Satellite imagery to support flood risk modelling in large European rivers

Floods are increasing in severity, duration and frequency, owing to changes in climate, land use, infrastructure and population demographics, along with the damage they cause. In 2021, Europe experienced a series of disastrous floods, and their negative impact could be also related to shortcomings in flood risk assessment, not only in terms of planning strategies (e.g., overdevelopment along floodplains) but also because of uncertainties in flood models (e.g., floods are usually modelled only accounting for clear water). The current state-of-art in flood management, indeed, has many limitations, which are now becoming increasingly evident and need to be addressed with a joint effort of academia and practitioners.

With the growing availability of big geospatial data and access to platforms that support multi-temporal analyses, the use of remotely sensed information for monitoring riverine hydro-morpho-biodynamics is growing. The opportunity to map, quantify and detect changes in the wider riverscape (i.e., water, sediment and vegetation) at an unprecedented spatiotemporal resolution can uniquely support river management and flood risk modelling. Analysis of big geospatial data is also embedded in cloud-based platforms such as Google Earth Engine (GEE), which combines a multi-petabyte catalogue of satellite imagery and geospatial datasets with planetary-scale analysis capabilities made available for scientists, researchers, and developers to detect changes, map trends, and quantify differences on the Earth's surface. Despite the increasing opportunity to monitor riverine dynamics from satellite imagery, few studies have leveraged this information to improve the reliability of flood models.

Hydro-morphodynamics models are knowingly complex, still, before applying a specific code a thorough study of the water body is required. Indeed, historical geomorphic analyses can inform on selecting the most adequate modelling tools (e.g. geomorphic, hydraulic, morphodynamic), providing a better understanding of how river morphology, in planform and section, evolved. Such preliminary studies should evaluate the impact of modelling choices (i.e. simplistic clear water modelling versus accounting for the presence of vegetation and sediments) in the estimate of the flood risk, supporting the water managers in choosing an ad-hoc monitoring and modelling approach.

Using the Vistula (Poland) and the Po (Italy) rivers as case studies, the project aims to i) investigate the fluvial bio-morphodynamics at a very high spatiotemporal resolution (images 10x10m, acquired every few days); ii) develop a novel flood risk modelling chain to account for such changes, therefore reproducing the fluvial environment more reliably. The Vistula and Po rivers are strategically important from a flood risk perspective, as they flow through many cities and industrial areas, with millions of people living within proximity to the river and therefore exposed to potential flooding events. A comparison of the outcomes can provide additional insights on the importance of considering local, catchment-specific conditions in developing flood risk management plans.

The two case studies will be investigated, in parallel, following the same workflow:

- GEE will be used for analyzing satellite-derived remote sensing imagery to derive fluvial dynamics at a sub-seasonal scale. GEE scripts will be created to derive a series of established multispectral indices (e.g., Normalized Difference Vegetation Index, Modified Normalized Difference Water Index, Normalized Difference Turbidity Index, Normalized Difference Built-up Index) to evaluate river evolution during the last 40 years. The opportunity to create ad-hoc Python and JavaScript codes in the online environments of GEE allows for the elasticity required by the project, as updates of both the indices and the scale of analysis could be possible in the future, depending on the availability of new satellite data. For the case study rivers, multitemporal maps will be generated to show seasonal changes in: i) vegetation; ii) exposed sediment; iii) water surfaces. The riverscape maps will be exported from the GEE environment and used as input for the subsequent stages of the PhD workflow.
- iRIC is a free numerical modelling suite that allows for simulating riverine dynamics at multiple scales, thanks to the opportunity to couple various solvers. For each river, a series of models will be created based on the available data and the GEE information (e.g., status of vegetation, presence of buildings in the floodplains), by means of the 2D solver MFlow_02, which allows for hydro-morpho-biodynamics simulations. Multiple reach- to segment-scale models will be built before upscaling to the entire river, allowing for a comprehensive calibration and validation. This operation will be performed using past records (5 years per phase). The various models will be applied for creating flood inundation maps of not only the entire river, but also focusing on specific critical areas, based on past disruptive floods. Multiple scenarios will be created and compared to flood evidence (e.g., reports), aiming to show that the concept of yearly return period and “fixed” river can lead to a non-correct representation of flood risk.