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Probable Maximum Precipitation in Iceland – Station Values –

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The meteorological stations in Iceland are rather few compared to the size of the country, and their service time is short compared to other developed countries. Investigations of individual 24-hour station PMP values computed by the Hershfield and NERC methods show trends that are important for the application of PMP values in engineering design. The results fall into two series, one with high PMP values and the other with lower values. The low values originate from station groups situated in areas with mildly sloping terrain and here the results compare fully with what should be expected from experience from other countries. The other series shows results that do not compare as well with previously published results. Their general characteristics is that PMP values calculated hy the Hershfield method are of the order 80% higher than the corresponding results obtained by the NERC method. The results of this high series do not check against results obtained from meteorological models. It is noteworthy, that all the stations of the low series belong to station groups where the terrain is gently sloping, *i.e.* average terrain slopes less than 1.4%, while in the high series all the stations belong to station groups where the terrain slopes steeply from a highland plateau down to sea level. It is concluded that the generalized estimates of PMP values needed in engineering design could be obtained.

PMP and Precipitation Depth

In designing hydraulic structures it is almost always necessary to estimate extreme precipitation, usually by the Probable Maximum Precipitation, or PMP.

According to the WMO (1986), any PMP should represent the greatest depth of precipitation meteorologically possible. The meteorologically possible moisture content of an air column is well known. But rain concentration mechanism and time does not seem to be known well enough for reliable precipitation models to be built. PMP estimates are therefore more or less based on statistical methods.

Many authors have published envelope curves for maximum observed precipitation, see Landsberg (1981), Roberson (1988) and WMO (1986). A comparison of their envelope values is given in Table 1.

Bearing in mind that all the envelope values are based on the same data, the results could seem to be in some disagreement with each other. However, the envelope curves have only two degrees of freedom, so the difference is understandable.

The following formula for maximum orographic precipitation is descriped in Elíasson (1978)

$$R = V \alpha \rho X \tag{1}$$

$$X \equiv \frac{1}{1.6\,P}\left[\frac{T}{250}\right]^{19.7} \tag{2}$$

where

V – Wind speed, m/s
R – Precipitation depth, mm/s
α – Upward streamline inclination of the wind, m/m
ϱ – Density of the air, kg/m^3
P – Air pressure, mb
T – Air temperature, K
X – Specific humidity, kg/kg.

A method to calculate maximum precipitation based on scaling actual records with the ratio of actual moisture against maximum moisture is quoted in Landsberg (1981). Maximum moisture is a function of temperature, and a study of the data behind the envelope curves reveals that a 15-20°C temperature difference must be anticipated between these climatic regions and Iceland. This would mean that PMP for Iceland should be at least 2-4 times smaller than the comparable world record. This would mean PMP values for 24 hr rain in Iceland in the range 460-950 mm. As

Table 1 – Maximum observation envelope values, mm

Time	5 min	20 min	1 hr	24 hrs	5 days
WMO	106	214	373	1,863	4,206
Roberson	116	227	388	1,817	3,971
Landsberg	129	249	420	1,898	4,077

will be seen in the following, this is a close estimate for Icelandic PMP figures indeed.

The world record figures are all convective rain so Icelandic observation, that are almost all orographic rain, are not comparable to the world record figures so the above comparison does not have any scientific value. Nevertheless, some idea is obtained about what PMP figures are meteorologically possible.

Data and Data Preparation

The original data is the yearly maximum 24-hour precipitation values for the Icelandic observation stations published by the Icelandic Meteorological Office (Veðurstofa Íslands 1924-1989). Their location is indicated in Fig. 1.

The data is prepared and corrected with the following correction factors.

Wind and splash: +25%

This correction factor depends really on the wind speed. For the sake of simplicity it was decided to use a fixed correction factor in this investigation. The actual figure was selected 25% in order to make the resulting estimates applicable in design of hydraulic structures.

Fixed observation time: +13%

WMO recommends this standard correction factor (WMO 1986). Using it should make up for the error introduced by using a fixed 24-hour observation period while higher 24-hour values would result from a scan for any 24-hour maxima in a continuous record.

All together this correction mounts to a multiplication by a factor 1.4125. Bearing this in mind, comparison to actual observation values is easy.

Area Selection

All precipitation data are taken from Elíasson and Hilmarsson (1991), which also contains the calculations of the actual NERC and Hershfield values. The resulting PMP figures are calculated for 6 areas, indicated by roman numbers in Fig, 1, and named in Table 2.

These areas have different geographical characteristics, because of different geological history and age. The main boundary in between them, coincides with the main topographical water-divide between the north country and the south country. North of this line the main precipitation is by northerly winds, this goes for group II. South of the line the main precipitation is by southerly winds, this is especially true for groups IV and V. The remaining groups belong to the west and east country and there the wind direction carrying the bulk of the precipitation is more uncertain.

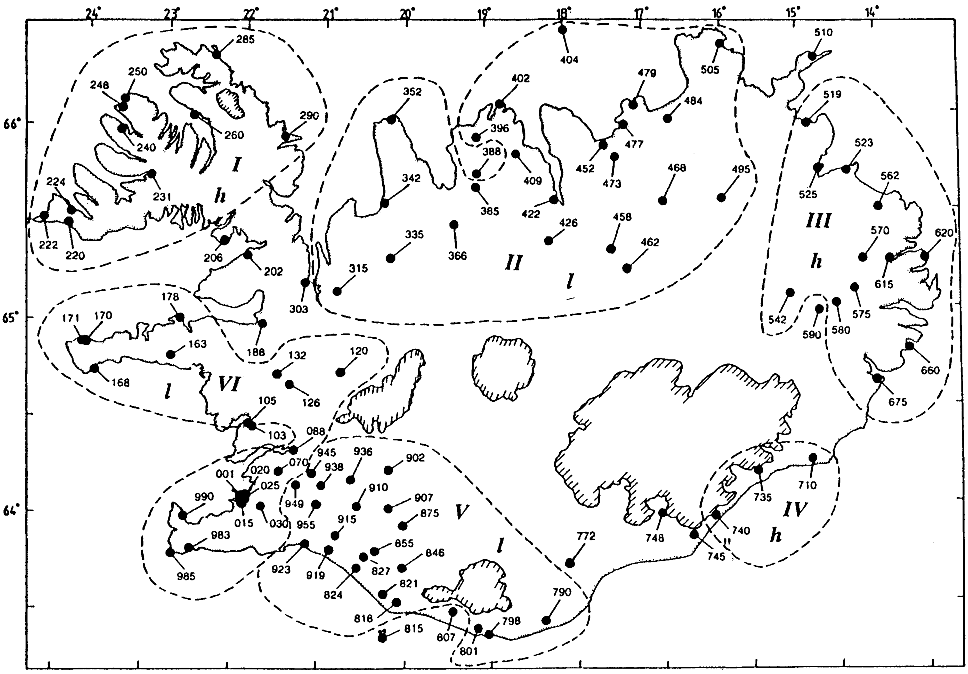

Fig. 1. Meteorological station groups.

Legend: ------- Group boundary; I, etc Group number; High series; Low series

Table 2 – Area names

Nr.	Label	Full name
I	V-F	Vestfirðir
II	N-L	Norðurland
III	A-L	Austurland
IV	SA-L	Suðausturland
V	SV-L	Suðvesturland
VI	V-L	Vesturlund

The individual stations in the groups have by no means identical characteristics. They are all below 400 metres altitude, but some are affected by nearby highland areas, *e.g.* all stations in group IV. Most of the stations in group V are situated in a relatively flat terrain, but the other stations are more or less affected by landscape features. A close examination of these characteristics could reveal some other grouping to be more appropriate.

The groups do not include all meteorological stations in Iceland. Some were left out in order to diminish the effects of the special station characteristics. Fig. 1 shows the stations left out as well as the stations included in the groups. The rule used was to exclude two, maximum three stations from each group to increase the homogeneity of the groups. The results are only slightly affected by this process.

Adopted Methods for PMP Estimation

WMO (1986) recommends that statistical methods are particularly useful for quick estimates of PMP. It is recommend not to use stations with fewer values than 20.

Two methods are used in Elíasson and Hilmarsson (1991) for estimating PMP values for individual station (see Fig. 1). The first is the method originally devised by Hershfield and described in WMO (1986) and most handbooks on hydrology. The second is the NERC (National Environmental Resource Council, London U.K.) method described by Førland (1987), Førland and Kristoffersen (1988), and Førland and Kristoffersen (1989). About other possible methods, there is some discussion included in ICOLD (1988), where the Hershfield and NERC methods are used to estimate the individual station values.

The individual station values are grouped together in the six area groups described in the chapter Area Selection. The PMP values calculated for each area are the average values for all the stations in the group. This is not supposed to be the correct area value for the area concerned. Measures have not been taken to define the correct boundaries of the areas the station groups represent. The SA-L area is the smallest area size of the Vl groups, and N-L the largest. The correct area PMP value should therefore be larger for SA-L than for N-L all other circumstances equal (Roberson 1988). These problems can only be settled by generalized estimates of the PMP, so instead the average values of the individual station PMP's are used to represent each group.

Nevertheless it is of a certain interest to know, how the group values compare to values computed by meteorological models representing orographic or frontal rain. In these models the altitude increase of the air due to terrain or front inclination is of primary importance. Investigations of this factor showed that the minimum upward streamline inclination that could produce the actual figures was 1/70, or 1.4% inclination. This is by no means a small inclination, the average land inclination is smaller for the groups N-L, SV-L and V-L. But this minimum inclination is found to be very plausible when we are dealing with maximum storms, in such an event, small topographic streamline inclination must be somewhat augmented by frontal effects. Therefore, average topographic land inclination is used when it is larger than 1/70, otherwise the minimum value is used. Other parameters used in the model calculations are as follows;

Wind velocity: 25 m/s
Ground (1,000 mb) temperature: 13°C I, 12°C II, 15°C other groups

Eqs. (1) and (2) are used for the calculations, and the results are labelled MET in Table 3. The calculations of individual station values are performed in Elíasson and Hilmarsson (1991).

Results and Comparison

The PMP values calculated by the methods of the preceding chapter are tabulated in Table 3. Now the Hershfield and NERC methods to compute PMP rain are both statistical methods, based upon the mean annual maxima of the individual stations and their standard deviations. These base values are therefore shown in the first two columns of Table 3. As may be noted standard deviation has to be multiplied by a factor 15-19 and added to the mean to obtain the Hershfield value. This value of the multiplication factor compares to similar results from elsewhere see *e.g.* Førland and Kristoffersen (1988).

The next two columns show the maximum observed values. To avoid misunderstanding the uncorrected and the corrected values are both shown. Note that the column labelled Max observed is the only value where the correction factor 1.41 has not been applied.

Comparison of the statistically based values show, that the Hershfield value is of the order twice the maximum (Max corrected) value, and NERC is somewhere in between these values. Taking the MET values into this picture shows, that all the Hershfield and NERC values are indeed possible PMP values from the meteorological point of view, *i.e.* with the sole exception of V-F where the Hershfield Value is significantly higher than the MET.

Now turn to Fig. 2 showing the statistical values plotted so that the groups are sorted in order of ascending values of the Hershfield method. The results fall into two series of three groups each. The first three, which are the groups N-L, V-L and SV-L, show that the Hershfield and NERC values compare nicely with the NERC values with the Hershfield values in the order of 20% higher than NERC. The MET values of these groups compare very well to the Hershfield values.

The second group series shows a different behaviour. Here, the Hershfield values are of the order 80% higher than the NERC values. The highest Hershfield value (SA-L) has an even higher MET value, and the lowest Hershfield value (V-F) has an even lower MET value. In the middle group, the Hershfield and the MET value compare as before.

Table 3 – Precipitation values, mm/24-hrs (St. dev.: Mean value of standard deviation from the individual stations)

	Observations				PMP values		
Group	Mean	St. dev.	Max corr.	Max obs.	Hershfield	NERC	MET
V-F	98	17	181	128	468	308	377
N-L	62	21	140	99	295	247	306
A-L	108	38	283	200	520	315	494
SA-L	200	67	343	243	712	388	1,153
SV-L	87	20	170	120	382	306	376
V-L	83	16	162	115	387	295	376

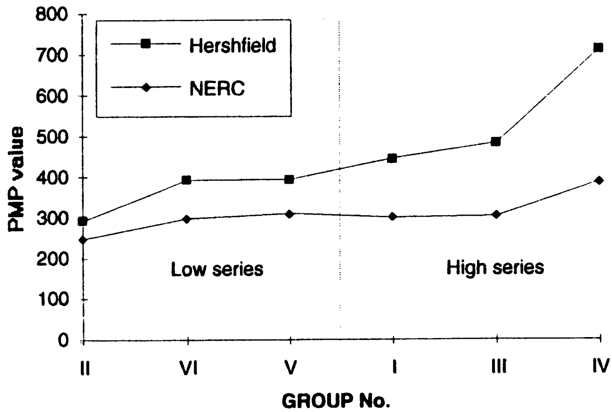

Fig. 2. Comparison of values.

It is quite astonishing that comparison of the series to the envelope values in Table 1 lead to the same results. The low series render values comparable to the envelope values, but the high series renders significantly higher values. The significance of this is not quite clear, though.

Concluding Remarks

The preceding discussion raises the question, what is the difference between the group series. They are not a geographical unity, but what they have in common is, that the first (lower) series contains all the groups with the gently sloping terrain, and the second has all the groups where terrain slopes are very steep all the way from a highland plateau down to sea level.

Taking this into account, the present investigation leads to the following conclusion:

Examination of 24-hr PMP values from individual stations in Iceland show two series, the first shows the same behaviour as could be expected from similar locations (Førland (1987) and Førland and Kristoffersen (1988)), but the second shows higher and more scattered values.

All station groups showing high and scattered values in the investigation are highland plateaus with steep seaward slopes.

The purpose of this work was to look for evidence if the observation results of the Icelandic meteorological stations could be used to produce an overall picture of PMP values in Iceland that could show the way to obtain generalized estimates of PMP values needed in engineering design in Iceland. There is a long way to go yet, but it is the authors belief, that in spite of the small number of meteorological stations in Iceland, and their relative short time of operation, this can be done.

Acknowledgements

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