ESA Validation Strategy for Optical Land imaging sensors

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Outline

- Background and Motivations
- Vision and Principles
- Rationale and Approach
- Status and needs from Land Validation WS 2020
- Detailed recommendations from the WS
- Conclusion and Outlook

Background and Motivations

- The **fleet** of **current and future ESA optical land** imaging sensors (S-2, S-3, Proba-V, FLEX, CHIME) ensures **unprecedented** observation capability in terms of spatio-temporal-spectral coverage.

- Yet, critical questions remain as **how to harness the full potential of such big amount of data**, which are complementary in principle, but inherently **diverse** in terms of: spatio-temporal resolution, radiometric accuracy and sensitivity, spectral coverage.

- Likewise, there is a recent increase in availability of **Cal/Val data** for Land, although **inconsistencies** in the used practices and associated quality information still hamper their integrated and synergistic use for satellite products validation.

Vision and Principles

Vision

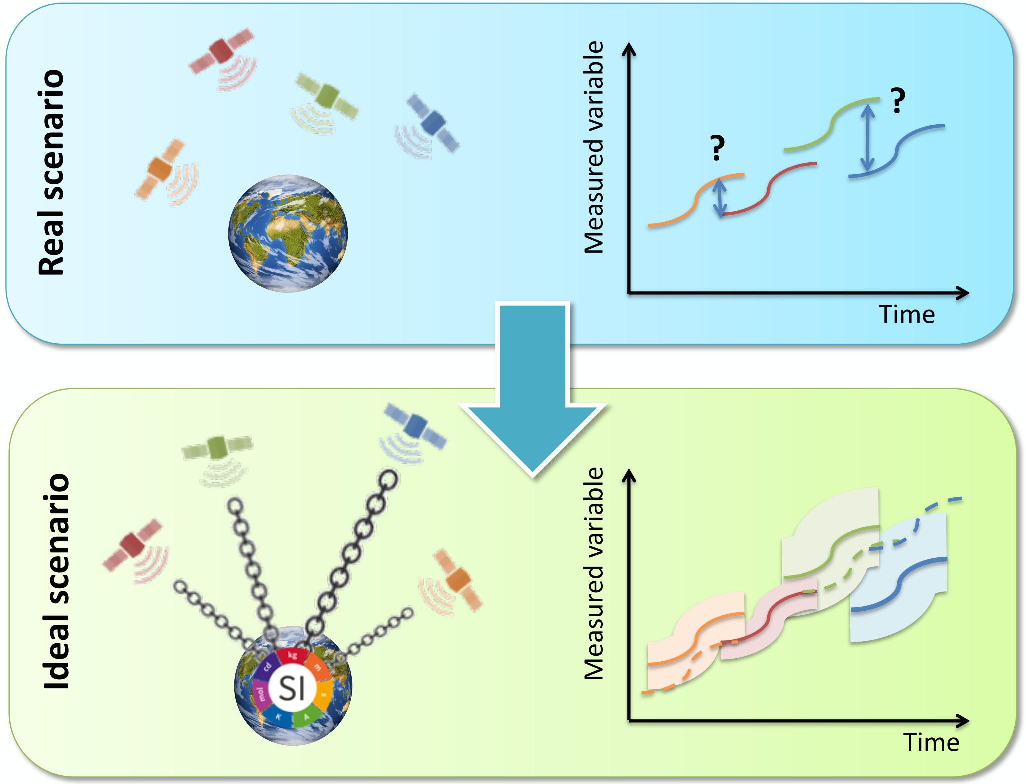
- Work towards **enhancing interoperability** of current and future ESA optical land sensors.
- The long-term vision is a **system-of-systems** concept enabling seamless exploitation of current and future EO optical data for downstream applications.

Principles (stem from QA4EO)

- Ensuring that the EO data is provided with fully **traceable** indicator of their quality, properly documented and quantitatively tied to an international **standard** (ideally to SI).
- **Traceability** and **uncertainty** estimates allow understanding and characterizing cross-mission **biases**, therefore enabling interoperability.

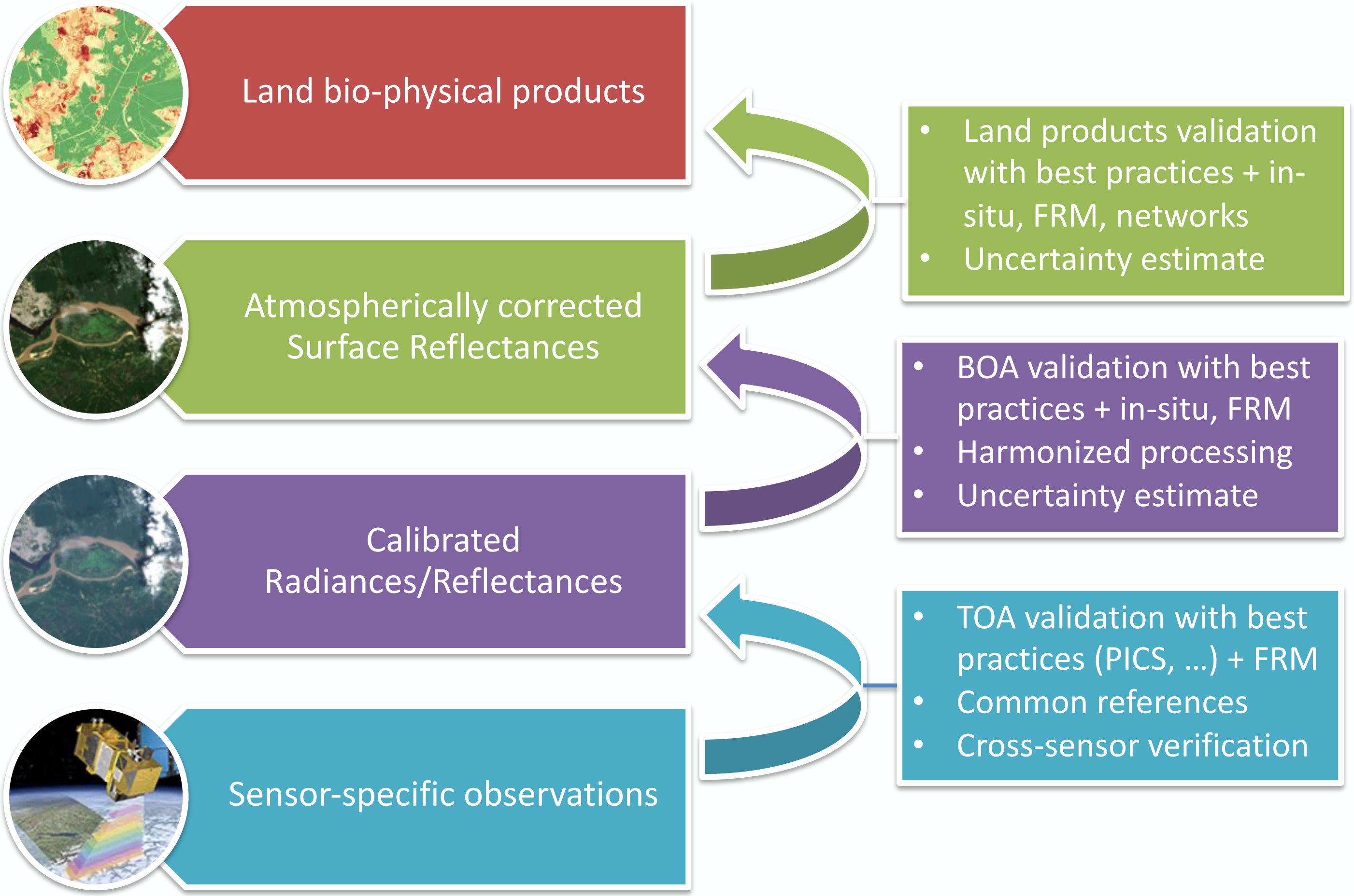
QA4EO A QUALITY ASSURANCE FRAMEWORK FOR EARTH OBSERVATION

- The Quality Assurance framework for Earth Observation (QA4EO)
- Looks to make the GUM accessible to the EO community



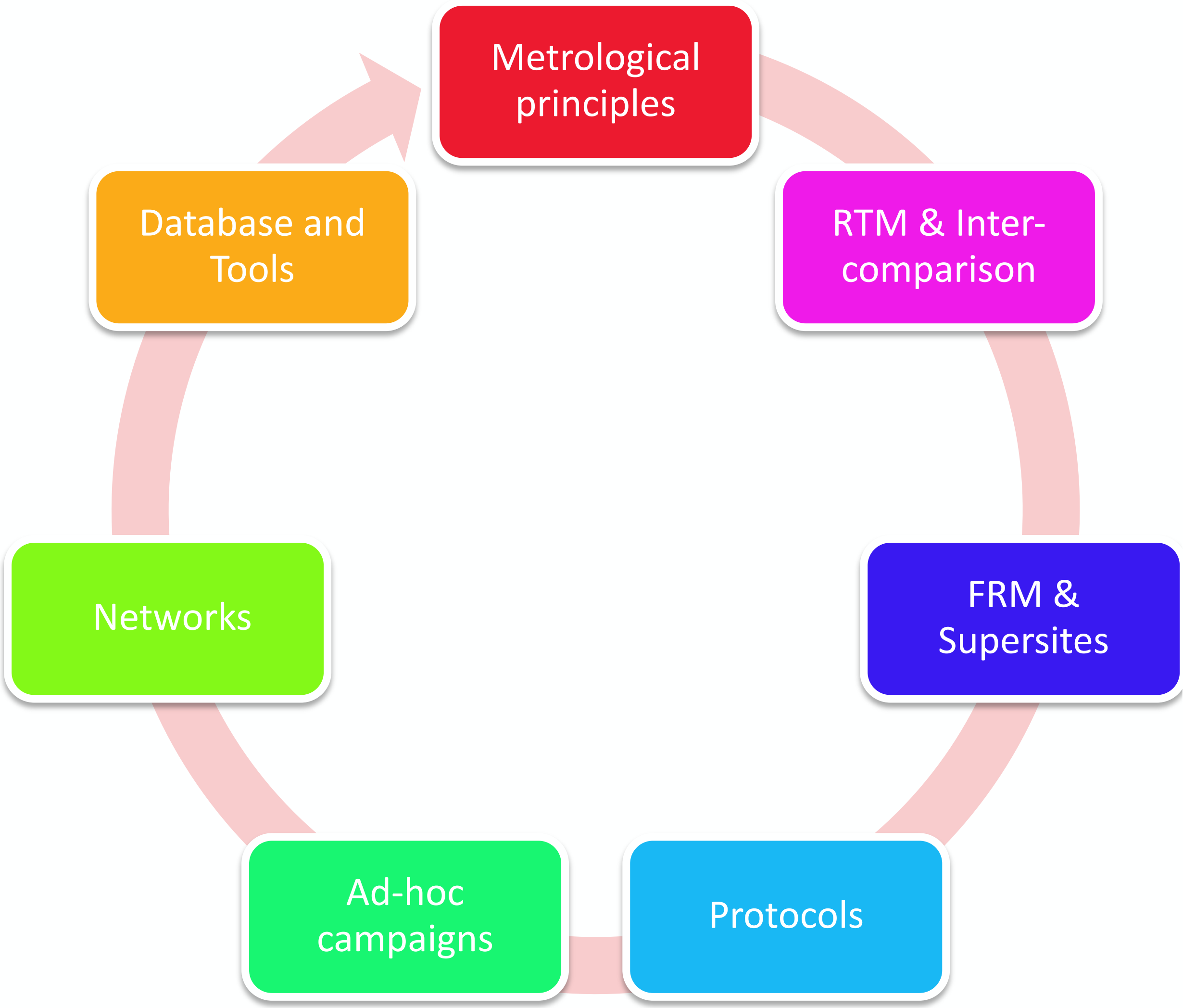
Rationale and Approach

- **Consistency** across sensors shall be ensured **starting at TOA level** and verified along the full chain in a **stepwise** approach → BOA → Land products
- Provision of **uncertainty** (ideally at pixel level) to be propagated along the full chain starting from L1 → L2 ,…
- **Benchmarking** exercises to understand and solve potential discrepancies between algorithms (e.g., cloud mask, AC)
- Adoption of common **practices** and internationally agreed **references**
- Use of community-agreed **protocols** in Cal/Val measurements



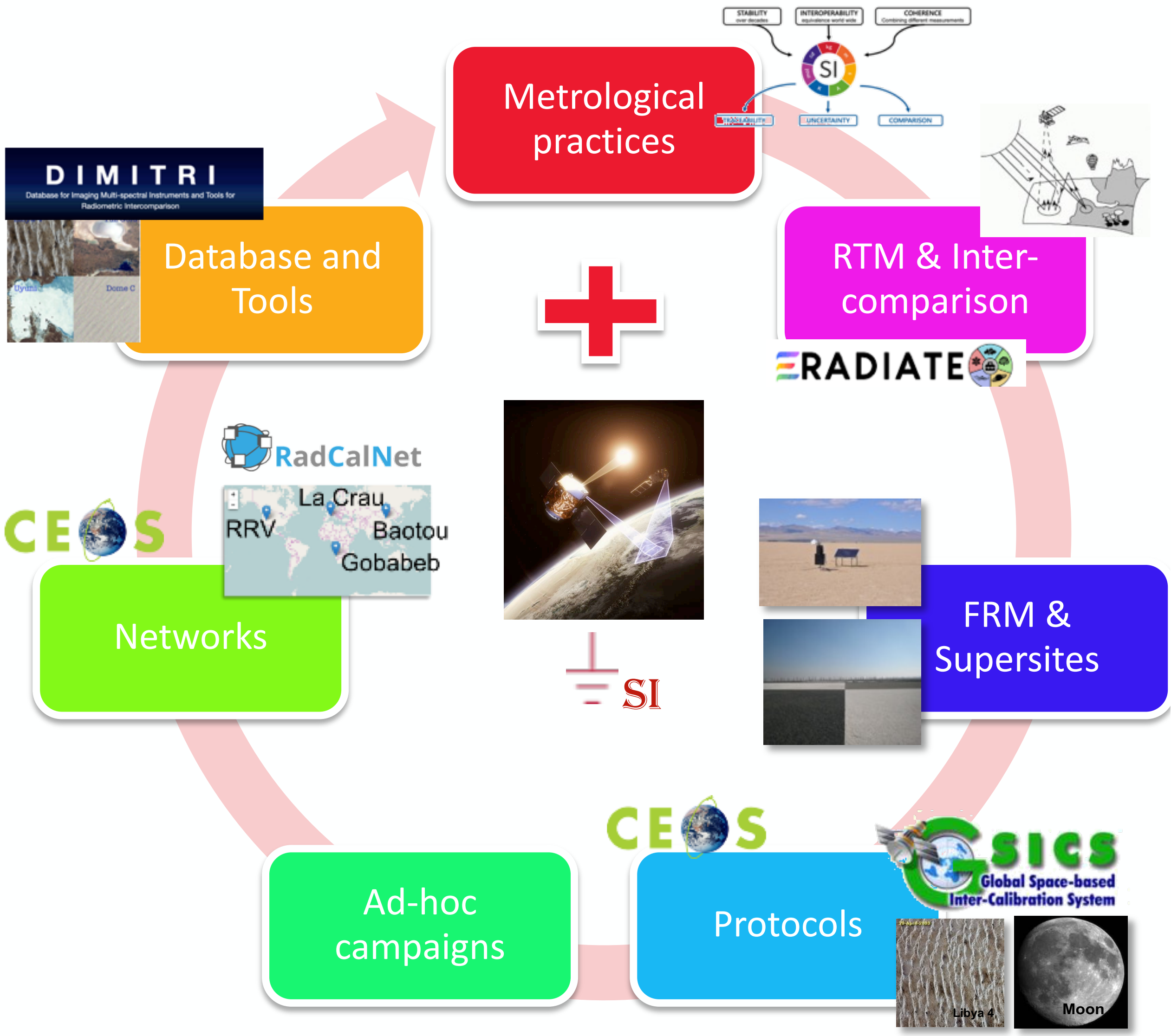
Building blocks for a Cal/Val integrated solution

- **Metrology:** to provide the framework and practices to derive uncertainty quantified EO data
- **RTM & Inter-comparison**: to fully understand the uncertainty budget and perform benchmarking
- **FRM & Supersites**: super-characterized sites (metrology & 3D) to establish Cal/Val protocols
- **Protocols**: to provide community-agreed practices for measurements and spatio-temporal upscaling
- **Ad-hoc campaigns**: to test/verify advanced techniques, and in-depth validation at local scale
- **Networks**: to scale-up the Cal/Val analysis at global scale in an operational context
- **Database and tools**: to facilitate uptake of Cal/Val data using standardized procedures



Example application to TOA radiometry Cal/Val

- If we apply this general framework to **Level 1** (TOA radiometry) we observe that we have very **good level of readiness.**
- All **building blocks** are in place, some fully operational (many RTMs, GSICS, RadCalNet, DIMITRI), some coming soon (Eradiate), some planned (TRUTHS).
- We have **good confidence** on our ability to assess TOA radiometry and understand cross-mission biases at TOA level.
- Similar good situation in the **Ocean Color** domain (AERONET-OC, BOUSSOLE, …).
- On the other hand, in the **Land domain** we see clear **gaps**, already at BOA level.



Needs and way forward for Land Cal/Val strategy

- In order to understand the **status and gaps** in the Land validation domain a **Strategy WS** was organized by ESA during 30 Nov – 1 Dec 2020.
- Presentations were arranged into **three main thematic** areas (metrological practices in Cal/Val, operational Cal/Val and recent advances) and concluded with discussion.
- The WS was attended by key EU partners in the Land Cal/Val domain (CEOS, JRC, NPL, UoS, ACRI-ST, Rayference, VITO, RBINS, WUR, NRC).
- A list of clear **recommendations** and actions were collected and elaborated into a **Report**, which is **published on-line**:

  https://earth.esa.int/eogateway/events/esa-workshop-on-land-validation-strategy

Land Validation in a metrological context
- Metrological Practices (NPL)
- FRM for Vegetation (NPL)
- Eradiate RTM (Rayference)

Land Validation in an operational context
- CCVS Copernicus Validation (ACRI-ST)
- CEOS LPV Super-sites (CEOS-LPV)
- GBOV Copernicus service (ACRI-ST)
- Land Cal/Val for S3 MPC (U. Southampton)

Recent advances in Land Cal/Val
- RadCalNet (CEOS)
- HYPERNETS (RBINS for ESA/EC)
- UAV-based and low-cost sensors (WUR for ESA)
- UAV-based (NRC)

Main take-home from the WS

- A large number of concurrent projects are running under different umbrellas (ESA, EC, CEOS, …).
- **Synergies** are still largely **under-exploited**, notably for Sentinels, causing duplication of efforts and increase of associated costs.
- Existing EU and US networks are potentially available, although most of them were **not primarily designed** for Cal/Val.
- The one-take-home-message form the WS:

  “We **cannot just leverage on existing infrastructure**, we should work to **fill the gaps** (with priorities) with a **sustainable** long-term solution”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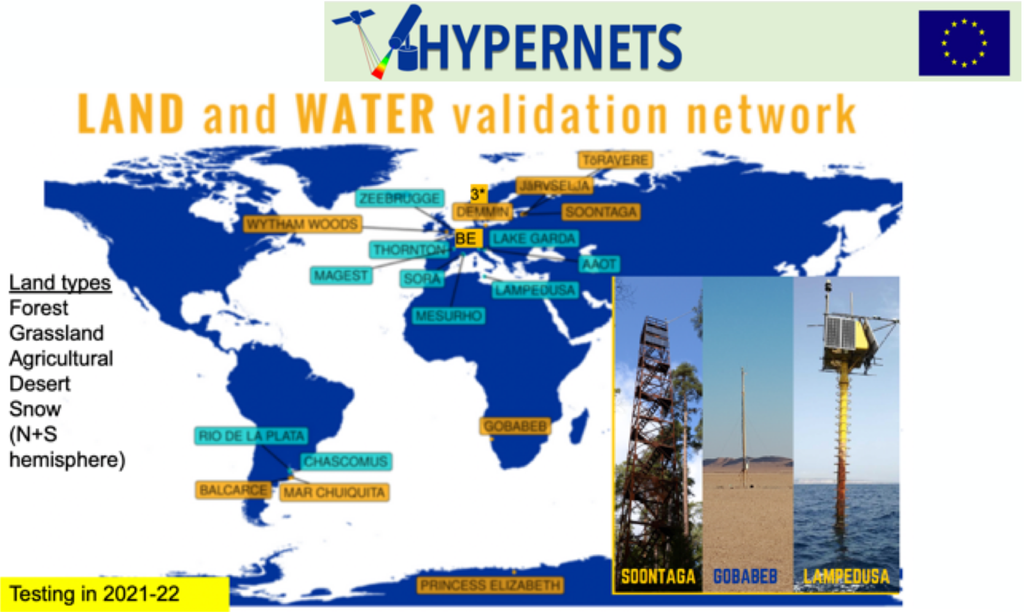
DOCUMENT

ESA Workshop on Land Validation Strategy (30/11– 1/12/2020): Highlights and Recommendations

Cal/Val networks thematic and geographical data gaps

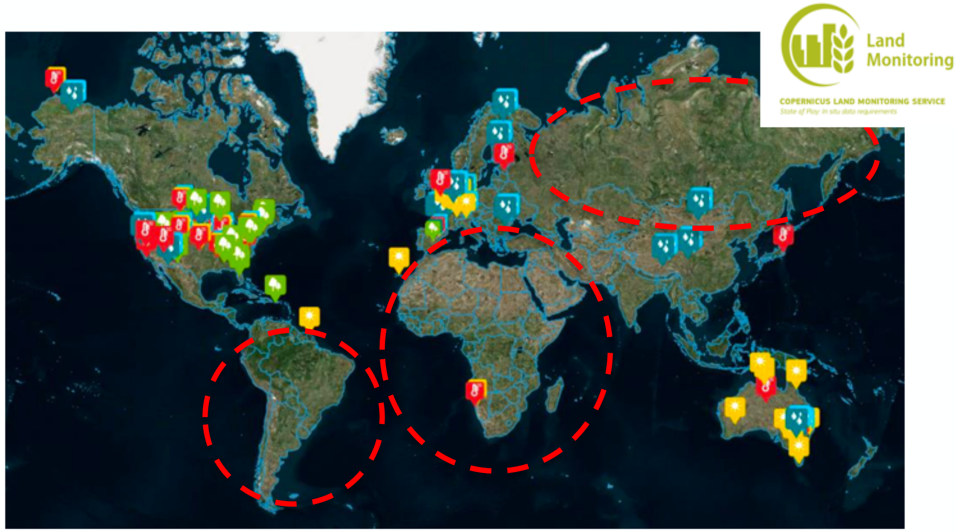
- The **lack** of a ground-based reference data network for **SR validation** still limits our ability to validate BOA products and understand the discrepancies in the adopted AC approaches.

[REC] → **To set-up** a ground-based global network of **Surface Reflectance** automated measurements, ideally hyper-spectral (multi-mission) and multi-angular (BRF characterisation) → The **HYPERNETS** project is currently working in this direction.



- Clear data gap in the geographical coverage of existing networks, notably in Africa, South- America and Asia, for validation of vegetation parameters, LAI, FAPAR.

[REC] → To fill this **geographical gap**, the GBOV project has started to fill the gap, but much more effort is still required.



Cal/Val networks readiness

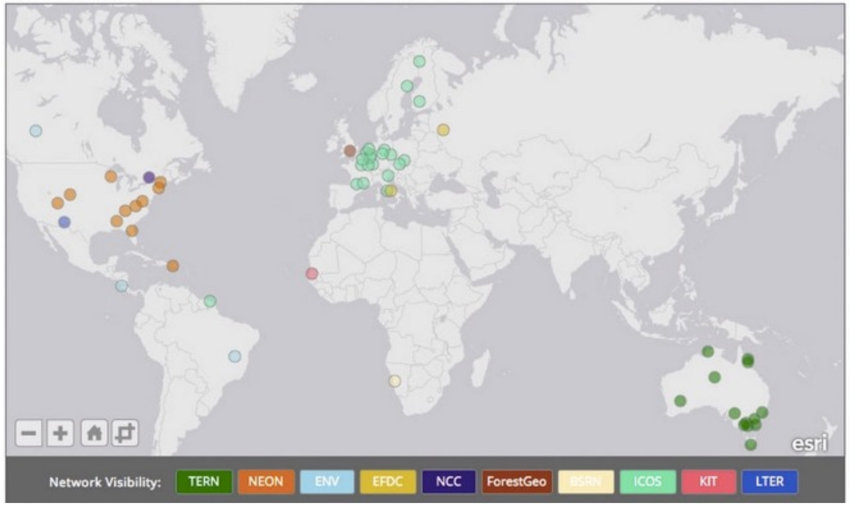
- **Existing networks are not primarily designed for validation** purposes; the lack of uncertainty information and the **disparity** of used protocols still limit their integrated usage in satellite-products validation.

[REC] → To foster adoption of Cal/Val best practices across existing networks and support **adaptation** of these networks for meeting Cal/Val needs.

- ESA in collaboration with EC is developing a suite of innovative space-borne optical sensors focusing on land, namely: FLEX, LSTM and CHIME.

[REC] → To enhance readiness to support Cal/Val needs of future missions (e.g., fluorescence), exploiting synergies, such as using **super-sites** for measuring multiple geo-physical variables (multi-mission purpose).

ICOS INTEGRATED CARBON OBSERVATION SYSTEM



CEOS Cal/Val super-sites

Cal/Val protocols and FRM

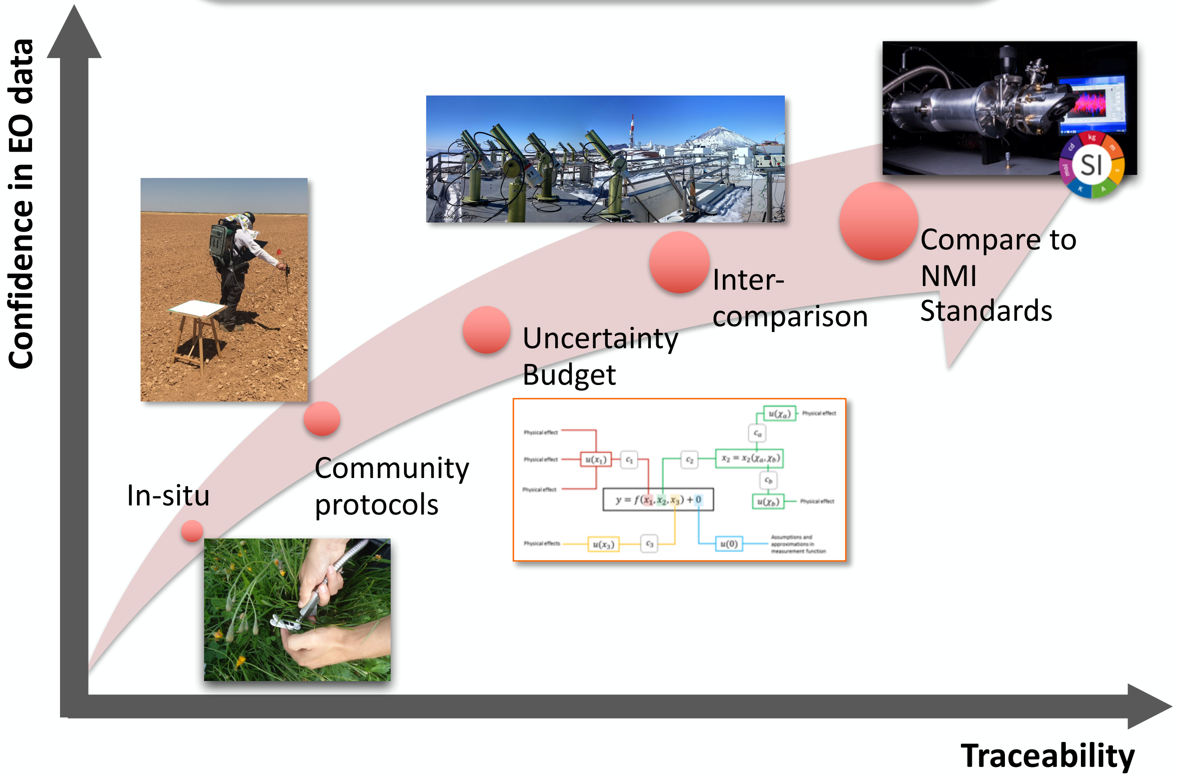
- Provision of **FRMs** in a **sustainable** way over **globally** representative network of sites is necessary for operational land Cal/Val system (to reach **stage 4**).

[REC] → To enable **transition** of FRM from R&D to an **operational** system of permanent sites and to expand their geographical coverage.

- **Community-Agreed-upon protocols** are still missing for some terrestrial ECVs, notably for **SR, FAPAR, and phenology**.

[REC] → To fill this gap (e.g. FRM4VEG protocols for SR, FAPAR) and collaborate with other CEOS agencies to buy-in **consensus** and promote wide adoption by the community.

FRM concept
- Evidence of metrological SI-traceability
- Follow community agreed protocols
- Include full uncertainty budget
- Inter-comparison exercise



Advanced technological solutions

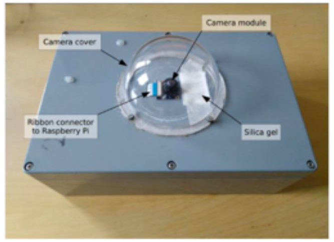
- Advanced technological devices (**UAV-based, automated sensors**) are becoming an **attractive** and **cost-effective** solution for enhancing **spatio/temporal sampling** in Land Cal/Val.

- **Lidar** systems have the additional advantage of being illumination-independent and allow detailed 3D characterisation of the sites and estimation of vegetation parameters (e.g., LAI).

[REC] → To **update CEOS-LPV protocols** to keep pace with technological evolution.

[REC] → To **better characterize the accuracy** of such advanced devices, for Cal/Val and biophysical parameters estimation, by benchmarking against traditional methods or RTM simulations.

Courtesy of B. Brede (WUR)



PiLAI 1.0 (Vellekoop 2019)

PiLAI 2.0 (concept)

Courtesy of L. Brown (UoS)

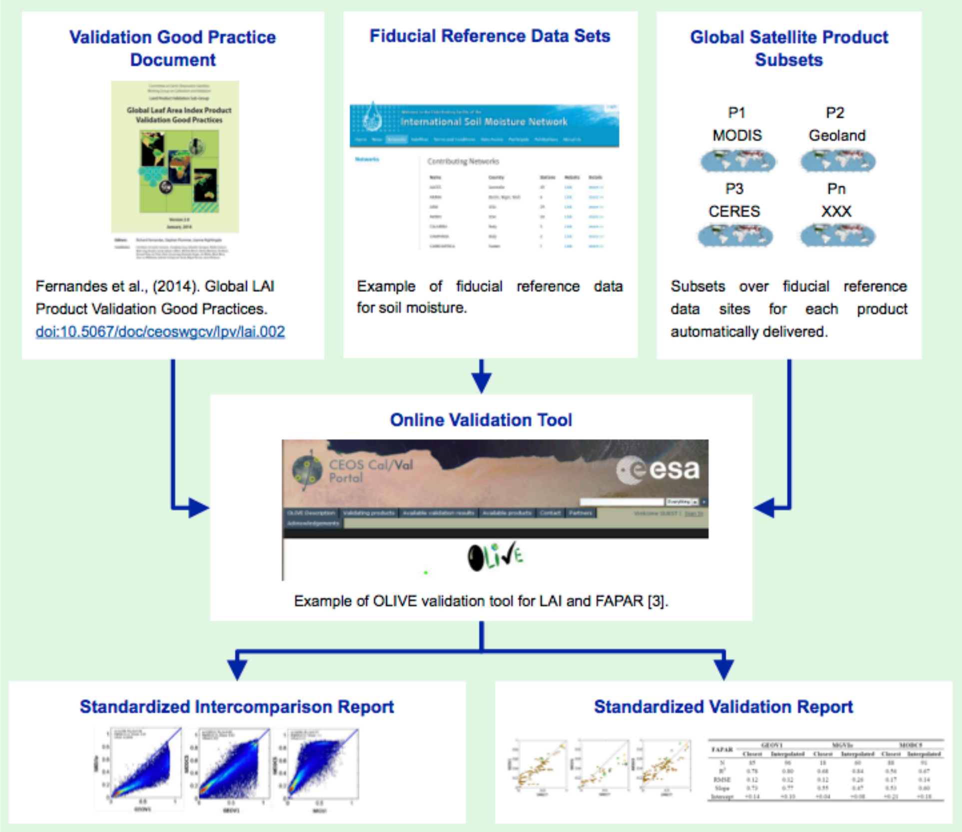
Cal/Val data discoverability and accessibility

- The **uptake of Cal/Val data** from the community is strongly **limited** by the difficulty in discovering, accessing, and using the available measurements, in particular for field campaigns.

[REC] → To set-up a **centralized** repository of Cal/Val data for Land, following the **FAIR** guiding principles, to collect data acquired within current and future initiatives.

- **Online validation tools** based on community protocols allow transparent and standardised validation. The **OLIVE** tool was valuable example in this respect, but it is currently outdated and not maintained.

[REC] → To support upgrade and secure the maintenance of OLIVE and improve BELMANIP site selection (update LC map and optimize sampling for S-2 resolution).



Conclusion and Outlook

- ESA is putting forward a Land Validation strategy with the long-term objective to facilitate **interoperability** of current and future **land imaging optical sensors.**

- The foundation of this strategy stem from the **QA4EO principles** of ensuring that a fully traceable and documented quality indicator is attached to each EO products.

- Traceability and uncertainty estimate coupled with inter-comparison exercises enable us for **understanding** and fully characterizing **cross-mission biases.**

- The strategy is built around a set of **building blocks** (metrology, RTM, FRM, super-sites, networks, campaigns, database and tools); readiness of these blocks is assessed starting from Level 1.

- While for TOA we see good level of readiness, in the Land domain some clear gaps were identified (already at BOA), which currently limit our ability to assess inter-sensors biases.

- **Leveraging** existing infrastructures for **Land** is **not enough**, clear **need to fill the gaps** (surface reflectance, geographical coverage, network suitability, protocols readiness, tools).

- ESA in strong liaison with CEOS-LPV will work to **fill these gaps**, promoting adoption of common practices, exploiting synergies and facilitating the **uptake** of Cal/Val data (tools).

Q&A