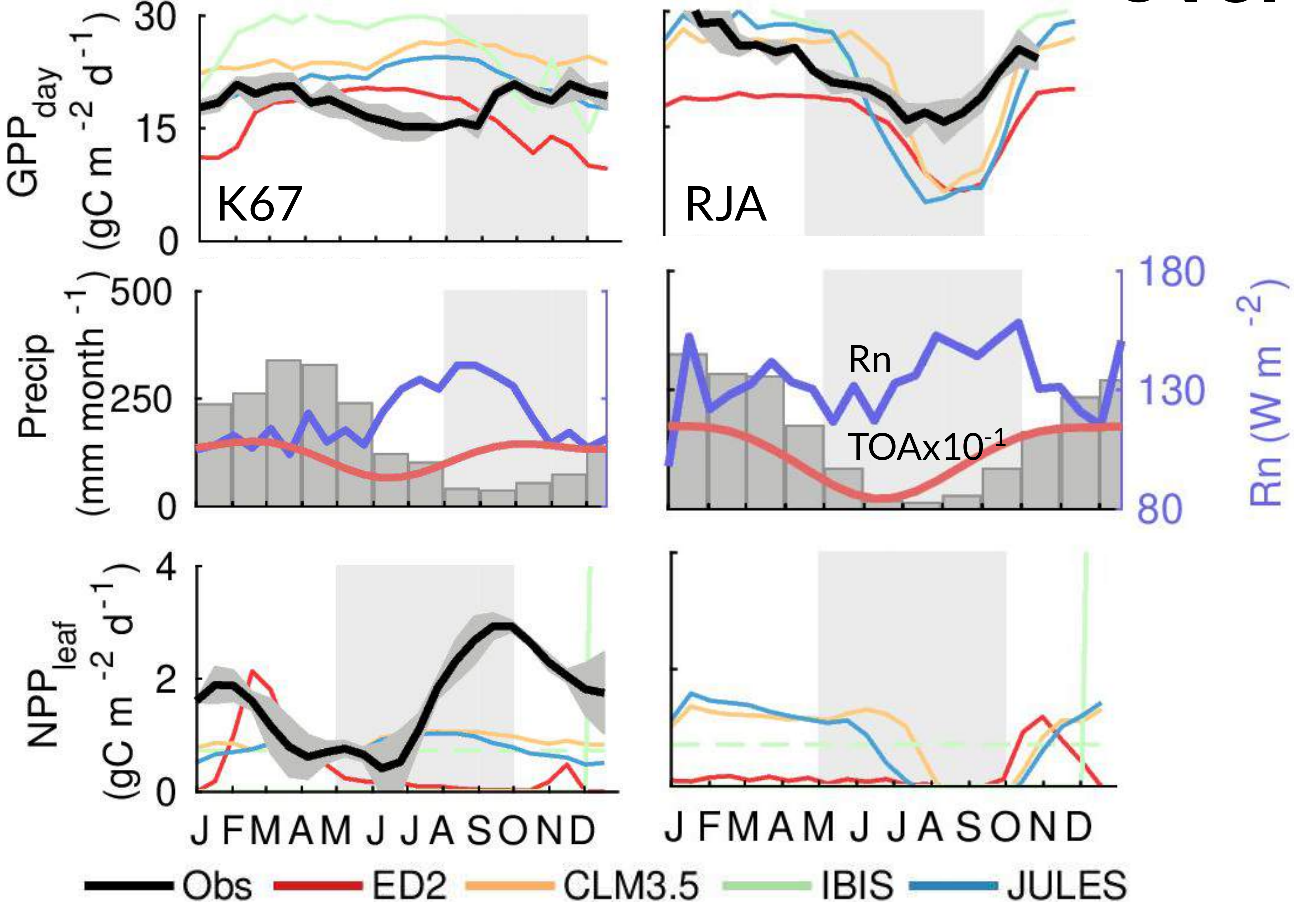
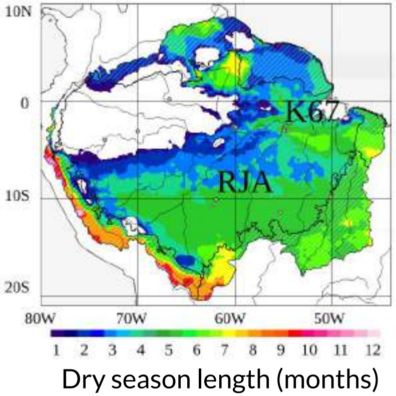
Testing Satellite-based Scaling of Tropical Forest Photosynthesis with a New Network of Cameras and Fluorescence Spectrometers in Amazonia

N Restrepo-Coupe, S. Saleska (PI), M. Smith, B. Nelson, A. Kornfeld, N. Prohasha, Shuli Chen, S. Stark…. et al.

Overall Motivation



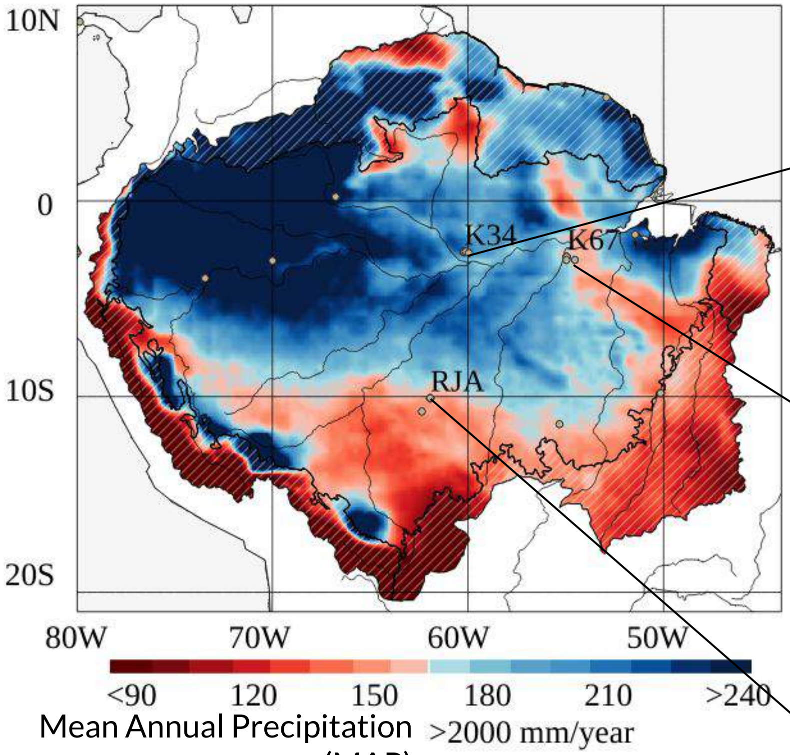


What controls the response of photosynthesis in Amazonian forests to seasonal and interannual variations in climate? This question, despite its apparent simplicity, remains difficult for modern earth system models to answer, and the subject of controversy in the remote-sensing literature.

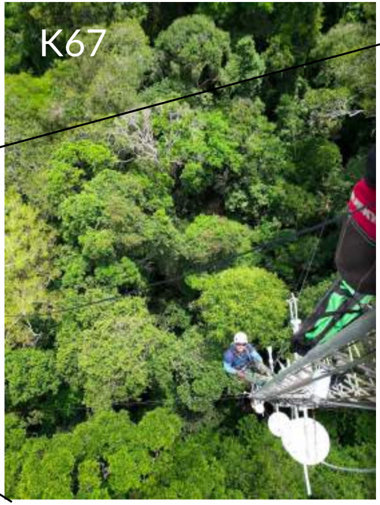
Questions

1. Is ***leaf phenology*** important for explaining differences in ***photosynthesis*** among different tropical forests across the Amazon? (example: intriguing contrast between K67 and RJA)
2. What is the phenology of whole forest canopy structure?
3. Can we characterize and separate the “slow” (e.g. canopy structure and photosynthetic capacity) and the “fast” (e.g. stomatal control) vegetation changes that drive photosynthesis using different methods?

Methods: Sites locations



Mean Annual Precipitation (MAP)

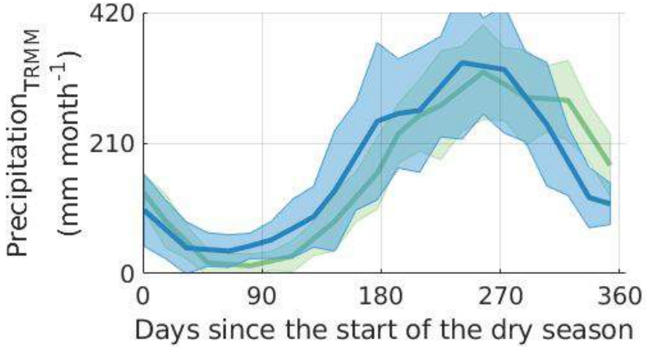


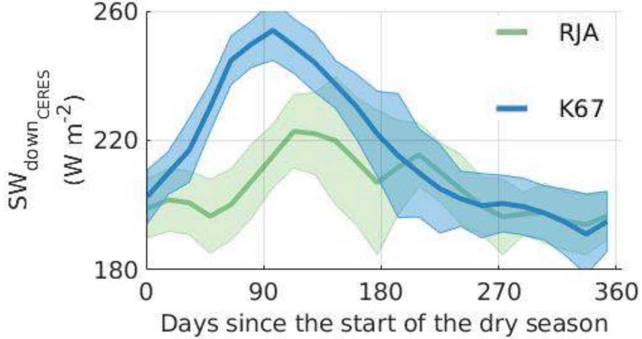
Methods: Measurements

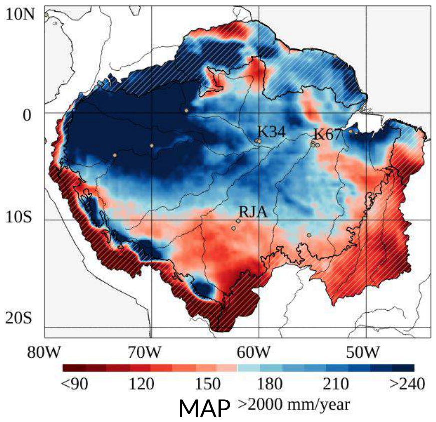
-Eddy covariance flux
-Meteorology
-Solar Induced Fluorescence (SIF)
-Soil moisture
-Litter
-LAI (LiDAR)
-Biometry (inventories)

-Phenocameras (all sites)

1. Can phenology explain the differences in GPP between K67 and RJA?





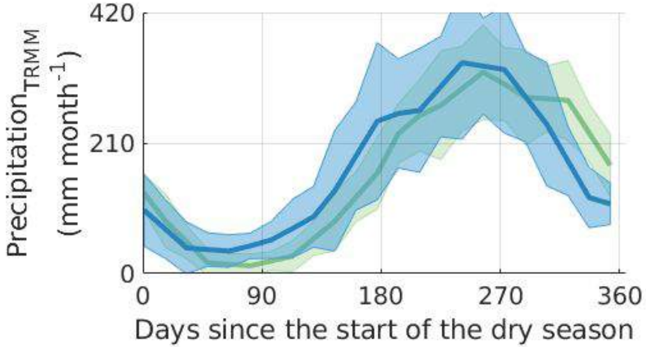


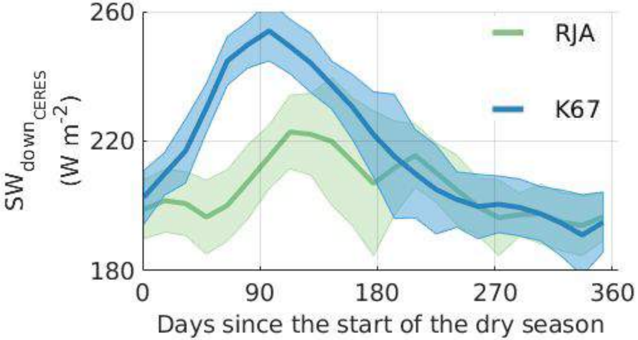
Background:

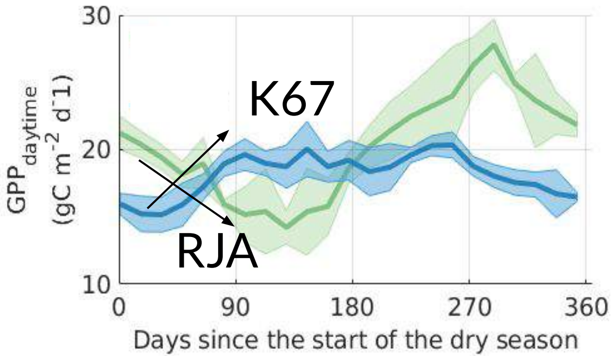
Similar mean annual precipitation, yet different incoming light seasonality (low amplitude at RJA)

Days since the start of the dry season

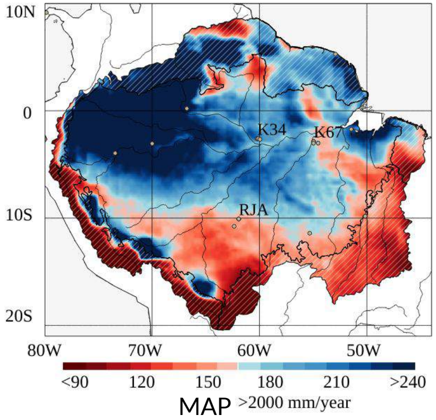
1. Can phenology explain the differences in GPP between K67 and RJA?







Background: Different ecosystem productivity patterns...



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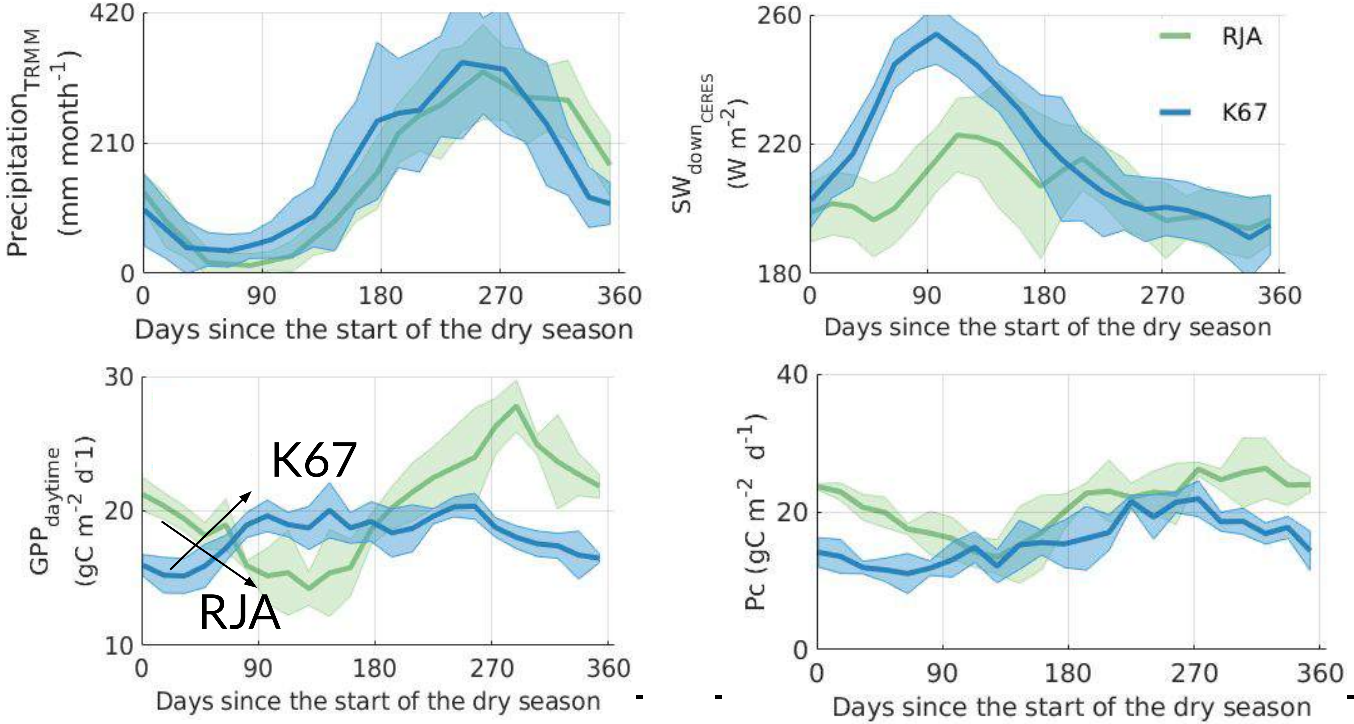

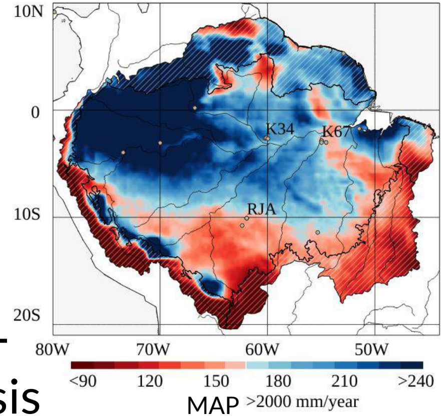

Background: Environmental v. phenological drivers of photosynthesis

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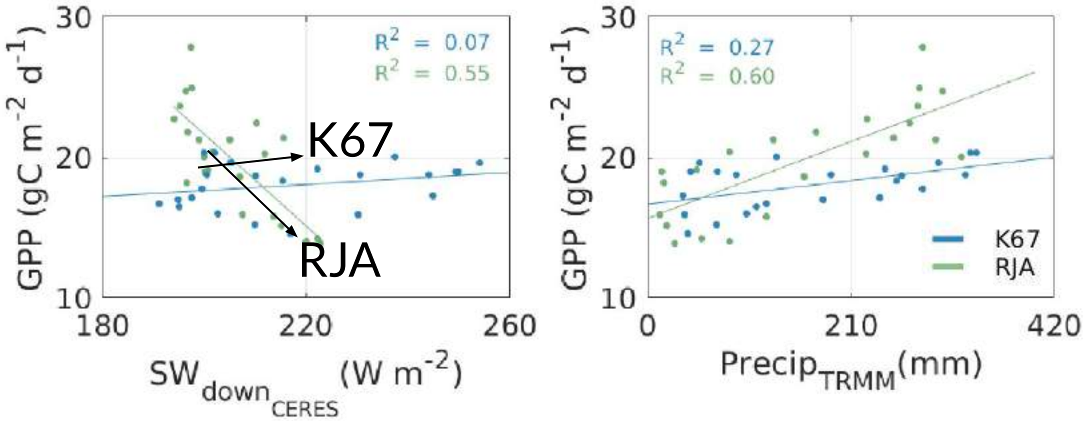

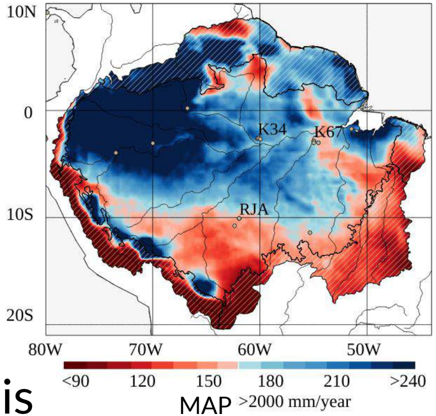

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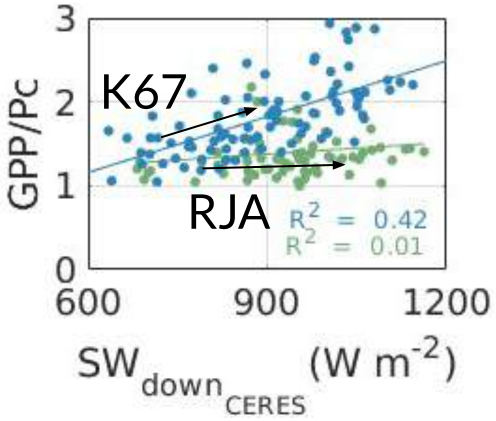

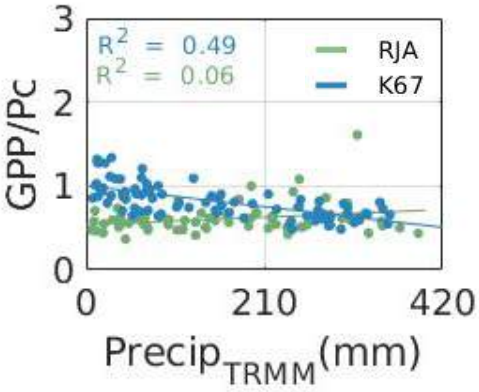

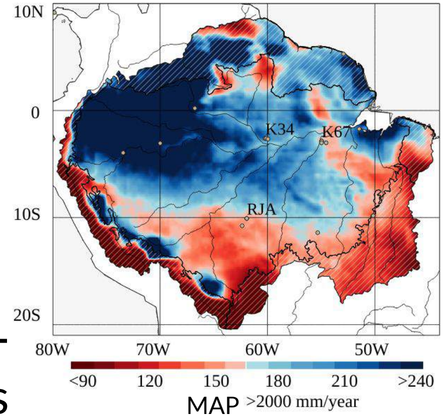

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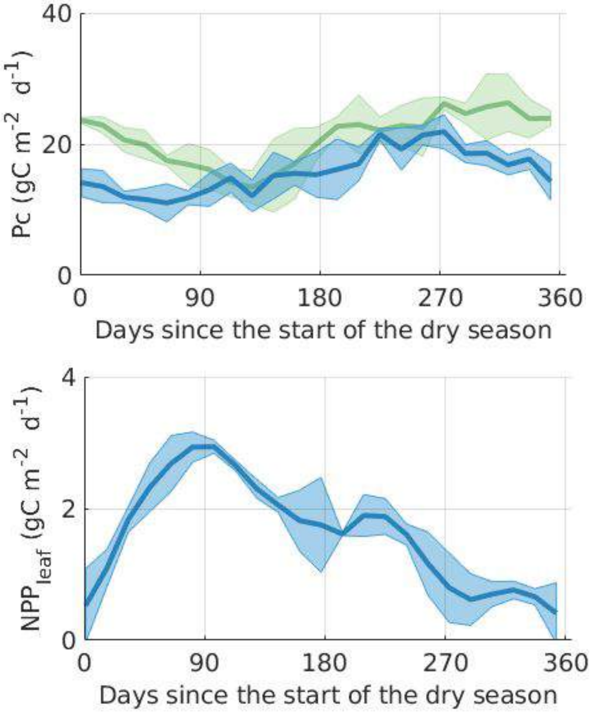
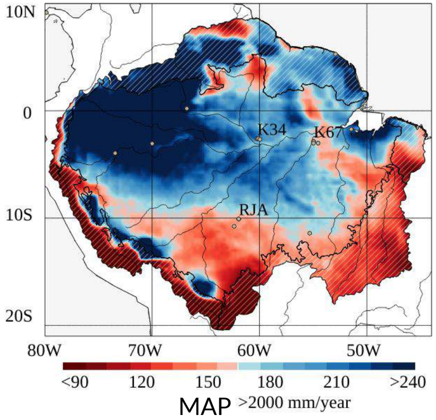
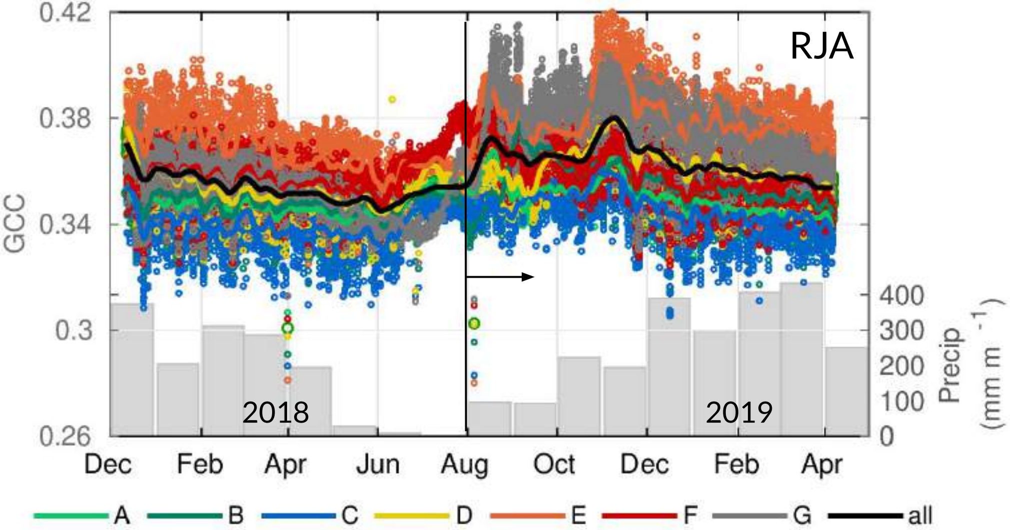




Background: Phenological drivers of photosynthesis

1. Can phenology help us explain the differences in GPP between K67 and RJA?



GCC = Green/(Green+Blue+Red)

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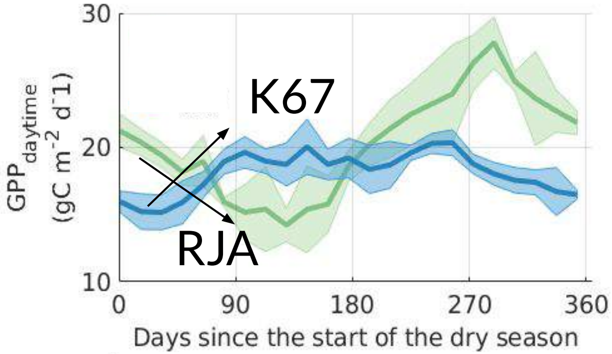

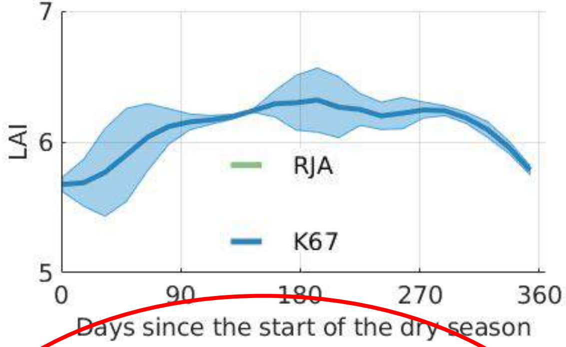

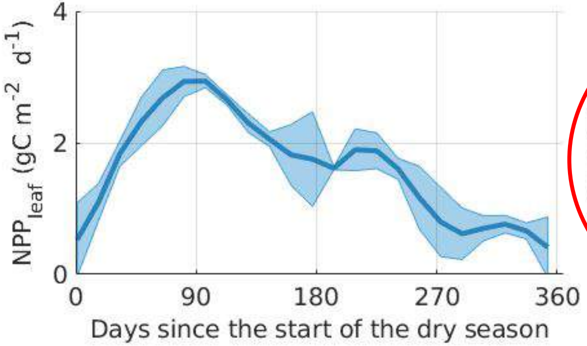

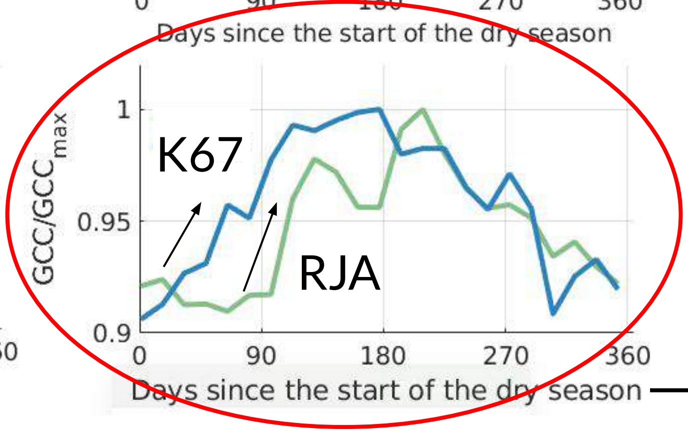

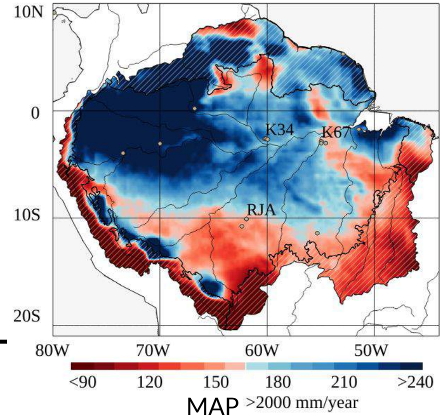

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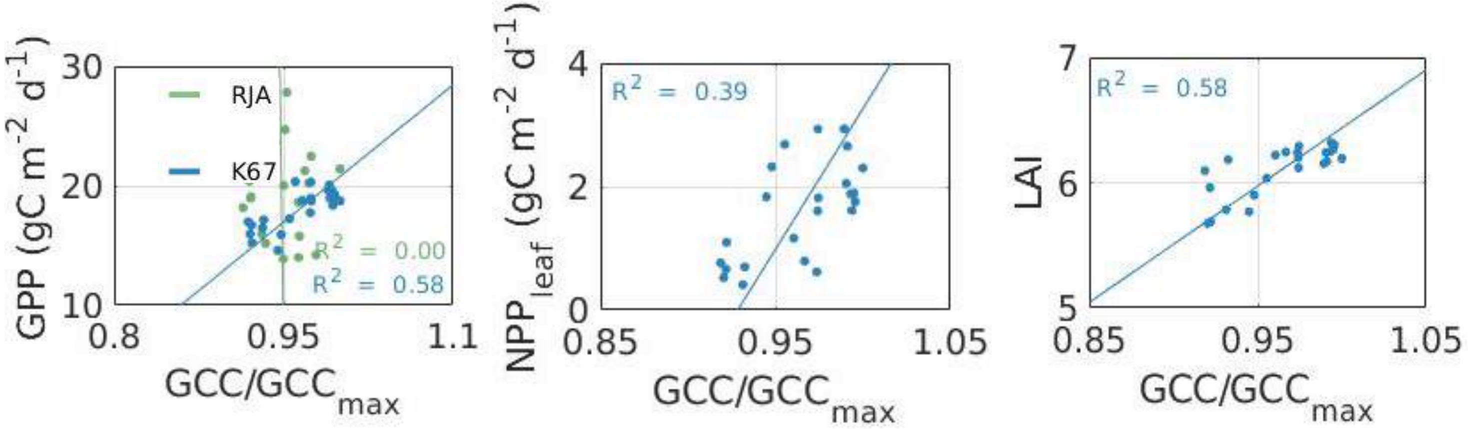

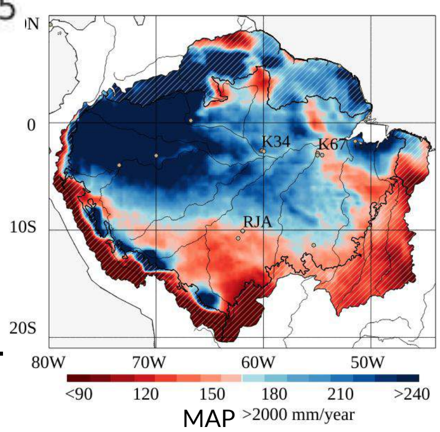

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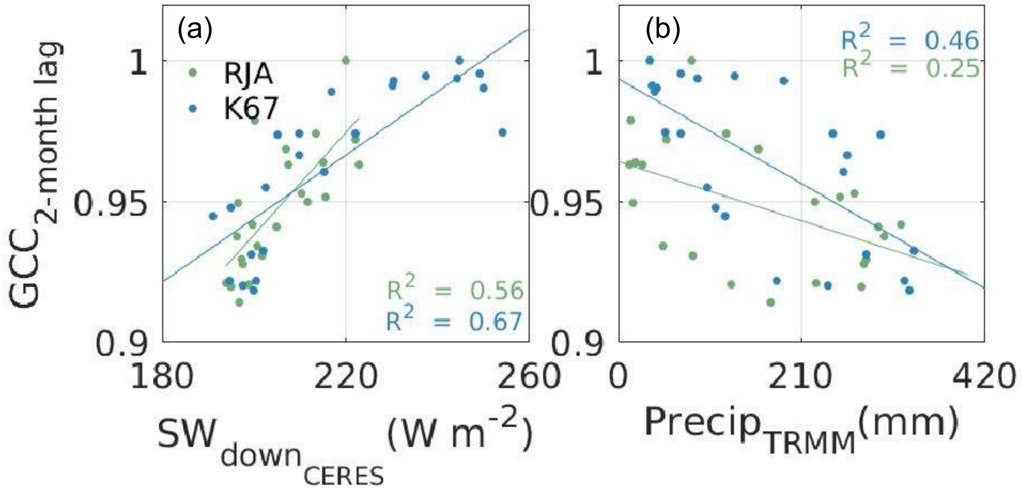

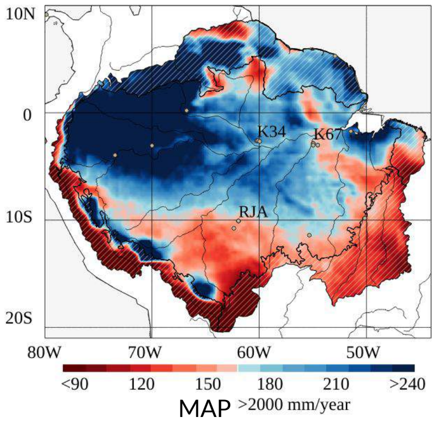

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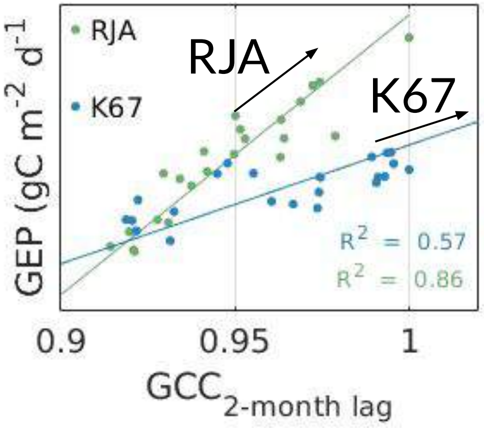
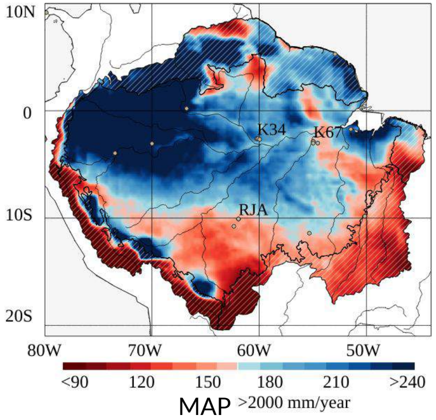


Answer:

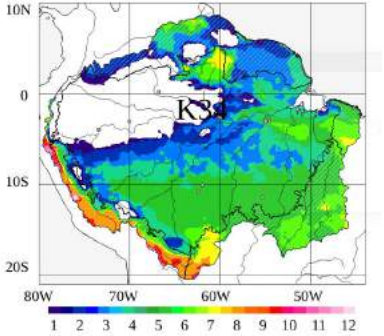
RJA: Maximum GCC and two months after we observe maximum GPP

K67: One month between GCC and GPP



Future work RJA: See leaf/crown demography using phenocams -Manaus, K34

Crowns flushing new leaves in five wetter months | Crowns flushing new leaves in five drier months



Dry season length (months)

Seasonality of new leaf formation over a full year of normal climate seasonality (December 2012 – November 2013) at K34 micromet tower, Central Amazon, near Manaus, Brazil. Leaf flush is concentrated in the drier months, June to October.

Gonçalves, N. et al. 2019

Questions

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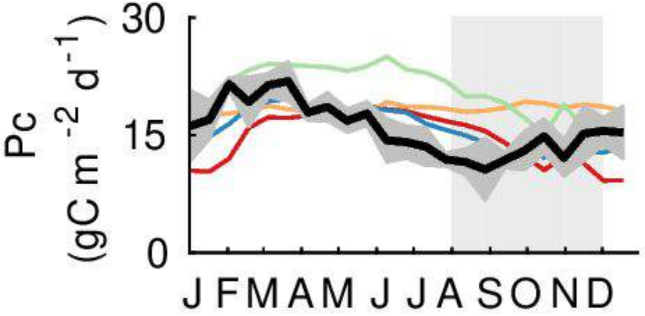
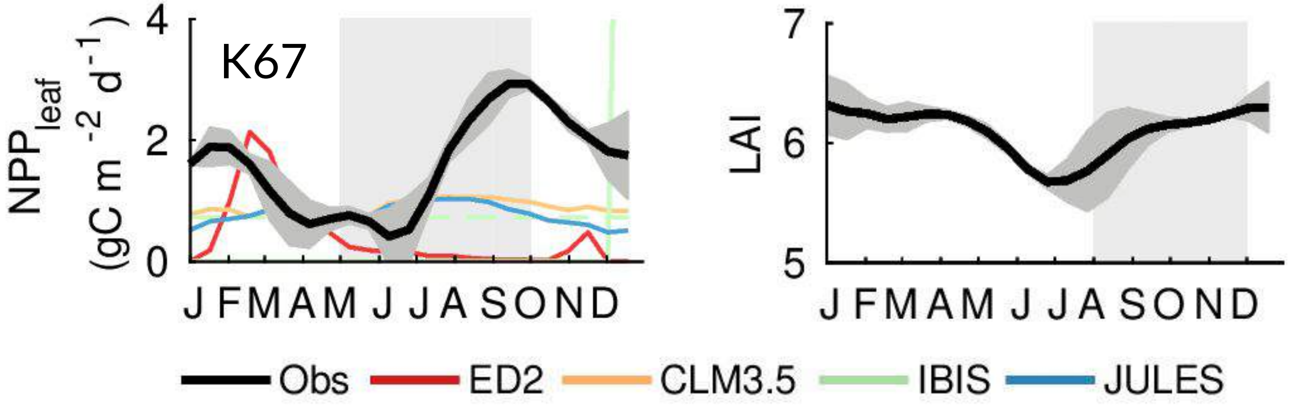
2. How does canopy structure seasonally changes?

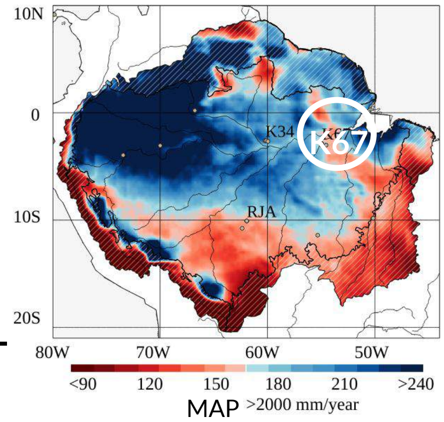
Initial analysis showed leaf QUANTITY were not nearly as important in determining the seasonality of GPP.

These studies only considered total LAI (low seasonal variation).

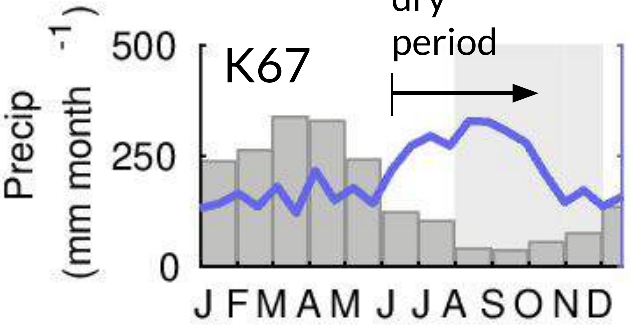
What about vertical distribution of LAI?

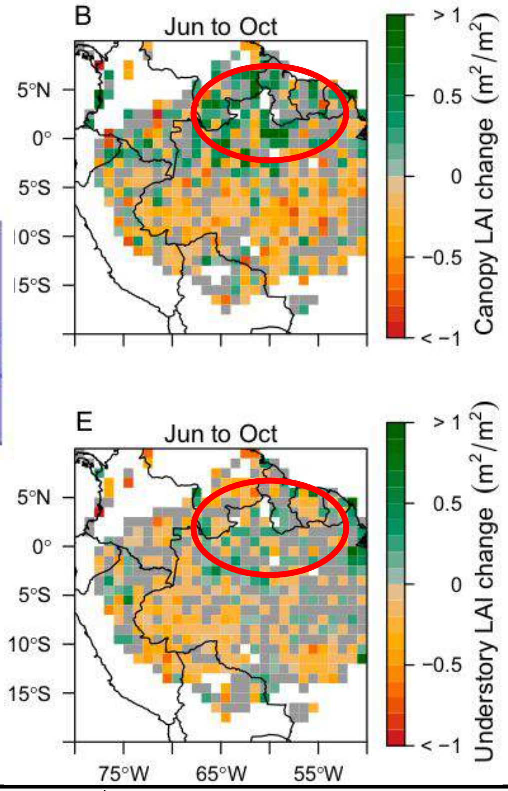






2. How does canopy structure seasonally changes? Amazonia





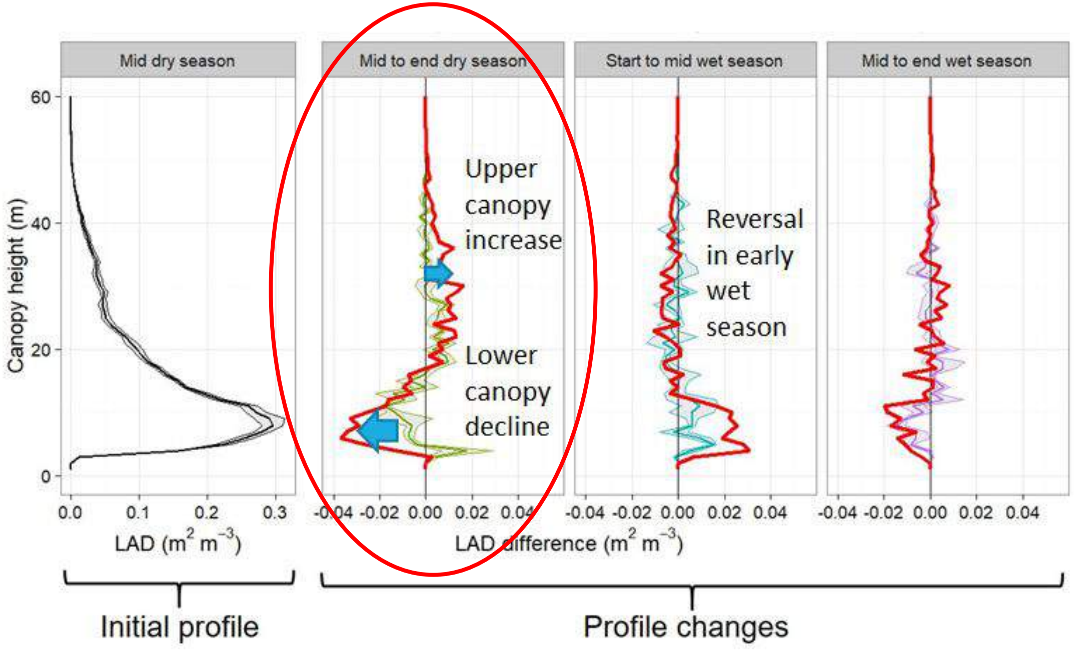
Southern Amazonia:
Seasonal understory ***is correlated*** to the upper canopy layer dynamics and weakly or not correlated to seasonal rainfall or insolation**.**

Net leaf flushing in early dry season, and is followed by net abscission in late dry season

Central Amazon: upper canopy and understory leaf area index (LAI) ***is a more complicated pattern*** with **opposing variations.**

Tang, H. and Dubayah, R. 2017 (corrected 2019), Light-driven growth in Amazon evergreen forests explained by seasonal variations of vertical canopy structure, PNAS

2. How does canopy structure seasonally changes? K67



Smith, M. et al.,2018. Seasonal and drought related changes in leaf area profiles with dependencies on height and light environment in an Amazon forest. New Phytol.

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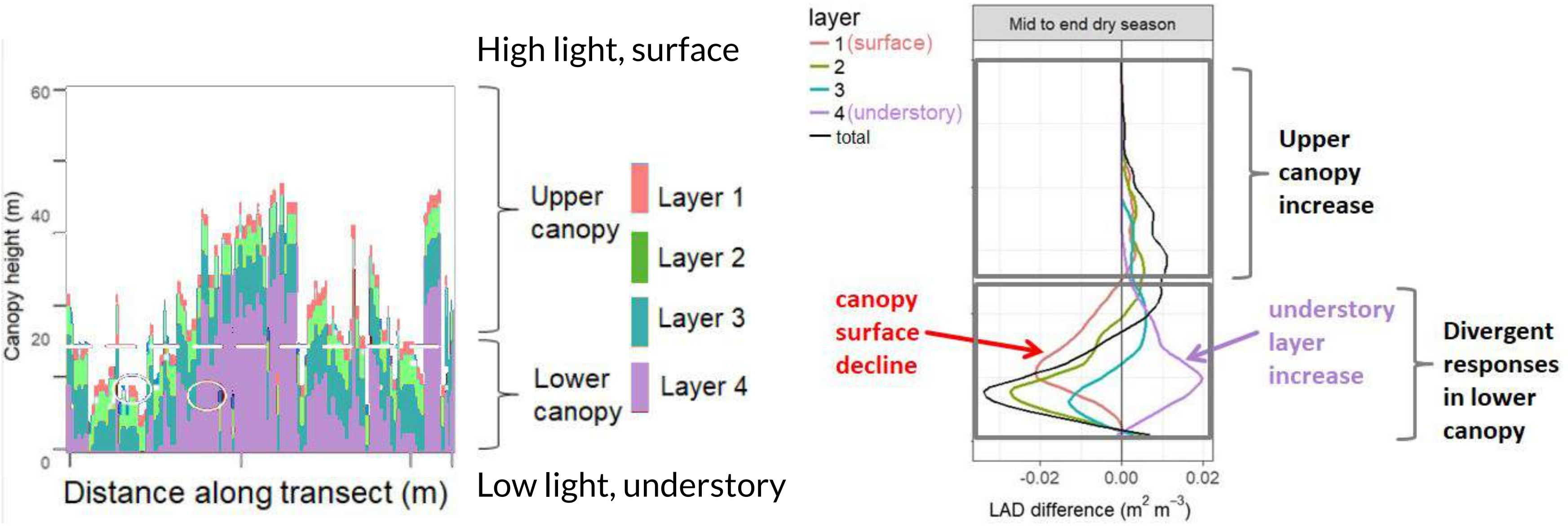

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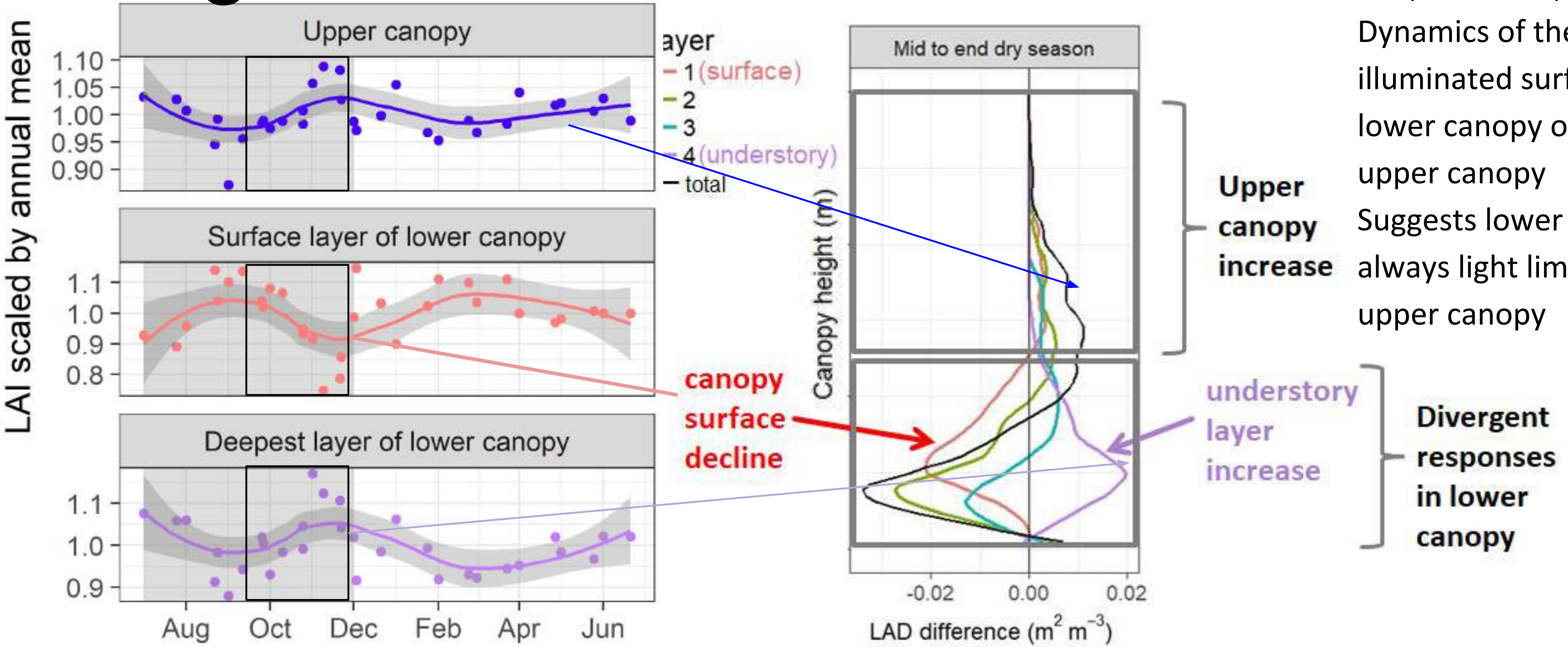

Similar seasonality of the deepest and upper canopy

Dynamics of the well illuminated surface layer of lower canopy opposed the upper canopy

Suggests lower canopy not always light limited by upper canopy

Smith, M. et al.,2018. Seasonal and drought related changes in leaf area profiles with dependencies on height and light environment in an Amazon forest. New Phytol.

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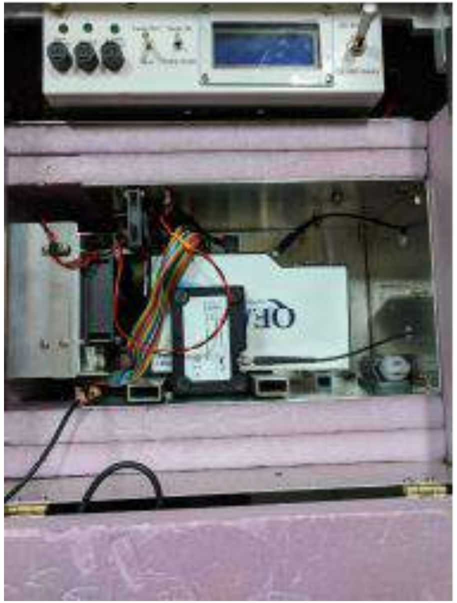
(Parenthesis) Methods: SIF measurements



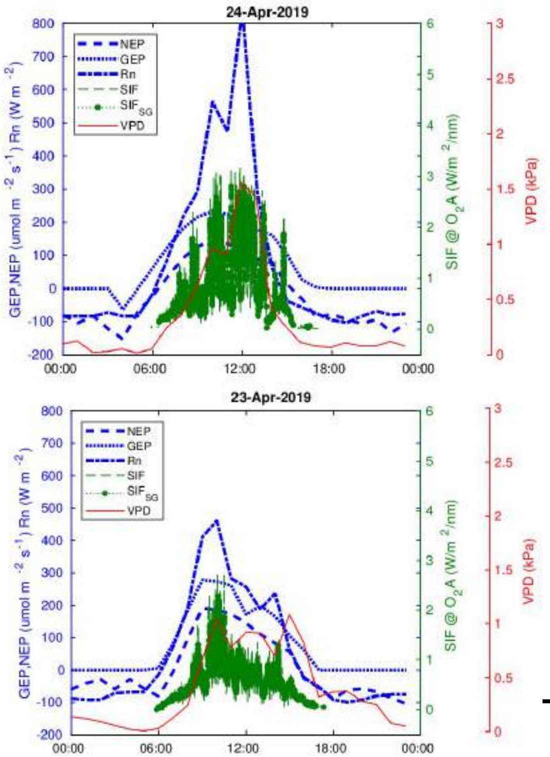
QEpro: 5um and later a 25um slit (3 pixels) fitted with a long-pass filter (transmits > 695 nm) and a grating H15 installed for light between 730 and 786 nm. Targeting the outgoing spectra at 760 nm -the oxygen absorption band (O_2 A-band: 745-770nm and **Fraun**: 744-759nm).

FLAME-S-VIS-NIR-ES: 25 um slit, 350-1000 nm range.

Bifurcated fiber 100 m length: 600 nm (QEpro) and 200 nm (Flame) width.

All credit to A. Kornfeld

What we are learning from observed SIF and other spectral measurements



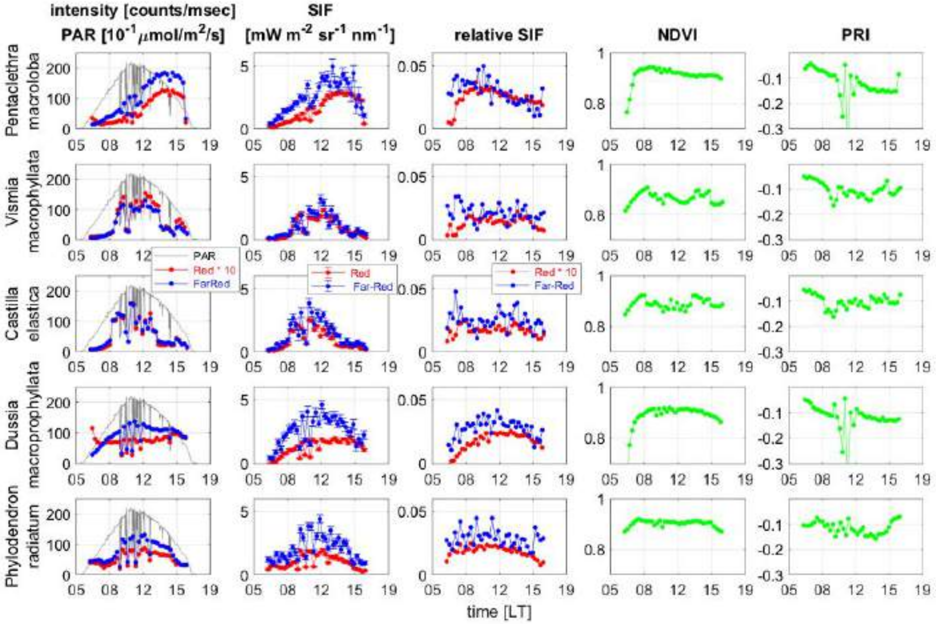
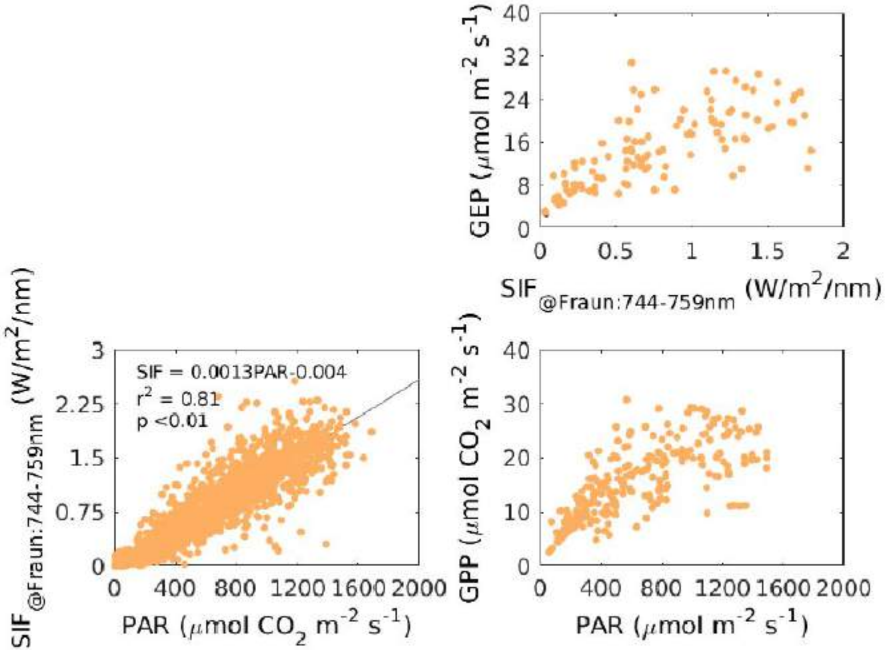


Fig. 11. Diurnal cycle of intensity and PAR (column 1), SIF (column 2), relative SIF (column 3), NDVI (column 4), and PRI (column 5) of five different species at La Selva on 4/21/2017 (SZA < 75°, α = elevation viewing angle): *Penthaclethra macroloba* ($\alpha = -44°$, row 1), *Vismia macrophyllata* ($\alpha = -67°$, row 2), *Castilla elastica* ($\alpha = -70°$, row 3), *Dussia macrophyllata* ($\alpha = -15°$, row 4), *Phylodendron radiatum* ($\alpha = -25°$, row 5). The intensity of the *Dussia macrophyllata* in the red wavelength range has a peak in the morning during clear days. This peak, which disappears during cloudy periods, will be studied in the future.

Grossmann, K. et al. 2018, PhotoSpec: A new instrument to measure spatially distributed red and far-red Solar-Induced Chlorophyll Fluorescence, RSE

What we are learning from observed SIF and other spectral measurements

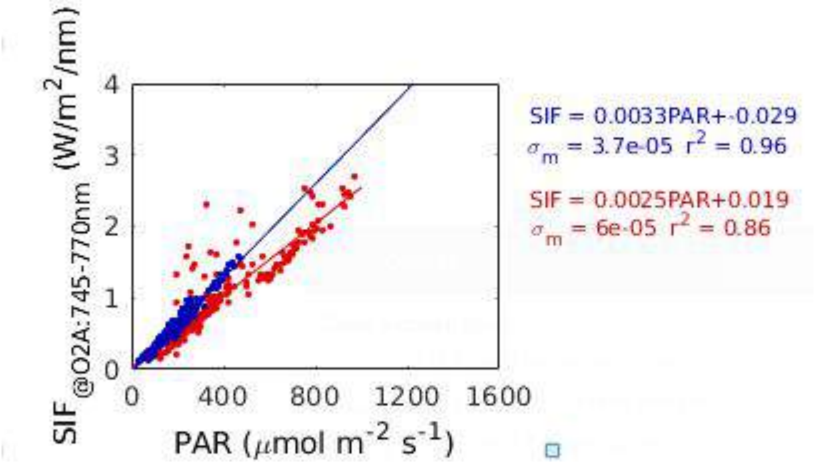


Previous leaf level studies (tobacco) suggest that under high incoming radiation GPP tends to saturate while SIF keeps increasing [van der Tol et al., 2014].

Yang et al. 2018 found SIF strongly related to absorbed light rather than to GPP (rice paddy).

April 2019 SZA<70 Independent PAR measurement

What we are learning from observed SIF and other spectral measurements



Consecutive cloudy (blue) vs. sunny days (red)

GEP will be driven by environment and the long and fast responses of vegetation.

“Slow” vegetation response == phenology (e.g. LAI, leaf demography, standing photosynthetic infrastructure, etc). VIs as proxy?

“Fast” vegetation response==stomatal conductance. SIF as proxy?

Days under different conditions. SIF/PAR v. temperature, VPD, turbulence, CO2 concentration.

References

Gonçalves, N. et al. 2019, Both near-surface and satellite remote sensing confirm drought legacy effect on tropical forest leaf phenology after 2015 ENSO drought, RSE

Smith, M.N., Scott C. Stark, Tyeen C. Taylor, Mauricio Ferreira, Eronaldo de Oliveira, Natalia Restrepo-Coupe, Shuli Chen, Tara Woodcock, Darlisson Bentes dos Santos, Luciana F. Alves, Michela Figueira, Plinio B. de Camargo, Raimundo C. de Oliveira, Luiz E. O. C. Aragão, Donald A. Falk, Sean M. McMahon, Travis E. Huxman, Scott R. Saleska, 2018. Seasonal and drought related changes in leaf area profiles with dependencies on height and light environment in an Amazon forest. New Phytol.