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Aerosol and gamma background measurements at Basic Environmental Observatory Moussala

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Abstract: ***Trans boundary and local pollution, global climate changes and cosmic rays are the main areas of research performed at the regional Global Atmospheric Watch (GAW) station Moussala BEO (2925 m a.s.l., 42°10'45'' N, 23°35'07'' E). Real time measurements and observations are performed in the field of atmospheric chemistry and physics. Complex information about the aerosol is obtained by using a three-wavelength integrating Nephelometer for measuring the scattering and backscattering coefficients, a continuous light absorption photometer and a scanning mobile particle sizer. The system for measuring radioactivity and heavy metals in aerosols allows us to monitor a large scale radioactive aerosol transport. The measurements of the gamma background and the gamma-rays spectrum in the air near Moussala peak are carried out in real time. The HYSPLIT back trajectory model is used to determine the origin of the data registered. DREAM code calculations [2] are used to forecast the air mass trajectory. The information obtained combined with a full set of corresponding meteorological parameters is transmitted via a high frequency radio telecommunication system to the Internet.***

Keywords***: atmospheric physics, aerosols, radioactive aerosols, gamma background***

Introduction

A unique facility was established in 1999 and has been operated since then by the Institute for Nuclear Research and Nuclear Energy of the Bulgarian Academy of Sciences, namely, the Moussala Basic Environmental Observatory (BEO). The Observatory's location was chosen after a careful consideration. Moussala Peak in Rila Mountain National Park, Bulgaria, being the highest peak in the Balkan Peninsula, is an important reference point for assessing the anthropogenic influence in the large South-East European region. BEO Moussala possesses modern infrastructure and equipment for scientific investigations. The station has a long tradition as a high-mountain scientific facility, as a cosmic rays observatory since the late 1950s, and, later on, as a complex ecological observatory. The study of the high-mountain environmental

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parameters (meteorology, atmospheric physics and chemistry, background radiation, and cosmic rays), as measured at BEO Moussala, gives the possibility of a comprehensive evaluation of the anthropogenic and biogenic impacts on the climate. The meteorological conditions of BEO Moussala operation are extreme, as are the phenomena and processes studied, namely, extraordinarily quickly changing air, space and environmental parameters under high-mountain conditions. Being equipped with modern devices for following atmospheric processes, BEO Moussala fulfilled the technical requirements for a Regional Global Atmosphere Watch (GAW) Station and joined the World Meteorological Organization's Program for Global Atmospheric Studies. The latter has established a global network of collaborating ecological observatories and facilitates the exchange of data, equipment and specialists between them. The data registered are uploaded to the BEO Moussala's website (http://beo-db.inrne.bas.bg/moussala) and are being sent to worldwide data bases (WDCGG, Kyoto, Japan; NILU, Norway; NOAA, USA; JRC, Italy; RECETOX, Czech Republic). The gamma-probe data recorded are being sent automatically to the Bulgarian Nuclear Regulatory Agency. The information is transferred to the Internet via a high-frequency radio-telecommunication system (5 GHz, 100 Mbit/sec) and is saved for analysis in the data bases of the international programs GAW, EURDEP, UNBSS and the projects ACTRIS and MONET. BEO Moussala's team continued its research work in the framework of FP7 project ACTRIS (Aerosols, Clouds, Trace Gasses Infrastructure, 2011-2015). Data for aerosol measurements were regularly sent to the Norwegian Institute for Air Research (NILU), Norway, and The National Oceanic and Atmospheric Administration (NOAA), USA. Under a Letter of Intent with RECETOX, Masaryk University, Brno, Czech Republic, a set of filters for a five-year project for investigating POPs distribution over Europe were prepared at the BEO Moussala. Gamma background and meteorological data are being sent in real time to the European Commission through the Joint Research Center (JRC, Ispra), Italy. The automatic weather station "Vaisala" is equipped with sensors for air temperature, relative humidity, atmospheric pressure, wind speed, wind direction and precipitations. Greenhouse and trace gases measurements are performed by atmospheric gas analyzing system. HYSPLIT back trajectory model and forecast for air mass trajectory calculated by the DREAM code are used [1, 2]. Having been a Regional Station in the Global Atmosphere Watch (GAW) program since February 1, 2010, Moussala BEO sends data from gas analyzers as well meteorological data to WDCGG (http://gaw.kishou.go.jp/wdcgg/). In 2015, Moussala BEO was recertified by IQNET for compliance with the ISO 9001:2008 and ISO 14001:2004 standards.

High Mountain Air Monitoring at Moussala BEO

Atmospheric aerosols are fine solid or liquid particles "floating" (suspended) in the atmosphere. Since 2006 under the framework of the EU projects EUSAAR and ACTRIS, long-term measurements of aerosols have been carried out at many research centers, including at Moussala BEO, whose data are relevant in detecting possible anthropogenic influence and monitoring natural sources.

Scanning Mobility Particle Sizer (SMPS)

The measurements at the Moussala BEO station showed that the site lies above the Planetary Boundary Layer (PBL) for about a half of the year: from autumn to early spring (September to February). Changes in the situation occur in March, when the station is found to be below the PBL, and in August, when it is above it. The months from May to August are typical, as the daily variation are influenced by local convection processes of air masses with a high concentration of particles, especially in the period from noon until evening, with a maximum in July and August. During the spring and summer months, when a strong influence of convection processes is present, a time window exists from midnight to morning which enables one to perform measurements under the conditions of the lower free troposphere (Figure1. and 2).

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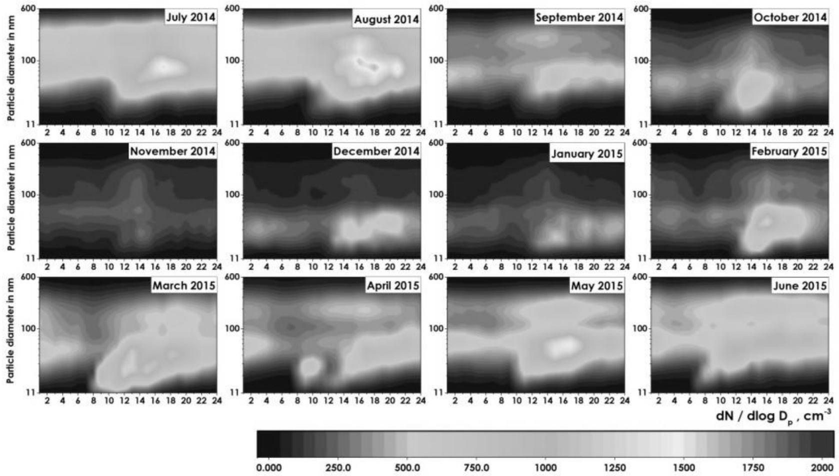

Figure1. Monthly mean daily variation of particle number concentration in the size range from 11 nm to 600 nm at Moussala site for the period July 2014 to June 2015, represented by a black-and-white code in the range from 0 to 2000 dN/dlogDpcm^{-3}

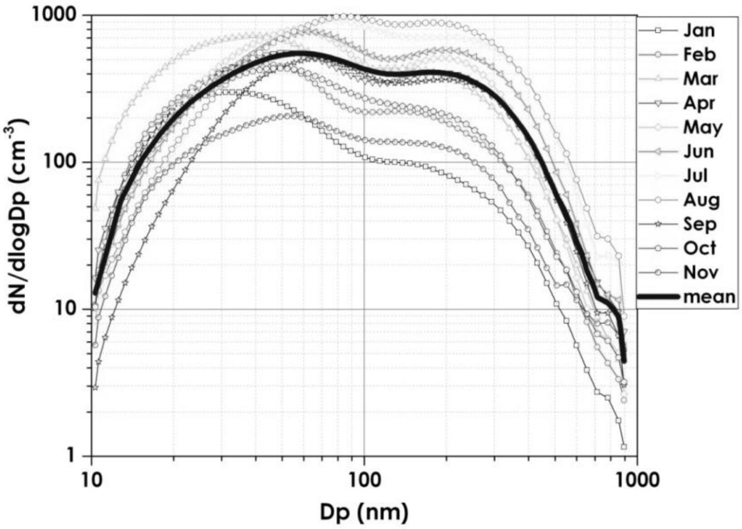

Figure 2. Monthly mean distribution of aerosols, dN/dlogDp (cm^{-3})

These detailed data yields information about the aerosol dynamics and the related meteorological processes throughout the year. Similar results for ultrafine aerosol particles variations have been obtained at the high-mountain station Zugspitze (2650 m a.s.l.), Germany [3].

Nephelometer

Additional aerosol measurements at Moussala BEO are being performed using a TSI Integrating Nephelometer model 3563 and an SMPS particle sizer. Both of them have been performing continuous measurements since 2007 and 2008, respectively. The measurements of the aerosol properties during the whole period have shown permanent seasonal trends [4], [5], which have been confirmed by the data from the past two years, 2013 and 2014. In the latter period, the observations showed predominantly clean air from the troposphere at Moussala with periods of relatively polluted air masses, mainly during daytime in the summer [5], as it is clearly seen in the SMPS presented in Fig.1 and Fig. 2. These results are also confirmed by the scattering and absorption data obtained by the Nephelometer. The peak in the aerosol loading is clearly in the summer, in August for both years. BEO Moussala is located at such a distance from Sahara that arrival of Saharan dust takes place several times every year.

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Continuous Light Absorption Photometer (CLAP)

The Saharan dust events are natural phenomena estimated as “the world’s most powerful dust source’. Strong surface winds uplift dust to high altitudes and the convection transports it typically westwards but also to our latitudes. After such transports several times each winter, the snow surface becomes colored while the nephelometer registers increased scattering from the fraction closer to the coarse mode that makes it visible. The aerosol influences the radiation balance of the Earth through scattering and absorption of solar radiation. In June 2012, a continuous light absorption photometer (CLAP) for real-time measurements was installed at BEO Moussala. The CLAP is a filter-based instrument for photometric measurements, using the scattering and absorption coefficients measured for the 700 nm, 550 nm and 450 nm wavelengths. Figure 3 illustrates the correlation between the DREAM model forecast and the real measured data in the period when bigger particles were dominating in the atmosphere during one Saharan dust event.

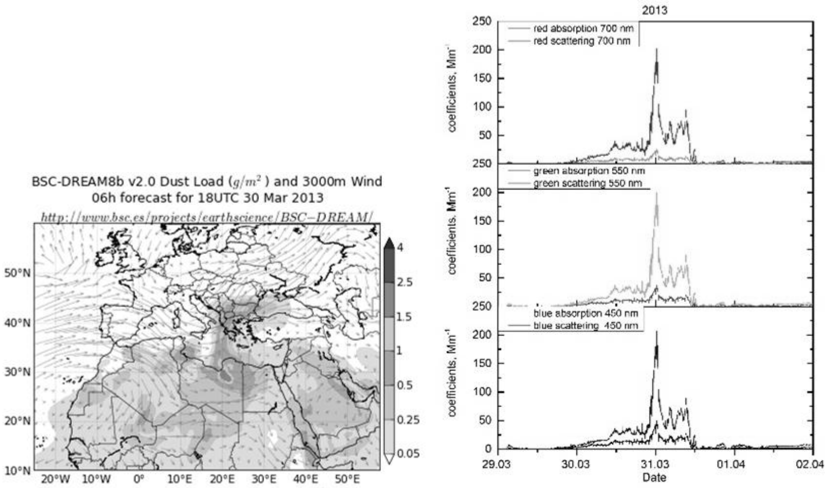

Figure3. Dust concentration (g/m^3) forecast calculated by the DREAM model (left) and real data (right) on 30 March 2013 at 18 UTC

System for measurements of radioactivity in aerosols

The importance of Moussala BEO location was demonstrated during the Fukushima accident. Monitoring the radioactive isotopes in air aerosols carried out at Moussala BEO using our system for measurements of radioactivity in aerosols [6] enabled us to observe the anthropogenic atmospheric radioactivity for the period March – April 2011. The data acquired during the Fukushima accident are shown in Figure 4. The low concentration of this trans-boundary radioactive pollution did not affect the gamma background near peak Moussala during the Fukushima accident (Figure 5.)

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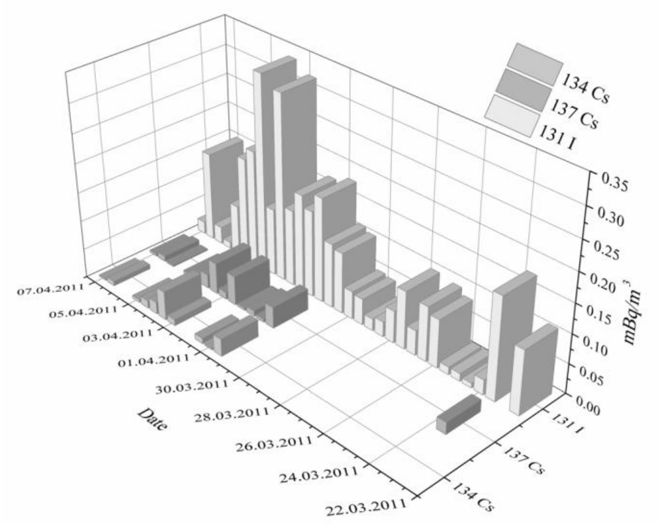

Figure 4. ^{134}Cs, ^{137}Cs and ^{131}I measured at BEO Moussala after the Fukushima accident 2011, mBq/m^3

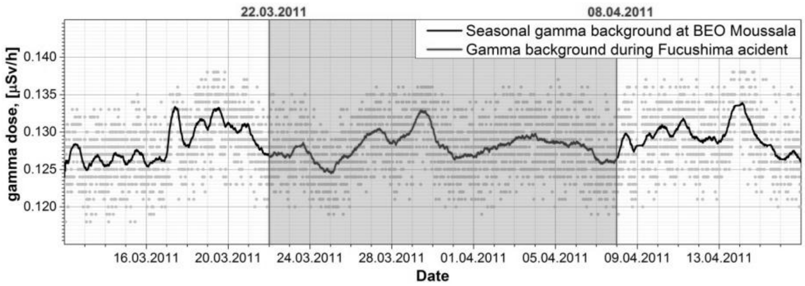

Figure 5. Gamma background near peak Moussala during Fukushima accident

Na(I) spectrometer

In addition to the gamma background measurements (the IGS 421 gamma probe and Ge-spectrometer), a Na(I) spectrometer was installed at BEO Moussala for on-line measurement of the gamma-rays spectrum in the air at the Moussala Peak. The energy interval of gamma-rays measurement is 100 – 6500 keV, where, one can observe the main isotopes of natural and anthropogenic radioactivity, including such from nuclear accidents and the cosmic gamma-rays background [7]. The unique BEO Moussala location permits us to obtain fast preliminary information on local or transboundary radioactive pollution [8].

Using the gamma spectrometer, we are able to establish in real time which isotope is responsible for the increase of the gamma background. The variation in the gamma background intensity is in a good correlation with that of the natural radioactive isotope ^{222}Rn. This could be due to the variation of the meteorological conditions, e.g. precipitation (Figure 6).

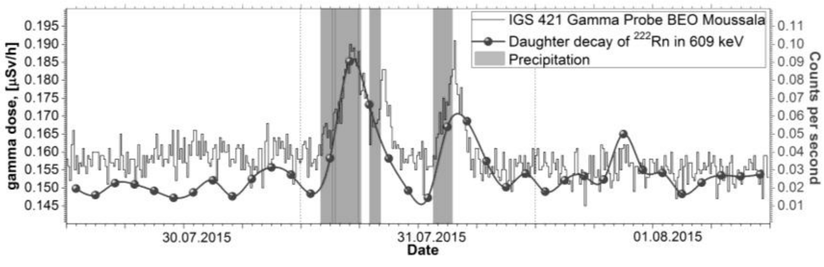

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Figure 6. Intensity of gamma background and natural radioactive isotope ^{222}Rn. Precipitation during this period is in dark.

Conclusions

The data from the analyses provide up-to-date reliable information on the presence of pollutants in the air near Moussala Peak, thus allowing one to determine the trends in the variations of the concentration of harmful substances released in the environment, the causes and possible impact of these variations, and the location of the pollution sources. The high-mountain monitoring allows one to follow the transboundary transport of polluted air masses and to model the trends related to the climate changes. Moreover, the ground measurements conducted at Moussala BEO can be used as reference data for calibrating satellite measurements, the latter being of importance due to the fact that they provide information on the atmospheric condition over large regions where no ground stations are located. The Moussala BEO location, namely, at a large distance away from any local pollution sources and at the boundary of free troposphere, favors the studies of the processes playing a key role in the climate formation.

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