Calibration methodology of remote PRI sensor for plant photosynthesis rate status assessment in greenhouse

This research is co-financed by Greece and the European Union (European Social Fund- ESF) through the Operational Programme «Human Resources Development, Education and Lifelong Learning» in the context of the project “Reinforcement of Postdoctoral Researchers - 2nd Cycle” (MIS-5033021), implemented by the State Scholarships Foundation (IKY).

Scientific Responsible: **Angeliki Elvanidi**
Scientific Consultant: **Nikolaos Katsoulas**

Circular Economy-Protected cultivation

Soilless (growing a crop without soil) crops - are very resource-intensive and may be considered circular since plants can grow in closed systems where water and nutrients are recirculated

Direct and real-time monitoring of plant responses and processes under specific environmental and root conditions can help to improve climate and irrigation control and overall production over time and space

Greenhouse control using climate data: Ta, RH, SR

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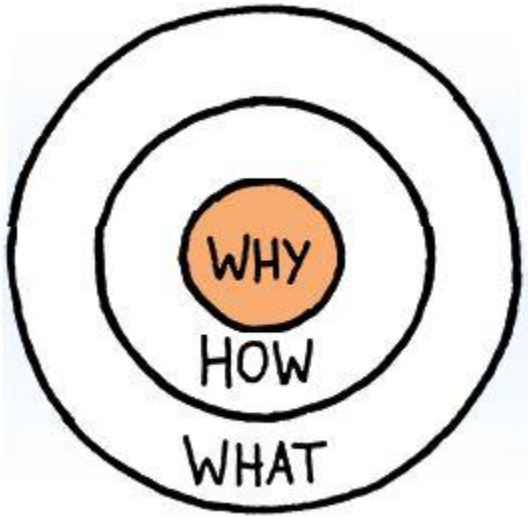
- **Why** we choose to estimate a *crop Ps remotely*
- **How** the *crop Ps is measured using Photochemical Reflectance Index (PRI)*
- **What** is the correlation between remote PRI and Ps values



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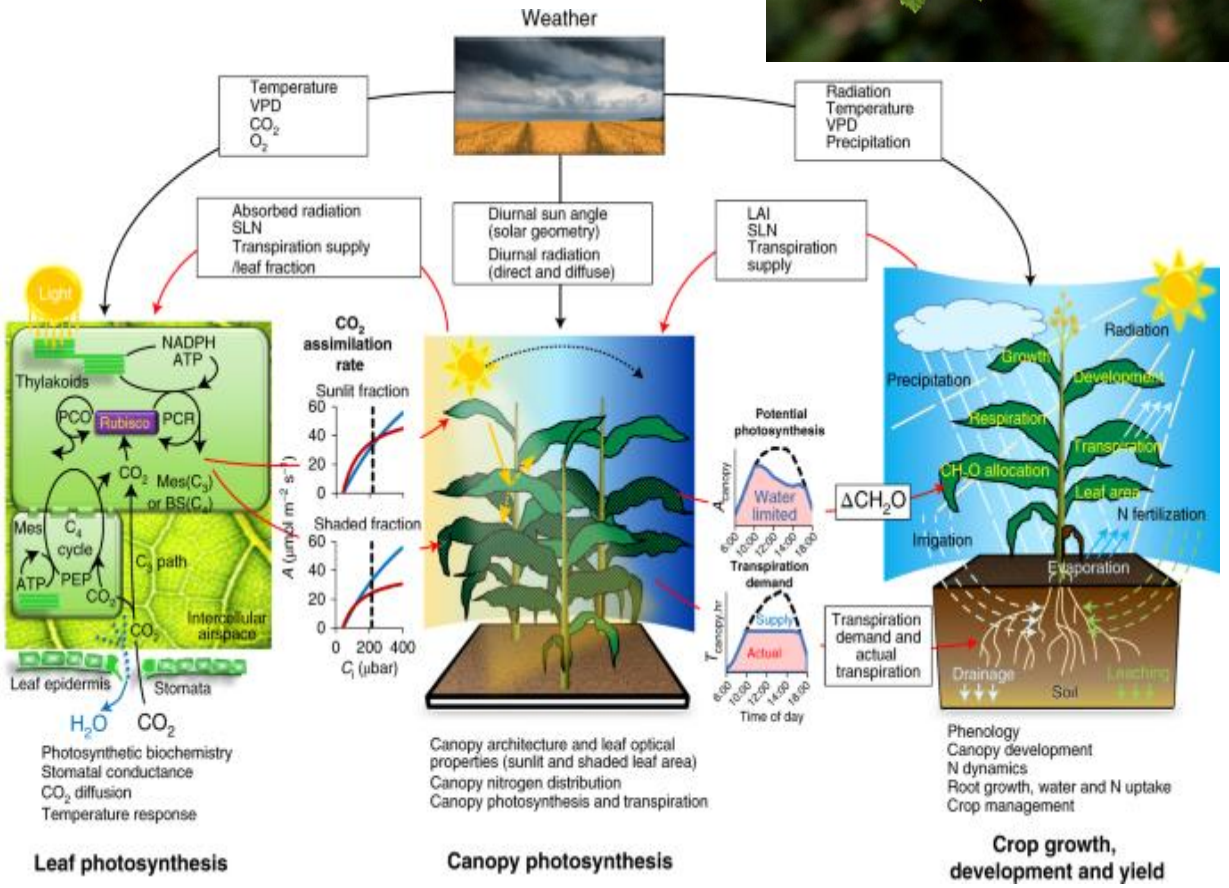
Photosynthesis rate Ps (µmol m^{-2} s^{-1})

- Uptake of CO_2 by plants
- Release of O_2
- Dry matter content
- Carbohydrate production
- Measure light-dependent photosynthesis using Hill's reaction
- Chlorophyll fluorescence

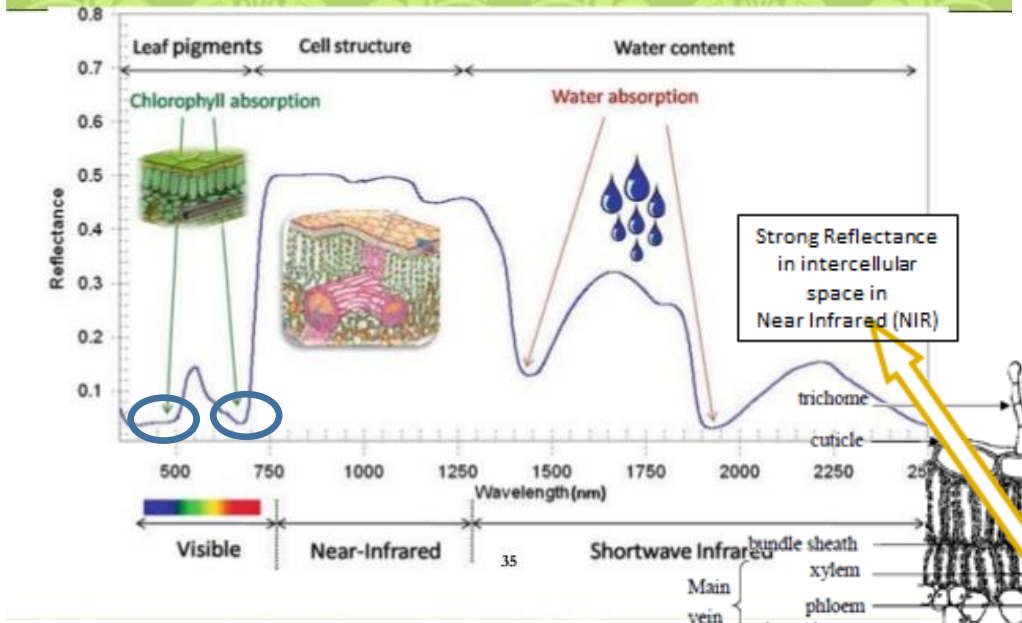


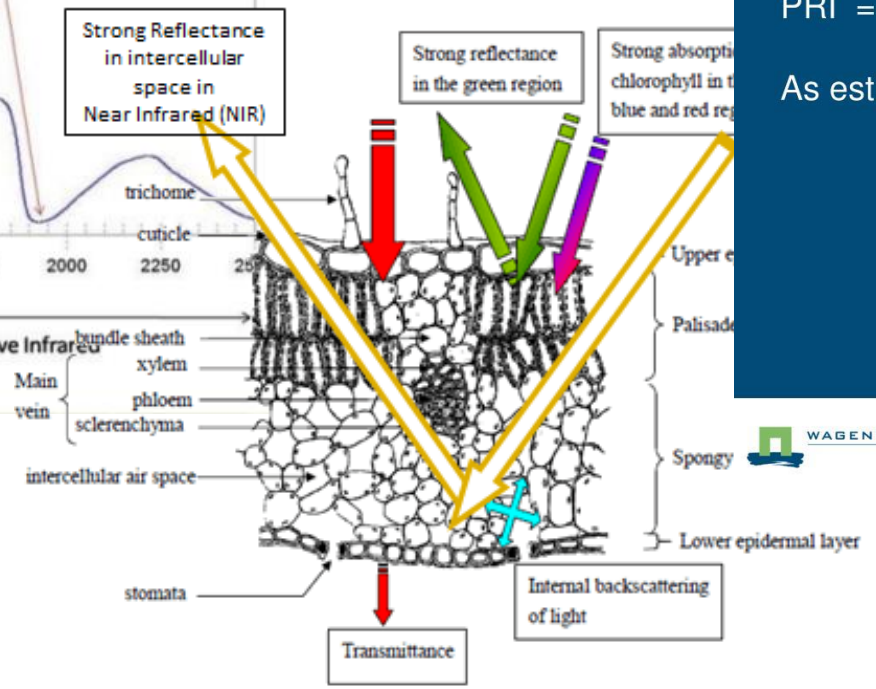
Lab or Field

Commercial Instruments

- Infrared Gas Analyzer
- Electrochemical Gas Sensor

Plant reflectance
Photochemical Reflectance Index-PRI





Photochemical Reflectance Index (PRI)

$PRI = (R_{531\ nm} - R_{570\ nm}) / (R_{531\ nm} + R_{570\ nm})$

As estimator of photosynthetic activity

Gamon et al., Remote Sensing of Environment 41 (1992), 35 – 44.

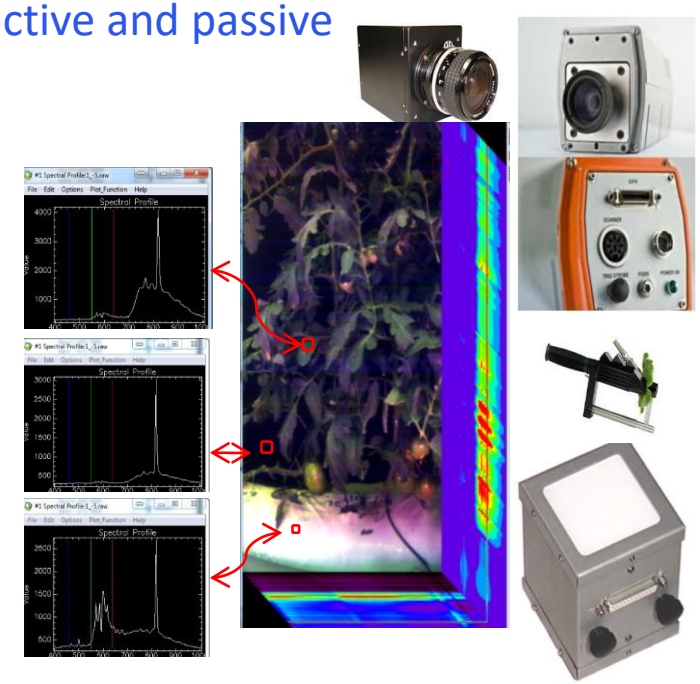
Methods of measuring PRI

➢ Different types of ground based sensors can detect PRI in real time by monitoring plant reflectance

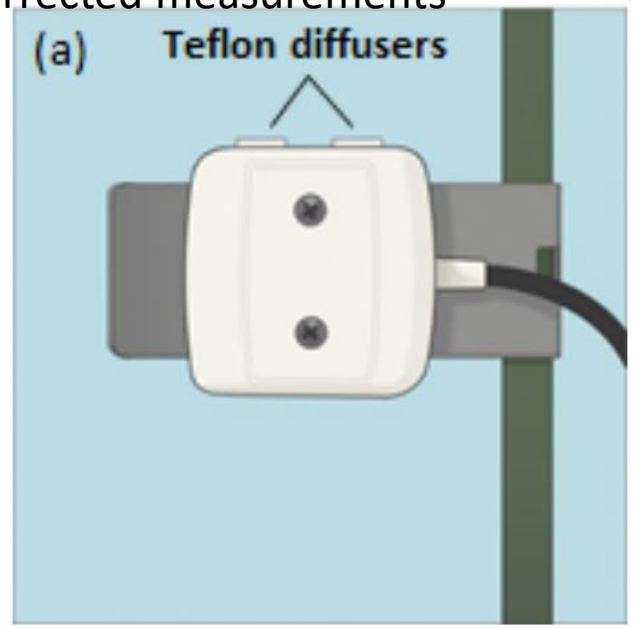
Spectral Remote Sensor:
PRI Wavebands: 532 and 570 nm central wavelengths, with 10 nm full width half maximum band widths

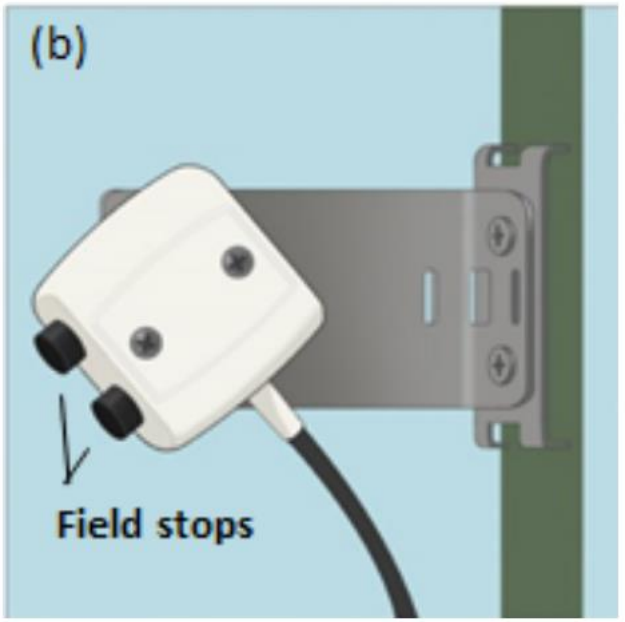
Ground based sensors can be classified into three distinct categories:

(a) spectrometers and radiometers
(b) imaging and non-imaging and
(c) active and passive



➢Up-looking sensor
➢Hemispherical 180◦ FOV
➢Teflon diffusers for making cosine-corrected measurements





➢Down-looking sensor
➢Field of View 36◦
➢Canopy reflected radiation

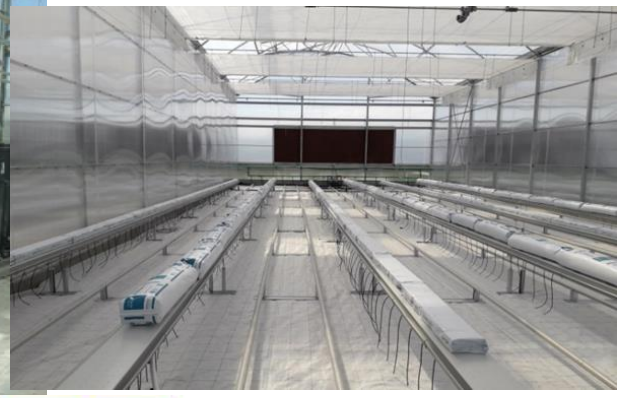
Facilities-Experiment set-up

WHAT IS . . .

The establishments were located at the facilities of University of Thessaly, Velestino, Volos (Latitude 39º 22΄, longitude 22º 44΄ and altitude 85m), on the continental area of eastern Greece

Multitunnel greenhouse 1500 m^2: 2 of 6 compartments (250 m^2 each)

Air temperature and relative humidity were automatically controlled using a climate control computer (SERCOM, Automation SL, Netherlands)



6 crops lines per compartment:
20 m length x 25 cm width

19 rockwool slabs/line:
totally 114 slabs per compartment

Tomato Crop: LAI 4

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SRS establishment

The up-looking SRS sensor was mounted above the canopy with an unobstructed view of the sky

The down-looking SRS sensor was placed
- **in 2 m above the ground**
- **in 0.20 m from the crop**
- **at a constant angle of 45º from the vertical axis**
- **in order to record a leaf area of young and fully developed leaves**

The surface area sensed was about 2000 mm^2

Readings are output in units of radiant flux density ($W\ m^{-2}\ nm^{-1}$) and particularly in nanometers the PRI is calculated

PRI is calculated as the ratio between reflected and incident radiation, measured using down-looking and up-looking sensors, respectively

WHAT IS . . .

Solar radiation sensor (SR) (Rn, $W\ m^{-2}$; SP-SS, Apogee Instruments, North Logan, USA) was used to measure the light intensity above the canopy

Measurements were performed every 30 s and 5-min average values were recorded

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SRS Calibration

WHAT IS . . .

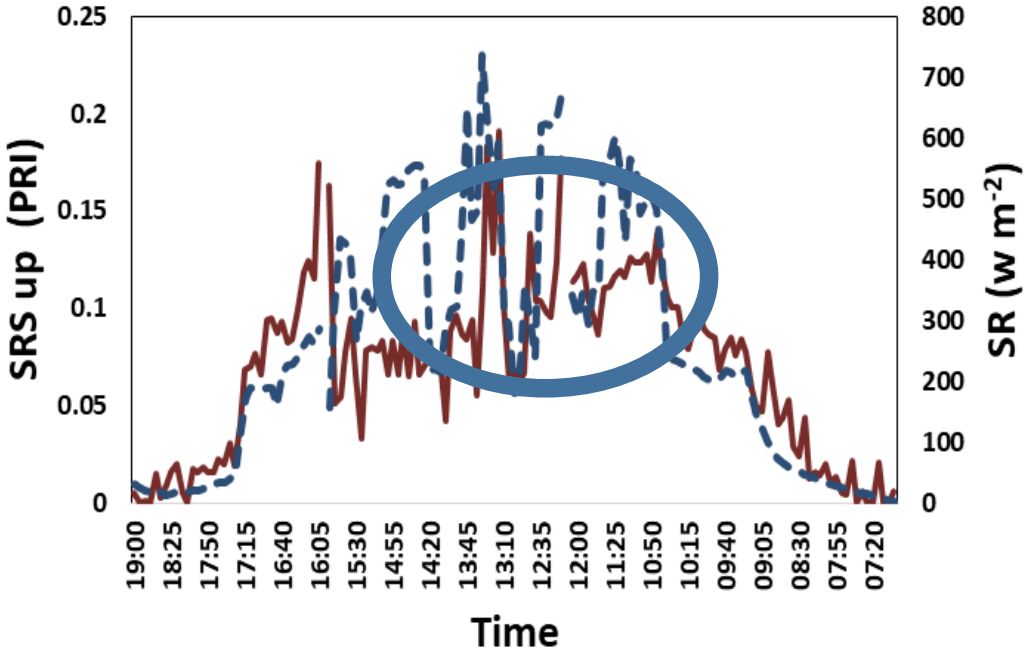
The mean PRI of the plant leaf measured using non-destructive sensing was correlated by means of an PRI_L sensor performing measurements in contact with the leaf (PlantPen PRI Meter, Alpha Omega-Electronics, Spain) for the same set of leaf area

Additionally, remote PRI values were correlated with the photosynthesis rate (*As*, μmol m^{-2} s^{-1}) obtained using a portable photosynthesis measurements system (LCpro, ADC Bioscientific Ltd., UK) for the same set of leaf area

The correlation was performed under different climatic conditions and light intensity

WHAT IS . . .

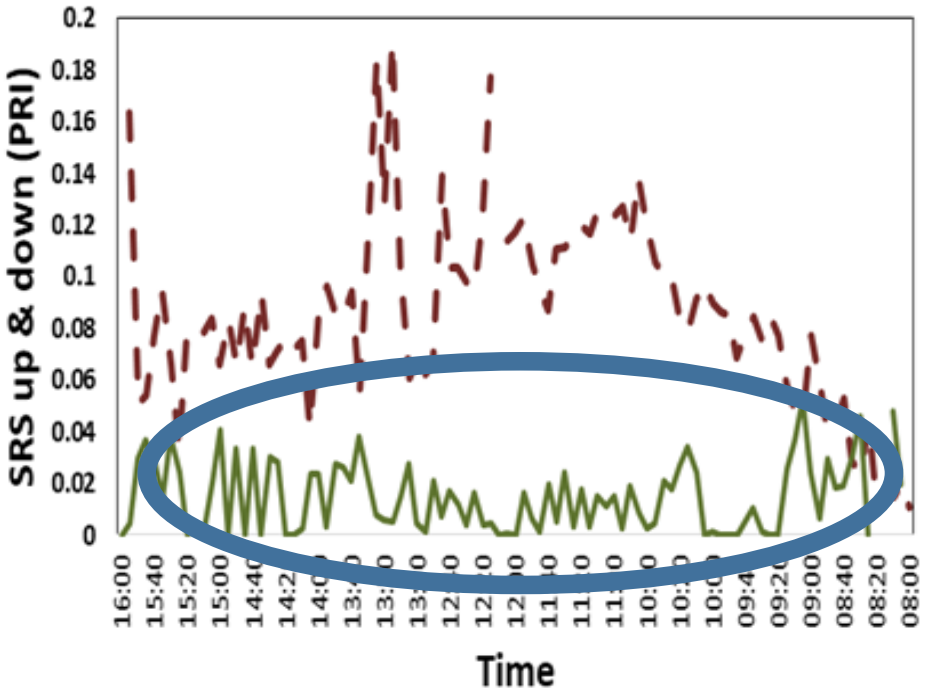
SRS indication based on indoor light intensity



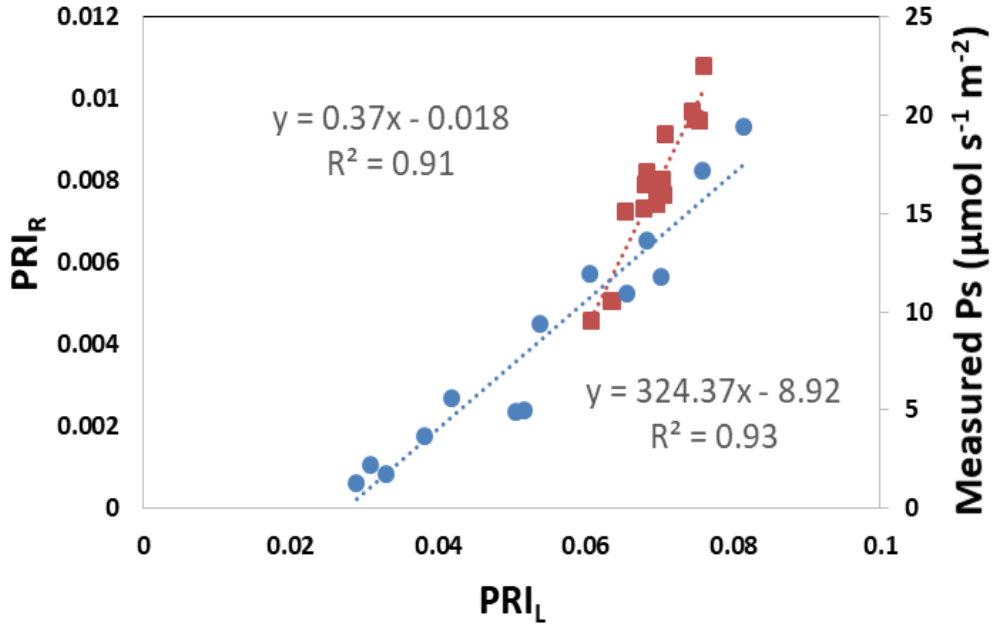
The down-looking values contain high amounts of variability

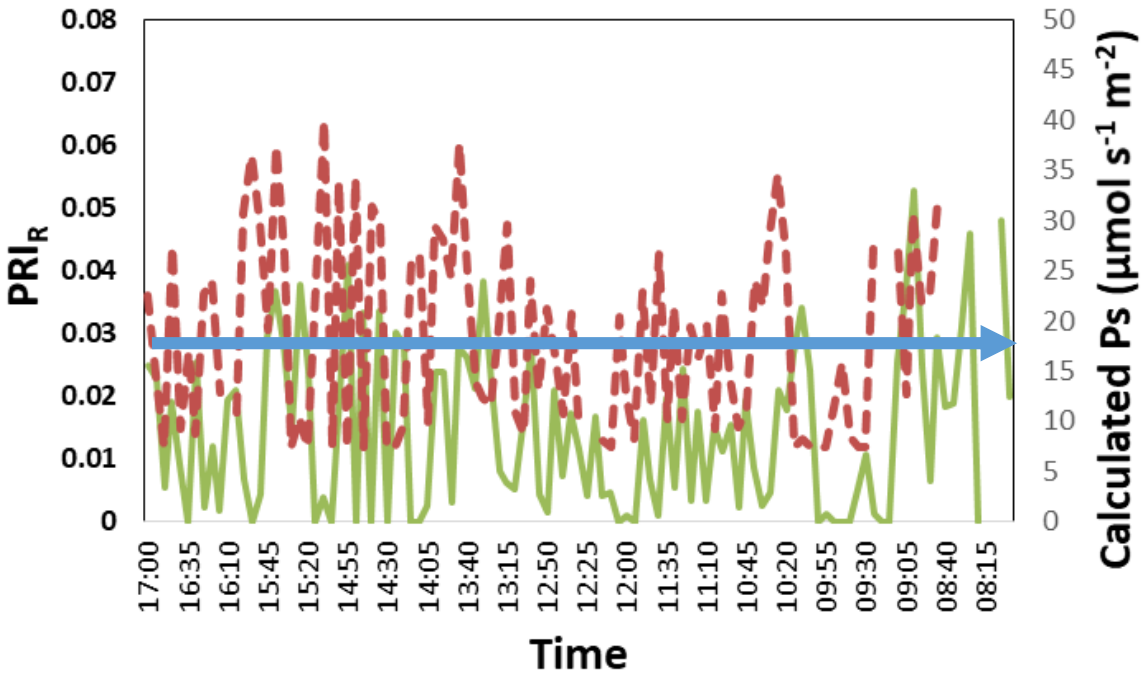
The daily sun moving during the sky didn't affect the down-looking values progress, otherwise a concave pattern should be noticed

The data above the canopy follow the same trend with the incident radiation that was measured by the solar radiation sensor placed in the indoor roof



Ps estimation based on remote PRI values





The Correlation between PRI_R and A_s is significant

- **only the light intensity was higher than 100 W m^{-2}**
- **In tomato crop with LAI 4**
- **In north position of the greenhouse**

WHAT IS . . .

Future perspectives

- • Correlation of PRIr with PS values under
  - Different positions of the SRS sensor within the greenhouse
  - Different Crop Leaf Area

- • Integration of the PRI_R values in the process of developing a model for crop stress detection in order to improve the greenhouse control system

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