SNOW AND ITS RELATIONSHIP TO EXPERIMENTAL METEOROLOGY

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Snow in its many forms has been the subject of observation, conjecture, and scientific discussion for many centuries. It has long been recognized that a better understanding of the formation of snow in the atmosphere would eventually explain some of the little-known but important meteorological processes related to the development of precipitation.

The occurrence of supercooled clouds in the free atmosphere is one of the most common of meteorological phenomena, even in many parts of the tropics. The importance of such clouds as the source of much heavy precipitation has been pointed out by Bergeron [2]. The differential in vapor pressure between water and ice at all temperatures below 0C permits the rapid growth of snow particles at the expense of the liquid cloud droplets. This process is of basic importance in the formation of snow and is a primary mechanism in the science of experimental meteorology.

Types of Solid Precipitation

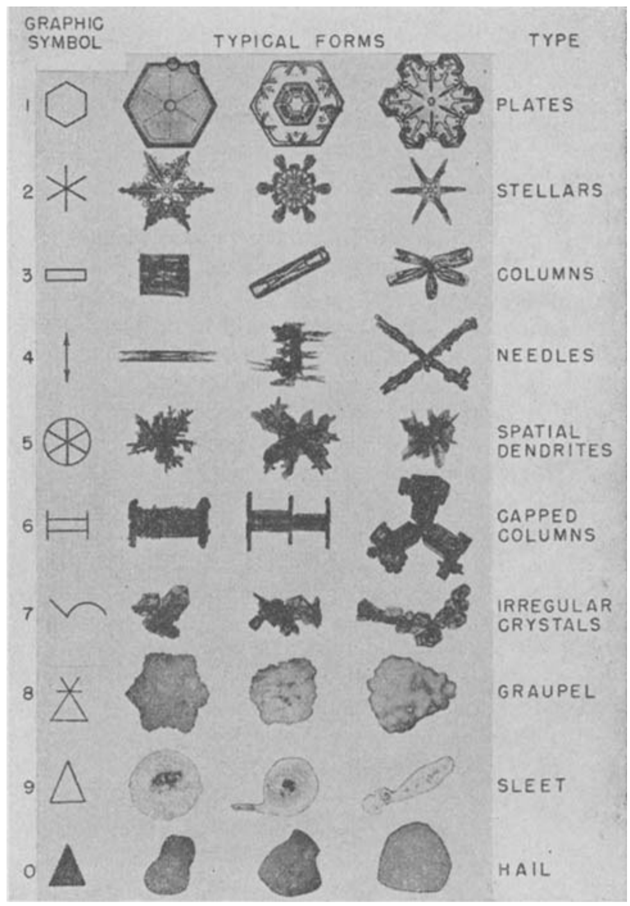
Over the years, many attempts [25] have been made to devise a classification system for describing the observed forms of solid precipitation. Most of these have been either too elaborate for easy use or have failed to include important forms.

During the course of snowstorm studies in 1944, an effort was made to devise a simple system which might be used in the field under adverse weather conditions. Revisions of this system were made as extensive field experience demonstrated the need. In the fall of 1949, an effort was made to pool the experience of workers concerned with this problem in Switzerland, Japan, Canada, and the United States. The chart shown in Fig. 1 illustrates the classification decided upon and the code and types proposed for international use. Although subject to further revision, it is believed that the types shown on this chart include most of the basic forms which occur in the atmosphere throughout the world.

As may be expected, there is an almost infinite variation in the forms of the basic types of this solid precipitation. These differences may be so minor as to be visible only under high-power magnification or great enough to be easily seen by the unaided eye. Typical variations in structure and relative size of the plate-type crystal are illustrated in Fig. 2.

Nakaya [16], in his ice-crystal experiments, showed that the crystal habit of snow may be due entirely to the temperature of the environment and the moisture supply available. It is quite likely that most crystals in the free atmosphere grow as they do because of these environmental conditions.

It should be pointed out, however, that the habit of crystals may also be modified by an entirely different mechanism—the blocking of the growth on certain crystal faces by the adsorption of surface-active chemicals [27]. Figure 3 illustrates the effects which may be induced by traces of an impurity in the air where crystals grow. Further research to understand these effects better is under way in the General Electric Research Laboratory.



The Use of Replica Techniques for Studying Snow. In 1941 a method was devised by the writer [18, 19] for making permanent replicas of snow crystals. The technique encases a snow or frost crystal within a thin plastic film which, as it forms, makes an exact three-dimensional impression of the surface features of the crystal. The replica solution, consisting of one to three parts of the synthetic plastic polyvinyl formal dissolved in 100 parts of ethylene dichloride, readily wets an ice surface. By capillarity and surface activity it rapidly covers any ice crystal which comes in contact with it.

H. R. Byers et al., *Compendium of Meteorology*

The solvent evaporates in five to ten minutes, after which the slide (glass, cardboard, etc.) bearing the samples may be warmed above freezing. Upon melting, the water molecules evaporate through the thin film, leaving a hollow shell which refracts and scatters light in a manner quite similar to the optical properties of the original crystals. Figure 4 shows a typical replica of a stellar crystal.

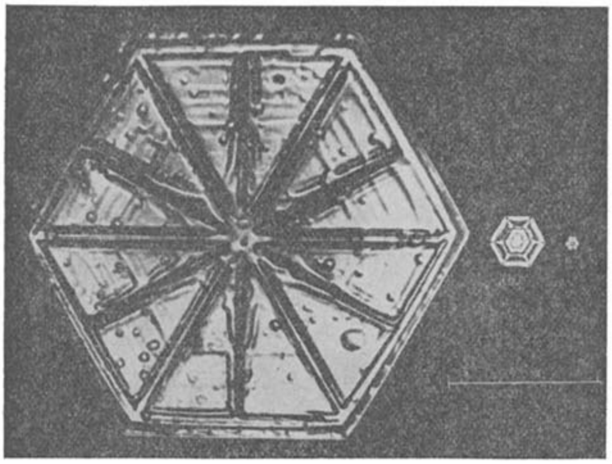


FIG. 2.—Variation in size and structure of hexagonal plates (*a*) from low and middle type clouds, (*b*) from high cirrus type clouds, and (*c*) from very low altitudes, forming in clear air.

This technique is also very useful in making surveys of snowstorms since it permits the accumulation during the course of a storm of many samples of crystals for subsequent study. Samples have now been obtained by this method in most parts of the world as well as at high altitudes in the atmosphere during flight studies with Project Cirrus airplanes. Figure 5 shows some of these replicas.

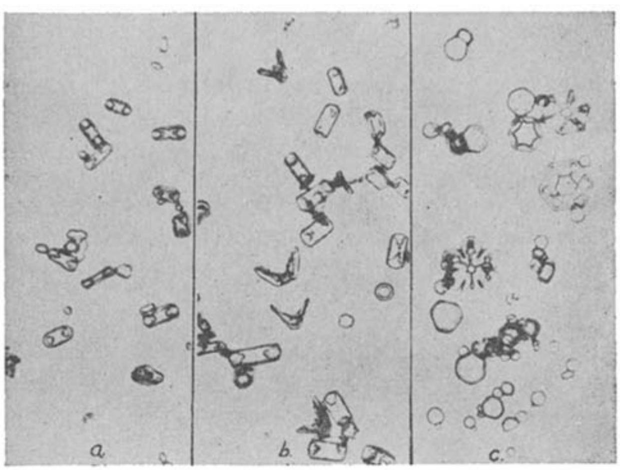


FIG. 3.—The effect of acetone vapor on the crystal habit of snow. (*a*) Effect of 1 molecule of acetone to 10 molecules of water. (*b*) Effect of 1 molecule of acetone to 100 molecules of water. (*c*) Effect of 1 molecule of acetone to 1000 molecules of water.

A more recent technique for making replicas utilizes a plastic spray.[1] Although the solvent used in this spray would not work under normal conditions, since it would tend to dissolve the ice structure, its evaporation is so rapid that satisfactory replicas are obtainable if brief applications are made. This technique works best if the spray container is cooled below 0C. However, if the spraying is carried out in air at temperatures below freezing, enough entrainment of cold air takes place so that good replicas have been made at −10C with the dispenser temperature at 25C.

1. Such as Krylon, made by Foster & Kester, Philadelphia, or Plastic Spray, made by the Bridgeport Brass Co., Bridgeport, Conn.

Solid Precipitation in the Free Atmosphere

Precipitation in the form of snow crystals, graupel, sleet, or hail forms under varied conditions of temperature, humidity, and turbulence, and in the presence of a variety of suitable nuclei to be described later. The moisture content of the air in which such precipitation may form at temperatures below 0C range from more than 3 g m^{-3} in supercooled water-droplet clouds to such small amounts that the air contains no visible cloud, although it is supersaturated with respect to ice.

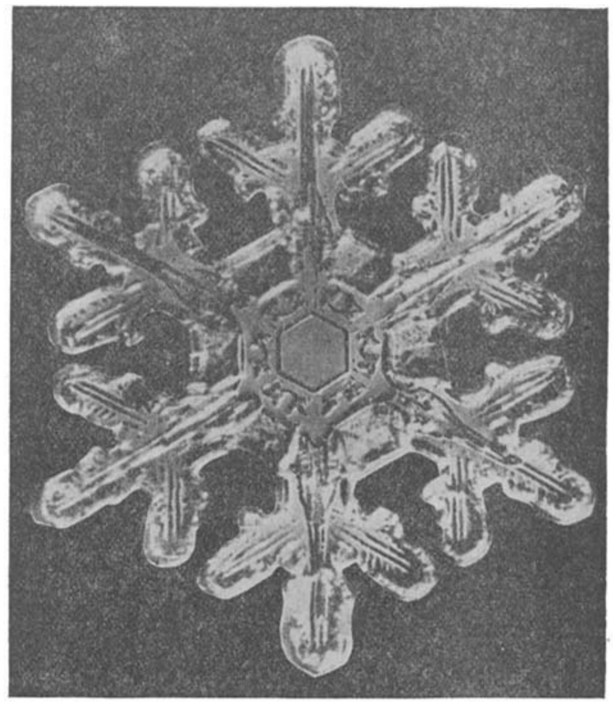


FIG. 4.—Typical replica of a stellar snow crystal.

Ice Crystals in Cirrus Clouds. The highest clouds commonly found throughout the world are the cirrus types. Evidence is accumulating suggesting that most clouds of this type form at temperatures below −39C. At this temperature, spontaneous nucleation occurs, that is, foreign particles are not required to initiate the formation of ice crystals.

The simple 22° halo and the more complex optical phenomena of cirrus clouds are generally produced by snow crystals of special form floating with a particular orientation in the air. Since the initial formation of such crystals may take place in clear air having a very low total water content, it is obvious that they must be very small and their growth quite slow. The crystal types common to these high-level clouds are the hex-