LONG TERM MONITORING OF THE LIQUID WATER CONTENT OF THE LOW CLOUDS AND FOGS IN SELECTED MOUNTAINOUS SMALL CATCHMENTS IN THE CZECH REPUBLIC

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Introduction

Knowledge of the liquid water content (LWC) of clouds and fogs is important in order to evaluate the deposition of pollutants via cloud and fog water droplet deposition. The LWC values are also considered as a significant input parameter in calculation models of the fog precipitation deposits. Knowledge of LWC allows us to define the concentration of the pollutants in the air from the analysis their concentration in the samples of fog water (Fuzzi et al., 1994, Tago et al., 2006). The LWC is not routinely measured and because the direct measurement of LWC is expensive, other methods are being applied for its estimation. The most commonly used calculation of LWC is the calculation through measured visibility. The LWC – visibility relation can be found for example in Kunkel (1984) or in Fišák et al. (2006).

Site description

The meteorological observatory is situated at the top of Milešovka, a conical isolated mountain (50°33´17”N, 13°55´57”E, 837 m a.s.l.). Milešovka lies in the close vicinity of the North Bohemian brown coal basin, which is considered to be a region strongly affected by air pollution. Several power plants are situated close to the Krušné Hory mountain chain, which represents the north-western border of the opencast lignite mine area. There is a road with heavy traffic from both freight and public transport near Milešovka. The measurement of visibility is performed by the PWD 21 device (Vaisala, Finland).

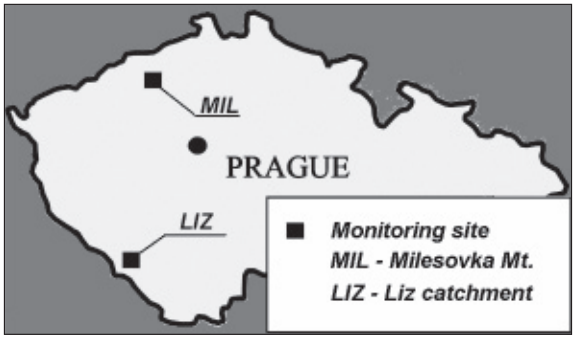

Figure 1. Position of monitoring sites

The Liz catchment (LIZ) is situated in the mountainous and submontane region of the Šumava Mts. This watershed lies in south-eastern part to the Landscape Protected Area and National Park of the Sumava Mts. The LIZ basin is fully forested. Forest

cover belongs to the acid spruce beech type. The coordinates are 13°40' 01" – 13°41' 00" E and 49°03' 23" – 49°04' 09" N. Maximum elevation is 1074 m a.s.l., minimum elevation 828 m a.s.l., mean elevation 941.5 m a.s.l., average land slope 16.55%, catchment length 1.45 km, length of streams 2.28 km. The position of the meteorological observatory Milešovka and LIZ catchment are shown in Figure 1.

Processing

A data set of visibility measurement at the Milešovka Observatory was processed in the period from 2003 to 2005. During this time, two outages of the visibility measurement were detected, i.e. from the middle of June to the end of July 2003 and in December 2004. A fifteen minute averages of visibility were used to calculate the LWC according to relation published by Fišák et al. (2006):

$$LWC = 0.0152\ VIS^{-0.8582} \qquad (1)$$

where: LWC is the content of water in the fog [g·m^{-3}] and VIS is the horizontal visibility [km].

All cases, where at least one of the visibility fifteen minute averages was less than 1km, were processed. It means that the analysis also included the cases of short term fog (lasting from 15 minutes up to 2 hours), temporarily caused by low frontal or orographic cloud. Fog episodes, which lasted for a period longer than 2 hours (long term episodes), were processed separately. In total, 4172 hours (16688 values of the fifteen minute averages) of measured visibility in fog at Milešovka were processed.

A data set of visibility measurement at the LIZ experimental watershed was processed in the period from March 2002 to May 2005. The *LWC* values for LIZ were calculated by following equation for clean environment published by Kunkel (1984):

$$LWC = \left(\frac{-\ln \varepsilon}{99 \times VIS} \right)^{\frac{1}{0.92}} \qquad (2)$$

where: *LWC* represents the content of water in the fog [g·m^{-3}], VIS is the horizontal visibility [km] and ε = 0,02.

In total, 10102.75 hours (40411 values of the fifteen minute averages) of measured visibility in fog at LIZ were processed. The results of the analysis can be seen in Figures. 2 and 3.

Figure 2 shows the monthly changes of LWC at the Milešovka and at the LIZ. Grey columns show the monthly changes of LWC for all fog episodes while black columns represents only the long-term fog episodes. In both cases we can see that the month changes have two maxima. The first maximum at Milešovka is 0.135g·m^{-3}/0.141g·m^{-3} in November, and the second is 0.130g·m^{-3}/0.147g·m^{-3} in April for all/long-term fog episodes. The first maximum at LIZ is in April (0.169g·m^{-3}/0.1184g·m^{-3}) and the second is in November (0.145g·m^{-3}/0.148g·m^{-3}). The monthly changes of LWC also include 2 minima. The main minimum at Milešovka is in February (0.072g·m^{-3}/0.080g·m^{-3}) and secondary one is in July (0.085g·m^{-3}/0.097g·m^{-3}). The main minimum at Liz is in September (0.041g·m^{-3}/0.040g·m^{-3}) and secondary minimum is in February (0.121g·m^{-3}/0.122g·m^{-3}). By comparing both graphs in Fig. 2 it is apparent that the average values are higher in the case of long-term episodes than in the case of all episodes.

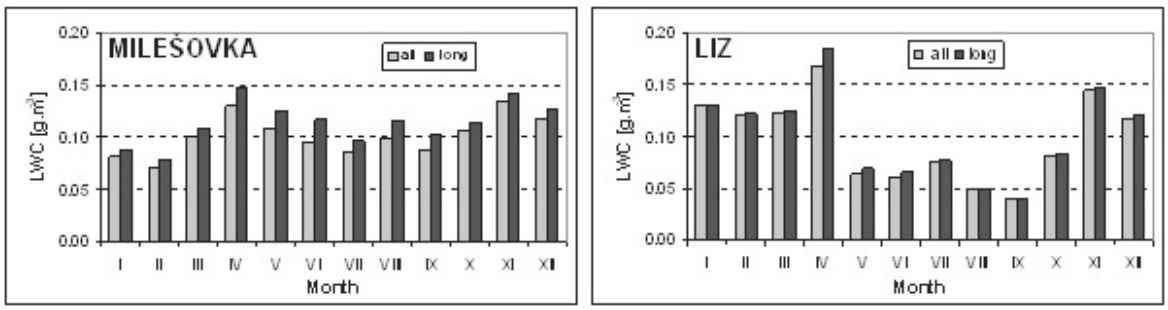

Figure 2. Monthly values of LWC at Milešovka and Liz

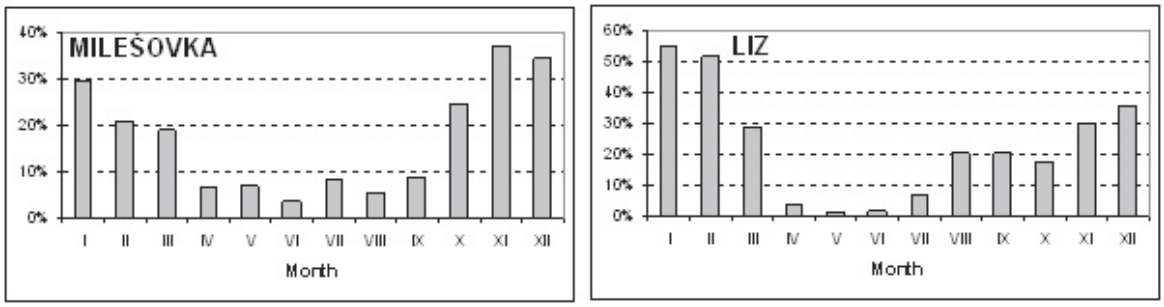

Figure 3. Percentage of foggy time for each individual month at Milešovka and LIZ

In Figure 2 it is illustrated that LWC values reach considerably higher values at the LIZ contrary to Milešovka during the cold part of the year. Vice versa LWC values are considerably lower at the LIZ contrary to Milešovka. The increase of LWC appears at the Liz in the course of the summer period in July already, at the Milešovka till in August.

From Figure 3 it is apparent that at the Milešovka the fog duration does not exceed 10 % of the possible duration since April to September and at the LIZ this is valid only for four months (since April till July). Figure 3 shows that fog lasts 25 and more % possible time only in the course of the four months (October, November, December and January) at the Milešovka while in the course of five months at the Liz (from November to March). In January and February fog duration exceeds 50 % of the possible time.

Discussion

In Figure 2 it is apparent that the LWC time variation at the Milešovka and LIZ loccalities has similar time behaviour. The main maximum occurs in April. Differences exist as the range of the variation is concerned. This range is 0.058 $g \cdot m^{-3}$ for all and 0.067 $g \cdot m^{-3}$ for long lasted fog events at the Milešovka while 0.128 and 0.144 $g \cdot m^{-3}$, respectivelly at the LIZ.

At the Milešovka more expressive differences exist between LWC values during long lasted and all fog events while at the LIZ this fact occurs only in April.

From the comparison Figures 2 and 3 for the Milešovka and for the LIZ it is apparent that the main maximum of LWC values (in April) at the same time falls on the months with short mean fog duration (Milešovka 6.4%, LIZ 3.3%). The secondary maximum of LWC values on the contrary falls on months with the longest average fog duration at the Milešovka (November).

According to Podzimek (1959) the LWC is in a convective cloud Cu hum – 0.5 $g \cdot m^{-3}$ and stratus St – 0.2 up to 0.3 $g \cdot m^{-3}$ and As – 0.2 $g \cdot m^{-3}$. From Figure 2 it is apparent that average LWC values neither at the Milešovka nor at the LIZ reach the values cited for St or As. Right these two types of clouds with the bottom base on the Earth surface it is possible to take into account as a fog.

Conclusions

Higher LWC values at the LIZ in comparison with the Milešovka can be caused by the relationship used for the calculation of LWC based on the visibility. As mentioned above the LWC value was calculated with the help of the general relationship valid for the clean region. For the Milešovka the relationship derived from direct measurements of LWC and visibility measurements made at the Milešovka bservatory was used. During evaluating of relationships for the calculation of LWC based on the visibility (Fišák et al., 2006) it was proved that general equations mostly overestimate the calculated LWC values. The difference in fraction of occurrence of long lasting fog events at the Milešovka is caused by the character of the terrain. The shape of the top of Milešovka Mt. and its unique situation in the ambient terrain (see chapter 2) cause that the top of the mountain is often immersed in the quickly approaching frontal clouds. As well as the locally forming orographic clouds have only limited duration.

Without wishing to generalize obtained results these can be assumed as a benefit. It was proved that time variation of LWC values is controlled by the certain general regularities that are not connected with the locality itself (see similarity of yearly changes at the Milešovka and Liz localities in Figures 2 and 3). In order to take the deposition from wind driven low clouds and fogs into account it is necessary to fill two basic assumptions: i) sufficiently enough values of LWC and ii) sufficiently enough the duration of fog events.

Pollutant concentrations at the fog water ranges in order of magnitudes from tenths to units of $\mu g.m^{-3}$, as it was published by Fišák et al. (2007). From this reason it is rather debatable if the deposition of fog water take into account or not in the course of months with low LWC or with low mean fog duration. But the input of low clouds and fogs deposition is certainly important in the course of the cold period of the year from October to March when both LWC values and fog duration are high enough.

Acknowledgements

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