DEPARTMENT OF TRANSPORT AND POWER - METEOROLOGICAL SERVICE

INTERNAL MEMORANDUM IM 79/74

STORMS OF JANUARY 1974

by

Th. Keane, B.Sc.
M.F. Sheahan, B.Sc.

U.D.C.
551.56
551.515.3(417)

Dublin

May 1974

S T O R M S OF J A N U A R Y 1 9 7 4

1. Climatological and Storm Damage Summary

The weather in Ireland during January, 1974 was mild, wet and stormy. Its mildness was noteworthy, and very welcome in a winter of fuel scarcity, but inevitably it will live in Irish memories because of its many gales.

The surface weather charts for the month show that the North Atlantic and a large section of Northwest Europe was under the sway of a complex low pressure area. A procession of frontal systems swinging round the southern and eastern flanks of this low pressure area brought frequent rain and gales to these islands and much of the Continent. Rainfall was very high varying from 150% to 220% of normal. The figures for Valentia Observatory (records began in the area in 1866) and Cork Airport (began 1962) constitute new January maxima, and Roches Point had its highest January total since 1873.

Mean temperature was also very high, being 1.0^{o}C above normal at Valentia Observatory and 2.6^{o}C above normal at Casement Airport. At Dublin and Shannon Airports 1974 was the warmest January since 1944 and at Roches Point, Birr, Mullingar and Claremorris it was the warmest since January, 1949.

Days on which the wind reached storm force in gusts, i.e. $\geqslant$48 kts, were numerous at the more exposed stations, viz. 21 days at Malin Head, 17 at Roches Point, 15 at Rosslare, Valentia Observatory, Belmullet and at Casement Airport.

A scrutiny of the records of winds gusting to severe storm force ($\geqslant$64 kts) narrows our attention to two major storms affecting all areas and to four others of more local significance. The first major storm was on the evening of 11th and morning of 12th January and the second began on the evening of 27th and persisted in northern areas throughout much of the following day.

Both of these storms were associated with deep occluding depressions as they swept northeastwards off the west coast. A similar but less deep depression, moving along the South coast on 16th also caused widespread gales but reports of gusts $\geqslant$64 kts were confined to southwestern stations. Widespread gales on 10th and early 11th were associated with troughs of a deep depression on a more remote Atlantic track while a shallow trough in a cold westerly flow gave gales in many places, especially northern areas on 15th. An occluding frontal wave caused extensive southerly gales on afternoon and evening of 29th but severe storm force in gusts was recorded only at Roches Point.

The only considerable lull occurred from 17th to 25th. This period was marked on the weather charts by the re-establishment of the Azores high and the extension of a ridge from it northeastwards to France and Germany.

/...

Table I, attached, gives details for days on which the maximum gusts reached severe storm force at any of our recording stations. The number of hours on these days during which gusts reached storm force or more is included to provide some indication of the duration of the storm conditions. The highest gust recorded at each station during the month is also listed and in six of these the speed attained constituted a new record for that station. Five of these records were made on 12th January at Cork Airport, Birr, Kilkenny, Casement Airport and Dublin Airport while the sixth record was reached at Claremorris on 27th. Table II supplies the same data (where available) for 16th September 1961 on which day a tropical storm known as "Hurricane Debbie" skirted the western seaboard and gave records which were fairly comparable with the storms of 11th-12th and 27th-28th January, 1974.

Table III gives a rough comparison between these two recent storms and "Hurricane Debbie" as indicated by the maximum mean wind speeds over a 10-minute period recorded in each. A similar comparison using maximum gusts as a yardstick may be readily compiled from Tables I and II.

These tables indicate that the storm of 11th-12th January was more prolonged and widespread in effect than that of 27th-28th but that in their areas of maximum vigour they might be considered as equals. These areas may be loosely described as the South for the earlier and the West for the later storm.

Comparison with the figures for "Hurricane Debbie" would also suggest approximate equality - the hurricane being generally the more intense in the West and North but being surpassed in January 1974 at all eastern and some southern stations.

Five lives were lost as a result of accidents during these two January storms - two in Dublin and one in Co. Tipperary during the first and two in Co. Derry during the second. Many minor injuries were sustained and numerous lucky escapes were reported.

Extensive damage was caused in all areas by the storm of 11th-12th Jan. In coastal and tidal areas full moon spring tides, augmented by wind and low pressure exacted a heavy toll on low lying farms and premises. Coastal roads were blocked by seaweed, rocks or other debris and in some sections destroyed. Seaside promenades were badly damaged in many areas especially in Lahinch, Co. Clare. Many small craft some of which had been considered safe above the high-tide mark were lost and a few larger vessels were torn from their moorings and destroyed or damaged.

The island of Innisboffin off the Donegal coast was temporarily cut in two by waves sweeping over its central area - an event not previously witnessed. An interesting freak effect was noted by farmers harvesting seaweed at Crushoa in south Galway on the evening of 11th. The incoming tide reversed for about an hour and then returned with full force and a vigour not discernable in its earlier movement (Connaught Tribune 18/1/1974)

/...

Newspaper reports give a picture of widespread damage to trees, electric and telephone cables and poles, roofs, chimneys, windows, greenhouses, exposed walls and outhouses. Some cattle were killed - usually by falling trees but in a few cases by lightning or by contacting fallen electric cables. Many pigs were lost when their styes collapsed on them, as well as thousands of poultry for similar reasons.

It is evident from the reports that many thousands of trees were blown down, blocking innumerable roads and several railway lines for a time. Copious rainfall enabled swollen rivers to avail of the many blockages to cause inland flooding to damage farmland and road alike. Transport was halted in many areas and adversely affected in most. C.I.E. reported city bus services in Cork and Limerick reduced by half while only 15% of the country bus services were operating into Dublin on the morning of 12th. A figure of 10% was quoted for provincial bus services in the Waterford area. Rail traffic was also disrupted by trees, and, near Headford, Co. Kerry, by a landslide which wrecked part of the main line to Tralee.

Widespread breakage of power and telephone cables occurred and electricity supplies and telephone communications were not restored completely for over a week afterwards. In fact the E.S.B. report speaks of this storm as the worst disaster in the history of the Board with supplies disrupted to nearly 250,000 consumers and damage estimated at £467,000. The Boards returns show that 60% of the damage was suffered in the counties Kerry, Cork, Limerick and Waterford.

The brunt of the storm of 27th-28th January was borne by western and northern counties whereas southern counties had suffered most severely, during that of 11th-12th. New moon spring tides were associated with this storm but there was generally less rainfall. The history of damage and disruption by wind and wave was largely as given earlier in the month but the emphasis was very much shifted to Western and northwestern areas. The E.S.B. estimates that about 100,000 subscribers were affected by power disruption the main damage being in the Western half of the country. Repairs estimated were at £100,000.

Officials of the Forestry Department estimate that 200,000 cubic metres of timber was felled by the months gales. They welcome the fact that 90% of this timber was uprooted (and only 10% smashed) perhaps as a result of the wet state of the soil. Their opinion is that most of the damage in the South was caused by the first, and that in the West by the second storm. The Forestry officials are quite assured that damage in the West in January 1974 was not nearly as severe as that inflicted there by "Hurricane Debbie" in 1961.

/...

A study of the reports in the national and provincial newspapers concerning these storms draws attention to the vulnerability, under severe gale conditons, of a rather predictable list of objects. This includes trees, television aerials, electricity and telephone poles, some roofs and chimneys, tall cranes, incomplete buildings, farm outhouses, caravans and large vehicles of the juggernaut class.

Direct wind damage to tiled roofs was rather rarely mentioned but slate-stripping got widespread prominence. Whether this reflects a superiority of tile over slate or merely the more common usage of the latter term remains an open question. Roofs of outhouses, haybarns, and factories comprising of large sections, or sheets, such as corrugated iron, made many a newspaper paragraph by their collapse and hazardous flights over large distances. Some breakage of glass panes, even of plate glass windows was reported and much greenhouse damage occurred.

In many coastal areas wind, wave and tide combined to cause extensive damage to sturdy constructions such as shore roads, seaside promenades and, even sea and harbour walls. Inland, some damage to dwellings was caused (mainly by falling trees) and by wind alone to some prefabricated structures such as temporary schools.

2. The January Anomalous Circulation and its Implications

The Synoptic Development. In early December the surface meteorological situation over northwest Europe was dominated by a ridge of high pressure. Gradually this ridge was displaced northwestwards into the North Atlantic towards Iceland, but during Christmas it drifted in over Europe again as part of a high cell then centred near the Azores. This latter development enabled the North Atlantic depressions to penetrate again further southeastwards thereby establishing an increased south to southwest gradient over northwest Europe. Gradually as the high itself decayed near the Azores, and as another ridge over eastern Europe intensified through Finland into the Arctic Sea, a more southerly flow was established for a time over western Europe. A steady state situation was established and further depressions moving into the North Atlantic from the United States remained trapped, mainly to the south of Iceland. The ensuing stable (used here in the steady state sense) meteorological situation changed little during the first half of January and though temporarily weakening somewhat shortly after the middle of the month it was quickly re-established so that the North Atlantic depressions again formed and intensified much as they did earlier in the month.

The Circulation Anomalies. To enable us to get some idea of the extreme circulation prevailing in January, some insight into the anomalous hemispheric flow pattern should prove useful. At the 500 mb level the mean hemispheric flow in the northern latitudes was described basically by wave number two; that is two complete waves were sufficient to encompass the

/...

entire hemisphere. Past evidence suggests that the lower wave number situations tend to be very persistent, whereby the interchange of large amounts of energy between the poles and the lower latitudes is more uniformly accomplished.

Figures 1 and 2 show the January departures from the mean flow over the North Atlantic side of the northern hemisphere at the 500 mb and surface levels for both the first half and the second half of the month respectively. In Fig. 1b, representing the first half of January, the unusually large positive anomalies at 500 mb over Scandinavia, and over Europe in general, are shown (partly off the map however) as well as the increased ridging in the southwest North Atlantic. On the other hand, most of the North Atlantic however was under the influence of substantially increased mean vorticity as indicated by the large negative anomalies. The average 500 mb heights in this region reached a maximum 320 metres below normal. Ireland, too, was within the area affected by increased vorticity. Fig. 1c shows that the anomalous pattern for the 1000/500 mb thickness values was also very similar. From both of these effects the resultant average surface pressure pattern reached a maximum of 36 mb below normal at 58°N 21°W and also an average surface pressure some 18 to 24 mb below normal over Ireland (Fig. 1a). The increased surface troughing stretching from the west of Ireland southwestwards towards the Azores and then westwards towards the States north of 40°N agrees well with the series of deepening waves that took this track.

In Figure 2 also we see that, for the second half of January, the broad anomalous pattern has changed little except in detail. Here increased positive anomalies occurred over central Europe at 500 mb and the anomalies over Scandinavia have weakened somewhat Fig. 2b. The positive anomalies in the southwest Atlantic have intensified and have drifted northwestwards towards the United States. The large negative area in mid North Atlantic has drifted northwards while the range of these anomalies have been reduced. In the 1000/500 mb thickness pattern (Fig. 2c), positive thickness anomalies were enhanced over the Continents and the negative anomalies were not quite so pronounced in the North Atlantic. Average surface pressure reached a maximum of 24 mb below normal at 62°N 21°W and 4 to 12 mb below normal over Ireland. The increased influence of the troughing from the Azores to the west of Ireland also emerges from the anomalies charts.

Gale Warnings. The gale warnings, issued by CAFO*, for the Irish coastal waters and the Irish sea were in operation almost continuously from December 27, right through January, into the first week of February. During January these almost continuous warnings proved always justified particularly on the west and northwest coasts; on some ten occasions,

* Central Analysis and Forecasting Office, Dublin.

equivalent to about 50 hours, they were partially justified only as the winds on the east coasts proved slacker generally than those in the west and therefore were more likely to fall below gale force for longer periods. During January cancellation of warnings was necessary on seven occasions only giving a total of 126 hours in which warnings were not in operation.

Three Storms. The development of three depressions are described in the following sections of this memorandum. These particular depressions were chosen because, having approached closer to Ireland, either their effects, weatherwise, were greatest (as in the case of the storms of the 11/12th and 27/28th) or the particular development was considered to be more meteorologically interesting (such as the depression of the 16th). These depressions were little different however from the many others that fed into the North Atlantic during the month. The entire life cycle of forming, tracking, deepening and decaying of all depressions was substantially regulated by the basic overall quasi-stable flow pattern that had been established since the last days of December. Some were of Arctic origin but in the main the depressions were originally of the warm type.

3. The First Major Storm Depression on January 11/12th

The Establishment of the initial Field. After the broad meteorological features from Europe to North America had stabilised, waves of different origin, some of Arctic origin but more frequently of the warm type, were advected into the North Atlantic and deepened there under the influence of increased vorticity and the impinging cold air. Following repeated warm air advection from a series of these waves, considerable warm air had been induced northeastwards towards the Arctic Ocean and Scandinavia where it was absorbed into the existing easterly circulation north of the main region of low pressure in the North Atlantic. Gradually advected westwards through the Arctic regions into Greenland and beyond, an extensive pool of warm air was already formed southwest of Greenland by 100000Z (Fig. 3a). This accumulation of warm air took place immediately to the north of an Arctic pool; part of the cold advection field induced behind a relatively warm depression which had already emerged into the mid North Atlantic from the Great Lakes through Newfoundland, deepening considerably on reaching the sea. Near 50^{o}N 35^{o}W this depression turned cyclonically northeastwards and, absorbing the previous depression, it continued to deepen to a central pressure of 936 mb at 57^{o}N 21^{o}W on 101200Z. This was the deepest surface depression of the January series in the North Atlantic. Widespread gales associated with this depression occurred in Ireland on the 10th and 11th of January.

While the warm advection (north of the main North Atlantic depression) continued westwards the warm pool southwest of Greenland continued to intensify. Gradually a northwesterly surface airstream developed to the southwest of Greenland and warm advection then took place southwards to the

/...

mid North Atlantic. Mixing with the Arctic pool here the cold field circulation moderated. An interesting feature of this breakthrough of warm air from the north was that a localised surface depression was temporarily formed at 49°N 33°W on 101200Z but was quickly absorbed again as it was advected northeastwards due to lack of any warm supporting feed of air from the south at that time.

In the meantime a further wave on a more southerly track emerged into the North Atlantic from North America at 35°N 60°W. This had earlier moved northeastwards through the States but later veered southeastwards as it approached the east coast. It continued eastwards over the ocean along 38°N without further development. As it approached the Azores however it gradually turned on a northeasterly course and began to deepen significantly. Surface deepening on this occasion was supported in part (for comparison purposes we do not here consider vorticity) by the successful induction of warm air into this wave from the south. This thermal development was again facilitated by the prior reduction in intensity of the cold air field to the immediate north.

At the upper levels also the warm air advection south of Greenland was of considerable importance. This upper level flow, like the surface, consisted of a deep and extensive depression over most of the North Atlantic flanked by ridging over both the North American and European Continents. At 500 mb, therefore, the warm advection was initially experienced as a temporary strengthening of the ridge, on its eastern side, then dominating Labrador. Later, however, as the warm air moved down into the mid North Atlantic, (the ridge again reverting to its original state), the influence of the warm advection was propagated onwards so that the leading trough filled considerably and another minor ridge formed further downstream. In the meantime the main depression centre, at all levels, had moved rapidly northeastwards and with the thermal advection downstream, as described, the succeeding height rises were later quickly transmitted on to 20°W thereby resulting in a strong west-southwesterly flow being established by 110000Z in mid North Atlantic. The thickness pattern was also deformed and a minor thermal ridge was induced southwest of Ireland between 15° and 20°W. The thermal steering field had therefore become mainly southwesterly.

<u>The Developing Storm</u>. Meanwhile, northwest of the Azores, the push of warm air northeastwards continued and this induced the already deepening surface wave into a region of considerably lower 500 mb heights and increased, though as yet only slight, vorticity. Central pressure falls at the surface reached a rate of 1 mb per hour in the 12-hour period 101200Z and 110000Z even as the thickness of the associated warm air remained unchanged. The widespread warm air advection both from the north and south also contributed

/...

to bringing the upper trough more into phase with the developing surface wave and this was effected by a temporary slowing down of this trough off Newfoundland. By 110000Z therefore the vertical motion field, as a measure of the degree in which both the vorticity and the thermal field are in phase, centred near 41°N 34°W, was significant enough to ensure the continued development of this depression.

In the meantime the preceding deep surface depression was centred, on 111200Z, between Scotland and Iceland and by that stage it was experiencing the steering effects of the southeasterly flow established to the southwest of the blocking Arctic ridge. It was therefore turning cyclonically northwards towards Iceland. However the next faster moving depression was coming more under the influence of this leading depression and a newly acquired dumbbelling motion of both tended to reduce the cyclonic curvature of the track of the later depression. Surface analysis would even suggest that the movement of this depression was temporarily more anticyclonic as it approached 52.5°N 15.5°W between 111800Z and 120000Z (Fig. 3b). This latter development brought the storm closer to Ireland and this, coupled with the blocking ridge, increased the gradient at that time. At that stage the depression had a central pressure of 956 mb. Later the depression moved northeastwards off the north of Scotland and subsequently took over as the main depression southeast of Iceland.

Surface Wind Distribution. The geostrophic winds to the south and southeast of this depression reached a maximum of some 110 kts while the centre of the depression was still southwest of Ireland. In general, the geostrophic gradient exceeded 80 kts in both these directions in the range 160 to 340 nautical miles from the centre. As the depression moved to the northwest of Ireland the mean maximum geostrophic gradient measured 145 kts, again to the south and southeast of the depression centre, and the range of geostrophic winds exceeding 80 kts had extended to some 450 nautical miles in both these directions. While the induced eastern component of motion of the depression, coupled with the immediate build-up of the Azores ridge, resulted in some tightening of the gradient, maximum gusts were recorded however, mainly in the southwest to west flow behind the centre. The intensity of the gusts was in part supported by the isallobaric effect (see Pettersen), which was also mainly directed from the south to southwest, and whose contribution equalled some one-fifth of the gradient wind at that time.

/...

4. The Second Major Depression on January 16th

Wave Series in the North Atlantic. The meteorological situation at the middle of January was part of that quasi-stable situation that had already been established earlier in the month where the Azores high continued to intensify towards Europe and link up with the blocking ridge stretching from the Baltic to Northern Greenland. The centre of low pressure therefore still continued to be trapped in mid-North Atlantic, mainly to the southeast of Greenland. At the upper levels too a series of troughs were embedded in the southwesterly airstream that had been established to the north of the Azores high. Again at the surface a further series of waves, which had emerged into the North Atlantic at the lower latitudes from North America, moved quickly eastwards towards the Azores but then turned cyclonically and headed northeastwards to the north of Scotland (Fig. 3c).

One of the first of this series of surface waves (A), which had centred at 54^{O}N 19^{O}W on 140000Z, continued to deepen steadily as it moved towards the Norwegian coast (Fig. 3c). This deepening was derived mainly from an intensified local thermal advection field. With the continued enhancement of the associated upward motion a localised intense upper level vortex was established to the northeast of Scotland as this cell approached the Norwegian coast.

As this vortex intensified a cold advection field was established in its wake thereby inducing cold air into much of the northeast North Atlantic. On the western side of the North Atlantic also an extensive Arctic pool of air had advected southeastwards from Hudson Bay well out over the ocean. The combined effect of both of these incursions of cold air resulted in the thermal field in the mid-North Atlantic cooling considerably. One of the more immediate effects however was that the next wave (B), though embedded in an apparently significant thermal ridge (Fig. 3c), but nevertheless lacking any worthwhile upper level vorticity support, began to fill slowly under this cooling influence.

The third wave of the series (C), centred at 38^{O}N 48^{O}W,also on 141200Z, was located directly at the bottom of the Arctic thermal trough (Fig. 3c). The most notable feature at this stage was that the airmass ahead of this wave had also been cooling extensively, a feature that would normally have indicated a tendency for the surface cell to fade subsequently, particularly when but little upper level positive vorticity support only was then available to it.

/...

Support coming from the Northwest. Some considerable distance to the northwest however a relatively warm wave was approaching the east coast of Canada. This wave was on a more northerly track and was moving northeastwards through the United States. The associated warm air did not penetrate, however, north of the Great Lakes into the Arctic circulation present over Hudson Bay. The push of warm air otherwise resulted in the development of a flat upper level ridge which quickly propagated eastwards. The Arctic pool of air that had already emerged into the North Atlantic southeast of Newfoundland and had then encompassed the third North Atlantic wave (C) (Fig. 3d) was thereby modified by the influx of this relatively warmer air. The mixing of the two air types resulted in a weakening of the cold field against the push of warm air from the South. Quantitatively, some 360 metres in thickness of the airmass above the wave centre was effected in the twelve-hour period 141200 to 150000Z. In addition, even while the upper level vorticity was as yet not significant, an enhanced vorticity field had however been created by some sharpening of the upper level trough arising from the greater eastwards development of the succeeding ridge, as just described, compared to the slower movement of the preceding trough. With these modifications a thermal ridge, in association with the surface wave, was enabled to develop in the mid North Atlantic. In the meantime, also, the surface depression had deepened by some 8 mb in the previous twelve hours and had moved northeastwards steadily at a speed of some 50 kts but on a track which was already somewhat to the east of the earlier waves of this series. Also the thermal ridge accompanying an earlier wave (B), at that stage off the northwest of Ireland (Fig. 3d), had weakened so that a slack mainly southwesterly thermal flow was established ahead of this next depression (C).

On 151200Z extensive warm air advection was already occurring in both the mid and the west regions of the North Atlantic. While much of the warm field arose from the more northerly wave system south of Newfoundland, warm air advection was now equally effected in association with the surface depression (C) in mid North Atlantic (Fig. 3c). This warm advection led to extensive preceding upper level height rises throughout most of the North Atlantic and also to some filling of the upper level low off the southwest of Greenland. While up to then the surface wave depression had been turning cyclonically northeastwards the thermal flow had lately become more westerly and, in the changed circumstances, a more pronounced eastward movement south of Ireland towards the Bristol channel was at that time considered probable. However, after it had continued to move on its track, which still was cyclonic, for a further twelve hours, the depression (C) was located at 51°N 16.5°W at 160000Z (Fig. 3f). It then had a central pressure of 980 mb. By that time an

/...

intense surface circulation had been established and the continuous heavy rain observed near the centre indicated that a strong upward motion field already existed. This was also confirmed by the intense associated vortex induced at the upper levels, indicating that the vertical advection of vorticity was already very great.

<u>The Changing Thermal Steering</u>. Meanwhile, a cold pool of air, that had previously been trapped between the old persistent thermal ridge established on its northern side in the Norway to Greenland region and the developing thermal ridge, associated with the new deepening depression (C), to its south in mid-Atlantic (Fig. 3e), was induced into the cold advection field to the rear of the depression (C) as both fields moved into phase. On 160000Z, therefore, a strong thermal gradient field had thus been created, a factor that enhanced the influence of the thermal field both on the rate of development achieved at the surface and on the northerly component of motion of the system (Fig. 3f).

Following on these developments the cold air breakthrough had therefore temporarily cut off the warm air advection from the west North Atlantic. However, this latter warm advection field had again asserted its influence and, mixing with the leading cold air, it largely destroyed the intensity of the thermal field (Figs. 3f, 3g). This led to the strong thermal gradient being effectively eliminated and the thermal steering influence was thereby considerably reduced. The upper level flow therefore was to become the important steering factor in the subsequent development and advection of the surface depression.

<u>500 mb Steering from now on the only Important Factor</u>. At the upper levels the succeeding warm ridge continued to build quickly northeastwards so that the axis of this ridge had reached 20^{o}W by 161200Z. The leading trough circulation, by then over Ireland, had sharpened and this resulted in the upper level vorticity advection field having a maximum some 300 km south-southeast of the 500 mb centre. This 500 mb centre was located immediately to the northwest of Ireland. In the absence of a more significant thermal steering the more favourable upper level vorticity support centre was located to the right of track thereby inducing the surface depression to veer anticyclonically towards the southwest Irish coast (Fig. 3g). As the following ridge was intensifying and pushing ahead quite rapidly the surface low moved steadily eastwards without stalling or without being deflected off the south-southwest coast of Ireland. Another developing feature arising from the reduced thermal effect was that the trough at the upper levels had caught up with the surface trough. The surface centre was eventually steered on a track passing through Dingle Bay, south of the Galtee Mountains and entering the Irish Sea south

/...

of the Wicklow Mountains. As the upper air trough itself continued to steer northeastwards towards the south of Scandinavia under the influence of the Azores high, the depression again veered on a northeasterly track after it reached the Irish Sea. It then moved across the north of Wales, through Great Britain, and into the North Sea as it headed towards Denmark.

The Orographic Influence. While it is very probable that the path taken by this surface depression when passing through Ireland was to some extent influenced by the orographic steering effect, it is clear that the associated upper air depression centre stayed on course. It is significant too that because this upper air centre continued to move northeastwards the surface depression again turned northeastwards in the Irish Sea and crossed the Welsh Mountains though a small change of track more towards the north would have deflected it away from these barriers. One concludes, however, that in the absence of both a vigorous vorticity and thermal steering the orographic effect in Munster and south of Leinster can have some influence on the steering of surface depression centres. Quite likely the final slight adjustment achieved in the distribution of the upper level vorticity was fed back from this orographic influence at the lower levels.

The Uncertain Weather Forecast Conditions. Some uncertainty as to the forecast conditions, particularly wind, likely to prevail was brought about by the uncertainty in the probable path the depression would take in the neighbourhood of Ireland. On January 15 the eighteen hundred forecast, based on 1200Z data, expected the depression to quickly pass by the south coast of Ireland as it approached Great Britain from the southwest. Strong southeasterly winds later becoming northerly were forecast to occur throughout the country on the 16th. The later forecast, issued at 2345Z, and also those issued on the following morning, while expressing an element of uncertainty, expected the depression centre to pass over the northwest coast of Ireland during the day. Strong easterly winds with gale gusts, backing northerly during the day, were forecast for the northwest and northeast regions while the remainder of the country would have squally south to southwesterly winds. Thundery showers and longer periods of rain were also forecast; later, strong northwesterly winds would set in.

The strong northwesterly flow had set in by mid-day in the Southwest and West gusting to 71 kts at Cork Airport and 74 kts at Roche's Point, 50 to 55 kts elsewhere in the West. Conditions in the east midlands had improved since the rain stopped at Dublin at 1300Z. Weather conditions in Dublin in the afternoon were generally better than

/...

had been forecast earlier in the morning and this caused some unfavourable feedback from some irate recipients - for example some of the smaller builders who had once again let their employees home on reduced pay because of the forecast of very squally winds and prolonged heavy showers. The local forecasts issued in reply to telephone enquiries during the morning too had been more pessimistic than subsequent events warranted.

5. The 3rd Storm Depression of January 27/28

The Leading Synoptic Situation. The series of surface analyses in the 48-hour lead period up to January 27/28 when another deep depression passed close to the west of Ireland, in many ways looked similar to the surface analyses in the equivalent period leading up to the passage of the storm of January 12. However, conditions at the upper levels were significantly different in some important respects (Figs. 3a, 3h). On the one hand, as the warm advection in the northeast North Atlantic was able to continue northwards well past Iceland, the formation of a warm pool of air south of Greenland was not repeated. On the other hand, neither did an Arctic cold pool exist to the southeast of Newfoundland; the Arctic cold centre was still contained north of Labrador, Nevertheless a broad pattern, quite similar to the earlier quasi-stationary state, established during the first half of January, had formed and stabilised after the Azores high had receded around the 23rd of January. Ridging, though not nearly as strong as the previous development, was established over Europe through the Arctic to northern Greenland, thereby blocking the northeasterly exist of the North Atlantic depressions. These depressions first moved into the North Atlantic from the United States as minor waves, but then deepened rapidly as they moved northeastwards. Maximum wave deepening was generally reached in the region lying between Iceland and Ireland and any of the earlier depressions. already existing in this area, were pushed ahead northwards as the new depressions arrived from the southwest. While the first depressions were entering the North Atlantic on quite northerly tracks the last one, which was of greatest significance in the Irish context, moved initially on a track as far south as the Azores.

The upper air picture on the 250000Z shows the existence of a broad uniform current centred along 50^{O}N and having a long fetch from deep inside North America to the west coast of Europe. Surface waves, embedded in this airstream, were induced northeastwards and later northwards as they approached the blocking European ridge. Specifically at this time a deep depression of 964 mb was centred to the northwest of Iceland. A cold front trailed from this centre southwards along 15^{O}W and, stretching back north of the Azores, it joined a warm front associated with the next deepening wave

/...

depression already in the North Atlantic close to Newfoundland. An extensive warm tongue of air was associated with this wave. From this centre the cold front stretched back again southwestwards into the more southern States of the United States. Additional minor waves were forming and moving along this latter part of the cold front. To the north of this frontal section, over the east of the North American Continent, there existed a double cell anticyclone; the northern cell was of cold origin while the more southern cell was of a milder character. A weak surface trough stretching through this high into the North Atlantic along 45°N, reflected this separation of the Arctic air from the milder air on the south. Finally, minor thermal waves, at the upper levels, were forming in association with the surface waves and these were mainly moving along the latitude 40°N (Fig. 3h).

As the leading North Atlantic depression, at 261200Z, had reached the south of Iceland its cold field circulation was also moving northeastwards to the west of Ireland. With the attendant temporary easing in the southwards push of cold air, the Azores ridge was again rallying and incoming warm advection from the southwest was supported and intensified. The thermal steering was gradually turning northeastwards and both a 500 mb high and a thermal ridge were developing in the southeast North Atlantic.

<u>The Arrival of the Arctic Cold Field</u>. The induced localised upper level trough associated with the then Icelandic cell was quickly absorbed into the main upper air centre that was already deepening to the southwest of Greenland. By 271200Z the trough induced on the southern side of this upper air centre at 35°W was also deepening in the North Atlantic, so that the Arctic pool of air was finally induced into the North Atlantic by this development.

The main upper level developments to the north of the Azores therefore were an increase in both the cyclonic and thermal steering arising from the enhancement of both the vorticity field and the thermal gradient due to this new inducement of Arctic air into the North Atlantic circulation. However increased airmass thickness above the depression centre was also effected. The increase in thickness of the thermal ridge seems to have arisen not alone from warm air advection but also from liberated latent heat and local airmass instability set up from increased convergence of warm air, especially at the lower levels. At 271200Z therefore the vertical motion field had intensified by some 3 to 4 times that at 270000Z.

After a further period of considerable vertical motion a localised upper air depression centre was induced, by 280000Z, immediately to the northwest of Ireland; this quickly became a more significant controlling influence, than the thermal field, in the maintenance and feedback mechanism of the surface depression. With some slowing down of the surface depression the thermal ridge moved on ahead out from the centre and the surface frontal system occluded (Fig. 3i). Later the depression drifted northwards by the

/...

east of Iceland as it was then mainly controlled by the upper level vorticity field.

Pressure Gradient Distribution over Ireland. As the depression passed to the northwest of Belmullet at 272315Z a pressure of 949 mb MSL was recorded at that station. This suggests that a central pressure of 944 mb in this depression was possible which was some 12 mb lower than the system of the 12th. The track of the later depression was also closer to Ireland by some 3^{o} longitude when it was off the west coast. Additionally, when the centres of both storms were off the northwest coast, the average pressure gradient over the northwest of the country (Belmullet to Birr) measured, for this later storm, 1.7 times the pressure gradient of the previous storm of the 12th, but to the southeast of the country (Birr to Rosslare) the gradient was about equal for both. The additional isallobaric effect was again present in this later storm and it was similarly supportive when the maximum gusts were recorded. In this case also it was particularly effective in the northwest of the country where maximum wind gusting (96 kts.) for the country was recorded at Claremorris. Again these maximum winds occurred generally in the southwesterly flow after the depression centre had passed to the north of the area.

APPENDIX

Storm of 11/12th January 1974 : Summary of newspaper reports of damage

Kerry: Two mile line of trees in Muckross National Park flattened. A Spanish trawler went ashore at Valentia and another trawler sank at Fenit. The railway line near Headford collapsed in a landslide. Widespread wreckage of caravans.

Cork: High tides and severe flooding in city area in advance of storm. Premises of William Transport Group at Cork Airport demolished and Joyce Aviation hangar with several light aircraft damaged. Roof blown off grainstore at Midleton. Roof of an incompleted factory at Charleville blown across a field some of it landing on top of a 30 ft. tree. Fermoy reported many trees down in the town and plate glass windows broken. Caravan blown over a 5 ft. wall at Blackrock. Holiday caravans wrecked in many places. Bandon and Kinsale areas reported extensive damage to dwellings and outhouses. Much glass breakage at nurseries at Upton and Ardkeena. Lightning killed several cattle near Nohoval.

Waterford: Damage and disruption of flooding was reported at coastal and inland areas. Also destruction of walls, aerials, chimneys and trees.

Clare: Serious damage to seaside promenade and car park at Lahinch while a sea wall was burst at Kilbaha. At Shannon Airport the roof of a new terminal building ripped off, a handball alley wrecked and much plate glass smashed. A large prefab schoolroom at Kilmihil was shifted from its concrete moorings. Houses under construction at O'Callaghan Mills extensively damaged. Much flooding over the tops of high corcass banks near Kildysart.

Limerick: Sheds and out offices damaged in many parts of the city and a wall collapsed in Mallow Street. A tall crane toppled into the Shannon at Foynes. At Askeaton incomplete factory damaged and the roof partly blown off the courthouse. Houses under construction damaged in Newcastle West.

Tipperary: Widespread damage to roofs, trees and outhouses. A new slate roof in Roscrea was completely removed. Disruption by flooding also got prominence. Six cattle killed near Nenagh when a wall behind which they were sheltering collapsed on them.

Galway: Extensive sea damage to promenades and bathing facilities in the Salthill-Blackrock area - damage in Blackrock described as the "most severe of recent times". Much other coastal damage. Heavy seas at Cave, Clarenbridge rolled over fields dislodging walls and gates. Many dead fish washed ashore along Connemara coast. Wreckage of caravans received much

/...

prominence and also roof damage especially in Loughrea. Four cattle killed near Tuam by lightning, which also smashed two electricity poles nearby.

Mayo: Damage to slipways and piers reported. Fishing boats damaged, and one wrecked at Killala harbour. Flooding in Westport, Claremorris and Ballina areas. The latter floods stated to be an "all time record". Cattle electrocuted by fallen cables near Claremorris.

Sligo: Worst affected areas near the coast where the tides reached "new records". At Mullaghmore portion of a road washed away. Damage to roofs and to many houses under construction. Flooding caused estimated £100,000 worth of damage in Sligo harbour vicinity. Damage to caravans and sea-side installations at Rosses Point.

Roscommon: Damage to roofs and incomplete buildings and also heavy flooding, but the newspapers consider that the county escaped rather lightly.

Leitrim: Damage to roofs and outhouses and also flooding but here again the effects of the storm considered light.

Donegal: Extensive damage to roads, sea walls, and boats reported all along the coast and on the off-shore islands. Many people in coastal areas evacuated homes which were menaced by the "highest tides within living memory" though a report from Dungloe speaks of the "highest seas recorded since 1927". On Tory Island entire poultry houses lifted into the air and blown out to sea. As previously mentioned Innisbofin Island temporarily divided in two by seas sweeping over centre. Extensive flood damage mainly by sea water in coastal towns. Roof damage, main feature inland.

Cavan: Widespread damage to roofs, trees and farm outhouses also a good deal of glass breakage.

Monaghan: The few reports available give similar picture to that for Cavan.

Wexford: The pier wall at Kilmore Quay breached in a number of places. Widespread damage to trees, roofs, chimneys, outhouses and several factories. The British Rail ferry Caledonian Princess set out for Fishguard but diverted to Holyhead to prevent juggernauts on board from overturning in cross winds. Ten foot boundary wall at New Ross flattened. Much damage to caravans along east coast. Several valuable cattle electrocuted.

Kilkenny: Widespread damage to trees, roofs, glass outhouses and mobile homes. Some cattle and pigs electrocuted and poultry also lost.

Leix: Extensive damage to trees, roofs and outhouses. Some cattle and many pigs lost. Flooding also reported.

/...

Offaly: Extensive damage to trees, roofs and outhouses. The hangar at Birr Airfield demolished, its roof being carried 200 ft. and other parts being found 800 yards away. A small aircraft inside severely damaged.

Westmeath: Roof and tree and some glass damage. Extensive flooding but the overall impression that the county escaped lightly.

Carlow: Trees blocking roads and flooding, received most prominence as well as the destruction of some mobile homes.

Wicklow: Tree damage widespread. Considerable damage to caravans and the roof of N.E.T. factory at Arklow. Flooding and locally severe damage to slate roofs and outhouses reported, as well as the electrocution of several cattle.

Kildare: Extensive damage to roofs and trees, and also flooding. Several cattle killed by falling trees on one farm. Large poultry farm completely destroyed. Large glass house destroyed. Factory roof blown off.

Dublin: Windows blown in and many roads blocked by fallen trees even in the city. A modern bungalow on Howth Hill had its roof blown off. At Tallaght a prefab school and some caravans were destroyed. Some greenhouse damage reported. Flooding in some coastal areas.

Meath: Widespread tree felling estimated at 2,000 for the county. Much roof damage including that of a supermarket in Kills which took an adjacent chimney with it in its flight. The two cwt. copper dome of the "Spire of Loyd" (also in Kells) ripped off and landed thirty yards away.

Louth: Widespread roof and tree damage. Extensive flooding in Drogheda and along the Boyne estuary, where local inhabitants could not remember the river reaching such heights on any previous occasion. In Dundalk the asbestos roofs blown off four "system built" houses, cleared a row of two storey houses on the opposite side of the road.

Longford: Extensive damage to trees, roofs and outhouses. A block wall knocked down at Moyne. Three cows were electrocuted at Drumlis.

/...

Newspaper data of damage in storm of 27th - 28th January, 1974

Kerry: A quay wall destroyed at Dingle and a trawler driven aground. The flat rubberized roof blown off the technical school and chalets and caravans in the district badly damaged. At Abbeyfeale huge sections of an incomplete factory roof, weighing nine tons, and composed of cladding and iron girders, torn off and cleared an adjacent house before landing 200 yards away. Flooding reported in Killarney.

Cork: Some roof damage and many trees down, blocking some roads. It is suggested that these were trees which had been dislodged in previous gale. Some flooding in city and vicinity.

Clare: The sea wall at Ballymote breached and part of the road swept away. Caravans and an army hut destroyed at Lahinch. Kildysart area again flooded as corcass bank was breached. Fish washed up on beaches in Ross district.

Galway: Extensive damage to trees, roofs, caravans and outhouses. Salthill suffered severely with heavy damage to a large entertainment complex and an incomplete tennis pavilion. Here also several caravans were blown over a 4 ft. wall. Little news from Connemara as all telephone communication cut but it was reported that a garage at Ballyconneely collapsed, damaging a car, lorry and some machinery. At Corrib Park Estate whole sections of the roofs of a "low-cost housing scheme" ripped off. Cattle killed in the Belclare areas.

Mayo: Widespread damage to roofs, tress, and caravans. Houses under construction badly affected and some, in Claremorris, demolished. Also in Claremorris a 35 ton gantry blown off its rails and a depot in the industrial estate extensively damaged. Flooding in many areas. A plate glass window blown in in Ballyhaunis.

Sligo: Roof, tree, caravan, outhouse and haybarn damage widespread. A new silo blown down at Cooly also killing a number of cattle. At Culleenamore a section of the "Boathouse" premises completely demolished. Walls were toppled at Maugheraboy. A local E.S.B. official was quoted as saying "Debbie was a great deal worse than this storm".

Roscommon: Several reports agree that this was more violent than the earlier storm causing much damage to trees, roofs and power supplies. A goods wagon blown off its rails at Collooney.

Leitrim: Much worse than the previous storm according to the one report available.

Donegal: Many trees and poles, both telephone and electricity, knocked over. This storm described as the "worst since Debbie" in the Ballyshannon area where roof of hosiery factory was badly damaged. Caravans damaged or smashed here and at several other seaside places. A 36 ft. fishing vessel wrecked at Arranmore. A trawler at Killybegs, torn from its anchorage and grounded on a rocky beach.

Reports from other counties are scarce but that the storm had widespread effect is indicated by reports of road or rail blockage between Longford and Mullingar, New Ross and Enniscorthy and between Dublin and Sligo. Blockage due to fallen trees was also reported at Avoca in Wicklow, Killester in Dublin and at Sixmilebridge Road in Co. Clare.

ABLE I Wind data for January 1974 showing the incidence of max. gusts ≥64 kts at Irish Anemograph Stations and indicating the number of hours on these dates during which gusts ≥48 kts were recorded

ate	10th				11th				12th				15th				16th			
Jan '74 / Station	Dirn	Speed kts	Time GMT	hrs with gusts	Dirn	Speed kts	Time GMT	hrs with gusts	Dirn	Speed kts	Time GMT	hrs with gusts	Dirn	Speed kts	Time GMT	hrs with gusts	Dirn	Speed kts	Time GMT	hrs with gusts
alentia Obs.	150	66	0318	15	210	74	2205	10	190	86	0017	6				1	110	68	0132	10
oches Point				10	160	66	2107	7	210	83	0314	7				-	310	74	1600	13
ork Airport				5	180	68	2329	5	210	94	0258	7				-	300	69	1522	7
osslare				9				4	200	76	0401	8				-				9
hannon Airport				4				4	220	79	0429	7				1				1
irr				1				-	220	85	0455	8				-				1
ilkenny				-				3	200	77	0302	6				-				-
asement Airport	160	65	0750	6	150	66	2210	4	190	77	0345	9				1				2
ublin Airport				1				4	230	75	0634	8				1				1
ullingar				2				2	220	76	0528	8				1				1
lones				3				1	220	74	0618	9				4				1
laremorris				3				4	260	65	0602	6				3				-
elmullet	220	71	2330	16	240	73	0655	14	260	78	0600	11	280	72	1245	8				1
lenamoy	140	66	0451	10	240	68	0441	9	260	64	0559	7	260	65	1114	5				-
alin Head	150	65	0954	16	240	66	1102	13	240	79	0800	14	280	65	1345	10				6

/...

TABLE I (Contd) Wind data for January 1974 showing the incidence of gux gusts ≥ 64 kts. at Irish Anemograph Stations and indicating the number of hours on these dates during which gusts ≥ 48 kts were recorded

DATE	27th				28th				29th				Extreme		
Station / Jan. 1974	Dirn	Speed kts	Time GMT	hrs with gusts	Dirn	Speed kts	Time GMT	hrs with gusts	Dirn	Speed kts	Time GMT	hrs with gusts	Dirn	Speed kts	Date
Valentia Obs.	200	87	1951	10				1				3	200	87	27th
Roches Point	220	77	2130	9				4	170	65	1603	12	210	83	12th
Cork Airport	220	72	2158	8				-				8	210	94	12th
Rosslare	160	67	1810	7				5				10	200	76	12th
Shannon Airport	220	74	2213	5				1				-	220	79	12th
Birr	220	65	2320	6				1				1	220	85	12th
Kilkenny				5				-				1	200	77	12th
Casement Airport	190	66	2315	5	200	64	0100	4				7	190	77	12th
Dublin Airport	200	64	2349	5				3				-	230	75	12th
Mullingar				3	210	66	0016	2				-	220	76	12th
Clones	180	71	2322	3	230	74	1355	5				2	(220 230	74	12th 28th)
Claremorris	210	96	2249	6	220	73	0003	3				-	210	96	27th
Belmullet				2	250	74	1255	10					260	78	12th
Glenamoy				3	240	62	0130	5					240	68	11th
Malin Head	110	69	2158	5	190	87	0134	18				3	190	87	28th

TABLE II: Highest gusts recorded during Hurricane Debbie 16/9/1961 together with the number of hours during which gusts ⩾48 kts. occurred

Station	Highest Gust		Hours with Gusts
	Direction	Speed	No.
	o	kts.	
Valentia Observatory	240	88	8
Roches Point	180	71	10
Cork Airport	-	-	-
Rosslare	200	72	9
Shannon Airport	200	93	10
Birr	200	81	9
Kilkenny	200	65	8
Casement Airport	-	-	-
Dublin Airport	220	64	3
Mullingar	220	79	8
Clones	200	87	9
Claremorris	230	91	7
Belmullet	250	80	4
Glenamoy	240	85	7
Malin Head	210	98	*

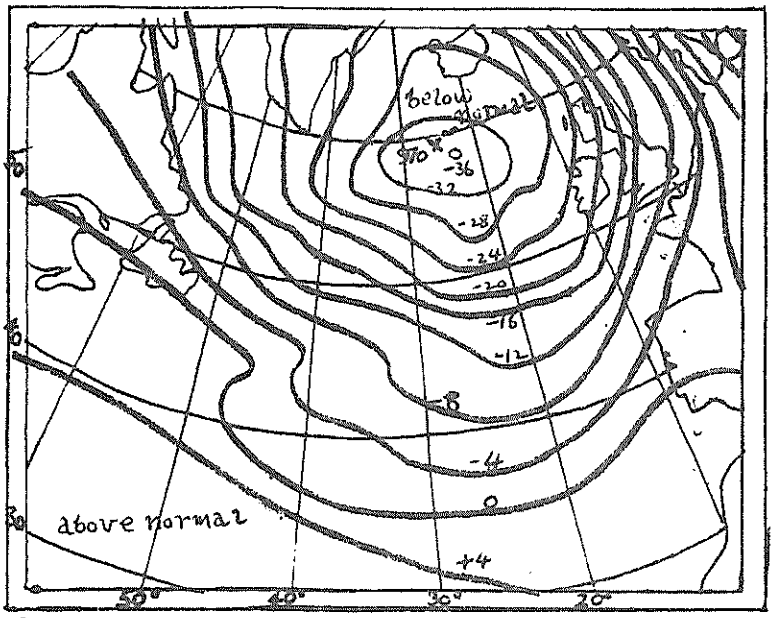
* Record defective

TABLE III: Highest mean speeds over a 10-minute interval during hurricane "Debbie" and two storms of January, 1974

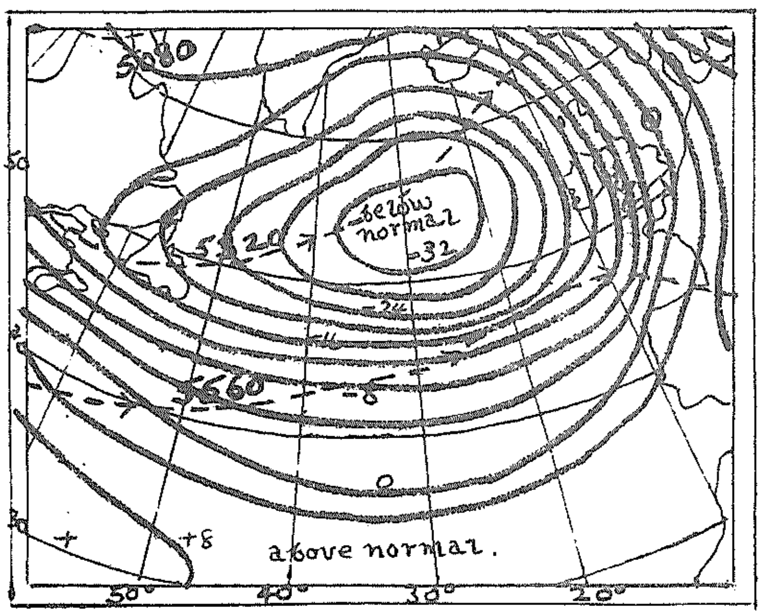
Station	"Debbie" 16/9/61		11-12/1/74		27-28/1/1974		"Debbie" minus 1st Storm	"Debbie" minus 2nd Storm
	Direction	Mean Speed	Direction	Mean Speed	Direction	Mean Speed		
	o	kts.	o	kts.	o	kts.	kts.	kts.
Valentia Observatory	240	58	190	54	200	54	4	4
Roches Point	180	52	210	62	220	53	-10	-1
Cork Airport	-	-	210	58	220	48	-	-
Rosslare	200	47	200	46	160	42	1	5
Shannon Airport	210	60	220	55	220	53	5	7
Birr	190	39	220	47	210	39	-8	0
Kilkenny	180	40	200	44	200	36	-4	4
Casement Airport	-	-	190	53	190	45	-	-
Dublin Airport	220	34	230	47	200	35	-13	-1
Mullingar	220	45	220	45	200	38	0	7
Clones	190	50	220	43	230	44	7	6
Claremorris	230	60	260	40	220	59	20	1
Belmullet	250	57	260	50	240	49	7	8
Glenamoy	-	-	260	39	140	40	-	-
Malin Head	210	66	240	54	190	61	12	5

UK.

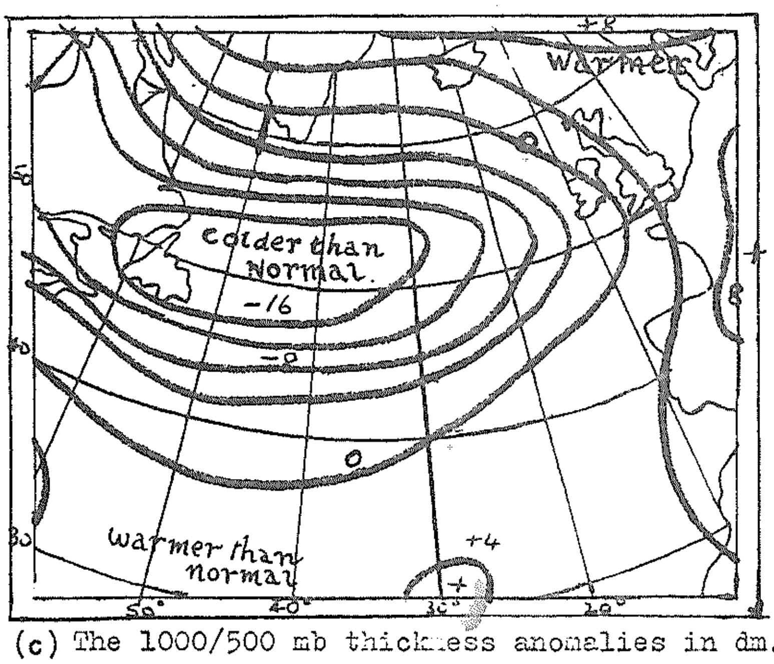
Fig. 1 (1-15) January, 1974



(a) **Surface** anomalies (departures from average) in 4mb intervals.

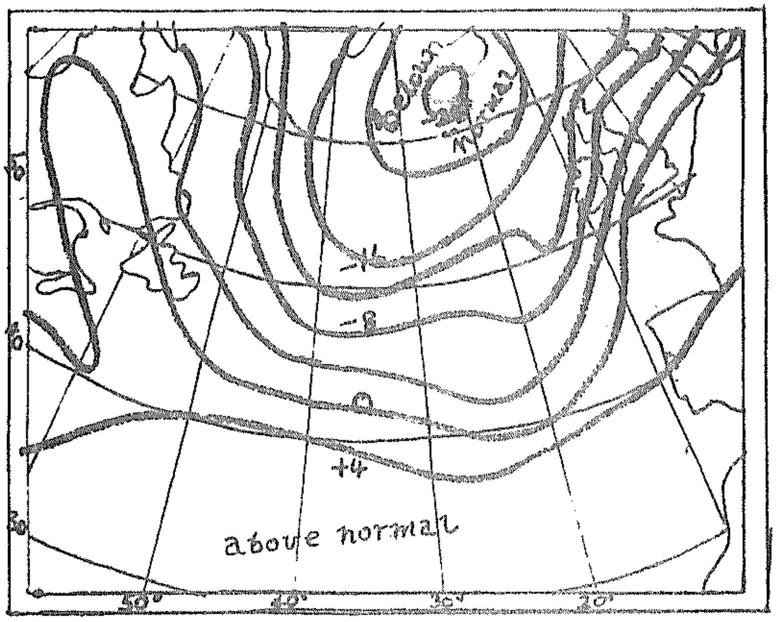


(b) 500 mb anomalies in 4 dm intervals
Dashed lines indicate the normal flow for January.

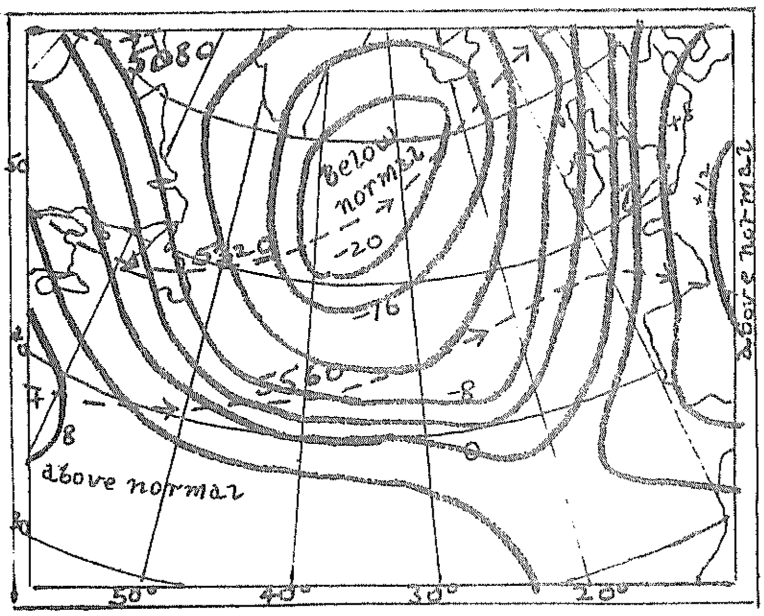


(c) The 1000/500 mb thickness anomalies in dm.

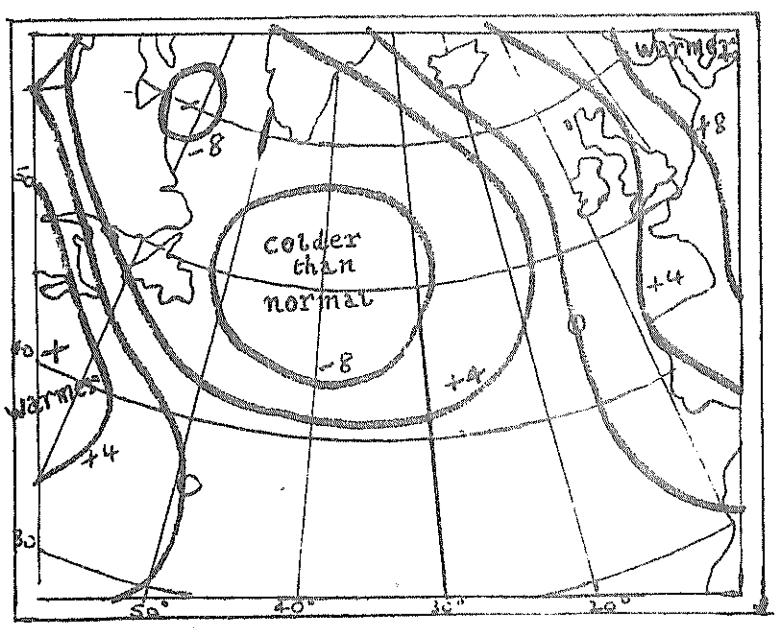
Fig. 2 (16-31) January 1974



(a) Surface anomalies (departures from average) in 4 mb intervals.

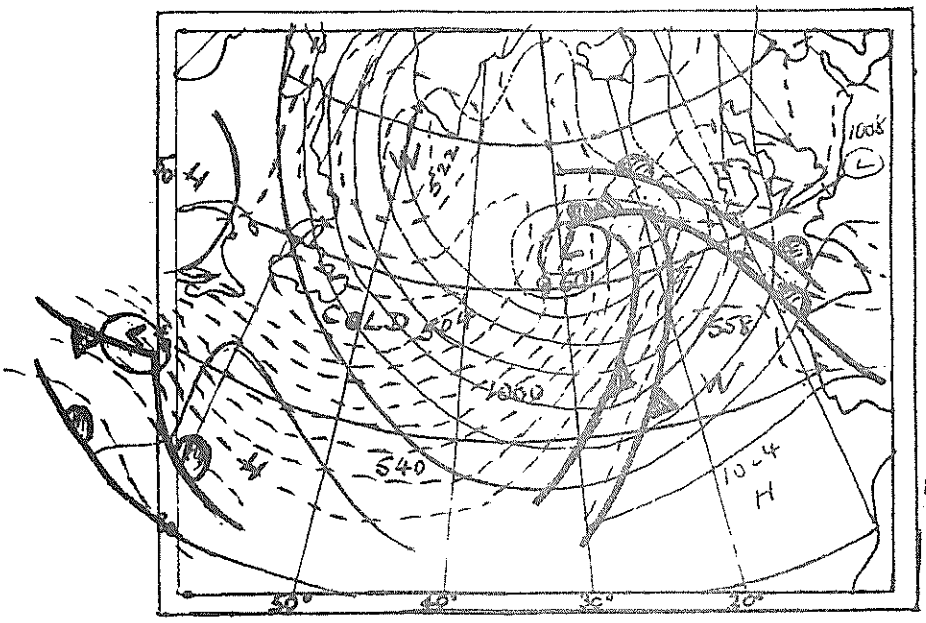


(b) 500 mb anomalies in 4 dm intervals. Dashed lines indicate the normal flow for January.

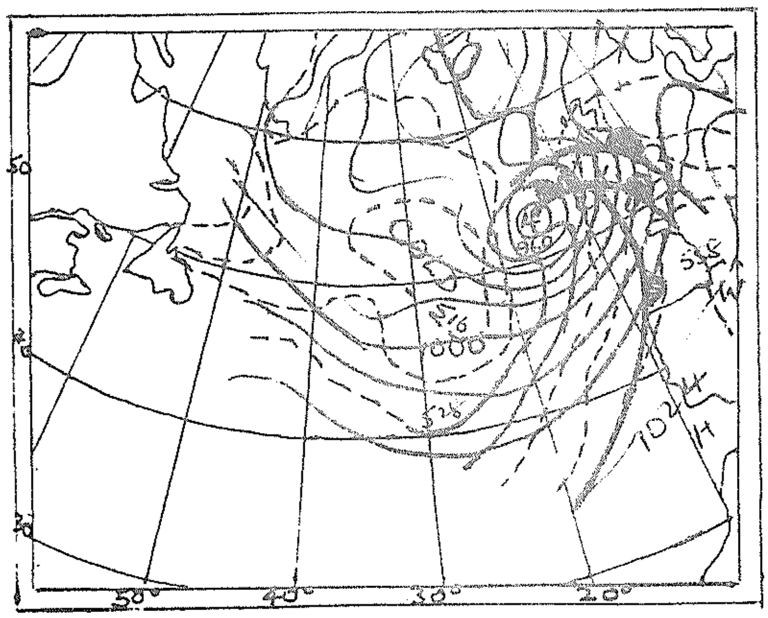


(c) The 1000/500 mb thickness anomalies in dm.

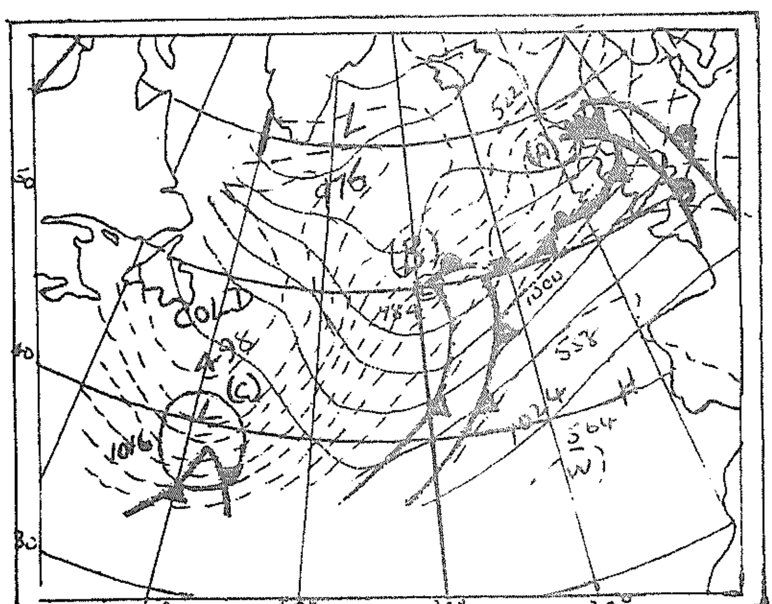
Fig. 3



(a) 100000Z : Surface synoptic (solid lines) and 1000/500 thickness analysis (dashed lines) in dm.

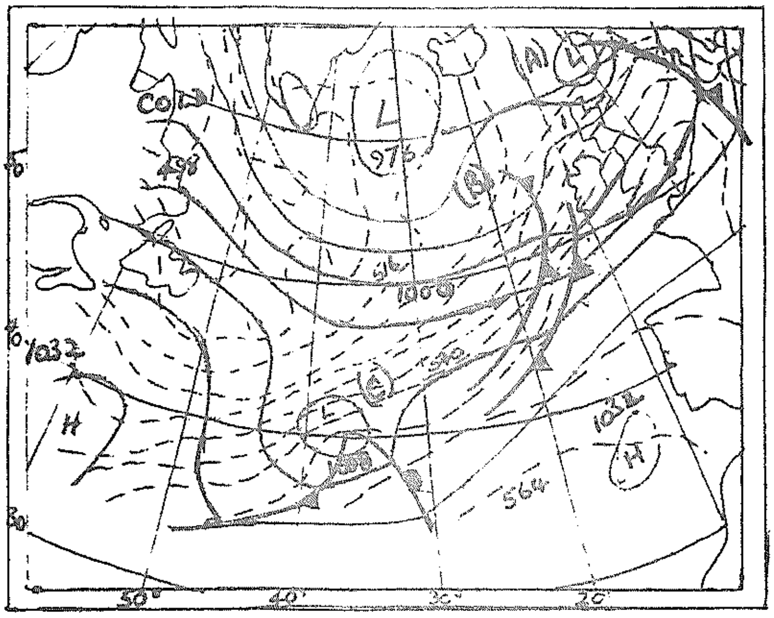


(b) 120000Z : Surface synoptic (solid lines) and 1000/500 thickness analysis (dashed lines) in dm.

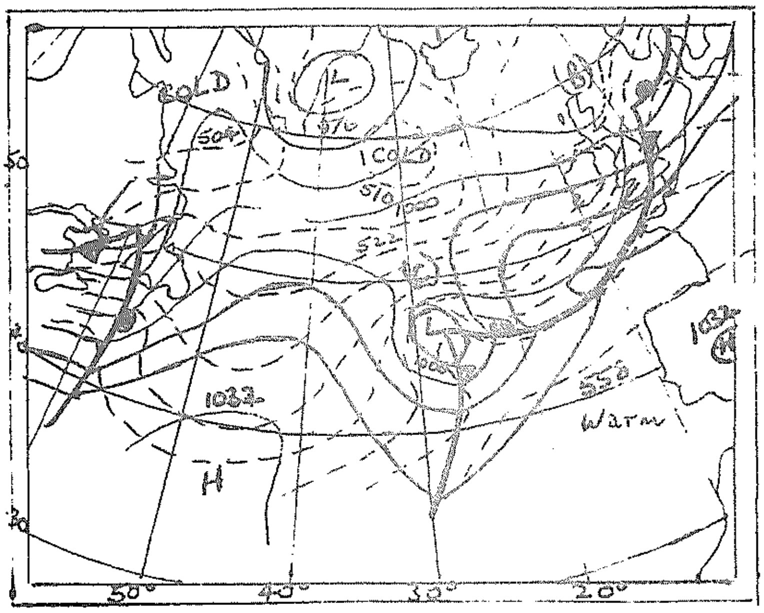


(c) 141200Z : Surface synoptic (solid lines) and 1000/500 thickness analysis (dashed lines) in dm.

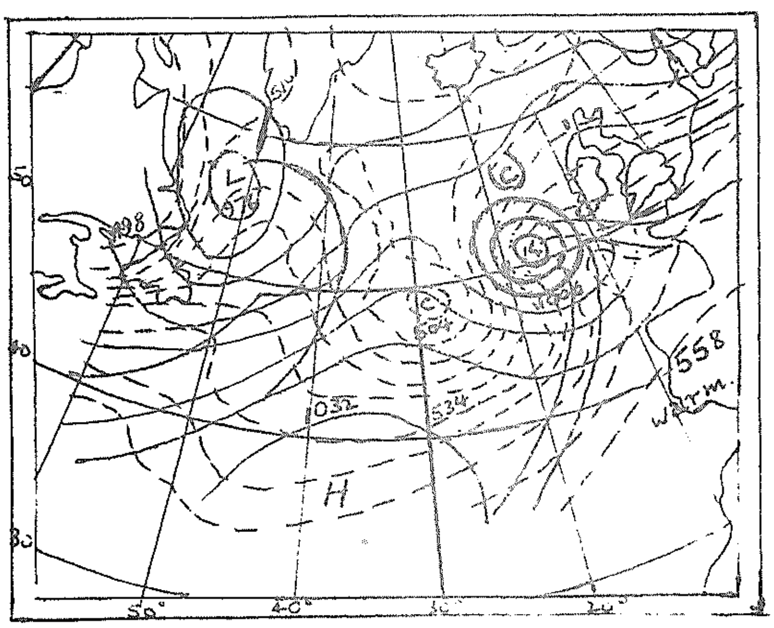
Fig. 3



(d) 150000Z: Surface synoptic (solid lines) and 1000/500 mb thickness analysis (dashed lines) in dm.

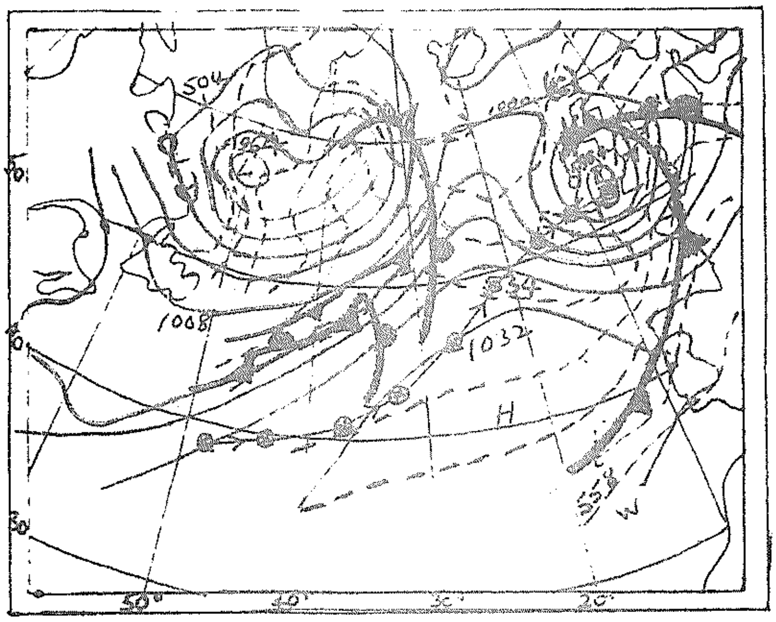


(e) 151200Z: Surface synoptic (solid lines) and 1000/500 mb thickness analysis (dashed lines) in dm.

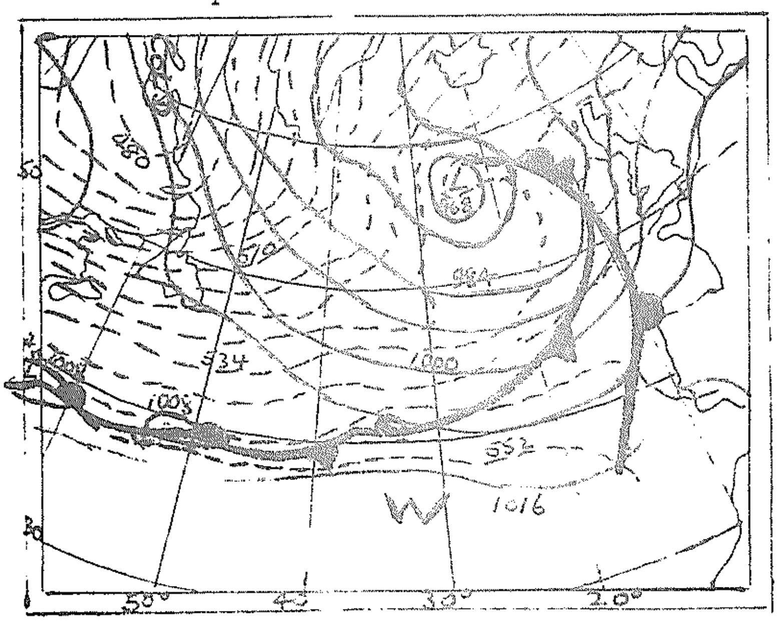


(f) 160000Z: Surface synoptic (solid lines) and 1000/500 mb thickness analysis (dashed lines) in dm.

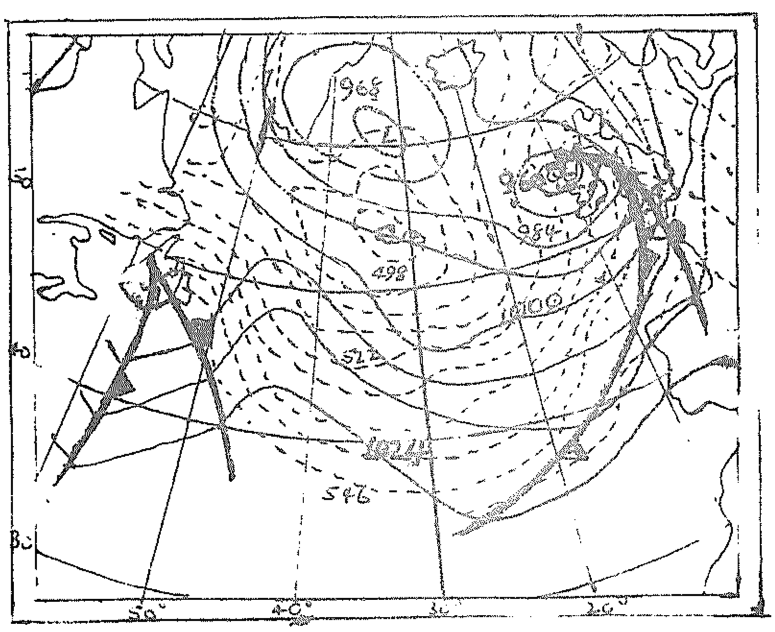
Fig. 3



(g) 161200Z : Surface synoptic (solid lines) and 1000/500 thickness analysis (dashed lines) in dm. ◎ Successive six hour positions of the depression centre



(h) 260000Z : Surface synoptic (solid lines) and 1000/500 thickness anlaysis (dashed lines) in dm.



(i) 280000Z : Surface synoptic (solid lines) and 1000/500 thickness analysis (dashed lines) in dm.