MEDCLUB—starting line and first activities

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Abstract The working group MEDCLUB, proposed by Fiorentino and Iacobellis (2005), is aimed at developing a wide range of activities dealing with Climate–Soil–Vegetation (CSV) interactions in Mediterranean basins. The goal of the project is to reduce uncertainty in predictions regarding hydrological extremes, soil water balance and ecosystem response to hydrological fluctuations. The research will focus on the controlling or dominant processes acting at basin or local scale that may allow model classification in terms of temporal and spatial scales, local climate, data requirements and type of application. In the present work, we briefly present the main framework of the project and its future perspective.

Key words climate–soil–vegetation interactions; Mediterranean regions

INTRODUCTION

In the last few years, as new hydrological models and advanced technologies for Earth monitoring have been developed, improving our knowledge and understanding of the scientific value of data has become a pressing issue. This problem can be tackled by focusing our efforts on a specific hydroclimatic zone, comparing and sharing our scientific experience on basins characterized by similar hydrological forcing, such as those of the Mediterranean area.

In spite of a huge body of scientific works, the reduction of uncertainty in estimating the frequency of floods and droughts is still one of the main challenges for hydrologists and one of the major needs for water control agencies. In this context, the best way to increase model reliability is to evaluate the role of base processes and their impact on the frequency of extreme events. In order to achieve this, fundamental laws underlying runoff generation mechanisms, evapotranspiration processes, soil moisture dynamics and plant ecological response, should not only be correctly identified, but should also be modelled as simply as possible, thus allowing them to be used in a theoretical framework.

In this context, the IAHS decade on Predictions in Ungauged basins (PUBs) represents an important opportunity for the scientific community to support sustainable management policies for water-related issues such as the correct governance of all exploitation-conflicts, the protection of natural ecosystems, the prediction and mitigation of natural hazards. The PUB scientific community has adopted an interdisciplinary approach, on the assumption that breakthrough advances are most

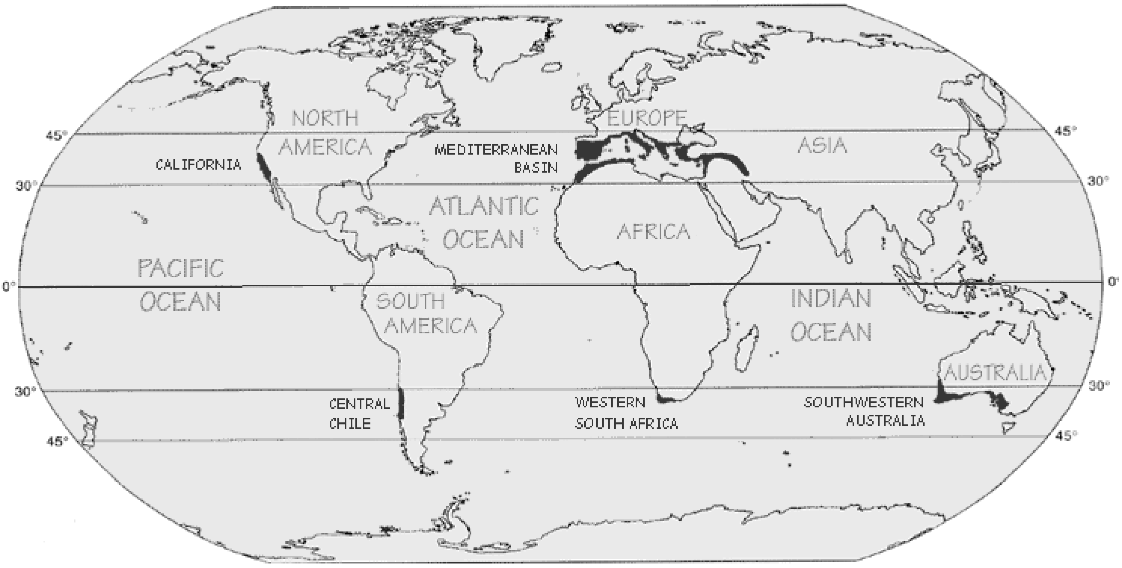

Fig. 1 Basins with a Mediterranean climate in the world.

likely to come from reconciling theories and measurements developed at different spatial scales, from the parcel to basin through hillslope scale. Important insights into hydrological dynamics are also expected from in depth analyses of soil moisture dynamics (e.g. Montaldo *et al*., 2001; Zanotti *et al*., 2004) coupled with monitoring of the hydrological behaviour of natural basins, and from the comparison of different models (e.g. from the contextual use of lumped and distributed models).

One of the expected goals of the PUB initiative is the harmonization of models through comparison and classification, in terms of space–time scales and hydroclimatic areas (Sivapalan *et al*., 2003). In particular, major differences in hydrological response have been observed in different hydroclimatic zones, and this paper will look specifically into Mediterranean-type areas (Fig. 1). Five areas which share similar Mediterranean climatic conditions can be identified in the world: the Mediterranean itself, California, western South Africa, central Chile, and southwestern Australia (Fiorentino & Iacobellis, 2005).

HYDROLOGY AND PREDICTION UNCERTAINTY IN MEDITERRANEAN CLIMATES

In order to define the peculiarity of hydrological issues, we will start from the definition most commonly adopted in literature for the Mediterranean climate: generally hot and dry summers, mild to cool and rainy winters, and warm-temperate coasts. The climate is strongly influenced by westerly air-streams in winter and sub-tropical high pressure in summer.

The regions with so-called Mediterranean climates receive relatively low rainfall, with most falling in the winter. They also have low summer humidity, which creates high solar radiation intensity and high rates of evapotranspiration. They have moderate temperatures year-round and enjoy the marine influences of their coastal locations. They also often have rugged coastal mountain ranges parallel to the coastline, which influence and modify climatic patterns, forming rain shadows and microclimates.

The hydrological variability of these Mediterranean climate regions is due to a combination of heavy rainfall (irregularly distributed in time and space), hetero–geneous land topography and high anthropogenic pressure. As a consequence, it is essential that we improve our knowledge of the hydrological processes in Mediterranean regions and, in particular, of their spatial and temporal variability, of extreme events and of surface and groundwater transfer mechanisms over river basins.

It should also be noted that a large hydroclimatic area may be identified as "Mediterranean", rather than only a geographical zone. As stated above, the third of the initial targets of PUB is to "understand which processes are dominant or controlling at different scales in the different hydroclimatic regions of the world".

Nevertheless, within Mediterranean basins there is a variety of climatic regions owing to the complex configuration of seas and mountainous peninsulas. Considering these characteristics, there are five areas in the world, all sharing a latitude around 35°–40°N or 35°–40°S: besides the Mediterranean basins, the others are California, western South Africa, central Chile, and southwestern Australia.

OBJECTIVES, QUESTIONS, AND STRUCTURED METHODOLOGY

The main objective of the proposed group is the improvement of techniques for flood and drought prediction and forecasting, with particular reference to the evaluation and reduction of uncertainty for medium-high return period events, in Mediterranean ungauged basins. This is, indeed, an urgent task in Mediterranean hydrology, yet today it is far from being fully accomplished.

We suggest that a necessary stage in the development of new methods (or the improvement of existing ones) for reducing uncertainty of prediction, is to acquire an understanding of the fundamental physical processes, and relative sub-models, underlying the complete hydrological process. Floods and droughts are extremes of the same complex and continuous process of "transformation" known as the water cycle, so the role of climate–soil–vegetation interactions, as well as the impact of human activities need to be thoroughly investigated, in order to take into account the nonlinear and non-stationary events that can influence prediction.

Moreover, in many regions of the Mediterranean countries the hydrological regimes have been greatly altered by the construction of dams with a diffusely claimed feedback on local and regional climate. The increasing demand for freshwater has led to a general overexploitation of groundwater resources far beyond the natural recharge rates, causing salt water intrusion in coastal areas and water table depletion in continental territories.

To respond to such research questions, MEDCLUB mainly focuses on field experiments at basin scale through the analysis of climate–soil–vegetation dynamics and their impact on hydrological processes and extremes, and will work, in collaboration with the already established PUB core research projects.

Lines of investigation

MEDCLUB objectives will be pursued in collaboration with the already-established PUB working groups and will hopefully lead to the identification, within a Mediterranean context, of: (1) processes which are dominant or controlling at different scales;

(2) the role of ecological functioning and human impact on hydrological basins and associated ecosystems; (3) a classification of model performance in terms of time and space scales, local climate, data requirements and type of application.

This research, developed through comparative evaluation within the network of PUB working groups, will also lead to the correct collocation of different classes of models in the unifying framework of model harmonization.

Strictly speaking, MEDCLUB can be said to have already started to work in this direction, since it originates from a group of researchers who are already involved in a project focused on "Field experiments at basin scale for the analysis of the climate–soil–vegetation dynamics and their impact on hydrological processes and extremes". Nevertheless, MEDCLUB is open to any researcher genuinely committed to the spirit of PUB and will hopefully gain more value through the harmonization of other contributions.

The group began as a collaborative project on the evaluation of basin hydrological signatures, such as the frequency distribution of extremes and probabilistic flow duration curves. The work involved an analysis of the spatial variability of parameters and their dependence on basin features, a classification of statistical homogeneity, and also a definition of probabilistic model structure. Investigations into the definition of the prevalent mechanisms of runoff generation represent a logical continuation of this work, to be conducted in collaboration with other PUB working groups, by means of downward and upward approaches. This research will be characterized by investigation into the "geomorphoclimatic" classification of basins and its relative best performing model.

Knowledge gaps

It is useful at this point to pinpoint the key gaps in our knowledge of Mediterranean hydrology that limit our capacity to generate reliable predictions in ungauged basins. MEDCLUB activities in fact arise from the consideration that the current best performing methods in terms of accuracy of prediction of extremes are still those based on statistical and regional analyses (e.g. Rossi & Villani, 1998). The following knowledge gaps have been identified:

(1) These methods are generally based on hypotheses of process stationarity and statistical homogeneity of climatic and physiographic variables. Such models are susceptible to improvement through a more thorough analysis of the spatial variability of the hydrological information, but they are, nonetheless, limited by the use of extrapolation procedures needed to extend the probability distribution to high return periods. These well known limits greatly affect prediction uncertainty. This gap increases if an attempt is made to remove the hypothesis of stationarity without adding more information. For example, it may come as a surprise to learn that the most used methodologies today are still based on annual maximum series of rainfall or discharge, while, at least in principle, they could benefit from the huge amounts of data on Earth observations which are today commonly available, but are not clearly exploitable in the framework of prediction.

(2) Numerous international studies have pointed out the problem of non-uniqueness of solution in the estimation of parameters and in the identification of models. The authors of these studies all agree that there is a need for methodological alternatives for calibrating models, such as objective estimation procedures (Beven & Feyen, 2002).

(3) There is a clear need to take into account the effects of climatic forcing on the vegetation–soil system and anthropogenic activities. Neglecting the effects of spatial-temporal dynamics of the climate–soil–vegetation system in prediction models causes not only a considerable growth in uncertainty but also a strong bias. In fact, many processes observed in Mediterranean areas are characterized by interannual and multidecadal fluctuations that are not easily detectable. Thus, even without considering the effect of climate change, the importance of understanding base processes for the evaluation of extremes is fundamental in order that all the dependences and nonlinearities that affect the extremes behaviour and their frequency can be taken into account.

(4) For example, a general application method does not exist (Fernandez & Salas, 1999) in the framework of statistical methods for the estimation of return period and risk of failure of water supplies, due to the great complexity of hydrological phenomena with temporal persistency (river flows, low-flows, aquifer levels and reservoir volumes). Moreover, the intrinsic shortage of hydrological samples, particularly for drought analysis, requires the use of stochastic simulations which, in the case of ungauged or ephemeral streams, consists in the modelling of precipitation (e.g. Veneziano & Iacobellis, 2002) adopted as input to deterministic rainfall–runoff models.

RESEARCH TARGETS

For the prediction of hydrological extremes, regional analysis is a well recognized method for increasing the effective sample size by substituting space for time, but it is based on the assumption that the basins used to derive the regional distributions form a homogeneous set. These methods rely on an analysis of existing data in order to find regional estimates of parameters and regional distributions, with regard to the hypothesis of statistical stationarity in space and time.

To date, the physical factors controlling regional frequency distributions of extremes still need investigation. For example, how important is climate, reflected primarily by the rainfall and evapotranspiration regimes which jointly control soil moisture (Laio *et al*., 2001; Isham *et al*., 2005), in comparison with other basin factors, and also how do these interact to determine the shape of the frequency distributions? This provides the rationale for the programme of research which will use analytical and simulation approaches supported with remote sensing and field experiments to enhance understanding of the physical factors controlling statistical features of basin flows, and to develop and validate the use of improved methods for hydrological risk estimation (including floods and droughts).

Interesting developments have been achieved by the "theoretically derived distribution" approach (e.g. Iacobellis & Fiorentino, 2000; Sivapalan *et al*., 2005) in which a stochastic model of rainfall is linked to a deterministic (or stochastic) model of runoff production and routing, to obtain the distribution of a required flood characteristic (e.g. peak discharge, flood volume or hydrograph). On the other hand, a continuous simulation approach via distributed models is considered one of the most promising tools for flood risk prediction (e.g. Cameron *et al*., 2000). Both theoretical (lumped) and continuous simulation (distributed) approaches provide analytical and numerical tools for the representation of physical processes.

The MEDCLUB analysis will be aimed at characterizing the nonlinearities in the process of runoff generation, possibly due to the presence of different runoff thresholds that influence the coefficients of scale and shape of flood frequency, as well as of other hydrological signatures.

The major innovative thrust of the project is related to the coupled use of theoretically derived distributions and continuous simulation by distributed models, in order to gain a new understanding of the role of climate and basin factors in the frequency of hydrological extremes. Current practice prescribes how to estimate a frequency distribution, but cannot explain why one basin might have a different frequency distribution from another. Such a new understanding would be invaluable in extrapolating statistical features and in identifying homogeneous groups of basins for regional analysis. Moreover, the "theoretical" approach will facilitate widespread application of the results at regional scales, while the simulation approach (e.g. DREAM model by Manfreda *et al*., 2005) will allow more detailed studies at basin-scale.

These targets are among the working paradigms defined in the PUB initiative, in which the opportunity for basin-scale investigations is pursued as the basis for advances in research. In our proposal, focus is given to the Mediterranean context including those semiarid areas in which water shortage is endemic and hydrological prediction becomes more complex due to climate–soil–vegetation interactions and human-induced perturbations.

Dealing with drought frequency also involves investigations into techniques for the estimation of return time of runs of deficit. In most cases, the propagation of drought from meteorological to agricultural, hydrological and socio-economic implications implies a complex interaction of processes and process autocorrelation becomes a controlling factor. In fact, droughts should not be merely considered as natural meteorological phenomena. Their impact on human activities and ecosystems derives from the interplay between climate forcing, hydrological cycle and water demands (for civil and agricultural uses), which often worsen the environmental damage (overexploitation of slow recovery resources, drastic reduction of artificial lakes, releases for environmental purposes, etc.). In this way the deep percolation feeding the aquifers needs to be evaluated in detail. The continuous simulation of unsaturated zone and deep flows allow the interactions of surface and subsurface water bodies to be analysed throughout the year, and, in particular in the case of seasonal, annual and multi-annual droughts.

The search for a deeper understanding of dominant hydrological controls aims at improving water balance models and has practical implications for water resource purposes. In this case, the research activity, besides trying to recognize the processes controlling streamflow generation at suitable spatial and temporal scales, is also engaged in analysing the role of ecological functioning and human impact on hydrological response (Portoghese, 2005).

The major innovative thrust of MEDCLUB will be to use physically-based derived distribution approaches to gain new understanding of how climate and basin factors control the frequency distribution of hydrological fluxes.

Mediterranean Hydrology Research: a World Perspective

One of the structuring points in the MEDCLUB working group is to involve as many (groups of) investigators as possible from all Mediterranean regions around the world.

We believe, in fact, that the open sharing of scientific experience is a prerequisite for the successful construction of knowledge. Besides, we believe strongly that the plurality of hydrological issues under the generic definition of “Mediterranean climate” deserves systematic classification in order to obtain to any generalization of results and theories.

In our concept, therefore, MEDCLUB is hoped to be a place for exchanging and comparing research priorities, methods, data, knowledge and results, acquired by scientific teams who are working for a better understanding of the hydrological processes observed under Mediterranean climate. Together with the setting-up of collaboration groups and the strengthening of synergies, which should lead to a real partnership among MEDCLUB teams, one of the first goals for the foreseeable future should be the institution of a global archive of river basins that are candidate experimental sites for the entire working group. This archive will serve as a scheme to draw the main lines of research for the future and to compare different approaches of investigation.

A few noteworthy initiatives that could be taken as an example and prototype for this activity are listed below:

(a) The AMHY-FRIEND project is a regional component of the FRIEND initiative (Flow Regimes from International Experimental and Network Data), placed under the auspices of UNESCO. It was established to coordinate hydrological research in the Alpine and Mediterranean regions of southern Europe and northwest Africa. Its aim is to develop research on flow regimes at the regional level, and to improve understanding of how such hydrological regimes can vary in space and in time.

(b) The MED-HYCOS project is a regional component of the WHYCOS (World Hydrological Cycle Observing System) by WMO. The MED-HYCOS information system is based on a World Wide Web to Database connectivity dealing with managing and numerical/graphical processing of Hydro-Meteorological data.

(c) The GRDC is the digital worldwide depository of discharge data and associated metadata. GRDC’s role is to serve as a facilitator between data providers and data users. It serves under the auspices of the World Meteorological Organization (WMO) and was established at the Federal Institute of Hydrology (BfG), Germany, in 1988, in order to support the hydrological and climatological research community by collecting and disseminating a comprehensive and sound runoff database.

(d) Based on such groups, our aim is to develop a network of research teams based on a common research philosophy focused on Mediterranean hydrology and also to integrate MEDCLUB activities with those operated by the above mentioned projects. The set-up of a database of hydrological research into Mediterranean climates, including a rational classification of prediction needs, applied models and tools, and experimental basins, will be an extraordinary opportunity to enhance the effectiveness and general applicability of MEDCLUB research targets.

Activities Aimed at the Estimation and Reduction of Predictive Uncertainty in MEDCLUB

The instruments and objects through which MEDCLUB proposes to overcome the knowledge gaps reported above are: field experimentation for the analysis of base processes supported by the use of new observation technologies, and the development of models representing such processes and the analysis of the impact of such dynamics on base processes and the frequency of extreme events.

The base processes of water balance, including nonlinearity and complexity of space–time dynamics, and their correct modelling are in our opinion essentially referred to three areas in order to reach consistent scientific advance:

(1) Soil–Atmosphere Interaction: energy budget models for soil and low atmosphere interaction, and an interface with hydrological models.
(2) Analysis of vegetation dynamics: models for the description of growing state or stress of different species of plants, based on an analysis of biomass variation and species competitiveness.
(3) Assessment of the hydrological properties of soils and their representation for distributed model applications.

Each of these three points should be further developed and integrated to be adopted as a tool for the reduction of predictive uncertainty.

In the field of land–atmosphere interaction models, the gap between the scales of hydrological distributed models and that of limited-area models (LAM), such as MM5, WORF, LOKALMODEL and BOLAM, still persists, although many attempts to combine the atmospheric processes with a detailed hydrological description have been proposed, such as: Entekhabi *et al.*, 1992; Porporato *et al.*, 2000; Albertson & Kiely, 2001.

On the other hand, the role played by vegetation in regulating energy and water partitioning across several space–time scales is universally recognized. This also highlights the importance of a quantitative analysis of the water stress condition of vegetation. The expected result in this field is the formulation of a fully analytical model for vegetation dynamics in Mediterranean conditions, based on the crossing properties of the soil moisture process for particular thresholds characterizing vegetation states.

MEDCLUB recognizes the necessity to integrate soil hydrology with both land–atmosphere interaction and vegetation dynamic modelling. In fact, soil hydrology is generally concerned with describing basic hydrological processes, as well as predicting their evolution under spatial scales comprising plots and hillslopes or an entire catchment, and across temporal scales ranging from hours to some years or more (Kutílek & Nielsen, 1994).

Within this range of space and time scales, soil hydrology shows a definite multidisciplinary character, and in this context the relationship with agricultural ecology is specifically important if one considers that vegetation exerts a key control on the dynamics of the major phenomena occurring in soil. Moreover, rainfall–runoff distributed models also require effective information on soil spatial variability (Romano & Santini, 1997, 2002).

The ensemble of these three areas of activities will surely benefit from the employment of new observational technologies that will allow the gap between theoretical hypothesis on CSV dynamics and basin-scale experimentation to be bridged. In fact satellite observation supplies information on many physical variables related to hydrological processes. It is fundamental to define the relationship between remote sensed products and climate, soil, and vegetation to assimilate row data into pertinent information. With this aim, field analysis is particularly useful for the description of relationship and the possible extension of models to ungauged basins.

Recent developments in remote sensing refer to the launch of new sensors with enhanced spatial and temporal resolutions, and with applications ranging from topography to thematic maps, to soil/vegetation temperature and fluxes. Not surprisingly, a very promising frontier for these land-observation tools is the development of innovative eco-hydrological models for the monitoring of water and energy fluxes (e.g. Albertson & Kiely, 2001).

Another basic activity aimed at the enhancement of prediction methods is the assessment of uncertainty in data and models. The analysis of uncertainty propagation through models and the contribution of different sources of uncertainty to the overall uncertainties in prediction is the way forward for an efficient assessment of prediction models. The reduction of modelling and parametric error, in fact, should be based on the effectiveness of pieces of information with respect to the adopted prediction objectives.

It is accepted in the literature on simulation models (e.g. Beven & Feyen, 2002) that the achievement of prediction objectives is a trade-off between model complexity and available data sources for process constraints. Therefore, in view of the reduction of prediction uncertainty, the process of selection of an efficient model structure and parameterization will profit from the assimilation of new spatial information, including eco-hydrological controls.

For the latter activity particularly, MEDCLUB will benefit from the collaboration with the Uncertainty Working Group inside PUB.

Value of Comparative Approach: Experimental Basins and Models

Research on experimental basins and data collection is programmed in a nested system with the aim of regionalizing model schemes (structure and parameters). An analysis of hydrological processes will be the basis for model construction (data-driven approach) in order to extend model capability beyond the available data records, through a genuine understanding of processes.

MEDCLUB activities at the present stage include an extensive experimental field campaign over five basins differing in climate, vegetation and soil characteristics. These basins, though all located in Italy, embrace a wide gradient of climatic conditions and hydrological issues; major differences arise from their geomorphological features, such as elevation, topography and geology, but also vegetation cover, land use and anthropogenic impact are characterized by relevant diversities.

The five basins are: the Tovel and Val Rendena Creek (Alps, Trentino), the Fiumarella di Corleto (southern Appennine, Basilicata), Mulargia Creek (Sardinia) and Candelaro basin (southeast, Puglia). These basins are all located in the same country, but we hope to extend the MEDCLUB database to cover the entire Mediterranean, California, western South Africa, central Chile, and southwestern Australia.

The main characteristics of the present candidate basins for MEDCLUB are the following:

(a) The Fiumarella di Corleto basin, subcatchment of the Sauro River (tributary of the Agri River, Basilicata) covers a surface of 32 km^2. Instrumentation includes traditional rainfall tipping bucket at high resolution and water level gauges, but also tensiometers, TDR probes and tension-infiltrometers for soil hydraulic characterization have been recently acquired. A soil–landscape map and a high-resolution land-use map will be produced, with a quantitative assessment of the vegetation cover (biomass and Leaf Area Index for individual plants) and a root-system sampling of different vegetation species, in order to quantify distribution and depth.

(b) The Candelaro River basin (area of about 1700 km^2) has a typical Mediterranean semiarid climate with a seasonal alternation of drought period and flash floods. Its area is mostly covered by intensive agriculture (approximately 80%) with frequent water supply shortages. Besides the traditional hydrological information, a DEM is available with 90 m resolution from technology SRTM, a pedological database (ACLA2) and a new network of meteoclimatic gauge stations.

(c) The Tovel basin (50 km^2) has a complex morphology, mostly of karst origin. Its elevation ranges between 2900 and 1100 m a.s.l. The basin is the subject of a detailed environmental–biological–geological study and is now under a monitoring campaign as is the Val Rendena basin. High resolution topographic, hydro-meteorological records, IKONOS and other satellite data even multitemporal scenes (MODIS, ASTER, LANDSAT, ERS, IKONOS), mostly concerning vegetation cover (NDVI), soil temperature and moisture, albedo, snow cover, precipitation, soil hydraulic parameters and soil roughness are also available.

(d) The Mulargia River basin (area of about 65 km^2) is a sub-basin of the Flumendosa River (area of about 1800 km^2), located in centre–east Sardinia. An extensive campaign is presently collecting soil moisture data using TDR techniques in several basin points to test soil moisture estimates derived from remote sensing. This data set will be available for testing the hydrological model developed at basin scale.

As an example of experimental activity, we report in Fig. 2 and in Tables 1 and 2 the first results obtained in terms of data acquisition and availability at the Fiumarella di Corleto. Three stations are located respectively on the hillslopes and at the outlet (Figure 2A); they provide precipitation (two raingauges) and snow measurements (one snow-gauge), and all quantities useful for the evaluation of evapotranspiration (incident solar radiation, temperature, air relative humidity, atmospheric pressure, wind direction and speed). The hydrometric level is measured by an ultrasonic sensor, while the depth-discharge relationship was analysed by Carriero & Oliveto (2004). A list of the available measurements with their pertinent time resolution is reported in Table 1.

In Fig. 2(b), the detailed information available on the spatial distribution of vegetative and soil characteristics are identified using the units of the "*Keys to Soil Taxonomy*" system (see Santini *et al*., 1999). In addition, several studies have been conducted by means of field measurement campaigns along transects on the basin hillslopes obtaining a complete physical and hydrological soil characterization in terms of texture, organic matter content, bulk density, water content at different matric pressure heads, etc. (Romano & Palladino, 2002). A high resolution digital elevation model (1 × 1 m) was obtained by a special survey using a laser technique (Fig. 2(c)). The previously described measurements represent a valid support for statistical analyses among variables linked to the soil and morphological and vegetational variables, already investigated on a large scale (Carriero *et al*., 2004). The data, collected between 2002 and 2005 are shown in Fig. 2(d) and the main features of flood events are reported in Table 2.

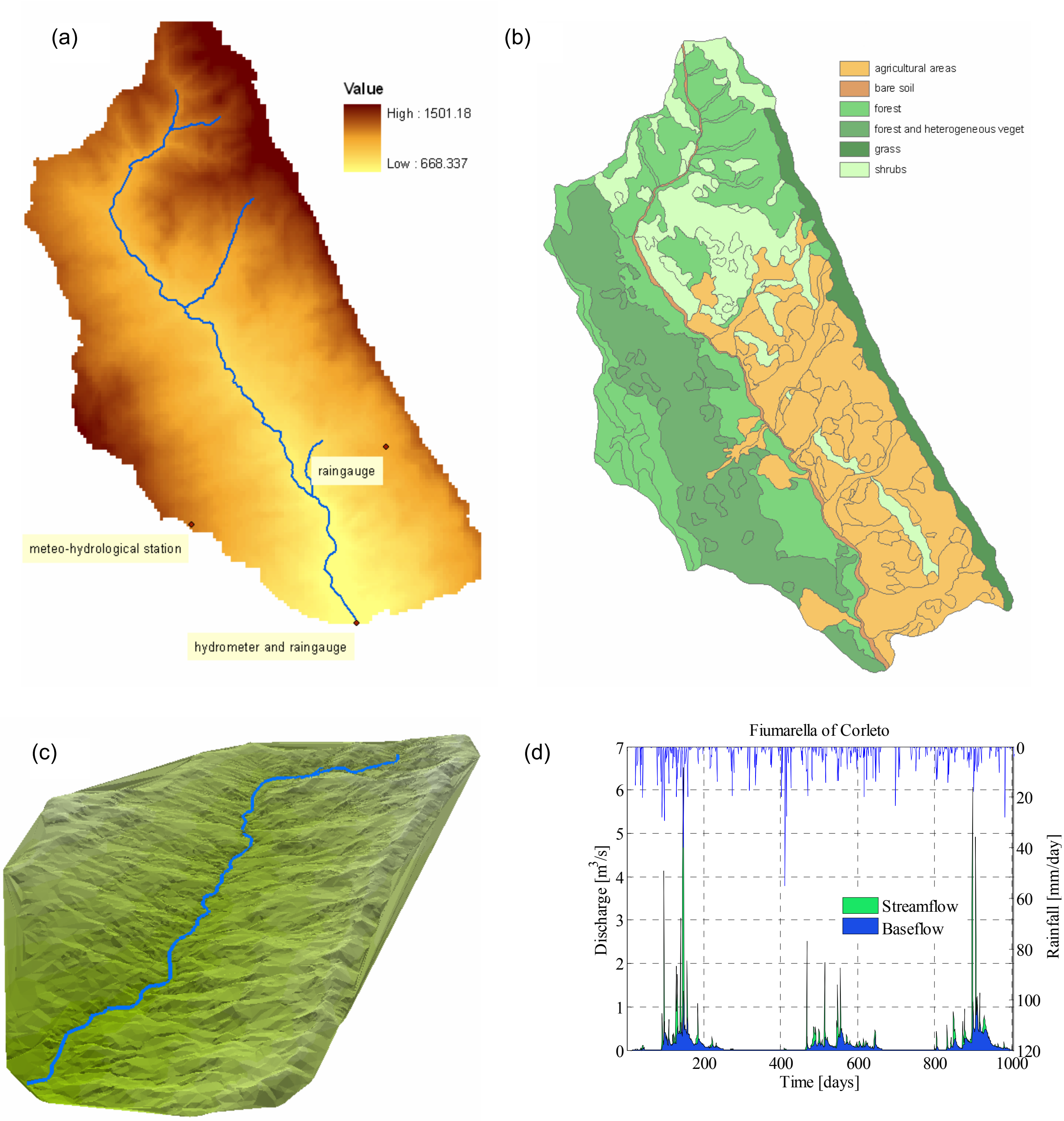

Fig. 2 Characteristics of the Fiumarella di Corleto catchment: digital elevation model (1 × 1 m) and instrumentation (a), land system (b), 3-D elaboration of morphology (c), and basin response with the definition of the superficial runoff and base flow components obtained using a mathematical filter (see Manfreda *et al.*, 2003) (d).

For the scope of the project, both distributed and conceptual models will be implemented and applied to the experimental basins, since detailed knowledge of their physical characteristics is available, in order to define the controlling processes and validate the reliability of the models. Through the extension of the MEDCLUB to the

(Mediterranean) planetary dimension we expect to embrace a plurality of investigation approaches aimed at different hydrological applications.

Table 1 Meteo-hydrological data measured at the Fiumarella (for instrument location see Fig. 1).

Meteo-hydrological quantity	Time resolution (min)	Measurement start date	Instrument location
Precipitation	10	September 2002	1–2–3
Snowy precipitation	10	September 2002	1
Hydrometer level	15	September 2002	2
Temperature	60	September 2002	1
Incident solar radiation	60	November 2004	1
Air relative humidity	60	November 2004	1
Atmospheric pressure	60	November 2004	1
Wind direction	10	November 2004	1
Wind speed	10	November 2004	1

Table 2 Main flood events registered from the date of instrument installation (P, total precipitation; Q_p: peak flow; snow, presence of snowy precipitation).

Date	P (mm)	Q_p (m^3/s)	Snow	Date	P (mm)	Q_p (m^3/s)	Snow
07/10/2002	7.24	0.13	no	07/03/2004	7.33	7.06	yes
01/12/2002	26.96	4.86	no	24/03/2004	5.35	0.84	yes
07/12/2002	37.77	20.43	yes	27/04/2004	3.84	0.44	no
19/12/2002	17.70	3.15	yes	06/05/2004	8.62	0.75	no
28/12/2002	11.17	0.46	no	06/06/2004	12.56	9.55	no
05/01/2003	7.72	0.51	no	08/11/2004	9.09	0.18	yes
07/01/2003	18.19	7.30	yes	12/11/2004	31.36	4.06	no
18/01/2003	15.45	14.94	yes	09/12/2004	32.72	11.44	yes
24/01/2003	25.57	21.81	yes	20/12/2004	3.60	0.44	yes
04/02/2003	18.78	14.04	yes	19/01/2005	13.43	4.86	yes
04/03/2003	7.00	5.49	yes	24/01/2005	13.43	7.54	yes
21/04/2003	8.66	0.34	no	28/03/2005	4.07	0.46	no
03/01/2004	2.96	2.49	yes	20/04/2005	10.24	0.24	no
28/01/2004	12.01	6.37	yes	05/05/2005	29.00	0.39	no
28/02/2004	12.92	3.33	yes	13/05/2005	0.84	0.13	no
01/03/2004	12.36	3.51	yes				

CONCLUSIONS

The study of hydrological processes and the dynamics of climate–soil–vegetation interactions is of crucial interest for the understanding of extreme events, their frequency and magnitude, the impact of climate change, and finally for the improve–ment of prediction and risk-management techniques in ungauged basins. Hence the MEDCLUB activity has not only a technical-practical interest associated with significant economic implications, but is also of scientific relevance. As recognized worldwide, the main challenge in the improvement of frequency analysis of extreme events consists in the representation of nonlinearities and the removal of the stationarity hypothesis of processes. This is, moreover, the only way of understanding the impact of climate change.

Furthermore, according to the PUB definition of ungauged basin, we know that, due to the tremendous heterogeneity of natural processes and to the spatial and temporal scales of hydrological observations, every basin may be considered ungauged in some respect. It is clear that the great potential of PUB is directly linked both to the understanding of mechanisms that control extreme hydrological processes, and to the exploitation of information potentially available from remote sensing that may supply data on wide and heterogeneous portions of territory with great detail in space–time.

The scope of the research is to provide technical and scientific instruments to predict basin response with improved accuracy, incorporating the nonlinearity effects of catchment response and accounting for non-stationarity of processes. The coupled use of physically-based models (theoretically derived distributions and continuous simulation by distributed hydrological models) will lead to more accurate estimates of extremes allowing the study to be extended to ungauged basins and basin response to be predicted under changing forcing (climate change) or land use changes.

For the scope of the project, since detailed knowledge of the physical characteristics of the experimental basins, such as soil hydraulic properties, morphology and vegetation status, is available, complete rainfall–runoff models will be implemented and applied to the basins, in order to define controlling processes and validate the reliability of the hydrological models adopted.

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