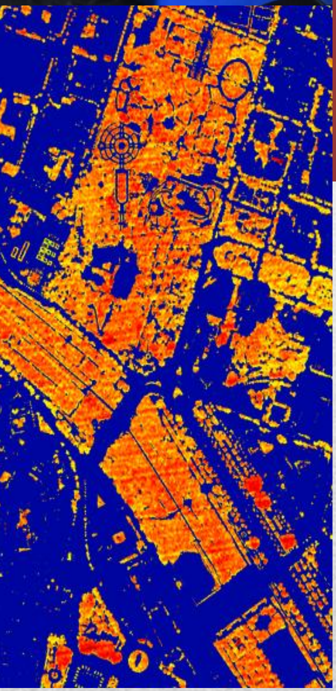

Chlorophyll fluorescence of urban vegetation in relation to traffic exposure:

a novel biomonitoring approach

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universiteit hasselt

BIOHYPE

Belgian Earth Observation Day, 5 september, Brugge

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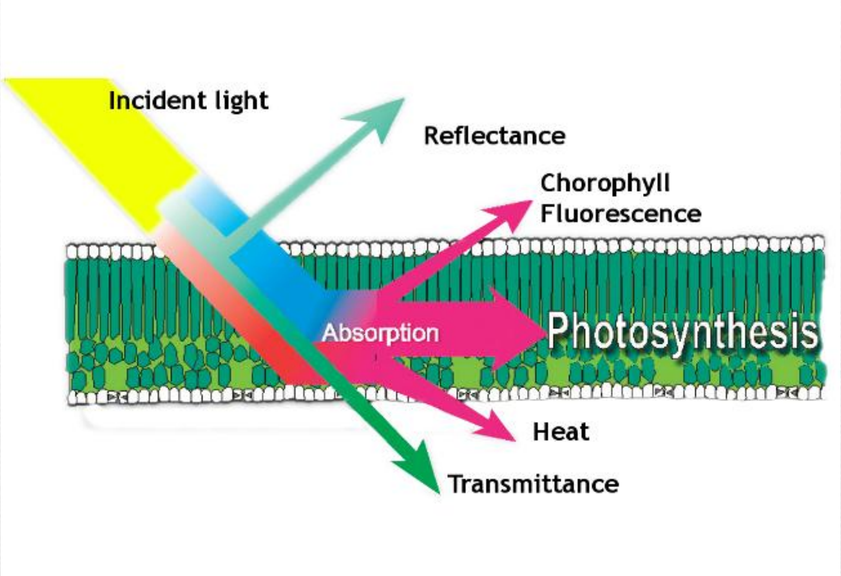
- Introduction: Steady-state Chl fluorescence (Fs)
- Objectives
- Campaign site: Valencia (Spain)
- Fluorescence yield (FY) at leaf level
  - ❖ M&M: FluoWat leafclip
  - ❖ Results & Discussion
- Steady-state fluorescence Fs at canopy level
  - ❖ M&M: iFLD estimation from CASI 1500i
  - ❖ Results & Discussion
- Conclusions

Steady-state or passive chlorophyll fluorescence Fs

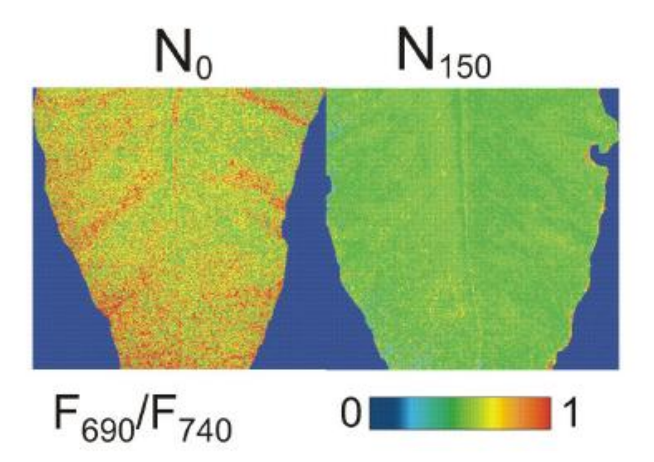


Source: http://ipl.uv.es/flex-parcs/

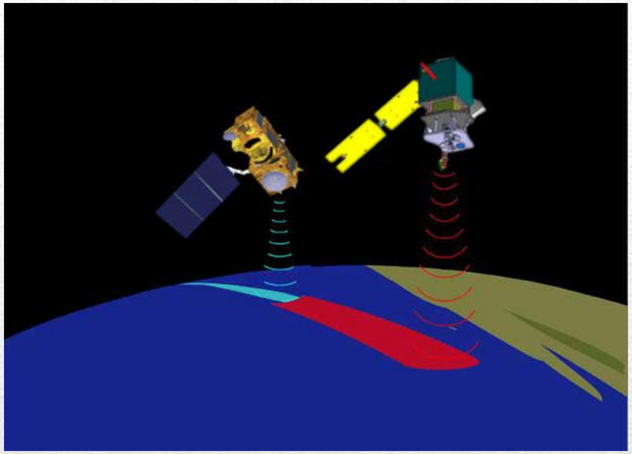
- Plants fluorescence continously thus adding a weak signal to the reflected solar radiation (Meroni et al 2009)
- Competes with photosynthesis in the process of deactivation of excited pigments
- In first instance depending on incoming light (as photosynthesis)
- Weak F signal compared to reflectance (1-5% of the reflected radiation in the NIR)
- Emmited in the region 650-850 nm

INTRODUCTION: Steady-state Chl fluorescence (Fs)

Applications



Lichtenthaler et al. 2005



Source: http://ipl.uv.es/flex-parcs/

- Instrument for basic photosynthesis research on small-scale leaf to canopy level: Single spot measurements to imaging
- Applied plant physiology: detection and analysis of stress effects on plants e.g. N deficiency
- Advantages for RS: increased knowledge on actual photosynthesis compared to the more often used reflectance data
- Early and more direct approach for diagnosis of the actual functional status of vegetation (Meroni et al. 2009)

OBJECTIVES

To develop, test and validate a **passive biomonitoring** methodology based on **airborne hyperspectral observations**

(i) Estimation of spatial distribution overall pollution air (& soil)

(ii) Spatial distribution & seasonal evolution **sub-leaf level** , **leaf level** & **canopy level** parameters

(iii) Compare and validate hyperspectral airborne measurements & ground measurements

(iv) Describing a protocol for the estimation of urban habitat quality distribution with high spatial resolution

CAMPAIGN SITE: VALENCIA

Species selection

- Orthophoto Valencia
- Species Vector layer
- Species List
- **Traffic density layer**

- < 500 m air monitoring station
- Crown > 4m
- Link with Ghent campaign?
- Amount of trees

Field visists

Species selection

Species & Location selection

Platanus x acerifolia
Phoenix canariensis
Celtis australis
Morus alba

+ 10 locations

CAMPAIGN SITE: VALENCIA

Platanus x acerifolia

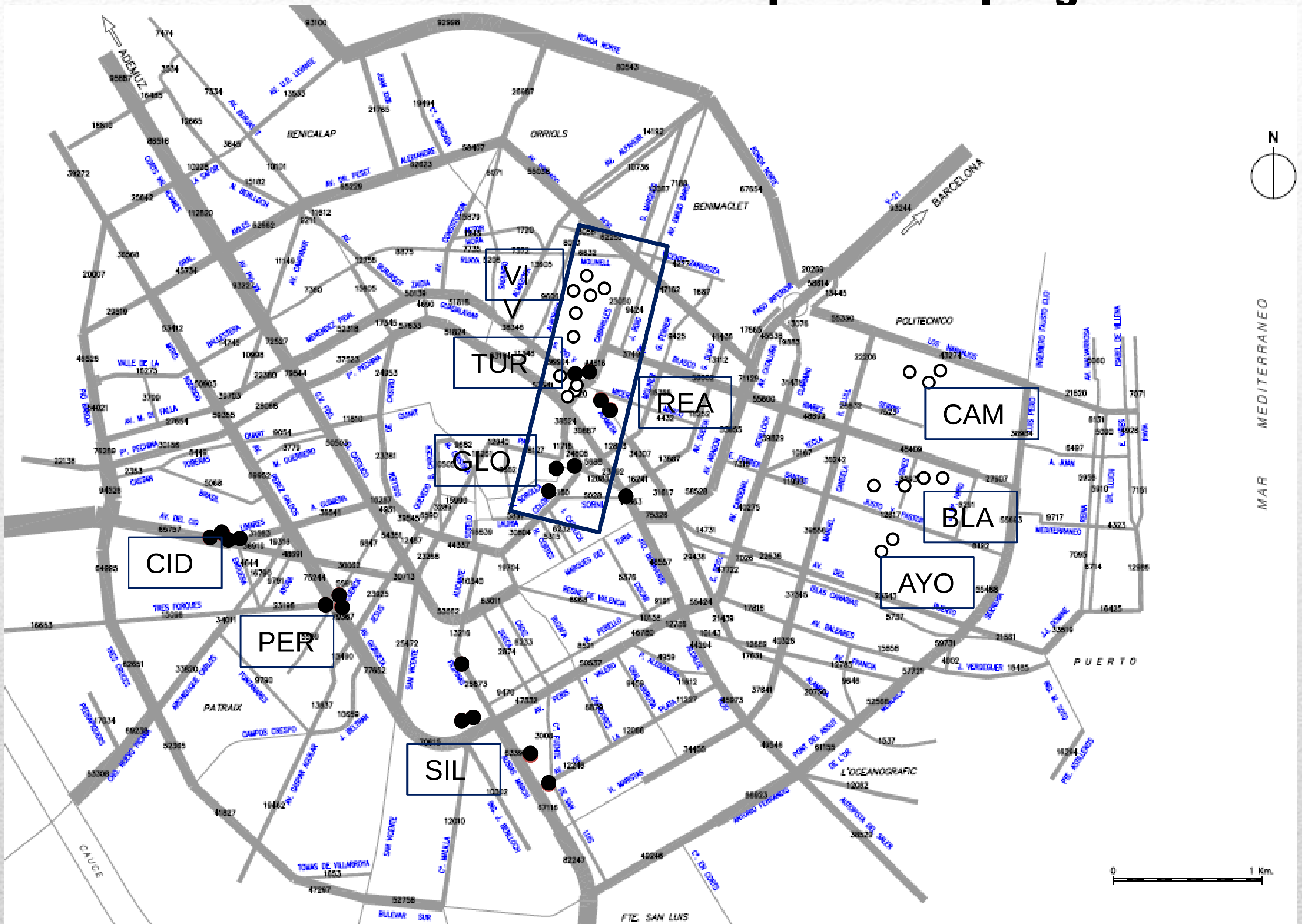
Phoenix canariensis

Morus alba

Celtis australis

CAMPAIGN SITE: VALENCIA

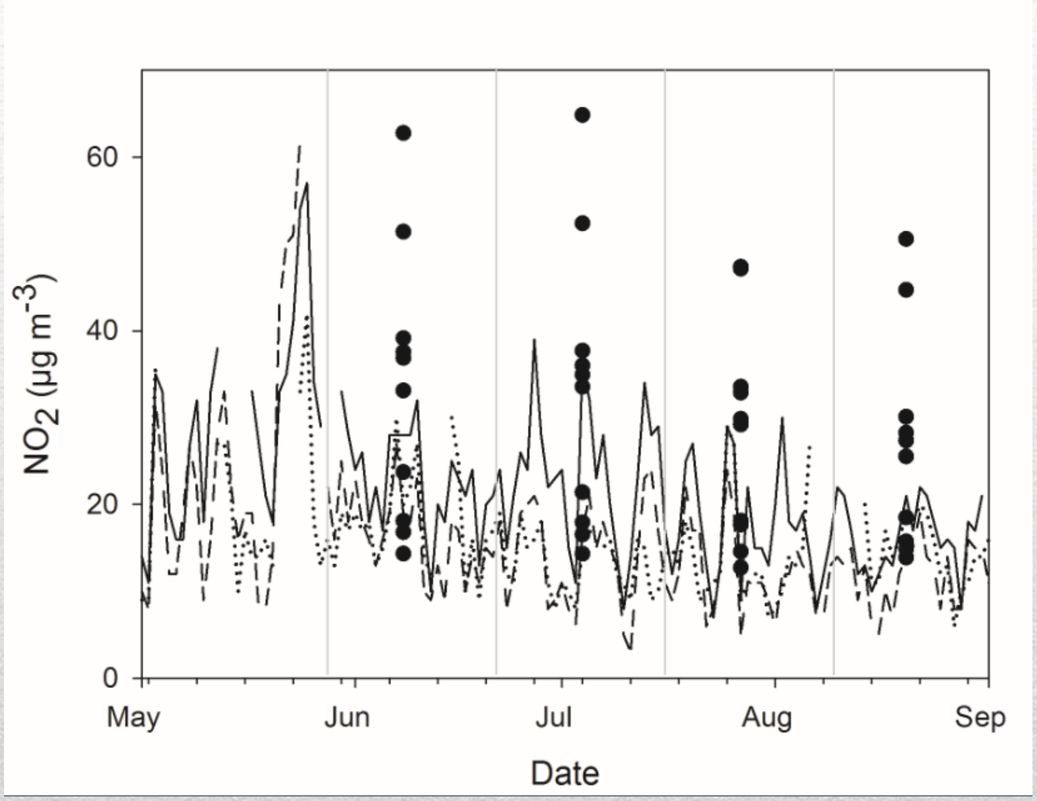
10 Locations and 40 trees for the spatial sampling



Traffic intensity map: thicker road, higher traffic intensity

Air quality

- NO_2 data from air quality stations: maxima during working days, minima during weekends
- Passive NO_2 samplers (●) at the 10 locations, 4x mean over one month during 25/05-02/09
- Contrasting traffic intensity sites



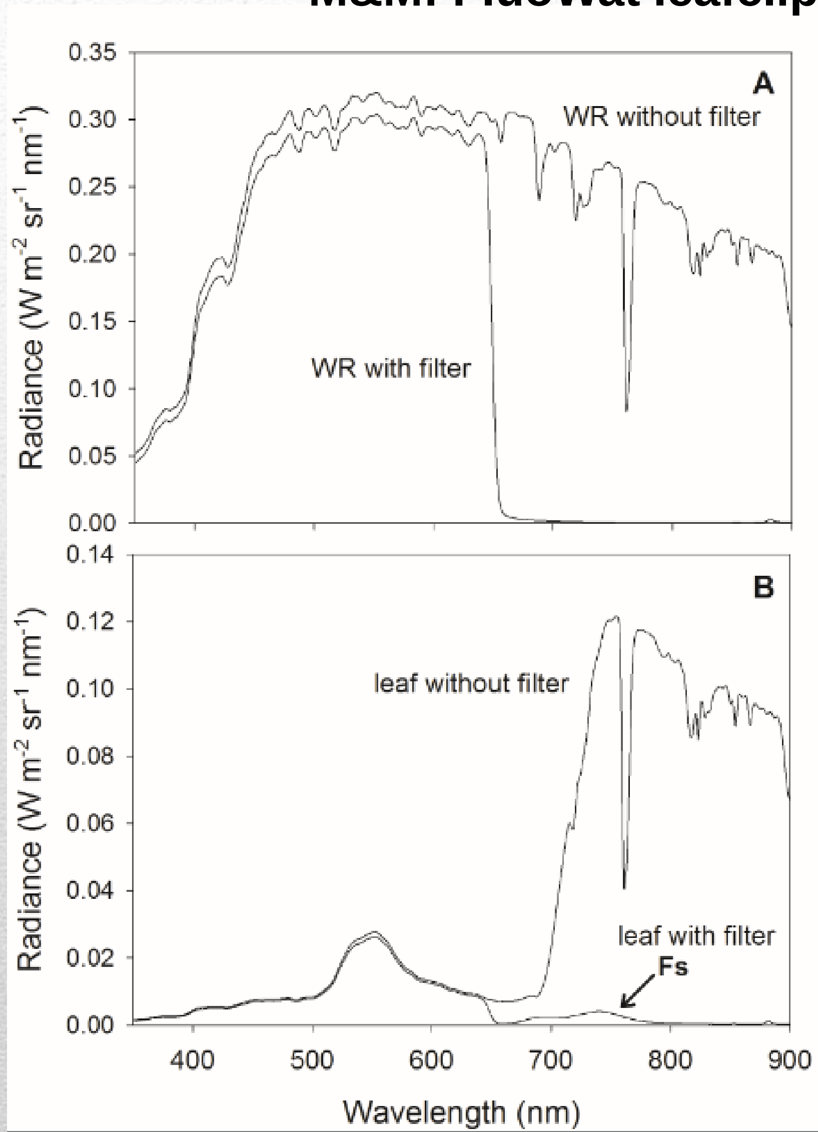
Fluorescence yield (FY) at leaf level

M&M: FluoWat leafclip

- portable device to measure **upward and downward** leaf **reflectance, transmittance and fluorescence** (F) emission under natural conditions
- measured under natural conditions, after light adaptation, but not on a constant moment of the day
- Leaf nerves are avoided
- F is measured by cutting off the light spectrum with a **short-pass filter (<650 nm)**

Fluorescence yield (FY) at leaf level

M&M: FluoWat leafclip



$$PAR = \int_{400}^{700} I \cdot d\lambda \qquad \text{(Eq. 1)}$$

$$fAPAR = \int_{400}^{700} A \cdot d\lambda = \int_{400}^{700} (1 - R - T) \cdot d\lambda \qquad \text{(Eq. 2)}$$

$$APAR = fAPAR \times PAR \qquad \text{(Eq. 3)}$$

$$\uparrow FY = \frac{\uparrow Fs}{APAR} \qquad \text{(Eq. 4)}$$

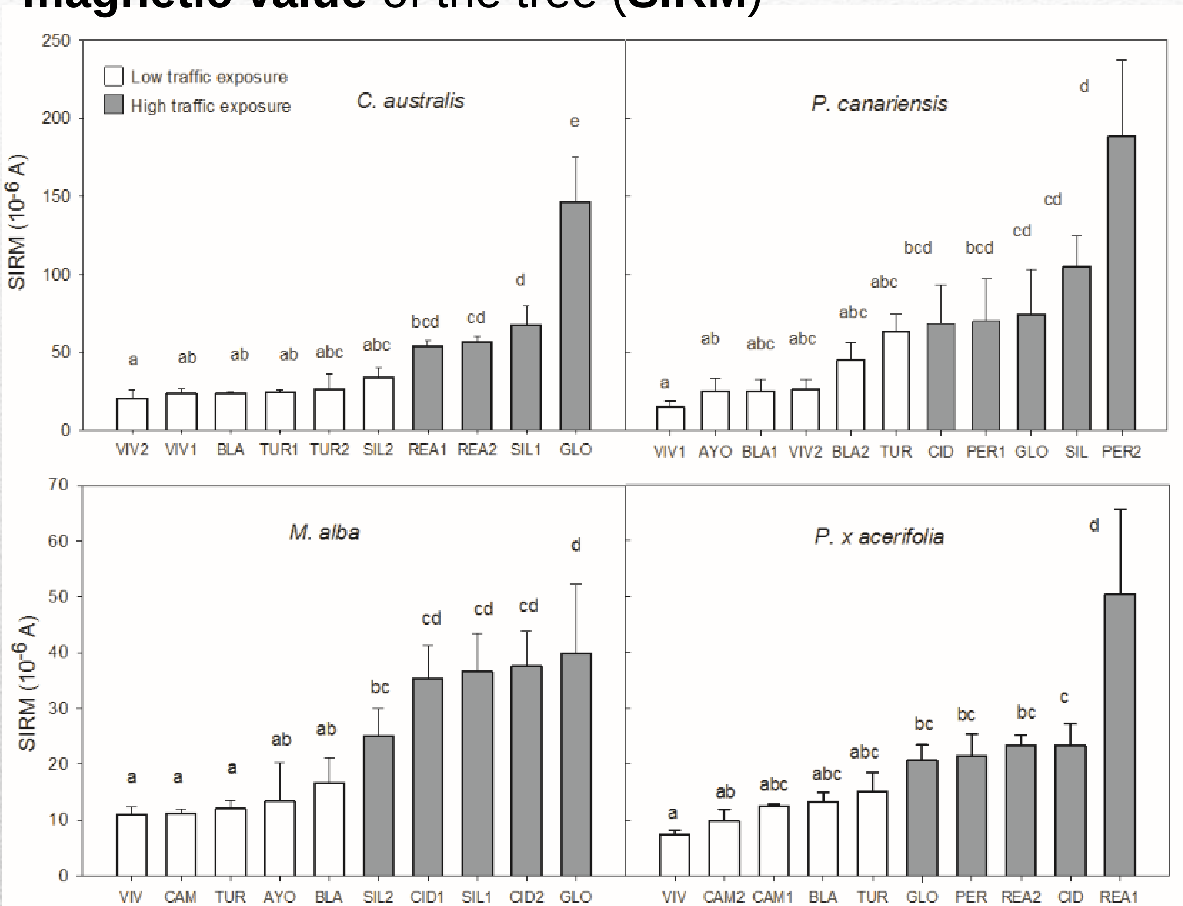
$$\uparrow FY\ (e.g.\ 687) = \frac{\uparrow Fs\,(687)}{APAR} \qquad \text{(Eq. 5)}$$

$$FY = \frac{\text{Emitted fluorescence radiance}}{\text{Absorbed radiance}}$$

Fluorescence yield (FY) at leaf level

M&M: FluoWat leafclip

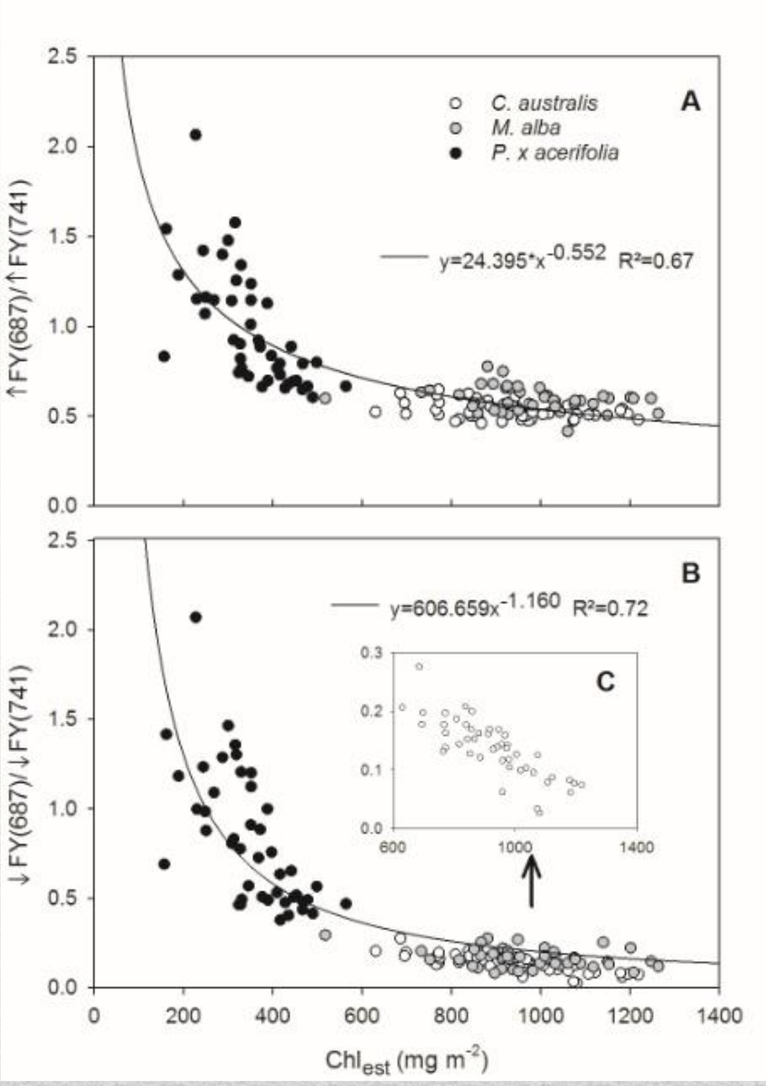
Low and high traffic exposure ultimately based on the **magnetic value** of the tree (**SIRM**)



- Log(SIRM) is linearly correlated with log(Vehicles/hour/m)
- SIRM can be interpreted as a measure for the exposure of each tree to the local traffic emmissions

Fluorescence yield (FY) at leaf level

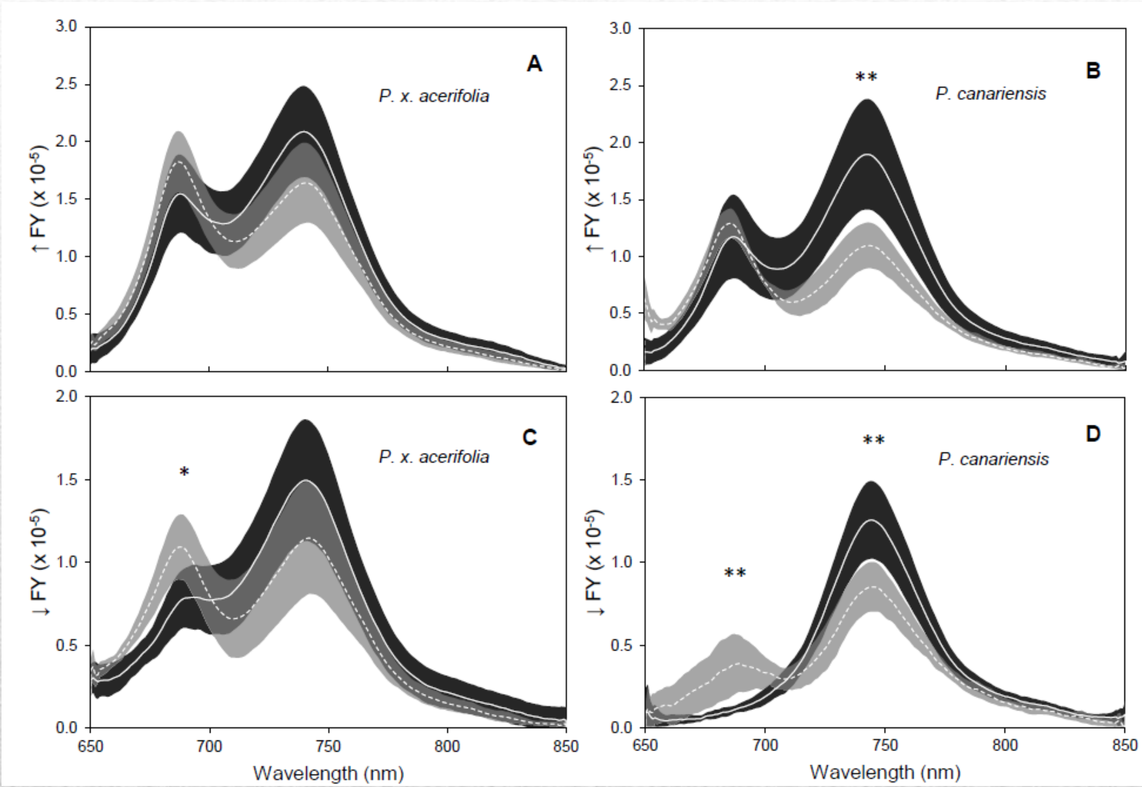
Results & Discussion



- F emission in the red region (685-690 nm) overlaps with the spectral region of Chl absorption
- Higher Chl content → higher re-absorption around 687 nm
- Re-absorption is stronger when measuring abaxially (higher light penetration depth)
- No difference in Chl content between high & low traffic exposure, thus no significant degradation of Chl pigments

Fluorescence yield (FY) at leaf level

Results & Discussion



- ↑FY & ↓FY show significant different peak heights for *P. x acerifolia* and *P. canariensis*
- ↑FY(687)/↑FY(741) & ↓FY(687)/↓FY(741) are significantly higher for the highly traffic exposed trees
- Influence of Chlorophyll content

High traffic exposure
Low traffic exposure

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Results & Discussion

Only P. canariensis and P. x acerifolia show a significant effect of traffic exposure class on their FY indices

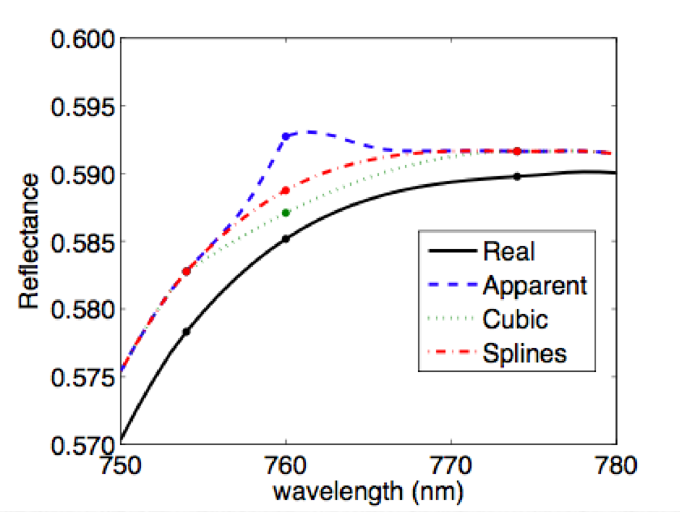
- Long exposure time/ increased susceptibility

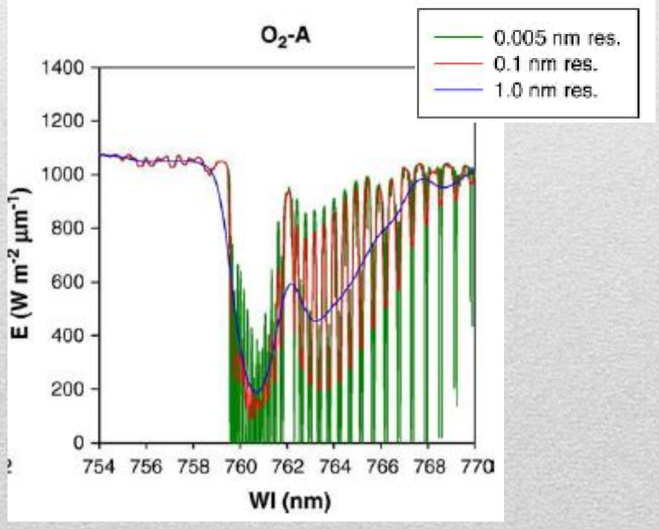
FY indices can indicate stress where no Chl content degradation occurs

- Environmental stress effects affect chlorophyll fluorescence in an indirect way by influencing Chl content, leaf structure and internal substances
- Steady-state fluorescence is able to detect plant stress before irreversible damage occurs (Meroni et al. 2009)

M&M: iFLD estimation from CASI 1500i

- Apparent R= real R+ F
- F can be detected in narrow dark lines of the solar and atmospheric spectrum in which irradiance is strongly reduced
- These Fraunhofer lines are used for F estimation, e.g. the O_2 absorption bands **O_2-B (687.0 nm) and O_2-A (760.4 nm)**
- **High spectral resolution** is needed for accurate estimation of band position, width and depth
- As the emitted F is re-absorbed along the atmospheric path, a **precise atmospheric correction** is required



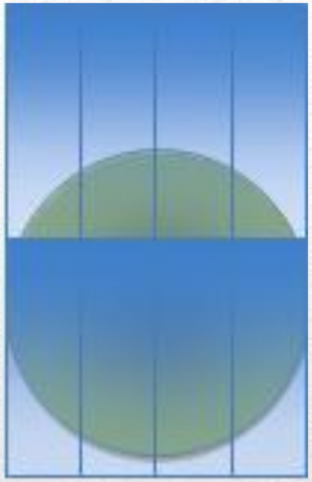


Meroni et al. 2009

M&M: iFLD estimation from CASI 1500i

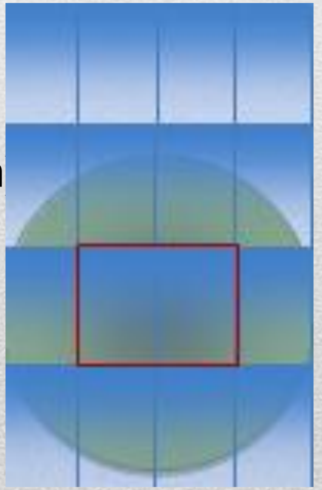
Configuration A)

- Spectral range: 366-1054 nm
- **288 spectral bands** evenly distributed in VNIR
- FWHM: 2.4 nm
- Minimum Integration Time – MIT at Min FOV: 43 ms
- Pixel size (2km altitude)
  - **Along track: 3.1 m (flying at 72ms-1/140Kts)**
  - Across track: 1.0 m



Configuration B) -experimental-

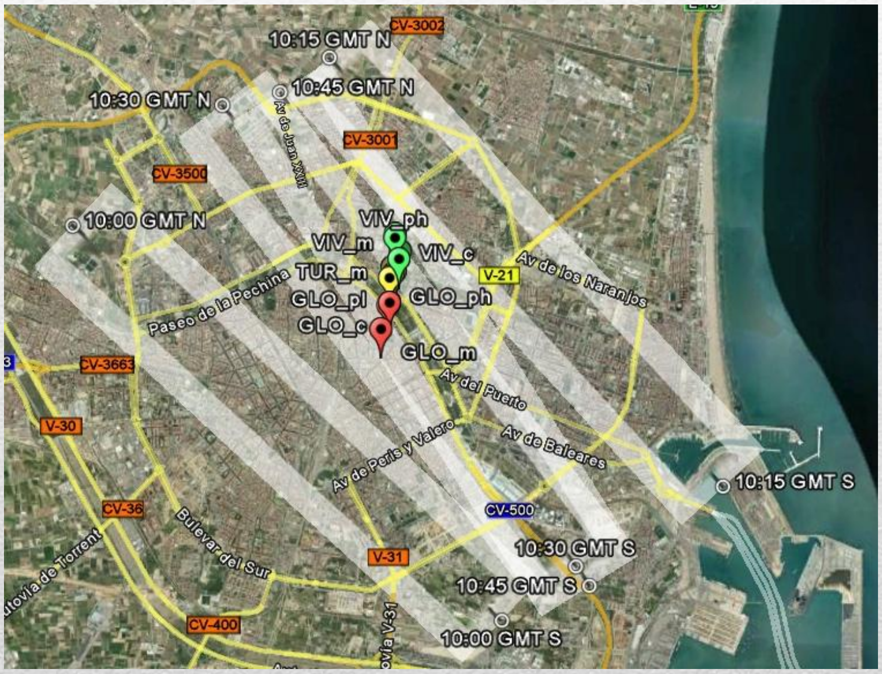
- Spectral range: 366-1054 nm
- **144 spectral bands** using binning outside areas of interest
- FWHM: 2.4 nm at O2 absorptions and red-edge (630-802 nm and PRI bands
- FWHM: 4.8 nm at the rest of spectrum
- Minimum Integration Time – MIT: 22 ms
- Pixel size
  - **Along track: 1.6 m (flying at 72ms-1/140Kts)**
  - Across track: 1.0 m

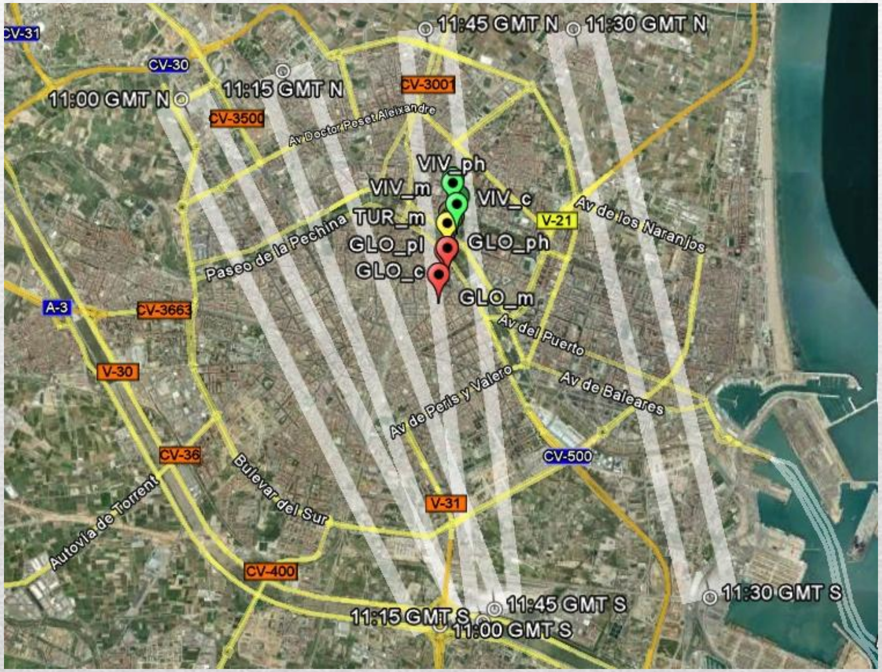


Steady-state fluorescence Fs at canopy level

M&M: iFLD estimation from CASI 1500i

- **10:00 – 10:45** with CASI @288 bands, pixel size of 1m (across track) x 3.1m (along-track)
- **11:00 - 11:45** with CASI @144 bands, pixel size of 1m (across track) x 1.58m (along-track)





Ground measurements at:

- VIVEROS
- TURIA
- GLORIETA

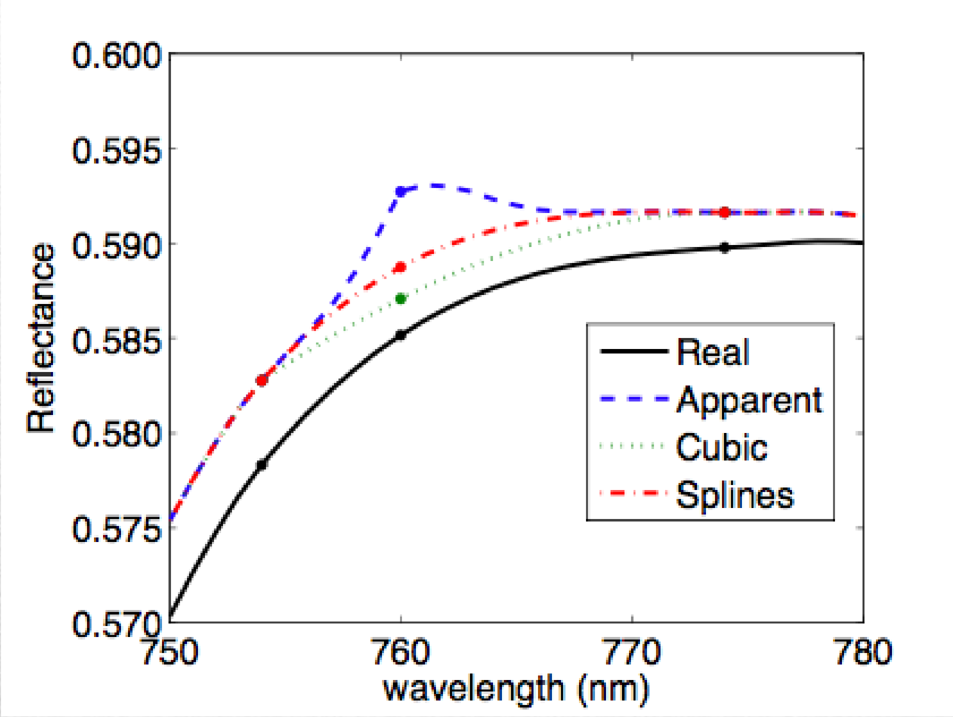
Steady-state fluorescence Fs at canopy level

M&M: iFLD estimation from CASI 1500i

- Interpolate $\tilde{R}_{in}$ using continuous spectrum

$$\hat{a}_R \circ \frac{\hat{R}_{out}}{\tilde{R}_{in}} \gg a_R$$

- Small error ~0.2% in reflectance factor
- Acceptable error in fluorescence
- **Interpolation method is critical!!**



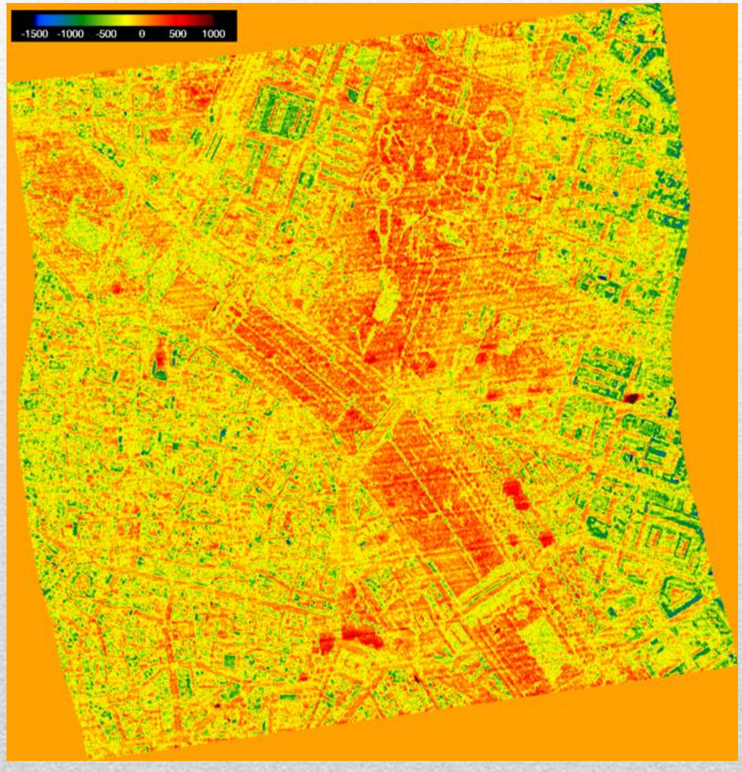
Steady-state fluorescence Fs at canopy level

M&M: iFLD estimation from CASI 1500i

P24SX

$\lambda_{in} = 755.0$ nm
$\lambda_{out} = 762.2$ nm

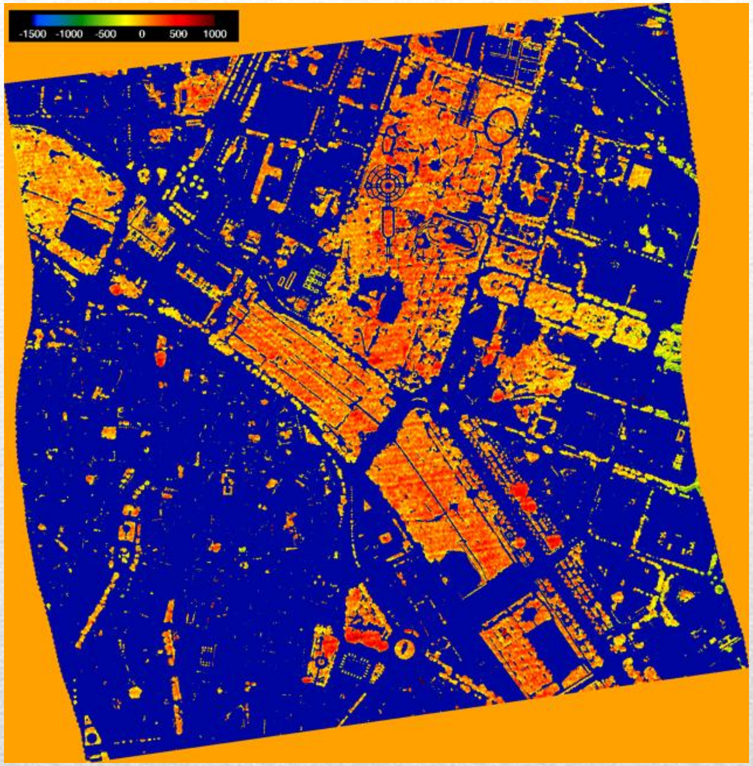
Linear interpolation of reflectance and radiance
Single reference surface
Disregarding varying optical path:
- Different target altitudes
- Different view zenith angles



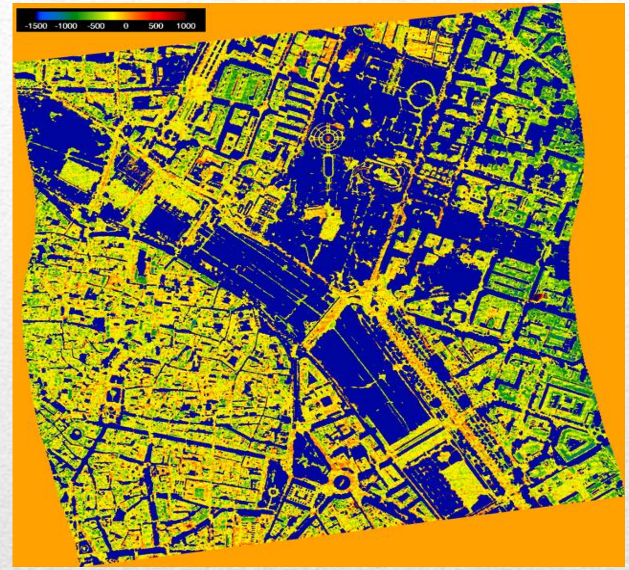
High values on narrow streets and dark surfaces
Striping noise
Across-track decrement

Steady-state fluorescence Fs at canopy level

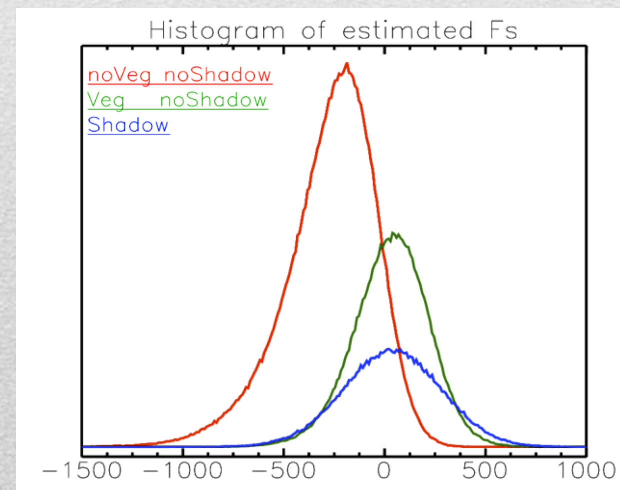
Results & Discussion



A



B



Different modes for each distr.
Higher for vegetation
Wide distribution widths
Values in shadows overlap veg.
Evidently wrong F_s values

Steady-state fluorescence Fs at canopy level

Results & Discussion

Sources of error

FOV lengthens path
Height shortens path
Striping both ways

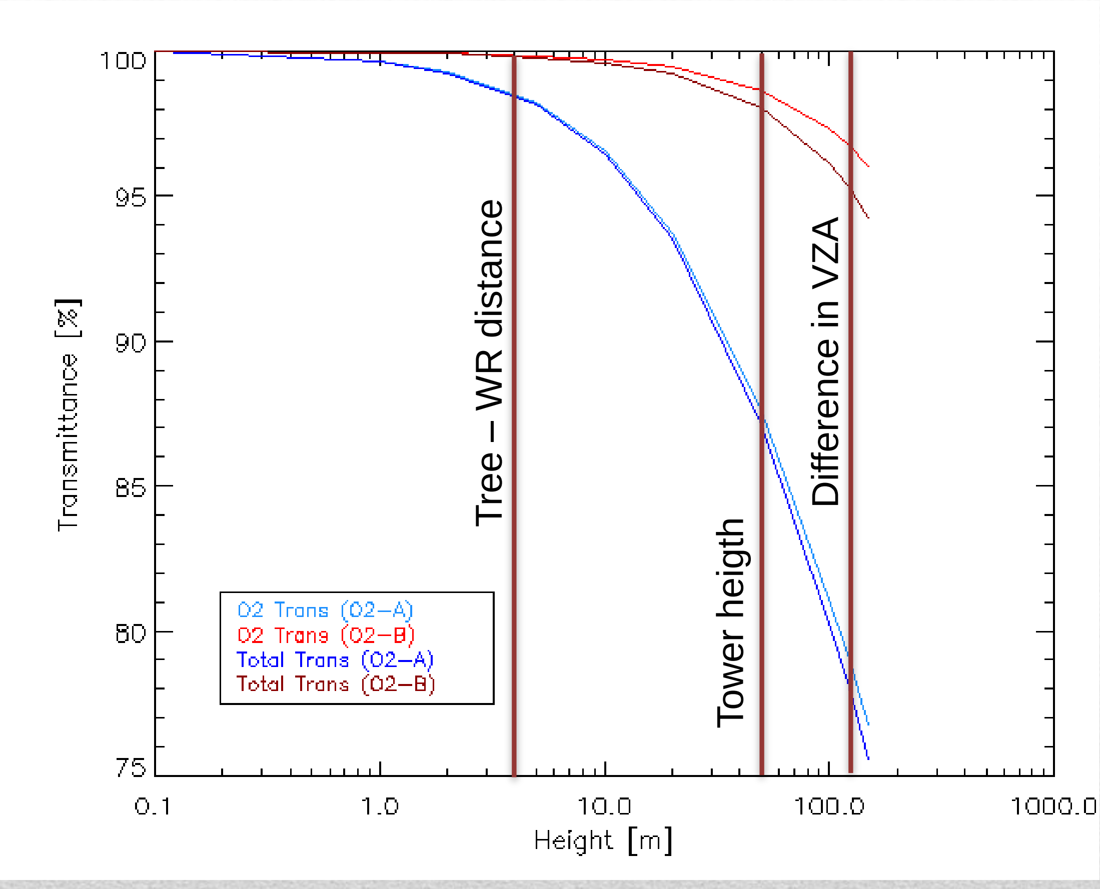
Solutions

Take into account FOV
Use hi-res DEM
Find reference surface per column (IFOV)
Previous noise reduction

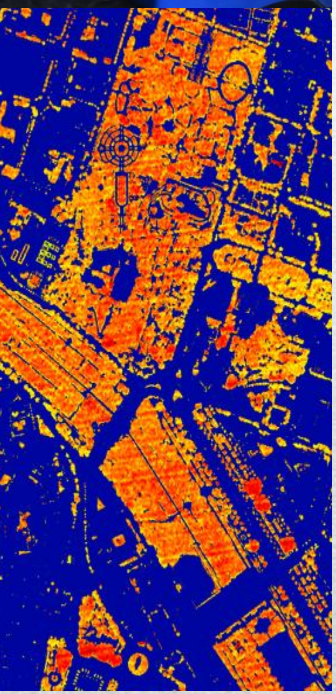
Other

Dark targets present a radiance level in the order of noise level

Changes in transmittance due to optical path



CONCLUSIONS



- Stress induced by traffic pollution can be detected by steady-state FY indices at leaf level for some urban tree species
- FY indices are shown to indicate early stress or a change in the regulation of photosynthesis, while no significant change in Chl pigments were found
- The signal level in the O2-A of CASI is in principle sufficient to detect fluorescence; most factors that introduce noise to the retrieved F are due to simplications applied to the iFLD method
- Mapping solar-induced Chl fluorescence is still in a developing stage, but will serve in many applications in the future