ISPRA
Istituto Superiore per la Protezione
e la Ricerca Ambientale

**REGIONE AUTONOMA
DELLA SARDEGNA**

MINISTERO DELL'AMBIENTE
E DELLA TUTELA DEL TERRITORIO E DEL MARE

Working Group F
Thematic workshop

FLASH FLOODS AND PLUVIAL FLOODING

Abstracts and Full Papers

26th-28th May 2010,
Cagliari, Italy

ATTI

Cover photographs:

- Oxford, July 2007 – Courtesy of Environment Agency (United Kingdom)
- Lyon, November 2008 – Courtesy of Cemagref (France)
- Vibo Valentia, July 2006 – Courtesy of Agenzia Regionale per la Protezione dell'Ambiente della Calabria, Centro Funzionale (Italy)
- Dresden, August 2002 – Courtesy of Technische Universität Dresden (Germany)
- Vibo Valentia, July 2006 – Courtesy of Agenzia Regionale per la Protezione dell'Ambiente della Calabria, Centro Funzionale (Italy)

Legal information

ISPRA has been established by Decree no. 112 of 25 June 2008, converted into Law no. 133 (with amendments) on 21 August 2008. ISPRA performs, with the inherent financial resources, equipment and personnel, the duties of ex-APAT, Italian Environment Protection and Technical Services Agency, ex-INFS, National Institute for Wildlife and ex-ICRAM, Central Institute for Scientific and Technological Research applied to the Sea (Decree no. 496, article 1-bis, December 4, 1993, converted into Law no. 61, Article 1, January 21, 1994, with amendments).

The Institute acts under the vigilance and policy guidance of the Italian Ministry for the Environment and the Protection of Land and Sea (*Ministero dell'Ambiente e della Tutela del Territorio e del Mare*).

ISPRA – Istituto Superiore per la Protezione e la Ricerca Ambientale
Via Vitaliano Brancati 48
00144 Rome, Italy
http://www.isprambiente.gov.it/

ISBN 978-88-448-0511-1

Graphic design by:
Stefano Mariani, Barbara Lastoria and Elena Porrazzo, ISPRA

May 2011

This publication is to be cited as follows:

Mariani S. and Lastoria B. (Eds.), 2011: *Working Group F Thematic Workshop on FLASH FLOODS AND PLUVIAL FLOODING – Abstracts and Full Papers*. Istituto Superiore per la Protezione e la Ricerca Ambientale, Rome, Italy, 182 pp.

INDEX

PLENARY SESSION: Setting the scene

THEME 1: Events characterization, analysis and approaches to hazard assessment

THEME 2: High intensity storms and flood: monitoring, nowcasting and forecasting

THEME 3: Structural and non structural measures: planning and prioritization

THEME 4: Socio-economic aspects

POSTER SESSION

PREFACE

This booklet collects abstracts and full papers of the oral and poster contributions to the Thematic Workshop on "Flash Floods and Pluvial Flooding", held in Cagliari (Italy) on 26–28 May 2010. The workshop is part of a series sponsored by Working Group F on Floods of the EC Common Implementation Strategy for the Water Framework Directive 2000/60/EC looking at the implementation of Directive 2007/60/EC on the assessment and management of flood risks (Floods Directive).

The main objective of the Floods Directive is the reduction of the destructive effects of floods through the assessment and management of flood risk, respecting fixed deadlines. Member States must indeed analyze which areas are at serious risk by 2011 and produce flood risk management maps by 2013 and flood risk management plans by the end of 2015. In elaborating their risk management plans, Member States shall consider the entire spectrum of types of flood event, some of which can have disastrous consequences on their territories.

The Cagliari Thematic Workshop, which was organized by the Institute for Environmental Protection and Research (ISPRA, IT) with the support of Working Group F, the Italian Ministry of Environment and Sardinia Region (IT), was focused on addressing the problem of the elaboration of risk management plans in the particular case of flash flood or pluvial flooding events, which are frequently occurring all around Europe.

In the last decade, many catastrophic flash floods caused severe damage and loss of life in Europe. Noticeable examples include the events occurred in Spain in 2000 (Montserrat, Catalonia region), Southern France in 2002 (Cévennes), Germany in 2003 (Dresden), Central Romania in 2005, Italy in 2008 (Cagliari, Sardinia region) and in 2009 (Messina, Sicily region), and Portugal in 2010 (Madeira). Also pluvial flooding events can give rise to major damage, particularly in urban areas. An example is provided by the floods occurred in England during the summer 2007 which caused over 3 billion Euros of damage.

An organizing board was set up for the workshop composed by three different committees: Working Group F Planning Committee (European Commission, Belgium, Czech Republic, France, Germany, Ireland, Italy and the European Water Association) dealing with strategic issues, a technical-scientific committee dealing with selection of themes and papers, coordination of sessions and outcomes, and a national organising committee dealing with logistics and administrative issues in general.

Almost 120 among delegates from Member States and invited speakers across Europe attended the workshop. A plenary session, which provided a characterization of flash flood and pluvial flooding events across Europe, was then followed by four thematic sessions on:

- Events characterization, analysis and approaches to hazard assessment;
- High intensity storms and flood: monitoring, nowcasting and forecasting;
- Structural and non structural measures: planning and prioritization;
- Socio-economic aspects.

All presentations are downloadable from the Cagliari Workshop webpage available on the ISPRA's website: http://www.isprambiente.it/site/en-GB/Archive/Events/Documents/flash_floods.html and on the password-protected European CIRCA website: http://circa.europa.eu/Members/irc/env/wfd/library?l=/framework_directive/thematic_documents/flood_management/information_exchange/documents_information/cagliari_26-28520 10&vm=detailed&sb=Title.

The National Technical-Scientific Committee

PLENARY SESSION:

Setting the scene

M. Borga[1]

CHARACTERISATION OF FLASH FLOODS IN EUROPE: IMPLICATIONS FOR FLOOD RISK MANAGEMENT

Corresponding author: Prof. Marco Borga
Department of Land and Agroforest Environment, University of Padova
c/o Agripolis, viale dell'Università 16 – 35020 Legnaro (PD), Italy
E-mail: *marco.borga@unipd.it*

Abstract

High-resolution data enabling identification and analysis of the hydrometeorological causative processes of flash floods have been collected and analysed for 25 extreme flash floods (60 drainage basins) across Europe in the frame of the EU HYDRATE project. Criteria for flood selection were high intensity of triggering rainfall and flood response and availability of high-resolution reliable data. Hydrometeorological data collected and collated for each event were checked by using a hydrological model. The derivation and analysis of summarising variables based on the data archive has made it possible to outline some characteristics of flash floods in various morphoclimatic regions of Europe.

Peak discharge data for more than 50% of the studied watersheds derive from post-flood surveys in ungauged streams. This stresses both the significance of post-flood surveys in building and extending flash flood data bases, and the need to develop new methods for flash-flood hazard assessment able to take into account data from post-event analysis.

Examination of data shows a peculiar seasonality effect on flash flood occurrence, with events in the Mediterranean and Alpine-Mediterranean regions mostly occurring in autumn whereas events in the inland Continental region commonly occur in summer, revealing different climatic forcing. Consistently with this seasonality effect, spatial extent and duration of the events is generally smaller for the Continental events with respect to those occurring in the Mediterranean region. Furthermore, the flash flood regime is generally more intense in the Mediterranean Region than in the Continental areas.

The runoff coefficients of the studied flash floods are usually rather low (mean value: 0.35). Antecedent saturation conditions have a significant impact on event runoff coefficients, showing the influence of initial soil moisture status even on extreme flash flood events and stressing the importance of accounting soil moisture for operational flash flood

---

[1] Department of Land and Agroforest Environment, University of Padova, Legnaro, Italy

forecasting. The runoff response displays short lag times (mostly < 6 hours).

Examination of the triggering storm events and model analyses provides indications about the time resolution and the spatial density of the networks required for monitoring and forecasting flash flood events in Europe. Implications concerning flood risk management options will be also considered and discussed.

R. Falconer[1]

PLUVIAL FLOODING IN EUROPE

Corresponding author: Mr. Ronnie Falconer – Senior Consultant

Jacobs Engineering UK Ltd

95 Bothwell Street – Glasgow G2 7HX, Scotland, United Kingdom

E-mail: ronnie.falconer@jacobs.com

Abstract

This paper will summarise outcomes from the European Water Association expert meeting on Pluvial Flooding in Europe held in Brussels last October in support of this thematic workshop. It also aims to review feedback from the questionnaire specifically in relation to pluvial flooding and discuss the significance and characteristics of pluvial flooding for different parts of Europe, and some of the approaches adopted in dealing with this type of flooding.

The paper will also describe some recent experience in responding to pluvial flood risk in the UK through the preparation of Surface Water Management Plans and refer to current European research initiatives such as the INTERREG IVB “Flood Resilient City” project.

---

[1] Jacobs Enginering UK Ltd, Scotland, United Kingdom and European Water Association, Hennef, Germany

THEME 1:

Events characterization, analysis and approaches to hazard assessment

D. N. Porter[1]

DEVELOPMENT OF THE PLUVIAL FLOOD MAP FOR NORTHERN IRELAND

Corresponding author: Mr. David N. Porter – B.Eng C.Eng MICE MCIHT, Director of Development

Department of Agriculture and Rural Development, Rivers Agency

4 Hospital Road Belfast, Northern Ireland

E-mail: david.porter@dardni.gov.uk

Abstract

This paper will outline the development of the pluvial or surface water flood map for Northern Ireland and will focus on the technical approach taken, the assumptions involved and the quality of the outputs. The refinement of the assumptions between the first and second generation maps will be examined and in particular the characteristics of the model and impact of the rain event profile. The assumptions used to build the base model must be understood, as they will directly influence the outputs. The testing of the emerging maps against known historical flooded areas will be detailed as this is absolutely necessary in order to gain an acceptable level of confidence in the model and therefore the map. The paper will also consider the need for a common or industry standard approach to risk from this source if the long-term aim of reducing the citizen's exposure to and impact from surface water flooding is to be realised while complying with the requirements of the EC Floods Directive.

1 Introduction

The Floods Directive 2007/60/EC requires each Member State to "*undertake a preliminary flood risk assessment*" (PFRA; Chapter II, Article 4.1) using "*available or readily derivable information*" (Chapter II, Article 42). As delegated competent authority the Department of Agriculture and Rural Development (DARD) through its Executive Agency, Rivers Agency, undertook the assessment for Northern Ireland.

The first step of the process was to determine the scope of the exercise and this involved detailing the available information in the form of maps, reports and historical data. The identification of information gaps was then possible which, enabled a forward programme of work to be generated. One such gap that was immediately obvious was that of surface or pluvial flood mapping. The Agency had already created and published a strategic

---

[1] Department of Agriculture and Rural Development, Rivers Agency, Belfast, Northern Ireland

flood map[*] indicating areas which are predicted to be at risk in a 100 year fluvial or river flood event or a 200 year coastal event, but there was no publicly available pluvial or surface water layer to this map. To close this gap Rivers Agency commissioned WDR & RT Taggart, a Belfast based engineering consultant from the existing framework contract, who partnered with JBA Consulting on the production of the strategic surface water flood map.

2 First Generation Map

The original surface water map was intended to be a high level screening exercise of the areas at risk and so was based on some coarse assumptions and a high intensity rain event which, without doubt, would overwhelm the entire engineered storm water drainage infrastructure.
The rain event and assumptions applied were as follows:

(a) 0.5% AEP (Annual Exceedance Probability) or 200 year rainfall;

(b) 6.25 hour rainfall duration;

(c) 100% ground run off;

(d) all engineered storm water drainage systems would be overwhelmed;

(e) bare earth DTM (Digital Terrain Model) edited to remove structures such as bridges that cause an obstruction to flow pathways.

After production of the map and in addition to the above criteria, a 0.3 m depth threshold tolerance was applied to the output. In essence this removed any flooding less than 0.3 m deep from the map in an attempt to regulate some of the coarse assumptions and to ignore flooding which would be unlikely to enter buildings. This allowed the production of the first generation map which started the process and enabled quality assurance of the model and output to be carried out. Figure 1 shows a sample output from the first generation surface water map.

3 Real Life Event

On 12 June 2007 there was a significant flood event in Northern Ireland which predominately impacted upon the East of the capital city, Belfast. This event resulted in relatively widespread flooding of an urban area impacting upon 961 residential properties and numerous commercial properties.

Rainfall records were available from a number of sites nearby which showed that there was a prolonged wet period with detailed analysis indicated that approximately 48 mm of rain fell in a one hour period giving an estimated return period of 0.3 to 0.2% AEP or between a 1 in 300 to 500 year rainfall event[†].

---

[*] http://www.riversagencyni.gov.uk/index/stategic-flood-maps.htm.

[†] Smyth et al, 2008, 'Fluvial and Pluvial Flood Risk East Belfast Flooding – June 2007' DEFRA Conference, Manchester 1-3 July 2008.

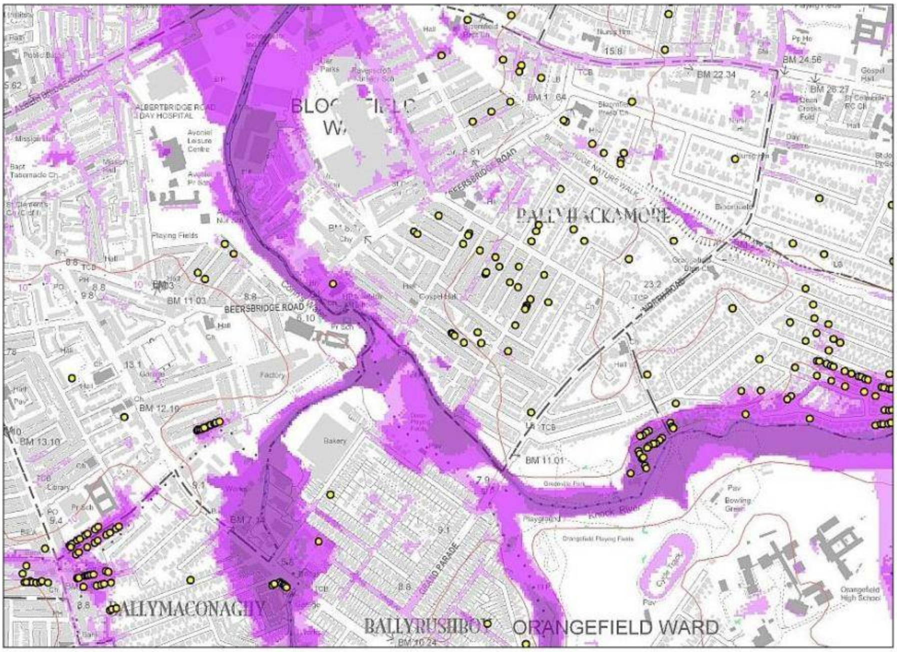


Figure 1: Version 1 of the surface water map. The yellow dots indicate 2007 hardship payments.

The widespread flooding of East Belfast in June 2007 prompted a political reaction from the Northern Ireland Executive who announced a £1,000 hardship payment to all householders affected by event. This resulted in over 900 payments in the area and as an unforeseen consequence provided flood impact data which was subject to third party validation. This, hardship payment data set, has proven to be invaluable when developing and validating the surface water map.

After this flood event extensive evaluation of the causes and impacts were carried out, with particular focus on the Knock and Loop Rivers in order to identify possible measures which would reduce the reoccurrence likelihood of the impact of a flood event of this type. This analysis showed that of the 427 properties affected with these catchments, 229 or 54% where as a result of fluvial flooding and 198 or 46% from pluvial sources. In addition this area is subject to coastal inundation and in order to determine if this was an influencing factor in the extent of this event, the rising river levels were plotted against the tidal level. The results are shown in Figure 2.

It can be clearly seen that the event of 12 June 2007 was not a coastal event neither did the sea level influence the extent or severity of the flooding as the peak river water level occurred during the low tide. The hydrograph in Figure 2 also illustrates the speed of reaction of the river to this rain event. The rainfall recorders indicate that the peak rain event occurred between 12:30 and 13:30 and by 14:00 the Loop and Knock

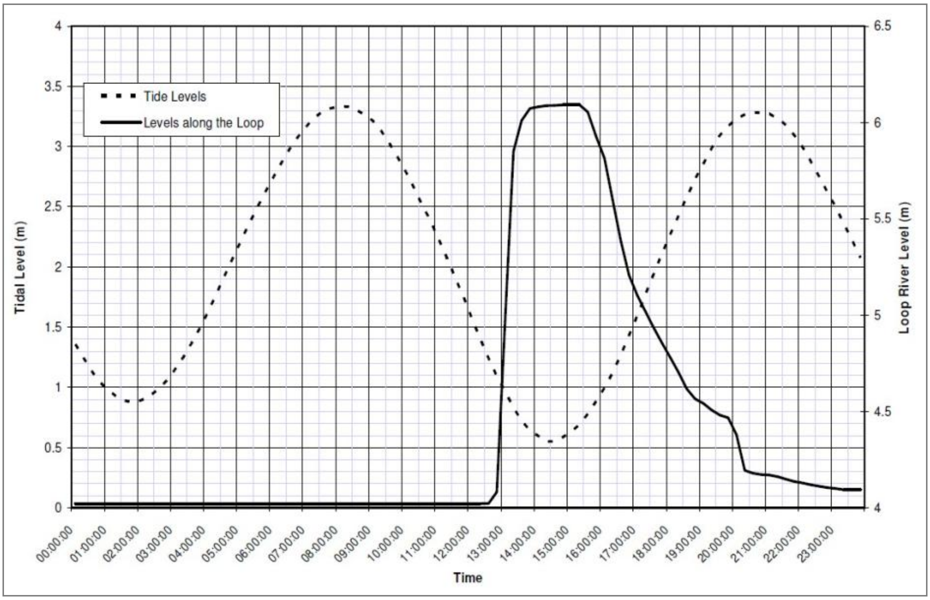


Figure 2: Comparison between the Loop River and tide levels on 12th June 2007, East Belfast Flooding. After "Flood evaluation report" by Jacobs for Rivers Agency.

Rivers had risen by over 2m. Whilst the speed of pluvial events is not the subject of this paper, it is worth noting this data and considering it in the context of emergency response and effectiveness of pluvial flood warning in an urban situation.

4 Quality Assurance of Surface Water Map

The first generation surface water map was tested against the flood outline and hardship payment data generated from the June 2007 flood event. This analysis indicated that it captured many properties whose owners had received hardship payment but it had also developed a much larger flood extent and therefore included many properties that had not experienced flooding during the 2007 event, indeed up to 3,000 in the Belfast test area of 36km^2. It was therefore concluded that the map "*was conservative, and appropriate for use in the Preliminary Flood Risk Assessment as a screening device*"[‡]. This map provided information that was incorporated into analysis that determined the flood risk indicators across Northern Ireland which will be subsequently used to inform the PFRA. It will also be useful when identifying the areas of "*potential significant flood risk*" as required by the Floods Directive (Chapter II, Article 5.1).

In addition to the Belfast test area the surface water map was examined against a number of other known pluvial flood hotspots across Northern Ireland. This testing added to our understanding and level of confidence in

---

[‡] Version 2 of the Surface water Map Northern', Hankin et al, JBA, FEB 2010.

the outputs but was not as robust as the Belfast quality assurance given there was no externally checked data sources to validate the flooded area. In these cases we relied upon local knowledge and/or visual inspection to confirm the outputs of the maps.

In all modelling exercises the outputs are a direct consequence of the inputs, therefore the decisions taken at the early stages of development must be recorded and refreshed during the evolution of the model to ensure that the outputs and their inherent inaccuracies are understood. For example, if the base DTM is a bare earth this means that buildings and trees have been removed from the data as part of the survey post-processing. Surface water flood progression is influenced by such features and so any map produced with a bare earth DTM will only ever deliver a high level screening output and will never be able to provide very accurate site specific data. The accuracy of the DTM is also determined by the vertical accuracy and grid spacing of the topographical survey inputs. Typically, this is generated using IfSAR (Interferometric Synthetic Aperture Radar), which can have a tolerance of ± 1.0m RMSE (Root Mean Square Error), or LiDAR (Light Detection And Ranging) surveys which can have a tolerance of approximately ± 0.15m RMSE, or a combination of both. For large models, covering a significant land area there may also be variances in the survey dates, quality and vertical accuracy so some areas of the map may show a closer representation of the real life flood event.

The output from the 1st generation surface water map indicated that 3.8% of properties within Northern Ireland are at risk from this source of flooding, which equates to approximately 31,500 properties. A predicted "climate change" version of the 1st generation surface water map was also produced and this indicated an increase in properties at risk to 38,000 or 4.6% of the building stock.

5 2nd Generation Map

Whilst it was concluded that the first version of the surface water map was suitable for inclusion in the PFRA the assumptions and inherent tolerances resulted in an overly conservative risk envelope which would have impacted upon future land use decisions. It was therefore decided to refine the map to better represent the real life experience of flood events. The second generation map included the following changes and improvements.

1) Rainfall – 0.1% AEP (1000 year), 0.5% AEP (200 year) and 1.33% AEP (75 year) events all with a 1 hr duration.
2) Infiltration and sewer capacity determined by catchment characteristic:
    a) infiltration – run off set at 80% for urban and 38–39% for rural;
    b) effective sewer capacity set at 12 mm h^{-1} where present.
3) DTM – buildings and roads layers incorporated and modified to reflect conveyance and obstructions to flow:

   a) buildings raised by 5 m;
   b) roads lowered by 0.15 m.
4) Variable Manning coefficient dependant on ground type.
5) GIS Post-Processing:
   a) flood depths below 0.1 m removed as the infiltration and sewer capacity detailed above, ensured that standing water less than this depth and over a few hundred square metres was not considered to be significant;
   b) isolated water polygons removed;
   c) dry islands removed.

In addition to these improvements the new version of the model was run for three flood scenarios; low, medium and high probability. This enabled annualised damages to be calculated, similar to those available for flooding from rivers and the sea, ensuring full representation of all sources within the PFRA analysis. Looking to the future, the ability to generate these different scenarios will assist when developing the flood hazard and risk maps as required by the Floods Directive (Chapter II, Article 6.3).

When the 2nd generation surface water map was tested against the hardship payment data from the study area in East Belfast, it encompassed a similar number of effected properties compared to the previous version but now there was a smaller number of properties that had not been flooded in the June 2007 event. Previously there were approximately 3,000 properties that where outside the hardship payment dataset, now about 2,000 in a 36 km^2 test area, a reduction of a third. This was achieved after testing a wide range of options and confirmed to the project team that the optimum configuration had been achieved. In addition the map outputs were examined against other areas across Northern Ireland that are known to be susceptible to surface water flooding which confirmed the results from the Belfast study area. A sample output from the second generation map can be seen in Figure 3.

6 Input Sensitivity

In essence there were two significant changes to the inputs which generated the surface water maps for Northern Ireland; namely the model parameters and the rain event profile.

The changes to the base model parameters where implemented to ensure that the model was a better representation of real life flood events. These enhanced the usefulness, accuracy and application of the map outputs. The initial flood outlines, based on the bare earth DTM with no allowance for the existence of storm water drainage systems, resulted in exaggerated or overly conservative results which would rarely, if ever, be observed during a flood event caused by the magnitude of rain event used

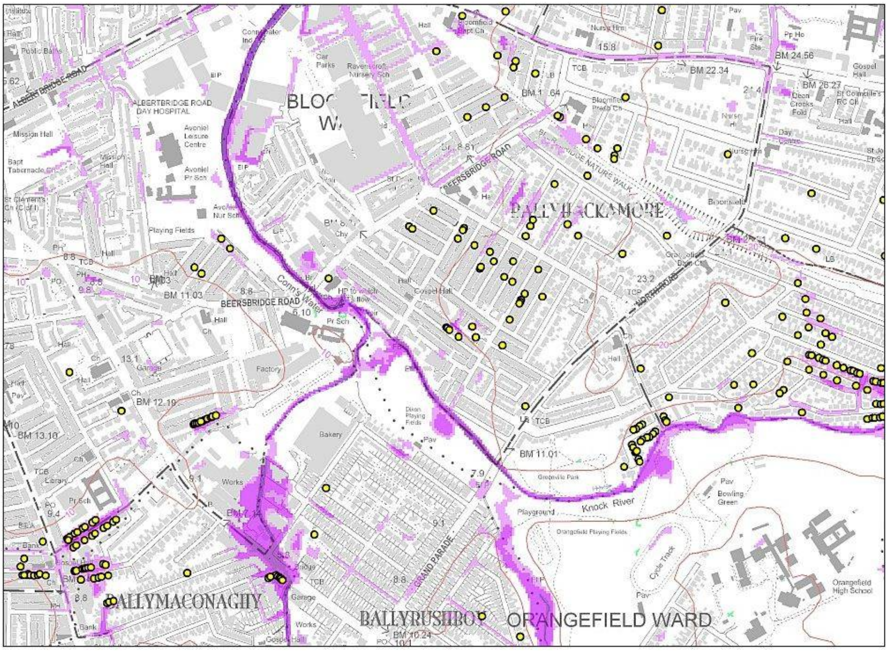


Figure 3: Version 2 of the surface water map. The yellow dots indicate 2007 hardship payments.

in the model. The improvements described in this paper were therefore fundamental to the operation of the model as they ensured delivery of a product which, whilst still strategic in nature, is now refined and capable of informing the public about the residual surface water flood risk. Given its accuracy it is also useful to drainage infrastructure owners as they can now identify areas that require closer attention and it provides land use policy makers with detailed information which will ensure that Flood Risk Management informs their decision making process.

The changes to the rain event profile present a slightly different challenge in that an assessment is required to determine how close the chosen rain event is to the real life weather patterns experienced in any particular region. This will obviously change by country and most importantly will be influenced in the future by the predicted impacts of climate change. An increase in surface water flooding is a very likely direct consequence of climate change as the design standards for storm water drainage systems is based on a commonly occurring rain event, typically 1 in 30 year return period. Systems built to this standard will not be able to cope with the more extreme, high intensity, short duration storms. This pattern of storm event will overwhelm the systems' ability to perform. With an increase in storminess predicted we can therefore expect more surface water flooding and this leads to a dilemma for flood risk mapping and policy makers. If we use a longer duration high intensity rain event to generate our surface water maps this will result in a large "at risk" area which will then impact on land use decisions in those areas. If however we use an unrealistically short duration event this may grossly under estimate the risk which in the short term would bring a false comfort to those who live and work in these areas, and then undermine and discredit the map when a significant flood event occurs which was not predicted. In this regard there is a decision required by government as to the level of risk that is acceptable. There is a well established understanding of fluvial and coastal risk modelling. There is also established communication terms which reflect the 'industry standards', such as the 100 year flood events. There is, however, no such standard for pluvial flooding, given the emerging nature of this technology and the inherent difficult in predicting such events, thought needs to be given to this so that design standards are reasonable, affordable and defendable while at the same time offering an appropriate level of protection to those at risk.

7 Public Perception

Flood risk is a complex subject involving detailed topographical surveying, computer models and the communication of risk of a future weather event which is outside the control of mankind. The public when flooded are not generally interested in the source neither can they understand the differences between a map which is generated to show the impact of rising flood waters from rivers and the sea or one generated to show the consequence of intense rainfall, as in pluvial flood mapping. The person whose property has been subject to flooding wants to know what can be done to ensure that it does not reoccur and who is going to offer them assistance. We must always keep this and the use of our maps in mind during their development.

Conclusion

The needs for a surface water flood map for Northern Ireland was established by a gap in the information available to develop the PFRA. The first generation map was too conservative given the bare-earth nature of the base model and the extreme nature of the rain event. The availability of good data from the June 2007 flood event ensured excellent quality assurance of the map outputs and enabled the inputs to be refined in order to produce a more accurate prediction of a flood event from this source. The risk appetite of the public still needs to be established in order that unnecessary blight or risk exposure is not a consequence in the long term. In conclusion the new surface water map will improve the information available to the public on the risk of any particular area and therefore will ensure that they and their government are in a position to make informed decisions particularly related to land use issues.

Acknowledgements

Malcolm Calvert (Rivers Agency, Belfast) and Barry Hankin (JBA Consulting, Skipton).

B. Mazzorana[1]*, F. Comiti*[2]*, and C. Scherer*[3]

DETERMINING FLOOD HAZARD PATTERNS THROUGH A COMBINED STOCHASTIC-DETERMINISTIC APPROACH

Corresponding author: Dr. Bruno Mazzorana
Department of Hydraulic Engineering, Autonomous Province of Bolzano
Via Cesare Battisti 23 – 39100 Bolzano, Italy
E-mail: bruno.mazzorana@provincia.bz.it

Abstract

A sound, evidence-based hazard mapping requires the analysis of stochastic processes taking place at critical configurations (e.g., bridges, levees) in order to reliably determine the spatial patterns of flood intensities and probabilities. Here we discuss an approach aiming to support an enhanced determination of flood hazard patterns by identifying within alluvial fans and river corridors two main types of spatial domains based on the predictability of their dynamics, that is, stochastic and quasi-deterministic domains. The former represent critical configurations whose dynamic evolution (e.g., clogging by driftwood, failure due to breaching) cannot be realistically specified by deterministic models, whereas the latter refers to the part of the system where the flood propagation can be computed with sufficient precision and accuracy by hydrodynamic models. The applicability of the proposed approach is discussed on the basis of a case study in the Autonomous Province of Bolzano (Italy).

1 Introduction

In the European Alps, during the last two decades considerable economic losses were caused by torrential processes and by river inundations (Barredo, 2007). An increase over time of such losses was attributed to both augmented hazards, that is, to higher natural process magnitude (Solomon et al., 2007) and to the increase of values at risk (Fuchs, 2009). The analysis of the most recent flood events in the Alps highlighted considerable shortcomings in the current procedures used for natural hazard and risk assessment (Autonomous Province of Bolzano-Bozen, 2008). In particular, the effects of changing channel morphology during the event and the reduction of cross-sectional area due to wood clogging were found to significantly amplify process intensities (e.g., Comiti et al., 2008, Figure 1). Furthermore, existing hazard maps turned out to be not as reliable as expected (e.g., Bezzola and Hegg, 2007). In order to

---

[1] Department of Hydraulic Engineering, Autonomous Province of Bolzano, Italy
[2] Faculty of Science and Technology, Free University of Bolzano, Italy
[3] Obrist & Partner Engineering, Caldaro (Bolzano), Italy

improve risk analyses and to support decision making, flood event scenarios need to be re-established based on such issues, in particular to cope with the different sources of uncertainty affecting the predictability of hazard process paths (e.g., Paté-Cornell, 1996).

Figure 1: Flash flood in the Davča basin (Slovenia, September 2007). Driftwood and aggradation clogged the bridge (arrow), causing channel avulsion and thus damages to the house on the right of the picture (http://www.davca.si/).

As a consequence of morphodynamic changes, driftwood obstructions and levee failures, actual flooded areas are in many cases different from those predicted by deterministic hydrodynamic models – no matter how accurate – implementing fixed channel geometries. In many cases, such discrepancies between predicted and actual flood scenarios are expected and predictable – at least in qualitative terms – by river managers, but current hazard maps do not take them into consideration because hydrodynamic 2D models have been adopted “enthusiastically” as the ultimate solution. Furthermore, in a perspective of stochastic processes occurring at nodes (i.e., bridges) along the channel network, the frequency of inundation (i.e., the return period) of many areas does not correspond to the frequency of the hydrologic event itself (i.e., the return time of a certain peak discharge).

In this paper we propose a nested scenarios approach in order to determine and map the expected flood scenarios including stochastic processes occurring at critical cross-sections, with the ultimate goal of establishing a sounder risk mapping procedure.

2 Theoretical background of flood risk assessment

The concept of risk with respect to natural hazards is defined as a function of the probability of occurrence of a process and of the related extent of damage. The latter is in turn specified by the damage potential and vulnerability of exposed objects. For an ex-ante quantification of risk (Fuchs et al., 2007) induced by a specific hazard scenario k (expressed in terms of process intensities I, for instance, flow depth, flow velocity or their combination) for a given object m, risk can be expressed as:

$$R_{k,m} = f(p_k, A_m, e_{k,m}, v_{k,m}), \tag{1}$$

where $R_{k,m}$ is the risk associated to the scenario k and object m; p_k is the spatial probability of occurrence of scenario k in the vicinity of the object m, A_m is the economic value of object m, $e_{m,k}$ is the probability of exposure of object m to scenario k, $v_{m,k}$ is the vulnerability of object m, depending on the local intensity of scenario k.

Working in a raster-style (i.e., grid-based) spatial environment, for each cell c of the grid, where the probability of occurrence of the hazard can be assumed to be equal, n objects can be exposed to the natural hazard, and therefore Eq. (1) becomes:

$$R_{k,c} = f(p_k, A_{k,m=1,\ldots n}, e_{k,m=1,\ldots.n}, v_{k,m=1\ldots n}) \tag{2}$$

The overall risk for a given cell c is then determined by the sum of all the possible hazard scenarios K occurring on that spatial location, and therefore reads:

$$R_c = \sum_{k=1}^{K} R_{k,c} \tag{3}$$

Finally, for a given area composed of C cells, the total risk is given by:

$$R = \sum_{c=1}^{C} R_c \tag{4}$$

The most critical step to actually apply Eq. (2) to real cases is the evaluation of the spatial probability of process intensities (p_k).

3 Coupling deterministic and stochastic processes

Within an area subject to flood flows (e.g., alluvial fans, floodplains), we can identify two main types of spatial domains based on the predictability of their flood dynamics, that is, stochastic and quasi-deterministic domains. The former represents the critical configurations whose dynamic evolution (e.g., clogging by driftwood, failure due to levee breaching) cannot be realistically specified by deterministic models, whereas the latter refers to the part of the system where the flood propagation can be computed with sufficient precision and accuracy by hydrodynamic models.

For each stochastic domain, we postulate that depending on the intensity of the hazard process, it can feature only a finite set of possible states (e.g., levee stable/breached; bridge clear/clogged). A domain undergoes a variation of its state through a finite number of transitions. Therefore, a matrix describing the possible transitions among domain states for different process intensity can be derived.

The main problem in the attempt to introduce stochastic domains in flood hazard mapping is the determination of the transition probabilities. Two distinct approaches to solve such a problem can be applied, that is, an objective method and a subjective one. The first relies on the use of either empirical or theoretical relationships between the transition under analysis and the physical processes. When such relationships are not available, a subjective method can be applied, built upon the concept of the subjective probability theory.

Let us now consider a hypothetical area within a river corridor with well defined flood inflow conditions, either in terms of intensity and frequency (i.e., based on a purely "hydrologic" magnitude-frequency relationship). We call this region – which may consist of floodplains, alluvial fans and stream channels – the "response system", that is, the spatial region which responds to the loading from the upstream river reach, called the "loading system". Starting from the analyzed response system, a simplified response system is derived (Figure 2) based on an *ex ante* identification of all possible critical configurations and existing flood hazard index maps. Within the response system depicted in Figure 2, we can identify two stochastic domains, that is, one bridge and one levee section, within the deterministic domain of the fan area. First, experts select the relevant stochastic domains for hazard scenarios.

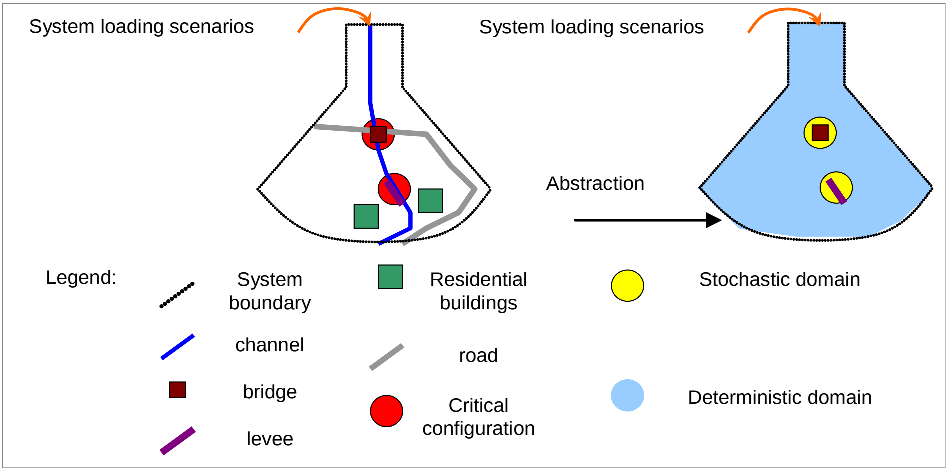


Figure 2: Example of a response system (alluvial fan). Starting from the real system (left), its simplified model (right) is derived, where the relevant stochastic domains (critical nodes) are identified within a "deterministic" area.

For each relevant stochastic domain, the experts assign for several process intensities a conditional probability to the relevant state transitions (i.e., they fill up the transition matrix mentioned above).

Subsequently, several 2D hydrodynamic simulations are run implementing the relevant combinations of stochastic domains states. Finally, applying the transition probability matrix to the virtual (i.e., hydrological) event probability of each simulation will lead to derive a map of flooded areas where recurrence intervals (R.I.) actually include the possible transitions at critical sections.

It is clear that the overall flood recurrence interval map is strongly conditioned by "tipping" processes taking place at critical nodes. Neglecting or overlooking such evidences heavily increases the uncertainty associated with hazard maps, which are crucial for the subsequent risk analysis (Eq. (2)) and mitigation.

4 Testing the methodology: the Rienz river in Bruneck

The city of Bruneck (Aut. Prov. Bolzano) lies on the floodplain (i.e., the response system) of the Rienz river (drainage area 640 km^2), whose channel flows through the downtown with several bridges (Figure 3). Loading systems scenarios (i.e., Rienz inflows from upstream of Bruneck for flood events > R.I. 100 yr) foresee, along with water and sediment fluxes, large driftwood transport rates, which would likely cause obstructions at the most critical bridges (i.e., those featuring the smaller free-board for the analyzed discharge). A preliminary 1D simulation helped identify two bridges (see Figure 3) as critical nodes, and as such these were categorized as stochastic domains (see section 2) within the quasi-deterministic domain of the channel-floodplain system. Only two possible states for each stochastic domain are implemented, that is, bridge cross-section totally clear or totally obstructed.

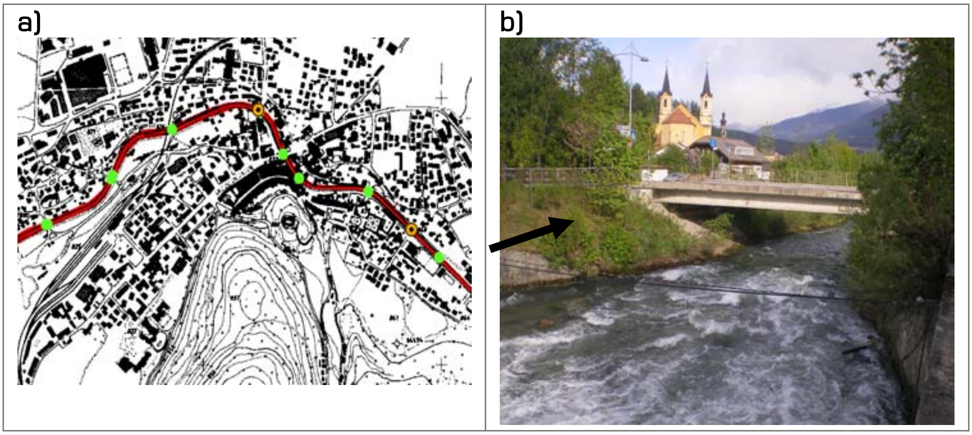


Figure 3: The Rienz in Bruneck: a) the two "critical" bridges (stochastic domains) are the orange dots, those assumed to be negligible for flood propagation are in green. Flow is right to left; b) photo of the first critical bridge.

Four flood propagation scenarios (i.e., no obstructions at all, obstruction of the 2 bridges, obstruction of only one of the two bridges) were simulated by the 2D hydrodynamic model "Sobek-River" for the same inflow hydrograph (re100 yr). As depicted in Figure 4, significant differences in terms of flood intensity (i.e., water depth) would stem from bridge clogging. Flooding temporal evolution (i.e., onset and duration) is also heavily affected (not shown).

The final step to actually calculate the spatial probability for each process intensity (p_k in Eqs. (1) and (2)) is to assign the probability of clogging for the each bridge under different inflow discharges – just 2 flow ranges can be used – based on the expected driftwood rate and size. Recent experimental works (e.g., Imhof, 2008) can provide guidance for such evaluation, which nevertheless could be also solely expert-based, that is, adopting a subjective probability approach (see Gilboa, 2009).

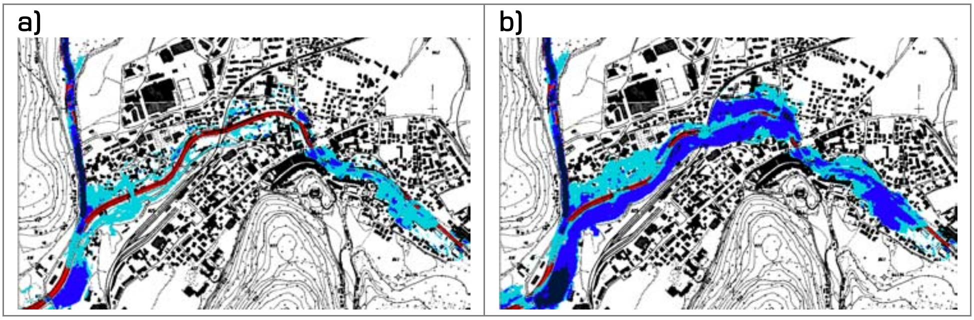


Figure 4: Inundation maps at the flood peak (inflow hydrograph R.I. 100 yr) for a subset of the possible propagation scenarios for the Rienz in Bruneck: a) bridges not clogged; b) both critical bridges clogged (see Figure 3). Note the larger flooded areas and the deeper water depths (darker blue) for case b.

Conclusions

The present paper has illustrated how flood hazard mapping procedures carried out without taking into account different scenarios – arising from stochastic processes at critical cross-sections (e.g., bridges) – can result in highly erroneous evaluations, especially in forested basins whose channels naturally transport high wood loads. A nested approach entailing deterministic simulations as well as stochastic evaluation is thus advocated for in order to achieve a more reliable determination of flood risks.

Acknowledgements

The authors thank Claudio Volcan (Dept. Hydraulic Engineering, Autonomous Province of Bolzano) for assisting with the hydrodynamic model simulations.

References

Autonome Provinz Bozen-Südtirol: Informationssystem zu hydrogeologischen Risiken. Methodischer Endbericht. Bozen, 2008.

Barredo, J.: Major flood disasters in Europe: 1950–2005. *Natural Hazards,* 42(1), 125–148, 2007.

Bezzola, G., und Hegg, C.: Ereignisanalyse Hochwasser 2005, Teil 1 – Prozesse, Schäden und erste Einordnung. Bern und Birmensdorf: Bundesamt für Umwelt BAFU, Eidgenössische Forschungsanstalt WSL, 2007.

Comiti, F., Mao, L., Preciso, E., Picco, L., Marchi, L., and Borga, M.: Large wood and flash floods: evidences from the 2007 event in the the Davča basin (Slovenia). In: *Monitoring, simulation, prevention and remediation of dense and debris flow II*, WIT press, 173–182, 2008.

Fuchs, S., Heiss, K., and Hübl, J.: Towards an empirical vulnerability function for use in debris flow risk assessment. *Nat. Hazards Earth Syst. Sci.*, 7, 495–506, 2008.

Fuchs, S.: Susceptibility versus resilience to mountain hazards in Austria – Paradigms of vulnerability revisited. *Nat. Hazards Earth Syst. Sci.,* 9(2), 337–352, 2009.

Gilboa, I.: Theory of decision under uncertainty. Cambridge University Press, 2009.

Imhof, M.: Modelluntersuchungen Verklausung von Schwemmholz an Bauwerken - Einfluss der Abflussverhältnisse. MSc thesis, ETH Zürich, 102 pp., 2008.

Paté-Cornell, E.: Uncertainty in risk analysis: Six levels of treatment. *Reliability Engineering and System Safety*, 54(2–3), 95–111, 1996.

Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K., Tignor, M., and Miller, H.: Climate change 2007. The scientific basis: Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press, 2007.

C. García Montañés[1] and A. Jiménez Álvarez[1]

EXAMPLE OF FLASH FLOODS IN SPAIN: PALANCIA RIVER

Corresponding author: Dr. Celia García Montañés
CEDEX – Center of Hydrographic Studies
Paso Bajo de la Virgen del Puerto 3 – 28005 Madrid, Spain
E-mail: celia.garcia@cedex.es

Abstract

In Spain, floods may result from highly different meteorological phenomena. Flash floods are provoked by mainly two kinds of rains, medium or large-scale convective rains that take place in autumn, lasting less than 24 hours and affecting mostly medium-sized Mediterranean basins, and small-scale convective rain which are highly intense but short (2 or 3 hours) and not particularly extensive, and take place in small mountain basins or in headwaters of rivers.

The complexity due to such floods may increase when the geomorphology of the affected areas contributes in an intensification of the effects of floods, mainly when the movement of water becomes two-dimensional. This occurs when the slope of the river suddenly change as it flows into an alluvial plain. Formations known as alluvial fans are usually created, where the water flow is two-dimensional whit high speeds and shallow waters. These are usually found in arid and mountainous areas, and create triangular flood plains.

As a response to the Floods Directive on the second phase of mapping the risk, a National Cartography System of flood prone areas is being developed in Spain. Some examples are being carried out in order to improve this System and trying to find the best way to study the different types of floods. Aspects such as the hydrological characterization of the events, criteria for hydraulic modelling, the inclusion of historical events and geomorphology in the analysis of information and which is the best information to be represented in risk and hazard maps, are discussed. In order to study flash floods, the Palancia River, located on the Mediterranean area, has been selected as pilot case. Results and conclusions of this study case are presented in the following paper.

---

[1] CEDEX – Center of Hydrographic Studies, Madrid, Spain

THEME 2:

High intensity storms and flood: monitoring, nowcasting and forecasting

D. Sempere-Torres[1] and C. Wittwer[2]

IMPRINTS: A JOINT EC EFFORT TO PROVIDE ADVANCED TOOLS FOR FLASH FLOOD RISK MANAGEMENT

Corresponding author: Prof. Daniel Sempere-Torres

Centre de Recerca Aplicada en Hidrometeorologia, Universitat Politécnica de Catalunya,

Gran Capità 2-4 – 08034 Barcelona, Spain

E-mail: imprints@imprints-fp7.eu

Abstract

IMPRINTS (acronym for IMproving Preparedness and RIsk maNagemenT for flash floods and debriS flow events) is a FP7 project (2009-2012) whose ultimate objective is to contribute to the reduction of loss of life and economic damage through the improvement of the preparedness and the operational risk management of flash flood and debris flow (from now on FF/DF) generating events, as well as contributing to sustainable development through reducing damages to the environment. To achieve this ultimate objective, the project is oriented to produce methods and tools to be used by practitioners of the emergency agencies and utility companies responsible for the management of FF/DF risks and associated effects. Impacts of future changes, including climatic, land use and socioeconomic changes will be also analysed, in order to provide guidelines for mitigation and adaptation measures.

Specifically, the consortium will develop three methodologies of different complexities to provide FF/DF forecasting and warnings:

(i) an early warning FF/DF system based on simplified calculations;

(ii) an integrated probabilistic forecasting FF/DF system; and

(iii) a probabilistic rule-based forecasting system adapted to the operational use by practitioners.

These systems will be tested on five selected flash flood prone areas, two located in mountainous catchments in the Alps, and three in Mediterranean catchments. The practitioner partners of IMPRINTS, namely the risk management authorities and the utility company managers in charge of emergency management in these areas, will supervise these tests. The development of such systems will be carried out using, and

---

[1] Centre de Recerca Aplicada en Hidrometeorologia, Universitat Politécnica de Catalunya, Barcelona, Spain

[2] Service Central d'Hydrométéorologique et d'Appui à la Prévision des Inondations, Toulouse, France

capitalising on, the results of the previous and ongoing research on forecasting and warning systems for FF/DF, in which several of the partners have already played a prominent role.

One major result of the project will be a prototype of the operational platform including the tools and methodologies developed under the project (http://www.imprints-fp7.eu/).

A. M. Rossa[1], F. Laudanna Del Guerra[1-2], M. Borga[3], T. Settin[4] and D. Leuenberger[5]

RADAR-DRIVEN HIGH-RESOLUTION HYDRO-METEOROLOGICAL FORECASTS OF THE 26 SEPTEMBER 2007 VENICE FLASH FLOOD

Corresponding author: Prof. Marco Borga
Department of Land and Agroforest Environment, University of Padova,
c/o Agripolis, viale dell'Università 16 – 35020 Legnaro (PD), Italy
E-mail: marco.borga@unipd.it

Abstract

This study aims to assess the feasibility of using carefully checked radar-derived quantitative precipitation estimates (QPE) by assimilation into numerical weather prediction (NWP) and hydrological models for flash flood forecasting. The hydrometeorological modelling chain includes the convection-permitting NWP model COSMO-2 and a hydrologic-hydraulic model built upon the concept of geomorphological transport. Radar rainfall observations are assimilated into the NWP model via the latent heat nudging method. The study is focused on 26 September 2007 extreme flash flood event which impacted the coastal area of north-eastern Italy around Venice. The hydro-meteorological modelling system is implemented over the Dese river, a 90 km^2 catchment flowing to the Venice Lagoon.

The radar rainfall observations are carefully checked for artifacts, including beam attenuation, by means of physics-based correction procedures and comparison with a dense network of rain gauges.

The impact of the radar QPE in the assimilation cycle of the NWP model is very significant, in that the main individual organized convective systems were successfully introduced into the model state, both in terms of timing and localization. Also, incorrectly localized precipitation in the model reference run without rainfall assimilation was correctly reduced to about the observed levels. On the other hand, the highest rainfall intensities were underestimated by 20% at a scale of a few tens of kilometres, the local peaks at a scale of a few kilometres by 50%. The positive impact of the assimilated radar rainfall was carried over into the free forecast for

---

[1] ARPA Veneto, DRST – Meteorological Centre of Teolo, Padua, Italy

[2] Department of Physics, University of Bologna, Italy

[3] Department of Land and Agroforest Environment, University of Padua, Legnaro, Italy

[4] ARPA Veneto, DRST, Marghera, Italy

[5] MeteoSwiss, Zurich, Switzerland

about 2-5 hours, depending on when this forecast was started, and was larger, when the main mesoscale convective system was present in the initial conditions. The improvements of the meteorological model simulations were directly propagated to the river flow simulations, with an extension of the warning lead time up to three hours.

L. Alfieri[1], J. Thielen[1] and A. de Roo[1]

FLASH FLOOD EARLY WARNING USING ENSEMBLE WEATHER FORECASTS

Corresponding author: Dr. Ad de Roo

European Commission, Joint Research Centre, Institute for Environment and Sustainability, Land Management and Natural Hazards Unit

Via Fermi 2749 – 21027 Ispra (VA), Italy

E-mail: ad.de-roo@jrc.ec.europa.eu

Abstract

Focus of this work is to test a hydrometeorological simulation framework for a flash flood early warning system based on probabilistic weather forecasts. Limited area Ensemble Prediction System (LEPS) provided by the COSMO Consortium are used as meteorological inputs into a distributed hydrological model. Initial conditions are taken from the coarser, 5-km operational run of the European Flood Alert System (EFAS) of the European Commission. When a signal for possible flash flooding is detected across Europe, a catchment simulation is run on a fine spatial scale (1 km grid resolution). Forecasted ensemble hydrographs, with lead time of 5.5 days, are estimated and results are compared to a reference climatology run. Coherent reference climatology is obtained through hydrological simulation of a continuous meteorological dataset based on 30-year COSMO-LEPS hindcasts. This is particularly useful for flash flood events, as they often take place in small watersheds, where no gauge measurement is available.

Continuous simulations are carried out over a 17-month time span for a Swiss catchment and prediction skill is evaluated for different forecast lead time. The concept of persistence of meteorological forecasts is also tested as a way to improve the detection of severe events.

First results look promising for future operational implementation as a flash flood early warning system. However, further analyses and comparisons with observed events is recommended, as particular care is to be put in the choice of alert thresholds.

---

[1] European Commission, Joint Research Centre, Ispra, Italy

S. Pecora[1] *and P. P. Alberoni*[1]

THE RADAR RAINFALL ESTIMATES IN A FLOOD FORECASTING SYSTEM FOR THE PO RIVER IN ITALY

Corresponding author: Dr. Silvano Pecora
HydroMeteorological Service, ARPA Emilia-Romagna
Via Garibaldi 75 – 43121 Parma, Italy
E-mail: specora@arpa.emr.it

Abstract

The amount of residual risk must be taken in account, evaluated and controlled by opportune structural and non-structural measures. Among this latter a modelling system to forecast and control flood propagation along Po river has an important strategic feature in risk management context. The Italian civil protection directive was published for the management of national and regional operational activities during hydrogeological events. In particular, during flood events affecting a number of regions, it is identified an authority of civil protection, supported by an operative centre collecting real time data and providing forecasting scenarios. The purpose of the system is to furnish a number of tools for the Po floods to be controlled and managed objectively by any civil protection unit and local/regional authority concerned, where the objective approach is a general consensus among all users concerning the validity of the methodology.

The operational system for Po flood forecasting in Italy takes into account deterministic and probabilistic meteorological predictions, modelling techniques for hydrological and hydrodynamic simulations. The innovations of the system rely upon its modular and highly configurable nature and the implementation of ensemble forecast techniques useful in estimating the prediction uncertainty. The system collects telemetry data from the hydrometeorological gauges and precipitation field estimations from radar network across the whole basin. Radar data are processed to remove artifacts like anomalous propagation clutter, bright band and to attenuate the beam blocking as results of the impact of orography on the radar propagation. The discharge simulations of the different radar QPE based on level of processing selected were analyzed in order to assess the relative impact of the algorithms implemented in the processing chain. The optimal configuration of radar data processing chain and the uncertainty related to radar QPE add a promising technique to the early warning system, in particular for small catchments, such as the Po tributaries.

---

[1] HydroMeteorological Service, ARPA Emilia-Romagna, Italy

J. Daňhelka[1]

STORM RAINFALL DETECTION AND FORECASTING - THE CZECH EXPERIENCE

Corresponding author: Mr. Jan Daňhelka
Czech Hydrometeorological Institute
Na Sabatce 17 – 14306 Praha, Czech Republic
E-mail: danhelka@chmi.cz

Abstract

Contribution presents the state of the art of operational radar meteorology in the Czech Republic. Some common treads are documented on the case of Nový Jičín disastrous flash flood in June 2009. Nowcasting and other tools developed in the Czech Republic to warn and inform on the flash flood risk are also introduced.

Introduction

This paper presents current practice of storm precipitation forecasting and detection in the Czech Republic. Rainstorms causing flash floods in Central Europe are often of relatively small spatial extent and duration. In addition they are not always connected to mesoscale atmospheric phenomena such as fronts. Therefore its prediction by Numerical Weather Prediction (NWP) model is very complicated. In general a favourable condition for convection can be forecasted by NWP, but not the exact locality and intensity of rainstorms.

1 Precipitation detection and observation

Meteorological radars

Meteorological radars provide spatial information on reflectivity of raindrops in clouds. Than an empirical Z-R relation is used to estimate the precipitation intensity. Czech radar network consists of 2 radars covering fully the area of the Czech Republic (scanning frequency is 5 minutes, 1 km grid, CAPPI 2km). Operational radar precipitation estimates are corrected for long term bias and adjusted by coefficients delivered from real-time evaluation of radar estimates and data from the network of operational rain gauges.

Meteorological radars are the most effective tool for storm detection. However estimates of rainfall intensity may fail in some cases. A significant underestimation of rainfall intensity occurred in case of Nový Jičín flash flood in June 2009 (Figure 1). Two main reasons of

---

[1] Czech Hydrometeorological Institute, Prague, Czech Republic

underestimation were documented. Attenuation of radar beam due to presence of other storms between the radar and affected area was the one (Figure 2). The second reason was the extraordinary physic of the storm. Due to very moist, hot and unstable air mass storm clouds a warm convection process developed (between the altitude of condensation and altitude of zero isotherm), therefore raindrops diameter was smaller, but their number was much higher than in typical convective storm. Smaller raindrops provide smaller reflectivity for the same amount of water in the cloud.

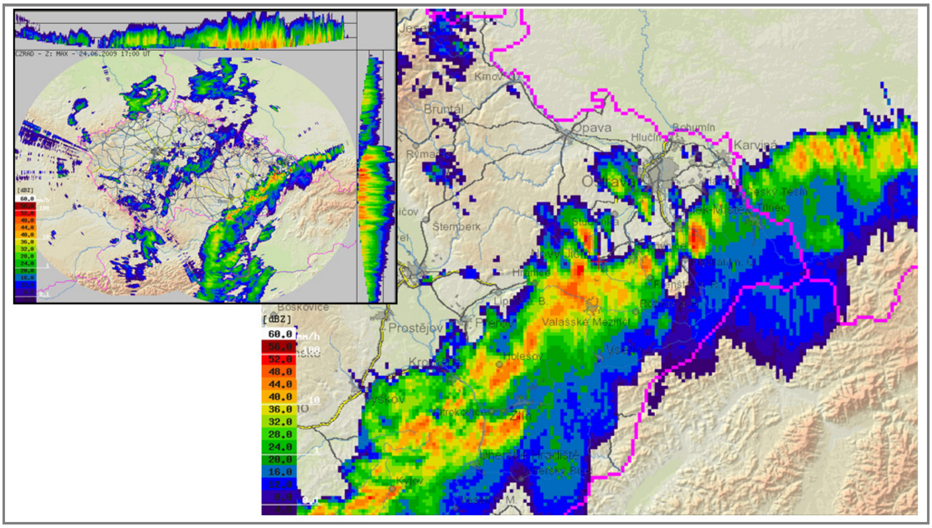


Figure 1: Operational radar rainfall estimates over the Nový Jičín district during June 24th, 2009.

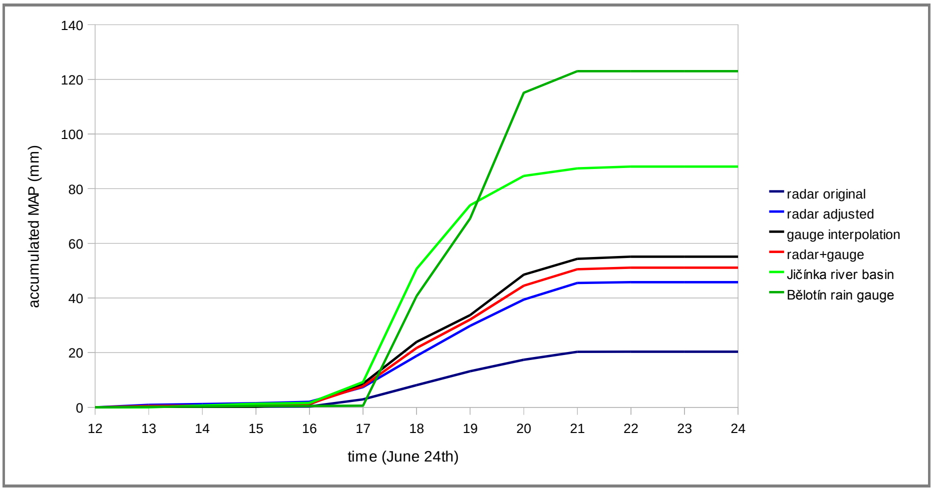


Figure 2: Comparison of radar estimates and rain gauge measurements over the Nový Jičín district during June 24th, 2009. The evaluated amount of rainfall reached 124 mm in about 3 hours in Bělotín rain gauge.

Radar-rain gauge combined product is prepared in real-time for different aggregation time from 1h to 24h. Radar precipitation estimate is adjusted to point rain gauges measurement using regression krigging (in case of missing radar data for more than 20% of time the rain gauge data interpolation is used instead). For adjustment in shorter periods (1h, 3h, 6h) the correction factor is based on evaluation of data from last 20 hours.

Nowcasting

Radar echo extrapolation using COTREC procedure and NWP ALADIN wind field are used as a storm movement vector field are used in the Czech Republic. Extrapolation up to 90 minutes is operated. Extrapolation methods analyse movement of existing storm cells but do not change its intensity and do not create new storm cells.

Small basins (generally <50 km^2) are the one mostly affected by flash floods in the Czech Republic. Those are especially sensitive to nowcasting disadvantages as described above and proved by Šálek et al. (2006) who researched the coupled system of nowcasting and hydrological model HYDROG in the case of Hodonínka 2005 flash flood.

2 Response to 2009 flash floods

Experience from 2009 flash flood showed that meteorologists need more frequent information on rain gauge measured precipitation to support radar information for issuing the warning. Hourly precipitation sum from rain gauge was not sufficient. Therefore the frequency of data transmission and summing was increased to 10 minutes. In addition radar-rainfall combination was implemented in moving 10 minute time step. Another simple tool was made to evaluate maximum radar rainfall estimates (including nowcasting up to 90 minutes) on district level (warning are defined on the scale of districts). WarnView (Figure 3) uses defined precipitation thresholds for different temporal aggregations (15-, 30-, 60-, 180-minutes). The future plan is to implement variable thresholds (in time and space) based on Flash Flood Guidance evaluation of flash flood risk.

Flash Flood Guidance (FFG – Figure 4 and Figure 5) is system operated in the United States by National Weather Service, but FFG could by understand as a general concept of flash flood risk evaluation in real-time. FFG evaluates basic relevant geographical conditions of landscape (at basin scale or grid) to estimate its retention capacity. Than an actual soil saturation is computed and consequently thresholds of precipitation possibly causing the fast surface runoff are derived. Thus FFG provides precipitation limits that if exceeded may lead to pluvial flood of flash flood at site. Publishing those limits, Flood Authority may start its action sooner based on precipitation rather than based on the observed river rise.

FFG-CZ has been developed since 2008 and it is based on a Curve Number (CN) method. CN values were evaluated based on infiltration and

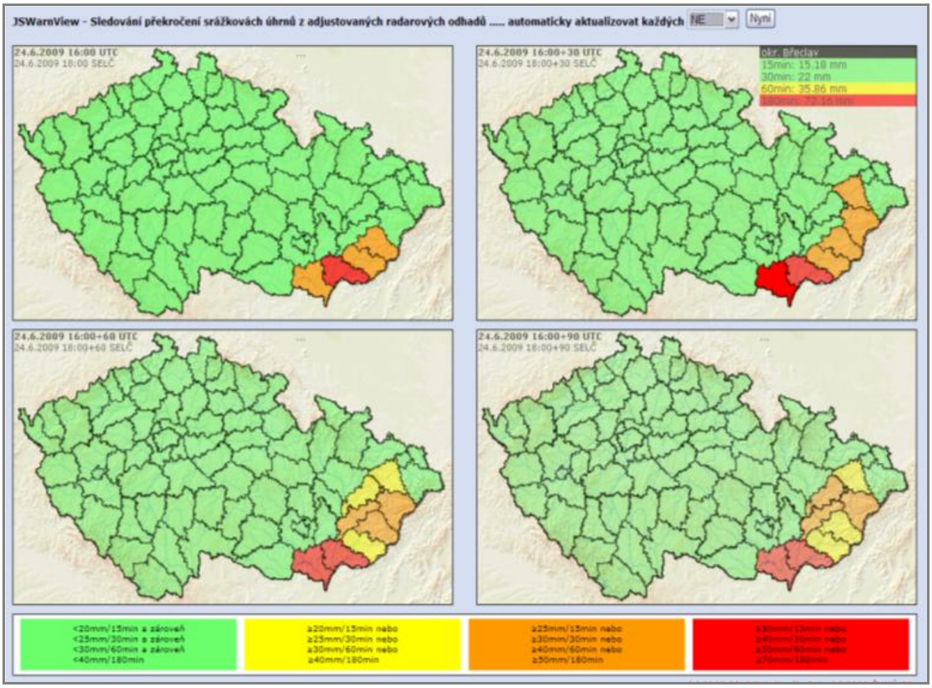


Figure 3: Warnview – a tool for real time evaluation of maximum radar estimates at district level for observation and three nowcasting horizons – case of June 24th, 2009.

retention of soils and vegetation cover and the average slope of the area. CN values are updated daily based on the radar-rain gauge precipitation estimate between stage I (dry condition) and III (wet condition). Method of CN values updating was developed by CHMI for the condition of the Czech Republic. Based on actual CN a critical rainfall for 1 and 3 hours are computed using ESRI GIS environment.

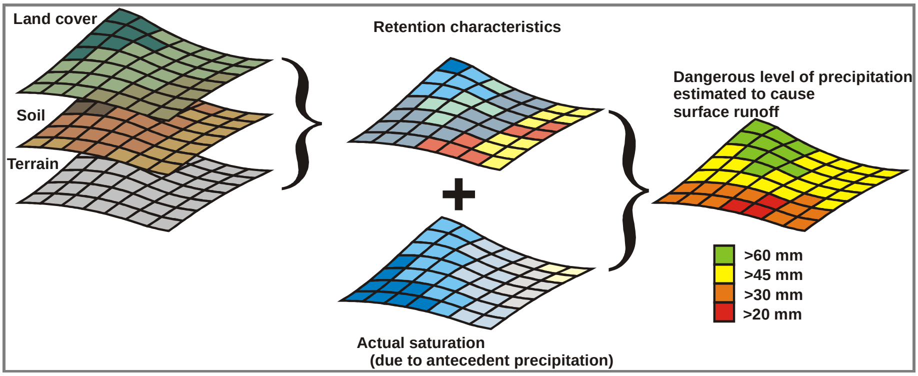


Figure 4: Flash flood guidance general principle – retention characteristics are described by CN value, while actual saturation is accounted trough CN value update based on precipitation in last 30 days.

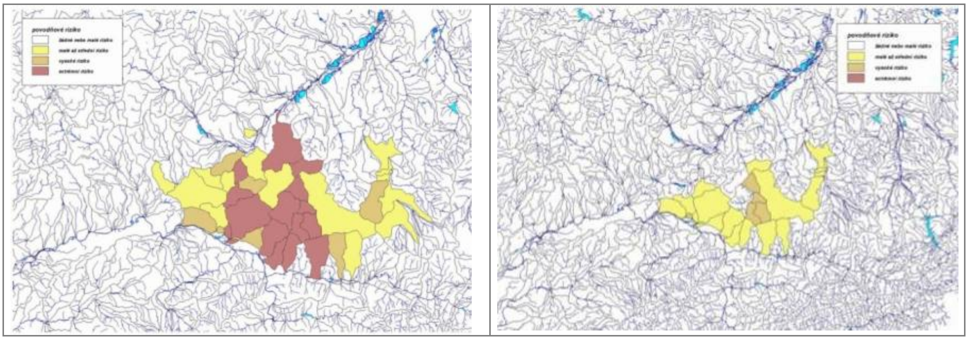


Figure 5: FFG-CZ a simulation of the 24th June 2009 flash flood in Nový Jičín district. Hindcast of flash flood risk level for adjusted radar rainfall estimate (left) and raw radar rainfall estimate (right) for 15:30 19:30 UTC.

In the second step HEC-HMS model was implemented for headwater areas (including simple river networking) representing about 2/3 of the area of the Czech Republic. A 10 minute operational radar precipitation estimates input automatically FFG-CZ. Based on this a runoff response is computed and then compared to theoretical limits of 0.4*Q100, 0.6*Q100, 0.8*Q100 (Q100 for ungauged basins was computed based on theoretical equation using geographical characteristics of the basin).

Conclusions

Meteorological radars provide the most valuable information on development of heavy precipitation. However its precipitation estimates could not provide exact amounts of precipitation especially in some specific cases. Therefore the network of automatic rain gauges is important to be used together with radars. In case of small basins local flash flood warning systems based on one or more rain gauges seems to be reasonable solution.

Central and eastern Europe is vulnerable to small scale rainstorms and flash floods. Therefore the development of flash floods are sudden and does not provide enough time for modelling of potential response to the precipitation and targeted central warning in real time. Therefore an effort is given to the development of automatic evaluation tools and especially to providing preliminary information on flash flood risk based on evaluation of basin saturation and characteristics. That information will be available to flood authorities to support (together with the local information on precipitation) the decision making.

References

Šálek, M., Březková, L., and Novák, P. 2006: The use of radar in hydrological modeling in the Czech Republic – case studies of flash floods. *Nat. Hazards Earth Syst. Sci.*, 6, 229–236, 2006.

L. G. Lanza[1] and E. Vuerich[2]

THE ACCURACY OF RAIN INTENSITY MEASUREMENTS AND ITS INFLUENCE ON EXTREME EVENTS STATISTICS

Corresponding author: Prof. Luca G. Lanza

Department of Civil, Environmental and Territorial Engineering, University of Genova

Via Montallegro 1 – 16145 Genoa, Italy

E-mail: luca.lanza@unige.it

Abstract

As an outcome of the recent intercomparison of rainfall intensity (RI) gauges organized by the World Meteorological Organization (WMO), it has been recommended that RI measurements be standardized at an international level based on knowledge obtained from those initiatives. During the WMO instrument intercomparison in the field and the associated laboratory tests, highly accurate RI measurements have been collected and made available for scientific investigation. The resulting high quality data set (contemporary one-minute RI data from 26 gauges based on various measuring principles) was an important resource to provide insights into the expected behaviour of RI gauges in operational conditions and further useful information for National Meteorological Services and other users. Errors in measurements from operational rain gauges are here reported and the propagation of measurement errors into the most common statistics of rainfall extremes is recalled based on previous work.

1 Introduction

The attention paid to accuracy and reliability in rainfall intensity (RI) measurements is currently increasing, following the increased awareness of scientific and practical issues related to the assessment of possible climatic trends, the mitigation of natural disasters (including flash floods), the hindering of desertification, the design of structures (building, construction works) and drainage infrastructure. This notwithstanding, the effects of inaccurate rainfall data on the information derived from rain records is not much documented in the literature.

The World Meteorological Organisation (WMO) recognised these emerging needs and promoted a first Expert Meeting on rainfall intensity in 2001 in Bratislava (Slovakia). Further to the definition of rainfall

---

[1] Department of Civil, Environmental and Territorial Engineering, University of Genova, Italy

[2] Italian Meteorological Service, ReSMA, km 20,100 Braccianese Claudia, 00062 Bracciano, Italy

intensity and the related reference accuracy and resolution, the convened experts suggested to organise an international intercomparison of RI measurement instruments, to be held first in the laboratory and then in the field. The first Intercomparison started in 2004 and was concluded in 2005. An international standardized procedure for laboratory calibration of catching type RI gauges and the reference instruments to be used for the Intercomparison in the Field have become recommendations of the WMO Commission for Instruments and Methods of Observation (CIMO/WMO). Final results are available on the WMO Web site, and have been published elsewhere (Lanza et al., 2005; Lanza and Stagi, 2008).

Note that some RI gauges were properly modified by manufacturers or NMHS (National Meteo-Hydrological Services) after the results of the first Laboratory Intercomparison and before taking part into the Field Intercomparison, by improving their performance in terms of accuracy and according to the above-mentioned international recommendations, demonstrating the immediate usefulness of the intercomparison results.

The main objective of the follow-up Field Intercomparison was to test the performance of rainfall intensity measurement instruments in real world conditions and with a special focus on high rainfall rates. In terms of accuracy, both the Laboratory and Field Intercomparison efforts have contributed to a quantitative evaluation of counting errors (systematic – “ability to sense”) and catching errors (weather related, wetting, splashing, evaporation – “ability to collect”) of RI gauges. Comparison of several rain gauges demonstrated the possibility to evaluate the performance of RI gauges at one-minute resolution in time, as recommended by CIMO/WMO.

2 The WMO Intercomparison of RI gauges

The WMO Field Intercomparison of RI gauges was held at the Centre of Meteorological Instruments Experimentations and historic observatory (RESMA) of the Italian Air Force sited in Vigna di Valle (Rome). The field site selected to host the Intercomparison is a green grass area of 400 m^2, equipped with 34 evenly positioned concrete platforms for data acquisition (see Figure 1), and a central pit with four positions, used for the installation of the working reference – a set of four RI gauges as identified and recommended in the previous WMO Laboratory Intercomparison.

The working reference gauges were inserted in a four-fold Reference Rain Gauge Pit with gauge collectors at the ground level, according to the standard EN13798: “Specifications for a reference rain gauge pit”. The combined analysis of the reference gauges did provide the best possible estimation of RI in the field, based on their demonstrated performance during the previous Laboratory Intercomparison. Based on results of the WMO Laboratory Intercomparison of RI gauges, corrected tipping bucket rain gauges (TBRG) and weighing gauges (WG) with a short step response and low uncertainty were used as working reference instruments.

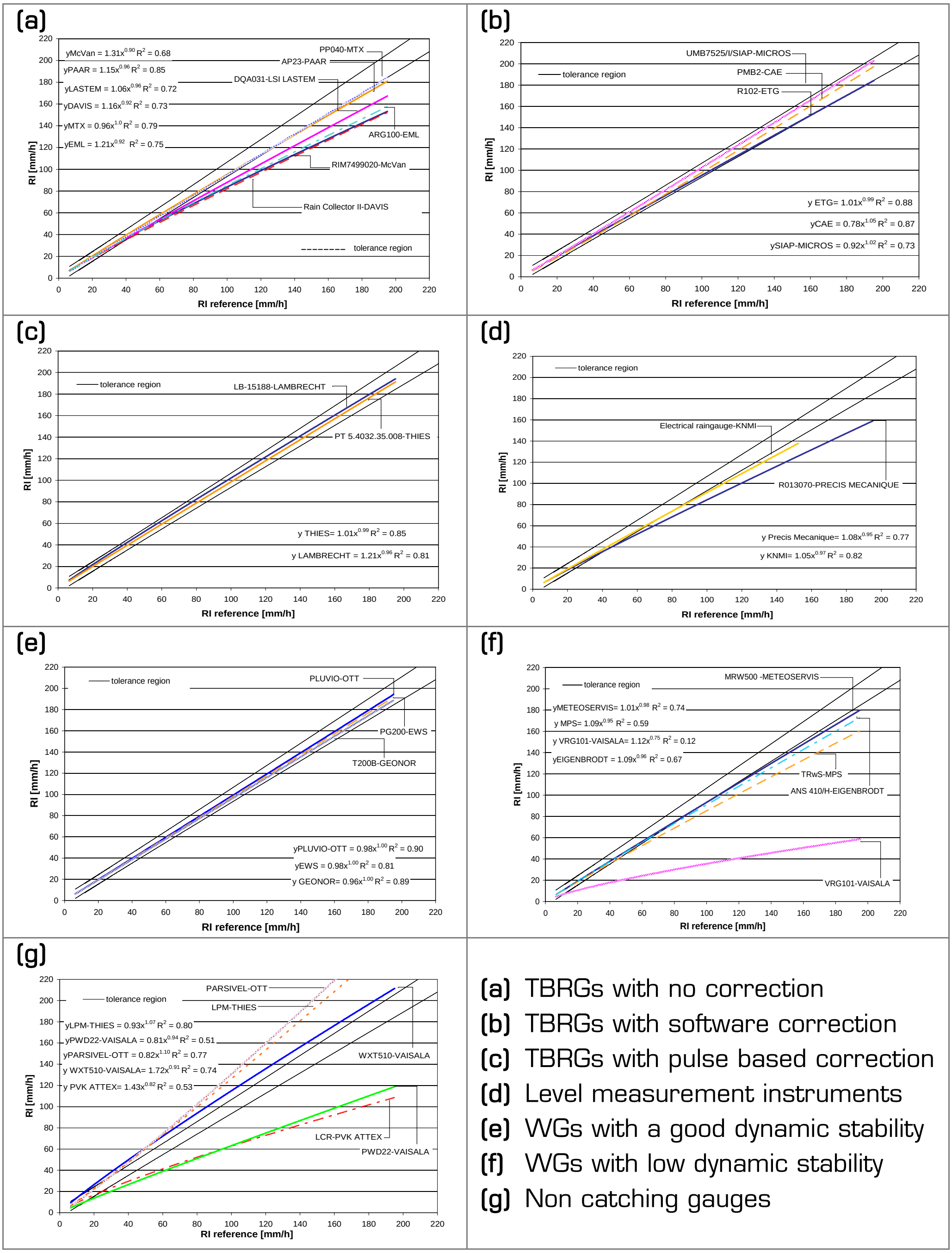
Figure 1: The experimental field in Vigna di Valle (Italy).

Those catching type instruments, out of the selected rain gauges based on various measuring principles, and the four rain gauges selected as reference instruments to be installed in a pit, were preliminarily calibrated in the laboratory before their final installation at the Field Intercomparison site. The recognized WMO laboratory at the University of Genoa was involved in this task (Lanza and Stagi, 2009), using the same standard tests adopted for the previously held WMO Laboratory Intercomparison of RI gauges. Further tests were performed to investigate the one-minute performance of the involved instruments.

The results reported in this section illustrate the trend of each instrument compared to the RI composite working reference, where the trend line is obtained from a power law fitting of the experimental data in the (RI, RI_{ref}) domain. In order to assess the accuracy of field measurements compared to the reference, the lines of the tolerance region, calculated with the procedure described in Vuerich et al. (2009), are represented in dashed lines. For easier comparison, the instruments have been grouped according to the measurement technique, as shown in Figure 2.

Results (see, e.g., Lanza and Vuerich, 2009) indicate that one-minute synchronized TBRGs, corrected by internal algorithms, and WGs with the better dynamical stability and shortest step response are the most accurate instruments for one-minute RI measurement, since providing the highest measurement accuracy with respect to the reference chosen.

Pulse-corrected TBRGs show similar, but less accurate results. The non-corrected TBRGs, can apply corrections via a post processing software or provide a correction curve/table to be almost as accurate as the corrected ones. WGs with lower dynamical stability or lack of synchronization/large step response at the one minute time scale are less accurate. None of the non-catching rain gauges agreed well with the reference. Disdrometers tended to overestimate the rainfall intensity. The microwave radar and the optical/capacitive sensor tended to underestimate the rainfall intensity.



(a) TBRGs with no correction
(b) TBRGs with software correction
(c) TBRGs with pulse based correction
(d) Level measurement instruments
(e) WGs with a good dynamic stability
(f) WGs with low dynamic stability
(g) Non catching gauges

Figure 2: Performance of the various instruments against the reference RI.

3 Error propagation and its impact on statistics

The impact of inaccurate rainfall measurements on the results of scientific investigation in rainfall related fields is not yet fully clear or quantified.

With the exception of very few dedicated papers and/or various papers dealing with the analysis of measurement errors themselves, the issue of how deeply affected are the obtained results by the actual accuracy of the data sources is rarely addressed. The scarce attention paid at the quality of data often poses serious doubts about the significance of both experimental and theoretical results made available in the literature.

The effects are not always dramatic, since the error propagation could be negligible as well, depending on the application. Nonetheless scientific soundness requires that all possible uncertainties are properly taken into account, and the quality of basic data sources – such as rainfall measurements – should not be an exception. Also, certified accuracy is needed for operational meteo-hydrological networks operating within the framework of a quality assurance system.

La Barbera et al*.* (2002) investigated the propagation of measurement errors into the most common statistics of rainfall extremes and found that systematic mechanical errors of tipping-bucket rain gauges may lead to biases, for instance, in the assessment of the return period T (or the related non-exceedance probability) of short-duration/high intensity events. The bias introduced by systematic mechanical errors of tipping bucket rain gauges in the estimation of return periods and other statistics of rainfall extremes was quantified in that work and in Molini et al*.* (2001), based on the error figures obtained after laboratory tests over a wide set of operational rain gauges from the network of the Liguria region of Italy. An equivalent sample size was defined as a simple index that practitioner engineers can use to measure the influence of systematic mechanical errors on common hydrological practice and the derived hydraulic engineering design.

The development of standard limits for the accuracy of rainfall measurements obtained from tipping-bucket and other types of gauges was proposed for use in scientific investigations and as a reference for operational rain gauge networks to comply with quality assurance systems in meteorological observations (Lanza and Stagi, 2008).

Molini et al*.* (2005 a,b) estimated the effect of systematic mechanical errors on the assessment of design rainfall for urban scale applications based on two rain rate data sets recorded at very different resolution in time. A random cascade downscaling algorithm was used for the processing of coarse resolution data so that correction could be applied at suitable time scales. The resulting depth-duration-frequency curves obtained from the original and corrected data sets were derived to quantify the impact of non corrected rain intensity measurements on design rainfall and the related statistical parameters.

Conclusions

The bias induced by systematic mechanical errors of tipping-bucket rain gauges is usually neglected in the hydrological practice, based on the assumption that it has little influence on the total recorded rainfall depth. It has been demonstrated in recent works that, since the error increases with rainfall intensity, the assumption is not acceptable for the assessment of design rainfall in hydrological applications. Indeed, the high resolution required for the monitoring of rainfall intensities (due to the very short response time of small size catchment basins) amplifies the influence of mechanical errors on the derived statistics of rainfall extremes, with a bias that can be quantified as an underestimation of about 60 to 100% on the assessment of the return period of design rainfall for duration one hour and return periods from 20 to 200 years.

The WMO Field Intercomparison of Rainfall Intensity Gauges was the first intercomparison of quantitative rainfall intensity measurements in field conditions and one of the most extensive in terms of the number of instruments involved. The results of the intercomparison confirmed the feasibility to measure and compare rainfall intensities on a one minute time scale as required by users and recommended by CIMO and provided information on the achievable measurement uncertainties.

References

La Barbera, P., Lanza, L. G., and Stagi, L.: Influence of systematic mechanical errors of tipping-bucket rain gauges on the statistics of rainfall extremes. *Water Sci. Techn.*, 45(2), 1–9, 2002.

Lanza, L. G., and Stagi, L.: Certified accuracy of rainfall data as a standard requirement in scientific investigations. *Adv. Geosci.*, 16, 43–48, 2008.

Lanza, L. G., Leroy, M., Alexadropoulos, C., Stagi, L., and Wauben, W.: *WMO Laboratory Intercomparison of Rainfall Intensity Gauges*. IOM Rep. No. 84, WMO/TD 1304, 2005.

Lanza, L. G., and Vuerich, E.: The WMO Field Intercomparison of Rain Intensity Gauges. *Amos. Res.*, 94, 534–543, 2009.

Molini, A., La Barbera, P., Lanza, L. G., and Stagi, L.: Rainfall intermittency and the sampling error of tipping-bucket rain gauges. *Phys. Chem. Earth,* 26, 737–742, 2001.

Molini, A., Lanza, L. G., and La Barbera, P.: The impact of tipping-bucket raingauge measurement errors on design rainfall for urban-scale applications. *Hydrol. Proc.*, 19, 1073–1088, 2005a.

Molini, A., Lanza, L. G., and La Barbera, P.: Improving the uncertainty of rain intensity records by disaggregation techniques. *Atmos. Res.*, 77, 203–217, 2005b.

Vuerich, E., Monesi, C., Lanza, L. G., Stagi, L., and Lanzinger, E.: *WMO Field Intercomparison of Rainfall Intensity Gauges*. World Meteorological Organisation – IOM Rep. No. 99, WMO/TD No. 1504, 286 pp., 2009.

THEME 3:

Structural and non structural measures: planning and prioritization

M. L. V. Martina[1]

FLASH FLOOD GUIDANCE BASED ON RAINFALL THRESHOLDS: AN EXAMPLE OF A PROBABILISTIC DECISION APPROACH FOR EARLY WARNING SYSTEMS

Corresponding author: Prof. Mario L. V. Martina
Department of Earth and Geo-Environmental Sciences, University of Bologna
Via Zamboni 67 – 40126 – Bologna, Italy
E-mail: mario.martina@unibo.it

Abstract

Early warning systems for flash floods are substantially different from those designed for other types of floods not only in the time scales but in the predicting variables, the data availability and the predictive uncertainty. Therefore the monitored variables, the statistical approach and the data requirements should be specifically selected or designed in order to maximize the skills of the warning systems. In this work is proposed a warning system for flash floods based on critical rainfall thresholds to be compared directly with the quantitative precipitation forecast. Rainfall thresholds are here defined as the cumulated volume of rainfall during a storm event which can generate a critical water stage (or discharge) at a specific river section. It is show how to determine the Flash Flood Guidance (FFG) rainfall depth based on the minimization of a Bayesian Loss Function of the discharge in the target river section conditional upon the state of saturation of the catchment.

1 Introduction

The different approaches of the warning systems based on thresholds assume that there is relationship, physical-mechanical or statistical, between a variable called “predictor” and a variable called “predictand”. The distinction between the predictor and the predictand is conceptually important but has also some practical importance for the efficiency of a warning system. By definition the predictor is the variable which can be observed and which shares a certain relationship with the predictand variable which is the variable to be predicted. In the context of the warning system of any natural hazard, usually the predictand is related with the effects of the hazard such as damages which one would reduce or avoid by means of adequate operations which require adequate decisions. The decisions are instead related to, that is, can be made on the basis of, the predictor.

---

[1] Department of Earth and Geo-Environmental Sciences, University of Bologna, Italy

The thresholds are a simplification of the problem of how to define a decision rule (such as send or not an alarm/warning) and they are necessary applied on the predictor on the basis of a scope (e.g., reducing the damages) and some criteria. The criteria can be expressed coherently with the definition of the risk which is the product of exposure, vulnerability and hazard. Practically a threshold could divide the values of the predictor which result in an acceptable risk from those which result in an unacceptable risk.

In this work the predictand is the discharge in a target river section, the predictor is the rainfall depth at different duration, the relationship between the predictor and the predictand is represented as a joint probability distribution, the damages are function of the discharge and the threshold are defined in terms of rainfall depth based on which can be send or not a flood warning.

Warning systems designed for flash floods have also some differences from the general cases: the time scale is smaller, the relationship predictor-predictand (typically rainfall-discharge) is affected by uncertainty, the predictand often is not monitored. For this reason it is necessary to specifically design the approach in order to maximize the overall skill of the system.

2 The Bayesian Rainfall thresholds methodology

Rainfall thresholds are here defined as the cumulated volume of rainfall during a storm event which can generate a critical water stage (or discharge) at a specific river section. When the rainfall threshold value is exceeded, the likelihood that the critical river level (or discharge) will be reached is high and consequently it becomes appropriate to issue a flood alert; alternatively, no flood alert is going to be is-sued when the threshold level is not reached. In other words the rainfall thresholds must incorporate a “convenient” dependence between the cumulated rainfall volume during the storm duration and the possible consequences on the water level or discharge in a river section. The term "convenient" is here used according to the meaning of the decision theory under uncertainty conditions, namely the decision which corresponds to the minimum (or the maximum) expected value of a Bayesian cost utility function.

There are two possible approaches for the same Bayesian Rainfall Threshold methodology: (1) using the Monte-Carlo simulations (BRT-MC) or (2) using the Normal Quantile Transform (BRT-NQT). The main difference of the two is the requirements in terms of data, that is, the time series of rainfall and discharge.

2.1 The Bayesian Rainfall Threshold using the Monte-Carlo approach

This approach was developed by Martina et al. (2006) and it can be referred to that paper for a more detailed description. In order to ease the description of the methodology, illustrated in Figure 1, two phases are here distinguished: (1) the rainfall thresholds estimation phase and (2) the operational utilization phase. The first phase includes all the procedures aimed at estimating the rainfall thresholds related to the risk of exceeding a critical water stage (or discharge) value at a river section. These procedures are executed just once for each river section of interest. The second phase includes all the operations to be carried out each time a significant storm is foreseen, in order to compare the precipitation volume forecasted by a meteorological model with the critical threshold value already determined as in phase 1.

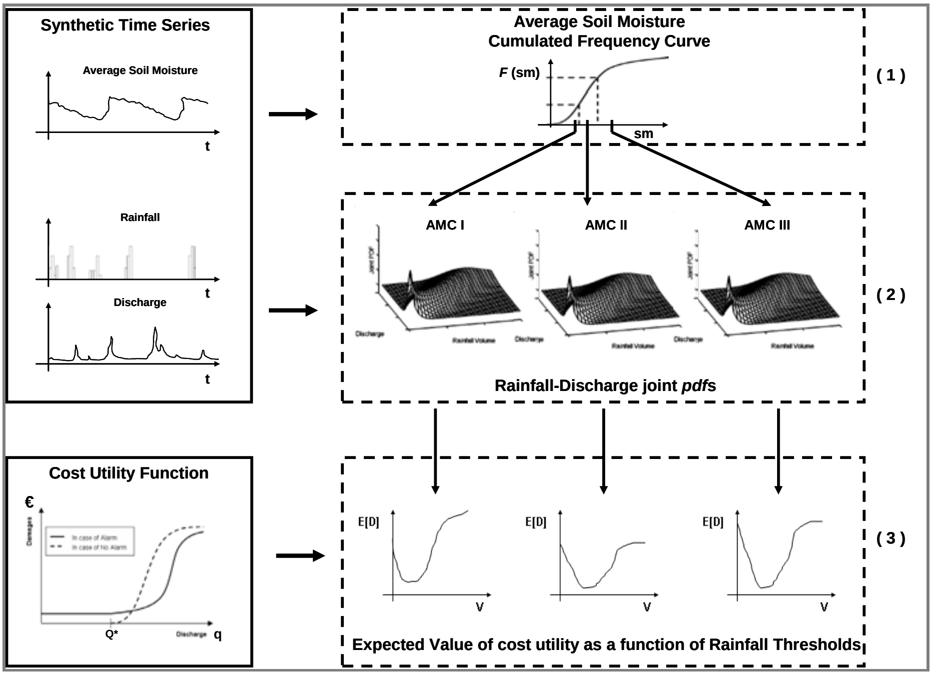


Figure 1: Schematic representation of the proposed methodology. (1) Subdivision of the three synthetic time series according to the soil moisture conditions (AMC); (2) Estimation of the joint probability density function between rainfall volume and water stage or discharge; (3) Estimation of the "convenient" rainfall threshold based on the minimisation of the expected value of the associated utility function.

2.2 The Bayesian Rainfall Thresholds using the Normal Quantile Transform

One of the limits of the method described in Martina et al. (2006) is represented by the excessive data requirement. To overcome the limit of the BRT-MC methodology, a second methodology, namely BRT-NQT, has been recently developed. The difference with BRT-MC consists in the inference of the joint probability density (PDF). Instead of the classical Monte Carlo approach the inference of the joint PDF is performed by trans-forming the two variables, *V(T)* and *Qp*, into two standard normally distributed variables by means of the NQT. This procedure ensures, by construction, that the marginal distribution of the variables is standard normal, but does not guarantee that the joint PDF is multivariate standard normal distribution. Therefore generally the normality of the joint distribution must be tested by comparing the empirical (based on the data) distribution with the theoretical form or existing goodness of fitting test. The NQT leads to the inference of the meta-Gaussian joint PDF which can be performed using a much smaller amount of data then the BRT-MC (e.g., tens of years).

The BRT-NQT has been developed and implemented such that the only data requirement is the rainfall and discharge time series (for the joint PDF inference) and the average soil moisture time series which conditions the rainfall thresholds. The average soil moisture conditions, which often necessitate to be simulated by a rainfall-runoff model, can be substituted with a reliable antecedent conditions index (such as API, AMC, etc.) computed based on the precipitation. A computer program which performs the BRT-NQT methodology has been developed and implemented on the pilot basins.

2.3 Application on a real catchment of the BRT

In order to test the capability of the methodology at reproducing the criteria of the decision maker by means of the Cost/Utility functions, it has be designed an experiment which reproduces different “attitudes” or different decision criteria for the alarm management and the methodology has been applied on the Posina catchment, a medium-sized watershed located in a mountainous region in northern Italy. This could be done by selecting appropriate parameters of the Utility/Cost function. The Utility/Cost function has be defined as (Martina et al., 2006) $U(q,v|V_T,T)$ which if $v \leq V_T$ expresses the perception of damages when no alert is issued no costs will occur if the discharge q will remain smaller than a critical value Q^*, while damage costs will grow noticeably if the critical value is overtopped. On the contrary, if $v > V_T$ it expresses the perception of damages when the alert is issued a cost which will be inevitably paid to issue the alert (evacuation costs, operational cost including personnel, machinery etc.), and damage costs growing less significantly when the critical value Q^* is overtopped and the flood occurs. The utility function to be used will differ depending on the value of the cumulated rainfall forecast v and the rainfall threshold V_T. If the forecast precipitation value is smaller or equal to the threshold value, the alert will not be issued; on the contrary, if the forecasted precipitation value is greater than the threshold value, an alarm will be issued.

Three different attitudes of the decision maker have been selected which generated three different cases for the application of the utility/cost function (Figure 2): (1) the “risk-averse” case, (2) the “risk-prone” case, (3) the “real” case. The first two cases have been chosen in order to represent some sort of extreme attitudes of the decision makers, while the third case has been designed on the basis of real experience. It is important to say that, especially for the first two cases, the utility/cost function represents more the “perception” of the costs and of the

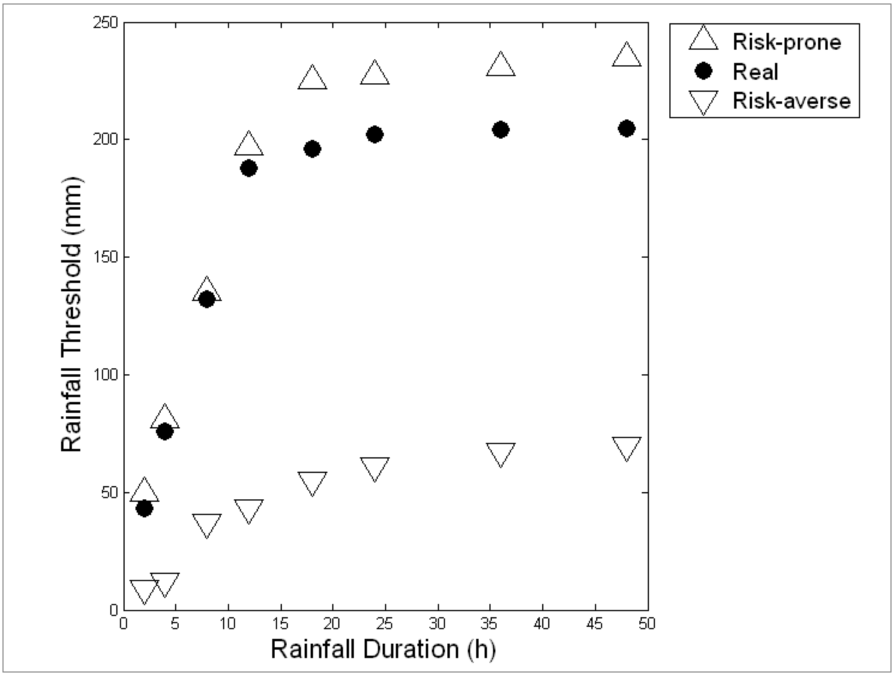


Figure 2: Comparison of the rainfall thresholds for the examined cases.

damages rather than the real costs. This means that not only the real costs are important but also the weights which each decision maker attribute to them. The reasons for that are: (1) there are some costs which are not valuable as the credibility loss; (2) there is a different perception of the costs in terms of social and psychological impacts than only the economic one.

In order to compare the described cases with some references, two criteria independent by the cost function have been also defined.

Conclusions

It was here presented a general view on the key concepts of a warning system.

In particular it is necessary to clearly define:

- the predictor variable which should be observable (or at last predicted before the predictand);
- the predictand variable on which depends the negative effects of the hazard (damages);
- the relationship, physical or statistical, between predictand and predictor;
- the function damages-predictand;
- the decision criteria (e.g., threshold) in function of the predictor.

It was also presented an example of a FFG (flash flood guidance) based on the rainfall thresholds. Rainfall thresholds seem to be suitable as basis for flash flood warning system.

References

Gandin, L. S., and Murphy, A. H.: Equitable skill scores for categorical forecasts. *Mon. Weather Rev.*, 120, 361–370, 1992.

Georgakakos, K. P.: Analytical results for operational flash flood guidance. *J. Hydrology*, 317, 81–103, 2006.

Martina, M. L. V., Todini, E., and Libralon, A.: A Bayesian decision approach to rainfall thresholds based flood warning. *Hydrology and Earth System Sciences*, 10, 1–14, 2006.

Mason, S. J.: A model for assessment of weather forecasts. *Aust. Meteor. Mag.*, 30, 291–303, 1982.

Mason, S. J., and Graham, N. E.: Conditional Probabilities, Relative Operating Characteristics and Relative Operating Levels. *Wea. Forecasting*, 14, 713–725, 1999.

Montesarchio, V, Lombardo, F, and Napolitano, F.: Rainfall thresholds and flood warning: an operative case study. *Nat. Hazards Earth Syst. Sci.,* 9,135–144, 2009.

Norbiato, D., Borga, M., Degli Esposti, S., Gaume, E., and Anquetin, S.: Flash flood warning based on rainfall depth-duration thresholds and soil moisture conditions: an assessment for gauged and ungauged basins. *J. Hydrology*, 362 (3–4), 274–29, 2008.

Sweeney, T. L.: Modernized areal flash flood guidance. NOAA Technical Report NWS HYDRO 44, Hydrologic Research Laboratory, National Weather Service, NOAA, Silver Spring, MD, October, 21 pp. and an appendix, 1992.

C. Wittwer[1], A. Escudier[1] and A. Marchandise[1]

FLOOD WARNING PROCEDURE IN FRANCE: CURRENT STATUS AND EVOLUTION TO IMPROVE FLASH FLOOD FORECASTING

Corresponding author: Dr. Caroline Wittwer

SHAPI – National Flood Forecasting Centre, Ministry of ecology, energy, sustainable development and sea

42 avenue Gaspard Coriolis – 31057 Toulouse, France

E-mail: caroline.wittwer@developpement-durable.gouv.fr

Abstract

Since 2003, a new act "loi Risques n. 2003-699" related to prevention of natural and technological risks and reparation of damage gives a legal framework to flood forecasting in France. The existing local services responsible of flood watch and hydrometry have been completely reorganized to create a national system collecting all relevant hydrological data and exchanging the meteorological data with the national weather service (Météo France).

A new hydrological warning procedure is opened since July 2006 to increase anticipation through regular and formatted information, to use a common decision-aid system for a graduated involvement of civil security, as well as to directly inform the population to help them become actor (http://www.vigicrues.gouv.fr/).

Flood warnings are currently assessed for about 250 sections representing a network of 20,000 km of river courses, covering therefore about 90% of the areas at risk. A number of relatively small watersheds (order of less than 500 km^2) are subject to flash floods and surveyed by the national system. Various hydrological procedures are implemented, and rainfall-runoff models are being improved, to produce reliable forecasts.

Pluvial floods, currently assessed by heavy rainfall thresholds, are combined with the river flood warnings into a concerted rainfall-flood vigilance. This procedure is operationally produced by Météo France and SCHAPI. Due to the occurrence of flash floods on smaller areas, generating important damage over the last years, an extension of the flood forecasting service is under work, together with Météo France, in order to account for the effect of localised heavy rainfall events.

---

[1] SCHAPI – National Flood Forecasting Centre, Ministry of ecology, energy, sustainable development and sea, Toulouse, France

F. Comiti[1], P. Macconi[2], L. Marchi[3], M. Arattano[4], M. Borga[5], F. Brardinoni[6], M. Cavalli[3], V. D'Agostino[5], S. Hellweger[2], S. Trevisani[3] and M. Vischi[7]

DEBRIS FLOW MONITORING AND WARNING SYSTEMS: A NEW STUDY SITE IN THE ALPS

Corresponding author: Prof. Francesco Comiti
Faculty of Science and Technology, Free University of Bolzano
Piazza Università 1 – 39100 Bolzano, Italy
E-mail: francesco.comiti@unibz.it

Abstract

Debris flows are one of the most relevant natural hazards in mountain regions. A combination of structural (e.g., check-dams) and non-structural (e.g., warning systems) measures is needed in most cases to reduce debris flow risks, and both benefit from experimental data on debris flow characteristics. A new experimental site is being equipped in the Autonomous Province of Bolzano (Italy) for both monitoring purposes and testing warning systems. The study site (Gadria basin) is a small channel subjected to frequent debris flows. The overall system includes the following components: 4 rain gauges located at different elevations, 5 radar sensors and 5 geophones, and 3 video cameras and flash lights to record the propagation and the deposition of the debris flow. Transmission of data and alerts from the instruments will use radio technology because GSM coverage is not available in the basin.

1 Introduction

Flash flooding in steep mountain catchments may result in the development and propagation of non-newtonian flows along their channels, such as hyperconcentrated and debris flows (Pierson and Costa, 1987; Coussot and Meunier, 1996). The high sediment concentration typical of these phenomena causes their rheology to differ from water flows with bedload and suspended transports, imparting them a great hazard potential due to large dynamic forces, thick sediment deposits, cross-

---

[1] Faculty of Science and Technology, Free University of Bolzano, Italy
[2] Dept. Hydraulic Engineering, Autonomous Province of Bolzano, Italy
[3] CNR-IRPI, Padua, Italy
[4] CNR-IRPI, Torino, Italy
[5] Dept. Land and Agroforest Environments, University of Padua, Italy
[6] Dept. Geological Sciences and Geotechnologies, University of Milano-Bicocca, Italy
[7] Dept. Civil Protection, Autonomous Province of Bolzano, Italy

section obstructions. Indeed, debris flows represent one of the most relevant natural hazards in mountainous regions. In Europe, debris flows cause extensive damages (Figure 1) and casualties every year.

Figure 1: Examples of debris flow damage in Italy: a) Campestrin (Trento, July 1989); b) Cancia (Belluno, June 1996); c) Rudavoi (Belluno, September 1997); Pollein (Aosta, October 2000).

Construction of residential buildings and transport infrastructures on debris flow fans has progressively increased the vulnerability to such events, thus augmenting the overall risk.

Structural measures such as check-dams, retention basins, dikes, and artificial channels have been built for decades in order to stop, divert or “flush” debris flow from sensitive locations. However, such interventions present some management problems. Indeed, they are very expensive to build and to maintain (e.g., sediment removal and disposal after events, restoration of damaged works) and they may have adverse impacts on the continuity of sediment fluxes through the drainage system. In addition, in many cases they cannot eliminate altogether the debris flow risk, that is, a residual risk is still present after their implementation.

Therefore, it is nowadays recognized that a combination of structural and non-structural measures is needed in most cases to cope with debris flow risks. Non-structural measures aim to diminish the vulnerability of a certain area to debris flows phenomena, by reducing either permanently (land use planning) or temporarily (warning systems) the probability that humans and their belongings might be hit by a debris flow.

In the present paper we first present a brief state-of-the-art on monitoring and warning systems for debris flows, with particular references to Europe, and then we describe a new experimental station which is being installed in the Italian Alps aiming to both monitor such flow processes and to test reliable warning systems.

2 Debris flow monitoring and warning systems

The quantification of sediment volumes transported by debris flows along with their temporal frequency, timing, flow characteristics (i.e., velocity, flow depth, density) are of crucial importance for hazard assessment, land-use planning and design of torrent control structures. To this aim, long-term instrumental observations of debris flows are of extreme value, similarly to experimental stations for bedload transport (see, e.g., Lenzi et al., 2006; Mao et al., 2009). In addition, instrumented basins provide high-quality information for deriving regional thresholds of rainfall intensity and/or cumulated values for debris flow triggering to be used in warning systems.

Relatively few monitoring sites for debris flows have been or are still operating in Europe (Marchi et al., 2002; Hürlimann et al., 2003, Tecca et al., 2003; McArdell et al., 2007; Hürlimann et al., 2009) whereas in Japan, Taiwan and China several monitoring stations are at work since the 1970s (see for a summary Takahashi, 2007).

As to warning systems for debris flows, they can be classified into two main types: advance warning and event warning (Hungr et al. 1987; Arattano and Marchi, 2008). Advance warning systems predict the possible occurrence of a debris flow event beforehand by monitoring the possible onset of triggering conditions. Event warning or alert systems detect a debris flow when it has already started its propagation downstream. Advance warning usually combine rainfall forecasting and real-time measurements of precipitation within the basin and compare them to empirical regional thresholds for debris flow triggering (e.g., Caine, 1980; Guzzetti et al., 2008). However, such approaches are heavily affected by the quality of rainfall prediction and by reliability of threshold curves. Event warning or alert systems are potentially more reliable (Bacchini and Zannoni, 2003; Chang, 2003; Badoux et al., 2009) because the alarm is issued based on the actual detection of debris flows (by wire sensors, geophones or stage meters, see Arattano and Marchi, 2008) upstream of the object to protect (e.g., road, town). Unfortunately, in many cases the time interval between the detection and the arrival of the debris flow to the vulnerable site is very short (e.g., few minutes), thus making the evacuation procedure very challenging.

3 The experimental basin

A system for monitoring debris flows and testing warning procedures is under construction (summer 2010) in the Gadria basin (upper Venosta/Vinschgau valley, Autonomous Province of Bolzano, Italy, Figure 2). The Gadria catchment (drainage area 6 km^2) presents one of the largest fans in the Alps (10.9 km^2) and frequent debris flows (1-2 per year). Geologically, it consists mostly of highly fractured metamorphic rocks (phylites, schists, gneiss). The average precipitation in the main valley is quite low (about 500 mm) compared to similar debris flow basins in the Alps (Marchi and D'Agostino, 2004). Snow cover usually lasts from mid November to mid April, and summer thunderstorms are responsible for most of debris flow occurrences.

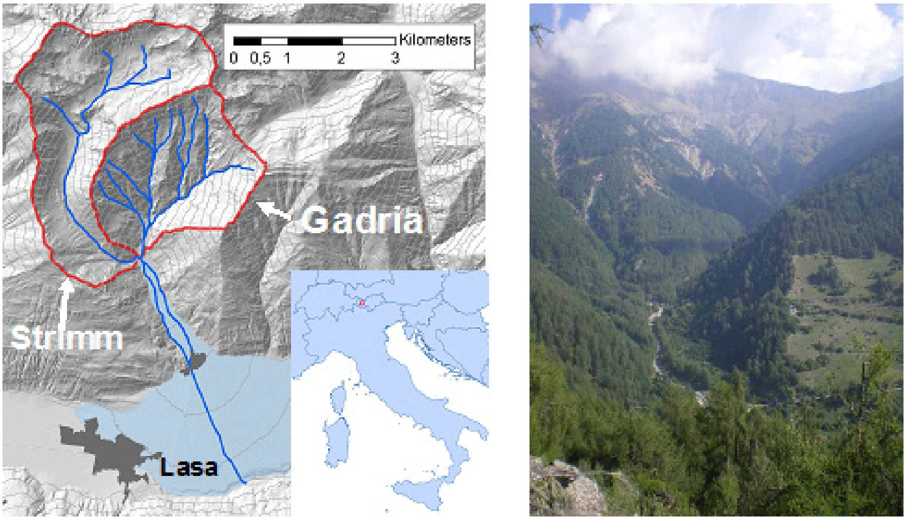


Figure 2: Basin map and location (left) and view of the main channel (right).

In the late 1800s, a 2 km-long stream reach on the fan was diverted to an artificial straight paved channel. Consolidation check-dams were built along the upstream natural channel starting in the early 1900s, and in the 1970s an open check dam with a retention basin of about 80,000 m^3 was built at the fan apex. This now prevents debris flows from propagating on the fan but requires very high maintenance costs (about 200,000 €/yr). A bedload creek (Strimm, drainage area 7.7 km^2) joins the Gadria channel right at the retention basin.

4 Description of the monitoring and warning systems

The overall system (monitoring and warning) in the Gadria and Strimm basins includes the following equipment (Figure 3): 4 rain gauges located at different elevations covering the main sub-basins; 3 radar stage sensors and 5 geophones to detect the debris-flow surges and to measure flow depth and its velocity upstream of the retention basin, and 3 video cameras with spotlights to record the propagation and the deposition of the debris flow in the proximity of the retention basin. In the Strimm creek and downstream of the open check-dam two additional radar sensors will be installed to monitor flow stage, thus allowing to determine water budgets for single events in the Gadria channel.

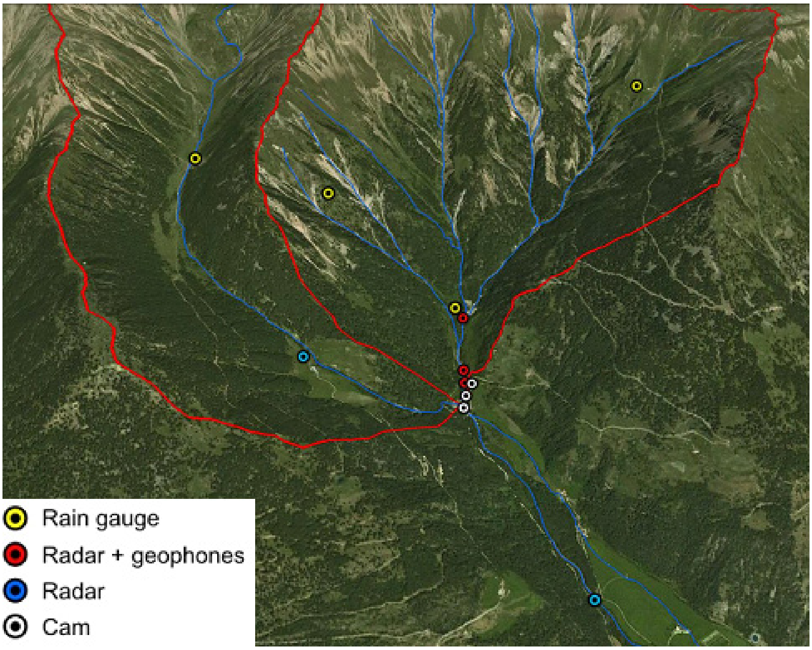


Figure 3: Location of the instruments in the Gadria and Strimm basins.

Because the basin is not covered by GSM networks, the rain gauges and the upper radar and geophone sensors will transmit data via radio to a receiving station placed at the filter check-dam. Here, a computer will store the videos and the data recorded from the nearer wire-connected sensors. From the station, the alert message as well as video frames and sensor data can be forwarded automatically via radio – when pre-defined multiple signal thresholds are exceeded – to the Internet, to the main control office of the Civil Protection in Bolzano, and to the local Fire Department.

Conclusions

Close collaboration between research institutions and governmental agencies are a promising way to carry out debris flow monitoring in highly active basins. This ensures a valuable support in the management of the monitoring instrumentation and allows efficient transfer of empirical data and know-how to those agencies in charge of the protection against natural hazards.

Acknowledgements

The authors thank Rudolf Pollinger and Hanspeter Staffler, head of the Dept. of Hydraulic Engineering and head of the Dept. of Civil Protection of the Autonomous Province of Bolzano respectively, for supporting the monitoring programme. Participation of researchers is funded by the EU South East Europe project “Monitor II” (Practical Use of MONITORing in Natural Disaster Management).

References

Arattano, M.: On the use of seismic detectors as monitoring and warning systems for debris flows. *Natural Hazards*, 20(2–3), 197–213, 1999.

Arattano, M., and Marchi, L.: Measurement of debris flow velocity through cross-correlation of instrumentation data. *Nat. Hazards Earth Syst. Sci.*, 5, 137–142, 2005.

Arattano, M., and Marchi, L.: Systems and Sensors for Debris-flow Monitoring and Warning Sensors. *Sensors*, 8, 2436–2452, 2008.

Bacchini, M., and Zannoni, A.: Relations between rainfall and triggering of debris-flow: case study of Cancia (Dolomites, Northeastern Italy). *Nat. Hazards Earth Syst. Sci.*, 3(1–2) 71–79, 2003.

Badoux, A., Graf, C., Rhyner, J., Kuntner, R., and McArdell, B. W.: A debris-flow alarm system for the Alpine Illgraben catchment: design and performance. *Natural Hazards*, 49, 517–539, 2009.

Caine, N.: The rainfall intensity–duration control of shallow landslides and debris flows. *Geogr. Ann. A*, 62, 23–27, 1980.

Chang, S. Y.: Evaluation of a system for detecting debris flows and warning road traffic at bridges susceptible to debris flow hazard. Proc. 3rd Int. Conf. on Debris flow Hazards Mitigation: Mechanics, Prediction and Assessment, Rickenmann, D., and Chen, C. L. (Eds.), Millpress, 731–742, 2003.

Coussot, P., and Meunier, M.: Recognition, classification and mechanical description of debris flows. *Earth-Science Reviews*, 40, 209–227, 1996.

Guzzetti, F., Peruccacci, S., Rossi, M., and Stark, C.P.: The rainfall intensity–duration control of shallow landslides and debris flows: an update. *Landslides*, 5, 3–17, 2007.

Hungr, O., Morgan, G. C., Van Dine, D. F., and Lister, R. D.: Debris flow defenses in British Columbia. In Debris Flows / Avalanches: Process, Recognition, and Mitigation, Costa, J. E. and Wieczorek, G. F. (Eds.), Geological Society of America, Reviews in Engineering Geology, 7, 201–222, 1987.

Hürlimann, M., Rickenmann, D., and Graf, C.: Field and monitoring data of debris-flow events in the Swiss Alps, *Canadian Geotechnical Journal*, 40, 161–175, 2003.

Hürlimann, M., Moya, J., Abancó, C., Portilla, M., Chevalier, G., Baeza, C., Ramat, C., Graf, C., Torrebadella, J., Oller, P., Copons, R., and Masas, M.: Peligrosidad de corrientes de derrubios a ascala de cuenca en el Pirineo Oriental. Primeros resultados del proyecto “DEBRIS-CATCH”. VII Simposio Nacional sobre Taludes y Laderas Inestables, E.Alonso, J. Corominas y M. Hürlimann (Eds.), CIMNE, Barcelona, 12 pp., 2009.

Lenzi, M. A., Mao, L., and Comiti, F.: Effective discharge for sediment transport in a mountain river: computational approaches and geomorphic effectiveness. *J. Hydrology*, 326, 257–276, 2006.

Mao, L., Cavalli, M., Comiti, F., Marchi, L., Lenzi, M. A., and Arattano, M: Sediment transfer processes in two Alpine catchments of contrasting morphological settings. *J. Hydrology*, 364(1–2), 88–98, 2009.

Marchi, L., Arattano, M., and Deganutti, A. M.: Ten years of debris-flow monitoring in the Moscardo Torrent (Italian Alps). *Geomorphology*, 46(1–2), 1–17, 2002.

Marchi, L., and D'Agostino, V.: Estimation of debris-flow magnitude in the Eastern Italian Alps. *Earth Surf. Proces. Landforms*, 29(2), 207–220, 2004.

McArdell, B., Bartelt, P., and Kowalski, J.: Field observations of basal forces and fluid pore pressure in a debris flow. *Geophysical Research Letters*, L07406, 34, 2007.

Pierson, T. C., and Costa, J. E.: A rheologic classification of subaerial sediment - water flows. In: *Debris Flows/Avalanches: Process, Recognition, and Mitigation*, Costa, J. E. and Wieczorek, G. F. (Eds.), Geological Society of America, *Reviews in Engineering Geology*, 7, 1–12, 1987.

Takahashi, T.: Debris flow – Mechanics, Prediction and Countermeasures. Taylor and Francis, London, 448 pp., 2007.

Tecca, P. R., Galgaro, A., Genevois, R., and Deganutti, A. M.: Development of a remotely controlled debris flow monitoring system in the Dolomites (Acquabona, Italy). *Hydrological Processes*, 17(9), 1771–1784, 2003.

J. Daňhelka[1]

FLASH FLOOD EARLY WARNING SYSTEMS AND LEGISLATION ASPECTS IN THE CZECH REPUBLIC

Corresponding author: Mr. Jan Daňhelka
Czech Hydrometeorological Institute
Na Sabatce 17 – 14306 Praha, Czech Republic
E-mail: danhelka@chmi.cz

Abstract

Rainstorms causing flash floods in Central Europe are often of relatively small spatial extent and duration. Therefore the central warning system may fail to deliver the warning on site in time. Therefore local flood authorities are responsible for information provision and flood managing at local scale according to Water Act in the Czech Republic. They can declare the “flood stage” based on water level in stream, its forecast or even based on precipitation (the new Act will enable declaration based on precipitation forecast too).

To support a development of local automatic warning systems EU funding programme is operated in the Czech Republic. Several systems using rain gauge and water gauge automatic SMS generation if set threshold is exceeded were put in operation in recent years. Some examples will be introduced.

Czech Hydrometeorological Institute is responsible for flood forecasting warning service (including rain storms) in the Czech Republic. “Forecast” warning is issued 1 to 2 days before the event, while “Occurrence” warnings are issued if some dangerous phenomena are detected. “Occurrence” warnings include some very short term prediction of development of the phenomena. Tools used for warning issuing and the distribution system will be described. Some problems of warning system in frame of current legislation will be documented in case of June 2009 flash flood user’s feedback and warning delivery evaluation.

In addition, the flash flood guidance (FFG) system is developed by CHMI to provide real time evaluation of flash flood risk based on updated basin saturation and thus the estimation of potential rainfall amount that could cause fast surface runoff. The system called FFG-CZ will be demonstrated.

---

[1] Czech Hydrometeorological Institute, Prague, Czech Republic

M. Kováč[1]

LOCAL WATER PLANNING – INTEGRATED APPROACH TOWARDS FLOOD RISKS REDUCTION

Corresponding author: Mr. Martin Kováč
Association of Towns and Communities of Slovakia
Bezrucova 9 – 811 09 Bratislava, Slovak Republic
E-mail: kovac@zmos.sk

Abstract

Some critical links and interactions between various parts of the ecosystems are overlooked with fatal impacts. Function of the landscapes in the distribution of the rainwater and role of vegetation in the dissipation of solar energy in the landscapes are overlooked.

There is need for integrated approach instead of isolated public policies and public funding. Key challenges are to achieve good status of the water and stakeholders involvement. Integrated approach includes balanced management of vegetation cover, water and soil resources and physical area adaptation of landscape profile in water basins. Local Water Planning process supports such integration and adaptation. Radical reform of Common Agricultural Policy is required as it is today biggest contributor to climate change, flood risks and consumer of EU budget.

1 Introduction

In distribution of rainwater, landscape has three basic functions: 1. optimally infiltrate water to the soil profile and underlay, based on their natural physical parameters; 2. create favourable conditions for water evaporation from soil, plants, water bodies and surfaces; 3. drain only natural surplus of water from basin through the river basin network.

Deforestation, agriculture and urbanization accelerate the runoff, decrease evaporation and infiltration of rainwater, cause draining and decrease of soil quality of the transformed land. The lack of water and vegetation on landscape surface leads to increased temperature of the landscape. Immense flows of solar energy are changed into sensible heat instead of the latent heat of water evaporation. Increased heat production in the landscape accelerates extreme weather events and changes in precipitation patterns. 2/3 of the rainwater comes from water evaporation in water basins. Thus, if we decrease evaporation we decrease average amount of rain and change precipitation patterns in

---

[1] Director, Department of Local Development, Association of Towns and Communities of Slovakia, Bratislava, Slovak Republic

water basins. Alteration of the land (during the centuries and decades) without compensation measures for rainwater retention and soil protection leads to desertification. Droughts and floods have common denominator, which is small water cycle distorted (not least) by current methods of water and soil management with minimising functioning vegetation in the country.

There is need for territorial adaptation of the landscape profile due to loosen water storage capacity and huge soil erosion of the water basins. That is why it is necessary to adopt new culture of managing water and vegetation at all levels of the territory. Rainwater harvesting, renewal of wood and vegetation cover of the landscapes project on massive scale are necessary steps to recovery of local, regional and global climate and for radical flood risks reduction.

Important part of such planning and adaptation processes is water planning in which **local water planning** plays key role. Local water planning leads to the elaboration of the **Local Plan of the Integrated Water Resources and Soil Management (Community plans of IWRM)**. Such plan fosters integrated approach by balancing management of water and soil resources and vegetation cover in the territory of every community, in sum in territory of whole water basin.

Association of Towns and Communities of Slovakia developed the methodology and provides set of special instruments for local water planning processes and local communities including innovative early warning system (http://www.meteoradar.eu/). The methodology fully supports the implementation of the EU Water Framework Directive, EU Floods Directive and the integrated water resources and soil management.

Principles for sustainable protection of towns and villages cadastre territories against floods

A key to ensure preparation and implementation of flood defence measures is a role of local municipality and cooperation of partners and landowners in the river basin. Through implementation of simple and investment not demanding technical and biotechnical adaptation measures in urban zones, agricultural land, woodland and water units, we can improve surface of the landscape and to revitalize ability of the river basin to retain water in the landscapes via water cycle circulation.

We can therefore reverse a trend of a negative water balance to a positive water balance in the landscape and to achieve equilibrium after some time. With this approach, we have to adhere to the following principles: area water protection; solidarity; partnership; subsidiary; sustainability and natural processes auto-regulation principles.

Principles of integrated water resources management in municipalities and their river basins

Integrated water resources management (IWRM) is a complex process of water resources use and protection that respects soil and water cycle in the landscape. In addition, IWRM can be used to assess impacts of water abstraction from ecosystems. IWRM should promote sustainable – new water culture for local communities and governments.

Following nine principles enable to ensure better, cost effective and more systematic sustainable water resources management in the long-term. They are based on detailed analysis of individual public policies in the area of protection and use of soil and water resources; analyses of the tasks and roles of local municipalities and landowners, new water paradigm approach, theoretical-expert knowledge of ecosystem and economic causalities of water cycle in the landscape.

<u>Towards rainwater protection and its active utilization in landscapes</u>

1. Principle of spatial protection of water resources in landscape and prior implementation of spatial flood prevention measures in river basins.
2. Principle of respecting importance of rain water as well as the role of landscape in rain water distribution.
3. Principle of cooperation and merging land and building owners and co-owners in order to protect and use rain water and to protect soil against erosion.

<u>Planning processes and reassessment of land changes</u>

4. Principle of assessment of an impact of planned construction, investment and economic activities on water cycle in the landscape.
5. Principle of reassessment of present land adjustments which influence water balance and water regime of the landscape during future implementation of integrated water resources management.

<u>Economical sustainability principles</u>

6. Principle of sound waste water treatment and economic analysis of the most cost effective system of drinking water supply, waste water treatment and sewage system.
7. Principle of water efficiency and water recycling.
8. Principle of establishment and implementation of real water pricing.

<u>Filling the gap of water policy on local level</u>

9. Principle of preparation and approval of municipalities integrated water resources management plans as a local part of river basin management planning process.

2 Data

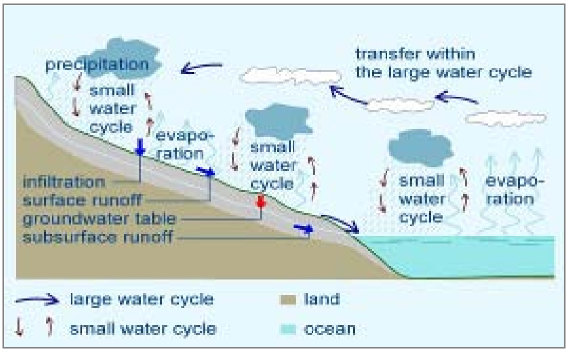


Figure 1: In circulation of the water in continents is more important small water cycle where circulates more water than in large water cycle.

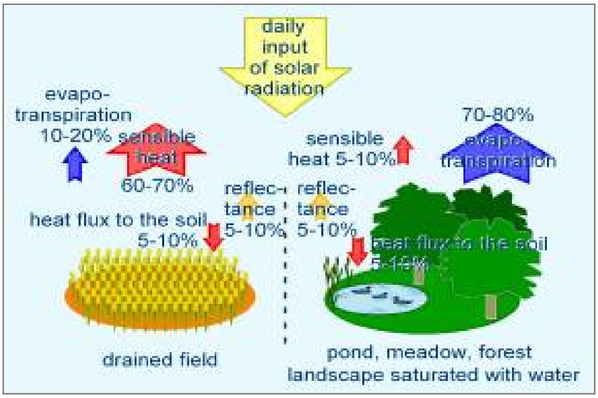


Figure 2: Dry land: Most solar energy is changed into sensible heat. Wet land: most solar energy is consumed in phase change

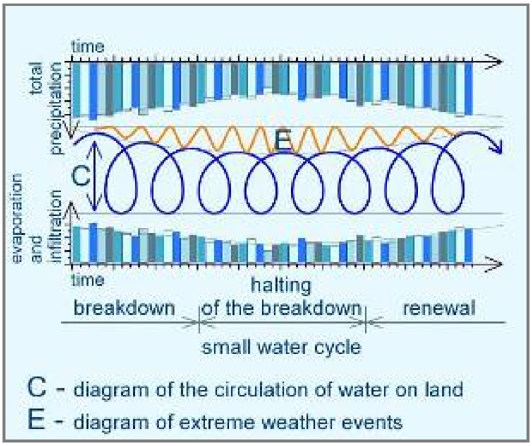


Figure 3: Description of today development, possible halting and renewal of small water cycle.

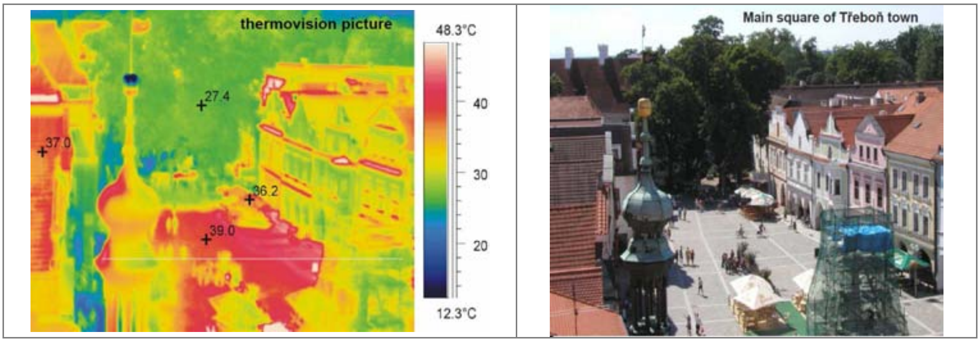


Figure 4: Infrared monitoring is an effective tool for problems identification and planning adaptation measures

3 Methodology

A part of the elaboration such **Community plan of IWRM** is evaluation of the surface water runoff of various parts of the landscapes [using *Ven Te Chow (ed.) (1964) Handbook of Applied Hydrology*] in three steps:

- Segmentation of the community territory (cadastre) for micro-water basins of common or similar surface runoff characteristics
- Calculation of surface runoff of particular micro-water basins
- Proposal of adaptation measures on the base of calculation and local characteristics

Output of the evaluation is identified potential (in cubic meters per hectare) for creation of micro-retention spaces for rainwater and other measures that need to be implemented in the landscape profile as part of the adaptation to climate change and flood risks reduction measures. Such plan is an effective document that proposes set of local measures that can be implemented via standard management tools as tax policy, territorial planning, nature protection, land adjustment, agricultural policy, forestry policy, water policy, etc.

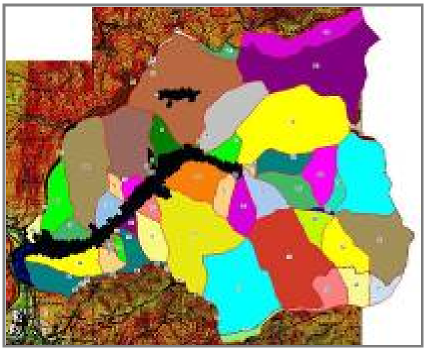


Figure 5: Example of surface runoff analysis – Oscadnica community, Slovakia

Community plans of IWRM should be prepared in cooperation and consensus with all stakeholders. They should respect principles of IWRM and public interest in the area of water protection and use on the territory of local community. Local level, level of the local municipality is the most appropriate level to put principles of integrated water resources management into practice.

Conclusions

To achieve real flood risk reduction we need to:

- Analyse surface runoff, propose and implement adequate adaptation measures (rainwater retention and soil protection) in landscape of all type for average 100mm precipitation event
- Minimise (close to 0) rainwater drainage from towns and urban zones
- Maximise (up to 100%) application of no till farming methods
- Establish and practise local water planning

Key impacts of integrated approach are: decreasing speed of sea level rise; halting the speed of desertification processes; improvement of precipitation patterns in the water basins; increase of biodiversity, vegetation cover and water resources in the landscapes; reduction of flood risks; reduction of landslides; soil erosion and river bad erosion reduction.

There is opportunity for flood risks reduction from 10% up to 80% depending on the complexity and scale of landscape adaptation. Community plans of IWRM are after its elaboration powerful communication and management tools for communication and co-operation with farmers, foresters, property owners and users, water courses administrators, landowners, neighbouring local governments, state administration and institutions.

Acknowledgements

Author express thanks to organisers of the Cagliari Workshop: Flash floods and Pluvial Flooding for enabling Association of Towns and Communities to take part in workshop and share experiences of the association. Author expresses thanks on behalf of the CEMR and its members as well.

References

Strategy of the Association of Towns and Communities of Slovakia on prevention and defence of towns and villages against floods, Association of Towns and Communities of Slovakia, May 2007, Slovak Republic.

Water for the Recovery of the Climate - A New Water Paradigm, M. KRAVCIK, J. POKORNY, Juraj KOHUTIAR, Martin KOVAC, Eugen TOTH, September 2007, Slovak Republic, http://ww.waterparadigm.org/.

Principles of integrated water resources management in municipalities and their river basins, Association of Towns and Communities of Slovakia, May 2008, Slovak Republic.

The substantial role of water in the climate system of the Earth - discussion contribution to the UN Climate Change Conference in Copenhagen on 7–18 December 2009, Jan POKORNY, Michal KRAVCIK, Juraj KOHUTIAR and Martin KOVAC, August 2009, Slovak Republic.

Košice Civic Protocol on Water, Vegetation and Climate Change (and COP15), November 2009, Košice, Slovak Republic.

Methodology for Preparation of Integrated Water Resources Management Plan of the Local Municipality, Association of Towns and Communities of Slovakia, May 2010, Slovak Republic.

http://www.zmos.sk/integrovany-manazment-vodnych-zdrojov.phtml?id3=48208.

Catalogue of solutions, measures and best practices. Available online at: http://www.zmos.sk/katalog-opatreni-rieseni-a-prikladov-z-praxe.phtml?id3=49905.

GIS portal for local communities. Available on line at: http://www.municipalia.sk/geoportal/.

Innovative early warning system. Available online at: http://www.meteoradar.eu/English/index.html.

http://www.ourclimate.eu/, Cemagref, INRA.

THEME 4:
Socio-economic aspects

B. De Marchi[1]

INTRODUCTION TO THEME 4: "SOCIO-ECONOMIC ASPECTS"

Corresponding author: Prof. Bruna De Marchi
Institute of International Sociology of Gorizia
Via Mazzini 13 – 34170 Gorizia, Italy
E-mail: bruna.de-marchi@fastwebnet.it

Abstract

The papers in the session address some key challenges in devising tools and procedures for improving flood risk protection and management. Whilst there is a broad consensus that accurate flood maps are a basic starting point, their construction is problematic, and not only for technical reasons.

In introducing the presenters and their topics, I will defend the view that the effective design and implementation of flood risk management measures requires a continuous and transparent communication among a multiplicity of stakeholders, so that their different (and normally differing) perspectives, perceptions, interests, and stakes are made explicit. Dialogue does not necessarily reduce conflict, but is a pre-condition for bringing together, and possibly integrating, different types of skills, knowledge, and expertise.

I will invite the presenters and the participants to dedicate some attention to whether and how such dialogue can be pursued or, alternatively, to challenge my view.

---

[1] Institute of International Sociology of Gorizia, Italy

W. Vanneuville[1]

CRUE ERA-NET: INTERNATIONAL RESEARCH FLASH FLOOD RESULTS

Corresponding author: Mr. Wouter Vanneuville
Flemish Government Department of Mobility and Public Works
Berchemlei 115 – 2140 Antwerp, Belgium
E-mail: wouter.vanneuville@mow.vlaanderen.be

Abstract

CRUE, the flooding ERA-Net, is developing future activities as a self-sustainable flooding network. In their first common call, the focus was mainly on types of measures with particular regard to the relevant of non structural measures. Results were presented at Working Group F. The second common call – with 7 ongoing research projects has the title: “Flood resilient communities – managing the consequences of flooding”. The sub-topics of the call indicate that the effects of flooding are more than an economic damage analysis only:

- improvement of risk awareness and increased public participation;
- effects of improved risk communication;
- communicating the residual risk and uncertainties;
- interaction of different actors;
- tools and improvements for flood event management;
- interaction of local scale and basin scale; and
- facilitation of recovery.

This presentation will give an overview of what is going on in these projects, for the socio-economic aspects in general and for flash and pluvial flooding in particularly. This will be compared with the strategic research areas defined in the CRUE Research Agenda of 2009 to indicate open research questions.

---

[1] CRUE Network Ambassador

B. Falkenhagen[1]

FLASH FLOOD AND PLUVIAL FLOODING FROM THE POINT OF VIEW OF THE INSURANCE INDUSTRY

Corresponding author: Ms. Bettina Falkenhagen
German Insurance Association (GDV) & CEA, Insurers of Europe
Wilhelmstraße 43/43 G – 10117 Berlin, Germany
E-mail: b.falkenhagen@gdv.de

1 *Introduction*

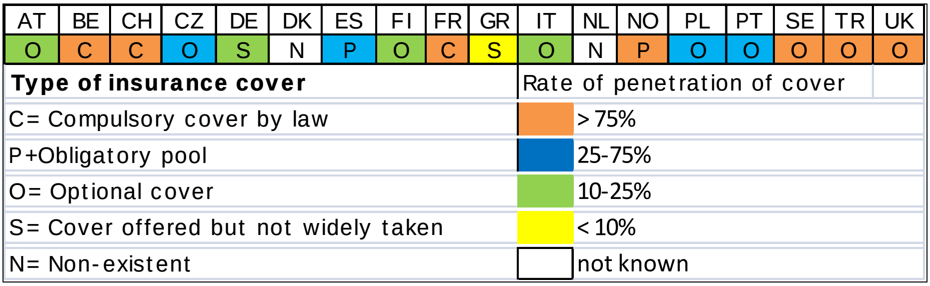
Major flood events are not only the cause for high losses, they are also deeply engraved in people's minds.

The risk of flooding in places away from rivers is generally overlooked. Scarcely anybody realises, that even a thundershower is enough, to create losses in order of magnitude similar to river floods. Altogether nearly half of all insured losses do not result from flood events near big rivers but from local events of flooding at small rivers or in places far from rivers. The insurance industry sees itself as a partner in securing one's livelihood in case of natural hazards and offers solutions as a contribution to the climate change adaptation process.

2 *Possibilities of insurance*

Insurance solutions developed for the flood cover widely vary across Europe. So does the market penetration (e.g., less than 10% in Greece, 20% in Germany and more than 75% in the United Kingdom), depending on the risk perception and risk exposure (see Table 1).

Table 1: Flood insurance coverage across Europe; CEA.



AT	BE	CH	CZ	DE	DK	ES	FI	FR	GR	IT	NL	NO	PL	PT	SE	TR	UK
🟩 O	🟧 C	🟧 C	🟦 O	🟩 S	⬜ N	🟦 P	🟩 O	🟧 C	🟨 S	🟩 O	⬜ N	🟧 P	🟦 O	🟦 O	🟧 O	🟧 O	🟧 O

Type of insurance cover	Rate of penetration of cover
C= Compulsory cover by law	🟧 > 75%
P+Obligatory pool	🟦 25-75%
O= Optional cover	🟩 10-25%
S= Cover offered but not widely taken	🟨 < 10%
N= Non-existent	⬜ not known

In the United Kingdom, flood cover is standard in home insurance,

---

[1] German Insurance Association (GDV), Germany; CEA, Insurers of Europe

including for those buildings located in a high risk area. This results from the flooding agreement between insurers and the government, which expires in 2013. The Association of British Insurers (ABI) is working with the government to ensure a commercially viable and competitive insurance market can offer affordable flood insurance to as many people as possible. In order to achieve this, it is imperative that the Government works on reducing flood risks and improving flood risk assessment.

In Germany it has been possible since 1994 to acquire insurance cover against flooding within the so called "extended coverage for elementary perils" as part of home insurance.

This insurance package is voluntary in Germany. The scope covers approximate 98.5% of inhabited areas. However, due to the general public's lack of risk awareness and expected post-disaster relief from the State, demand is modest. There was about 20% market penetration in 2009, unevenly distributed. In federal states with former insurance monopoly (former east German states until 1990; Baden-Wurttemberg until 1994) market penetration is high while in all other areas it is comparatively low.

Insurers use statistical data and management ratios to calculate premium rates and deductibles.

Since each risk has to be assessed on a case-by-case basis using statistical data, GDV´s zoning system ZÜRS Geo has become an important element of catastrophic hazard insurance in Germany.

3 Tools for risk assessment

In many countries the (re)insurance industry has developed or disseminated zoning tools, sometimes in cooperation with public authorities. This is the case, for example, of the HORA-platform in Austria, which is currently being extended to flash and pluvial floods. In France, the MRN GIS provides insurers all the flood hazard areas produced by public authorities. In the UK, the ABI concluded an informal agreement with the Environment Agency under which insurance companies have access to improved public data sets.

In Germany, ZÜRS Geo* provides an online risk assessment tool for the insurance industry as a means of assessing flood risk and offering a risk-related premium.

At the heart of the ZÜRS Geo system there is a geo-database using address information (road network, house number data etc.) to show the risk of flooding for any requested area. ZÜRS Geo is employed as a technical basis also for other automated zoning systems (e.g.,

---

* ZÜRS shortly means (Z)onierungssystem für (Ü)berschwemmung, (R)ückstau und (S)tarkregen [zoning system for floods, backwater and torrential rainfall], Geo stands for Geographical Information System (GIS).

environmental liability) and as a viewer for web based services (WMS, WFS etc.) provided by the German authorities.

The varying river flood hazards are depicted in different hazard zones, whereas backwater and torrential rain are uniformly distributed over Germany and therefore also uniformly considered in the calculation of the required premium.

In ZÜRS the flood hazard areas are represented by four zones. The hazard zones GK1, GK2, GK3 and GK4 refer to the following periods of return of the event (Figure 1):

- GK4 – high hazard: flooding occurs on average statistically at least once in 10 years;
- GK 3 – moderate hazard: flooding occurs on average statistically at least once in 50 years but less than once in 10 years;
- GK 2 – low hazard: flooding occurs on average statistically at least once in 200 years but less than once in 50 years (also incorporating the risk of breaching or overtopping of a dike);
- GK 1 – very low hazard: flooding occurs on average statistically less than once in 200 years;

In 2006 the GDV added further information on 150.000 km of small rivers (brooks) and thus a new so called "Bachzone" (brook zone) to ZÜRS Geo. Now it is also possible to identify the flood hazard of brooks in Germany.

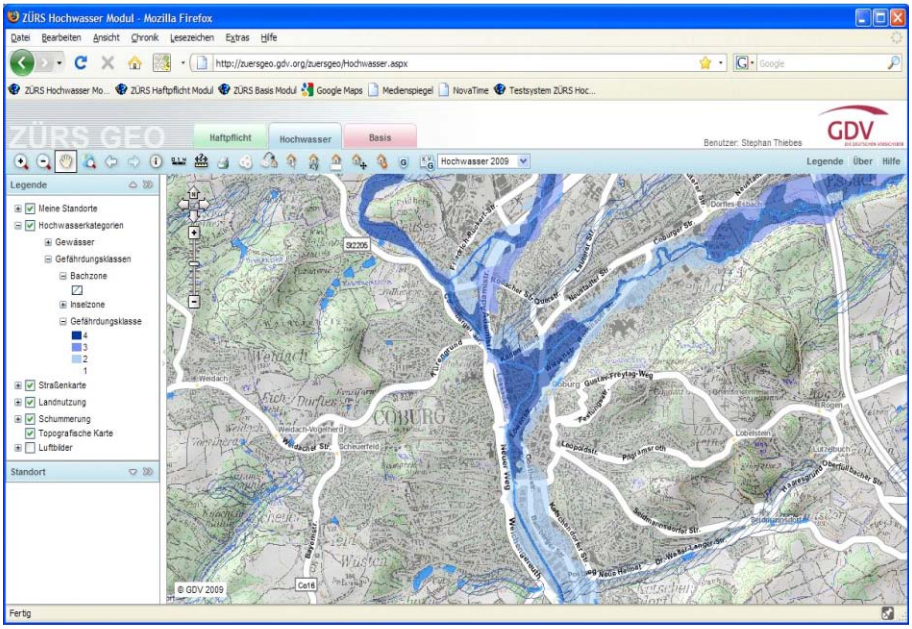


Figure 1: ZÜRS Viewer. River: bright blue; GK4 (10-year flood): dark blue; GK3 (10 to 50-year flood): blue; GK2 (50-200-year flood): light blue; GK1: residual area.

Until now, it is not possible to zone the risk of torrential rain resulting in flash floods and pluvial flooding for actuarial purposes.

Due to an eager demand for research, the German insurance industry works together with the Climate Service Centre (CSC), an initiative of the German Government.

4 Flood losses

There are many reasons for damages resulting from flash floods/pluvial flooding such as, for example, water flowing off along the surface, backwater rising in the urban drainage system, water accumulating in lower-lying areas or landslide as a result of a ground which can no longer absorb water.

The big flood catastrophes in Germany since 1993 resulted in losses of more than 14 billion Euros (Table 2). The many small- and medium-scale floodings all together add losses of several billion Euros. Since flooding at the main rivers and major tributaries cause only part of the damages, all local losses together account for the remaining large portion of flood damages. In Table 2 river floods are marked in black, flash floods in red and mixed floods in purple. Altogether nearly half of all insured losses do not result from flood events at big rivers but from local events of flooding at small rivers or in places far from rivers.

Table 2: Most expensive flood catastrophes in Germany since 1990, Source Munich Re NatCatSERVICE.

YEAR	AFFECTED AREA	TOTAL LOSS [BILLION EURO]	INSURED LOSS [BILLION EURO]	INSURED PART [%]
1993	Rhine area	730	220	30
1994	Saale-Unstrut- area	220	80	36
1995	Rhine area	390	160	41
1997	Oder	320	30	9
1998	All Germany	100	?	?
1999	Danube area	325	65	20
2002	Western Bavaria	100	50	50
2002	Elbe - and Danube area	11 600	1 800	16
2005	Danube area	175	40	23
2006	Elbe	120	20	17
2007	Central Franconia (Baiersdorf)	100	< 5	< 5
2008	Baden-Württemberg (Killertal)	>100	>100	?

Also in other countries, there is an increasing problem of high and increasing flood damages in areas away from rivers.

For example, in Great Britain two flood events in summer 2007 cost nearly 6 billion euro. Here also it was not the river flood which caused massive flooding, but mostly local rain exceeding the capacity of the drainage system. The Environment Agency informed that 80% of the buildings were damaged by water flowing off along the surface, by backwater coming out of the canalization or by water accumulating in low lying areas, some 17,000 in the city of Hull only. Following the 2007 floods the ABI conducted a major research project looking at surface water flood risk in England. The aim of the research was to highlight the challenges likely to be faced by Local Authorities in preparing surface water flooding strategies and to give an indication of the measures and costs involved in tackling surface water flooding in a typical local area[†].

The tropical storm Allison flooded the city of Houston/Texas including several hospitals and malls; financial loss: 6,5 billion euro.

After a thunderstorm in Beijing in July 2004 the traffic in several areas was interrupted and many subways were flooded. In Taipei, the underground was inundated due to the typhoon Nari in January 2001.

The most dramatic catastrophe beside the flash flood-catastrophe in Madeira in February 2010, was the one in Istanbul in September 2009. Nearly 40 people died, when water came down the streets in the manner of wild brooks.

In the field of loss data it is mostly impossible for the insurance industry too distinguish systematically between individual flood types. Most flash floods in Europe are categorized under "severe storm", in other parts of the world under hurricanes und typhoons. As a result, it is not possible to obtain direct information on events of flash floods and pluvial flooding.

Munich Re, with its database NatCatSERVICE, possesses the most comprehensive database of natural catastrophe losses worldwide. Here it is sometimes possible, to obtain rough flash flood information.
Table 3 shows as an example of how the information is stored the costliest flash floods in Europe since 1980.

Up to now nearly all big cities in Germany have stayed untroubled by such sudden flood events, mostly small towns and villages were affected. This fact is not only because of the broad dimensioning praxis, it was simply luck.

However, flash floods following heavy rain can strike anywhere. But we do not know, when and especially where it will happen.

[†] ABI: Urban surface water management planning – Implementation issues, ABI research paper 13, 2009. Available online at: *http://www.abi.org.uk/Publications/Urban_Surface_Water_Management_Planning_-_Implementation_issues1.aspx*.

Conclusions

Worldwide every year there are high losses caused by flood events. They divide into several quite different types, half of all flood losses result from local floods at small rivers or in places far from rivers.

Table 3: The costliest flash floods in Europe since 1980, source: © 2010 Münchener Rückversicherungs-Gesellschaft, Geo Risks Research, NatCatSERVICE – As in April 2010.

Period	**Event**			**Description**	**Losses (US$ m, original**		**Fatalities**
					overall losses	**insured losses**	
3.-9.11.1987	C: Flash flood, landslide	Spain	Mediterranean Sea, Valencia, Murcia, Alicante	Floods up to 2,5 m high, torrential rain (1000 mm/38 hours), landslides. Train services disrupted, communication and power lines cut. Damage to citrus crops US$ 30m.	**1000**	**185**	**16**
31.10.-2.11.1990	C: Flood	Croatia	Zagreb area	Heaviest rain for 50 years (220-260 mm/48 h). Landslides. River Savinja burst its banks, bridges washed away, roads blocked, houses flooded. Also affected: Slovenia.	**800**	**0**	**0**
31.10.-2.11.1992	C: Flash floods, severe storm	Italy	esp. Tuscany, Rome, Sicily	Torrential rain. Rivers burst their banks. Houses, cellars flooded. Toskany: worst rain since 1813 (510mm/October). Homeless: 1,000, injured: numerous.	**712**	**2**	**3**
8.-11.9.2009	C: Floods, flash floods	Turkey	Istanbul, Sariyer, Kilyos suburbs; Tekirdag, Kumbag; Canakkale; Bursa; Balikesir; Aydin; Izmir; Antalya	Heavy rain, flash floods up to 4 metres. Worst precipitation for 80 years (220mm), worst flooding in 500 years. Rivers burst their banks. >4,000 houses, several industrial facilities flooded/damaged. 200 cars destroyed. Major damage to infrastructure. Roads flooded, bridges damaged/destroyed. Trees downed. Injured: 20, missing: 5, evacuated: 200.	**600**	**250**	**38**
1.-4.10.1988	C: Flash floods, severe storm, rainstorm	France	Nîmes	Torrential rain (300 mm/24 h), heavy flooding. 18,000 houses damaged. Shops, factories and warehouses affected. Streets flooded. More than 1,000 cars destroyed. Power and telephone lines cut. Affected: 50,000.	**500**	**315**	**11**
12.-14.11.1999	C: Flash floods	France	Tarn, Lacabarede; Aude; Pyrénées-Oriental, Herault; Labastide-Rouairoux, Villedaigne	Torrential rain (240 mm/18 hours, Aude, max. rainfall intensity 112 mm/1 hour), wind speeds up to 100 km/h (worst storm for 50 years in the region), landslides. Houses, businesses flooded, dozens of cars destroyed. Roads, railways, bridges destroyed. Power, communication and water supplies disrupted. Losses to agriculture. Missing: 3.	**500**	**400**	**33**

The insurance industry has a substantial interest in analysing the subject torrential rain/flash floods/pluvial flooding in more detail. The target is to estimate the risk of local flooding, so that the insurance industry can offer risk based products.

Therefore further research is required in this area and easy access to detailed data should be ensured, free of charge, for all stakeholders, including the insurance sector.

References

Falkenhagen, B.: ZÜRS – Das Zonierungssystem der deutschen Versicherungswirtschaft zur Einschätzung der Überschwemmungsgefährdung. In: H.-b. Kleeberg (Hrsg.) Hochwasser-Gefahrenkarten, Beiträge zum workshop Gefahrenkarten am 21. November 2004 in Potsdam, Forum Hydrologie und Wasserbewirtschaftung, Heft 08/05, Hennef, ATV-DVWK, 85-91, 2005.

Kron, W.: Elementarschutz: Weit weg vom Gewässer – sicher vor Überflutung? Versicherungswirtschaft 65. Jg., Heft 3 (1. Februar 2010), 210–217, 2010. ISSN 0042-4358.

CEA, Tackling climate change. The vital contribution of insurers, December 2009.

A. C. Taramasso[1] and G. Roth[1]

FLOOD MAPS INFORMATION CONTENT FOR INSURANCE AND RE-INSURANCE INDUSTRIES

Corresponding author: Dr. Angela Celeste Taramasso
University of Genoa, Geo Risk Management Lab
Via Magliotto 2 – 17100 Savona, Italy
E-mail: act@dist.unige.it

Abstract

The Italian National Association of Insurance Companies (ANIA) has recently financed a project with the aim to develop a **Flood Insurance Risk Management Integrated System**, known as SIGRA. Based on the knowledge of the insured portfolio, the system is able to perform a variety of insurance and re-insurance related quantitative economic analyses. Within SIGRA, flood maps are used to identify hazard prone areas, to provide vulnerability estimates, and as a basis to simulate flood scenarios areal extent. For each location recognized as prone to flood, as well as for each ensemble of risks (i.e., portfolio), SIGRA is able to produce physically realistic flood scenarios that take into proper account flood maps information produced with reference to the different return periods. The system is therefore able to simulate the release of hydraulic forces, which will affect and cause damages to properties located in flood prone areas. Finally, SIGRA estimate insurance and re-insurance related economic parameters as the Annual Expected Loss, the Possible Maximum Loss and the Maximum Possible Loss.

1 Introduction

The main goal of the SIGRA project is to develop a nation-wide integrated system to assess and manage insurance and re-insurance aspects of the flood risk in Italy. The project was developed in work-packages: the first deals with the setup of a database related to the essential elements linked to the physical aspects of the inundation process, and the basic insurance aspects related to the different elements exposed to the hazard; the second deals with the development and validation of algorithms and procedures needed to estimate insurance parameters, a requirement to meet the client's expectations.

The first step is based on the identification of the hierarchy of rivers segments with regards to the potential risk (Kirkby, 1975). This was performed taking into account official territorial data, including high resolution satellite data and remotely sensed surveys from laser scanner

---

[1] Geo Risk Management Lab, University of Genoa, Italy

techniques for quasi-2D and 2D flood simulations, completing the official information where needed (Giannoni et al., 2003), and computing flood forcing products (e.g., flow depth), where not available. Stored data were homogenized, validated and corrected to develop flood scenarios simulation at the national scale, taking into account temporal and spatial correlation among flood-prone sites (see, e.g., Ghizzoni et al., 2010; Lomazzi et al., 2009; Taramasso et al., 2009 and 2010). The combination, through probabilistic algorithms, of hazard and vulnerability information, allows the estimation of insurance parameters. Eventually, a complete portfolio flood risk assessment is produced.

The project was carried out taking into account the European Parliament and Council Directive 2007/60/EC on the assessment and management of floods (November 2007), and the corresponding Italian law (Italian Legislative Decree n. 49, 23 February 2010).

2 Description of the SIGRA Project

The project identifies the flood prone areas linked to a specifically defined hydraulic network (La Barbera and Roth, 1994). In fact, the final use of the results is relevant to commercial and industrial insurance companies' clients. To identify areas to be studied, we have applied a ranking approach introducing, for each municipality, the following information:

- number of inhabitants;
- presence of industrial or commercial activities;
- number of workers;
- presence of industrial districts;
- presence of high risk industries.

An example of the results of this ranking analysis is shown in Figure 1.

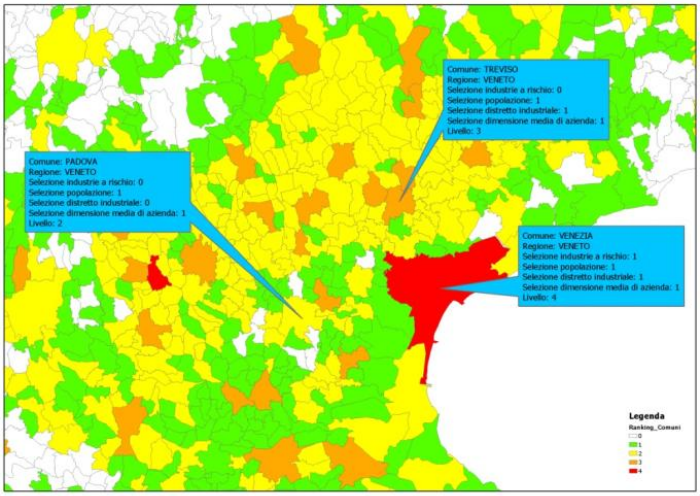


Figure 1: Example of territory risk classification using the ranking approach.

Another important information is the record, in the municipalities, of historical flood data. For this analysis, the AVI database is used, that is, the main database of flood damages occurred on Italian territory (see, e.g., Guzzetti and Tonelli, 2004 and Guzzetti et al., 1994).

To collect this data is important also to compare the actually available modelled flood areas with historical data. An example of this analysis is shown in Figure 2 and Figure 3.

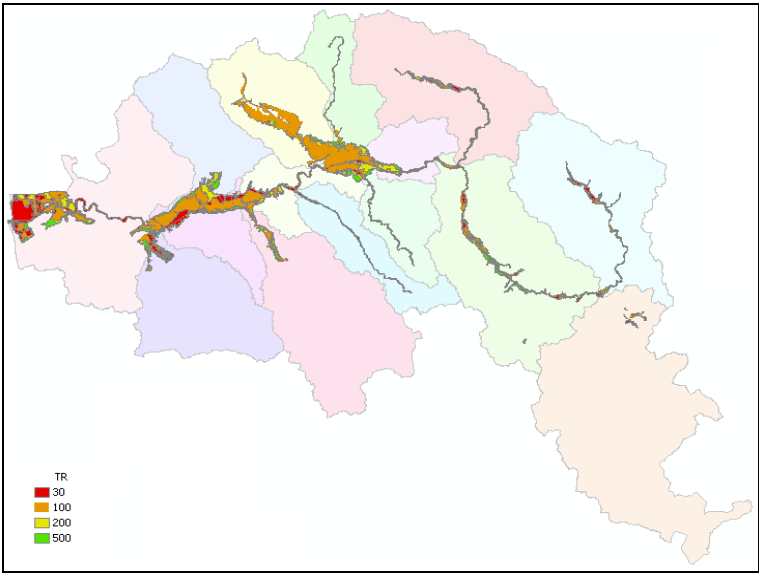


Figure 2: Modelled flood prone areas, Arno basin.

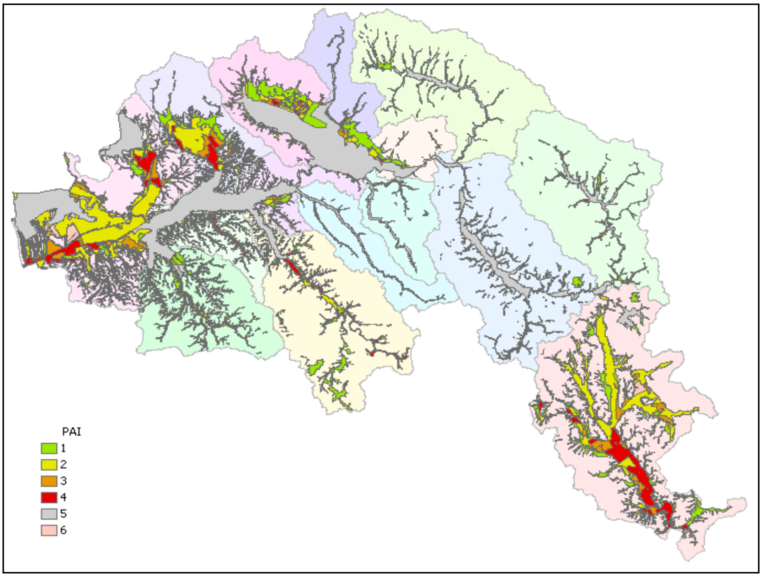


Figure 3: Historically flooded areas, Arno basin.

3 Scenarios Simulation

To simulate possible risk scenarios, the Italian territory is divided in 288 reference areas, classified using available hydrologic related information and historical flood data. The model proposed for the scenarios generation starts from a statistical approach, and it is also able to evaluate the damage to insured elements. Scenario generation take into account the definition of a flood event as perceived by the insurance companies: all damages and casualties described at the reference area scale, and reported within a 168 hours (7 days) time window.

The main data used to characterize the model are:

- from the AVI data base, the historical flood data with temporal and spatial indications, and sometimes also with damage estimation;
- the spatial domain (Italian territory), classified in macro and micro areas;
- the definition of a binary matrix with indication of expected past events correlation among different areas, estimated by taking into account also meteorological and morphological factors.

The synthetic scenario is therefore generated through a statistic model, calibrated on the basis of the large-scale knowledge provided by the AVI catalogue.

An example is provided in Figure 4 starting from the database of historical events (i.e., the Florence flood on 1966) and the identification of the areas involved in the simulated scenario is shown in Figure 5.

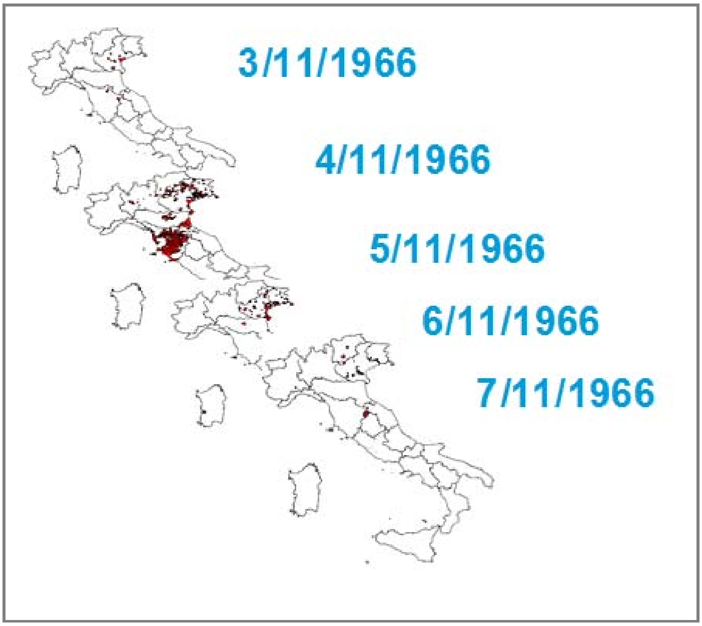


Figure 4: Example of the areas involved during the Florence 1966 flood.

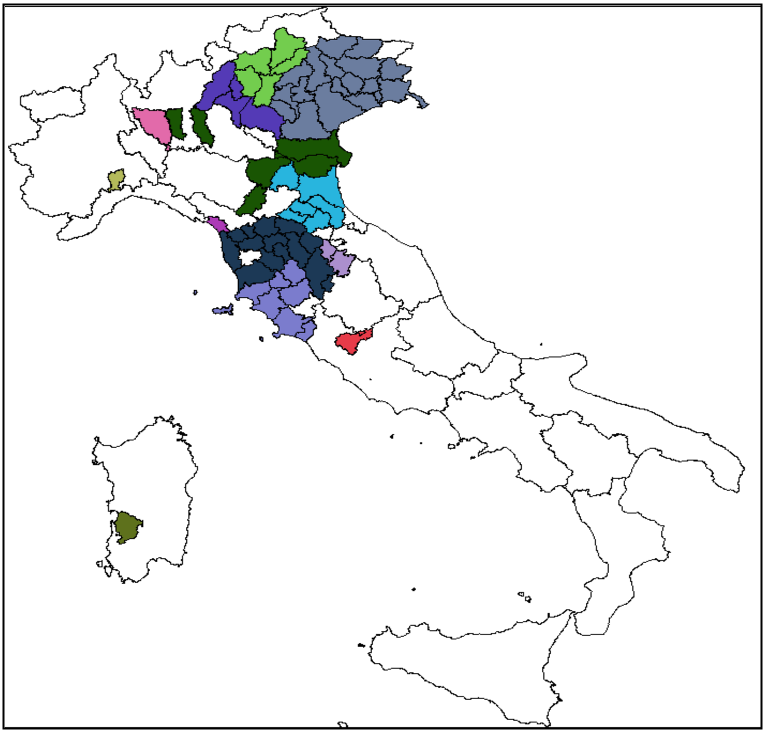


Figure 5: Example of areas involved in the Florence 1966 flood event for the duration utilized in the project (7 days).

4 Insurance and Re-Insurance parameters

To estimate the possible risk linked to a given single element or a given portfolio, it is necessary to evaluate the following quantities.

Probable Maximum Loss (PML). Represents the damage correlated to an assigned return period for a specific element or portfolio exposed to a flood event. The SIGRA project utilizes the available hazard flood maps for the usual return time period (high, mean and low probability of occurrence), produced by Basin Authorities. Each element can show a maximum of three different PML values, if located inside the area characterized by the highest probability of occurrence (in Italy usually equal to 50 years).

Annual Expected Loss (AEL). Represents the expected damage for the element (or the insurance company's portfolio) in one year, derived from the analysis of a long simulation. This represents the insurance rate and it is correlated to the mean PML value for the different return periods, each of them with an appropriate weight.

Maximum Possible Loss (MPL). Represents the maxim possible damage that could happen for one or more insured elements. It is equal to the PML value for a given (high enough) return period.

For each single element, as well as for given portfolios spread over the Italian territory, the SIGRA system evaluates the different insurance parameters taking into account the result of the statically analysis above described.

In this framework, an import role is played by the elements' vulnerability. It is therefore not only necessary to estimate if the location is inside the flood area, but also the values of dynamic flood parameters, like water depth and velocity. Knowing these parameters, vulnerability tables correlated to the flooding risk, and available in the international literature, can be used. All of these parameters are needed to define the price insurances and to limit the overall risk assumed by a single company.

Conclusions

The SIGRA database contains:

- a map of flood prone areas. For each location it specify flood return period and flow depth. For a single target, this is enough to evaluate hazard and insurance risk parameters;
- 100.000 synthetic scenarios characterized by a space structure statistically similar to the one provided by the AVI historic catalogue;
- the portfolio for which the estimation of insurance related parameters – AEL, PML and MPL – is needed (locations, values and vulnerabilities).

Through this procedure, the portfolio is excited by the ensemble of synthetic scenarios (providing <u>space coherence</u>). Damage is then associated to each event within each scenario taking into account:

1) flood maps information at portfolio sites (providing <u>actual hazard</u>),
2) the values of the expositions, and
3) their vulnerability.

The damage series is finally analyzed to give AEL, PML and MPL. An example is shown in Table 1.

Table 1: Example of the SIGRA project outcomes.

Total elements	Insurance amount (10^6 €)	Element exposed at risk	Insurance amount at risk (10^6 €)	PML (Euro)	AEL [°/°°]	MPL (10^6 €)
20	36	4	4	0.4	0.040	0.9

Acknowledgement

Work adapted from the SIGRA official project documentation. The project is owned by ANIA, and was developed in cooperation with Telespazio and Agriconsulting.

References

Ghizzoni, T., Roth, G., and Rudari, R.: Multivariate skew-t approach to the design of accumulation risk scenarios for the flooding hazard. *Advances in Water Resources*, 33, 1243–1255, 2010. doi:10.1016/j.advwatres.2010.08.003.

Giannoni, F., Roth, G., and Rudari, R.: Can the behaviour of different basins be described by the same model's parameter set? A geomorphologic framework. *Physics and Chemistry of the Earth*, 28(6-7), 289–295, 2003.

Guzzetti, F., and Tonelli, G.: Information system on hydrological and geomorphological catastrophes in Italy (SICI): a tool for managing landslide and flood hazards. *Nat. Hazards Earth Syst. Sci.*, 4(2), 213–232, 2004.

Guzzetti, F., Cardinali, M., and Reichenbach, P.: The AVI project: A bibliographical and archive inventory of landslide and flood in Italy. *Environmental Management*, 18, 623–633, 1994.

Kirkby, M. J.: Hydrograph modelling strategies. In: *Progress in Physical and Human Geography*, Peel, R. F., Chisholm, M. D., and Haggett, P. (Eds.), Heinemann, London, 69–90, 1975.

La Barbera, P., and Roth, G.: Scale properties & scale problems: network morphology & network identification from digital elevation maps. In: *Advances in Distributed Hydrology*, Rosso, R. et al. (Eds.), Water Resources Publications, Highlands Ranch, Colorado, 131–148, 1994.

Lomazzi, M., Roth, G., Rudari, R., Taramasso, A. C., Ghizzoni, T., Benedetti, R., Espa, G., and Terpessi, C.: Frequency assessment of spatially distributed generations of flood scenarios: an application on the Italian territory, American Geophysical Union Fall Meeting, San Francisco, USA, 14–18 December, NH54B-06, 2009.

Taramasso, A. C., Degiorgis, M., Gorni, S., and Roth, G.: Digital terrain model's resolution influence on flood scenario design. *Geophysical Research Abstracts*, 12, EGU2010-10419, EGU General Assembly, Wien, 2–7 May, 2010.

Taramasso, A. C., Roth, G., Rudari, R., Lomazzi, M., and Ghizzoni, T.: On the identification of flood prone areas from national scale territorial information: the case study of Italy, American Geophysical Union Fall Meeting, San Francisco, USA, 14–18 December, NH51C-1064, 2009.

D. J. Parker[1] *and S. J. Priest*[1]

EXPLORING THE POTENTIAL FOR PLUVIAL FLOOD WARNINGS WITH PROFESSIONAL RESPONDERS AND THE PUBLIC IN ENGLAND AND WALES

Corresponding author: Prof. Dennis J. Parker
Middlesex University, Flood Hazard Research Centre
Trent Park, Bramley Road – London N14 4YZ, United Kingdom
E-mail: denjpark@btinternet.com

Abstract

This paper discusses research completed in 2010 for the Environment Agency in England and Wales into the potential for pluvial flood warnings. An opportunity exists to develop Extreme Rainfall Alerts into pluvial flood warnings. However, currently insufficient linkages between rainfall intensity, duration and frequency and flooding, and uncertainties concerning probability of events, their location and their impact complicate flood prediction, risk communication and warning response. Interviews and workshops involving professional responders and public focus groups were undertaken during 2009. Professional responders already find rainfall alerts helpful and they and the at-risk public want rainfall alert based pluvial flood warnings even if warning lead times are short. Warning locational specificity, accuracy and reliability need to be enhanced and public warning recipients need greater confidence in the warning and related authorities before such a service is launched, but these problems appear surmountable.

1 Introduction

Research into flood warnings demonstrates the importance of discovering user requirements before designing and launching flood warnings (Emergency Management Australia, 1999; Parker, 2004). Otherwise there is a high risk of formal warnings being of limited use (Parker and Handmer, 1998). Following serious pluvial flooding in 2007 when there were no surface water flood warnings, pluvial flood warnings are desirable. The UK Met Office and the Environment Agency (i.e., the flood risk management agency) formed a new Flood Forecasting Centre (FFC) to enhance flood forecasting capability. A pilot was developed between 2008-09 to issue "Extreme Rainfall Alerts" (ERAs) to professional emergency responders (PRs) such as local authority highways departments and utility companies. The alerts are a first step towards forecasting and warning of surface water floods (SWFs) of pluvial origin.

---

[1] Flood Hazard Research Centre, Middlesex University, London, United Kingdom

The objective of this paper is to examine the potential for launching pluvial flood warnings based on ERAs by exploring requirements and preferences of PRs and the public. The paper is based on research for the Environment Agency including a technical ERAs assessment (Priest et al., 2010a; 2010b).

2 Pluvial flooding, rainfall alerts and the ERA service

Pluvial flooding is a SWF type usually arising through the surcharging of drains overwhelmed following intense rainfall. Such flooding often occurs as "ponding" in low-lying areas (Figure 1) or it may flow down hillsides and gullies, across fields and through streets. Pluvial flood or SWF warnings are currently rare with only a few very localised warning systems in the UK (Priest et al., 2010b). Outside the UK few services exist which provide specific pluvial flood or SWF warnings closely attuned to local conditions and flooding thresholds. The rainfall and flood alert system of Marseilles, France appears to be close to a genuine pluvial flood warning service because it links rainfall intensities to locally relevant flooding thresholds for floods of different estimated return periods (Deshons, 2002).

Rainfall-based alert services of the UK Met Office include the National Severe Weather Warning Service (NSWWS) and the ERA service: both on-line for media and public use.

Figure 1: Typical pluvial flooding of a suburban area (Courtesy of Mel Evans, Environment Agency).

Advisories are issued daily and up to 5 days ahead, indicating the confidence (between 20% and 60%) of expected weather. Severe weather warnings are normally issued several days ahead when the risk of widespread disruption is 60% or greater. Flash warnings of severe weather are issued when confidence is above 80%, and should give a minimum of 2 hours notice. The ERA service is a state-of-the-art tool for predicting extreme rainfall events at county level likely to lead to pluvially-driven SWFs (FFC, 2009, 2010) but does not provide specific SWF warnings. Making a connection between rainfall intensity and duration and flooding is a critical step in developing pluvial, SWF warnings. Currently, only nationally-applicable rainfall thresholds are available indicating when urban pluvial flooding will occur. Until rainfall thresholds can be locally-refined the rainfall-flooding connection will be of limited quality. Probabilistic rainfall forecasts are derived from outputs from ensemble forecasts and currently these are assessed against rainfall thresholds to be those likely to cause urban SWFs. Rainfall values for 1, 3 and 6 hour storms in eight UK cities were averaged and rounded to the nearest 5 mm to provide "national" thresholds: 30 mm in one hour, 40 mm in three hours, or 50 mm in six hours assuming a design storm of 1:30 years overwhelms drains. The alert level depends on event probability and if a probabilistic forecast represents a probability of over 10% of one of the three rainfall thresholds being breached, then an ERA is issued. ERAs are not currently issued directly to the media or the public (FFC, 2009). They are issued to, and are now incorporated into, Flood Guidance Statements (FFC, 2009) issued daily by the FFC. The public also now have on-line access to a public version of flood guidance but not to ERAs.

3 Data and methods

Feedback from PRs was gathered on ERA advisories and alerts and resulting actions. 18 PR interviews were also undertaken in 2009. Respondents included ones from the Environment Agency, National Grid, Local Authorities and emergency services etc. Potential users were invited to (a) at-risk public focus groups and (b) PRs workshops in 2 pluvial flood risk areas. Wealdstone Brook, NW London is a location with multiple flood risks (i.e., fluvial, pluvial and sewer) whereas the areas in Rotherham (Yorkshire) currently only suffer pluvial floods.

Most of Wealdstone's at-risk population have no pluvial flood experience and are unaware of the risk but an active group of residents, knowledgeable about their local flood mechanisms and who have flood warning experience, were well represented in the Wealdstone focus groups. Participants cited fluvial, sewer and pluvial flooding, often combined. Some have adapted their homes to increase flood resilience. The Rotherham communities experienced SWFs from a pluvial event in June 2009 (82 mm of rainfall in 6 hours). Until then, half believed themselves to be safe from flooding whereas the other half had experienced sewer flooding or "near misses" fairly frequently. Some areas flooded had not previously appeared on flood risk maps and were not low-lying. Since, some residents have demanded action from the local council to install flood resilience measures at at-risk properties.

Four public focus groups were organised: two in November 2009 in Wealdstone and another two in December 2009 in Rotherham. 31 people participated (11 from Wealdstone, 20 from Rotherham). Participants were recruited according to a representativeness strategy but it proved difficult to persuade at-risk members of the public from Wealdstone with no recent flood experience to participate. The sampling design, socio-economic characteristics, focus group mechanics etc. are all recorded in Priest et al. (2010b). One half-day invitational workshop was organised for PRs in each area during November 2009. Participation was good with 33 participants in total and only the fire service unable to participate in Wealdstone and the utilities absent from both workshops. Most participants had flood emergency experience (Priest et al., 2009b).

4 Results

86% of PRs believed that ERAs are useful; the remainder are concerned about uncertainty or inadequate lead time. PRs are of two types: (a) primarily proactive responders, that is, those for whom early warning permits essential actions to be taken to reduce damage or to get organised in the aftermath, and (b) primarily reactive responders, that is, those who perceive their role as mainly reactive or focused on the emergency aftermath. Utilities and the emergency services are type (a) and find ERAs most useful. Utility companies value early warning to avoid installation damage where pro-active response is feasible. Although most local authority functions perceived their role as reactive, this was not so of local authority highways departments. They valued time to move to a higher state of readiness. Again utilities stand out with a higher active response percentage followed by emergency services. Although 59% of PRs report taking some action emergency actions on receipt of ERAs (Figure 2) they want greater certainty, greater locational specificity associated with alerts and warnings and a minimum warning lead time of two hours. Currently, translating ERAs into flood predictions presents difficulties which adversely impact actions taken. Information is lacking on local flood triggers (i.e., rainfall or runoff thresholds which when exceeded generate flooding). PRs are still clarifying their practical range of effective action.

PRs appreciate that ERAs are a rainfall alert which may be developed into pluvial flood or SWF warnings and that they should be developed to improve warning quality. PRs believed that effective communication channels for receiving ERAs are required within their own organisations: these are not yet present.

Overall, use of the same averaged and rounded, “national”, rainfall thresholds for all England and Wales locations is limiting. Most PRs recognised that variable, locally-determined rainfall and runoff thresholds are preferable for pluvial flood warnings and want alerts and warnings to be tailored to local flooding triggers. PRs perceive the value of all three alert or warning options. On balance option (b) (i.e., rainfall-based alerts utilising locally specific runoff thresholds) is preferred. Among PRs there were questions over what is meant by 40% or 60% in the context of ERAs. Some believed erroneously that although the probability of flooding occurring in the wide area in which a flood was forecast might be say 60%, that the chance of their small area being flooded was less than 60%, and that the chance of a particular householder being flooded was even less than this.

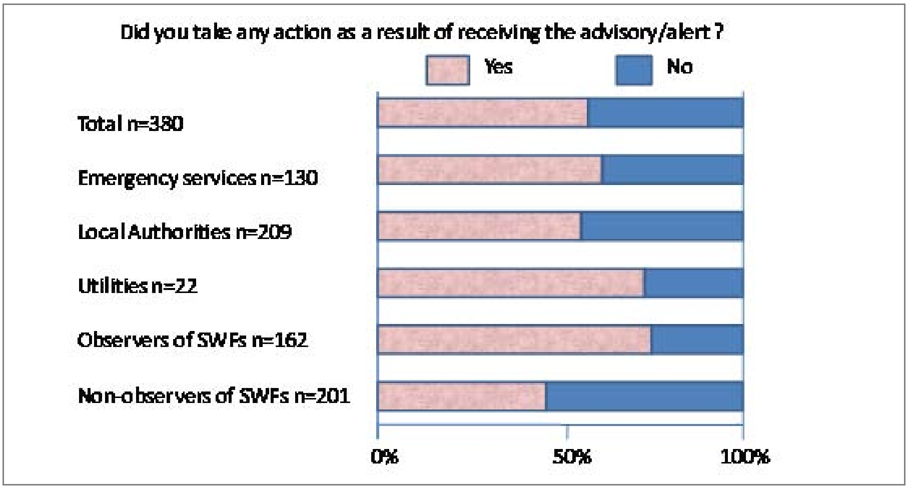


Figure 2: Professional responders responses to ERAs (Data collected by ERA pilot team and reproduced in Priest et al., 2009b).

Most public participants preferred structural flood prevention to warnings viewed as "second class". Inadequate drainage capacity and maintenance were highlighted as causing pluvial flooding. Across England and Wales many at risk from riverine and tidal flooding receive false alarms (about 50% of recent survey respondents) but these do not have a significant impact on public confidence in these flood warnings (National Flood Forum and Environment Agency, 2009). In this study, most public participants believed that a flood warning was better than no warning. Most had some false warning tolerance given the prediction uncertainties. However, those with recent flood experience (in Rotherham and Wealdstone) indicated that losing confidence in warnings is either an issue or could become an issue following repeated false or "missed warnings". False warnings had reduced Wealdstone participants' confidence in warnings because they had already experienced problems with them. These problems included more than a few false alarms. Wealdstone participants also complained about receiving vague, unspecific warnings and warnings issued by one agency and contradicted by another. Most Rotherham participants also expressed a preference for a warning of any kind to no warning at all. However, a few who had experienced more floods and near misses disagreed. Negative comments are attributable to participants' voiced distrust of weather and flood warning agencies or those giving advice and assistance following flooding reflecting experience of 'missed warnings' and allegedly not receiving post-flood assistance. To summarise most focus group participants want SWF warnings and most would tolerate a degree of unreliability in these warnings. However, unfortunately, for a significant proportion adverse experiences have already undermined their trust in weather and flood warnings. Most public participants believed that warnings would need to be accurate and specific to be beneficial but that, because they believed that only short warning lead times are feasible, they felt that the benefit would be limited. All focus group participants believed that they understood probability information but subsequent discussion revealed uncertainty about meanings.

Conclusions

The ERA service can develop into a pluvial, SWF warning service. Understanding user experiences and requirements for such warnings will be critically important to their successful design and launch. Initially, pilot warnings should be targeted at PRs. When suitable warning reliability levels are reached, these warnings should be extended to the public. PRs desire such warnings: the majority find them useful but want a more specific warning than the current ERAs. Greater certainty in terms of probabilities and locational specificity and a minimum warning lead time of 2 hours are required. Rainfall-based alerts utilising locally specific rainfall and runoff thresholds are preferred for developing warnings. Those who recognise that they are at risk from pluvial, SWFs also want warnings as long as they are reasonably locationally accurate, reliable and timely.

A stronger linkage needs to be made between rainfall intensity and duration and flooding employing locally-refined rainfall and runoff thresholds linked to SWF risk mapping which is currently being enhanced. Flood modelling is required to take into account variables such as drainage system capacity, land use, antecedent conditions and mitigation measures. Second, some stakeholders need to be drawn more closely into pluvial, SWF warnings. Some PRs and the public clearly require more training in understanding ERAs and probabilities. There is no system to capture local pluvial, SWF knowledge which resides in local council files, among local drainage engineers and those who experience pluvial, SWFs and this knowledge needs to be co-produced in future. When pluvial, SWF warnings are provided for the public, the confidence and trust of those at risk in the agencies providing weather and pluvial/SWF warnings needs to be very significantly increased including by risk awareness raising.

Acknowledgements

The research was a Science Project (SC080034) sponsored by the Environment Agency. The authors are grateful to the Environment Agency and PRs, as well as to members of the public, who engaged in this project. Thanks also to Helen Stanley, Anna Field, Duncan Struggles, Jon Hunter and Paul Davies for their input; to members of the project board and to Sue Tapsell and Joanna Pardoe who assisted with data collection

and analysis. Finally, we wish to acknowledge the contributions of our co-researcher from HR Wallingford, Anthony Hurford.

References

Deshons, P.: Prévision et suivi des crues urbaines. Expérience de la ville de Marseille. *La Houilles Blancin*, 2, 56–59, 2002. DOI: 10.1051/lhb/2002022.

Emergency Management Australia: Flood Warning, 2nd Ed. Part III D Emergency Management Practice, Vo. 3 – Guidelines, Guide 5. EMA, Dickson, ACT, 1999.

Flood Forecasting Centre (FFC): Extreme Rainfall Alert Service (ERA) Briefing paper for Category 1 and 2 responders. Flood Forecasting Centre, London, 2009.

Flood Forecasting Centre (FFC): Extreme Rainfall Alert (ERA) Service User Guide. Available online at: http://www.ffc-environment-agency.metoffice.gov.uk/media/pdf/ FFC_ERA_User_Guide.pdf, 2010.

National Flood Forum and Environment Agency: Summary of findings: National Flood Forum Survey on the Environment Agency's Flood Warning Service, Report by O. Harmar and C. Strong, July, Environment Agency, Bristol, 2009.

Parker, D. J.: Designing flood forecasting, warning and response systems from a societal perspective. *Meteorologische Zeitschrift*, 13(1), 5–11, 2004.

Parker, D. J., and Handmer, J. W.: The role of unofficial flood warning systems, *Journal of Contingencies and Crisis Management*, 6(1), 45–60, 1998.

Priest, S. J., Parker, D. J., Hurford, A. P., and Lumbroso, D.: An assessment of current experiences of the Extreme Rainfall Alert (ERA) service – Final Report, Environment Agency Science Programme Report, Science Report – SC080034/SR2, 2010a.

Priest, S. J., Parker, D. J., Hurford, A. P., Pardoe, J. L., McCarthy, S. S., and Tapsell, S. M.: Surface Water Flood Warning Scoping Project – Final Report, Environment Agency Science Programme Report, Science Report – SC080034/SR1, 2010b.

POSTER SESSION

J. Daňhelka[1], K. Drbal[2] and P. Štěpánková[2]

FLASH FLOODS IN THE CZECH REPUBLIC – EVENT OF 2009 & METHOD OF FLASH FLOD RISK EVALUATION

Corresponding author: Mr. Jan Daňhelka
Czech Hydrometeorological Institute
Na Sabatce 17 – 14306 Praha, Czech Republic
E-mail: danhelka@chmi.cz

Abstract

Paper presents some basic outputs from evaluation of June-July 2009 flash floods in the Czech Republic. Flash flood risk evaluation methodology to be used in Floods Directive implementation process in introduced. Methodology for potential damage is also briefly described.

1 Introduction

The Czech Republic experienced catastrophic flash floods in June and July 2009 (Figure 1). It affected several locations and in total demanded 15 victims and caused damage of 330 mil. EUR. The project on evaluation of flash floods was made under the coordination of Czech Hydrometeorological Institute. It proved that in affected small basins (< 100 km^2) a causing precipitation usually prevailed for 2 to 3 hours and reached 60 to 120 mm. Evaluation proved the significant impact of initial saturation of the basin on the flash flood response. Synoptic situation of eastern warm and moist air flow prevail for 12 day, what was extraordinary long duration in last 65 years.

2 Flash Flood Risk Evaluation Methodology

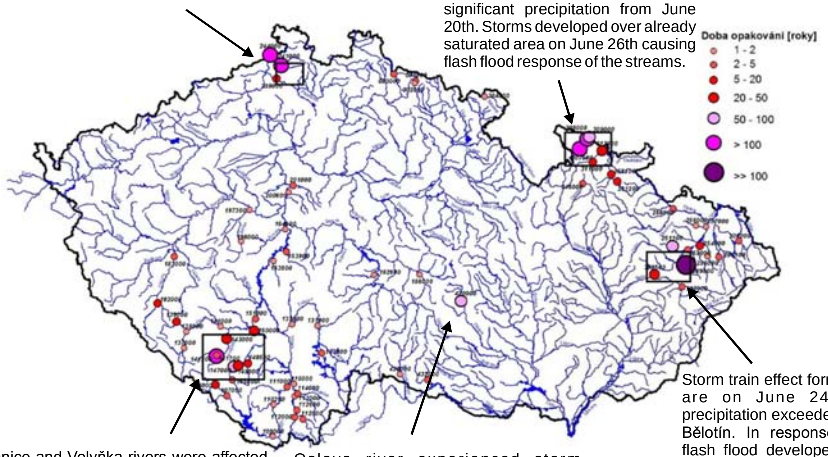
The flash flood evaluation included (among others) the application, verification and further development of methods for flash flood risk assessment and methods for potential damage estimation. To identify critical areas for surface runoff development the drainage areas above intravilan are selected according following criteria:

1) drainage area ≥ 0.3 km^2;
2) average slope ≥ 3.5%;
3) arable land portion ≥ 40% (not applied if drainage area ≥ 1 km^2 and average slope ≥ 5%);
4) critical criteria $F \geq 1.85$.

---

[1] Czech Hydrometeorological Institute, Prague, Czech Republic

[2] T.G. Masaryk Water Research Institute, public research institution, Brno Office



Kamenice and Bystrá rivers were affected by storms repeatedly on July 1st and 4th.

Vidnávka and Bělá rivers (and other streams in the area) recieved significant precipitation from June 20th. Storms developed over already saturated area on June 26th causing flash flood response of the streams.

Blanice and Volyňka rivers were affected by permanent precipitation from June 20th. Saturated basins were hit by storm precipitation on June 27th.

Oslava river experienced storm precipitation on July 2nd. The flash flood was successfully transformed by Mostiště reservoir situated just downstream from highly affected area.

Storm train effect formed over the are on June 24th. 3-hour precipitation exceeded 120 mm in Bělotín. In response disastrous flash flood developed on Luha and Jičínka rivers.
In addition close basin of Husí potok creek was affected by flood on July 2nd.

Figure 1: Overview of areas affected by flash floods in the Czech Republic in June-July 2009.

A synthetic criteria (*F*) was developed to assess the hazard of surface runoff development in small basins of size < 10 km^2. F index is based on basin characteristics (basin area, average slope, arable land area, CN value) and theoretical 100-year daily precipitation estimate (see equation).

Basin flash flood hazard (*F*) with respect to potential damage to urbanized areas is going to be used for preliminary flash flood risk evaluation (according to Floods Directive) in the Czech Republic. It should be also mentioned that the affected area of Luha and Jičínka river basins rank among the areas of highest *F* values in the Czech Republic as based on first computations (Figure 2).

$$F = P_{p,r} \cdot H_{m,r} \cdot (a_1 \cdot I_p + a_2 \cdot ORP + a_3 \cdot CNII)$$

F critical criterion, *a* weights vector [1,48876; 3,09204; 0,467171], $P_{p,r}$ relative area (to 10 km^2), I_p average slope [%], *ORP* arable land fraction [%], *CNII* CN value for normal saturation, $H_{m,r}$ relative value of theoretical 100-year daily precipitation (to max of. 285.7 mm).

3 Damage Estimation Methodology

The evaluation of potential flood damages is done for larger rivers based on inundation extent delimitation and special damage curves application. The method was applied in flash flood affected area. To do that, the field research of real damage and flood inundation extent there has to be done.

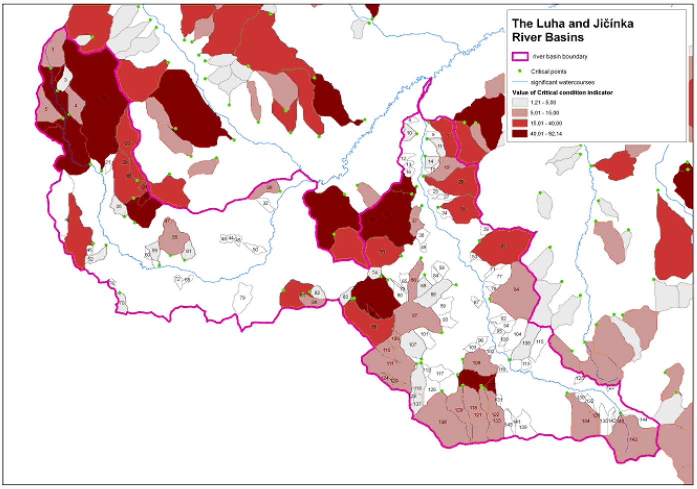


Figure 2: Concept of critical points was used. Critical points are situated at drainage paths of the area between 0.3 to 10 km^2 at its entrance to the polygon of intravilan (build up area). Detail map of Jičínka and Luha rivers basins shows identified critical points and evaluation of risk based on F criterion.

The method estimated 36.1 to 61.3 mil. EUR damage in Nový Jičín, while actual damage reached 64.4 mil. EUR. The underestimation was due to underestimated damage to transport infrastructure. In that case probably the dynamic power of flow increased the damage roads and bridges are often damaged or destroyed by flash floods, while static inundation of roads cause minimal damage.

4 Damage Estimation Methodology

The evaluation of potential flood damages is done for larger rivers based on inundation extent delimitation and special damage curves application. The method was applied in flash flood affected area. To do that, the field research of real damage and flood inundation extent there has to be done.
The method estimated 36.1 to 61.3 mil. EUR damage in Nový Jičín, while actual damage reached 64.4 mil. EUR. The underestimation was due to underestimated damage to transport infrastructure. In that case probably the dynamic power of flow increased the damage roads and bridges are often damaged or destroyed by flash floods, while static inundation of roads cause minimal damage.

Conclusions

Flash Floods in the CEE region are specific for its generally smaller spatial extent, but it could cause significant economic damage and lost of lives.

References

Ministry of the Environment, 2009: Evaluation of floods in June and July 2009 in the Czech Republic. http://voda.chmi.cz/ps09/index.html.

A. Néron[1], F. Martini[1] and O. Payrastre[2]

PRELIMINARY FLOOD RISK ASSESSMENT OF FLASH FLOOD AND PLUVIAL FLOODING IN FRANCE

Corresponding authors: Ms. Alice Néron and Dr. Frédérique Martini

Ministry of Ecology, Energy, Sustainable Development and Sea – General Directorate for Risk Prevention – Department of Natural and Hydraulic Risks, Meteorological Risks Unit

Arche Nord – 92055 Paris La Défense Cedex, France

Phone: +33 (0)1 40 81 88 53

E-mail: alice.neron@developpement-durable.gouv.fr;
frederique.martini@developpement-durable.gouv.fr

Corresponding author: Mr. Olivier Payrastre

Laboratoire Central des Ponts et Chaussées, Centre de Nantes

Route de Bouaye – BP 4129 44341 Bouguenais Cedex, France

Phone: + 33 (0)2 40 84 57 04

E-mail: olivier.payrastre@lcpc.fr

Abstract

France has decided to carry out a preliminary flood risk assessment (PFRA). This PFRA will be carried out on a large scale using available knowledge as a basis and will set methodological problems for flash flood and pluvial flooding. Care must be taken at this scale to understand very localised phenomena, knowledge of which is confused and incomplete, and for which historical flooding does not give an overall understanding of the country's vulnerability. The methodology proposed is based on the calculation of a global indicator of the risk of flash flood and pluvial flooding, which incorporates vulnerability and past events and that can thus supplement the knowledge about locations that have been seriously affected in the past.

1 Flash flood and pluvial flooding in France: serious impacts, in association with a few dramatic events and the repetition of more regular events

France has experienced flooding of very diverse origins, including pluvial flooding and flash flood, that had in the past a serious impact, both on

---

[1] Ministry of Ecology, Energy, Sustainable Development and Sea, General Directorate for Risk Prevention, Paris La Défense, France

[2] Laboratoire Central des Ponts et Chaussées, Bouguenais, France

human life and on property. In the recent past, the events at Nîmes in 1988 (10 deaths, 500 million Euros), Vaison-la-Romaine in 1992 (47 deaths, 250 million Euros) and in the Gard in 2002 (24 deaths, 1.2 billion Euros) are examples that are etched on the memory and have caused protection policy to be developed. Even without considering these catastrophic events, the risk of pluvial flooding and flash flood has a serious impact in France due to the regular occurrence of less serious events over the whole country.

2 The challenges posed by the preparation of PFRA

Pluvial flooding and flash flood have the particular feature of being small- to medium-scale phenomena, that can be encountered just about anywhere in the country, caused by differing factors. Contrary to fluvial flood, it is therefore difficult, both in terms of knowledge and of representation, to gain an overall vision of this risk on the scale of a hydrographic district (scale on which the PFRA is prepared).

As the whole of France is potentially affected, the PFRA must allow locations to be identified where this risk seems to be greatest. So, the knowledge of zones that are likely to be flooded, available for most large watercourses, is very confused and incomplete for small watercourses and valley lines affected by the risk of pluvial flooding or flash flood.

3 Work on the methodology to prepare the PFRA

3.1 Gathering of historical information on flooding

The events of the past and their impact comprise the first source of information on potential risks. France has decided to take advantage of the preparation of the PFRA to create a national database on historical flooding. This database will cover all types of flooding, including pluvial flooding and flash flood.

In order to supplement this information, since the implementation of the natural disaster system in 1982, France now has information on events declared as natural disasters (CatNat) and on the extent of certain losses. This information is essential, but did not seem to be sufficient for the preparation of the PFRA: past flooding provides information essentially on the locations where the heaviest storms have occurred and not on those locations that are most vulnerable to such phenomena. In order to supplement this knowledge, ways have been sought to find elements that characterise the vulnerability to pluvial flooding.

3.2 Search for elements representative of the hazards variables and the vulnerability associated with pluvial flooding and flash flood

The following data were examined:

1/ mapping of rainfall hazards records and of susceptibility to erosion

Maps of the quantiles of rainfall already cover the whole of France. This data shows certain homogeneity of the phenomena at a national level, apart from the Mediterranean region and the Cévennes, where the intensity of flooding is substantially higher. The susceptibility of the soil to erosion has also been mapped.

These various factors are indeed contrasted over the whole of France, but do not, alone, allow the consequences of the phenomena on the country to be estimated. It can be seen, in particular, that they fail to explain the distribution of known major events.

2/ zones of concentration of flooding

Our knowledge of the hydrographic system, required for the identification of zones liable to flooding, is incomplete and lacks homogeneity over the whole country.

In addition, maps of zones liable to flooding are only available for a small part of those watercourses potentially liable to flash flood. In order to increase our knowledge of the hydrographic system and of zones liable to flooding, CETE Méditerranée has developed the EXZECO method, which consists of pointing out zones of low altitude in relation to valley lines, on the basis of the processing of the DTM available for the whole of France.

This method has been used to create an artificial layer of "low zones", that can be considered to be the most likely to be flooded.

3/ vulnerability

For these very localised phenomena, the most simple indicator, and the one that incorporates the most impacts that can be calculated, is the ground area of buildings in a zone liable to flooding. The overlapping of the low zones and the ground area of buildings enables those communes to be identified that would seem to be the most sensitive, where a more detailed analysis should be carried out.

4 Methodology currently proposed to evaluate the potential negative consequences of future flooding

The principle is to cover the whole of France, but to stress only those locations that are potentially the worst affected, for which the first cycle of implementation of the Floods Directive will be carried out.

The selected method consists of:

1) calculating, on a homogeneous basis and at a national level, that can be refined to a local level, an indicator for each commune of the risk of pluvial flooding and of flash flood, for those national communes that exceed the respective thresholds of 4 CatNat records and 1,000 m² of built area affected:

   *(CatNat No. 3)*built area affected.*

2) examining in detail the case of communes brought to light by the indicator (threshold to be set according to the national flood risk management strategy), together with those communes known to have suffered significant flooding in the past.

Acknowledgements

The authors thank all the members of the "pluvial flood and flash flooding PFRA" workgroup: LCPC, CETE Méditerranée, LROP, CETE Normandie-Centre, SCHAPI, Météo France, Cemagref, INRA.

G. Braca[1], E. Esposito[2], G. Monacelli[1], S. Porfido[2], G. Tranfaglia[1] and C. Violante[2]

FLASH FLOOD EVENTS ON SALERNO COAST (SOUTHERN THYREHNIAN SEA)

Corresponding author: Dr. Giovanni Braca

ISPRA – Institute for Environmental Protection and Research, Department for Protection of Inland and Marine Waters

Via Curtatone 3 – 00185 Rome, Italy

E-mail: giovanni.braca@isprambiente.it

Abstract

The coast off the city of Salerno in south Italy on the Tyrrhenian sea is subject to frequent extreme rainfall events, confined in space and in time, that can trigger landslide, debris flows and flash flood phenomena. These latter events are affected by the peculiar geomorphology of the area characterized by high orographic gradient from the sea level and short and steep streams.

One of the major events occurred on October 25 and 26, 1954 and resulted in more than 300 casualties. Rainfall lasted about 12 hours with a total value of 504 millimetres and maximum intensity of 150 mm per hour. The area most affected included the Regina Major stream in the town of Maiori, Bonea torrent in Vietri sul Mare and the town of Salerno with several very small streams. This rainfall event, though of limited extension, was well recorded because the rain gauge network resolution at that time was quite adequate. But no stream gauge in the hit area was installed (not is one installed today). Peak discharge is estimated from post-event survey or by hydrological model.

Despite the well known seasonal recurrence of this kind of event in that area, that (mostly in autumn) are typical of the Mediterranean climate, and the very limited extension in space and time of the event (not allowing for recording), high resolution monitoring systems (like weather radar) are still not available and it is difficult to improve knowledge on this type of event and for flash flood hazard and risk assessment.

---

[1] ISPRA – Institute for Environmental Protection and Research, Rome, Italy

[2] IAMC-CNR – Institute for Coastal Marine Environment-National Research Council, Naples, Italy

M. Brugioni[1] *, B. Mazzanti*[1] *and S. Franceschini*[1]

HOW MEANINGFUL IS FLASH FLOOD RISK MAPPING?

Corresponding author: Dr. Bernardo Mazzanti
Arno River Basin Authority
Via dei Servi 15 – 50122 Florence, Italy
E-mail: b.mazzanti@adbarno.it

Abstract

Flood hazard and risk mapping is one of the most significant tasks of River Basin Authorities in Italy. In the production line of this analysis attention was always focused on the basin scale, that is, on the simulation of large scale flood events, in critical condition and duration of event calibrated for the primary river channel and the main tributaries. Nevertheless, flash flood events are constantly recorded with a relevant amount of damages and number of victims. The proposal of a similar approach of hazard and risk mapping for flash flood events is discussed, with a survey strategy based on Depth-Duration-Frequency available models, and a spatial distribution analysis of model parameters or assigned frequency values for short duration rainfall.

The results in term of hazard and subsequent risk classification are presented and discussed, evaluating both urban exposure and geomorphological vulnerability.

1 Introduction

Hydrologic and hydraulic modelling is being used to identify the areas with high hydraulic hazard and to evaluate the effects of structural and non-structural actions programmed by the Plan on hydraulic hazard on the basin. With the aim to apply a similar procedure to flash flood mapping, the approach is based on the following statement: spatial and temporal scale limit of flash floods are clearly defined, and the attention is focused on rainfall-driven events.

The flash flood definition used in this paper is based on a fixed rainfall intensity value and a threshold basin dimension of 500 km^2. We realize that such assumptions can oversimplify the complexity of phenomena. The aim of this research, however, is to explore and evaluate the possibility and the effectiveness of a consistent, wide applicable mapping procedure, dealing with a previous established set of flash flood characteristics or parameters. Some preliminary results are shown for the Arno river basin.

---

[1] Arno River Basin Authority, Florence, Italy

2 Data

Rainfall depth-duration-frequency (DDF) relationship is defined in a consistent and homogeneous manner all over the national territory (Calenda et al., 1994). The calibration of DDF curves has been based on extreme rainfall time series, typically on a normal duration varying from 1 hour up to 24 hours, providing therefore the parameter of the equation:

$$h = a \cdot t^{n} \cdot Tr^{m} \tag{1}$$

where *h* is the rainfall depth, in mm; *t* the rainfall duration, in hour; *Tr* the return period, in year. The *a*, *n*, *m* parameters reported for a dense network of rain gauges, allow the calculation of spatial distribution of equal return period curves with fixed rainfall intensity. For example, assuming 50 mm rainfall in 1 hour as a threshold value for the occurrence of flash flood phenomena, it is possible to map on a fixed grid the corresponding return period evaluation (Figure 1). This map shows the spatial distribution of short, heavy rainfall events – a sort of simplified hazard distribution for flash flood events.

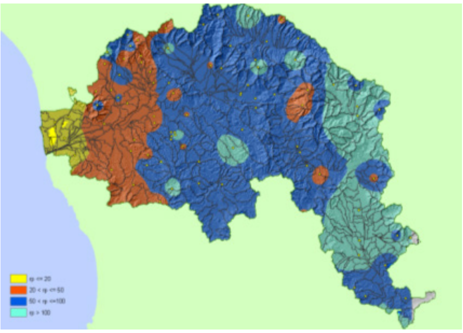


Figure 1: Heavy rainfall hazard map (return period for 50 mm h^{-1}).

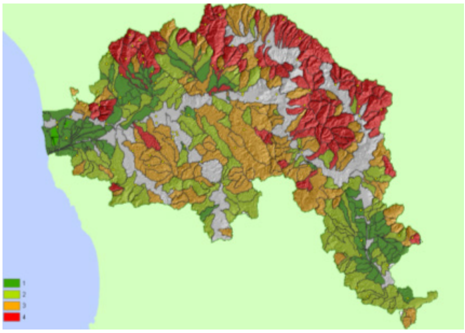


Figure 2: Classification of small size basin depending on “corrivation time” (1=longest – 4=shortest response time).

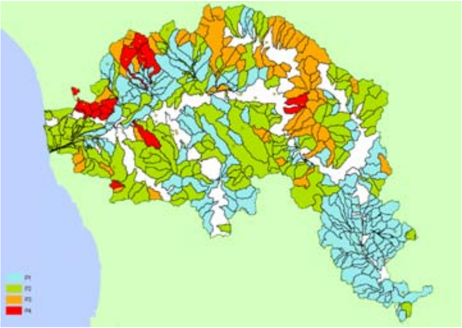


Figure 3: Map of flash flood hazard (1=lowest – 4=highest hazard).

Figure 4: Risk map example (portion across two different hazard classes).

3 Methodology

The rainfall-discharge transformation develops flash flood characteristics only if the recipient body (i.e., the river basin) shows some geomorphological characteristics that produce a single, very high peak discharge. Therefore, a basin threshold of 500 km^2 has been taken into account, and for each basin the susceptibility to a flash flood response is synthesized by the basin "corrivation time". This is given by the characteristic temporal scale of the hydrological response of the basin, and is here classified in 4 intervals (Figure 2), ranging between minutes and 6 hours.

It seems possible to derive the spatial distribution of a potential flash flood response, or the tendency of small scale basin to transform heavy, short precipitation events in very high discharge levels, by overlapping the above mentioned heavy rainfall map and spatial data on basin corrivation time. By clustering the return period distribution for assigned rainfall threshold in 4 classes, it is possible to classify the basins where the combination of rainfall hazard and short hydrological response time causes the most likely situation for flash floods to happen. It is interesting to point out that preliminary results for the Arno River (Figure 3) show a complex distribution over the basin, not necessarily following clear morphological or geographical patterns: for example, exposition, presence of mountain relief and distance from the coast.

The availability of a high resolution vector map of buildings and infrastructures or a low resolution land use map can help identify the risk areas, and can quantify the amount of potentially damaged goods (Figure 4).

Conclusions

Even if the simplified initial hypothesis of the procedure (use of DDF curves, fixed rainfall threshold, unique parameter for basin characterization) can oversimplify the phenomena, the suggested maps show some interesting characteristics, in order to identify a spatial differentiation of flash flood predisposition. Moreover, an attentive calibration of the procedure should be carried out, and should also take a large number of historical events of each basin with different geomorphological characteristics into consideration.

Technical-operative team and consultants[1]

DETAILED STUDY FOR THE ZONING OF THE HIGHEST HYDROGEOLOGICAL RISK AREAS IN MOUNTAIN BASINS

Corresponding author: Mr.Massimo Morea
Basin Authority of the Liri-Garigliano and Volturno Rivers
Viale Lincoln – 81100 Caserta, Italy
E-mail: m.morea@autoritadibacino.it

Abstract

This work shows the most significant results of a detailed study for the zoning of the highest hydrogeological risk areas of mountain basins in Volturno river basin. The study concerned a pilot area of some mountain basins of 35 territorial municipality in the Basin Authority of the Liri-Garigliano and Volturno rivers which are characterized by a complex morphology and by different types of hazards (*flowslides*, *debris flow*, *falls* and *hyperconcentrated flows*).

The methodology used is synthesized as follows. Lithotypes have been defined through the analysis of aerial photographies, studies of detail and inspections; models have been chosen after the geologic and geomorphologic classification for the analysis of the phases of initiation and propagation of the flowslides. For the initiation phase the models, on wide area selected, were the “grid-based” type as Shastab and Trigrs models; for the propagation phase, it has been used the Flo-2D model. The prior parameters calibration of the used models has been made through the analysis of a significant known phenomenon of landslide. An application of the methodology proposed will be shown for one of the studied mountain basins.

---

[1] Basin Authority of the Liri-Garigliano and Volturno Rivers, Caserta, Italy

C. Leeb[1] and M. Moser[2]

PLUVIAL FLOODS – CRITERIA FOR THE PRELIMINARY FLOOD RISK ASSESSMENT IN THE SOUTH OF GERMANY

Corresponding author: Mr. Christian Leeb

Bavarian State Ministry of the Environment and Public Health – Unit 55 – State owned Rivers and Lakes

Rosenkavalierplatz 2, 81925 München, Germany

E-mail: christian.leeb@stmug.bayern.de

Corresponding author: Mr. Markus Moser

Regierungspräsidium Stuttgart

Ruppmannstr. 21, 70565 Stuttgart, Germany

E-mail: markus.moser@rps.bwl.de

Abstract

The methodology described in the following is the result of a workshop held in Karlsruhe on the 12th April 2010. The workshop was attended by representatives of German and Swiss authorities, science, engineering and other institutions involved in the implementation of the European Floods Directive (FD).

In the south of Germany pluvial flood incidents are caused typically by local intense rainfall of convective cells.

The following part describes criteria for the assessment of pluvial floods, considering those having occurred in the past, and an estimation if such impacts have to be expected for similar events in the future. The conclusion is arrived that floodings of surface runoff, due to intense precipitation, are not significant in the sense of FD.

1 Introduction

The aim of the FD is the reduction of the adverse consequences for human health, the environment, cultural heritage and economic activity associated with floods. Therefore, all types of floods should be taken into consideration. Besides floodings along surface water bodies, there are also appearing those caused by surface runoff due to intense rainfall.

In the context of the preliminary flood risk assessment, according to

---

[1] Bavarian State Ministry of the Environment and Public Health, München, Germany

[2] Regierungspräsidium Stuttgart, Stuttgart, Germany

Articles 4 and 5 of the FD, available information on pluvial floods is analysed for mapping the areas with a significant flood risk by surface run-off where appropriate.

2 Surrounding conditions in the south of Germany

Flood incidents are natural appearances having different causes and characteristics, especially hydro-meteorological and geomorphologic ones. The south of Germany is located in temperate climate zone, having a moderate-warm rain climate. The oceanic influence provides mild winters and moderate hot summers. In the warm season, convective cells occur, which provide intense precipitation of large height. These convective precipitation cells are at small scale – in most cases less than a few square-kilometres. They can occur anywhere in the south of Germany, which makes it not possible to map areas with a significant flood risk.

For those torrential precipitation incidents in the south of Germany, which have caused appreciable impacts, where gauged precipitation heights of 240 mm within three hours or less. These values exceed far those mentioned in the statistical convective precipitation analysis (KOSTRA) of the German state weather service (DWD). For this reason, they have to be considered as an extreme incident with a very low occurrence probability.

The relief of the south of Germany is highly structured and shaped by the low mountain ranges, covered of woodlands in a high percentage. Only 5–8% of the territories are sealed. Water storage capacity in the area can be considered as high, according to the rank vegetation and the abundantly covered soil. Due to the highly structured relief and the widely ramified water distribution network the drainage capability can be regarded as convenient. During torrential rainfall, the surface runoff can easily reach the next water body within a short range. Therewith the sub-basins to survey in the context of surface runoff are comparatively small. This also means that accumulations of surface runoff have only little adverse impact.

3 Summary of previous incidents

Within the research project “Forecasting and management of pluvial floods in urban areas (URBAS)” previous pluvial flood incidents in Germany have been analysed. The database of URBAS contains 422 incidents within a period of rather 30 years. The given sums for the adverse impacts base on uncertain estimations, mixing different kinds of damages.

Mainly, there are documented singular incidents with relatively high damage sums, with an average of 160 million € per year in Germany. Almost all damages of such torrential rainfall are located in very small areas. Often only a district of a municipality is affected. Pluvial floods are hydrological reactions of areas due to convective precipitation with short durations and large precipitation heights respectively intensities.

According to the widely ramified water distribution network and the relatively small sub basins, precipitation incidents of middle (return period 100 years) or high (return period 10 years) occurrence probability do not cause noteworthy damages. Only extreme incidents cause higher damages.

4 Assessment of future flood incidents in Baden-Württemberg

In addition to Bavaria and Rhineland-Palatinate, where only previous incidents of pluvial were surveyed, Baden-Württemberg has done a further analysis for the assessment of future incidents. The model is based available data for soil, geology, topography and soil-sealing. It displays surface runoff and infiltration by using physical equations.

The essential results of this analysis are:

- In slope areas the water depths of surface runoff are less than 5 cm.
- The duration of surface runoff is very short.
- Floodings with depths more than 50 cm appear only in the flood plains in the bottom of the valley; due to fluvial floods.
- Asserted damages in slope areas are mostly related to soil erosion or alluvial sedimentation.

5 Assessment of the potential significant flood risk

As described above, intense rainfall appears at small scale and does only activate appreciable surface runoff at incidents with a return period considerable over 100 years. Such events can occur anywhere in the south of Germany, so that areas with a significant higher risk cannot be identified. Previous incidents have shown that adverse impacts to the FD subjects of protection occur only in a local scale.

In Germany, the assessment of the significance of flood risks is also linked to the public interest in flood protection infrastructure. Measures of public interest are required, where human lives or health are affected in a larger number or economic activities are impacted in a regional scale. Flood protection against pluvial floods can easily be realised by individuals.

For this reasons, in our point of view, for floodings of surface runoff a potential significant flood risk does not exist nor could it be considered likely to occur.

Acknowledgements

The authors thank Mrs. Merz (Bavarian Environment Agency), Mr. Hennegriff (LUBW, Baden-Württemberg) and Mr. Schernikau (Ministry for the environment, forestry and consumer protection Rhineland-Palatinate) for their support.

References

Deutscher Wetterdienst [Hrsg.]: KOSTRA-DWD-2000 Starkniederschlagshöhen für Deutschland (1951-2000), Offenbach, 2005.

Bundesministerium für Bildung und Forschung [Hrsg.]: Vorhersage und Management von Sturzfluten in urbanen Gebieten (URBAS), Aachen, 2008.

University of Padova et. al. [Hrsg.]: Hydrometeorological Data Resources and Technologies for Effective Flash Flood Forecasting (HYDRATE Project): Post Flood Event Analysis, Report on the Starzel River Flash Flood, 2008.

Weiler, M., and Steinbrich, A.: „Integrative Ausweisung von Abflussbildungsprozessen zur räumlichen und zeitlichen Bewirtschaftung von Wassermenge und Wassergüte“ Institut für Hydrologie, Universität Freiburg, Vortrag zum „Tag der Hydrologie 2010“ am 25./26. März 2010 in Braunschweig.

Q. A. Cossu[1], A. Bodini[2] and M. L. V. Martina[3]

VULNERABILITY ASSESSMENT OF SARDINIA (ITALY) TO EXTREME RAINFALL EVENTS

Corresponding author: Mr. Quirico Antonio Cossu
Sardinian Environmental Protection Agency
Via Rockfeller 58-60 - 07100 Sassari, Italy
E-mail: qacossu@arpa.sardegna.it

Abstract

During the last ten years, at least 5 flash floods caused several deaths, the destruction of houses, land and properties in Sardinia. Despite a clear evidence for the vulnerability of Sardinia to severe rainfall events, at the official level the lack of complete and extended data about damaging hydro-geologic events yields misinformation about the true extent of hydro-geological risk. To make up for this lack of information, authors study the role of meteorological and climatic conditions in the occurrence of damaging hydro-geologic events in Sardinia.

1 Introduction

Violent storms are characteristic of Mediterranean climate areas, leading to flash floods that often represent important natural hazards. In Sardinia, flash floods have occurred frequently in the last 5 years hitting the Central-East and South-West areas mainly. Here, intense rainfall is usually caused by warm and moist air flows coming from North Africa and meeting the steep mountains near the sea. Statistical analysis of daily rainfall data has been performed to estimate return levels of main rainfall events and to check for trends in extreme events. A few recent flash floods have been analysed in detail (Cossu et al., 2007, De Waele et al., *in press*): the analysis of one of them is briefly presented here.

2 Methodology

Heavy rainfall has been modelled by fitting a Generalized Extreme Values distribution to annual maxima (period from 1951-2000, 144 pluviometric stations). Trend analysis has been carried out on several indices of extreme event (see Bodini & Cossu, 2010 and therein references).

Peak discharge has been estimated by empirical formulae (Manning, Jarret and Costa equations). The distributed physically based hydrological

---

[1] Sardinian Environmental Protection Agency, Sassari, Italy
[2] Inst. of Applied Mathematics and Information Technology, Milano, Italy
[3] Department of Earth Sciences, University of Bologna, Bologna, Italy

model TOPKAPI (Ciarapica & Todini, 2002) has been used to compute what it would have been the river flow of December 2004 without karst losses in the river, but only considering the distributed hydrological processes on the hillslopes (such as infiltration, percolation, subsurface flow, etc.).

3 Climatic analysis

Only a few stations show decreasing annual precipitation. None of the considered indices show clear trend. Only in the case of the maximum 5-day precipitation total (R5D), the analysis suggests a decreasing trend, which is limited to the central-eastern area.

However, the area most affected by extreme events, is only marginally interested by this result, as shown in Figure 1.

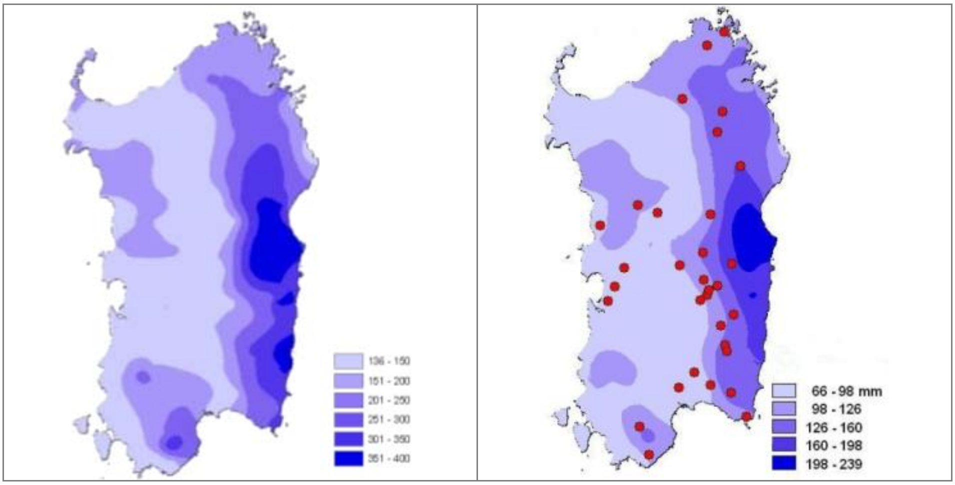


Figure 1: Spatial variability of 50 year-return level (left) and R5D, red dots indicate stations showing a significant negative trend (right).

4 Flash flood case study

In Figure 2 the results of the analysis of the flash flood occurred in December 2004 at the Flumineddu river are summarized, in terms of the computed river peak flow and the estimated karst losses or gains in some river reaches.

An extremely high runoff event of ~10 $m^3/s/km^2$ together with a very complex karst dynamic, with water losses of ~200 $m^3/s/km$ and water gains of > 300 $m^3/s/km$ along the river, indicate the exceptionality of the triggering rainfall event (~70 year return time).

These results are confirmed by the presence of the main known caves, as shown in Figure 3 where they are overlapped on the conceptual representation of the water balance in the river reaches.

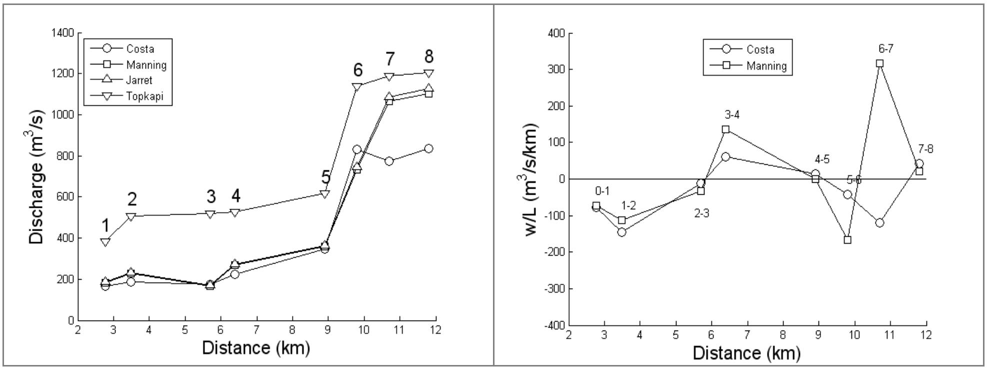


Figure 2: River peak flow at different transects estimate by the empirical formulae and by the hydrological model TOPKAPI (left); karst losses/gains estimated by comparison along the river reaches (right).

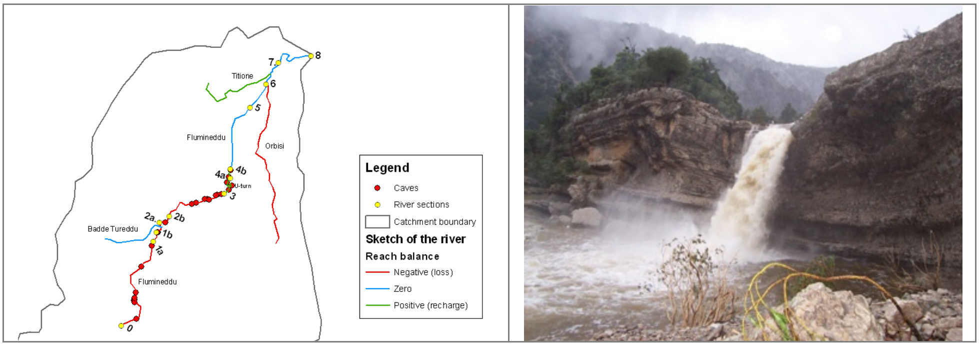


Figure 3: Conceptual scheme of the water balance in the river reaches as estimated by the model and location of the main known caves (left) and waterfall during flood at the confluence of Orbisi torrent and Flumineddu river (right).

Conclusions

To assess the vulnerability of Sardinia to hydro-geological events, a deep analysis of the effects of past events in terms of types of triggered phenomena, meteorological conditions, and economical and environmental damage has been undertaken (PROTERINA C project). Sardinia to the occurrence of heavy rainfall can also depend on land use, these information will be compared to a few informative layers like forested areas, land abandonment, roads and urban development.

References

Bodini, A., and Cossu, Q. A.: Observed trends in heavy rainfall during the 2nd half of the 20th Century in an area of Sardinia (Italy) at high hydro-geological risk. *Nat. Hazards Earth Syst. Sci., Special Issue: Advances in Mediterranean Meteorology*, 10, 61–72, 2010.

Ciarapica, L., and Todini, E.: TOPKAPI: a model for the representation of the rainfallrunoff process at different scales. *Hydrological Processes*, 16, 207–229, 2002.

Cossu, Q. A., De Waele, J., and Di Gregorio, F.: Coastal karst geomorphosites at risk? A case study: the floods of 6–9 December 2004 in central-east Sardinia. From: Parise, M. and Gunn, J. (Eds.). *Natural and Anthropogenic Hazards in Karst Areas: Recognition, Analysis and Mitigation*. Geological Society, London, Special Publications, 279, 85–95, 2007.

De Waele, J., Martina, M. L. V., Sanna, L., Cabras, S., and Cossu, Q. A.: Flash flood hydrology in karstic terrain: Flumineddu Canyon, central-east Sardinia. *Geomorphology*, 120, 162–173, 2010. doi:10.1016/j.geomorph.2010.03.021.

M. Casaioli[1], S. Mariani[1], B. Lastoria[1], M. Bussettini[1] and G. Monacelli[1]

NUMERICAL HYDRO-METEO-MARINE MODELLING AT ISPRA IN THE CONTEXT OF THE FLASH-FLOOD EVENT MONITORING, FORECASTING AND STATISTICAL ANALYSIS ACTIVITIES

Corresponding author: Mr. Marco Casaioli

ISPRA, – Institute for Environmental Protection and Research, Department for Protection of Inland and Marine Waters

Via Curtatone 3 – 00185 Rome, Italy

E-mail: marco.casaioli@isprambiente.it

1 *Introduction*

Mediterranean weather is characterized by a complex phenomenology which involves the interaction of synoptic-scale patterns with local forcing, including orography, moist processes, and sea/land distribution. A correct prediction of all these interconnected phenomena is then essential to face operationally, at different time and space scales, a wide class of natural hazards and hydrological cycle extremes. These motivations drove the development of an integrated numerical model chain, named *Sistema Idro-Meteo-Mare* (SIMM – Hydro-Meteo-Marine forecasting; Figure 1), which provides, since 2000, integrated hydro-meteorological and sea-state forecasts over the entire Mediterranean area, bridging from planetary to local scales of atmospheric motion (Speranza et al., 2004; 2007).

The SIMM operational products are a key element for the activities of the ISPRA's Department for Protection of Inland and Marine Waters, including intense and damaging events monitoring and study, development of statistical methodologies suitable for flood risk management tasks, water resources assessment, etc. Such products and activities are briefly described in the following sections.

2 *The SIMM chain*

The SIMM system consists of a cascade of meteorological (the hydrostatic BOlogna Limited Area Model; BOLAM), wave propagation (the spectral Wave Model; WAM), and sea elevation (a 2-D version of the Princeton Ocean Model and a finite-element model on the Venice lagoon; POM and VL-FEM) models operational over the whole Mediterranean area (Figure 2) with a horizontal grid spacing about 10 km and telescoping to the Venice Lagoon (since forecasting the *acqua alta* phenomenon is, among the

---

[1] ISPRA – Institute for Environmental Protection and Research, Rome, Italy

others, one of the main tasks of SIMM). The physically based, fully distributed, rainfall-runoff model (TOPKAPI) model is also integrated, in a research configuration, into the system over the Reno (Central-eastern Italy) and Adige (North-eastern Italy) river basins.

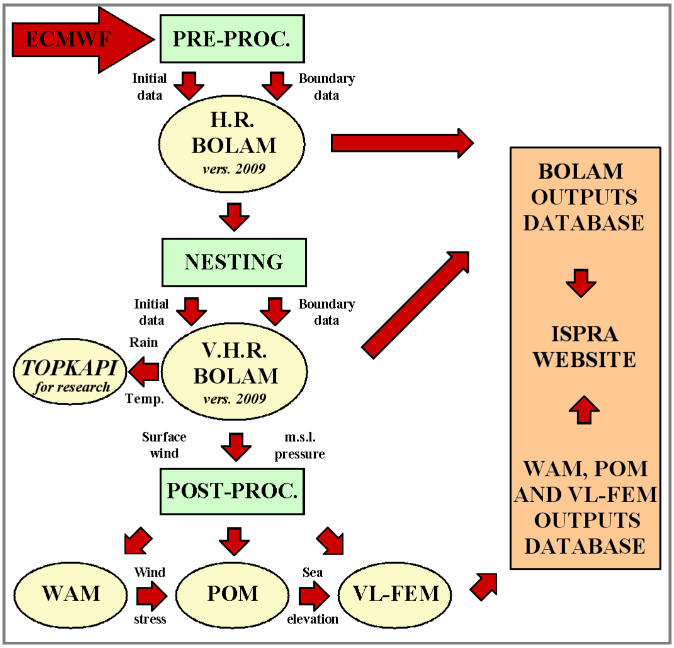


Figure 1: SIMM model sequence and operational chain. Initial and boundary conditions for a 60-h 0.3° BOLAM (H.R.) forecast are derived from ECMWF analysis and forecast issued at 1200 UTC on the previous day. The 0.1° BOLAM (V.H.R.) is then forced with the H.R. boundary data, neglecting the first 12 h, and producing a 48 h forecast starting at 0000 UTC. The 0.1° grid size 10-m wind field and mean sea level pressure are then used to force WAM, POM and VL-FEM.

The SIMM products have been mostly designed for local forecasting agencies for civil protection, water resources and land management purposes, but they have also been used for research and study purposes.

Plots of the meteorological and marine forecast fields (every 3h, from +12h to +60h) over the Mediterranean basin are daily available online on the ISPRA website (http://www.isprambiente.gov.it/pre_meteo/ and http://www.isprambiente.gov.it/pre_mare/, in Italian).

Recently, the system is undergoing a major upgrade, which includes the implementation of a parallel version of the latest-version of the BOLAM code (operational since October 2009, and regularly updated), the increasing of the spatial resolution (up to 7/8 km – ongoing), the extension of the BOLAM domain and of the models' forecast time (ongoing) and the inclusion of a coastal forecasting system in cascade to the WAM model (testing phase over selected areas).

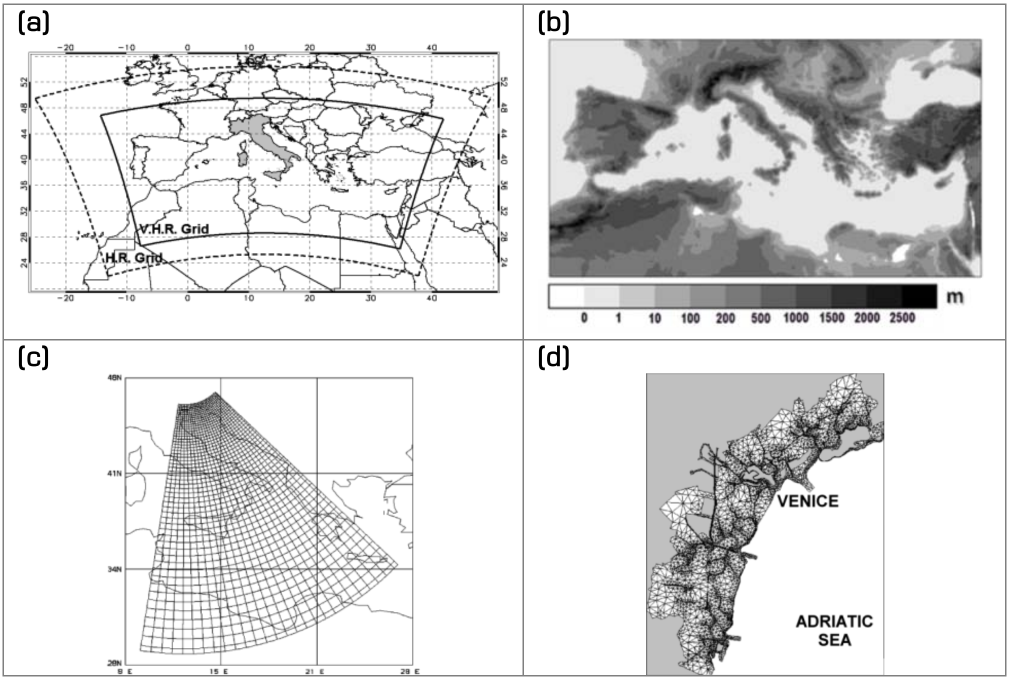


Figure 2: (a) BOLAM domains for the 0.3° H.R. BOLAM ("father" – dashed line) and the 0.1° V.H.R. BOLAM ("son" – solid line); (b) Topography (in m) for the V.H.R. BOLAM; (c) POM grid; (d) VL-FEM grid.

3 Research activities

Monitoring, forecasting and statistical analyses performed at ISPRA have been often developed in the framework of international and EU-funded projects concerning operational hydro-meteorology tasks and, in particular, the flash flood issue.

These projects have been focussed on either monitoring and modelling events in specific problematic areas, such as the Alpine region, as done in FORALPS (INTERREG IIIB Alpine Space) and in MAP D-PHASE (WMO WWRP), developing flood forecasting in itself (INTERREG IIC Floods, HYDROPTIMET–INTERREG IIIB MEDOCC), improving rainfall observational analyses and forecast verification methodologies (VOLTAIRE–FP5), reconstructing the hydrological cycle as performed in HYDROCARE (INTERREG IIIB MEDOCC), assessing new tools on flood early warning (the JRC European Flood Alert System – EFAS) or monitoring, co-ordinating and funding flood-related research projects at European level in the framework of CRUE ERA-Net (FP6). In particular, within the latter project two Research Funding Initiatives have been launched to support the implementation of the EU Floods Directive, which requires a broad basis of knowledge and tools and the development of improved management and governance strategies and to establish trans-national collaborative research projects. The first initiative, concluded in September 2008, was on "*Risk Assessment and Risk Management*", whereas the second one, which will be concluded in 2011, is on “*Flood Resilient Communities – managing the consequences of flooding*”.

One major activity related to numerical modelling has been the assessment of the performance of the SIMM products in both an operational and research context using state-to-the-art methodologies.

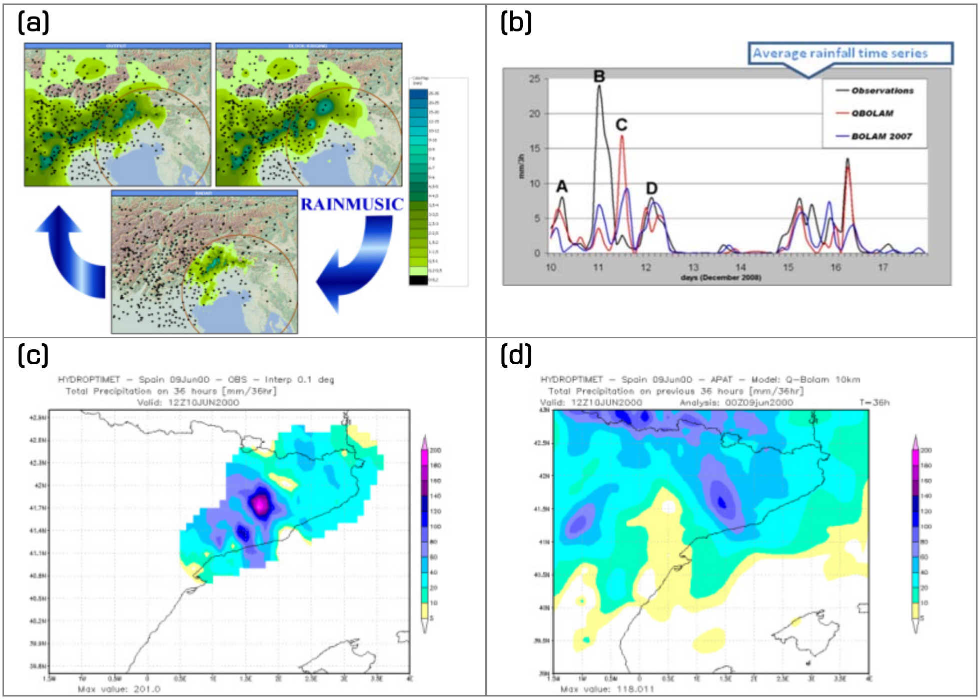


Figure 3: Example of the monitoring, forecasting and statistical analysis activities: (a) rain gauge-radar combination (through a Bayesian-based method named RainMusic), for the 24 November 2007 flood event (north-eastern Italy); (b) time series comparison during the Rome December 2008 flood event (Tiber valley, central Italy; Casaioli et al., 2010); (c) 36-h accumulated precipitation observed during the “Montserrat-2000” flash flood event on 9–10 June 2000; (d) 36-h accumulated BOLAM forecast for the “Montserrat-2000” event (Mariani et al., 2005).

Meteorological forecasting, as a key issue in flood risk management, should be indeed supported by a **thorough verification process**, based on a reliable observational analysis (see Figure 3). In this frame, the ISPRA research activities focus on:

- representativeness of the rainfall predicted and observed fields: how to “optimal interpolate” available data from different sources (rain gauges, weather radars, satellite instruments); comparing and contrasting space-time scales present in forecasts and observation analyses, etc.;
- statistical analysis of flood events (long-term/case-study approach);

- forecast verification (using subjective, object-oriented, multi-scale techniques, etc.) and intercomparison studies;
- combining verification results from different techniques ("multi-method" approach) to identify, characterize and quantify forecast errors and to categorize their sources.

Conclusion

An overview of the ISPRA activities related to the SIMM forecasting products as shown at the Cagliari Workshop is reported here. By presenting these activities, authors aim also to stress how an efficient experience exchange by means of international and European co-operation initiatives with hydro-meteorological services and research institutions provides unique opportunity to face up to common – or analogous – tasks and problems in the flood risk management frame.

References

Casaioli, M., Lastoria, B., Mariani, S., and Bussettini, M.: Evaluating the improvements of the BOLAM model of the ISPRA Sistema Idro-Meteo-Mare on the December 2008 flood event in Rome. *Adv. Geosci.*, 25, 135–141, 2010. doi:10.5194/adgeo-25-135-2010.

Mariani, S., Casaioli, M., Accadia, C., Llasat, M. C., Pasi, F., Davolio, S., Elementi, M., Ficca, G., and Romero, R.: A limited area model intercomparison on the "Montserrat-2000" flash-flood event using statistical and deterministic methods. *Nat. Hazards Earth Syst. Sci.*, 5, 565–581, 2005.

Speranza, A., Accadia, C., Casaioli, M., Mariani, S., Monacelli, G., Inghilesi, R., Tartaglione, N., Ruti, P. M., Carillo, A., Bargagli, A., Pisacane, G., Valentinotti, F., and Lavagnini, A.: POSEIDON: An integrated system for analysis and forecast of hydrological, meteorological and surface marine fields in the Mediterranean area. *Nuovo Cimento*, 27C, 329–345, 2004.

Speranza, A., Accadia, C., Mariani, S., Casaioli, M., Tartaglione, N., Monacelli, G., Ruti, P. M., and Lavagnini, A.: SIMM: An integrated forecasting system for the Mediterranean Area. *Meteorol. Appl.*, 14, 337–350, 2007.

F. Ponziani[1], M. Stelluti[1], N. Berni[1], A. Viterbo[1], C. Pandolfo[1] and L. Brocca[2]

THE REAL TIME USE OF SOIL MOISTURE SENSORS TO IMPROVE THE ACCURACY OF FLOOD FORECASTING MODELS AND FOR THE DETECTION OF THE LANDSLIDES TRIGGER IN UMBRIAN CATCHMENTS IN THE TERRITORY OF COMPETENCE OF THE TIBER RIVER BASIN AUTHORITY

Corresponding author: Mr. Francesco Ponziani

Umbria Region Functional Centre

Via Romana Vecchia – 06034 Foligno (PG), Italy

E-mail: centrofunzionale@regione.umbria.it

---

1 Introduction

The soil moisture in the vadose zone represents a key factor in the modelling of the hydrologic cycle and is significant both for the forecast of floods and shallow landslide triggering. The knowledge of this quantity is essential to determine the catchment response in terms of runoff and erosion; moreover, acting on the pore water pressure, soil moisture modulates the strength-stress ratio in soils and so is a precondition for the triggering of landslides maybe as important as thresholds based on accumulated rain values as shown from recent works performed by Umbria Region Functional Centre (CFD).

Compared to other European countries, Italy is one of the most flood risk prone areas and, more in particular the Umbria Region, located in central Italy, is almost yearly affected by landslide and flood events at different spatial and temporal scales. Umbria Region covers almost the Upper Medium Tiber River catchment.

Currently, the estimation of soil moisture can be addressed by field (or in-situ) measurements, remote sensing techniques and soil water balance simulation models.

During the last 30 years, in situ observations of soil moisture are becoming more and more available. The most important advantages of these techniques are: high temporal resolution, rapidity of acquisition and repeatability (precision) of measurements. Moreover, in many cases, a specific calibration is not required. On the other hand, measurements

---

[1] Umbria Region Functional Centre, Foligno (PG), Italy

[2] Research Institute for Geo-Hydrological Protection, National Research Council, Perugia, Italy

provide information about a small volume of soil and the monitoring of large areas could be quite expensive, when at least not possible.

Being potentially a powerful technique for mapping soil moisture over large areas, a growing interest has also been addressed by remote sensing retrievals from space. The two most attractive features of remote sensing are: the good cost-effectiveness ratio and the ability to provide regular and reliable large area measurements avoiding errors induced by sensor-to-sensor variability. However, the interpretation of remotely sensed signals is not straightforward. In addition, issues on the low and poorly defined investigation soil depth and, for some applications, on the inadequate space and time resolution make the use of remote sensing sensors still difficult.

Many water (and energy) balance models are available for calculating soil moisture, also for the whole soil profile. In this case, drawbacks can be identified in the parameterization and structure, as well as in the data requirement.

The integration of these three techniques can provide reliable estimates of soil moisture at the temporal and spatial resolution required for operational activities related to floods and shallow landslides.

On these bases, for this study, the CFD, in cooperation with the Institute for Geo-Hydrological Protection of the National Research Council (IRPI-CNR), developed and tested a continuous real time physically based soil water balance model (now in a test phase), for estimate soil moisture condition over Umbria Region. In-situ observed soil moisture data were used for the development of the structure of the model and also for its parameterization. Moreover, since the rainfall thresholds used at the CFD to evaluate the criticity level for hydrogeological risk depend on the soil saturation conditions, the output of the soil water balance model is also used to analyze the influence of soil moisture on landslide triggering.

2 Results

The soil water balance model was tested with experimental measurements made in a multi-year period (half hour time step) in two experimental areas of Central Italy (Brocca et al., 2008), achieving satisfactory results (Figure 1) during calibration and verification. In particular, the model has proven reliable in the estimation of the time evolution of soil moisture, even if calibrated with a limited number of observations. This ensures the robustness and exportability of the model across different areas.

The analysis of several landslide events (extracted from the data set of “Aree Vulnerate Italiane” AVI) occurred in the Umbria region for the period 1990-2005 demonstrated the strong influence of the soil moisture content on the triggering of landslides (Ponziani et al, 2009). For instance, Figure 2 shows that the accumulated rainfall needed to trigger a landslide decrease with increasing soil moisture.

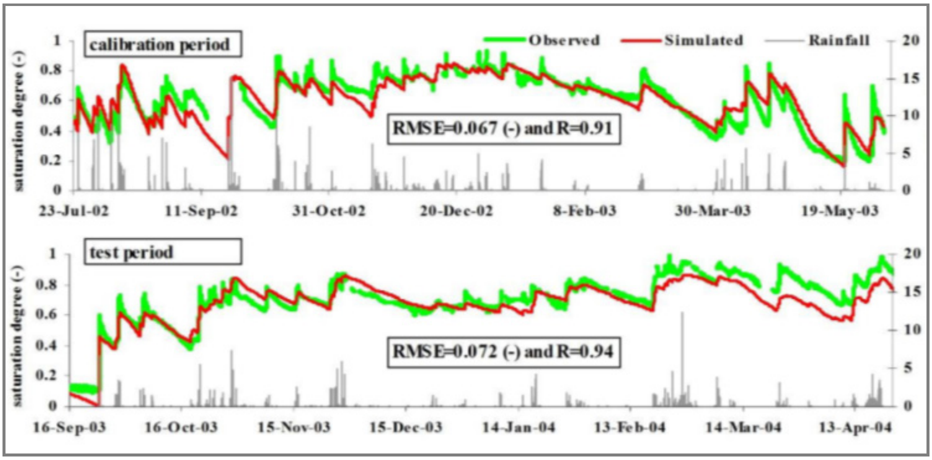


Figure 1: Comparison between the observed and simulated saturation degree by the Soil Water Balance model for a 15 cm depth.

At the same time, high risk landslides are now monitored using a pre-alert system based on observed and predicted rainfall along with real time soil moisture data extracted from the soil water balance model. Based on rainfall and soil moisture conditions, the system furnishes a specific threshold useful for civil protection actions.

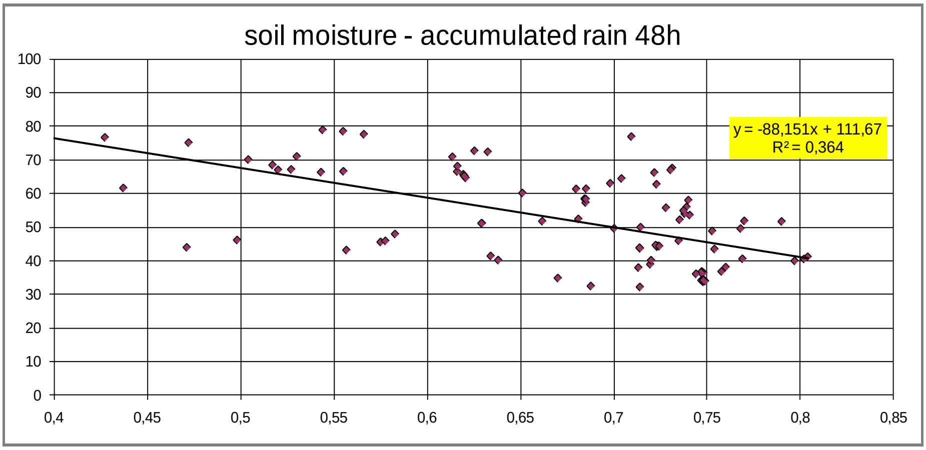


Figure 2: Relative soil moisture conditions vs. max accumulated rain values on landslides sites.

Conclusions

Based on these preliminary results, the CFD is testing a procedure aimed to the evaluation of the soil moisture content at regional and local scale, and the emission of pre-alert advices in case of intense meteorological event observed or predicted.

The real time soil moisture data, even though referred to few points, can furnish a reliable estimation of the average conditions of the water content at the catchment scale, allowing to improve the reliability, robustness and performances of the soil water balance model as well as of the rainfall thresholds.

References

Ponziani, F., Pandolfo, C., Stelluti, M., Berni, N., and Brocca, L.: "Test and calibration of rainfall thresholds for use in a regional civil defense emergency management system". European Geosciences Union – General Assembly 2009 Vienna, Austria, 19–24 April 2009.

Brocca, L., Melone, F., and Moramarco, T.: On the estimation of antecedent wetness condition in rainfall-runoff modeling. *Hydrological Processes*, 22, 629–642, 2008.

R. Hornich[1]

PROGRAM GRAZ STREAMS: FLOOD MANAGEMENT IN URBAN AREAS

Corresponding author: Mr. Rudolf Hornich

Office of the Styrian Government, Department 19 B – Flood Water Management

Stempfergasse 7 – 8010 Graz, Austria

E-mail: rudolf.hornich@stmk.gv.at

Abstract

The Graz urban area counts more than 50 streams. Along the lower course, flood catchment areas are disappearing while discharge cross sections are falling rather than rising. Tubing and covers as well as canalisation out of the depth contour compound the situation by utterly separating run off from the stream bed and leaving water masses to flow off uncontrolled through the urban area.

Calculations revealed that there are about 1000 flood-endangered objects in Graz. The flooding of many streams in 2005 and 2009 caused by flush flood reached such a scale that a state of civil emergency had to be for the Graz urban area.

A study carried out yielded a strategic paper called "Graz Streams Program". The objective: "To achieve sustainable flood protection of endangered objects in the City of Graz".

And yet, notwithstanding the widest possible exploitation of local possibilities and extensive acquisition of land, it will not be possible to guarantee HQ_{100} protection for all settlement areas at risk. As compared to the present state, though, clear improvements will be made everywhere. For those segments where technical defence is not going to suffice to grant adequate flood protection, integrative measures are to be adopted directly at the objects' sites and further detailed alert and intervention plans are to be worked out for civil defence forces.

The total cost of this ten-year programme has been estimated at € 65.0 million. Parallel to the first implementation schemes, preliminary work has begun for the drawing up of individual stream management plans, flood prediction models, analyses of residual risk as well as alert and intervention plans. Particular attention is being devoted to public relations. Citizens are to be shown how each and every one who is affected by the problem can contribute to enhance public protection measures through their own initiatives.

---

[1] Office of the Styrian Government, Graz, Austria

B. C. Braskerud[1]

DETENTION OF HEAVY RAIN ON AN EXTENSIVE NORWEGIAN SEDUM ROOF

Corresponding author: Dr. Bent C. Braskerud
NVE– Norwegian Water Resources and Energy Directorate
P.O.Box 5091, Majorstua – 0301 Oslo, Norway
E-mail: bcb@nve.no

Abstract

Roofs with vegetation cover are used as a measure to hinder precipitation becoming pluvial urban floods. This paper shows how a shallow soil (3 cm) green roof functioned under a wet month in July. The runoff intensity under a rare, heavy precipitation episode (29 mm in 30 min.) was decreased by at least 26% when the roof was initially dry. However, even on a wet green roof the runoff intensities are decreased.

1 Introduction

Using green vegetative roofs and other SUDS are possible ways of meeting the requirements from the floods directive tackling pluvial floods in urban areas. Green roofs are becoming popular in European countries and retention of more than 50% of the annual precipitation is not unusual (Berndtsson, 2010). This paper presents results from the first summer of a green roof experiment in Oslo. Results include an intensive precipitation episode, which has the return interval in Oslo of approximately 40 years. The question often raised is: How will extensive (shallow), green roofs perform during intensive precipitation?

2 Methodology

A 25 year old garage roof in Oslo was divided into 3 equal parts, each 8 m^2 (see photo in Figure 1). An extensive sedum roof, with soil depth 3 cm, was installed on part 1 and 3, while part 2 was the reference. The green roof was a product from Veg Tech (http://www.vegtech.se/). Only roof no. 1 (Veg Tech System XMS 0-4) and the reference (no vegetation) are compared in this paper. The roof slope was 3.2 degrees.

Runoff water from the roof was sampled in insulated 250 l barrels, and monitored in 5 min. intervals. Pumps emptied the barrels automatically when full. A Lambrecht precipitation sensor (1518 H3) monitored the rainfall.

---

[1] NVE – Norwegian Water Resources and Energy Directorate, Oslo, Norway

Figure 1: The left hand side sedum roof and the reference were compared.

3 Results and discussion

Intensive precipitation on the 3rd of July (29 mm in 30 min), after a week of warm weather and drought, gave a reduction in peak runoff of 26% from the green roof compared with the reference (Figure 2). The first 9 mm was absorbed into the green roof. The green roof peak was delayed a few minutes and the runoff was distributed over longer time than the black roof.

The peak retention may have been larger than observed in Figure 2. Some water may have splashed from the reference roof onto the green roof due to the precipitation intensity as indicated by the precipitation gauge. The difference between the first precipitation gauge peak and the green roof peak is 40%. After the first 9 mm the green roof is wet, but it still gives a small reduction of the peak runoff.

The rest of July was wet; total precipitation was 200 mm. For the whole month the runoff from the green roof was 25% less than the reference roof. Wet green roofs also influence the runoff intensities. In late July the runoff peak after 14 mm rainwater (in 2 hours) was decreased by 51 and 36% (Figure 3).

Conclusions

The future climate change projections for Norway indicate a warmer climate and more incidents with heavy rain. This could mean a situation like in Figure 2; a dry roof receiving loads of water within a short time period. Green roofs are a possible measure to reduce the inundation after heavy rain over urban areas. Using green roofs and other SUDS are possible ways of meeting the requirements from the floods directive in urban areas.

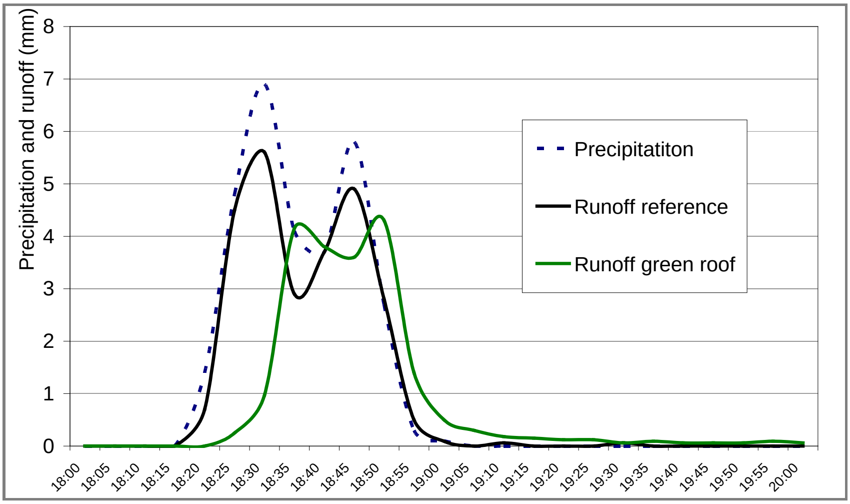


Figure 2: Precipitation (29 mm) and runoff from a roof with no vegetation (reference) and sedum vegetation, after one week of drought.

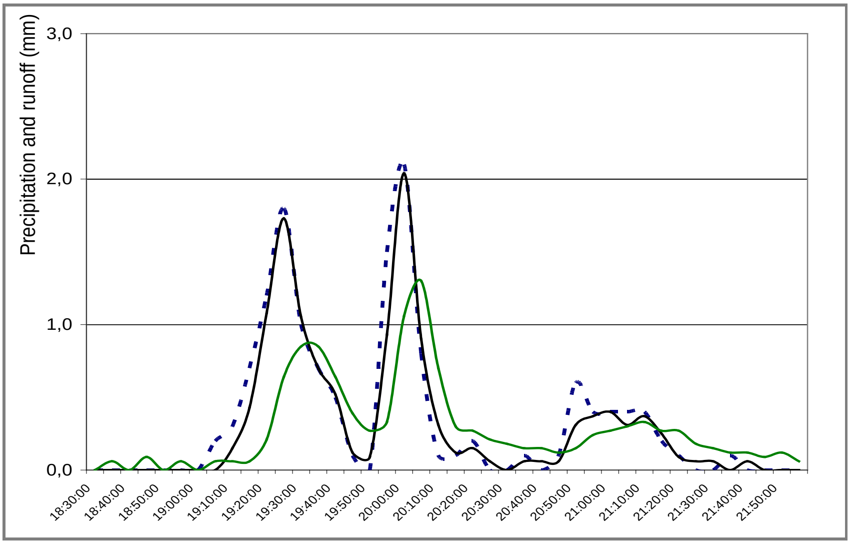


Figure 3: Precipitation on a wet green roof also reduces the peak runoff. Note that precipitation equals the runoff from the reference roof.

Acknowledgements

I would like to thank the INTERREG 4B project SAWA and NVE for financial support of the experiment.

References

Berndtsson, J. C.: Green roof performance towards management of runoff water quantity and quality: A review. *Ecological Engineering*, 36, 351–360, 2010.

B. Lastoria[1], M. Casaioli[1], S. Mariani[1] and M. Bussettini[1]

HYDROLOGICAL EXTREMES OR SENSATIONALISM?

Corresponding author: Ms. Barbara Lastoria

ISPRA – Institute for Environmental Protection and Research, Department for Protection of Inland and Marine Waters

Via Curtatone 3 – 00185 Rome, Italy

E-mail: barbara.lastoria@isprambiente.it

Abstract

Mass media can play a major role in providing public with sufficient and correct information on flood risk and in improving their perception on flood consequences and damages. Moreover, they often present professed experts' view and opinion that might provide a distorted interpretation of the events.

As shown in the following sections, this is the case of a severe event that struck the Tiber river basin and the Aniene (Tiber's tributary) river basin in mid December 2008.

1 The flood event

On 10–12 December 2008, intense precipitation hit the Tyrrhenian Sea side of the Italian peninsula, inducing a flood event over the Tiber and the Aniene river basins.

The event captured the attention of the national and international media and was announced and labelled as an "extreme event" by several sources. High relevance to such flood event is attributed because of the actual damages occurred in several zones over Rome area, in particular due to failure and inefficiency of urban drainage systems, and to potentially devastating damages which would have occurred if the Tiber river had overflowed its banks.

The most critical situation in Rome was due to some boats that, by breaking loose from their moorings in the surging water together with floating materials, risked to trigger a dam effect at *Ponte Sant'Angelo* (Figure 1a). Also the Tiberina Island, a boat-shaped island located in the southern bend of the Tiber, where it is present *Fatebenefratelli* hospital and a church, was marginally inundated with water (see Figure 1b-c). At the Tiber river outlet, two sites located on the opposite banks of the river were struck by both the Tiber flood and the Tyrrhenian Sea tidal waves.

---

[1] ISPRA – Institute for Environmental Protection and Research, Rome, Italy

Figure 1: (a) Boats trapped in Ponte Sant'Angelo during the December 2008 flood event. (b) Tiberina Island in ordinary condition. (c) Tiberina Island during the December 2008 flood event.

2 The frequency analysis

To validate the actual "extremity" of such event, a frequency analysis has been performed from both a pluviometric and a hydrometric point of view by considering rain gauges and stream gauges available over the stricken area (Figure 2).

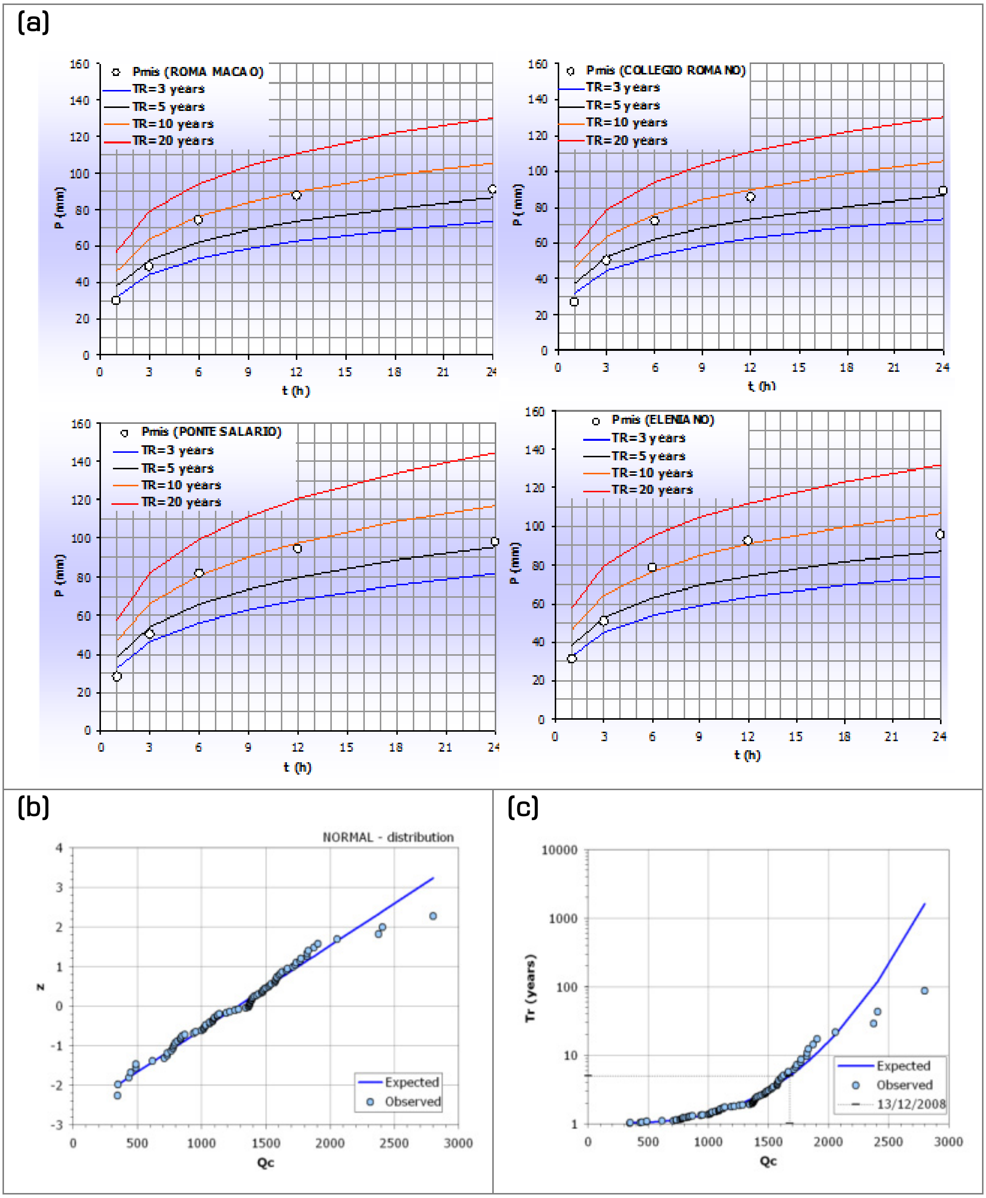


Figure 2: (a) Precipitation return periods for four rain gauges in the Rome urban area, as a function of the accumulation time. (b) Quantile-quantile plot of the river discharge frequency distribution at the Ripetta station. (c) Return period associated to the observed peak discharge value (Qc = 1676.12 m^3 s^{-1}) using a normal distribution.

This analysis has shown that rain gauge stations located in the central Rome urban area have a return period of about 10 years, whereas the return period for the stations located in the Aniene river basin was generally about less than 5 years. Moreover return periods corresponding to the observed peak discharge values are equal to about 5 years (Casaioli et al., 2010). These results have been also confirmed by comparing the Tiber peak water level observed during the event in the centre of Rome at the Ripetta station (12.55 m) with the peak values recorded in the last ten years and the historical maximum of 16.90 m registered in 1937.

Conclusions

The performed frequency analysis denies the "extremity" of such event, as instead sensationalized by mass media. Sites inundated by Aniene and its tributary are instead located in high flood risk areas. Moreover, perplexity arises from the fact that vulnerability of these frequently inundated areas has been increased, improving exposed elements value (e.g., by placing industrial and commercial activities), rather than decreased, preserving "natural storage" for natural attenuation of extreme floods. Similarly, such vulnerability is increased by the presence of unauthorized settlements in areas naturally subjected to inundation, also for flood events with return period less than 10 years.

The critical situation induced by boats along the Tiber river is not so rare, considering that a similar situation occurred also during the Tiber flood event in December 2005. So it is evident that, the presence of boats and floating structures, very often lacking moorings dimensioned to resist dragging force of stream flow during flood events, is a constant risk element in the Tiber urban area.

References

Casaioli, M., Lastoria, B., Mariani, S., and Bussettini, M.: Evaluating the improvements of the BOLAM model of the ISPRA Sistema Idro-Meteo-Mare on the December 2008 flood event in Rome. *Adv. Geosci.*, 25, 135–141, 2010. doi:10.5194/adgeo-25-135-2010.

G. T. Aronica[1] *and G. Brigandì*[1]

CHARACTERISTICS OF THE EXTREME RAINFALL EVENT AND CONSEQUENT FLASH FLOODS IN NORTH-EAST PART OF SICILY, ITALY IN OCTOBER 2009

Corresponding author: Prof. Giuseppe T. Aronica
Department of Civil Engineering, University of Messina
Via Panoramica dello Stretto – 90168 Messina, Italy
E-mail: aronica@ingegneria.unime.it

Abstract

The catastrophic events that occurred on 1st October 2009 in the area of Messina, Sicily highlighted the destructive potential of flash flood and mud/debris flows. More than 40 people were killed and severe property damages (ca. 300 M€) took place when debris flows, triggered by heavy rainfall, inundated various towns and villages located along the coast.

Main goal of the study here presented is put together available meteorological and hydrological data in order to get better insight into temporal and spatial variability of the rain storm, the soil moisture condition and the consequent flash floods in the catchment of the Giampilieri river. The area of the catchment is approximately 10 km^2, predominantly rural with woods and sparse shrubs in the upper mountainous part, while the areas next to the outlet are highly urbanized. The topography is very rugged and the slope is steep, as is that of a number of its tributaries, some of which are incised into narrow pathways as they approach the main channel. As a consequence, short concentration times are to be expected with fast hydrological response. The area under study has been subjected to unstable weather with high values of precipitation during all the September period. In fact, more than 40 percent of the annual total precipitation occurred during this period and consequently the catchment was totally saturated at the beginning of the event, as the post event analysis has shown. The event was investigated using observed data from a rain gauge network and hydraulic evidences. Statistical analysis using GEV distribution was performed and rainfall return period (storm severity) was estimated. Further, measured rainfall data and rainfall-runoff modelling were used to analyze the hydrological behaviour and to reconstruct flood and debris hydrographs. Post-flood investigation emphasized the significant importance of the antecedent soil moisture conditions on the hydrological response of the catchment in the occurrences of these kinds of phenomena.

---

[1] Department of Civil Engineering, University of Messina, Italy

LIST OF AUTHORS

Thematic Workshop "FLASH FLOODS AND PLUVIAL FLOODING"

WG F PLANNING COMMITTEE:

Maria Brättemark, European Commission – DG Environment
Ad de Roo, European Commission – JRC
Mark Adams, Ireland
Jan Danhelka, Czech Republic
Meike Gierk, Germany
Frédérique Martini, France
Giuseppina Monacelli, Italy
Wouter Vanneuville, Belgium
Ronnie Falconer, EWA

NATIONAL TECHNICAL-SCIENTIFIC COMMITTEE:

Giusy Lombardi, Ministry for the Environment and Protection of Land and Sea, IT
Giovanni Braca, ISPRA, IT
Martina Bussettini, ISPRA, IT
Marco Casaioli, ISPRA, IT
Barbara Lastoria, ISPRA, IT
Stefano Mariani, ISPRA, IT
Giuseppina Monacelli, ISPRA, IT
Silvano Pecora, ARPA Emilia Romagna, IT
Cinzia Balia, District Authorities, IT
Marcello Brugioni, District Authorities, IT
Carlo Ferranti, District Authorities, IT

NATIONAL ORGANIZING COMMITTEE:

Sabrina Farris, ISPRA, IT
Elena Giusta, ISPRA, IT
Rossella Sisti, ISPRA, IT
Stefania Nascimben, Hydrographic District Agency of Sardinia Region, IT