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Seasonal Cycles of Atmospheric Ion and Aerosol Concentrations in an Urban Area

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Abstract: Here, the results of monitoring campaign on cluster ions and aerosol concentrations are presented. This measurement procedure was carried out in an urban center, Shkodra City. During this campaign there are measured continuously the concentrations of both ions and aerosols. The measured ions belong to the cluster ion category while measured aerosol particles belong to fine and coarse modes. After monitoring process, measurement data undergo a statistical analyze to obtain the seasonal cycles of these concentrations. These variations let us to estimate the contribution of varying factors on their concentrations as well as their reciprocal interactions. Seasonal variations of ion concentrations show maximums during warm seasons and minimums during cold seasons. In the case of aerosol concentrations, their seasonal variations strongly depend on the aerosol modes.

Key words: Atmospheric ion concentrations, aerosol concentration, seasonal cycles, cluster, Albania

INTRODUCTION

Atmospheric ions have recently been measured by Dhanorkar and Kamra (1994), Hensen and van der Hage (1994), Wilkening (1985) and Mochizuki *et al.* (1977). Considering different locations, the ionization rate could exhibit considerable variation depending on the content of radioactive substances in the ground, on the soil properties, on the water content of the snow cover, etc. The measurements below 1 m strongly depend on the ionization profile. The ionization rate decreases with altitude near the ground up to about 1-2 km and increases with altitude with a maximum of about 50 ion pairs/ cm^3/sec^1 near 15 km (Rosen *et al.*, 1985; Hoppel *et al.*, 1986).

The air ions were discriminated as small ions (charged molecular aggregates of the diameter of <2.5 nm), intermediate ions (charged aerosol particles of the diameter of 2.5-8 nm) and large ions (charged aerosol particles of the diameter of 8-20 nm). Statistical characteristics of the ion concentrations and the parameters of ion balance in the atmosphere are presented separately for the nucleation event days and non-event days (Horrak *et al.*, 2008).

Small positive and negative ions are generated in the atmosphere mainly by cosmic radiation and natural radioactivity. Two concurrent processes, ion-ion recombination and adsorption of small ions by aerosol particles are responsible for the loss of small ions. The simplified balance equation of small ions in a bipolar environment, considering equal numbers of positive and negative small ions and symmetrical charging of aerosol particles can be written as (Hoppel and Frick, 1986):

$$\frac{dn}{dt} = q - \alpha n^2 - \beta_{eff} N_{tot} n \quad (1)$$

The time constant of the transfer to the steady state condition (dn/dt = 0) is about 1 min in the continental boundary layer air. The importance of air ions in the particle formation processes has been shown in several laboratory experiments. The mobility spectrum of small ions is sensitive to the content of many trace species (gases or vapors at concentrations below 1 part per billion) in the air giving rise to certain specific ion families with characteristic mobilities (Nagato and Ogawa, 1998; Parts and Luts, 2004).

The formation and growth of ultrafine aerosol particles in the atmosphere have been studied during the last decade at many different locations around the world because of their possible impact on the radiation balance and thereby on the climate of the earth (Birmili *et al.*, 2003; Iida *et al.*, 2006; Tunved *et al.*, 2003; Kulmala *et al.*, 2004). In this region many other monitoring campaigns for ion and aerosol research are carried out (Mandija *et al.*, 2010; Mandija, 2011a, b).

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MATERIALS AND METHODS

Monitoring process was carried out during the period August 2011 to 2012 for about 13 months. During this period researchers have extracted values of ion and aerosol concentrations in order to construct the seasonal variations.

Measurements under fair weather meteorological conditions excluding rainy days and days associated with strong winds. Measurements of atmospheric ions, aerosol particles and meteorological parameters were realized in 1-2 m altitude above the ground. In order to obtain reliable results for variations of ion and aerosol concentrations, measurement site was fixed on a same location. This site was located in the urban area of Shkodra which is a city with a population of about 120,000 inhabitants.

Measuring site is distanced by 120 m from the main road of the city and separated from it by several 15 m high buildings. Researchers have measured the values of ion and aerosol concentrations during each month. Then, there are averaged these values according to their seasons to obtain season variations of these concentrations.

Measurements of atmospheric ions are made using two types of air ion counters; Models ITC 201A and AIC. Principal specifications of both air ion counters used in our monitoring campaign are presented in Table 1.

Both ion counters are composed of two parallel plates which according to their polarity (user selective) can collect air ions entering into their inner space. Aerosol concentrations were measured simultaneously with atmospheric ions. The instrument used for measurements of aerosol concentrations is a handheld particle counter, Model HandiLaz mini 301. This instrument measures aerosol number concentrations up to the maximum value 2.10^6 particles/ft^3. Flow rate of instrument is 2.83 L min^{-1}. Operation principle is light scattering. Based on the intensity of light scattered by aerosol particles, aerosols can be numbered in the different size channel. The measurement instrument measures aerosol concentrations in the size range 0.3-100 μm, dividing in three channels with thresholds on 0.3, 0.5 and 5.0 μm.

For measuring meteorological parameters like air temperature, relative humidity, atmospheric pressure and wind speed, researchers have used information from the weather station Davis, Vantage Pro2 Plus™. This weather station is located quite near the measurement site in a distance about 100 m.

Table 1: Principal specifications of air ion counters

Models	Flow rate (cc sec^{-1})	Max. Conc. (PCs/cc)	Ion mobility (cm^2/VS)
Model ITC 201A	500	1,236,000	0.5
Model AIC	800	2,000,000	0.6

RESULTS AND DISCUSSION

Monitoring results of atmospheric ion concentration are expressed as average values over each season of the year. Table 2 shows values ion concentrations over four seasons. Measurement instrument classifies aerosol particles into three channels, according to their size. For every measurement process, researchers obtain three aerosol concentration values. These three aerosol groups are described as follows:

- Fine: size range 0.3-0.5 μm
- Mixed: size range 0.5-5.0 μm
- Coarse: size range 5.0-100 μm

Table 3 shows values aerosol number concentrations over four seasons of the year. Meteorological parameters were recorded during the entire monitoring campaign. Every measurement process is associated at the same time also with measurement of meteorological parameters. Table 4 presents seasonally averaged values of meteorological parameters.

Based on the values of Table 2-3, researchers construct seasonal variation of ion concentrations. These variations are presented graphically by Fig. 1.

Table 2: Seasonal ion concentrations

	Negative polarity (cm^{-3})			Positive polarity (cm^{-3})			Total ions (cm^{-3})		
Seasons	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.
Spring	743.7	250	1600	1539.3	230	2700	2282.0	480	4300
Summer	1293.5	500	2000	1841.3	1000	2550	3134.8	1800	4550
Autumn	656.4	60	2000	1655.3	650	2500	2311.7	710	4500
Winter	492.5	80	800	1525.1	350	1900	2017.6	430	2400

Table 3: Seasonal aerosol concentrations

	Fine aerosols (10^6 m^{-3})			Mixed aerosols (10^6 m^{-3})			Coarse aerosols (10^4 m^{-3})		
Seasons	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.
Spring	3.40	1.27	4.50	0.64	0.10	1.60	7.37	0.64	32.0
Summer	3.68	1.16	4.35	0.69	0.08	1.94	10.2	1.91	29.0
Autumn	3.75	1.90	4.54	1.48	0.27	3.18	8.54	0.85	13.6
Winter	3.52	1.51	4.98	1.88	0.43	3.50	6.36	0.64	20.1

Table 4: Seasonal meteorological conditions

Seasons	Temperature (°C)	Relative humidity (%)	Atmospheric pressure (hPa)	Wind speed (km h^{-1})
Spring	22.2	48.7	1017.9	0.87
Summer	31.7	44.3	1012.4	0.43
Autumn	22.5	65.6	1017.2	0.13
Winter	13.4	62.9	1015.6	0.33

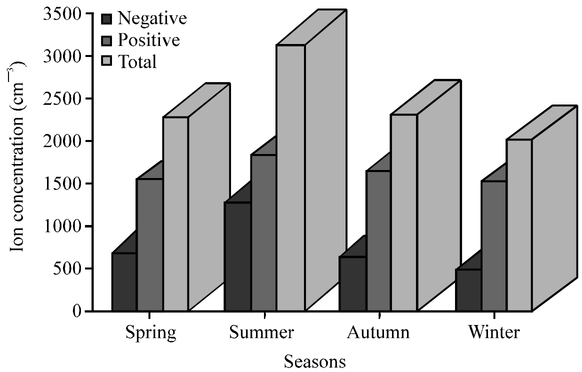

Fig. 1: Seasonal variations of ion concentrations

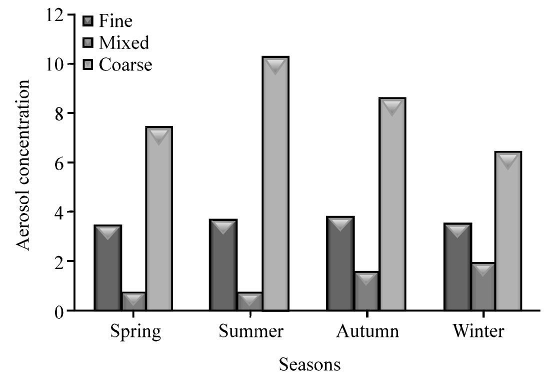

Fig. 2: Seasonal variations of aerosol concentrations

Figure 1 present overall results of the ion concentrations. From this Fig. 1, researchers see that maximal concentrations were obtained during the warm season while minimal values during cold season. Let introduce the coefficient:

$$k = \frac{\text{Standard deviation}}{\text{Average}}$$

This coefficient takes the values 0.44 and 0.09 for negative and positive polarities. The low value of positive polarity shows the smooth season variation of the concentrations of positive polarity. Meanwhile, the concentrations of negative polarity are more sensitive to seasonal variations. During the summer season the temperature is higher and this factor influence on radon exhalation. Another factor which explains the maximal ion concentrations during summer season is the enrichment of photochemical processes. Meanwhile during winter season, sometimes the ground surface is covered by snow which prevent radon exhalation from the ground. This is the major reason of low ion concentrations during the cold season. Season variations of aerosol concentrations are presented in Fig. 2.

Figure 2 shows that the seasonal variation of the total concentrations of aerosols (fine aerosols make the major part of their total number) is almost smooth. The coefficient k in this case is only 0.04. This concentration is considered as a background concentration in this area. The concentration of fine aerosols is influenced by local sources and by the mechanism of long range transport. In the case of coarse aerosols, the maximums during warm seasons and the minimums during cold seasons. This is mostly related to resuspension processes during dry conditions on the ground surface.

Let us determine correlations among ion concentrations and other influencing factors (concentrations of fine aerosols and meteorological parameters). Table 5 shows the parameters (intercept and slope) of linear regression analysis on the data of ion concentrations and influencing factors.

Table 5: Parameters of multiple regression analysis

Parameters	Intercept value	Intercept error	Slope value	Slope error	Statistics Adj. R^2
B	-2244.4	6979.2	1944.0	1944.0	-0.20511
C	1058.6	341.1	61.4	14.6	0.84753
D	4313.5	1248.7	-33.9	22.2	0.30552
E	160144.3	87956.2	-155.3	86.5	0.42473
F	2419.5	565.3	38.7	1094.2	-0.49906

In the first column there are these correspondences; B: Aerosol concentration; C: Temperature; D: Relative humidity; E: Atmospheric pressure; F: Wind speed

The relationships of ion concentration; positively related to aerosol presence, temperature, wind speed and negatively related to relative humidity and atmospheric pressure. Usually ion concentrations are negatively related to aerosol presence but in this case their sources have both the same variation of their activation. Temperature stimulates the process of radon exhalation from the ground. This fact argues the positive relationship of ion concentrations to temperature. The increase of atmospheric pressure increases the concentrations of atmospheric aerosols. Because of attachment processes which occur among ions and aerosols, the concentration of ions is reduced in the presence of aerosol particles (Mandija, 2011a, b; Mohnen, 1977). This is the explanation of negative relationship of ion concentrations and atmospheric pressure.

CONCLUSION

During the monitoring campaign carried out over a 1 year period are obtained many interesting results. Meteorological parameters take normal values during measurement processes. Seasonal variations of ion concentrations show maximum during warm and minimum during cold seasons. The seasonal variation of positive ion concentrations are smother that those of negative ions. Seasonal variations of fine aerosols are very smooth. Meanwhile the variation of coarse aerosols shows maximum during summer months and minimum in Winter.

Ion concentrations are positively related to aerosol concentrations, temperature and wind speed. On the other hand these concentrations are negatively related to relative humidity and atmospheric pressure. The overall results of this monitoring campaign give a clear picture on atmospheric particle concentrations over the investigated area.

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