EXTREME PRECIPITATION

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Contents

Summary

This article provides: statistical characteristics of precipitation; absolute maxima of intensity and amount of precipitation, and maximum duration of precipitation. It focuses on precipitation of extreme intensity, hurricanes, and inflows of heat and water vapor into hurricanes from the ocean. Consideration is also given to advective inflow of cold air into hurricanes, amount of precipitation in a hurricane, plus spouts, dust storms, monsoon precipitation, and frontal precipitation.

1. Introduction

Maximum values of precipitation intensity and amount, as well as of wind velocity and lightning discharges can be observed in tropical cyclones (TC), also referred to as hurricanes or typhoons. The spiral structure of the cloud field shows that the influence (interaction) of the cyclone spreads horizontally well beyond the width of the cyclone itself (which is visible as a wall of clouds). The spiral cloud formations can extend for a distance of up to 3000 km. Cyclones form with inflow of colder air onto the warm surface of water (with a temperature higher than 26 to 27 °C). The major source of energy for TC is heat and water vapor (latent heat) from the ocean. Depending on the thickness of the surface water layer, the temperature drop, and the radius and velocity of the TC, the amount (flux) of heat (sensible and latent) coming from the ocean across 1 m^2 of the lower surface of the cyclone, varies from 1 to 15 kW/m^2. This amount of heat spreading throughout the entire cyclone by means of vertical motions and turbulent exchange should cause an increase in temperature of from 1 to 8 ^oC per hour.

Since this significant temperature growth within cyclones is not observed, there must be a process causing a temperature drop at approximately the same rate. In the lower and middle troposphere, these processes are the advection of the colder air entrained into the cyclone and an outflow of the warm air in its upper part.

In accordance with the equation of vortex transfer and the results of numerical modelling, the advection of cold air (baroclinical factor) is accompanied by intensification of the vortex and an increase in vortex motion speed up to 50 to 70 m/s. An important role in intensification of the whirl is played by the warm advection between the frontal and rear parts of the cyclone, which creates asymmetry in the distribution of wind velocity and other meteorological parameters in the cyclone, and to complicated trajectories.

The intensity and amount of precipitation falling from TC have been determined from estimations of the inflow of water vapor from the ocean. The intensity of precipitation varies within 1.8 and 14.8 mm/hr. The amount of precipitation falling in a TC with a radius of 200 km during a day is between 5.2 and 44.7 billion tons.

Not only TC but also most of the cyclones with abundant precipitation arise and deepen as a result of the transfer (advection) of cold air onto a warmer underlying surface, or when air masses interact in cold fronts. Such are monsoons, i.e. phenomena when a vortex motion arises and intensifies simultaneously both in vertical and horizontal planes. In summer, when the ocean is colder than the mainland, and in the coastal part of the mainland, in the lower troposphere, a cold advection is observed; cyclones arise with their cumulonimbus clouds and abundant precipitation. The precipitation intensifies with the passage of the cyclone, and weakens or completely stops in the space between cyclones. As a result of this, the intensity of monsoon precipitation varies rather drastically with time. Statistical characteristics of extreme precipitation at different points and areas of the earth are presented in the following section.

2. Statistical characteristics

Since formation of precipitation field is affected by many factors, one of the most typical properties of this field is the wide variation in intensity (I), amount (Q), duration (t_{pr}) and other characteristics of precipitation in time and space.

Along with information about extreme values of *I* and *Q*, based on observational data from different parts of the Earth, much attention is given in this article to the ascertaining of those physical and meteorological conditions, when extreme precipitation is possible and is actually observed.

2.1. Absolute maximum of intensity and amount of precipitation

Table 1 gives the values of absolute maximum of intensity (I_{max}) and amount (Q_{max}) of precipitation of different duration ($a - t_{pr} \leq 1$ hour, $b - 1 < t_{pr} \leq 3$ hours and $c - t_{pr} > 3$ hours) from several areas of the former Soviet Union:

	I_{max}, mm/min			Q_{max}, mm		
	a	**b**	**c**	**a**	**b**	**c**
NW European part of Russia	3.90	5.80	3.70	21	56	62
Ukraine	2.75	2.38	1.51	38	48	86
Upper Volga	2.22	4.60	3.05	28	98	52
Urals	1.40	1.78	1.59	24	91	50
Transbaikal Region	2.10	3.17	1.88	29	40	57
Primorye	2.67	1.83	2.00	20	20	79
Khabarovsk Territory	4.60	3.20	3.60	17	38	100
East Siberia	1.52	1.10	2.20	13	20	33
Sakhalin	1.20	3.61	0.70	10	22	84
West Transcaucasia (within Georgia)	1.94	1.90	2.21	49	43	209
East Transcaucasia	4.00	6.00	2.64	21	66	109
North Caucasus:						
Western part	4.95	1.54	1.70	29	56	17
Eastern part	1.33	2.46	1.42	14	64	61
South Kazakhstan	1.13	0.85	1.00	22	18	52

Table 1. Absolute maxima of intensity (I_{max}) and amount (Q_{max}) of precipitation of different duration (t_{pr}) across the territory of the former Soviet Union

Averaged peak values of rain intensity range within 0.50 mm/min (Ukraine, Transbaikal Region) and 0.05 mm/min (coast of the Tatar Strait).

There is no marked dependence of absolute maxima or mean values of maximum rain intensity on geographical features of the terrain. So, almost equal values (5.80 and 6.00 mm/min) of absolute maxima *I* are observed on the flat territory of the north-west of the European part of Russia (EPR) and in East Transcaucasia; equal values (4.60 mm/min), in the Upper Volga and in Khabarovsk Territory. These data do not indicate any significant influence of mountains on precipitation. In East Transcaucasia the absolute precipitation maxima (more often occurring on the lee side of mountains) are 2 to 3 times those in Western Transcaucasia (with prevailing western air currents, on the windward side of mountains).

In the western part of the Northern Caucasus the absolute maximum *I* is three times smaller than in the eastern part, when precipitation duration is not more than 1 hour.

However, when the duration is 1-3 hours, the relation is inverse: in the western part I_{max} = 1.54 mm/min, and in the eastern one, I_{max} = 2.46 mm/min.

The oscillations of Q_{max} are as significant as I_{max}: within 10 - 49 mm, 18 - 98 mm and 17 - 209 mm, with precipitation duration not longer than 1 hour, 1-3 hours and more than 3 hours, respectively.

The probability of precipitation of different intensity in Western Europe varies between 6.6 and 18.5% at I = 0.05 - 0.1 mm/min, between 1.3 and 6.8% at I = 0.1 - 0.20 mm/min and between 1.8 and 10.6% at I > 0.20 mm/min.

2.2. Maximum duration of precipitation

The maximum duration of rains for April to October in the territory of the former Soviet Union ranges between 1489 hours (Ust-Kamchatsk) and 172 hours (Balkhash); the mean values are between 1076 and 126 hours (at the same stations).

The ratio of the time interval during which the intensity of precipitation exceeds the pre-set values, to the total duration of observation for Western Europe, on the average, is given in Table 2.

I, mm/min	1.70	1.00	0.50	0.33	0.17	0.10	0.05	0.03
Ratio, %	0.01	0.15	0.20	0.30	0.60	1.00	1.50	2.00

Table 2. Ratio (in %) of the time interval during which the intensity of precipitation exceeds the pre-set values, to the total duration of observation

These relations for different stations in Western Europe vary, at I > 0.50 mm/min, within 0.08% (London) and 1.70 % (Leruik); at I > 0.10 mm/min, 0.40% and 8.40 % (at the same stations).

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Biographical Sketches

Leonid T. Matveev is Leader Scientist in Research Department of Physics of Atmosphere, Cloud Dynamics and Large Scale Atmospheric Processes. He has the following Degrees: BSc in maths from State Pedagogical Inst. Moscow, 1941, MSc. in meteorology from High Mil. Hydrometeorological Inst., !944, and Dr. habil. Physics and Math from Hydromet. Center, 1959. He has been a Professor since 1961, an Honoured Scientist of the Russian Federation since 1973, and an Honorary Prof. of Mozhaisky Mil. Academy of Space and Eng. since 1995.

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