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AVIATION SIGNIFICANT WEATHER CHARTS, DERIVED FROM 10-LEVEL MODEL FORECAST DATA.

P.G.Wickham and S.K.Rich

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AVIATION SIGNIFICANT WEATHER CHARTS, DERIVED FROM 10-LEVEL MODEL FORECAST DATA.

by P. G.Wickham and S.K.Rich

INTRODUCTION

This is a report on an investigation, carried out between November 1975 and February 1976, into the extent to which forecast data from the 10-level model (coarse-mesh, octagon, version) might be used to produce high-level significant weather charts automatically.

The aim of the project was not to produce an operational system in any particular respect, but simply to have a preliminary look at the problems in their broadest terms; to get a 'feel' for what is possible and where some of the problems lie.

Forecast charts were produced routinely over a period of two months in January/February 1976 and some examples are included, but the forecasts have not been verified against any actual observations.

Operational significant weather charts. Those currently supplied to aircrew

(1) refer to levels above 400mb

(2) refer to a time-span ± 6 hours about the nominal forecast time

(3) "significant" weather is defined broadly as weather which could have a hazardous effect on airfraft in flight, namely:

Moderate or severe turbulence
Moderate or severe icing
Freezing rain
Hail
Thunder/lightning
Tropical storms
Sand storms

(4) in addition the charts normally display the locations of

Major surface pressure centres (with central pressure and expected movement)
Surface fronts (with expected movement)
Jet-stream axes
Areas of Cb cloud (with depth) and frontal cloud, dense enough to produce severe icing.

The numerical data used have been (T+24) forecasts from the octagon (grid-length=300km near the North Pole). This simulates a forecast chart valid between 18-30 hours after the data time.

The data items available from the numerical model above 400mb are as follows:

mb	Winds	Vert.Vel.	Thickness	HMR
100	$u_{100}v_{100}$			
150		ω_{150}	h'_{150}	
200	$u_{200}v_{200}$			
250		ω_{250}	h'_{250}	
300	$u_{300}v_{300}$			
350		ω_{350}	h'_{350}	r_{350}
400	$u_{400}v_{400}$			

Winds at 400, 300, 200mb were used for the display of jet-streams and turbulence. r_{350} and h'_{350} for icing. Horizontal and vertical derivatives of u, v, ω were also used for turbulence. In addition, the surface pressure was computed from h_{1000} and h'_{950}.

METEOROLOGICAL ELEMENTS PLOTTED ON THE FORECAST CHARTS.

Surface pressure centres

A high (or low) pressure centre is identified where a maximum (or minimum) pressure value occurs at the middle point of a 5x5 array of grid-point pressure

- 2a -

INSERT

By these means nearly all the minor highs and lows which occur around the boundaries and in broad areas of rather uniform pressure were rejected. Conversely, a number of lows were discarded which probably should not have been. A threshold of $p_{min} \leq 1010$mb would be worth trying, coupled with a test to discard the higher of two low centres that are identified within 5 grid-lengths of each other.

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Thus no centres are identified in the outermost two rows of grid-points of the octagon area. Also, highs are only considered significant if $p_{max} \geq 1025$mb and lows only if $p_{min} \leq 1005$mb. A further device for discarding superfluous centres is to reject the one with the lower pressure where two high pressure centres are identified within 5 grid-lengths (1500km) of each other.

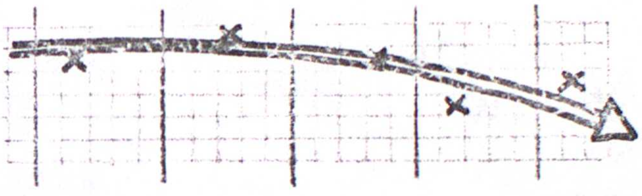
The average number of pressure centres plotted on each chart was 15, which seemed the optimum number if the chart is not to become over-cluttered with unimportant detail. One of the practical difficulties met in automatic chart presentation is the over-writing of symbols of various kinds. It is advisable that less important parameters (such as surface pressure centres) be restricted to a minimum.

No attempt was made to evaluate the forecast movement of the surface pressure centres. Past experience within the Branch has shown that with data only available at 6-hourly intervals, the unambiguous identification of a given pressure centre from one data-set to the next is difficult. With hourly data-sets the problem becomes soluble.

Jet-streams

The largest amount of effort in the project was directed towards this item. The essence of the exercise is to draw a smooth curve (representing the jet axis) through the general line of wind-speed maxima given by the forecast grid-point values, where the latter are not completely smooth but exhibit a certain amount of noise or roughness.

Initially only the forecast wind field at 300mb was used for identifying the jets, but later the 400, 300, 200mb levels were all used. A lower speed limit of 45 m/s was the normal criterion for a grid-point wind to be included in a jet-stream.



The basis of the technique used for drawing the jet-stream axes was a simple procedure which works well in the normal case of an elongated jet with small curvature, but which was found to be unable to cope with some rare, complex patterns. After identifying the elongated jet area, it is split into segments and a smooth (double-lined) curve drawn through the wind maxima in each segment. By inspecting the wind-directions an arrow head is added to the down-wind end of the curve. Local maximum wind speeds are entered in small boxes every 1800km along the curve.

Practical problems encountered:

(a) Very long jets.

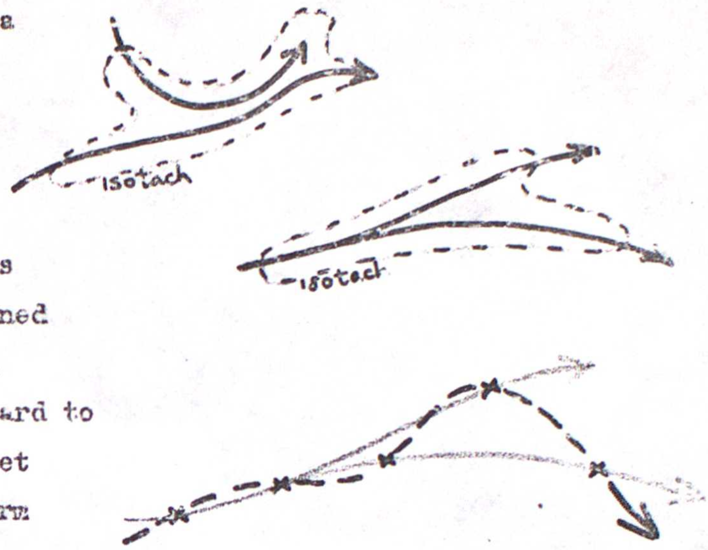
It was frequently found that jets extending over 30 grid-lengths (9000km) occurred in the Asiatic/Pacific sector of the chart. With these features there is difficulty in eliminating wobbles in the drawing of the jet axis, while at the same time including synoptically significant features of a similar scale.

(b) Short jets.

A jet was normally taken to be a significant feature if it occupied at least 12 grid points (each of the 12 being contiguous with at least one other. The whole pattern may be a regular 3 x 4, or something very irregular in shape). Smaller jets that were located near the U.K. were also included, but a difficulty with these was to satisfactorily identify the minimum number of 3 points along the short jet axis which was required by the curve-drawing routine. The resulting jets were normally unnaturally straight, or sometimes incorrectly curved.

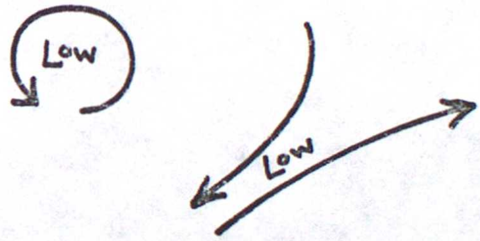
(c) Abnormally shaped jets.

Although the majority of jets fall into the standard elongated pattern there are many variations from this. Some of these seem likely to be difficult to handle even with a more sophisticated system than that used in this project. Probably the most important, and the most difficult, is a double-jet pattern. This may take the form of a confluence of two jets, possibly at different levels (e.g. polar jet and sub-tropical jet) or it may be a bifurcated pattern.



In these cases, unless the two arms of the jets can be unambiguously defined (either by their levels or their wind directions) it was found to be very hard to avoid absurd drawings in which the jet axis is shown to oscillate from one arm of the jet to the other.

Other variations from the standard pattern, which caused some difficulties in analysis, were an occasional quasi-circular jet around a cut-off cyclonic centre or the more usual, sharp V-shape pattern which occurs when both arms of the flow around an upper trough (or ridge) are equally strong.



Airframe icing.

The symbol ψ is used to signify a high risk of airframe icing at forecast grid-points where high relative humidity is coupled with a temperature in the range 0° to -40°C.

In the 10-level model, there is only one layer above 400mb which contains moisture (350mb). The particular values used for plotting the icing symbol were:

$$h'_{350} > 2020\text{m} \quad \text{(corresponding to a temperature warmer than } -33^\circ\text{C)}$$

$$RH_{350} \geq 95\%$$

No verifications were made on the accuracy of the forecasts. And since in January - February it is very rare to have temperatures warmer than -40°C in polar air-masses at levels above 400mb, nearly all the forecast icing symbols occurred in latitudes south of 40°N. So even to check the synoptic reasonableness of the forecasts was difficult.

The particular values of the icing discriminators were chosen mainly with a view to limiting the extent of the icing areas and minimising the amount of over-printing with other symbols.

Clear Air Turbulence

A brief attempt was made to utilise some 'empirical formulae' which have been devised in Met.O.9 for forecasting CAT using numerical date derived from early versions of the 10-level model. However, further informal contacts with Met.O.9 indicated that the current formulation of the model did not produce comparably good results. With this information it did not seem worthwhile pursuing the Met.O.9 approach and there was no time to embark on anything new.

The symbol ⎍ , to indicate CAT, has been plotted on our charts on the simple criterion:

Wind-speed $\geqslant$ 50 m/s at any grid-point which is not part of a jet-stream previously selected for display by the program.

Surface fronts

It was originally intended to utilise other work going on in the Branch to draw surface frontal positions on the significant weather charts. It was not possible to incorporate this feature in the time available.

SUMMARY

There are many problems, both of interpretation and presentation, which should be tackled before the current hand-drawn significant weather charts can be adequately reproduced by automatic methods.

Meteorological aspects.

Some features of a significant weather chart could be reasonably well represented by automatic means now - though with an unknown accuracy. For example: surface centres, jet streams.

Others could be added to this category, though the effort required might well be out of proportion to the results attainable - e.g. movement of pressure centres, fronts.

With further research some progress could be made towards the identification of areas of Cb, areas of CAT and areas of icing. It is difficult to assess how useful such forecasts would be, as derived from model data.

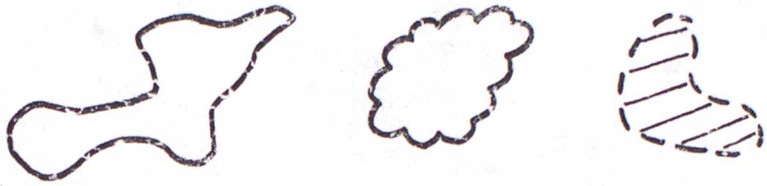
Other meteorological elements seem rather unlikely ever to be forecastable from 10-level model data (e.g. tropical storms, sand-storms) and there are others for which the prospect is only slightly less bleak (e.g. hail, thunder, freezing rain, distinguising moderate from severe intensities of icing or CAT).

Presentational aspects.

It needs only a little experience of this kind of work to convince one that the ability of the human brain to pick out the significant features from a number of more or less noisy patterns is extremely hard to match by automatic methods. And the standard of presentation achieved by subjective means is the standard which must be approached by objective techniques if their results are to carry conviction.

Among the problems which need tackling in the presentation of automatic charts (and which would require much effort for rather specialised returns) are:

1. Avoiding the overprinting of symbols and figures.
2. Drawing smooth lines which eliminate noise but preserve real short-wave features.
3. Recognising irregular (or discontinuous) areas of a certain type of weather and outlining (or shading) them in distinctive ways.



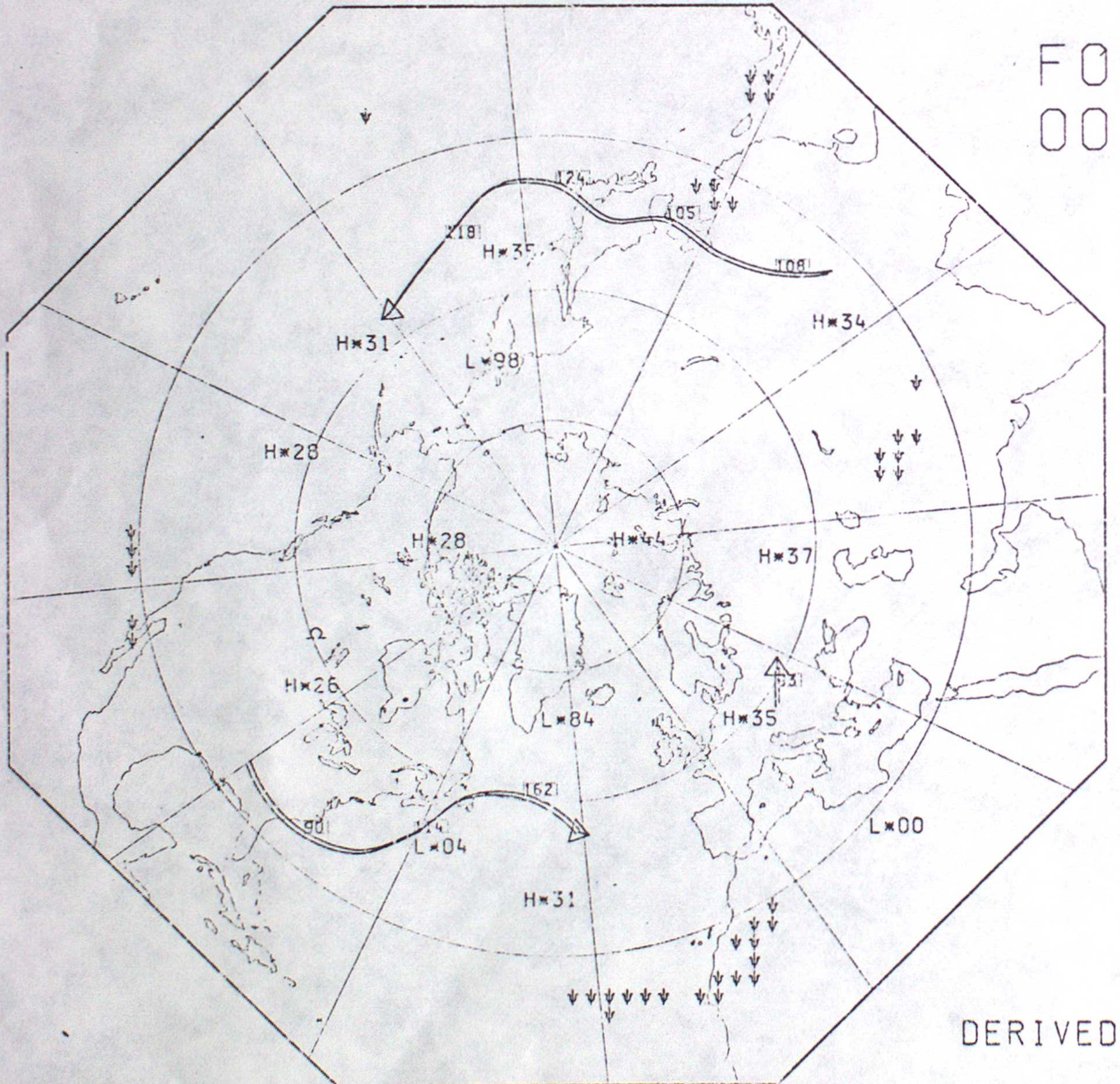
Diagrams

Four pairs of diagrams follow:-

In each pair (a) is a significant weather chart

(b) is a strealine chart (with a 45 m/s isotach included) for 300mb winds for comparison with the jet-streams drawn on the significant weather chart.

SIG WX CHART (400-150MB)



FORECAST FOR
00Z 11/3/76
(DATA TIME 00Z 10/3/76)

KEY	
L*92 H*36	SURFACE PRESSURE CENTRES
⟹	JETSTREAM IN DIRECTION OF ARROW. MAX-VEL IN KT.
↓	LIKELIHOOD OF AIRFRAME ICING
Ω	AREA OF CLEAR AIR TURBULENCE

Example of typical output, showing the standard currently attainable.

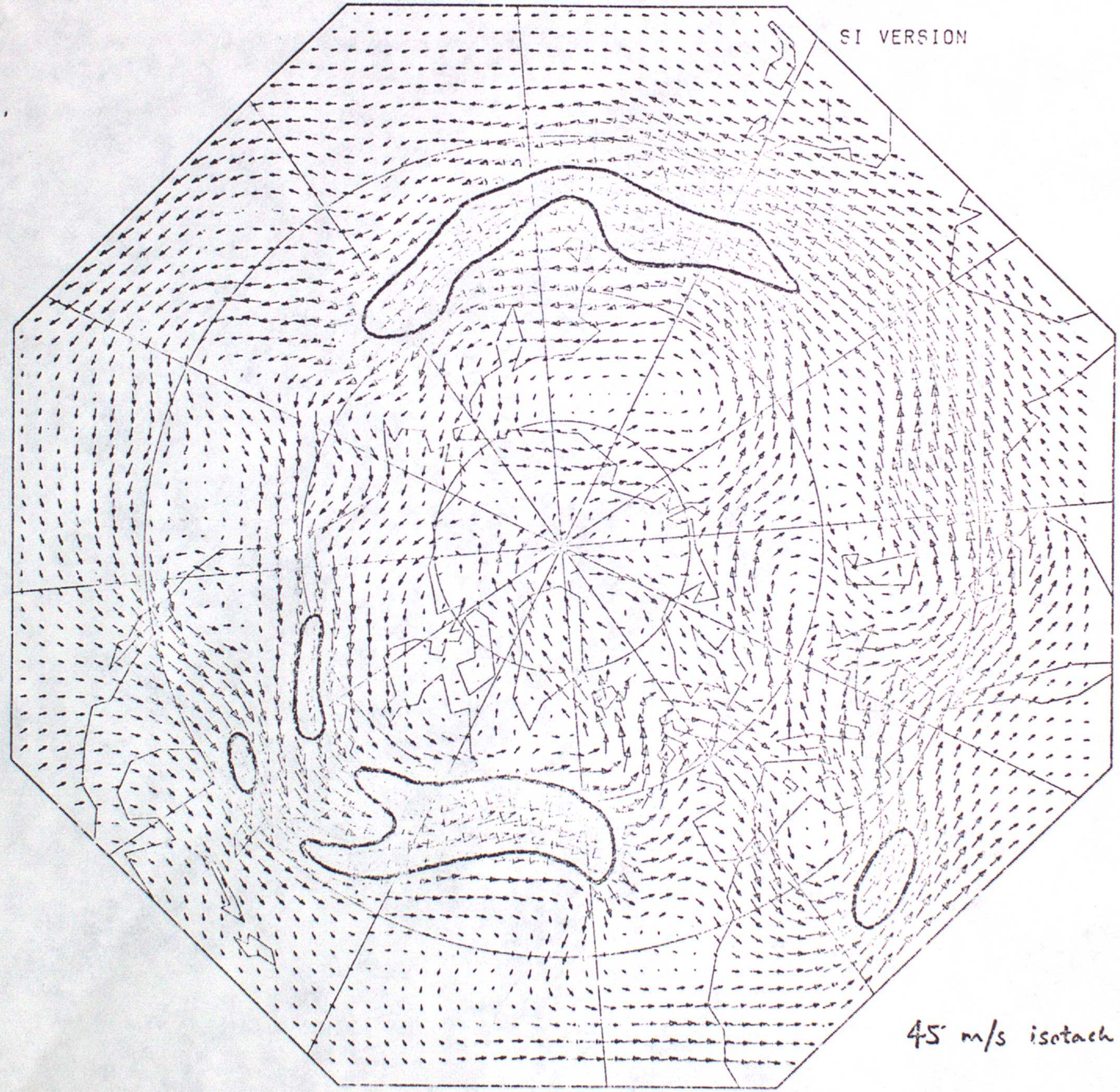
DERIVED FROM 10 LEVEL MODEL DATA

FIG: 1 (a)

300MB WIND DIRN

24 HR.FORECAST. DATA TIME 0 Z 10 / 3 / 76. VERIFICATION TIME 0 Z 11 / 3 / 76

SI VERSION

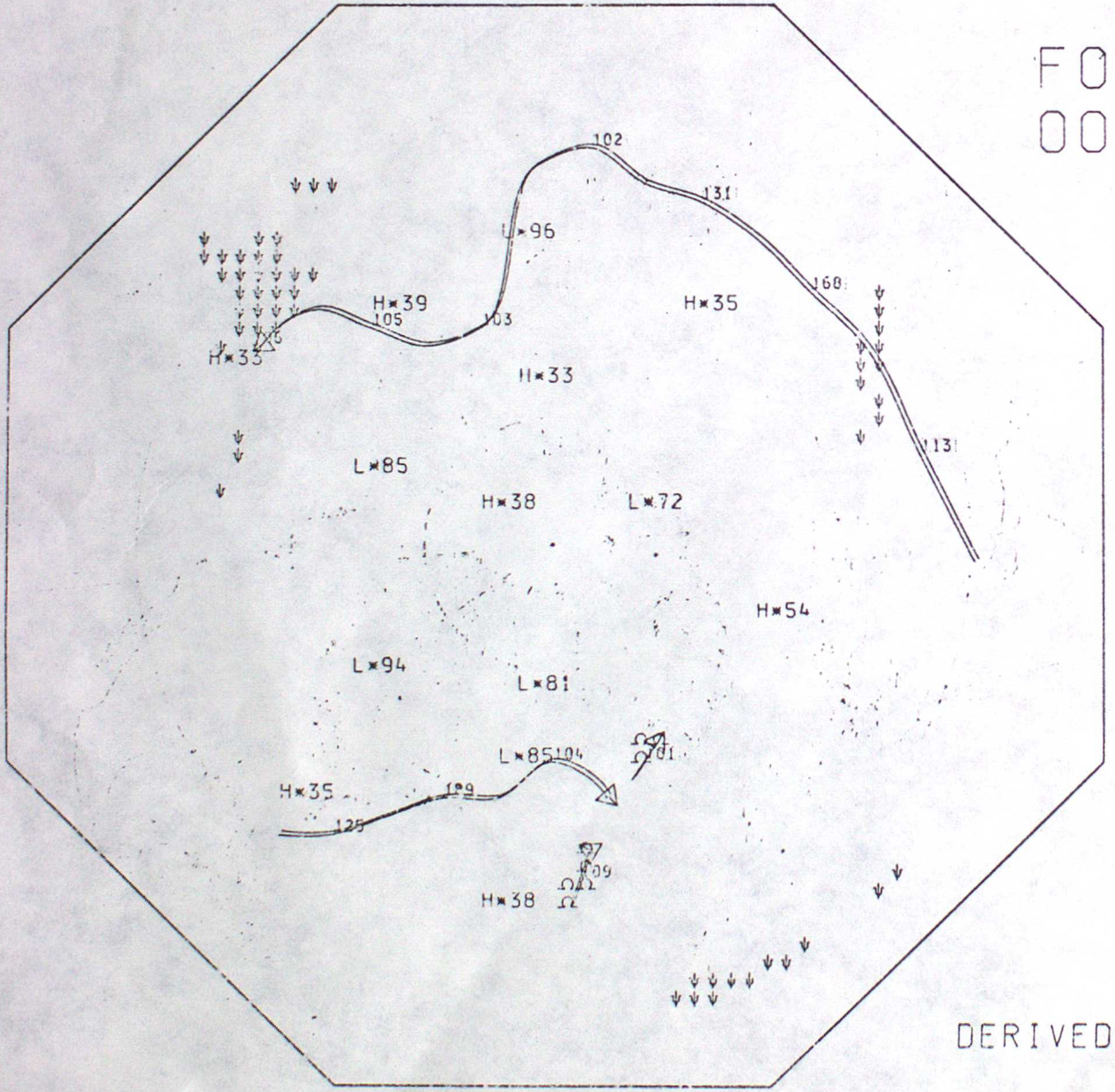


45 m/s isotach

FIG: 1 (b)

SIG WX CHART (400-150MB)

FORECAST FOR
00Z 24/2/76
(DATA TIME 00Z 23/2/76)



KEY

L*92
H*36 } SURFACE PRESSURE CENTRES

⟹ JETSTREAM IN DIRECTION OF ARROW. MAX-VEL IN KT.

↓ LIKELIHOOD OF AIRFRAME ICING

Ω AREA OF CLEAR AIR TURBULENCE

Example showing:
(a) Very long Asiatic-Pacific jet.
(b) Short jets near UK
(c) Some overprinting

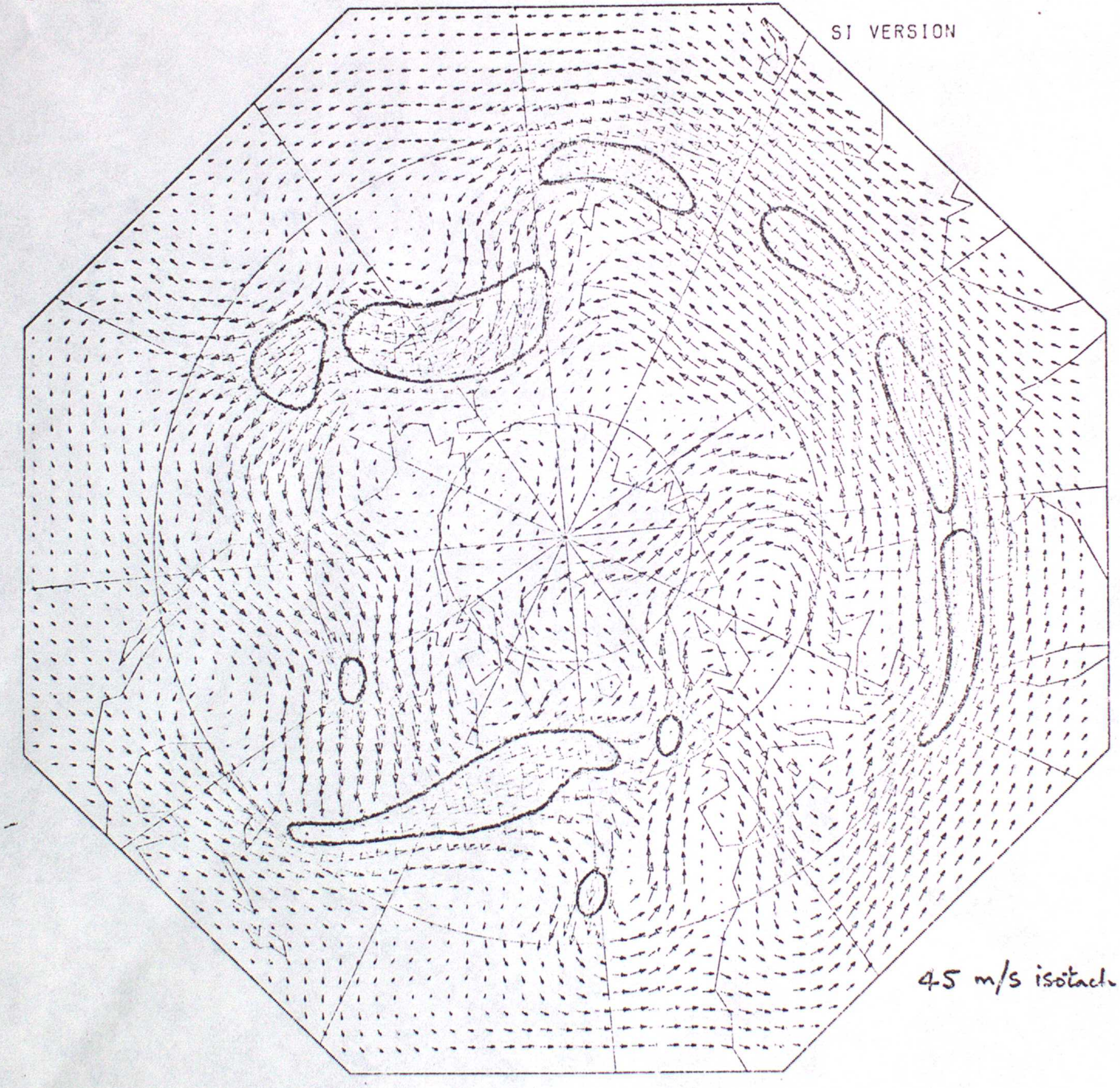
DERIVED FROM 10 LEVEL MODEL DATA

FIG: 2(a)

300MB WIND DIRN

24 HR.FORECAST. DATA TIME 0 Z 23 / 2 / 76. VERIFICATION TIME 0 Z 24 / 2 / 76

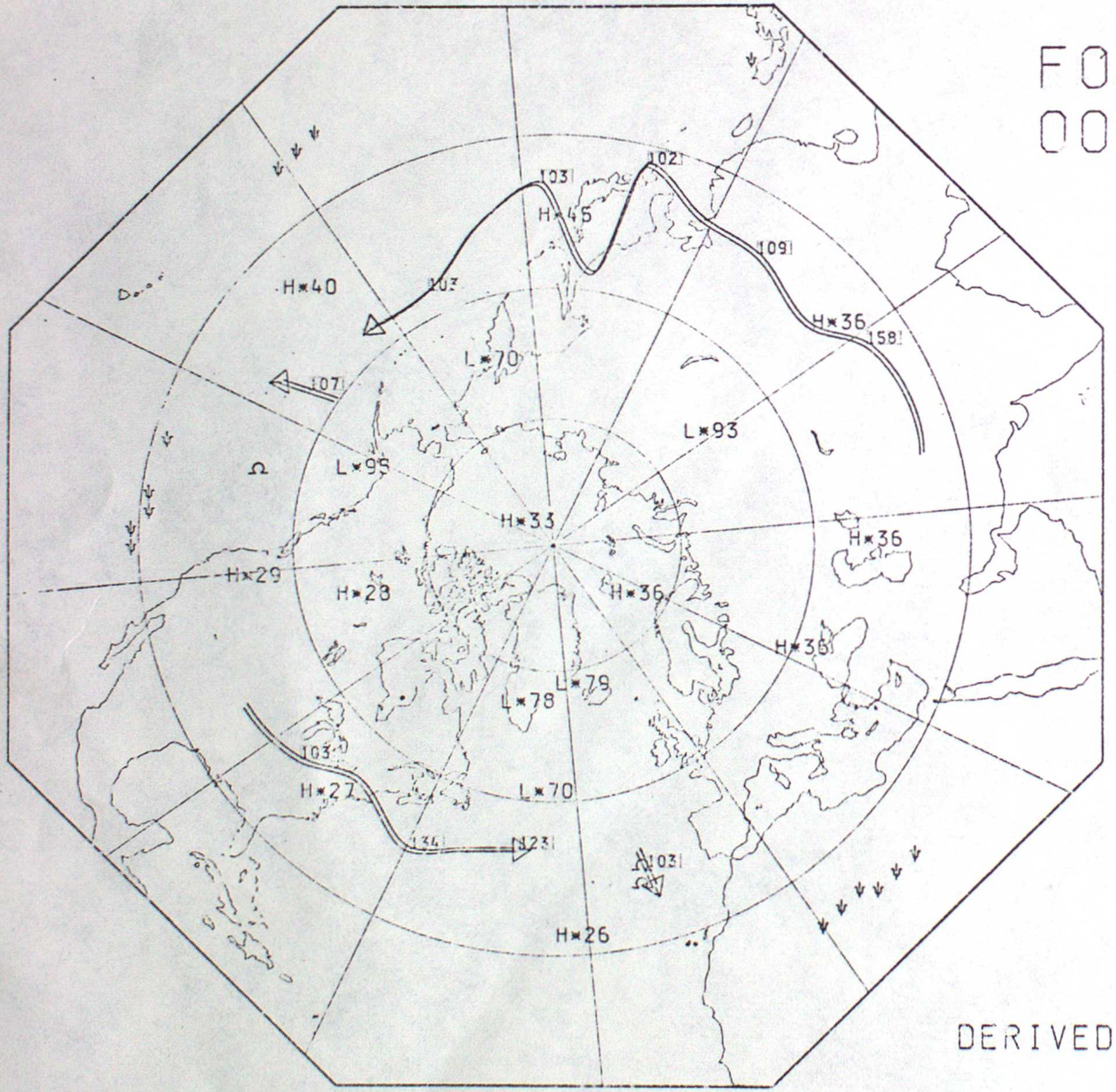
SI VERSION



45 m/s isotach

FIG: 2(b)

SIG WX CHART (400-150MB)



FORECAST FOR
00Z 21/2/76
(DATA TIME 00Z 20/2/76)

KEY

L*92 / H*36 } SURFACE PRESSURE CENTRES

⟹ JETSTREAM IN DIRECTION OF ARROW. MAX-VEL IN KT.

ψ LIKELIHOOD OF AIRFRAME ICING

Ω AREA OF CLEAR AIR TURBULENCE

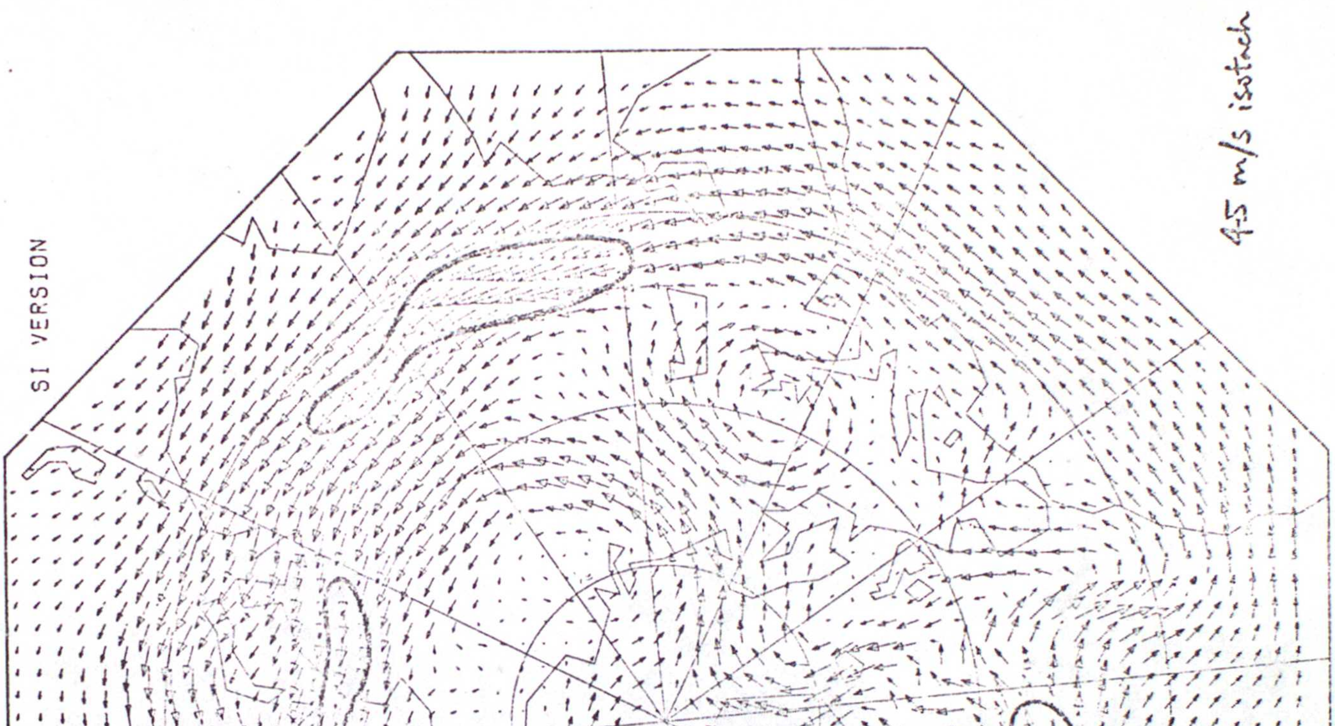
Example showing:

(a) Double jet over Japan, wrongly analysed

DERIVED FROM 10 LEVEL MODEL DATA

FIG: 3(a)

FIG: 3(b)



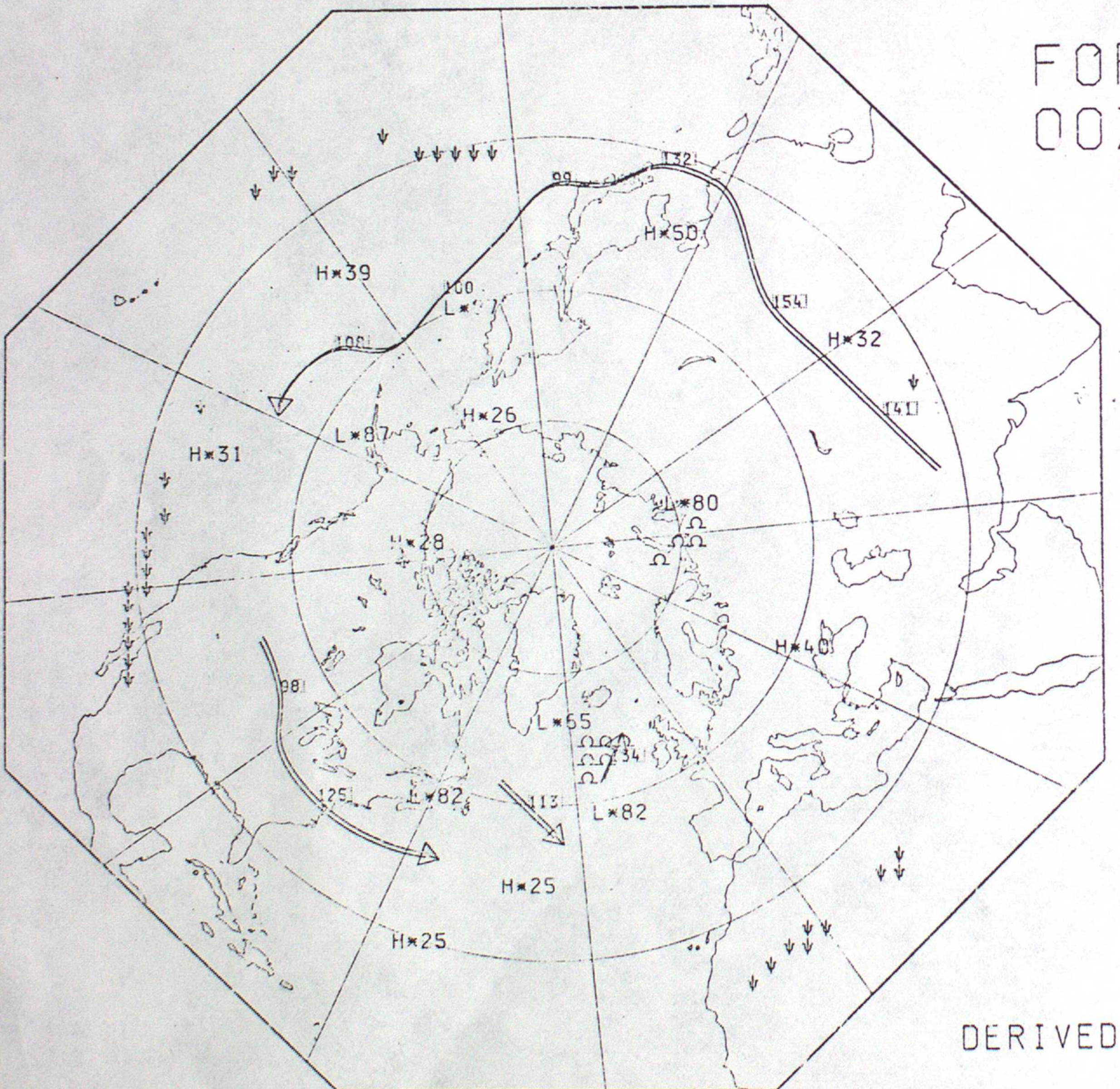
300MB WIND DIRN

24 HR.FORECAST. DATA TIME 0 Z 20 / 2 / 76. VERIFICATION TIME 0 Z 21 / 2 / 76

SI VERSION

SIG WX CHART (400-150MB.)

FORECAST FOR
00Z 20/2/76
(DATA TIME 00Z 19/2/76)



KEY

L*92
H*36 } SURFACE PRESSURE CENTRES

⟹ JETSTREAM IN DIRECTION OF ARROW. MAX-VEL IN KT.

ψ LIKELIHOOD OF AIRFRAME ICING

Ω AREA OF CLEAR AIR TURBULENCE

Example showing:
(a) Confusing jet pattern over Atlantic

DERIVED FROM 10 LEVEL MODEL DATA

FIG: 4(a)

300MB WIND DIRN

24 HR.FORECAST. DATA TIME 0 Z 19 / 2 / 76. VERIFICATION TIME 0 Z 20 / 2 / 76

SI VERSION

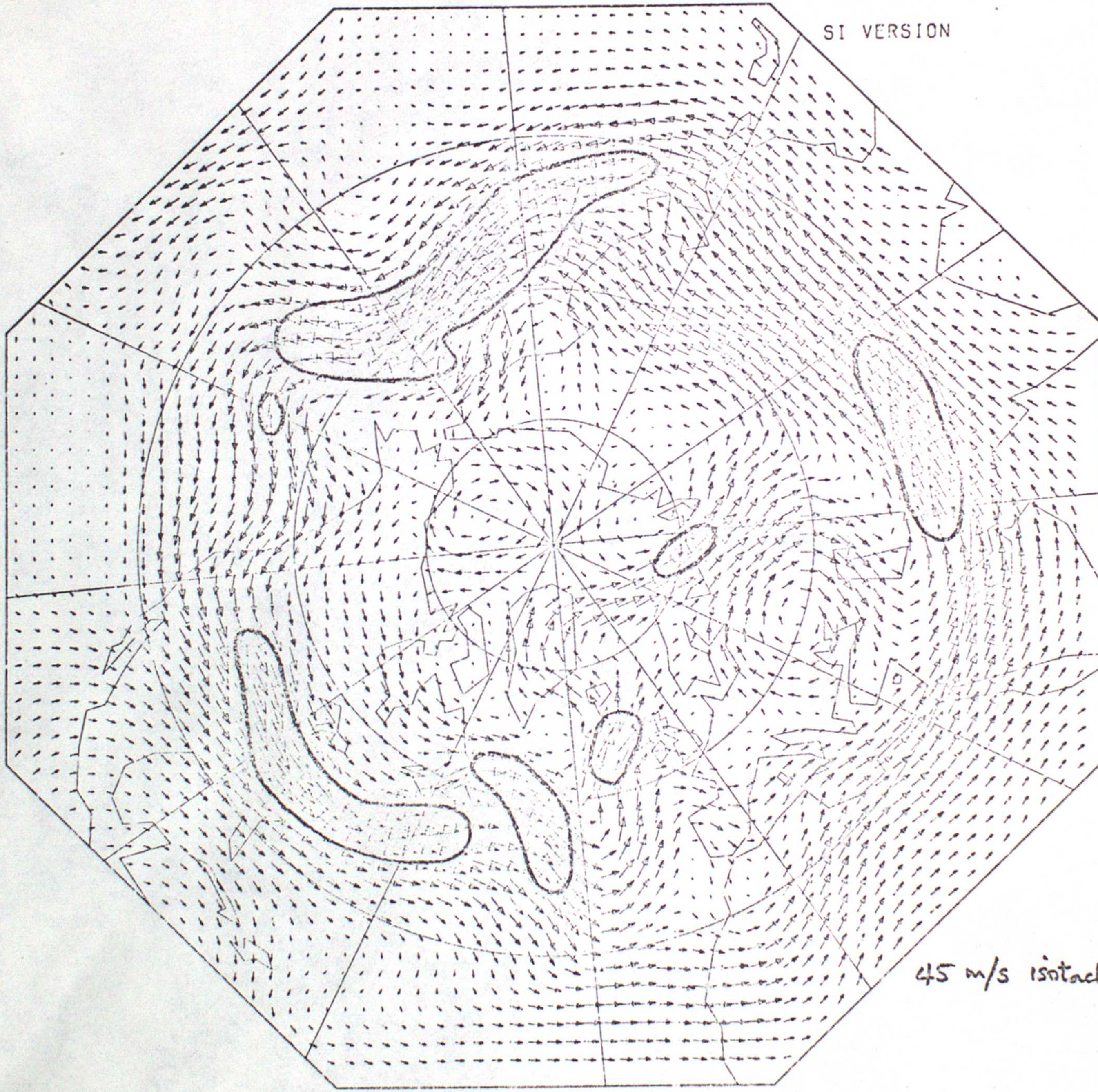


FIG: 4(b)