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ETH zürich

OPEN-SOURCE, LOW-COST TURBIDITY SENSOR NETWORK

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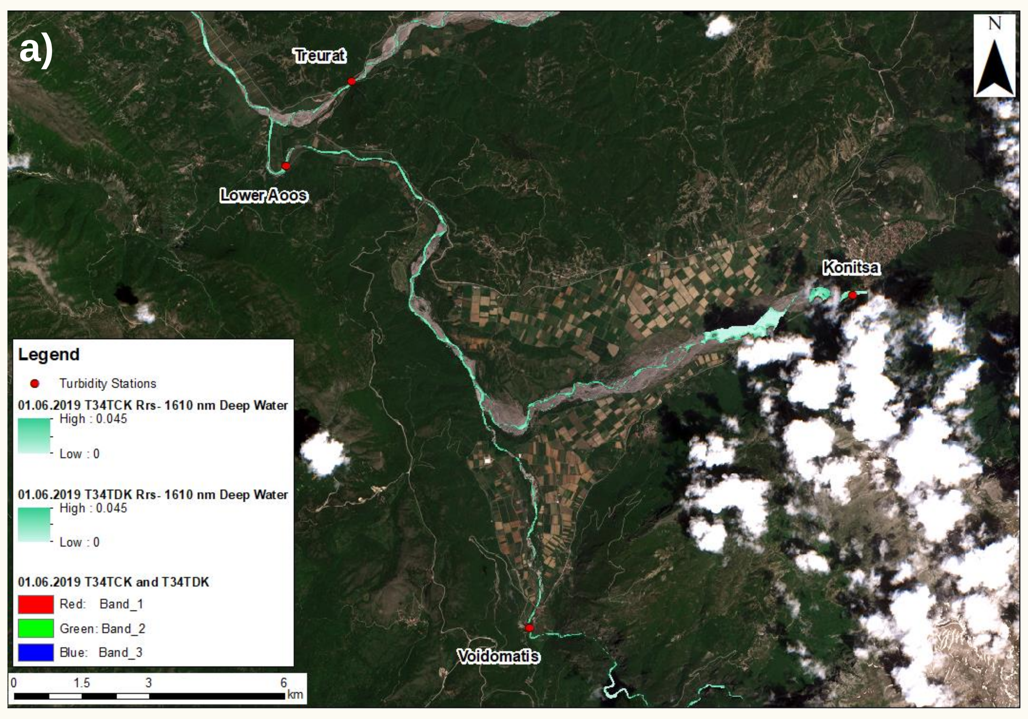
INTRODUCTION

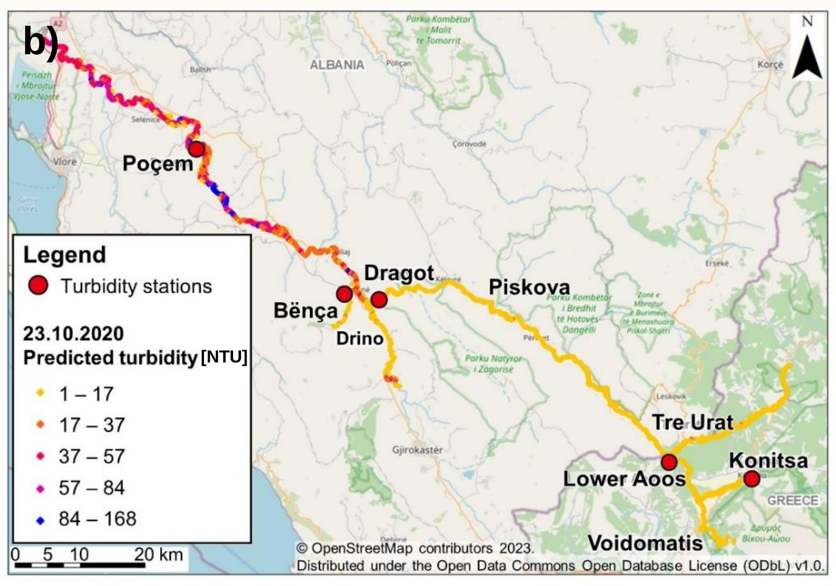
Fine sediments play a crucial role in influencing **catchment nutrient fluxes**, **global biogeochemical cycles**, and **pollution levels** in riverine ecosystems. About 36 Gt/yr of sediment is eroded annually (Borrelli et al., 2017) while ~18 Gt/yr is **delivered into global oceans** by the 2,000+ largest rivers (Cohen et al., 2022). **Agriculture** is predicted to increase sediment delivery by 215% while **dams** may decrease delivery by 49% (Syvitski et al., 2022).

The estimates above rely on models and are not sufficiently supported by observed data. The monitoring of suspended sediment in rivers using current methodologies poses **significant challenges**: they **expensive** and are restricted **to few single site** measurements. **Traditionally, we would measure the sediment yield at a catchment outlet, but this doesn't tell us about the different sources and pathways of sediment.**

We identified these sources and pathways of sediments by deploying (c) a small network of sensors (b) and satellite imagery (a - Sentinel-2) on the Vjosa river in Albania/Greece. This river has morphological variability that is not seen anymore in other European rivers at this scale.

Sentinel-2 has a satellite overpass of 4-5 days, but in reality we had even less data due to clouds. We also lost 45'000 EUR of sensors.





LESSON: For sediment source and pathway identification, we need a new, low-cost multiparameter sonde that measures temperature, pressure, and turbidity, to increase sampling frequency and redundancy.

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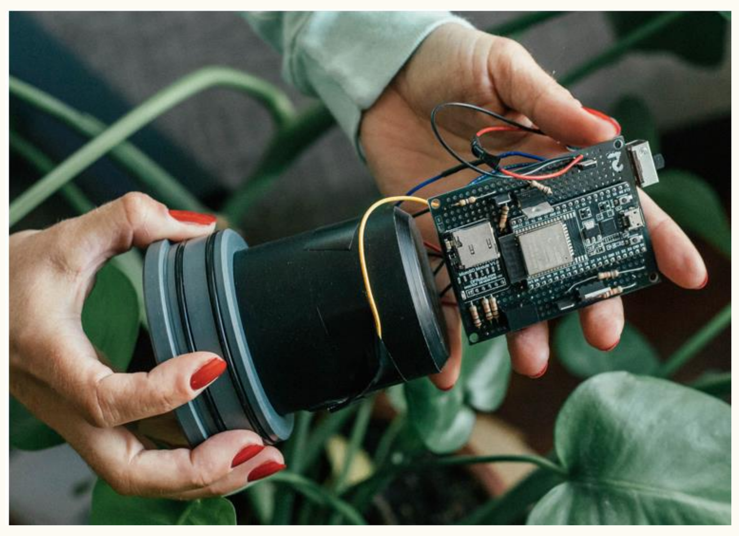
METHODS

We spent the last 3.5 years developing a low-cost, open-source, in-situ sensor for river deployment that measures temperature, pressure (water level), and turbidity, and sends data remotely.

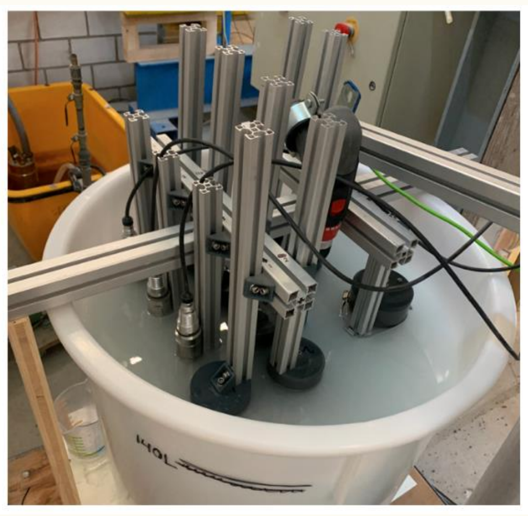


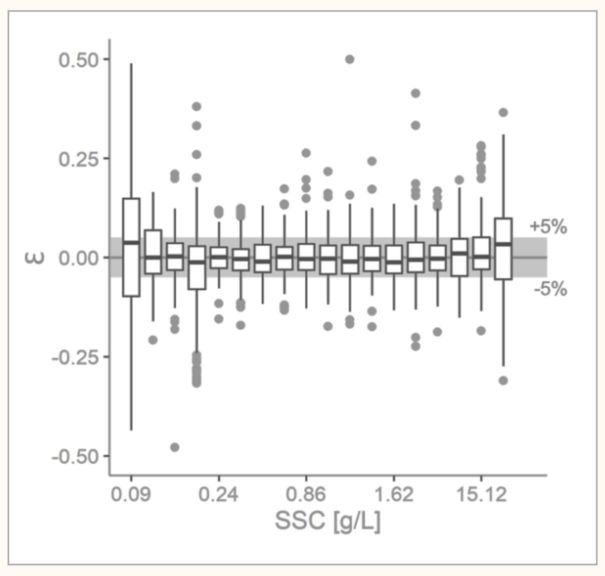
FIRST TURBIDITY PROTOTYPE: Consists of a control volume that is illuminated by an IR LED and the scatter is measured by two detectors (*ABOVE*).

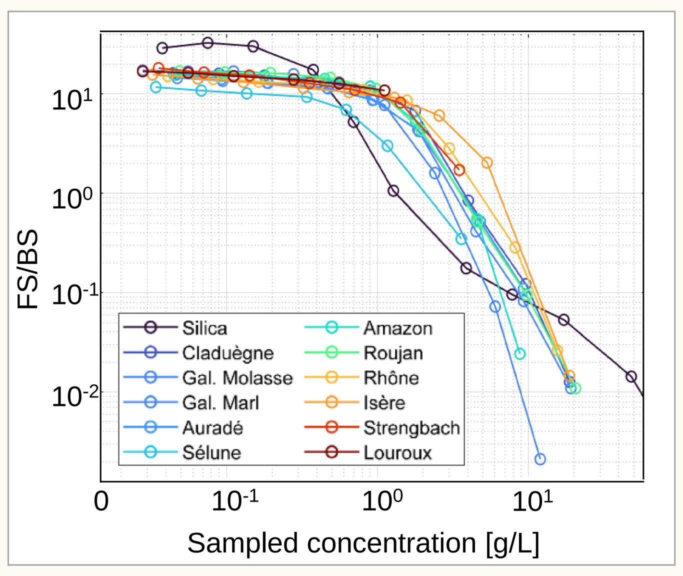
We tested 8 duplicates of our sensors in a mixing tank (*RIGHT*) along with 3 commercial sensors.

Experiments done using two powders:

- Feldspar (d_{50}=30μm)
- Sand from the Fieschertal hydropower plant (d_{50}=90μm).







scientific reports

We found that our sensor has a low measurement uncertainty over a larger range of suspended sediment concentrations (SSC), up to 15 g/L (*ABOVE LEFT*). And it works up to at least 20 g/L in 12 sediment types (*ABOVE RIGHT* – Bakker et al. *Submitted*).

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SECOND PROTOTYPE (a): Based on the design of the optical elements, a next prototype was made using an Arduino MRKWAN 1310 (ultra low-power) and a custom PCB shield. We also included a pressure & temperature sensor. This sensor is entirely 3D printed using a hobby printer (accessibility).

(b): We added a motor (to wipe the optics) and LoRaWAN but this was abandoned.

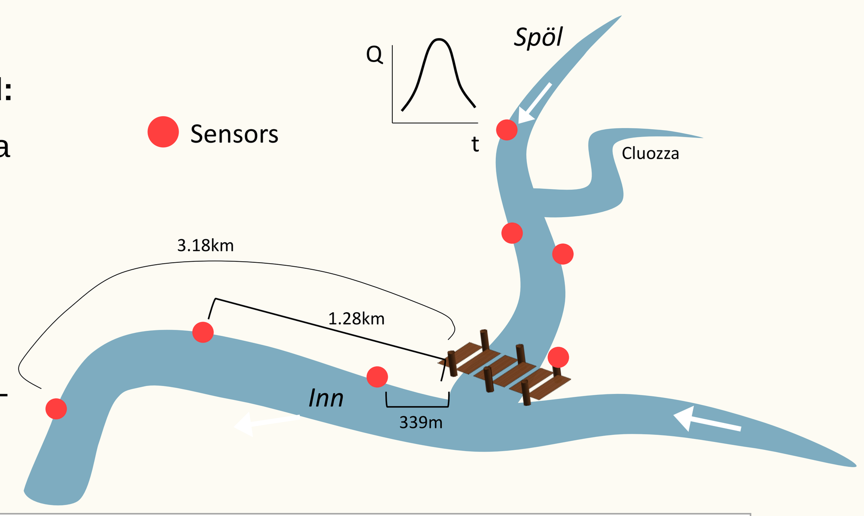
Get all of the .stl and Github files here!

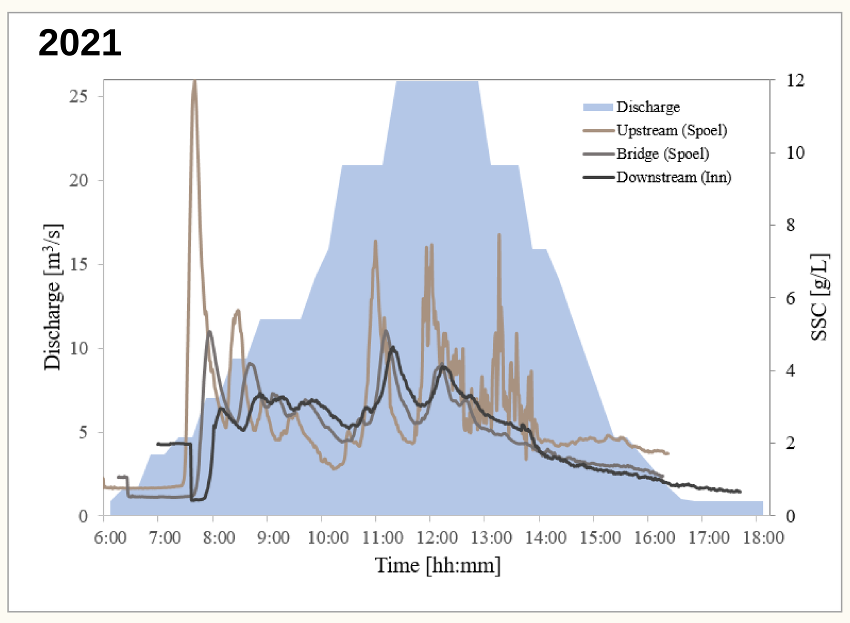
CASE STUDIES

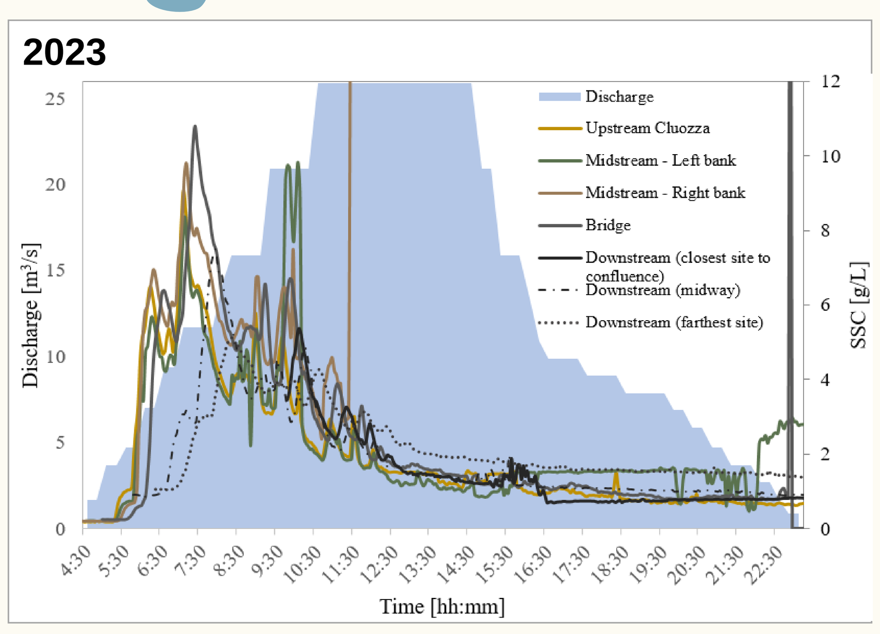
1 Environmental floods (e-floods) on the Spöl, Switzerland:

Since 2000, 1-2 e-floods are released annually on the Spöl, a tributary of the Inn river. We investigated the effects of these e-floods on the Spöl and downstream Inn, especially on the duration of high sediment concentrations that can damage fish.

We installed 7 sensors on both rivers (*RIGHT*) in 2021 & 2023, and both floods lasted 10-19h. The dam released 0.9 – 25.9 m³/s (*BELOW*).







We observed very high SSCs with the onset of the floods, along with SSC pulsations. We estimated 1'305 t (2021) and 1'936 t (2023) of total load delivered to the Inn during each flood. This is ~5% of the total annual load of the Inn!

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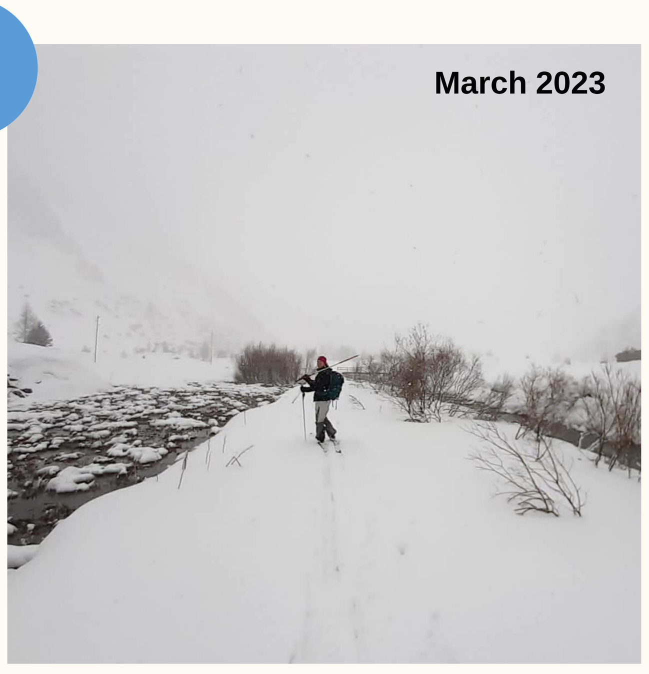
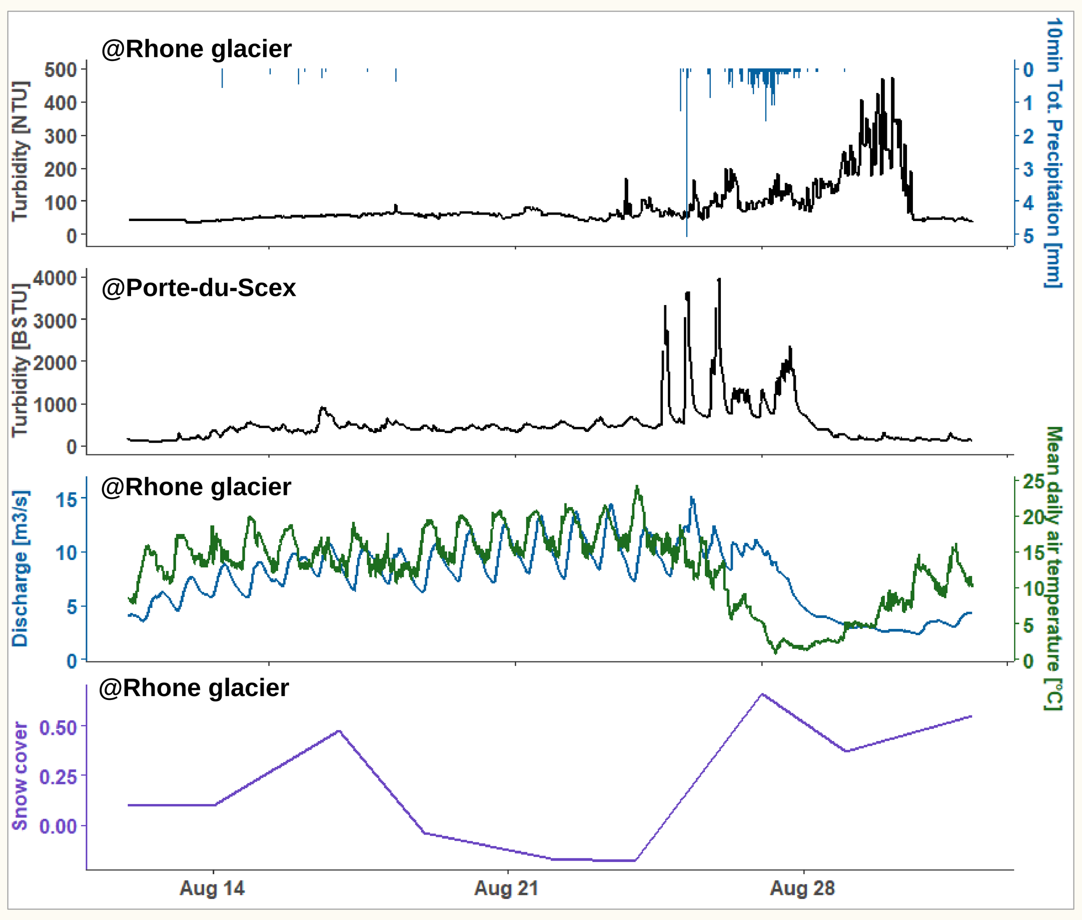


Rhône 2023 glacial ablation:

We measured one ablation season of sediment production by rainfall, snowmelt, icemelt, and glacial erosion, with the highest turbidity in late Summer.



OUTLOOK

LATEST PROTOTYPE: Sends data remotely using LoRaWAN and soon Iridium. We will also be integrating an electrical conductivity sensor! See the real-time data here

website

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