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WIND CLIMATE IN VATSFJORD/YRKEFJORD.

METHODS FOR LOCAL WIND FORECASTING.

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Wind tunnel (w.t.) results from Vats-Yrkefjord are verified by full scale data from Kattrauv, K (26 m asl.) and Raudnesvarden, R (334 m asl.) for S-wind and W-wind. A deviating pattern appears during easterly wind: Effects generated by the Langfjella mountain chain make the wind blow harder at K than at R, and this is not observed in the w.t. test. Transfer coefficients from Utsira, U to K are calculated from full scale data, and w.t. data are used to transfer the coefficients to the operation sites. Forecasting methods are developed and extreme wind speed statistics are updated, using Utsira as reference station.

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SUMMARY

Wind records at Kattrauv and Raudnesvarden in the Vats area are used to check results from the wind tunnel experiment carried out by Danish Maritime Institute in 1983. Except for easterly wind, the experimental results were verified. For easterly wind we nevertheless presume that the wind connection between Kattrauv and the operation sites A, C, D and E in Yrkefjord (level 0-100 m) are identical for the model and the full scale situation.

We compute transfer coefficients from the regular weather station, Utsira, to the temporary station, Kattrauv, and, by the wind tunnel results, from Kattrauv to the operation sites in the area. This gives us transfer coefficients from Utsira to the operation sites. Coefficients for directions not covered by the wind tunnel experiment are given by an educated guess from what is learned from the work.

Wind direction transitions from Utsira to the Vats area are given by using the comparing technique. Also visual results from the wind tunnel experiments (flags, sugar spreading) are used in establishing those transitions.

Sola is also tried used as a reference station, ground level as well as 850 hPa. However, Utsira proved to be the best reference station, showing lowest standard deviation of the transfer coefficients.

Wind Speed.

Utsira	K/U	A/U	B/U	C/U	D/U	E/U
030-080^0	1.27	1.0	0.4	1.0	0.7	1.0
090-100^0	1.27	1.0	0.2	1.0	0.7	1.0
110-130^0	1.09	0.9	0.2	0.9	0.6	0.9
140-150^0	0.84	0.7	0.3	0.7	0.5	0.7
160-170^0	0.68	0.6	0.5	0.5	0.7	0.6
180-190^0	0.54	0.4	0.5	0.5	0.7	0.4
200-220^0	0.67	0.6	0.2	0.5	0.5	0.6
230-290^0	0.67	0.6	0.2	0.5	0.2	0.6
300-330^0	0.71	0.4	0.4	0.4	0.6	0.5
340-020^0	0.57	0.3	0.4	0.4	0.5	0.3

Transfer coefficients from Utsira to Kattrauv (26 m above fjord surface) and to the operation sites, A,B,C,D and E (10 m above fjord surface). For sectors where more than one wind direction may be expected, the coefficients for the highest wind speed are given.

Wind direction.

Utsira	K	A	B	C	D	E
030-080^0	70^0	70^0	30^0	70^0	20^0	70^0
090-100^0	70^0	70^0	90^0	70^0	90^0	70^0
110-130^0	80^0	70^0	100^0	70^0	100^0	80^0
140-150^0	90^0	70^0	110^0	80^0	110^0	90^0
160-170^0	100^0	70^0	170^0	80^0	170^0	100^0
180-190^0	150^0	210^0	170^0	200^0	180^0	210^0
200-220^0	210^0	230^0	170^0	220^0	200^0	230^0
230-290^0	240^0	240^0	260^0	240^0	200^0	230^0
300-330^0	300^0	270^0	300^0	270^0	300^0	270^0
340-360^0	300^0	270^0	330^0	360^0	330^0	270^0
010-020^0	330^0	270^0	360^0	360^0	360^0	330^0

Wind direction at different sites in the Vats area for given sectors at Utsira. For sectors able to give more than one wind direction, the direction of highest wind speed are given.

Influence of stability.

For southerly and westerly winds the transfer coefficients from Utsira to Kattrauv, and correspondingly to site C, D, and E, should be increased by 10-20% in neutral air masses, and reduced by 10-20 % for fairly stable air masses.

Extreme wind conditions.

Updated extreme values of 10 min, 1 min, and 3 sec wind speed (m/s) at the sites C, D and E are given, the return periods being 2, 10 and 100 years:

SITE C (reference height: 10 m)

SECTOR	10 MIN			1 MIN			3 SEC		
RET. PER.	2	10	100y	2	10	100y	2	10	100y
310-040^0	7	9	10	11	13	15	16	19	21
040-090^0	17	22	26	22	28	33	28	36	42
090-150^0	10	12	13	15	18	20	21	26	28
150-310^0	16	19	21	20	23	27	26	30	34

SITE D (reference height: 10 m)

SECTOR	10 MIN			1 MIN			3 SEC		
RET. PER.	2	10	100y	2	10	100y	2	10	100y
320-090^0	12	14	15	15	18	20	19	23	26
090-150^0	13	16	19	19	25	29	28	35	42
150-180^0	20	23	27	24	27	32	29	32	38
180-220^0	17	19	22	21	23	27	25	28	33
220-270^0	5	7	8	9	11	13	14	18	20
270-320^0	16	21	23	21	27	30	27	35	39

SITE E (reference height: 10 m)

SECTOR	10 MIN			1 MIN			3 SEC		
RET. PER.	2	10	100y	2	10	100y	2	10	100y
320-030^0	7	9	10	11	13	15	16	19	21
030-120^0	18	23	27	22	28	33	27	35	41
120-190^0	11	12	14	15	17	20	20	23	27
190-320^0	17	20	23	21	25	29	26	31	36

CONTENTS

1. INTRODUCTION

The background of the special interest of the Vatsfjord/ Yrkefjord area is the activity related to oil industry constructions. This activity has been in progress for the last 10 years. In this connection the Norwegian Meteorological Institute (DNMI) has been consulted several times concerning extreme wind conditions (1), (2). Also it has been carried out a wind tunnel model of the area (3). Wind records at the islet Kattrauv has been made since 1983, and at the mountain top, Raudnesvarden (325 m asl.), since 1986. In (2) is summarized what in 1985 was known about the extreme wind conditions in the area.

When operating the large constructions in the Vatsfjord/ Yrkefjord area, it is extremely important to know the wind conditions and to receive informations of any changes in the wind speed and direction. Thus the purpose of this study is to develop transfer coefficients that can prescribe the change in the wind fields when advancing from open sea to the rough topography of the Vats area. These coefficients then can be used to formulate prediction rules, and if possible, to give a check of the extreme wind estimates given for the area. Data from Kattrauv and Raudnesvarden can also be used in checking some of the results of the wind tunnel experiment.

2. SITE AND TOPOGRAPHY

2.1 Regional location.

The Vatsfjord/Yrkefjord area is situated at the western coast of southern Norway (Fig.1), 40 km inland. At a large scale, we may say that the area is lying near to the foot of the westward slope of the Langfjella mountain chain. This chain is approximately 200 km wide and has a north - south extension. The Vats area is near to the southwest end of it. The ridge is some 1500 m high east of the area. The chain is wider just further north of Vats. The highest and broadest part, however, is found 300 km to the north where the chain also turns to northeast.

2.2 Local terrain.

The average height of the terrain in the area is 200-300 m. The terrain, however, is complex. The fjord system Yrkefjorden (WSW-ENE) and the branch towards north, Vatsfjorden, cuts off the topograpy, and the hill sides along the fjords are steep. Yrkefjorden is continuing towards the east, making a pronounced channel from that direction.

The aim is to get a better knowledge of the wind conditions (wind loads) at the three sites A, C, and E at Yrkefjorden, and the two sites B and D at Vatsfjorden (Fig.2), due to the ongoing/planned operations there. The two sites of measurements, Kattrauv and Raudnesvarden, are chosen in a trial of getting a representative picture of these wind conditions.

3. INSTRUMENTATION AND DATA

3.1 Automatic weather stations.

The automatic weather station at Kattrauv is supposed to describe the wind conditions in the outlet of Vatsfjord, near the operation sites. The station at Raudnesvarden is more freely exposed and will have wind conditions more similar to a coastal station than a point near the fjord surface. With these two stations it is now possible to verify or invalidate the wind tunnel experiments.

The two automatic weather stations are equipped with sensors for wind speed, wind direction, air temperature and air pressure. The wind speed sensors both give the average speed for the logging interval and the maximum gust (2 sec.) over the same interval. The wind direction, temperature and pressure are instantaneous values at the end of the logging interval. The wind direction sensors, however, are equipped with some friction to reduce short-periodic fluctuations.

Kattrauv.

This station was established in May 1983, at the islet Kattrauv in Yrkefjord, close to the outlet of Vatsfjord to the east (Fig.2). The islet has a rock face, is some 200 m long, 100-150 m wide and has heights of 15-20 m. The wind instruments are situated at the southern top of the islet (14 m asl.) The anemometer height is 12 m above ground and thus 26 m above mean sea level.

On a local scale the anemometer is freely exposed to winds along Yrkefjord. To south-southeast and west there is a relatively short distance (1 km) to the other side of the fjord. We see, however, that the exposition is relatively free in the whole sector 060-180-330^0, compared to the sector 340-050^0, where there are steep hills up to Gaupefjellet (415 m asl.). Close to the fjords the terrain level is some 200-400 m.

From the beginning the data was collected on magnetic tapes with a standard Aanderaa data logger with 10 minutes logging intervals. The capacity of one tape is then about one month. The reason for choosing 10 minutes intervals is that the wind data then are in correspondance with standard meteorological data.

There has been a lot of trouble with the data collection and just a few periods are available for data processing. The data has been transmitted on VHF to a data storage in Vats.

Kattrauv was rebuilt 12 December 1985 with a Data Storage Unit (DSU) at the station, in order to save the data that frequently was lost by the radio transmission.

Raudnesvarden.

This station was established 12 December 1985 with a DSU at the station from the very beginning. The anemometer height is 10 m above ground and 335 m above sea level.

Raudnesvarden is lying 1.5 km WSW of Kattrauv. The anemometer is freely exposed, but at a distance of a few kilometers, Gaupefjell (415 m asl.) in the NE, Gaupåsen (531 m asl.) in the ESE, the mountains around Lammanuten (631 m asl. in the sector 170-210^0) and particularly a mountain area from Strandfjellet (545 m asl.) to Jamnafjellet (462 m asl.) in the sector 240-330^0, 1.5 km away, will affect the wind conditions at the station. There is an open sector right to the sea towards 220-230^0 and relatively unsheltered towards 330-010^0 and 060-090^0. Northwesterly winds, however, have to travel a long distance over nearly the same heights, and correspondingly the speed is reduced by surface friction.

Like Kattrauv there has been many problems with the data collection. In Table 3.1 the available data from both stations are presented.

The automatic weather station at Kattrauv has been running for a longer period than that at Raudnesvarden. We have twice as many useful observations from Kattrauv, but still the observations are too few to give a quite reliable connection between the coastal stations and the actual fjord area.

YEAR	KATTRAUV	RAUDNESVARDEN
1983	11/8 - 14/9	
	4/11 - 6/12	
1984	1/2 - 29/2	
	8/3 - 16/4	
1985	9/3 - 9/5	
1986	5/4 - 21/8	5/4 - 21/8

Table 3.1
The available data periods for the two weather stations in the Vatsfjord/Yrke-fjord area.

3.2 Ordinary weather stations.

There are two freely exposed weather stations in the region with wind instruments : Sola and Utsira. Both stations are equipped with an anemograph, Fuess 90z, which shows the instantaneous values of wind speed and the direction, and also the 10 minute mean wind speed.

Sola.

The area around the weather station is entirely flat. The only obstacles are habitation in the surroundings.

The anemometer heigth is 11 m above the ground and 17 m above sea level.

Utsira.

Utsira is a detached island, relatively flat, with highest ground level some 50-60 m above sea level. Most of the island consists of bare rock and areas with grass and heather. Off the island there are free waters in the sector south-southeast through west to north. In the remaining sector lies the mainland about 15 km to the east.

The anemometer is placed 11 m above ground on a hill 70 m above sea and has a good exposure to winds from all directions. The recordings are representative for the open sea (10 m level), to within 5-10% (4).

3.3 The wind tunnel experiment.

At Danish Maritime Institute (SL) it was carried out a wind tunnel experiment on a terrain model. This test was performed in the boundary layer wind tunnel at SL. The results are given in (3) and summarized in (1). Transfer coefficients from strong gradient wind during neutral conditions were established to the sites A, B, C, D and E at different levels between 5 and 110 m. Also found were coefficients to the two sites of full scale wind measurements, Kattrauv and Raudnesvarden. The gradient wind directions tested in the model were 90^0, 165^0, 180^0, and 260^0.

The area included in the model was the local area around the Vatsfjord/Yrkefjord area. To the east the extension was long enough to represent the regional effect of channeling easterly wind through Yrkefjorden. However, only neutral conditions were used, and larger scale effects originating from the mountain chain, Langfjella, will be excluded from the model results. It is therefore necessary to make a full scale test of the results.

4. RESULTS

Data from the temporary weather stations at Kattrauv and Raudnesvarden can now be used for a check of some results from the wind tunnel experiment (3). Further on, by comparing data from the temporary stations and data from the ordinary weather stations, Utsira and Sola, we hope to improve our understanding of the wind conditions in the area, and give prediction rules for the Vats area.

4.1 Evaluating wind tunnel results.

From the wind tunnel experiment, transfer coefficients from the gradient wind (800 m level) to different sites, A, B, C, D and E in the fjord area, were established at levels 10 - 100 m asl.. At the islet Kattrauv, the lowest level was 26 m above sea surface. Also established were coefficients to the the weather station, Raudnesvarden, 325 m asl., at levels 10-100 m above the top. The gradient wind directions tested were 90, 165, 180 and 260°.

To get a check of the model results, we now compute transfer coefficients from Raudnesvarden to Kattrauv from the wind tunnel model and from the full scale data. This is done for different large scale wind directions.

WIND DIRECTIONS		NUMBER OF OBSERV.	OBSERVED K/R	MODELLED K/R
UTSIRA	DIR. RAUDNES.			
70°-110°	98°	5	1.89(0.26)	0.80 (90°)
120°-170° R≤120°	104°	14	1.47(0.31)	0.80 (90°)
160°-200° R>120°	172°	19	0.70(0.24)	0.79(165°) 0.64(180°)
230°-280°	230°	10	0.80(0.20)	0.70(260°)

Table 4.1.
Transfer coefficients, K/R, from Raudnesvarden (10m above local surface) to Kattrauv (26 m asl.), with the standard deviation in parenthesis, calculated from full scale observations and from the wind tunnel experiment (wind direction in the model test in parenthesis). The situations are classified according to the wind directions at Utsira, and partly at Raudnesvarden (R). The average wind direction at Raudnesvarden for each sector group is given. According to results from the wind tunnel model, this direction should be close to the direction of the gradient wind.

The table show that the full scale transfer coefficients from Raudnesvarden to Kattrauv are in accordance with the modelled coefficients during southerly and westerly ambient wind conditions.

Also in easterly and southeasterly wind the wind tunnel results shows higher wind speeds at Raudnesvarden than at Kattrauv. The full scale data, however, show that the real wind conditions now are different: The wind speed at Kattrauv is considerably higher than at Raudnesvarden, the difference being larger the more easterly the wind is at Utsira.

The wind tunnel model therefore do not reflect reality when the wind is easterly. The reason is that the input atmospheric situation to the model is far from reality. The stratification above the lowest 200 - 300 m is probably not neutral, and the wind profile is strongly modified by the inner mountains (Langfjella) which are not considered in the model. Strong winds are concentrated at lower levels probably by a wave effect accelerating stable air downhill. Such a stratification also makes the general wind speed increase through channel zones larger.

We also see from Table 4.1 that during southeasterly wind at Utsira, the wind at Raudnesvarden is easterly, while only minor differences occur at other directions. Since the wind tunnel results indicate that the wind direction at Raudnesvarden is identical to the direction of the gradient wind, this difference has not come up from surface friction neither by other local effects, but must result from large scale effects of the inner mountain chain.

4.2 Transfer coefficients from Kattrauv to the operation sites of the fjord area.

Since the large value of K/R for easterly wind might be explained as a remote effect from the high mountains to the east, we can postulate that the relative local wind distribution at the low levels (approx. 100 m) is well described by the model experiment. As we have seen from the previous section the wind distribution is well modelled for southerly and westerly wind. We then compute the transfer coefficients from Kattrauv to site A, B, C, D and E (A/K, B/K, C/K, D/K and E/K) from the experimental results. By establishing transfer coefficients from a known weather station to Kattrauv, we can predict the wind at most of the actual sites.

Table 4.2 shows that there is stronger wind at Kattrauv than at 10 m level at the sites A, C, and E when the wind blows along Yrkefjord, and considerably stronger than at site B. (Remember, however, that the wind at Kattrauv is measured at 26 m level, and is correspondingly 15 % stronger than at 10 m level). Such wind are stronger at site E than at site A and C, except that westerly wind is strongest at site A.

Easterly wind crossing the mountains over Vatsfjord has a lower wind speed than Kattrauv and correspondingly the low level stations at Yrkefjord. In the model the situation is different, the wind speed at the low levels is lower than at the high levels (Raudnesvarden). The wind at point B must origin from high level wind just above the local mountains. The wind speed correspondingly must be low, and the transfer factor lower than 0.53 which is the factor from Kattrauv to point B in the model. It may conservatively be estimated to

0.5.

	A/K	B/K	C/K	D/K	E/K
90^0	0.79	(0.53)	0.75	0.55	0.79
165^0	0.74	0.95	0.84	1.26	0.37
180^0	0.83	1.00	1.00	1.03	0.66
260^0	0.96	0.36	0.81	0.26	0.87

Table 4.2
Transfer coefficients from Kattrauv (26 m asl.) to the sites A, B, C, D and E (10 m asl.) calculated from the wind tunnel experiment.

Southerly wind (165^0 - 180^0) which is much reduced at Kattrauv, is as expected stronger at site D which is situated along the south - north directed Vatsfjord, while site E is especially shielded due to the mountains north and south of that site.

4.3 Choice of reference station.

We have compared data from the station Raudnesvården to data from the weather stations, Utsira and Sola. Transfer coefficients for different sectors are calculated and average coefficients found.

It is seen from Table 4.3 that the transfer coefficients from Utsira has lower standard deviations than those from Sola. Also the percental values are lower, though not that strikingly. Hence it follows that Utsira is the most favourable station to use when predicting the wind at Raudnesvarden. The reason probably is that Sola is a land station with directionally variations of surface friction, while the conditions at Utsira are more homogeneous. Since the wind conditions at Raudnesvarden are less disturbed by local topography than the lower lying districts of the Vatsfjord/Yrkefjord area, it should be clear that Utsira is the most favourable station also when predicting the wind near the fjord level.

SECTORS	N	MEAN		STAND. DEV.	
		R/S	R/U	R/S	R/U
80^0 - 100^0	14	0.80	0.64	0.25(31)	0.16(25)
110^0 - 130^0	7	0.83	0.74	0.19(23)	0.23(31)
140^0 - 160^0	7	1.30	0.79	0.62(48)	0.14(18)
170^0 - 190^0	10	1.27	0.89	0.25(20)	0.19(21)
200^0 - 220^0	7	1.39	0.97	0.33(24)	0.18(19)
230^0 - 250^0	3	1.02	0.79	0.14(14)	0.13(16)
260^0 - 280^0	4	1.16	0.93	0.23(20)	0.27(29)
290^0 - 310^0	3	0.70	0.56	0.06(9)	0.03(5)
320^0 - 350^0	3	0.80	0.47	0.25(31)	0.13(28)
80^0 - 160^0	28	0.93	0.70	0.41(44)	0.18(26)
170^0 - 350^0	30	1.13	0.83	0.38(34)	0.24(28)
ALL	58	1.03	0.75	0.25(24)	0.16(21)

Table 4.3
Transfer coefficients, R/S, and R/U from Sola and Utsira to Raudnesvarden in different sectors and sector groups. The wind direction refer to Raudnesvarden. Also standard deviation of the coefficients is given, the percental value in parenthesis.

4.4 Wind relations between the Vatsfjord/Yrkefjord area and Utsira.

In order to find a connection between the wind conditions in the Vatsfjord/Yrkefjord area and at Utsira we have compared the simultaneous observations from the stations Kattrauv/ Raudnesvarden and Utsira. We have chosen weather situations where an approximately homogeneous wind field is covering both the coast and the fjord districts. Irregular patterns in the field due to a topographical influence are of course acceptable. With simultaneous observations we here mean the maximum 10 minutes wind speed and concurrent wind direction within a reasonable period of time. Because of the distance between Utsira and Vats/Yrkefjord there will frequently be a a displacement of time between the maximum values at the two places. We have accepted such differences within 6-8 hours.

Since the aim of this investigation is to connect the best key station (Utsira) to the different sites in the fjord area, we find it adequate to avoid Raudnesvarden, and connect Utsira directly to Kattrauv for further transition to the operation sites by the local coefficients A/K, B/K, C/K, D/K and E/K in Table 4.2.

Utsira - Kattrauv.

WIND DIRECTION			WIND SPEED	COMMENTS
UTSIRA	KATTRAUV →	MEAN(SD)	k-MEAN(SD)	k = speed(K) / speed(U)
030 - 040^0				N=0
050 - 100^0	060 - 080^0	070^0(13)	1.27(0.29)	N=7. Direction of poor stability at Utsira. Small frequency. Also 50 and 90^0 are possible directions at Kattrauv.
110 - 130^0	060 - 090^0	075^0(14)	1.09(0.23)	N=22. Also 050^0 and 100^0 is possible at K.
140 - 170^0	070 - 140^0	094^0(27)	0.75(0.20)	N=29. 060-090^0 are still the most frequent directions at Kattrauv. k decreases a little as the direction at Utsira changes from 140 to 170^0.
180 - 190^0	130 - 180^0	152^0(24)	0.54(0.10)	N=10. Mostly 10-60^0 backing at Kattrauv.
200 - 210^0	200 - 230^0	210^0(17)	0.67(0.02)	N=3. No change of direction or possibly veering to 230^0 (direct. of Yrkefj.)
220^0				N=0.
230 - 290^0	210 - 280^0	244^0(29)	0.67(0.13)	N=18. 0-50^0 backing at Kattrauv. Also 10^0 veering is possible.
300^0				N=0.
310 - 330^0	290 - 320^0	298^0(13)	0.71(0.10)	N=5. 10-40^0 backing at Kattrauv.
340 - 020^0	290 - 340^0	316^0(18)	0.57(0.14)	N=14. 30-60^0 backing at Kattrauv.

Table 4.4a
Results from a comparison between "simultaneous" observations at Utsira (U) and Kattrauv (K) during the period 1983-1986 (108 episodes). N is the number of observations and SD the standard deviation. The wind sectors at Kattrauv represent the 10-90 percentile range of the values. Observations with maximum 10 minutes wind speed at Utsira < 15 knots are omitted.

When comparing wind conditions at two sites, it is important that the wind field is not too weak, because local winds then is decoupled from the main wind field. However, when excluding too many periods the sample size is getting small. As a compromise we have considered all episodes where the maximum 10 minutes wind speed at Utsira exceeds 15 knots (≈ 8 m/s).

We define a transfer coefficient (k-factor) for each simultaneous observation to be the ratio between the maximum wind speed at Kattrauv and Utsira. The k-factors are distributed on directions and speeds at Utsira, and on directions at Utsira and Kattrauv, respectively. From these arrangements we have grouped the data in as homogeneous sectors as possible. The Figures 3 and 4 are extracts from these arrangements. The connection between Utsira and Kattrauv is presented in Table 4.4a. The arithmetical mean of the transfer coefficient within each sector is calculated and also the standard deviation. Under "comments" we have tried to point at essential relations between the two stations.

From Table 4.4a we see that the two directions 220^0 and 300^0, which are without any observations, divide the sector $200\text{-}330^0$ into three parts. There is no weighty argument for this partition. If the sector $200\text{-}290^0$, or the sector $200\text{-}330^0$, is handled as one sector, the result will be :

NUM. OF OBS.	WIND DIRECTION UTSIRA	CHANGE OF DIRECTION UTSIRA - KATTRAUV MEAN (SD)	WIND SPEED k-MEAN (SD)
21	$200 - 290^0$	15^0 (22)	0.67 (0.12)
26	$200 - 330^0$	17^0 (21)	0.68 (0.12)

Table 4.4b
An extract from Table 4.4a concerning the sector $200\text{-}330^0$. The mean wind direction is slightly backing from Utsira to Kattrauv. The k-factor is defined in the beginning of this section.

The k-values decreases systematically when the wind direction turns from northeast/east to south. When the wind direction is $050\text{-}100^0$ at Utsira, 6 of 7 available observations show higher wind speed at Kattrauv than at Utsira. In the sector $110\text{-}130^0$ the percentage is not so high, but exceeds half of the observations (59 %). Most probably the reason is that during easterly wind fields, Utsira is shielded, while turning southeasterly, the station is exposed for wind deflection around Southern Norway. At

Kattrauv strong easterly winds prevail for the whole sector.

The standard deviation of the k-values is rather high in the total land wind sector, except for the northerly winds at Utsira. From south (180^0) to west and north there is no distinct change in the k-value and the standard deviation is smaller. The sea wind is strong at Utsira and much reduced at Kattrauv due to surface friction and because the wind is forced upwards towards the mountain chain instead of downwards to the fjord area.

The k-values are examined in relation to the mean wind speed at Utsira and this is presented in Table 4.5. In the table 13 m/s (25 knots) is the limit chosen to divide the observation into two near equal parts.

WIND DIRECTION UTSIRA	WIND SPEED UTSIRA					
	N	v < 25 kn k-MEAN(SD)	N	v ≥ 25 kn k-MEAN(SD)	N	v ≥ 35 kn k-MEAN(SD)
050 - 100^0	7	1.27(0.29)				
110 - 130^0	12	1.10(0.24)	10	1.08(0.22)		
140 - 170^0	12	0.86(0.20)	17	0.68(0.16)	7	0.72(0.18)
180 - 190^0	4	0.59(0.10)	6	0.50(0.10)	2	0.49(0.04)
200 - 210^0	2	0.68(0.00)	1	0.65		
230 - 290^0	7	0.64(0.14)	11	0.69(0.13)	2	0.64(0.11)
310 - 330^0	2	0.80(0.09)	3	0.66(0.07)	3	0.66(0.07)
340 - 020^0	4	0.72(0.16)	10	0.52(0.08)	6	0.51(0.08)

Table 4.5
The transfer coefficients from Utsira to Kattrauv (k-factor) in relation to "low" and "high" wind speeds at Utsira.

There is no distinct difference in the k-factors whether the wind speed at Utsira is below 13 m/s or above this value, though in the sectors $140\text{-}190^0$ and $310\text{-}020^0$ at Utsira there is a slight tendency to a somewhat lower k-factor when the wind speed is above this limit.

The uncertainty in the transfer coefficients lies in the limited numbers of useful weather situations. Especially we have too few situations with strong easterly wind at Utsira. This is, however, a rare event.

4.5 Transfer coefficients from Utsira to the operation sites of the area.

Concerning the mean wind speed, each of the operation sites (P) in Vatsfjord/Yrkefjord is related to Kattrauv (K) from the wind tunnel experiment, in the following manner (see 4.2) :

$$P = k(P) \cdot K \qquad \text{(Eq. 1)}$$

From 4.4 we have the following relation between Kattrauv and Utsira (U), for the different wind sectors :

$$K = k(K) \cdot U \qquad \text{(Eq. 2)}$$

These two equations together give

$$P = k(P) \cdot k(K) \cdot U \qquad \text{(Eq. 3)}$$

From (Eq. 3) we compute the transfer coefficients from Utsira to the sites A, B, C, D and E (A/U, B/U, etc.). A condition for such computations is that the direction of the wind flow over Raudnesvarden is comparable with the wind directions used in the model experiment. A study of the interdependency of the wind directions Utsira-Raudnesvarden-Kattrauv leads to the directions shown in Table 4.6.

The data available do not allow to distinguish between the directions 165^0 and 180^0, which is used in the model experiment. Correspondingly the 173^0 at Raudnesvarden has to represent these two directions.

It is not possible, with the few observations available, to find a wind sector at Utsira, that give a 260^0 flow at Raudnesvarden. This is probably an unstable direction because of the mountain chain further inland. In stabilized air there will be a tendency to turn the wind counter-clockwise (towards 200^0), resulting in a mean direction of near 230^0. Combining the Tables 4.2 and 4.4a we find a simplified relationship between Utsira and the operation sites. The results are presented in Table 4.6.

There is a natural change of direction from Kattrauv to the operation sites. This will complicate the directional connection between Utsira and A, B, C, D and E, but the Figures 5,6,7 and 8 visually give a general impression of how the wind varies inside the fjord area.

Note that in an easterly wind flow the model experiment gives a non-realistic value at site B, in the northern part of Vatsfjord. An estimation for this site will be given later. The coefficients equal to 1.0 at the sites A, C and E are in good accordance with the 1.27 value at Kattrauv, considering the height difference of 16 m and the position of Kattrauv near the steep hill side to the north.

Utsira	Raudn.v.	Kattrauv	K/U	A/U	B/U	C/U	D/U	E/U
090-100°	100°	050-090°	1.27	1.0		1.0	0.7	1.0
110-130°	100°	060-090°	1.09	0.9		0.8	0.6	0.9
140-150°	102°	070-100°	0.84	0.7		0.6	0.5	0.7
180-190°	173°	130-180°	0.54	0.4	0.5	0.5	0.7	0.4
230-290°	228°	210-280°	0.67	0.6	0.2	0.5	0.2	0.6

Table 4.6
Transfer coefficients from Utsira to the sites A, B, C, D and E (10 m asl.) on the basis of the transfer coefficients Utsira/Kattrauv and Kattrauv/A,B,C,D,E.

4.6 The relationship of the wind conditions between the Vatsfjord/Yrkefjord area and the 850 hPa-level at Sola.

Another way to connect a known wind velocity at the coast to the unknown wind in the Vatsfjord/Yrkefjord area is to use the data for the 850 hPa-level at Sola. Again, weather

NUM. OF OBS.	WIND DIRECTION SOLA-850 hPa	CHANGE OF DIRECTION RAUDNESVARDEN →	MEAN (SD)	WIND SPEED k-MEAN (SD) (R/S-850Hpa)
0	010 - 100°			
20	110 - 180°	10-70°	41° (27)	0.47 (0.18) (38 %)
30	190 - 320°	10-40°	23° (17)	0.71 (0.18) (25 %)
0	330 - 360°			

Table 4.7
Results from a comparison between "simultaneous" observations from Sola-850 hPa and Raudnesvarden during the period April - August 1986 (50 weather situations). SD is the standard deviation, with the percental value below. Observations with v(Sola-850 hPa) < 20 knots are omitted. The wind direction is backing from Sola-850 hPa to Raudnesvarden.

situations have been picked in such a way that the maximum wind speed values at Raudnesvarden are comparable with the 850 hPa-values at Sola. Only weather situations where the maximum wind speed at Sola-850 hPa exceeds 20 knots (≈ 10 m/s) are used. The Figures 9 and 10 show the distribution of the observations/transfer coefficients. Because of just two observations a day in the upper air level, at 00 and 12 GMT, and that we do not know the maximum wind speed between these observations, there has been a limited number of observations to use. A difference of time of about two hours between Sola and Raudnesvarden has been tolerated. The results are presented in Table 4.7.

Because of not knowing the maximum values of the 850 hPa-level, it is a risk of overestimating the k-values.

The table shows no observations from the north-northwest and none from the east either. Nevertheless we will try to compare the results in the Tables 4.3 and 4.7. Then we find that the relative standard deviation of R/U is less than that of R/S-850, both from the land wind sector (110-180^0) and the sea wind sector (190-320^0), especially the former. Thus there is no reason to choose the 850 hPa-values as a basis for forecasting the wind conditions in the Vatsfjord/-Yrkefjord area.

4.7 Forecasting rules.

Wind speed.

From Chapt. 4.5 we now have established transfer coefficients from Utsira to operation sites in the Vats area. Mostly due to the wind tunnel experiment carried out for only 4 directions, the coefficients cannot be calculated for all sectors, and we have to interpolate for the missing. The wind records together with the wind tunnel experiment, however, enable us to give improved results in relation to previous knowledge.

It should be stressed that we do not pretend to give a correct wind forecast for the Vatsfjord/Yrkefjord area in every weather situation. For example, in situations with a weak background wind field, sea breeze, or when there are irregularities in the field, the connection between Vats and Utsira will be changed and may be difficult to find. A careful analysis of the situation should always be done to get the quality of the forecast as high as possible. We nevertheless think that the work made should be a good help in preparing the forecasts.

Utsira	K/U	A/U	B/U	C/U	D/U	E/U
030-080^0	1.27	1.0*	0.4*	1.0*	0.7*	1.0*
090-100^0	1.27	1.0	0.2*	1.0	0.7	1.0
110-130^0	1.09	0.9	0.2*	0.9	0.6	0.9
140-150^0	0.84	0.7	0.3*	0.7	0.5	0.7
160-170^0	0.68	0.6*	0.5*	0.5*	0.7*	0.6*
180-190^0	0.54	0.4	0.5	0.5	0.7	0.4
200-220^0	0.67	0.6*	0.2*	0.5*	0.5*	0.6*
230-290^0	0.67	0.6	0.2	0.5	0.2	0.6
300-330^0	0.71	0.4*	0.4*	0.4*	0.6*	0.5*
340-020^0	0.57	0.3*	0.4*	0.4*	0.5*	0.3*

Table 4.8
Transfer coefficients from Utsira to Kattrauv (26 m above fjord surface), and to the operation sites, A,B,C,D and E (10 m above fjord surface). Interpolated values are marked by *. For sectors where more than one wind direction may be expected, the coefficients for the highest wind speed are given.

Wind directions.

To give forecast rules of the wind direction in the Vats area, we have made Table 4.9. The table is built on what is learnt from the wind tunnel experiment (Fig. 5,6,7 and 8), and the wind records at Kattrauv. Some wind sectors give variable wind at some sites. This variation may be short-periodic, or long periodic. In the first case the wind will be gusty, and rotate, in the last case two different steady wind directions may occur. In Table 4.9 that wind direction is given which have the probable strongest wind.

Utsira	K	A	B	C	D	E
030-080^0	70^0	70^0	30^0	70^0	20^0	70^0
090-100^0	70^0	70^0	90^0	70^0	90^0	70^0
110-130^0	80^0	70^0	100^0	70^0	100^0	80^0
140-150^0	90^0	70^0	110^0	80^0	110^0	90^0
160-170^0	100^0	70^0	170^0	80^0	170^0	100^0
180-190^0	150^0	210^0	170^0	200^0	180^0	210^0
200-220^0	210^0	230^0	170^0	220^0	200^0	230^0
230-290^0	240^0	240^0	260^0	240^0	200^0	230^0
300-330^0	300^0	270^0	300^0	270^0	300^0	270^0
340-360^0	300^0	270^0	330^0	360^0	330^0	270^0
010-020^0	330^0	270^0	360^0	360^0	360^0	330^0

Table 4.9.
Wind direction at different sites in the Vats area for given sectors at Utsira. For sectors where more than one wind direction may be expected, the direction of highest wind speed are given. The variation in wind direction at Kattrauv is described in Table 4.4a.

4.8 Influences of stability.

To look upon influences on the transfer coefficients by stability, it is essential to get a measure of the stability of an approaching air mass non-influenced by the local terrain in the Vats area. For southerly (160-190^0) and westerly (200-280^0) winds at Raudnesvarden, the upper air observations from Sola should be representative for this approaching air mass.

We therefore have used data from the upper air station at Sola. The stability parameter is calculated by excluding the lowest level (60-70m) and calculate the average temperature gradient, $\delta T/\delta Z$ (^{0}C/100m) up to 500-600 m.

Each sector group is divided into two subgroups according to stability. The air mass is defined stable for $\delta T/\delta Z >$ -0.90 ^{0}C/100m ($\delta T_1/\delta Z$), and neutral for $\delta T/\delta Z \leq$ -0.90 ^{0}C/100m ($\delta T_2/\delta Z$). The air is assumed dry, so the release of heat from condensation by lifting saturated air is not modelled. This may in some cases reduce the stability above cloud base (200-300 m).

STAB.PAR. (^{0}C/100m)	160 - 190^{0}				200 - 280^{0}			
	N	$\delta T/\delta z$	K/U	R/U	N	$\delta T/\delta z$	K/U	R/U
$\delta T_1/\delta z$	9	-0.52	0.52	0.74	7	-0.40	0.49	0.63
$\delta T_2/\delta z$	7	-0.94	0.78	0.79	7	-0.95	0.60	0.69
$\delta T/\delta z$	16	-0.70	0.63	0.76	14	-0.68	0.54	0.66

Table 4.10.
The variation of transfer coefficients from Utsira to Kattrauv (K/U) and to Raudnesvarden (R/U) with stability in southerly (160-190^{0}) and westerly wind (200-280^{0}) at Raudnesvarden.

Table 4.10 indicates that the transfer coefficients from Utsira to Kattrauv should be increased by 10-20% in neutral air masses, and reduced by 10-20 % for fairly stable air masses. No mountain wave effects is found in the area for southerly and westerly winds, increasing stability seems to prevent strong winds in the lower area of Vats/Yrkefjord. It should be stressed, however, that the episodes are few, and the standard deviation within the groups as high as 0.20 (30-40%). The conclusion therefore should be drawn with care. It should also be stressed that these results are not valid for easterly winds (sector NE - SE) where mountain wave effects frequently occur.

4.9 Updating wind speed extremes.

We now have calculated transfer coefficients of the wind speed at Utsira to the operation sites in the Vats area for several wind directions. Our confidence in the wind tunnel results is increased through this investigation, the results tested are as expected. We therefore also made a more careful analysis using gust factors and turbulence intensities recorded in the wind tunnel to give the best estimates for the extreme gust values at the Vats area.

Referring to Appendix B, taken from (2), we can give updated values for easterly, southerly and westerly winds at position C, D and E.

For the directions of the approaching wind flows tested in the wind tunnel experiment, the transfer coefficients found between Utsira and the operation sites are used to compute the 10 min extreme values in Vatsfjord/Yrkefjord from the extremes at Utsira (4). During extreme wind conditions neutral conditions probably dominate for southerly and westerly wind. According to Chapt. 4.8 the transfer coefficients therefore are increased by 20% (southerly wind) and by 10 % (southwesterly to westerly wind).

From the wind tunnel experiment we have 1 min gust factors at level 40 m, but not at level 10 m. We do have turbulence intensities, I, however, for 40 as well as 10 m. Many authors give a simple linear relationship between the gust factor and I. We are here able to test such a relationship by a simple regression analysis. 28 values at 40 m (4 directions at each of the five operation sites together with Kattrauv and Raudnesvarden) give us :

$$GF_{1\,min} = 1.007 + 1.118\ I \qquad \text{(Eq.4)}$$

and the correlation coefficient, r=0.91. This is very close to the form 1 + a I, which is physically reasonable because the gust factor should approach 1 when no turbulence occur. We therefore give the equation

$$GF_{1\,min} = 1.00 + 1.15\ I \qquad \text{(Eq.5)}$$

which is unbiased for average values, and give only slightly lower correlation between estimated and measured gust factors.

If we now state

$$GF_{1\,min} = 1 + 0.44\ (GF_{3\,s} - 1) \qquad \text{(Eq.6)}$$

where GF is the gust factors (3s, and 1 minute), related to a 10 minute mean wind speed, calculated from (5): Table 3.2, we get

$$GF_{3\,s} = 1.00 + 2.6\ I \qquad \text{(Eq.7)}$$

which is close to

$$GF_{3\,s} = 1.00 + 2.7\ I \qquad \text{(Eq.8)}$$

found when using an average of the spectra suggested by Davenport and Harris (6).

We are now able to calculate the 1 min and 3 sec extreme values at 10 m level from the 10 minutes values and the turbulence intensities, using Eq.6 and Eq.7.

For directions not covered by the wind tunnel experiment, the 1 minute gust factor is not known, and the previous 1 minute extreme values are unchanged. The 10 minute extreme values then are estimated by using the transfer coefficients from Table 4.8, or for sectors where the wind is blowing across the fjord direction to the operation site, from the 1 minute wind speeds previously given, by a gust factor of 1.5. To calculate the 3s gusts, Eq.6 is used for all sectors.

Updated extreme values of 10 min, 1 min and 3 sec. wind speed with return periods 2, 10 and 100 years are given in Table 4.11. It should be stressed that we now give values rounded off to the nearest 1 m/s, while the previous 100 year values were rounded off to the nearest 5 m/s. We do think that our data are somewhat more accurate, but not as much as indicated by the difference above. Methodically we find the new way better, however, because the numbers are used in calculations of wind speeds of different mean length, return periods and in wind profiles. Rounding off errors might then occur.

The standard errors of the numbers are lowest in sectors covered by the wind tunnel tests and adequate transfer coefficients. Standard deviations of transfer coefficients suggest an accuracy of ± 3 m/s for such estimates, while errors of up to ± 5 m/s should otherwise be used.

SITE C (reference height: 10 m)

SECTOR	10 MIN			1 MIN			3 SEC		
RET. PER.	2	10	100y	2	10	100y	2	10	100y
310-040°	7	9	10	11	13	15	16	19	21
040-090°	17	22	26	22	28	33	28	36	42
090-150°	10	12	13	15	18	20	21	26	28
150-310°	16	19	21	20	23	27	26	30	34

SITE D (reference height: 10 m)

SECTOR	10 MIN			1 MIN			3 SEC		
RET. PER.	2	10	100y	2	10	100y	2	10	100y
320-090°	12	14	15	15	18	20	19	23	26
090-150°	13	16	19	19	25	29	28	35	42
150-180°	20	23	27	24	27	32	29	32	38
180-220°	17	19	22	21	23	27	25	28	33
220-270°	5	7	8	9	11	13	14	18	20
270-320°	16	21	23	21	27	30	27	35	39

SITE E (reference height: 10 m)

SECTOR	10 MIN			1 MIN			3 SEC		
RET. PER.	2	10	100y	2	10	100y	2	10	100y
320-030°	7	9	10	11	13	15	16	19	21
030-120°	18	23	27	22	28	33	27	35	41
120-190°	11	12	14	15	17	20	20	23	27
190-320°	17	20	23	21	25	29	26	31	36

Table 4.11.
Updated extreme values of 10 min, 1 min, and 3 sec wind speed (m/s) at the sites C, D and E for return periods 2, 10 and 100 years.

Comments to the table:

Easterly wind.

The 1 min extreme values of easterly wind at point C and E are increased. However, the difference between new and old values at point E strictly spoken are only 1 m/s because the old values were rounded off from 32 to 30 m/s. We now have more data. However, we will stress that we do not have data at Vats during strong easterly wind at Utsira. This is a rare event.

Southerly to westerly wind.

The extreme values of 1 min gust speed are confirmed (site E) or slightly reduced (site C and D). However, the estimates now are better founded.

The main conclusion is that the changes are small, and that most of the extremes are confirmed.

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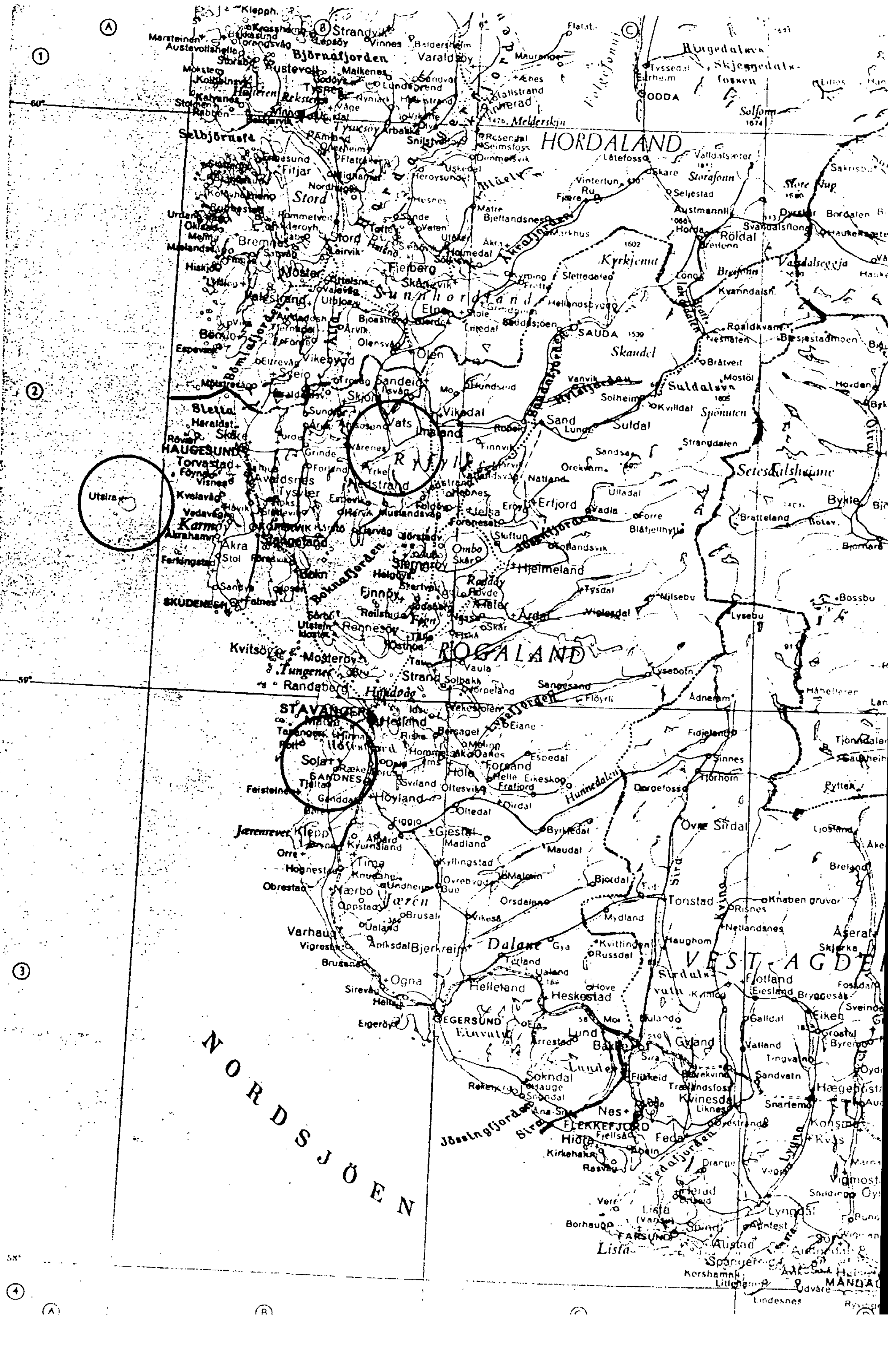
Figure 1. Map showing the location of the Vatsfjord Yrkefjord area and the weather stations Utsira and Sola.



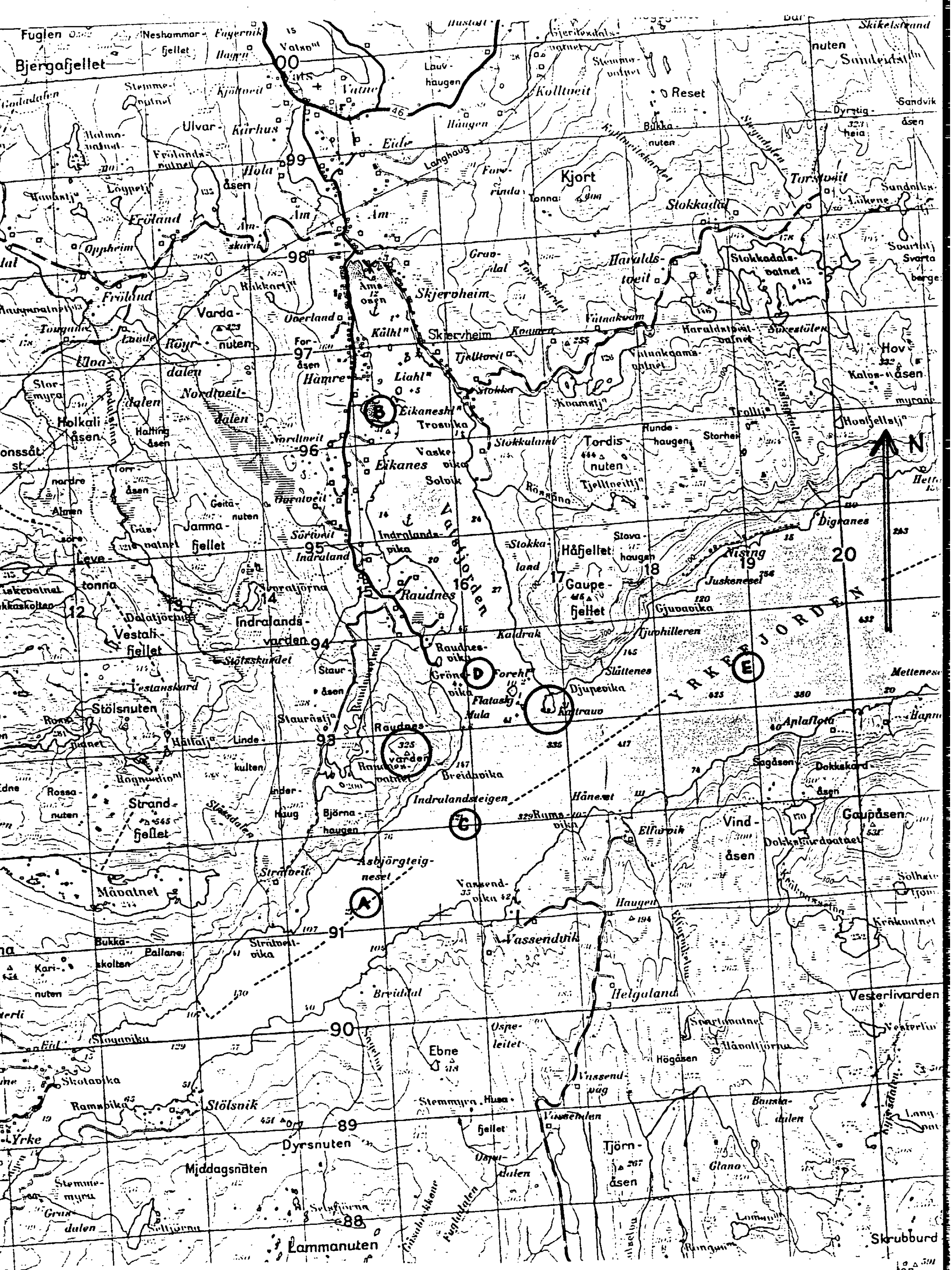
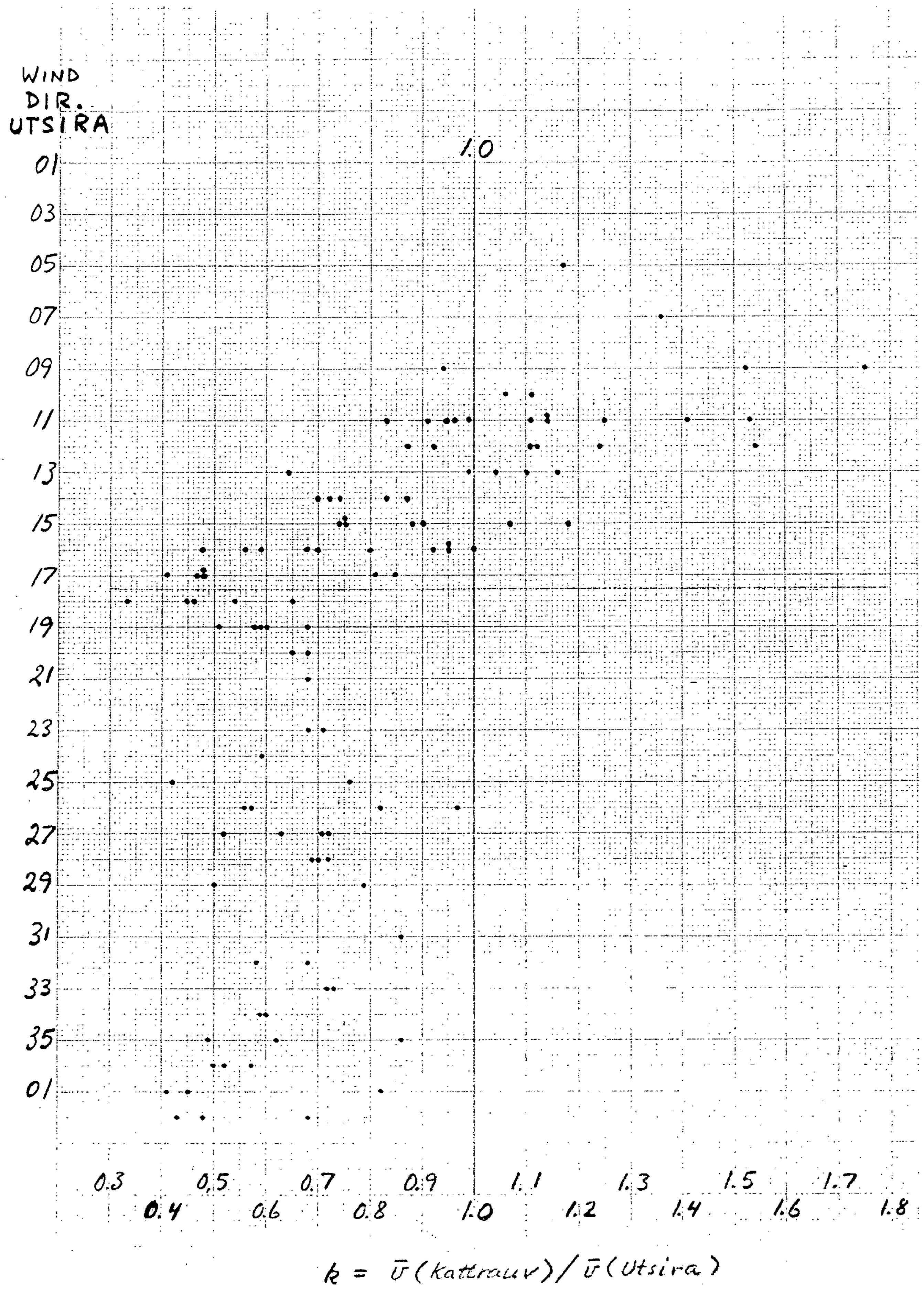


Figure 2. Map of the Vatsfjord/Yrkefjord area with the two automatic weather stations, Kattrauv and Raudnesvarden.

Figure 3. A scatter diagram of the transfer coefficients, Utsira → Kattrauv, distributed on the wind directions of Utsira.



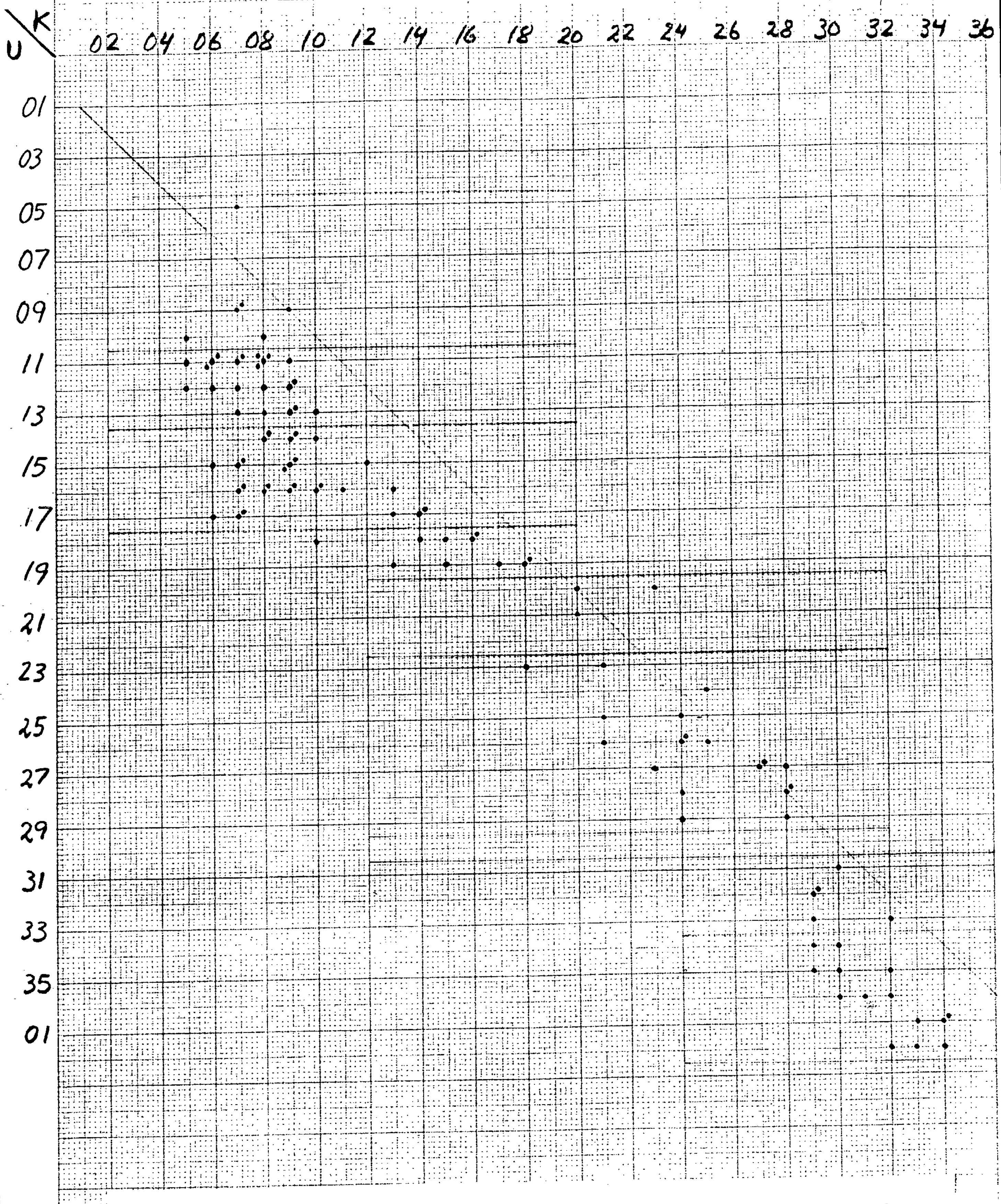


Figure 4. A scatter diagram of the wind directions at Utsira and Kattrauv.

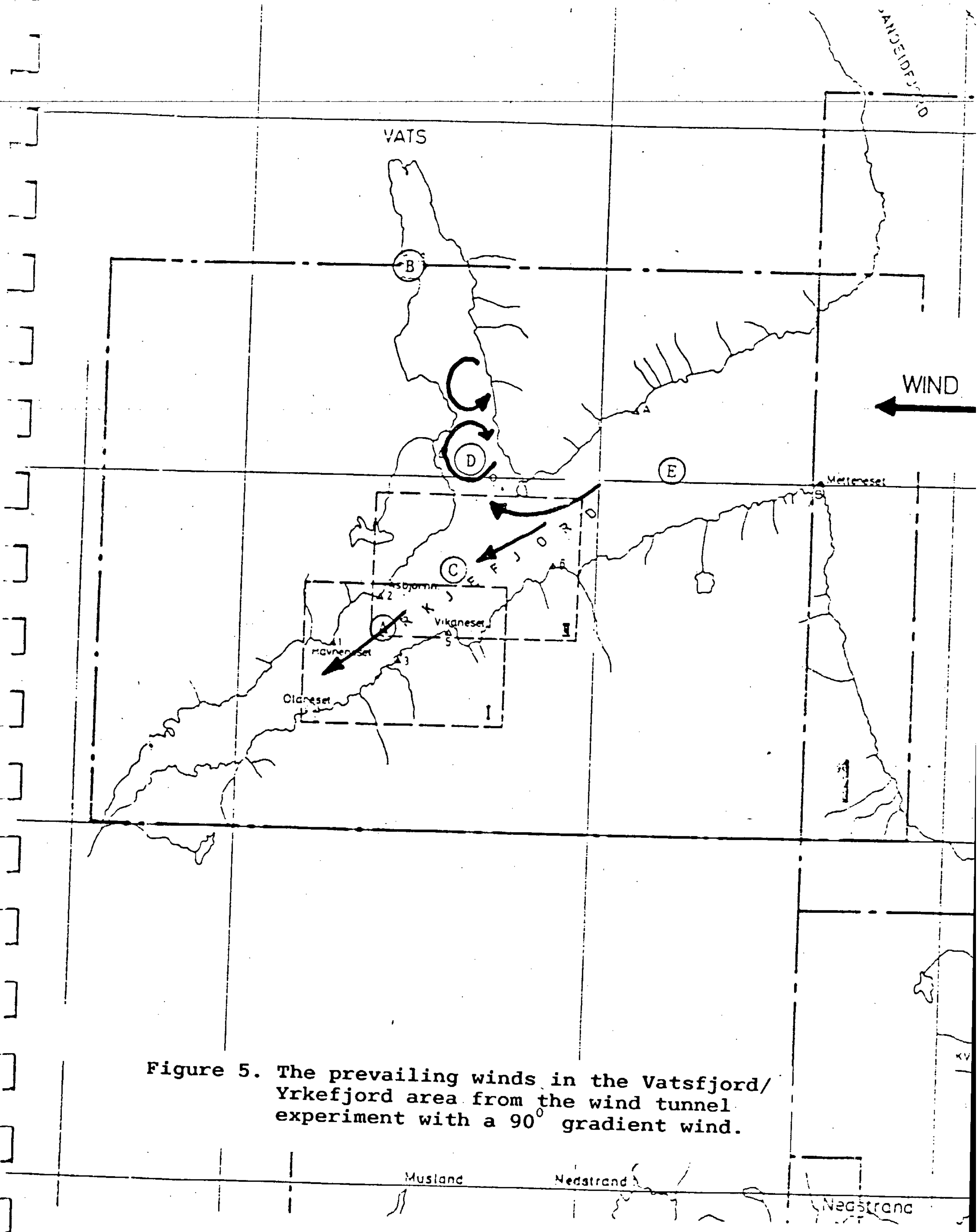


Figure 5. The prevailing winds in the Vatsfjord/ Yrkefjord area from the wind tunnel experiment with a 90° gradient wind.

SKIBSTEKNISK LABORATORIUM LYNGBY DANMARK	Skala:	Tegn.:	Dato:
		Kopi:	Afd.:
		Efters.:	Fag:
Characteristic Flow Pattern 90 deg. Wind		Godk.:	Skf.:
	Tegn.	83067	C9

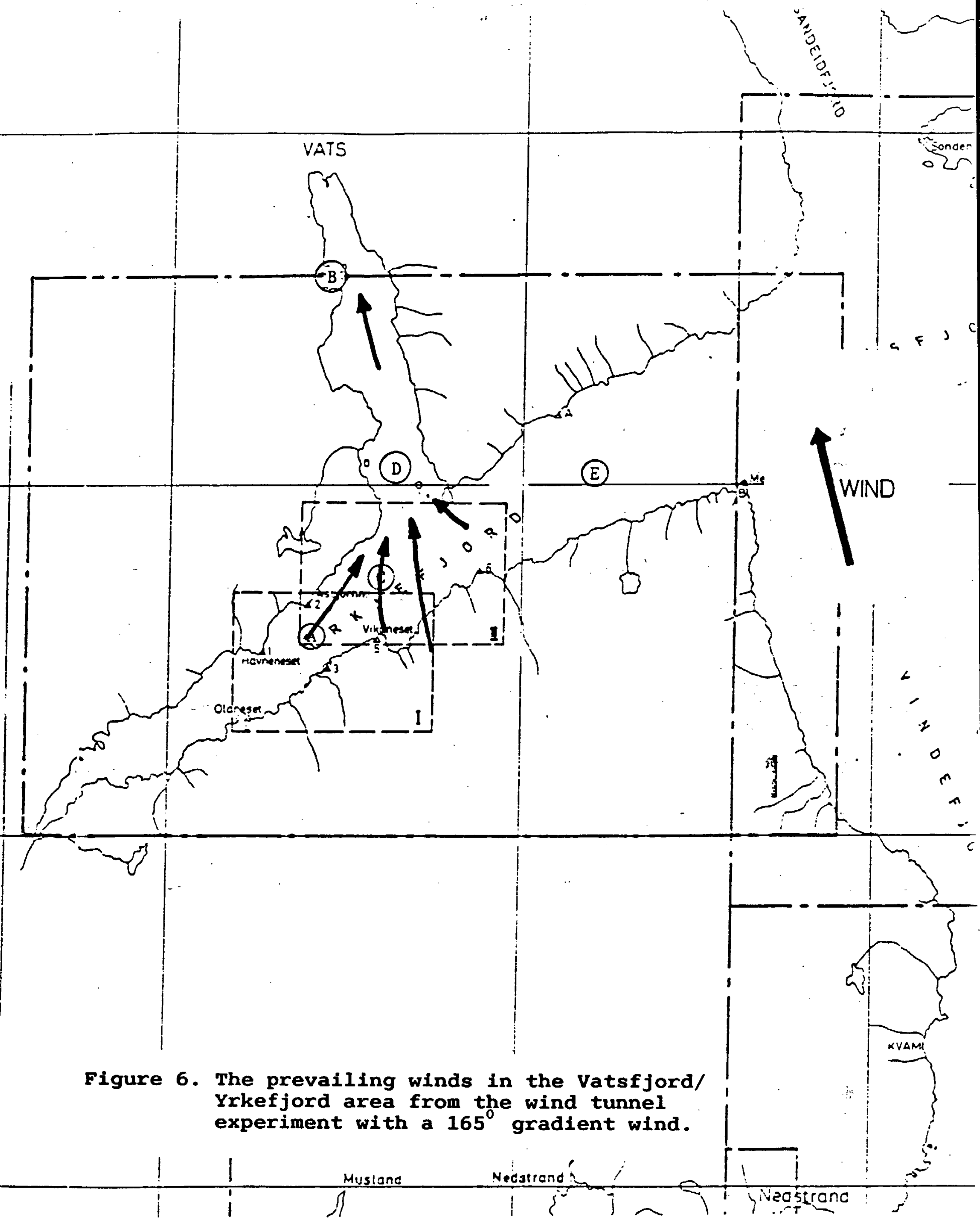


Figure 6. The prevailing winds in the Vatsfjord/ Yrkefjord area from the wind tunnel experiment with a 165^{0} gradient wind.

SKIBSTEKNISK LABORATORIUM LYNGBY DANMARK	Skala:	Tegn.:	Dato:
		Kopi:	Afd.:
		Efters.:	Fag:
Characteristic Flow Pattern, 165 deg. Wind		Godk.:	Skf.:
	Tegn.	83067 /	C10

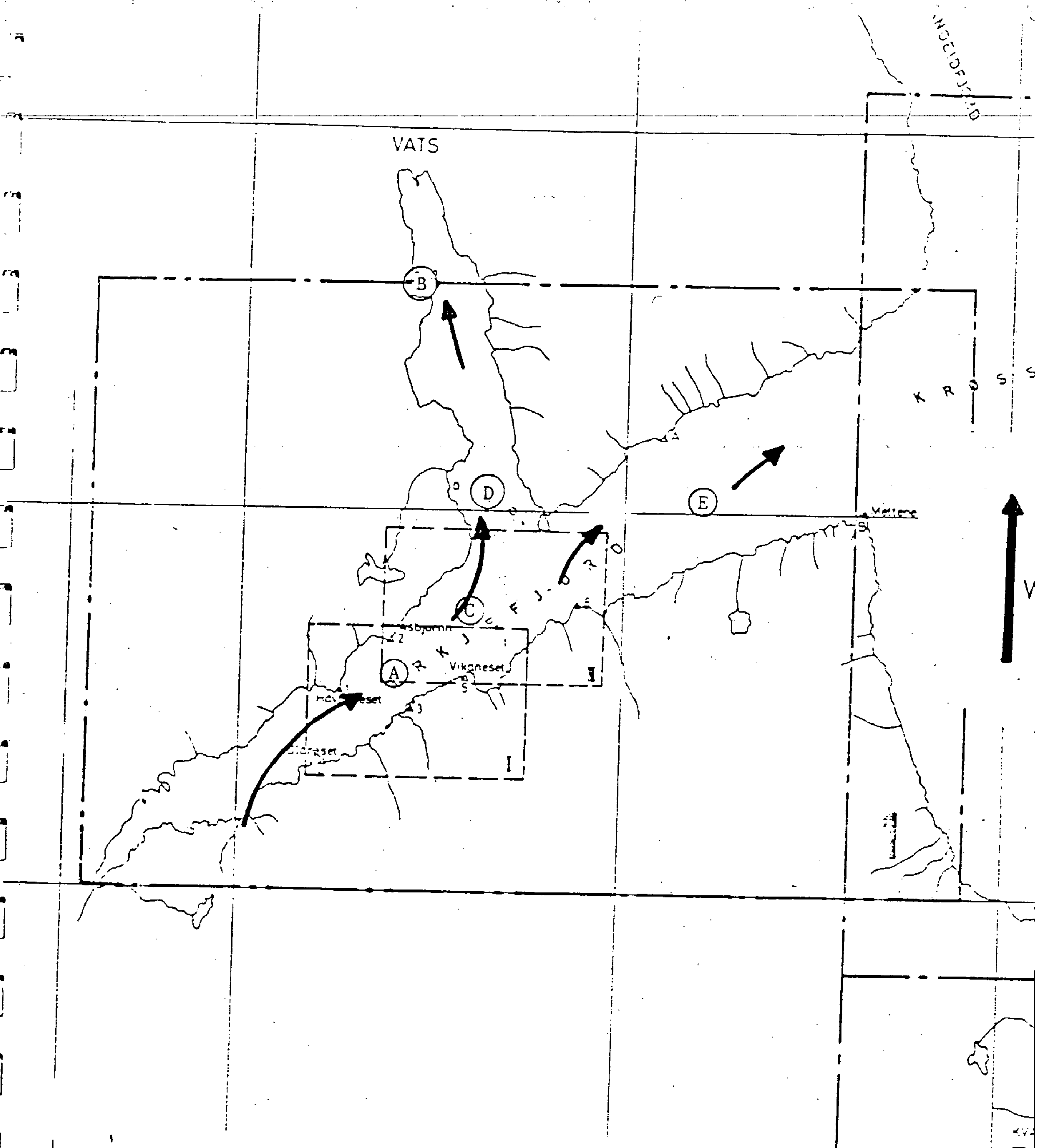


Figure 7. The prevailing winds in the Vatsfjord/ Yrkefjord area from the wind tunnel experiment with a 180^0 gradient wind.

SKIBSTEKNISK LABORATORIUM LYNGBY DANMARK	Skala:	Tegn.:	Dato:
		Kopi:	Afd.:
Characteristic Flow Pattern, 180 deg. Wind		Efters.:	Fag:
		Godk.:	Skf.:
	Tegn. nr.	83067 /	C11

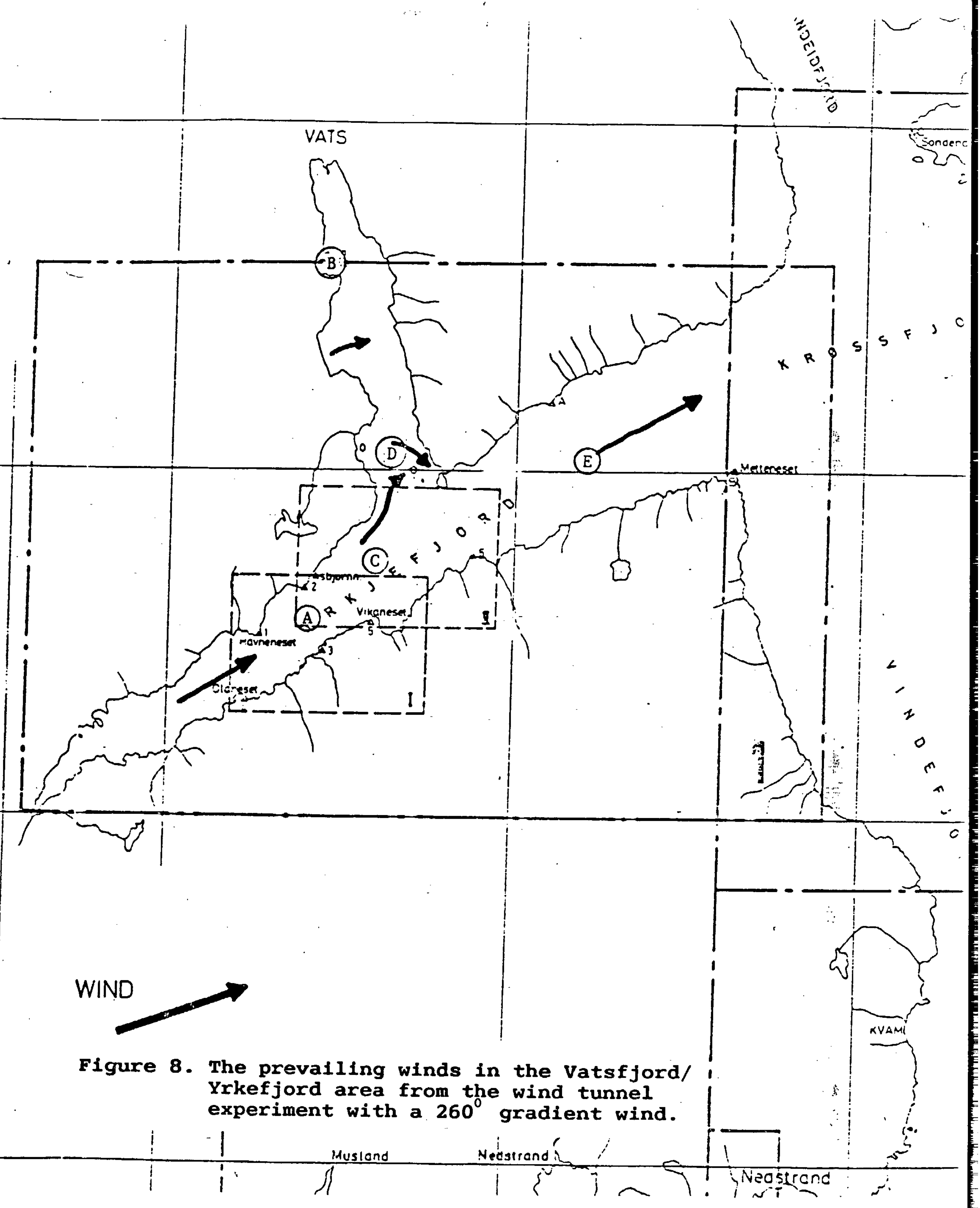
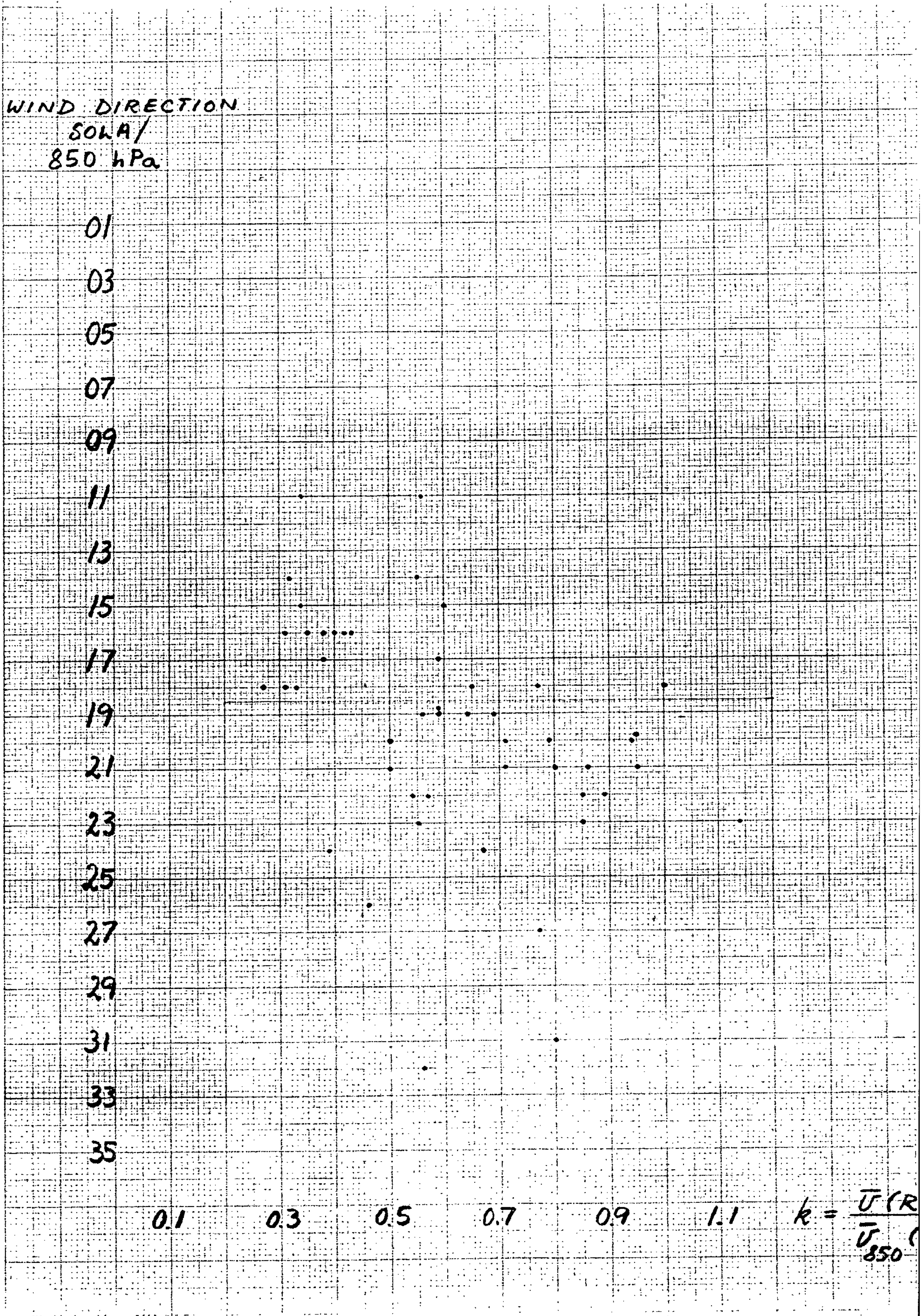


Figure 8. The prevailing winds in the Vatsfjord/ Yrkefjord area from the wind tunnel experiment with a 260° gradient wind.

SKIBSTEKNISK LABORATORIUM LYNGBY DANMARK	Skala:	Tegn.:	Dato:
		Kopi:	Afd.:
		Efters.:	Fag:
		Godk.:	Skf.:
Characteristic Flow Pattern, 260 deg. Wind	Tegn. nr.:	83067	/ C12

Figure 9. A scatter diagram of the transfer coefficients, Sola 850 hPa → Raudnesvarden, distributed on the wind directions of Sola 850 hPa.



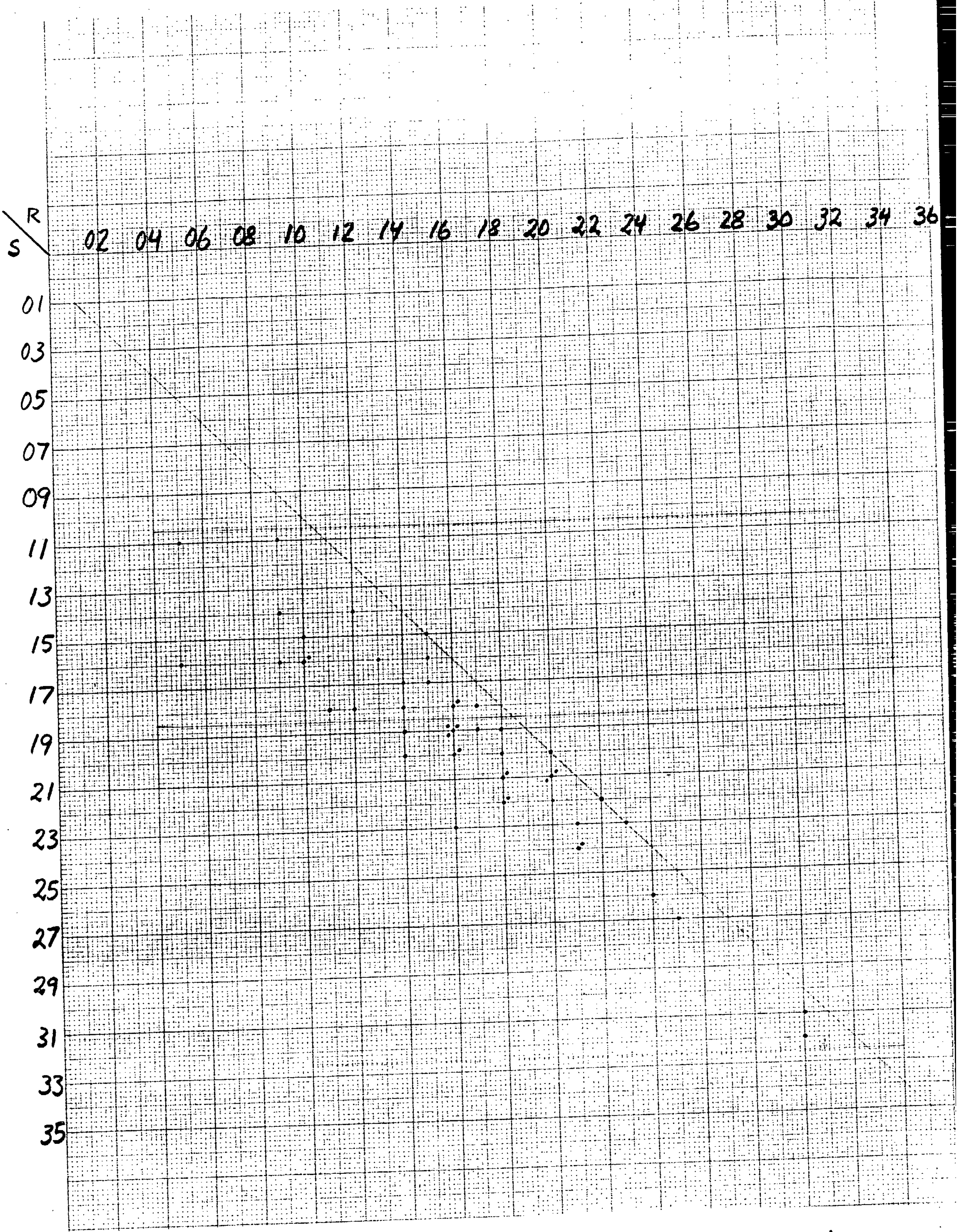


Figure 10. A scatter diagram of the wind directions of Sola 850 hPa and Raudnesvarden.

APPENDIX A.

SOME WEATHER SITUATIONS ANALYZED (FIGURE A.1 - A.12).

Comments to the Figures.

The figures show weather maps of some of the situations from the wind comparing analysis. Isobars are drawn, and the wind speed and the typical wind direction at Utsira, Kattrauv and Raudnesvarden are illustrated.

Figure A.1 - A.9.
These figures show wind fields in the sector E - SSW.

Figure A.1 - A.3 show easterly wind at Vats. A typical thermal blocking high pressure nose is situated at South-East Norway, and the associated lee low at the Western Coast. The wind at Vats, both at Kattrauv and Raudnesvarden, is blowing across the isobars, and thus is a-geostrophic. High wind speed is concentrated at low levels to the lee of the mountains, and the wind speed therefore is considerably higher at Kattrauv than at Raudnesvarden.

The figures (A.1 - A.3) clearly show that Utsira is shielded to easterly wind fields. While turning to southeast, wind fields blowing arround the southern part of the mountain chain reach the station.

Figure A.4 shows a front passage with a southeasterly, stable air mass ahead of the front. After the passage the pressure field turns SSW, and the air mass is less stable. The change of wind direction therefore is pronounced, especially at Vats where it turns from easterly to SSW.

Before the passage the wind speed at Kattrauv and Utsira is of equal magnitude, while it is strongest at Utsira after the passage. Kattrauv is then shielded, and the wind speed is also lower than at Raudnesvarden.

Figure A.5 - A.7 show a a southerly pressure field turning prefrontal southeasterly, and SSW in the warm sector. It is worth remarking that when the wind at Utsira is southerly, the wind is SSE at Kattrauv and Raudnesvarden. The change from SSW - SW wind to southerly wind at Utsira and probably of the wind over Vats (level 500-800 m), reflects deflection of stable air by the high mountains. The stable air will more easily blow along the coast than be lifted over. Sometimes also the pressure field is turned because some lifting of stable air produces a thermal high. This can be seen in Figure A.9, where a pressure ridge over the area appear.

For southerly wind at Utsira the wind speed at Utsira and Raudnesvarden are of the same magnitude, and considerably higher than at Kattrauv which is locally shielded.

Figure A.8 shows a S - SSW prefrontal pressure field. The stable air mass gives deflected SSE wind at Utsira, SE at Raudnesvarden and ESE at Kattrauv. The pressure nose can now be seen east of Sola.

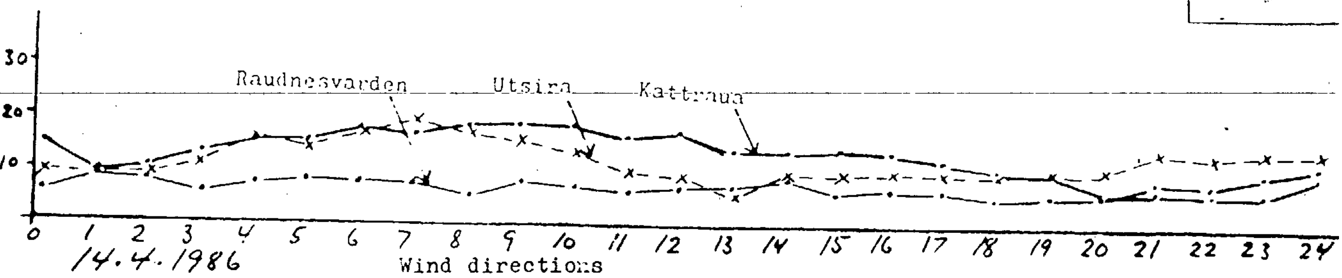
Figure A.10 show how the stable air mass to the right of a trough (west of Utsira) is producing a pressure ridge over the Western part of the mountain chain. The wind is slightly backed from Utsira to Vats. The wind is now stronger at Raudnesvarden than at Kattrauv. Most of the time, however, it is strongest at Utsira. The maximum wind speed at Raudnesvarden and Utsira, however, is of equal magnitude. This occur in the trough passage where the stability is lowest. The retardation effect by lifting the air mass to the mountain chain then is small.

Figure A.11 illustrates northwesterly wind at Utsira with a slightly backing to WNW at Vats. The wind speed is reduced both at Raudnesvarden and Kattrauv. Northwesterly wind reaching Raudnesvarden has to pass a distance of high level landscape and the speed thus is reduced by surface friction.

Figure A.12 shows a rather less typical weather situation. Northeasterly wind is modified by the mountains, creating a lee low SSW of the mountain chain (east of Sola). The a-geostrophic wind at Vats is directed across the isobars, and therefore is blowing NNW. The wind speed is rather low because most of the wind is deflected on both sides of the mountain chain (Skagerrak - the coast of Møre and Romsdal). At Utsira a geostrophic NNE - wind is blowing.

Fig. A

Knots — 10 min.mean wind



Wind directions	
Utsira	SE
Raudnesvarden	E
Kattraua	E

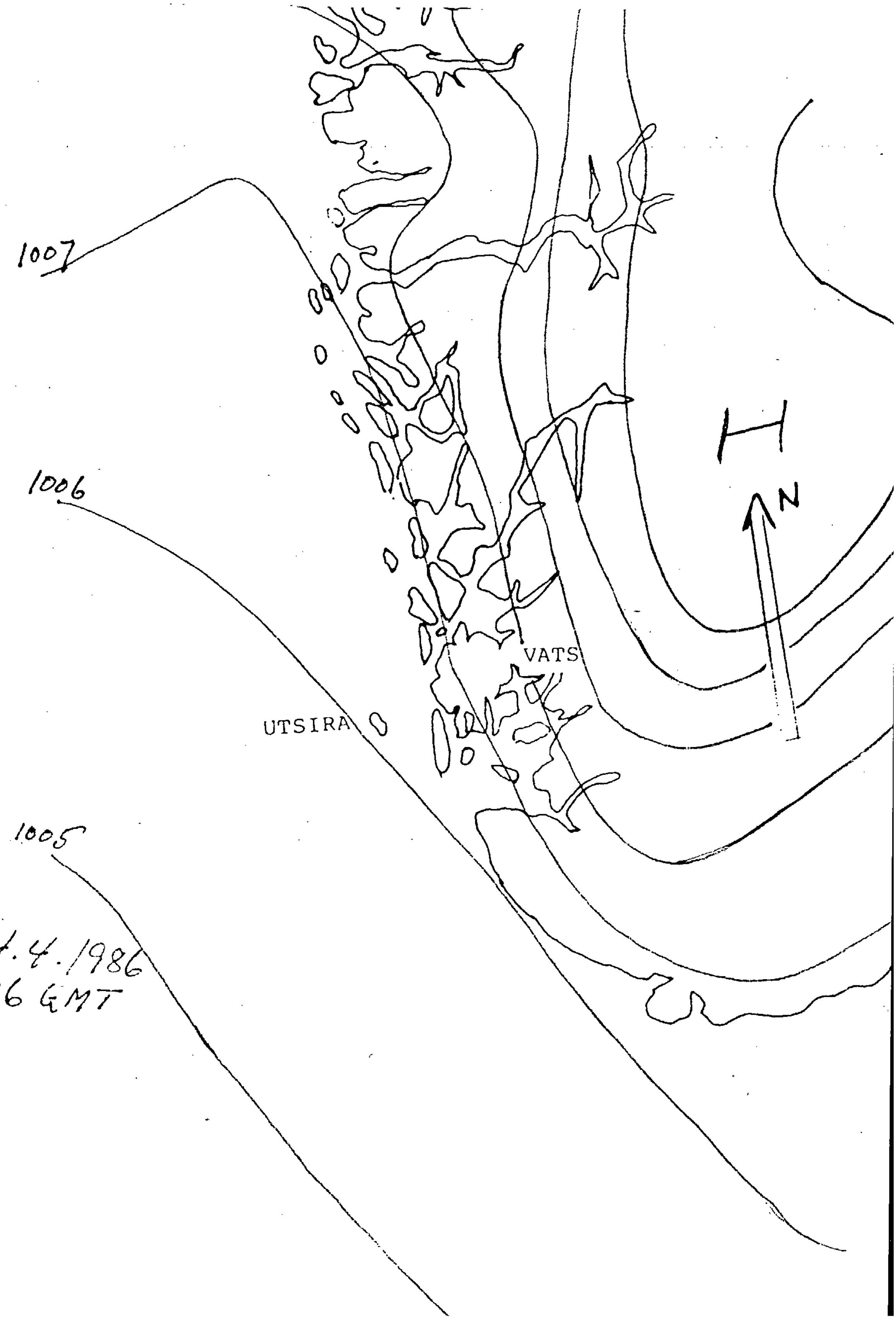
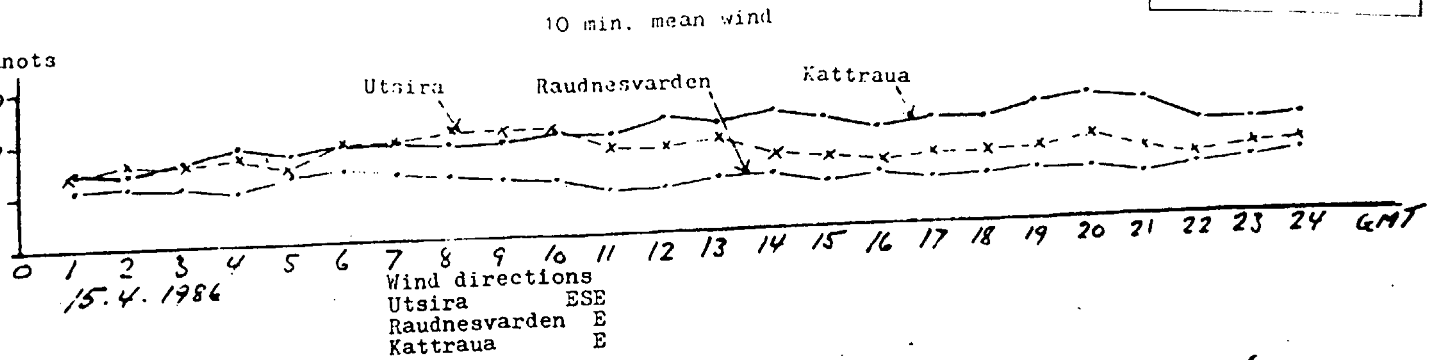


Fig. A.2


10 min. mean wind
nots
Utsira
Raudnesvarden
Kattraua
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 GMT
15.4.1986
Wind directions
Utsira ESE
Raudnesvarden E
Kattraua E

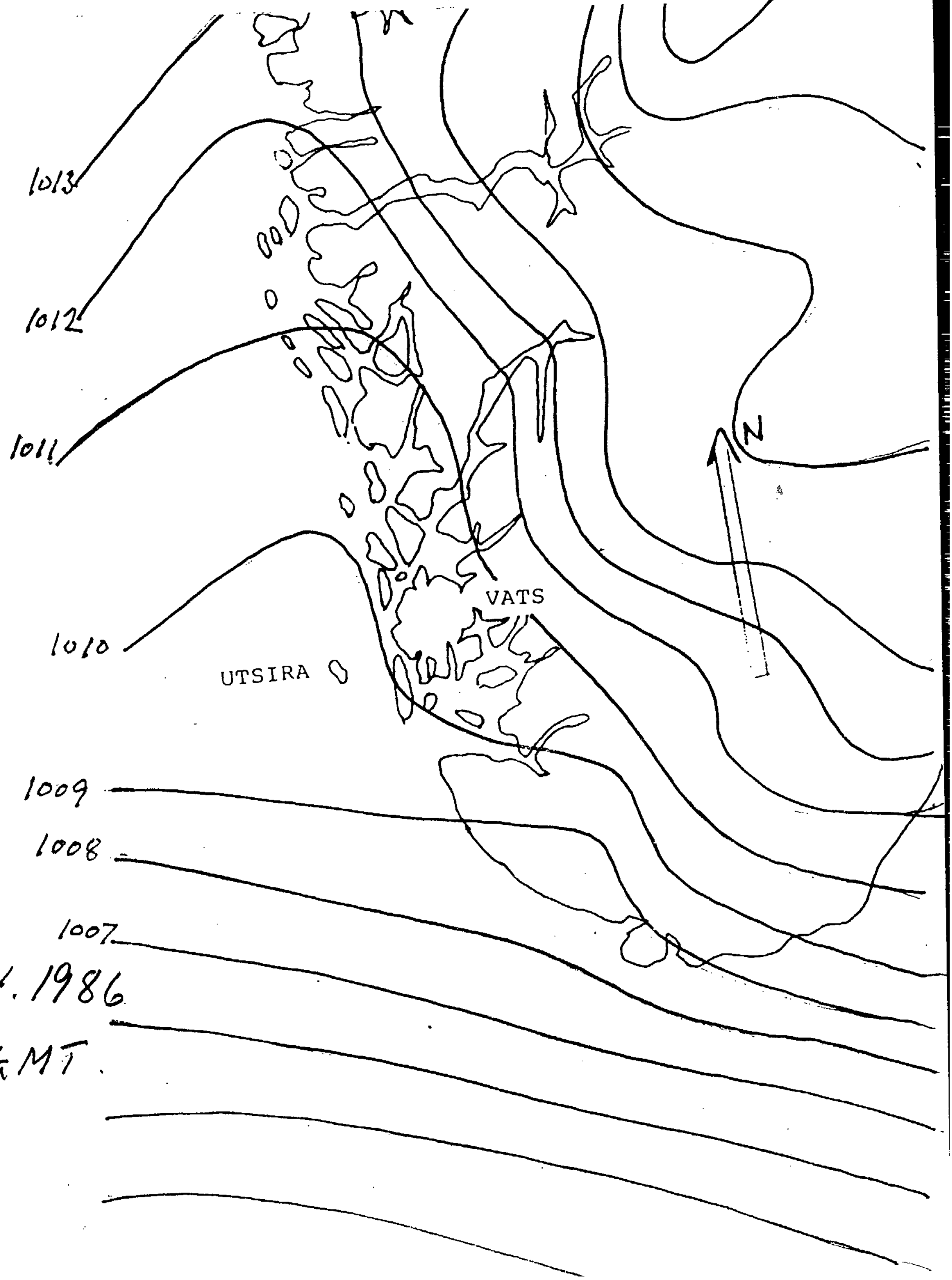
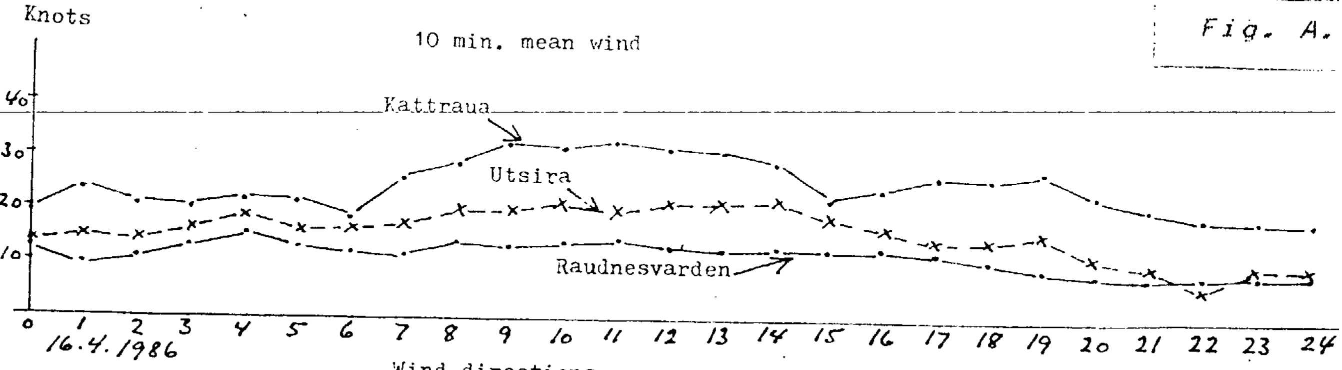
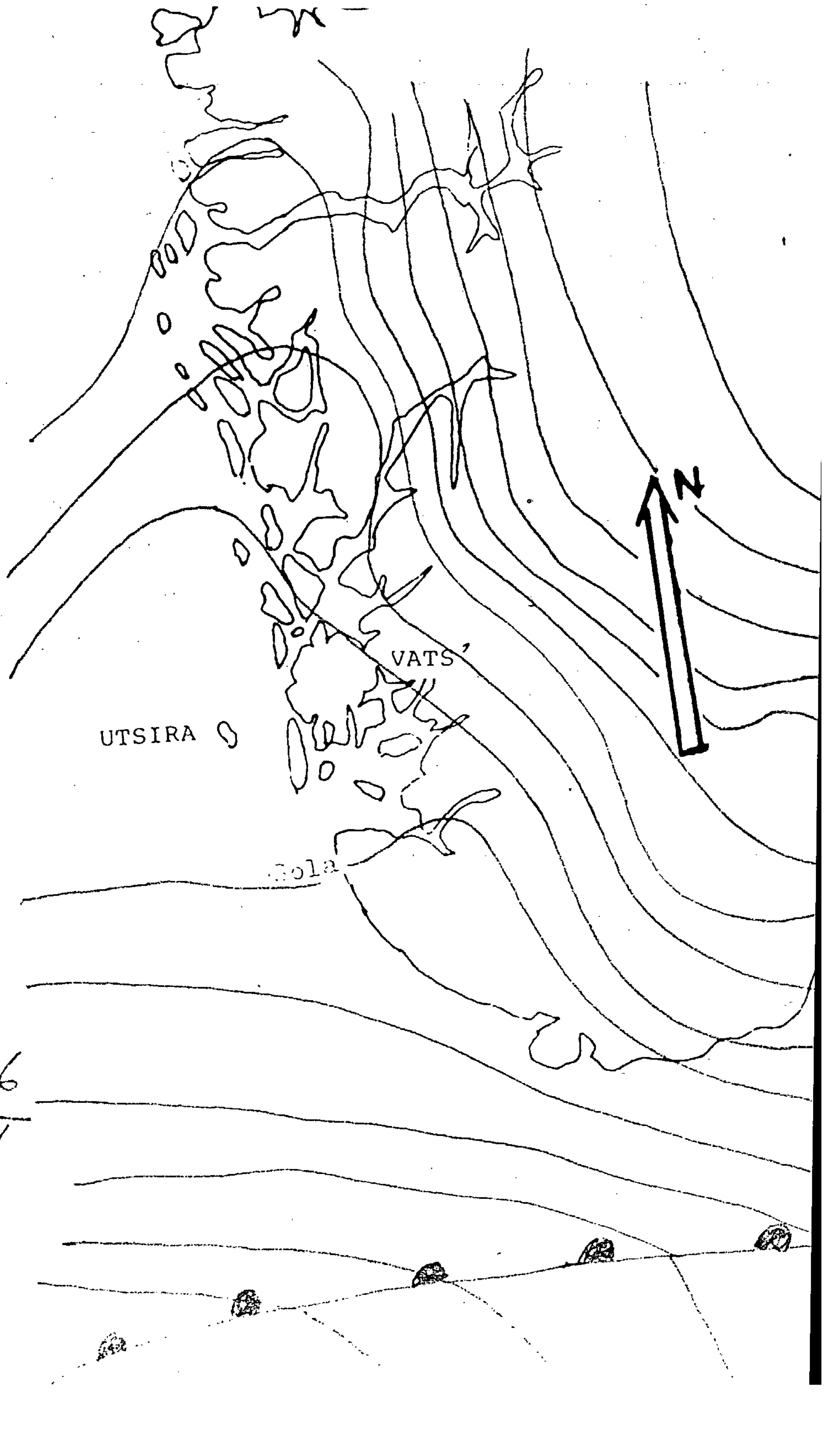

1013
1012
1011
1010
1009
1008
1007
VATS
UTSIRA
N
15.4.1986
18 GMT

Fig. A.



Wind directions:
Utsira E
Raudnesvarden E
Kattraua E



16.4.1986
12 GMT

Fig. A.4

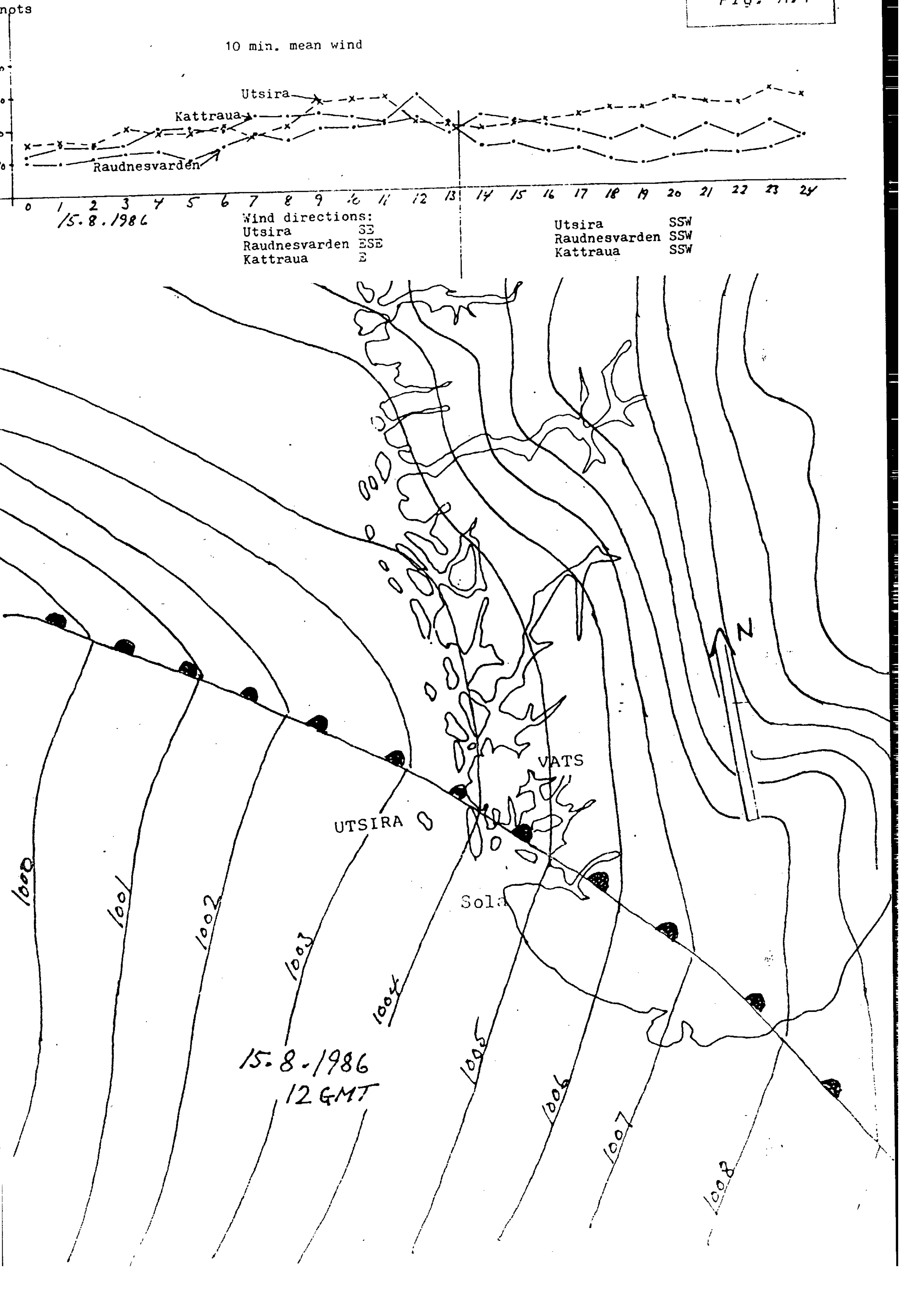
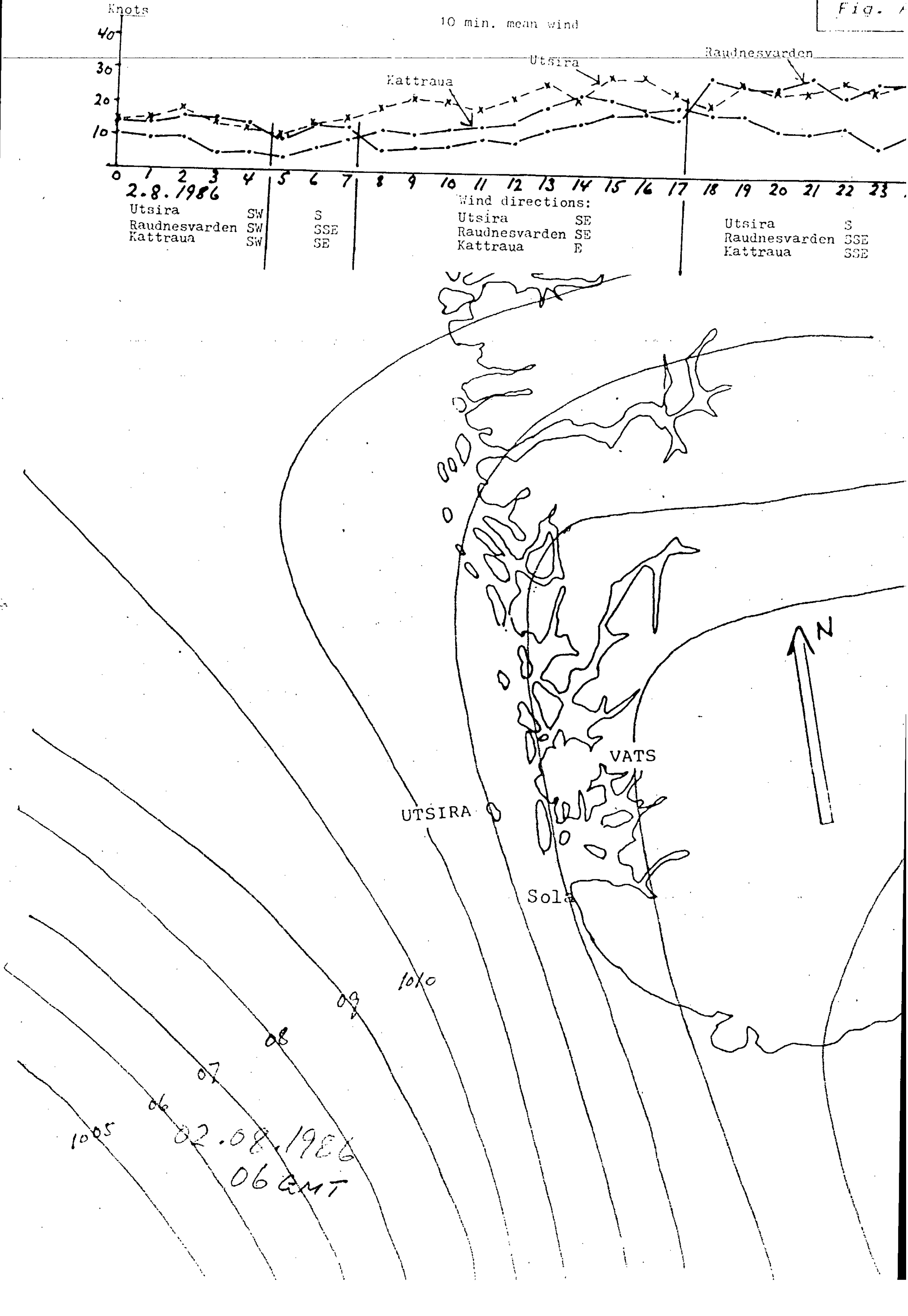
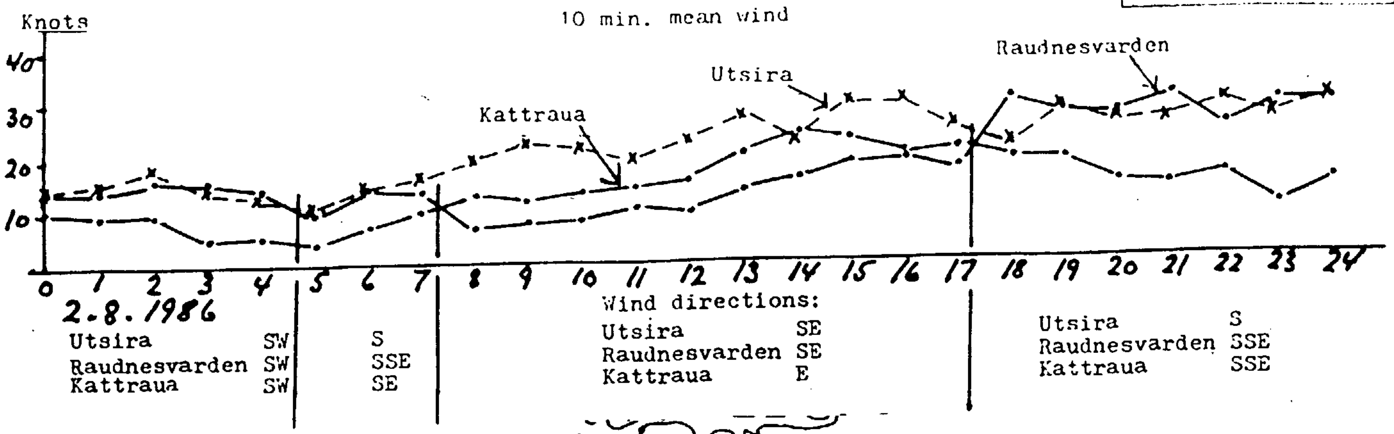

knots
10 min. mean wind
Utsira
Kattraua
Raudnesvarden
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
15.8.1986
Wind directions:
Utsira SE
Raudnesvarden ESE
Kattraua E
Utsira SSW
Raudnesvarden SSW
Kattraua SSW
N
VATS
UTSIRA
Sola
1000
1001
1002
1003
1004
1005
1006
1007
1008
15.8.1986
12 GMT

Fig.

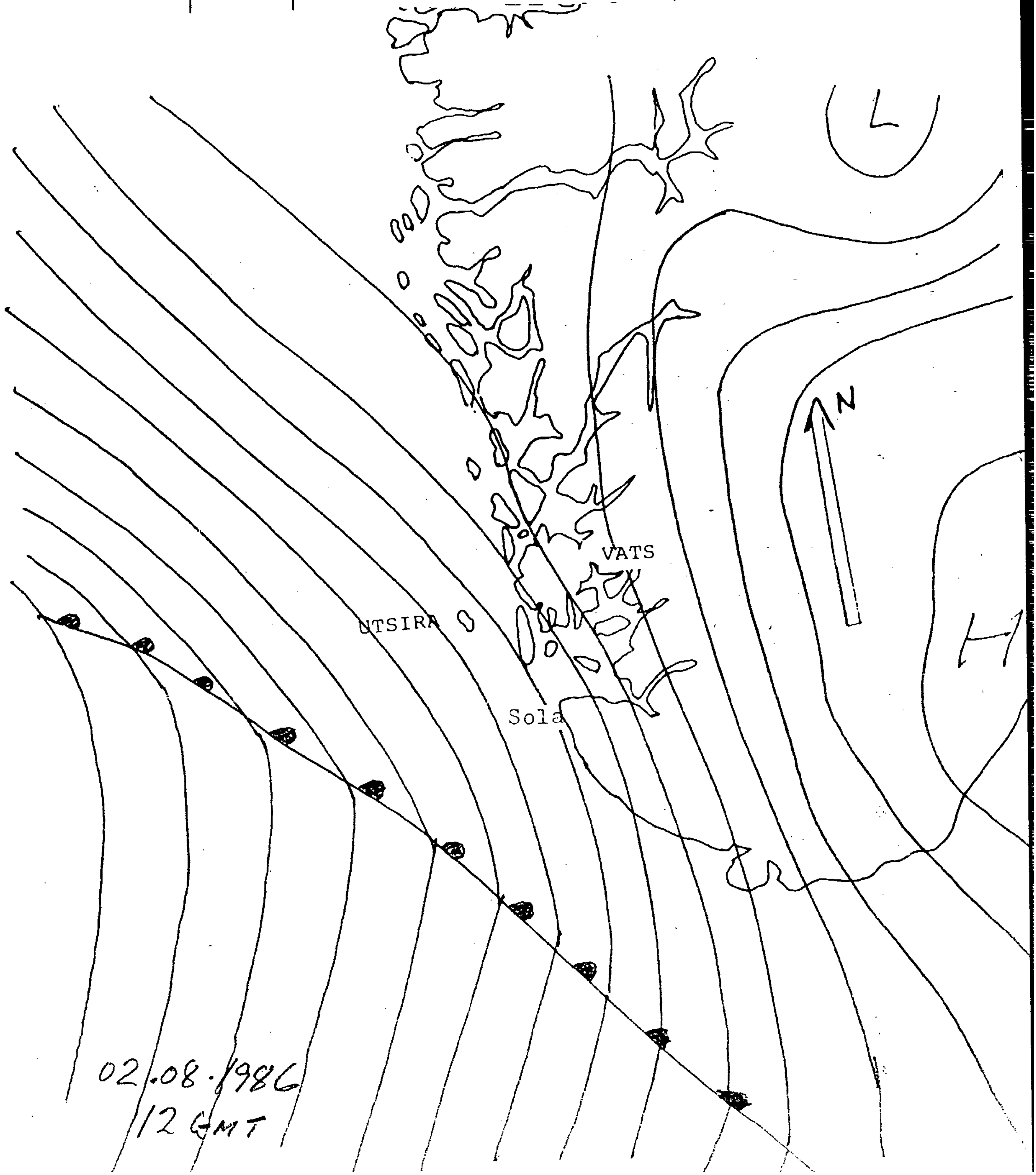


Knots
10 min. mean wind
40
30
20
10
Utsira
Kattraua
Raudnesvarden
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
2.8.1986
Utsira SW
Raudnesvarden SW
Kattraua SW
S
SSE
SE
Wind directions:
Utsira SE
Raudnesvarden SE
Kattraua E
Utsira S
Raudnesvarden SSE
Kattraua SSE
N
VATS
UTSIRA
Sola
1010
08
07
06
1005
02.08.1986
06 GMT

Fig. A.6

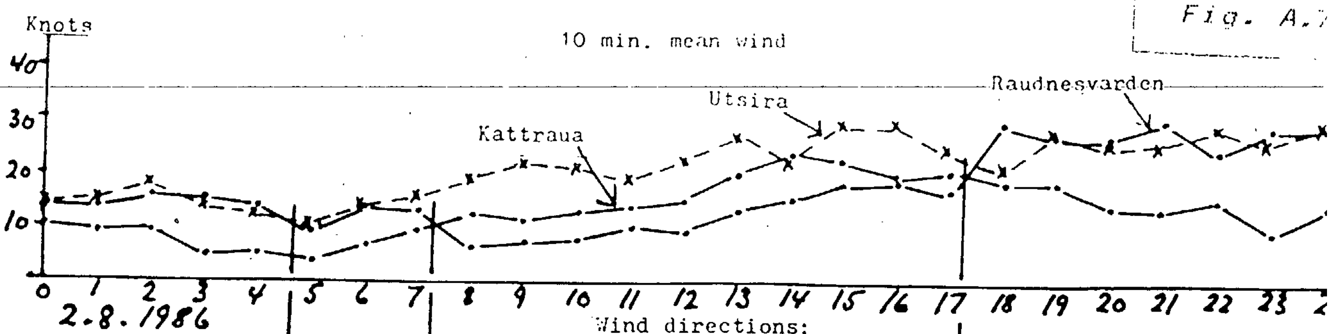


Knots
10 min. mean wind
40
30
20
10
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Raudnesvarden
Utsira
Kattraua
2.8.1986
Utsira SW
Raudnesvarden SW
Kattraua SW
S
SSE
SE
Wind directions:
Utsira SE
Raudnesvarden SE
Kattraua E
Utsira S
Raudnesvarden SSE
Kattraua SSE



L
N
VATS
UTSIRA
Sola
H
02.08.1986
12 GMT

Fig. A.7



Wind directions:

	0–4	5–7	8–17	18–
Utsira	SW	S	SE	S
Raudnesvarden	SW	SSE	SE	SSE
Kattraua	SW	SE	E	SSE

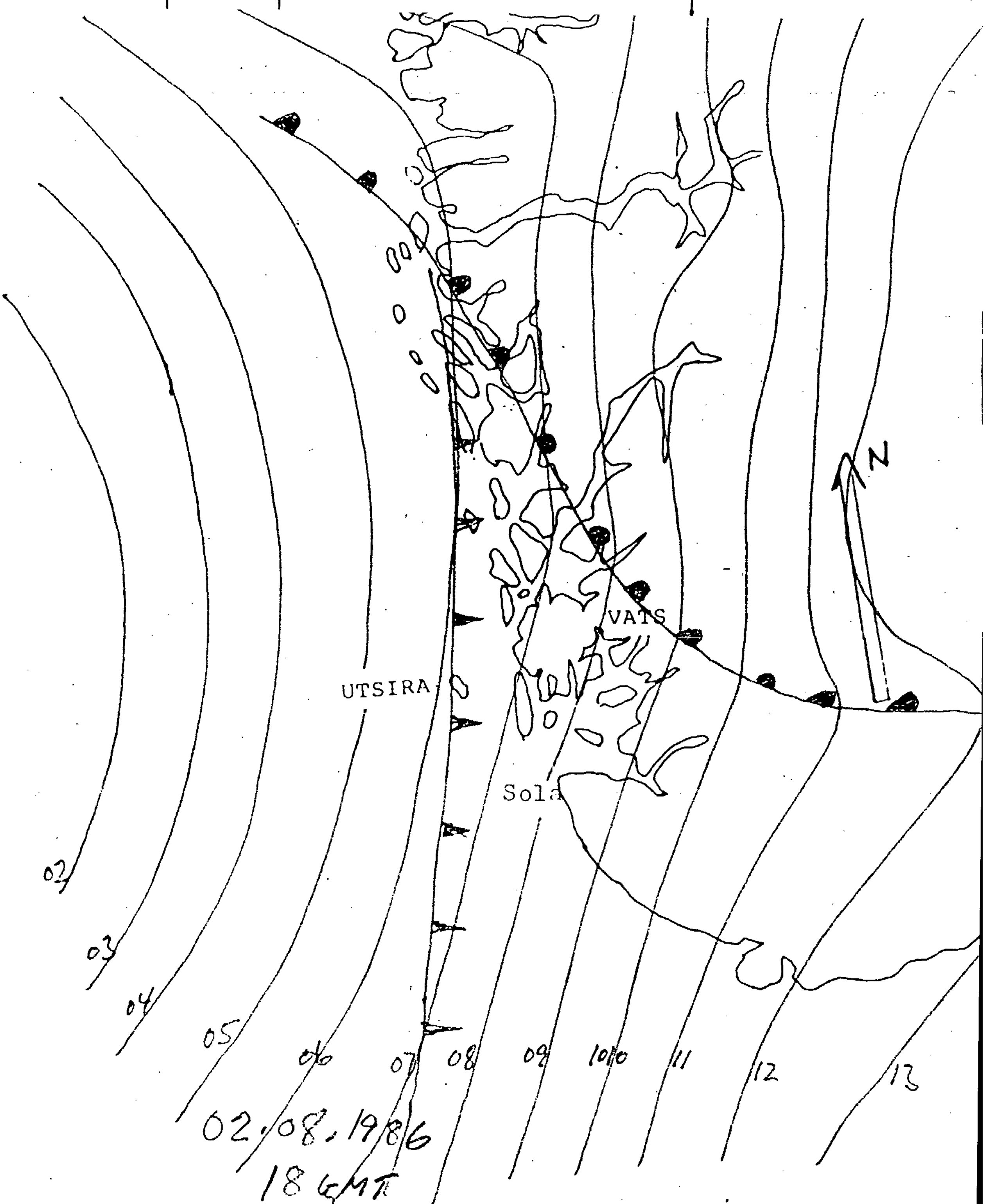


Fig. A.8

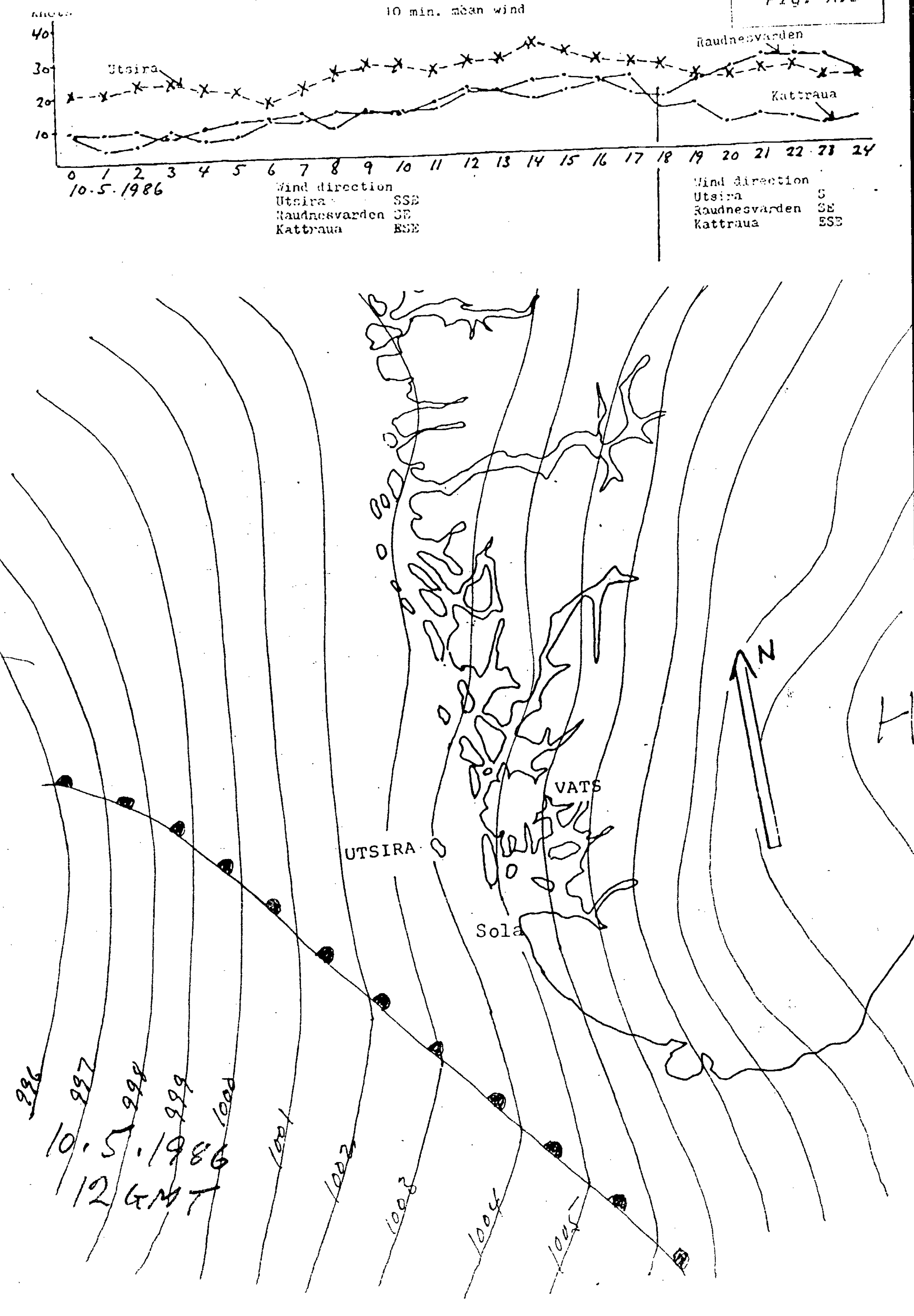
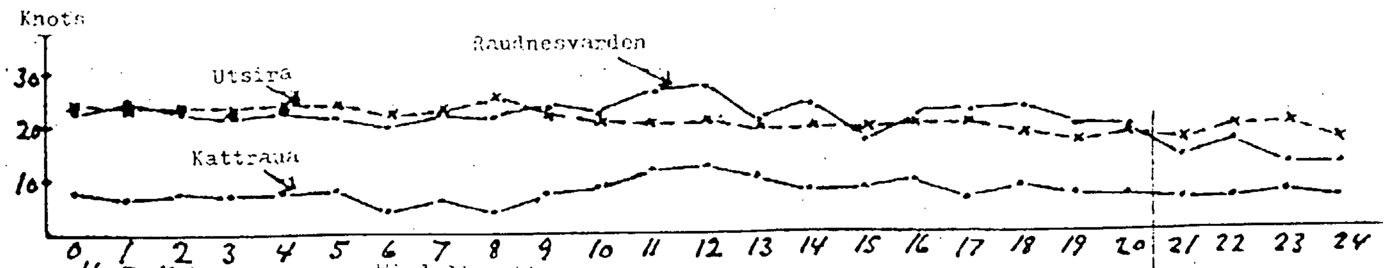

knots
10 min. mean wind
40
30
20
10
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
10.5.1986
Utsira
Raudnesvarden
Kattraua
Wind direction
Utsira SSE
Raudnesvarden SE
Kattraua ESE
Wind direction
Utsira S
Raudnesvarden SE
Kattraua ESE
N
H
VATS
UTSIRA
Sola
996
997
998
999
1000
1001
1002
1003
1004
1005
10.5.1986
12 GMT

Fig. A.9

10 min. mean wind



Wind directions:
Utsira S
Raudnesvarden SSE
Kattraua SSE

Utsira W
Raudnesvarden S
Kattraua SW

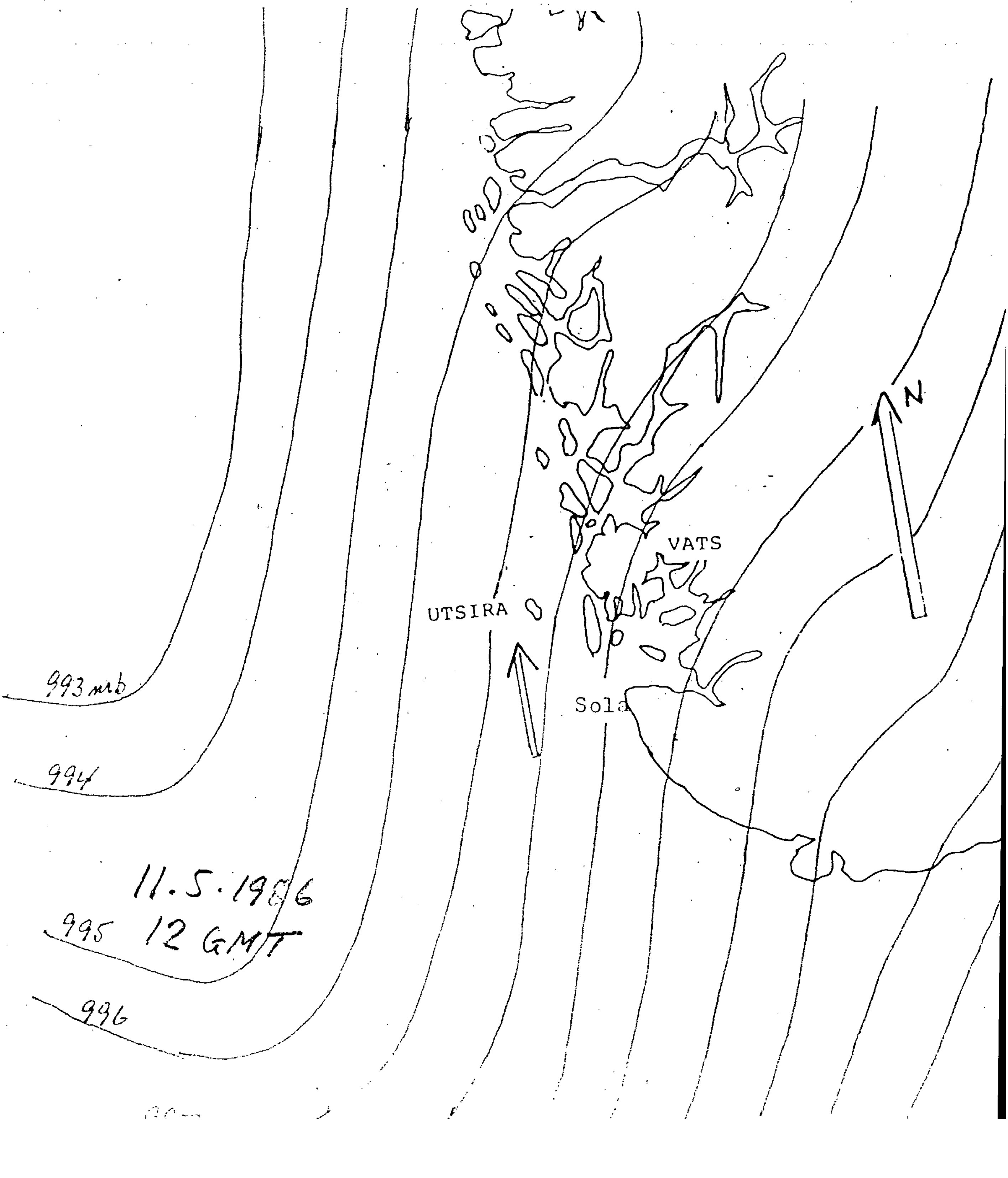


Fig. A.10

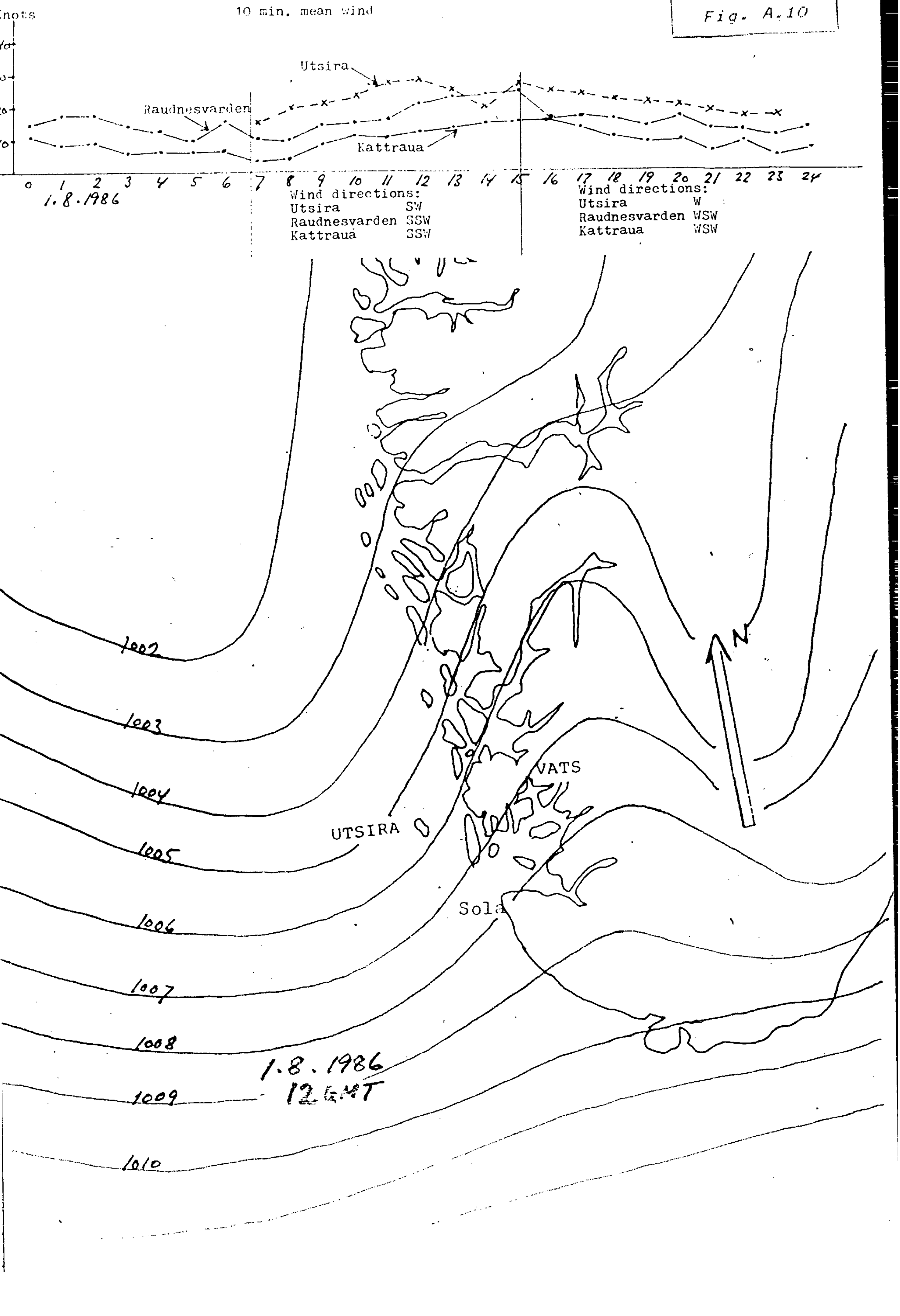
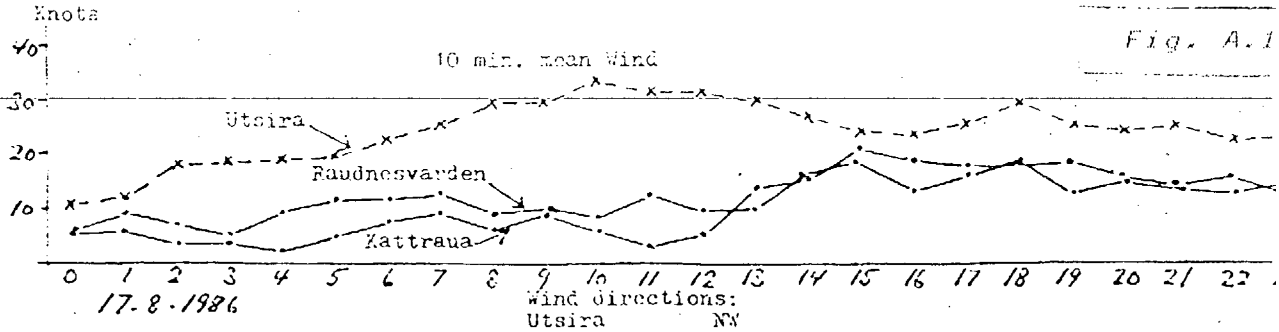

knots
10 min. mean wind
Utsira
Raudnesvarden
Kattraua
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
1.8.1986
Wind directions:
Utsira SW
Raudnesvarden SSW
Kattraua SSW
Wind directions:
Utsira W
Raudnesvarden WSW
Kattraua WSW
N
VATS
UTSIRA
Sola
1002
1003
1004
1005
1006
1007
1008
1009
1010
1.8.1986
12 GMT

Fig. A.1



Wind directions:

Utsira	NW
Raudnesvarden	WNW
Kattraua	WNW

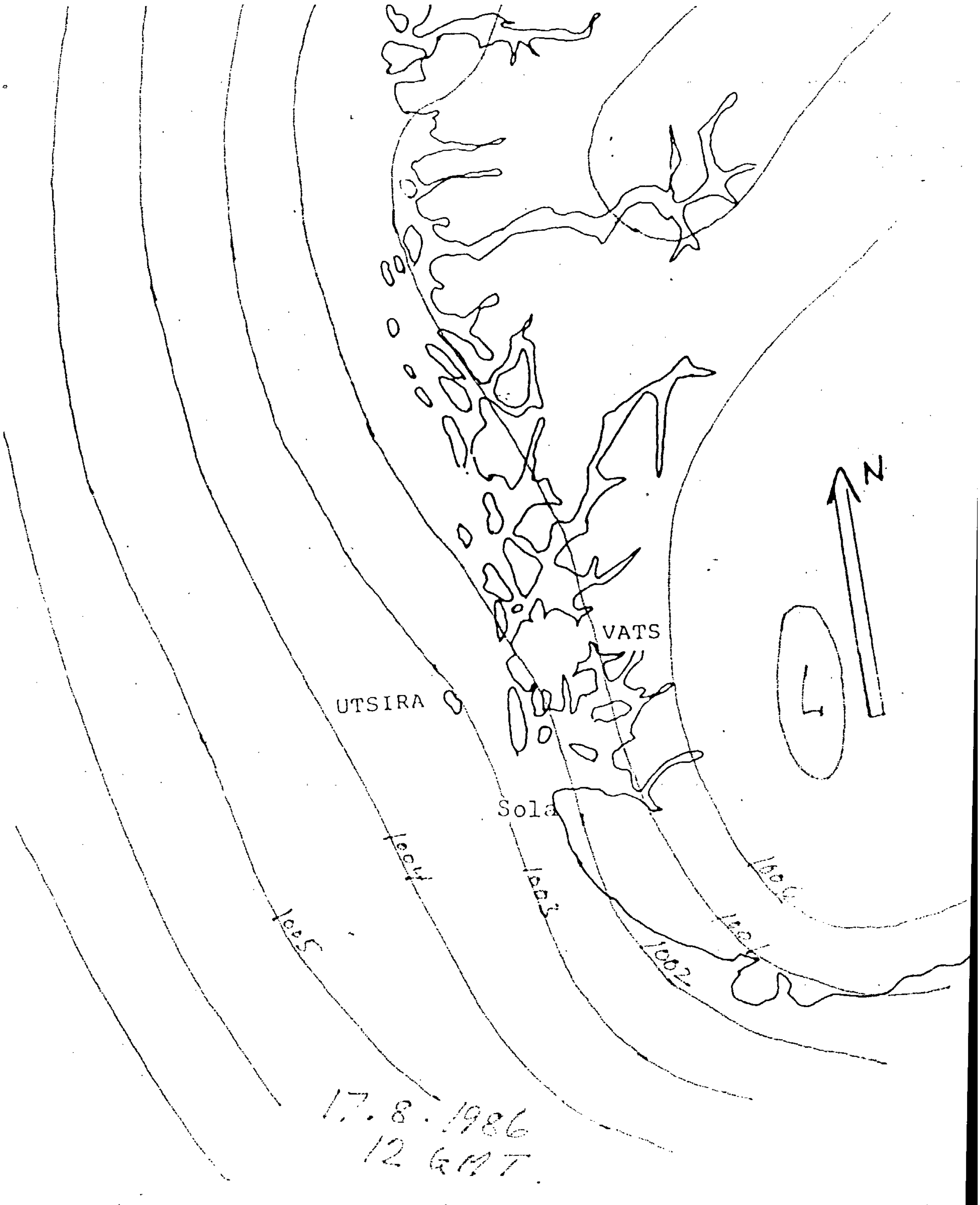
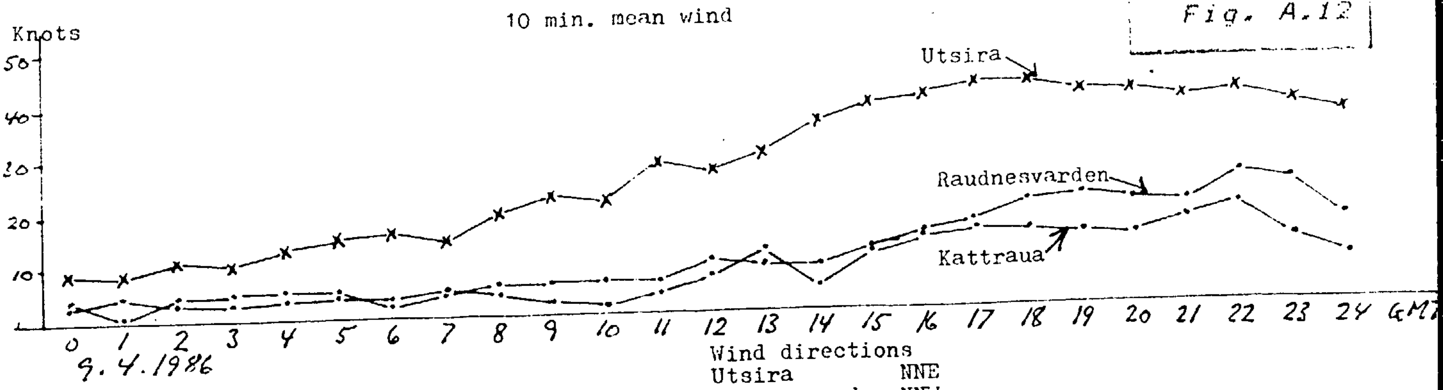
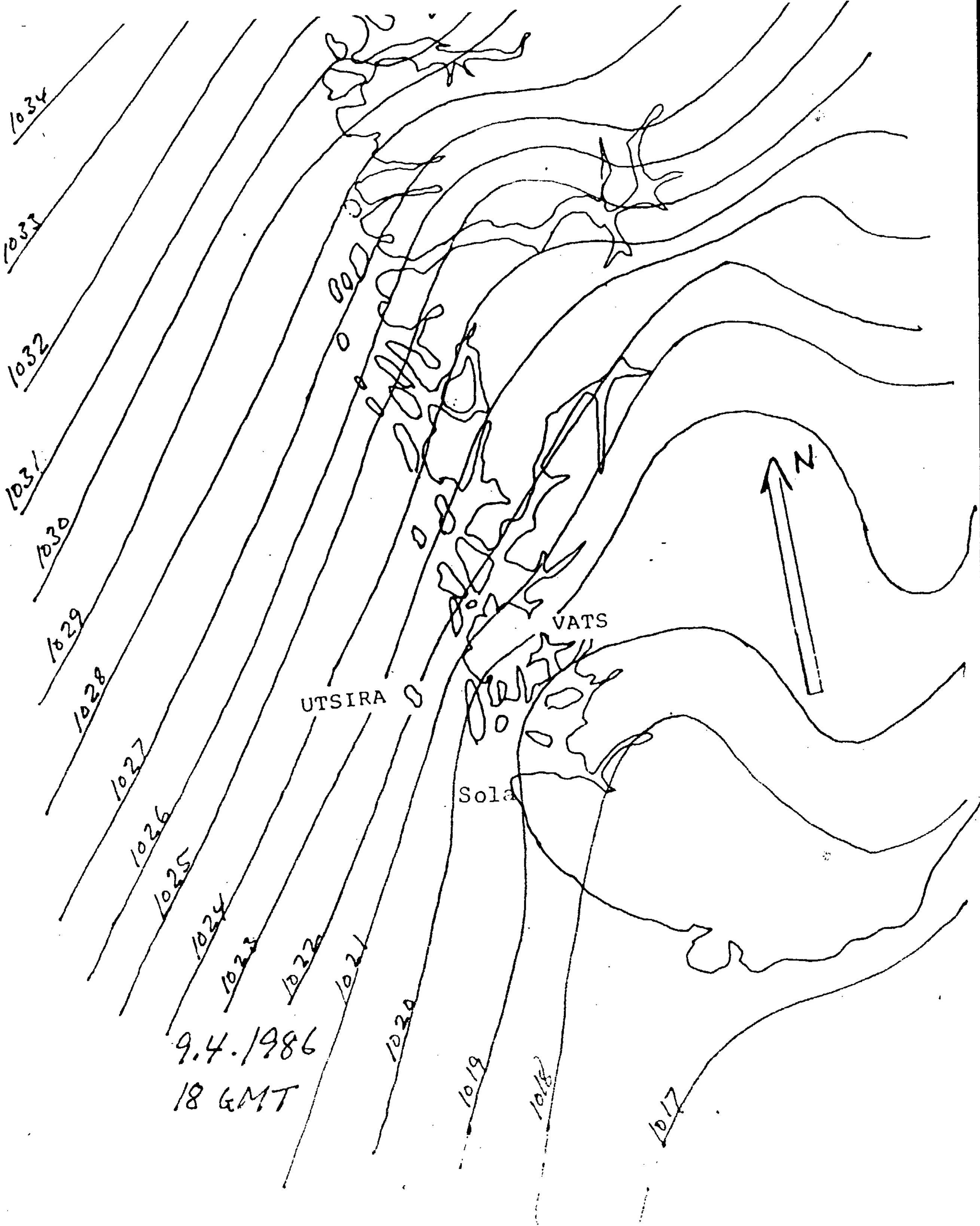


Fig. A.12


10 min. mean wind
Knots
50
40
30
20
10
Utsira
Raudnesvarden
Kattraua
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 GMT
9.4.1986
Wind directions
Utsira NNE
Raudnesvarden NNW
Kattraua NNW


1034
1033
1032
1031
1030
1029
1028
1027
1026
1025
1024
1023
1022
1021
1020
1019
1018
1017
N
VATS
UTSIRA
Sola
9.4.1986
18 GMT

APPENDIX B.

A PRESENTATION OF PREVIOUS 1 MINUTE EXTREME VALUES.

The 1 minute extreme values from (2) is presented below.

Table 4. 1 MINUTE WIND SPEEDS (m/s).
POSITION C.
Reference height: 10 m.

Sector (degrees)	Return period (years) 2	10	100
310-040	11	13	15
040-090	18	21	25
090-150	15	18	20
150-310	21	27	30

Table 5. 1 MINUTE WIND SPEEDS (m/s).
POSITION D.
Reference height: 10 m.

Sector (degrees)	Return period (years) 2	10	100
320-090	15	18	20
090-150	23	26	30
150-180	25	32	35
180-220	21	26	30
220-270	14	18	20
270-320	21	27	30

Table 6. 1 MINUTE WIND SPEEDS (m/s).
POSITION E.
Reference height: 10 m.

Sector (degrees)	Return period (years) 2	10	100
320-030	11	13	15
030-120	23	26	30
120-190	15	18	20
190-320	21	27	30

Contractors

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Phone: (02) 12 90 90
Telex: 76760 conde n
Telefax: 12 91 00

Det norske meteorologiske institutt
Postboks 318-320 BLINDERN

0314 OSLO 3

Our ref.: HR/ibj Your ref.: 1320 Stabekk, 9. februar 1987

Automatisk værstasjon i Vats

Ref. Deres brev av 12. desember 1986, ref. 331/5122/86 BA/OL.

Vi aksepterer tilbudet om analysearbeidet av data fra de automatiske værstasjonene i Vats, med en kostnadsramme på kr. 20.000.-.

Rapporten ønskes ferdig i løpet av mars 1987.

Vi håper arbeidet vil gi basis for en bedre forståelse av forholdet mellom Vats og Sola, jfr. også vindtunnelforsøket.

Vi ønsker også forslag til videre bearbeidelse av nye data fra værstasjonene slik at vi kan innarbeide en rutine for behandlingen.

Stasjonene vil bli forsøkt benyttet i varslingsøyemed for operasjoner i forbindelse med Gullfaks C og Gullfaks B.

Noen betraktninger om dette bør inngå i rapporten.

Med vennlig hilsen,
for NORWEGIAN CONTRACTORS

Helge Strøkaas
for R.H. Seim