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THE EUROPEAN METROLOGY NETWORK FOR CLIMATE AND OCEAN OBSERVATION

Emma Woolliams, Nigel Fox, Céline Pascale, Paola Fisicaro

EUROPEAN METROLOGY NETWORKS

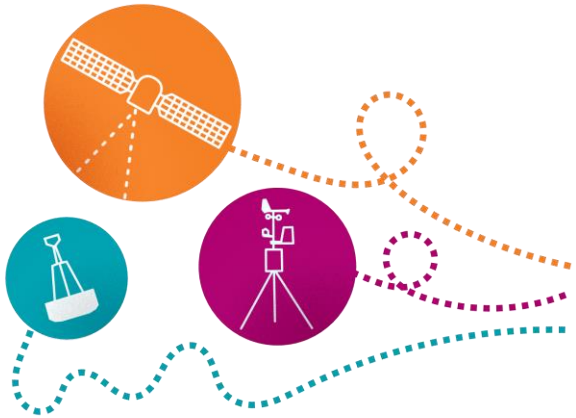
Parties should strengthen their cooperation [...], including with regard to:

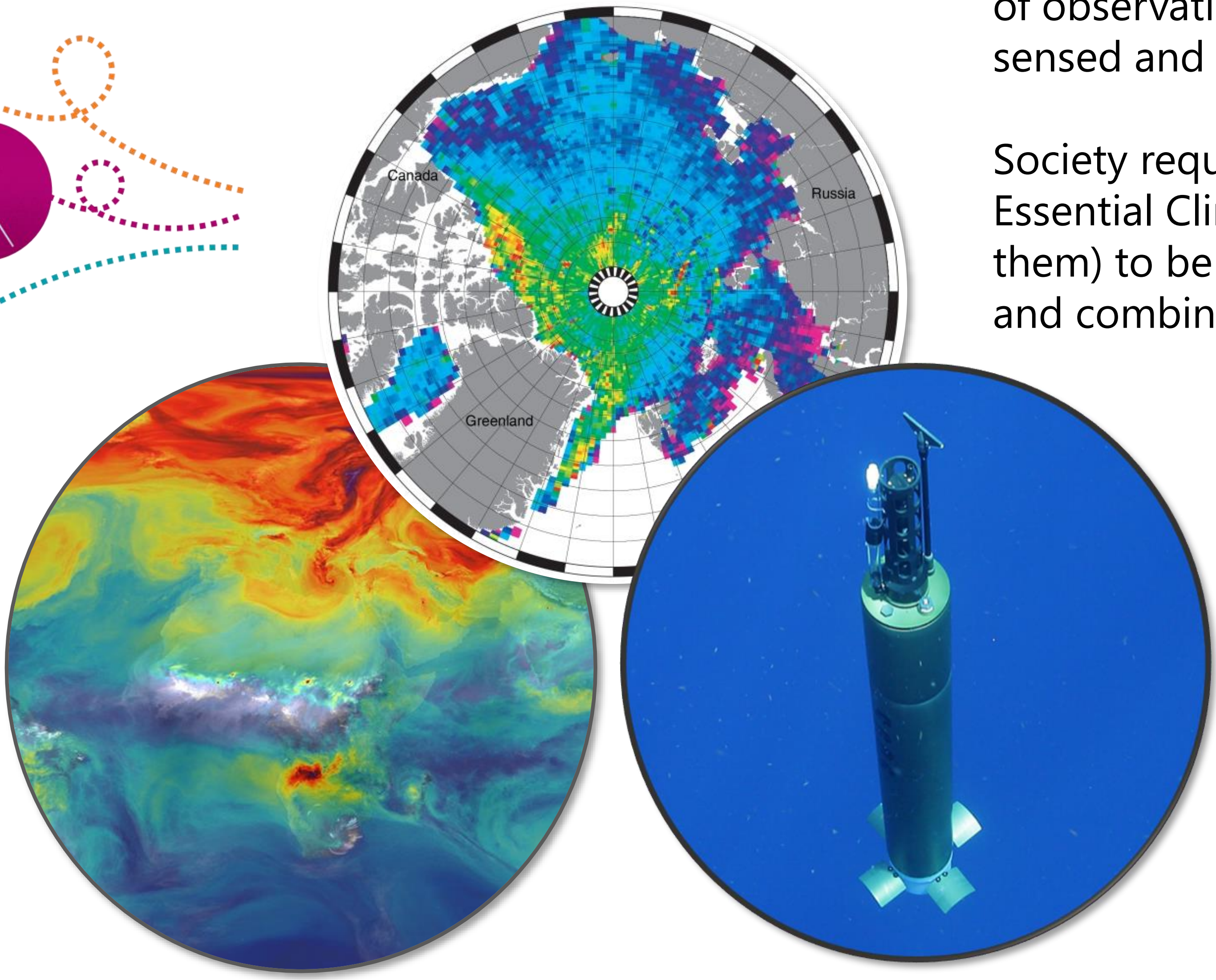
[...] Strengthening scientific knowledge on climate, including research, systematic observation of the climate system and early warning systems, in a manner that informs climate services and supports decision-making.

Paris Climate Agreement (2015), Article 7, point 7(c)

"The ocean covers 71% of the Earth's surface, and is linked to human livelihoods in numerous ways. From its role in modulating the climate to how it provides a variety of socio-economical, cultural and environmental benefits, the ocean contributes greatly to human wellbeing.

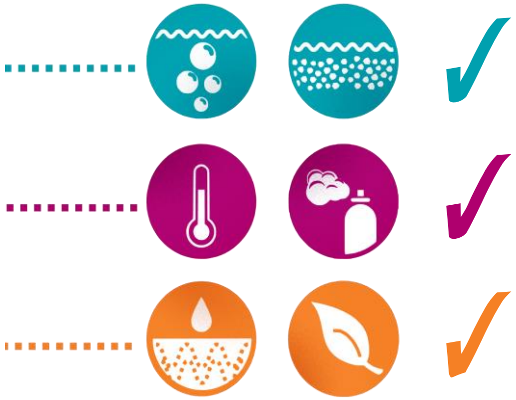
A better understanding of ocean climate and ecosystems, as well as human impacts and vulnerabilities, requires the coordination of a continuous and long-term system of ocean observations."





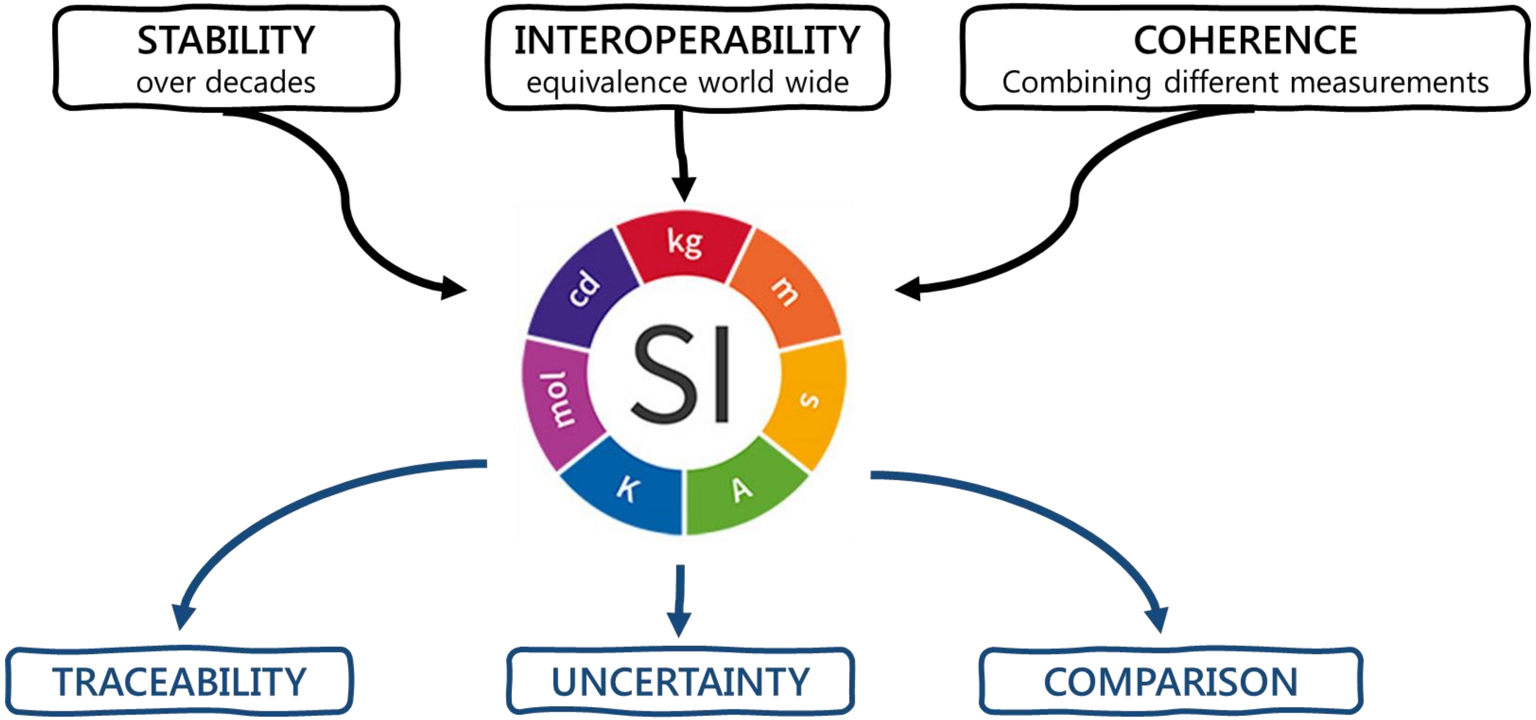
Understanding our climate and protecting our oceans require observations – from a wide range of observational methods (in situ, remotely sensed and mixing observations and models).

Society requires those observations (and the Essential Climate/Ocean Variables derived from them) to be robust: stable long term, comparable and combinable and quality assured.



Images: Sentinel-3 by ESA, Argo Float deployment by Robert Todd, WHOI, NASA CO_2 simulation

ROLE OF METROLOGY

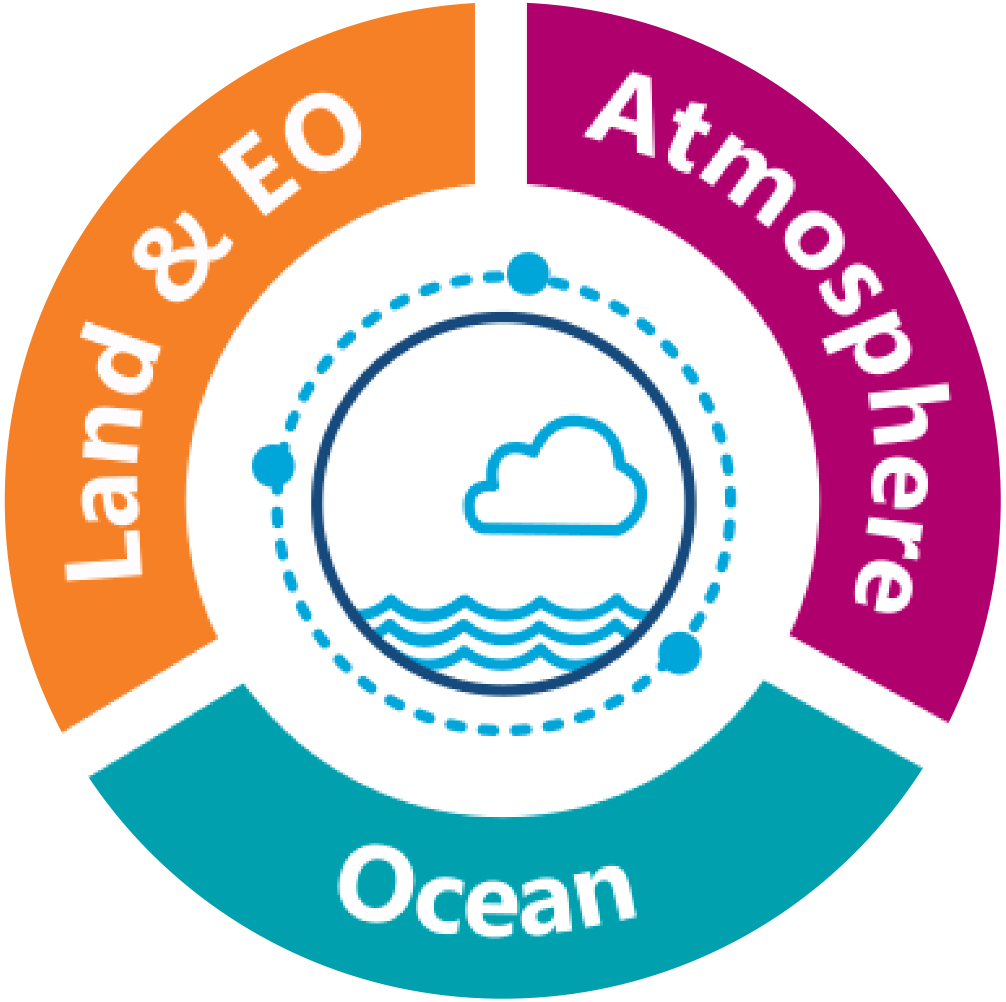


Metrology, the science of measurement, is the discipline that maintains the International System of Units (the SI).

Metrology has ensured the SI system is stable, interoperable and coherent through a formal system of "SI traceability" built up on robust uncertainty analysis and regular global and regional comparisons.

Metrological techniques are already improving the quality assurance and robustness of climate and ocean observations. And we support increased collaboration between those making and using such observations and the metrologists in Europe's metrology institutes.

EMN STRUCTURE



The European Metrology Network for Climate and Ocean Observation is an entity of EURAMET – the European Association of National Metrology Institutes

Chair: Emma Woolliams
Atmosphere Section co-chair: Céline Pascale
Ocean Section co-chair: Paola Fisicaro
Land and EO Section co-chair: Nigel Fox

MEMBER INSTITUTIONS

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33 formal metrology community institutions across Europe

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It is the European contribution to a global effort to underpin climate and ocean observation with the robust metrological principles.

EMN AIMS

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Strengthen existing partnerships with climate and ocean observation community, and create new links

Coordinate European metrology to meet community needs

→ Guide research priorities through interaction with community
→ Create a single focal point for metrology services

Showcase what metrology can do

Put metrology at the core of climate and ocean observation

CURRENT ACTIVITY TO ESTABLISH A STRATEGIC RESEARCH AGENDA IN EMPIR JNP 18NET04

Surveys launched 20/11/19 to gather stakeholder needs. Different questions for different stakeholders:

- Instrument manufacturers, calibrators, deployers and networks
- Satellite instrument manufacturers, calibrators, space agencies
- ECV / EOV record developers and users

Literature review of reports of workshops, stakeholder strategies etc to identify metrology needs

Database established to record metrology needs from stakeholders in a systematic way

Webinars 12/13 February 2020 to prioritise needs from users

Annual General Meeting 10-11 June 2020 (virtual) includes workshop for NMIs to consider how to respond to user needs

LIKELY EMN PRIORITIES FROM STRATEGIC REVIEW

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GENERAL

- UN Carbon **stocktake** (2028) QA: Understanding and attribution of GHG cycle – emissions (local, city, global) and sinks (ocean, vegetation, artificial)
- Data science techniques / **AI** for ECV analysis, big data and "big quality"; nonlinear model uncertainties, combining data from different sources
- Satellite-to-satellite and satellite-to-ground **interoperability** and harmonisation
- Establish "**supersites**" (multiple ECV observations, full SI-traceability) as climate-quality reference sites for networks / satellite validation. "Fiducial Reference Measurements" for the Copernicus Climate Change Services
- Ways to **evidence** quality to users (MRA-style validation?)
- Definition of **vocabularies**/ontologies for metrological terms in observations
- **Training** scientific communities in metrology (and vice versa)

ATMOSPHERE

- NMIs/DIs to fulfil the requirements of GAW '**central calibration laboratories**'
- Support for **reference networks** (e.g. GRUAN, GRSN, Cryonet)
- Improved SI-traceability for reference scales
- **Uncertainty** analysis for in situ and on site observations

OCEAN

- Improved **SI traceability** for physico-chemical ECVs and EOVs (e.g. pH, salinity, temperature)
- **Quality assurance** tools (e.g. Interlaboratory comparisons, accreditation schemes)
- Support for existing ocean observation **networks** (e.g. EOOS, EuroGOOS, JPI OCEANS, JERICO)

LAND & EO

- Fundamental Data Records (**FDR**) – SI traceability to satellite observations
- Address metrological needs of **Copernicus satellites** – existing and "high priority candidates"
- Upgrade operational **meteorological satellites** and cube-sats to "climate quality"

FIND OUT MORE AND PARTICIPATE IN OUR PRIORITISATION

Our website:

- https://www.euramet.org/climate-ocean

Contact us directly:

- climocnet@euramet.org

Read a short conference paper about us:

- https://cfmetrologie.edpsciences.org/articles/metrology/pdf/2019/01/metrology_cim2019_05001.pdf

SOME SURVEY RESULTS

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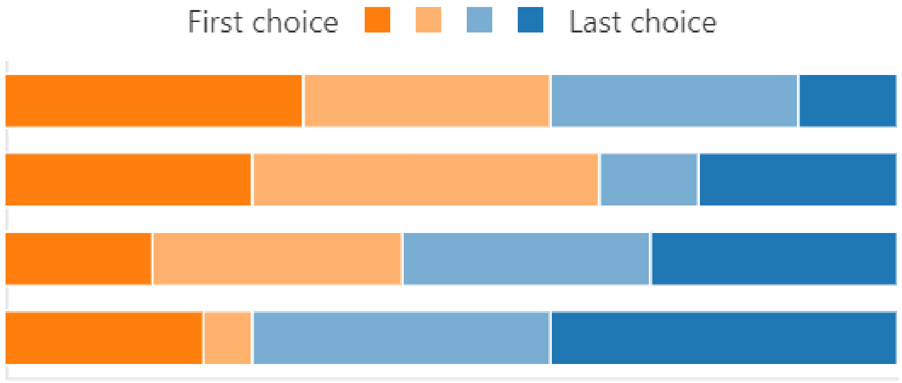
20. Which of the GCOS requirements are most challenging for providers to meet?

More Details

Rank	Options
1	Measurement uncertainty
2	Stability
3	Frequency
4	Resolution

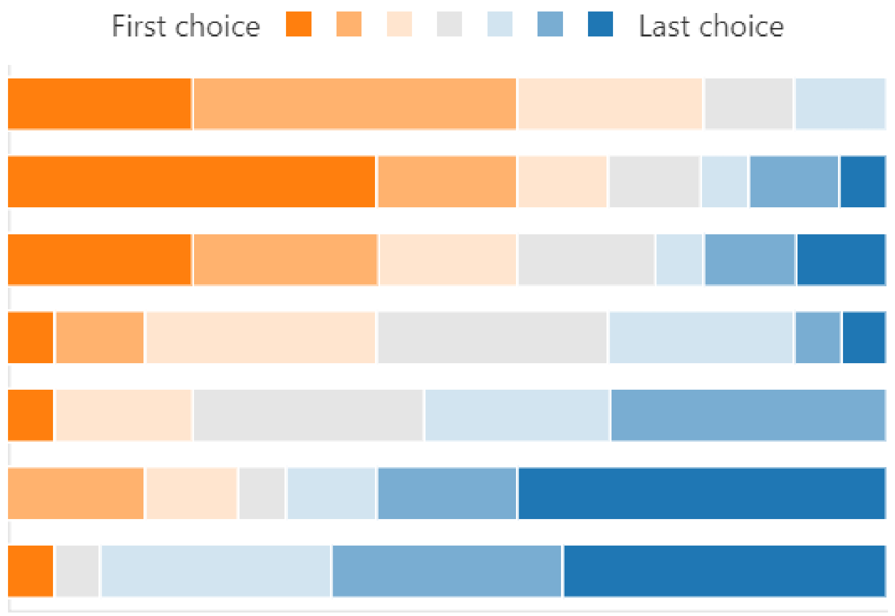


Meeting some of the GCOS requirements is simply a function of data availability - for example data resolution is dependent on the sensors/data available. Other requirements such as uncertainties are related primarily to data quality and retrieval skill, but understanding the inherent uncertainties (and whether they are therefore correctly quantified) is somewhere that metrology could contribute.

21. What do you think users look for in a long-term record of ECV quantities?

More Details

Rank	Options
1	Duration of record
2	Ease of use
3	Long term stability
4	Quality assurance
5	Low uncertainties
6	Data provenance
7	Detailed uncertainty informati...



- Minimize data volume for users
- Data should be easy to read and understand
- Provide sufficient uncertainty information to allow correct propagation of uncertainty to spatial and temporal averages of data
- Provide information about temporal stability of observations

Merchant et al, Earth Syst. Sci Data, 9. 511-527, 2017

OBSERVATION PROCESS

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Observations from wide range of in situ, on site and remote sensing techniques

Processing

- Combining data from different sources
- Data selection
- Gap filling, gridding
- Processing to ECV products
- Data assimilation into climate models, reanalysis

Information services

Atmosphere (CAMS)
Marine (CMEMS)
Land (CLMS)
Climate (C3S)
Emergency (EMS)
Security

OBSERVATIONS: ISSUES

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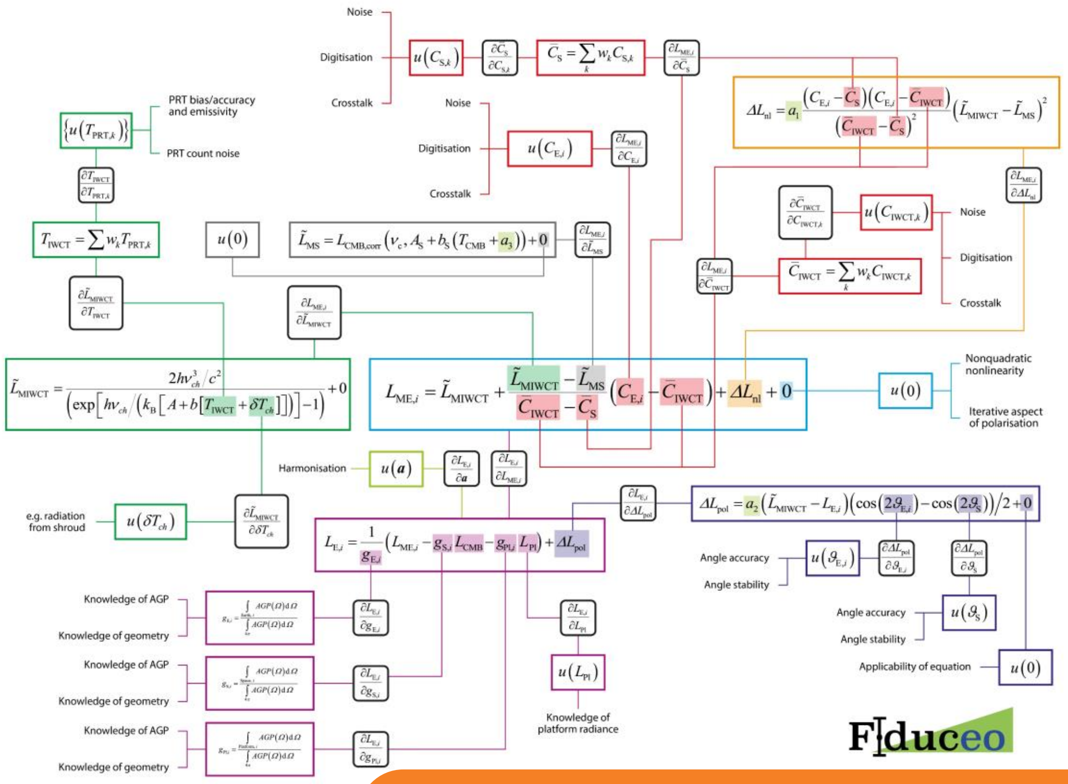
- Clear/robust definition of the measurand
  - (sea ice concentration, soil moisture, leaf area index, land surface temperature, pH, salinity,...)
- Improved instruments / methods of measurement
- Traceability to reference standards
- Traceability to low cost sensors
- Rigour in uncertainty analysis:
  - Language
  - Mathematics and methods
  - Examples
  - Tools
  - Including error covariance between observations
- Comparisons / Common approaches

What is the problem?
What can metrology do?

Provision of references gases to improve the quality of in-situ observations, e.g. for NO_2.

Yes. The development of testing facilities is required, and the development of new measurement techniques.



Analysis of error correlation structures, which is slow, difficult work that doesn't usually result in publications and so can't be done by postdocs without some amount of self-sacrifice.

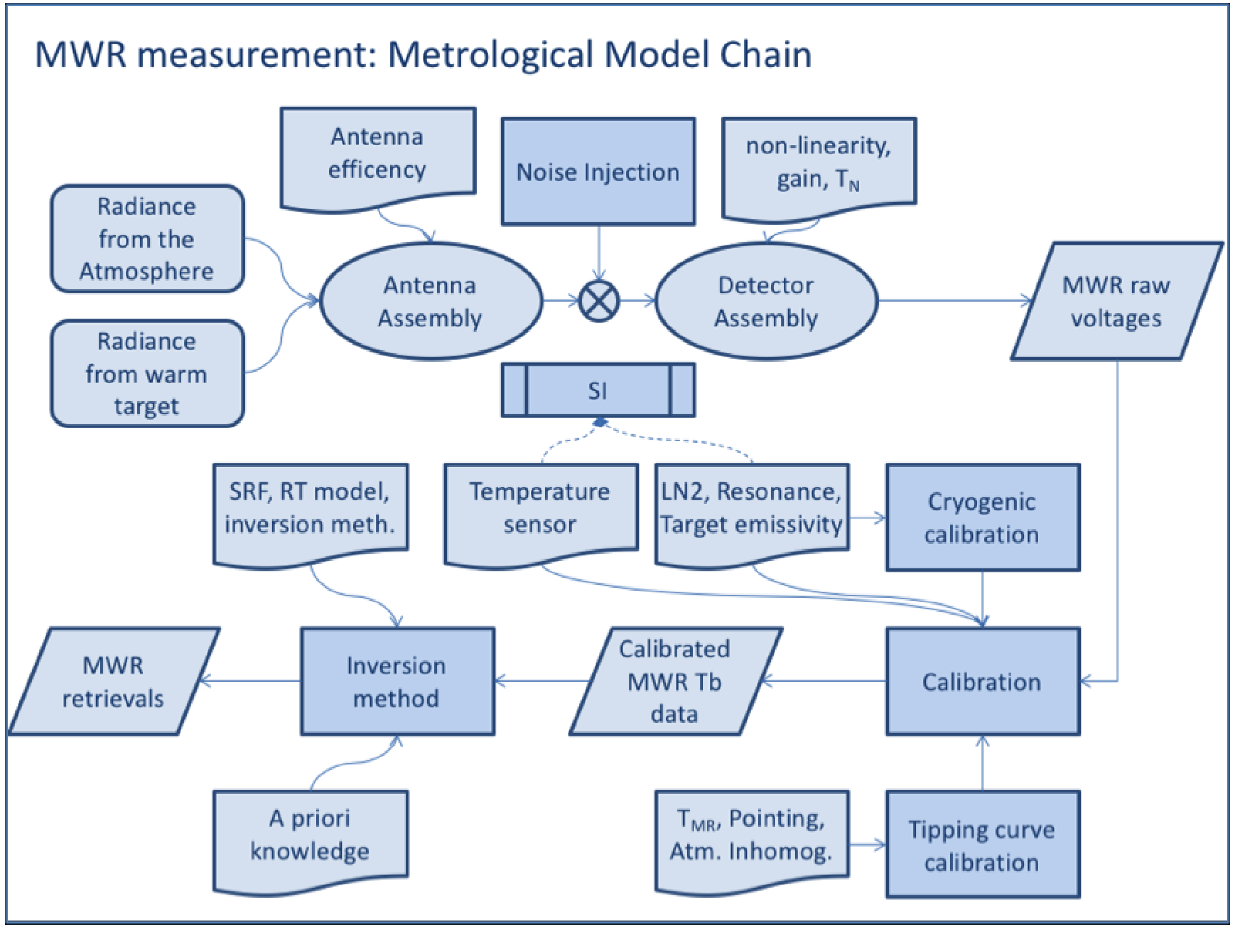
help implement / spread the FIDUCEO concept

PROCESSING ISSUES

- Combining data sets – (consistency in merged data sets)
    - from in situ, ground-based remote sensing, and satellites,
    - from chemical and physical techniques, and biological/ecological ECVs/EOVs
    - from different sensors making similar measurements
    - from observations and reanalyses
    - from observations and geological records (paleo-climatology)
- Critical to understand uncertainty in long-term (decadal) stabilities
- Traceability chains and uncertainty tree diagrams
- Retrieval algorithm cross comparisons
- Uncertainties in models used (e.g. radiative transfer models)

What is the problem?
What can metrology do?

TRACEABILITY CHAINS AND UNCERTAINTY TREE DIAGRAMS (GAIA-CLIM, FIDUCEO)



A grounded framework for the propagation of uncertainties in complex algorithms is still missing in the field. Using the term "covariance" is different from actually propagating/evaluating the statistical distribution of errors.

INFORMATION SERVICES ISSUES

- Reproducible, open science – data and code on shared platforms, open information
- Metadata, data flags – consistency of approach
- Judging “fitness for purpose”

Details	Generation	Quality flags	Uncertainty Characterisation	Validation	Inter-comparison
Product Information	Input data and uncertainties	Quality Flags	Uncertainty Characterisation Method	Reference data representativeness	Scale of inter-comparison activities
Product Description	Sensor Calibration		Uncertainty sources included	Reference data uncertainty inclusion	Inter-comparison method
Coverage and Resolution	Algorithm method		Uncertainty values provided	Validation method	Product uncertainties inclusion
Data gaps	Algorithm tuning		Temporal stability	Validation results	Discrepancy between products identified and, if possible, resolved
Data set limitations and target applications	Sensitivity analysis		Geolocation uncertainty		
Documentation	Internal Processes				
	Traceability				

THANKS AND ACKNOWLEDGEMENTS

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Thank you for your attention

For more information contact

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