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Calculation of the effect of curvature of the Isobars on the Gradient Wind

by A. W. Brewer

It is well known that the difference between the gradient wind and the geostrophic wind is quite considerable when the wind is high and the track appreciably curved. Tables permitting computation of the effect have been given by Shaw and Petterson, and Petterson has described how the tables may be used to construct a celluloid scale to perform the calculation. The methods, however, are not such as to be conducive to use in ordinary forecasting, and the purpose of this note is to give a method by which the calculation can be very easily carried out.

Briefly the method consists of measuring the length of the chord to one isobar, which is tangential to the next inner isobar. From this length only (or rather the length of the half chord) a table is consulted to find the corresponding factor which will be the ratio between the gradient wind and the geostrophic wind as read off from an ordinary wind scale. The method permits of the design of a "gradient wind scale" which is almost as simple to use as the ordinary geostrophic wind scale.

The equation of the gradient wind is (see Brunt "Physical and Dynamical Meteorology")

$$\overrightarrow{\text{grad}}\, p = 2\,\omega\rho \sin\phi\, V + \frac{\rho V^2}{R} \text{ for cyclonic curvature}$$

where $\overrightarrow{\text{grad}}\, p$. is the horizontal pressure gradient, ρ the density of the air, ω the angular velocity of the earth, ϕ the latitude, V is the velocity of the air = gradient wind speed, and R the radius of the curvature of the isobars.

This equation has a root.

$$V = \frac{\text{grad } p}{2\omega\rho \sin\phi}\left(\frac{1}{1+\alpha}\right) \qquad \text{............(1)}$$

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/where

where α is defined by

$$\alpha(1 + \alpha) = \frac{\rho \text{ grad } p}{R(2\omega\rho \sin \phi)^2} = \frac{\rho}{2\omega\rho \sin \phi} \; \frac{\overrightarrow{\text{grad } p}}{2\omega\rho \sin \phi \; R} \quad \ldots\ldots(1a)$$

By putting $v = \frac{\text{grad } p}{2\omega\rho \sin \phi}$ = geostrophic wind, we may rewrite equation (1) and (1a) as

$$V = v\left(\frac{1}{1 + \alpha}\right)$$

where α is defined by

$$\alpha(1 + \alpha) = \frac{1}{2\omega \sin \phi} \; \frac{V}{R}$$

Thus the factor $\frac{1}{1 + \alpha}$ may be regarded as a curvature correction of the ordinary geostrophic wind.

To evaluate the factor $\frac{1}{1 + \alpha}$, consider two isobars of curvature R and separation d.

If a chord to the outer isobar is drawn tangential to the inner isobar then we have from an elementary theorem of geometry.

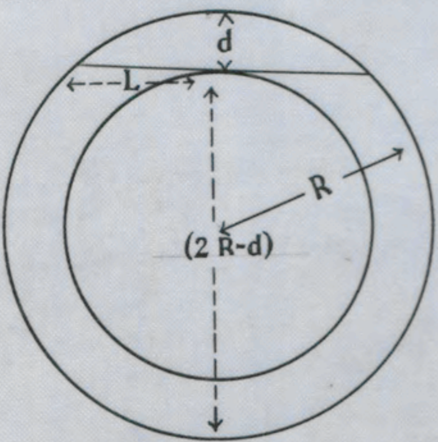
$$L^2 = d(2R - d)$$

$$= 2\,Rd \text{ if d is small compared with R}$$

but we have v proportioned to 1/d

$$L^2 \propto \frac{2R}{v}$$

and $\alpha(1 + \alpha) = \frac{1}{2\omega \sin \phi} \frac{V}{R} = \frac{K}{L^2}$ where K is a constant depending on the units used.


d
L
R
(2 R-d)

For isobars drawn on a chart scale 1: 5 x 10^6 at 2 mb intervals the constant K has a value 10.0* if L is measured as the length of the half chord in centimetres on the chart, (or 4.5 for the chart scale 1: 7.5 x 10^6). Strictly, of course, it is necessary to use the circles which osculate with the isobars, but for moderate and small values of L it is not usually possible to distinguish the difference.

The equation $\alpha(1+\alpha) = \frac{10}{L^2}$ is very easily computed on a slide rule, but we tabulate the correcting factors as below

L (half chord) for 2 mb isobars	$\frac{1}{1+\alpha}$ = ratio, gradient wind/geostrophic wind.	
	chart scale 1:5x10	chart scale 1:7.5x10
7.0 cm	.85	
6.0 cm	.81	
5.0 cm	.76	
4.0 cm	.70	.81
3.0 cm	.60	.73
2.5 cm	.54	.67
2.0 cm	.46	.60
1.5 cm	.38	.50
1.25 cm		.44
1.0 cm		.38

for L greater than 7 cm (4 cm on a chart scale 7.5 x 10^6) the effect of the curvature of the isobars is small and is usually less than other effects which result in departures of the wind from the geostrophic or gradient wind. Nor is it usually possible to estimate accurately the corresponding large curvature of the isobars.

A similar table of corrections can easily be computed for anticyclonic curvature, but in this case the difference between the geostrophic wind and the gradient wind is usually small, or due to other effects.

A special scale automatically incorporating these corrections can be made as shown in the attached diagram ~~below~~. In use the line "OX" is placed tangential to an isobar at the

* at 55°.

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point A where it is required to make the measurement and, by moving the scale, O is made to lie on the next isobar. Then along the direction AN, normal to the isobars, we get a gradient wind scale, corresponding to a geostrophic wind scale reduced in accordance with the appropriate correction for the length OA, which is the length tabulated as "L". Thus we may read off the gradient wind directly.

Example.

The red lines correspond to a geostrophic wind of 30 m/sec = 67 m.p.h. and radius of curvature of 500 Km = 300 miles = 10 cm on chart. This is tabulated by Petterson (Weather Analysis and Forecasting P.218). The gradient wind is about 22 m/sec = 50 m.p.h. approximately, as may be read off directly from the scale. (Note to conform with normal practice the speed is calibrated in mph/unit pressure difference).

Radiation from a Vertical Wall.

Mr. G.A. Bull has pointed out that in the note on this subject in the "Meteorological Magazine" for June, "h" was incorrectly stated to be the "hour angle" of the sun from south. The values of "h" used were the azimuth angles of the sun from south at each hour; which differ slightly from the hour angle. The relation is given by

$$\text{Sun azimuth} = \frac{\text{sin hour angle} \times \text{cos declination}}{\text{cos elevation}}$$

and the difference increases from zero at noon to a maximum at sunrise and sunset.

Hailstorm of June 6th, 1942.

A severe local hailstorm was experienced in the Stroud-Stonehouse district (Gloucestershire) on June 6th 1942, between 10 p.m. and 10.30 p.m. double summer time, accompanied by thunder and lightning. The shape of the hailstones varied, one $1\frac{1}{4}$in. by $\frac{3}{4}$in. was noted and others were described as flattened ellipsoids, larger than a shilling.

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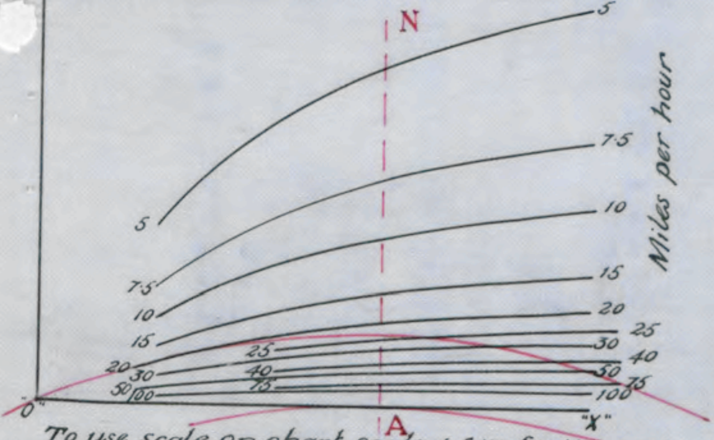
GRADIENT WIND SCALE

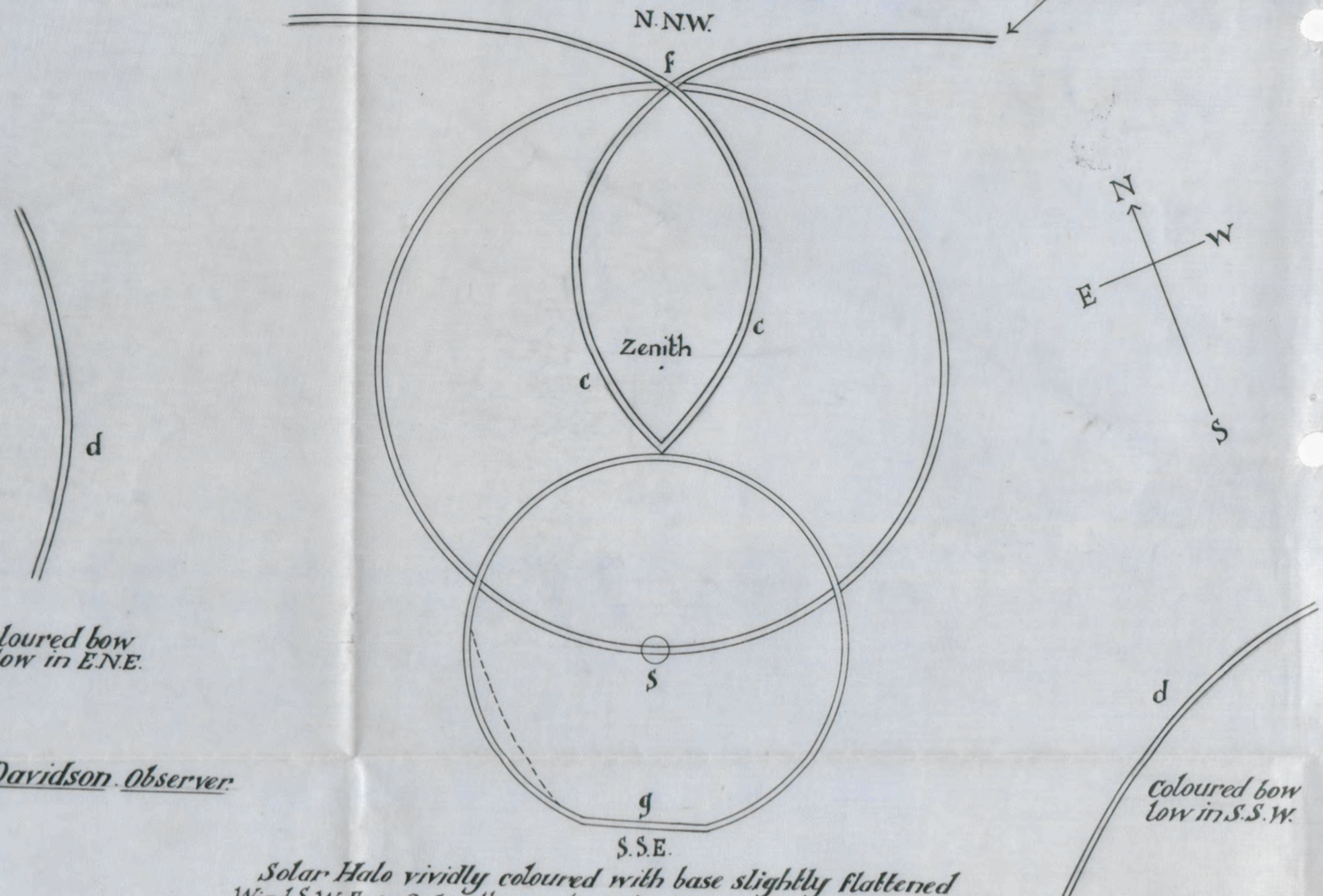
Chart, Scale 1:5×10⁶ Cyclonic Curvature only



To use scale on chart scale 1:5 X10⁶ with 2mb. isobars; place line "OX" tangential to isobar at point where measurement is required, and move scale so that the point "O" lies on the next isobar. The intersections of the curves and the normal to the isobars at the point of measurement, give a gradient wind scale for L.M.B. isobars and the gradient wind is read off in the usual way.

Solar Halo observed at Dalwhinnie July 1st. 1942

Two white colourless arcs bisecting a white colourless ring at 180° from Sun
The ring was unbroken passing through the sun



J.J. Davidson. Observer.

Solar Halo vividly coloured with base slightly flattened
Wind S.W. Force 2. Small cumulous clouds passed across phenomena during observation

Halo Complex in Scotland on July 1, 1942.

An interesting display of halo phenomena occurred in northern Scotland on July 1st. The most complete description is that sent by Mr. J.J. Davidson of Dalwhinnie, Inverness-shire.

"At 1245 hours B.S.T. when first I saw this phenomenon it was remarkably clear in every detail. The halo was strongly marked in colour; red, orange, yellow and green - the green fading into white - could clearly be distinguished. The halo was a true circle at first but later became distinctly flattened at the base while a segment in the lower left hand quarter showed up brighter against the gray background.

The horizontal circle passed through the sun while two arcs beginning outside the circle met at a point 180° from the sun, from this point the arcs swept round more quickly converging on the halo between the zenith and sun.

Concurrent with this phenomenon I observed two coloured bows at low altitude, one in the SSW, the other in the ENE. These did not touch the mountains nor were they of any great length.

The sky began to clear from the west, thereafter the phenomena faded slowly, the halo losing its colour was the last object visible and this disappeared at 1325 hours B.S.T."

A number of other reports were received at the Meteorological Office, Edinburgh, or were published in the Scotsman. The reports came from Dalwhinnie and neighbouring places, Kettins, Foyers and Beauly in Inverness-shire, Dingwall and Ardnadam (Argyllshire). The reports in general showed the features illustrated by Mr. Davidson, but that from Foyers includes also oblique arcs intersecting the mock-sun ring at 120° from the sun, the points of intersection being marked by mock suns. At Ardnadam an arc was shown 120° to the north-west of the sun extending far outside the parhelic circle. At Kettins the points where the oblique arcs through the anthelion met the halo of 22° were not coincident but about 60° apart, and the arcs, if produced, would apparently have met at the sun. These rare arcs are believed to be produced by reflection from ice needles floating with the major axis and two faces horizontal. An excellent photograph of oblique arcs through the anthelion is given on p.538 of Humphreys Physics of the Air (3rd ed.).

Drought of April 10 - May 9, 1942.

There was no measurable rain at Camden Square (London) during the 30 days April 10 to May 9, 1942. In the record which commenced in 1858 there has only been one longer dry period viz. the 37 days August 23 to September 28, 1929. The long period of dry weather in 1942 was widespread in the south of England. Over the Thames Valley draining to Teddington the 30 days April 10 to May 9, 1942 gave a general rainfall of only about .01 in. and it was the driest period of 30 days there since comparable statistics became available in 1911.

J.G.

REVIEW.

Synoptic Analysis over the Southern Oceans.
by C.E.Palmer. New Zealand Meteorological Office, Professional Note No.1 Wellington, N.Z., 1942.

This remarkable paper, which only claims to be an interim report on a work yet to be completed, commences with an historical survey of synoptic meteorology in the Australasian region and then proceeds to the modern developments of the subject which have been so largely due to the New Zealand meteorologist E.Kidson. Frontal methods were introduced or suggested by Kidson in 1923, by Wehrle and Schereschewsky in 1927 and more definitely by Lamment in 1932, who tried to fit the Bjerknes scheme and in doing so discovered a cold front in the pressure trough between two anticyclones moving over Australia. These investigators had difficulty in finding the warm front and their analyses are generally erroneous in this particular; nevertheless the Bjerknes theory of cyclone families is implicit in the work of Kidson and Holmboe in their paper of 1935.

Two conflicting schools of thought emerge from the literature of southern hemisphere meteorology. The first school, represented by Hepworth, DeMonts and Serra, requires the permanence of oceanic highs, while the second school with which Russell, Lockyer and Kidson are associated postulates anticyclones which travel across the map. It is significant that the need for the theory of the travelling anticyclone is only felt in Australasia, a fact which suggests that this region has something exceptional about it.

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The meridional front, now suggested in this paper, is a simple cold front of occlusion type, without cyclone waves, lying in the moving low pressure trough. There is no corresponding warm front. As the meridional front crosses Australia the rainfall at its passage is brief, but much heavier than the synoptic reports from the sparse network of stations often seem to indicate; and on reaching the Tasman Sea the front may become complicated in structure by the formation of cyclone waves upon it. The meridional front is found to originate in the south Indian Ocean, and the travelling anticyclone which follows it begins its career as a wedge of high pressure from the cold outbreak of air* behind a deep depression in latitude 60°S., which itself ultimately had its origin on the Indian Ocean polar front in the north-west extension of the latter towards eastern South Africa.

Some of the material used in the investigation comes from the German South Polar expedition of 1901-04 and from Whaling ships in the Antarctic in the Polar Year of 1932-33, while Tasman Sea charts refer to 1940-41. The treatment is largely in accordance with Bergen methods, and to make the best use of the observations the author also constructs meteorograms, a method which recalls Bergeron's ≠≠ skilful reconstructions (in 1933) of historic storms in the British Isles, e.g. the storms of 13th November 1875 and 28th December 1879 (Tay Bridge).

Palmer rejects Simpson's hypothesis of pressure waves travelling out from the south pole and supports the contention of Meinardus that the strong east winds at Gauss Station in the position 66°S., 89½E. were due to travelling depressions.

Synoptic meteorologists will await with interest the completion of the work, which will depend mostly on the meteorological observations made by Norwegian Whaling floating factories during 1932-33; though the author does put forward the suggestion that the whole of the German material of 1901-04 could with advantage be re-analysed on modern lines.

J. WADSWORTH.

n/ * c.f. Houzlik's cold travelling anticyclones.
≠ See Petermann's Mitteilungen, Ergänzungsheft 191 (1927).
≠≠ U.G.G.I. Lisbon Meeting 1933.

OBITUARY.

Sir Daniel Hall F.R.S. We regret to announce the death on July 5th, 1942 of Sir Daniel Hall, a leading agricultural expert and a pioneer in agricultural education. He was associated with the work of the Lawes Agricultural Trust at Rothamsted for many years and later was instrumental in bringing into being the "Crop-Weather Scheme". The conferences which led up to this collaboration between the Meteorological Office and the Ministry of Agriculture and Fisheries were held in 1923 under Sir Daniel's presidency (he was then Chief Scientific Adviser and Director-General, Intelligence Department, Ministry of Agriculture and Fisheries). In 1934 he read a paper on "Why things grow" at the conference on Agricultural Meteorology held at the Meteorological Office under the chairmanship of Sir Napier Shaw. He contributed largely to the literature of agriculture and horticulture and his wide interests, his high ideals and his charm of manner endeared him to his friends and colleagues.

Professor Dr. Carl Dorno died at Davos Platz on April 23rd 1942. He was a doctor of medicine as well as of philosophy and was Director of the Physical and Meteorological Observatory at Davos from 1906 to 1926. He was best know for his work on solar radiation and allied subjects, and his published works include some on medical climatology.

Commodore Sir Richard Williams-Bulkeley Bt.R.N.R. died suddenly on July 7th 1942. Among his many interests and activities he found time for meteorological observations. In 1933, he installed a rain-gauge and other instruments at his home at Pen-y-Parc, Beaumaris and was particularly interested in the local variations of climate. His rainfall record has been included in "British Rainfall" since 1934.
