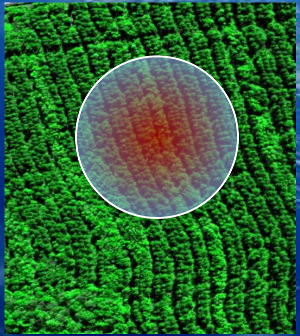
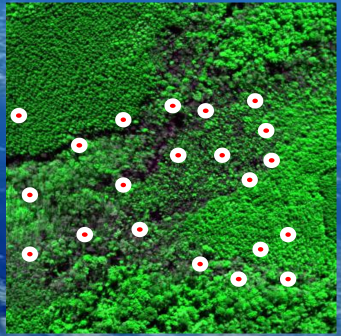
FLEX & Sentinel 2/3 Mission Development & Validation





D. Schüttemeyer & F. Gascon

M. Drusch, P. Goryl, S. Dransfeld

Limassol, February 2017

Overview of my presentation

- Overview: Campaigns at Work
- Latest developments at ESA
- FLEX Phase A/B
- FLEX Phase C/D
- Sentinel 2/3 & FLEX
- Some brief conclusions

Why are ESA Earth Observation campaigns required ?

Explore EO possibilities before going to space

Prove EO measurement concepts work

Develop interpretation methodology

Develop calibration approach

Develop validation methods using independent data

Simulate data products (pre-launch)

Validate results using independent data

Develop applications

Close range observation during new development phase

Programmatic Background

ESA campaign activities started in 1981

142 campaigns as of September 2016

Typically 6 -10 campaigns/year

Strategic objectives:

Support strategic goals of EO Science Strategy

Transnational access to airborne facilities in member states

Foster partnerships with national and international organisations

Campaign activities address:

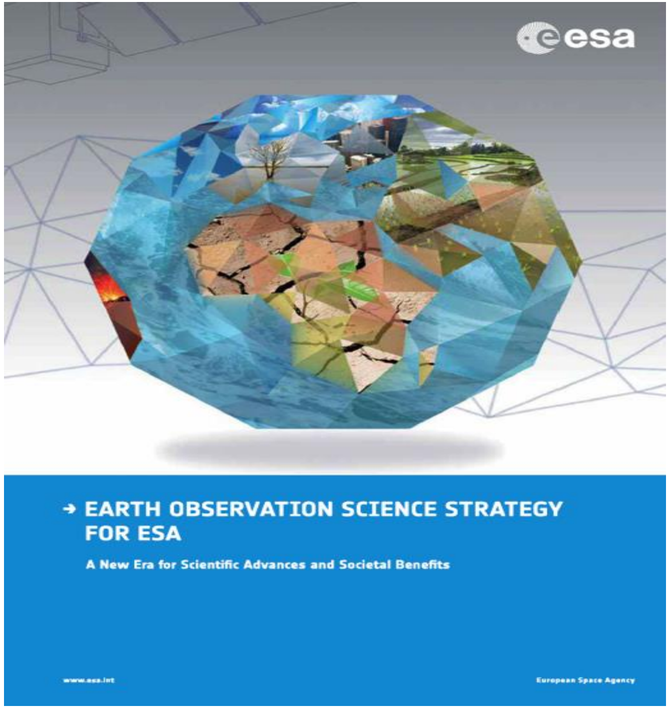
Testing technology/Observing techniques

Optimising requirements/design and reducing mission risk

L1-L2 Algorithm prototyping/Product simulation

Calibration/Validation

Campaign data archive supporting science and applications



Campaigns for different project phases

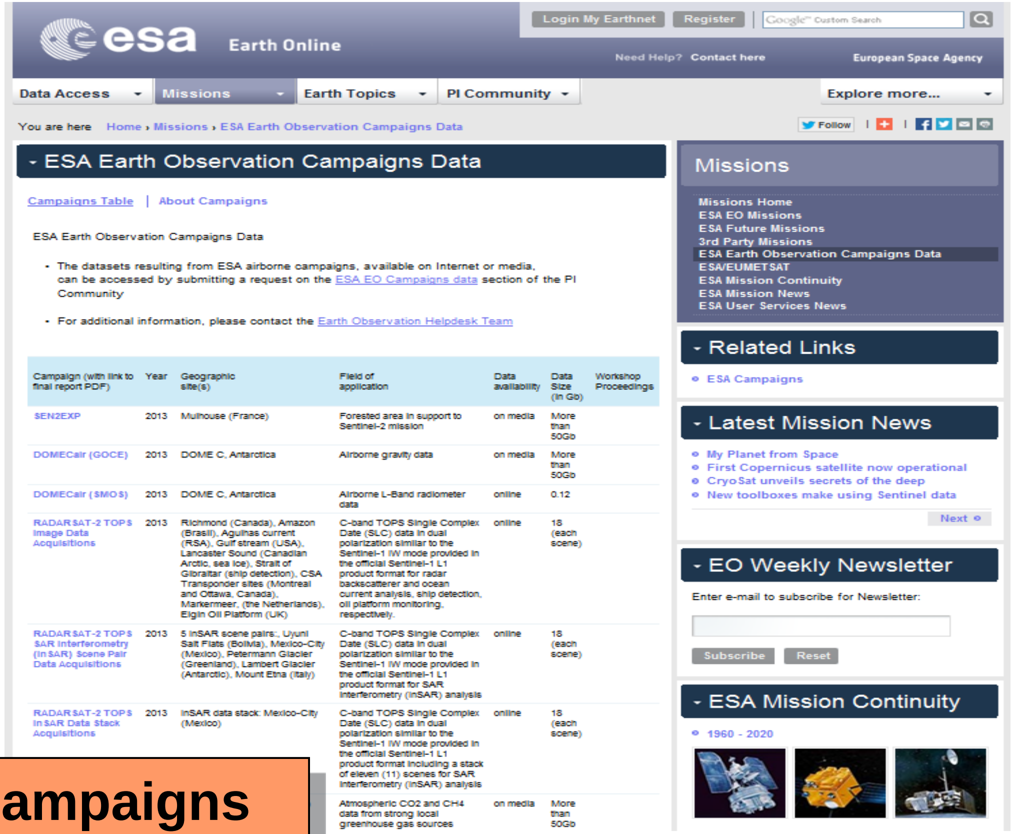
ESA campaigns are performed during full life cycle of a typical ESA space mission

Different types of campaigns are performed during specific phases of a space mission (concept, feasibility, development and operations)

	Pre-Phase A	Phase A Feasibility	Phase B Design	Phase C/D Development	Phase E1 Commissioning	Phase E2 Operation	Data Archive
Technology	X	X					X
Mission Development (Geophysical)	X	X	X	X			X
Mission Development (Simulation)	X	X	X	X			X
Cal/Val				X	X	X	X
Science/ Applications						X	X

Access to ESA Campaign Data

- ESA campaign data available to interested PIs
  - Formatted and documented datasets
  - Data Inventory
  - Final report with full description of campaign activity and analyses
- Final report accessible directly through web
- Access to datasets provided through Category 1 mechanism (short proposal incl. identification of desired datasets)
- Currently **64** campaign datasets available



https://earth.esa.int/web/guest/campaigns

Recent developments

Key role of campaigns in preparation of future EO missions (up to Phase-0/-AB)

- EE8 FLEX Mission Consolidation
- New campaign initiatives supporting future mission concepts (e.g. SAOCOM-CS/Convoy or Satellite companion concepts)
- Several cross-cutting activities addressing multiple missions (e.g. MULTIPLY for EarthCARE/ADM and other missions)

Use of campaign data in Thematic Exploitation Platforms or TEPs (e.g. BIOMASS)

International cooperation (Member states, EU, NASA)

- Pooling of resources and enhanced technical/science return

FLEX Takes on Mutants

ESA Portal Webstory Aug 25 2016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FLEX TAKES ON MUTANTS

Mutant strip

25 August 2016 Because a plant isn't green doesn't mean it can't photosynthesise as well as its more usual counterpart, but when measured by satellites, these non-green varieties skew results on plant health. FLEX is different. Experiments using 'mutants' show that colour won't be an obstacle in this new mission's task of mapping plant health from space.

Planned to be launch around 2022, ESA's Fluorescence Explorer – FLEX – will use a novel technique to track the health of the world's vegetation.

This technique involves detecting and measuring the faint glow that plants give off as they use sunlight to convert carbon dioxide into energy-rich carbohydrates – photosynthesis.

FLEX will improve our understanding of the way carbon moves between plants and the atmosphere and how photosynthesis affects the carbon and water cycles.

Moreover, accurate information about the health and stress of the planet's vegetation is important as the growing global population places increasing demands on the production of food and animal feed.

As part of the development of this new satellite mission, scientists in Italy and Germany have been studying different crops to understand the relationship between the light reflected by different plants and their carbon uptake.

The latest field campaigns focus on the natural mutant soybean MinnGold, which only has 20% of the chlorophyll of 'normal' green plants.

Mutants on the right

Such chlorophyll deficiency changes the properties of the leaves, which are a yellowy colour. As such, these mutant soybean leaves reflect much more sunlight than their green cousins, leaving the plant with less energy to photosynthesise.

Although they have less energy, these mutants are surprisingly more efficient at fixing carbon dioxide from the air.

Traditional satellite techniques rely on measuring aspects of reflected light to estimate plant productivity and cannot account for unusual coloured plants.

Radoslaw Juszczak from the Poznań University of Life Sciences in Poland explained, "Chlorophyll-deficient plants have similar photosynthetic rates as their green counterparts.

Search here

Earth Explorers

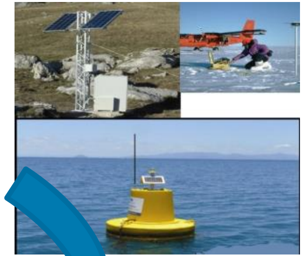
Related news
- Poznań University of Life Sciences
- FZ-Juelich
- Specim
- University of Milano-Bicocca
- CzechGlobe
- University of Udine
- University of Minnesota – MinnGold

Fluorescence photosynthesis and vegetation workshop

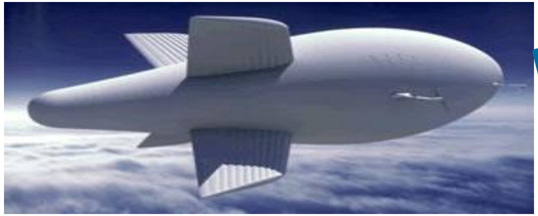
Remotely Piloted Aircraft Systems

- Remotely Piloted Aircraft Systems (RPAS) can bridge the gap between satellite Earth observation and ground measurements
- In particular, RPAS enabling persistent (> 4 weeks), high resolution, local-to-regional scale observations would fill a critical niche within Earth Observation data:

Satellites: Global perspective on changes in the Earth-ocean-atmosphere system

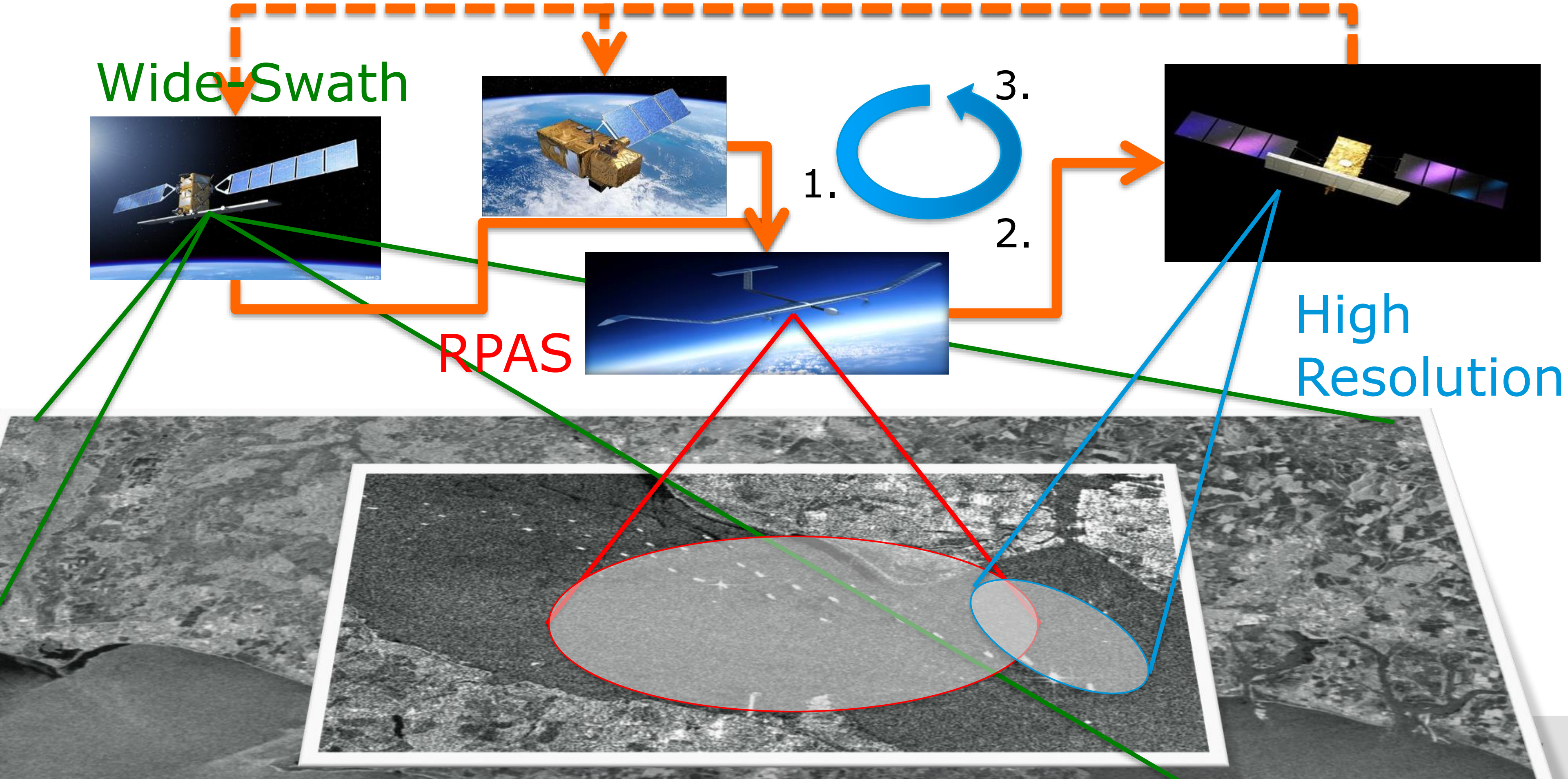


In-situ sensors: local measurements at fine spatio-temporal scales



Critical link between small scale and regional/global long-term processes
➔ Stratospheric platforms (h> 18000 m, endurance > 4 weeks)

Cross-Tasking



ESA position vis-à-vis European Industry and potential users for HAP RPAS

- Industry involved in study and development of HAP RPAS is the same involved in space programme
- There is a great deal of technology overlap that provides an opportunity for rationalisation at the benefit of competitiveness
- ESA can augment the application potential and make it sustainable through complementarity with space systems
- Existing users of ESA assets (e.g. scientists, Agencies and Public Bodies) would be exposed to new services, so reinforcing the mutual bonds
- ESA is the only R&D body in Europe that can enable the economic potential stemming from HAP through technological advances

Phase A Feasibility Campaigns

2012: *HyPlant* becomes operational Campaign in Finland and Germany
⇨ First airborne maps of F_{760}

2013: *HyPlant* technically refined Campaign in Germany, France, Czech Republic and USA
⇨ Two peaks of fluorescence are retrieved

2014: *HyPlant* technically refined Campaign in Germany, Czech Republic and Italy
⇨ Time series of dynamic stress detection in vegetation
⇨ Improvement of GPP estimates

2015: *HyPlant* optical path fundamentally improved and great improvement of the Point Spread Function; campaign in Germany, Czech Republic and Italy
⇨ Virtual cloud experiment

2016: HyPlant flown over Germany, CZ & Italy
⇨ Field Laboratory: ‘FLEX takes on mutants

Phase C/D FLEX Activities

- **SS10 (start 2016 / 24 months):**

Fluorescence Network Data Base / Validation Anchor Sites - Initial Phase

- **SS11 (start 2018 / 48 months):**

Fluorescence Network Data Base / Validation Anchor Sites – Maintenance and Expansion Phase

- **C1 (2017 / 72 months): ContiFLEX**

Ensure continuation of long time series for retrieval verification, investigate SNR / FR performance relationship experimentally, support selection and location of ground based in-situ measurements at the suggested Anchor sites.

- **C2 (2017 / 12 months): AtmoFLEX**

Support L1 to L2 algorithm development, verification of final algorithm, support atmospheric parameter retrieval.

- **C3 (2018 / 18 months): TransFLEX**

Verify the fluorescence retrieval over heterogeneous targets and a wide range of biomes.

- **C4 (2019 / 12 months): PhytoFLEX**

Understanding of the added value of FLEX over coastal areas (oceans).

- **C5 (2021 / 6 months): Commissioning Rehearsal**

Phase C/D FLEX Activities

1. **Step: Atmospheric correction**

Make use of existing infrastructure related to S2 and S3

enable ground-based longterm measurements by means of FloX Boxes

perform dedicated airborne campaigns coordinated with S2/S3

evaluate the option of deploying a high altitude platform for FL measurements

=> Link to ContiFLEX

2. Step: ContiFLEX

Perform airborne campaigns in the coming years

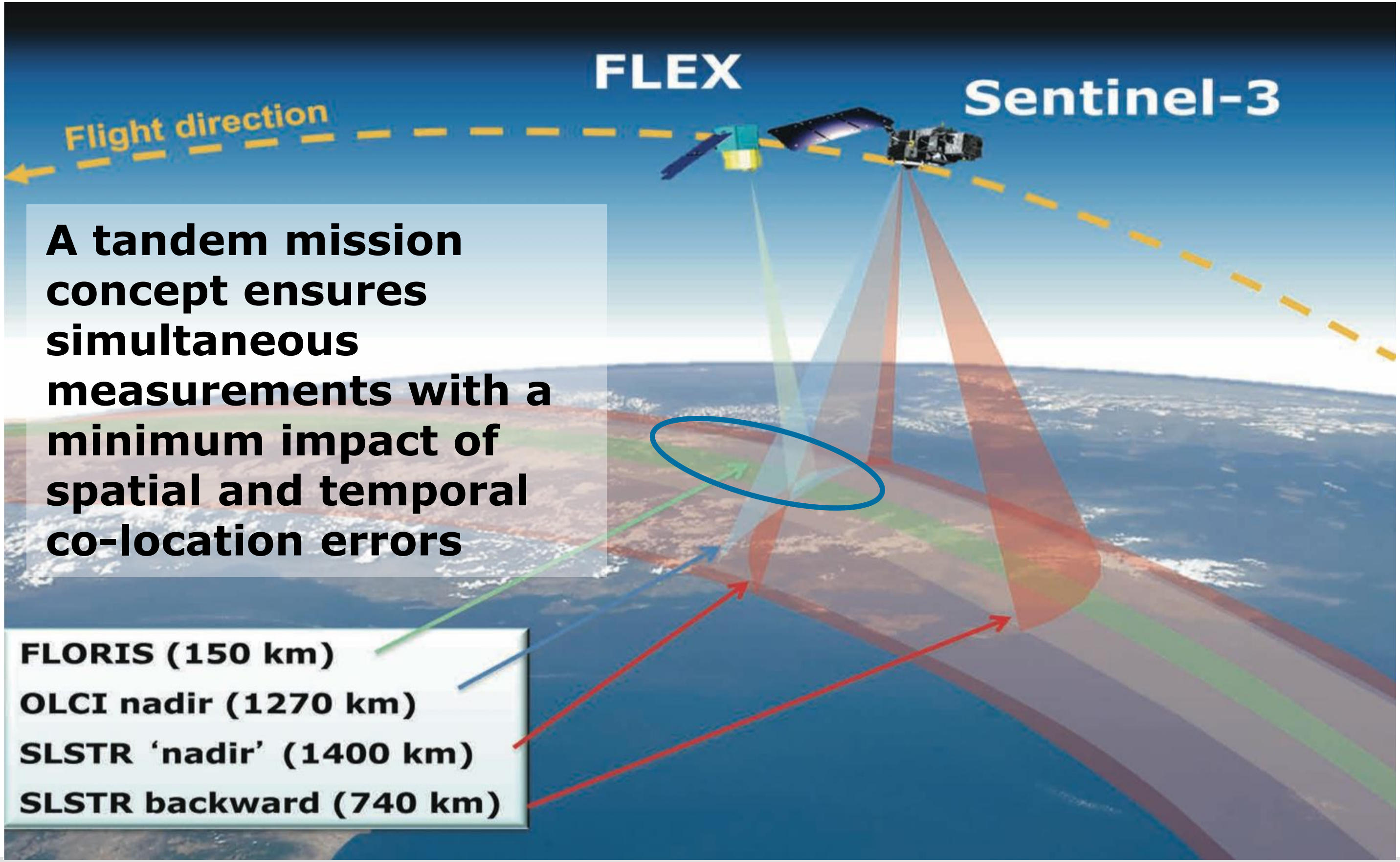
2017 to cover test-sites in Germany, Belgium?, Italy by also underflying S2/S3

=> Link to AtmoFLEX & Networks

3. Step: TRANSFLEX heterogeneous targets and a wider range of biomes.

Potential activity together with NASA

FLEX/Sentinel-3 Formation Flying



Introduction

- *"Validation is the process of assessing, by independent means, the quality of the data products derived from a system outputs."*

- Missions:

- Provide an overview of the approach foreseen by ESA for the validation of land operational products.

Land Operational Products

Acronym	Product	Brief Description
SR	Surface Reflectance	Bottom-of-atmosphere and topography corrected reflectance
OGVI	OLCI Global Vegetation Index	Green Fraction of Absorbed Photosynthetically Active Radiation (FAPAR)
OTCI	OLCI Terrestrial Chlorophyll Index	Index related to related to the total chlorophyll content.
LST	Land Surface Temperature	Radiative skin temperature (°K) of the ground.

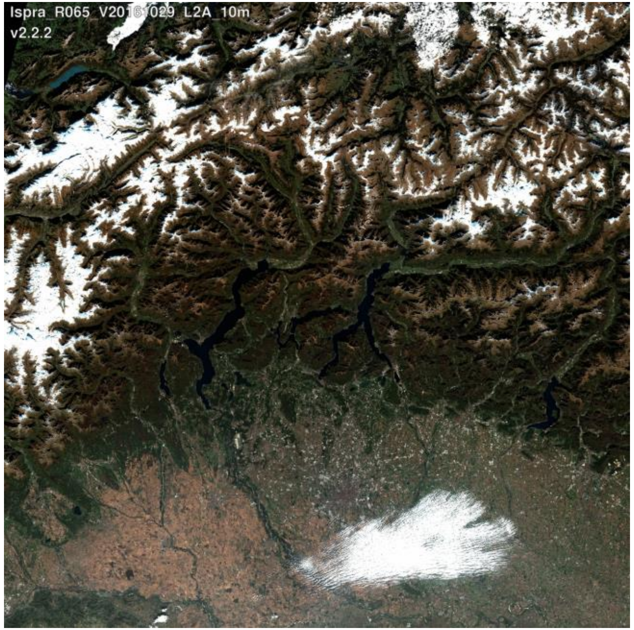
✓ Many more coming soon...

Sentinel-2

✓ SR (Surface Reflectance)

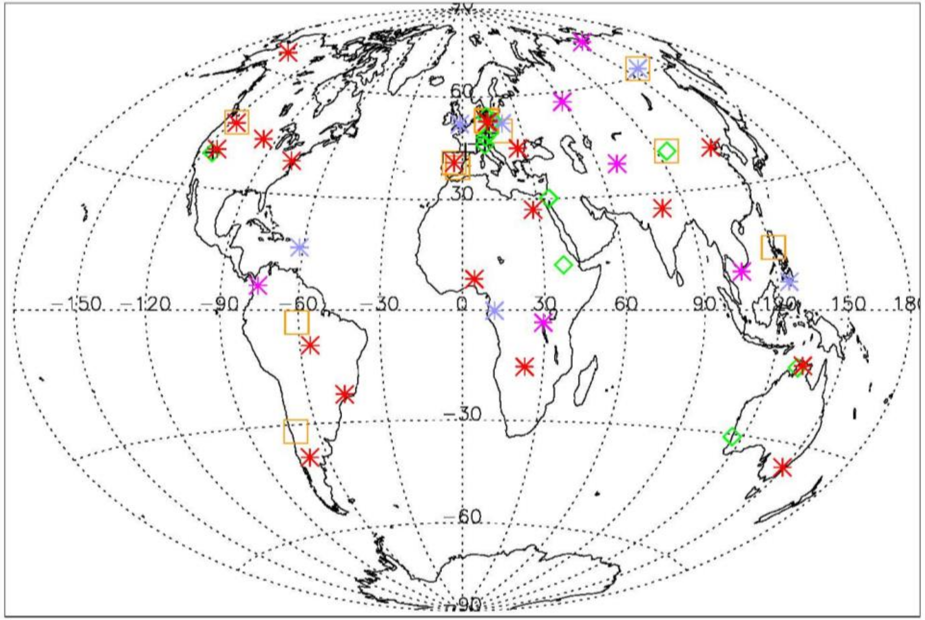
Algorithm description at:

https://sentinels.copernicus.eu/web/sentinel/technical-guides/sentinel-2-msi/level-2a/algorithm



Sentinel-2

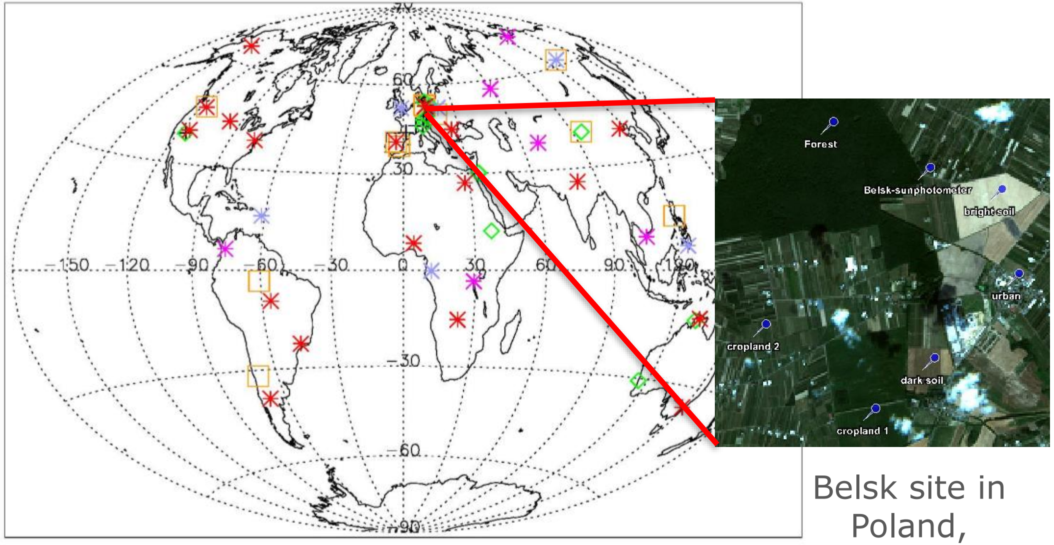
✓ SR (Surface Reflectance)



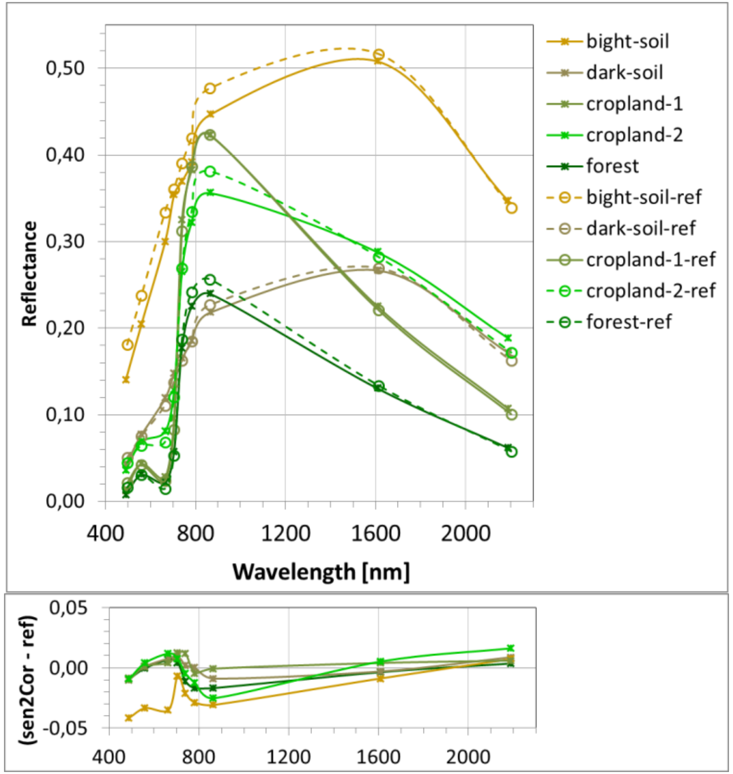
Asterisks:	Sunphotometer test sites [9x9 km^2] for validation of AOT, WV and SR products
Black plus signs:	Test sites for ad-hoc campaigns in 2015 with surface reflectance measurements
Green diamonds:	Test sites for ad-hoc campaigns in 2016 with surface reflectance measurements
Orange squares:	Test sites [100x100 km^2] for Cloud Screening and Scene Classification Validation

Sentinel-2

✓ SR (Surface Reflectance)



Belsk site in Poland, August 14, 2015



Sentinel-3

✓ OGVI (OLCI Global Vegetation Index)

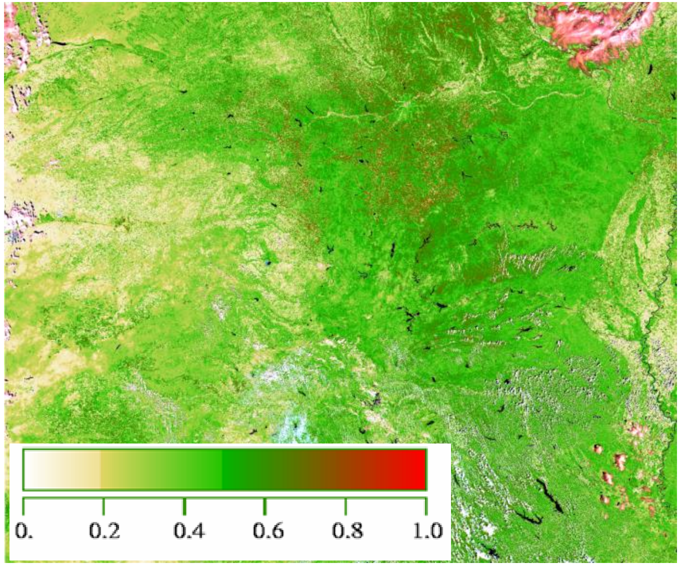
Use information in blue, red and near-infrared OLCI bands for deriving the Fraction of Absorbed Photosynthetic Active Radiation (Gobron et al., 1999, Gobron, 2012).

$$g_n[\tilde{\rho}(\lambda_i), \tilde{\rho}(\lambda_j)] = P(\lambda_i, \lambda_j) / Q(\lambda_i, \lambda_j)$$

$$P(\lambda_i, \lambda_j) = l_{n1}(\tilde{\rho}(\lambda_i) + l_{n2})^2 + l_{n3}(\tilde{\rho}(\lambda_j) + l_{n4})^2 + l_{n5}\, \tilde{\rho}(\lambda_i)\, \tilde{\rho}(\lambda_j)$$

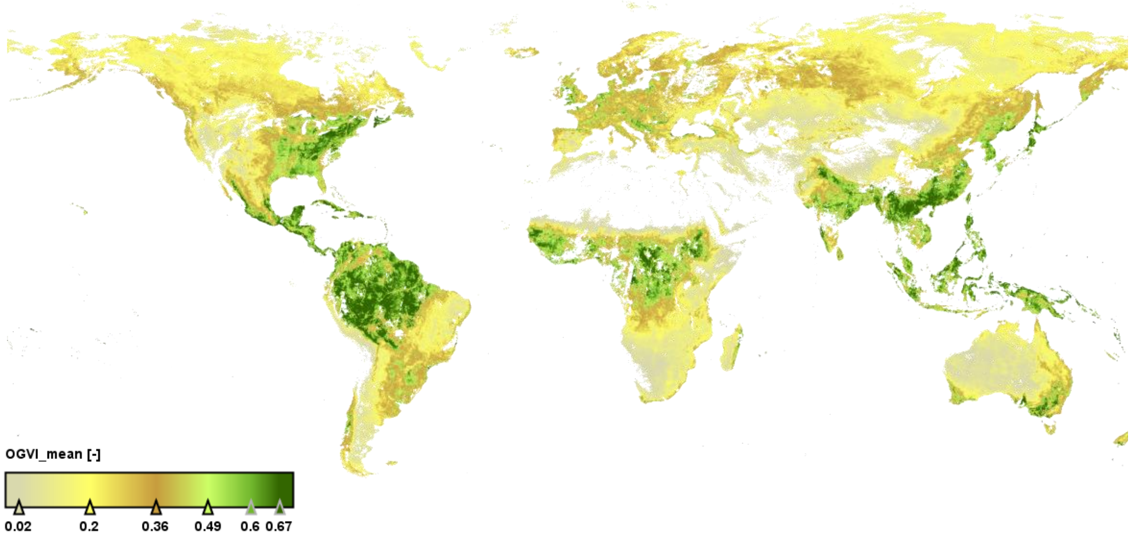
$$Q(\lambda_i, \lambda_j) = l_{n6}(\tilde{\rho}(\lambda_i) + l_{n7})^2 + l_{n8}(\tilde{\rho}(\lambda_j) + l_{n9})^2 + l_{n10}\, \tilde{\rho}(\lambda_i)\, \tilde{\rho}(\lambda_j) + l_{n11}$$

$$\mathrm{FAPAR} = g_0(\rho_{Rred}, \rho_{Rnir}) = \frac{l_{01}\rho_{Rnir} - l_{02}\rho_{Rred} - l_{03}}{(l_{04} - \rho_{Rred})^2 + (l_{05} - \rho_{Rnir})^2 + l_{06}}$$

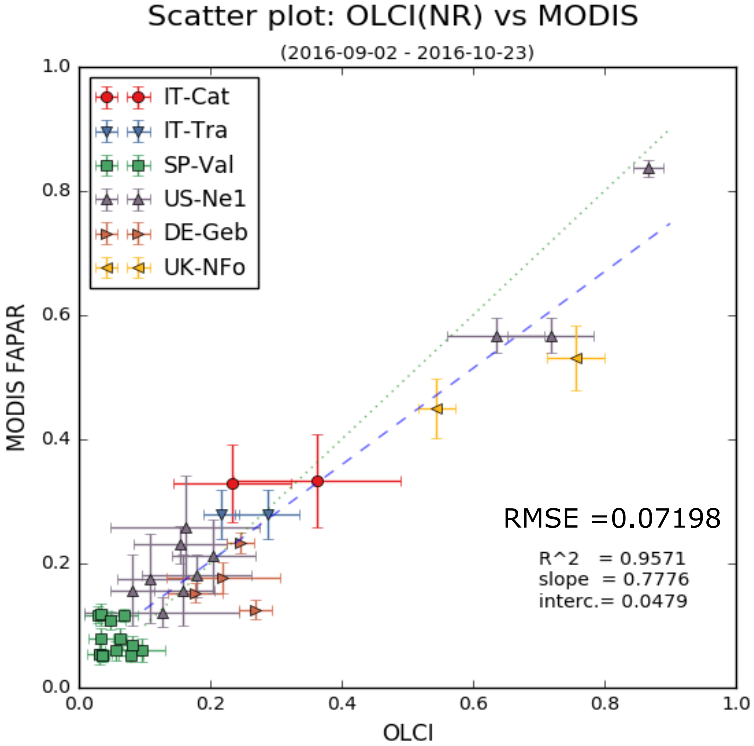


Sentinel-3

✓ OGVI (OLCI Global Vegetation Index)



OGVI mean, 4 days 20-21-22-23 September 2016



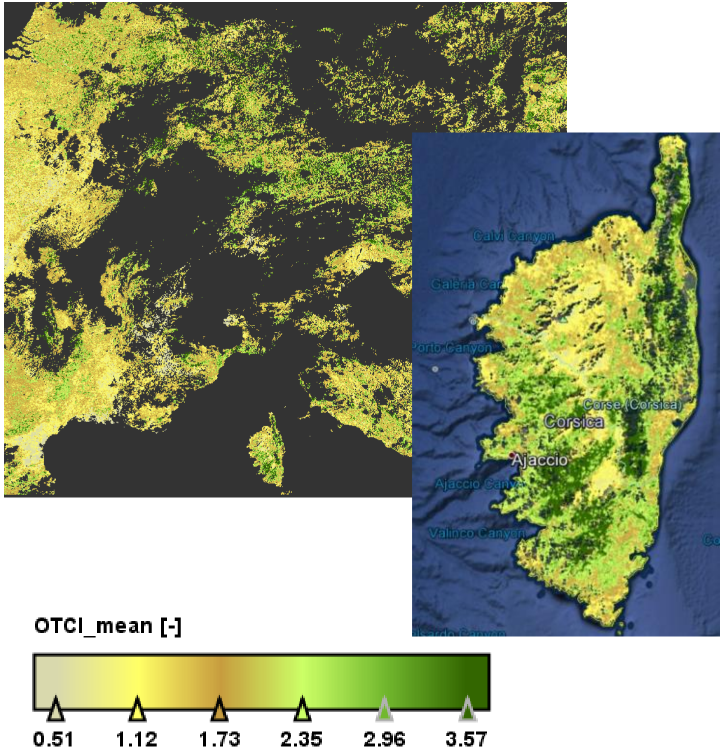
Sentinel-3

✓ OTCI (OLCI Terrestrial Chlorophyll Index)

Use of the high spectral resolution of OLCI to track the position of the Red Edge (Dash and Curran, 2004 Dash 2012).

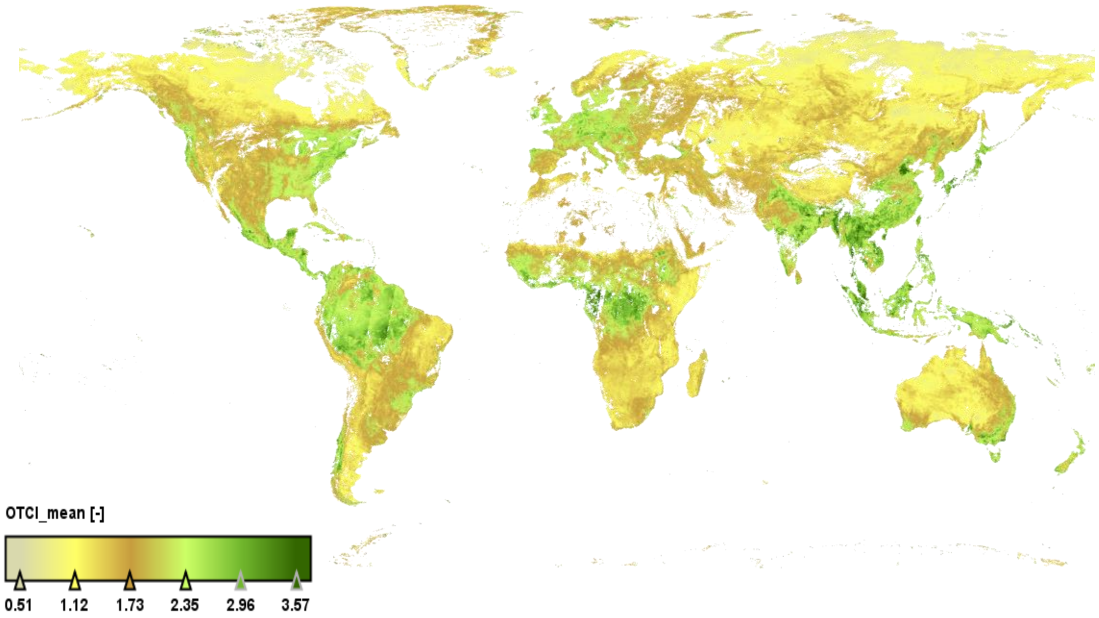
$$OTCI = \frac{R_{Band10} - R_{Band9}}{R_{Band9} - R_{Band8}}$$

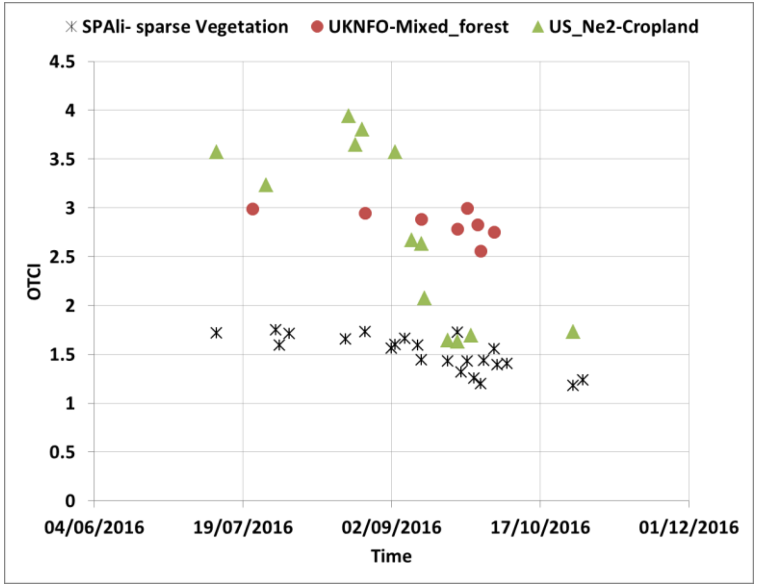
The magnitude of the OTCI is related to the total chlorophyll content.



Sentinel-3

✓ OTCI (OLCI Terrestrial Chlorophyll Index)

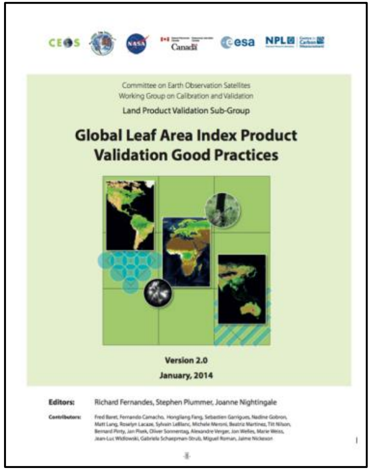




OCTI Global Mean, 4 days 20-21-22-23 September 2016

Challenges

- Lack of multi-mission & long-term strategy for validation.
- Lack of networks for validation of land products, to give continuity to the validation activities.
- Lack of international standards (with some exceptions: CEOS LPV "Global Leaf Area Index Product Validation Good Practices").
- Product uncertainties not always assessed trough a statistically representative set of locations and time periods.
- Spatial representiveness of the in situ measurements, and upscaling to satellite resolution.
- Need to automate individual measurements (drones?).


Committee on Earth Observation Satellites
Working Group on Calibration and Validation
Land Product Validation Sub-Group

Global Leaf Area Index Product Validation Good Practices

Version 2.0
January, 2014

Editors: Richard Fernandes, Stephen Plummer, Joanne Nightingale

Contributors: Fred Baret, Fernando Camacho, Hongliang Fang, Sebastien Garrigues, Nadine Gobron, Matt Lang, Roselyn Lacaze, Sylvain LeBlanc, Michele Meroni, Beatriz Martinez, Tiit Nilson, Bernard Pinty, Jan Pisek, Oliver Sonnentag, Alexandre Verger, Jon Welles, Marie Weiss, Jean-Luc Widlowski, Gabriela Schaepman-Strub, Miguel Roman, Jaime Nickeson

ESA Validation Approach

1. **Multi-mission** approach for the validation of all land products:
   - ✓ Sentinel-2 Surface Reflectance
   - ✓ Sentinel-3 OGVI
   - ✓ Sentinel-3 OTCI
   - ✓ Sentinel-3 Land Surface Temperature
   - ✓ FLEX products (>2022)

2. **Combine validation approaches,** with particular emphasis on Fiducial Reference Measurements (FRM).

3. **Network of sites** for ensuring a comprehensive validation (sites selected in coordination with existing international networks).

Validation approaches

✓ Statistical Analysis

- Generation of level-3 products for trend analysis as well as sensor intercomparison over spatial and temporal domains.

✓ Match-up Comparisons

Comparison of match-ups from different product sources or missions.

✓ Fiducial Reference Measurements (FRM)

- Next slide...

Fiducial Reference Measurements (FRM)

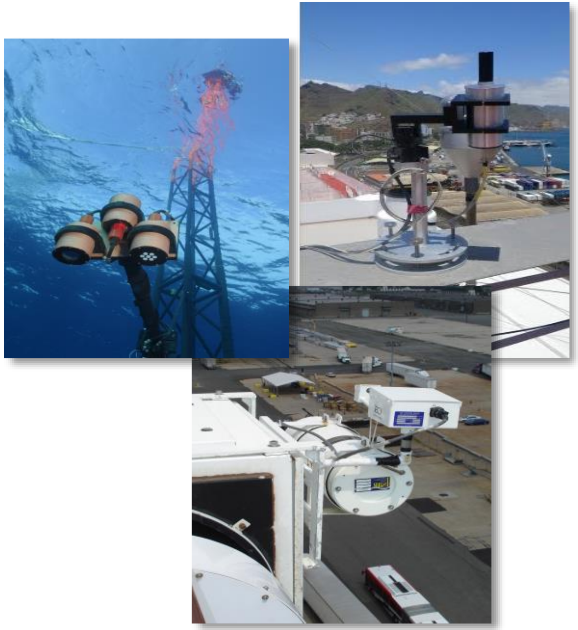
✓ **fi·du·cial** *(adj) Regarded or employed as a standard of reference, as in surveying*

[Late Latin fiducialis, equivalent to fidi(a) trust, from fidere, to trust.]

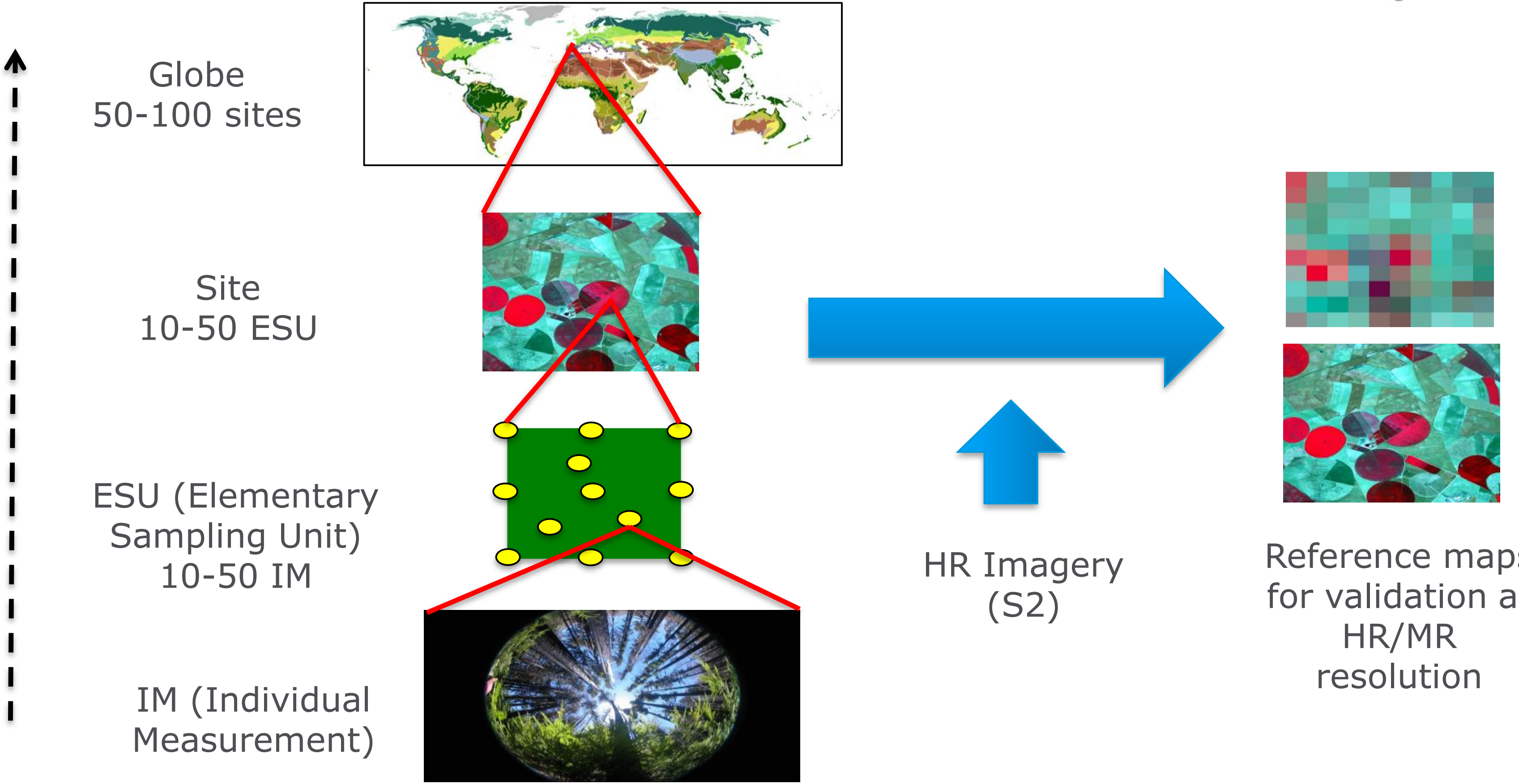
✓ Fiducial Reference Measurements:

- Validation of Mission Requirements
- Linked to a mission’s Cal/Val plan activities
- Building on the existing capabilities
- Not necessarily mission specific and can address multi-mission needs

✓ FRM4VEG project planed for Cab, FAPAR and LAI validation (Kick-off Q2 2017).



Land Products Validation Concept



Instrumentation

- ✓ Ground spectrometers for reflectance and fluorescence
- ✓ Instruments for atmospheric characterization
- ✓ Spectrometers on drones
- ✓ Airborne sensors
- ✓ Additional measurements (e.g. ecological)

Both satellite products and ground measurements have associated uncertainties from contributors such as:

- *Instrument accuracy caused by random and systematic noises.*
- *Natural variability of target optical properties at different spatial scales, modulated by sampling strategy.*
- *Environmental variations in illumination during ground truth measurements.*
- *Error propagation in retrieval algorithms or radiative transfer modeling (indirect estimation).*

Sites Evaluation

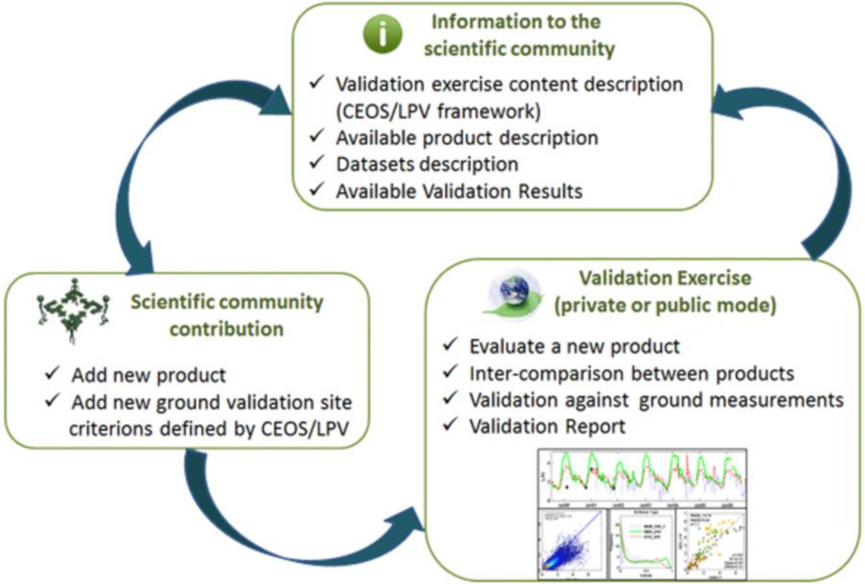
Site requirement	Indicator	Evaluation			Relative Importance
		Acceptable	Medium	Unacceptable	Very important Fairly important Slightly or not at all important
Science question	ESA SP-1329/2, 2015				VI
Size&homogeneity	# of endmembers and size				VI
Land cover	Representativeness				VI
Topography	Slope				FI
Sun angles	Cosθ				SI
Site position	Nadir				SI
Meteorology	Cloud cover				FI
Flight	High risk/medium/low				FI
Facilities, logistic	Yes/No				VI
Maintenance	Euro				FI
Fs Heritage	Yes/No				FI
Pixel story	SNR NDVI/Ts				FI
Membership to other EO cal/val	Yes/No				FI
Nationality	Yes/No				SI
					FINAL SITE SCORE (E·R):

International Networks Considered

- ✓ **ICOS**: Standardized network of eddy towers across Europe.
- ✓ **FLUXNET**: Hyperspectral sensors across the globe
- ✓ **COST action OPTIMIZE**: Network to standardize methods for vegetation reflectance and fluorescence.
- ✓ **EMPHASIS**: European network to link plant phenotyping infrastructure.

On-Line Validation Exercise

- ✓ OLIVE is a platform designed to quantify the performances of land products.
- ✓ Supported by CEOS LPV (Land Products Validation) sub-group.



Some general summary comments

- ESA campaign activities responding directly needs of the EO programmes in efficient and effective way and play a key role in
  - preparing future EO missions
  - supporting mission development
  - Cal/val for missions in orbit
  - supporting wider science community through the ESA campaign database on the EOPI portal
- Expanding industrial interest in airborne sensors and activities in the context of UAVs/Drones and medium and high altitude platforms
- Expanding international collaboration (NASA, EC e.g. EUFAR, National Agencies) leading to pooling of resources and enhanced science and mission related return (e.g. enabling campaign activities not possible in isolation)
- No dedicated airborne programme at ESA at present (i.e. no regular calls for industry or similar). Requirements and implementation solutions usually through advisory mechanisms, PIs and knowledge of opportunities.

FLEX summary comments

- Large amount of data available from campaigns starting in 2012
- Latest data might be used in the context of your activities
- Upcoming activities focus on atmospheric correction and extending time series
- Focus on a mix of ground-based and airborne activities
- Planning for related activities just started

- We need your input!!!

Summary Validation S2/S3 + FLEX

esa

1. **Multi-mission** approach for the validation of all land products:

SENTINEL 2

SENTINEL 3

flex

2. **Combine different validation approaches** with particular emphasis on Fiducial Reference Measurements (FRM).

3. **Network of sites** for ensuring a comprehensive and long-term validation.

Many thanks!