The M5 method for Japan – a pilot study

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Introduction

The M5 method is a statistical method to estimate precipitation fo a given return period and PMP (Probable Maximum Precipitation) and then the response runoff can be calculated to provide hazard information for river regulations and dam construction as well as river basin risk estimation. The M5 is an abbreviation for 24h precipitation with a 5 year return period which was found to be proper variable for an empirical function to deduce MT (precipitation with a T year return period) through analysis of a great amount of precipitation data (NERC 1975). This method is somewhat handier than many others as the M5 can be geographically mapped and in the same time used as index variable for intensity duration frequency curves. The M5 method originates from the UK (NERC 1975) and is used in Iceland (Elíasson 2000), Norway (Alexandersson et al. 2001). In Iceland, a set of M5 maps are published and free accessible to facilitate engineering design of bridges, culverts and storm water systems (Elíasson 2000). An example is presented in Figure 1.

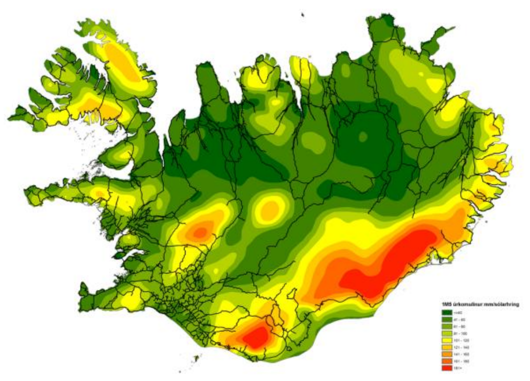

Figure 1 Expected value of annual maximum 24h precipitation in Iceland with 5 year return period, M5.

Because of convenience of M5 method, in this study, we try to introduce M5 method to Japan. On the other hand, the long records of rainfall data in Japan may also provide an opportunity to test the M5 method.

M5 method

The essential aspect of M5 method is taking M5 value as index to deduce precipitation of certain years return period as well as to estimate intensity duration frequency relations. Since M5 value is an index and can be spatially mapped, the MT value and IDF relations calculated from M5 can also be spatially obtained, which id convenient in practical engineering work.

One of the important step for M5 is selection of a proper probability distribution for the rainfall data. The General Extreme Value (GEV) distribution functions are proved to be proper candidates for extreme rainfall data. (Leadbetter et al, 2012, Koutsoyiannis 2003, Eliasson 1997). Hence in this presentation, discussion of M5 is within the range of GEV distribution

The MT value

Written in terms of the M5 and EV1 distribution, MT could be calculated in the following form.

$$MT = M5\ (1 + C_i\ (y - 1.5)); \qquad y < y_{lim}\ (3)$$

Where y=-log(-log(1 – 1/T)), t_r is duration, M5 is the 5-year rainfall, MT is the T-year rainfall. y_{lim} is upper bond of Gumbel viriate which could calculate by 10.7 - 0.0071M5, when 25<M5<200 mm/day. If $y>y_{lim,}$ MT reaches maximum precipitation. The coefficient C_i is calculated by $0.78/(0.72 + 1/C_v)$, where C_v is coefficient of variation.

The IDF curve

Novotny et al. (1989) originally proposed a generalized formula for a regional IDF curve, with separated frequency-amount and intensity-duration relationships. The former one can be represented by M5 and then a version of the IDF curve involving M5 is proposed by Eliasson (1999).

$$I = M5(1 + C_i (y - 1.5))\ g(t_r)$$

Where y = -log (-log (1 – 1/T)), t_r is duration, M5 is from the 5-year 24h event, MT is the T-year event. $g(t_r)$ is the intensity duration relationship estimated intensity-duration data.

Case study 1: All Japan

In the first case study, we investigate the overall situation in Japan. The 123 years rainfall data are collected from 18 meteorological stations cover Japan. As shown in figure 2.

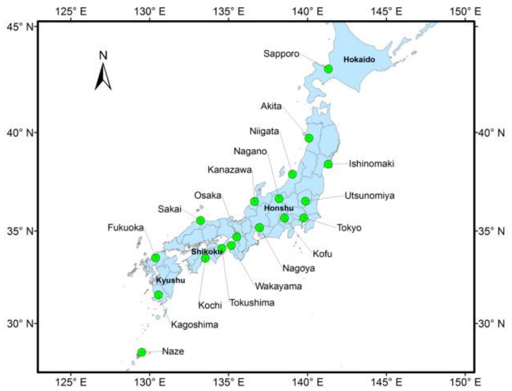

Figure 2 Location of 18 meteorological stations

Table 1. Distributions and M5 value for stations

	Stations	Distri	Location	Scale	Shape	L-rtP	M5	Ci	M50	M100	M200	M1000
1	Akita	EVI	-0.442	0.741	0	0.342	102	0.20	152	166	180	213
2	Fukuoka	EVI	-0.438	0.721	0	0.108	156	0.24	245	271	297	357
3	Ishinomaki	EVI	-0.442	0.752	0	0.54	105	0.22	161	178	194	232
4	Kagoshima	EVI	-0.465	0.83	0	0.291	187	0.20	276	302	328	388
5	Kanazawa	EVI	-0.448	0.765	0	0.713	122	0.21	184	202	220	261
6	Kochi	EVI	-0.399	0.658	0	0.064	251	0.24	394	435	477	572
7	Kofu	EVII	-0.493	0.653	0.16	0.033	132	0.26	216	240	264	321
8	Nagano	EVI	-0.448	0.755	0	0.449	74	0.22	112	123	134	159
9	Nagoya	EVII	-0.455	0.588	0.172	0.009	146	0.25	234	260	285	345
10	Naze	EVI	-0.431	0.718	0	0.219	289	0.27	476	530	584	709
11	Niigata	EVII	-0.458	0.612	0.151	0.017	100	0.24	156	172	189	227
12	Osaka	EVI	-0.436	0.741	0	0.464	114	0.22	175	193	211	251
13	Sakai	EVI	-0.437	0.726	0	0.166	143	0.25	230	255	281	339
14	Sapporo	EVI	-0.434	0.71	0	0.067	94	0.25	149	166	182	219
15	Tokushima	EVII	-0.452	0.637	0.116	0.042	205	0.26	334	371	409	495
16	Tokyo	EVI	-0.434	0.722	0	0.164	159	0.26	256	284	312	377
17	Utsunomiya	EVI	-0.461	0.819	0	0.371	132	0.21	199	218	238	283
18	Wakayama	EVII	-0.482	0.605	0.193	0.007	152	0.27	251	279	308	374

The probability distribution and M5 value are calculated for each stations, as shown in table 1. It is found that EV1 is sufficiently good to estimate M5. The EV2 can be used for large T´s in a few stations.

Case study 2: Example of a regional study

A regional study in Aichi prefecture is conducted. 16 stations with 35 years rainfall records are used, as shown in figure 3.

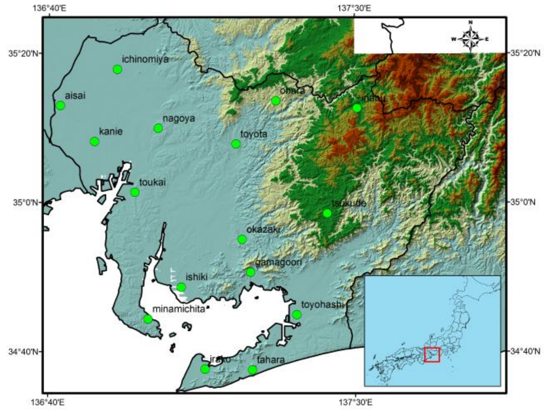

Figure 3. Location of 16 meteorological stations

In this study, we calculated M5 value through GEV distributions and made a primary M5 map by spline interpolation. However, this M5 map is rather rough that many issues should be further discussed.

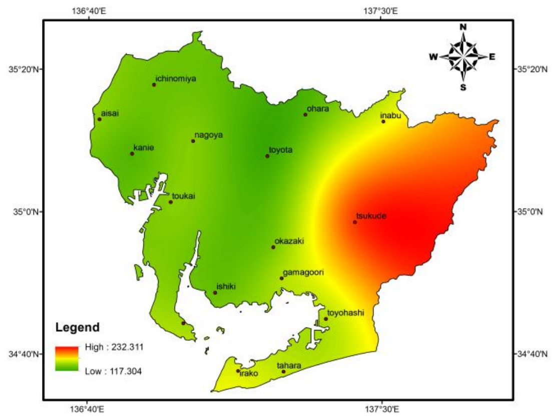

Figure 4. Primary M5 map by spline interpolation

Future work and discussion

This study of applying M5 in Japan is still ongoing.

1. Regional M5 - average annual rainfall relation should be analyzed for stations that have short records.
2. M5-elevation relation should be analyzed for areas where there is a strong orographic effect.
3. The use of M5 value and M5 map should be demonstrated, for instance, estimation of flood risk.
4. The spatial interpolation should be carefully considered for M5 mapping which is important for ungauged area.