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# Visibility chain Rotterdam The Hague airport

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# 1. Introduction

Visibility (visibility for aeronautical purposes, VIS) and the related quantity Runway Visible Range (RVR) are meteorological parameters that are crucial for the operations at an airport. Visibility together with ceiling determines the so-called Low Visibility Procedure (LVP) category, which in turn affects the capacity of a runway (Wijngaard et al., 2007). Furthermore, the RVR at touchdown is a critical parameter which, when missing, makes the runway unavailable for instrument precision approach and landing, although the runway can still be used for so-called visual flight rules (VFR) if the visibility exceeds 5 km (KNMI, 1994), or so-called special visual flight rules (SVFR) if the visibility is between 3 and 5 km and for take-off. The automation of the meteorological aeronautical observations, the so-called AUTO METAR system[1], at Rotterdam The Hague Airport automated the measurements and reporting of visibility. Although the sensor information is processed and inserted automatically, an aeronautical meteorological forecaster (AMF) located at the main premises of KNMI in De Bilt monitors all meteorological data and reports using the near real-time sensor data and information from other sources such as video cameras. Furthermore the AMF adds the TREND, a landing forecast with a validity of 2 hours, to the AUTO METAR, AUTO ACTUAL and AUTO SPECIAL and can issue other reports. During the evaluation of the AUTO METAR system several questions related to visibility arose, which eventually led to the drafting of this document. This document describes the entire chain of visibility ranging from definitions, measurements, sensors, calibration, sensor usage, derivations, backup rules, to data available to the aeronautical users. The main purpose of this document is to give insight in the visibility chain used at Rotterdam The Hague Airport. The situation at other airports is sometimes reported, but it should be noted that there are differences between Rotterdam The Hague Airport and the other civil airports. These differences are mainly the result of differences in instrumentation (see. e.g. Wauben and Sondij, 2009 and Wauben, 2009 for details of the situation at Amsterdam Airport Schiphol).

# 2. Sources of meteorological information for users

The meteorological information is provided to the users in various ways:

AUTO[2] METAR and AUTO SPECI[3]

The AUTO METAR is an aviation routine meteorological report for dissemination beyond the aerodrome. The meteorological information contained in the AUTO METAR is generally representative for the aerodrome and its immediate vicinity. The AUTO METAR is generated at H+20 and H+50 using corresponding sensor data and disseminated after validation and complementation by a remote aeronautical meteorological forecaster. The time label of the AUTO METAR is H+25 or H+55. Since a half hourly AUTO METAR is supplied a special report, a so-called AUTO SPECI is not required by ICAO. For civil airports only the half hourly AUTO METAR is issued, but for military airbases a half hourly AUTO METAR is issued in combination with AUTO SPECI reports. This AUTO SPECI is issued when certain criteria are met, e.g. a change of the visibility

[1] The term "AUTO METAR system" is used to denote the entire system used for the automated production of the meteorological aeronautical reports. This includes not only the AUTO METAR, but also the AUTO ACTUAL and AUTO SPECIAL reports. Furthermore it doesn't only designates the sensors, the associated technical infrastructure for data-acquisition, -processing and -dissemination in suitable formats, but the term also includes the usage of backup sensors and systems, the remote monitoring by meteorologists and service staff using suitable tools including video cameras and local points of contact at air traffic control and the airport itself for verification. Also included are the updated documentation, procedures and the service level agreement. The AUTO METAR system is described in detail in Wauben and Sondij, 2011.

[2] The term "AUTO" distinguishes the automatically generated AUTO METAR report from the manual METAR report. The coding and contents of the meteorological reports are basically the same although there are some differences. Apart from the inclusion of the term AUTO itself and specific codes related to sensor limitations like NCD (No Clouds Detected) or UP (Unknown Precipitation) some specific weather phenomena or descriptors are not reported in the AUTO METAR since there are no suitable sensors to detect them - e.g. patches of fog (BC) or smoke (FU). Also note that whereas the AUTO METAR is not fully automated since all reports are monitored and complemented by a remote meteorologist, neither is the METAR generated completely manually. The so-called visual parameters related to visibility, cloud and weather information are generally entered manually, but most fields in the METAR are filled in automatically using processed sensor information. The observer can overrule sensor values, but for some parameters, like RVR, the sensor value can be discarded but no alternative value can be given.

[3] At Rotterdam The Hague Airport no AUTO SPECI is issued. Therefore only the term "AUTO METAR" is used in this document. It should be noted that, except for the difference in the reason for the issuance of an AUTO SPECI and AUTO METAR, both reports are identical so that what is said for the AUTO METAR also applies for the AUTO SPECI.

exceeding specified thresholds. An AUTO METAR or AUTO SPECI is generated on the airport server system (or central system in De Bilt for the North Sea platforms) and is send via the network to the message switch (MSS) in De Bilt from where it is disseminated via the Global Telecommunication System (GTS) of the World Meteorological Organization (WMO).

AUTO ACTUAL and AUTO SPECIAL[4]
The AUTO ACTUAL is a local routine report for landing for dissemination at the aerodrome. Only at Schiphol there is also a separate local routine report for departure. The meteorological information contained in the AUTO ACTUAL is generally representative for the touchdown (take-off) zone or the situation along the runway. The AUTO ACTUAL is generated at H+20 and H+50 using corresponding sensor data and disseminated after validation and complementation by a remote aeronautical meteorological forecaster. The time label of the AUTO ACTUAL is H+25 or H+55. When certain criteria are met, e.g. a change of the runway in use, a local special report, the so-called AUTO SPECIAL, is issued. At military airbases the local routine and local special report are called QAM and contains identical sensor information as the AUTO ACTUAL and AUTO SPECIAL. A so-called colour state and a colour state forecast are added to the QAM. An AUTO ACTUAL, AUTO SPECIAL or QAM is generated on the airport server system and is made available, via a local network connection, to users at the aerodrome. Users at an airport generally consist of the airport itself, airlines and air traffic control (ATC)[5]. ATC for example uses the meteorological information of the AUTO ACTUAL and AUTO SPECIAL in their Closed Circuit Information System (CCIS), Wind Information System (WIS) and Automatic Terminal Information Service (ATIS), the voice system of ATC that broadcasts the meteorological information of the AUTO ACTUAL and AUTO SPECIAL to the pilots.

Sensor information
Users at airports have access to (processed) sensor data. The data is either continuously provided, e.g. wind information for all runways is available to ATC so that they know what conditions to encounter after change of a runway, or under specific conditions, e.g. if one or more of the visibility sensors reports a visibility below 1500 m then ATC starts acquiring visibility information of all sensors. The sensor information is made available, via a local network connection, to users at the aerodrome. Furthermore all (derived) sensor information is made available to service staff and meteorologists via a client system that can be located anywhere on the KNMI network. This information is also archived centrally in De Bilt.

Manual information
There is regular contact between the aeronautical meteorological forecaster (AMF) and air traffic control (ATC) staff. Each morning a briefing is held during which the expected meteorological conditions of the next 24 hours is reported. Furthermore, contact is established when there is a significant deviation in the expected meteorological conditions, in case there is a need for an update for a specific event, in case of reasonable doubt concerning the meteorological information provided, or when there is a malfunction in the observation infrastructure.

## 3. Definitions of visibility

In this section the different parameters related to visibility, i.e. Meteorological Optical Range (MOR), visibility for aeronautical purposes (VIS) and Runway Visible Range (RVR) are introduced. Detailed descriptions of the parameters can be found in WMO (2008) and ICAO (2010).

The Meteorological Optical Range (MOR), which is also indicated by meteorological visibility, is defined as the atmospheric path (m) that is required to reduce the luminous flux (lm) of a collimated beam of light to 5% of its original value. The light source is specified as incandescent lamp with a color temperature of 2700 K. The spectrum of such a lamp has a maximum near 550 nm which corresponds with the averaged luminous efficiency of the human eye. MOR is the basic physical parameter of “visibility” that is inversely proportional to the atmospheric extinction ($m^{-1}$). The so-called Bouger-Lambert law gives the relation between the MOR and the atmospheric extinction coefficient, where extinction is the result of scattering as well as absorption.

[4] AUTO ACTUAL and AUTO SPECIAL are the names used in The Netherlands for the local routine and local special report, respectively. The AUTO SPECIAL and AUTO ACTUAL are identical reports. In this document the term “AUTO ACTUAL” is use to denote both the AUTO ACTUAL and the AUTO SPECIAL.
[5] Air Traffic Control (ATC) is called Luchtverkeersleiding Nederland (LVNL) in The Netherlands.

Note that the clarity of the atmosphere can also be expressed in terms of transmissivity or transmittance, where the first is per unit length and the latter for a given path length.

Visibility for aeronautical purposes (VIS) is defined as the greater of (i) the greatest distance at which a black object of suitable dimensions, located near the ground, can be seen and recognized against a bright background and (ii) the greatest distance at which lights with a luminous intensity of 1000 cd (=lm/sr) can be seen and identified. The first definition is applicable during daytime when an object is visible when the luminance contrast, i.e. the ratio of the difference between the luminance (cd/m$^2$) of the object and the background and the luminance of the background exceeds the contrast threshold. The contrast threshold is the minimum value of the luminance contrast that the human eye can detect. The contrast threshold varies with the individual, but for aeronautical purposes a value of 0.05 is adopted. The luminance of a black object is zero and the luminance of the background is determined by the atmospheric scattering of Sun and sky light along the line of sight. The relationship between daytime visibility and the atmospheric scattering coefficient is given by Koschmieder's law, which is similar to Bouger-Lambert law. Since scattering is the primary source of atmospheric extinction and the factor 0.05 appears both in the definition of MOR and visibility, the daytime visibility equals MOR. The latter definition is applicable during nighttime and involves the illumination threshold i.e. the smallest illuminance (lm/m$^2$) for the detection of point sources of light against the background luminance. The illumination threshold is a function of the background luminance and is described by a logarithmic relationship. The relation between intensity and illuminance is given by Allard's law and involves the distance of the light source and the extinction coefficient. For a light source just visible, i.e. the illuminance equal to the illumination threshold, VIS can be determined.

The Runway Visible Range (RVR) is defined as the range over which the pilot of an aircraft on the centre line of a runway can see the runway surface marking or lights delineating the runway or identifying its centre line. In case RVR is determined from runway surface markings, i.e. during daytime and without lights, it equals MOR. Otherwise RVR is evaluated from the "visibility" of lights, but unlike VIS which is determined by using the intensity of a standard lamp with a luminous intensity of 1000 cd, the RVR is determined by using the actual light intensity of the runway lamps. For that purpose the characteristics of the center and edge lights (specifically the dependency of the intensity on direction generally expressed in so-called isocandela diagrams), the intensity settings of the runways lights or the actual current going through the lamps, the effect of ageing and contamination of the lamps, but also the height of the pilot and the distance of the edge lights from the centre line of the runway need to be taken into account.

## 4. Causes of visibility reductions

The visibility is always restricted to some extend by scattering and absorption of light by atmospheric particles suspended or falling through the atmosphere. Even in the absence of particles, molecular scattering limits visibility. Mist and fog are the primary causes for significant visibility restrictions in The Netherlands. Both consist of hydrometeors, suspended water or ice droplets or wet hygroscopic particles, limiting visibility to 1 – 5 km (mist) or even below 1 km (fog). In addition heavy precipitation and particularly snow can cause reduced visibility. The suspended or falling hydrometeors have the properties that they have virtually no wavelength dependency and that they do not absorb radiation. Visibility can also be reduced by haze (suspended dry particles), smoke, dust or sand. These so-called lithometeors generally exhibit a wavelength dependency and partially absorb radiation. The visibility reduction caused by lithometeors is generally small although sand and dust storms can lead to significant reductions in arid and desert areas during periods with substantial wind speeds.

## 5. Visibility requirements

Table 1 gives an overview of the range and reporting steps of the visibility parameters and the uncertainty requirements. The first 2 columns give the requirements for the MOR reported in the (AUTO) SYNOP reports using WMO code table 4377 for reporting the horizontal visibility VV (WMO, 2010) and a national code 5975Vm for reporting the horizontal visibility below 100 m in steps of 10 m (KNMI, 1994). WMO (2008) specifies the range of MOR as 10 m to 100 km, whereas the reporting range of VV is only 100 m to >70 km. The required uncertainty of the MOR below 100 m is not specified. The next 2 columns of Table 1 pertain to VIS as reported in the AUTO METAR and AUTO ACTUAL (including AUTO SPECIAL and QAM) in the VVVV group (ICAO, 2010). The uncertainty of VIS is the same as for MOR. The last 2 columns give the specifications for RVR reported in the AUTO METAR in the $V_RV_RV_RV_R$ group (ICAO, 2010). WMO

(2008) specifies the range of RVR as 10 to 1500 m, whereas ICAO (2010) recommends a RVR range from 50 to 2000 m. The required measurement uncertainty for RVR is given in ICAO (2010). RVR is not reported directly in the AUTO ACTUAL. The AUTO ACTUAL contains a flag which indicates whether the RVR or VIS reported by any of the visibility sensors at the airport is below 1500 m. In that case ATC starts requesting all RVR information for further distribution. Note that in this situation the RVR information is not directly broadcasted to the pilots by the ATIS system of ATC, but ATIS informs the pilots that RVR information is available. The range, reporting steps and accuracy requirements of the RVR used in the AUTO METAR also apply to the RVR information provided directly to ATC. In this document the RVR information provided directly to ATC is considered also as being part of the AUTO ACTUAL and AUTO SPECIAL.

Table 1: Reporting range and resolution and the uncertainty required for visibility related parameters in (AUTO) SYNOP, AUTO METAR and AUTO ACTUAL reports.

| **MOR (SYNOP Vm, VV)** | | **VIS (METAR/ACTUAL VVVV)** | | **RVR (METAR/ACTUAL $V_RV_RV_RV_R$)** | |
|---|---|---|---|---|---|
| Range (Step) | Accuracy | Range (Step) | Accuracy | Range (Step) | Accuracy |
| 0-100 m (10) | - | 0-800 m (50) | * | 50-400 m (25) | ±10 m |
| 100-5000 m (100) | * | 800-5000 m (100) | * | 400-800 m (50) | ±25 m |
| 5-30 km (1) | ±20 % | 5-10 km (1) | ±20 % | 800-1500 m (100) | ±10 % |
| 30-70 km (5) | ±20 % | ≥10 km | | 1500-2000# m (100) | ±10 % |
| >70 km | | | | >2 km | |

*MOR and VIS accuracy: ±50 m for MOR≤600m; ±10 % for 600<MOR≤1500m; and ±20 % for MOR>1500m.

#RVR is reported up to 2000 m at civil airports, but up to 3000 m at military airbases in The Netherlands (KNMI, 1994). Note that RVR values outside the range are reported as M0050 and P2000 or P3000.

VIS and RVR are both derived from MOR, but also involve the background luminance and the lamp intensity. Hence the requirements for MOR used in the calculation of VIS and RVR should in fact be stricter than those for VIS and RVR since the uncertainty of the background luminance and the lamp intensity contribute to the uncertainty of VIS and RVR. The contribution of the background luminance and the lamp intensity is, however, smaller than that of MOR so they are not considered here. The overall requirements on range, reporting step and the uncertainty of MOR are the complement the requirements of the individual visibility parameters, using the strictest values. The range of MOR is 10 m to 100 km. The reporting resolution is 10 m for MOR<100m; 25 m for 100≤MOR<400m; 50 m for 400≤MOR<800m; 100 m for 800≤MOR<5000m; 1 km for 5≤MOR<30km and 5 km for 30≤MOR<100km. The required uncertainty is ±10 m for MOR<400m; ±25 m 400≤MOR<800m; ±10 % 800≤MOR<2000m; and ±20 % for MOR≥2000m.

Note that, according to WMO and ICAO, MOR and VIS reported in (AUTO) SYNOP and AUTO METAR can be determined either by an instrument measurement or manually by using visual markers. Instrumental RVR on the other hand is mandatory for CAT II and III runways for instrument approach and landing and recommended for CAT I runways.

The requirements for the background luminance are not clearly stated. The four illumination threshold classes for night, intermediate, normal day and bright day conditions use the background luminance limits ≤50, 1000 and >12,000 cd/m$^2$. The logarithmic relationship between the background luminance and illumination threshold, however, spans the range 8 to 38000 cd/m$^2$ between the illumination thresholds for night and bright day, respectively. An uncertainty of ±10 % is considered acceptable by ICAO (2006).

## 6. Sensors for the measurement of MOR

In this section the instruments for measuring MOR are described. General information on MOR measurements is available in WMO (2008) and ICAO (2010). ICAO recommends using either a transmissometers or forward scatter meters for assessing visibility. A transmissometer has the advantage that it can serve as a reference and is used by KNMI as such. A forward scatter meter is used by KNMI for operational visibility measurements. Both instruments are discussed below. Details on the instruments used by KNMI can be obtained from the manufacturer's manuals (Vaisala, 1992, 2001, 2002a, 2002b and 2006).

A transmissometer (TMM) measures the extinction of a light beam over an atmospheric path between an emitter and a receiver (cf. Figure 1). The atmospheric transmittance is directly related to the extinction and hence to MOR. Since a TMM measures transmittance, its signal varies exponentially with MOR. As a result a TMM can only measure low MOR values very accurately, although a second receiver, placed at a larger distance from the emitter, is often used to increase the MOR range of a TMM. A so-called forward scatter meter (FS) measures the amount of light scattered by a small measurement volume at an angle of about 33 ° (cf. Figure 2). The scattered signal varies linearly with MOR so that it can be used to measure higher MOR values. An angle of 33 ° is used because in this direction the amount of scattering has the smallest dependency on the optical properties of the scattering particles. However a relation between the amount of forward scattering and the extinction of the scattering medium needs to be taken into account. The advantages of a FS compared to a TMM are: (i) the lower procurement and installation costs (a double baseline TMM consists of 3 separate sensor units that need to be carefully aligned); (ii) lower maintenance due to lesser sensitivity of MOR measurements to contamination of lenses; and (iii) the possibility to measure up to higher MOR values, and some FS sensors, like the FD12P used by KNMI, have extensions so that it can measure the so-called present weather, i.e. precipitation type and intensity. In fact, the FD12P and similar instruments are often called present weather sensors (PWS). The advantages of a TMM are: (i) that it measures transmittance from which extinction and MOR can be derived unambiguously; and (ii) that it can be calibrated through neutral density filters with a known transmittance.


Figure 1: The Vaisala MITRAS transmissometer with the transmitter equipped with background luminance sensor in the foreground (right), the short baseline receiver (middle), and the long baseline receiver in the background (left).

KNMI uses a Vaisala MITRAS transmissometer as a reference sensor for MOR measurements that is used for the calibration of the forward scatter meters (cf. Figure 3). The reference setup in De Bilt consists of a transmitter, a short baseline receiver at 11.4 m and a long baseline receiver at 74.4 m. The MITRAS makes a direct measurement of the atmospheric transmittance between the light transmitter and the receiver. The light source is a Xenon flash lamp with a wide spectral range (300 – 1100 nm). The transmitter unit contains a reference photodiode which measures the intensity of each pulse of emitted light. The emitted light is focused into a beam that is directed toward the receivers. The receiver measures the intensity of the light with a photodiode. The light incident at the photodiode first passes a green filter with a spectral range of 300 to

700 nm and a peak at 550 nm to match with the sensitivity characteristics of the human eye. The transmittance is the ratio of the received to the transmitted intensity; so aging and instability of the lamp are automatically compensated for. The field of view of the receiver is 9 mrad so that transmitter and receivers need to be carefully aligned. The measured transmittance is affected by the contamination of the windows of the transmitter and receivers. The MITRAS measures the contamination by dedicated contamination lamps and photodiodes. The transmittance loss caused by contamination of the windows is estimated and compensated for. The MITRAS generates warnings and alarms if the window contamination exceeds thresholds. The transmitter and receivers windows are heated in order to prevent condensation. The MITRAS is operated in a 1-minute averaging mode. For the conversion of transmittance into MOR the distance between the transmitter and the receiver(s) must be known. The range of the MOR reported by the MITRAS is 3 m to 125 km, but in the dual-baseline setup used by KNMI only MOR values below about 1500 m meet the accuracy requirements.

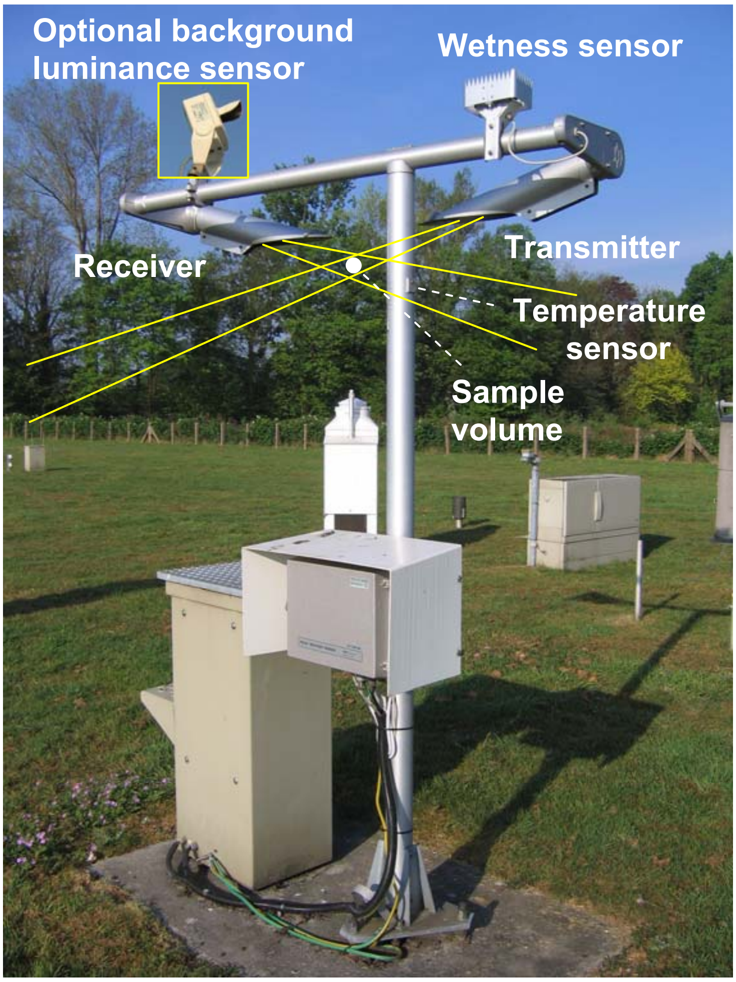


Figure 2: The Vaisala FD12P forward scatter meter with indication of the sensor parts.

For operational purposes KNMI uses the Vaisala FD12P forward scatter meter for measurements of the MOR along the runways at airports (cf. Figure 2). The FD12P uses a near-infrared LED with a peak wavelength of 875 nm as a light source and a photodiode with a broad spectral response with a maximum at 850 nm as the receiver. Atmospheric extinction and scattering has a smooth spectral dependency in the visible and near-infrared and the difference at 550 nm and 850 nm is taken into account in the calibration factor. This LED and photodiode are operated with a modulation frequency of 2.3 kHz and measure the amount of radiation scattered by a sample volume of about 0.1 $dm^3$. The transmitter is equipped with a reference photodiode that is used to monitor and control the light source. Furthermore, a backscatter photodiode is used to measure the amount of radiation reflected by the lens of the transmitter. The backscattered signal is used to monitor the contamination or blocking of the lens of the transmitter. Similarly, a backscatter near-infrared LED is used to check the contamination or blocking of the lens of the receiver. The lens and the hood of the receiver and transmitter are heated to prevent condensation or accumulation of solid precipitation.

During the 15 second measurement cycle of the FD12P the backscatter of the receiver and transmitter as well as the signal offset due to internal noise are determined in addition to the measurements of the amount of scattered radiation. The internal processing of the FD12P analyses the scattered signal sampled at about 8 ms. The averaged scatter signal, corrected for internal noise, is used in the determination of the MOR. Note that peaks occur in the scattered signal due to precipitation. The amplitude of these peaks is proportional to the droplet size. The FD12P uses the optical signal in combination with the information of a wetness sensor and the temperature to determine the precipitation type. Also note that the receiver and transmitter backscatter signals are only used to monitor contamination or blocking of the lenses and not for compensation of the contamination. The FD12P issues warnings and alarms for contamination or blocking when backscatter threshold levels are exceeded. The downward looking optical configuration minimizes contamination of the lenses. In order to prevent possible interference from external light sources the receiver and transmitter optics should not be pointed towards powerful light sources. Furthermore, the surface in the line of sight of the receiver and transmitter beams should be free of obstacles or reflecting surfaces. In the field setup the FD12P is placed according to the above recommendations with the receiver pointing North in order to avoid incoming sunlight or sunlight reflected by the surface. The range of the MOR of the FD12P is 10 m to 50 km and the accuracy is given as ±10 % for MOR below 10 km and ±20 % for higher values.

The Vaisala MITRAS transmissometer and the FD12P forward scatter meter can optionally be equipped with a LM11 or LM21 background luminance sensor. Both sensors measure the background luminance with a field of view of about 6 to 7 ° and a spectral response ranging from 400 to 700 nm with a maximum at 550 nm, resembling that of the human eye. The LM11 is the old Vaisala sensor that has recently been replaced by the LM21. The background luminance sensor is equipped with an infrared LED to check the sensitivity of the photodiode. A dedicated photodiode and infrared LED are used to measure the lens backscatter. The background luminance sensor, in contrast to the optical system for measuring scattered radiation, does make a first order correction for the lens contamination in the determination of the background luminance value. If the backscatter exceeds thresholds warning or error messages are generated. Again the lens and hood of the sensor are heated to overcome dew formation and blocking by solid precipitation. The background luminance sensor can be mounted on top of the FD12P or the MITRAS and is connected to its CPU board so that the background luminance is reported together with the MOR. In order to avoid interference from the Sun and bright light sources the background luminance sensor is generally pointed to the North at an elevation of about 30 °. The range of the background luminance sensor is 2 to 40,000 cd/m$^2$ and the accuracy is ±10 %.

## 7. Calibration of MOR measurements

In this section the calibration of the MOR measurements is presented. Bloemink (2006 and 2007) describes the reference setup at KNMI and the data processing in detail. The corresponding work instructions (KNMI, 2008) are part of the ISO 9001-2008 certified quality management system. Background information on the calibration setup can be found in WMO (1990) and ICAO (2005).

The advantages of a transmissometer with respect to a forward scatter meter are that it measures atmospheric transmittance from which MOR can be derived unambiguously and that it can serve as a standard for MOR measurements. A TMM be calibrated through neutral density filters with a known transmittance. The transmittance of the neutral density filters can be verified or determined in a laboratory setup by a relative measurement that requires a light source and detector with optical properties and spectral response similar to that of the TMM. At KNMI this is realized in the radiation laboratory by using a 1000 W FEL quartz halogen lamp in combination with a green filter (the same as used in the MITRAS) and a power meter in between which a neutral density filter can be placed. The calibration of the TMM is performed in the field setup on a clear day with a good visibility (i.e. MOR exceeding 10 km) in order to minimize the contribution of atmospheric extinction. When a filter or a combination of filters is placed in the optical path of a TMM in the field, the TMM should give the correct transmittance value. Using a set of filters the linearity of the TMM can be verified as well. KNMI uses a set of five neutral density filters with transmissivities of 0.27, 0.43, 0.56, 0.69 and 0.95. For the conversion of transmittance into MOR the distance between the transmitter and the receiver(s) must be accurately known. The alignment of transmitter and receiver(s) must be correct to give optimal results and should not change over time. Also it is essential that the windows should be kept clean to minimize errors due to contamination. The MITRAS TMM which is part of the visibility reference setup in De Bilt is cleaned every month or more often if the status indicates contamination of the windows and the calibration and linearity are verified every 2 months when the weather permits it.

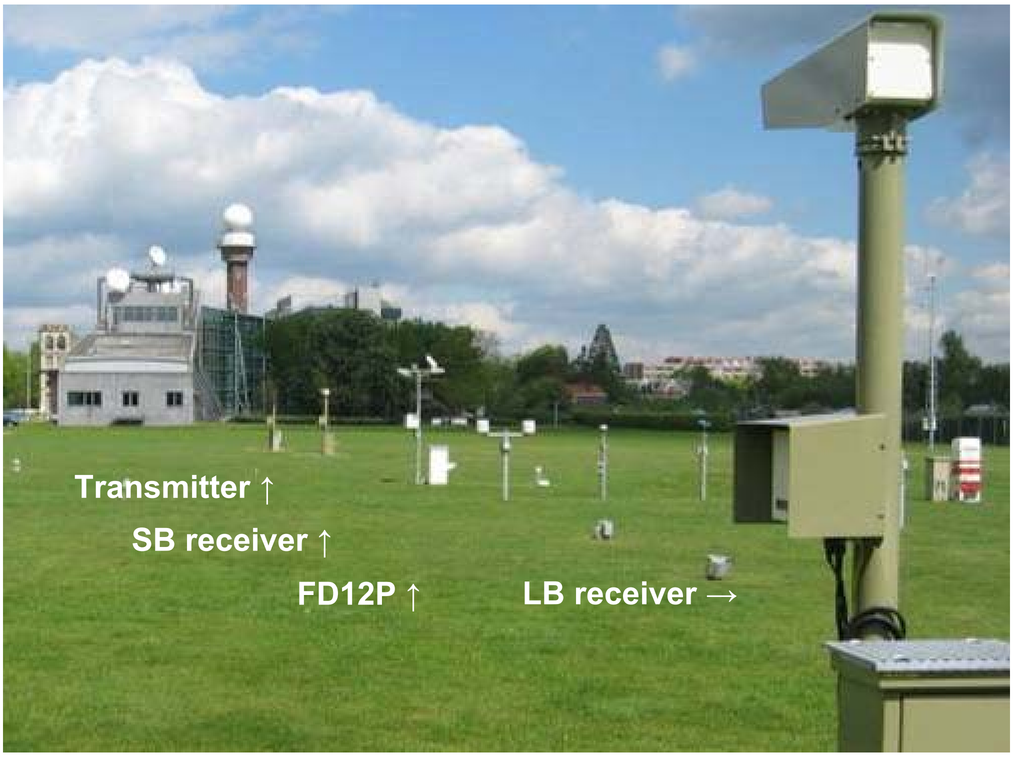


Figure 3: Setup for MOR calibration of the FD12P in De Bilt showing the transmitter and short baseline (SB) receiver of the TMM in the background (left), the reference FD12P in the middle, and the long baseline (LB) receiver of the TMM in the foreground (right).

The calibration of the optical signal of the FD12P is performed by means of a so-called scatter plate (cf. Figure 6) which, when placed at a fixed position in the sample volume should give a prescribed value. However, the scatter plate cannot be calibrated in terms of MOR in a laboratory. The calibration of the FD12P requires a field setup by which the MOR of a reference FS can be directly related to that of a calibrated TMM. KNMI operates a visibility reference setup for the FD12P at De Bilt consisting of a reference FD12P and a double baseline MITRAS TMM (cf. Figure 3). Both instruments measure the MOR at a height of 2.5 m above the surface and the FD12P is located halfway between the transmitter and long baseline receiver of the TMM. The FD12P is located 3 m East of the North South optical path of the TMM. The MOR of both instruments is measured continuously, but for the evaluation of the calibration of the MOR of the reference FD12P only a subset of the data is used. The MOR of the TMM should be less than 1500 m since at higher values the accuracy of the TMM is insufficient. Only situations with sufficient 1-minute data and without precipitation and sensor warnings are considered. Stable situations with little variability in the 1-minute MOR values of both sensors are used for the comparison. The 10-minute averaged MOR values of the FD12P and TMM that meet the above criteria are used for the evaluation of the MOR of the FD12P. The field setup is used to make sure that the MOR of the FD12P is within the required uncertainty limits from the MOR of the TMM for MOR values up to 1500 m. In case a deviation of 10 % or more is detected the calibration of the FD12P is adjusted by an appropriate change of the prescribed value of the scatter plate that compensates for the observed differences in MOR (Figure 4).

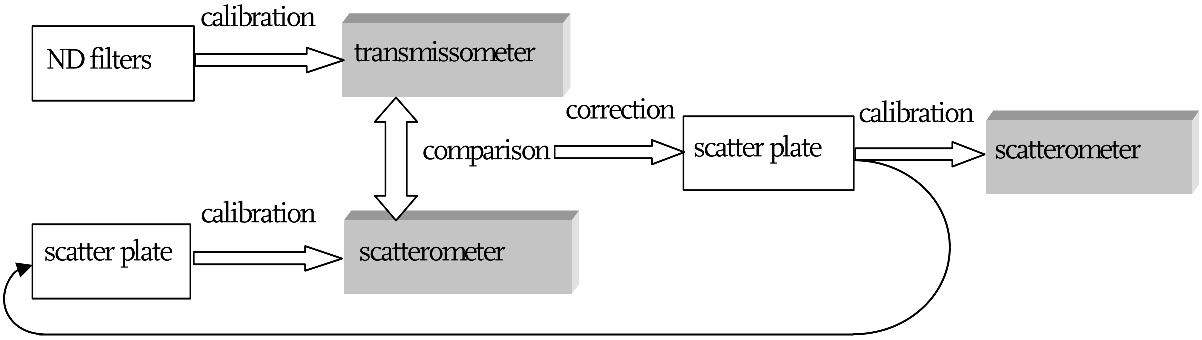


Figure 4: Schematic illustration of the visibility calibration procedure for the forward scatter meter.

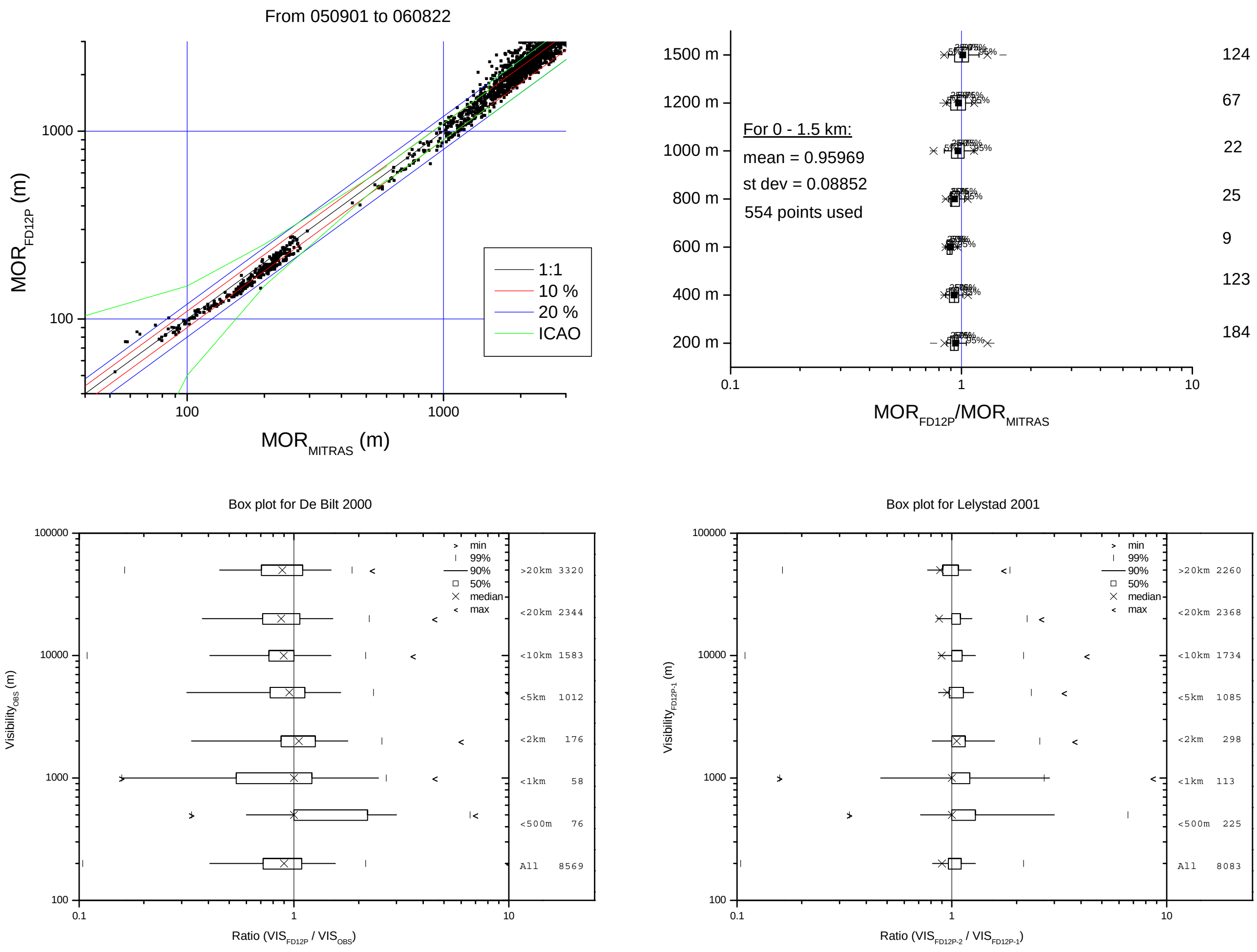


Figure 5: Illustration of the 10 minute averaged MOR obtained by the TMM and the FD12P at the visibility reference setup for a 12 months period (top left) and the corresponding boxplot (top right). The lower left panel shows a boxplot of the hourly visibility observed manually at De Bilt in 2000 versus the 10 minute averaged MOR of the FD12P whereas the lower right panel shows a boxplot obtained at Lelystad in 2001 from 2 FD12P sensors at opposite ends of the runway separated by about 675 m. Note that the visibility ranges used in the upper and lower boxplots differ since the lower plots cover the full visibility range. Also the lower panels contain all valid hourly data whereas the upper panels consider only 10-minute data during homogeneous situations without precipitation. The observed visibility in the lower left panel does not serve as a reference, but the panel indicates the differences that can be expected between manual evaluation of the minimum visibility around and the 10-minute averaged MOR reported by a FD12P.

The MOR calibration of the reference FD12P is transferred to a scatter plate by measuring the optical signal when the scatter plate is placed in the sample volume of the reference FD12P in clear conditions. The scatter plate is then used to calibrate the optical signal of all other FD12Ps. When a FD12P reports a signal that deviates more than 3% from the expected value then the MOR calibration of the FD12P is adjusted. Note that the calibration of the optical signal of the FD12P is in fact a 2 point calibration which includes the scatter plate, which corresponds to a MOR of about 10 m, and a blocked receiver, which corresponds to an infinite MOR value. The uncertainty of the MOR calibration of the FD12P has been estimated to be about ±18 % for MOR values below 1500 m (Bloemink, 2007). The FD12P assumes that MOR varies linearly with the scattered optical signal between these 2 extremes, which is a valid assumption for a small sample volume where single scatting is dominant and if the response of the electronics is linear. Note that there is no field reference for high MOR values although sensor inter-comparisons and comparisons with human observations over the full MOR range have been performed (cf. e.g. Wauben, 2003). Note that the spatial variability of the extinction is the main source of error when the visibility is not homogenous. Furthermore note that the calibration of the FD12P depends on the relationship between scattering and extinction or the medium causing the obstruction. The relationship therefore may differ in case of fog or precipitation (e.g. drizzle or snow) and might depend on local conditions (e.g. dry or humid, maritime or urban involving factors that affect the composition, size distribution and density of the medium). The effect of the scattering medium on the MOR assessed by a forward scatter meter is largely unknown.

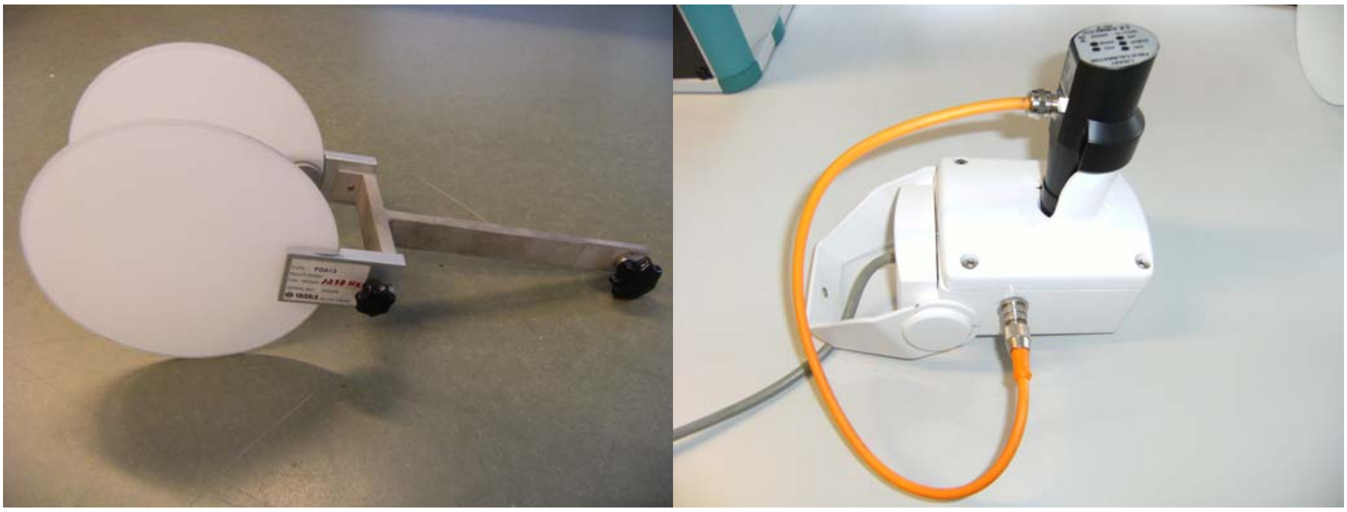

Figure 6: The scatter plate used for the transfer of the calibration to the FD12P (left); and the calibrator in front of the background luminance sensor (right).

The background luminance sensor can be calibrated by a field calibrator that can be mounted in front of the background luminance sensor (cf. Figure 6). The deviation should be within ±2 %. The field calibrator is returned to the manufacturer every five years for a recalibration.

## 8. Maintenance and effect of contamination

The optical visibility sensors are susceptible for contamination. In order to assure correct performance of the visibility measurements a maintenance interval of 2 months is used for the FD12P forward scatter meters at airports. During maintenance the sensor is inspected, spider rags or other contamination are removed from the FD12P and the lenses of the transmitter and receiver are cleaned. After cleaning it is verified that the window backscatter of the transmitter and receiver returned to normal values. The cleaning interval of 2 months is based on experience, but the development of contamination can change rapidly under specific situations, e.g. during precipitation when the wind is blowing directly into the optics of the transmitter or receiver. For that purpose the window backscatter of the FD12P is monitored and in case a backscatter warning limit is exceeded additional maintenance is performed. Note that the window backscatter measured by the FD12P is not used for a compensation of the lens contamination. The maintenance interval of the FD12P of 2 months at airports is shorter than for other locations, where an interval of 6 months is used. Generally cleaning of the FD12P is performed by KNMI service staff, but for remote locations such as off-shore platforms cleaning can be performed by the local administrator. In the latter case cleaning is performed only upon request of KNMI, on an agreed time and afterwards the correct operation of the FD12P is verified remotely by KNMI. A cleaning kit and instructions are provided to the local administrator for this purpose (cf. Figure 7). At civil airports contact can be established with the Airport Operations Manager (AOM) or a local firm that does the maintenance of the measurement field in case cleaning of the windows of optical sensors is urgently required. However, in practice this service is seldom needed.


Figure 7: The FD12P cleaning kit (top left); an example of a contaminated lens of the FD12P resulting in an error status (top right); spider webs with dew on the FD12P (bottom left); and flying insects around the FD12P (bottom right panel).

Contamination on the lenses will generally lead to higher values of MOR (Vaisala, 2002). A test on a platform in the North Sea showed that the FD12P can give too high MOR values during extreme contamination conditions (Wauben, 2003b). In this case contamination is mainly caused by salt deposition on the lenses which reduces the optical signal due to scattering. For a visibility sensor along the runway at an airport, soot is a more probable cause of contamination, which reduces the optical signal due to absorption, and hence also leads to higher MOR values. Note that generally no significant changes in the MOR can be observed before and after cleaning, but in most cases cleaning is performed when the window backscatter just exceeded the warning threshold. The statistical analysis of De Haij (2008) showed that there were only a few cases where contamination of the FD12P had a significant effect on the monthly distribution of MOR. Differences in the monthly mean MOR of 5 to 10 % between a contaminated FD12P and a co-located sensor have been observed. However, no clear relationship has been found between contamination of the sensor and the observed MOR. Although the MOR of the contaminated FD12P is generally higher, as expected, some of the analyzed months indicated a reduction of the MOR. Whereas contamination on the lenses leads to reduced MOR values, objects in the sample volume enhance the scattered signal and hence reduce MOR. Objects that cause such reduced MOR values are spider rags, especially in combination with dew, and flying insects (cf.

Figure 7). The first gives a constant signal that cannot be distinguished from the continuous MOR signal. During humid and windy conditions it can sometimes be noted as faulty precipitation, but generally it shows up as too low MOR values during good visibility conditions. The reduced MOR due to flying insects shows up internally in the optical signal of the FD12P as individual spikes when the insect traverses the sample volume. In contrast to precipitation the insect signal does not coincide with enhanced values of the wetness detector. Therefore it is possible to identify the spikes caused by insects and omit them during the calculation of MOR. The evaluation of Wauben (2011) showed that the newly developed insect filtering of MOR by the FD12P showed good results (cf. Figure 8) and KNMI currently plans to introduce this filtering for FD12P sensors at airports.

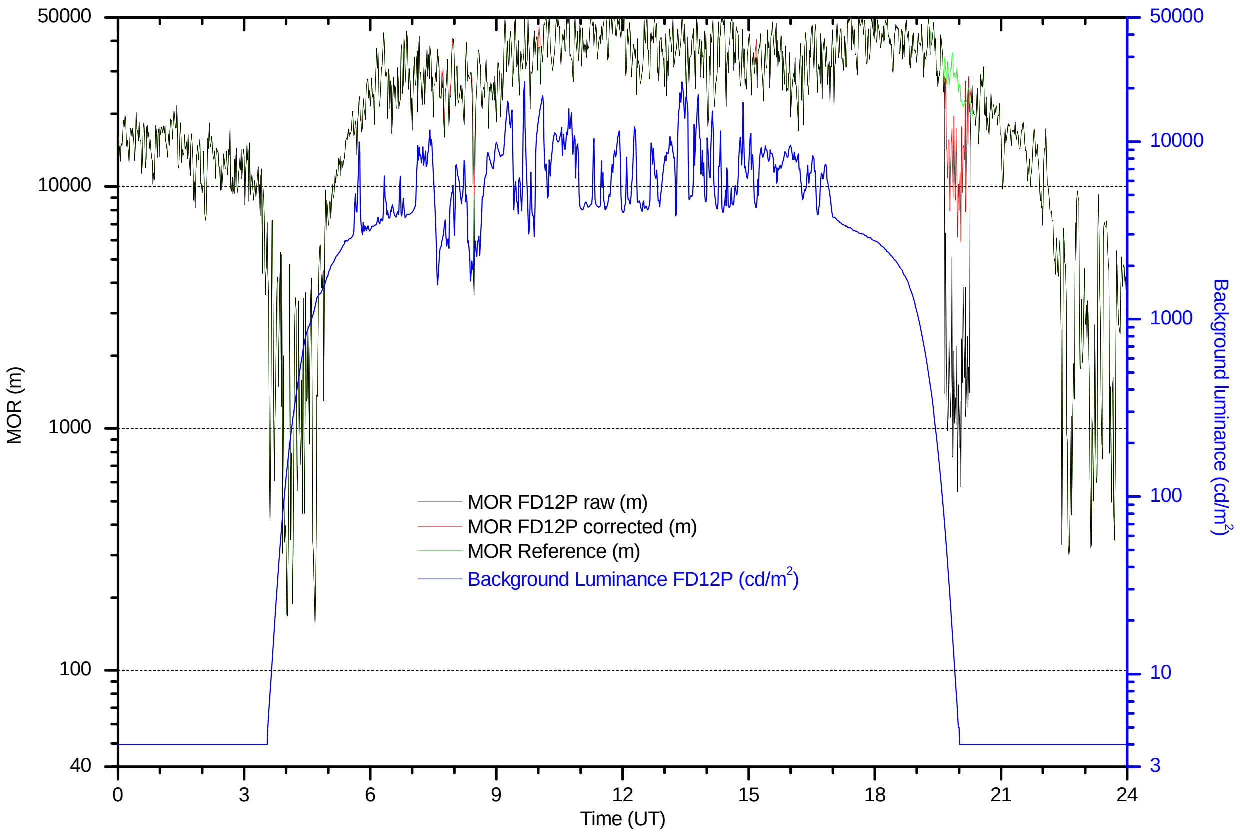


Figure 8: The 1-minute averaged MOR and background luminance observed by a FD12P in De Bilt on August 5, 2010. The background luminance (blue curve with scale on the right) is 4 cd/m$^2$ at nighttime and show a sharp increase near sunrise (3:30 UT) and a decrease near sunset (20 UT). The MOR (black curve with scale on the left) show values exceeding 10 km. Around sunrise (3 to 5 UT) and at night (22-24 UT) low MOR values occur during fog. Similar MOR values are reported by the TMM in De Bilt during these periods (not shown). Reduced MOR values due to insects occur around sunset (19:30 to 20:30 UT) with values below 1 km. The MOR of the TMM shows no reduced MOR values during this period. The insect filtering of the FD12P mitigates the MOR reduction significantly (red curve) although the corrected MOR still shows MOR reductions compared to a constructed reference (green curve) which is in fact the rescaled MOR of the TMM. The corrected MOR is, however, above aeronautical limits.

## 9. Sensor locations

RVR cannot be measured on the runway itself, but is measured on grass along the runway. The runway is made of concrete or asphalt. The resulting temperature differences can affect the distribution and density of fog along the runway. The visibility is furthermore affected by the aircraft themselves via turbulence and the exhaust gasses. The spatial variability of the visibility is the main source of error when the visibility is not homogenous. ICAO (2005) gives detailed information on the position of the RVR sensors at airports in order to standardize the measurement of RVR so that there is uniformity in the RVR information that is made available to the user and to ensure that the measurements meet user requirements. The requirements are: (i) the recommended measurement height above the runway elevation is 2.5 m; (ii) the sensor should be between 75 and 120 m from the centre line of the runway; and (iii) the position along the runway should be representative for the touchdown zone (non-precision approach and CAT I, II and III operations); mid-point (CAT II and III operations); and the end of the runway (CAT III operations). Touchdown generally is located about 300 m along the runway from the threshold; mid is located at a distance of 1000 to 1500 m along the runway from the threshold; and end is located about 300 m from the end of the runway. The end of the runway becomes the touchdown position when the runway is used in the opposite direction. A CAT III runway at Schiphol is therefore generally equipped with 3 visibility sensors at the touchdown, mid and end position. For Rotterdam The Hague Airport only one sensor at touchdown is required, but since the runway can be used from both directions a FD12P visibility sensor is located at both ends of the runways. Both of these FD12P sensors are equipped with a background luminance sensor although in principle only one is required by ICAO. The use of two or more background luminance sensors is preferable for redundancy. The sensor usage at of Rotterdam The Hague Airport is in agreement with the practice of KNMI to use a background luminance sensor on the visibility sensor at each touchdown position of a runway at civil airports. The FD12Ps at 24 and 06 touchdown of Rotterdam The Hague Airport are positioned near the respective aiming points in the touchdown zone (cf. Figure 9). The visibility sensors are located about 500 m from the end of the runway because the thresholds of runway 06 and 24 are displaced by 200 m. Both visibility sensors are placed 115 m from the runway centre line and are equipped with a background luminance sensor. The distance between the two FD12P visibility sensors is about 1100 m. The runway at Rotterdam The Hague Airport has an overall length of 2200 m and a width of 45 m.

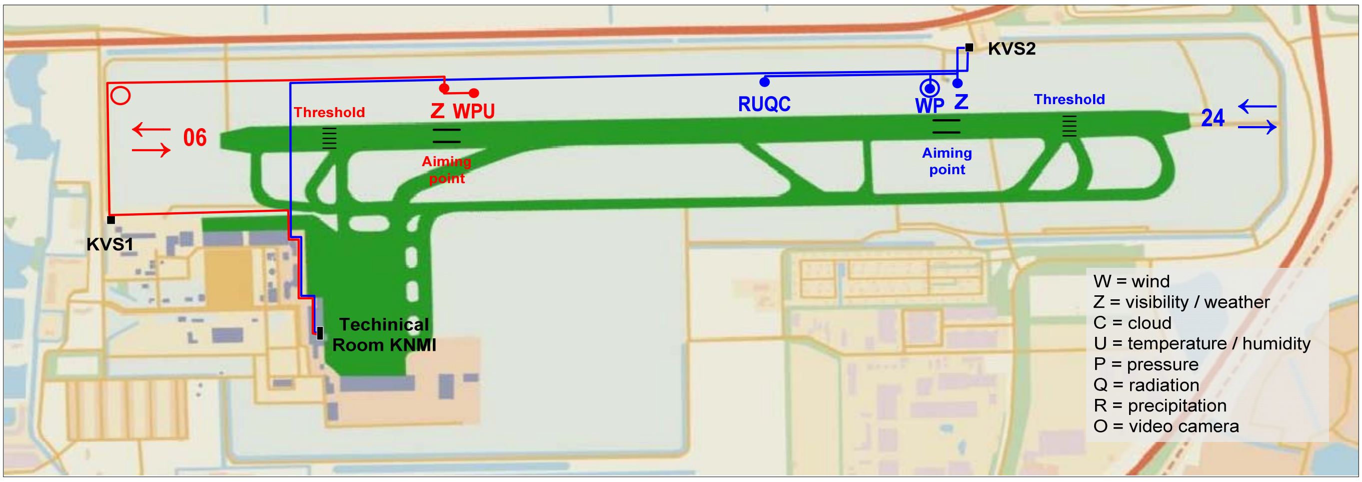


Figure 9: The position of the meteorological sensors and video cameras at Rotterdam The Hague Airport. The sensors and cameras associated to touchdown 06 and 24 and their respective relay station (KVS) and data communication line to the technical room of KNMI at the airport are shown in red and blue, respectively. The measurement field not only contains temperature and humidity sensors and a ceilometer for cloud observations, but also a rain gauge and a global radiation sensor for synoptic purposes.

Video cameras are installed at the wind mast of 24 touchdown at about 2 m and 9 m height. The pair of cameras in the wind mast has been installed to facilitate the detection or identification of patches of fog and shallow fog. Note that the cameras cannot be used to estimate the visibility accurately. They mainly serve as a verification tool for the aeronautical meteorological forecaster or as a means to check the meteorological situation. An additional camera is installed at 2.5 m height near at the VHF direction finder (VDF) building 500 m before the threshold of runway 06. The cameras at 9 m and at 2.5 m have a 16 mm lens with a field of view (width x height) of about 16° x 11° whereas the camera at 2 m has a 6 mm lens with a field of view of about 40° x 30°. All cameras are pointed towards 24 touchdown.

## 10. SIAM sensor interface and MUF cascade

All sensors are operated in combination with a so-called SIAM sensor interface, a Sensor Intelligent Adaptation Module. A SIAM communicates with the sensor and converts the sensor output into meteorological quantities in a fixed serial format. The FD12P sensor is operated in combination with the DZ4

SIAM (Bijma, 2007). A SIAM runs asynchronously and polls the sensor every 12 seconds and gets the status information as well as the MOR, background luminance, precipitation intensity and precipitation type. Note that the FD12P operates with an internal update period of 15 seconds; hence the SIAM gets 2 identical sensor replies every minute. The SIAM performs a format and a range check on the meteorological quantities and generates an output string every 12 seconds. Note that the FD12P already reports a 1-minute averaged MOR, which is directly used as the sample value as well as the 1-minute averaged MOR reported by the SIAM. The SIAM also calculates the 10-minute averaged MOR, by averaging the extinction coefficient, which is used for synoptic purposes. An example of the output string of the DZ4 SIAM is given below. In fact the example shows a so-called MUF string, which contains a single SIAM string and a check sum enclosed in a pre- and post amble. The MUF (MUltiplexing Facility) is a multiplexer that is used to put SIAM or MUF strings received from 4 serial input channels onto a single serial output line. During that process the triple redundancy of each SIAM string received is checked and removed and the transmitted MUF string is forwarded with a baud rate of 19.2 kbps. Table 2 gives an example of the DZ4 MUF string of the FD12P sensor with a brief description of its contents.

Table 2: Example of a DZ4 MUF string of the FD12P sensor with a description of its contents.

| | |
|---|---|
| <STX>M<CR><LF><br>X0A ZM1AZA43NI6CND95PWBE ZM 0 4 4219 4219 5187 4219 4823 4756 00 ZA 0 4 4122 4117 4122 3744 3884 3145 00 NI 0 4 3740 3740 3740 0000 2765 3186 00 ND 0 4 0012 0060 //// //// 0108 //// 00 PW 0 4 0070 0070 0070 0000 0070 //// 00 <CR><LF><br>CS<ETX> | |
| <STX>M<CR><LF> | Fixed four character preamble of MUF string |
| X | Fixed first character of SIAM string denoting X SIAM type |
| 0A | Two character hexadecimal location code (00-FF).<br>Each SIAM unit - location code combination uniquely identifies the associated instrument in the meteorological network |
| ZM1AZA43NI6CND95PWBE | ID field containing 1 to 6 entries of SIAM unit (two characters) and unit position (two character hexadecimal denoting start position of unit in SIAM string). E.g. DZ4 has 5 units and unit ZM start at position 1A=26 in SIAM string |
| ZM | SIAM unit ZM i.e. MOR in m |
| 0 | Status character denoting the status of the instantaneous measurement (0=OK, 1-9=test modes, a-z=warnings, A-Z= fatal errors) |
| 4 | Number indicating the sensor type (4=FD12P, 2=MITRAS) |
| 4219 4219 5187 4219 4823 4756 | Data fields reporting the sample=instantaneous, 1' averaged, 10' maximum, 10' minimum, 10' averaged values and 10' standard deviation of the MOR. MOR is reported in exponential notation ABCD=.BCD*10^A. E.g. instantaneous MOR is 2190 m |
| 00 | % sample values missed in 10' derivations (00-99). 99 % indicates that no samples values are available, 0 indicates that all 50 samples values were available while calculating the 10' values. |
| ZA 0 4 4122 4117 4122 3744 3884 3145 00 | Data fields for SIAM unit ZA i.e. background luminance in cd/$m^2$ in exponential notation. E.g. instantaneous background luminance is 1220 cd/$m^2$. |
| NI 0 4 3740 3740 3740 0000 2765 3186 00 | Data fields for SIAM unit NI i.e. precipitation intensity in 0.001 mm/h in exponential notation. E.g. instantaneous precipitation intensity is .74 mm/h. |
| ND 0 4 0012 0060 //// //// 0108 //// 00 | Data fields for SIAM unit ND i.e. precipitation duration in sec in integer notation. Derived by SIAM when instantaneous precipitation intensity > 0.03mm/h. E.g. instantaneous precipitation duration is 12 sec.<br>Note that meaningless fields are indicated by ////, as are instantaneous values with fatal status or 10' values with 99% missed |

| | |
|---|---|
| PW 0 4 0070 0070 0070 0000 0070 //// 00 | Data fields for SIAM unit PW i.e. precipitation type in WMO code format. E.g. instantaneous precipitation type is snow. |
| <CR><LF> | End of SIAM string |
| CS<ETX> | Three character post amble of MUF string where CS is the checksum |

The sensors and SIAM sensor interfaces are installed in the field and are connected via fixed copper lines to a nearby relay station of LVNL (KVS) which also supplies the no-break power supply. A relay station typically serves half of the runway, e.g. the sensors associated with 06 touchdown are connected to KVS1 and the sensors associated with 24 touchdown and the measurement field are connected to KVS2. The SIAM sensor interfaces are situated in the field either directly at the sensor, e.g. in the electronic box of the wind mast or of the visibility sensor or in the central data box at the measurement field. The latter also contains a MUF multiplexer so that all SIAM data can be sent to KVS2 via a single data line. At the relay station the serial SIAM information is multiplexed on a single serial line and forwarded to the technical room via copper lines. In the technical room all incoming MUF strings are duplicated by splitters, multiplexed on to a single line and given to the ADCM server pair for further processing. An overview of the technical observation infrastructure at Rotterdam The Hague Airport is shown in Figure 10. Note that information of the Runway Information System (RIS) of LVNL, which indicates which runway is in use, is also fed as a SIAM string into the MUF cascade. Table 3 gives an example of the DB0 MUF string of the RIS with a brief description of its contents.

Table 3: Example of a DB0 MUF string of the RIS with a description of its contents.

| | |
|---|---|
| <STX>M<CR><LF><br>X08 BB0E BB 0 0 0002 0000 0000 0000 0000 0000 00 <CR><LF><br>CS<ETX> | |
| BB0E BB 0 0 0002 0000 0000 0000 0000 0000 00 | Data fields for SIAM unit BB i.e. runway in use indicator. Instantaneous value 0, 1 and 2 indicate runway closed, runway 24, and runway 06, respectively |

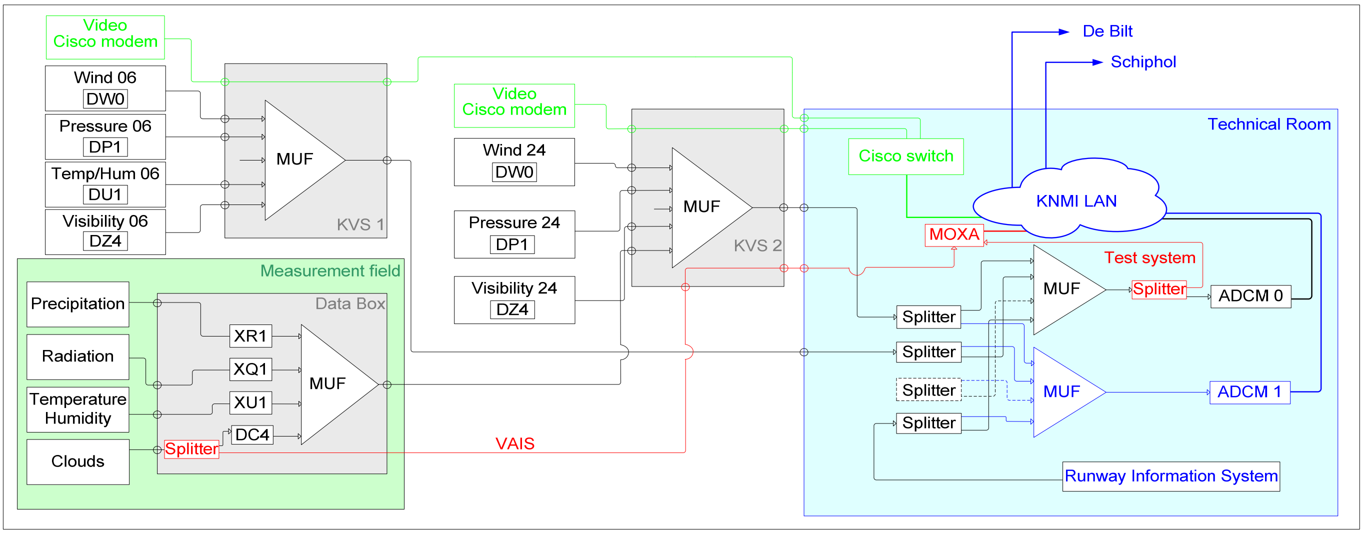


Figure 10: An overview of the sensors and SIAMs and splitters in the MUF cascade at Rotterdam The Hague Airport. Black line and boxes denote connections and components which a single point of failure. Blue lines and boxes show the secondary server system with associated sensor data. The video cameras components are denoted in green and the sensor data that is forwarded to the test server system in De Bilt is shown in red. The backscatter information of the ceilometer that is forwarded to De Bilt for monitoring of volcanic ash is also given in red.

The sensors and sensor interface in the field are single points of failure. However, for most sensors a backup sensor is situated at another physical location. The only exceptions are the visibility sensors near touchdown, since by rule RVR at touchdown may not be backed up by a sensor further along the runway, and the ceilometer of which there is only one. When the information of the visibility sensor at touchdown is not available the associated runway cannot be used for CAT I instrument precision approach and landing operations. In such a situation the runway can still be approached from the opposite side under Low Visibility Procedure procedures. A failure of a multiplexer/splitter or connection to or from a KVS disables all sensors at that end of the runway. However, even in such a case sensor information for wind, pressure, temperature, humidity, visibility and weather is available via an automated backup by sensors situated at the opposite side of the runway. The Runway Information System can be backed up by manual selection of the runway in use. The manually entered runway in use is normally overruled by valid data obtained by RIS.

A dual video camera system is mounted on the wind mast of 24 touchdown (cf. Figure 11). The system consists of cameras mounted at 2 and about 9 m, and facilitates monitoring of the representativeness of the visibility measurements at the touchdown zone during daytime. In addition a video camera is located 500 m before the threshold of runway 06 at a height of 2.5 m and pointed towards 24 touchdown. This camera can be used by the aeronautical meteorological forecaster to check the general meteorological conditions, particularly of cloudiness and visibility at the airport. Note that no quantitative information on the MOR can be derived from these images. Only a rough check of the measured visibility can be estimated from the images. However, the cameras provide information on the nature of obscuration (shallow fog, patches). The video signal is made available via the network to the central weather room and service staff of KNMI in De Bilt.

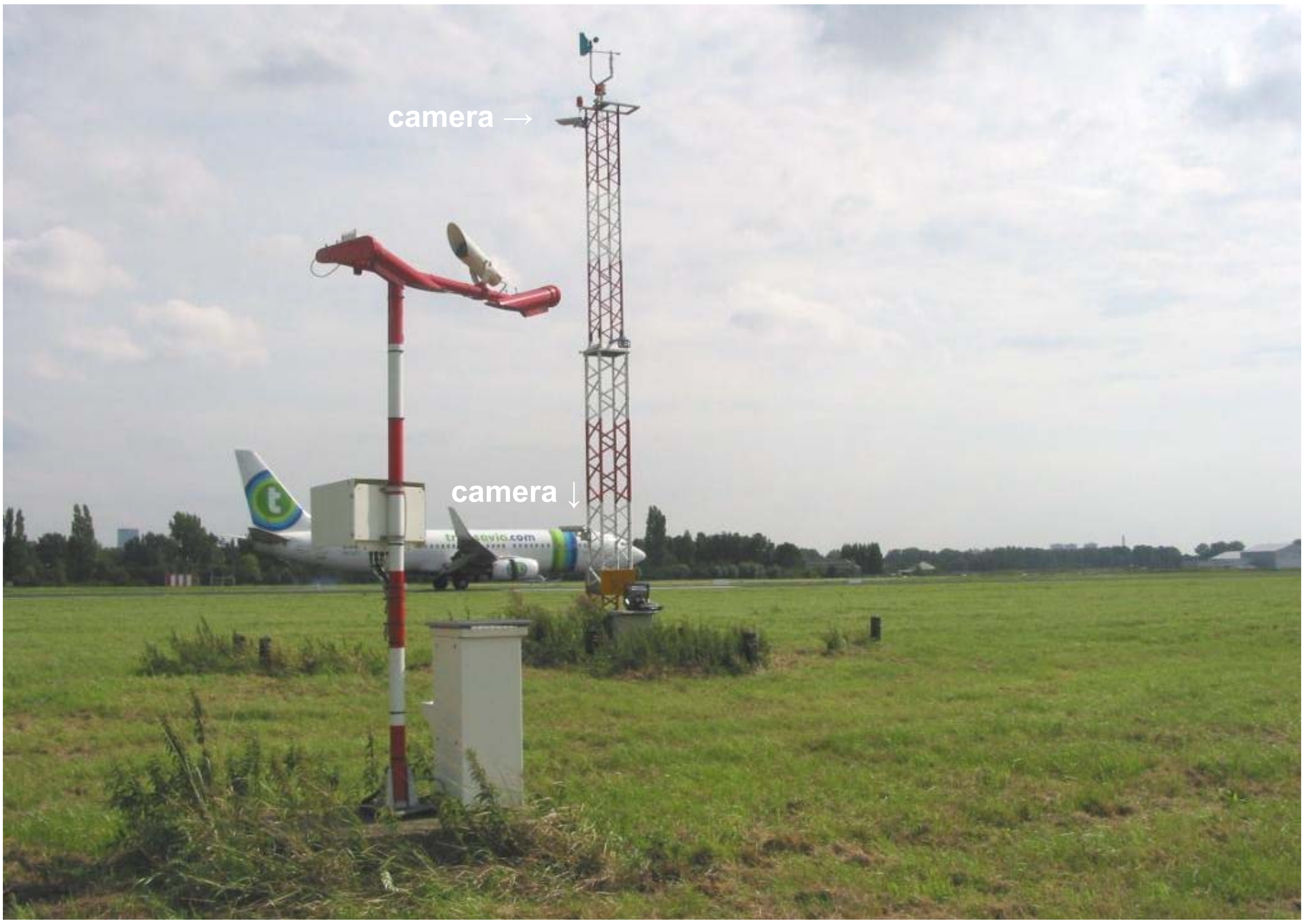


Figure 11: The FD12P and wind mast near 24 touchdown at Rotterdam The Hague Airport. Video cameras are mounted at 2 m and near the top of the frangible wind mast.

## 11. Server and client network systems

The 2 outputs of the MUF cascade, each containing all sensor and RIS information, are fed into a redundant central server pair. In normal operation one of these ADCM (Aviation Data-acquisition and Communication

Module) servers is hot and ingests all sensor data. The SIAM data that is transmitted asynchronously by the SIAM is assigned to a 12 second interval at the hot ADCM. Generally the last SIAM string of each sensor that arrived at the server in a 12 second interval is labeled with the time at the end of the interval. Some processing is involved to handle reception of either none or two SIAM strings in a 12 second interval. While processing the SIAM data the hexadecimal SIAM location code is uniquely translated into a MetNet station name (cf. Table 4) and value of the SIAM unit is put in the associated variable in the 12 second update group of the station. The SIAM unit is kept in the variable name, but in addition the SIAM data field is indicated, e.g. MetNet variable ZMs contains the sample value of SIAM unit ZM (cf. Table 5). During this assignment of the sample value, the corresponding SIAM status is uniquely translated into a quality value and assigned to the data quality of the MetNet variable. The ADCM monitors the status of the sensors and it also takes care of derivations, e.g. RVR and cross wind calculations and the handling of automated backup of sensors, and the generation of meteorological reports. A copy of all raw and derived data is forwarded to the cold server that stores it. The cold server continuously monitors whether the hot server is available. If communication is lost the cold becomes hot and starts processing the data. It is also possible to force a manual failover so that maintenance of the cold server can occur without interruption of the data flow. During a start-up the server checks whether a hot server is present in which case it will go into the cold mode. When 2 servers are hot, e.g. after a failure of the network communication between the 2 servers, the secondary server will automatically switch to cold. Both servers are connected to the KNMI LAN at Rotterdam The Hague Airport. Note that the server systems have 2 network cards and are connected to 2 separate network switches. The sensor and derived data is generally updated every 12 seconds. About 275 out of the total amount of 770 variables available at Rotterdam The Hague Airport update every 12 seconds. The ADCM server performs the crucial tasks of data-acquisition and processing. In order to avoid any loss of performance due to data requests by users a copy of all data is put on the MIS (Meteorological Information Server) server pair which handles the data requests for local users at the aerodrome.

Table 4: SIAM location codes and corresponding MetNet stations names used at Rotterdam The Hague Airport.

| SIAM location code | MetNet StationName | Description |
|---:|---:|---:|
| 08 | VRD24t | Sensors/variables at 24 touchdown[1] |
| 09 | VRD06t | Sensors/variables at 06 touchdown |
| 0A | VRD24pws | Visibility sensor at 24 touchdown[2] |
| - | VRD_MR | Main runway pseudo station[3] |
| - | VRD24e | Pseudo station for variables at 24 end[4] |
| - | VRD06e | Pseudo station for variables at 06 end[4] |

[1] also serves as main station for AUTO METAR and AUTO ACTUAL information.
[2] separate code/name required to distinguish precipitation intensity of FD12P form that of the rain gauge.
[3] information of either 06 or 24 touchdown is automatically copied to this station so that runway dependent information is available.
[4] information for VIS and RVR is calculated for the end positions.

The Rotterdam The Hague Airport LAN is connected via a WAN to the KNMI LAN of the main KNMI facilities in De Bilt. A GDIS (Graphic DISplay) client system can be located anywhere on the LAN/WAN and can be used to monitor the system and sensor status, view the measurements and derived products, validate and complement the meteorological reports and change the system configuration. The functionality available on a GDIS depends on the user group and is password protected. Via De Bilt the observations of the Dutch meteorological network (MetNet) can be made available to other meteorological network systems of which the Rotterdam The Hague Airport system is also part. Specifically the information of the lightning detection system is forwarded to the Rotterdam server in order to be able to report lightning (TS) in the meteorological reports and a combination of the information from the lightning detection system, the precipitation radar, and satellite data is used to report the presence of convective clouds (CB/TCU). Hence in case of a failure of a single server system or a network component the server systems at Rotterdam The Hague Airport still are able to acquire, process and disseminate the local sensor information. In case of a failure of the WAN to De Bilt the lightning and convective cloud information is not available, which is mentioned as a remark in the meteorological reports. In such a situation the remote monitoring of the meteorological information at Rotterdam airport from De Bilt is not possible. There is an additional WAN connection between Rotterdam and Schiphol so that in case of a the network malfunction between Rotterdam and De Bilt the aeronautical meteorological observer (AMO) at Schiphol can connect to the server system at Rotterdam airport in order to monitor and complement the meteorological information at Rotterdam The Hague Airport.

Table 5: The relation between the SIAM data fields and the MetNet variable name.

| SIAM data field | MetNet indicator | MetNet variable for MOR |
|---|---|---|
| sample | s | ZMs |
| 1-minute average | m | ZMm |
| 10-minute minimum | n | ZMn[1] |
| 10-minute maximum | x | ZMx[1] |
| 10-minute average | a | ZMa |
| 10-minute standard deviation | d | ZMd[1] |

[1] these variables are not required/available for MOR.

The full set of MUF sensor data arriving at the primary ADCM server at Rotterdam The Hague Airport is duplicated and via a MOXA N-Port the MUF data is made available to the network. In De Bilt this data is extracted and fed into a test server system so that new software releases and/or configurations can be tested with live data and can be compared against the operational airport system. De Bilt also hosts the Aerodrome Database System (ADS), the database server that stores all MetNet data and reports from all civil airports in The Netherlands for a period of 100 days. All data is supplied to the ADS directly by the ADCMs via network connections and in case of a network failures, the ADS has an automatic recovery mechanism built in. On a daily basis all data is extracted from the ADS and stored indefinitely in the mass storage system (MOS).

## 12. System monitoring and data validation

The visibility sensor and the SIAM sensor interface perform a first real-time validation step of the measurements. The FD12P checks for the correct functioning of its modules as well as the intensity of the optical transmitter and the sensitivity of the optical receiver. Furthermore the contamination of the lenses is monitored and blocking of the optical path is determined. Since the visibility can vary rapidly in time, the sensor interface can only check whether the reported MOR is within the sensor range and that the information received from the sensor is complete and compliant with the manufacturer's data format. The result of the checks of the sensor and the sensor interface are made available to the measurement network and is uniquely transformed into the data quality. Hence users as well as maintenance staff can see immediately when a warning or error status is issued. KNMI service staff monitors the sensor status of the entire network on a daily basis using the SIAM status information. Based on this information corrective or preventive maintenance is planned. If e.g. contamination of the lenses is reported then an additional maintenance visit is made to clean the lenses. A real-time check of the sensor status and output is made during and after maintenance has been performed. If a sensor fails, or if the sensor produces an error status, then action is taken according to the Service Level Agreement (SLA) which is part of the ISO 9001-2008 certified quality management system of the Weather and Information and Observation Technology departments of KNMI (KNMI, 2010). The importance and hence the priority of the maintenance of the visibility sensor depends on the (expected) visibility and varies with the LVP class. If applicable corrective maintenance will be applied on a 24*7 basis.

Apart from the daily monitoring and planning of maintenance by service, an operator (the so-called "procesbewaker") monitors the correct functioning of all crucial KNMI systems continuously. In case of malfunctions service staff can be alerted or requested. The procesbewaker is supported by various tools that facilitate the monitoring of the correct operation of crucial server systems and the availability of sensors and sensor information. Figure 12 shows some examples of screen available on a GDIS showing the status of sensors and MetNet systems at Rotterdam The Hague Airport. Finally a daily off-line validation of hourly sensor data is performed. At this stage data of the entire measurement network as well as from other sources such as satellites is used to validate and complete the data for climatological purposes. The hourly data extracted from SYNOP reports is automatically flagged when missing or if it does not meet a range check, temporal or spatial validity test or a cross parameter check. In a next step the flagged data is evaluated manually. When the data is missing or considered wrong it is flagged as such and a best estimate of the actual hourly value is given, and if required service staff is notified to undertake action at sensor level in the field. De Haij (2008) investigated the inclusion of the above mentioned off-line validation in the near real-time processing chain and application on a higher temporal resolution.

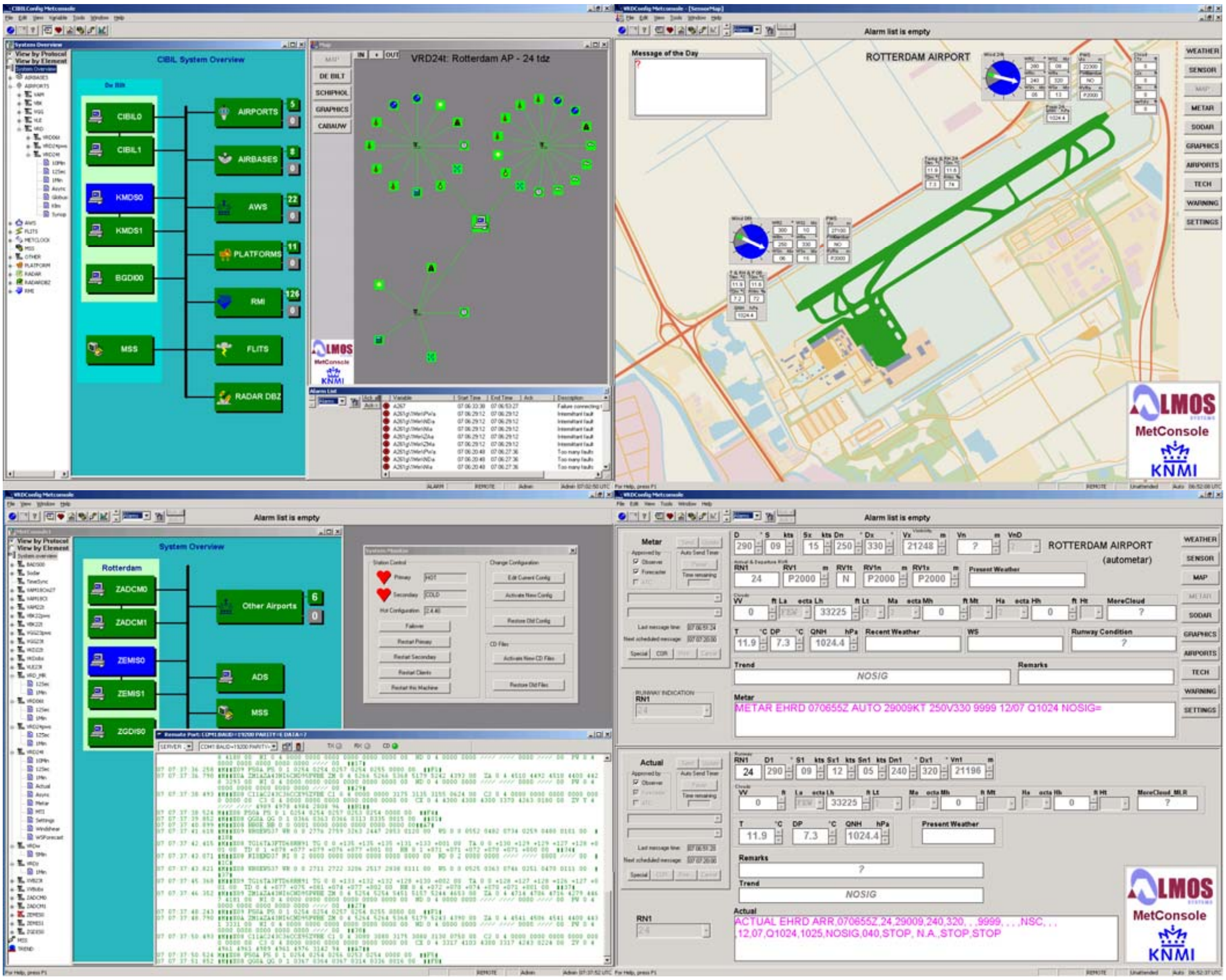


Figure 12: Screen shots of MetNet systems giving an overview of the status of Rotterdam The Hague Airport. Going clockwise from top left they show: (i) central server in De Bilt (CIBIL) giving an overview of the entire MetNet including the server and sensor status at Rotterdam; (ii) ADCM server at Rotterdam showing the (derived) sensor data on a map (iii) and in the AUTO METAR and AUTO ACTUAL report generation screen (both use the convention black data is valid; magenta denotes warning or backup; red ? is faulty or missing; and italic is manually confirmed/adjusted); (iv) the final screen shows the incoming MUF data (again color code to indicate good, warning status and error of corrupt data). The latter also shows an overview of the status of the server systems at Rotterdam The Hague Airport.

The SLA requires an overall availability of 99.4 % for the GDIS system and 99 % for sensor data for aviation. The availability of an AUTO METAR for closed (and probably also for the currently unmanned) airports is 99.8 % and the availability of precipitation radar and lightning data used in the AUTO METAR is specified at 99.3 %. Note that the current SLA is not up to date since the video cameras of Rotterdam The Hague Airport and the other regional airports are not included. Also the SLA sometimes does not state clearly what the agreed response time is to a malfunction of a specific component. The general requirements are met by the MetNet systems and related sensors which have an overall availability of 99.98 % for aviation. When MetNet is running it will automatically generate an AUTO METAR, but this could actually be an empty report in case all sensor information is missing. Hence the contents of the AUTO METAR and the specific sensors (including a possible backup) used in the report need to be considered. The same applies to the AUTO ACTUAL and AUTO SPECIAL and the (processed) sensor information that is directly made available to the aeronautical users. Recently KNMI conducted an analysis of the AUTO ACTUAL and AUTO SPECIAL reports generated at Maastricht Aachen Airport (EHBK) and Groningen Eelde Airport (EHGG) for the 21 months period from January 2009 to September 2010 (Koetse en Sondij, 2010). The available archived data showed no missing AUTO ACTUAL reports and less then 0.1 % of the reports were incomplete. The 26 (EHBK) and 35 (EHGG) events with missing visibility in AUTO ACTUAL or AUTO SPECIAL occurred mainly due to a malfunction of the visibility sensor without a backup. Note that these numbers include a large fraction of AUTO SPECIAL reports.

## 13. Continuous remote verification

A near real-time verification of the validity of the meteorological information is performed by the aeronautical meteorological forecaster who has access to the 12 second visibility data. In case of serious doubt the sensor value can be rejected. The validation is performed by using the information from other nearby visibility sensors, by consulting the video camera images at the airport and by considering the general meteorological conditions using other (sensor) information. The aeronautical meteorological forecaster has also access to near real-time data from other airports, off-shore platforms and automated weather stations that are part of MetNet, as well as satellite and weather model information. Some sources of meteorological information are illustrated in the three figures below. Figure 13 gives an example of the images obtained continuously from the video cameras at Rotterdam The Hague Airport. Figure 14 shows graphs of some meteorological variables centrally available in MetNet with an update every minute. Note that meteorological information of Rotterdam The Hague Airport can also be viewed on a GDIS with a 12 second update by connecting to the ADCM server system. Figure 15 presents a geographical overview of the visibility observations centrally available in MetNet with an update every 10 minutes. Contact between the aeronautical meteorological forecaster and local staff of the airport or air traffic control can be established in order to give information or feedback on the current and upcoming meteorological conditions. Note that the aeronautical meteorological forecaster can overrule the sensor derived visibility values reported in the aeronautical reports orally or force sensors to fault so that the sensor data is disabled or, if applicable, the backup is used. Note that is not feasible to estimate RVR manually during relevant conditions, i.e. below 1500 m, not even by an aeronautical meteorological observer, since the RVR should be evaluated near the relevant positions along the runway using the runways markings or lamps. The aeronautical meteorological forecaster also adds the TREND, a landing forecast with a validity of 2 hours, to the meteorological reports. Furthermore the aeronautical meteorological forecaster adds, if required, the runway state to the AUTO METAR report and can issue other reports (wind shear report, wind shear forecast and low level temperature inversion) manually.


Figure 13: Illustration of the images obtained with the video cameras at 24 touchdown at Rotterdam The Hague Airport (top panels) and the camera before the threshold of runway 06.The yellow rectangle indicates the field of view of the video camera at 9 m equipped with a tele lens in the image obtained with the video camera at 2 m equipped with a wide-angle lens.

Figure 14: Time series of the sensor data that is centrally available in MetNet with an update every minute. The screen has four panels showing information for the civil airports Amsterdam Airport Schiphol (top left), Groningen Eelde Airport (top right), Maastricht Aachen Airport (bottom right), and Rotterdam The Hague Airport (bottom left), respectively.


Figure 15: Illustration of the MetNet visibility information in The Netherlands that is centrally available and can be visualized geographically with an update every 10 minutes.

## 14. Derivation of VIS and RVR

This section describes the VIS and RVR derivation that is performed on the airport server system. Further details, including the derivation of VIS and RVR can be found in van der Meulen (2001), ICAO (2005).

KNMI uses the FD12P forward scatter meter to measure MOR. A background luminance sensor mounted on the FD12P measures the background luminance. The instantaneous values of MOR and background luminance reported by the SIAM are used to calculate VIS using a standard lamp with a luminous intensity of 1000 cd. The relationship between the illumination threshold and the background luminance is given by the logarithmic expression specified by ICAO. VIS cannot be calculated directly from MOR, but the derivation involves an iteration process. The iteration process is stopped when the accuracy of the VIS calculation is better than 1 m. The VIS derivation requires that the VIS is larger or equal than the MOR (which in fact is the limiting case during daytime with good visibility). Although the instantaneous MOR reported by the FD12P is in fact a 1-minute averaged value, the MOR and the derived VIS are treated as instantaneous values. The

MOR and the background luminance are updated by the SIAM every 12 seconds, and the instantaneous VIS is also calculated every 12 seconds.

As for VIS the calculation of RVR involves the instantaneous values of MOR and background luminance reported by the SIAM, but instead of a fixed luminous intensity of 1000 cd the actual intensity of runway lights should be used. In fact, the light intensity in the direction of the aircraft varies with RVR which also needs to be taken into account in the iterative derivation of RVR. The light intensity of runway lights depends on the type of lamp used but it also depends on the viewing angle. The light intensity is usually specified in so-called isocandela contour diagrams or tables that specify the intensity as a function of the vertical and horizontal viewing angle. This angular dependency of the runways lights can be expressed as an analytical function. The runway light intensity varies with RVR since the geometry and hence the viewing angles change. In order to calculate this geometry the height of the observer at 5 m (the eye level representative of a pilot for an aircraft on the runway) is adopted and the distance of the edge light to the centre line of 22.5m is used. At low RVR values (below 350 m) only the centre lights need to be considered since the edge lights are only visible at slant angles, whereas at high RVR values (above 600 m) only the edge lights, which have a greater intensity than the centre light, are used. For RVR between 350 and 600 m a mixture of centre and edge lights is used that makes a linear transition from centre to edge lights. Note that ICAO (2005) reports 200 and 550 m as the RVR boundaries for transition from centre to edge lights. KNMI does not know the characteristics of all types of centre and edge lights used at runways at airports and the intensity setting of the lights or the actual current going through the lamps are not available. KNMI uses the lamp characteristics of the most commonly used centre and edge lights at civil airports in The Netherlands and assumes an intensity setting of 100 % for the METAR and the local routine and special reports. From this the runway light intensity dependency with RVR can be derived, which is stored on the server system as a lookup table (cf. Table 6) while intermediate values are derived by linear interpolation. As an approximation for the effect of aging and contamination of the runway lights fixed factors of 80% and 50% are used for edge and a centre lights, respectively, following ICAO (2005).

Table 6: Runway light intensity as a function of distance as used in MetNet.

| RVR (m) | Runway light intensity (cd) |
|---|---|
| 50 | 12919 |
| 80 | 10945 |
| 110 | 9443 |
| 150 | 8220 |
| 200 | 7325 |
| 275 | 6570 |
| 350 | 6131 |
| 600 | 11001 |
| 800 | 10390 |
| 1000 | 10000 |
| 1250 | 9678 |
| 1600 | 9389 |
| 2000 | 9179 |

During a bright day with visibility above 1000 m, there is no difference between the three visibility parameters MOR, VIS and RVR (cf. Figure 16), i.e. VIS and RVR equal MOR. As the background luminance or visibility decreases, the differences between the visibility parameters increase. In case of differences, RVR always has the highest value, MOR has the lowest value and the VIS value is in between. Under certain circumstances (low visibility at night), the RVR value can be up to 5 times as large as the MOR value.

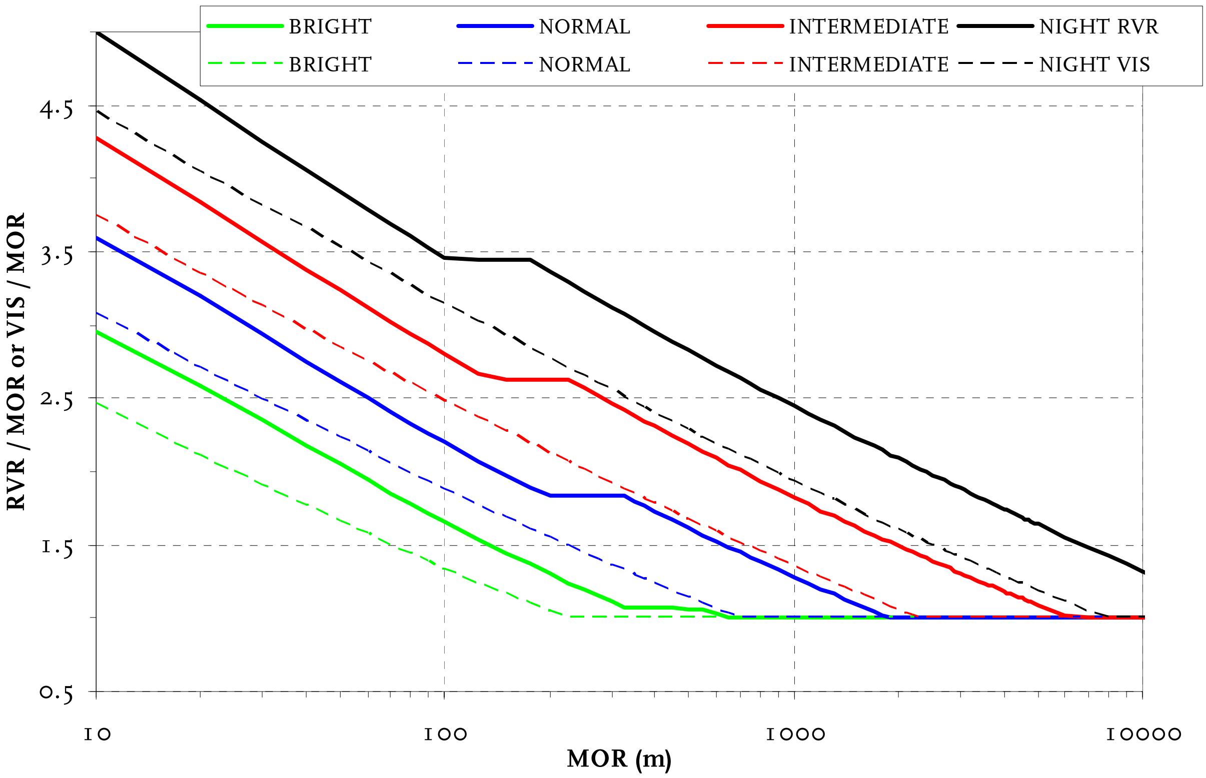


Figure 16: The ratio of RVR to MOR and VIS to MOR as a function of the MOR for four atmospheric brightness conditions.

The MOR and background luminance (BL) sensor usage in the VIS and RVR calculations at Rotterdam The Hague Airport is given in Table 7. Note the VIS and RVR are also calculated for the end positions. For a CAT I runway the VIS and RVR only needs need to be available for the A position. However since the runway can be used for CAT I instrument precision landing and approach from both ends, the visibility sensors at the opposite end of the runway can also be used for the end position. It can be observed that in the calculation of VIS the MOR and BL sensor of the location itself are used since the location 24 end corresponds with 06 touchdown and 06 end corresponds with 24 touchdown. In the calculation of RVR the local MOR sensor is used in combination the BL sensor at touchdown. The reason for the latter is related to the fact that in the past the BL sensor was oriented parallel to the runway so that the BL as experienced by the pilot during landing was measured. However, since currently all BL sensors are oriented North the BL usage for RVR calculations could be reconsidered.

Table 7: Overview of the MOR and BL sensor usage for VIS and RVR calculations for the CAT I runways 24 and 06 at Rotterdam The Hague Airport.

| | | | VIS | | RVR | |
|---|---|---|---|---|---|---|
| **Runway** | **Position** | **StationName** | **MOR sensor** | **BL sensor** | **MOR sensor** | **BL sensor** |
| 24 | A | VRD24t | VRD24pws | VRD24pws | VRD24pws | VRD24pws |
| | C | VRD24e | VRD06t | VRD06t | VRD06t | VRD24pws |
| 06 | A | VRD06t | VRD06t | VRD06t | VRD06t | VRD06t |
| | C | VRD06e | VRD24pws | VRD24pws | VRD24pws | VRD06t |

## 15. Averaging of VIS and RVR

The calculated VIS and RVR are treated as 12 second averaged sample values. For aeronautical purposes 1- and 10-minute averaged VIS and RVR are required. The 1-minute averaged values are generally used for the local AUTO ACTUAL and AUTO SPECIAL reports and 10-minute averaged values are used in the AUTO

METAR. Note that in MetNet the 10-minute averaged VIS is used in the AUTO METAR as well as in the local AUTO ACTUAL and AUTO SPECIAL reports. The 10-minute averaged RVR is reported in the AUTO METAR, but RVR is not included in the AUTO ACTUAL and AUTO SPECIAL. If one or more of the 10-minute averaged VIS or RVR values at the airport is below 1500 m a flag is set in the AUTO ACTUAL and AUTO SPECIAL. When the flag is set ATC starts requesting all 10-minute averaged VIS and 1-minute averaged RVR values.

The calculation of the 1-minute averaged VIS and RVR is straightforward. The calculation of the 10-minute averaged VIS and RVR is more complex since it needs to take a so-called marked discontinuity into account. A marked discontinuity is an abrupt and sustained change in VIS or RVR, lasting at least 2 minutes, which reaches or passes through criteria for the issuance of a AUTO SPECIAL report. The AUTO SPECIAL thresholds for VIS are 800, 1500, 3000, 5000 and 8000 m (note that the last criterion is not specified by ICAO, but by local agreement) and the thresholds for RVR are 150, 350, 600 and 800 m. In case of a marked discontinuity only the VIS or RVR values after the marked discontinuity are used in calculating the mean. When a marked discontinuity occurs the 10-minute averaged VIS or RVR are in fact 2-minute averaged values. Next, the 2-minute interval is gradually increased at each subsequent update interval until the maximum interval of 10-minute is reached or a new marked discontinuity occurs. The 10-minute averaged RVR is reported in the AUTO METAR in combination with the tendency. The RVR tendency is determined from the current value of the 10-minute averaged RVR and the value 10 minutes ago (note that ICAO specifies using the two 5-minute averaged RVR values obtained by splitting the last 10-minunte interval in two). There is no RVR tendency when the difference between the two RVRs is less than 100 m and either upward or downward when the differences exceed +100 m or −100 m, respectively. In case there are variations in the RVR, i.e. the extremes of the 1-minute RVR differ more than 50 m and more than 20 % from the 10-minute averaged RVR, then the minimum and maximum 1-minuted averaged RVR values in the 10-minute interval are reported instead of the 10-minute averaged RVR. Note that KNMI calculates the minimum and maximum RVR from the extremes of the RVR sample values in the past 10 minutes, whereas ICAO specifies using the extremes of the 1-minute running averaged RVR values. The special cases for minimum VIS (report prevailing VIS and minimum VIS if possible with indication of the direction with respect to the aerodrome reference point when the latter is below 1500 m or less than 50 % of the prevailing VIS) and fluctuating VIS (criterion not specified, but is only relevant for manual observations) in the AUTO METAR are not used by KNMI.

## 16. Selection and backup of VIS and RVR

In this section the selection of the correct sensor for reporting VIS and RVR and the backup of VIS and RVR is described. The practices for a CAT III runway at Amsterdam Airport Schiphol have been described in Wauben (2009). Here the practices for a CAT I runway of Rotterdam The Hague Airport is presented.

Runway 06/24 of Rotterdam The Hague Airport is equipped with a FD12P forward scatter visibility sensor with background luminance sensor at the touchdown zones of runway 06 and runway 24 (Figure 17). Since runways 06 and 24 of Rotterdam The Hague Airport are used for CAT I operations only a single visibility sensor at touchdown position, the so-called “A” position, is required. Hence the 2 visibility sensors are in accordance with the CAT I requirements for runway 06 and runway 24. The visibility sensor at the opposite side of the runway serves in principle as the end position, but a visibility sensor representative for the mid-point, which is required for CAT II and III operations, is not present. The Runway Information System of LVNL provides real-time information on which runway is in use. This is used to automatically select the RVR and VIS of the runway in use that are reported in the AUTO METAR and the AUTO ACTUAL and AUTO SPECIAL, respectively.

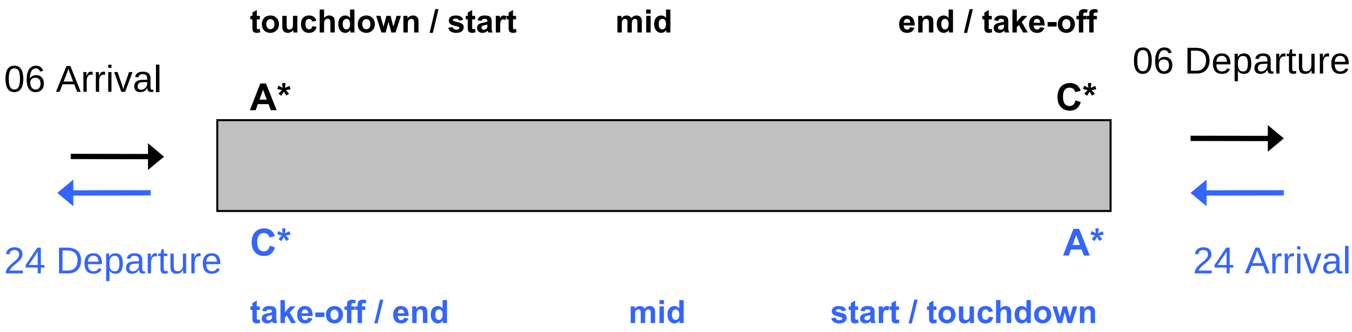


Figure 17: Overview of the visibility sensors along the CAT I runway at Rotterdam The Hague Airport and their nomenclature when the runway can be used for take-off and landing from both ends. The asterisk denotes a visibility sensor equipped with a background luminance sensor. There is only one sensor at each touchdown position, but its nomenclature changes when the runway is approached from the other side.

The RVR at touchdown is crucial for aeronautical purposes and a backup by another visibility sensor is only allowed if the backup sensor also reports the RVR representative for the touchdown zone. This in fact means that the backup visibility sensor should also be situated near the touchdown zone. Hence the visibility sensor at the other end of the runway (C position) cannot be used as a backup nor can a sensor near the mid-point, which is the setup at a CAT III runway at Schiphol equipped with 3 visibility sensors, be used for this purpose. ICAO does not specify the representativeness of the RVR measurements for departure. However, since at Rotterdam The Hague Airport a runway can be used for arrival as well as departure the rules for arrival apply and a backup of RVR with the current setup is not allowed. The visibility measurements at touchdown are an accepted single point of failure. In case the sensor or associated SIAM, MUF or data line fails the runway is unavailable for instrument precision approach and landing. In such a situation the runway can still be used for VFR operations if the visibility exceeds 5 km. The runway can be approached from the other side since it uses a different visibility sensor and associated infrastructure.

The visibility reported in the AUTO METAR should be representative for the aerodrome. At present KNMI uses the visibility sensor at 24 touchdown for reporting VIS in the AUTO METAR, and the sensor at 06 touchdown serves as the backup. KNMI considers using a combination of the available visibility sensors for reporting prevailing VIS, in which case, following ICAO, the median VIS of all available sensors would be reported in the AUTO METAR. Regarding VIS in the AUTO ACTUAL and AUTO SPECIAL ICAO recommends the VIS reported for departure should be representative for conditions along the runway, whereas for arrival it should be representative for the touchdown zone. By using the same rationale as above it can be concluded that a backup of VIS is not allowed in the local reports. For a CAT III runway at Schiphol equipped with 3 visibility sensors a backup of VIS at all three positions is implemented. For departure backup of VIS at start by mid seems in line with the ICAO recommendations, but for arrival VIS at touchdown should not be backed up by mid. In fact since RVR is not available the runway cannot be used for instrument precision approach and landing operations, except under so-called Visual Flight Rules (VFR) conditions. Hence the main issue in case of a malfunction of a visibility sensor at Rotterdam The Hague Airport is whether VFR conditions are applicable or not, i.e. concerning visibility whether it can be correctly assessed that VIS exceeds 5 km or not.

The decision if VFR conditions apply is made by the aeronautical meteorological forecaster by using all information available described above. The criteria for deciding whether VFR visibility conditions apply, so that in case of unavailability of a visibility sensor the visibility reported by the sensor at the other end of the runway may be used instead, are:
1. the visibility reported by the other forward scatter meter at Rotterdam The Hague Airport must exceed 8 km;
2. all video camera images at the airport show no indication of obscurations, i.e. the camera before the threshold of 06 should clearly show the tree lines at near other end of the runway;
3. the visibility reported at nearby stations (Valkenburg, Nieuwkoop, Cabauw, Gilze Rijen, Woensdrecht, Wilheminadorp and Lichteiland Goeree) all exceed 8 km or the atmospheric conditions shall be such that no significant reduction of the visibility is to be expected at the airport.

Note that all these criteria must be met in order that it can be decided that VFR visibility conditions apply. The images of the video cameras on the wind mast of 24 touchdown cannot be used to evaluate whether the visibility exceeds 5 km since the line of tress is only about 500 m away and the distance of the buildings visible from the camera at 9 m is also not sufficient. The video camera before the threshold of runway 06 gives a view over the runway. However, there are no visibility markers at a range of 5 km or beyond and the markers at the airport itself are within 2.5 km. Hence the video camera images can only be used as a check that the visibility exceeds about 2 km when the tree line near the centre of the image is visible. However, it should be noted that the quality of the images is rather poor and the images are susceptible to contamination of the lenses. Due to these limitations the meteorological situation is verified with local staff of the airport or ATC. This is facilitated by asking closed questions, e.g. whether visibility marker “X” can be seen or not, since KNMI is still responsible for the reported visibility. Currently no discrimination between VFR (visibility above 5km) and SVFR (visibility between 3 and 5 km) conditions is made in the backup procedure. When VFR conditions apply, then the visibility reported by the visibility sensor at the opposite end of the runway is used instead and is reported orally to the users. Naturally the failure is handled by KNMI service staff according to the agreed response time as stated in the service level agreement. Also note that visibility reported in the METAR uses and automated backup sensor in case the primary sensor of 24 touchdown is not available. A backup of the RVR is, however, not allowed. As a result R24//// or R06//// is reported in the AUTO METAR.

## 17. Available VIS and RVR variables

Table 8 gives a list of all variables in the configuration of the server systems at Rotterdam The Hague Airport related to visibility. The variable is reported together with the group which either indicates the update period of the variable (12Sec, 1Min) or whether the variable is part of the AUTO ACTUAL or AUTO METAR reports (Actual, Metar) which have an update period of 30 minutes. Note that the AUTO SPECIAL is included in the Actual group so that in principle an Actual group can occur every minute (i.e. the period at which criteria are checked and AUTO SPECIAL can be issued). Note that the AUTO ACTUAL and AUTO METAR variables come in pairs, the basic variable contains the temporary data that changes while editing the reports and the variable with underscore contains the valid value at the time when the report is “send”. The table also indicates at which MetNet station a variable is present. Here VRD24t, VRD06t and VRD24pws (see Table 4) contain the sensors; VRD24t is the main station at which the reports and other general data are available. VRD_MR is the station which contains the information which depends on the runway in use. For that purpose the variables of the station corresponding to the runway in use are copied to VRD_MR. VRD24e and VRD06e contain the variables for the end position of the runway. The table also shows whether data is stored, presented on a GDIS client screen (note that the GDIS user can select any stored variable containing numerical data to show as a trend curve in the graphic screens, but the other display items are fixed and can only be changed by a configuration update through the administrator) and whether the ATC has interest in the variable, either directly (x) or indirectly via the AUTO ACTUAL (a, i), where “a” indicates an element of the ACTUAL and “i” indicates a variable that serves as input for the AUTO ACTUAL. The gray fields of Table 8 indicate either variables that are obsolete or items that are not available on the screen, or at least not all of them.

Table 8: List of the variables related to visibility in the configuration of the server systems at Rotterdam The Hague Airport.

| Group/ Variable | Description | VRD06t | VRD24t | VRD24pws | VRD_MR | VRD24e | VRD06e | Stored | Screen | ATC |
|---|---|---|---|---|---|---|---|---|---|---|
| 12Sec/BB | SIAM BaanBakenPaneel, MLR | | x | | | | | x | | |
| 12Sec/BBb | BaanBakenPaneel, Backed up | | x | | | | | x | | |
| 12Sec/BBm | BaanBakenPaneel, Manual | | x | | | | | x | | |
| 12Sec/Runway | Runway Name | | x | | | | | x | | |
| 12Sec/RVR | RVR Sample Value | x | | x | | x | x | | | |
| 12Sec/RVRa | RVR 10 Min Average | x | | x | x | x | x | x | x | x |
| 12Sec/RVRBoolean | State of the RVR (true if RVR < 1500) | | x | | | | | x | | |
| 12Sec/RVRBooleanb | State of the RVR (true if RVR < 1500) Backed up | | x | | | | | x | | i |
| 12Sec/RVRBooleanm | State of the RVR (true if RVR < 1500) Manual | | x | | | | | x | x | |
| 12Sec/RVRm | RVR 1 Min Average | x | | x | | x | x | x | | x |
| 12Sec/RVRn | RVR 10 Min Minimum | x | | x | x | x | x | x | | |
| 12Sec/RVRopt | RVR Sample Value | x | | x | | x | x | x | | |

| Group/ Variable | Description | VRD06t | VRD24t | VRD24pws | VRD_MR | VRD24e | VRD06e | Stored | Screen | ATC |
|---|---|---|---|---|---|---|---|---|---|---|
| 12Sec/RVRt | RVR Tendency | x | | x | x | x | x | x | | x |
| 12Sec/RVRx | RVR 10 Min Maximum | x | | x | x | x | x | x | | |
| 12Sec/RwName | Runway Name | | x | | | | | x | x | x,i |
| 12Sec/Va | Visibility 10Min Average MD | x | | x | | x | x | x | x | i |
| 12Sec/Vab | Visibility 10Min Average MD, Backed up | x | | x | | | | x | x | |
| 12Sec/Vis | Visibility Sample Value | x | x | x | | x | x | x | | |
| 12Sec/Visb | Visibility Sample Value, Backed up | x | x | x | | | | x | | |
| 12Sec/ZAa | SIAM Background Luminance 10 Min Average | x | | x | | | | x | | |
| 12Sec/ZAm | SIAM Background Luminance 1 Min Average | x | | x | | | | x | x | |
| 12Sec/ZAs | SIAM Background Luminance Sample Value | x | | x | | | | x | | |
| 12Sec/ZMa | SIAM MOR 10 Min Average | x | | x | | | | x | | |
| 12Sec/ZMm | SIAM MOR 1 Min Average | x | | x | | | | x | | |
| 12Sec/ZMs | SIAM MOR Sample Value | x | | x | | | | x | | |
| 1Min/RLL | Runway Lighting | | x | | | | | | | |
| 1Min/RVRa | RVR 10 Min Average | | | x | | | | x | x | |
| 1Min/Va | Visibility 10Min Average MD | x | | x | x | x | x | x | | |
| 1Min/Vab | Visibility 10Min Average MD, Backed up | x | | x | | | | x | x | |
| 1Min/VertVis | Calculated Vertical Visibility | | | | | | | x | | |
| 1Min/VFR | VFR type | | x | | | | | x | | |
| 1Min/Vis | Visibility Sample Value | x | x | x | | x | x | x | | |
| 1Min/Visb | Visibility Sample Value, Backed up | x | x | x | | | | x | | |
| 1Min/Vn | Visibility, MLR | | | | x | | | | | |
| 1Min/w’w’ | Present Weather | x | x | | | | | | | |
| 1Min/w’w’2 | Present Weather Actual | | | | x | | | | | i |
| 1Min/ZAa | SIAM Background Luminance 10 Min Average | x | | x | | | | x | | |
| 1Min/ZAm | SIAM Background Luminance 1 Min Average | x | | x | | | | x | | |
| 1Min/ZMa | SIAM MOR 10 Min Average | x | | x | | | | x | | |
| 1Min/ZMm | SIAM MOR 1 Min Average | x | | x | | | | x | | |
| Actual/Actual | Actual or Special, String | | x | | | | | x | x | |
| Actual/Actual_ | Valid Actual or Special, String | | x | | | | | x | x | x |
| Actual/RN1 | MLR | | x | | | | | | x | |
| Actual/RN1_ | Valid MLR | | x | | | | | x | | a |
| Actual/RVR | State of RVR (true if RVR < 1500) | | x | | | | | | | |
| Actual/RVR_ | Valid State of RVR (true if RVR < 1500) | | x | | | | | x | | a |
| Actual/Vn | Visibility, MLR | | x | | | | | | x | |
| Actual/Vn_ | Valid Visibility, MLR | | x | | | | | x | | a |
| Actual/w'w'_MLR | Present Weather, MLR | | | | | | | | x | |
| Actual/w'w'_MLR_ | Valid Present Weather, MLR | | | | | | | x | | a |
| Actual/w'w'2 | Present Weather Actual | | x | | | | | x | | |
| Metar/Metar | Metar, String | | x | | | | | x | x | |
| Metar/Metar_ | Valid Metar, String | | x | | | | | x | x | |
| Metar/RE | Recent Weather | | x | | | | | | x | |
| Metar/RE_ | Valid Recent Weather | | x | | | | | x | | |
| Metar/RiU | Runway in Use | | x | | | | | | | |
| Metar/RiU_ | Valid Runway in Use | | x | | | | | x | | |
| Metar/RN1 | Runway in Use | | x | | | | | x | x | |
| Metar/RN1_ | Valid Runway in Use | | x | | | | | x | | |
| Metar/RV1 | RVR 10 Min Average, MR | | x | | | | | | x | |
| Metar/RV1_ | Valid RVR 10 Min Average, MR | | x | | | | | x | | |
| Metar/RV1n | RVR 10 Min Minimum, MR | | x | | | | | | x | |
| Metar/RV1n_ | Valid RVR 10 Min Minimum, MR | | x | | | | | x | | |
| Metar/RV1t | RVR Tendency, MR | | x | | | | | | x | |
| Metar/RV1t_ | Valid RVR Tendency, MR | | x | | | | | x | | |
| Metar/RV1x | RVR 10 Min Maximum, MR | | x | | | | | | x | |
| Metar/RV1x_ | Valid RVR 10 Min Maximum, MR | | x | | | | | x | | |
| Metar/Vn | Horizontal Visibility | | x | | | | | | x | |
| Metar/Vn_ | Valid Horizontal Visibility | | x | | | | | x | | |
| Metar/VnD | Direction of Minimum Horizontal Visibility | | x | | | | | | x | |
| Metar/VnD_ | Valid Direction of Minimum Horizontal Visibility | | x | | | | | x | | |
| Metar/Vx | Maximum Horizontal Visibility, for future use | | x | | | | | | x | |
| Metar/Vx_ | Valid Maximum Horizontal Visibility | | x | | | | | x | | |
| Metar/VxD | Direction of Maximum Horizontal Visibility | | x | | | | | | | |
| Metar/VxD_ | Valid Direction of Maximum Horizontal Visibility | | x | | | | | x | | |
| Metar/w'w' | Present Weather | | x | | | | | | x | |
| Metar/w'w'_ | Valid Present Weather | | x | | | | | x | | |

## 18. Meteorological reports

VIS and RVR are included in meteorological reports, i.e. the AUTO METAR and AUTO ACTUAL and AUTO SPECIAL. In the following sections the VIS and RVR items in the METAR and ACTUAL and on the MetNet screen for entering the values in the reports are shown.

METAR
or (COR) CCCC YYGGggZ (NIL) AUTO dddff(f)G$f_mf_m$($f_m$)KT ($d_nd_nd_n$V$d_xd_xd_x$)
SPECI

| | | | | |
|---|---|---|---|---|
| | | | | $N_sN_sN_sh_sh_sh_s$ |
| | | | | or |
| ~~***VVVVNDV***~~ | | | | $N_sN_sN_sh_sh_sh_s$/// |
| or | | (**R$D_RD_R$/$V_RV_RV_RV_R$*i***) | | or |
| ***VVVV*** | ~~(***$V_NV_NV_NV_N$DV***)~~ | or | (***$w_a$'$w_a$'***) | ***VV$h_sh_sh_s$*** |
| or | | (**R$D_RD_R$/$V_RV_RV_RV_R$V$V_RV_RV_RV_R$*i***) | | or |
| ~~***CAVOK***~~ | | | | NCD |
| | | | | or |
| | | | | NSC |

| | | | |
|---|---|---|---|
| | | (WS R$D_RD_R$) | |
| T'T'/T'$_d$T'$_d$ Q$P_HP_HP_HP_H$ (***RE$w_a$'$w_a$'***) | | or | (W$T_sT_s$/SS') (R$D_RD_R$/$E_RC_Re_Re_RB_RB_R$) |
| | | (WS ALL RWY) | |

TREND (RMK)

The general code form of the AUTO METAR is given above (cf. WMO, 2010 and KNMI, 1994). The code form shows the items that can be included in the AUTO METAR during opening hours of the airport. The brackets denote items that are only included if suitable conditions are valid. The items involving visibility, either VIS or RVR directly or derived parameters are:

- Visibility is reported in the VVVV group of the AUTO METAR, a group which contains the prevailing visibility. The variable VRD24pws/12Sec/Vab containing the 10-minute averaged (except in case of a marked discontinuity) VIS of the 24 touchdown with VIS of 06 touchdown as backup is used for that purpose. This backed up variable is automatically inserted in appropriate field of the METAR screen (cf. Figure 18, item A). In case VIS information is not available the group is encoded as "////". The abbreviation NDV is not used although ICAO states that when visibility sensors are used and they are sited in such a manner that no directional variations can be given, the abbreviation NDV shall be appended to the visibility reported.
- Directional variation in visibility (group $V_NV_NV_NV_ND_V$) is not used in the AUTO METAR in The Netherlands. The fields for the minimum visibility and the direction are included on the METAR screen (cf. Figure 18 item B), but they are only used at the manned location Schiphol Airport.
- Note that CAVOK (Cloud and visibility OK) is also not used in the AUTO METAR in The Netherlands.
- RVR is reported in the R$D_RD_R$/$V_RV_RV_RV_R$i or R$D_RD_R$/$V_RV_RV_RV_R$V$V_RV_RV_RV_R$i group of the AUTO METAR. The group is included when either the horizontal visibility reported in the VVVV group or the RVR for one or more runways available for landing is less than 1500 m. The latter form is used automatically when the RVR varies significantly, i.e. the one-minute mean extreme values assessed in the 10-minute period immediately preceding the observation vary from the 10-minute mean value by more than 50 m or more than 20 % of the mean value, whichever is greater. The variable VRD24t/12Sec/RWName is used for the runway designator $D_RD_R$ and the variables VRD_MR/12Sec/RVRa, RVRt, RVRn, RVRx for the 10-minute averaged RVR (except in case of a marked discontinuity), tendency, 10-minute minimum and 10-minute maximum and are inserted in the appropriate fields of the METAR screen (Figure 18, item C). Note that the RVR variables of the runway in use are reported. In case RVR information is not available the group is encoded as "R$D_RD_R$//////" or "R////////".
- The $w_a$'$w_a$' present weather group of the METAR can contain up to three weather phenomena. These phenomena include fog (FG), mist (BR, brume) and haze (HZ), which are related to visibility. Here fog is defined as VIS < 1000 m; mist corresponds to 1000 m ≤ VIS < 5000 m and relative humidity (RH) ≥ 80%, whereas haze requires 1000 m ≤ VIS < 5000 m and RH < 80%. Note that be definition a visibility below 1000 m is considered to be fog since other severe visibility obscurations caused by sand or dust

storms do not occur in The Netherlands. A hysteresis of 3 % is used in the RH to eliminate fluctuations between BR and HZ in case RH is close to 80 %. Freezing (FZ) is the only visibility descriptor that is used in combination with fog in the AUTO METAR in The Netherlands. The fog descriptors MI (shallow), BC (patches), PR (partial), VC (vicinity) are not used. This fact is reflected in the group name wa'wa', whereas the manual w'w' weather group contains the full list of weather phenomena and descriptors. The actual weather is contained in variable VRD24t/1Min/w'w' and automatically inserted in the appropriate field of the METAR screen (Figure 18, item D). The derivation of present and recent weather uses the visibility information of the sensor at 24 touchdown (VRD24pws\1Min\Va). Since the METAR should report the weather phenomena observed at or near the aerodrome a backup or the use of multiple sensors can be considered. When visibility is not available then weather information (same sensor) is generally also unavailable and the group is encoded as “//”.

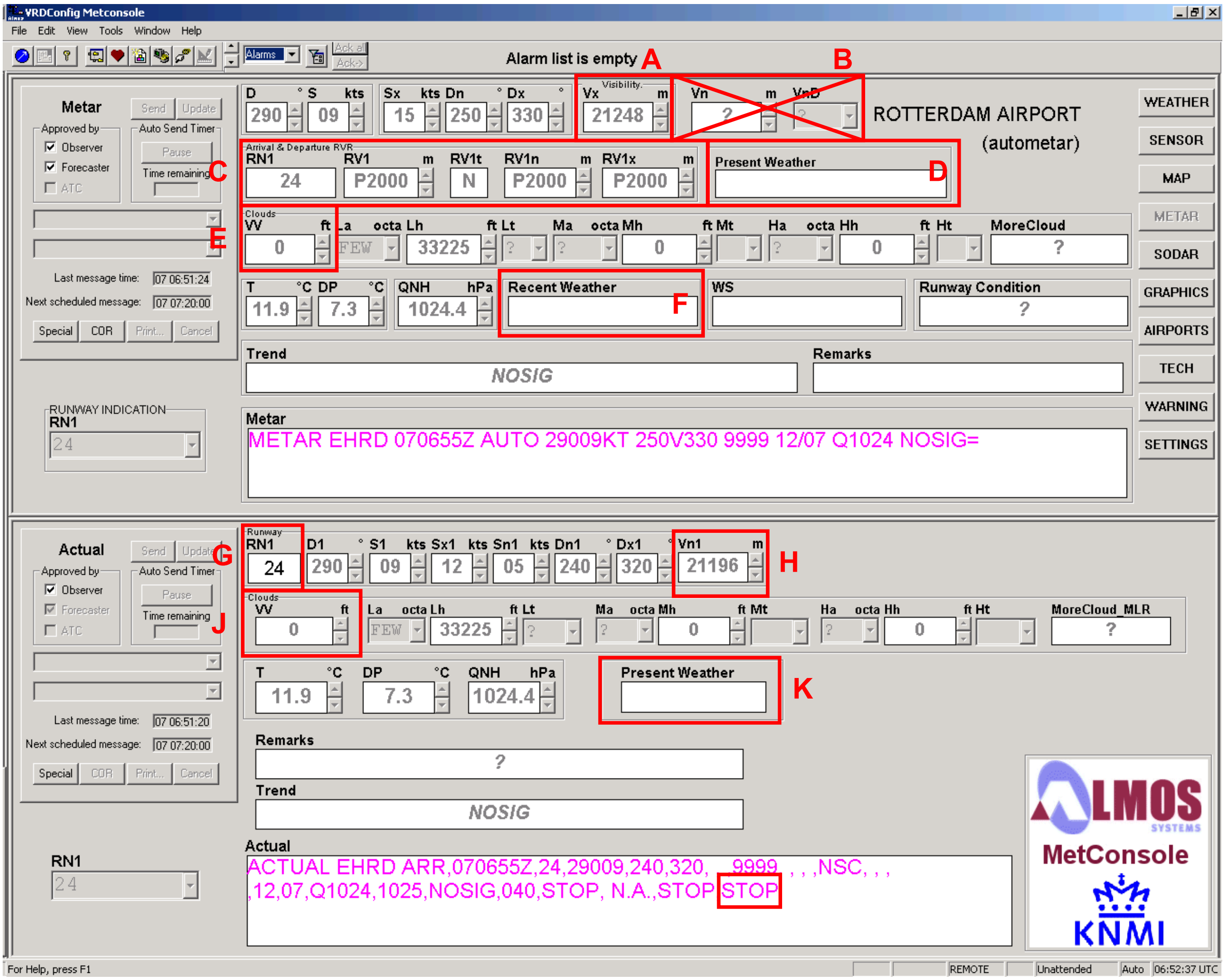


Figure 18: Screen shot of the AUTO METAR (top) and AUTO ACTUAL (bottom) report generation screen of a GDIS connected to the server systems of Rotterdam The Hague Airport.

- When the sky is obscured the vertical visibility group VVhshshs is included instead of cloud group in the METAR. The AUTO METAR criteria that need to be valid for reporting vertical visibility are (i) there is only one cloud layer with base below 500 ft and amount overcast (OVC); (ii) there is no CB/CTU; and (iii) VIS < 1000 m. For the evaluation whether vertical visibility conditions apply the variable VRD24pws\1Min\Va is used. This is the visibility of the sensor that is closest to the ceilometer and is identical to the horizontal visibility reported in the METAR. In case vertical visibility conditions apply the cloud base height is copied into the variable VRD24t/1Min/VertVis, which is automatically inserted in the

appropriate field of the METAR screen (Figure 18, item E). Note that a value of zero is used to indicate that vertical visibility does not apply. In case VIS information is not available vertical visibility will not be reported.
- Note that visibility related phenomena are not included in the REw$_a$'w$_a$' recent weather group (
- Figure 18, item F and associated variable VRD24t/1Min/RE).

ACTUAL CCCC ARR,DDHHMM,***RD1***,DDDFF1,DN1,DX1,FX1,FN1,***VV1***,***WW1***,***WW2***,***WW3***, ***CLD1***,CLD2,CLD3,CLD4,TT1,TD1,QNH1,QFE1,TREND1,TL,WS,REMARK1,MTI,***RVR***

The general code form of the AUTO ACTUAL is given below (KNMI, 2003). The AUTO SPECIAL is identical to the AUTO ACTUAL, except of course that the time will be different. The AUTO ACTUAL is issued at H+25 and H+55. In fact the sensor data of H+20 and H+50 is used to construct the AUTO ACTUAL which is than presented to the aeronautical meteorological forecaster for complementation. The ACTUAL is a comma separated string containing multiple items. An item is generally reported using the same reporting rules and encoding of the parameter as in the METAR. An item is left blank (space) when nothing needs to be reported (corresponds to omitting a group of the METAR), and N.A. (Not Available) is reported when the information is missing (corresponds to slashes in the METAR). The items in the ACTUAL related to visibility are:

- RD1 reports the main landing runway by inserting variable VRD24t/12Sec/RWName in the appropriate field of the ACTUAL screen (Figure 18, item G). The variable RWName is 24, 06 or Closed depending on which runway is in use.
- VV1 reports the VIS of the main landing runway by inserting variable VRD_MR/12Sec/Va in the appropriate field of the ACTUAL screen (Figure 18, item H). The variable Va contains the 10-minute averaged VIS (except in case of a marked discontinuity) although ICAO (2010) recommends a 1-minute averaged VIS for local routine and special reports. The Va value of location VRD24pws, VRD06t or NULL is copied to location VRD_MR depending of the runway in use as indicated by variable VRD24t/Actual/RN1. Note that the runway selection does not use the value received by ATC with manual backup directly (VRD24t/12Sec/BBb) but a variable containing the runway in use after insertion in the ACTUAL.
- CLD1 reports the cloud information which includes the vertical visibility if the sky is obscured (see VVh$_s$h$_s$h$_s$ group of the METAR). CLD1 generally reports the amount, height and type of the first cloud layer or else NSC or NCD, but in case of vertical visibility CLD1 reports the vertical visibility using in the VVh$_s$h$_s$h$_s$ format. In case of vertical visibility the items CLD2, CLD3 and CLD 4 are left blank. In the AUTO ACTUAL this is handled by the variable VRD24t/1Min/VertVis, which is inserted in the appropriate field of the ACTUAL screen (Figure 18, item J).
- WW1,WW2,WW3 report up to three present weather phenomena which can contain indicators related to visibility (see w$_a$'w$_a$' group of the METAR). For that purpose the variable VRD_MR/1Min/w'w'2 is inserted in the appropriate field of the ACTUAL screen (Figure 18, item K). The w'w' value of location VRD24pws, VRD06t or NULL is copied into w'w'2 of location VRD_MR depending of the runway in use as indicated by variable VRD24t/Actual/RN1. Hence the weather information of the runway in use is reported in the AUTO ACTUAL although ICAO (2010) recommends that the present weather information in local routine and special reports should be representative of conditions at the aerodrome.
- RVR is an indicator for whether any of the RVR of VIS at the airport is below 1500 m. The indicator is set to FREE when one or more of the visibility sensors at the aerodrome report(s) a 10-minute averaged VIS and/or RVR with marked discontinuity below 1500 m. It is set to STOP immediately when all operational visibility sensors report VIS and RVR values of 2000 m or more. The variable VRD24t/12Sec/ RVRBooleanb is inserted into the ACTUAL automatically for that purpose but it is not shown on the ACTUAL screen. A manual over rule of the indicator (variable RVRBooleanm) is located on the Sensor screen, but this is left empty so that the automatically derived value (variable RVRBoolean) is used.

Every minute the criteria are assessed and if one or more criteria are met an AUTO SPECIAL is issued. The (AUTO) SPECIAL criteria used at civil airports in The Netherlands are reported in KNMI (2011). The SPECIAL criteria related to visibility are:
- A change of the runway in use.

- Immediately when the horizontal visibility drops below a thresholds or after a 5 minute prolongation of a visibility improvement when reaching or exceeding a visibility threshold. The visibility thresholds are 800, 1500, 3000, 5000 and 8000 m.
- Immediately when the vertical visibility drops below on or more threshold or after a 10 minute prolongation of the improvement when the vertical visibility reaches or exceeds one or more vertical visibility thresholds. The vertical visibility thresholds are 100, 200, 300, 500 and 1000 ft.
- Immediately at the onset or cessation of freezing fog (FZFG).
- A change of the indicator for RVR.
- An additional AUTO SPECIAL criterion is related to the so-called VFR status. A change in the VFR status leads immediately to the issuance of an AUTO SPECIAL. The VFR status is either normal VFR, SPECIAL VFR or below limits. The VFR status is derived according to criteria in Table 9 and uses the visibility (VRD_MR/12Sec/Va) and cloud information provided to the ACTUAL. It is not specified that the vertical visibility affects the VFR status.

Table 9: Criteria for determination of the VFR status. An AUTO SPECIAL is issued in case the VFR status changes.

| Visibility | Cloud base (BKN or OVC) | Cloud base (FEW or more) | VFR status |
|---|---|---|---|
| ≥ 5 km | ≥1500 ft | all | normal |
| ≥ 5 km | <1500 ft | ≥ 600 ft | special |
| ≥ 5 km | <1500 ft | < 600 ft | below limits |
| ≥3km and <5km | ≥1500 ft | ≥ 600 ft | special |
| ≥3km and <5km | ≥1500 ft | < 600 ft | below limits |
| ≥3km and <5km | <1500 ft | ≥ 600 ft | special |
| ≥3km and <5km | <1500 ft | < 600 ft | below limits |
| <3km | all | all | below limits |

Also note that the loss or return of data delivery of one or more variables in the ACTUAL report is reason for issuing an AUTO SPECIAL immediately.

## 19. Technical infrastructure

Figure 19 shows a graphical overview of the technical infrastructure at Rotterdam The Hague Airport indicating the various hardware components and the data communication lines. Black boxes and lines denote the hardware and the serial lines that have no redundancy, whereas blue boxes and lines indicate the hardware and the serial lines with redundancy. Green indicates the server systems and network connections with redundancy. Finally, the LVNL systems are denoted in red.

A full redundancy of the system at Rotterdam Airport is available after the splitters in the technical room (cf. Figure 19). In case of a failure or malfunction of a system or communication line after the splitter, the full set of information is still available or after an automated failover to the secondary system. The GDIS client system is also redundant since there are several GDIS systems in the central weather room of KNMI in De Bilt and all can connect to the ADCM server of Rotterdam airport. The splitters themselves and the components before the splitters like a sensor are also redundant, but in a different way. In case e.g. a sensor fails a backup sensor will be used automatically.

A sensor and its backup sensor are located at different physical location on the airport and they use other parts of the observation infrastructure such as power supply, multiplexers, splitters, data communication lines and relay stations in order to get to sensor information to the servers systems in the technical room. Hence, when a sensor or an associated component of the observation infrastructure fails then the backup sensor is still available. Even if a connection to a relay station or a MUF at a relay station or a splitter in the technical room fails and all the sensor data of that end of the runway is not available, the backup sensors of pressure, wind, temperature, humidity and weather are still available. There is, however, no backup for visibility representative for the touchdown position and clouds.

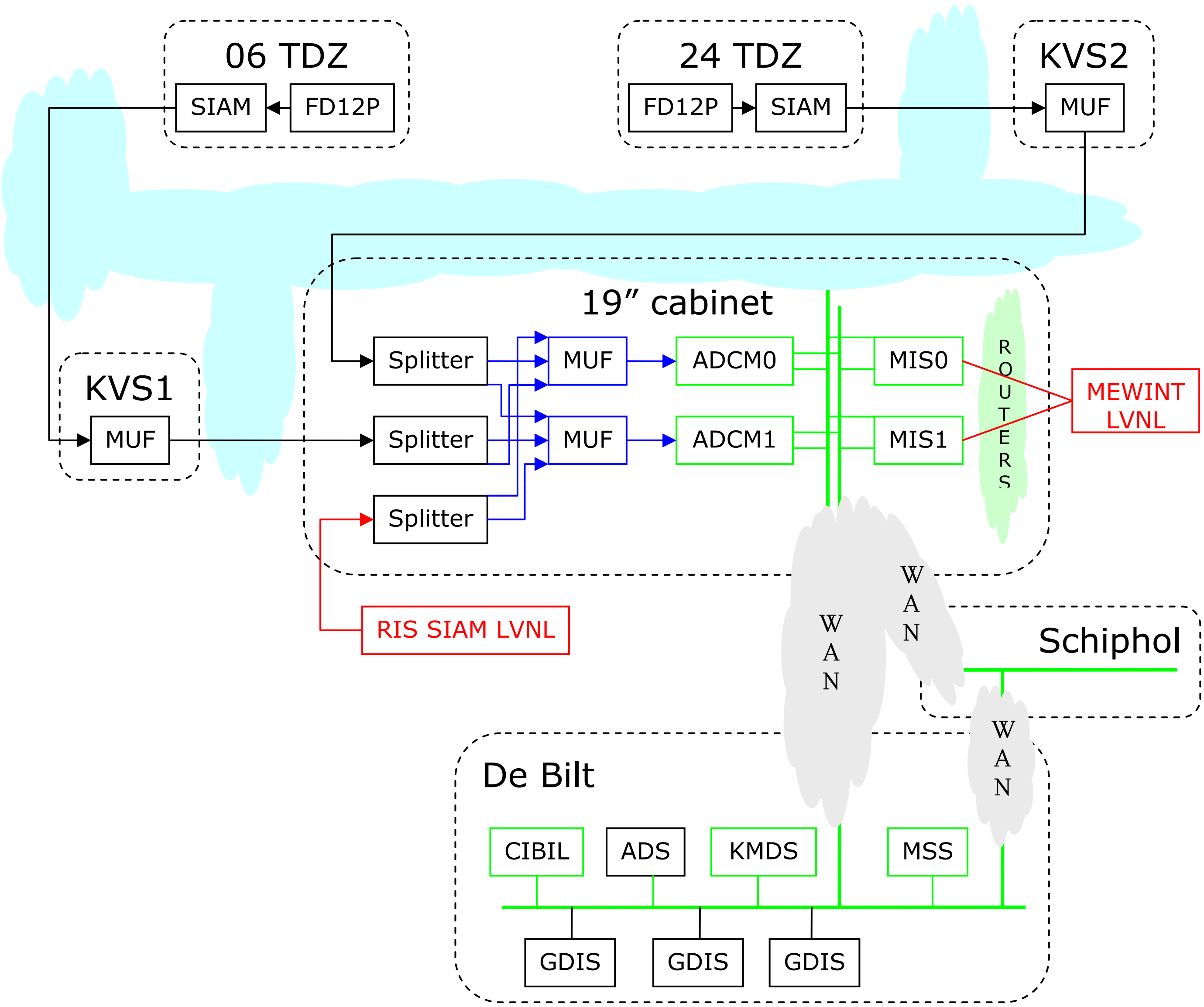


Figure 19: Overview of the technical infrastructure at Rotterdam The Hague Airport indicating the visibility sensors and the related hardware components and data communication lines.

## 20. Data flow

Table 10 again gives the variables in the configuration of the server systems at Rotterdam The Hague Airport related to visibility and the associated group and describes how the variables have been derived. For specific cases the station is mentioned as well. For the other cases the description applies to all stations having that particular variable. Gray fields indicate variables that are obsolete or not used. **Error! Reference source not found.** illustrates the data flow and the relationship between the variables related to visibility and the calculations in the configuration of the server systems at Rotterdam The Hague Airport. The calculations are indicated by the square boxes. The arrows indicate the input and output variables. Note that the order of the calculations is relevant.

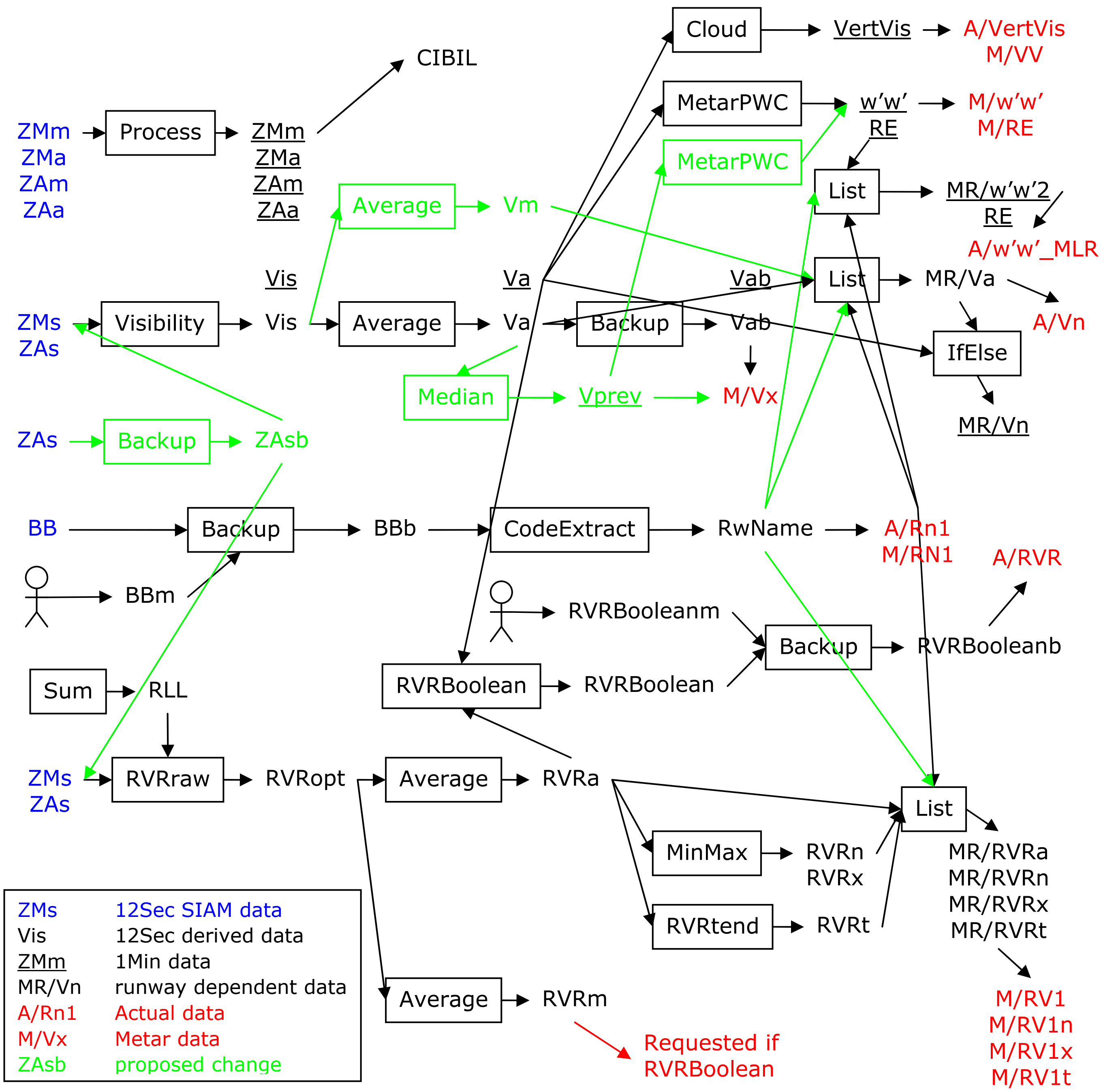


Figure 20: Overview of the data flow and the relationship between the variables related to visibility and the calculations in the configuration of the server systems at Rotterdam The Hague Airport.

Table 10: The relation between the various variables related to visibility in the configuration of the server systems at Rotterdam The Hague Airport.

| Station/Group/Variable | Description |
|---|---|
| VRD24t/12Sec/BB | ADCM parses DB0 MUF string.<br>String assigned to 12Sec interval.<br>SIAM location code 08 → Station VRD24t.<br>Sample field → value 2 (runway 06). |
| 12Sec/ZMs | ADCM parses DZ4 MUF string.<br>String assigned to 12Sec interval.<br>SIAM location code 0A → Station VRD24pws (09→ VRD06t) |

| Station/Group/Variable | Description |
|---|---|
| | ZM sample field → ZMs variable.<br>SIAM value 4219 in exponential notation → MOR value 2190 m.<br>Status → data quality using configurable status code table for conversion. |
| 12Sec/ZMm | " |
| 12Sec/ZMa | " |
| 12Sec/ZAs | " |
| 12Sec/ZAm | " |
| 12Sec/ZAa | " |
| VRD24t/1Min/RLL | Constant for runway lighting setting (100%) set in Sum Calc. |
| VRD24t/12Sec/RWName | Conversion of VRD24t/12Sec/BBb into text using Runway code table value (0, 1, 2) → (Closed, 24, 06). |
| 12Sec/RVRBooleanm | Manual selection of RVRBoolean via SENSOR screen using RVRBoolean code table (STOP, FREE) → value (0, 1). |
| 1Min/ZMm | 1Min/ZMm taken from respective 12Sec/ZMm with Process Calc. |
| 1Min/ZMa | " |
| 1Min/ZAm | " |
| 1Min/ZAa | " |
| VRD24t/12Sec/BBm | Manually selected main runway using Runway code table (Closed→0, 24→1, 06→2). |
| VRD24t/12Sec/BBb | SIAM runway 12Sec/BB is backed up with manual runway 12Sec/BBm in Process Calc. |
| 12Sec/Vis | Sample VIS calculated with Visibility Calc from ZMs and ZAs using 1000 cd light intensity.<br>06 uses ZMs and ZAs from local sensor, idem 24. |
| 1Min/Vis | 1Min/Vis taken from respective 12Sec/Vis with Process Calc. |
| 12Sec/Va | Average from last 50 12Sec/Vis in Average Calc (using 800, 1500, 3000, 5000, 8000 m and 120 sec in MD). |
| 1Min/Va | " |
| 12Sec/Vab | 12Sec/Va is backed up in Process Calc. |
| 1Min/Vab | " |
| 12Sec/Visb | 12Sec/Vis is backed up in Process Calc. |
| 1Min/Visb | " |
| VRD24t/12Sec/Vis | Taken from VRD24pws/12Sec/Vis with VRD06t as backup in Process Calc. |
| 12Sec/RVRopt | Sample RVR calculated in RVRraw Calc rom ZMs and ZAs using light intensity from 9999 code table, VRD24t/1Min/RLL, 80% edge and 50% centre factors and runway width 50 m.<br>06 uses ZMs and ZAs from local sensor, idem 24. |
| 12Sec/RVRm | Average from last 5 12Sec/RVRopt in Average Calc. |
| 12Sec/RVRa | Average from last 50 12Sec/RVRopt in Average Calc (no MD criteria specified). |
| 12Sec/RVRt | Tendency calculated from last 50 12Sec/RVRa with threshold 100 m with RVRtend Calc. |
| 12Sec/RVRn | RVR extremes calculated from last 50 12Sec/RVRopt with MinMax Calc. |
| 12Sec/RVRx | " |
| VRD24pws/1Min/RVRa | Copied from VRD24pws/12Sec/RVRa in Process Calc. |
| VRD24t/12Sec/RVRBoolean | Boolean calculated from 12Sec/RVRa and 1Min/Va of VRD06t and VRD24pws in RVRBoolean Calc. |
| VRD24t/12Sec/RVRBooleanb | Manual 12Sec/RVRBooleanm is backed up with calculated 12Sec/RVRBoolean in Process Calc. |
| VRD_MR/12Sec/RVRa | Selected 12sec/RVRa from runway VRD24t/Actual/RN1 using Runway code table with List Calc (24→VRD24pws, 06→VRD06t, Closed→NULL). |
| VRD_MR/12Sec/RVRn | " |
| VRD_MR/12Sec/RVRx | " |
| VRD_MR/12Sec/RVRt | " |
| VRD_MR/1Min/Va | Selected 1Min/Vab from runway VRD24t/Actual/RN1 using Runway code table with List Calc (24→VRD24pws, 06→VRD06t, Closed→NULL). |
| VRD_MR/1Min/Vn | Set to VRD_MR/1Min/Va in IfElse Calc (VRD24pws/1Min/Va is used if Va>50km). |
| 1Min/w'w' | METAR present weather calculated using local 1Min/Va with MetarPWC Calc. |
| 1Min/RE | " recent weather. |
| 1Min/w'w'2 | Selected 1Min/w'w' from runway VRD24t/Actual/RN1 using Runway code table with List Calc (24→VRD24t, 06→VRD06t, Closed→NULL). |
| 1Min/VertVis | Cloud calc uses VRD24pws/1Min/Va for VertVis criterion (VIS<1000m). |

| Station/Group/Variable | Description |
|---|---|
| Actual/Rn1 | Synop Calc uses VRD24t/12Sec/RwName. |
| Actual/Vn | Synop Calc uses VRD_MR/12Sec/Va. |
| Actual/'w'w'_MLR | Synop Calc uses VRD_MR/1Min/w'w'2. |
| Actual/VertVis | Synop Calc uses VRD24t/1Min/VertVis. |
| Actual/RVR | Synop Calc uses VRD24t/12Sec/RVRBooleanb. |
| Metar/Vn | - |
| Metar/VnD | - |
| Metar/Vx | Metar Calc uses VRD24pws/12Sec/Vab. |
| Metar/VxD | - |
| Metar/VV | Metar Calc uses VRD24t/1Min/VertVis. |
| Metar/w'w' | Metar Calc uses VRD24t/1Min/w'w'. |
| Metar/RE | Metar Calc uses VRD24t/1Min/RE. |
| Metar/RiU | - |
| Metar/RN1 | Metar Calc uses VRD24t/12Sec/RwName. |
| Metar/RV1 | Metar Calc uses VRD_MR/12Sec/RVRa. |
| Metar/RV1n | Metar Calc uses VRD_MR/12Sec/RVRn. |
| Metar/RV1x | Metar Calc uses VRD_MR/12Sec/RVRx. |
| Metar/RV1t | Metar Calc uses VRD_MR/12Sec/RVRt. |

## 21. Conclusions and recommendations

The document gives an overview of the current visibility chain used at Rotterdam The Hague Airport. Below some recommendations are given.
*The recommendations drafted in July 29, 2011 have been discussed and evaluated by a KNMI expert team. The decisions or actions related to the recommendations are indicated in italic.*

This first group of recommendations lists items that are related to indistinctness, omissions or inconsistencies in the WMO and ICAO requirements and recommendations. Note that the inconsistencies may be introduced by the fact that the ICAO and WMO are updated at different moments so that they do not match temporarily. However, this does not always need to be the case and since changes with respect to the previous version are not indicated in the documents they might be overlooked. The relevant sections of the WMO and/or ICAO documents have been reported to facilitate the interested reader.

a. The accuracy requirements of background luminance are unclear. ICAO (2006, section 4.5.4) states that an uncertainty of 10 % is considered acceptable, but only the accuracy of VIS and RVR are relevant for aviation purposes. The required range and resolution of background luminance are also not specified. Some examples given use the range 7 to 30,000 cd/m$^2$ and the logarithmic relationship between the background luminance and illumination threshold spans the range 8 to 38,000 cd/m$^2$ between the illumination thresholds for night and bright day, respectively.
   *The background luminance sensor used by KNMI has an uncertainty of 10 % according to the manufacturer and the range covers the values observed in The Netherlands. The dependency of the VIS and RVR accuracy requirements on the background luminance will be investigated so that suitable en realistic accuracy requirements of the background luminance can be proposed to the international community as well as the range of the background luminance.*
b. ICAO (2005, section 9.1.5) reports that a single background luminance sensor may be used on aerodromes, even if equipped with several (visibility) instruments. However, to enhance representativeness of the measurement and system reliability, the use of two or more sensors may be preferable. WMO (2008, Part 2, section 2.4.3.3), on the other hand, specifies that a background luminance sensor should be placed at the end of the runway along which one or more visibility sensors have been installed. One or more luminance sensors may be installed on the airport depending on the number of runways covered.
   *The KNMI practice at civil airports complies with the practices reported by ICAO and WMO. It is not clear whether the discrepancy between WMO and ICAO is caused by the different update cycles of ICAO and WMO documents. The discrepancy between the documents will be reported to ICAO so that it can be taken into account in the update of ICAO (2005).*

c. The relationship between the illumination threshold and the background luminance is reported by ICAO (2010, Attachment D and 2005, section 6.6.6) using 2 significant digits; WMO (2008, Part 2, section 2.4.3.3) gives the relation with 3 significant digits; and van der Meulen (2001) and Wauben (2001) use 4 significant digits.
*The effect of using more than 2 significant digits in the calculation of visibility and RVR is considered negligible. The background and uncertainty of the coefficients and their impact will be clarified.*
d. ICAO (2010, section 4.6.3.4) states that RVR shall be representative for touchdown zone midpoint and end of the runway intended for instrument approach and landing operations. The required or recommended representativeness of RVR for take-off is unclear. This might e.g. have consequences for the backup of the RVR at the "A" position, which is not allowed when it should be representative for start position of the runway.
*KNMI employs the same rules for landing and take-off operations and does e.g. not allow backup of the RVR at start by that of the mid position. The KNMI practices for RVR during departure meet the more strict requirements during arrival.*
e. WMO (2008, Chapter 1, Annex 1.B) requires a MOR range of 10 m - 100 km and a RVR range 10-1500 m, both with a resolution of 1 m. Note that on the other hand the reporting range of MOR according to WMO (2010, code table 4377) is <100 m to > 70 km and ICAO (2010, Appendix 3, section 4.3.6.2) recommends a RVR range from 50 to 2000 m.
*The difference in MOR is related to the reporting range and resolution allowed by WMO in the SYNOP reports and is not relevant for aviation. It will be resolved when the change form the SYNOP to the BUFR code has been made. The RVR range up to 1500 m reported by WMO is considered incorrect. RVR should be reported when the RVR is below 1500 m, but the RVR for other runways in use should then also be reported with values up to 2000 m. This anomaly in the documentation will be communicated to WMO.*
f. WMO (2008, Part 2, section 2.3) states VIS steps of 50 m below 500 m and steps of 100 m between 500 m and 5000 m , whereas ICAO (2010, Appendix 3, section 4.2.4 and Attachment C) specifies VIS steps of 50 m up to 800 m.
*KNMI follows the more recent and correct ICAO VIS reporting rules. The inconsistency will be reported to WMO.*

This second group lists items where KNMI practices deviate from the WMO and ICAO requirements and recommendations. Note that these deviations are probably mainly historic of nature, i.e. KNMI kept in line with former specifications or the practices at airports. However, it is good to verify and reconsider the deviations and, if kept, to document and communicate the deviations.

g. KNMI operates a background luminance sensor at the touchdown position of each runway (both ends if the runway can be used from either side) at civil airports. The number of background luminance sensors operated at an airport may be reconsidered by using the above stated ICAO or WMO specifications.
*The standard KNMI practice at civil airports concerning usage of background luminance sensors complies with the practices reported by ICAO and WMO. There is no need for reconsideration.*
h. The relationship between the illumination threshold and the background luminance using 4 significant digits as reported by Wauben (2001) has been used for the implementation of the VIS calculation in MetNet. Consider using the "rounded" ICAO values with 2 significant digits. It is unclear from the documentation which relationship is used in the RVR calculation.
*The source code of the RVR calculation in MetNet has been inspected together with the manufacturer. The RVR calculation uses the relationship log10(Et)=-7.0+0.89*log10(BL) which is the former relation log10(Et)=-6.95+0.8875*log10(BL) reported by WMO (1996, Part II 2.4.3.2), but with rounded coefficients. The relationship and coefficients in the calculations will be changed so that they match the ICAO recommendations.*
i. ICAO (2005, section 6.6.6) recommends using the lower limit of the illumination threshold of 8 $10^{-7}$ lx to account for the fact that the cockpit is never completely dark. This lower limit is not used in the current VIS calculation and it is not clear from the documentation whether it is used for RVR.
*The source code of the RVR calculation in MetNet has been inspected together with the manufacturer. MetNet does not use a lower limit for the illumination threshold Et. Indirectly it does since a background luminance below or equal zero is set to unity (Et=1.e-7) and the background luminance used by KNMI has a minimum range 3* cd/m$^2$ *(Et=2.66e-7). The lower limit of the illumination threshold corresponds to a background luminance of about 8 cd/m$^2$. The lower threshold will be included in the calculations depending on the impact on the calculated VIS and RVR.*
j. ICAO (2005, section 6.5.4) recommends that 200 and 550 m are the boundaries for the transition from centre to edge lights whereas KNMI uses 350 and 600 m.

*The source code of the RVR calculation in MetNet has been inspected together with the manufacturer. The lamp intensity of centre and edge lights combined is specified in code table 9999 and can be changed to match the 200 and 550 m boundaries. However, MetNet uses hard coded boundaries of 350 and 600 m in order to take account of the configured ageing/contamination factor for centre and edge lights, i.e. below 350 m the factor for centre lights is used, above 600 m the edge factor, and in between a linear transition The boundaries for the transition from centre to edge lights will be changed in MetNet depending on the impact on the calculated RVR.*

k. According to ICAO (2010, section 4.6.2.2) VIS in local routine and local special reports used for departure should be representative of conditions along runway so backup of the visibility sensor at touchdown by a sensor at the mid position, as used at Amsterdam Airport Schiphol, seems valid. One might even consider using a runway visibility (e.g. median of the three values).
*This item is not relevant for the regional civil airports where only an actual arrival is generated. The handling of VIS for departure at Schiphol will be discussed and decided upon in the appropriate expert meeting.*

l. For arrival VIS, like RVR, in local routine and local special reports should be representative of the touchdown zone (ICAO, 2010, section 4.6.2.2) so that a backup is only possible in case the backup value is representative. Hence the backup of VIS at touchdown by the mid position, as used at Amsterdam Airport Schiphol, for arriving aircraft should be reconsidered.
*The AUTO ACTUAL of Rotterdam The Hague airport uses the VIS at touchdown without backup. The handling of VIS for arrival at Schiphol (and Beek) will be discussed and decided upon in the appropriate expert meeting.*

m. ATC only uses the VIS reported in the AUTO ACTUAL and SPECIAL. Hence the VIS derived at the B and C position might be reconsidered.
*KNMI decided to make the VIS available for all positions equipped with a visibility sensor, which is in line with the template for the local routine and local special reports (ICAO 2010, Appendix 3, table A3-1). Currently LVNL only uses the RVR for all positions, but in the future VIS might be used as well, specifically during conditions outside the RVR range (P2000).*

n. Following ICAO (2005, section 6.5.7) KNMI should consider using the runway light intensity determined by the isocandela diagrams of the runway lights in use. Note that in case the runway lights differ this might require using airport and even runway dependent light intensity characteristics.
*KNMI will perform an analysis of the impact of using the isocandela diagrams of the runway lights in use on the derived RVR. Depending on outcome of this study and the availability of the actual runway light characteristics their operational use will be considered.*

o. The ACTUAL should use, if possible, the actual light intensity setting (*ICAO 2010, Appendix 3, section 4.3.5*). Only for the RVR in the AUTO METAR a maximum light intensity should be assumed.
*Real-time availability of the intensity setting of the runway lights is not feasible. The study mentioned above will also investigate the dependency of the RVR to the intensity settings. For that purpose the intensity settings used by LVNL will be considered.*

p. ICAO (2010, Appendix 3, section 4.3.6.6) recommends that the RVR tendency is to be determined from the difference between the mean during the first 5 minutes of the 10 minute interval and that of the second 5 minute period. KNMI derives the RVR tendency from the current 10 minute mean and the 10 minute mean ten minutes ago.
*The source code of the RVR tendency calculation in MetNet has been inspected together with the manufacturer. MetNet determines the tendency using the RVR of the last and previous 5 minute interval and a threshold of 100 m. However, the configuration uses the 10 minute averaged RVR as input instead of the instantaneous RVR. A marked discontinuity can be taken into account in which case the tendency is determined from the 2 halves of the interval, but the ICAO documentation does not explicitly mention how the tendency should be determined in case of the marked discontinuity. An upgrade to the RVR tendency calculation and configuration will be considered in combination with the other changes to the RVR calculations.*

q. ICAO (2010, Appendix 3, section 4.3.6.6) recommends that the 1 minute mean minimum and maximum RVR values should be reported instead of the 10 minute mean RVR in the AUTO METAR in case of variations, i.e. the 1 minute RVR values in the 10-minute interval vary by more than 50 m or more than 20 % from the mean. KNMI should consider following the ICAO recommendation.
*The handling of the RVR variations in MetNet has been inspected together with the manufacturer.. MetNet determines the minimum and maximum sample value of the RVR (not the 1 minute averaged RVR) in the 10 minute interval (or less in case of a marked discontinuity). The METAR will report the minimum and maximum RVR when at least one of these differ more than 50 m or 20% from the 10 minute averaged RVR. An upgrade to the handling of the RVR variations will be considered in combination with the other changes to the RVR calculations. It should be noted that it is proposed to delete the RVR variations from the METAR /SPECI in the next amendment of ICAO Annex 3, which is envisaged for applicability on 14 November 2013.*

r. ICAO (2010, Appendix 3, section 4.2.3) recommends using a 1 minute averaging of VIS for local routine and local special reports and for displays in air traffic services, whereas KNMI uses a 10 minute averaged VIS including marked discontinuity (in which case the averaging interval is reduced to 2 minutes).
*The usage of a 1 minute averaged VIS will lead to larger fluctuations in the reported VIS. This issue will be discussed with LVNL in the Workgroup SPECIAL. If the current practice is agreed upon it will be filed as a difference.*

s. ICAO (2010, Appendix 3, section 4.2.4.4) recommends using prevailing visibility in the AUTO METAR in combination with the special case for minimum visibility. Prevailing visibility can be determined according to ICAO (2006, section 4.3.3) as the median of the visibilities reported by all available sensors. In addition a weight can be assigned to each sensor to establish the percentage of the area of the aerodrome for that is nominally to be represented by each sensor. The prevailing visibility is then the visibility value reached or exceeded within at least half of the surface of the aerodrome. KNMI uses the VIS reported by an assigned sensor with backup in the AUTO METAR.
*This issue has a low priority for KNMI and has not been requested by the user community. KNMI decided to keep the current practice of using the VIS of a fixed assigned visibility sensor (with a backup) in the AUTO METAR and to file a difference. A study will be performed in the near future on the use of the information of multiple present weather sensors for the generation of present weather, including the visibility phenomena and handling of backup.*

This third group lists items that do not fall in the above categories.

t. The traceability of the calibration of the background luminance sensor is needs to be verified.
*The traceability of the background luminance will be verified with the manufacturer of the background luminance sensor.*

u. Since a background luminance sensor is pointed toward the Northern sky the usage of a backed up background luminance in the VIS and RVR calculation can be considered.
*The backup of the background luminance is recommended by ICAO and as there are no specific requirements for the location of the background luminance sensor KNMI decided to implement a backup of the background luminance in order to improve the availability of VIS and RVR. The background luminance at touchdown will be used for the RVR calculation, but the background luminance at the end position will serve as a backup. Similarly the background luminance at the other end of the runway will serve as the backup for the VIS calculation.*

v. It is recommended to investigate the spatial variability and representativeness of the measured background luminance. Depending on the outcome the number of background luminance sensors per airport might be reconsidered.
*KNMI decided to stay with the standard practice at civil airports of using a background luminance sensor at the touchdown position of each runway (item g). A study into the spatial variability and representativeness of the measured background luminance is endorsed.*

w. The transition from centre to edge lights is achieved by a linear transition of the intensity or by using a linear relation between RVR and MOR (ICAO 2005, section 6.5.4). It is unclear why such a transition should be used instead of a suitable selection of the runway lights e.g. based on the maximum intensity in combination with a maximum viewing angle.
*This will also be investigated in RVR study mentioned above. The impact on RVR between the two transitions from centre to edge lights should be made clear and a preferred practice should be recommended to ICAO.*

x. The visibility reference of KNMI is only valid for MOR values up to about 1500 m. It should be investigated whether the current reference setup can be used, possibly with some modifications, up to an extended range of 2000 m (RVR upper limit ICAO) or 3000 m (RVR upper limit military airbases). The differences in MOR values of FD12P and TMM up to 2000 m and 3000 m obtained from the reference setup should at least correspond with the estimated and required uncertainties of both.
*The current range of 1500 m covers the RVR requirements for civil aviation. The extended range is important for VIS for aeronautical purposes as well as for other meteorological and climatological applications. Hence extending the range of the visibility reference is required for weather and climate applications in general and should be handled by the Infrastructure department of KNMI via appropriate channels.*

y. KNMI has no reference sensor for higher visibility values. However, the linearity of the forward scatter meter at the higher MOR range could possibly be checked by using the scatter plate in combination with neutral density filters.
*The remarks of previous item apply here as well and should be handled by the Infrastructure department of KNMI via appropriate channels.*

z. The performance and experiences of the visibility reference of KNMI are not routinely reported.

*This item should also be handled by the Infrastructure department of KNMI, but it will be addressed in the SLA meeting.*

aa. The correct usage of marked discontinuity in the RVR averaging cannot be verified since the AUTO SPECIAL boundaries are not included in the configuration (unlike marked discontinuity averaging VIS).
*The handling of marked discontinuity in the RVR calculation in MetNet has been inspected together with the manufacturer. The RVR calculation uses a hard coded 120 sec interval and SPECIAL boundaries 150, 350, 600 and 800 m for the handling of marked discontinuity. Alternatively the handling of marked discontinuity in RVR could also be performed in the same way as for visibility i.e. in the averaging calculation where the marked discontinuity interval and SPECIAL boundaries can be explicitly specified in the configuration. It should be noted that the proposed change to the RVR SPECI boundaries in the next amendment of ICAO Annex 3 could also be taken into account when handling the marked discontinuity in the RVR by using the averaging calculation.*

bb. KNMI should consider performing the statistical analysis of MOR measurements reported by De Haij (2008) on a regular basis by using a suitable monitoring tool.
*This item should also be handled by the Infrastructure department of KNMI, via appropriate channels.*

cc. The configuration of the RVR calculation of Rotterdam The Hague Airport uses a distance between edge lights of 50 instead of 45 m (the value used at EHAM). Also the maximum number of iterations differs (40 at EHRD and 50 at EHAM) although both numbers largely exceed the number of iteration steps that is generally required.
*This affect RVR only applies when edge lights are used, i.e. when RVR is above 350 m, so the impact of the 2.5 m is small. This will also be considered in RVR study mentioned above and will be considered in combination with the other changes to the RVR calculations.*

dd. Suitable visibility markers should be made available so that the VFR criterion (VIS exceeding 5 km) can be estimated from the video camera images.
*This item is related to the update of the video camera systems which is ongoing. The position of the video camera is also crucial. The possibility to mount a camera on the ATC tower is currently under investigation. Once the camera images are available suitable visibility markers will be determined.*

ee. The criteria for deciding that VFR visibility conditions apply, so that in case of unavailability of a visibility sensor the visibility reported by the sensor at the other end of the runway may be used as a backup, should be documented in a work instruction and approved.
*The current practice is hampered by the quality of the video camera systems. After the evaluation of the AUTO METAR system of Rotterdam The Hague airport and experience with a new video camera system the criteria and procedure will be updated.*

ff. Backup of the runway in use is achieved at Rotterdam The Hague Airport by forcing the corresponding SIAM variable. Backup via entering the corresponding manual variable is not available on a screen Furthermore, the selection of the runway dependent variables via the list calculation using the corresponding Actual variable is inconsistent with the Schiphol configuration which uses the corresponding backed up SIAM variable and it is not clear whether this leads to a delay in the update of the runway dependent variables.
*The inconsistency in the handling of the backup of the runway in use will be investigated and solved.*

gg. The usage of a backed up visibility for reporting the visibility in the AUTO METAR should be considered.
*The usage of a backed up VIS in the AUTO METAR has been implemented in the update of November 2011.*

hh. Usage of separate AUTO METAR (w'w') and AUTO ACTUAL (w'w'2) weather variables and associated calculations should be implemented. The AUTO ACTUAL MetarPWC calc should only use the sensor information of the touchdown position whereas the AUTO METAR calc should use all available sensor information so that the resulting weather is a best as possible representative of the aerodrome. The visibility used in generating the weather should be identical to the visibility used in the report itself; hence for the AUTO METAR a backup and usage of prevailing visibility are applicable.
*An algorithm that uses the information of all present weather sensors at an airport for the determination of present weather, including the visibility phenomena and handling of backup will be developed and tested. The consistency of the current usage of a single present weather sensor for reporting the weather and VIS in AUTO METAR and AUTO ACTUAL will be verified.*

ii. The airport and airbase configurations are inconsistent and contain obsolete variables. KNMI should specify the variables and their relations including the usage, order and backup rules in a document. Sections 17 and 19 as well as Wauben (2009) can be used for that purpose. Once the specification documentation is complete (all variables and all calculations) and confirmed, all configurations should be verified and updated according to these specifications. Future changes should only be made to the configuration once new or updated specifications have been documented and approved.

*With the update of November 2011 of all airports and airbases the consistency of the configurations has been restored. There is still a need for specification of the configuration in readable form that can serve as the reference against which the configurations can be verified and future changes can be introduced and agreed. The formal handling of changes is also addressed in the new change procedure.*

jj. The service level agreement (KNMI, 2010) is not up to date with respect to regional airports operating in automated mode during opening hours of the aerodrome. Furthermore the required availability of the video cameras has not been specified and the promptness of service required during malfunctions is not always stated clearly.
*This will be addressed in the SLA meeting.*

kk. Tracking of changes in the ICAO and WMO documentation should be considered in order to facilitate the user in the process of checking whether their systems meet the requirements and recommendations or if changes are required.
*The proposed amendment to ICAO Annex 3 has been distributed to parties involved in a convenient document showing all changes and a rationale. However this document is not available to all users.*

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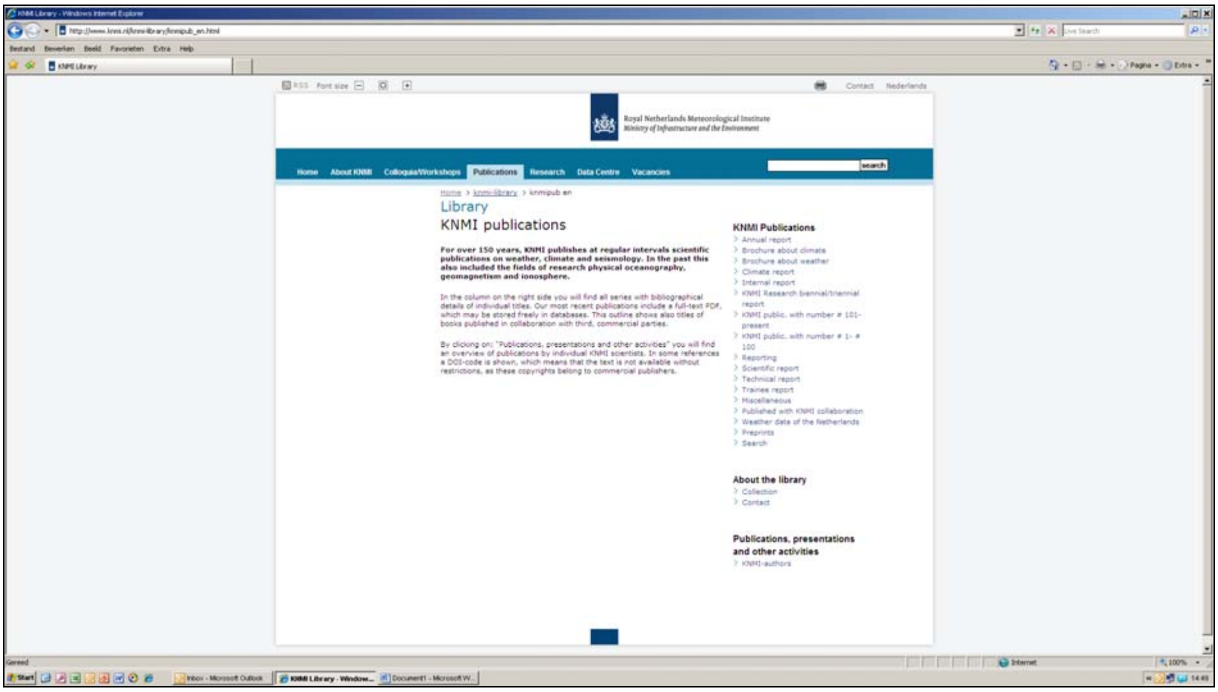


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