The Challenge Of Ground Truth Data for Water Resource Management (West Africa)

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International Space Science Institute Workshop: "Global Change in Africa: Role of Space Observations", Bern, Switzerland

January 12, 2021. Session 2: Water Resources in Africa

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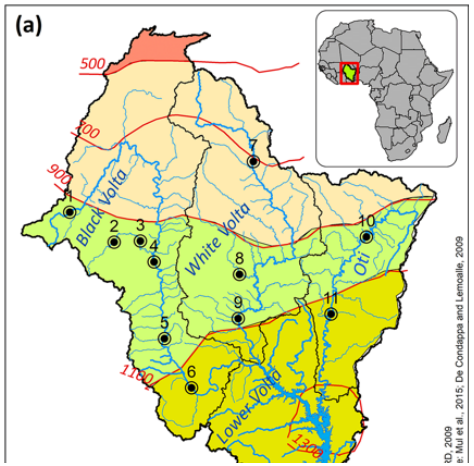
1. Journey to a place

Evaporation

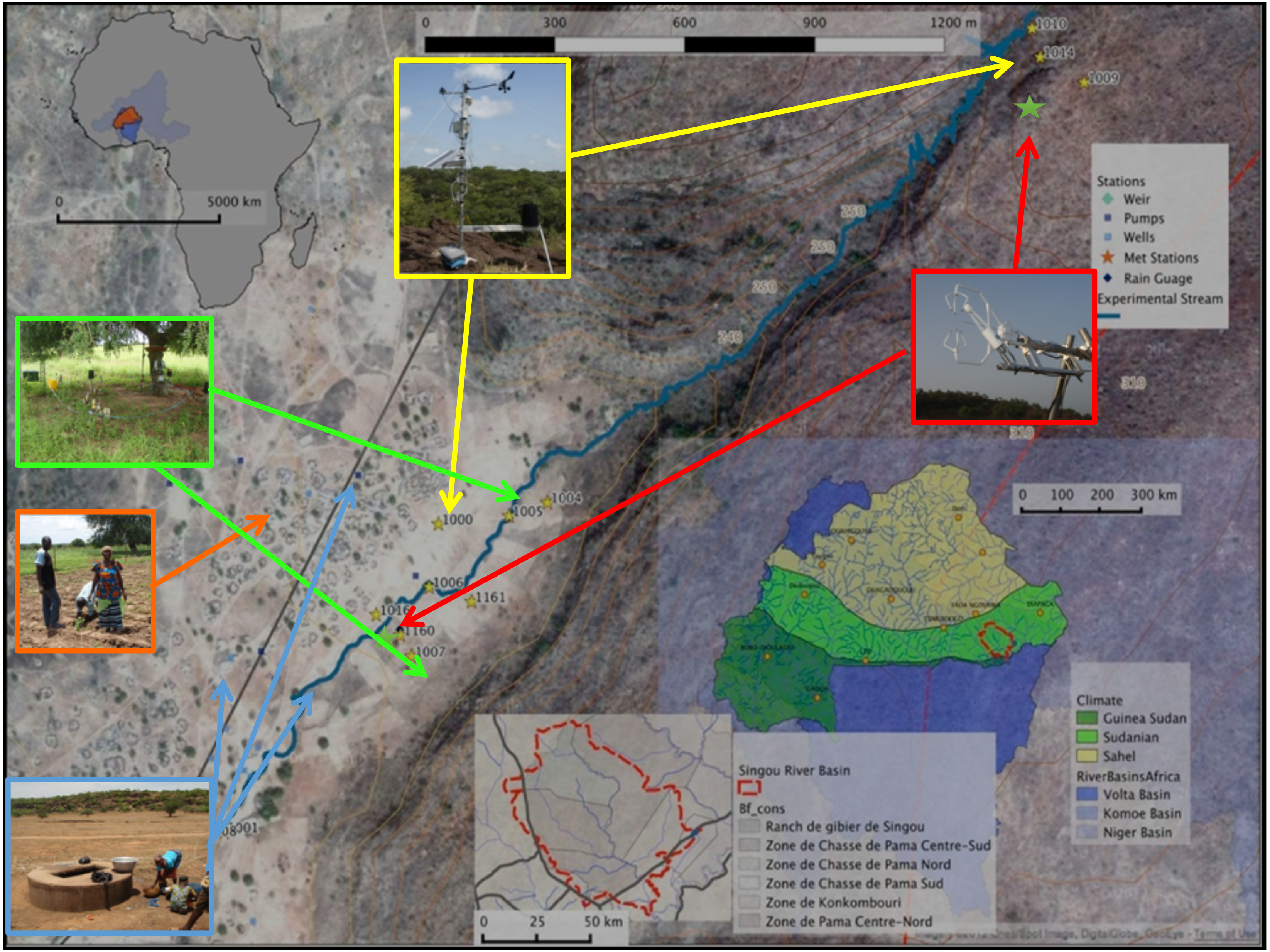
2. Field measurements and conditions

Comparison

3. Large scale model improved with remote sensed data



4. Solution:
Think about scale and participation



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Eddy Covariance

- Goal: Observe Turbulent Fluxes, understand variations

- 2 Stations, May 2009 – October 2010
  - Gallery Forest
  - Agricultural Field
- 1 Station, July 2011 – November 2013
  - Agricultural Field

Evaporation: Couple between Energy and Water Balance

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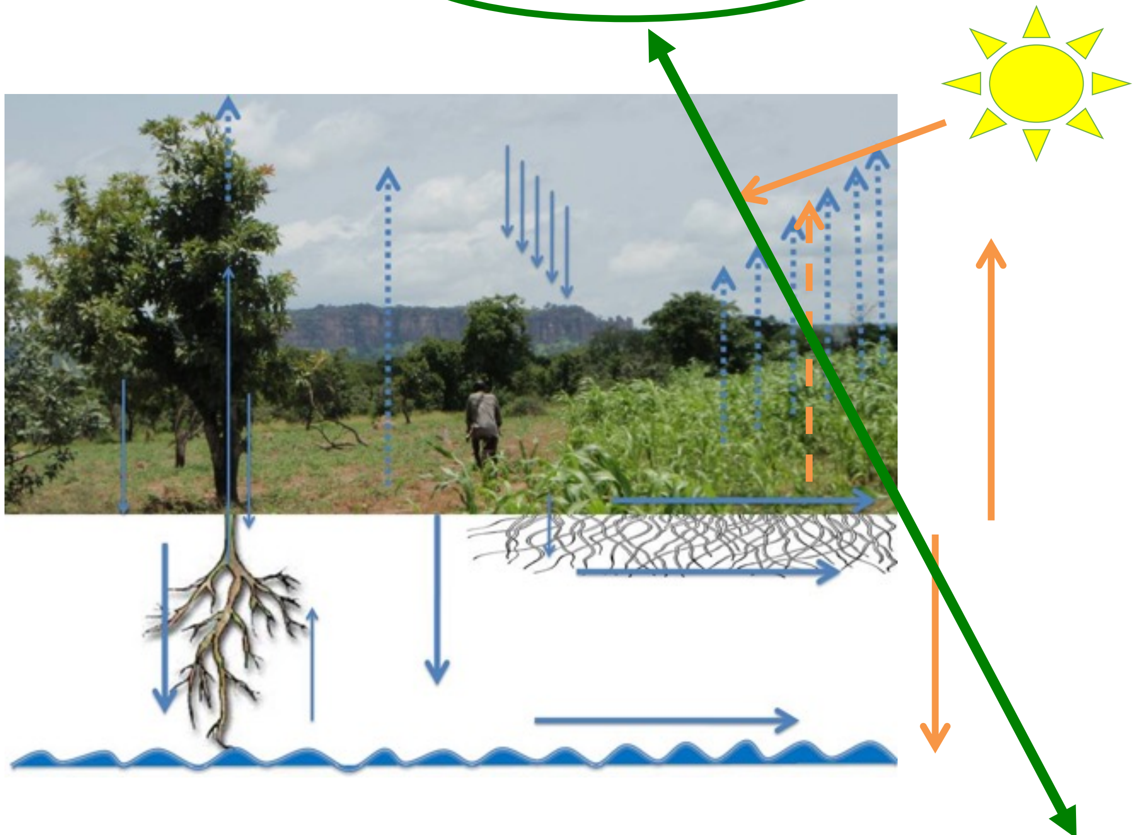
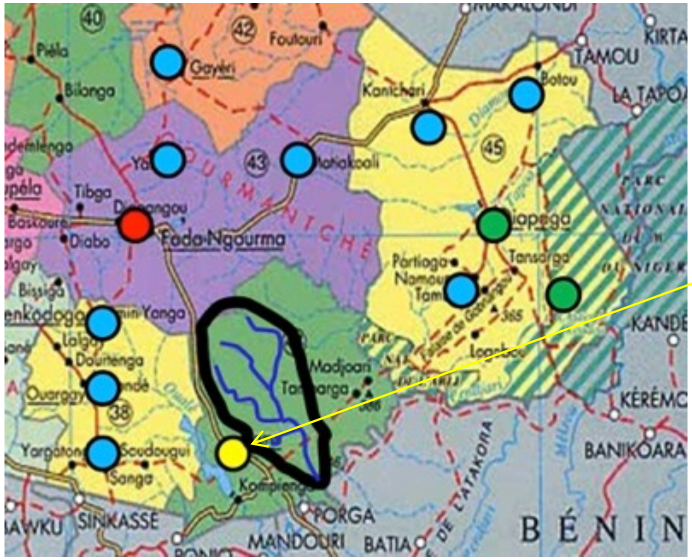
Radation = **S**ensible**H**eat+ **L**atent**E**nergy + **G**round



Rain = **I**nterception +**L**eakage +Runoff(**Q**) +**E**vaporation

Limited direct measured of Evapotranspiration



Available Stations in the Region

Weather Station @ Kompienga

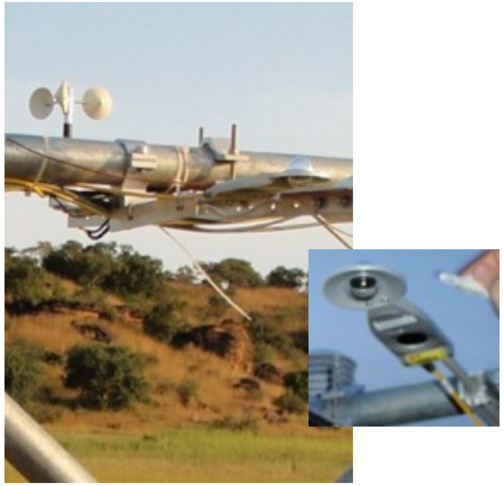
- Little or no availability of EC data
- National Weather Station data is scarce, or unreliable

Energy Balance

- Eddy Correlation, planar fit
- Sensible and Latent Heat Fluxes

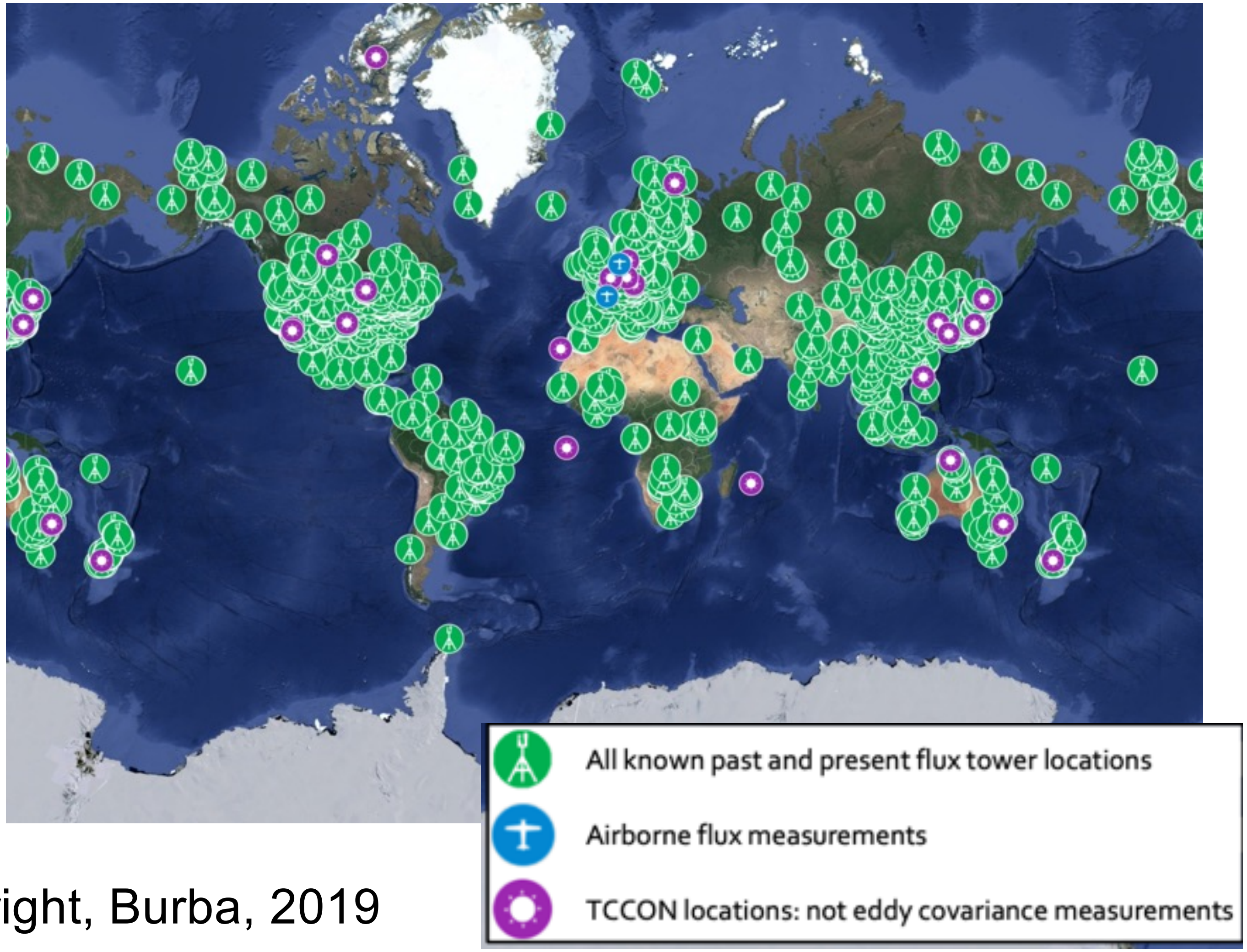
$$H = \hat{\rho} c_p \overline{w'T'}$$
$$L_e E = L_e \hat{\rho} \overline{w'q'}$$

- Measure Net Radiation
- Ground Heat = Remainder Energy Balance
- Scale depends on wind, up to 50 m distance upwind



$$G = R_n - L_e E - H$$

Eddy- Covariance Measurements World Wide



Left,Weerasingeh, 2020, and right, Burba, 2019

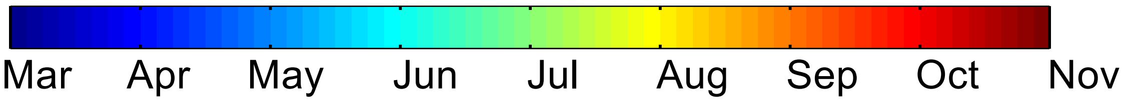
Two stations over two land-covers: forest and field

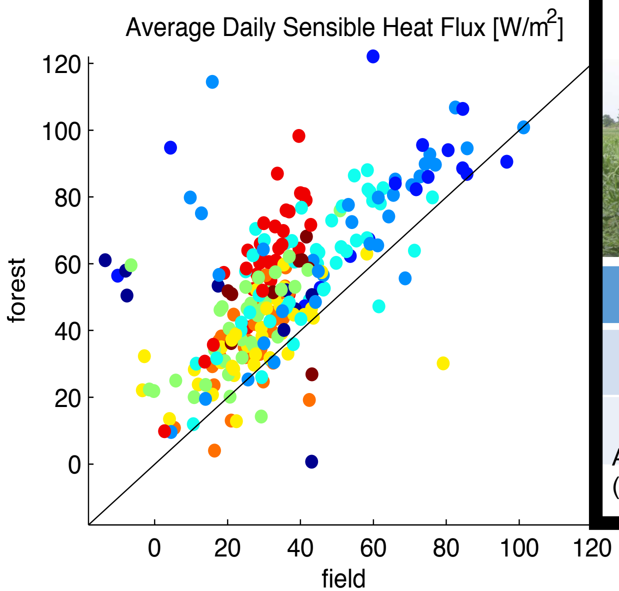
- Higher H & LE over Gallery Forest than Field

Field

Forest

pooled 2009-2010

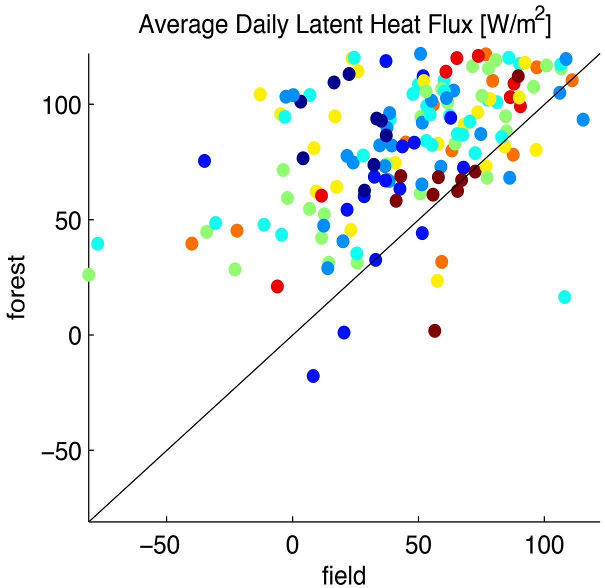


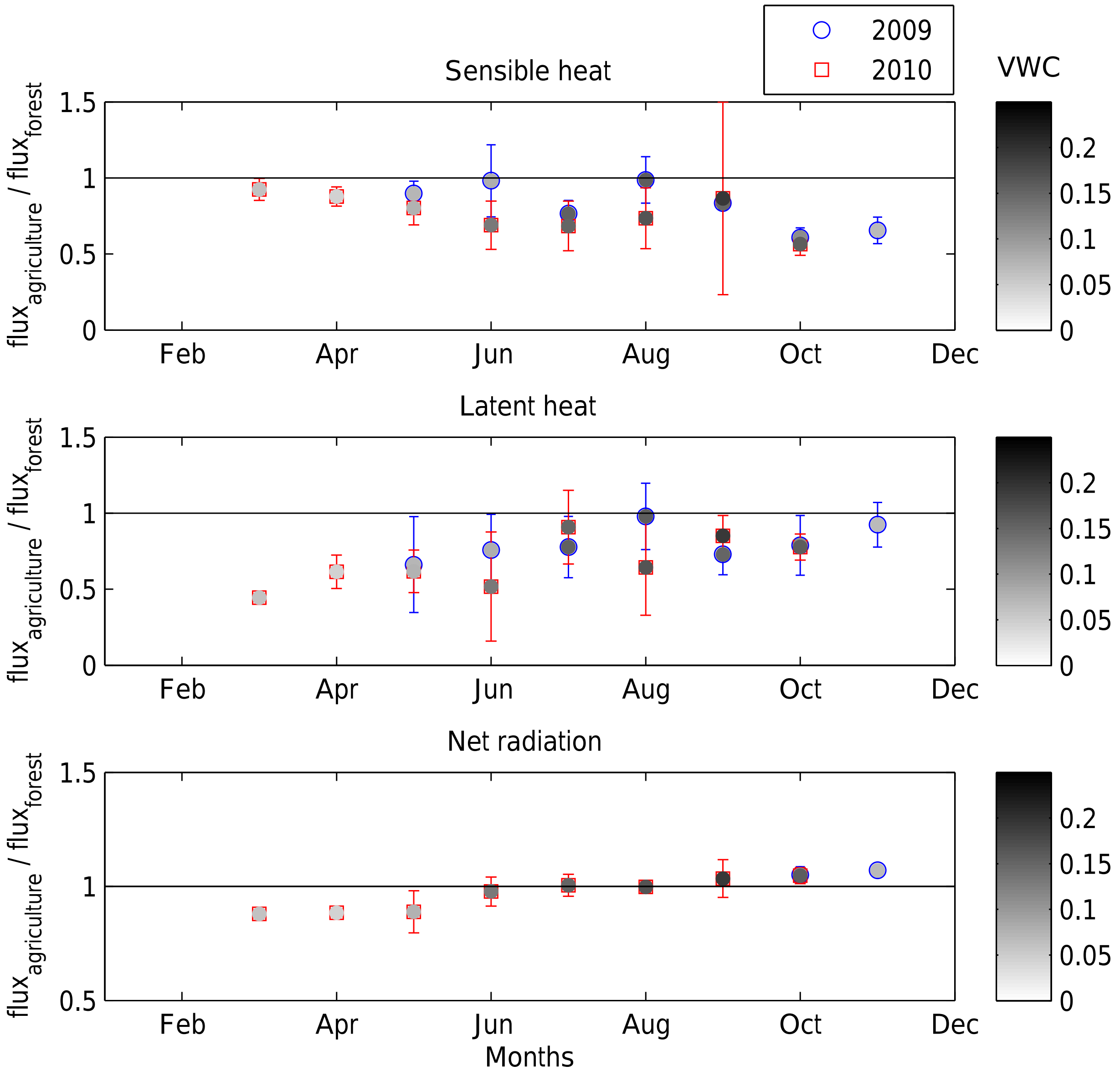


Compare

W/m²	Wet	Dry
H	81	158-176
L	176	33-41

At Kompienga: 2003-04 (Bagayoko, 2007)





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The Diurnal Cycle of Energy Balance over Forest vs. Agriculture

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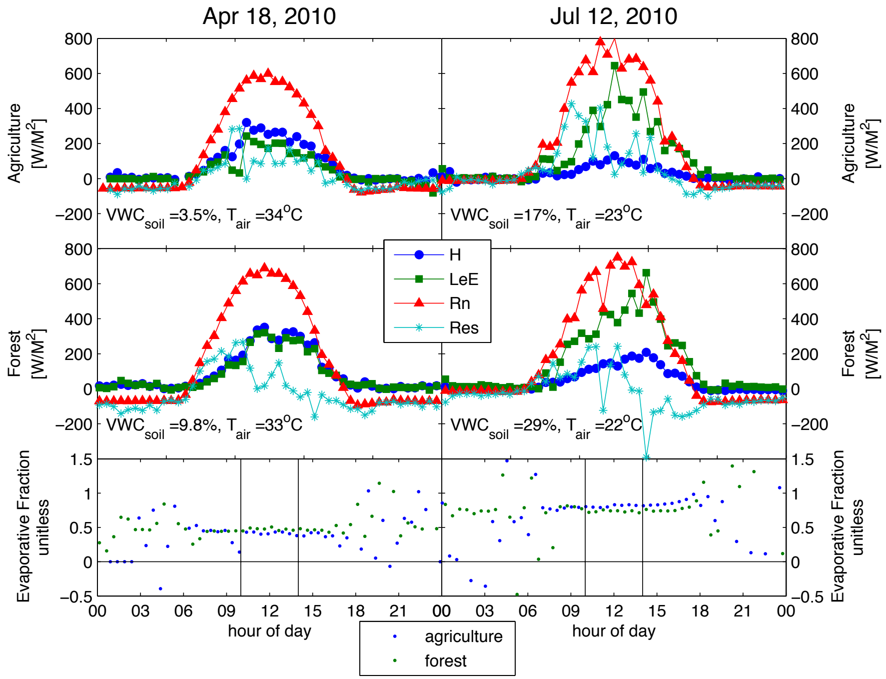
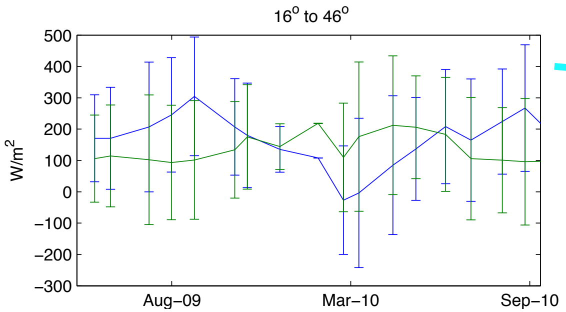
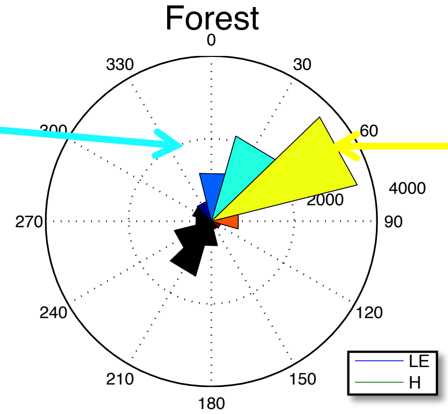
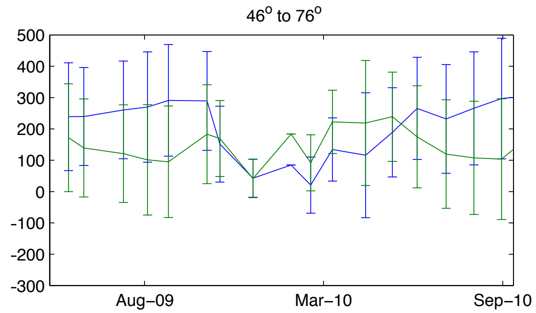


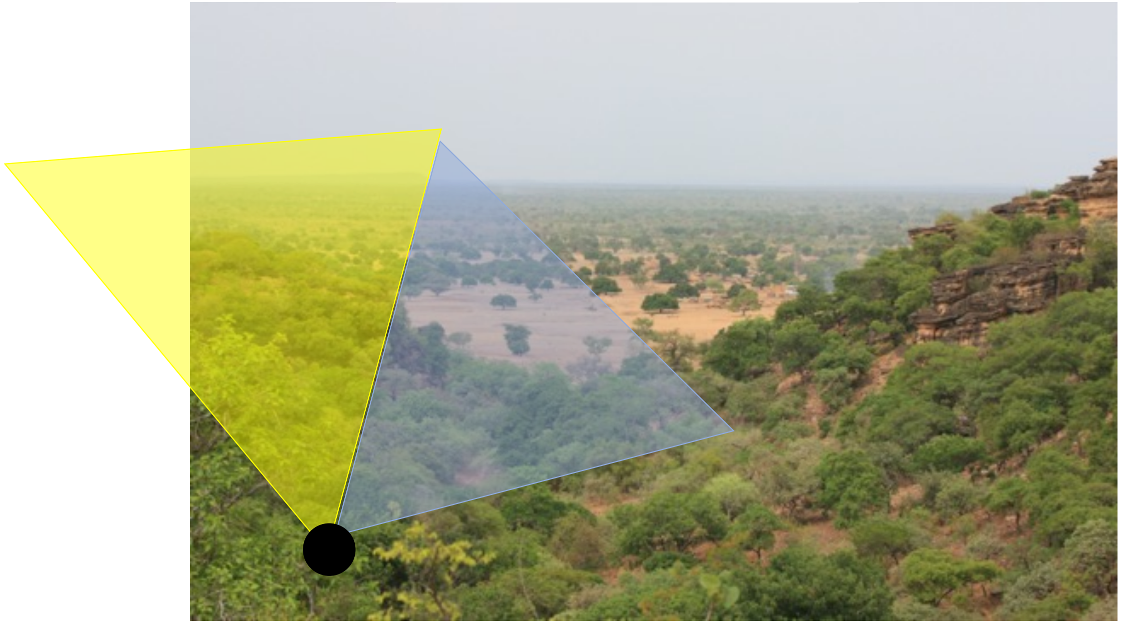
- Sensible heat (H, blue, [W/m2])
- Latent heat (LeE, green, [W/m2])
- Net radiation (Rn, red, [W/m2])
- Residual = Rn – H – LeE (Res, turquoise, [W/m2])
- Half hour calculation of evaporative fraction, averaged between 10 and 14h

Comparison of wind directions

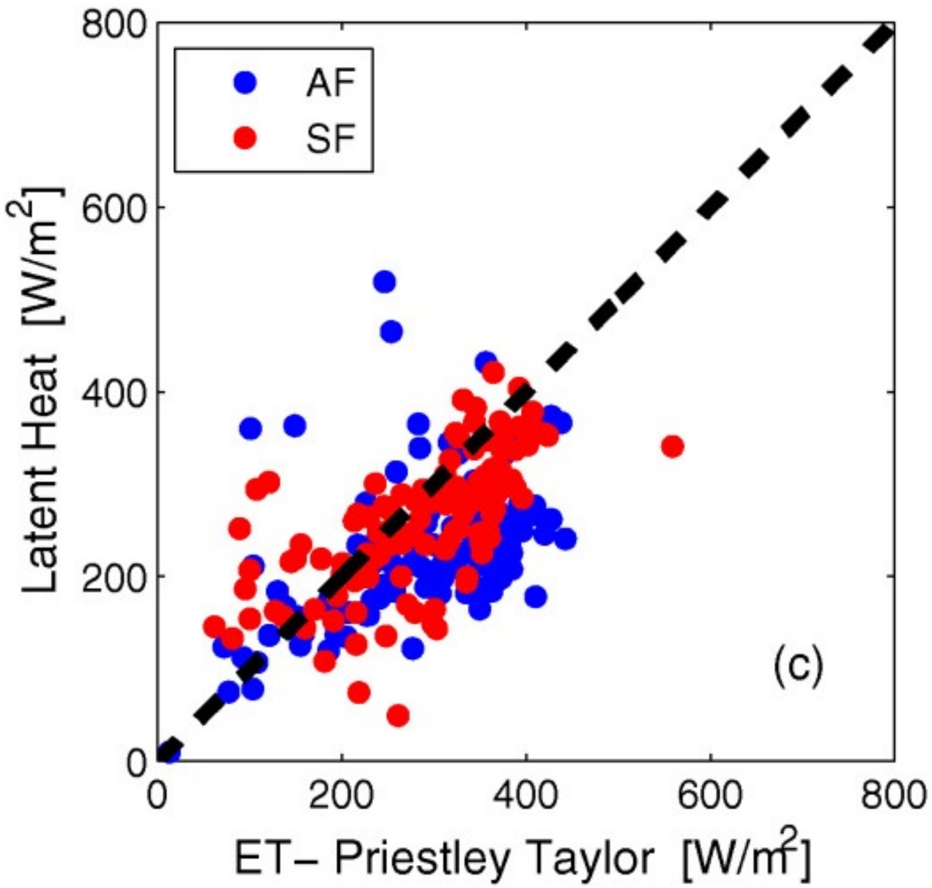








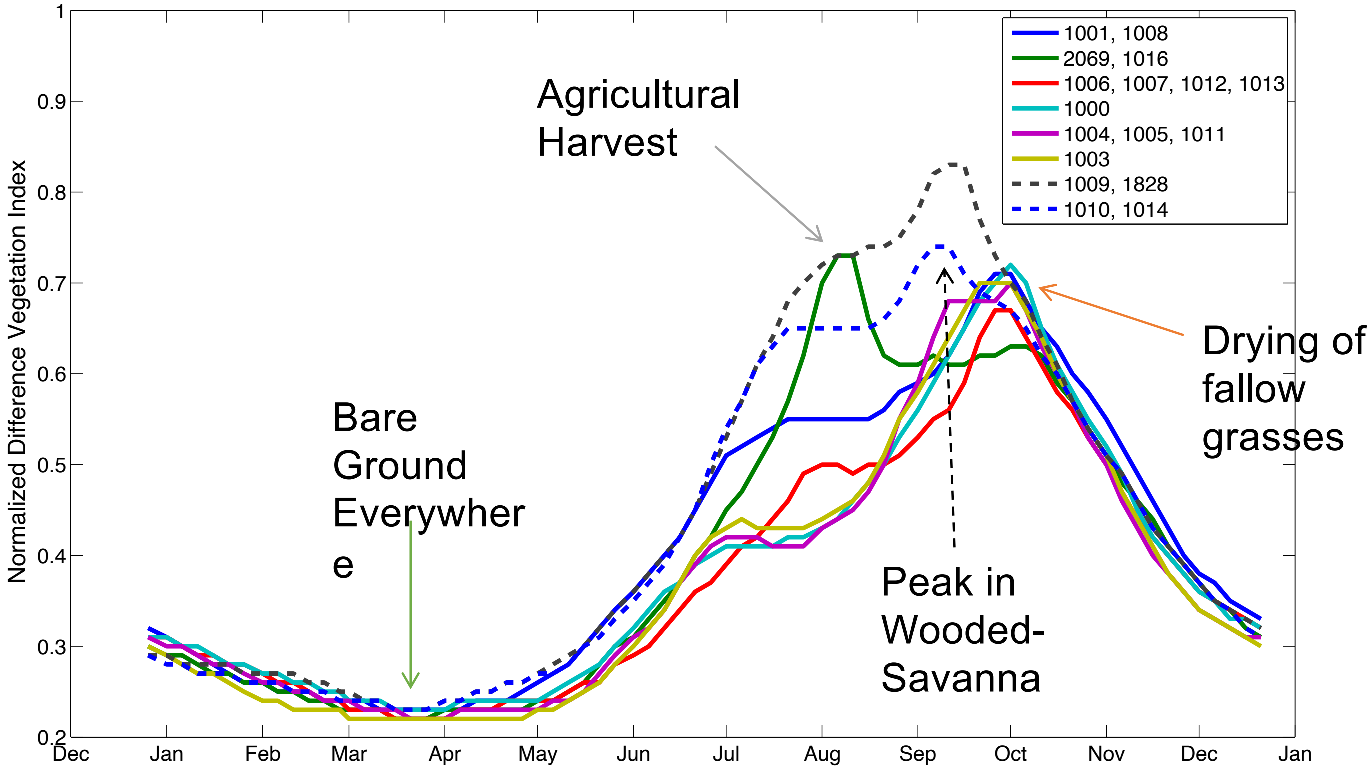
Comparison with calculations from ground based measurements



Suppressed convective rainfall by agricultural expansion in southeastern Burkina Faso
Mande, T. et al. Water Resources Research, Volume: 51, Issue: 7, Pages: 5521-5530, First published: 19 June 2015, DOI: (10.1002/2015WR017144)

Seasonal Change in NDVI

- 250 meter resolution = multiple stations / pixel



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Indirect measures of evaporation: Weather station data

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TAHMO weather station data

TAHMO, with goal to install 20000 weather stations in Africa.

Algorithms to determine PET, AET, ET0 depend on various combinations of meteorological variables, for example:

- Penman, Menman Monteith, Shuttleworth, Brutsaert-Strickler and others: Tmin – Tmax, Rs, Uz, Rhmin, Rhmax
- Priestley-Taylor: Tmin – Tmax, Rs, Rhmin, Rhmax
- Others require sunchine hours, Dew Point temperature, and pan-evaporation

=> Limited by quality of data and appropriateness for algorithm

Advances in Water Resources
Volume 143, September 2020, 103667

Potential of satellite and reanalysis evaporation datasets for hydrological modelling under various model calibration strategies

Moctar Dembélé [a], Natalie Ceperley [a, e], Sander J. Zwart [b], Elga Salvadore [c, d], Gregoire Mariethoz [a], Bettina Schaefli [a, e]

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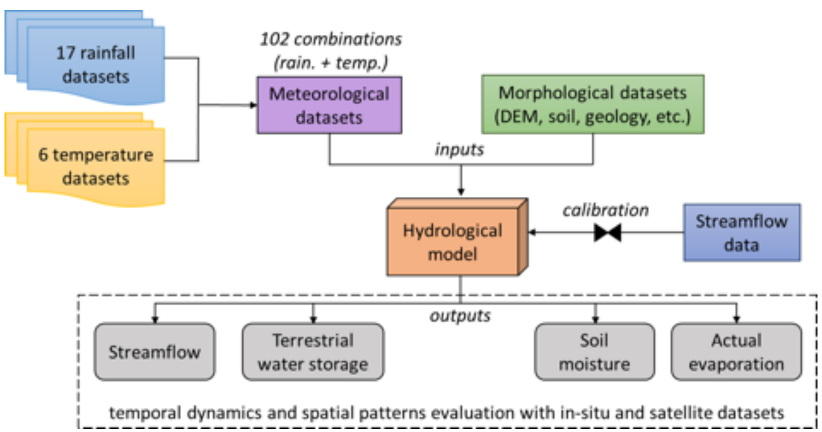
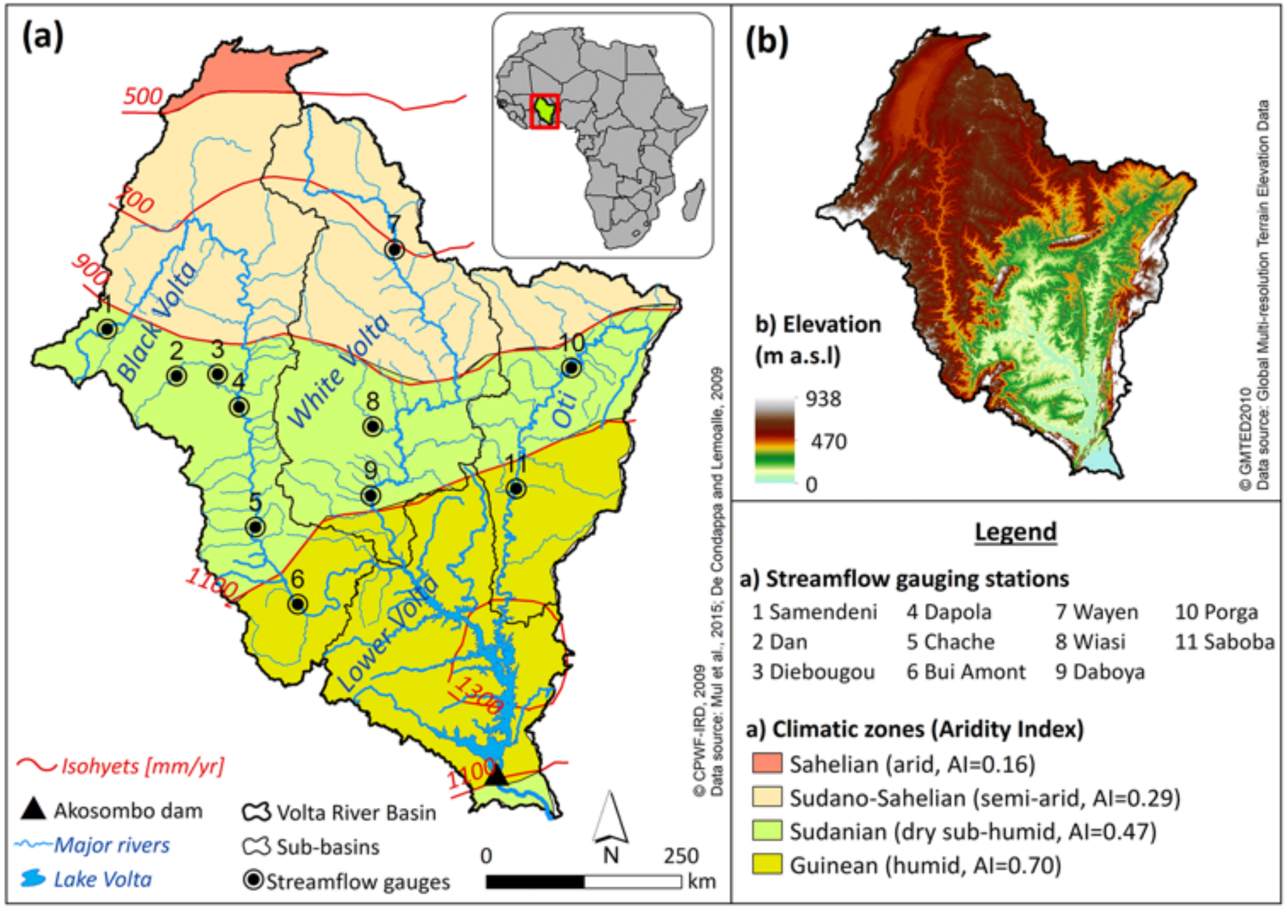
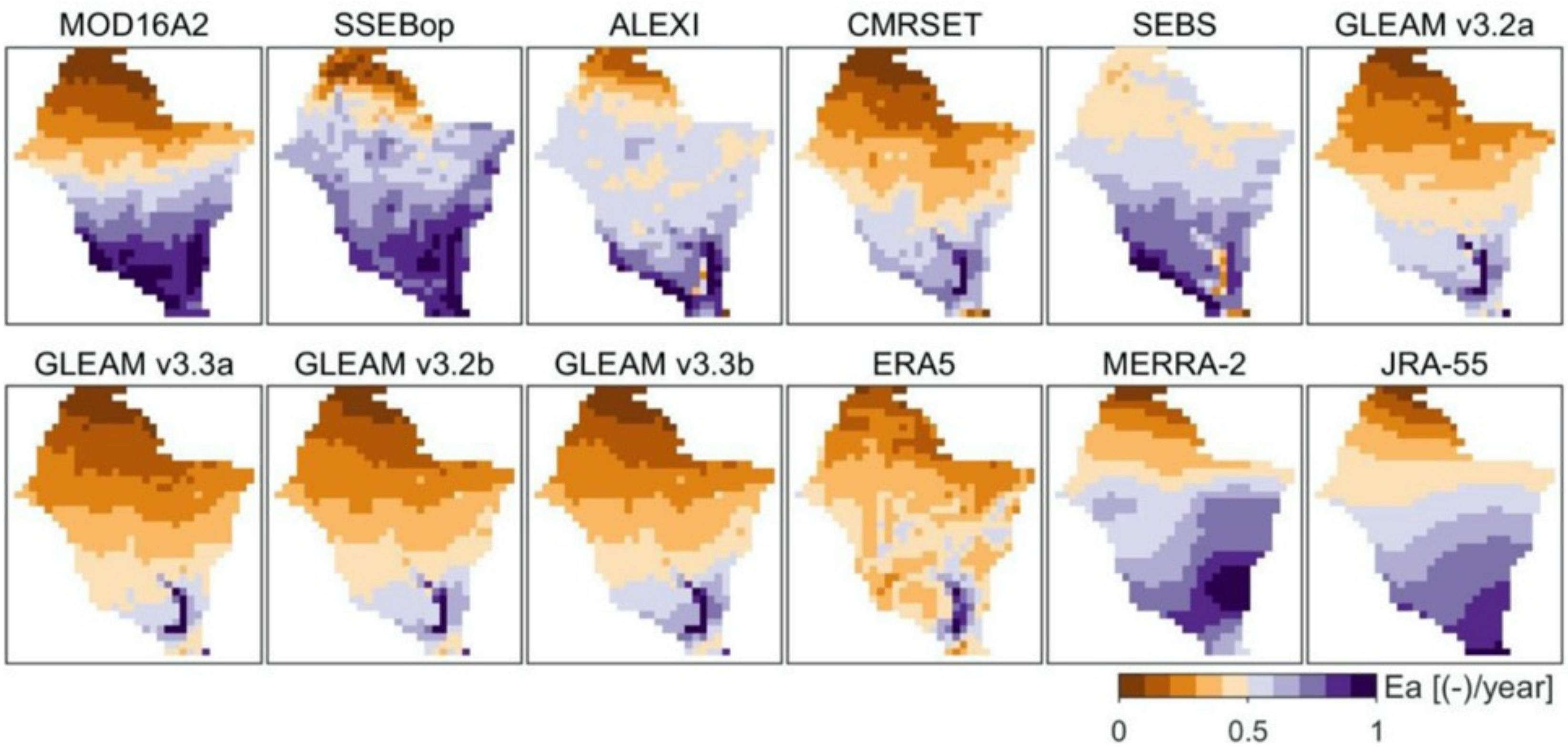


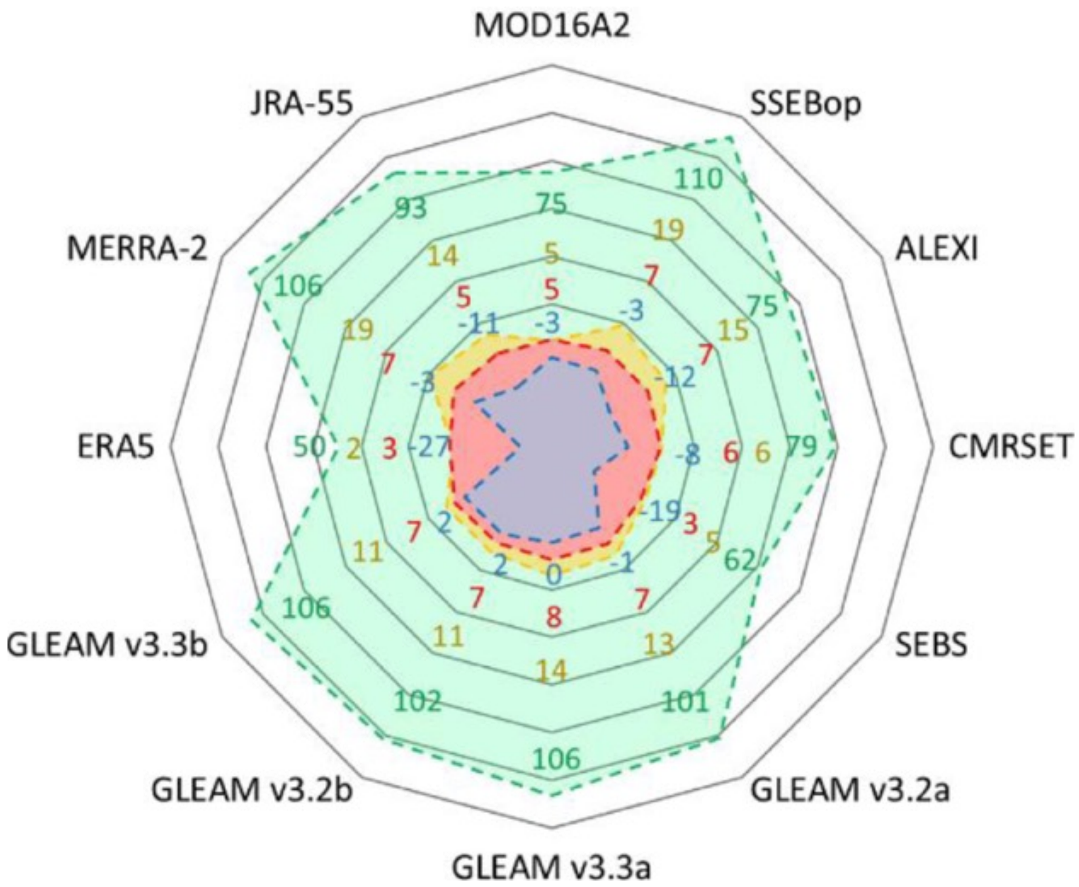


Total annual actual evaporation (E_a)



- gridded evaporation datasets
- Volta River basin
- Averaged 2003-2012
- min-max normalization

Hydrological Model Performance with Evaporation



- Values give the relative difference in model performance as compared to the Q-only calibration
- MERRA-2, GLEAM v3.3a and SSEBop improve model performance most
- Spatial patterns of gridded evaporation data for calibration, vs. absolute values, => higher performance than basin average evaporation signal or based only on streamflow

Comparison of satellite data sets

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Datasets	Name/ Data portal	Spatial coverage	Spatial resolution	Temporal coverage	Temporal resolution
MOD16A2	Moderate Resolution Imaging Spectroradiometer (MODIS) Global Terrestrial Evapotranspiration Algorithm version 5	Global	0,0085° (~1 km)	2001-2014	Monthly
SSEBop (FEWS)	Operational Simplified Surface Energy Balance	Global	0.0083° (~1 km)	2003-2014	Monthly
ALEXI	Atmosphere-Land Exchange Inverse	70° N–60° S	0.05° (~5.6 km)	2003-2015	Monthly
CMRSET	CSIRO MODIS Reflectance Scaling EvapoTranspiration	Global	0.05° (~5.6 km)	2001-2013	Monthly
SEBS	Surface Energy Balance System	40° N–40° S	0.05° (~5.6 km)	2001-2012	Monthly
GLEAM v3.2a – 3.3b	Global Land Evaporation Amsterdam Model	Global (dep. Version)	0.25° (~28 km)	1980-present (dep. Version)	Daily

Comparison Evaporation from Eddy-Correlation and FEWS, Gleam, and MOD-16A2 data

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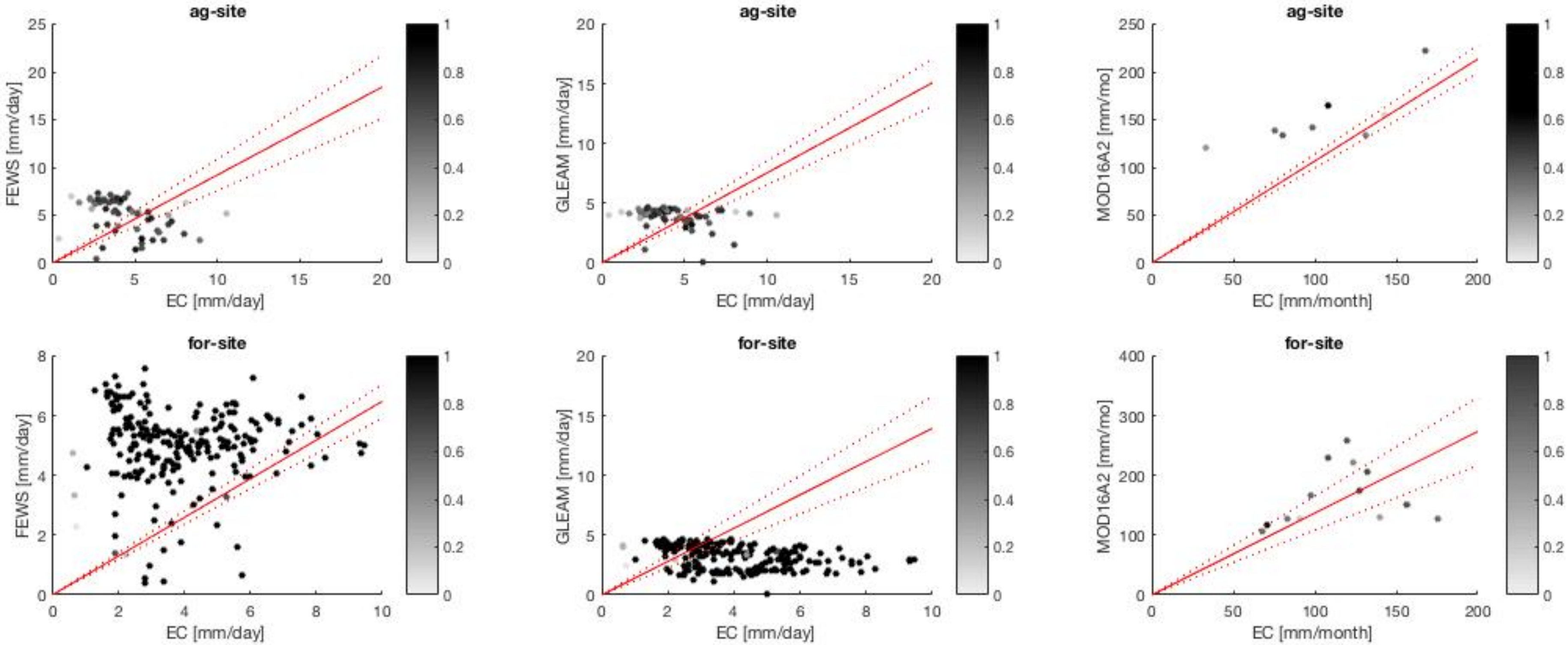
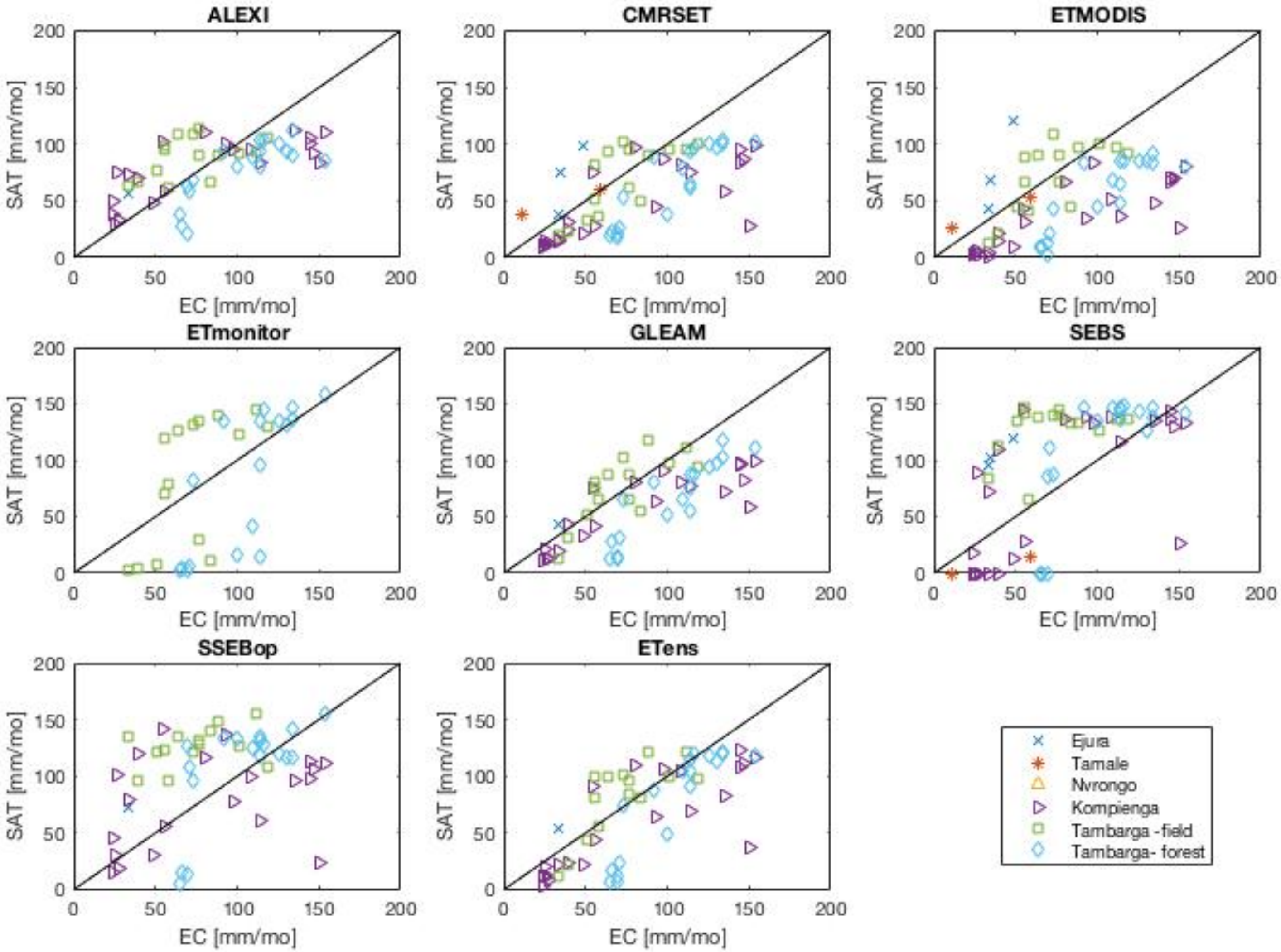
agricultural

forest





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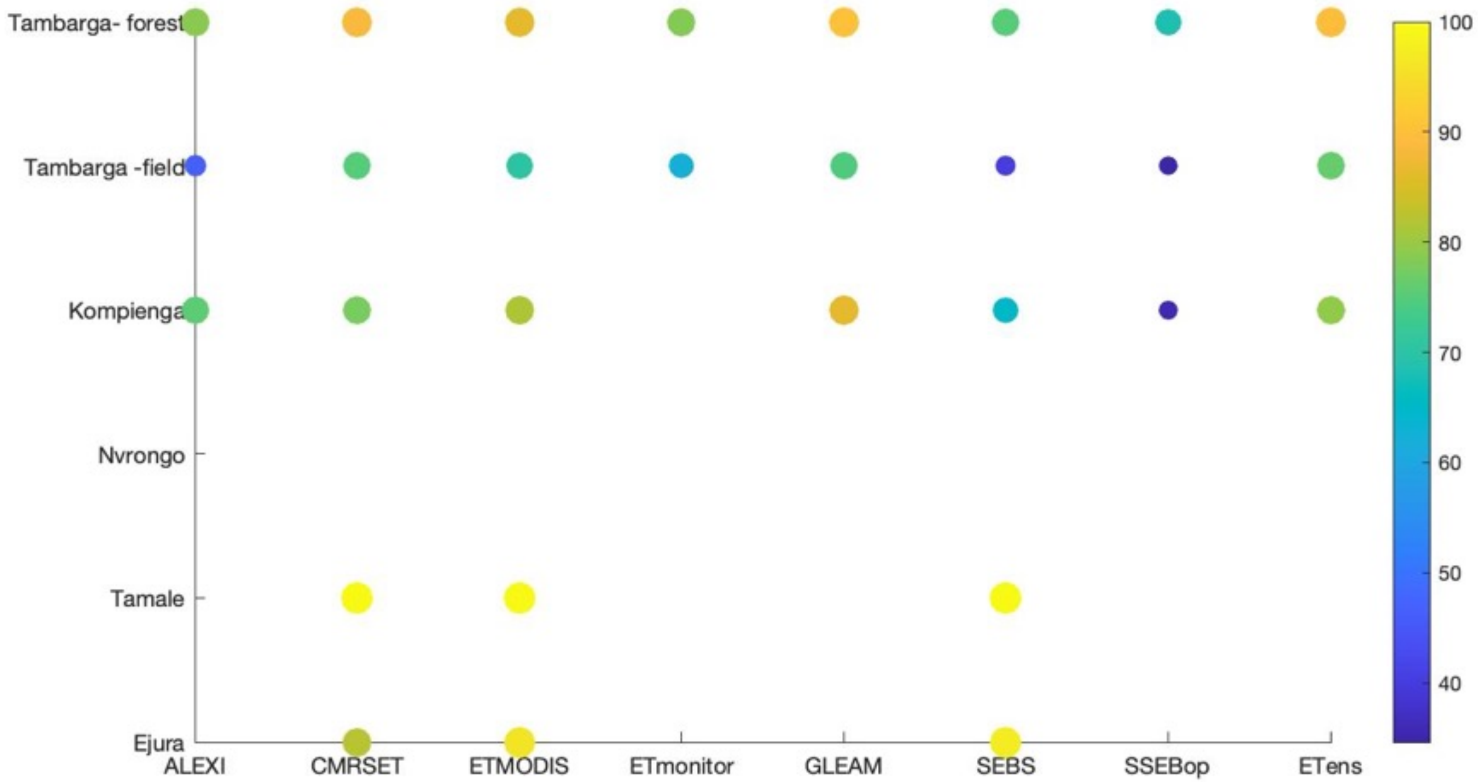
Pairwise Corelation Coefficients by Product and Site



Could an algorithm based on the object identification (tree) paired with a model based on processes work better?

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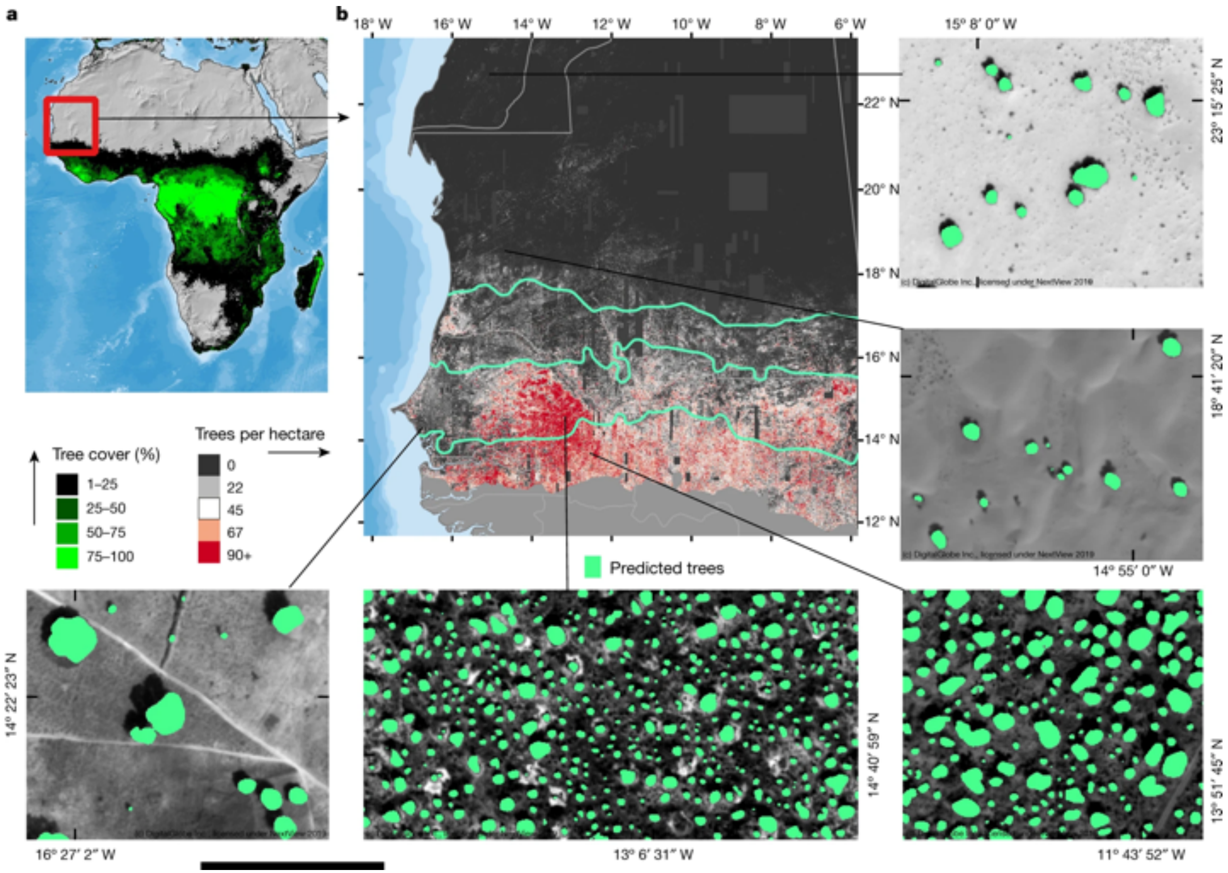


- 50,000 DigitalGlobe multispectral images from the QuickBird-2, GeoEye-1, WorldView-2 and WorldView-3 satellites, collected from 2005–2018 (in November to March) from 12° to 24° N latitude within Universal Transverse Mercator zones 28 and 29
- Classified with deep learning

An unexpectedly large count of trees in the West African Sahara and Sahel

Brandt et al., *Nature* **volume 587**, pages78–82 (2020)

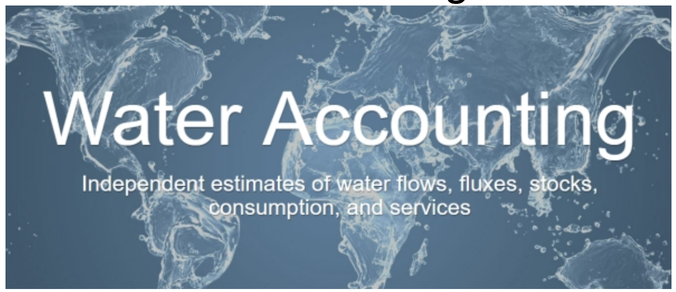
<u>Solution</u>:

Combine large scale, remotely sensed data and corresponding models with:

1. Local process-based understanding

2. Citizen-based field observations

i.e. Water Accounting Plus



3. Innovative frameworks between data, research, policy

Summary

1. Field measurements (eddy covariance) show high variability
2. At large scale, ET improves model performance
3. Difficult to validate with field measurments at this point
4. Solution: Adjust scale, citizen-based validation

Current Contact:

- Natalie Ceperley, Geography Institute, University of Bern, natalie.Ceperley@giub.unibe.ch

Key Publications:

- Ceperley, N., T. Mande, N. Van de Giesen, S.W. Tyler, H. Yacouba, and M.B. Parlange. “Evaporation from Cultivated and Semi-Wild Savanna in West Africa.” *Hydrology and Earth System Sciences* 21 (2017). https://doi.org/10/gbtpk7.
- Dembélé, Moctar, Natalie Ceperley, Sander J. Zwart, Elga Salvadore, Gregoire Mariethoz, and Bettina Schaefli. “Potential of Satellite and Reanalysis Evaporation Datasets for Hydrological Modelling under Various Model Calibration Strategies.” *Advances in Water Resources* 143 (September 1, 2020): 103667. https://doi.org/10/gg3jtk.