Environmental monitoring and modeling with the support of UAS and satellites

Mónica García
Senior researcher
CEIGRAM and Consejo Superior de Investigaciones Cientificas (CSIC)
Escuela Técnica Superior de Ingeniería Agronómica, Alimentaria y de Biosistemas
Universidad Politécnica de Madrid
SPAIN

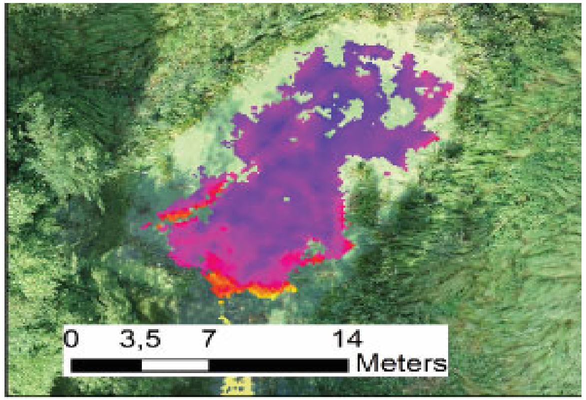
ceigram
Centro de Estudios e Investigación para la Gestión de Riesgos Agrarios y Medioambientales
POLITÉCNICA
UNIVERSIDAD POLITÉCNICA DE MADRID

A European vision for hydrological observations and experimentation

Naples | Italy | 12–15 June 2023

EGU European Geosciences Union

Pressure on water resources and dependent ecosystems



Algal bloom in DK


Fires in Alberta 2023

Floods in North Italy 2023

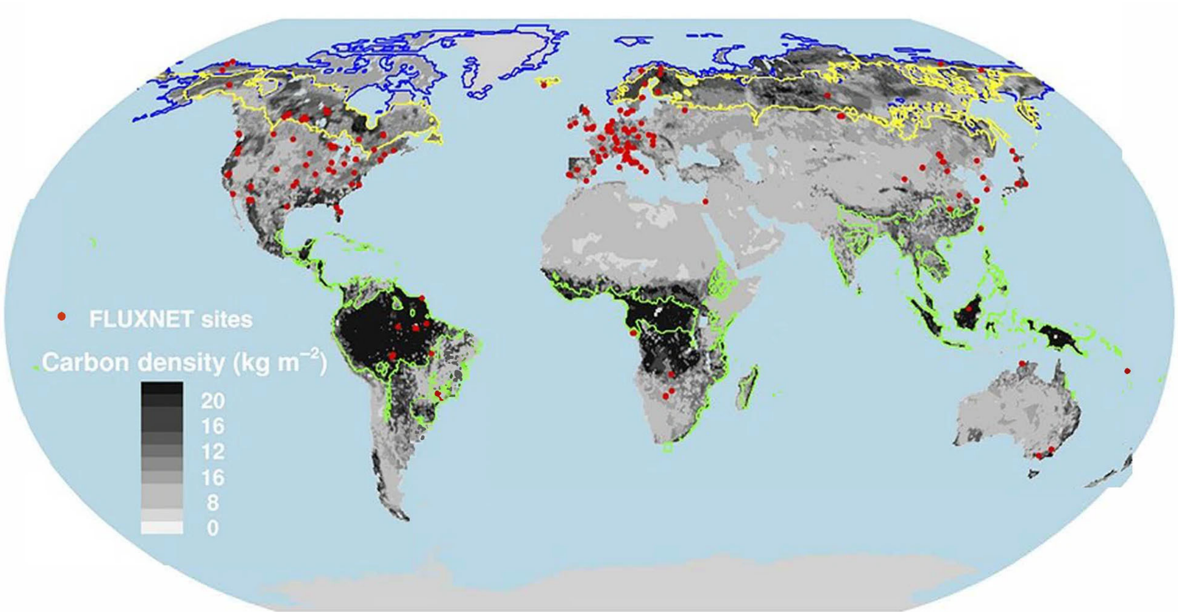

Soil degradation


Drought in Doñana National Park 2023

Forest dieback California

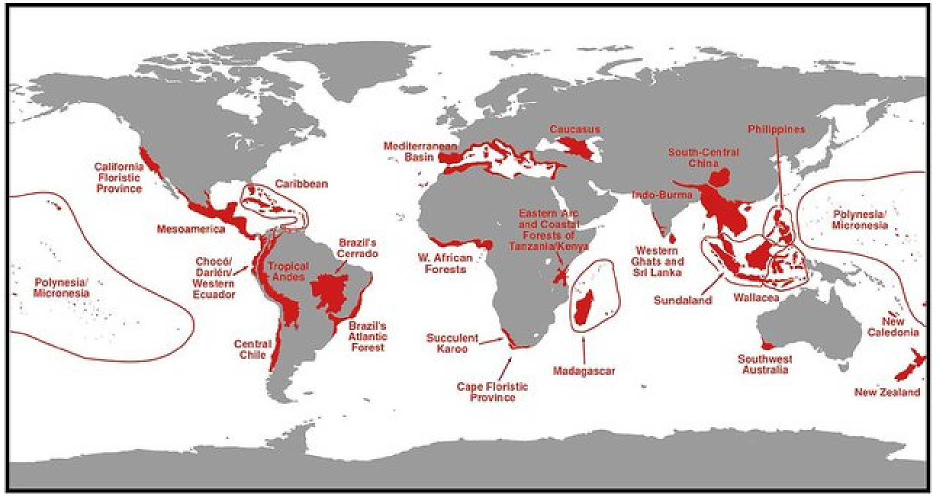
Remote sensing to augment in-situ field observations

- ✓ Limited terrestrial observations of water, carbon and energy fluxes: FLUXNET
- ✓ Earth Observation can cover this gap: robust and operative models



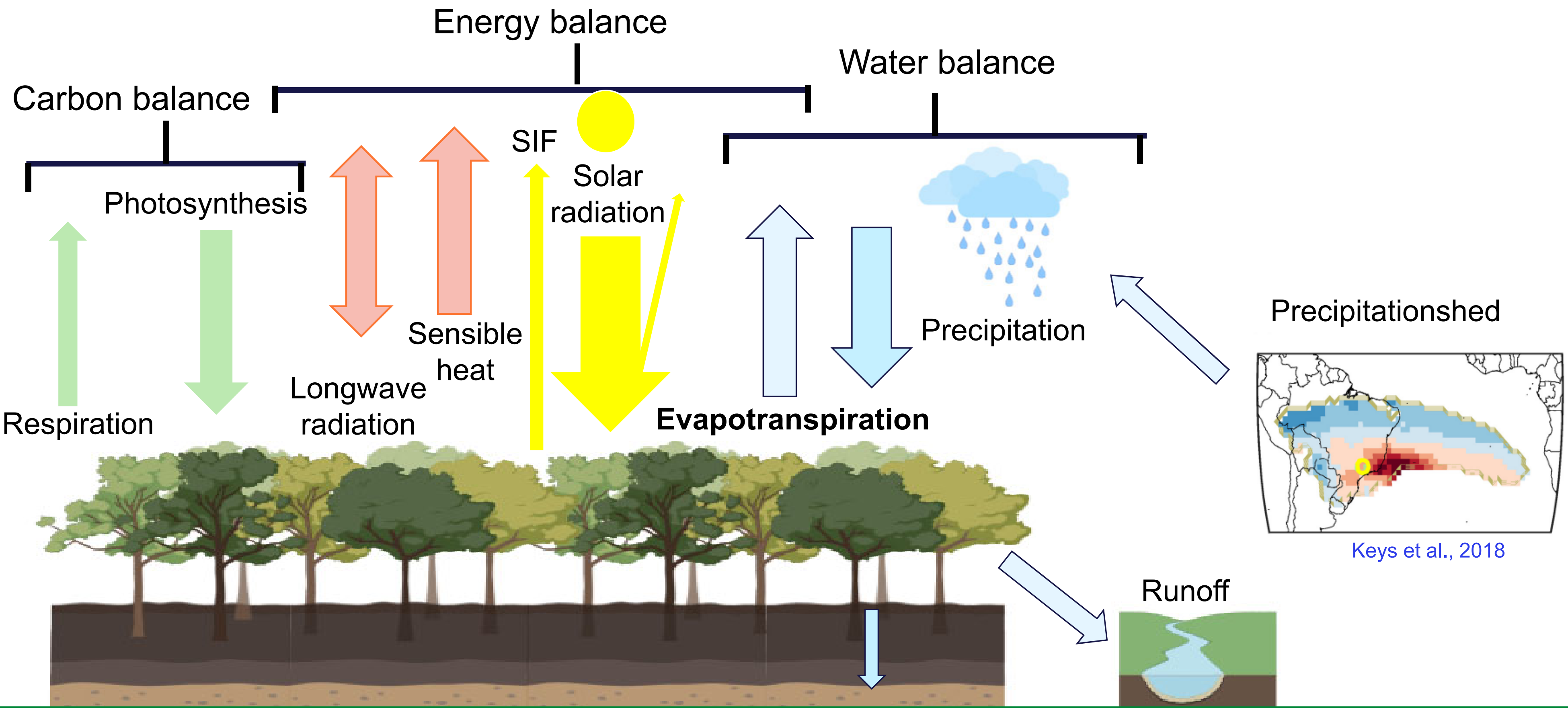
Climate change tipping points and Fluxnet sites (Lenton et al., 2008)

Ustin et al., 2022



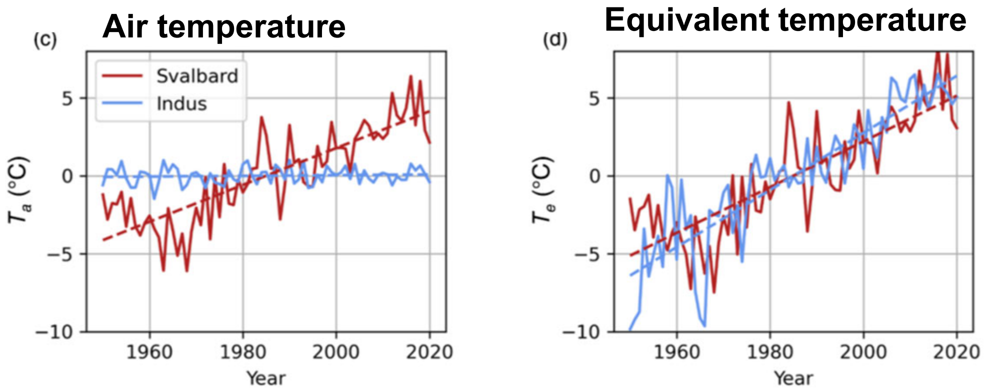
Biodiversity Hotspots

Hydrological cycle→ joint regulation of processes: uncertainty



Evapotranspiration as key in land-atmosphere interactions

✓ Metric of extra energy stored in the atmosphere

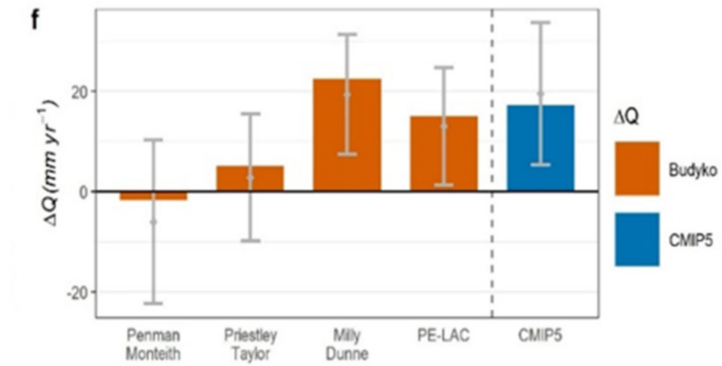


Annual mean anomalies for the Indus (tropic) and Svalbard (Arctic) sites.

Matthews, T., et al., (2022)

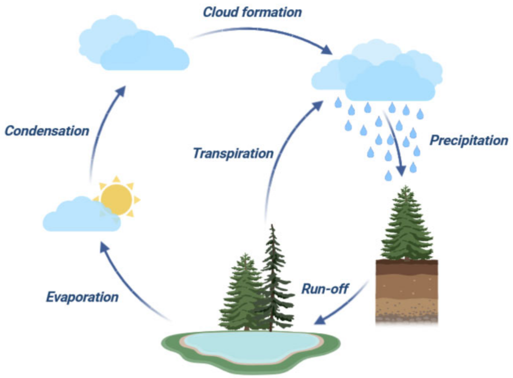
✓ Potential evapotranspiration projections?

Berg & McColl, 2021



Runoff projection changes 2081-2100 (RCP 8.5)

Kim Y, et al., 2022)



Shifts in regional water availability due to global tree restoration

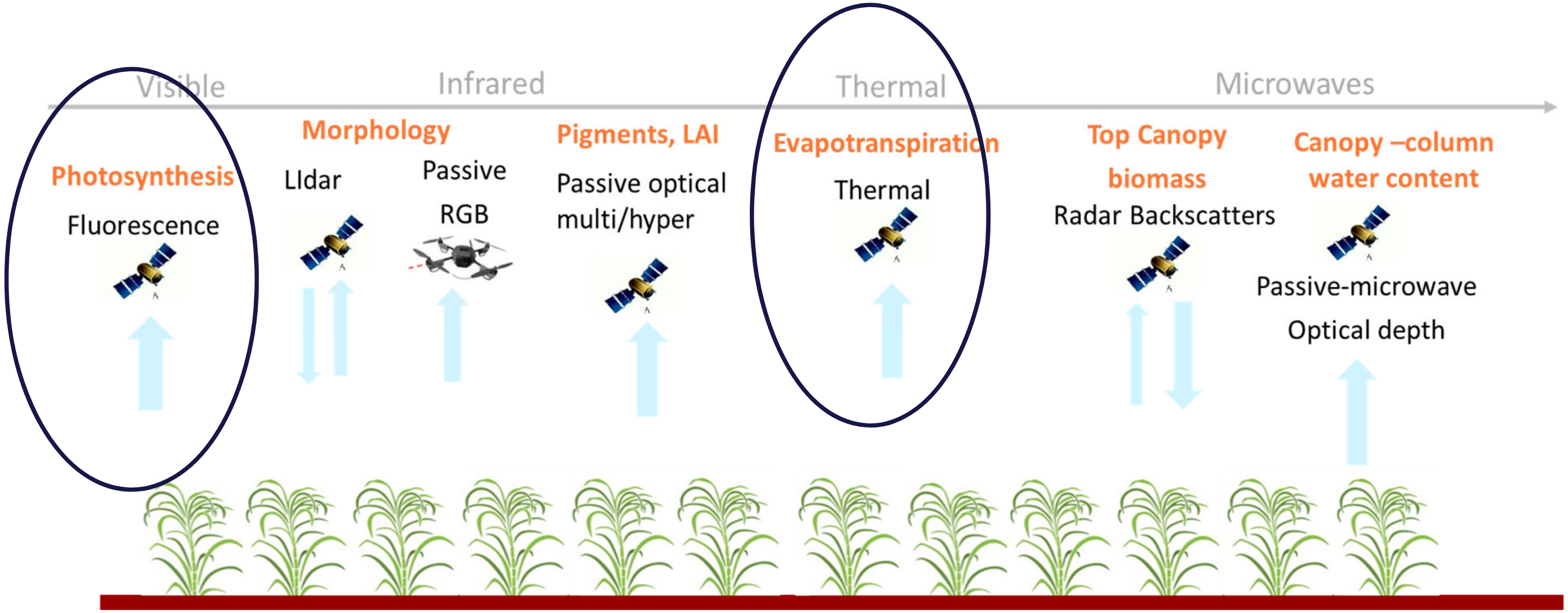
Anne J. Hoek van Dijke, Martin Herold, Kaniska Mallick, Imme Benedict, Miriam Machwitz, Martin Schlerf, Agnes Pranindita, Jolanda J. E. Theeuwen, Jean-François Bastin & Adriaan J. Teuling

Nature Geoscience **15**, 363–368 (2022) | Cite this article

18k Accesses | **43** Citations | **352** Altmetric | Metrics

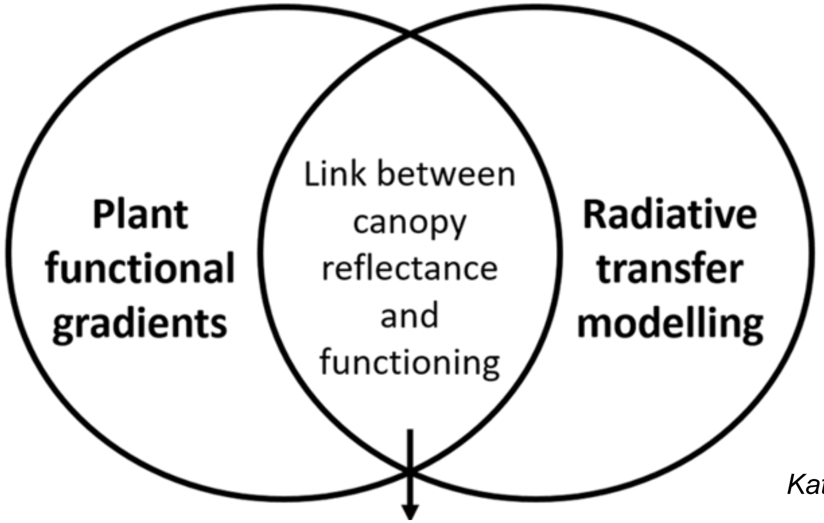
Remote sensing challenges

- ✓ **Integrate** data types and processes
- ✓ Translate electromagnetic signals into relevant variables
- ✓ Energy balance: broadband to narrowband



Guan et al., 2018 RSE; Berger et al., 2022 RSE

Challenges to link remote sensing and plant function



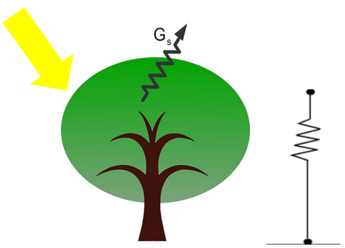
Katternborn et al., 2019.

- Reflectance mostly morphological and biochemical trait info
- VI respond to phenology and other effects
- Scaling up from tissue level traits to individual, canopy and large pixels
- Not all relevant traits have optical or thermal responses e.g. hydraulic safety
- Dynamic modeling: transient conditions
- Different set of traits can lead to same function (flux) ”equifinality in nature”

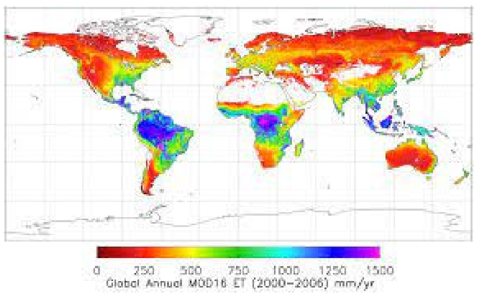
Mencucini et al., 2019 GCB, Damm et al., 2019; Manzoni et al., 2014

Land Surface modeling

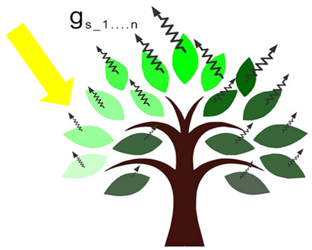
Biophysical "Top down" ⟷ Biophysical "Bottom up" ⟷ Data driven or ML

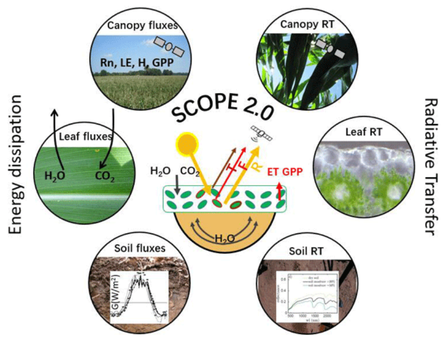


Luo et al., 2008

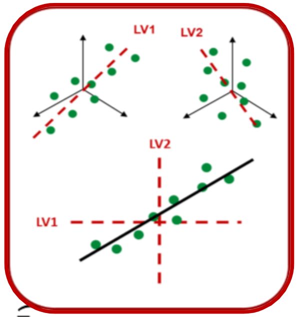


Global evapotranspiration model MOD16



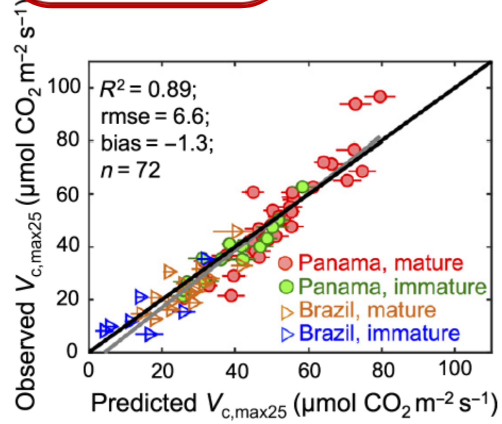


Van der Tol et al., 2009



- -Pure
- -Hybrid:

Parameters ML+ biophysical



Shang et al., 2023 *Wu et al., 2019*

Stomatal conductance constrained with SIF

Biophysical bottom up

Two Source Energy Balance with canopy conductance TSEB-Gc at six dryland sites

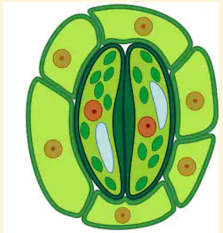
(Kustas et al., 1995; Bu et al., 2021)

Optimal stomatal conductance model

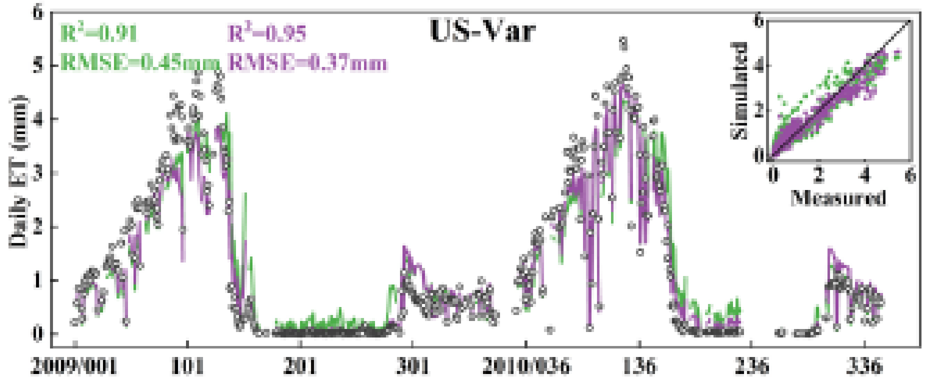
Marginal water cost of carbon gain

Gross Primary Productivity

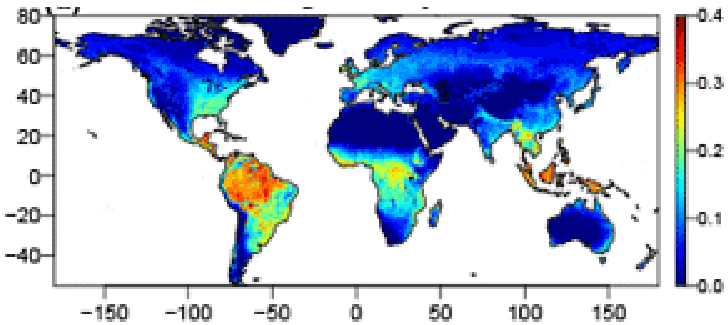
$$G_c = 1.6\left(1 + \frac{g_1}{\sqrt{VPD}}\right)\frac{GPP}{C_a}$$



Medlyn et al., (2011)



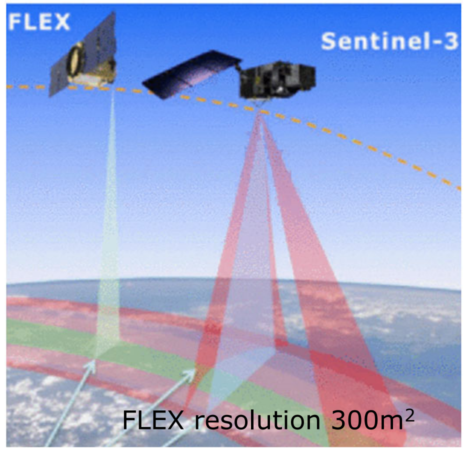
CSIF from OCO-2 + MODIS (0.05° 4day)



Zhang et al., (2018)

Issues:

- Relation between GPP and SIF (Magney et al., 2020)
- Soil water stress factors (de Kauwe et al., 2015)
- Scale



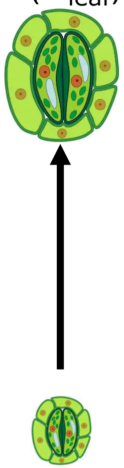
Bu et al., 2022. Dryland evapotranspiration from remote sensing solar-induced chlorophyll fluorescence: constraining an optimal stomatal model within a two-source energy balance model. arxiv.

Stomatal conductance and leaf physiology

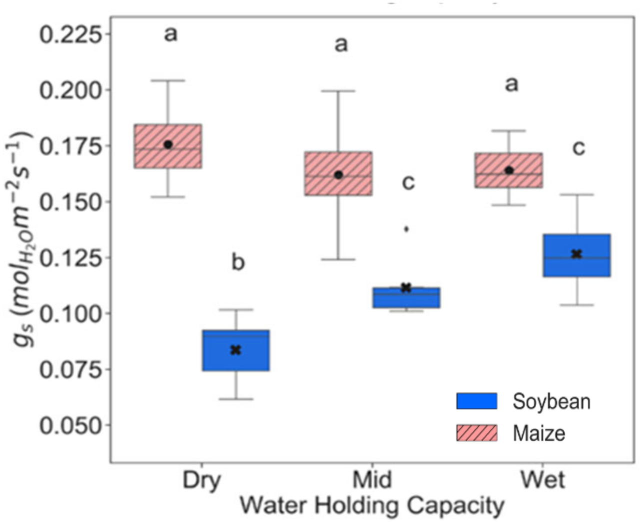
Data driven or ML

Soy (C3 and more isohydric) and maize (C4 and more anisohydric) water relations with hyperspectral and thermal

+ anisohydric (Ψ_{leaf})

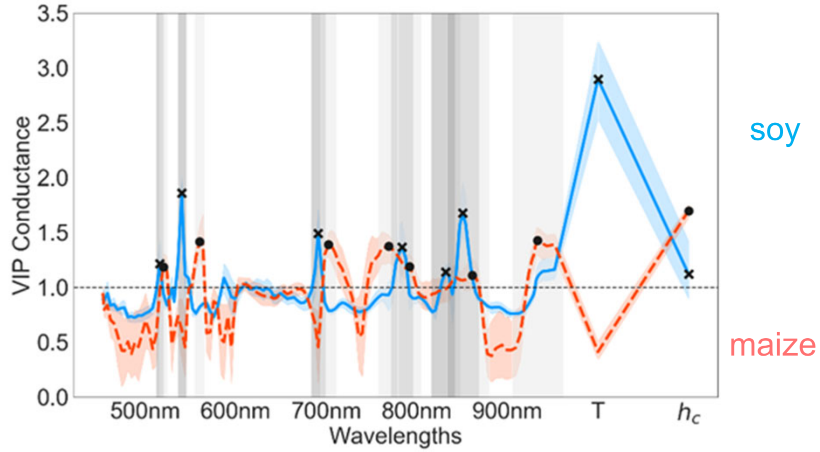


+ isohydric (Ψ_{leaf} change less)



- Soil Water Content +

PLS-R



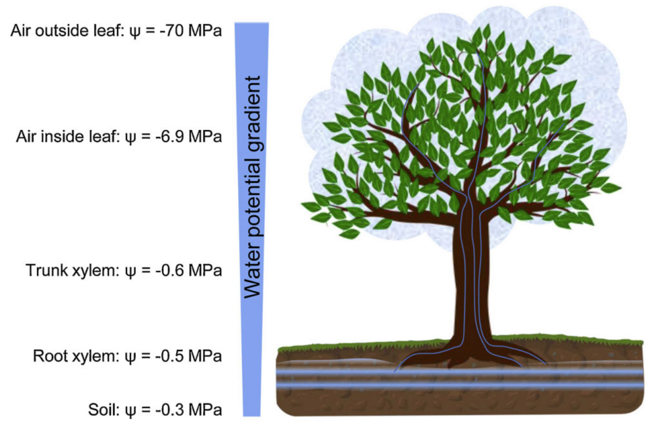
✓ PLS-R of photosynthesis, transpiration and conductance

✓ Most relevant wavelenghts are not typical VIs

Sobejano-Paz, V., Mikkelsen, T. N., Baum, A., Mo, X., Liu, S., Köppl, C. J., Johnson, M. S., Gulyas, L., & García, M. (2020). Hyperspectral and thermal sensing of stomatal conductance, transpiration, and photosynthesis for soybean and maize under drought. Remote Sensing, 12(19). https://doi.org/10.3390/rs12193182

Leaf water potential with remote sensing?

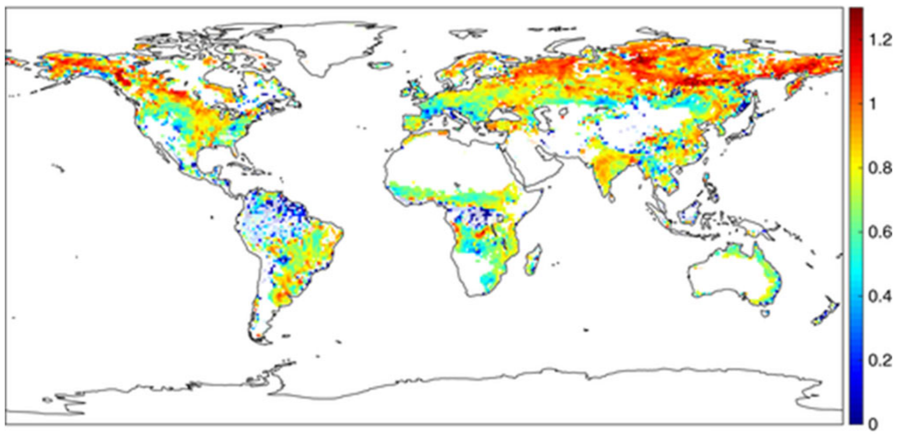
Biophysical bottom up



PERSPECTIVE
https://doi.org/10.1038/s41561-022-00909-2
nature geoscience
Check for updates

Confronting the water potential information gap

Kimberly A. Novick[1], Darren L. Ficklin[2], Dennis Baldocchi[3], Kenneth J. Davis[4], Teamrat A. Ghezzehei[5], Alexandra G. Konings[6], Natasha MacBean[2], Nina Raoult[7], Russell L. Scott[8], Yuning Shi[9], Benjamin N. Sulman[10] and Jeffrey D. Wood[11]



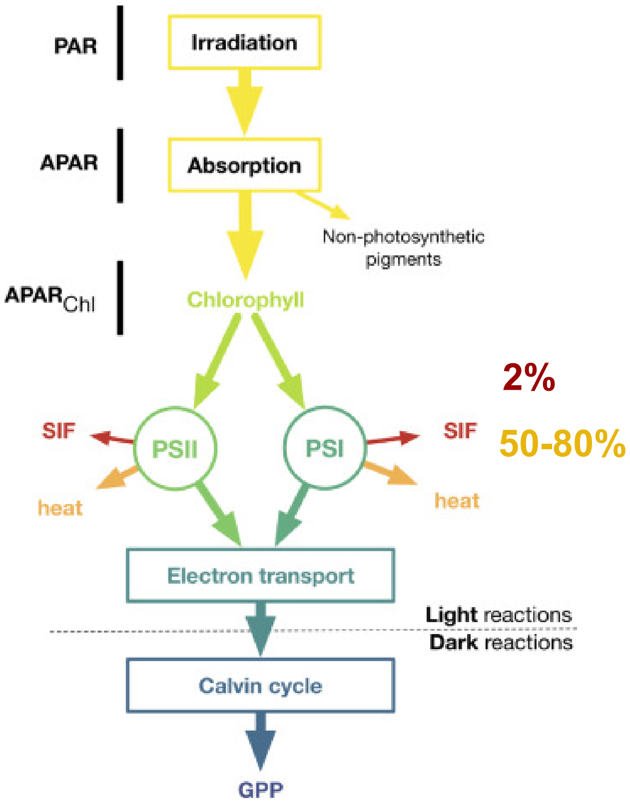
$$\mathrm{VOD}^{\mathrm{midday}} = \sigma \mathrm{VOD}^{\mathrm{midnight}} + (1-\sigma)\beta b + \Lambda \alpha \beta$$

Konings et al., 2018

Progress

- ✓ Microwaves for “vegetation optical depth” as a proxy (Konings et al., 2018)
- ✓ SMAP L4 soil moisture improves estimates (Qiu et al., 2022)
- ✓ Exploring thermal, SIF, optical integrated in models like STEMMUS-SCOPE (Wang et al., 2022)

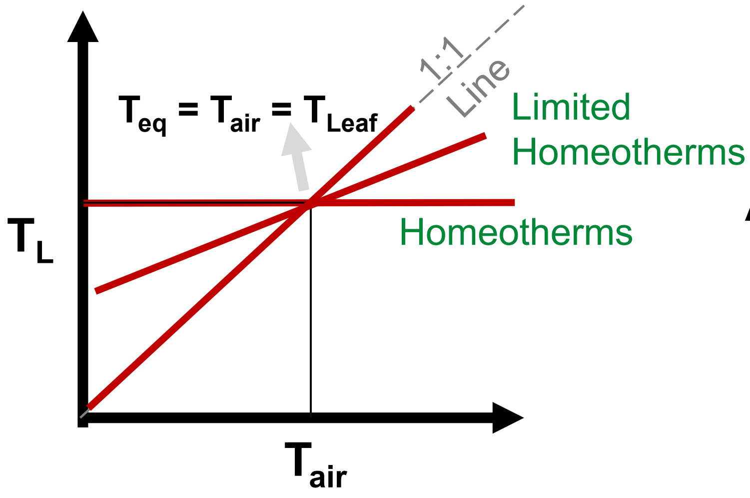
Energy balance of absorbed PAR: photochemistry

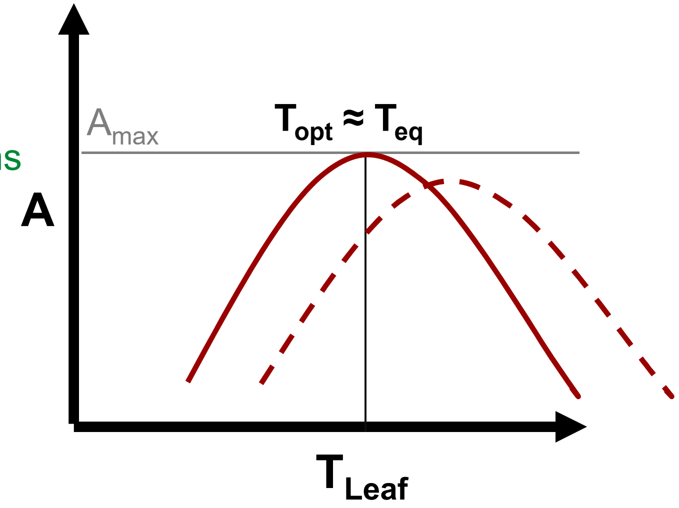


Jonard et al., 2020

- ✓ Plant thermoregulation controversy

  (Mitcheletz et al., 2020, Geange et al., 2020; Still et al, 2022)
- ✓ NPQ contribution to thermal emission? Kaňa and Vass (2008)
- ✓ Relationships with thermal optimum and acclimation?





T_{eq} = leaf equivalence temperature point

T_{opt} = optimum temperature for photosynthesis

Yamori et al., 2014

Uncrewed Aerial Systems (UAS) for environmental monitoring

- High resolution (<1m)
- Flexibility/cost
- Below clouds
- Multisensor (LiDAR, altimetry, RGB, thermal, optical…)

Corrections

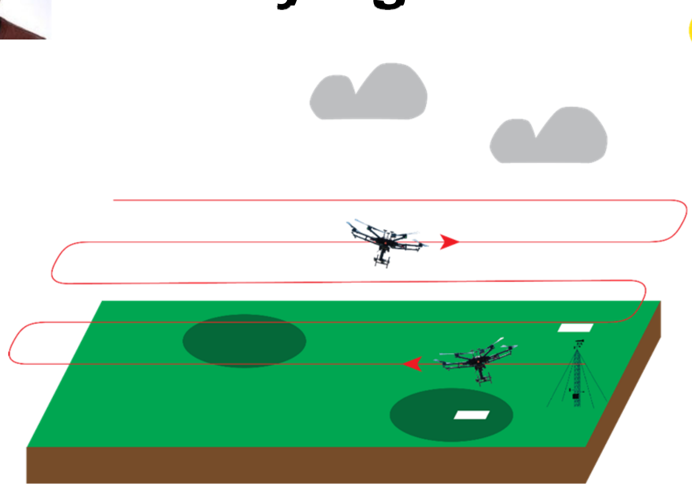
↓

Assimilation into models

↓ ↑

Cal/Val

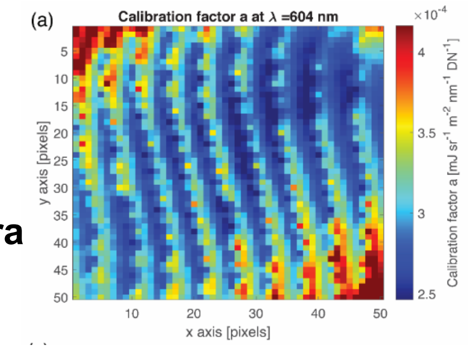
Flying under intermittent clouds and turbulences



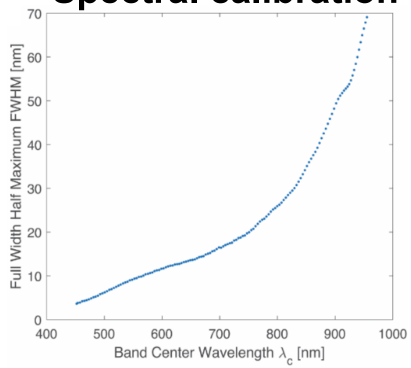
Hyperspectral camera

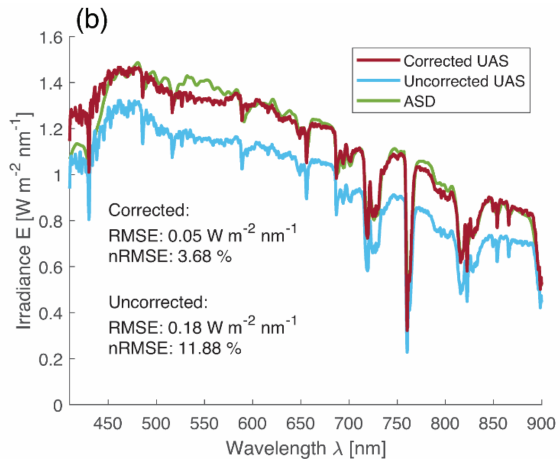
Cubert Firefleye
138 bands
450 – 998 nm

Radiometric Calibration

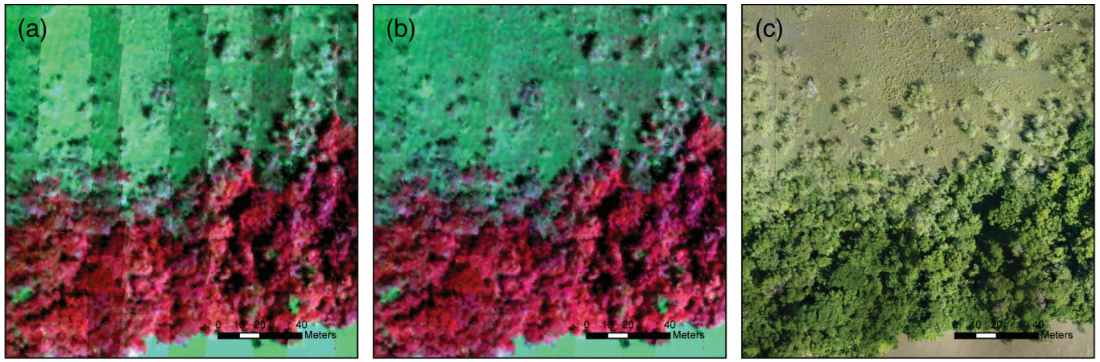


Spectral calibration





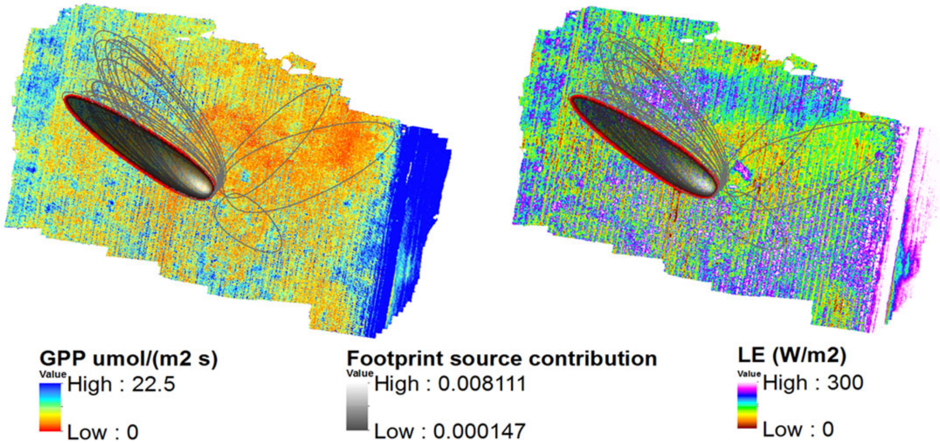
Reflectance: Palo Verde National Park (Costa Rica)



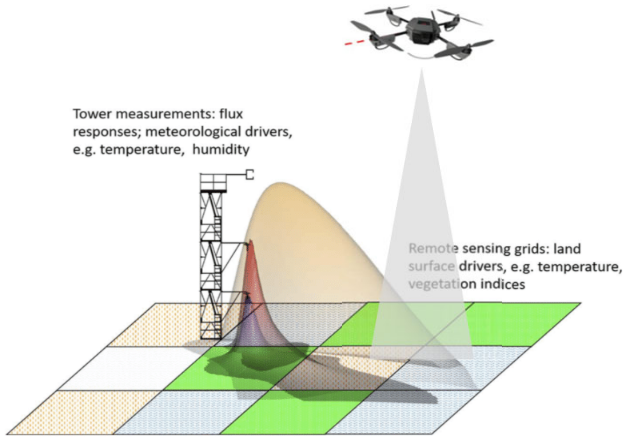
Köppl C.J., R. et al.. 2021. Hyperspectral reflectance measurements from UAS under intermittent clouds: Correcting irradiance measurements for sensor tilt. *Remote Sensing of Environment* 267, 112719.

Coupling evapotranspiration and GPP: crop applications

- ✓ Water Use Efficiency (WUE)
- ✓ Optimum spatial resolution?

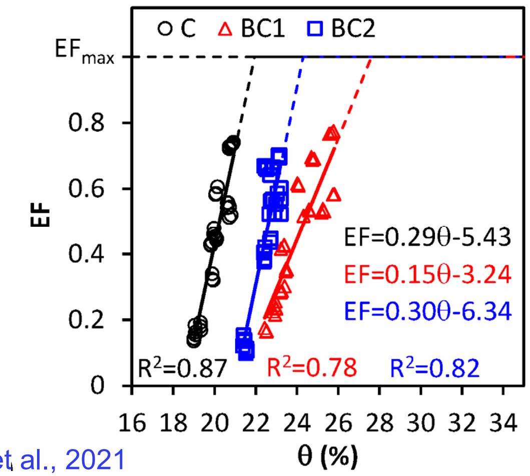


Wang et al., 2019



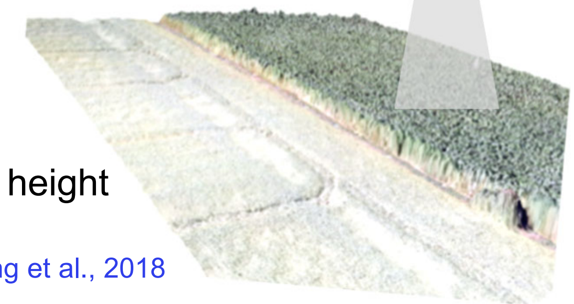
Metzger et al., 2018

Biochar for drought adaptation



Jin et al., 2021

Risø willow flux site



- ✓ Root zone soil moisture
- ✓ Point cloud RGB to estimate height

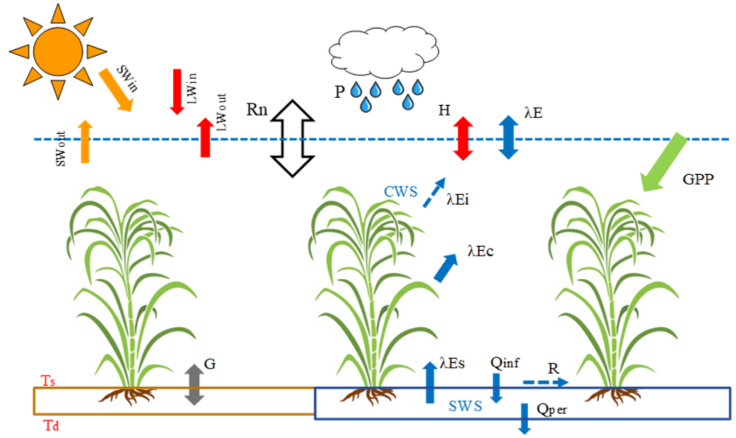
Wang et al., 2018

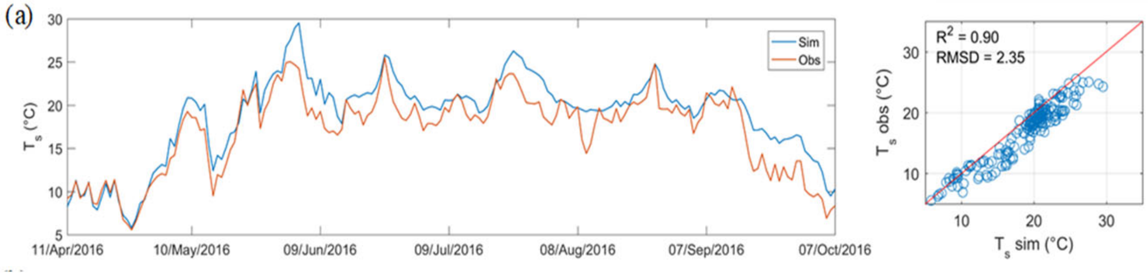
Dynamic modeling and temporal interpolation:

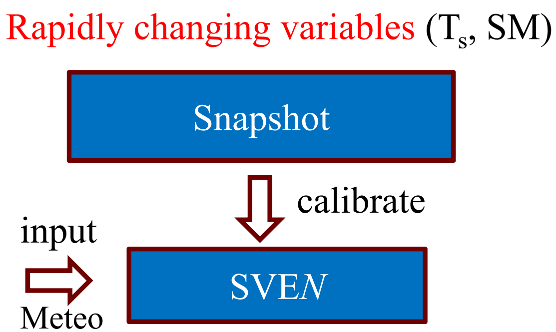
Snapshots as ”ground truth” for parameter retrieval

An operational and simple SVAT model: Soil-Vegetation Energy, water and CO_2 traNsfer model (SVEN) to interpolate rapidly changed land surface variables.

The joint ET and GPP model + ‘force-restore’ method (Noilhan and Planton, 1989) + simple bucket model to simulate the canopy wetness and SM





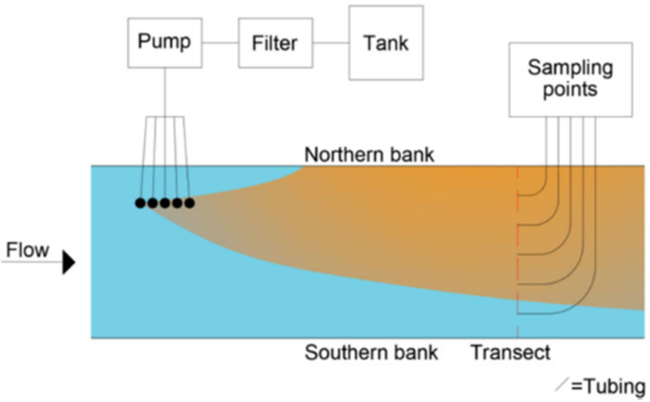


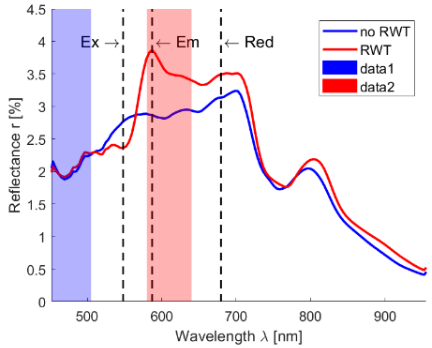
Wang, S., García, M., Ibrom, A., & Bauer-Gottwein, P. (2020). Temporal interpolation of land surface fluxes derived from remote sensing – results with an unmanned aerial system. *Hydrology and Earth System Sciences*, 24(7), 3643–3661. https://doi.org/10.5194/hess-24-3643-2020

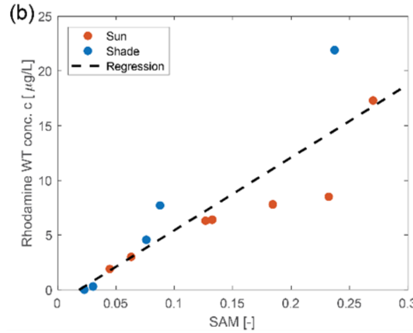
Ecological state of freshwater streams

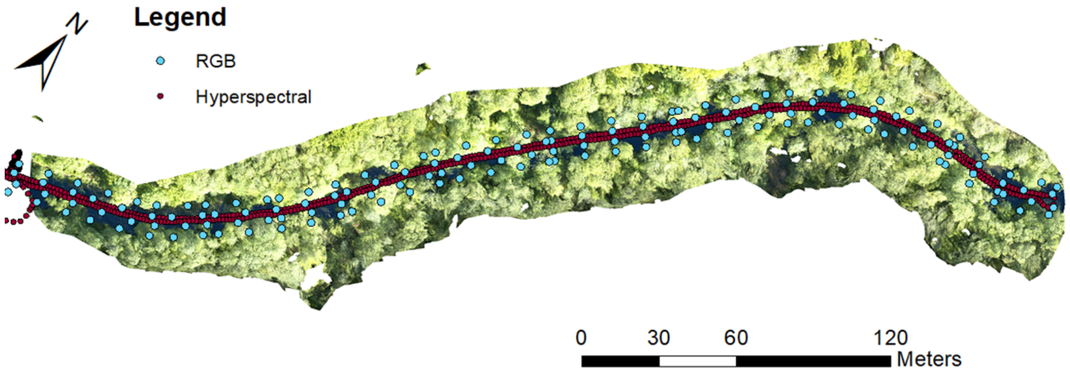
Mixing length contaminant plumes? Rhodamine as tracer

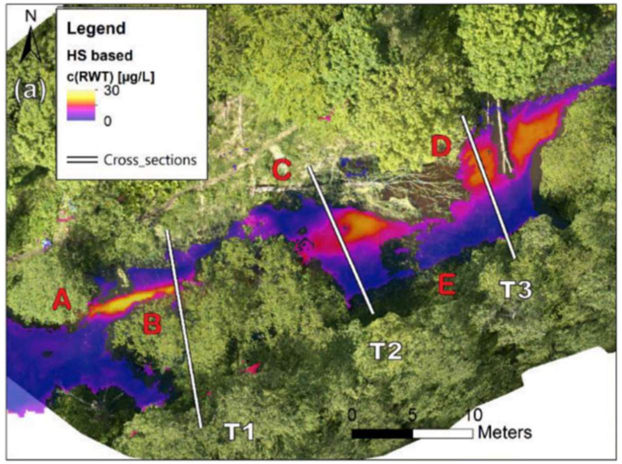
(Legleiter et al., 2019)







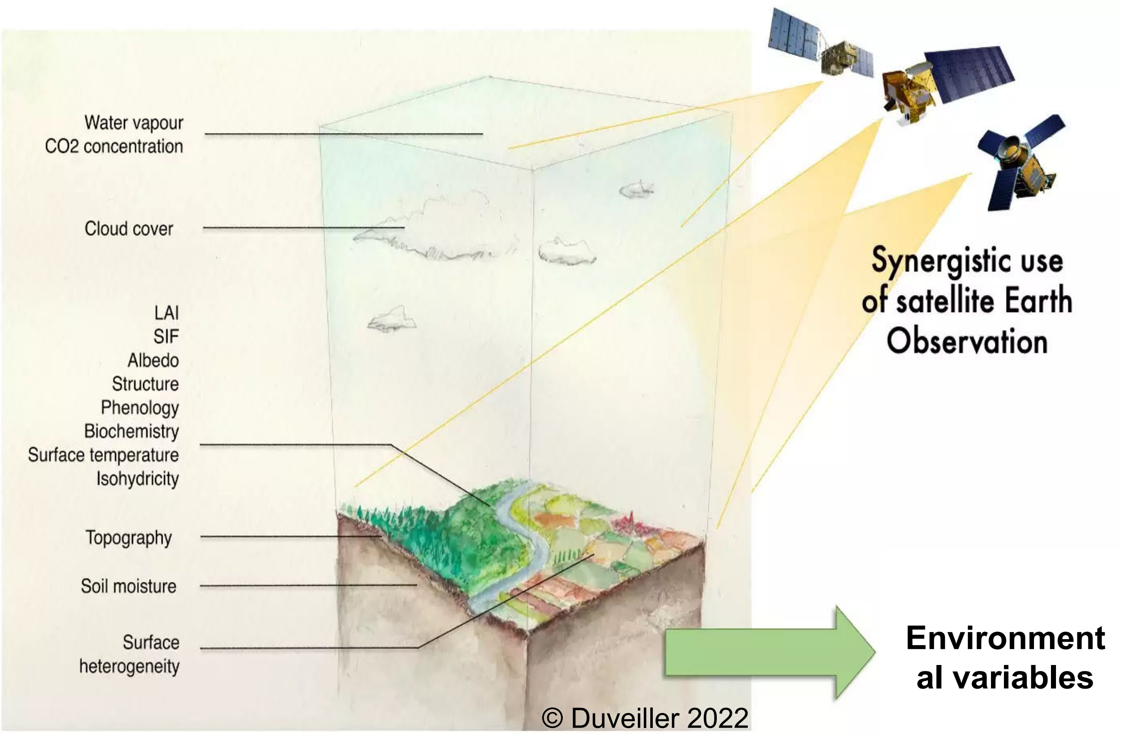




Köppl et al. 2023. Imaging Tracer Mixing Concentration 2D in a Stream with Hyperspectral Sensing from an Unmanned Aerial System, PREPRINT available at Research Square [https://doi.org/10.21203/rs.3.rs-2499200/v1]

Outlook

- Focus on estimating environmental variables by merging sensors and coupling models
- Evapotranspiration is a key variable: uncertainty
- Improving in sensors: ECOSTRESS, FLEX mission, Sentinel, hyperspectral LiDAR→ drones?

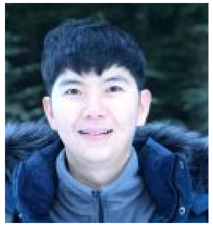


cegram
Centro de Estudios e Investigación para la Gestión de Riesgos Agrarios y Medioambientales

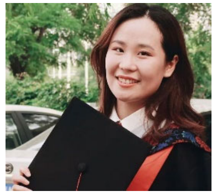
POLITÉCNICA
UNIVERSIDAD POLITÉCNICA DE MADRID

Thanks!








dronesystems.dk
skaber overblik

Water JPI

Innovation Fund Denmark
RESEARCH, TECHNOLOGY & GROWTH

OPTIMISE

DTU Fotonik
Department of Photonics Engineering

DTU Space
National Space Institute

UNIVERSIDAD DE COSTA RICA

HIDROCEC-UNA
Centro de Recursos Hídricos para Centroamérica y el Caribe

UBC

LUXEMBOURG INSTITUTE OF SCIENCE AND TECHNOLOGY
LIST

HARMONIOUS
uas for environmental monitoring