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Flood events

Dr. Andre Paquier

4.1. Various floods

Usually, various kinds of floods are distinguished based on the origin or on the main processes. Basically, the cause of the flood can be overflow over the banks of the main channel, direct runoff or failure of a levee or other structure. Flash floods are typical of steep beds and / or high intensity rainfalls. In mountain areas, they can be associated to debris flows or highly concentrated bed load. In urban areas, reaching the limits of infiltration rate and of conveyance of the drainage network can be the cause of flooding.

4.2. Factors influencing floods

Although, as recalled here above, various processes can create floods, a list of the main factors that influence the features of a flood can be set. Most of the corresponding parameters can be influenced by climate change or more directly by other anthropogenic changes. Some parameters control the quantity of water provided to hydrographical network. They can be linked with climate change: rainfall is particularly studied; runoff (related to vegetation, land use, surface structure, etc) is also linked directly with the rise of temperature while change in groundwater behaviour is mainly related to infiltration rate and precipitation chronic. Other parameters concern the conveyance of the hydrographical network: vegetation, sediment load, bed morphology, hydraulic structures (design, operation, failure), wind, sea (or lake) level, etc. Corresponding relations with climate change can be detailed.

If stationary conditions are applied, a riverbed will reach equilibrium (with small variations around) depending of the geology (available material), the hydrologic regime (including both water and sediment) and the vegetation (that itself depends on the two previous factors and the maintenance of the bed). A change in these latter conditions will imply a change in bed morphology that can lead to a long destabilization. A decrease of sediment inputs can lead to a deepening of the main channel (such as downstream from a newly built dam), which means less overflows upstream but flow acceleration with further consequences downstream. Bed morphology itself will impact hydraulic structures: efficiency will be reduced by sediment deposition while stability can be reduced by bed erosion.

Failures of structures such as earthen embankments can be linked to excess flow, damages created by animals, cracks (linked with drought, for instance), local bed erosion, etc. Levee failures can cause catastrophic floods because they are often associated with high discharges and can hit people that are not prepared both because the flow can come very quickly and because people believe be protected face to any flood event. The first consequence of climate

change will be a modified probability of reaching the water level for which the safety of the levee can be questioned. However, the local climatic features will also impact the stability conditions of the levee and thus the real degree of protection for the population.

4.3. Some examples

Thus, connections of floods with climate change can be multiple. Generally because of the high variations in flow discharges from one year to the other one, only a statistical analysis can bring a real answer to a question of evolution in floods. The answer can be different for “usual” floods or for “catastrophic” floods; the first ones will depend on a general trend that can be observed while the latter ones require longer observations periods (not often available) and depend on flow processes that may be different because of sediment entrainment, failures of structures, etc. Because of the difficulty to downscale future climate change scenarios and to integrate all these processes, one can try to learn from the past and to detect trends from historical long series (Lang and Renard, 2007). Uncertainty on measurements of higher discharges including changes in measurement techniques as well as works (on the river itself or more upstream) that change hydrological regime (dams for hydropower, irrigation, etc) imply that the task is not an easy one. After a selection of the more trustable hydrometric stations in France and application of various statistical tests, (Renard et al., 2008) concluded that only in the North East part of France, a significant trend can be detected for annual maximum flow. This difficulty to determine a clear trend does not mean that a historical trend does not exist but variability (and uncertainty) is too high. Trend (but with similar degree of uncertainty) was also obtained for future conditions on basis of simulations using global climate models and hydrological models: on Seine basin at Paris, the 10-year peak flow decreases slightly while the 100-year peak flow remains constant (Ducharne et al., 2010). For exploring future trends, understanding of the main processes and particularly of potential feedback effects should be improved to integrate this variability (for instance, seasonal effects).

4.4. Challenges to cope with climate change

One central question is downscaling from meteorological parameters at regional scale to rainfall at local scale. It means that not only a trend for the amount of the highest rainfall events is necessary but also a description of how is evolving the structure of the rainy events. The structure is essential for the smaller basins with risk of flash flood but also to detect trend in the rivers downstream in larger basins (for instance, because of the concomitance of high flows from two tributaries).

Passing from rainfall to discharge implies taking into account the land use that will govern runoff parameters. This land use depends on climate (selection of plants, plant growth, etc) but

also of economic activity (agricultural choices, urban development, etc). Once land use is described, a hydrological model for river basin is required. It can be physically based or not but, in any case, will depend strongly on the calibration data set. In this respect, the analysis of previous periods is required.

Special care should be for urban basins in which the drainage network is dense and surface structure quite complicated. In these cases, rainfall intensity can be a key factor and urban planning that can favour local storage or infiltration is an essential point.

Estimating conveyance of the river is also obviously a basic issue. (Lang et al., 2006) show that discharges are often not measured accurately; even at hydrometric stations; the relation between water elevation and discharge can be difficult to estimate. Flood plain conveyance will depend on land use, hydraulic structures and interaction with main channel. Sediment transport and morphological changes will also make difficult the estimate of the conveyance of the main channel.

The possibilities of adaptation of the (structural and non-structural) measures to mitigate floods (Paquier et al, 2009b) should be evaluated considering that reference events will change because of climate change. For instance, levees designed to resist up to return period cannot be adapted easily to resist to a slightly higher flow.

4.5 Methodologies: key issues for future

As written here above, the first objective consists in defining the trend for intensity of flood events. Simple cases require to determinate extreme events either for flow discharges in rivers or for rainfall intensities (Paquier et al, 2009a) or for sea levels. More challenging is the combination of the various climatic factors: for instance, tide, wind and atmospheric pressure are essential to forecast sea level in coastal areas. However, damages can increase drastically because of local circumstances such as in case of failure of protection structures such as dikes or if high rainfalls are combined with high water level in the river of the sea, which hinders proper evacuation of excess runoff waters. The definition of combined probabilities due to climatic forcing or the early detection of the combination of risky situations (essential for efficient warning of populations) should be enhanced.

For urban areas in which damages are concentrated, methodologies to assess potential damages in advance are necessary. Another way consists in evaluating priorities for evacuation of risky areas with the various steps corresponding to the progressive improvement of the forecasts as time is marching. Understanding of the processes met during an urban flood (Mignot et al., 2008) is also required to link all the mitigation measures to an accurate assessment of hydraulic parameters both in streets and in built-up blocks.

Hydraulic tools to be used still rely on numerical models based on 1-D and 2-D shallow water equations (El kadi Abderrezzak et al., 2009) and their improved developments (Proust et al., 2009) but they should be coupled with uncertainties assessments. The evaluation of scenarios consequences pass also by the use of dike failure models (Paquier and Beraud, 2010) and sediment transport models (particularly in steep slope areas or extreme events) that provide uncertain results basically even after appropriate calibration (El kadi Abderrezzak and Paquier, 2009).

4.6. Conclusions

Floods are local events that depend of local conditions, often linked with anthropogenic factors. Changes (due to climate change) in rainfall amounts or even, in peak discharges are often not enough to evaluate future flood extents because the transformation from discharge to flood is a local one and because, for instance, roughness cannot be considered as constant. Understanding of the main flood processes at the right scale is necessary to forecast the changes in flood risk. Moreover, in the past, changes in flood conditions were mainly due to other anthropogenic factors and such an assumption may remain true in the future.

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