Theme: Innovation in education and training in hydroinformatics

HydroEurope Project: Open educational resources on flash flood modelling for 6 European catchment case studies

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Abstract. HydroEurope is an Erasmus cooperative partnership project of 6 European universities dealing with flash flood modelling teaching material for six catchment case studies in Europe as open educational resources. Initiated by several flash floods in 2021, the HydroEurope partners identified relevant gaps in their local course programs related to flash floods. To overcome this gap, six case studies were selected to develop teaching units on the topics: uncertainties in hydrological and hydraulic modelling for flash floods, climate change impact to flash floods and accidental water pollution due to flash floods on a European scale. These teaching units were evaluated in training courses with 319 students and 18 teachers in total and are available as open educational resources. This material is a valuable extension in hydroinformatics education for the challenge of flash flood modelling and management tasks using real case studies as pre-professional training for students in Europe.

Keywords: open educational resources, flash flood modelling, uncertainty, climate change, water pollution

1 Introduction

Several flash flood disasters occurred 2021 in different parts of Europe due to intensive rainfall events [1] but also in other parts of the world [2]. Experts in hydrology and hydroengineering at universities were contacted by the public (citizens, public authorities, consulting companies) as well as internally (students, colleagues from other disciplines) asking for explanation of these events and about required strategies for adaptations to future flash flood events triggered by climate change. While flood modelling and management (time scale several hours to days, medium and large catchment size) in general are part of existing course programmes, there were no courses/teaching units and limited expertise by the teaching staff dealing with these new extreme phenomena of short time scales (minutes to few hours) of higher rainfall intensity (e.g. 50 mm/h, or 25 mm/10min) in small catchments including related statistical analysis (requiring update of old return periods and hazard classes). The external stakeholder questions and demands and the limited expertise within the universities (as for other scientists in the discipline) was identified as an important gap in the educational course programmes and in the expertise of teaching staff. Existing educational materials on flash flood modelling using hydroinformatics methods and tools, including results analysis and interpretation, required extension by the creation of new teaching units for uncertainties, climate change impacts and accidental water pollution aspects related to flash floods.

Six partner universities (Université Côte d'Azur Nice (F), Brandenburg University of Technology Cottbus (D); Universitat Politècnica de Catalunya, BarcelonaTech (ES); Vrije Universiteit Brussel (BE); Warsaw University of Technology (PL); Newcastle University (UK)) ran the EU funded Erasmus cooperative partnership project HydroEurope 2022-2025 to overcome this gap in their national and international water related course programs. The primary target of the project was the creation of innovative teaching material on flash flood modelling, all offered as open educational resources, to be applied at the project institutions and other universities in a flexible manner. The second target of the HydroEurope project was to apply a pan-European approach by selecting and using six European case study catchments, representing typical European topographic and climatic zones. This allows each partner university to extend its course curricula from regional/national case studies to include five additional European case studies and European flood management aspects. It is also the basis for transferring the pedagogic concepts to any other specific case study in Europe by other universities for their local, national demands. Another target was the preparation of the students for the professional world. Using real case studies with available data including all related problems/challenges such as missing and incomplete data, anthropogenic interventions and actual regulations/guidelines the materials and teaching approach span a professional environment such as in real consulting projects. Even if the time in academic courses is limited to touch and to deepen all relevant aspects the applied POPBL (Project-Oriented Problem-Based Learning) pedagogic approach is an important element to increase student readiness and capability for their professional career.

2 Case Studies

The six HydroEurope project partners selected six real case studies representing different topographic characteristic (from mountainous catchments via hilly landscapes to more flat urbanized regions) and climate zones (from Mediterranean via Atlantic to continental climate conditions):

- Ahr (Germany)
- Ouseburn (UK)
- Skawa (Poland)
- Tervuren (Belgium)
- Tordera (Spain)
- Var –Vésubie (France)

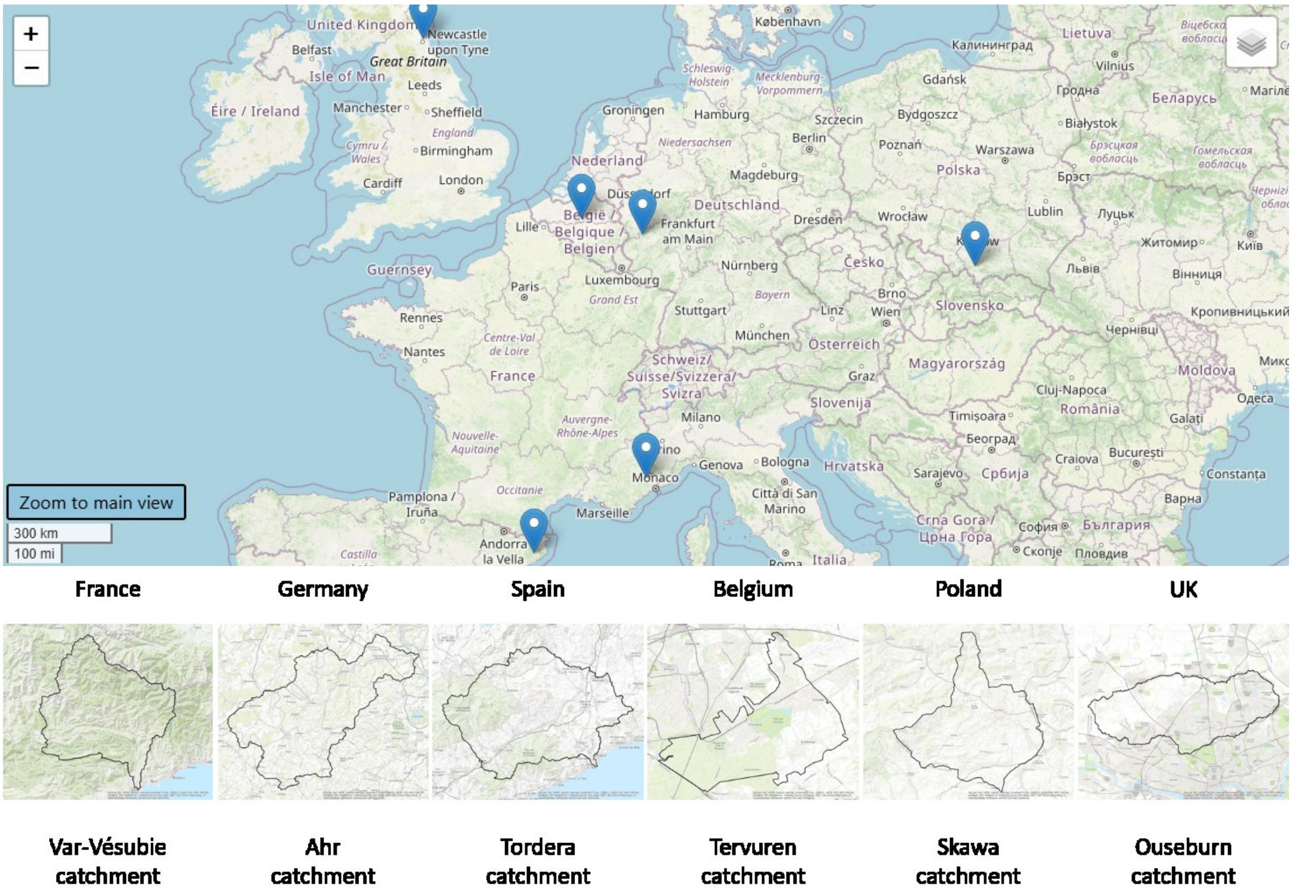

Figure 1 Six case study catchments in Europe

The selection and composition of the 6 case studies were chosen to represent a range of typical European catchment characteristics in different climate / meteorological conditions from mountainous catchments via hilly landscapes to more flat urbanized regions as well as from Mediterranean via Atlantic to continental climate conditions.

Table 1 Case study characteristics

Catchment	size km^2	climate	dominant land-cover	topography
Ahr	899	transitional	forest, agriculture	52-718 m hilly, steep valleys
Tervuren	34	Atlantic, transitional	artificial, forest	50-124 m gently slopy, flat
Tordera	864	Mediterranean	forest	0-1712 m hilly, mountainous
Skawa (upper part)	240	transitional, continental	forest, agriculture	388-1355 m hilly, mountainous
Ouseburn	55	Atlantic	artificial, agriculture	46-120 m slopy, flat
Var-Vesubie	2865	Mediterranean	semi-natural, forest	0-3072 m mountainous

For each of the six selected catchment case studies an extensive data set has been collected covering spatial oriented data such as elevation, land-cover, soil types, human infrastructure, river cross-sections, and temporal data such as meteorological/precipitation station data, water/groundwater level measurements as well as temporal/spatial data such as precipitation radar data. These data sets are combined with local flood management concepts, national regulations and climate change projections. The data sets provide essential tools for teaching students with real case problems in data pre-processing and analysis, advanced model set-up, calibration and application with a wide range of hydroinformatics software tools.

3 Teaching Unit Topics

The new teaching material for all six case studies is structured around three teaching topics:

1. Uncertainties in Advanced Hydrologic & Hydraulic Modelling for Flash Floods
2. Climate Change Impacts on Flash Floods
3. Accidental Water Pollution due to Flash Floods

Each teaching topic has been combined with the six case studies to generate 18 teaching units. Each teaching unit covers 2 ECTS (European Credit Transfer and Accumulation System) credits, so in total 36 ECTS credits, 6 ECTS credits for each case study. This allows a flexible combination of the teaching units towards courses/modules in any master course programme as well as to be used for self-studying e.g. as vocational training. The teaching units do have theoretical parts but are mainly based on modelling/analysis tutorials to apply the data sets, hydroinformatics tools, result analysis and interpretation in a manner consistent with professional projects on flash flood risk and hazard management.

3.1 Uncertainties in Advanced Hydrologic & Hydraulic Modelling

Hydrological and hydraulic modelling are a key component of any forecast/warning system and flood risk water management. A precise and reliable forecast helps prevent flood damage and properly plan interventions in case of a flood event. The accuracy of a forecast depends on the sources of uncertainty within the models. According to the paper “Hydrological data uncertainty and its implications” [3], the consideration of the uncertainties leads to improved water management and related decisions/activities. It has been observed in the project partner universities that students nowadays lack a good understanding of the basics in water related modelling. Many of them view and use hydoinformatics tools as "pressing the buttons" software or “black boxes”, which are run without seriously considering and understanding the underlining principles, assumptions and uncertainties to evaluate the model results on the required level. The first specific objective of the project was thus production of teaching units concerning “Uncertainties in Advanced Hydrological and Hydraulic Modelling for Flash Floods”. Each partner produced one teaching unit using the specific case study from its country and the related different national/regional regulations and conventions to examine uncertainty. Screen shot examples from an uncertainty analysis for two parameters taken from a hydrological modelling tutorial (Ahr catchment, HEC-HMS) are shown below:

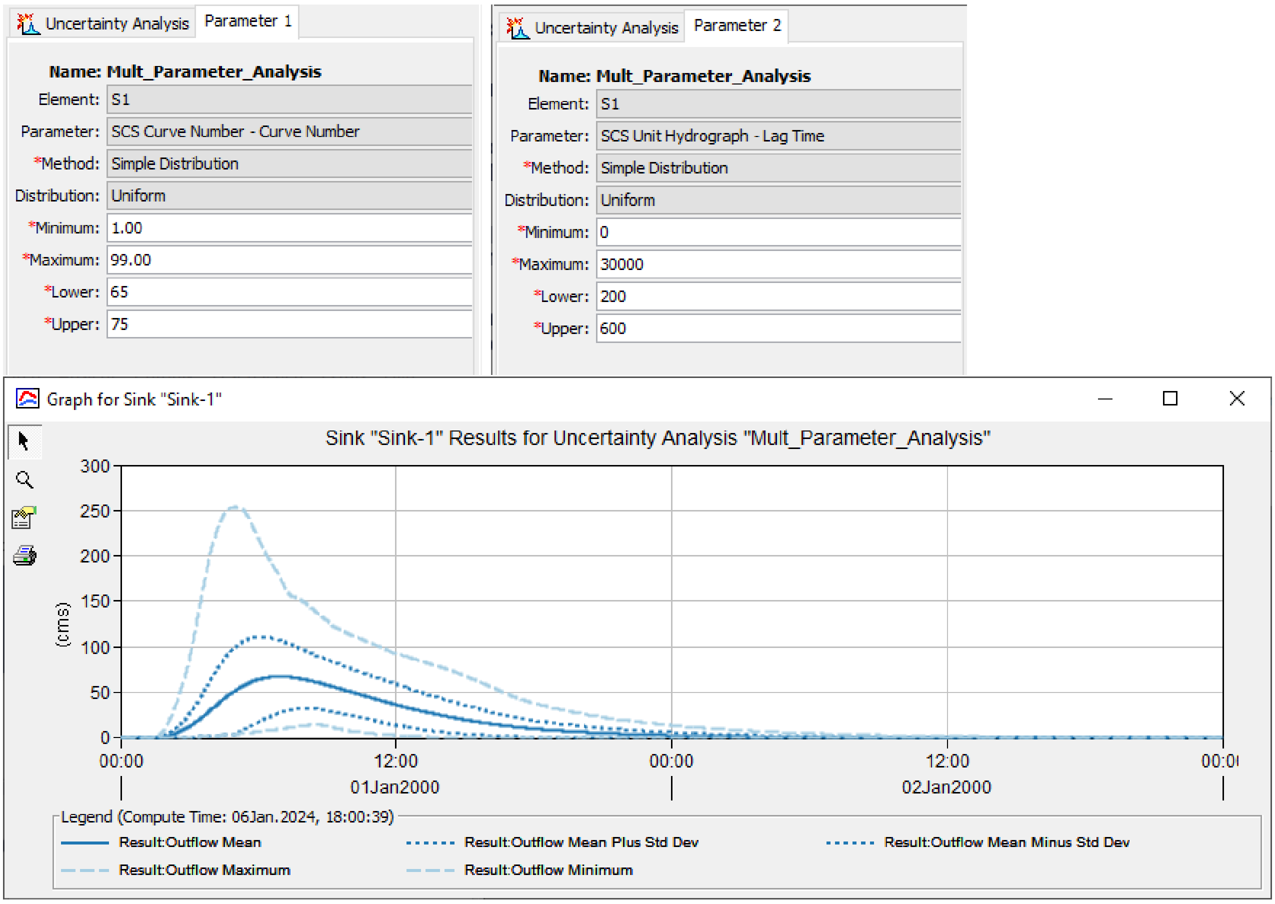

Figure 2 Uncertainty Analysis with two parameters (curve number, lag time) in HEC-HMS
(see Teaching Unit 2_1 Ahr_HMS_UA_Tutorial)

3.2 Climate Change Impacts on Flash Floods

According to the EU action for climate change adaptation, climate change is expected to lead to an increase in precipitation intensities in many European regions and as consequent to an increase in the frequency of flooding in the coming years, esp. due to flash floods. Flash floods are rapidly-rising floods are most often caused by heavy rains over short periods (hours). Therefore, it is important that future water engineers are well equipped with the knowledge and experience of managing flash floods. The current curricula in universities tend to focus on traditional flooding issues and only consider climate change impacts as an afterthought. Thus, the project aimed with its 2nd topic to bring the climate change to the foreground, where the focus is climate change impacts on extreme events and their implications for the evolution of flash floods' behaviour. Teaching units on this topic were produced for each of the six case studies based on climate projections and national regulations. Figure 3 shows screen shot examples from one tutorial in which spatial distribution of rainfall intensities based on statistics are input to hydrological models to assess climate change scenarios:

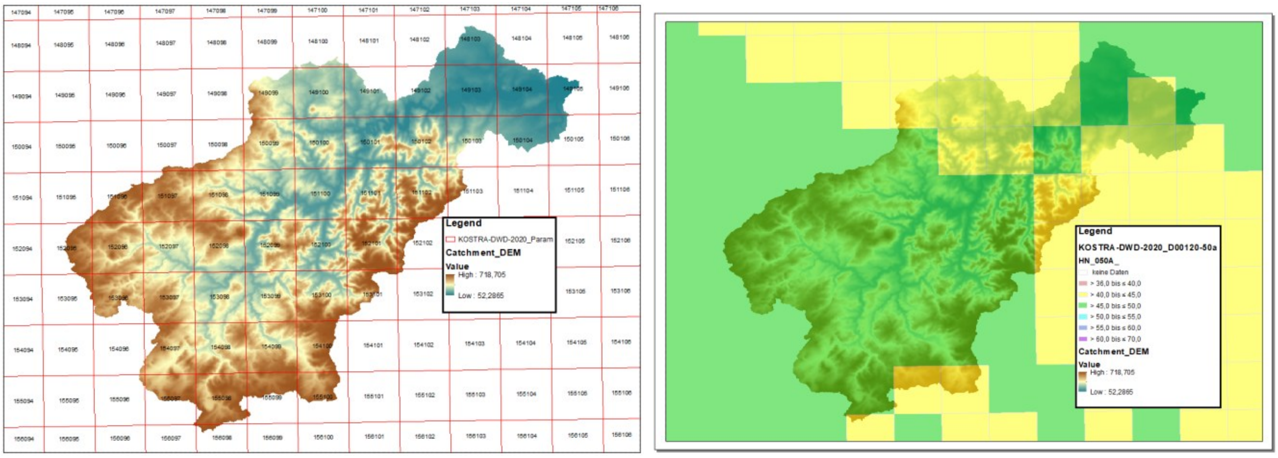

Figure 3 Spatial distribution of Rainfall intensities for a 2 hours event and 50 years return period
(see Teaching Unit 2_2 Ahr_ClimateChange_Tutorial)

3.3 Accidental Water Pollution

According to EEA report “Drivers of and pressures arising from selected key water management challenges — A European overview” [4], current key problems include pollution from urban and industrial waste water, diffuse pollution from agriculture, and pollution from mining and dwellings that are not connected to a sewage system. Thus, it is important to increase the competencies of future water engineers by producing high quality pedagogic resources with a European perspective on "Accidental Water Pollution", covering management of pollutant contamination in surface waters, ground waters, sewers and rivers during flash floods. There is a need at the project partner universities to add more focus on modelling and managing water pollution and water quality due to flash floods in the curricula. This 3rd project topic was implemented by producing teaching units for each of the six case studies covering water pollution due to flash floods in flood modelling including groundwater modelling (Skawa case study). Figure 4 shows screen shot examples from pollution transport and accumulation using 2D hydrodynamic models (Telemac2D) during and after the flash floods.

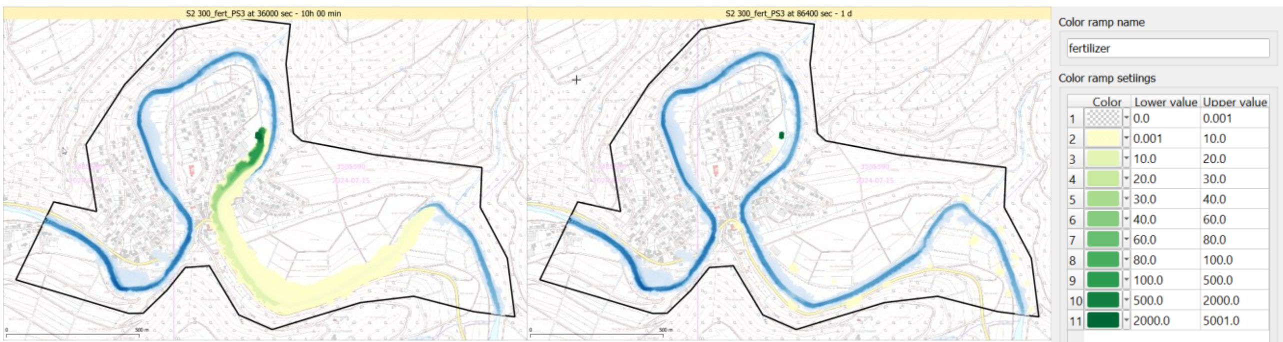

Figure 4 Point source fertilizer transport (tank burst) after 10 h (during flood wave) and after 24 hours (remaining pollution after flood wave)
(see Teaching Unit 2_3 Ahr_Telemac_Tracer_Tutorial)

4 Courses

The teaching units were evaluated in three annual courses 2023 (topic uncertainty), 2024 (topic climate change impact) and 2025 (topic water pollution) with 319 students and 18 teaching staff members from the partner universities. The students formed inter-institutional teams to work on the case study teaching units with supervisors / teaching staff from the partner universities using the collaborative engineering approach in education [5]. The teamwork was done from November to mid of February by online collaboration on a web-based collaboration platform and during a two week face-to-face meeting in Nice (2023 and 2024) and Barcelona (2025). All teams documented step wise their team work in three engineering reports as well as giving three presentations on their work progress during the face-to-face meeting (Figure 5). Reports and presentations are free accessible on the project platform [6] as well as on the team platforms e.g. for the 2025 course [7]. These courses are being continued on an annual base independent of the project and are open for other interested universities. The 2026 course was running when this paper was written.

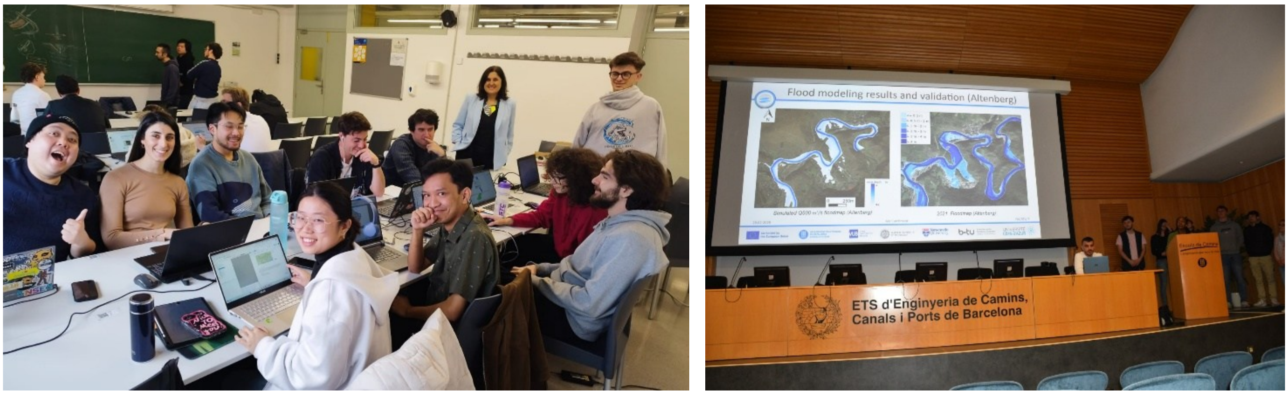

Figure 5 Team work during the face-to-face meeting and team work result presentation

The courses were used to evaluate and to improve the teaching material developed, to measure and to assess the impact on students and teaching staff (knowledge, technical capability, analytic, skills, overall competences). Testimonials from students and staff are available on the project platform [8]. In addition to providing new flash flood insights, this team-based POPBL pedagogic approach leads to international collaboration skills and to an increased understanding the European dimension / transborder aspects on flash flood modelling and management on pre-professional level.

5 Open Educational Resources

Erasmus cooperative partnership results are financed by European tax money and results have to be free available for non-commercial use. The teaching units of the HydroEurope project have been published on the Website [9] including lecture notes, data sets and tutorials to be used for academic / educational use as open educational resources. The project partners can be also contacted for joint activities and additional information and support for the use of the teaching material by other universities.
This chosen catchment characteristics selection and the three flash flood topics allows at least an implicit transferability to most parts of Europe. The six catchment examples can be used as prototypes to develop similar teaching material for additional case studies in any part of Europe by other universities. The platform is open to be extended for additional teaching material related to the flash flood topic from universities in Europe.

6 Conclusion

The teaching material developed is available as open educational resources on the project platform https://hydroeurope.upc.edu/ [9]. The material can be used by individuals for self-study as well as by other universities in their curricula. The chosen catchment characteristics (combination of topography classes and climate zones) and the three flash flood topics with the related theory, methods and tools allow transferability to other catchments in Europe to be used in any national oriented course programme.

The limited resources at most universities in Europe do not facilitate consistent updating of educational course programmes in parallel to the ongoing progress in research and ICT/hydroinformatics and the increasing demands from society related to environmental protection, climate change and water management at local, national and European scales. This challenge can be tackled by cooperative partnerships of colleagues from different university and different expertise sharing resources and expertise to create joint teaching material and joint courses with high synergy effects. Preparing teaching material not only for local use but as open educational resources enables the sharing of general and specific teaching resources beyond local limitations and allows a wider offer for teaching topics esp. for smaller groups of students and teaching staff. As an extra benefit of this way of working students gain experiences in pan-European collaboration and understanding international collaboration, which is are key skills for transnational water management in Europe. Using real case studies and related problems beyond well-defined academic problems gives students an insight into the way professional projects are run, better preparing them for their professional careers.

HydroEurope with its topic of flash flood modelling in Europe is a good practise example of this approach leading to large synergy effects and new teaching material to be used in local and joint courses. This concept will be also used to update courses and teaching material in a collaborative partnership focusing on the opposites of floods: the increasing problem of water scarcity and droughts in several European regions. A related proposal has been submitted to the EU Erasmus programme in March 2026.

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