PRECIPITATION

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Contents

Summary

Precipitation is an important component of the Earth's hydrological cycle. Over the land areas, it is a major source of fresh water for both flora and fauna. This chapter provides a brief review of the precipitation distribution over the globe, its temporal distribution, its major forms, and methods of measurement. Peculiarities of frozen precipitation (snow) and its special role in the Earth's climatic system are discussed. The present trends in changes in land precipitation during the period of instrumental observations (the past hundred years) are provided. Any changes in mean precipitation (increase or decrease) are exaggerated on the right tail of the precipitation distribution. Therefore, the importance of "heavy" and "very heavy" precipitation events that can generate floods are stressed, and the most recent findings about changes in the frequency of these events are provided for several regions of the world.

1. Introduction

Atmospheric precipitation is a vital component of the Earth's hydrological and energy cycles. Water that evaporates mostly from the oceans and humid land areas is redistributed by atmospheric circulation over the Earth and precipitates at a global mean rate of one meter per year. The systematic nature of this distribution (from the tropics to mid- and high latitudes and from the humid to the dry areas) changes and dampens (smoothes) the otherwise continental climate of the land. About half of the meridional heat transfer across the 30° N and 30° S lines of latitude comes from latent heat transfer, i.e. by the water that evaporates in the tropics and then precipitates beyond the tropical band. Thus, precipitation plays also an important role in the warming of the high

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latitudes. Precipitation cleans the atmosphere, washing out the man-made air pollution and natural aerosols. However, the most important function of atmospheric precipitation for terrestrial ecosystems and humankind is water supply.

2. Spatial distribution of precipitation field

Precipitation is distributed over the globe very unequally (see Figure 1). Precipitation events (periods with more or less continuous non-zero precipitation) can last from a few minutes to several days and are separated by periods of dry weather. Sometimes these periods can be lengthy (many months), and the absence of precipitation (especially an unusual absence that represents a deviation from the expected climatological mean precipitation values) shows how vitally important it is for all land ecosystems.

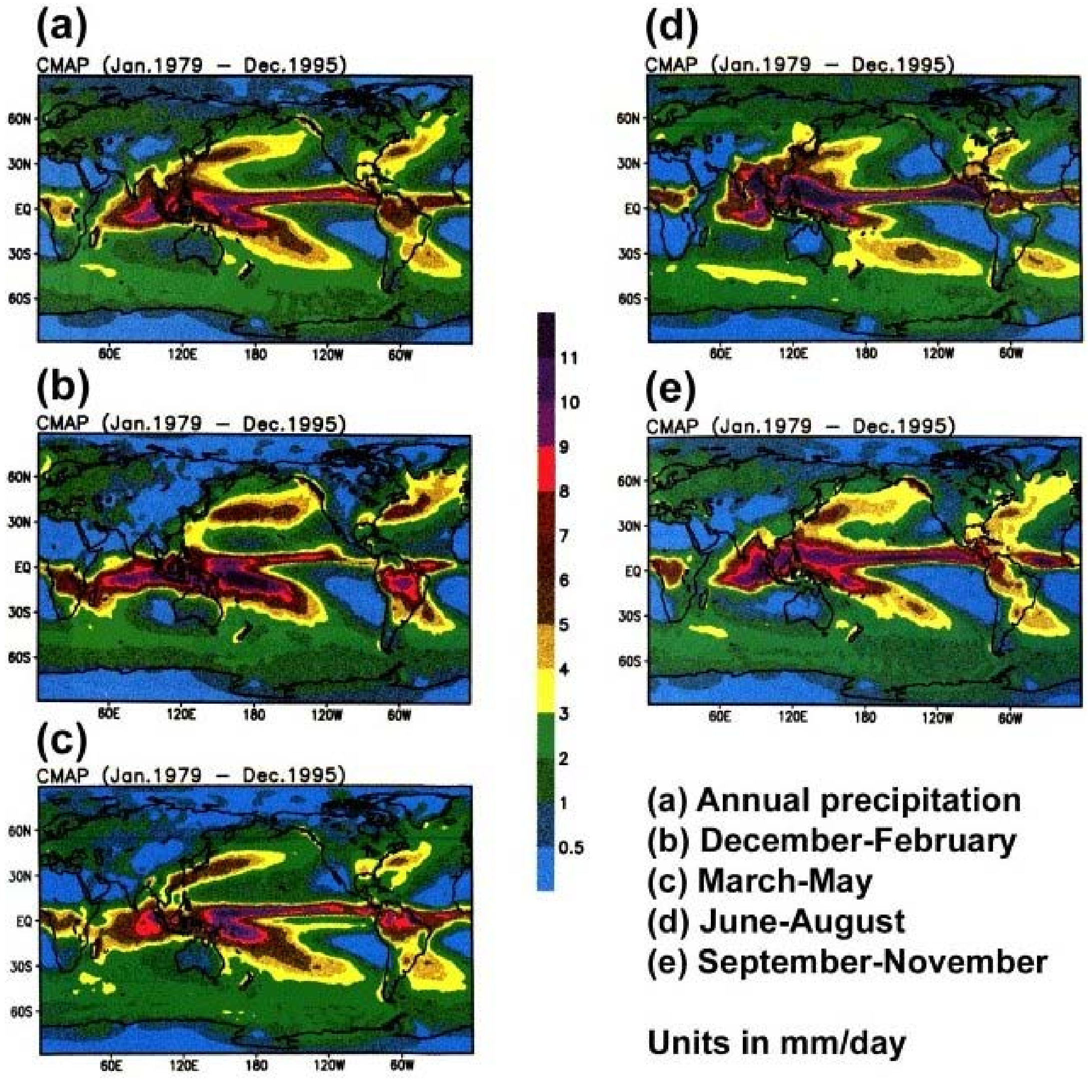

Figure 1. Annual and seasonal spatial distribution of precipitation over the globe as obtained by Merged Analysis of Precipitation in the U.S. Climate Prediction Center from in-situ, satellite, and numerical model calculations (adapted from Xie and Arkin 1997).

Unusual negative (droughts) and positive (extremely wet periods) deviations in precipitation regime represent a danger both for the land ecosystem and for human society that has gradually adjusted to the prevailing (mean) climate conditions. There are many examples in the history of the Old and New Worlds when droughts and/or flooding caused by heavy rains wiped out thriving societies. It is no surprise, therefore, that the first meteorological variable that was measured by humans was precipitation. Currently more than 100 000 stations worldwide routinely observe precipitation at least once per day. Remote methods of precipitation measurements allow us to reliably estimate precipitation over the oceans (Table 1 and Figure 1). A detailed description of the spatial distribution of precipitation is provided in *Types and Characteristics of Precipitation*. Here we simply outline several of the most general features of precipitation.

Area	Dec. – Feb.	Mar - May	Jun - Aug	Sep - Nov	Annual
Land	1.76	1.82	2.07	1.80	1.86
Ocean	2.99	3.01	3.07	3.01	3.02
Globe	2.64	2.67	2.79	2.67	2.69

Table 1. Global mean precipitation (mm day^{-1}) from all sources: in-situ rain gauge measurements, satellite estimates, and numerical model infilling. (Adapted from Xie and Arkin 1997)

The warmer the atmosphere, the more water vapor it can keep (according to the equation of Clausius-Clapeyron) and, thus, the more water it can potentially release in the form of precipitation. Therefore, the zonal distribution of precipitation has a maximum at the equator and minimum around the poles. The most spectacular high precipitation values are observed over the islands in the tropical ocean (Figure 1). The appropriate atmospheric conditions for precipitation usually require upward air motion (e.g. orography induced) and/or conditions for atmospheric instability (e.g. convection, cyclonic activity, or air movement over rough terrain). This generates a local precipitation increase in the upwind slopes of the mountains and over mountainous regions as a whole (e.g. Cordilleras, Himalayas, Alps), and over the parts of the continents and islands that face a major wind stream directed from the ocean (e.g. western Europe, eastern Australia, and monsoon regions of Asia, Africa, and North America). Conversely, in regions and seasons where/when anticyclonic weather conditions dominate and/or the major wind stream comes from dry areas within the continents, local precipitation decreases compared to its zonal mean values. Seasonally, summer precipitation is larger than winter precipitation over most land areas except those where the water vapor deficit (e.g. deserts of Central Asia) and/or atmospheric circulation (e.g. western USA) reverse the seasonal cycle of precipitation.

3. Measurement of Precipitation

There are still unresolved problems in the accuracy of in situ precipitation measurements, especially that fallen in the frozen form. Precipitation is the only meteorological variable that does not have a standard instrument approved by the World Meteorological Organization (WMO). Each country has its own methodology of precipitation observation and uses precipitation gauges that differ in design. WMO

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reports show scores of national gauges that were used in different parts of the world throughout the past two centuries. These gauges have different aerodynamic properties and, particularly in regions where frozen precipitation makes a significant contribution to annual totals (high latitudes and mountainous regions), they are differently affected by the so-called ‘wind undercatch’. This undercatch is caused by wind-induced turbulence and speeding of the air movement over the gauge orifice. This prevents a fraction of precipitation particles (raindrops and, particularly, snow flakes) from entering the gauge collector (see Figure 2). The “ground true” precipitation, i.e. the amount of water fallen on a vertical unit of the ground, is not measured by contemporary (and past) rain gauges. This value should be estimated from observed precipitation. As a result of this estimation, adjusted precipitation values differ and sometimes differ significantly from measured amounts of precipitation. Climatological (i.e. long-term mean) adjustments for wind undercatch and for several other less-important causes of measurement inaccuracy can be as large as 70% of the annual precipitation totals.

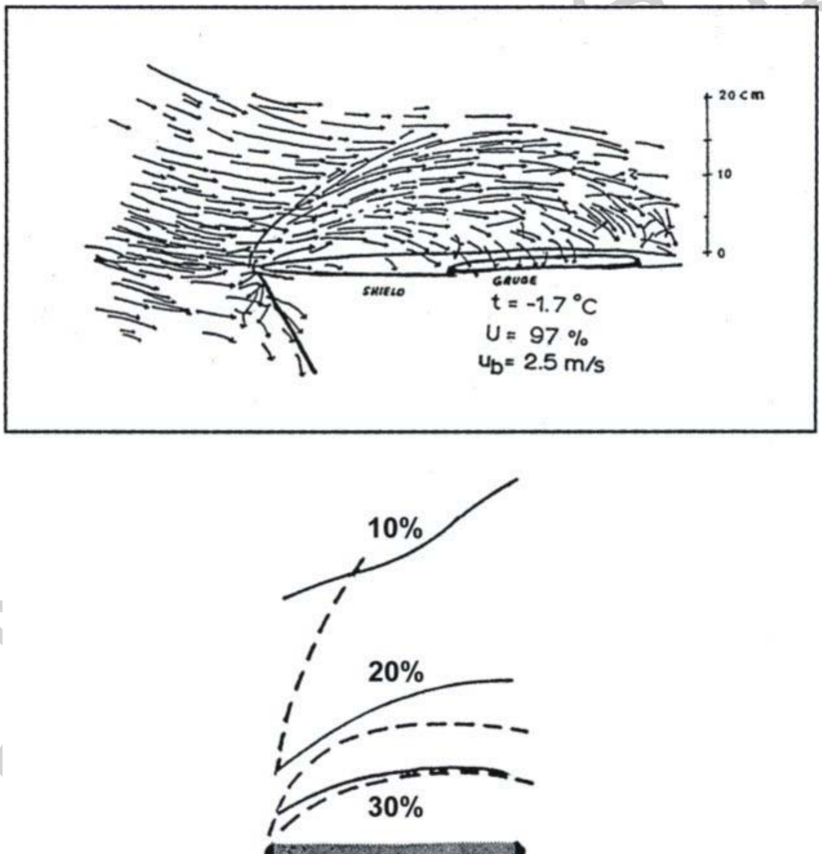

Figure 2. Turbulence over the gauge orifice prevents the total amount of precipitation entering the gauge collector and being measured. ***Top***. Example of flow field over the gauge orifice obtained by combined sequential frames of movie film. Lengths of arrows are proportional to velocities of snowflakes. ***Bottom***. Isopleths of wind speed percentage increment above the rain gauge orifice in wind tunnel experiments. (Sevruk 1990).

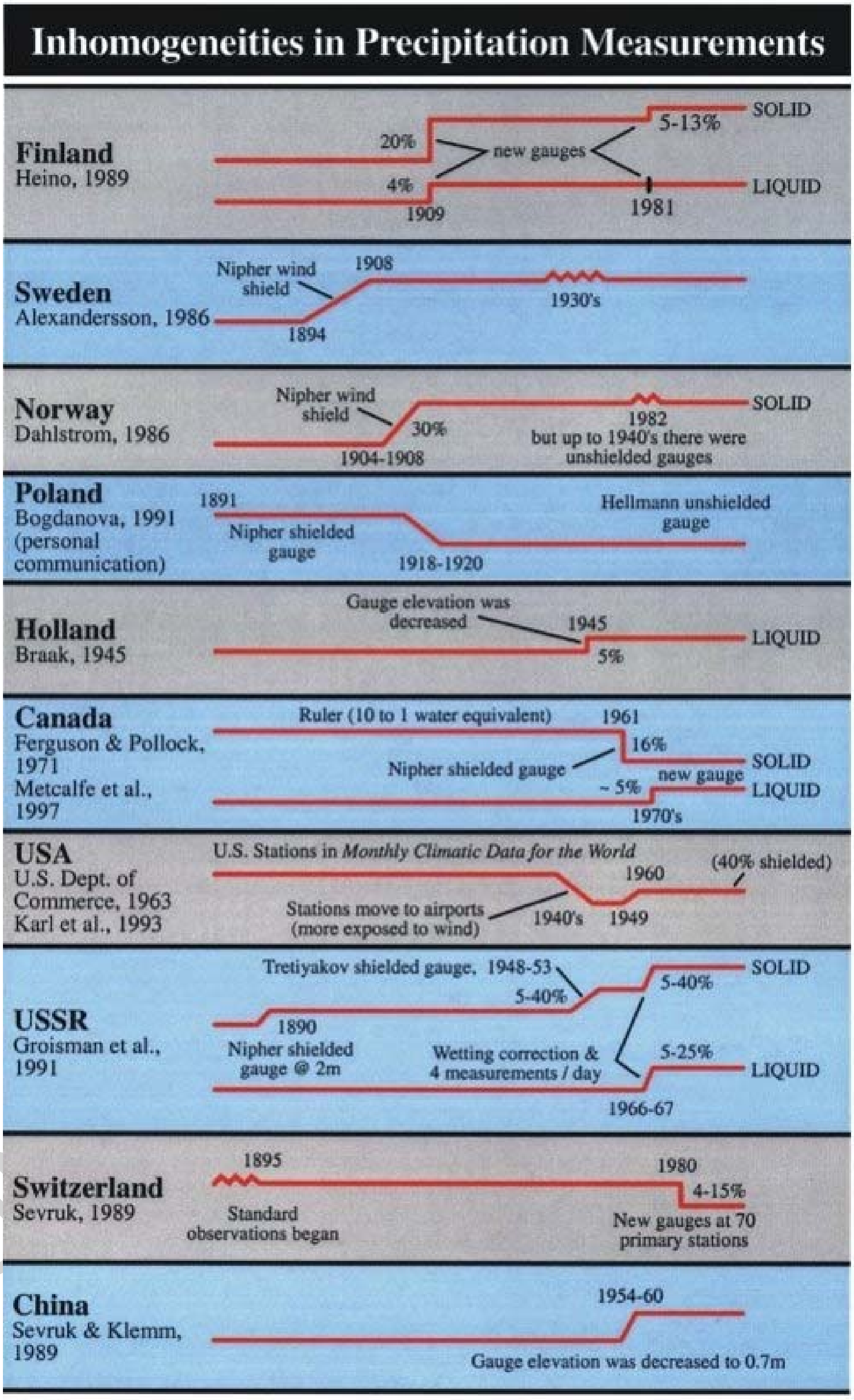

Figure 3. Major instrument and/or methodology changes in the national precipitation network of several countries of the northern hemisphere, and average order of biases caused by these changes. (Karl et al. 1993, updated).

Because historically different instruments and procedures were used to measure precipitation, the studies of the changes in this important climatic variable are hampered and a thorough pre-processing is required to distinguish the systematic changes in the gauge performance from real low frequency climatic signals (Figure 3).

Until recent decades, precipitation observations over the oceans (i.e. over 70% of the globe surface) were sparse, inaccurate, and confined to major shipping routes. Development of remote observational methods from satellites dramatically changed this situation. Figure 1 has been constructed in the framework of the Global Precipitation Climatology Project, a multi-decadal international effort, as a combination of the in-situ rain gauge measurements and several technologies based on satellite-borne atmospheric soundings in the visible, infrared, near-infrared and microwave parts of the spectra, and numerical model simulations—in total seven data sources. The latest and most important addition to the observational tools for ocean precipitation, the Tropical Rainfall Measuring Mission (TRMM) became operational in November 1997. Present TRMM instrumentation located on low orbit satellites provides a 4.3 km spatial footprint and, in combination with other satellites, generates daily precipitation with 1° x 1° resolution over the regions where no in-situ observations were present, and where Figure 1 shows global maximum mean precipitation values.

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