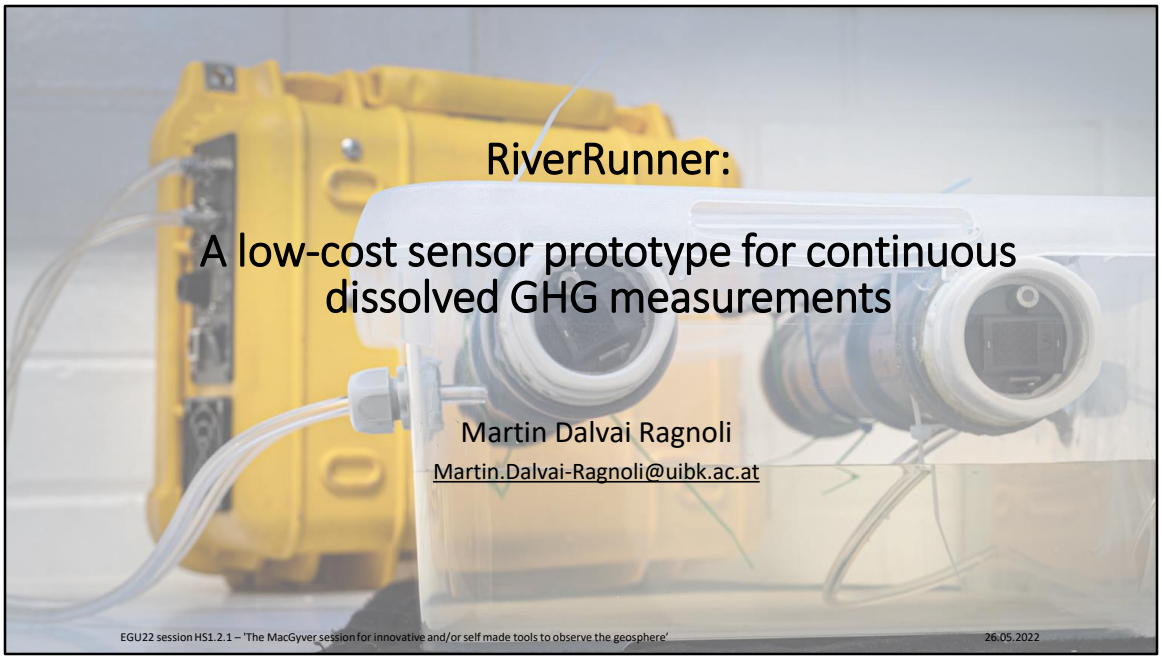


RiverRunner:

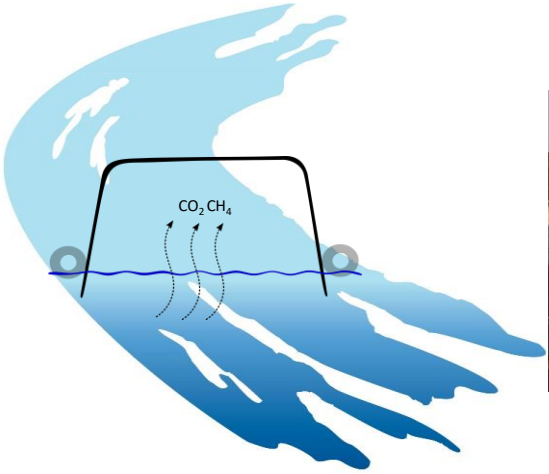
A low-cost sensor prototype for continuous dissolved GHG measurements

Martin Dalvai Ragnoli
Martin.Dalvai-Ragnoli@uibk.ac.at

EGU22 session HS1.2.1 – 'The MacGyver session for innovative and/or self made tools to observe the geosphere' 26.05.2022

Martin Dalvai Ragnoli
martin.dalvai-ragnoli@uibk.ac
universität innsbruck

Freshwater ecosystems and the GHG emission problem



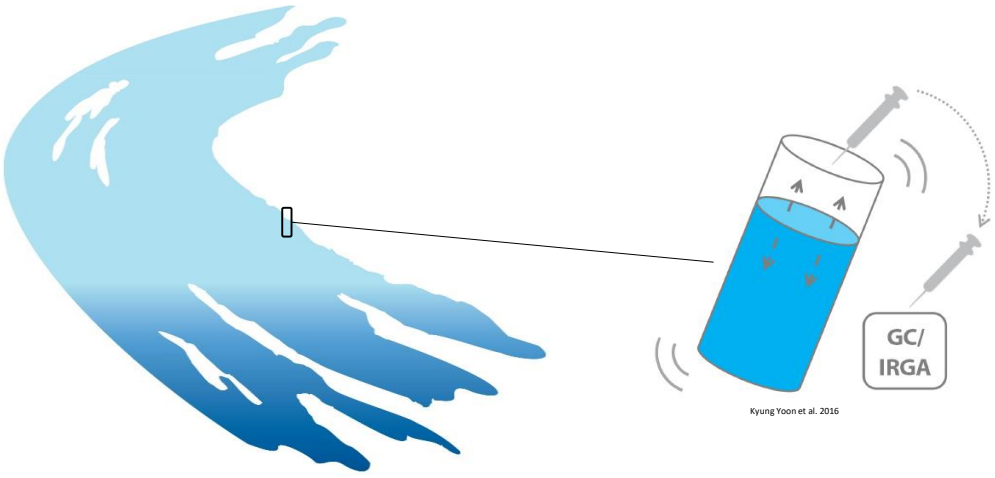
Freshwater ecosystems are a source of GHG (CO2 & CH4)

Current methods rely on expensive equipment and/or include labor demanding procedures:

Emissions can be directly measured with floating chambers. But these are not feasible on turbulent rivers.

Martin Dalvai Ragnoli
martin.dalvai-ragnoli@uibk.ac
universität innsbruck

Freshwater ecosystems and the GHG emission problem



Kyung Yoon et al. 2016

Emissions can be computed from concentration.

Dissolved gas concentration is measured via grab samples, which need to be equilibrated (with the head space technique) and further gas analysis

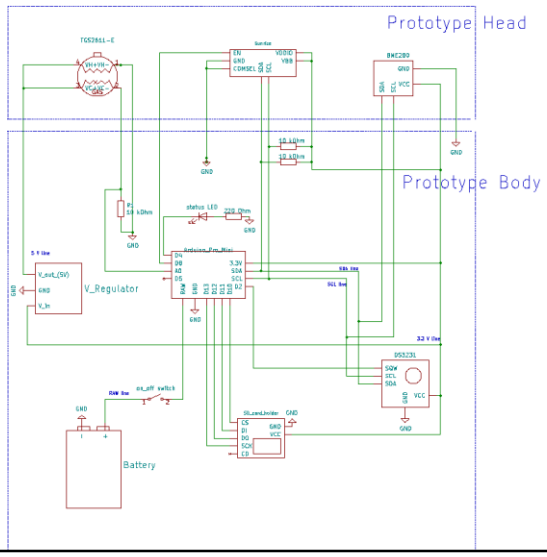
Martin Dalvai Ragnoli
martin.dalvai-ragnoli@uibk.ac
universität innsbruck

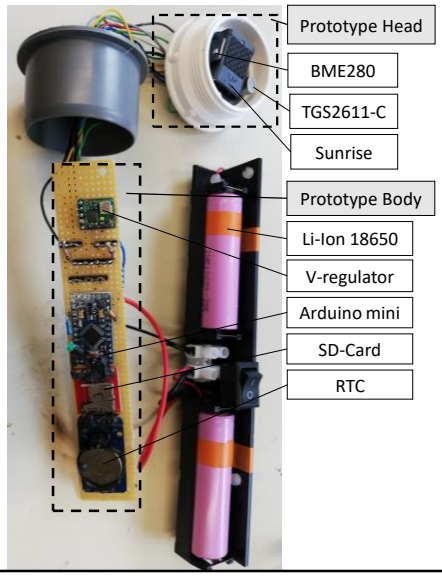
Freshwater ecosystems and the GHG emission problem

My goal is to measure continuously in-situ dissolved GHG concentration with my sensor prototype.

Martin Dalvai Ragnoli
martin.dalvai-ragnoli@uibk.ac
universität innsbruck

River Runner Prototype





The Prototype consist of two parts: a sensor head and a sensor body. The latter houses all the electronics and the battery.

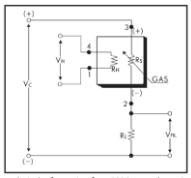
An Arduino mini is used as microprocessor, additionally I use a RTC and data is stored on SD card.

The Prototype is powered with two Li ion batteries connected in series

Martin Dalvai Ragnoli
martin.dalvai-ragnoli@uibk.ac
universität innsbruck

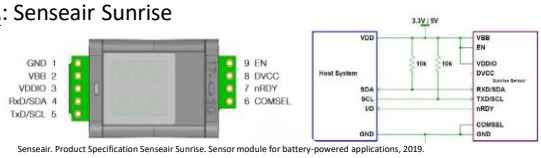
River Runner: Prototype Head

CH_4: TGS2611-C



Figaro Engineering Inc. Data Sheet: Technical Information for TGS2611 Methane Gas Sensor, 2017.

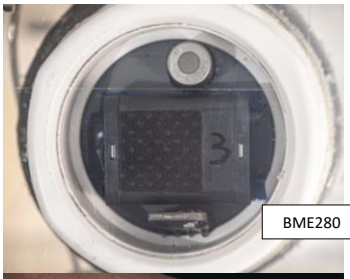
CO_2: Senseair Sunrise



Senseair. Product Specification Senseair Sunrise. Sensor module for battery-powered applications, 2019.

T, p, relH: Bosch, BME280

https://www.info4blog.it/wp-content/uploads/2020/04/617X2VRygxL._AC_SL1001_.jpg



BME280

The prototype Head houses the gas sensors:
To measure CH4:
Low cost semiconductor sensor. Resistance of the sensor changes in presence of oxidizing compounds and can be indirectly measured by change in voltage applied across the sensor.

To measure CO2: miniature NDIR type Sensor.

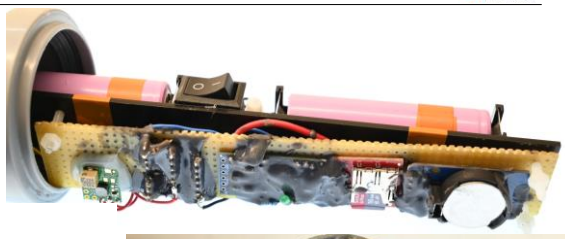
BME280 measures p, relative humidity and temperature.

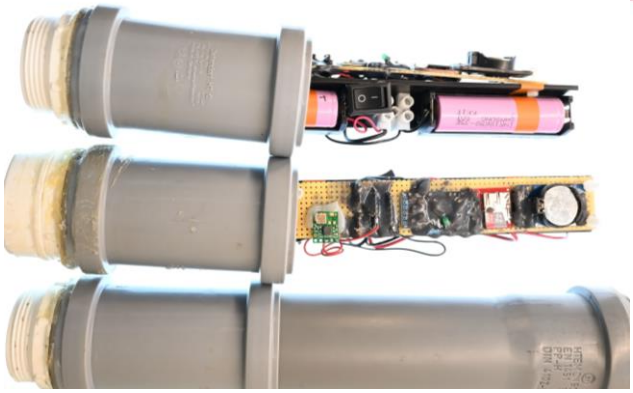
The Prototype Head is further covered by hydrophobic but gas permeable membrane, which allows equilibrium with the water phase on the outside of the membrane and the gaseous phase inside the sensor head. Thereby gas concentration in the sensor head can be measured and equilibrium concentration in the water phase computed.

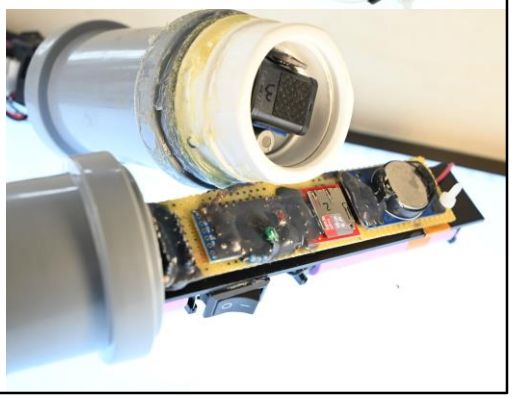
Martin Dalvai Ragnoli
martin.dalvai-ragnoli@uibk.ac
universität innsbruck

River Runner Prototype

total costs < 250 €







The Prototype Body is completely waterproof inside PP based tubing.

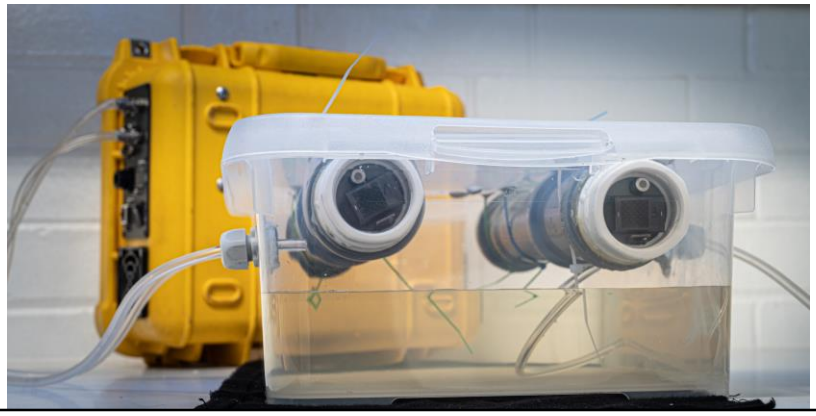
Electronics covered with PU resin to protect them from corrosion.

Total cost less than 250 €.

Martin Dalvai Ragnoli
martin.dalvai-ragnoli@uibk.ac
universität innsbruck

CH_4 Sensor

- Calibration setup to resemble real measurement condition
- 2-step Calibration:



As already mentioned the methane sensor reacts in presence of oxidizing compounds like CH4 but also H2 or C2H3.
In freshwater environments we assume there is only CH4 present.

But sensor resistance also changes with T and humidity and therefore needs to be calibrated to compensate these effects.

Calibration setup is designed to resemble real measurement conditions: The Sensors re placed inside a sealed box, which contains water.
The box is placed inside a climatic chamber to allow T control. As temperature and humidity covary near moist surfaces alteration of T results in variation of absolute humidity.

The gaseous phase is continuously circulated between the sensor head space and a portable gas analyzer used as reference instrument.

Calibration consist of two steps.

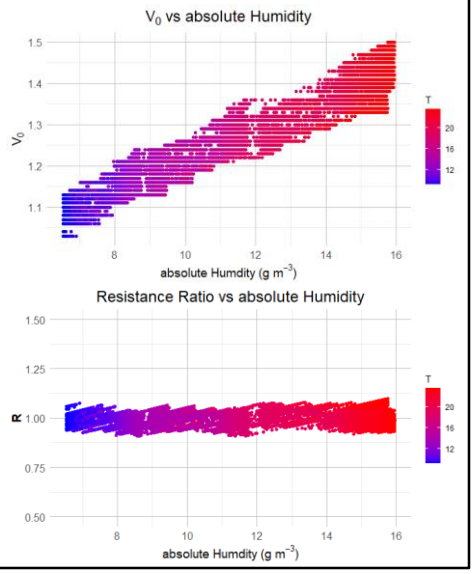
Martin Dalvai Ragnoli
martin.dalvai-ragnoli@uibk.ac
universität innsbruck

CH_4 Sensor

- Calibration setup to resemble real measurement conditions
- 2-step Calibration:

1st Step:

- $V_0 \sim f(T, absH)$
- $R \sim f(V_0, V_{out})$



First step: Sensor reference output voltage (V0) at background atmospheric CH4 levels is modelled. V0 is dependent from T and humidity

Further resistance ratio (R) is computed as ratio of sensor signal and reference output voltage at given T and humidity.
R is not independent of environmental factors anymore.

Martin Dalvai Ragnoli
martin.dalvai-ragnoli@uibk.ac
universität innsbruck

CH_4 Sensor

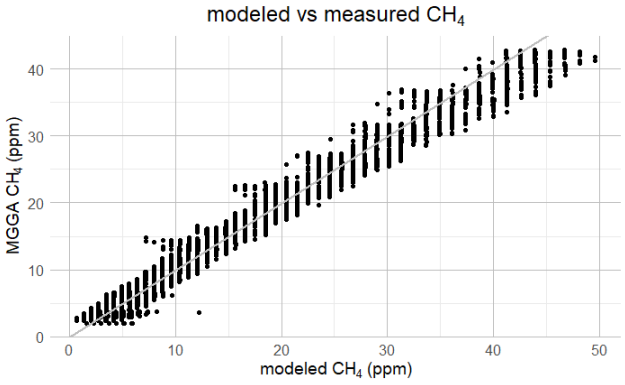
- Calibration setup to resemble real measurement conditions
- 2-step Calibration:

1st Step:

- $V_0 \sim f(T, absH)$
- $R \sim f(V_0, V_{out})$

2nd Step:

- $CH_4 \sim f(R)$

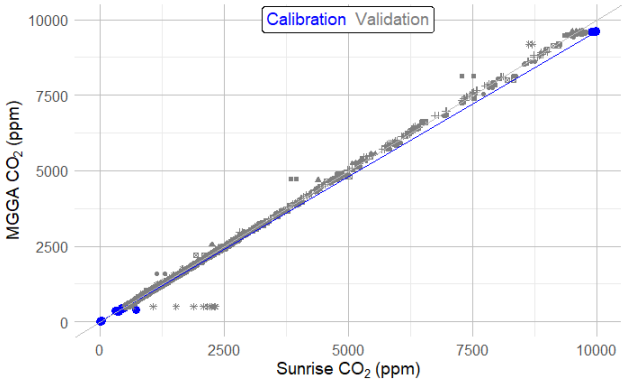


Second step: stepwise introduction of methane. Mole fraction of CH4 is modelled based on R

Martin Dalvai Ragnoli
martin.dalvai-ragnoli@uibk.ac
universität innsbruck

CO_2 Sensor

- Disable automatic baseline correction
- Calibration: Standard gas with 0 , 350, 10000 ppm CO_2
- Validation: During CH_4 Calibration
- Accuracy ± 65 ppm



Sunrsie Sensor communicates via I2C communication with the Arduino.

Disable ABC (automatic baseline correction) which is an integrated function to correct baseline drift to 400 ppm (atmospheric concentration).

Calibration with standard gas (0, 350 and 10000 ppm) and a reference instrument in parallel.

Validation during of Sunrise calibration during CH4 calibration.

Martin Dalvai Ragnoli
martin.dalvai-ragnoli@uibk.ac
universität innsbruck

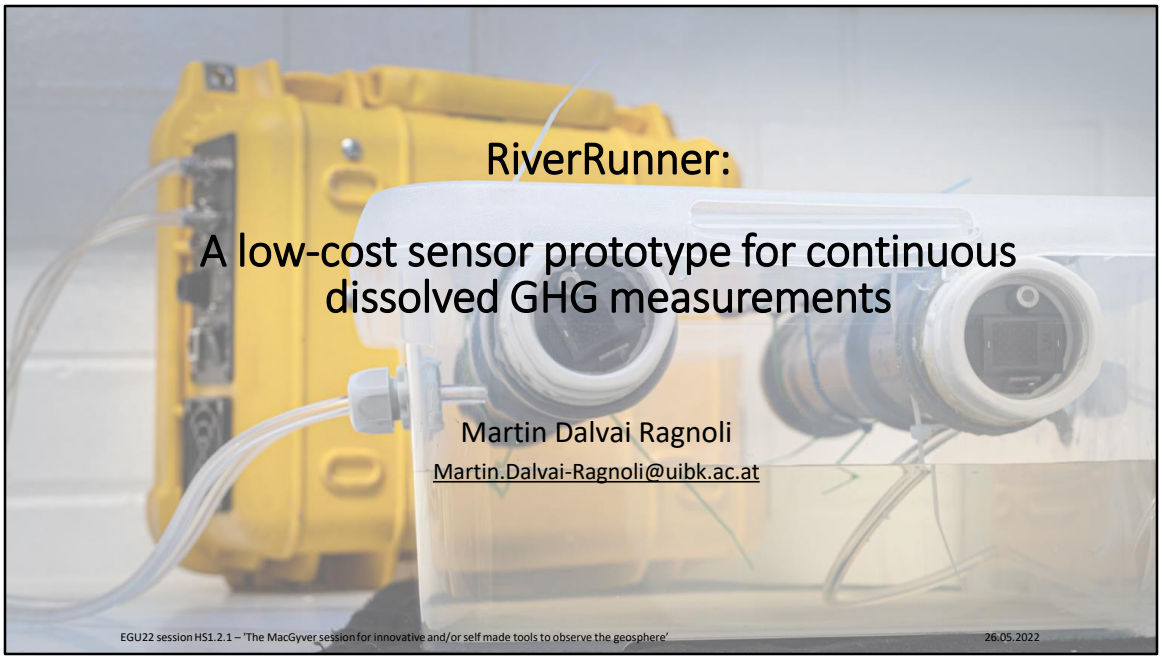
Outlook

- Validation CH_4
- In- situ measurements
- Battery lifetime

What still needs to be done is the validation of the methane sensor.

In situ measurements directly in the field with a reference instrument operating in parallel.

Prolonging the battery lifetime from the current 24h in order to measure really continuously.



RiverRunner:

A low-cost sensor prototype for continuous dissolved GHG measurements

Martin Dalvai Ragnoli
Martin.Dalvai-Ragnoli@uibk.ac.at