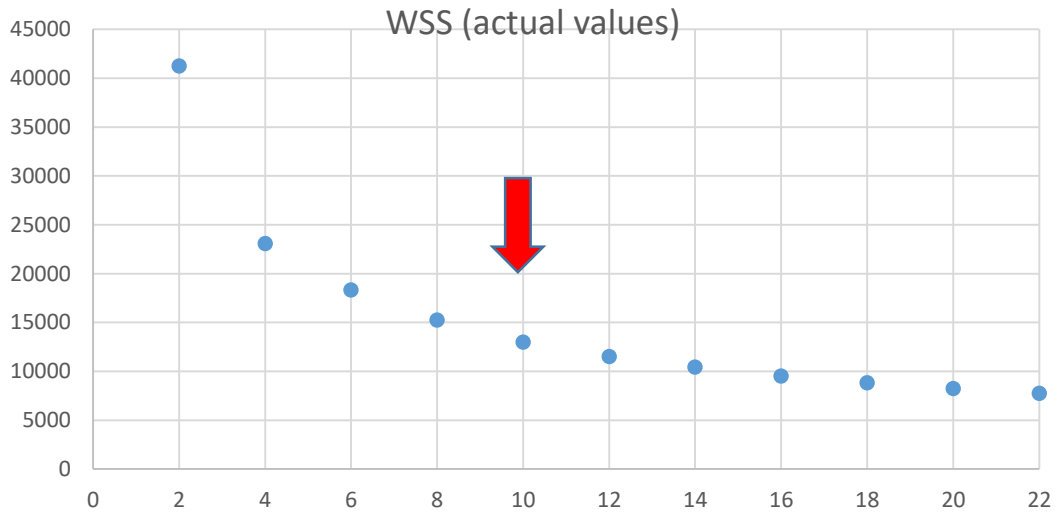
- In the k-means cluster analysis, a number of **n** vectors is partitioned to preselected **k** groups called clusters.

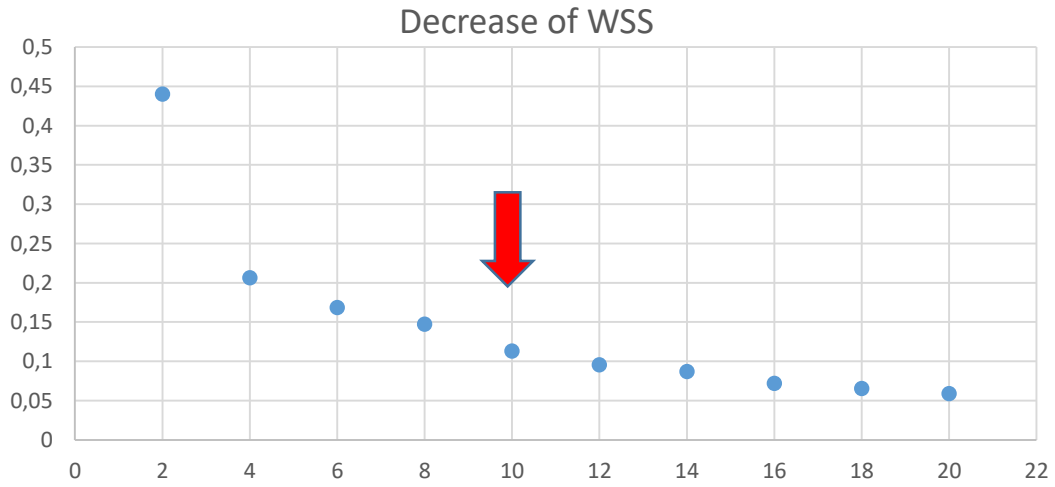
k-means Cluster Analysis Results

$$WSS(k) = \sum_{n=1}^{k} \sum_{x \in Ci} || x - zi || ^2$$

where x denotes all data objects belonging to the cluster Ci; zi is the ith corresponding cluster centroids (CC).

$$fractional\ decrease\ in\ WWS(k) = \frac{WWS(k) - WSS(k+1)}{WWS(k)}$$

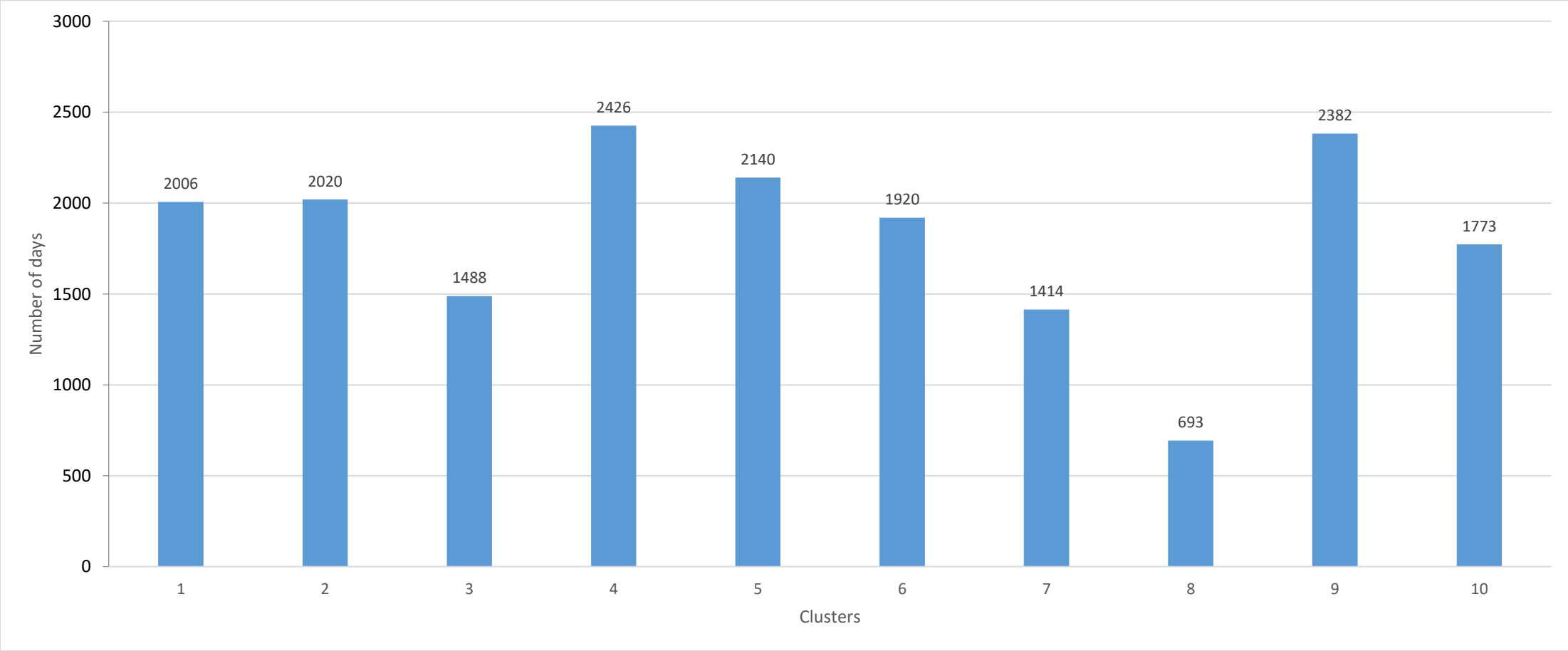




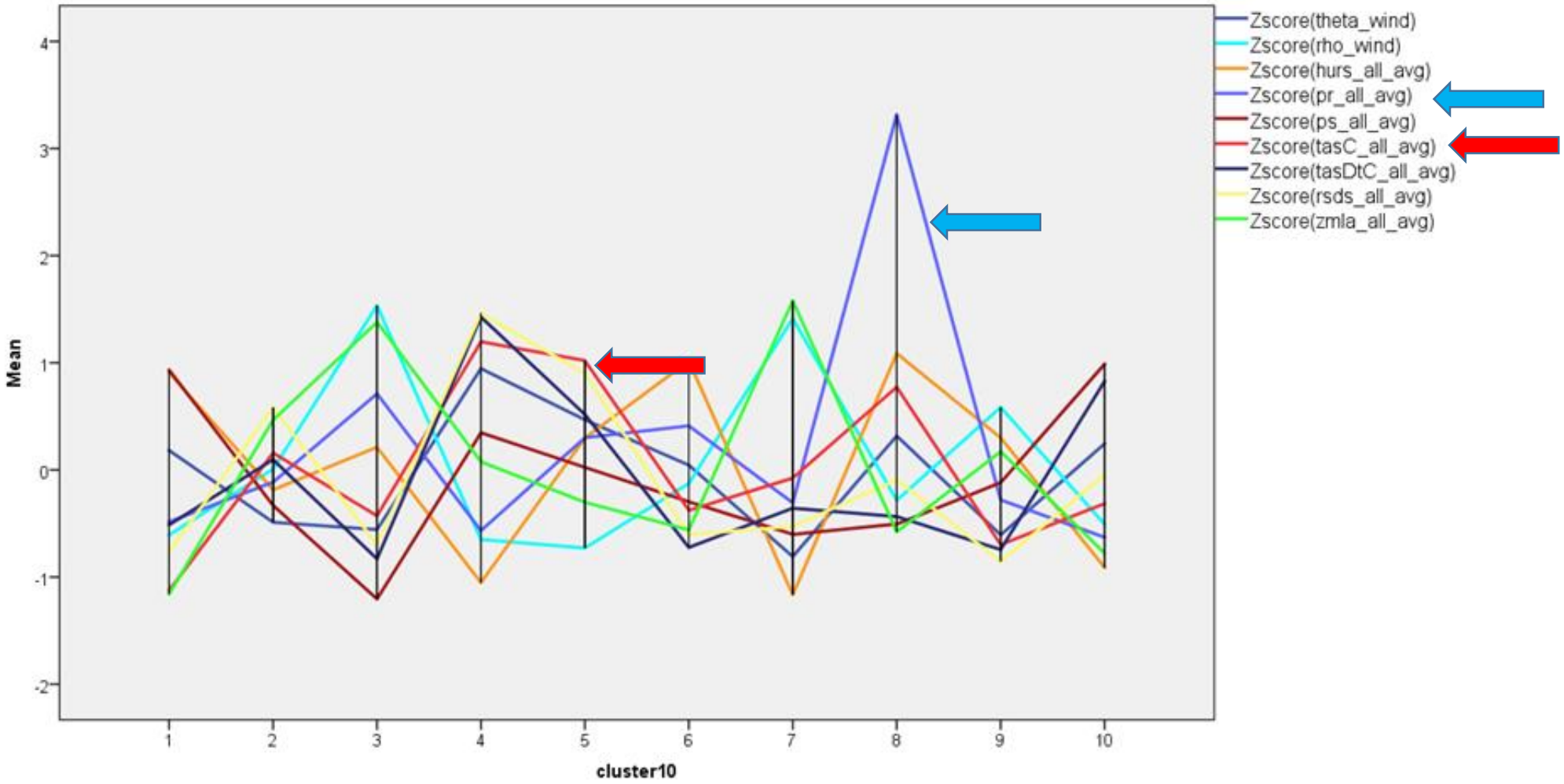
Clusters interpretation methodology

- ***Clusters characterization :*** It is mainly based on the weather parameters statistics (Average, SD, Min, Max) as well as wind patterns.
- **Cluster frequency of occurrence** along the 50yr period as **a climatic change indicator** (use a 5-year time step).
- **The clusters associated with elevated concentrations** for the priority air pollutants (e.g. NO_2, O_3, PM).

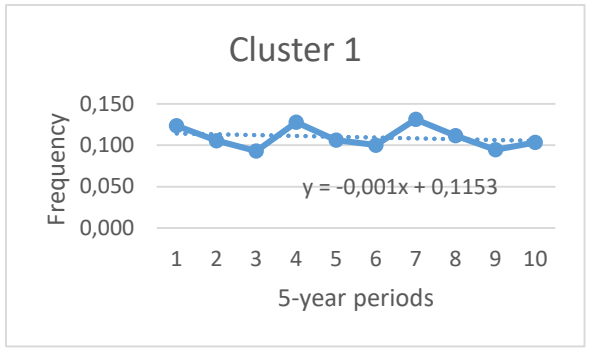
Results - Days distribution

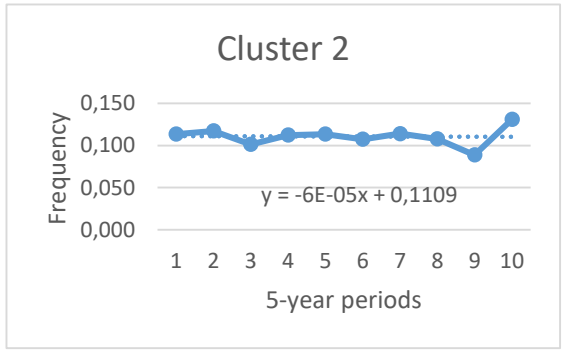


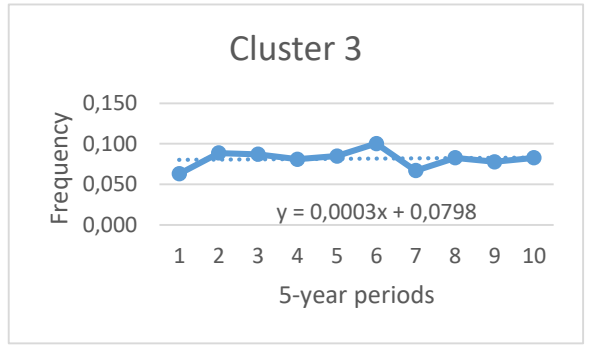
Results – Weather variables averaged per cluster

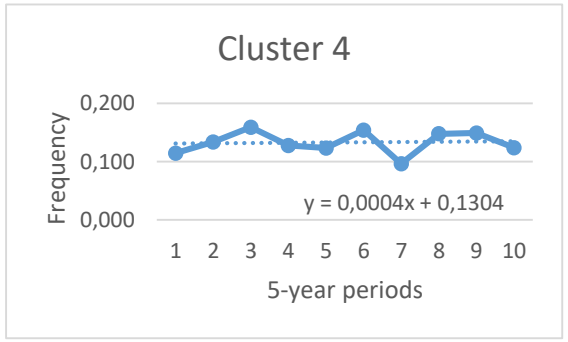


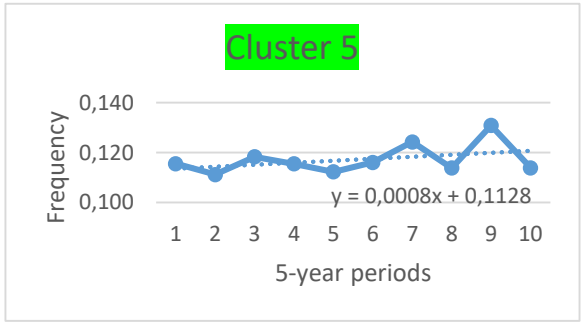
Results - Cluster trends

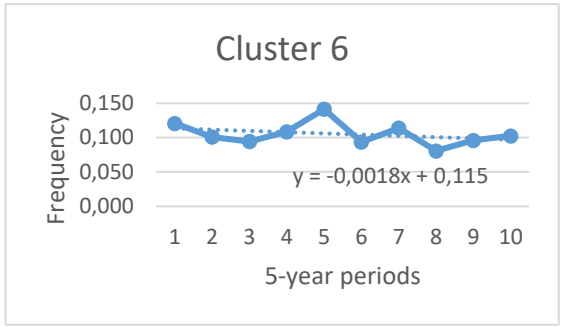


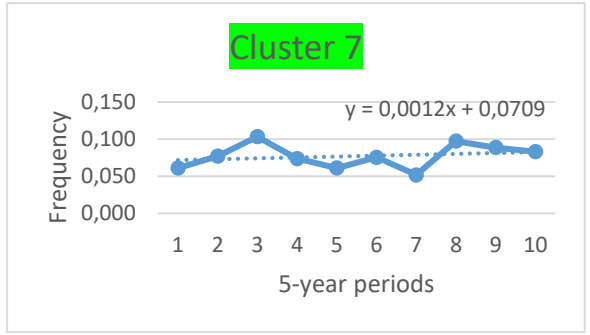


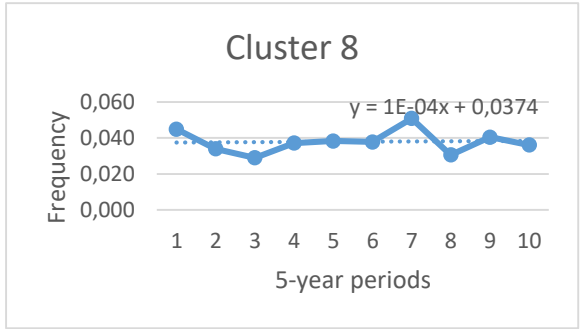


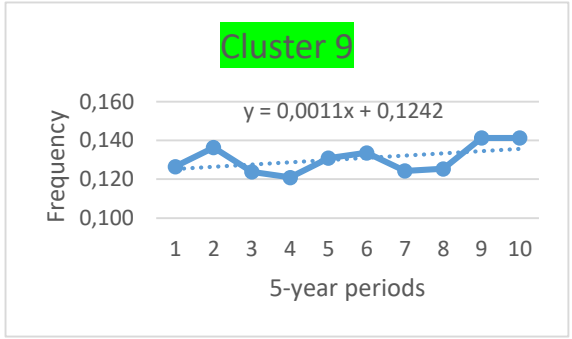


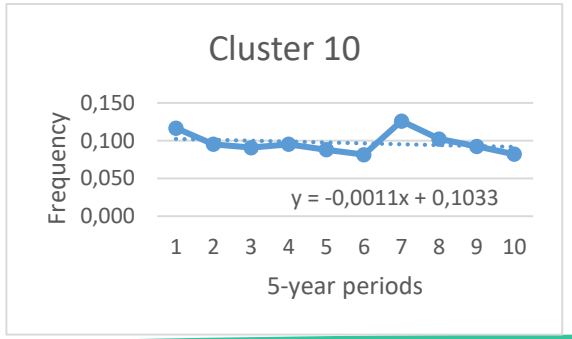






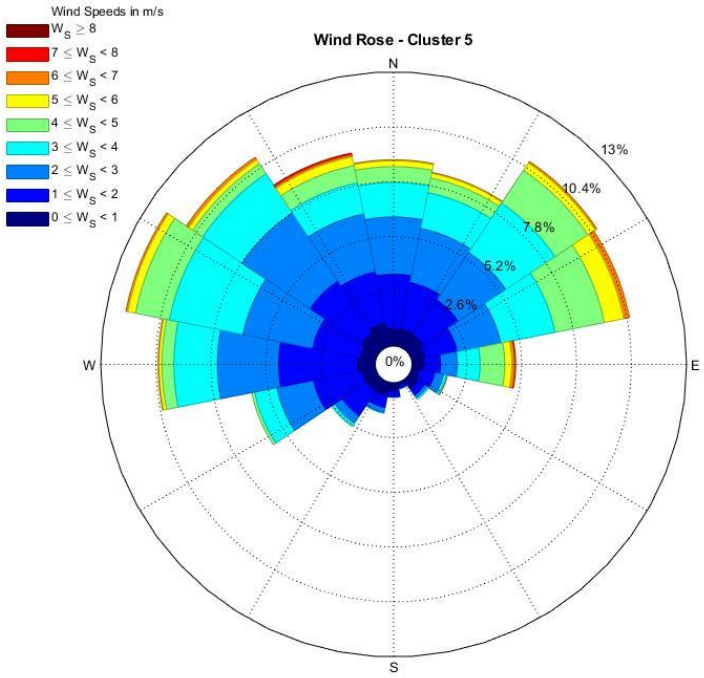


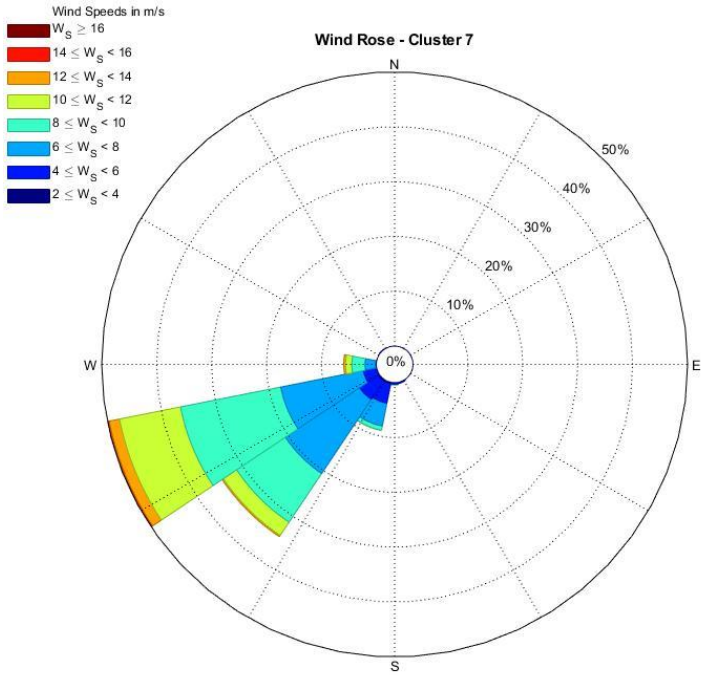


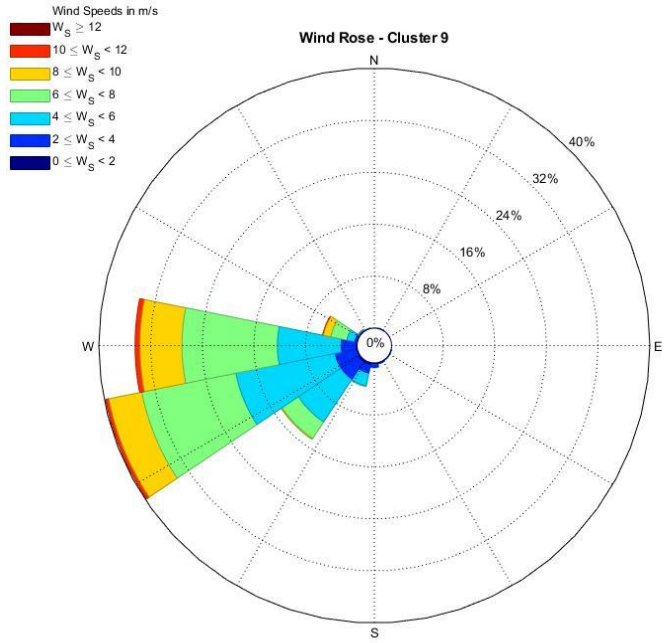


Results - Prevailing Wind directions

Examples of wind direction for 3 selected clusters

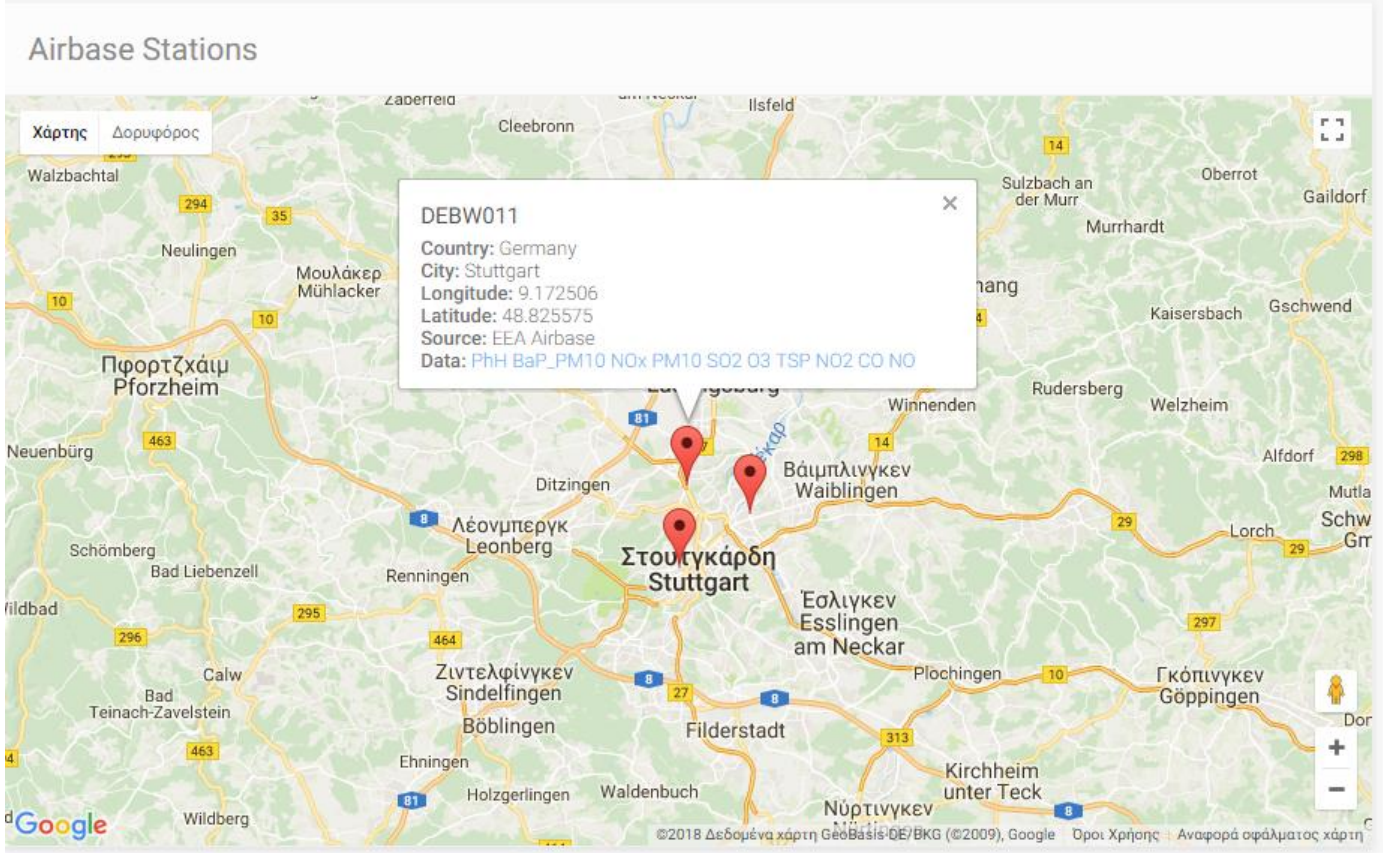




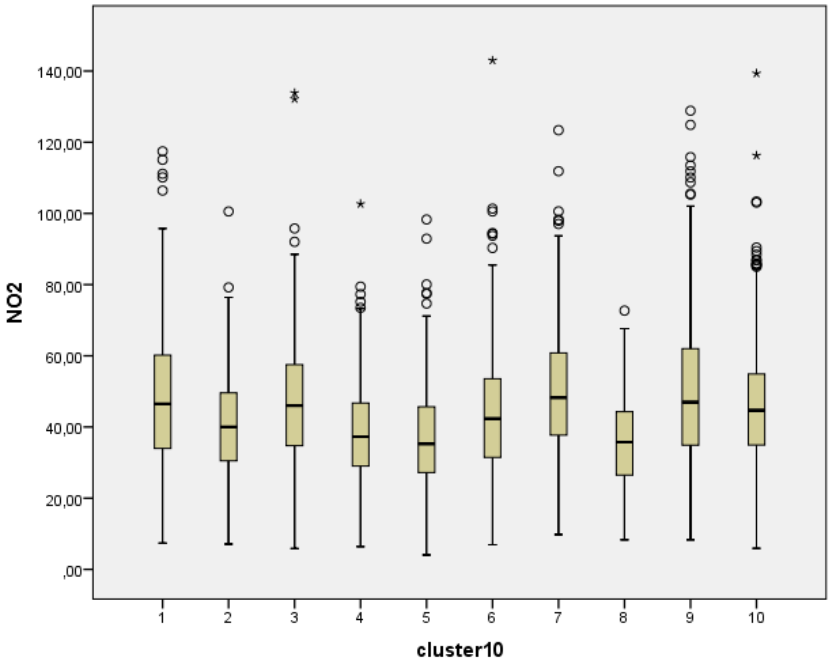


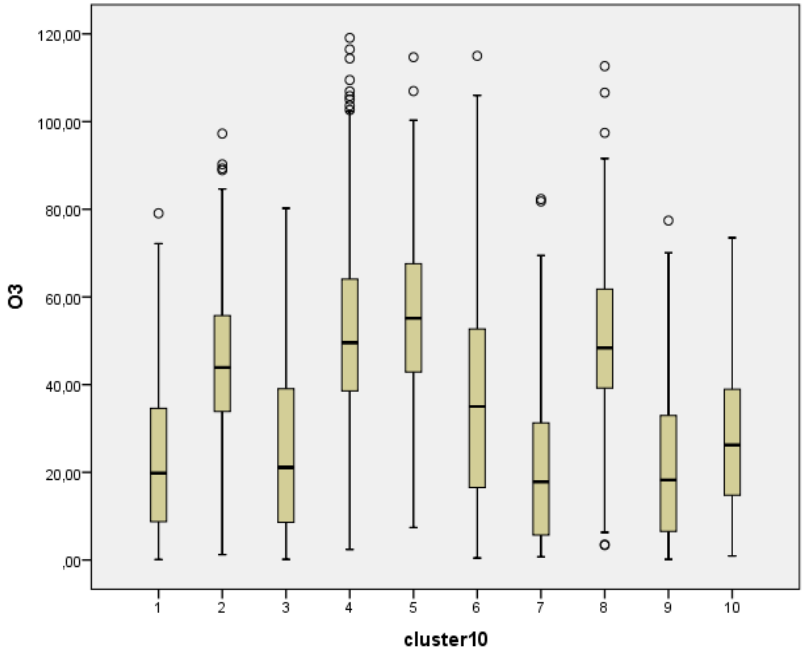
Results - Characterize the clusters with respect to air pollution levels – The Air Pollution Data

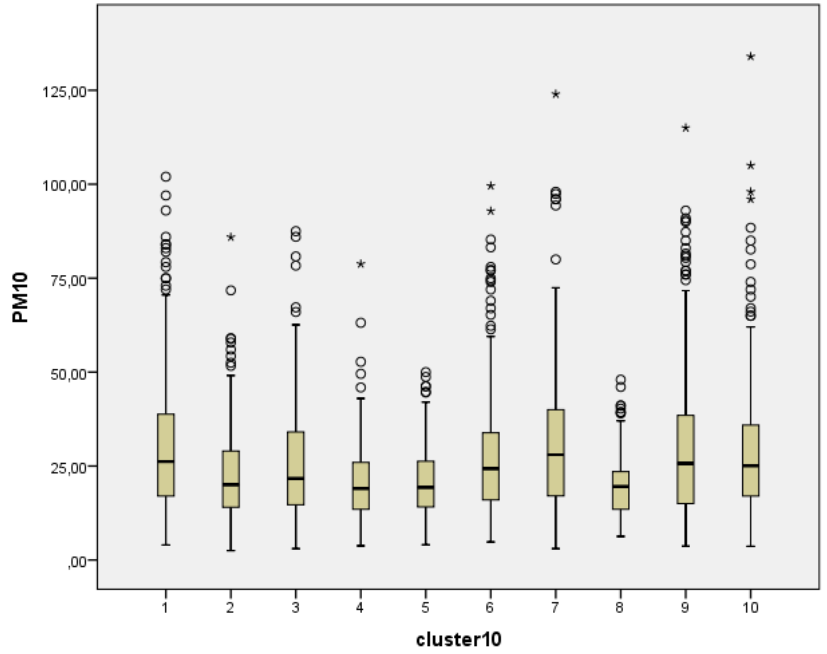
EEA data derived from HEALS EDMS (http://heals.uowm.gr/)- Meteorological stations DEBW011&13



Results – Clusters vs Air pollutants







Stuttgart - Clusters vs Air Pollutants

- Elevated NO2 : Cluster 7
- Elevated O3 : Cluster 5
- Elevated PM10 : Cluster 7

Concluding Remarks and Future work

- A novel approach based on weather clustering is inaugurated to study climate change effect on air quality levels

- With respect to **cluster frequency trend over the 50year period** slight changes are observed**.** More specifically**:**

  - The clusters associated with elevated PM show an increase in Stuttgart area.
  - The clusters with elevated NO_2 concentrations show also an increase.
  - The cluster associated with elevated O3 show a slight increase.

- Detailed Modeling studies are on the way to reveal pollutants concentrations time trends

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Ευχαριστώ
Thank you

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