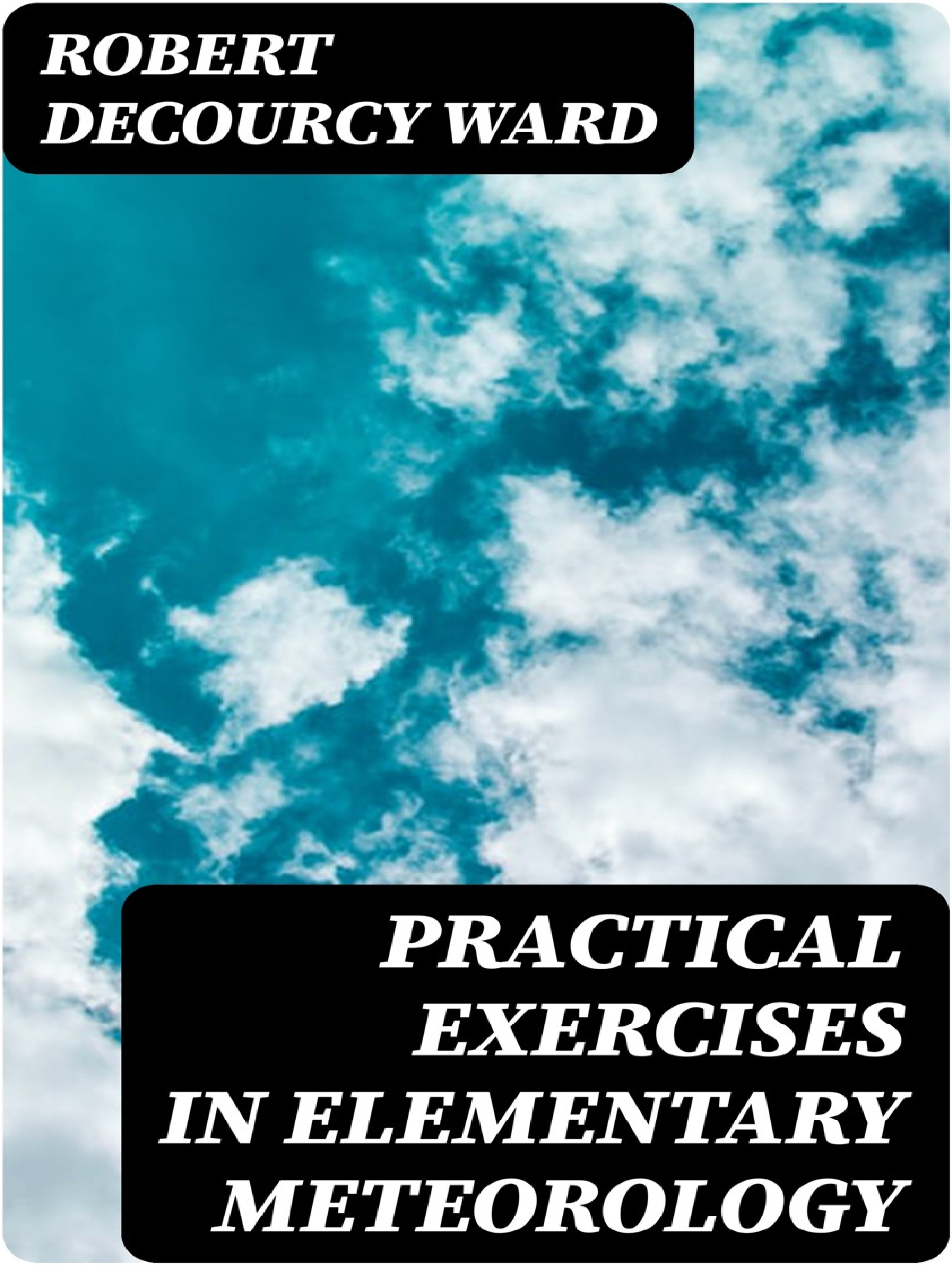
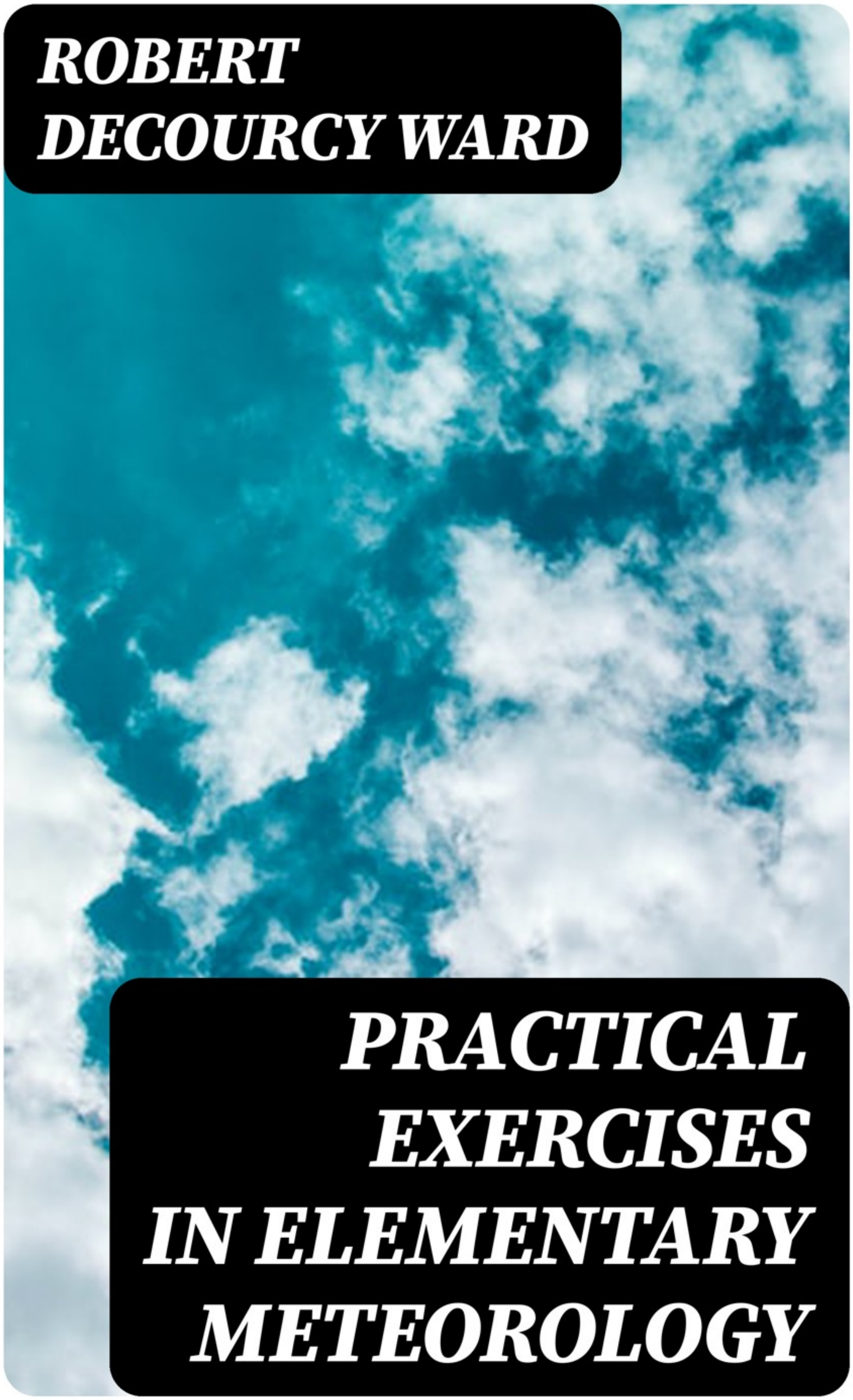


ROBERT DECOURCY WARD

PRACTICAL EXERCISES IN ELEMENTARY METEOROLOGY



ROBERT DECOURCY WARD

PRACTICAL EXERCISES IN ELEMENTARY METEOROLOGY

Robert DeCourcy Ward

Practical Exercises in Elementary Meteorology

EAN 8596547144267

DigiCat, 2022
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Table of Contents

PREFACE.

Table of Contents

The advance of meteorology as a school study has been much hampered by the lack of a published outline of work in this subject which may be undertaken during the school years. There are several excellent text-books for more advanced study, but there is no laboratory manual for use in the elementary portions of the science. In many secondary schools some instruction in meteorology is given, and the keeping of meteorological records by the scholars is every year becoming more general. There is yet, however, but little system in this work, and, in consequence, there is little definite result. The object of this book is to supply a guide in the elementary observational and inductive studies in meteorology. This Manual is not intended to replace the text-books, but is designed to prepare the way for their more intelligent use. Simple preliminary exercises in the taking of meteorological observations, and in the study of the daily weather maps, as herein suggested, will lay a good foundation on which later studies, in connection with the text-books, may be built up. Explanations of the various facts discovered through these exercises are not considered to lie within the scope of this book. They may be found in any of the newer text-books.

This Manual lays little claim to originality. Its essential features are based on the recommendations in the Report on Geography of the Committee of Ten. A scheme of laboratory exercises, substantially the same as that proposed in this Report, was, for some fifteen years, the basis of the work in elementary meteorology done in Harvard College under the direction of Professor William M. Davis. The plan proposed by the Committee of Ten has been thoroughly tested by the writer during the past five years, not only in college classes, but also in University Extension work among school teachers, and the present book embodies such modifications of that scheme and additions to it as have been suggested by experience. Emphasis is laid throughout this Manual on the larger lessons to be learned from the individual exercises, and on the relations of various atmospheric phenomena to human life and activities. No attempt is made to specify in exactly what school years this work should be undertaken. At present, and until meteorology attains a recognized position as a school study, teachers must obviously be left to decide this matter according to the opportunities offered in each school. The general outline of the work, however, as herein set forth, is intended to cover the grammar and the high school years, and may readily be adapted by the teacher to fit the circumstances of any particular case.

This book contains specific instructions to the student as to the use of the instruments; the carrying out of meteorological observations; the investigation of special simple problems by means of the instruments; and the practical use of the daily weather maps. The Notes for the Teacher, at the end of the book, are explanatory, and contain suggestions which may be useful in directing the laboratory work of the class.

It has been the privilege of the author during the past ten years to study the science of meteorology, and the methods of teaching that science, under the constant direction of Professor William Morris Davis, of Harvard University. To Professor Davis the author is further indebted for many valuable suggestions in connection with the arrangement and treatment of the subject-matter of this book. Thanks are due also to Mr. William H. Snyder,

of Worcester (Mass.) Academy, and to Mr. John W. Smith, Local Forecast Official of the United States Weather Bureau, Boston, Mass., for valued criticisms.

ROBERT DeC. WARD.

HARVARD UNIVERSITY, CAMBRIDGE, MASS.,
September, 1899.

ACKNOWLEDGMENT OF FIGURES.

Table of Contents

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INTRODUCTION.

Table of Contents

THE IMPORTANCE OF METEOROLOGY: ITS RELATIONS TO MAN.

We live in the laboratory of the earth’s atmosphere. The changes from hot to cold, wet to dry, clear to cloudy, or the reverse, profoundly affect us. We make and unmake our daily plans; we study or we enjoy vacations; we vary our amusements and our clothing according to these changes. The weather forecasts for the day in the newspaper are read even before the telegraphic despatches of important events. Sailors about to put to sea govern themselves according to the storm warnings of our Weather Bureau. Farmers and shippers of fruit, meat, and vegetables anxiously watch the bulletins of cold or warm waves, and guard against damage by frost or excessive heat. Steam and electric railways prepare their snow-plows when a severe snowstorm is predicted.

Meteorology, the science of the atmosphere, is thus of very great interest and importance. There is no subject a knowledge of which does more to make our daily life interesting. Since we live in the midst of the atmosphere and cannot escape from the changes that take place in it, we must, consciously or unconsciously, become observers of these changes. Examples of the varying processes at work in the atmosphere are always with us. There is no end to the number and the variety of our illustrations of these processes. Man is so profoundly affected by weather changes from day to day that all civilized countries have established weather services. Observers taking regular weather records are stationed at thousands of different places in all parts of the world, and the observations which they make are used by meteorologists in preparing daily weather maps and forecasts, and in studying the conditions of temperature, winds, and rainfall. In the United States alone there are about 3000 of these observers.

These observations are not made on land only. Hundreds of ship captains on all the oceans of the world are making their regular daily meteorological records, which at the end of the voyage are sent to some central office,[1] where they are studied and employed in the preparation of Pilot Charts for the use of mariners. By means of these ocean meteorological observations, which were first systematized and carried out on a large scale under the direction of Lieutenant Matthew Fontaine Maury (born, 1806; died, 1873), of the United States Navy, it has become possible to lay out the most favorable sailing routes for vessels engaged in commerce in all parts of the world.

[1] In the United States, marine meteorological observations are forwarded to the United States Hydrographic Office, Navy Department, Washington.

So important is a knowledge of the conditions of the winds and the weather, that scientific expeditions into unexplored or little-known regions give much of their time to meteorological observations. On the famous Lady Franklin Bay Expedition (1881-1884) of Lieutenant (now General) A. W. Greely, of the United States Army, meteorological observations were kept up by the few feeble survivors, after death by disease and starvation had almost wiped out the party altogether, and when those who were left had but a few hours to live unless rescue came at once. On Nansen's expedition to the "Farthest North," on Peary's trips to Greenland, and on every recent voyage to the Arctic or the Antarctic, meteorological instruments have formed an important part of the equipment.

Not content with obtaining records from the air near the earth's surface, meteorologists have sent up their instruments by means of small, un-manned balloons to heights of 10 miles; and the use of kites for carrying up such instruments has been so successful that, at Blue Hill Observatory, near Boston, Mass., records have been obtained from a height of over 2 miles. Observatories have also been established on mountain summits, where meteorological observations have been made with more or less regularity. Such observatories are those on Pike's Peak, Colorado (14,134 feet), Mont Blanc, Switzerland (15,780 feet), and on El Misti, in southern Peru. The latter, 19,200 feet above sea level, is the highest meteorological station in the world.

The study of the meteorological conditions prevailing over the earth has thus become of world-wide importance. In the following exercises we shall carry out, in a small way, investigations similar to those which have occupied and are now occupying the attention of meteorologists all over the world.

PRACTICAL EXERCISES IN ELEMENTARY METEOROLOGY.

Part I.—Non-Instrumental Observations.

CHAPTER I.

Table of Contents

OBSERVATIONS OF TEMPERATURE; WIND DIRECTION AND VELOCITY; STATE OF SKY, AND RAINFALL.

Before beginning observations with the ordinary instruments, accustom yourself to making and recording observations of a general character, such as may be carried out without the use of any instruments whatever. Such records include: *Temperature*; *Wind Direction and Velocity*; *State of the Sky*, *and Rainfall*.

Temperature.—In keeping a record[2] of temperature without the use of a thermometer, excellent practice is given in observations of the temperature actually felt by the human body. Our bodies are not thermometers. They do not indicate, by our sensations of heat or cold, just what is the temperature of the surrounding air, but they try to adjust themselves to the conditions in which they are. This adjustment depends on many things beside the temperature of the air; *e.g.*, the moisture or humidity of the air; the movement of the air; the temperature and the nearness of surrounding objects. In summer, a day on which the temperature reaches 80° or 85° often seems much hotter than another day on which the temperature rises to 95°. In winter, temperatures registered by the thermometer as 10° or 15° above zero often feel a great deal colder than temperatures of -5° or -10°. In recording your observations on temperature, the record book may be divided into columns as follows:—

[2] Each scholar will need a blank book in which to preserve the observations.

Sample Record of Temperature.

Date.	Hour.	Temperature.	Remarks.
Jan. 16	9 A.M.	Chilly	
“ “	12 M.	Warmer	
“ “	4 P.M.	“	Growing slowly warmer all day.
“ 17	8 A.M.	Warm	About the same as Jan. 16, 4 P.M.
“ “	11 A.M.	Cooler	Began to grow cooler about 10 A.M.
“ “	3 P.M.	Colder	Steadily becoming colder.

The following are some of the questions you should ask yourself in carrying out this work. It is not expected that you will be able to answer all these questions at once, but that you will keep them in mind during your studies, and try to discover the answers, as a result of your own observations.

How does it feel to you out of doors to-day? Is it hot, warm, cool, or cold? What is the difference between your feelings yesterday and to-day? Between day before yesterday and to-day? Have you noticed any *regular* change in your feelings as to warmth and cold during three or four successive days? During the past week or two? During the past month? Is there any difference between the temperature of morning, noon, afternoon, and evening? Is there any *regular* variation in temperature during the day? Have there been any *sudden* changes in temperature during the last few days? Have these sudden changes brought warmer or cooler weather? Has the warmer or cooler weather continued for a day or so, or has another change quickly followed the first? Have the sudden changes, if you have noted any, come at any regular times (as morning, afternoon, evening) or at irregular intervals? Does there seem to you to be any definite system, of any kind, in our changes of temperature? In what ways are people in general affected by hot weather? By cold weather? What difference does a very hot or a very cold day make in your own case?

Wind Direction and Velocity.—Wind is an important meteorological element because it has many close relations to human life. It affects very markedly our bodily sensations of heat or cold. A cold, calm day is pleasanter than a cold, windy day. On the other hand, a hot, calm day is usually much more uncomfortable than a hot, windy day. High winds cause wrecks along seacoasts and damage houses, crops, and fruit trees. Sea breezes bring in fresh, cool, pure air from the ocean on hot summer days. In the tropics the sea breeze is so important in preserving the health of Europeans in many places that it is known as "the doctor." The movement of wind through large cities carries off the foul air which has collected in the narrow streets and alleys, and is thus a great purifying agent.

Record the *direction of the wind* according to the four cardinal points of the compass (N., E., S., and W.) and the four intermediate points (NE., SE., SW., and NW.). The direction of the wind is the point *from* which the wind blows. You can determine the points of the compass roughly by noting where the sun rises and where it sets.

Note the *velocity of the wind* according to the following scale, proposed by Professor H. A. Hazen of the United States Weather Bureau.

0 Calm.

1 Light; just moving the leaves of trees.

2 Moderate; moving branches.

3 Brisk; swaying branches; blowing up dust.

4 High; blowing up twigs from the ground, swaying whole trees.

5 Gale; breaking small branches, loosening bricks on chimneys.

6 Hurricane or tornado; destroying everything in its path.

The record book will need two additional columns when wind observations are begun, as follows:—

Sample Record of Temperature and Wind.

Date.	Hour.	Temperature.	Wind Direction.	Wind Velocity.	Remarks.
Oct. 3	7.30 A.M.	Cool	NE.	Moderate	Temperature falling since last evening. Wind velocity increasing.
"	11	"	"	Brisk	Temperature the

	A.M.				same. Wind velocity still increasing.
“	3 P.M.	“	“	High	Wind velocity still increasing.

What is the direction of the wind to-day? What is its velocity? Has its direction or velocity changed since yesterday? If so, was the change sudden or gradual? Have you noticed any calms? What was the direction of the wind before the calm? What after the calm? Does there seem to be more wind from one compass point than from another? Is there any relation between the direction of the wind and its velocity? *i.e.*, is the NW. wind, for instance, usually a brisk or a high wind, or, is the SE. or S. wind usually moderate? Does the wind usually change its direction gradually, as from SE. to S., then to SW., then to W., etc., or does it jump all at once, as from SE. to W.? Is there any relation between the velocity of the wind and the hour of the day, *i.e.*, does the wind seem stronger or weaker at noon than in the morning or at night? Is it a common occurrence to have a wind from the same direction for several successive days, or are we apt to have different winds almost every day? Do you notice any *systematic* changes in wind direction which are often repeated? What are these changes? Can you make a simple rule for them? In what ways does the wind affect us?

State of the Sky.—By the *state of the sky* is meant the condition of the sky as to its cloudiness. Clouds add much to the beauty and variety of nature. They are often gorgeously colored at sunset. By their changes in form, color, and amount from day to day they relieve what might otherwise be a wearisome succession of the same weather types. Prevailingly overcast skies have a depressing effect. Prevailingly clear skies become monotonous. A proper amount of bright sunshine is essential for the ripening of crops, but too much sunshine may parch soil and vegetation, and become injurious. Clouds bring rain; hence a sufficient amount of cloudiness is just as necessary as a sufficient amount of sunshine. The drift of clouds shows us the direction of movement of the air above us, and is of considerable help in forecasting the weather. Fog, which is a very low cloud, is in some cases so common as to be a meteorological element of great importance. In the city of London, where fogs are very prevalent, especially in winter, the average number of hours of bright sunshine in December and January is only fifteen in each month. The London fogs are, in great part, due to the presence in the air of vast numbers of particles of soot and smoke from millions of fires. These particles increase the density of the fog and prolong its duration.

The amount of cloudiness is recorded on a scale of *tenths*. A *clear* sky is one that is less than $^3/_{10}$ cloudy; a *fair* sky is from $^3/_{10}$ to $^7/_{10}$ cloudy; and a *cloudy* sky is over $^7/_{10}$ cloudy. In observing the state of the sky, note such points as the times of clouding and of clearing; the arrangement of the clouds, *i.e.*, whether they are few and scattered, or cover the sky with a uniform layer; the common forms of clouds; the changes in the amounts of cloudiness, etc.

Another new column must be added in the record book for the cloudiness. The table will now appear thus:—

Sample Record of Temperature, Wind, and State of the Sky.

Date.	Hour.	Temperature.	Wind	Wind	State	Remarks.

			Direction.	Velocity.	of sky.	
Dec. 18	9 A.M.	Very cold	NW.	Brisk	Clear	Very cold all night. Everything frozen up.
“ “	5 P.M.	“ “	“	“	“	Same conditions.
“ 19	8.30 A.M.	A little warmer	“	Moderate	Fair	Wind less violent. Small clouds scattered over the sky.

Is the sky *clear*, *fair*, or *cloudy* to-day? Is there more or less cloud than there was yesterday? Than the day before yesterday? Is to-day a day of increasing or of decreasing cloudiness? Is the sky usually perfectly clear, or is it oftenest somewhat clouded over? How long does it take for the sky to become completely covered with clouds from the time when it first begins to become cloudy? When there are a few clouds in the sky, are these usually scattered all over the sky, or are they in groups? Have you noticed any particular form of clouds which seemed familiar to you? Do clouds seem to have certain definite shapes and appearances which are to be seen often? Do you discover any variation of cloudiness during the day, *i.e.*, is it apt to be more cloudy in the afternoon than in the morning or at night? Can you make a list describing some of the clouds that you see most often? Can you give these common kinds of clouds some names of your own that shall describe them briefly? In what ways does a clear sky, with bright sunshine, affect us?

Rainfall.—Under the general term *rainfall*, meteorologists include, besides *rain* itself, *snow*, *hail*, *sleet*, etc. The term *precipitation* is also often used. Rainfall stands in close relation to human life and occupations. It feeds lakes and rivers, thus furnishing means of transportation, power for running mills and factories, and water supplies for cities. Regions of abundant rainfall are usually heavily forested, like the Amazon valley in South America, and parts of Equatorial Africa. In civilized countries lumbering is apt to be an important occupation in districts of heavy rainfall, as in Oregon and Washington in our own country, and in Southern Chile in South America. Where there is a moderate rainfall, and other conditions are favorable, there agriculture is possible, and farming becomes one of the chief occupations, as in the Mississippi and Missouri valleys in the United States, and in Western Canada. Districts which have a rainfall too small for successful agriculture, but are not by any means deserts, are often excellent grazing lands, as in the case of parts of Texas, Nebraska, and Kansas in the United States, and the Argentine Republic in South America. Where there is very little rainfall deserts are found. Cities are not built in deserts, because there are no occupations to attract large numbers of men. The inhabitants of the desert are wandering tribes, which move from place to place in search of water and food for themselves and their animals. Rain and snow cleanse the air, washing out impurities such as dust and smoke. Hence they are important agents in preserving health.

Note the *kind* of precipitation (rain, snow, hail, sleet); the *amount* (heavy, moderate, light, trace); and the *time of the beginning and ending* of the storm or shower.

The record book must now be further subdivided into columns, to make room for the rainfall observations, in this manner:—

SAMPLE RECORD OF TEMPERATURE, WIND, STATE OF SKY, AND PRECIPITATION.

DATE.	HOUR.	TEMPERATURE.	WIND.		STATE OF SKY.	PRECIPITATION.		
			DIRECTION.	VELOCITY.		TIME OF BEGINN.	KIND.	AM'T.
Mar. 21	8.30 A.M.	Mild	S.	Light	Overcast	8 A.M.	Rain	Light
" "	12 M.	"	"	"	Overcast		"	"
" "	4 P.M.	"	"	Moderate	Overcast			
" 22	8 A.M.	Cool	NW.	Brisk	Clear			

Does most of our rain come in brief showers, or in storms lasting a day or two? Do we have about the same amount of rain or snow every week and every month, or does the amount vary a good deal from week to week and from month to month? Do you notice much difference in the characteristics of successive storms, or do they all seem pretty much alike? Are thunderstorms limited to any particular season of the year? If so, to what season? Have you discovered any rule as to the time of day when rainstorms or snowstorms begin? When thunderstorms begin and end? Is it common or uncommon for us to have a storm lasting three or four days? How long does a thunderstorm usually last? Do we have most hail in winter or in summer? In what ways does a rainy day affect people? How are you yourself affected? How does a heavy snowstorm affect travel and transportation? In what ways does a snowstorm differ from a rainstorm as to the character of the precipitation and its effects?

After studying the *temperature*, *wind*, *state of sky*, and *rainfall* separately, take two elements together and see what relation one has to the other. Try to answer such questions as these:—

Temperature and Wind.—What relations can you discover between the direction of the wind and the temperature? Which winds are the coolest? Which the warmest? Does a hot, calm day seem warmer or cooler than a hot, windy day? Does a cold, calm day seem colder or warmer than a cold, windy day? Does the *velocity* of the wind have any effect on your feeling of cold or of warmth? If so, what effect?

Wind and State of Sky.—Has the direction of the wind anything to do with the cloudiness? Is there more apt to be considerable cloudiness with wind from one direction than from another? What winds are usually accompanied by the largest amount of cloud? What winds usually blow when the sky is clear? Is the relation of cloudiness to certain wind directions so close that, if you know the wind direction, you can make a prediction as to the probable cloudiness? Are the winds with clouds more common in one month than another? In one season than another? If so, which month? which season?

Temperature and State of Sky.—Do you notice any relation between the temperature and the state of the sky? In winter are our coldest days usually cloudy or clear? In summer are our hottest days cloudy or clear? Are the winds that give us the most cloudiness warm or cold winds in winter and in summer? Is a cloudy night colder or warmer than a clear night? Is a cloudy day colder or warmer than a clear day?

State of Sky and Precipitation.—How is rainfall or snowfall related to the cloudiness? Do we ever have rain or snow when the sky is not completely covered with clouds? Does the sky usually become quickly covered with clouds before a rain? Does a sky wholly covered with clouds always give us rain or snow? Does the sky clear rapidly or slowly after a rain? Are any particular kinds of clouds associated with rain or with snowstorms? With brief showers? With thunderstorms?

Wind and Precipitation.—Are any particular wind directions more likely than others to give us rain or snow? Are these the same winds as those which give us the most cloudiness? What winds are they? Has the velocity of the wind any relation to the rain or snowstorm? Does the wind blow harder before, during, or after the rain or snow? What changes of wind direction have you noted before, during, and after any storm? Have you noticed these same changes in other storms? Are they so common in our storms that you can make a rule as to these changes?

Temperature and Precipitation.—Does a shower or a rainstorm in the hotter months affect the temperature of the air in any way? How? In the winter does the temperature show any changes before a snowstorm? Is it usually warmer or colder then than a day or two before the storm and the day after? Is it usually uncomfortably cold during a snowstorm? Are rainy spells in the spring and the autumn months cooler or warmer than clear dry weather?

Part II.—Instrumental Observations.

CHAPTER II.

Table of Contents

ELEMENTARY INSTRUMENTAL OBSERVATIONS.

The non-instrumental observations, suggested in the preceding chapter, prepare the way for the more exact records of the weather elements which are obtainable only by the use of instruments. The non-instrumental records are not to be entirely given up, even after the instrumental work and the weather-map exercises have begun, but should be continued throughout the course. Notes on the forms and changes of clouds, on the times of beginning and ending, and on the character of the precipitation, as outlined in the last chapter, and other observations made without the use of instruments, are an essential part of even the most advanced meteorological records.

The simpler instruments are the *ordinary thermometer*, the *wind vane*, the *rain gauge*, and the *mercurial barometer* (in a modified form). Observations with these instruments, although of a simple character, can be made very useful. The advance over the non-instrumental observations, which latter may be termed observations of *sensation*, is a decided one. In place of the vague and untrustworthy statements concerning hot and cold, warm and cool days, we now have actual degrees of temperature to serve as a basis for comparison of day with day or month with month. The measurements of rain and snowfall enable us to study the amounts brought in different storms, the average precipitation of the various months, etc. The important facts of change of pressure now become known, and also the relation of these changes to the weather. Just as we have, in the earlier work, become familiar with our typical weather changes and types, so we shall now have our eyes opened to the actual values of the temperatures and precipitation connected with these changes.

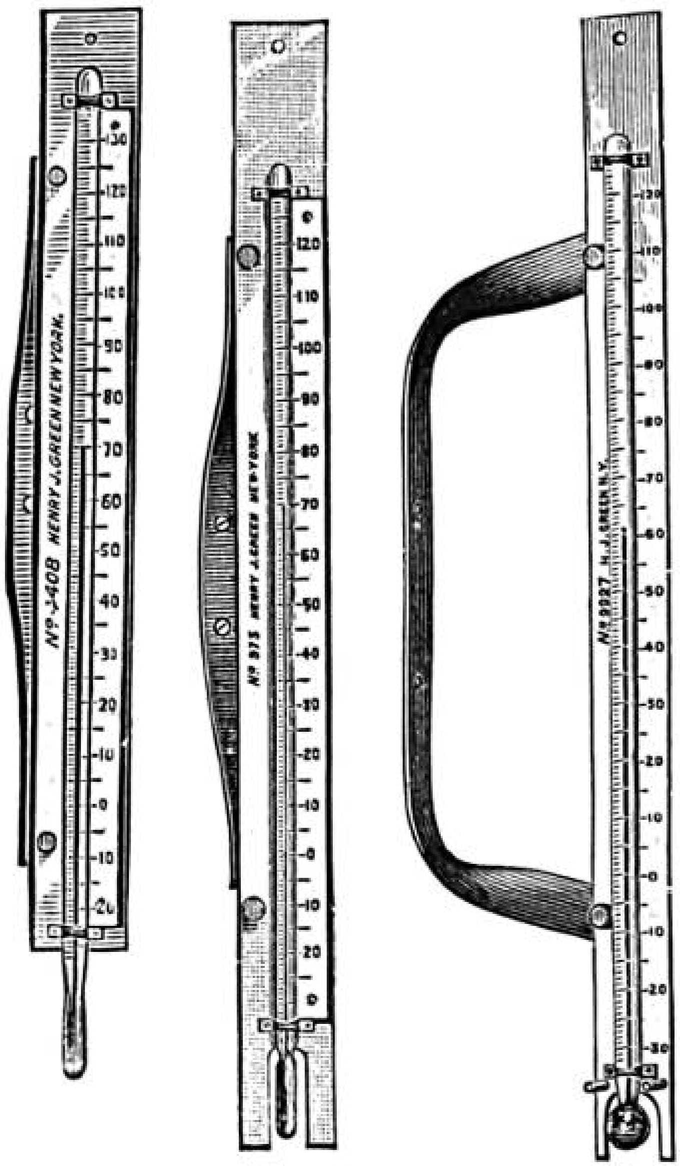

Fig. 1.

The **ordinary thermometer** (Greek: *heat measure*), the most commonly used and most widely known of all meteorological instruments, was in an elementary form known to Galileo, and was used by him in his lectures at the

University of Padua during the years 1592 to 1609. Thermometers enable us to measure the temperatures of different bodies by comparison with certain universally accepted standards of temperature. These standards are the freezing and boiling points of distilled water. In its common form the thermometer consists of a glass tube, closed at the top, and expanding at its lower end into a hollow spherical or cylindrical glass bulb. This bulb and part of the tube are filled with mercury or alcohol. As the temperature rises, the liquid expands, flows out of the bulb, and rises in the tube. As the temperature falls, the mercury or alcohol contracts, and therefore stands at a lower level in the tube. In order that the amount of this rise or fall may be accurately known, some definite scale for measurement must be adopted. The scale commonly used in this country owes its name to Fahrenheit (born in Danzig in 1686; died in 1736), who was the first to settle upon the use of mercury as the liquid in thermometers, and also the first definitely to adopt two fixed points in graduating the scale. The division of this scale into 180° between the freezing point (32°) and the boiling point (212°) seems to have been taken from the graduation of a semicircle. Fahrenheit was a manufacturer of all sorts of physical apparatus, and it has been thought probable that he had some special facilities for dividing his thermometer tubes into 180 parts. Mercury is most commonly used as the liquid in thermometers, because it readily indicates changes of temperature, and because over most of the world the winter cold is not sufficient to freeze it. The freezing point of mercury is about 40° below zero (-40° F.). Alcohol, which has a much lower freezing point, is therefore used in thermometers which are to be employed in very cold regions. Alcohol thermometers must, for instance, be used in Northern Siberia, where the mean January temperature is 60° below zero.

The temperature which meteorologists desire to obtain by the ordinary thermometer is the *temperature of the free air in the shade*. In order that thermometers may indicate this temperature, they must, if possible, be placed in an open space where there is an unobstructed circulation of the air, and they must be protected from the direct rays of the sun. They are, therefore, usually *exposed* inside of a cubical enclosure of wooden lattice work, in an open space away from buildings, and at a height of 4 to 10 feet above the ground, preferably a grass-covered surface. This enclosure is called the *shelter*, and its object is to screen the instrument from the direct and reflected sunshine, to allow free circulation of air around the bulb, and to keep the thermometer dry. Sometimes the shelter, instead of being in an open space on the ground, is built on the roof or against the north wall of a building, or outside of one of the windows. Fig. 2 shows an ordinary shelter.

A still simpler method of exposure is described in the "Instructions for Voluntary Observers" (United States Weather Bureau, 1892) as follows: "Select a north window, preferably of an unoccupied room, especially in winter. Fasten the blinds open at right angles to the wall of the house. Fasten a narrow strip 3 inches wide across the window outside, and from 8 to 12 inches from the window-pane. To this fasten the thermometers." If none of these methods of sheltering the instrument is feasible, the thermometer may be fastened to the window frame, about a foot from the window, and so arranged that it can be read from the inside of the room without opening the window.

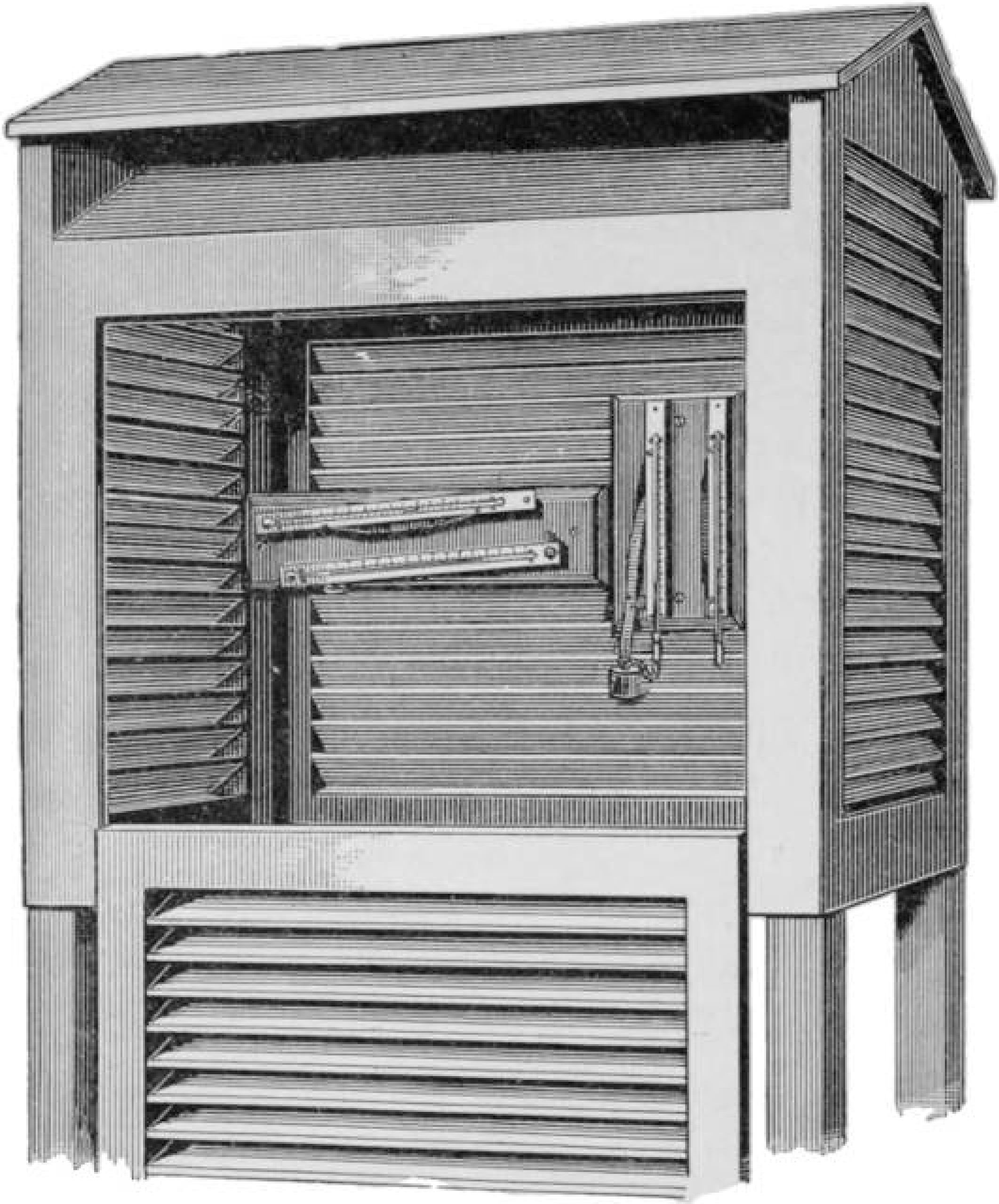

FIG. 2.

Readings of the thermometer, to the nearest degree of temperature indicated on the scale by the top of the mercury column, are to be made at the regular observation hours, and are to be entered in your record book. Temperatures below zero are preceded by a minus sign (-). A table similar to that suggested towards the close of the last chapter (p. 8) may be used in keeping these instrumental records, except that actual thermometer readings can now be entered in the column headed “Temperature,” instead of using only the general terms *warm*, *cold*, *chilly*, etc. This is a great gain. You will now be able to give fairly definite answers to many of the questions asked in Chapter I. Answer these questions with the help of your thermometer readings, as fully as you can.

The greater part of the Temperate Zone, in which we live, is peculiar in having frequent and rapid changes of temperature, not only from season to season, but from day to day, and during a single day. In winter, we are apt to have a warm wind immediately after a spell of crisp cold weather. In summer, cloudy, cool days come as a sudden relief when we have been suffering from intense heat, with brilliant sunshine.

These changes give a variety to our climate which is, on the whole, very beneficial to man. The North Temperate Zone, with strong seasonal changes in temperature and weather, is the zone of the highest civilization and of the greatest energy of man. In the Torrid Zone the changes of temperature are, as a whole, small. There is no harsh winter. The climate is monotonous and deadening, rather than enlivening. Man finds it easy to live without much work, and the inhabitants of the Torrid Zone have not, as a rule, advanced far in the scale of civilization.

The **wind vane** used by the Weather Bureau is about 6 feet long, and has a divided tail made of pine boards, the two pieces making an angle of 22½°. The purpose of this divided tail is to steady the vane and to make it more sensitive to light currents.

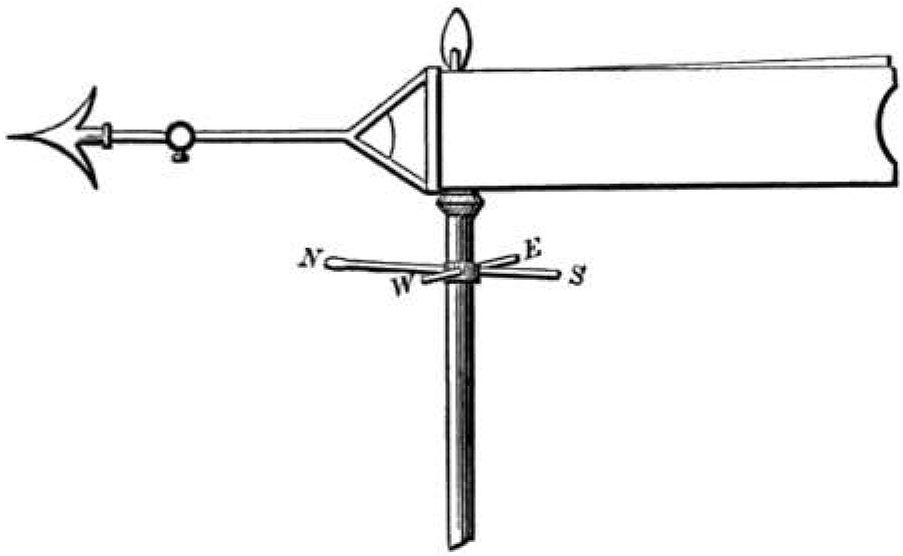

FIG. 3.

A common wind vane on a neighboring church steeple or flagstaff will usually serve sufficiently well for ordinary use. Observations of wind direction (to eight compass points) are to be made as a part of the ordinary weather record, and to be entered in the proper column of the record book.

The **rain gauge** consists of three separate parts, the receiver *A*, the overflow attachment *B*, and the measuring tube *C*.

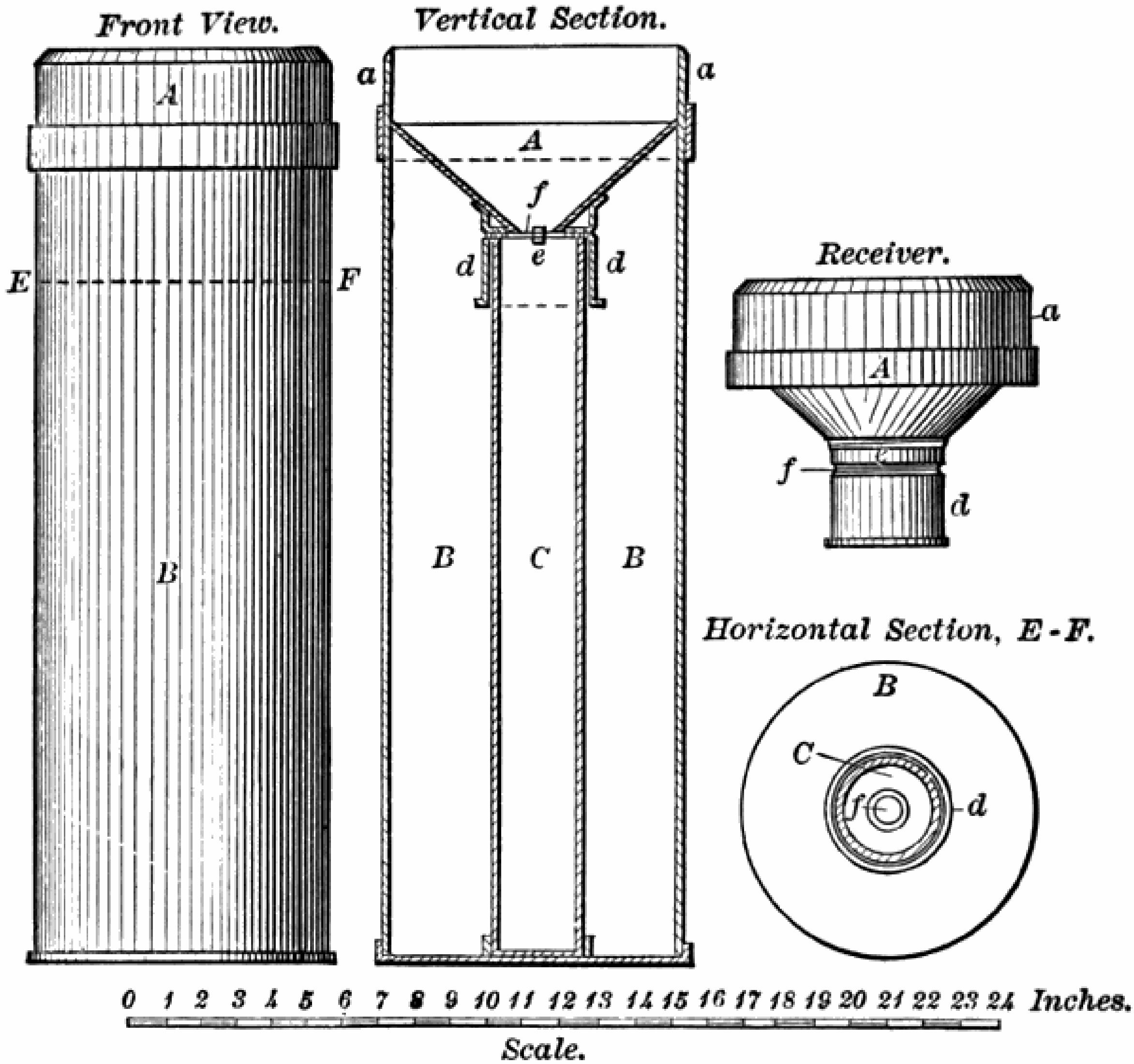

FIG. 4.

The inside diameter of the top of the receiver in the standard Weather Bureau gauge is 8 inches (at *a* in Fig. 4). This receiver has a funnel-shaped bottom, so that all the precipitation which falls into it is carried at once into the measuring tube *C*, whose inside height is 20 inches. The diameter of the measuring tube is 2.53 inches. The rain falling into the receiver *A* fills this tube *C* to a depth greater than the actual rainfall, in proportion as the area of the receiver is greater than the area of the measuring tube. In the standard Weather Bureau gauges the ratio of the area of the receiver to the area of the measuring tube is such that the depth of rainfall is magnified exactly ten times. The object of magnifying the amount in this way is to measure a very small quantity more easily. The narrow portion of the receiver [*d*] fits over the top of the measuring tube, holding the latter firmly in place and preventing any loss of rainfall. An opening, *e*, in the lower portion of the receiver [*d*], just on a level with the top of the measuring tube, serves as an escape for the water into the overflow attachment *B*, in case the rainfall is so heavy as to more than fill the tube. The inside diameter of the overflow attachment is the same as that of the receiver (8 inches), as will be seen from the figure.

The rain gauge should be firmly set in a wooden frame, so arranged that the overflow attachment can readily be removed from the frame. The box in which the gauge is sent out by the manufacturer is usually designed to serve as a permanent support when the gauge is set up. The best exposure for the gauge is an open space unobstructed by large trees, buildings, or fences. Fences, walls, or trees should be at a distance from the gauge not less than their own height. If an exposure upon the ground is out of the question, the gauge may be placed upon a roof, in which case the middle of a flat unobstructed roof is the best position.

Records of Rainfall.—Every rain gauge is provided with a measuring stick, which is graduated into inches and hundredths. It must be remembered that the amount of rain in the measuring tube is, by the construction of the ordinary gauge, ten times greater than the actual rainfall. This fact need not, however, be taken into account by the observer, for the numbers used in graduating the measuring sticks have all been divided by 10, and therefore they represent the actual rainfall. The graduations on the stick indicate hundredths of an inch, and should appear in the record as decimals (.10, .20, etc.). Ten inches of water in the measuring tube will reach the mark 1.00 on the stick; thus 1.00 denotes 1 inch and zero hundredths of rain. One inch of water in the tube will reach the .10 mark, indicating $^{10}/_{100}$ of an inch. The shortest lines on the measuring stick denote successive hundredths of an inch. Thus, if water collected comes to a point halfway between the .10 and .20 lines, the amount is .15 inch, and so on. In measuring rainfall, the stick is lowered through the bottom of the receiver into the measuring tube, and on being withdrawn the wet portion of the stick at once shows the depth of water in the tube. Care must be exercised to put the end of the stick where the numbering begins first into the gauge, and to pass the stick through the middle of the tube. After each observation the gauge should be emptied and drained, and immediately put back into place. When the total rainfall more than fills the measuring tube, *i.e.*, exceeds 2 inches, the receiver should first be lifted off and the tube removed with great care so as not to spill any water. After emptying the tube, the surplus water in the overflow attachment must be poured into the measuring tube and measured. The amount of rainfall thus found is to be added to the 2 inches contained in the measuring tube in order to give the total rainfall. If any water happens to be spilled during its removal from the overflow attachment, then the amount in the tube will be less than 2 inches, and it must be carefully measured before the latter is emptied.

During the winter season, in all regions where snow forms the chief part of the precipitation, the only portion of the rain gauge that need be exposed is the overflow attachment. The snow which falls into the gauge may be measured by first melting the snow and then measuring the water as rainfall. About 10 inches of snow give, on the average, 1 inch of water, but the ratio varies very greatly according to the density of the snow. Besides the measurement of the melted snow collected in the gauge, it is customary to keep a record of the depth of snowfall in inches, as measured by means of an ordinary foot rule or a yardstick, on some level place where there has been little or no drifting.

Measurements of rain and snowfall are usually made once a day, at 8 P.M., and also at the end of every storm. Enter the amounts of precipitation in the column of the table headed “Amount” and state always whether it is *rain* or *melted snow* that you have measured. When there has been no precipitation since the last observation, an entry of 0.00 should be made in the column of the record book devoted to “Amount of Precipitation.” When the amount is too small to measure, the entry T (for *Trace*) should be made.

Continue your non-instrumental record of the time of beginning and ending of the precipitation as before. Whenever it is possible, keep a record of the total amount of precipitation in each storm, noting this under “Remarks.” Try to answer such questions as are asked in Chapter I with the