A preliminary Overview of Cal/Val Activities for the CHIME Mission

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2nd Workshop on International Imaging Spectroscopy

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Overview of Cal/Val Activities

Pre-launch calibration & characterization of the key instruments performance (proper traceability, documentation, etc.)

Post-launch in-flight calibration (allowing monitoring of performance, adjustments, modelling, etc.)

Post-launch vicarious calibration (PICS, RadCalNet, equipped sites, etc.)

Validation activities

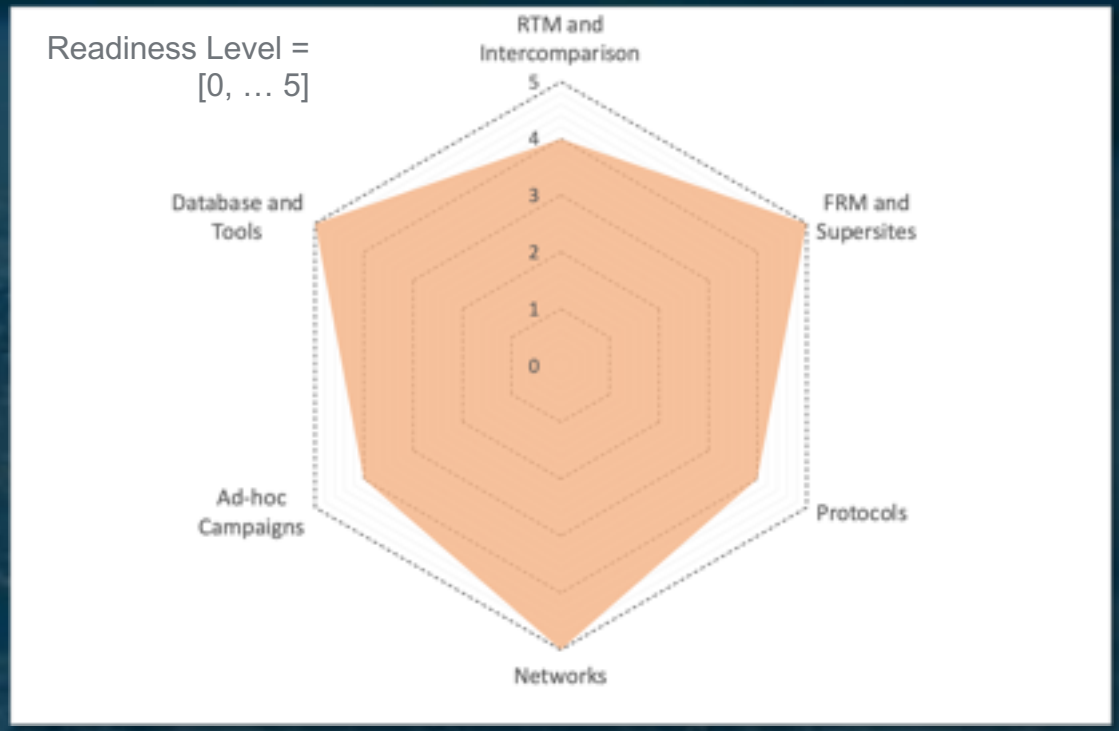
- **Inter-comparison against in-situ measurements** (more and less precise)

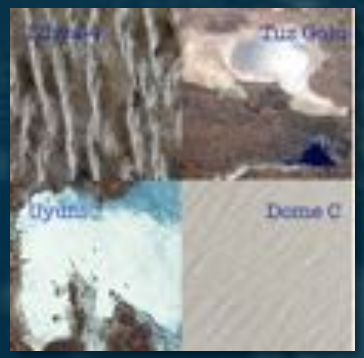
Parallel supporting Cal/Val activities

- **Measurements (FRM)** (few points but precise)
- **Inter-comparison against other satellites**
- **Networks** to enhance geographical coverage for assessing satellite uncertainties over global conditions
- **Usage of monitoring tools** (statistics, trends, systematic quality control, etc.)
- **Indirect validation** using Level-3 data

Readiness Level for L1 TOA products

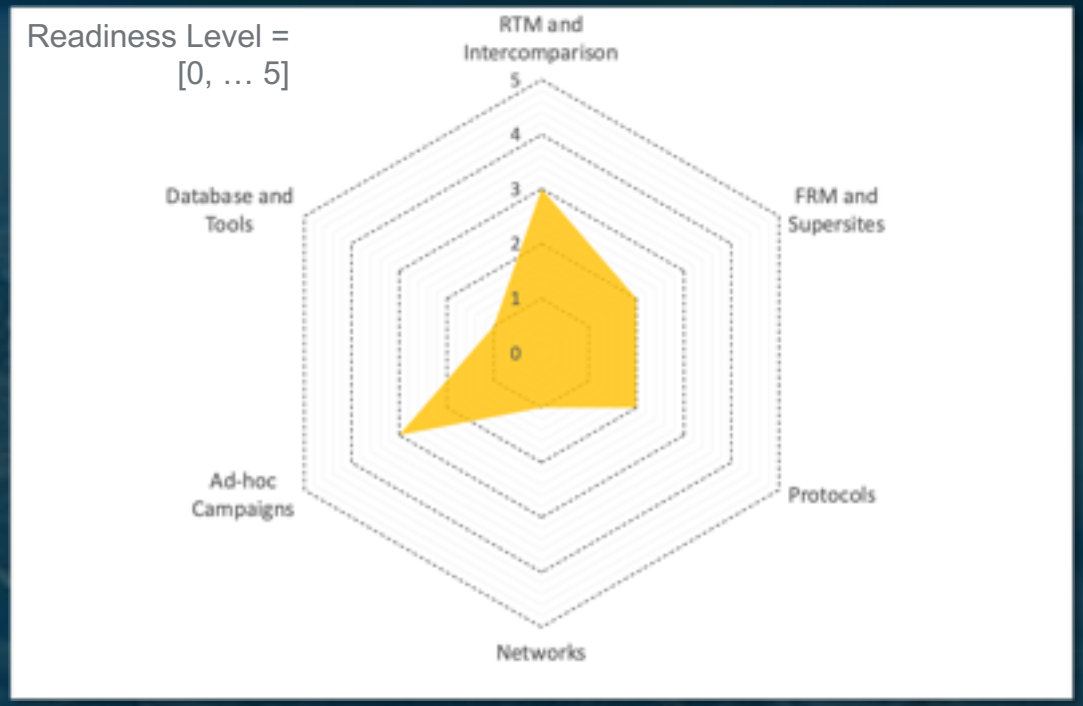
- Cal/Val solutions at **Level 1** (TOA radiometry) are at a very **good level of readiness**
- All **building blocks** are in place, some of them fully operational (RadCalNet, DIMITRI), some under development (Eradiate)
- We have **good confidence** on our ability to assess TOA radiometry and understand and characterize cross-mission **biases** at TOA level
- **Protocols** were developed since many years and consolidated in the frame of CEOS-IVOS, GSICS
- **Database** and **tools** are also routinely used to assess radiometry of current ESA optical sensors
- The final step, aiming at attaining full **traceability** in space is also planned and underway (NASA Clarreo Path Finder, ESA TRUTHS)





Readiness Level for L2 BOA products

- **Conversely** to L1, the readiness level at L2 BOA is still **poor** in many aspects, since protocols are still not consolidated, uncertainties not properly characterized and there is no operational network
- **ESA** in the frame of **CEOS-WGCV** devoted great effort in recent years to address some of these challenges, supporting a number of activities to fill the gaps (ACIX, CMIX, FRM4Veg, SRIX4Veg, HyperNet, Eradiate)
- The main priority for the years to come will be to consolidate best **practices**, prepare the ground for an operational **network** and accurately characterize **uncertainty** budget at BOA level



ERADIATE

HYPERNETS

ACIX | CMIX

- Atmospheric Correction Intercomparion eXercise
- Cloud Mask Intercomparion eXercise

CMIX ACIX-II

CMIX

Sentinel-2, Landsat 8
10 processors
5 validation datasets
Results
Publication in RSE link
Website in CEOS Cal/Val portal link

ACIX-II Land

Sentinel-2, Landsat 8
12 processors
120 AERONET sites
Results
Publication (soon)
Website in CEOS Cal/Val portal link

ACIX-II Aqua

Sentinel-2, Landsat 8,
8 processors
20 AERONET OC sites
Results
Publication in RSE link
Website in CEOS Cal/Val portal link

1st Workshop ACIX-III Land, Aqua and CMIX-II

-- 20-21 June 2022, ESA/ESRIN, Frascati (Italy) --

https://earth.esa.int/eogateway/events/1st-workshop-of-acix-iii-land-aqua-and-cmix-ii

CMIX-II ACIX-III

CMIX

Sentinel-2, Landsat 8, PRISMA
8 participants (up today)

ACIX-III Land

PRISMA
10 participants (up today)

ACIX-II Aqua

Sentinel-2, Landsat 8, PRISMA
10 participants (up today)

HYPERNET

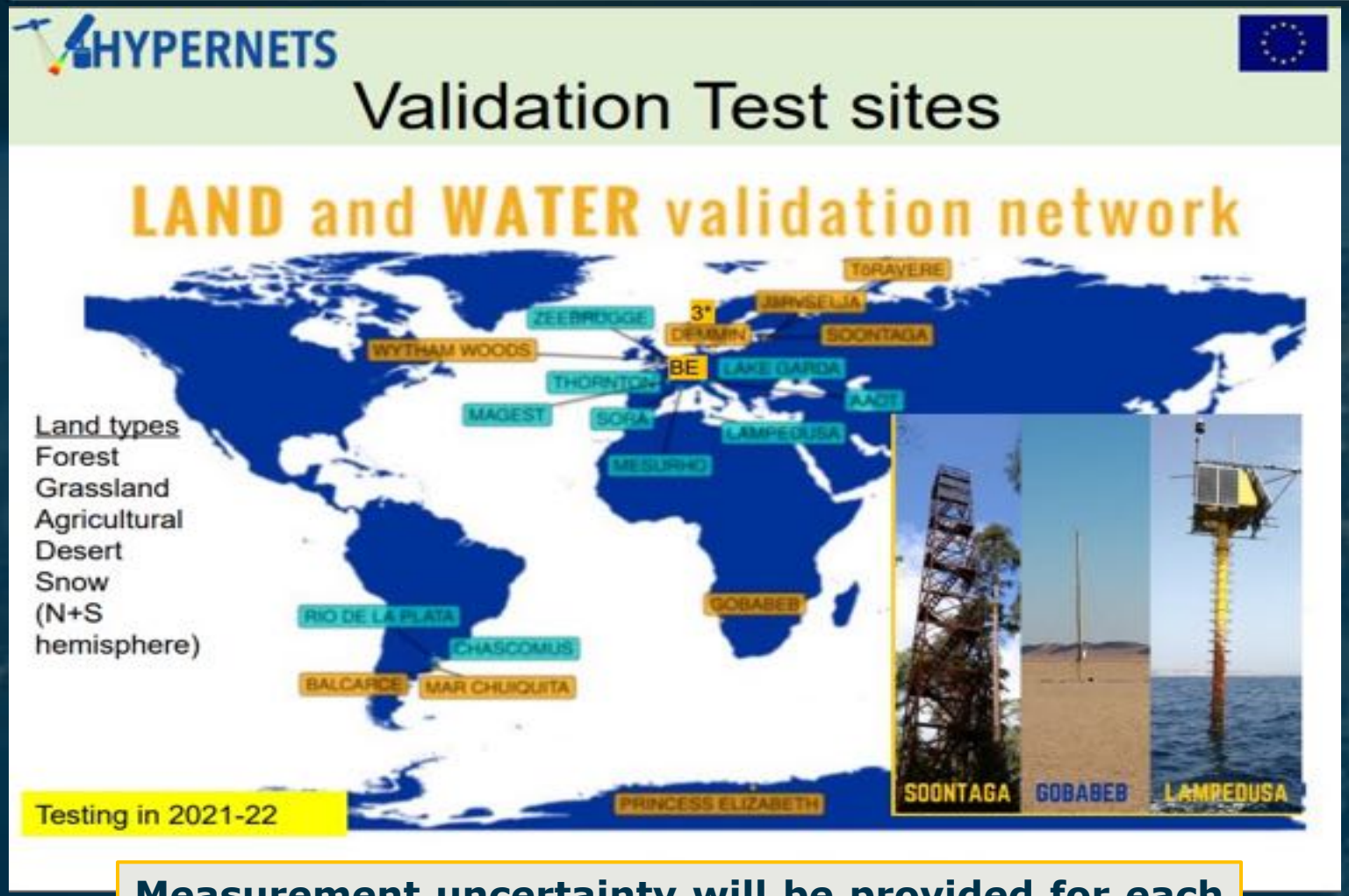
- Following ACIX recommendations, ESA in collaboration with EC, promoted a project (**HYPERNET**) for developing a ground based network for L2 BOA products validation
- HYPERNET aims at developing a global automated network of ground-based **hyperspectral radiometers**, measuring water and land bidirectional SR
- The radiometers are equipped with a **pointing** system allowing full characterisation of surface BRF
- HYPERNET network will support the needs of any space-borne optical sensor, including current and upcoming **hyperspectral** missions (PRISMA, EnMAP, CHIME, SBG)
- HYPERNET will fill a long lasting **data gap** in the land domain, and in the water domain it will allow to overcome the **limitations** of current multi-spectral based networks (AERONET-OC), i.e., minimising uncertainties induced by band adjustment

HYPERNETS

(PANTHYR radiometer System and HYPSTAR® radiometer system. Cable tie spikes are used for bird avoidance)

Courtesy of K. Ruddick, RBINS

HYPERNET

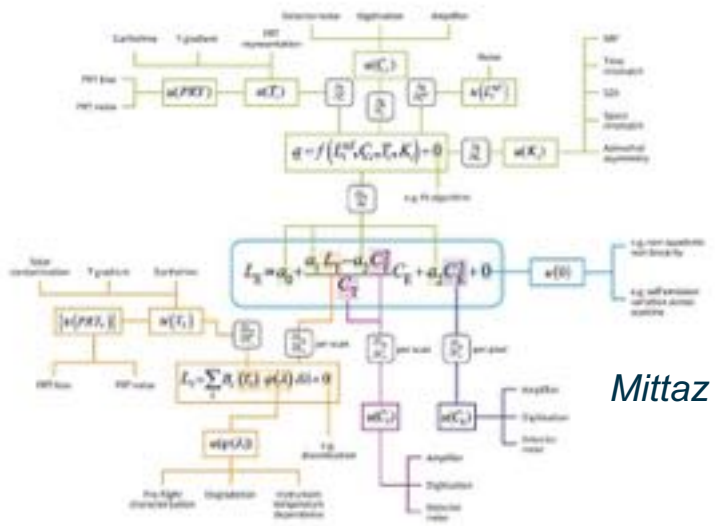


Measurement uncertainty will be provided for each measured value (so not just each location but also each time and each wavelength).

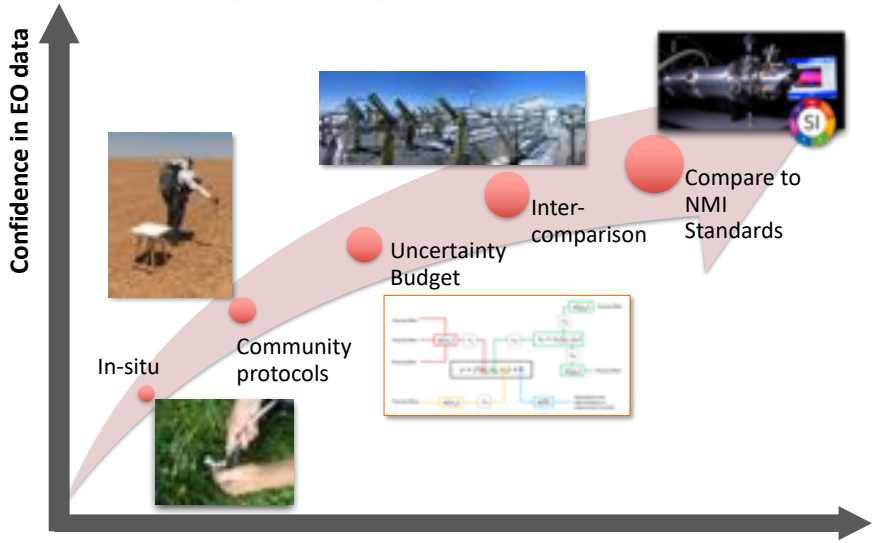
Satellite/Instrument	Agency	Launch date	Spectral coverage
Sentinel-2/MSI	ESA (Copernicus)	A: Jun 2015 B: Mar 2017 C: 2024? D: ?	442-2202 nm Multispectral
Sentinel-3/OLCI	EUMETSAT/ ESA (Copernicus)	A: Feb 2016 B: Apr 2018 C: 2024? D: ?	400-1020 nm Multispectral
PRISMA	ASI (Italy)	Mar 2019	400-2500 nm Hyperspectral
ENMAP	DLR (Germany)	Apr 2022	420 to 2450 nm Hyperspectral
Landsat-8/OLI	NASA/USGS	Feb 2013	423-2300 nm Multispectral (+thermal infrared)
Landsat-9/OLI	NASA/USGS	Sep 2021	423-2300 nm Multispectral (+thermal infrared)
VIIRS	NOAA	Oct 2011	402-2275 nm Multispectral (+thermal infrared)
Doves Superdoves Skysats	Planet	2015 + many	430-885 nm Multispectral
Pléiades	CNES/EADS	1A: Dec 2011 1B: Dec 2012 Neo3-6: Apr 2021+	450-915 nm Multispectral
CHRIS-PROBA	ESA	Oct 2001	400-1050 nm
MTG (geo)	EUMETSAT	I1: Nov 2022 ? I2/I3/I4: ?	400-2200 nm Multispectral (+thermal infrared)
CHIME	ESA	2028	Hyperspectral
[illegible]	NASA	?	Hyperspectral
SBG	NASA	?	Hyperspectral
GLIMR (geo)	NASA	?	Hyperspectral
Newspace	Various	?	Multispectral/ Hyperspectral?
Many others ...	Various	?	Various

Metrology focus

- Provision of **uncertainty** for both the reference and satellite data is a prerequisite in order to have a rigorous and meaningful validation.
- **Ideally** the reference measurement should be traceable to metrological standards
- In the **real** scenario, Cal/Val data are seldom traceable and uncertainties are often not estimated, this limit their proper use for assessing the quality of satellite-based EO data
- In order to address this gap, ESA is putting forward a new concept in Cal/Val, the ***Fiducial Reference Measurements*** (FRM)
- **What makes a Cal/Val measurement a FRM**:
  - Documented metrological SI-traceability
  - Follow community agreed best practices for measurements
  - Rigorous uncertainty budget, e.g., uncertainty tree diagrams
  - Inter-comparison exercises are regularly performed



Mittaz et al. 2019



Niro et al, 2021

FRM4Veg & SRIX4Veg

FRM4Veg = Fiducial Reference Measurements for Vegetation

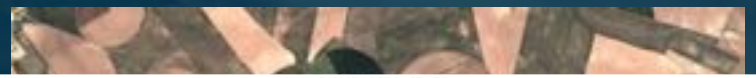
It is an ESA-founded project aiming at **applying the FRM concept to in-situ measurements of the several land products ESA distributes** (surface reflectance, the fraction of absorbed photosynthetically active radiation (FAPAR), canopy chlorophyll content, etc.).

SRIX4Veg = Surface Reflectance Inter-comparison eXercise for Vegetation

It is an ESA-funded joint effort **to ensure consensus on a Surface Reflectance Validation Protocol using drones.**

Requirements for participation:
UAV-mounted hyperspectral imagers capable of measuring 400 – 1000 nm contiguously; <= 10 nm spectral resolution.

Corn



Endorsed by:

CEOS Committee on Earth Observation Satellites

Funded by:

esa

In cooperation with:

USGS science for a changing world | CSIRO | ASI | DLR

In partnership with:

Universidad de Castilla-La Mancha | ITAP

Project partners:

NPL National Physical Laboratory | EOLAB | University of Southampton

Summer and winter wheat

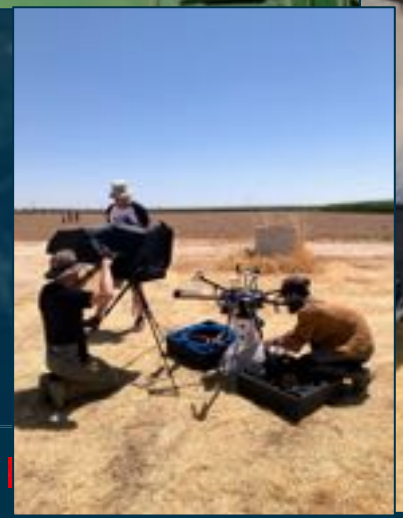
FRM4Veg & SRIX4Veg

SRIX4Veg = Surface Reflectance Inter-comparison eXercise for Vegetation

Workshop 1
28th March 2022
- Official workshop 1
- Additional participant meetings

Field Campaign
18th – 22nd July 2022
- Exercise implementation over Las Tiesas – Barrax (Spain)

Workshop 2
Q1 2023
- Official workshop 2
- Discussion of the results
- SRIX4VEG report and publication
- Initial contribution to development of international good practice guidelines for validating surface reflectance products



https://frm4veg.org/srix4veg/

Cal/Val Park

- ✓ Dedicated to **VHR** and **HR** optical missions;
- ✓ Open to both **multi-spectral** and **hyperspectral** missions;
- ✓ For both **TOA radiance and reflectance** and **BOA reflectance**;
- ✓ Open to be used by both the **"institutional space"** and the **"commercial/new space"**;
- ✓ Common "playground" to test and run **new cal/val methodologies, instruments, and initiatives**;
- ✓ Open to include **temporary and long-term instrumentation** and initiatives;
- ✓ **Scalable** (as far as possible) to accommodate new needs and new types of EO missions that may come in the next years;
- ✓ Building on already existing cal/val technologies AND new technologies and methods;
- ✓ Able to support the ever growing European and international EO industrial ecosystem;
- ✓ **Multi-Agency joint effort**;
- ✓ Synergetic approach not to duplicate efforts (and budgets).

- ❖ The "Cal/Val Park" concept is under **definition phase**. Phase-1 starting in Q1 2023.
- ❖ Discussions are on-going for a **joint ESA-ASI effort** (interest from other space agencies and institutions to be investigated).

CEM-PAL

The purpose of the Expansion Mission Product Algorithm Laboratory (or CEM-PAL) is to provide an environment for efficient prototyping of algorithms used to generate Expansion Missions Level 2 products, including algorithm modification, hosted processing, qualification functionalities and scientific validation environment.

The prototypes/processors/libraries/specific tools/validation data will be provided by external entities (i.e. specific contract for Product Algorithm Definition for each mission).

The ultimate goal is to allow the efficient development of extensions to the processing capabilities of the mission, especially the definition of improved or new core products and their migration to the ground segment

PAL = central role for the data quality activities - cal/val, processing algorithms improvements

Thank you for your kind attention

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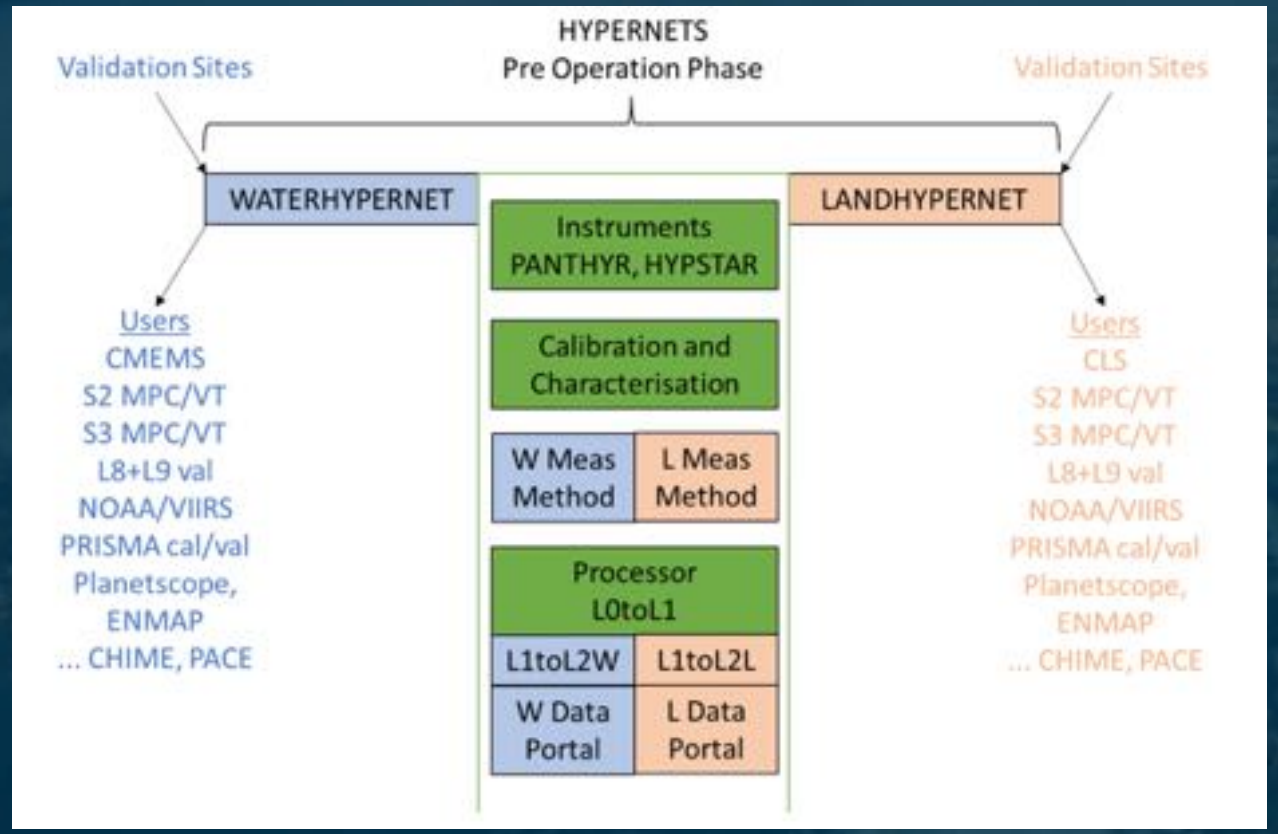
Backup slides

HYPERNET project

The HYPERNET project is the Next Generation Hyperspectral Radiometric Validation Network for Water and Land Surface Reflectance.



Overview of synergies and differences between water reflectance and land surface reflectance activities with common activities (green), water-specific activities (blue) and land-specific activities (beige).

- For land, measuring upwelling radiance from multiple nadir and azimuth angle to build up information on the Hemispheric-Directional Reflectance Function (HDRF) *(Schaepman-Strub et al. 2006; Kuester et al. 2014)*;
- For both water and land, scanning the skydome to check for clouds and/or obstructions or to estimate aerosol properties.

(PANTHYR radiometer System and HYPSTAR® radiometer system. Cable tie spikes are used for bird avoidance)

HYPERNET project

Based on the success of the AERONET-OC federated network for multispectral measurement of water reflectance, the HYPERNETS concept is to operate a:

- Hyperspectral radiometer(s) with both radiance and irradiance heads,
- on a Pan-and-tilt pointing system, with
- A control system comprised of computer, electronics and auxiliary sensors, power supply and communications (e.g. Ethernet/2G/3G/4G) ensuring data acquisition and transmission, deployed over an
- International network of autonomous sites, acquiring data following a
- Standardised measurement method, and transmitting data for
- Standardised data processing and web portal data distribution, backed up by SI traceable laboratory calibration and characterisation of radiometers, and Full estimation of measurement uncertainties, according to Fiducial Reference Measurement (FRM) principles.

While this approach clearly follows closely the prior AERONET-OC organisation (G. Zibordi et al. 2009) the following differences are noted (in addition to the obvious multispectral/hyperspectral difference):

- **Two types of hyperspectral radiometer** (and associated pan-tilt and control systems) are accepted in the network: the TRIOS/RAMSES radiometer (a mature, high performance COTS radiometer available since 2000 with radiance and irradiance variants) or the HYPSTAR® radiometer (a new prototype twin-head radiance/irradiance radiometer currently being tested within H2020/HYPERNETS to be commercialised from 2023).

- **Land surface reflectance** is measured in addition to water reflectance

Measurement uncertainty will be provided for each measured value (so not just each location but also each time and each wavelength).