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Expected Rainy Days: Tendency of Rainfall in Indian Context

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ABSTRACT: An attempt has been made on determining expected percentage of rainy days, with an objective of obtaining tendency of rainfall in terms of degree of confidence, on the basis of the extension of the statistical definition of probability extended to the situation where outcomes of the associated trials happen automatically. This article presents expected percentage of number of rainy days in each of the 12 months at 30 stations in India .

KEYWORDS*:* Probability, Extended Statistical Definition, Expectation Percentage of Rainy Days

I. INTRODUCTION

Statistical analysis of data obtained from experiment or survey of phenomena is basically based on the concept of probability and the findings obtained from analysis are also interpreted with the help of probability. Probability has become a vital player of playing the role of understanding and explaining of various phenomena in almost every branch of science [92]. The theory of probability, the beginning of whose history was lost in the dust of antiquity [89], has been developed by the six approaches namely Subjective Approach [2], Intuitive Approach [86 , 87 , 94 , 95], Classical Approach [3 , 6 , 7 , 8 , 10 , 12 , 14 , 15], Empirical Approach (also known as Statistical Approach [6 , 10 , 13 , 98 , 99 , 100], Axiomatic Approach [4 , 5 , 6 , 80 , 84 , 85] and Theoretical Approach [9 , 13 – 20 , 53 , 56]. The first two approaches are subjective while the other approaches are based on scientific logic [76]. Recently, one definition of probability, that can be interpreted as an extended definition of empirical probability, has been developed on the basis of outcomes that do happen automatically [63 – 75].

Central tendency [28 – 30 , 29 , 44 , 51 , 101] is one of the basic characteristics of data which plays a vital role in statistical analysis of data. A number of formulations, though may not be as sufficient as to handle all the real situation, have already been developed for measuring central tendency of data [45 , 46 , 49 , 50 , 54 , 55 , 57 , 102] which is basically based on measures of average [30 , 31 , 33 – 38 , 41 – 43 , 47 , 48]. There had already been several studies on various aspects like trend analysis [1 , 77 , 78 , 81 – 83, 88 , 91 , 93 , 96 , 97], analysis of tendency [59 – 75 , 79 , 90], estimation and forecasting [11 , 27 , 40 , 52] etc. which are mostly based on non-probabilistic approach. The recent trend is towards the study on rainfall by probabilistic approach [63 – 75]. In a study, done recently, the definition of probability based on automatically happened outcomes has been applied in estimating the expected number of rainy days in each of the 12 months at 30 stations in India with an objective of obtaining a picture, though not deterministic and appropriate but probabilistic and approximate, of tendency of rainfall in India [75]. However, it becomes more meaningful and/or more convenient to interpret if the percentage of rainy days in a period is obtained since the conclusion can in this case be drawn in terms of degree of confidence. This article presents expected percentage of number of rainy days in each of the 12 months at 30 stations in India with an objective of obtaining tendency of rainfall in terms of degree of confidence.

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II. RAINY DAY IN A PERIOD – MATHEMATICAL EXPECTATION

Automatically Happened Outcomes and Probability

Let us use the standard notation $P(E)$ to denote the probability of occurrence or happening of event E .
Probability is defined on the basis of automatically happened outcomes of a natural phenomenon as follows [[63 – 75]:

If in a set of N repetitions of a natural phenomenon already happened, an event E has occurred n times then the probability of occurrence of E is
the limiting value of the ratio $\frac{n}{N}$ as $N \to \infty$
i.e. $P(E)$ can be approximated by the ratio provided N is large..
Conversely, in a set of N repetitions of a natural phenomenon automatically happened, number of occurrence n of an event E with probability of occurrence $P(E)$ is
the limiting value of the ratio $N.P(E)$ as $N \to \infty$
i.e. n can be approximated by $N.P(E)$ provided N is large.

Probability of Number of Rainy Days

Suppose that E is an event that denotes occurrence of r rainy days in a month.
If out of N repetitions the event E occurs $N(E)$ times then the probability of occurrence of the event E, denoted by $P(E)$, can be defined by the number towards which the ratio $\frac{n}{N}$
approaches as N becomes larger i.e.

$$\frac{n}{N} \to P(E) \text{ as } N \to \infty$$

i.e. $P(E)$ is the limiting value of $\frac{n}{N}$ as N becomes larger and larger [69 – 75]..

Mathematical Expectation of Number of Rainy Days
If

$$r_1 , r_2 , \dots \dots \dots , r_n$$

are the possible values of number of rainy days R occurring in a period with respective probabilities

$$p_1 , p_2 , \dots \dots \dots , p_n$$

then the mathematical expectation of the number of rainy days R in the period is defined by

$$E(R) = \sum_{i=1}^{n} r_i \, P(R = r_i) = \sum_{i=1}^{n} p_i \, r_i$$

[75].
Accordingly, the mathematical expectation of the percentage of rainy days in the period, denoted by $E(P)$, becomes

$$E(P) = 100E(R) = 100 \sum_{i=1}^{n} p_i \, r_i$$

III. EXPECTED RAINY DAYS IN INDIA

The definition of probability based on the data on already happened outcomes has been applied in estimating expected percentage of rainy days in each of the 12 months at the following 30 stations
Agartala , Ahmadabad , Allahabad , Amritsar , Bangalore , Bhopal , Bhubaneswar , Bhunter , Chennai , Guwahati , Hisar , Hyderabad , Imphal , Jaipur , Kolkata , Lucknow , Mumbai , Nagpur , New Delhi , Palam , Panjim , Patna , Pondicherry , Port Blair , Pune , Shillong , Tezpur , Trivandrum , Udaipur , Varanasi
in India.
For this purpose, data on number of rainy days (month-wise) at the 30 stations [11] have been collected from the year 1969 onwards from Meteorological Department of Government of India.
and then the above formulation of probability has been applied in computing the desired values of probabilities.
The number of rainy days considered here are the point values

$$0 , 1 , 2 , 3 , 4 , 5$$

and the interval values

$$6 – 10 , 11 – 15 , 16 – 20 , 21 – 25 , 26 – 30$$

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At the first step, estimated values of probabilities corresponding to these point/interval values of number of rainy days in each of the 12 months at the 30 stations had been computed by the formulation of probability defined above.
At the next step, estimated values of expected percentage of rainy days in each of the 12 months at the 30 stations were computed by the formulation of mathematical expectation of percentage of rainy days as mentioned above.
The estimated values of expected percentage of rainy days obtained have been shown in **Table – 3.1**.

Table – 3.1
Expected Percentage of Rainy Days

Month	Estimated Value				
	Agartala	Ahmadabad	Allahabad	Amritsar	Bangalore
January	2.0645	**0.7056**	5.2419	6.5494	**0.6048**
February	7.8571	**0.4464**	4.1295	11.4719	1.6741
March	10.4516	**0.10**	2.4194	11.0459	2.2177
April	28.8	**0.625**	2.1875	6.7677	9.5833
May	42.0645	1.9153	3.4339	6.9404	22.2782
June	50.4	13.75	15.1042	11.9192	20.5208
July	50.9677	36.4919	38.609	29.3255	23.0847
August	49.9355	34.4758	37.7732	23.8514	32.4597
September	39.0667	16.4583	28.172	11.25	33.2292
October	21.4193	2.4194	5.8273	3.5282	25.9073
November	6.5333	1.9792	1.7204	1.7172	13.125
December	2.1935	**0.7056**	1.3527	3.7146	5.746

Table – 3.1: Continuation (1)
Expected Number of Rainy Days

Month	Estimated Value				
	Bhopal	Bhubaneswar	Bhunter	Chennai	Guwahati
January	4.086	1.3142	18.7305	3.9785	4.1475
February	3.9286	6.3492	22.4654	1.9048	7.2704
March	1.828	5.3764	26.1186	1.1828	12.9032
April	1.4943	6.6667	18.7097	2.6667	30.5747
May	2.9954	12.788	20.2914	4.7312	41.6019
June	23.4483	33.3333	14.7778	15.2222	49.3103
July	45.8287	48.6174	28.8172	21.7204	54.95
August	46.941	50.1151	28.2796	25.8065	41.6019
September	25.5556	39.643	16.2222	23.9785	33.4483
October	6.2291	23.8479	6.1395	32.4732	16.0178
November	3.6782	6.1728	5.1111	34.3333	5.1282
December	2.0737	1.4337	8.2314	17.4194	2.3226

Table – 3.1: Continuation (2)
Expected Number of Rainy Days

Month	Estimated Value				
	Hisar	Hyderabad	Imphal	Jaipur	Kolkata
January	4.0078	1.7204	3.9426	1.7137	3.341
February	5.5195	1.601	11.8623	3.683	6.6326
March	4.7898	1.891	19.7005	1.4113	7.4885
April	3.8384	4.7778	32.9885	2.3958	9.881
May	5.8651	8.2796	33.5929	4.7379	22.0046
June	11.875	24.4444	51.4943	12.5806	42.143
July	23.9492	31.1457	50.9455	32.8823	56.7971

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August	20.9677	35.1613	41.6019	30.385	54.1474
September	10	25.5556	31.3793	11.828	44.2857
October	2.4438	18.4946	21.0234	3.642	21.0829
November	1.0417	6.4444	10.8333	**0.4839**	4.0476
December	2.1169	1.1828	3.629	**1.0**	2.18897

Table – 3.1: Continuation (3)
Expected Number of Rainy Days

Month	Estimated Value				
	Lucknow	Mumbai	Nagpur	New Delhi	Palam
January	4.1623	**0.2016**	4.0045	3.7603	4.8387
February	5.6452	**0.3348**	5.2956	4.4974	5.8441
March	2.9136	**0.10**	4.3011	3.9293	4.3011
April	1.9355	**0.3125**	3.3333	3.5598	4.2424
May	5.6192	2.4194	7.8044	4.1797	5.8273
June	16.5591	43.646	28.3333	6.5102	12.1212
July	38.0855	72.9448	44.7165	8.479	31.6715
August	35.5881	69.5565	43.3816	8.3681	29.4233
September	28.0645	46.146	27.1111	6.7179	15.1042
October	4.6826	11.7944	9.6774	3.4473	3.7146
November	1.6129	3.4375	3.4483	2.1181	1.4583
December	2.0812	**1.0081**	2.5345	3.125	2.4194

Table – 3.1: Continuation (4)
Expected Number of Rainy Days

Month	Estimated Value				
	Panjim	Patna	Pondicherry	Port Blair	Pune
January	**0.3226**	4.5161	3.4409	5.3764	4.0403
February	**0.119**	4.3104	2.1429	3.5714	12.7551
March	**0.10**	3.0033	1.9355	3.3299	0.782
April	1.5556	3.3333	1.1111	14.0860	2.9293
May	10.1075	9.4624	5.2280	51.4048	7.4291
June	71.111	6.3333	9	61.2903	30
July	84.5161	46.3848	15.6989	60.8742	39.3939
August	77.6345	40.9345	20.5376	59.1052	30.3030
September	41.2223	10.3333	6.3722	59.8923	24.5455
October	18.7097	10.4561	31.3978	47.6587	14.3695
November	7.7778	1.1111	37	41.398	2.2048
December	**0.6452**	1.6685	20.5376	13.9438	1.2708

Table – 3.1: Continuation (5)
Expected Number of Rainy Days

Month	Estimated Value				
	Shillong	Tezpur	Trivandrum	Udaipur	Varanasi
January	4.8387	4.779	3.2258	**0.9677**	3.854
February	7.5255	6.8878	5.119	1.2673	4.4245
March	12.788	12.788	7.5269	**0.4162**	2.3465
April	28.6905	35.2873	21.8889	1.8889	2.2057
May	51.03678	40.4894	31.3978	4.1935	3.6102
June	62.738	50.4597	54.4443	15.8889	6.4261
July	59.1013	52.9477	43.3332	26.3626	8.8627

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August	49.8848	42.3803	33.0106	31.9244	8.8421
September	54.762	39.5403	29.6667	16.9048	8.4837
October	26.8433	18.2425	37.2042	4.9539	4.5667
November	8.7179	5.3571	30.7777	2.2989	2.5074
December	4.0943	3.8232	13.9785	**0.7786**	2.5244

IV. RESULT AND DISCUSSION

If the percentage of occurrence of rainy day at a place during a period is 0 then the period can be regarded as a period having perfect non-rainfall tendency. In reality, there may be rainfall during a period having non-rainfall tendency due to some random cause that occurs accidently but not regularly and not always so that the probability of occurrence of a rainy day in that period is very small (near to 0). Thus, if the percentage of occurrence of rainy day in a period is not 0 but very near to 0 then the period can be regarded as a period having significant non-rainfall tendency. Statistically, if the percentage of occurrence of rainy day in a period is not more than 1 then the period is non-rainy with 99% confidence. Similarly, if the percentage of occurrence of rainy day in a period is more than 1 but not more than 5 then the period is non-rainy with 95% confidence.

The periods having significant non-rainfall tendency can be identified from the estimated values presented in **Table – 3.1**. It has been found from the numerical finding that no month at each of the stations under study has perfect non-rainfall tendency. The months/periods having significant (also highly significant) non-rainfall tendency, identified from the numerical results, in **Table – 3.1**, have been shown in **Table – 4.1**.

Table – 4.1
Month/Period experiencing significant rainfall tendency

Station	Month/Period experiencing		Station	Month/Period experiencing	
	Significant non-rainfall tendency	Highly significant non-rainfall tendency		Significant non-rainfall tendency	Highly significant non-rainfall tendency
Agartala	December , January	/NIL	Lucknow	October – January , March – April	NIL
Ahmadabad	May , October , November	December – April	Mumbai	May , November	December – April
Allahabad	February – June , November , December	/NIL	Nagpur	November – January , March – April	NIL
Amritsar	October – December	/NIL	New Delhi	October – May	NIL
Bangalore	February – March	January	Palam	October – April	NIL
Bhopal	November – May	NIL	Panjim	April	December – March
Bhubaneswar	December – January	NIL	Patna	November – April	NIL
Bhunter	NIL	NIL	Pondicherry	January – April	NIL
Chennai	January – May	NIL	Port Blair	February – March	NIL

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Guwahati	December – January	NIL	Pune	November – January , April	NIL
Hisar	October – January , March – April	NIL	Shillong	December – January	NIL
Hyderabad	December – April	NIL	Tezpur	December – January	NIL
Imphal	December – January	NIL	Trivandrum	January	NIL
Jaipur	December – May , October	November	Udaipur	February , April – May	December – January , March
Kolkata	November – January	NIL	Varanasi	October – May	NIL

It is to be mentioned that the findings obtained in this study are based on the assumption that data used in the analysis satisfy the condition(s) under which the definition of probability is valid. Thus the accuracy of findings is subject to the validity of this assumption.

It is to be mentioned that in this study attempt has been made on estimating expected number of rainy days at some places. This has been done by the extension of its empirical definition extended to the situation where outcomes of the associated trials happen automatically. Similar study can be made for the other places in the globe.

Finally, one can conclude that the extended definition of statistical probability extended to the situation where outcomes of the associated trials happen automatically can be a suitable tool of analysis of data obtained from automatically happened or naturally happened phenomena. Therefore, as per the meaning of research [21 – 26 , 32 , 37 , 39 , 58], the development of this extended definition of statistical probability can be regarded as a significant output of a fundamental research carrying significant applicability in research and investigation where analysis of data is an unavoidable component.

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Dr. Dhritikesh Chakrabarty passed B.Sc. (with Honours in Statistics) Examination from Darrang College, Gauhati University, in 1981 securing 1st class &1st position. He passed M.Sc. Examination (in Statistics) from the same university in the year 1983 securing 1st class & 1st position and successively passed M.Sc. Examination (in Mathematics) from the same university in 1987 securing 1st class (5th position). He obtained the degree of Ph.D. (in Statistics) in the year 1993 from Gauhati University. Later on, he obtained the degree of Sangeet Visharad (inVocal Music) in the year 2000 from Bhatkhande Sangeet vidyapith securing 1st class, the degree of Sangeet Visharad (in Tabla) from Pracheen Kala Kendra in 2010 securing 2nd class, the degree of Sangeet Pravakar (in Tabla) from Prayag Sangeet Samiti in 2012 securing 1st class, the degree of Sangeet Bhaskar (in Tabla) from Pracheen Kala Kendra in 2014 securing 1st class and Sangeet Pravakar (in Guitar) from Prayag Sangeet Samiti in 2021 securing 1st class. He obtained Jawaharlal Nehru Award for securing 1st position in Degree Examination in the year 1981. He also obtained Academic Gold Medal of Gauhati University and Prof. V. D. Thawani Academic Award for securing 1st position in Post Graduate Examination in the year 1983.

Dr. Dhritikesh Chakrabarty also did post doctoral research under the Post Doctoral Research Award by the University Grants Commission for the period 2002 – 05.

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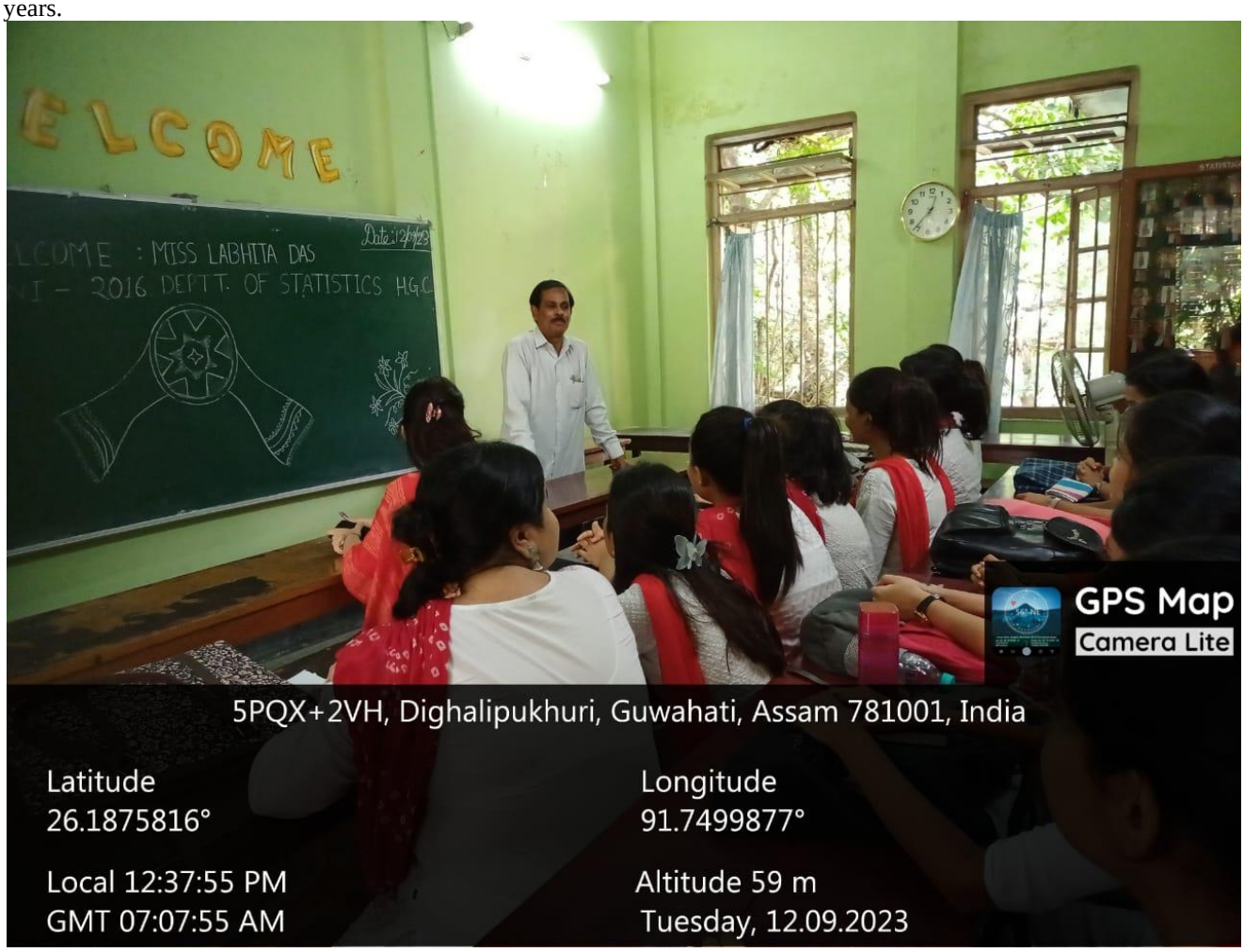
He attended five of orientation/refresher course held in Gauhati University, Indian Statistical Institute, University of Calicut and Cochin University of Science & Technology sponsored/organized by University Grants Commission/Indian Academy of Science. He also attended/participated eleven workshops/training programmes of different fields at various institutes.

Dr. Dhritikesh Chakrabarty, currently an independent researcher, served Handique Girls' College, Gauhati University, during the period of 34 years from December 09, 1987 to December 31, 2021, as Professor (first Assistant and then Associate) in the Department of Statistics along with Head of the Department for 9 years and also as Vice Principal of the college. He also served the National Institute of Pharmaceutical Education & Research (NIPER) Guwahati, as guest faculty (teacher cum research guide), during the period from May, 2010 to December, 2016. Moreover, he is a Research Guide (Ph.D. Guide) in the Department of Statistics of Gauhati University and also a Research Guide (Ph.D. Guide) in the Department of Statistics of Assam Down Town University. He has been guiding a number of Ph.D. students in the two universities. He acted as Guest Faculty in the Department of Statistics and also in the Department of Physics of Gauhati University. He also acted as Guest Faculty cum Resource Person in the Ph.D. Course work Programme in the Department of Computer Science and also in the Department of Biotechnology of the same University for the last six years.



(Dr. Dhritikesh Chakrabarty in an interactive talk with the students in the Department of Statistics of Handique Girls' College on September 12, 2023)

Dr. Chakrabarty has been working as an independent researcher for the last more than thirty years. He has already been an author of 260 published research items namely research papers, chapter in books / conference proceedings, books etc. He visited U.S.A. in 2007, Canada in 2011, U.K. in 2014 and Taiwan in 2017. He has already completed one post doctoral

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research project (2002 – 05) and one minor research project (2010 – 11). He is an active life member of the academic cum research organizations namely (1) Assam Science Society (ASS), (2) Assam Statistical Review (ASR), (3) Indian Statistical Association (ISA), (4) Indian Society for Probability & Statistics (ISPS), (5) Forum for Interdisciplinary Mathematics (FIM), (6) Electronics Scientists & Engineers Society (ESES) and (7) International Association of Engineers (IAENG). Moreover, he is a Reviewer/Referee of (1) Journal of Assam Science Society (JASS) & (2) Biometrics & Biostatistics International Journal (BBIJ); a member of the executive committee of Electronic Scientists and Engineers Society (ESES); and a Member of the Editorial Board of (1) Journal of Environmental Science, Computer Science and Engineering & Technology (JECET), (2) Journal of Mathematics and System Science (JMSS) & (3) Partners Universal International Research Journal (PUIRJ). Dr. Chakrabarty acted as members (at various capacities) of the organizing committees of a number of conferences/seminars already held.

Dr. Chakrabarty was awarded with the prestigious SAS Eminent Fellow Membership (SEFM) with membership ID No. SAS/SEFM/132/2022 by Scholars Academic and Scientific Society (SAS Society) on March 27, 2022.

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