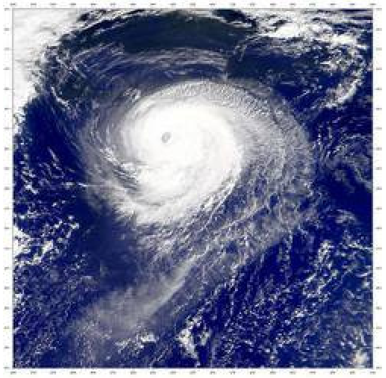

The Climatic Characteristic of Extreme Precipitations for Short-term Intervals in the Watershed of Lake Maggiore

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Introduction

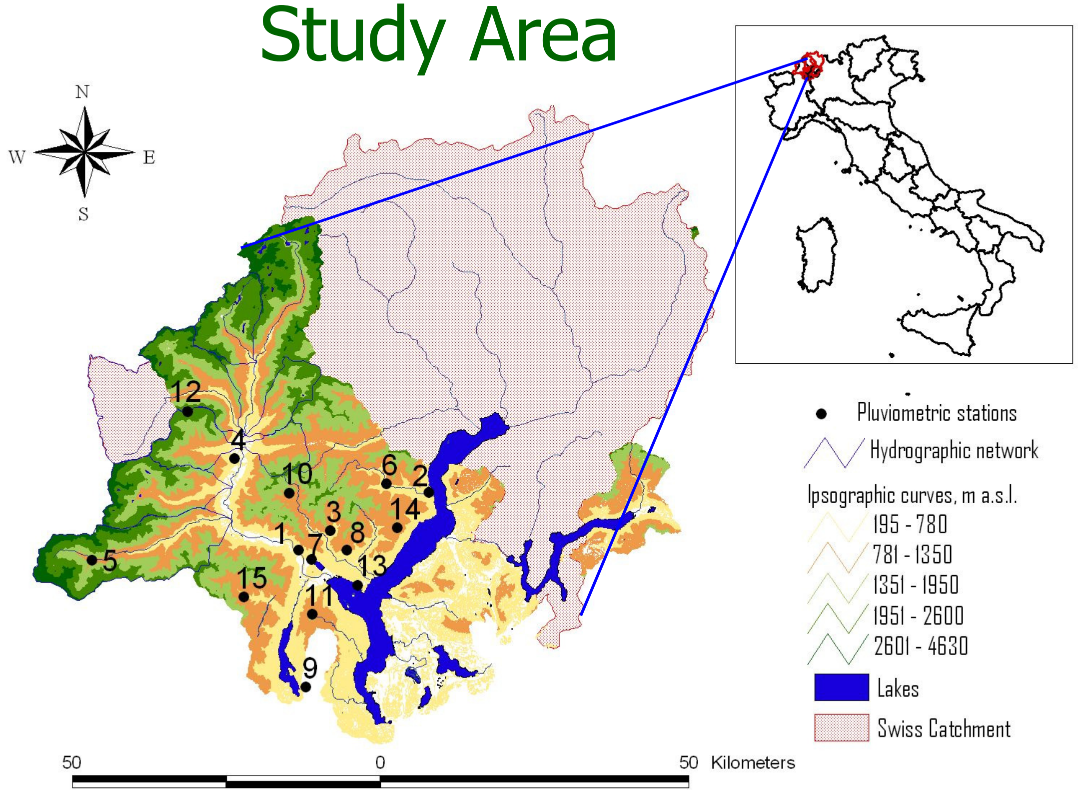
- In recent years we are observing a profound change in rainfall typology and distribution in Alpine and Mediterranean area which is probably linked to "global climate change". In particular, we can observe an increase in consecutive non-rainy days, and an escalation of extreme rainy events which are short and very intense.

- Regional pooling of 5 to 45 minutes and above 1, 2, 3, 6, 12 and 24h annual maxima from 15 sites is used to a standard regional frequency analysis to produce extreme value growth curves for some return period rainfall events for each defined climatogical regions.

- The historical extreme rainfall series were described by the Generalized Extreme Value (GEV) and the Two Component Extreme Value (TCEV) distributions .

- The estimation of the parameters of the GEV and the TCEV distribution was based on the analysis of the extreme series by mean of the L-moment and the Maximum Likelihood technique.

Study Area



Lake Maggiore (Figure above) is located in North-Western Italy and is the second largest freshwater basin in Italy and one of the most important lakes of the European Community. It represents an important resource for tourism, fisheries and agriculture. Lake Maggiore is included in the southern alpine lacustrine district characterized by the presence of several large lakes (Lake Como, Lake Garda, etc.), with an area of 212.2 square kilometres (80% in Italy and 20% in Switzerland) and a water volume of 37.5 cubic kilometres.

Study Area

- The Lake Maggiore watershed extends for 6599 km^2 shared between Italy (3299 km^2) and Switzerland (3369 km^2). In the catchment of Lake Maggiore there are a lot of streams and rivers, some natural alpine lakes and numerous reservoirs, formed by river barred to produce hydroelectric power. Some other important lakes that share the Lake Maggiore catchment, are Lakes Lugano, Varese, Orta and Mergozzo.

- The highest altitude of the lake basin is Peak Dufour with 4634 m a.l.s. in the Monte Rosa Mountain. The lowest level is the altitude of lake above level sea: 193 m a.s.l.

Data and methods

- The basic data for this analysis were the yearly maximum 5, 10, 15, 20, 30, 45 and 60 minutes as well as the 2, 3, 6, 12 and 24 hour precipitation amounts from the period 1987-2010

STATION	X	Y	Elevation a.s.l.	COVERED PERIOD
CANNOBIO	476626	5101249	**220**	1938-1998 and 2006-2010
LUNECCO	469645	5102406	**415**	1986-2010
MERGOZZO	457529	5090130	**195**	1978-99 and 2003-2010
CICOGNA	460527	5094840	**770**	1921-2010
MIAZZINA	463252	5091628	**721**	1914-2010
PIANCAVALLO	471381	5095332	**1240**	1986-2010
PALLANZA	465025	5086015	**211**	1873-1893 and 1921-2008
Paione	437475	5114095	**2269**	1987-2010
Mottac	453935	5100948	**1690**	1985-2010

Statistical Methods

- The first step is the definition of the homogeneous regions and sub-regions over the study area
- Regional analysis were performed using L-moment of the annual maximum series.
- Hosking suggested to use the L-moment expressed as linear combination of PWM

$$\lambda_{r+1} = \sum_{k=0}^{r} p^{*}_{r,k} \beta_k \quad \text{where } p^{*}_{r,k} = (-1)^{r-k} \binom{r}{k} \binom{r+k}{k}$$

Statistical Methods

- L-moments are robust to outliers and virtually unbiased for small samples. It's convenient to standardize the L-moments such that the rth L-moment ratio is given by:

$$\tau_r = \frac{\lambda_r}{\lambda_2}$$

Where :

τ_3 is the symmetry of the sample and is referred to as L-skewness

τ_4 is a measure of peakedness and is referred as L.kurtosis

$\tau = \frac{\lambda_2}{\lambda_1}$ is analogous to the conventional coefficient of variation (Lcv)

The idea to detect heterogeneity statistics is to measure the sample variability of the L-moment ratios and compare it to the variation that would be expected in a homogeneous region. The latter is estimated through repeated simulations of homogeneous regions with samples drawn from a four parameter kappa distribution.

Statistical Methods

Based on the L-coefficient of variation Lcv, the weighted standard deviation of Lcv is calculated as :

$$V = \frac{\sum_{n=1}^{N} n_i \left(L^i_{cv} - \overline{L}_{cv}\right)^2}{\sum_{i=1}^{N} ni}$$

An heterogeneity measure called H1 is finally found as :

$$H_1 = \frac{(V - \mu_v)}{\sigma_v}$$

The region under analysis can therefore be regarded:

- acceptably homogenous if H1 < 1
- possibly heterogeneous if 1≤ H1 < 2
- heterogeneous if H1 > 2

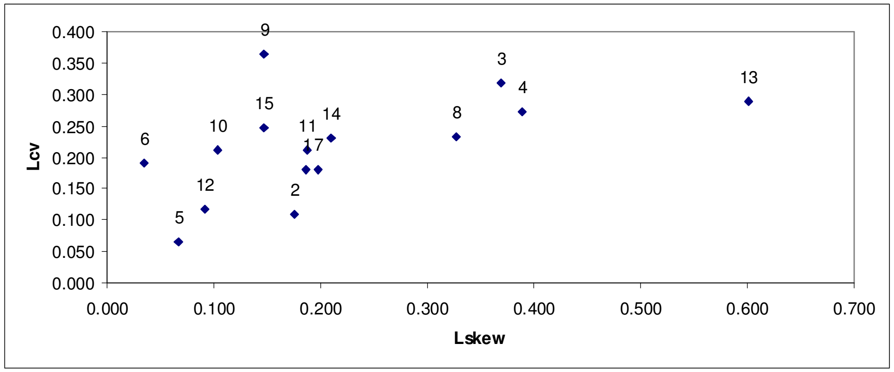
We did also the same test (H2) based on Lskew

Results

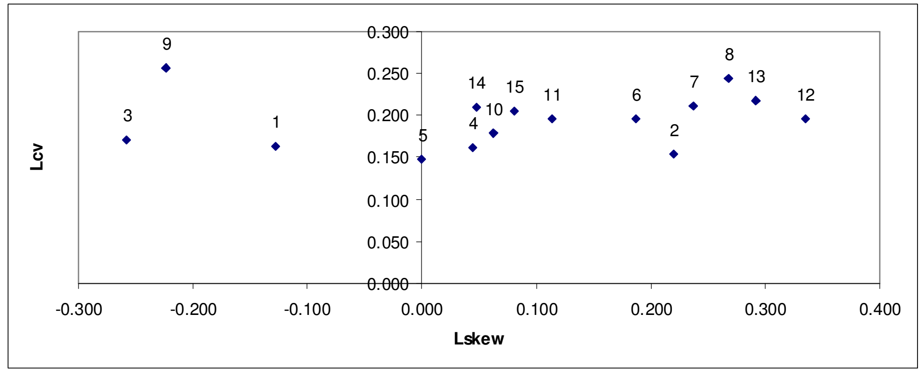
- Result of the H1 statistical test of homogeneity

Storm duration (min)	H_1	H_2	$\overline{L}_{cv}$	$\overline{L}_{skew}$	$\overline{L}_{kur}$
5	**1.99**	-0.17	0.215	0.216	0.229
10	0.14	1.92	0.200	0.129	0.203
30	**4.72**	2.84	0.194	0.085	0.163
60	0.68	1.77	0.192	0.134	0.141
120	-0.18	0.15	0.194	0.218	0.206
1440	0.343	1.65	0.203	0.246	0.103

Results



a



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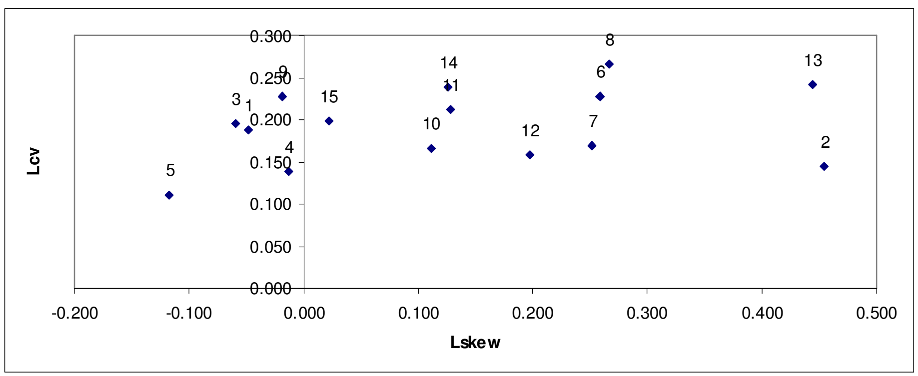

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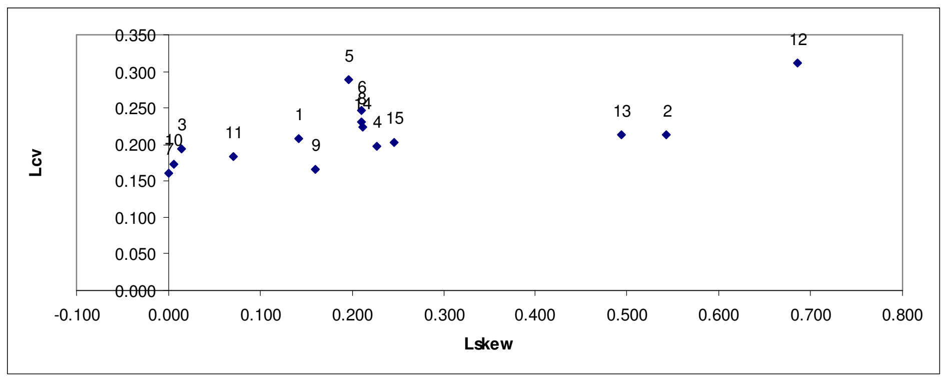
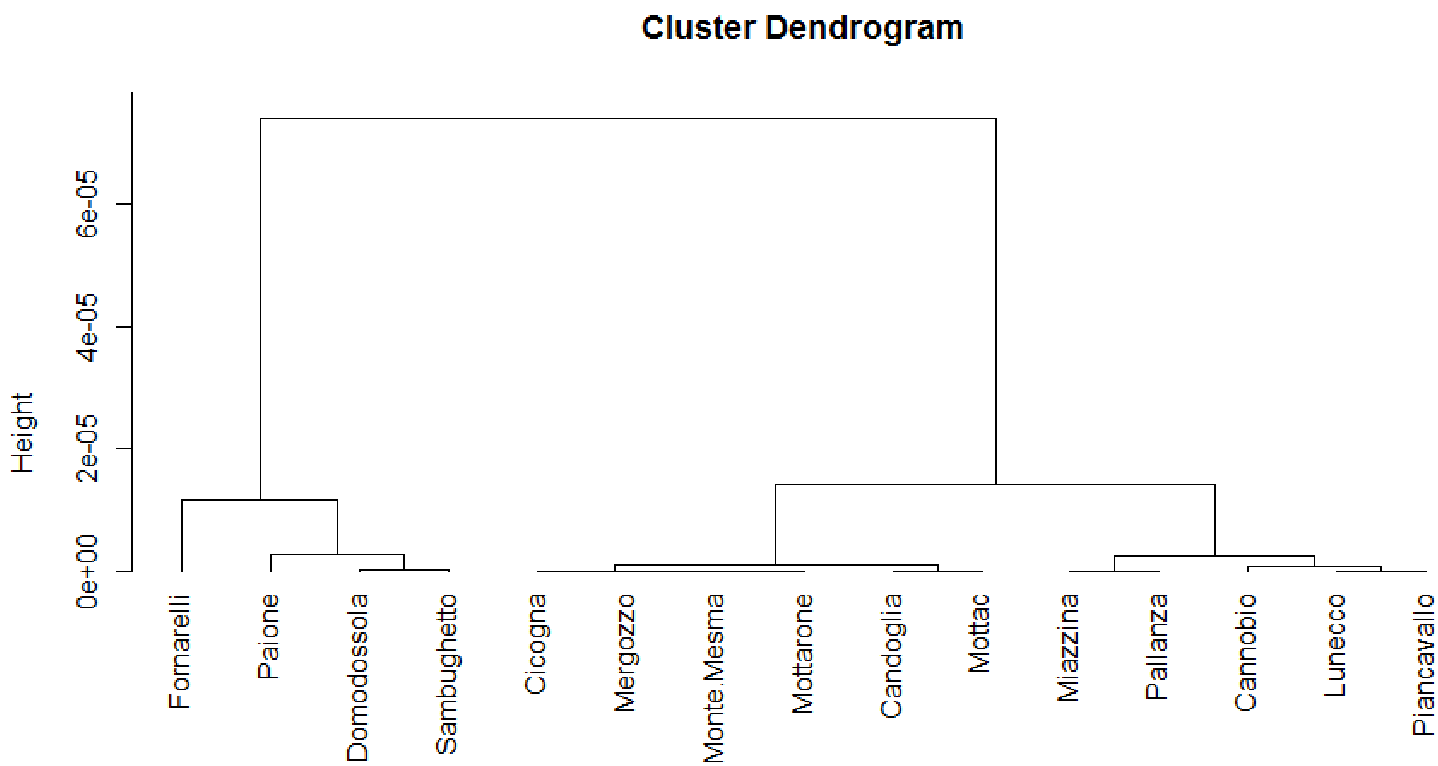


d

Plots of L-CV against L-skewness for the maximum value of a) 5 min b) 30 min c) 60 min d) 1day precipitation

Results: Hierarchical clustering



Results: Hierarchical clustering

- **30 Min**

S.R1:	Domodossola					
S.R2:	Fornarelli	Paione	Sambughetto			
S.R3:	Cannobio	Lunecco	Miazzina	Pallanza	Piancavallo	
S.R4:	Candoglia	Cicogna	Mergozzo	Monte Mesma	Mottac	Mottarone

Result of H1 and H2 statistical test

30 min	S.R2	S.R3	SR4
H_1	-0.38	-0.55	-0.45
H_2	0.13	-0.46	2.85

GEV Distribution

- After identifying the homogeneous regions it's necessary identify probability distribution applicable to each region and that best estimates the statistical parameters for extreme rainfall .

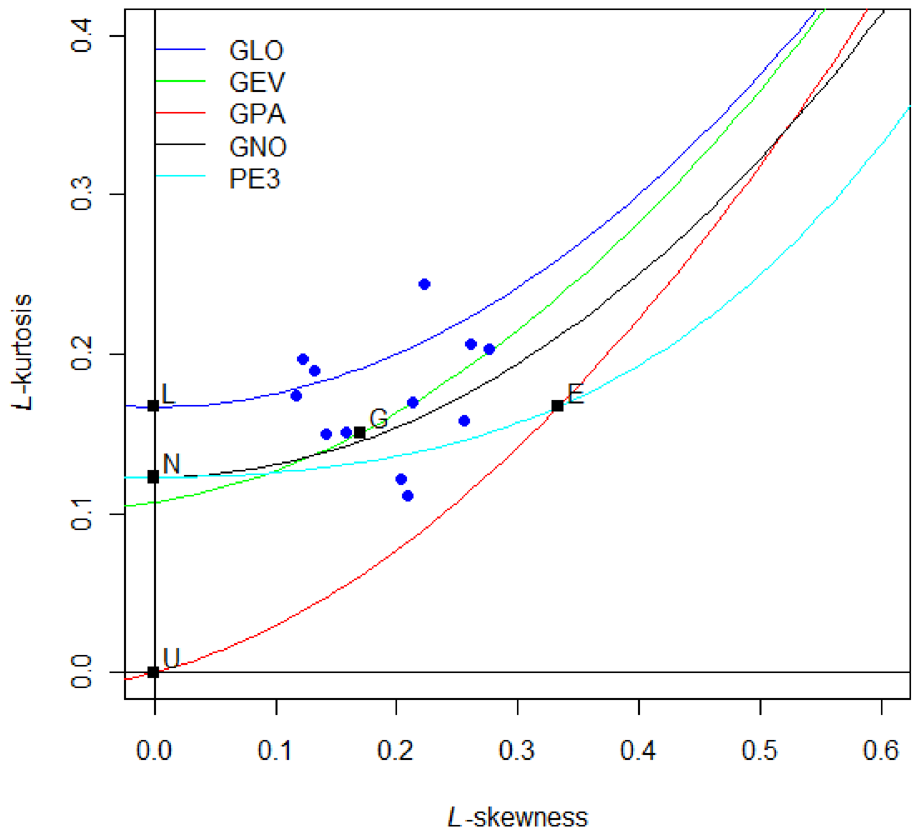
- The GEV distribution has 3 parameters and is described by :

$$X(F) = \varepsilon + \frac{\alpha}{k}\left[1 - (-\ln F)^{k}\right] \quad (k \neq 0)$$

Where ε is the location parameter, α the scale parameter, k the shape parameter and F refers to a given quantile.

The Gumbel reduced varaiate defined by y= - ln(- lnF). Than a growth curve was fitted for each annual maxima series

GEV Distribution



L-moment ratio diagram for the 5, 10, 15, 20, 30, 45, 60, 120, 180, 360, 720 min and 24 hour and theoretical L-moment ratio diagram

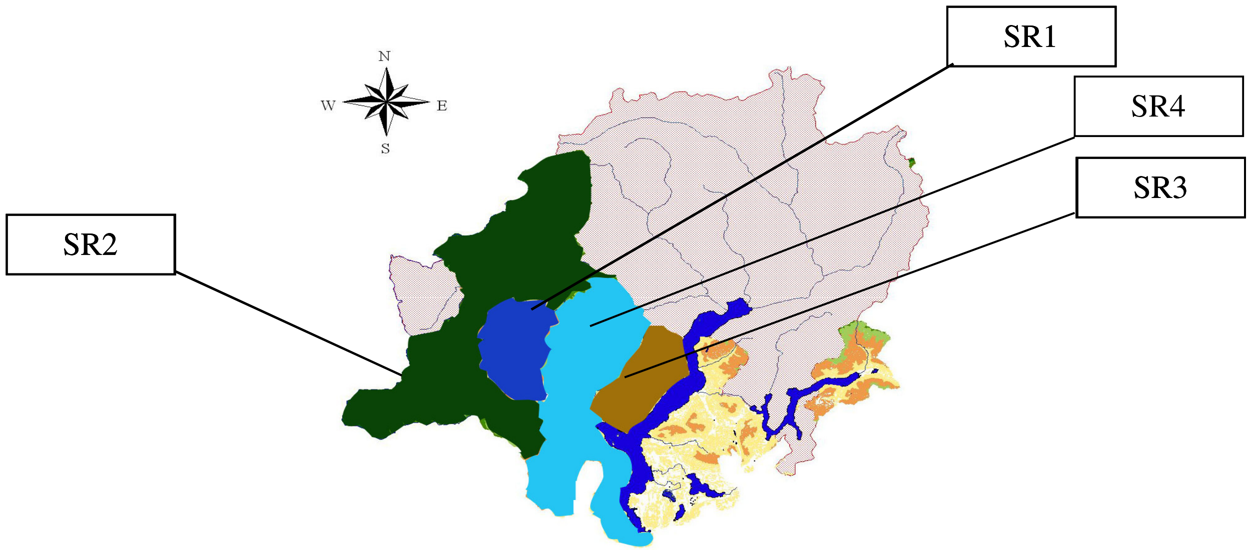
GEV Distribution

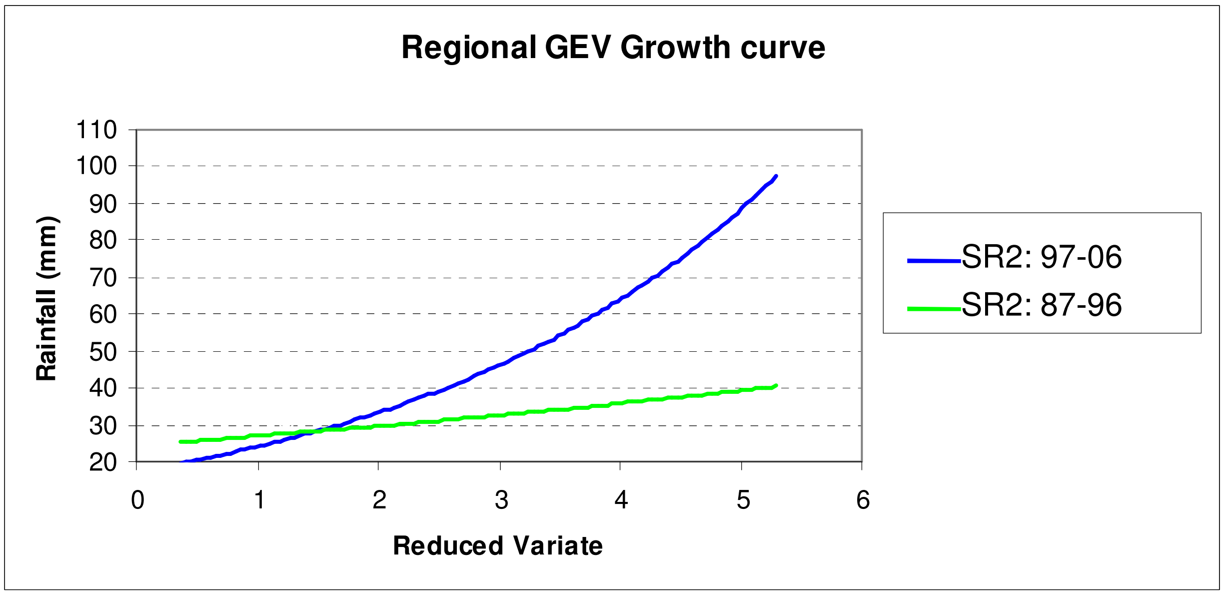
- The L-moment diagrams are useful for discerning grouping of sites with similar precipitation frequency behaviour and identifying the statistical distribution likely to adequate describe this behaviour. The plot shows the L-moment ratio diagram for the all stations in project area. As the sample L-moments, are unbiased, the sample point should be distributed above and below the theoretical line of a suitable distribution. From the diagrams, it appears that the GEV is appropriate for our data.

- **30 Min**

Sub Region	Duration (min)	GEV parameters			L-moment ratios			Kolmogorov – Smirnov Test
		ε	α	k	L_{cv}	$L_{skewness}$	$L_{kurtosis}$	
SR1	30	14.43	4.43	0.21	0.16	0.04	-0.07	0.099
SR2	30	15.03	6.76	-0.05	0.26	0.20	0.11	0.112
SR3	30	22.67	8.04	-0.04	0.21	0.20	0.16	0.063
SR4	30	21.51	8.99	0.11	0.22	0.10	0.15	0.046

Sub Region	Duration (min)	growth factor
SR1	30	$Kt = 14.43 + 1.09*(1-e^{0.21y})$
SR2	30	$Kt= 15.03 -133.2*(1-e-^{0.05y})$
SR3	30	$Kt= 22.67 -3.07*(1-e-^{004y})$
SR4	30	$Kt= 21.51 -1.01*(1-e^{011y})$





Example of temporal changes in 30 min annual maxima precipitation for the Sub-region 2 using 10 year moving window and the fixed decades of 1987-96 and 1997-2006. Growth curve is increasing in gradient for this case.

TCEV Distribution

- The cumulative distribution of the TCEV distribution is the following:

$$F(x) = \exp\left[-\Lambda_1 \exp\left[\frac{-x}{\theta_1}\right] - \Lambda_2 \exp\left[\frac{-x}{\theta_2}\right]\right]$$

Where Λ_1, Λ_2 are the shape parameters and θ_1, θ_2 are the scale parameters, respectively of the basic and outlying components. The TCEV distribution is characterised as the maximum of two indepently distributed extreme value : A “basic” series and “outlier” series.

Introducing the standardized variable $y = (x/\theta_1) - \ln(\Lambda_1)$

$$F(y) = \exp\left[-\exp[-y] - \Lambda^* \exp\left[\frac{-y}{\theta^*}\right]\right]$$

In which $\theta^* = \theta_2/\theta_1$ and $\Lambda^* = \Lambda_2/\Lambda_1^{1/\theta^*}$

The θ^* and Λ^* parameters therefore synthetically represent, at the regional scale, the relationship between the basic and the outlying component.

The growth curve is given by:

$$F(x') = \exp\left[-\Lambda_1 \exp[-\eta x'] - \Lambda_* \left[\Lambda_1^{(1/\theta_*)}\right] \exp\left[\frac{-\eta x'}{\theta_*}\right]\right]$$

TCEV Distribution

- Regional TCEV distribution were fitted to our data using both the L-moments and the Probability Weighted Moments, and compared with a distribution fitted by Maximum Likelihood

Regional TCEV parameter

5 min	TCEV-PWM	TCEV-MLE
θ*	4.922	7.292
Λ*	0.028	0.018
Λ1	10.444	9.583

15 min	TCEV-PWM	TCEV-MLE
θ*	1	1
Λ*	0.174	0.069
Λ1	10.901	9.884

30 min	TCEV-PWM	TCEV-MLE
θ*	0.999	1
Λ*	0.063	0.062
Λ1	10.54	9.741

60 min	TCEV-PWM	TCEV-MLE
θ*	1.724	1.984
Λ*	0.499	1.933
Λ1	10.602	9.525

TCEV Distribution

- The proportion of data values which derive from the outlier series is of interest. This proportion p is given by:

$$p = \frac{\lambda^*}{\theta^*} \sum_{j=0}^{\infty} \frac{(-1)^j}{j!} \lambda^{*j} \Gamma\left(\frac{j+1}{\theta^*}\right)$$

- This series converge rapidly for p<0.9

	5 Min	15 Min	30 Min	60 Min	120 Min	360 Min
outlier probability	0.0003	0.026	0.004	0.107	0.021	0.654

Conclusion

- Regional analysis were performed on high resolution precipitation data from 15 stations across the study area and based on the _moment diagram.

- The study area can be considered as one homogeneous region for some short term rainfall and heterogeneous for others.

- The annual maxima of precipitation data of short duration 5 to 60 min and above can be described by the GEV and the TCEV distribution.

- The PWM and MLE estimators can give quite different parameters estimates when applied to the same data set.

- There are occasion when the TCEV procedure does not reach a solution. This happen when there are very few outliers in the pooled data set.

- Do we really have a changing climate in the Lake Maggiore catchment? the impression from the international literature is that no one has ever found significant non-stationarity in hydrological extreme data and it's may be just a scare story promoted by environmentalists exploiting confusion between the natural phenomenon itself and the cost implications of the consequences of a flood.

Thank you for your attention!

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