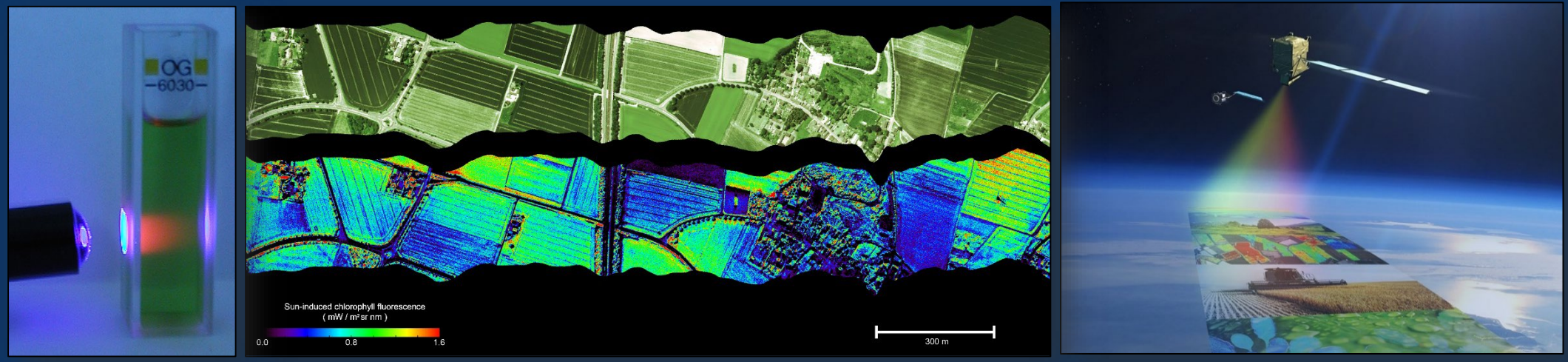
Institut für Bio- und Geowissenschaften
IBG-2: Pflanzenwissenschaften

Constraining plant mediated carbon and water fluxes by means of **solar-induced fluorescence (SIF)** – HyPlant airborne imaging spectrometer

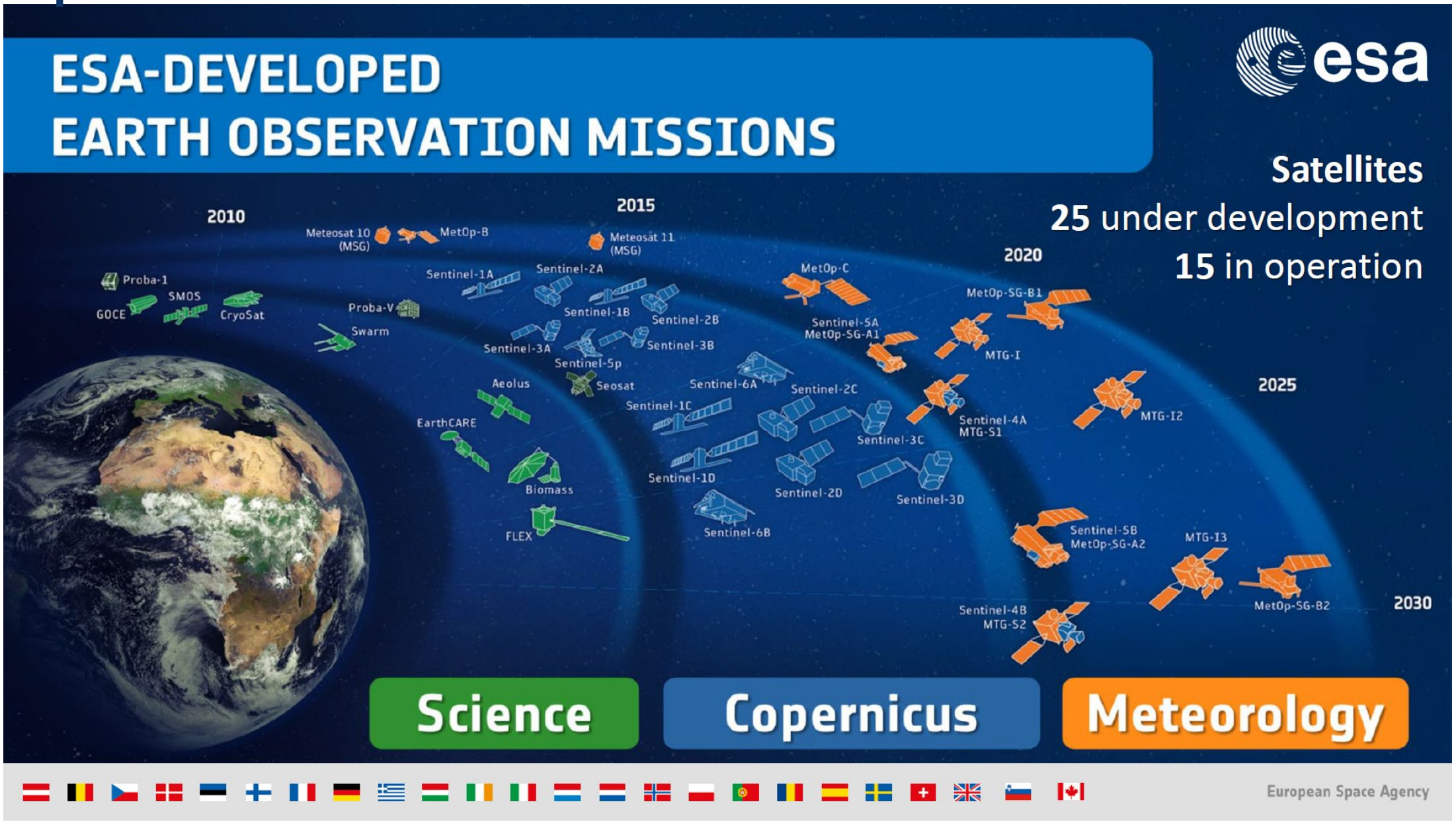
Uwe Rascher, Bastian Siegmann, Patrick Rademske (operator), Stephanie Baum (administration)

* Forschungszentrum Jülich, Institute of Bio- and Geosciences, IBG-2: Plant Sciences, Germany



LIASE – online - 25 Jan 2021

FLEX Satellite Mission will become the 8th Earth Explorer of ESA



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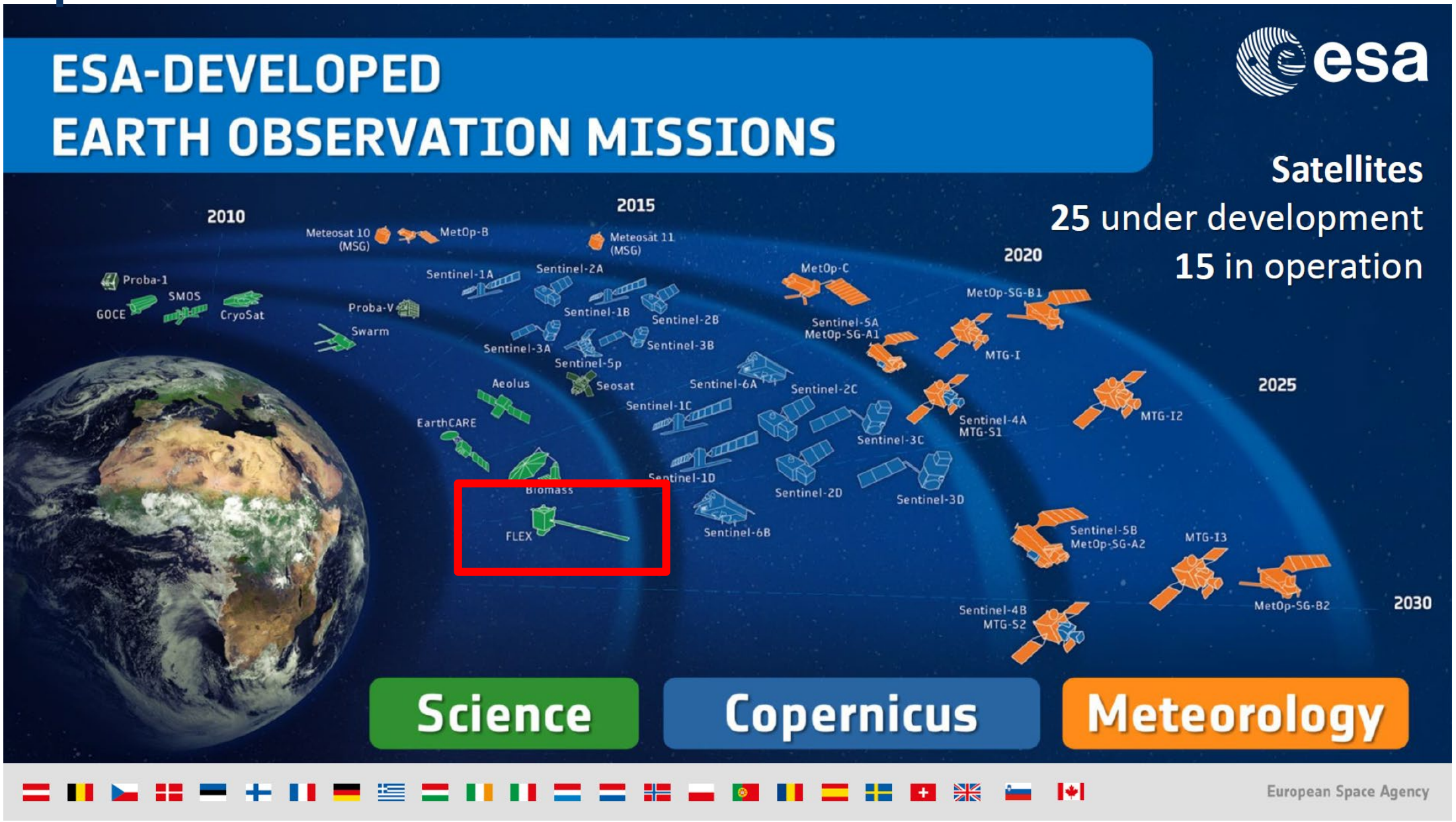

FLEX Satellite Mission will become the 8th Earth Explorer of ESA

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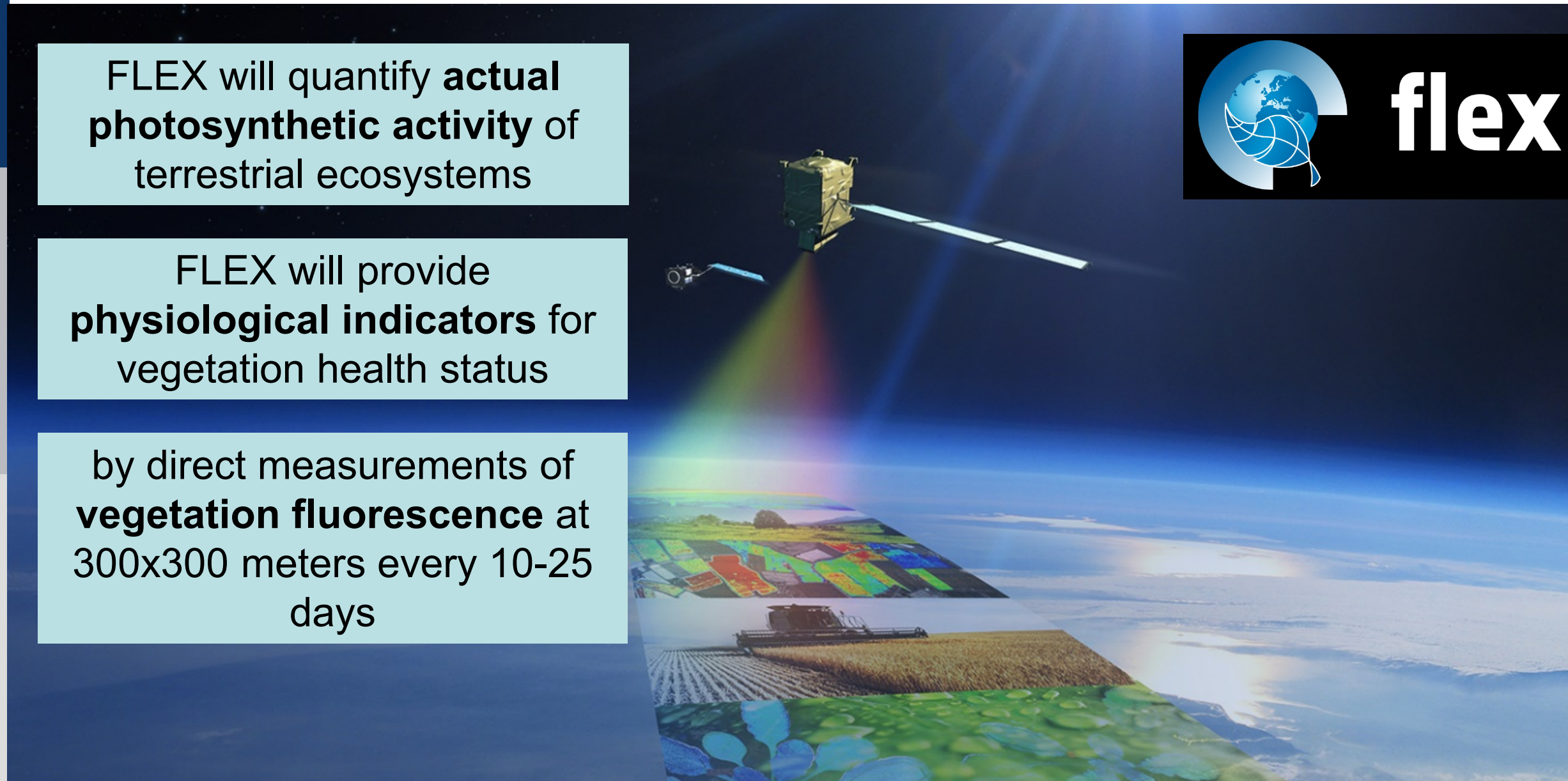
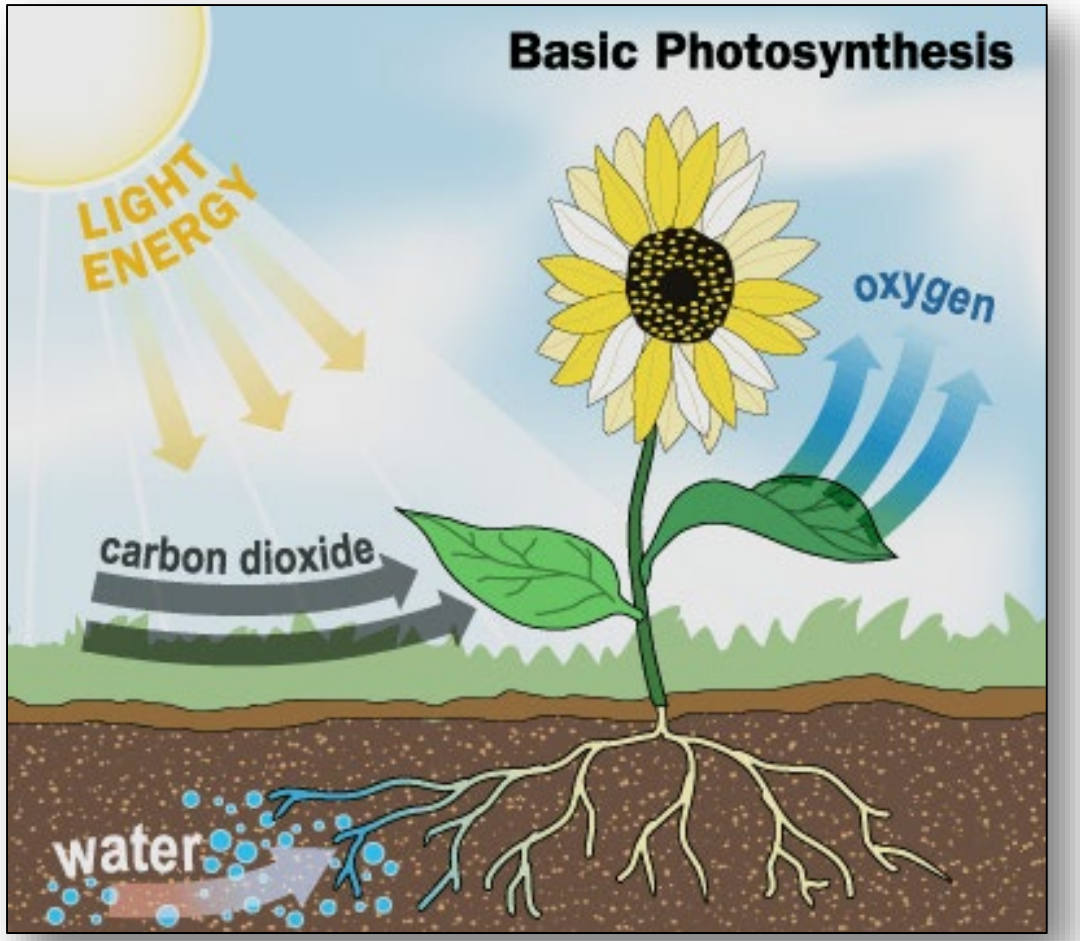
FLEX will quantify **actual photosynthetic activity** of terrestrial ecosystems

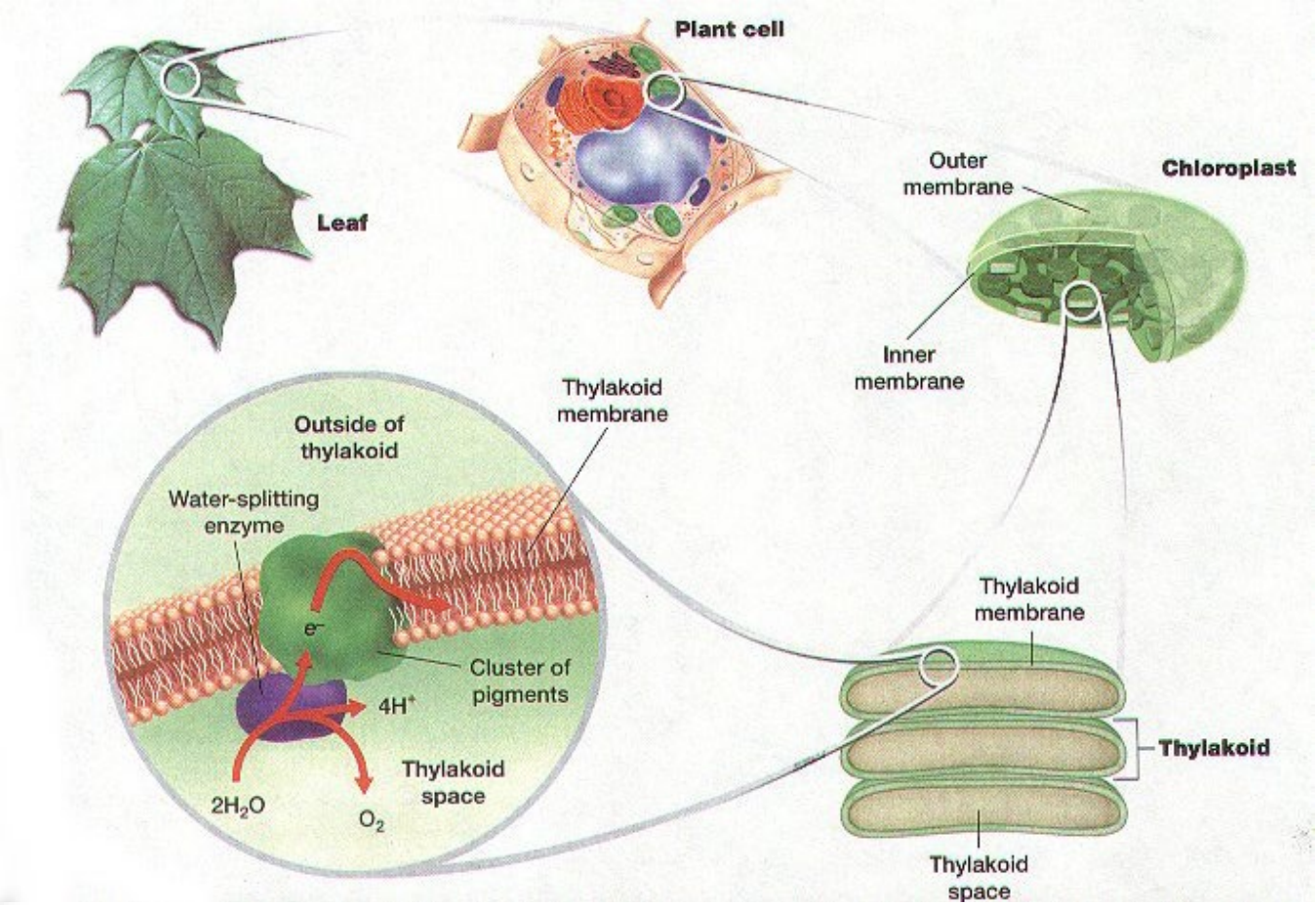
FLEX will provide **physiological indicators** for vegetation health status

by direct measurements of **vegetation fluorescence** at 300x300 meters every 10-25 days

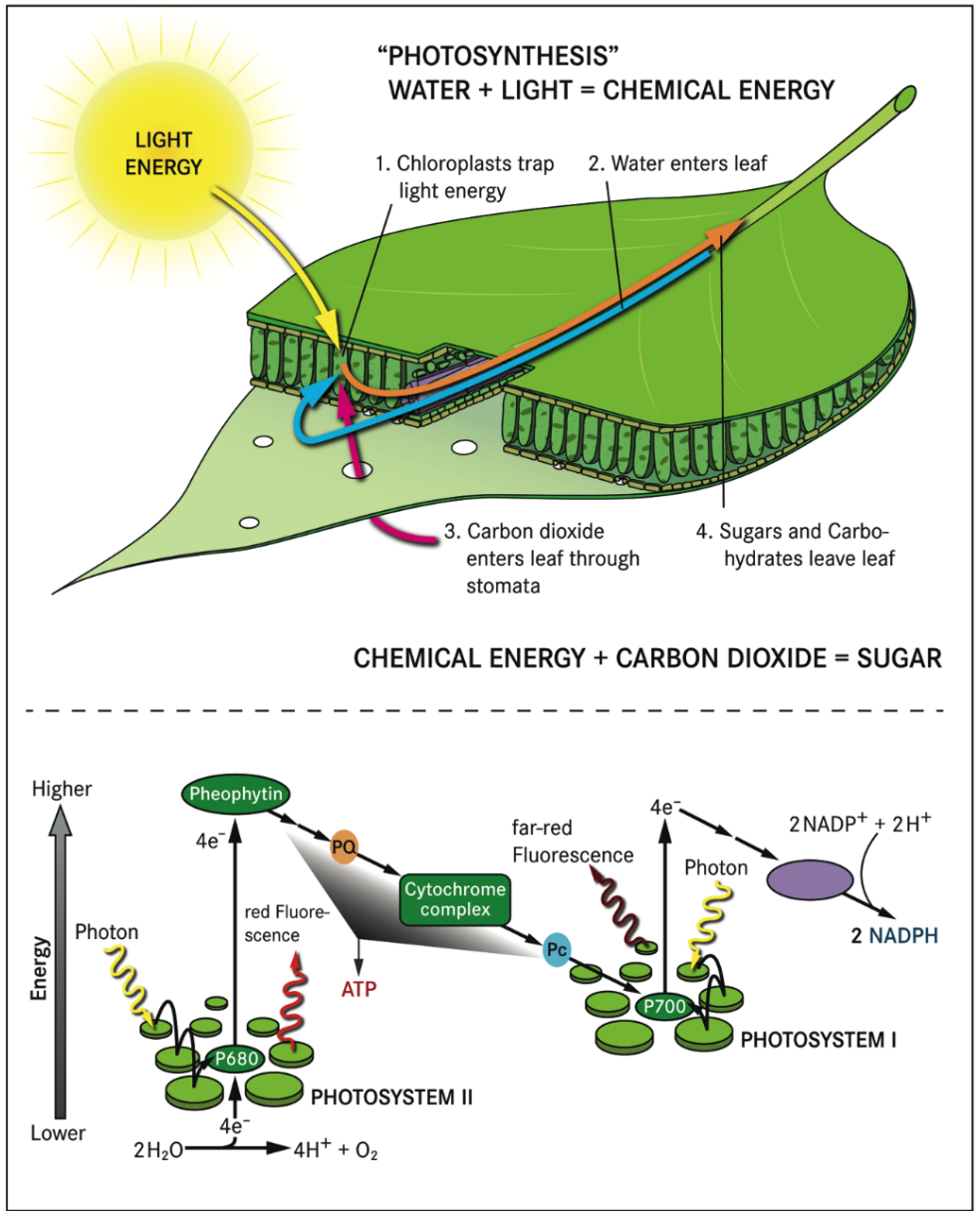


Photosynthesis: The fundamental biophysical and biochemical process to sustain life on earth



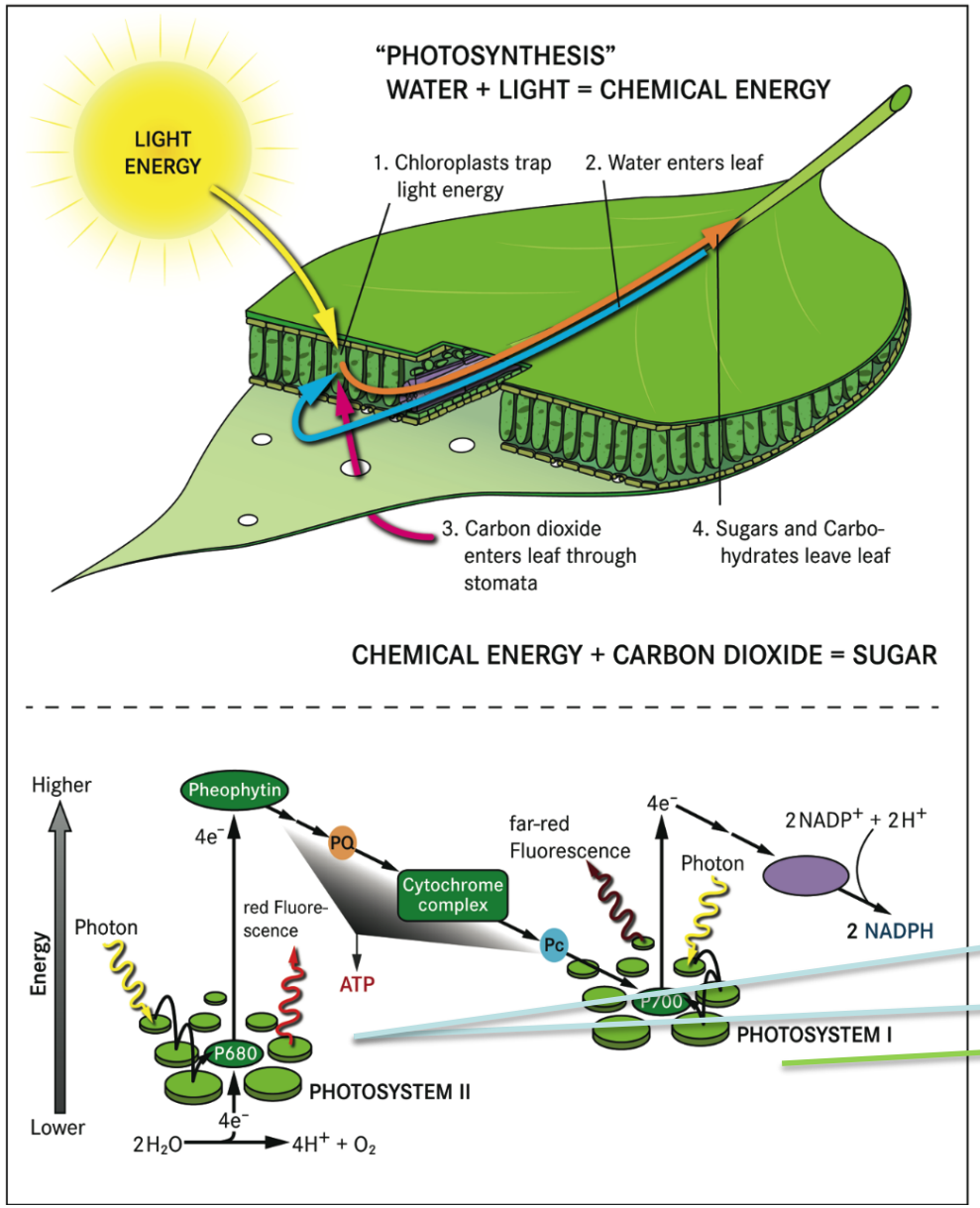


The origin of fluorescence – an indicator for photosynthetic efficiency

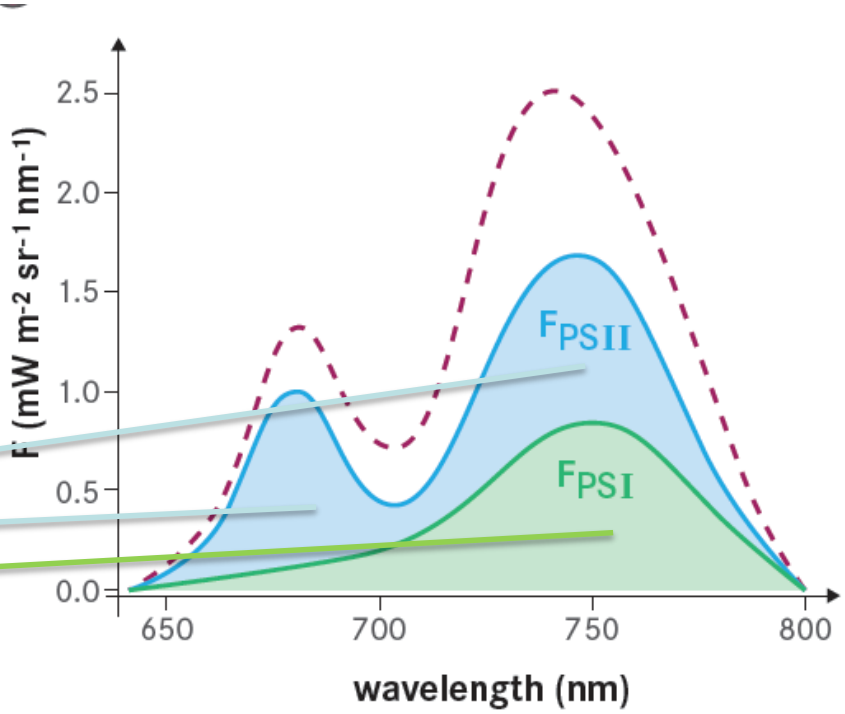


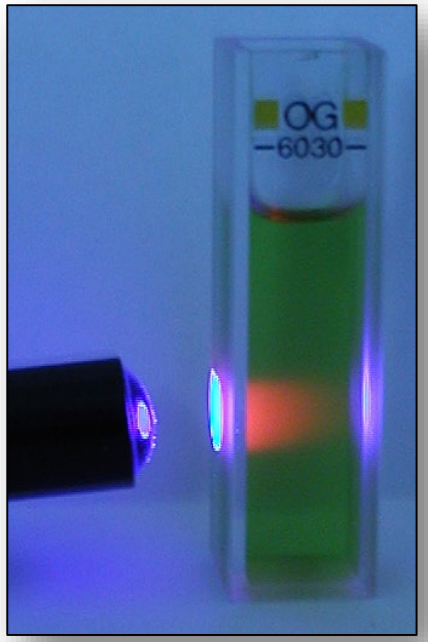
- Photosynthesis is a highly regulated process that involves a cascade of electron transfers (*Light reaction*) to fuel carbon fixation (*Calvin cycle*)
- Fluorescence is emitted from the cores of the photosynthetic machinery: Photosystems I and II

The origin of fluorescence – an indicator for photosynthetic efficiency

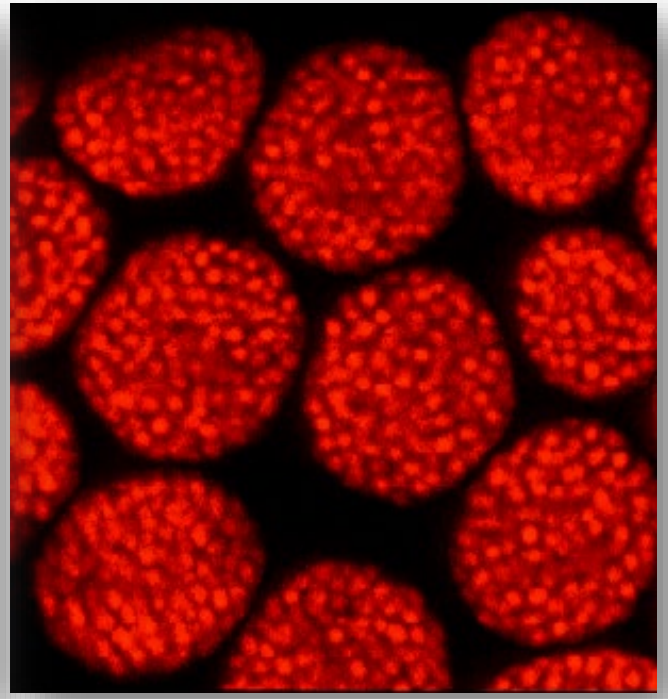


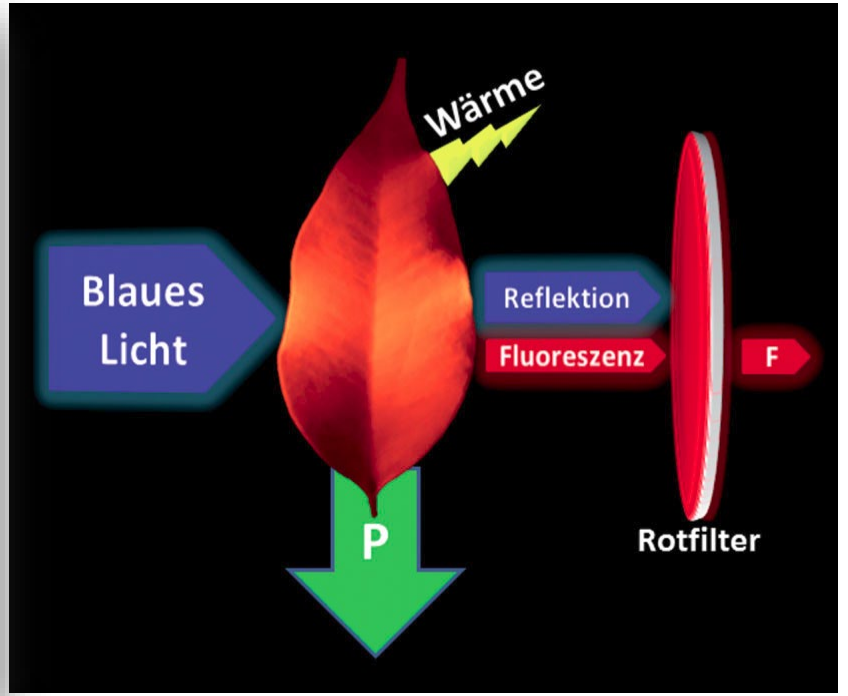
- Photosynthesis is a highly regulated process that involves a cascade of electron transfers (*Light reaction*) to fuel carbon fixation (*Calvin cycle*)
- Fluorescence is emitted from the cores of the photosynthetic machinery: Photosystems I and II
- Two-peak feature of fluorescence

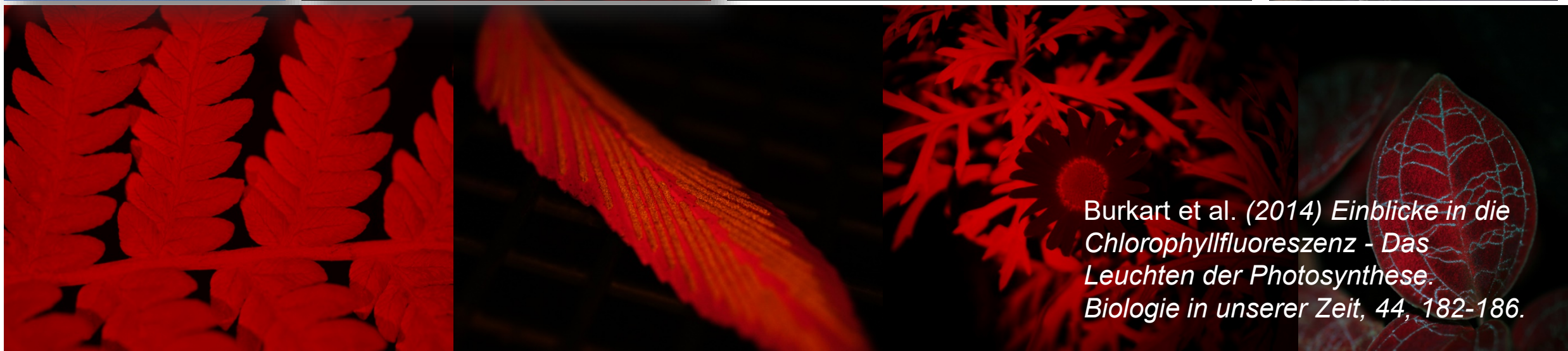




Pigments, photosystems and photosynthesis: a highly structured biological ‘super-complex’ that emits fluorescence

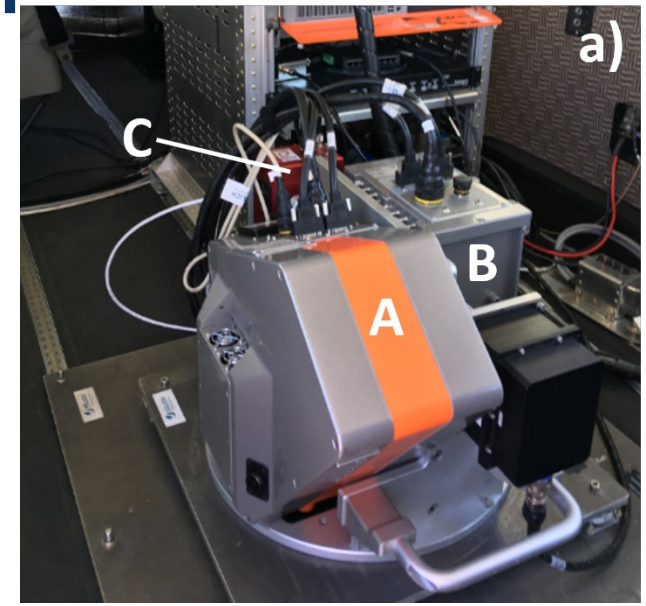


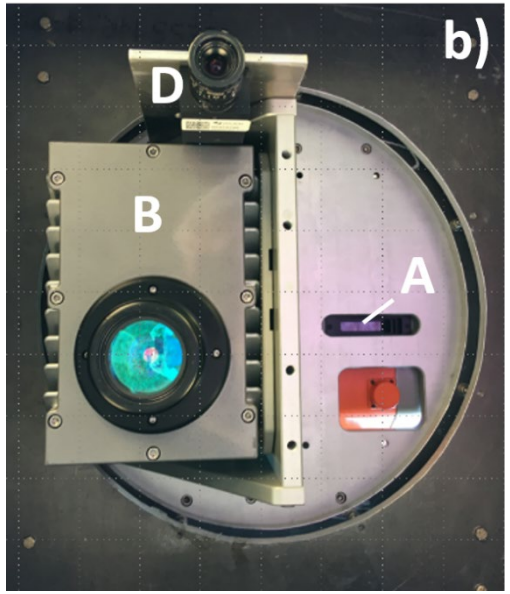




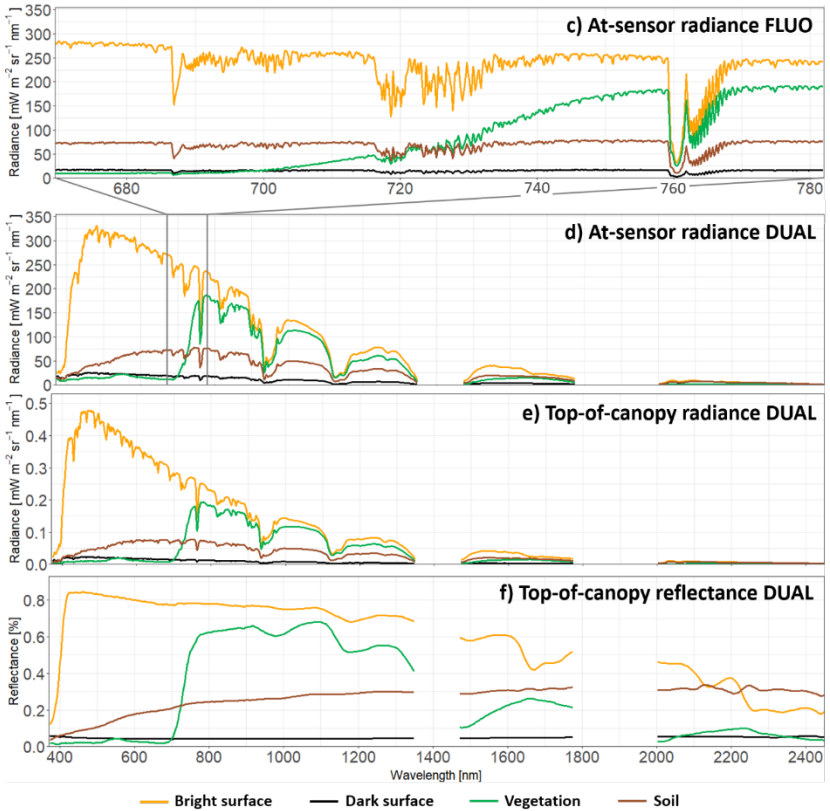
Burkart et al. *(2014) Einblicke in die Chlorophyllfluoreszenz - Das Leuchten der Photosynthese. Biologie in unserer Zeit, 44, 182-186.*

HyPlant: A high-resolution airborne spectrometer to map solar-induced fluorescence





- (A) DUAL module (380 – 2500 nm)
  VIS/NIR: 3-4 nm FWHM, 1.7 nm SSI, SNR >510
  SWIR: 13 nm FWHM, 5.5 nm SSI, SNR >1100
- (B) FLUO module (670 – 780 nm)
  0.25 nm FWHM, 0.11 nm SSI, SNR >210



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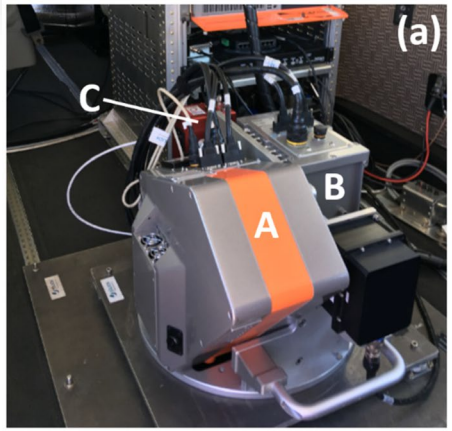
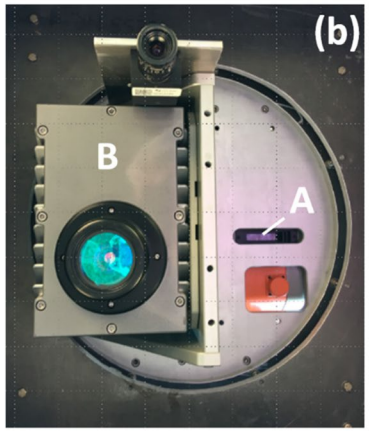
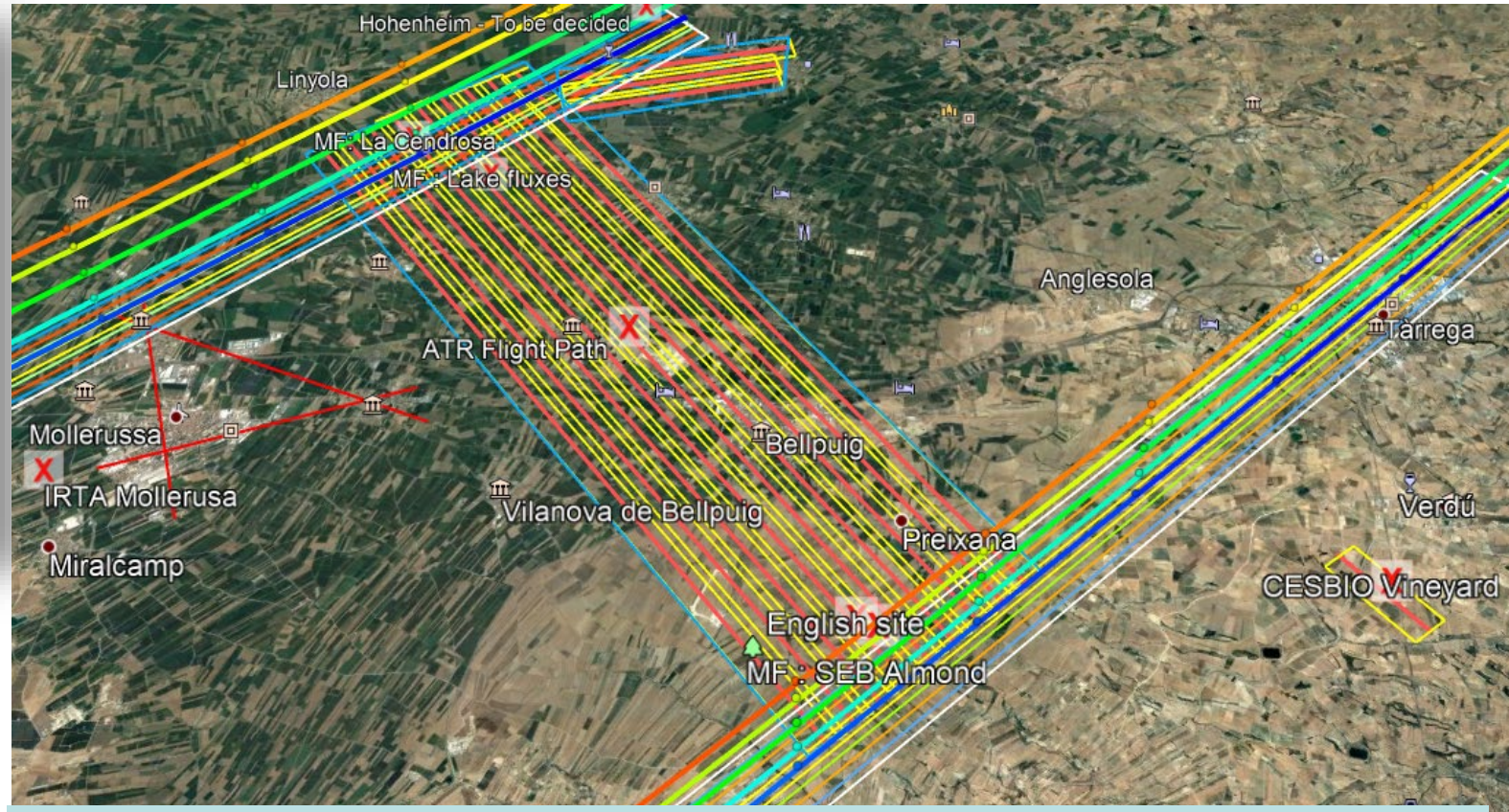




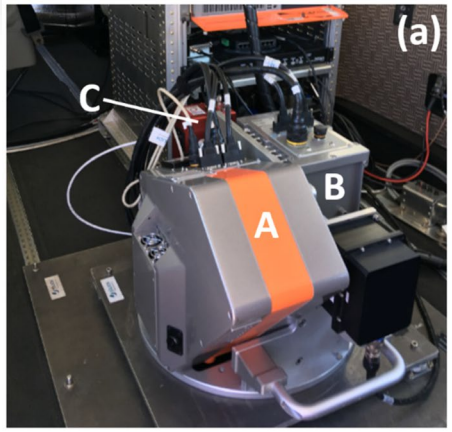


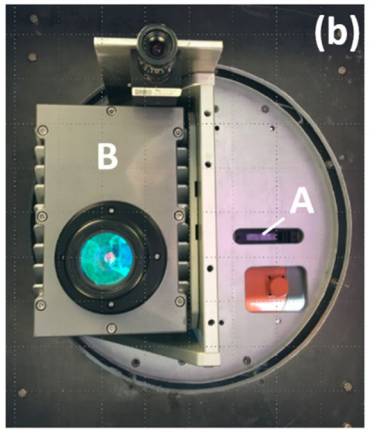
maps (1-3 m pixel resolution) of

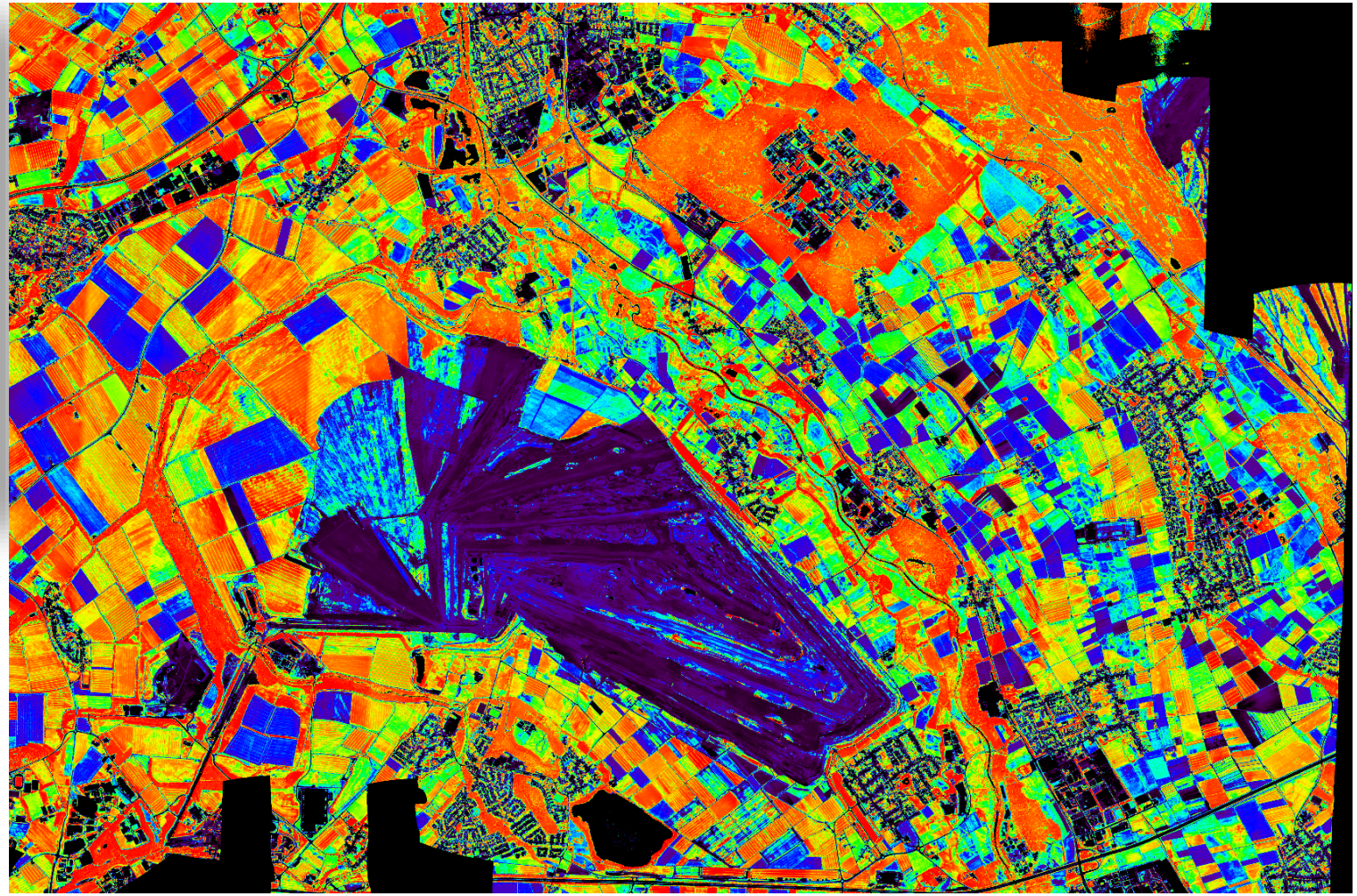
- top-of-canopy radiance & reflectance (400 – 2500nm)
- solar-induced fluorescence (SIF_{760}, SIF_{687})
- vegetation indices (NDVI, EVI, PRI; etc)

Rascher et al. (2015) *Global Change Biology, 21*, 4673–4684
Siegmann et al. (2019) *Remote Sensing, 11*, article no. 2760

HyPlant: A high-resolution airborne spectrometer to map solar-induced fluorescence







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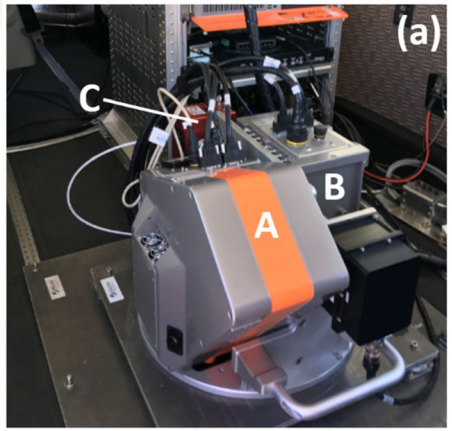
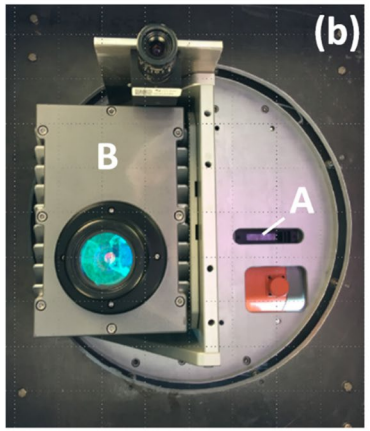
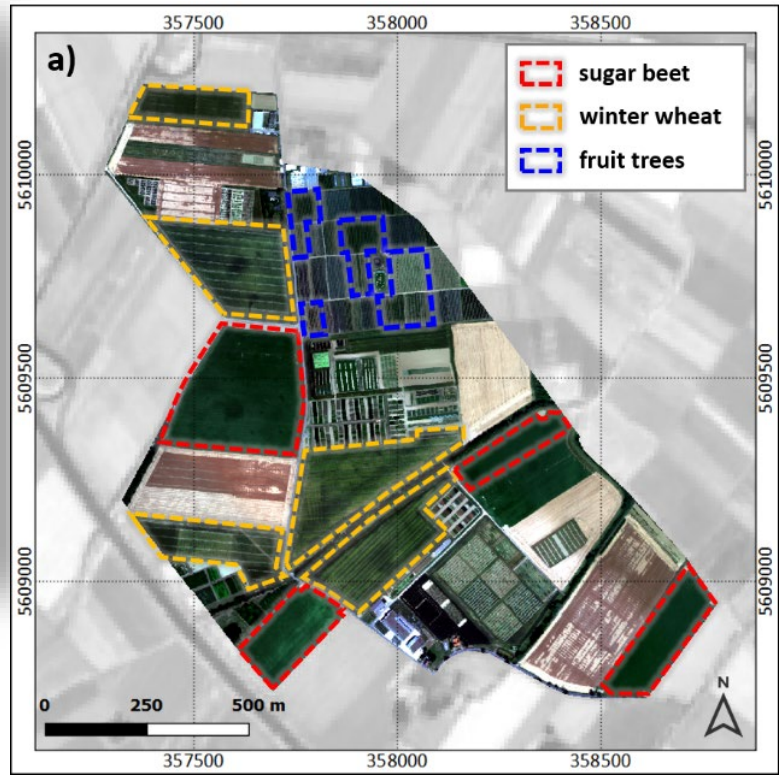
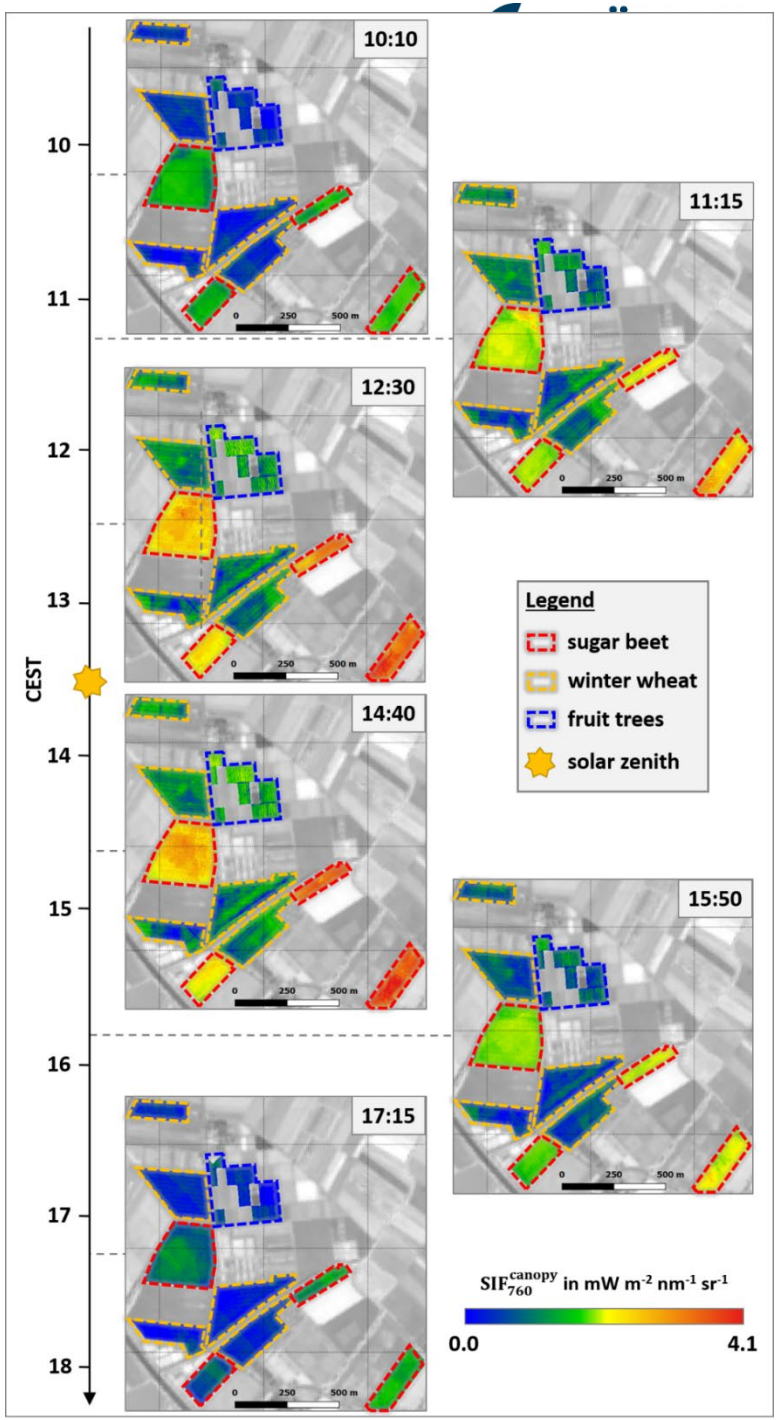






Campus Klein-Altendorf, Bonn University



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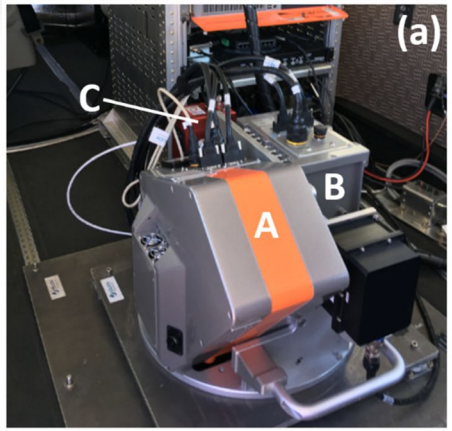
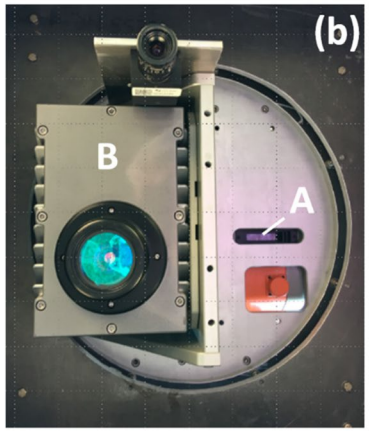
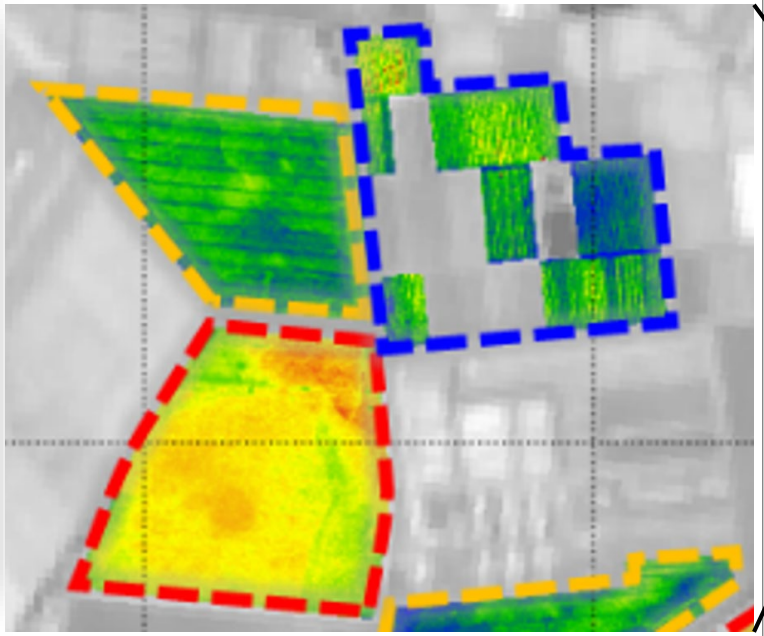
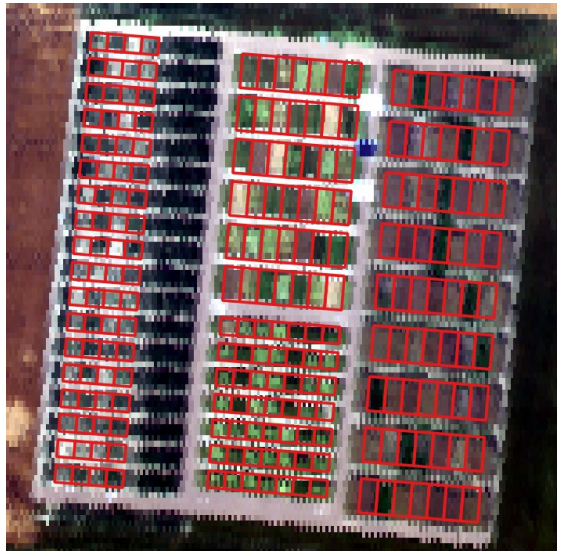
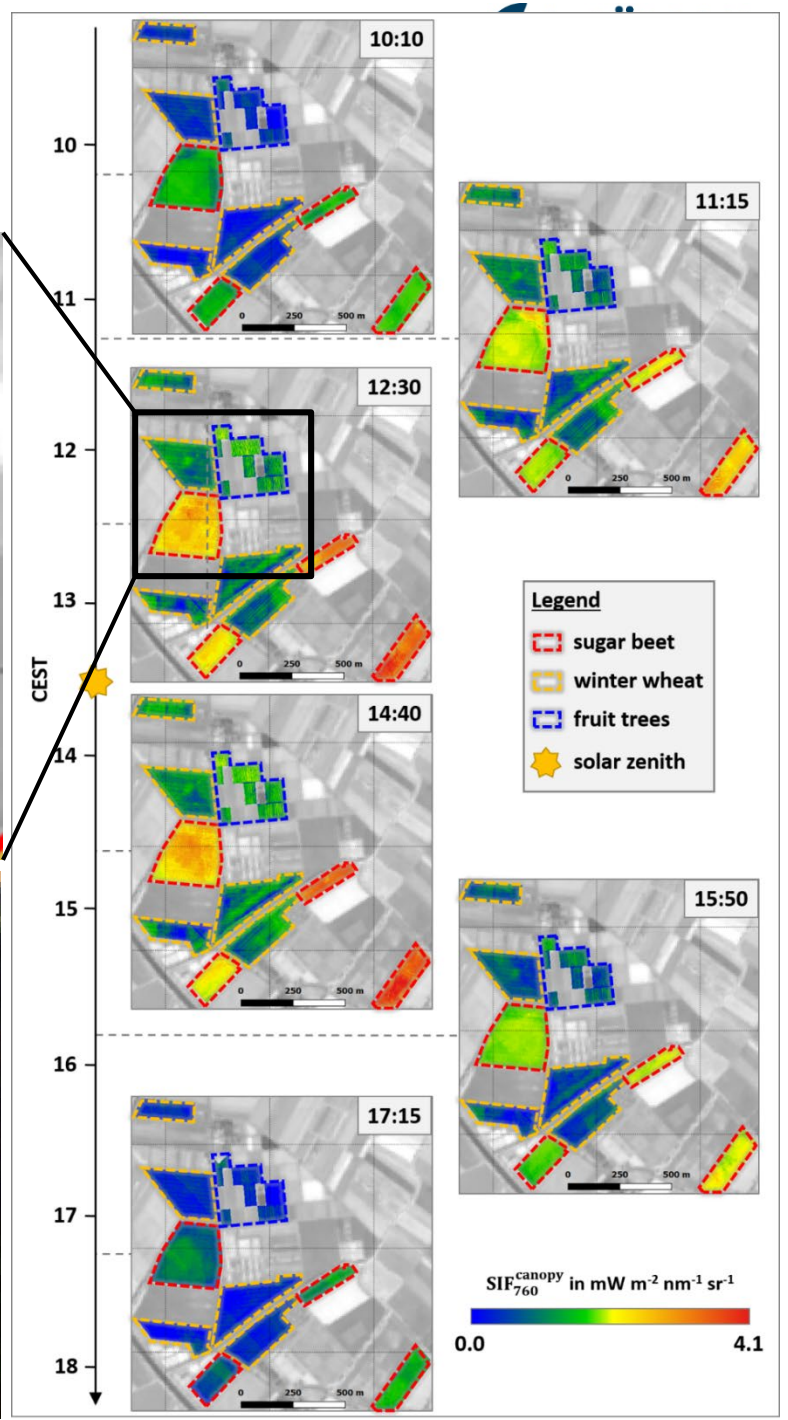






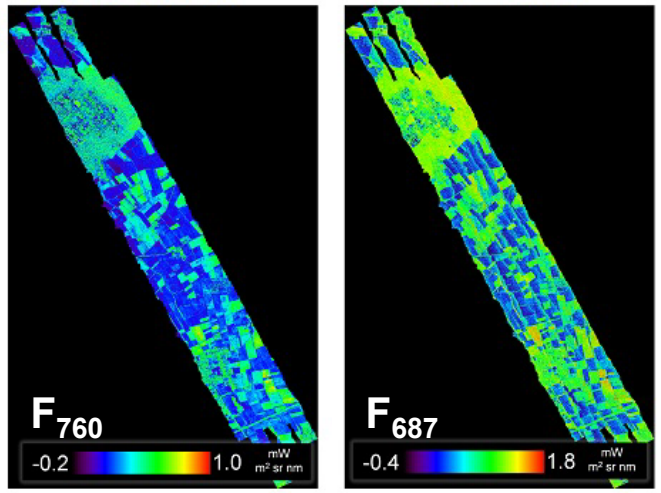


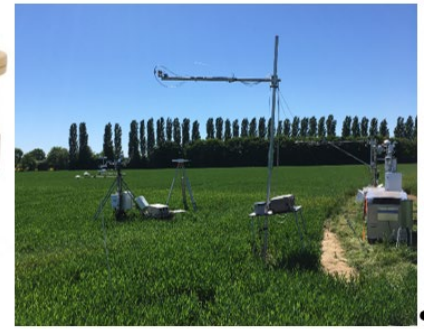


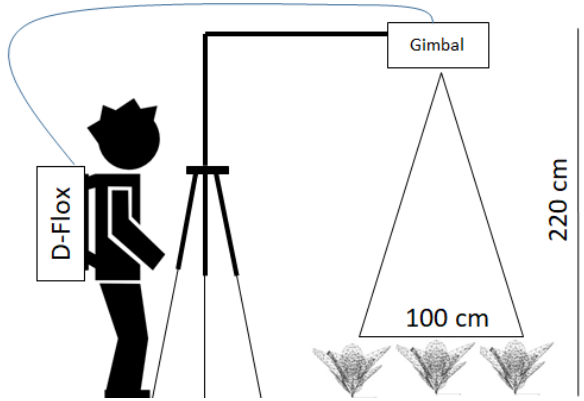
Rascher et al. (2015) *Global Change Biology, 21*, 4673–4684
Siegmann et al. (2019) *Remote Sensing, 11*, article no. 2760

Summary: Fluorescence during the 2021 LIASE campaign

- We aim to have a complete mapping of the LIASE site and deliver quantitative data of **solar-induced fluorescence (SIF)**, surface radiance & reflectance, and vegetation indices
- **Ground based measurements** of SIF and reflectance at selected sites (in cooperation with Yves Goulas)
- Reference measurements of **plant photosynthesis and related plant traits** of selected crops / vegetation types







HyPlant: list of publications

- 2015 -

Rascher U. et al. (2015) Sun-induced fluorescence - a new probe of photosynthesis: First maps from the imaging spectrometer HyPlant. *Global Change Biology*, 21, 4673–4684; doi: 10.1111/gcb.13017.

Rossini M. et al. (2015) Red and far red Sun-induced chlorophyll fluorescence as a measure of plant photosynthesis. *Geophysical Research Letters*, 42, 1632-1639.

Simmer C. et al. (2015) Monitoring and modeling the terrestrial system from pores to catchments – the Transregional Collaborative Research Center on Patterns in the Soil-Vegetation-Atmosphere System. *BAMS – Bulletin of the American Meteorological Society*, 96, 1765-1787.

- 2016 -

Wieneke S., Ahrends H., Damm A., Pinto F., Stadler A., Rossini M. & Rascher U. (2016) Airborne based spectroscopy of red and far-red sun-induced chlorophyll fluorescence: Implications for improved estimates of gross primary productivity. *Remote Sensing of Environment*, 184, 654-667, doi: 10.1016/j.rse.2016.07.025

- 2017 -

Drusch M. et al. (2017) The FLuorescence EXplorer mission concept - ESA's Earth Explorer 8. *IEEE Transactions on Geoscience and Remote Sensing*, 55, 1273-1284, doi: 10.1109/TGRS.2016.2621820.

Middleton E.M.et al. (2017) The 2013 FLEX – US Airborne Campaign at the Parker Tract Loblolly Pine Plantation in North Carolina, USA. *Remote Sensing*, 9, article no. 612, doi:10.3390/rs9060612.

HyPlant: list of publications

- 2018 -

Colombo R. et al. (2018) Variability of sun-induced chlorophyll fluorescence according to stand age-related processes in a managed Loblolly pine forest. *Global Change Biology*, 24, 2980-2996, doi: 10.1111/gcb.14097.

Gerhards M., Schlerf M., Rascher U., Udelhoven T., Juszczak R., Alberti G., Miglietta F., & Inoue Y (2018) Remote sensing of water stress symptoms based on airborne optical and thermal images. *Remote Sensing*, 10, article no. 1139, doi: 10.3390/rs10071139.

von Hebel C. et al. (2018) Understanding soil and plant interaction by combining ground-based quantitative electromagnetic induction and airborne hyperspectral data. *Geophysical Research Letters*, doi: 10.1029/2018GL078658

- 2019 -

Bandopadhyay S. et al. (2019) HyPlant derived sun-induced fluorescence - a new opportunity to disentangle complex vegetation signals from diverse vegetation types. *Remote Sensing, 11*, article no. 1691, doi: 10.3390/rs11141691.

Gamon J.A., Somers B., Malenovsky Z., Middleton E., Rascher U. & Schaepman M., (2019) Assessing vegetation function with imaging spectroscopy. *Surveys in Geophysics, 40*, 489-513, doi: 10.1007/s10712-019-09511-5.

Liu X. et al. (2019) Downscaling of solar-induced chlorophyll fluorescence from canopy level to photosystem level using a random forest model. *Remote Sensing of Environment*, doi: 10.1016/j.rse.2018.05.035.

HyPlant: list of publications

- 2019 cont. -

Siegmann B. et al. (2019) The high-performance airborne imaging spectrometer HyPlant – From raw images to top-of-canopy reflectance and fluorescence products: Introduction of an automatized processing chain. *Remote Sensing, 11*, article no. 2760, doi: 10.3390/rs11232760.

Tagliabue G., Panigada C., Dechant B., Baret F., Cogliati S., Colombo R., Migliavacca M., Rademske P., Schickling A., Schüttemeyer D., Verrelst J., Rascher U., Ryu Y. & Rossini M. (2019) Exploring the spatial relationship between airborne-derived red and far-red sun-induced fluorescence and process-based GPP estimates in a forest ecosystem. *Remote Sensing of Environment, 231*, article no. 111272, doi: 10.1016/j.rse.2019.111272

Yang P., van der Tol C., Verhoef W., Damm A., Schickling A., Kraska T., Muller O. & Rascher U. (2019) Response of crops to a heat wave: Insights from airborne based reflectance and chlorophyll fluorescence measurement. *Remote Sensing of Environment, 231*, article no. 110996, doi: 10.1016/j.rse.2018.11.039.

- 2020 -

Pinto F., Celesti M., Acebron K., Alberti G., Cogliati S., Colombo R., Juszczak R., Matsubara S., Miglietta F., Palombo A., Panigada C, Pignatti S, Rossini M., Sakowska K., Schickling A., Schüttemeyer D., Stróżecki M., Tudoroiu M. & Rascher U. (2020) Dynamics of sun-induced chlorophyll fluorescence and reflectance to detect stress-induced variations in canopy photosynthesis. *Plant, Cell & Environment, 43*, 1637-1654, doi: 10.1111/pce.13754.

HyPlant: list of publications

- 2020 cont. -

Tagliabue G., Panigada C., Celesti M., Cogliati S., Colombo R., Migliavacca M., Rascher U., Rocchini D., Schüttemeyer D. & Rossini M. (2020) Sun-induced fluorescence heterogeneity as a measure of functional diversity. *Remote Sensing of Environment, 247*, article no. 111934, doi: 10.1016/j.rse.2020.111934.

Vila-Guerau de Arellan J. et al. (2020) CloudRoots: integration of advanced instrumental techniques and process modelling of sub-hourly and sub-kilometre land-atmosphere interactions. *Biogeosciences, 17*, 4375-4404, doi: 10.5194/bg-17-4375-2020.

- 2021 -

Hornero A., North P.R.J., Zarco-Tejada P.J., Rascher U., Martíne M.P., Migliavacca M. & Hernández-Clemente R. (2021) Assessing the contribution of understory sun-induced chlorophyll fluorescence through 3-D radiative transfer modelling and field data. *Remote Sensing of Environment, 253*, article no. 112195, doi: 10.1016/j.rse.2020.112195.

HyPlant: list of publications

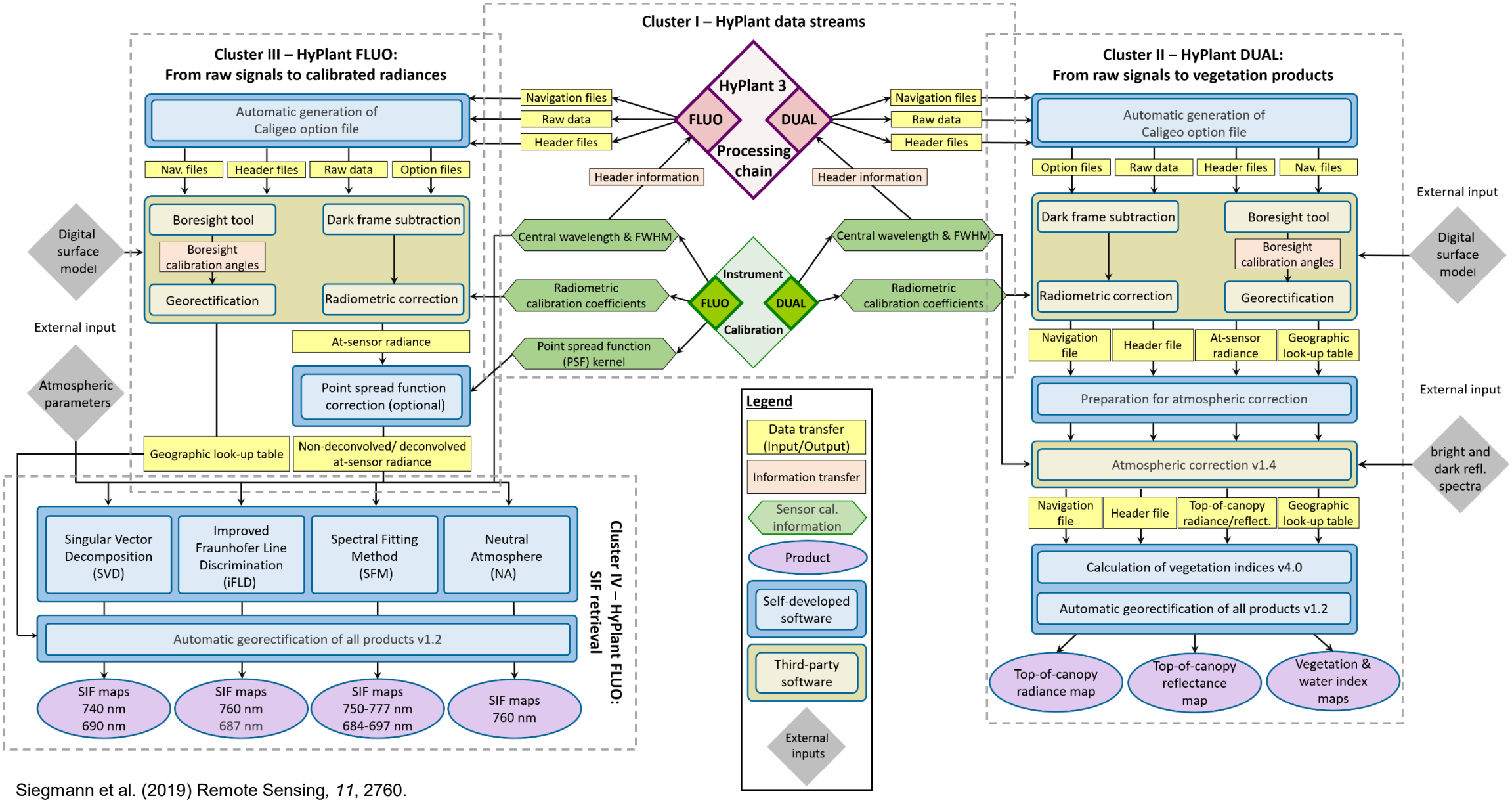
- recent reviews -

Damm A., et al. (2018) Remote sensing of plant-water relations: An overview and future perspectives. *Journal of Plant Physiology*, *227*, 3-19, doi: 10.1016/j.jplph.2018.04.012

Mohammed G.H., Colombo R, Middleton E.M., Rascher U., van der Tol C., Nedbal L., Goulas Y., Pérez-Priego O., Damm A., Meroni M., Joiner J., Cogliati S., Verhoef W., Malenovský Z., Gastellu-Etchegorry J.-P., Miller J.R., Guanter L., Moreno J., Moya I., Berry J.A., Frankenberg C. & Zarco-Tejada P.J. (2019) Remote sensing of solar-induced chlorophyll fluorescence (SIF) in vegetation: 50 years of progress. *Remote Sensing of Environment, 231*, article no. 111177, doi: 10.1016/j.rse.2019.04.030.

Jonard F., De Cannière S., Brüggemann N., Gentine P., Short Gianotti D.J., Lobet G., Miralles D.G., Montzka C., Pagán B.R., Rascher U. & Vereecken H. (2020) Value of sun-induced chlorophyll fluorescence for quantifying hydrological states and fluxes: current status and challenges. *Agricultural and Forest Meteorology, 291*, article no. 108088, doi: 10.1016/j.agrformet.2020.108088.

HyPlant processing scheme



Siegmann et al. (2019) Remote Sensing, *11*, 2760.

HyPlant imaging spectrometer