INVESTIGATION OF SAHARAN DUST TRANSPORT ON THE BASIS OF AEROLOGICAL MEASUREMENTS

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ABSTRACT. – Investigation of Saharan dust transport on the basis of aerological measurements. The Sahara Desert is the largest dust source on Earth. Its dust is frequently emitted into the Mediterranean atmosphere and transported by the winds sometimes as far north as Central Europe. The accumulated particles contribute to soil forming processes, while the atmospheric mineral dust has an impact on the radiation budget, cloud forming processes, the pH of precipitation and biogeochemical cycles of marine ecosystems. The PM (particulate matter) in ambient air does not contain only primary particles but secondary particles formed in the atmosphere from precursor gases as well. Especially these latter ones have significant negative impacts to human health.

There are in average four-five Saharan dust episodes annually in Hungary, sometimes in form of colour precipitation (brown rainfall, red snow). There are several possibilities for providing evidence for the Saharan origin of the dust observed in our country: back-trajectories using NOAA HYSPLIT model, TOMS satellite maps of NASA, maps of aerosol index of Ozone Monitoring Instrument, observations of spectral aerosol optical depth of Aerosol Robotic Network, satellite maps of EUMETSAT, elemental analysis of dust samples.

In this study we try to reveal the suitability of the upper-air wind fields in detection of Saharan dust episodes in Central Europe. We deployed the global upper-air data base of the last 41 years that is available by courtesy of College of Engineering and Applied Sciences at University of Wyoming. We apply this method also for tracking air pollution of vegetation fires.

Keywords: upper-air, aerological measurement, Saharan dust transport, back-trajectories.

1. INTRODUCTION

The Sahara Desert is the largest dust source on Earth (Tilev-Tanriover and Kahraman, 2015). Its dust is frequently emitted into the Mediterranean atmosphere and transported by the winds sometimes as far north as Central Europe. Wind-blown (or aeolian) dust emissions of arid/semi-arid areas contribute of 1-3 billion tons to the global atmospheric mineral dust load. Several hundred million tons of dust is transported every year from Saharan source areas in the direction of European continent. The accumulated particles contribute to soil forming processes, while the atmospheric mineral dust has an impact on the radiation budget, cloud forming processes, the pH of precipitation and biogeochemical cycles of marine ecosystems (Varga et al., 2014).

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Fig. 1 shows the long-term spatial distribution of dust storms, which are the sources of dust transport depositing in Europe. Dust arrives to Central Europe mainly from Sahara but sometimes from Arabian Peninsula or Central Asia. Saharan dust events in the Carpathian Basin typically occur in spring, with a secondary maximum in summer (Varga et al., 2014). There are in average four-five Saharan dust episodes annually in Hungary, sometimes in form of colour precipitation (brown rainfall, red snow), but there happened 11 cases in 2008 and 10 in 2001.

The PM (particulate matter) in ambient air does not contain only primary particles but secondary particles formed in the atmosphere from precursor gases as well. Especially these latter ones have significant negative impacts to human health (Kiesewetter and Amann, 2014). Since Saharan dust is mainly of mineral origin so it is usually non toxic.

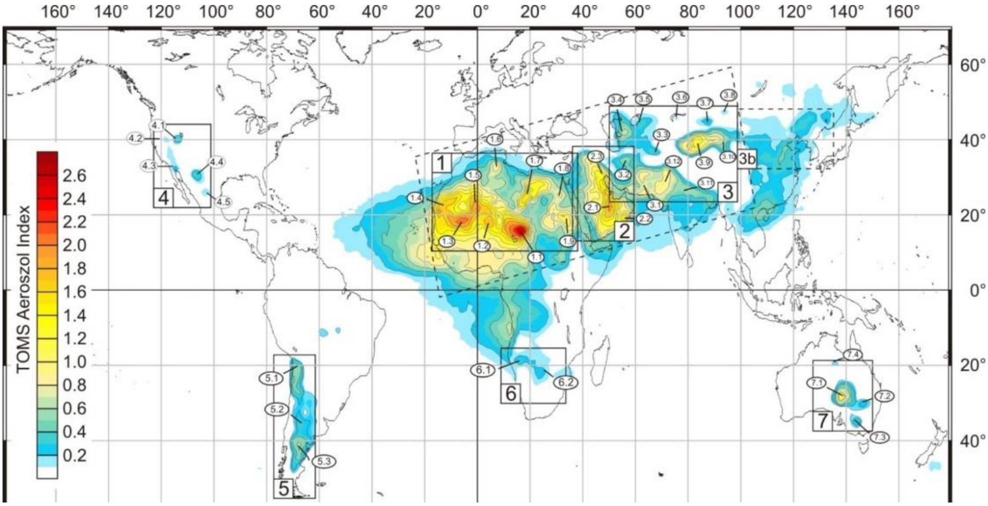


Fig. 1. ***Spatial distribution of dust storms – a global coverage using NASA Total Ozone Mapping Spectrometer aerosol measurements (1979–2011) (Varga, 2012)***

There are several tools for identifying Saharan dust outbreak episodes:

- back trajectories by HYSPLIT model of NOAA
- TOMS (Total Ozone Mapping Spectrometer) maps of NASA
- OMI (Ozone Monitoring Instruments) AI (Aerosol Index)
- AERONET (Aerosol Robotic Network) measurement of aerosol optical depth by sun photometers
- satellite maps of EUMETSAT
- models of ECMWF
- analysis of dust samples, size distribution.

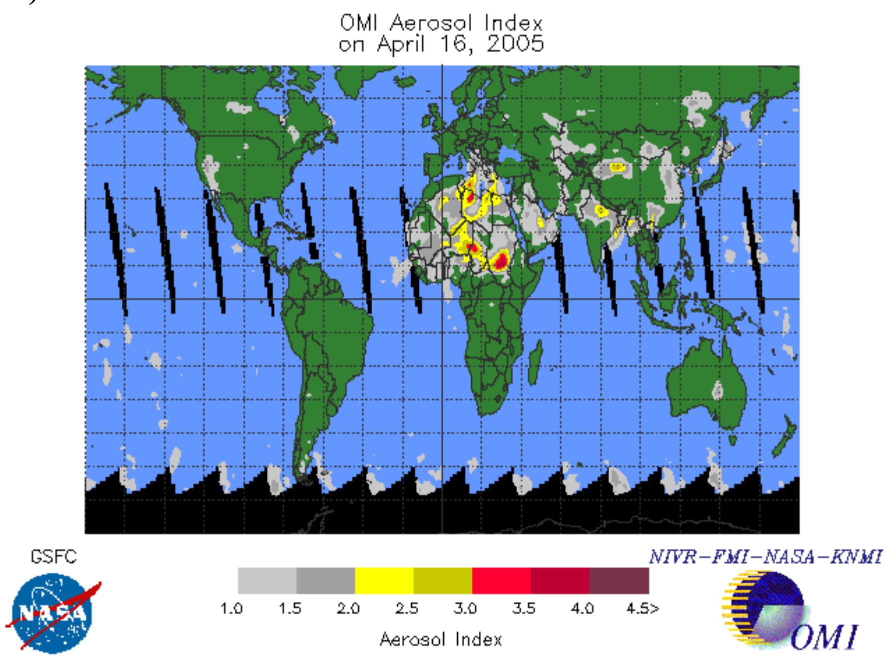
2. DATA AND WORKING METHODS

In this study we try to reveal the suitability of the upper-air wind fields in detection of Saharan dust episodes in Central Europe. We deployed the global upper-air database of the last 41 years that is available by courtesy of College of Engineering and Applied Sciences at University of Wyoming. This database contains the most aerological measurements required to TEMP messages.

The surface in desert areas is usually very dry. Several studies indicate that a surface wind speed exceeding 10 m/s is sufficient to mobilise a considerable amount of dust (Tilev-Tanriover and Kahraman, 2015). Durable, strong south, south-west wind can transport dust from Africa over Mediterranean Sea to Europe. Anticyclone over Central Europe can urge deposition of dust from the air.

Let us investigate a specific episode from 2005 when in Borsod-Abaúj-Zemplén county of Hungary colour precipitation was observed. Our colleagues at Hungarian Meteorological Service (Erdődiné Molnár and Kovács, 2005) analysed this episode and gave evidence of its Saharan origin. (Spreading of the dust can be followed on the maps of Fig. 2.) They showed by the help of SYNOP data and ECMWF analysis that conditions in Libya were suitable (dry surface, strong wind) for considerable dust transport. Local PM monitoring stations in the county registered peaks on 18th April when a shower washed out the pollution and the minerals transported from Africa coloured the precipitation.

Fig. 3 confirms the analysis of Erdődiné and Kovács. We prepared the wind fields by the help of TEMP data base of Wyoming University (Nyitrai and Tóth, 2015).



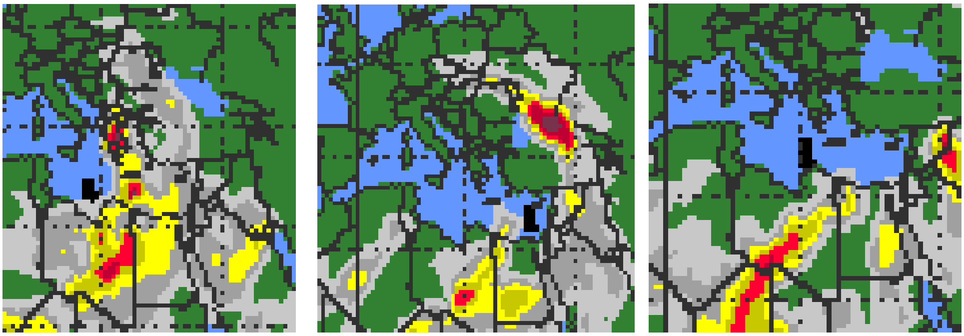
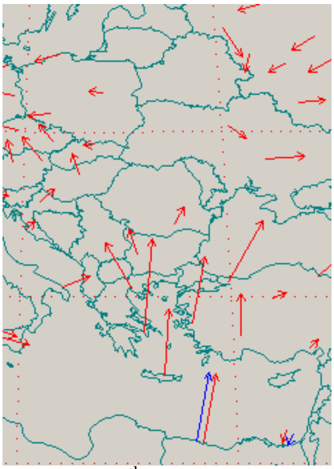


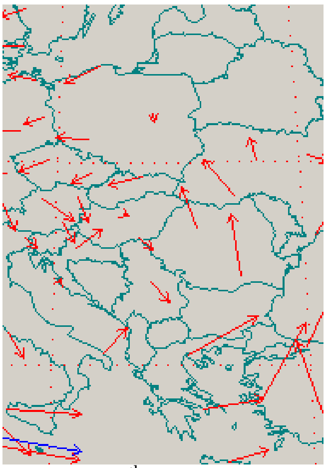
Fig. 2. ***OMI AI maps on 16-19 April, 2005***

The length of wind vectors are proportional to the wind speed. Strong south wind (~30 m/s) transported the Saharan dust through the Mediterranean Sea and Balkan Peninsula on 17th April. On 18th April the dust arrived to Hungary from Romania and the precipitation in the evening and night washed it out from the air. OMI AI map on 19th April shows no more aerosols in the atmosphere over Central Europe.

Another Saharan dust episode took place on 19-20th February, 2014. Those days from the territory of Sahara in Algeria a huge amount of aerosol were re-suspended into the air and the strong south wind transported it over Europe. This is reflected on the maps of Fig. 4 and confirmed by the aerological measurements (Fig. 5).



17th of April



18th of April

Fig. 3. ***Wind field of the level of 850 hPa (~1.5 km) on 17-18 April, 2005 at 00 by radiosonde measurements***

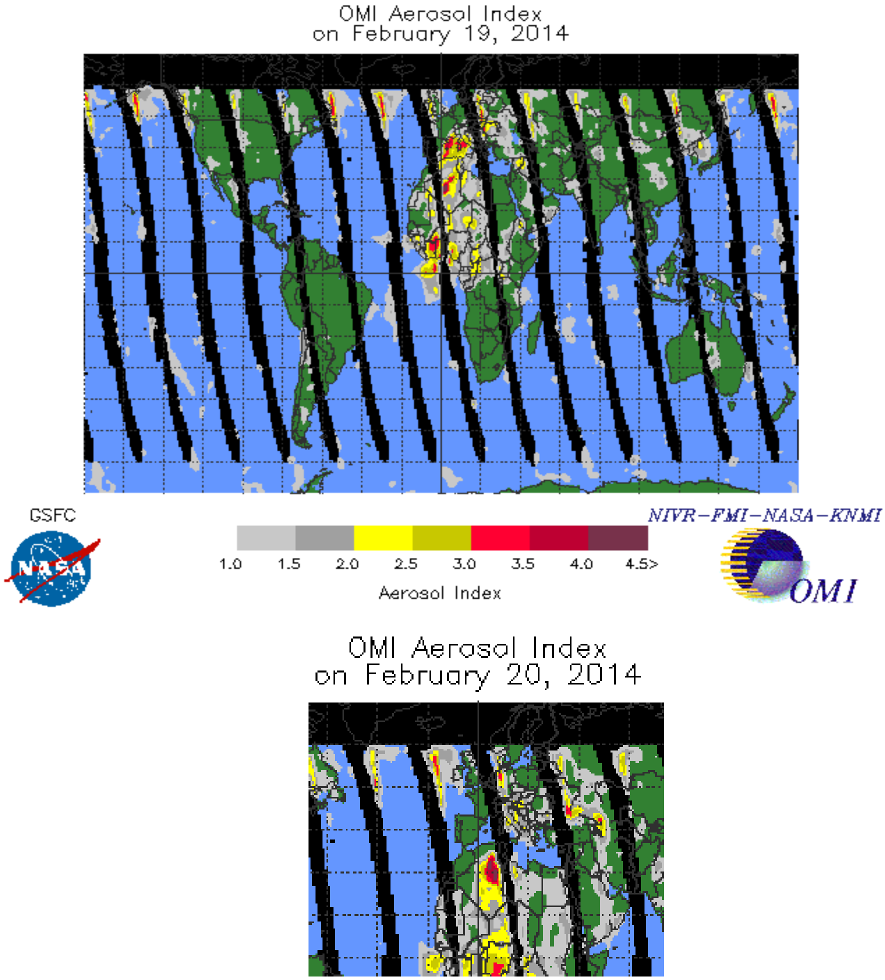
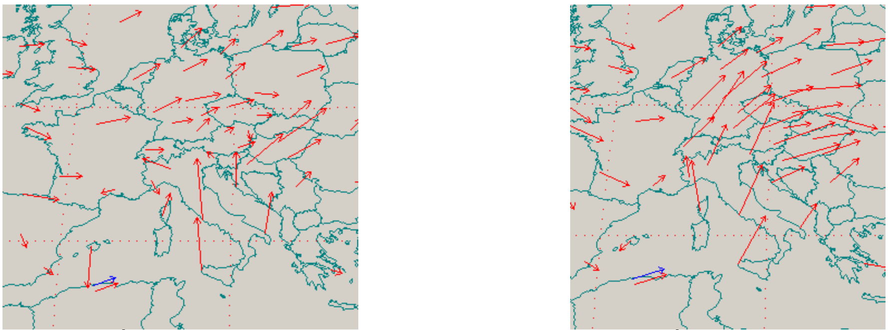


Fig. 4. ***OMI AI maps on 19-20 February, 2014***



19^{th} 850 hPa 19^{th} 700 hPa

Fig. 5. ***Wind field of the level of 850 hPa (~1.5 km) and 700 hPa (~2.7 km) on 19-20 February, 2014 at 00 by radiosonde measurements***

Considerable amount of Saharan dust deposited in South-East Europe on 29th May, 2013 (Fig. 6).

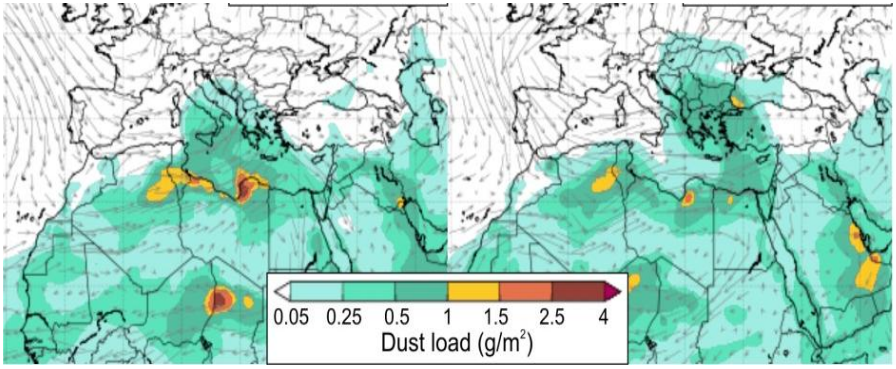


Fig. 6. ***Dust load on 28th and 29th May, 2013 (Varga and Kolláth, 2015).***

Transport of dust can be tracked on OMI AI maps (Fig. 7.). Aerosol got even to Poland and Belarus. Unfortunately, aerological stations in Africa are extremely rare and sporadic so the source areas of the episodes are hardly detectable by only radiosonde measurements. We can make, however, assumptions concerning the track of the dust (Fig. 8).

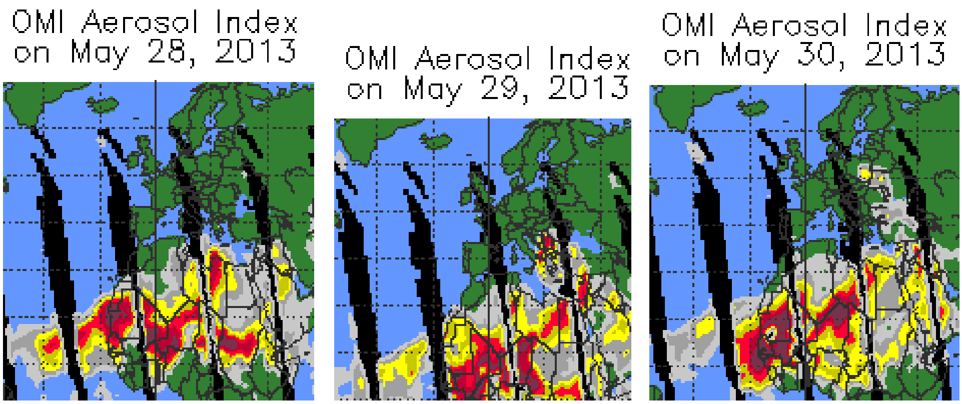


Fig. 7. ***Dispersion of Saharan dust on 28-30th May, 2013***

Let us to try to track the transport of dust stemming from open-air vegetation fire. On 8th July, 2014 agricultural biomass was burning on 10 ha area in a Hungarian village (Erk). By the help of NOAA HYSPLIT model we determined the possible forward trajectory of the plume (Fig. 10). Dust moved to north that is indicated by the wind field outlined by aerological measurements (Fig. 9). The assumed trajectory went through Salgótarján where Hungarian Meteorological Service operates an automatic air quality monitoring station recording PM_{10} as well.

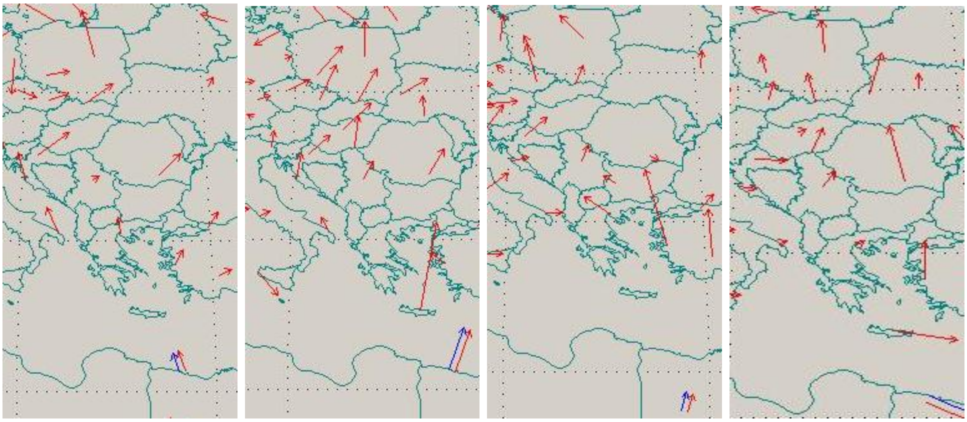
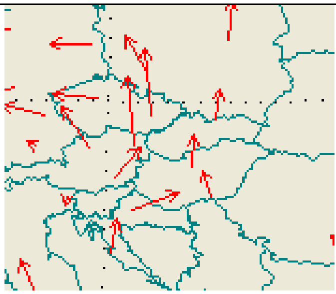
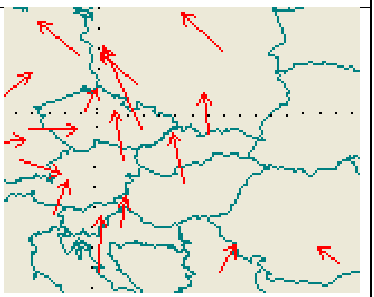


Fig. 8. ***Wind field of the level of 850 hPa (~1.5 km) on 28th April at 00, on 29th April at 00 and 12 as well as on 30th April, 2015 at 00 by radiosonde measurements***



00 UTC



12 UTC

Fig. 9. ***Wind field of the level of 900 hPa (~1 km) on 8th July, 2014 at 00 and 12 UTC***

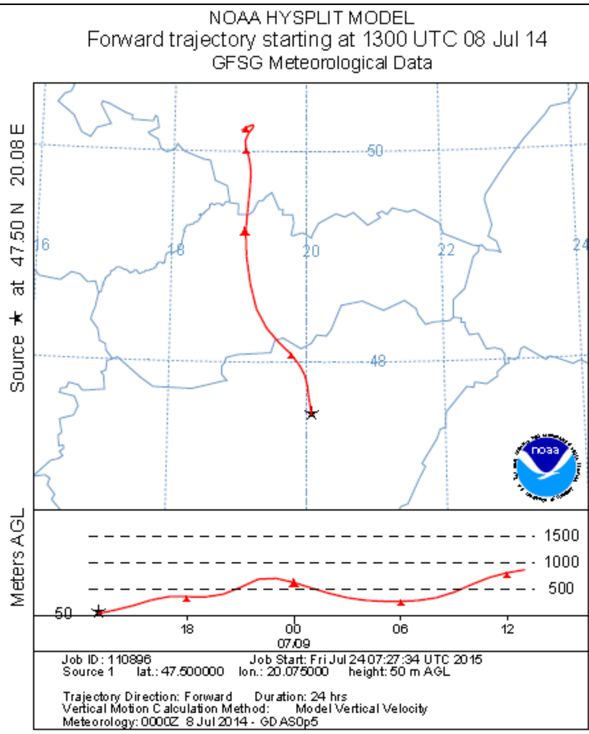


Fig. 10. ***Trajectory of the emission caused by fire on 8th July, 2014***

From 15 pm a strong rise started reaching the maximum value at 17 pm (Fig. 11). We did not register similar high value neither on the previous two days or next day so it is highly probable the high PM concentration was due to the fire in Erk. Effect of a vegetation fire spreading on 10 ha was detectable in 60 km distance.

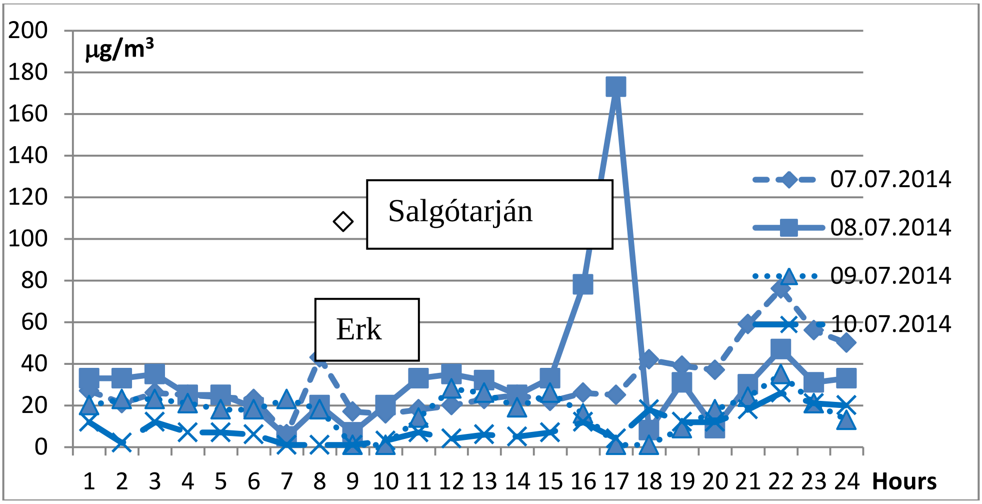


Fig. 11. ***PM_{10} concentration in Salgótarján on 7-10th July, 2014***

3. CONCLUSIONS

The main purpose of the aerological measurements is to obtain sufficient high-quality input data for the weather forecasting models. However, data produced by radio sounding are suitable for several other purposes as well. Two years ago we investigated the relation between intensity of radio sounding activity in many countries and the political, societal and economic events or movements (Nyitrai and Tóth, 2014). Last year we analysed long-term trends in wind speed, temperature and relative humidity of the upper air.

In this paper we tried to demonstrate the suitability and usefulness of the tropospheric wind field in detection of atmospheric transport of different airborne pollutants. We can conclude that aerological measurements provide useful orientation but in most cases they are not sufficient to get a clear picture.

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