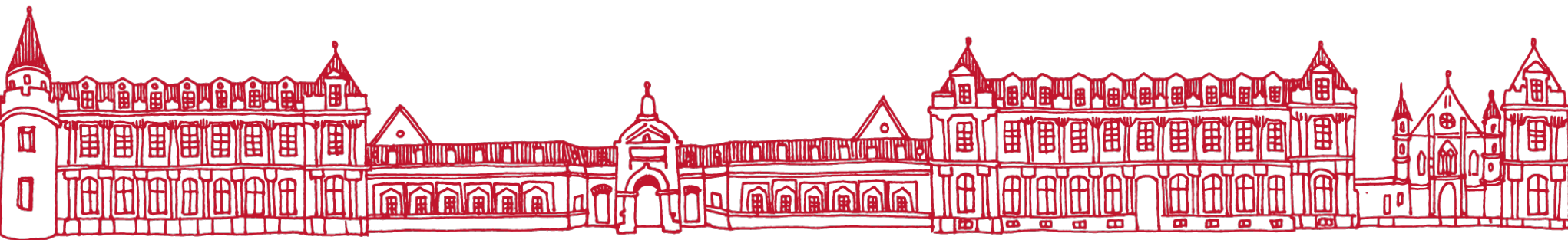


Citizen metrology : a key challenging issue



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Abstract

In the past decades the collection of data directly obtained by individual citizens has been developed in many fields of measurements, especially for environmental monitoring, climate science, human health, or more specifically for analysis such as air pollution or water quality... This **citizen metrology** aims to help official bodies in their measuring work, but also to get data independent from authorities, even to act as whistleblowers. Measurements are often performed with numerous low-cost sensors giving many widely disseminated data easily aggregated in digital platforms. This is a favourable signal toward the appropriation of results by the public (and the acceptance of related common decisions).



However, **to enforce trust in the results**, citizen metrology has to face **several challenges** : the quality, conformity and traceability of sensors, the validation of applied methodologies, the **technical and ethical literacies** of the participants, the objectivity of data collection and modeling... Progress have been made to develop management rules, training platforms and guides, traceability methods and ethical or legal compliance charts. Interaction with research consortiums have been also developed, including in humanities and social sciences.

These subject are illustrated with the **TERRA FORMA research project**, recently launched in France by the CNRS to design and test Anthropocene observatories. It gathers laboratories in **technology** and in **humanities** and will help to open the way to stronger collaboration between professionals and 'citizen metrologists', the actors of "**crowdsensing**".



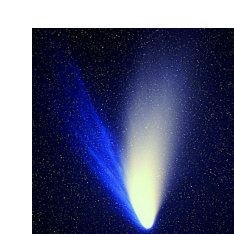
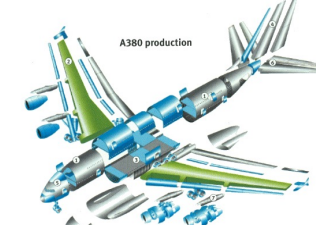
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Citizen metrology : what do you mean ?

Metrology is the art of measurement
Citizenship give rights and responsibilities

Citizens are directly concerned by most of the issues of measurement :

- * fairness of trade, observance of legal regulations
- * scientific progress
- * new technological developments
- * security and safety



Citizen measurement in science

Participation of "non-experts" in data collection for scientific purpose

- * observations of **stellar objects**
- * observation and counting of **live species** (plants, insects, ...)
- * more generally huge extension of data collection upon time and space for many scientific applications



Citizen metrology

Ordinary citizens are involved in practical measurements and data collection processes

- * involvement may be extended to **analysis and interpretation** of results
- * even to the issued **decision process**

This activity **increases fastly** according to the **digital transform** and to the set up of **«Internet of Things»**

Major fields

Environment : quality of air, quality of water, bio-diversity, nuclear pollutants, ...
Climate change : temperature, CO₂ emissions, ...
Agriculture and food : contaminations, ...
Health and quality of life : EM emission levels, noise pollution, ...



Issues and Assets

To get results independent from authorities : near the nuclear power plants ...
To impulse new standards or higher regulations : near the phone antennas ...
To act as whistleblowers : nanoparticles in food or cosmetics ...



Large participation : 20000 citizens versus 20 pros, who is right ?
Personal commitments : How can long term involvement be conformed ?

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Citizen metrology : several technical assets, but some metrological requirements

Sensors

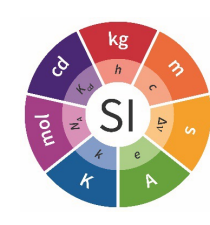
Low cost to very low cost sensors : easy access, easy renewal
Easy to disseminate : minimal installation constraints
Easy to use (plug-in ?) : minimal interaction with the operator
Automatic collection of data



Toward Internet of Sensors : from IoT to IoS

Traceability

Metrological traceability : often unestablished, very often not renewed
(the best case is the use of disposable sensors)



A huge number of highly disseminate results does not ensure accuracy

Methodology

Skills and traceability of the operator(s) : far away from accreditation requirements (!)
Environmental parameters : rarely controlled, exceptionnaly collected ?



Are citizens real actors of their own measurements ?
A delicate balance between expected commitment and lack of useful skills

Data collection and data analysis

Data collection on platform aligned with FAIR principles :
Findable, Accessible, Interoperable, Reusable

Data analysis and return to operator : a key for continuous commitment

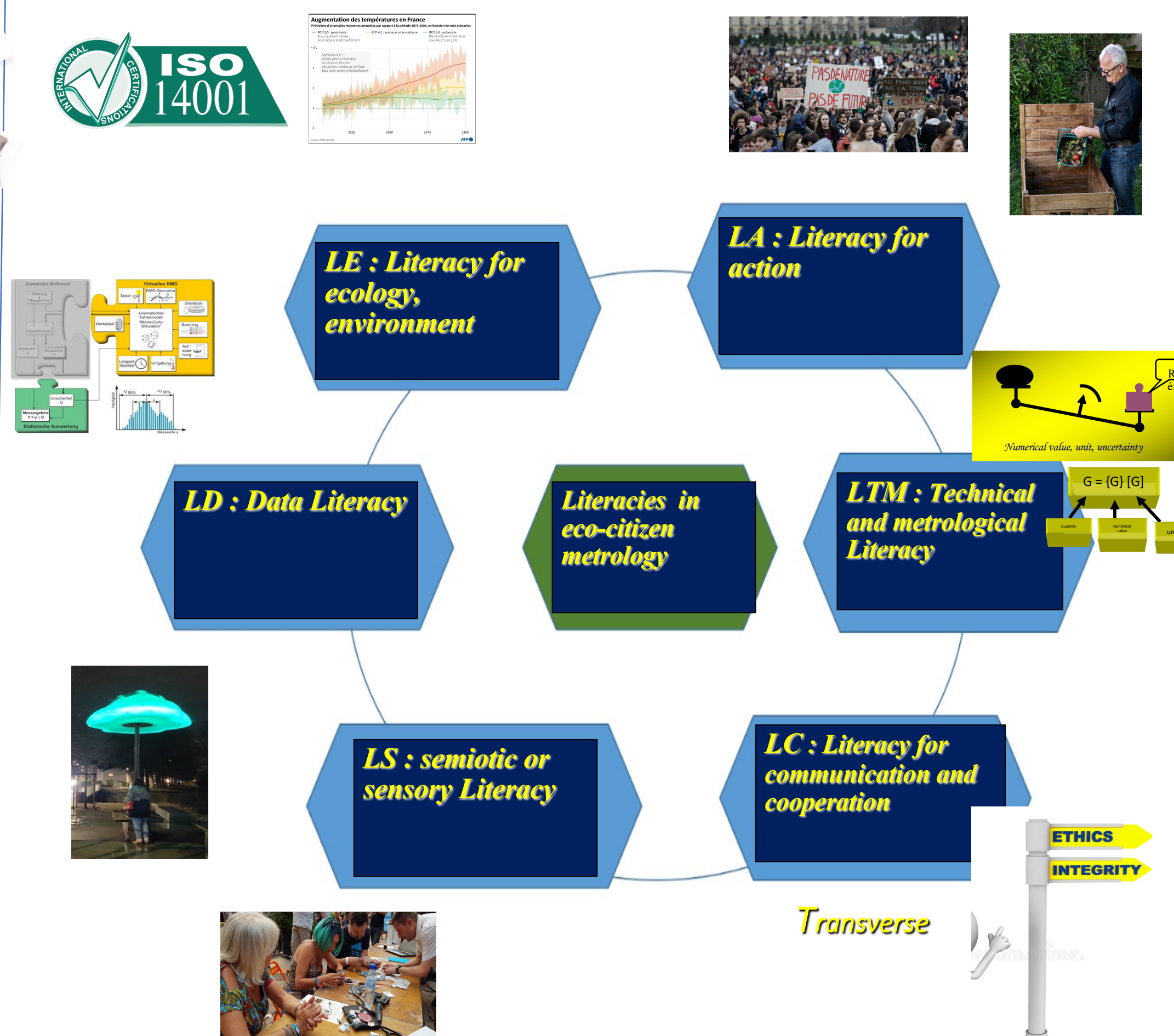
Evaluation of final uncertainty : should be a key for
- confidence in the platform by citizens
- endorsement by authorities



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Citizen metrology : essential literacies

A literacy gathers everything needed to describe and understand practice and representations in an assigned field or for a given purpose



Citizen metrology helps to disseminate among individuals the skills linked with the activity of measurement. Furthermore the efficiency and utility of citizen metrology increases with the dissemination of these relevant literacies

Mixing of the themes results in the collective required skills
This transliteracy may be a prerequisite for public financing – and recognition – of a project

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TERRA FORMA¹ Research Program



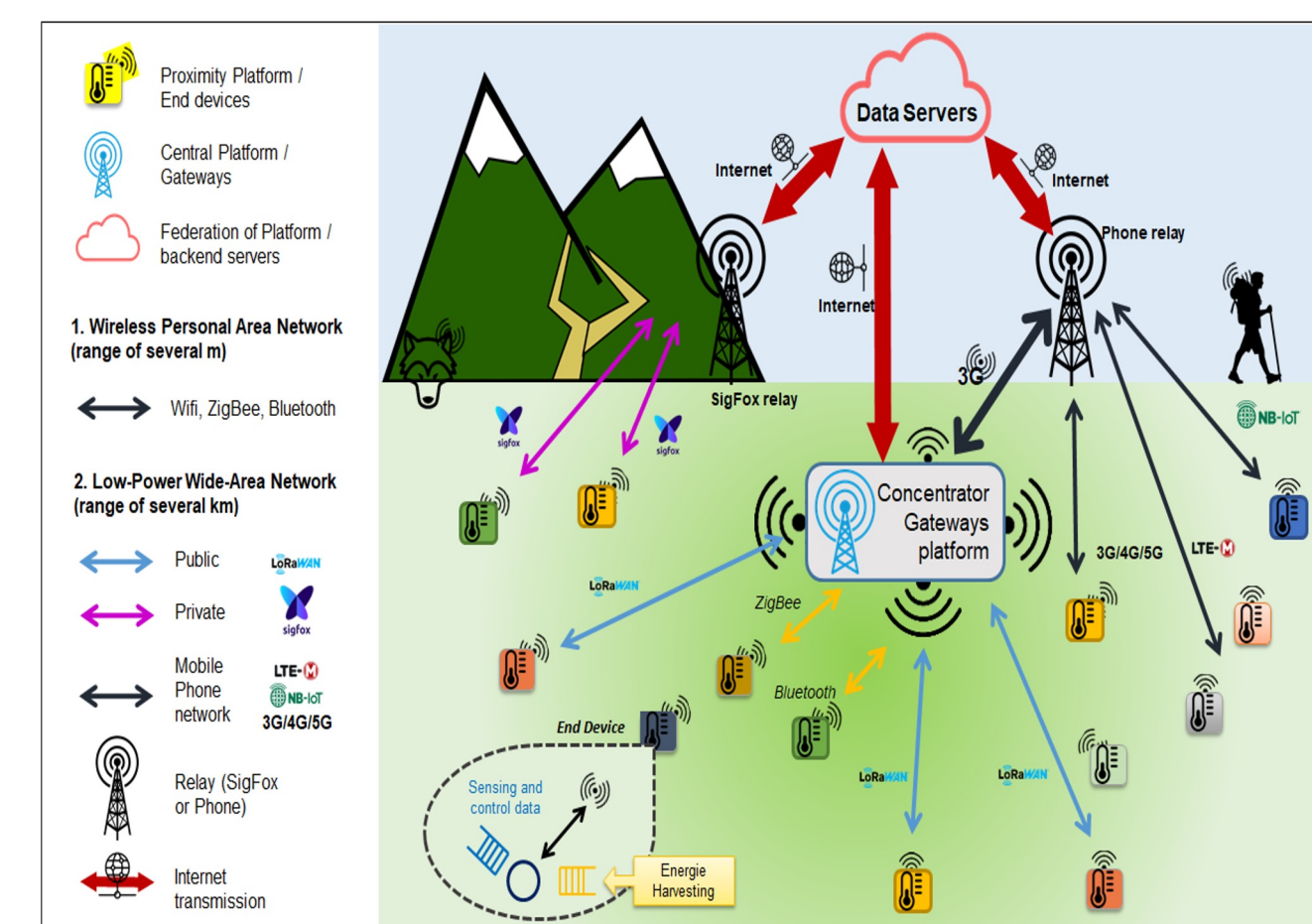
Designing an interdisciplinary and hybrid observatory for the Anthropocene

A new paradigm for monitoring environments and socio-ecosystems

TERRA FORMA aims to establish a new value chain, from sensors to in-situ acquired data, in order to promote data sharing based on open science principles

A platform designed to support the development of systemic approaches and to contribute to place-based research.

A set of modular building blocks that, when assembled, form a **next-generation network of frugal sensors, orchestrated by a plug-and-play communication infrastructure, contributing to data and knowledge production for academic research and beyond.**



Dense and scalable networks of heterogeneous sensors



- A resource center, a catalog of existing hardware and software solutions for environmental sensors, serving as a meeting tool between developers and thematic experts;
- An shared instrument pool, integrating instruments and expertise, facilitating collaborations between developers and site stakeholders to acquire original data using a systemic approach (essential variables, high spatial and temporal resolution);
- A national server for managing multi-protocol data transfer, ensuring their convergence towards a TERRA FORMA cloud, before integration into national data centers. Specific services for managing a national LoRaWAN solution are also being developed

¹Project funded by the French National Research Agency 2022-2029



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TERRA FORMA Scientific and technical challenges

More than thirty measuring devices developed by research teams throughout France.

A wide range of fields : analysis of aquatic systems, greenhouse gas measurements, soil capital, chemical pressure, wildlife monitoring, etc.

- In-situ and mobile sensors
- Low energy consumption – energetic frugality
- Accessible – easy duplication and use
- On-board intelligence – numeric frugality
- Miniaturisation
- Low cost, durability, eco-conception

to bridge the « Valley of Death » in the Technical Readiness Levels (TRL 4 => 7)

Examples

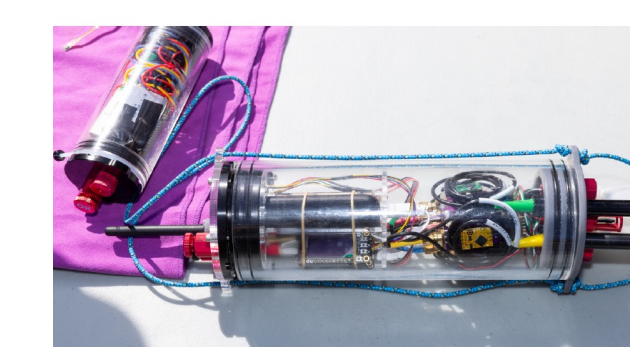
Hyperspectral camera : Sensor from space area / diverted for landscape evolution and hydrosedimentary research



Physico-chemical flux of running water and lakes
Sensor for oceanographic applications adapted to running water and lakes + spectrometer (challenge of miniaturisation)



River metabolism / Mapping and measuring dissolved carbon continuously or by survey



Multiparameter probe for water analysis
Flow, temperature, conductivity, PAR, turbidity, Chl-a, O₂, pH, CO₂, nitrates.

Smartphone application and use of AI for pollinator recognition

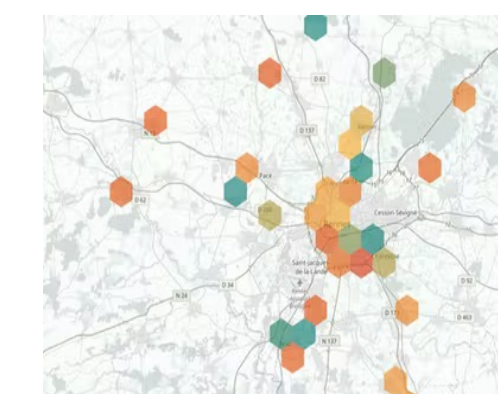
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TERRA FORMA : a collaborative programme



Collaborative research programmes and citizen metrology

- Shift instrumental research towards stakeholders through programmes on socio-ecosystems with stakeholders (beyond experts)
- Supporting cooperation between the scientific community, regional managers and civil society
- Encourage the use of the TERRA FORMA technical and metrological infrastructure, its development and the enhancement of the measurements and data produced.



A community platform to support the emergence of citizen metrology in participatory science initiatives and provide an environment for data visualization and analysis.

TERRA FORMA's observatories are focal points for the scientific community and stakeholders => provision of services + under what conditions can the Terra Forma program and related participatory mechanisms bring the creation of new collective and territorial knowledge, new learning and, in so doing, new eco-political relationships

Several Actions with local players and residents

- **Participatory metrology, Crowdsensing** : participation involving the production of measurements and data from TERRA FORMA sensors and Contributory digital practices: photos, stories, annotations, etc.
- **Collaborative research** : co-definition of issues, protocol and methods through to co-analysis of results (varying scales and opportunities for participation)
- **Adaptation of instruments** : Fablab duplication

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Citizen metrology : issues and conclusion

Issues

- **Supporting the development of literacies** : environmental, technical (understanding how sensors work), metrological (selection of relevant sensors, supervision of the protocols or semi-autonomous approach), and digital/data literacy
- Document protocols and feedback
- **Making the data acquired more reliable and comparing it with other sources**
- Enhance knowledge of environments and phenomena, by **interpreting measurements with the public and extending observations over time and space.**
- **Supporting the levers of participation, interest and commitment**: designing learning communities and promoting the **hybridisation of situated and scientific knowledge**
- **Impact on knowledge, debates, behaviours as follow**

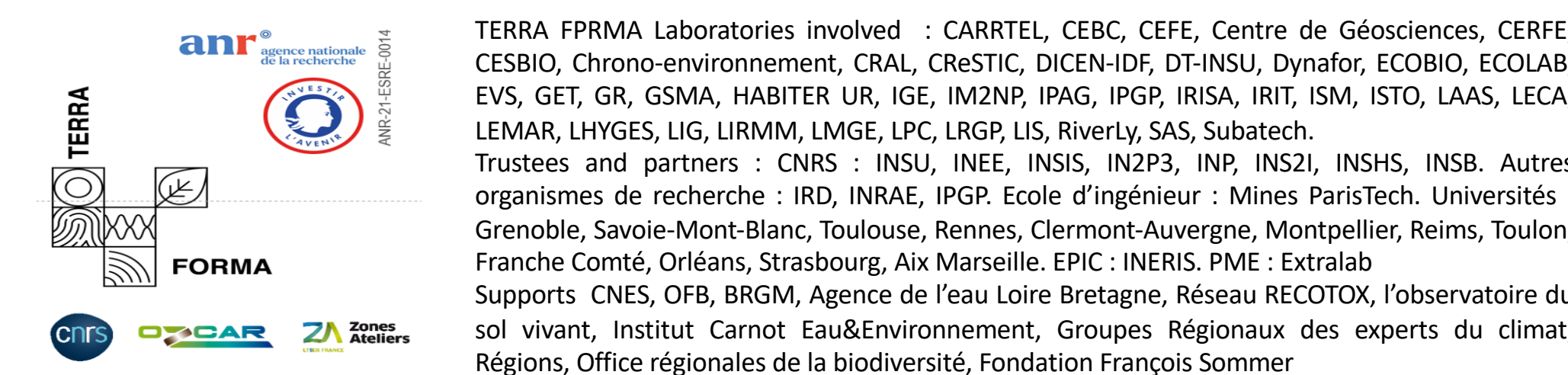
Prospects

*** Citizen metrology requires dissemination of the metrological culture to create a reliable and robust knowledge**

Traceability : to give sense to results
Uncertainty : to confort any assessment
Innovation and Standardisation : to comply to FAIR principles
Ethics : to recognise inter-subjectivity processes

*** Citizen metrology opens the way to enriched public debates or large controversies : science / society better accepted or shared decisions and choices : changing perception and behaviors**

Toward an enforced citizenship



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