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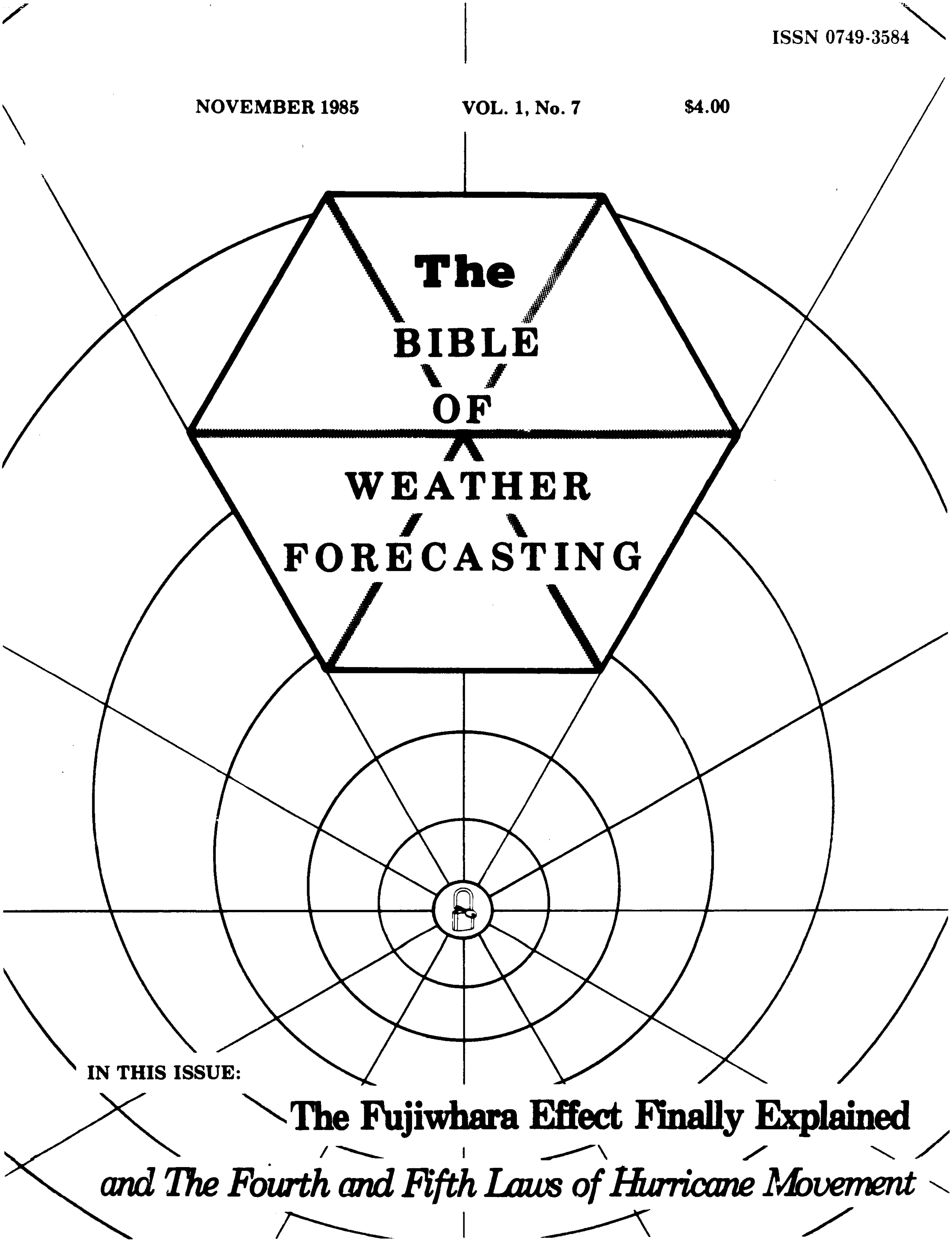

The BIBLE OF WEATHER FORECASTING

IN THIS ISSUE:

The Fujiwhara Effect Finally Explained

and The Fourth and Fifth Laws of Hurricane Movement

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Forecasting the Movement of Hurricanes, Part VII

EDITORIAL

This issue marks our first anniversary. I wish I could personally thank all of you who have renewed your subscriptions for a second year. You will find that your confidence in this publication will be well repaid. I find it a privilege to have a select group with whom this fascinating subject can be shared. Thank you.

OSCAR SINGER
Editor

47.0.0 A LITTLE MORE ON UPPER AIR CHARTS

The previous issues may have given the impression that the upper level charts are inaccurate. Not true. Some parts of the intricate patterns of highs and lows that are found on the surface can also be located (with precision) on the constant pressure charts for the higher levels in the atmosphere. The rub is, that some fine (and important) structural details are lost in the final upper air charts that are transmitted for use by meteorological services.

One problem with the upper air constant pressure charts is that they cannot be simply (and directly) compared with the surface chart (which is constructed for a constant height of mean sea level). It is like comparing apples and oranges. To compare the two charts we have to invoke an extra step of complexity, which is not needed if we used only constant height charts.

Some of you may be acquainted with the great ferment in the world of computers. Every month we see great improvements. One of the reasons for this continual progress is the incessant work to simplify programs and hardware; whether it requires the crunching of numbers, or the use of written or spoken commands by the means of artificial intelligence. The weather forecasting procedures have enough complexity of their own; it would be refreshing to say "Begone!" to an extra step of confusion which has no special redeeming features.

48.0.0 AND A LITTLE MORE ON THE QUANTUM VORTEX

One more item is added here to supplement the last issue. There is another tidbit to be squeezed out of the article by McBride and Zehr (1981) that was mentioned on page 106 of **THE BIBLE OF WEATHER FORECASTING**, issue No. 6. They stated that:

> "The radius of maximum tangential wind is about 4° latitude or 444 km. This is a fundamental difference between the cloud cluster and the fully developed tropical storm which has its radius of maximum wind at about 35 km from the center."

It is to be noted that the size of cloud clusters averaged out at "about 4°." Since they were not aware of the quantum principle, they could not know that the average size of cloud clusters had to fluctuate back and forth across 3.7500°. Without this knowledge, they did the reasonable thing and rounded off their results to the nearest whole degree. We know better however. Their value for the size of cloud clusters is in the right range for the requirements of the quantum principle.

A cloud cluster that decides to become important and change into a hurricane (like Dr Jekyll into Mr Hyde), uses the territory at its disposal (as originally authorized by the rest of the atmosphere). The cluster proceeds to break up its real estate into equal sized lots along radial and circumferential lines in shapes as indicated by Figure 9-4, page 93 of the book **SINGER'S LOCK: The Revolution in the Understanding of Weather, Part I**. When the radius of maximum winds is 34.725 km, we can describe that distance as one tract of the property commandeered by the hurricane from an erstwhile cloud cluster.

Next, let us take up the main menu of this issue.

49.0.0 THE FUJIWHARA EFFECT

We will now plunge into an investigation of the Fujiwhara effect in order to understand its cause and to also use it as a vehicle to introduce the *Fourth and Fifth Laws of Hurricane Movement.*

I have found that the Fujiwhara effect does indeed exist, but not for the currently accepted reasons. To appreciate the significance of my solution of the cause of this famous effect, I will first introduce Fujiwhara's 1923 explanation; and then, follow the attempts made by some others to explain it. Finally I will present the correct theoretical and physical justification for its occurrence.

49.1.0 Conclusions of Fujiwhara

Dr S. Fujiwhara wrote **ON THE GROWTH AND DECAY OF VORTICAL SYSTEMS** in 1923. He studied the reactions of neighboring vortexes by using laboratory experiments and geophysical observations. His results, known as the *Fujiwhara effect*, demonstrated that a relative motion would take place whereby one vortex moved around the other in a counterclockwise revolution. He also found two types of occurrences:

1. A tendency for two vortexes, both spinning in the same direction, to come together and intensify.
2. A tendency for two vortexes, each spinning in opposite directions, to separate. When this type of vortex pair was forced together, for whatever reason, the result was a destruction of the weaker one and a decrease in strength of the stronger one.

Fujiwhara also found that some of the effects mentioned above could be masked or reversed if the vortexes were embedded in a current that swept both vortexes along as if they were a unit. A stronger outside current could overwhelm the weaker Fujiwhara forces.

Fujiwhara indicated that 1 and 2 above were foreshadowed by Okada's law (1907)—a general rule of meteorology known to Japanese forecasters:

"When a cyclone [low] moving from west to east is followed by an anticyclone [high], its velocity is accelerated, and when it is preceded by an anticyclone its velocity is retarded. With a succession of cyclones the opposite is the case." (When a low moving from west to east is followed by a low its velocity is retarded, and when it is preceded by a low its velocity is accelerated).

49.2.0 Conclusions of Haurwitz

Bernard Haurwitz (1951) introduced the concept of a center of mass around which two storms rotate. He developed a formula connecting the rotation rate and the sum of the total circulation of the mass of two nearby cyclones. However, his equations applied to actual observations were not completely satisfactory according to Chang (1983) and others.

49.3.0 Conclusions of Hoover

Eugene Hoover (1961) presented evidence that in the Atlantic, cyclone pairs would tend to rotate in a clockwise direction, while in the Pacific counterclockwise motion usually prevailed. He suggested that the different behavior in the Atlantic basin occurred because Atlantic double systems (binary systems) occurred farther north (as compared to the Pacific) where they were subjected to a counterclockwise steering shear.

Hoover elaborated in his article on how to determine the *relative motion* of two storm centers as follows (see Figure 49.3.1):

1. Draw two circles having a common center with radii of 600 and 1200 nautical miles on tracing paper (as shown in the Figure). Also draw a line through the circle center to indicate the north-south direction.
2. Lay the tracing paper on the weather map so that the center of the circles is over one of the hurricanes and then line up the north-south line along the longitude of this hurricane.
3. Mark the position and date of the second storm center to enter its relative position at that time.

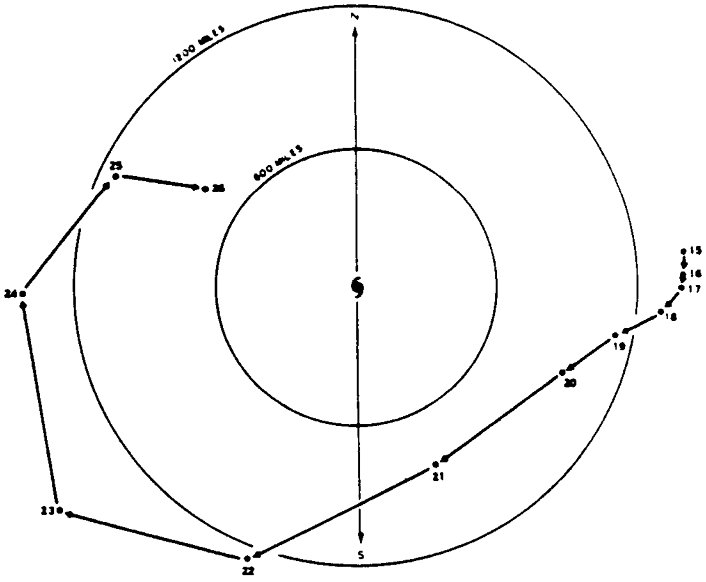

FIGURE 49.3.1 The relative motion of an Atlantic hurricane pair, August 15-26, 1893. The first hurricane is located at the center of the concentric circles. The path of the second hurricane relative to the first is given by the arrows connecting daily relative position points. (Hoover, *Monthly Weather Review*)

4. The next day, center the circles over the new position of the first storm, orient the north-south line, and mark the new position of the second storm.

5. Keep repeating the above procedure for each following day for as long as the two storms make themselves available.

6. Connect their daily positions to give the relative movement of the two storms during the period of interest. (It must be remembered that the storm at the center was itself moving all the time, but its motion is removed by this procedure. All we get is the relative motion of storm 2 as compared to storm 1).

This is similar to plotting the relative motion of two boxers circling, approaching, or retreating from each other on a moving ship. Both are on the Earth which is rotating and circling the fleeing sun. In making a plot of their relative motion we eliminate any motion common to both, including the movement of the ship. Likewise, the plot made in Figure 49.3.1 subtracted the movement of the first storm from the movement of the second storm to give us what was left—the relative motion.

In this Figure, the second storm moved in a clockwise direction around the first storm from the 15th to the 26th of August, 1893. Also to be noted:

1. The second storm was moving or flying past the first storm from the 15th to the 17th, since it maintained an unchanging distance from the center; even though it did move towards the south. (Anytime the relative motion of one storm is in a circular path around another storm, we know that they are not approaching or retreating from each other).

2. The second storm moved closer to the center of the first storm from day 17 to day 21, but it moved away from the 21st to the 23rd. Nevertheless it moved continuously in almost a straight line of relative motion from day 17 to day 22. This was in effect a *relative fly-by* where neither storm seemed to affect the other.

3. The second storm moved away from the center during days 21 through 23.

4. The second storm moved towards the center during days 23 through 26.

49.4.0 Conclusions of Brand

Samson Brand (1970) wrote in his abstract:

> "Fifteen years of typhoon data (1953-67) were evaluated to determine the general character of the 'Fujiwhara effect' with respect to the separation distance between two interacting tropical cyclones. The results show that the rotation of the binary [double] system is sharply dependent upon separation distance for distances less than 750 nautical miles There appears also to be a slight attraction between the two vortex systems, which becomes well defined at separation distances less than 400 nautical miles. . . ."

He also mentioned that forecasters had increased difficulty forecasting the future position of hurricanes when they were exhibiting the Fujiwhara effect.

The Fujiwhara effect describes two different phenomena of double storms: (1) the change in separation distance between them, and (2) the counterclockwise rotation about each other. Brand computed the 6-hour distance between two storms, and the 12-hour angular change in orientation of a straight line joining the centers of the two storms as shown in Figure 49.4.1.

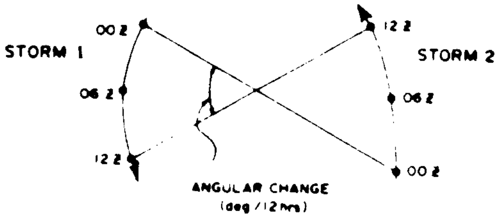

FIGURE 49.4.1 Determination of 12-hr angular change. (Brand, *Journal of Applied Meteorology*)

This type of calculation was made for 22 pairs of hurricanes and he found that:

> "There was a distinct break in the pattern of 12-hr angular changes at separation distances around 700-800 nautical miles. At smaller separation distances the angular change seems to increase sharply, in an almost linear manner. Thus for tropical cyclones separated by less than 700 nautical miles, the large rotational values seem to indicate a definitive mutual interaction. . . ."

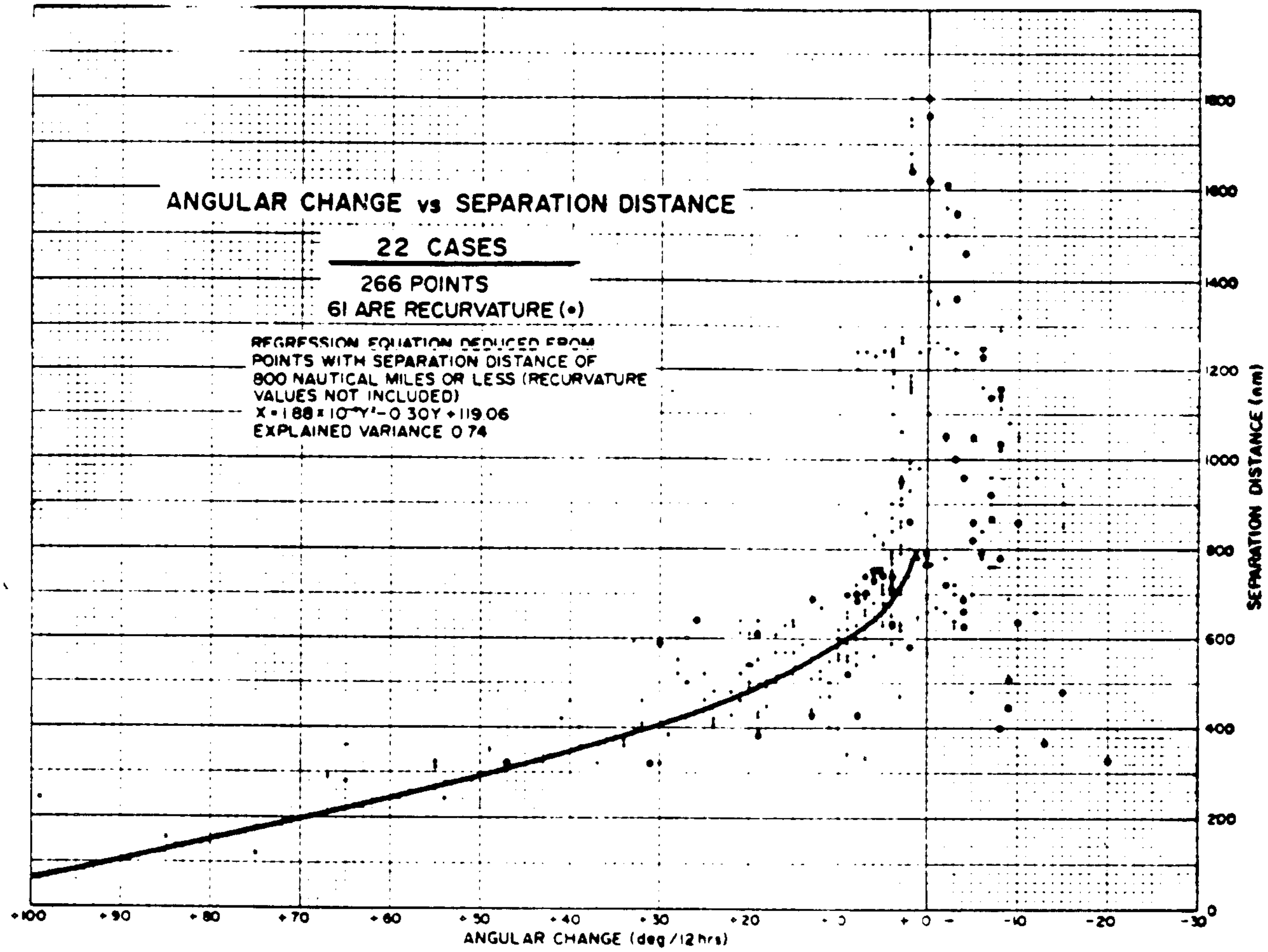

FIGURE 49.4.2 12-hr angular change vs average separation distance between tropical cyclone pairs over the 12-hr period. (Brand, *Journal of Applied Meteorology*)

Figure 49.4.2 shows how he plotted a graph of separation distance versus angular change. Also shown is the complex formula he developed from this graph.

The decrease in the distance between the two storms could be a measure of their mutual attraction (he thought). To explain the reason for this attraction, he constructed Figure 49.4.3 below, and gave the following explanation:

"The arrows represent low-level transport into the vortices. At large separation distances (3a), there is very little interaction; but at relatively close distances (3b), the transport at the closest point between the two vortices is reduced in such a manner as to produce a net force on each vortex, with the result that the separation distance between the two vortices decreases as they rotate about each other (3c)."

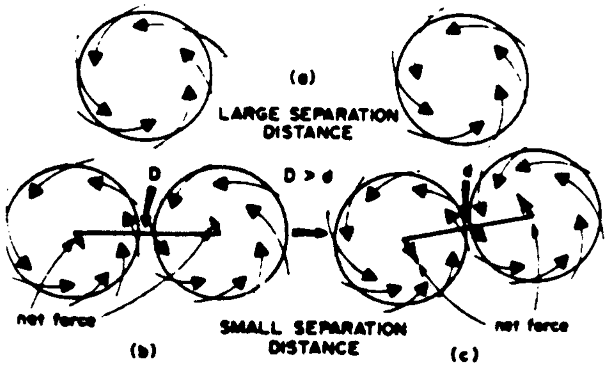

FIGURE 49.4.3 Representation of the mutual attraction of two vortices exhibiting convergent inflow according to Brand. (*Journal of Applied Meteorology*)

According to his understanding (at that time), two storms move towards each other because the transport at their closest point is reduced. There is no further explanation as to how and why this lack of transport would cause the separation distance to decrease. He simply states that there is a net force that somehow does this chore of bringing the storms together. He also concluded that the results of his study indicated a definite relationship between the separation distance of the two tropical cyclones and their angular rotation rate.

49.5.0 Conclusions of Dong and Neumann

Keqin Dong and Charles J. Neumann (1983) looked for the Fujiwhara effect in 43 double cyclone systems that occurred over the Western North Pacific from 1949 to 78. Although the effect was present in most cases, there were some exceptions. These were situations where the environmental currents (in which the storms were embedded) had a sufficient impact on their movement to hide the Fujiwhara effect.

Of the 43 different binary systems they studied, with some pairs lasting for five days, they found that:

1. In thirty cases the relative movement about the midpoint between each pair was in a counterclockwise direction.
2. In five cases the relative movement was clockwise.
3. In eight cases the relative movement was indeterminate.

They also found that a pair of storms that were 900 km or less apart:

1. Would come closer together about 60% of the time, as predicted by the Fujiwhara effect.
2. Would not change the separation distance between them about 25% of the time.
3. Would increase the separation distance between them about 15% of the time contrary to the Fujiwhara concept.

49.5.1 Analysis of Clockwise Relative Rotation

Dong and Neumann analyzed the five cases of clockwise circulation that did not comply with the precepts of Fujiwhara. In three cases the separation between the hurricanes was more than 1112 kilometers and the steering of both hurricanes in each case was under the influence of a similar type of subtropical high. Figure 49.5.1.1 shows the pair Della and Faye, which is one of these three. According to Dong and Neumann the Fujiwhara effect was masked by (1) the large scale steering forces and (2) the large separation distance between storms. Figure 49.5.1.2 shows the relative motion of this pair. The upper track shows the relative motion of Della when Faye is considered as the storm in the center; while the lower track shows the relative motion of Faye with Della in the center. (The number 6017 refers to the 17th storm of 1960. This is the system of reference used by some countries in the Western Pacific).

Look at the relative track marked Faye. It can be seen that the final 12-hour relative movement (the one which is terminated by the tip of the arrow), is in a south-southwest direction. From the track in Figure 49.5.1.1 we know that Faye never moved to the south-southwest. What we have gained from Figure 49.5.1.2 is the information that Faye found itself at a greater distance from Della in the last 12-hours (Faye began falling behind in its movement)—and that the increase in separation distance took place in a south-southwestern direction.

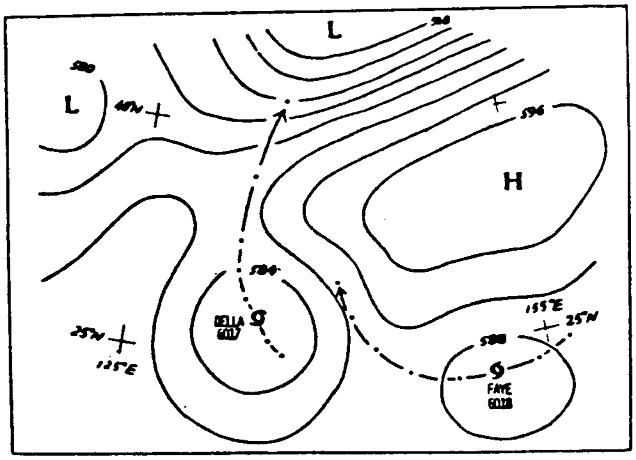

FIGURE 49.5.1.1 The 500 mb upper air flow and the surface tracks of Della and Faye at 1200 GMT 27 August 1960. Designated storm positions (dots) are at 12 hourly intervals. (Dong and Neumann, *Monthly Weather Review*)

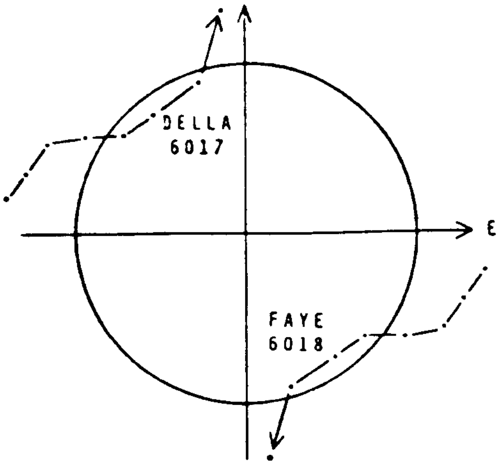

FIGURE 49.5.1.2 Relative Motion of the tropical cyclone pair Della and Faye, 27-30 August 1960. Storm center positions are given every 12 hours. Radius of circle is approximately 650 km and origin represents mid-point of line connecting storm centers. (Dong and Neumann, *Monthly Weather Review*)

Hurricane Gilda and Ivy in 1962, and Lucretia and Missatha in 1950 were the remaining pairs that moved in a clockwise relative motion. Figure 49.5.1.3 shows the actual path of Gilda and Ivy while Figure 49.5.1.4 shows their clockwise relative motion. According to Dong and Neumann: (1) the two storms were close enough for a counterclockwise rotation, but this was masked by the background flow; and (2) the distance between the two storms did decrease in accordance with Fujiwhara, but this decrease was principally due to steering shear.

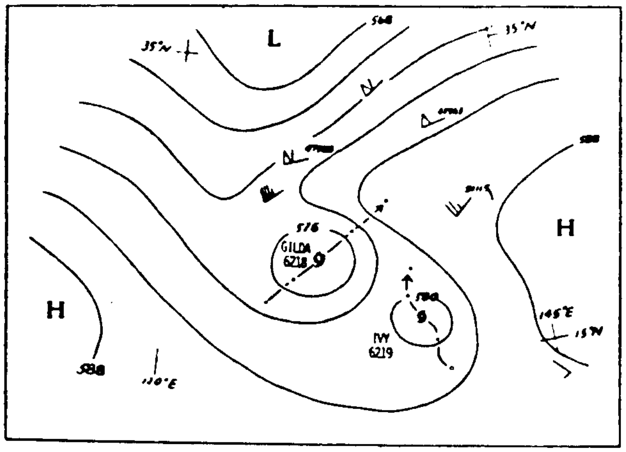

FIGURE 49.5.1.3 The 500 mb upper air flow and the surface tracks of Gilda and Ivy at 1200 GMT 28 October 1962. (Dong and Neumann, *Monthly Weather Review*)

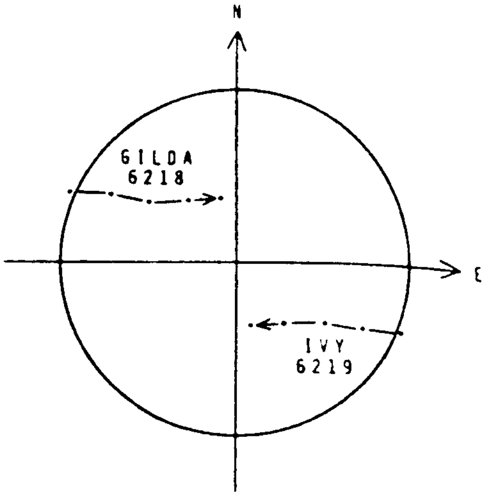

FIGURE 49.5.1.4 As in Figure 49.5.1.2 except for Gilda and Ivy (27-29 October 1962). (Dong and Neumann, *Monthly Weather Review*)

The term "steering shear" doesn't give a satisfactory picture. Let us analyze what happened in finer detail. In Figure 49.5.1.3 the actual path of Gilda is virtually a straight line, which indicates a steady control of its movement by some resultant of forces. The actual curvy path of Ivy indicates that it was the one that had to accommodate itself to the Gorrilla-like hurricane to its north. In an avoidance attempt, Ivy turned to the northeast and tried to move into a path that would run parallel to that of the monster. Unfortunately Ivy couldn't make it past the point indicated by the arrow-tip in the figure, where it combined willy-nilly with Gilda (the so-called Ape). Again we note that the relative motion of Ivy with respect to Gilda is also, nearly a straight line (and vice versa for Gilda). If we look at the relative motion, however, in Figure 49.5.1.4, we see that Ivy was moving in a relative straight line towards Gilda (but aiming off-center). *Presumably Ivy would have continued in a straight line (of relative motion) past the tip of the arrow if it had not combined with Gilda at that position. Ivy failed in an attempted fly-by that stumbled at the last marked position.* Ivy could not sneak by Gilda because its size was large enough to scrape and bang against Gilda who then proceeded to eat Ivy (like an unsociable Gorrilla).

49.5.2 Analysis of Counterclockwise Relative Rotation

Of the 30 counterclockwise rotating pairs, about 20 were located in or near the *ITCZ* (Intertropical Convergence Zone, which is the dividing line between the trade winds of each hemisphere, with easterly flow to the north and westerly flow to the south of the zone). This should not be surprising, since this region is often isolated from the effects of storm activity in either hemisphere; thereby occasionally permitting two storms to interact with each other without outside interference.

Figure 49.5.2.1 shows the relative motion of tropical cyclone pair Marie and Kathy, giving us a fine example of counterclockwise rotation and mutual approach of two centers over a long period of time. Figure 49.5.2.2 shows the actual tracks of Marie and Kathy.

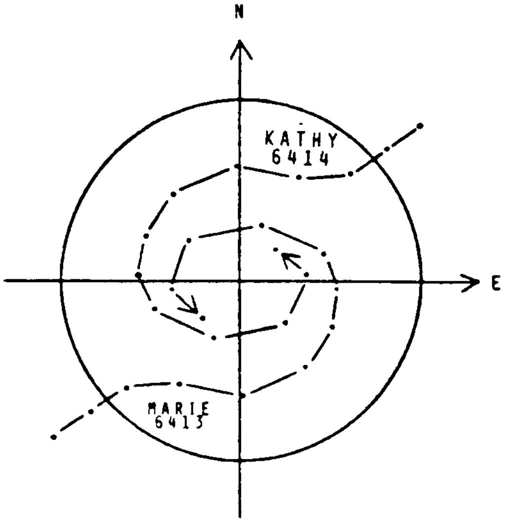

FIGURE 49.5.2.1 As in Figure 49.5.1.2 except for Marie and Kathy (14-20 August 1964). (Dong and Neumann, *Monthly Weather Review*)

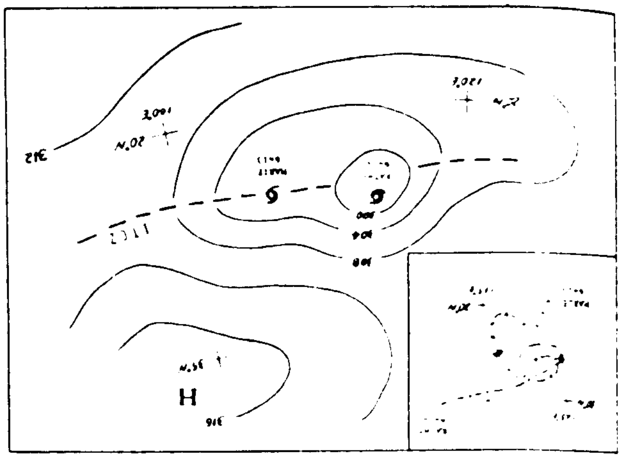

FIGURE 49.5.2.2 The 700 mb upper air flow at 1200 GMT 17 August 1964, and the surface tracks of Marie and Kathy. Insert shows tracks of Marie (6413) and Kathy (6414) from 0000 GMT 14 August to 0000 GMT 20 August 1964. (Dong and Neumann, *Monthly Weather Review*)

Since storm center positions are given for each 12 hours (Figure 49.5.2.1), it can be seen that the 12-hour distance (of the relative motion between two centers) is greater when the movement is in a relative east-west direction. This is what might be expected with a general easterly flow north of the ITCZ zone.

It can also be seen that the storms approach each other more directly whenever they are lined up in a northeast-southwest direction; however, the approach is slowed down, with a tendency for the distance between the centers to increase when they are aligned in a northwest-southeast direction.

Dong and Neumann indicate that these results "show that the observed distribution of angular rotation rates and separation distances between binary pairs may be satisfactorily interpreted as the steering effect of basic ITCZ currents on the embedded tropical cyclone pair. . . ."

50.0.0 WHY A FUJIWHARA EFFECT?

The two effects described by Fujiwhara were based on empirical observations about the reactions between vortexes. The preceding has been a summary of some of the articles written on his famous observations. We have seen that the investigating authors attempted to verify that these effects really occur; and also attempted to establish some sort of physical and theoretical explanation as to why storms should revolve around each other, move towards each other, and finally combine to form a single vortex. All of the above analysts acknowledge that their conclusions as to why these things happen are only tentative and further research is necessary.

So, let us explain the first part of the Fujiwhara effect by presenting the precise physical and theoretical reasons *why* and *when* vortexes are forced to rotate around each other. To do so, we will take a close look at the seemingly innocuous "col".

50.1.0 The Mighty Col

In the vast amount of meteorological literature accumulated over the years, I can't recall any articles in the research journals on the seeming nonentity that is called a "col." How could a zone located between vortexes (where the wind is as calm and as peaceful as a sleeping leopard) influence the colossal weather machine? Let us scrutinize three classes of cols to get a better appreciation of the character of this "ground zero" zone where the wind speed is zero.

50.1.1 Class I

Two high pressure centers dominate the col. Figure 50.1.1.1 is an example from an actual weather map for December 9, 1950. Figure 50.1.1.2 is an artists conception showing two highs that are responsible for the col zone of no winds. The winds of high A collide with the winds of high B to form a dead zone without wind. (These two contrary circulations can meet along an extended line to form a col line and not just merely a point.) The two rotating highs are completely insulated from each other by this zone of quiet and calm. They can have no contact or grind against each other, unless:

1. Their centers approach closer to each other.
2. The separation distance of the two high centers remains the same but one or both increase in intensity.

The two high vortexes are totally isolated from each other by the belt of zero wind in the col, if:

1. The highs increase their separation distance (without an increase in relative intensity), or
2. One or both weaken. They can approach closer to each other without affecting each other if the weaker highs occupy less territory.

IMPORTANT NOTE: The two associated lows have no direct, mechanical, or hands-on contact with each other since the belt of zero wind at the col (created by the two highs) keeps them far apart and completely isolated from each other.

This is not to imply that the two lows therefore cannot affect each other. They can. One low works in concert with the high to which it is attached. This same high can act as a proxy, in turn, to influence the other low which is also directly linked to this high (and vice versa). This type of indirect effect is not uncommon and is to be expected since each high is directly and mechanically geared to a number of lows.

The important feature of this type of col is that none of the Fujiwhara effects can occur because there is no direct mechanical linkage between the lows. There was one theme that consistently came through in the articles discussed above, namely; beyond a certain distance (say 900 km), the effect was not evident or weak if present. Instead of some uncertain distance, we can say flat out, that if the col between two lows is controlled by the surrounding highs—no Fujiwhara effect is possible.

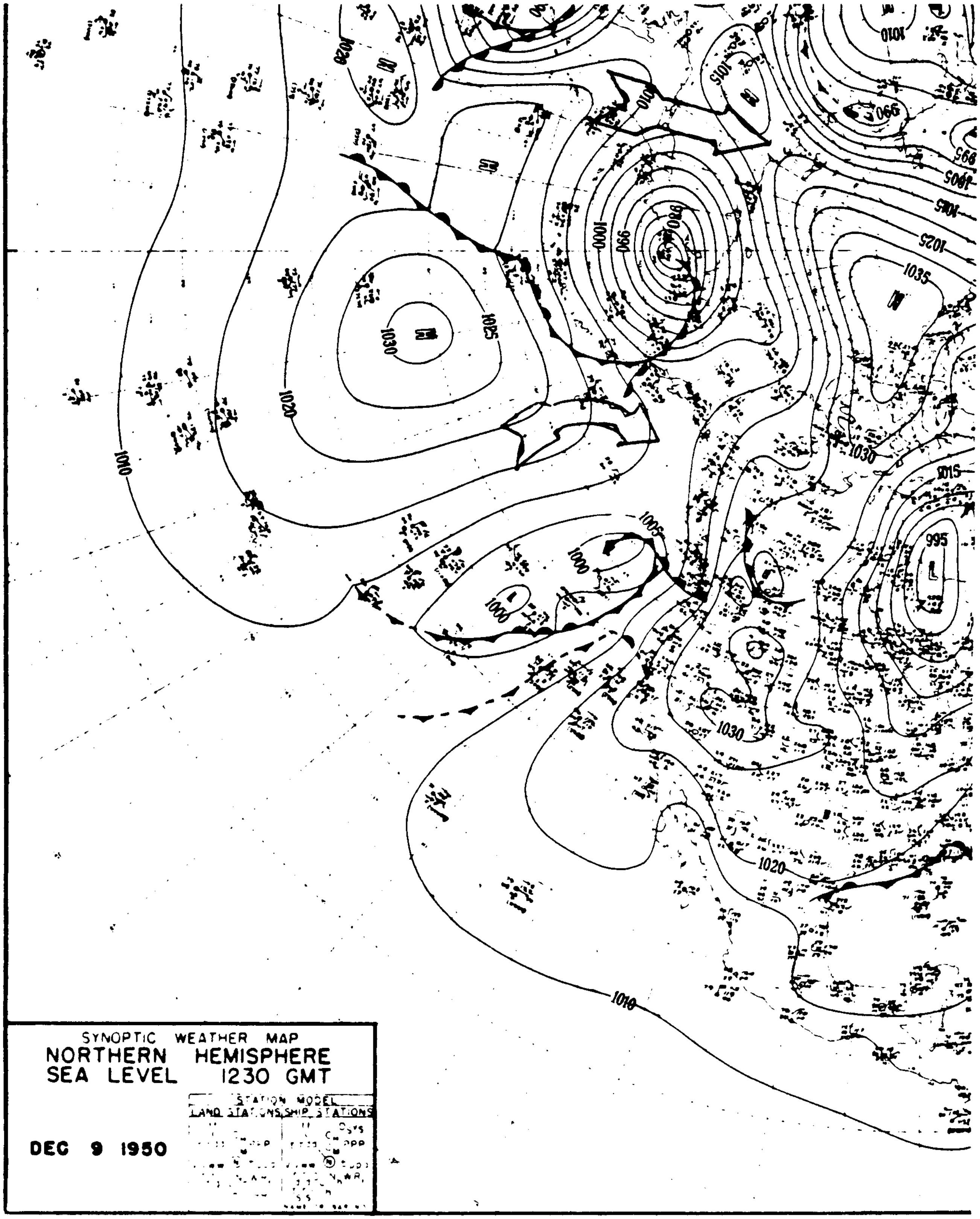

FIGURE 50.1.1.1 Weather map with two adjacent high vortexes dominating a col.

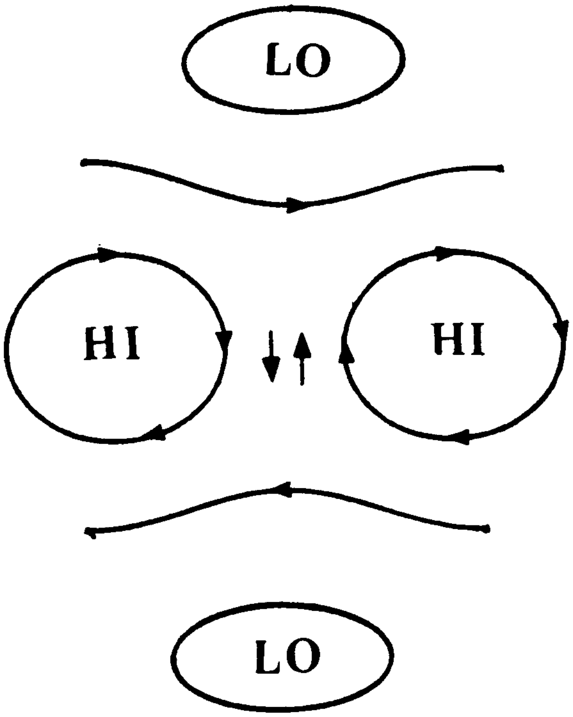

FIGURE 50.1.1.2 Drawing of two adjacent high vortexes dominating a col. The opposing winds of the two highs create the col point or col line.

50.1.2 Class II.

Two low pressure centers dominate the col. Figure 50.1.2.1, December 1, 1950 is an example from an actual weather map. In Figure 50.1.2.2 we can see that two lows are creating the col zone of zero wind. The winds of low A collide with the winds of low B to cancel each other and form the dead zone with no wind. In this class the two lows have no contact when one or both weakens, or when their separation distance increases; since they are totally insulated from a direct contact by a shield of no wind at all.

IMPORTANT NOTE: The two low vortexes do have direct contact and can grind against each other only when:

1. Their centers approach closer to each other without any decrease in intensity.
2. The separation distance of the two low centers remains the same but one or both increase in intensity.

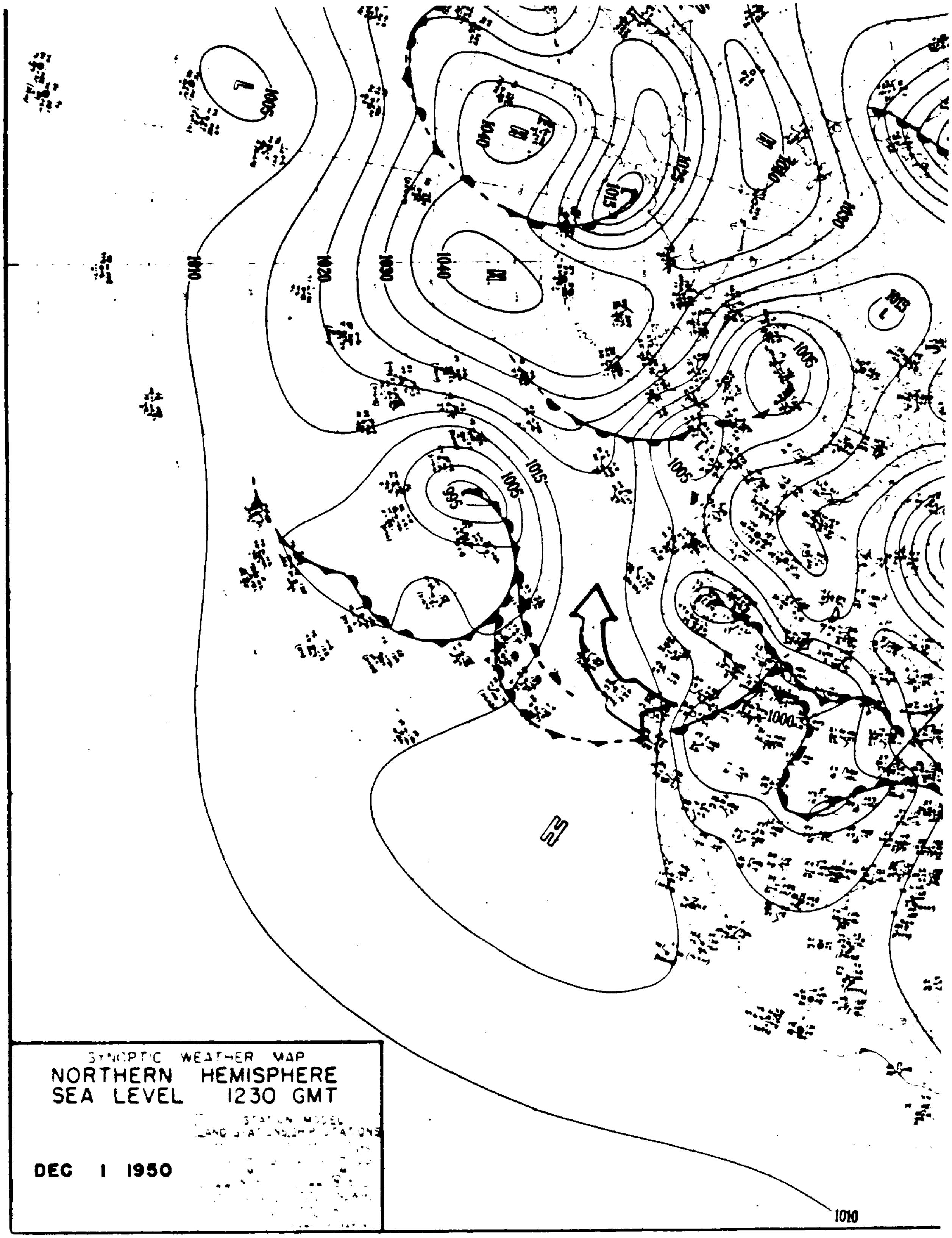

FIGURE 50.1.2.1 Weather map with two adjacent low vortexes dominating a col.

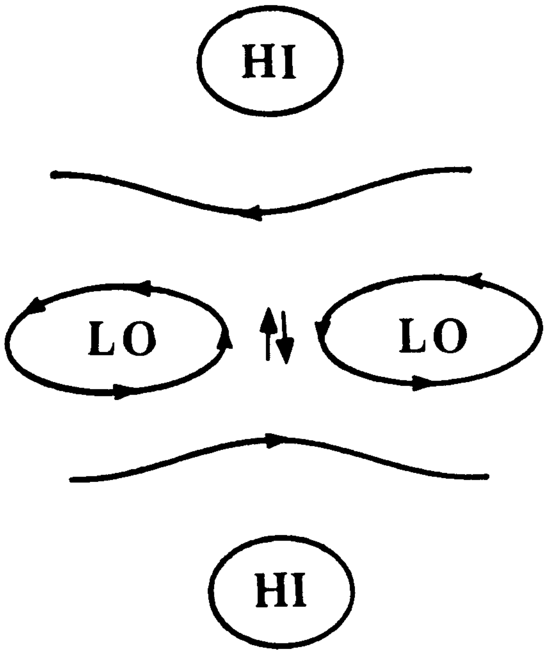

FIGURE 50.1.2.2 Drawing of two adjacent low vortexes dominating a col. The opposing winds of the two lows create the col point or col line.

50.1.3 Classs III.

The col zone is symmetrically located between both the highs and lows. Now the two highs and/or the two lows have direct access to each other. Contact between opposing winds (in spite of the dead zone) can occur only if a new force springs into action that can push one or the other of the two vortex groups closer together. So we see that Class III can easily be converted at the slightest provocation into either Class I or Class II—since it is the equilibrium position between the two. These conditions are not to be considered as graven in stone by a bolt of lightning on a mountain top, since the atmosphere is in continuous turmoil, and any class can change into any other class with the passage of time. At any given instant, however, only one class listed above can prevail.

50.2.0 The Physical Cause of Part of the Fujiwhara Effect.

Lets go directly to the heart of the matter and see why two lows will circle each other in a counterclockwise direction, (clockwise for highs). Let us suspend a wheel by a string attached to its axle as shown in Figure 50.2.1. Now spin the wheel in a counterclockwise direction and then touch the spinning wheel lightly on its rim with a finger as indicated in the figure. Zap! The wheel will try to roll around your finger in a counterclockwise direction in the same sense as its original rotation. What else could you expect? The friction at the point of contact with the finger serves to brake the spin at that point, but the angular momentum of the rest of the wheel carries the wheel around the friction point. For a wheel rotating in a clockwise direction the revolving effect will be clockwise.

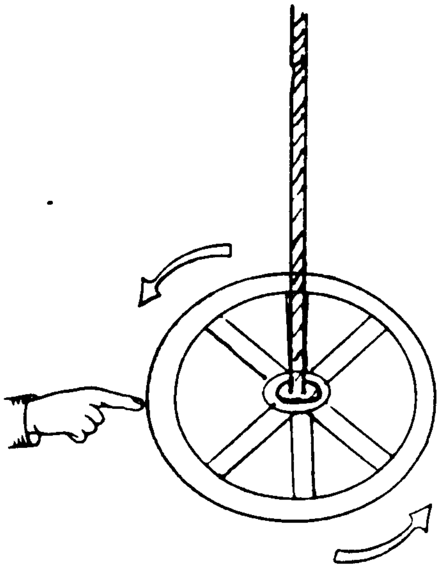

FIGURE 50.2.1 A wheel suspended by a string is made to spin in a counterclockwise direction. The wheel will wrap itself around a finger (at the point of frictional contact) in a counterclockwise direction when touched by a finger. For a clockwise spinning wheel, the wrap-around will be in a clockwise direction.

Now let us consider two hurricanes (each one with its own built-in counterclockwise rotation); but separated from each other by a col of their own making as described in section 50.1.2 above. Each hurricane is engrossed in its own activities. The path of each hurricane is usually individually determined by the outside forces running rampant over the hemisphere. Each hurricane may have some visible input in determining where it will move if the outer forces should weaken. Each one will try to seek out warm waters, if permitted, and also will use extreme force to remove any obstacles in its path if it can. *There is absolutely nothing that can bring these two hurricanes together or to cause them to rotate about each other unless their direction of movement (as determined individually for each hurricane by all outside and internal forces) is such that their paths will cross.* Each hurricane considers the other hurricane as just one of the many forces out there somewhere.

A novel situation develops when both of the following occur simultaneously:

1. A col exists between two storms as described in section 50.1.2.

2. A series of events (usually from the outside but not necessarily so) driving both storms to follow trajectories that will cross, which will in turn, lead to a collision.

Under these conditions the zone of zero winds between these two vortexes becomes a flimsy barrier as the two lows move towards each other. A continuously new zone of calm is being created by opposing winds being forced together. Presto! We have a positive, mechanical zone of friction touching each hurricane at the point or line where they are making physical contact in the shifting col zone. The results will now be what Fujiwhara first noticed empirically but has never been properly explained until now. . . . The two lows will start to revolve about each other in a counterclockwise direction as indicated in Figure 50.2.1 (if the rest of the world's atmosphere doesn't come up with some additive new force at the same time which can cause a different resultant movement).

An important factor must be recognized at this juncture. The start of this counterclockwise revolution does not inherently cause the two hurricanes to also move towards each other and reduce their separation distance. This is definitely not a case of which came first—the chicken? Or the egg? *When some combination of forces reduce the separation distance, then (and only then), can the counterclockwise spin begin as was empirically observed by Fujiwhara.*

It should be recognized that sometimes two storms can rotate in a counterclockwise (or clockwise) direction around each other simply because outside forces are pushing or permitting them to move in that fashion regardless of the location of associated cols. . . .

51.0.0 THE SECRET CONNECTION BETWEEN THE AMOUNT OF ANGULAR ROTATION AND THE SEPARATION DISTANCE BETWEEN STORMS

Brand and Dong-and-Neumann came to the conclusion from the historical data that the rate of counterclockwise angular rotation of two storms increases as they move closer to each other. They then developed some mildly involved mathematical formulas (with additional qualifying assumptions) to explain why this happens. Instead of these complications, let us explain this increase in the rate of angular revolution with the aid of Figure 51.1 and the following formula:

$$s = r\,\theta \qquad (1)$$

where,

s = the distance along an arc of the circumference of a circle.
r = the radius of the circle
θ = the angle in radians cut off by the arc.
(one radian equals 57.3°).

Solving for θ, we get

$$\theta = s/r \qquad (2)$$

The cut-off angle, θ, equals the distance divided by the radius.

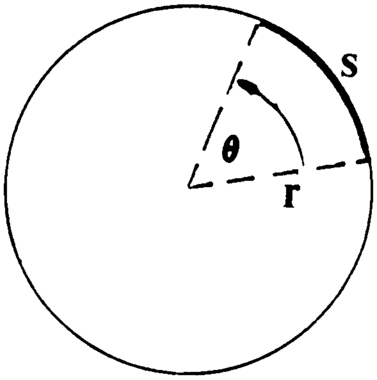

FIGURE 51.1 See Text.

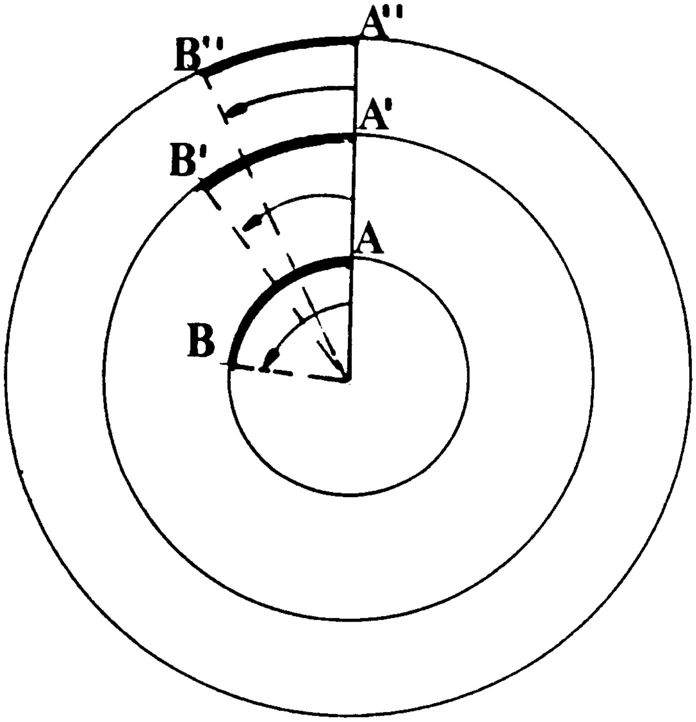

FIGURE 51.2 The same length of arc on circles of different sizes will subtend or cut off larger angles for smaller circles. The angle from A to B is larger than the angle from A' to B', which is larger, in turn, than the angle A'' to B''.

The arc drawn on each of the circles in Figure 51.2 is the same length, yet the number of degrees that this arc represents on any circle is strictly determined by the size of the circle. The smaller the circle, the greater the number of degrees for the same length arc. If a hurricane is cautiously circling another hurricane, at constant speed at a given separation distance (radius), its track will describe an arc of a fixed number of degrees in 24-hours. Now let this same hurricane maintain the same speed, but move closer to the first hurricane. The length of the track will be the same, but the arc will show a greater angular change. As the hurricane continues to reduce the separation gap, it will take less and less time to circle the first hurricane, and the rotation as measured by the change in angular degrees will increase for each succeeding 24 hour period.

In the above description we consider the quantity s to be a constant. Rewriting equation (1) we get:

$$\mathbf{constant} = \mathbf{r}\,\boldsymbol{\theta} \tag{3}$$

which is the elementary formula for a rectangular hyperbola.

If the hurricane changes its speed, there will be an appropriate change in the degrees of arc described each 24 hours. The essential point of all this is that the *rate of angular change* of one storm revolving about another is determined by simple, classical rules of standard geometry as defined by formula (1) above.

It may seem (to some) that I am spending too much time on something that is elementary and obvious. However, in the articles by Brandt, and also by Dong-and-Neumann, you will find that one of their conclusions is that when storms get nearer to each other, the rate of angular rotation increases—and this increase in angular rotation is therefore a proof (more or less) that the Fujiwhara effect is occurring. In addition, Chang (1983) has an involved formula relating the separation distance and the angular rotation, with the help of various assumptions—instead of using simple geometrical relationships as above with no extraneous assumptions necessary. Perhaps fomula (1) above is not obvious!

52.0.0 DO VORTEXES HAVE A FATAL ATTRACTION FOR EACH OTHER OR DO THEY RANDOMLY MOVE TOWARDS EACH OTHER?

We have delved into two of Fujiwhara's observations, namely; relative counterclockwise rotation and the rate of relative angular rotation. Now we will proceed with an analysis of the moving together or attraction (sic) between vortexes. For the sake of clarity, the word "attraction" implies the existence of some force inherent in two vortexes that would draw them together (similar in some way to the gravitational force between material bodies). The words "move towards each other," however, implies no inherent force—simply that bodies were moving about in their normal manner and their trajectories crossed somehow. Prior to their collision they would simply be reducing their separation distance and giving the appearance of being attracted to each other. This could be considered as similar to the collision of two automobiles on a freeway. One would not suggest that the colliding automobiles were "attracted" to each other prior to the collision (unless you believe in occult forces). Strangely, though, if you were to sift through all auto crashes, you would find that the collisions occurred only when they were relatively close to each other! Automobiles that were more than a certain threshold distance apart rarely crashed; and if they were far enough apart they never crashed!

The problem to be resolved, then, is to find and name a force of attraction; or to prove that what appears as an attraction, is simply a crossing of trajectories. In all these many years, no one has been able to define or explain a special force that strangely draws two vortexes toward each other—since there is none to be found! Let us instead approach the problem from the standpoint of two randomly moving vortexes; with each vortex subject to a different cluster of forces. The resultant of these different clusters of forces are such as to cause the vortexes to approach and collide. Note the significant detail that in place of a single force of attraction we will invoke the resultant of known, varying groups of forces. Let us, therefore, make a list of all the lurking forces (that we already know to exist) that can influence the direction in which a vortex will move.

52.1.0 Known Forces or Conditions that Entice or Force a Hurricane to Move in a Specific Direction

The following is a list of known forces or conditions that can cause any hurricane to move either as an individual vortex or as a member of a double vortex (binary system). It is intended to show subsequently, that one or more of these forces are always in operation *as a necessary condition* for the Fujiwhara effect to occur. There is no need to invoke any strange force of attraction between vortexes. . . .

1. Foremost is the "steering force" exerted on a hurricane by a controlling center which can cause the hurricane to squirt off at a right angle or move away at 180°.
2. Second is the force exerted on a hurricane to simply follow another vortex that is moving away.

(These first two types of forces can exist in combinations and be very strong, moderate, weak, or even non-existent in rare cases. When these forces are strong or moderate, they virtually over-ride all other forces attempting to control the direction of movement of a hurricane. This is similar to a grasshopper being blown about in a strong wind; but it takes over control and hops about where it pleases when the wind is weak or non-existent. When the first two forces are weak or non-existent, the following other conditions become predominant, or share with the weak forces of 1 and 2 above in controlling the movement of a hurricane.)

(Any slight increase or decrease in the intensity of a vortex can result in a slight increase or decrease in the territory occupied by the hurricane, and/or it can result in the hurricane sending out slightly stronger gravity wave pulses. These slight changes can interfere slightly with the intensity and direction of the surrounding forces in the rest of the hemisphere, which can result in a slight change in direction of movement of the hurricane.)

3. We can't even have a normal, well-adjusted hurricane unless the sea-surface temperature is 26° Centigrade, or higher. It is only at that temperature (or higher), that there is the proper amount of heat and enough moisture evaporated into the air to support a self-sustaining release of latent heat through condensation and precipitation processes. We can look at the sea-surface temperature as the source for changing the air into a fuel that can power a hurricane. A forest fire will move in the direction of unburnt vegetation where there is always fresh fuel available; likewise, a hurricane will move in the direction of air warmed and moistened by a sea surface temperature of at least 26° Centigrade because that's where the most combustible fuel lies. So, if there were no other forces around, a hurricane would simply go to (or stay) where the sea-surface temperature (and its overlying moistened air) is the warmest.

4. The moisture content of the air in the hurricane could influence the direction of movement, since a hurricane would be lured in the direction of greatest moisture (provided none of the other forces were active). The more moisture—the more latent heat—the greater the intensification of the hurricane. We can generally assume that the fresh air being drawn into the maw of the hurricane always has a high moisture content when it is over an ocean surface; however, when it nears land areas, the moisture content can decrease.

5. The solar and lunar high and low tides can also have a small effect on direction of movement. To this we can even add the effect of the tide or storm surge in the ocean created by the hurricane itself. The slight lifting of the entire air mass of the hurricane by a few feet will by itself cause a slight intensification of the hurricane due to increased release of latent heat. Intensification would either result in a hurricane occupying more territory and/or increasing its pressure against the outside world by the means of stronger gravity waves. For low tides the effects would be reversed.

6. The Coriolis effect of the earth's rotation will cause a deflection in the direction of movement for hurricanes moving in a north or south direction.

7. The diurnal effect of radiational heating by day and cooling by night can alter the air temperatures in the environment of the hurricane and thereby subtly affect its direction of movement. Figure 52.1.1 from an article by Muramatsu (1983) shows the diurnal changes of the eye-diameter for typhoon 8019. The size of the eye is a maximum at 1600 LST (local standard time) and a minimum at 0500 LST. The author points out that when comparing two different storms it is necessary to account for this diurnal effect whenever the local times of their occurrences are not the same.

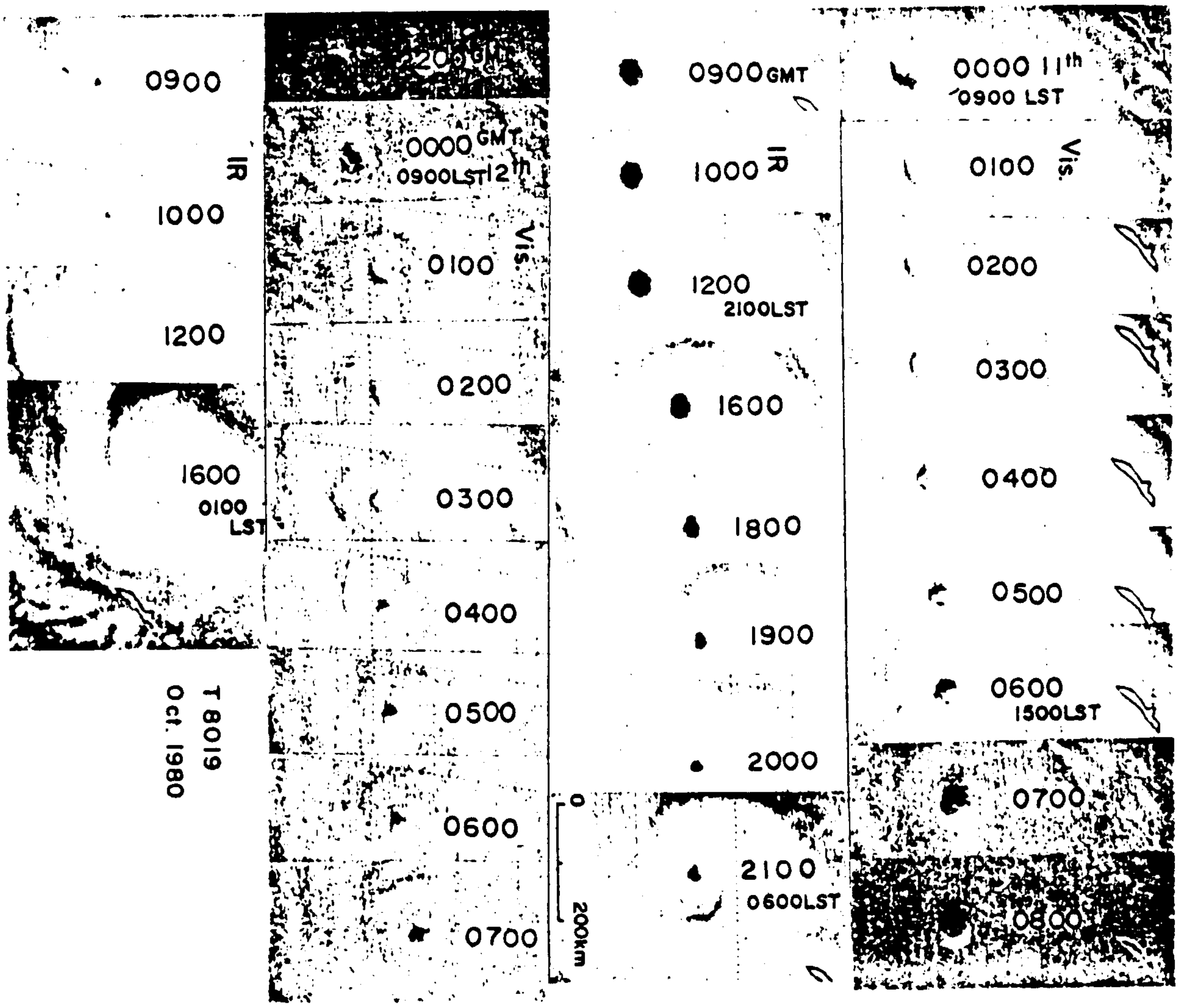

FIGURE 52.1.1 Diurnal variation of the eye diameter for typhoon 8019 for the period from 0000 GMT on the 12th to 1600 GMT on the 13th October 1980. Visible images are shown for daylight hours, while infrared images are shown for the nighttime. (Muramatsu, *Journal of the Meteorological Society of Japan*)

52.2.0 Additional Factors that can Affect the Relative Motion of two Hurricanes

Two hurricanes that exhibit the Fujiwhara effect can be as much as 900 km apart. This means that depending on their relative positions:

1. The tidal effect could reach one hurricane slightly sooner than the other.

2. The diurnal radiation effects would occur at a different local standard times, so that the phase of expansion or contraction of their respective eye-diameters would not be coordinated.

3. The sea-surface temperatures and the air mass temperatures could have slight variations so as to favor the relative intensity of one as compared to the other.

4. The strength of the Coriolis forces would not be identical due to differences in their speed and latitudinal positions.

5. Either one or both hurricanes can be larger or smaller than the stable quantum vortex size. Pressure from the outer world will attempt to force them to conform to the proper size which will induce a small relative movement.

6. When the two hurricanes are not a stable quantum size, there can be destructive resonance effects resulting from their out-of-phase size and out-of-phase gravity wave activity which will induce a relative movement. This can cause one vortex to grow at the expense of the other.

52.3.0 Why the Urge for two Hurricanes to Collide Increases when Their Separation Distance Decreases

The fact that people become more interested in or attracted to each other, the closer they get, is called the "proximity effect." Hurricanes also exhibit a "proximity effect," but this effect is a "horse of different color" than the people thing. Perhaps it should be called "an elephant of a different color" since the closer two hurricanes get to each other, the more they get in each others way!

Again it is a matter of simple geometry. The space for maneuvering is decreased the closer they get. This fact is shown by Figure 52.3.1 in which we use circles of equal diameters to represent vortexes.

1. In Figure 52.3.1a we show two vortexes that are on the verge of making contact, but they have not yet had a chance to scratch at each other. It can be seen that the center of A must move in any direction that falls only in the semi-circle, indicated by the arrows, if no part of the rotating body of A is to touch any part of B (assuming that B is stationary). Likewise, B can move only in a direction of the semi-circle (indicated by the arrows) if it wants to dodge A. We can see that the slightest relative movement of A with any westerly component will result in immediate contact and resulting interference with B. The reverse is also true. The slightest relative easterly component movement of B will cause a grinding action against A.

2. In Figure 52.3.1b we show two vortexes (A' and B') that are a little farther apart. Here we see a smaller shaded area available (for direction of movement) where the two vortexes can reach out to touch each other.

3. In Figure 52.3.1c we show two vortexes (A'' and B'') that are still farther apart. Here we see that with a still smaller shaded area the opportunity for a chance meeting is correspondingly reduced.

53.0.0 CAUSE OF THE FUJIWHARA EFFECT FINALLY EXPLAINED

We have now established a formidable list of reasons each hurricane in a pair is always subjected to individual forces that cause a relative movement every minute of the day. The conditions listed in section 52.2.0 become most important if the conditions listed in section 52.1.0 are weak or non-existent. In any event, there is always a push for movement—some movement—any movement.

Let us consider for example the tidal effect only. If there is a small separation distance between two nearby hurricanes the tidal surge will reach one hurricane first. This will cause that hurricane to expand slightly into the territory of its close neighbor by striking fearlessly across the col zone against the winds of opposing direction.

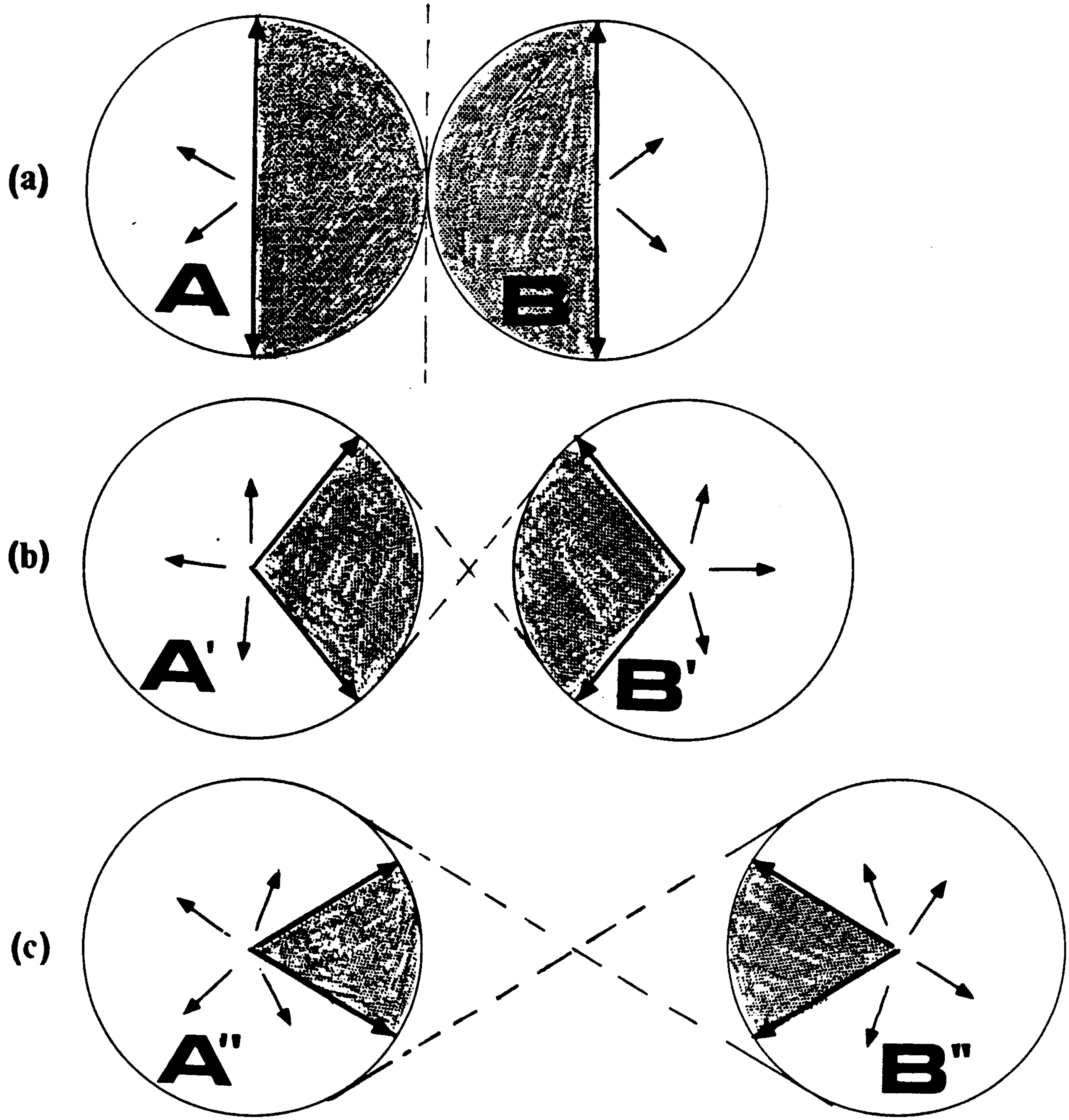

FIGURE 52.3.1 The smaller the separation distance between two vortexes, the greater is the probability that their paths will cross. Each circle represents the body of an equal-size rotating vortex. The shaded areas show the range for the direction of movement (of either vortex center) that will force a contact between them. The arrows are in the portion of the circle where the direction of movement of either vortex can result in no contact.

I~~n (a) the vortexes barely touch, the directions of movement which can lead to contact lie in the zone of angle AB. In (b) and (c) the angles are represented by A'B' and A''B'' respectively~~.

If the sizes of the vortexes are not equal, then the size of the shaded zones will be different, proportionately.

Likewise let us consider the diurnal variation in radiation as shown by Figure 52.1.1. Once again, even for a small separation distance, the small difference in local time between the two hurricanes will cause one hurricane to expand into the territory of the other, with a resulting increase in friction at the point of contact, which then results in a Fujiwhara counterclockwise maneuver. Even when both storms are at the same local time, they can expand slightly into each others territory simultaneously (if it is the time of day for expansion), again leading to disastrous frictional effects when they are separated by a naked, unprotected col.

Add to this all the other reasons for movement listed earlier. Then add the fact that the closer the pair get to each other, the more they start slugging at each other, since they can hardly avoid each other. Each push inward makes the next push in an inward direction more likely—which gives us the end result of lows being attracted (perhaps not so mysteriously now) to each other.

Fujiwhara's effect can now be explained from the preceding standard theoretical and physical principles alone. Nevertheless, since the forces that cause all the movements are (relatively speaking) random, there are times when they can cause vortexes to separate from each other. This occurs when the resultant of all the forces add up to force a separation even though they are in close proximity. In addition, with all the forces and conditions available, their resultant can add up at times to a clockwise rotation for two low centers as indicated in the article by Dong and Neumann.

Recapitulating. A multitude of forces can cause two hurricanes to move towards each other. With the right type of col set up, the two hurricanes will rub against each other which will start a counterclockwise rotation as described by Fujiwhara. The nearer the hurricanes are pushed toward each other, the greater the likelihood that they will be pushed still more towards each other, until they coalesce—since they get in each others way—which explains the second part of Fujiwhara's observations.

54.0.0 THE FOURTH AND FIFTH LAWS OF HURRICANE MOVEMENT

The original reason I started this exploration into the Fujiwhara effect was to demonstrate the existence of the Fourth and Fifth Laws of Hurricane Movement. I was always aware of these two laws, but had overlooked them in the previous issues because they seemed so simple and obvious. In order to make the explanation complete, it is necessary to add them to the three previous laws; since there are two additional laws of nature, describing bodies in motion, namely:

1. At times, bodies will simply move past each other without contact like two airplanes flying-by each other.
2. At other times, two bodies will simply collide and coalesce or smash up—just like a car mash-up.

Likewise, *The Fourth Law of Hurricane Movement* states that *two storms can simply fly-by each other without making contact.*

Again likewise, *The Fifth Law of Hurricane Movement* states that *two storms can collide and coalesce.*

To prove the existence of the Fourth law would be redundant since it is self evident wherever you turn in nature. Nevertheless, we can look back at sections 49.3.0 and 49.5.1 where there are some examples of fly-by analyzed. There are also straight fly-bys where both storms simply move past each other in opposite directions; or at other times they can both be moving in the same direction but at different relative speed.

To prove the existence of the Fifth Law should also be redundant since we have had its existence acknowledged since the times of Fujiwhara. It is important, however, to recognize that the Fifth Law can stand on its own feet as a fundamental law of nature; and that it has a rightful place with the other four laws on its own merits.

55.0.0 CONCLUSION

We find that the old philosophical principle of "Occam's razor" which states that *the simplest theory that explains the known facts is most likely to be true*, also applies comfortably to the preceding explanation of the Fujiwhara effect. As a bonus the Fourth and Fifth Laws of Hurricane Movement were also introduced. Some other mysteries and obscurities will crumble in the next issue.

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