Nîmes 3rd October 1988, up to 410 mm/h, up to 3m water downtown, 11 deads, 600 M€ damage, 45 000 affected people, 30 km of pipes destroyed

Big Data Analytics for Natural Disaster Management

Improvement of flash flood forecasting thanks to AI

In the frame
of the ExtremeXP project

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Agenda

- Some features about floods and context
- Inundation key features : types, characteristics, impacts
- Reasoning of the flash flood selection for our study
- Objectives of the study
- Methodology
- Scenarii of use
- Conclusion

Main flood types & characteristics

- For our use case point of view, inundations may be separated in 2 main types: plain versus flash flood
- Main characteristics (rough classification) :

characteristics	plain	flash
Event cinematic	Slow (days to week),	Minutes (water rising up) - days (for duration)
occurrence	very progressive	brutal
Morphological environment	Plain, smooth topography	Relief (in mountains), streets, buildings (in urban)
extension	Large (province)	Small (few km^2)
Required data precision	low precision	High level of details

Flash flood specific features

What makes flash floods specific and difficult to model

flash floods occur mainly in mountainous and in urban areas

- Urban flash flood specificities are mainly due to:
  - brutal occurrence of the flooding event
  - It often concerns populated area
  - And many human activities (industry, services ..)

    ➔ impact is very often dramatic as human and economic cost

- Therefore there is a strong need for modelling the event and elaborate reliable forecast
  - To anticipate (resiliency approach, feedback, long term infrastructures planning)
  - To trigger actions at the right time, (population alert, restricted zones …)
  - To decrease/avoid the consequences

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Challenges for flash flood modelling

Considering the flash flood characteristics, **their modelling must cope with specific performances**

- **Constraints on model**
  - Traditional hydrological modelling tend to be based on all physical parameters influencing the event
  - Data are numerous, heterogenic, sometimes difficult to acquire or totally missing (see later)

    ➔ very few places/organizations can acquire these data in the real life/conditions
  - The model tuning is difficult and fastidious since all parameters are interacting
  - The model execution is usually time and CPU consuming

- **Operational needs to use the models in crisis conditions**

  because events occurrences are extremely rapid and versatile

  It should be possible to re-execute the model rapidly to take into account the most recent data (ex : 15 minutes) : precipitation amount, wind direction, water level in river etc …

  ➔ Short execution time and low CPU consumption

Objective : flash flood modelling using IA approach

Project global objective :

- Use of **AI models** along with and/or as a replacement of hydrodynamical models
- to reduce the difficulties/complexity of flash flood modelling in urban areas
  to make it more accessible in operation
- to be **able to model flash floods** and **predict their evolution as fast as possible**
- Potentially, to simulate more easily unknown event/conditions

2 main axis to make it more accessible :

- **Reducing the constraints on required input data**
  - Less data (type, density of measure, lower frequency, missing data in series …)
  - Lower precision
- **Making the execution time acceptable with operational conditions**
  - Simple operation (non specialists) (task automation)
  - Short execution time

Using IA modelling requires :

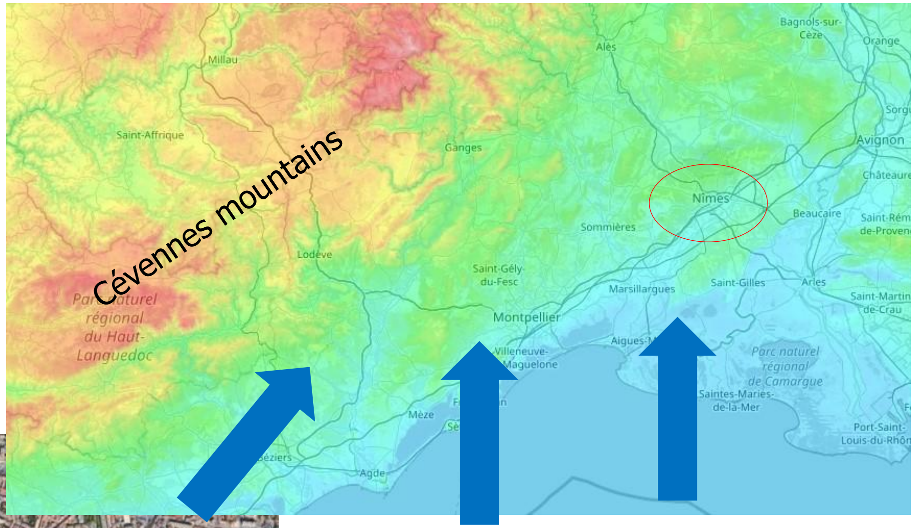
- Representative data for the training phase (amount, various conditions, space, time..)
- Result verification : thanks to existing records, other way to model

Use case : city of Nîmes (France)

Very representative case with major consequences (destruction, human casualties..)

- Geographic localisation :
  - close to Mediterranean sea and backed by mountains (Cevennes)
  - contrasted mediterranean climate
    - ➔ Meteorological events : in autumn large amount of warm H^2O available from the sea are blocked by relief
    - ➔ Old city flash flood events with surface runoff

- City characteristics
  - Old city with narrow streets in downtown district
  - 150 000 residents
  - Stress of urbanization, ground imperviousness, runoff increase
  - Natural drainage channels partly obstructed



Use case : city of Nîmes

- Existing modelling system
  - Operationnal modelisation & forecasting, sensors
  - Studies, archived data of all major events since 1988
  - Difficulties : evolution of hydro infrastructures to reduce flooding impact (reservoir, surge tank…)
  - ➔ hydraulic conditions changed

- Data, documentation available

➔ Acceptable conditions of experimentation
  - To train an IA model
  - To validate it versus validated existing data

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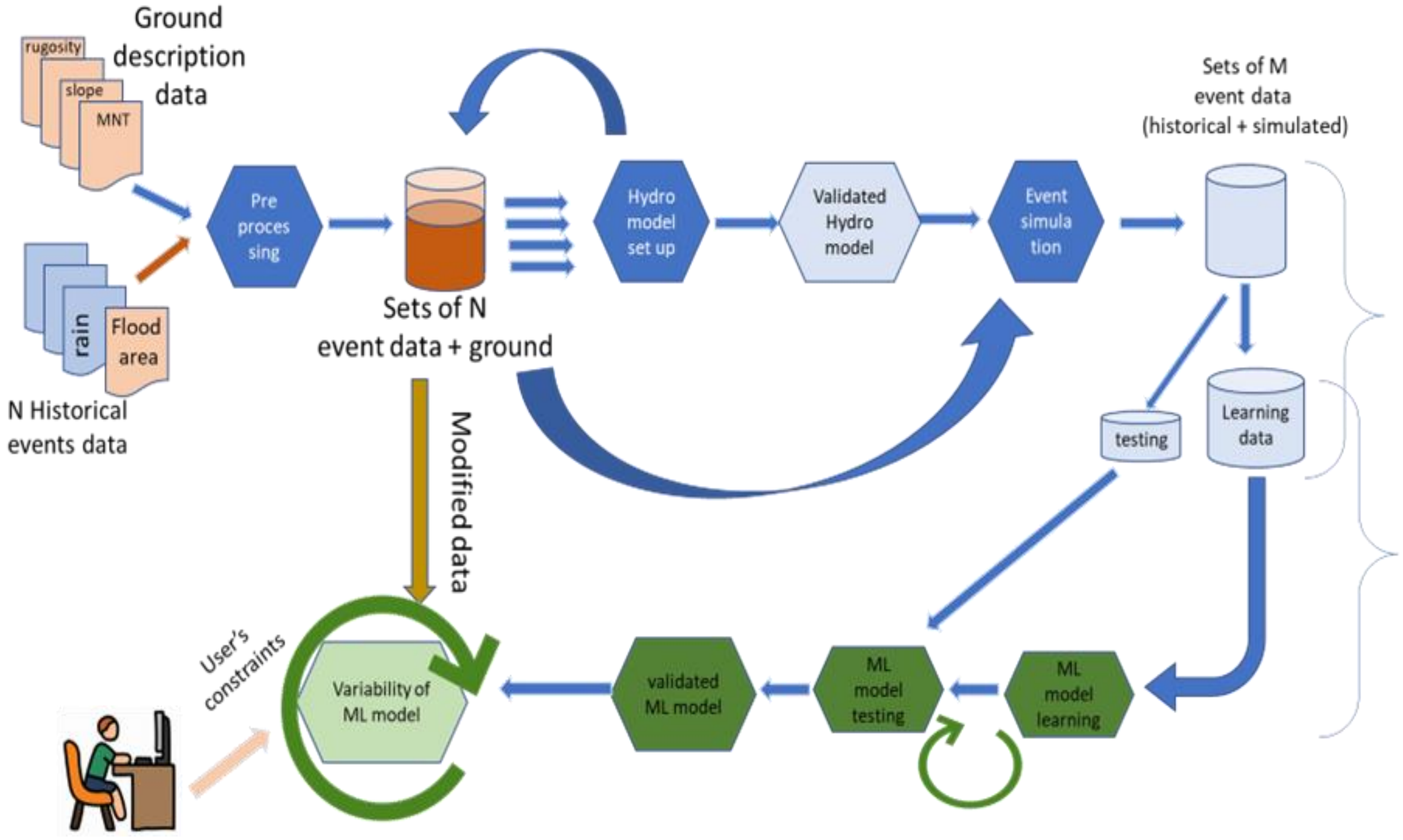
General methodology for AI model set up

- 1° **To set up a hydrodynamic model (as a reference)**
  - Based on physical parameters, that we can fully control/parameter/exploit
  - To produce many reference outputs in various run conditions to validate the future AI model (simulated events)

- 2° **To set up the AI model**
  - To train it with existing field and simulated data
  - to validate AI results against a set of hydrodynamic model outputs



Data Complexity

Complexity due to use of data variability [space, time, sampling frequency, formats]

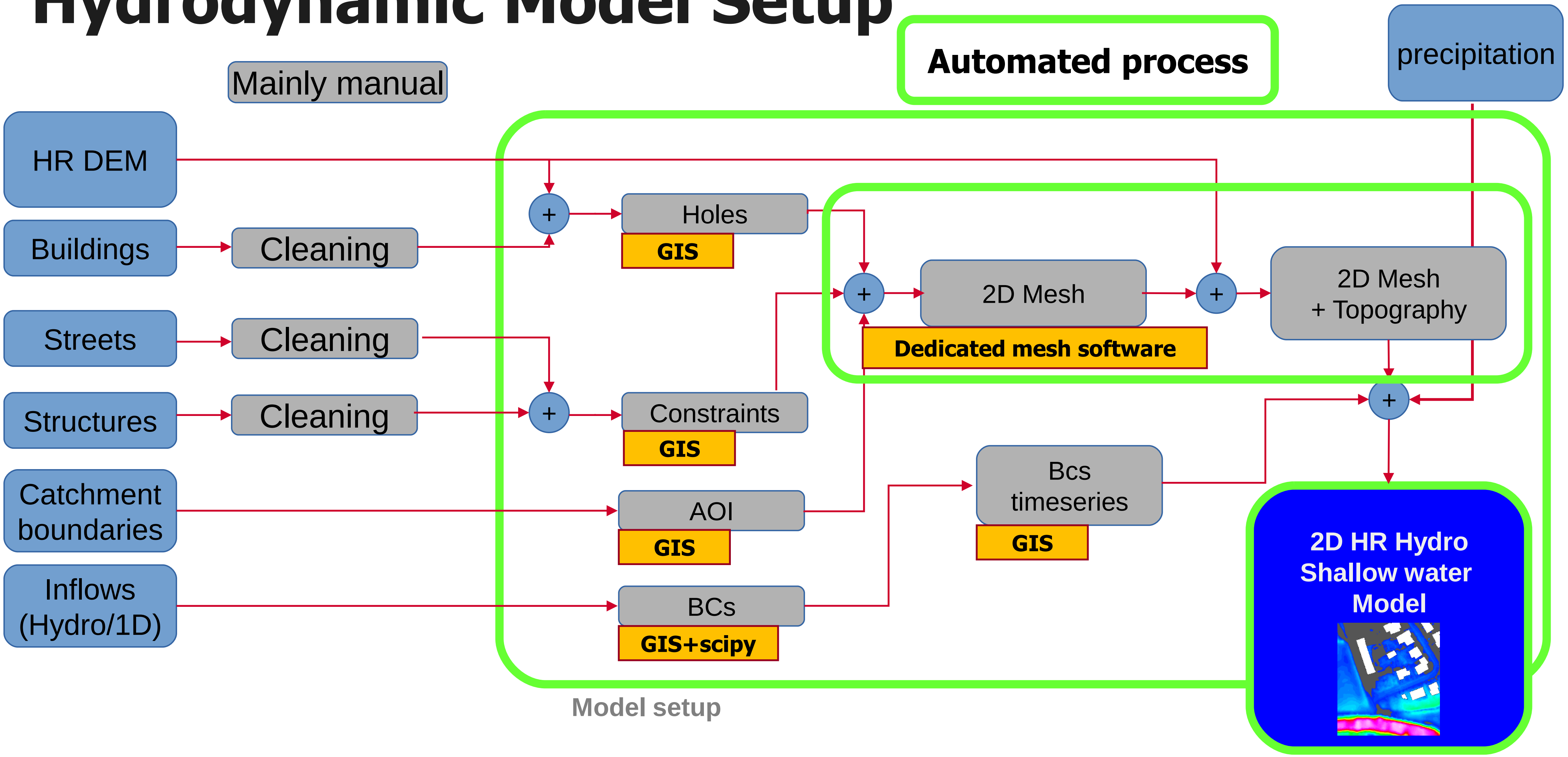
- Various types and Formats (raster, vector, grid, time series csv, etc ….)
- Spatial resolution
- Registration (geographically stacking)
- Temporal registration (need for data interpolation)
- Need to be “cleaned” (not adapted for model, artefacts)

➔ Intensive use of GIS (PostGIS) and libraries

❑ Some are massive (long time series) , grid data (rain radar, HR lidar)

- Splitting the area of interest in small triangles (< 50m)
- All data must have a value for each triangle as for all output calculation

Hydrodynamic Model Setup



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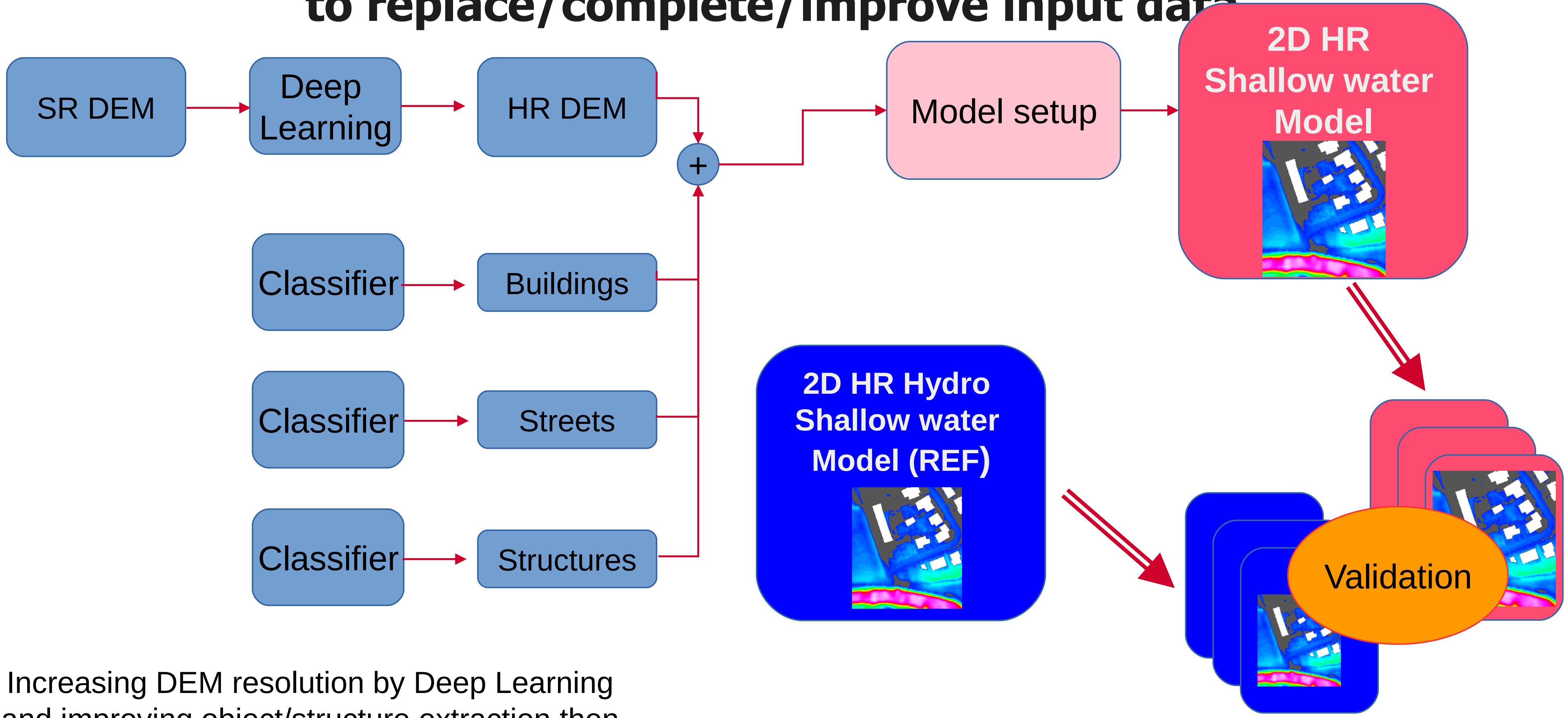
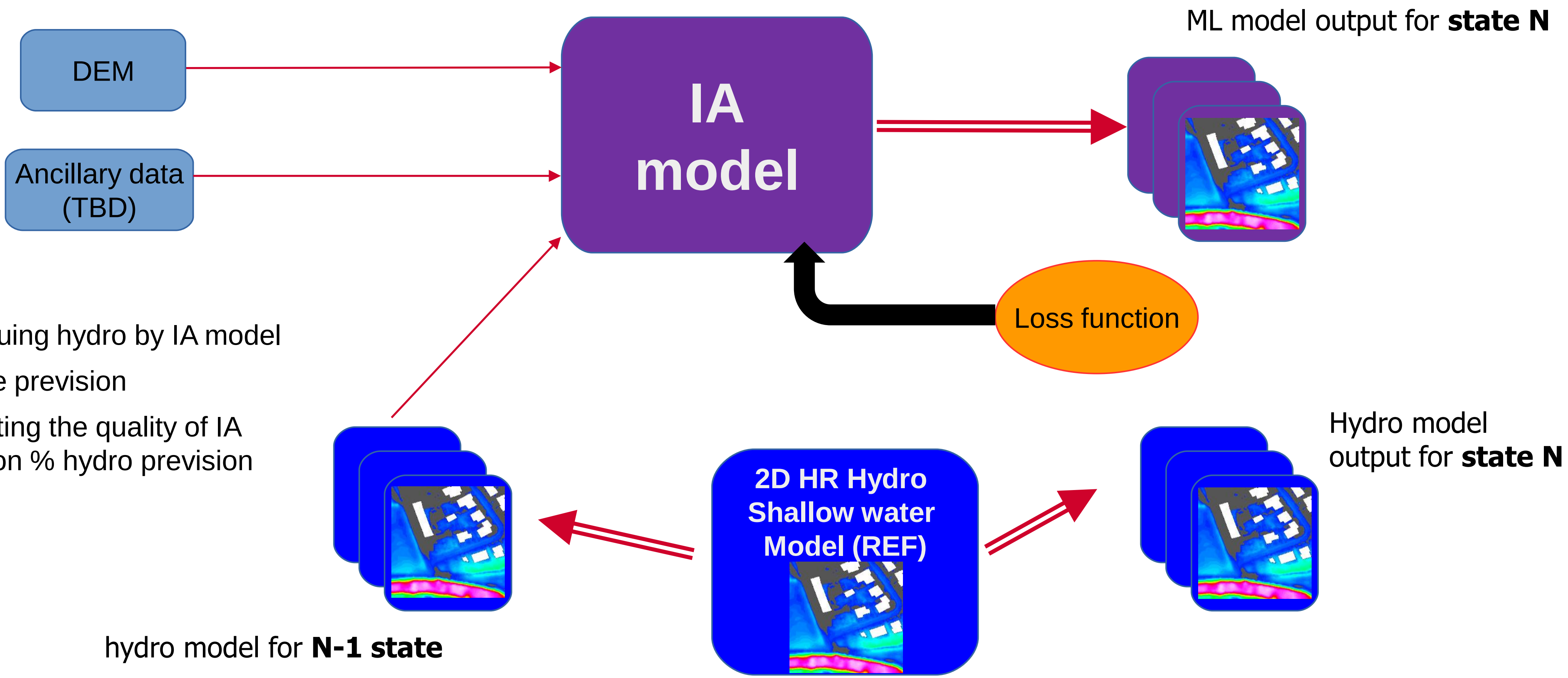
ML Experiments – scenario type 1

to replace/complete/improve input data



Increasing DEM resolution by Deep Learning and improving object/structure extraction then evaluation of the model sensitivity

ML Experiments – scenario 2 surrogate model



- Substituting hydro by IA model to calculate prevision
- Evaluating the quality of IA prevision % hydro prevision

Conclusion

- A very challenging objectives due to data complexity and variability

- Work in progress : automatization of the workflow in order for the non-specialist user, to try/test/evaluate various sets of input data

- Model sensitivity evaluation

- When successful, it will ease the flash flood modelling
  - Example : To evaluate potential impact of changes in the city (ex : new road, building, infrastructure etc …) even if data are partially missing
  - Potential use in country with few/no sensors/data to model the flood