DEPARTMENT OF THE INTERIOR.

WEATHER BUREAU.

THE BAROCYCLONOMETER

BY

REV. JOSÉ ALGUÉ, S. J.,

DIRECTOR OF THE PHILIPPINE WEATHER BUREAU,

MANILA OBSERVATORY.

REPRINT FROM THE AUTHOR'S "THE CYCLONES OF THE FAR EAST."

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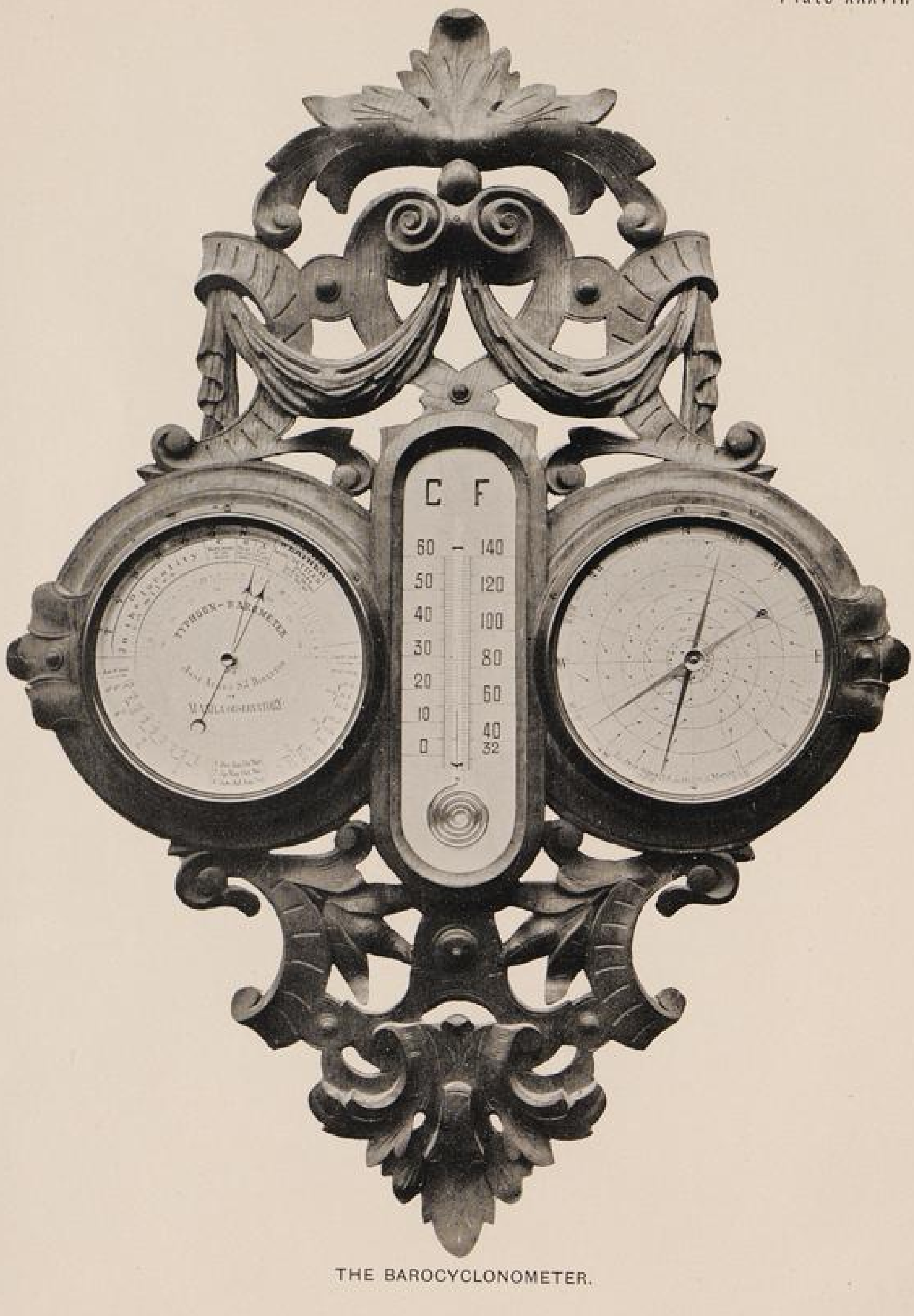
AUTHOR'S NOTE.

The following pages, descriptive of the barocyclonometer and its applications, are in the main a reprint from the special report of the Director of the Philippine Weather Bureau, "The Cyclones of the Far East," of which they form Chapters VI and VII of Part II. Slight modifications and a few additions have been made in order to render the pamphlet intelligible independently of the work from which the same is taken.

José Algué, S. J.,
Director of the Philippine Weather Bureau.

Manila Observatory, *May, 1904.*



THE BAROCYCLONOMETER.

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DESCRIPTION OF THE BAROCYCLONOMETER.

Although it can not be denied that there exists a certain relation between the height of the barometer within the body of a cyclonic storm and the distance of the vortex, still the reading of the barometer does not give us any information with regard to the direction in which the center is moving, information which is frequently of the greatest importance to the observer, especially if the latter is a sailor. Fortunately, we can obtain this knowledge by applying the laws of cyclonic circulation to the observed direction of the prevailing wind. Hence it follows that if, by combining the typhoon indications given by the barometer with those derived from the direction of the wind, we could reduce them to a practical method by means of a simple mechanical instrument, we would have an efficacious means of reassuring us at the first signs of a typhoon. This has been our aim in inventing the apparatus which we have called the "barocyclonometer." The present chapter deals with the description of the instrument and the scientific principles on which each part of it is based, leaving for the next the use and management thereof.

Necessity of such an instrument.—In the preface of a descriptive pamphlet on the barocyclonometer published by this Observatory in 1898 I wrote:

Two reasons mainly induced me to procure the construction of the new apparatus which is described in this pamphlet. The first was the great convenience, not to say necessity, of a barometer which could be used indiscriminately in all the latitudes of the Far East, especially now that the exigencies of traffic and commerce on the one hand, and the manifold complications of an international character on the other, open each day new courses to the frequent navigation of our mariners of the Navy as well as of the merchant marine. Moreover, since in these seas the meteorological elements present such different characteristics that the navigator sometimes in a single voyage finds normal barometric heights as diverse as 754 and 758 millimeters in the short distance which separates Hongkong from Manila, and 771 and 759 millimeters between Chefoo and Iloilo, it is quite impossible in these cases to apply the fixed readings which are commonly engraved on the faces of barometers. Even the best of them have this defect, as, for instance, the barometer of Father Faura, which consequently is applicable only to the limited zone of our Archipelago. Add to this that in the seas of this Far East the barometric height limit of the outermost zone of the typhoons, a datum of capital importance, fluctuates between very different values, being 765 millimeters for the twenty-fifth to the thirty-second parallels of north latitude, and 756 millimeters for the tenth to the sixteenth parallels of north latitude during the winter months. For which reason it is impossible for the mariner to navigate securely and to forestall the danger of such terrible meteors by using a "common reading" in seas where the extreme barometric heights of the body of the cyclone differ normally more than 8 millimeters. How this difficulty has been obviated in the aneroid the reader will see in the course of this work.

The other reason, of no less weight, is the sad fact that the growing popularity of Father Faura's barometer has induced some manufacturing firms to imitate said aneroids, but—in order to profitably meet industrial competition—in such a way that frequently the observer, instead of finding in them an accurate and trustworthy instrument, as would be right, finds in his possession a mere hardware toy which would be capable of discrediting Father Faura's good arrangement of the indications and readings engraved on the face thereof, if its fame were not so justly established. Several times we have heard Father Faura lament this pernicious abuse, which, unfortunately, has no remedy. Now that the advisability is recognized of offering to the public a new apparatus which, on account of being universal, may be used also in other latitudes than those of our Archipelago, we shall from the very beginning make sure of the most important point, which is the fidelity of the instrument, so that persons who wish to have the quality of their barometer guaranteed can have it.[1]

[1] The construction of this instrument has been intrusted to the firm G. Lufft, of Stuttgart. The barometer and the cyclonometer are also constructed separately, in order that those who use Father Faura's barometer, which is so popular in this Archipelago, may complete it without great expense by simply procuring the cyclonometer.

Above reasons refer exclusively to the aneroid of the new apparatus. Touching the cyclonometer, it is superfluous to enlarge on the practical advantages which the mariner may derive from it, principally in his voyages on the high seas. Whoever reads this pamphlet may judge for himself of it. All we claim is to offer him, as it were, a guide, simplifying the apparatus so that he can manage it even in cases when the manifold attentions to diverse maneuvers and the anxiety and confusion which usually accompany the imminence of danger do not permit complicated calculations.

The first of the reasons mentioned above is to-day certainly stronger than ever before. For, since these Islands have come into the possession of the United States of America, navigation on the seas to the north and east of Luzon has vastly increased, and consequently an instrument which to the merit of Father Faura's barometer adds the incomparable advantage of being applicable with the greatest facility to different latitudes throughout the Far East must be highly appreciated by mariners.

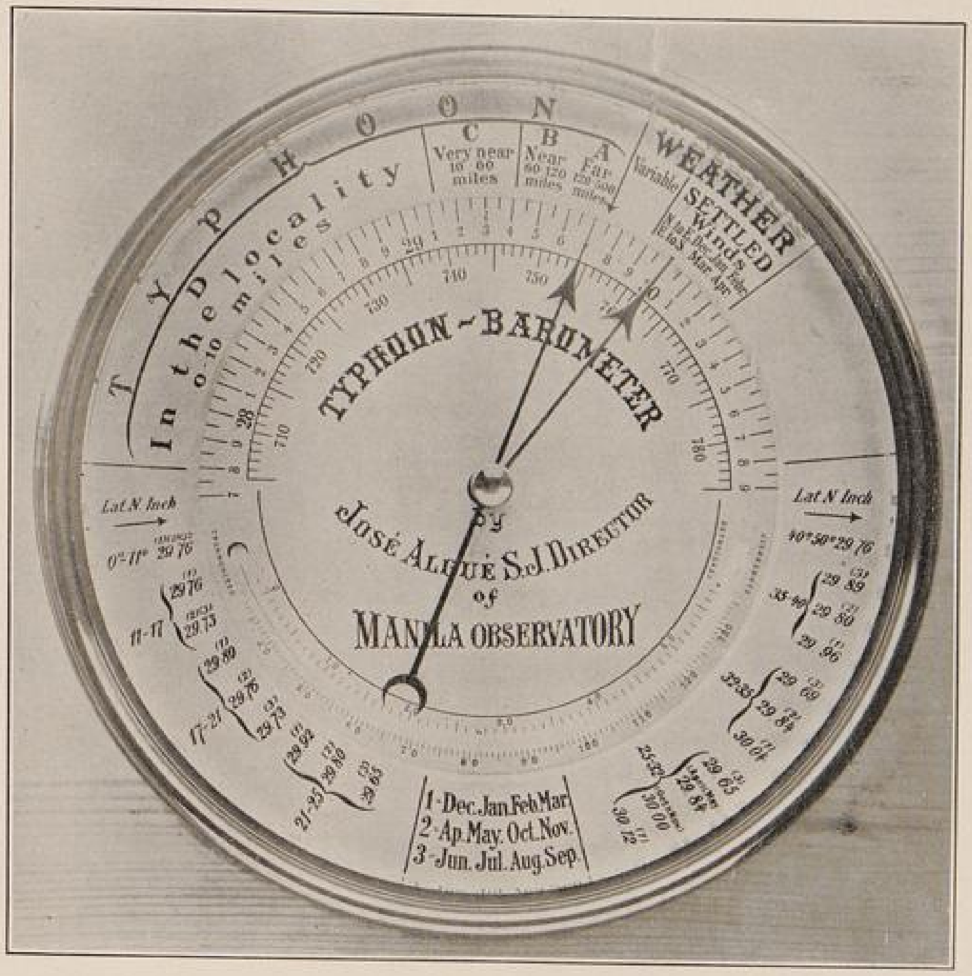
The documents requesting from the Spanish Government the privilege of importation and patent of the instrument for the Philippines were lost, owing to the disturbances in this Archipelago. Imitations of the instrument can not therefore be now legally prevented. It has been constructed in London and in Germany, the indications on the rim having been translated into German.

The barocyclonometer (Pl. XXXVII)[1].—As its name suggests, the barocyclonometer is a combination of a barometer and of a novel contrivance which we have named cyclonometer. As the instrument is actually constructed it also comprises a thermometer, showing the temperature in both Fahrenheit and Centigrade degrees, but, although this addition augments the convenience of the apparatus, it is none of its essential parts.

I. The aneroid barometer (Pl. XXXVIII.)—The barometer, which if it is to meet requirements must be a first-class instrument, has some remote resemblance to the barometer of Fr. Faura, on which it is based, but differs from it in several important points. The face of the aneroid exhibits the double graduation corresponding to the millimeter and the inch scale, respectively, of the mercurial barometer. Around this face is laid a flat ring of silvered brass about 23 millimeters wide, which, being attached to the rim that holds the cover glass, can be made to revolve around the dial by turning said rim. The divisions and legends engraved upon this ring bear no relation to definite lines of the graduation. Those of the upper half, however, correspond to the groups "fair weather," "change," "unsteady," or "stormy weather" of the ordinary aneroid for popular use, while the fact that the ring can be turned about the center of the face constitutes the adaptability of this barometer to different latitudes and to the various seasons of the year. The data necessary for effecting this adjustment are engraved on the lower half of the ring itself.

(1) **The first group.**—"Fair weather," "settled" occupies a considerable portion of the first quadrant, its limits toward the right being as vaguely defined as those of the group "unsettled" or "stormy"—"typhoon" toward the left. Since for the Philippines the lower limit of pressure during variable weather lies between 755 and 756 millimeters (29.73 and 29.76 inches) and the width of this group is 4 millimeters (0.15 inch), the lower limit indicating "fair weather" will vary between 759 and 760 millimeters (29.88 and 29.91 inches). The group "fair weather" is automatically determined by setting the index for variable weather as will be explained forthwith. (See 2.) This division also gives the directions of the winds which usually prevail when the barometer needle indicates high pressure—that is, north to east in December, January, and February, and east to south during March and April. The northeasterly winds commence already in November. In February they draw more to the eastward, while in March and April we have southeasterly winds. Experience teaches us that they are all the steadier the higher the needle points. The north to east winds of the period November to February drive to the eastern coast of Luzon masses of clouds from the ocean, where they have been formed in consequence of the ascending air currents during the daytime. These clouds condense and are the source of rain on the east coast,

[1] Another form of the barocyclonometer (aneroid and cyclonometer in separate boxes) is shown on Plates XXXVIII and XXXIX. In this case the thermometer is inserted on the face of the aneroid.



THE BAROMETER OF THE BAROCYCLONOMETER.

which is all the more copious the steadier the winds remain. Occasionally it happens that the cloud masses are driven across the whole island, and in such cases they bring heavy rains over the west coast also. But these are exceptions; there usually prevails at this time of the year fine and dry weather on the west coast of Luzon and in the greater part of the interior of the Archipelago.

(2) **The second group.**—"Variable," having, as stated, a range of 4 millimeters (0.15 inch), corresponds to "changeable" of the ordinary barometer, and needs no explanation. This division comprises the normal barometric readings for the months from May to October. The hand of the aneroid will also recede to it whenever a cyclone is more than 500 nautical miles distant and consequently still very far off. As the months May to October show a great tendency for atmospheric disturbances, the weather is unsteady or changeable if the needle moves in this division.

With northerly winds the weather is always unreliable, whatever may be the time of the year, as soon as the needle enters this group, except perhaps during October. The reason for this is that during the months from May to September northerly winds are abnormal for the region of the Philippines, and hence indicate abnormal conditions of the atmosphere, while from November to April this whole section of the barometric scale lies below the normal level of the barometer.

Adjustment of the barometer.—Special attention is called to the limit of this second group toward the left, which is marked by a red line or arrow and serves as index for adapting the instrument to latitude and season, as previously stated. It may also be used to correct the weather indications for elevation above the level of the sea.

The mean barometric readings on the outskirts of a typhoon—or in other words, the upper limits of atmospheric pressure for "stormy weather"—differs not only for different latitudes but in the majority of instances also for the same parallel during the various parts of the year. As to the latter, careful observation has proved beyond doubt that certain months have common characteristics as regards cyclonic disturbances, differing more or less from others which again agree among themselves. On the basis of these similarities we divide the year into three groups of months, namely, December, January, February, March forming the first group; April, May, October, November, the second; and June, July, August, September, the third. Whenever in the following pages "groups" are mentioned, reference is made to this division.

These variations of pressure in the outermost part of a cyclone, ascertained by long experience and not inconsiderable comparative study, we have laid down in the following table:

HEIGHT OF BAROMETER CORRESPONDING TO THE OUTER LIMIT OF ZONE A OF A CYCLONE.

Between parallels—	Inches.	Millimeters.	Season.
0°–11° N	29.76	756	Throughout the year.
11°–17° N	29.76	756	During months of first group.
	29.73	755	During months of second and third groups.
17°–21° N	29.80	757	During months of first group.
	29.76	756	During months of second group.
	29.73	755	During months of third group.
21°–25° N	29.92	760	During months of first group.
	29.80	757	During months of second group.
	29.65	753	During months of third group.
25°–32° N	30.12	765	During months of first group.
	30.00	762	During October and November.
	29.84	758	During April and May.
	29.65	753	During months of third group.
32°–35° N	30.04	763	During months of first group.
	29.84	758	During months of second group.
	29.69	754	During months of third group.
35°–40° N	29.96	761	During months of first group.
	29.80	757	During months of second group.
	29.69	754	During months of third group.
40°–50° N	29.76	756	Throughout the year.

Regarding the use of the foregoing table we must add:

(1) The limiting months of two consecutive groups exhibit characteristics of both groups—that is, May and June, November and December, March and April, September and October.

(2) The same may be said of the parallels of latitude adjacent to the limits of above zones—that is, 10°–12°, 31°–33°, etc.

(3) The barometer readings have reference to the lowest reading occuring during the day and accordingly either to the morning or the afternoon minimum.

(4) Whenever the barometer at the time of the daily minimum falls as far as the tabular value corresponding to the place of observation and the time of the year, the observer may be reasonably sure of the presence of an atmospheric disturbance, but he will not be able to tell whether the storm will burst over his location or not unless he is acquainted with the characteristic barometric movements of the region. It must be well borne in mind that in zone A the diurnal and nocturnal oscillations are not completely lost, but only modified. It is on this knowledge that the observer has to found his prevision of the danger into which he may be running, as well as the probability of avoiding it.

For the convenience of the observer the data of the above table are also engraved on the lower half of the movable ring surrounding the face of the aneroid. In the lowest section of the annular sector are found the months constituting the groups 1, 2, 3. To the right and left of it are given the different zone limits and the corresponding barometer readings for the various groups—e. g., 0°–11°, 29.76[1)2)3)] (inches), 756[1)2)3)] (millimeters), reads: "In the zone bounded by the equator and the eleventh parallel of north latitude the mean atmospheric pressure at the outskirts of a typhoon is 29.76 inches (756 millimeters) throughout the year." In the zone included between the eleventh and seventeenth degrees of north latitude the same limit will be seen to be 29.76 inches (756 millimeters) for the first group and 29.73 inches (755 millimeters) for groups 2 and 3, while for the zone 25°–32° north latitude there is not only a different value assigned for each group but two different values for group 2, one for April and May, the other for October and November. Thus it is seen that the whole of the table is given on the instrument.

The process of adaptation is best shown by an example. Suppose a captain finds that on May 15, at a given instant, the ship's place is 7^h 46.4^m east and 18° 3′ north. Turning to his aneroid, he finds 29.76 inches (756 millimeters) to be the mean upper limit of pressure indicating stormy weather in his latitude and month (group 2). He will now turn the ring until the red arrow, above spoken of, points to 29.76 inches, and his barometer is adjusted as far as weather indications are concerned. The farther the needle points to the right of the red index, so much the steadier the weather will be. But should, after adjustment, the needle either constantly or at least at the hours of minimum point to the left, the ship has entered the outermost zone of a typhoon.

The same arrangement serves also to correct the indications for elevation of the instrument above sea level, etc. The graduations corresponding to the heights of the mercurial column at 0° C. (32° F.) and the level of the sea, any considerable elevation of the barometer above said level can not be neglected. Unless great heights are in question we may assume that the decrease of atmospheric pressure is roughly 0.01 inch for every 10 feet (or about 1 millimeter per 11 meters) elevation. This amount is therefore to be subtracted from the tabular reading and the index arrow set accordingly. On board ship the elevation can never give rise to great errors, but the case may be very different with instruments installed on land. Unless the elevation is small the corresponding correction should be ascertained and applied. If this precaution were neglected a barocyclonometer at an elevation of 800 feet might cause considerable alarm by indicating a typhoon in close proximity (10 to 60 miles), when it should promise settled fair weather.

(3) **Third group—"Typhoon."**—This group corresponds to "stormy weather" of the ordinary aneroid, because, the barometer being adjusted according to directions just given, the needle never moves into this section unless the instrument is under the influence of a typhoon less than 500 nautical miles distant. This section, the largest of all, is subdivided so as to make its parts correspond to the atmospheric pressures prevalent in the four zones, into which we consider the horizontal sec-

tion of the lower portion of the typhoon divided. The corresponding divisions are lettered in accordance with these zones A, B, C, and D. (See Pl. XXXIX.)

Zone A—Typhoon distant.—If the needle has reached this division and the barometer shows an inclination to fall we may be tolerably certain that the center of a typhoon is between 500 and 120 miles distant. The width of this zone is 4 millimeters (0.16 inch).

Zone B—Typhoon near.—The needle moving in this division indicates that most probably there is a cyclonic vortex somewhere at a distance varying between 120 and 60 miles. The range of pressure for this zone is, like that of the preceding, 4 millimeters (0.16 inch).

Zone C—Typhoon very near.—When the needle reaches this division, which has a range of 7 millimeters (0.28 inch), it is a sign that the center of the typhoon has approached to within 60–10 miles. A careful study of the minima recorded during the passage of more than 280 cyclones makes it almost certain that the vortex will have arrived at less than 60 miles distance from Manila when the barometer has fallen to 747 millimeters (29.41 inches) at the time of the daily minimum.

Zone D—Typhoon at the place of observation.—Distance of the center, 10–0 miles. Having carefully noted the barometric minima at the passage of typhoons over a place or very close to it, we have observed that in almost every instance the upper limit of atmospheric pressure is 740 millimeters (29.134 inches). Toward the left, however, this division is undefined, though the barometer very rarely falls below 700 millimeters (27.56 inches).

Before we conclude the description of this portion of the barocyclonometer we must call attention to the following important points:

(*a*) The bearing of the center and the direction of its progressive movement can not be ascertained from the observations of the barometer alone; they must be determined by means of the laws of cyclonic movements.

(*b*) Nor does the barometric height as such give us any clue as to the force of the wind or the violence which the cyclone is likely to develop. The intensity of a cyclone depends in the main on the barometric gradient, and the latter, in turn, is not dependent on the absolute amount of pressure, but on the rapidity with which it diminishes, as is evident from the definition of barometric gradient and has been proven by experience. The inclination of the cyclone axis, which also has no connection with the barometer level, has a very great influence upon the force of the wind.

(*c*) Once more we repeat, that the aneroid must be of the very best quality to be of service. We have found on board ships instruments of a very poor class, which are of no use whatever. To make sure of the quality of the aneroid it ought to be compared for some time with a standard barometer. But even after its excellence has thus been established before the apparatus was set up, this comparison should be repeated at least once a year, especially after the aneroid has been exposed to very great oscillations—e. g., in passing through the vortex of a cyclone. In this case the comparison should be made as soon as practicable. These investigations are best instituted at one of the large observatories of the Far East—e. g., Hongkong, Shanghai, Tokio, Manila—whose directors will, no doubt, willingly lend their aid.

(*d*) It is very important to have a clear idea of what is meant by *normal barometric height.* The normal barometric height of a place is the *mean* of the barometer readings made at that place during a given period of time, reduced to sea level and to 0° C. (32° F.), also corrected, if one wishes, for the effect of gravity. Where the range of pressure is small, as is the case in the Tropics, it is convenient to group the months together, and, taking the mean of all the readings of each group, deduce therefrom the normal barometric level for the respective groups. Where, however, the annual variation is considerable, it will be necessary to find from the respective monthly means the normal atmospheric pressure for each month.

The normal barometric height, therefore, varies (1) with the various seasons of the year, (2) with latitude, and (3) with the geodetic position.[1] Hence it is also easily understood that the

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[1] By geodetic position we denote here the position of a place with regard to continents and seas, whether the place is on the coast (and on which coast) or in the interior, on an island, how far from the continent, etc.

standard value 760 millimeters is very improperly termed the *general normal height of the barometer at the level of the sea,* since the pressure at sea level is necessarily different at places differently situated, and even at one and the same place varies with the seasons.

From the preceding remarks we can draw the following conclusions, which are paramount in meteorology:

(1) According to the very nature of normal barometric height, this furnishes us the only correct point of reference from which to estimate high and low barometers. For instance, for certain points of the interior of Siberia the monthly mean for January, corrected for elevation and temperature, gives as normal barometric height for this month 774 millimeters (30.472 inches). Consequently, at these places the barometer has to be called *low* if at the time of the diurnal maximum it indicates a pressure of 773 millimeters (30.433 inches), although this level is rather high if compared with the conventional value of 760 millimeters.

Whenever, therefore, the needle oscillates about the point of reference—that is, about the normal barometric height of the place of observation for the season in which the reading is made—it is not possible to say whether the weather will improve or become worse. The weather is *variable* because the *normal barometric height of the place and time, and not 760 millimeters, is the barometer level indicative of variable weather.*

(2) Supposing, for example, that at a given point the normal barometric height is 769 millimeters, it is perfectly absurd to say that this barometric level is 9 millimeters higher than the normal barometric height at sea level for this place. The reason is that the idea of normal barometric height essentially includes that the barometer means be reduced to the level of the sea.

II. The cyclonometer or wind disk.—The cyclonometer resembles the aneroid in shape and dimensions, but is, of course, an entirely different instrument. (See Pl. XXXIX.)

The face plate of the cyclonometer, which is immovable, has a circular recess of a radius somewhat less than the plate itself cut into its surface. On the rim thus formed are engraved the sixteen principal points of the compass. The whole face is covered by a glass plate, likewise immovable, which on its inner side has eight diameters intersecting at equal angles, etched in red. These lines are so placed that their extremities mark the sixteen points just mentioned, and consequently they serve as lines of bearing all over the field of the wind disk. Underneath this cover glass, fitting into the recess of the face plate, is a disk of silvered brass, which, by means of a knob passing through the cover glass, can be made to revolve around its center. Four concentric circles divide this disk into five zones corresponding to the zones A, B, C, and D and the central area of a typhoon. Above letters will be found in the respective annular sectors. Across the central area is drawn a heavy black arrow, to be set in the direction in which the storm is supposed to move, while in each of the zones the winds prevailing in it are represented by smaller arrows. For the right and left part of the cyclone (with reference to the central arrow) only three wind directions are given in each zone; but for the front and rear five of them are indicated, since it is in these portions that the influence of the progressive movement of the vortex upon the directions of the wind is chiefly felt. The missing arrows can easily be interpolated. As is readily seen, the whole arrangement reproduces a horizontal section of a cyclone near the surface of the earth.

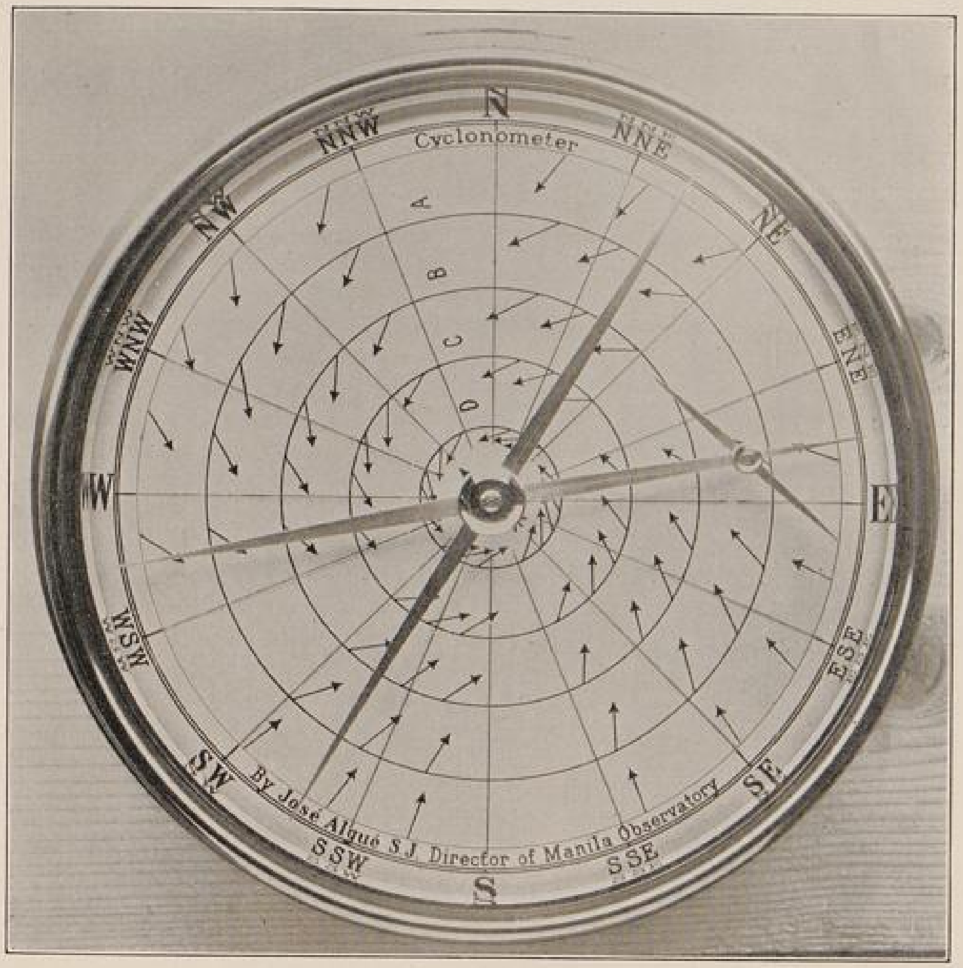
Outside of the cover glass will be seen two needles whose length equals the diameter of the face. These pivot at the center and can be moved directly by hand. One of them bears a graduation, the inner two-thirds of one of its halves being divided into 100 equal parts, with the zero point at the center. In the subsequent description of its use we shall refer to it as the "graduated needle." The other carries, at the point marking the end of the inner two-thirds of its half length, a pivot around which a smaller needle can be turned. We may call it the "double needle."

This may suffice for a description of the barocyclonometer. Its application to the problems, the solution of which it is designed to facilitate, will be shown in the following chapter.

Remarks.—(1) The directions of the wind are inclined toward the center of the cyclone.

(2) The degree of convergence is not the same at various distances, nor is it the same on various sides at the same distance from the center.

Plate XXXIX.



THE WIND-DISK OF THE BAROCYCLONOMETER.

(3) The direction of the center exercises an influence upon the variations of the angle between the direction of the wind and the radius vector. The following factors influence the variations in convergence:

(*a*) The direction of the prevailing wind.
(*b*) The topographical conditions.
(*c*) The progressive movement.
(*d*) The shape of zone D.

The general winds which prevail on the edge of the cyclones make their influence felt only at places which are far distant from the center, and in such a way that southerly winds modify the convergence of the winds on the south side, but not of those on the north side. In a similar way northerly winds affect the convergence of cyclonic winds on the north side only, but have no effect on those of the south side. The cyclonic winds of the south side lie between the points northwest through south to southeast, those of the north side between northwest through north to southeast. It results from this for the Archipelago, that, owing to the general winds on the outside of cyclones, the outer cyclonic winds of the southern side—southwest, south, and southeast—show a strong inclination toward the center during the months of the second and third group; during the months of the first group the winds of the northern side are less convergent.

The directions of the wind for zone A of the cyclonometer are more convergent than those of the other zones. It is, of course, impossible to express on the wind disk of the barocyclonometer the influence which the prevailing winds have upon the convergence of cyclonic winds.

The influence which topographical conditions may exercise needs hardly be considered by the sailor. An observer at a fixed observatory will soon find out these influences (as they are exerted, for example, by a mountain chain close at hand).

The wind directions will be less convergent on the front side, owing to the progressive movement of the cyclone, so that they will more approach a circular form than is the case in the rear. The directions of the wind on the two sides of the track undergo, owing to the direction of the track and the intensity of the progressive movement, changes which are all the greater the greater the velocity of the cyclone.

In drawing the wind disk we have taken 45° to be the value of the mean inclination of the wind.[1] The shape of the central region of cyclones changes the wind direction but slightly. As the shape changes a great deal this can not be taken into account when drawing the wind disk. We have preferred to represent it as circular, and this representation can not be a source of serious mistakes.

There is no mention of rain on the dial, because its relation to pressure depends entirely on its causes, and precipitation may occur with different barometric heights.

WORKS WHICH MAY BE CONSULTED IN CONNECTION WITH THE PRECEDING.

BAROMETER MANUAL FOR THE USE OF SEAMEN. London, 1896.
COMTÉ. Theorie des Variations Brusques que Presentent les Curves du Barométre Enregistreur Pendant les Orages. Ann. de la Soc. Met. de France, 1884.
DALLET. La Prévision du Temps et les Prédictions Météorologiques. 1887.
HERMOSO, LEÓN. El Barómetro Aneroide y Modo de Graduarlo para la Previsión del Tiempo. Boletin Meteorol. de Neherlesoom.
PERNTER. Reglas para el Uso del Barómetro Aneroide. 1881.
PLUMANDON, J. R. Le Barométre Applique á la Prévision du Temps en France. Paris, 1883.
WHYMPER, E. A New Mountain Aneroid. Amer. Geo. Soc., vol. 31, p. 75.

[1] Ferrel, "A Popular Treatise on the Winds," p. 304.

USE OF THE BAROCYCLONOMETER.

If an observer after consulting the given data and rules has satisfied himself of the approach of a cyclone, he must (by turning the projecting knob) set the central arrow of the wind disk in the mean direction of the tracks followed by the cyclones of the region during the respective seasons. For this purpose the mean trajectories followed by the typhoons during the various months of the year have been laid down in the large map accompanying this book. The instrument is now ready for approximately indicating the position and direction of the center.

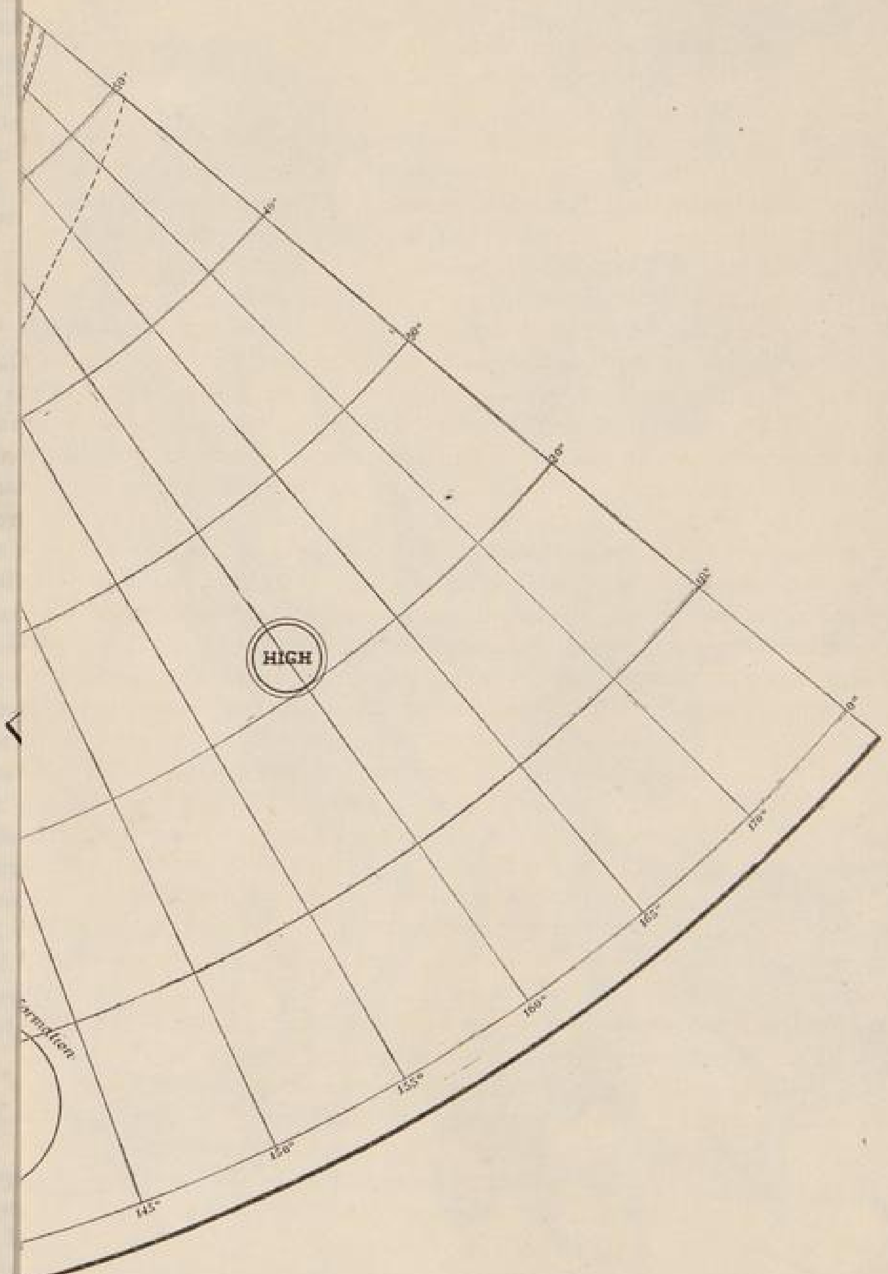
The first approximation.—The observer must get accustomed to imagining himself placed according to the state of the barometer and the direction of the wind at a point of the concentric rings of the wind disk; this will in no small degree facilitate his calculation. In order to arrive at a first approximation as to the whereabouts of the storm, we must note which of the wind arrows represented in zone A corresponds to the direction of the wind prevailing at the place of observation.[1] If none of the arrows actually drawn corresponds exactly to this wind direction, it will not be difficult to find the place of the ring where the arrow ought to lie. Having found the wind arrow, we must set one of the two large needles in such a way that the plain end of it passes through the starting point of the arrow on the circle; the other end of the needle will then point toward the direction in which the center lies.

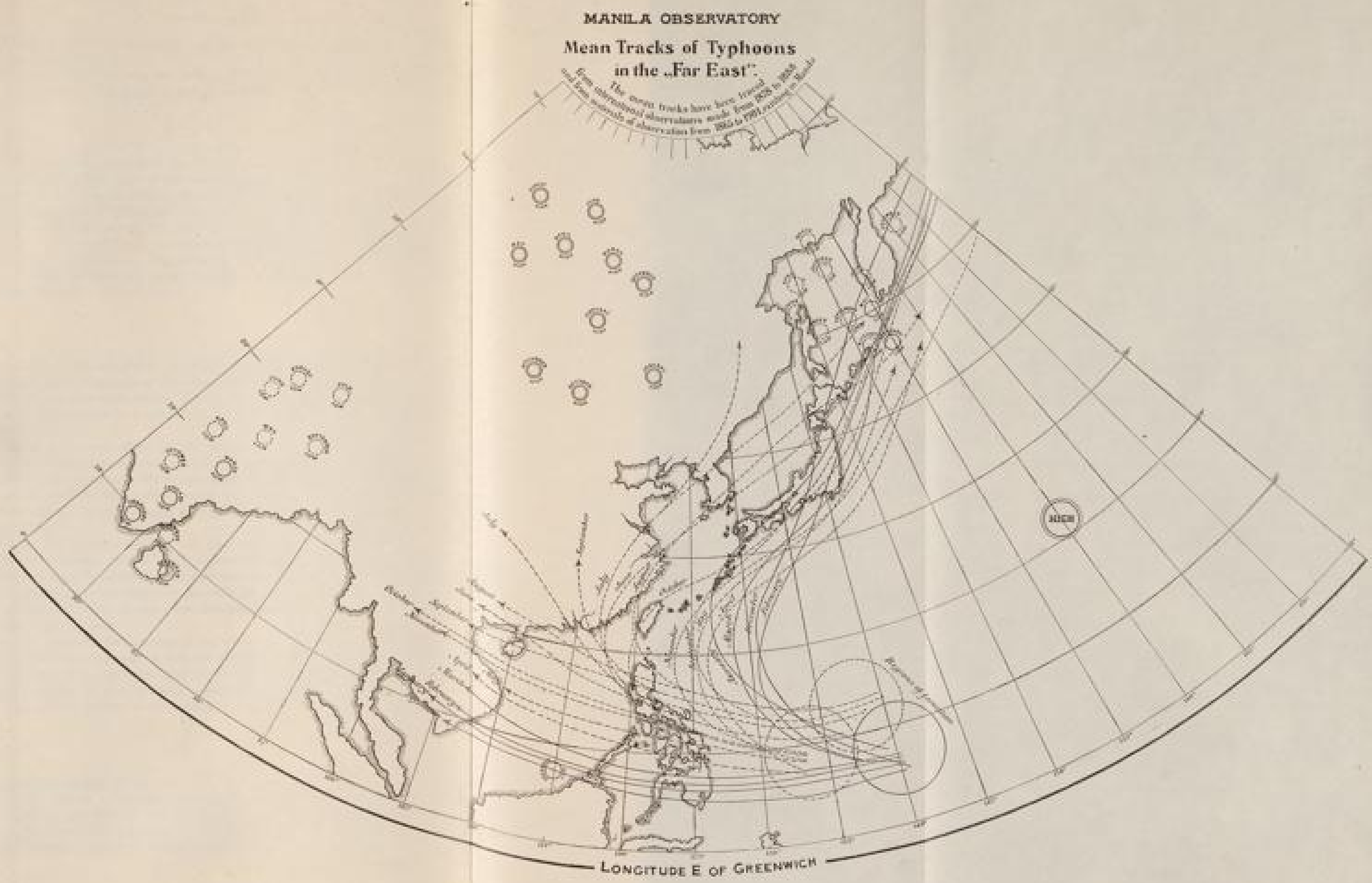
If the barometer falls, even though slowly, or if there is a partial change in the barometrical curve but the wind is still blowing from the same point or from a direction close to it, this is a proof that the position of the center has been determined with sufficient accuracy. In proportion as the barometer keeps on falling, the indications given by the wind direction will be more reliable.

The second approximation.—If by a further fall of the barometer and by a partial change in the daily range of pressure the barometrical reading already corresponds to the ring for zone B, we must determine the prevailing direction of the wind and find out the wind arrow in ring B which corresponds to this direction of the wind. Next we must bring the needle to cut the wind arrow at its starting point, as before, then the other end points with greater certainty than before toward the direction in which the center lies. If the wind veers we must repeat the operation. If the wind veers without a total change in the daily curve of the barometer taking place, we may take it for granted that the center will not pass over the place of observation. The instrument shows the observer with sufficient accuracy for practical purposes not only the direction in which the center lies but also—and this is for the sailor most important—the distance of the center and the direction in which it is most probably moving.

The third approximation—The determination of the direction of the center.—If the barometer keeps on falling, the observer determines the prevailing wind direction as before, searches for the corresponding wind arrow and, using now the double needle, brings its single end to cut the wind arrow as before. The end to which the small needle is fastened shows the position of the center. If the wind continues to blow from the same point and the barometer keeps on falling we need not proceed further; the center is approaching the place of observation exactly from the direction which the needle indicates. If, however, the wind direction in two or three hours changes, then we must repeat the observation with the graduated needle, leaving the double needle un-

[1] With regard to all the applications of the barocyclonometer it is important to remember that, in speaking of wind directions, the direction of the *prevailing* wind is meant, not that of passing gusts and squalls the directions of which are often misleading, especially near the outermost parts of the typhoon.


HIGH
145°
150°
155°
160°
165°
170°


MANILA OBSERVATORY
Mean Tracks of Typhoons
in the „Far East“.
HIGH
LONGITUDE E OF GREENWICH

touched; we can then by the aid of Fournier's rule find by calculation the direction of the center's advance with sufficient accuracy.

According to Commander Fournier the following proportion expresses the relation between the descent of the barometer within a cyclone and the distance of the center—

$$\frac{P-P_2}{P-P_1}=\frac{D_1}{D_2}.$$

Here P is the atmospheric pressure at the outskirts of the storm, P_1 and P_2 are the heights of the barometer at two different times of observation, D_1 and D_2 the distances of the vortex at the respective moments. P may be taken from the table given on page 7, while P_1 will be the barometer reading at the time of setting the double needle for third approximation, corrected, if necessary for daily oscillation, and P_2 the reading when the graduated needle is set eventually similiarly corrected. $P-P_1$ and $P-P_2$ are consequently easily found. But in order to solve the problem we must know a third term. Not necessarily, because the *absolute* values of the distances do not affect the *direction* in which the center is moving; this direction depends upon their *relative* values and the included angle. But we know—

$$\frac{D_1}{D_2}$$

since the terms of the left side are given. In order to arrive at numerical results we assume D_1 divided into 100 equal parts, thus making it a numerical constant, though the unit by which it is measured may vary within very wide limits. The solution of the proportion will now give us the proportional value of D_2 expressed in a number of the equal parts of D_1, which number may be greater or less than 100.

In the apparatus D_1 is represented by the distance of the pivot of the small needle from the center of the wind disk, which distance, as will be remembered, equals the graduated portion of the other needle=100. Having therefore calculated D_2 from the above proportion, all that is necessary is to set the small needle in such manner that it points to that division line of the graduated needle whose ordinal number is equal to D_2, then the small needle will be parallel to the trajectory of the cyclone.

Corresponding to this direction we turn the disk of the cyclonometer until the central arrow is parallel to the small needle. Should the barometer continue to fall rapidly, it will be very advisable to repeat the whole operation, taking now into consideration the wind directions given for zone C or D. But there is an imperative necessity of repeating the third approximation as often as the *prevailing* wind veers; it may prove disastrous to wait until the wind has run through two or three points of the compass.

It may be well to point out the meaning of the whole procedure. The problem of determining the direction of the trajectory resolves into the following: Given one angle of a triangle and the proportion of the two including sides: find the direction of the third side. The two determinations of the center's bearing, the first of which is laid down on the wind disk by the position of the double needle and the second by that of the graduated needle, give us the included angle, while the fraction—

$$\frac{P-P_2}{P-P_1}$$

furnishes the proportional lengths of the sides. D_1, represented by two-thirds of the half-length of the double needle, having a constant *numerical* value equal to 100 (whatever its linear magnitude may be), we calculate D_2 and lay it off on the graduated needle by pointing the small needle at the corresponding division of the graduated end, which manipulation brings the small needle into a position parallel to the line whose direction is sought—that is, the trajectory of the typhoon.

The determination of the direction of the progressive movement being founded upon mean values, the result is essentially approximate. But there is still another source of inaccuracy. The equation—

$$\frac{P-P_2}{P-P_1}=\frac{D_1}{D_2}$$

states that the decrease of atmospheric pressure from the outer limit of a typhoon to any two points within it is inversely proportional to their distances from the center. There can be no doubt that this assertion is not rigorously true. Still in actual application the error is found to be sufficiently small to give results which have all the accuracy required for practical purposes.

Correction for daily oscillation.—Above we stated that the barometer readings, P_1 and P_2 should be corrected for daily oscillation *if necessary*. For this purpose we give a set of tables containing the mean corrections to be added (algebraically) to these readings, if it is desired to correct them. The tables (pp. 15–19) have been compiled from the records of the observatories of Manila, Hongkong, Zi-ka-wei, Tokio, and Nemuro, and consequently cover the seas most exposed to typhoons. From them the observer can select the one corresponding to his latitude.

Theoretically there can be no doubt that these corrections are required, because the formula—

$$\frac{P-P_2}{P-P_1}=\frac{D_1}{D_2}$$

in which P is a constant mean value, supposes the differences $P-P_1$ and $P-P_2$ to express the barometric fall due to the cyclone. The actual reading, however, gives the combined effect of the cyclone and the daily oscillation, though the latter may be *hidden* by the overwhelming influence of the former.

But practically these corrections will rarely be of great importance. The tables give as *extremes* +1.8 millimeters (0.070 inch) and −1.4 millimeters (−0.056 inch). A glance at the formula makes it clear that whenever the differences $P-P_1$ and $P-P_2$ are rather large, the application or omission of the corrections will have little effect on the resulting value of D_2. Moreover, we must not forget that the whole process is based upon mean values, hence in a concrete case it can not give rigorously exact results. Nor is this necessary. The discrepancy between the values of D_2, as obtained with uncorrected respectively corrected readings, appears chiefly in zones A and B, where the differences $P-P_1$ and $P-P_2$ are small; the nearer we approach the vortex the less the value of D_2 is affected by slight corrections. Now it is easily understood that in the outer parts of the storm a small error in the determination of the direction of the storm's track is not likely to have grave consequences. Still it will be advisable to try the effect of the corrections in zones A and B whenever they have opposite signs for P_1 and P_2, or even when they are of the same quality but the barometric fall between the two observations has been small. We will show by an example the effect which the corrections *can* have in extreme cases.

Suppose, on May 15 at 9 a. m., the barometric reading on board a steamer in the latitude of Manila is found to be 753.2 millimeters (for sea level). The wind having veered, another observation at 4 p. m. gives 747.6 millimeters. Hence the total fall is 5.6 millimeters. But is this due solely to the approach of the cyclone? By no means. During May the correction for oscillation is at Manila −1 millimeter at 9 a. m. and +1.6 at 4 p. m. Fully 2.6 millimeters of the change are therefore due to the daily oscillation.

Applying Fournier's rule to the original readings we have:

$$\frac{755-747.6}{755-753.2}=\frac{7.4}{1.8}=\frac{100}{x}\ \therefore\ x=(D_2)=24$$

But applying the same formula to the corrected readings we obtain:

$$\left.\begin{matrix}\text{9 a. m.: } 753.2-1.0=752.2\\ \text{4 p. m.: } 747.6+1.6=749.2\end{matrix}\right\}\ \therefore\ \frac{755-749.2}{755-752.2}=\frac{5.8}{2.8}=\frac{100}{y}\ \therefore\ y=(D_2)=49$$

If the wind has veered very much between the two observations, this difference in the values of D_2 and the consequent difference in the storm's direction determined therefrom may not be serious, but if the wind has changed only a few points said difference might easily prove disastrous to the steamer.

The statements concerning the effect of the corrections for oscillation are further illustrated and confirmed by the table given at the end of this section.

TABLES OF CORRECTIONS TO P_1 AND P_2 FOR DAILY OSCILLATION.

I. MANILA.

[120° 58′ east of Greenwich; 14° 35′ north latitude.]

Hour.	January.		February.		March.		April.		May.		June.	
	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.
1 a. m.	—0.006	—0.2	—0.007	—0.2	—0.010	—0.3	—0.012	—0.3	—0.010	—0.3	—0.011	—0.3
2 a. m.	0.007	0.2	0.005	0.1	0.004	0.1	0.002	0.1	0.002	0.1	0.001	0.0
3 a. m.	0.017	0.4	0.014	0.4	0.011	0.3	0.011	0.3	0.010	0.3	0.009	0.2
4 a. m.	0.016	0.4	0.014	0.4	0.013	0.3	0.010	0.3	0.010	0.3	0.011	0.3
5 a. m.	0.007	0.2	0.006	0.2	0.005	0.1	0.000	0.0	0.003	0.1	0.006	0.2
6 a. m.	—0.006	—0.2	—0.010	—0.3	—0.012	—0.3	—0.014	—0.4	—0.009	—0.2	—0.005	—0.1
7 a. m.	—0.024	—0.6	—0.028	—0.7	—0.032	—0.8	—0.032	—0.8	—0.025	—0.6	—0.018	—0.5
8 a. m.	—0.042	—1.1	—0.044	—1.1	—0.047	—1.2	—0.049	—1.2	—0.036	—0.9	—0.025	—0.6
9 a. m.	—0.053	—1.3	—0.056	—1.4	—0.056	—1.4	—0.055	—1.4	—0.041	—1.0	—0.029	—0.7
10 a. m.	—0.047	—1.2	—0.054	—1.4	—0.050	—1.3	—0.047	—1.2	—0.037	—0.9	—0.026	—0.7
11 a. m.	—0.031	—0.8	—0.037	—0.9	—0.037	—0.9	—0.033	—0.8	—0.024	—0.6	—0.015	—0.4
Noon	—0.007	—0.2	—0.013	—0.3	—0.013	—0.3	—0.012	—0.3	—0.006	—0.2	—0.002	—0.1
1 p. m.	0.024	0.6	0.018	0.5	0.018	0.5	0.021	0.5	0.020	0.5	0.018	0.5
2 p. m.	0.048	1.2	0.044	1.1	0.046	1.2	0.048	1.2	0.043	1.1	0.035	0.9
3 p. m.	0.061	1.5	0.061	1.5	0.064	1.6	0.065	1.7	0.057	1.4	0.049	1.2
4 p. m.	0.056	1.4	0.061	1.5	0.067	1.7	0.070	1.8	0.062	1.6	0.052	1.3
5 p. m.	0.041	1.0	0.050	1.3	0.057	1.4	0.063	1.4	0.054	1.4	0.044	1.1
6 p. m.	0.026	0.7	0.036	0.9	0.041	1.0	0.042	1.1	0.033	0.8	0.028	0.7
7 p. m.	0.008	0.2	0.020	0.5	0.023	0.6	0.022	0.6	0.014	0.4	0.010	0.3
8 p. m.	—0.008	—0.2	0.001	0.0	0.003	0.1	0.002	0.1	—0.004	—0.1	—0.008	—0.2
9 p. m.	—0.020	—0.5	—0.014	—0.4	—0.016	—0.4	—0.017	—0.4	—0.022	—0.6	—0.024	—0.6
10 p. m.	—0.024	—0.6	—0.022	—0.6	—0.027	—0.7	—0.032	—0.8	—0.034	—0.9	—0.035	—0.9
11 p. m.	—0.022	—0.6	—0.023	—0.6	—0.030	—0.8	—0.033	—0.8	—0.035	—0.9	—0.038	—1.0
Midnight	—0.017	—0.4	—0.019	—0.5	—0.022	—0.6	—0.022	—0.6	—0.023	—0.6	—0.027	—0.7

Hour.	July.		August.		September.		October.		November.		December.	
	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.
1 a. m.	—0.008	—0.2	—0.010	—0.3	—0.007	—0.2	—0.002	—0.1	—0.003	—0.1	—0.006	—0.2
2 a. m.	0.005	0.1	0.005	0.1	0.007	0.2	0.011	0.3	0.012	0.3	0.009	0.2
3 a. m.	0.013	0.3	0.014	0.4	0.016	0.4	0.019	0.5	0.022	0.6	0.020	0.5
4 a. m.	0.015	0.4	0.016	0.4	0.018	0.5	0.020	0.5	0.022	0.6	0.018	0.5
5 a. m.	0.012	0.3	0.012	0.3	0.012	0.3	0.013	0.3	0.013	0.3	0.010	0.3
6 a. m.	0.001	0.0	0.004	0.1	0.002	0.1	—0.004	—0.1	—0.004	—0.1	0.003	0.1
7 a. m.	—0.011	—0.3	—0.010	—0.3	—0.013	—0.3	—0.020	—0.5	—0.021	—0.5	—0.021	—0.5
8 a. m.	—0.020	—0.5	—0.023	—0.6	—0.029	—0.7	—0.034	—0.9	—0.036	—0.9	—0.041	—1.0
9 a. m.	—0.026	—0.7	—0.030	—0.8	—0.035	—0.9	—0.043	—1.1	—0.045	—1.1	—0.048	—1.2
10 a. m.	—0.024	—0.6	—0.027	—0.7	—0.033	—0.8	—0.040	—1.0	—0.040	—1.0	—0.042	—1.1
11 a. m.	—0.017	—0.4	—0.020	—0.5	—0.024	—0.6	—0.024	—0.6	—0.024	—0.6	—0.027	—0.7
Noon	—0.005	—0.1	—0.007	—0.2	—0.004	—0.1	—0.002	—0.1	—0.003	—0.1	—0.005	—0.1
1 p. m.	0.014	0.4	0.016	0.4	0.021	0.5	0.023	0.6	0.024	0.6	0.025	0.6
2 p. m.	0.029	0.7	0.033	0.8	0.040	1.0	0.044	1.1	0.044	1.1	0.047	1.2
3 p. m.	0.040	1.0	0.044	1.1	0.049	1.2	0.053	1.3	0.051	1.3	0.057	1.4
4 p. m.	0.044	1.1	0.047	1.2	0.047	1.2	0.048	1.2	0.047	1.2	0.052	1.3
5 p. m.	0.038	1.0	0.040	1.0	0.038	1.0	0.036	0.9	0.034	0.9	0.037	0.9
6 p. m.	0.024	0.6	0.026	0.7	0.022	0.6	0.023	0.6	0.021	0.5	0.022	0.6
7 p. m.	0.007	0.2	0.008	0.2	0.005	0.1	0.004	0.1	0.002	0.1	0.004	0.1
8 p. m.	—0.009	—0.2	—0.009	—0.2	—0.012	—0.3	—0.015	—0.4	—0.016	—0.4	—0.014	—0.4
9 p. m.	—0.023	—0.6	—0.026	—0.7	—0.028	—0.7	—0.029	—0.7	—0.027	—0.7	—0.025	—0.6
10 p. m.	—0.035	—0.9	—0.037	—0.9	—0.037	—0.9	—0.033	—0.8	—0.030	—0.8	—0.028	—0.7
11 p. m.	—0.035	—0.9	—0.036	—0.9	—0.033	—0.8	—0.030	—0.8	—0.027	—0.7	—0.024	—0.6
Midnight	—0.024	—0.6	—0.024	—0.6	—0.020	—0.5	—0.020	—0.5	—0.017	—0.4	—0.014	—0.4

TABLES OF CORRECTIONS TO P_1 AND P_2 FOR DAILY OSCILLATION—Continued.

II. HONGKONG.

[114° 12′ east of Greenwich; 22° 18′ north latitude.]

Hour.	January.		February.		March.		April.		May.		June.	
	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.
1 a. m.	—0. 007	—0. 2	—0. 010	—0. 3	—0. 010	—0. 3	—0. 003	—0. 1	—0. 003	—0. 1	—0. 003	—0. 1
2 a. m.	—0. 001	0. 0	—0. 001	0. 0	0. 003	0. 1	0. 012	0. 3	0. 009	0. 2	0. 007	0. 2
3 a. m.	0. 007	0. 2	0. 009	0. 2	0. 016	0. 4	0. 023	0. 6	0. 017	0. 4	0. 014	0. 4
4 a. m.	0. 011	0. 3	0. 014	0. 4	0. 020	0. 5	0. 025	0. 6	0. 016	0. 4	0. 015	0. 4
5 a. m.	0. 008	0. 2	0. 010	0. 3	0. 012	0. 3	0. 015	0. 4	0. 011	0. 3	0. 013	0. 3
6 a. m.	—0. 004	—0. 1	—0. 003	—0. 1	—0. 004	—0. 1	0. 000	0. 0	—0. 002	—0. 1	—0. 002	—0. 1
7 a. m.	—0. 019	—0. 5	—0. 020	—0. 5	—0. 022	—0. 6	—0. 018	—0. 5	—0. 019	—0. 5	—0. 011	—0. 3
8 a. m.	—0. 036	—0. 9	—0. 035	—0. 9	—0. 040	—1. 0	—0. 035	—0. 9	—0. 032	—0. 8	—0. 020	—0. 5
9 a. m.	—0. 053	—1. 3	—0. 048	—1. 2	—0. 052	—1. 3	—0. 045	—1. 1	—0. 041	—1. 0	—0. 027	—0. 7
10 a. m.	—0. 055	—1. 4	—0. 054	—1. 4	—0. 052	—1. 3	—0. 047	—1. 2	—0. 041	—1. 0	—0. 029	—0. 7
11 a. m.	—0. 039	—1. 0	—0. 043	—1. 1	—0. 043	—1. 1	—0. 039	—1. 0	—0. 036	—0. 9	—0. 024	—0. 6
Noon	—0. 012	—0. 3	—0. 020	—0. 5	—0. 022	—0. 6	—0. 025	—0. 6	—0. 023	—0. 6	—0. 015	—0. 4
1 p. m.	0. 020	0. 5	0. 000	0. 0	—0. 005	—0. 1	0. 000	0. 0	—0. 004	—0. 1	—0. 002	—0. 1
2 p. m.	0. 041	1. 0	0. 035	0. 9	0. 031	0. 8	0. 022	0. 6	0. 015	0. 4	0. 013	0. 3
3 p. m.	0. 051	1. 3	0. 050	1. 3	0. 048	1. 2	0. 039	1. 0	0. 033	0. 8	0. 025	0. 6
4 p. m.	0. 048	1. 2	0. 051	1. 3	0. 054	1. 4	0. 047	1. 2	0. 044	1. 1	0. 036	0. 9
5 p. m.	0. 037	0. 9	0. 042	1. 1	0. 051	1. 3	0. 046	1. 2	0. 045	1. 1	0. 036	0. 9
6 p. m.	0. 026	0. 7	0. 032	0. 8	0. 040	1. 0	0. 036	0. 9	0. 037	0. 9	0. 029	0. 7
7 p. m.	0. 012	0. 3	0. 020	0. 5	0. 026	0. 7	0. 022	0. 6	0. 025	0. 6	0. 014	0. 4
8 p. m.	—0. 003	—0. 1	0. 005	0. 1	0. 008	0. 2	0. 005	0. 1	0. 007	0. 2	—0. 002	—0. 1
9 p. m.	—0. 009	—0. 2	—0. 007	—0. 2	—0. 009	—0. 2	—0. 012	—0. 3	—0. 006	—0. 2	—0. 013	—0. 3
10 p. m.	—0. 013	—0. 3	—0. 014	—0. 4	—0. 019	—0. 5	—0. 023	—0. 6	—0. 019	—0. 5	—0. 025	—0. 6
11 p. m.	—0. 012	—0. 3	—0. 015	—0. 4	—0. 019	—0. 5	—0. 023	—0. 6	—0. 020	—0. 5	—0. 024	—0. 6
Midnight	—0. 011	—0. 3	—0. 015	—0. 4	—0. 015	—0. 4	—0. 016	—0. 4	—0. 012	—0. 3	—0. 012	—0. 3

Hour.	July.		August.		September.		October.		November.		December.	
	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.
1 a. m.	—0. 003	—0. 1	—0. 005	—0. 1	—0. 002	—0. 1	—0. 003	—0. 1	—0. 003	—0. 1	—0. 007	—0. 2
2 a. m.	0. 008	0. 2	0. 007	0. 2	0. 009	0. 2	0. 011	0. 3	0. 007	0. 2	0. 001	0. 0
3 a. m.	0. 014	0. 4	0. 015	0. 4	0. 017	0. 4	0. 019	0. 5	0. 016	0. 4	0. 009	0. 2
4 a. m.	0. 015	0. 4	0. 018	0. 5	0. 019	0. 5	0. 021	0. 5	0. 020	0. 5	0. 011	0. 3
5 a. m.	0. 011	0. 3	0. 015	0. 4	0. 013	0. 3	0. 012	0. 3	0. 017	0. 4	0. 007	0. 2
6 a. m.	0. 000	0. 0	0. 005	0. 1	—0. 001	0. 0	—0. 004	—0. 1	0. 001	0. 0	—0. 005	—0. 1
7 a. m.	—0. 012	—0. 3	—0. 008	—0. 2	—0. 015	—0. 4	—0. 021	—0. 5	—0. 016	—0. 4	—0. 022	—0. 6
8 a. m.	—0. 020	—0. 5	—0. 020	—0. 5	—0. 030	—0. 8	—0. 036	—0. 9	—0. 033	—0. 8	—0. 040	—1. 0
9 a. m.	—0. 027	—0. 7	—0. 028	—0. 7	—0. 038	—1. 0	—0. 047	—1. 2	—0. 048	—1. 2	—0. 054	—1. 4
10 a. m.	—0. 029	—0. 7	—0. 032	—0. 8	—0. 041	—1. 0	—0. 047	—1. 2	—0. 046	—1. 2	—0. 054	—1. 4
11 a. m.	—0. 026	—0. 7	—0. 028	—0. 7	—0. 033	—0. 8	—0. 033	—0. 8	—0. 030	—0. 8	—0. 038	—1. 0
Noon	—0. 017	—0. 4	—0. 017	—0. 4	—0. 016	—0. 4	—0. 010	—0. 3	—0. 006	—0. 2	—0. 009	—0. 2
1 p. m.	—0. 015	—0. 4	—0. 001	0. 0	0. 005	0. 1	0. 015	0. 4	0. 024	0. 6	0. 023	0. 6
2 p. m.	0. 010	0. 3	0. 016	0. 4	0. 024	0. 6	0. 036	0. 9	0. 041	1. 0	0. 044	1. 1
3 p. m.	0. 022	0. 6	0. 030	0. 8	0. 038	1. 0	0. 046	1. 2	0. 048	1. 2	0. 054	1. 4
4 p. m.	0. 034	0. 9	0. 039	1. 0	0. 042	1. 1	0. 044	1. 1	0. 044	1. 1	0. 051	1. 3
5 p. m.	0. 038	1. 0	0. 041	1. 0	0. 040	1. 0	0. 035	0. 9	0. 034	0. 9	0. 040	1. 0
6 p. m.	0. 031	0. 8	0. 034	0. 9	0. 031	0. 8	0. 026	0. 7	0. 022	0. 6	0. 027	0. 7
7 p. m.	0. 018	0. 5	0. 018	0. 5	0. 017	0. 4	0. 009	0. 2	0. 005	0. 1	0. 012	0. 3
8 p. m.	0. 003	0. 1	—0. 001	0. 0	—0. 002	—0. 1	—0. 011	—0. 3	—0. 011	—0. 3	—0. 002	—0. 1
9 p. m.	—0. 012	—0. 3	—0. 019	—0. 5	—0. 018	—0. 5	—0. 021	—0. 5	—0. 018	—0. 5	—0. 011	—0. 3
10 p. m.	—0. 023	—0. 6	—0. 029	—0. 7	—0. 024	—0. 6	—0. 023	—0. 6	—0. 023	—0. 6	—0. 016	—0. 4
11 p. m.	—0. 024	—0. 6	—0. 027	—0. 7	—0. 022	—0. 6	—0. 020	—0. 5	—0. 021	—0. 5	—0. 014	—0. 4
Midnight	—0. 017	—0. 4	—0. 019	—0. 5	—0. 015	—0. 4	—0. 013	—0. 3	—0. 014	—0. 4	—0. 011	—0. 3

TABLES OF CORRECTIONS TO P_1 AND P_2 FOR DAILY OSCILLATION—Continued.

III. ZI-KA-WEI.

[121° 26′ east of Greenwich; 31° 11′ north latitude.]

Hour.	January.		February.		March.		April.		May.		June.	
	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.
1 a. m	-0.009	-0.2	-0.008	-0.2	-0.012	-0.3	-0.002	-0.1	-0.006	-0.2	-0.006	-0.2
2 a. m	-0.007	-0.2	-0.003	-0.1	-0.004	-0.1	0.007	0.2	0.003	0.1	0.002	0.1
3 a. m	0.000	0.0	0.006	0.2	0.009	0.2	0.017	0.4	0.009	0.2	0.005	0.1
4 a. m	0.007	0.2	0.011	0.3	0.015	0.4	0.020	0.5	0.011	0.3	0.010	0.3
5 a. m	0.007	0.2	0.011	0.3	0.011	0.3	0.016	0.4	0.008	0.2	0.007	0.2
6 a. m	-0.001	0.0	-0.002	0.1	0.003	0.1	0.003	0.1	-0.002	-0.1	-0.002	-0.1
7 a. m	-0.011	-0.3	-0.009	-0.2	-0.012	-0.3	-0.012	-0.3	-0.012	-0.3	-0.012	-0.3
8 a. m	-0.023	-0.6	-0.023	-0.6	-0.026	-0.7	-0.023	-0.6	-0.021	-0.5	-0.020	-0.5
9 a. m	-0.027	-0.7	-0.032	-0.8	-0.033	-0.8	-0.032	-0.8	-0.027	-0.7	-0.022	-0.6
10 a. m	-0.039	-1.0	-0.035	-0.9	-0.034	-0.9	-0.036	-0.9	-0.027	-0.7	-0.022	-0.6
11 a. m	-0.022	-0.6	-0.029	-0.7	-0.028	-0.7	-0.029	-0.7	-0.022	-0.6	-0.019	-0.5
Noon	0.007	0.2	-0.008	-0.2	-0.011	-0.3	-0.017	-0.4	-0.010	-0.3	-0.009	-0.2
1 p. m	0.032	0.8	0.017	0.4	0.010	0.3	0.001	0.0	0.005	0.1	0.004	0.1
2 p. m	0.041	1.0	0.033	0.8	0.028	0.7	0.016	0.4	0.017	0.4	0.013	0.3
3 p. m	0.041	1.0	0.036	0.9	0.036	0.9	0.030	0.8	0.027	0.7	0.021	0.5
4 p. m	0.032	0.8	0.032	0.8	0.038	1.0	0.035	0.9	0.032	0.8	0.029	0.7
5 p. m	0.023	0.6	0.024	0.6	0.033	0.8	0.032	0.8	0.033	0.8	0.032	0.8
6 p. m	0.012	0.3	0.012	0.3	0.023	0.6	0.024	0.6	0.025	0.6	0.026	0.7
7 p. m	0.003	0.1	0.005	0.1	0.014	0.4	0.014	0.4	0.015	0.4	0.013	0.3
8 p. m	-0.006	-0.2	-0.003	-0.1	0.000	0.0	-0.002	-0.1	0.001	0.0	0.000	0.0
9 p. m	-0.012	-0.3	-0.010	-0.3	-0.013	-0.3	-0.015	-0.4	-0.013	-0.3	-0.013	-0.3
10 p. m	-0.013	-0.3	-0.013	-0.3	-0.017	-0.4	-0.019	-0.5	-0.017	-0.4	-0.019	-0.5
11 p. m	-0.011	-0.3	-0.012	-0.3	-0.014	-0.4	-0.017	-0.4	-0.014	-0.4	-0.015	-0.4
Midnight	-0.012	-0.3	-0.009	-0.2	-0.018	-0.5	-0.012	-0.3	-0.015	-0.4	-0.015	-0.4

Hour.	July.		August.		September.		October.		November.		December.	
	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.
1 a. m	-0.001	0.0	-0.002	-0.1	-0.002	-0.1	0.002	0.1	-0.003	-0.1	-0.006	-0.2
2 a. m	0.007	0.2	0.006	0.2	0.005	0.1	0.008	0.2	0.002	0.1	0.003	0.1
3 a. m	0.012	0.3	0.011	0.3	0.012	0.3	0.015	0.4	0.007	0.2	0.001	0.0
4 a. m	0.013	0.3	0.014	0.4	0.015	0.4	0.018	0.5	0.012	0.3	0.009	0.2
5 a. m	0.009	0.2	0.010	0.3	0.012	0.3	0.012	0.3	0.010	0.3	0.009	0.2
6 a. m	0.001	0.0	0.001	0.0	0.003	0.1	0.003	0.1	0.000	0.0	0.001	0.0
7 a. m	-0.010	-0.3	-0.011	-0.3	-0.009	-0.2	-0.012	-0.3	-0.014	-0.4	-0.010	-0.3
8 a. m	-0.017	-0.4	-0.019	-0.5	-0.019	-0.5	-0.029	-0.7	-0.030	-0.8	-0.023	-0.6
9 a. m	-0.021	-0.5	-0.025	-0.6	-0.027	-0.7	-0.034	-0.9	-0.038	-1.0	-0.036	-0.9
10 a. m	-0.021	-0.5	-0.026	-0.7	-0.028	-0.7	-0.030	-0.8	-0.037	-0.9	-0.038	-1.0
11 a. m	-0.016	-0.4	-0.019	-0.5	-0.020	-0.5	-0.020	-0.5	-0.024	-0.6	-0.023	-0.6
Noon	-0.009	-0.2	-0.008	-0.2	-0.007	-0.2	-0.001	0.0	0.000	0.0	0.004	0.1
1 p. m	0.001	0.0	0.003	0.1	0.008	0.2	0.021	0.5	0.022	0.6	0.028	0.7
2 p. m	0.011	0.3	0.015	0.4	0.020	0.5	0.029	0.7	0.030	0.8	0.038	1.0
3 p. m	0.019	0.5	0.024	0.6	0.025	0.6	0.030	0.8	0.032	0.8	0.038	1.0
4 p. m	0.025	0.6	0.026	0.7	0.023	0.6	0.027	0.7	0.026	0.7	0.030	0.8
5 p. m	0.028	0.7	0.029	0.7	0.019	0.5	0.021	0.5	0.018	0.5	0.021	0.5
6 p. m	0.022	0.6	0.024	0.6	0.013	0.3	0.012	0.3	0.005	0.1	0.009	0.2
7 p. m	0.013	0.3	0.015	0.4	0.004	0.1	0.001	0.0	-0.005	-0.1	-0.001	0.0
8 p. m	-0.001	0.0	0.000	0.0	-0.012	-0.3	-0.010	-0.3	-0.012	-0.3	-0.006	-0.2
9 p. m	-0.013	-0.3	-0.015	-0.4	-0.023	-0.6	-0.017	-0.4	-0.018	-0.5	-0.011	-0.3
10 p. m	-0.019	-0.5	-0.019	-0.5	-0.024	-0.6	-0.018	-0.5	-0.021	-0.5	-0.012	-0.3
11 p. m	-0.017	-0.4	-0.018	-0.5	-0.021	-0.5	-0.014	-0.4	-0.016	-0.4	-0.011	-0.3
Midnight	-0.009	-0.2	-0.009	-0.2	-0.010	-0.3	-0.003	-0.1	-0.007	-0.2	-0.010	-0.3

TABLES OF CORRECTIONS TO P_1 AND P_2 FOR DAILY OSCILLATION—Continued.

IV. TOKIO.

[139° 45′ east of Greenwich; 35° 41′ north latitude.]

Hour.	January.		February.		March.		April.		May.		June.	
	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.
1 a. m	—0.007	—0.2	—0.003	—0.1	—0.010	—0.3	—0.005	—0.1	—0.003	—0.1	0.004	0.1
2 a. m	—0.009	—0.2	—0.002	—0.1	—0.003	—0.1	0.003	0.1	0.002	0.1	0.004	0.1
3 a. m	—0.002	—0.1	0.004	0.1	0.004	0.1	0.005	0.1	0.002	0.1	0.004	0.1
4 a. m	0.002	0.1	0.004	0.1	0.001	0.0	0.004	0.1	0.001	0.0	0.000	0.0
5 a. m	0.000	0.0	—0.003	—0.1	—0.007	—0.2	—0.004	—0.1	—0.009	—0.2	—0.009	—0.2
6 a. m	—0.009	—0.2	—0.011	—0.3	—0.017	—0.4	—0.017	—0.4	—0.019	—0.5	—0.017	—0.4
7 a. m	—0.019	—0.5	—0.026	—0.7	—0.028	—0.7	—0.026	—0.7	—0.025	—0.6	—0.025	—0.6
8 a. m	—0.029	—0.7	—0.034	—0.9	—0.035	—0.9	—0.028	—0.7	—0.028	—0.7	—0.028	—0.7
9 a. m	—0.036	—0.9	—0.035	—0.9	—0.037	—0.9	—0.029	—0.7	—0.025	—0.6	—0.025	—0.6
10 a. m	—0.030	—0.8	—0.030	—0.8	—0.029	—0.7	—0.025	—0.6	—0.022	—0.6	—0.022	—0.6
11 a. m	—0.006	—0.2	—0.016	—0.4	—0.016	—0.4	—0.012	—0.3	—0.013	—0.3	—0.015	—0.4
Noon	0.023	0.6	0.009	0.2	0.002	0.1	0.006	0.2	0.002	0.1	—0.003	—0.1
1 p. m	0.043	1.1	0.033	0.8	0.026	0.7	0.021	0.5	0.015	0.4	0.009	0.2
2 p. m	0.045	1.1	0.043	1.1	0.039	1.0	0.034	0.9	0.027	0.7	0.019	0.5
3 p. m	0.041	1.0	0.042	1.1	0.042	1.1	0.043	1.1	0.034	0.9	0.025	0.6
4 p. m	0.032	0.8	0.038	1.0	0.042	1.1	0.041	1.0	0.036	0.9	0.031	0.8
5 p. m	0.019	0.5	0.025	0.6	0.033	0.8	0.036	0.9	0.035	0.9	0.034	0.9
6 p. m	0.005	0.1	0.012	0.3	0.020	0.5	0.024	0.6	0.027	0.7	0.024	0.6
7 p. m	—0.005	—0.1	0.001	0.0	0.009	0.2	0.009	0.2	0.014	0.4	0.014	0.4
8 p. m	—0.011	—0.3	—0.007	—0.2	—0.004	—0.1	—0.010	—0.3	0.001	0.0	0.002	0.1
9 p. m	—0.014	—0.4	—0.011	—0.3	—0.012	—0.3	—0.017	—0.4	—0.009	—0.2	—0.011	—0.3
10 p. m	—0.014	—0.4	—0.011	—0.3	—0.014	—0.4	—0.018	—0.5	—0.011	—0.3	—0.014	—0.4
11 p. m	—0.012	—0.3	—0.009	—0.2	—0.011	—0.3	—0.017	—0.4	—0.008	—0.2	—0.011	—0.3
Midnight	—0.007	—0.2	—0.007	—0.2	—0.007	—0.2	—0.014	—0.4	—0.002	—0.1	—0.004	—0.1

Hour.	July.		August.		September.		October.		November.		December.	
	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.	Inches.	Millimeters.
1 a. m	—0.002	—0.1	—0.001	0.0	0.001	0.0	0.002	0.1	0.000	0.0	0.001	0.0
2 a. m	0.003	0.1	0.003	0.1	0.005	0.1	0.006	0.2	0.001	0.0	0.000	0.0
3 a. m	0.003	0.1	0.005	0.1	0.009	0.2	0.009	0.2	0.005	0.1	0.003	0.1
4 a. m	—0.001	0.0	0.003	0.1	0.009	0.2	0.005	0.1	0.002	0.1	0.006	0.2
5 a. m	—0.009	—0.2	—0.006	—0.1	0.003	0.1	—0.002	—0.1	—0.004	—0.1	0.001	0.0
6 a. m	—0.014	—0.4	—0.013	—0.3	—0.005	—0.1	—0.011	—0.3	—0.014	—0.4	—0.012	—0.3
7 a. m	—0.019	—0.5	—0.019	—0.5	—0.014	—0.4	—0.022	—0.6	—0.028	—0.7	—0.022	—0.6
8 a. m	—0.019	—0.5	—0.021	—0.5	—0.018	—0.5	—0.031	—0.8	—0.037	—0.9	—0.033	—0.8
9 a. m	—0.017	—0.4	—0.023	—0.6	—0.022	—0.6	—0.030	—0.8	—0.037	—0.9	—0.042	—1.1
10 a. m	—0.014	—0.4	—0.019	—0.5	—0.020	—0.5	—0.022	—0.6	—0.031	—0.8	—0.036	—0.9
11 a. m	—0.008	—0.2	—0.009	—0.2	—0.009	—0.2	—0.010	—0.3	—0.011	—0.3	—0.019	—0.3
Noon	0.002	0.1	0.003	0.1	0.004	0.1	0.013	0.3	0.015	0.4	0.016	0.4
1 p. m	0.011	0.3	0.014	0.4	0.016	0.4	0.031	0.8	0.032	0.8	0.035	0.9
2 p. m	0.020	0.5	0.024	0.6	0.026	0.7	0.039	1.0	0.037	0.9	0.040	1.0
3 p. m	0.026	0.7	0.031	0.8	0.028	0.7	0.039	1.0	0.035	0.9	0.036	0.9
4 p. m	0.029	0.7	0.031	0.8	0.026	0.7	0.033	0.8	0.031	0.8	0.026	0.7
5 p. m	0.027	0.7	0.028	0.7	0.019	0.5	0.023	0.6	0.021	0.5	0.016	0.4
6 p. m	0.018	0.5	0.020	0.5	0.013	0.3	0.011	0.3	0.010	0.3	0.005	0.1
7 p. m	0.008	0.2	0.007	0.2	—0.002	—0.1	0.001	0.0	0.001	0.0	—0.004	—0.1
8 p. m	—0.003	—0.1	—0.009	—0.2	—0.014	—0.4	—0.006	—0.2	—0.005	—0.1	—0.010	—0.3
9 p. m	—0.013	—0.3	—0.015	—0.4	—0.016	—0.4	—0.011	—0.3	—0.008	—0.2	—0.012	—0.3
10 p. m	—0.015	—0.4	—0.016	—0.4	—0.015	—0.4	—0.010	—0.3	—0.007	—0.2	—0.010	—0.3
11 p. m	—0.014	—0.4	—0.014	—0.4	—0.012	—0.3	—0.006	—0.2	—0.006	—0.2	—0.007	—0.2
Midnight	—0.009	—0.2	—0.008	—0.2	—0.007	—0.2	—0.003	—0.1	—0.003	—0.1	—0.001	0.0

TABLES OF CORRECTIONS TO P_1 AND P_2 FOR DAILY OSCILLATION—Continued.

V. NEMURO.

[145° 35′ east of Greenwich; 45° 20′ north latitude.]

Hour.	January.		February.		March.		April.		May.		June.	
	Inches.	Milli-meters.	Inches.	Milli-meters.	Inches.	Milli-meters.	Inches.	Milli-meters.	Inches.	Milli-meters.	Inches.	Milli-meters.
1 a. m	—0.003	—0.1	0.000	0.0	—0.006	—0.2	—0.001	0.0	—0.008	—0.2	0.004	0.1
2 a. m	—0.005	—0.1	0.002	0.1	0.002	0.1	0.001	0.0	—0.004	—0.1	0.008	0.2
3 a. m	0.001	0.0	0.006	0.2	0.005	0.1	0.003	0.1	—0.001	0.0	0.008	0.2
4 a. m	0.005	0.1	0.005	0.1	0.004	0.1	0.002	0.1	—0.004	—0.1	0.004	0.1
5 a. m	0.003	0.1	0.004	0.1	0.001	0.0	—0.004	—0.1	—0.007	—0.2	—0.001	0.0
6 a. m	—0.001	0.0	0.000	0.0	—0.004	—0.1	—0.011	—0.3	—0.010	—0.3	—0.004	—0.1
7 a. m	—0.011	—0.3	—0.008	—0.2	—0.009	—0.2	—0.013	—0.3	—0.010	—0.3	—0.008	—0.2
8 a. m	—0.017	—0.4	—0.012	—0.3	—0.011	—0.3	—0.011	—0.3	—0.006	—0.2	—0.007	—0.2
9 a. m	—0.019	—0.5	—0.014	—0.4	—0.011	—0.3	—0.014	—0.4	—0.004	—0.1	—0.006	—0.2
10 a. m	—0.014	—0.4	—0.013	—0.3	—0.008	—0.2	—0.006	—0.2	—0.002	—0.1	—0.005	—0.1
11 a. m	0.005	0.1	—0.004	—0.1	0.000	0.0	0.001	0.0	0.005	0.1	0.000	0.0
Noon	0.019	0.5	0.011	0.3	0.011	0.3	0.011	0.3	0.012	0.3	0.006	0.2
1 p. m	0.024	0.6	0.021	0.5	0.022	0.6	0.018	0.5	0.017	0.4	0.010	0.3
2 p. m	0.021	0.5	0.022	0.6	0.024	0.6	0.025	0.6	0.023	0.6	0.012	0.3
3 p. m	0.013	0.3	0.017	0.4	0.020	0.5	0.027	0.7	0.024	0.6	0.013	0.3
4 p. m	0.008	0.2	0.011	0.3	0.015	0.4	0.023	0.6	0.020	0.5	0.013	0.3
5 p. m	0.003	0.1	0.003	0.1	0.008	0.2	0.016	0.4	0.017	0.4	0.009	0.2
6 p. m	—0.004	—0.1	—0.005	—0.1	—0.001	0.0	0.008	0.2	0.008	0.2	0.002	0.1
7 p. m	—0.005	—0.1	—0.009	—0.2	—0.009	—0.2	—0.006	—0.2	—0.001	0.0	—0.005	—0.1
8 p. m	—0.008	—0.2	—0.012	—0.3	—0.014	—0.4	—0.017	—0.4	—0.013	—0.3	—0.014	—0.4
9 p. m	—0.007	—0.2	—0.012	—0.3	—0.016	—0.4	—0.017	—0.4	—0.015	—0.4	—0.016	—0.4
10 p. m	—0.006	—0.2	—0.011	—0.3	—0.017	—0.4	—0.017	—0.4	—0.016	—0.4	—0.015	—0.4
11 p. m	—0.001	0.0	—0.007	—0.2	—0.012	—0.3	—0.014	—0.4	—0.014	—0.4	—0.010	—0.3
Midnight	0.003	0.1	—0.001	0.0	—0.009	—0.2	—0.009	—0.2	—0.008	—0.2	—0.005	—0.1

Hour.	July.		August.		September.		October.		November.		December.	
	Inches.	Milli-meters.	Inches.	Milli-meters.	Inches.	Milli-meters.	Inches.	Milli-meters.	Inches.	Milli-meters.	Inches.	Milli-meters.
1 a. m	0.004	0.1	0.004	0.1	0.002	0.1	0.000	0.0	—0.003	—0.1	—0.002	—0.1
2 a. m	0.007	0.2	0.008	0.2	0.004	0.1	0.004	0.1	0.000	0.0	—0.004	—0.1
3 a. m	0.008	0.2	0.010	0.3	0.003	0.1	0.003	0.1	0.003	0.1	0.002	0.1
4 a. m	0.002	0.1	0.007	0.2	—0.001	0.0	—0.002	—0.1	0.002	0.1	0.003	0.1
5 a. m	—0.002	—0.1	—0.001	0.0	—0.005	—0.1	—0.004	—0.1	0.002	0.1	0.002	0.1
6 a. m	—0.006	—0.2	—0.004	—0.1	—0.013	—0.3	—0.010	—0.3	—0.004	—0.1	—0.004	—0.1
7 a. m	—0.008	—0.2	—0.007	—0.2	—0.013	—0.3	—0.017	—0.4	—0.014	—0.4	—0.009	—0.2
8 a. m	—0.008	—0.2	—0.008	—0.2	—0.015	—0.4	—0.018	—0.5	—0.017	—0.4	—0.015	—0.4
9 a. m	—0.008	—0.2	—0.009	—0.2	—0.018	—0.5	—0.017	—0.4	—0.016	—0.4	—0.018	—0.5
10 a. m	—0.007	—0.2	—0.006	—0.2	—0.012	—0.3	—0.012	—0.3	—0.011	—0.3	—0.011	—0.3
11 a. m	—0.002	—0.1	—0.002	—0.1	—0.004	—0.1	—0.003	—0.1	0.005	0.1	0.009	0.2
Noon	0.003	0.1	0.003	0.1	0.005	0.1	0.013	0.3	0.023	0.6	0.025	0.6
1 p. m	0.007	0.2	0.009	0.2	0.011	0.3	0.023	0.6	0.025	0.6	0.030	0.8
2 p. m	0.011	0.3	0.015	0.4	0.018	0.5	0.022	0.6	0.023	0.6	0.027	0.7
3 p. m	0.012	0.3	0.015	0.4	0.018	0.5	0.018	0.5	0.015	0.4	0.018	0.5
4 p. m	0.013	0.3	0.012	0.3	0.016	0.4	0.016	0.4	0.009	0.2	0.012	0.3
5 p. m	0.011	0.3	0.011	0.3	0.011	0.3	0.010	0.3	0.002	0.1	0.003	0.1
6 p. m	0.004	0.1	0.005	0.1	0.008	0.2	0.002	0.1	—0.003	—0.1	—0.005	—0.1
7 p. m	—0.002	—0.1	—0.006	—0.2	—0.003	—0.1	—0.001	0.0	—0.006	—0.2	—0.009	—0.2
8 p. m	—0.012	—0.3	—0.013	—0.3	—0.008	—0.2	—0.006	—0.2	—0.009	—0.2	—0.012	—0.3
9 p. m	—0.013	—0.3	—0.013	—0.3	—0.009	—0.2	—0.010	—0.3	—0.010	—0.3	—0.014	—0.4
10 p. m	—0.012	—0.3	—0.013	—0.3	—0.008	—0.2	—0.010	—0.3	—0.008	—0.2	—0.015	—0.4
11 p. m	—0.006	—0.2	—0.009	—0.2	—0.005	—0.1	—0.005	—0.1	—0.004	—0.1	—0.014	—0.3
Midnight	0.000	0.0	—0.004	—0.1	0.000	0.0	—0.004	—0.1	0.001	0.0	—0.008	—0.2

Limitation of the use of the barocyclonometer.—The direction of the cyclone's movement determined by means of the barocyclonometer, as described, has all the reliability which can be secured without telegraphic dispatches from places over which the center is passing in succession, *provided the place of observation has been stationary during the interval between the two observations,* as, for instance, a station on land or a ship at anchor. But what about the chief use of the instrument—that is, on board of ships under way? We are far from claiming for the barocyclonometer a usefulness which it does not possess. We do not recommend its use for determining the direction in which the storm is moving by means of the "third approximation" as long as the ship, steaming on her course, finds herself in zone A. The vessel's speed may be considerable compared with that of the storm's advance, and it might easily happen that, owing to the course of the ship and the distance covered, the small needle pointed in a seemingly entirely wrong direction—as each one may easily ascertain for himself by means of a few pencil lines. But with the vortex at such a distance as the ship's position in zone A implies it suffices to know the direction in which the center lies, the approximate distance of the center and, in a general way, whether the combined effect of its movement and the ship's course and speed brings the observer nearer to the vortex or not. The two latter points can be learned from the indications and behavior of the barometer; the former, with great reliability, from the wind disk. From both together a fairly good estimate can be formed of the direction of the trajectory.

The case is, however, different in zone B, and especially in zone C. There the ship will rarely make much headway while the rapid veering of the wind will allow of making the third approximation at short intervals, so that the place of observation will be but little displaced during the interval, although some allowance should always be made for the ship's course and run.

When applying the barocyclonometer for the purpose for which it has been designed the observer must bear in mind the sound advice concerning the use of this instrument given by Fr. Froc, S. J., in his memoir on the "De Witte Typhoon" of August 1–6, 1901:

To finish, we will answer a question which has been put to us by several officers, who, at anchor during the typhoon, took advantage of its approach to study the indications of the barocyclonometer, an instrument of somewhat recent use, constructed and perfected by Rev. Father José Algué, Director of the Manila Observatory. This instrument is really very valuable, and may be of most signal service at sea if handled by a practiced observer and read with an experienced eye. One must, however, never forget that like any other apparatus constructed for general requirements, the indications it gives are based upon means, that consequently they may not, in exceptional cases, be taken literally and rigorously, but need, in such circumstances, to be fitted to particular wants. Thus used, the instrument gives useful information, but it would be excessive there to seek a guide for particulars in the study of exceptional cases.

We shall therefore say of it what must be said of all the most perfect instruments of navigation: It is well worth recommending to captains, but neither this nor any other instrument will dispense the commander of a ship to appeal to his experience. This is the most valuable of all instruments, which must never be locked up, particularly when it has been acquired, increased, and enriched by ten, fifteen, twenty years and more of sailing in the same parts, and of conscientious, diligent observation. For a captain thus qualified, certain small signs, insignificant for anyone else, and which it would even be difficult to explain in a general treatise, may give more reliable warnings of the danger than all those that are met with in the best books. Thus the barocyclonometer is a great progress, but it requires commentaries and explanations. We will here only mention one point on which some seamen may have been led astray, namely, the direction of the wind in certain parts on the approach of cyclones, and, to speak of the regions best known to us, we shall limit ourselves to the mouth of the Yangtze-Kiang between the group of the Chusan Islands and the old bed of the Hoangho.

It is almost a rule that, each time a typhoon approaches, particularly when it comes to strike the coast to the south of Ningpo, the bearing of the wind grievously leads in error those who witness the phenomenon for the first time. Keeping to the study of the typhoon of August 3, let us take the report of Zi-ka-wei, printed in the appendix, or that of the North Saddle Island light-house, which is situated farther off. We shall find, at the Observatory, winds (and we may add clouds) coming from the east, and at the light-house continual breezes from east-southeast, force 6, 7, and even 8—that is, typhoon winds—during the whole day, on the 2d, on the 3d, not only when the typhoon landed on the coast, almost right to the south, but at the time when it was clearly in the south-southeast and southeast between Formosa and Nafa.

The explanation which we give without development is twofold. In the first place, the apparent anomaly results from the shape of the isobars, which, far from keeping to the circular or even elliptical shape, assume along the coast undulated, tortuous, and apparently most capricious contours, though all submitted to laws which will some day be formulated.

The second cause of the deviation of the wind, which is not without influence upon the deformation of the isobars, is the call of air taking place generally in summer from the sea toward the overheated plains situated on the continent to the northwest and to the north of Shanghai (Western China, Mongolia, and Chili). The air put in motion by the typhoon ought to incline to northeast or at most to east-northeast. On the other hand, on getting near the coasts it finds a slope and a certain attraction which ought to make it flow from south-southeast or from southeast. As long as the typhoon's vigor has not entered into the period of violence, close to the center, the air, subject to two forces at an angle between them, follows the resultant and seems to diverge, while at other times of the year—in October, for instance—the air will rush straight in the direction of the center of a distant typhoon.

We would advise those who could find the leisure to study Father Algué's instrument, reading again in quiet, far from the turmoil of the storm, the report of Capt. Geo. Payne, of the steamship *Laisang*, who bore the brunt of the cyclone in open sea. We are confident that this study will be fruitful and lead to satisfactory results.

Practical application of the barocyclonometer.—In order to illustrate the application of the preceding rules we give a few instances taken from actual observations. The calculations are made without corrections for oscillation except in cases in which the difference of the two values of D_2 exceeds five units. In every instance, however, the value y, resulting from calculation with corrections applied, is given in brackets.

(1) (*a*) During the typhoon of October 12 and 13, 1897, the famous "Typhoon of Samar and Leyte,"[1] the observations at Capiz, on the Island of Panay, were as follows:

October 12, 7.30 p.m.: Barometer 739.0 millimeters; wind, W.
October 12, 8.05 p.m.: Barometer 738.0 millimeters; wind, SW. } Zone D.

Capiz is within zone 11°—17°, October in Group II; hence, P=755. Hence we have, according to formula,

$$\frac{755-738}{755-739}=\frac{100}{x} \quad \therefore x=94 \qquad [y=94]$$

The resulting positions of the needles are given on Plate XLI; and from that follows a direction of the track toward west by north.

(*b*) During the same typhoon the observations at Manila were:

October 13, 6 a. m.: Barometer, 752.38; wind, NE.
October 13, 11 a. m.: Barometer, 753.25; wind, E. } Zone A.

Hence,

$$\frac{755-753.25}{755-752.38}=\frac{100}{x} \quad \therefore x=149 \qquad [y=145]$$

Plate XLI shows the positions of the needles; the direction of the track is west-northwest by north.

(2) During the typhoon of September 16–17, 1894, the observations at Manila (P=755) on the 16th were:

September 16, 1 p.m.: Barometer, 749.84; lowest clouds, WNW.
September 16, 6 p.m.: Barometer, 746.85; lowest clouds, W. } Zone B–C.

According to formula,

$$\frac{755-746.85}{755-749.84}=\frac{100}{x} \quad \therefore x=63 \qquad [y=64]$$

Plate XLII shows the disposition of the different needles; direction of motion of the center, west by north.

(3) During the "Gravina Typhoon" of May 13, 1895,[2] at San Isidro, Province of Nueva Ecija, the observations were as follows:

May 13, 10.00 a.m.: Barometer, 749.76; wind, SE.
May 13, 10.30 a.m.: Barometer, 748.00; wind, S. } Zone B.

The formula reads:

$$\frac{755-748.00}{755-749.76}=\frac{100}{x} \quad \therefore x=75 \qquad [y=80]$$

The direction of the track as shown by Plate XLII was northeast by north.

[1] See "El Baguio de Samar y Leyte," Manila, 1898.
[2] "Baguio de Gravina," Manila, 1895.

(4) During the terrific storm of September 7, 1902, which caused so much damage in certain parts of Japan, the observations made on board the U. S. A. T. *Sumner* could have been made good use of to find the track of the typhoon by means of the barocyclonometer.

OBSERVATIONS MADE ON BOARD THE U. S. A. T. SUMNER.

[From San Francisco to Manila.]

Date.		Position.		Barometer.	Wind.		Remarks.
Day.	Hour.	Latitude (north).	Longitude (east).		Direction.	Force, 0-12.	
		° ′	° ′	*Inches.*			
Sept. 5	6.45 a. m	34 18	138 13	29.65	ESE.	2	SSE.; swell; squally.
	10.51 a. m	34 08			ESE.	2	Do.
	2.54 p. m	33 46	136 40	.54			Do.
	8 p. m	33 42		.54	SSE.	5	Mountainous sea from SSE.; squally; exceptionally heavy sea. Expecting we are either overtaking a typhoon coming across the China Sea or are already near its outer edge; put the engine under slow bell and heave the ship to, awaiting results. "Very heavy sea running, hard wind and rain squalls of short duration, wind hauling to NE. about 9.30 p. m.
Sept. 6	6.59 a. m	33 02	135 71	.52	NE.	10	Barometer falling $\frac{4}{100}$ of an inch per hour; sea from NE.
	8 p. m	32 30	133 23	.42	NE.	7	Terrible, mountainous sea from NE.
Sept. 7	12.30 a. m	31 57	132 46				Wind and sea increasing; barometer dropping rapidly.
	7 a. m			28.22	N. by E.	12	The center of the storm can not be very far distant.
	11 a. m	31 44	133 44	.17	E. by N.	12	
	3.04 p. m			.12	E. by N.	12	The storm raged with unabated fury; terrible sea running and ship rolling something fearful until 4.30 p.m.; the wind suddenly shifting to SSE. and barometer commenced rising slowly.
	4.03 p. m	32 05	133 25	.09	E. by N.	12	
	8 p. m	31 54	133 10	.82	S.	10	Mountainous sea from NE.; the wind throughout the worst part of the gale coming from about E. by N. true and the sea being NNE.
Sept. 8	8 p. m	31 13	131 17	29.64	Variable.	2	First part of day heavy sea; sea from E. by N.-NNE.

We find that on September 6 at 8 p. m. the barometer reading was 29.42 inches and the wind was blowing strongly from the northeast. The barometer shows that the ship was then in zone B. At 7 a. m. of the 7th the barometer had fallen to 28.22 inches, corresponding to zone C, and the wind came from north by east. The use of the barocyclonometer would have been as follows:

Before commencing operations the observer would have set the central arrow of the wind disk in the direction of the mean trajectory of typhoons for the ship's place (32° 30′ north latitude and 133° 23′ east longitude) during September. The large chart shows this to be southwest-northeast. Having set the central arrow in this direction, he would have determined the ship's position relative to the vortex at 8 p. m. of the 6th, using the single end of the "double needle." The wind was from the northeast, the barometer reading indicated that he was in zone B. He would have moved the double needle until its single end passed through the tail end of that arrow in zone B, which was most nearly parallel to the direction of the wind—that is, northeast-southwest—then the other, double, end of the needle would have shown that the vortex lay south by east of the ship. After the observation at 7 a. m. of the next morning he would have determined the new position of the vortex by means of the plain end of the "graduated needle," without disturbing the rest of the arrangement. The barometer now showed that the ship was in zone C, the wind came from north by east. There is no arrow in zone C of the wind disk, which (with the arrangement described, see plate) is parallel to the north by east and south by west line. But Plate XLIII, which represents the present case, shows that the position of this arrow is between northwest and north-northwest—about 4° west of the latter point. By making the plain end of the second needle pass through the interpolated point the observer would have found that he had then the vortex to the south-southeast. For the use of Fournier's rule the two observations furnished the following data:

September 6, 8 p.m.: Barometer, 29.42 inches; wind, NE.
September 7, 7 a.m.: Barometer, 28.22 inches; wind, N. by E.

The ship being between 25°—32° (at least on the 7th), and September belonging to Group III, the value of P was 29.65 inches.

Hence,

$$\frac{29.65-28.22}{29.65-29.42}=\frac{100}{x} \therefore x=19 \qquad [y=20]$$

With disposition of the apparatus as described, the small needle pointing to 19 on the graduation of the graduated needle would have shown the track of the cyclone to be south by west to north by east. However, the course of the ship during the interval between the two observations, which was south by east, would have had to be taken into consideration. On account of this course the instrument would have shown a less inclination of the track to the northeast than it actually had. The composed direction was north-northeast. (See Pl. XL.)

The vortex was, therefore, recurving to the west of the ship, as was shown in the Weather Bulletin for September, 1902, issued by the Philippine Weather Bureau.

(5) (*a*) At noon July 26, 1902, the barometer on board the steamship *Loonsang* was 29.33 inches, and the wind blew from west by north; she was in zone C. At 3 p. m. the barometer had fallen to 29.22 inches, and the wind had backed to southwest. By Fournier's rule we have:

$$\frac{29.73-29.22}{29.73-29.33}=\frac{100}{x} \therefore x=78.$$

The position of the needles would have been as shown on Plate XLIII, the resulting direction being east by south—west by north.

The calculation with readings corrected for daily oscillation gives a somewhat different result. Since the ship was below the twenty-first degree of north latitude, we take the corrections from the Manila table:

July 26, noon, 29.33—0.02 inches=29.31 inches.
July 26, 3 p.m., 29.22+0.02 inches=29.24 inches.

Hence,

$$\frac{29.73-29.24}{29.73-29.31}=\frac{100}{y} \therefore y=86$$

The direction corresponding to this value of D_2 is shown on the plate by means of a dotted line.

(*b*) On the same day, July 26, at 3 p. m. the barometer of the steamship *Rosetta Maru* stood at 29.22 inches, and the wind came from north-northwest. At 6 p. m. the barometer indicated 29.12 inches, with the wind blowing from northeast.

Fournier's formula gives,

$$\frac{29.73-29.12}{29.73-29.22}=\frac{100}{x} \therefore x=84 \qquad [y=80]$$

The track resulted, therefore, as shown by the small needle on Plate XLIV, east-northeast by north to west-southwest by south. But owing to the ship's course being almost opposite to the motion of the vortex (see Pl. XL), the composition of the two motions will give the true direction of the track, which in the present case will be east by south to west by north, as was the case with the *Loonsang*.

(*c*) On the 27th at 3 a. m. the barometer reading on the *Rosetta Maru* was 28.85 inches with wind coming from southeast. Comparing this observation with the one made at 6 p. m. on the preceding day, we find by Fournier's rule:

$$\frac{29.73-28.85}{29.73-29.12}=\frac{100}{x} \therefore x=69 \qquad [y=70]$$

The small needle will point to northwest, and, composing this with the ship's course, we find that the average direction of the center from 6 p. m. of the 26th till 3 a. m. of 27th was northwest by west. (See Pl. XLIV.)

(6) Another typhoon which was felt so severely in Hongkong in the beginning of August, 1902, crossed to the north of Aparri on the evening of July 31. The trajectory found by means of the barocyclonometer was east by south to west by north. Aparri was successively in zones A and B from July 31 to August 1, and the following observations were made:

July 31, 10 p. m.: Barometer, 751.1 millimeters; wind, NW.
August 1, 6 a. m.: Barometer, 746.4 millimeters; wind, WSW. } Zone B.

Whence we have,

$$\frac{755-746.4}{755-751.1}=\frac{100}{x} \therefore x=45.$$

Applying the corrections for daily oscillation we obtain the following:

July 31, 10 p. m.: 751.1—0.9=750.2 millimeters
August 1, 6 a. m.: 746.4—0.0=746.4 millimeters }, which gives $y=55$.

The two resulting directions are shown on Plate XLV.

(7) Observations made on board the German cruiser *Hertha* furnish some very interesting instances concerning the use of the barocyclonometer. From observations made at Nagasaki (see No. 8) we learn that that harbor was within zone A of a typhoon (passing afterwards close by to the south) on the morning of August 8, 1902. Hence the *Hertha,* which had left Nagasaki at 3.25 p. m. of the 7th, and was some hundred miles to the southeast by south of the port at noon of the 8th, found herself far within zone A. In fact at 8 p. m. of the 8th the barometer showed 751.79 millimeters—that is, between zones A and B—and at midnight it had fallen to 748.87 millimeters. By that time the ship had entered zone B. By taking the readings and wind-directions we can find the bearing of the center of the typhoon at the corresponding hours.

OBSERVATIONS MADE ON BOARD THE GERMAN CRUISER HERTHA.

No.	Date.		Barometer.	Wind.	Zone.	Fournier's formula.		Track of center to—	Approximate distance of center.
	Day.	Hour.				Uncorrected readings.	Corrected readings.		
			Mm.						Miles.
1	Aug. 8	Midnight.	748.87	ESE.	B.	------	------	------------	138
2	Aug. 9	2.00 a.m.	745.61	ESE.	C.	------	------	------------	118
3	----do ----	5.30 a.m.	743.01	SE. by E.	C.	74	73	NE.	79
4	----do ----	7.30 a.m.	740.58	E.	C.	80	78	NE. by E.	55
5	----do ----	8.30 a.m.	739.85	ESE.	C.	94	93	NE. by E.	42
6	----do ----	10.00 a.m.	730.99	SE. by E.	D.	60	60	NE. by E.	21
7	----do ----	11.45 am.	712.37	SE.	D.	54	55	NE. by E.	8

Observations 1 and 2 can not be combined for a determination of the direction of the trajectory since the wind had not changed during the interval.

The combination of readings 2 and 3 furnishes a remarkable instance of the influence of the ship's course upon the trajectory as found by means of the instrument. The small needle pointing to 74 gives the direction south by west and north by east, the course of the ship being almost southeast at that time. The actual bearing of the center, therefore, ought to have been, during the interval of the two readings, from about southwest to northeast. The position of the needles is shown on Plate XLV. Another instance is found by combining readings 6 and 7.

8. During the same typhoon which gave such a rough shaking to the *Hertha* another man-of-war, the French cruiser *Friant*, was at anchor in the harbor of Nagasaki. The following table exhibits the observations made on board and the results derived therefrom:

OBSERVATIONS MADE ON BOARD THE FRENCH CRUISER FRIANT.

No.	Date.		Barometer.	Wind.	Zone.	Fournier's formula.		Track of center to—	Approximate distance of center.
	Day.	Hour.				Uncorrected readings.	Corrected readings.		
			Mm.						*Miles.*
1	Aug. 9	8.00 a.m.	752.9	NE.	A.				
2	----do ----	Noon.	751.9	ENE.	A.	52	70	NE. by E.	300
3	----do ----	Midnight.	748.3	E.	B.	37	39	NE. by E.	200
4	Aug. 10	4.00 a.m.	745.4	ESE.	C.	66	72	NE. by E.	120
5	----do ----	8.00 a.m.	740.2	ENE.	C.	62	57	NE. by E.	90
6	----do ----	Noon.	729.3	NNE.	D.	56	57	NE. by E.	50
7	----do ----	2.00 p.m.	728.8	N. by W.	D.	98	100	NE. by E.	25
8	----do ----	4.00 p.m.	736.0	NW.	D.	139	143	NE. by E.	

Fournier's rule has been applied by combining observations 1 and 2, 2 and 3, and so on. The direction of the trajectory thus found coincides with Track VI on Plate XL.

Important caution.—Before applying the barocyclonometer it is of the greatest importance to ascertain whether the aneroid of the apparatus as installed in the chart room or the captain's cabin shows the pressure corresponding to its elevation above sea level or to the sea level itself. It should be corrected to show the latter.

Table of comparison.—To close this treatise we present the comparative table spoken of on page 15. The same needs no further explanation.

Zone.	Place of observation.	D_2 from uncorrected readings.	D_2 from corrected readings.	D_2-D_2.	Correction to P_1.	Correction to P_2.	Fall of barometer during interval, corrected for oscillation.
					Mm.	*Mm.*	
A.	Manila	149	145	+ 4	— 0.1	— 0.6	—[1] 0.82
A.	Nagasaki (Friant)	52	70	—18	— 0.5	— 0.2	0.7
B.	San Isidro	75	80	— 5	— 1.0	— 0.8	1.56
B.	Aparri	45	55	—10	— 0.9	0.0	3.8
B.	Nagasaki (Friant)	37	39	— 2	— 0.2	— 0.2	3.6
B–C.	Manila	63	64	— 1	+ 0.6	+ 0.6	2.99
C.	U. S. A. T. Sumner	19	20	— 1	0.0	— 0.3	[2] 30.70
C.	Steamship Loonsang	78	86	— 8	— 0.5	+ 0.5	[3] 1.8
C.	Cruiser Hertha	74	73	+ 1	+ 0.20	+ 0.15	2.65
C.	----do	80	78	+ 2	+ 0.15	— 0.15	2.73
C.	----do	94	93	+ 1	— 0.15	— 0.40	0.98
C.	Nagasaki (Friant)	66	72	— 6	— 0.2	+ 0.4	2.3
C.	----do	62	57	+ 5	+ 0.4	— 0.5	6.1
D.	Capiz	94	94	0	— 0.7	— 0.9	1.02
D.	Steamship Rosetta Maru	84	80	+ 4	+ 1.0	+ 0.5	[4] 3.05
D.	----do	69	70	— 1	+ 0.5	+ 1.0	[5] 6.35
D.	Cruiser Hertha	60	60	0	— 0.40	— 0.70	9.16
D.	----do	54	55	— 1	— 0.70	— 0.53	18.45
D.	Nagasaki (Friant)	56	57	— 1	— 0.5	— 0.2	10.6
D.	----do	98	100	— 2	— 0.2	+ 0.4	— 0.1
D.	----do	139	143	— 4	+ 0.4	+ 0.7	— 7.5

[1] Barometer rose.
[2] Fall, 1.21 inches; correction of P_2 = 0.01 inch.
[3] Fall, 0.07 inch; corrections = ±0.02 inch.
[4] Fall, 0.12 inch; corrections = +0.04 and +0.02 inch.
[5] Fall, 0.25 inch; corrections = +0.02 and +0.04 inch.

Note.—In order to safeguard the scientific reputation of the late Rev. B. Faura, S. J., but above all to prevent serious consequences which might result, we believe it to be our painful duty to protest on this occasion against a form of aneroid barometer bearing the name of the founder of Manila Observatory, and to warn the seafaring community against confiding in the characteristic feature of said instruments.

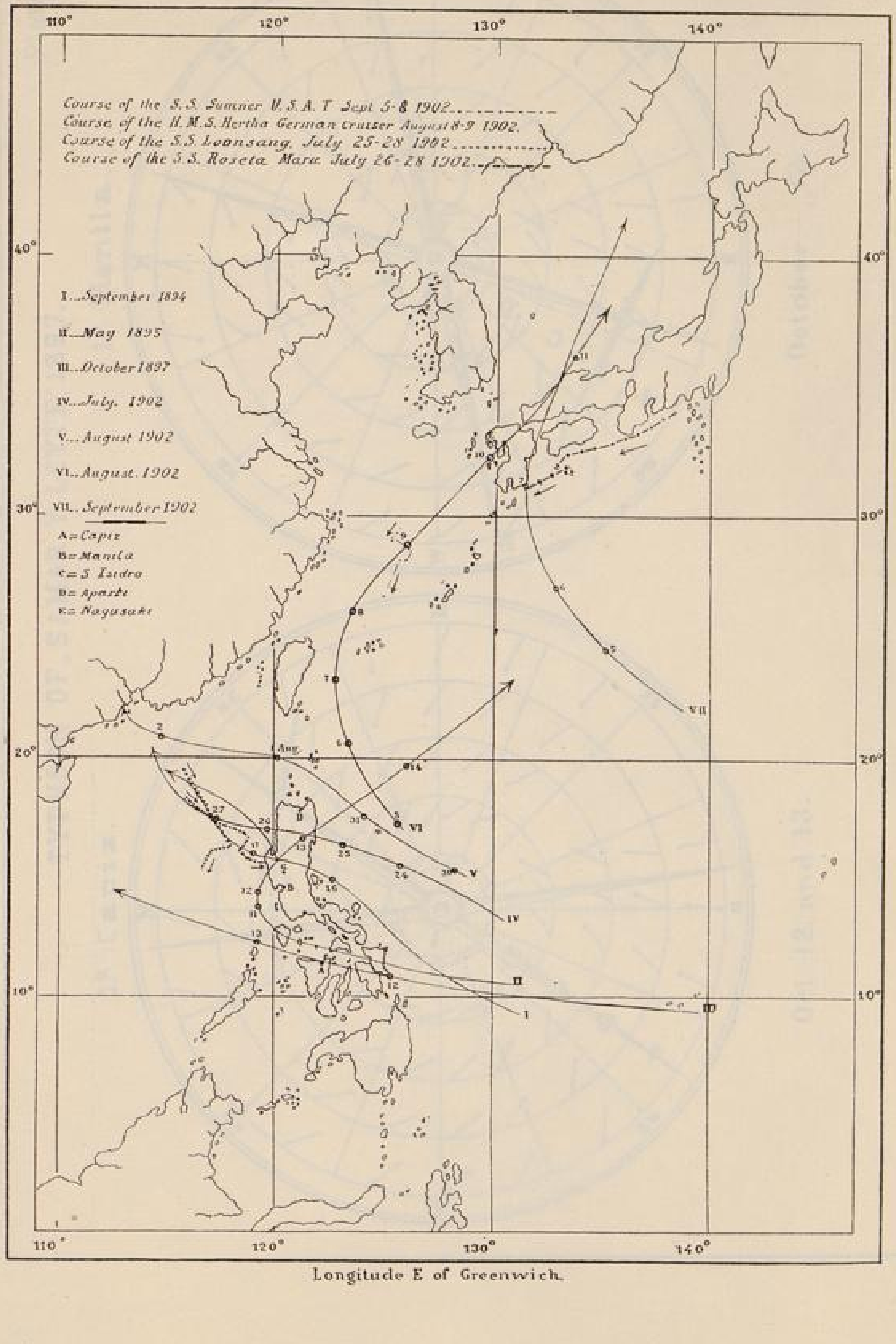
In the year 1890 Fr. Faura entrusted to a well-known firm at Paris the specifications of an aneroid which, besides the peculiar arrangement of the face characteristic of the popular Faura barometer, carried on the rim of the same 16 points of the compass, while to the knob at the center were attached three additional pointers forming fixed angles with each other. These were intended to automatically indicate the bearing of the vortex and the course which the ship should steer whenever—the barometer exhibiting readings found within the body of cyclonic storms—the wind index was set in the direction of the prevailing wind. Only six instruments were ordered for experimental purposes and it was understood that the barometer was not to be placed on the market until its reliability had been fully established by actual experience. The instrument did *not* prove satisfactory and, consequently, *has never been made public property.*

To our great astonishment several such barometers, bearing the name of Fr. Faura and constructed by the firm mentioned, have lately been brought to this Observatory for comparison. Our efforts to obtain satisfactory explanations have not been successful and hence we do not know on whom to lay the blame. But we caution those in possession of such instruments not to place any reliance upon the peculiar arrangement. Provided the aneroids are of good quality, they may be used as ordinary Faura barometers, but the best thing which their owners can do is to have two of the additional pointers removed, using the one remaining as the ordinary pointer for marking the reading.

○

TRACKS OF DIFFERENT TYPHOONS Plate. XL.

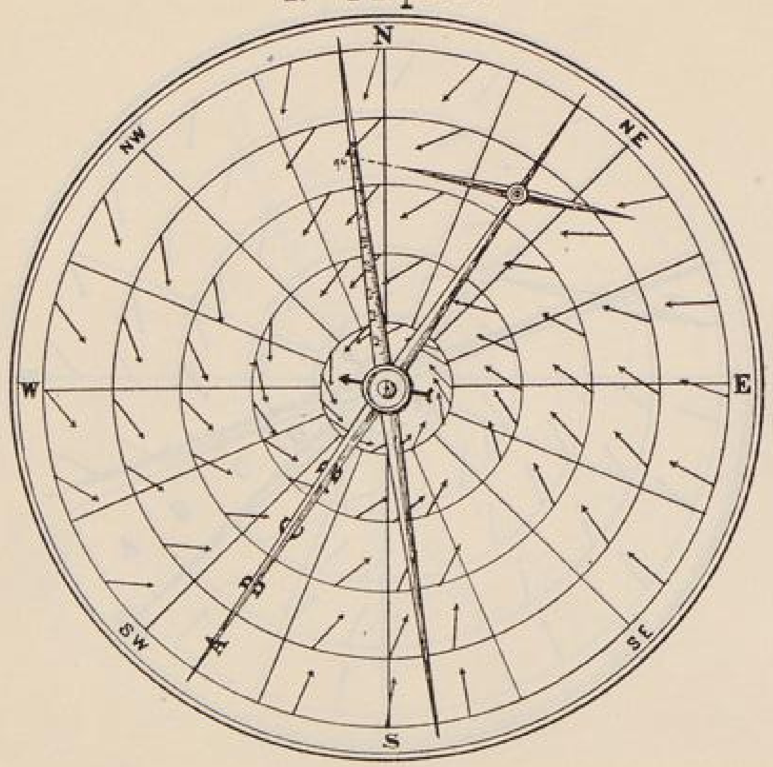
IN CONNECTION WITH THE USE OF THE BAROCYCLONOMETER



Longitude E of Greenwich.

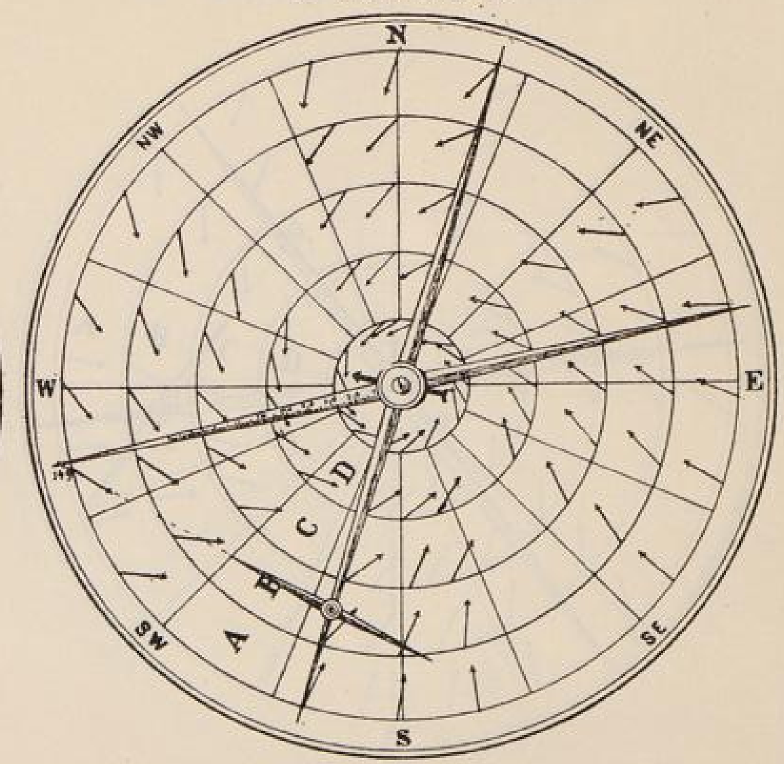
TYPHOON OF „SAMAR Y LEYTE" 1897.

1.ª Capiz.



Oct 12. and 13.

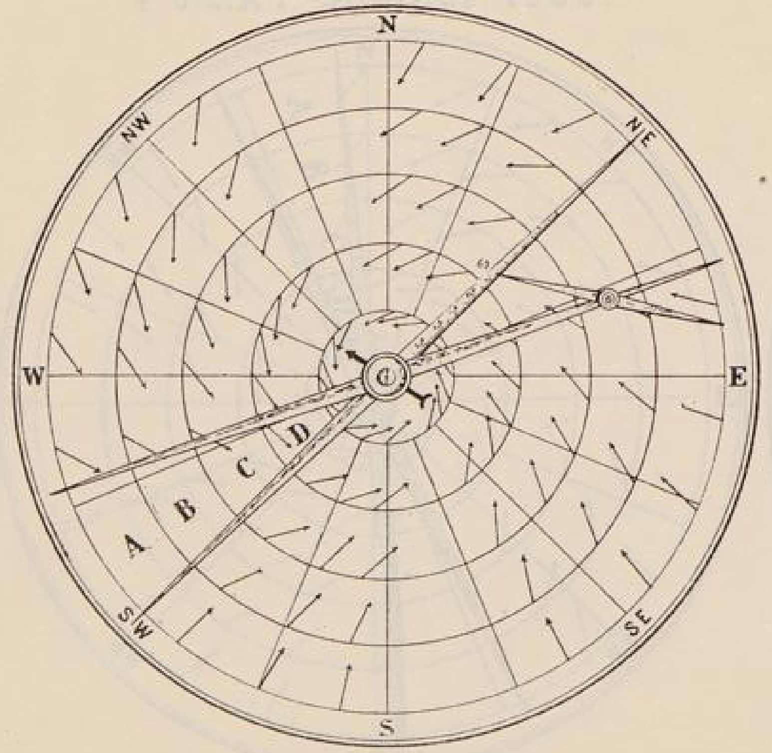
1.ᵇ Manila.



October 13.

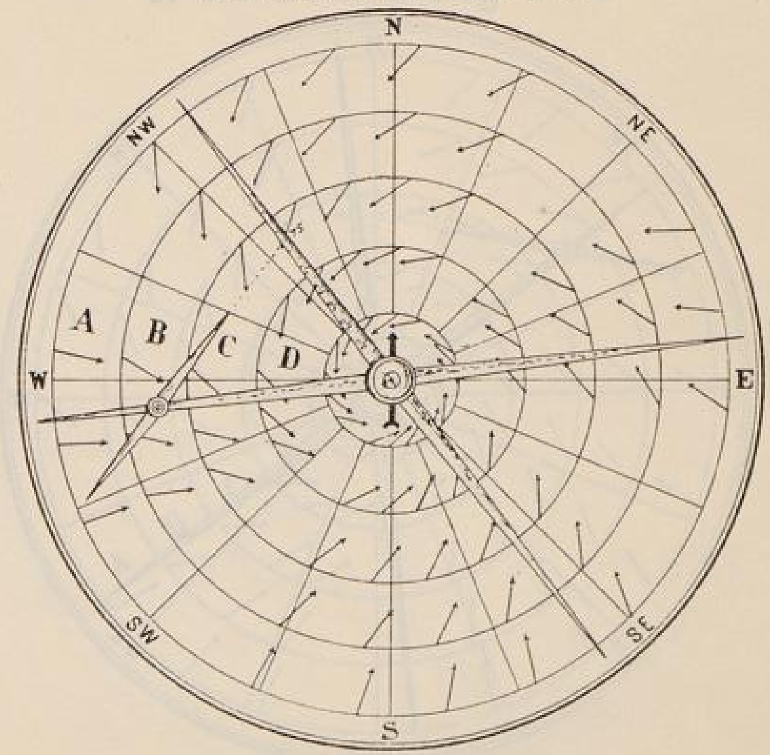
Plate XLII.

2. Manila 1896.



September 16.

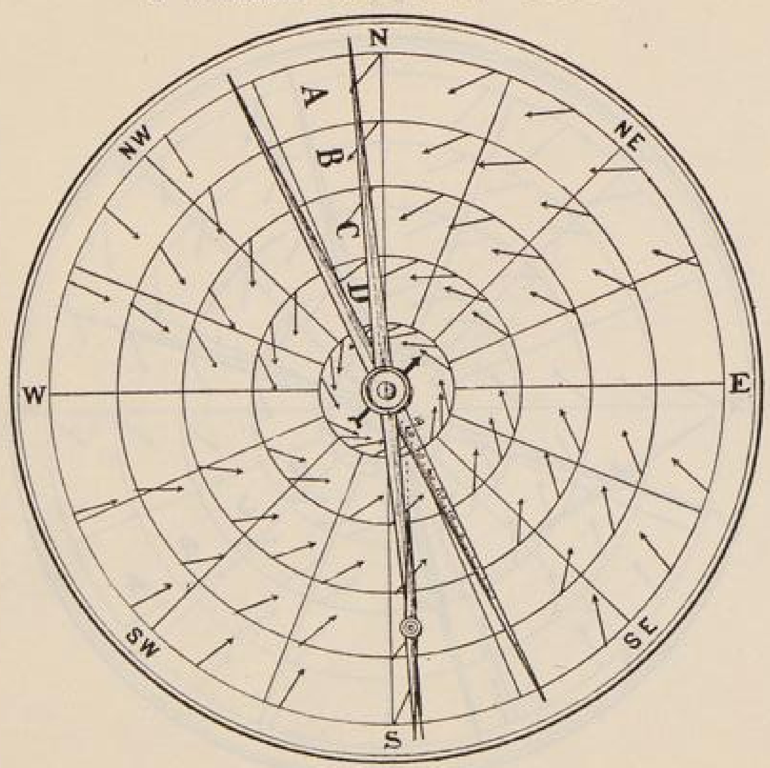
3. San Isidro 1895.



„Gravina" cyclone, May 13.

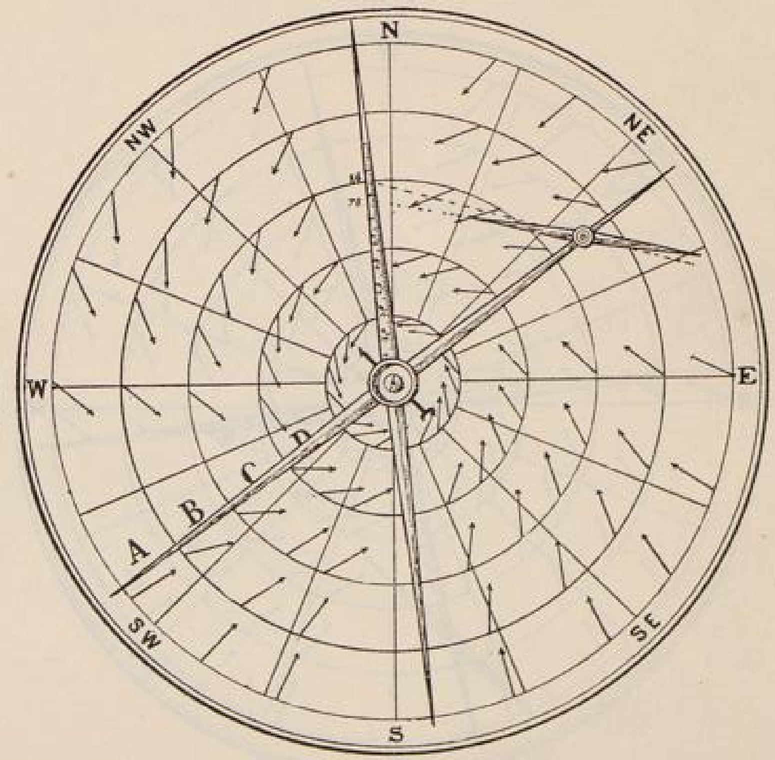
Plate XLIII.

4 U.S.A.T. Sumner 1902.*



September 6.– 7.

5a S.S. Loonsang 1902.

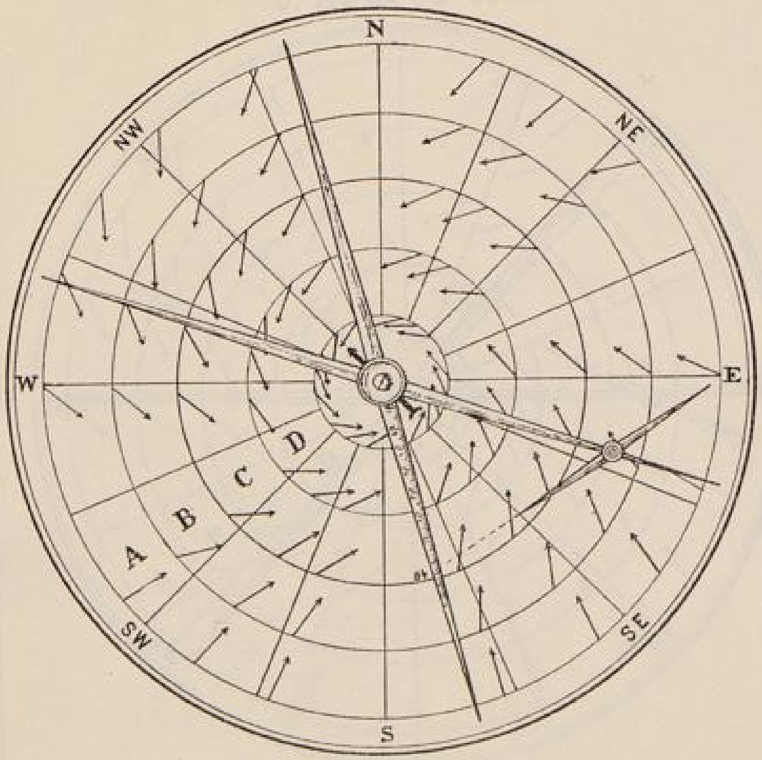


July 26.

Plate XLIV.

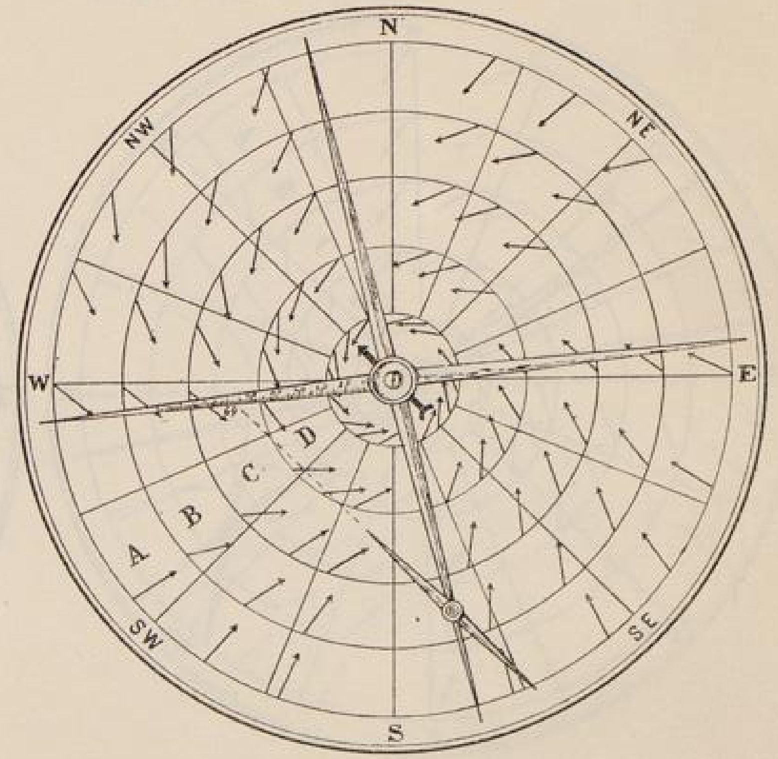
S.S. ROSETA MARU 1902.

5.b



July 26.

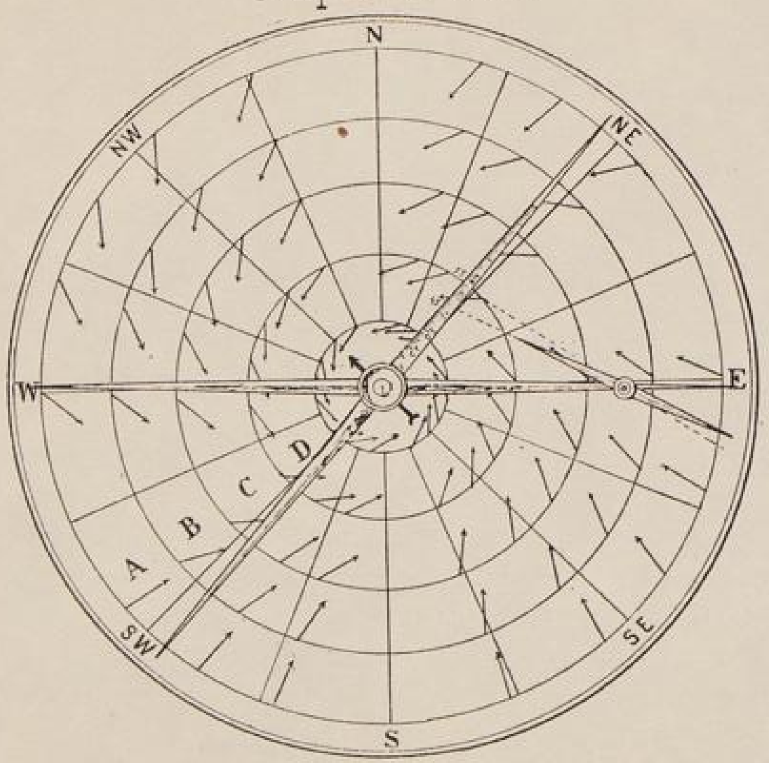
5.c



July 27.

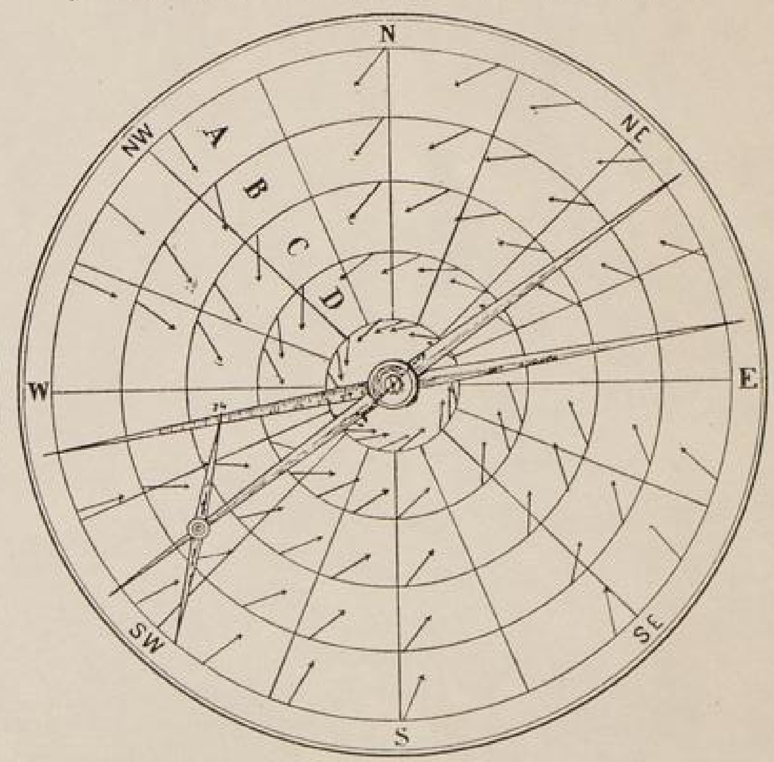
Plate XLV.

6. Aparri 1902.



July 31.–Aug 1.

7. German Cruiser Hertha 1902.



August 9.