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INTERCOMPARISON OF VISIBILITY INSTRUMENTS AT OSLO AIRPORT - GARDERMOEN.

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INTERCOMPARISON OF VISIBILITY INSTRUMENTS AT OSLO AIRPORT - GARDERMOEN

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ORDERED BY

CIVIL AVIATION AUTHORITY (LUFTFARTSVERKET)
DNMI - CLIMATOLOGY DIVISION

SUMMARY

A comparison of visibility measurements from Impulsphysik transmissometer (IPH) and Vaisala transmissometer (VAI) and forward scatter visibility meter (VFS) was performed at Gardermoen.

For the total test period and all fog types, snow excepted, we found statistically significant average MOR ratios VAI/IPH≈1.15 and VFS/IPH≈1.12. There was no significant difference between VAI and VFS below 500 m MOR.

The large difference in transmittance between VAI and IPH must be due to differences in transmissometer measurement design, with consequences for measurements in a droplet environment.

A comparison between instrumental RVR and "visual RVR" shows a good correspondence between IPH-RVR and RVR, while VAI-RVR is some percent too high, especially in radiation fog.

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SUMMARY

From November 1990 until May 1993 The Norwegian Meteorological Institute measured visibility at three positions along the runway at Oslo Airport Gardermoen. The measurements were performed by Impulsphysik transmissometers. From December 1991 there were measurements also with Vaisala instruments, one transmissometer and one forward scatter visibility meter, at the midway position.

The three visibility instruments were compared during two winter seasons. The instruments are denoted IPH (Impulsphysik transmissometer at position M), VAI (Vaisala transmissometer) and VFS (Vaisala forward scatter visibility meter).

Comparison of transmissometers.

For the total test period 19.12.91-25.3.93 and all fog types, snow excepted, we found a MOR ratio VAI/IPH ≈ 1.15. From a Student's t-test with autocorrelation this result represents a difference between the two transmissometers, which is probably significant (95% level of significance). The result is in good accordance with the results from the first WMO intercomparison of visibility measurements, where IPH and VAI were compared over a base line of 75 m.

For the lower MOR intervals this means an absolute difference in transmittance of more than 5% between the instruments, which is far beyond the uncertainty level of measurements, even when an inaccuracy of 1% is considered. As the instruments both showed the same transmittance (within instrumental accuracy) to 25% external filters, this result must be due to differences in transmissometer measurement design, with consequences for measurements in a droplet environment like dense fog.

We found a probably significant difference of 0.06 between VAI/IPH ratios in radiation fog and advection fog. In fog situations the VAI/IPH ratio increases when the visibility decreases.

In snow there is an opposite trend. We found that ratios varied between 1.0 and 1.4. With strong winds a lot of cases gives higher ratios. With relatively weak winds, below 5 m/s, the ratios seem to lie between 1.0 and 1.2 at visibility around 600-1000 m.

Transmissometers versus forward scatter visibility meter.

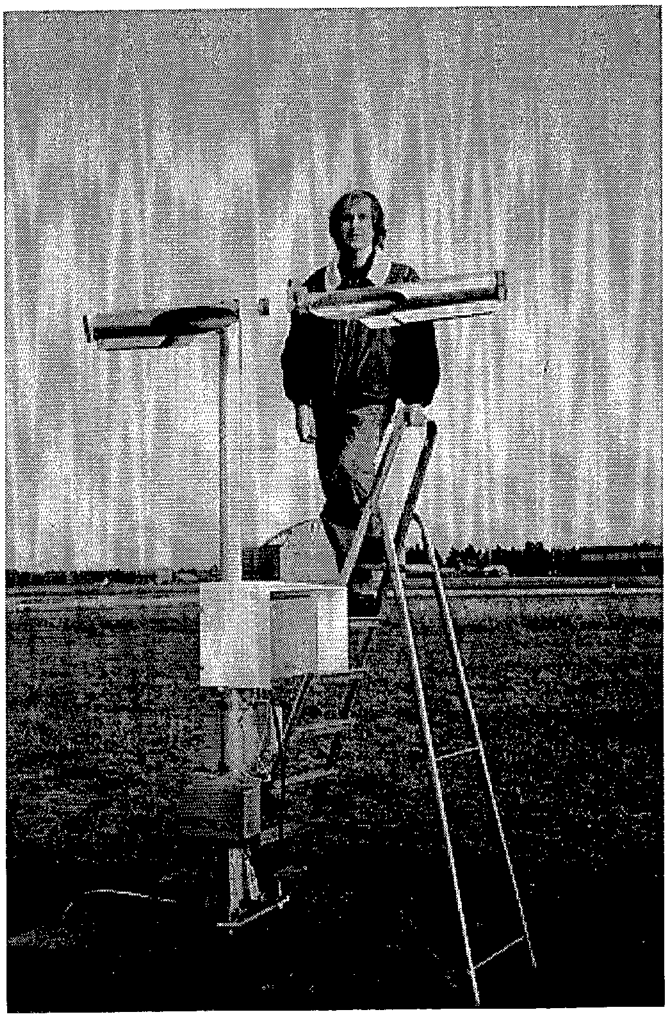
For the period 19.12.91-13.5.92 and all fog types, snow excepted, we found a MOR ratio VAI/VFS ≈ 1.03. This ratio represent a difference between the two instruments, which are not statistically significant. However, the ratio is increasing with increasing visibility. Above 500 m the ratio is greater than 1.05, which is a significant result. For the same period we found a MOR ratio VFS/IPH ≈ 1.12. This ratio is lesser than the VAI/IPH ratio, but still probably significant.

Runway visual range.

A comparison between instrumental RVR and "visual RVR" shows a good correspondence between IPH-RVR and RVR, while VAI-RVR is some percent too high, especially in radiation fog.

Owing to a difference in determination of the illumination threshold the RVR differences between VAI and IPH become smaller than otherwise expected. The RVR ratios VAI/IPH are about 10% lower at night and 15% lower at day compared with the MOR ratios.

Forward scatter visibility meter for the first time in Norway.



Harri Kortelathi, Vaisala Oy, calibrating the instrument
at Gardermoen 19.12.1991.

INTERCOMPARISON OF VISIBILITY INSTRUMENTS AT OSLO AIRPORT - GARDERMOEN.

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APPENDICES

1. INTRODUCTION

Visibility instruments were introduced in Norway during the late 1960's and were in operation for a few years at Oslo Airport - Fornebu. The Norwegian Meteorological Institute (DNMI) acquired further knowledge about operating transmissometers for fog climate research during the "HURUM PROJECT" (1988-90) (1). DNMI was engaged by the Civil Aviation Authority (LV) to give statistics on calculated runway visual range (RVR) for the planned new main airport for the Oslo region. The meteorological statistics proved to be negative for the airport project - and the planned airport area at Hurum was cancelled by Stortinget (the Norwegian Parliament) 1.6.1993.

An interesting continuation of the visibility measurements was the "GARDERMOEN PROJECT" (1990-93) (2) at the existing Oslo Airport - Gardermoen. Again RVR statistics were calculated, and now based on a complete RVR measurement system. Three transmissometers were sited along the runway, in a north, south and a midway position.

In both projects DNMI used one type of transmissometers, produced by Impulsphysik Gmbh, Hamburg: the "SKOPOGRAPH II - FLAMINGO". During the research it appeared that also other airports wanted visibility instruments to avoid the often stressful visual observation of RVR. Thus it was a growing interest at DNMI of making a comparison between different kind of instruments. In November 1991 we were able to establish a test site containing a Vaisala transmissometer, "MITRAS", and a Vaisala forward scatter visibility meter,"FD12", in addition to the existing "SKOPOGRAPH II".

The measurements taken during this intercomparison test have been analysed and the results are presented in this report. Our main efforts were to establish reliable and comparable data series to find the relations between the visibility measurements of the two different transmissometers. Further the forward scatter visibility meter was compared with the transmissometers.

1.1. Acknowledgements.

Vaisala Oy,	who kindly lent their instruments, made the installation and contributed with discussions and advices.
Impulsphysik GMBH.,	for their user support and advices, and for always being ready for discussions.
Technical staff at DNMI:	Ove Grasbakken and Håvard Østby, responsible for the technical maintenance and troubleshooting.

2. DESCRIPTION OF MEASUREMENT SITE

A topographical description of the measurement site is given on regional and local scale. Typical fog categories and characteristics are discussed to understand the variety of the collected data series. Information about general wind conditions supplement the meteorological description.

The instrumental test site is described into details on changes during measurement period.

2.1. General site description and fog characteristics.

Gardermoen is positioned in the lowlands of Southeastern Norway, east of the central high mountain area, 36 km northeast of Oslo. The lowlands are well exposed to the humidity sources south and southwest of Oslo: Oslofjorden and Skagerak. To the west the region is shielded against low stratus and fog.

Gardermoen is located in the western part of a large plain of glacifluvial material, 200 m a.s.l.. This plain is shielded to the west and northwest by hills, Romeriksåsene and Hurdalsåsene, 500-700 m a.s.l.. To the east and south the area is open. To the north the lake Mjøsa is the most important local humidity source and it is freezing late. But also the lake Hurdalssjøen and the river Vorma have some importance for formation of fog at Gardermoen during early winter. See Figure 2.1.

There are two main types of fog at Gardermoen (2): A type mainly dependent of humidity advection from a southerly direction and a type mainly dependent of radiation processes. For a lot of fog situations it is difficult to decide whether of the two fog forming processes is the most important one.

If possible, the weather station Tryvasshøgda, north of the capital, 530 m a.s.l., is often used to determine whether the fog is of advection or radiation type. See Chapter 4.2.

For the period 1957-91 an examination of the two types showed 47% advection fog and 53% radiation fog at Gardermoen. The fog season is lasting from September to April with the highest frequencies in November and December. In fog situations the visibility has a typical value of 100-300 m.

Prevailing winds are 350-040° (29%) and 170-220° (25%). The northerly winds are prevailing in winter, the southerly winds in summer. Calm weather exist in 12% of the time of the year and in 99% of the time the wind force is moderate breeze (4 Beaufort) or lower.

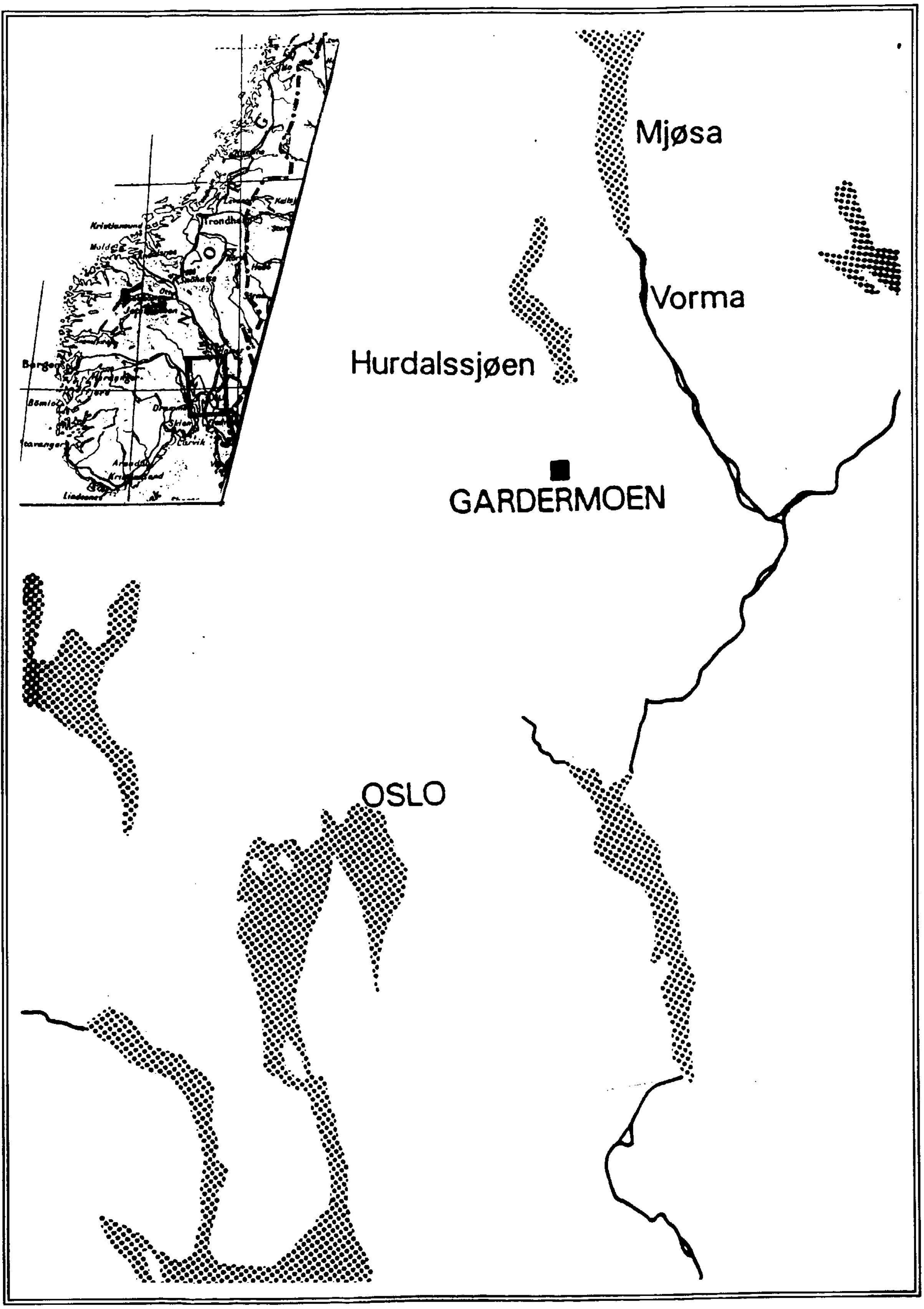


Figure 2.1.
The location of Gardermoen in the lowland east of the central mountain ridge.

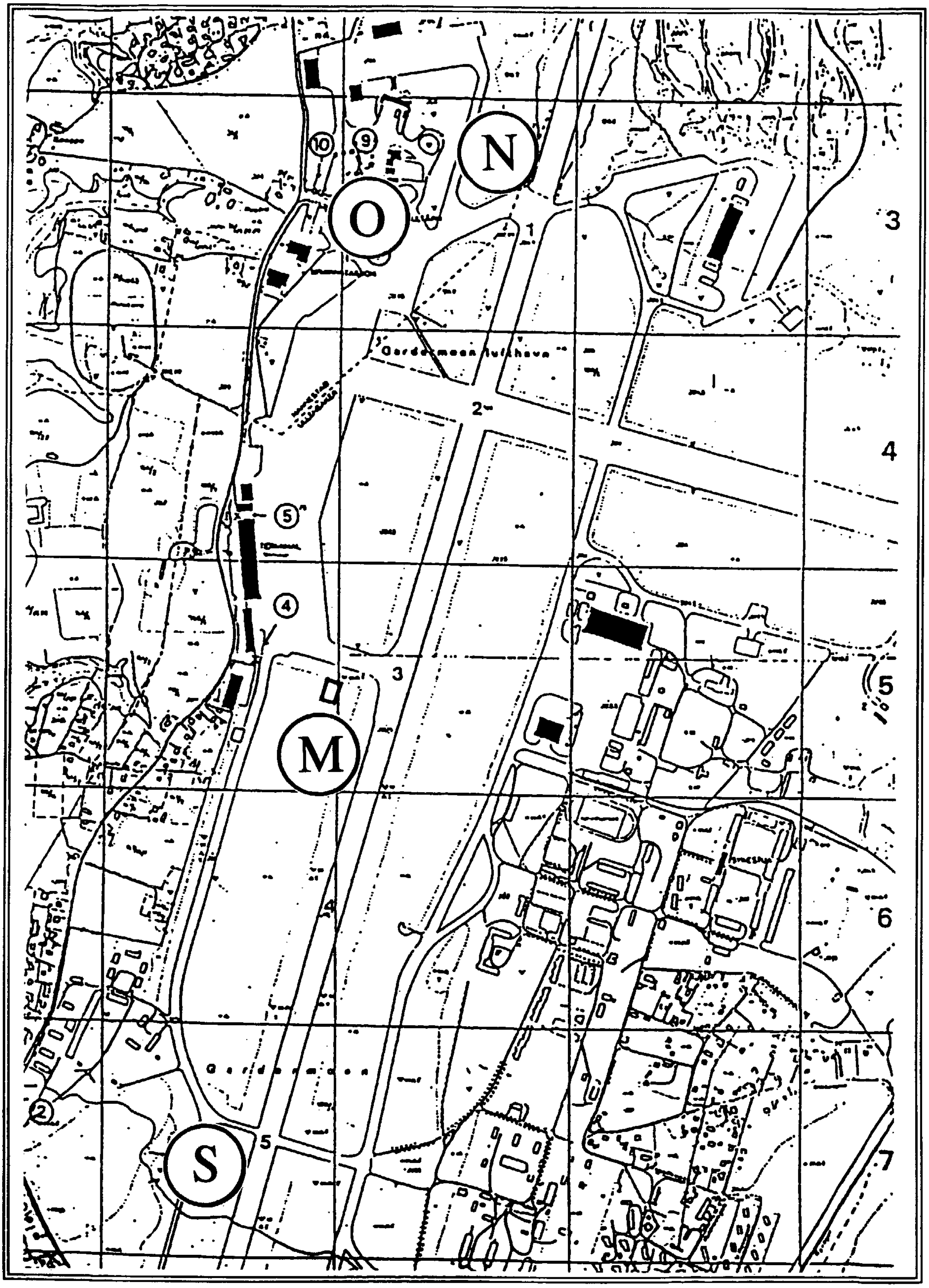


Figure 2.2.
The Oslo Airport - Gardermoen. The instrument positions are marked with capital letters. See text in paragraph 2.2. At M the test site are marked with a square.

2.2. Test site description.

The location of instruments in the measurement project is related to the 01/19 runway at Gardermoen, to the west side of the runway. See Figure 2.2. The locations are marked as **N** (north), **M** (midway) and **S** (south). **O** marks the meteorological observation site at the airport.

Visibility instruments and background luminance sensors are located in this way:

N - One "SKOPOGRAPH II" transmissometer.
- One "STILBUS" background luminance meter.

This is Impulsphysik equipment and is denoted the **IPH-N** instrument.

M - One "SKOPOGRAPH II" transmissometer, **IPH-M**.
- One "MITRAS", Vaisala transmissometer, **VAI**.
- One "FD 12", Vaisala forward scatter visibility meter, denoted **VFS**.

S - One "SKOPOGRAPH II" transmissometer.
- One "STILBUS" background luminance meter.

This is denoted the **IPH-S** instrument.

This notation will be used throughout the report. The location of IPH-transmissometers are according to ICAO recommendations for CAT III operations. The visibility instruments in location N and S serve as reference instruments. The main test site is then located to the position **M**. There we find the three visibility instruments to be compared.

A detailed map covering the test site **M** is shown in figure 2.3. During the measurement period we found it necessary to move the Vaisala transmissometer. This was done after discussions with the manufacturers on possible interference between the transmissometers. The first position of VAI was quite close-up to the IPH-M. Both positions are marked on the map as "**first**" and "**final**" positions. See Picture 1 and 2.

The IPH-M transmissometer is located 90 m aside of the runway. The first position of the VAI transmissometer was as close as 2 m to the west of IPH-M. The final position was 28 m to the west of IPH-M. Between this final position of the VAI and the IPH-M transmissometers we find the forward scatter visibility meter, 11 m to the west of IPH-M. All these instruments are aligned along the runway direction 017-197°, with the transmitters to the north and the receivers to the south (pointing north).

The operation centre for the instruments was located to a minor hut 20 m to the south of the

VFS-instrument. See Picture 1. It contained units for instrument control, data processing, data storing and communication. The hut was 3 m high above ground and the floor was 2x4 m.

The test site M are well exposed to fog in all directions. The small hut has no effect in that respect.

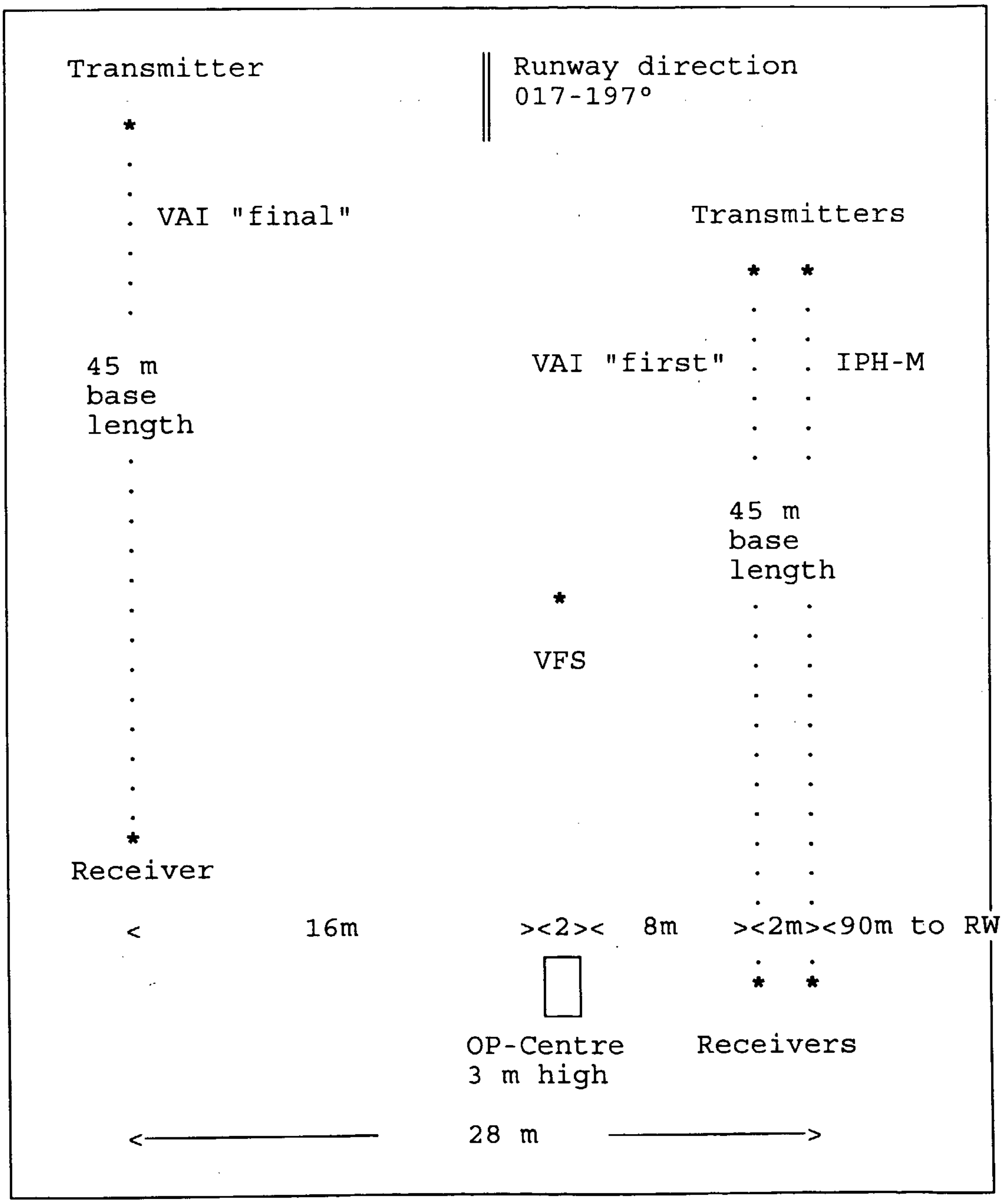
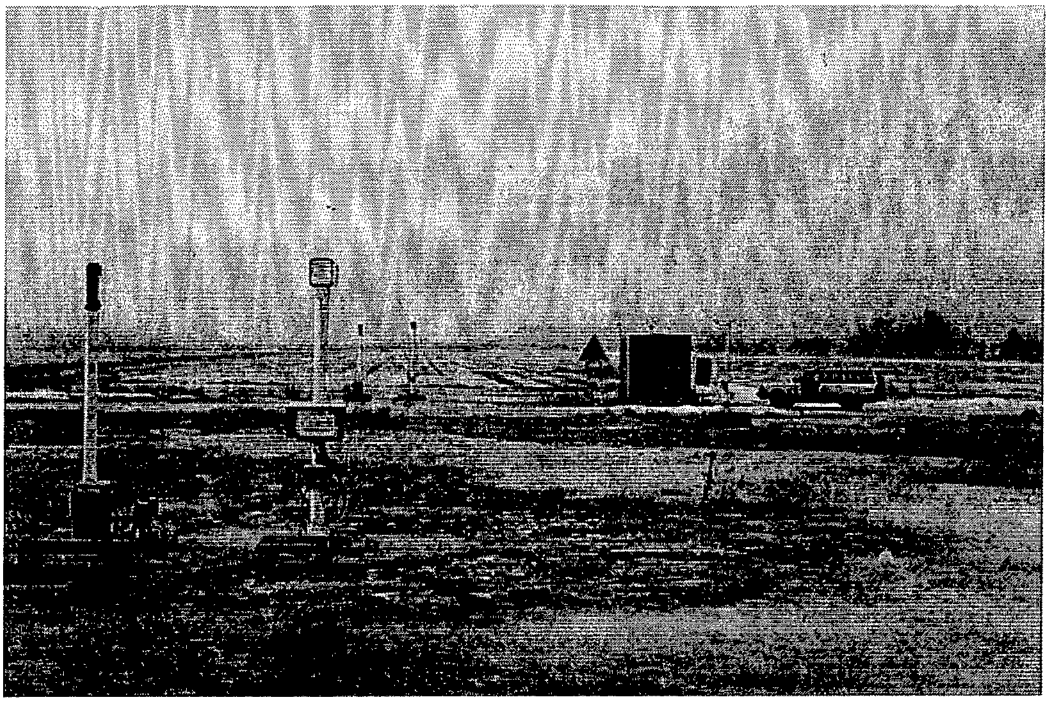
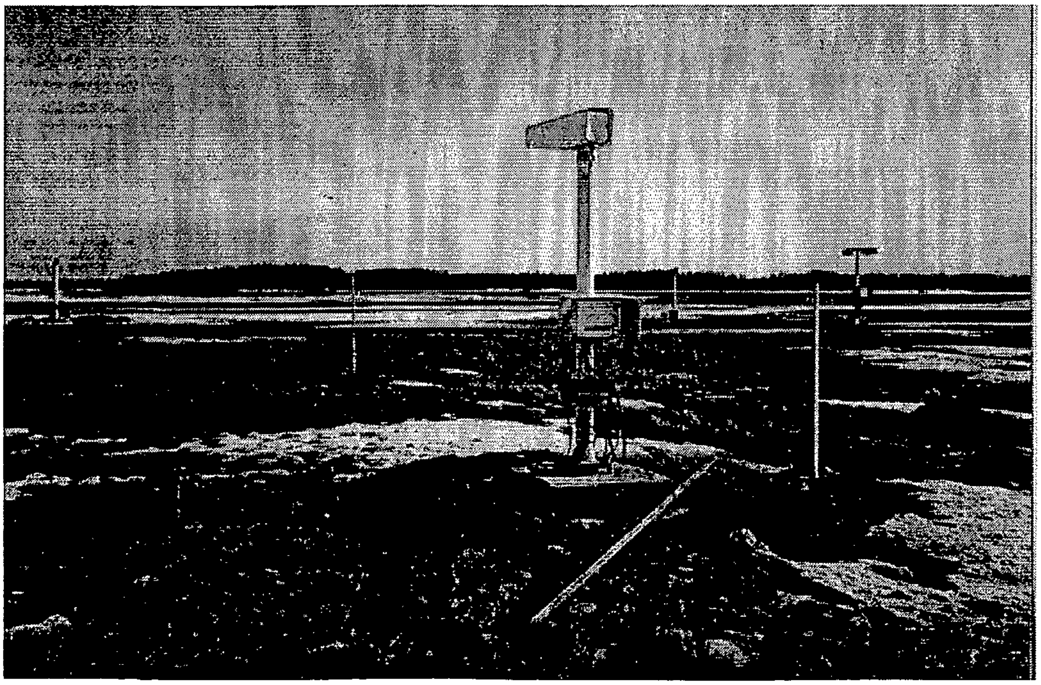


Figure 2.3.
*Details of test site **M**, 90 - 120 m west of runway 01/19. Both first and final location of the Vaisala transmissometer are marked. Instrument positions are denoted *.*



Picture 1.
Test site before removal of Vaisala transmissometer. View to the south.



Picture 2.
Test site after removal of Vaisala transmissometer. View to the northeast.

3. INSTRUMENTS

The main principles of measurement for transmissometers and forward scatter visibility meter are drawn in this chapter. Differences in instrument specifications are outlined. Measuring procedure, sampling interval, accuracy of the instruments, routine maintenance and service are described.

3.1. Principles of measurement.

3.1.1. Transmissometers.

The visibility is deteriorated as the light is attenuated by scattering and absorption. The transmissometer measures the light transmittance of the atmosphere. The instrument consists of a light transmitter and a receiver located within a precisely determined measuring distance, base line (B). The transmitter and the receiver are optically exactly aligned to each other.

The transmitter emits short high-power light pulses in the direction of the receiver. The light beam is narrow, but with a correct optical alignment the intensity of light is equally distributed over the receivers "footprint" i.e. the cross section of the optical viewing angle of the receiver and the transmitter.

The receiver contains a photo diode and an amplifier which receives the light flashes of the transmitter. A filter selects a narrow spectral band to pass to the photo diode. The electrical signals of the photo diode are amplified, integrated and converted to engineering units.

In addition to the measured transmittance, a processing unit computes the value of "Meteorological Optical Range" (MOR) and "Runway Visual Range" (RVR) by Koschmieder's and Allard's law, respectively (3):

$$MOR = \frac{B \cdot \ln \epsilon}{\ln T} \qquad \textbf{Eq. (3.1)}$$

$$MOR = \frac{RVR \cdot \ln \epsilon}{\ln \left(RVR^2 \cdot E_t / I\right)} \qquad \textbf{Eq. (3.1)}$$

with ϵ representing the brightness contrast threshold of human eye, B is the base line, T the transmittance, E_t the illumination threshold and I the runway lights intensity as a function of RVR. MOR is defined by the value 0.05 for ϵ.

3.1.2. Forward Scatter Visibility Meter.

This description is according to Vaisala FD 12.

The deterioration of visibility are represented by the intensity of forward scattered light. The forward scatter visibility meter consists of a transmitter generating infrared light pulses, and a receiver detecting the scattered light at an angle of 33° to the light beam.

The transmitter emits infrared light pulses at high frequency, 2.3 kHz. The scattered light is detected at the receiver by a photo diode and phase sensitive amplifier. The background level of scattered light is measured as an offset value while the transmitter is out of phase with the receiving photodiode.

The signal current generated by the photodiode in the receiver is converted to frequency which is measured by the processor. The frequency above offset is caused by the scattered part of the light produced by the instrument.

Fog, haze and precipitation affects the frequency in different ways. The calculation procedure involves a precipitation procedure to define the part of the frequency profile to be used in the average signal from raw samples. This average signal is then applied as a parameter to a transfer function to get visibility (MOR). The transfer function is defined empiric using a VAISALA MITRAS transmissometer.

3.2. Instrument specification and description.

3.2.1. SKOPOGRAPH II transmissometer (4).

Base length	45 m
Measuring range	30 m - 1800 m MOR
Light source	Xenon flash lamp FX 800
Flash frequency	2.5 - 3.5 Hz
Optics, transmitter	46 mm
receiver	50 mm
Viewing angle, transmitter	± 0.46°
receiver	± 0.60°
Measurement volume	2.0 m^3
Accuracy	1% in transmittance.
Resolution	0.01%
Time constant	30 sec.
Update interval	30 sec.

Measurement volume means the air volume, V, enclosed by the viewing angle of transmitter, α_1, and receiver, α_2. The formula for the double cone is:

$$V = \frac{B^3}{3} \cdot \pi \cdot \left(\frac{tg\alpha_1 \cdot tg\alpha_2}{tg\alpha_1 + tg\alpha_2} \right)^2 \qquad \textbf{Eq. (3.3)}$$

where B is the base line as before.

A hood with a narrow horizontal tube is covering the instrument windows. See Picture 3. In addition a fan directs an air stream at the angled windows from inside and out the tube. This reduce contamination from particles and precipitation on the windows. There is no compensation in measured values for the contamination on the windows.

External test filters are mounted on the receiver hood-tube for calibration purposes. In addition an internal test filter in the receiver enables a quick functional check of the instrument. This may be operated from the receiver or remote.

The receiver photo diode is continuously sensing light flashes from the transmitter. The processor integrates the amplified amplitudes and calculate an average transmittance and MOR value. The sampling period is set to 30 seconds. This means that approx. 90 flashes contribute to the calculated average.

3.2.2. MITRAS transmissometer (5).

Base length	45 m
Measuring range	30 m - 1800 m MOR
Light source	Xenon flash lamp
Flash frequency	1 - 0.1 Hz
Optics, transmitter	50 mm
receiver	96 mm
Viewing angle, transmitter	± 2.7°
receiver	± 0.63°
Measurement volume	7.6 m^3
Accuracy	1% in transmittance.
Resolution	0.01%
Time constant	30 sec.
Update interval of stored data to disk	30 sec.

The instrument windows are open and quite unprotected to contamination from particles and precipitation. See Picture 3. However the contamination is measured by a detector that makes it possible for the software to correct the measured transmittance. During heavy contamination on the instrument windows the software will alarm the user to do the cleaning.

External test filters are mounted on the receiver hood-tube for calibration purposes. The calibration process is based on software adjustments of the calibration curve according to external filter transmittance values.

The receiver photo diode is triggered by the transmitter to sense the light flash (synchronized) to avoid ambient light disturbances. The processor calculate an average of 30 instant transmittance values every 30 second as the flash frequency is 1 Hz in standard measurement mode. The corresponding MOR value is also computed.

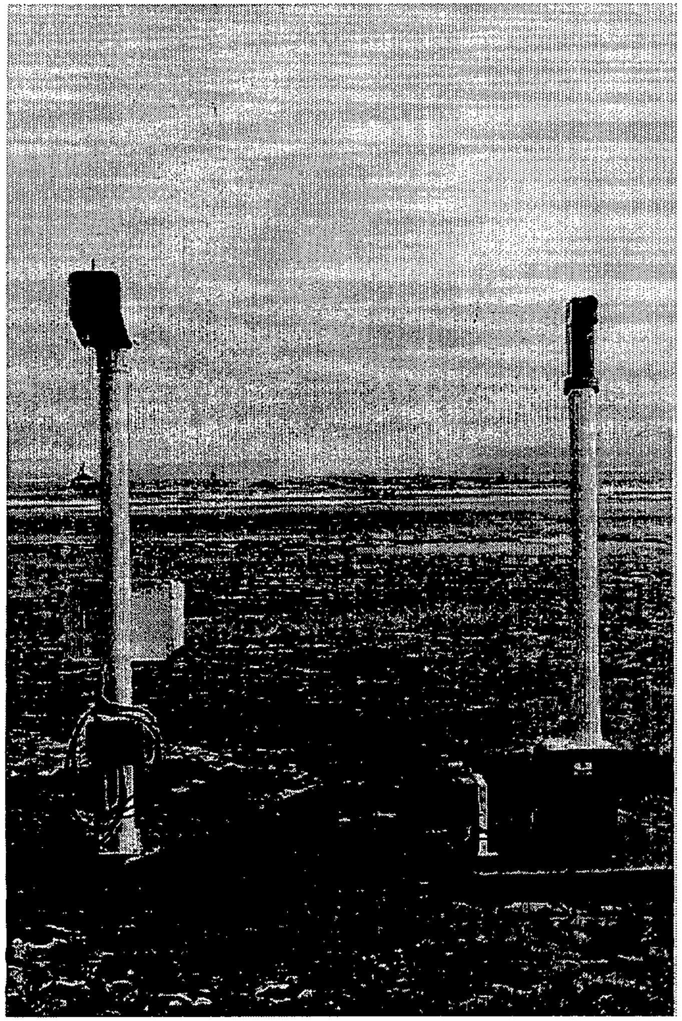
3.2.3. Visibility Meter FD 12 (6)

Measuring range	10 m - 20000 m MOR
Light source	Near-infrared Light Emitting Diode.
Modulation frequency	2.3 kHz
Forward scatter angle	33°
Accuracy in MOR values (in 80% of time)	±20% (non-frozen fog) ±30% (precipitation)
Resolution	1 m
Time constant	60 sec.
Update interval of stored data to disk	30 sec.

Narrow tubes are covering the lenses (see Picture 4) to reduce contamination and avoid direct sunlight (receiver). A back scatter measurement provides alarm status as contamination increase above a limit. Dirty lenses give too good visibility. Cleaning of lenses should be done at least every sixth month.

The calibration procedure checks two points; zero scatter signal (∞ MOR) and a very high scatter signal (approx. 10 m MOR). This is obtained by using a blocking plate and a calibrated scatterer (two white plates). See picture on page after Summary. Weather conditions should be: No precipitation and visibility more than 500 m.

The measurement procedure is shortly described in 3.1.2. The one minute average of instantaneous visibility values is stored to disk every 30 second.



Picture 3.
Impulsphysik and Vaisala transmissometers.

Picture 4.
Vaisala forward scatter visibility meter.

3.3. Routine maintenance and service.

The intercomparison period started with a complete calibration of all instruments at 22.10.91 (IPH) and 8.11.91 (Vaisala) with satisfactory results. The instruments were cleaned, aligned and checked with external filters. The Vaisala instruments were calibrated by a Vaisala representative, and our technicians were instructed to do the procedure later. The Impulsphysik transmissometers were checked by DNMI as these instruments are well known to us. Because of unexpected differences between Vaisala transmissometer and forward scatter meter, these instruments were recalibrated at 19.12.91 by a Vaisala representative.

Because of on-line contact with the IPH instruments we were able to check the status of these instruments remote. In this way we mainly visited the test site when there was a need to do adjustments, i.e. when the contamination reached an unacceptable level, or if there were other technical reasons for doing so. The instruments were cleaned about every second week. The calibration curve was checked several times and reported okay. Our technicians reported some over-compensation for contamination at the Vaisala transmissometer.

During the "first" and close position of the Vaisala transmissometer to the IPH-M transmissometer, we made several tests to find out if there was any influence between the instruments, because of the large differences in transmittance during fog conditions. Representatives from Vaisala and Impulsphysik rechecked their instruments. Both verified okay status on the instruments during calibration tests with external filters. During these tests we also checked the SKOPOGRAPH II with the external MITRAS filters and the result was within the accuracy of filters and instruments. The conclusion was:

Differences in measurements are not due to any deviations with respect to installation and calibration guides (3 and 4). The differences occur only when visibility reducing particles (droplets, snow, etc.) are introduced into the test site.

Any instrumental interference is discussed in Chapter 5.

The calibration of the instruments were checked in June 92 and found okay. As we moved the MITRAS to a more distant "final" position the instrument was again aligned and calibrated (9.12.92). The IPH transmissometers were also checked by external filters (6.1.93) and later supervised by use of internal filters. The routine maintenance and service continued throughout the test period.

3.4. Discussions about differences in transmissometer measurements.

During visits of representatives there were several discussions on possible reasons for differences in transmissometer measurements.

If we suppose no interference between instruments (as shown i Ch.5), the most plausible explanation is perhaps difference in measurement volume (defined in Paragraph 3.2.1). The contribution from scattered light to the total light intensity increases as the volume increases, i.e. a larger volume gives a higher transmittance (7).

The MITRAS transmissometer has a larger measurement volume than the SKOPOGRAPH II. This effect is not treated in the calibration curves. If they were we would be able to discover the difference while using external filters, which have no scattering effect. As we have seen no such difference in "filter transmittance", the difference in measurement volume contribute to the explanation of differences in VAI/IPH ratios (see Ch.6).

4. DATA COLLECTION

In this report we have used different types of meteorological data, project data and ordinary weather station data.

4.1. Project data.

At the position M we used an instrument hut containing data collection equipment like PC's and an EDAS station. Both the IPH PC's and the EDAS station were connected to DNMI by a telephone link. In that way we could supervise the instruments. The Vaisala PC had no such connection.

4.1.1. Impulsphysik.

The IPH transmissometers sent telegrams every 30th second to PC, consisting of transmittance, computed MOR value, background luminance, computed RVR and a number of instrument status data. The data was stored in files at an hourly basis.

4.1.2. EDAS.

The EDAS station collected 1) meteorological data, from position S and N, like wind parameters, temperature, relative humidity and precipitation yes/no from position M as 10 minute values and 2) IPH telegram data, that resulted in different 10 minute values of visibility as mean, median, minimum and maximum, and background luminance and illumination threshold.

The mean MOR values were computed by averaging the transmittance and using Koschmieder's law.

4.1.3. Vaisala.

The Vaisala PC was sampling data from the transmissometer and the forward scatter meter in a similar way as by the IPH system. Data storage was updated every 30th second by 30 second (moving) averages from the transmissometer and 1 minute (moving) averages from the forward scatter visibility meter. The 10 minute visibility means were computed by DNMI on the basis of transmittance data.

4.2. Weather station data.

4.2.1. Gardermoen.

The weather station 0478 Gardermoen is located 36 km from Oslo city to the northeast at a height of 202 m a.s.l., see Paragraph 2.1.

Gardermoen is a synoptic station with hourly observations of meteorological parameters like air pressure, temperature, wind speed and direction, visibility, precipitation, cloudiness and other weather parameters.

The exposition to fogs is described in Chapter 2.

4.2.2. Tryvasshøgda.

The weather station 1896 Tryvasshøgda is located on the top of a hill 8 km from Oslo city to the north at a height of 528 m a.s.l.. The hill is wooded, but near the top and in the southerly direction the wood is relatively sparse and from the station there is mostly an open view to all directions.

Tryvasshøgda is a synoptic station with observations at 06, 12 and 18 UTC. The meteorological parameters observed are the same as for Gardermoen.

Due to the height radiation fog very seldom reach the weather station. But low stratus frequently move from the Oslofjord area northwards and shrouds the station in fog. Thus fog observations (visibility below 1000 m) have an annual frequency of approx. 25%.

4.3. Organization of data. Fog categories.

Since a transmissometer and a forward scatter meter has a different mode of operation, it is interesting to see how fog droplets, drizzle, rain and snow affect the visibility results.

We therefore have classified the episodes with reduced visibility, MOR < 1800 m, by fog type and precipitation. The fog type classification is based on observations from Tryvasshøgda. The weather station frequently observe fog when low stratus is advancing, mainly from the southerly direction. We define this type as advection fog, FA. In calm weather when radiation fog, FR, is developing in the low lands, Tryvasshøgda most commonly is lying above the top of the fog layer. When there is doubt about which of the two fog types is dominating, the episode is classified by F. A criterion for defining a weather situation as FA, is that the weather is mainly dry. More than 0.2 mm precipitation during 6 hours at the weather station is not allowed. Another criterion is that the precipitation yes/no sensor shows no.

If this is not the case the weather type is defined as either fog with precipitation: fog and drizzle/rain, FD, or as just precipitation type: drizzle, D, rain, R, or snow, S, when precipitation is the dominating feature or the visibility is greater than 1000 m. Note: We do not require precipitation at every time interval of 10 minutes.

For the period before Vaisala transmissometer was moved, 19.12.1991-13.5.1992, there are 21 episodes separated by at least one date without fog. See Table B.1, Appendix B. For the period after the removal, 10.12.92-6.4.1993, there are 20 independent episodes. See Table B.2. The distribution of the observations on visibility is presented in Table D.2, Appendix D.

The distribution on visibility by fog/weather type for the total period is presented in Table 4.1.

Table 4.1.

Number of observations distributed on fog/weather type for the total period. All snow episodes are included. For explanation of codes, see text.

IPH-M-MOR	FR	F	FA	FD	DR	RS	S
0- 499 m	679	602	354	167	8	16	106
500- 999 m	150	136	177	79	13	54	212
1000-1499 m	97	97	112	11	82	71	262
1500-1800 m	57	92	71	9	74	78	168

In fog situations, mostly without precipitation, the visibility is mainly below 500 m. This is also the case in fog with light drizzle. When precipitation is dominating, the visibility is mainly above 500 m or 1000 m.

5. INSTRUMENTAL INTERFERENCE

The VAI transmissometer was situated close to the IPH-M instrument, only 2 m in distance, to secure exactly the same weather conditions. The Vaisala representatives claimed that IPH-M would have no influence on their instrument. After one season of measurements we found a distinct difference between the transmissometers. But this fact, was it due to any instrument being influenced by the other? The Impulsphysik representatives claimed the possibility that their instrument could have received disturbing light from the VAI transmitter, causing a lower transmittance than normal. From an Impulsphysik point of view the minimum distance between transmissometers ought to be 15 m. For that reason VAI was moved beyond this limit. The following season the measurements then was performed without any instrumental influence.

5.1. Significant changes?

To find out if visibility measurements, during the first season of test period (19.12.91-13.5.92), changed for one instrument (compared with a reference instrument) or if the relationship between two instruments differed significantly, we will use the Student's t-test of significance. Our null hypotheses are that there are no differences between instruments. Any differences will be tested at a 95% level of significance. That means that a null hypothesis may be accepted or rejected with a 95% probability for this consequence being correct. It is usual to use the technical term "probably significance" in such cases.

In time series with observations at every 10 minute there is a high dependence between the data. In order to handle this problem we use the autocorrelation of each time series to correct the significance test.

The equations used for the significance test with corrections are described in Appendix C.

5.2. Any change of IPH-M transmittance?

At Gardermoen 3 IPH transmissometers were situated along the runway, at a distance of 1000 m between position S (south) and M (midway), of 1200 m between position N (north) and M.

We now compare IPH-M with the middle value of IPH-S and IPH-N (IPH-S,N).

In some fog situations the instruments, all with base line 45 m, show a rather great difference in visibility along the runway. To secure relatively homogeneous conditions from south to north we define the following premises: The ratio between 10 minute mean values of MOR-S and MOR-N shall be between 0.7 and 1.3. At a typical visibility of 100 m (1000 m) MOR this means a maximum permitted difference of about 30 m (300 m) between these two instruments.

To secure a relatively time stable homogeneity a ratio of 1.0-1.5 between the 30 second maximum and minimum values during 10 minutes is demanded. Here upper maximum MOR limit of all 3 instruments is set to 1800 m.

The comparison between the instruments is performed for 3 periods of time: P1) 20.4.91-31.10.91, P2) 9.11.91-6.2.92 and P3) 10.12.92-25.3.93. All weather situations with MOR below 1800 m is included. The result is presented in Table 5.1. For further details see Appendix D, Table D.1.

Explanation to the dates:

19.4.91:	IPH-M amplifier unit (receiver) changed.
1.11.-8.11.91:	Vaisala transmissometer system established.
19.12.91:	Calibration of Vaisala instruments completed.
7.2.92:	IPH-S amplifier unit (receiver) changed and new one out of calibration.
13.5.92:	End of first season.
10.12.92:	Removal of Vaisala transmissometer finished.
25.3.93:	Vaisala transmissometer dismounted.
6.4.93:	End of second season.

Table 5.1.

A comparison between MOR values of IPH-M and IPH-S,N for 3 periods: P1) Before VAI was installed, P2) VAI and IPH 2 m apart and P3) VAI and IPH 28 m apart. Average ratio, k=IPH-M/IPH-S,N and corresponding standard deviation (STD) is presented. NO is number of observations.

IPH-M/ IPH-S,N M-MOR [m]	P1			P2			P3		
	NO	k	STD	NO	k	STD	NO	k	STD
0- 499	60	1.01	0.10	234	1.00	0.11	189	0.99	0.10
500- 999	29	1.02	0.07	50	0.96	0.11	48	0.96	0.11
1000-1499	22	1.03	0.12	48	0.91	0.06	33	0.94	0.08

Here all weather types are included, both precipitation and no precipitation situations. Only one period with snow is omitted: 27-28.2.93. This is a period with snow drift and extraordinary visibility conditions and will be described later.

There is no significant difference between the 3 periods as far as visibility below 500 m MOR are considered. We have also checked the interval 0-200 m MOR with the same result. Primarily an influence should be expected for the lower visibility values (see below). Then we can say that there is highly probable that IPH-M is not affected by the presence of a Vaisala transmissometer.

For visibility above 1000 m it seems to be significant lower IPH-M visibility values for the period when IPH-M and Vaisala were situated close together. But now it is relevant to look at the accuracy in the measurements. The 100% transmittance level has to be adjusted regularly. This can only be done in near 100% conditions. In periods with fog, a difference of 1-2% in relative transmittance between two of the instruments must be regarded as normal. With reference to Appendix A, Table A.1 one will see that 1% relative change in the transmittance means a ratio of 1.01-1.03 at MOR=200-400 m and around 1.10 at MOR between 1000 and 1800 m. This fact gives a reasonable explanation of the difference between the periods.

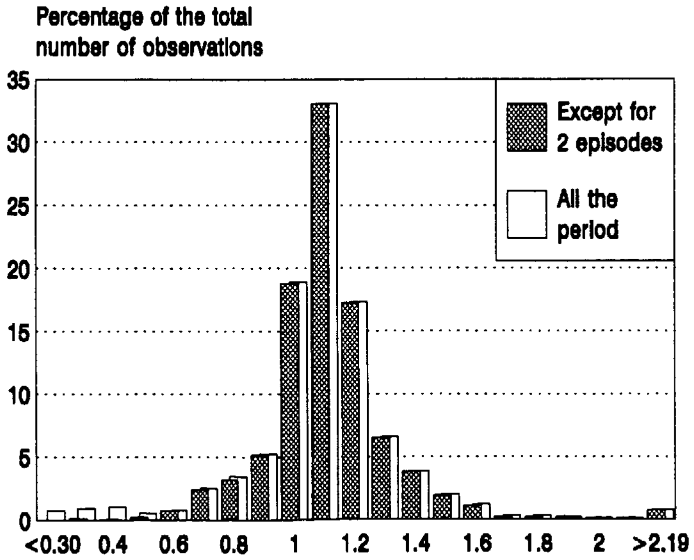
Our conclusion therefore is that IPH-M is not affected by the presence of a Vaisala transmissometer during the period 19.12.91-13.5.92.

5.3. Any change of Vaisala transmittance?

To find out whether VAI transmissometer measurements are affected by the presence of the IPH-M transmissometer, we have to study the 2 periods: Q1) 19.12.91-13.5.92 and Q2) 10.12.92-25.3.93.

We start with the total period and look for the ratio VAI/IPH. For all IPH-M 10 minute mean MOR values below 1800 m and VAI values below 3000 m we find the VAI/IPH distribution in Figure 5.1. Except for the ratio below 0.5 it looks like a symmetrical distribution around an average value in the interval 1.10-1.19. An analysis of the data shows that the lowest ratios are mainly due to two snow drifting periods: 2.4.92 10:10-18:00 and 27.2.93 04:40-28.2.93 07:00. During these periods the 10 minute mean wind speed was above 11 knots and partially above 15 knots with wind from northerly direction. The latter of these periods is the same which was omitted under Paragraph 5.2. If the two periods are omitted we have a reasonable distribution of the ratio. See Figure 5.1.

Figure 5.1.
The ratio VAI/IPH distribution in truncated values for 1) the total period of measurement: 19.12.91-25.3.93 and 2) when two snow drifting periods are omitted.



For the further analysis we do not take into account the ratios higher than 2.1. When the two mentioned periods are omitted the high ratio data represents only 0.8% of the total data. If these data were included they would contribute unreasonably to the average and the standard deviation.

The comparison between the IPH and VAI transmissometers for the two periods, Q1 and Q2, is presented in Table 5.2.

Table 5.2.

A comparison between MOR values of VAI and IPH-M for 2 periods: Q1) VAI and IPH 2 m apart and Q2) VAI and IPH 28 m apart. Average ratio, k=VAI/IPH and corresponding standard deviation (STD) is presented. NO is number of observations.

VAI/IPH	Q1			Q2		
MOR [m]	NO	k	STD	NO	k	STD
0- 499	1205	1.15	0.12	589	1.16	0.11
500- 999	481	1.12	0.19	220	1.09	0.22
1000-1499	445	1.20	0.20	232	1.12	0.27

For visibility below 500 m the table shows just a small difference between the two periods. For visibility above 1000 m the difference appear to be significant, but can be explained by the decrease in the IPH-M values. A comparison between VAI and IPH-S,N gives a ratio of 1.09 and 1.05 respectively. Table D.2, Appendix D, shows no significant change between the two periods for the interval 0-200 m.

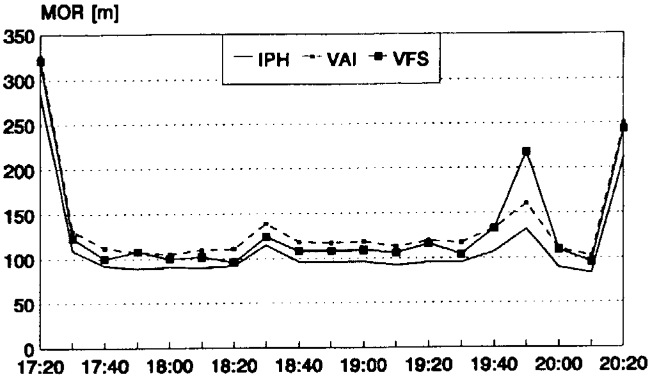
For the same reason as for the conclusion in the previous paragraph it is highly probable that VAI is not affected by the presence of an Impulsphysik transmissometer during the period 19.12.91-13.5.92.

6. COMPARISON BETWEEN VISIBILITY INSTRUMENTS

We have shown that there has not been any interference between the VAI and the IPH transmissometers. We can then do our analysis on the total period 19.12.91-25.3.93, with exception for 13.5.-9.12.92, when no comparable measurements were done because of the removal of the Vaisala transmissometer by 26 m to the northwest.

A typical relationship between the three instruments in dense fog is shown in Figure 6.1. IPH measures mostly the lowest visibility values, VAI mostly the highest ones.

Figure 6.1.
Visibility measurements at Gardermoen 1.2.92 under normal fog conditions.



6.1. Difference in transmittance between Vaisala and Impulsphysik transmissometers.

So far we have looked upon differences and ratios of MOR values. We will now consider the transmittances. We have seen from Table 5.2 that the average ratio between VAI and IPH is about 1.15, all visibility intervals included. We now want to look at the typical real difference in transmittance between VAI and IPH compared with the effects of reasonable deviations and the instrumental accuracy. This is shown in Figure 6.2. See also Appendix A.

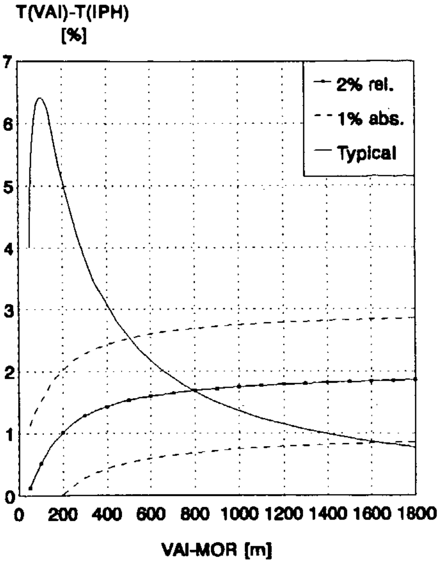


Figure 6.2.
The real difference in transmittance between VAI and IPH distributed on VAI-MOR values in the interval 0-1800 m in typical fog situations. See also Paragraph 6.2. In addition is shown a theoretical relative difference of 2% and an absolute uncertainty of 1% transmittance.

From Figure 6.2 we see that above 800 m the difference in observed transmittance between the instruments can be explained by a difference of 2% in the 100%-level. This is a difference that may be due to contamination on the lenses combined with the fact that Vaisala transmissometer compensates for this.

Below 500 m the difference in transmittance is increasing to values that exceed the instrumental accuracy. As the instruments both showed the same transmittance (within instrumental accuracy) to 25% external filters, the difference between the two instruments in dense fog must be due to consequences of differences in measurement design. See Ch.3.

The 500 m level described here is not absolute. It will change with weather type and with the relative difference in the 100%-level. It is reasonable that this level will mostly lie between 400-600 m.

As we have seen so far differences between the two instruments for visibility above 500 m can be explained by a 2% difference in transmittance at the 100% level combined with an absolute difference in transmittance of 1%.

Further analysis will concentrate on visibility below 500 m.

6.2. Vaisala's transmissometer versus Impulsphysik's.

We have seen from Table 5.2 that the average ratio between VAI and IPH is about 1.15, all visibility intervals included. Table 6.1 shows that this result is probably significant, when differences in the mean MOR values of VAI and IPH are considered.

Table 6.1.

Result of the significance test of differences in MOR values between VAI and IPH for different types of fog at Gardermoen. Effect.no. and k-auto critical means respectively the number to use in the t-test (VAI first, IPH second no.) and resulting k-critical value from the t-test when autocorrelation is considered, Δ_{MOR}*=VAI(avg)-IPH(avg),* k_{MOR}*=VAI(avg)/IPH(avg), k-critical means critical k-value from the t-test without autocorrelation.*

MOR [m]	WEATHER	NO. OF OBS.	EFFECT. NO.	Δ_{MOR} [m]	k_{MOR}	k-auto critical	k-critical
0-200	All fog	971	165/144	22	1.16	1.05	1.02
0-500	All fog	1774	274/242	29	1.14	1.08	1.03
0-200	Rad. fog	412	135/119	26	1.19	1.05	1.03
0-500	Rad. fog	652	217/184	32	1.16	1.08	1.04
0-200	Adv. fog	185	26/ 22	19	1.13	1.10	1.03
0-500	Adv. fog	524	46/ 49	25	1.10	1.16	1.04

The "all fog situations" include situations with or without precipitation, except for snow. If we divide the situations into radiation fog (FR) and advection fog (FADR) we still have significant k-values for radiation fog in both intervals and for advection fog in the interval 0-200 m. In the next paragraph we shall see if the differences in k-values between radiation fog and advection fog are probably significant.

Data for all fog types (snow situations excluded) is presented in Figure 6.3. Figure 6.4 shows that the ratio between VAI and IPH varies between 1.2 and 1.1 in the interval 0-500 m and the ratio increases when the visibility decreases.

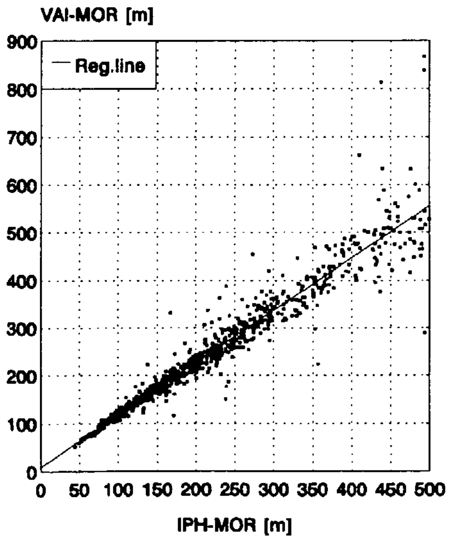
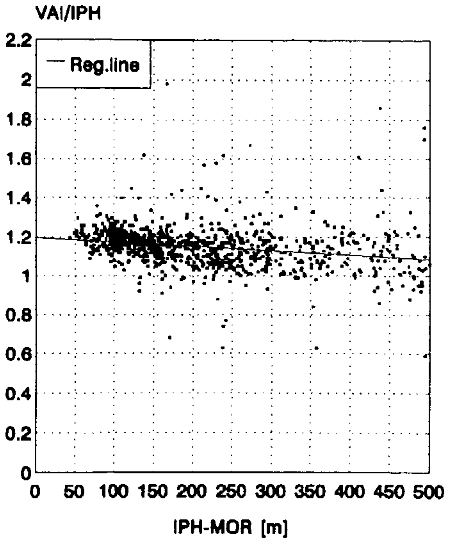


Figure 6.3.

VAI-MOR distributed on IPH-MOR values in the interval 0-500 m (all fog, total test period). Ratios above 2.1 is omitted. About every second observation is shown in the figure (887 of 1783 due to software limitations). Regression line:
VAI(MOR)=1.09·IPH(MOR)+9.50.
Correlation: 96%.

Figure 6.4.
The ratio VAI/IPH distributed on IPH-MOR values in the interval 0-500 m (all fog, total test period). Regression line: VAI/IPH=-0.00023·IPH(MOR)+1.199.



The first WMO intercomparison of visibility instruments (9) during the winter season 17.10.88-10.5.89 also showed higher Vaisala MOR values than SKOP D75 (Impulsphysik) ones, with a base line of 75 m. The following ratios are taken from figures, where both no precipitation and any precipitation situations are considered. All numbers are approximately. R denotes a reference value which is a median value of extinction coefficient determined from the measurements of all instruments (or a subset of instruments). In no precipitation at MOR interval 0-200 m they found VAISALA/R $\approx$ 0.95 and SKOP D75/R $\approx$ 0.8-0.85. In any precipitation situations at MOR interval 0-500 m they found VAISALA/R $\approx$ 1.1 and SKOP D75/R $\approx$ 0.95. This gives a VAISALA/SKOP D75 ratio of about 1.15, which is in good accordance with our results.

6.2.1. VAI versus IPH in different fog types.

We will now see how the ratio VAI/IPH is distributed on different weather types. See Table 6.2 and Appendix E. The two snow drifting periods mentioned in Paragraph 5.3 is omitted.

Table 6.2 shows that Vaisala has higher MOR values than Impulsphysik for all types of weather. The ratio is highest in radiation fog and snow, lowest in advection fog and drizzle/rain. Scatter diagrams of the simultaneous VAI and IPH observations are shown in Appendix E, Figure E.3-E.4. In this paragraph we will deal with three main types of weather: 1) Radiation fog (FR), 2) advection fog with drizzle/rain included (FA, FD and DR, shortly FADR) and 3) snow, where two snow drifting periods are omitted (SX).

Table 6.2.
Upper part shows the number of observations, lower part the ratio between MOR values of VAI and IPH distributed on fog/weather type for the total period. For explanation of codes, see text in Paragraph 4.3.

IPH-MOR	FR	F	FA	FD	DR	RS	SX
0- 499 m	652	598	349	167	8	7	14
500- 999 m	138	130	169	79	13	43	129
1000-1499 m	87	96	110	11	82	63	228
1500-1800 m	45	89	71	9	74	68	135

VAI/IPH	FR	F	FA	FD	DR	RS	SX
0- 499 m	1.18	1.16	1.11	1.10	1.03	1.30	1.26
500- 999 m	1.18	1.13	1.04	1.10	1.01	1.11	1.12
1000-1499 m	1.31	1.19	1.04	1.17	1.04	1.24	1.20
1500-1800 m	1.30	1.27	1.06	1.17	1.16	1.23	1.24

As mentioned scatter diagrams for the two first weather types are shown in Appendix E. The third weather type is shown in Paragraph 6.2.2. The types F and RS will not be commented further. The Type F distribution lies between FR and FA (nearest FR), RS is similar to SX, but we do not want to include observations of rain in the pure snow situations. The ratios of DR, RS and SX for the 0-499 m interval can not be attached great importance, due to only a few observations.

We have found the k-values of radiation fog and advection fog in Table 6.1. Table 6.3 shows that the differences between these k-values are probably significant.

Table 6.3.
Result of the significance test of differences in k-values between radiation fog (FR) and advection fog (FADR) at Gardermoen. Effect. no. and k-auto critical means respectively the number to use in the t-test (FR first, FADR second no.) and resulting Δ_k-critical value from the t-test when autocorrelation is considered, $\Delta_k = k_{FR}(avg) - k_{FADR}(avg)$, Δ_k-critical means critical Δ_k-value from the t-test without autocorrelation.

MOR [m]	WEATHER	NO. OF OBS.	EFFECT. NO.	Δ_k	Δ_k-auto critical	Δ_k- critical
0-200	FR versus FADR	412/185	236/ 77	0.06	0.02	0.01
0-500		652/524	430/239	0.08	0.02	0.01

6.2.2. VAI versus IPH in snow.

There are just a few observations of snow with visibility below 500 m. These are too few and the scattering too high to give any significant result. Here we are content to present the scatter diagrams for the interval 0-1800 m (Figures 6.5-6.6). More about snow situations in Paragraph 6.5.

Figure 6.5.
The VAI-MOR distributed on IPH-MOR values in the interval 0-1800 m in periods with snow. Total period, except for two snow drifting episodes. Regression line: VAI(MOR) = 1.31·IPH(MOR)-127.28. Correlation: 91%.

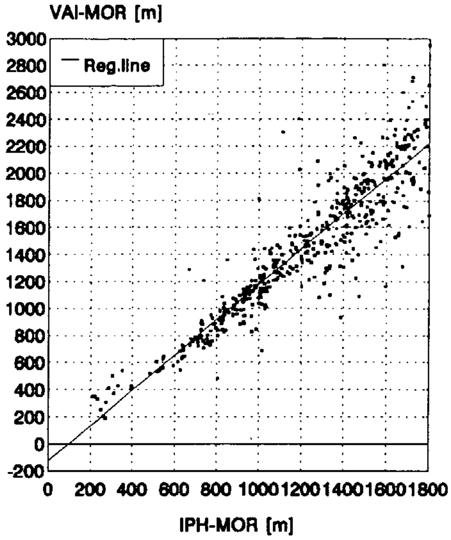
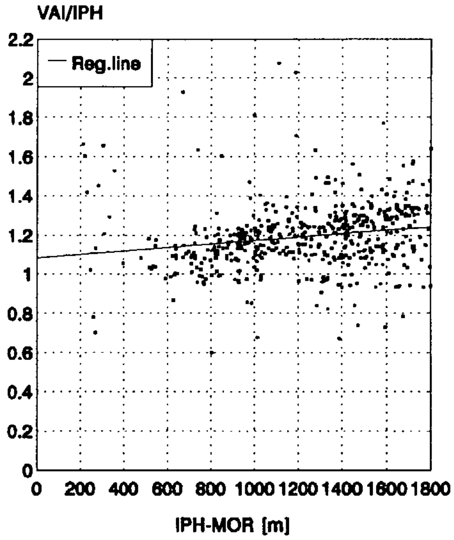


Figure 6.6.
The ratio VAI/IPH distributed on IPH-MOR values in the interval 0-1800 m in periods with snow. Total period, except for two snow drifting episodes. Regression line: VAI/IPH= 0.00009·IPH(MOR)+1.084.



We have seen that the VAI/IPH ratio increases when the visibility decreases. This is the case in typical fog situations, but not in snow. Figure 6.6 shows an opposite trend. In the interval 500-1800 m the ratio varies between 1.0 and 1.4. It has the lowest value in low visibility, but seems to increase with decreasing snow intensity. The outliers are caused by snow drift (see Paragraph 6.5).

6.3. Vaisala's transmissometer versus forward scatter visibility meter.

Before starting the measurements in December 1991 a representative of Vaisala calibrated the VFS instrument. During the second period, the instrument was calibrated by DNMI. This was not done before January 1993, and then incorrectly by mounting the control plates the wrong way. This affected the measurements in January and February 1993.

Due to uncertainty about the calibration we decide to use the first period only in the analysis of the forward scatter meter to continue.

We now analyse the relationship between simultaneous data from the Vaisala transmissometer and forward scatter meter. The ratio is distributed on different weather types. See Table 6.4 and Appendix E. One snow drifting period, 2.4.92 08:00-18:00 is omitted.

Table 6.4.

Upper part shows the number of observations, lower part the ratio between MOR values of VAI and VFS distributed on fog/weather type for the period 19.12.91-13.5.92. For explanation of codes, see text in Paragraph 4.3.

VAI-MOR	FR	F	FA	FD	DR	RS	S
0- 499 m	506	275	240	120	8		2
500- 999 m	88	73	134	84	7	28	49
1000-1499 m	45	37	77	11	31	27	102
1500-1999 m	39	39	68	11	20	40	83
2000-2499 m	32	30	37	4	33	80	43
2500-2999 m	23	13	15	2	16	28	28

VAI/VFS	FR	F	FA	FD	DR	RS	S
0- 499 m	1.03	1.06	1.02	1.03	1.08		1.24
500- 999 m	1.04	1.11	1.04	1.13	1.06	1.07	1.07
1000-1499 m	1.14	1.12	1.13	1.25	1.09	1.17	1.08
1500-1999 m	1.13	1.07	1.17	1.15	1.23	1.21	1.12
2000-2499 m	1.26	1.12	1.23	1.23	1.25	1.19	1.10
2500-2999 m	1.29	1.20	1.37	1.25	1.18	1.18	1.16

For all weather types, with a possible exception for snow (only 2 observations), the ratio VAI/VFS is around 1.03 for the lowest visibility interval. For this interval the difference between the two Vaisala instruments is not significant, nor for the 0-200 m interval. See Table 6.5 and scatter diagrams in Appendix E, Figure E.5 and E.6. The ratio is increasing with increasing visibility and reaches 1.2-1.3 for the 2000-3000 m interval. In snow situations and visibility above 1000 m it looks like the ratio is increasing when snow is melting to rain drops.

The VAI transmittance never exceed 100%. Thus the high ratios at higher visibility must be due to a real measure difference between the instruments. This difference is significant for visibility above approx. 500 m. See Table 6.5.

Table 6.5.
Result of the significance test of differences in MOR values between VAI and VFS for all types of fog at Gardermoen, for the period 19.12.91-13.5.92, for different MOR-intervals. For explanations see Table 6.1.

MOR [m]	WEATHER	NO. OF OBS.	EFFECT. NO.	Δ_{MOR} [m]	k_{MOR}	k-auto critical	k-critical
0- 200	All fog	503	101/ 94	4	1.03	1.06	1.02
0- 500	All fog	1150	191/192	4	1.02	1.08	1.03
500-1000	All fog	386	191/125	37	1.05	1.04	1.03
1000-1500	All fog	301	129/ 70	116	1.10	1.04	1.03

6.4. Vaisala's forward scatter visibility meter versus Impulsphysik's transmissometer.

We now analyse the relationship between simultaneous data from the Vaisala forward scatter meter and IPH transmissometer. The ratio is distributed on different weather types. See Table 6.6 and Appendix E. One snow drifting period, 2.4.92 08:00-18:00 is omitted.

Table 6.6.
Upper part shows the number of observations, lower part the ratio between MOR values of VFS and IPH distributed on fog/weather type for the period 19.12.91-13.5.92. For explanation of codes, see text in Paragraph 4.3.

IPH-MOR	FR	F	FA	FD	DR	RS	S
0- 499 m	493	297	248	133	8	2	2
500- 999 m	99	66	122	77	8	33	70
1000-1499 m	64	38	99	9	42	49	129
1500-1800 m	38	29	56	9	46	54	58

VFS/IPH	FR	F	FA	FD	DR	RS	S
0- 499 m	1.14	1.11	1.09	1.05	0.97	1.12	1.35
500- 999 m	1.16	1.06	0.97	0.97	0.98	1.04	1.14
1000-1499 m	1.14	1.11	0.96	0.91	0.98	1.03	1.13
1500-1800 m	1.17	1.07	0.92	0.95	1.07	1.05	1.11

The VFS instrument is calibrated on the basis of VAI measure values. We therefore must expect similar results like those we found for VAI/IPH in Paragraph 6.2. The table shows somewhat reduced ratios for the 0-500 m interval. For higher intervals the ratios are considerably lower, especially for the advection fog types.

For all fog situations the ratio VFS/IPH is around 1.10 (Table 6.7) for visibility below 500 m. For the radiation fog situations the ratio is around 1.15 for all visibility intervals. For advection fog the ratio is about 1.05-1.10 for the lowest visibility interval and is below 1 for the 500-1000 m interval. It is further decreasing with increasing visibility and reaches 0.90-0.95 for the 1000-1800 m interval (Table 6.6).

When we have snow the ratio rises to 1.10-1.15 for the 500-1800 m interval. With melting snow and rain drops included the ratio is decreasing by about 10%.

For all fog types included the significance test shows a similar result as for the relationship VAI/IPH. See Table 6.7. Ratios of 1.13-1.10 for the 0-200 m and 0-500 m intervals respectively are probably significant.

Table 6.7.

Result of the significance test of differences in MOR values between VAI and VFS for all types of fog at Gardermoen, for the period 19.12.91-13.5.92. For explanations see Table 6.1.

MOR [m]	WEATHER	NO. OF OBS.	EFFECT. NO.	Δ_{MOR} [m]	k_{MOR}	k-auto critical	k-critical
0-200	All fog	594	133/121	18	1.13	1.05	1.02
0-500	All fog	1180	209/173	22	1.10	1.09	1.03

Significance for higher visibility intervals is not considered, for the same reasons as before.

6.5. Snow situations.

Regarding the relationship between instruments in snow situations, we have so far omitted two situations: S1) 2.4.92 08:10 (10:10)-18:00 and S2) 27.2.93 04:40 - 28.2.93 07:00. In these situations there was a rather high snow intensity and a 10-minute mean velocity around 7-8 m/s from north. The temperature was approx. -3°C during both the periods. Figure 6.7-6.8 shows the MOR-values of IPH, VAI and VFS for these two periods.

Figure 6.7.

The snow drifting period 2.4.1992. IPH is marked with the thick line. Something is happening to VAI between 9:00 and 10:00, with consequences for many hours ahead.

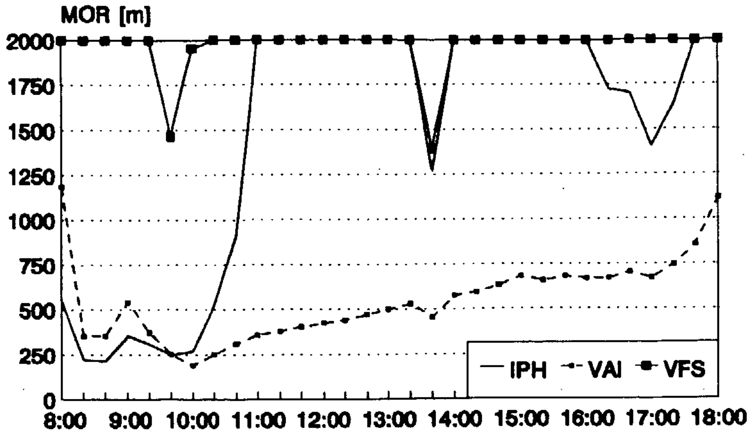
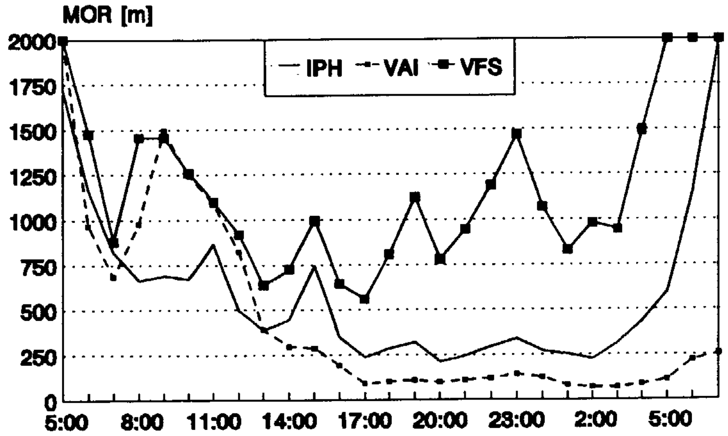


Figure 6.8.

The snow drifting period 27-28.2.1993. IPH is marked with the thick line. Something is happening to VAI at the 27th between 5:30 and 7:30, but the instrument seems to correct itself. From 14:00 VAI lies below IPH for the rest of the period.



The figures shows that the "normal" relationship between VAI and IPH breaks down, resulting in an unreasonable VAI/IPH ratio. This must be due to the weather conditions. We do not know the outward influence on the instruments. It seems as if both instruments are influenced, but IPH to a lesser degree.

Thus there is a reason for taking into account the wind conditions when VAI and IPH is compared in snow situations. We set a mean wind speed level to 5 m/s and find the VAI/IPH ratio for these two cases. The results are shown i Figure 6.9-6.10.

Figure 6.9.
The ratio VAI/IPH distributed on IPH-MOR values in the interval 0-1800 m in periods with snow and 10-minute mean wind speed below 5 m/s (total test period).

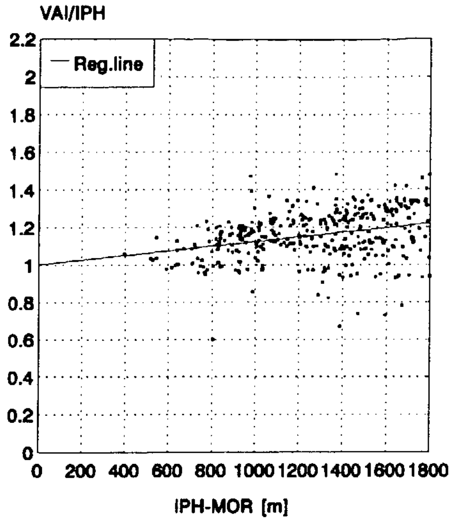
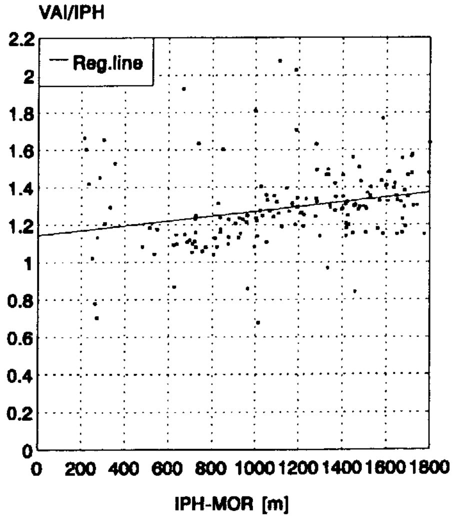


Figure 6.10.
The ratio VAI/IPH distributed on IPH-MOR values in the interval 0-1800 m in periods with snow and 10-minute mean wind speed above 5 m/s (total test period, except for the two mentioned wind drifting episodes).



In opposition to the fog situations it looks like the ratio VAI/IPH is decreasing with decreasing MOR values. The ratio is higher when the wind speed is high, but then the standard deviation is also higher.

We see that the VAI and IPH transmissometer measurements are differently influenced in snow, and with strong winds the scattering of the VAI/IPH ratios are strong. With weak winds the ratios seem to lie between 1.0 and 1.2 at visibility around 600-1000 m.

6.6. RVR considerations.

Instrumental RVR is based on Allards law and the ICAO recommendations for determination of runway lights intensity (3). One has to measure transmittance and background luminance. In addition the runway lights intensity as a function of RVR must be known.

Vaisala's procedure of calculating RVR differ a little from Impulsphysik's, concerning the illumination threshold, E_t. See Equation 6.1 and 6.3. This parameter is a function of the background luminance, B_L. See Table 6.8.

Impulsphysik.

IPH uses the following formula:

$$E_t = 10^{\log STX + A1(\log B_L - \log A2)} \qquad \text{Eq. (6.1)}$$

The values used in the calculations is presented in Table 6.8.

Table 6.8.

The parameter values for Equation 6.1.

B_L [cd/m^2]	log B_L	log STX	A1	log A2
0 - 100	0 - 2	-6.70	0.675	0
100 - 10000	2 - 4	-5.35	0.9	2
10000 - 100000	4 - 5	-3.55	1.2	4

At Gardermoen the background luminance meter measures in the interval 1-100000 cd/m^2. When the value is below 1 B_L is set to 1. This value corresponds to $E_t = 10^{-6.7}$.

Vaisala.

VAI uses the following formula (10):

$$E_{t,m} = 10^{-7.0 + 0.89 \cdot \log B_L} \qquad \text{Eq. (6.2)}$$

where $E_{t,m}$ is the uncorrected illumination threshold. The background luminance at night increases as fog becomes denser due to the forward scatter of light from runway approach and lighting systems. The illumination threshold is corrected by a factor, k:

$$E_t = k \cdot E_{t,m} \qquad \text{Eq. (6.3)}$$

The correction factors are presented in Table 6.9.

Table 6.9.
The correction factor in Equation 6.3 depends on the illumination threshold level.

$E_{t,m}$ [lux]	10^{-3}	10^{-4}	10^{-5}	10^{-6}
MOR $\geq$ 50 m	1	1.8	3	5
MOR < 50 m	1	2.2	4	10

The table shows higher correction factors when fog is denser (MOR < 50 m). There is no correction factor for $E_{t,m}=10^{-7}$. It seems reasonable that these factors are greater than those for $E_{t,m}=10^{-6}$, but this is not taken into account for the calculations in this report.

Effect of different RVR procedures.

The differences in RVR values between the two procedures are shown i Appendix F.

The practical consequences of different RVR procedures for radiation fog and advection fog at Gardermoen is shown in Table 6.10. For radiation fog the MOR ratio is found from Figure E.1: $VAI/IPH=-0.000235 \cdot IPH+1.22$. For advection fog the MOR ratio is found from Figure E.2: $VAI/IPH=-0.000243 \cdot IPH+1.17$. These ratios is used in the calculations of RVR (see table on next page). Only night and day conditions are shown. Twilight conditions are close to day conditions, as they are defined here. See Appendix F.

Table 6.10.

The ratio between RVR values of VAI and IPH at night ($B_L=1$ cd/m^2) and day ($B_L=1000$ cd/m^2) conditions, in radiation fog and advection fog, for MOR values below 500 m.

Generally for IPH			Radiation fog			Advection fog		
	Night	Day		Night	Day		Night	Day
MOR [m]	RVR [m]	RVR [m]	MOR [m]	RVR [m]	RVR [m]	MOR [m]	RVR [m]	RVR [m]
IPH	IPH	IPH	VAI/ IPH	VAI/ IPH	VAI/ IPH	VAI/ IPH	VAI/ IPH	VAI/ IPH
100	393	250	1.20	1.09	1.04	1.15	1.05	1.01
200	708	429	1.17	1.06	1.01	1.12	1.02	0.98
300	994	582	1.15	1.03	0.98	1.10	1.00	0.95
400	1261	719	1.13	1.01	0.96	1.07	0.97	0.93
500	1515	845	1.10	0.99	0.94	1.05	0.95	0.91

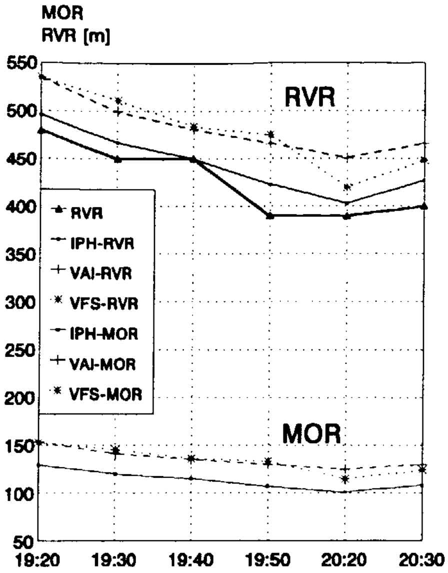
The Table shows 10-15% lower ratios between RVR values than between MOR values. This is mainly due to the increasing background luminance because of the runway lights, that Vaisala has taken into account, as opposed to Impulsphysik. For the lowest MOR values, around 100 m, the RVR ratios VAI/IPH are still higher than 1, about 1.10 in radiation fog at night, 1.05 in radiation fog during the day and in advection fog at night. In advection fog during the day the ratios are close to 1. For higher MOR values the ratios are decreasing and lower than 1 for MOR values higher than 200-500 m, depending on night/day conditions and fog type.

We have earlier made a comparison between visual observed RVR by personnel of the Civil Aviation Authority at the airport and instrumental RVR from the IPH instruments (2). For RVR below 600 m we found for relatively homogeneous conditions for the south and the north position respectively: $IRVR=1.04 \cdot RVR_{01}$ and $IRVR=0.99 \cdot RVR_{19}$. This was a rather poor comparison because of some non-simultaneous observations. For 29 simultaneous observations (time accuracy 1 minute) at the midway position, the RVR between 240 and 1200 m, we found $IRVR(<600\text{ m})=1.01 \cdot RVR_M$. This indicates that the IPH-RVR values are close to the visual observed RVR. VAI-RVR would possibly give some percent higher factor than 1.01, compared with RVR_M.

The authors were permitted by the air traffic controller to observe the visual RVR at the midway position at 10.2.1993 19:15-20:30 under stable and homogeneous radiation fog conditions. The instrumental RVR values are computed and presented in Figure 6.11.

Figure 6.11.

A comparison between visually observed RVR and instrumental ones at Gardermoen at 10.2.1993 19:20-20:30. The visual observations are based on counting of runway lights, all 60 m apart, at each 30 second. To the distances are added 30 m. The VAI values are computed in accordance with Vaisala's procedure, with a correction factor, k=5. For the present situation runway light intensity, $I_{RVR=390\text{-}480\ m}$, *is set to 5000 cd (2).*



The figure shows that IPH-RVR values are about 4% too high compared with the visual observed ones, and that VAI-RVR values are even higher, about 14%. At MOR-values of 100-130 m we found a VAI_{MOR}/IPH_{MOR} ratio around 1.2 and a VAI_{RVR}/IPH_{RVR} ratio around 1.1. This is in good agreement with the results found in Table 6.10.

7. CONCLUSIONS

All transmissometers at Gardermoen measured over a base line of 45 m. Calibration of instruments were performed several times during the test period with satisfactory results. Necessary adjustments of the 100% level were done regularly.

VAI versus IPH transmissometer.

A comparison between the three IPH transmissometers in position S, M and N respectively, during relatively homogeneous and time stable fog conditions, showed that IPH-M was not affected by the presence of a Vaisala transmissometer.

This fact was used to answer the corresponding question: Was VAI affected by the presence of an Impulsphysik transmissometer? Again the answer was no.

For the total test period 19.12.91-25.3.93 and all fog types, snow excepted, we found a MOR ratio VAI/IPH=1.16 and 1.14 for the IPH-MOR intervals 0-200 and 0-500 m respectively. From a Student's t-test with autocorrelation this result represents a difference between the two transmissometers, which is probably significant (95% level of significance). The result is in good accordance with the results from the first WMO intercomparison of visibility measurements, where IPH and VAI were compared over a base line of 75 m.

For the 0-200 m VAI-MOR interval this means an absolute difference in transmittance of more than 5% between the instruments, which is far beyond the uncertainty level of measurements, even when an inaccuracy of 1% is considered.

As the instruments both showed the same transmittance (within instrumental accuracy) to 25% external filters, the above result must be due to differences in measurement design, with consequences for measurements in dense fog.

For the 0-200 m MOR interval we found a VAI/MOR ratio of 1.19 and 1.13 in radiation fog and advection fog respectively. For the 0-500 m interval the ratios fell to 1.16 and 1.10. These differences of 0.06 is probably significant. In fog situations the VAI/IPH ratio increases when the visibility decreases.

In snow there is an opposite trend. In the MOR interval 500-1800 m most of the ratios varied between 1.0 and 1.4. With strong winds a lot of cases give higher ratios. With relatively weak winds, below 5 m/s, the ratios seem to lie between 1.0 and 1.2 at visibility around 600-1000 m.

Transmissometers versus forward scatter meter.

For the period 19.12.91-13.5.92 and all fog types, snow excepted, we found a MOR ratio VAI/VFS=1.03 and 1.02 for the VAI-MOR intervals 0-200 and 0-500 m respectively. These ratios represent a difference between the two instruments, which are not significant. However, the ratio is increasing with increasing visibility. Above 500 m the ratio is greater than 1.05, which is a significant result. For the same period we found a MOR ratio VFS/IPH=1.13 and 1.10 for the two intervals. The ratios are lesser than the VAI/IPH ratio, but still probably significant.

Runway visual range.

Owing to a difference in determination of the illumination threshold the RVR differences between VAI and IPH become smaller than otherwise expected. The RVR ratios VAI/IPH are about 10% lower at night and 15% lower at day compared with the MOR ratios. When IPH-MOR=100 m the RVR ratio VAI/IPH=1.09 at night and 1.04 at day in radiation fog and 1.05 and 1.01 respectively in advection fog.

A comparison between instrumental RVR and "visual RVR" shows a good correspondence between IPH-RVR and RVR, while VAI-RVR is some percent too high, especially in radiation fog.

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APPENDIX

APPENDIX A. ACCURACY OF THE MEASUREMENTS

Table A.1.
Consequencies for the relationship between two visibility instruments when one has a relative error of -1 or -2% and eventually in addition an absolute error of +1%.

MOR-A	Transm.-A	Rel. error: -1%	Transm.-B	MOR-B	MOR-A/ MOR-B	Abs. error: 1%	Transm-C	MOR-C	MOR-A/ MOR-C
50	0.0675	-0.0007	0.0668	49.8	1.00	0.0775	0.0768	52.5	0.95
100	0.2597	-0.0026	0.2571	99.3	1.01	0.2697	0.2671	102.1	0.98
200	0.5096	-0.0051	0.5045	197.1	1.01	0.5196	0.5145	202.9	0.99
300	0.6380	-0.0064	0.6317	293.4	1.02	0.6480	0.6417	303.8	0.99
400	0.7139	-0.0071	0.7068	388.4	1.03	0.7239	0.7168	404.8	0.99
500	0.7637	-0.0076	0.7560	482.0	1.04	0.7737	0.7660	505.8	0.99
600	0.7988	-0.0080	0.7908	574.3	1.04	0.8088	0.8008	606.8	0.99
700	0.8248	-0.0082	0.8166	665.3	1.05	0.8348	0.8266	707.8	0.99
800	0.8449	-0.0084	0.8365	755.0	1.06	0.8549	0.8465	808.8	0.99
900	0.8609	-0.0086	0.8523	843.4	1.07	0.8709	0.8623	909.8	0.99
1000	0.8739	-0.0087	0.8651	930.6	1.07	0.8839	0.8751	1010.8	0.99
1100	0.8847	-0.0088	0.8758	1016.6	1.08	0.8947	0.8858	1111.8	0.99
1200	0.8937	-0.0089	0.8848	1101.5	1.09	0.9037	0.8948	1212.8	0.99
1300	0.9015	-0.0090	0.8925	1185.1	1.10	0.9115	0.9025	1313.8	0.99
1400	0.9082	-0.0091	0.8991	1267.7	1.10	0.9182	0.9091	1414.8	0.99
1500	0.9140	-0.0091	0.9049	1349.1	1.11	0.9240	0.9149	1515.9	0.99
1600	0.9192	-0.0092	0.9100	1429.5	1.12	0.9292	0.9200	1616.9	0.99
1700	0.9238	-0.0092	0.9145	1508.8	1.13	0.9338	0.9245	1717.9	0.99
1800	0.9278	-0.0093	0.9186	1587.0	1.13	0.9378	0.9286	1818.9	0.99

MOR-A	Transm.-A	Rel. error: -2%	Transm.-B	MOR-B	MOR-A/ MOR-B	Abs. error: 1%	Transm-C	MOR-C	MOR-A/ MOR-C
50	0.0675	-0.0013	0.0661	49.6	1.01	0.0775	0.0761	52.3	0.96
100	0.2597	-0.0052	0.2545	98.5	1.01	0.2697	0.2645	101.4	0.99
200	0.5096	-0.0102	0.4995	194.2	1.03	0.5196	0.5095	199.9	1.00
300	0.6380	-0.0128	0.6253	287.1	1.04	0.6480	0.6353	297.1	1.01
400	0.7139	-0.0143	0.6996	377.4	1.06	0.7239	0.7096	393.0	1.02
500	0.7637	-0.0153	0.7484	465.1	1.07	0.7737	0.7584	487.5	1.03
600	0.7988	-0.0160	0.7828	550.5	1.09	0.8088	0.7928	580.6	1.03
700	0.8248	-0.0165	0.8083	633.5	1.10	0.8348	0.8183	672.4	1.04
800	0.8449	-0.0169	0.8280	714.4	1.12	0.8549	0.8380	762.9	1.05
900	0.8609	-0.0172	0.8437	793.0	1.13	0.8709	0.8537	852.1	1.06
1000	0.8739	-0.0175	0.8564	869.7	1.15	0.8839	0.8664	940.1	1.06
1100	0.8847	-0.0177	0.8670	944.3	1.16	0.8947	0.8770	1026.8	1.07
1200	0.8937	-0.0179	0.8759	1017.1	1.18	0.9037	0.8859	1112.4	1.08
1300	0.9015	-0.0180	0.8835	1088.0	1.19	0.9115	0.8935	1196.7	1.09
1400	0.9082	-0.0182	0.8900	1157.2	1.21	0.9182	0.9000	1280.0	1.09
1500	0.9140	-0.0183	0.8958	1224.7	1.22	0.9240	0.9058	1362.1	1.10
1600	0.9192	-0.0184	0.9008	1290.6	1.24	0.9292	0.9108	1443.1	1.11
1700	0.9238	-0.0185	0.9053	1354.8	1.25	0.9338	0.9153	1523.0	1.12
1800	0.9278	-0.0186	0.9093	1417.6	1.27	0.9378	0.9193	1601.8	1.12

Table A.2.

Consequencies for the relationship between two visibility instruments when one has a relative error of -1 or -2% and eventually in addition an absolute error of -1%.

MOR-A	Transm.-A	Rel. error: -1%	Transm.-B	MOR-B	MOR-A/ MOR-B	Abs. error: -1%	Transm-C	MOR-C	MOR-A/ MOR-C
50	0.0675	-0.0007	0.0668	49.8	1.00	0.0575	0.0568	47.0	1.06
100	0.2597	-0.0026	0.2571	99.3	1.01	0.2497	0.2471	96.4	1.04
200	0.5096	-0.0051	0.5045	197.1	1.01	0.4996	0.4945	191.5	1.04
300	0.6380	-0.0064	0.6317	293.4	1.02	0.6280	0.6217	283.6	1.06
400	0.7139	-0.0071	0.7068	388.4	1.03	0.7039	0.6968	373.1	1.07
500	0.7637	-0.0076	0.7560	482.0	1.04	0.7537	0.7460	460.1	1.09
600	0.7988	-0.0080	0.7908	574.3	1.04	0.7888	0.7808	544.8	1.10
700	0.8248	-0.0082	0.8166	665.3	1.05	0.8148	0.8066	627.1	1.12
800	0.8449	-0.0084	0.8365	755.0	1.06	0.8349	0.8265	707.3	1.13
900	0.8609	-0.0086	0.8523	843.4	1.07	0.8509	0.8423	785.4	1.15
1000	0.8739	-0.0087	0.8651	930.6	1.07	0.8639	0.8551	861.5	1.16
1100	0.8847	-0.0088	0.8758	1016.6	1.08	0.8747	0.8658	935.6	1.18
1200	0.8937	-0.0089	0.8848	1101.5	1.09	0.8837	0.8748	1007.9	1.19
1300	0.9015	-0.0090	0.8925	1185.1	1.10	0.8915	0.8825	1078.3	1.21
1400	0.9082	-0.0091	0.8991	1267.7	1.10	0.8982	0.8891	1147.0	1.22
1500	0.9140	-0.0091	0.9049	1349.1	1.11	0.9040	0.8949	1214.1	1.24
1600	0.9192	-0.0092	0.9100	1429.5	1.12	0.9092	0.9000	1279.6	1.25
1700	0.9238	-0.0092	0.9145	1508.8	1.13	0.9138	0.9045	1343.5	1.27
1800	0.9278	-0.0093	0.9186	1587.0	1.13	0.9178	0.9086	1405.9	1.28

MOR-A	Transm.-A	Rel. error: -2%	Transm.-B	MOR-B	MOR-A/ MOR-B	Abs. error: -1%	Transm-C	MOR-C	MOR-A/ MOR-C
50	0.0675	-0.0013	0.0661	49.6	1.01	0.0575	0.0561	46.8	1.07
100	0.2597	-0.0052	0.2545	98.5	1.01	0.2497	0.2445	95.7	1.04
200	0.5096	-0.0102	0.4995	194.2	1.03	0.4996	0.4895	188.7	1.06
300	0.6380	-0.0128	0.6253	287.1	1.04	0.6280	0.6153	277.6	1.08
400	0.7139	-0.0143	0.6996	377.4	1.06	0.7039	0.6896	362.8	1.10
500	0.7637	-0.0153	0.7484	465.1	1.07	0.7537	0.7384	444.5	1.12
600	0.7988	-0.0160	0.7828	550.5	1.09	0.7888	0.7728	523.0	1.15
700	0.8248	-0.0165	0.8083	633.5	1.10	0.8148	0.7983	598.5	1.17
800	0.8449	-0.0169	0.8280	714.4	1.12	0.8349	0.8180	671.1	1.19
900	0.8609	-0.0172	0.8437	793.0	1.13	0.8509	0.8337	741.1	1.21
1000	0.8739	-0.0175	0.8564	869.7	1.15	0.8639	0.8464	808.4	1.24
1100	0.8847	-0.0177	0.8670	944.3	1.16	0.8747	0.8570	873.4	1.26
1200	0.8937	-0.0179	0.8759	1017.1	1.18	0.8837	0.8659	936.0	1.28
1300	0.9015	-0.0180	0.8835	1088.0	1.19	0.8915	0.8735	996.5	1.30
1400	0.9082	-0.0182	0.8900	1157.2	1.21	0.8982	0.8800	1054.9	1.33
1500	0.9140	-0.0183	0.8958	1224.7	1.22	0.9040	0.8858	1111.4	1.35
1600	0.9192	-0.0184	0.9008	1290.6	1.24	0.9092	0.8908	1165.9	1.37
1700	0.9238	-0.0185	0.9053	1354.8	1.25	0.9138	0.8953	1218.8	1.39
1800	0.9278	-0.0186	0.9093	1417.6	1.27	0.9178	0.8993	1269.9	1.42

APPENDIX B. FOG SITUATIONS / CATEGORIES

Table B.1.
Episodes with reduced visibility at Gardermoen, before removal of Vaisala transmissometer. Weather type, result of the precipitatation yes/no sensor and typical visibility of each episode is shown. The weather types are coded:

FA:	**Advection fog**
FR:	**Radiation fog**
F:	**Fog (most typhical type is difficult to determine)**
FD:	**Fog and drizzle/rain**
FS:	**Fog and rain/snow**
D:	**Drizzle**
R:	**Rain**
S:	**Snow**

RR + x shows the 6 hours precipitation [mm] during the episodes, measured at 01, 07, 13 and 19 local time. Number in parenthesis means that the precipitation probably has fallen outside the episode.
M means missing value of the yes/no sensor and U no correspondence between the sensor and measured precipitation.

		Episode			Duration	Typhical	Type of	Precip.	RR	RR	RR	RR	RR	RR	Remarks
from			to		(d:h:min)	MOR [m]	weather	Y/N		+ 6	+ 12	+ 18	+ 24	+ 30	
19.12.91	14:00	-	19.12.91	18:30	0:04:30	500 - 1300	S	Y	7.6						
22.12.91	18:00	-	23.12.91	02:00	0:08:00	700 - 1500	S	Y	0.2	5.5	0.0				
25.12.91	17:30	-	25.12.91	22:00	0:04:30	600 - 1200	S	Y	0.8	5.5					
26.12.91	07:30	-	26.12.91	10:30	0:03:00	200 - 600	FA	N	0.0						snow
26.12.91	14:00	-	26.12.91	15:30	0:01:30	1300 - 1700	S	Y	1.0						
06.01.92	18:10	-	06.01.92	20:30	0:02:20	800 - 1100	S	Y	0.4	3.0					
06.01.92	22:00	-	07.01.92	03:30	0:05:30	200 - 400	F	N	(3.0)	-					
07.01.92	23:00	-	08.01.92	11:00	0:12:00	100 - 500	F	N	0.0	-	-				sleet
18.01.92	22:00	-	19.01.92	07:00	0:09:00	900 - 1500	S	Y	5.0	4.5					
19.01.92	16:30	-	19.01.92	18:00	0:01:30	800 - 1600	FR	N	(1.0)						
20.01.92	16:30	-	21.01.92	01:00	0:08:30	100 - 400	FR	N	-	-					
21.01.92	04:00	-	21.01.92	05:30	0:01:30	600 - 800	FR	N	-						
21.01.92	15:30	-	22.01.92	00:50	0:09:20	80 - 300	F	N	0.1	-					snow grains
22.01.92	01:00	-	22.01.92	07:30	0:06:30	300 - 500	F	N	0.2	0.0					snow grains
22.01.92	16:00		23.01.92	13:30	0:21:30	100 - 500	FR	N	0.0	-	0.0	0.0			snow grains
23.01.92	17:00	-	24.01.92	05:00	0:12:00	100 - 200	FR	N	0.0	-	-				rime
24.01.92	07:30	-	24.01.92	13:00	0:05:30	200 - 500	FR	N	-						
24.01.92	17:30	-	24.01.92	19:30	0:02:00	500 - 1500	F	N	0.0	0.0					snow grains
27.01.92	20:30	-	28.01.92	10:30	0:14:00	100 - 300	FR	N	-	-	-				
30.01.92	02:00	-	30.01.92	12:00	0:10:00	200 - 400	FR	N	-	-					
30.01.92	16:00	-	31.01.92	06:50	0:14:50	100 - 200	FR	N	-	-	-				
31.01.92	07:00	-	01.02.92	01:00	0:18:00	200 - 500	F	N	0.1	0.0	0.1				snow grains
01.02.92	06:30	-	01.02.92	11:00	0:04:30	100 - 200	FR	M	0.1	0.0					snow grains
01.02.92	16:00	-	02.02.92	04:00	0:12:00	90 - 200	FR	M	(0.0)	-	-				
06.02.92	07:30	-	06.02.92	09:00	0:01:30	700 - 1400	S	Y	1.7						
06.02.92	16:30	-	06.02.92	23:00	0:06:30	100 - 500	FR	N	0.0	0.0					snow grains
08.02.92	16:00	-	09.02.92	00:50	0:08:50	90 - 500	F	N	-	0.1					drizzle
09.02.92	01:00	-	09.02.92	07:20	0:06:20	300 - 600	FD	Y	0.9	0.4					
09.02.92	07:30	-	09.02.92	11:00	0:03:30	200 - 500	F	N	(0.4)						
09.02.92	17:00	-	09.02.92	19:00	0:02:00	1600 - 1800	DR	U	0.6						
09.02.92	19:10	-	10.02.92	18:50	0:23:40	600 - 1800	DRS	Y	0.3	1.2	1.0	2.1			
10.02.92	19:00	-	10.02.92	21:30	0:02:30	200 - 1300	F	N	0.0						drizzle
12.02.92	20:30	-	13.02.92	03:50	0:07:20	200 - 600	F	N	-	(1.8)					
13.02.92	04:00	-	13.02.92	10:00	0:06:00	800 - 1700	RS	Y	1.8	7.3					
14.02.92	00:30	-	14.02.92	03:30	0:03:00	100 - 200	FR	N	-	-					
14.02.92	16:30	-	15.02.92	05:00	0:12:30	1000 - 1800	S	Y	1.3	2.2	1.3				
20.02.92	21:30	-	21.02.92	13:00	0:15:30	100 - 400	FR	N	-	-	0.0				snow grains
26.02.92	11:30	-	26.02.92	16:30	0:05:00	200 - 600	FA	N	0.1	0.1					snow, drizzle
27.02.92	05:30	-	27.02.92	12:30	0:07:00	100 - 300	F	N	(0.1)						
27.02.92	20:00	-	28.02.92	10:00	0:14:00	200 - 1000	FA	N	-	0.0	0.1	-			drizzle
01.03.92	18:30	-	01.03.92	23:00	0:04:30	200 - 1500	FA	N	0.1	(0.1)					rain
01.03.92	23:10	-	02.03.92	05:30	0:06:20	100 - 200	FD	Y	0.1	0.7					

02.03.92	18:30	-	02.03.92	20:30	0:02:00	200	-	400	R	Y	1.3	1.0			
05.03.92	06:00	-	05.03.92	13:00	0:07:00	100	-	400	FA	N	0.0	0.2			drizzle
05.03.92	18:30	-	06.03.92	08:30	0:14:00	200	-	1400	FA	N	0.0	0.1	0.2	(0.2)	drizzle
06.03.92	08:40	-	06.03.92	16:50	0:08:10	900	-	1500	DR	Y	0.2	2.8			
06.03.92	17:00	-	07.03.92	06:00	0:13:00	200	-	1300	FA	N	(2.8)	-	-		
08.03.92	04:00	-	08.03.92	07:00	0:03:00	400	-	1800	FA	N	-				
08.03.92	07:10	-	08.03.92	18:00	0:10:50	100	-	500	FD	Y	0.1	0.2			
08.03.92	18:10	-	09.03.92	06:00	0:11:50	100	-	200	FA	N	(0.2)	0.0	0.0		drizzle
09.03.92	06:10	-	09.03.92	17:00	0:10:50	100	-	800	FD	Y	0.2	0.1			
12.03.92	07:10	-	12.03.92	09:50	0:02:40	500	-	800	S	Y	5.9				
20.03.92	06:30	-	20.03.92	09:30	0:03:00	1400	-	1800	S	Y	0.0	1.7			
20.03.92	15:00	-	20.03.92	19:00	0:04:00	300	-	1000	FD	Y	0.5				
21.03.92	01:30	-	21.03.92	03:00	0:01:30	600	-	1000	FA	N	(0.2)				
21.03.92	15:00	-	21.03.92	20:30	0:05:30	1600	-	1800	DR	Y	2.4	3.2			
25.03.92	22:30	-	26.03.92	06:30	0:08:00	1000	-	1800	RS	Y	1.0	2.7			
02.04.92	01:00	-	02.04.92	11:00	0:10:00	200	-	1500	S	Y	2.2	3.6			
02.04.92	16:00	-	02.04.92	18:00	0:02:00	1400	-	1800	S	U	2.4				
03.04.92	04:00	-	03.04.92	09:00	0:05:00	1200	-	1800	S	Y	1.8	0.7			
04.04.92	17:00	-	04.04.92	20:00	0:03:00	1200	-	1800	DR	Y	0.8	0.3			
06.04.92	03:00	-	06.04.92	12:00	0:09:00	200	-	1800	FA	N	-	-			
07.04.92	03:00	-	07.04.92	07:00	0:04:00	200	-	500	F	N	-				
10.04.92	03:00	-	10.04.92	07:30	0:04:30	400	-	1000	FA	N	-				
10.04.92	21:00	-	11.04.92	08:30	0:11:30	90	-	1500	FR	N	-	-	-		
12.04.92	23:00	-	13.04.92	08:30	0:09:30	90	-	200	F	N	-	0.0	(1.5)		drizzle, rain
13.04.92	16:40	-	14.04.92	00:00	0:07:20	1200	-	1800	S	Y	10.7	5.0			
05.05.92	02:30	-	05.05.92	09:00	0:06:30	200	-	400	FA	N	0.0	-			drizzle
12.05.92	23:30	-	13.05.92	02:00	0:02:30	100	-	500	FR	N	-	-			

Table B.2.
Episodes with reduced visibility at Gardermoen, after removal of Vaisala transmissometer. Weather type, result of the precipitatation yes/no sensor and typical visibility of each episode is shown. The weather types are coded (see Table B.1).

RR + x shows the 6 hours precipitation [mm] during the episodes, measured at 01, 07, 13 and 19 local time. Number in parenthesis means that the precipitation probably has fallen outside the episode. M means missing value of the yes/no sensor and U no correspondence between the sensor and measured precipitation.

Episode from			to		Duration (d:h:min)	Typhical MOR [m]	Type of weather	Precip. Y/N	RR	RR + 6	RR + 12	RR + 18	RR + 24	RR + 30	Remarks
10.12.92	06:00	-	10.12.92	10:10	0:04:10	600 - 800	F	N	-	-					
14.12.92	00:00	-	14.12.92	07:00	0:07:00	600 - 1800	S	Y	0.2	8.1					
14.12.92	10:00	-	14.12.92	20:00	0:10:00	200 - 500	FA	N	(0.7)	-	-				
18.12.92	11:00	-	18.12.92	16:00	0:05:00	1200 - 1600	D	N	1.1	0.3					drizzle, rain
18.12.92	23:30	-	19.12.92	04:30	0:05:00	1000 - 1700	R	Y	0.3	6.8					
21.12.92	23:00	-	22.12.92	06:30	0:07:30	100 - 600	FR	N	-	-					
22.12.92	06:40	-	22.12.92	08:30	0:01:50	1000 - 1200	S	Y	0.0						snow
23.12.92	20:20	-	24.12.92	05:30	0:09:10	100 - 300	F	N	-	-					
25.12.92	05:10	-	25.12.92	11:50	0:06:40	500 - 1500	F	N	-	-					
28.12.92	06:10	-	28.12.92	07:10	0:01:00	200 - 600	FR	N	-						
30.12.92	14:50	-	30.12.92	19:20	0:04:30	700 - 1500	FA	Y	-						snow
05.01.93	14:30	-	05.01.93	22:00	0:07:30	600 - 1000	S	Y	3.9	2.5					
08.01.93	05:00	-	08.01.93	08:00	0:03:00	700 - 1100	RS	Y	1.2	2.0					
09.01.93	12:00	-	09.01.93	19:00	0:07:00	300 - 600	RS	Y	1.0	4.3					
10.01.93	20:30	-	10.01.93	23:00	0:02:30	1000 - 1500	RS	Y	8.0						
15.01.93	14:30	-	15.01.93	19:00	0:04:30	300 - 600	FA	N	(8.3)						
17.01.93	04:30	-	17.01.93	11:00	0:06:30	100 - 300	FD	N	0.0	0.4					rain
20.01.93	08:30	-	20.01.93	12:00	0:03:30	1000 - 1800	S	Y	3.6						
20.01.93	14:30	-	20.01.93	17:00	0:02:30	200 - 400	FA	N	(0.2)						
23.01.93	23:00	-	24.01.93	07:00	0:08:00	600 - 1000	S	Y	0.1	7.1					
24.01.93	21:30	-	25.01.93	00:00	0:02:30	1000 - 1500	S	Y	1.4						
29.01.93	10:00	-	29.01.93	13:30	0:03:30	100 - 300	FR	N	-						
29.01.93	17:00	-	29.01.93	21:30	0:04:30	100 - 1000	FR	N	-	(0.0)					
29.01.93	23:30	-	30.01.93	04:30	0:05:00	200 - 1000	FR	N	0.0	-					snow grains
10.02.93	04:30	-	10.02.93	09:30	0:05:00	100 - 200	FR	N	-	0.0					snow grains
10.02.93	13:00	-	11.02.93	08:00	0:19:00	100 - 200	F	Y	-	0.0	0.0	(0.0)			snow grains
11.02.93	10:00	-	11.02.93	12:00	0:02:00	1100 - 1800	D	N	0.0						drizzle
12.02.93	01:00	-	12.02.93	04:00	0:03:00	1100 - 1500	D	N	0.0						drizzle
13.02.93	05:30	-	13.02.93	11:00	0:05:30	100 - 400	FR	N	-	-					
13.02.93	19:30	-	13.02.93	21:00	0:01:30	300 - 600	FR	N	-						
14.02.93	00:30	-	14.02.93	08:30	0:08:00	100 - 500	FA	Y	-	0.1					snow grains
14.02.93	15:00	-	14.02.93	19:00	0:04:00	300 - 600	FA	N	0.0						snow grains
20.02.93	12:00	-	20.02.93	14:30	0:02:30	400 - 1000	S	Y	0.4	3.0					
20.02.93	19:30	-	21.02.93	00:00	0:04:30	1000 - 1800	S	Y	2.2						
26.02.93	00:00	-	26.02.93	05:00	0:05:00	1400 - 1800	S	Y	0.0	0.1					
26.02.93	08:00	-	26.02.93	11:30	0:03:30	1300 - 1800	S	Y	1.5						
26.02.93	13:00	-	28.02.93	07:00	1:18:00	200 - 1800	S	Y	1.7	2.6	3.8	5.7	7.1	8.6	
02.03.93	07:00	-	02.03.93	11:30	0:04:30	100 - 300	FR	M	-						
02.03.93	18:00	-	02.03.93	19:30	0:01:30	500 - 1600	FR	N	-	-					
03.03.93	02:00	-	03.03.93	09:30	0:07:30	100 - 300	FR	N	-	-					
13.03.93	01:30	-	13.03.93	05:50	0:04:20	100 - 300	F	N	0.0						snow grains
13.03.93	19:00	-	14.03.93	12:00	0:17:00	80 - 200	F	N	-	-	-				
14.03.93	20:00	-	15.03.93	13:00	1:02:30	60 - 200	F	N	-	-	-				
15.03.93	13:10	-	15.03.93	22:30	7:08:50	600 - 1800	F	Y	0.0	-					rain
22.03.93	19:30	-	22.03.93	22:00	0:02:30	1000 - 1600	RS	Y	5.1						
23.03.93	00:30	-	23.03.93	02:30	0:02:00	500 - 1700	RS	Y	0.1						
05.04.93	20:30	-	06.04.93	02:00	0:05:30	1000 - 1600	S	Y	2.6	2.4					
06.04.93	07:30	-	06.04.93	08:30	0:01:00	800 - 900	FA	M	0.3						rain

APPENDIX C. STUDENT t-TEST WITH CORRECTION FOR AUTOCORRELATION

In this report we are testing time series of visibility, if mean values of series are changing in time or if mean values of two synoptic series are really different. For this purpose we use the well known Student t-test, which gives a critical value of significance concerning the difference in mean values.

Assume that two time series consist of N_1 and N_2 observations, each with a mean value, m_1 and m_2, and standard deviation, s_1 and s_2, respectively. The t-test gives the following relation:

$$\Delta m_{crit} = t_{crit} \sqrt{\frac{N_1 s_1^2 + N_2 s_2^2}{N_1 + N_2 - 2} \cdot \left(\frac{1}{N_1} + \frac{1}{N_2}\right)} \qquad \textbf{Eq. (C1)}$$

where Δm_{crit} is the critical difference between m1 and m2 for significance. t_{crit} is to be found in a statistic handbook and is dependent of the chosen significance level and degrees of freedom ($N_1 + N_2 - 2$). If the real difference $| m1 - m2 | > \Delta m_{crit}$, the difference is significant.

Autocorrelation (8).

In an autocorrelated series, each observation repeats part of information contained in previous observations. Therefore, N observations of a non-random time series having an autocorrelation, $\tau > 0$, give as much information about the mean as some lesser number, N, of observations in random time series. This lesser number of observations is called the effective number of observations and is defined as

$$N_E = N \cdot \left[\frac{1+\tau}{1-\tau} - \frac{2 \cdot \tau (1-\tau^N)}{N \cdot (1-\tau)^2}\right]^{-1} \qquad \textbf{Eq. (C2)}$$

Here the autocorrelation, τ, means the correlation between values separated by one time unit, i.e. 10 minutes in our data series.

For large N (>200) and $\tau < 0.7$, Eq.(C2) gives

$$N_E \approx N \cdot \left[\frac{1+\tau}{1-\tau}\right]^{-1} = N \cdot \left[\frac{1-\tau}{1+\tau}\right] \qquad \textbf{Eq. (C3)}$$

This relation is used in Eq.(C1), where N_1 and N_2 are replaced by N_{E_1} and N_{E_2}.

APPENDIX D. COMPARISON OF INSTRUMENTS BEFORE AND AFTER REMOVAL OF VAISALA TRANSMISSOMETER

Table D.1.
The ratio IPH-M/((IPH-S + IPH-N)/2) for the periods: P1) 20.4.-31.10.1991, before Vaisala instruments were introduced; P2) 9.11.1991-6.2.1992, when IPH-M and Vaisala transmissometer were 2 m apart and P3) 10.12.1992-25.3.1993, except for the period 27.-28.2., when the two instruments were 28 m apart. IPH-MOR denotes truncated values, i.e. intervals of 100, 500 and 1000 m respectively.

	P1					P2					P3				
IPH-MOR [m]	No. of obs.	Avg	Min	Max	Std	No. of obs.	Avg	Min	Max	Std	No. of obs.	Avg	Min	Max	Std
0	7	0.93	0.81	1.00	0.06	19	0.92	0.77	1.01	0.08	60	0.97	0.68	1.29	0.08
100	18	1.02	0.82	1.41	0.14	121	0.99	0.65	1.33	0.10	79	0.96	0.76	1.30	0.09
200	6	1.09	0.88	1.22	0.12	54	1.01	0.73	1.36	0.12	33	1.06	0.93	1.30	0.08
300	10	1.00	0.96	1.06	0.03	28	1.04	0.87	1.52	0.15	10	0.97	0.82	1.20	0.11
400	19	1.01	0.93	1.08	0.04	12	1.00	0.92	1.15	0.06	7	1.06	0.89	1.43	0.18
500	9	1.03	0.97	1.09	0.04	10	1.00	0.77	1.12	0.09	8	0.97	0.66	1.11	0.15
600	3	1.02	0.97	1.11	0.08	8	0.97	0.84	1.11	0.10	5	0.91	0.82	1.02	0.09
700	8	1.02	0.99	1.05	0.02	6	0.92	0.58	1.01	0.17	10	0.95	0.55	1.09	0.15
800	6	1.04	0.99	1.08	0.03	12	0.95	0.62	1.09	0.12	9	0.98	0.74	1.13	0.10
900	3	0.97	0.75	1.15	0.21	14	0.96	0.86	1.13	0.07	16	0.95	0.74	1.09	0.09
1000	3	0.88	0.78	1.02	0.12	17	0.91	0.82	0.99	0.04	8	0.92	0.85	0.99	0.05
1100	5	0.97	0.82	1.05	0.09	11	0.89	0.79	1.06	0.07	9	0.93	0.79	1.13	0.11
1200	5	1.07	0.98	1.14	0.07	10	0.91	0.83	0.97	0.05	9	0.93	0.85	1.09	0.09
1300	5	1.07	0.92	1.24	0.12	7	0.94	0.86	1.05	0.08	5	0.99	0.92	1.05	0.05
1400	4	1.11	0.97	1.20	0.11	3	0.96	0.93	0.98	0.02	2	1.03	1.01	1.05	0.03
1500	2	1.04	1.03	1.06	0.02	-	-	-	-	-	4	1.16	0.99	1.61	0.30
1600	1	1.02	1.02	1.02	0.00	-	-	-	-	-	1	1.04	1.04	1.04	0.00
1700	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0	60	1.01	0.81	1.41	0.10	234	1.00	0.65	1.52	0.11	189	0.99	0.68	1.43	0.10
500	29	1.02	0.75	1.15	0.07	50	0.96	0.58	1.13	0.11	48	0.96	0.55	1.13	0.11
1000	22	1.03	0.78	1.24	0.12	48	0.91	0.79	1.06	0.06	33	0.94	0.79	1.13	0.08
1500	3	1.04	1.02	1.06	0.03	-	-	-	-	-	5	1.14	0.99	1.61	0.26
0	89	1.01	0.75	1.41	0.09	284	0.99	0.58	1.52	0.11	237	0.98	0.55	1.43	0.10
1000	25	1.03	0.78	1.24	0.11	48	0.91	0.79	1.06	0.06	38	0.97	0.79	1.61	0.13

Table D.2.
The ratio VAI/IPH-M for the periods: Q1) 19.12.1991-13.5.1992, except for 2.4., before Vaisala transmissometer was moved; Q2) 10.12.1992-25.3.1992, except for 27.-28., after Vaisala transmissometer was moved. Ratios above 2.1 are excluded. IPH-MOR denotes truncated values, i.e. intervals of 100, 500 and 1000 m respectively.

	Q1					Q2				
IPH-MOR [m]	No. of obs.	Avg	Min	Max	Std	No. of obs.	Avg	Min	Max	Std
0	84	1.20	1.05	1.36	0.05	112	1.20	1.09	1.36	0.06
100	510	1.16	0.40	1.98	0.10	260	1.16	0.93	1.66	0.08
200	326	1.13	0.63	1.67	0.12	126	1.13	0.77	1.67	0.13
300	159	1.13	0.63	1.66	0.12	60	1.12	0.55	1.52	0.14
400	126	1.11	0.59	2.04	0.18	31	1.17	0.71	1.70	0.23
500	116	1.11	0.36	1.61	0.18	50	1.05	0.57	1.61	0.20
600	98	1.14	0.36	1.93	0.17	35	1.19	0.77	2.04	0.29
700	95	1.13	0.40	1.71	0.19	35	1.05	0.78	1.64	0.17
800	74	1.11	0.52	1.90	0.21	44	1.05	0.71	1.63	0.19
900	98	1.10	0.39	1.62	0.18	56	1.13	0.71	1.78	0.21
1000	105	1.13	0.68	1.81	0.17	42	1.14	0.78	1.99	0.23
1100	87	1.25	0.82	2.08	0.24	51	1.15	0.35	1.97	0.28
1200	71	1.18	0.69	1.63	0.18	36	1.08	0.71	1.87	0.26
1300	80	1.20	0.90	1.77	0.17	35	1.09	0.67	1.92	0.28
1400	102	1.23	0.83	1.82	0.20	68	1.13	0.57	1.85	0.27
1500	89	1.20	0.47	1.85	0.20	67	1.12	0.68	1.97	0.28
1600	97	1.25	0.74	1.58	0.17	65	1.11	0.59	1.71	0.31
1700	109	1.27	0.81	1.65	0.19	64	1.25	0.67	1.69	0.32
0	1205	1.15	0.40	2.04	0.12	589	1.16	0.55	1.70	0.11
500	481	1.12	0.36	1.93	0.19	220	1.09	0.57	2.04	0.22
1000	445	1.20	0.68	2.08	0.20	232	1.12	0.35	1.99	0.27
1500	295	1.24	0.47	1.85	0.19	196	1.16	0.59	1.97	0.31
0	1686	1.14	0.36	2.04	0.14	809	1.14	0.55	2.04	0.15
1000	740	1.21	0.47	2.08	0.20	428	1.14	0.35	1.99	0.29

APPENDIX E. COMPARISON OF INSTRUMENTS FOR DIFFERENT WEATHER TYPES

Table E.1.
The ratio VAI/IPH for the total period 19.12.1991-25.3.1993.
SX means snow where two snow drifting periods are excluded: 2.4.1992 10:10-18:00 and 27.2.1993 04:40 - 28.2.1993 07:00.
B1, B3, B4 and B5 denotes the 10 minute Beaufort values. GRAINS denotes snow grains, mainly in radiation fog situations.
SEED denotes the period after seeding. Concerning other codes, see Appendix B. MOR denotes truncated values, i.e. intervals of 100 m (0 means 0-99, 100 means 100-199, and so forth).

	Fog (FR-F-FA-FD-D-R)					Fog (FR-F-FA)					Fog (FA-FD-D-R)				
IPH-MOR [m]	No. of obs.	Avg	Min	Max	Std	No. of obs.	Avg	Min	Max	Std	No. of obs.	Avg	Min	Max	Std
0	196	1.2	1.05	1.36	0.06	191	1.20	1.05	1.36	0.06	10	1.19	1.12	1.35	0.07
100	770	1.16	0.4	1.98	0.1	702	1.17	0.40	1.98	0.10	175	1.13	0.98	1.34	0.05
200	443	1.13	0.63	1.67	0.11	405	1.13	0.63	1.67	0.12	174	1.11	0.88	1.67	0.08
300	213	1.12	0.55	1.52	0.11	186	1.12	0.55	1.52	0.12	95	1.08	0.55	1.35	0.11
400	151	1.11	0.59	2.04	0.19	115	1.13	0.59	2.04	0.21	69	1.06	0.86	1.86	0.12
500	152	1.09	0.36	1.61	0.19	124	1.09	0.36	1.61	0.21	74	1.07	0.57	1.30	0.13
600	112	1.16	0.36	2.04	0.21	92	1.17	0.36	2.04	0.23	53	1.11	0.85	2.04	0.20
700	93	1.11	0.4	1.71	0.21	77	1.11	0.40	1.71	0.23	44	1.00	0.40	1.22	0.14
800	74	1.07	0.52	1.9	0.23	61	1.08	0.52	1.90	0.25	40	1.00	0.71	1.43	0.13
900	98	1.09	0.39	1.78	0.22	83	1.10	0.39	1.78	0.24	50	1.06	0.76	1.44	0.14
1000	80	1.08	0.78	1.69	0.19	70	1.08	0.78	1.69	0.20	50	1.01	0.83	1.33	0.13
1100	93	1.18	0.35	1.97	0.28	73	1.20	0.35	1.97	0.30	39	1.07	0.35	1.60	0.22
1200	63	1.11	0.69	1.87	0.25	40	1.18	0.69	1.87	0.26	36	1.02	0.71	1.57	0.18
1300	56	1.15	0.71	1.92	0.25	43	1.19	0.71	1.92	0.24	26	1.09	0.72	1.46	0.20
1400	94	1.16	0.57	1.85	0.29	67	1.20	0.69	1.85	0.28	52	1.06	0.57	1.51	0.24
1500	93	1.15	0.47	1.97	0.28	69	1.15	0.47	1.97	0.30	49	1.08	0.68	1.51	0.22
1600	90	1.16	0.59	1.71	0.3	62	1.17	0.59	1.71	0.30	48	1.10	0.59	1.58	0.28
1700	105	1.26	0.67	1.69	0.3	74	1.28	0.68	1.69	0.29	57	1.16	0.67	1.64	0.27

	Radiation fog (FR)					Fog (F)					Advection fog (FA)				
IPH-MOR [m]	No. of obs.	Avg	Min	Max	Std	No. of obs.	Avg	Min	Max	Std	No. of obs.	Avg	Min	Max	Std
0	63	1.22	1.05	1.36	0.05	123	1.19	1.09	1.36	0.06	5	1.23	1.16	1.35	0.08
100	347	1.19	0.40	1.98	0.12	248	1.16	0.66	1.47	0.08	107	1.13	0.98	1.34	0.05
200	142	1.14	0.63	1.62	0.15	127	1.14	0.73	1.62	0.11	136	1.12	0.88	1.67	0.08
300	56	1.16	0.72	1.52	0.12	62	1.14	0.82	1.41	0.10	68	1.08	0.55	1.35	0.12
400	44	1.13	0.59	1.70	0.25	38	1.20	0.92	2.04	0.20	33	1.06	0.86	1.86	0.16
500	44	1.08	0.36	1.61	0.27	34	1.16	0.70	1.61	0.18	46	1.05	0.57	1.30	0.15
600	31	1.28	0.85	1.68	0.20	28	1.12	0.36	1.45	0.20	33	1.11	0.85	2.04	0.25
700	29	1.24	0.56	1.64	0.20	20	1.15	0.84	1.71	0.21	28	0.95	0.40	1.19	0.15
800	13	1.24	0.52	1.90	0.39	21	1.10	0.60	1.35	0.21	27	0.98	0.81	1.43	0.13
900	21	1.13	0.39	1.78	0.32	27	1.13	0.64	1.62	0.25	35	1.06	0.76	1.44	0.16
1000	14	1.24	0.78	1.69	0.25	16	1.15	0.81	1.51	0.22	40	0.99	0.83	1.33	0.13
1100	25	1.36	0.90	1.97	0.27	29	1.18	0.75	1.87	0.28	19	1.01	0.35	1.60	0.27
1200	16	1.28	0.69	1.87	0.28	11	1.16	0.75	1.48	0.25	13	1.06	0.79	1.57	0.19
1300	16	1.26	0.71	1.92	0.30	14	1.16	0.72	1.48	0.24	13	1.14	0.99	1.46	0.12
1400	16	1.35	0.74	1.85	0.29	26	1.24	0.69	1.82	0.30	25	1.07	0.70	1.50	0.19
1500	16	1.37	0.85	1.97	0.27	28	1.15	0.47	1.65	0.33	25	1.02	0.71	1.35	0.19
1600	15	1.14	0.74	1.58	0.30	27	1.26	0.71	1.71	0.32	20	1.07	0.59	1.57	0.23
1700	14	1.39	0.77	1.65	0.25	34	1.38	0.70	1.69	0.30	26	1.09	0.68	1.64	0.20

	Fog and drizzle (FD)					Drizzle and rain (DR)					Rain and snow (RS)				
IPH-MOR [m]	No. of obs.	Avg	Min	Max	Std	No. of obs.	Avg	Min	Max	Std	No. of obs.	Avg	Min	Max	Std
0	5	1.15	1.12	1.18	0.02	-	-	-	-	-	-	-	-	-	-
100	67	1.12	1.03	1.33	0.05	1	1.08	1.08	1.08	0.00	-	-	-	-	-
200	34	1.08	1.00	1.19	0.05	4	1.04	1.01	1.07	0.03	1	1.49	1.49	1.49	0.00
300	27	1.10	0.93	1.20	0.07	1	1.09	1.09	1.09	0.00	1	1.44	1.44	1.44	0.00
400	34	1.07	0.95	1.19	0.06	2	0.95	0.89	1.01	0.08	5	1.23	0.99	1.49	0.21
500	28	1.10	0.94	1.23	0.08	-	-	-	-	-	6	1.09	0.78	1.25	0.16
600	20	1.12	0.97	1.31	0.10	-	-	-	-	-	6	1.06	0.77	1.15	0.14
700	15	1.08	0.96	1.21	0.07	1	1.22	1.22	1.22	0.00	10	1.14	1.04	1.37	0.09
800	8	1.11	1.02	1.21	0.09	5	0.94	0.71	1.01	0.13	10	1.08	0.85	1.23	0.12
900	8	1.09	0.96	1.24	0.10	7	1.03	0.89	1.10	0.07	11	1.16	1.06	1.56	0.14
1000	3	1.14	0.92	1.29	0.19	7	1.07	0.94	1.12	0.06	18	1.19	1.01	1.99	0.21
1100	2	1.28	1.23	1.32	0.06	18	1.11	0.88	1.35	0.14	14	1.29	1.11	1.39	0.10
1200	2	1.21	1.10	1.32	0.16	21	0.97	0.71	1.34	0.16	6	1.22	1.12	1.36	0.10
1300	-	-	-	-	-	13	1.04	0.72	1.43	0.26	14	1.21	1.04	1.50	0.14
1400	4	1.12	0.91	1.37	0.19	23	1.03	0.57	1.51	0.30	11	1.29	1.16	1.48	0.12
1500	4	1.12	0.96	1.33	0.15	20	1.14	0.68	1.51	0.26	17	1.17	0.89	1.45	0.14
1600	3	1.09	1.06	1.15	0.05	25	1.13	0.69	1.58	0.33	23	1.26	0.92	1.51	0.14
1700	2	1.40	1.39	1.41	0.02	29	1.21	0.67	1.55	0.32	28	1.24	1.12	1.52	0.09

	Snow (S)					Snow (SX)					Snow (S-B1-B3)				
IPH-MOR [m]	No. of obs.	Avg	Min	Max	Std	No. of obs.	Avg	Min	Max	Std	No. of obs.	Avg	Min	Max	Std
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
100	3	0.58	0.52	0.62	0.05	-	-	-	-	-	-	-	-	-	-
200	62	0.50	0.23	1.67	0.32	8	1.22	0.70	1.67	0.37	-	-	-	-	-
300	27	0.69	0.21	1.66	0.46	5	1.35	1.06	1.66	0.24	1	1.06	1.06	1.06	0.00
400	10	0.92	0.20	1.83	0.61	1	1.08	1.08	1.08	0.00	-	-	-	-	-
500	18	0.96	0.18	1.88	0.51	8	1.08	0.98	1.18	0.08	5	1.04	0.98	1.15	0.06
600	29	1.06	0.17	1.93	0.51	15	1.12	0.87	1.93	0.24	7	1.04	0.99	1.13	0.06
700	40	1.07	0.16	1.76	0.36	27	1.10	0.95	1.64	0.14	17	1.06	0.95	1.23	0.09
800	48	1.07	0.24	1.70	0.28	34	1.13	0.60	1.60	0.14	25	1.10	0.60	1.23	0.12
900	48	1.10	0.21	1.47	0.21	45	1.14	0.86	1.47	0.12	36	1.14	0.86	1.47	0.12
1000	49	1.19	0.68	1.81	0.15	49	1.19	0.68	1.81	0.15	36	1.16	0.97	1.37	0.09
1100	33	1.23	0.19	2.08	0.31	31	1.28	1.08	2.08	0.24	22	1.19	1.08	1.34	0.09
1200	38	1.19	0.84	1.63	0.14	38	1.19	0.84	1.63	0.14	31	1.16	0.84	1.41	0.12
1300	47	1.13	0.16	1.50	0.27	45	1.17	0.67	1.50	0.18	37	1.13	0.67	1.48	0.16
1400	67	1.20	0.48	1.56	0.17	65	1.21	0.74	1.56	0.15	45	1.18	0.74	1.36	0.13
1500	47	1.19	0.44	1.77	0.20	46	1.20	0.73	1.77	0.16	35	1.16	0.73	1.37	0.14
1600	54	1.19	0.14	1.56	0.26	49	1.24	0.78	1.56	0.16	36	1.21	0.78	1.42	0.16
1700	45	1.18	0.38	1.64	0.32	40	1.27	0.93	1.64	0.17	31	1.23	0.93	1.48	0.15

	Snow (SX-B4-B5)					Snow (GRAINS)					Snow (SEED)				
IPH-MOR [m]	No. of obs.	Avg	Min	Max	Std	No. of obs.	Avg	Min	Max	Std	No. of obs.	Avg	Min	Max	Std
0	-	-	-	-	-	44	1.17	1.09	1.33	0.06	33	1.24	1.18	1.36	0.04
100	-	-	-	-	-	170	1.16	0.40	1.66	0.13	167	1.21	0.91	1.66	0.09
200	8	1.22	0.70	1.67	0.37	84	1.17	0.70	1.62	0.12	72	1.18	0.70	1.62	0.15
300	4	1.42	1.21	1.66	0.21	40	1.18	0.72	1.41	0.11	29	1.18	0.72	1.41	0.12
400	1	1.08	1.08	1.08	0.00	22	1.14	0.59	1.39	0.20	20	1.10	0.59	1.39	0.23
500	3	1.13	1.04	1.18	0.08	32	1.20	0.51	1.61	0.20	24	1.19	0.36	1.61	0.27
600	8	1.19	0.87	1.93	0.31	15	1.29	1.08	1.68	0.16	12	1.30	1.20	1.48	0.09
700	10	1.18	1.05	1.64	0.18	15	1.26	0.56	1.71	0.26	19	1.27	0.56	1.54	0.21
800	12	1.20	1.04	1.60	0.15	16	1.18	0.52	1.64	0.25	12	1.21	0.52	1.64	0.30
900	9	1.15	0.86	1.25	0.12	14	1.31	0.79	1.78	0.24	11	1.27	0.79	1.78	0.29
1000	15	1.27	0.68	1.81	0.23	6	1.38	1.28	1.51	0.08	7	1.31	1.00	1.51	0.18
1100	12	1.45	1.19	2.08	0.31	12	1.40	1.20	1.88	0.17	14	1.46	1.26	1.88	0.16
1200	10	1.32	1.14	1.63	0.15	8	1.32	0.97	1.56	0.21	7	1.39	1.22	1.56	0.14
1300	10	1.33	0.97	1.50	0.15	3	1.25	1.11	1.35	0.13	4	1.35	1.11	1.77	0.29
1400	21	1.29	0.84	1.56	0.15	9	1.49	1.41	1.63	0.07	9	1.52	1.42	1.69	0.09
1500	12	1.34	1.15	1.77	0.16	9	1.34	0.85	1.65	0.23	6	1.39	0.85	1.65	0.28
1600	16	1.34	1.15	1.56	0.11	10	1.42	1.03	1.63	0.21	5	1.39	1.07	1.57	0.20
1700	9	1.44	1.15	1.64	0.16	11	1.46	0.88	1.65	0.22	6	1.39	0.88	1.65	0.29

Table E.2.

The ratio VAI/VFS for the first period 19.12.1991-13.5.1992.
SX means snow where one snow drifting period are excluded: 2.4.1992 08:10-18:00.
B1, B3, B4 and B5 denotes the 10 minute Beaufort values. GRAINS denotes snow grains, mainly in radiation fog situations.
SEED denotes the period after seeding. Concerning other codes, see Appendix B. For explanation of MOR, see Table E.1.

	Fog (FR-F-FA-FD-D-R)					Fog (FR-F-FA)					Fog (FA-FD-D-R)				
VAI-MOR [m]	No. of obs.	Avg	Min	Max	Std	No. of obs.	Avg	Min	Max	Std	No. of obs.	Avg	Min	Max	Std
0	24	0.96	0.38	1.20	0.26	24	0.96	0.38	1.20	0.26	-	-	-	-	-
100	475	1.05	0.45	1.23	0.10	434	1.05	0.45	1.23	0.10	113	1.02	0.91	1.18	0.05
200	332	1.02	0.45	1.23	0.12	296	1.02	0.45	1.23	0.12	119	1.01	0.49	1.21	0.08
300	187	1.04	0.43	1.29	0.12	164	1.04	0.43	1.28	0.13	80	1.04	0.43	1.29	0.10
400	131	1.04	0.64	1.23	0.11	103	1.03	0.64	1.23	0.12	56	1.03	0.88	1.16	0.07
500	89	1.06	0.77	1.25	0.11	61	1.04	0.77	1.25	0.12	48	1.08	0.82	1.21	0.08
600	90	1.10	0.75	1.48	0.12	70	1.09	0.75	1.48	0.13	59	1.08	0.80	1.24	0.10
700	75	1.11	0.81	1.39	0.13	58	1.11	0.81	1.39	0.14	38	1.10	0.81	1.28	0.11
800	72	1.04	0.67	1.36	0.16	57	1.01	0.67	1.36	0.16	42	1.06	0.76	1.26	0.13
900	60	1.05	0.84	1.41	0.14	49	1.04	0.84	1.41	0.15	38	1.04	0.85	1.37	0.14
1000	48	1.13	0.76	1.48	0.15	41	1.12	0.76	1.48	0.16	30	1.13	0.76	1.34	0.13
1100	40	1.13	0.78	1.52	0.18	32	1.13	0.78	1.52	0.19	24	1.15	0.78	1.33	0.11
1200	34	1.10	0.78	1.49	0.18	23	1.13	0.78	1.49	0.20	21	1.09	0.78	1.39	0.16
1300	46	1.14	0.76	1.48	0.17	34	1.12	0.76	1.48	0.18	24	1.15	0.76	1.40	0.15
1400	33	1.14	0.70	1.37	0.15	29	1.14	0.70	1.37	0.16	20	1.12	0.70	1.29	0.15
1500	36	1.14	0.67	1.51	0.20	29	1.13	0.67	1.51	0.21	20	1.17	0.67	1.40	0.15
1600	47	1.11	0.55	1.56	0.23	36	1.08	0.55	1.56	0.25	25	1.16	0.63	1.45	0.17
1700	40	1.18	0.59	1.52	0.20	34	1.18	0.59	1.52	0.21	22	1.17	0.59	1.39	0.16
1800	32	1.15	0.67	1.43	0.18	29	1.14	0.67	1.43	0.19	20	1.23	1.04	1.35	0.10
1900	22	1.16	0.64	1.44	0.19	18	1.15	0.64	1.44	0.19	12	1.18	0.92	1.36	0.14
2000	32	1.24	0.73	1.54	0.18	24	1.21	0.73	1.54	0.19	19	1.30	1.09	1.54	0.10
2100	36	1.23	0.78	1.56	0.20	27	1.22	0.78	1.56	0.22	22	1.24	0.90	1.56	0.17
2200	30	1.20	0.95	1.60	0.17	23	1.20	0.95	1.60	0.19	13	1.14	1.01	1.33	0.11
2300	24	1.17	0.84	1.62	0.20	17	1.15	0.84	1.62	0.22	12	1.22	1.05	1.46	0.14
2400	14	1.28	0.94	1.82	0.24	8	1.28	0.94	1.82	0.30	8	1.27	0.96	1.54	0.20
2500	15	1.20	0.89	1.53	0.19	8	1.21	0.89	1.53	0.23	9	1.20	0.99	1.45	0.16

	Radiation fog (FR)					Fog (F)					Advection fog (FA)				
VAI-MOR [m]	No. of obs.	Avg	Min	Max	Std	No. of obs.	Avg	Min	Max	Std	No. of obs.	Avg	Min	Max	Std
0	13	0.87	0.38	1.15	0.29	11	1.07	0.56	1.20	0.18	-	-	-	-	-
100	255	1.04	0.45	1.23	0.12	107	1.08	0.85	1.22	0.08	72	1.03	0.91	1.18	0.06
200	137	1.02	0.45	1.23	0.15	76	1.04	0.73	1.21	0.10	83	1.01	0.49	1.21	0.09
300	63	1.03	0.50	1.28	0.16	44	1.06	0.88	1.25	0.11	57	1.02	0.43	1.18	0.11
400	38	1.03	0.66	1.23	0.13	37	1.05	0.64	1.22	0.12	28	1.01	0.88	1.16	0.07
500	17	0.98	0.77	1.20	0.13	24	1.07	0.83	1.25	0.12	20	1.05	0.82	1.17	0.10
600	13	1.10	0.75	1.48	0.19	18	1.15	0.90	1.28	0.11	39	1.06	0.80	1.24	0.10
700	22	1.09	0.82	1.33	0.14	15	1.18	0.95	1.39	0.15	21	1.07	0.81	1.27	0.12
800	21	0.98	0.67	1.36	0.20	9	1.10	0.90	1.29	0.10	27	1.00	0.76	1.21	0.12
900	15	1.09	0.84	1.41	0.16	7	1.04	0.89	1.32	0.15	27	1.01	0.85	1.37	0.14
1000	10	1.09	0.85	1.48	0.21	8	1.19	1.01	1.38	0.12	23	1.12	0.76	1.34	0.14
1100	8	1.08	0.82	1.52	0.28	8	1.13	0.84	1.43	0.22	16	1.16	0.78	1.29	0.12
1200	8	1.24	0.89	1.49	0.17	5	0.94	0.84	1.10	0.11	10	1.13	0.78	1.39	0.20
1300	11	1.13	0.83	1.25	0.13	11	1.11	0.79	1.48	0.26	12	1.12	0.76	1.40	0.16
1400	8	1.15	0.93	1.37	0.14	5	1.16	0.81	1.33	0.20	16	1.12	0.70	1.29	0.16
1500	7	1.14	0.83	1.35	0.16	9	1.08	0.75	1.51	0.31	13	1.15	0.67	1.32	0.16
1600	13	1.05	0.55	1.56	0.27	9	1.04	0.68	1.45	0.29	14	1.13	0.63	1.41	0.20
1700	10	1.23	0.91	1.52	0.17	8	1.15	0.67	1.46	0.31	16	1.17	0.59	1.39	0.19
1800	6	1.09	0.99	1.35	0.14	6	0.96	0.67	1.43	0.29	17	1.22	1.04	1.34	0.09
1900	3	1.23	1.06	1.44	0.19	7	1.08	0.64	1.39	0.25	8	1.18	1.05	1.29	0.11
2000	7	1.19	0.97	1.43	0.15	6	1.12	0.73	1.52	0.30	11	1.27	1.09	1.54	0.12
2100	7	1.21	0.81	1.52	0.25	7	1.19	0.78	1.52	0.25	13	1.25	1.03	1.56	0.20
2200	10	1.31	1.03	1.60	0.20	7	1.15	0.95	1.50	0.18	6	1.07	1.01	1.10	0.04
2300	4	1.26	1.05	1.44	0.17	8	1.04	0.84	1.62	0.24	5	1.25	1.05	1.44	0.15
2400	4	1.34	1.08	1.82	0.33	2	1.16	0.94	1.39	0.32	2	1.27	1.00	1.54	0.38
2500	2	1.41	1.30	1.53	0.16	4	1.11	0.89	1.35	0.23	2	1.18	0.99	1.37	0.27

	Fog and drizzle (FD)					Drizzle and rain (DR)					Rain and snow (RS)				
VAI-MOR [m]	No. of obs.	Avg	Min	Max	Std	No. of obs.	Avg	Min	Max	Std	No. of obs.	Avg	Min	Max	Std
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
100	41	1.01	0.95	1.08	0.04	-	-	-	-	-	-	-	-	-	-
200	31	1.01	0.93	1.08	0.04	5	1.03	1.00	1.08	0.04	-	-	-	-	-
300	21	1.05	0.93	1.17	0.07	2	1.17	1.05	1.29	0.17	-	-	-	-	-
400	27	1.06	0.94	1.15	0.06	1	1.14	1.14	1.14	0.00	-	-	-	-	-
500	28	1.10	0.98	1.21	0.05	-	-	-	-	-	4	1.02	0.99	1.04	0.02
600	20	1.11	1.01	1.21	0.07	-	-	-	-	-	5	1.02	0.99	1.04	0.02
700	17	1.14	1.05	1.28	0.08	-	-	-	-	-	6	1.04	1.01	1.09	0.03
800	12	1.19	1.06	1.26	0.05	3	1.02	1.00	1.03	0.02	6	1.09	1.00	1.26	0.09
900	7	1.13	1.04	1.25	0.07	4	1.09	1.03	1.16	0.06	7	1.13	1.05	1.33	0.09
1000	5	1.21	1.09	1.32	0.09	2	1.10	1.05	1.15	0.07	5	1.11	1.06	1.22	0.07
1100	2	1.29	1.26	1.33	0.05	6	1.10	0.98	1.15	0.07	10	1.14	1.01	1.35	0.12
1200	-	-	-	-	-	11	1.06	0.96	1.27	0.10	7	1.23	0.94	1.49	0.18
1300	4	1.29	1.19	1.38	0.10	8	1.13	0.95	1.31	0.12	-	-	-	-	-
1400	-	-	-	-	-	4	1.11	0.95	1.21	0.11	5	1.18	0.91	1.42	0.19
1500	3	1.17	0.99	1.40	0.21	4	1.24	1.17	1.29	0.05	11	1.17	0.93	1.40	0.16
1600	4	1.18	1.06	1.40	0.15	7	1.22	1.15	1.45	0.10	8	1.21	0.98	1.43	0.15
1700	2	1.18	1.16	1.19	0.02	4	1.14	1.11	1.17	0.02	5	1.22	1.15	1.33	0.07
1800	-	-	-	-	-	3	1.28	1.17	1.35	0.10	5	1.18	1.07	1.26	0.08
1900	2	1.01	0.92	1.11	0.13	2	1.36	1.35	1.36	0.01	11	1.27	0.86	1.49	0.18
2000	1	1.50	1.50	1.50	0.00	7	1.32	1.24	1.35	0.04	21	1.22	0.82	1.67	0.21
2100	1	0.90	0.90	0.90	0.00	8	1.28	1.15	1.36	0.07	15	1.19	0.96	1.35	0.13
2200	1	1.05	1.05	1.05	0.00	6	1.22	1.06	1.33	0.12	20	1.19	1.01	1.45	0.12
2300	1	1.46	1.46	1.46	0.00	6	1.16	1.05	1.29	0.11	13	1.20	1.04	1.57	0.15
2400	-	-	-	-	-	6	1.27	0.96	1.39	0.16	11	1.14	0.95	1.50	0.15
2500	2	1.25	1.06	1.45	0.28	5	1.19	1.04	1.28	0.11	11	1.21	0.99	1.69	0.24

	Snow (S)					Snow (SX)					Snow (S-B1-B3)				
VAI-MOR [m]	No. of obs.	Avg	Min	Max	Std	No. of obs.	Avg	Min	Max	Std	No. of obs.	Avg	Min	Max	Std
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
100	1	0.10	0.10	0.10	0.00	-	-	-	-	-	-	-	-	-	-
200	5	0.12	0.09	0.17	0.04	-	-	-	-	-	-	-	-	-	-
300	5	0.17	0.15	0.20	0.02	-	-	-	-	-	-	-	-	-	-
400	4	0.73	0.21	1.47	0.61	2	1.24	1.01	1.47	0.33	2	1.24	1.01	1.47	0.33
500	5	0.54	0.21	1.12	0.37	3	0.74	0.55	1.12	0.33	1	1.12	1.12	1.12	0.00
600	10	0.91	0.24	2.16	0.70	7	1.19	0.51	2.16	0.66	4	1.61	1.02	2.16	0.55
700	12	0.92	0.26	1.53	0.42	10	1.05	0.60	1.53	0.32	7	1.18	0.82	1.53	0.28
800	11	0.84	0.29	2.15	0.50	10	0.90	0.29	2.15	0.49	5	1.17	0.79	2.15	0.56
900	19	1.18	0.57	1.96	0.42	19	1.18	0.57	1.96	0.42	17	1.23	0.57	1.96	0.42
1000	17	1.17	0.55	1.92	0.36	17	1.17	0.55	1.92	0.36	14	1.24	0.72	1.92	0.33
1100	14	0.97	0.46	1.66	0.29	14	0.97	0.46	1.66	0.29	12	1.05	0.80	1.66	0.22
1200	22	1.06	0.46	1.65	0.29	22	1.06	0.46	1.65	0.29	19	1.14	0.82	1.65	0.20
1300	20	1.08	0.64	1.39	0.20	20	1.08	0.64	1.39	0.20	19	1.11	0.75	1.39	0.17
1400	29	1.09	0.49	1.78	0.29	29	1.09	0.49	1.78	0.29	23	1.18	0.80	1.78	0.24
1500	18	1.07	0.60	1.40	0.23	18	1.07	0.60	1.40	0.23	16	1.10	0.82	1.40	0.21
1600	18	1.14	0.69	1.63	0.29	18	1.14	0.69	1.63	0.29	18	1.14	0.69	1.63	0.29
1700	23	1.10	0.60	1.66	0.26	23	1.10	0.60	1.66	0.26	18	1.16	0.86	1.66	0.21
1800	9	1.14	0.88	1.37	0.16	9	1.14	0.88	1.37	0.16	8	1.12	0.88	1.37	0.17
1900	15	1.15	0.68	1.55	0.25	15	1.15	0.68	1.55	0.25	10	1.22	0.80	1.55	0.22
2000	16	1.13	0.80	1.51	0.17	16	1.13	0.80	1.51	0.17	16	1.13	0.80	1.51	0.17
2100	8	1.13	0.73	1.46	0.22	8	1.13	0.73	1.46	0.22	7	1.13	0.73	1.46	0.24
2200	11	1.06	0.81	1.24	0.12	11	1.06	0.81	1.24	0.12	7	1.05	0.81	1.24	0.15
2300	5	1.13	0.96	1.24	0.14	5	1.13	0.96	1.24	0.14	4	1.16	0.96	1.24	0.13
2400	3	1.02	0.90	1.09	0.10	3	1.02	0.90	1.09	0.10	1	1.07	1.07	1.07	0.00
2500	9	1.13	0.96	1.32	0.12	9	1.13	0.96	1.32	0.12	8	1.13	0.96	1.32	0.13

	Snow (SX-B4-B5)					Snow (GRAINS)					Snow (SEED)				
VAI-MOR [m]	No. of obs.	Avg	Min	Max	Std	No. of obs.	Avg	Min	Max	Std	No. of obs.	Avg	Min	Max	Std
0	-	-	-	-	-	10	0.93	0.38	1.20	0.32	10	1.02	0.58	1.20	0.23
100	-	-	-	-	-	60	1.06	0.59	1.17	0.09	116	1.03	0.56	1.20	0.14
200	-	-	-	-	-	55	1.05	0.66	1.22	0.10	76	1.02	0.59	1.22	0.12
300	-	-	-	-	-	28	1.05	0.60	1.25	0.13	31	1.02	0.60	1.25	0.17
400	-	-	-	-	-	29	1.06	0.64	1.23	0.14	25	1.02	0.64	1.23	0.18
500	2	0.55	0.55	0.55	0.01	11	1.07	0.83	1.25	0.15	9	0.95	0.77	1.24	0.16
600	3	0.63	0.51	0.78	0.13	12	1.14	0.75	1.28	0.15	9	1.07	0.75	1.26	0.15
700	3	0.76	0.60	0.96	0.18	14	1.18	0.96	1.39	0.15	14	1.13	0.90	1.30	0.15
800	5	0.62	0.29	0.85	0.21	10	1.02	0.80	1.35	0.18	12	0.90	0.67	1.17	0.16
900	4	0.89	0.57	1.50	0.42	11	1.04	0.84	1.41	0.19	11	1.02	0.84	1.21	0.13
1000	4	0.93	0.55	1.22	0.32	4	1.30	1.14	1.39	0.12	8	1.07	0.85	1.39	0.21
1100	2	0.49	0.46	0.53	0.05	7	1.15	0.84	1.43	0.21	8	1.04	0.82	1.43	0.21
1200	3	0.52	0.46	0.57	0.06	3	1.04	0.84	1.17	0.17	4	1.15	0.89	1.36	0.20
1300	3	1.03	0.64	1.35	0.36	5	1.14	0.82	1.48	0.25	6	1.12	0.82	1.48	0.26
1400	6	0.78	0.49	1.16	0.26	5	1.23	0.98	1.37	0.16	5	1.15	0.93	1.37	0.19
1500	5	1.07	0.60	1.40	0.34	5	1.36	1.12	1.51	0.15	6	1.32	1.10	1.51	0.17
1600	3	1.12	0.87	1.35	0.24	3	1.03	0.64	1.45	0.41	7	1.00	0.64	1.43	0.24
1700	6	0.95	0.60	1.34	0.32	5	1.22	0.67	1.42	0.31	4	1.22	1.07	1.42	0.17
1800	2	1.25	1.24	1.26	0.01	2	0.99	0.85	1.13	0.19	3	0.99	0.85	1.13	0.14
1900	6	1.05	0.68	1.32	0.25	3	1.25	0.99	1.44	0.23	3	1.25	0.99	1.44	0.23
2000	2	0.99	0.97	1.01	0.03	3	1.30	0.97	1.52	0.29	2	1.19	0.97	1.41	0.32
2100	1	1.11	1.11	1.11	0.00	3	1.24	0.98	1.52	0.27	3	1.24	0.98	1.52	0.27
2200	6	1.08	1.03	1.19	0.06	5	1.29	1.10	1.60	0.21	8	1.31	1.03	1.60	0.21
2300	2	1.11	1.01	1.21	0.14	1	1.62	1.62	1.62	0.00	1	1.20	1.20	1.20	0.00
2400	2	0.99	0.90	1.09	0.13	1	1.39	1.39	1.39	0.00	2	1.24	1.08	1.39	0.22
2500	1	1.14	1.14	1.14	0.00	2	1.29	1.27	1.30	0.02	3	1.37	1.27	1.53	0.14

Table E.3.

The ratio VFS/IPH for the first period 19.12.1991-13.5.1992.
SX means snow where one snow drifting period are excluded: 2.4.1992 08:10-18:00.
B1, B3, B4 and B5 denotes the 10 minute Beaufort values. GRAINS denotes snow grains, mainly in radiation fog situations.
SEED denotes the period after seeding. Concerning other codes, see Appendix B. For explanation of MOR, see Table E.1.

	Fog (FR-F-FA-FD-D-R)					Fog (FR-F-FA)					Fog (FA-FD-D-R)				
IPH-MOR [m]	No. of obs.	Avg	Min	Max	Std	No. of obs.	Avg	Min	Max	Std	No. of obs.	Avg	Min	Max	Std
0	84	1.16	0.92	2.10	0.22	79	1.16	0.92	2.10	0.23	5	1.10	1.04	1.16	0.05
100	507	1.13	0.83	2.04	0.13	462	1.13	0.83	2.04	0.14	127	1.09	0.98	1.24	0.05
200	311	1.10	0.57	2.09	0.16	277	1.11	0.57	2.09	0.16	129	1.09	0.92	1.36	0.08
300	154	1.09	0.75	2.01	0.17	131	1.10	0.75	2.01	0.18	68	1.05	0.81	1.34	0.10
400	123	1.06	0.61	1.87	0.19	89	1.09	0.61	1.87	0.21	60	1.02	0.69	1.87	0.14
500	108	1.04	0.33	2.00	0.22	81	1.06	0.33	2.00	0.25	55	1.01	0.88	1.30	0.08
600	84	1.05	0.38	1.76	0.20	64	1.07	0.38	1.76	0.23	46	0.99	0.84	1.20	0.09
700	68	1.10	0.60	2.02	0.27	54	1.14	0.60	2.02	0.29	33	0.94	0.76	1.16	0.09
800	43	1.01	0.51	1.81	0.23	32	1.03	0.51	1.81	0.26	28	0.96	0.83	1.26	0.10
900	69	0.98	0.40	2.03	0.23	56	0.99	0.40	2.03	0.26	45	0.94	0.76	1.16	0.08
1000	60	1.00	0.80	1.97	0.19	52	1.01	0.83	1.97	0.20	46	0.95	0.80	1.28	0.09
1100	53	1.07	0.65	1.66	0.22	42	1.10	0.65	1.66	0.23	27	0.97	0.82	1.30	0.10
1200	39	1.04	0.58	1.73	0.22	27	1.06	0.58	1.73	0.26	23	0.97	0.87	1.22	0.07
1300	40	0.99	0.81	1.62	0.15	34	0.99	0.81	1.62	0.16	20	0.99	0.85	1.62	0.16
1400	60	1.05	0.75	1.68	0.21	46	1.06	0.80	1.68	0.23	34	0.96	0.75	1.31	0.13
1500	59	1.03	0.49	1.77	0.23	42	1.03	0.49	1.77	0.25	34	0.98	0.82	1.37	0.14
1600	50	1.04	0.49	1.65	0.21	32	1.03	0.49	1.65	0.24	34	1.01	0.83	1.45	0.16
1700	69	1.05	0.65	1.74	0.20	49	1.04	0.65	1.74	0.21	43	0.98	0.65	1.48	0.17

	Radiation fog (FR)					Fog (F)					Advection fog (FA)				
IPH-MOR [m]	No. of obs.	Avg	Min	Max	Std	No. of obs.	Avg	Min	Max	Std	No. of obs.	Avg	Min	Max	Std
0	50	1.21	0.92	2.10	0.27	29	1.08	1.05	1.21	0.03	-	-	-	-	-
100	275	1.15	0.83	2.04	0.17	105	1.10	0.93	1.33	0.08	82	1.10	0.98	1.23	0.06
200	96	1.12	0.57	2.09	0.23	86	1.10	0.73	1.54	0.14	95	1.10	0.92	1.36	0.08
300	42	1.10	0.75	2.01	0.21	44	1.14	0.80	1.93	0.21	45	1.06	0.81	1.34	0.11
400	30	1.06	0.61	1.49	0.24	33	1.13	0.79	1.75	0.21	26	1.06	0.86	1.87	0.19
500	33	1.08	0.33	2.00	0.36	20	1.06	0.78	1.72	0.19	28	1.02	0.88	1.30	0.09
600	22	1.22	0.86	1.76	0.27	16	0.99	0.38	1.30	0.21	26	0.99	0.84	1.20	0.10
700	25	1.25	0.60	1.88	0.29	10	1.23	0.77	2.02	0.35	19	0.94	0.76	1.16	0.11
800	7	1.19	0.51	1.81	0.43	8	1.05	0.62	1.60	0.29	17	0.96	0.83	1.26	0.12
900	12	1.07	0.40	2.03	0.44	12	1.04	0.60	1.64	0.32	32	0.95	0.76	1.16	0.09
1000	10	1.22	0.98	1.97	0.31	4	1.11	0.91	1.52	0.28	38	0.95	0.83	1.28	0.09
1100	18	1.23	0.65	1.66	0.27	8	1.04	0.89	1.30	0.13	16	0.97	0.82	1.30	0.13
1200	11	1.14	0.58	1.62	0.32	5	1.11	0.84	1.73	0.36	11	0.97	0.87	1.22	0.09
1300	12	0.99	0.81	1.32	0.18	8	0.98	0.81	1.13	0.11	14	1.00	0.87	1.62	0.19
1400	13	1.08	0.88	1.56	0.21	13	1.22	0.85	1.68	0.28	20	0.94	0.80	1.19	0.11
1500	13	1.19	0.68	1.77	0.31	12	1.01	0.49	1.67	0.28	17	0.92	0.83	1.06	0.06
1600	9	1.17	0.49	1.65	0.36	7	1.06	0.74	1.39	0.20	16	0.94	0.83	1.14	0.10
1700	16	1.16	0.94	1.74	0.23	10	1.15	0.88	1.53	0.21	23	0.91	0.65	1.22	0.12

	Fog and drizzle (FD)					Drizzle and rain (DR)					Rain and snow (RS)				
IPH-MOR [m]	No. of obs.	Avg	Min	Max	Std	No. of obs.	Avg	Min	Max	Std	No. of obs.	Avg	Min	Max	Std
0	5	1.10	1.04	1.16	0.05	-	-	-	-	-	-	-	-	-	-
100	44	1.09	0.99	1.24	0.05	1	0.99	0.99	0.99	0.00	-	-	-	-	-
200	30	1.05	0.98	1.25	0.06	4	1.03	0.96	1.08	0.05	-	-	-	-	-
300	22	1.03	0.81	1.24	0.09	1	1.04	1.04	1.04	0.00	-	-	-	-	-
400	32	1.00	0.89	1.12	0.06	2	0.79	0.69	0.89	0.14	2	1.12	1.09	1.14	0.04
500	27	1.00	0.89	1.18	0.07	-	-	-	-	-	4	1.10	1.07	1.14	0.03
600	20	1.00	0.86	1.13	0.08	-	-	-	-	-	5	1.10	1.06	1.13	0.03
700	14	0.94	0.83	1.12	0.07	-	-	-	-	-	10	1.06	0.93	1.28	0.09
800	8	0.95	0.85	1.11	0.08	3	0.99	0.97	1.01	0.02	7	1.01	0.92	1.07	0.05
900	8	0.91	0.83	0.96	0.04	5	0.97	0.93	1.00	0.03	7	0.98	0.85	1.04	0.07
1000	2	0.87	0.80	0.94	0.10	6	0.97	0.96	0.99	0.01	13	1.00	0.81	1.09	0.09
1100	2	0.92	0.89	0.94	0.03	9	0.97	0.87	1.06	0.06	11	1.05	0.87	1.22	0.12
1200	2	0.93	0.92	0.94	0.01	10	0.98	0.89	1.06	0.06	5	1.07	0.94	1.27	0.13
1300	-	-	-	-	-	6	0.96	0.85	1.07	0.09	11	1.05	0.94	1.21	0.09
1400	3	0.92	0.75	1.06	0.16	11	1.02	0.88	1.31	0.14	9	0.98	0.84	1.19	0.11
1500	4	0.95	0.88	0.98	0.04	13	1.05	0.82	1.37	0.19	8	1.05	0.93	1.42	0.16
1600	3	0.95	0.89	1.04	0.08	15	1.09	0.86	1.45	0.18	20	1.06	0.86	1.32	0.15
1700	2	0.96	0.95	0.98	0.02	18	1.08	0.88	1.48	0.19	26	1.05	0.86	1.50	0.16

	Snow (S)					Snow (SX)					Snow (S-B1-B3)				
IPH-MOR [m]	No. of obs.	Avg	Min	Max	Std	No. of obs.	Avg	Min	Max	Std	No. of obs.	Avg	Min	Max	Std
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
200	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
300	1	0.72	0.72	0.72	0.00	1	0.72	0.72	0.72	0.00	1	0.72	0.72	0.72	0.00
400	1	1.98	1.98	1.98	0.00	1	1.98	1.98	1.98	0.00	-	-	-	-	-
500	4	1.24	0.57	1.96	0.62	4	1.24	0.57	1.96	0.62	2	0.75	0.57	0.92	0.25
600	8	1.17	0.46	1.83	0.47	8	1.17	0.46	1.83	0.47	5	0.87	0.46	1.24	0.29
700	16	1.14	0.52	2.02	0.41	16	1.14	0.52	2.02	0.41	11	0.96	0.52	1.34	0.30
800	22	1.19	0.60	2.06	0.38	22	1.19	0.60	2.06	0.38	18	1.13	0.60	2.06	0.38
900	20	1.05	0.59	1.52	0.30	20	1.05	0.59	1.52	0.30	20	1.05	0.59	1.52	0.30
1000	30	1.16	0.58	2.01	0.31	30	1.16	0.58	2.01	0.31	25	1.08	0.58	1.45	0.21
1100	19	1.09	0.66	1.62	0.23	19	1.09	0.66	1.62	0.23	17	1.08	0.66	1.62	0.24
1200	25	1.17	0.75	2.07	0.31	25	1.17	0.75	2.07	0.31	22	1.13	0.75	1.54	0.26
1300	28	1.09	0.64	2.05	0.31	28	1.09	0.64	2.05	0.31	23	0.99	0.64	1.40	0.19
1400	28	1.15	0.68	2.07	0.34	27	1.13	0.68	2.07	0.33	22	1.05	0.68	1.64	0.27
1500	23	1.12	0.71	1.89	0.30	22	1.09	0.71	1.89	0.28	20	1.04	0.71	1.41	0.22
1600	21	1.15	0.65	1.52	0.20	20	1.13	0.65	1.52	0.18	18	1.12	0.65	1.52	0.18
1700	18	1.19	0.78	1.73	0.28	16	1.13	0.78	1.51	0.24	12	1.07	0.78	1.51	0.24

	Snow (SX-B4-B5)					Snow (GRAINS)					Snow (SEED)				
IPH-MOR [m]	No. of obs.	Avg	Min	Max	Std	No. of obs.	Avg	Min	Max	Std	No. of obs.	Avg	Min	Max	Std
0	-	-	-	-	-	14	1.13	1.04	1.33	0.09	33	1.27	1.04	2.10	0.32
100	-	-	-	-	-	69	1.12	0.96	1.61	0.10	123	1.20	0.83	2.04	0.21
200	-	-	-	-	-	57	1.12	0.62	2.09	0.21	59	1.15	0.62	2.09	0.26
300	-	-	-	-	-	29	1.18	0.75	1.93	0.25	26	1.20	0.75	2.01	0.30
400	1	1.98	1.98	1.98	0.00	19	1.04	0.62	1.45	0.23	17	1.08	0.61	1.47	0.29
500	2	1.74	1.52	1.96	0.32	20	1.14	0.65	1.72	0.29	18	1.25	0.33	2.00	0.39
600	3	1.66	1.57	1.83	0.15	9	1.16	0.96	1.50	0.22	11	1.33	0.96	1.76	0.31
700	5	1.55	1.15	2.02	0.32	14	1.27	0.60	2.02	0.32	19	1.31	0.60	1.88	0.29
800	7	1.38	0.77	2.06	0.45	9	1.07	0.51	1.60	0.35	8	1.20	0.51	1.81	0.44
900						10	1.21	0.63	2.03	0.43	11	1.21	0.63	2.03	0.45
1000	7	1.45	0.92	2.01	0.40	4	1.38	1.01	1.97	0.46	7	1.28	0.98	1.97	0.38
1100	5	1.23	0.94	1.58	0.23	9	1.09	0.92	1.29	0.10	12	1.27	0.92	1.66	0.22
1200	6	1.31	0.94	2.07	0.44	5	1.22	0.83	1.73	0.43	5	1.34	0.84	1.73	0.37
1300	7	1.39	0.99	2.05	0.41	2	0.86	0.81	0.91	0.07	4	0.93	0.81	1.15	0.15
1400	6	1.40	0.98	2.07	0.39	5	1.30	0.93	1.59	0.25	6	1.36	1.04	1.59	0.21
1500	4	1.49	1.33	1.89	0.27	9	1.24	0.68	1.77	0.38	8	1.23	0.68	1.77	0.36
1600	5	1.24	1.17	1.38	0.09	3	1.02	0.83	1.18	0.18	4	1.10	0.83	1.33	0.21
1700	4	1.31	1.25	1.35	0.05	7	1.17	1.02	1.38	0.16	8	1.29	0.98	1.74	0.28

Figure E.1.

The ratio VAI/IPH distributed on IPH-MOR values in the interval 0-500 m in periods with radiation fog. Regression line: VAI/IPH=-0.00023·IPH(MOR)+1.219.

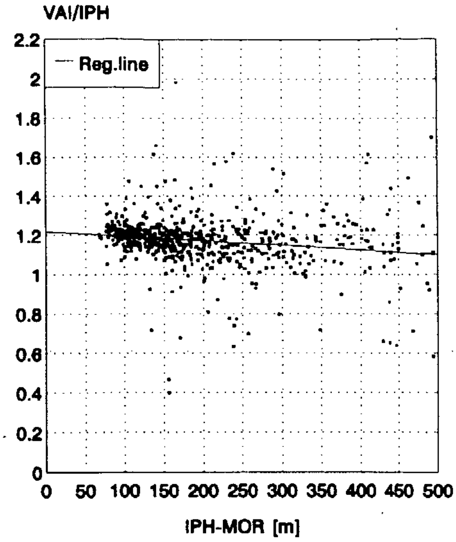


Figure E.2.

The ratio VAI/IPH distributed on IPH-MOR values in the interval 0-500 m in periods with advection fog and drizzle/ rain. Regression line: VAI/IPH=-0.00024·IPH(MOR)+1.170.

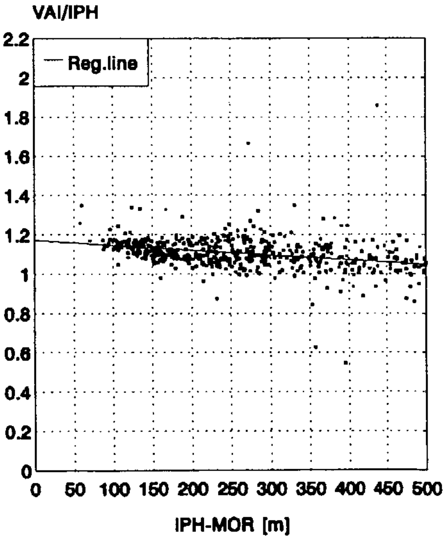


Figure E.3.

The VAI-MOR distributed on IPH-MOR values in the interval 0-500 m in periods with radiation fog. Regression line: VAI(MOR) = 1.11·IPH(MOR) + 10.23. Correlation: 94%.

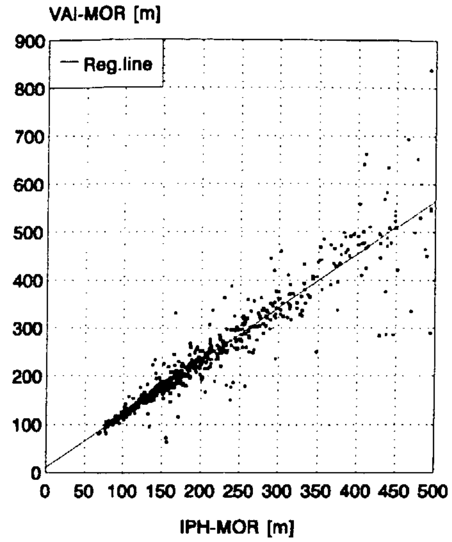


Figure E.4.

The VAI-MOR distributed on IPH-MOR values in the interval 0-500 in periods with advection fog and drizzle/rain. Regression line: VAI(MOR) = 1.03·IPH(MOR) + 16.27. Correlation: 97%.

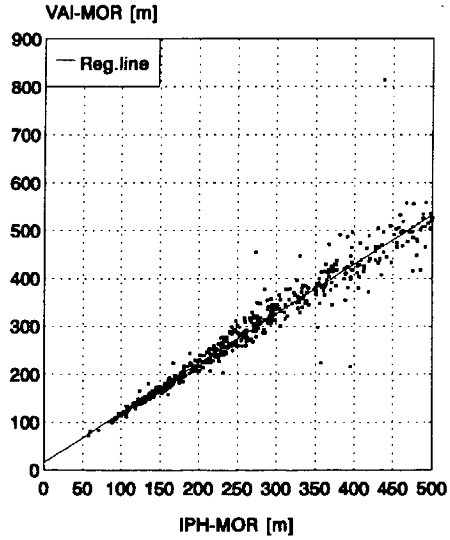


Figure E.5.

The VFS-MOR distributed on VAI-MOR values in the interval 0-500 m (all fog, snow excepted, first season of test period). Regression line: VAI(MOR)=0.98·VAI(MOR)+1.79. Correlation: 92%.

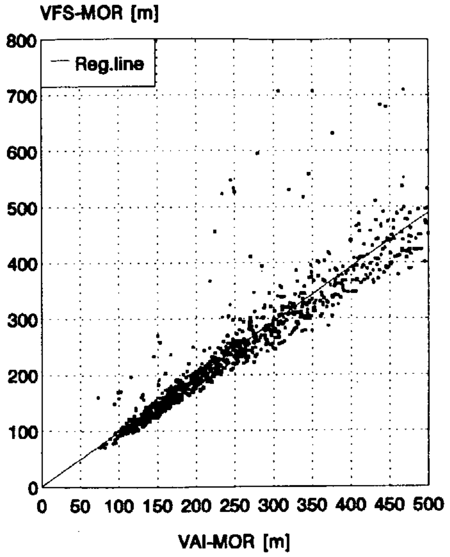
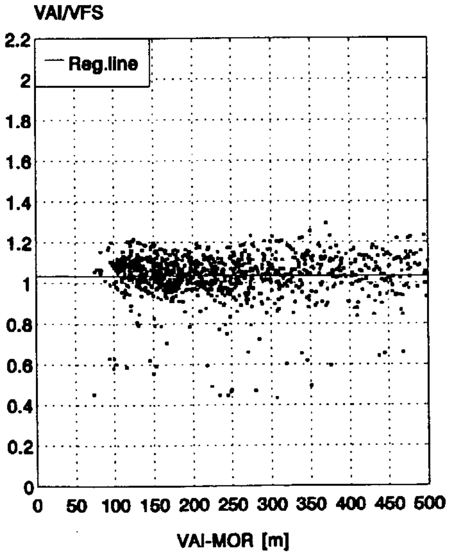


Figure E.6.

The ratio VAI/VFS distributed on VAI-MOR values in the interval 0-500 m (all fog, snow excepted, first season of test period). Regression line: VAI/VFS≈1.04.



APPENDIX F. COMPARISON OF IMPULSPHYSIK AND VAISALA CALCULATIONS OF RVR

Tabell F.1.
Night conditions of RVR calculations.

Runway light intencity:	4000	
Background luminance:	1	
Illumination threshold (IPH):	10^	-6.7
Illumination threshold (VAI):	10^	-7.0
Correction factor:	5	
Corrected illum. thresh. (VAI):	10^	-6.3

IPH MOR	IPH RVR
50	**216**

VAI/ IPH MOR	VAI MOR	VAI RVR	VAI/ IPH RVR
1.00	50	203	0.94
1.05	53	212	0.98
1.10	55	220	1.02
1.15	58	229	1.06
1.20	60	238	1.10
1.25	63	246	1.14

IPH MOR	IPH RVR
100	**393**

VAI/ IPH MOR	VAI MOR	VAI RVR	VAI/ IPH RVR
1.00	100	367	0.93
1.05	105	382	0.97
1.10	110	398	1.01
1.15	115	413	1.05
1.20	120	428	1.09
1.25	125	443	1.13

IPH MOR	IPH RVR
150	**555**

VAI/ IPH MOR	VAI MOR	VAI RVR	VAI/ IPH RVR
1.00	150	516	0.93
1.05	158	538	0.97
1.10	165	559	1.01
1.15	173	580	1.05
1.20	180	601	1.08
1.25	188	622	1.12

IPH MOR	IPH RVR
200	**708**

VAI/ IPH MOR	VAI MOR	VAI RVR	VAI/ IPH RVR
1.00	200	656	0.93
1.05	210	684	0.97
1.10	220	711	1.00
1.15	230	737	1.04
1.20	240	764	1.08
1.25	250	790	1.12

IPH MOR	IPH RVR
250	**853**

VAI/ IPH MOR	VAI MOR	VAI RVR	VAI/ IPH RVR
1.00	250	790	0.93
1.05	263	822	0.96
1.10	275	854	1.00
1.15	288	886	1.04
1.20	300	918	1.08
1.25	313	949	1.11

IPH MOR	IPH RVR
300	**994**

VAI/ IPH MOR	VAI MOR	VAI RVR	VAI/ IPH RVR
1.00	300	918	0.92
1.05	315	955	0.96
1.10	330	992	1.00
1.15	345	1029	1.04
1.20	360	1065	1.07
1.25	375	1101	1.11

IPH MOR	IPH RVR
400	**1261**

VAI/ IPH MOR	VAI MOR	VAI RVR	VAI/ IPH RVR
1.00	400	1161	0.92
1.05	420	1208	0.96
1.10	440	1254	0.99
1.15	460	1300	1.03
1.20	480	1346	1.07
1.25	500	1391	1.10

IPH MOR	IPH RVR
500	**1515**

VAI/ IPH MOR	VAI MOR	VAI RVR	VAI/ IPH RVR
1.00	500	1391	0.92
1.05	525	1446	0.95
1.10	550	1502	0.99
1.15	575	1556	1.03
1.20	600	1610	1.06
1.25	625	1664	1.10

IPH MOR	IPH RVR
600	**1759**

VAI/ IPH MOR	VAI MOR	VAI RVR	VAI/ IPH RVR
1.00	600	1610	0.92
1.05	630	1674	0.95
1.10	660	1738	0.99
1.15	690	1800	1.02
1.20	720	1862	1.06
1.25	750	1923	1.09

Tabell F.2.
Twilight conditions of RVR calculations.

Runway light intencity:	4000	
Background luminance:	50	
Illumination threshold (IPH):	10^	-5.6
Illumination threshold (VAI):	10^	-5.5
Correction factor:	3	
Corrected illum. thresh. (VAI):	10^	-5.0

IPH MOR	IPH RVR
50	**179**

VAI/ IPH MOR	VAI MOR	VAI RVR	VAI/ IPH RVR
1.00	50	161	0.90
1.05	53	168	0.94
1.10	55	175	0.98
1.15	58	181	1.01
1.20	60	188	1.05
1.25	63	194	1.09

IPH MOR	IPH RVR
100	**319**

VAI/ IPH MOR	VAI MOR	VAI RVR	VAI/ IPH RVR
1.00	100	285	0.89
1.05	105	296	0.93
1.10	110	308	0.96
1.15	115	319	1.00
1.20	120	330	1.03
1.25	125	341	1.07

IPH MOR	IPH RVR
150	**445**

VAI/ IPH MOR	VAI MOR	VAI RVR	VAI/ IPH RVR
1.00	150	395	0.89
1.05	158	410	0.92
1.10	165	426	0.96
1.15	173	441	0.99
1.20	180	456	1.02
1.25	188	471	1.06

IPH MOR	IPH RVR
200	**562**

VAI/ IPH MOR	VAI MOR	VAI RVR	VAI/ IPH RVR
1.00	200	496	0.88
1.05	210	515	0.92
1.10	220	534	0.95
1.15	230	553	0.98
1.20	240	572	1.02
1.25	250	590	1.05

IPH MOR	IPH RVR
250	**673**

VAI/ IPH MOR	VAI MOR	VAI RVR	VAI/ IPH RVR
1.00	250	590	0.88
1.05	263	613	0.91
1.10	275	636	0.94
1.15	288	658	0.98
1.20	300	680	1.01
1.25	313	702	1.04

IPH MOR	IPH RVR
300	**778**

VAI/ IPH MOR	VAI MOR	VAI RVR	VAI/ IPH RVR
1.00	300	680	0.87
1.05	315	706	0.91
1.10	330	732	0.94
1.15	345	757	0.97
1.20	360	782	1.01
1.25	375	807	1.04

IPH MOR	IPH RVR
400	**977**

VAI/ IPH MOR	VAI MOR	VAI RVR	VAI/ IPH RVR
1.00	400	848	0.87
1.05	420	880	0.90
1.10	440	911	0.93
1.15	460	942	0.96
1.20	480	973	1.00
1.25	500	1003	1.03

IPH MOR	IPH RVR
500	**1163**

VAI/ IPH MOR	VAI MOR	VAI RVR	VAI/ IPH RVR
1.00	500	1003	0.86
1.05	525	1041	0.89
1.10	550	1077	0.93
1.15	575	1114	0.96
1.20	600	1149	0.99
1.25	625	1185	1.02

IPH MOR	IPH RVR
600	**1339**

VAI/ IPH MOR	VAI MOR	VAI RVR	VAI/ IPH RVR
1.00	600	1149	0.86
1.05	630	1192	0.89
1.10	660	1233	0.92
1.15	690	1274	0.95
1.20	720	1315	0.98
1.25	750	1355	1.01

Tabell F.3.
Day conditions of RVR calculations.

Runway light intencity:	4000	
Background luminance:	1000	
Illumination threshold (IPH):	10^	-4.5
Illumination threshold (VAI):	10^	-4.3
Correction factor:	1.8	
Corrected illum. thresh. (VAI):	10^	-4.1

IPH MOR	IPH RVR
50	**144**

VAI/ IPH MOR	VAI MOR	VAI RVR	VAI/ IPH RVR
1.00	50	132	0.92
1.05	53	137	0.96
1.10	55	143	0.99
1.15	58	148	1.03
1.20	60	153	1.06
1.25	63	158	1.10

IPH MOR	IPH RVR
100	**250**

VAI/ IPH MOR	VAI MOR	VAI RVR	VAI/ IPH RVR
1.00	100	228	0.91
1.05	105	236	0.94
1.10	110	245	0.98
1.15	115	254	1.01
1.20	120	262	1.05
1.25	125	270	1.08

IPH MOR	IPH RVR
150	**344**

VAI/ IPH MOR	VAI MOR	VAI RVR	VAI/ IPH RVR
1.00	150	311	0.90
1.05	158	322	0.94
1.10	165	334	0.97
1.15	173	345	1.00
1.20	180	356	1.04
1.25	188	367	1.07

IPH MOR	IPH RVR
200	**429**

VAI/ IPH MOR	VAI MOR	VAI RVR	VAI/ IPH RVR
1.00	200	385	0.90
1.05	210	399	0.93
1.10	220	413	0.96
1.15	230	427	1.00
1.20	240	441	1.03
1.25	250	454	1.06

IPH MOR	IPH RVR
250	**508**

VAI/ IPH MOR	VAI MOR	VAI RVR	VAI/ IPH RVR
1.00	250	454	0.89
1.05	263	471	0.93
1.10	275	487	0.96
1.15	288	503	0.99
1.20	300	518	1.02
1.25	313	534	1.05

IPH MOR	IPH RVR
300	**582**

VAI/ IPH MOR	VAI MOR	VAI RVR	VAI/ IPH RVR
1.00	300	518	0.89
1.05	315	537	0.92
1.10	330	555	0.95
1.15	345	573	0.98
1.20	360	591	1.02
1.25	375	608	1.04

IPH MOR	IPH RVR
400	**719**

VAI/ IPH MOR	VAI MOR	VAI RVR	VAI/ IPH RVR
1.00	400	636	0.88
1.05	420	658	0.92
1.10	440	680	0.95
1.15	460	702	0.98
1.20	480	723	1.01
1.25	500	743	1.03

IPH MOR	IPH RVR
500	**845**

VAI/ IPH MOR	VAI MOR	VAI RVR	VAI/ IPH RVR
1.00	500	743	0.88
1.05	525	769	0.91
1.10	550	794	0.94
1.15	575	818	0.97
1.20	600	842	1.00
1.25	625	866	1.02

IPH MOR	IPH RVR
600	**962**

VAI/ IPH MOR	VAI MOR	VAI RVR	VAI/ IPH RVR
1.00	600	842	0.88
1.05	630	870	0.90
1.10	660	898	0.93
1.15	690	925	0.96
1.20	720	952	0.99
1.25	750	978	1.02