LUXEMBOURG
INSTITUTE OF SCIENCE
AND TECHNOLOGY

HYDRO-CSI

CLUSTER 1 – INNOVATIVE FIELD-DEPLOYABLE INSTRUMENTS FOR HIGH-FREQUENCY MONITORING

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Summary of Hydro-CSI research clusters

INTRODUCTION

The doctoral Education Unit in Hydrological Sciences (Hydro-CSI) is contributing to the exploration of new and interdisciplinary research avenues to overcome limitations in our current understanding of catchment functioning.

Hydro-CSI is led by LIST in partnership with the University of Luxembourg (LU), Vienna University of Technology (AT), Wageningen UR (NL), Karlsruher Institute of Technology (DE) and is supported by the FNR.

Hydro-CSI is composed of four research clusters:

- **Cluster 1 – Innovative field-deployable instruments for high-frequency monitoring**
- Cluster 2 – New tracers and approaches for investigating hydrological processes
- Cluster 3 – Remote sensing applied to hydrology
- Cluster 4 – Hydrological forecasts and projections under global change

In this document, please find the presentation of Cluster 1.

1.1 PHD PROJECT OF CAROL TAMEZ MELENDEZ

Topic: **Isotope hydrology**

Project objectives:
Carol Tamez-Melendez has defined four main objectives in her research proposal. First, she aims at characterizing the seasonality of floods and their associated hydro-meteorological characteristics in the Sûre River basin (L). Second, she will characterize (extreme) rainfall-runoff events across a wide range of physiographic conditions. Third, she will identify and characterize precipitation-runoff transformation processes by using isotope and/or hydro-geochemical tracers. Forth, she will use high-frequency isotope signals of O and H in precipitation and streamwater for investigation rainfall-runoff transformation during convective events in the Ernz Blanche River basin (Luxembourg).

Abstract:

Prior work in the nested catchment set-up in the Alzette River basin (Luxembourg) has shown the strong controls exerted by bedrock geology on fundamental hydrological functions of water collection, storage, mixing and release. However, precipitation and stream water sampling protocols for isotope analyses essentially remained restricted to fortnightly or daily time steps (except for isolated events that were sampled at hourly intervals) in distinct locations. A major shortcoming of these protocols is their supposed lack of representativeness. Isotope signatures of O and H in precipitation are indeed known to exhibit a large variability in space and time. Amplitudes may be related to the origin of air masses, latitudinal and altitudinal effects, as well as event-specific convective processes (the latter prone to unfold within hours to minutes).
The recent advent of new (field deployable) instruments for monitoring isotope signatures in precipitation and stream water has paved the way for investigating their variability at unprecedented temporal resolution. The prospect of handling large numbers of water samples for O and H stable isotope analyses also has paved the way for citizen-science based initiatives – where precipitation samples are collected in multiple point locations over large river basins. The collected datasets ultimately provide maps of isotope signatures in precipitation of unprecedented spatial resolution.
Here, we propose to leverage prior work at LIST on high spatial and temporal resolution monitoring of isotope signatures in precipitation and stream water by extending the use of a new generation of laser and mass spectrometers to gain new insights into both seasonal and event-based O and H stable isotope signatures and related rainfall-runoff transformation processes across a wide range of physiographic settings (in the Alzette River basin in Luxembourg and the HOAL experimental catchment in Austria).

Carol Tamez Melendez will contribute to solve pressing challenges and research questions posed by global change impacts on river systems – more specifically the need for high frequency monitoring of hydrological processes for gaining a better mechanistic understanding of extreme rainfall-runoff events. More specifically, she will:

- Design, craft and implement her research proposal, based on a thorough analysis of the current state-of-the art in isotope hydrology.
- Build a set of testable hypotheses related to non-stationarity of hydrological systems and their response to global change.
- Build-up on past and ongoing research on the spatial and temporal variability of isotope signatures of O and H in a nested catchment set-up in Luxembourg.
- Explore the potential for new generations of laser and mass spectrometers to measure stable isotopes of O and H in precipitation and stream water (and possibly groundwater, soil water and plants).
- Design and implement an innovative (high-frequency) tritium sampling protocol for precipitation and stream water.

- Carry out your own snapshot water sampling in Luxembourg's river system for isotope analyses with a view for identifying spatial and temporal patterns in precipitation and stream response.
- Translate the newly gained data on isotope signatures in precipitation and stream water into new mechanistic conceptualisations of rainfall-runoff transformation (with a view to global change and non-stationarity of hydrological systems).

1.2 PHD PROJECT OF ENRICO BONANNO

Topic: **In-stream hydrology** <u>Project objectives</u>: Pollutant transport, nutrient cycling and ecological behaviour of a riverine system are strongly influenced by how the groundwater exchanges with the stream. Here, we investigate groundwater and stream interactions in order to characterize the physical processes that control the water/solute exchange and their variability over time.	

Abstract:

Streamflow ecological functions are coupled to streamflow properties, transport of water, solutes, nutrients, biogeochemical activity and streambed material features. In this viewpoint, the hyporheic zone, a saturated transition layer between river and groundwater, is able to modify surface streamflow paths making them pass through the streambed, increasing their retention time, exchange of organic matter, nutrients, oxygen and solutes with a consequent modification of local biota activity. These characteristics allow the hyporheic zone to be a relevant biogeochemical and hydrological site in the streamflow ecosystem and in the last fifty years, the scientific interest in its processes increased substantially. Modern research aims toward a holistic and mechanistic approach able to increase the understanding and quantification of solutes travel times, dispersion and retaining in the hyporheic and/or dead zones. One of the most challenging aims is to obtain a coherent scientific framework capable to link transport features across different spatial and temporal scales. For these reasons, the PhD project will focus on the in-stream transport of solutes and nutrients in order to quantify, for separate stream reaches, the transient storage and its properties. The field work relates to high-resolution data acquired in a long-term approach for different catchments and data will be analysed to highlight streamflow hydraulic and morphological properties across seasons and climate patterns. Degradation of nutrients and their dynamics will be related to streamflow values, background concentration and hyporheic exchange as well. Ultimately, the outcome of this research will contribute to the preservation of water quality in relation to the EU water framework directive.

1.3 PHD PROJECT OF DHRUV SEHGAL

Topic: **Sediment fingerprinting**

Project objectives:

Transport of suspended sediments (SS) within a river is a spatially and temporally dynamic process, which requires high frequency monitoring to capture SS dynamics and quantify SS fluxes. However, current optical methods to quantify SS fluxes are highly influenced by composition, size and concentration of SS. Here, we propose to use *in-situ* sensors to measure the characteristics of SS and ultimately improve flux estimations.

Abstract:

Suspended sediments play a key role in our ecosystems. The amount (too much or too little), particle size distribution and chemistry of suspended sediment have a huge influence on nutrient and contaminant transport, the natural formation of sandbars, deltas and beaches, and favour or unfavour the environment as habitat to particular life forms. Hence, a good characterization of suspended sediment properties and quantification of fluxes and of their changes over time is necessary to gain comprehensive understanding and improve hydrodynamic and sediment transport modelling. In this respect, it is often neglected that most rivers transport significant proportions of fine-grained cohesive sediment (composite rather than primary particles), which is known to be transported primarily as aggregated material. Flocs are a complex matrix of organic particles, inorganic particles, microbial communities and interfloc spaces. Excluding those systems with high proportions of sand particles, which do not flocculate, flocculation has a large impact on sediment and contaminant transport as it changes the hydrodynamic properties of the sediment (e.g. increasing the effective particle size by orders of magnitude, and changing the effective particle shape, density, porosity and fall velocity). We aim at investigating suspended sediment transport and floc properties under changing hydrodynamic forcing by combining different submersible sensors that can provide high frequency data. Special attention will be paid to important controlling factors of riverine flocculation (e.g. dissolved and particulate organic carbon concentration, suspended solids concentration, temperature, pH and salinity). To this end, we will design a combination of laboratory, flume and field based experiments.