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Met O 11 Technical Note No 151

Some error statistics for ECMWF forecasts up to 7 days ahead (500mb Zonal and Meridional Indices, 850mb temperature and 1000mb height) - Part I : Winter 1980-1981.

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THE MET O 11 GRID CODE PROGRAM

Assessment of forecasts - ECMWF model.

HISTORY. As part of the synoptic assessments which have been carried out in Met O 11 since late 1979 a note has been made of the 500 mb Zonal and Meridional Indices (forecast and actual) over the UK. The temperatures at 850 mb over the Atlantic and sub-tropical highs were also noted as being too warm or cold. It was hoped to infer from these some general model behaviour as regards over or under-zonality and the boundary surface fluxes. With the advent of grid-code data it was thought that the above tasks could be computerised. This was done and the opportunity taken to expand the area over which the data are collected to points every 30° longitude round the N. Hemisphere. In the case of the M.I's and Z.I's error statistics were collected around latitudes 45° N, effectively giving information about the model's treatment of the wind flow between 40° and 50°N, and 50° and 60°N respectively; in the case of the 850 mb temperature (T850), values were again collected every 30° of longitude but at 30°, 40°, 50°, 60°, and 70°N. Errors in the 1000 mb heights were also included at the same points as T850. Verification values came from ECMWF's own analyses (in GRID code format).

Mean and RMS errors covering the period from late OCT 1980 to Mar 1981 have been produced for the ECMWF forecasts up to seven days ahead. They are here interpreted, again with a view to determining <u>gross</u> model characteristics and should be used in alliance with the synoptic assessments to give the lie or not to the inferences within.

ECMWF Error Statistics

Description and Interpretation of the Met O 11 program results:- ECMWF 7 day forecasts, Winter.

1. Zonal and Meridional Indices. (ZI & MI)

The Zonal Index for a point is defined as the difference in geopotential height between two latitudes spanning that point. W'ly flow is arbitrarily positive and the unit of measurement is geopotential decametres. The Meridional Index is defined as the difference in height between two longitudes, with S'ly flow positive. The width of the span is about 1100Km or 600 NM (equivalent to 10 degrees of latitude) e.g. for a point at 55N 00W the span was from 50°N to 60°N and from approx. 8½°E to 8½°W.

The program stores Z.I. & M.I. errors (differences of forecast from actual) every 30 degrees round latitudes 45°N & 55°N with a value in the Greenwich Meridian.

The purpose of storing Z.I & M.I values was to find out if the model jets were generally too strong or too weak.

Results for 116 days, Nov 1980 to Mar 1981.

Day 1 The means already show a slight tendency for the model to be too zonal, especially at 45°N, but the overall meridionality is about correct.

The worst points are at 90°E at 45°N and 120°E at 45°N and 55°N. Another poor point is in Alaska. Eastern America and the Atlantic fare relatively well in that the average error is small, but this seems to disguise some fluctuations in the forecasts as this is one of the poorer areas for RMS errors, the other being the South and East Pacific. Land area RMS errors are relatively low compared with sea area RMS errors.

Day 7 (c.f.FIG 1) The means by day 7 show a more definite pattern. The Atlantic and Pacific are too W'ly and N'ly, the American and Asian continents are not zonal enough and too S'ly. The overall effect is to produce an anomalous troughing over the seas and an anomalous ridging over the land. This wave pattern is similar to that generated by the T850 means (q.v) so that the model has warm ridges and cold troughs at wavenumber two.

In the RMS error field the worst areas forecast are again the sea areas, particularly in the south. The area over S. Russia and China which was poor at Day 1 has actually a lower mean error than on Day 1 and the RMS errors have grown more slowly than on most of the rest of the chart. This could reflect an initial adjustment by the model to the analysis round the Siberian anticyclone and then a maintenance of the model anticyclone with a small error throughout.

As we are talking about errors in zonal and meridional indices rather than errors in heights, we may infer some information directly about the wind flow. The error in the winds at 45°N (too Westerly) is 4 times as large as at 55°N. This implies that the jet stream has been moved too far south (probably by about 5 degrees). The pattern in the chart shows that this occurs almost entirely over the oceans. This could be caused by main depressions being steered too far south or from over-development of secondaries; the latter explanation could account for the extension of the anomalous zonality into the USA and Eurasia. (Upper trough over-extension S.E. into Europe has occasionally been noted in our weekly synoptic appraisal). As an example of the size of the effect let us look at the errors at 30°W. (c.f.Fig 2) at 45°N the worst error on the chart at Day 7 occurred. Deriving the wind from the Dec 1980 mean flow from ECMWF FORECAST REPORTS (held in Met O 11) the wind at 45°N 30°W was about 24029 (kt). Vectorial addition of the mean winter anomaly would give a model wind speed of about 25542, a significant veering and a large increase in speed. At 55° 30°W, the actual wind of about 25039 becomes about 25540, an insignificant difference at 7 days.

2. 1000mb height errors

The error is defined as the actual value minus the forecast value, so that (i) a positive anomaly means that pressure is too low, i.e. Depressions too deep or Highs not high enough.

(ii) a negative anomaly means that pressure is too high, i.e. Depressions not deep enough or Highs too high.

The 1000 mb height is recorded every 30 degrees of longitude starting at the Greenwich meridian, and every 10 degrees of latitude from 30°N to 70°N inclusive. Values are in geopotential decametres.

Results for 116 days from Nov 1980 to Mar 1981 (c.f. FIGS 3 &4)

The worst initial anomaly was near the Siberian anticyclone where the mean pressure forecast deteriorated till Day 2 (5 mb too low) then slowly improved. The rate of growth of RMS error showed the same pattern. This is similar behaviour to that noted for the zonal and meridional Indices near that area.

The positive (f/c low) maximum near Alaska persisted throughout and this was also an area of maximum RMS error. This area seemed to be a combination of two errors, one North of the Bering Sea at 70N where a High cell was forecast too low (as in Siberia) and one near Vancouver where lows were forecast too low.

The negative maximum over the N. Atlantic persisted throughout, and after Day 1 the Pacific followed suit by becoming increasingly negative, but in both cases the RMS values were relatively small.

A noteable feature was the growth of the maximum positive mean error and RMS error over N.W. Europe. By Day 7 this and the Alaskan area were the two areas worst forecast by the model.

Generally, forecast mean and RMS errors were small around 30 N and there was a small tendency with time to forecast this latitude too negative. Higher latitudes became generally positive.

The main stationary features (the Siberian anti-cyclone & the sub-tropical highs) are forecast well; as with the 'jets' (i.e. Z.I's & M.I's of section 1) there seems to be an initial model adjustment to the Siberian high, and thereafter a smaller, persistent error (forecast too low). The sub-tropical highs are forecast slightly too high generally, but the Pacific mean error grows to be 6 mb too high by Day 7.

The growth of errors over N.W. Europe could be linked to the 'jet' anomaly. I interpret this as due to either over-development of lows (possibly secondaries) by the model in the Eastern Atlantic or the model's tendency to take them too far south. The spread of the area to the north does betoken some element of over-development.

After two days pressure is forecast too high off the Eastern seaboard of America, seeming to imply that initial conditions give reasonable depth to lows at first, but when the model has to develop its own lows it does not do so quickly enough or does them too weakly. The similar pattern covering the other area of worst forecast over the Pacific and N.W. America can be given the same explanation.

3. Temperature errors at 850 mb.

Again, the error is defined as actual value minus forecast value, so that (i) a negative anomaly means temperature has been forecast too warm

(ii) a positive anomaly means temperature has been forecast too cold.

The 850 mb temperature error is recorded every 30 degrees of longitude starting at the Greenwich meridian, and every 10 degrees of latitude from 30° to 70° inclusive (same as 1000 mb heights). Values are in degrees Kelvin.

Results for 116 days from Nov 1980 to Mar 1981. (c.f. FIGS 5 & 6)

At Day 1 the T850 anomaly pattern has similarities to that of the 1000 mb height (Fig 3) with mean and RMS error maxima over N. Alaska and Siberia (negative) and over the northern north Atlantic (positive) i.e. where the model forecasts pressure too low (high), it forecasts temperature too warm(cold). This relationship is reversed with time near the major depression tracks.

The area to the south of the Alaskan pressure anomaly becomes a positive mean error max by Day 3 and this persists to Day 7, and the area near the European pressure anomaly also becomes too cold, although to a lesser extent.

The Arctic grid points (70°North) stay generally too warm throughout.

The most obvious pattern emerges over the main land masses where the model soon (by Day 2) establishes negative anomalies and over the seas where it establishes positive ones. An exception is around 30°N where this pattern is reversed.

One is therefore left with a striking wavenumber two pattern—forecast too warm over the main continental land masses and too cold over the oceans with the reverse true near the sub-tropical anticyclone belt.

Generally, the main temperature errors were of the order of 1°K throughout. The main exception was over Canada where steady growth gave a mean error of -3.1°K by Day 5 and -3.8°K by Day 7, and off N.E. Canada where $+3.0^{\circ}$K was realised by Day 7. A curiosity on Day 1 is the large area of poor forecast (in RMS terms) over the USA and S.W. Atlantic; it implies an analysis error in that area (It did not appear on an earlier chart of Oct to Dec 1980 error fields and is therefore a feature of the Jan to Mar (inc.) 1981 period).
As we run into model forecast time (see FIG 6b) we can see that in general America and central Russia are forecast relatively poorly and the Atlantic and Pacific relatively well and also that in general RMS errors increase with increasing latitude.

Summary

One may look for the following features in synoptic assessments of ECMWF forecasts (these comments apply to Wintertime).

1. Main jet streams become slightly veered over the Atlantic and become too zonal and displaced South over both the Atlantic and Pacific. They penetrate slightly too far into America and much too far into Europe between 40°N & 50°N. The effects should be that associated frontal systems go too far south with non-developing frontal waves moving too fast over the Oceans and are eventually taken too far south-east into America and (particularly) Europe. (It should be noted that the weekly assessments tend to judge the ECMWF model a little slow near the UK. this is for developed or developing systems and these tend to overdevelop - see 3 below).

If the extension into Europe is not caused by parent lows being taken too far south or being over-developed, it could be spuriously or over-developing secondaries from the Atlantic, or be developing new lows in the Western Mediterranean (near the front which is brought too far south) and advecting these lows ENE.

2. The standards of the forecasts of pressure deteriorate badly after Day 3 over the N.E. Atlantic and the N.E. Pacific as do the forecasts of T850 in central N. America and Russia.

3. Lows in the Atlantic are initially well forecast, but exhibit a tendency after two days to be deepened too late or too little over the W. Atlantic, and deepened too much over the E. Atlantic and also brought too far south and east into Europe (perhaps as secondaries)

This behaviour should be particularly evident during the period when explosively deepening lows occur around February.

3a. The same syndrome in the Pacific. The deepening of lows underdone in mid-Pacific and overdone in E. Pacific and centres brought a little too far south and east into northern USA/Canada (perhaps as secondaries).

4. Sub-tropical highs tend to be forecast slightly too high from Day 2 on (by 1 to 4 mb) and forecast too warm over the sea and too cold over the land at 850 mb (by about 1°K)

5. The Siberian High seems to adjust in the first two days then steadies:- loses 5 mb then recovers slightly, becomes 1.5°K too warm at 850 mb then remains so, imposes a slight Southerly component on the 500 mb winds.

6. The development with time of a spuriously warm T850 area N of the Great Lakes and a spuriously cold T850 area between Canada and Greenland.

7. Lowest medium range forecast errors (T850 and surface pressures) are near large quasi-permanent features such as sub-tropical and Siberian anticyclones.

Final note.

I am unable to say from the T850 errors alone that wave number 2 is being forced since the model may only be at fault over a shallow layer near 850mb. The Z.I. and M.I. error fields indicate however, that the large-scale wind flow is being affected and I would infer therefore that the effect is spread over a larger depth of the model. The growth is steady and is an obvious model characteristic. I imagine it is more likely that the temperature field forces the wind field than vice-versa.

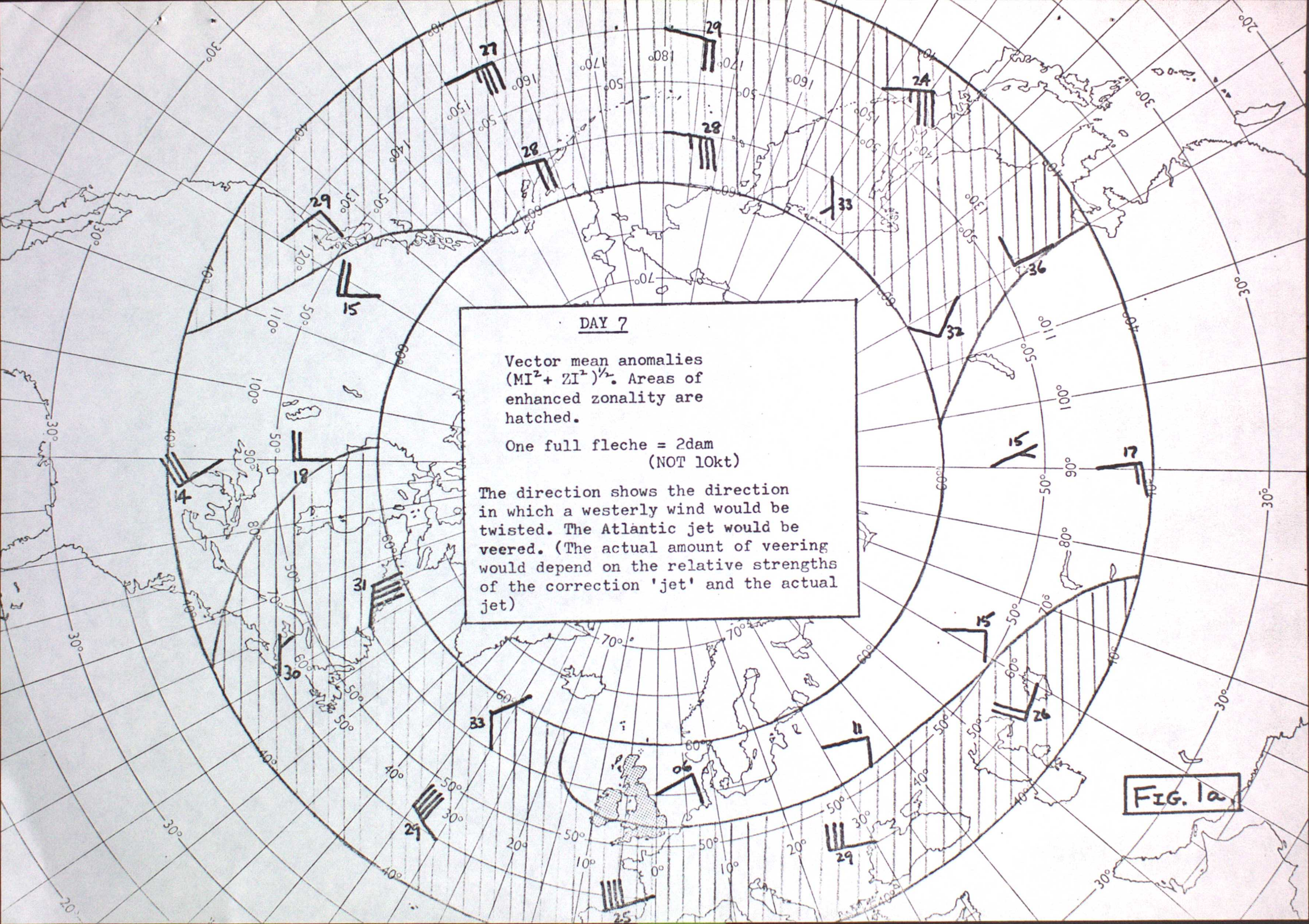
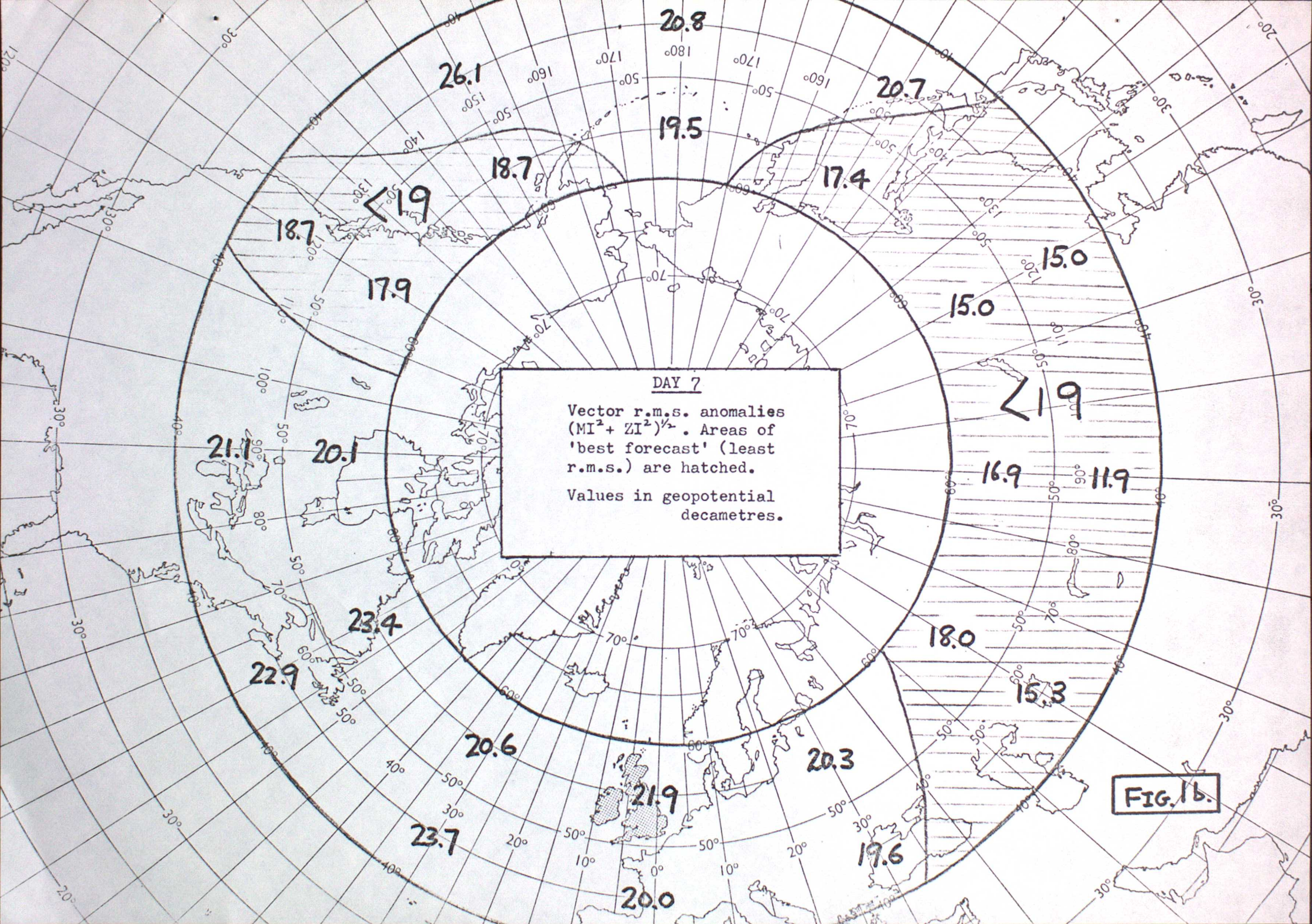
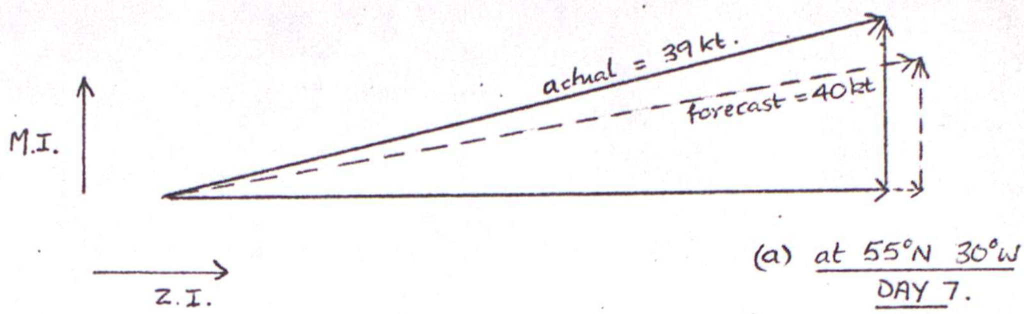

DAY 7
Vector mean anomalies ($MI^2 + ZI^2)^{1/2}$. Areas of enhanced zonality are hatched.
One full fleche = 2dam (NOT 10kt)
The direction shows the direction in which a westerly wind would be twisted. The Atlantic jet would be veered. (The actual amount of veering would depend on the relative strengths of the correction 'jet' and the actual jet)

FIG. 1a


DAY 7
Vector r.m.s. anomalies $(MI^2 + ZI^2)^{1/2}$. Areas of 'best forecast' (least r.m.s.) are hatched.
Values in geopotential decametres.
20.8
26.1
20.7
19.5
18.7
17.4
<19
18.7
15.0
17.9
15.0
<19
21.1
20.1
16.9
11.9
23.4
18.0
22.9
15.3
20.6
20.3
21.9
23.7
19.6
20.0
FIG. 1b.



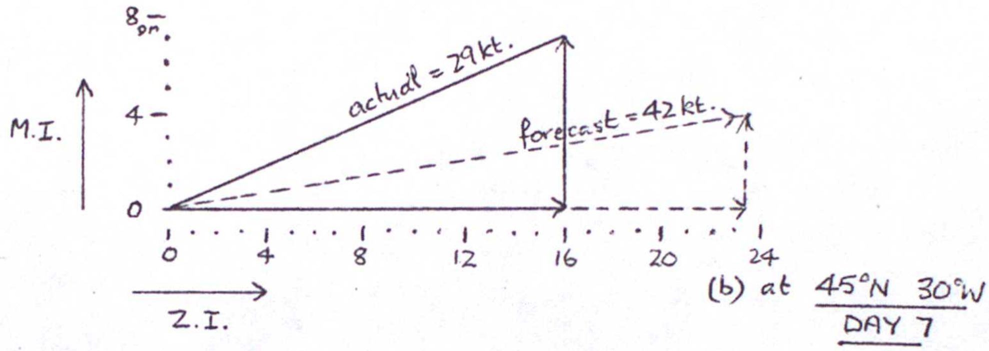


Fig. 2. Mean Dec. 500 mb winds. solid line - actual.
pecked line - forecast.

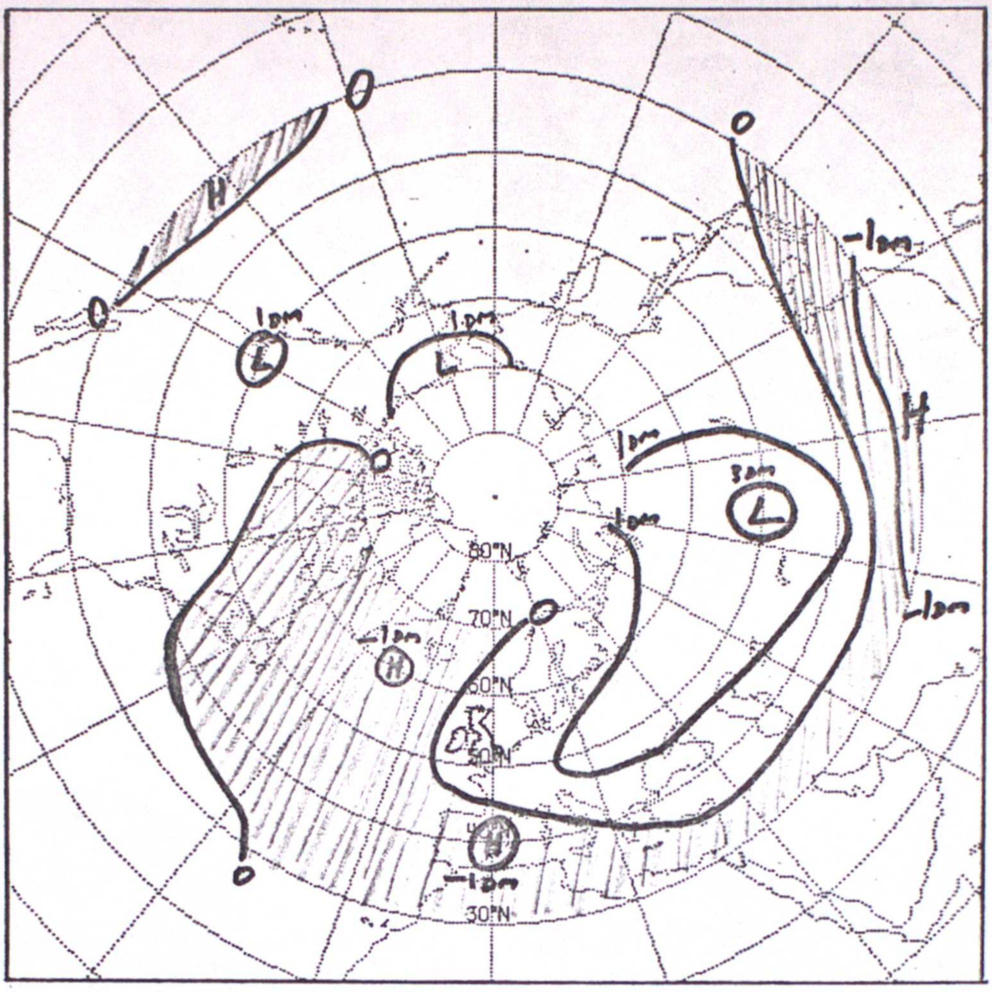


Fig. 3(a)

Z1000

MEANS

H— F/C TOO HIGH

L— F/C TOO LOW

ECMWF WINTER 1980-81 DAY 1.

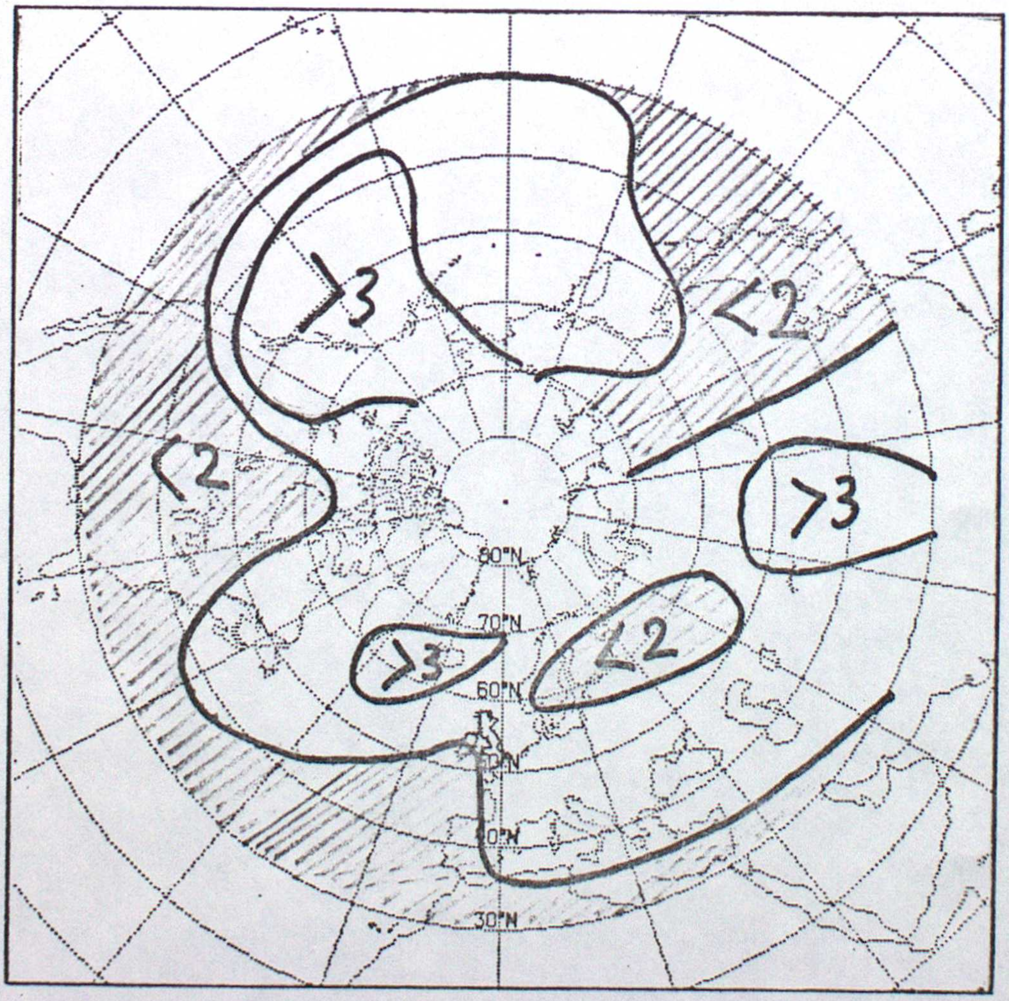


Fig. 3(b)

Z1000

RMS

Areas of least
RMS hatched.

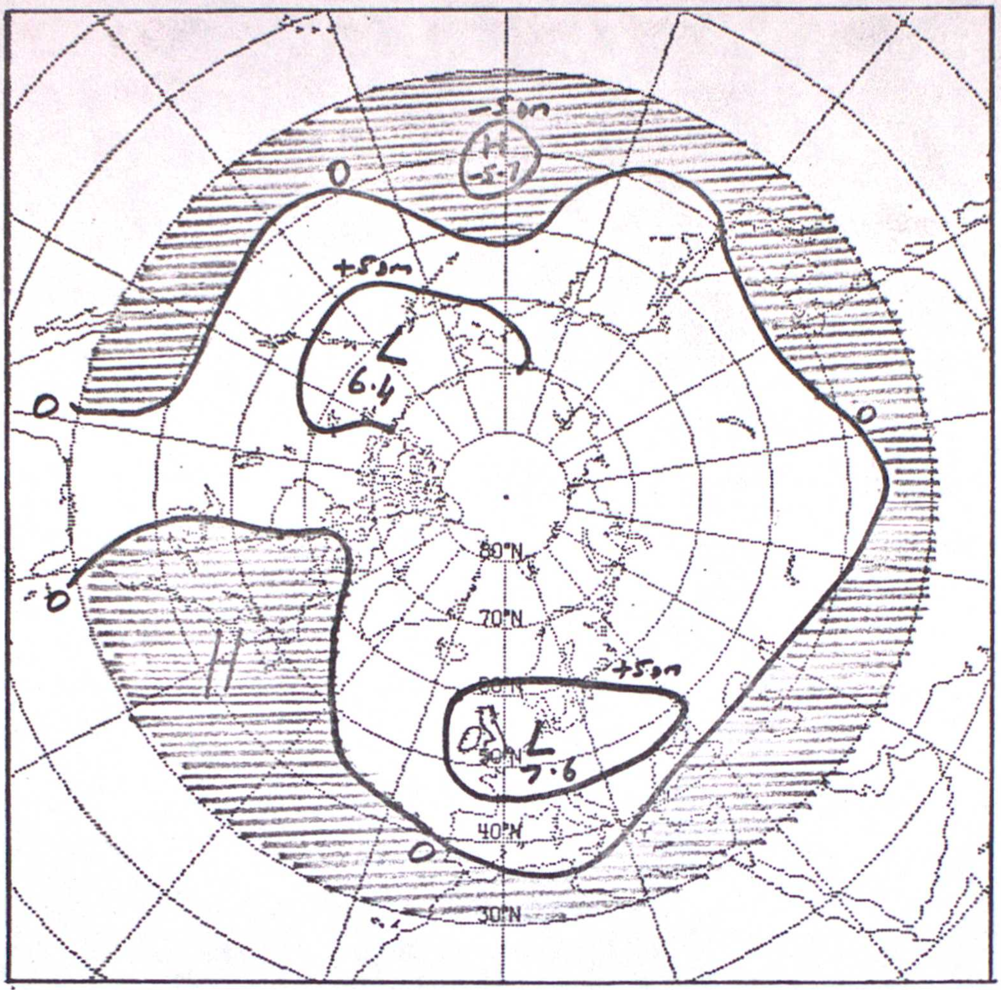


Fig. 4(a)

Z1000

MEANS

H— F/C TOO HIGH
L— F/C TOO LOW

ECMWF WINTER 1980-81 DAY 7.

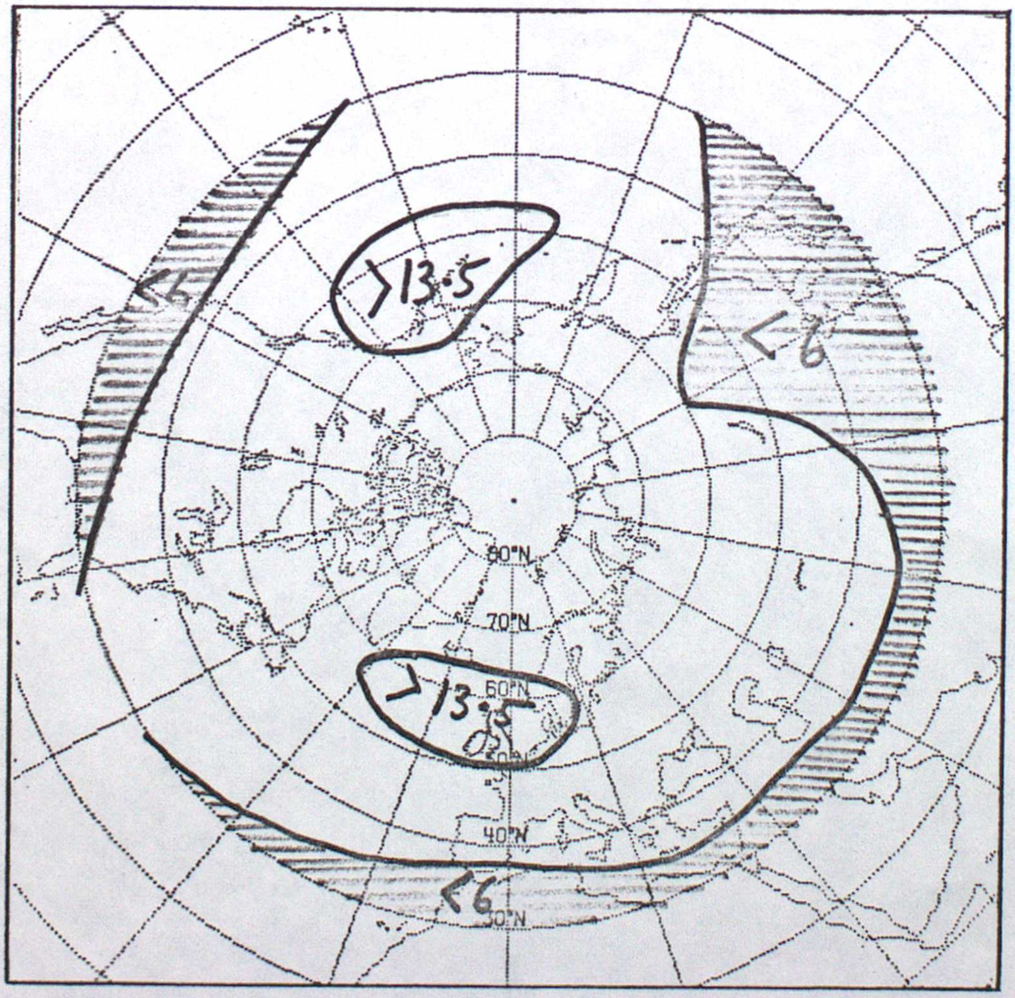


Fig. 4(b)

Z1000

RMS

Areas of least
RMS hatched.

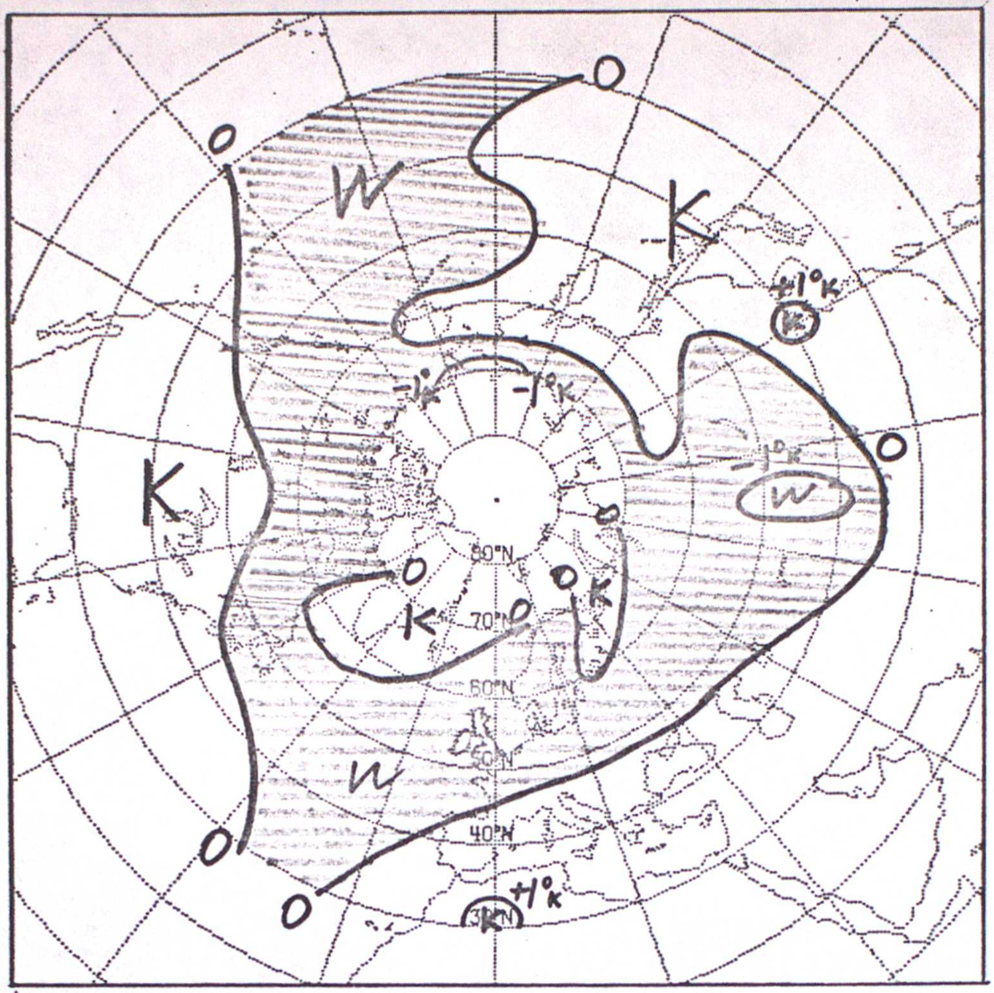


Fig. 5(a)

T 850

MEANS

W— F/C TOO WARM
K— F/C TOO COLD

ECMWF WINTER 1980-81   DAY 1

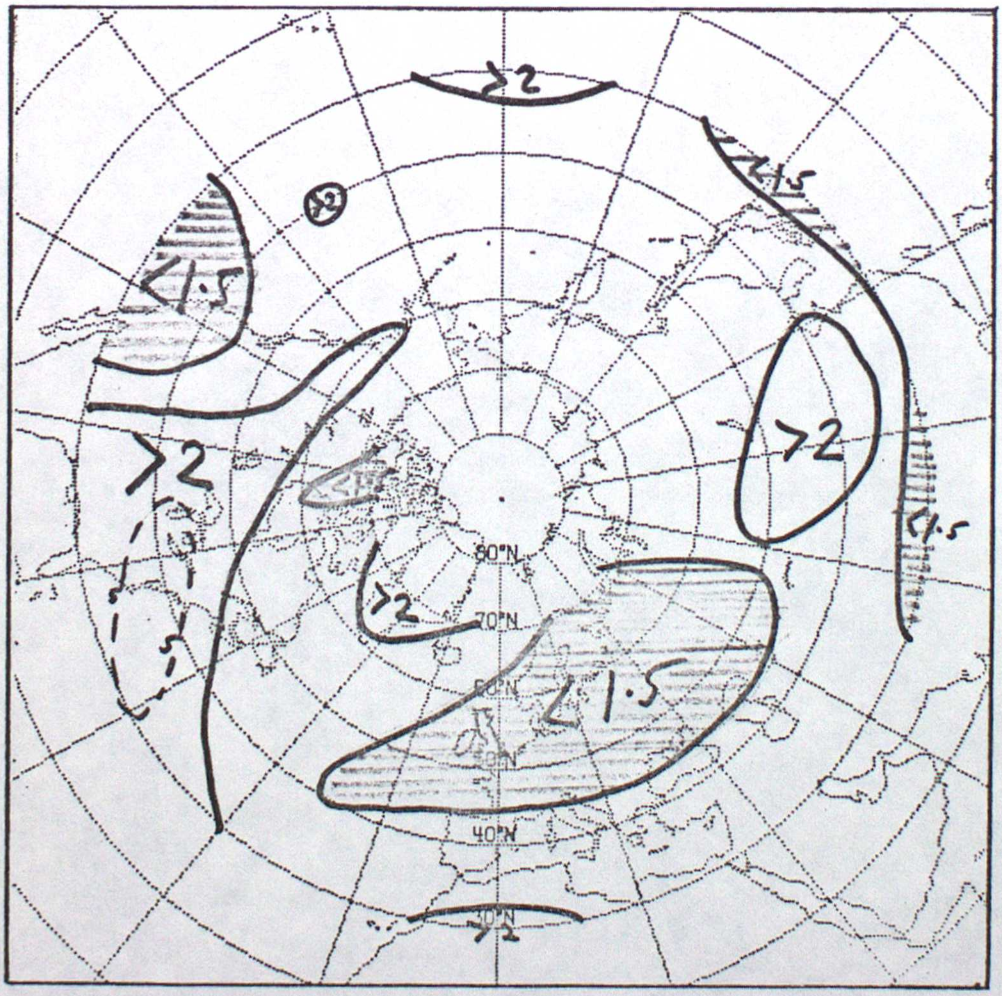


Fig. 5(b)

T 850

RMS

Areas of least
RMS are shaded.

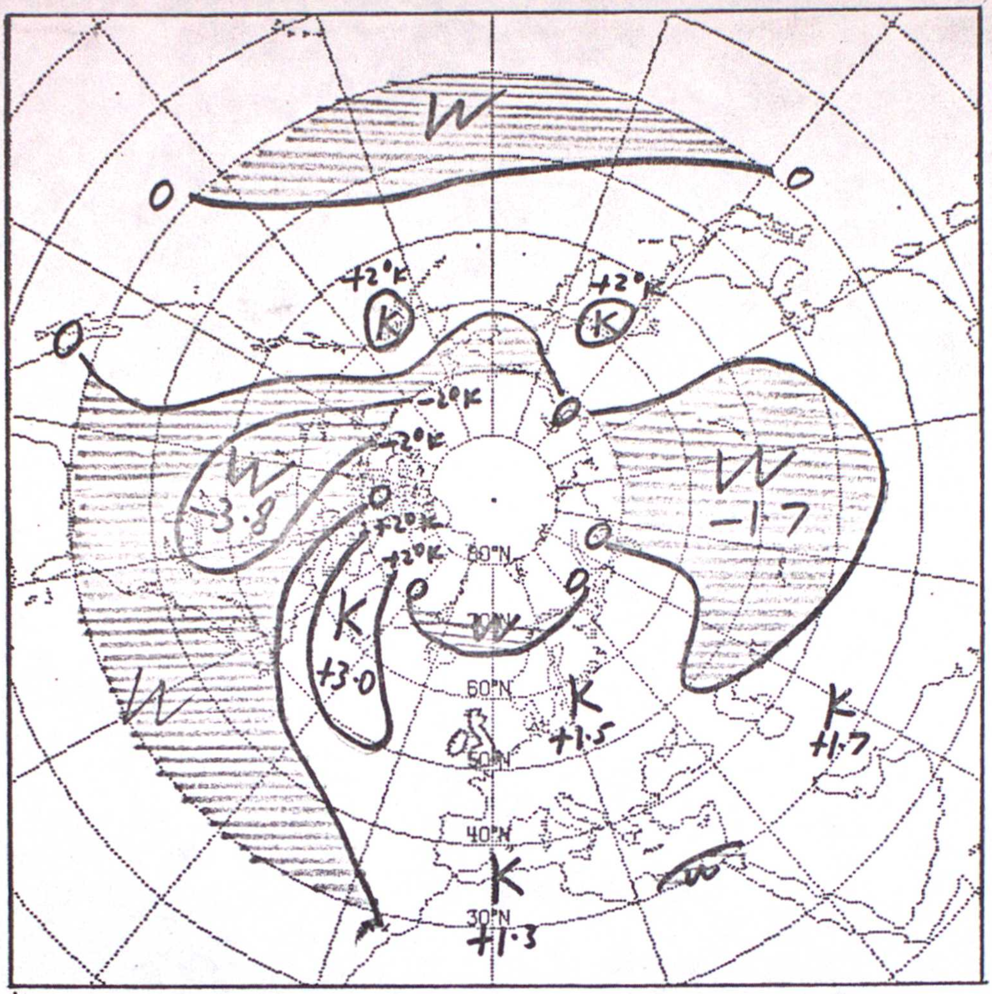


Fig. 6(a)

T. 850

MEANS

W— F/C TOO WARM

K— F/C TOO COLD

ECMWF WINTER 1980-81 DAY 7.

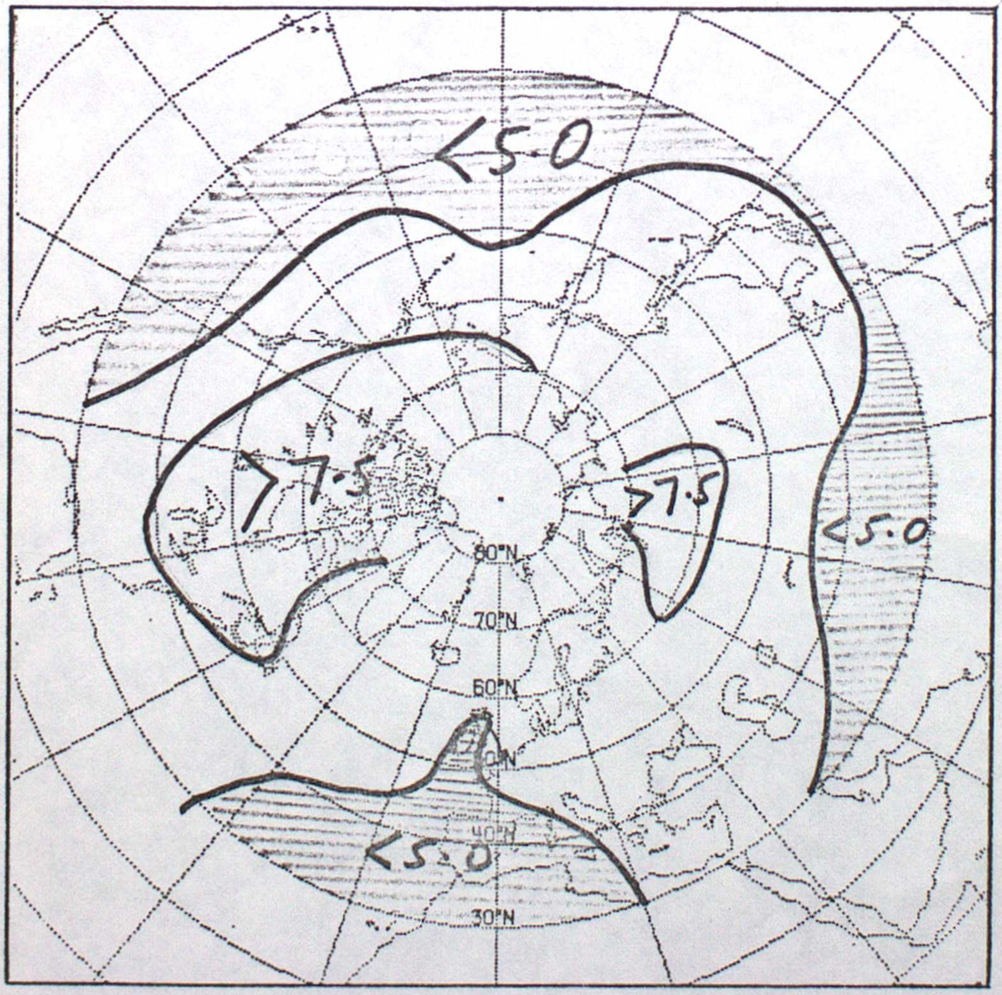


Fig. 6(b)

T 850

RMS

Areas of least RMS are shaded.