TYPES AND CHARACTERISTICS OF PRECIPITATION

I.I. Borzenkova
Department of Climatology, State Hydrological Institute, Russia

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Contents

Summary

Precipitation can be liquid, solid and mixed. Liquid precipitation includes rain and drizzle. Solid precipitation can be of more diverse forms. This article presents the peculiarities of liquid and solid forms of precipitation.

It describes the main types and classification of precipitation according annual and daily variations. Annual precipitation variations depend both on the general atmospheric circulation and local (topographic) conditions. We consider the main features of equatorial, tropical, Mediterranean, monsoonal and mid-latitudinal types of annual precipitation. As regards causes, precipitation is subdivided into cyclones (frontal), convective, orographic, and monsoon.

1. Introduction

Moisture entering the atmosphere as a result of evaporation from water and land surfaces is transported with air fluxes; it condenses and again falls as precipitation on the surface of the Earth. Total atmospheric moisture is estimated at 12 to 14 km^3, a volume that would form a water layer 25 mm thick on the Earth's surface.

Up to 90% of water vapor is concentrated in the layer up to 5 km. It rapidly decreases with altitude. Atmospheric moisture turnover is 9 to 10 days, so this relatively insignificant amount of water plays an important role in processes occurring on the Earth's surface. During a year, about 580 000 km^3 of water fall from the atmosphere in different forms of precipitation.

Precipitation is the water in a liquid or solid state falling from clouds or formed on the earth's surface and ground objects due to condensation of airborne water vapor. Depending on the mechanism of cloud development and structure, precipitation may be *continuous* (temperate-intense) and produced predominantly from stratocumulus clouds, *heavy*, from cumulonimbus, or *drizzle*, often from stratus clouds.

Precipitation formed on the earth's surface is called ground hydrometeors and includes dew, different type of rime, hoarfrost, black and hard frost and glaze. At meteorological stations, precipitation is measured with rain gauges of different types, recording rain gauges (pluviographs) or by radar, which allows estimation of both precipitation fall area and its intensity.

2. Precipitation Forms

Precipitation is liquid or solid water falling from clouds to the Earth's surface or formed on different bodies as a result of atmospheric water vapor condensation. Precipitation can be liquid, solid, or mixed. Liquid precipitation includes rain and drizzle. On the Earth's surface or on different objects, liquid precipitation can be formed as dew or liquid film. Figure 1 shows the main types of precipitation.

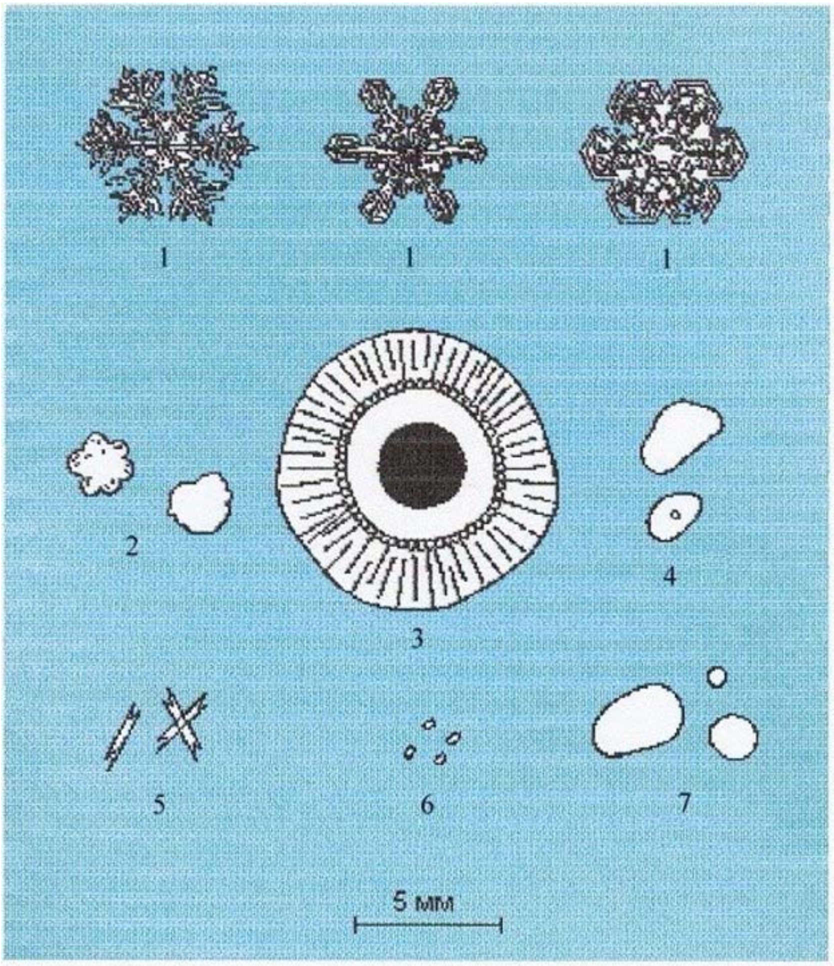

Figure 1. The main types of the precipitation. 1 - snow; 2 - small hail; 3 - large hail; 4 - ice pellets (graupel); 5 - snow pellets (ice needles, ice crystals); 6 - droplets of drizzle; 7 - rain drops.

Solid precipitation can be of forms that are more diverse. It falls as snow, hail, snow and ice pellets, ice needles, and ice crystals. At lower surface temperatures ice forming on solid objects are solid surface hydrometeors—frost, solid film, and ice. In free atmosphere, an analogue of such phenomena is airplane icing, when super-cooled cloud drops or precipitation freeze on the surface of an airplane.

2.1. Liquid Precipitation

2.1.1 Rain, Drizzle and Freezing rain

The differentiation between rain and drizzle is to a certain extent arbitrary. These two forms of liquid precipitation differ from each other only in the size of drops. The diameter of raindrops is usually 5 to 6 mm, whereas drizzle drops are smaller (between 0.2 and 0.5 mm) and their terminal velocities are between 70 and 200 cm per second. Drizzle falls mostly from low stratus clouds and is frequently accompanied with fog and poor visibility.

The diameter of raindrops is usually larger than 0.5 mm, but they only rarely reach 6 mm or more because larger raindrops are destroyed during falling. Small raindrops are of almost spherical shape, but bigger ones are flattened when falling, especially in the lower part of the cloud. The terminal velocities of rain drops range from two meters per second for the smallest to about 10 meters per second for the largest.

During heavy rains, raindrops are considerably bigger than in light rain. The largest drops of more than six millimeters in diameter appear only in heavy rains, especially at the start of a rain storm.

When raindrops pass through cold air layers (below 0 °C), they become super-cooled, and freezing rain or super-cooled drizzle occur. Freezing rain falls in liquid form but freezes upon impact to form a coating of glaze on the ground and exposed objects. Often these frozen raindrops form a very slippery and almost transparent “glazed” film which is dangerous for both pedestrians and transport.

2.1.2 Ground Liquid Precipitation (Dew and Liquid Deposit)

Dew is the smallest water drop formed during condensation on the Earth’s surface, most frequently on grass during the warm period of a year. Dew arises mostly with clear and calm weather in the evening hours and at night when there is no fog. Dew develops when soil and vegetation (grass and leaves) cool to the temperature typical of the dew point.

Dew can produce a large amount of precipitation. For example, in England on flat ground, dew produces 10 to 30 millimeter of precipitation a year. In the mid-latitudes of Europe this amount is about 10 millimeter a year, and in southern Africa 40 millimeter a year. In warm, humid tropical regions, dew is so abundant that it can drip from roofs of buildings and tree leaves.

In Northern Europe (Finland), abundant dew can produce a water layer of 0.1 to 0.2 mm each night. From the data measured by Divdevany’s dew meter at a number of Finnish stations during May to October in 1967 and 1968, the dew amount is about 10 mm, or 3% of precipitation for the warm period of the year. In Northern Finland, the dew in warm periods is as much as 1.5% of total precipitation for the same period.

There is a relationship between the dates of dew appearance, cloudiness, and air humidity. Dew mainly arises with a low cloudiness of 30 to 50% and relative humidity of 60 to 80%. In northern and north-western Russia, dew falls with air temperature above 7 to 8 °C. In southern regions of Russia, dew develops at temperatures above 5-6 °C. In some regions, where the temperature is above 0 °C throughout the year, dew develops continuously.

The liquid film is a water layer arising on cold, mostly vertical, surfaces in gloomy and windy weather. Liquid film arises from a cause different from dew. It is formed from warmer and humid air advection after prolonged cold weather. It occurs where water vapor condenses on cooled surfaces (e.g. buildings, walls, trees, and fences). The process is most apparent on the windward sides of objects: as if they are misted when covered with tiny drops. A liquid film also forms under artificial conditions, such as when warm and humid interior air condenses on the inside of cold windowpanes in a warm house.

2.2. Solid Precipitation

Solid precipitation is of more diverse forms than liquid ones. There include snow, snow and ice pellets, hail, etc. In addition, as stated above, there is a great variety of surface solid precipitation (surface hydrometeors).

2.2.1 Snow

Snow is solid atmospheric precipitation of different forms of ice crystals. Groups of ice crystals form snowflakes in the shape of six-cone stars, needles or multiple combinations. The size of snowflakes varies from one millimeter to a few centimeters depending on air temperature: the higher the temperature and weaker the wind, the larger the flakes. The largest flakes fall with heavy precipitation.

The diversity of snowflakes is endless. Mostly they are stars, columns, or their combinations. The velocity of snowflake fall is a function of their shape and air temperature, being in the range of 0.1 to 2 meter per second in motionless air. Figure 2 shows the shapes of snowflakes according to the international classification.

Japanese researchers have shown a particular interest in snowflake shape. As long ago as the second half of the nineteenth century, Dai-Toshizura made a large number of delicate drawings of snowflakes of different shapes using a microscope. The artist reached a high level of accuracy with the original. His outstanding work remains unsurpassed.

Wilson Bentley (1865-1931), in the US State of Vermont, took pictures of snowflakes for many years and developed a big collection of different shapes. His album containing 300 photos of snowflakes was published in 1931, the year of his death.

The Japanese researcher U. Nakaya (Hokkaido University) discovered when studying the process of developing snow crystals under man-made conditions (in a chamber) that ice crystals in the shape of stars develop only in the narrow temperature range of -14 to -17 °C. At temperature above -7 °C (from –3 °C to –5 °C) only ice needles are formed. Plates and columns are formed at temperatures form –10 °C to –22 °C.

Snow falls from clouds of different shapes, mostly strato-cumulus, high-stratus and cumulo-nimbus, during the cold period of the year. By their size snowflakes are classified as tiny (particles < 5 millimeter), small flakes (5 to 15 mm), or large flakes (> 15 mm). Snowflake fall velocity ranges from < 0.1 meter per second (slow flying) to > 0.8 meter per second. Plates and stars fall with velocity of 0.5 to 1 meter per second, needles and columns – a few decimeters per second, and snow and ice pellets at 1 to 2.7 meters per second.

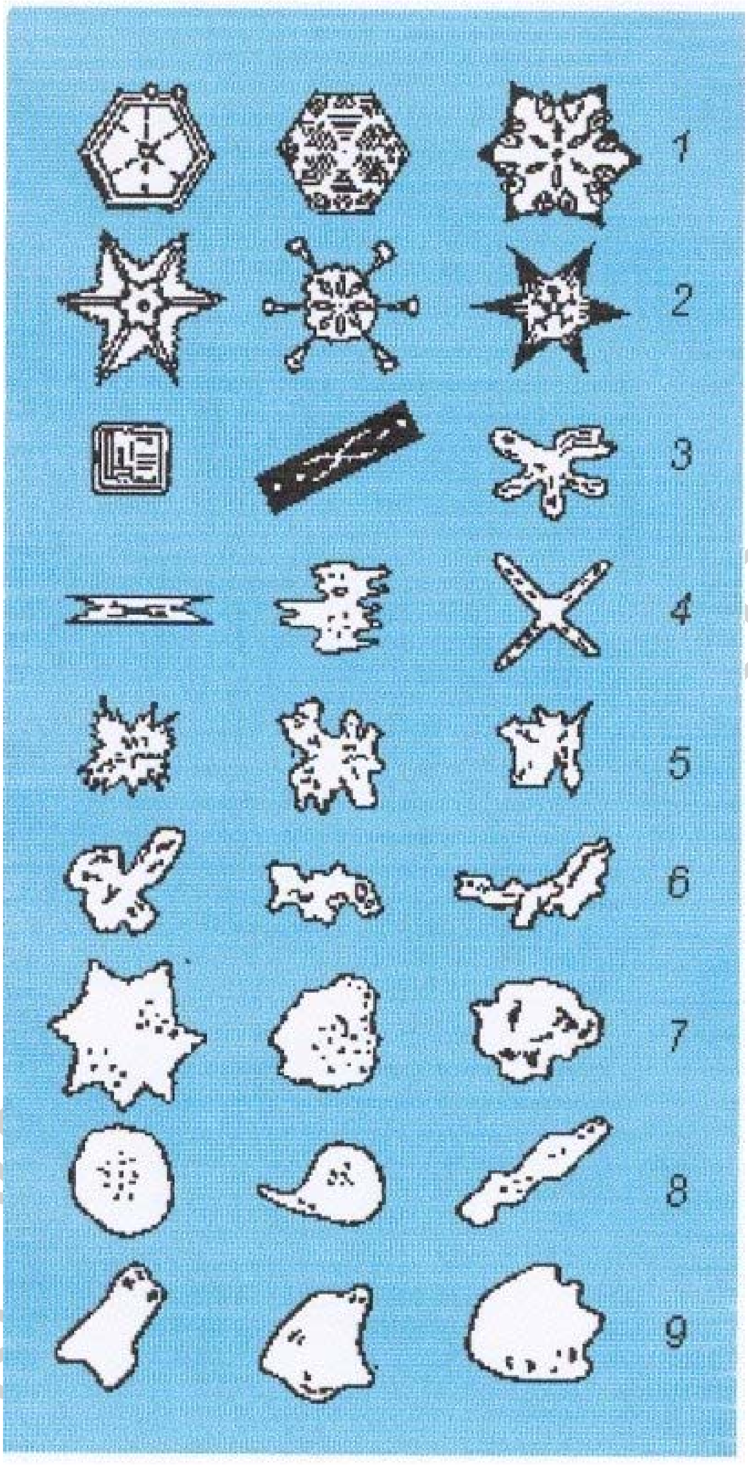

Figure 2: International classification of frozen precipitation. 1-Thin hexagonal plates; 2 -Dendritic crystals, 3-columns; 4-needles; 5-dendritic forms; 6-incorrect crystals; 7-snow pellets (graupel); 8-freezing rain; 9-hail.

The rate of snowfall is measured by precipitation amount in 1 mm water layers per unit of time, mostly per hour or 24 hours. Weak snow has a rate of less than 0.1 mm/hour, average snow – from 0.1 to 1 mm per hour, and heavy snow – more than 1mm per hour. Vision in dense snow can be reduced to 1 km or less. The length of snowfall period is usually inversely proportional to the rate of its fall. Dense snowfall rarely lasts more than 1 to 2 hours, and weak snow can last 24 hours or even longer.

At meteorological stations several types of snow are distinguished: snow with rain, rain with snow, drizzle, and heavy snow. The later is sometimes called a snow shower. There is also such an event as a snow storm (or snow charge), as well as snow under clear sky.

Rain with snow usually falls at positive surface temperature and represents rain with a small amount of separate snowflakes. Snow with rain is a mixture of snowflakes and raindrops occurring at the temperatures close to 0 °C.

Overcasting snow falls mostly from stratocumulus or from high stratus clouds and can last for several hours continuously.

Pouring snow falls usually from cumulus-nimbus clouds at a temperatures close to 0 °C. This kind of snow falls due to a cold front and unstable air mass. A snow storm is formed in an unstable stratified cold air mass passing over relatively warm underlying surface.

Sometimes colored snow occurs. The color is derived from mineral or organic admixtures. Colored snow is mostly of a brown or red shades due to dust settling on snow, or algae or bacteria reproducing on snow. Color snow mostly occurs in the high latitudes in spring when soil is partly bared and partly covered with snow.

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Bibliography

Kotlyakov B.M. (1994). *World of snow and ice*. 285 pp. "Nauka", Moscow. [This book presents data about snow and ice distribution]. (In Russian).

Glaciologial Dictionary. (1984). V.M. Kotlyakov (Ed.). 527 pp. Hydrometeoizdat, Leningrad. (In Russian). [This dictionary contains much information about snow and ice]. (In Russian).

Geneve R. (1961). *La grele*. Paris. [This presents data about the origin of hail and its distribution]. (In French).

Karpenko V.N. (1974). *The Dew*. Hydrometeoizdat, Leningrad, 102 pp. [This book presents data about the origin of dew and its distribution on the USSR territory]. (In Russian).

Lamb H.H. (1972). *Climate: Present, Past and Future*. Vol.2, 613 pp. Methuen and Co. Ltd. London etc. [This book presents information about past and present climate changes and climatic variability].

Khromov S.P., Petros'yants M.A. (1994). *Meteorology and Climatology*. Moscow Univ. Press. Moscow, 519 pp. [This is a textbook of meteorology and climatology for the higher school]. (In Russian).

Atmosphere Guidebook. (1991). Gidrometeoizdat, Leningrad. [This guidebook presents factual information about precipitation in different countries]. (In Russian).

Biographical Sketch

Irena I. Borzenkova, is the leader of the Climatology Scientific Research Department, for the State Hydrological Institute, Russia. She has the following degrees: M.S. Meteologiya and Climatologiya. Gidrometeorological Institute, 1960, Leningrad, Russia; Ph.D. Geographical Sciences (Physical Climatology), 1966. (Thesis: *"The heat balance of mountain regions"*, Advisor: Prof. M. Budyko, and Doctor of Sci., Geographical Sciences, 1991. Thesis: *"Climatic change during the Cretaceous-Cenozoic"***.** She has made about 40 speeches at national and International meetings and conferences.

Research areas: Global climate change in the present and the geological past, secular changes in global and regional temperature and precipitation, reconstructions of past climate, moisture conditions in past and present.

She has published about 70 scientific papers and seven monographs, including:

Global paleoclimate of the Late Cenozoic. Ser. Developments in Paleontology. 12. Elsevier, Amst. etc. 1990. 456 pp.

Anthropogenic climate change. (Co-authors M. Budyko, E. Butner, I. Karol, K. Kobak, A. Velichko et al. 1987. (in Russian). (Translated into English, Arizona Press, 1992).

Cambios anthropogenicos del clima en America del Sur. (Co-authors M. Budyko, G. Menzhulin, I. Shiklomanov). Buenos Aires, 1994.

Climate change in the Cenozoic. 1992. St. Petersburg. 246 pp. (in Russian). An English translation was made under the auspices of Working Group VIII USA/Russia, 1995.