~~CONFIDENTIAL~~ DERESTRICTED

M.R.P.125
7 August 1943.

~~SECRET~~

AIR MINISTRY

METEOROLOGICAL RESEARCH COMMITTEE.

Draft Report on the Trial of Symmetry Points and Pressure Waves as a method of Long Range Forecasting.

by J. Wadsworth.

Part I Symmetry Points and Forecasts of Isobars.

During the trial the positions of future symmetry points were found in practice by means of the symmetry point slide rule, using data derived from the synoptic harmonic analysis of the weather maps. The values of the Fourier coefficients were read off the resultant charts at individual stations, and then converted into phase constant and amplitude. This method was an alternative to using the results from the pressure graphs at individual stations given by the Henrici-Coradi machine, which were not satisfactory at the time owing to defects in the instrument or possibly to the method of manipulating it. The results from the machine would have been preferable, if they had been available, because they would, I think, have given more accurate and more consistent results.

Since the trial ended a further examination of the material has led to the recognition after the event of a symmetry point near the 21st of November, which if it had been detected at the time, should have been used for forecasts for six weeks from about mid-December.

The symmetry points used during the trial for the forecasts issued during this period were as under -

No. of forecast	Range	Symmetry Point in Use
14	9th-21st December	Late October
15	12th-24th December	November and December
16	15th-27th December	No maps were prepared with this forecast.
17	18th-30th December	Symmetry point not stated.
17a	21st December - 2nd January	" " " "
18	24th December-5th January	Russia 25th Nov; Iceland 16th December; Spain 6th December; Germany 4th December
19	30th December-11th January	December symmetry points as follows:- Azores 7th; England, France, Spain 6th; Germany 4th; North Russia 15th; Iceland 16th.
20	6th-18th January	North Russia 29th Nov. The remainder of the map December symmetry points:- England, France, Spain 9th; Germany 6th; Azores 5th; Iceland 13th.
21	9th-21st January	Iceland 31st Dec; British Isles 27th Dec; North Russia 4th January; France, Spain, Azores, Germany 11th January.

These forecasts have already been discussed by the Meteorological Research Committee.

The symmetry point of the 21st November was not expected nor recognized in time in the experiment and in consequence it was not used. Attention was focussed instead on the end of October and the end of December as being likely symmetry dates according to the classical writings of the Leipzig school. The dates in early December used above correspond to the symmetry point at the end of October, being about 36 days later. This note will deal next with the symmetry point of the 21st of November and the forecasts of isobars which should have been deduced from it for the period 12th December to 20th January.

A series of charts x is attached showing a forecast of pressure distribution up to January 20th 1943 based on November symmetry points in western Europe. The series taken as a whole gives a good general forecast of the type of pressure distribution actually experienced during this time. One anomalous map should be mentioned, namely that for the 18th December 1942, in which the high pressure near Thorshavn in the forecast failed to appear in reality in the daily weather charts; but the stations in this area had a high positive secular change, which was not allowed for, and this caused the forecast of pressure to be generally too high in the Thorshavn region throughout the series of maps.

Timely Recognition of Symmetry Points. It is important to consider whether the symmetry points used in constructing the charts just described could have been recognized in time for them to have been used in an actual forecast. Taking a selection of nine stations we get the following table of results:-

Date of Recognition of Symmetry Points

Station	Symmetry Point.	Series	Date	Delay (days)	Notes
Archangel	Nov.28-29	41	Dec.22	24	Earlier series give Nov.24-26
Biarritz	Nov.21	39	Dec.16	25	
Corunna	Nov.21	37	Dec.10	19	
Hamburg	Nov.18	35	Dec.14	16	
Kew	Nov.20	37	Dec.10	20	
Moscow	Nov.29	-	-	-	Not shown by harmonics
Seydisfjord	Nov.26	39	Dec.16	20	
Stornoway	Nov.21	33	Nov.28	7	
Thorshavn	Nov.24	35	Dec. 4	10	

The delay in recognizing a symmetry point varied from 16 to 25 days with the exception of Stornoway and Thorshavn, where the delay was apparently much smaller. Moscow failed to give a result at all, perhaps by reason of faults in the original data or mistakes in the analysis at the edge of the map. The presence of a symmetry point is normally detected by the indexes 30 days after it occurs, so that the slide rule method could have saved about ten days with these stations.

Symmetry Points The existence of symmetry points in the pressure graphs of a large number of stations during the period October 1942 to March 1943 was demonstrated by means of an index of symmetry. The indexes were corrected for secular change during the interval of 60 days over which the symmetry was measured. The results are shown in the attached table x where the stations are arranged in

x. not reproduced

alphabetical order. The table gives the following information:-

(1) day of the year on which the symmetry point occurred counting from January 1st as day number one
(2) calendar date
(3) the value of S, the uncorrected index of symmetry; standard values:-

$S = 0$ perfect symmetry
$S = \frac{1}{2}$ absence of symmetry
$S = 1$ perfect inverse symmetry

(4) the corrected value of S (=S')
(5) the constant of secular change (=2c). The approximate units are millibars per day.

The table shows that symmetry points satisfying the criterion $S' < 0.2$ occurred at many stations in each of the six months October to March inclusive. The total number of stations included in the table is 90, and they are distributed in Europe and North America. The number of symmetry points found in each month is as follows:-

Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Grand Total
75	80	91	119	196	119	680

The numbers in January, February and March are slightly exaggerated by the inclusion of duplicate symmetry points when the criterion $S' < 0.2$ was satisfied on several days consecutively, and also by the fact that the number of symmetry stations in use was greater at the end of the trial than at the beginning.

Part II The 24-day Wave of 1942-43.

Summary. The morphology of the 24-day wave of pressure is described during an interval of 288 days between June 1942 and April 1943 by means of charts of phase constant and amplitude. In autumn and spring the crests of this wave converge towards an area of the western North Atlantic off Newfoundland. This fact is held to indicate that two separate supplies of cold air, which travel by different routes, meet in that region, forming with the warm tropical air to the south a triple point, the date of formation of which depends on the phase of the 24-day wave. This result immediately suggests a basis for predicting the formation of deep depressions in the western North Atlantic.

Phase diagrams confirm the persistence of the 24-day wave, and they show that its true period in 1942-43 was of the order of 20-24 days, being somewhat shorter in the north than in the south.

Introduction. The analysis extends from the 13th of June 1942 to the 27th of April 1943, the interval covered being a little more than ten months. A large number of overlapping harmonic analyses are available, computed by the synoptic graphical process of Egersdörfer and advancing by steps of three days or six days at a time. The fundamental interval for each analysis is 72 days and the 24-day wave is computed as a third harmonic.

The series numbered 1, 25, 49 and 73 include four consecutive periods of 72 days without any overlap. The terminal dates of the series are as follows:-

Series No.1	13th June 1942	-	24th August 1942
" " 25	24th August 1942-		4th November 1942
" " 49	4th November 1942-		15th January 1943
" " 73	15th January 1943-		28th March 1943.

Description of Charts The maps included herewith show the geographical distribution of amplitudes and phase constants. They refer to the intervals quoted in the foregoing paragraph corresponding to the four series Nos.1, 25, 49 and 73. In series 1, which represents approximately the months June, July and August the 24-day wave of pressure apparently has its maximum activity in the middle of the North Atlantic roughly in latitude 50°N., and there are smaller centres of activity in the Norwegian Sea and off Newfoundland, while yet another small centre of activity is seen over the south of Greenland. Four amphidromes are shown on this chart. Their positions are (1) Baffin Bay (2) the Atlantic to the South of Greenland in latitude 55°N., and longitude 30°W. (3) Skager Rak (4) northern Russia, near the White Sea. The amphidromes are the points where the amplitude of the pressure oscillation due to the 24-day wave vanishes.

The 24-day wave is practically stationary in the centres over the Norwegian Sea and off Newfoundland, but over the Atlantic the crests of the pressure wave move towards the west, completing the journey from the Norwegian Sea to Newfoundland via the British Isles in about 12 days. This statement follows from the fact that the pressure wave is in opposite phase in the Norwegian Sea and in Newfoundland.

The next series (No.25) refers mostly to the months of September and October. The chart shows that the pressure wave has by now undergone certain modifications, chief of which is the appearance of an amphidrome in mid-Atlantic. The stationary centre of wave activity is still seen to be in the Norwegian Sea and it has grown somewhat more intense than previously, and there is still also a stationary centre in the Atlantic off Newfoundland, but it is much further out to sea. The previous centre of activity in mid-Atlantic also appears to have moved eastwards towards Portugal, where it is found just off the coast. Denmark and Scandinavia remain as areas in which the wave amplitude is small, although there are now no points of zero amplitude there; while the Baltic States and Russia have a more definite centre of activity over them than they had in the previous chart.

The westward movement of the crests of the pressure wave continues over the Atlantic from the centres in the Norwegian Sea and Russia to the stationary centre on the other side of the ocean, but the route followed now lies in lower latitudes than previously.

Oneother centre of maximum amplitude remains to be mentioned, namely the centre in Baffin Bay, which is not far distant from the centre previously found in Series No. 1 over southern Greenland.

The chart for series 49 gives a picture of the pressure wave during the months November, December and January. The main region of activity of the wave is in the Atlantic and the Norwegian Sea, though a smaller centre is still found near Newfoundland. The pressure wave is again almost stationary over the ocean off Newfoundland, and also over the ocean off the coast of Portugal, but across Iceland and Finland the crests travel eastwards circulating clockwise round the amphidrome over Germany. Another amphidrome is indicated in the North Atlantic in latitude 40°N, longitude 50°W., while others are shown near the West Indies and over the American continent.

The last series (No.73) refers to the conditions in January, February and March. The area principally affected by the pressure wave includes Russia and the Baltic Sea, Iceland and the Atlantic Ocean, and the crests of the wave circulate in a counter-clockwise direction round an amphidrome in the north of Scotland. The direction of propagation of the pressure wave is thus southwards over the Atlantic Ocean. Other amphidromes exist in the south of Greenland, and there is a narrow region of small amplitudes which stretches from these across the north of Canada.

In North America the 24-day wave has a centre of maximum amplitude near the Great Lakes, across which the wave crests move eastwards into the ocean off Nova Scotia, where the wave is again almost stationary.

Interpretation of Results. According to L.Weickmann the 24-day wave of pressure is of thermal origin, the relationship with temperature being an inverse one, in which high pressure corresponds with low temperature. Furthermore the seat of the 24-day wave is the lower troposphere, and the hypothesis is that this pressure wave is closely associated with oscillations of the polar cap of cold air and outbreaks of cold air from the arctic regions. If therefore we accept this point of view we may regard the progression of the crests of the wave across the map as showing the mass movement of cold air. Accordingly from June to October (inclusive) the analysis indicates a general westward drift of cold air from the Norwegian Sea in middle latitudes across the North Atlantic ocean to the region lying off Newfoundland, while at the same time cold air from Canada drifts eastwards towards the same region. In other words cold air of arctic origin tends to converge by two different routes into the region of the North Atlantic which is off the coast of Newfoundland. The cold air mass which has drifted across the Atlantic from the European side will presumably have become modified en route so that it arrives off Newfoundland not quite so cold as the air mass which has come across northern Canada. We thus have the conditions necessary for the formation of a triple point where these polar air masses impinge on the warm tropical air lying to the south of them. Hence from time to time according to the pulsation of the 24-day wave of pressure we should expect to find in the western North Atlantic off Newfoundland conditions favourable for the formation of deep depressions.

The mechanism just described gives place in the interval from early November to mid-January (Series 49) to another in which the drift of cold air is towards the east across Iceland, Scandinavia and Russia. There is no longer the westward drift of cold air across the middle latitudes of the North Atlantic, and it would seem that in these months the tendency to form triple points in the vicinity of Newfoundland is in abeyance.

The triple-point formation tendency reappears however in the interval from mid-January to March (inclusive), as shown by the chart for series 73. In this series we see very approximately a repetition of the conditions revealed by the chart for Series No.1. The crests of the pressure wave move southwards and westwards across the Norwegian Sea and the Atlantic, while other wave crests move eastwards across Canada. The meeting place is again a stationary wave area off Newfoundland, and it is here, bordering on the warmer tropical air to the south, that we should again expect to find the triple point and the breeding place of deep depressions.

The ~~Time~~ True Period of the 24-day Pressure Wave

The period of the 24-day wave was separately determined at several stations by means of phase diagrams extending over the whole of the interval of time covered by the series Nos. 1-85, i.e. from the 13th of June 1942 to the 3rd of May 1943. The period at northern stations actually appears to be shorter than at southern stations, the values being about 21 days and 24 days respectively, though some stations show values which are exceptions to this rule. The phase diagrams were constructed from the 72-day interval harmonic analysis performed by the synoptic graphical method of Egersdörfer, the Fourier coefficients for each station being read off the resultant charts by inspection and interpolation. The results do not therefore claim to have the highest degree of accuracy. Two of the stations concerned were also tested on the 60-day interval analysis, the period of the pressure wave being given by this analysis as 23.5 days at Valentia and 20.0 days at Seydisfjord, which result approximately confirms the values derived from the 72-day analysis. The following table gives the results of the measurements of the phase diagrams in detail:-

Period of the 24-day Wave (from phase diagrams)

72-day Analysis

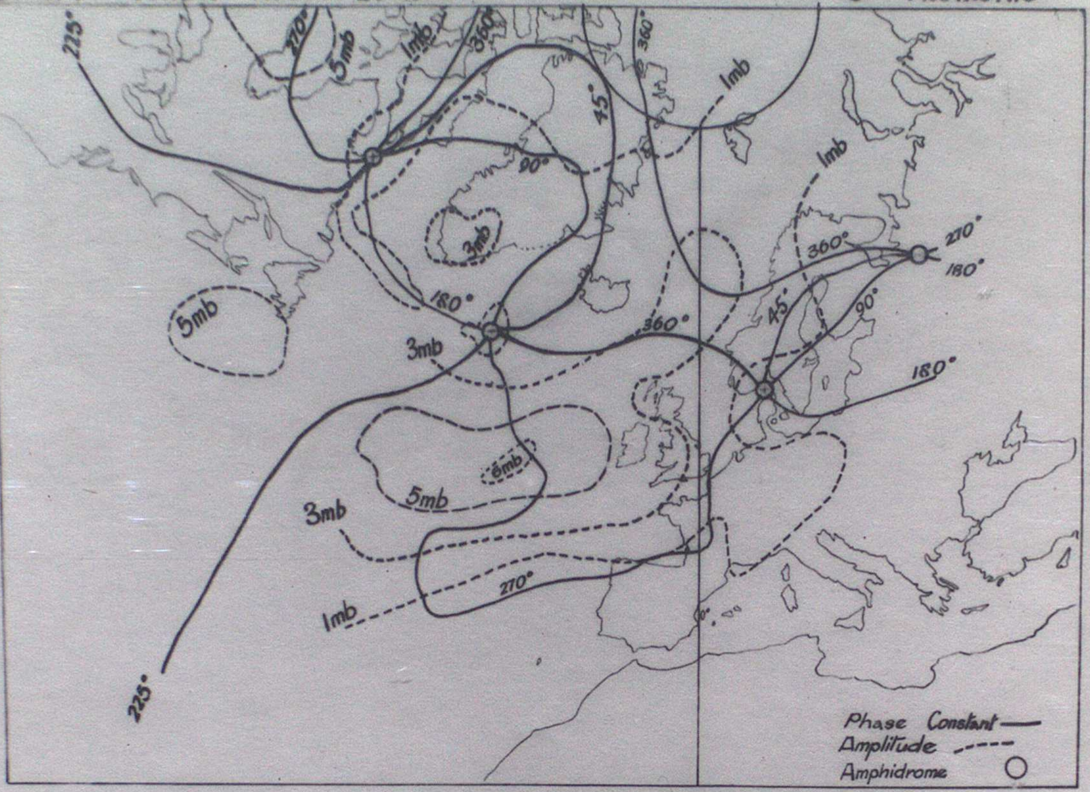
Archangel	21.4 days	Horta	23.2 days	Paris	26.3 days
Blacksod Pt,	23.8	Ingoy	22.7	Röst	19.5
Brest	24.0	Jan Mayen	20.9	Seydisfjord	21.0
Corunna	24.7	Leningrad	21.2	Sumburgh Hd.	22.6
Helsingfors	22.1	Moscow	21.2	Thorshavn	20.9

60-day Analysis

Seydisfjord	20.0 days	Valentia	23.5 days

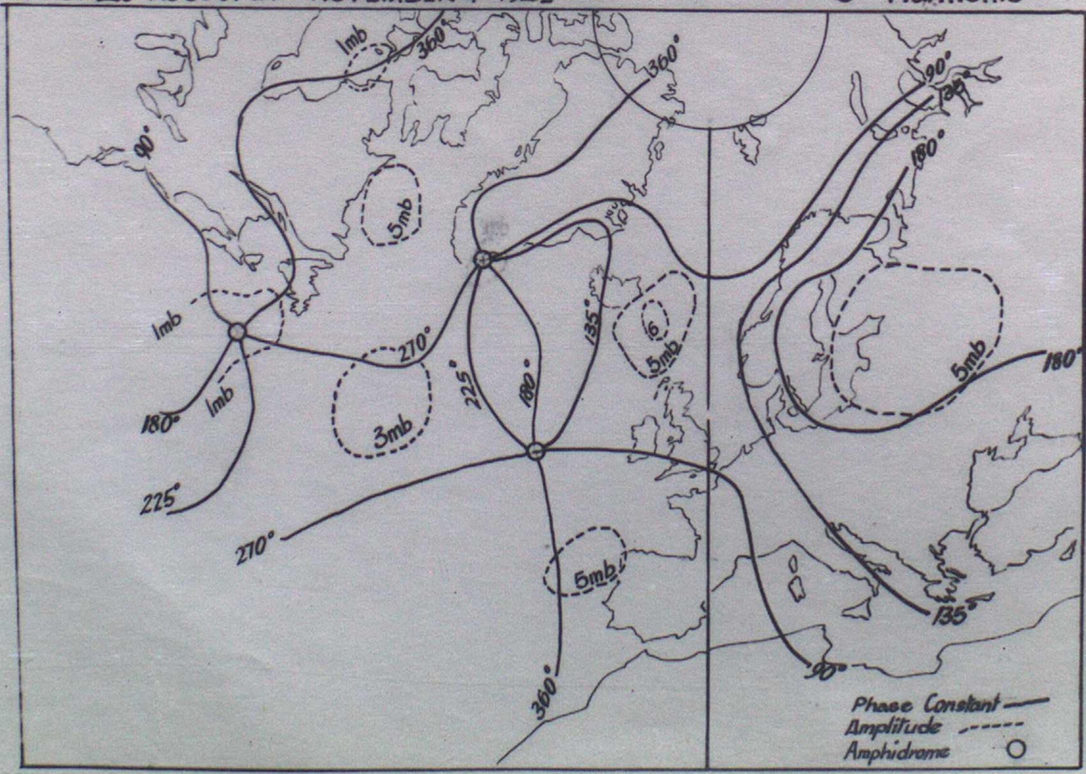
THE 24-DAY WAVE

Series 1 JUNE 13th - AUGUST 24th 1942 3rd Harmonic



THE 24-DAY WAVE

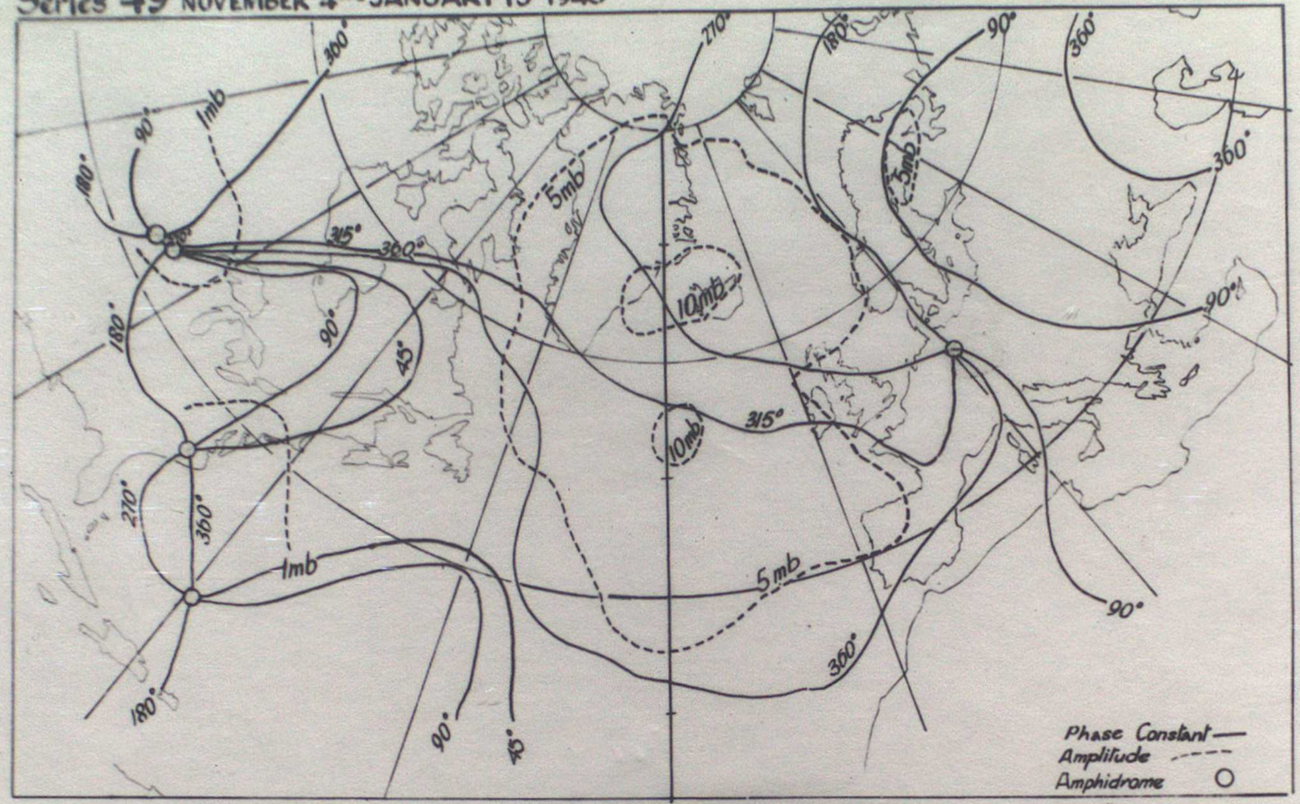
Series 25 AUGUST 24th - NOVEMBER 4th 1942 3rd Harmonic



THE 24-DAY WAVE

Series 49 NOVEMBER 4th - JANUARY 15th 1943

3rd Harmonic



THE 24-DAY WAVE

Series 73 JANUARY 15th - MARCH 28th 1943

3rd Harmonic