

***Continuous Active Fluorescence Measurements
at Canopy Level for Pre Visual Detection
of Vegetation Water Stress***

***Medidas Continuas de Fluorescencia Activa
para la Deteccion Pre visual
del Estress Hidrico de la Vegetacion***

**I. Moya
ML. Lopez Gonzalez
H. Loayza**

**CNRS LMD, Ecole Polytechnique, Palaiseau, France
CIP, Lima, Perú**

PLAN

- 1. Cambio Climático y Fotosíntesis**
- 2. La Fluorescencia Variable de la Clorofila**
- 3. Signatura del Estrés Hídrico con LedFlex**
- 4. Campaña de Medidas de Barrax (España)**
 - Fluorescencia con luz solar**
 - Comparación activa y pasiva**
- 5. Conclusión**

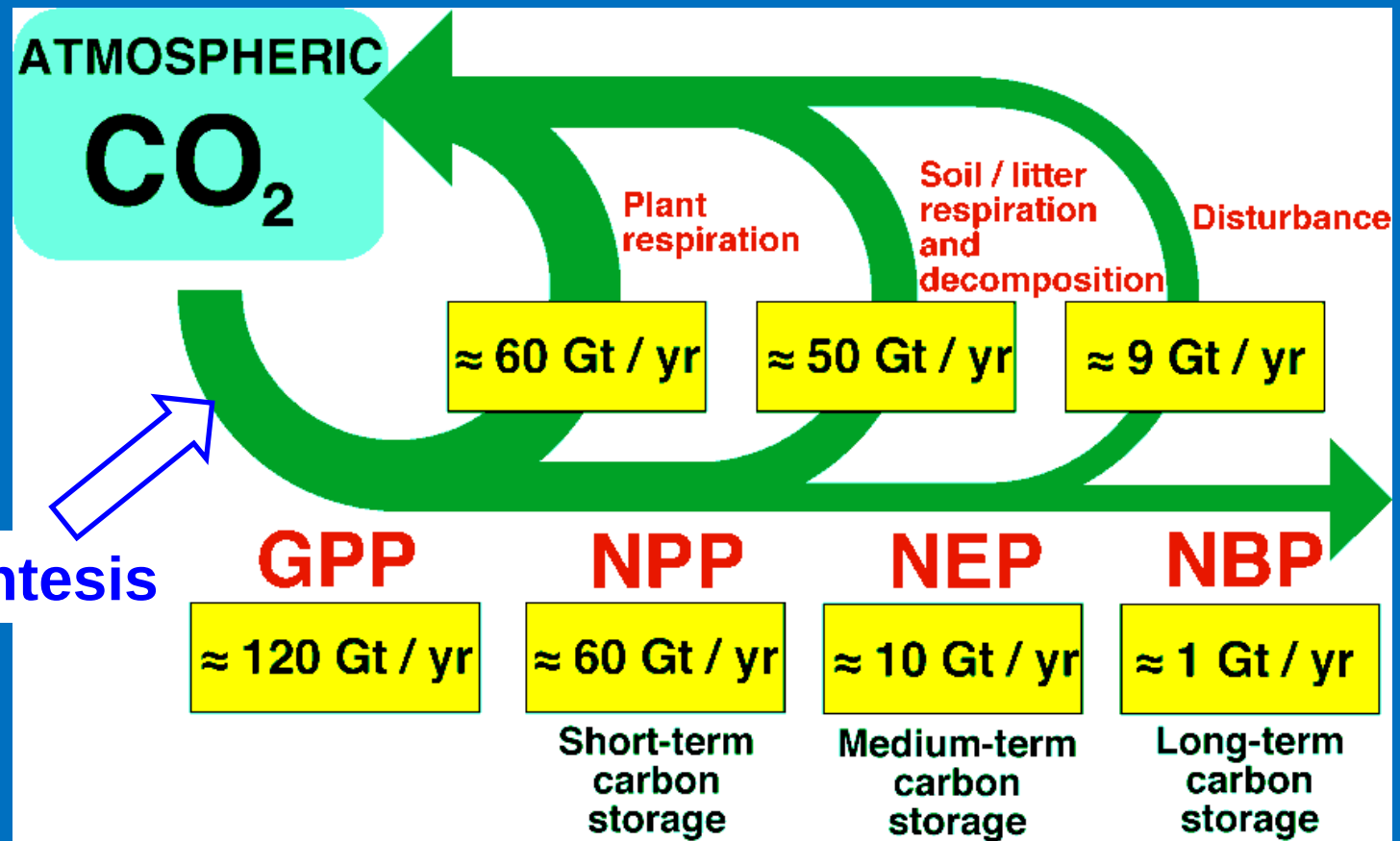
La actividad humana genera cada vez mas de CO₂,
el mayor responsable del efecto invernadero



Los modelizadores del clima necesitan el conocimiento de la fotosintesis
poque esta contibuye a restar CO₂ de la atmosfera

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Cycle Global du carbone

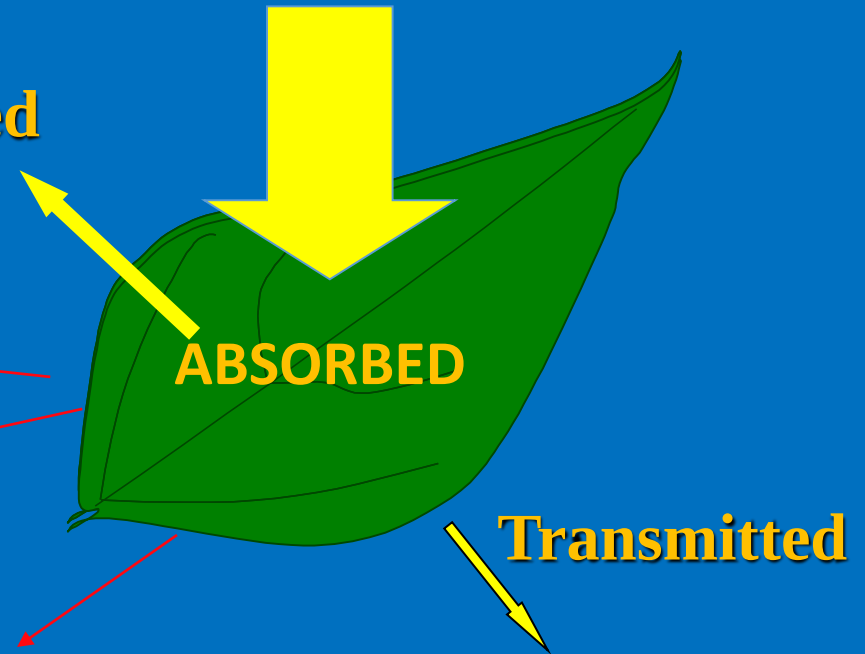
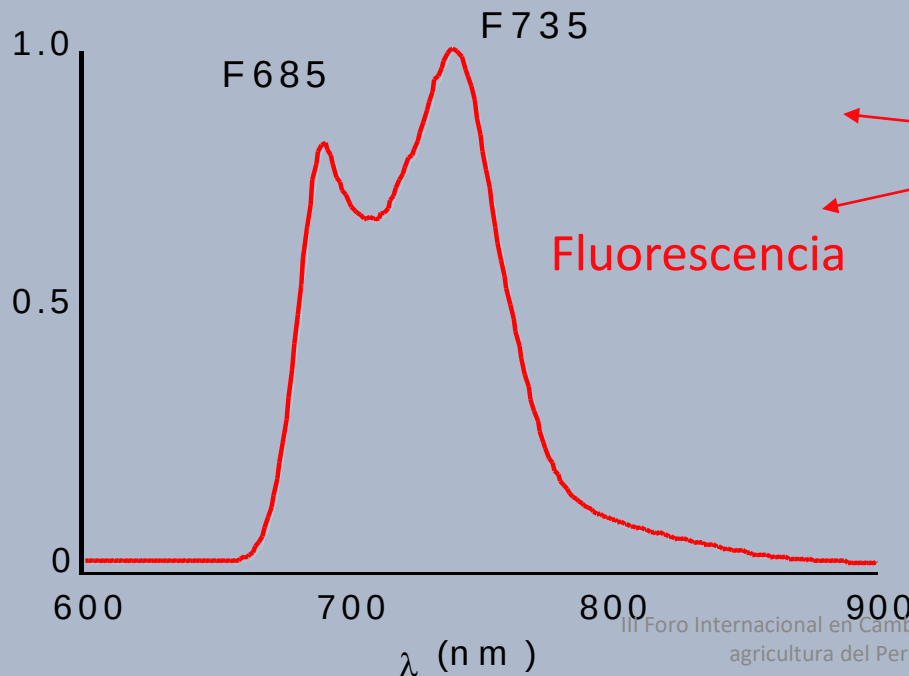


BALANCE ENERGETICO DE UNA HOJA VERDE

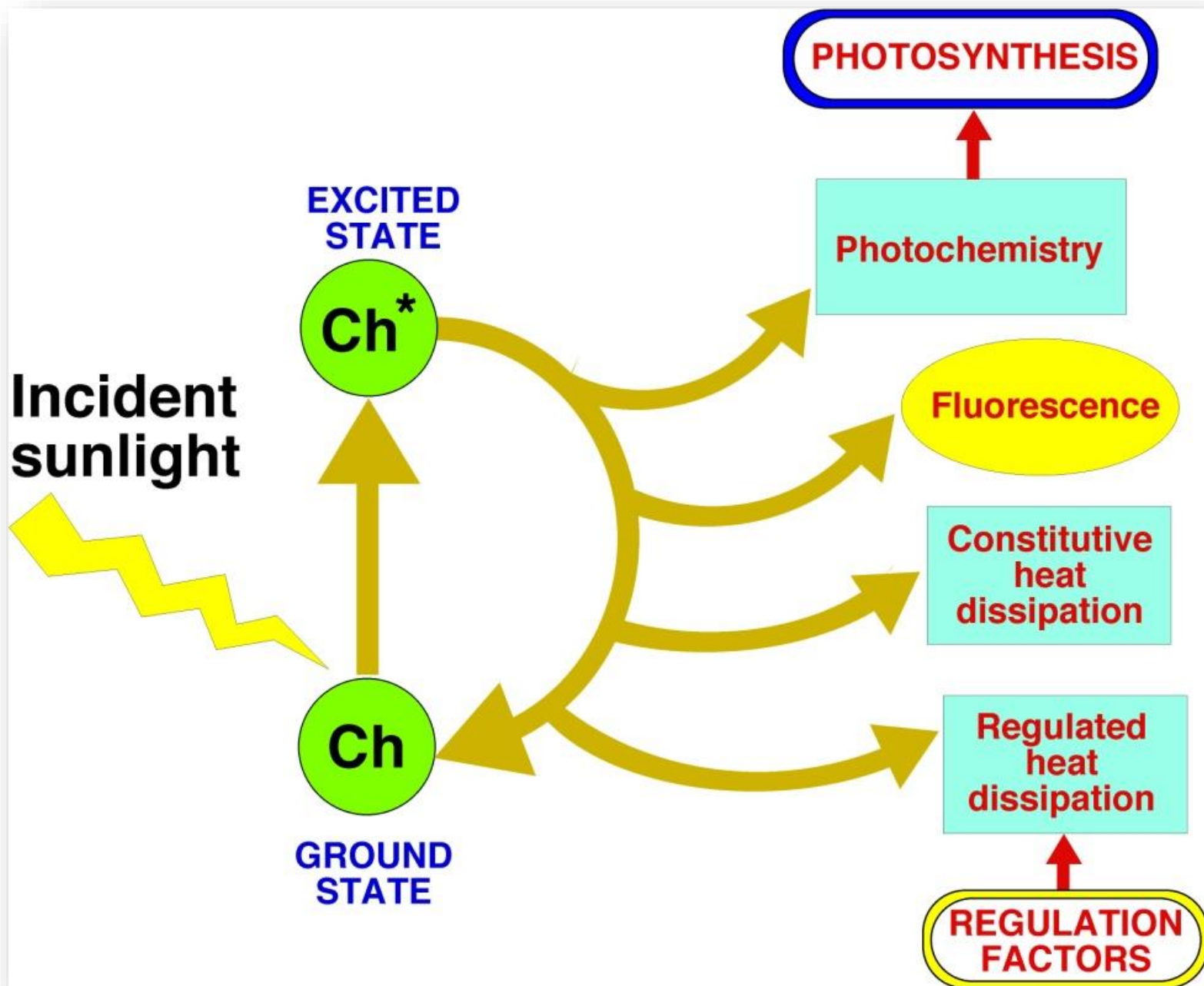
Photosynthetic Active Radiation
(PAR 400-700 nm)

La fluorescencia es $< 2\%$ de
la radiation absorbida

Reflected



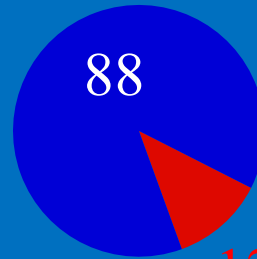
La fluorescencia solo proviene de
la clorofila_a



Fluorímetros portátiles de terreno

PAM-2000 Portable Chlorophyll Fluorometer

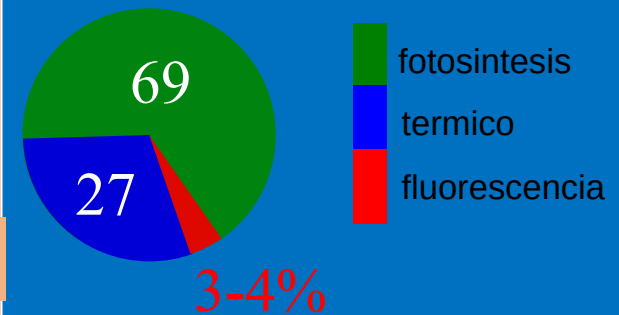
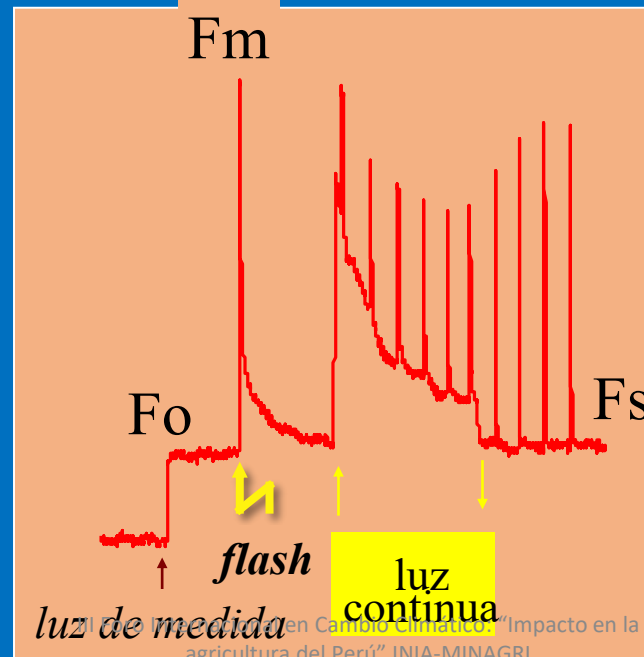
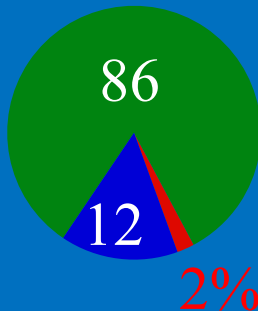
for investigating
photosynthesis in the field,
greenhouse and laboratory



PEA, Hansatech, UK



EARS-PPM,
Netherlands



**La Fluorescencia es
VARIABLE !!**

- Son medidas de rendimiento
- Son medidas de contacto
- **NO** son medidas a nivel de la cubierta vegetal

Para eso hicimos LEDFLEX

LedFlex



LEDFLEX source of light

4 Blue LEDs in series

3 Amperes / LED

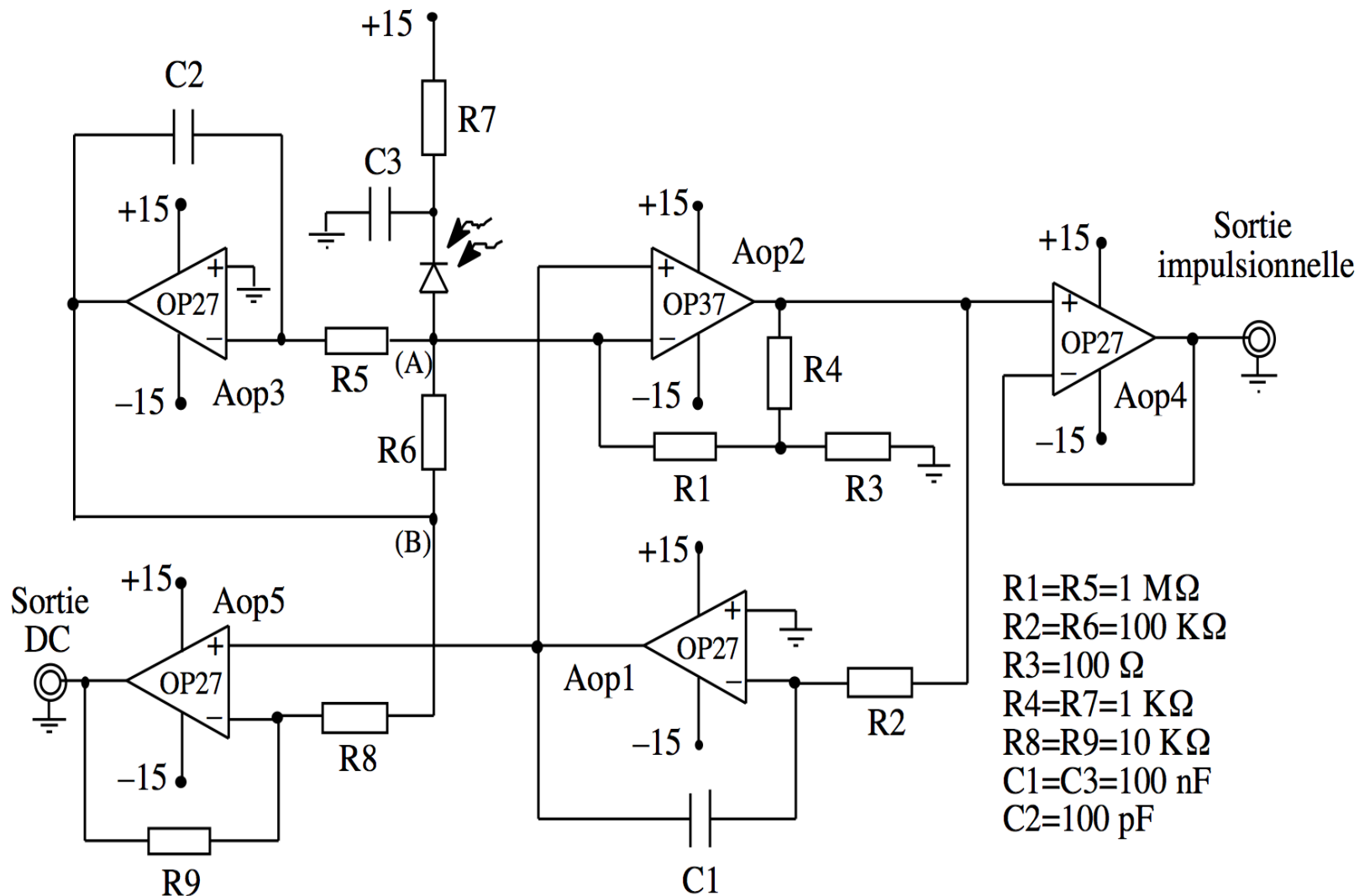
5 μ s pulse duration

100 Hz modulation frequency

LED with Ball Lens



Half divergence 7°

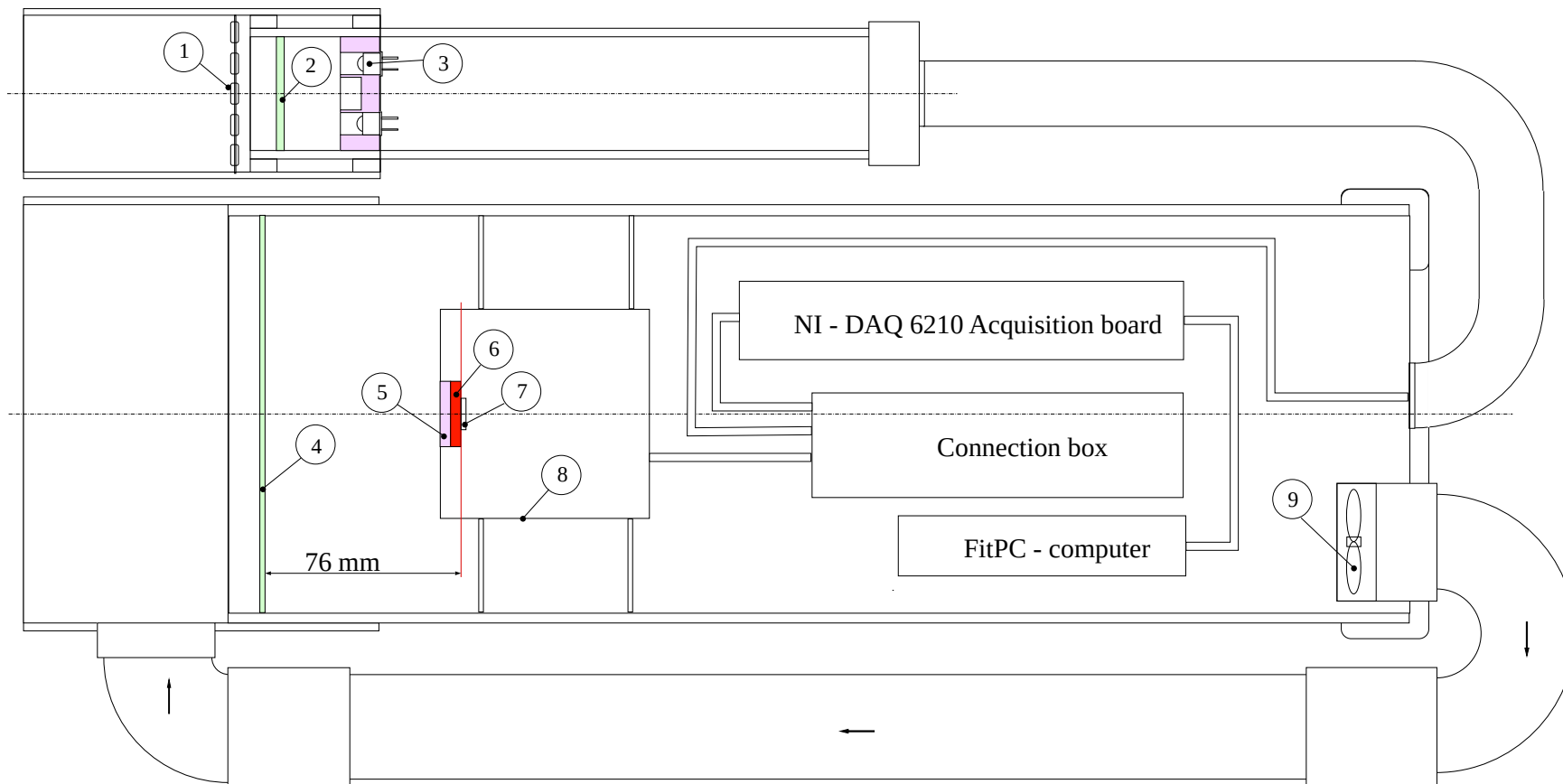


Doble circuito electrónico continuo (reflectividad) e impulsional (pulsos de fluorescencia) desarrollado en el laboratorio por Maurice Bergher

The NI 6210 board has 8 channels with which we measure:

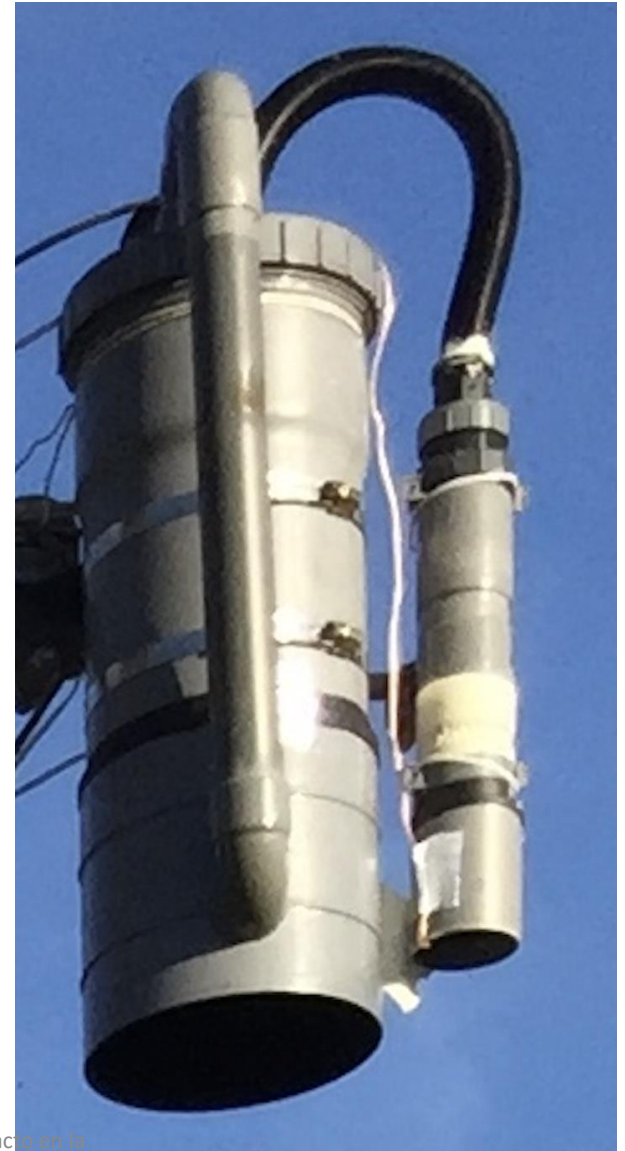
- F_s (stationary fluorescence)
- Reflectance of the target
- T_{led}
- $T_{detector}$
- T_{air}
- PAR

every 1.5 second



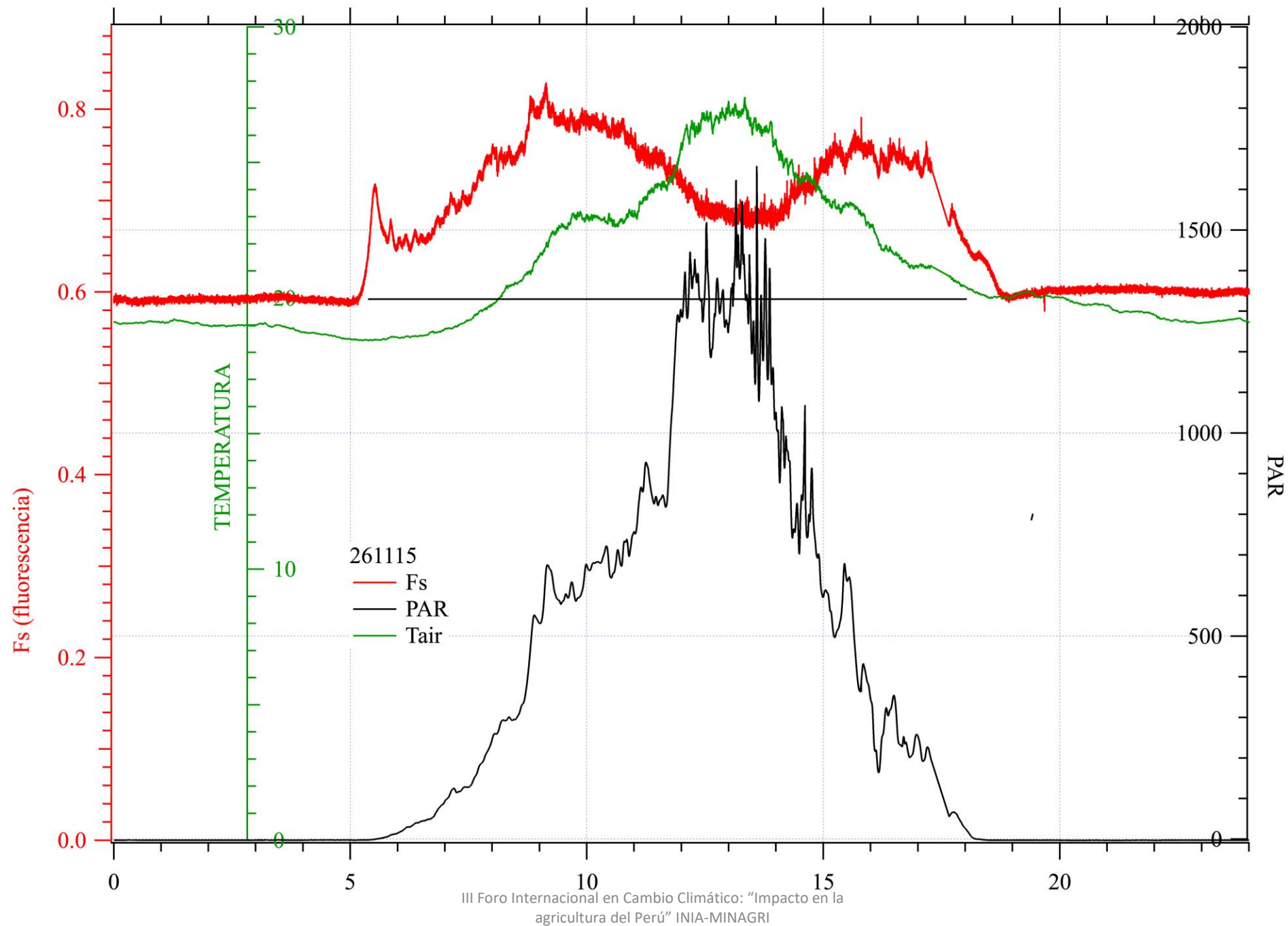


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CIP, Lima, Perú





Aplicación de LedFlex la detección del estrés hídrico



ARVEJAS

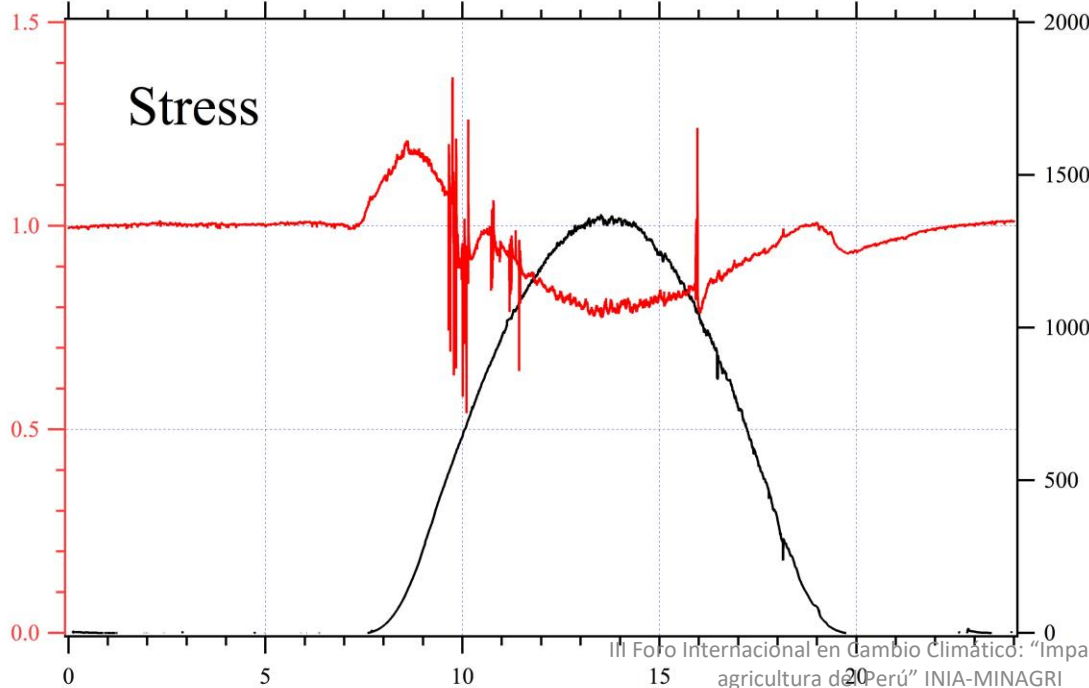
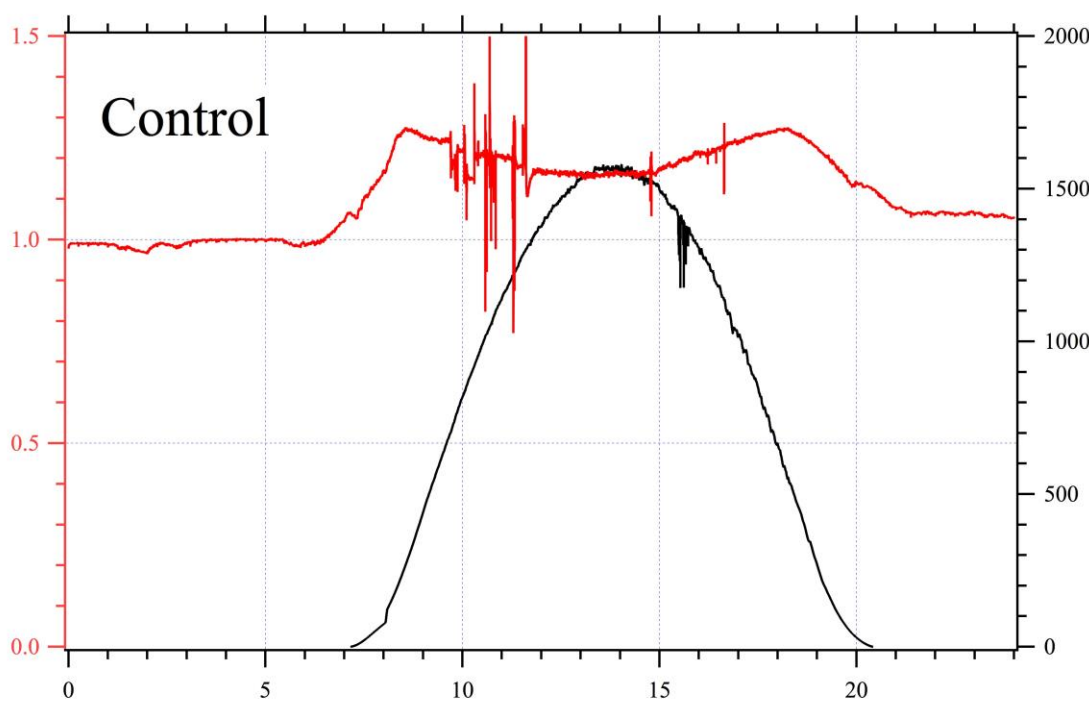
Measurements on a small canopy of peas.

*In red the F_s signal divided by the value during night.
In black the Photosynthetic Active Radiation (PAR) in $\mu\text{Moles photons/m}^2/\text{s}$*

Top: Sunny-day of the well-watered canopy

Bottom: Same plants after several days withholding watering.

Observe the huge decrease at noon ($\approx 14:00$ local time) well below the level during the night



ORIGINAL ARTICLE



Canopy chlorophyll fluorescence applied to stress detection using an easy-to-build micro-lidar

Ismael Moya¹  · Hildo Loayza²  · Maria Llanos López³ · Roberto Quiroz⁴ · Abderrahmane Ounis¹ · Yves Goulas¹

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Abstract

LEDFLEX is a micro-lidar dedicated to the measurement of vegetation fluorescence. The light source consists of 4 blue Light-Emitting Diodes (LED) to illuminate part of the canopy in order to average the spatial variability of small crops. The fluorescence emitted in response to a 5- μ s width pulse is separated from the ambient light through a synchronized detection. Both the reflectance and the fluorescence of the target are acquired simultaneously in exactly the same field of view, as well as the photosynthetic active radiation and air temperature. The footprint is about 1 m² at a distance of 8 m. By increasing the number of LEDs longer ranges can be reached. The micro-lidar has been successfully applied under full sunlight conditions to establish the signature of water stress on pea (*Pisum Sativum*) canopy. Under well-watered conditions the diurnal cycle presents an M shape with a minimum (Fmin) at noon which is Fmin > Fo. After several days withholding watering, Fs decreases and Fmin < Fo. The same patterns were observed on mint (*Menta Spicata*) and sweet potatoes (*Ipomoea batatas*) canopies. Active fluorescence measurements with LEDFLEX produced robust fluorescence yield data as a result of the constancy of the excitation intensity and its geometry fixity. Passive methods based on Sun-Induced chlorophyll Fluorescence (SIF) that uses high-resolution spectrometers generate only flux data and are dependent on both the 3D structure of vegetation and variable irradiance conditions along the day. Parallel measurements with LEDFLEX should greatly improve the interpretation of SIF changes.

CAMPAÑA DE BARRAX (ALBACETE – ESPAÑA)

OBJECTIVOS:

- Detectar a nivel de campo el estrés hídrico con LedFlex
- Comparar medidas de temperatura con la fluorescencia
- Comparar la fluorescencia Activa con la medidas **PASIVA**



Campaña de BARRAX (Albacete – España)

Julio 2017

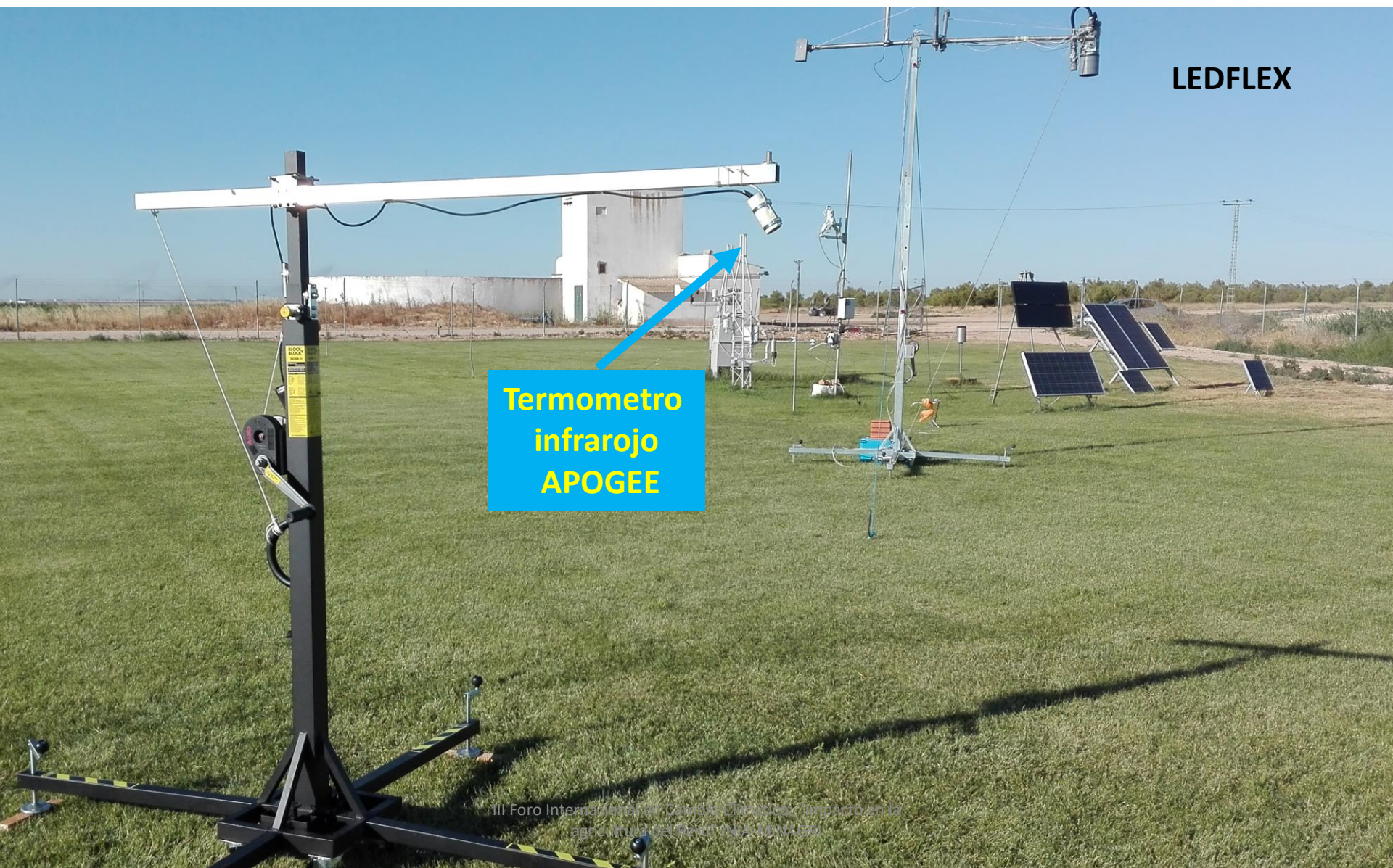


A close-up, top-down view of a lush green field of Festuca grass. The grass blades are long, narrow, and densely packed, creating a textured, vibrant green surface. A white rectangular box with the word "FESTUCA" in red capital letters is centered in the upper portion of the image.

FESTUCA

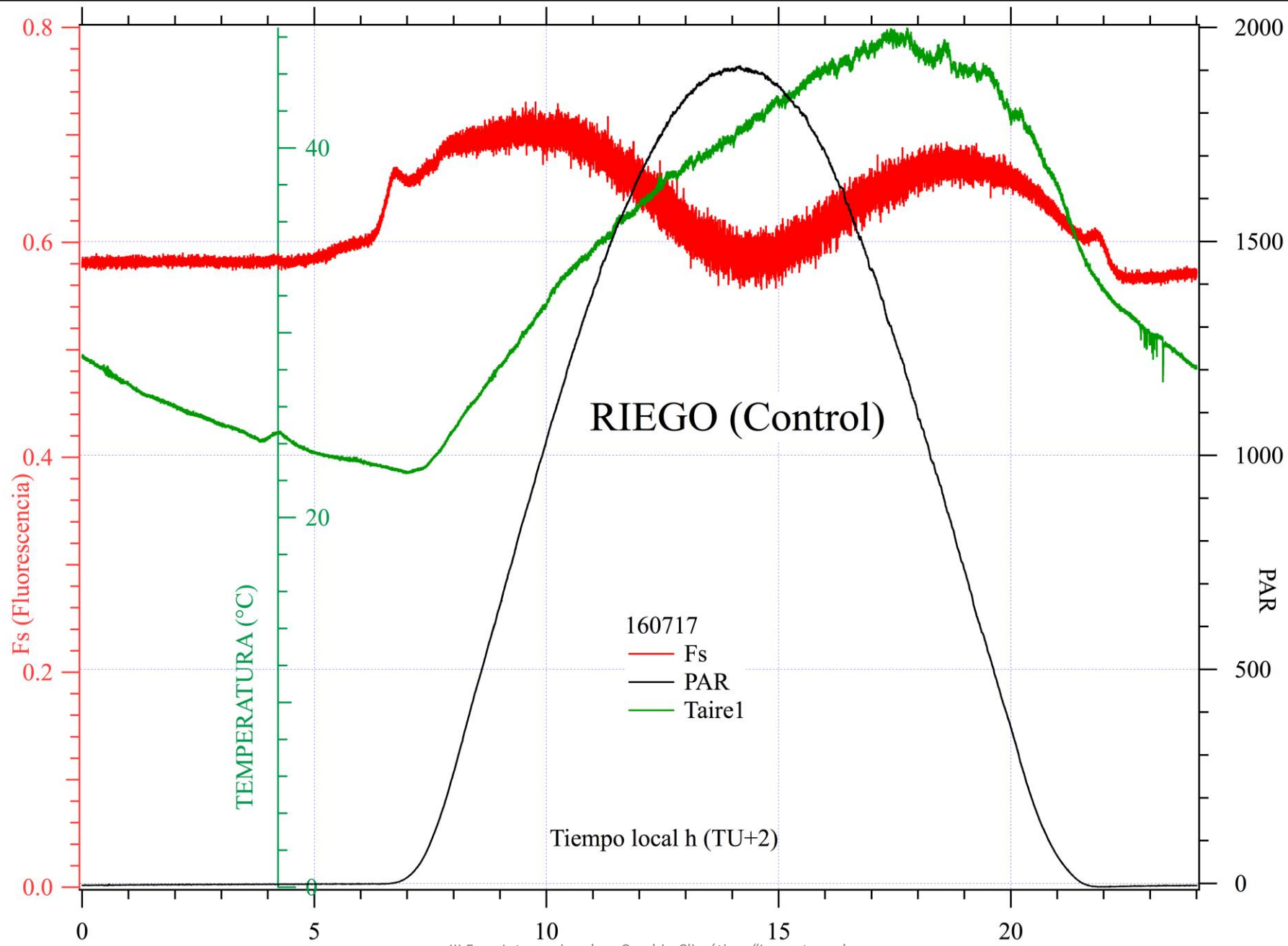
Termometro infrarojo y LEDFLEX en la parcela estresada

Se ajustaron los campos de vision a un valor similar (diam 0.8m)



Termometro infrarojo en la zona control

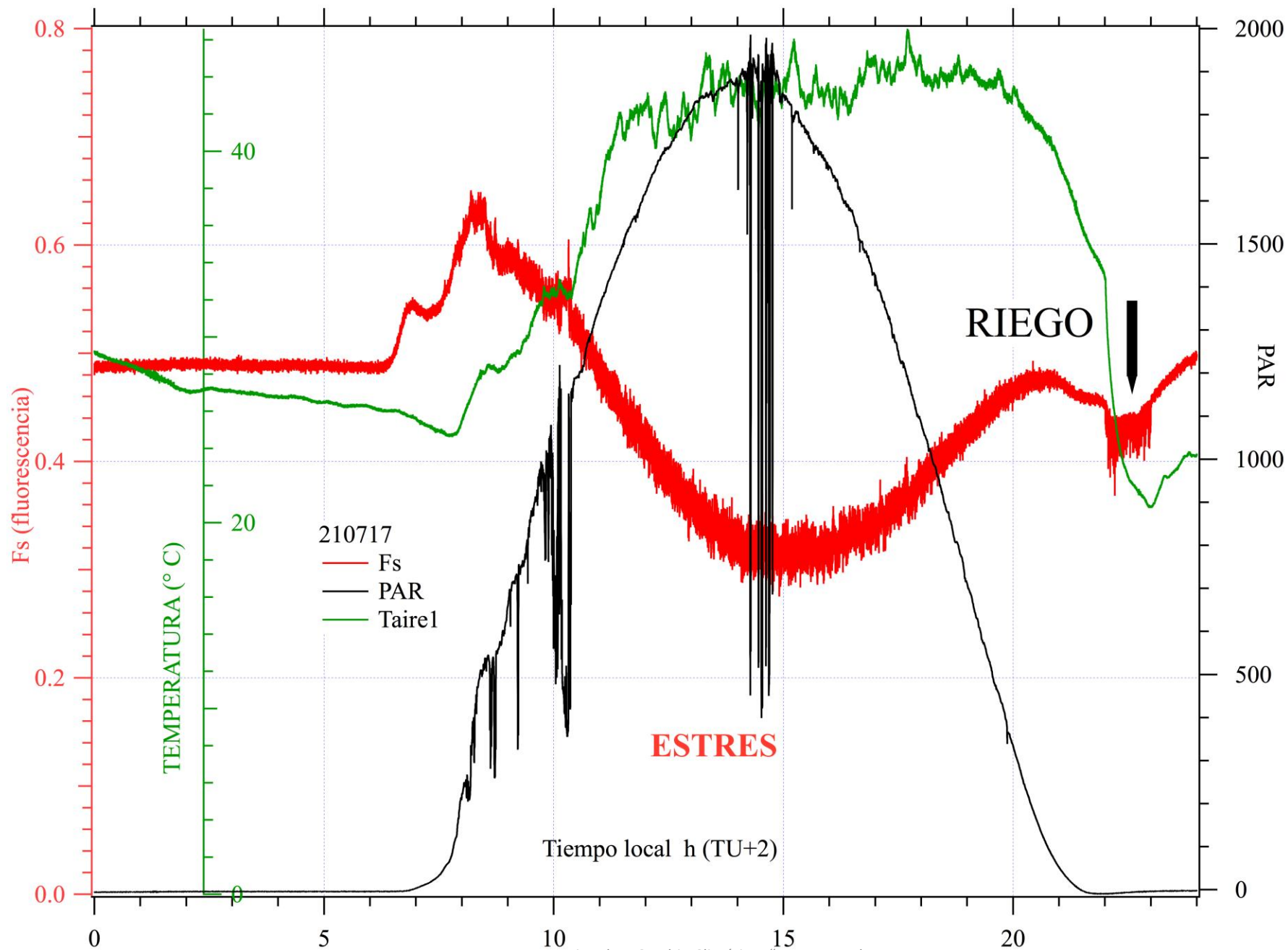


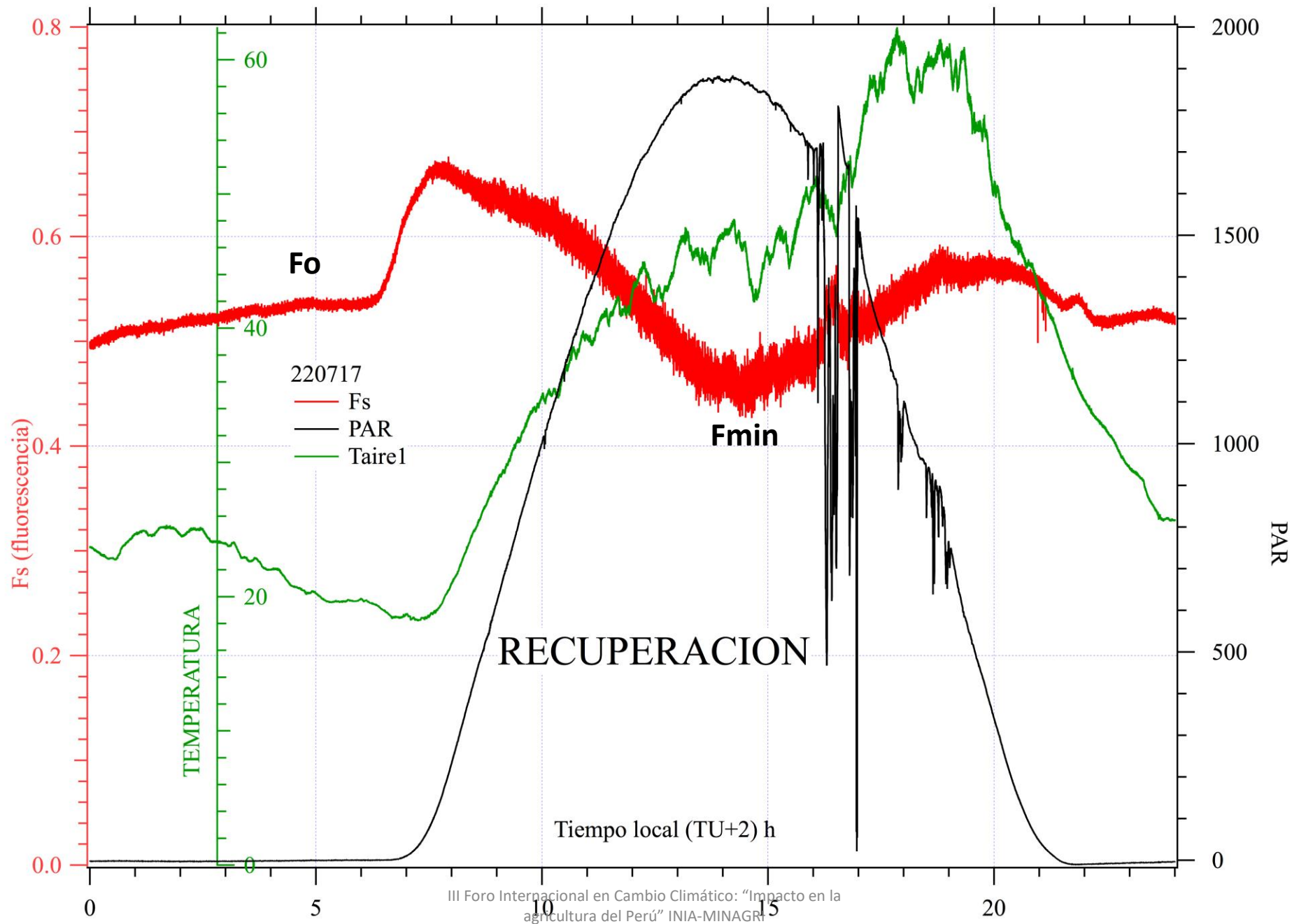


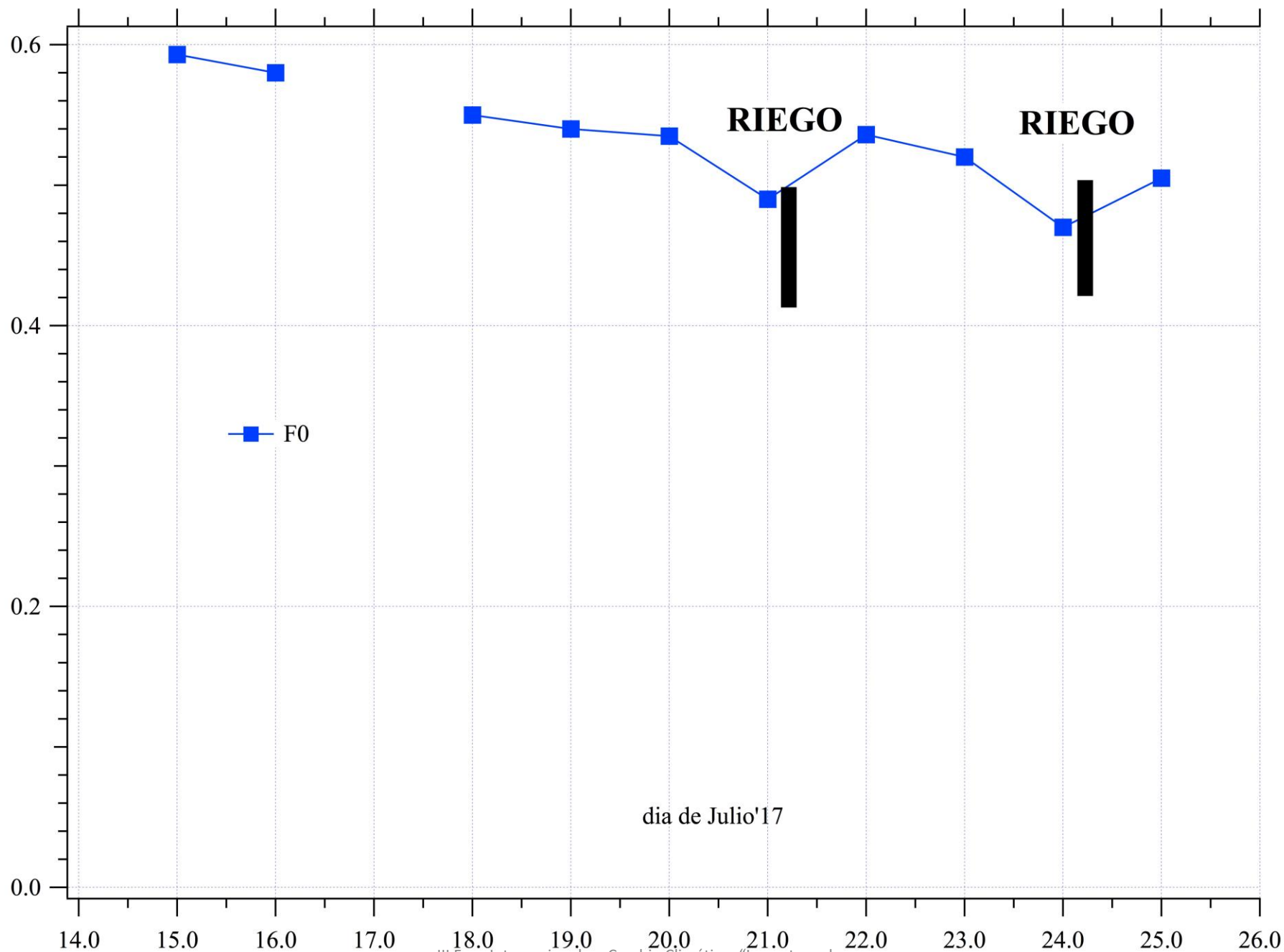
RIEGO (Control)

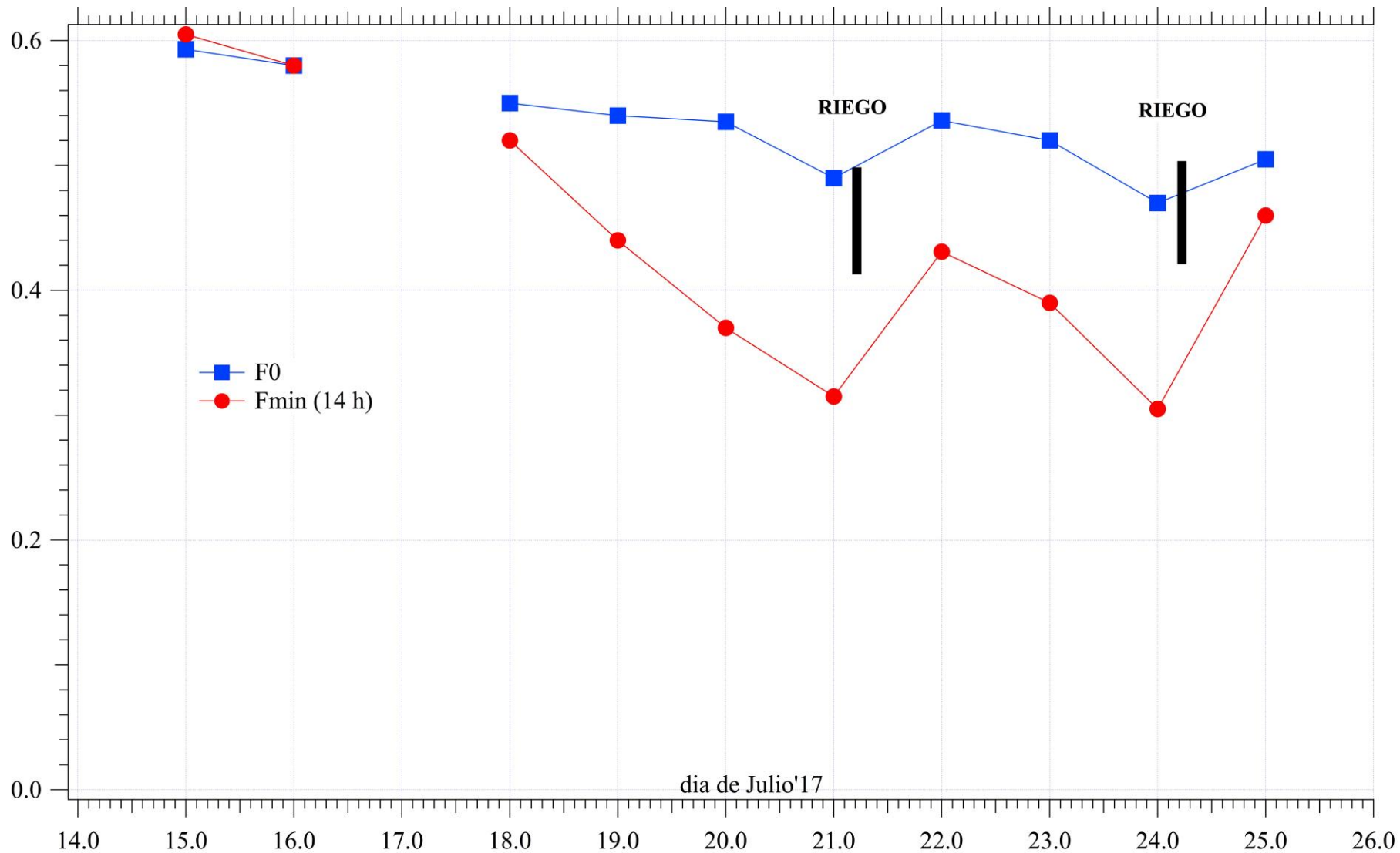
160717
— Fs
— PAR
— Taire1

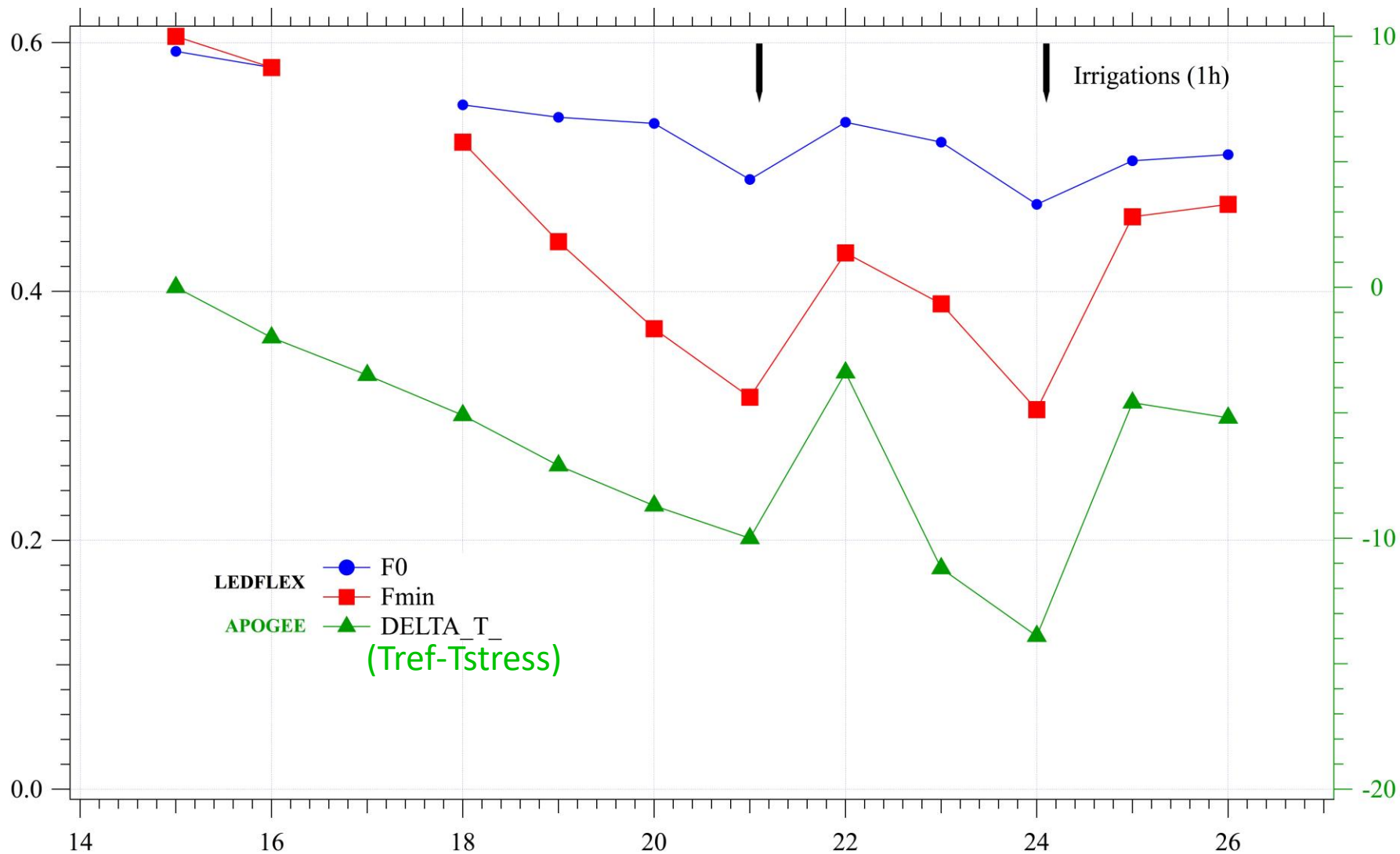
Tiempo local h (TU+2)











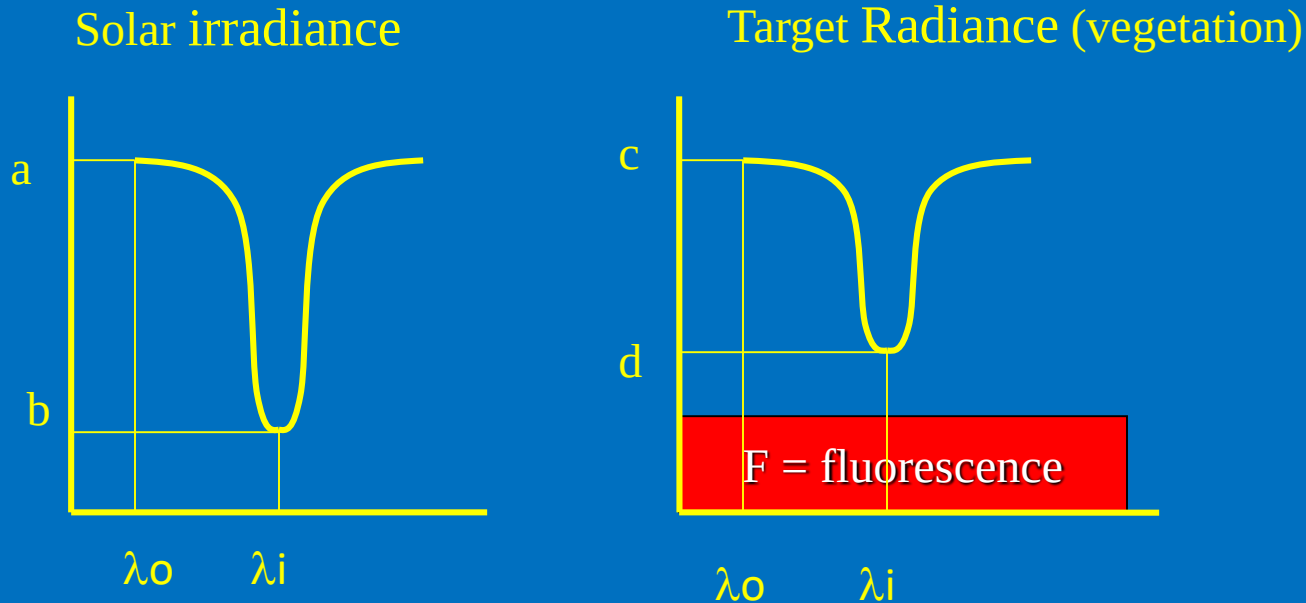
Fluorescencia con luz solar

MOYA, I et al. (1999) *An instrument for the measurement of sunlight excited plant fluorescence*. In Proceedings of the XIth International Congress on Photosynthesis (ed. G. Garab), Kluwer Academic Publishers, Dordrecht . Vol V, pp 4265-4370.

MOYA, I. et al. (2004). *A new instrument for passive remote sensing: 1. Measurements of sunlight induced chlorophyll fluorescence*.

Remote Sens. Environ. 91: pp 186-197

The Fraunhofer Line Discrimination Method in the atmospheric O₂ absorption bands

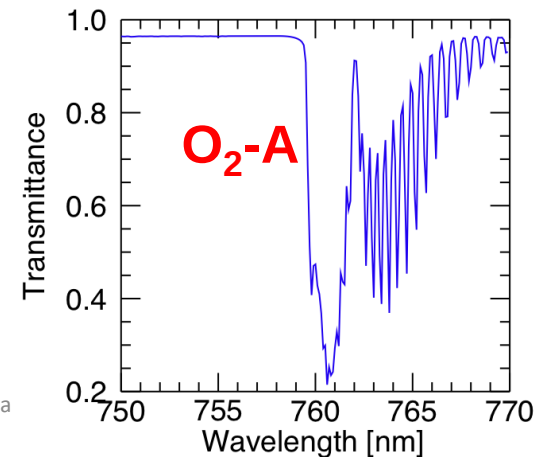
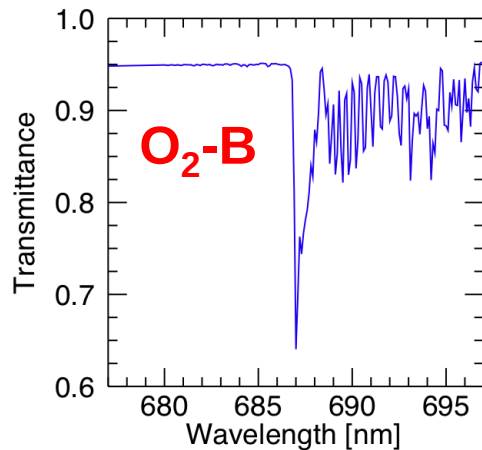
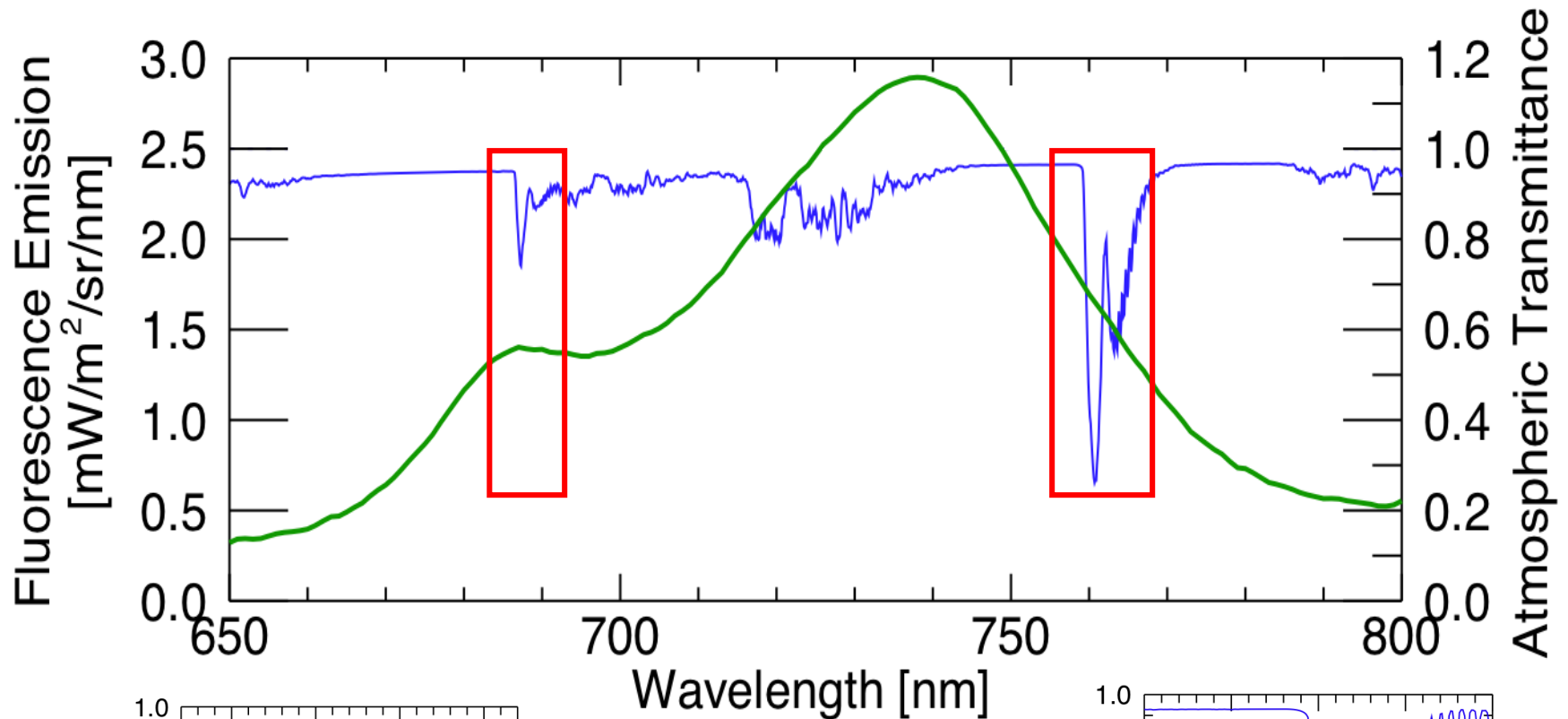


$$R = (c-d)/(a-b)$$

$$F = d - R b$$

$R(\lambda)$ and $F(\lambda)$ are supposed to be constant between λ_o and λ_i

Two absorption bands of the atmospheric oxygen are well situated to monitor the Chl fluorescence emission spectrum



MOYA, I et al. (1999) *An instrument for the measurement of sunlight excited plant fluorescence*. In Proceedings of the XIth International Congress on Photosynthesis (ed. G. Garab), Kluwer Academic Publishers, Dordrecht . Vol V, pp 4265-4370.

MOYA, I. et al. (2004). *A new instrument for passive remote sensing: 1. Measurements of sunlight induced chlorophyll fluorescence*.

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FLEX

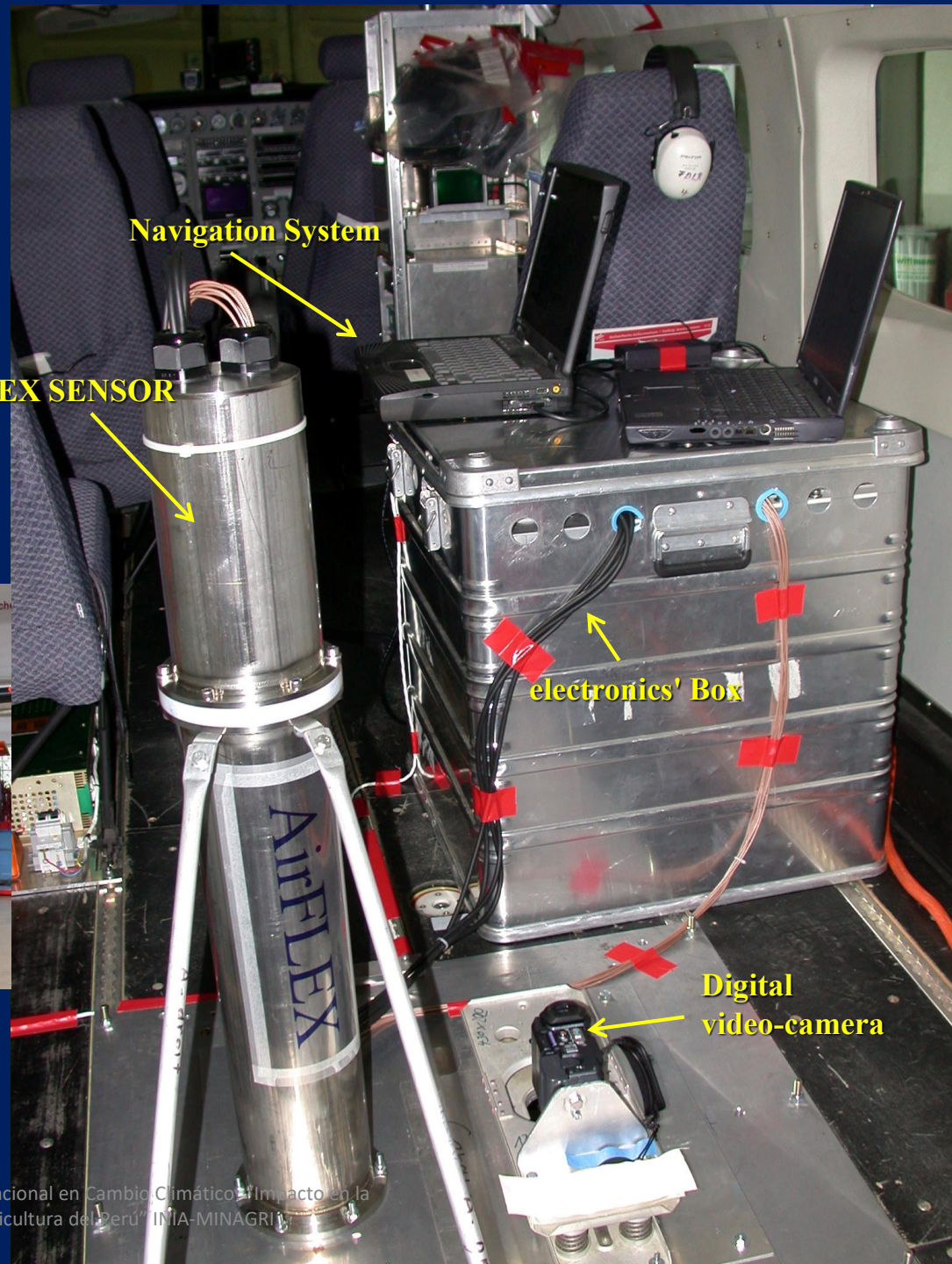
Sentinel-3

Flight direction

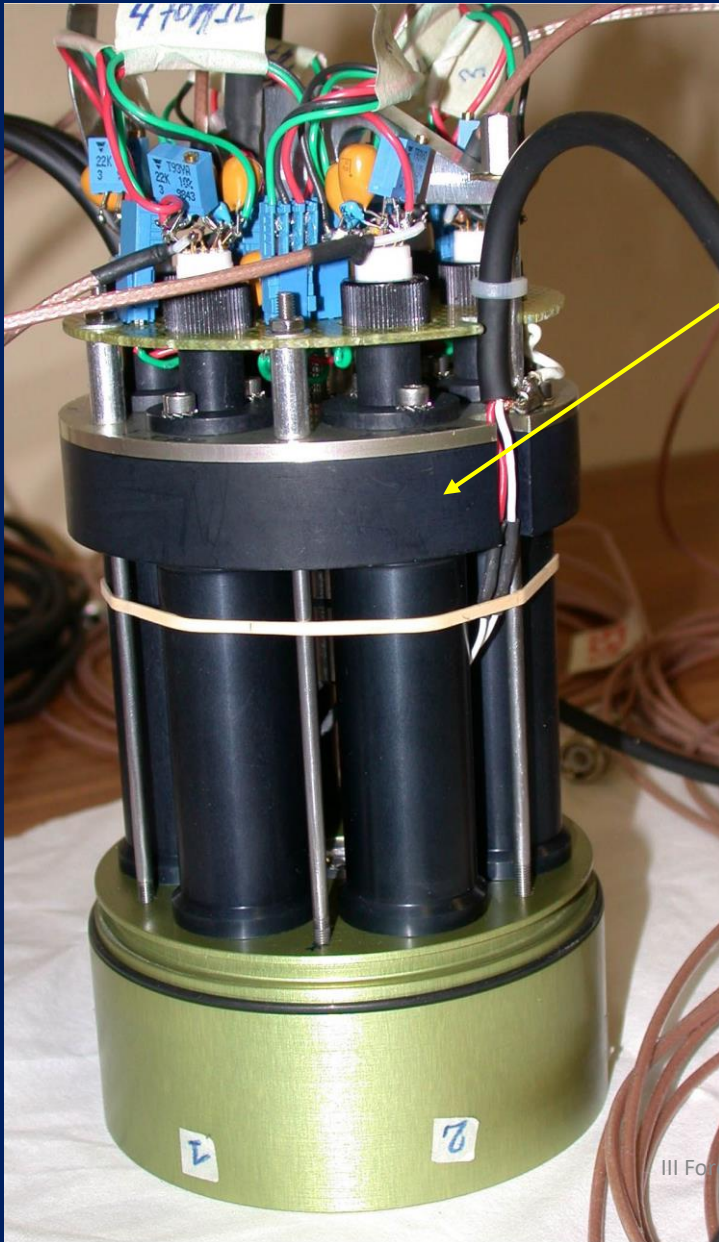
FLORIS (150 km)
OLCI nadir (1270 km)
SLSTR 'nadir' (1400 km)
SLSTR backward (740 km)

ESA : European Space Agency
FLEX : Fluorescence EXplorer

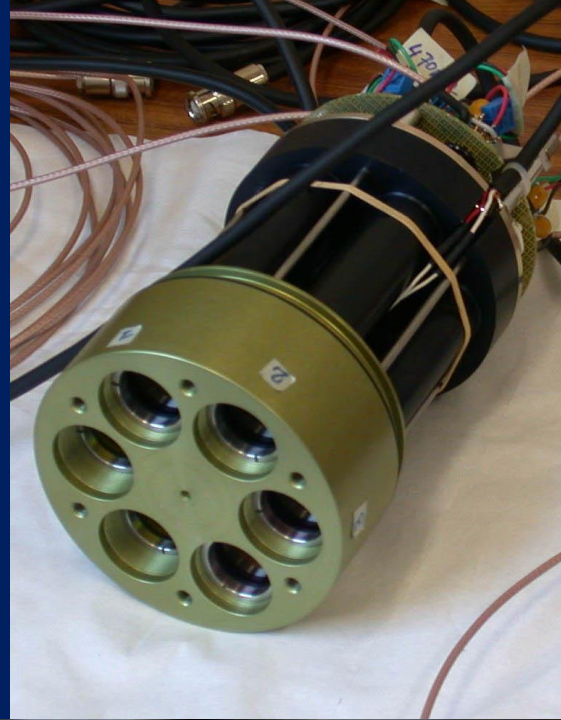
DLR - CESSNA Grand Caravan
Oberpfaffenhofen
(Munich - Germany)

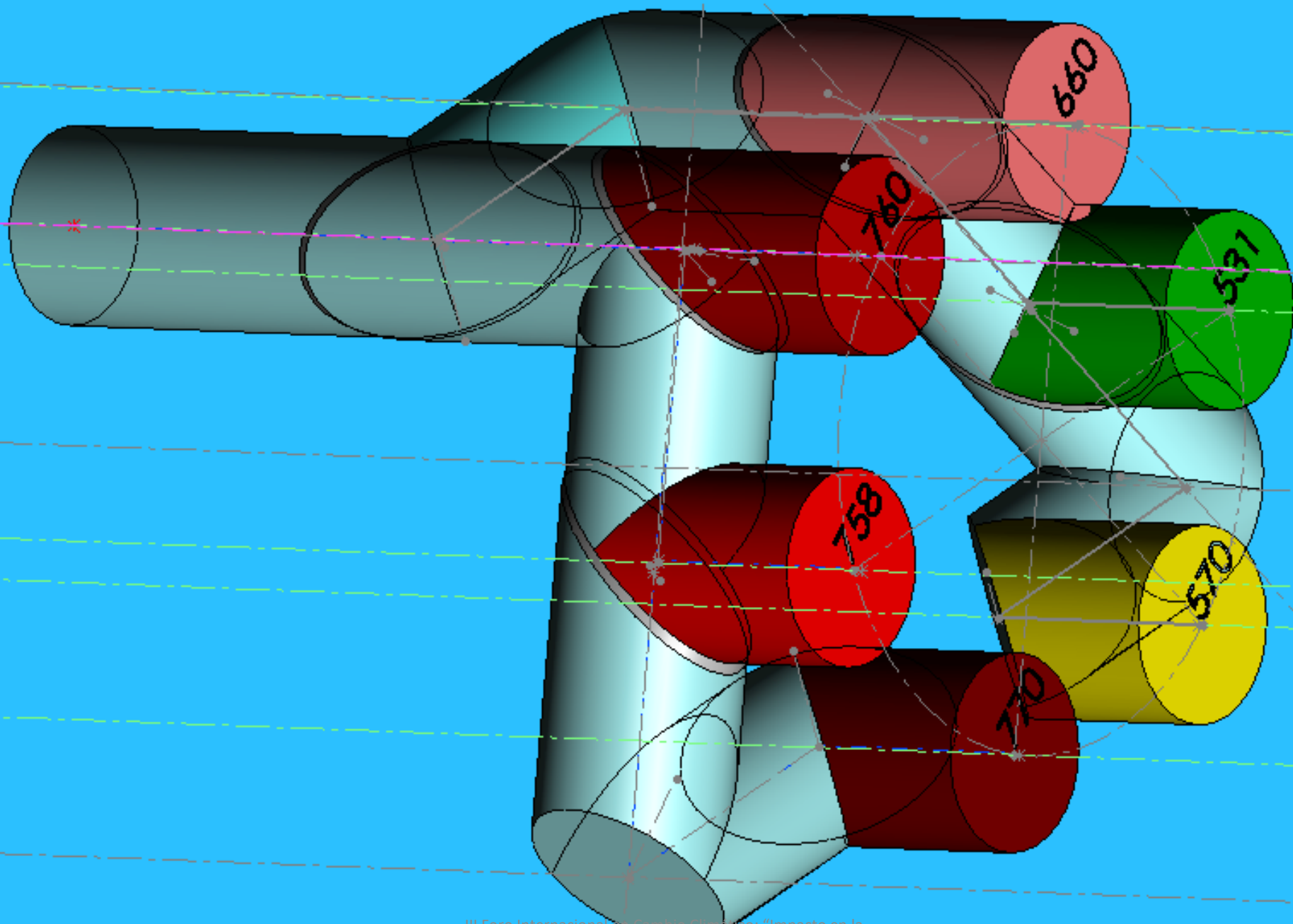


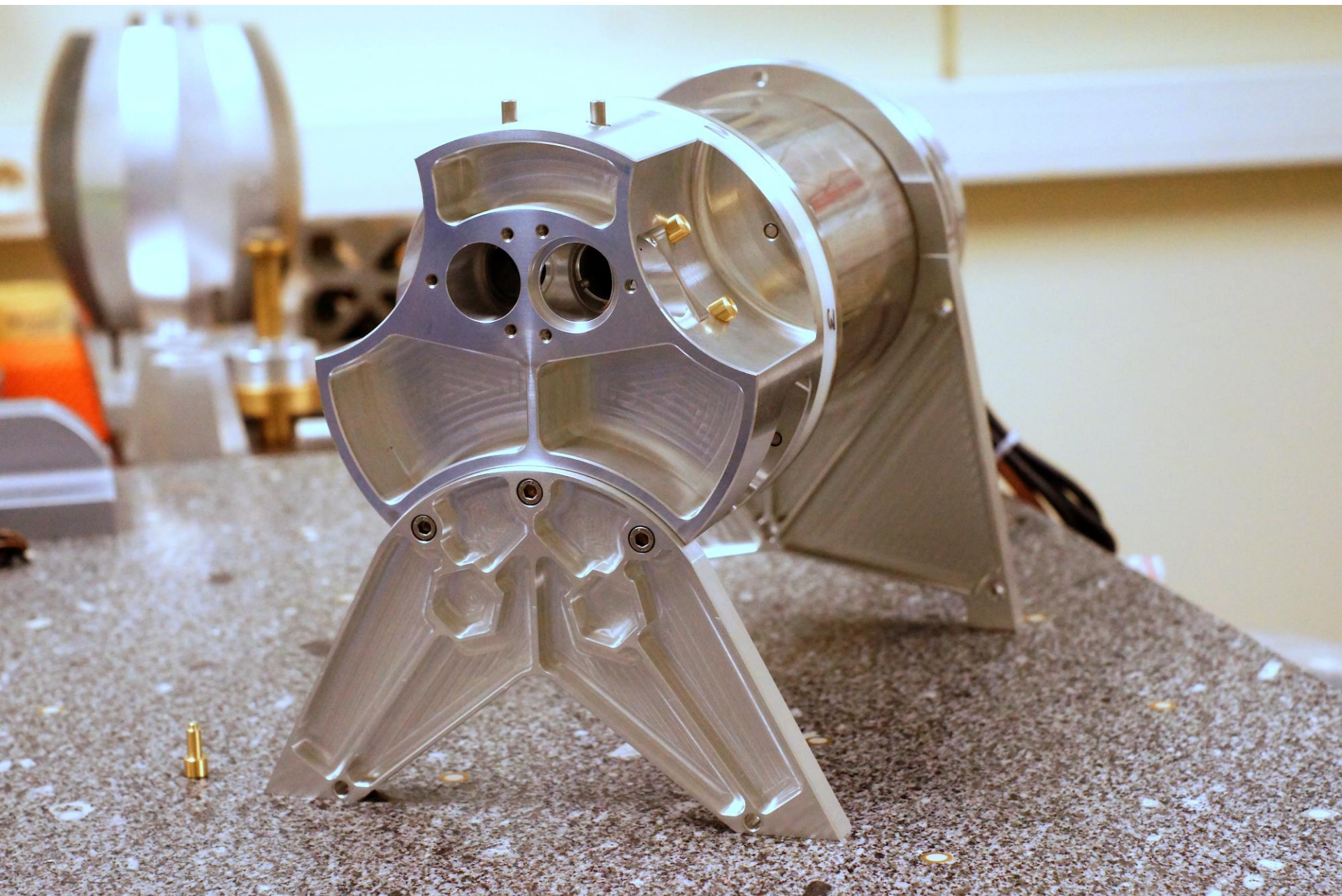
Wired Sensor (naked)



mechanical shutter



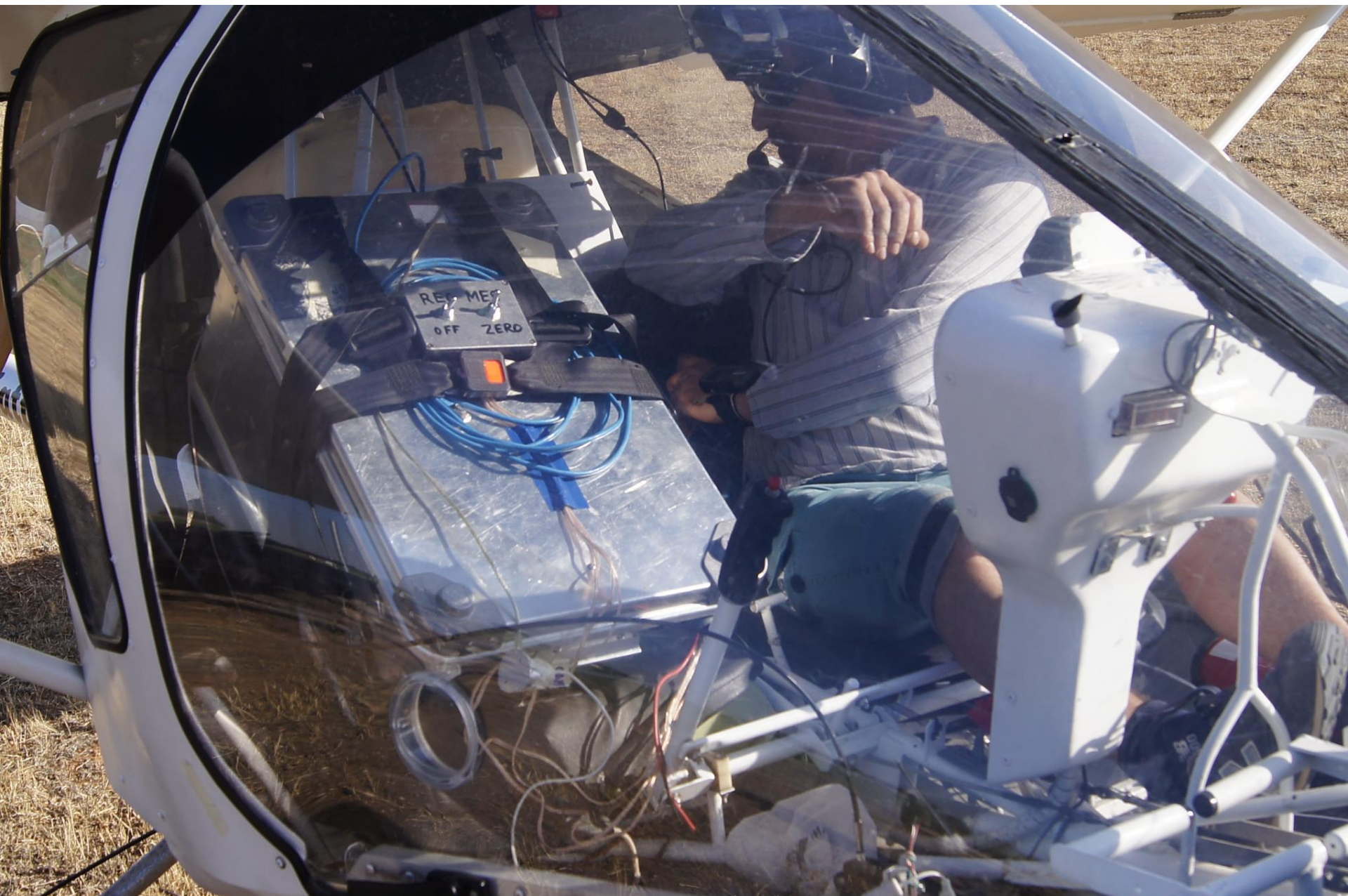




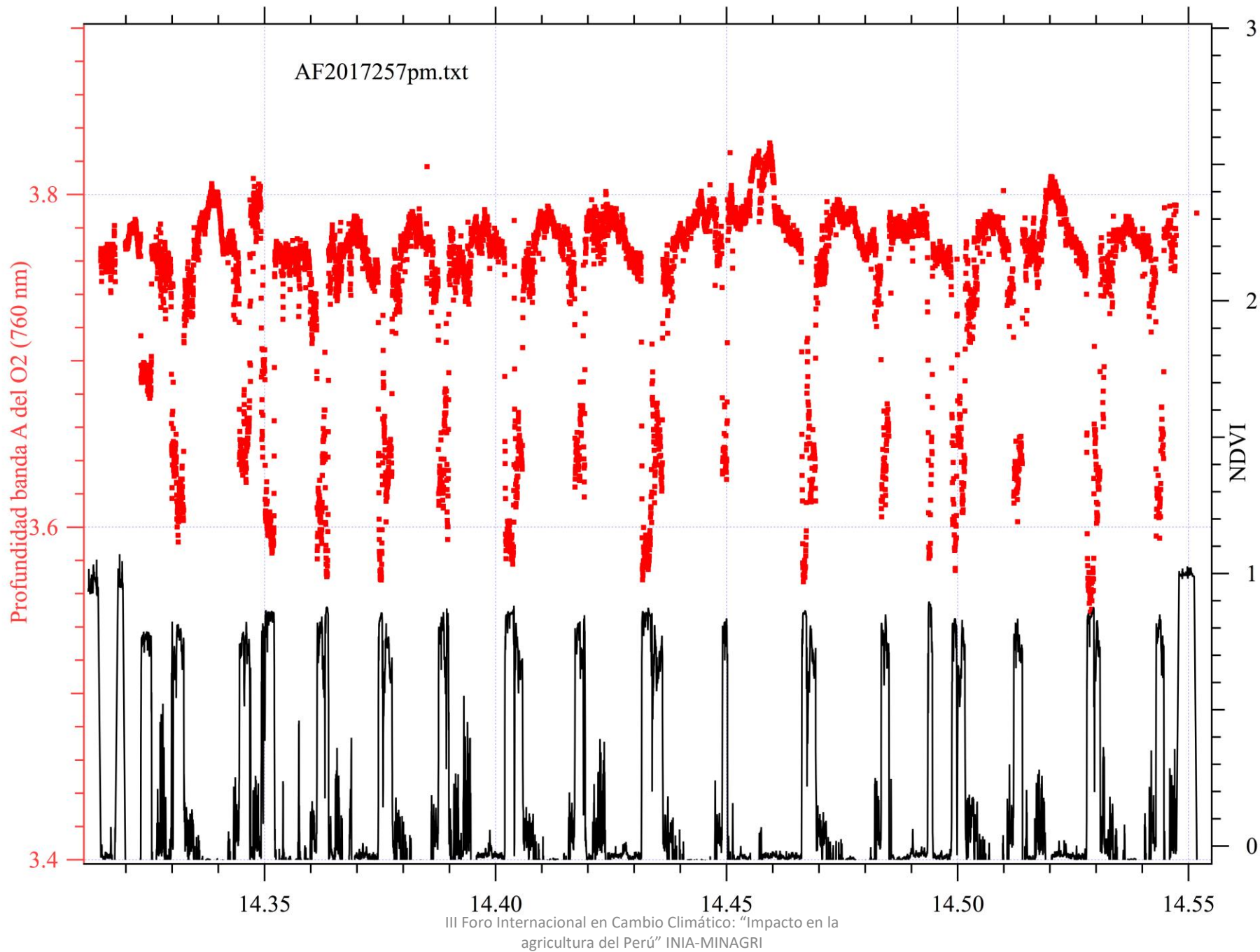
3 días de vuelo a las $\approx 9h$ y las 14h (mediodía solar)

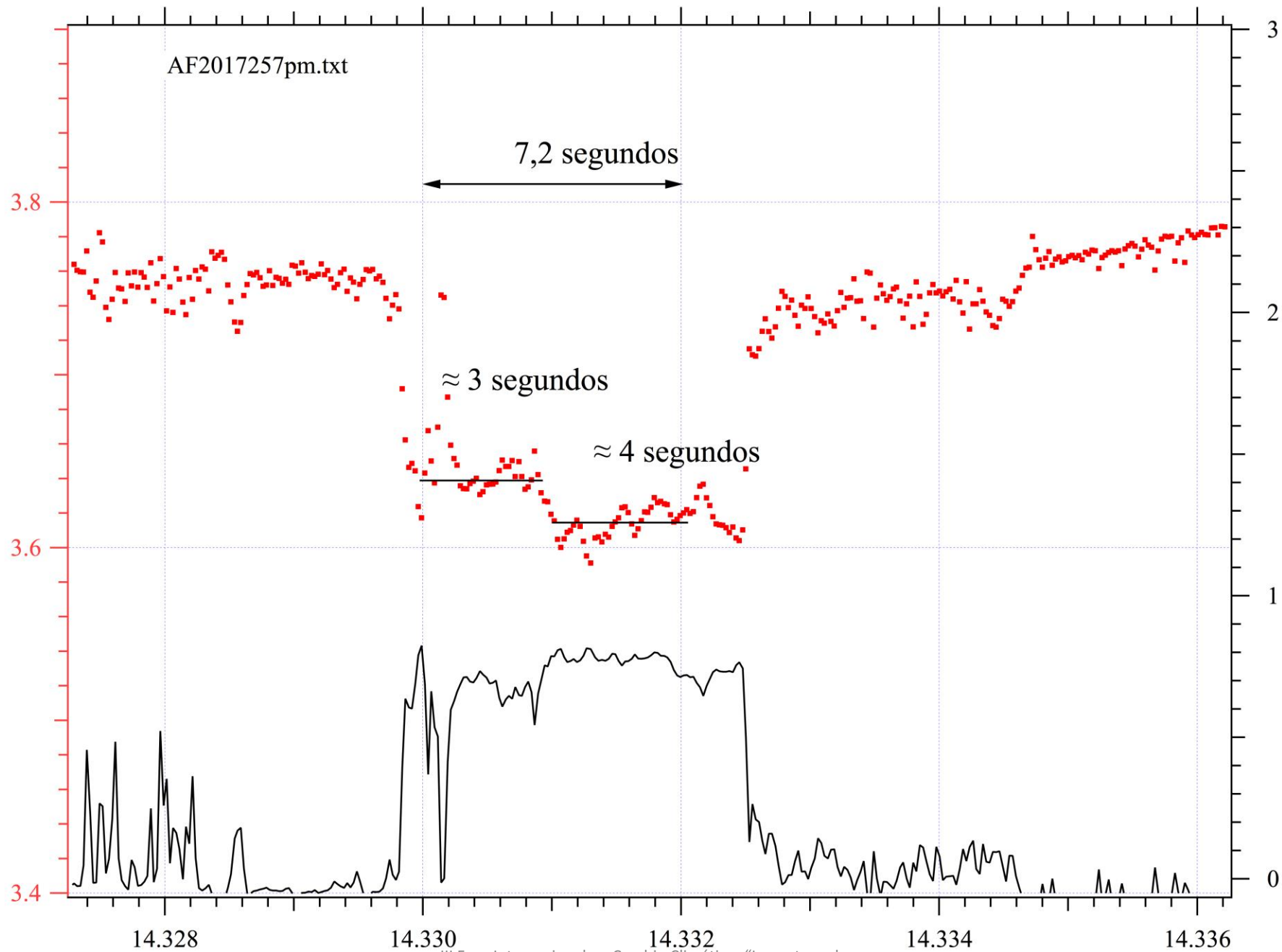


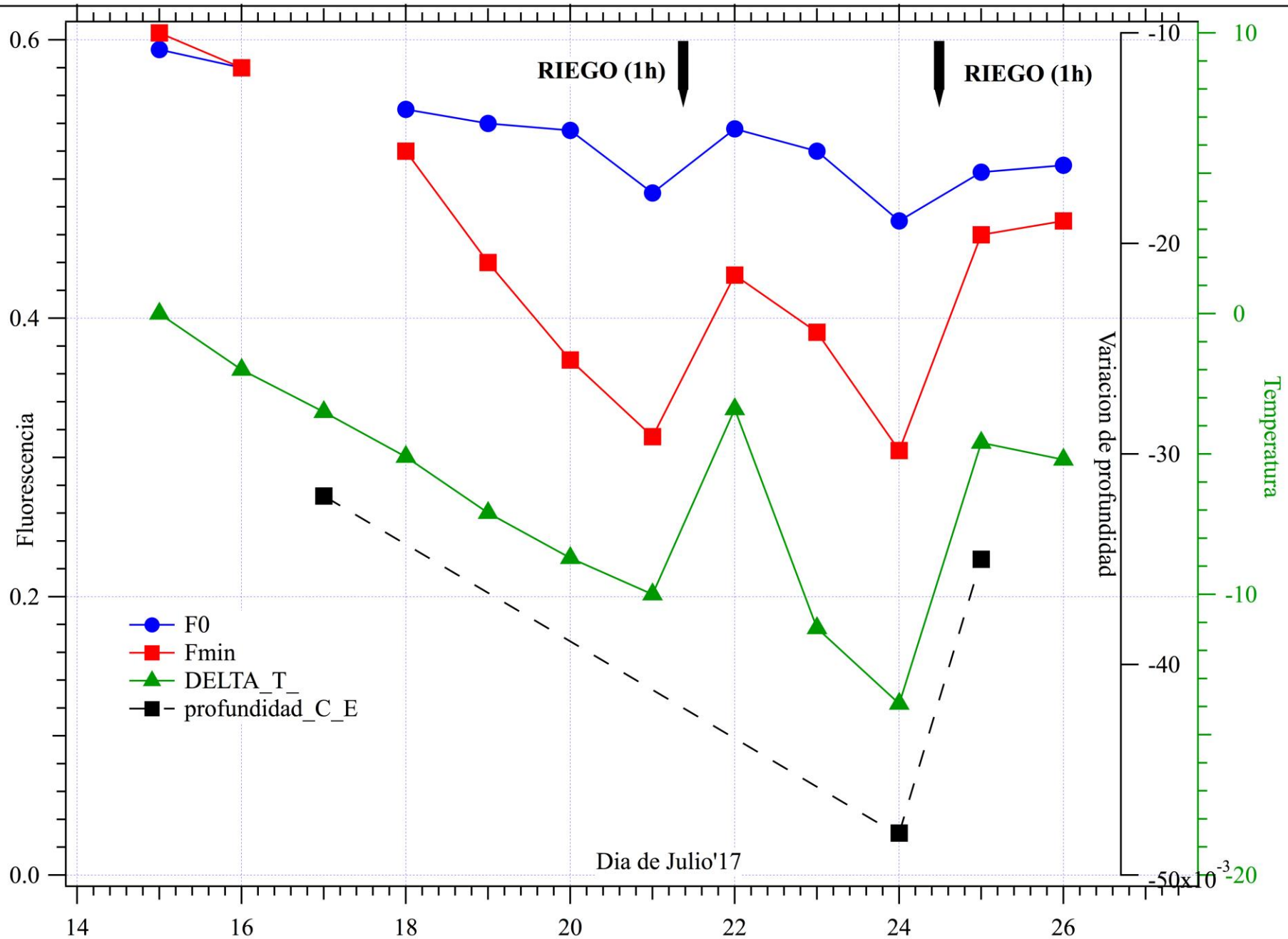




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CONCLUSIONES

- Hemos realizado un sistema **analítico**, simple, barato y de alta resolución que cualquier laboratorio puede duplicar.
- Permite el seguimiento continuo del ciclo diario de la fluorescencia.
- Detectamos con alta sensibilidad el estrés hídrico reversible del campo de festuca.
- Las medidas pasivas confirman cualitativamente los resultados activos

gracias por su atención

**Sin esperar FLEX, otros ya detectan
la fluorescencia de la clorofila desde el espacio**

First observations of global and seasonal terrestrial chlorophyll fluorescence from space

J. Joiner, Y. Yoshida, A. P. Vasilkov, Y. Yoshida, L. A. Corp, and E. M. Middleton

Biogeosciences, 8, 637–651, 2011

Thermal And Near-infrared Sensor for carbon Observation
– Fourier Transform Spectrometer (TANSO-FTS)
on the Japanese Greenhouse gases Observing SATellite (GOSAT)

GOSAT was launched on 23 January 2009 into a sun-synchronous orbit with a descending node equatorial crossing time near 13:00 LT.

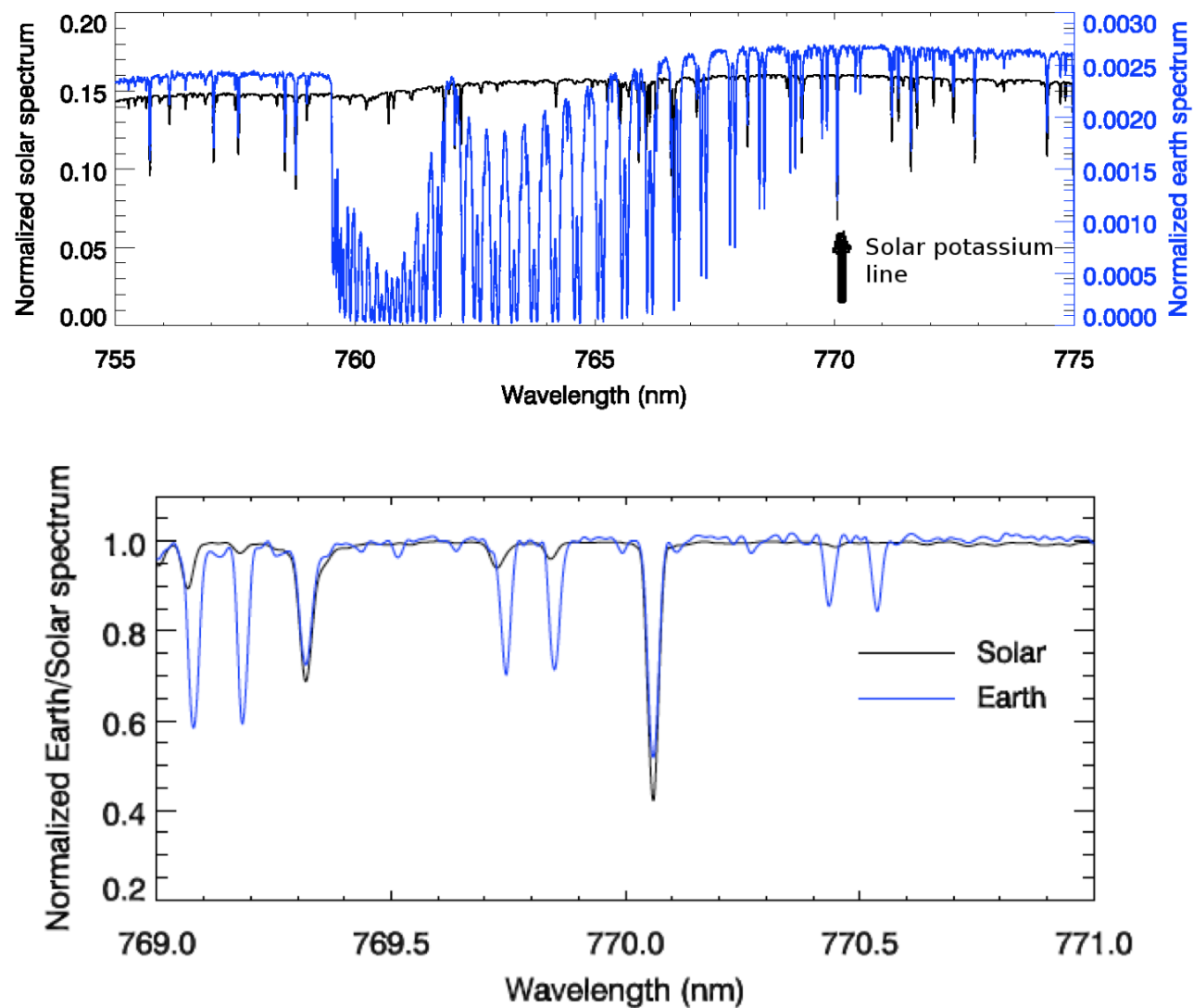


Fig. 4. GOSAT solar and Earth spectra in band 1 P polarization with the K I line (top) and zoom near the wavelengths used in our fitting window (bottom). Spectral data are interpolated using a spline function.

Extraction of fluorescence from reflectance
is like determining the weight of a tie ...



... limited accuracy !

AIRFLEX specifications :

Interferential Filters

O₂-A Band : 757.31 & 760.5 nm - FWHM =1 nm

~~0.5-n**O₂-B Band** : 685.61 & 687.19 nm - FWHM = 0.5 nm~~

694.1 FWHM 5.8 & 770.36 nm - FWHM = 2.25 nm

Field of View : 34 mradianes (2°)

Footprint : 20 m at 600 m of altitude

Useful Pupil Diameter : 19 mm

Detection : PIN Si photodiode (ϕ 2.54 mm)

Integration time: 20 ms or 200 ms

Samples / s : 12 or 2.2