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Integrating new in situ, airborne and spaceborne elevation data to improve river floods hydraulic modeling

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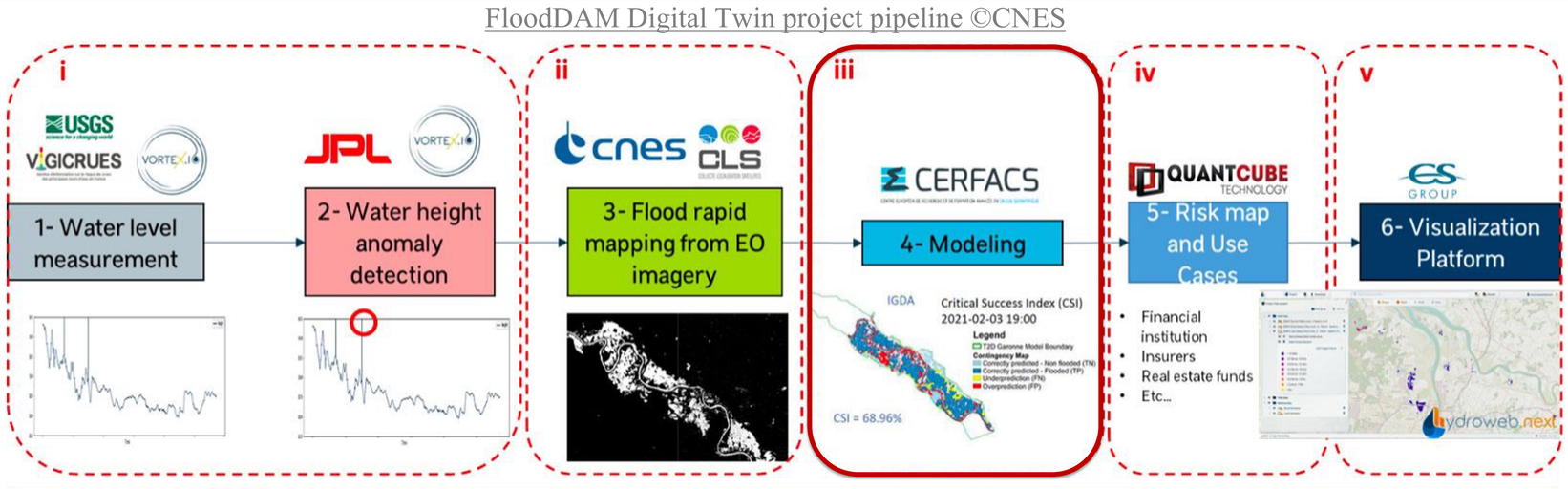
FloodDAM-DT project & Context of study :

The Space Climate Observatory - Flood Detection, Alert, and rapid Mapping Digital Twin (FloodDAM- DT) is a research project that aims to provide an automated service for reliable flood detection, monitoring and assessment, and to improve the resolution, reactivity, and forecast capability in the flood-prone areas at a global scale within a Franco-American collaboration. With the aim of understanding and anticipating these extreme events, a sensor fusion approach is being deployed, incorporating multiple satellite and ground-based sensors and the Telemac-2D local-scale hydrodynamic model (step iii).

FloodDAM Digital Twin project pipeline ©CNES



The accuracy and reliability of river and floodplain hydraulic modelling depends on the quality of the topographic and bathymetric data used to generate the Digital Elevation Models (DEMs) on which the hydrodynamic predictions are based. Recent advances in airborne and spaceborne remote sensing technologies, which cover large spatial areas with regular observations, make these technologies very relevant for producing topographic maps to be used in these models.

Objective & Study area : Evaluate the use of recently acquired ground measurements and software-updated remote sensing data to produce an up-to-date and more accurate Digital Elevation Model (DEM) version on which Telemac-2D model relies when computing water flow dynamics within rivers and floodplains.
The study is carried out on a 50 km reach of the Garonne River (south-west France), highly prone to flooding and where an aged mesh based on 1995 field surveys is the one currently used to compute river flood simulations.

Dataset :

- <u>In-situ bathymetric surveys :</u>
  - Surveys from 2013 (DDTM47) : 21 cross-sections over the Garonne reach + 6 below bridges
  - Surveys from 2005-2007 (SMEAG) : Focus on Tonneins and Marmande
- <u>River centerline trace :</u>
  - SWORD (versions 7, 15)
  - SANDRE Eau France
- <u>Land use maps :</u>
  - IOTA2 Land Cover maps 2019 / 2022
- <u>LIDAR surveys :</u>
  - 1x1 m DTM from IGN (RGE Alti : Nov. 2019 Apr. 2021)
  - 1x1 m DTM produced by *Sintégra* (July 2019)
- <u>Existing hydraulic mesh identifying structures :</u>
  - Hydraulic floodplain mesh from SPC (2020 study)

Riverbed

Floodplains

Evolution of bathymetry from 1995 in Garonne river :

Significant morphological evolution of riverbed from 1995 (the former DEM (of '95) to 2013 (ground surveys by the DDTM47).

Upstream of Marmande city :
- significant drop in all hydraulic characteristics of the riverbed : 175m^2 less capacity for 8m water height.
- riverbed overflows from recent floods (>2013) to be observed earlier than what can currently be modeled

Fig.1 : River cross-section upstream Marmande

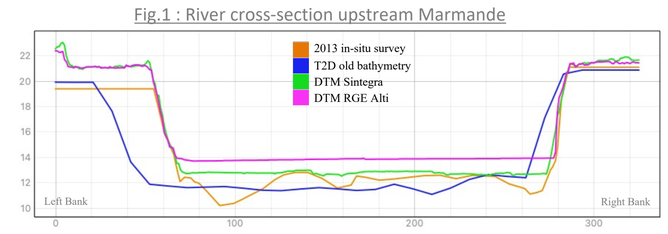


Fig.2 : Telemac-2D vs 2013 survey river cross-section upstream Marmande

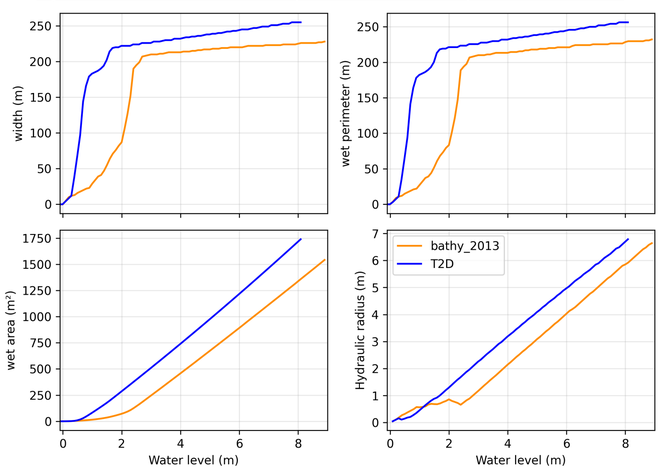
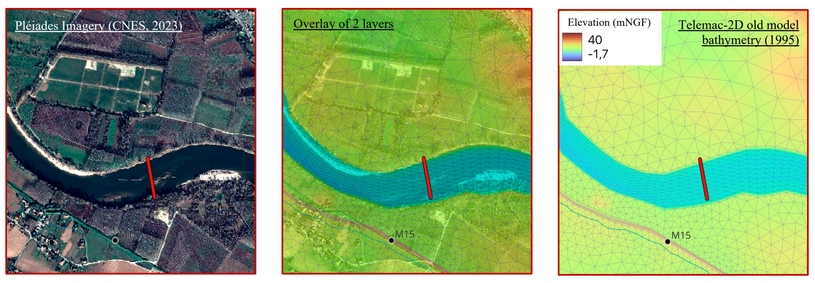
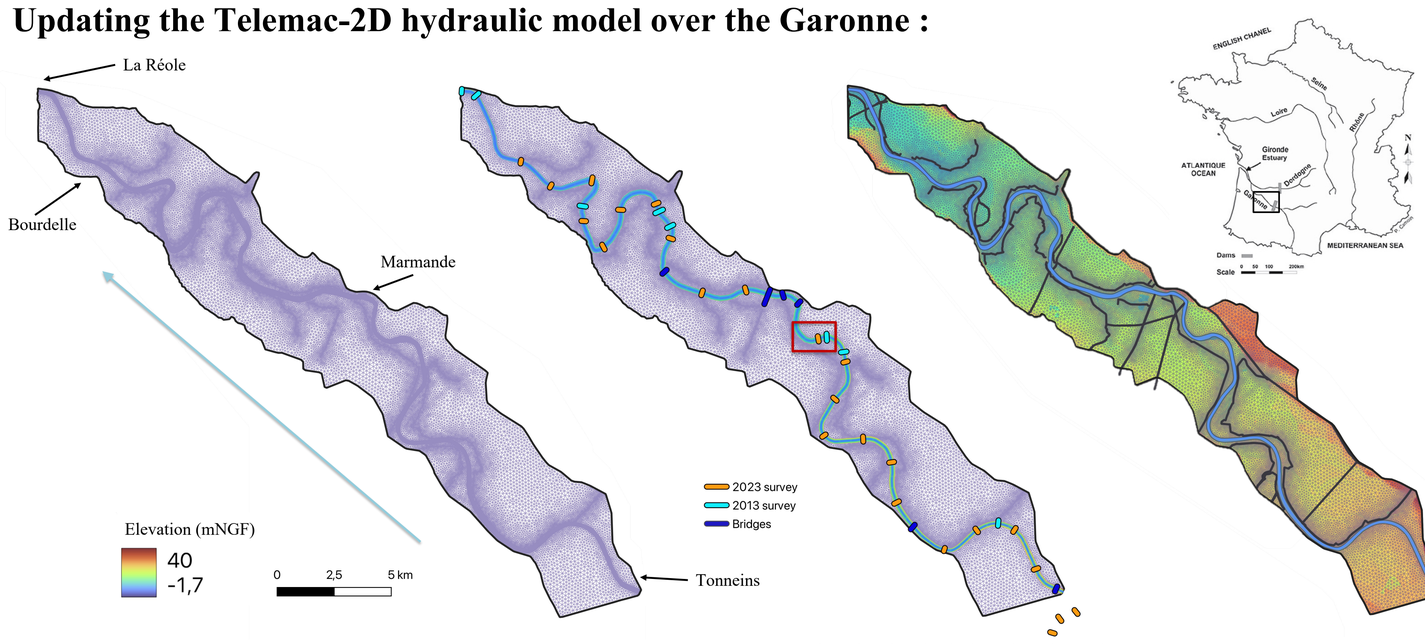


Fig.3 : Pleiades imagery (2023) vs old Telemac-2D river trace (95') upstream Marmande



- Overall change of the river's course over the study area, shown by elevation differences between IGN RGE Alti DTM and the Telemac mesh topography
- Good consistency between in-situ surveys (2013) and *Sintegra* (2019) / RGE Alti (2019, 2021) DTMs, particularly at bank level.
- No significant change observed in the river's course between 2013 and 2021 at the 21 cross-sections

Updating the Telemac-2D hydraulic model over the Garonne :



Old Telemac-2D model

Reconstructing the riverbed elevation through interpolation between the in situ bathymetric surveys conducted on the red cross-sections (from 2013)

Identification of new stress lines and updating topography based on LIDAR surveys and SPC hydraulic mesh

- <u>Reconstructing the riverbed</u>:
  - Bank delineation and elevation reconstructed from DTMs (1x1m)
  - More bathymetry data in Sintegra DTM (surveys conducted at dry period). Not covering the entire study area; IGN DTM is used to complete coverage of the riverbanks downstream.
  - The bottom of the bed not observable by the DTMs Rebuilt by interpolating the 21 cross-sections surveyed in 2013
- <u>Floodplains</u>:
  - Good consistency between the 2 DTMs over the floodplains;
  - Model topography updated from the RGE Alti DTM
  - Constraint lines updated from DTMs and SPC hydraulic mesh
- <u>Hydraulic structures:</u>
  - Hydraulic structures of interest (bridges) identified on the river and floodplains
  - Bathymetry surveys available below all 6 bridges along the river in the study area

<u>Perspectives :</u>

Upcoming data :
- Updated surveys at the level of 2013 cross-sections + complementary surveys coming in October 2023.
- Upcoming CNES' DEM from 50cm resolution *Pleiades* optical stereoscopic images (February and April 2023)
- Upcoming CNES' CO3D mission : constellation of optical satellites producing 3D images of Earth's surface at 50cm spatial resolution (data available in 2025)

→ The updated topography/bathymetry to be meshed to provide the geometry of the Telemac-2D model.
→ Features to be integrated in the model : evapotranspiration, ground infiltration capability, precipitation during flood event.
→ The impact of these improvements to be assessed on simulation results for recent floods in the Garonne catchment.
→ The new model will replace the old one and will be used in research studies on remote sensing data assimilation for flood risk forecasting.

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<u>Key words:</u> Flooding, hydraulic modeling, In-situ measurement, Remote Sensing, Satellite Imagery, Garonne, Telemac-2D.

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