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Occurrence and advection of fog at Amsterdam/Airport (Schiphol)

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SUMMARY

This report describes a study regarding the advection and occurrence of fog at Amsterdam Airport (Schiphol) and its surroundings.

In the introduction a short description is given of the automatic stations at Nieuwkoop and Waveramstel.

In section 2 a classification of fogs is described. It appears that an objective division of the fogs into radiation and advection fogs based on certain combinations of windspeed and vertical temperature gradient is possible.

Section 3 contains the numbers and durations of all fogs that occurred in the two years of observation.

Effects on temperature, humidity and the occurrence of radiation fogs by the Amsterdam/Amstelveen conurbation are described in section 4. It is shown that in nights potentially favourable for the formation of radiation fog Schiphol is significantly drier and warmer than Nieuwkoop. This is especially so for wind directions of 320°-100°.

Probabilities of occurrence of fog at Schiphol within two hours from the time of first appearance of fog at Waveramstel resp. Nieuwkoop are given in section 5. For advection fogs these probabilities are much larger than for radiation fogs.

Section 6 deals with a comparison of visibility minima at Nieuwkoop, Waveramstel and Schiphol during the same fog episodes. In about 50% of the advection fogs Schiphol had the same minimum visibility (class) as Nieuwkoop and Waveramstel. The probability that Schiphol has a higher minimum visibility than Nieuwkoop and Waveramstel is about as large as the probability that Schiphol has a lower minimum visibility. For radiation fogs, however, the probability of a lower minimum visibility at Schiphol is considerably smaller than the probability of a higher minimum visibility. The reason for this is attributed to local circumstances: Schiphol is drier and warmer than Nieuwkoop in nights that are potentially favourable for the formation of radiation fog.

Section 7 is devoted to the advection of fog. Advection patterns both large-scale (the whole of the Netherlands) and meso-scale (the Schiphol, Nieuwkoop and Waveramstel area) are given for a number of fogs. The influence of the Amsterdam/Amstelveen conurbation in the flow patterns is shown. Furthermore, in sections 7.2 and 7.3 observed times of advection of the fog from Nieuwkoop resp. Waveramstel to Schiphol are compared with advection times calculated by means of the 80m-wind at Cabauw. For the advection of fog from Nieuwkoop resp. Waveramstel to Schiphol the correlation coefficient between observed and calculated advection times for advection directions 110^{o}-270^{o} resp. 100^{o}-210^{o} is 0.7 à 0.8. For advection directions 000^{o}-100^{o} the effect of the urban area of Amsterdam/Amstelveen manifests itself in observed advection times which are systematically larger than the calculated ones. In paragraph 7.4 the extinction coefficients measured at Nieuwkoop, Waveramstel and Schiphol as a function of time are given. In many cases it can be concluded that changes in extinction at Waveramstel and Nieuwkoop are mainly due to advection and not to formation or dissipation. The influence of the urban area of Amsterdam/Amstelveen not only on the time of arrival but also on the density of the advection fogs is evident.

Finally, in section 8 conclusions which could be drawn from the foregoing sections are given.

CONTENTS

OCCURRENCE AND ADVECTION OF FOG AT AMSTERDAM/AIRPORT (SCHIPHOL)

F. Cannemeijer,

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1. INTRODUCTION

From observations it appeared that fog which occurs at Schiphol (the airport of Amsterdam) is often not locally formed, but is advected.

A strong feeling existed that information with regard to some meteorological parameters such as visibility, wind speed and wind direction in the surroundings of Schiphol would contribute to the accuracy of the forecasts. Already in the early 1960s wishes were expressed with a view to improving the visibility forecasts for Schiphol to have continuous observations of the visibility in the area south of Schiphol because of the high frequency of fog occurrence at the airport, when the wind direction is between south-east and south-west [1].

Although in meetings of staff members in 1965, two locations had already been recommended as suitable visibility-stations, it was not before 1970 that procedures were started for the establishment of the stations, and by the end of 1972 the registrations of the instruments were of such quality that they were thought suitable for research purposes.

One station is situated at Waveramstel, about 8 km south-east of Schiphol, the other at Nieuwkoop, about 16 km south of Schiphol. (see Fig.1). The surface of this sector south-east of Schiphol lies a few metres below sea level, is flat and mainly covered with grass. Several lakes and many ditches are present in the area. At about 40 km south of Schiphol a small village named Cabauw is situated. At Cabauw stands a 213 m high meteorological tower. This tower is equipped with instrumentation to measure continuously temperature, extinction of light in the atmosphere as well as wind speed and wind direction on several levels [2].

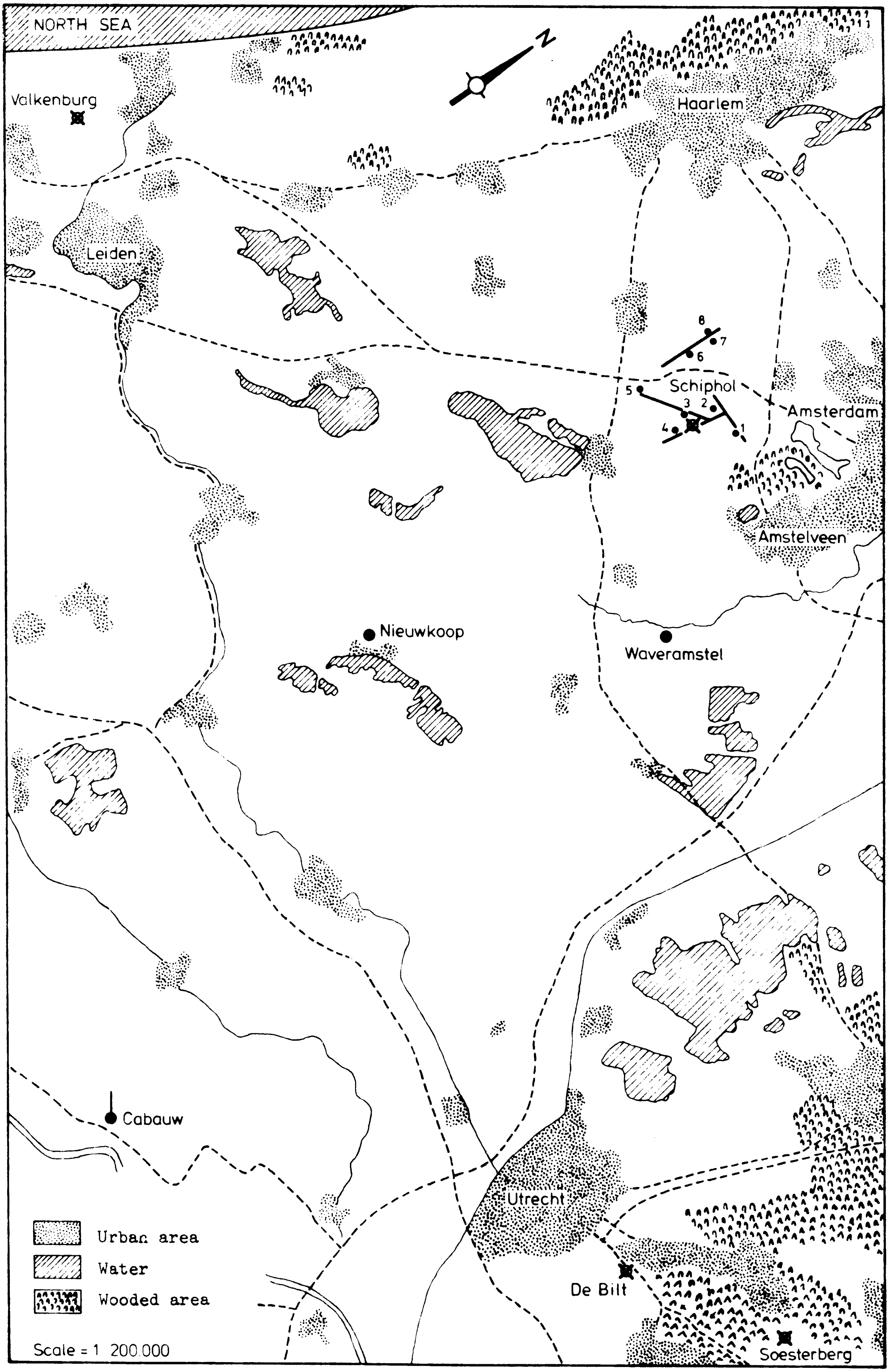

Fig. 1 Positions of the stations Nieuwkoop and Waveramstel relative to Schiphol.
■ : Synoptic stations. •1.....•8 : 160m base transmissometers.
♁ : Meteorological tower with a height of 213 meter.

At the stations Nieuwkoop and Waveramstel the following elements are measured:

- extinction — by a transmissometer with a baseline of 16 m measuring at a height of 2 m.
- wind speed, wind direction — at a height of 10 m.
- relative humidity, temperature — at a height of 2 m.
- temperature difference between a height of 10 m and 2 m.
- temperature difference between a height of 2 m and 0.5 m.

The extinction is transmitted three times during a 10-minute cycle, and the other elements are transmitted only once every 10 minutes by means of a telephone cable to Schiphol. There the signal is decoded (transformed from a frequency into a voltage) and recorded.

Figures 2 and 3 show pictures of the stations at Nieuwkoop resp. Waveramstel. Whereas the station at Nieuwkoop is surrounded by flat grassland, the station at Waveramstel is situated near a lot of obstructions such as houses, trees and a dyke.

Since December 15th 1972 the registrations have been of a sufficiently good quality to be used for a study of the advection of fog.

This report deals with a study of the advection of fog and the occurrence of radiation fog at Schiphol, Nieuwkoop and Waveramstel in relation to registrations obtained during fog occurrences in the period December 15th 1972 up to and including December 31st 1974. The fog which occurred in the first eight months of this periode (December 15th 1972 till August 20th 1973) have been used to study the differences in the fog-onset between advection fog and radiation fog. This is dealt with in section 2. The remaining sections of this report deal with all the fogs which occurred in the two-year period.

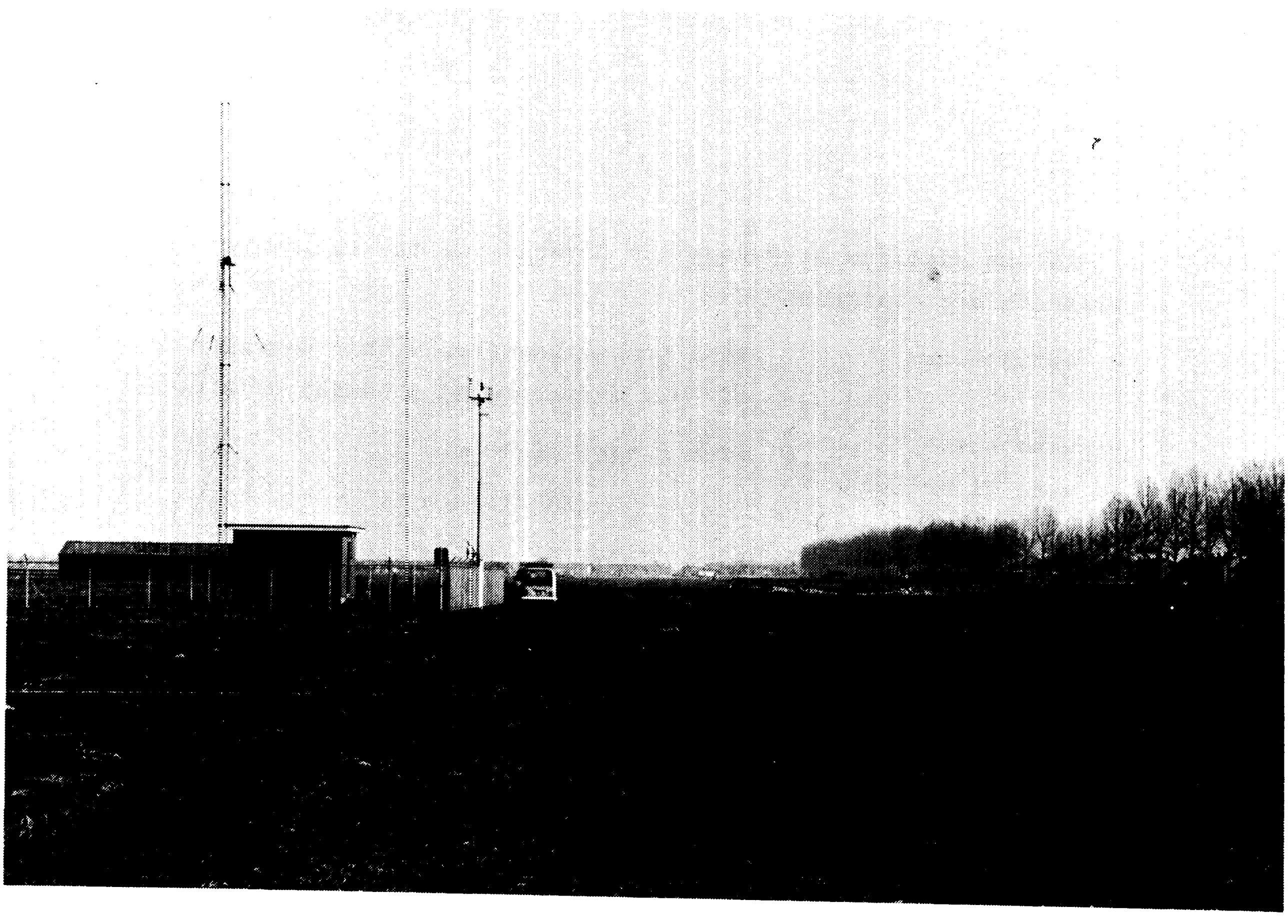

Fig. 2 Station at Nieuwkoop.

Fig. 3 Station at Waveramstel.

2. CLASSIFICATION OF FOGS

The general objective of this fog project is twofold: first, to study the advection of fog and second, the occurrence c.q. non-occurrence of radiation fog at the stations Nieuwkoop, Waveramstel and Schiphol. Therefore the available fog data should first be divided into two groups, according to the radiational or advective character of the fogs.

Radiation fog is a fog which develops at night, over-land, in light wind situations due to radiational cooling of the air. All the other types of fog are classified as advection fog.

At the stations Schiphol, Nieuwkoop and Waveramstel a direct observation of the net radiation is not available. However, at the stations temperature differences between a height of 10 m and 2 m and between 2 m and 0.5 m are measured.

Besides humidity, a very important parameter in the process of formation of radiation fog is turbulence and thus stability of the air [3]. The stability of an air-layer may be characterized by the vertical gradients of temperature and wind velocity which exist across the layer. (The Richardson-number is an example of such a characterization). Because of this dependence we plotted for the above-mentioned fogs the wind speed u, measured during the half hour before the beginning of each fog, against the vertical temperature difference ΔT obtained during the same half hour. Fig. 4 shows such plots for the onsets of the fogs at the three stations Nieuwkoop, Waveramstel and Schiphol.

For Schiphol the wind speed $\overline{u}$ and the temperature difference $\overline{\Delta T}_{1.5-0.1}$ (between 1.5 and 0.1 m) are obtained by averaging three 5-minute averages (the first 5 minutes of every 10 minutes give one value for u and ΔT) measured during the half-hourly period before the beginning of the fog. As can be seen, a separation between the advection fogs and the radiation fogs can be obtained by a criterion based on either wind speed or temperature difference. We rather prefer a criterion based on both parameters, because - as we have seen above - these together characterize the stability of the air-layer. In that case a good separation between the advection fogs and the radiation fogs can be obtained

by means of the line $\frac{\bar{u}}{2\ m/s} - \frac{\overline{\Delta T}_{1.5-0.1}}{1.6\ ^{o}C} = 0$ (or $\bar{u} = 1.3\ \overline{\Delta T}$).
If $\frac{\bar{u}}{2} - \frac{\bar{T}}{1.6} \geqslant 0$ ($\bar{u} \geqslant 1.3\ \overline{\Delta T}$), then a fog is called an advection fog, otherwise it is a radiation fog.

For Nieuwkoop and Waveramstel the $\bar{u}$- and $\overline{\Delta T}_{10-0.5}$ values are obtained by averaging over the three values (every 10 minutes one value of u and one value of $\Delta T_{10-0.5}$ (= $\Delta T_{10-2} + \Delta T_{2-0.5}$) are recorded) obtained in the half hour preceding the onset of the fog. The distinction between radiation fogs (symbol ● in Fig. 4) and advection fogs (symbol + in Fig. 4) was made taking into account wind speed, cloud cover and the general weather situation.*) It can be seen that for Waveramstel and for Nieuwkoop the discrimination between advection fogs and radiation fogs can objectively be obtained by a line $\frac{\bar{u}}{2\ m/s} - \frac{\Delta T_{10-0.5}}{1.6\ ^{o}C} = 0$ ($\bar{u} = 1.3\ \overline{\Delta T}$).
In general: the local character of the fog at a station can be determined from the u- and ΔT-values obtained in the half-hourly period before the beginning of the fog. The character of the fog is generally the same at the stations Nieuwkoop, Waveramstel and Schiphol. In Table I it can be seen that in 88% respectively 90% of the cases the character of the fog at Waveramstel is the same as the character of the fog at Nieuwkoop respectively Schiphol. If all fogs of the two-year period are classified as advection fogs or radiation fogs, the same percentages are obtained.

Table I

Numbers of advection fogs and radiation fogs at Nieuwkoop and Schiphol as related to the advective or radiative character at Waveramstel.

Fog character →		Nieuwkoop		Schiphol	
		advective	radiative	advective	radiative
Waveramstel	advective	13	2	15	2
	radiative	3	23	1	13

*) This distinction in radiation fogs and advection fogs was independently made by a chief meteorologist of Schiphol.

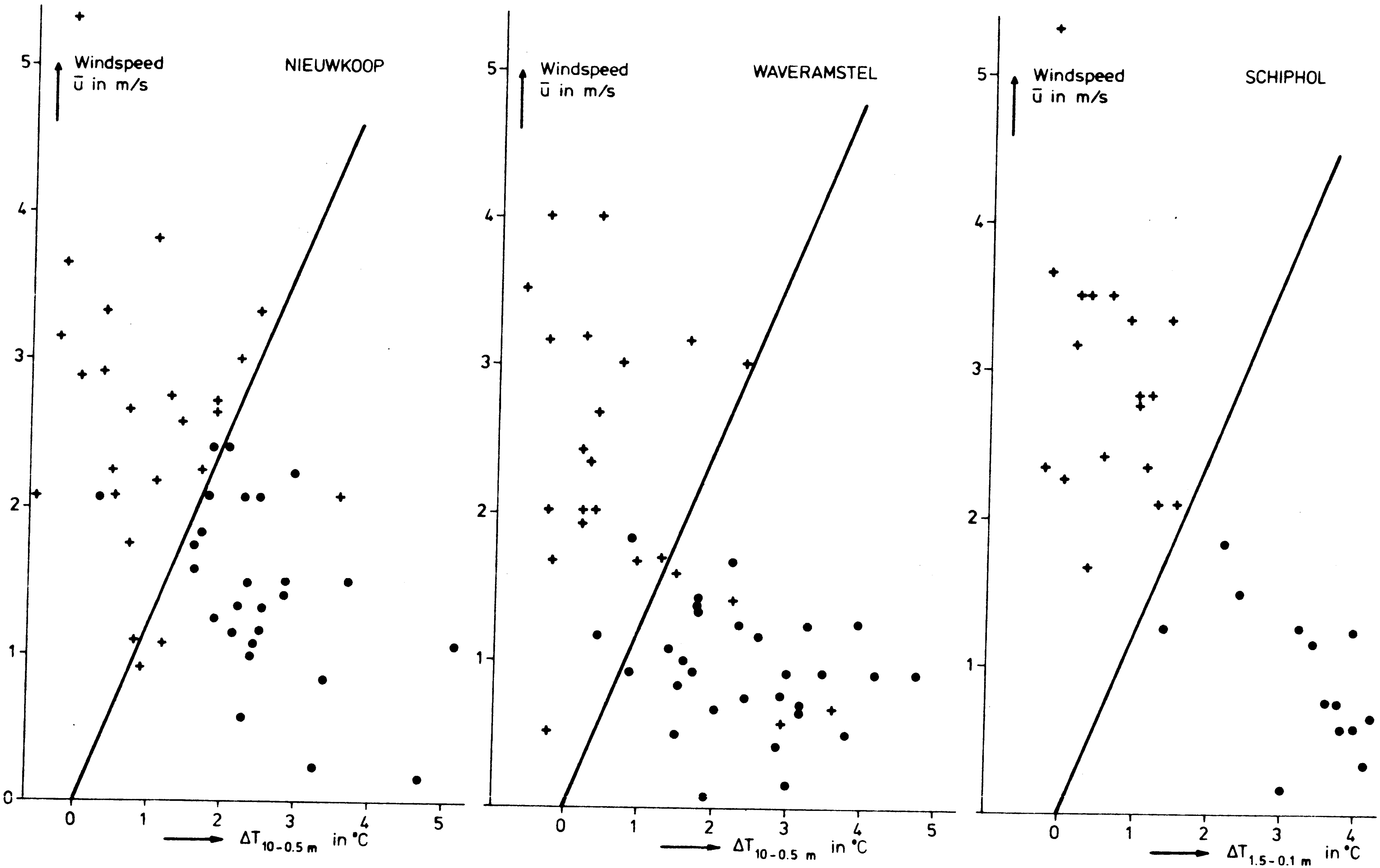

Fig. 4 Windspeed as a function of vertical temperature difference for Nieuwkoop, Waveramstel and Schiphol before onset of fog.
+ : Advection fog, ●: Radiation fog.

The following sections deal with all the fog data which had become available in the years 1973 and 1974. According to the criterion mentioned above all fogs were classified as advection fogs or radiation fogs. As is shown later, it appears that the probability of a fog to occur at Schiphol within two hours after the beginning of the fog at respectively Nieuwkoop and Waveramstel depends a.o. on the values of the wind speed ($\overline{u}$) and the temperature difference between 10 m and 0.5 m ($\overline{\Delta T}_{10-0.5}$) measured in the half hour preceding the onset of the fog at Nieuwkoop respectively Waveramstel.

3. NUMBER AND DURATION OF THE FOGS

The two-year period of 745 days showed on 188 days (a day being defined by the period between 15.00 GMT and 15.00 GMT the following day) fog on at least one of the three stations. (This means on 25% of the available days). Fog is here defined by an extinction coefficient of 3 km^{-1} or more, which means a 5% contrast visibility of 1000 m or less. Table II shows the number of days with fog for the three stations respectively. For Schiphol use has been made of the registrations of the transmissometer on runway 24, one of the eight transmissometers available at the airport.

Table II

Numbers of days with fog				
Stations with fog	Number of days	fog at		
		Schiphol	Nieuwkoop	Waveramstel
Schiphol, Nieuwkoop, Waveramstel	95	95	95	95
Schiphol, Waveramstel	7	7	-	7
Schiphol, Nieuwkoop	0	0	0	-
Schiphol	0	0	-	-
Nieuwkoop, Waveramstel	58	-	58	58
Nieuwkoop	16	-	16	-
Waveramstel	12	-	-	12
Total	188	102	169	172

The 188 fog days included 95 days (≈ 50%) with fog at all three stations, 65 days (≈ 35%) with fog at two stations, and 28 days (≈ 15%) with fog at only one station.

One may conclude from this table that Schiphol (at position 24) has about 40% fewer days with fog than Nieuwkoop and Waveramstel.

This can also be seen in Table III, which gives a survey of the total time (in hours) that the extinction coefficient σ exceeded certain values (3, 7.5, 15, 30 and 60 km^{-1}, corresponding with a visibility of respectively 1000, 400, 200, 100 and 50 m). For Schiphol the registrations of the transmissometer on runway 24 from which 5-minute averaged extinction coefficients were determined, have been used.

At Waveramstel and Nieuwkoop, on the other hand, the extinction coefficient is recorded three times per 10 minutes during 55 seconds at a time. This frequency of observation is sufficient as indicated by an analysis of the fluctuations in the extinction coefficient for the measured extinction coefficients to be representative for the complete 10-minute cycle. In those cases for which no extinction registrations were available for Nieuwkoop and Waveramstel the duration of the fog, at the station concerned, has been put equal to the duration of the fog at the other station.

Table III shows that Nieuwkoop and Waveramstel experienced almost twice as many fog hours than Schiphol during the period considered. As can be seen, this is mainly due to radiation fogs. This is not very surprising, since in contradistinction to Nieuwkoop and Waveramstel the Schiphol-area is well drained. Especially radiation fogs are affected by local circumstances such as high soil moisture.

Table III

Time (in hours) of fog with an extinction coefficient higher than specified values during the period 15-12-1972 till 31-12-1973						
$\sigma \geqslant$ VV $\leqslant$	3 km^{-1} 1000 m	7.5 km^{-1} 400 m	15 km^{-1} 200 m	30 km^{-1} 100 m	60 km^{-1} 50 m	
Schiphol	540	357	244	101	*)	total
Waveramstel	963	679	478	216	47	
Nieuwkoop	1025	782	560	262	45	
Schiphol	375	245	161	51	*)	advection fogs
Waveramstel	432	282	184	71	27	
Nieuwkoop	431	336	212	93	12	
Schiphol	165	112	83	50	*)	radiation fogs
Waveramstel	531	397	294	145	20	
Nieuwkoop	594	446	348	169	33	

*) No values are given, because for the Schiphol-figures mainly a transmissometer with a base of 160 m has been used.

N.B. VV is the 5% contrast visibility.

4. URBAN EFFECTS ON THE OCCURRENCE c.q. NON-OCCURRENCE OF RADIATION FOG

4.1 Selection of nights favourable for the formation of radiation fog

From experience it is known [4] that radiation fog forms by preference during night and early morning hours, when the wind speed is low and the sky almost cloudless. Therefore, when studying the occurrence of radiation fog at the stations Schiphol, Nieuwkoop and Waveramstel, in order to select nights that are favourable for the formation of radiation fog, a criterion is used which is based on hourly observations of wind speed and clouds during night hours at Schiphol. Since radiation fog often maintains itself and even sometimes forms after sunrise, the night is defined as the time from sunset till one and a half hour after sunrise. A night is assumed to be favourable for the formation of radiation fog if at least four hourly observations occur with a wind speed $\leqslant 2.5$ m/s and a cloud amount of low and/or medium clouds $\leqslant 4/8$.

Using the above-mentioned criterion for the period 15-12-1972 till 1-1-1975, 186 nights have been selected, which are accepted as nights that were potentially favourable for the formation of radiation fog. In order to see how effective the criteria are, all the fogs at Schiphol at transmissometer station 24 during the night, in the said period, have been divided into two groups on account of the requirement $\overline{u}/2 - \overline{\Delta T}/1.6 \geqslant 0$ mentioned in section 2. Here, $\overline{u}$ denotes the wind speed in m/s and $\overline{\Delta T}$ the vertical temperature difference between 1.5 and 0.1 m, when fog is formed at Schiphol. If $\overline{u}/2 - \overline{\Delta T}/1.6 \geqslant 0$, the fog is supposed to be of an advective character (A). If not, it is supposed to be of a radiative character (R). In the period considered there are at Schiphol 93 cases with fog during the night, 47 of type A and 46 of type R. Out of the 186 nights that have been selected there were only 56 with fog at Schiphol, notably 12 nights with fog of type A and 44 with fog of type R. It appears that only two nights with fog of type R have not been selected, mainly because the requirement regarding cloud cover was not met.

The distribution of fog occurrence at the three stations in the selected 186 nights can be seen from Table IV.

Table IV

Distribution of fog nights, total number 186		
	Fog at Schiphol	No fog at Schiphol
Fog at Nieuwkoop and Waveramstel	50	37
Fog at Nieuwkoop, no fog at Waveramstel	0	6
Fog at Nieuwkoop, no transmissometer data at Waveramstel	1	7
No fog at Nieuwkoop, fog at Waveramstel	1	7
No transmissometer data at Nieuwkoop, fot at Waveramstel	4	4
No fog at Nieuwkoop and Waveramstel	0	69

For each hour of the selected 186 nights and for all three stations the following data are determined: hourly averaged values of wind speed and wind direction and hourly readings of the relative humidity, temperature and vertical temperature difference. The data thus gathered for this study refer to 186 nights with hourly values of the above-mentioned parameters.

4.2 Comparison of temperature and relative humidity values

Since the Schiphol-data, unlike those of the other stations, are measured over a well-drained surface, it seems interesting to compare simultaneously measured values of the temperature as well as the relative humidity at the three stations. The relative humidity values at Waveramstel, however, are not very reliable, and for the station Nieuwkoop both relative humidity and temperature are only reliable till 2-10-1973. Therefore, only 83 nights are available for this comparison. Furthermore, when the second hour after sunset is selected, only 76 nights are left for the combination

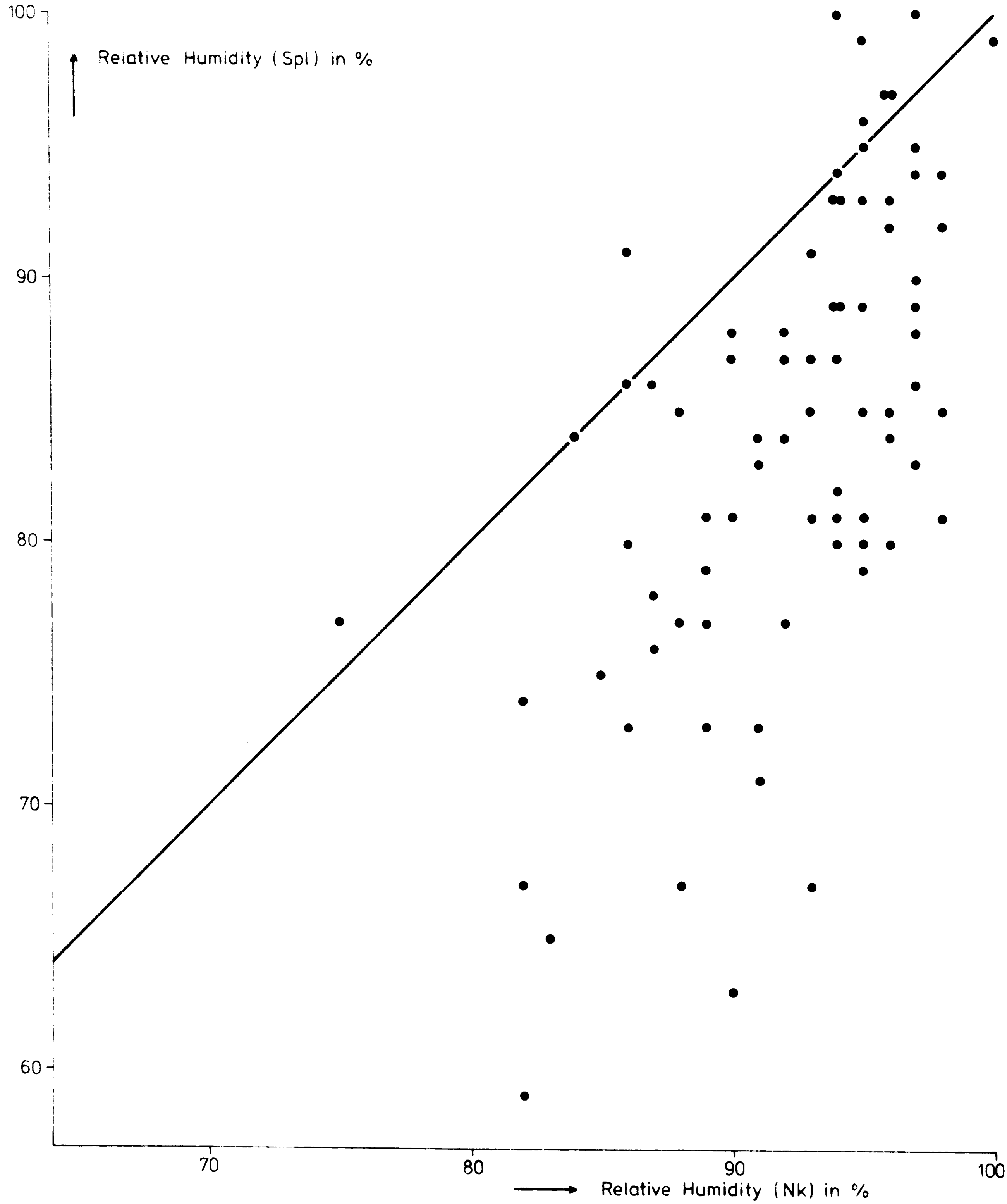

Fig. 5 Relative humidity values at Schiphol (Spl) vs relative humidity values at Nieuwkoop (Nk) for the second hour after sunset in nights selected as potentially favourable for the formation of radiation fog.

Schiphol-Nieuwkoop, because for Nieuwkoop there are no transmissometer data in 3 nights, while in 4 other nights there was already fog in the second hour after sunset, and we wish to compare only data of hours without fogs. The simultaneously measured relative humidity values of both stations are given in Fig. 5. From this figure it appears that the relative humidity value at Schiphol is in general less than that at Nieuwkoop.

When the wind direction at Schiphol at the second hour after sunset is taken into account, a dependence on wind direction for both temperature and relative humidity can be observed. This is illustrated in fig. 6, where the difference between the temperature (lower graph) and the relative humidity (middle graph) values of Schiphol and Nieuwkoop are given as a function of the wind direction at Schiphol.

The mean difference in temperature irrespective of wind direction is about +0.7°C (± 0.2°C); this means that Schiphol is in general warmer than Nieuwkoop. The mean difference in relative humidity irrespective of wind direction is about -8 per cent (± 1%); the relative humidity at Schiphol is generally lower than at Nieuwkoop, as we have already seen from Fig. 5. Using temperature and relative humidity data, the vapour pressure at each station can be calculated. The difference between the vapour pressure values of Schiphol and Nieuwkoop as a function of the wind direction at Schiphol is also presented in Fig. 6 (upper graph). The mean difference of vapour pressure is about -0.48 mbar (± 0.13 mbar). We may conclude that at Schiphol the air is in general not only warmer but also drier than at Nieuwkoop. Application of Fisher's test (t-test) for the deviations of the means from zero results in all three cases in a significance below the 1%-level, as is shown further on.

Although the temperature and the relative humidity observations at Schiphol and Nieuwkoop were carried out, unlike in other similar studies, on special conditions (second hour after sunset in selected nights), the size of the calculated mean difference both of temperature and vapour pressure is in agreement with values published elsewhere. The mean difference of temperature and that of relative humidity between suburbs and surrounding country of the London area obtained from table V published in [5] are almost the same as the

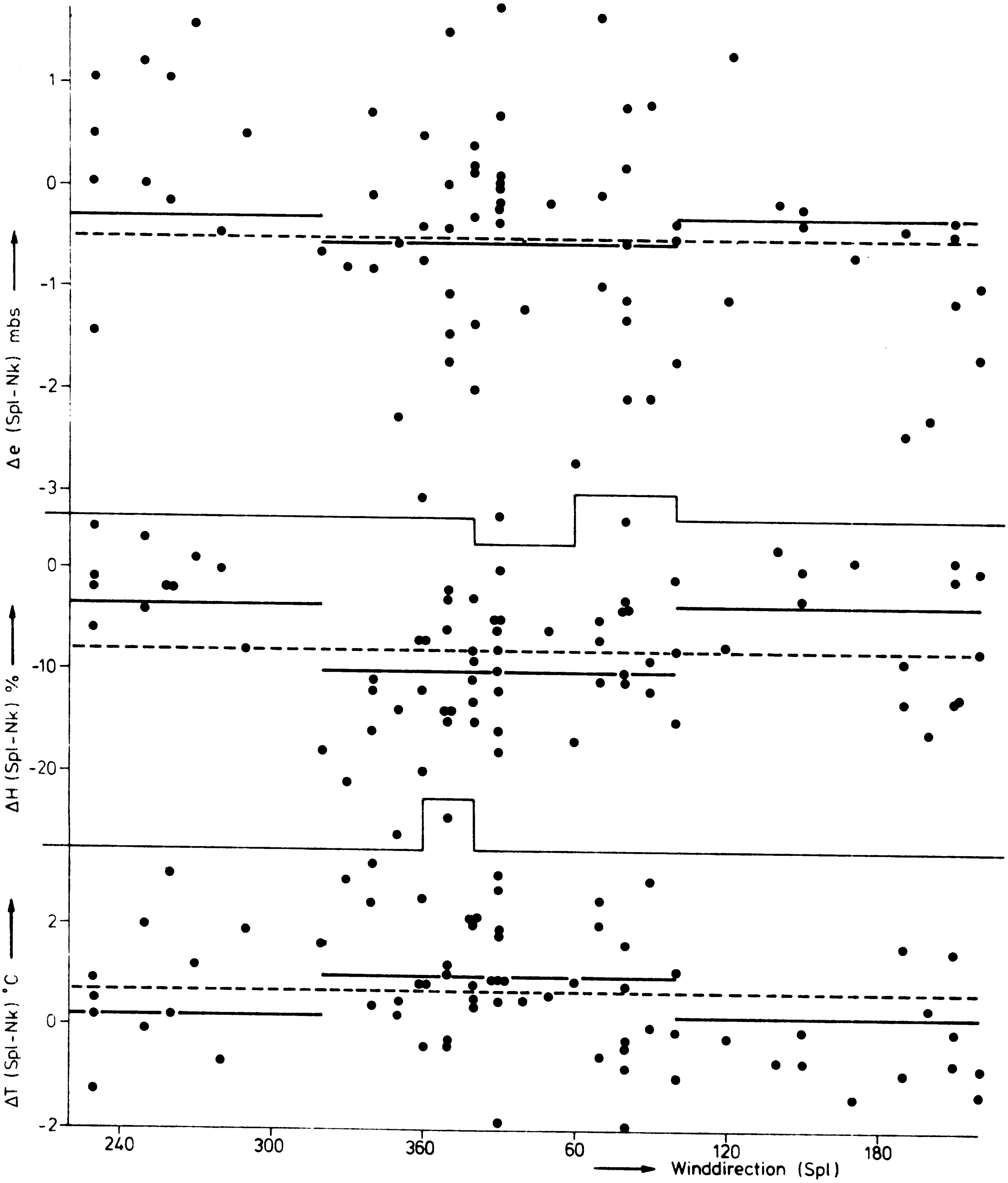

Fig. 6 Difference of temperature (T, lower graph), relative humidity (H, middle graph) and watervapour pressure (e, upper graph) between observations at Schiphol (Spl) and Nieuwkoop (Nk) as a function of winddirection at Schiphol for the second hour after sunset in nights selected as potentially favourable for the formation of radiation fog.

--------- : Average value irrespective of winddirection.

———— : Average value for each winddirection class.

values found between Schiphol (suburbs of the Amsterdam-area) and Nieuwkoop (rural country of the Amsterdam-area). The size of the calculated mean difference of temperature is also in agreement with the values published by Schmidt [6] in his study concerning the effect of air pollution on visibility, and by Conrads [7] in his study about meteorological urban effects.

In order to study the effect of wind direction on the temperature and humidity values of Schiphol, the data were divided into two groups according to wind direction. One group consists of wind directions from 320° up to and including 100°. For these directions the air flows across the built-up area of Amsterdam, Amstelveen and Schiphol (see Fig. 11). Mean values of the differences in temperature, relative humidity and vapour pressure between Schiphol and Nieuwkoop are indicated in Fig. 6.

When the mean values in each group are compared with zero, i.e. the assumption that no difference exists between Schiphol and Nieuwkoop, the significance of the difference can be judged by applying Fisher's test.

Since the difference in time between the observations is at least 1 day, it can be assumed that the observations are mutually independent.

The result is presented in Table V, where m = mean value, t_o= value required for significance of the difference below 1 per cent, t = computed value of the parameter, and N = number of observations in the group. If $|t| \geqslant t_o$, the difference is significant on the 1 percent level.

Table V

Mean values and Fisher's t-values

	all wind directions N=73 ; t_o= 2.65		wind direction 320°-100° N=49 ; t_o=2.68		wind direction 110°-310° N=24 ; t_o=2.81	
difference in:	m	t	m	t	m	t
temperature (°C)	+0.7	4.72	+1.0	5.29	+0.2	0.74
relative humidity (%)	-8	-10.04	-10	-8.08	-3.5	-3.15
vapour pressure (mb)	-0.48	3.93	-0.53	-3.31	-0.30	-1.47

The values of the computed parameter $t \geqslant t_o$ are underlined.

In relation to Table V the following comments can be made:
All mean values of differences irrespective of wind direction are significant as was noticed before.

All mean values of differences in the sector 320°-100° are significant. This means that with wind directions in this sector the temperature at Schiphol, although measured at a height which is 0.5 metres below the measuring height at Nieuwkoop, is significantly higher than at Nieuwkoop, while both the relative humidity and the vapour pressure at Schiphol are significantly lower than the relative humidity and the vapour pressure at Nieuwkoop.

In the sector 110°-310° only the mean value of the difference in relative humidity is significant. It is, however, open to question whether the air at Schiphol is drier than the air at Nieuwkoop with wind directions between 110° and 310°. The measuring procedure of the relative humidity at Schiphol is different from that at Nieuwkoop. Although the same measuring instrument is used at both stations, the result of the measurement can be different due to the mounting of the instrument in a thermometer-screen at Schiphol. It is known [8] that the temperature and consequently also the relative humidity, when measured in a screen, lag behind the true value. The time-lag can amount to 0.5-1 hour, while with respect to the relative humidity the error can amount to 3 à 4 per cent. Since in this study relative humidity values of the second hour after sunset are used, values which in general are measured in a period with steadily increasing relative humidity, it is not unlikely that due to this effect the relative humidity values of Schiphol are systematically lower than those of Nieuwkoop. Taking into account this possible error, the experimental inaccuracy of the measurement, which is about 3 to 5 per cent, and the size of the mean value of only 3.5 per cent, we may say that the displayed significance of the relative humidity difference in the sector 110°-310° is of no importance.

4.3 The occurrence of fog in connection with wind direction

In 56 out of the selected 186 nights there was fog at Schiphol; no fog at Schiphol but at least at one of the other stations occurred in 61 nights.

If the mean wind direction at a height of 80 m at Cabauw is determined over the past hour, when fog forms at one of the three stations, the occurrence of fog can be examined in connection with this wind direction. Dividing the fogs into type A and type R, the following table can be formed.

Table VI

Distribution of fog occurrence in connection with wind direction at 80 m

		316°-105°	106°-315°	no direction
Fog at Schiphol and at other station(s)	type A	3	9	0
	type R	16	27	1
No fog at Schiphol; fog at other atation(s)	type A	3	2	0
	type R	35	21	0

With wind directions between 316° and 105° 57 nights in all show fog at at least one of the three stations. Out of these 57 nights there are only 19 with fog at Schiphol, which is 33 per cent. For wind directions between 106° and 315° in 59 nights fog occurred at at least one of the three stations. In these cases fog was present at Schiphol in 36 nights, which is about 61 per cent. The difference in the percentages of occurrence of fog at Schiphol in the sectors 316°-105° and 106°-315°, respectively 33 and 61 per cent, is probably connected with the differences in temperature and humidity between Schiphol and Nieuwkoop, which exist for wind directions in these sectors.

5. THE OCCURRENCE OF FOG AT SCHIPHOL IN RELATION TO THE OCCURRENCE OF FOG AT NIEUWKOOP AND WAVERAMSTEL

For the benefit of the short-term forecast which is issued at Schiphol every half hour it is of importance to know the probability of occurrence of fog and/or low stratus at Schiphol when at Waveramstel and/or Nieuwkoop fog is beginning to appear. The short-term forecast (the landing forecast) has a validity of two hours. Therefore, in this section, we consider the probabilities of fog and/or low stratus occurrence at Schiphol within 2 hours from the moment that at Nieuwkoop and/or Waveramstel fog appears or begins to form.

In Fig. 7, for Nieuwkoop as well as for Waveramstel the values of the wind velocity averaged over the three values obtained during the half-hourly period prior to the beginning of the fog at Nieuwkoop respectively Waveramstel are plotted against the average value of $\Delta T_{10-0.5}$ (averaged over the three $\Delta T_{10-2} + \Delta T_{2-0.5}$ values of the same half hour). Those fog onsets which within two hours were followed or preceded by fog and/or low stratus at Schiphol are indicated by a cross (+). For those cases that Schiphol encountered fog and/or low stratus earlier than Nieuwkoop and Waveramstel the cross is encircled ⊕.

One may observe that the fogs which are characterized by a wind speed and a $\overline{\Delta T}_{10-0.5}$ such that they appear in region I in Fig. 7 (that is $\bar{u} \geqslant 1.3\ \overline{\Delta T}_{10-0.5}$) have a much larger probability to be followed or preceded by fog at Schiphol within two hours than the fogs for which $\bar{u}$ is smaller than $1.3\ \overline{\Delta T}_{10-0.5}$ (regions II and III). In Table VII these probabilities are given.

From this table it can be seen that the advection fogs occurring at Waveramstel and Nieuwkoop have a larger probability of being followed or preceded by fog within two hours at Schiphol than the radiative type of fog. The probability that Schiphol will have fog within two hours from the time of onset of the fog at Waveramstel is larger than the probability of fog at Schiphol within two hours from the time of onset of the fog at Nieuwkoop. This is plausible, because the distance between Schiphol and Waveramstel is half the distance between Schiphol and Nieuwkoop.

Table VII

Probabilities of occurrence at Schiphol of advection fogs and radiation fogs within 2 hours from the time of the first appearance at Waveramstel respectively Nieuwkoop.

Fog type	WAVERAMSTEL			NIEUWKOOP		
	number	at Schiphol within 2 hrs		number	at Schiphol within 2 hrs	
		number	%		number	%
Advection ($\bar{u} \geq 1.3\ \bar{T}$)	56	52	93	61	49	80
Radiation ($\bar{u} < 1.3\ \bar{T}$)	121	31	26	107	20	19
Total	177	83	47	168	69	41

The division into groups with a distinct difference in probability of fog at Schiphol may be extended by drawing lines in Fig. 7a and b with a flatter slope (dashed lines). In this way one gets for Nieuwkoop as well as for Waveramstel three groups, each with a distinct probability of fog at Schiphol.

Table VIII gives the appropriate numbers and probabilities of fog in the various groups for both stations.

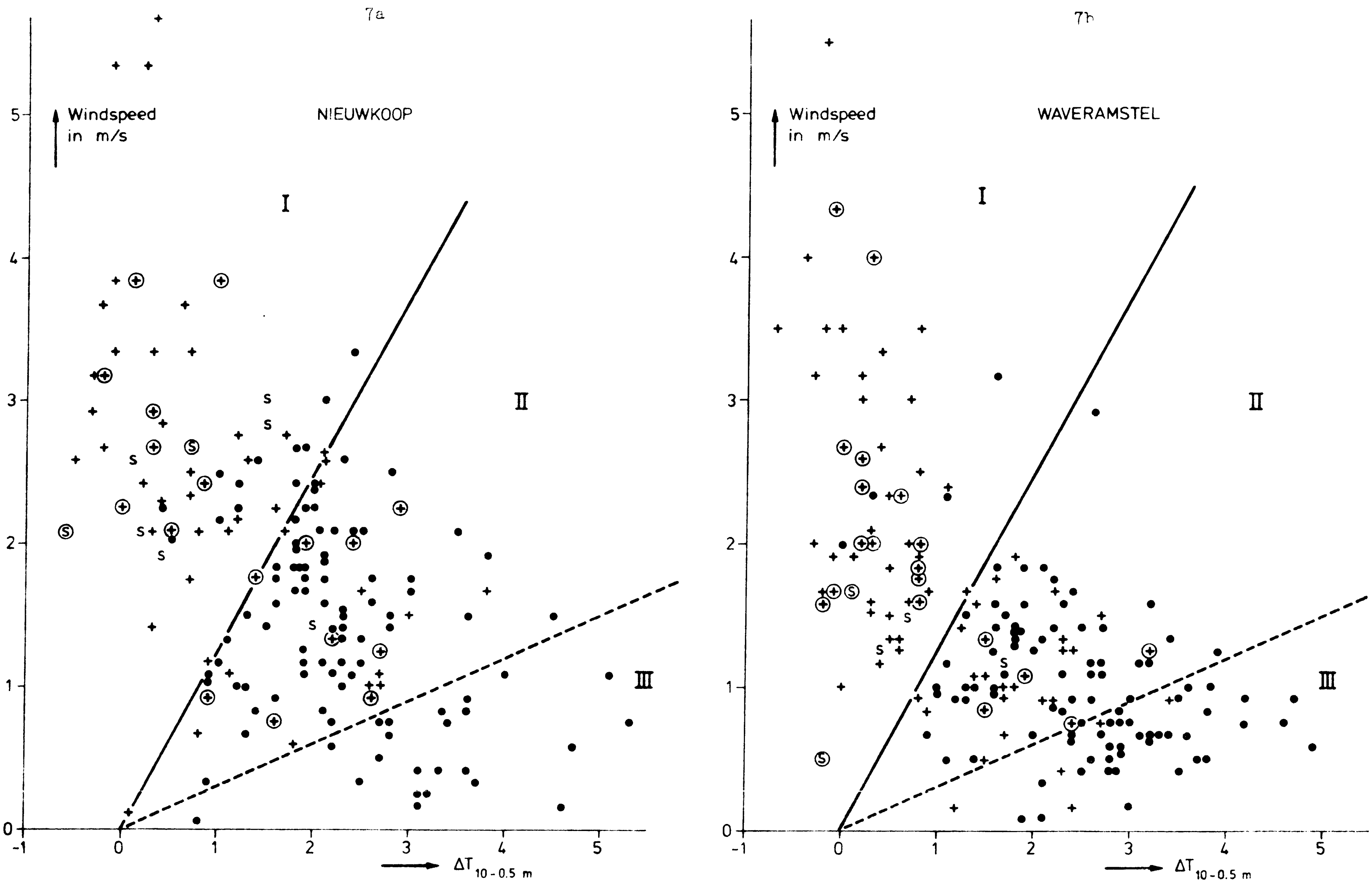

Fig. 7 Windspeed as a function of the vertical temperature difference measured during the half hour before the onset of the fog at Nieuwkoop (left) and Waveramstel (right).
+ : fog within 2 hrs at Schiphol, S : low stratus within 2 hrs at Schiphol, ● : no fog or low stratus within 2 hrs at Schiphol. A circle around a symbol means that Schiphol experienced fog or low stratus before Nieuwkoop resp Waveramstel.

Table VIII

Probabilities of occurrence at Schiphol of fogs in different $\overline{u}$, $\overline{\Delta T}$ groups within 2 hours from the time of the first appearance at Waveramstel respectively Nieuwkoop.

Group	Criterion	WAVERAMSTEL			NIEUWKOOP		
		number	at Schiphol within 2 hrs		number	at Schiphol within 2 hrs	
			number	%		number	%
I	$\overline{u} \geqslant 1.3\ \overline{\Delta T}$	56	52	93	61	49	80
II	$0.34\ \overline{\Delta T} \leqslant \overline{u} < 1.3\ \overline{\Delta T}$	78	27	35	84	20	24
III	$\overline{u} < 0.34\ \overline{\Delta T}$	43	4	9	23	0	0
Total		177	83	47	168	69	41

6. COMPARISON OF VISIBILITY MINIMA AT NIEUWKOOP, WAVERAMSTEL AND SCHIPHOL

An important problem in forecasting visibility at a particular station using the visibility data of another station is, to what extent variations in the visibility at one station are reflected in the visibility at the other station. In pure advection fogs, especially when the direction of the advection is along the line connecting the two stations, one may expect that the correlation between the extinction coefficients measured at the two stations is much larger than in the case of radiation fogs. Indeed, Chisholm and Kruse [9] in their study on the variability of visibility in the Hanscom meso-network found for advection fogs a space correlation of 0.94 for stations 2 km apart, decreasing to 0.8 for stations with a mutual distance of 16 km. For radiation fogs the space correlation was much lower, namely 0.55 respectively 0.3.

In order to get an idea about the minimum visibilities reached at Schiphol compared to the minimum values for the same fog episodes at Nieuwkoop respectively Waveramstel, we determined the average of the lowest two adjacent extinction coefficients of the fogs measured at Nieuwkoop and Waveramstel, and the lowest 5-minute averages of the fogs at Schiphol. To make things easier, the following classification has been used:

		class
1000 m $\geq$ VV > 400 m	($3\ km^{-1} \leq \sigma < 7.5\ km^{-1}$)	1
400 m $\geq$ VV > 200 m	($7.5\ km^{-1} \leq \sigma < 15\ km^{-1}$)	2
200 m $\geq$ VV > 100 m	($15\ km^{-1} \leq \sigma < 30\ km^{-1}$)	3
100 m $\geq$ VV	($30\ km^{-1} \leq \sigma$)	4

Table IX shows the distribution of fog minima (fog classes) which occurred at Schiphol for each fog minimum class at Nieuwkoop and Waveramstel for advection fog and radiation fogs respectively. The figures show that for the advection fogs at Nieuwkoop and Waveramstel in about 50% of the cases the minimum visibility reached at Schiphol is the same (class) as at Nieuwkoop and Waveramstel. The deviations (non-diagonal elements) show more or less a symmetric behaviour: the probability that fog at Schiphol has a higher minimum visibility than fogs at Nieuwkoop and Waveramstel is about as large as the probability that Schiphol has a lower minimum visibility. For radiation fogs, however, the probability of a lower minimum visibility at Schiphol is considerably smaller than the probability of a higher minmum visibility. This is understandable, since the occurrence of radiation fog is more dependent on local circumstances than the occurrence of advection fog. In section 4 we have shown that in light wind situations ($\overline{u} < 5$ kts) the Schiphol-area is warmer and drier than the Nieuwkoop-area. This, of course, will not only influence the formation but also the duration and the density of radiation fog.

Table IX

Comparison of visibility minima during fogs at Schiphol with those at Nieuwkoop respectively Waveramstel.

Fog class		ADVECTION FOGS					RADIATION FOGS				
		Nieuwkoop					Nieuwkoop				
		1	2	3	4	Total	1	2	3	4	Total
Schiphol	1	4	0	3	0	7	2	1	2	9	14
	2	4	2	2	1	9	0	0	2	6	8
	3	0	1	9	1	11	0	0	0	8	8
	4	2	0	5	7	14	1	0	1	16	18
Total		10	3	19	9	41	3	1	5	39	48

Fog class		ADVECTION FOG					RADIATION FOG				
		Waveramstel					**Waveramstel**				
		1	2	3	4	Total	1	2	3	4	Total
Schiphol	1	3	6	1	0	10	1	2	2	11	16
	2	2	2	1	1	6	1	3	2	7	13
	3	1	0	7	2	10	0	0	4	5	9
	4	4	1	3	10	18	0	0	2	20	22
Total		10	9	12	13	44	2	5	10	43	60

Fog class	Visibility	Extinction coefficient
1	1000 m $\geqslant$ VV $>$ 400 m	$3\ km^{-1} \leqslant \sigma < 7.5\ km^{-1}$
2	400 m $\geqslant$ VV $>$ 200 m	$7.5\ km^{-1} \leqslant \sigma < 15\ km^{-1}$
3	200 m $\geqslant$ VV $>$ 100 m	$15\ km^{-1} \leqslant \sigma < 30\ km^{-1}$
4	100 m $\geqslant$ VV	$30\ km^{-1} \leqslant \sigma$

7. THE ADVECTION OF FOG

7.1 Advection patterns

Often advection of fog can be observed over the whole area of the Netherlands. Fig. 8 shows the network of synoptic stations in the Netherlands. The circles with numbers indicate stations which, except for station 272, reported hourly. The stations 200 and 325 reported only between 06.00 and 16.00 GMT respectively 06.00 and 21.00 GMT. Station 272 reported between 06.00 and 18.00 GMT once every three hours. The positions of the stations Waveramstel, Nieuwkoop and Cabauw are also indicated. At the stations Lelystad and Willemstad the extinction has been measured continuously by a transmissometer since 1-11-1973.

The hatched area lies at 10 m or more above sea-level. Its soil is in general of a different composition than the non-hatched area. The latter type of soil mainly consists of grass or agricultural land, while the higher grounds are of a more sandy type with a much drier composition.

Figures 9 and 10 show advection patterns typical of fogs advected from the north-east (4-1-73 resp. 8-4-74). The data mentioned in this report refer to 24-hr periods from 15.00 GMT till 15.00 GMT the following day. Thus 4-1-73 means 4-1-73 15.00 GMT till 5-1-73 15.00 GMT. The numbers in the circles indicate the time (GMT) of the first synoptic hour when fog (visibility $<$ 1000 m) or low stratus (N=4, height $\leqslant$ 400 ft) is reported. The wind arrows show the surface wind at that hour: each black triangle stands for 5 kts and each bar for 1 kt. The fog of 4-1-73 (Fig. 9) had a height of more than 180 m at Cabauw and was persistent throughout the day. The fog of 8-4-74 had a height of only about 60 m, and one can see from Fig. 10 that after sunrise, at 05.00 GMT, the fog did not appear at the stations in the south of the country.

In both cases we can observe the screening effect by Amsterdam/Amstelveen: first Waveramstel encounters the fog, then Nieuwkoop and finally Schiphol. This screening effect can be seen more clearly in the advection patterns on a smaller scale as shown in the Figures 11 and 12. For these advection analyses use was made

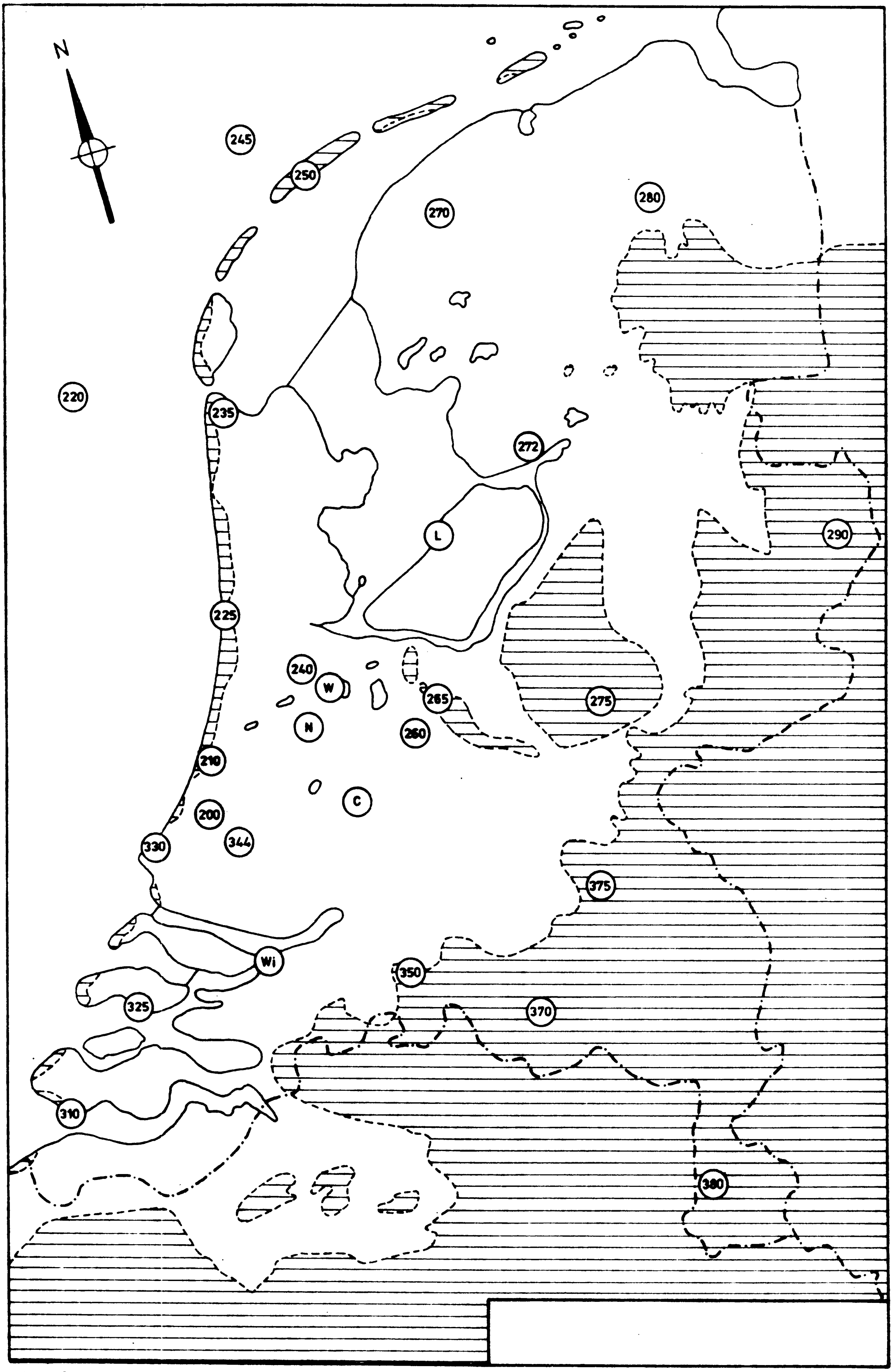

Fig. 8 Map of the Netherlands. Circles with numbers inside are synoptic stations. Shaded area is country which lies 10 meters or more above sealevel. W = Waveramstel, N = Nieuwkoop, C = Cabauw, L = Lelystad, Wi = Willemstad.

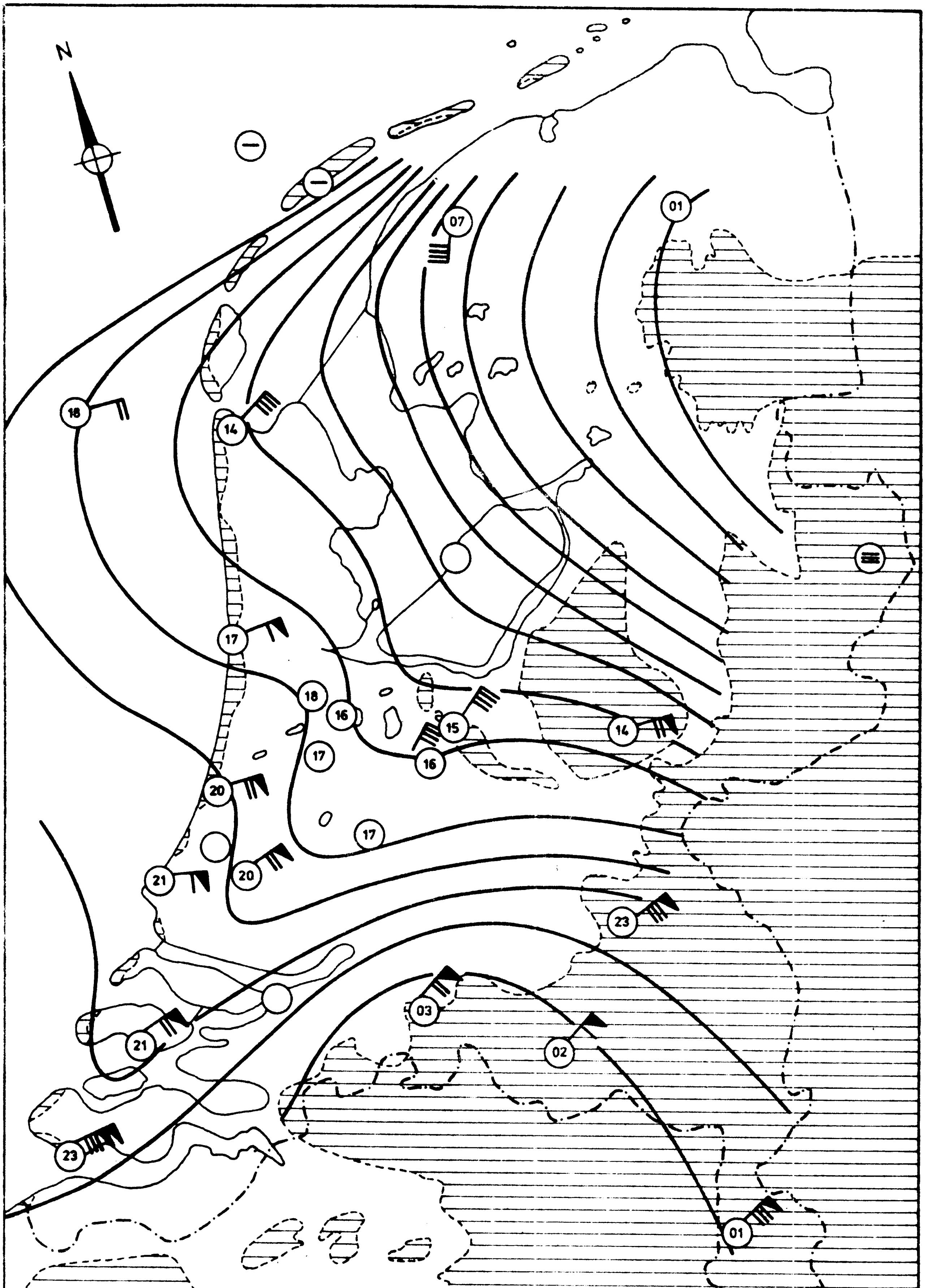

Fig. 9 Advection of fog on 4-1-1973. The figure in a circle is the first hour at which fog and/or low stratus (height ≤ 400ft) is reported. The arrows indicate the wind at that hour. Each bar stands for 1 kt and each triangle 5 kts.

⊖: No fog or low stratus. ⊜: Fog all the time.

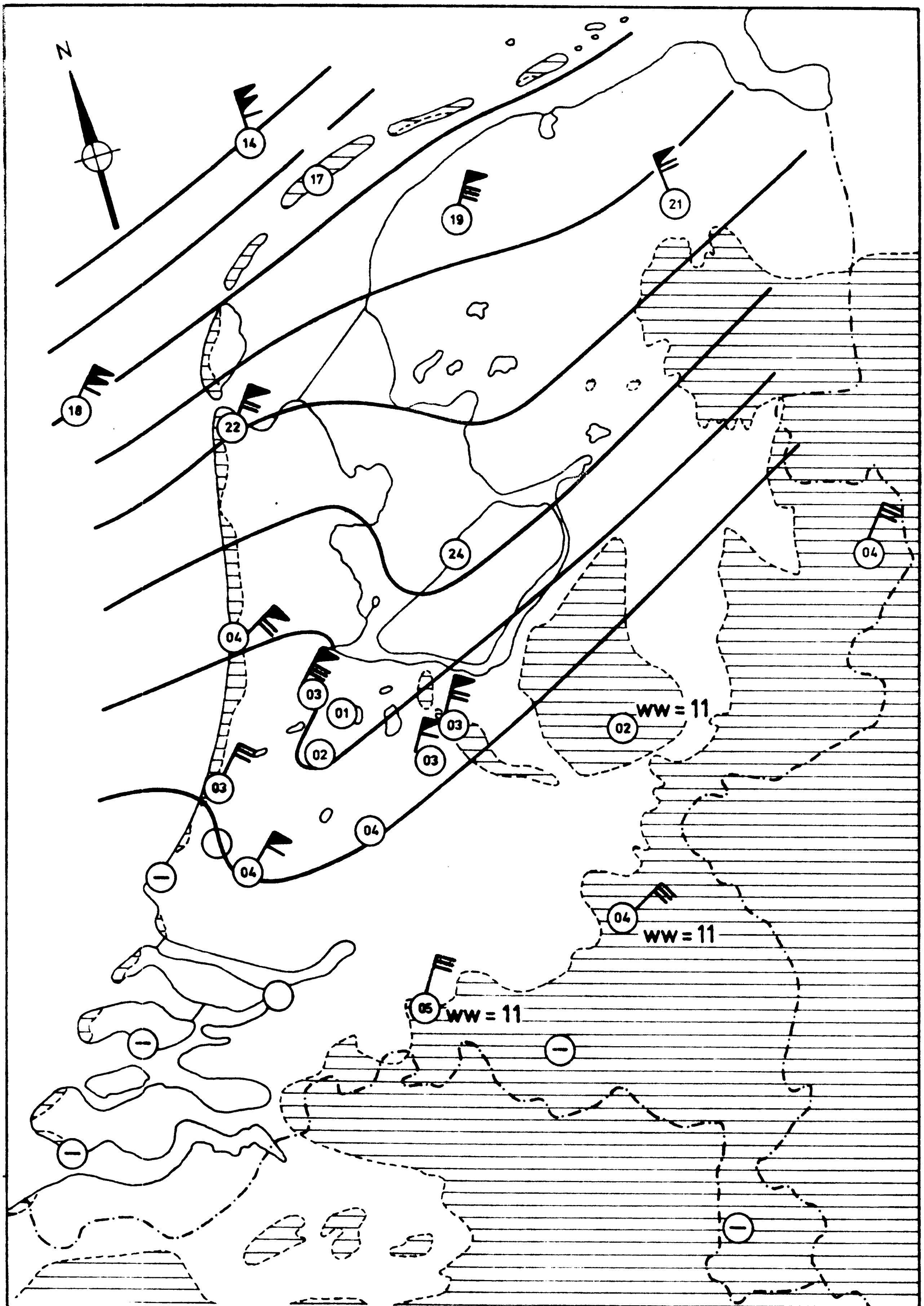

Fig. 10 Advection of fog on 8-4-1974. The figure in a circle is the first hour at which fog and/or low stratus (height ≤ 400ft) is reported. The arrows indicate the wind at that hour. Each bar stands for 1 kt and each triangle 5 kts.

⊖ : No fog or low stratus. ◎ : Calm.

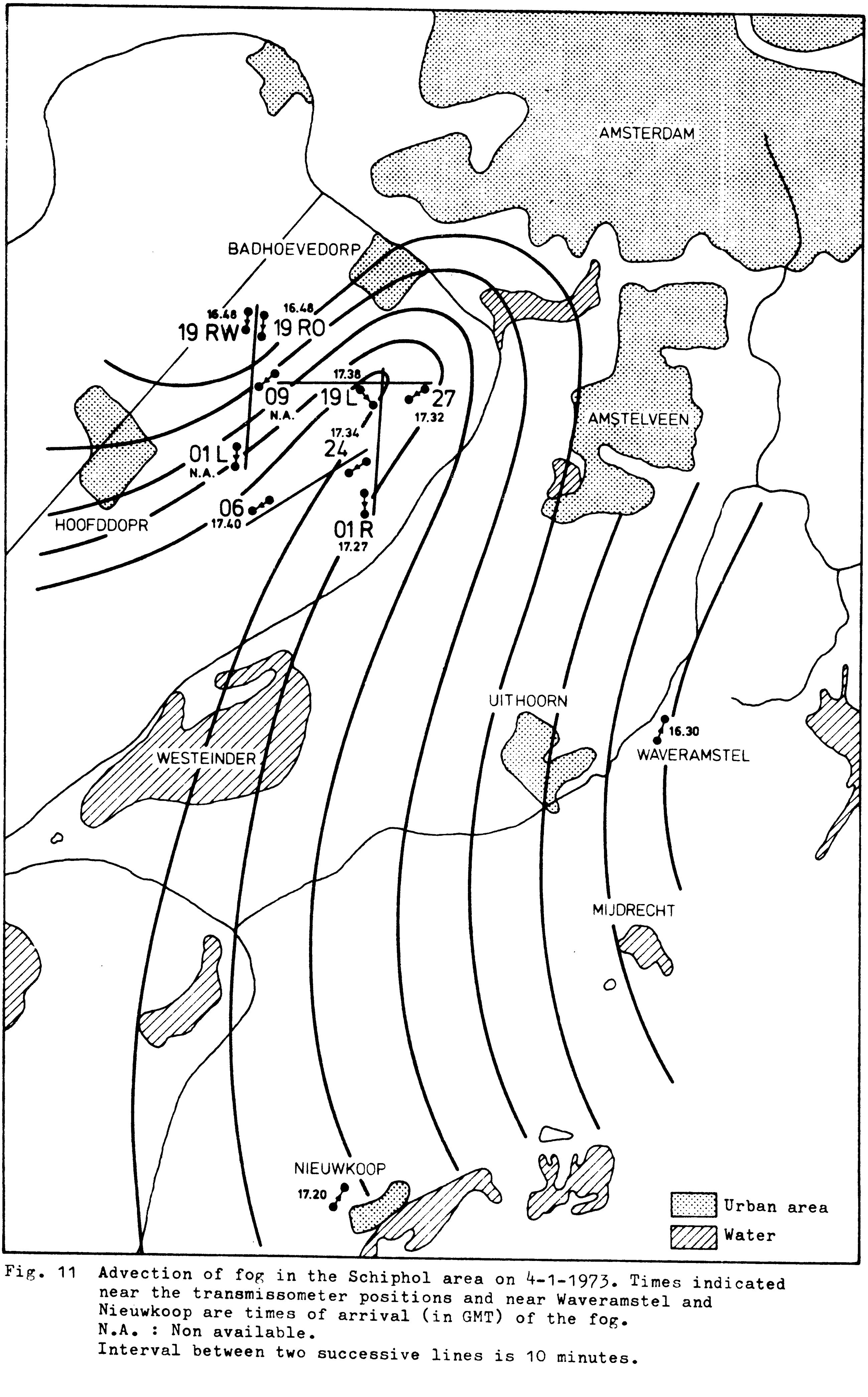

Fig. 11 Advection of fog in the Schiphol area on 4-1-1973. Times indicated near the transmissometer positions and near Waveramstel and Nieuwkoop are times of arrival (in GMT) of the fog.
N.A. : Non available.
Interval between two successive lines is 10 minutes.

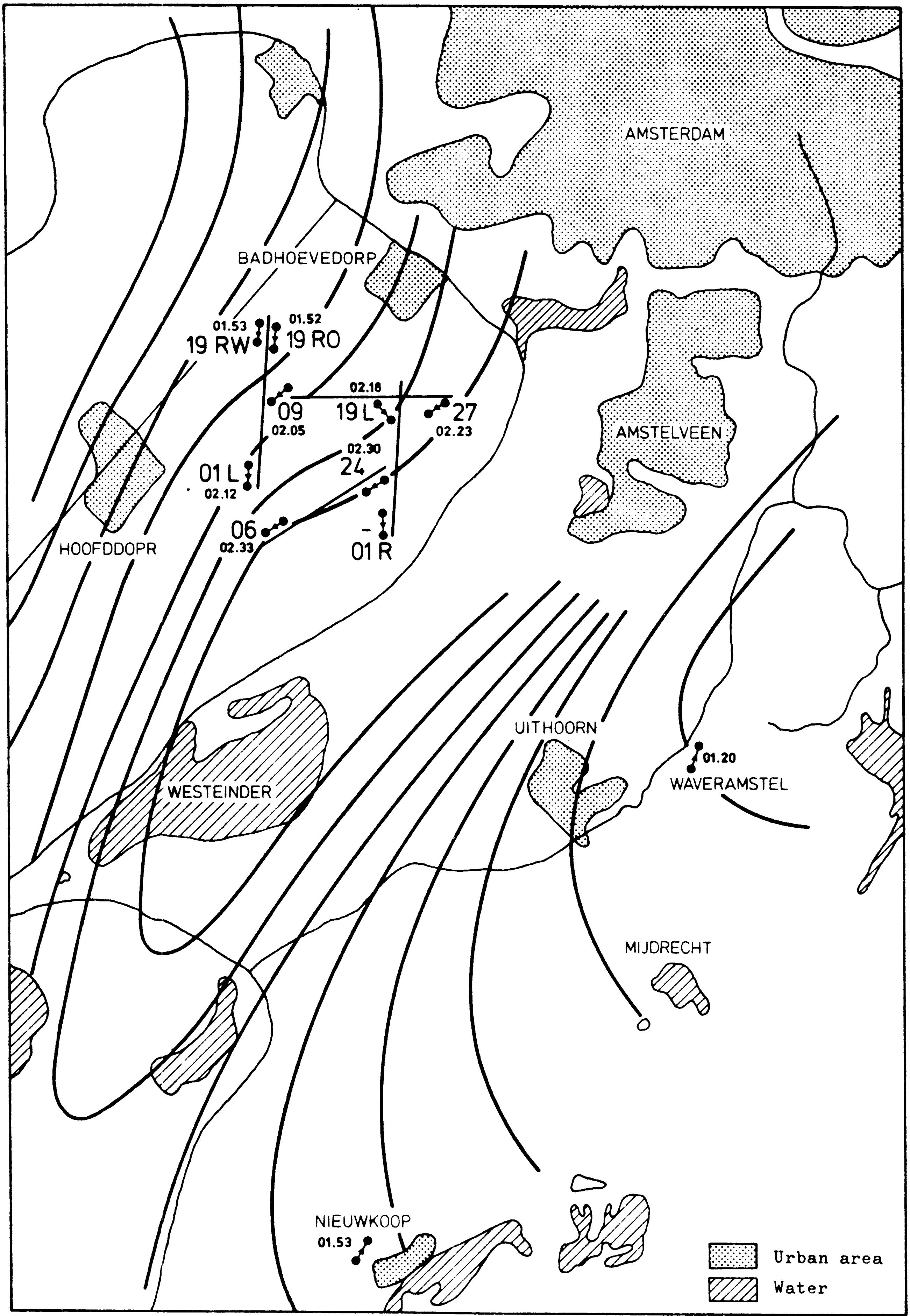

Fig. 12 Advection of fog in the Schiphol area on 8-4-1974. Times indicated near the transmissometer positions and near Waveramstel and Nieuwkoop are times (GMT) of arrival of the fog.
N.B. Transmissometer 01R did not encounter fog.
Interval between two successive lines is 10 minutes.

of the registrations of the nine 160m-base transmissometers, which are in operation at Schiphol Airport. Fig. 13 shows the positions of the transmissometers in the Schiphol area.

The analysis of the advection has been done using the times of onset of the fog at each transmissometer (at a height of 2 m). The fog may however manifest itself in the area at an earlier time in the form of low stratus. Indeed, in the case of 8-4-1974 (Fig. 12) low stratus (4/8 St at 200 ft) was reported at 01.25 GMT, while the fog arrived at the various transmissometer positions between 01.53 GMT and 02.33 GMT. The minimum visibilities in the fog at the transmossimeter positions showed an increase from the north-west to the south-east: at the positions 19RO/19RW/09 the minimum visibility was 100-200 m, at the positions 19L and 06 400-500 m, and at the positions 01L, 27, 24 and 01R respectively 700 m, 800 m, 900 m, more than 1000 m.

The case of 4-1-1973 (Fig. 11) shows a first reporting of low stratus (1/8 St at 100 ft) at 17.25 GMT, while the first transmissometer-recorded fog was 01R at 17.27 GMT. So in the latter case there was no stratus prior to the fog.

The small-scale advection patterns as presented in Figs. 11 and 12 clearly show the influence of the Amsterdam/Amstelveen conurbation. Due to this effect the time difference between the fog onsets at Schiphol and Waveramstel is larger than it would have been without the large built-up area. For fogs advected from the north-east this means a benefit in case the station Waveramstel is used for the short-term visibility forecasts of Schiphol. Since many of the advection fogs are advected from directions 340° to 070°, the most suitable position for a possible third stations is at about 20 km to the north of Schiphol. In Fig. 8 it can be seen that in the sector 340°-090° the synoptic station nearest to Schiphol, station 235, lies at about 70 km to the north. The four other synoptic stations in this sector are situated at at least 120 km from Schiphol, with an expanse of water between Schiphol and these stations. If one has the goal to improve the short-term visibility forecasts at Schiphol, the situation described above suggests a visibility measuring station at about 20 km to the north of Schiphol.

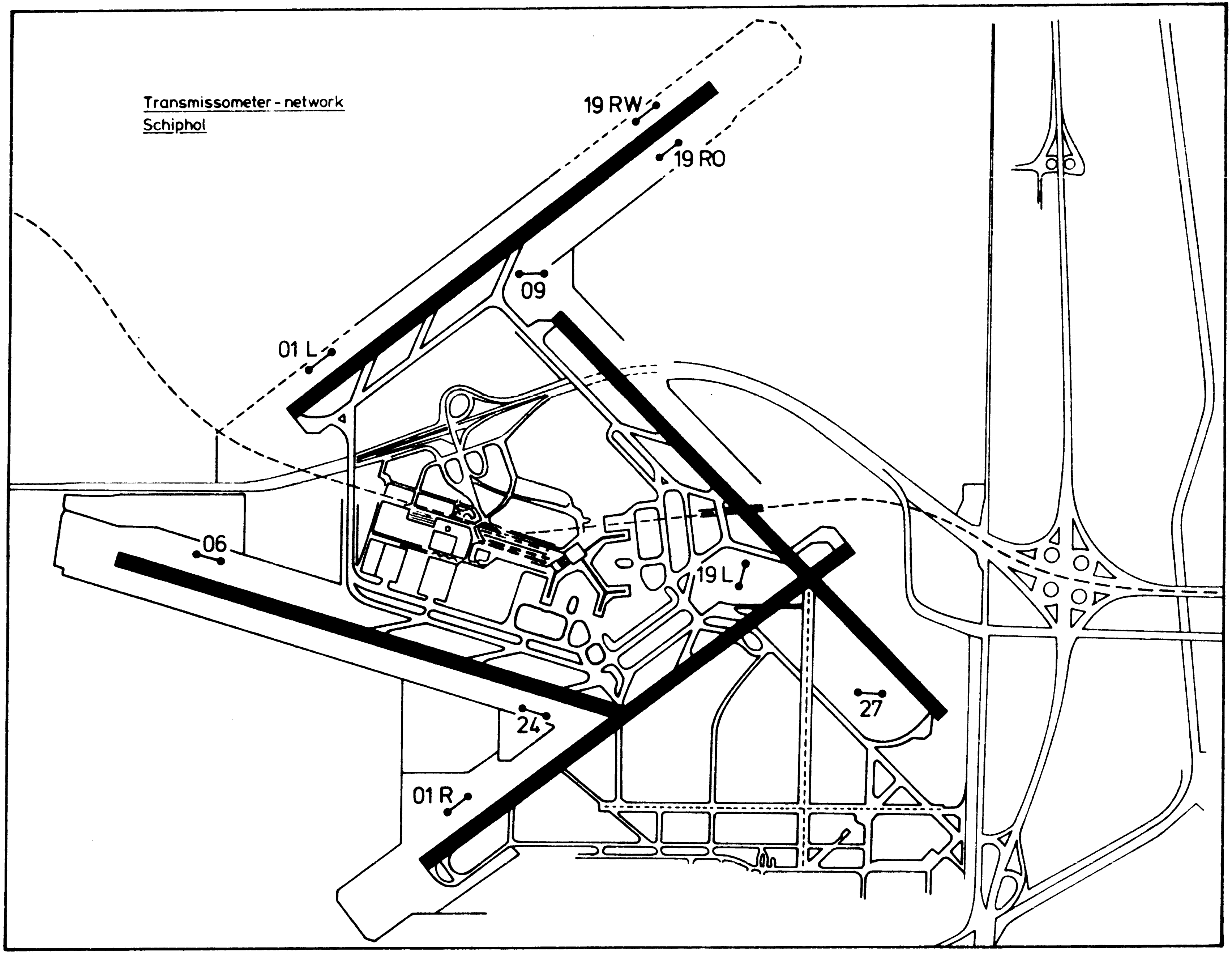

Fig. 13 Positions of the 160m base transmissometers at Amsterdam Airport (Schiphol).
●—● : 160m base transmissometer.

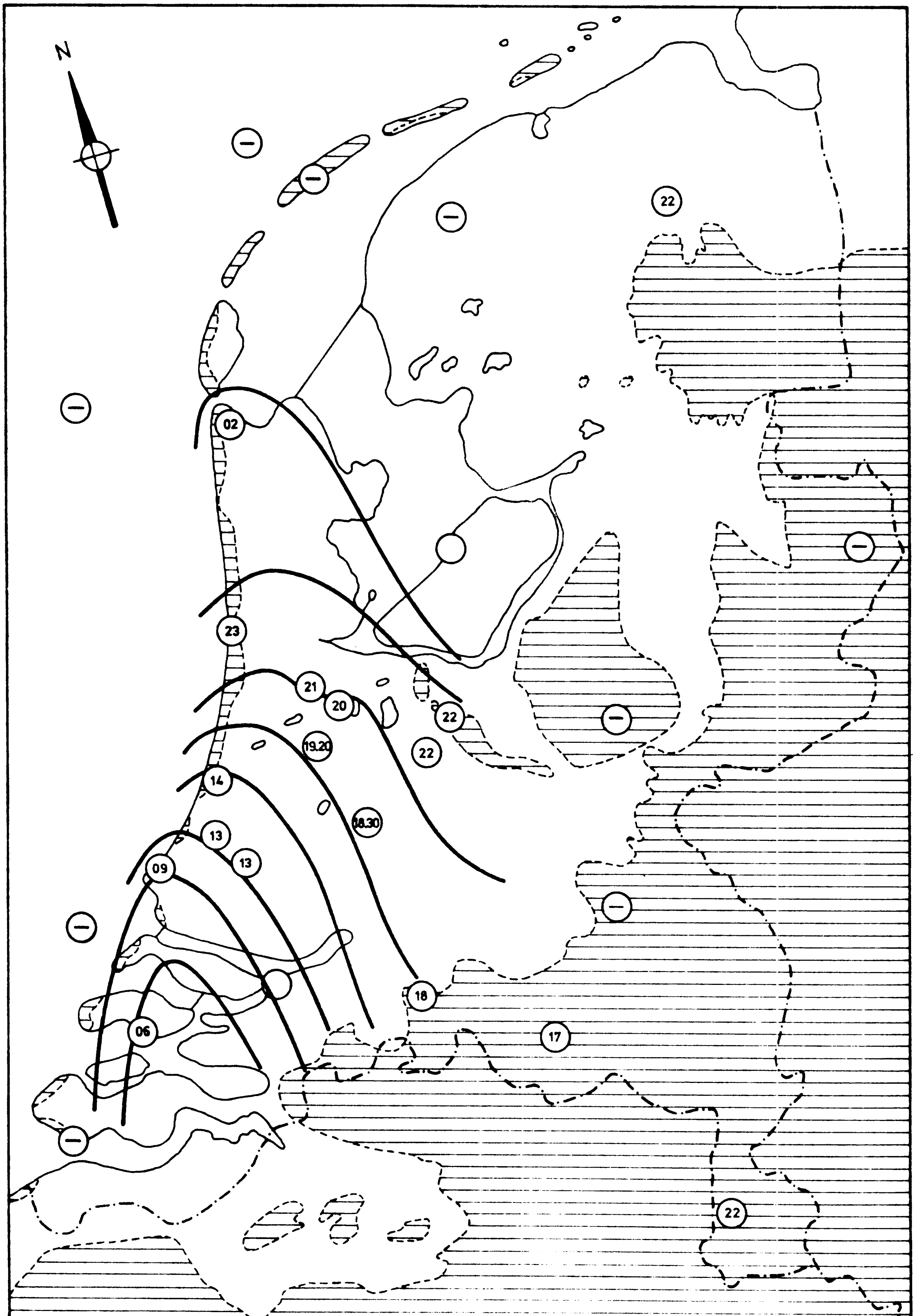

Fig. 14 Advection of fog on 21-12-1972. The figure in a circle is the first hour at which fog and/or low stratus (height ≤ 400ft) is reported.
⊖ : No fog or low stratus.

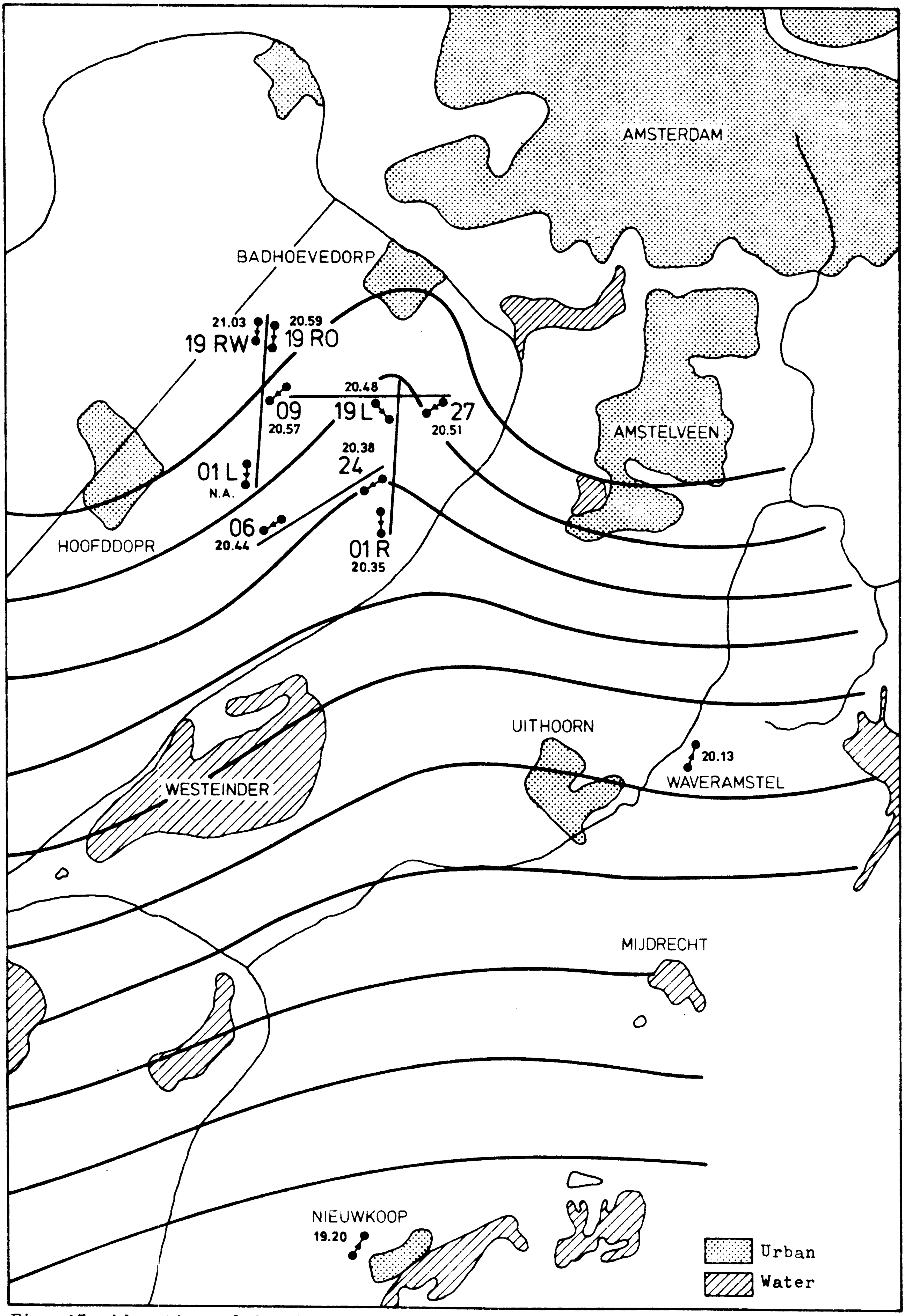

Fig. 15 Advection of fog in the Schiphol area on 21-12-1972.
Times indicated near the transmissometer positions and near Waveramstel and Nieuwkoop are times of arrival (in GMT) of the fog.
N.A. = non available.
Interval between two successive lines is 10 minutes.

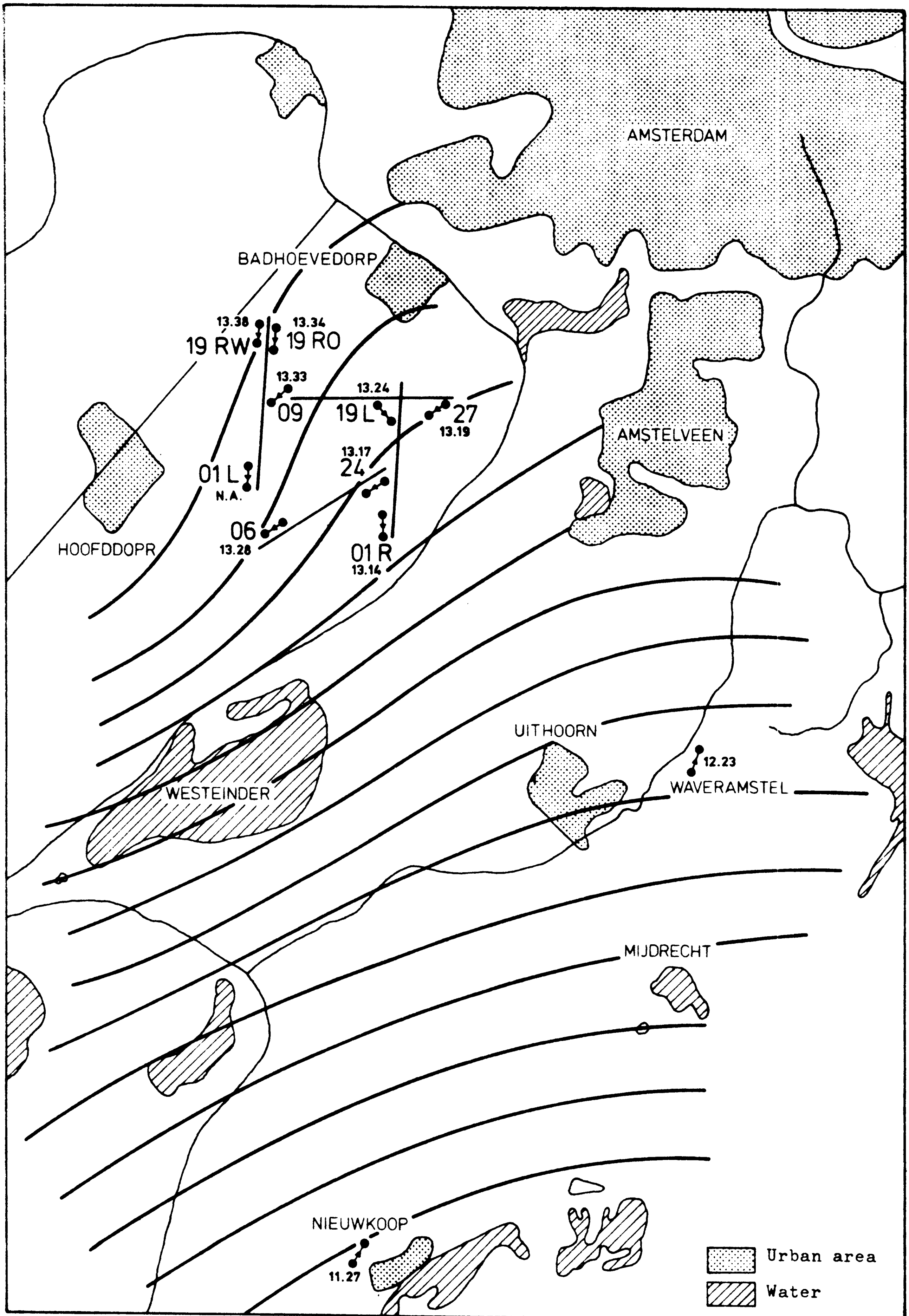

Fig. 16 Advection of fog in the Schiphol area on 16-1-1973.
Times indicated near the transmissometer positions and near Waveramstel and Nieuwkoop are times of arrival (GMT) of the fog.
N.A. = not available.
Time interval between successive lines is 10 minutes.

An example of an advection from the south can be seen in Fig. 14. This advection pattern is typical of southerly directions. Often only the coastal parts do experience this advection fog, whereas the stations more inland have no fog or are subjected to radiation fog. Fig. 15 shows how the fog moved through the Nieuwkoop-, Waveramstel- and Schiphol-areas. Between 19.00 and 20.00 GMT the wind at Cabauw at a height of 80 and 200 m was 2.5 m/s from 180°. Using these wind data and assuming a straight fog front we computed a time necessary for advection from Nieuwkoop to Schiphol of 105 minutes, and from Waveramstel to Schiphol of 41 minutes. The observed times were 78 and 25 minutes respectively. The agreement between computed and observed advection times seems satisfactory.

The examples given thus far concern cases when the advection of fog occurs at such a scale that other synoptic stations report fog before Schiphol encounters fog. In these cases, of course, the meteorologist is alert that fog is approaching the area. The stations Nieuwkoop and Waveramstel may then serve to forecast in a more accurate way the onset of fog at Schiphol. But there are also cases when there is fog in the area south-east of Schiphol, which is not observed at the synoptic stations. This fog, eventually, may be transported towards Schiphol. Fig. 16 shows such a case. Then the stations are very useful in forecasting a deterioration of the visibility at Schiphol.

7.2 Advection of fog from Waveramstel to Schiphol

In section 5 we presented the probabilities of fog occurrence at Schiphol within two hours from the fog onset at respectively Waveramstel and Nieuwkoop. It appeared that these possibilities were strongly dependent on a certain combination of wind speed and vertical temperature gradient (between 10 m and 0.5 m). Advection fogs (for which $\overline{u} \geqslant 1.3\ \overline{\Delta T}$) appeared to have the highest probabilities for fog occurrence at Schiphol (Table VI). Besides these possibilities it would be valuable to get the time of the fog onset more accurate than "within two hours". Therefore, we have used a very simple model of fog advection: we assumed a straight fog front which is advected in a direction perpendicular to the front. We used the half-horly means of the wind at Cabauw at a height of 80 m at the time of first appearance of the fog at respectively Waveramstel, Nieuwkoop and Schiphol. The choice of the wind at a height of 80 m instead of 10 m or 200 m, which were also available, is a compromise. It is, of course, not realistic to assume that the 80 m wind is representative of the advection in all cases. On the other hand, the 10 m wind will certainly be an underestimate. A substantial part of the advection fogs does not reach a height of 200 m. In these cases a considerable difference in wind direction between the height of 80 m and that of 200 m may exist. If an advection fog is higher than 200 m, the 200 m winds and the 80 m winds are quite similar in size and direction. Therefore we used the 80 m wind for the calculation of the time needed for advection of the fog from one station to another assuming that the fog front is perpendicular to the direction of the 80 m wind. We shall use the term "advection time" from now on.

For the determination of the calculated and the observed advection times we used the registrations of the transmissometer at position 01R (see Fig. 13). This transmissometer position is the most undisturbed position at Schiphol with respect to the advection of fog from southerly directions. Fig. 17 shows a comparison of the calculated advection times with the observed advection times for the advection of fog from Waveramstel to Schiphol. For convenience the times corresponding with advection velocities of 2, 4, 8 and 16 m/s are indicated on both axes. It can be noted that the correlation between the calculated and the observed times is low (a correlation coefficient of 0.5 for all cases irrespective of wind direction). Out of all 51 advection fogs 37 fogs (= 73%) first appeared at Waveramstel before reaching post 01R at Schiphol. A strong dependence on wind direction can be observed. All fogs but one with wind direction between 090^{o} and 210^{o} (symbol x in Fig. 17) arrive at Waveramstel before arriving at Schiphol. This is to be expected, for Waveramstel lies at about 140^{o} relative to Schiphol. The agreement between calculated and observed times is reasonable. The correlation coefficient between observed and calculated advection times (one case excluded, when Schiphol got the fog first) is 0.77. It can be seen that 16 out of the 18 fogs show calculated advection times which are within 20 minutes from the observed times.

Eleven fogs out of the 12 with 80 m wind directions 000° to 090° (symbol o in Fig. 17) show observed advection times which are (much) more than the calculated times. The differences range from 7 minutes to 87 minutes. The reason for these delays in the fog onsets at Schiphol is the result of the screening effect by Amsterdam/Amstelveen already described in section 7.1.

Eight out of the ten fogs with wind directions 250° to 350° (symbol + in Fig. 17) show negative advection times, i.e. they arrive first at Schiphol (01R). For all ten fogs a positive correlation between calculated and observed advection times can be observed (with a correlation coefficient of 0.66). For advection of fog from wind directions 250° to 350° the station Waveramstel has no operational value.

Finally, we have a large number of 9 fogs with 80 m wind directions 220° to 240° (symbol • in Fig. 17). Although the calculated advection times are small, all within ± 5 minutes (because the wind direction is more or less perpendicular to the line through Schiphol and Waveramstel), the observed times range from -25 minutes (Schiphol 25 minutes earlier in fog than Waveramstel) to +138 minutes. For these fogs the line of advection is more or less perpendicular to the connection line between Schiphol and Waveramstel. Therefore, the assumption of a straight fog front is required over the full distance of 8 km between Schiphol and Waveramstel. To fulfil this requirement is much more difficult than in the case the line of advection is more or less parallel to the connection line between Schiphol and Waveramstel.

We may conclude that for the advection fogs coming from 000° to 210° the visibility measurements at Waveramstel are valuable to the short-term forecast at Schiphol. For wind directions 100° to 210° the fog arrives at Schiphol within the calculated advection time ± 20 minutes after Waveramstel got the fog. The average advection time is 40 ± 23 minutes. For wind directions 000° to 090° all that can be said is that Schiphol gets fog within 1½ hours after the fog onset at Waveramstel. Here the average advection time is 45 ± 29 minutes.

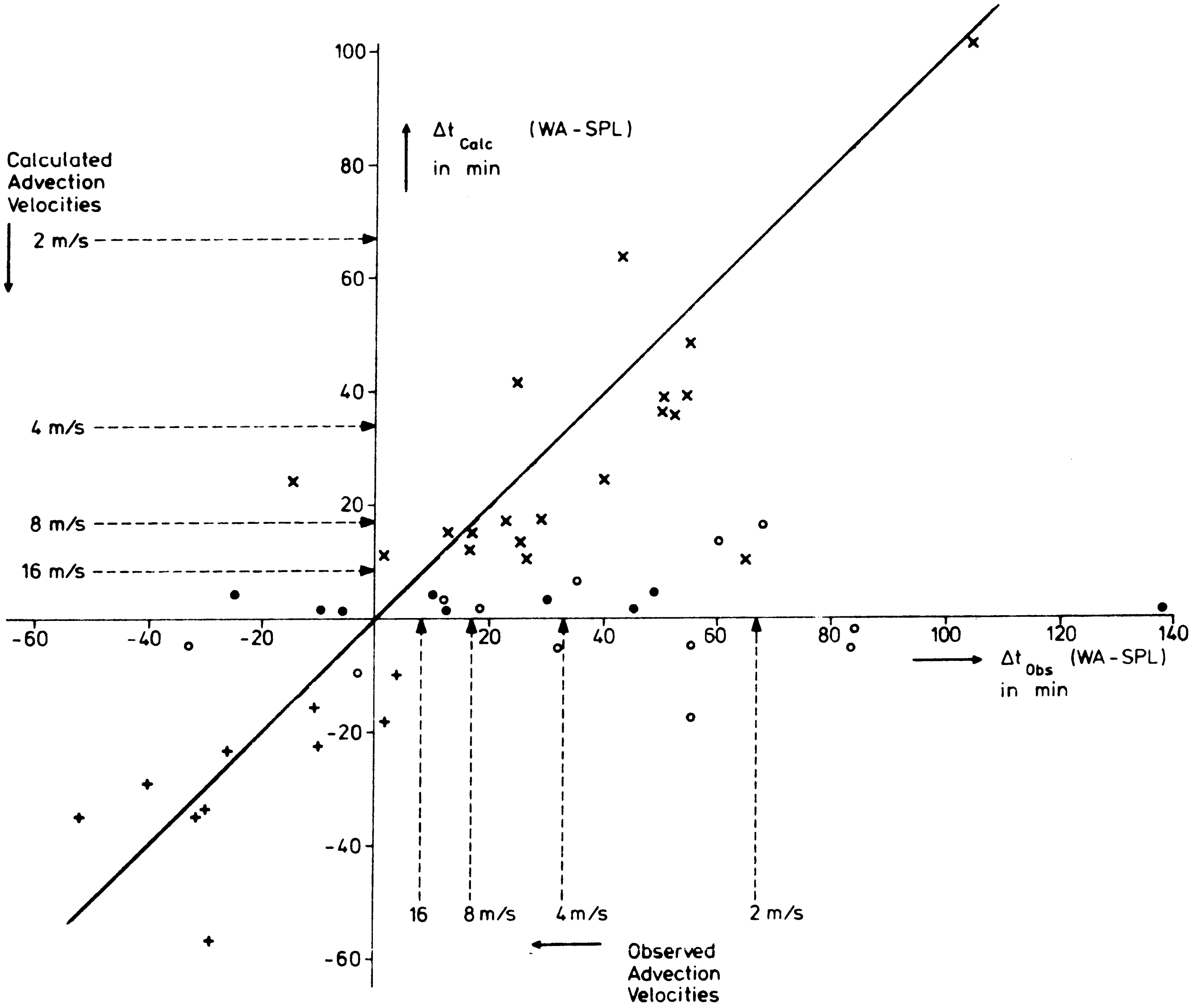

Fig. 17 Calculated advection times vs observed advection times for advection of fog from Waveramstel to Schiphol.

x : 100° - 210°
o : 000° - 090°
+ : 250° - 350°
● : 220° - 240°

} direction of the 80m wind at Cabauw at the time of first appearance of the fog at Spl or WA.

7.3 Advection of fog from Nieuwkoop to Schiphol

In Fig. 18 calculated advection times are plotted against observed advection times for the advection of fog from Nieuwkoop to Schiphol (01R). Here we can distinguish three groups of fog.

First, the fogs with 80 m wind directions 110° to 270° (symbol x in Fig. 18). 28 Out of 31 arrive at Nieuwkoop before they arrive at Schiphol (01R). These 28 fogs show a reasonable positive correlation between calculated and observed advection times (correlation coefficient 0.7). 23 Fogs had observed advection times within 30 minutes from the calculated times. The average observed advection time was 55 ± 33 minutes.

Second, the group with wind directions 000° to 100° (symbol o in Fig. 18) containing 12 fogs, shows, as in the case of the Waveramstel-Schiphol advection, that the observed advection times are larger than those calculated. The average advection time is 49 ± 28 minutes, which is the same as for the fogs in the first group. The difference between the two groups lies in the fact that for the fogs with wind directions 110° to 270° the calculated advection times may be used for the short-term visibility forecast in precisely reporting the beginning of the visibility deterioration. If the wind direction is between 000° and 100° it can only be said that fog is expected within 1½ hours.

The third group consists of five fogs with wind directions 280° to 350° (symbol + in Fig. 18). Four of these fogs first arrive at Schiphol (01R). It is evident that for operational forecasting of fog at Schiphol with these 80 m wind directions the station Nieuwkoop is of little value.

7.4 Variability of the visibility during advection fogs

In section 6 a comparison has been made between the visibility minima reached during fogs at Nieuwkoop resp. Waveramstel and those obtained during the same fog episodes at Schiphol. This was done irrespective of the wind direction. In section 6 it was stated that in pure advection fogs the space correlation between the extinction coefficients measured at two stations should be rather high. To illustrate this high correlation we will show some examples of the advection of fog from directions 040° to 230°.

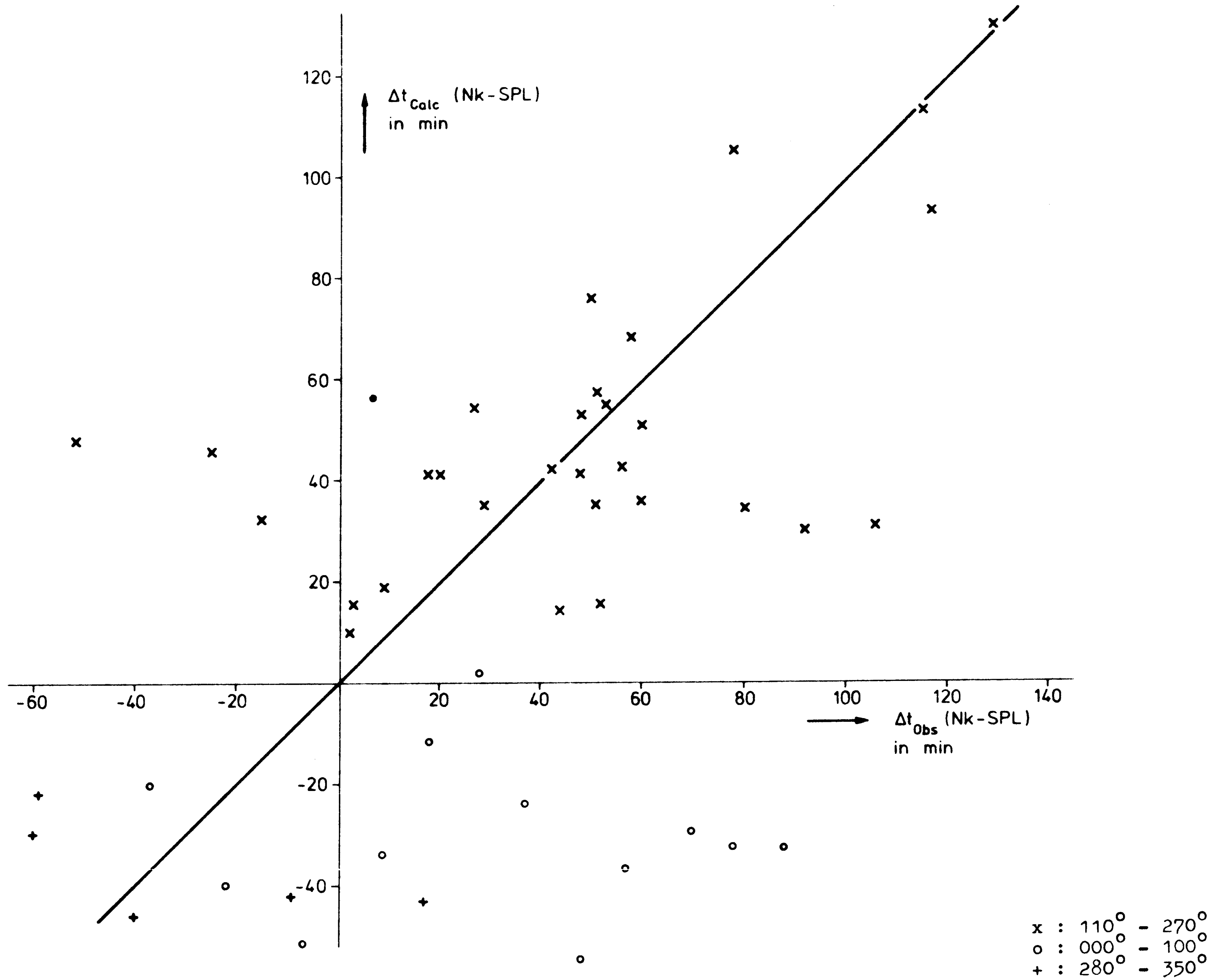

Fig. 18 Calculated advection times vs observed advection times for advection of fog from Nieuwkoop to Schiphol.

7.4.1 Example of fog advection from 040°-060°

Fig. 19 shows the time history of a fog advection from about 060°. It can be seen that within 10 minutes the extinction coefficient at Waveramstel, the first station to encounter fog, increases from 5 km^{-1} (a visibility of 600 m) to 40 km^{-1} (a visibility of 75 m). After this sudden increase the extinction coefficient lowered during the next 2 hours to about 25 km^{-1}, after which it remained the same with small fluctuations till 04.00 GMT. From 04.00 GMT till 06.00 GMT the fog gradually cleared.

About one hour after the onset of the fog at Waveramstel the fog enters Nieuwkoop, with a similar jump in the extinction coefficient. Hereafter, during 3 hours of increasing visibility the extinction coefficient remains more or less constant at about 20 to 25 km^{-1} overnight. The two extinction coefficient profiles are very much alike. The 80 m wind direction during the night till 02.00 GMT is 040°-060°. This direction is more or less parallel to the direction of the line Waveramstel-Nieuwkoop (042°). As can be seen, the wind direction at Nieuwkoop and Waveramstel was constant during the whole night (average at Nieuwkoop and Waveramstel 060°). The wind speed at Waveramstel ($\bar{u}$ = 3.6 kts) was considerably less than at Nieuwkoop ($\bar{u}$ = 6.0 kts). This is the result of the obstructions (trees, houses) to the north-east of the anemometer at Waveramstel (see Fig. 3). For the fog at Schiphol we observe that 25 minutes after the onset at Waveramstel the fog reaches Schiphol (as observed at transmissometer 24, see Fig. 13). The shape of the extinction coefficient curve of Schiphol is clearly different from those of Nieuwkoop and Waveramstel: after 1½ hours of fog with a minimum visibility less than 100 m we observe a period of 1½ hours in which the visibility has increased to 2500 m. From 21.00 GMT to 04.00 GMT the visibility at Schiphol is comparable with those at Nieuwkoop and Waveramstel. Between 04.00 GMT and 06.00 GMT the visibility gradually increased, whereas at Schiphol the visibility remains below 200 m till 07.30 GMT, half an hour after sunrise.

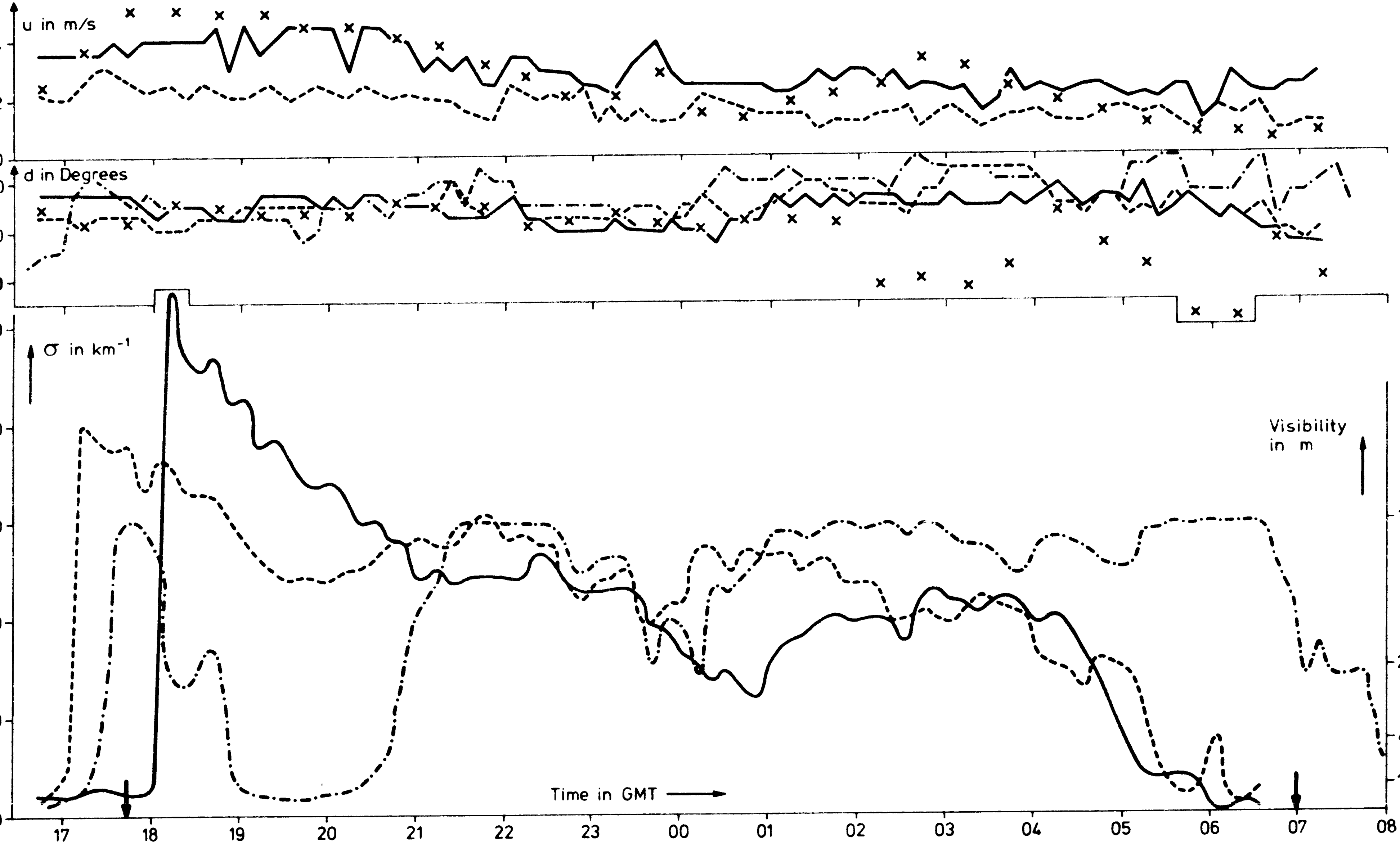

Fig. 19 Extinction coefficient, winddirection and windvelocity as a function of time (GMT) for the stations Nieuwkoop (——), Waveramstel (----) and Schiphol (-.-) on 13-3-1974.
x : windvelocity and winddirection at 80m at Cabauw. ↓ : time of sunset resp. sunrise.

Fig. 21 (lower part) shows again the extinction coefficient as a function of time for the three stations. Only this time the curves of Nieuwkoop and Schiphol are shifted in time. The curve of Nieuwkoop has been shifted 59 minutes backwards in time (Δt (Nk) = -59 min.). These 59 minutes are obtained by using the half-hourly mean of the 80 m wind at Cabauw at the moment of fog onset at Waveramstel ($\overline{d}/\overline{u}$ = 040°/3.7 m/s). It is remarkable how well the curve of Nieuwkoop coincides with the curve of Waveramstel. The space correlation coefficient is optimal for a time shift of 60 minutes and amounts to 0.89. Thus in this case not only the onset of the fog at Nieuwkoop could have been predicted very accurately, but also the visibility during the fog at Nieuwkoop from the visibility measured at Waveramstel about one hour in advance.

For Schiphol the predicted time of arrival of the fog is 6 minutes <u>before</u> the fog onset at Waveramstel. Instead of 6 minutes earlier the fog arrives at Schiphol about 20 minutes later than the time of fog onset at Waveramstel. The arrival of the fog at Schiphol is retarded due to the Amsterdam/Amstelveen conurbation (see also section 7.1). Thanks to this delay for wind direction 000°-050° the station Waveramstel may still be used to indicate that fog is approaching the Schiphol area. The correlation between the extinction coefficients at Waveramstel and those at Schiphol is in this case much lower than the correlation between the extinction coefficients at Waveramstel and Nieuwkoop. This means that during this fog the measurements of the extinction coefficient at Waveramstel could not serve as a means of forecasting visibility at Schiphol. One could of course expect this, because as was shown by the high correlation between the extinction coefficients at Waveramstel and Nieuwkoop the 80m wind appeared to be the fog-driving wind. The wind direction of 040° is almost perpendicular to the line connecting Waveramstel and Schiphol ($\sim$ 140°) and thus not optimal for a high correlation between the visibilities at Schiphol and Waveramstel.

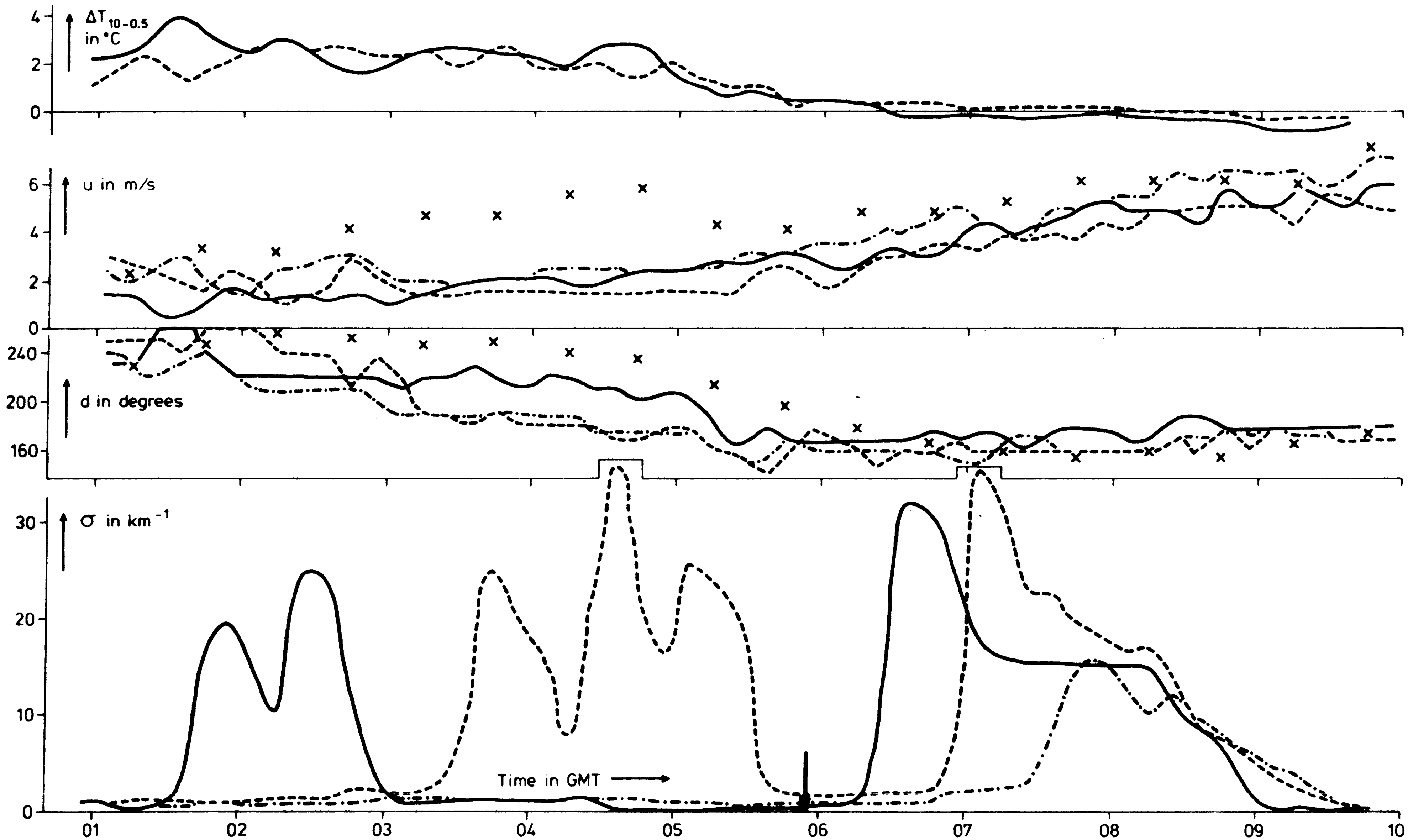

Fig. 20 Extinction coefficient, winddirection, windvelocity and vertical temperature difference as a function of time (GMT) for the stations Nieuwkoop (——), Waveramstel (----) and Schiphol (-.-.) on 14-3-1974.
x : windvelocity and winddirection at 80m at Cabauw. ↓: time of sunrise.

7.4.2 Example of fog advection from 180°

Fig. 20 shows an interesting example of a night with radiation fog at the two stations Waveramstel and Nieuwkoop followed by an advection fog in the morning, half an hour after sunrise.

At Nieuwkoop, between 01.30 GMT and 03.00 GMT, fog exists accompanied by a large temperature difference between heights of 10 m and 0.5 m and a wind speed of about 1½ m/s. At Waveramstel a radiation fog is also forming during the night. However, Schiphol encounters no radiation fog. At Cabauw, between 01.00 GMT and 03.00 GMT, a radiation fog is present with a height of 5 to 20 m.

Half an hour before sunrise we observe an increase in wind speed at all three stations accompanied by a gradual break-down of the temperature inversion. At sunrise all stations are without fog. We also notice a gradual backing of the wind during the night from directions of about 240° to directions of about 160°, due to the passage of a weak ridge of high pressure. About half an hour after sunrise the stations Nieuwkoop, Waveramstel and Schiphol are successively subjected to a typical advection fog. The 80m wind direction at the time of the beginning of the fog at Nieuwkoop is 180°. Although this direction is parallel to the connection line between Nieuwkoop and Schiphol, the courses of the extinction coefficient at Nieuwkoop and Schiphol are not similar unlike those of Nieuwkoop and Waveramstel.

Calculating the time needed for advection from Nieuwkoop towards Waveramstel and Schiphol, making use of the 80m wind at the time of fog onset at Nieuwkoop (180°/4.8 m/s), we obtain 34 minutes and 55 minutes. By shifting the extinction coefficient curves of Waveramstel and Schiphol back in time accordingly, we obtain the result as drawn in Fig. 21 (upper part). One can see that the time of arrival of the fog at Waveramstel can be calculated very accurately from the time of arrival at Nieuwkoop and the 80m wind as measured at Cabauw. For Schiphol this is not the case: the fog onset at Schiphol is about 15 minutes later than calculated. Moreover, the extinction coefficients measured at Schiphol are not so large as those obtained at Nieuwkoop. Part of the difference

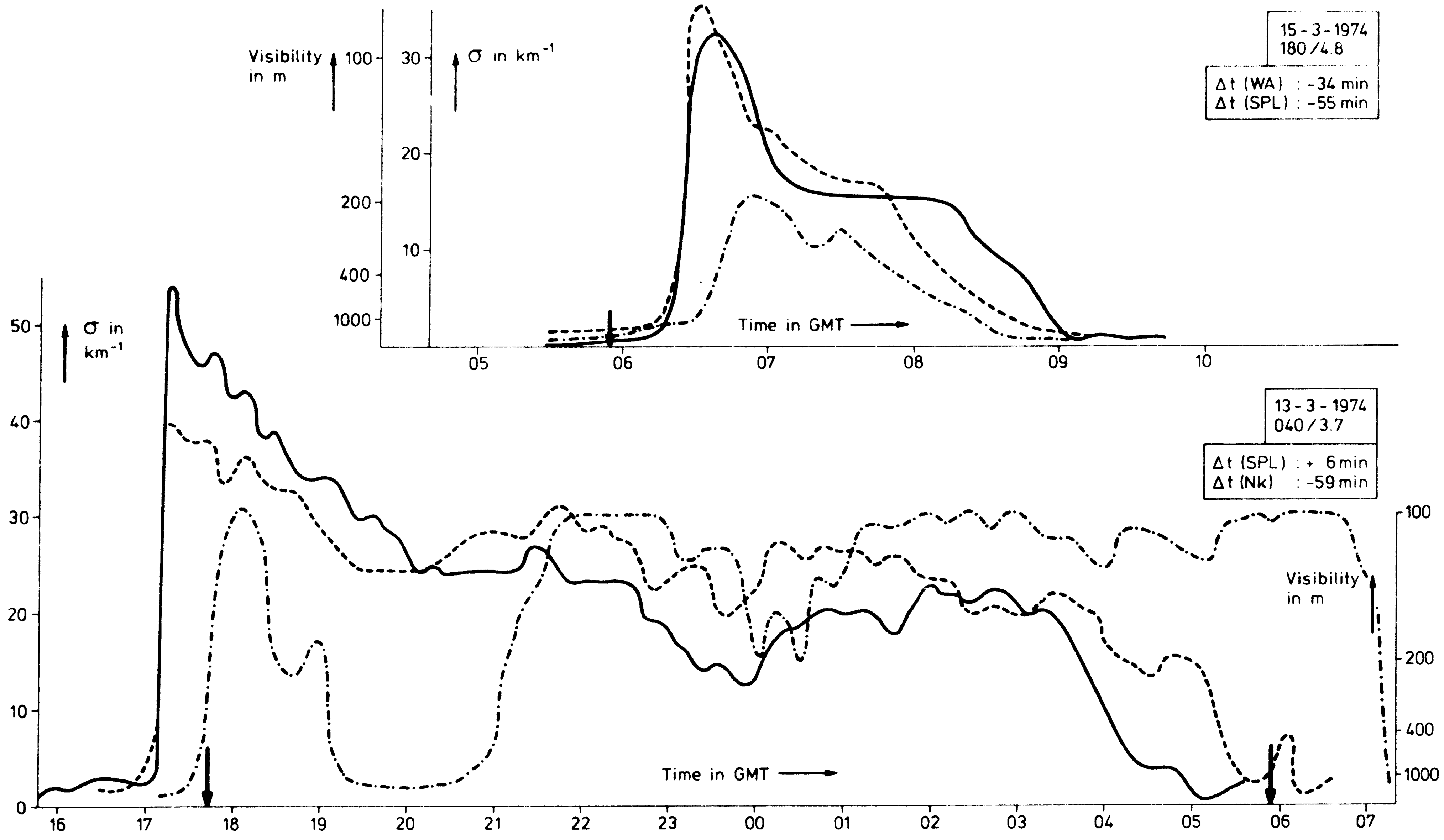

Fig. 21 Extinction coefficient σ as a function of time (GMT).
Advection of fog on 15-3-1974 (upper graph) and on 13-3-1973 (lower graph).
——— Nieuwkoop, ----- Waveramstel, -.-.- Schiphol. Vertical arrows indicate times of sunset and sunrise.
Below each date the half hour means of the 80m wind at Cabauw at the time of arrival of the fog at Nieuwkoop (upper graph) resp. Waveramstel (lower graph) is presented. Δ t(Nk) = -59 min means that the Nieuwkoop curve is shifted 59 minutes backward in time. Δt(SPL) = +6 min means a shift of the Schiphol curve of 6 minutes forward in time.

may be explained by the fact that the fog arrives 55 minutes later at Schiphol than at Nieuwkoop. During that time the sun reached an elevation of 16^o (at 07.45 GMT) and evidently started clearing the fog.

7.4.3 Fogs advected from 040^o-070^o

In Fig. 22 the extinction coefficient curves are drawn for six fogs advected from directions 040^o-070^o. In all six cases the time scale in GMT corresponds with the Waveramstel observations. The curves of Nieuwkoop and Schiphol have all been shifted by time delays calculated by means of the 80m wind measured at the time of fog onset at Waveramstel. The wind speed and wind direction used in each case are mentioned in the figure just below each date and are indicated in m/s and degrees. The vertical arrows indicate the time of sunset or sunrise. The time shift for the curves of Schiphol and Nieuwkoop is also given in the figure (Δt (SPL) and Δt (Nk) in minutes).

Taking also into account the fog of 13-3-1974 (Fig. 21, lower part) we have seven fogs in all with 80m wind directions from 040^o-070^o. All these fogs have in common that they are synoptic-scale advection fogs, i.e. they appeared in the north-east of the Netherlands at an earlier time. The advection of the fogs on 4-1-1973 resp. 8-4-1974 through the country have been analyzed. These advection patterns are described in section 7.1 and drawn in Fig. 8 resp. Fig. 9.

A feature which almost all seven fogs have in common is that they appear at the stations Waveramstel and Nieuwkoop as a sudden increase in extinction coefficient. For Schiphol only four fogs show a similar sudden increase. It can be noticed that in four out of the seven cases the sudden increase in extinction coefficient at Nieuwkoop does coincide with the increase at Waveramstel. This means that in these cases the calculated time of advection is equal to the observed time. In Table X both advection times (calculated and observed) for each fog are given.

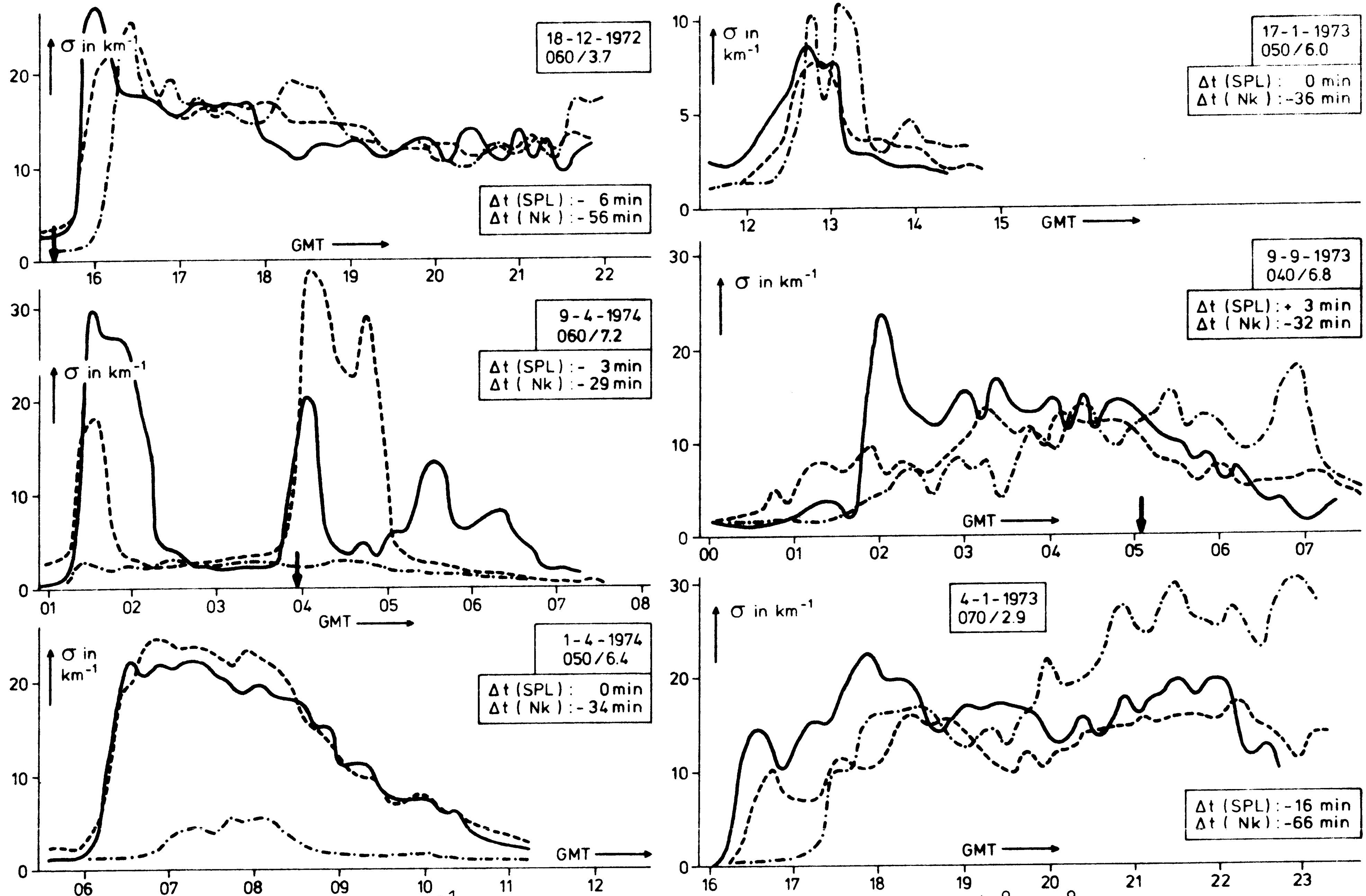

Fig. 22 Extinction coefficient σ (km^{-1}) as a function of time for fogs advected from 040°- 070°.
——— Nieuwkoop, ----- Waveramstel, -.-.- Schiphol.
Vertical arrows indicate time of sunset or sunrise. Below each date the 80m wind at Cabauw is given (in degrees/ m/s).
The Nieuwkoop (Nk) and Schiphol (SPL) curves are shifted in time. Negative Δt : a shift backward in time.

Table X

Comparison of calculated advection times with observed advection times for the advection of fog from Nieuwkoop to Waveramstel

date	height of fog at Cabauw (m)	80m wind $\bar{d}/\bar{u}$	80m Δt(WA-Nk) calculated (min.)	Δt(WA-Nk) observed (min.)	200m wind d/u	200m Δt(WA-Nk) calculated (min.)
18-12-1972	>180	060/3.7	56	60	100/5.4	24
4- 1-1973	>180	070/2.9	66	55	060/4.7	44
16- 1-1973	>180	050/6.0	36	~15	080/10.9	16
8- 9-1973	100	040/6.8	32	~70	090/5.7	25
13- 3-1974	60	040/3.7	59	60	070/2.8	68
31- 3-1974	>180	050/6.4	34	35	100/7.2	16
8- 4-1974	40	060/7.2	29	30	090/6.9	21

For five fogs the agreement between the calculated and the observed advection times is very good. In Table X the height of the fog measured at Cabauw during its first half hour of existence is given. Four fogs had a height of more than 180 m in the first half hour. It is interesting to see that the fogs with heights during the first half hour of only 60 m and 40 m show a very good agreement between the observed times of advection and the times calculated by means of the 80m wind.

For the five fogs with a good agreement between the calculated and the observed times of advection the 80m winds which have been used were measured at a time that Cabauw still had no fog. This means that the 80m winds used are winds which existed in front of the fog. In the two cases that a considerable difference exists between the calculated and the observed times (the fog of 16-1-1973 and the fog of 8-9-1973) 80m winds were used which had been observed during fog at Cabauw.

The calculated times for advection from Waveramstel to Schiphol are all very small (-6 minutes up to +16 minutes), due to the fact that the 80m wind directions for these cases (040°-070°) have an angle of 70°-100° with the connection line between Waveramstel and Schiphol. The observed times range from +10 to +70 minutes. This delay, as has already been stated in section 7.2, is due to the screening effect of the Amsterdam/Amstelveen built-up area. Furthermore, one may note that in two cases, namely the fogs of 31-3-1974 and 8-4-1974, the fog at Schiphol was considerably less dense than at Nieuwkoop and Waveramstel. The other five fogs show at all three stations a more or less similar behaviour.

The resemblance of the extinction coefficient profiles of Nieuwkoop to those of Waveramstel is, except for the case of 8-9-1973, good and in some cases, e.g. the fogs of 31-3-1974 and 18-12-1972, perfect. Noteworthy is the fog of 8-4-1974. At Waveramstel this fog consisted of two periods with large extinction coefficients ($\sigma > 15$ km^{-1}) about 2½ hours apart. Nieuwkoop shows, in a similar way, two peaks with an extinction coefficient more than 15 km^{-1}. Although the times of arrival of the two sharp increases in the extinction coefficient at Nieuwkoop could almost exactly be calculated by means of the 80m wind, the ultimate maximum extinction coefficients reached at Nieuwkoop are not equal to those at Waveramstel. The first period shows a larger extinction maximum at Nieuwkoop than at Waveramstel, whereas the second period shows the opposite. Moreover, the widths of the fog episodes at Nieuwkoop are not equal to those at Waveramstel. The first period shows a longer spell of fog at Nieuwkoop than at Waveramstel, whereas in the second period Waveramstel is the station with the longer spell.

7.4.4 Fog advected from 180°-200°

Fig. 21 (upper part) and Fig. 23 show seven cases of advection fog with 80m wind direction ranging from 180° to 200°. For these directions one may expect that the extinction coefficient as a function of time at Nieuwkoop is reflected in the time-dependence of the extinction coefficient at Schiphol. Indeed, we observe that except for the fog of 21-12-1972 all fogs show a reasonable agreement between the courses of the extinction coefficient at Schiphol and those at Nieuwkoop.

Although the 80m wind direction is most favourable for a high correlation between the curves of Nieuwkoop and Schiphol, we may notice that in five out of the seven fogs the correlation between the curves of Nieuwkoop and Waveramstel is as high or even higher. The impression exists that at Schiphol the fog is denser than at Nieuwkoop: five fogs show a larger extinction coefficient at Schiphol than at Nieuwkoop. Especially the fogs of 31-12-1973 and 21-12-1972 show this effect. Before attributing this to a physical cause, some remarks have to be made about the measurement of the extinction at Schiphol. Here the extinction is measured by a transmissometer with a base of 160 m, which means that for an extinction coefficient of more than 20 km^{-1} the transmission is only smaller than 4%. So, for extinction coefficients $\sigma > 20\ km^{-1}$ the accuracy of the measurement by the 160m transmissometer is rapidly diminishing. Apart from this fundamental shortcoming of a long-base transmissometer for measuring high extinctions, it appeared, in a separate study [10], that these 160m-base transmissometers did not possess a linear response characteristic. The (ultimate) recorder transmission values systematically appeared to be too low. This was inherent in the way in which the light entering the detector was transformed into electrical pulses. Meanwhile all the transmissometer detectors have been modified in such a way [11] that they now have a linear response characteristic. An exact correction of the measurements made in 1973/1974 is not possible. All that can be said is that for extinction coefficients of more than 15 km^{-1} the 160m transmissometer produced values 5 to 10 km^{-1} too high.

The impression that five out of the seven fogs coming from 180^{o}-200^{o} show a higher extinction coefficient (thus a lower visibility) at Schiphol than at Nieuwkoop is, in the light of the comments given above, a false one. It is to be expected that fogs like the ones of 29-12-1973 and 31-12-1973, which appear to be very homogeneous at Waveramstel and Nieuwkoop, will show a (more or less) similar value of extinction coeffcient at Schiphol.

As to the times of arrival of these fogs at Schiphol all that can be said is that five out of the seven fogs arrive within 1½ hours from the time of arrival at Nieuwkoop, and that all seven fogs arrive within 2 hours at Schihol. The agreement between the calculated and the observed advection times is much less than

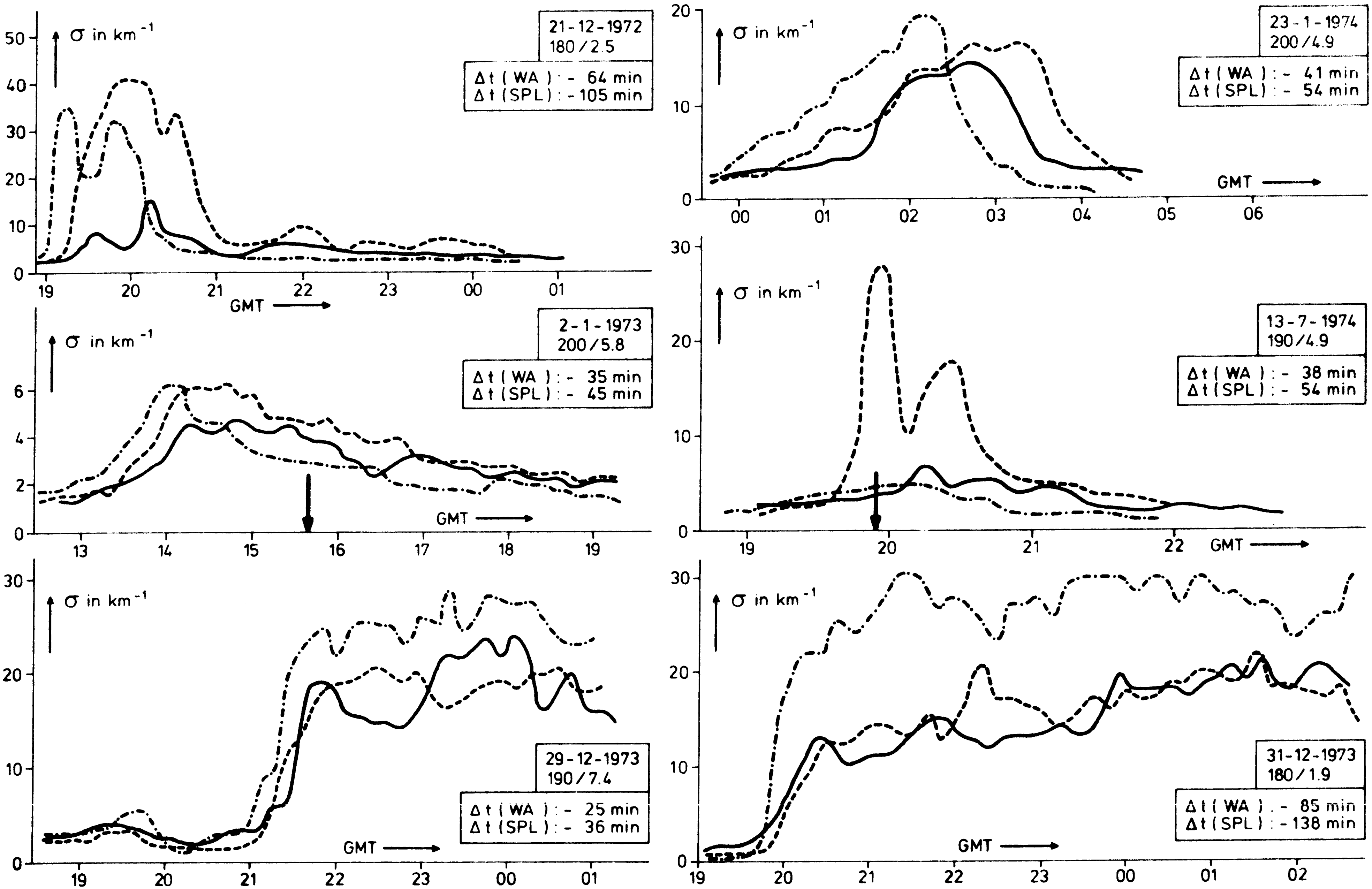

Fig. 23 Extinction coefficient σ (km^{-1}) as a function of time for fogs advected from 180° - 200°.
——— Nieuwkoop, ---- Waveramstel, -.-.- Schiphol.
Vertical arrows indicate time of sunset or sunrise. Below each date the 80m wind at Cabauw is given (in degrees/ m/s).
The Waveramstel (WA) and Schiphol (SPL) curves are shifted in time. Negative Δt : a shift backward in time.

in the case of the advection fog from Waveramstel to Nieuwkoop with wind directions 040°-070°, as described in section 7.4.3. The observed times for the advection from Nieuwkoop to Schiphol are on the average about 20 minutes less than the calculated times. In Fig. 23 it can be seen that the Schiphol extinction coefficients start to increase earlier than the Nieuwkoop extinction coefficients do.

7.4.5 Fog advected from 090°-150°

Fig. 24 shows the advection fogs with 80m wind directions between 090° and 160°.

The three fogs advected from 130° show a fair agreement between the Waveramstel and the Schiphol curves. This is to be expected, since the direction of 130° is close to the direction of the line connecting the stations Waveramstel and Schiphol (140°). The fog of 3-11-1973 with a high wind speed of 7.8 m/s at 80 m shows at Nieuwkoop more or less the same extinction coefficient profile as at Waveramstel and Schiphol, while the other two fog with much lower 80m wind speeds (3.4 resp. 2.1 m/s) show an extinction coefficient at Nieuwkoop which is much higher than those at Waveramstel and Schiphol.

The fog of 2-11-1973 shows a reasonable agreement between the Nieuwkoop and Schiphol curves, although the wind direction at 80 m is 150°. Waveramstel has a much larger extinction coefficient. This is due to radiational cooling: from 15.10 GMT till 15.40 GMT the temperature difference between 10 m and 0.5 m is increasing. Up to 15.40 GMT the wind speed and temperature still had such values that $\overline{u} \geqslant 1.3\,\Delta T$. From 15.40 GMT till 16.40 GMT the wind speed $\overline{u}$ was less than $1.3\,\overline{\Delta T}$. The stations Schiphol and Nieuwkoop do not show this behaviour: all the time the vertical temperature differences were zero. Thus the large difference in extinction between Waveramstel and Schiphol is due to the fact that between 15.40 GMT and 16.40 GMT a strong radiational cooling occurred at Waveramstel.

The fog of 22-12-1972 with a 80m wind direction of 110° was composed of low stratus (with a height of $\sim$60 m) which now and then touched the ground.

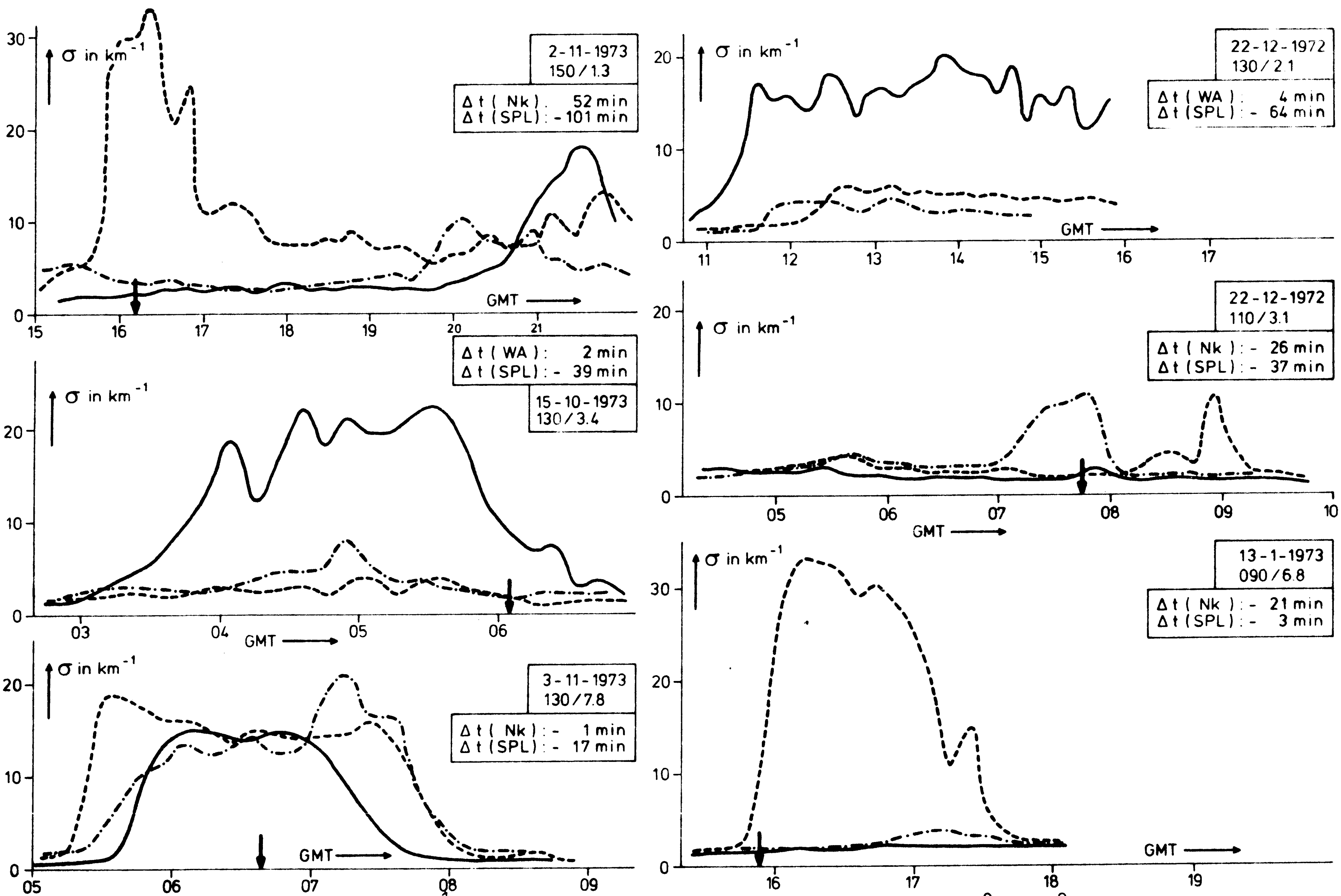

Fig. 24 Extinction coefficient σ (km^{-1}) as a function of time for fogs advected from 090° - 150°.
——— Nieuwkoop, ----- Waveramstel, -.-.- Schiphol. Vertical arrows indicate time of sunset or sunrise.
Below each date the 80m wind at Cabauw is given (in degrees/ m/s). Four Nieuwkoop (Nk), two Waveramstel (WA) and all the Schiphol (SPL) curves are shifted in time.
Negative Δt : a shift backward in time.

The fog of 13-1-1973 shows a very high extinction ($\sigma > 30\ km^{-1}$) at Waveramstel and only a low extinction at Schiphol ($\sigma_{max} = 4\ km^{-1}$, i.e. a visibility of 750 m). This fog originated from the large lake to the north-east of Amsterdam (IJsselmeer). Station 272 (see Fig. 8) reports dense fog (100 m resp. 200 m) at 06.00 and 09.00 GMT. No other stations in the country experienced fog. At 16.00 GMT station 225 at the coast, to the north-northwest of Schiphol, reports a visibility of 200 m with a wind of 14 kts/080°. One hour later, at 17.00 GMT, there still exists fog with a visibility of 500 m. At 18.00 GMT the visibility is reported to be 2500 m. Nieuwkoop also experienced a period of 2 hours of fog (16.00-18.00 GMT). Schiphol reports 2 hours of low stratus (4 oktas at 200 ft at 17.00 GMT and 2 oktas at 200 ft at 18.00 GMT). Due to the built-up area to the north-east of Schiphol the fog most probably lifted and passed Schiphol as low stratus. Except for the stations 272, 225, 240 (Schiphol) and Nieuwkoop no other stations in the country experienced fog and/or low stratus on 13-1-1973.

7.4.6 Fog advected from 210°-230°

Fig. 25 shows six fogs with 80m wind directions of 210°, 220° or 230°. A few fogs for which Schiphol was the station that first ran into fog are not shown. For fogs coming from a direction of about 220° one expects that Waveramstel would show the same pattern as Nieuwkoop does. In section 7.4.3, for fogs coming from directions 040°-070°, we have seen a very good agreement between the extinction curves of Waveramstel and Nieuwkoop. In the case of directions of about 220° we see in Fig. 25 that the agreement is less good.

The fogs, namely those of 12-8-1974 and 16-1-1973, consisted of low stratus which now and then reached the ground.

Two other fogs, namely those of 6-3-1974 and 4-9-1973, showed up at Waveramstel first, in spite of the wind direction 230°.

Together with the fogs which arrived at Schiphol first, mainly fogs which originated by lowering stratus, we may conclude that with wind directions 210°-230° the predictability of the onset of the fog and the variation of the fog density for a station using the measurements at another station is very low.

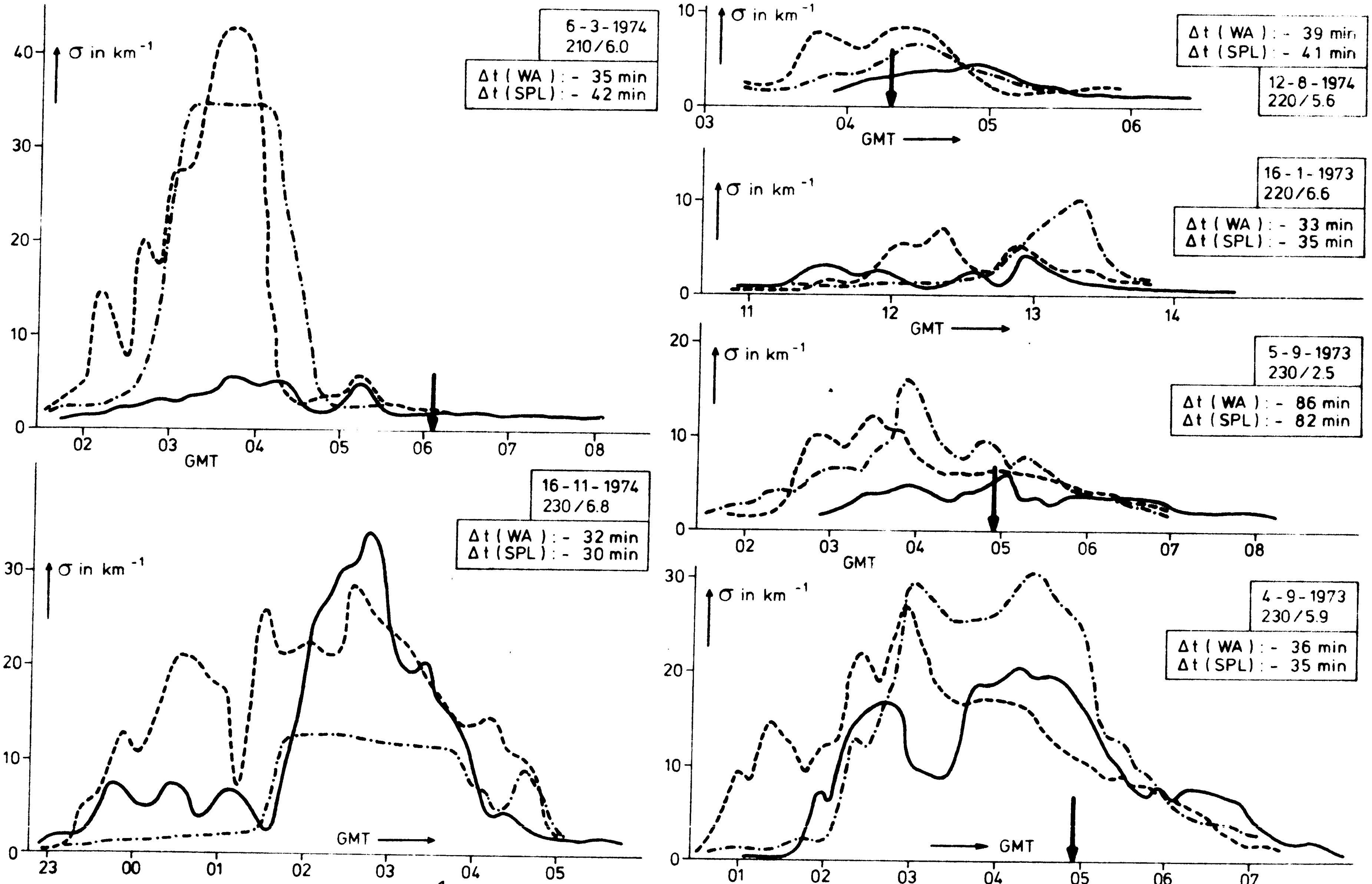

Fig. 25 Extinction coefficient $\sigma(km^{-1})$ as a function of time for fogs advected from 210° - 230°.
——— Nieuwkoop, ----- Waveramstel, -.-.- Schiphol.
Vertical arrows indicate time of sunset or sunrise. Below each date the 80m wind at Cabauw is given (in degrees/ m/s). The Nieuwkoop (Nk) and Schiphol (SPL) curves are shifted in time.
Negative Δt : a shift backward in time.

8. CONCLUSIONS

- On the basis of eight months of measurements of the extinction coefficient during fog episodes at Schiphol, Waveramstel and Nieuwkoop a criterion has been found to distinguish objectively between radiation fogs and advection fogs. This criterion is based on a certain combination of mean wind speed at a height of 10 m and mean temperature difference between 10 m and 0.5 m during the half-hourly period preceding the onset of fog at Waveramstel or Nieuwkoop. If $\overline{u} \geqslant 1.3\,\overline{\Delta T}$, in which the wind speed $\overline{u}$ is in m/s and the vertical temperature difference $\overline{\Delta T}$ is in ^{o}C, we speak of advection fog, otherwise the radiational character dominates.

- Analysis of the observations of the two-year period (1973-1974) has shown that Schiphol had 40% fewer days with fog (characterized by an extinction coefficient of 3 km^{-1} or more) than Nieuwkoop and Waveramstel.

- Schiphol experienced about 45% less time with an extinction coeffcient $> 3\ km^{-1}$ than Nieuwkoop and Waveramstel. Distinguishing the fogs according to their radiative or advective character, it was noted that the difference in fog duration (hours) between Schiphol on the one hand and Nieuwkoop and Waveramstel on the other is mainly due to radiation fogs.

- Furthermore, it has been shown by comparing measured values of temperature and humidity at Nieuwkoop with simultaneously measured values at Schiphol that, irrespective of the wind direction, Schiphol is significantly warmer (+0.7 ^{o}C) and drier (-8% in relative humidity, -0.5 mbar in absolute humidity) than Nieuwkoop. These effects were clearly due to the heat-island effect of Amsterdam/Amstelveen: the sector with wind directions 320^{o} up to and including 100^{o} showed this warmer and drier effect, while with other wind directions Schiphol was not significantly different from Nieuwkoop as far as temperature and humidity are concerned.

- For advection fogs (as defined by $\overline{u} \geqslant 1.3\,\overline{\Delta T}$ during the half hour before the onset of the fog) the probability that Schiphol encounters fog and/or low stratus within 2 hours from the onset of the fog at Nieuwkoop resp. Waveramstel is 80% resp. 96%. For radiation fogs this probability is much smaller, namely 19% resp. 26%.

- The radiation fogs may be divided into two groups, each with a dinstinct difference in probability of occurrence within 2 hours at Schiphol: one group for which $0.34\,\overline{\Delta T} \leqslant \overline{u} < 1.3\,\overline{\Delta T}$ with a probability of 33% resp. 24% of occurrence within 2 hours after the onset of the fog at Waveramstel resp. Nieuwkoop. The probability of fogs of the other group for which $\overline{u} < 0.34\,\overline{\Delta T}$ equals 12% resp. 0%.

- For fog advection from directions 100^{o}-210^{o} a good correlation has been found between the, by means of the 80m wind, calculated time of advection from Waveramstel to Schiphol and the observed time: for 16 out of the 18 fogs the difference between the calculated and the observed advection time is 20 minutes or less. The averaged observed advection time for fogs from these directions is 38 minutes.

- For advection directions 000^{o}-090^{o} for advection from Waveramstel to Schiphol 11 out of the 12 fogs show observed times which are (much) more than the calculated ones. These delays range from 7 minutes up to 87 minutes.
  The station Waveramstel is of little or no importance for the short-term visibility forecast at Schiphol in case the fog advection takes place from directions 220^{o}-350^{o}.

- For the forecasting of fog at Schiphol in case of advection of fog from Nieuwkoop to Schiphol the optimal direction sector is 110^{o}-270^{o}. 28 Out of the 31 fogs arrive at Nieuwkoop before they arrive at Schiphol. 23 Fogs out of those 28 show observed advection times which are within 30 minutes from the calculated times. The average observed advection times for fogs advecting from 110^{o}-270^{o} is 55 minutes. For fog advection from 000^{o}-100^{o},

just like in the case of Waveramstel, a delayed transport of the fog towards Schiphol was observed. 11 Out of the 12 fogs advected from 000°-100° have observed advection times which are (much) more than the calculated ones. These delays amount from 18 minutes up to 121 minutes.
The station Nieuwkoop is of little or no value for the short-term visibility forecast of Schiphol in case of fog advection from 280°-350°, since 4 out of the 5 fogs arrived at Schiphol before they arrived at Nieuwkoop.

- It has been shown that Nieuwkoop and Waveramstel experienced more radiation fog than Schiphol. Moreover, if one compares the minimum visibility, classified in 4 categories (class 1: 1000m-400m; class 2: 400m-200m; class 3: 200m-100m, class 4: $<$ 100m), the probability of a lower minimim visibility at Schiphol than at Nieuwkoop resp. Waveramstel (2% resp. 5%) is considerably smaller than the probability of a higher visibility (58% resp. 48%). This is not the case for the advection fogs: here the probability of a lower minimum visibility at Schiphol than at Nieuwkoop resp. Waveramstel (29% resp. 25%) is of the same order of magnitude as the probability of a higher minimum visibility (15% resp. 25%).

- A more detailed comparison of the courses in time of the extinction coefficient during advection fogs at the various stations is given in the Figures 21-25. For advection directions 180°-200° and 040°-070° a very good agreement between the extinction coefficient curves of Nieuwkoop and those of Waveramstel is noted in many cases. In 10 out of 14 cases the curves are so similar that one may conclude that the advective character of those fogs dominates over the formation and dissipation effects during the transport of the fogs from one station to the other.
The resemblance of the extinction coefficient curves measured at Schiphol to those measured at Nieuwkoop and Waveramstel is less striking than the resemblance between the Nieuwkoop and Waveramstel curves. The influence of the Amsterdam/Amstelveen

conurbation manifests itself not only in a retarded arrival of the fog at Schiphol but also in changes in the density of the advection fogs.

- The wind speed and wind direction as measured at Cabauw at a height of 80 meter in general represents the fog-driving wind. This agrees with the conclusion of Entrekin [12], who states that speed and direction of movement of the fields of transmittance and cloud-base height frequently could not be estimated from surface winds alone.

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