Optimisation of Nature Based Solutions for urban stormwater management, high resolution of radar data and fully distributed modelling: The Bièvre case study

Optimisation des Solutions Fondées sur la Nature pour la gestion des eaux pluviales : haute résolution des données radar et de la modélisation totalement distribuée - Le cas d'étude de la Bièvre

B.WILLINGER[1], L. MONIER[2], H. CARDINAL[3], A.GIRES[4], N. ROUX[5], B. TISSERAND[5], D.SCHERTZER[4], I.TCHIGUIRINSKAIA[4]

[1] Veolia Eau - Ile de France (bernard.willinger@veolia.com)
[2] Veolia Direction Technique et Performance (laurent.monier@veolia.com)
[3] Syndicat Intercommunal de l'Assainissement de la Vallée de la Bièvre (SIAVB) (h.cardinal@siavb.fr)
[4] Ecole des Ponts ParisTech (ENPC) - Laboratoire Hydrologie Météorologie et Complexité (auguste.gires@enpc.fr, ioulia.tchiguirinskaia@enpc.fr, daniel.schertzer@enpc.fr)
[5] Veolia Recherche et Innovation (VERI) (nicolas.roux@veolia.com, bruno.tisserand@veolia.com)

ABSTRACT

Significant paradigm shifts have occurred in water management, especially with Nature-Based Solutions. This is particularly the case for semi-urban catchments such as the one of the Upper Bièvre Valley. We show how their management can be better assessed, and therefore optimised, by combining high resolution X-band and double-polarised radar data with fully distributed physical-based hydraulic model. Both have the advantage of overcoming the traditional calibration problems that become more and more difficult with the increase of the resolution, and thus offer an easier framework for downscaling.

RÉSUMÉ

D'importants changements de paradigmes sont intervenus dans la gestion de l'eau, notamment avec les Solutions Fondées sur la Nature. C'est particulièrement le cas pour des bassins versants semi-urbains comme celui de la Haute Vallée de la Bièvre. Nous montrons comment leur gestion peut être mieux évaluée, et donc optimisée, en combinant la haute résolution de données radar en bande X et à double polarisation, avec celle d'un modèle hydraulique totalement distribué à base physique. Tous les deux ont en effet l'avantage de s'affranchir des problèmes traditionnels de calibration qui deviennent de plus en plus ardus avec l'accroissement de la résolution et donc offrent un cadre plus aisé pour la descente en échelle.

KEY WORDS

double polarization radar, fully distributed modelling, high resolution precipitation, nature based solutions, urban resilience

1 CONTEXT

21st century challenges - including globalisation, urbanisation, social equity and climate change, - require 21st century solutions for building a more inclusive society, city, and world. Urban resilience becomes a pressing, worldwide issue. The City Resilience Profiling Programme (CRPP) of the UN Habitat, the United Nations agency for human settlement, “support[s] local governments to build their capacity to improve resilience by developing a comprehensive and integrated urban planning and management approach, and tools for measuring and profiling city resilience to all types of hazards.“

Urban rivers and streams, which have become a central nexus of the relationship between people and nature, also generate threats that force local authorities to innovate on hard structural defences, causing biodiversity losses. Yet, urban streams, as part of the urban ecosystems, have important roles in cities and surroundings providing ecosystem services. Technology that first allowed mankind to settle these areas is now advanced enough to allow people to be able to predict multiple risks, measure the socio-economic impacts and take informed decisions. This will ensure the ecologically coherent urban planning and city-making process, adapting to environmental changes and therefore greatly reducing the impact of climate and global threats. This can be obtained with the help of rational multi-scale implementation of non-sedentary nature-based solutions (NBS), encompassing a more dynamic vision of the co-evolution of a complex urban environment and its bionetwork, to trigger new types of across-scale resilience, as a major component of smart stormwater management.

This objective has been stimulating the evolution of the Chair “Hydrology for Resilient Cities” created by Ecole des Ponts ParisTech (ENPC) and Veolia in 2010. The activities of the Chair were initially rather focused on heavy rainfalls and urban floods, in particular with the help of the recent polarimetric X-band radar technology, but they have quickly extended from resilience to water to resilience to extreme weather, climate change and finally to urban resilience.

2 RESILIENCE AND NEW SERVICES TO BE PROVIDED, A CASE STUDY ON THE BIEVRE RIVER

During the last two and half year period, particularly intense rainy episodes have struck hard various parts of the Ile-de-France region and its neighbourhoods. The recorded accumulations enhance the idea of a rather exceptional situation, which took place twice in eighteen months. For instance, the sudden rise of the Seine river up to 6.10 m during the 2016 summer flood was caused by precipitations that fell in the middle of the Seine river catchment. While a rather slow water rise of 5.84 m during 2018 winter flood resulted from precipitations centred in the east of the Seine river catchment. During these significantly different floods, the Bièvre river remained one of the very few tributaries that did not flood in the Paris region. It provides an example of best practices with expertise on across-scale stormwater management in the Bièvre Valley, expanding historical legacy by combining smart technologies, like high-resolution remote sensing and sensor networks, with nature-induced operational innovation.

The area of interest is managed by the Syndicat Intercommunal de l’Assainissement de la Vallée de la Bièvre (SIAVB) with an over 25-year technical assistance of Veolia. Following severe flooding in 1982, the SIAVB developed all along the river a network of storage basins that can hold up to one million cubic meters of water. The streams are analysed, monitored and managed across all basins to optimize them in real time, to ensure that no flooding will occur for rainfall events smaller than 20 years return period for 2h duration.

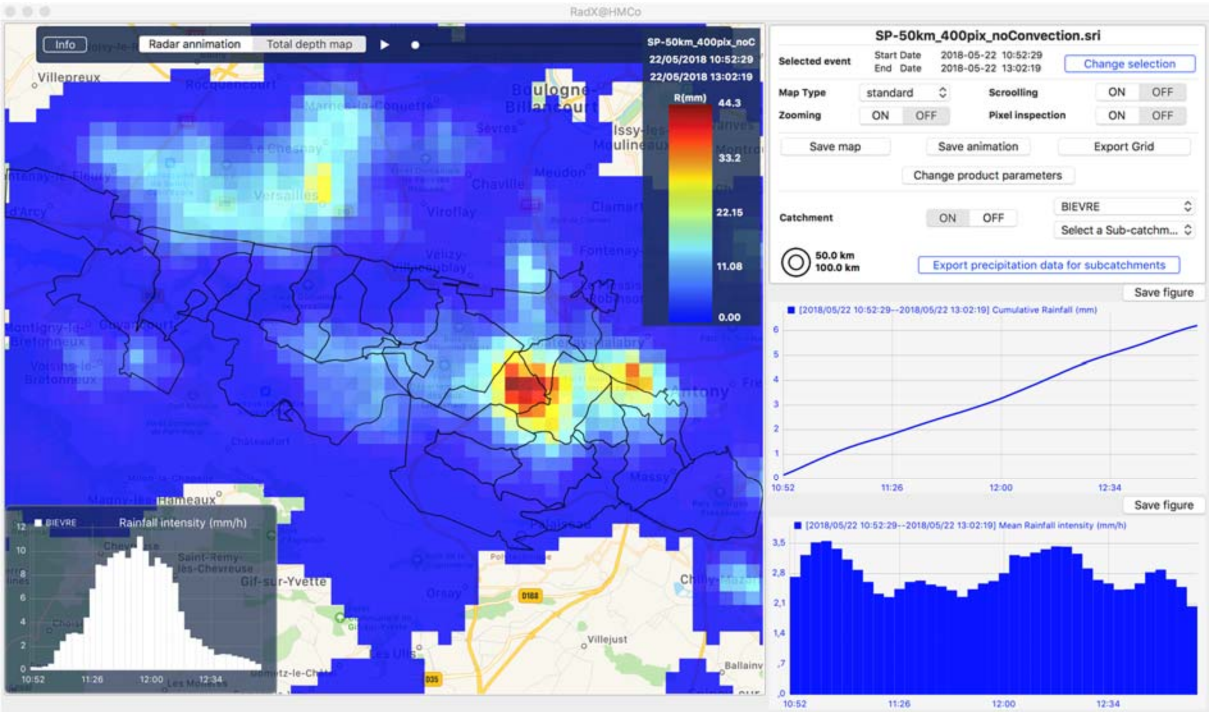
The Bièvre Valley provides a pivotal knowledge in re-naturalization of rivers. This includes more natural ways to reverse the risk of flooding by draining developed urban areas using the multi-functional nature based solutions (NBS) as alternatives to structural water retention solutions. Continuous restoration actions were undertaken to improve the river quality as well as its aesthetic aspect. For instance, the artificial storage was emptied in the area of Massy and converted into a wetland that stretches over 15 hectares. The implementation of such measures reduces the speed and variability of urban runoff as well as flooding and erosion of the natural watercourse. It also shows that restoration of aquatic ecosystems is not only ecologically and socially desirable, but also economically.

3 THE MAJOR ROLE OF THE RAINFALL INFORMATION

The higher frequency of intense precipitations makes water management important issues, strongly relying on a finer knowledge of the space-time configuration of rainfall cells. In addition to the Meteo-France C-band radar located in Trappes, south west of Paris, the Bièvre Valley benefits from rainfall measurements of the X-band radar, located on the East of Paris and operated at Ecole des Ponts with a resolution of 250m x 3.4min. The initial studies were rather focusing on the comparison of a set of rainfall estimates over instrumented sub-catchments of the Bièvre Valley to validate the ENPC X-band radar products. The preliminary results of this validation, in relation to the C-band radar products, the rain gauge data and the hydrological simulations, were presented at the ASTEE Congress 2016 (Monier et al., 2016).

An extension of this analysis of the X-band rainfall products for recent years confirms an overall semi-quantitative agreement between the X-band and C-band radar estimates, while the X-band radar enables to observe some very local cells of extreme intensities that were smoothed out by the C-band radar. The dynamics of such small-scale cells defines the rapid aggregation of a multi-cellular thunderstorm, or super-cellular configurations, - a step towards better stormwater management during highly intensive convective events. This highlights the interest of the X-band radar technology, notably to improve the high resolution nowcasting.

It was also confirmed that polarimetric X-band radar products, such as DPSRI (Dual Polarisation Surface Rainfall Intensity), with an ad-hoc choice of parameters for single polarisation estimates of low intensity rain rates could underestimate them (Paz et al., 2018). Multifractal developments are proposed to improve the automatic choice of these parameters for low intensities of the X-band radar rainfall.



Demonstrator of the ENPC X-band Radar Platform, with the zoomed view over the Bièvre Valley on May 22, 2018, 11AM-1PM UTC. The hot spot corresponds to 26 mm of 2h cumulative rainfall over the BIEV sub-catchment, situated just in between the three rain gauges (JOUY3, SYGAM and VER1 sub-catchments), the maximum per pixel is above 44 mm. This is a very heterogeneous event, only 6 mm were obtained over the full rainy area of the X-band radar observations (up to 100 km radius around the ENPC).

4 OFFLINE MODELLING VS. OPERATIONAL MODE : WHERE IS A FRONTIER IN COMPLEXITY ?

Many engineering tools have been developed up to now to work conveniently using either very local rain gauge networks or C-band weather radars as the main rainfall input data. For the Bièvre Valley, the semi-distributed conceptually-based InfoWorks model for the whole Bièvre catchment is currently used by Veolia for operational purposes, as well as in the OptimSim model that optimises the management of the water flows and storage basins. The average size of the sub-catchments remains comparable to the C-band rainfall data resolution, given that the 110 km^2 area was divided into 27 sub-catchments, considered as homogeneous. Such model resolution does not enable to fully benefit from higher resolution rainfall data (Ochoa-Rodriguez et al., 2015). As a potential alternative, the fully distributed physical-based Multi-Hydro model was implemented on several sub-catchments: Guyancourt, Jouy-en-Josas (Gires et al. 2018) and Massy (Alves de Souza et al. 2018). Multi-Hydro developed by Ecole des Ponts is equipped with a data assimilation toolbox that enables to easily implement the model, by optimising the pixel size that generally ranges from few meters to few hundred meters, depending on the quality of available data (Ichiba et al. 2018). This scalable model does not need any particular calibration and has a much higher sensitivity to high resolution X-band rainfall data.

Using fully distributed models that non-linearly integrates the rainfall distributions over the Bièvre catchment with measured water levels in the Bièvre river have been providing a more scientific framework to validate the available rainfall products.

Fully distributed models should also improve the assessment of various and multiscale resilience measures to help optimising the choice of Nature Based Solutions and ecosystem services.

BIBLIOGRAPHIE

Alves de Souza, B., da Silva Rocha Paz, I., Ichiba, A., Willinger, B., Gires, A., Amorim, J.C., de Miranda Reis, M., Tisserand, B., Tchiguirinskaia, I. and Schertzer, D. (2018). *Multi-hydro hydrological modelling of a complex peri-urban catchment with storage basins comparing C-band and X-band radar rainfall data*. Hydrological Sciences Journal, 63:11, 1619-1635.

Gires, A., Abbes, J.-B., da Silva Rocha Paz, I., Tchiguirinskaia, I. and Schertzer, D. (2018). *Multifractal characterisation of a simulated surface flow: A case study with Multi-Hydro in Jouy-en-Josas, France*. Journal of Hydrology, 2018, 558, 482 - 495

Ichiba, A., Gires, A., Tchiguirinskaia, I., Schertzer, D., Bompard, P., and Ten Veldhuis, M.-C. (2018).*Scale effect challenges in urban hydrology highlighted with a distributed hydrological model.* Hydrology and Earth System Sciences, 22, 331-350.

Monier, L., Thouvenel, F., Paz, I., Gires, A., Zobrist C., Willinger, B., Boisson, P., Schertzer, D. and Tchiguirinskaia, I. (2016). *Utilisation du radar Bande-X pour l'amélioration de la gestion des événements pluvieux en zones urbaines*. Congès ASTEE 2016, Jun 2016, Issy-les-Moulineaux, France

Ochoa-Rodriguez, S., Wang, L.-P., Gires, A., Pina, R. D., Reinoso-Rondinel, R., Bruni, G., Ichiba, A., Gaitan, S., Cristiano, E., van Assel, J., Kroll, S., Murlà-Tuyls, D., Tisserand, B., Schertzer, D., Tchiguirinskaia, I., Onof, C., Willems, P. and ten Veldhuis, M.-C. (2015). *Impact of spatial and temporal resolution of rainfall inputs on urban hydrodynamic modelling outputs: A multi-catchment investigation.* Journal of Hydrology, 531, Part 2, 389-407.

Paz, I., Willinger, B., Gires, A., Ichiba, A., Monier, L., Zobrist, C., Tisserand, B., Tchiguirinskaia, I., and Schertzer, D. (2018). *Multifractal Comparison of Reflectivity and Polarimetric Rainfall Data from C- and X-Band Radars and Respective Hydrological Responses of a Complex Catchment Model.* Water, 10, 269.