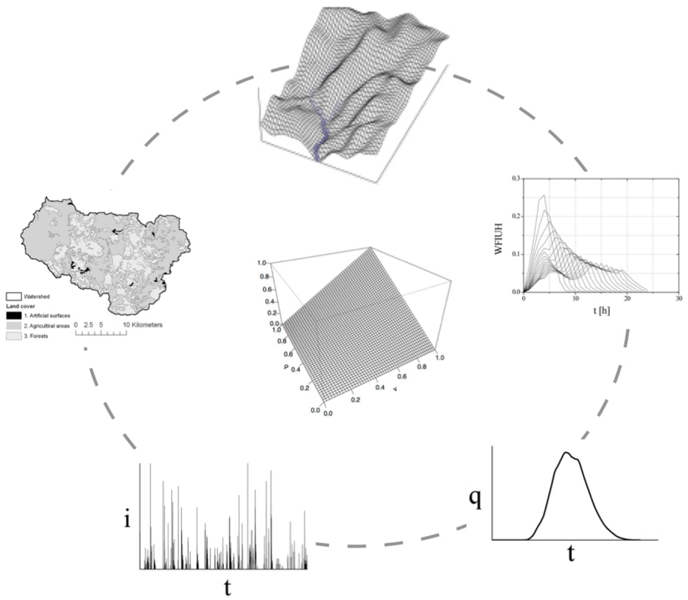

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HOW TO COMMUNICATE STATISTICS TO THE HYDROLOGICAL COMMUNITY/PRACTICE PARTNERS

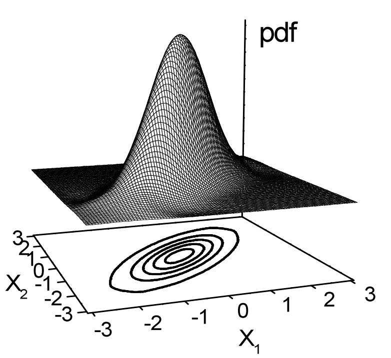
EARLY CAREER COURSE

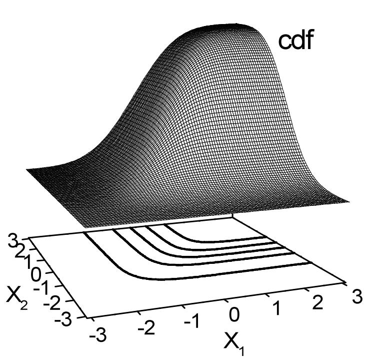
Salvatore Grimaldi

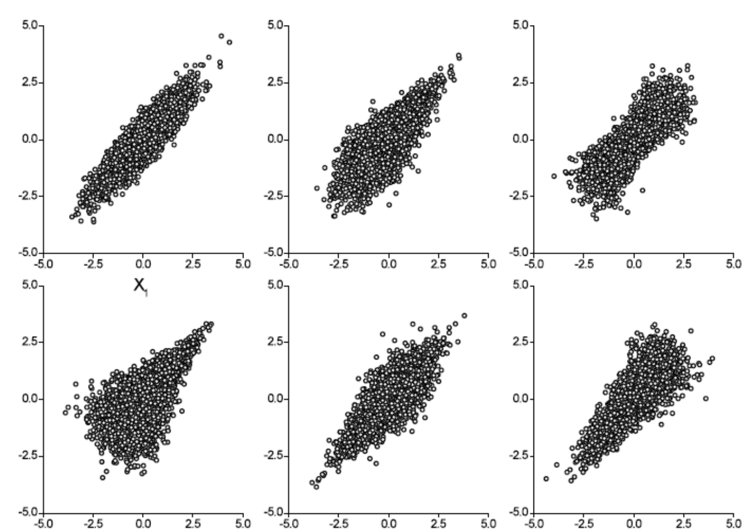
Università della Tuscia, Viterbo, Italy

SUMMARY

- My relationship with statistical hydrology
- Topics, papers, and divulgation
- Vision for the future and suggestions







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My relationship with statistical hydrology

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1998-2000 - PhD thesis on liner parametric models (ARMA, FARMA, Hurst effect)

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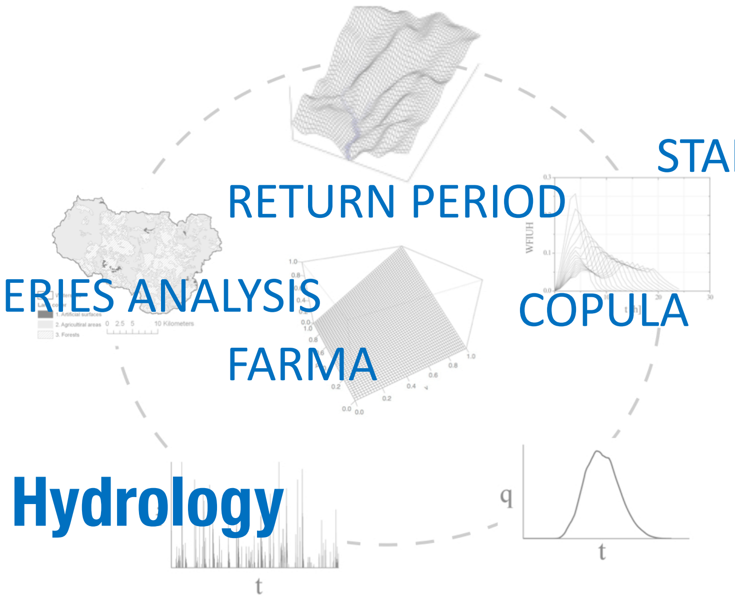
2006 - my first paper on Copula for hydrological applications

2008 - attracted by experimental hydrology and sensoring

2010 - my first paper on experimental hydrology

My research interests



Statistical Hydrology

RETURN PERIOD

TIME SERIES ANALYSIS

COPULA

FARMA

STAHY

ICSH

COSMO4SUB

GISTAR

WFIUH-1par

EBA4SUB

GFPLAIN250m,

PEM4PIT

CN4GA

GIS Terrain Analysis Research

GIS Terrain Analysis - Hydrology in Ungauged Basins

Experimental Hydrology

CAPE FEAR

GAUGE CAM

LSPIV

PTV

GIANT RAINGAUGE

DRONES

MOXXI

FLUORESCENT PARTICLES

CandHy
Citizen and Hydrology
IAHS-WG

CANDHY

MOXXI Measurements & Observations in the 21st Century

Working Group - International Association of Hydrological Sciences

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Topic 1 - Time series analysis
FARMA - Seasonal Component, Hurst parameter

$$\phi(B)\nabla^d X_t = \theta(B) a_t \qquad d = H - 0.5;$$

$$d(X_t, Y_t) = \sqrt{\sum_{j=1}^{\infty} (\pi_{jx} - \pi_{jy})^2}$$

Linear Parametric Models Applied to Daily Hydrological Series

Salvatore Grimaldi[1]

Abstract: The aim of this paper is to describe, and solve in same cases, the problems that arise in hydrological daily time series modeling developed via linear parametric models. The preliminary analysis, the identification, and the simulation steps of the standard procedure are thoroughly studied. The effects of Box and Cox transformation are commented on, a procedure to smooth the seasonal component is described, and a new technique for the initial parameter estimation of fractional models is introduced and tested. The revised procedure was applied to the time series of Tevere daily flows.

DOI: 10.1061/(ASCE)1084-0699(2004)9:5(383)

CE Database subject headings: Time series analysis; Simulation models; Auto-regressive moving-average model; Seasonal variation; Hydrological models.

Introduction

To analyze hydrological processes, the use of statistical tools is needed. In fact, the complexity of hydrological phenomena does not allow us to develop deterministic forecast or management systems. Therefore, an approach that overlooks the physics of the problem and only uses the observed data information is helpful.

In this perspective, the time series parametric modeling has had, and still has, an important role in hydrological analysis. The possibility to identify the dynamic component of a signal fostered the development of simulation and forecast procedures.

In the water resources management, there are different applications based on the use of scenarios similar to the real one obtained by generating synthetic series.

In the last years, interesting results were obtained by the use of the simple linear parametric models (LPMs) applied with annual or monthly aggregation scales. Here by LPM we mean all the family of linear models that, starting from the Box and Jenkins (1976) definition, is increased with the creation of many model subtypes. In fact, from the simple autoregressive moving-average model (ARIMA) model we obtained (periodic autoregressive moving-average), Seasonal ARMA, fractional ARMA (FARMA), seasonal fractional ARIMA, contemporaneous ARMA, space–time ARMA), etc. [for a description of these models see Hipel and McLoad (1994) and Montanari et al. 2000], that in any case are linear models and they roughly follow a common procedure to be built.

Perhaps, by extending the modeling to series with daily aggregation scale, potential applications concerning the water resources management will be more widespread and useful. The daily series not only gives the desired information with more details, but statistically it also makes more numerous samples available, providing a more consistent parameter estimation of the identified model. However this type of series shows that the problem has larger variability that makes it difficult to conform to the stochastic processes basic hypotheses.

Consequently, the traditional procedure, developed above all for hydrological applications with annual and monthly series, has to be modified in order to be related to model daily series.

The aim of this paper is to study the methodological problems present in the analysis of hydrological daily series and to suggest some improvements. In the following paragraphs, every standard procedure step is synthetically described highlighting the problems to solve.

From the main references about this topic (Box and Jenkins 1976; Brockwell and Davis 1987; Piccolo 1990a; Salas 1993; Bras and Rodriguez-Iturbe 1994; Hipel and McLoad 1994) it is possible to resume the LPM modeling standard procedure in the following steps called: "Preliminary Analysis, Identification, Estimation, Verification, Optimal Model Chosen."

The "Preliminary Analysis" is the step by which the analyst usually checks that the basic conditions are followed. In fact, in order to apply a LPM, the series has to be schematized as stochastic processes. The main hypotheses of these processes are the Gaussian distribution and the stationarity condition. Usually, the observed series are not exactly Gaussian or stationary; therefore to overcome the eventual distortions in the procedure some transformations are suggested. As for the distribution, the Box and Cox (1964) formulas were largely described and recommended. Regarding the stationarity, the attention is focused mainly on the seasonal behavior of the subannual series. In the literature, some different approaches to rise above this problem were introduced (Kottegoda 1980; Hipel and McLeod 1994).

During the "Identification" step, the preliminary parameter estimation of the hypothesized model configurations is made. For a very simple configuration, this step could be neglected because the improved estimation techniques no longer need the initial values. For more complex configuration and for particular models, like the fractional models, this step remains important. Moreover, during the identification step, some procedures to verify whether

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Note. Discussion open until February 1, 2005. Separate discussions must be submitted for individual papers. To extend the closing date by one month, a written request must be filed with the ASCE Managing Editor. The manuscript for this paper was submitted for review and possible publication on February 7, 2003; approved on January 11, 2004. This paper is part of the ***Journal of Hydrologic Engineering***, Vol. 9, No. 5, September, 2004. ©ASCE, ISSN 1084-0699/2004/5-383–391/$18.00.

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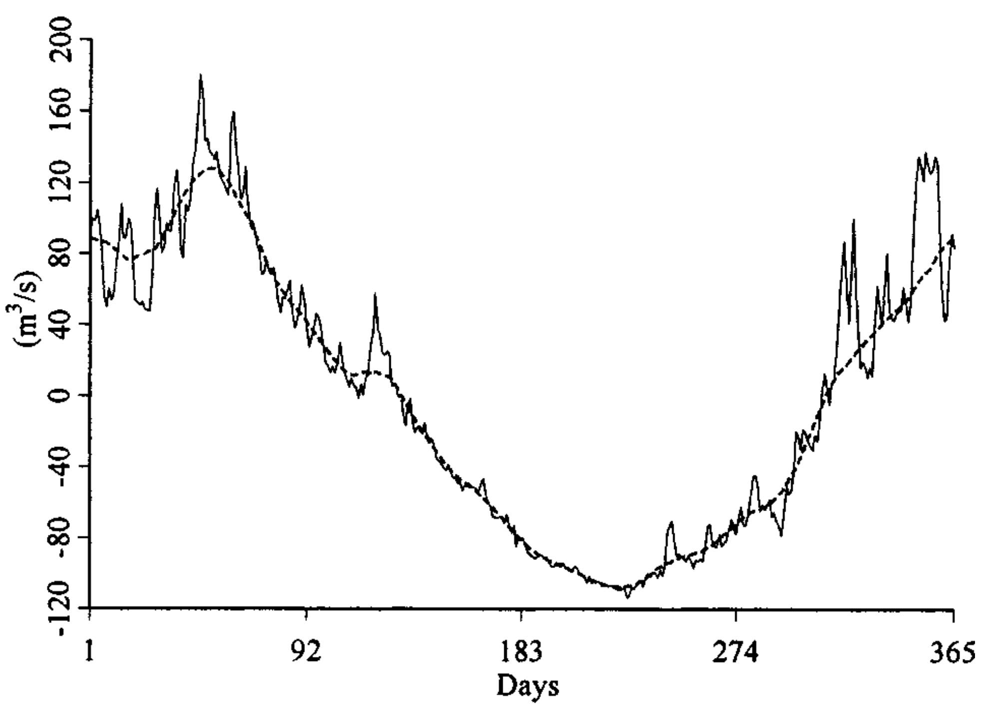

Fig. 1. Mean periodic components estimated by classical method and by seasonal trend decomposition based on loess modified method (dashed line) with smoothing window=30

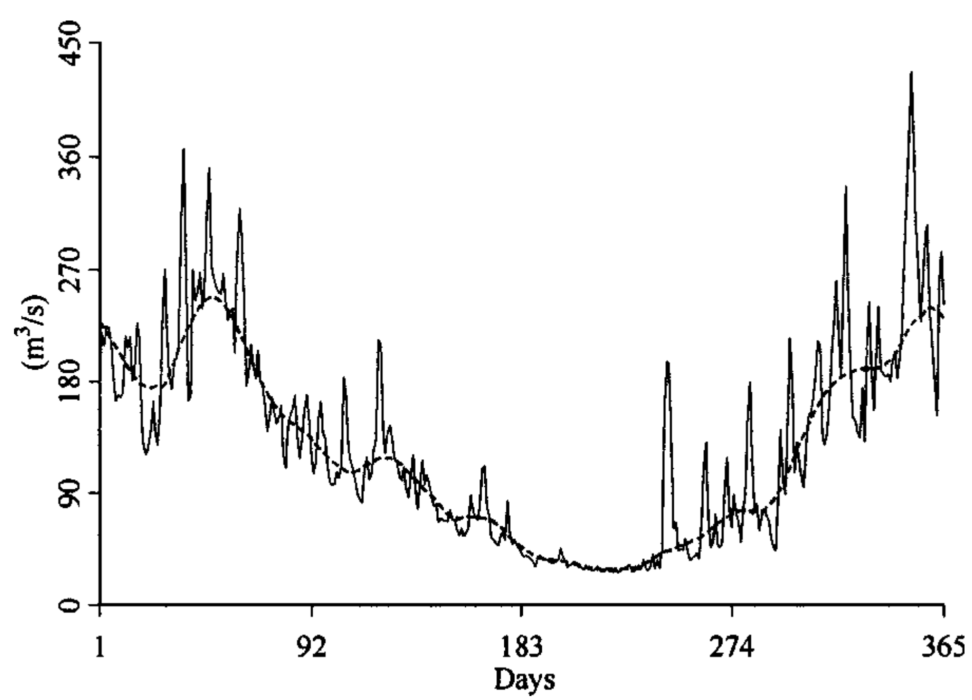

Fig. 2. Variance periodic components estimated by classical method and by seasonal trend decomposition based on loess modified method (dashed line) with smoothing window=30

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Topic 1 - Time series analysis
FARMA - Seasonal Component, Hurst parameter

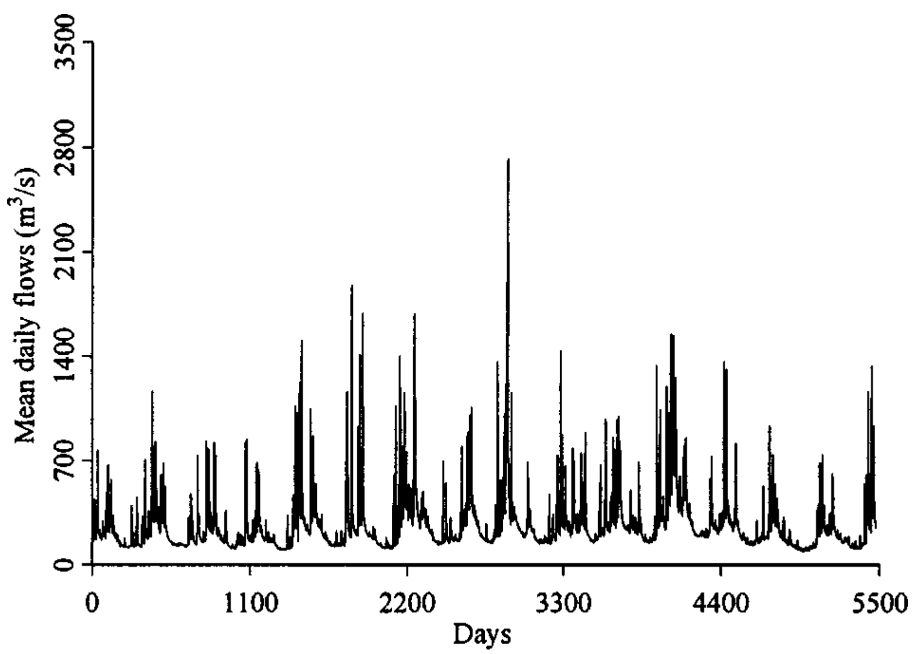

Fig. 4. Tevere mean daily discharge series observed from 1930 to 1944

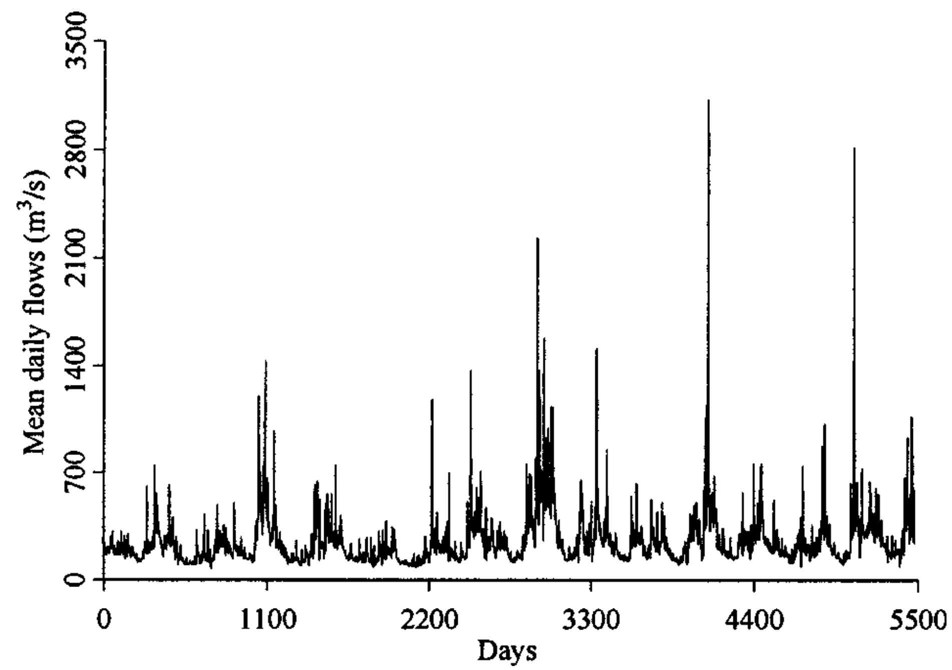

Fig. 10. Example of simulated series of Tevere observed from 1930 to 1944

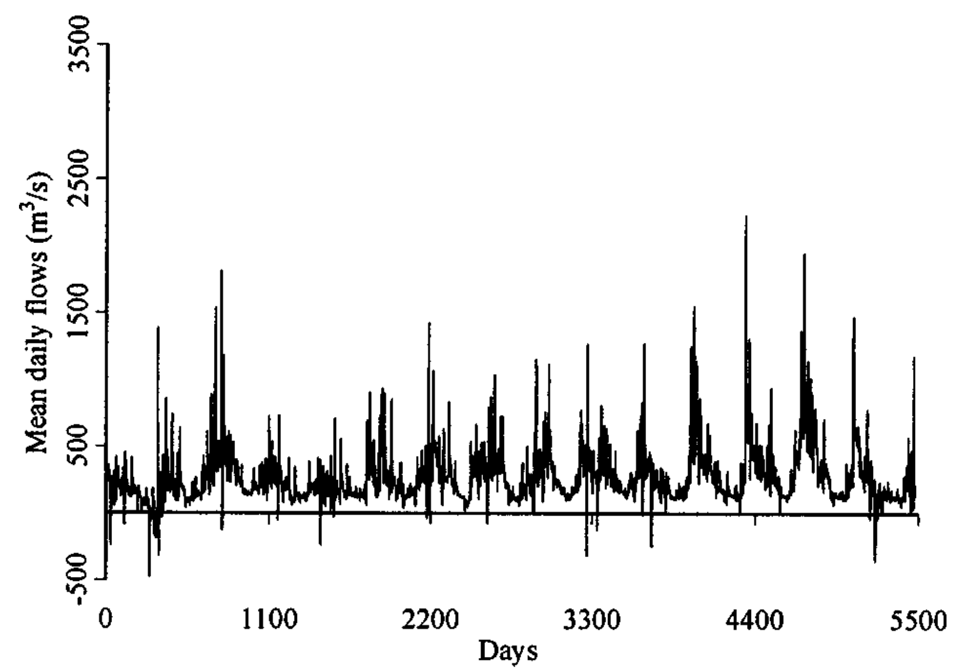

Fig. 11. Example of simulated series of Tevere observed from 1930 to 1944 obtained modeling series without any preliminary Box and Cox transformation

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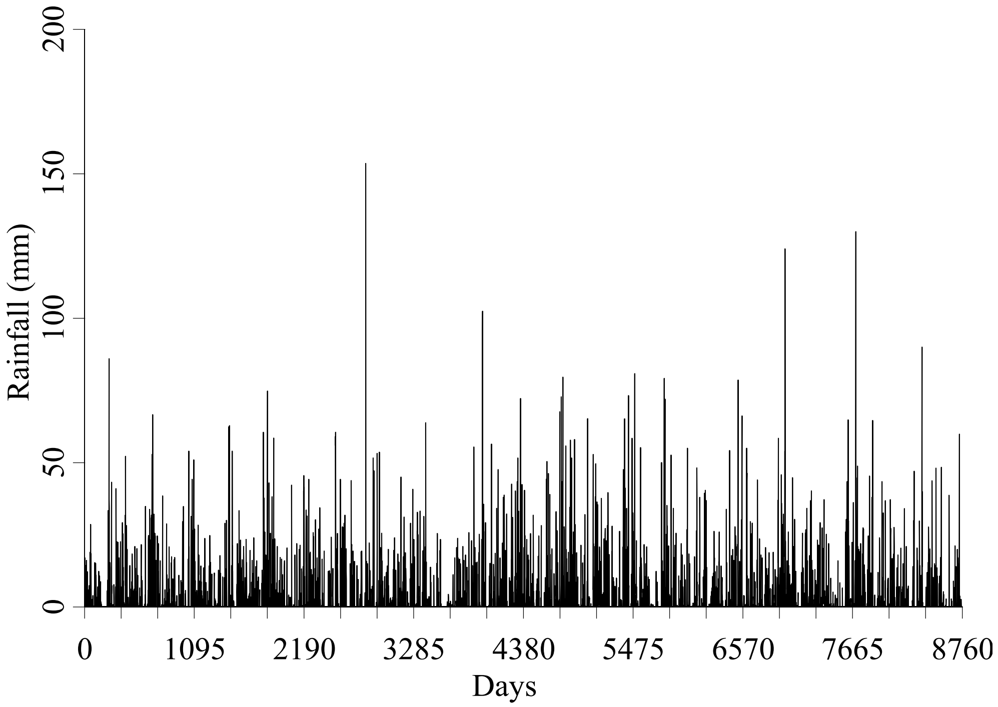
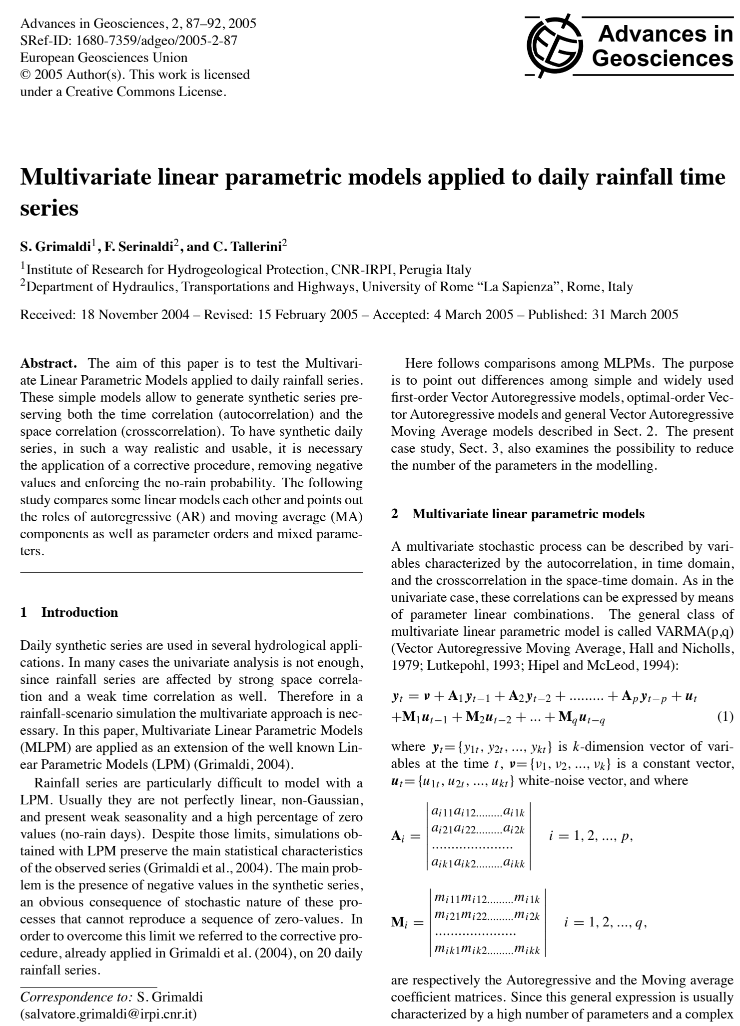


$$\boldsymbol{y}_t = \boldsymbol{\nu} + \mathbf{A}_1 \boldsymbol{y}_{t-1} + \mathbf{A}_2 \boldsymbol{y}_{t-2} + \ldots\ldots\ldots + \mathbf{A}_p \boldsymbol{y}_{t-p} + \boldsymbol{u}_t$$
$$+\mathbf{M}_1 \boldsymbol{u}_{t-1} + \mathbf{M}_2 \boldsymbol{u}_{t-2} + \ldots + \mathbf{M}_q \boldsymbol{u}_{t-q} \qquad (1)$$

where $\boldsymbol{y}_t = \{y_{1t}, y_{2t}, \ldots, y_{kt}\}$ is k-dimension vector of variables at the time t, $\boldsymbol{\nu} = \{\nu_1, \nu_2, \ldots, \nu_k\}$ is a constant vector, $\boldsymbol{u}_t = \{u_{1t}, u_{2t}, \ldots, u_{kt}\}$ white-noise vector, and where

$$\mathbf{A}_i = \left| \begin{array}{l} a_{i11} a_{i12} \ldots\ldots\ldots a_{i1k} \\ a_{i21} a_{i22} \ldots\ldots\ldots a_{i2k} \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ a_{ik1} a_{ik2} \ldots\ldots\ldots a_{ikk} \end{array} \right| \qquad i = 1, 2, \ldots, p,$$

$$\mathbf{M}_i = \left| \begin{array}{l} m_{i11} m_{i12} \ldots\ldots\ldots m_{i1k} \\ m_{i21} m_{i22} \ldots\ldots\ldots m_{i2k} \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ m_{ik1} m_{ik2} \ldots\ldots\ldots m_{ikk} \end{array} \right| \qquad i = 1, 2, \ldots, q,$$



Advances in Geosciences, 2, 87–92, 2005
SRef-ID: 1680-7359/adgeo/2005-2-87
European Geosciences Union

Advances in Geosciences

Multivariate linear parametric models applied to daily rainfall time series

S. Grimaldi[1], F. Serinaldi[2], and C. Tallerini[2]

[1]Institute of Research for Hydrogeological Protection, CNR-IRPI, Perugia Italy
[2]Department of Hydraulics, Transportations and Highways, University of Rome "La Sapienza", Rome, Italy

Received: 18 November 2004 – Revised: 15 February 2005 – Accepted: 4 March 2005 – Published: 31 March 2005

Abstract. The aim of this paper is to test the Multivariate Linear Parametric Models applied to daily rainfall series. These simple models allow to generate synthetic series preserving both the time correlation (autocorrelation) and the space correlation (crosscorrelation). To have synthetic daily series, in such a way realistic and usable, it is necessary the application of a corrective procedure, removing negative values and enforcing the no-rain probability. The following study compares some linear models each other and points out the roles of autoregressive (AR) and moving average (MA) components as well as parameter orders and mixed parameters.

1 Introduction

Daily synthetic series are used in several hydrological applications. In many cases the univariate analysis is not enough, since rainfall series are affected by strong space correlation and a weak time correlation as well. Therefore in a rainfall-scenario simulation the multivariate approach is necessary. In this paper, Multivariate Linear Parametric Models (MLPM) are applied as an extension of the well known Linear Parametric Models (LPM) (Grimaldi, 2004).

Rainfall series are particularly difficult to model with a LPM. Usually they are not perfectly linear, non-Gaussian, and present weak seasonality and a high percentage of zero values (no-rain days). Despite those limits, simulations obtained with LPM preserve the main statistical characteristics of the observed series (Grimaldi et al., 2004). The main problem is the presence of negative values in the synthetic series, an obvious consequence of stochastic nature of these processes that cannot reproduce a sequence of zero-values. In order to overcome this limit we referred to the corrective procedure, already applied in Grimaldi et al. (2004), on 20 daily rainfall series.

Correspondence to: S. Grimaldi
(salvatore.grimaldi@irpi.cnr.it)

Here follows comparisons among MLPMs. The purpose is to point out differences among simple and widely used first-order Vector Autoregressive models, optimal-order Vector Autoregressive models and general Vector Autoregressive Moving Average models described in Sect. 2. The present case study, Sect. 3, also examines the possibility to reduce the number of the parameters in the modelling.

2 Multivariate linear parametric models

A multivariate stochastic process can be described by variables characterized by the autocorrelation, in time domain, and the crosscorrelation in the space-time domain. As in the univariate case, these correlations can be expressed by means of parameter linear combinations. The general class of multivariate linear parametric model is called VARMA(p,q) (Vector Autoregressive Moving Average, Hall and Nicholls, 1979; Lutkepohl, 1993; Hipel and McLeod, 1994):

$$\boldsymbol{y}_t = \boldsymbol{\nu} + \mathbf{A}_1 \boldsymbol{y}_{t-1} + \mathbf{A}_2 \boldsymbol{y}_{t-2} + \ldots\ldots\ldots + \mathbf{A}_p \boldsymbol{y}_{t-p} + \boldsymbol{u}_t$$
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$$\mathbf{M}_i = \left| \begin{array}{l} m_{i11} m_{i12} \ldots\ldots\ldots m_{i1k} \\ m_{i21} m_{i22} \ldots\ldots\ldots m_{i2k} \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ m_{ik1} m_{ik2} \ldots\ldots\ldots m_{ikk} \end{array} \right| \qquad i = 1, 2, \ldots, q,$$

are respectively the Autoregressive and the Moving average coefficient matrices. Since this general expression is usually characterized by a high number of parameters and a complex

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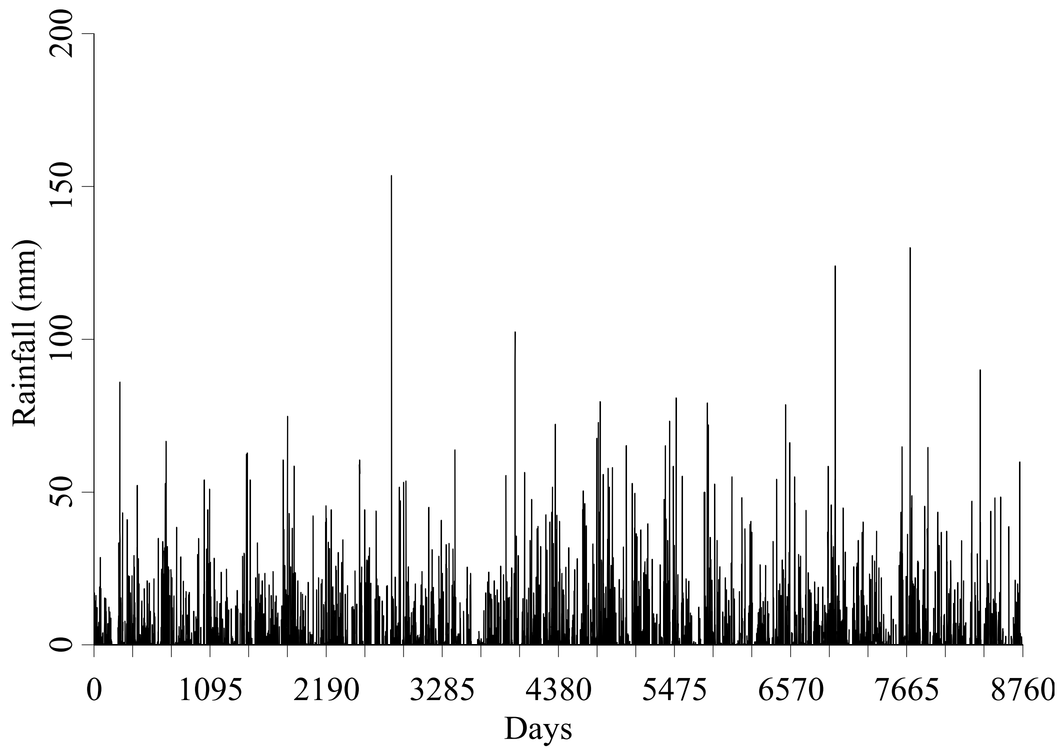

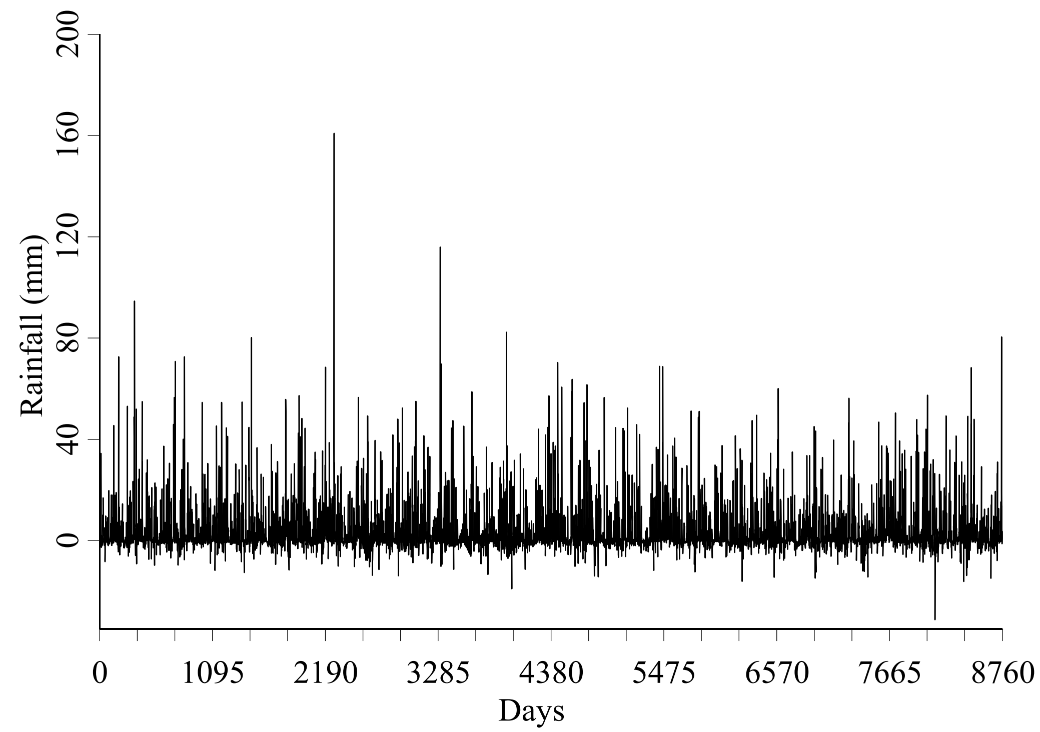

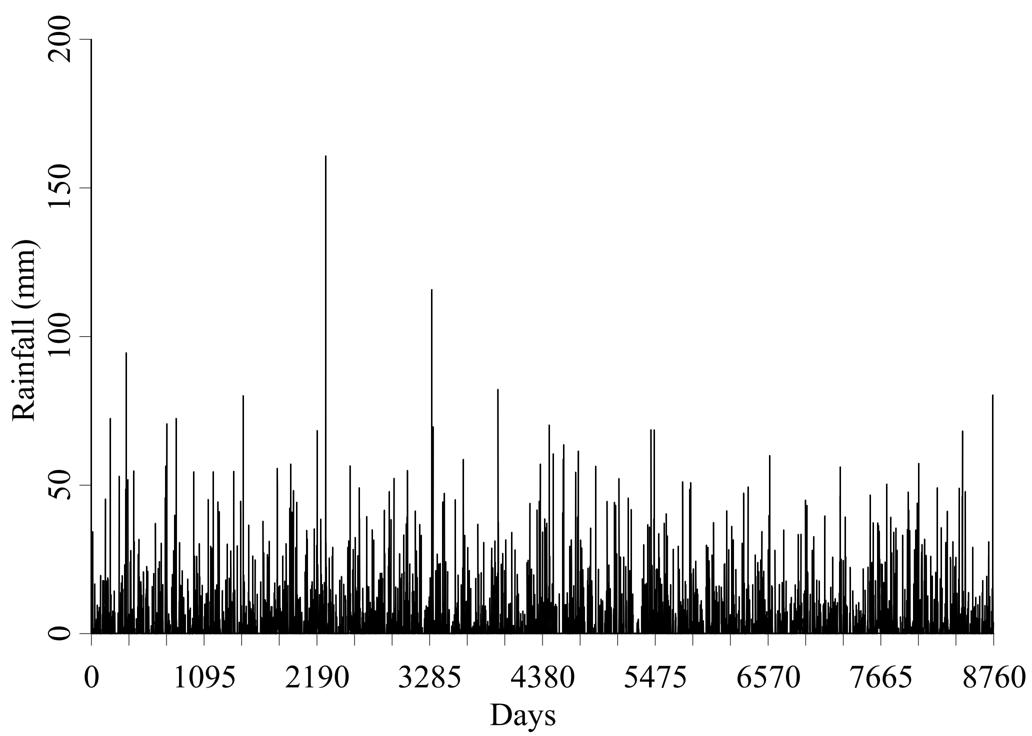

$$X_{s1} = X_s - \xi_1 \qquad P_{NV}\left[X_{s1}\right] = P_{NR}\left[X_t\right]$$

$$X_{s2} = \begin{Bmatrix} X_{s1} & if & X_{s1} > 0 \\ 0 & if & X_{s1} < 0 \end{Bmatrix}$$

$$X_{s3} = \begin{Bmatrix} X_{s2} + \xi_2 & if & X_{s2} > 0 \\ 0 & if & X_{s2} = 0 \end{Bmatrix} \quad V\left[X_{s3}\right] = V\left[X_t\right]$$

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Reasons of the failure:

- I was young and I was in a group without deep scientific attitude;
- I did not believed on myself and on my ideas;
- I did not realised that the topic was good and that a paper is a starting point and not a final aim;
- I did not have idea on what does it mean “communicate”, “share” , and “research goal”.

Topic 1 - Time series analysis
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…indeed…..here there are some papers published in 2017-2018-2019

Chandrasekaran, S., Poomalai, S., Saminathan, B., Suthanthiravel, S., Sundaram, K., Abdul Hakkim, F.F. An investigation on the relationship between the Hurst exponent and the predictability of a rainfall time series(2019) Meteorological Applications, 26 (3), pp. 511-519.

Dawley, S., Zhang, Y., Liu, X., Jiang, P., Tick, G.R., Sun, H., Zheng, C., Chen, L. Statistical analysis of extreme events in precipitation, stream discharge, and groundwater head fluctuation: Distribution, memory, and correlation (2019) Water (Switzerland), 11 (4), art. no. 707, . Cited 1 time.

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Nikolopoulos, D., Moustris, K., Petraki, E., Koulougliotis, D., Cantzos, D. Fractal and long-memory traces in PM<inf>10</inf> time series in Athens, Greece 2019) Environments - MDPI, 6 (3), art. no. 29, .

Tsoukalas, I., Makropoulos, C., Koutsoyiannis, D. Simulation of Stochastic Processes Exhibiting Any-Range Dependence and Arbitrary Marginal Distributions (2018) Water Resources Research, 54 (11), pp. 9484-9513. Cited 4 times.

Markonis, Y., Moustakis, Y., Nasika, C., Sychova, P., Dimitriadis, P., Hanel, M., Máca, P., Papalexiou, S.M. Global estimation of long-term persistence in annual river runoff (2018) Advances in Water Resources, 113, pp. 1-12. Cited 5 times.

Tong, S., Lai, Q., Zhang, J., Bao, Y., Lusi, A., Ma, Q., Li, X., Zhang, F. Spatiotemporal drought variability on the Mongolian Plateau from 1980–2014 based on the SPEI-PM, intensity analysis and Hurst exponent (2018) Science of the Total Environment, 615, pp. 1557-1565. Cited 15 times.

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Iliopoulou, T., Papalexiou, S.M., Markonis, Y., Koutsoyiannis, D. Revisiting long-range dependence in annual precipitation (2018) Journal of Hydrology, 556, pp. 891-900. Cited 17 times.

Tyralis, H., Dimitriadis, P., Koutsoyiannis, D., O'Connell, P.E., Tzouka, K., Iliopoulou, T. On the long-range dependence properties of annual precipitation using a global network of instrumental measurements (2018) Advances in Water Resources, 111, pp. 301-318. Cited 10 times.

Zamani, R., Mirabbasi, R., Abdollahi, S., Jhajharia, D. Streamflow trend analysis by considering autocorrelation structure, long-term persistence, and Hurst coefficient in a semi-arid region of Iran (2017) Theoretical and Applied Climatology, 129 (1-2), pp. 33-45. Cited 21 times.

Topic 1 - Time series analysis
FARMA - Seasonal Component, Hurst parameter

…and in the same period……:

Koutsoyiannis, D. Climate change, the Hurst phenomenon, and hydrological statistics (2003) Hydrological Sciences Journal, 48 (1), pp. 3-24. Cited 213 times.

Climate change, the Hurst phenomenon, and hydrological statistics

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Abstract The intensive research of recent years on climate change has led to the strong conclusion that climate has always, throughout the Earth's history, changed irregularly on all time scales. Climate changes are closely related to the Hurst phenomenon, which has been detected in many long hydroclimatic time series and is stochastically equivalent to a simple scaling behaviour of climate variability over time scale. The climate variability, anthropogenic or natural, increases the uncertainty of the hydrological processes. It is shown that hydrological statistics, the branch of hydrology that deals with uncertainty, in its current state is not consistent with the varying character of climate. Typical statistics used in hydrology such as means, variances, cross- and auto-correlations and Hurst coefficients, and the variability thereof, are revisited under the hypothesis of a varying climate following a simple scaling law, and new estimators are studied which, in many cases, differ dramatically from the classical ones. The new statistical framework is applied to real-world examples for typical tasks such as estimation and hypothesis testing where, again, the results depart significantly from those of the classical statistics.

Key words climate change; Hurst phenomenon; hydrological persistence; hydrological statistics; hydrological estimation; hydrological prediction; statistical testing; uncertainty

Changement climatique, phénomène de Hurst et statistiques hydrologiques

Résumé La recherche intensive des années récentes sur le changement climatique a conduit à la conclusion sûre que le climat a toujours changé dans l'histoire de la planète, et ceci de manière irrégulière à toutes les échelles de temps. Les changements climatiques sont étroitement liés au phénomène de Hurst, qui a été détecté dans de nombreuses séries temporelles longues d'hydroclimatologie et qui est stochastiquement équivalent à un comportement d'échelle simple de la variabilité climatique sur l'échelle de temps. La variabilité climatique, qu'elle soit d'origine anthropique ou naturelle, augmente l'incertitude liée aux processus hydrologiques. Il est démontré que l'hydrologie statistique, la branche de l'hydrologie qui s'occupe de l'incertitude, n'est pas, dans son état actuel, consistante avec le caractère variable du climat. Quelques caractéristiques statistiques typiquement utilisées en hydrologie comme les moyennes, les variances, les auto-corrélations et corrélations croisées, et le coefficient de Hurst, ainsi que leur variabilité, sont ré-examinées sous l'hypothèse d'un climat variable suivant une loi d'échelle simple. De plus de nouveaux estimateurs, pour la plupart très différents des estimateurs classiques, sont étudiés. Le nouveau cadre statistique est appliqué à des exemples réels, pour des travaux typiques comme l'estimation et le test d'hypothèses, où, à nouveau, les résultats diffèrent significativement de ceux des statistiques classiques.

Mots clefs changement climatique; phénomène de Hurst; persistance hydrologique; statistiques hydrologiques; estimation hydrologique; prédiction hydrologique; tests statistiques; incertitude

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General Definition

A special multivariate distribution that allows to create any multivariate distribution

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A d-dimensional copula is a c.d.f. on $[0, 1]^d$ with standard uniform marginal c.d.f.s.

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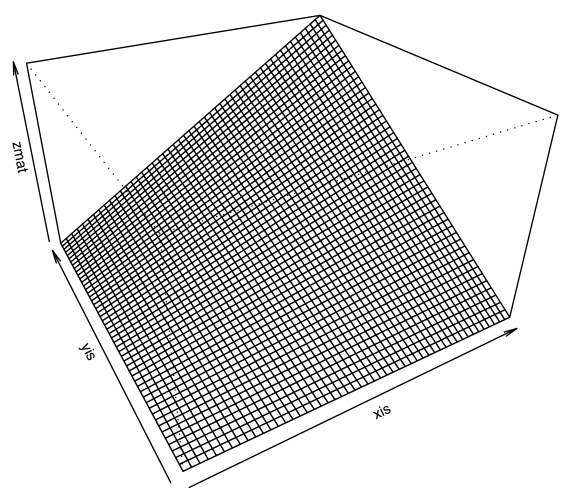

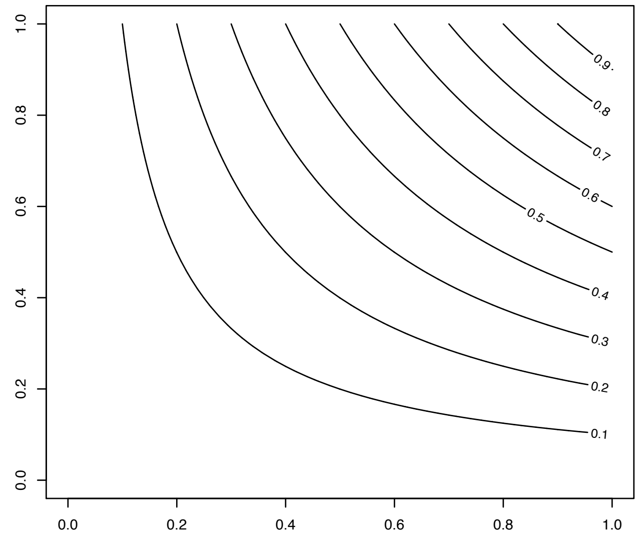

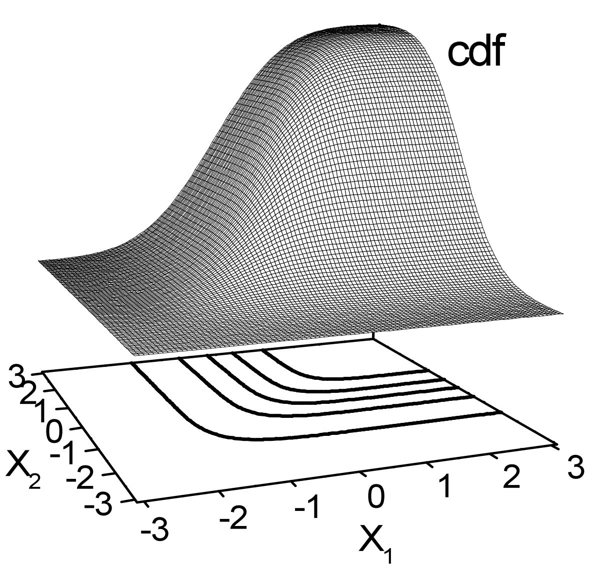

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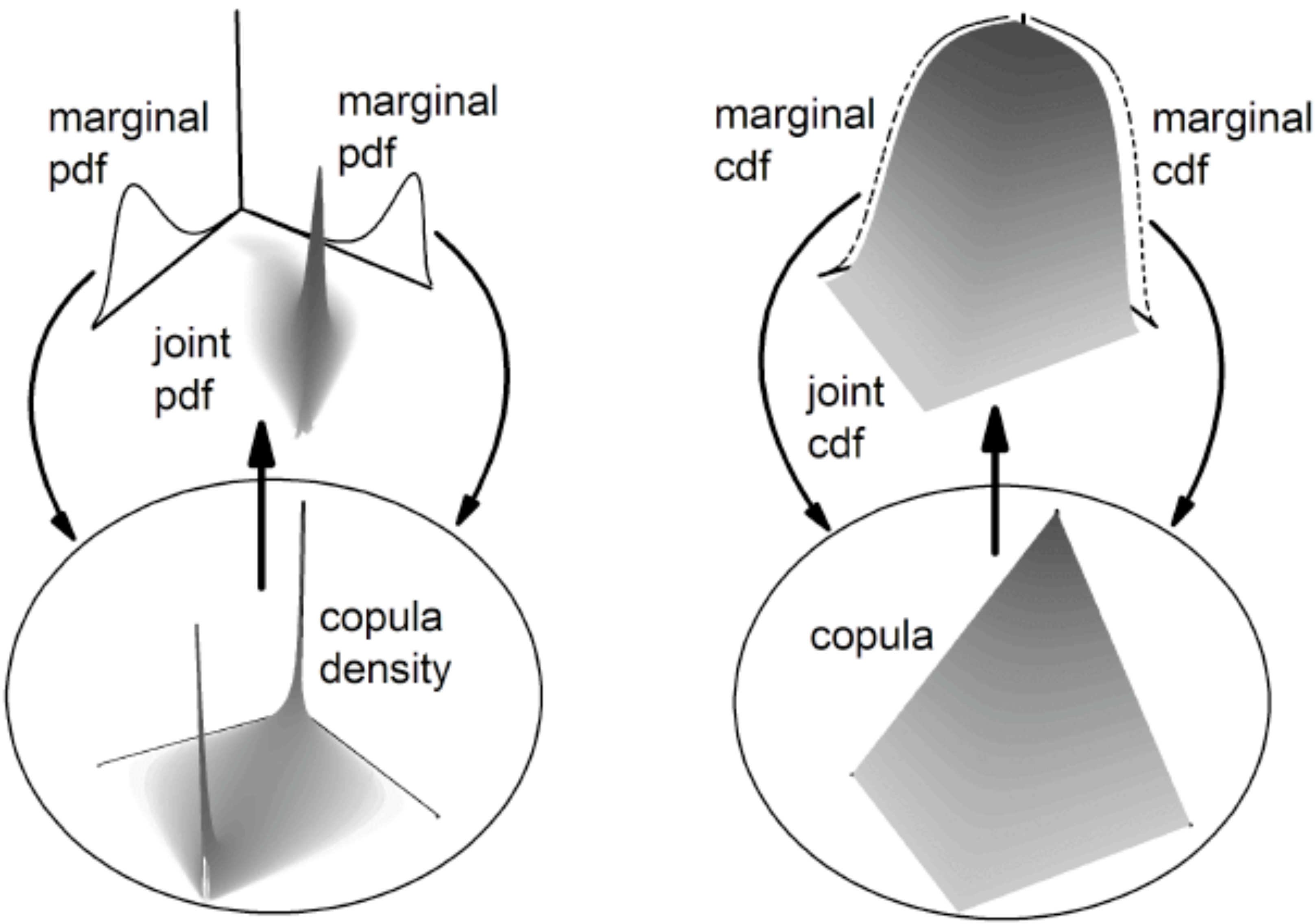

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Advances in Water Resources 29 (2006) 1155–1167

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Asymmetric copula in multivariate flood frequency analysis

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Abstract

The univariate flood frequency analysis is widely used in hydrological studies. Often only flood peak or flood volume is statistically analyzed. For a more complete analysis the three main characteristics of a flood event i.e. peak, volume and duration are required. To fully understand these variables and their relationships, a multivariate statistical approach is necessary. The main aim of this paper is to define the trivariate probability density and cumulative distribution functions. When the joint distribution is known, it is possible to define the bivariate distribution of volume and duration conditioned on the peak discharge. Consequently volume–duration pairs, statistically linked to peak values, become available. The authors build trivariate joint distribution of flood event variables using the fully nested or asymmetric Archimedean copula functions. They describe properties of this copula class and perform extensive simulations to highlight differences with the well-known symmetric Archimedean copulas. They apply asymmetric distributions to observed flood data and compare the results those obtained using distributions built with symmetric copula and the standard Gumbel Logistic model.

Keywords: Multivariate analysis; Fully nested copula; Asymmetric copula; Flood frequency analysis

1. Introduction

The main aim of the flood frequency analysis in hydrology is to determine the relationship hydrograph—return period. Until now, most of the literature investigated on flood peak univariate statistical procedures. However, concerning hydraulic works above all for flooding and inundation management, it is not enough to know information about flood peak only, but it is also useful to statistically value flood volume and duration. In order to have this information, joint cumulative distribution function (cdf) and probability density function (pdf) of involved variables is needed, and so multivariate statistical analyses have to be applied.

In the last years, some multivariate approaches were introduced in hydrological and environmental applications. At the beginning, the most used joint cdf was the Gaussian one. It is widely studied in the literature and easy to apply, but it has the obvious limit that the marginal distributions must be normal. Goel et al. [18] and Yue [33] achieve this condition by preliminary data transformation through Box–Cox's formulas [2]. However, these transformations, do not always ensure that the recorded series follow a Gaussian distribution, and sometimes they provide significant distortions of sample statistical properties. Consequently, further bivariate distributions with non-normal margins have been topic of research. Bacchi et al. [1] apply Gumbel bivariate exponential model [21], with exponential marginals. Yue [35] suggests bivariate Gamma distribution in flood

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doi:10.1016/j.advwatres.2005.09.005

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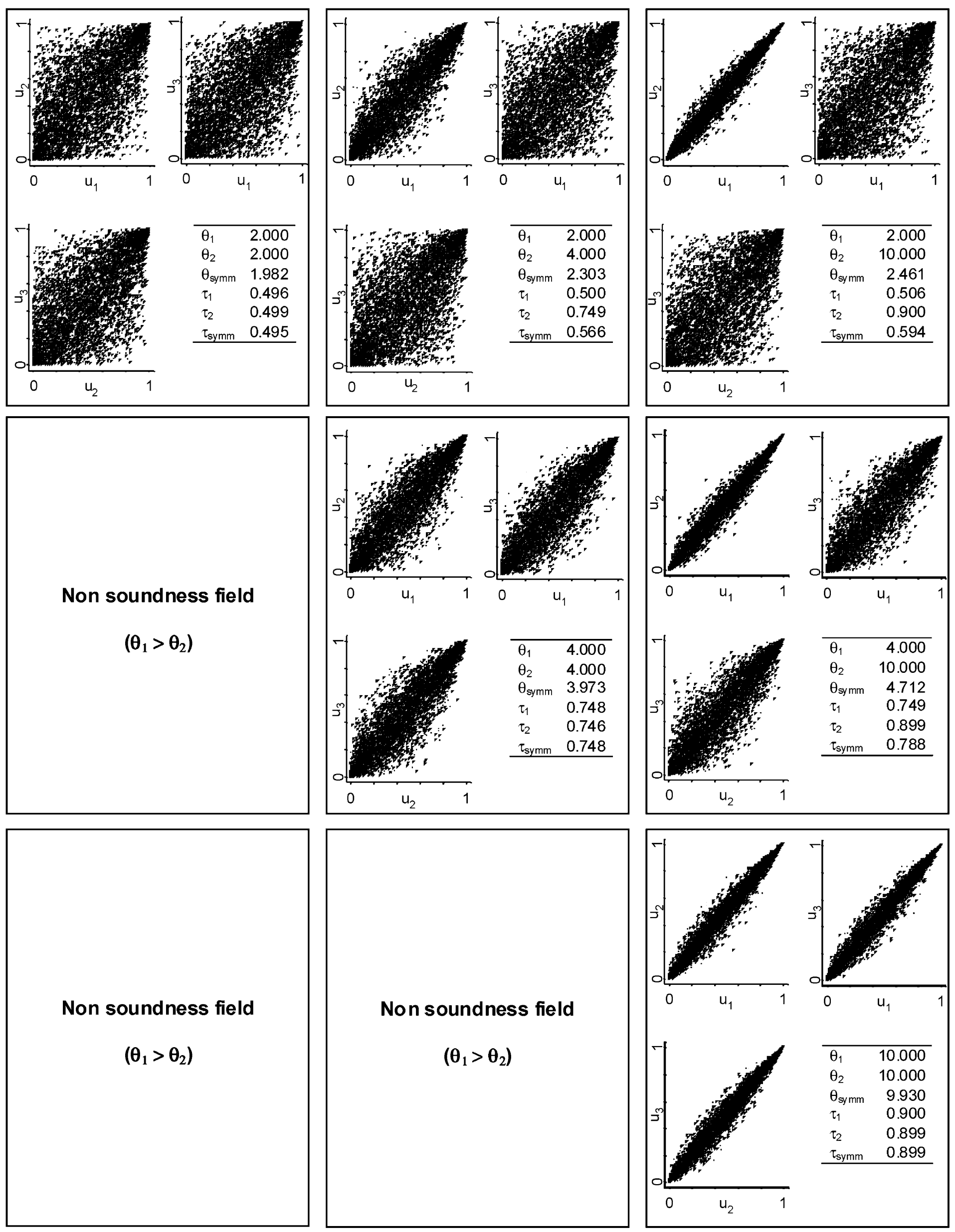

Fig. 1. Scatter plots of pairs (u_1, u_2), (u_1, u_3), (u_2, u_3) from triplets (u_1, u_2, u_3) simulated by asymmetric Gumbel copula for several h_1, h_2. For $h_1 > h_2$ Eq. (4) is not a copula, so in lower triangular matrix there are not samples. For $h_1 = h_2$ asymmetric copula degenerate in symmetric one, then, in main diagonal, symmetric samples are shown. For $h_1 < h_2$ Eq. (4) is a proper asymmetric copula, so in upper triangular matrix asymmetric samples are shown.

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Hydrological Sciences–Journal–des Sciences Hydrologiques, **51**(2) April 2006 223

Design hyetographs analysis with 3-copula function

SALVATORE GRIMALDI[1,3] **& FRANCESCO SERINALDI**[2]

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Abstract A design hyetograph is a synthetic rainfall temporal pattern associated with a return period, usually determined by means of statistical analysis of observed mean rainfall intensity through intensity–duration–frequency (IDF) curves. Since the univariate approach is simple to apply and data availability is scarce, only the mean intensity of rainfall storm is usually analysed statistically. The other characteristics of rainfall storm, such as peak (maximum intensity), total depth and duration, are found indirectly throughout the several phases of hydrological analysis by suitable work assumptions. The aim of this paper is to apply a multivariate approach in order to analyse jointly observed data of critical depth, peak and total depth. In particular, bivariate analysis of peak–total depth conditioned on critical depth is developed using a 3-copula function to define the trivariate joint distribution. Following the proposed procedure, once design return period and related critical depth are selected, it is possible to determine—in a probabilistic way—peak and total depth, without advancing *a priori* hypotheses on the design hyetograph pattern.

Key words copula function; design hyetograph; intensity–duration–frequency; multivariate analysis; rainfall pattern

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Multivariate return periods in hydrology: a critical and practical review focusing on synthetic design hydrograph estimation

B. Gräler[1], M. J. van den Berg[2], S. Vandenberghe[2], A. Petroselli[3], S. Grimaldi[4,5,6], B. De Baets[7], and N. E. C. Verhoest[2]

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Advances in Water Resources 90 (2016) 116–133

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Catchment compatibility via copulas: A non-parametric study of the dependence structures of hydrological responses

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ARTICLE INFO

Article history:
Received 22 October 2015
Revised 1 February 2016
Accepted 4 February 2016
Available online 28 February 2016

Keywords:
Copula
Catchment compatibility
Rainfall-runoff transformation
Non-parametric test

ABSTRACT

The similarity of catchment responses is a fundamental issue for regionalization studies, and hydrograph attributes (i.e., Discharge Peak, Volume, and Duration) can reveal the signature and the synthesis of local scale processes. Here, we focus the attention on the "compatibility" between catchments, viz. on the possibility to transfer, from one catchment to another, the information about the dependence structures at play. In particular, we statistically investigate the possible relationships between the features of different Basin Scenarios (characterized via the Concentration Time T_c and the Curve Number CN) and the corresponding dependence structures ruling the joint statistics of Discharge, Volume, and Duration. Given a large set of synthetic runoff time series, generated via a rainfall-runoff model, recent non-parametric tests, based on empirical copulas, are used to compare the dependence structures associated with different soil uses and concentration times. The results indicate how the hydrological properties may affect the dependence structure. The outcomes of the investigation could be particularly effective in two practical applications: (1) for determining the degree of compatibility of the dependence structures associated with different basin scenarios, and (2) for enriching scanty data bases, in order to improve the estimation of multivariate copulas.

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Topic 2 - Copula function

Grimaldi, S., Serinaldi, F. Asymmetric copula in multivariate flood frequency analysis (2006) Advances in Water Resources, 29 (8), pp. 1155-1167. **Cited 221 times.**

Gřaler, B., Van Den Berg, M.J., Vandenberghe, S., Petroselli, A., Grimaldi, S., De Baets, B., Verhoest, N.E.C. Multivariate return periods in hydrology: A critical and practical review focusing on synthetic design hydrograph estimation (2013) Hydrology and Earth System Sciences, 17 (4), pp. 1281-1296. **Cited 116 times.**

Serinaldi, F., Bonaccorso, B., Cancelliere, A., Grimaldi, S. Probabilistic characterization of drought properties through copulas (2009) Physics and Chemistry of the Earth, 34 (10-12), pp. 596-605. **Cited 107 times.**

Grimaldi, S., Serinaldi, F. Design hyetograph analysis with 3-copula function (2006) Hydrological Sciences Journal, 51 (2), pp. 223-238. **Cited 92 times.**

Serinaldi, F., Grimaldi, S. Fully nested 3-copula: Procedure and application on hydrological data (2007) Journal of Hydrologic Engineering, 12 (4), pp. 420-430. **Cited 74 times.**

Serinaldi, F., Grimaldi, S. Synthetic design hydrographs based on distribution functions with finite support (2011) Journal of Hydrologic Engineering, 16 (5), pp. 434-446. **Cited 40 times.**

Grimaldi, S., Petroselli, A., Salvadori, G., De Michele, C. Catchment compatibility via copulas: A non-parametric study of the dependence structures of hydrological responses (2016) Advances in Water Resources, 90, pp. 116-133. **Cited 22 times.**

Topic 2 - Copula function

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Compared to the Topic 1, Copula topic was surely a success!

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in research:

studying a topic looking to the future

studying a topic looking to the practical application (we are not statistician!)

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in research:
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studying a topic looking to the practical application (we are not statistician!)

in communication:
sharing with and meeting the community

My experience in communicating statistical hydrology research

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Concerning Statistical Hydrology the situation is even worse since typically our papers, and the topic in general, are considered boring and not easy to understand.

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My ingredients for an effective communication either to the scientific and professional community:

- Identify a clear aim in your research that combines theoretical, methodological and, above all, practical implications;
- A long term practical aim should be visible;
- MEET the community.

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- read papers;
- review papers;
- participate to the topical workshops;
- participate to short courses;
- share your research.

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Read and learn are crucial for your culture and for understanding the community needs

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The real impact factor of your research is not given by ISI-Web but by the professional community!!!!

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How can we interact with the professional community?

- through related Associations, giving seminars, short courses
- providing them user-friendly software packages
- translating and simplifying complex methodologies
- clearly identifying the added value of your methodologies.

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- through related Associations, giving seminars, short courses
- providing them user-friendly software packages
- translating and simplifying complex methodologies
- clearly identifying the added value of your methodologies.

You could feel to waste time….but it is not true!

Of course these are long term activities appropriate when you complete a research topic.
It is not a PhD, of PostDoc activity however it is useful to know it in advance to have a VISION.

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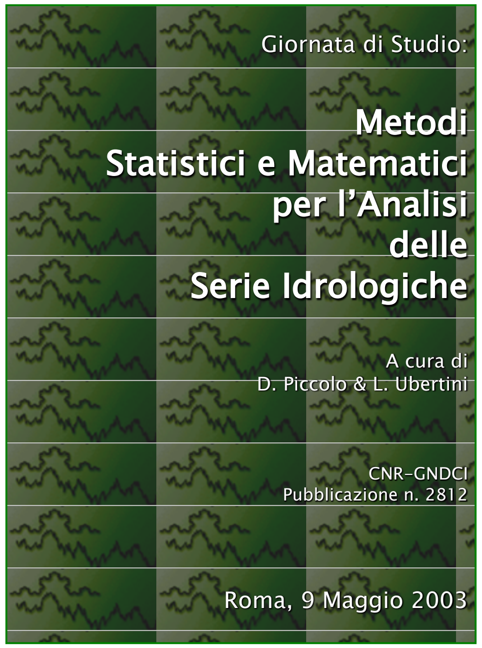

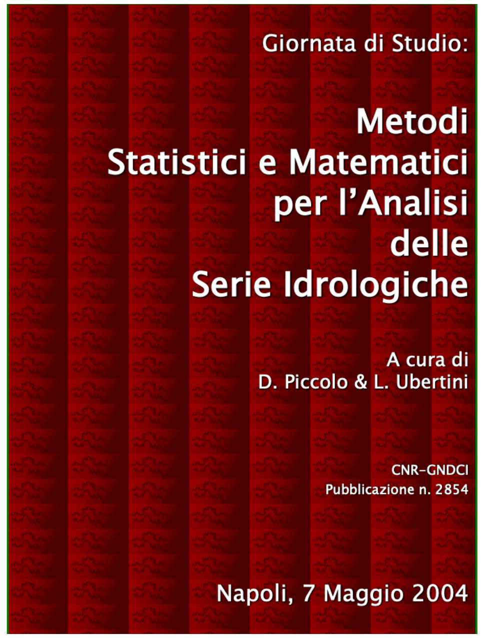

- Being involved in organisation of topical national conferences
- Proposing and pro-actively organising sessions in international conferences (EGU, AGU, IAHS)
- Organising Short courses

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➡ Short Courses on Copula Function

SHORT COURSE "Copula Function: Theory and Practice"
Columbia University + NYU-Poly + PACE University, **New York**, 2009

SHORT COURSE "Copula Function: Theory and Practice" - 2nd Edition,
Università degli Studi della Tuscia, **Viterbo**, Italiy, 2011


SHORT COURSE "Copula for hydrological application" 2013
Leibniz University Hannover, Institute of Water Resources Management, Germany, **Hannover**

SHORT COURSE "Copula for hydrology and climate applications"
The Henry Samueli School of Engineering, University of California **Irvine,** USA, 2014

SHORT COURSE "Copula for hydrology and environmental science"
Université de Pau et des Pays de l'Adour, **Pau**, France. 2015

SHORT COURSE "Copula for hydrology and environmental science"
Università degli Studi della Tuscia, **Pieve Tesino**, Italy. 2016

SHORT COURSE "Copula for hydrology and environmental science"
Hohai University, **Nanjing**, China. 2017

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Working Group created in 2007

Capri 2008

Taormina 2010

Tunis 2012

Kos 2013

Abu Dhabi 2014

2011 - from STAHY to ICSH

ICSH-STAHY Workshop 2015 Addis Ababa, Ethiopia

ICSH-STAHY Workshop 2016 Quebec City, Canada

ICSH-STAHY Workshop 2017 Warsaw, Poland

ICSH-STAHY Workshop 2018 Adelaide, South Australia

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- Meet the scientific community and share your ideas in order to adapt your plan and vision!

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- Once your research reaches the maturity, meet (directly or indirectly) the professional community in order to guarantee a real impact of your research!

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GRAZIE

謝謝

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