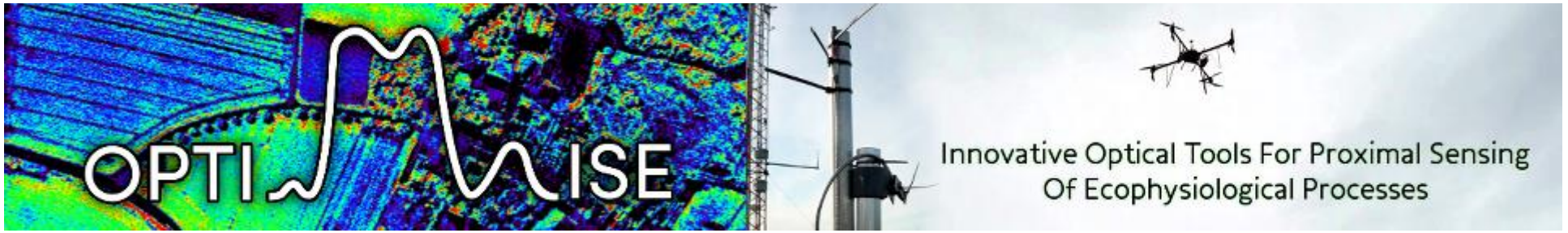

Field set up

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Palaiseau, France

Yves Goulas

COST is supported by the EU
Framework Programme Horizon 2020

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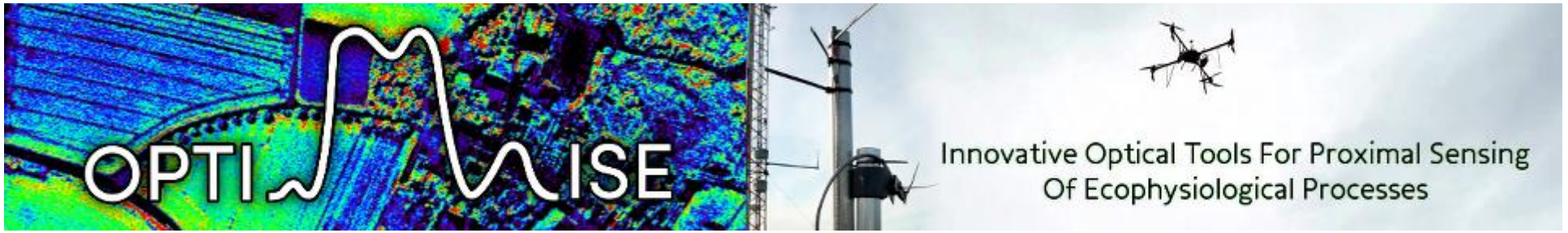
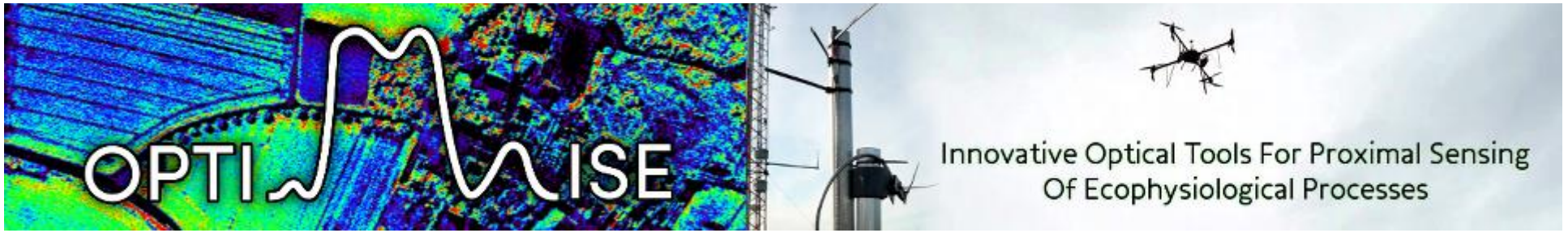


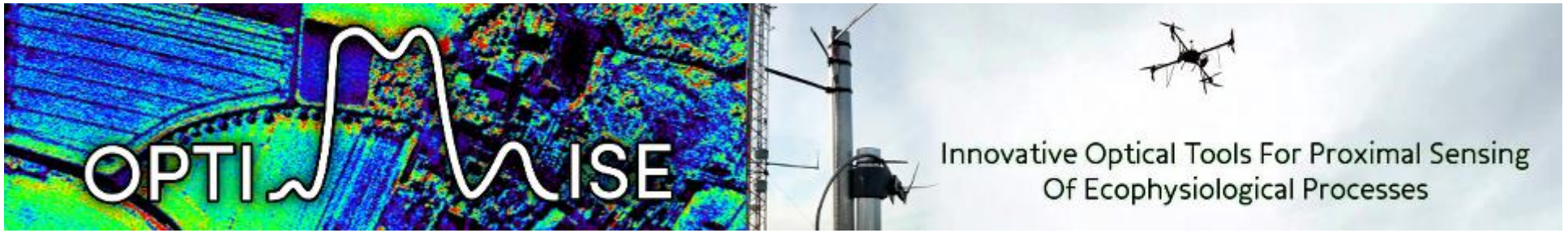
Paper 2 (Section 3?): Measurements protocols

- Current outline (section 3):
- 3.1 Operational characteristics
  - Single/dual beam spectrometers
  - Field of view
  - Reference standard
- 3.2 Field set up
- 3.3 Pre-processing
  - From raw data to radiance (calibration, dark, linearity, spectral)
  - Atmospheric corrections
- 3.4 Post-processing (SIF retrieval)



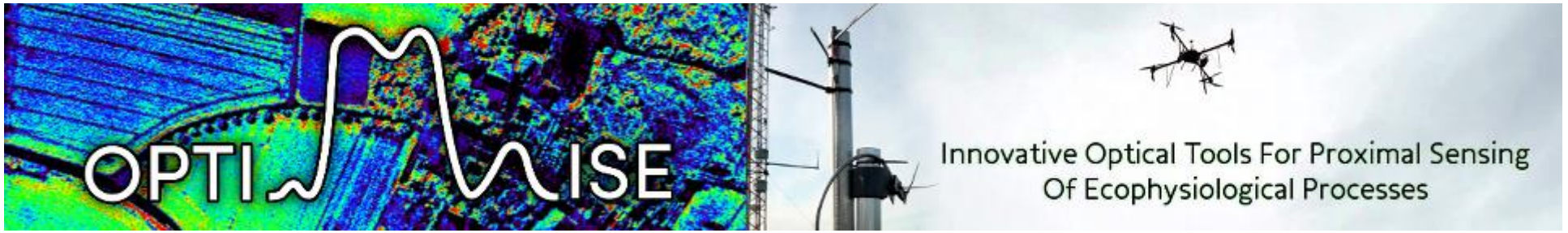
Basic guidelines

- Target :
  - New user, address state of the art, issues, unresolved points
  - More experimented user: -> standard, reference ?
- From Reflectance -> Fluorescence: point out differences , fluorescence specific
- Scope :
  - Ground measurements =low altitude < 100 m (pods, towers, cranes ≠ satellite, airborne, drones)
  - Non-imaging: mention imaging systems and measurements
  - Canopy : leaf measurements: Fluowat, active (PAM), spectrofluorometers
- Not a research paper : current literature -> bibliography



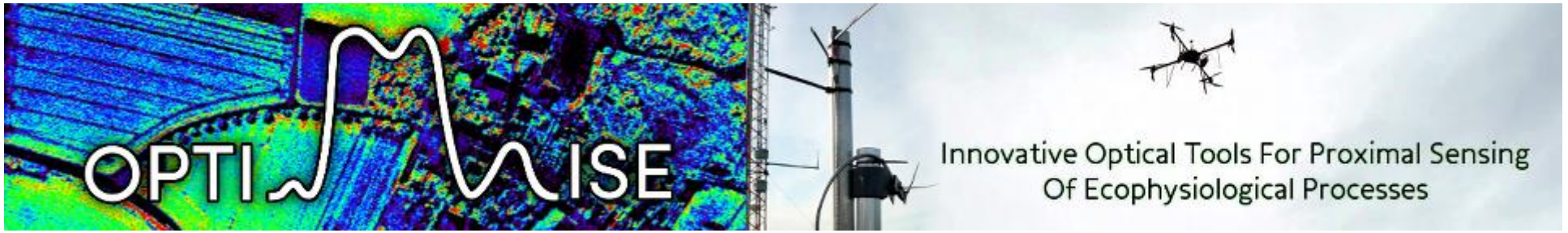
Field set up

- Field set up <–> Operational characteristics (Alasdair)
- 1. Instrument location and installation
- 2. Field of view, target size, measuring distance
- 3. Viewing angle
- 4. Measuring the reference
- 5. Meteorological conditions, illumination geometry
- 6. Time of measurements, sampling rate,…
- 7. Fluorescence standards
- 8. Retrieval of the fluorescence yield



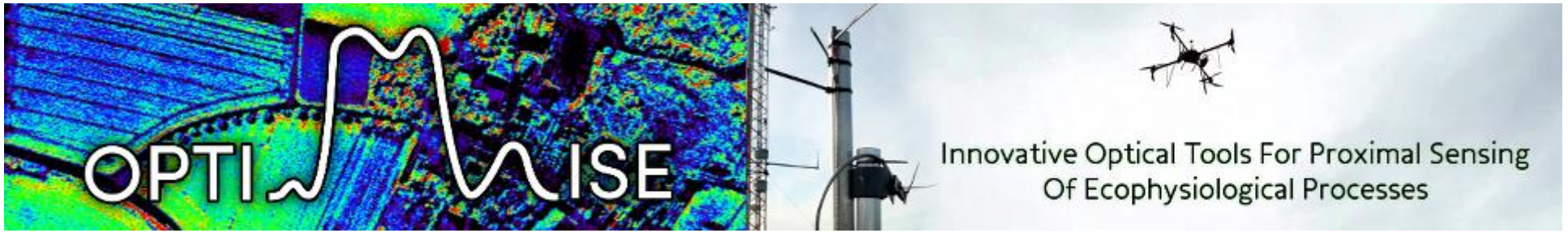
Instrument location and installation

- Installation
  - Pod, tripod: Julitta 2016, Rossini 2010, Cogliati 2015, …
  - Scaffolding; Fournier 2012,
  - Tower (EC): Louis 2005, Cogliati 2015, Yang 2015, …
  - Aerial bucket: Rossini 2015,…
  - Crane: Daumard 2010,2012, Goulas 2017
- Issues
  - Avoid shadowing, illumination interferences
  - Trade-off between target size, FOV, distance



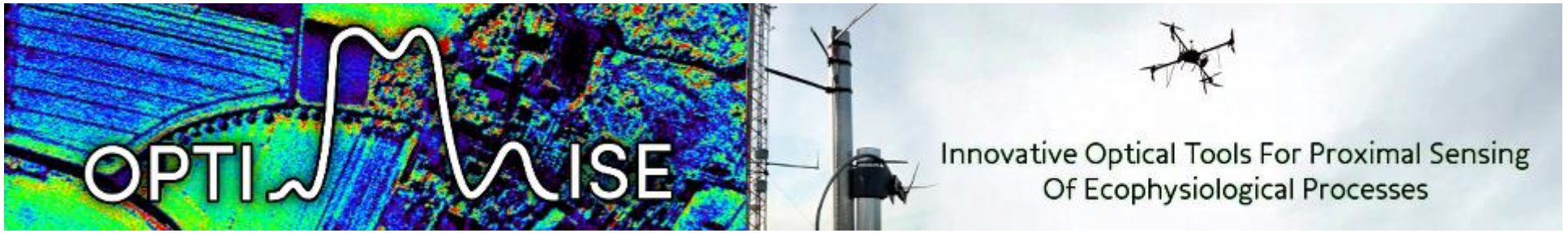
Field of view (FOV), target size (TS), measuring distance (MD)

- General relationship : TS = FOV x TS
- Field of view (FOV) (Instrumental) :
  - bare optic fiber / collimator (custom, commercial): change FOV
  - Relationship between FOV, NA, fiber core, focal length -> paper 1
  - Viewing angle -> paper 2
- Target size
  - wrt canopy architecture : leaf size, clustering, heterogeneity -> paper 2
- Measuring distance
  - Atmospheric correction -> paper 2 or 3?
  - Instrument installation
- wrt application: Cal/Val, crop/ecosystem monitoring



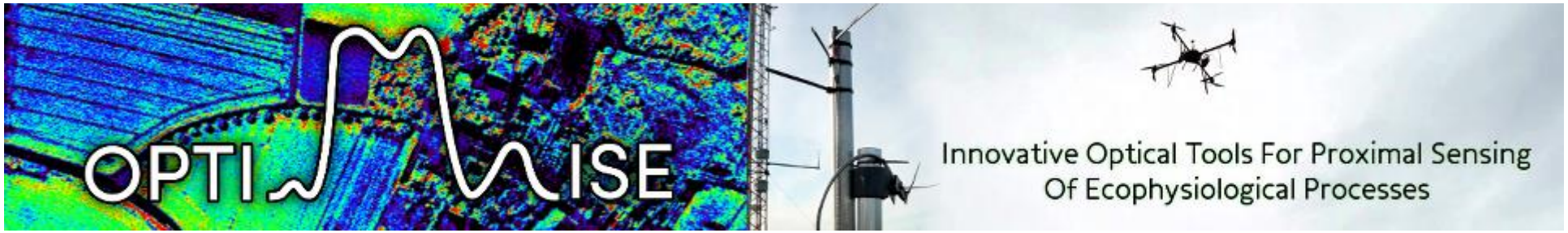
Viewing angle

- Important parameter to consider:
  - Bi-directional properties of canopy reflectance and fluorescence
  - Cal/Val of satellite/airborne data
  - Nadir view could be an issue for measurements from a tower
  - To be consider for large FOV
- Poorly studied:
- Off-nadir measurements : azimuth angle (observer, sun) + (observer, canopy) (e.g. crops, vineyard)



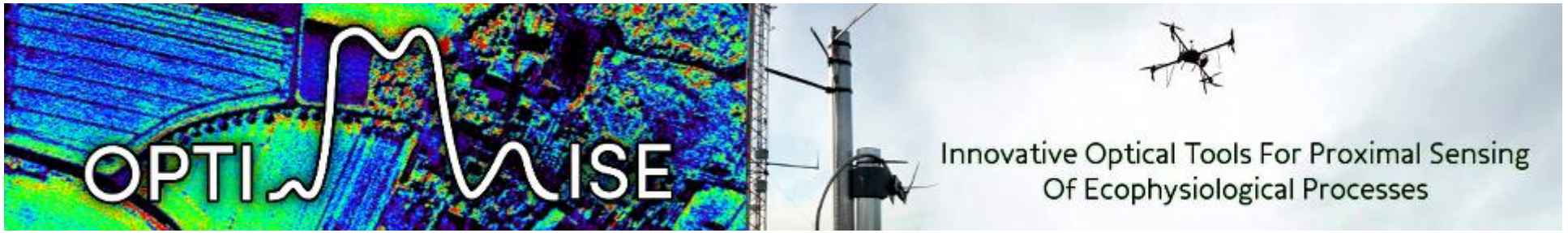
Measuring the reference

- 3.1 Observational characteristics (Alasdair)
- Downward/upward, reference panel/cosine corrector
- Materials, characterization, etc -> paper 1
- Paper 2:
  - Location, move the reference or the instrument?, maintenance
  - Issue: different bi-directional properties between reference panel or cosine corrector and canopy (related also to meteorological conditions) (Guanter 2010, Fournier 2014, Cogliati 2015,…)



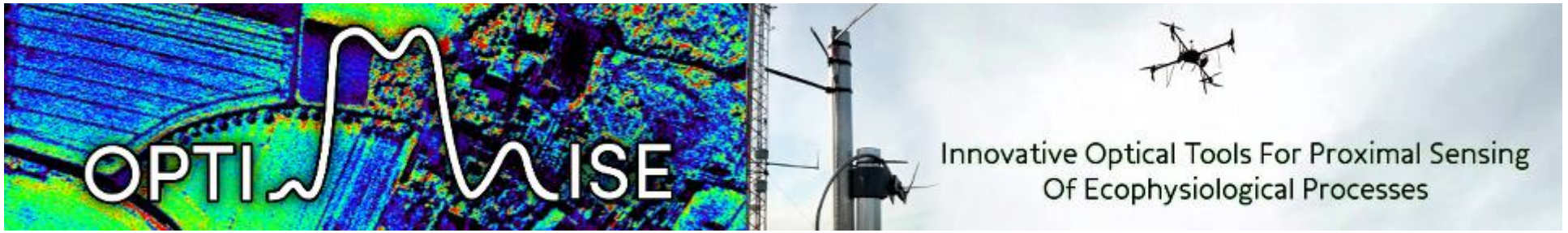
Meteorological conditions, illumination geometry

- Are all meteorological conditions suitable for SIF measurements ?
  - Yang 2015, Goulas 2017, Fournier 2011, 2014, ….
  - Issues: changes in the diffuse/direct fraction, interfere with bi-directional properties,
  - Limitation : not considered for cal/val
  - But: to be considered for studies on ecosystems photosynthesis



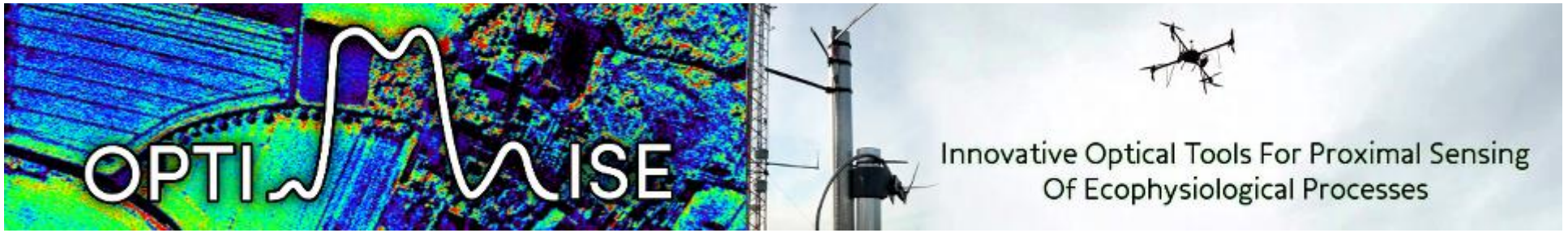
Time of measurements, sampling rate,…

- Fluorescence and photosynthesis are highly dynamics: change with light, temperature, stress level,…
- Light is changing rapidly (days, hours, min, sec) according to meteorological conditions
- Research focus on the changes of SIF with light, environmental parameters
- No recommended time sampling rate, or sampling time
- Mention issues:
  - Limitations: time delay between vegetation and reference, dual beam corrections, changes in diffuse/direct fraction



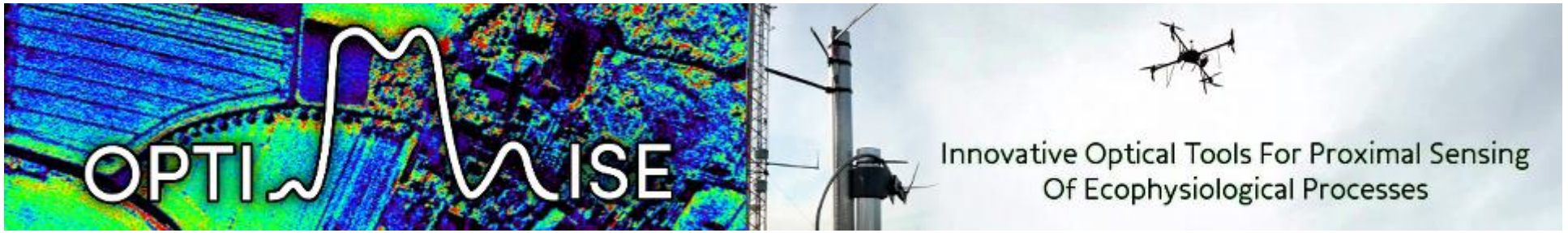
Fluorescence standards

- Fluorescence standard : quinine sulfate (Velapoldi & Mielenz 1980) (QSEU units)
- Zero fluorescence test: non-fluorescence surface, 2nd reference panel, bare soil, etc
- FLEX PARCS study, Validation plan:
  - O_2 luminescence sensor (Kebabian 1999) (not tested)
  - Rhodamine (Plascyk 1975) (not tested)
  - Chloroplasts on Solid Support (CSS) (not tested)
  - Artificial fluorescence simulator: tested, Burkart 2015



Retrieval of the fluorescence yield

- SIF dynamic:
  - Irradiance level
  - Fraction of absorbed radiation (fAPAR), depends on LAI, Chl
  - Fluorescence yield at molecular level : physiology dependent
- To retrieve fluorescence yield from SIF -> Paper 3
  - Yield indices: Louis 2005, Damm 2010, Daumard 2010, 2012, Colombo 2016, Goulas 2017
  - Spectral indices: Lichtenthaler 1988, Campbell 2007,…
  - Model inversion and/or data assimilation: FLEX reports



Some other points

- Paper 1/Instrument:
  - spectrometers vs multi-spectral radiometers/FLD approach (e.g. Carter 1990, Moya 2004, 2006, Zarco-Tejada 2013, etc)
- Paper 1, 2: Imaging systems (Pinto et al. 2016,…)
- Paper 2, upscaling :
  - how to measure and interpret leaf fluorescence wrt variable fluorescence