Met O 11 Technical Note No 153

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

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Preliminary note on summer 1981 results.

The results assessed here were aggregated during the period 1st April 1981 to 17th August 1981. Unfortunately when the Met. Office Grid Code Data Bank went operational in April 1981 much data were lost and a great deal of corruption occurred. The Grid Code program can cope with missing or badly corrupt data but some faulty data may have been accepted by the minimal quality control. For this reason this summer's eventual total of 94 days data has been dumped separately and was initially treated with suspicion, but the data have exhibited sufficient spatial and temporal coherence to lend them credibility and it was deemed worthwhile to produce this note which is a sequel to the wintertime assessment of part I. Met O 11 Tech Note No 151).

A second cautionary note should be sounded in that this particular summer's results may not be representative of summers in general in our area. One of the areas of worst forecast (in RMS terms) was around 30°W. The Atlantic/Europe region centred around this area was marked consistently poorly in the Met O 11 weekly subjective appraisals in June, July and August of this year. This coincided with the introduction of new topography into the ECMWF model but it is not thought that this contributed significantly to the model's poor performance. All the forecast models appraised performed poorly; in particular after Day 3 they seemed to go badly awry whereas historically they had usually shown some merit. My own feeling is that summer 1981 was a season which was for some reason or another, inherently poorly predictable locally and that the model's results in this area are therefore worse than for most summers. The same may apply to the other area with higher RMS errors than wintertime, that near Japan (about 180° removed from 30°W).

It should however, be said that the subjective appraisal is done on only one forecast per week and that the OCTAGON 6-day objective MEAN and RMS errors (held by Met O 2b) are unexceptional. ECMWF's own figures are not yet to hand.

ECMWF Error statistics

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

1. Zonal and meridional Indices. (Z.I. and M.I.)

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 600NM (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. $8\frac{1}{2}$°E to $8\frac{1}{2}$°W.

The program stores Z.I. & M.I. errors (differences of forecast from actual) every 30 degrees round latitude 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 94 days, April 1st to August 17th 1981

Day 1 As in the winter case the overall meridionality between 40°N and 60°N is about right but now the excessive overall westerly component is largely confined to the oceans between 50°N and 60°N; indeed around 45°N there is a net easterly anomaly. This could mean that the model Hadley circulation is too far North but the presence of both the polar and sub-tropical jets in these latitudes confuses the issue and the 1000 mb height (Z1000) field is too low except over the Atlantic, indicating the reverse.

The larger biases are at 30°W and 150°E and these may be associated fairly well with the Z1000 anomolies (q.v.) in that the Atlantic pressure is forecast too high (in this summer this probably means that lows were forecast not deep enough) giving too slack a jet to the south and not enough weakening of the jet to the north of the lows, and that the pressure off E.Asia was forecast too deep giving too strong a southwesterly jet.

Day 7 (c.f. Fig 1) There is a gradual encroachment of the westerly anomaly from the Atlantic into Europe and Asia until by Day 7 the Atlantic and the Pacific westerlies are linked. Unlike the winter where the westerly anomaly penetrated at 45°N, it is now mainly at 55°N, although from Day 4 at 45°N it penetrates through Europe.

The easterly anomaly over America is more resilient and eventual encroachment only occurs over Western Canada, again at 55°N rather than 45°N as in winter.

After Day 3 the oceans are generally too westerly and northerly and the continents too easterly and southerly (similar to the winter pattern) and this persists, apart from the encroachment mentioned above, once again giving the impression that the land and/or sea masses are forcing a planetary wave.

In general biases and RMS errors were a little less than in winter but significant exceptions were at 30°W and 150°E where the maximum errors mentioned at Day 1 continued to grow. They could still be related to the Z1000 pattern ; pressure around 150°E continued to be forecast too deep (this is usually a non-descript pressure area) and after three days the Atlantic is forecast generally too low rather than high & the anomaly 'jet' along 45°N becomes westerly rather than easterly.

2. <u>1000 mb height errors (Z1000)</u>

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 100 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 94 days from April 1st to August 17th 1981 (c.f. Figs 2 & 3)

At Day 1 the Atlantic pressure was forecast too high and the rest of the chart too low with positive maxima off E.Asia and W.America and Alaska.

The Atlantic negative cell was gradually eroded through the forecast period and persisted only in the N.E. Canada/W.Greenland area, the Atlantic being generally positive after Day 3 as a low (positive) maximum built in Europe with another maximum appearing between days 6 and 7 around 30°W.

The low cell over Alaska grows throughout and this area was a secondary maximum of bias and of RMS error. The positive anomaly around 150°E was the worst mean error throughout, this and the 30°W area being the worst areas forecast in RMS terms.

The Pacific became slightly negative after Day 1 but only in the south and not nearly so marked as in winter; biases and RMS errors here were fairly small whereas in winter both the Atlantic and Pacific sub-tropical highs were forecast too high, only the Pacific was during this summer period.

There is a change of sign in the bias around 30°N over Africa and Asia from winter to summer (which was not echoed in the T850 figure); from being negative over the winter it is now forecast too low, generally. One is tempted to relate this to actual change of monsoon flow and one might also term the marked errors off E.Asia a 'monsoon anomaly'.

The mean errors are less than in winter (except at 150°E, about 9 mb too low by Day 7) as are the RMS errors (except at 30°W).

The normal main summer cyclone track is along 60°N from 90°W to Scandanavia and like winter by late in the forecast period lows appear to be underdeveloped (though only a little) west of 50°W and overdeveloped over the eastern Atlantic and Europe, the main biases being slightly south of the usual cyclone path (though not necessarily south of this summer's predominant cyclone path)

The positive mean errors predominated throughout meaning that pressure was generally forecast too low over the region 30°N to 70°N.

3. Temperature errors at 850 mb (T850)

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 1000mb heights). Values are in degrees Kelvin.

Results for 94 days from April 1st to August 17th 1981 (c.f. Figs 4 & 5)

Initially the oceans and eastern America are forecast too warm and Asia and western America are too cold. This pattern largely persists and reaches maximum intensity after 3 or 4 days, the major change being that a small, anomalous cold cell is evident south of Iceland after Day 2 and this grows rapidly on days 6 and 7. The mean errors over the Asian land mass and the Pacific mostly have the opposite sign to that of winter, whereas the Atlantic and America are similar. The warm area over eastern America is puzzling, the expectation being that the model underestimates extremes. It seems too far removed to be due to a warm ridge thrown up by the Alaskan Z1000 low and the weakening of lows over E Canada seems too minor to cause a marked loss of advection.

The fact that the lower atmosphere over the oceans is generally too warm in both summer and winter, may point to error in the treatment of latent heat flux.

The cold cell in the N.Atlantic is probably generated initially by advection round the anomalous high cell near S.Greenland and then boosted on days 6 and 7 by the growing low pressure cell west of the UK. A meteorological interpretation of this statement poses problems. Since the high pressure cell is coincident with or west of the cold temperature cells it is as easy to interpret cold advection round an anomalous high in a cyclone track as over-advection round the mobile highs rather than under-advection round the lows; ie. the highs are forecast too high rather than the lows not deep enough as suggested in the Z1000 interpretation. Alternatively Greenland itself may be affecting the situation. Latterly, one cannot tell if the over-cold air generates over-deep lows west of the UK or vice-versa.

RMS errors were larger than the wintertime case on day 1 - much larger in N.Asia, the northern N.Atlantic and America, and the Pacific around 30°N. By day 2 they had dropped markedly and then increased monotonically throughout the rest of the forecast period. This may be due to a change in the humidity analysis which occurred on Mar 10th (and continued until Nov 1981). A tongue of low RMS errors extended up the Rockies throughout the forecast period.

SUMMARY

Repeating the caveat that this particular summer may have been atypical (perhaps more 'wintery' than usual) over the Atlantic and W.Europe, one may look for the following features in ECMWF forecasts in summer.

1. Main jet streams become slightly veered over the Atlantic and soon become too strong over the Pacific and Atlantic. In the first few days of the forecast the jets are not westerly enough over America and Eurasia, but the extra Atlantic zonality eventually penetrates through most of Europe and northern Asia, and the Pacific jet edges into W.Canada. The effect should be that non-developing frontal systems move too quickly over the oceans and too slowly over America, and that towards the end of the forecast period systems are taken just too far south-east into Canada, too far south into Europe and much too far east into Europe and Asia. As in winter the jet extension into Europe could be caused by parent lows being taken too far south or being over-developed, or by spuriously developing secondaries from the Atlantic, or from the Mediterranean if the front is brought too far south.

2. The standard of forecasts of pressure over Europe is good at Day 1, but poor after Day 3. The standard of forecasts of pressure, temperature and wind around 30°W is bad, as it is over the west Pacific near Japan. Pressure forecasts over Alaska are poor by Day 6.

3. Lows exhibit the tendency to be developed too little or too late off the eastern Canadian seaboard and then deepened too much as they cross the Atlantic but to a lesser extent than in winter; for example after 5 days pressure near the UK is about 3.5 mb too low compared to 6 mb in winter.

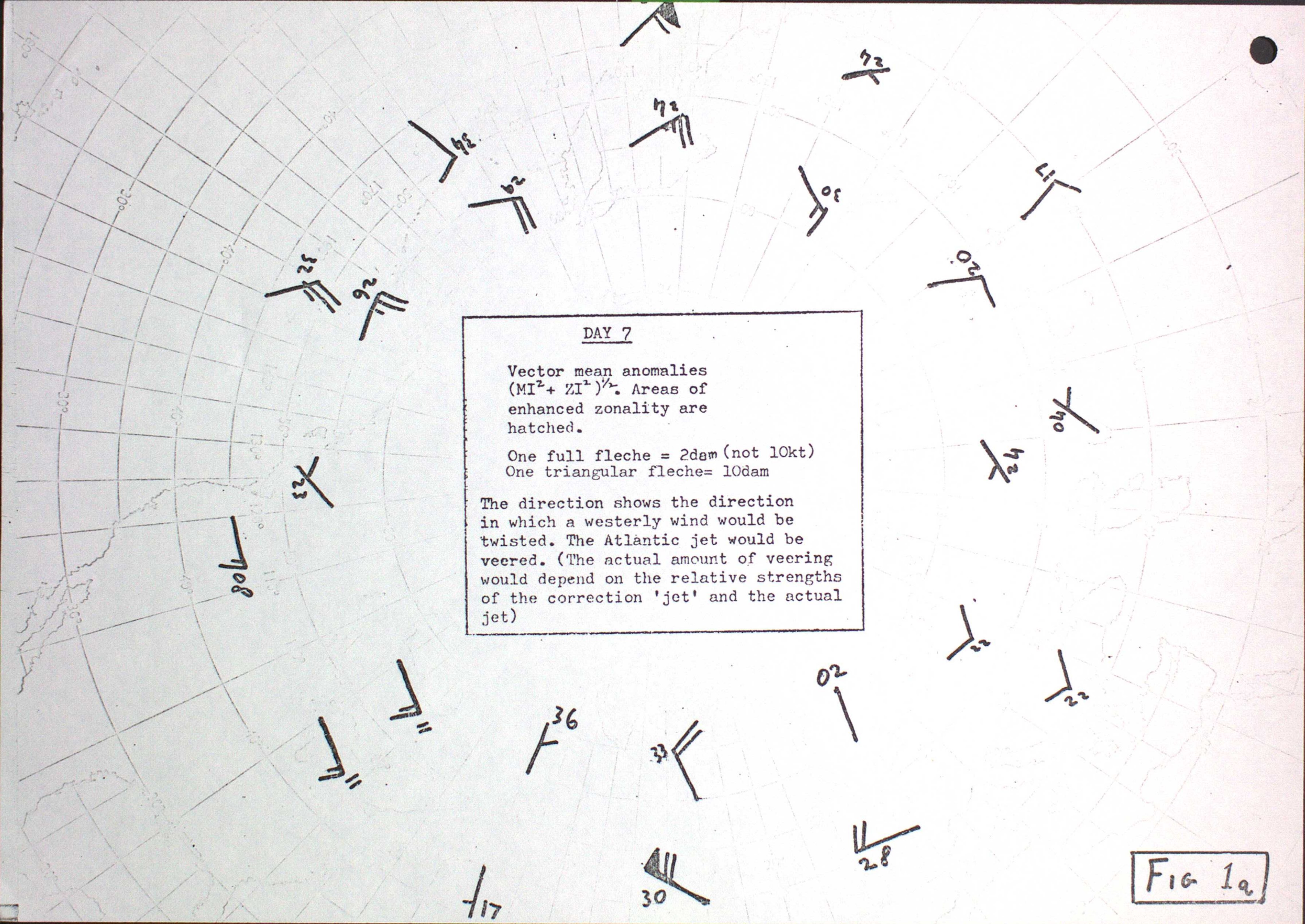
4. The 500 mb flow off E.Asia is backed and strengthened throughout the forecast with lows which are either too deep or (more likely) often spurious. This throws up an anomalously warm ridge over the Pacific

5. The gradual development of a spuriously warm T850 area north of the Great Lakes and, late in the period, the development of a spuriously cold 850 mb area south of Iceland. Asia becomes gradually colder for about 4 days then steadies.

6. Smallest medium range forecast errors are around 30°N over America, Asia and the east Pacific anticyclone.

In winter the worst areas of 7-day forecasts were near the UK and Alaska, in summer they are around 30°W and 150°E. The coincidence of the maximum errors of pressure, temperature and wind in summer, and to a large extent in winter, help support the idea evolved lately during the Met O 11 weekly appraisals, that the structure and development of Atlantic depressions slowly deteriorates with increasing forecast time. It appears that mature depressions are too cold in their south-west quadrants. This means that either the coldest air associated with a new depression is not advected round the low as part of the occlusion process or that, although it is advected correctly, colder air is apparently generated in situ to the west or southwest of the low. An extra thermal component is added to the associated jet causing it to be veered and strengthened. This in turn would probably mean that the low would subsequently deepen too much, be late in filling and be steered too far south (it certainly would in a real atmosphere) and these are commonly observed faults of the ECMWF model.

One may of course argue the reverse; that the jet is not propagating properly round the low and that the cold air is therefore not properly advected and cold air is drawn in from the north for too long. The latter could be due to adjustment steps effectively regressing the advection steps, while the former could perhaps be due to the deep convection scheme. Whatever the reason, this appears to be a major fault in the model and is frequently the cause of rapid deterioration in the forecasts beyond three days so that investigation and cure of the problem would pay large dividends.



DAY 7

Vector mean anomalies $(MI^2 + ZI^2)^{1/2}$. Areas of enhanced zonality are hatched.

One full fleche = 2dam (not 10kt)
One triangular fleche= 10dam

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

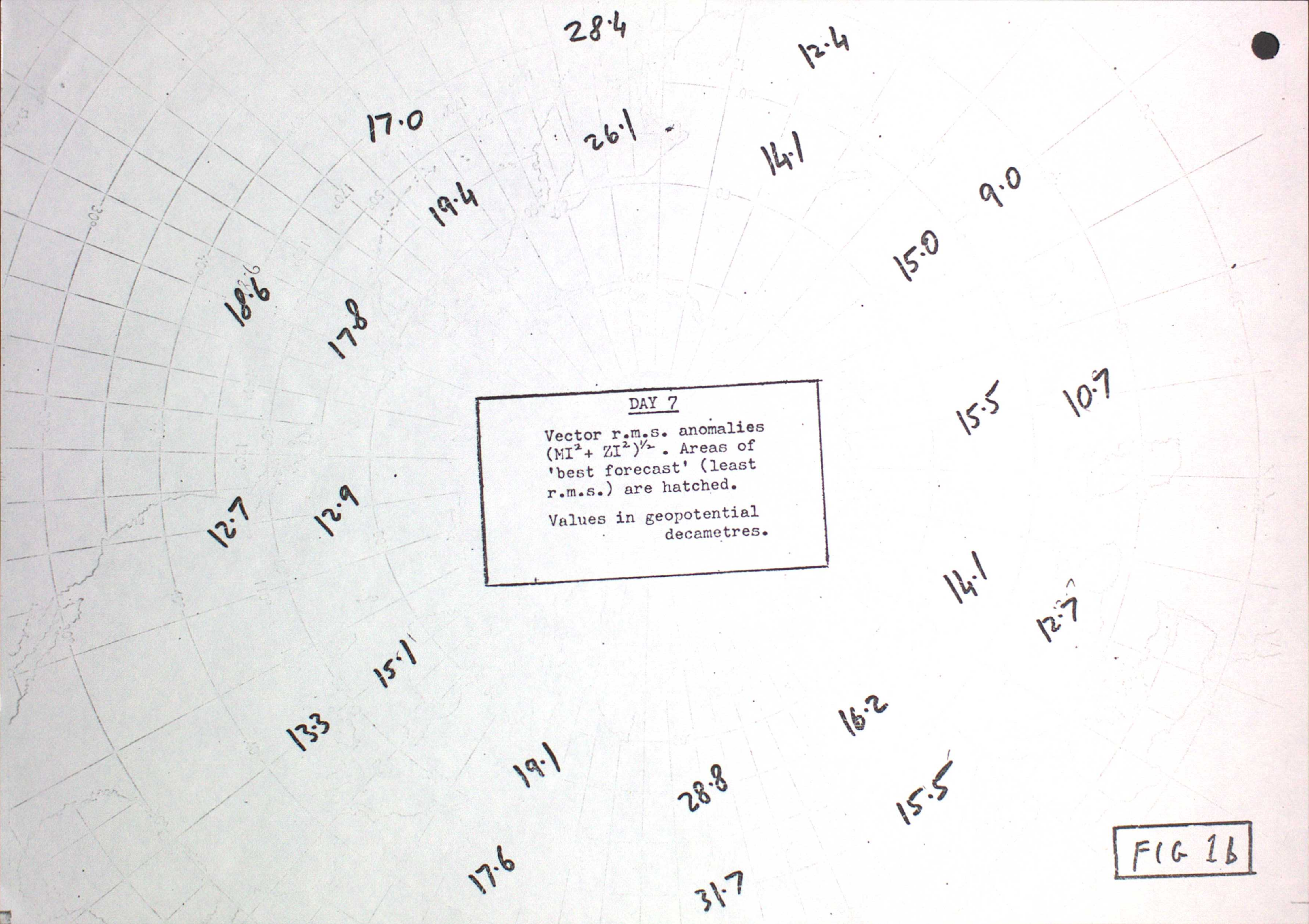

DAY 7
Vector r.m.s. anomalies $(MI^2 + ZI^2)^{1/2}$. Areas of 'best forecast' (least r.m.s.) are hatched.
Values in geopotential decametres.
28·4
12·4
17·0
26·1
14·1
9·0
19·4
15·0
18·6
17·8
15·5
10·7
12·7
12·9
14·1
12·7
15·1
16·2
13·3
19·1
28·8
15·5
17·6
31·7

FIG 1b

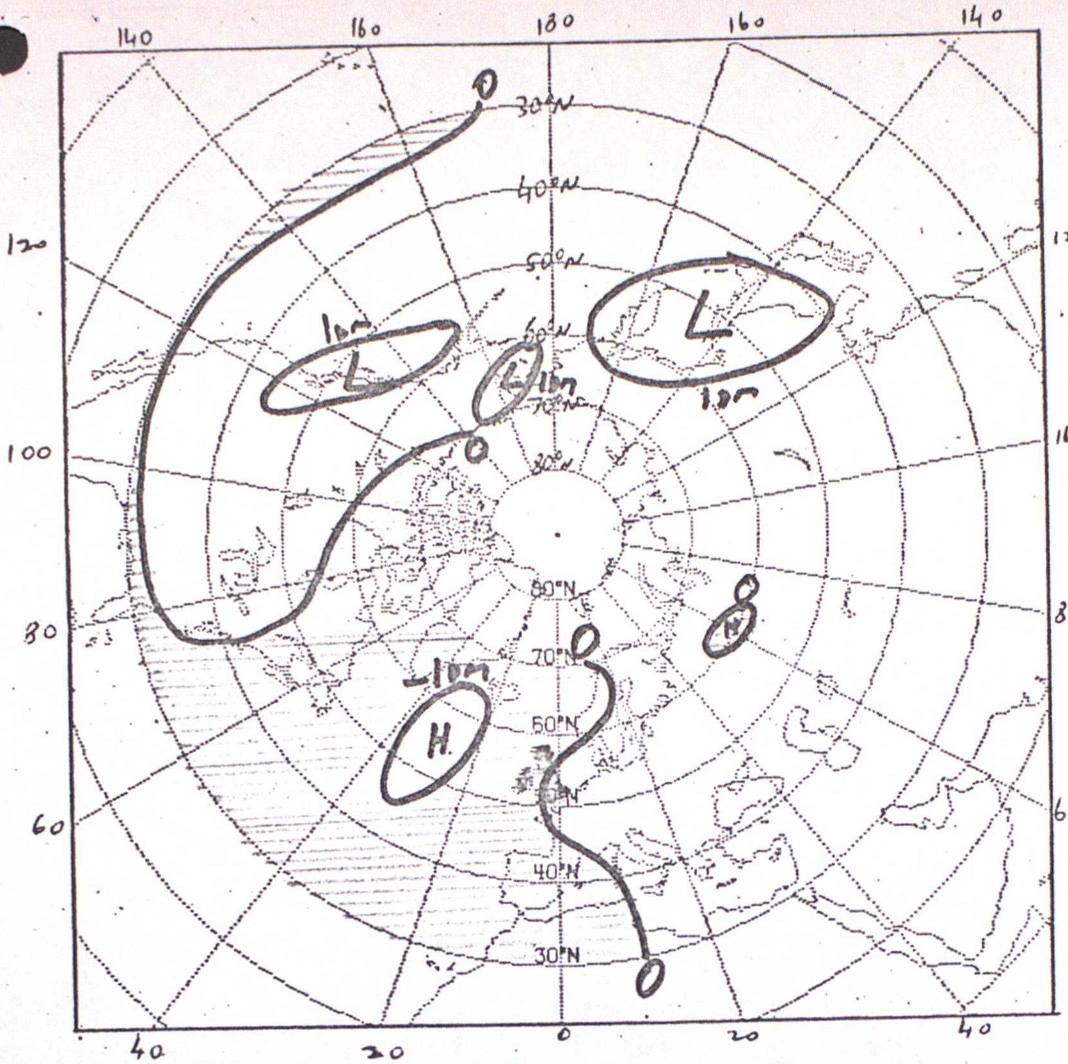


Fig. 2(a)

Z1000

MEANS

H - F/C TOO HIGH

L - F/C TOO LOW

ECMWF SUMMER 1981 DAY 1.

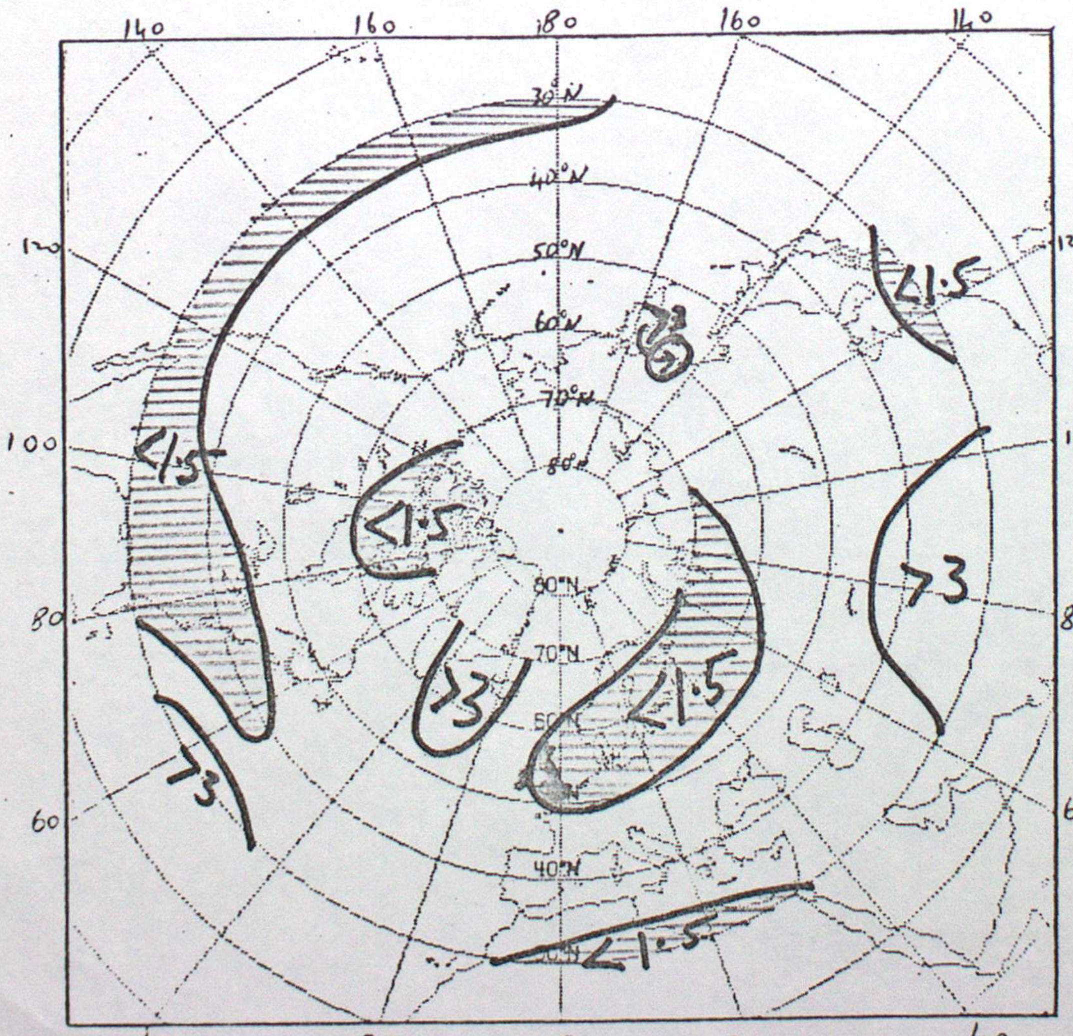


Fig. 2(b)

Z1000

RMS

areas of least
RMS hatched.

1

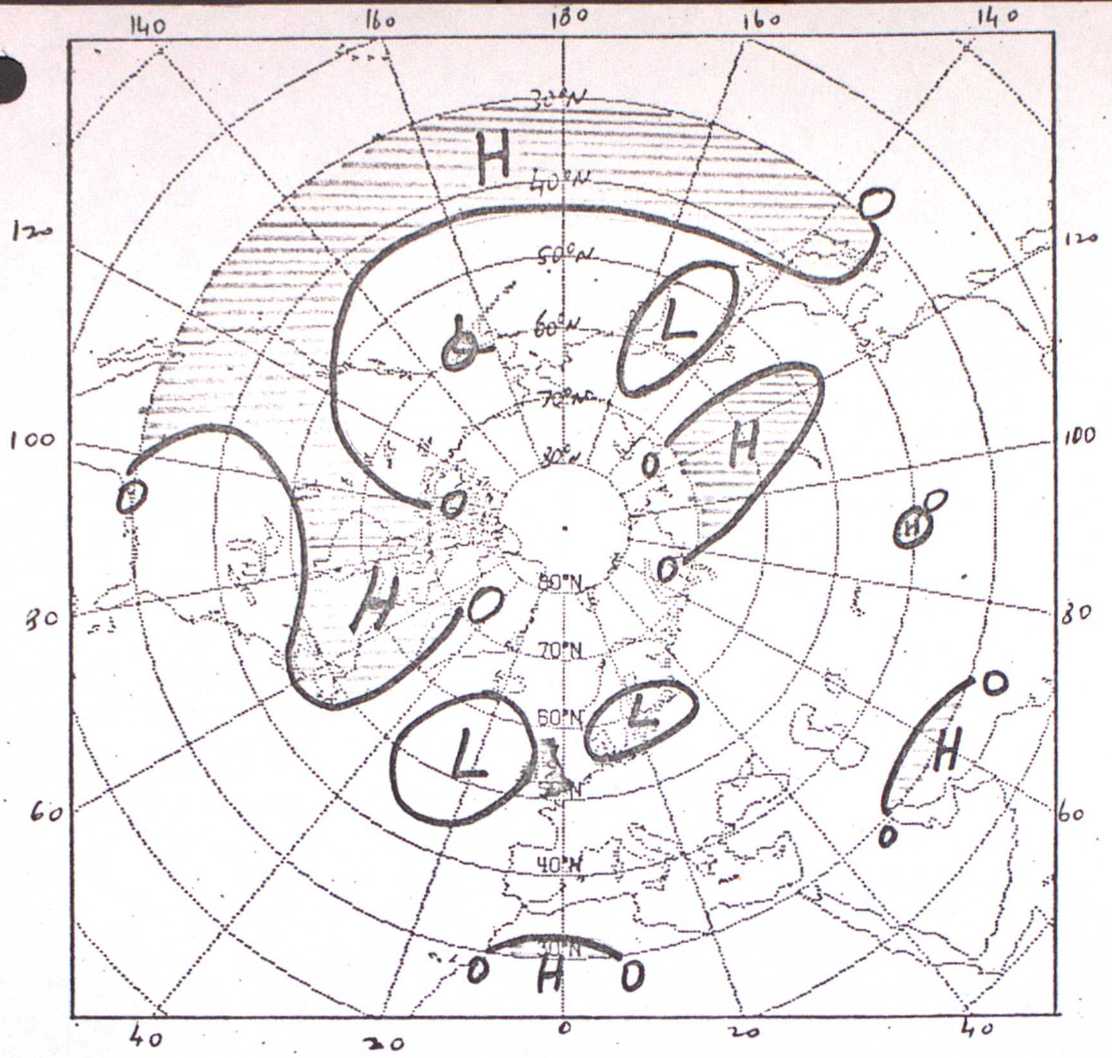


Fig. 3(a)

Z1000

MEANS

H - F/C TOO HIGH

L - F/C TOO LOW

ECMWF SUMMER 1981 DAY 7.

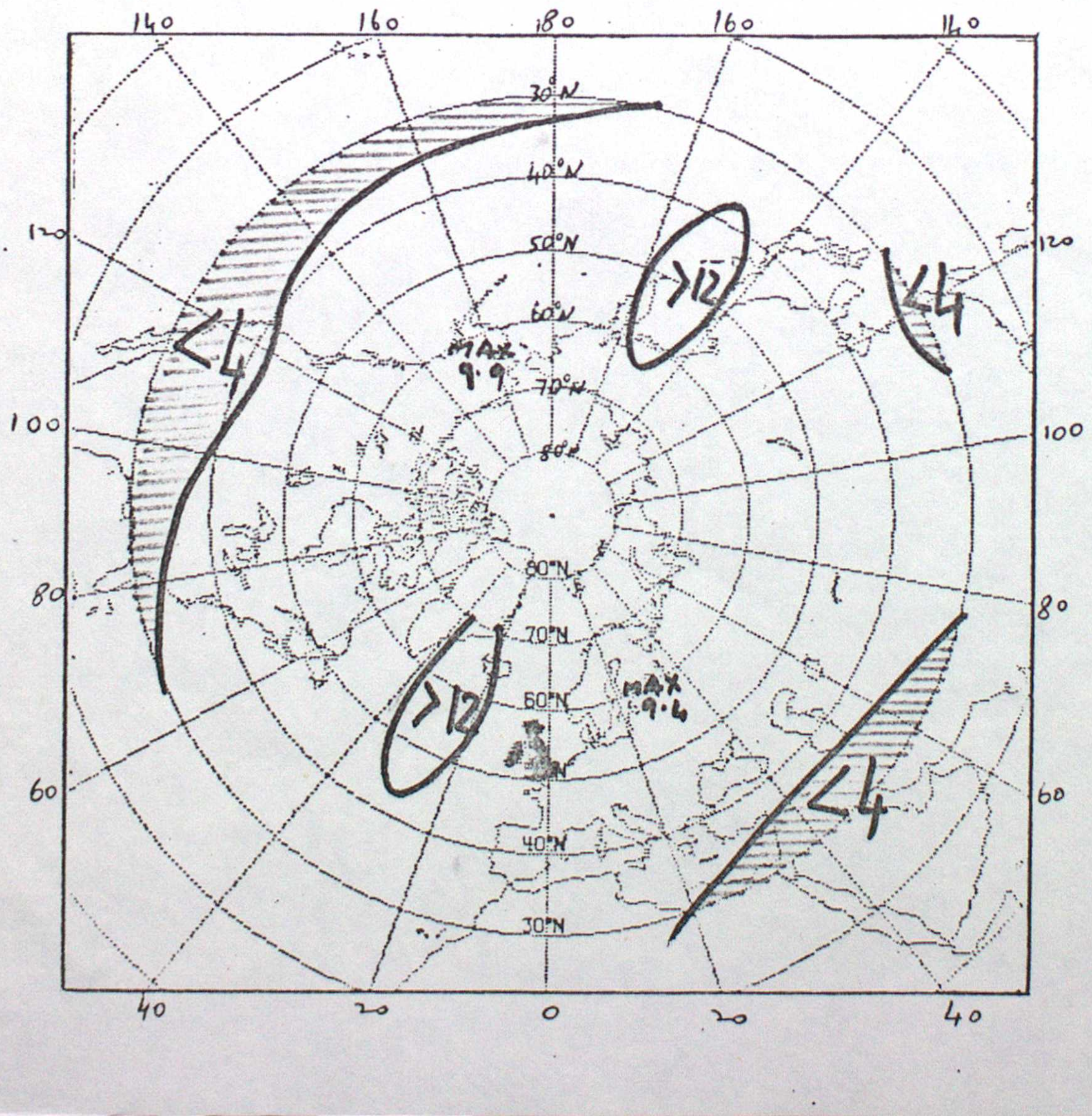


Fig. 3(b)

Z1000

RMS

areas of least RMS hatched

1

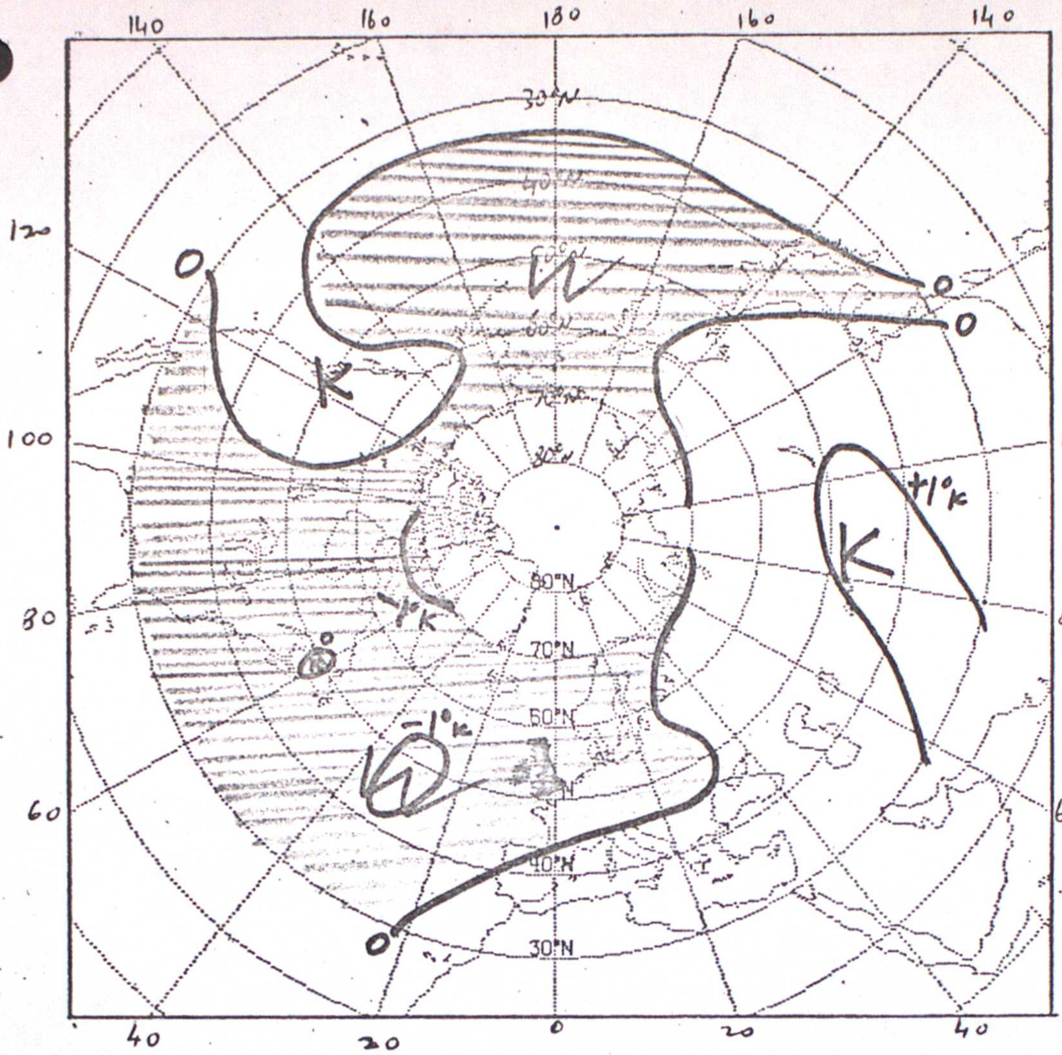


Fig. 4(a)

T850

MEANS

W - F/C TOO WARM

K - F/C TOO COLD

ECMWF SUMMER 1981 DAY 1.

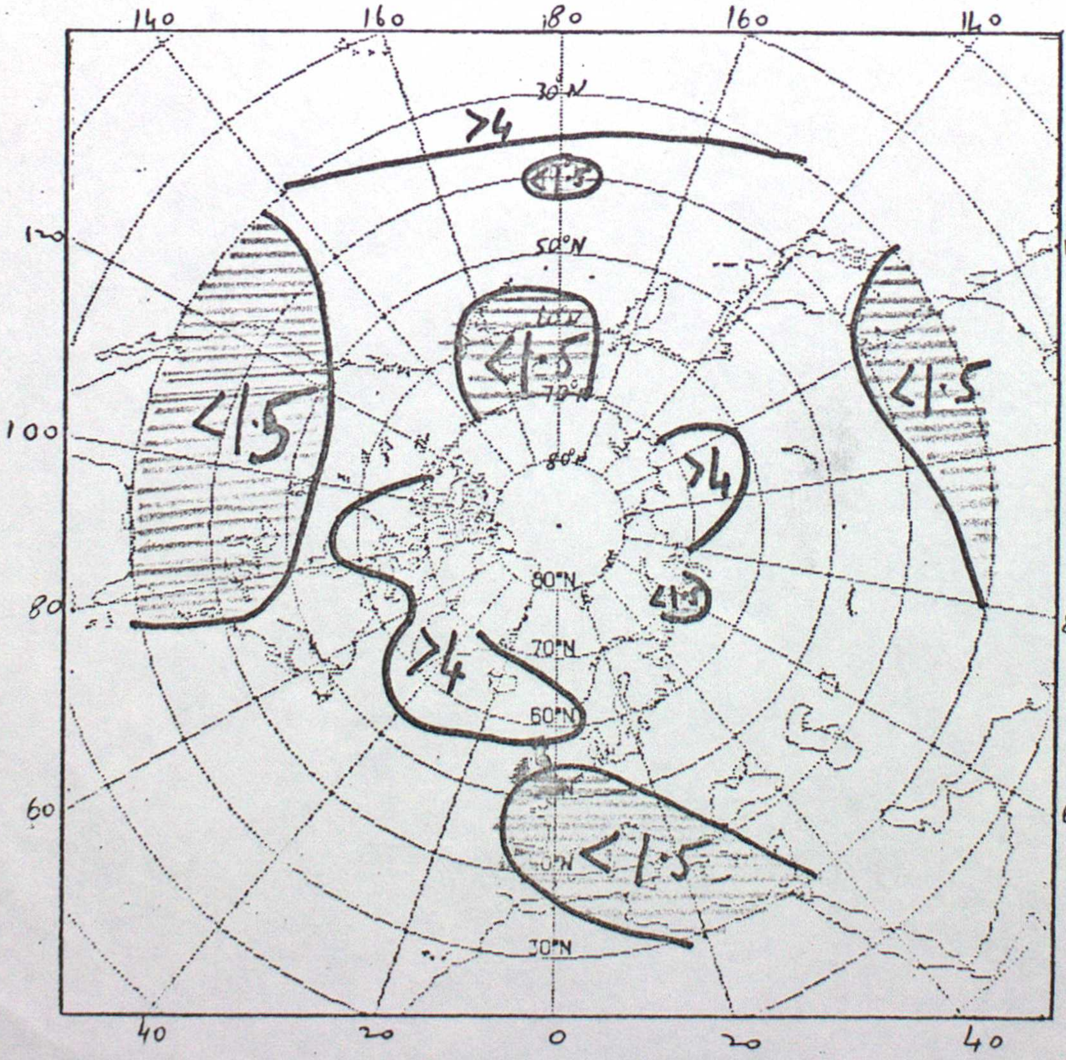


Fig. 4(b)

T850

RMS

areas of least RMS hatched

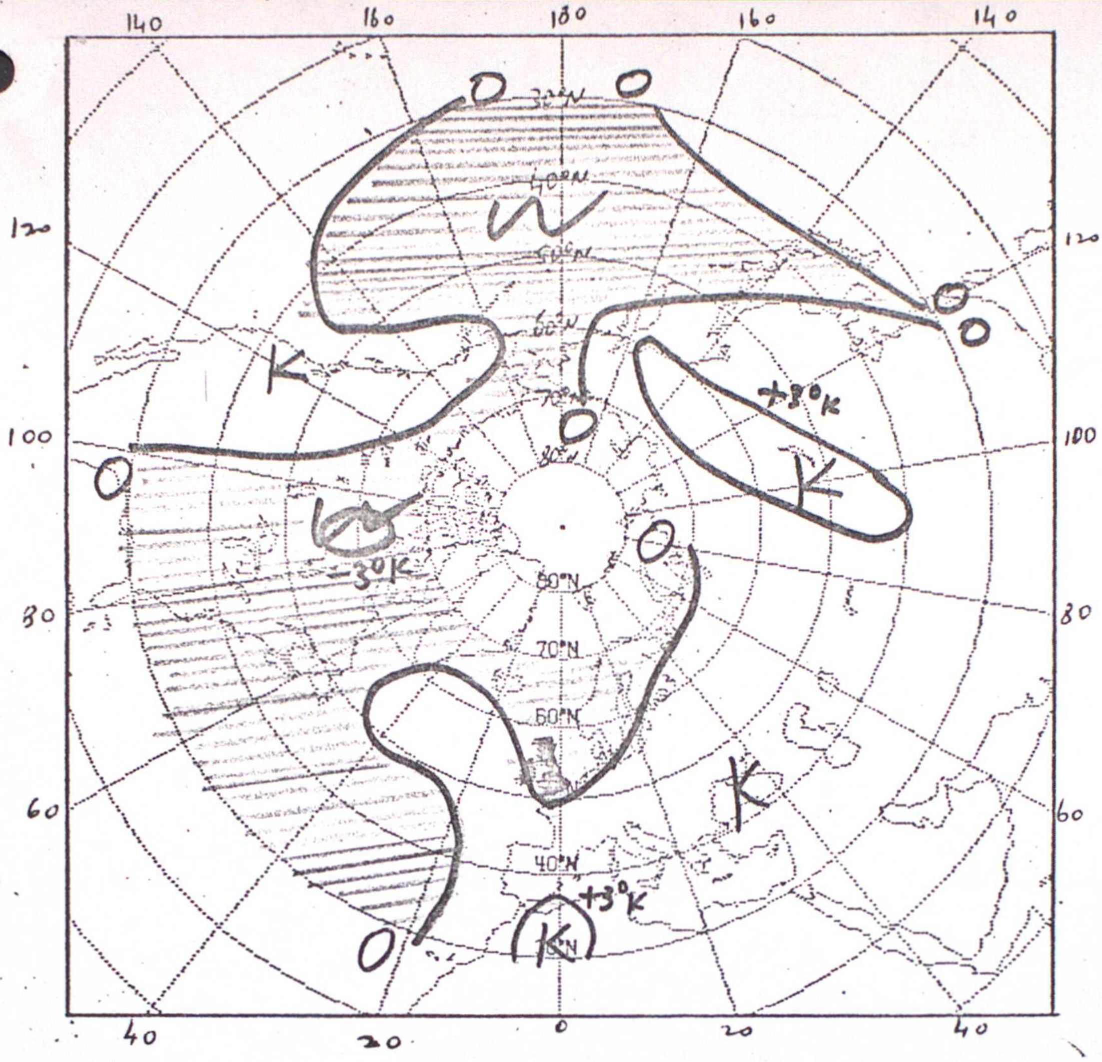


Fig. 5(a)

T850

MEANS

W - F/C TOO WARM

K - F/C TOO COLD

ECMWF SUMMER 1981 DAY 7.

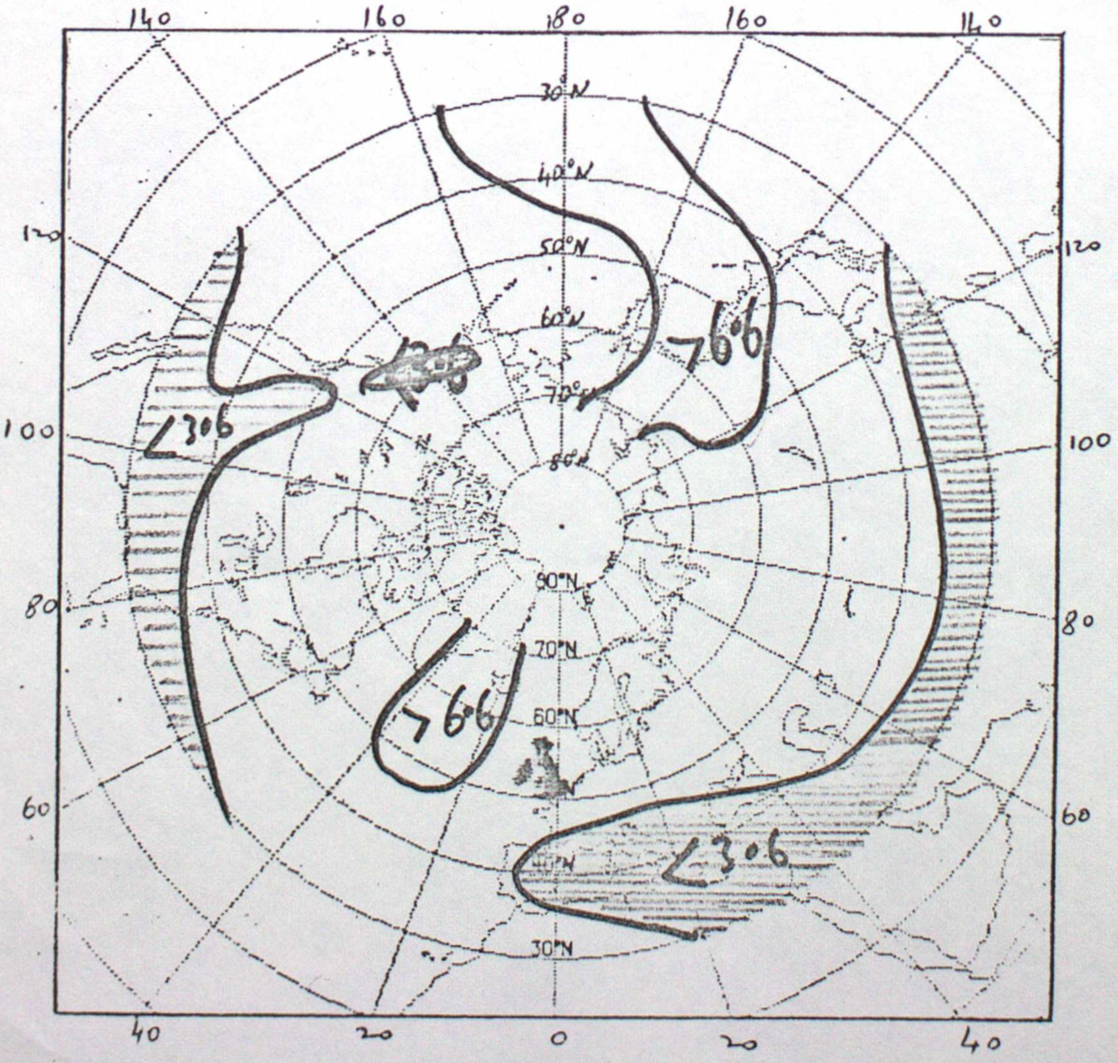


Fig. 5(b)

T850

RMS

areas of least RMS hatched