EU COST Action ES0901: European Procedures for Flood Frequency Estimation (FloodFreq)

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WG2: Assessment of statistical methods for flood frequency estimation

Review of existing statistical methods for flood frequency estimation in Greece

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FLOODFREQ COST Action ES0901
European Procedures for Flood Frequency Estimation

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Research on statistical methods in Greece

- **Statistical modelling of rainfall**
  - Construction of intensity-duration-frequency curves
  - Selection of appropriate distribution functions for extreme rainfall
  - Revision of the concept of Probable Maximum Precipitation
  - Entropic-stochastic representation of rainfall intermittency
  - Multivariate stochastic rainfall models
  - Multifractal models
- **Regionalization approaches**
- **Statistical software**
  - Hydrological data processing and analysis (Hydrognomon)
  - Stochastic disaggregation of fine-scale rainfall (Hyetos)
  - Multivariate disaggregation of rainfall (MuDRain)

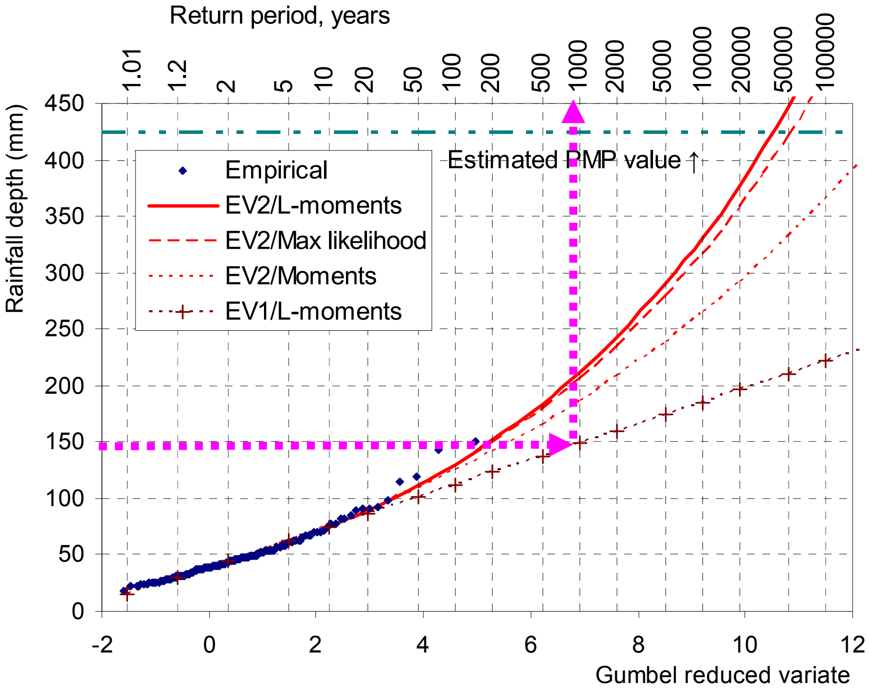
Construction of IDF curves

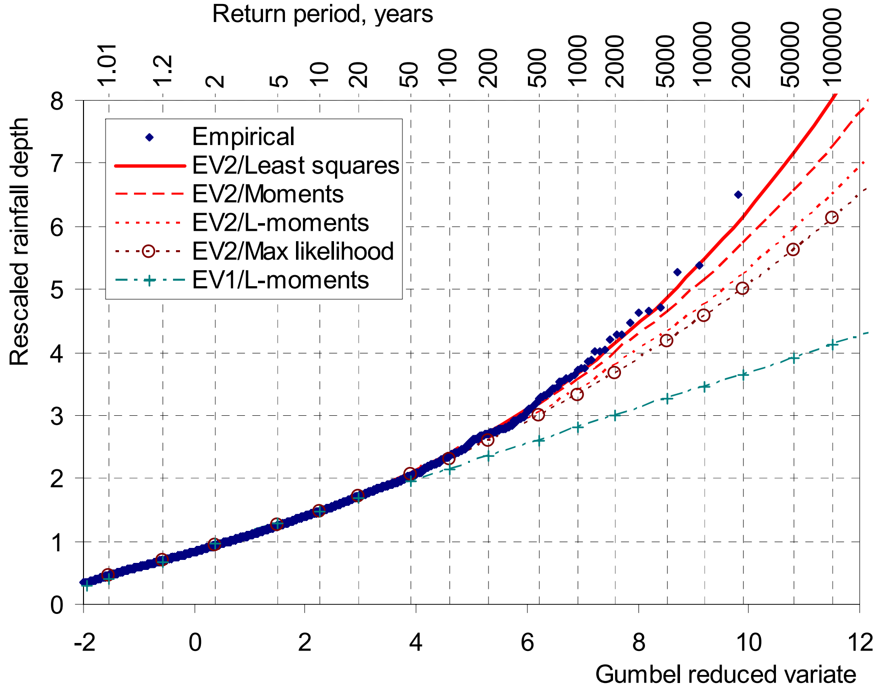
- Major tool in hydrological design – mathematical relationships for estimating the average rainfall intensity i, over a given time scale d ("duration") and for a given return period T ("frequency").
- Since only the distribution tail is of interest and that range of scales of interest is relatively narrow, the following assumptions are made:
  - the influences of the return period and time scale are separable, thus $i(d, T) = a(T) / b(d)$, where $a(T)$, $b(d)$ are mathematical expressions to be determined;
  - the use of the Pareto distribution for the rainfall intensity over some threshold at any time scale provides a simple expression for $a(T)$;
  - $b(d)$ is written in the simple form $(1 + d/\theta)^{\eta}$, where θ, $\eta > 0$ are parameters, whose consistent estimation is employed through specific algorithms.
- Additional advantages of the proposed framework:
  - it constitutes an efficient parameterisation, thus facilitating the description of the geographical variability and regionalisation of idf curves;
  - it allows for incorporating data from non-recording rainfall stations (with 24h and 48h rainfall depths), thus remedying the problem of establishing idf curves in places with a sparse network of rain-recording stations.

Selection of appropriate probability distributions for extreme rainfall

- Prevailing (grace to its simplicity, analytical estimation of parameters) model of extremes in hydrological practice: EV1 (Gumbel).
- The Gumbel distribution results in significantly lower risk for $T > 50$ years, if compared to EV2; for $T > 1000$ years, the return periods estimated by the two methods may differ orders of magnitude.
- Comparisons of actual and asymptotic extreme value distributions, as well as on the principle of maximum entropy, indicated that the three-parameter Generalized Extreme Value (GEV) Type 2 distribution should replace the Gumbel distribution.
- Analysis of a large number of datasets worldwide indicated that the shape parameter of the EV2 distribution is constant for all examined geographical zones (Europe and North America), with value $\kappa = 0.15$.
- Actual research is focused on distributions with good performance for all time scales (from few minutes to annual), e.g. the three-parameter Burr type VII.

EV2 vs. Gumbel distribution





- Annual maximum daily rainfall of Athens, National Observatory, Greece
- 143 years (1860-2002)
- Maximum observed value 147 mm
- Estimated return period of PMP (= 424 mm) from 37 000 to 300 000 years (EV2 method) and 4×10^{10} (Gumbel).

- 169 stations from Europe and North America (6 major climatic zones)
- Record lengths 100-154 years
- 18 065 station-years in total
- Hypothesis of constant dimensionless shape and location parameters (κ, ψ)
- Rescaling of each records by its mean

The concept of PMP

- The Probable Maximum Precipitation (PMP) method has been widely used for the design of major flood protection works, to which a very large (theoretically infinite) return period should be considered.
- The concept is based on the following assumptions: (a) there exists an upper physical limit of the precipitation depth over a given area at a particular geographical location at a certain time of year, and (b) this limit can be estimated based on deterministic considerations.
- It is proved that the sample of maxima events, analysed by Hershfield (1961), which is the basis of the PMP hypothesis, do not support the hypothesis of an upper bound in precipitation; rather it is consistent with the EV2 distribution with $\kappa = 0.13$ ($\kappa = 0.15$ is also acceptable).
- The PMP is typically estimated through the moisture maximization method, which uses historical records of dew points; however, there is any evidence of an upper bound either in moisture or precipitation.
- A probabilistic approach is more consistent to the natural behaviour and provides better grounds for estimating extreme precipitation.

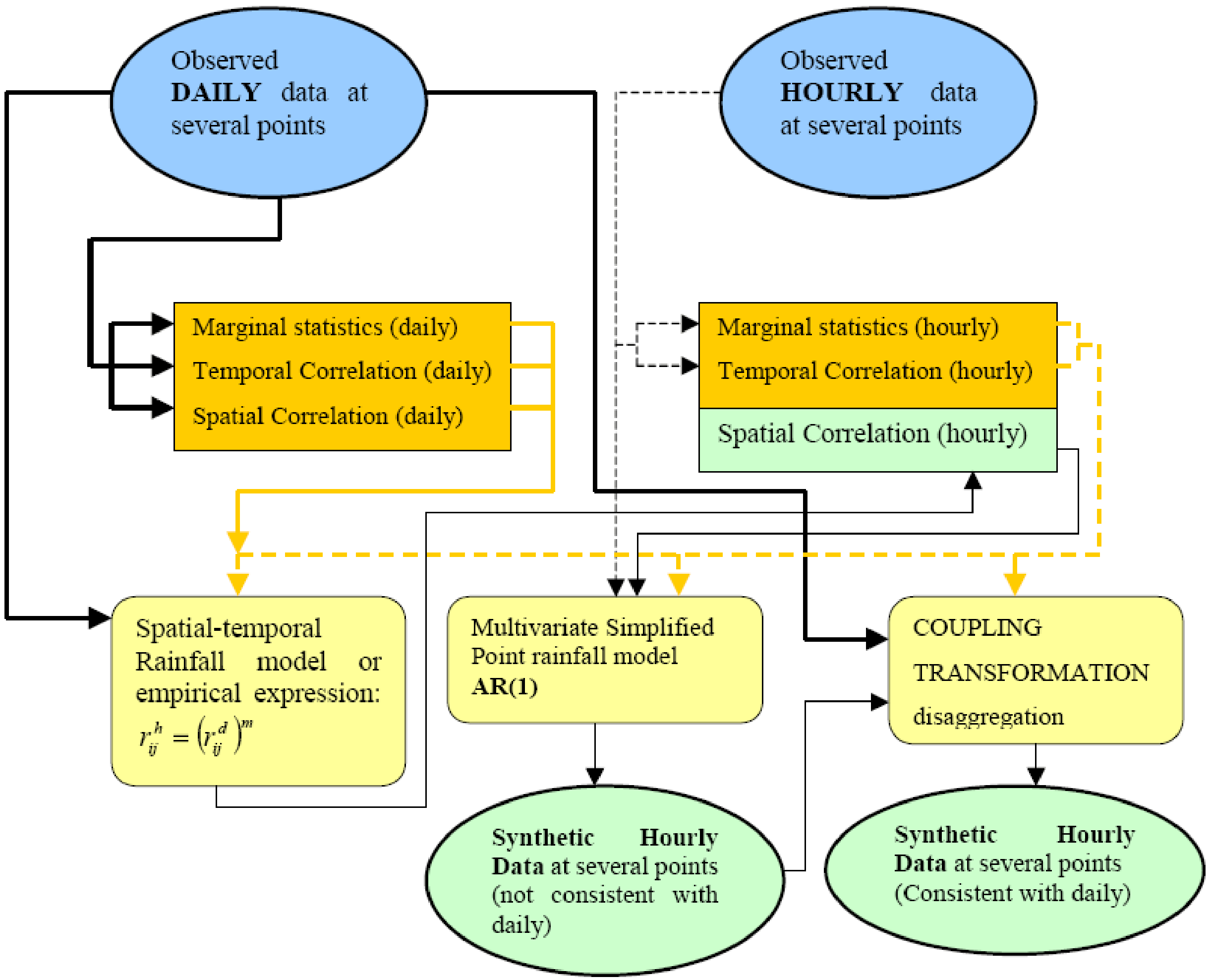
Multivariate stochastic rainfall models

- Stochastic rainfall modelling is the only approach ensuring a faithful representation of the essential statistical properties (e.g. variability, auto- and cross-correlation) of rainfall across the temporal and spatial scales of interest, thus avoiding simplified-empirical (and usually inconsistent) assumptions of the common engineering practice.
- Areas of application of stochastic models:
  - Enhancement of historical daily rainfall series, guided by hourly rainfall data at a single rain gauge.
  - Temporal disaggregation of rainfall, i.e. synthesis of finely resolved storm hyetographs, for given total characteristics (duration, depth);
  - Flood simulation under multiple precipitation events, with common statistical characteristics, instead of using a single design storm;
- Innovative methodologies are developed and implemented within software tools **Hyetos** (stochastic disaggregation of fine-scale rainfall, based on the Barlett-Lewis approach) and **MuDRain** (multivariate disaggregation of rainfall).

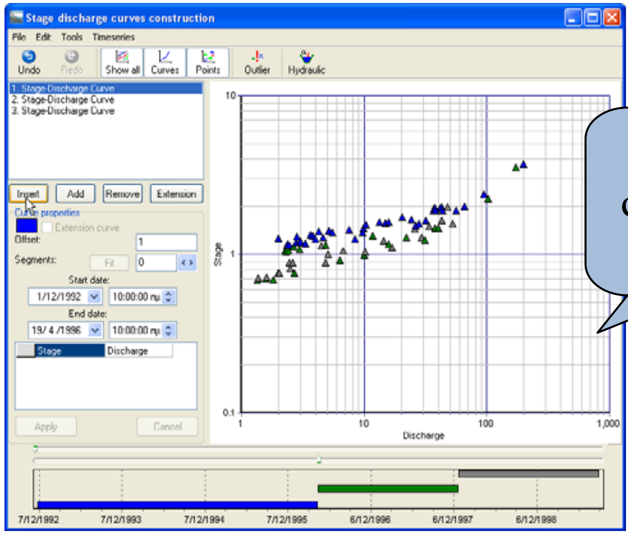
Regionalization studies

- Few approaches, due to the limited flow data.
- Mimikou and Gordios (1989) examined the spatial variation of the mean annual flood of both mean daily and instantaneous extremes and the variation of the parameters of the EV1 distribution for catchments in the NW and W regions of Greece, using multiple regression techniques with physiographic and climatological characteristics of the catchments.
    - Characteristics: drainage area, mean annual areal precipitation, stream frequency, main stream slope and length, intensity of the one-day rainfall of five-year return period, and a soil type index;
    - Estimation of annual flood frequency curves and flood quantiles.
- Mimikou *et al*. (1994) uses five nomographs in which flood and storm characteristics are associated. Design flood peak and volume values were derived, once the return period, storm duration and depth had been determined.

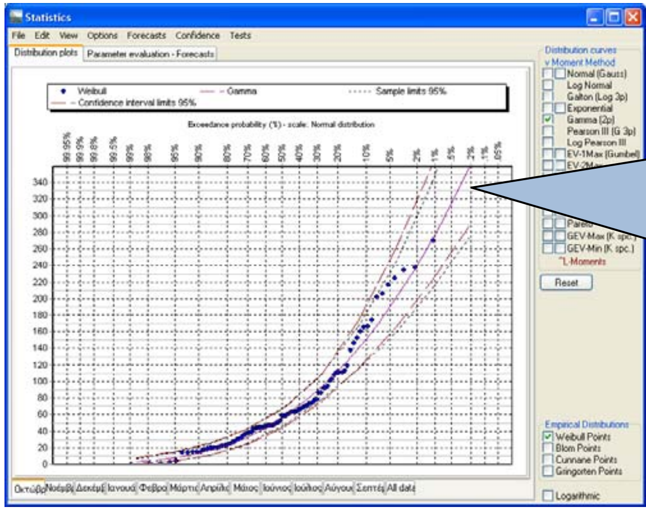
Outline of the modelling scheme implemented within MuDRain



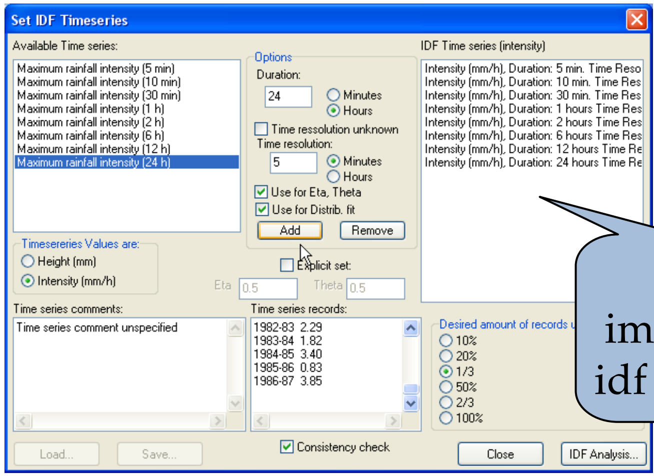
Hydrognomon: General-purpose tool for hydrological data processing and analysis



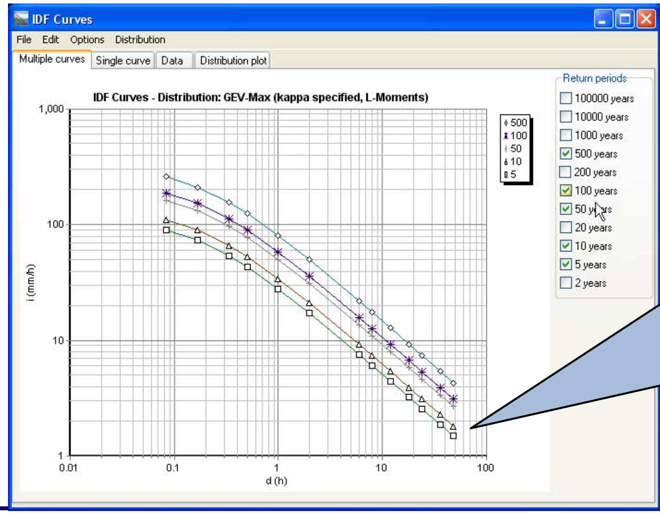
Stage-discharge analysis



Fitting of empirical and theoretical distribution functions



Data import for idf analysis



Construction of ombrian (idf) curves for various return periods

Relevant papers

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Software links

- **Hyetos (academic edition)**

  http://www.itia.ntua.gr/en/softinfo/3/

- **MuDRain (academic edition)**

  http://www.itia.ntua.gr/en/softinfo/1/

- **Hydrognomon (operational edition)**

  http://hydrognomon.org/