PICS: towards Integrated Nowcasting of Flash Flood Impacts

PICS: vers une prévision immédiate intégrée des impacts des crues soudaines

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Project summary

Flash-flood forecasting is of crucial importance to mitigate the devastating effects of flash-floods. However, its development has experienced serious setbacks, due to the large number of affected catchments, their small surface areas (1 to 500 km²), their very short response times (limited to a few hours), and the limited knowledge of the assets being exposed. First operational flash flood warning systems have recently been implemented in France and other countries. Nevertheless, the capacities of these systems can still largely be improved (limited anticipation, limited geographic coverage, impacts not represented). In this context, the PICS project proposes a step forward by designing and evaluating integrated forecasting chains capable of anticipating the impacts of flash-floods with a few hours lead-time. This objective will be reached through interactions between varied scientific teams (meteorologists, hydrologists, hydraulic engineers, economists, sociologists) and operational actors (civil security, local authorities, insurance companies, hydropower companies, transport network operators). The integrated short-range forecasting (or nowcasting) chains designed in the project will incorporate the following components: high resolution quantitative precipitation estimates and short range precipitation forecasts (or nowcasts), highly distributed rainfall runoff models designed to simulate river discharges in ungauged conditions, DTM based hydraulic models for the delineation of potentially flooded areas, and finally several impacts models aiming to represent varied socio-economic effects: insurance losses, inundation of critical infrastructures, and also dynamic population exposure and vulnerability. The project will work towards: effectively coupling these various modelling components, evaluating these components in terms of uncertainties and complementarity, and finally assessing the capacity of these nowcasting chains to meet the end-users needs. A particular attention will be put on the consistency across the various components of these

chains, in terms of variables used, spatial and temporal resolutions, application scale, and degree of uncertainty. One critical aspect of the project will also be the validation of the results based on case studies. The small ungauged basins context, indeed, is generally synonym of serious data scarcity. For this reason, a particular effort will be devoted in the project to the gathering of appropriate validation datasets (impacts, flood areas, etc.) and to define relevant validation strategies. The project will include case studies related to recent extreme rainfall events observed in the French Mediterranean area: June 2010 floods in the Argens basin, September-October 2014 floods in the Gardons, Vidourle, Hérault and Lez watersheds, and October 2015 floods in several small basins in the Alpes Maritimes territory. This list of case studies will be complemented at the beginning of the project based on the exchanges with the end users. The project will also entail significant efforts to improve and adapt the different components involved in the modelling chains: improvement of distributed hydrological modelling in ungauged conditions, qualification of uncertainties on discharges estimates based on rainfall observations and nowcasts, improvement of 1-D approaches and test of a 2-D model for large scale automatic hydraulic computations, and finally adaptation of the impacts models to take benefit from information on flooded areas provided by the forecasting chain. Considering this work program, the project should enable significant breakthroughs in the field of integrated flash floods impacts nowcasting. The wide representation of potential end users in the project, as members of the end-users group and as project partners, should finally facilitate the transfer of project results towards operational applications.

Mains changes introduced in the full proposal compared to the pre-proposal

A great effort has been made to limit the project budget to the strict necessary. For this reason, half a PhD grant has been removed from the requested funding, considering the possibility the possibility to get complementary grants elsewhere. Consequently, the project duration has been extended to 48 months, to provide the time necessary for the mobilization of these additional means, and considering that at least one PhD involved in the project will not begin before the autumn of 2018.

I. Proposal's context, positioning and objective(s)

I.1. Objectives and scientific hypotheses

Flash floods are among the most devastating and dangerous natural phenomena, especially in Mediterranean regions where extreme rainfall events are the most frequent in Europe (Gaume *et al.*, 2009). The most recent major flash flood occurred on October 3rd 2015 in the Alpes-Maritimes region in France (20 deaths, €600 million damages), strikingly illustrated again the necessity to better anticipate these floods and especially their possible impacts. The development of new immediate forecasting ("nowcasting") systems, providing sensible information at the appropriate time and space scales, is considered of critical necessity to strengthen the coping capacity of the population and crisis management services to these flash floods (Creutin *et al.*, 2009; Borga *et al.*, 2011; Gourley *et al.*, 2014).

The production of sensible forecasts, in terms of rainfall intensity and spatial location, magnitude and timing of flood peak discharges, and also extent of flooded areas along the river network and corresponding possible impacts (risks to lives, economic losses), remains a key challenge for operational forecasting services (Pagano *et al.*, 2015). This objective is extremely difficult to reach in case of flash floods, due to the speed at which the meteorological context evolves and the catchment basins respond, as well as to the multitude of small watercourses potentially affected. First operational flash flood warning systems have recently been implemented in France (APIC rainfall service in 2013 and *Vigicrues Flash* in March 2017). But these new services only still offer partial geographic coverage, too limited anticipation capabilities, and no estimation of possible flash-flood impacts. Further improvements are thus necessary, and require a coordinated involvement of different disciplines, including: meteorology (formation of intense precipitation), hydrology (apparition of flood surges along watercourses), hydraulics (overflows in flood plains), economics (property damage evaluation), and human geography (exposure and vulnerability of the population and society). The PICS project aims to tackle this challenge, by designing a full forecasting suite for anticipating up to 3-6 hours in advance the impacts of flash floods. This objective requires to combine and improve each of the following methods:

- the rainfall nowcasting methods, which should provide rainfall forecats at high time and space resolutions in the 0-6 h anticipation range, and the explicit quantification of the corresponding uncertainties (Vincendon *et al.*, 2011; Alfieri *et al.*, 2011; Liguori *et al.*, 2012; Caseri *et al.*, 2015). Rainfall nowcasts should combine extrapolation techniques based on quantitative radar estimates for 1 or 2 hours lead-times, and numerical weather prediction for lead times up to 6 hours (Auger *et al.*, 2015);
- the flood forecasting methods based on robust and regionalized hydrological models. These methods should be able to simulate flood discharges in all small ungauged headwater streams (i.e. 1-500 km²). The use of proxy data (flood impact data) in ungauged areas for the calibration and validation of these models is a particular challenge (Randrianasolo *et al.*, 2010; Naulin *et al.*, 2013; Javelle *et al.*, 2014);
- the hydraulic modelling methods for the automatic computation of reasonably accurate inundation maps (Pons *et al.*, 2014). These methods should provide results for a large range of discharge values (flood magnitudes), and over an extended and dense river network including small headwater streams (Le Bihan *et al.*, 2016). The limits of the available topographic and bathymetric data and the possibilities of the new high resolution acquisition devices have to be evaluated;
- lastly, the methods enabling the evaluation of impacts in inundated areas, based on first-hand knowledge and dynamic representation of the exposure and vulnerability of individuals and property across a given territory. These methods should account for the strong variability over time and space (Ruin *et al.*, 2014; Terti *et al.*, 2016; Debionne *et al.*, 2016; Shabou *et al.*, 2016).

Significant breakthroughs have been achieved on each of these issues over the recent years, by the various teams involved in the PICS project. Until now however, progress has remained somewhat compartmentalized. Therefore, the PICS project aims at gathering this individual know-how to design and test first integrated flash-flood impacts forecasting chains. This objective entails (1) establishing an appropriate coupling of the various models, with data requirements and complexity levels adapted to the nowcasting context; (2) assessing the uncertainty and complementarity of the different modelling steps based on advanced validation strategies; (3) adapting the completed chains to fulfill the end user's operational needs. This will be achieved through the contribution within a single project of partners from the various necessary scientific fields (meteorologists - hydrologists - hydraulic engineers - economists - geographers), alongside operational actors (crisis managers, insurers, infrastructure managers, citizens).

Finally, the PICS project is expected to provide significant advances on the following aspects:

- understanding and specifying the needs of various possible users of flash flood forecasts: civil security agencies, transportation network managers, insurance companies, and residents;
- design of several integrated forecasting chains complying to the different end user’s needs (type of impacts to be represented, intended use of information). The key challenge here will be to guarantee consistency across the various components of each chain: the variables used, resolution, accuracy, representative scales, physical approximations;

- the use of new data sources that until now had gone unused or underutilized to validate flood impacts predictions: incoming calls and responses by fire safety teams, insurance claims, activity recorded on social media, post-event field investigations;
- the identification of the primary limiting factors (e.g. input data, performance of the components of the chain) by means of sensitivity analyses.

I.2. Originality and relevance in relation to the state of the art

The main originality of the PICS project lies in the combination of varied modelling approaches for the design of continuous and integrated forecasting chains: short range rainfall nowcasting, distributed rainfall-runoff modelling, hydraulic modelling, and finally flood impacts modelling. The combination of these methods will nevertheless raise important scientific questions in each of the related research fields, which will be addressed during the project. These contributions of the project in relation to the state of the art are detailed hereafter.

High resolution rainfall observations, short-range rainfall nowcasts and their combination in hydrological modelling

As far as the requested anticipation range does not exceed the catchment response time, hydrological forecasts can be based on rainfall observations. Weather radar are now able to provide high frequency quantitative precipitation estimates (QPE), such as the French PANTHERE network that covers the whole France at a 5-minute time step (Tabary et al, 2013). Moreover, QPE based on merging rain-gauge measurements and weather radar data have been improved in the recent years, for instance relying on methods like kriging with external drift (Velasco-Forero et al., 2009; Berndt et al., 2014; Delrieu et al., 2014), in which raingauge data constitute the main variable and radar data are used to compute the external drift. Methods to estimate the uncertainties of QPE at each radar pixels are currently designed (Laurantin, 2008, 2013). This information may be used to drive high resolution hydrological models. **The PICS project will investigate the added value of this new information on rainfall measurements uncertainties for hydrological modelling**.

For longer forecast ranges, rainfall nowcasts are becoming available in real time, coming from convection resolving numerical weather prediction (NWP) models. Those NWP models allow to anticipate small-scale phenomena thanks to kilometric resolutions and to the assimilation of high-resolution data (Doppler radar reflectivities, etc.). Their use for very short range forecasting implies a rapid update cycle (generally 1 hour) with a short time assimilation window. Several meteorological centers in the world run convection resolving NWP models in operations with update cycles of 3 to 6 hours for short-range forecasts purpose: the UK Met Office Unified model used at a 1.5-km resolution (Ballard et al., 2011) produces forecasts to 36 hours ahead; in the US, the Rapid Refresh system of NCEP uses the WRF model at a 3-km resolution for nowcasting (Weygandt et al., 2008); the Japan Meteorological Agency, the DWD in Germany, also configure their models for nowcasting purposes. In France, the AROME–NWC model has been developed by Météo-France (Auger et al., 2015). AROME–NWC is a version of the AROME mesoscale model dedicated to 0-6h ranges. It has been running operationally at Météo-France since March 2016. Its lateral boundary conditions and first-guess come from the AROME-France model. Its observation window length is +/-10 minutes and its cut-off time is very short. This allows assimilating high frequency radar data. A meteorological forecast ranging from 1 to 6 hours is produced every hour (at H+35 minutes). The outputs frequency is 15 minutes. These innovative rainfall nowcasting products open broad prospect for flash-floods forecasting since their resolutions make it possible to drive highly distributed hydrological models. Such hydrometeorological forecasting chains have been implemented for instance with the ISBA-TOP system (Bouilloud et al., 2010; Vincendon et al., 2010) but up to now limited to gauged watersheds and to larger (24-h to 36-h) forecasts ranges (Edouard et al., submitted). For these large lead times, intense rainfall location and amplitude remain uncertain (Vincendon et al., 2011). **Based on the new AROME-NWC model, the PICS project now aims to investigate the question of shorter time horizons, in the context of small ungauged watersheds prone to flash floods.** Another issue will be to investigate how to combine rainfall estimates and nowcasts in a seamless way. This is required to provide consistent rainfall information from 0-h to 6-h lead times and to finally ensure a consistent hydrological forecast.

Distributed hydrological prediction in ungauged catchments

Though clear progresses can be expected from the higher spatio-temporal resolution of precipitation forecasts as detailed above, the quality of hydrological forecasts remains also highly dependent on the hydrological information available in real-time. In France, the national warning network (called Vigicrues, www.vigicrues.gouv.fr, under the coordination of the national hydrometeorological centre for flood forecasting (SCHAPI)) includes more than 1000 hydrometric stations spread over the main streams, where regional forecasting centres make forecasts routinely. At these stations, assimilation techniques can be applied to use the available flow measurements to improve the forecasts. However, this quite dense network leaves many zones uncovered, in spite of important socio-economic stakes. Consequently, SCHAPI developed a new product called Vigicrues Flash specifically designed for flash floods warning on small ungauged catchments, which runs operationally since march 2017 (De Saint-Aubin et al., 2016) . This product is based on the AIGA model (Javelle et al., 2014), which combines a regionalized hydrological model and simplified routing schemes. The model parameters are estimated on a 1-km² grid and the model uses detailed radar information to estimate the severity of an event compared to historical estimates. The approach demonstrated its operational added value and performance in the Mediterranean region within the RHYTMME project (Javelle et al., 2016).

The application of this model raises the difficult issue of running hydrological models in ungauged basins, where no flow data is available for parameter estimation, and for data assimilation in real time. The results of the Prediction of ungauged basins (PUB) initiative (Blöschl et al., 2013; Hrachowitz et al., 2013; Perrin et al., 2015) underlined the difficulty to get satisfactory model parameterization through regionalization approaches. This limits the accuracy of flood forecasts. To overcome these limitations, neighbouring approaches can be designed to make use of flow measurements available in nearby catchments. Indirect assimilation schemes, as done by Randrianasolo (2012), or variational approaches (Jay-Allemand et al., 2017), can also be implemented. **The PICS project will contribute to experiment and strengthen the robustness of these approaches in ungauged conditions.** Moreover, there is still a need to quantify the uncertainties in such ungauged conditions with specific tools to account for modelling (Bourgin et al., 2015) or rainfall uncertainties (Caseri et al., 2016). Since no flow measurements are available, indirect validation approaches based on proxy data can be used to evaluate the actual efficiency of the forecasts. Such proxy data include road cuts investigated in the PreDiFlood project (Naulin et al., 2013; Vincendon et al., 2016), damage costs covered by insurance companies (Le Bihan et al., 2016), and post-event surveys (Defrance, 2014; Javelle et al., 2014). However, setting-up spatio-temporal validation strategies applicable at large scales in the context of nowcasting techniques remains a challenge, especially when probabilistic approaches are used. **The PICS project will help moving ahead in this challenge of evaluating hydrological forecasts in ungauged conditions.**

Large scale (and high resolution) hydraulic modelling of flood areas

The translation of flood magnitudes into local impacts requires a detailed representation of the hazard related to discharge forecasts: i.e. flooded areas and associated physical variables (e.g. water heights, velocities, duration). This information is nevertheless difficult to obtain in the case of flash floods, provided the large amount of small watercourses potentially affected over large territories. Large-scale hazard mapping approaches based on DTMs have been proposed (Pappenberger et al., 2012; Sampson et al., 2015; Yamazaki et al., 2011) but were not designed up to now for the simulation of a wide range of flood magnitudes (including small floods), and were applied at large spatial resolutions (from 100 m up to 1 km² grids), clearly not adapted for the representation of small rivers or to evaluate detailed impacts. On the other hand, high resolution inundation mapping approaches were proposed (Nguyen et al., 2015; Sanders, 2007), but still require large computational resources, limiting the possibility of large scale application of these methods.

Nevertheless, some recent approaches were specifically designed to combine a large scale applicability (computational efficiency), a high-resolution enabling an appropriate representation of floodplains of small ungauged rivers (based on High Resolution DEM, HRDEM), and the capacity of being integrated in a real time forecasting chain. The method developed within the Flood Interoperability Experiment in the US (Maidment et al., 2016), for instance, proposes to build local stage-discharge relations at the river reach scale to derive associated flood areas. In France, an ongoing PhD (C. Rebolho, Irstea) is developping a storage areas mapping approach which may be directly linked to a hydrologic model. Le Bihan et al. (2016, Ifsttar) also proposed to build comprehensive catalogs of flood maps in a large range of discharge values based on steady state 1D hydraulic computations. The approach was based on an adaptation of the Cartino method (Cerema) enabling to automatically build (location and shape of cross sectional profiles) and run 1-D hydrodynamic models (Pons et al., 2014). Simplified and computationally light 2D hydraulic models are also being developed such as the Floodos model (Davy et al., Geosciences Rennes) and may solve mapping problems encountered by 1D models for local complex river bed geometries. **The PICS project will propose new developments of these approaches, and common experimentations in varied contexts, with an emphasis on the compromise between the level of complexity of the methods, the quality of input data, and the accuracy of the results.** Indeed, all these methods have neglected up to now information on river bathymetry (not included in HRDEM input data), which may result in significant uncertainty in estimated inundations patterns (e.g., Cook and Merwade, 2009). This calls for new methods to get synoptic measurements of river bathymetry using topo-bathymetric airborne lidar (Mandlburger et al., 2015; Lague, 2016), or to propagate the bathymetric uncertainty into the predictions of inundated areas, as well as other elements such as spatially variable hydraulic roughness effects (e.g., Forzieri et al., 2012).

Modelling socio-economic exposure and vulnerability, and associated impacts

Some significant advances have been proposed by the project partners in the field of modelling population exposure related to its daily mobility. Within the ANR PreDiFlood project, a Road Inundation Warning System (RIWS) was developed to estimate the risks of fast submersion of the road network during flash-floods (Ifsttar, Naulin et al., 2013). The approach was based on a preliminary analysis of the road network sensitivity to flooding, based on a morphological analysis of its intersections with rivers. Based on the RIWS outputs, the ANR ADAPTflood and MobiCLIMEX projects, developed a complementary modelling approach (MobRISK) to assess the exposure and vulnerability of road users to the submersions of the road network IGE, Debionne *et al*., 2016; Shabou, 2016; Shabou *et al*., 2017). This model connects road-users socio-demographic characteristics with activity-based mobility patterns to evaluate in space and time the number and characteristics of the people that are most exposed to road flooding. An additional decision-making module incorporates behavioural rules to simulate the adaptation of traveller’s behaviour according to the evolution of the environmental context (hydro-meteorological circumstances, reception of warning message, visibility issues, etc). Up to now, both models were applied and tested on the Gard department territory which offers an interesting framework for models calibration and validation. **The PICS project will enable to further improve these approaches and to enhance their applicability in more generic context.**

The operational Vigicrues-Flash system run by the SCHAPI is currently sending warnings to municipalities on the basis of estimated hazard levels. The question of integrating the notion of exposure and risk in such a system is currently addressed by an on-going PhD at Irstea (Saint-Martin et al, 2016). This work aims to develop synthetic exposure and vulnerability indexes, integrating a hierarchy of the elements at risk, and helping to assess the significance of damages for a given level of hazard and a given area (for instance a municipality). However, the main limitation of this approach is the definition of the flooded area used to calculate the proposed indexes. **The PICS project will provide detailed information on the flooded areas (WP2) related to the different hazard levels. As a consequence, it will help improving this approach for more relevant information on possible damages**.

The modelling of insurance losses related to natural hazards is crucial for insurance companies to provide an assessment of their exposure to risk. As inundations constitute one of the main natural risks in France, CCR (*Caisse Centrale de Réassurance*) developed since 2005 a damage model able to estimate the cost of flooding events a few days after their occurrence (Moncoulon et al., 2014; Moncoulon et al., 2016). This operational model is based on a large scale rainfall-runoff model used to assess hazard resulting from the meteorological conditions. A vulnerability model was built based on a claims and insurance policy database built by CCR, combining information such as risk type, class of business and insured values. During the event, the damage model uses outputs of hazard and economic vulnerability models to evaluate insured losses. This approach has shown promising results, but improvements of the hazard part of this modelling chain should probably still enable significant progress. **The PICS project will illustrate the potential of improving the hazard description in such an insurance losses simulation model.**

I.3. List of connected projects

Title of the call for proposals, source of funding	**Project title**	**Name of coordinator**	**Starting date/End date**	**Grant amount**	**Involvement of PICS project partners**
ANR RISKNAT 2008	PREDIFLOOD	E.Gaume & O.Payrastre	2009-2012	650 k€	Ifsttar (O. Payrastre), Irstea (P. Javelle), IGE (G. Delrieu), CNRM (B. Vincendon)
CPER PACA	RYTHMME	Samuel Westrelin	2008-2013	10,400 k€	Irstea (P. Arnaud, P. Javelle)
INSU/MISTRALS	HYMEX	V. Ducrocq P. Dobrinski	2010-2020	2,000 k€	CNRM (V. Ducrocq, B. Vincendon), Ifsttar (O. Payrastre), Irstea (P. Javelle)
ANR Retour Post-Doc	ADAPTflood	Isabelle Ruin	2010-2013	376k€	IGE (I. Ruin, 36 h.m)
ANR BLANC SIMI5-6	FLOODSCALE	I. Braud	2012-2016	740 k€	
ANR société et Changement Environnementaux	MobiCLIMEX	Céline Lutoff	2013-2017	760k€	IGE (I. Ruin, 28 h.m), CNRM (V. Ducrocq, B. Vincendon)
H2020 DRS_01_2015	ANYWHERE	Daniel Sempere	2016-2019	11,973k€	IGE (I. Ruin, 23 h.m)
CPER PACA	PORTE		2015-2020		Cerema (F. Pons), Irstea (P. Javelle)
Joint Research Initiatiave AXA Foundation	Prévision couplée des crues et inondations à l'échelle de la France	V. Andréassian	2015-2018	229 k€	Irstea (V.Andréassian)

II. Project organisation and means implemented

II.1. Project organisation, methodology and risk management

The project proposes to design and experiment **integrated forecasting chains** for flash-flood impact forecasting. The characteristics and objectives assigned to these forecasting chains will be defined with the support of knowledge gained by future potential users (**end users group**, see hereafter). The forecasting chains will be evaluated over selected test **case studies**, at a broad enough scale (of the order of a full administrative department) to assess their subsequent applicability at a regional, or even national, scale. Interactions are expected between scientists and end-users, but also between scientists coming from different fields (meteorology, hydrology, hydraulics, social sciences…).

The project is structured in four scientific work packages (WP1 to WP4), complemented with a general **coordination and dissemination** work package (**WP0**). This structure is presented in Figure 1. It is organized around a central work package (**WP4**), in which **integrated forecasting chains** will be tested. This WP4 offers the greatest potential of innovation of the project: all the contributors and end-users of the project will meet and interact in this WP. The three other scientific work packages are designed with the objective in mind of improving, adapting, and evaluating uncertainties of the various key components to be incorporated in the integrated forecasting chains, namely:

- **the short range (0-6h) discharge forecasts (WP1)**, obtained by coupling the state-of-the-art very short-range precipitation forecasts with distributed hydrological models,
- **the methods for flood areas estimation (WP2),** which include innovative 1D and 2D hydraulic computations methods to convert flow rates into information on the flood areas and water heights / speeds,
- **the socio-economic impacts modelling methods (WP3),** which have to proceed with an explicit integration of information relative to the flood areas and water heights / speeds for the estimation of impacts of different nature.

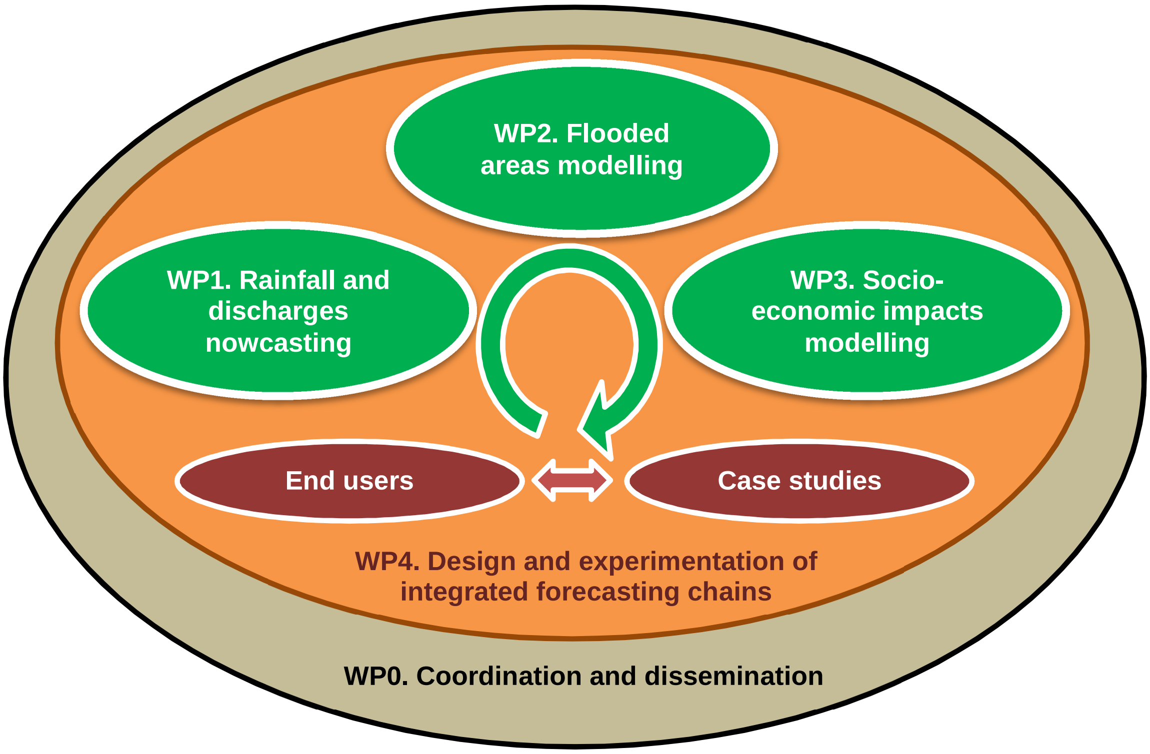

Figure 1. General organization of the PICS project

The **end users group** will include at least the state civil security authorities (DGSCGC), one local firemen and rescue service (SDIS 30 or 83), the SCHAPI, one municipality (city of Cannes), one insurance company (AXA Global P&C), two electric power companies (EDF, CNR), and one public transport company (SNCF). All the members of this group confirmed their great interest for being part of the project (see the letters of support included in appendices). One risk identified may be the capacity of the methods involved in the project to address the issues raised by this end users group. On this specific point, a discussion will be organized at the beginning of the project (WP4.1) to define common and reasonable objectives, accounting for the current state of the art.

The **case studies** will be partly located (but not exclusively) in the Mediterranean Region: indeed, several recent flood events in this region offer a particularly favorable context in terms of data availability (including damage data), applicability of the different modelling components to be integrated in the forecasting chains, and feasibility of complementary Lidar data acquisition. These events include the September-October 2014 floods in the Gardons, Vidourle, Hérault and Lez basins, the June 2010 floods in the Argens watershed, and the October 2015 floods Alpes-Maritimes region (Brague, Argentière, and Grande Frayère basins). However, the final list of selected case studies will be defined at the beginning of the project based on the exchanges with the end users group (WP4.1). The objective will be to select the most relevant areas and events for each forecasting chain to be tested. The list of case studies may also be updated during the project in case of occurrence of particularly interesting events.

One critical aspect of the project will be the capacity of validation of the results of the integrated forecasting chains: forecasted impacts, but also estimated discharges and flooded areas. Significant risks are related to the possible lack of observation data for validation, and also to the possible mismatch between the nature of information provided by models outputs and the data available for validation. To limit these risks, a particular effort will be put in the project on gathering and formatting appropriate and varied validation data (WP4.3), related to all components of the modelling chains (discharges, inundation patterns and impacts). A specific task will also address the question of the appropriate validation methodologies (WP4.2), considering the nature of validation datasets available for each case study.

II.2. Consortium

The complementarity of contributions and competences brought by the different project partners is summarised in the following table (X= Contributor; **X**=WP leader):

Partner	Competences	WP0	WP1	WP2	WP3	WP4	Subsidy (k€)
Ifsttar	Distributed hydrological modelling in ungauged context. Integrated rainfall - runoff – inundation and impacts modelling (ANR PreDiFlood, Versini *et al.*, 2010 a,b; Naulin *et al.*, 2013; Le Bihan *et al.*, 2016).	**X**	X	**X**	X	X	200
CCR	Vulnerability, damage, and insurance losses modelling (Moncoulon *et al.*, 2014, 2016)	X			X	X	50
Cerema	DEM treatment, and semi-automated 1D/2D hydraulic modelling (Pons *et al.*, 2014; Cartino model)	X		X		X	88
CNRM UMR 3589	Numerical forecasting of precipitating systems. Integrated hydrometeorological modelling (Vincendon, 2011; Vincendon *et al.*, 2016).	X	**X**			X	51

Geosciences Rennes UMR 6118	Topo-bathymetric Lidar data acquisition and treatment (Brodu and Lague, 2012), 2D hydraulic modelling (Floodos, Davy et al., subm.)	X		X		X	43
Irstea	Hydrological modelling in ungauged context (Randrianasolo et al., 2011; Javelle et al., 2014). Hydrometeorological forecasting and uncertainties quantification (Caseri et al., 2014; Pagano et al., 2014; Bourgin et al., 2014). Impacts indicators (Saint Martin et al., 2016).	X	X	X	X	**X**	158
IGE UMR 5001	Modelling population exposure and vunerability. Use of social networks data for validation (Ruin et al., 2014, Debionne et al., 2016; Shabou et al., 2017; Terti et al., 2015; Terti et al, 2016; Terti et al., 2017).	X	X		**X**	X	142
MEEM-SCHAPI	Operational hydrology and flood forecasting. Operation of current “Vigicrues-Flash” warning system.	X				X	0

II.3. Scientific coordinator

The project scientific coordinator, O. Payrastre (Ifsttar), is a senior researcher who has developed his activity in the fields of flash floods observation, understanding, frequency estimation, modelling and forecasting. He joined the Ifsttar team in 2009, where he is in charge of the coordination of research activities related to “river networks”. He was formerly head of the forecasting unit of the Grand Delta Flood Forecasting Service (southern France, 2005-2009), and has therefore an excellent knowledge of operational flood forecasting issues in a context of intense and fast evolving meteorological events. In the last years his research activity has been mainly focused on the question of flash floods impacts forecasting: he coordinated (2009-2012) the ANR PreDiFlood project on road networks inundation warning, and recently supervised the PhD of G. Le Bihan (2016), focused on the forecasting of flood areas and associated impacts. He authored 16 scientific publications (280 citations). He is currently involved in the Hymex project (www.hymex.fr, as coordinator of the TTO2d “Post event surveys” task team and in the “Towards integrated prediction of heavy precipitation, flash-floods and impacts” science team steering committee). He has also been contributing for a long period to the OHMCV (www.ohmcv.fr) research observatory.

II.4. Permanent staff involved in the project

The project involves 31 contributors (non-permanent staff excluded), for a total contribution in time of 203 persons-months. A detailed table of the persons involved in the project, and the CVs of the main contributors, are presented in the appendices.

II.5. Means of achieving the objectives

The objectives, contents and tasks related to each work package, the associated partners contributions, and the requested means are detailed hereafter.

WP0: project coordination, communication and dissemination (leader: Ifsttar)

Objectives: this work package is dedicated to the project coordination, and to the project results dissemination and valorization.

WP0.1 Project animation and reporting (Isfttar) This task includes the overall project animation and coordination. It includes the work of reporting to ANR (mid-term and final project reports). Two project meetings per year will also be organized, involving all the project contributors, to share the project results and maintain the connection between the different partners.

WP0.2 Scientific communication and publication (all partners) This task includes the scientific communication of project results in seminars, international conferences, and scientific publications. A conference will also be organized at the end of project to communicate the whole project results.

WP0.3 Website (Isfttar) A website dedicated to the project will be developed to help communicating outside of the scientific community. This site will also enable the partners to share information and documents.

WP0.4 Communication with end users (Ifsttar, Irstea) This task includes the organization of the different workshops planned in the WP4 (beginning and end of project) for exchanges with the end users group.

WP0: deliverables	
D0.1	Project mid-term and final reports
D0.2a	Scientific publications
D0.2b	Scientific conference
D0.3	Project Website
D0.4	Workshops with end users

WP0: requested means		
Partner	**Affectation**	**Cost (k€)**
All partners	Traveling expenses for bi-annual meetings for all partners	38.750
All partners	Scientific conferences for all partners	19.000
Ifsttar	Coordination expenses (end users group, website, communication and publications)	12.000
	Structural costs	5.573
	Total WP0	**75.323**

WP1: rainfall and discharges nowcasting (leader: CNRM)

Objectives: This work package aims to investigate several methods of nowcasting combining rainfall nowcasting strategies, which cover the 0-6h forecasting range, and high resolution rainfall-runoff modelling to simulate the hydrological response of watersheds smaller than 500 km². The different components of the hydro-meteorological chain have to be assessed together with the associated uncertainty.

WP1.1 Preparation of rainfall nowcasts (QPFs) and estimates (QPEs) for selected case studies (CNRM, IGE). This task includes the extraction and preparation of several types of rainfall fields, which will be made available for all partners contributing to the project (especially for WP1.2 and WP1.3), for the selected case studies. These products include:

- 1-km resolution radar QPEs from the French operational weather radar network (Tabary et al., 2007, 2013) at 5-minute time resolution,

- rainfall QPE reanalyses based on kriging with external drift, at a hourly time resolution, performed by IGE in the framework of OHMCV (Delrieu et al., 2014).
- the rainfall QPEs known as ANTILOPE QPEs (coming from the merging of raingauges and radar data), and the associated uncertainty estimation, at a hourly (and sub hourly if available) time resolution.
- the 15-minute rainfall forecasts from several AROME-NWC runs. Indeed, a numerical weather forecast ranging from one to six hours is delivered every hour (at H+35 minutes) in operations at Météo-France with AROME-NWC. As a matter of fact, 5 rainfall scenarii will be available simultaneously for a given time.

WP1.2 Improvement of hydrological models for application on small ungauged catchments (Irstea, Ifsttar, CNRM) This task includes several adaptations and improvements of hydrological models aiming to properly manage the issues related to hydrological forecasting in small ungauged watersheds. The efforts will be put on the following questions:
- Should the structures of models be modified? To address this question, some evolutions of the distributed GR model (Irstea Aix), which is currently run operationally by the SCHAPI in the framework of its “Vigicrues-Flash” system, will be tested. A first objective will be to obtain an integrated model structure running continuously (currently one daily continuous model is coupled with an event-based model). Several transfer function structures will also be compared based on the Cinecar model (Ifsttar).
- How to downscale the parameters description? This topic will include an adaptation of distributed GR model parametrization (Irstea Aix), in order to obtain optimal gridded parameter sets at a 1-km resolution, and to allow computing discharges at any associated grid point. The improvement of the parameters optimization using variational methods (4D-Var in the PhD proposed) will also be tested. The question of transfer parameters specification based on geomorphological analysis will also finally be addressed, based on the experience of the Cinecar model in this field (Ifsttar, Versini et al., 2010; Naulin et al., 2013), and on information provided by detailed Lidar data (WP2.1). Improving this transfer parameterization is expected to improve the temporal dynamics of the simulated hydrographs for ungauged basins, and consequently to improve the information on lead times.
- Which optimal model resolution? The impact of varying the space and time resolution of semi-distributed hydrological modelling tools will be evaluated to analyse the sensitivity of the simulations to the issue of space and time scales (Irstea Antony). In the purpose of providing predictions of intense runoff risks in urban areas, an attempt of providing runoff simulations at very high space (less than 1 km^2) and time (less than one hour) resolutions will also be undertaken with the ISBA -TOP model (CNRM, Bouilloud et al. 2010, Vincendon et al. 2011, 2016). A better representation of land use (bare soil, vegetation, impervious and urban, etc.) and soil texture will be needed for this purpose.

WP1.3 Experimentation of hydrological forecasts, uncertainties management and representation (Irstea, Ifsttar, CNRM) This task will explore the benefit of combining rainfall nowcasting products and high resolution distributed hydrological models, for flood forecasting at very short range over small and rapid responding watersheds. It will be based on the outputs of WP1.1 and WP1.2. Several sources of uncertainties affect the hydrometeorological forecasting chain. Efforts on quantifying and reducing those uncertainties will be made, and also on quantifying the global uncertainty on the forecasting model outputs, that will be transmitted then to the inundation models. The main questions addressed here will be the following:
- Can the information on QPEs uncertainty be usefully valuated? For instance, ISBA-TOP will be used to investigate if raingauge/radar merged QPE and associated uncertainty information allow moving forward in nowcasting river flow and runoff events in the Mediterranean region.

- How should the AROME-NWC scenarios be combined with QPEs to obtain relevant and consistent hydrological predictions? As indicated above, five scenarii of rainfall from AROME-NWC are available for a given time, and have to be used in combination with rainfall observations (QPEs). An issue will be here to assess if the last AROME-NWC forecasts should be used to drive hydrological models or if it is better to consider all the available forecasts. The hydrological forecast performance will be evaluated according to the lead time of the meteorological forecast used. The combination of rainfall nowcasts and estimates in a seamless approach will also be investigated here.
- What could be the benefit of data assimilation in a short range forecasting context? The benefit of an assimilation of discharges measured at several hydrological stations into a distributed model will be also assessed within this task. Can this additional information improve the hydrological forecasts? Does data assimilation impact nowcast range only or does it also impact longer forecast ranges? These questions will be addressed based on the PhD work planned on 4D-Var variational assimilation technique (Irstea Aix).

WP1: deliverables	
D1.1a	5-minute rainfall estimates coming from radar data on case studies
D1.1b	Hourly rainfall reanalyses on case studies
D1.1c	Hourly Antilope rainfall estimates on case studies with their associated uncertainty
D1.1d	15-minute rainfall forecasts up to 6 hours range on case studies
D1.2a	Improved rainfall runoff models
D1.2b	Discharge and runoff simulations on case studies
D1.3a	Discharge and runoff forecasts on case studies
D1.3b	Recommendations on how to use the AROME-NWC rainfall “multi-scenarii”
D1.3c	Recommendations on how to combine rainfall sources (QPEs and AROME-NWC) for hydrological forecasting

WP1: requested means		
Partner	**Affectation**	**Cost (k€)**
Irstea	½ PhD grant, affected to WP1.2 and 1.3, and co-supervised with Ifsttar	49.289
Irstea	½ PhD grant, affected to WP1.3 and 2.2	49.289
	Structural costs	7.886
	Total WP1	**106.463**

WP2: Flooded areas modelling (Leader: Ifsttar)

Objectives: Work package 2 aims at improving and evaluating semi-automatic hydraulic computation methods for the determination of flooded areas. The key objectives of the methods developed here are i) the applicability on the very detailed stream network potentially affected by flash floods, including small watercourses, and ii) the applicability in a real time context based on the hydro-meteorological discharges forecasts.

WP 2.1 Acquisition and pre-treatment of complementary Lidar Data (Geosciences Rennes) This task includes state of the art Lidar data acquisition, aiming to obtain an accurate description of riverbeds and fluvial annexes bathymetry (including small watercourses) for two of the case studies selected for the project (Gard and Var case studies). Data acquisition will use the state of the art topo-bathymetric Lidar Optech Titan operated by Geosciences Rennes that uses 2 laser wavelengths (1064 & 532 nm) to simultaneously acquire ultra-high resolution topography (30 pts/m²) and bathymetry (15 pts/m²), including full waveform data for accurate description of roughness features. New Lidar processing methods will be developed in Geosciences Rennes (e.g., Brodu and Lague, 2012) to parameterize hydraulic roughness from aboveground (vegetation, etc.) and bathymetric features (part of Arthur Le Guennec PhD project funded by University of Rennes 1). This dataset will finally serve as a reference in tasks 2.2 and 2.3 to evaluate the influence of point density, precision, and detailed knowledge of bathymetry and aboveground coverage, on flood areas estimation results by reference to the standard RGE Alti DEM information.

WP 2.2 Improvement of simplified hydraulic computation methods (storage areas and/or 1D Saint-Venant models) for flood inundation modelling (Cerema, Ifsttar, Isrtea)

This task includes the adaptation and improvement of several DEM treatment methods aiming to provide a fast estimation of flood areas based on the outputs of hydrological models (WP1). Three approaches will be investigated here:

- the storage areas computation approach developed by Rebolho (Irstea) which will be adapted here for an application to small rivers
- the local (0-D) approach already applied in the US within the FIE experiment (Maidment et al.,2016), which corresponds to estimation of the discharge - water height relationship at the reach scale
- the approach proposed by Le Bihan et al. (2016) based on the Cartino method (Cerema, Pons et al., 2014): application of a full 1D Saint-Venant hydraulic model in steady state regime to obtain a catalog of flood maps across a wide range of discharge magnitudes. This approach showed promising results, despite large simplifications introduced for automatization purposes (no head losses, no roughness calibration).

A key objective will be here to guarantee the adequacy between the complexity of the methods developed and the time and space scales of the intended applications. The methods will be evaluated by comparison with observed flooded areas, or with reference hydraulic computations involving detailed topographic and bathymetric data and the expertise of hydraulicians (for instance the inundation maps of the SCHAPI “Viginond” database). The main questions to be addressed in the project will be the following:

How sensitive are the results to topographic input data? A quantification of the effect of input topographic data, regarding the limitations and potential improvements of the currently available DTMs (RGE Alti IGN), will be conducted here. The question of the spatial resolution of data will be addressed, and a specific attention will also be put on the information on bathymetry, and on the description of soil coverage for the parametrization of hydraulic models (roughness coefficients).

Can automatic hydraulic 1D (or 0D) computation methods still be improved? The challenge will be mainly here to better represent the riverbeds in the models (detection of embankments and dikes, distinction of riverbed/floodplain in the computations, variable roughness, etc..). The capacity of description of riverbeds, indeed, remains limited in the case of small rivers prone to flash floods. This aspect currently appears as a critical point for a correct representation of the beginning of inundation, in the intermediate range of discharges.

WP 2.3 Application of 2-D modelling in areas with complex hydraulic features (Cerema, Geosciences Rennes, Ifsttar). This task will include the implementation and test of 2D hydraulic approaches, which may usefully complement the 1D approaches developed in task 2.2, particularly in areas with complex features of the floodplain. The Floodos model (Geosciences, Davy et al., subm.) will be used for this purpose: this model implements a cellular automata like approach to solve the 2D vertically averaged Saint-Venant equations with spatially variable roughness (cf WP 2.1). On a single CPU it currently outperforms other 2D models implementing the same equations (e.g., Almeida et al.). The main questions to be addressed here will be the following:

Is a simplified 2D hydraulic approach compatible with the large scale application objective? The objective will be here to improve the computational efficiency of Floodos, to remain compatible with the objective of applicability on a large number of “problematic” river reaches, potentially disseminated over large territories.

How significant is the added value of the 2D approach in a complex hydraulic context? Floodos will be used to obtain automatic ensemble flood inundation patterns accounting for uncertainties in topographic, bathymetric, infrastructure and roughness data. The potential added value of such a 2D computation approach in complex areas where 1D approaches are likely to fail will be illustrated. For this purpose, the results obtained will be compared with the 1D Cartino approach in different hydraulic contexts. The 2D model will also be used to define the optimal DEM resolution to be used depending on catchment size and required accuracy of flood extent mapping.

WP2: deliverables	
D2.1	Lidar dataset for selected case studies.
D2.2a	New version of Cartino software
D2.2b	Application, evaluation, and comparison of all methods (storage areas, 0-D FIE experiment, Cartino) on selected case studies, including sensitivity analyses to input topographic data
D2.3a	Application of the Floodos model to selected case studies
D2.3b	Recommendations on the combination of 1D/2D approaches

WP2: requested means		
Partner	**Affectation**	**Cost (k€)**
Cerema	15 month of experienced engineer, affected to WP2.2	66.212
Geosciences Rennes	Materials and operating cost for Lidar data acquisition (WP2.1)	30.000
Ifsttar	1 PhD grant affected to WP2.2 and WP 2.3 co-supervised with Géosciences Rennes	104.868
Isrtea	½ PhD grant, affected to WP1.3 and 2.2	*see WP1*
Irstea	6-month PostDoc Position at Irstea, affected to WP 2.2	21.000
Cerema, Ifsttar	IT equipments	7.500
	Structural costs	18.366
	Total WP2	**247.946**

WP3: socio-economic impacts modelling (Leader: IGE)

Objectives: WP 3 intends to improve three types of socio-economic impacts modelling approaches, with a common objective of integrating new knowledge on flood areas, water heights, and flow velocities provided by WP2 outputs. The main goals of these approaches are i) to better represent the dynamics of population exposure and response (WP3.1), ii) to provide synthetic impact indicators to enhance emergency management decision-making (WP3.2), and iii) to provide an estimation of insurance losses (WP3.3).

WP 3.1 Modelling of population’s dynamic exposure and vulnerability (Ifsttar, IGE). This task includes new developments of the methods developed by project partners in the field of modelling transport infrastructure inundation risks (RIWS, Ifsttar) and population exposure in situation of mobility (Mobrisk, IGE). The main question addressed will be the following:

How can the methods be improved based on information on flooded areas? First, the method for estimating the road network sensitivity to flooding will be revisited to include this new information, with a significant leap expected in the RIWS performances. Secondly, flooded areas will be valuated to develop based on MobRISK a global evaluation of the population exposure: MobRISK provides indeed information on where people move and where they go, which also includes information on where and when people stay in potentially exposed locations.

Can the methods be combined and simplified to favour their large scale applicability? The RIWS and MobRISK models will be connected here, offering a complete picture of the space-time patterns of human exposure and capability of response. The main objective will be then to make this modelling chain more operational and user-friendly, by optimizing and simplifying its functioning. This chain will be calibrated and tested based on the selected case studies. The identification of synthetic human vulnerability indicators which could be directly integrated in WP3.2 will also be attempted.

WP 3.2 Synthetic impacts indicators for emergency management decision-making (Irstea, IGE). This task includes the application of the synthetic impacts representation approach developed in the PhD of Clotilde Saint Martin (Irstea Aix). The approach will be adapted on the selected case studies based on the detailed information on flood areas provided by WP2. The main question here will be to **measure the added value of detailed information on flood areas** accounting for the intensity of the event and its temporal dynamics, by reference to an information limited to the maximum potential flooded area (so called “EAIP” defined during the application of the EU directive).

WP 3.3 Modelling of insurance losses (CCR, Ifsttar). This task aims includes the adaptation of the vulnerability module of the insurance losses model of CCR (Moncoulon et al., 2014), to take advantage of the enhanced hazard information provided by WP2. This is equivalent to replace the hazard part of the CCR model, with the underlying question: **to what extent can this enhanced hazard information improve the final modelling results?** The first contribution will be to calibrate specific damage curves from the hazard model results provided by the other project partners (Ifsttar). These functions, specifically fitted for flash floods, will be used to estimate damages over the selected case studies, and the results compared with the initial CCR modelling chain. The knowledge of real consequences in terms of damages (locations and losses) will also permit CCR to bring validation elements for the hazard simulation results. Finally, the damage model obtained will constitute a component in the modelling chain developed in the PICS project.

WP3: deliverables	
D3.1a	new versions of RIWS and MobRISK models, designed for an integration in continuous rainfall-runoff-impacts forecasting chains
D3.1b	application and validation of models results based on selected case studies
D3.2	adaptation and experimentation of synthetic impacts indicators proposed by C. Saint Martin
D3.3a	adapted version of the insurance loss model of CCR
D3.3b	validation results on the selected case studies.

WP3: requested means		
Partner	**Affectation**	**Cost (k€)**
Ifsttar and IGE	1 PhD grant affected to WP3.1, co-supervised	101.762
IGE	16-month of experimented engineer on WP3.1 and WP4.4	*see WP4*
Irstea	6-month PostDoc Position at Irstea affected on WP 3.2	21.000
CCR	Contribution to permanent staff costs (50%) for WP 3.3.	28.863
IGE and CCR	IT equipments	3.750
	Structural costs	29.740
	Total WP3	**185.115**

WP4: design and experimentation of integrated forecasting chains (Leader: Irstea)

Objectives: The work package 4 will involve all project contributors, from scientific teams to the different targeted end-users, offering opportunities for a rewarding dialogue at different steps of the project. Firstly, WP4 will have to identify the needs and expectations of the end-users, and to define the integrated forecasting chains to be tested, and to select the case studies to be integrated in the project. The WP4 will also be in charge of collecting varied validation data associated to these case studies. Finally, the WP4 will have to implement and test the integrated forecasting chains (hydro-meteorological, inundation and impacts) and to gather feedback from end-users. These feedbacks will then be communicated to the WP1-3 in order to consider possible improvements.

WP 4.1: Definition of end-users expectations (all partners, end users group). This task will take place at the beginning of the project. It will define the frame of the whole project: what are exactly the needs and how can we meet them? It will take the form of a common workshop involving all project contributors and the end-users group. The workshop will be dedicated to define the end-user expectations, but also to reformulate these needs according the current "state of the art" (what will be feasible or not), to finally converge to common reasonable objectives. These discussions will help the project team to define more precisely where to assign efforts that have been planned in this proposal. Finally, this workshop will also be dedicated to the identification of relevant case studies for an illustration of the capacity of integrated forecasting chains to fulfil the needs.

WP 4.2: Definition of the integrated forecasting chains to be tested and of the associated validation strategies (all partners). This second task aims at first to define the structure of the integrated forecasting chains to be tested in the project. For this purpose, a second technical workshop between scientific teams will be organised to define how the developments carried out in the different WPs (hydro-meteorological nowcasting, inundation and impacts) will be finally chained to meet the different end users expectations. A particular attention will be put here on the consistency across the various components of each chain regarding: the variables used, level of resolution, application scale, and degree of uncertainty. This workshop will also have to address the crucial question of the methodology to be used for results validation, depending on the selected case studies, the characteristics of the forecasting chains to be tested, and the available observation datasets (damages, etc.). Methodological aspects (testing schemes, criteria) related to the evaluation of probabilistic forecasts in space and time will also be addressed.

WP 4.3: Case studies selection and data collection (all partners, end users group). This task will have to select the **most relevant case studies** which will be used to illustrate the benefits of the integrated forecasting chains developed in the project. These case studies will correspond to past and well documented events (such as the June 2010 flood in the Argens basin or the October 2015 flood in the Alpes Maritimes region), but also, as far as possible, to events occurring during the project. The SCHAPI, which runs the national 'Vigicrues-Flash' warning service since the beginning of this year will help to identify relevant events, based on the feedbacks received from local actors. A strong effort will be put on the **collection of data** enabling to assess the performances of all components of the forecasting chains, based on the validation strategies defined in WP4.2. This data will include information on peak discharges (obtained if necessary from post event surveys), on the extent of observed flooded areas, and also all kind of useful information for the characterization of impacts (submersion of roads, habitations, etc) and of their timing. This last information will be collected through public data, such as social network or medias, and also based on the contribution of end users group and local authorities. For instance, information on road network closures, calls to firemen switchboard, firemen rescue operations, messages on social networks, will be gathered. A particular attention will be put on the resolution and geolocation of the information collected. This information will be complemented if necessary by field surveys in order to assess disorders and to interview witnesses (events occurring during the project), or with field information already gathered by project partners (past events). All this information will be centralized in a common database which will be available for all partners, with one exception: data on insurance damages will remain property of CCR and will therefore not be included, but will nevertheless be used in the project for validation of damage modelling results.

WP 4.4: Experimentation and validation of integrated forecasting chains (all partners, end users group). This last task is in charge of implementing, running, and evaluating the integrated forecasting chains for the selected events and case studies. Warnings of the 'Vigicrues-Flash' system will be used as benchmarks for the evaluation. The main questions addressed here will be the following:
Which accuracy of the forecasted results? Which critical components in terms of uncertainty? This part of the evaluation will rely on the impacts data available and collected in WP4.2. The accuracy of the impacts forecasted on the selected case studies will be examined. The question of false alarms (overestimation of impacts in no affected areas) will also be addressed. Some sensitivity analyses will finally be conducted in the purpose of comparing the respective weight of the different components of the forecasting chains, in the final uncertainty.
Which capacity to fulfil the end user's needs? This question will be addressed based on a final common workshop involving the project partners and end users group. The results obtained on the several case studies will be presented and discussed based on the operational experience of the end users

WP4: deliverables	
D4.1	one common workshop
D4.2a	definition of the structure of integrated forecasting chains to be tested
D4.2b	definition of the validation strategies
D4.3a	choice of the selected case studies
D4.3b	observation datasets for validation
D4.4a	reports on integrated forecasting chains evaluation
D4.4b	one common workshop

WP4: requested means		
Partner	**Affectation**	**Cost (k€)**
CNRM	12 months of engineer	40.824
IGE	16-month of experimented engineer on WP3 and WP4	61.257
IGE	2 6-months internships	6.600
	Structural costs	8.695
	Total WP4	**117.376**

II.6. Project Timetable

	2018				2019				2020				2021			
	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
WP0																
WP0.1	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
WP0.2	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	D0.2a	▨	D0.2b
WP0.3	▨	▨	D0.3													
WP0.4	▨	D0.4											▨	D0.4		
WP1																
WP 1.1	▨	D1.1														
WP 1.2		▨	▨	▨	▨	▨	▨	D1.2b	▨	▨	▨	▨	D1.2a D1.2c			
WP 1.3				▨	▨	▨	▨	▨	D1.3a	▨	▨	▨	▨	D1.3b D1.3c	▨	
WP2																
WP 2.1	▨	D2.1														
WP 2.2	▨	▨	▨	▨	▨	D2.2a	▨	▨	▨	D2.2b						
WP 2.3				▨	▨	▨	▨	▨	▨	D2.3a	▨	▨	D2.3b			
WP3																
WP 3.1			▨	▨	▨	▨	D3.1a	▨	▨	▨	▨	D3.1b				
WP 3.2					▨	▨	D3.2									
WP 3.3					▨	▨	▨	▨	▨	D3.3a	▨	D3.3b				
WP4																
WP 4.1	▨	D4.1														
WP 4.2		D4.2a	D4.2b													
WP 4.3		D4.3a	▨	▨	▨	D4.3b										
WP 4.4						▨	▨	▨	▨	▨	▨	▨	▨	▨	D4.4a D4.4b	▨

III. Impact and benefits of the project

The project is related to the Defi1 – axis 6 of the ANR 2017 Work Programme. This research axis is entitled “Integrated approaches for a sustainable territory development”, and includes a specific action on “integrated chains for risks evaluation, integrating hazards, vulnerabilities and impacts on territories”. This action should specifically address the questions of complex interactions between processes and their modelling. It should enable economic evaluation and also perception and representation of risks. By designing integrated flash flood impacts anticipation chains, the PICS project completely addresses the objectives of this action. Indeed, the modelling chains tested will represent a large variety of processes such as intense rainfall formation, rainfall-runoff relation, inundation of floodplains, and finally socio-economic impacts of flooding. The impacts and risks represented include economic aspects (insurance losses) as well as more societal aspects (infrastructures disruptions, population exposure, etc..).

The scientific benefits of this project are in direct relation with the detailed objectives set above: they mainly pertain to an improved capacity of forecasting risks related to flash floods, plus an increased capacity to evaluate the results of this forecasting exercise. The scientific dissemination of these benefits will rely on publications in international scientific journals and on technical presentations delivered in international scientific conferences, as well as national conferences addressing the various operational actors. A bilingual (English/French) website devoted to the project will be launched in a format to promote exchanges via social media (Twitter, blog, Facebook, etc.) that accelerate and extend the spread of project developments. A final scientific seminar will also be organized. This outreach strategy will benefit from the dynamic generated by the two hydrometeorological forecasting research networks currently operating at the international scale, i.e. the HyMex program (http://www.hymex.org/), and the HEPEX initiative (www.hepex.org), within which several PICS project partners are already active. The existence of these two communities will indeed ensure a large diffusion of the project scientific results.

The societal and economic benefits are directly related to the actors involved as project partners or as members of the end-users group. Therefore, a relatively large panel of impacts and benefits may be expected:

- The SCHAPI (Ministry of Environment, Energy and Ocean affairs) is directly interested by the project in the perspective of future improvements of the new *Vigicrues-Flash* warning system. This new service, indeed, still suffers from important limits: limited anticipation, limited territorial coverage, warnings generated based on hazard intensity without information on local vulnerability and impacts. The results of the PICS project will provide options and opportunities for futures updates and enhancement of *Vigicrues-Flash*: integration of rainfall forecasts, improvement of the rainfall-runoff model, integration of a simplified representation of impacts, etc.
- The national civil security and crisis management authority (DGSCGC, Ministry of Interior) also develops operational systems which may directly benefit from the project outcomes. The first one is the SYNAPSE decision-making support tool, which is a GIS system aiming to integrate and analyze all kind of information related to crisis events and their consequences. In the case of natural hazards, this system already integrates simplified computations of population impacted by a natural event. This system could clearly benefit from progress provided by the PICS project in the field of modelling the dynamics of population exposure. Another system is the SAIP (Système d'Alerte et d'Information des Populations), which is a smartphone application recently launched (2016) to directly inform the population in case of danger located at proximity. Given that the PICS project aims to provide detailed information on the possible flooded areas in case of flash floods, it should help to improve in the future the accuracy and relevance of messages sent by the SAIP system.
- Local Crisis managers and civil security officers (municipalities, fire safety agencies) are directly concerned by the potential progresses related to the project, in terms of anticipation and qualification of impacts of forthcoming flash-floods. The anticipation is indeed a crucial component of an efficient local crisis management, and the information on impacts may be of great interest for an appropriate mobilization and positioning of rescue means.
- The anticipation of floods is also a key challenge for hydropower companies, which are very active in France in the development of hydrological forecasting. These companies will directly benefit from the PICS project for the enhancement of their own flash flood anticipation capabilities.
- The managers of transport infrastructures will also take benefit from the project results for the purposes of analyzing the road and railway networks sensitivity to flooding, and of providing real time warnings on inundation risks.
- Finally, the project will bring value to insurance (AXA) and reinsurance (CCR) companies by providing information to anticipate the volume of claims and associated financial costs after a flood. Particularly, the insurance losses model of the CCR may directly benefit from the progress provided by the project in terms of hazard description (flooded areas), which may help to define future adaptations of this model. This last significant benefit of the project for private companies justifies its inclusion in the "PRCE" funding instrument.

In order to support all these possible operational integrations of the benefits of the PICS project, it will finally be envisaged to launch, alongside the project, a complementary national applied project ("Prevision immediate" project) devoted to large-scale demonstration and to transfer of technologies.