HYDROLOGICAL ASPECTS OF THE MESOSCALE ALPINE PROGRAMME: FINDINGS FROM FIELD EXPERIMENTS AND SIMULATIONS

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Abstract: Results of the Mesoscale Alpine Programme provide some answers to basic scientific questions of hydrological relevance posed in its scientific plan i.e:

1. verify the forecasting capabilities of a hydrological flood model, forced by the special measurements or coupled with advanced mesoscale atmospheric prediction models;
2. assess the role of the water storage in reservoirs on the runoff generation during floods in mountainous regions;
3. study the influence of soil moisture conditions prior to flood events in determining the production of runoff and investigate the capabilities and limitations of some soil moisture monitoring techniques over rugged terrain.

Summary results from investigations in some areas in the southern (Toce, Ticino, Verzasca and Maggia watersheds) and northern (Ammer watershed) side of the Alps during the Mesoscale Alpine Programme and the 1999 Special Observing Period experiment are presented.

Keywords *– Hydrology, flood forecasting, reservoirs, soil moisture,*

1. FLOOD FORECASING USING COUPLED HYDRO-METEOROLOGICAL MODELS

The first scientific objective of hydrological interest in the Mesoscale Alpine Programme was to demonstrate in real-time or near real-time the forecast capabilities of hydrological flood models, forced by special measurements or coupled with advanced mesoscale atmospheric models. Prior to the Special Observing Period (Bougeault et al., 2001) the Lago Maggiore and the Ammer watershed (see Fig. 1) areas were investigated, from a hydrological point of view, within the RAPHAEL Project (Bacchi and Ranzi, 2003). In that project several combinations of hydrological and meteorological mesoscale models were tested for simulating severe floods occurred in those watersheds (Jasper et al., 2002; Montaldo et al., 2002; Ludwig et al., 2003). Then, during the Special Observing period using two modelling chains it was possible, indeed, to issue runoff forecasts in advance to the major flood events: one, DIMOSOP, was forced by the BOLAM meteorological forecasts (Ranzi et al., 2003) and a second, WATFLOOD, was forced by the MC2 model's output (Benoit et al., 2003). Results were, on average, quite satisfactorily for both the modelling schemes, thus showing potentials, but also some limitations, of a coupled use of hydrological and mesoscale meteorological models for flood forecasting. By summarising the results of several combinations of rainfall data (observed by raingauge networks or radar and simulated or predicted by mesoscale models) and hydrological models (see also Jasper and Kaufmann, 2003; Bacchi et al., 2002) it can be said that today a time horizon of flood warning of one-two days seems realistic in basins lager than 1000-2000 km². For basins of this size one to two days of flood forecasts warning time seem to be realistic, resulting in peak errors predicted with a bias of about ± 30%-50%, on average, and uncertainties up to 60% in terms of standard error of a multi-model prediction vs. observed peak flow (Grossi and Kouwen, 2004; Ranzi, 2005)

2. EFFECT OF RESERVOIRS

The second aspect that was addressed was the role of some man-influenced initial conditions of the surface water system, in particular the water storage in reservoirs, on the runoff generation during floods. The role of reservoirs can be significant depending on the fraction of the basin gauged by artificial lakes and the storage volume. In areas heavily exploited for hydropower generation, as the Toce basin which is quite representative of many Alpine basins, the data of five major floods occurred in the past decade show that reservoirs can reduce flood volumes of about 10%, as a reference order of magnitude, in midsize basins. During the SOP hydropower companies transmitted on a regular basis data on the water level at some major reservoirs, thus giving useful

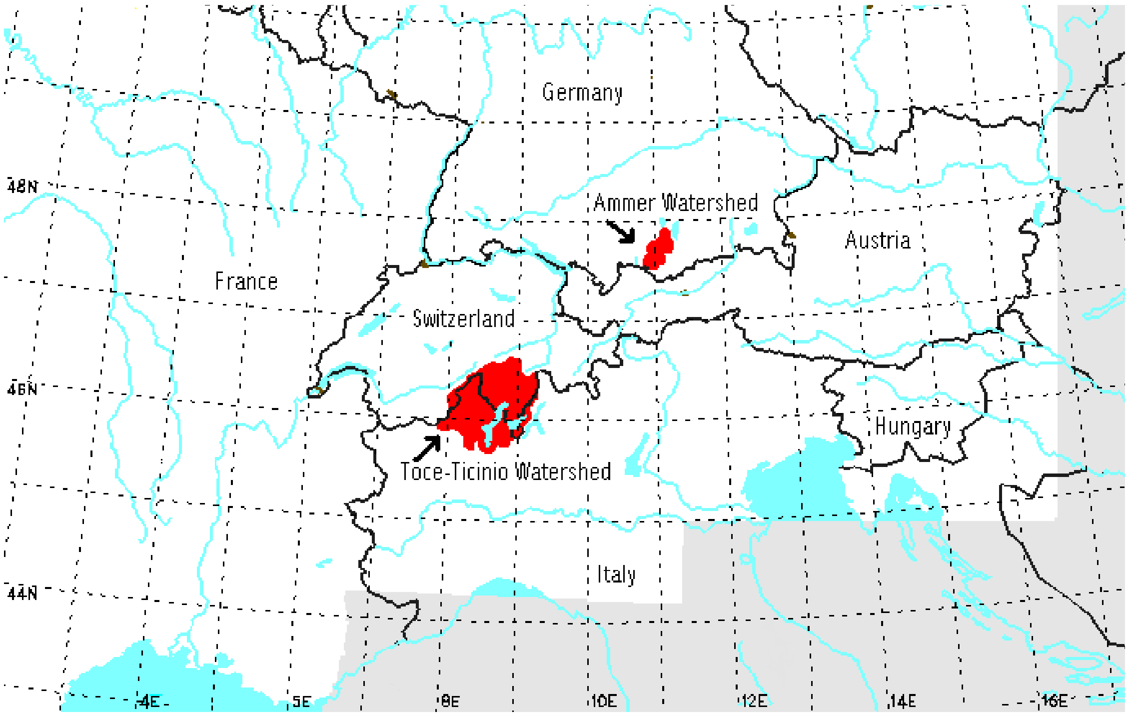

Figure 1. Location of the two investigated areas, the Toce-Ticino (including the Maggia and Verzasca) and the Ammer watershed, in the Bavarian Alps.

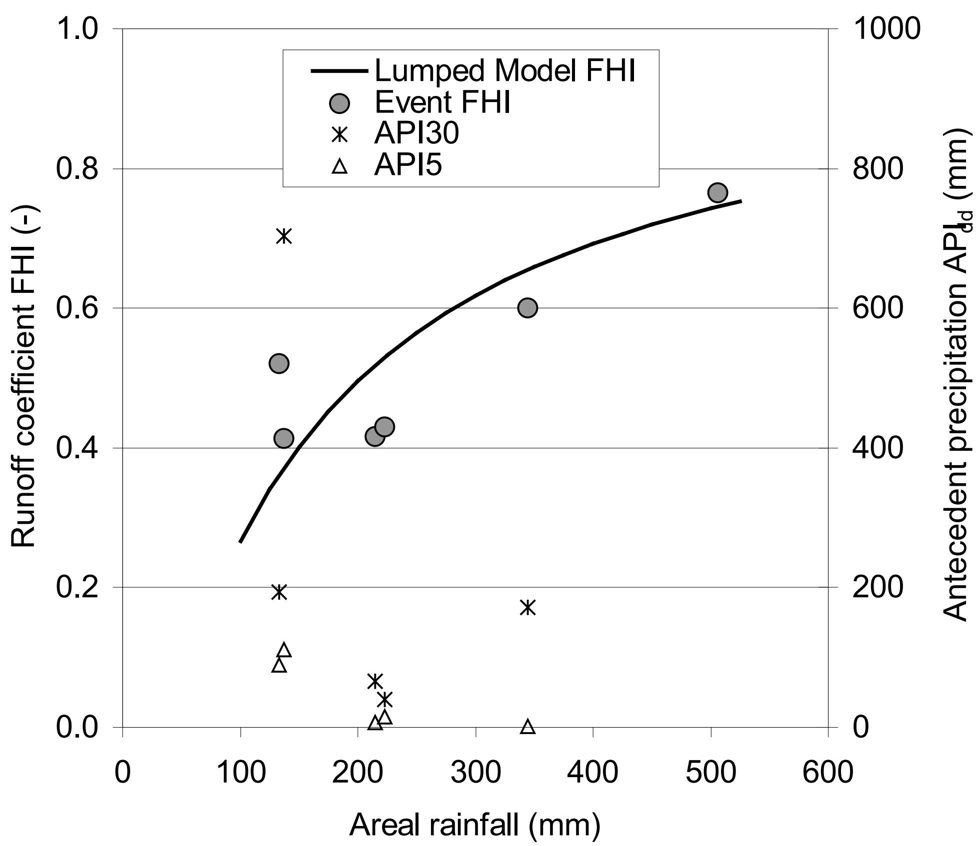

Figure 2. The runoff coefficient for 6 major floods in the Toce basin, including the IOP2b event, is represented on the left axis together with the theoretical curve of a conceptual model. On the right axis the 5 days and 30 days prior to the event precipitation.

indications on the residual storage capacities of reservoirs and their potential effect on the reduction of runoff volumes downstream the dams. For the major flood in the Toce river, that occurred during the September 20 (IOP-2) event, a reduction of about 10% of the total flood volume was observed.

3. SOIL MOISTURE

The third objective was to study the role of soil moisture prior to flood events in determining the production of runoff. During the SOP soil moisture was sampled on a continuous time basis at five sites and, with major spatial detail, during the four missions of a helicopter-borne microwave radiometer in the C, X and L band and different polarization (Macelloni et al., 2003). The sensitivity of the radiometer to different surface types was confirmed, although electromagnetic interferences prevented a completely successful use of the microwave antennas for soil moisture monitoring in the investigated area. The recent literature confirms that also active microwave sensors, although promising, are still far from being effective for soil moisture monitoring in mountain areas because the effect of surface roughness and topography prevents. In summary sever difficulties remain in monitoring soil moisture in mountain catchments.

Ground and laboratory measurements confirmed a relatively high variability of the soil moisture content during the Special Observing Period (Zappa and Gurtz, 2003; Menziani et al., 2003). It seems, however, that the role of soil moisture in areas covered by limited soil depths, as many steep mountain catchments, is less relevant than expected. As shown by Fig. 2 and as reported in Tab. 1 for example, different values of antecedent precipitation do not affect dramatically the resulting runoff coefficient, at least during major floods, thus indicating a minor sensitivity to initial soil moisture conditions, than generally assumed, of the hydrological response of soils to precipitation forcing. This result shoudl be confirmed by further investigations.

Table 1. Event data for major floods in the Toce, Ticino and Ammer basins.
API_{30}: rainfall in the 30 days prior to the event, API_5: rainfall in the 5 days prior to the event, P: rainfall event volume, Q: runoff volume, Φ: runoff coefficient.

Event	Date	API_{30} (mm)	API_5 (mm)	P (mm)	Q (mm)	Φ (-)
Toce at Candoglia (1532 km²)						
tt1	22-25 Sep. 1993	171	2	345	207	0.60
tt2	11-14 Oct. 1993	703	111	137	57	0.41
tt3	3-6 Nov. 1994	66	7	215	89	0.42
tt4	27-30 Jun. 1997	194	89	133	70	0.52
IOP2b	19-21 Sep. 1999	39	15	223	96	0.43
tt5	12-16 Oct. 2000			506	387	0.77
Ticino at Bellinzona (1515 km²)						
tt1	22-25 Sep. 1993	241	3	216	91	0.42
tt2	11-14 Oct. 1993	673	182	154	118	0.77
tt3	3-6 Nov. 1994	60	3	101	35	0.34
tt4	27-30 Jun. 1997	238	73	138	90	0.65
IOP2b	19-21 Sep. 1999	90	26	122	43	0.35
tt5	12-16 Oct. 2000	212	12	244	127	0.52
Ammer at Fischen (709 km²)						
am1	16-20 Jul. 1993	272	39	94	44	0.47
am2	27-30 Aug. 1995	164	39	105	44	0.42
am3	17-20 Jul. 1997	247	28	74	28	0.38
am4	20-24 May 1999	184	9	188	108	0.57

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