COMPARISON OF VISIBILITY OBSERVATIONS AT A METEOROLOGICAL TOWER TO CLOUD BASE HEIGHT OBSERVATIONS FROM NEARBY WEATHER STATIONS

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***Abstract**:* Cloud base height and poor visibility conditions aloft are strongly connected. In this study visibility measured at a tower and cloud base height measured further down are compared. Even without removing the other factors (e.g. precipitation and aerosols) that also reduce visibility from the data the results show that the main reason causing the very poor visibility conditions at tower is the low level cloudiness.

1. INTRODUCTION

Atmospheric icing above surface and visibility (VIS) aloft have strong connection because of the low level clouds. They both have strong gradient at around cloud base height (CBZ). To further illustrate CBZ-VIS connection visibility and cloud base height data gathered between Oct 2005 and May 2010 in Eastern Finland from three nearby weather stations is studied here. The measurement stations are Savilahti (87 m MSL) and EFKU (94 m MSL) at ground level and Puijo-tower (306 m MSL) over 200 m above ground level stations. CBZ was measured at ground level stations and VIS at Puijo-tower.

2. RESULTS AND DISCUSSION

In Figure 1 the frequency of EFKU CBZ and Puijo VIS and in Figure 2 Savilahti-CBZ and Puijo-VIS is compared statistically.

One can see that during low level cloudiness, CBZ between 82 m and 322 m MSL, the Puijo-VIS is dominantly below 200 m (line 1) having probability of 1-6.5% to occur.

When CBZ is clearly above Puijo-tower (CBZ>442 m MSL) then the dominant visibility measured in Puijo tower is better than 10 km (line 8).

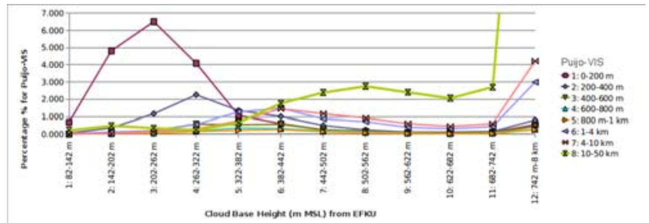

Figure 1: Distribution of Puijo-VIS (lines 1-8) with varying EFKU-CBZ values (x-axis, classes 1-12) from Oct 2005- May 2010 data.

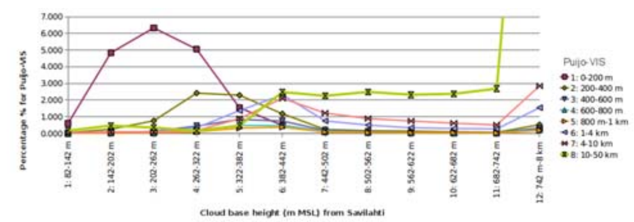

Figure 2: As in Figure 1 but with Savilahti-CBZ values.

3. CONCLUSION

The statistical distributions for the CBZ-VIS relation show that low cloudiness plays the major role in causing the very poor visibilities measured in Puijo tower.

Thus it is pretty likely that if Puijo-VIS is below 200 m then Puijo tower has to be in cloud. This is true with high probability even though the factors such as precipitation and atmospheric aerosols that also reduce visibility have not been removed from the data.

Comparison of visibility observations at a meteorological tower to cloud base height observations from nearby weather stations

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***Abstract*—Cloud base height and poor visibility conditions aloft are strongly connected. In this study visibility measured at a tower and cloud base height measured further down are compared. Even without removing the other factors (e.g. precipitation and aerosols) that also reduce visibility from the data the results show that the main reason causing the very poor visibility conditions at tower is the low level cloudiness.**

Keywords: cloud base height, visibility, atmospheric icing

I. Introduction

Atmospheric icing and visibility (VIS) aloft has been shown to have strong connection in many studies (e.g. [1] and [2]). This is because the numerous liquid cloud droplets above cloud base height (CBZ) have a great impact in producing poor visibility conditions and in freezing conditions supercooled liquid droplets also are the key element causing atmospheric icing. To further illustrate this fundamental CBZ-VIS connection data gathered between Oct 2005 and May 2010 in Eastern Finland is studied here.

II. Data and Measurements

A triplet of nearby weather stations in the region of city of Kuopio (62°54`N and 27°40`E), Eastern Finland has been producing continuous measurements of temperature, humidity, visibility, wind speed, wind direction and present weather since Oct 2005. The stations are listed in Table I and their locations shown in Figure 1.

In addition to the standard meteorological measurements, the Puijo tower station was also equipped with two ice detectors during the winter of 2009-2010, a web camera taking images regular, 15-min intervals. More specialized instruments, such as a Droplet Measurement Technologies Cloud Droplet Probe (CDP) and measurements of cloud and aerosol related properties have been carried there out for several test campaigns [3].

TABLE I. The three weather stations used in this study. MSL means meters above mean sea level, ALL meters above lake level. In this case above the larger water body of lake Kallavesi. “BELOW” is the elevation below Puijo tower and “Dist./Dir.” is distance and direction relative to Puijo.

name	location	MSL	ALL	Below	Dist./Dir.
Puijo	tower	306 m	224 m	-	-
Savilahti	UEF campus	87 m	5 m	219 m	2.2 km to SW
EFKU	Kuopio Airport	94 m	12 m	212 m	13.1 km to NW

Portin et al [4] showed that visibility measured at the Puijo station (Puijo-VIS) was generally less than 200 m when the CDP indicated significant numbers of cloud droplets at tower level. Hartsveit and Hirvonen [5] made a preliminary study to investigate the distribution between measured cloud base height at Savilahti (Savilahti-CBZ) and Puijo-VIS values over a three-month period.

In this study the data for a longer period between Oct 2005 and May 2010 is used to better assess the relation of Puijo-VIS to Savilahti-CBZ and EFKU-CBZ.

III. Data Manipulation

The comparisons was done using 10 minute time averaged values for VIS and CBZ measured every half an hour (twenty minutes after and ten minutes before the hour i.e. HH:20 and HH:50). CBZ and VIS were compared only if reported cloud fraction was more than 50 %, so that at least half of the sky was covered by at least one cloud layer at certain height (broken or overcast cloudiness). This way over 43007 and 42247 datapoints were available for comparisons between Savilahti and Puijo, and EFKU and Puijo, respectively.

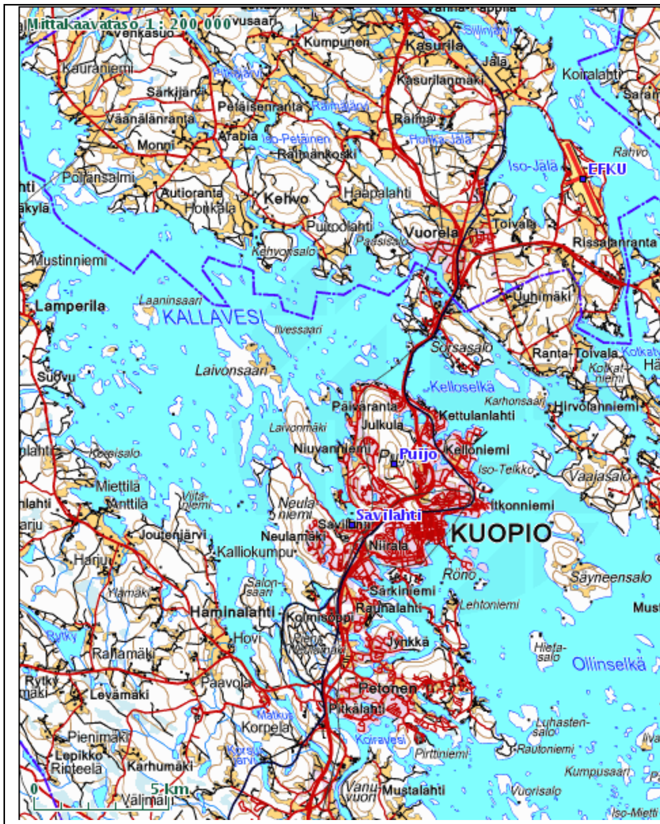

Figure 1. Map of the Kuopio area, including the location of the three observation sites Savilahti, Puijo and EFKU (Airport of Kuopio).

To study visually the statistics the comparison data was classified to Puijo-VIS categories and CBZ categories. The categories used in this study are shown in Table II. For VIS eight classes were used, five having bin width of 200 m for poor visibility conditions (VIS less than 1000 m) and three non-uniform classes for better visibilities (VIS over 1000 m). CBZ was classified in twelve classes starting from height of 82 m MSL (0 m ALL) with bin width of 60 m up to 742 m. The higher level clouds (CBZ over 742 m) were classified into single one bin as they were the least interesting ones in this study.

IV. Results and Discussion

The initial assumption based on previous studies is that if CBZ (measured either in Savilahti or EFKU) is below the height of the Puijo tower (306 m MSL) then the tower should be in cloud and reporting very poor visibility values i.e. VIS < 200 m. If CBZ indicates cloud base to be roughly at same height as the Puijo tower then VIS could be highly variable i.e. 0 m < VIS < 50 km. If CBZ clearly shows cloud base to be above Puijo tower then it is reasonable to assume that the station reports good visibilities i.e. VIS >= 10 km.

TABLE II. CATEGORIES FOR PUIJO VISIBILITY (PUIJO-VIS) AND CLOUD BASE HEIGHT (CBZ) USED IN THIS STUDY TO CLASSIFY VISIBILITY AND CLOUD BASE HEIGHT DATA.

#	Puijo VIS m	#	CBZ m
1:	0-200 m	1:	82-142 m
2:	200-400	2:	142-202 m
3:	400-600 m	3:	202-262 m
4:	600-800 m	4:	262-322 m
5:	800 m – 1 km	5:	322-382 m
6:	1 - 4 km	6:	382-442 m
7:	4 - 10 km	7:	442-502 m
8:	10 – 50 km	8:	502-562 m
		9:	562-622 m
		10:	622-682 m
		11:	682-742 m
		12:	742 m – 8 km

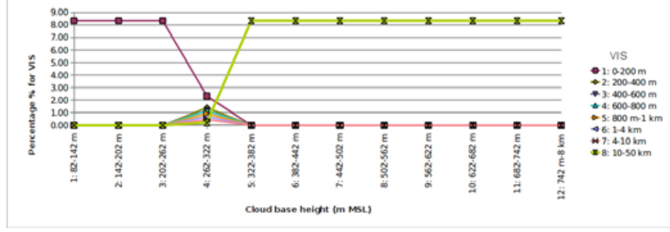

Figure 2. The statistical distribution of visibility (lines 1-8) with different cloud base height values (classes 1-12) assuming VIS and CBZ perfectly match each other. Perfect match is explained in the text in more.

Under this perfect match assumption one could expect to get an imaginary distribution for VIS with different CBZ values as presented in Figure 2. When low cloudiness prevails (CBZ<306 m MSL) only very poor visibilities (VIS<200m) are measured in Puijo tower (line 1). CBZ being roughly equal to the Puijo tower height VIS might be somewhat more variable (0-50 km), and all lines 1-8 possibly above zero. And when cloud base is clearly above Puijo tower good visibilities prevail (VIS >= 10 km, line 8). So Fig. 2 represents the imaginary statistics where CBZ and Puijo-VIS perfectly match.

The distributions which are actually calculated from real observations of CBZ from Savilahti and EFKU and VIS from Puijo can be compared to this hypothetical distribution. In Figure 3 is the frequency of EFKU CBZ and Puijo VIS compared and in Figure 4 Savilahti-CBZ and Puijo-VIS is compared.

In Figures 3 and 4 one can see that during low level cloudiness, CBZ between 82 m and 322 m MSL, the Puijo-VIS is dominantly below 200 m (line 1) having probability of 1-6.5% to occur. This is very similar feature as in Fig. 2 under perfect match assumption. But there are differences also. In real atmosphere only few cases occur when cloud base is very close to ground (CBZ ~ 82-142 m MSL), this was not assumed in perfect match but a uniform distribution of VIS over all low CBZ categories.

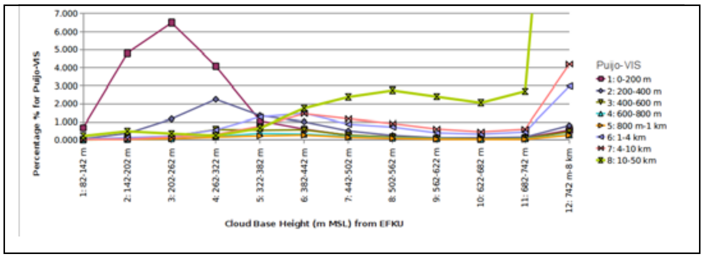

Figure 3. Distribution of Puijo-VIS (lines 1-8) with varying EFKU-CBZ values (x-axis, classes 1-12) from Oct 2005- May 2010 data. For EFKU-CBZ class 12 and Puijo-VIS class 8 the probability is 31% and thus out of y-axis scale in this graph.

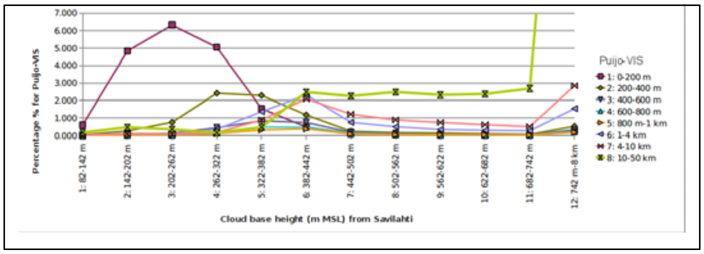

Figure 4. As in Figure 3 but with Savilahti-CBZ values. For Savilahti-CBZ class 12 and Puijo-VIS class 8 the probability is 32%.

The opposite is true for higher level clouds (CBZ>742 m) and good visibilities (Puijo-VIS>10 km), they are the most prevailing conditions (over 30 % of all comparison data points) in the atmosphere around Kuopio area.

Also can be noted that the highest visibility class 8 (VIS>10 km) has some probability (0.3-0.5%) to occur even in the three lowest CBZ classes 1-3. This can be explained by fog and very low and shallow cloud layers. Very low cloud base can be measured at Savilahti and/or EFKU but Puijo tower is above the top of that cloudiness in cloud-free atmosphere thus reporting good visibility.

When CBZ is around the height of Puijo tower or little bit above, between 296 m and 448 m MSL the probability for very poor visibility in Puijo (line 1) decreases significantly and the measured visibility in Puijo tower can be much more variable from 200 m up to even 50 km and all lines 1-8 show probabilities greater than zero as in Figure 2.

It is interesting to note that when CBZ is clearly above Puijo-tower (CBZ>442 m MSL) then the dominant visibility measured in Puijo tower is better than 10 km (line 8). This feature is not as distinctive as in very low cloud case with line 1 or in the perfect match case (Figure 2), as can be seen that poorer Puijo-VIS values are possible (lines 6 and 7).

The reason that Puijo-VIS in reality is not always better than 10 km when CBZ > 306 m MSL is probably that there can still be few cloud droplets (lower cloud patches) below the measured uniform cloud base. These fewer cloud droplets still reduce visibility at least a little. Also precipitation (drizzle, rain, snow, wet snow) and high concentrations of atmospheric aerosols below the measured broken or overcast cloud base can reduce visibility.

Some deviations from the perfect match are due to the fact the low clouds observed around Kuopio do have edges in horizontal direction. So a low cloud observed in EFKU might not reach to Puijo (or vice versa) because of the distance between these sites is 12 km. The likely hood for this to happen between Puijo and Savilahti is smaller because of the closeness of these stations.

V. Conclusion

The real CBZ-VIS distributions (Figures 3 and 4) show that low cloudiness plays the major role in causing very poor visibilities measured in Puijo tower. Thus it is pretty likely that if Puijo-VIS is below 200 m then Puijo tower has to be in cloud.

This information can be used to relate very poor visibility conditions to atmospheric icing if the ambient temperature (and possibly wind) is taken into account also. A potentially icing cloud event is present if following condition (VISgt200Tlt0) is true: Puijo-VIS is below 200 m and the temperature at the tower is less than 0°C.

Using VISgt200Tlt0-rule and Puijo data (2005-2010) Bernstein et al [6] created surrogate 5-year monthly climatology to verify another icing climatology created with an automated icing diagnosis tool LOW_ICE (Bernstein et al. 2011b).

In near future the relation of VISgt200Tlt0-rule to the real icing will be further studied using the icing detector data of winter 2009-2010 and web camera images taken in Puijo tower.

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