The FLuorescence EXplorer (FLEX) mission: current status, data products and exploitation plans

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and the FLEX team

flex

Quantitative global mapping of <u>actual photosynthetic activity </u>of terrestrial ecosystems, accounting for the spatial and temporal variability driven by environmental conditions

- Reduce uncertainty in global / regional estimates of carbon fluxes, in particular GPP (Gross Primary Productivity)

- Provide estimates of vegetation stress through variable photosynthesis rates (potential applications in agriculture / food security)
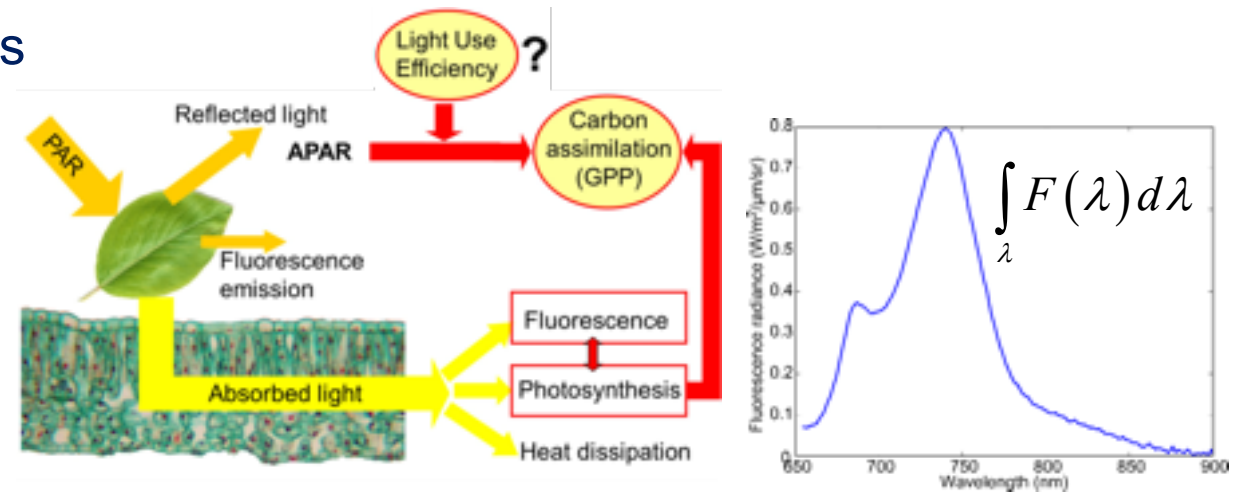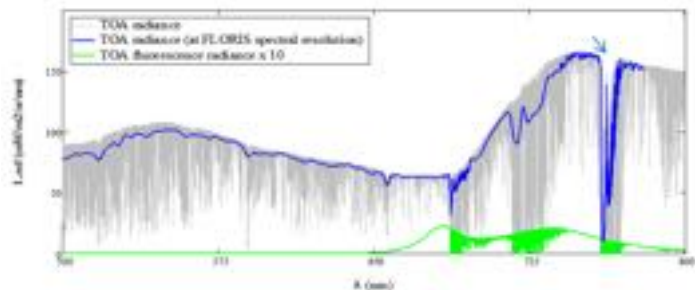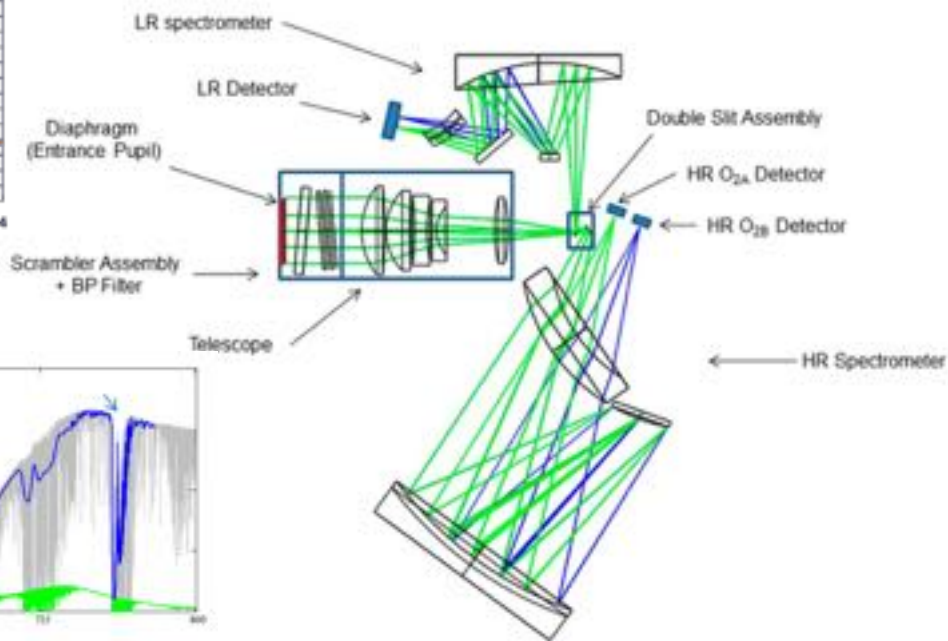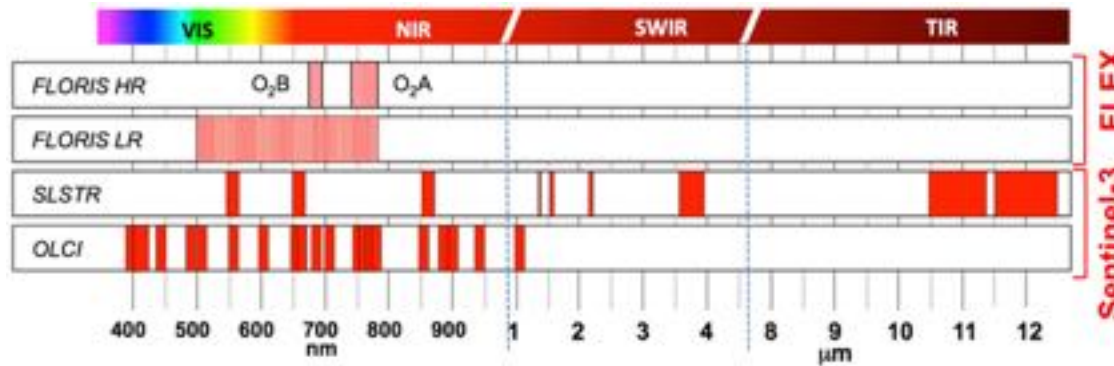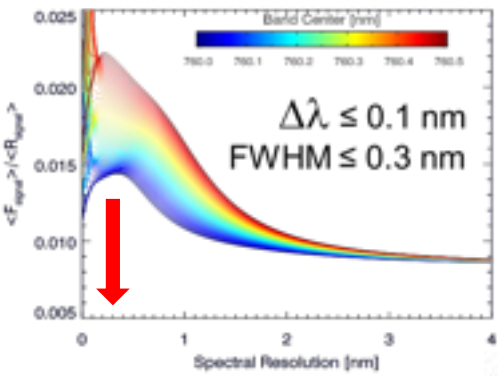
To develop <u>predictive models</u> able to forecast climate trends and vegetation adaptations with reduced uncertainty.

$$\int_{\lambda} F(\lambda)\, d\lambda$$
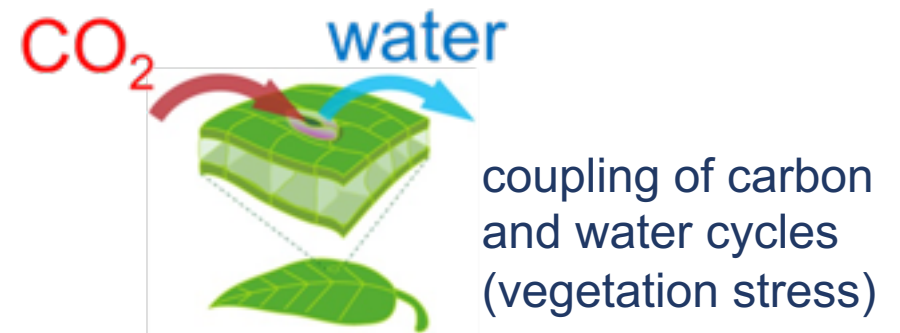
coupling of carbon and water cycles (vegetation stress)

FLORIS instrument

FLEX/Sentinel-3 Tandem Mission

- Spectral range
  500-780 nm
- Spectral sampling:
  0.093 nm (HR)
  0.6 nm (LR)

$\Delta\lambda \leq 0.1$ nm
FWHM ≤ 0.3 nm
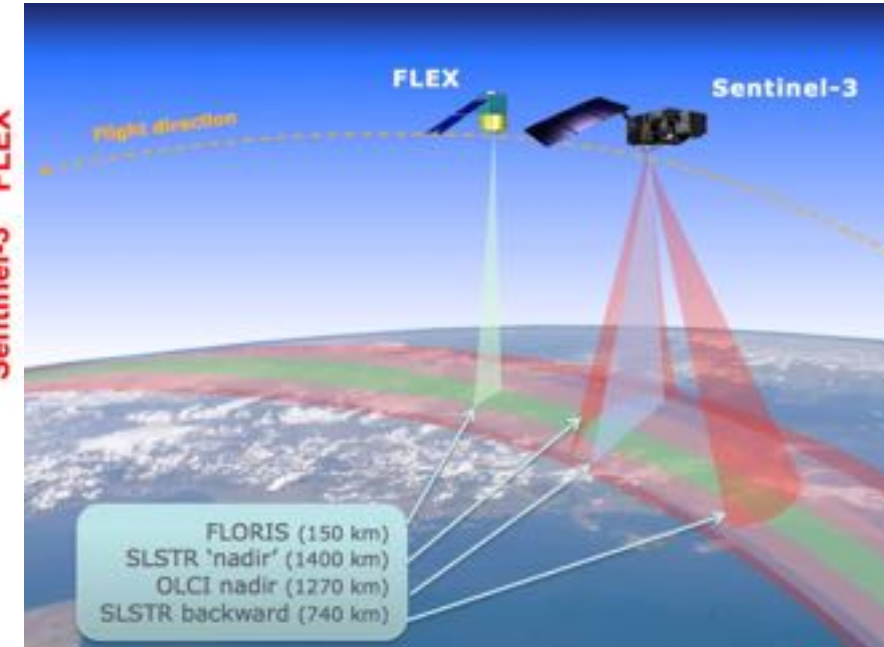
- Orbit: 815 km, tandem with Sentinel-3
  50-100 km ahead of Sentinel-3
- 27 days repeat cycle
- Swath 150 km, SSD 300 m
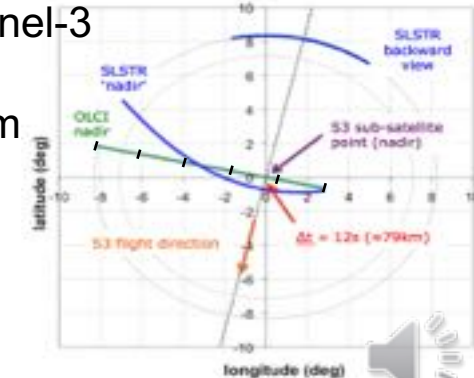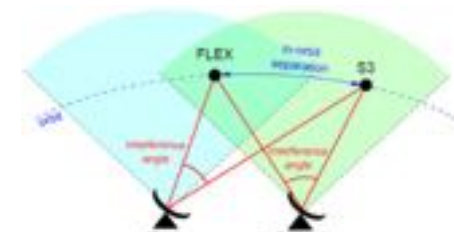
FLEX mission status
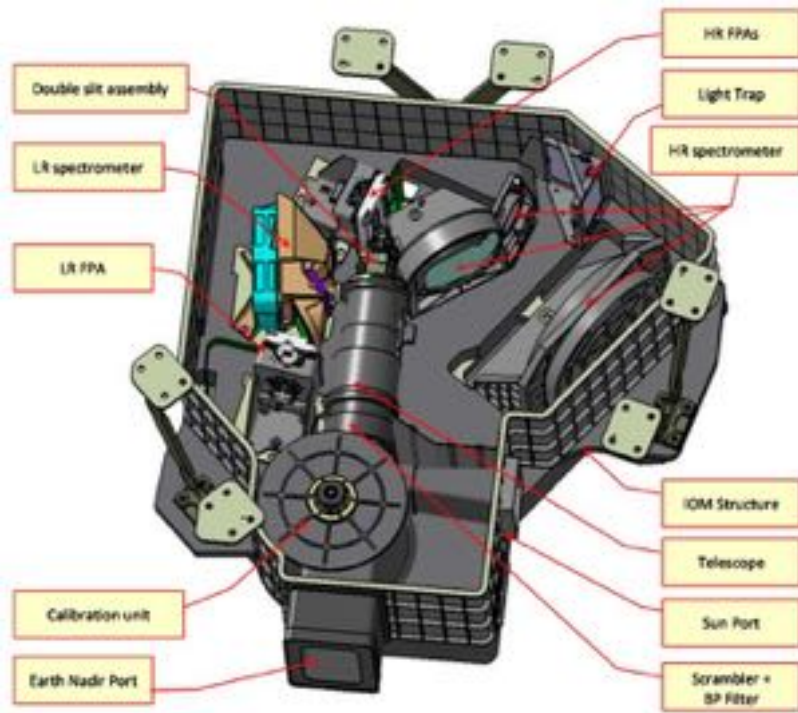
Spectral calibration (stability < 0.005 nm):
- ❑ Shifts, drifts (thermoelastic)
- ❑ Smile / keystone

CALIBRATION UNIT

DETECTOR

- • Mission CDR (on-going)
- • Start flight hardware integration

- • Ground Segment procurement
  - Level 1, Level 2, plus integrated Cal/Val

- • Cal/Val preparatory activities:
  - instruments and protocols
  - site network
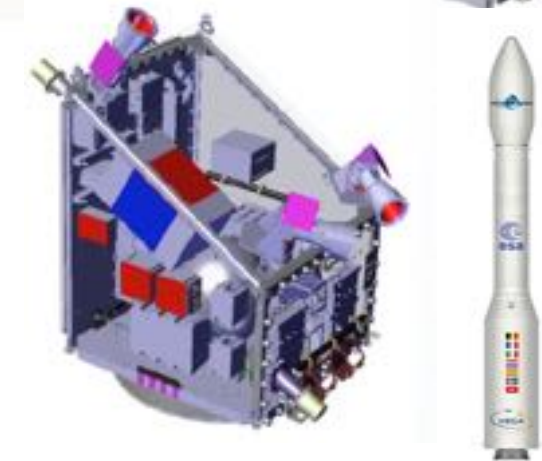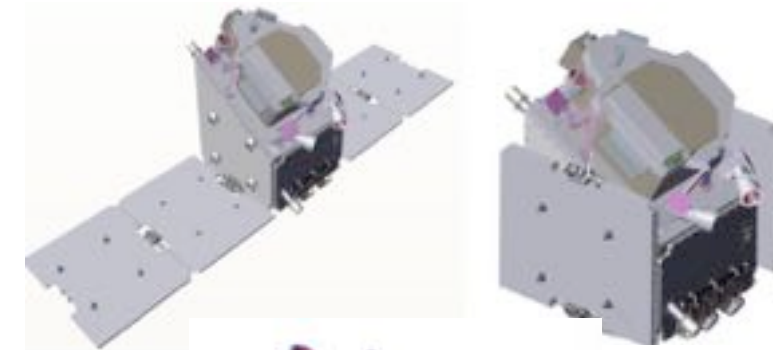
Vega launch

Launch planned for 2025
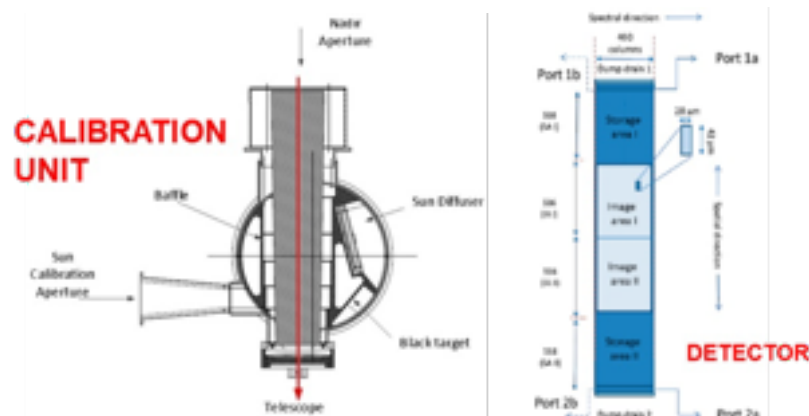
RETRIEVAL BASED ON SPECTRAL CONTRAST

spectrally smooth

$$\rho_{app} \equiv \rho + \frac{\tilde{F}}{\langle I^{\downarrow} \rangle}$$

strong spectral features

spectral distortions (spikes) appearing in surface reflectance retrievals due to inadequate modeling of atmospheric absorptions and instrumental effects (treated as noise and smoothed using cosmetic techniques) are just the source of information in FLEX to retrieve fluorescence

Information from dynamical surface reflectance

atmospheric effects

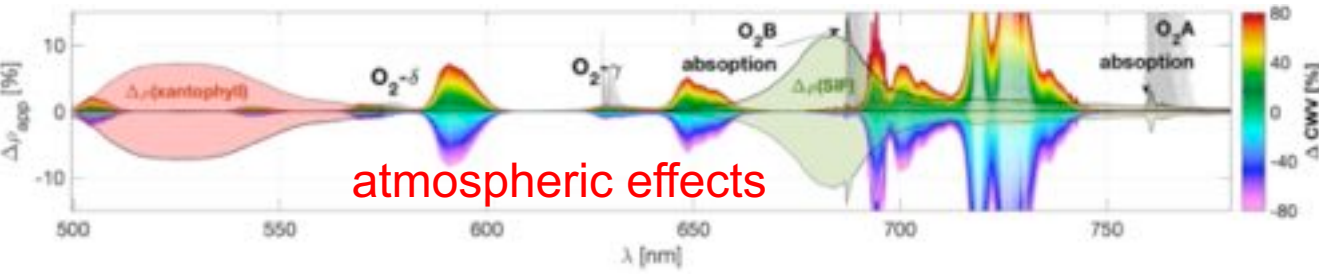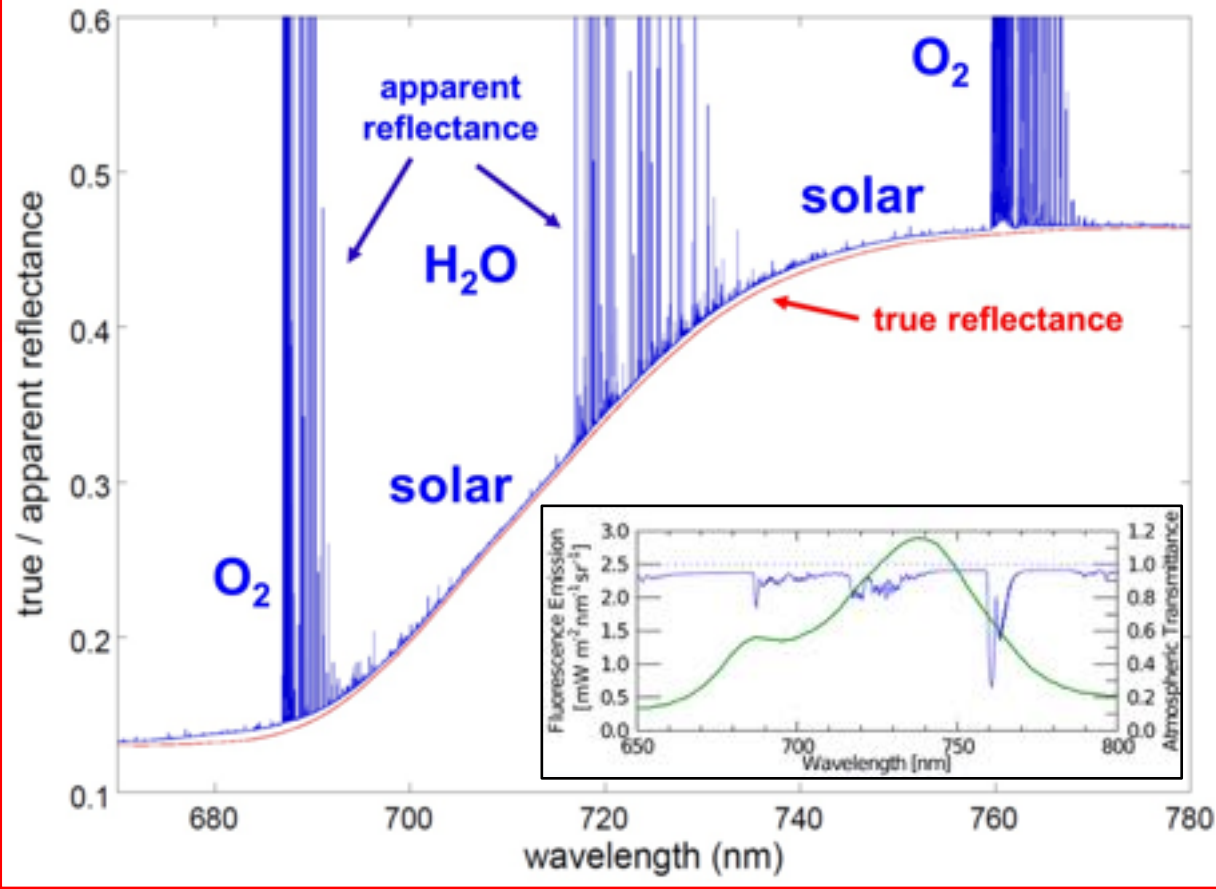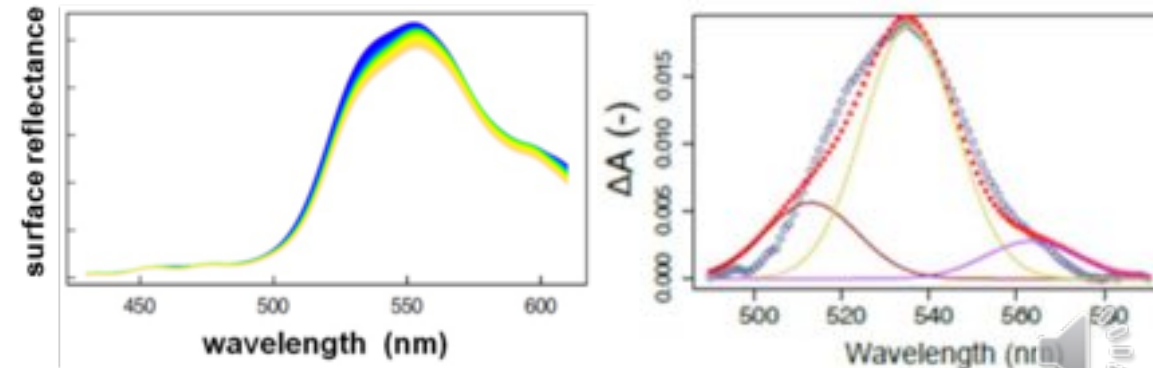Level-1 Processing → Level-2 "Land" Processing (land vegetation): vegetation fluorescence heat dissipation; - instantaneous photosynthesis; - static vegetation stress indicators. Level-2 "Water" Processing (inland waters, coastal areas): - water fluorescence; - water pigments; - water photosynthesis.

Level-3 Processing: spatial mosaics; time series; seasonal and multiannual vegetation dynamics; activation / deactivation of photosynthesis; integrates both land and water products into global mosaics.

Level-4 Processing: Data assimilation into a dynamical vegetation model; daily-cycle integrated net photosynthesis; coupling of carbon and water cycles; dynamic stress indicators; carbon assimilation; biomass accumulation.

✓ cal/val network
✓ producr validation strategy

Derivation and expression of product uncertainty

✓ **Montecarlo** error propagation (stratification, importance sampling) to provide consistent and realistic estimates of uncertainties
✓ Full **covariance matrices**, rather than single product uncertainty
✓ **Statistical distribution** associated to each product (physically meaningful, avoiding impossible ranges or without physical meaning)
✓ Accounting for **correlation** in derived quantities, even from uncorrelated inputs

Confidence interval for each product

random   systematic

$$\mu_F = \left\langle \overline{F} \right\rangle_{-\delta_\alpha^{(-)}}^{+\delta_\alpha^{(+)}} \pm \Delta_{sys}^{(F)}$$

*EXAMPLE: errors in **Surface Reflectance***

$$\varepsilon_{AOT} \longrightarrow \varepsilon_\rho \; [\text{systematic}]$$

$$\varepsilon_{\substack{instrument \\ noise}} \longrightarrow \varepsilon_\rho \; [\text{random}]$$
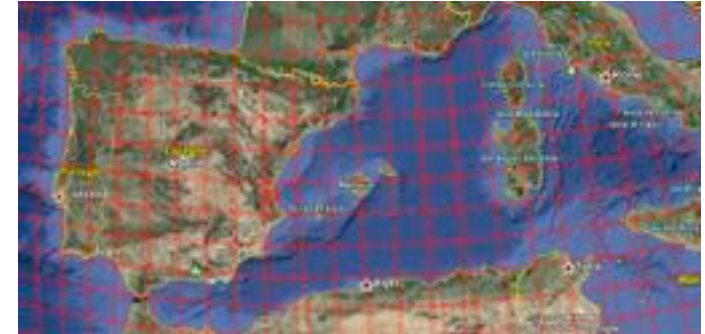
FLEX data exploitation plans

Full set of final high-level products available for end users
(ready to be incorporated in models and applications)

Analysis Ready Data (ARD)

Level-2 products

Provided in Sentinel-2 UTM Tiling Grid to facilitate combined exploitation with other missions

Initial set of TOA radiances and intermediate / raw products available for remote sensing specialists
(development of new algorithms, enhanced products, new applications)

Level-3 /-4 products:

Provided in multi-resolution Lat-Lon grid projection to optimize global data analysis and assimilation into global models

Multimission data exploitation:

✓ FLEX / Sentinel-3 by default in nominal L2 products

✓ Sentinel-2 for surface heterogeneity and scale analysis (L3/L4 products)

Final remarks

✓ Well defined objectives, quantification the role of vegetation photosynthesis in the carbon cycle
✓ Advanced retrievals methods to separate the small signal from the background perturbations
✓ High-level science products, ready to be used in models and applications
✓ Robust uncertainty estimates, quantitative product validation
✓ Multi-mission exploitation (FLEX / Sentinel-3, Sentinel-2), open-source free-access data exploitation tools to promote further usage of the data

Coordination of FLEX activities with other imaging spectroscopy missions:

❑ **Leaf/Canopy radiative transfer models** coupling structural, biochemical and physiological effects
❑ **New output products** (xanthophyll cycle pigments, dynamical changes in chlorophyll absorption, stress effects on reflectance,…)
❑ **End-to-End Simulation capabilities**, accounting for technical details of imaging spectrometers: from raw data up to high-level products.
❑ Dedicated **Cal/Val activities with robust statistical approaches** (confidence intervals, statistical tests)
❑ Shared / coordinated **airborne campaigns** and field experiments