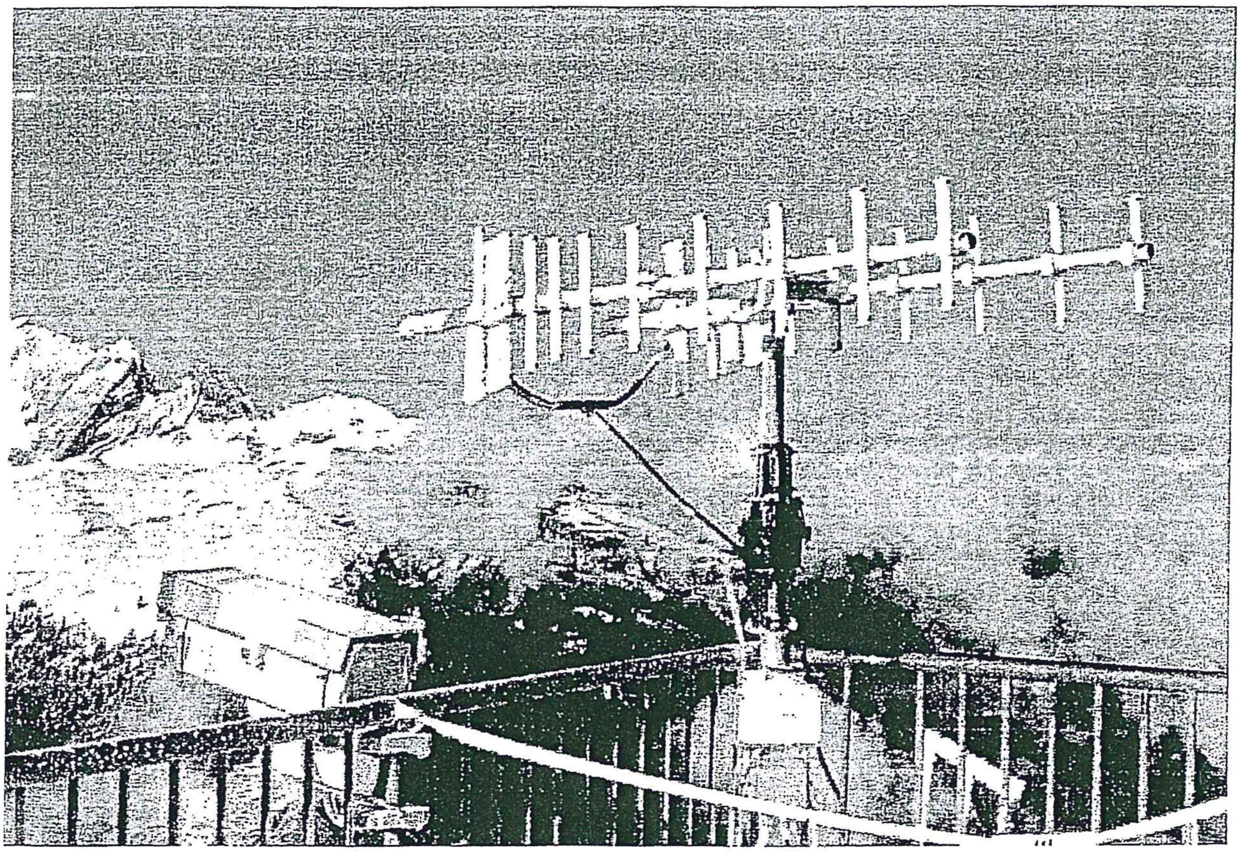
International Conference on Alpine Meteorology and MAP-Meeting 2003

ICAM 03 MAP BRIG

May 19 to 23, 2003 — Brig, Switzerland

Extended Abstracts

Volume B



MeteoSwiss

IACETH

EUMETSAT

Publications of MeteoSwiss, No. 66

The Role of the Antecedent Soil Moisture Condition on the Distributed Hydrologic Modelling of the Toce Alpine Basin Floods

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ABSTRACT

Event-based hydrologic models need the spatial distribution of the antecedent soil moisture condition, as critical boundary initial condition for flood simulation. Land-surface models (LSMs) have been developed to simulate mass and energy transfers, and to update the soil moisture conditions through time from the solution of surface moisture and energy balance equations. They are recently used in distributed hydrologic modeling for flood prediction systems. The evolution of distributed hydrologic modeling lead to increasing of parameterization and complexity of LSMs. In this study we address the following objectives: 1) investigate the role of soil moisture initial conditions in the modeling of Alpine basin floods; 2) define an adequate complexity level of the LSM for the modeling of Alpine basin floods.

1. Introduction

The study of river floods as the response of the watershed to rainfall events is a task to which modern surface hydrology addresses a substantial research effort (Rosso, 1994). Recently, the frequencies of occurrences of extreme floods also due to climate change, have increased the need for better investigation of floods. The rising and falling of the stream discharges following a rainfall, reflects the integrated effect of all the complex processes occurring within the catchment. Comprehension of processes involved is difficult because of a complex nonlinear relationship with the pattern of heterogeneity of catchment characteristics (Seyfried and Wilcox, 1995). In the context of flood simulation and prediction, it is widely recognized the influence of soil moisture condition prior to storm events on the formation of floods (Troch et al., 1993a, 1993b). Sanarath et al. (2000) demonstrates the model performance improvements through the use of a formulation that performs continuous soil moisture accounting The need to predict soil moisture led to the advent of SVAT (Soil-Vegetation-Atmosphere-Transfer) models that simulate mass and energy transfers at the land surface, and update the soil moisture conditions through time from the solution of surface moisture and energy balance equations. Encapsulation of physic processes description into distributed models should improve estimation of antecedent moisture condition and so rainfall-runoff transformation. On the counterpart a common strategy of improving performance of physically based models is to increase number of parameters and models' framework complexity. On the contrary, before any application of physic-based model, an effort should be made for the comprehension of the dominant physical processes involved in the rainfall-runoff transformation of a specific watershed (Beven, 2001). The aim of this study is to verify the role of a right representation of the antecedent soil moisture condition on the distributed hydrologic modelling and find the minimum complexity scheme for a good simulation of important flood events in an alpine watershed.

The Toce basin is the case study; it is located in the North Piedmont (Italian Alps), and it has a total drainage area of 1534 km2 at Candoglia section. The Toce is a typical alpine catchment, mostly without soil and more rocks and the process along the hillslope is mainly hortonian

Three models of different level of complexity are developed and compared: two (TDHM and SDHM) are continuous distributed hydrologic models, one (FEST03) is an event distributed hydrologic model based on the simplified SCS-CN method for rainfall abstractions. The TDHM model is a two-layer distributed LSM, which includes both saturation and infiltration excess runoff, and simulates the evolution of the water table spatial distribution using the topographic index; the SDHM model is a simplified one-layer distributed LSM, which only includes hortonian runoff, and doesn't simulate the water table dynamic.

Objectives of this study are:

1. investigate the importance of soil moisture initial conditions in Toce flood simulation. and how can be improved the modeling using continuous models.

2. understanding if, for an Alpine steep basin, it is enough to simplify the continuous LSM due to the no soil conditions.

2. The Toce basin case study

The case studied is the Toce river basin which, in the past decade, has been frequently flooded, in particular with disastrous effects in September 1993 and, very recently, in October 2000. The Toce basin analysis is a case study of the RAPHAEL (Runoff and Atmospheric Processes for flood Hazard forEcasting and controL) European Union research project, through which a comprehensive set of hydrologic, meteorological and physiographic data were collected.

The Toce watershed is a typical glacial basin with steep hillslopes bounding a narrow valley located in the North Piedmont (Italian Alps), and partially in the Switzerland (10% of the total area). The land cover is divided among: forest areas (70 %), bare rocks (9%), agricultural (7%), natural grassland (6%), urban (4%), water bodies (3%), and glaciers and perpetual snow (1%). The Toce lithology can be classified in five main classes: augean gneiss (49%), micaceous schists (27%), calcareous schists (11%), grindstones (7%), and granites (6%). Catchment hillslopes are mostly covered by bare rocks and trees developed in thin low soil layers rested on layers of rocks. The soil depth (i.e. soil conductivity) just increases in the downstream alluvial area. Hence, hillslope mountain areas significantly contribute to the flood generation, and the overland flow is mainly hortonian.

3. The distributed hydrologic models

We developed and tested three distributed hydrologic catchment models: 1) the FEST03 model (Montaldo et al., 2002a), 2) the topographically based distributed hydrologic model (TDHM), and 3) the simplify distributed hydrologic model (SDHM). They are improvements of the spatially-distributed modeling framework initiated at the Politecnico di Milano over the past decade (e. g., Brath et al., 1989; Orlandini et al., 1996; Mancini et al., 2000; Montaldo et al., 2002a). The main difference is that FEST03 is an event model, while TDHM and SDHM are continuous model. They also differ in the mechanism for surface runoff generation: the first one computes the surface runoff using the SCS-CN method, while the last two use an Hortonian mechanism (in part TDHM also use a saturation excess mechanism), and simulate soil water balance evolution performing continuous soil moisture accounting (Figure 1). Finally, they differ in the base flow computation: a lumped conceptual approach, namely a simple linear reservoir method (Sorooshian, 1983) in the FEST03 and SDHM, while in the TDHM base flow at the basin outlet section is computed through a lumped routing topographically based as in Sivapalan et al., 1987.

Details on FEST03 model are reported in Montaldo et al. (2002a), while details on fluxes computations in the TDHM are in Famiglietti and Wood (1994).

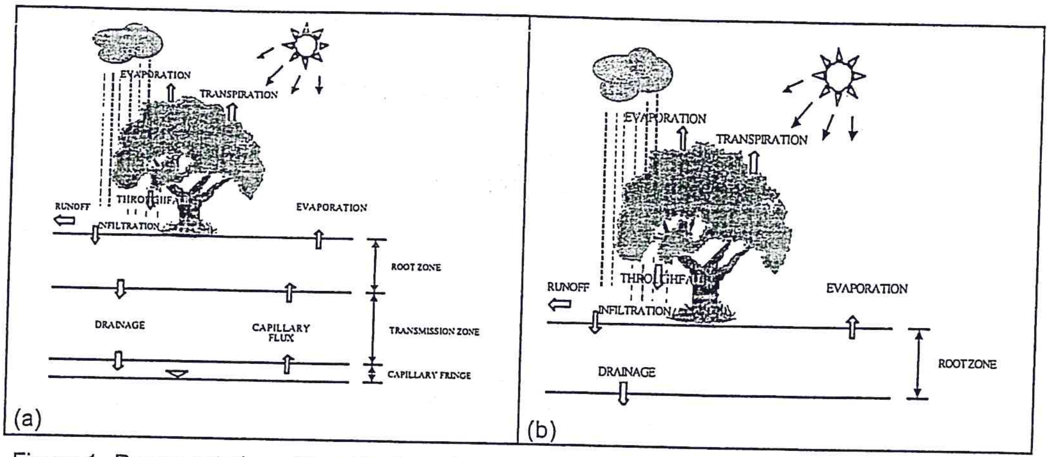

Figure 1. Representation of local hydrological processes included in the TDH model (a) and in the SDH model (b)

4. Application of the continuous hydrological models to the Toce basin

TDHM and SDHM have been applied for the two-year (1996 and 1997) simulation period, during which two major floods occurred in the November 1996 and in June 1997. The models have been validated comparing cumulative simulated and observed runoff at Candoglia (Figure 2). It was observed a spin-up period till first remarkable flood event (November 1996) that reset soil saturation condition.

The three model performances in the simulation of the two major floods are compared in figure 3. Benchmark indexes for a rapid comparison are showed in table I.

Interestingly, the results indicate that the SDHM model is able to sufficiently well predict the major floods of this Alpine basin; this model is a good compromise between the over-parameterized and complex TDHM model and the over-simplified FEST03 model

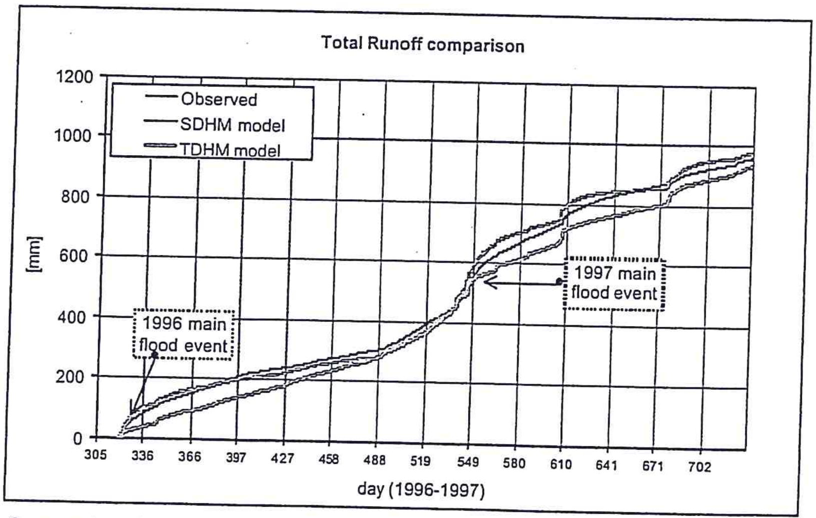

Figure 2. . Comparison between observed and modeled cumulative runoff after spin-up period. The two main flood events are indicated.

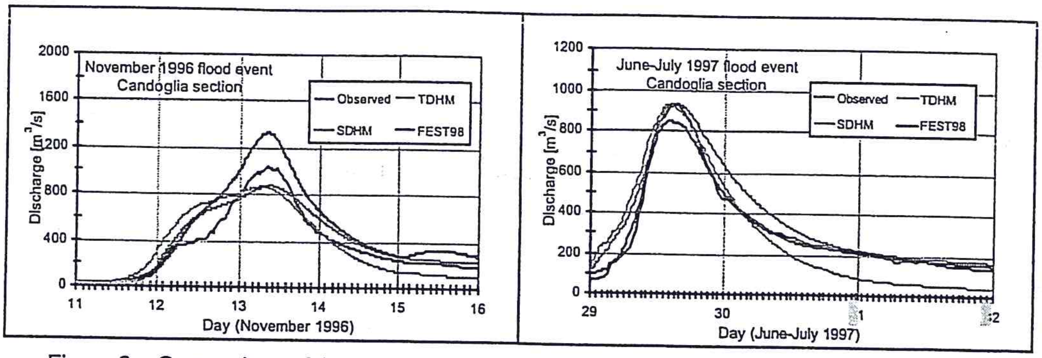

Figure 3. . Comparison of the results of the three models for flood simulation of the two major events.

Table I. Indexes related to the two major flood events simulation for a rapid comparison of models results: for the three models are reported the simulated/observed relationship of peak flow and flood volume, the Nash and Sutcliffe (1970) efficiency, the root mean square error and the time to peak error.

Flood Event	10÷15.11.96	28.06÷01.07.97
Observed Qmax mc/s	1035	930
Observed Volume mc	161170847	86477987
	TDHM	
Simulated/Observed Qmax	0.84	1
Simulated/Observed Volume	1	0.9
Nash Efficiency	0.83	0.81
RMSE	118	101
$T_{Psim-Pobs}$(h)	-0.95	-1.25
	SDHM	
Simulated/Observed Qmax	0.84	1.01
Simulated/Observed Volume	1.09	1.15
Nash Efficiency	0.91	0.9
RMSE	87	73
$T_{Psim-Pobs}$(h)	1.5	-0.49
	FEST03	
Simulated/Observed Qmax	1.28	0.91
Simulated/Observed Volume	1.3	0.99
Nash Efficiency	0.72	0.98
RMSE	149	28
$T_{Psim-Pobs}$(h)	0.3	-1

ACKNOWLEDGMENTS

This work was supported by the RAPHAEL European Union Research Project, grant ENV4–CT97–0552. This research was also funded by Gruppo Nazionale per la Difesa delle Catastrofi Idrologiche, of National Research Council of Italy through grant #01.01072.PF42, and the Ministero dell'Università e della Ricerca Scientifica e tecnologica (MURST) of Italy through grant #MM08103322_004.