

## **Titre du projet : Prévoir les impacts des événements hydrométéorologiques en intégrant la vulnérabilité sociale dans les modèles de prévision**

*Volet* : Recherche

*Porteur du projet* : Isabelle Ruin

*Laboratoires impliqués* : LTHE, PACTE, National Severe Storm Laboratory (NSSL), Disaster Research Center (DRC)

## **Bilan du projet pour l'année/la période**

### **Bilan d'activité** (1 page max)

For forecasters and emergency managers the prediction of human impacts due to such a sudden onset and localized event as Flash Flood remains a challenge. The starting point of our research is that the resonance of the spatial-temporal context of the hazard with the distribution of people and their characteristics across space and time reveals different paths of vulnerability and defines the final picture of an exposed area in terms of deadly impacts. In the case of flooding fatalities, for instance, the elderly are often said to be the most vulnerable, but when fatalities are mapped against basin size and response time, it has been shown that in fact it is young motorist who are most likely to be killed in flash flooding of small catchments, whereas the elderly most frequently perish in their homes from large scale fluvial flooding. In addition to that, impacts in terms of loss of life are very much related to the space-time distribution of the everyday life social activity. It means that, depending on contingent conditions (e.g. rush hours when there are errands to run and children to pick up and lots of other cars on the road, or working hours when people feel they must be at work regardless of the conditions) perception of environmental cues and warning messages may be hindered emerging different causes and outcomes of social vulnerability.

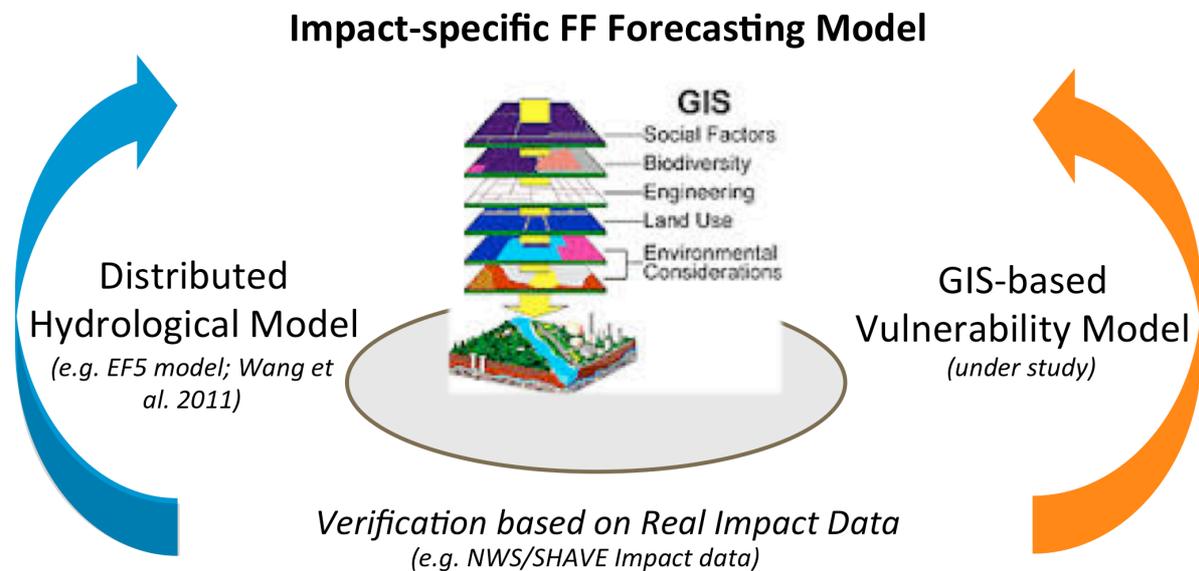
Unfortunately, flash flood monitoring and prediction tools (e.g. distributed hydrologic models) do not incorporate social vulnerability. In this work, we seek to develop an impact-specific forecasting tool that will integrate flash flood forecasting hydrological modelling with information about the social vulnerability of the exposed population. To do so, we need to i) measure and map index-based vulnerability scenarios that describe the space-time variability of the vulnerability level; ii) explore the link between the vulnerability levels resulted from different vulnerability scenarios with the level of human impacts; iii) combine the space-time vulnerability indices with the available distributed hydrologic models to test the efficacy of such integrated models in reproducing the impacts of selected past catastrophic events.

Galatia Terti's first year of research was dedicated to the understanding of the root vulnerability causes and to identification of the available dataset to measure social vulnerability to FF. Available literature was reviewed to support our research framework and to provide the required hypothesis for the FF vulnerability assessment. The main output of this phase is the submission of a scientific paper that conceptualizes the dynamic aspect of social vulnerability during a FF event (Terti et al., 2015). Furthermore, social (i.e. population socio-economic profile), exposure (i.e. population distribution, land

use), and physical (i.e. built and natural environment) information from various data sources in US have been explored. Especially, we focused on exploring different US census datasets to find out the available socio-economic variables relevant to describe our assumptions in social vulnerability measurement. In the second year of the PhD, human impact data were analyzed to in order to examine the circumstances in which they occur and identify proxy variables that could be tested as human risk predictors.

In addition to facilitating research development, the Labex OSUG@2020 research funds allowed Galateia Terti to attend two international summer schools to acquire new knowledge and techniques in developing interdisciplinary social-physical sciences projects and using complex system modelling (Agent-Based modelling, Cellular automata, Complex networks and Spatial statistics).

**Illustrations** - avec légende et crédit (*à envoyer également séparément*)



*Terti, G., 2014. Synthetic schema of the concept of the project*

# Dynamic Vulnerability: Space-Time vulnerability factors considering flash flood events

Galateia Terti

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**Abstract:**

The purpose of this research is the identification of the human-dependent vulnerability factors and their spatio-temporal scales that can alter the type and social distribution of Flash Flood (FF) events' impacts. Unlike previous studies, in this research vulnerability is not considered as a static picture/evaluation of a place or system but as an ever evolving process built from the interaction of social and physical dynamics across scales. Understanding the vulnerability processes and their dynamic interrelation in space and time is the first step towards the reliable quantification of FF spatial-temporal vulnerability. Based on this analysis, factors could be converted into relevant variables to serve as vulnerability indicators to measure and map dynamic vulnerability using the appropriate models and tools. In this way, this research could be a valuable tool for FF impacts prediction and forecasting approaches.

**1. Introduction**

**Global Environmental Change:** last decades FFs tend to increase with the increase of the climate change-related extreme precipitation as well as the progressive urbanization (De Roo et al., 2003).

**Flash Flood:** short-term inundation, occurring within 6 hours of the causative event (heavy rain, dam/break, levee failure, snowmelt and ice jams) and often within 2 hours of the start of high intensity rainfall (NOAA/NWS).

- ✓ Little or no warning
- ✓ Fast speeds
- ✓ Peak reach in a few minutes

**Vulnerability:** people's and property's susceptibility to harm due to their exposure to a specific hazard (Cutter et al., 2003).

- ✓ Most of the weather-related fatalities in US & Europe
- ✓ Damages to vehicles, road network, bridges & buildings (NOAA; Jonkman, 2003)

What are the main drivers of FF consequences?



**Social-environmental interactions** (Montz and Gunttst, 2002; Ruin et al., 2008; Creutin et al., 2009)

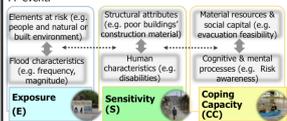
Need for **integrated study** of the multiscale natural & the human-related attributes (Turner et al., 2003; Adger, 2006)

What are the social-environmental vulnerability factors & their related scales that determine the spatio-temporal dynamic variability of vulnerability?  
How does the type of hazard (space & time scales) affect vulnerability & determine the FF impacts?

**2. Flash flood hazard-specific dynamic vulnerability**

**Dynamic vulnerability:**

continuous changes of physical & social characteristics as well as of their interactions in space (s) & time (t). Dynamic vulnerability encompasses the complex upwards or downwards linkages between social or natural processes, themselves as well as their interactions that make people & property susceptible to harm when they are exposed to a FF event.



$$Vulnerability = f(E(ts); S(ts); CC(ts)); (ts))$$

**Flash flood Spatial & temporal scale:**

- Sudden onset:** Hits anywhere & needs less than 6h (or less than 1h) from the rainfall start.
- Fast moving:** The rainfall intensity (storms) contributes to high flow rates within short duration (e.g. hours).
- Localized:** Occur usually over small catchments (a few km<sup>2</sup>).

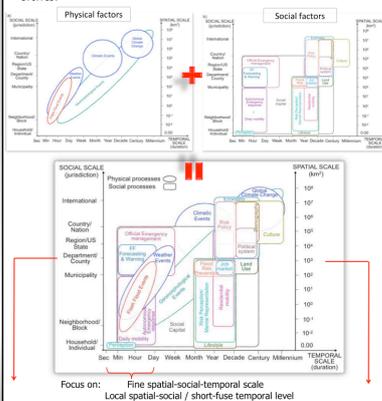
- ✗ In contrast with river flooding where the proximity to streams and rivers indicate a potential risk level, the spatial distribution of very small drainage areas prone to FF, limits the efficacy of flood zoning measures for FF prevention.
- ✗ Forecasting ability to predict the exact location of FF with much warning lead-time is hindered. Unlike river floods where extreme discharges can be predicted in advance and people have adequate time to move to safer places (i.e. higher grounds), the early and accurate FF prediction is a big challenge.
- ✗ The space-time scale of flooding alters the dynamic of the phenomenon and provokes differences in vulnerable targets. Such a dynamic and fast event has more chance to trap people in their vehicle or during activities in the open air especially during rush hours.

**3. Scales of Flash flood vulnerability factors**

**Scaling issue:** features related to physical & social science vary from local areas to global earth and from individual perspectives to international collective actions, respectively, depending on the time frame of reference (Gibson et al., 2000; Cash et al., 2006)

**Scales & levels of study:**

- ✓ **Spatial scale:** What is the geographical extent of physical/natural origin processes?
- ✓ **Social scale:** What is the jurisdictional level or the social network that is responsible for each social process?
- ✓ **Temporal scale:** How much a process lasts and so, how slow or fast it evolves?



**4. Discussion & conclusions**

**Vulnerability to FF is the result of:**

- ✓ **Environmental factors** related to global climate change (e.g. global warming/extreme precipitation increase) & the environmental change (e.g. land use change)
- ✓ **Social factors** related to human decisions (e.g. population growth in (or near) flood prone areas/ human behavior during crisis)

**Integrated vulnerability analysis:**

- **Need for multi-scale & multilevel interdisciplinary perspective**

Most of the processes that are critical for vulnerability to FF do not belong to the same level of one scale (e.g. spatial or temporal)

Focus only on the FF spatio-temporal level will lead to loss of information.

The variety of processes' nature (e.g. natural, anthropogenic, social) implies for using a variety of scales (e.g. spatial/social)

The scales need to be compatible & comparable.

- **Need for dynamic consideration of the vulnerability processes**

Every process varies across a spatial or temporal range  
Every spatio-temporal level does not constitute a point but has an extent.

Processes that take place in scales similar to the spatial-temporal context of the phenomenon under study can be characterized as the most dynamic

Changes in higher or lower levels provide possible constraints or further subdivisions of the studied problem, respectively.

Terti, G., 2014. Poster presented at the Water and Society summer school, May 11-17, Oléron, France.

**Production scientifique (articles scientifiques, actes de congrès...)**

Terti, G., Ruin, I., Anquetin, S., Gourley, J.J., 2015. Dynamic vulnerability factors for impact-based flash flood prediction. *Nat. Hazards*, **79(3)**, 1481-1497.

Terti, G., Ruin, I., Anquetin, S., Gourley, J.J., 2016. A Situation-based Analysis of Flash Flood Fatalities in the United States. *Bull. Amer. Meteor. Soc.* doi:10.1175/BAMS-D-15-00276.1, in press.

Terti, G., 2014. Forecasting of flash flood impacts integrating the space-time distribution of social vulnerability. Invited seminar at UTSA ESE, November, 21, San Antonio, Texas.

Terti, G., 2014. Dynamic Vulnerability: Space-Time factors considering flash flood events. Poster at Water and Society summer school, May 11-17, Oléron, France.

**Bilan financier succinct** (avec suivant les cas : co-financements éventuels, équipements achetés, missions, recrutements divers, fonctionnements divers...)

<b>Objet de la dépense</b>	<b>Date</b>	<b>Montant</b>
Participation G. Terti à l'école thématique Water and Society	11-17 Mai 2014	500€
Participation G. Terti à l'école thématique Spatial Structures and Dynamics	14-19 juillet 2014	791,66€
Séjour de travail avec le partenaire américain – frais de déplacement	Novembre 2014- printemps 2015	1072,28€
Participation aux frais de publication Le National Severe Storm Laboratory (NSSL) participera à 50% du coût final de publication.	2015	1136,06€

**Annexes si besoin ou lien sur des sites existants et pérennes jusqu'à la fin du Labex (2020)**