THE BAROCYCLONOMETER.

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.

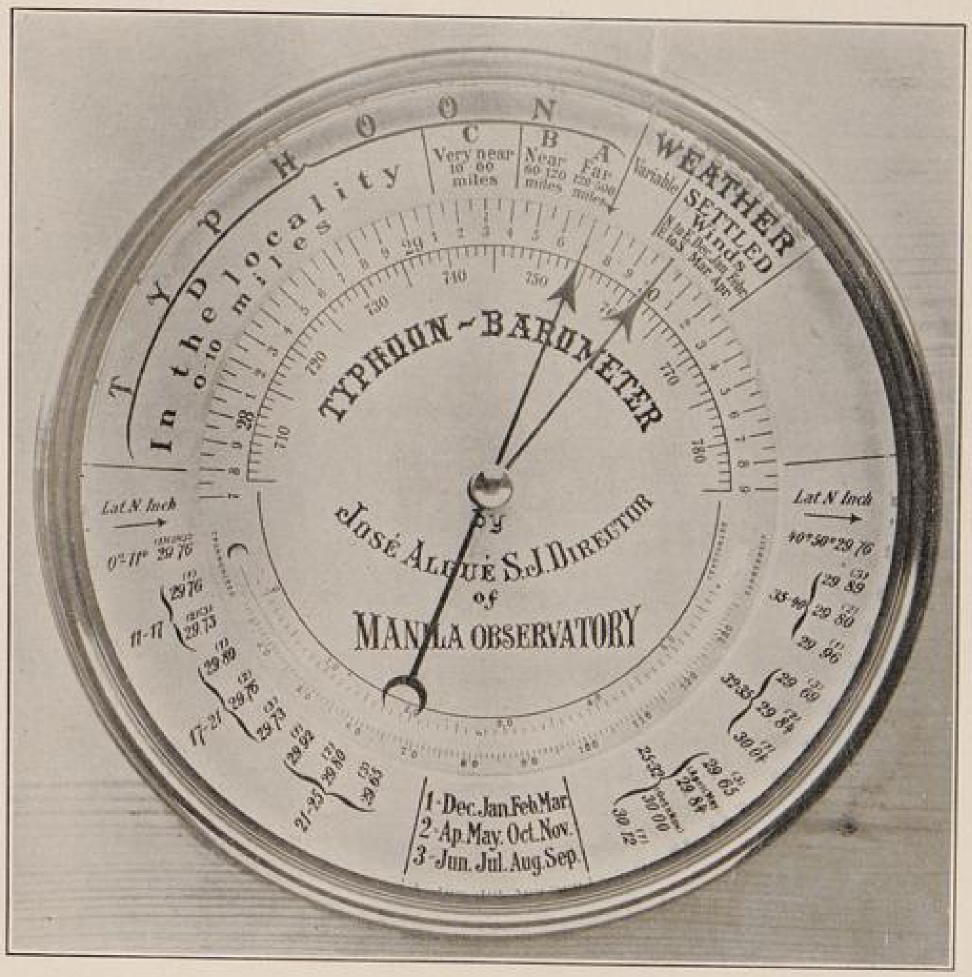
The barocyclonometer (Pl. XXXVII)[1].—As its name suggests, the barocyclonometer is a combination of a barometer and of a novel contrivance which we have named cyclonometer. As the instrument is actually constructed it also comprises a thermometer, showing the temperature in both Fahrenheit and Centigrade 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.

Plate XXXVIII.



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°, [1) 2) 3)] 29.76 (inches), [1) 2) 3)] 756 (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

[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.

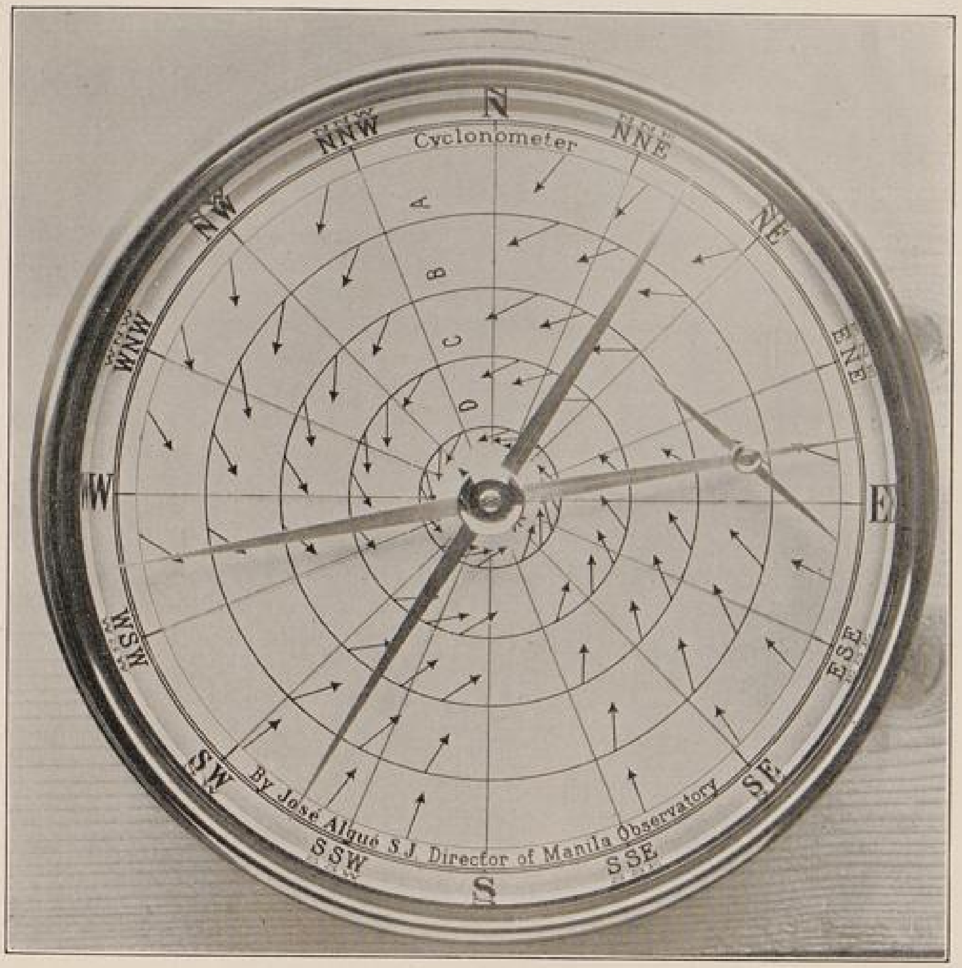
Outside of the cover glass will be seen two needles whose length equals the diameter of the face. These pivot at the center and can be moved directly by hand. One of them bears a graduation, the inner two-thirds of one of its halves being divided into 100 equal parts, with the zero point at the center. 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.

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