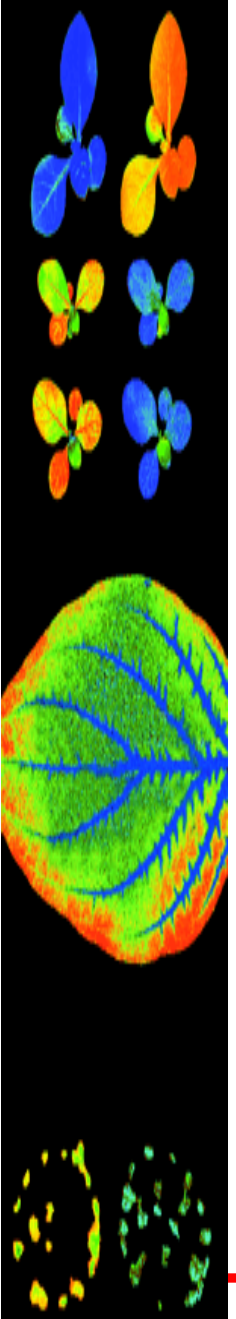


Monitoring terrestrial photosynthesis from space within the ESA Earth Explorer Programme

- Overview of the FLEX Mission Concept -

Luis Guanter

Atmospheric, Oceanic and Planetary Physics, University of Oxford, UK

on behalf of

S. Kraft, B. Carnicero, M. Drusch, J.-L. Bézy, R. Meynart

ESA/ESTEC, Directorate of Earth Observation Programmes

J. Moreno and the FLEX Mission Advisory Group

Image Processing Laboratory, University of Valencia, Spain

NCEO & CEOI Joint Science Conference 2011

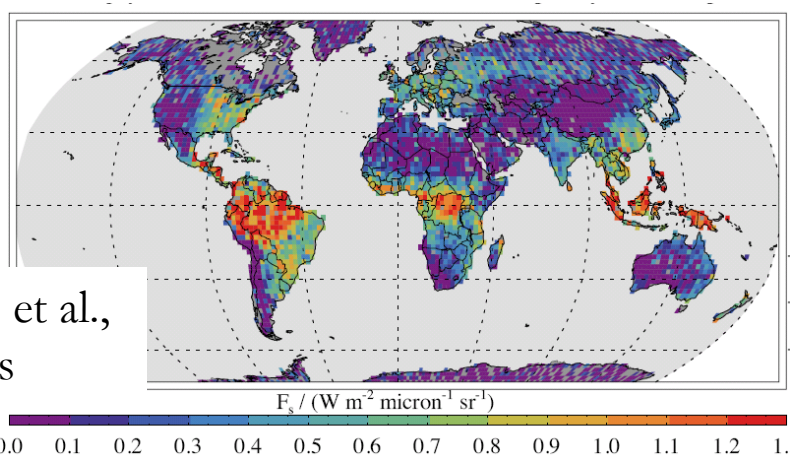
Land mission selected for phase-A/B1 studies in the frame of the 8th ESA Earth Explorer call (November 2010)

FLEX mission concept:

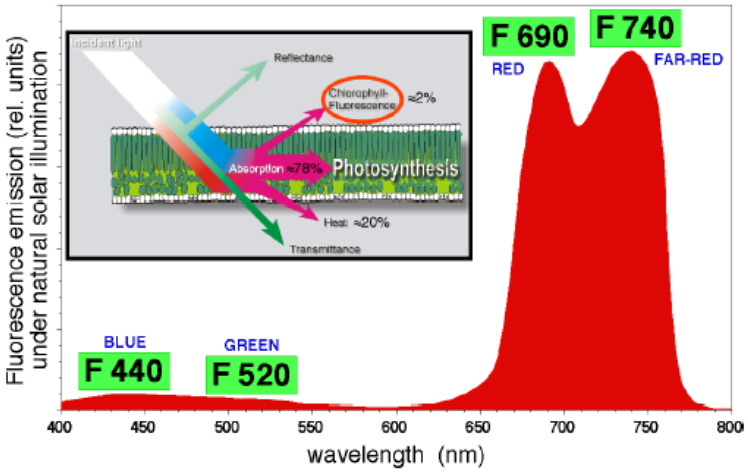
→ Imaging spectrometer (500-800nm) flying in tandem with Sentinel-3

Core scientific objectives:

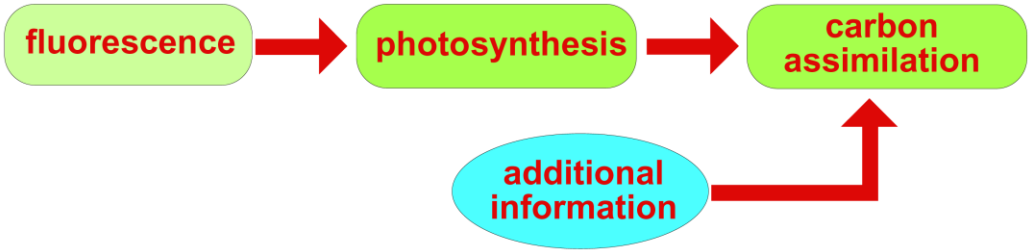
1. **Mapping of vegetation carbon assimilation** through the remote sensing of chlorophyll fluorescence and other vegetation parameters
2. **Monitoring of vegetation health** status from the response of fluorescence to environmental stress factors (water, temperature, N…)



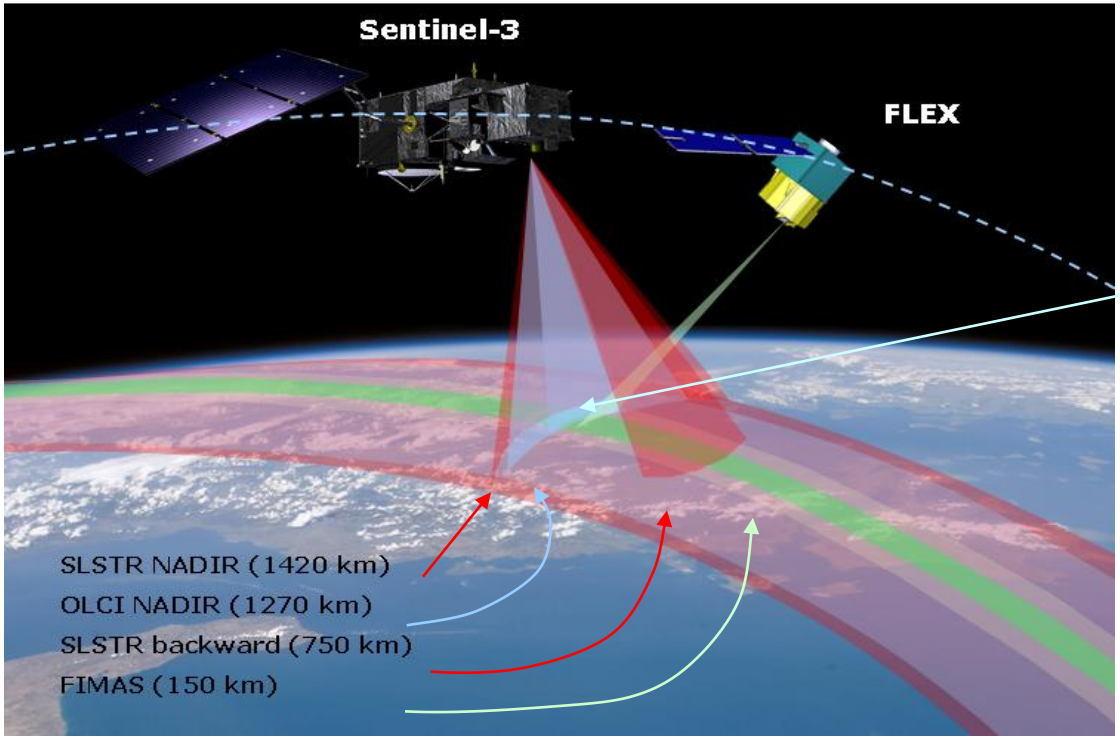
Frankenberg et al., GRL, in press

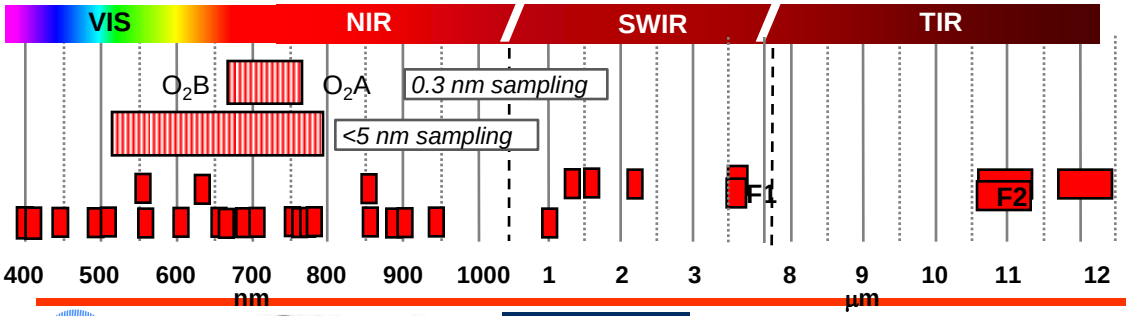


- **FLEX's target parameters:**
  1. **Photosynthesis rates** from chlorophyll fluorescence
  2. **Gross primary production** (GPP) from photosynthesis rates and complementary information (data assimilation)
- **Traditional satellite observations of GPP:**
  - Based on **reflectance-based vegetation indices** → indicate "vegetation greenness" rather than photochemical activity.
  - **Not able to constrain GPP** successfully
- **The FLEX concept → consistent observation of chlorophyll fluorescence and other key parameters to model GPP**
  1. **Photochemistry:** Fluorescence and PRI
  2. **Greenness, biomass:** reflectance-based indices (fAPAR, LAI, Cab…)
  3. **Meteorological forcing:** PAR, surface temperature and water vapour



FLEX concept EE8 - tandem with S3





1) FLORIS (300 m SSD)

- Fluorescence
- PRI
- Red-edge: Chl-a, LAI

2) S-3 OLCI (300 m SSD)

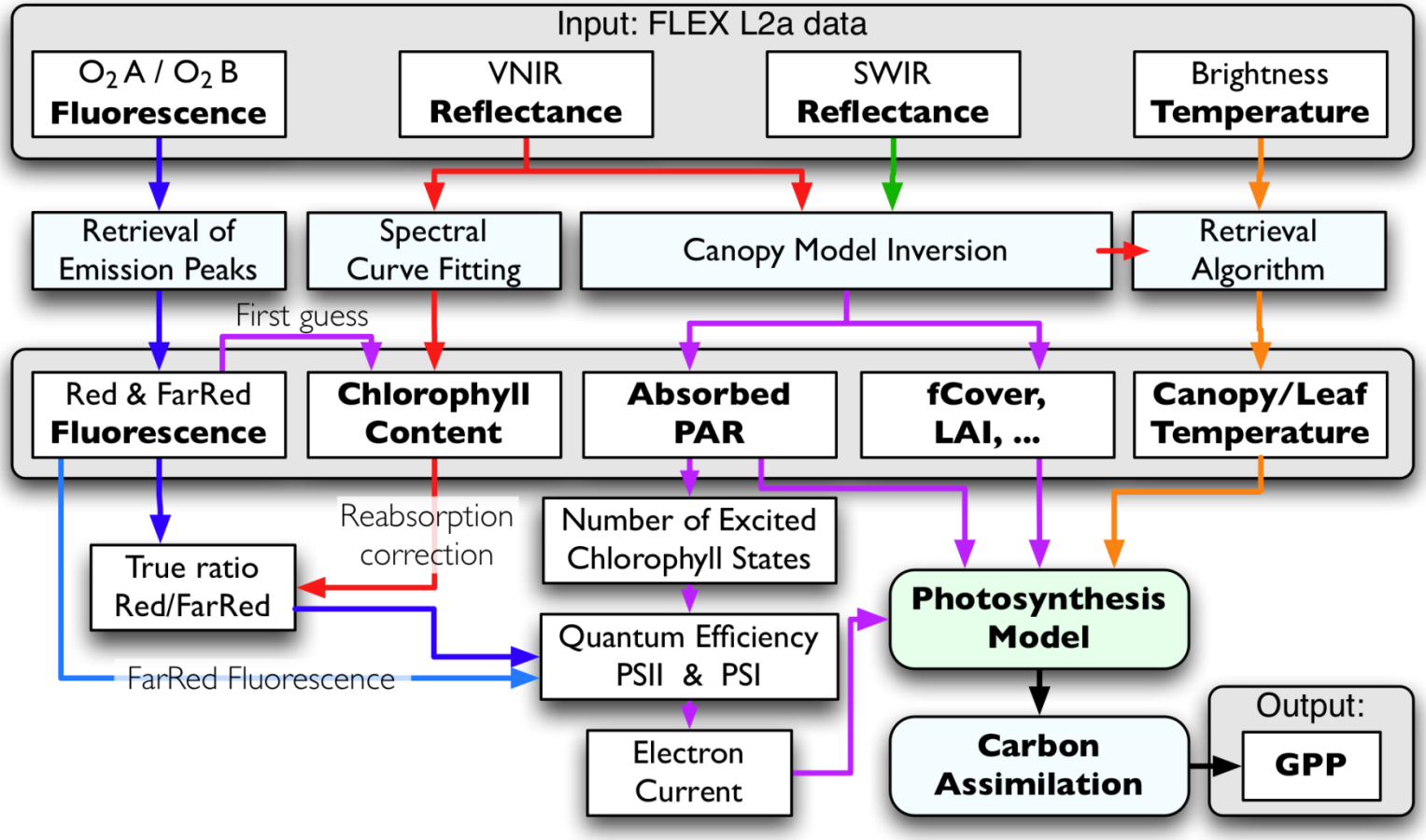
- O1 to O4 (400 to 490 nm)
  - Aerosols
  - Clouds
- O9-O16 (510 to 779 nm)
  - Chl-a, LAI
  - Cross calibration
- >O16 (870-900nm)
  - Water vapour

3) S-3 SLSTR (0.5-1 km SSD)

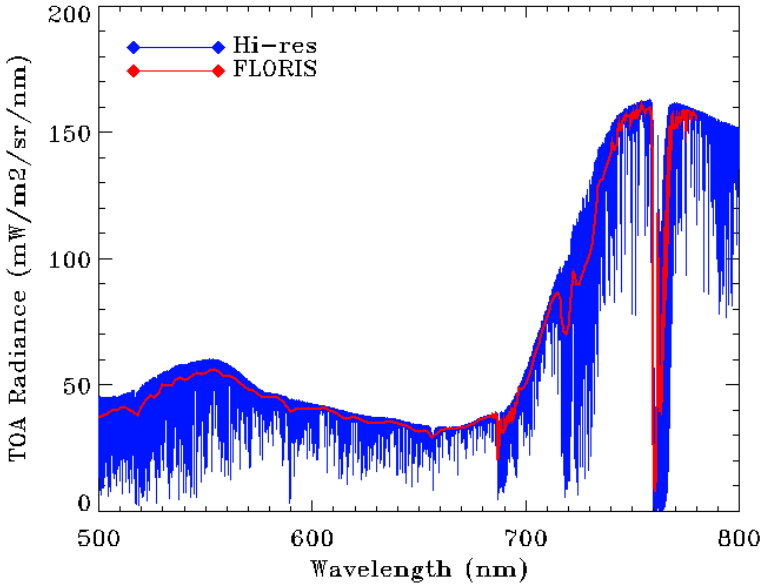
- VIS S1-S3 & off-nadir - aerosols & cirrus
- SWIR S4-S6 - Reflectance
- TIR S7-S9 - Temperature

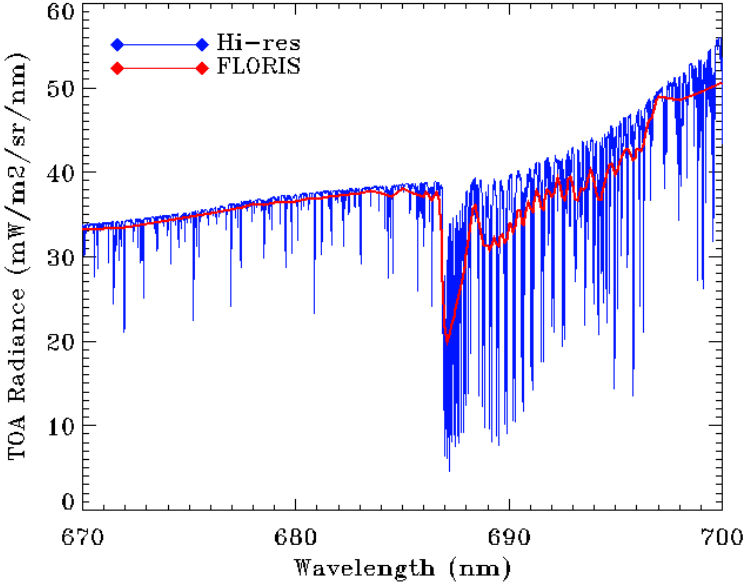
FIMAS + Sentinel-3

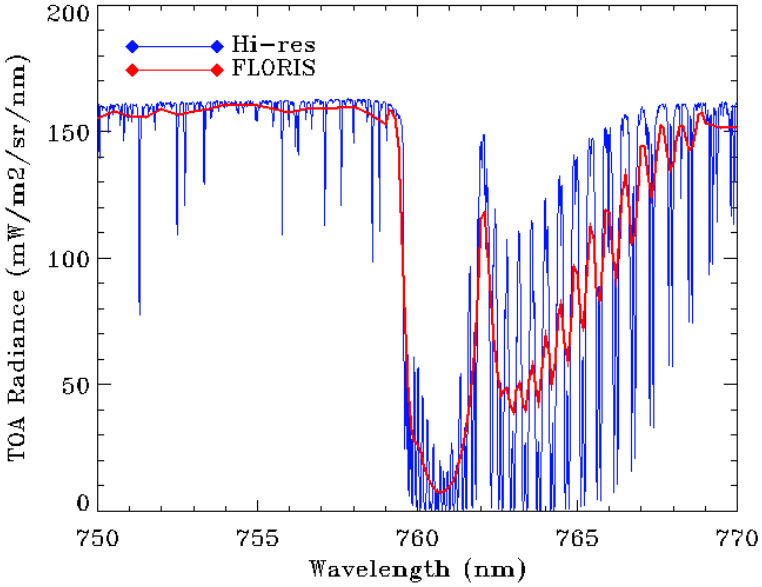
Higher level data processing

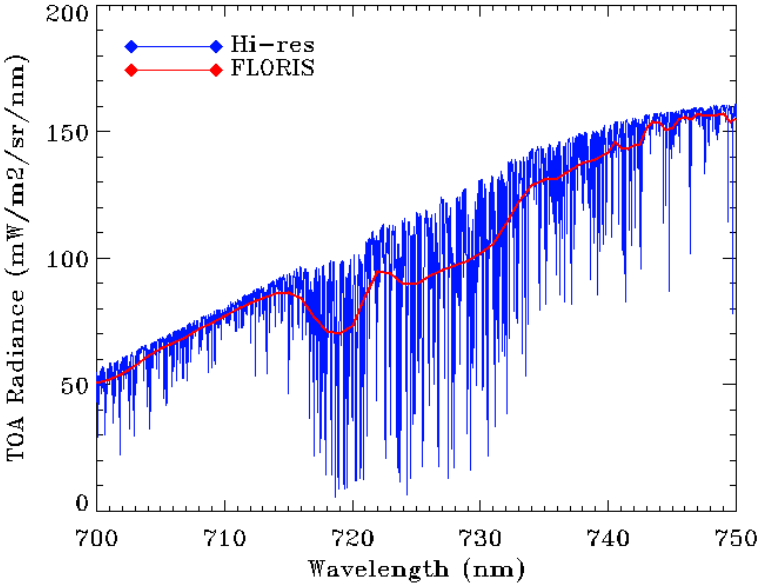


- Vapour pressure deficit (VPD) can be estimated through combination of temperature and precipitable water vapour measured by Sentinel-3/OLCI & SLSTR
- Exploitation of external data such as ECMWF Re-analysis data and MODIS (e.g. BRDF kernels) also considered


Hi-res
FLORIS
TOA Radiance (mW/m2/sr/nm)
Wavelength (nm)
0
50
100
150
200
500
600
700
800

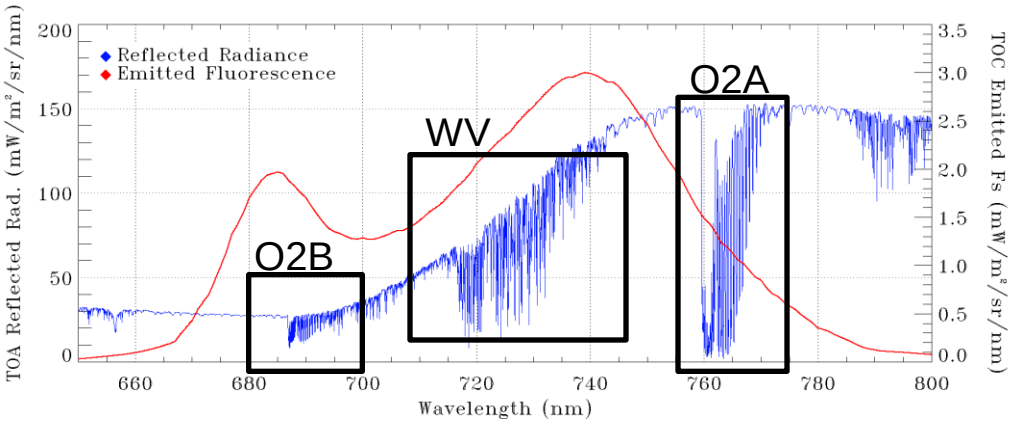

Hi-res
FLORIS
TOA Radiance (mW/m2/sr/nm)
Wavelength (nm)
0
10
20
30
40
50
60
670
680
690
700

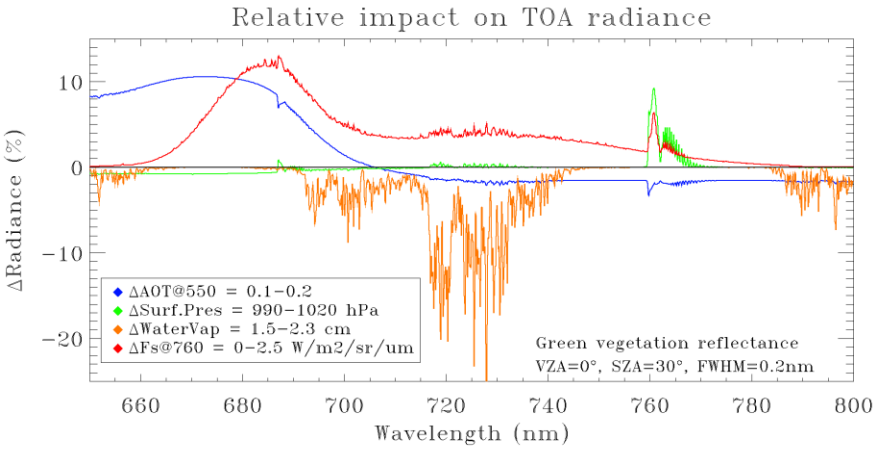

Hi-res
FLORIS
TOA Radiance (mW/m2/sr/nm)
Wavelength (nm)
0
50
100
150
200
750
755
760
765
770


Hi-res
FLORIS
TOA Radiance (mW/m2/sr/nm)
Wavelength (nm)
0
50
100
150
200
700
710
720
730
740
750

Disentangling fluorescence from solar-reflected radiation

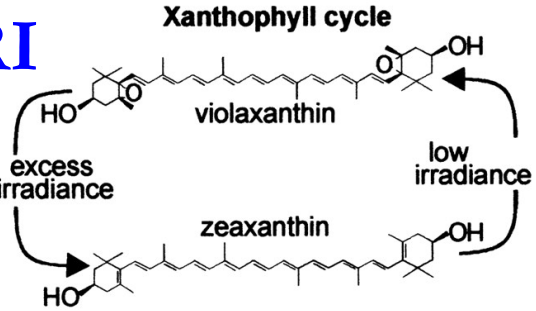
- **Aim** → To disentangle fluorescence from atmospheric and surface parameters with impact on TOA measurements in 650-800 nm:
  - Atmosphere: AOD, aerosol model (SSA & ph. function), aerosol height, surface pressure, water vapour…
  - Surface reflectance: Cab, LAI, soil background, BRDF…
  - Instrumental: noise, spectral shift & stretch/compression…
- **Multi-parameter retrieval approach**:
  - Consistent inversion of atmospheric/vegetation/instrument parameters
  - Atmospheric absorption features to decoupled solar-reflected from fluorescence signals

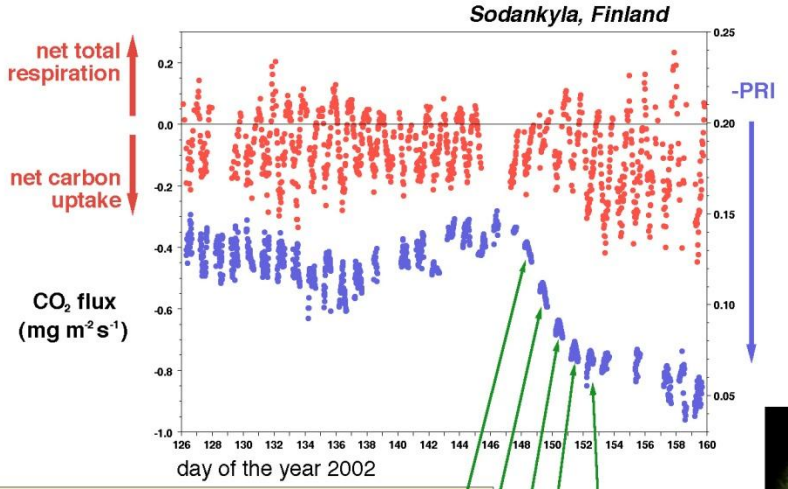




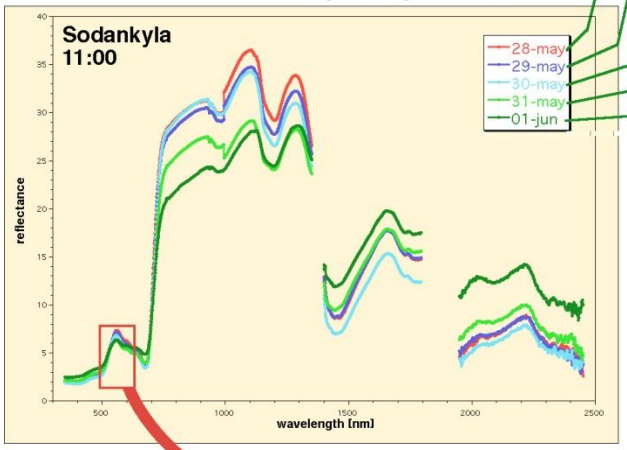
Sampling the xantophyll cycle through PRI

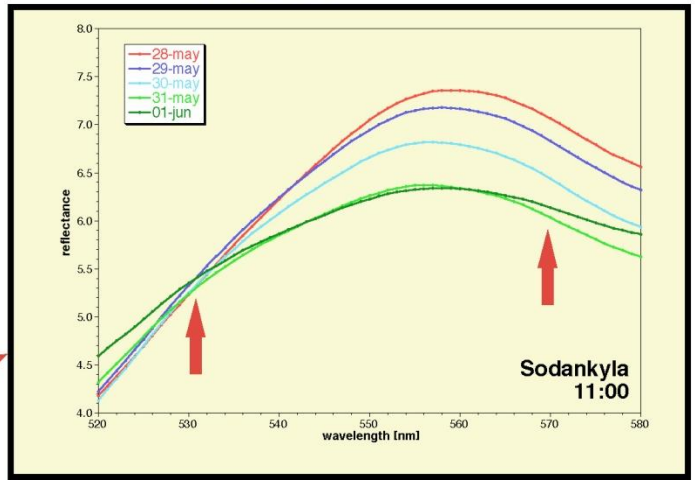
PRI benefit: Carbon uptake





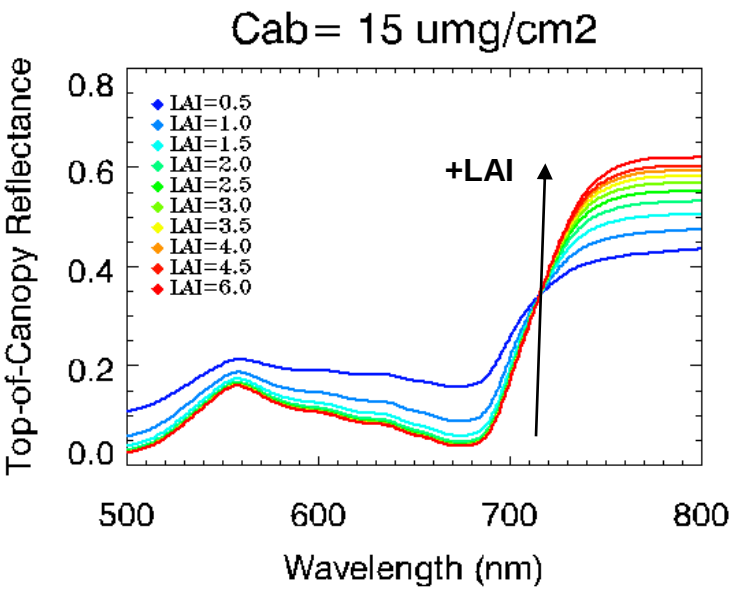
Boreal Forest Target

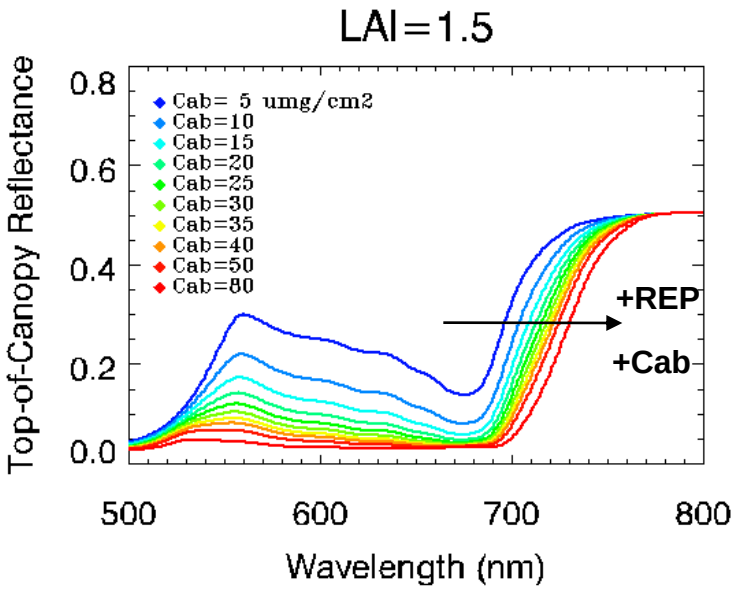




Results from SIFLEX field campaign in Finland

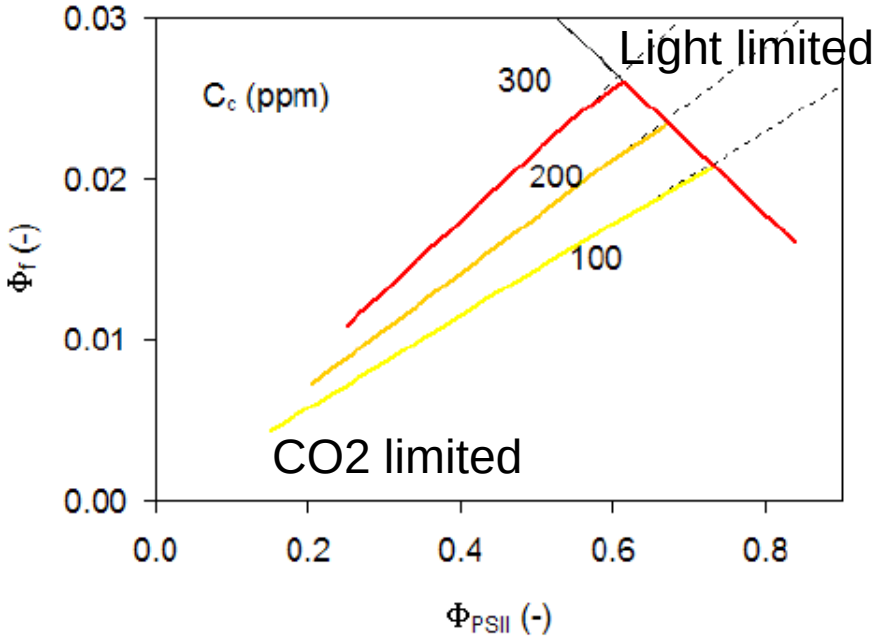
estimation of chlorophyll content and leaf area index

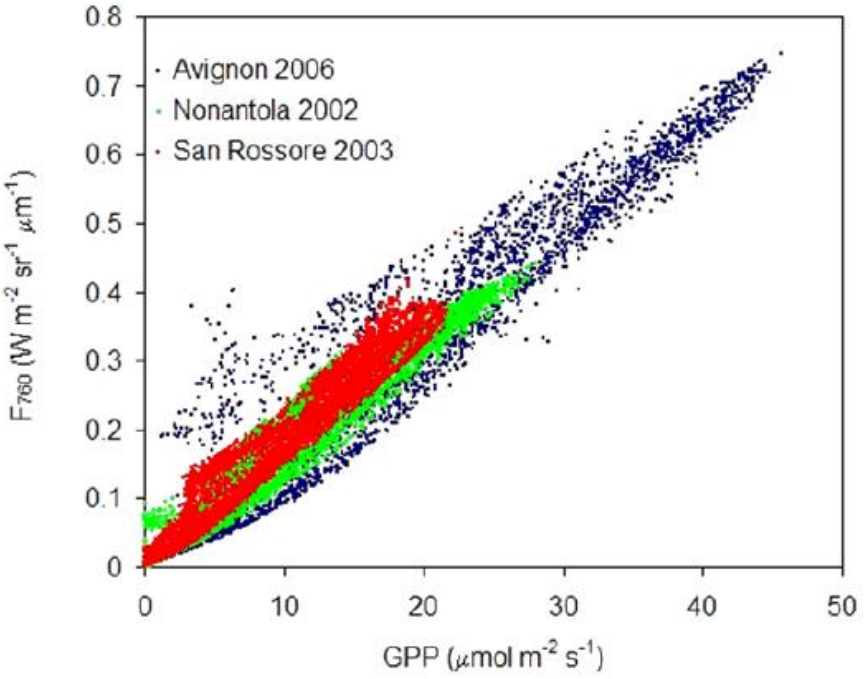




- Red edge position highly correlated with chlorophyll content, while red-edge slope highly correlated with leaf area index
- Sampling of red edge highly desirable to constrain parameters for Fs retrieval and signal interpretation

- Photosynthesis models including fluorescence being currently under development
- New modelling project about to start within FLEX phase-A studies.





(Figures from F. Magnani et al., 4th International Workshop on Remote Sensing of Vegetation Fluorescence, Valencia, Spain, 15-17/11/2010)

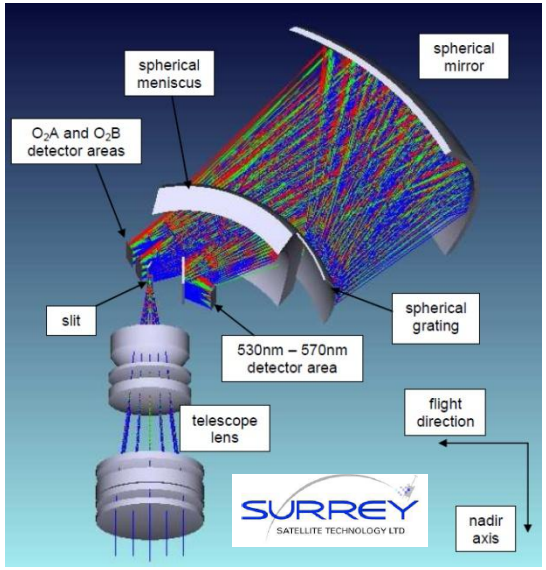
FLORIS instrument requirements

- **Broad Mission configuration**: FLORIS in tandem with S-3
  - ~815 km altitude
  - Local solar time: 10:00 LTDN
  - Temporal co-registration with S-3 < 6s
- **Mission Duration**
  - At least 3 full vegetation cycles
  - Target of 5 years
- **Spectral range** 520 nm to 800 nm
- **Spectral resolution** between 0.1 and 0.3 nm in core spectral range (Oxygen bands and red-edge)
- **Ground resolution** 300 m (500 m to enhance SNR)
- **Swath width** > 120 km – goal 150 km
- High imaging and spectral performance requirements

FIMAS Instrument configurations

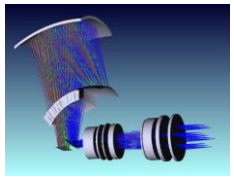
- FIMAS: FLEX precursor instrument study for FLEX-S3 low cost tandem approach
- Two examples of grating spectrometer from preparatory studies
- Complete spectral range provided by
  - Concept 1 - single instrument for concept 1 (80 mm aperture)
  - Concept 2 - double spectrometer (large aperture (80 mm x 100mm) and small aperture (~20mm))
- Compact spectrometers, volume optimisation performed
- PRI (Photochemical Reflectance Index) channels implemented
- Conclusion: Budget 75kg, 60W (Earth Explorer 8 compatible)

Concept 1

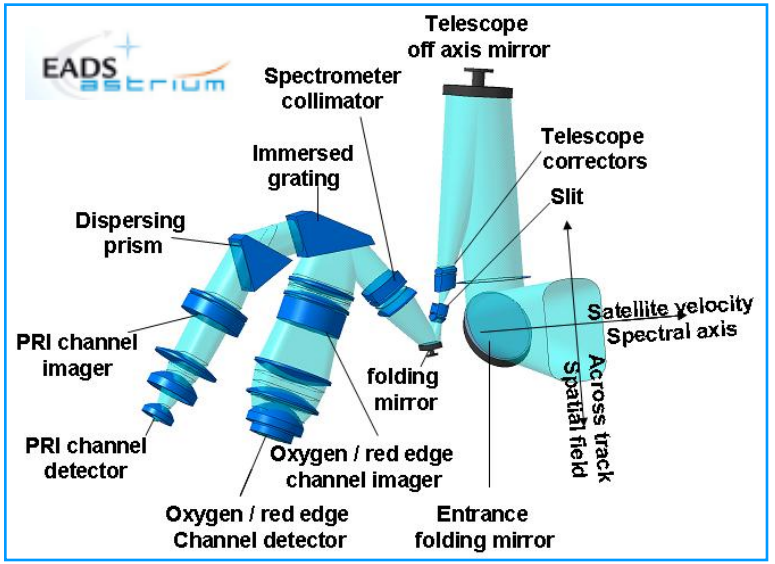


FIMAS-N

FIMAS-W

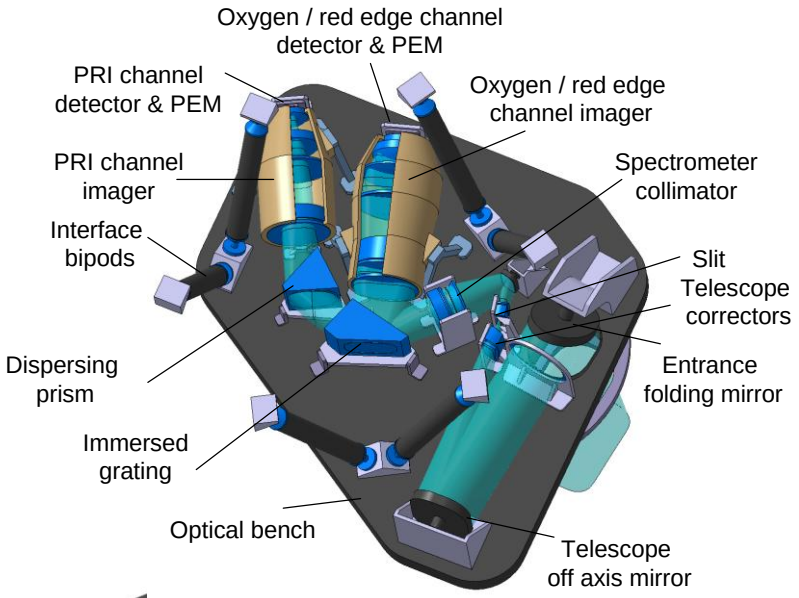


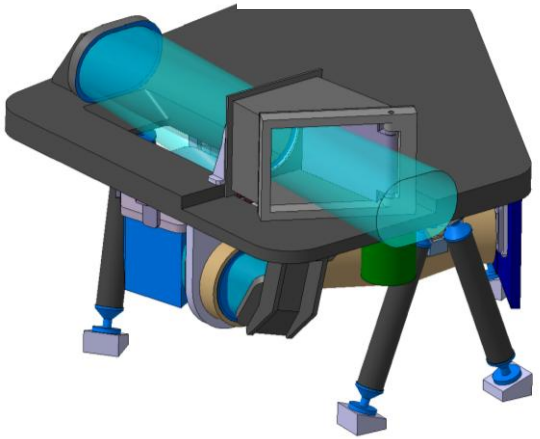
Concept 2



Instrument configuration – example

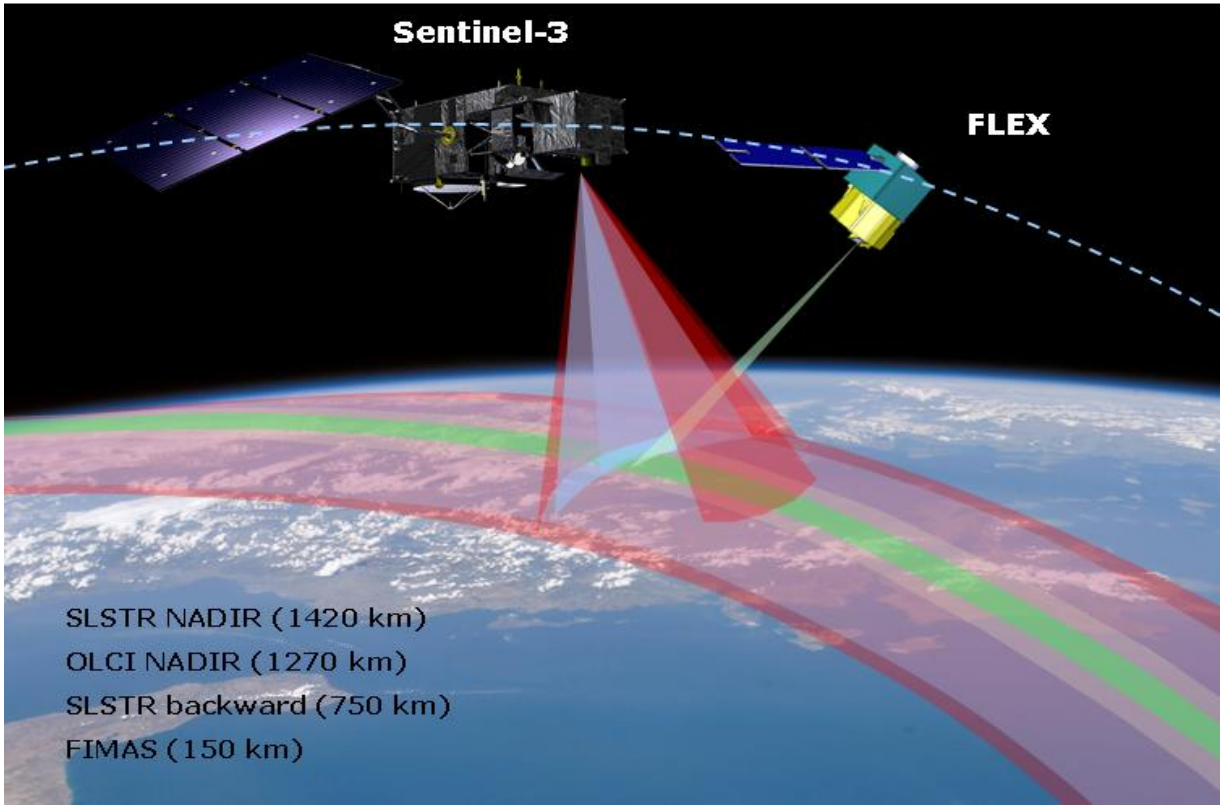
- Immersed grating spectrometer
- Mass ~73 kg
- Power ~60 W
- Data rate ~60 Mbit/s
- Volume ~65 x 63 x 50 cm^3, including
  - radiometric calibration mechanism
  - polarisation scrambler
  - CCD detectors and processing electronics
  - margin
- Design compatible with
  - 150 km swath width
  - decrease of spatial resolution at 450 km swath edge expected





Summary

- **FLEX** has been proposed under a **new configuration in tandem with Sentinel-3**
- Mission concept designed so that a **complete characterisation of photosynthetic rates** is possible
  - Full spectrum of chlorophyll fluorescence
  - PRI important to complement fluorescence in the modelling of plant photochemistry.
  - Red-edge important to improve retrievals – LAI, Cab…
- Current measurement approach supported by field campaigns
- Suitable instrument configuration identified
- Phase A of FLEX about to start



Thank you for your attention!

Matthias Drusch (matthias.drusch@esa.int)

Stefan Kraft (stefan.kraft@esa.int)

Jose Moreno (jose.moreno@uv.es)