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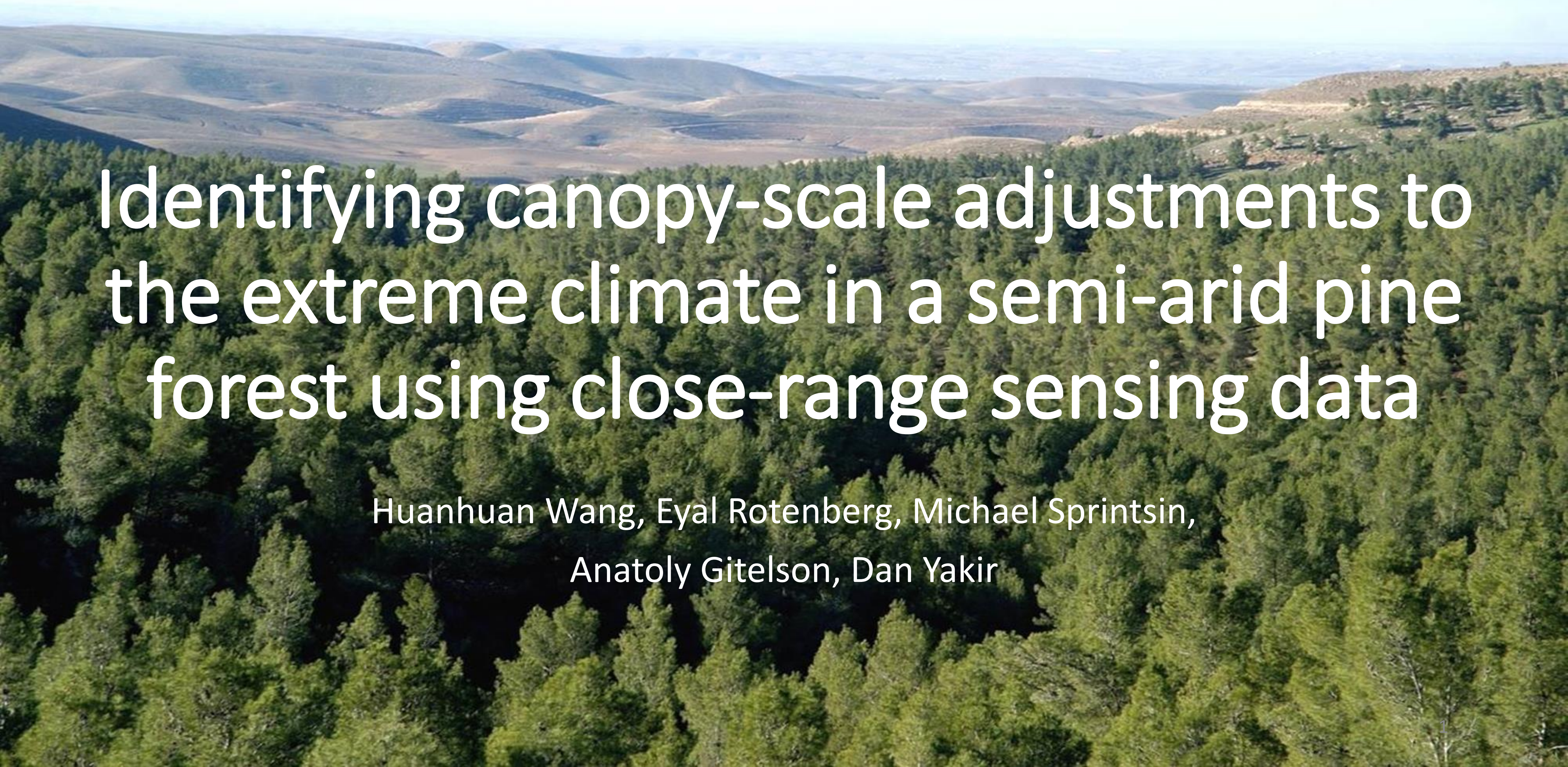

Identifying canopy-scale adjustments to the extreme climate in a semi-arid pine forest using close-range sensing data

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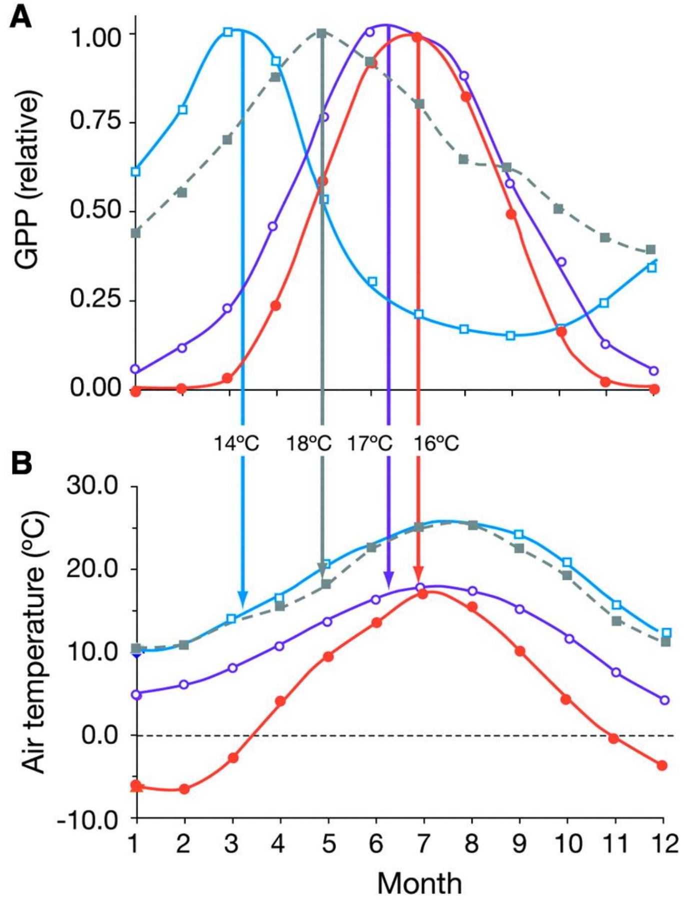
Introduction

- The time of peak photosynthetic activity is dominated by radiation levels in boreal ecosystems, and is significantly advanced to earlier periods with decreasing water availability in semi-arid and arid regions (Rotenberg & Yakir, 2010; Park *et al.*, 2019)

- Under global warming, many studies have reported reduction in forest productivity and enhanced mortality (Dai, 2013; Allen *et al.*, 2015), but some semi-arid ecosystems show surprisingly high productivity and resilience to stress (Grünzweig *et al.*, 2003; Cleverly *et al.*, 2013; Tagesson *et al.*, 2015; Yan *et al.*, 2019)

- Much less information is available, however, on the ecophysiological processes that underlie the plant adjustments to changes in these forcing, particularly at semi-arid ecosystems.

Israel Semi-arid ← Finland Temperate



Rotenberg & Yakir, 2010. Science.

Objectives

Combing eddy covariance **(EC)** and remote sensing **(RS)** measurements, to identify ecophysiological adjustments that:

1) Underlie the unusually short productive season during suboptimal radiation and temperature conditions

2) Provide tolerance during the long seasonal drought

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Methodology

Flux tower measurements:

- Gross Primary Production (GPP)
- Photosynthetic Active Radiation (PAR_{in})
- Air temperature (T)
- Vapor Pressure Deficit (VPD)
- Precipitation (P)
- Soil Water Content (SWC)

Close-range sensing measurements:

- Canopy reflectance at 570nm, 660nm, 860nm
- Leaf reflectance, 320-790nm, in 2nm step

Equations:

$$NDVI = (\rho_{NIR} - \rho_{red})/(\rho_{NIR} + \rho_{red})$$

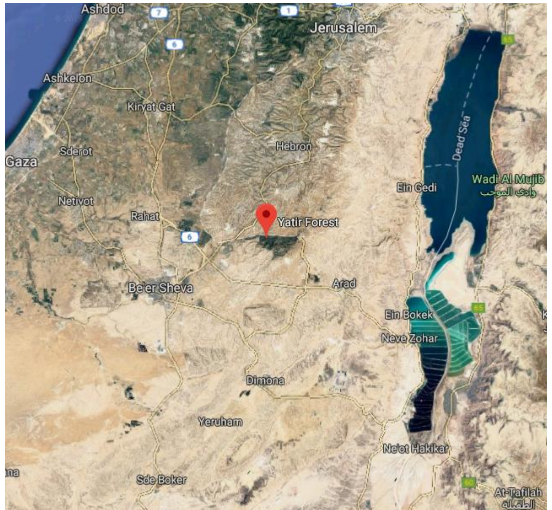
$$\alpha_{chl} = \rho_{NIR}/\rho_{green} - 1$$ **Absorption coefficient**

$$APAR = PAR_{in} \times NDVI$$ Absorbed PAR

$$LUE = GPP/APAR$$ Light Use Efficiency

$$CI_{re} = \rho_{NIR}/\rho_{re} - 1$$ Red edge Chlorophyll Index

$$Chl = 833.33\, CI_{re} - 2.25$$ Chlorophyll content



Eddy covariance tower

Skye spectrometer

Polypen leaf spectrometer

Results

Dynamics of GPP and other ecophysiological parameters

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PAR

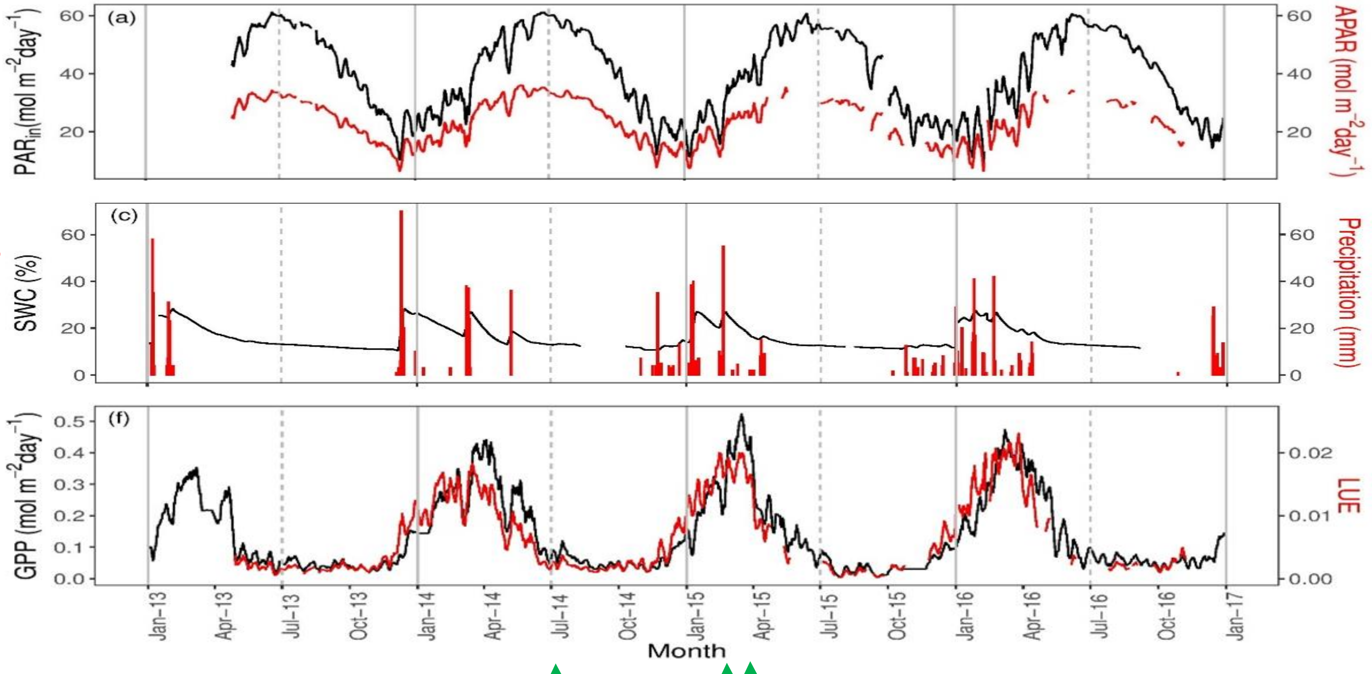
APAR

Soil Water Content

Precipitation

GPP

LUE

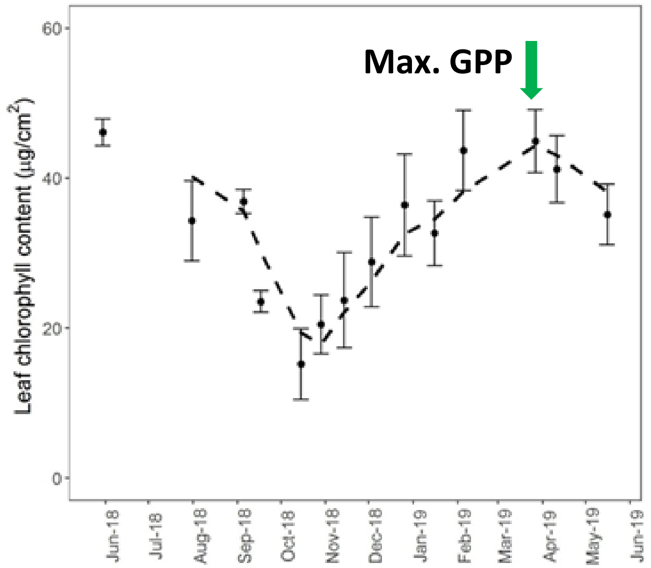


Peak time

PAR

SWC GPP

Leaf Chlorophyll Content (LCC)



- GPP and LUE did not follow PAR pattern, but rather peaked in low PAR, but high SWC periods.
- GPP maximized about 1 month later than the highest SWC.

Results

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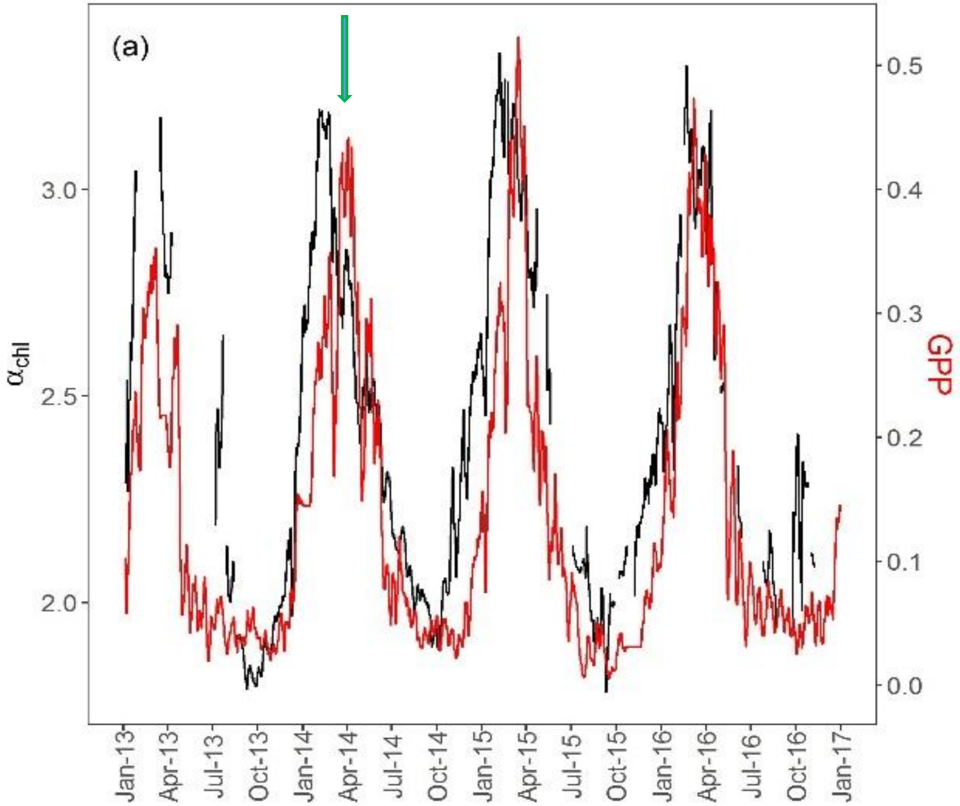
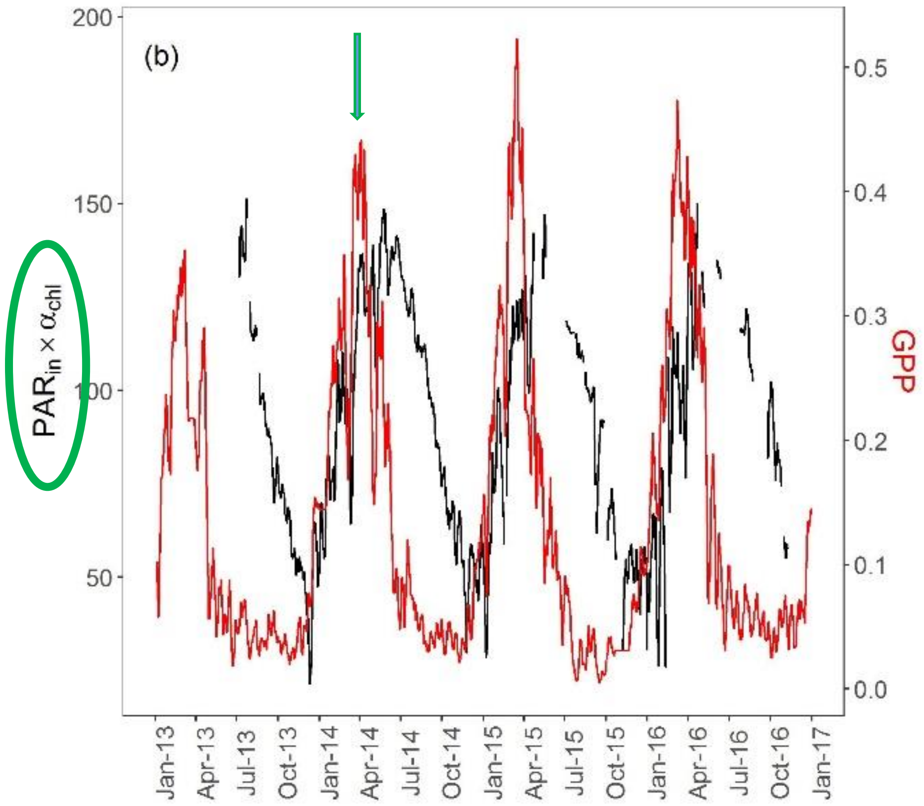
Light absorption and photosynthesis





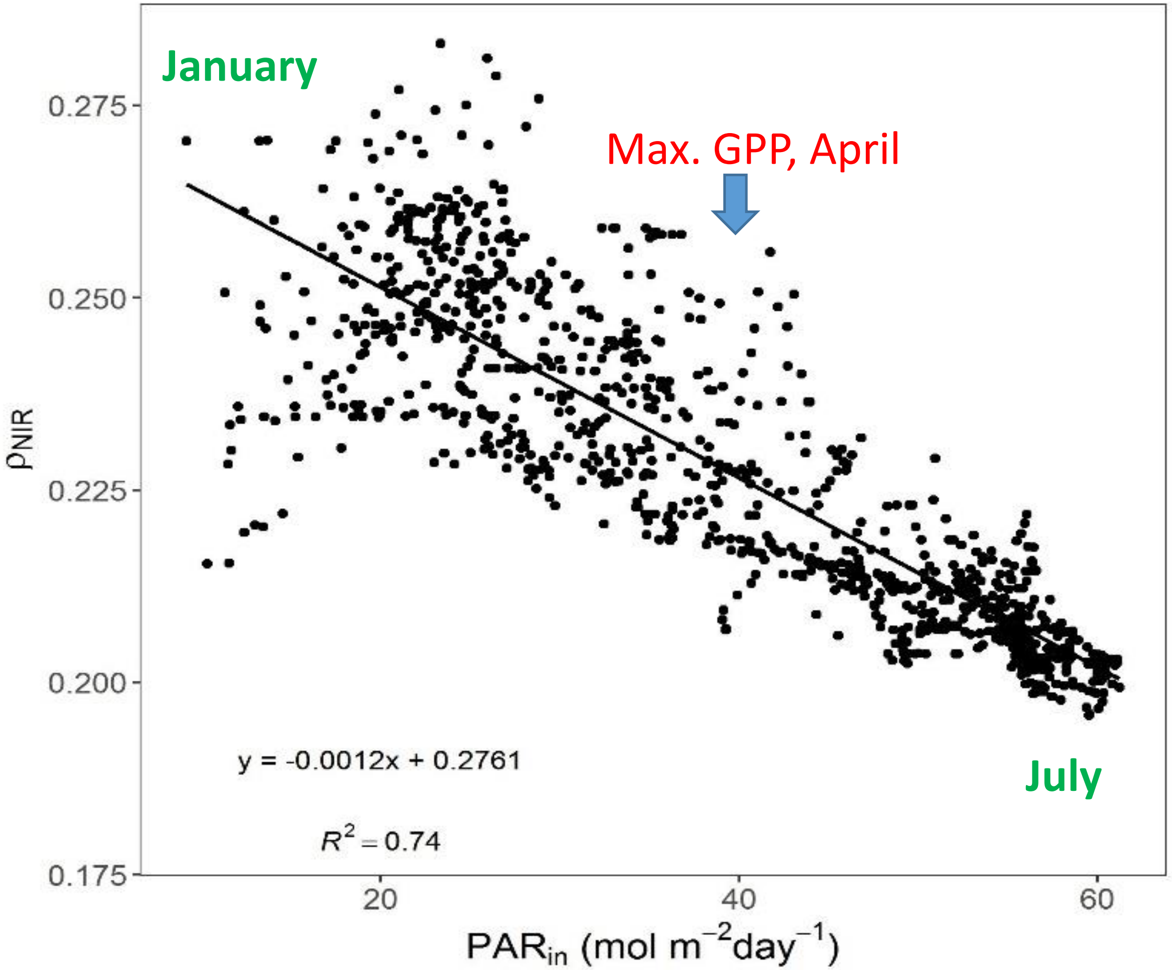
Absorption coefficient $\alpha_{chl} = \rho_{NIR}/\rho_{green} - 1$

$PAR_{in} \times \alpha_{chl} = \text{Scaled APAR}$

- Peak time of GPP is when there is a optimal combination of remaining SWC, sufficiently high PAR and APAR and temperature

Results

Relationship between canopy ρ_{NIR} and PAR_{in}



- Negative correlation between ρ_{NIR} and PAR_{in} reflects canopy structural changes, to enhance light absorption in the low PAR wet season and eliminate over-excitation in the high PAR dry summer

Conclusions

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1) Peaks in light use efficiency (LUE), leaf chlorophyll content (LCC), increase in the absorption of photosynthetic active radiation (PAR) and in near-infrared reflectance (ρ_{NIR}) intricately converged to support an early intensive spring peak (March) in gross primary productivity (GPP), exploiting the tradeoffs between increasing PAR and temperature, and rapidly drying soil.

2) In contrast, during the long dry stressful period with rapidly declining GPP under high and potentially damaging PAR, physiological photoprotection was conferred by decreasing LCC, LUE and ρ_{NIR}.

3) The results provide evidence for canopy-scale ecophysiological adjustments that can be detected by spectral measurements.

4) A pine forest under the harsh conditions prevailing at the dry timberline presents high productivity and resilience, which may soon apply to forests in other regions undergoing climate change.