On the evaluation of remotely sensed soil moisture…
…what are (the) errors?

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4th Satellite Soil Moisture Validation and Application Workshop
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Outline

- Towards standardized EO validation practices
- Where are we as a soil moisture community?
- Next steps

Towards standardized practices

- **CEOS** - The Committee of Earth Observation Satellites
  - **WGCV** - Working Group on Calibration and Validation
    - **LPV** - Land Product Validation Subgroup
  - **QA4EO** – Quality Assurance Framework for Earth Observation
    - **QA4ECV** – Quality Assurance for Essential Climate Variables

Guidelines for validation good practices
Assurance of the quality of data characterization

Definition of accuracy requirements?

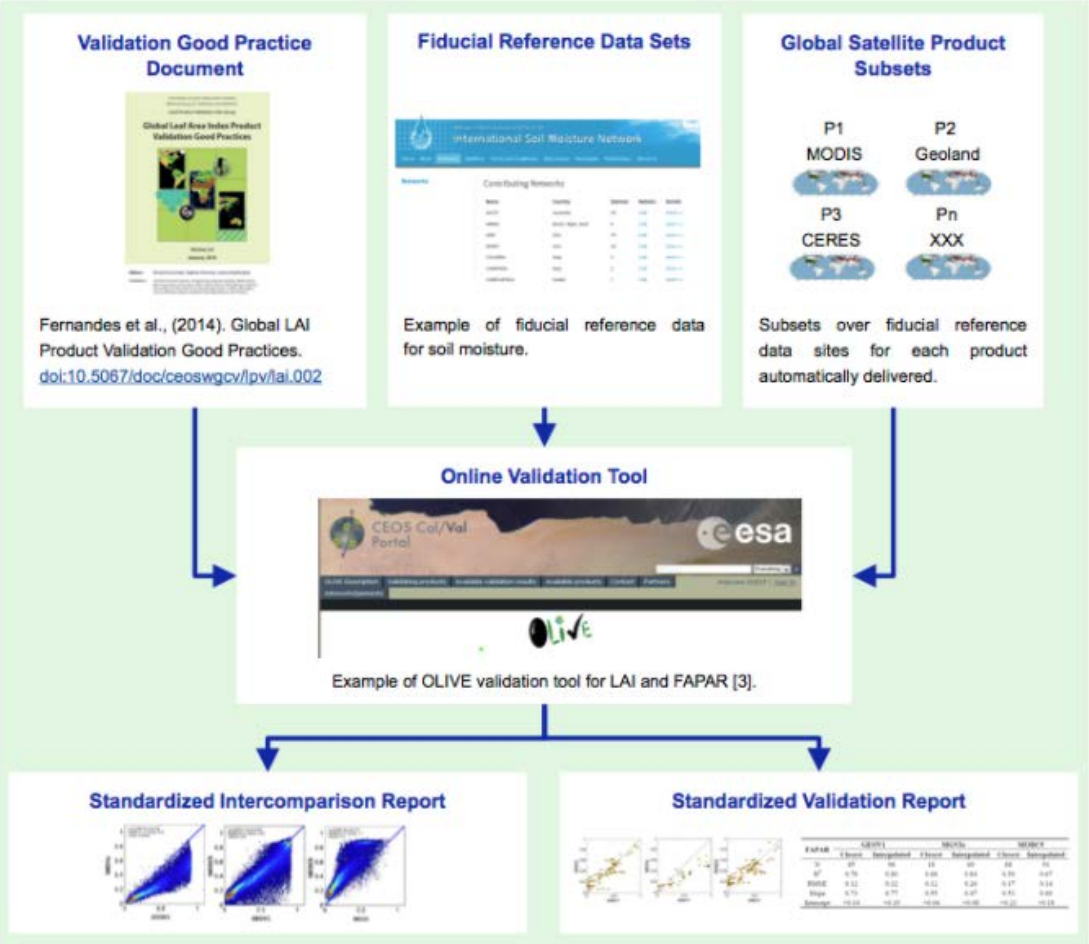
CEOS Validation Stages

- https://lpvs.gsfc.nasa.gov/index.html (CEOS WGCV LPV)

Validation Stage - Definition and Current State		Variable
1	Product accuracy is assessed from a small (typically < 30) set of locations and time periods by comparison with in-situ or other suitable reference data.	**Fapar** **Snow Cover** **Phenology** **LST & Emissivity** **Fire Radiative Power**
2	Product accuracy is estimated over a significant set of locations and time periods by comparison with reference in situ or other suitable reference data. Spatial and temporal consistency of the product and consistency with similar products has been evaluated over globally representative locations and time periods. Results are published in the peer-reviewed literature.	**Leaf Area Index** **Burned Area**
3	Uncertainties in the product and its associated structure are well quantified from comparison with reference in situ or other suitable reference data. Uncertainties are characterized in a statistically rigorous way over multiple locations and time periods representing global conditions. Spatial and temporal consistency of the product and with similar products has been evaluated over globally representative locations and periods. Results are published in the peer-reviewed literature.	**Land Cover** **Albedo** **Soil Moisture**
4	Validation results for stage 3 are systematically updated when new product versions are released and as the time-series expands.	

CEOS Validation Stages

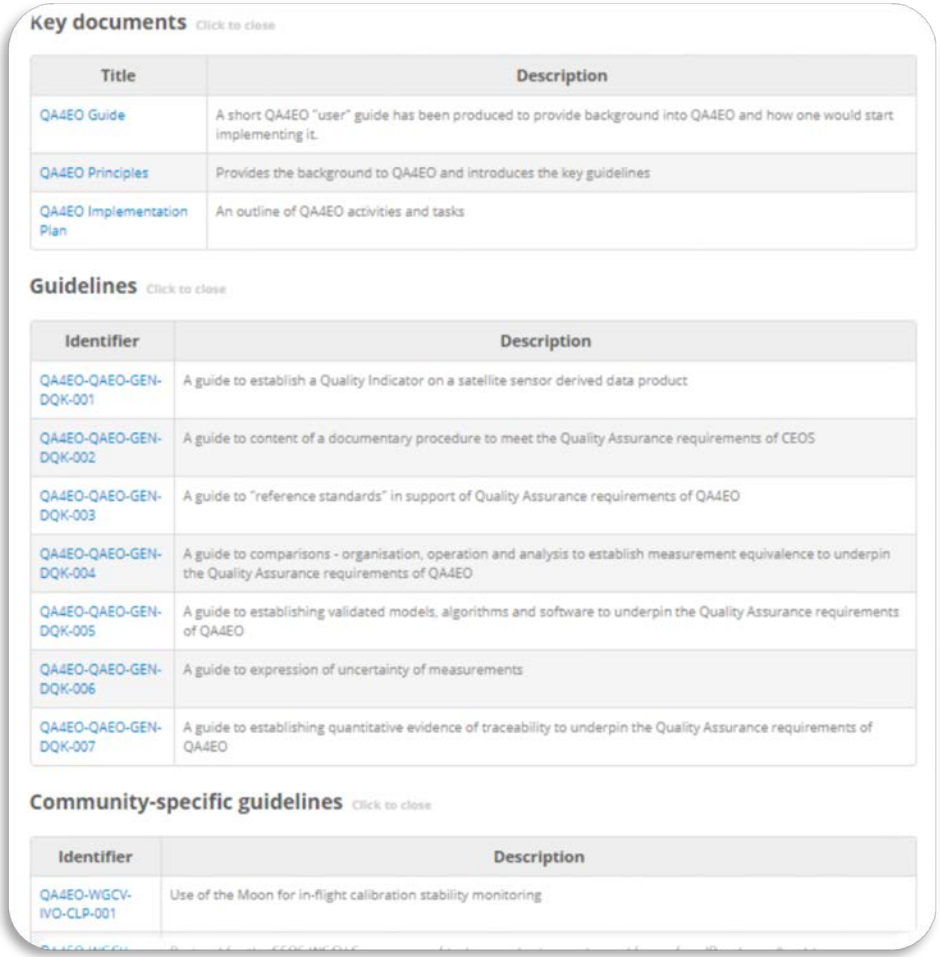
- To reach stage 4 a citable, automated protocol has to be implemented:



** Fiducial reference measurements are a suite of independent, fully characterized, and traceable ground measurements that follow the guidelines outlined by the GEO/CEOS Quality Assurance framework for Earth Observation (QA4EO)*

QA4EO

- Top-level guidance to all EO communities to harmonize good practices in their particular area
  - http://qa4eo.org/documentation/



Key documents Click to close

Title	Description
QA4EO Guide	A short QA4EO "user" guide has been produced to provide background into QA4EO and how one would start implementing it.
QA4EO Principles	Provides the background to QA4EO and introduces the key guidelines
QA4EO Implementation Plan	An outline of QA4EO activities and tasks

Guidelines Click to close

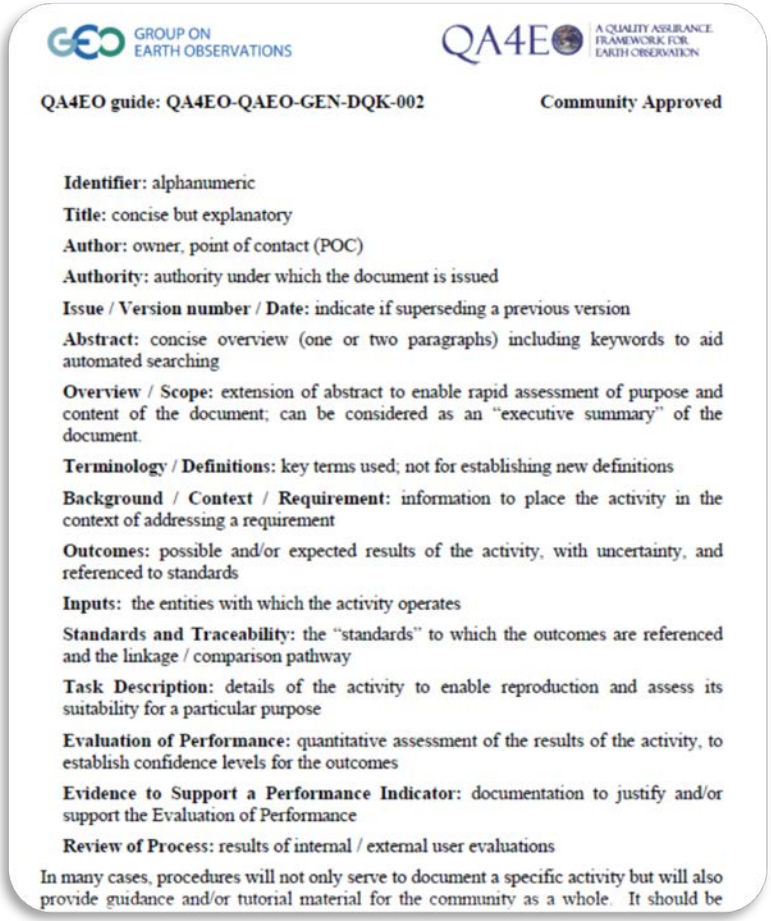
Identifier	Description
QA4EO-QAEO-GEN-DQK-001	A guide to establish a Quality Indicator on a satellite sensor derived data product
QA4EO-QAEO-GEN-DQK-002	A guide to content of a documentary procedure to meet the Quality Assurance requirements of CEOS
QA4EO-QAEO-GEN-DQK-003	A guide to "reference standards" in support of Quality Assurance requirements of QA4EO
QA4EO-QAEO-GEN-DQK-004	A guide to comparisons - organisation, operation and analysis to establish measurement equivalence to underpin the Quality Assurance requirements of QA4EO
QA4EO-QAEO-GEN-DQK-005	A guide to establishing validated models, algorithms and software to underpin the Quality Assurance requirements of QA4EO
QA4EO-QAEO-GEN-DQK-006	A guide to expression of uncertainty of measurements
QA4EO-QAEO-GEN-DQK-007	A guide to establishing quantitative evidence of traceability to underpin the Quality Assurance requirements of QA4EO

Community-specific guidelines Click to close

Identifier	Description
QA4EO-WGCV-IVO-CLP-001	Use of the Moon for in-flight calibration stability monitoring

QA4EO

- In essence:
  - Evaluate your products using traceable reference standards
  - Stick to the VIM/GUM guidelines
  - Use the following structure for documentation:



GROUP ON EARTH OBSERVATIONS

QA4EO A QUALITY ASSURANCE FRAMEWORK FOR EARTH OBSERVATION

QA4EO guide: QA4EO-QAEO-GEN-DQK-002 **Community Approved**

Identifier: alphanumeric

Title: concise but explanatory

Author: owner, point of contact (POC)

Authority: authority under which the document is issued

Issue / Version number / Date: indicate if superseding a previous version

Abstract: concise overview (one or two paragraphs) including keywords to aid automated searching

Overview / Scope: extension of abstract to enable rapid assessment of purpose and content of the document; can be considered as an "executive summary" of the document.

Terminology / Definitions: key terms used; not for establishing new definitions

Background / Context / Requirement: information to place the activity in the context of addressing a requirement

Outcomes: possible and/or expected results of the activity, with uncertainty, and referenced to standards

Inputs: the entities with which the activity operates

Standards and Traceability: the "standards" to which the outcomes are referenced and the linkage / comparison pathway

Task Description: details of the activity to enable reproduction and assess its suitability for a particular purpose

Evaluation of Performance: quantitative assessment of the results of the activity, to establish confidence levels for the outcomes

Evidence to Support a Performance Indicator: documentation to justify and/or support the Evaluation of Performance

Review of Process: results of internal / external user evaluations

In many cases, procedures will not only serve to document a specific activity but will also provide guidance and/or tutorial material for the community as a whole. It should be

International standards... Applicable to EO?

- **VIM** - The International vocabulary of metrology (2008)
  - Defines metrological terms (validation, evaluation, uncertainty, etc.)

- **GUM** – Guide to the expression of uncertainty in measurement (1995)
  - Defines metrological procedures

- Basic principle:
  - Use SI-traceable reference standards to characterize your **model inputs** and then apply an error propagation scheme (Gaussian errors) or Monte Carlo simulations (Non-Gaussian errors) in order to estimate the **uncertainty*** of your model estimate

** 'uncertainty' is understood as a concept to quantify all possible 'true' states given an estimated value…. e.g. fully described by expected value + standard deviation ('standard uncertainty') in case of Gaussian errors…*

** An 'error' is also a concept and refers to the true deviation of the estimate from the actual state of the modelled quantity. Therefore, it can never be known exactly, but it is feasible to estimate a range of possible values with estimated likelihood, i.e., the uncertainty.*

International standards... Applicable to EO?

- Not properly covered in the GUM:
  - Representativeness errors (spatial/temporal resolution)
  - Co-location issues
  - Algorithm deficiencies (incorrect vegetation treatment,…)

- The soil moisture community has established various practices to deal with these issues!
  - https://lpvs.gsfc.nasa.gov/SM/SM_home.html (CEOS WGCV LPV soil moisture focus area)

Validation Good Practice

Currently, most recent satellite product validation plan documents serve as best references for validation of soil moisture:

- SMAP - The SMAP Handbook includes a description of the Cal/Val plan.
- ASCAT - Brocca, L., F. Melone, T. Moramarco, W. Wagner, C. Albergel (2014) Scaling and filtering approaches for the use of satellite observations, Chapter 17 in *Remote Sensing of Engergy Fluxes and Soil Moisture Content*, G.P. Petropoulus (Ed), CRC Press, Boca Raton London New York, 411-425.
- ESA CCI Product Validation Plan
- GCOM W (AMSR2) Validation Protocol
- SMOS - Cal/Val Plan
  Y.H. Kerr, et al., Overview of SMOS performance in terms of global soil moisture monitoring after six years in operation, *Remote Sens. of Environment*, Volume 180, July 2016, Pages 40–63.

SMAP launch, January 31, 2015

Soil Moisture Validation Reference Data Sets

Best currently available in situ reference data for satellite-derived soil moisture product validation are provided by in situ operational networks, most of which can be found at the International Soil Moisture Network web site.

The current understanding of ‘validation good practice’

- Defining a “committed area” and synergistically exploit various ‘reference’ data sources:

- **Ground reference data**
  - Core validation sites
    - Ideally: Field calibration against gravimetric measurements as recommended reference standard
  - Sparse sites
    - Triple collocation to mitigate representativeness errors

- **Satellite inter-comparison**

- **Model-based validation**

- (Towers / Aircrafts)

- (Field experiments)

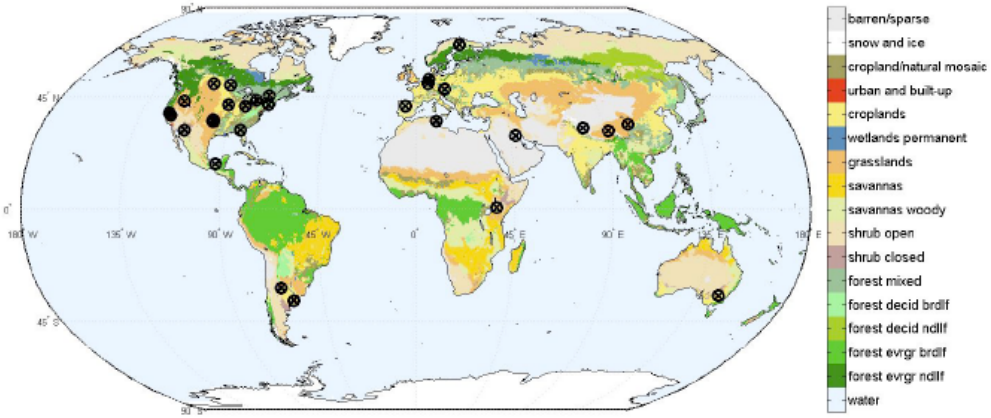


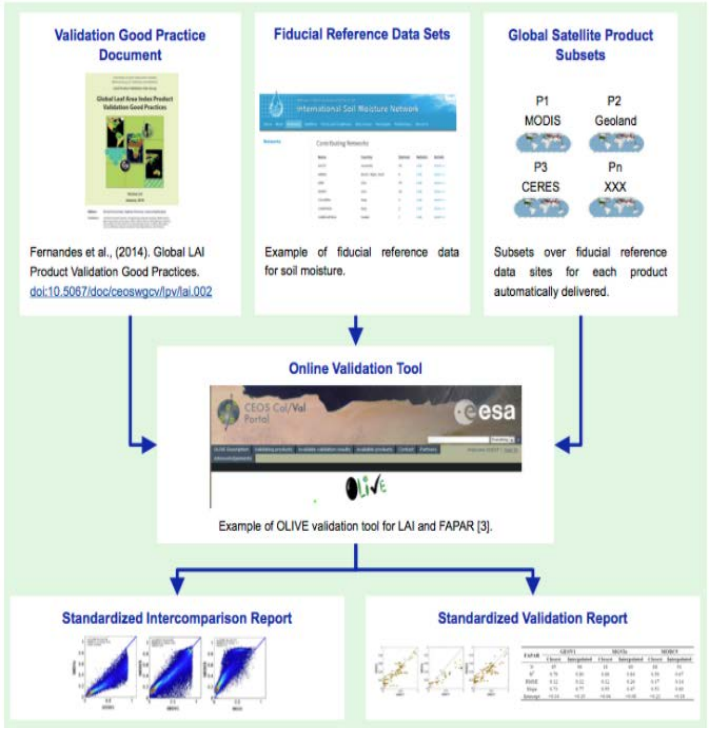
Figure 5-3. The selected Cal/Val Partners for potentially establishing SMAP Core Validation Sites.

[drawn from the SMAP Cal/Val Plan]

Whats next?

- A lot of “high level” documents are being produced…
  - QA4EO guidelines
  - Zeng, Y., Su, Z., Calvet, J. C., Manninen, T., Swinnen, E., Schulz, J., ... & Tanis, C. M. (2015). **Analysis of current validation practices in europe for space-based climate data records of essential climate variables**. *International journal of applied earth observation and geoinformation*, *42*, 150-161.
  - Loew, A., Bell, W., Brocca, L., Bulgin, C. E., Burdanowitz, J., Calbet, X., ... & Kinzel, J. (2017). **Validation practices for satellite based earth observation data across communities**. *Reviews of Geophysics*.
  - Merchant, C. J., Paul, F., Popp, T., Ablain, M., Bontemps, S., Defourny, P., ... & Mittaz, J. (2017). **Uncertainty information in climate data records from Earth observation**. *Earth System Science Data Discussions*.

- Meeting the CEOS requirements for Validation Stage 4
  - Online Validation Tool
    - An open-source (python) framework already exists!
    - Developed by **Christoph Paulik**
    - Available on GitHub
    - http://pytesmo.readthedocs.io/en/latest/validation_framework.html
  - Validation Good Practice Document
    - Writing in progress
    - Expected submission Dec. 2017!



A group effort….

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- Wolfgang Wagner
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- **…MORE TO COME?**

Want to contribute?

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