# Extreme hydrological events analysis – IDF curves

## Introduction

IDF curves (Intensity − Duration − Frequency curves), which comes from the term ‘curved intensity − duration − return period rainfall’, consist a statistical hydrology tool mainly used in flood defenses design. They are analytical or graphical expressions of the maximum rainfall intensity *i* as a function of the duration of the rainfall event *d* and the return period *T*. More details on the use of IDF curves, one can find in the majority of hydrology textbooks (e.g. Koutsoyiannis and Xanthopoulos, 1999).

The development of IDF curves from rain gauge measurements may be carried out into two stages, which in Hydrognomon come in the form of two distinct subsystems. The first step is to derive the time series of annual maximum mean intensities *ijl* for a broad range of aggregation durations such as *dj* = {5min, 10min, 30 min, 1h, 2h, 6h, 12h, 24h, 48h, which are obtained from the time series of the rainfall measurement (‘Extremes Evaluation’ subsystem in Hydrognomon). These samples *ijl* are used in the second stage of the procedure in order to develop the final IDF curves (‘Ombros’ subsystem in Hydrognomon).

The implementation of a coherent methodology that enables a single mathematical expression for the IDF curves *i*(*d*, *T*) is suggested. Additionally, it is also proposed to use a statistical distribution with EV−2 characteristics and the L−moments method for the estimation of its parameters (in contrast to the classical approach of EV−1/Gumbel fit and the common method of moments for the parameter estimation). However, the conventional methodology for estimating IDF curves in specific return periods is also given.

## Estimation of monthly – annual maximum mean intensities

The procedure of obtaining the monthly/annual maximum intensities (from this point the term ‘mean’ will be omitted) is a simple computational process of aggregation and detection of the maximum value. In general, this process initiates from a precipitation time series with a smaller time step, e.g. five-minute, ten-minute, hourly or in some cases daily. However in Hydrognomon the initial time step of the sample is restricted to ten-minute, hourly or daily.

More specifically, monthly maxima is better suited to the development of seasonal statistics tables, rather than the development of IDF curves; for the later, annual maxima time series are required (defined in hydrological-year format). If however, monthly-maxima time series are the only ones available, then they can be easily transformed to annual-maxima time series by the aggregation procedure described in Section 4.3. Notably, if the maxima time series are to be used exclusively for the development of IDF curves then obtaining directly the annual maxima from the sample is suggested, in order to avoid any marginal values errors.

The computational process to obtain the maxima is rather simple. If *δ* is the discreteness of the sample time series (essentially the time step: ten minute, hourly or daily), then a maxima time series of duration *d* will be drawn, where *d* is an integer multiple of *δ* (*n*×*δ*; *n* is a positive integer). This can be achieved by the application of a moving ‘time-window’, with dimensions *d*=*n*×*δ*, to the sample time series. This time-window goes through the whole series, aggregates the rainfall values and estimates a precipitation height *h* for any of given position. Then, the maximum value *h* is chosen, for each month or year, depending on the time step of the maxima series (monthly/annual). It must be underlined though that, the starting point of the time-window may move to the last of the rainfall values of the month/year aggregated, and thus values of the succeeding time step may be added. This means that the obtained maximum value might include values ​​contained in two consecutive time steps.

The maxima time series, *h*, for a specific duration *d*, can be easily transformed to maximum rainfall intensities *i*, by dividing *h* with *d.* However, in Hydrognomon the user may keep the format of maximum heights as the final output.

Although the whole process is fairly simple, special attention should be given to the existence of missing or marginal values. The user should use the flagging option (see Section 2.5) in order to outline the mean values that were estimated from samples with deficient records (MISSING flag), while a time series with the exact percentage of missing values is also (optionally) provided in a separate column. Accordingly, if the mean is drawn from a time window that borders to a period of missing values, the SUSPECT flag is raised, which means that the actual mean could be larger than the one estimated. This information is necessary in the case of transition from monthly to annual time series.

## Checks – Extrapolations/Deductions?

### Time series consistency check

The time series which are used for developing IDF curves should be checked for consistency. More specifically:

When the duration *d* is increased, then the maximum heights for each year should also increase: *h*(*d*1)>*h*(*d*2) for *d*1>*d*2

On the contrary, the rainfall intensities should decline if the duration increases: *i*(*d*1)<*i*(*d*2) for *d*1>*d*2.

In the above checks, the possibility of errors is taken into account by the introduction of an error coefficient *ε* = 0.02 (which is multiplied by the duration for the case of the heights). During the consistency check, there is the option for automatic correction of the inconsistent values by ​​equating any two consecutive values ​​of rainfall intensity or height which breach any of the two criteria mentioned above. If there is no consideration over the time series consistency, e.g. in the case of a synthetic time series (such as a time series created from data assembled from different meteorological stations), then this check may be deactivated.

Another check is applied to the minimum number of time series used and is set to 2 (two), when the user tries to define the elements of the denominator *b*(*d*), as described below. However, in the case of setting specifically the elements of the denominator (*η* and *θ*), then the minimum is limited to one time series. This feature is useful when the elements *η* and *θ* are drawn from a sample of a daily time step rain gauge, but then the final IDF curves are compiled from a rainfall time series using *η* and *θ* obtained from a smaller time step rain gauge.

### Time resolution Αναγωγές – Time series above threshold

#### The effect of time resolution

When the maximum intensity time series result from the aggregation of discrete values, underestimation of the actual maximum intensity for the given aggregation time step is observed (Koutsoyiannis, 1997). The closer the rainfall duration is to the temporal resolution, the greater the underestimation is. In order to remove the discretization error, a coefficient can be used based on the ratio *d*/*δ* (where *d* is the temporal resolution and *δ* the resolution). The coefficient originally suggested by Linsley et al. (1975, p 375) is given the maximum value 1.13 when the time series length is equal to the resolution.

Table 10.1: Sample values of the discretization error removal coefficient

|  |  |
| --- | --- |
| **Duration to resolution ratio (*d*/*δ*)** | **Discretization error removal coefficient** |
| 1 | 1.13 |
| 2 | 1.04 |
| 3-4 | 1.03 |
| 5-8 | 1.02 |
| 9-24 | 1.01 |

The following remarks should be underlined concerning the use of the above correction coefficient:

If samples with both high and low resolution are simultaneously used, then the coefficients should be applied with the appropriate criteria in order to remove the heterogeneity, i.e. higher weights should be used for the lower resolution samples.

If the maximum rainfall time series have been derived from the aggregation of high-resolution time series (e.g. 5 or 10 minutes), then application of the coefficients provides better estimates (weights) of the IDF curves in the small durations.

If the IDF curves are derived from rain gauge sample with daily time step, then a coefficient with value 1.13 should be used; in the opposite case there would be underestimation of the rainfall intensity throughout the whole range of time durations.

The temporal resolution can be individually set for each time series, which is suggested if the time series are obtained from instruments with different time steps. Alternatively, if the resolution is unknown it may not be introduced. In any case, its effect may or may not be taken into account on the following step, i.e. the development of the IDF curves (note that the default system option is not to be taken into account).

**Relationship between annual maxima time series and time series above threshold**

If the return period is small (T<10) then it has been shown that IDF curves derived from time series above threshold are more representative (Koutsoyiannis, 1997, p 287). Most often, however, only the annual maxima time series are available, and thus a relationship is needed in order to approximate the IDF curves derived from series above threshold. If *T* is the return period corresponding to the time series of annual maxima and *T*'’ the return period corresponding to the time series of maxima above threshold, then the following relation links *T* to *T*’:

 10.1

The relationship above can be approximated to precision of two decimal places by the following, simpler one:

*Τ* = *Τ’*+0.5 10.2

Both relationships are meaningful only for 2<*T*<10 and they can be used directly in the IDF curves equations, by replacing *T* with *T’*. This transformation may simplify the expressions of the IDF curves, especially in the case of EV distributions (see Section 10.4). In Hydrognomon the transformation is automatically applied if the corresponding option is selected, which results to slightly higher intensity values for the given durations and return periods.

## Statistical distributions

The statistical distributions which are used in the development of IDF curves by Hydrognomon are a subset of the distributions described in Section 9.4. More specifically, they distributions used are consisted by the group of gamma distributions, the EV maximum type distributions and by the Pareto distribution as well. Their parameters are estimated either by the moments or the L-moments method whenever this is possible, as described in Section 9.2.3. The L-moments method is generally preferable because the distributions refer to extreme hydrological events (see section 9.2.3).

All the types of the distributions used in the development of IDF curves are illustrated in Table 10.2, as well as the available methods for the parameter estimation. The parameters can be estimated either separately for each sample of specific duration *d* (conventional method) or by a sample of merging durations (consistent IDF curves development methods). Furthermore, the relationship between the quantile function *x*(*T*) and the return period *T*, and the unified relationship of the IDF curve (as a result from the merged durations method) is presented in the two last columns of Table 10.2. In the later case the generalized relation is:

*i* = *x*(*T*)/*b*(*d*) 10.3

where *x*(*T*) is the quantile function for the fitted distribution with parameters estimated for the unified sample, while the denominator *b*(*d*) is a relation which contains a constant term *θ* and an exponent *η*, according the following equation:

*b*(*d*) = (*d*+*θ*)η 10.4

The most frequently used distribution for the IDF curves development is the EV1-Max (Gumbel max). However, according to recent findings the distribution of the annual rainfall maxima is better approximated by a EV2-Max type distribution, and thus the GEV-Max distribution is recommended to the user (default option) with a predefined shape parameter *κ*=0.15 (which means that the GEV switches to EV2 type because *κ*>0). Other distribution types can be also examined, by checking the goodness-of-fit of the theoretical distribution to the points of the empirical distribution (see also Section 9).

In order to examine the goodness-of-fit a distribution plotting paper is used (see Section 9.5), which transforms the probability axis (i.e. the return periods). The GEV-Max paper (*κ*=0.15) is the default plotting distribution paper used, in order to match with the default statistical distribution applied in the IDF development and have a linearized illustration of the theoretical distribution. The empirical distribution which is used for the points illustration is the Weibull distribution (see Section 9.3).

Table 10.2: Distributions used in the development of IDF curves in relation to the return period *T*. Generalized IDF curves equations as they result after they division by a term *b*(*d*) (*d*: rainfall duration).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **s/n** | **Distribution** | **Moments method** | **L-Moments method** | **Quantile function in relation to the return period T: *x*(*T*)** | **Unified equation of the *i* IDF curve (intensity) in relation to the return period T and the duration *d*** |
| 1 | Expotential | √ | √ |  |  |
| 2 | Gamma | √ |  |  |  |
| 3 | Log-Pearson III | √ |  |  |  |
| 4 | EV1-Max | √ | √ |  |  |
| 5 | EV2-Max | √ | √ |  |  |
| 6 | GEV-Max | √ | √ |  |  |
| 7 | GEV-Max *(κ* predifened) | √ | √ |
| 8 | Pareto | √ | √ |  |  |

In Table 10.3 there are demonstrated the transformed quantile equations for the EV distributions, when the return period *T’* is used which corresponds to an above-threshold maxima time series. The transformation is made by introducing the expression of *T* in relation to *Τ*’ (Relationship 10.1). The resulting relationships may be alternatively used for small return periods (see Paragraph 10.3.2), which in Hydrognomon may be achieved by y=the simple numerical transformation *T* = *T’*+0.5.

Table 10.3: EV distributions used in the development of the IDF curves for return period *T’* that corresponds to the above-threshold time series of threshold *T’*.

|  |  |  |  |
| --- | --- | --- | --- |
| **s/n** | **Distribution** | **Quantile function in relation to the return period T’: *x*(*T’*)** | **Unified equation of the *i* IDF curve (intensity) in relation to the return period *T*' and the duration *d*** |
| 1 | EV1-Max |  |  |
| 2 | EV2-Max |  |  |
| 3 | GEV-Max |  |  |
| 4 | GEV-Max *(κ* predifened) |

## IDF curves development with the conventional method

IDF curves development is based primarily on consistent methods such as the merging durations method which will be addressed in Section 10.6. For completeness reasons, Hydrognomon also offers the option of deriving IDF curves for a given return period (which is called here as the ‘conventional method’). It should be considered by the user though that this method has the following disadvantages:

There is no single mathematical relationship for the IDF curves of any *d* and *T*.

The curves obtained are not consistent, which means they may intersect for a given duration *d*, which is physically unacceptable.

* These disadvantages do not appear in the consistent methods for extracting.

According to the conventional method, an IDF curve for a given return period is described by the following equation:

 10.5

It can be seen that the simplest form *b*(*d*)=*dη* is used the for the denominator, so that it can be easily estimated by linear regression. The methodology is described in the following steps:

A return period *T* is set for which the curve will be derived.

* A statistical distribution is chosen.
* Supposedly, there are *k* time series of annual maximum and *k* values of duration *di* *(i*=1..*.k*).
* Each time series of a specific duration *di* is regarded as an independent sample. Thus, for each time series the statistical characteristics of the sample are determined and the distribution parameters are adjusted according to the methodology of Chapter 9.
* When the distribution parameters are estimated, a statistical prediction is made for the specific return period *T* set. For this purpose, the percentile relations *x*(*T*) in Table 10.2 may be used.
* Eventually, *k* points [*di*, *xi*(*T*)] will be obtained; one for each time series. If these points are placed in a double logarithmic paper then they follow a straight line in a very close approximation. Thus, the application of simple linear regression (see Chapter 7, as well as Section 3.3) to the points x*i* = ln *di*, y*i*= ln *xi*(*T*)] results to a fitted line of type:

*y* = *ax*+*b* 10.6

Finally, the  IDF curve parameters for the *T* which was set are estimated by the relations:

 and *η* = -*b* 10.7

The values available to the user are the values of *ω* and *η*, as well as the goodness-of-fit determination coefficient.

## IDF curves development with the merging durations method

This methodology, suggested by Koutsoyiannis (1997, p. 270), allows the determination of a single mathematical expression for the IDF curves in relation to duration *d* and the return period *T*. For the determination of this expression the equations demonstrated in the last column of Table 10.2 may be used. However, the methodology described below requires a long series of several calculations and therefore its application in a software system is advantageous.

The denominator *b*(*d*)=(*d*+*θ*)*η* (*d*, *θ* e.g. in hours) is estimated by an exhaustive testing process. Specifically, the hypothesis is made for the control values ​​ *η* and *θ* and a statistical index *h* is calculated. After a number of trials for different *η* and *θ*, the pair of values that minimizes the statistical indicator *h*, is selected. So the derivation of the IDF curves will be roughly divided into the following two stages:

Determination of the values of the denominator *b*(*d*) *η* and *θ*

Determination of the distribution parameters (π.χ. *κ*, *λ* and *ψ*) for the merged sample.

### Merging durations – estimation of *η* and *θ*

Consider that the parameters *η* and *θ* are known. It will be shown how a statistical parameter *h* is calculated in relation to the rainfall samples and the denominator parameters. The optimal values *η* and *θ* derive from the minimization of this statistical parameter *h*.

If there are *k* time series of annual maxima with durations *dj*, *j*=1..*k* and sample sizes *nj* then it is possible to merge them into a sample with size:

 10.8

To merge the samples, each of the time series *ijl* is multiplied by *b*(*dj*)=(*dj*+*θ*)η: *yjl*=*ijlb*(*dj*), and then all of them are used as the new sample. This sample should be sorted in descending order, but in this step it is suggested to use only a subset of the data because in this manner the function *b*(*d*) is better fitted in the area of the higher intensities. Thus, initially each time series is sorted separately and only a partition of its highest values is taken to create the merged sample (the default value in Hydrognomon is 1/3). In this manner *m* may become smaller depending on the percentage drawn from the original samples which may vary from 10 to 100%.

The influence of this percentage in the final results is not significant and therefore it is suggested to use the default value.

For smaller samples a reduction of this percentage is made: if the percentage chosen is *ρ* and the maximum number of values from the times series is *n*max = max(*nj*), then the final percentage *q* is:

 10.9

When the *q* *nj* maximum values of each value have been chosen the size of the merged sample should be:

 10.10

Once the merged sample is sorted in descending order, a single rank is assigned to each value in ascending order, i.e. 1 to the highest value, 2 to the next, etc. If two sample values are identical then the mean of the corresponding ranks is used. Finally, the mean of each time series’ ranks is estimated separately:

 10.11

where a percentage of *q* *nj* is used instead of *nj*. If all the individual samples had the same distribution, then each  would have been very close to the value (m+1)/2. To achieve this goal, and eventually estimate the optimal values of *η* and *θ*, the statistical parameter *h* of the Kruskal-Wallis test is used:

 10.12

This statistical test examines the mean ranks of all the individual samples and the minimization of *h* is achieved after an exhaustive testing process. In Hydrognomon a 31x31 matrix is used for the estimation of the values *η* and *θ*, which range in the space (0,1). When the optimal combination *η*, *θ* is determined then a new 31x31 matrix is formed centered on this pair of values. This new matrix dimensions are 1/32x1/32 in order to have a better approximation of the optimal solution (third decimal place). Hence, a total of 1922 trials is required to derive the final values.

As an example for the algorithm’s efficiency, a comparison between the values of *η* and *θ* determined by Hydrognomon software (using the 1/3 of maxima) and Koutsoyiannis (1997, p. 280) for the station of Ellinikon (sample data demonstrated in Table 10.4). There is only a slight difference of magnitude about 1% in the findings of the two approaches, as Hydrognomon estimates *η*=0.792 and *θ*=0.186, while in the textbook *η*=0.796 and *θ*=0.189.

Πίνακας 10.4: Measured annual maximum rainfall at Ellinikon meteorological station (Source: Hellenic National Meteorological Service).

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Hyd. | Maximum rain intensity *i* (mm/h) for duration *d*= | | | | | | | |
| year | 5min | 10min | 30min | 1h | 2h | 6h | 12h | 24h |
| 1957-58 | 81.60 | 66.00 | 53.20 | 35.00 | 26.90 | 8.97 | 6.27 |  |
| 1958-59 | 58.80 | 48.00 | 33.00 | 21.50 | 11.20 | 6.75 | 3.98 |  |
| 1959-60 | 39.60 | 34.80 | 20.00 | 11.60 | 6.85 | 2.40 | 1.82 |  |
| 1960-61 | 54.00 | 34.80 | 18.40 | 11.00 | 6.65 | 3.62 | 2.28 |  |
| 1961-62 | 120.00 | 85.80 | 41.80 | 24.80 | 19.30 | 7.32 | 3.73 |  |
| 1962-63 | 67.20 | 60.00 | 23.60 | 13.80 | 7.20 | 3.03 | 1.94 |  |
| 1963-64 | 78.00 | 48.00 | 27.80 | 14.30 | 8.50 | 3.52 | 2.72 |  |
| 1964-65 | 96.00 | 63.00 | 28.00 | 15.50 | 10.65 | 4.28 | 2.17 |  |
| 1965-66 | 38.40 | 36.00 | 23.00 | 12.00 | 6.55 | 2.45 | 1.69 |  |
| 1966-67 | 74.40 | 63.60 | 28.40 | 15.10 | 7.55 | 4.88 | 2.46 |  |
| 1967-68 | 36.00 | 24.60 | 16.60 | 10.20 | 6.65 | 3.65 | 2.75 | 1.58 |
| 1968-69 | 126.00 | 69.00 | 43.20 | 26.80 | 15.15 | 5.93 | 2.97 | 1.48 |
| 1969-70 | 82.80 | 64.20 | 41.60 | 24.50 | 12.45 | 5.45 | 2.75 | 1.76 |
| 1970-71 | 42.00 | 42.00 | 25.20 | 17.70 | 8.95 | 3.70 | 3.09 | 1.55 |
| 1971-72 | 117.60 | 85.20 | 65.20 | 35.90 | 19.75 | 10.02 | 5.01 | 2.92 |
| 1972-73 | 68.40 | 49.80 | 39.40 | 33.50 | 17.75 | 6.78 | 5.27 | 2.68 |
| 1973-74 | 60.00 | 42.00 | 28.60 | 15.20 | 9.85 | 4.20 | 3.47 | 2.00 |
| 1974-75 | 48.00 | 48.00 | 30.60 | 15.90 | 8.30 | 4.27 | 2.60 | 1.30 |
| 1975-76 | 120.00 | 120.00 | 74.00 | 40.90 | 21.50 | 7.38 | 4.54 | 2.27 |
| 1976-77 | 115.20 | 87.60 | 41.40 | 23.20 | 14.90 | 6.12 | 3.30 | 1.65 |
| 1977-78 | 56.40 | 46.20 | 38.60 | 32.70 | 20.15 | 6.73 | 3.37 | 1.68 |
| 1978-79 | 78.00 | 66.60 | 47.60 | 30.00 | 19.55 | 11.93 | 6.12 | 3.37 |
| 1979-80 | 67.20 | 40.80 | 17.20 | 13.30 | 8.60 | 4.22 | 2.81 | 1.62 |
| 1980-81 | 58.80 | 56.40 | 30.40 | 19.40 | 11.10 | 5.58 | 3.27 | 1.95 |
| 1981-82 | 67.20 | 64.80 | 40.60 | 24.70 | 13.05 | 4.35 | 2.28 | 1.14 |
| 1982-83 | 141.60 | 79.80 | 49.60 | 36.20 | 22.90 | 7.63 | 4.52 | 2.29 |
| 1983-84 | 102.00 | 69.00 | 50.40 | 29.00 | 17.70 | 7.03 | 3.63 | 1.82 |
| 1984-85 | 40.80 | 31.80 | 16.40 | 12.90 | 12.15 | 9.87 | 6.00 | 3.40 |
| 1985-86 | 74.40 | 66.00 | 29.20 | 15.60 | 9.40 | 3.13 | 1.57 | 0.83 |
| 1986-87 |  |  | 32.20 | 29.10 | 18.55 | 9.50 | 7.24 | 3.85 |

Finally, there is the option to determine if each time series shall be used separately for the estimation of *η* and *θ*, or for the distribution parameters, or for both estimations. For example, *η* and *θ* may be extracted from 10-min time series, whereas distribution parameters may be derived from longer duration time series (i.e. 12, 24 or 48 h). There is even the option to set explicit values, if there is some prior knowledge for *η* and *θ* from other empirical studies (see also Koutsoyiannis 1997, p. 284).

### Determination of the distribution parameters

The final step in the development of IDF curves is to estimate the parameters of the statistical distribution adopted. The final merged sample *yjl* results from the multiplication of *ijl* with *b*(*dj*) = (*dj*+*θ*)η, i.e. *yjl* = *ijl b*(*dj*), and its statistical characteristics are then used in the determination of the distribution parameters. Again, the paradigm from Koutsoyiannis (1997, p. 282) comes handy in order to check the algorithm’s efficiency. The values demonstrate only a slight difference for the EV1-Max (Weibull) distribution: *λ*=7.962 and *ψ*=2.652 versus *λ*=7.95 and *ψ*=2.64 (which accounts for rounding errors). Implementation of GEV-Max (L-moments) with *κ*=0.15, which is the suggested (default) option, gives respectively: *λ*=7.04 and *ψ*=2.88.



Figure 10.1: IDF curves for return periods *T*=5, 10, 50, 500, 5000 at the Ellinikon meteorological station, derived by a robust unified equation and EV1-Max statistical distribution



Figure 10.2: Goodness-of-fit check by depicting simultaneously both the distribution functions Gumbel-Max (straight lines) and Weibull (empirical distribution points).

### Confidence intervals of IDF curves

After fitting the distribution parameters, the confidence intervals of any given IDF curve that corresponds to a return period *T* (or non-exceedance probability *u*=1-1/*T)* are easily estimated both for the sample and the population. To that end the methodology described in Section 9.7 (Monte-Carlo) is used to determine the confidence intervals *x*L και *x*U of *x*(*T*) at a specific location. Eventually, the confidence intervals for the IDF curve *i*=*x*(*T*)/*b*(*d*) shall be:

 10.13

Essentially, there are two "confidence IDF curves" that define the confidence intervals of the curve *i* for a given *T*. However, the problem difficulty lies in the assumptions about the sample size (Koutsoyiannis, 1987, p 289). If the sample size taken is the merged sample size *m* then confidence interval would be very small. Furthermore, this assumption is not mathematically correct as the sample is derived from the individual samples and hence demonstrates strong statistical dependence. In Hydrognomon the sample size *nm* is obtained from the mean of the full samples of the time series (an assumption that gives relatively large confidence intervals):

 10.14

In Figure 10.3 an application based on the example shown above is illustrated for return period *T* = 50. It is evident that there is almost no difference between the confidence intervals of the sample and the population; this is strongly affected by the use of logarithmic axes which mitigate the actual difference.



Figure 10.3: The 95% confidence intervals of the IDF curve for return period *T*=50. The EV1-Max (Gumbel) distribution was used in the sample from Ellinikon station.