# Attività cal/val missione FLEX e possibili sinergie con PRISMA

*Colombo R.* [1], *Miglietta F.* [2], *Cogliati S.* [1]

[1] Department of Earth and Environmental Sciences, University Milano-Bicocca, Milano, Italy

[2] CNR-IBIMET, Firenze, Italy

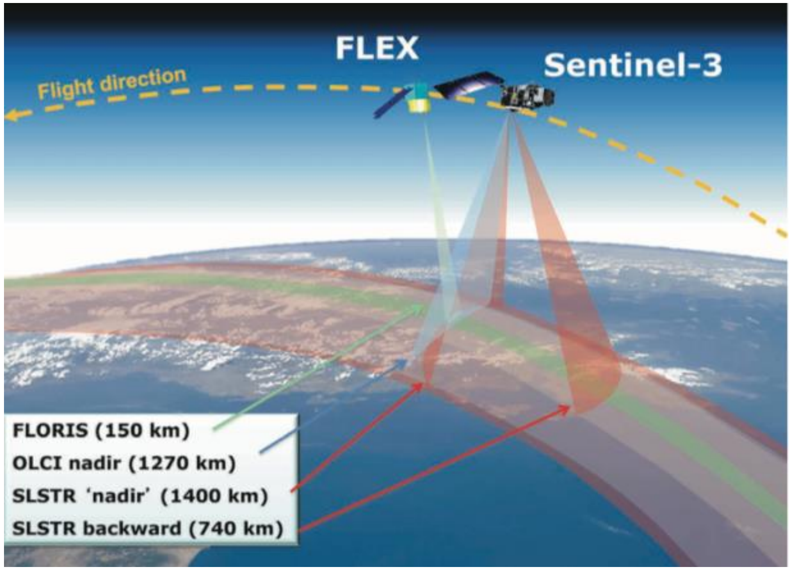
# Outlook

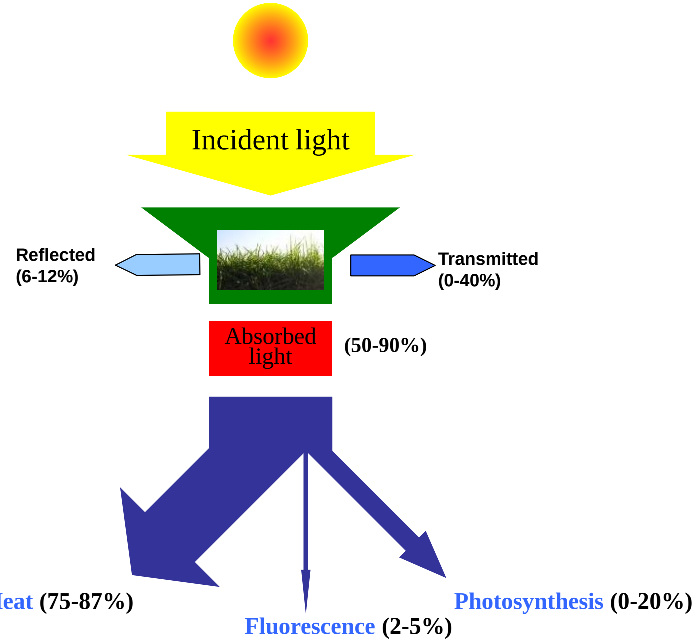
1. To present some experiments for fluorescence studies using field and airborne imaging spectroscopy;

2. To show preliminary concepts for Cal/Val activities in the context of FLEX and synergies with PRISMA

# FLEX Mission, tandem with Sentinel-3

The **FLuorescence EXplorer (FLEX)** is the next ESA Earth Explorer 8. The FLEX mission aims to provide global maps of vegetation fluorescence at 300m spatial resolution, which can be used to infer photosynthetic activity of natural and managed ecosystems.




**Fluorescence** is in direct competition with **Photosynthesis** (and **NPQ**) and can be measured remotely

This link can be exploited for:

- **Stress detection;**
- **GPP estimation.**

UNIVERSITA' DEGLI STUDI DI MILANO BICOCCA

# Some technical characteristics

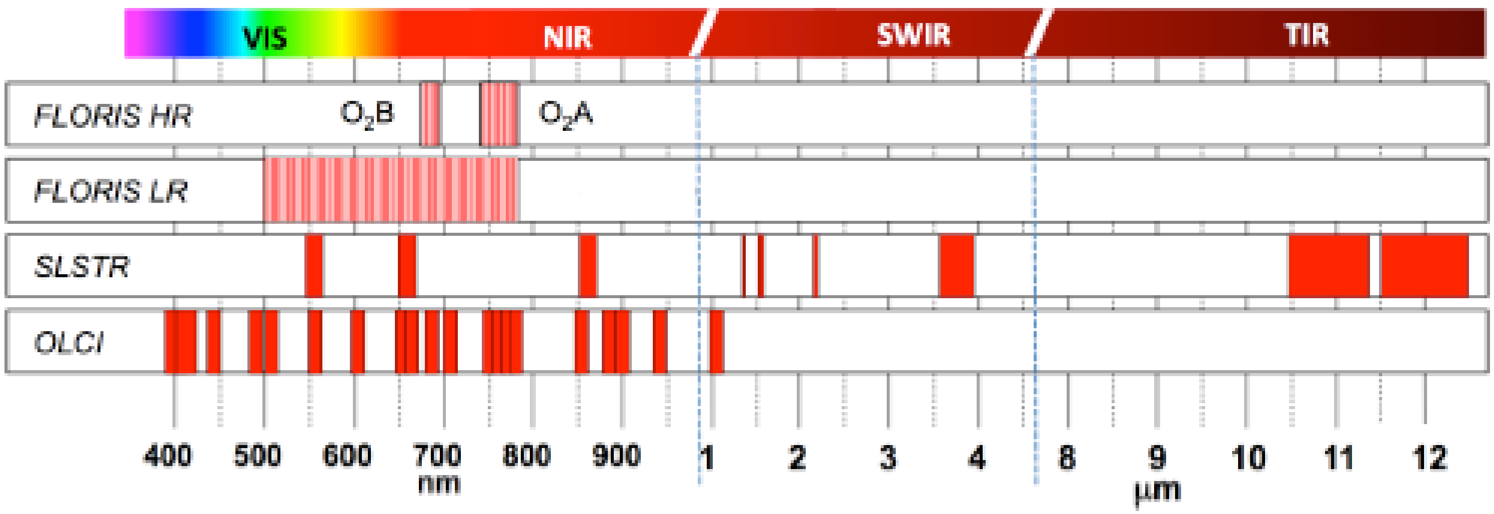



**Table 1**
Technical characteristics of the FLORIS spectra in terms of spectral resolution (SR), spectral sampling interval (SSI), and signal to noise ratio (SNR) for the different spectral regions.

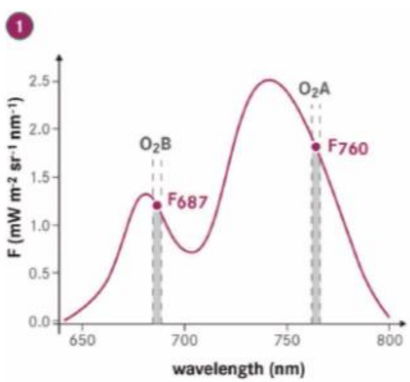
| Spectral region | Visible | | $SIF_{red}$ | | Red-edge | | | $SIF_{far-red}$ | |
|---|---|---|---|---|---|---|---|---|---|
| λ (nm) | 500–677 | 677–686 | 686–697 | 697–740 | 740–755 | 755–759 | 759–762 | 762–769 | 769–780 |
| SR (nm) | 3.0 | 0.6 | 0.3 | 2.0 | 0.7 | | | 0.3 | 0.7 |
| SSI (nm) | 2.0 | 0.5 | 0.1 | 0.65 | 0.5 | | | 0.1 | 0.5 |
| SNR | 245 | 340 | 175 | 425 | Linear from 510 to 1015 | 1015 | 115 | Linear from 115 to 455 | 1015 |

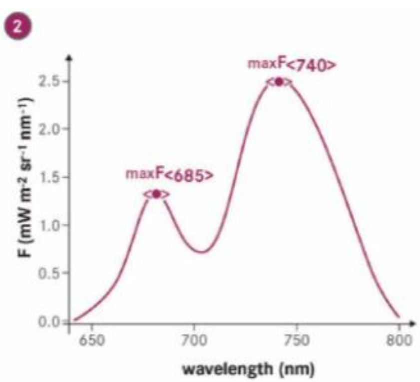
UNIVERSITÀ DEGLI STUDI DI MILANO BICOCCA

# Field spectroscopy for Cal/Val

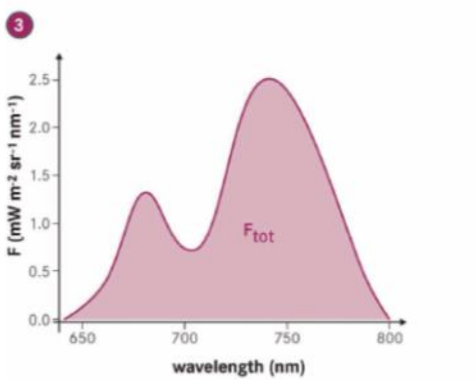
**Main goal. To assess the goodness of different FLEX Products:**

- $O_2$-A and $O_2$-B TOC fluorescence emission values (F687 and F760):
- Peak values and peak position of TOC fluorescence emission (maxFred, λred, maxFfar-red and λfar-red)
- Total TOC fluorescence emission ($F_{tot}$)




| Higher Level Products | Definition |
|---|---|
| PS I-PS II contributions | Derived from $F_{<680>}$ and $F_{<740>}$ to give the $F_{PS\ I}$, $F_{PS\ II}$ corresponding missions |
| Fluorescence quantum efficiency | Ratio between energy emitted as fluorescence versus actual chlorophyll specific absorbed energy (dimensionless) |
| Photosynthesis rate | Effective charge separation at PS II, interpreted as actual electron current resulting in photosynthetic reactions |
| Vegetation stress | Defined as 'actual photosynthesis/potential photosynthesis' using the ratio of the two emission peaks and estimate of non-photochemical energy dissipation |
| Spatial mosaics | Regional/continental/global maps |
| Temporal composites | Monthly/seasonal/annual composites |
| Activation/deactivation of photosynthetic machinery | Determines actual length of the growing season |
| Dynamic vegetation stress | Derived by data assimilation with dynamical vegetation model accounting for temporal changes |
| GPP | Derived by data assimilation with usage of external inputs (meteorological data, land-cover maps) |



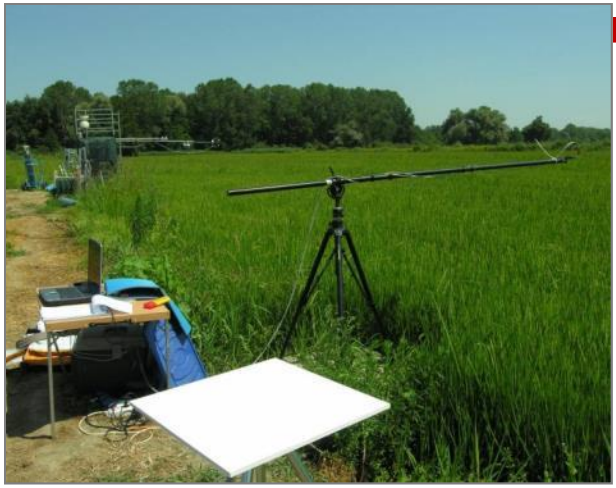

**Field spectral and atmo data can be also useful for FLEX and PRISMA**

- TOC radiances, and irradiance, apparent and true reflectance
- Canopy PRI and other Vis
- PS I–PS II contributions
- Temporal Composites Products
- *Land Surface temperature*

UNIVERSITA' DEGLI STUDI DI MILANO BICOCCA

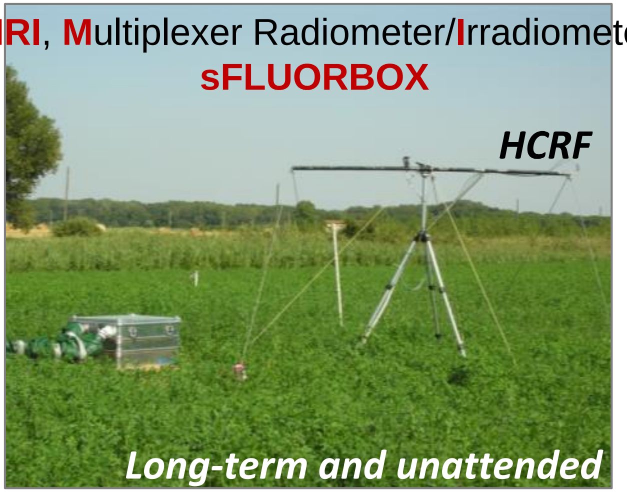
# Field spectroscopy for fluorescence retrieval

**Manual** spectrometric system

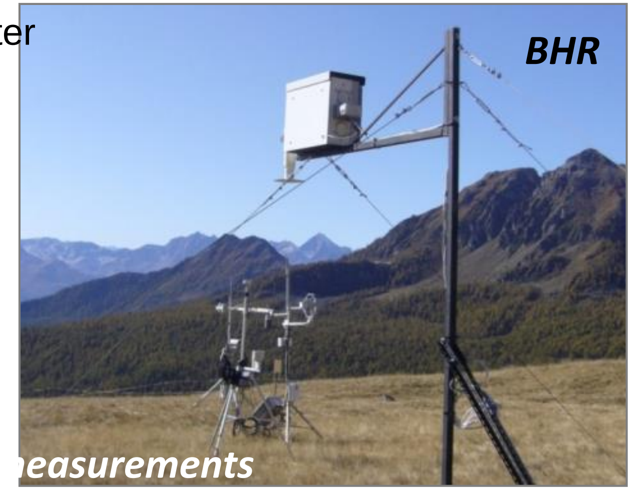


**MRI**, **M**ultiplexer Radiometer/**I**rradiometer

**sFLUORBOX**




**HSI**, **H**yper**S**pectral **I**rradiometer




*Long-term and unattended measurements*

*Different instruments concept, manual and continuous measurements*

| Optic | |
|---|---|
| Wavelength range | 650—800 nm |
| Spectral Sampling Interval (SSI) | 0.17 nm |
| Spectral resolution (FWHM) | 0.3 nm |
| Signal to Noise Ratio (SNR) | 1000 |
| Field Of View (FOV) | Dual FOV. Upwelling radiance 25°. Downwelling radiance 180° |

**FLOX**, **FL**uorescence b**OX**

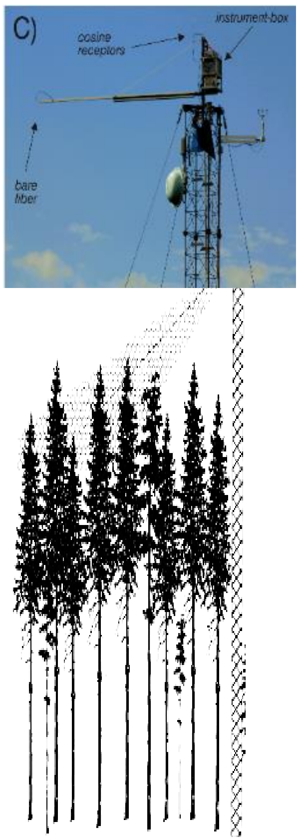
UNIVERSITA' DEGLI STUDI DI MILANO BICOCCA

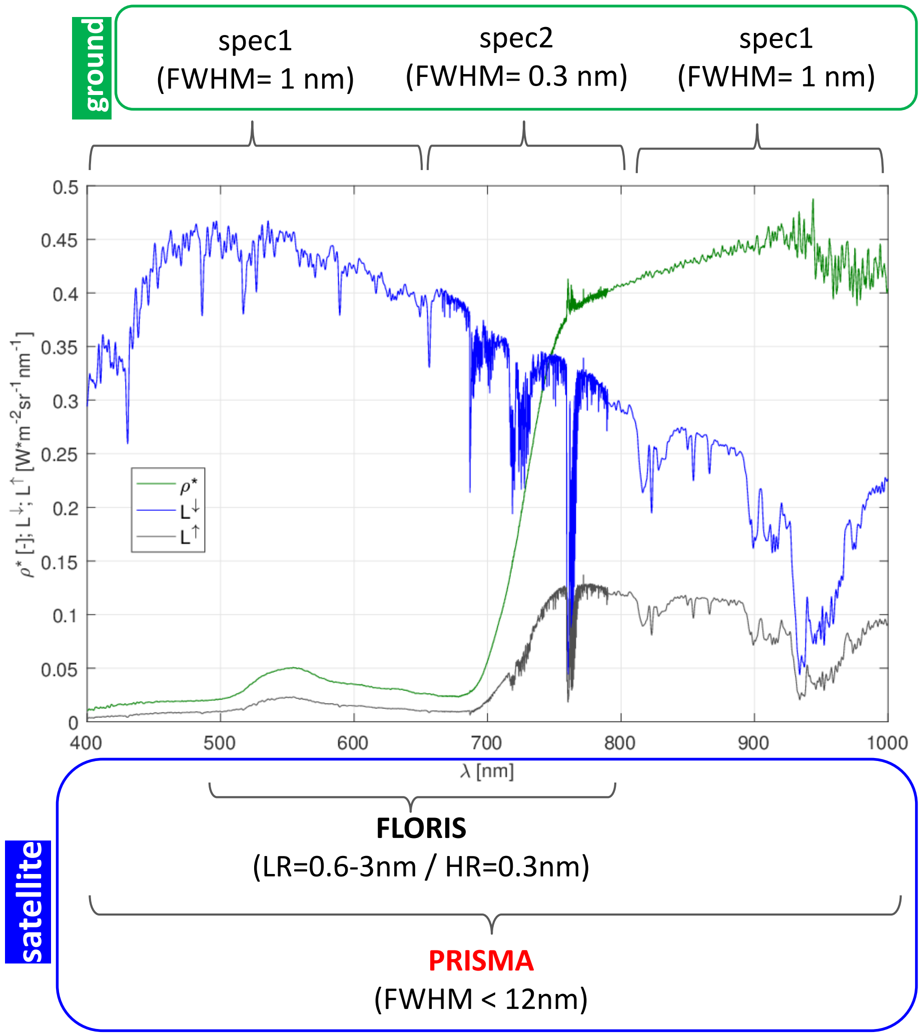
JÜLICH FORSCHUNGSZENTRUM

HYPERSPECTRAL DEVICES

# Measurements and spectral ranges

## Continuous/long-term ground hyperspectral measurements



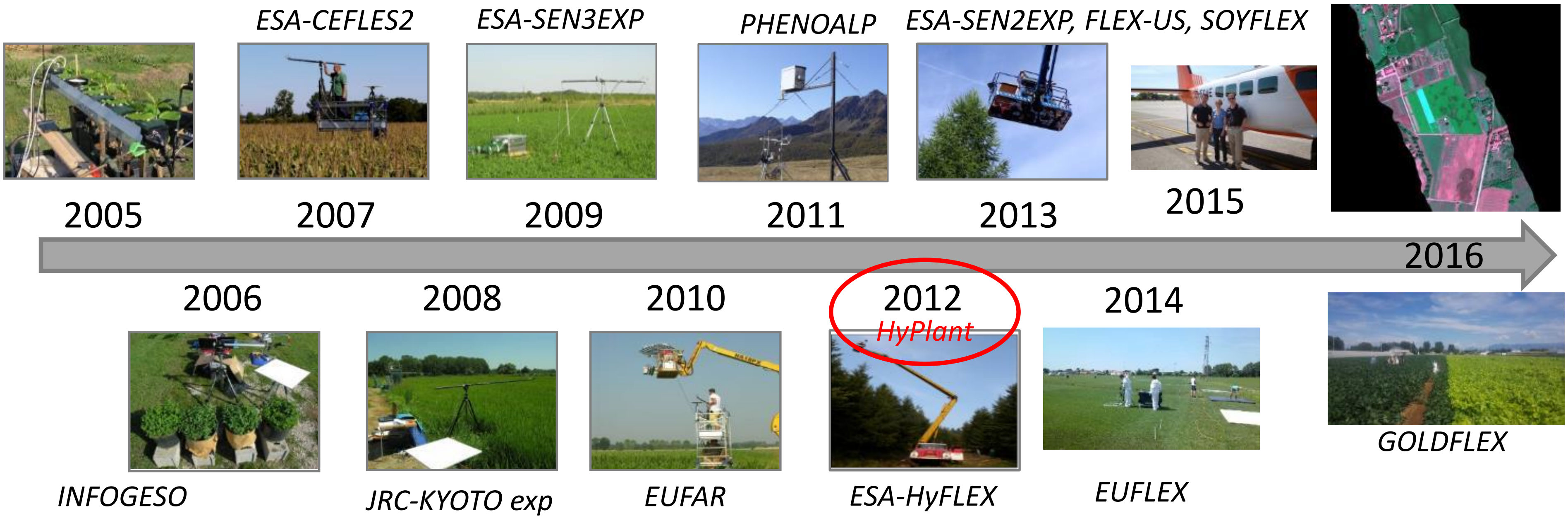

**Ground**

**Irradiance, TOC radiance, True and Apparent reflectance and Fluorescence**

**Satellite**

# Field/airborne campaigns

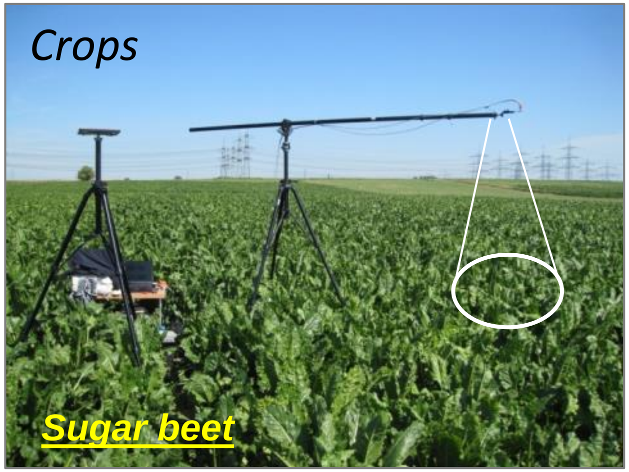
***Different context, ecosystems, scientific purposes***



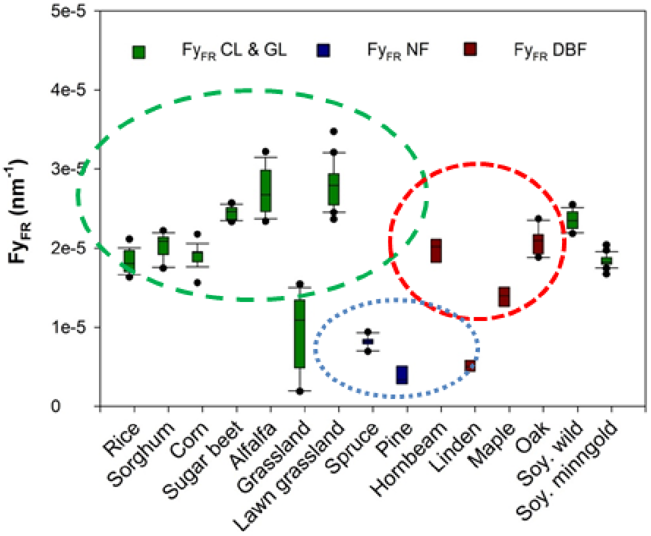

Field data have been collected with:
- similar spectrometers
- similar protocol
- similar viewing geometry

→ *(easy) comparison, fluorescence estimates of different ecosystems and temporal understanding*

# Sampling approach



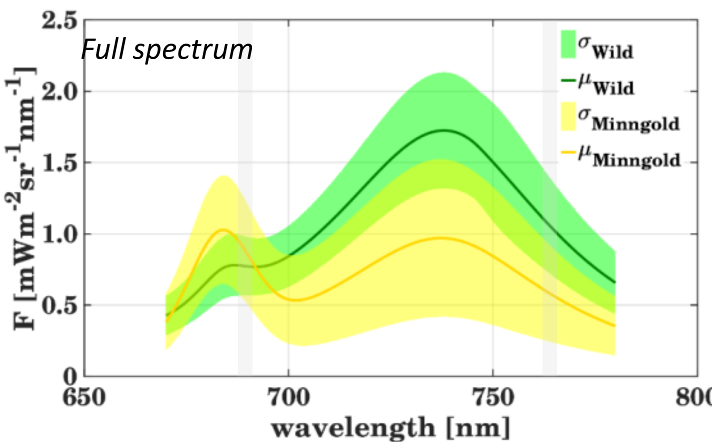


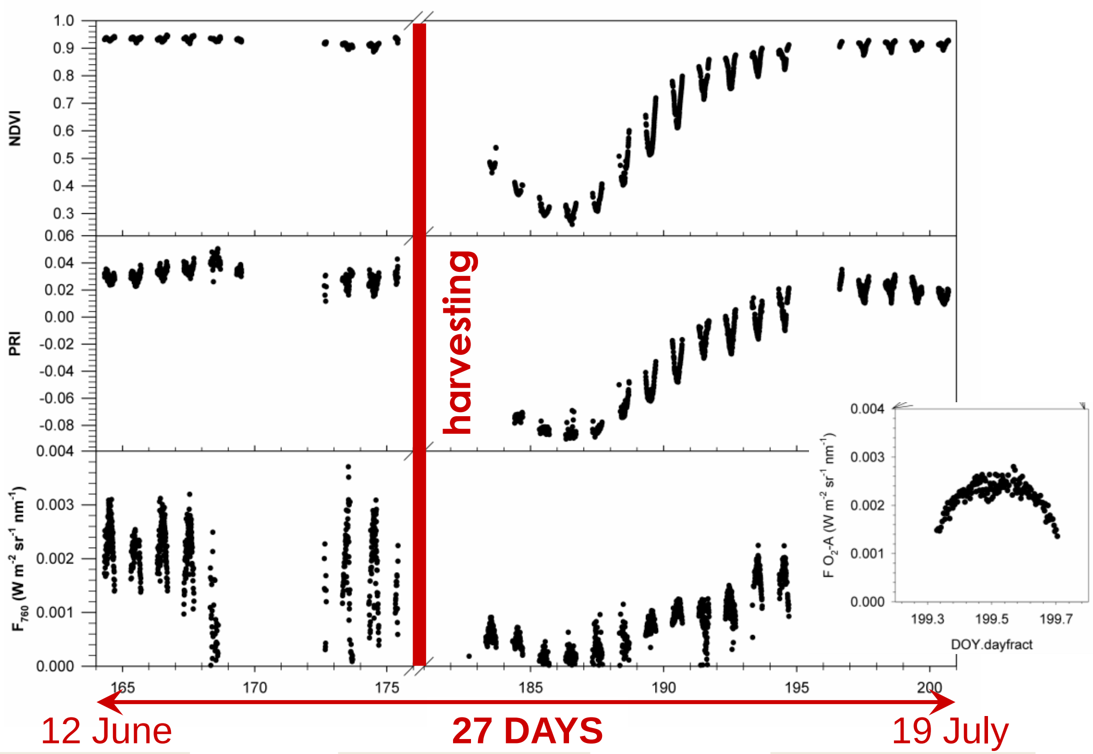


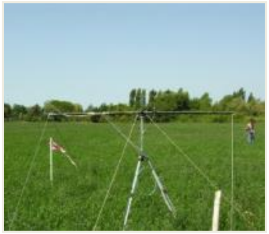

| | |
|---|---|
| **View angle** | nadir |
| **Field of view** | 25° |
| **Height above the canopy** | 150 - 450 cm |
| **Diameter of each observation** | 70 - 200 cm |

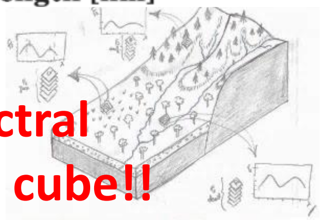
Canopy sampled from off-nadir (7° North)


# Example of spectral data and time series from automatic systems



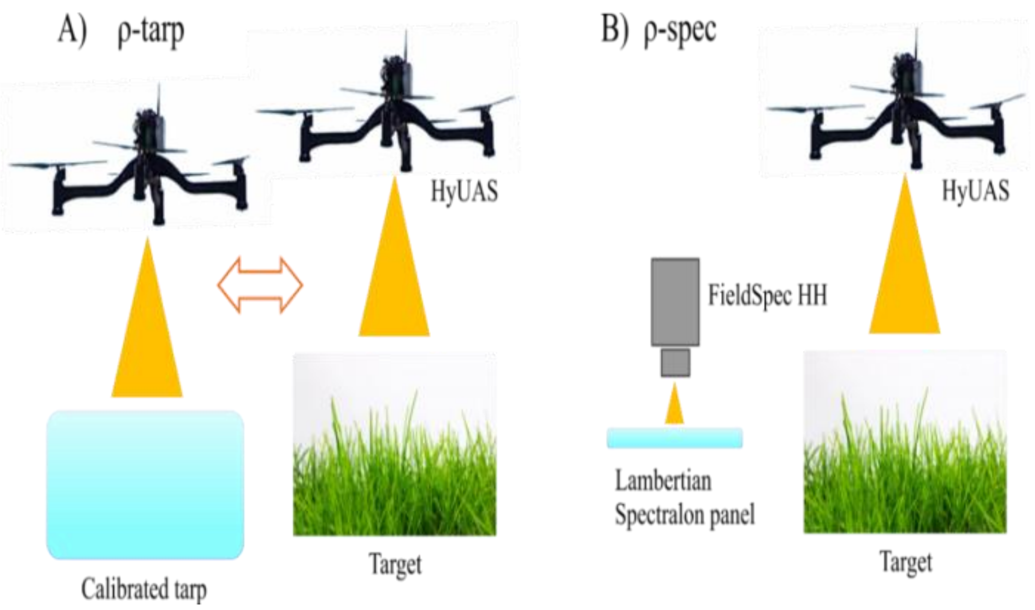


**Hyperspectral fluorescence cube!!**

# Sampling fluorescence from drones: the Hyperspectral UAS (HyUAS)

## Anteos platform

- Four-rotor platform with hovering capability, maximum payload of 2 Kg and flight time of 20 min
- Global Position System (GPS) coupled with the Inertial Movement Unit (IMU)
- Radio connection to the ground control station



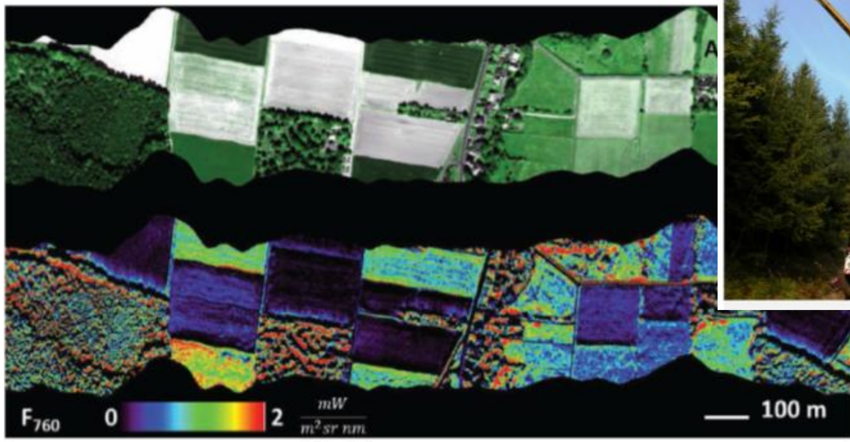

*Garzonio et al.,submitted*

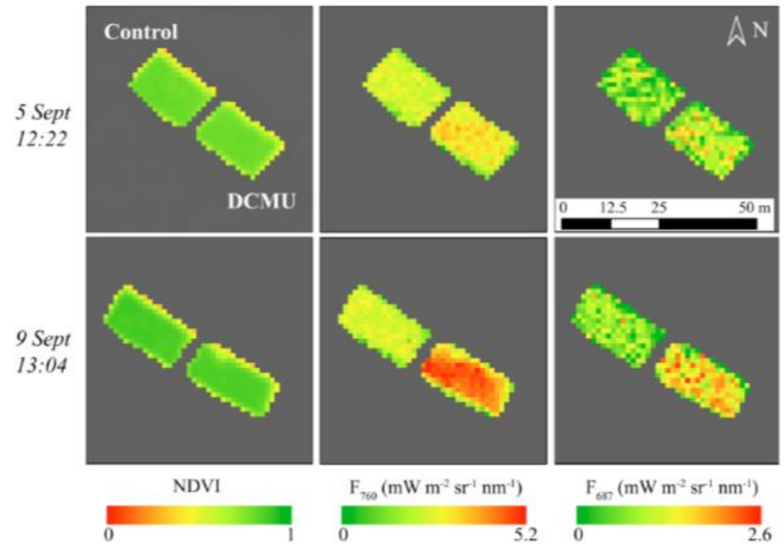
## Optical payload

- RGB digital camera (Canon S100)
- Ocean Optics USB4000 VNIR non-imaging spectrometer (350 -1000nm, 1.0 nm FWHM, 16bit)

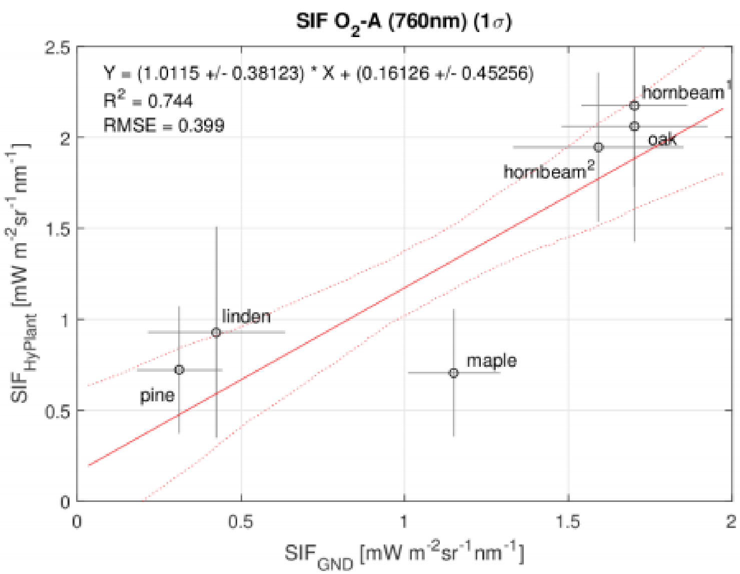
DC from shutter

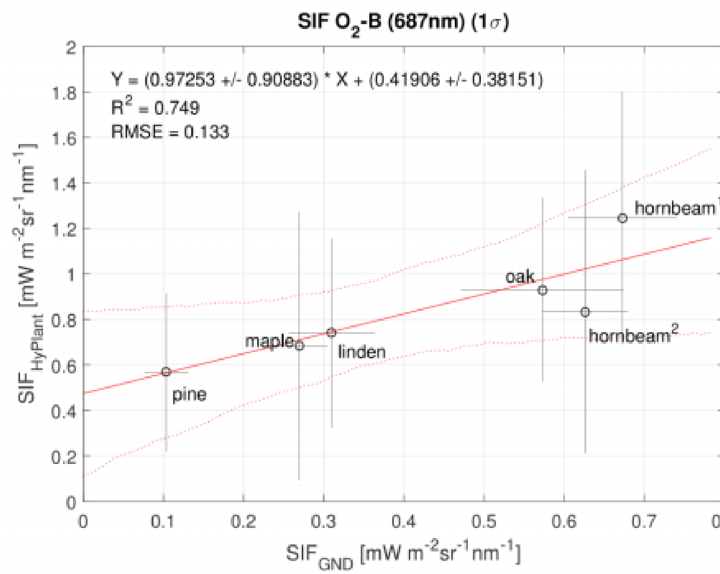
# Comparison between ground and airborne estimates




*importance of the pre-processing chain for both data*




UNIVERSITÀ DEGLI STUDI DI MILANO BICOCCA

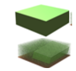
# CAL/VAL framework for FLEX

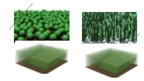
**Important points to be considered**

i. Definition of the validation approach;
ii. Parameters to be validated and error metrics
iii. Sites types and purposes;
iv. Site requirements at Core Sites;
v. Instruments requirements;
vi. Ecosystems types;
vii. Sampling terminology
viii. Link with existing networks

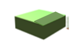
# What we are doing within the MAG. Criteria for selecting/characterising cal/val sites

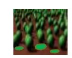
| | Site requirement | Criteria |
|---|---|---|
| | | |
| 1 | Science question | ESA SP-1329/2, 2015 |
| 2 | Land cover | Representativeness |
| 3 | Size&homogeneity | # of endmembers and size |
| 4 | Topography | Slope |
| 5 | Sun angles | Cosq |
| 6 | Site position | Nadir |
| 7 | Meteorology | Cloud cover |
| 8 | Facilities, logistic | Yes/No |
| 9 | Manipulation | Yes/no |
| 10 | Flight | High risk/medium/low |
| 11 | Maintenance | Euro |
| 12 | Heritage | Yes/No |
| 13 | Pixel story (temp. homogeneity) | SNR NDVI/Ts |
| 14 | Link | Yes/No, type |
| 15 | Nationality/cofunding | Yes/No |

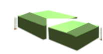
1)  Simple homogeneous crop type (e.g. planophyle crops on flat open terrain)

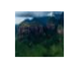
2)  Homogeneous, full cover single species forest (e.g. dec/needle)

3)  Homogeneous mixed forest (e.g. Sabaudia forest…)

4)  Two components agricultural type (e.g. large fields)

5)  Two vegetation components (e.g.trees/grassland, white spruce forest….).

6)  Fragmented agricultural landscape (e.g. small size fields)

7)  Rugged terrain (e.g. forest or crops)

- SIF-ρ: Ground spectrometers for Top of canopy radiance, reflectance and fluorescence
- Aτ : Instruments for atmospheric characterization
- Dr: Spectrometers on drones
- Air: Airborne sensors
- €: Additional instruments for environmental measurements (spectral, ecological…)
- EO: Earth Observation data

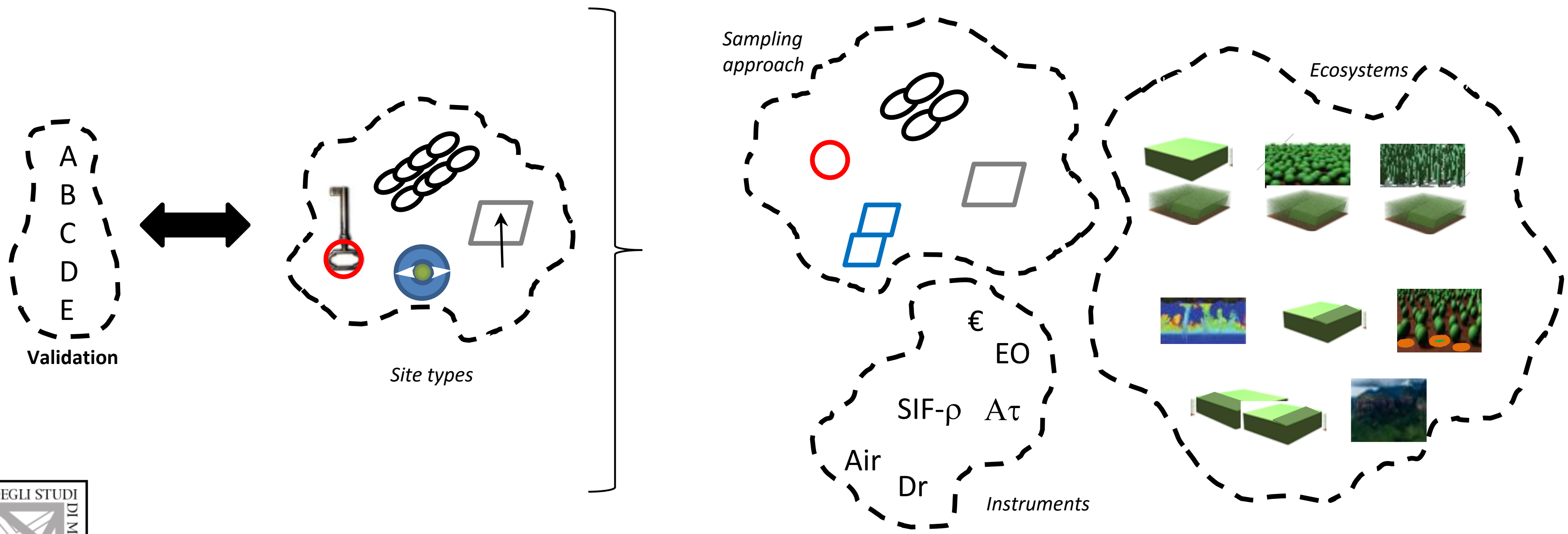
UNIVERSITA' DEGLI STUDI DI MILANO BICOCCA

# Pillars for upscaling and definition of validation sites

**direct validation, bottom up-approach and indirect schemes**

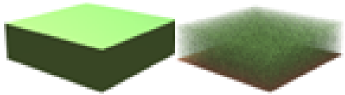
Leaf and single plant scale for mechanistic understanding

Mapping of heterogeneous FLEX pixels



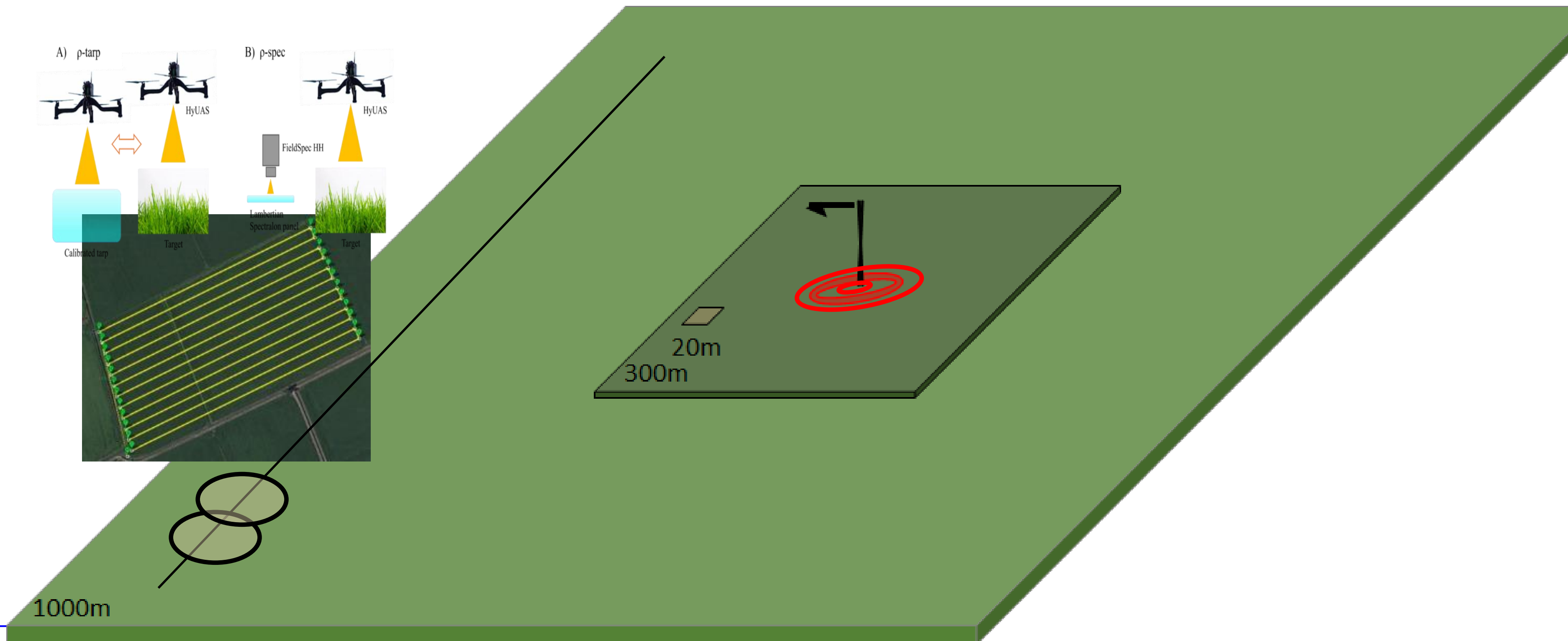
# Validation CoreSite#1. Simple case

Site#1. Totally homogeneous and 'simple' vegetation. The vegetation should be structurally easy and homogeneous covering an area of at least 1000 x 1000 meters. Something like this could be a homogeneous grassland, a large agricultural field or something similar.

Core site for intercomparison of different EO data

High temporal sampling + spatial heterogeneity + pixel characterization **(PRISMA)**
Need to have GPP



# Possible link and relationships between FLEX/PRISMA

**We should create an Italian well equipped supercoresite for PRISMA and FLEX hyperspectral measurements intercomparison (benchmark site) and to think on a new A-train hyperspectral satellite constellation**

- FLEX will generate core sites for **continuous hyperspectral measurements** (although only VIS-NIR region ☹ and limited to TOC radiance of vegetated surfaces) and PRISMA should benefit from it (i.e. intercalibration radiance/reflectance (spectral-radiometric), irradiance (atmo parameters)). The 300m of FLEX is a ***spatial opportunity for PRISMA*** cal/val activities, since it offers a large amount of PRISMA reflectance pixel;
- PRISMA could be a strong opportunity for FLEX if the **temporal mismatch** between two missions is reduced, at least in some sites (this allow to estimate APAR ☺). Maybe is still possible to evaluate flying in tandem configuration for specific experiments.
- PRISMA can provide valuable information to better characterize the spatial heterogeneity of structural/biophysical/biochemical parameters at the FLEX cal/val sites and may provide useful information to better interpret the fluorescence process at global scale. The knowledge of biophysical parameters in space and time will allow to better parametrize RT model for **indirect validation** at the selected sites. PRISMA can also contribute for **increasing temporal resolution** at cal val sites and to generate overall more consistent time series of vegetation indices and parameters. Maybe by exploiting PRISMA multi-view (pointing capability) for some sites.

# Conclusions

- This talk aimed to present instruments, field and airborne campaigns for fluorescence measurements. These information help for understanding the magnitude of fluorescence and for selecting the best configurations for cal/val activities in the context of FLEX mission;

- FLEX cal/val framework is an on-going activity and long term measurement sites as well as instruments requirements, sampling approach and validation scheme will be defined;

- FLEX and PRISMA can really benefit each other. A dedicated plan could be addressed in the near future.

# Many thanks to the numerous partners

University of Zurich UZH

Consiglio Nazionale delle Ricerche

University of Cologne

Centre de Recherche Public Gabriel Lippmann

JÜLICH FORSCHUNGSZENTRUM

P & M Technologies

Freie Universität Berlin

CzechGlobe

cnes

CARNEGIE INSTITUTION DEPARTMENT OF GLOBAL ECOLOGY *Extending the Frontiers of Science*

HELMHOLTZ CENTRE FOR ENVIRONMENTAL RESEARCH – UFZ

universitätbonn

Politechnika Poznańska

Institut Pierre Simon Laplace

FONDAZIONE Clima e Sostenibilità

UNIVERSITÀ DEGLI STUDI DI MILANO BICOCCA

ITC UNIVERSITY OF TWENTE.

VNIVERSITAT DE VALÈNCIA

Goddard SPACE FLIGHT CENTER

NASA

GFZ Helmholtz Centre POTSDAM

cost EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

esa

UNIVERSITÀ DEGLI STUDI DI MILANO BICOCCA


Thank you