Royal Netherlands
Meteorological Institute
Ministry of Infrastructure and the Environment

The implementation of automated Cb-Tcu detection

Paul de Valk, Rudolf van Westrhenen

De Bilt, 2011 | Intern rapport; IR 2011-05

Koninklijk Nederlands
Meteorologisch Instituut
Ministerie van Infrastructuur en Milieu

The implementation of automated Cb-Tcu detection

Versie 1.0

Datum December 2011
Status Definitief

Internal report on the implementation of Automated Cb-Tcu detection
authors: Paul de Valk, Rudolf van Westrhenen

Contents 1

Executive summary 2

1. Introduction 3
2. Algorithm description 4
3. Consecutive steps for implementation and bugs 8
4. Improvements 10
5. Consideration for implementation 13
6. Implementation 14
7. Data streams 15
8. Dependencies 17

Abbreviations 18

Literature 18

Appendices
1) operational coefficients and thresholds of the March 9, 2011 algorithm. 19
2) statistical scores 20
3) Results 2005 21
4) Results 2009 22

Executive Summary

This report describes the details of the operational implementation of Cb/Tcu detection algorithm. The algorithm is operational since March 9, 2011 and replaces the previous Meteo France (MF) base algorithm for EHGG, and EHBK. It replaces the human observer on EHRD.
The performance is good, as judged by the end user. A numerical evaluation in terms of POD and FAR will be given when a full year has been evaluated.

The report describes the impovements implemented since the research version described in De Valk and Westrhenen, 2010. An important change is the use of evaluated data set provided by an expert as the truth, versus the METAR used in the 2010, version. The motivation for this change was to assure that the collocation area for evaluated data set and algorithm study is the same. An additional benefit was the correct classification of embedded Cb.
One of the aims of the report is to disclose all involved data streams, inter-dependencies of required products, hardware platforms and software packages and their locations. This facilitates error tracking, and minimizes disturbances when introducing updates.
It also describes all the required steps to come from a research version to an operational version. The main message here is: allocate sufficient time for the whole process of implementation. Early communication with involved parties on their expectations and demands enables a smooth implementation.

During the research and implementation it became apparent:

1. That the synergistic system is sensitive to any changes in the instrumentation. A change in the products of the radar in 2008, made the results for 2005 unusable for 2009. So any upgrade in the systems used, radar and satellite, may impact the results.
2. The statement above means that the algorithm requires regular maintenance and this includes manpower.
3. The Meteo France based (MF) algorithm is applied for all airports in the Netherlands. The present output radar.xml file contains a merged product of the in 2010 developed operational algorithm for EHBK, EHGG, EHRD, EHAM and the MF algorithm for the others.
4. An extension for the other airports of the algorithm and the North Sea platforms is a major task requiring the evaluation of ~450000 situations.
5. The system is liable to improvement: frontal rain bands are classified as Cb, there is an overestimation of coverage, and extended MCS's are not classified as Cb. There are solutions for these weaknesses and they will be solved in a next version.
6. End users complain over the cloud base height. Frequently the Cb is not a consequence of ground based initiated convection. Within the ADCM the cloud base heights is always determined by (Ta-Td)x 400 ft with a minimum of 1500 ft. A more sophisticated method involving ceilometer data interpretation and Ta-Td could lead to a realistic cloud base height. This would increase the confidence of the user in the system. However, cloud base height determination is not a part of the developed algorithm.

An explicit request to differentiate between Cb and Tcu will be addressed when the evaluation mentioned under 4 is completed. It is however questionable if this will be achievable.

1. Introduction

The detection of convective clouds, Cumulonimbi (Cb) or towering cumuli (Tcu) is a prerequisite for safe aviation conditions. Especially in aerodromes the associated winds with convection can form a hazard. The detection of these clouds is therefore required by ICAO at airports. In the former century the detection of these clouds were mostly done by human observers.

In 2005 automated detection of Cb and Tcu based on radar observations was introduced for regional civil airports in the Netherlands, being a part of an automatic system covering a wide range of observations. Automated aeronautical meteorological observations were introduced at Groningen Airport Eelde (EHGG) and Maastricht Aachen Airport (EHBK) in May 2004. First this so-called AUTO METAR system was used only during closing hours of the airports, but since August 2007, after an evaluation by Air Traffic Control The Netherlands (ATC/LVNL), the AUTO METAR system became operational 24/7.
The performance of the automated detection appeared, however, to be poor.

In 2008 two studies were initiated to explore the possibility to improve the performance. Both studies employ the synergy of radar and satellite observations to come to an improvement (Carbajal-Henken et al 2009, and De Valk and Van Westrhenen, 2010). The former study employs derived products from satellite observations, and combines this with radar observations. It considers day time Summer cases only. The latter study uses satellite and radar observations directly, and considers day and night cases in Summer and Winter.

The latter study is used to define and develop an operational algorithm applicable in all seasons and times. The algorithm is used since March 9 2011 to replace the former operational algorithm at EHBK and EHGG. It also replaces the human observations on EHRD.

The report describes in the second chapter the employed studies and their results shortly. In the third part the steps towards implementation and encountered bugs are elucidated. The fourth chapter describes future improvements identified within the operational phase. The fifth and sixth part describe the considerations for implementation and implementation itself. The last two sections give the data streams and their dependencies.
In the appendixes the results are summarized, and background information is given.

2. Algorithm description

A discrimination between cloud occurrence and Cb/Tcu occurrence is required by ICAO for save aviation conditions. Since 2007 an automated Cb/Tcu detection system based on radar observations is operational 24/7 at two regional civil airports, EHGG and EHBK. The applied algorithm was based on a Meteo-France study by Leroy and will be further referred to as the MF application within the report.
The performance of the MF detection system showed room for improvement. Two studies were started in 2008 at KNMI to improve the performance of automated Cb/Tcu detection. Both studies employ the synergy of radar and satellite observations to come to an improvement of the performance, Carbajal-Henken et al 2009, and De Valk and Van Westrhenen, 2010.
A recent report from UK met office underlines the challenges of a Cb/Tcu classification with fixed thresholds for radar reflectivity, C Hord, 2011 as is applied in the MF algorithm.

A short summary of both reports is given here. For more information we refer to the reports and the article by Carbajal-Henken et al, 2010.

Both studies employ logistic regression (Wilkes 1995) to determine the relation between the Cb/Tcu classification and its predictors. From satellite and radar data it proved to be difficult to discriminate between Tcu and Cb. Hord, 2010 confirms the difficulty of discrimination when only using radar data. Therefore both cloud types are classified in one class in these studies: Convective clouds, for convenience labeled here as Cb/Tcu.

Carbajal-Henken employs derived products from satellite as given by Roebeling et al, 2006, as predictors, next to radar observations. The products from Roebeling are only derivable when the solar zenith angle is high enough. Therefore Carbajal-Henken only considers the summer day time period for four years, 2004-2007. As predictand the METAR reports of Cb/Tcu are used.
Carbajal-Henken finds a better performance for the classification of Cb in comparison to the Meteo-France based algorithms.
Additional calculations required for the products from Roebeling et al, 2006 introduce extra delays in the delivery of the results. Next to the argument that the Roebeling et al, 2006 products are not available throughout the year it was decided to use the results from the study of De Valk and Van Westrhenen, 2010 as the base for the operational algorithm.

De Valk and Van Westrhenen, 2010 employs the observations from the SEVIRI instrument on board of MSG and radar observations as predictors. Similar to Carbajal-Henken the METAR is used as predictand. This study only considers one year of data, 2005, but it is applicable day and night in Winter and Summer. The performance of Cb classification was slightly less than the performance for summer days found by Carbajal-Henken. It is still significantly better than the performance of the Meteo-France based algorithms.

Throughout the study of De Valk and Van Westrhenen, 2010, the extend of the collocation area as used was unclear. In the definition stage of the MF algorithm a radius of 30 km was used. Later in 2008 the radius was decreased to 15 km. The undocumented reason appears to be the high number of False Alarms. Also the area considered by the METAR is unclear. It depends on the observer judgment of the occurring situation and his observation position.

To address these uncertainties a separate study was initiated. An experienced forecaster evaluated all cases of 2005 for the major airports, EHAM, EHRD, EHGG, and EHBK. A classification for Cb/Tcu was produced for two collocation areas with 15 and 30 km radius respectively. The result consists of a large number of evaluations: 140160 [number of days times number of METARS times number of airports times number of collocation areas]. The forecaster had access to all radar and satellite observations. He had the advantage that he could scroll forward and backward in the time through the observations. An observer at the airports does not have the possibility to scroll forward in the time to interpret developments in the atmosphere. Often the view of the observer is obscured by other clouds, and he has a limited view in night conditions. The forecaster had also access to radio-sonde data and analysed weather maps, this helps to classify Cb/Tcu as the likelihood of instability is known. The forecaster can also discriminate embedded Cb's. The forecaster, however, will not be able to identify small sub pixel phenomena. It is however uncertain whether sub grid cloud phenomena will form a hazard for aviation when they remain smaller than a pixel. Therefore it is assumed that a wrong classification of the undetected small scale clouds will not hamper the development of a detection algorithm.

The created data set enabled a consistent evaluation of Cb/Tcu occurrence. The used radii for the collocation area were fixed and for the four separate aerodromes an identical identification method was used. A benefit is the classification of embedded Cb. An additional benefit was the inclusion of the night time cases for EHGG and EHBK into the study. The night time METARS for these airports were not available in 2005, as these observations were stopped earlier in May 2004. The evaluated data set was used as predictand in a logistic regression evaluation instead of the METAR used in De Valk and Van Westrhenen 2010.

The study also enabled an evaluation of the METAR. The previous studies Carbajal-Henken et al 2009, and De Valk and Van Westrhenen, 2010 showed that predictors from the 30 km collocation area appeared to correlate with the predictand, the METAR reports of Cb/Tcu. This indicates that the observer also reports Cb when they occur outside the 15 km radius collocation area, used since Summer 2008 in the MF algorithm.

Although a higher POD for Cb/Tcu classification was achieved for the 30 km radius collocation area also a higher FAR was achieved. (See appendix 2 when you are unfamiliar with POD, FAR and CSI).
There appeared to be overlap between the selected predictors when using the METAR Cb report as predictand and the selected predictors obtained when using the evaluated Cb classification as a predictand. The main difference is the occurrence of the 30 km radii based predictors when using the METAR as predictand which obviously do not occur when using the 15 km radius Cb evaluation as predictand.
As the collocation area with 30 km radius is not used anymore, the results considering this area are not given here. They are considered as obsolete.

Within the study of the 2005 evaluated data set the five predictors with the highest explanatory power were:

- The maximum radar contour,
- HRVmax-HRVmin daytime only,
- The averaged cloud top temperature,
- The standard deviation of the cloud top temperature,
- The number of pixels with T39-T108< 0 night time only

In the appendices (3) the POD-FAR diagrams of 2005 for EHAM only are shown. A comparison is made with the results obtained with the METAR as predictand and the results obtained with the evaluated data set as predictand. It underlines the problem of lacking an absolute truth in the development of the algorithm. It shows that the Meteo-France Based algorithm, with fixed dBz thresholds has a CSI maximum of 0.43. The METAR CSI varies from 0.45 to 0.61. The 2005 results show a CSI variance of 0.45-0.58 depending on the probability threshold selection when the evaluated data set is used as predictand. When the METAR serves as predictand the CSI varies from 0.25 to 0.52, which is lower in comparison to the evaluated data set results.

To extend the number of cases the forecaster also evaluated 2009. It was anticipated that the selected predictors found in the 2005 study would be applicable for the 2009 results. Using these predictors derived from 2005 for the 2009 cases showed unfortunately a poor performance.
A study on this poor performance revealed that the radar resolution was increased and the pseudo capi height was changed from 800 m to 1500 m. Before 2008 the radar results were distributed on 2.5 x 2.5 km^2 grid, in 2008 the observations were distributed on a 1 x 1 km^2 grid. The 2.5 x 2.5 km^2 is still distributed as a number of applications use this format as a basic input, but it is derived from the 1 x 1 km^2 grid.
Extended research indicated that these changes had an impact on the derived coefficients for the predictors.
An evaluation of the 2009 data set showed a change in the predictor set with explanatory power in comparison to the study based on the 2005 data set.

The five predictors with the highest explanatory power for the 2009 study were:

- number of radar contours with 14 dBZ (0.25 mm/hr)
- the maximum radar contour
- cloud top temperature average
- fraction of pixels T03.9-T10.8 < 0 (night time only)
- HRV maximum - HRV minimum, contrast (day time only.)

New in comparison to the De Valk and Westrhenen, 2010 study is the number of contours of the lowest defined contour in comparison to the predictors derived from the 2005 data set. An increase of the number of contours indicates an increase of the number of separate rain cells, which could correlate with Cb occurrence. The T03.9-T10.8 appears more frequently as predictor with significant explanatory power in the 2009 dataset compared to 2005 dataset.
The results of 2009 are shown in the appendices (4). Shown for four airports are the

- POD, FAR, CSI and BIAS as function of the probability threshold
- The histograms as function of the probability threshold
- The attribute diagrams,
- The POD-FAR diagrams

As HRV maximum - HRV minimum occurs frequently as combination, it is introduced as a single extra predictor. It is also explored what another extra predictor [fraction of pixels with reflectivity > 7dBZ (FRP7)] contributes. It is shown in POD-FAR diagrams what the impact of this extra information is, next to the 2005 based predictors.
The results show that combining HRV maximum and HRV minimum does not have a significant negative impact on the results, not shown here. It is therefore decided to keep

the combination as a single predictor. This facilitates the maintenance of the system.
The extra radar information has a small positive impact during the winter night, also not shown.

Based on the cycling between the three parts, where one part served as independent data (more details on this method are given in De Valk and Westrhenen, 2010), it can be concluded from the figures in the appendices that depending on the choice for the threshold a CSI ranging from 0.2 up to 0.7 seems achievable.
The METAR, only available for EHAM and EHRD achieves a CSI ranging form 0.4 to 0.55 compared to the evaluated data set.

The change in radar resolution and pseudo cappi height showed the sensitivity of the optimized merged systems to changes. Whenever there are instrument changes or additions the whole algorithm has to be recalibrated and evaluated. This also limits the possibility to share the system with other (third) parties, when they use different instrumentation. Although most likely the coefficients will differ it is expected that the predictors will be similar.

Based on these study results an operational algorithm was defined. The results of the study over 2009 were used to define the predictors and their coefficients, given in appendix(1). Minimization of the bias resulted in the threshold selection.
When a Cb is classified the coverage is calculated from radar observation [fraction of pixels with a rain rate above 0.1 mm/hr (or > 7dBz)]. The coverage is given in three classes: few,scattered,or broken (FEW, SCT, BRK) in accordance with the METAR.
This implies that even when the radar derived fraction is 100 % for the collocation area the maximum coverage is broken and for a low coverage but with a single Cb detection the coverage is set to few.
The classification and coverage are reported in the output.

3. Consecutive steps for implementation and bugs

The output XML file, containing Cb classification and coverage of all aerodromes, is collected and processed by the CIBIL system and send to ADCM's located at the airports. The ADCM processes also lightning data. The XML file and the lightning data are combined into Cb classification which is included into a METAR message as a fourth cloud group, e.g. FEW020Cb. The inclusion of a Cb classification can influence the other observations, e.g. OVC reported for one of the underlying cloud layers will be changed to BKN. The decision table applied within the ADCM is given in table 1.

The decision table indicates that a lightning stroke always will lead to a Cb classification. However several METAR messages are generated which contradict this decision table, see example below. It is unclear what causes this discrepancy. It is a bug in the executable of the ADCM software according the INFRA-ID topdesk-met people. It will be solved in the release of November 2011.

Example of METAR messages containing TSRA and no Cb classification:

```
METAR AUTO EHWO (2011-06-28) 18:25:00 14008G19KT 8000 -TSRA FEW009
SCT012 BKN017 22/19 Q1013

METAR AUTO EHRD (2011-06-28) 18:25:00 03006KT 350V060 9999 -TSRA FEW010
20/17 Q1011

METAR AUTO EHGR (2011-06-28) 22:55:00 24009KT 4000 TSRA FEW062 SCT068
BKN080 20/19 Q1014

METAR AUTO EHGR (2011-06-28) 23:25:00 24006KT 6000 TSRA FEW069 SCT074
BKN083 19/18 Q1014
```

The AUTO-METAR is broadcast to the world at HH+25 and HH+55. For these messages the satellite data has the time stamp from HH+00 and HH+30 and the radar data stamp is HH+10 and HH+40 respectively. The time stamp of the observation files denotes the start of the observation scan.
The result of these files are reported in the XML files of HH+20 and HH+50. This leaves some time to communicate the XML files from the production platform APL to the ADCM where the METAR is composed. It also leaves some time to add a trend by the forecaster. Correction of the message is not done by the forecaster.

A part of the METAR message contains the cloud base height. Although the base height is not a part of the detection algorithm its reported results cause complaints. Therefore we explain how the base height is determined, and suggest in the next section how it could be improved.
The cloud base height is calculated within the ADCMs on base of the on Ta- Td : ((Ta-Td)*400 ft), Ta air temperature at 2 m Td dew point temperature at 2 m at the airports. It has a minimum value of 1500 ft (e.g. FEW015Cb)
No ceilometer data is used as there may be various cloud layers present next to the Cb. The ceilometer data is only used for these cloud layers.

DBZ Class	Sfr1 > 0	Sfr2 > 0	Sfr1 and Sfr2 =0	Sfr 1,2 invalid
3	Cb	Cb	Cb	Cb
0	Cb	Cb	“”	“”
invalid	Cb	Cb	///	///

Table 1. Decision table at the ADCM to come to a Cb classification. Sfr1, Sfr2 denotes flashes within 15 and 20 km radii collocation areas. DBZ class refers to a radar DBZ classification. Formerly DBZ Class 1 and 2 (Tcu) could also occur.

The algorithm became operational in March 9, 2011 for EHBK, EHGG and EHRD. The EHRD is relevant as it is the backup of the main airport EHAM.

In the pre-operational phase it became apparent that the XML files were also used as input for the ACTUALS. This reduced the required availability time cycle of the files from every 30 minutes, for METAR, to every 5 minutes, in accordance with the update cycle from the radar observations.

Message HH+	Satellite HH+	Radar HH+	Xml HH+
05	(-60) 30	(-60) 50	00
10	(-60) 45	(-60) 55	05
15	(-60) 45	00	10
20	(-60) 45	05	15
25	00	10	20
30	00	15	25
35	00	20	30
40	15	25	35
45	15	30	40
50	15	35	45
55	30	40	50
60	30	45	55

Table 2. The time dependencies of the message files on the input files time stamps. HH+ refer to the hours + the minutes given in the table cells (-60) refers to an hour earlier. Message refers here to either METAR, or ACTUAL(LOCALS). SPECIALS will not be triggered by this part of the software as the radar dictates the update frequency. It is unknown to the authors what the impact of lightning information is on the generation of messages.
Satellite and Radar times refer to the start of the observations, Xml times refers to the time the message should be issued.

In table 2 the time stamps of the observations files, the resulting XML files and the resulting message (METAR, ACTUAL) files are given. This gives an impression of the offset in time for the various files and the resulting message file.

Furthermore it became apparent that XML files were produced for all the civilian and

military airports. This includes another ten airports next to the ones used in the previous studies.
The satellite and radar based algorithms are tuned for EHAM, EHGG, EHRD, and EHBK. The predictors, their coefficients, and thresholds are specific for each airport and will give a poorer performance in Cb classification at another location.

To ensure continuation in XML file production for all the desired locations it was decided to merge the MF algorithm results for the additional airports and use the results of the algorithm based on satellite and radar data for EHAM, EHGG, EHRD and EHBK.
The XML file produced since March 9, 2011 contains therefore the results of two algorithms, hence the end users will experience no difference in the output format and file length.

4. Improvements and further studies

A number of improvements could be identified. They are classified here below into short term and longer term improvements. The short term could be implemented in the next version with limited additional effort. The long term requires additional research on the impact of the suggestions on the results.

Short term:
1) Cape (NWP) information used as a filter to suppress erroneous Cb classification of frontal rain. NWP data use within observation should be done cautiously this observation may serve as input in some NWP models causing undesirable dependencies.
2) Raise the threshold for coverage from 7 dBZ to 30 dBZ to improve the reported overestimation of coverage.
At the moment of writing of this report feedback from end users was received that they experience the coverage in general as an overestimation.
This is explainable. During the algorithm development the focus was on Cb occurrence within the area under study. Evaluation of the Coverage was not considered in the study. In the definition of the evaluation study it was considered as unrealistic to let the forecaster estimate a Cb coverage solely based on radar and satellite data. Within the area under study also various cloud types at different height layers can occur hampering even more a Cb coverage estimate.
It is challenging maybe even impossible to obtain a reliable data set of Cb coverage from other sources. The observers view on Cb's can be obstructed by other clouds. The Cb's may also be embedded, disabling any coverage estimate by the observer.
It is also not well defined what part of the Cb cloud is of interest to the end user. The end user is mostly not interested in the size of the anvil. For save flight conditions the interest of the aviation forecaster is in these areas with lightning, significant up/downdrafts and gusts causing turbulence. This is only a part of the extended area of a Cb. High values in radar reflectivity can be considered as the only markers for the vicinity of these dangerous areas.
During the implementation of the software the choice for the threshold for coverage derived from radar observations was based on the assumption that the end user was interested in the extend of the whole Cb, hence a low threshold of 7 dBZ.

Acquired knowledge on the relevant information for the end users leads to the improvement to increase the radar threshold for Cb coverage determination, from 0.1

mm/hr to 3 mm/hr [7 to 30 dBz]. The coverage is solely based on radar observation. It will not be validated as there are no other reliable observations. Ceilometer data can supply an upper limit of Cb coverage, when there are no other cloud layers observed.
3) Adapt the contouring calculations to identify extended MCS's correctly as Cb.
On August 23, 2011, the Netherlands were struck by a series of extensive Mesoscale Convective systems (MCS). The software did not determine these systems correctly as Cb complexes. The cause could be traced. In the development of the software a focus was on the small Cb's. The number of radar contours occurring within the area under study appeared as an explanatory predictor. It was overlooked that a MCS can have a contour encompassing the whole area under study. In a next version this is addressed and solved.
4) Introduce a classification using only radar based predictors for the case that satellite data is not available. A short inventory showed that data stream failures can be attributed predominantly to the satellites data stream failure. At the moment of writing there is not sufficient redundancy for such a failure. When satellite data lacks there is no output. It is desirable to solve this in the next release. The system will produce a classification solely on radar data when satellite data lacks.

Long term:
1) Include cloud classification by SAFNWC into the algorithm to differentiate between low, middle and high, clouds. This would facilitate a cloud mask to determine cloud top temperature using only middle and high clouds.
2) include the physical interpretation results as developed by Roebeling. It provides a pseudo radar imagery that could support Cb classification for EHAK (limited radar coverage) during the day time.
3) Correct cloud base height estimation by using ceilometer data and Ta-Td
A significant part of Cb's are not triggered by ground based instability but by instabilities occurring higher up in the atmosphere. Here the Ta-Td difference at the ground has no relation with the instability.
The algorithm at the ACDM is configured thus that when Ta-Td evaluation is inconclusive a Cb cloud base height of 1500 ft is reported, resulting in a more frequent 1500 ft report than actual occurring. This reduces the reliability of the system as judged by the end user.

An improvement could be reached by merging ceilometer data and suspicious Ta-Td information for cases with a single layer of cloud observed by the ceilometer.
Unfortunately the attribution of height is done at the ADCM. On ADCM runs third party software which can not be improved by KNMI without additional costs. The configuration files of the ADCM could offer possibilities to improve the height attribution.

4) Explore the predictor capability of Echo Top heights from radar and its development in time.

Future studies
A consecutive study is started to produce a data set of evaluated Cb for all the airports for one year. Next to the airports also the majority of the North Sea platforms are considered in the evaluation, see Figure 2. The wish for platform Cb evaluation came from Weather-PROD based on a request from the Helicopter aviation group. Only the most Northern platform AK is excluded from the evaluation. It had no sufficient coverage in the radar files. The forecaster requires radar observations to classify a Cb/TCU occurrence with significant confidence.
This task involves a large number of evaluations 365x24x2x26=455520, requiring a

significant effort. Next to enabling an improved algorithm performance at all locations, the created data set also enables a performance evaluation of the operational algorithm for 2010.

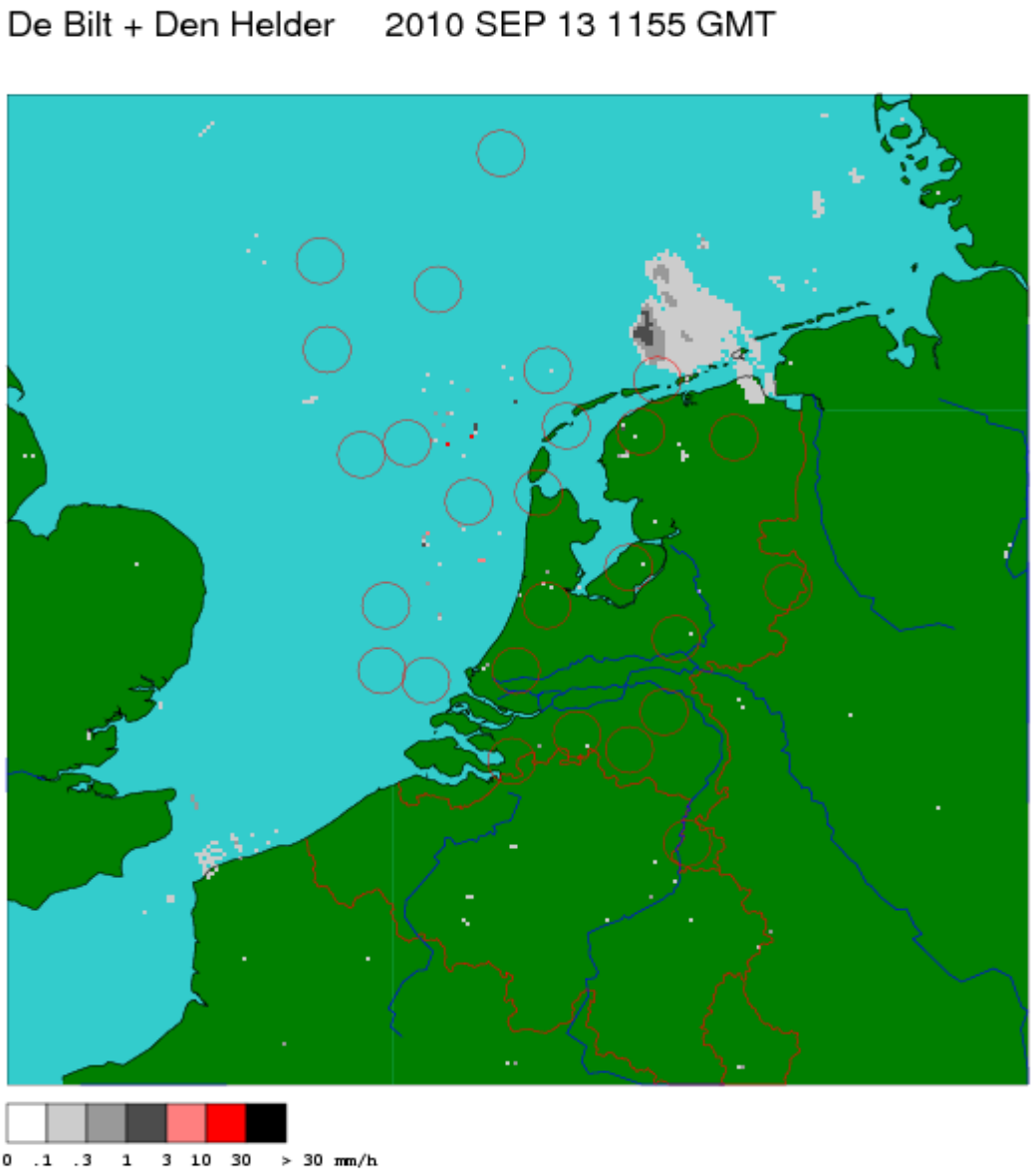


Figure 1. The circles denote the 26 stations for which an evaluation is required

5. Considerations for implementation

The implementation is done in consecutive steps. At each step the input requirements of the consecutive systems have to be considered. It is also beneficial in the implementation to use existing hardware and available procedures thus exploiting existing knowledge and minimizing the effort put into adaptations.

The developed software runs on the APL. On the APL the software has to compete for cpu and memory allocation with other application. A minimization on the cpu and memory consumption is therefore desirable and facilitates a smooth operationalization.

The operational system managers install the software on the APL. This introduces time constraints as it requires the presence of both developers and system managers at simultaneous moments, for the bulk information exchange and also for the details. This transition went smooth.
Before the software can be installed, data streams should be realized and data has to be stored in the agreed and communicated directory structures. On the Cinesat system a rescheduling of the product generation had to be optimized for the required satellite files.

In the MF algorithm operational since August 2007 it was not foreseen that other data sources next to radar would contribute to the Cb classification. Because the operational system consists of several separate software modules, some built by third parties, it was considered as most efficient to keep the new result file as a pseudo radar result file.

The interaction with I-ID and I-RD was efficient to realize the production of the XML file on the APL. A first version ran in November 2010.

CIBIL collects the output file from the APL and distributes them to ADCM. On the test CIBIL environment it appeared that the software on CIBIL is strict in accepting file formats. Comments in the beginning of the XML files, and additions in the existing format resulted in file rejection. We could not find documentation on the required formats for the CIBIL input. We produce a pseudo radar XML file and we would like to add some information on the used radar and satellite data. This enables failure tracking when required.
Without documentation we simply attempted various possibilities. The trials showed that a comment line at the very end of the file was accepted in by CIBIL.
In the comment line information on data availability and observation time stamps are included.
It was produced as the last line of the XML file which was the output of the algorithm using radar and satellite data as input. When merging with the MF based results this line had to be treated separately by the script and copied to the end of the resulting merged XML file.

In February 2011 the system was ready for transfer from test CIBIL to CIBIL. As there was similarity in file naming, directory-structure, and file format, the transition promised to be smooth. We overlooked that changes in CIBIL are not done instantaneously. CIBIL is an operational system and it is desirable to keep updates and changes to a minimum. So we had to wait for the system manager to implement several changes in one update cycle.

6. Implementation

The actual implementation involves several platforms.

The main software package runs on the APL. It consists of Fortran and “C” coded programs and c-shell scripts.
The radar data is already available on the APL.
The required satellite data is produced on the operational Cinesat system. Via Vivid the satellite results are copied into a prescribed directory on the APL. As there is some time variety in the availability of the files on Cinesat Vivid checks frequently whether the files are available.
Next to software also scripts on the APL had to be modified for an optimal timing of the start of the run. Given the time of availability of the satellite files (HH+17,47) and the required time (HH+20,50) to incorporate this observation into the METAR (HH+25,55) optimization of timeliness is essential.

CIBIL collects and distributes the XML file from the APL to the ADCMs.

A smooth transition from test-CIBIL to CIBIL was done in the morning on March 9, 2011.

No error on the processing have been reported since then until August 2011, the moment of writing this report.
The only hick-up in AUTO-METAR Cb production was a complete outage of satellite data. In April 2011 there was no data from the satellite nor from the operational back-up satellite for a few hours on one day.

7. Datastreams

The algorithm runs in an **APL** environment which is only accessible from APL ${HOME} .
All software, fortran and “C” code and “C”-shell scripts are located in:
${HOME}/MODELLEN/BEELDEN/Cb

The algorithm uses as input radar observations and satellite observations.
All the subsequent paths starting with “/net/” can be accessed from any KNMI workstation

The radar files (e.g. RAD_NL21_PCP_NA_201108080850.h5) are distributed by the **OMNIVOOR** or **OMBE** imagery system. They have a resolution of 2.5 x 2.5 km^2 and are available on the **APL** platform in the directory:
/net/apl/apl/data/RADAR/INPUT/

Four satellite files
MET9_120-108_Cb-NL_1011231230.h5
MET9_39-108_Cb-NL_1011231230.h5
MET9_HRV_Cb-NL_1011231230.h5
MET9_IR108_Cb-NL_1011231230.h5
are produced on the operational Cinesat system ”**bhlbcs02**”. They are produced as soon as the observation files are available.
The “**VIVID**” system collects the files by ftp from
/net/bhlbcs02/data/cinesat_oper/out/export
and stores them in the directory
/net/apl/apl/data/Cinesat/
The “**VIVID**” system attempts every minute to collect the files, as there is not a fixed availability time due to small deviations of broadcasting, and data traffic.

The algorithm collects the data and produces output files (radarCB_201108081145.xml).

Please note the subtle (CB versus cb) but essential differences with the Meteo France based algorithm output files (radarcb_201108081140.xml) which are stored into */net/apl/apl/data/RADAR/CB*

An APL script merges radarcb_201108081140.xml and radarCB_201108081145.xml into one radarCB_201108081145.xml in the output directory:
/net/apl/apl/data/CB

Allthough the file name of the output file “radarCB_YYYYMMDDHHmm.xml” contains “radar”, the content is based on both radar and satellite. The time stamp of radarcb_201108081140.xml is the start of the radar observation. The time stamp of radarCB_201108081145.xml is the moment that the message is issued, which is five minutes after the radar observation starts. Due to software dependencies the format of the resulting xml file is very limited in its format freedom. Only in the last line there is room for additional information on used satellite, time stamp and other information.

The **CIBIL** system collects the radar output file from the APL by ftp every five minutes and distributes it to the **ADCM** at the various airports. Within the ADCM the radar.xml files is used next to lightning data to come to a Cb classification, which is used for METAR,

SPECIAL and ACTUAL reports. The **ADCM** combines the Cb classification with Ta-Td information to come to a cloud base height. Should the base height data lead to an inconclusive result a cloud base height of 1500 ft is reported.
It is underlined here that the algorithm using radar and satellite information only provides a Cb classification and coverage and does NOT provide any information on the cloud base height.

For the North Sea platforms **CIBIL** combines the XML files with ceilometer and lightning to produce a METAR. This enables a software change to determine the cloud base height using ceilometer and Ta-Td together.

The data flow and file names are depicted in Figure 2 below.

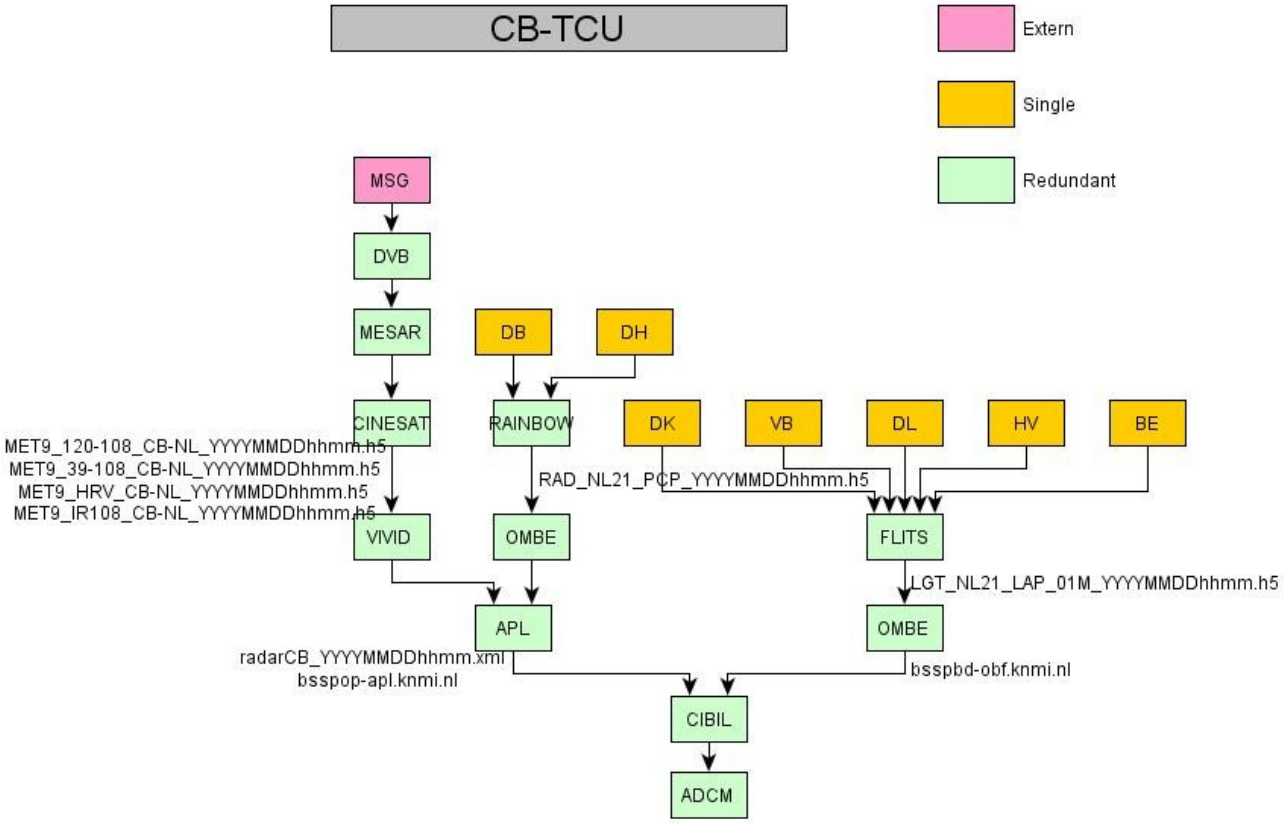


Figure 2. The data streams and file names as applied in the Cb-TCU algorithm. The ADCM produces the METAR, ACTUAL and SPECIAL message. Courtesy W. Wauben. The separate systems should be identifiable within the “blue print of KNMI”.
MSG meteosat second generation satellite DVB digital video broadcasting DB de Bilt DH den Helder DK De Kooy VB Valkenburg DL Deelen HV Hoogeveen BE Beek
Please note that for North Sea platforms the message production is different.

8. Dependencies

The algorithm only produces output when radar and satellite data is available. The assumption is that the radar data is always present. Should satellite data lack than the algorithm will look for satellite data of one time step earlier. It is also checked whether the operational satellite is replaced by the backup satellite.

The repeat cycle of the radar is five minutes, that of the satellite data is 15 minutes. This means that one satellite image will be used three times in combination with different radar inputs. The best collocation in time and space is the combination of satellites image at HH+
00, 15, 30 and 45 minutes with radar image of HH+ 10, 25, 40, 55 minutes see table 2. The other combination's will have an offset in observation time of five or ten minutes. It has not been studied what the impact of this offset is on the classifications because it is not feasible as there is no independent and validated data set available which provide Cb classifications with a five minutes repeat cycle.

Lacking of satellite data should be reported in the XML file.

The presence of the radar files will not assure that both radars are functioning. Should one of the radar be out of function then this will lead to deteriorated results. There is no fall back option for this.
Lacking of radar information should be reported in the XML file.

Abbrevations

ADCM Aviation Data-acquisition and Communication Module
APL Automatic Production Line
CIBIL Centrale Inwincomputer de BILt/Central Data Acquisition System De BILt
MF Meteo France based algorithm
OMNIVOOR Image archive of KNMI
VIVID Videotext for information and distribution

Literature

Carbajal Henken, C., Schmeits, M., Wolters, E. and Roebeling, R. Detection of Cb and Tcu clouds using MSG-SEVIRI cloud physical properties and weather radar observations. KNMI WR 2009-04

Carbajal Henken, C., Schmeits, M., Denek, H. and Roebeling, R. Using MSG-SEVIRI Cloud Physical Properties and Weather Radar Observations for the Detection of Cb/TCu Clouds, 2010, *Journal of Applied Meteorology and Climatology*, **50**, 1587-1600

Hord, C., 2011, "REPORT ON THE USE OF REMOTE SENSING CAPABILITIES TO FURTHER AUTOMATE AERONAUTICAL METEOROLOGICAL REPORTS IN THE UNITED KINGDOM" presented at the AERODROME METEOROLOGICAL OBSERVATION AND FORECAST
STUDY GROUP (AMOFSG), NINTH MEETING, Montréal, 26 to 30 September 2011

Leroy, M. 'Status of the Automatic Observations on Aerodrome and Ongoing Improvements in France' Meteo-France report.

Roebeling, R.A., A.J. Feijt and P. Stammes, 2006, Cloud property retrievals for climate monitoring: implications of differences between SEVIRI on METEOSAT-8 and AVHRR on NOAA-17, J. Geophys. Res., 111, D20210, doi:10.1029/2005JD006990

Specificaties autometar onbemand Cb/TCU (24uur/dag) v1.0

De Valk, P., R. van Westrhenen, 2010, Probability of Cb and Tcu occurrence based upon radar and satellite observations, KNMI WR 2010-04

Wilks, D.S., 1995, Statistical Method in the atmospheric sciences, academic press, New York

Appendices (1)

Operational coefficients implemented since March 9, 2011

1.312*\$9+0.354*\$26+0.330*\$191+0.022*\$197+-5.652	EHAM SD threshold 0.25
0.410*\$26+0.922*\$191+0.019*\$197+-5.962	EHBK SD threshold 0.30
0.788*\$9+0.307*\$26+0.755*\$191+0.022*\$197+-5.486	EHGG SD threshold 0.30
0.982*\$9+0.339*\$26+0.621*\$191+0.024*\$197+-6.218	EHRD SD threshold 0.30
1.459*\$9+0.612*\$26 +1.491*\$192+-4.184	EHAM SN threshold 0.25
0.341*\$26+1.511*\$191+-5.489	EHBK SN threshold 0.35
0.775*\$9+0.495*\$26+0.883*\$191+-4.492	EHGG SN threshold 0.35
1.112*\$9+0.487*\$26+0.399*\$191+0.979*\$192+-4.232	EHRD SN threshold 0.35
1.218*\$9+0.360*\$26+0.175*\$191+0.024*\$197+-6.022	EHAM WD threshold 0.30
0.197*\$26+1.287*\$191+0.020*\$197+-6.828	EHBK WD threshold 0.35
0.932*\$9+0.188*\$26+0.869*\$191+0.024*\$197+-6.359	EHGG WD threshold 0.40
0.811*\$9+0.268*\$26+0.609*\$191+0.026*\$197+-6.545	EHRD WD threshold 0.35
1.016*\$9+0.425*\$26+ 1.172*\$192+-3.695	EHAM WN threshold 0.30
0.494*\$9+0.334*\$26+1.402*\$191+1.185*\$192+-6.418	EHBK WN threshold 0.30
0.635*\$9+0.357*\$26+1.136*\$191+0.857*\$192+-5.287	EHGG WN threshold 0.40
0.863*\$9+0.319*\$26+0.552*\$191+1.059*\$192+-4.309	EHRD WN threshold 0.35

with \$9 = number of radar contours with 14 dBZ (0.25 mm/hr)
\$26 = the maximum occurring radar contour
\$191 = averaged cloud top temperature
\$192 = number of pixels with T03.9-T10.8 < 0
\$197 = HRV maximum - HRV minimum
SD Summer day, SN Summer night, WD Winter day, WN Winter night

In the operational code only the variables are considered which serve as predictors. This reduces the number of calculated variables from 200 to 30. The numbering of the variables as given above enables a swift comparison to the software used in the development of the algorithm.

Appendices (2)

Verification

Cb/Tcu occurrence is a dichotomous phenomenon. The frequency of Cb/Tcu occurrence is relatively low in comparison to the total number of METARs or evaluated classifications. The value of a forecast or classification can be assessed by comparison to an observation. Frequently used for assessment is the contingency table (Wilks 1995) given below. Here the occurrences of forecast/classification in comparison to observations are represented.

	observed yes	observed no
classified yes	hits	false alarms
classified no	misses	correct negatives

Contingency Table, (Wilks 1995). Relationship between the number of observed and classified cases of a dichotomous phenomenon. The sample size is the sum of the hits, misses, false alarms and correct negatives.

From the table a number of scores can be calculated. Given the large number of correct negatives for this Cb-Tcu classification/observation this number is not incorporated in any of the scores used in this report. It is omitted as its use may cause confusion when interpreting the results.
Considered are, the Probability of Detection (POD), The False Alarm Ratio (FAR) the Critical success index (CSI) or threat score, and the BIAS.

POD = Hits/ (Hits + Misses)

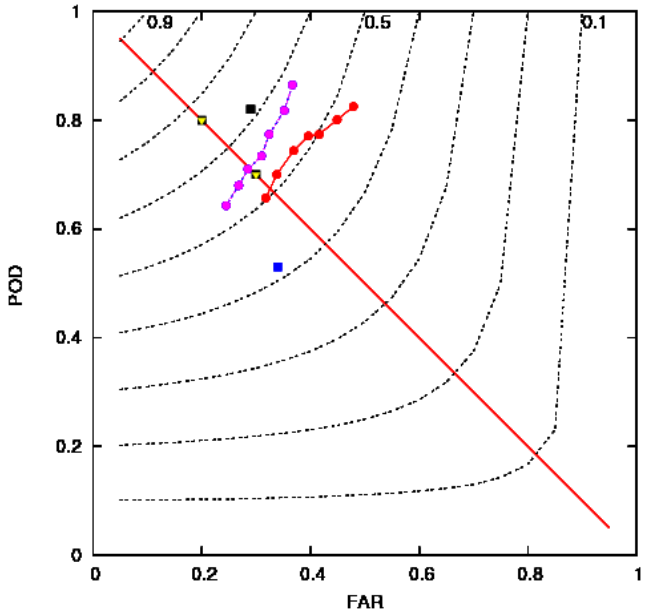
FAR = False Alarms / (Hits + False Alarms)

CSI = Hits/ (Hits + Misses + False Alarms)

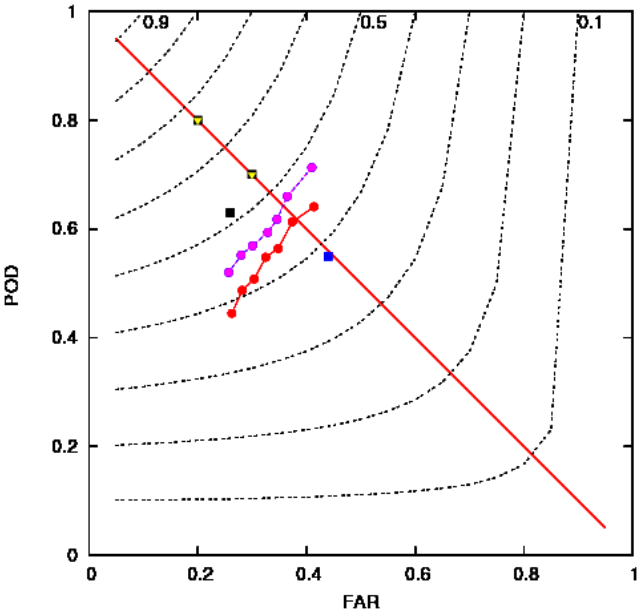
BIAS= (Hits + Misses) / (Hits + False Alarms)

Comparison of the algorithm based on the 2005 predictors derived with as predictand the METAR in red versus the algorithm with the evaluated data set as predictand, in purple.

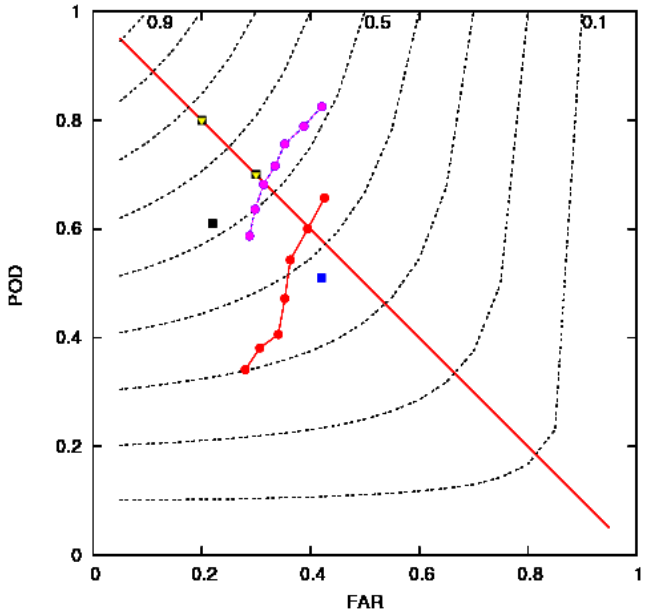
The results are shown for EHAM only. The results of the other aerodromes only confirm the drawn conclusions.



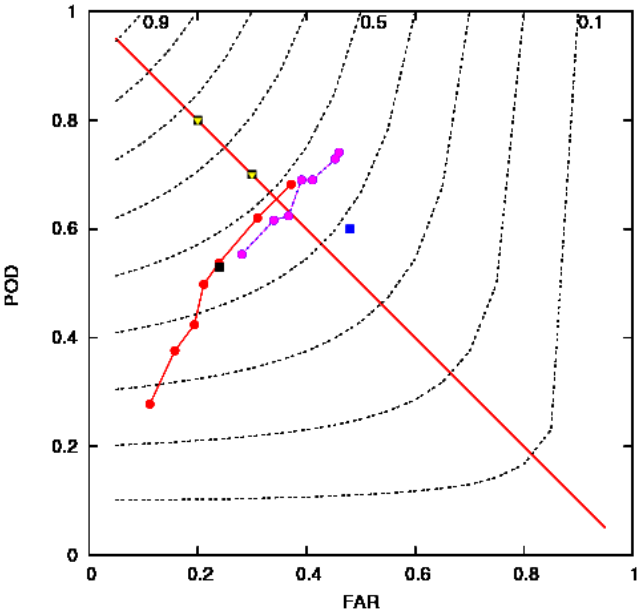
EHAM Winter day
Red: METAR based , Purple: Evaluated based. The dots refer to probability thresholds ranging from 0.2 upper left to 0.5 lower right in steps of 0.05. Black square METAR. Blue square MeteoFrance based result. Black yellow square: CSI 0.53 or 0.66



EHAM winter night

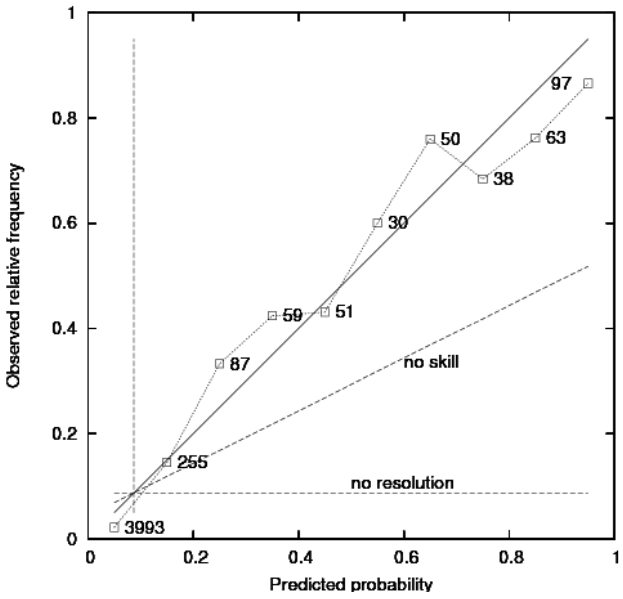


EHAM Summer day, as winter day

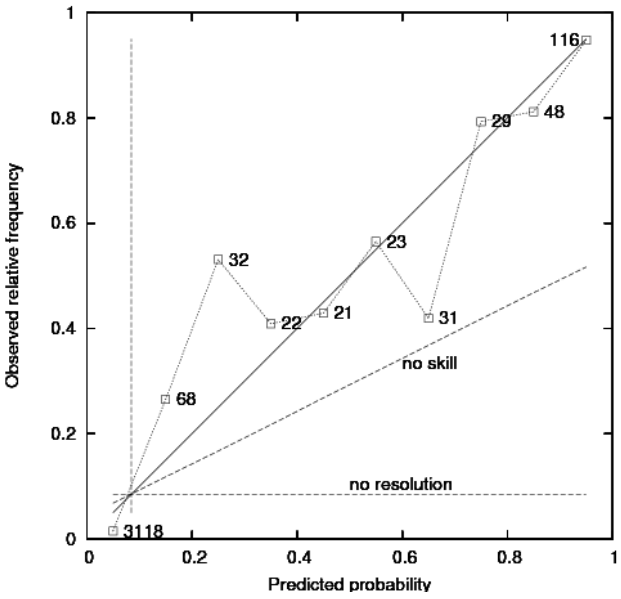


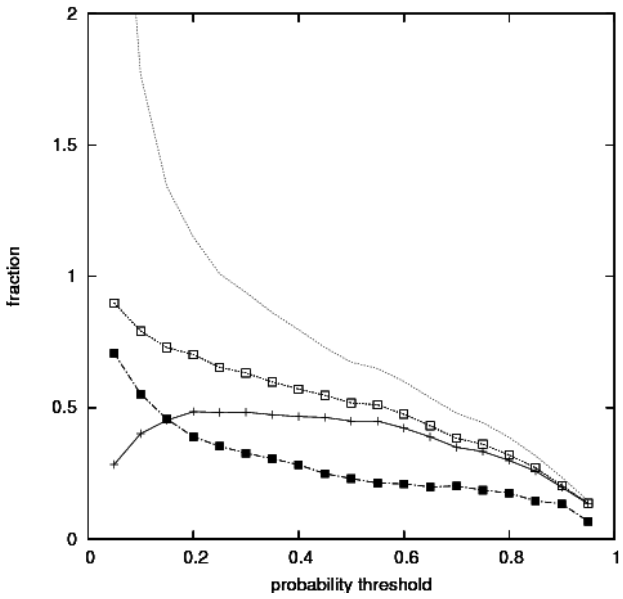
EHAM summer night

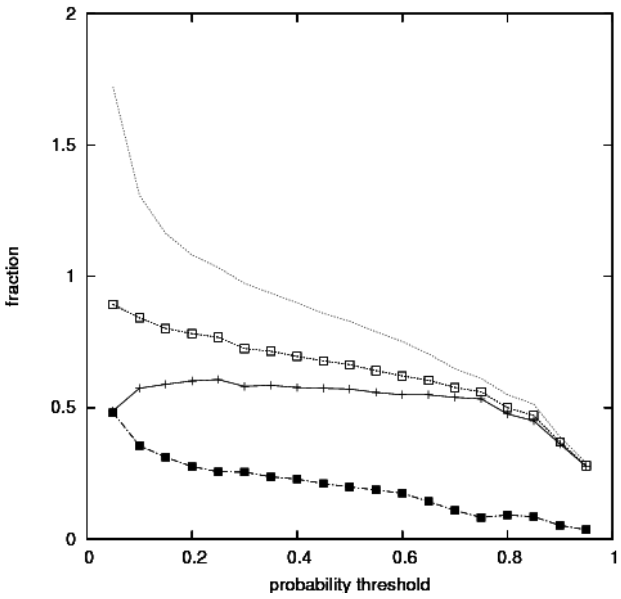
EHAM summer day 2009, attribute graph



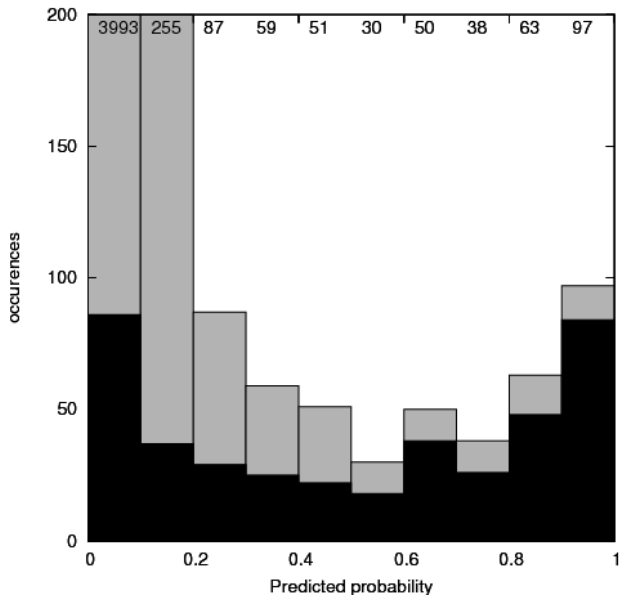
EHAM summer night 2009

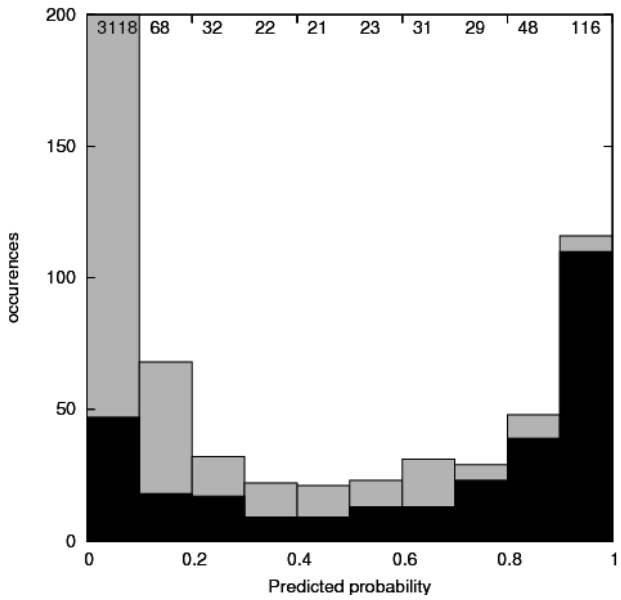






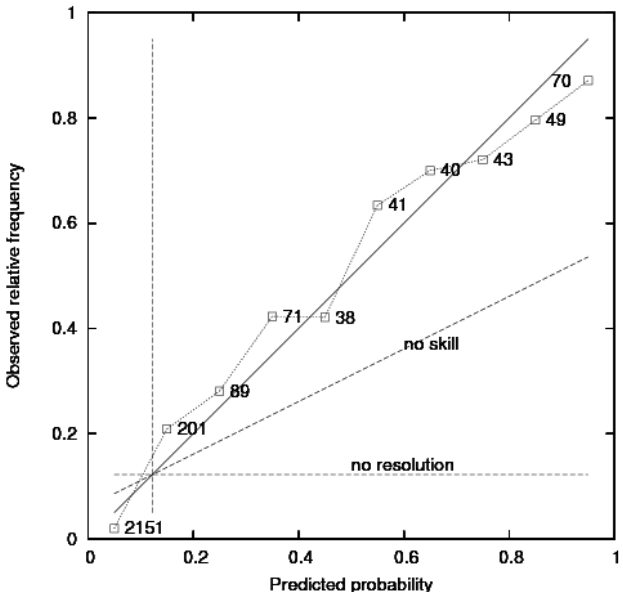
BIAS grey line, POD open squares, FAR black squares, CSI plusses

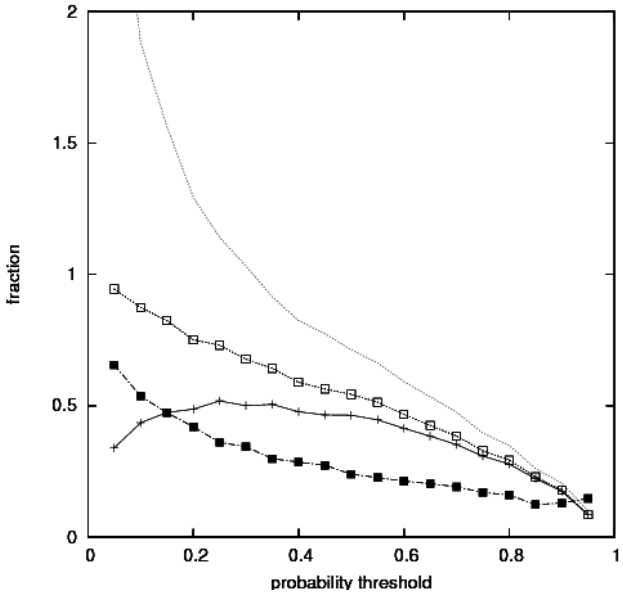


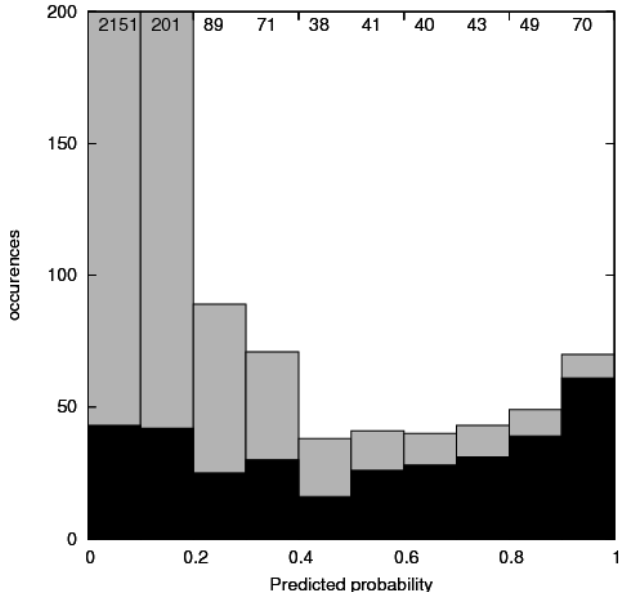


Grey all reports, Black Cb-TCu reports

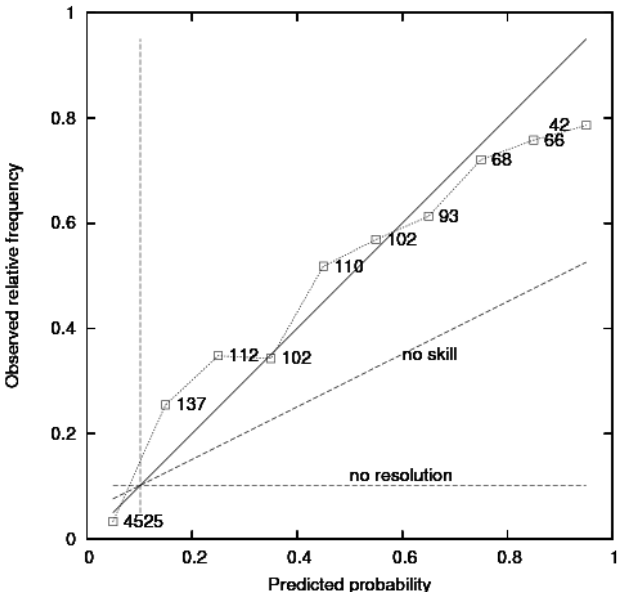
EHAM winter day 2009

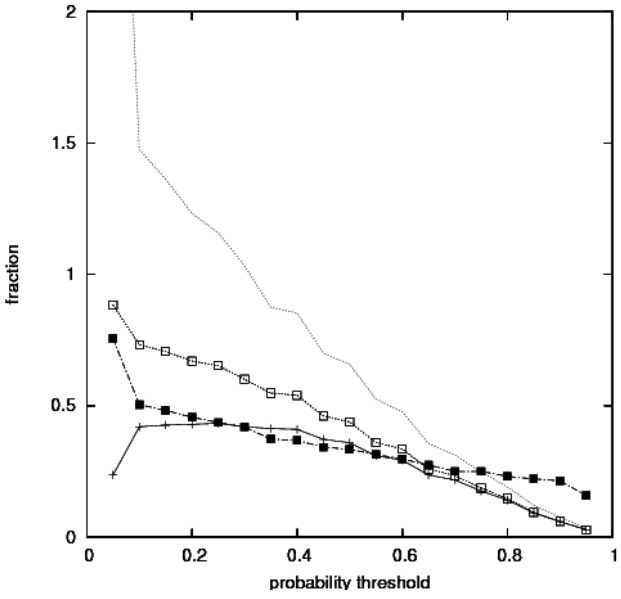


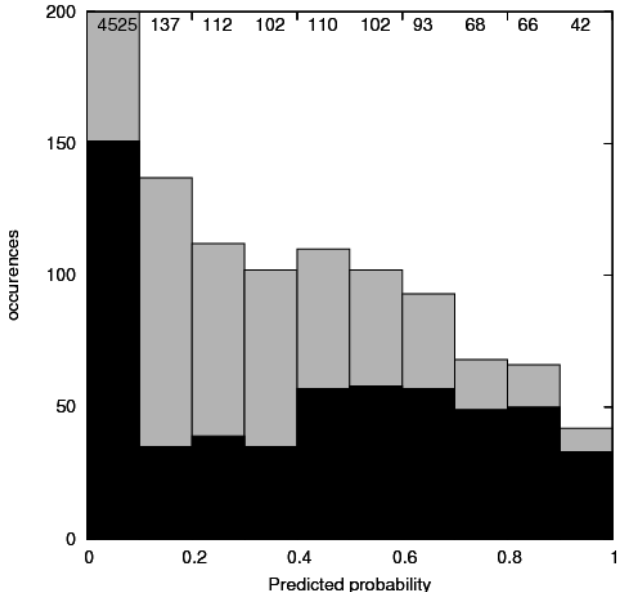




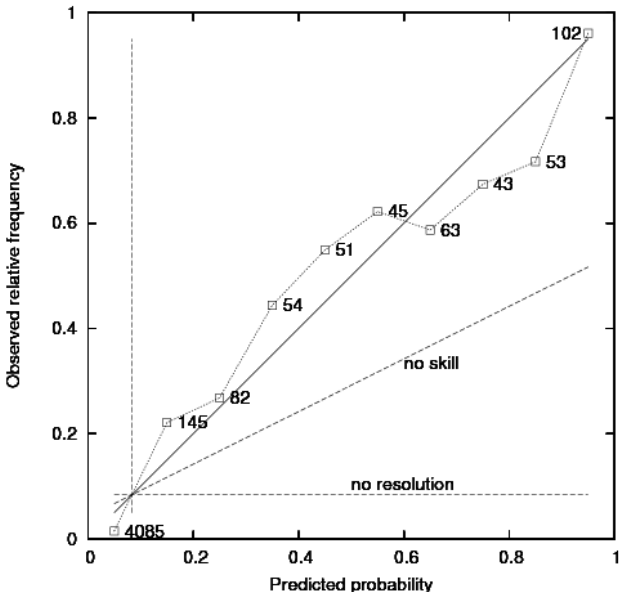
EHAM winter night 2009

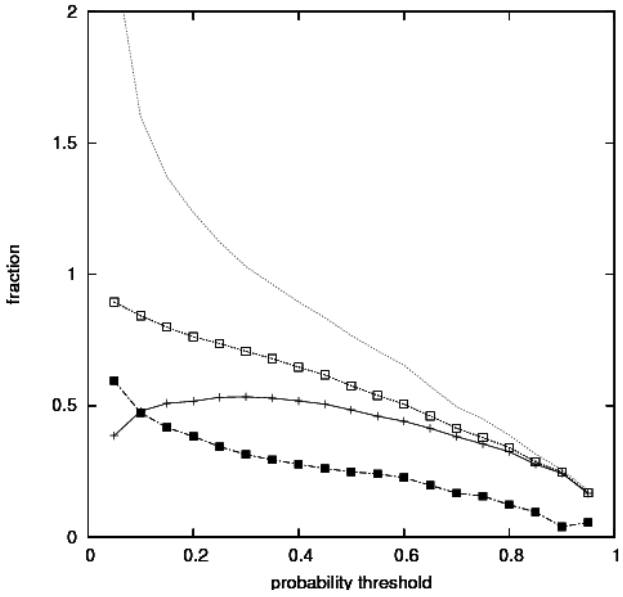


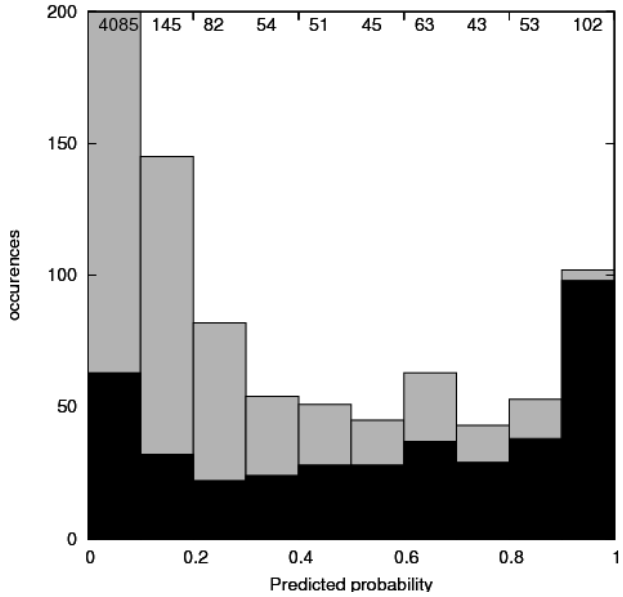




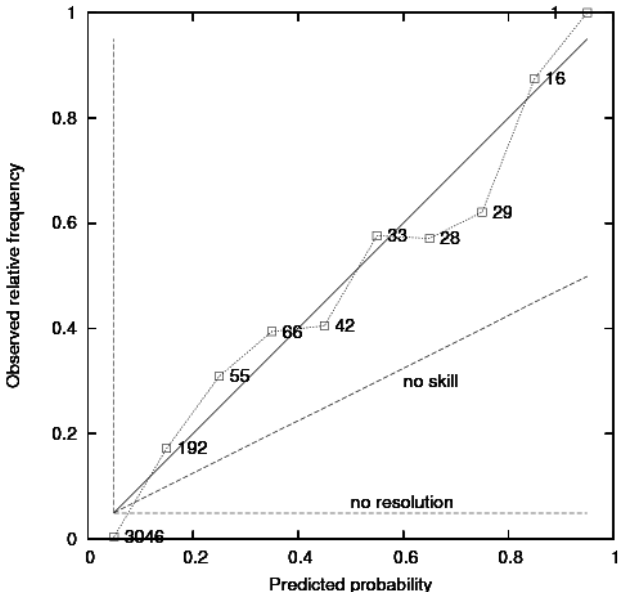
EHBK Summer day 2009

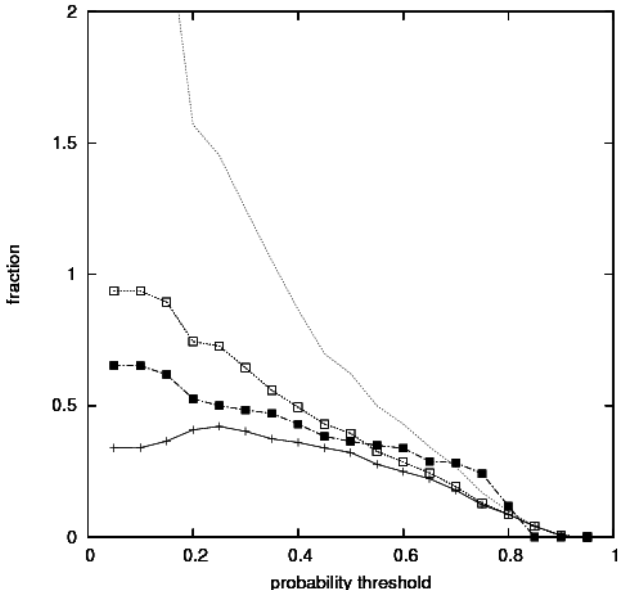


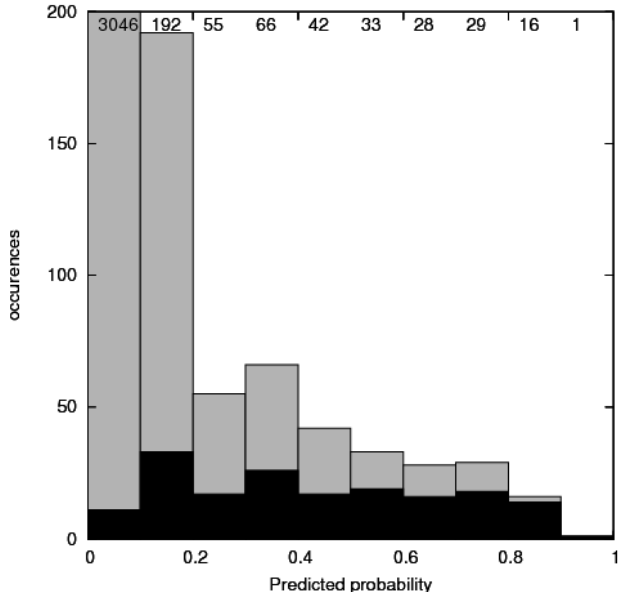




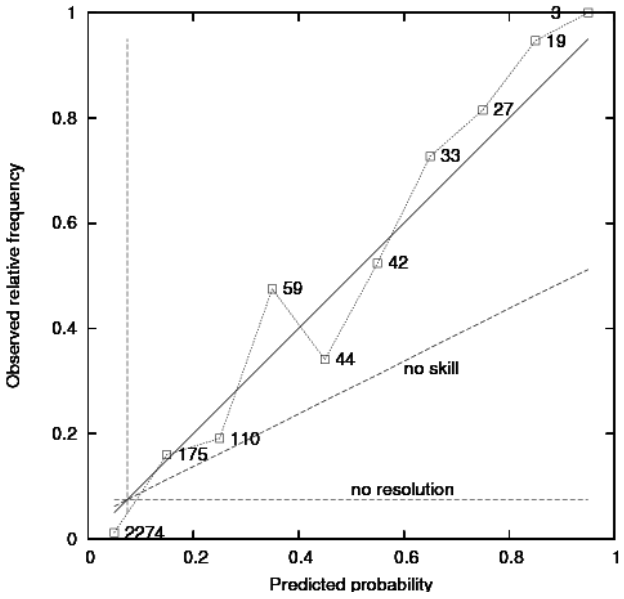
EHBK summer night 2009

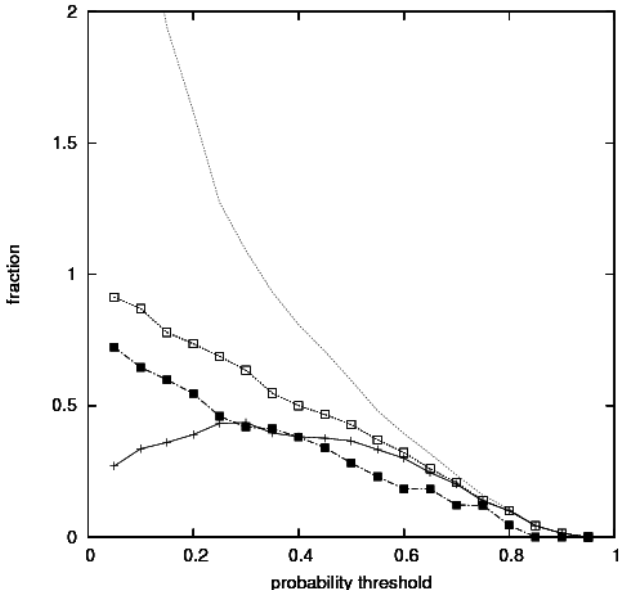


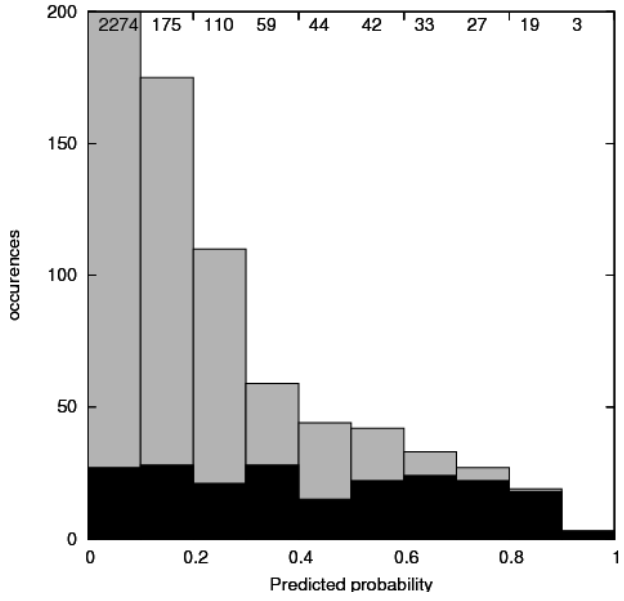




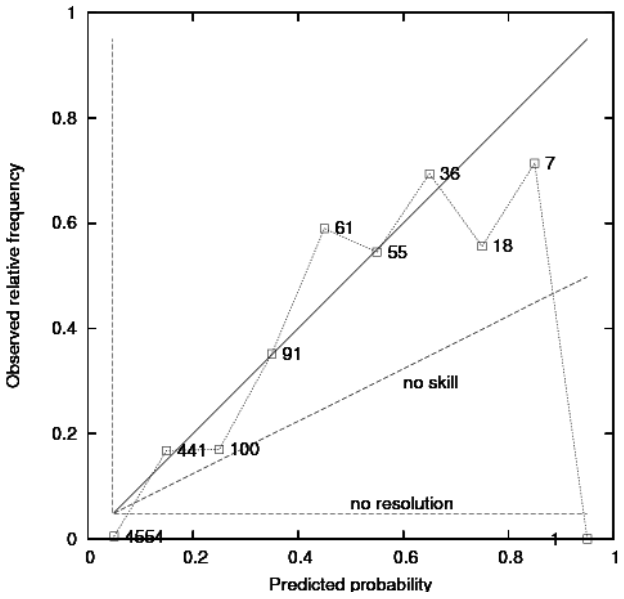
EHBK winter day 2009

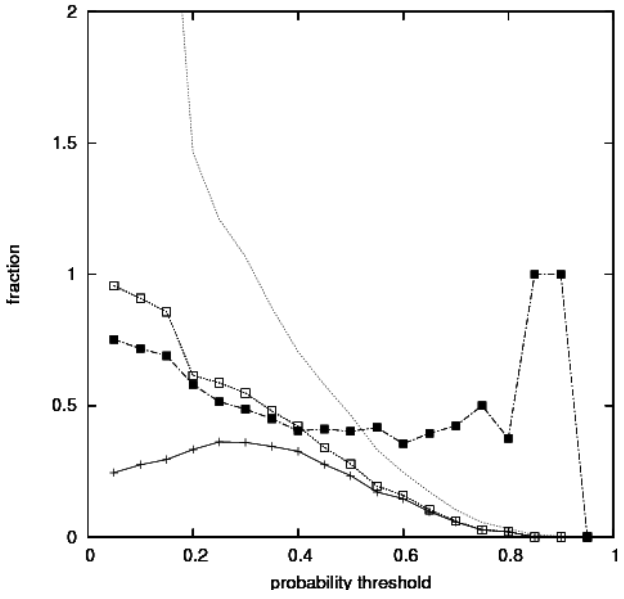


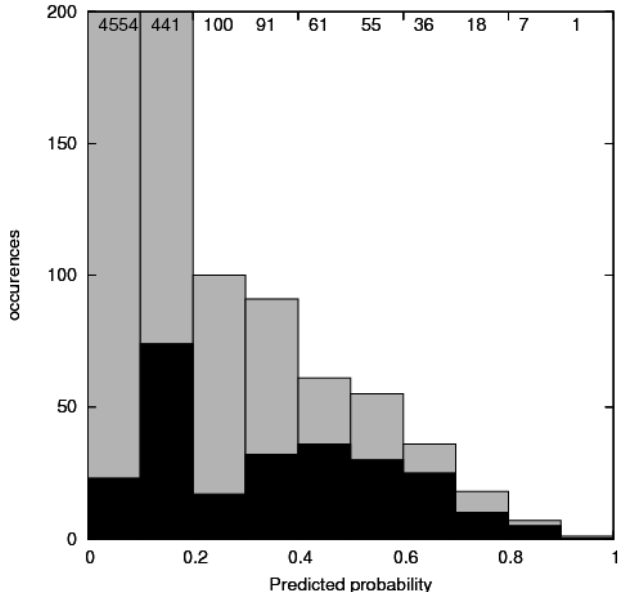




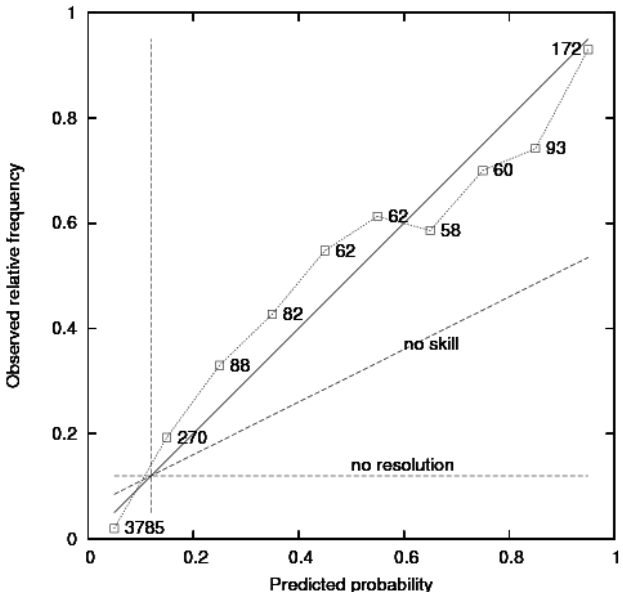
EHBK winter night 2009

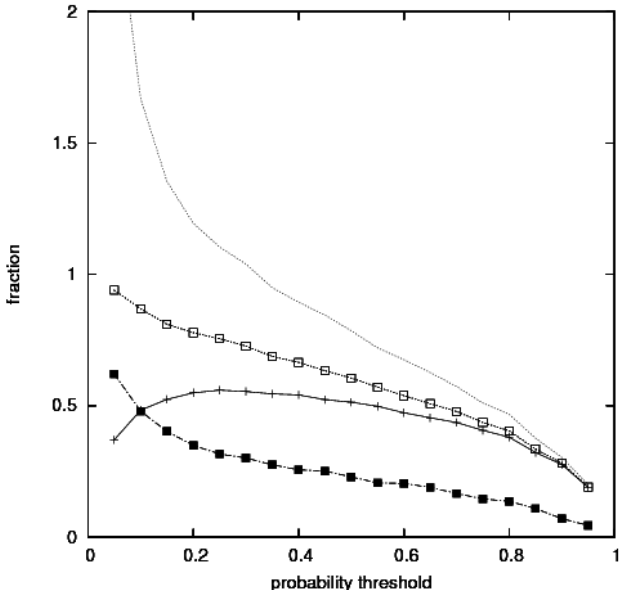


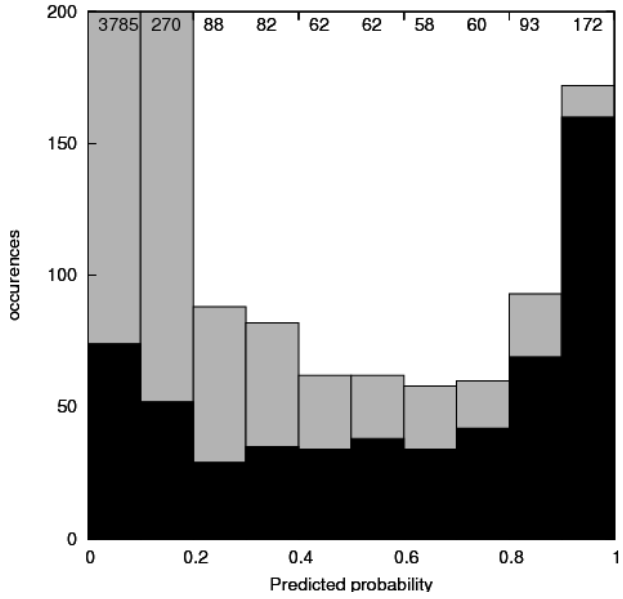




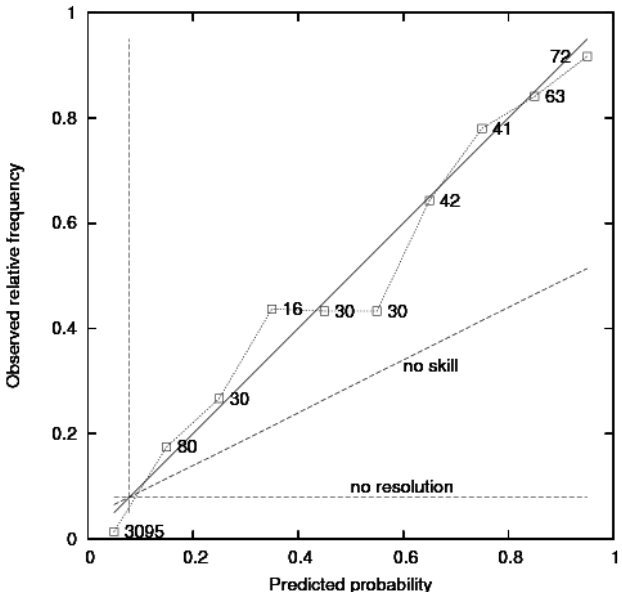
EHGG summer day 2009

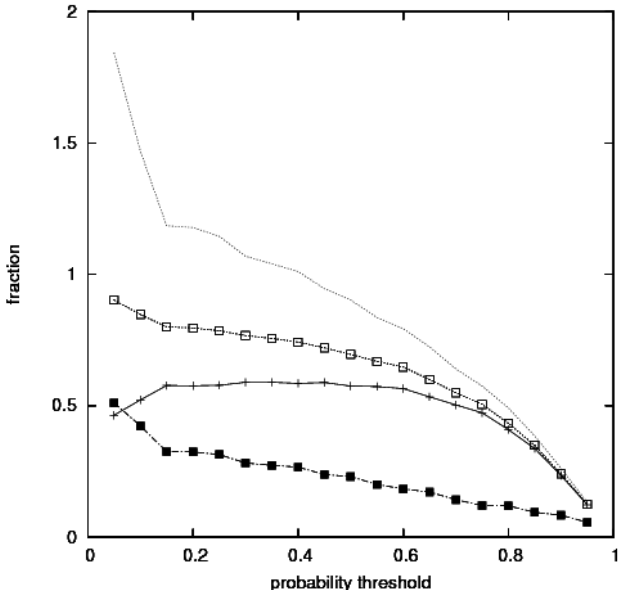


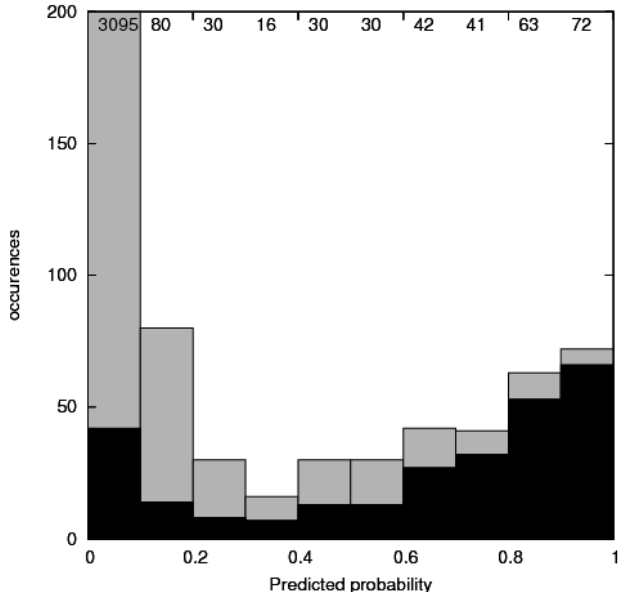




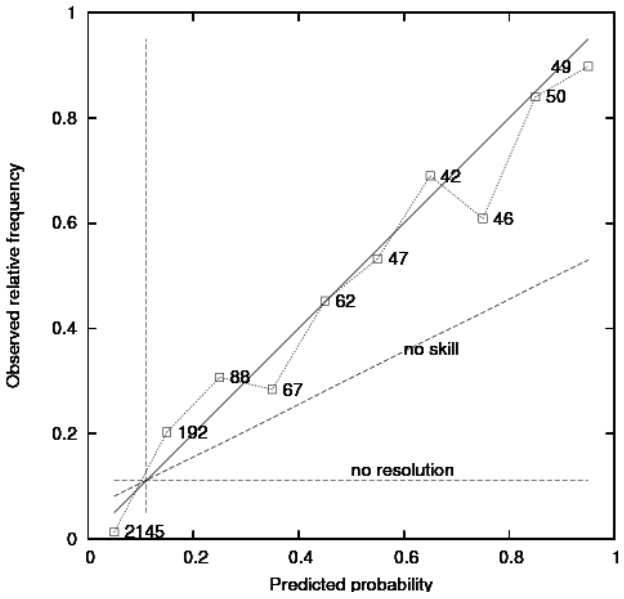
EHGG summer night

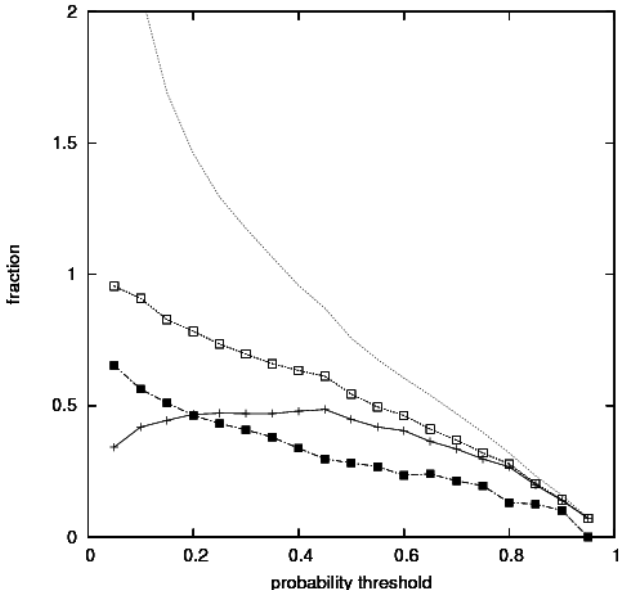


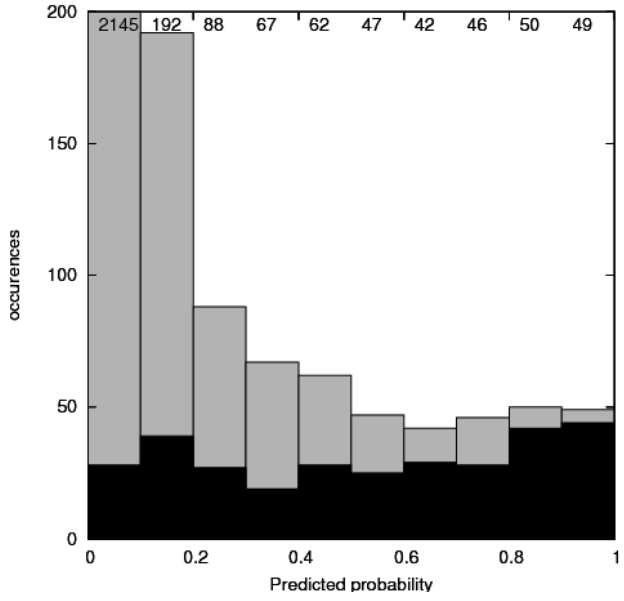




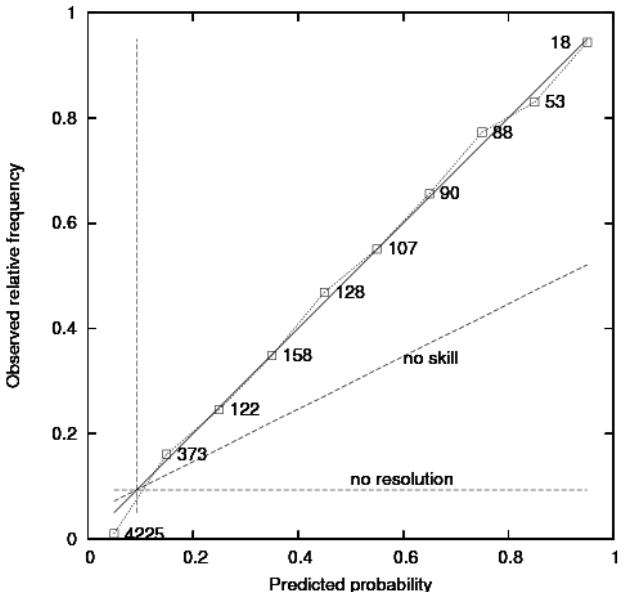
EHGG winter day 2009

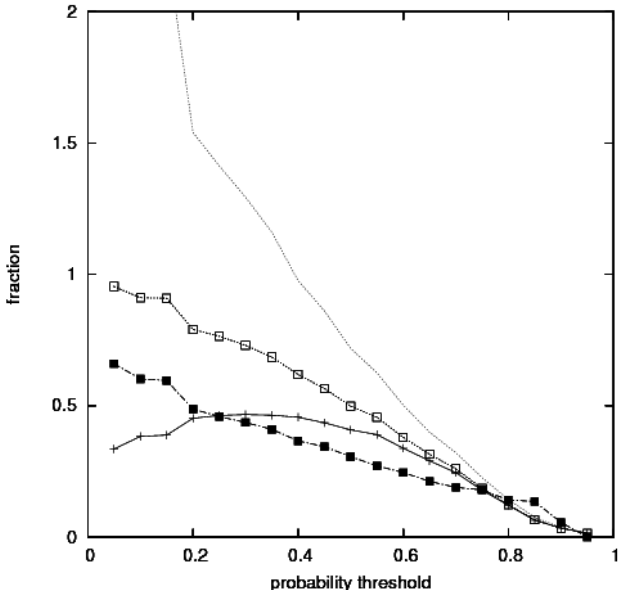


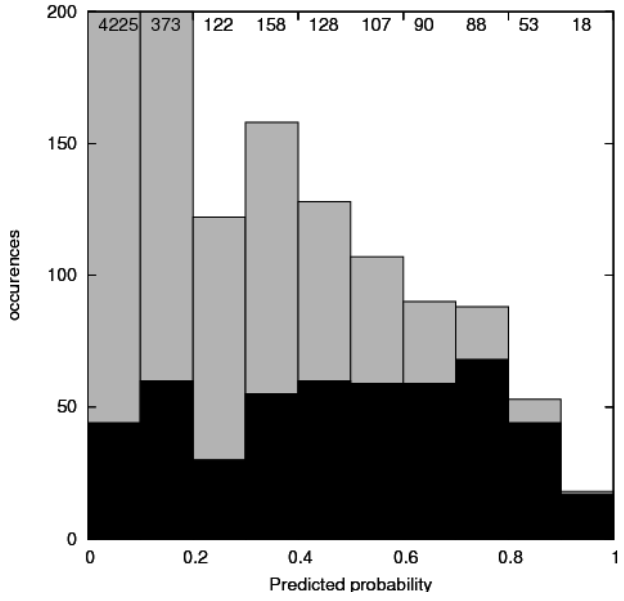




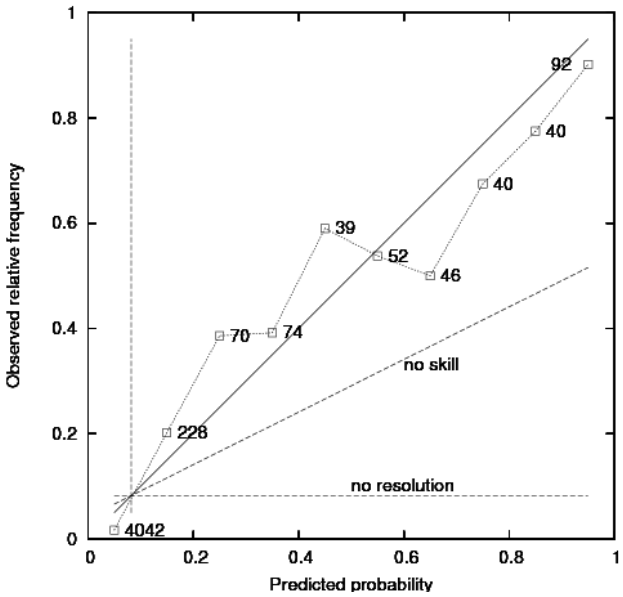
EHGG winter night 2009

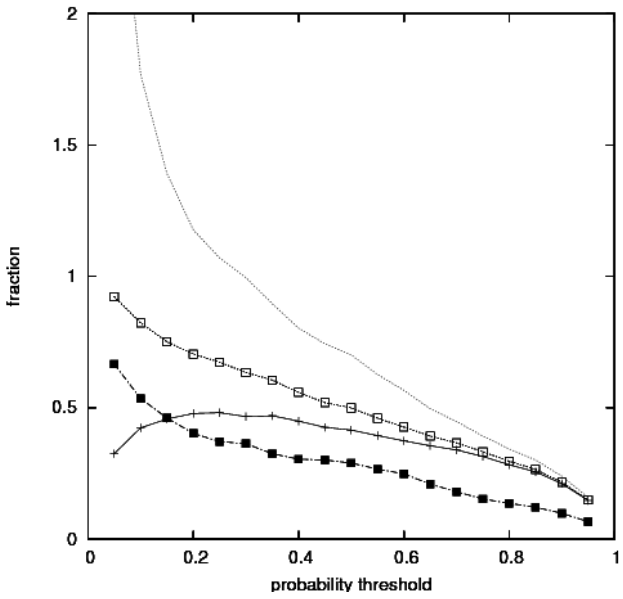


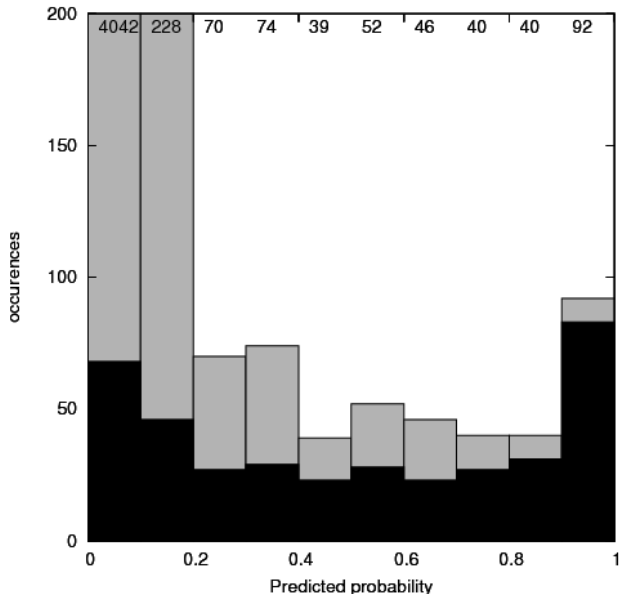




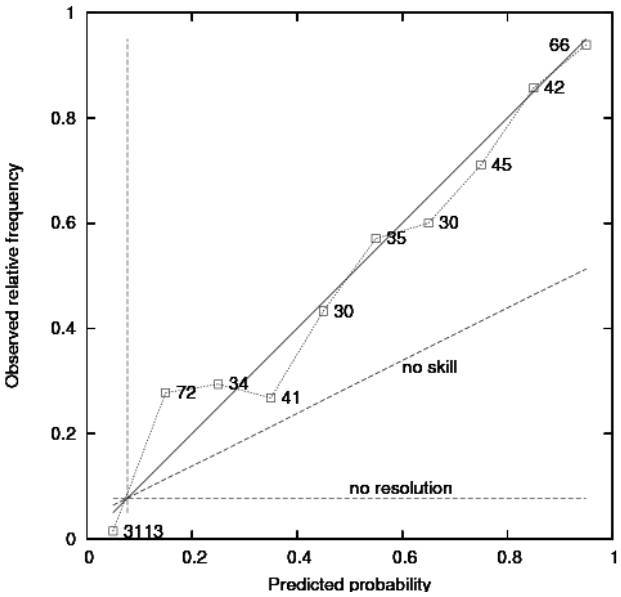
EHRD summer day 2009

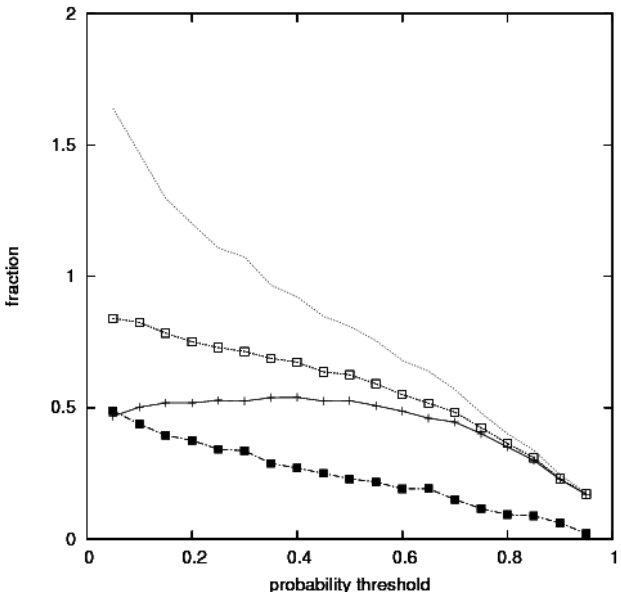


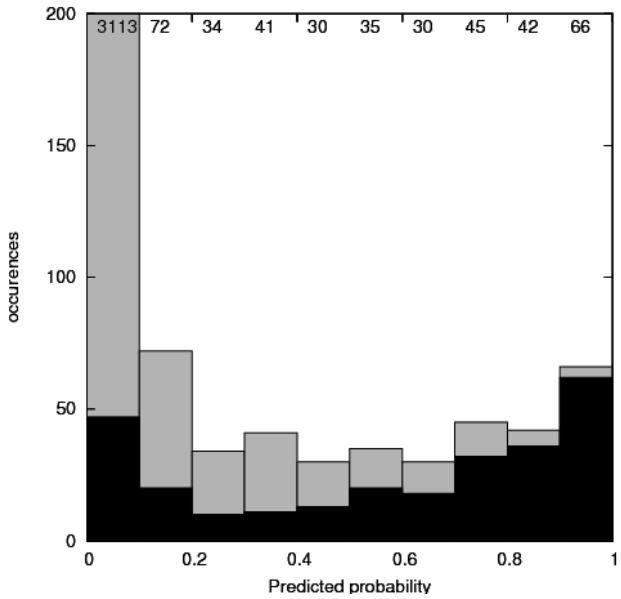




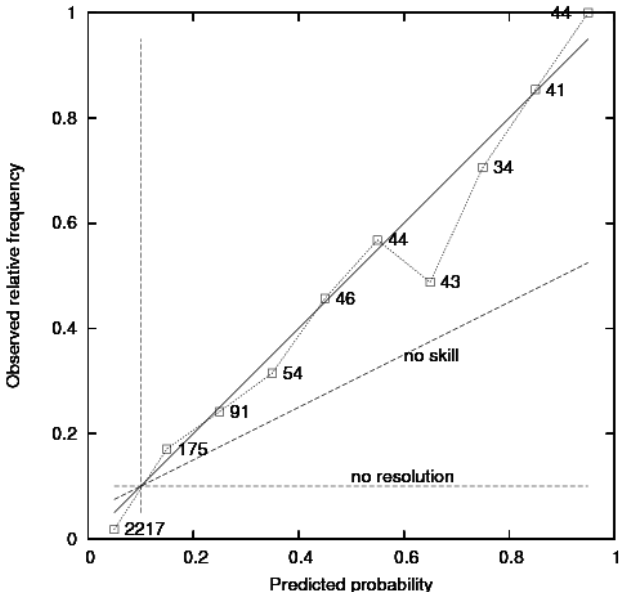
EHRD summer night 2009

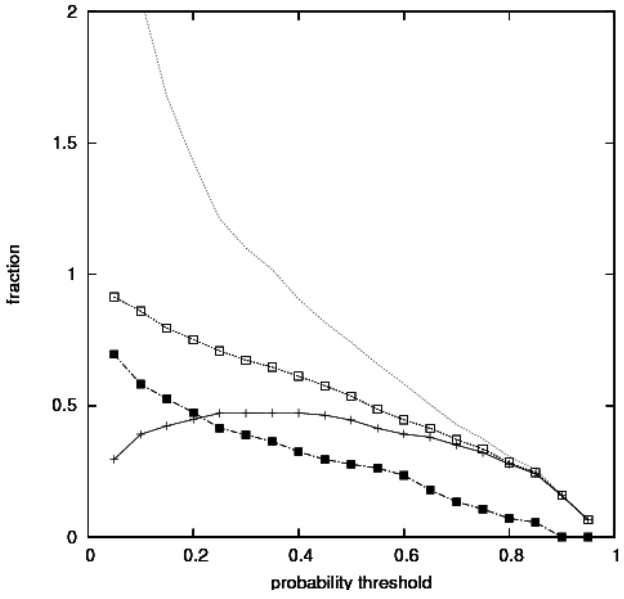


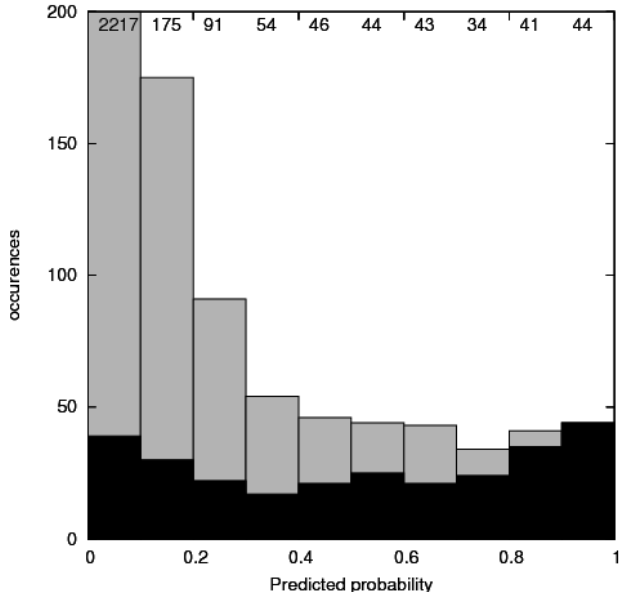




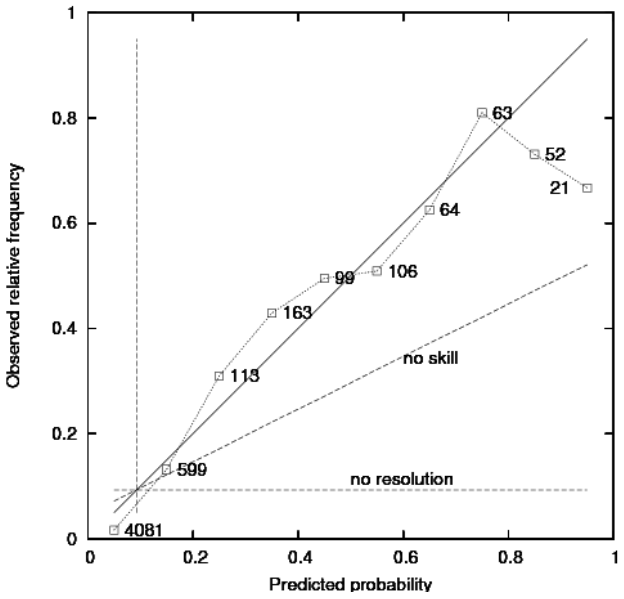
EHRD winter day 2009

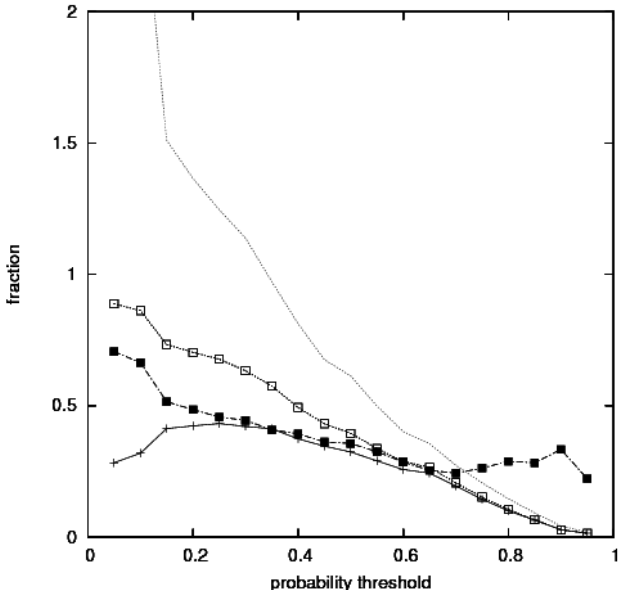


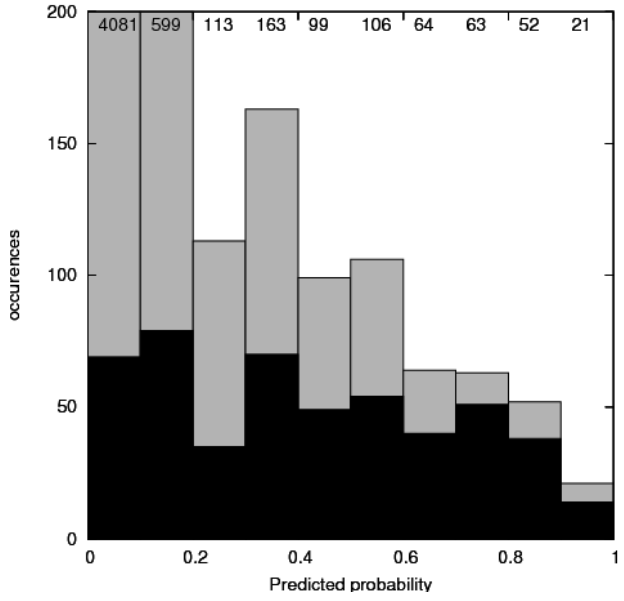




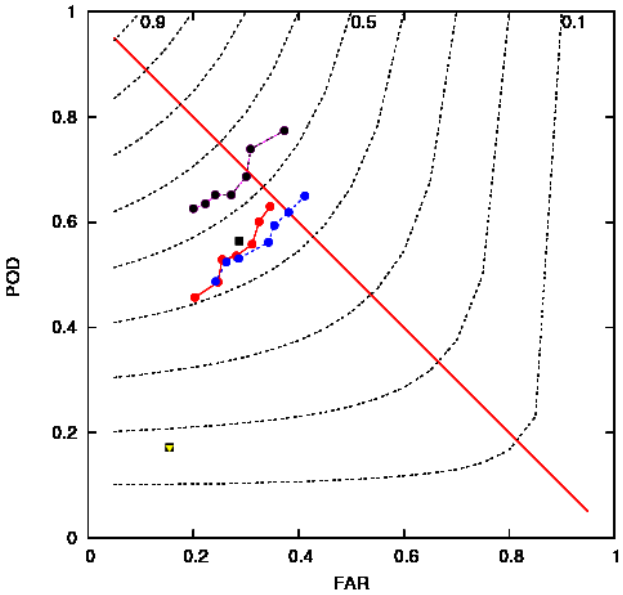
EHRD winter night 2009



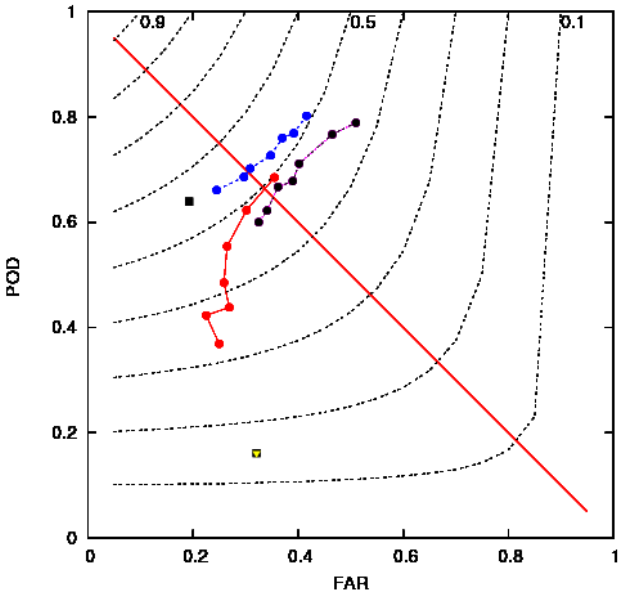




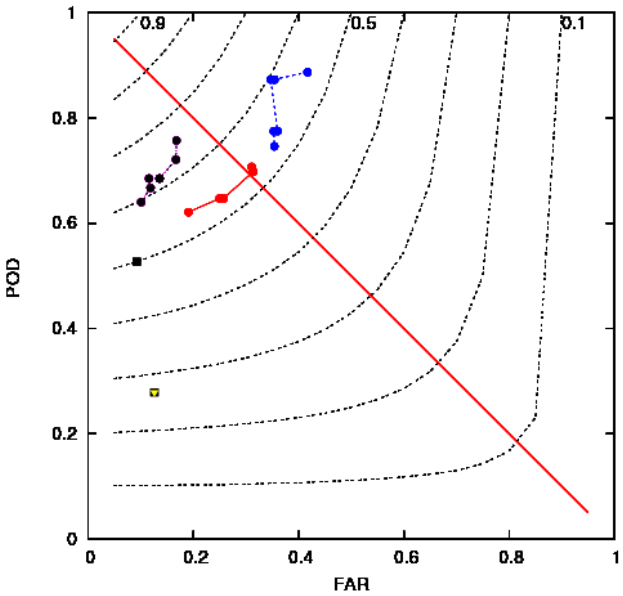
EHAM summer day three parts. One third is independent. This part is cycled between the three parts.
black square METAR
black yellow MF results



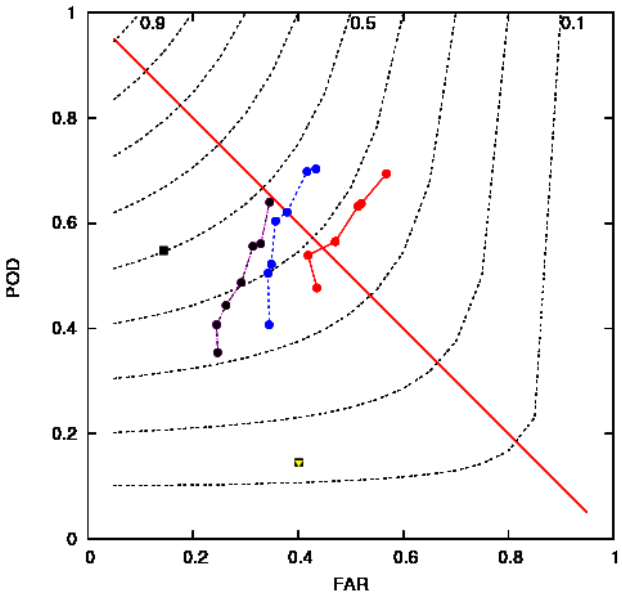
EHAM winter day three parts



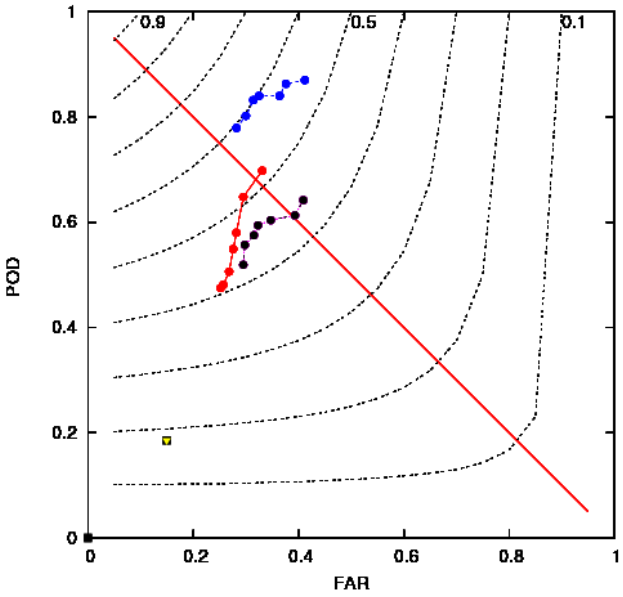
EHAM summer night three parts



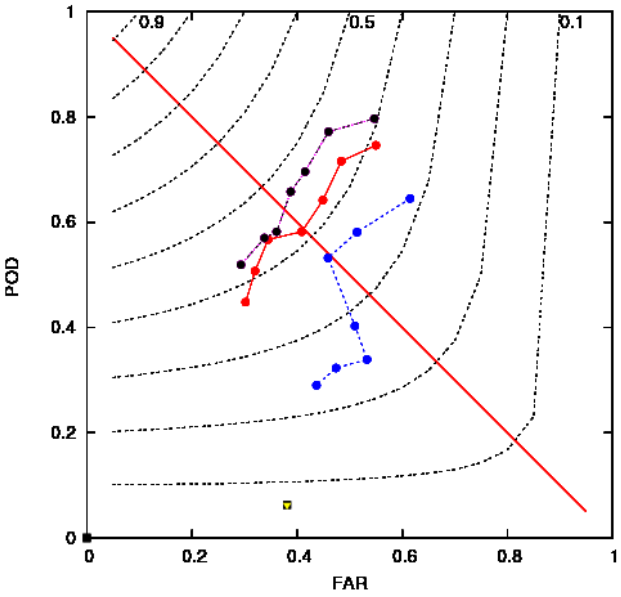
EHAM winter night three parts



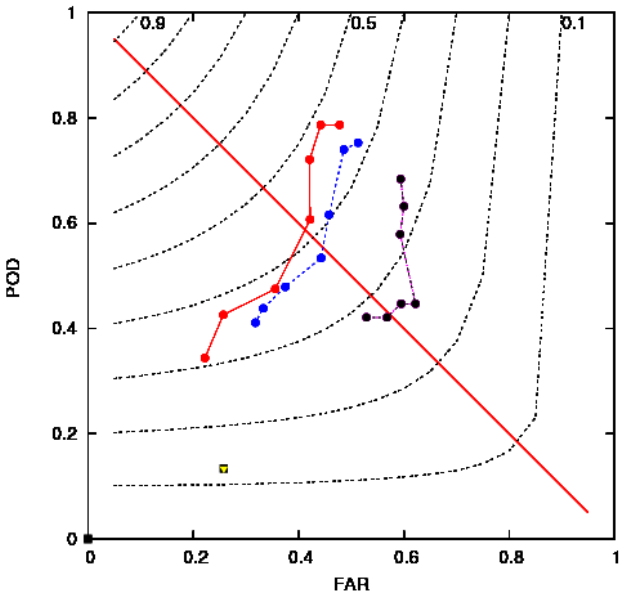
EHBK summer day three parts.One third is independent. This part is cycled between the three parts.
black square METAR
black yellow MF results



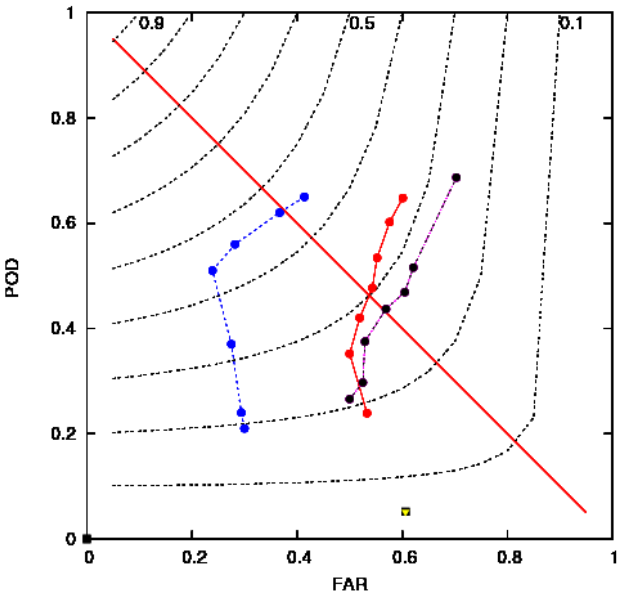
EHBK winter day three parts



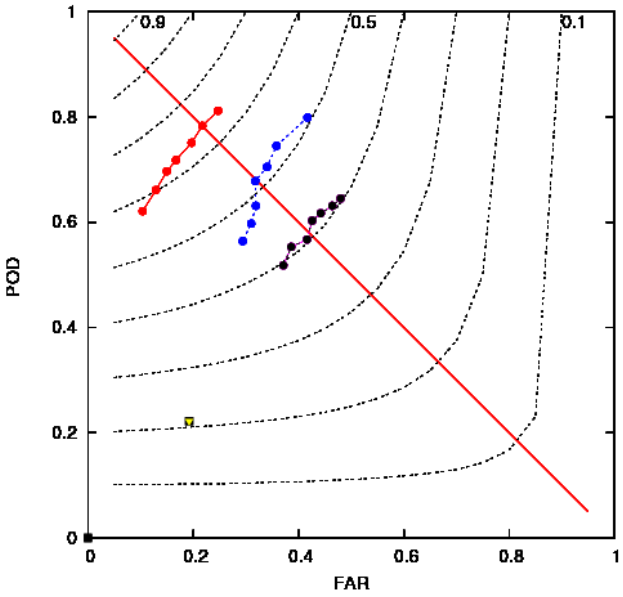
EHBK summer night three parts



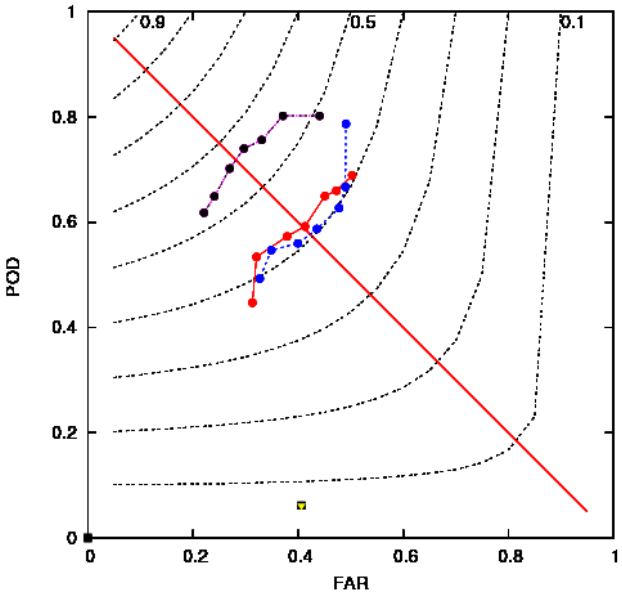
EHBK winter night three parts



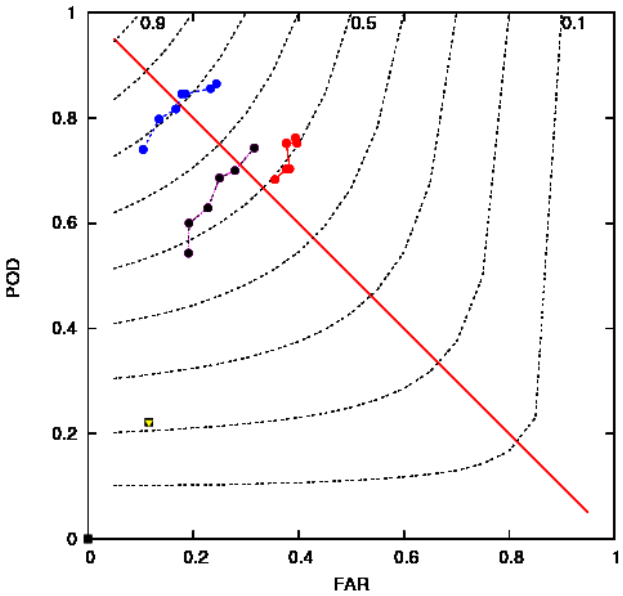
EHGG summer day three parts. One third is independent. This part is cycled between the three parts.
black square METAR
black yellow MF results



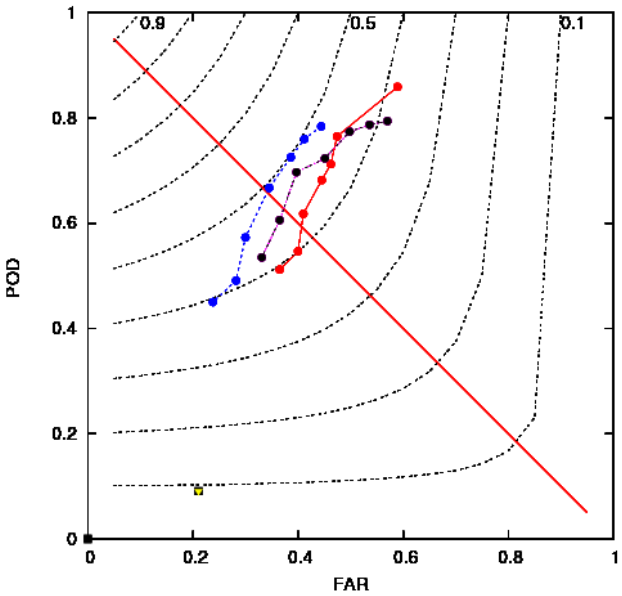
EHGG winter day three parts



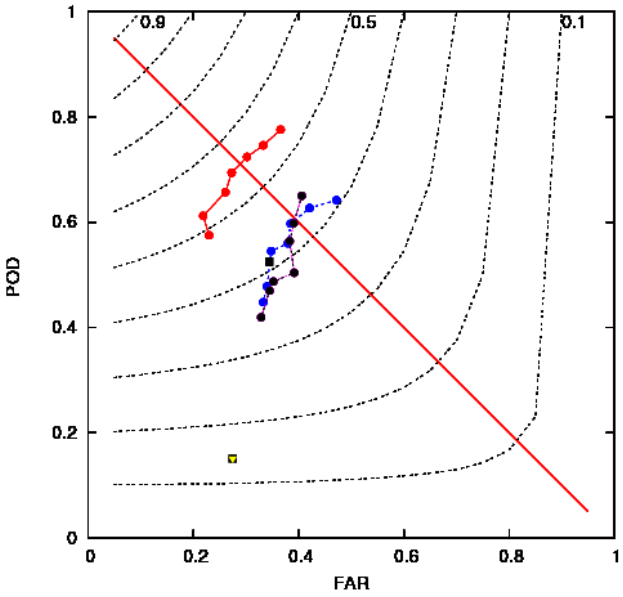
EHGG summer night three parts



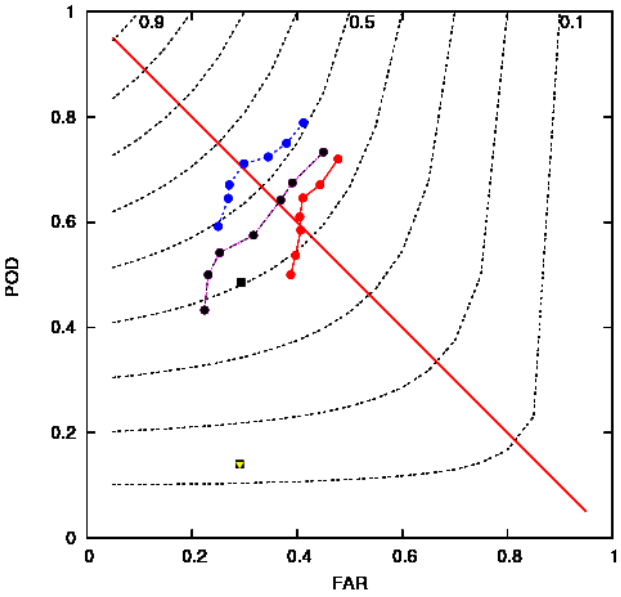
EHGG winter night three parts



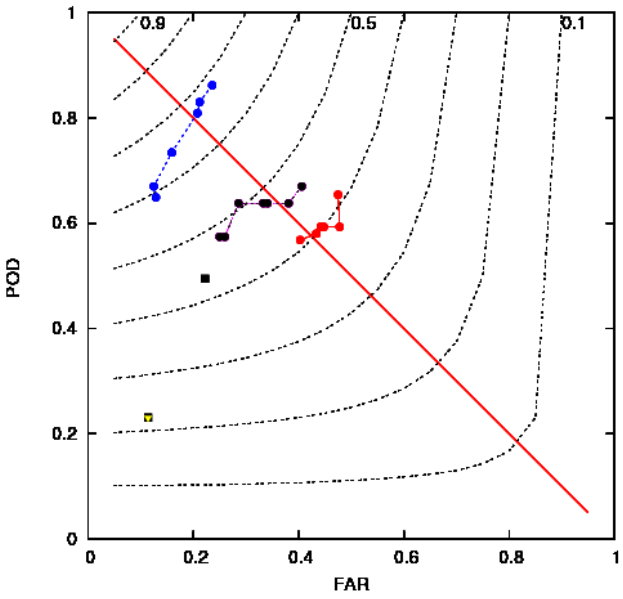
EHRD summer day three parts. One third is independent. This part is cycled between the three parts.
black square METAR
black yellow MF results



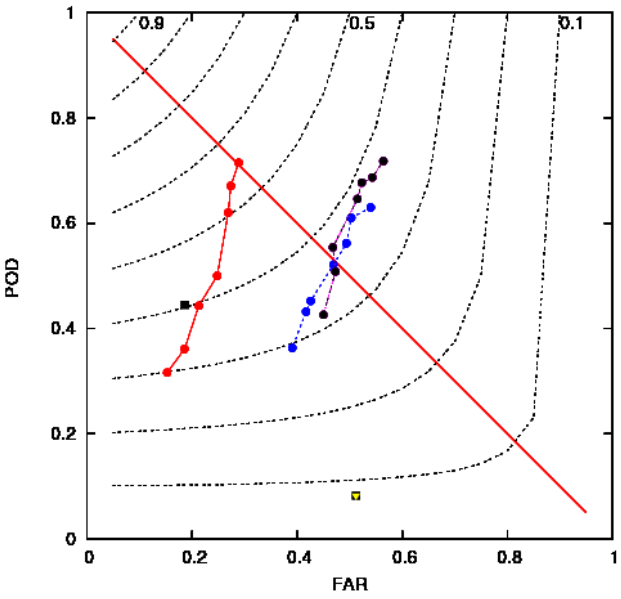
EHRD winter day three parts



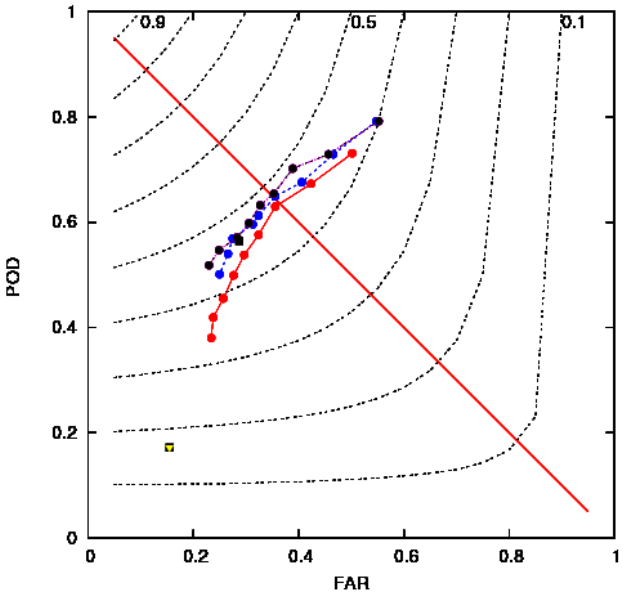
EHRD summer night three parts



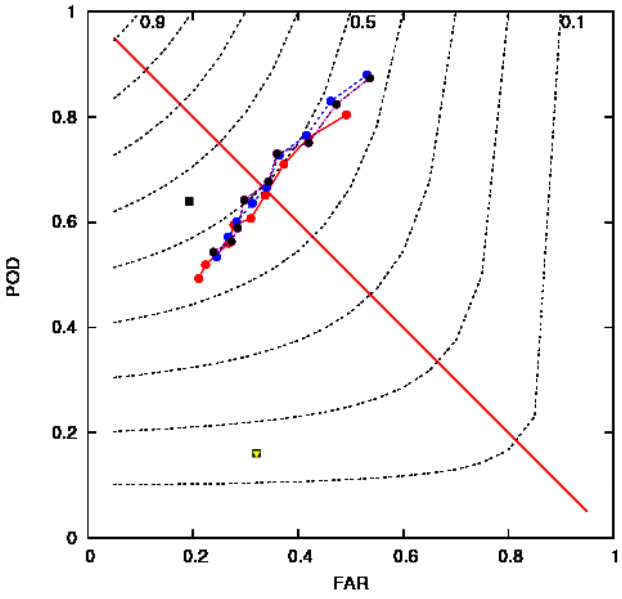
EHRD winter night three parts



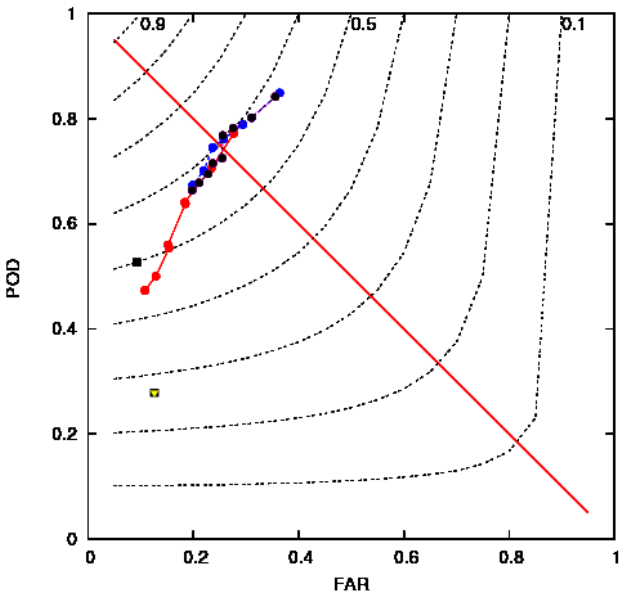
EHAM summer day
red 2005 predictors on 2009
blue 2009 predictors on 2009
black 2009 operational predictors, this corresponds to the histograms, attribute diagrams, and scores given above.
black square the METAR
black yellow MF results



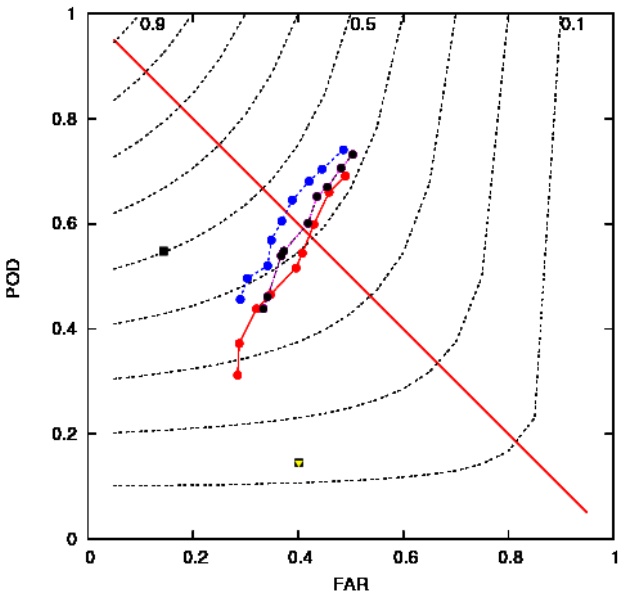
EHAM winter day



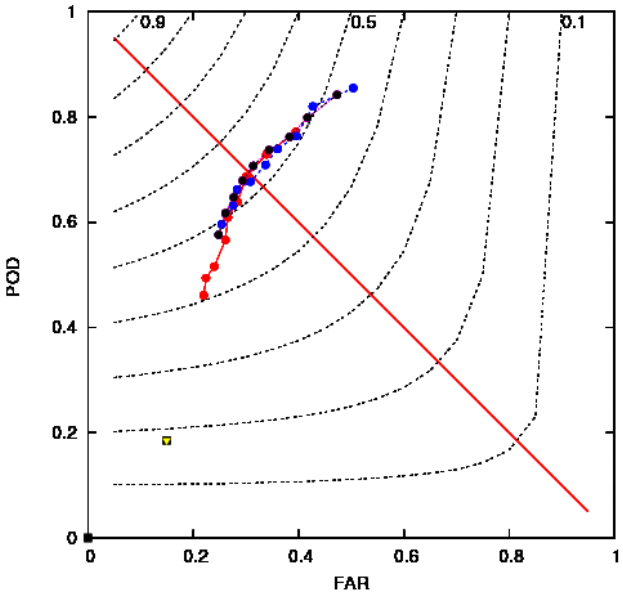
EHAM summer night



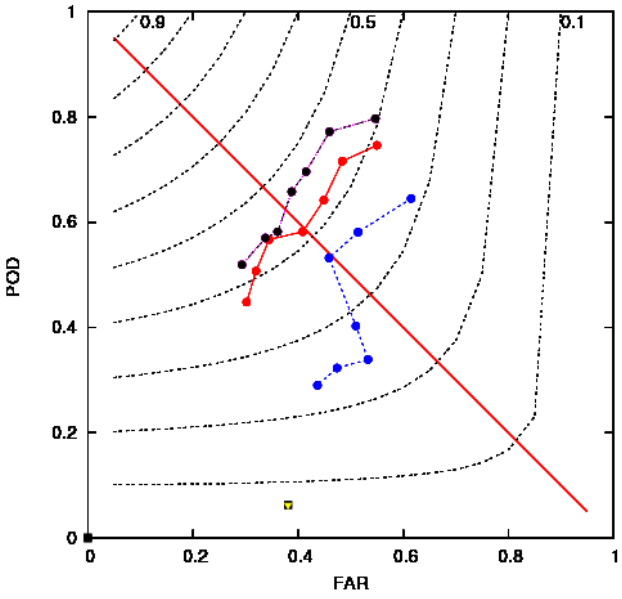
EHAM winter night



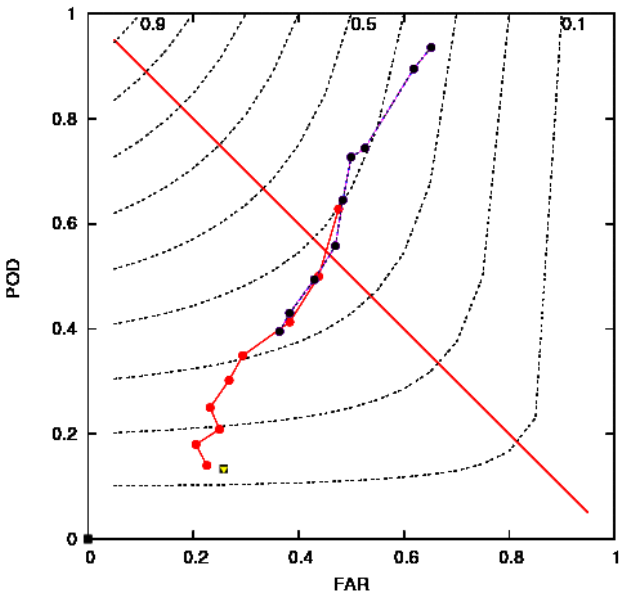
EHBK summer day
red 2005 predictors on 2009
blue 2009 predictors on 2009
black 2009 operational predictors this corresponds to the histograms, attribute diagrams, and scores given above.
black square the METAR
black yellow MF results



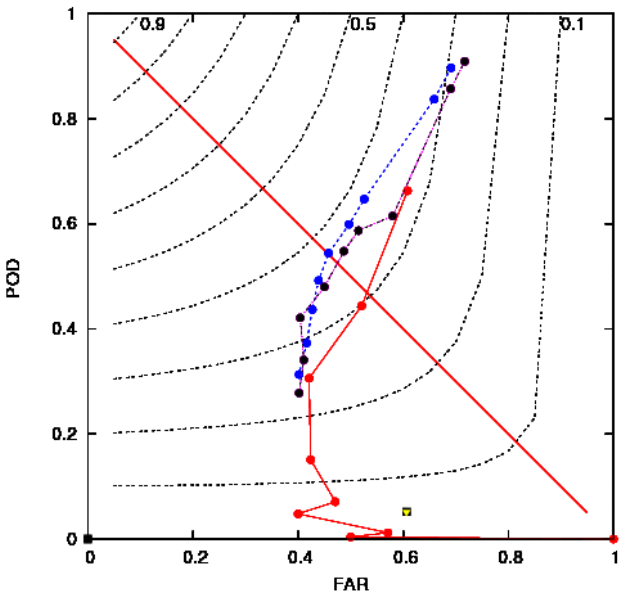
EHBK winter day



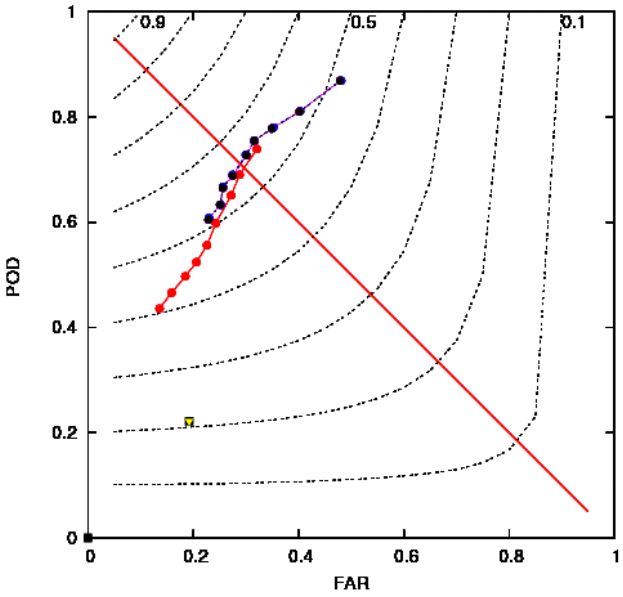
EHBK summer night



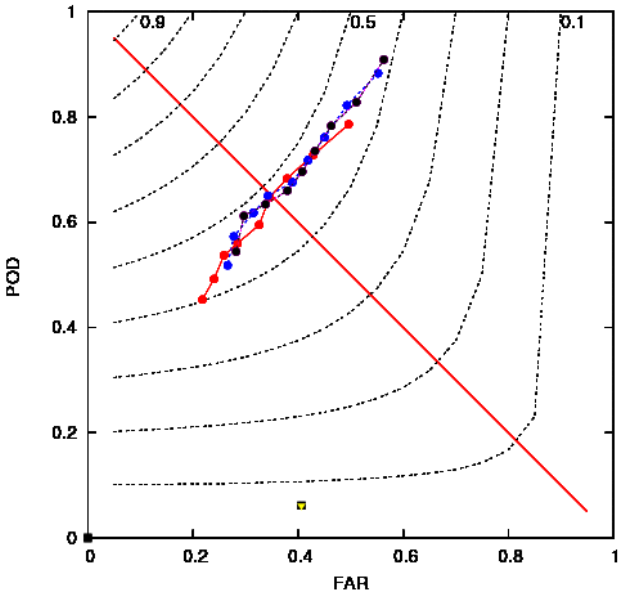
EHBK winter night



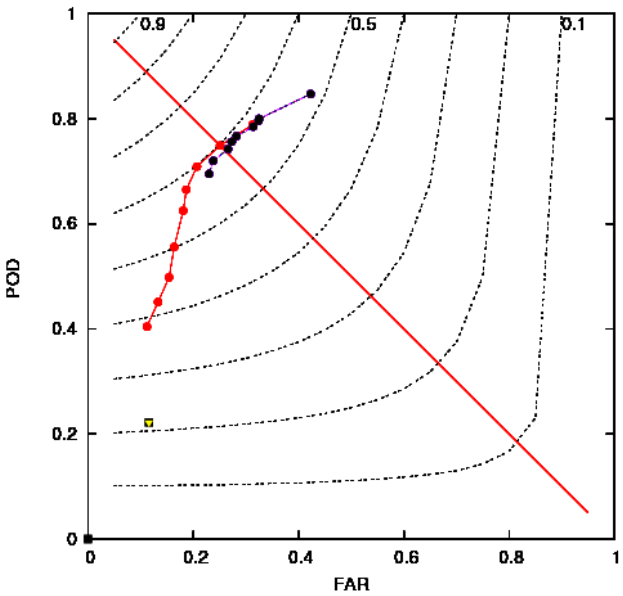
EHGG summer day
red 2005 predictors on 2009
blue 2009 predictors on 2009
black 2009 operational predictors this corresponds to the histograms, attribute diagrams, and scores given above.
black square the METAR
black yellow MF results



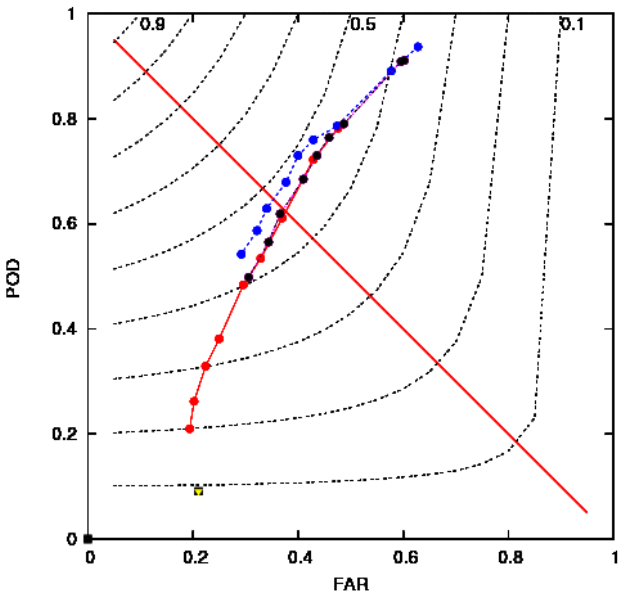
EHGG winter day



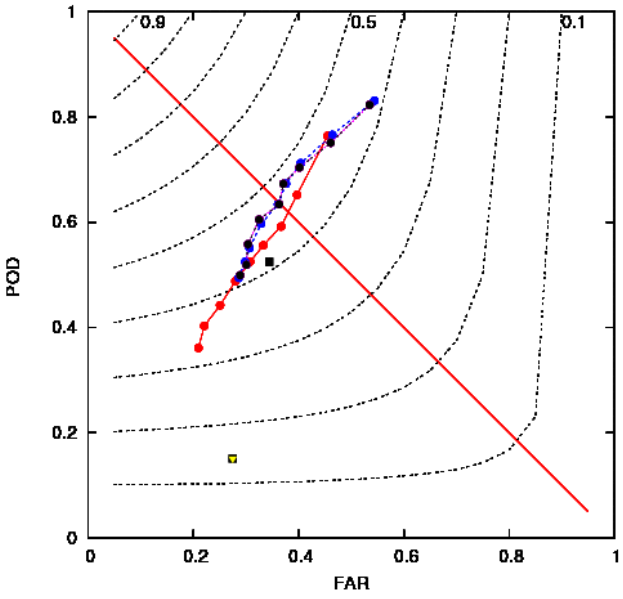
EHGG summer night



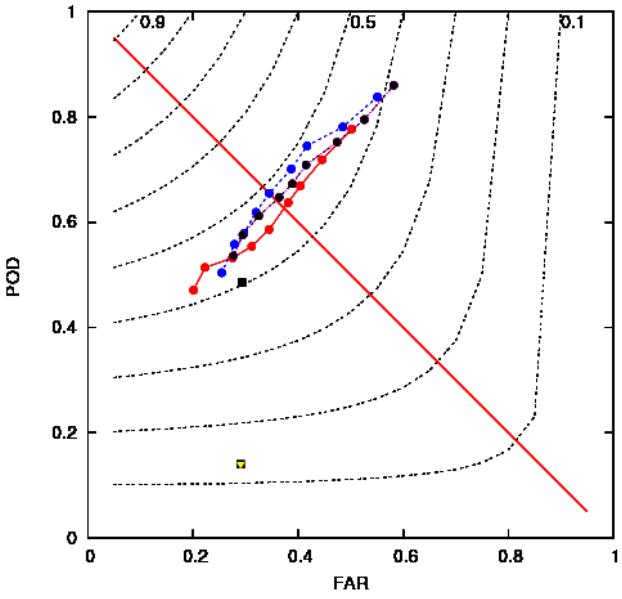
EHGG winter night



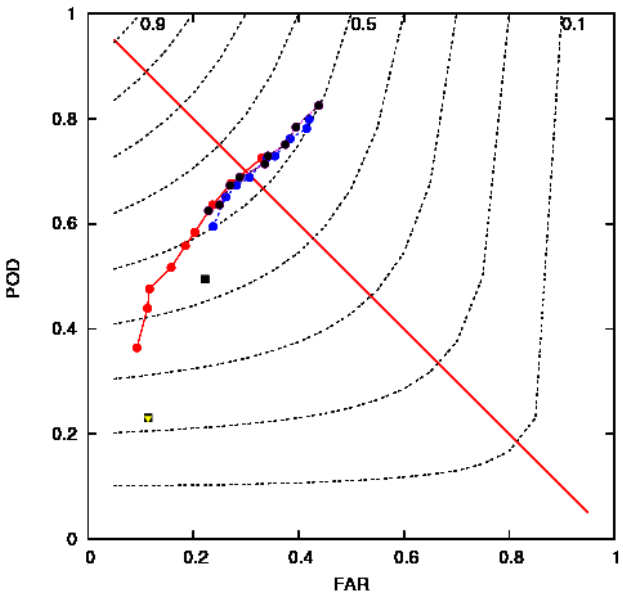
EHRD summer day
red 2005 predictors on 2009
blue 2009 dependent
black 2009 operational predictors this corresponds to the histograms, attribute diagrams, and scores given above.
black square the METAR
black yellow MF results



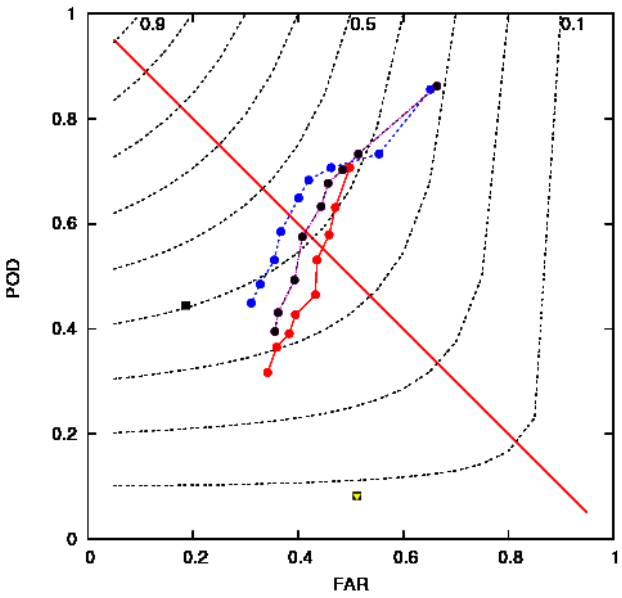
EHRD winter day



EHRD summer night

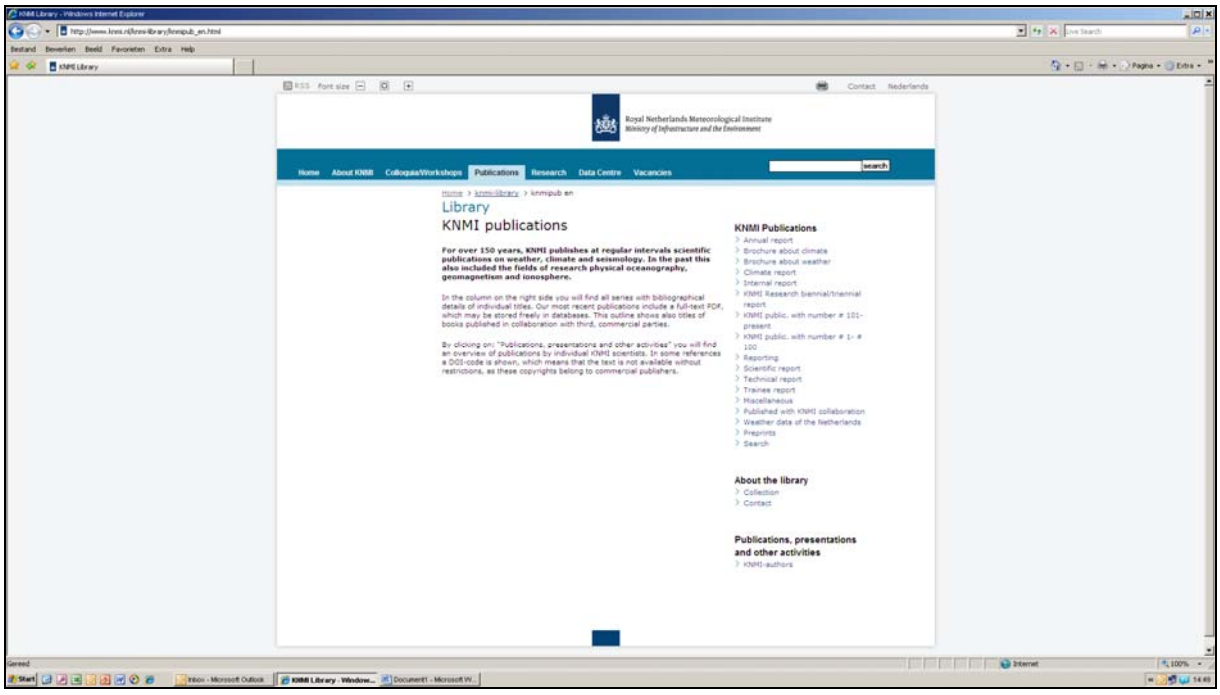


EHRD winter night



A complete list of all KNMI-publications (1854 – present) can be found on our website

www.knmi.nl/knmi-library/knmipub_en.html



The most recent reports are available as a PDF on this site.