PERSISTENCE OF WET AND DRY SPELLS IN ITALY. FIRST RESULTS IN MILANO FROM 1858 TO 2000.

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1. INTRODUCTION

The meteorological phenomenon "precipitation" can be analyzed through many different features: its physical (rain, snow, hail) or its quantitative (extreme events, cumulated values during different periods of time) or its qualitative features (persistence). So the climatic characterization of precipitation should be considered in different framework. Variability is the main precipitation characteristic so, try to find some systematical variation elements combined to climatic variations, it's very difficult.

The purpose of the present work is to investigate a specific precipitation feature: its persistence.

Many studies has been carried out in order to determine the most suitable probability model: Gabriel and Neumann (1962) among others, have found that sequences in daily rainfall occurences can be described by a simple Markov chain model. De Arruda (1980) showed that for tropical regions, the truncated negative binomial model is more efficient than Markov chain, nevertheless for wet days the Eggemberger-Polya distribution provides a good fit to observed data of Uccle (Berger and Goossens 1982).

Considering a wet day as one with ≥1,0 mm of rain, the purpose of the present work is to investigate:

a. the best probability model which is able to fit the observed data and to catch interactions between the typology of one day and the adjacent ones.
b. if the identified theoretical model is able to catch eventual different features of the spell distribution between two periods: the last 30 year series compared to the previous secular period, in order to give a further contribute to climatic change problems.

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2. MATERIALS AND METHODS

A ultra secular series (from 1858 to 2000) of daily rainfall data collected from the Brera Observatory Milan, Italy, was analyzed both in its annual and seasonal aggregations (considering the cold season from October to March and the warm season from April to September) taking into account that Italian climate presents a clear seasonal variability.

It has been already said, we consider a wet day (W) as one where the precipitation is ≥1,0 mm and, obviously, dry day (D) the one where there's not precipitation or is not > 1,0 mm, so each data set is organized in sequences of W and D.

A wet spell is a sequence of wet days and it begins and ends the day after and the day before a dry day, so, for example, a 4 days wet spell is identified with DWWWWD and these kind of sequences form the annual and the two seasonal sets.

A VISUAL-BASIC program is used to count systematically the dry and wet spell, their total number, their mean length and their distribution according to their length for annual as well for seasonal aggregation. When a spell overlaps a seasonal change (that is, it includes the 31st of March and the 1st of April or the 30th of September and the 1st of October) it is considered in its whole, up to its modality change even if it reaches the following season and we included it in the season in which it develops longer.

The sample gives the observed frequency of dry (wet) spell of *i* length (where *i* goes from 1 to the longest spell). The *i* length spell can be considered as a casual variable and its probability density, which can be calculated with theoretical model, is to compare to empiric frequency: if the difference between the theoretical and the empirical values falls within a predetermined range (significance test), we assume the theoretical model goodness of fit.

The first theoretical model, that has been used to describe the empirical data, is the Bernoulli model and the priori probabilities are calculated with the Binomial law. In this case, as the test results show, the Binomial law is a inadequate fitting model because it requires the data independence. Therefore, others theoretical models that consider data dependence, must be analyzed.

Several kind of models have been used to describe dry and wet spells frequencies of occurrences considering the climatic features of the different countries. We have tested:

- the Eggenberger-Polya model;
- the truncated negative binomial model;
- the logaritmic model;
- the exponential model (that can be applied only to wet spells);
- the Markov chain of order one and higher than one.

The χ^2 test for goodness of fit was employed as the significance test for every model, assuming the level of significance equal to 5% (α = 0,05).

Later, we divide each season in two periods the 1°(1858-1970) and the 2°(1971-2000) and the *p(i)* distribution calculated for the 1° period is compared to the one calculated for the 2° period.

The statistics hypothesis that both the samples belong to the same universe (it means unchanged climatic conditions) and the alternative hypotesis that they don't belong to the same universe (that is, a climatic change that concerns this specific aspect of precipitation) is evaluated.

First of all, sample mean and variance of the 1° and the 2° period are compared using t-Student and F-Fisher tests. We have to underline that these results are only indicative because these tests suppose the almost normality of the samples, condition which is not realized.

A more decisive evidence is achieved applying to the 2° period (the 30-year series) the Eggemberg-Polya model calculated with the parameters derived from the 1° period. In this case, if the model don't fit to the observed data, it'll mean that in the last 30 years, climatic scene is changed.

3. RESULTS

Tables 1_a and 1_b give the usual statistics parameters of wet and dry days distribution.

Main characteristic of D and W spell during wintertime		
	D	W
Total number of days	22545	7470
General probability	0.751	0.249
Number of spells	3364	3365
Mean lenght of spells (days)	6.70	2.22
Standar deviation (days)	7.99	1.61
Max lenght (days)	80	14

Tab 1_a

Main characteristic of D and W spell during summertime		
	D	W
Total number of days	17236	4973
General probability	0.776	0.224
Number of spells	2897	2897
Mean lenght of spells (days)	5.95	1.72
Standar deviation (days)	5.99	1.11
Max lenght (days)	64	13

Tab 1_b

The first phase of this work, shows that Eggemberg-Polya and truncated negative binomial models are more efficient than the other in fitting observed data, for wet and dry spell and for annual and seasonal aggregations. The other models fit only one phenomenon typology (Markov chains, logaritmic model, the exponential model that can be applied only to wet spells) or don't fit at all (logarithmic model) (examples in Tab 2 and 3, Fig 1)

Considering that the truncated negative binomial model needs three parameters (mean, variance and the empirical frequency of the 1 day spell) while Eggemberg-Polya needs only two parameters (mean and variance), we consider the latter as the theoretical model that can be more easily used.

MILANO - wet spells during wintertime							
length of spells (days)	observed frequency	thoretical frequency					
		Binomial	Markov 1	E. & P.	B.N.T.	LOG	EXP
1	1437	472.4	1515.9	1483.3	1437	1788.7	1558.8
2	930	117.6	833	854.8	857.7	680.8	836.6
3	471	29.3	457.7	471.8	480.7	345.5	449.0
4	235	7.3	251.5	256.6	263	197.2	241.0
5	132	1.8	138.2	138.5	141.8	120.1	129.3
6	68	0.5	75.9	74.4	75.7	76.2	69.4
7	42	0.1	41.7	39.9	40.1	49.7	37.3
8	24	0.0	22.9	21.3	21.2	33.1	20.0
9	11	0.0	12.6	11.4	11.1	22.4	120.7
10	7	0.0	6.9	6.1	5.8	15.3	5.8
>= 11	8	0.0	8.4	6.9	6.3	36	7.1
chi-square value			18.3	11.5	11.9	251,1	23.0
c. s. 95% level			19.7	19.7	18.3	19.7	19.7

Tab 2

length of spells (days)	observed frequency	thoretical frequency						
		Binomial	Markov 1	Markov 2	Markov 3	E. & P.	B.N.T.	LOG
1	582	112.7	487.0	582	582	603.0	582	940.3
2	406	87.5	405.1	373.6	406	411.9	422.5	444.6
3	305	67.9	337.0	313.3	303.1	318.3	327.1	280.3
4	268	52.7	280.4	262.8	255.0	255.4	260.9	198.8
5	219	40.9	233.2	220.4	214.5	208.7	211.7	150.4
6	190	31.7	194.0	184.8	180.4	172.4	173.8	118.5
7	160	24.6	161.4	155.0	151.8	143.5	143.8	96.1
8	117	19.1	134.3	130.0	127.7	120.0	119.7	79.5
9	78	14.8	111.7	109.0	107.4	100.8	100.1	66.8
10	106	11.5	92.9	91.4	90.4	84.9	84.0	56.9
11	71	8.9	77.3	76.6	76.0	71.6	70.8	48.9
12	69	6.9	64.3	64.3	63.9	60.6	59.7	42.4
13	53	5.4	53.5	53.9	53.8	51.3	50.5	37.0
14	39	4.2	44.5	45.2	45.2	43.5	42.8	32.5
15	30	3.2	37.0	37.9	38.1	37.0	36.3	28.7
16	36	2.5	30.8	31.8	32.0	31.4	30.9	25.4
17	22	2.0	25.6	26.7	26.9	26.7	26.3	22.6
18	19	1.5	21.3	22.4	22.7	22.8	22.4	20.2
19	20	1.2	17.7	18.7	19.1	19.4	19.1	18.1
20 - 24	60	2.9	52.8	57.0	58.4	61.7	61.0	67.0
25 - 29	24	0.8	21.0	23.6	24.6	28.1	28.0	41.2
30 - 39	14	0.3	11.7	13.9	14.7	18.8	19.1	43.4
>= 40	9	0.0	2.2	2.9	3.2	5.2	5.5	37.2
chi-square value			64.8	34.2	29.1	26,6	25.9	433,7
c. s. 95% level			31.4	30.1	28.9	31.4	30.1	31.4

MILANO - dry spells during summertime

Tab 3

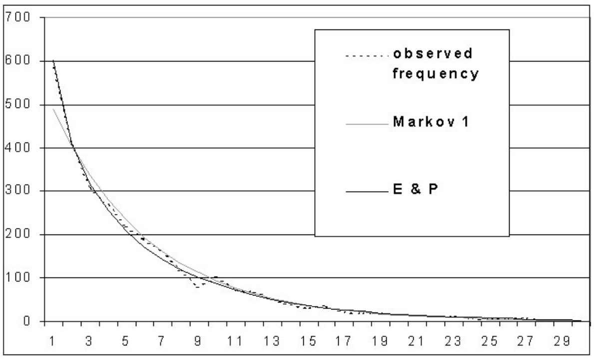

Fig 1 Dry spells on summertime: comparison among observed data and the results of Markov 1 and Eggemberg-Polya models.

The second phase of the work shows that the last 30–year series and the secular series:

- have not differences among the wet spells distributions;(Tab 4_a and 4_b)

Wet spells summertime					
length of spells (days)	observed freq. 1° per.	E. & P. 1° per.	observed freq. 1° per.	E. & P. 2° per.	E. & P. 2° with 1°
1	1348	1352.5	334	334.4	333.5
2	583	570.6	137	134.8	140.7
3	221	236.2	56	58.0	58.2
4	107	97.2	25	25.4	24.0
5	36	39.9	11	11.3	9.8
6	21	16.3	6	5.0	4.0
>= 7	8	11.3	4	4.1	2.8
χ^2 c s. 95% level=9,5		4.9		0.3	1.9

Tab 4_a

Wet spells wintertime					
length of spells (days)	observed freq. 1° per.	E. & P. 1° per.	observed freq. 2° per.	E. & P. 2° per.	E. & P. 2° with 1°
1	1141	1180.1	296	301.8	290.0
2	741	681.6	189	175.0	167.5
3	387	379.6	84	92.7	93.3
4	186	208.8	49	47.6	51.3
5	110	114.1	22	24.1	28.0
6	56	62.2	12	12.0	15.3
7	37	33.8	5	6.0	8.3
>=8	42	40.2	8	5.8	11.3
χ^2 c s. 95% level=11,1		10,2		3,3	8,2

Tab 4_b

- there are significant differences among the dry spell distributions both in the wintertime and summertime (Tab 5), in particular:

- both seasons show an increase in dry spell mean duration, essentially due to a considerable increase (+ 50%) of the longest spells frequency (> 25 days) but also, even if less remarkable, due to a decrease (about -8%) of the shortest spells (from 1 to 3 days). (Tab 6)

Dry spells summertime					
length of spells (days)	observed freq. 1° per	E. & P. 1° per.	observed freq. 1° per	E. & P. 2° per.	E. & P. 2° with 1°
1	450	476.8	132	122.6	117.5
2	337	333.9	69	78.3	82.3
3	252	259.8	53	59.5	64.1
4	229	208.8	39	47.6	51.5
5	173	170.6	46	39.0	42.1
6	161	140.6	29	32.5	34.7
7	123	116.7	37	27.3	28.8
8	90	97.2	27	23.1	24.0
9	65	81.3	13	19.7	20.0
10	88	68.2	18	16.8	16.8
11	55	57.3	16	14.4	14.1
12	51	48.2	18	12.3	11.9
13	43	40.6	10	10.6	10.0
14	27	34.3	12	9.2	8.4
15	25	28.9	5	7.9	7.1
16	29	24.4	7	6.8	6.0
17	16	20.7	6	5.9	5.1
18	14	17.5	5	5.1	4.3
19	15	14.8	5	4.4	3.7
20-24	44	46.4	16	14.9	11.4
25-29	20	20.5	4	7.4	5.0
30-39	12	13.1	2	5.7	3.2
>= 40	5	3.3	4	2.0	0.8
χ^2 c.s. 95% level=31,4		22.8		23.0	36.9

Tab 5

Probability of Dry Spells from 1 to 3 days	
1° period	p(D)= 0.461
2° period	p(D)= 0.455
Probability of Dry Spells > 25 days	
1° period	p(D)= 0.016
2° period	p(D)= 0.026

Tab 6

4. CONCLUSIONS

The Eggemberg-Polya model is able to describe the persistence of wet and dry spells in Milan in the annual and the seasonal aggregation. The application of this model has shown that climatic scene regarding this particular aspect of precipitation, has changed and that the occurrence of long period of absence of rainfall is higher than the past, at least for Milan station or for the climatic region that it represents.

The study of dry spell consist in an deeper study of the structure of dryness length and of its variation: these results seems to prove an increase of climate dry features in this region.

The extension of this application to other daily precipitation secular series will allow a better characterization of eventual climatic variation in our country and an deeper investigation on the eventual potentiality of this tool.

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