International Congress on Environmental Modelling and Software

8th International Congress on Environmental Modelling and Software - Toulouse, France - July 2016

Jul 11th, 3:10 PM - 3:30 PM

Participatory simulation of coastal flooding: building social learning on prevention measures with decision-makers

Nicolas Becu
CNRS, UMR LIENSs, nicolas.becu@cnrs.fr

Marion Amalric
University of Tours, marion.amalric@univ-tours.fr

Brice Anselme
University Paris 1, brice.anselme@univ-paris1.fr

Elise Beck
University of Grenoble, elise.beck@ujf-grenoble.fr

Xavier Bertin
CNRS, UMR LIENSs, xavier.bertin@univ-lr.fr

See next page for additional authors

Presenter/Author Information

Nicolas Becu, Marion Amalric, Brice Anselme, Elise Beck, Xavier Bertin, Etienne Delay, Nathalie Long, Corinne Manson, Nicolas Marilleau, Cecilia Pignon-Mussaud, and Frédéric Rousseaux

International Environmental Modelling and Software Society (iEMSs)
8th International Congress on Environmental Modelling and Software
Toulouse, France, Sabine Sauvage, José-Miguel Sánchez-Pérez, Andrea Rizzoli (Eds.)
http://www.iemss.org/society/index.php/iemss-2016-proceedings

Participatory simulation of coastal flooding: building social learning on prevention measures with decision-makers

Nicolas Becu [a], Marion Amalric [b], Brice Anselme [c], Elise Beck [d], Xavier Bertin [a], Etienne Delay [e], Nathalie Long [a], Corinne Manson [f], Nicolas Marilleau [g], Cécilia Pignon-Mussaud [a] and Frédéric Rousseaux [h]

[a] *CNRS, UMR LIENSs, La Rochelle, France (nicolas.becu@cnrs.fr, xavier.bertin@univ-lr.fr, nathalie.long@univ-lr.fr, cecilia.pignon-mussaud@univ-lr.fr)*
[b] *University of Tours, UMR CITERES, France (marion.amalric@univ-tours.fr)*
[c] *University Paris 1, UMR PRODIG, France (brice.anselme@univ-paris1.fr)*
[d] *University of Grenoble, UMR PACTE, France (elise.beck@ujf-grenoble.fr)*
[e] *University of Limoges, UMR GEOLAB, France (etienne.delay@unilim.fr)*
[f] *University of Tours, UMR LERAP, France (corinne.manson@univ-tours.fr)*
[g] *IRD, UMI UMMISCO, France (nicolas.marilleau@ird.fr)*
[h] *University of La Rochelle, UMR LIENSs, France (frederic.rousseaux@univ-lr.fr)*

Abstract: Due to the increase in coastal flooding risk associated with climate change, there is a strong need to develop efficient and long term management strategies. In 2010, the storm Xynthia highlighted the limits of coastal flooding risk management in France. Besides a deficient alert system, it revealed a lack of risk culture. This problem was especially prevalent among local decision-makers who fail to take into account alternative prevention measures and adaptive strategies. In partnership with the local administration of Oléron Island – a sector strongly affected by storm Xynthia - we developed a participatory simulation model to foster social learning about coastal risk prevention measures with local authorities and managers. This simulation integrates a coastal flooding simulation model and a spatially explicit agent-based model that simulates the development of the area and the management of prevention measures. The participatory set-up was made to create an immersive environment so that participants would remember the coastal flooding simulation displayed. A role game mechanism was added in order to simulate the coordination issues between the different decision bodies and levels involved in coastal risk management. Participants' interfaces were designed to reflect on the opposition between a short term strategy (building more dikes) and a long-term strategy (land-use and housing adaptation). A first participatory simulation session was conducted with local decision-makers in 2015. It proved to be very immersive thanks to the combination of displaying coastal flooding simulations on a very large screen and of using distributed user-control interfaces. Participants learned about the water expansion dynamics during flood events and the effects of building, raising and restoring dikes. Yet, the model still needs improvements to help decision-makers change their mindset on long-term alternative risk prevention measures.

***Keywords**: participatory simulation, coastal flooding, social learning, risk management*

1. INTRODUCTION

1.1. Coastal flooding, prevention measures and risk culture in France

Coastal flooding is among the most dreading natural disasters at present, and for instance correspond to the costliest natural disasters in Europe (IPCC, 2007; ONERC, 2010). It is likely that the intensity of such hazard will increase in the future, as a result of climate change, causing sea levels rise and possible local increased intensity of extreme weather events (IPCC, 2014). Estuaries, coastal lagoons and salt marshes are particularly affected because of their very low altitude. Since centuries, humans have constructed defenses, using burdensome techniques, against the sea in order to gain land and protect themselves. The importance of the issues – social (urbanization and economy of coastal areas), ecological (high coastal biodiversity), heritage and landscape – requires the implementation of a comprehensive and integrated risk approach of coastal flooding. Among the different approaches for integrated management, this paper proposes an integrated tool for collective reflection on defining and implementing coastal flooding prevention measures.

Coastal flooding occurs when dry and low-lying land is flooded episodically by the sea, during extreme meteorological and/or tidal conditions (Garry, 1997). In February 2010, coastal flooding caused by the storm Xynthia (Bertin et al., 2014) highlighted the limits of marine inundation risk management policy in France. This catastrophe has revealed deficiencies in the information provided to populations, in warning and alert systems, in managing dikes network and a relative unsuitability of coastal risk prevention plans. A whole series of decisions made before and during crisis have considerably worsen the situation, revealing a lack of risk culture (Cartier, 2004; Jousseaume and Mercier, 2008). This lack of risk culture has led to choices, both collective and individual, in which environmental issues and those related to risk have been relegated to the background, while exacerbating consequences of the disaster (Anziani, 2010). On the population side, the last report of the French High Committee for Civil Defense (HCDFC, 2011) pointed out a lack of information and awareness. Thus, Xynthia has clearly highlighted a lack of local culture of coastal risks in France, both for the population and for policymakers.

In France, the development and implementation of a natural risk prevention plan, PPRN, is under the responsibility of local authorities, mainly municipalities. In February 2011, after Xynthia event, the government urged a number of municipalities to revise their PPRN by 2014 in order to implement measures for the prevention, prediction, protection and safety of populations in areas prone to sudden phenomena of coastal flooding. Yet, less than a third of the 974 coastal municipalities in France metropole has an approved PPRN, and only 18% have a specific plan for coastal risks; furthermore reviewing of existing PPRN defined by the circular of July 2011 (IFEN, 2011) has hardly been started. Moreover, a large number of PPRN developed since this date focused their prevention strategy on coastal defenses such as human-made dikes or natural sand dunes. Yet, scientific bodies and many environmental services of the national and regional administration, are currently calling for a change of policy towards more alternative prevention measures such as strategic withdrawal, natural operation restoration, managed realignment or depolderization, which are less expensive and more environmentally friendly (Anselme et al., 2011; Cariolet and Suanez, 2008; Goeldner-Gianella, 2010).

In this first part, we identified the poor reflection of local decision bodies on a truly integrated approach to coastal risks management, especially the failure of taking into account alternative prevention measures and adaptive strategies. We now present participatory simulation approach as a suitable tool to foster social learning about coastal risk prevention measures with local authorities and managers.

1.2. Participatory simulation for collective learning

Participatory modeling as defined by Voinov and Bousquet (2010) regroups various approaches that use modeling in support of a decision-making process that involves stakeholders. Stakeholders may be involved at different stages of a modeling process (e.g. problem definition, conceptualization, calibration or scenario definition) (Barreteau et al. 2011). Among those techniques, participatory simulation (PS) is a branch that involves stakeholders during the latest stage: the simulation of scenario (Voinov and Bousquet, 2010). In PS, several participants are invited to interact with a simulated hybrid environment that incorporates social and computerized components – economic exchanges may be simulated through hand to hand exchanges while flooding or bird migration may be computerized process. Participants take decisions according to their own goals and their experience of what occurred at the previous steps of simulation. Throughout the simulation that lasts for a given number of steps, participants progressively build a collective scenario. In this branch of participation; *"the modelling itself is not participatory as the settings and the rules of the games cannot be modified by the stakeholders"* (Voinov and Bousquet 2010). A famous and emblematic application of such approach is the Fish Banks game (Meadows 1986) which mixes a computer simulation of renewable fish stocks and a role-playing game where participants own fishing companies and make decisions about fishing, buying and selling ships. Such simulation game may be used to demonstrate or to convey messages (such as using natural resources effectively and prudently) in an efficient manner as participants are actively involved in the learning process (Klabber 2009). PS is also used for interventions, changing agents, such as culture reshape, improving internal organization of a social system, or even for planning and scenario design (Marshev and Popov 1983). Risk and disaster management becomes nowadays a recurrent application domain of gaming and simulation as evidenced by Velasquez (2015) last keynote at the International Conference of Simulation & Gaming. The simulation of risk situations is used to encourage a change of behavior and practices in order to reduce vulnerability. Simulating the complex interactions between the many operators of risk management allows testing and evaluating the management and control mechanisms in place.

For this application to coastal flooding management in France, our goal is to use PS to raise awareness of municipalities' officials and managers (technicians) about alternative prevention measures, rather than building dikes. Our project is still at its primary phase: a first prototype of PS tool was developed and tested once. The project is carried out in collaboration with the Community of municipalities of Oléron, which groups together all municipalities of Oléron Island within a solidarity area. The purpose of this administration is to improve collaboration between local authorities on urban development. This partnership influenced the game design, anchoring the game into local stakes in order to respond to the needs of our partner. Besides, the test of the prototype was carried out with operational actors. This paper reports on the model development (modeling choices and implementation) as an exploratory approach to promote a change in risk management together with local stakeholders.

2. COASTAL FLOODING CONDITIONS IN OLÉRON ISLAND

The study area corresponds to the Oléron Island, located in the French central part of the Bay of Biscay (Figure 3). The eastern part of the island is low-lying, partly due to the presence of several land-reclaimed marshes. To the west, small cliffs and well developed aeolian dunes create a natural barrier against flooding. This area is subjected to tides ranging from less than 2 m to more than 6 m. The offshore wave regime is very energetic, with wave height temporarily exceeding 8 m during storms offshore of Oléron Island. Xynthia crossed the North-Western part of Spain and hit the central part of the Bay of Biscay in the night of the 27th to the 28th of February 2010. Sea-level pressure (SLP) reached its minimum at 969 hPa and winds from S to SW ranging from 25 to 30 m/s (hourly-mean wind speed at 10 m above ground, hereafter U10) blew over the Southern part of the Bay of Biscay. The analysis of available fluvial discharge data (Banque Hydro, 2012) reveals that fluvial discharges around Xynthia were close to yearly-mean conditions, which are too weak to induce freshwater flood in the marshes of the study area. Wave measurements in the Bay of Biscay showed that the significant wave height (Hs) during Xynthia slightly exceeded 7 m, a value that is regularly reached or exceeded during winter storms (Bertin et al., 2014). Although appearing as a classical winter storm, Xynthia induced a storm surge exceptional for the study area, estimated to more than 1.5 m at La Rochelle, which corresponds to the largest value since the installation of a permanent tide gauge at this station in 1997. This large storm surge peaked at a high spring tide and the subsequent exceptional water level caused the flooding of extensive low-lying coastal zones including the eastern part of Oléron Island, more than 2 billion Euros damage and 47 fatalities. Bertin et al. (2012, 2014) analyzed the causes for this exceptional storm surge and showed that it resulted mainly from an Ekman transport related to the SW-oriented wind, strongly enhanced by a particular sea-state characterized by young and steep waves. This particular sea state was explained by the unusual track of Xynthia, which reduced the fetch to a few hundred kilometers.

3. DESCRIPTION OF LITTOSIM MODEL

LittoSIM model is developed as a tool to foster social learning about coastal risk prevention measures with local authorities of Oléron. Together with our local partner, the Community of Municipalities of Oléron, we identified three main learning topics to focus on, representing the limits to the current risk management strategies in this area: (1) municipal officials act with a short-term planning strategy; (2) there is a lack of coordination between the municipalities of the island and (3) stakeholders are lacking knowledge about the spatiotemporal process of flooding during submersion events.

3.1. Modeling choices

In order to address the three main learning topics identified above, LittoSIM development was driven by the following modeling choices.
To promote learning about the flooding process itself, we chose to include a spatial simulation model of flooding. During a PS workshop with the stakeholders, this model simulates in real time the spatial evolution of a submersion event. The aim is to make the participants observing and understanding the water pathways but also to create an immersive environment that can be remembered. This objective was difficult to achieve because most submersion models used to simulate events such as Xynthia, require significant calculations time (several hours) which is incompatible with the interactive use we aimed for LittoSIM.
To address the issue of a short-term policy planning of local officials, we decided to focus LittoSIM development on the debate about two opposite prevention strategies: dikes (a straightforward and short-term strategy) or strategic withdrawal (a long term planning policy with implications on how to inhabit the island coasts). This opposition has a tangible form through the implementation of two different interfaces for participants to interact with the model. During a PS workshop, participants have thus to switch all the time between two separate interfaces (one for dikes and one for land use planning) and adjust their strategy based on the information they get from one or the other.
To account for coordination difficulties between the different decision-makers, we chose to simulate two directions of coordination. First a horizontal coordination between municipalities: LittoSIM thus includes several municipalities and their mutual interactions are part of the challenge. Second, a vertical coordination between different institutional and associative levels of intervention that goes from the regional to the local level (County Council > Community of Municipalities > Municipality > Residents' association). From the municipalities' perspective, some of these levels are exogenous of their decision arena. Therefore interactions with those who are *outside* are modeled differently.

3.2. Model classes and data sources

According to Le Page et al. (2011) LittoSIM simulation game is a hybrid composite simulation, meaning that some agents of the simulation are humans controlling an avatar (a computerized representative of a human agent), some other agents are autonomous avatar (all the decision-making processes are automatic and computerized) and some are a hybrid form between these two types. As so, LittoSIM includes three type of entities (Figure1): *i)* social entities controlled by humans, such as municipalities and Community of Municipalities, *ii)* social entities controlled by an automatic avatar among which the County Council and the Residents' Associations and *iii)* autonomous spatial or physical entities, mainly Land Management Units (LMU) and dikes which are resources for the agents.

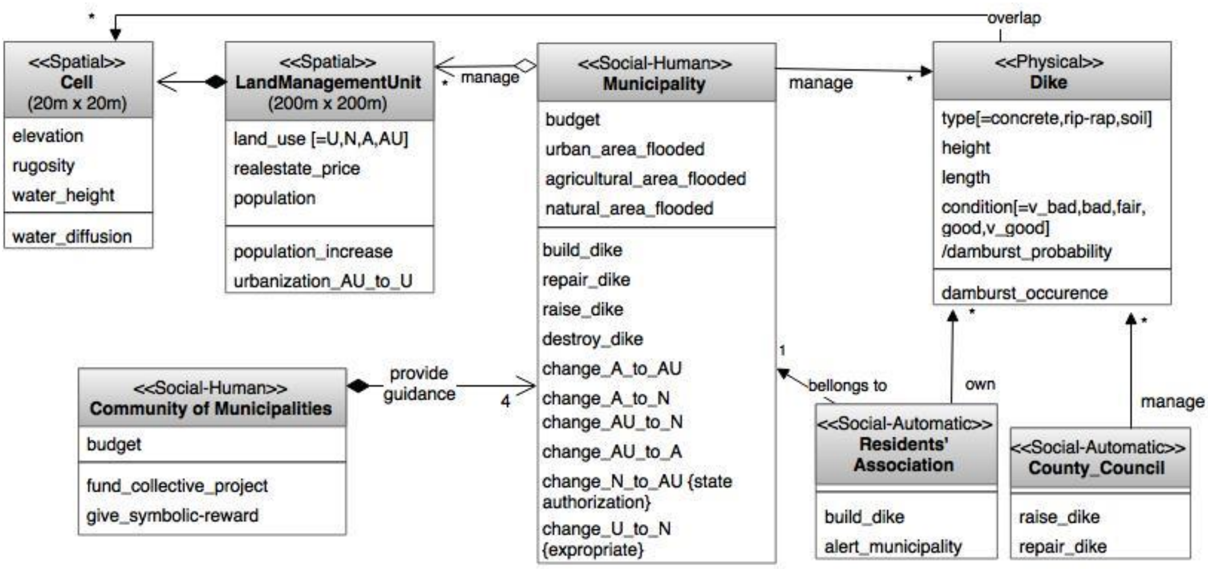

Figure 1. LittoSIM UML class diagram

Each of the four Municipalities of the simulation, manages a number of LMUs, composing the area of the Municipality, as well as a number of dikes. At each simulation step, the Municipalities automatically collect land taxes proportional to the LMUs' population. The player controlling a Municipality can then choose to execute a number of actions on his LMUs and dikes (the list of actions is shown in the lower box of the Municipality class, Figure 1) depending on his budget available[1]. Community of municipalities also owns a budget, which can be used to fund projects (land use change or dikes) involving more than one Municipality. It can reward Municipalities that have a righteous strategy with prizes such as the environmental friendly medal or the highest population increase award. While the Community of municipalities aims to facilitate coordination, the actions of the two automatic avatar classes of the model (County Council and Resident's association) are done without coordination with the Municipalities. It is controlled by a predefined schedule of construction works, unknown by the human players. Municipalities and Community of municipalities are informed about those activities when they occur and are forced to adjust their plan accordingly. There are two spatial units in LittoSIM: Cell and LMU, the latest being a composition of the first. The Cell is the unit scale used to calculate the diffusion of water levels to simulate the flooding process (see below). It holds the two parameters of the diffusion formula, elevation and rugosity, and the water height variable. Elevation is derived from the LIDAR 2010[2]. Cell elevation may be modified by the construction, raising or destruction of a dike or by a damburst, which is a function of a probability proportional to its condition. Cell rugosity depends on land use of the overlapping LMU. LMU land use is based on the zoning of the Local Urbanism Plan[3], which is a municipal regulation in the French Law. There are 4 main types of land use: N-natural, A-agricultural, U-urbanized and AU-authorized urbanization which corresponds to presently natural or agricultural zones, opened to urbanization (Figure 4). The model initializes with the real Local Urbanism Plan data of the four modeled Municipalities. Last class of the model is Dikes. It corresponds to the most difficult piece of data to be gathered. For the model to run we needed to collect for each dike of the study area its position, height, and length, the type of construction (which influence its deterioration) as well as its current condition. To do so, we combined the database shapefiles from the research program RISKS[4] and from the state department[5] and processed them (duplicating, removing dangle nodes, spatial joining and removing groynes and jetties) to obtain the most comprehensive data.

3.3. Computerized processes and players' actions

LittoSIM simulation includes two types of processes that influence the course of a simulation: computerized processes that are programed calculation operated at each step or once every n steps, and actions that are decided by human players. We first present the computerized process of flooding, then the interfaces used by human players to play with the simulation and finally a last set of computerized processes related to dikes and LMUs.

3.3.1. Simulation of coastal flooding

Modelling coastal flooding remains very challenging, for several reasons. First, this is a multiscale problem, which implies large spatial scales to properly simulate the development of waves and reproduce the effect of atmospheric pressure gradients as well as very fine resolution along the coast to represent dikes and barriers.

[1] Construction costs and municipalities' budgets (© Pays de Marennes – 2012 -www.marennes-oleron.com)

[2] DEM (20 meters resolution), resampled from LIDAR 2010 (1 meter) (© IGN – Litto3D ® 2010 - www.ign.fr)

[3] Current Local Urbanism Plan (PLU) - 2011-2012-2013 - (© Local authorities)

[4] Oléron Seawalls database of RISKS research program from 2014, including dikes condition (© LIENSs – RISKS – 2014)

[5] Oléron Seawalls database from DDTM state department, including dikes elevation (©DDTM 17 -2015)

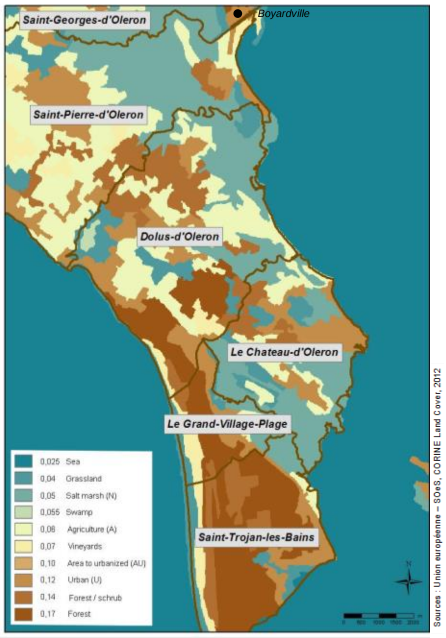

Figure 2. Map of the applied Manning n-roughness coefficients for Oléron Island

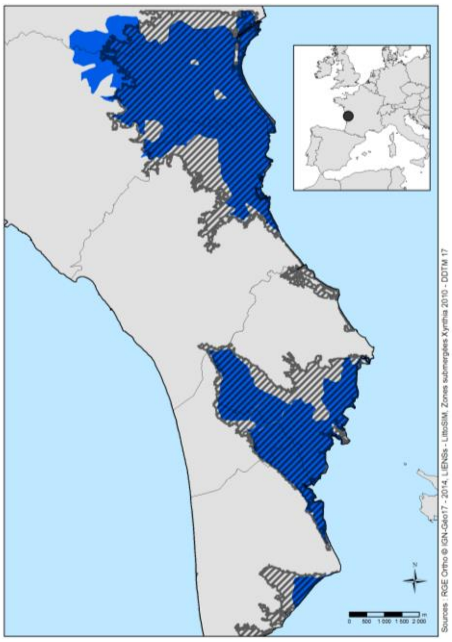

Figure 3. Comparison between the observed (blue) and the modeled maximum extension of the flooding during Xynthia, showing a reasonable agreement although the model overestimates the extension of the flooding.

Second, it is numerically challenging because the dikes and barriers induce very strong gradients and overflowing velocities can reach values above 5m/s. High resolution numerical modelling of coastal flooding associated with Xynthia and accounting for tides surge and waves is under development at UMR LIENSs (Bertin et al., 2014). However, this approach requires very significant computational resources. For LittoSIM application, we needed a flooding simulation model that would operate in real time, in less than 5 minutes. We thus opted for a soft coupling between the spatial simulation environment, GAMA 1.6[6] (Grignard et al. 2013), and LISFLOOD-FP (Neal et al. 2011). The latest is a two-dimensional hydrodynamic model specifically designed to simulate floodplain inundation in a computationally efficient manner over complex topography. The bathymetry of the intertidal zones and the topography used to construct the computational grid originate from a LIDAR survey, carried out a few months after Xynthia. LISFLOOD was forced with time-series of water levels measured at the nearest tide gauge operating during Xynthia (La Rochelle).
Surface roughness has been integrated into the model to improve the accuracy of floodplain inundation. We applied Manning's roughness coefficients from Bunya *et al.* (2010), slightly adapted to land use[7] of Oléron island (Figure 2). The comparison between the observed and the modeled maximum extension of the flooding reveals a fair agreement, although the model significantly overestimated the flooding (Figure 3). In order to quantify the agreement between the model and the observations, we employed the Fit measurements (eq. 1) introduced by Aronica et al. (2002):

$$F = \frac{A}{A+B+C} \qquad (1)$$

Where A corresponds to the area correctly predicted as flooded in the model, B the area predicted as flooded by the model while being dry in the observation and vice versa for C. Equation (1) implies that F can range between 0 (no overlap between model and observations) and 1 (perfect match). This computation yields a fit measurement of 0.66, which is the same order of magnitude as obtained by Bertin et al. (2014) for the same area using a High resolution numerical model. However, this first version of the model was forced with water levels observed in La Rochelle while Bertin et al. (2014) showed that maximum water levels strongly varied in space during Xynthia and were about 0.2 m lower along the study area compared to La Rochelle. Forcing the model with space-variable and more realistic water levels would certainly yield improved flooding predictions.

[6] GAMA is a modeling and simulation development environment for building spatially explicit agent-based simulations

[7] European Union – SOeS, CORINE Land Cover, 2012

3.3.2. Human-computer interactions

The list of actions that can be operated by human players during the simulation is presented in the above section. Here, we describe the interfaces developed to apply those actions. Only the Municipality players can operate actions that have a direct influence on the computer simulation[8]. Following the modeling choices made with our local partners, we developed two separate interfaces for the Municipality player from which he can switch at any time but he cannot display simultaneously (Figure 4).

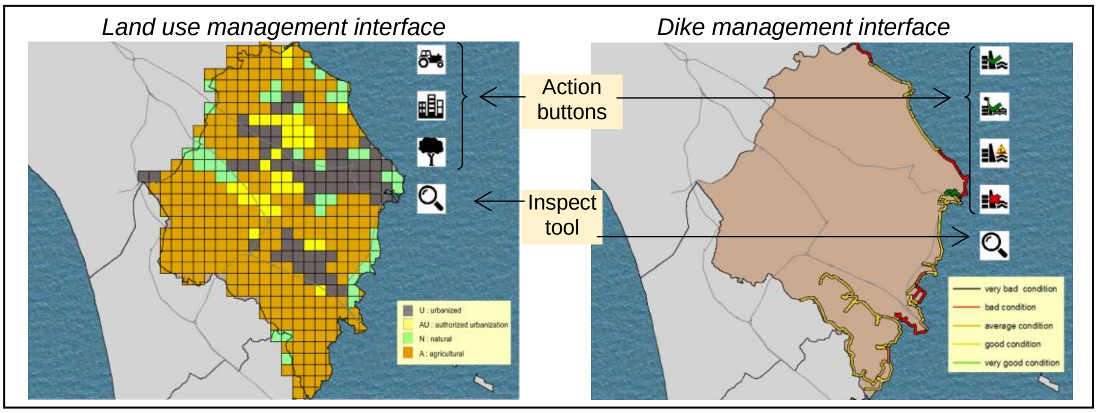

Figure 4. Municipality player interfaces (example of the interfaces of “Le Chateau” municipality)

The human player sees a view of Oléron Island zoomed on the municipality he controls and displaying municipalities’ delimitations and the main roads. With the *“Land use management”* interface, he sees the land use types of his municipality. He can inspect the population and the real estate price of each LMU. With the other buttons he can change the land use. With the *“Dike management”* interface, the player sees the localization of all dikes of his municipality. He has access to information on the condition, type and height of each of them by clicking on the inspect tool. The other tools are to build, raise, repair or destroy dikes.

3.3.3. Evolution processes of dikes and LMUs

A step in LittoSIM simulation corresponds to a one year period. The choice of this time step is justified by the decision-making temporality: budget of administration is allocated from year to year; decision-making (identified in section 3.3.2) therefore follows this periodicity. However, environmental events such as flooding or dyke degradation are considered extemporal because only the space impacts of these events are considered in LittoSim simulation (duration of events is not determinant for long term decision-making). In between each step of the simulation, several variables of the model classes are updated. First, the condition of dikes are updated. Every four steps, dike’s condition decreases of one degree (out of 3) until the worse one, “very bad condition” happens. When a municipality player repairs a dike, its status is reinitialized to the best state “very good condition”. When a submersion event occurs in the simulation, the probability that a damburst occurs varies from 0% to 85% depending on the condition and type of dike. A second process, is the demographic evolution. The simulation is based on the central scenario of the national statistical institute INSEE (2011) for human growth prospect, which estimates a growth by 16% from 2015 to 2040 for Charente-Maritime department (the county to which belongs Oléron Island). We assumed a homogeneous growth distribution and calculated a normalized population increase of 1.5 point per year. This growth rate is applied to each urbanized LMU, until it reaches a maximum of 10.000 inhabitants. LMU also holds calculations for the expropriation cost in case Municipality players operate the action *“change land use from U to A”*. The calculation assumes that land owners are compensated up to the real estate price, as it occurred for example after Xynthia storm in Boyardville city (Figure 2). The value of expropriation was therefore estimated to be the average square meter price known per municipality, normalized per built up square meter in each LMU.

[8] The Community of Municipalities player do not have a specific computer interface. To operate his action on funding collective projects of municipalities, he needs to ask the workshop facilitator to proceed on the main computer.

4. SETTING UP THE PARTICIPATORY SIMULATION

Duke (1974), who set up the foundations of gaming and simulation 40 years ago, defines a gaming/simulation as a *gestalt* communication mode (today we would call it a PS workshop), which combines a game-specific language (e.g. game rules), appropriate communication technologies (communication channel by which participants transmit and receive messages) and the multilogue interaction pattern (the multiple, simultaneous dialogue among members of a group that takes place during a gaming/simulation workshop). In the previous section, we presented the game rules. In the next section we report on the outcomes of the multilogue interactions that occurred during the first LittoSIM workshop organized with stakeholders. Here, we describe the design of the environment in which the interactions took place and how it contributes to define the communication channel. The LittoSIM workshop takes place in a large room and last for about three hours (30 minutes briefing, 100 minutes of simulation and 50 minutes debriefing).

4.1. Different spaces to tackle submersion consequences and prevention

In accordance with our modeling choices, we define two separate dialogue spaces in the room where the workshop took place. One is the place and time of planning during which the municipality players are seated at separate desks. On each desk, players use a computer tablet displaying the interfaces of the concerned municipality (Figure 4), access to information and act within their municipality limits. Yet, participants can move and communicate with the other municipality players and their collaboration is facilitated by the Community of Municipalities player who has a desk in the same room. The second dialogue space is dedicated to submersion events. It is located on the opposite side of the room. When a submersion event occurs, players are asked to move from one side of the room to the other, and to gather around a large table on which the submersion simulation is displayed. Players first watch where the submersion simulation takes place, then access the submersion results for each municipality (Figure 1), and then discuss collectively about those results, their causes and consequences, and what to do next. When this is over, players go back to their respective desks and a new planning phase begins.
To operate this set up, we use a distributed control of the simulation. The computer running the simulation model is placed on the side of the room where submersion simulations are displayed and the controls for each municipality are distributed remotely by Wi-Fi to the tablets located on the opposite side of the room. In order to have a favorable environment for dialogue around the submersion event, the flooding simulation is displayed horizontally on a table using an ultra-short throw projector allowing participants to see the others and the submersion at the same time.

4.2. Different times to experience coordination issues between municipalities

The PS set up aims at inducing a progressive understanding of the coordination issues between municipalities. It was therefore organized into three different consecutive phases. The first phase is the discovery of the simulation environment and of the submersion prevention issue. It starts with showing a first submersion event, then 5 years of simulated management. During this first phase, the Community of Municipalities player is not allowed to communicate with the others. It represents the situation of Oléron before the creation of the Community of Municipality in 2005. Then a second submersion event is simulated which marks the transition to the second phase. During that phase, the Community of Municipalities is operational and players experience a new communication pattern, moving from a star-network pattern to a core-network pattern (Duke 1974). This second management phase last for 3 simulated years. After a new submersion event simulation, the third management phase starts and lasts for 6 simulation years. At this stage, we assume that players had enough experience in the previous phases to identify the coordination problems, and this last management phase aims at establishing an effective coordination system between participants. This phase actually corresponds to the last stage of Kolb's experiential learning cycle (1984), which is the *active experimentation* stage following a reflective stage. The third phase ends with a last submersion event simulation for participants to evaluate the effectiveness of the management decisions they took. A debriefing follows.

4.3. Experiential learning debriefing

The debriefing of the participatory simulation is organized as a round table discussion covering the three current limits of coastal flooding management identified above. We first ask participants what they learned through the simulation about the diffusion process of coastal flooding in Oléron. Then, we question them on the strategy they followed in the simulation to prevent their Municipality from flooding, and if they encountered difficulties to apply it. We ask them which strategy between reinforcing dikes protection or strategic withdrawal they think is best and which one is most suitable on a long term perspective. The third and last topic is about the need for more coordination between municipalities: did they feel such a need during the simulation, did they encounter difficulties and how could they overcome them. The debriefing ends the workshop.

5. RESULTS FROM A FIRST APPLICATION

5.1. A first test workshop with stakeholders

A first LittoSIM workshop was organized with local stakeholders of Oléron in December 2015. The objective was to test the tool in real operating conditions and assess if it could drive participants to a higher risk culture. Two aspects were assessed. One is to know if watching the submersion simulation live, with the progression of the flooding area, would be an impressive element for participants. The second was to see whether the three targeted learning topics mentioned above were achieved. Twelve persons participated to a 3 hours and half workshop. Some were elected bodies, other were local officials or risk managers of Oléron Municipalities and of the Community of Municipalities. They were selected according to their interest for the issue and their availability. Participants were allocated to the different roles of the simulation (4 Municipalities and one Community of Municipalities) in such a way that everyone plays a different role than the one they have in the municipality they belongs to. In addition to the workshop set up described in the previous chapter, there was a workshop facilitator who explained the rules, answered questions, and kept time, as well as other organizing fellows who played the role of a coastal flooding expert answering participants technical questions, and of the State Authority answering participants questions on regulation aspects.

5.2. Stakeholders feedback on LittoSIM workshop and aspects to improve

A first feedback from the workshop participants is that the simulation environment is very immersive, especially thanks to the use of the ultra-short throw projector that displays the coastal flooding simulation horizontally on a table where participants are standing around. This placement made a dramatic setting that was strongly felt by participants. They were very attentive and concerned by the water level rise and its expansion which was made very obvious on the wide projected map. A learning by observing process occurred. After watching the flooding simulation, participants were eager to exchange their impressions and shared information or proposals. These results validate our objective to reinforce the learning experience through an environment that favors Kolb's learning cycle (1984).
Regarding our targeted learning topic on flooding process, it first must be clear that the participants of the workshop have a very good knowledge of submersion events. They all work with flood risk maps based on the flooding extend of Xynthia and some of them even work with coastal flooding models. Yet seeing a simulation model operating live was something new for most of them and they learned about the water expansion dynamic. They were also very interested in the possibility of testing the effects of building raising and restoring dikes live and direct. Nevertheless, this learning aspect did not work as planed due to the interfaces that did not allow participants to precisely know the maximum elevation of

the dikes they were managing all along the shore[9].
Regarding our goal to foster learning on alternative prevention measures (others than building or reinforcing dikes), participants' feedbacks showed evidence of a mixed success. The dissymmetry between the land use management interface and the dike management interface allowed to clearly distinguish the two strategies in participant's mind. It gave direction to the debate during the debriefing and helped to initiate discussion on a long-term or short-term coastal flood risk management. However, during the simulation participants hardly tried to implement innovative strategies such as giving more room for flood expansion or expropriate houses in flood-plains. This can be explained by the shortcomings of the current LittoSIM version. It was made too easy for participants to build dikes due to an excessive available budget and because it did not take into account operational constraints. Participants also mentioned that the model lacks to represent the administrative procedures for expropriation and implementation of strategic withdrawal which makes it unrealistic and inadequate for learning on such prevention measures.
Finally, participants reported that the simulation game was very interactive and favors many interactions between participants. Some of them tried to develop coordination strategies, quite unsuccessfully because the players focused on improving dikes and were not constrained enough. Participants validated the model as being appropriate and confirmed the learning process on horizontal coordination between municipalities is operational. Regarding vertical coordination (Figure 1), it was partly implemented when the workshop took place and there are no results to report on presently.

6. CONCLUSION AND PERSPECTIVES

LittoSIM is a simulation game where stakeholders play land planning actions of four coastal municipalities prone to marine submersion risk. The model makes the players interact with computerized events, such as the water rise and socio-economical evolutions. The prototype aims at testing the educational potential of such a tool and at enhancing methods of participatory simulation within risk prevention. The first live test of LittoSIM enables removing several methodological and technological obstacles.
A main challenge was to integrate a coastal flooding simulation model in a participatory workshop setting that requires the simulation to execute in a short period of time while maintaining a fair accuracy. This objective was successfully reached, using a soft coupling between a multi-agent spatial simulation environment and a two-dimensional hydrodynamic model which allows to compute a coastal flooding caused by a storm such as Xynthia in less than 4 minutes. Thanks to this performance, workshop participants can interactively and playfully try, experience and understand the effects of different risk prevention measures. Moreover, uses of a distributed control of the simulation and of an ultra-short throw projector for displaying the flooding simulation reinforced the immersive environment and proved to be very efficient to foster social learning. It also allowed featuring situations of asymmetric interactions between participants, encouraging learning about coordination with others, as showed by Becu et al. (2015).
Still, the current version of LittoSIM fails to help decision-makers change their mindset on risk prevention measures. If applied with an audience with very little experience of coastal risk prevention, we expect that the participatory simulation would reach its goal and participants would learn about coastal flooding processes and alternative prevention measures (as already tested). But when played with local decision bodies of Oléron Island, participants are keener on reproducing the current prevention strategies, rather based on dikes construction they already experienced, than trying alternative options. Such attitude corroborates a number of institutional reports (Anziani, 2010; IFEN 2011) and scientific papers (Cartier, 2004; Goeldner-Gianella, 2010) that demonstrate the poor risk culture and the great reluctance of local authorities to change.
Our perspectives are now on improving LittoSIM model to better integrate a number of elements, which refrain participants to get off the beaten tracks. It includes the need to take into account constraints linked to the duration of the land planning procedures (impact studies, authorizations), a larger choice of actions and a better determination of the cost of each action (in time or in value). We also consider incorporating facilitation methods that would force participants to try alternative prevention measures; which would turn the model towards an education tool-like application.

[9] In LittoSIM current version, the user interface displays the dikes in a 2D bird's eye view and provides information on dikes' height but not on their elevation above sea level.

ACKNOWLEDGMENTS

The authors are grateful to the SPRITE group of MAPS network research seminar for their inspiring prototype.

REFERENCES

Anselme B., Durand P., Thomas Y.F., Nicolae-Lerma A., 2011. Storm extreme levels and coastal flood hazards. A parametric approach on the French coast of Languedoc (district of Leucate). Comptes rendus géosciences 343 (10), 677-690.

Anziani, A., 2010. Xynthia : une culture du risque pour éviter de nouveaux drames, Rapport d'information de M. Alain ANZIANI, fait au nom de la mission commune d'information sur les conséquences de la tempête Xynthia, Rapport du Sénat n° 647.

Aronica, G., Bates, P. D., and Horritt, M. S., 2002. Assessing the uncertainty in distributed model predictions using observed binary pattern information within GLUE. Hydrological Processes 16, 2001–2016.

Banque Hydro: Online French hydrological database accessible at ttp://www.hydro.eaufrance.fr/, (last access: 15 November 2012), 2012.

Barreteau, O., Bousquet, F., Etienne, M., Souchère, V., d'Aquino, P., 2011. Companion modelling: a method of adaptive and participatory research. In: Etienne, M. (Ed.), Companion Modelling: A Participatory Approach to Support Sustainable Development. Quae Editions, Versailles, pp. 21–44.

Becu, N., Frascaria-Lacoste, N., Latune, J., 2015. Experiential learning based on the NewDistrict asymmetric simulation game: results of a dozen gameplay sessions. In: Hybrid Simulation & Gaming in the Networked Society: The 46th ISAGA Annual Conference. Kyoto, Japan, pp. 84–90.

Bertin X., Bruneau N., Breilh J.-F., Fortunato A.B., Karpytchev M., 2012. Importance of wave age and resonance in storm surges: The case Xynthia Bay of Biscay. Ocean Modell. 42, 16–30.

Bertin, X., Li, K., Roland, A., Breilh, J.F., Zhang, Y.L. and Chaumillon, E., 2014. A modeling-based analysis of the flooding associated with Xynthia, central Bay of Biscay. Coastal Engineering 94, 80-89.

Bunya S., Dietrich J.C., Westerink J.J., Ebersole B.A., Smith J.M., Atkinson J.H., Jensen R., Resio D.T., Luettich R.A., Dawson C., Cardone V.J., Cox A.T., Powell M.D., Westerink H.J., Roberts H.J., 2010. A High-Resolution Coupled Riverine Flow, Tide, Wind, Wind Wave and Storm Surge Model for Southern Louisiana and Mississippi. Part I: Model Development and Validation. Monthly Weather Review 18 (2), 345-377.

Cariolet, J.M., Suanez, S., 2008. Approche méthodologique pour une cartographie du risque de submersion des côtes basses. Actes du congrès SHF « Nouvelles approches sur les risques côtiers », Paris, France, 8 p.

Cartier, S., 2004. Implications du public face aux risques naturels, délégation aux pouvoirs publics ou construction locale des politiques participatives ? In de Larjartre A., Gaboriau V. (Eds), Les collectivités territoriales face aux risques physiques. L'Harmattan, collection logiques juridiques, pp. 141-155.

Duke, R.D., 1974. Gaming: The future's language. SAGE, London.

Garry, G., Graszk, E., Toulemont, M., Levoy F., 1997. Plan de prévention des risques littoraux (PPR), Guide méthodologique, Paris, La documentation française.

Goeldner-Gianella, L., 2010. Changement climatique et dépoldérisation : le rôle des acteurs et le poids des représentations sociales sur les côtes d'Europe Atlantique. Quaderni 1, 41–60.

Grignard, A., Taillandier, P., Gaudou, B., Vo, D-A., Huynh, N-Q., Drogoul A., 2013. GAMA 1.6: Advancing the Art of Complex Agent-Based Modeling and Simulation. In 'PRIMA 2013: Principles and Practice of Multi-Agent Systems', Lecture Notes in Computer Science, Vol. 8291, Springer, pp. 117-131.

Haut Comité Français pour la Défense Civile (HCFDC), 2012. Risques et menaces exceptionnels. Quelle préparation ? Rapport d'activité 2011, 139 p.

Institut National de la statistique et des études économiques (INSEE), 2011. Projections départementales et régionales de population à l'horizon 2040.

Institut Français pour l'Environnement (IFEN), 2011. Les risques naturels et industriels sur le littoral. Commissariat général au développement durable, service de l'observation et des statistiques. Rapport de mai 2011, pp. 131-155.

IPCC, 2007. Working Group I: The physical basis of Climate change. Contribution of working group I to the Fourth Final report.

IPCC, 2014. Climate Change, 2014. Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, edited by Pachauri, R.K., and Meyer, L.A.]. IPCC, Geneva, Switzerland, 151 p.

Jousseaume, V., Mercier, D., 2008. Évaluer la vulnérabilité architecturale de l'habitat en zone inondable, exemple du Val nantais. Colloque Vulnérabilités sociétales, risques et environnement, Toulouse, France.

Kolb, D.A., 1984. Experiential learning: Experience as the source of learning and development. Prentice-Hall, Englewood Cliffs, NJ.

Klabber, J.H.P., 2009. The magic circle: Principles of gaming & simulation. Edited by Jan Klabbers, British Journal

of Educational Technology. KPMC, The Netherlands.
Le Page, C., Abrami, G., Barreteau, O., Becu, N., Bommel, P., Botta, A., Dray, A., Monteil, C., Souchère, V., 2011. Models for sharing representations. In: Etienne, M. (Ed.), Companion Modelling. A Participatory Approach to Support Sustainable Development. Quae, pp. 69–96.
Marshev, V., Popov, A., 1983. Element of a theory of gaming. In: Ståhl, I. (Ed.), Operational Gaming: An International Approach. Pergamon Press, Oxford, pp. 53–59.
Meadows, D., 1986. Fish Banks, Ltd. Institute for Policy and Social Science Research, Durham, NH.
Neal J., Schumann G., Fewtrell T., Budimir M., Bates P., Mason D. (2011). Evaluating a new LISFLOOD-FP formulation with data from the summer 2007 floods in Tewkesbury, UK. Journal of Flood Risk Management, 4, 88-95.
Observatoire National sur les Effets du Réchauffement Climatique (ONERC), 2010. Prise en compte de l'élévation du niveau de la mer en vue de l'estimation des impacts du changement climatique et des mesures d'adaptation possibles. Rapport de synthèse, Direction Générale de l'Energie et du Climat, MEDDE, 6 p.
Velasquez, G., 2015. Building a Global Disaster Resilience Model, in: ISAGA 2015: Hybrid Simulation and Gaming in the Network Society. pp. 44–74.
Voinov, A., Bousquet, F., 2010. Modelling with stakeholders. Environmental Modelling and Software 25, 1267–1488.