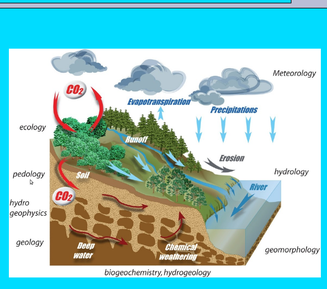
NETWORKS OF AUTONOMOUS IN SITU SOIL SENSORS

MONITORING PROFILES OF MOISTURE, SALINITY AND TEMPERATURE

X. Chavanne* et J.-P. Frangi (chavanne@ipgp.fr)
Institut de Physique du Globe de Paris Univ. Paris Cité, UMR 7154 CNRS
F75205 Paris cedex 13, France

APPLICATIONS: - hydrological studies in a catchment or watershed area over time and space;
- agriculture/agronomy (irrigation schedule, soil salinity monitoring, plant growth...);
- civil engineering (ground stability, concrete aging...);
- control of processes (concrete hardening, compost maturation, silo moisture...).

CHALLENGES: - cost-effective high quality measurement;
- temporal resolution (down to 5', infiltration study) and span (years, climate change)
- spatial resolution (lateral variation, ~100 m) and span (catchment, ~km^2); vertical profile (water balance);
- representativity (point probe ~0.5 l), limited invasiveness, compactness, robustness,
- autonomous in operation, transmission (real time) and energy,
- series production, industrialization: simplification, optimization for cost-effective sensor



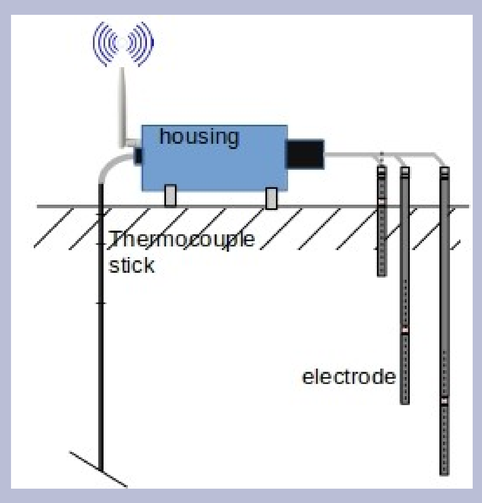
HyMeNet project: Hydro Measurement Network

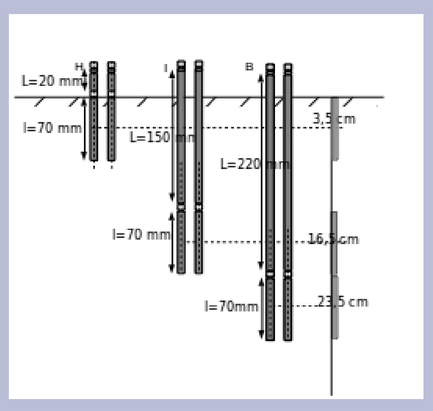
- Self-balanced bridge. High phase resolution. Linear response. (V_C, V_G) > (ε_r, σ)

Soil complex permittivity for real permittivity ε_r and conductivity σ;

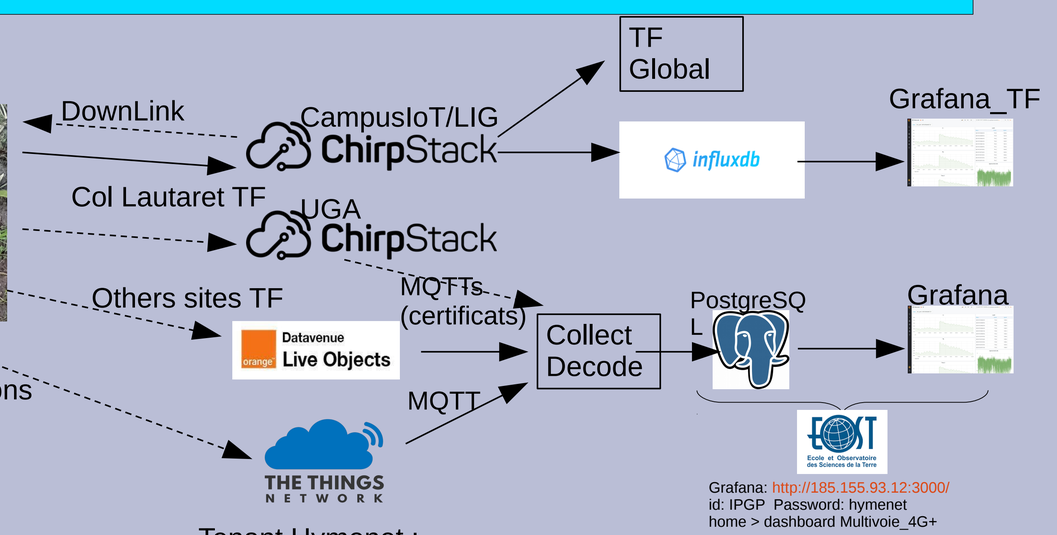
- use of conversion from literature (extended Archie laws, effective medium… Topp's correlation (fromTDR). (ε_r, σ) > (Θ_V, σ_{ion});
- electrode geometry: two parallel cylinders (representativity, water balance);
- limited flow perturbation: no trench, vertical probes, offset housing;
- direct temperature difference with thermocouples in a slim stick in soil;

Network of of compact easy to install sensors for spatial span:
- Integrated electronics. All in one (box IP67 12x12x6 cm³) at surface;
- modular low-cost probes;
- battery 3 – 5 V, e.g. Li+ (Si cell in parallel);
- Long Range Wide Area Ntw, > 10 km. Loss management;
- transfer in real time. Web-accessed visualization and retrieve;



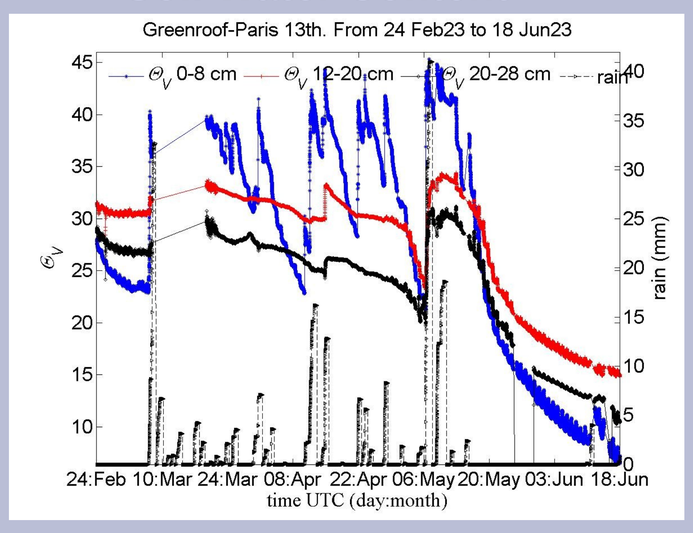


Payload 37 Bytes
- 5 (V_C, V_G) : 3 horizons
- 2 temperatures
- 5 thermocouples
- Vbattery
- n° point

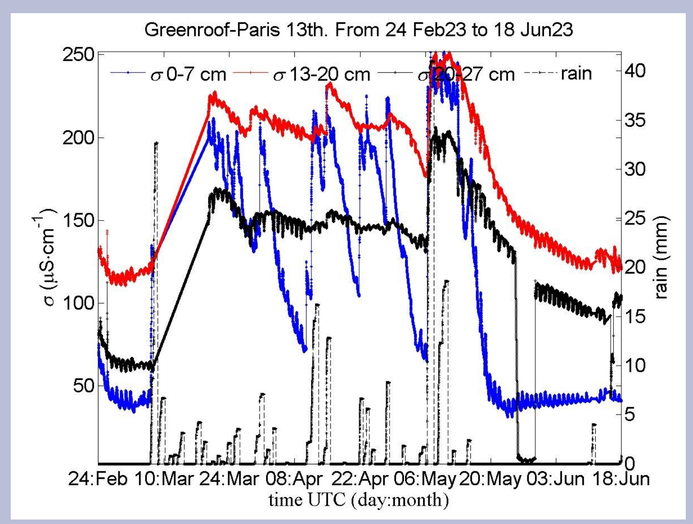


Tenant Hymenet :
sensors, keys, decoder
raw data, DownLink

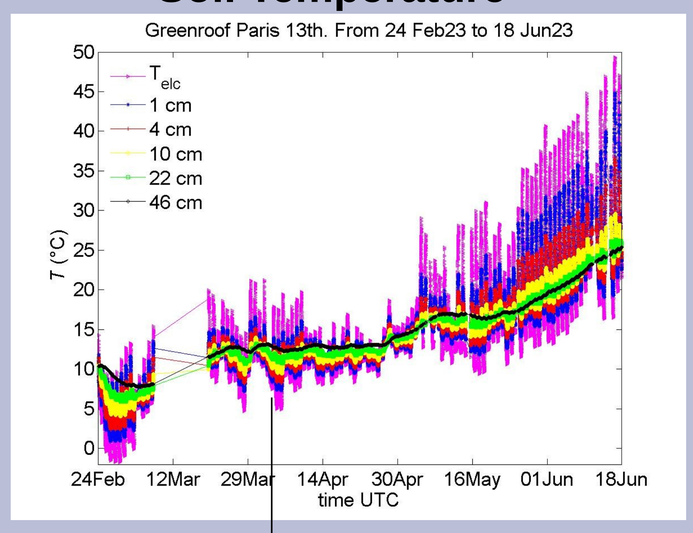
Soil Water Content



Soil bulk conductivity

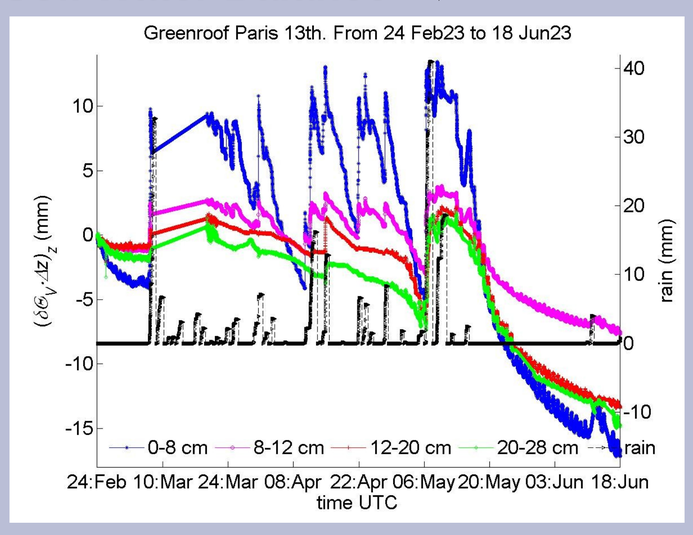


Soil Temperature

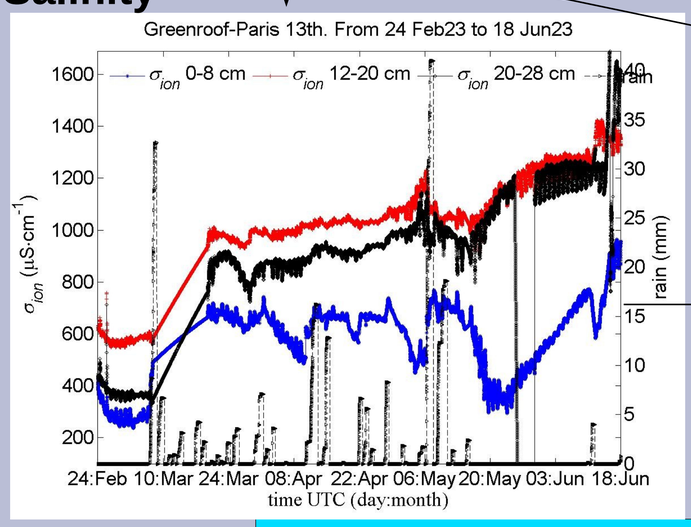


Soil Water Balance

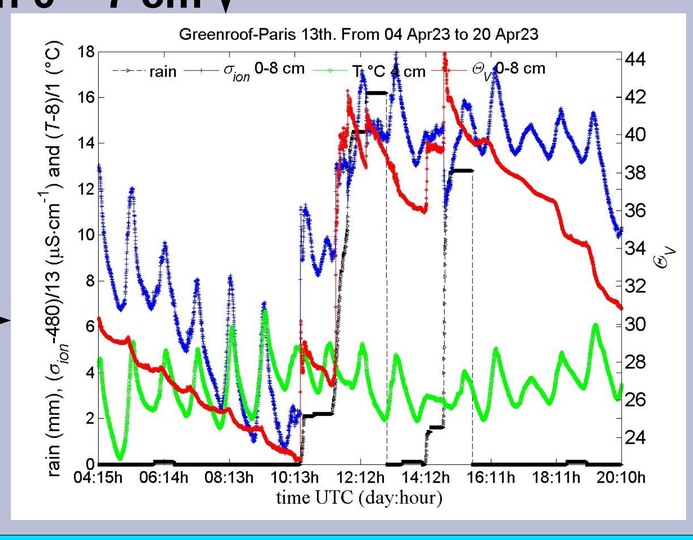
Θ_{Vj} z_j



Salinity



Horizon 0 – 7 cm



PERSPECTIVES

- test of demonstrators in TF pilot site;
- complete documentation from design files to user manual available > **duplication for 2 or 3 in research projects**;
- final optimization for a first-of-kind sensor; Series of 50 to 100 sensors to equip TF sites;
- industrial partnership.

BIBLIOGRAPHY

- X. Chavanne and J. Frangi. Wireless Sensors to Monitor Soil Moisture, Salinity and Temperature Profiles; Application for In situ Hydrological Balance. To be published 2024.
- X. Chavanne and J. Frangi. Smart Networks of Autonomous In-situ Soil Sensors. Eur J Env. and Civil Eng. 27(11), 3343–3362. 2022.
- X. Chavanne and J. Frangi. Monitoring soil water content and its salinity with high-precision and low-cost in-situ sensors. Eur J Env. and Civil Eng. 27(1), 457–478. 2022.
- X. Chavanne and J. Frangi. Study of fringe effects of a two-rod capacitor embedded in a medium in order to deduce its permittivity. Eur J Env. and Civil Eng. 26(6), 2439-52. 2020.
- X. Chavanne and J. Frangi. Sample Volume of a Capacitance Moisture Sensor in Function of its Geometry. Eur J Env. and Civil Eng. 24(13), 2168-86. 2019.
- X. Chavanne, A. Bruère and J. Frangi. Comments to: A Novel Low-Cost Instrumentation System for Measuring .... Sensors, 18(6), 1730. 2018.
- X. Chavanne and J. Frangi. Autonomous Sensors for Measuring Continuously the Moisture and Salinity of a Porous Medium. Sensors, 17(5) :1094–11. 2017