Automated Cb/Tcu METAR based on radar and satellite data.

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Abstract

Convective clouds of the Cumulonimbus (Cb) and Towering Cumulus (Tcu) form a hazard for aviation. Their detection near airports is an ICAO requirement to limit risks for air traffic. This paper presents a detection algorithm of Cb and Tcu based on a synergetic use of radar observations and satellite observed radiances as implemented since March 2011. The system has an improved performance in comparison to the previous automated system.

NWP information was used to decrease the number of False Alarms in stable conditions. Unfortunately it turned out that weak convection is not well described by NWP. The appliance of an NWP filter using the CAPE information showed that too many Cb cases were removed from the data set. For this purpose NWP does not supply the desired information.

Introduction

Cb and Tcu occurrence form a hazard for aviation. Their detection near airports is a requirement to limit risks for air traffic. The Cb and Tcu observations are predominantly done by human observers. In the Netherlands they were replaced in 2007 by automated observations at two airports: Maastricht-Aken (BK) and Groningen (GG). The performance of the automated system was poor. Hence in March 2011 an improved automated detection was introduced on three airports, the former two mentioned above and Rotterdam airport. The improved automated algorithm uses a synergetic evaluation of radar and satellite (MSG-SEVIRI) observations.

The request came to extent this method to all airports and platforms where landing and take-off occurs based on KNMI information, the so-called Flight Information Region. This paper captures this extension and explores a method to reduce the False Alarms by using NWP information. The study is a continuous development of which the results were presented at the EUMETSAT data user conferences in Cordoba 2010, in Oslo 2011, and Sopot 2012.

Method

Only radar and satellite observations provide the spatial and temporal coverage required to identify and track Cb and Tcu. These observation methods cannot distinguish between Cb and Tcu, nor between evolving and decaying Cb. Therefore only one cloud type, Cb is classified, representing both the Tcu and Cb occurrence.

A Cb occurrence data set was created through the significant effort of forecasters who evaluated manually some 450,000 cases for all the 26 stations, (see Figure 1 for their location). The forecasters used data from NWP, lightning, radar, satellites, and radio sondes, for 2010 with a 30 minutes time separation. On a best effort basis the forecasters made a distinction between Cb and Tcu. In previous studies (De Valk Cordoba, 2010) was shown that the forecasters classify more clouds as Cb than the ground based observers report. Obviously the possibility of forward and backward looping in time of both satellite and radar observations increases the early detection rate of the evaluating forecaster in comparison to the observer. This higher rate combined with the possibility of embedded Cb

detection by the forecaster explains partly the higher number of classified Cb's. The data set is split into four parts consisting of Winter day Winter night Summer day and Summer night.

For the area of interest, a circle of 15 km around an airfield (ARP), a number of variables were derived. They are from both radar, reflection signal, and satellite observations, the range between minimum and maximum in HRV channel during day light, and fraction of the collocation area with a difference between the 3.9 and 10.8 um channels lower than zero for night time. These variables were determined as predictors from a logistic regression study, presented at the EUMETSAT data user conference Sopot 2012, and have a correlation with Cb occurrence.

The predictors vary with season and illumination conditions (day-night). The predictors and coefficients are used in an equation to determine the probability **P=1/(1+exp(-c-c1*R-c2*S))** of Cb occurrence within the automated detection algorithm. Where **c, c1** and **c2** denote coefficients, **R** denote predictor(s) based on radar observations and **S** denotes predictor(s) based on satellite observations. The thresholds determining the dichotomous Cb classification (**P > threshold value**) vary per ARP.

After the automated Cb detection NWP information, the CAPE (convective available potential energy), is used to filter the results. When the CAPE is not over 50 J/kg, the Cb classification is labelled as False. This 50 J/kg was deemed to be a conservative value and it is introduced to distinguish frontal rain from convective rain, thus reducing the False Alarms.

Results

The probability equation for AM ARP see Figure 1 was derived using 2009 data and then applied to the summer day data of 2010. In Figure 2 the results are shown. The left part of the Figure shows a good CSI (Hits/(Hits+ False alarms + misses) score of 0.5 when a probability threshold of 0.2 is used. The right side of Figure 2 shows the attribute diagram with a good performance for high (>0.5) predicted probability. For lower predicted probability an underestimation occurs when compared to the observed relative frequency.

At the Sopot 2012 conference only the summer results of 2010 were evaluated. In a poster presentation the impact of the CAPE on the results was shown for one location Eindhoven airport EH, Figure 3. Predominantly the CAPE filtering method had a positive impact on the performance due to the reduction of the False Alarms Ratio (FAR=False alarms/(Hits + False Alarms). This is however accompanied with a reduction of the Probability of Detection (POD= Hits/(Hits+Misses)). Note that a higher CSI value is achieved in the right part of figure 3.

At the end of 2012 the Cb evaluation results for the whole year of 2010 became available. A closer study revealed that the application of the CAPE filter removed a significant number of Cb and Tcu classified clouds. Even when the NWP filter selection was relaxed to CAPE >0 KJ/kg close to quarter of the Cb cases were removed. This is an undesirable loss of Cb cases in the data set. The study was repeated focussing on Cb cases only as classified by the forecaster. Here the same loss of data occurred. Most likely the NWP does not describe weak convection accurately enough for this purpose. One should be careful when using present day NWP information to de-classify convection.

	No CAPE filtering	CAPE > 50 KJ/kg	CAPE > 0 KJ/kg
Cb + Tcu	28514	13186	20677
Cb	18984	10031	14886

Table. The impact on the number of Cb and Tcu cases by applying a filter on the determined NWP CAPE value for the ARP's under study.
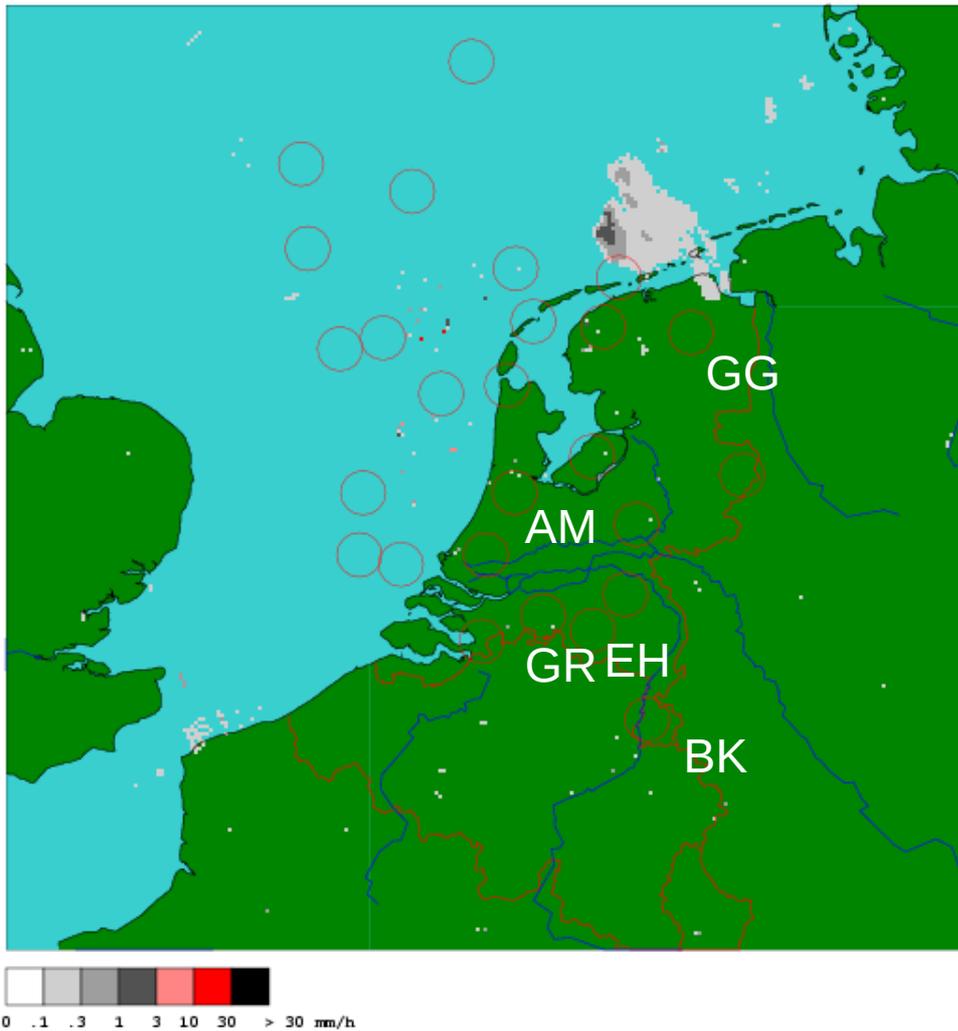
Figure 1. Areas with flight activities, Airport reference points, ARP names included refer to the circle NW of the name.
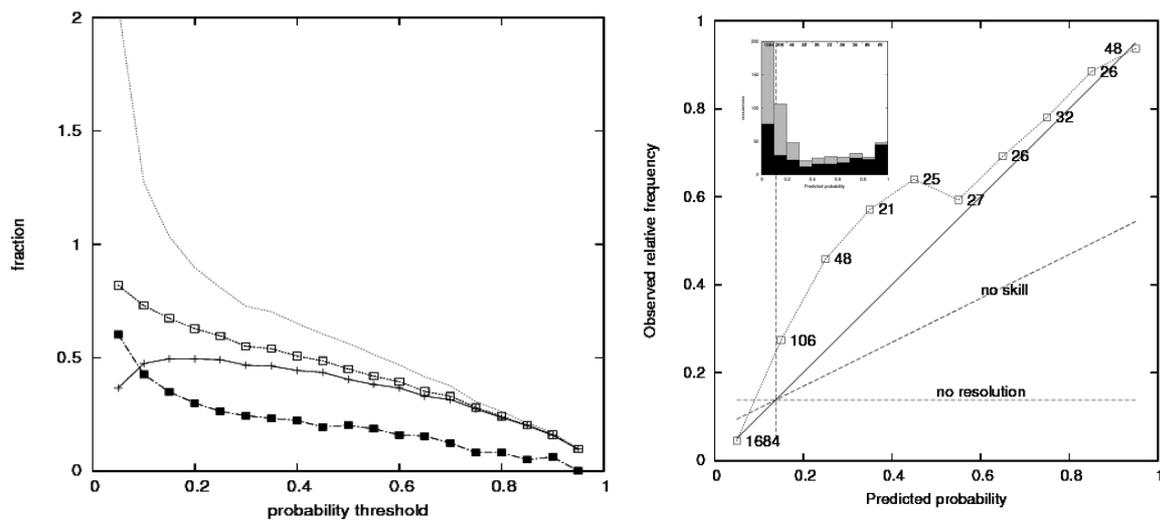

Figure 2:Predictors and coefficients derived from the 2009 evaluated dataset applied on the 2010 summer day data of ARP AM. Left the POD(open squares),FAR (closed squares), BIAS (dashed line) and CSI(+). Right the attribute diagram and histogram of Cb occurrence frequency.
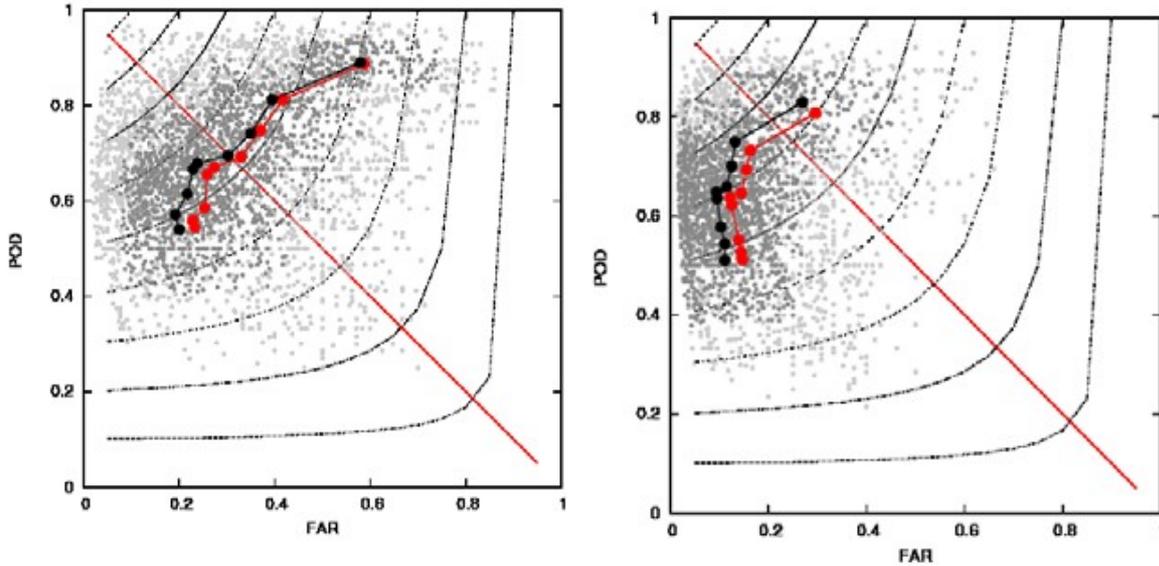
*Figure 3. Impact on the performance for EH without (left) and with (right) filtering by CAPE in a Probability of Detection (POD) and False Alarm Ratio (FAR) diagram. The upper left corner corresponds to a high POD and a low FAR. The curved dashed lines denote the CSI scores ranging from 0.1 (top right) to 0.9 (top left). Bootstrapping on an independent set resulted in Red line with dots average score for probability threshold from 0.1 (upper right) to 0.5 (lower left) in steps of 0.05, **black line** denotes the median for the same probabilities as the red line, dark grey denoted 66 percentile of all bootstrapped cases, and light grey denoted the 95 percentile. Note that a lower FAR in Figure 3(right) also shows a lower POD.*
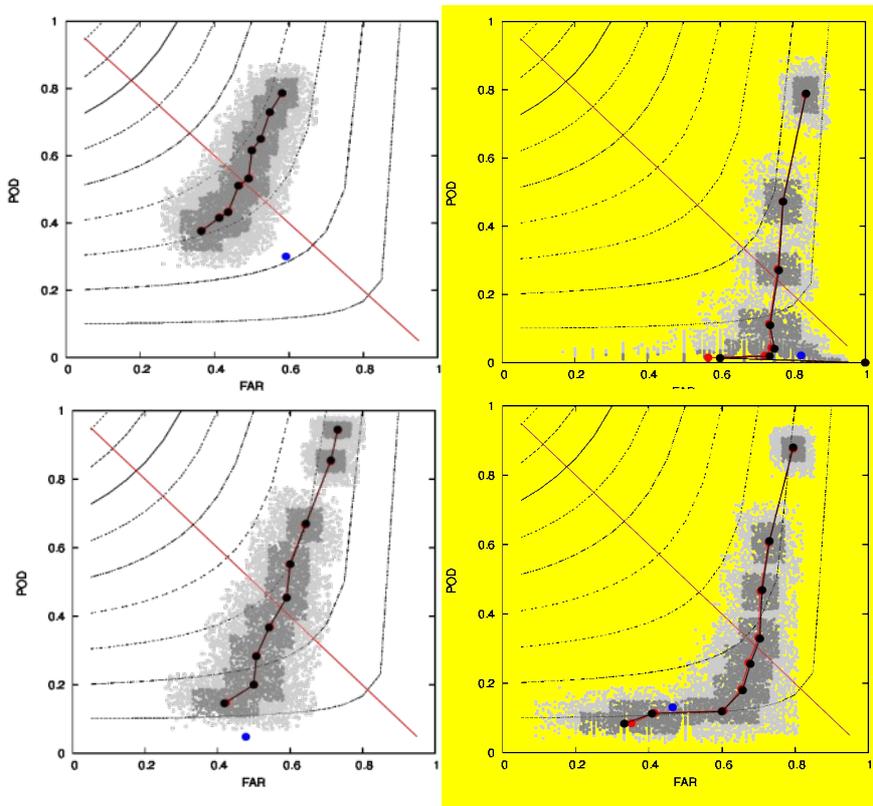

Figure 4. The POD FAR diagram like figure 3 for the Winter night fo ARP: AM (upper left) BK (upper right) GG (bottom left) GR (bottom right). The added blue dot represents the Cb detection performance of the former only Radar based detection algorithm applied in 2007. The yellow background indicate that the ARP has a large distance to the radar.

Next to the used maximum CAPE in a column also other NWP products, Convective inhibition, Lifted Condensation Level, and Level of Free Convection were studied for their added value. These NWP products removed even more Cb cases when used in a filter and were therefore not used.

Within this paper not all the results of 26 ARP's for four seasons can be shown. To give an impression of the performance four random cases over land from the season with the worst performance, winter night in Figure 4 and the same stations are shown for the season with the best performance, summer day Figure 5. As a reference point the performance of the previous only radar based detection is included into the graphs, indicated by a blue dot. The latter system was implemented in 2007.

For the winter night the distance to the radars influences the performance. The closer to the radar the ARP's are located the better the results are. Close to the radar ARP AM performance reaches a CSI of 0.3 to 0.4. The most remote ARP BK has a performance close to the CSI = 0.1 line. The occurrence frequency of CB in the winter night is low, and this is reflected in the performance. Closer to the coast the occurrence frequency is a bit higher leading to a somewhat higher CSI see ARP GR.
For the summer day there is less dependence on the distance of the ARP to the radar. Also higher CSI values up to 0.6 (at DL and TW not shown here) are achieved. During the summer season the occurrence frequency of Cb over land is significantly higher than in the winter night.
From the results not incorporated in this paper the conclusion can be drawn that over sea the night time detection in the summer is poor. Also over sea at night time the distance to the radar appears to be relevant for the detection of Cb.
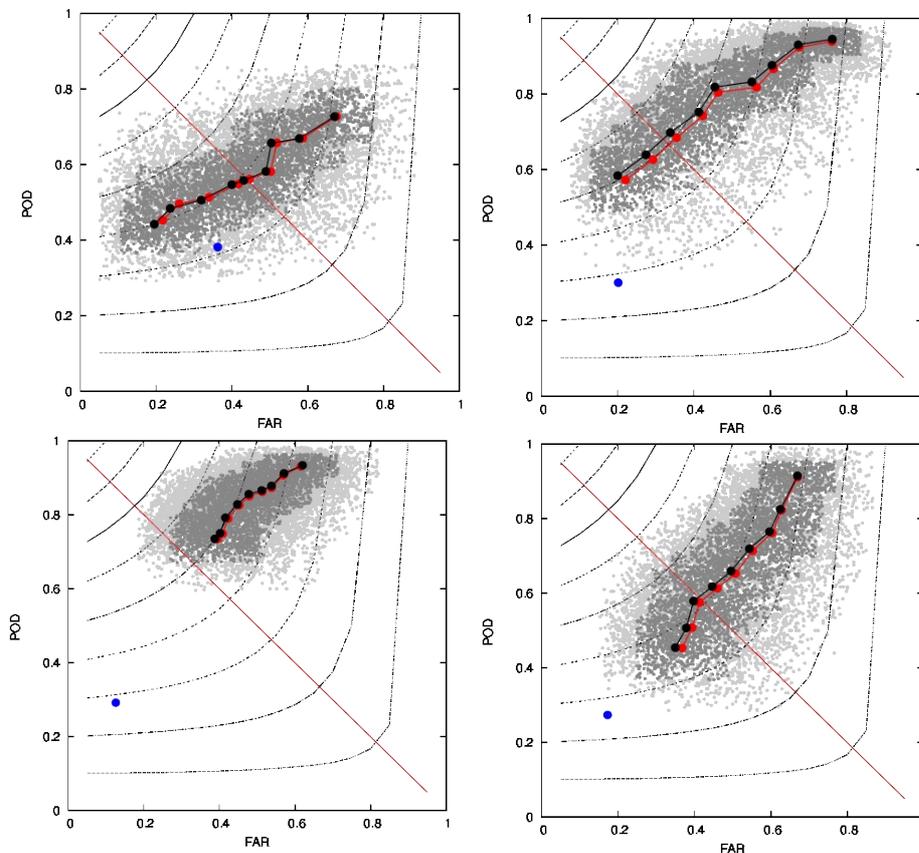

Figure 5 Caption as Figure 4 but for the Summer day over land. The same stations as in Figure 4are shown.

Conclusion/Outlook

Convective clouds of the Cumulonimbus (Cb) and Towering Cumulus (Tcu) form a hazard for aviation. Their detection near airports is a requirement to limit risks for air traffic. This paper presents a detection algorithm of Cb and Tcu based on a synergetic system of radar observations and satellite observed radiances as implemented since March 2011.

The automated system performance is evaluated for the year 2010 by comparison to a dataset created through the Cb classification by forecasters. The data set is split into four parts consisting of Winter day Winter night Summer day and Summer night.

Especially at night the distance to the radar influences the detection performance. The performance is in the summer better than in the winter period. Partly because of the increase of available potential energy over land in the summer time. And partly due to a higher occurrence frequency in the summer of Cb leading to a better probability equation derivation. In nearly all the cases the 2011 version shows an improved performance in comparison to the 2007 version.

NWP information was used to decrease the number of False Alarms in stable conditions. Unfortunately it turned out that weak convection is not well described by NWP. The appliance of an NWP filter using the CAPE information showed that too many Cb cases were removed from the data set. The use of a NWP filter was not applied based on these results. But there is still a need to improve upon the performance, especially during the night.

There are a number of predictors based on satellite and radar information which have not been exploited fully for their added value. To improve the performance the added value of these predictors is further studied.