WP4.

A FORECAST SYSTEM FOR BIRD MIGRATION IN SWEDEN

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Introduction

A preliminary forecast system for bird migration has been in use in Sweden during two test periods, in the autumns (Aug. - Nov.) of 1977 and 1978. Daily bird migration forecasts have been issued during these periods to military as well as civil air fields and authorities.

In this report we will briefly describe the operational routines and also present an evaluation of the forecast system based on the experience from the two test periods. After critical testing of the bird migration forecast system, the Swedish Air Force has decided to use the system regularly in the next few years, and to support parallell work to refine and develop further the system.

The biological basis of the forecast system

The forecast system allows predictions to be made about bird migratory intensity. These predictions are based on the relationship between migratory intensity and weather, so that, once the weather is given (predicted by meteorologists' forecasts), the most probable migratory intensity of a certain bird species at a certain date and time of day can be calculated.

The present forecast model is mainly based on extensive multivariate analyses of the relationship between weather and daily bird migratory intensity as recorded by eleven years' observations at Falsterbo in South Sweden. The analyses comprise more than thirty different weather variables and fifteen bird species of widely different kinds (cf. Table 1). Daily migratory intensities during each species' peak migratory period have been grouped into four different classes and related to weather by stepwise multiple discriminant analyses. The classification functions given by these analyses are then used in the forecast system for the purpose of predicting migratory intensity.

The detailed results from these analyses of the bird migration data from Falsterbo, together with a biological interpretation and discussion, has been published in:

Alerstam, T. 1978. Analysis and a theory of visible bird migration. - Oikos 30:273-349.

Table 1 is a summary of the overall correlation coefficients ("canonical correlation coefficients") between weather and different kinds of bird migratory intensity, indicating the degree of covariation between these factors.

Table 1. Canonical correlation coefficients from discriminant analyses of daily bird migratory intensity in relation to weather. Based on Alerstam (1978)

Eider	-August	0.33
Eider	-October	0.51
Common buzzard		0.61
Honey buzzard		0.59
Sparrow hawk		0.61
Black-headed gull		0.45
Wood pigeon		0.66
Swift		0.61
Swallow		0.58
Hooded crow		0.68
Jackdaw		0.70
Yellow wagtail		0.63
Starling	-August	0.70
Starling	-October	0.55
Chaffinch/Brambling		0.61
Siskin		0.48
Linnet		0.69

Further analyses by the same method are presently carried out and planned on the basis of extensive data on bird migration from other field observation sites than Falsterbo and for other kinds of birds.

The results of the analyses of the Falsterbo migration data form only part of the present forecast system. The system also takes into account information about the daily time distribution as well as seasonal and geographical distribution of the migration of the different species. This information is based on field observations of bird migration at many different sites as well as radar observations from a lot of stations in the south part of

Sweden. Since 1972 the Air Force and Board of Civil Aviation have supported a project to extend the knowledge, mainly by radar studies, of the distribution of migrating birds in space and time. Complementary work for species and regions of particular interest remains to be done in the forthcoming years.

Forecast Model

1. General back-ground

The results obtained by the method described above have been used to develop a warning system for bir migration. The aim is to predict migration activity, with sufficient accuracy, one day in advance by using weather forecasts as input. One preliminary model has been in use during two test periods, from the beginning of August to the middle of November in 1977 as well as in 1978. The bird migration forecasts were distributed by telefacsimile and teletype to all military and civil airports concerned. One forecast, in this report called preliminary, was issued one day in advance (Monday to Thursday) and another, called final, in the early morning the same day it was valid (Monday to Friday). The day was divided into four different periods, 07-10, 10-12, 12-14, and 14-17 hrs, and one forecast map was drawn for each of these periods. To make all calculations and comparisons with basic migratory pattern possible within available space of time it is necessary to use a small computer.

2. Weather, Sectors and Species

The southern part of Sweden shows the highest migratory activity and forecasts are presently made for that area only (Fig.1). In order to adapt, as far as possible, the bird forecast to the actual weather situation the forecast area is divided into six sectors (Fig.1). In each sector data from one representative weather observation station (●) are used for the bird forecasts in that sector. Some parameters such as relative humidity, maximum and minimum temperature (O) and upper winds at 850 mb level (x) are taken from other stations common for three sectors each (1,2,3 and 4,5,6 in Fig.1). For the final forecast most weather parameters refer to actual observations made at 05 GMT. For the preliminary forecast, however, all weather parameters have to be predicted for the next day by a meteorologist.

As the bird migration data are grouped into four intensity groups the intensity predicted on the basis of the results from the discriminant analyses is given by a figure 1 to 4 for each species and sector. The fifteen bird species used in this preliminary model are:

Sea birds : Eider and Blackheaded Gull

Light birds: Chaffinch/Brambling, Swallow, Yellow Wagtail, Starling, Siskin, Linnet and Swift

Heavy birds: Wood pigeon, Jackdaw, Hooded Crow, Sparrow Hawk, Common Buzzard and Honey Buzzard

3. Time and Geographical Distribution

The time and geographical distribution of the migration of different bird species are assumed to be the same as found from several years of visual countings and radar studies. One example (Common Buzzard) can be seen in Fig.2. Similar diagrams and maps are available for all species involved.

If the actual time of year and day falls outside the framed area in Fig.2 (left) the intensity figure is set to 1 (none or weak migration). If it falls within the frame but outside the shaded area the predicted intensity is reduced by one unit. Within the shaded area the prediction based on the discriminant models is not modified at all.

The geographical distribution (Fig.2 right) is transformed to a grid with 252 points (Fig.1). For each grid-point and species a check is made to ascertain that the final intensity figure is not allowed to have a higher value than that given by the geographical distribution for the species concerned.

As a result, there is for each species and period of the day a matrix (consisting of values 1 to 4 at each grid-point) covering the whole area.

4. Resulting Map

The next step is to have a print-out of points, where the intensity is exceeding the threshold for a warning to be issued. The present threshold demands that at least one of the species in a group (sea birds, light birds, heavy birds) must reach intensity 3 before there will be a warning for that group and grid-point. The threshold can of course be changed at the customer request.

The final map (Fig.3) is drawn by hand using the outprint from the computer. The maximum altitude of bird migration, usually estimated from meteorological radars, is added to the bird migration forecasts. Four daily forecast maps for different times of the day are then distributed.

Especially the military pilots are using the information when making their flight planning. The Swedish Air Force has decided that the pilots are not allowed to cross an area with warning without special reasons. As the squadrons are making much of the planning one day in advance it is of course of greatest interest to them that the preliminary bird forecast is as reliable as possible.

5. Evaluation

After two test periods an extensive evaluation has been made. Some of the results will be presented here. The total amount of warnings issued during the autumn in 1978 can be seen in Fig. 4. The warning threshold used in 1977 was much lower and therefore too many warnings were issued.

The differences between preliminary and final forecasts in 1978 are presented in Fig.5. These differences are of course due to errors in predicting the different weather parameters for the preliminary forecast. In that respect 1977 and 1978 are very much alike. The preliminary bird migration forecast is mainly based on 24 hours weather forecasts. Fig.6 a-d shows these errors in weather predictions and also means and standard deviations. The x-axis in all diagrams is 'observation' minus 'forecast'.

Naturally the most interesting question is: How accurate is the bird forecast? The only place where, at the moment, a relevant evaluation can be done is at Falsterbo, where the final forecast has been compared with actual visual countings (Fig.7). For this comparison, the threshold used in 1978 has been applied to the 1977 data.

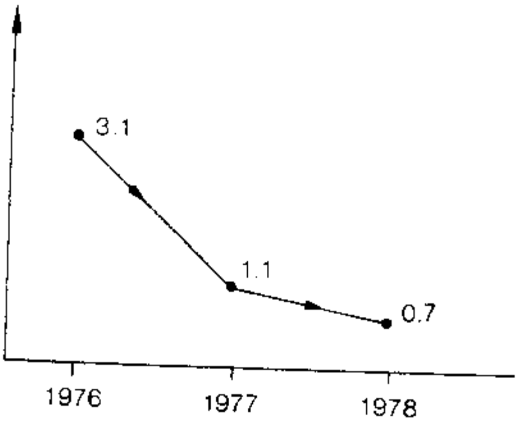
An interesting question is: If we compare predictions from the bird migration forecast system with random distribution of the warnings issued, what would the result be? This is the answer (random figures within brackets).

1977+1978	Sea	Light	Heavy
Forecast correct (%)	61 (49)	70 (61)	82 (53)
Warning unnecessary (%)	25 (3[illegible])	14 (19)	6 (21)
Warning missed (%)	14 (20)	16 (21)	12 (27)

In all cases the forecast is better than random but the differences are rather small for the sea and light groups. The sea bird data from Falsterbo used in the discriminant analyses are, however, not completely reliable because most sea-bird migration takes place far south of the counting site. Within the light group two species show very poor results and disturb the result of the whole group. Plans to attain higher accuracy especially for these two groups are presented below.

Evaluation of bird strikes with damage to the aircraft in the Air Force from July to December during the last three years gives a rather positive trend. (The warning system was introduced in 1977.)

Number of strikes with damage/10.000 movements
(July - December)



Future Work and Improvement

The present bird forecast system will run for at least another three years. After that the Air Force will decide whether the system will be permanent or not. Within two years we intend to introduce a limited spring migration forecast model.

Possibilities and need to extend the forecast area to the northern part of the country will be investigated. Already this year we are brushing up the sea bird model by using more representative countings from the east coast of Sweden. At the same time the number of sea bird species will be increased. We also intend to take a closer look at the weather parameters and try to improve the existing model especially for the light species and also for some of the heavy species.

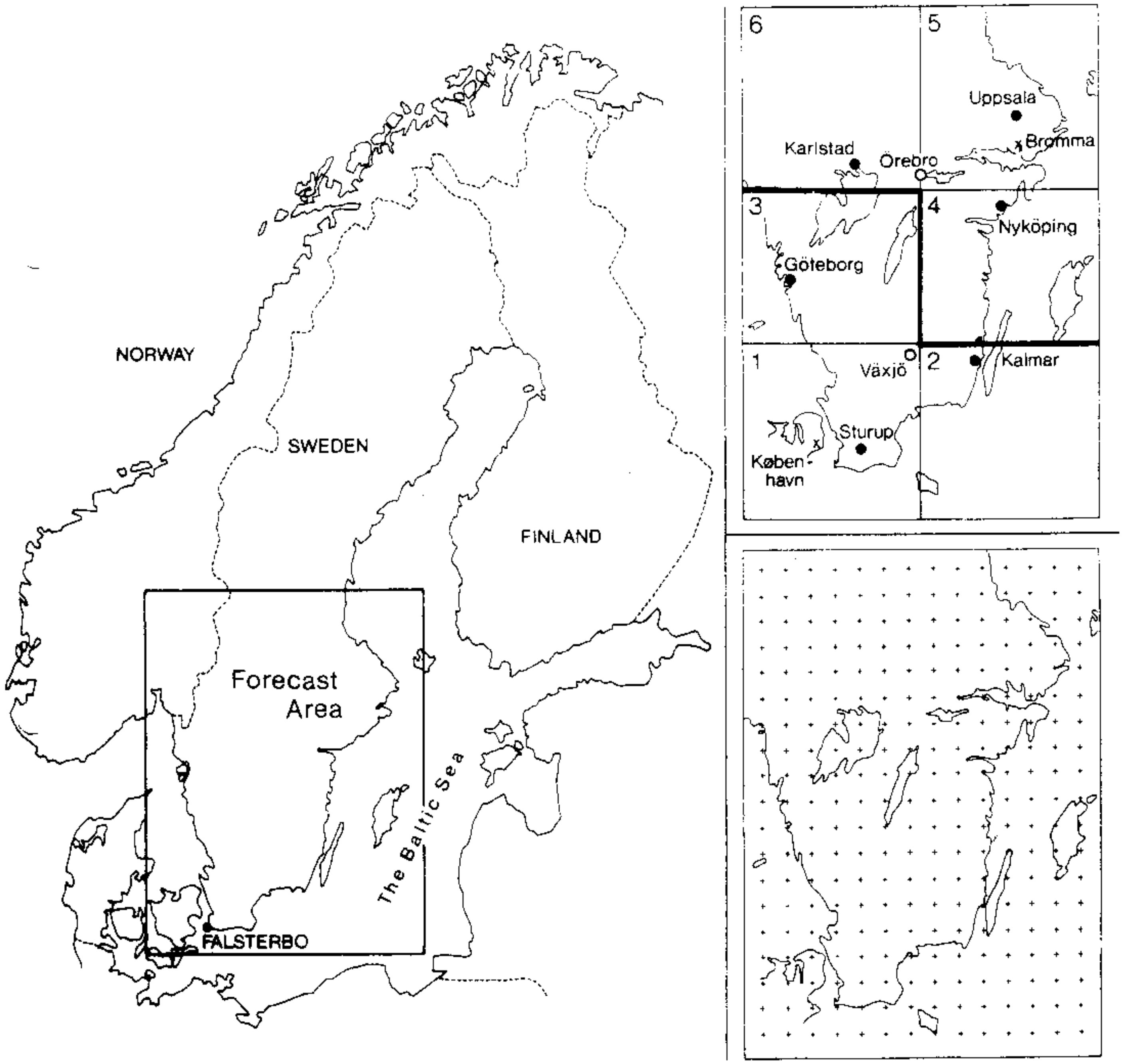
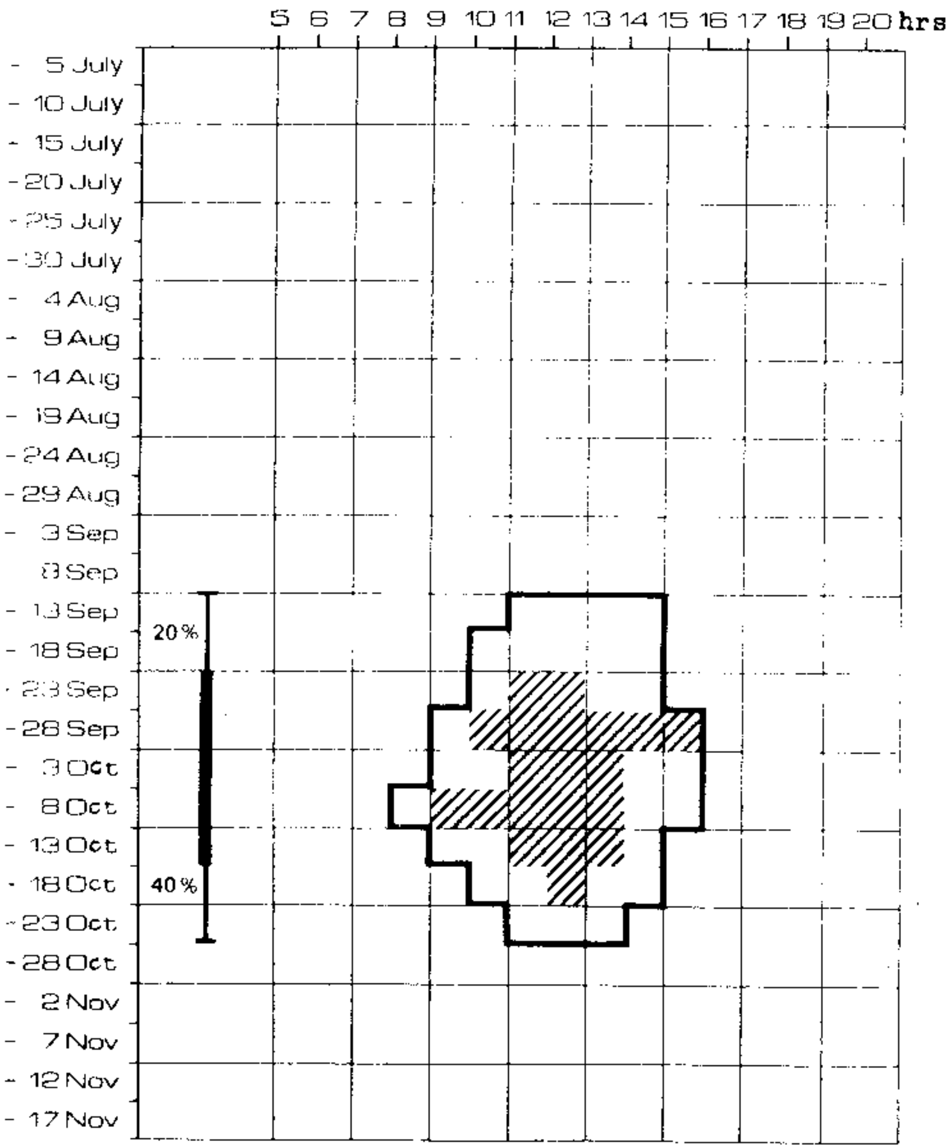
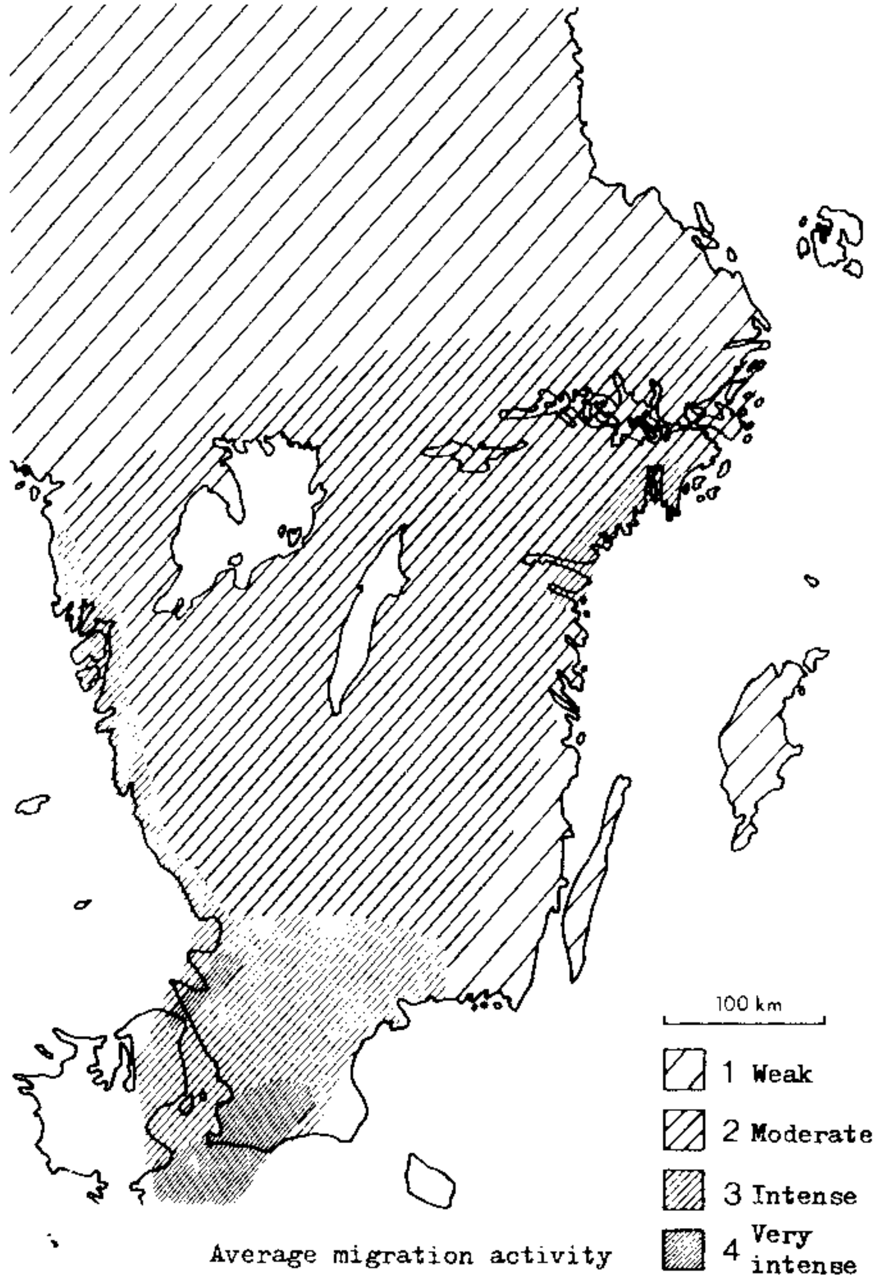

NORWAY
SWEDEN
FINLAND
Forecast
Area
FALSTERBO
The Baltic Sea
6
5
Uppsala
Bromma
Karlstad
Örebro
3
4
Nyköping
Göteborg
1
Växjö
2
Kalmar
Sturup
Køben-
havn

Fig. 1

Buzzard



Framed area = moderate/intense migration
Shaded area = very intense migration



Average migration activity

Fig. 2

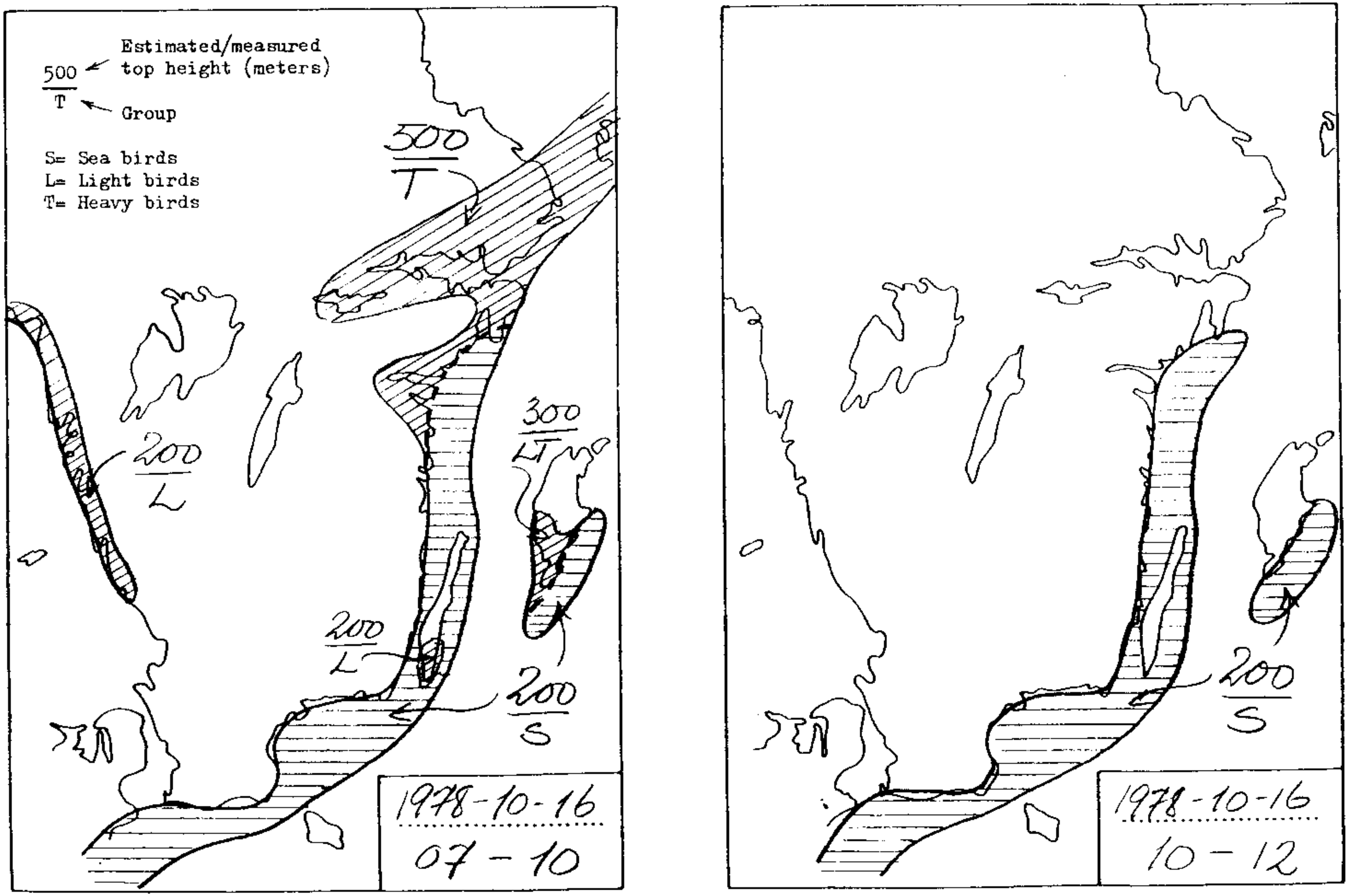

500 / T
Estimated/measured top height (meters)
Group
S= Sea birds
L= Light birds
T= Heavy birds
500 / T
200 / L
300 / LT
200 / L
200 / S
1978-10-16
07 - 10
200 / S
1978-10-16
10 - 12

Fig. 3

NUMBER OF DAYS WITH WARNING (%) 1978

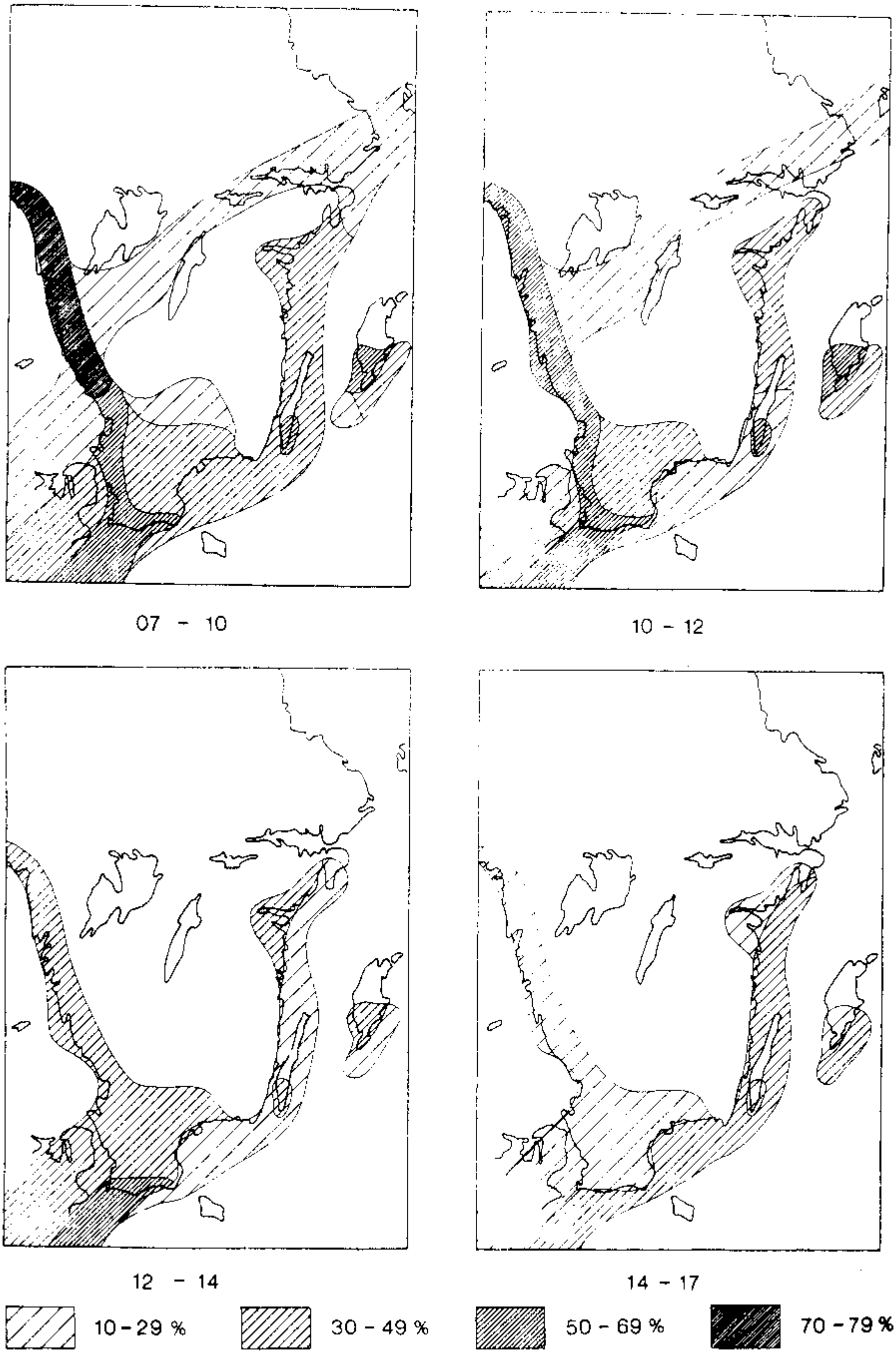


Fig 4

DIFFERENCES BETWEEN PRELIMINARY AND FINAL FORECAST

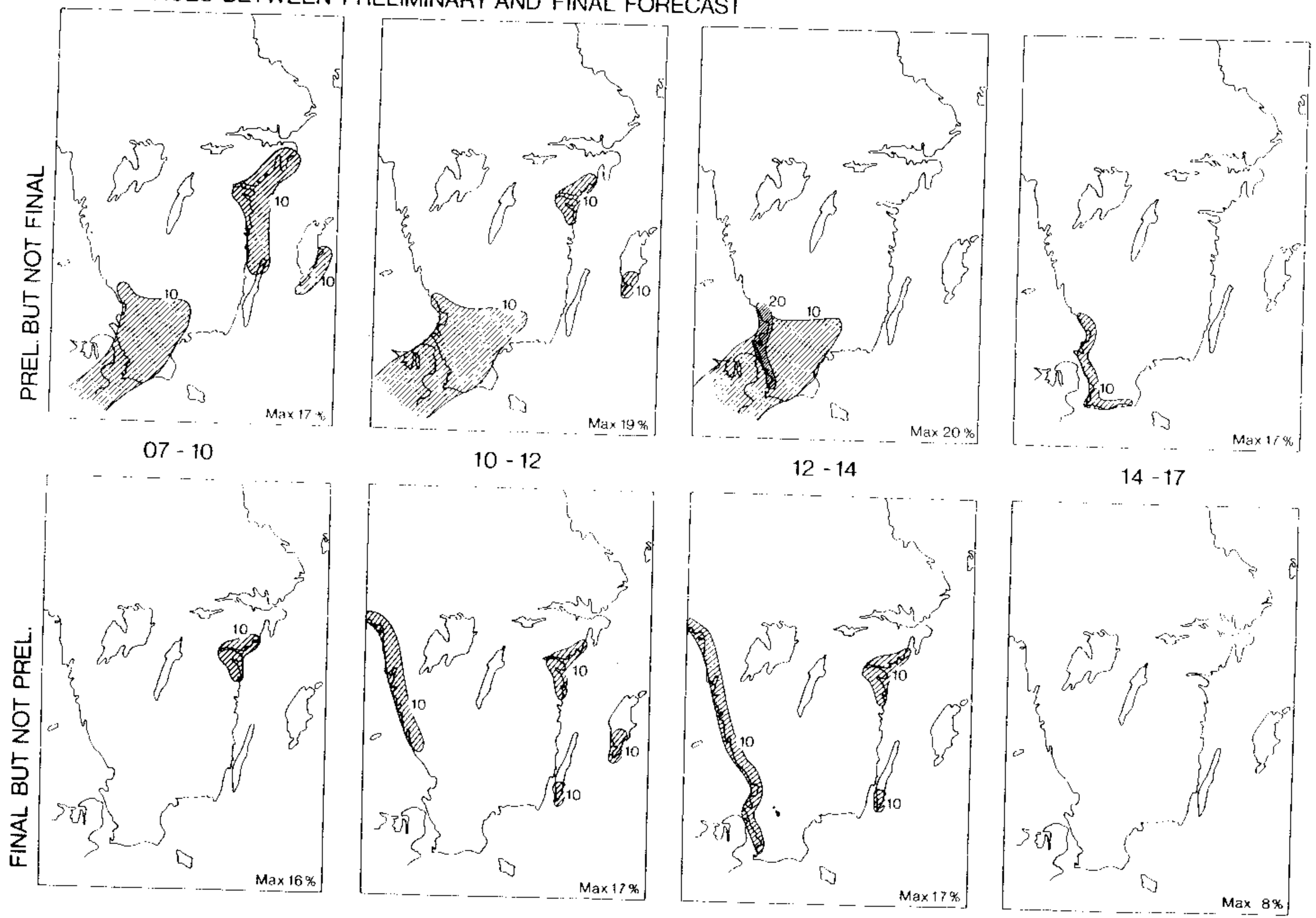


Fig. 5

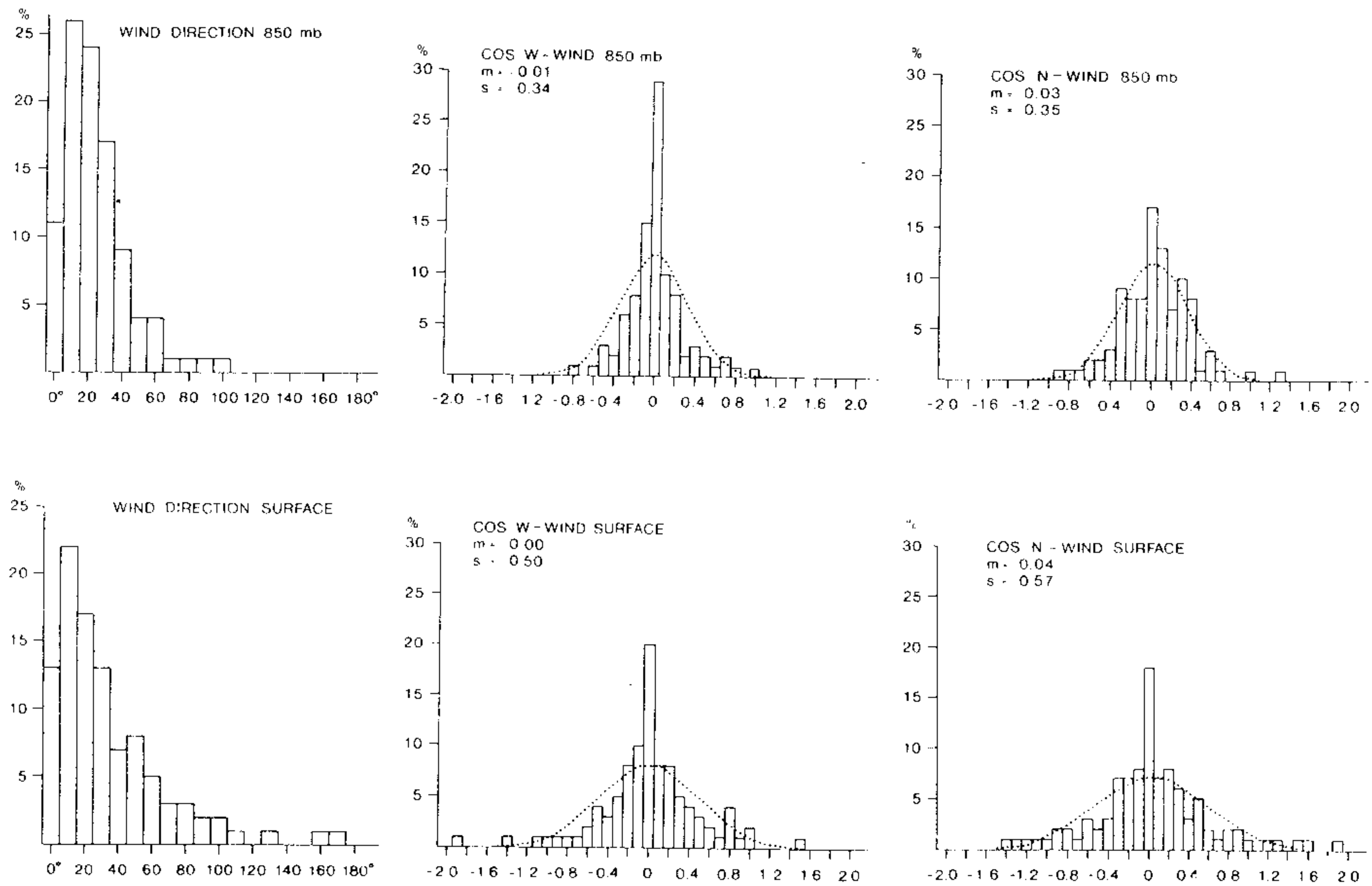

WIND DIRECTION 850 mb
COS W-WIND 850 mb
m = 0.01
s = 0.34
COS N-WIND 850 mb
m = 0.03
s = 0.35
WIND DIRECTION SURFACE
COS W-WIND SURFACE
m = 0.00
s = 0.50
COS N-WIND SURFACE
m = 0.04
s = 0.57

Fig. 6a

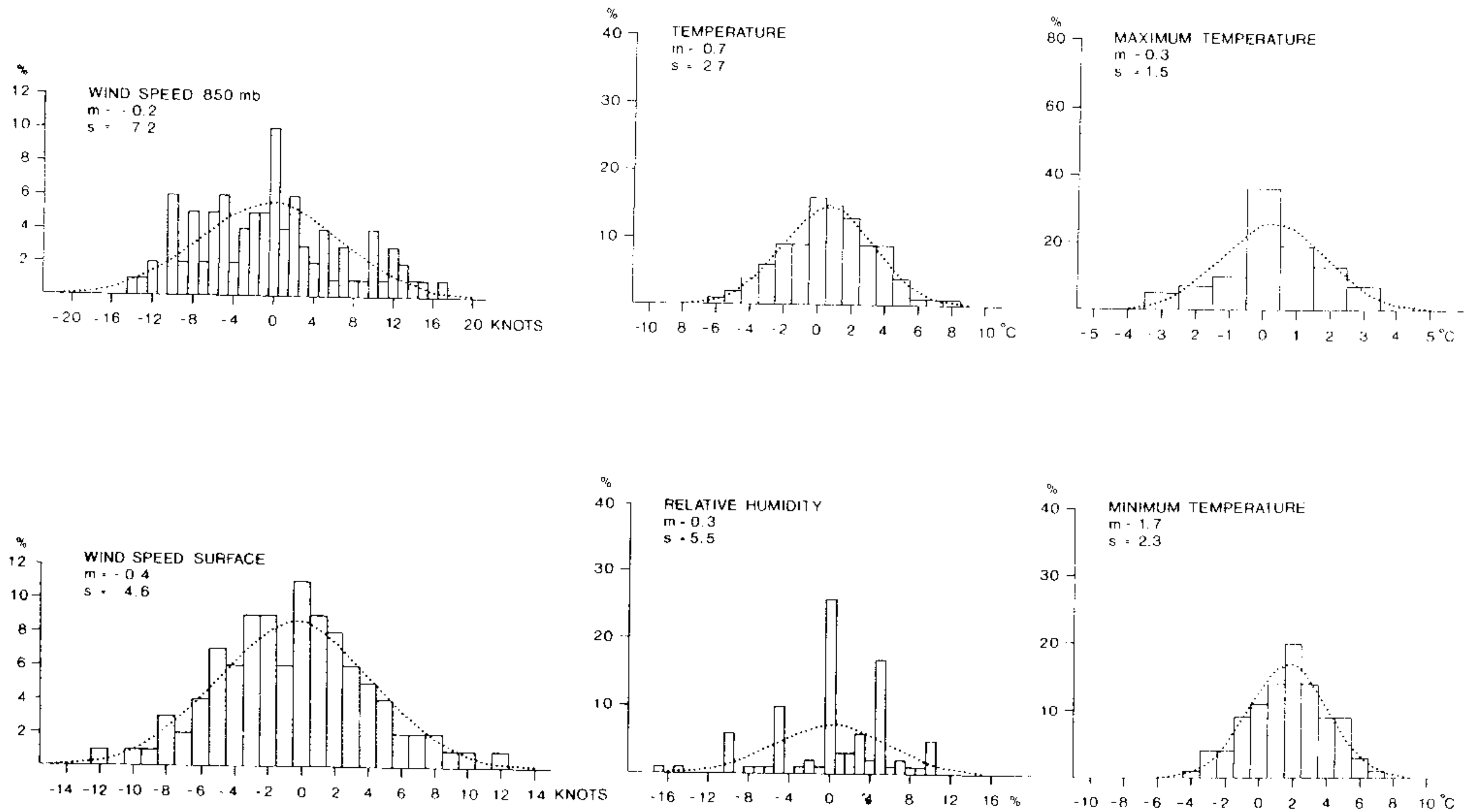

WIND SPEED 850 mb
m = -0.2
s = 7.2
%
KNOTS
TEMPERATURE
m = 0.7
s = 2.7
°C
MAXIMUM TEMPERATURE
m = 0.3
s = 1.5
5 °C
WIND SPEED SURFACE
m = -0.4
s = 4.6
14 KNOTS
RELATIVE HUMIDITY
m = 0.3
s = 5.5
MINIMUM TEMPERATURE
m = 1.7
s = 2.3
10 °C

Fig. 6 b

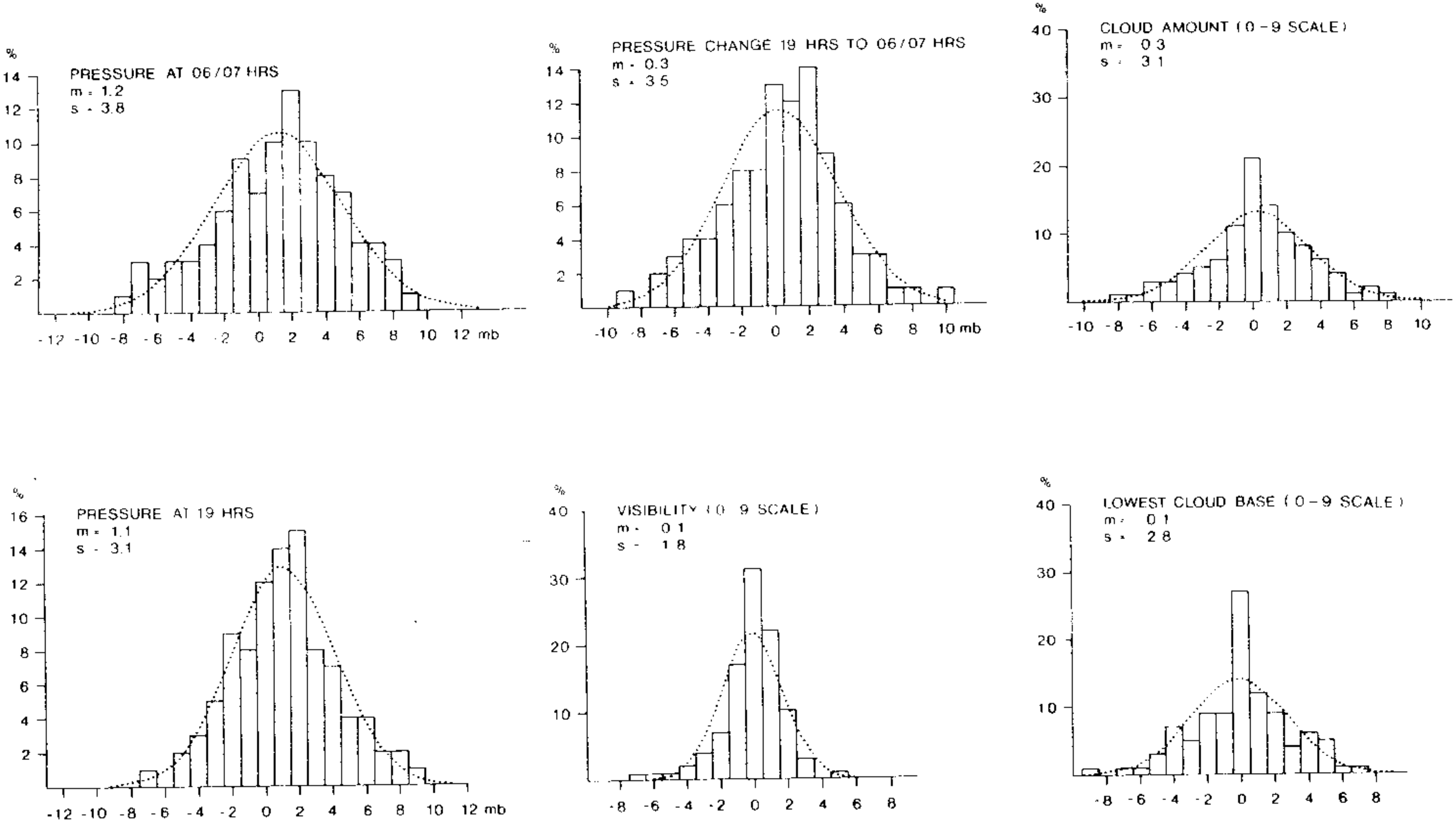

PRESSURE AT 06/07 HRS
m = 1.2
s = 3.8
PRESSURE CHANGE 19 HRS TO 06/07 HRS
m = 0.3
s = 3.5
CLOUD AMOUNT (0 – 9 SCALE)
m = 0.3
s = 3.1
PRESSURE AT 19 HRS
m = 1.1
s = 3.1
VISIBILITY (0 – 9 SCALE)
m = 0.1
s = 1.8
LOWEST CLOUD BASE (0 – 9 SCALE)
m = 0.1
s = 2.8
%
mb

Fig. 6 c

PRESENT WEATHER

PREL \ FINAL	0	1	2
0	78	0	6
1	5	0	0
2	7	0	3

PAST WEATHER

PREL \ FINAL	0	1	2
0	57	4	6
1	11	4	3
2	5	2	7

0 NO PRECIPITATION
1 SHOWERS
2 RAIN, DRIZZLE

CONVECTIVE CLOUDS

PREL \ FINAL	0	1
0	43	15
1	19	23

0 NO CONVECTIVE CLOUDS
1 CONVECTIVE CLOUDS

Fig. 6 d

```
      DAY NO   1   5   10   15   20   25   30   35   40   45   50   55   60   65
      SEA      0+++-00+ +000 -  +++ + --0-0 -00+ +-0000    0++-+00+000+ + --  -
1977  LIGHT    -000- 00000000000+00 00 0+++-0-00++0000 0000-0 +0+-0+00-0  00 0-
      HEAVY              000-000000 0 000000000   00-0 -00000+0000000---0 +0 00+
```

0=WARNING CORRECT +=WARNING UNNECESSARY -=WARNING MISSED

	SEA	LIGHT	HEAVY
WARNING NECESSARY %	48	72	68
WARNING ISSUED %	57	74	63
FORECAST CORRECT %	57	74	86
WARNING UNNECESSARY %	26	14	5
WARNING MISSED %	17	12	9

```
      DAY NO   1   5   10   15   20   25   30   35   40   45   50   55   60   65   70
      SEA      0++++0+++ 0      ++- +++ -  -0-000-00++      +00+00000000+   --0 -
1978  LIGHT    00-0000-0 00000+0-0++000++0000000000000--0++0 00-+0+ 00-+0-  0------
      HEAVY          +0 0-00+ 0-0-+00-0+00+  00000000  0000 00-00 000-0--000  -    -
```

0=WARNING CORRECT +=WARNING UNNECESSARY -=WARNING MISSED

	SEA	LIGHT	HEAVY
WARNING NECESSARY %	40	76	63
WARNING ISSUED %	53	70	56
FORECAST CORRECT %	64	66	79
WARNING UNNECESSARY %	24	14	7
WARNING MISSED %	11	20	14

MEAN 1977+1978

	SEA	LIGHT	HEAVY
WARNING NECESSARY %	44	74	65
WARNING ISSUED %	55	72	59
FORECAST CORRECT %	61	70	82
WARNING UNNECESSARY %	25	14	6
WARNING MISSED %	14	16	12

Fig. 7