

# Spaceborne observations of the land surface for the data-driven modelling of terrestrial carbon and energy exchange

**Sophia Walther**, Martin Jung, Paul Bodesheim, Markus Reichstein and the FLUXCOM team

International Surface Working Group workshop  
Montreal, July 2019



Max Planck Institute  
for Biogeochemistry



FluxCom



CO<sub>2</sub>  
Human  
Emissions

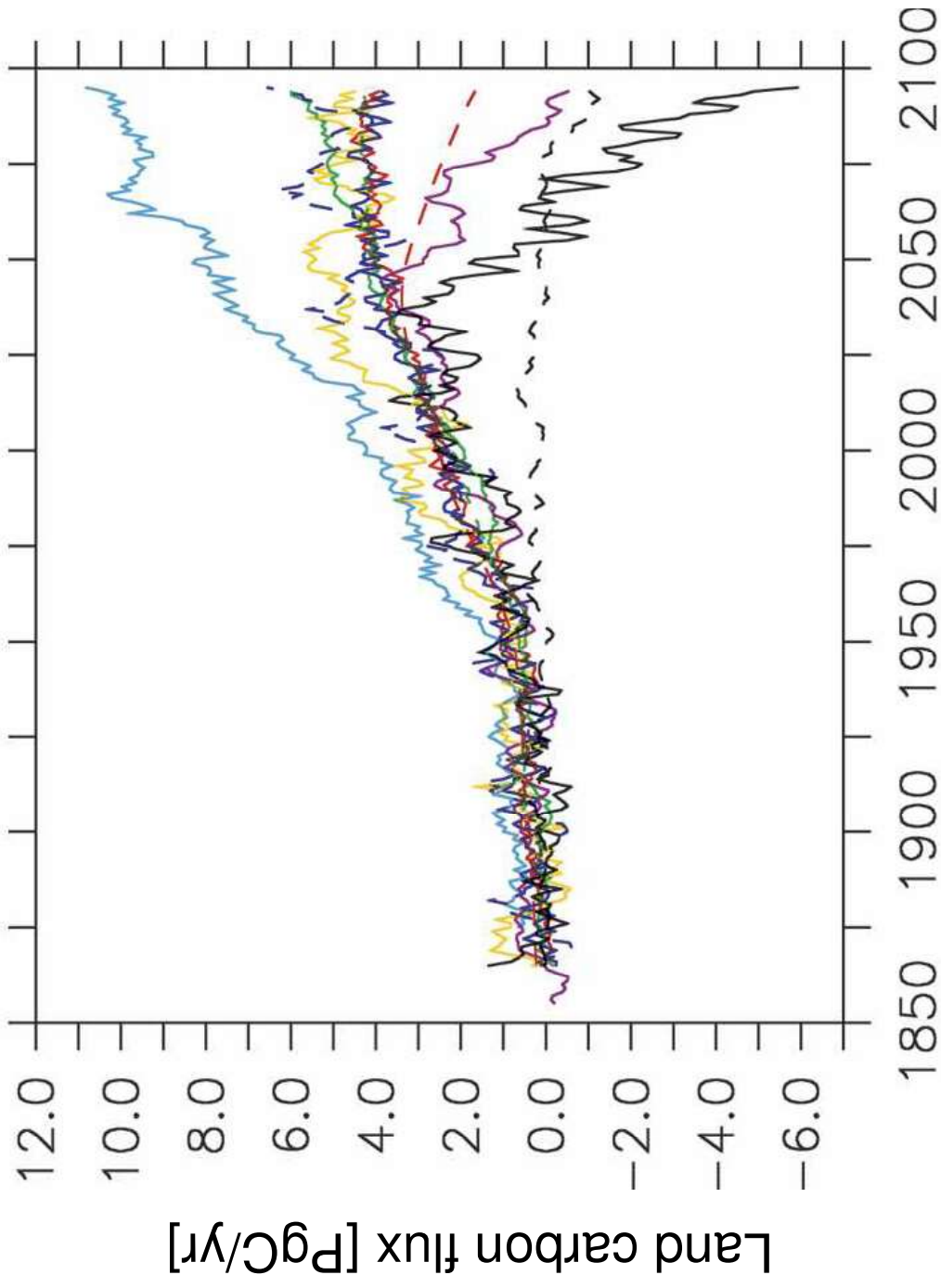


AMERIFLUX

INTEGRATED  
CARBON  
OBSERVATION  
SYSTEM

ICOS

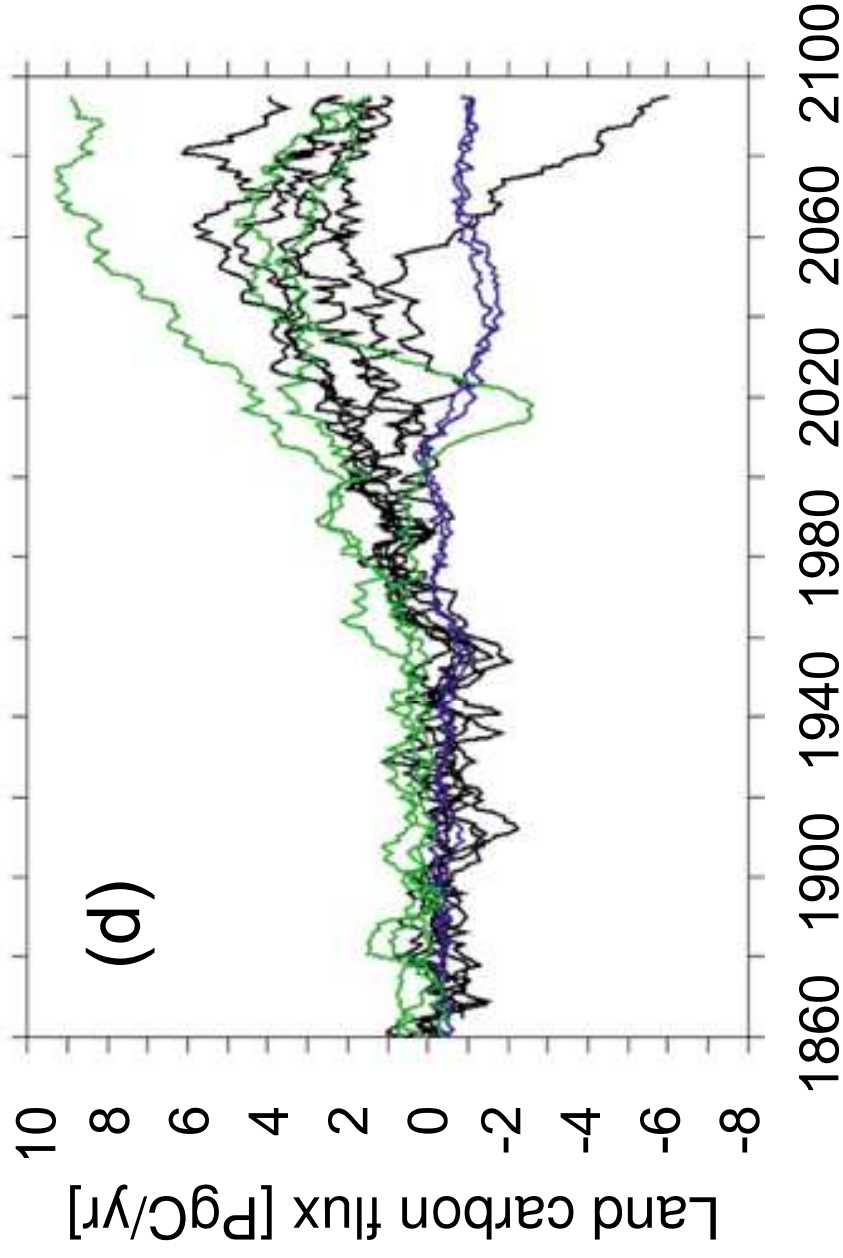
# Highly uncertain land carbon uptake



Friedlingstein et al., 2006, Journal of Climate

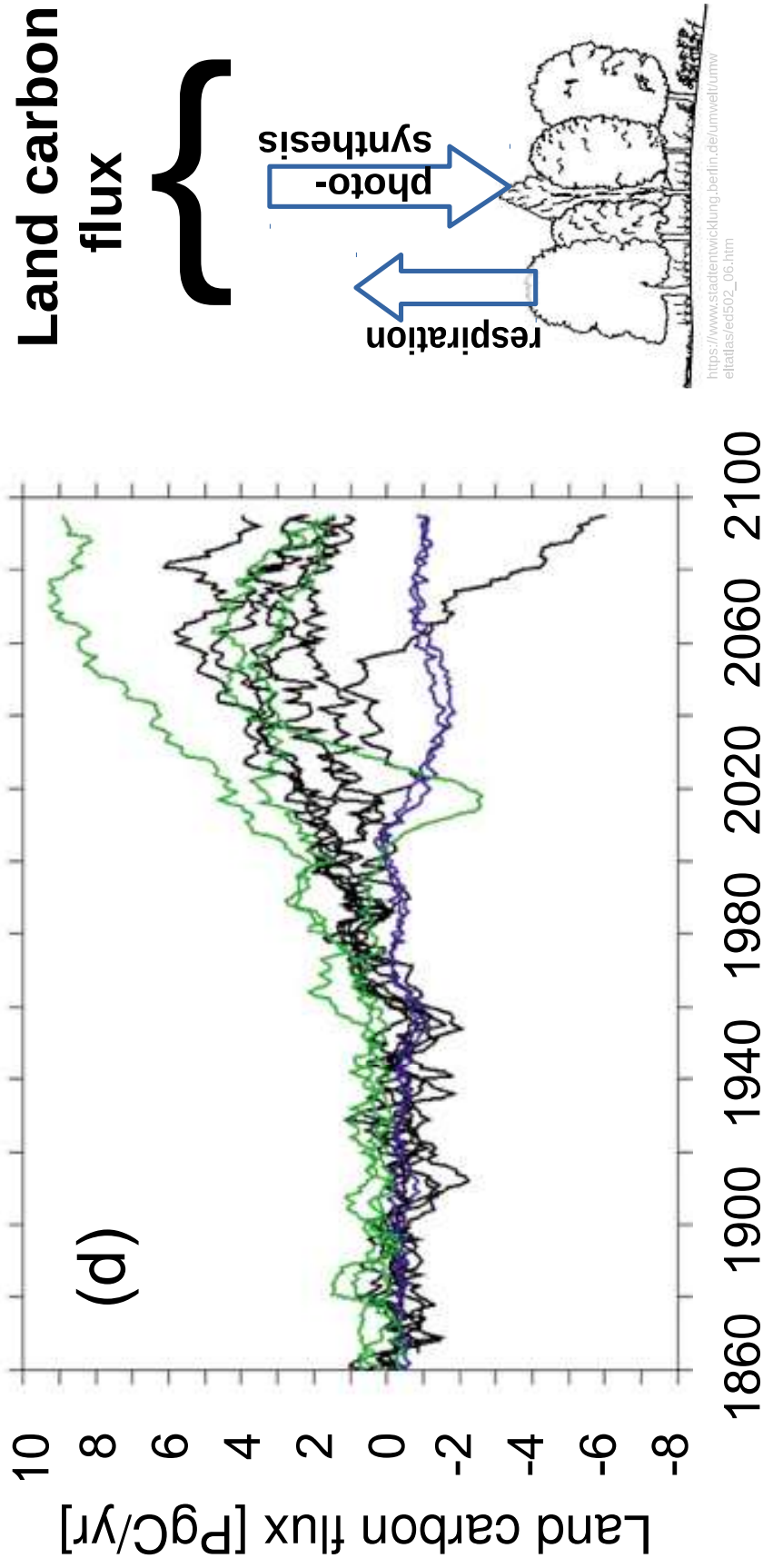
Simulations by different coupled climate-carbon cycle models

# 8yr later...still uncertain land C uptake



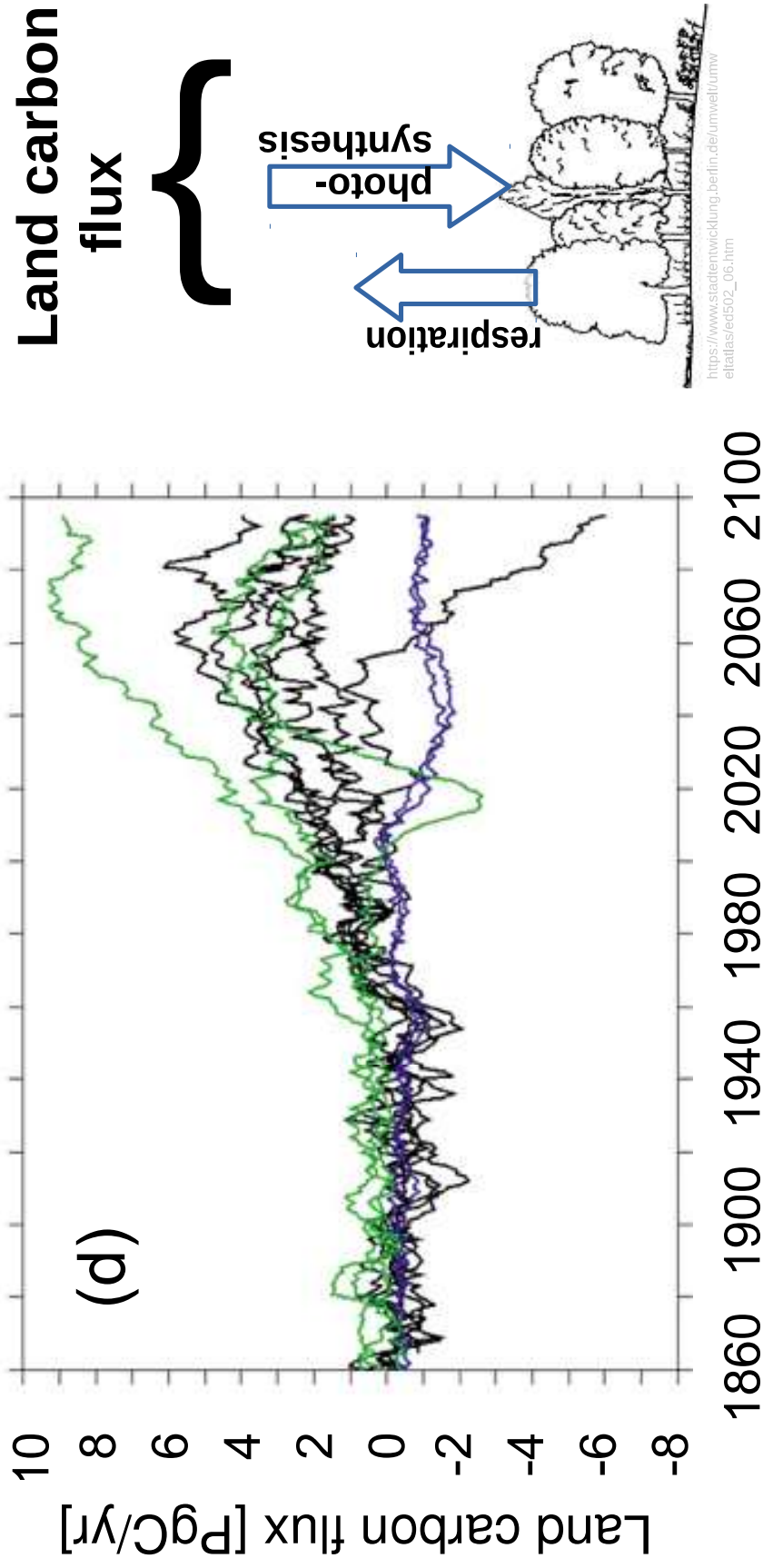
Friedlingstein et al., 2014, Journal of Climate

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Friedlingstein et al., 2014, Journal of Climate

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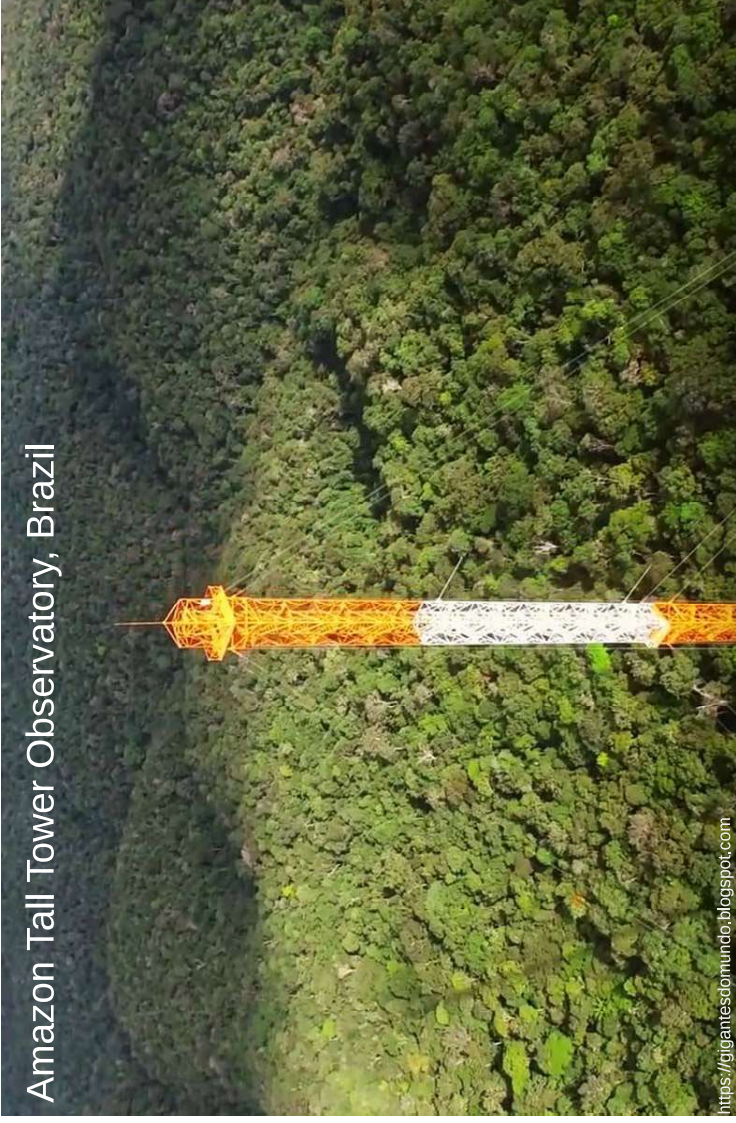


Friedlingstein et al., 2014, Journal of Climate

⇒ **incomplete process understanding of vegetation reactions to environmental conditions and limited observational constraints**

# Eddy-covariance: the only way to directly measure carbon exchange

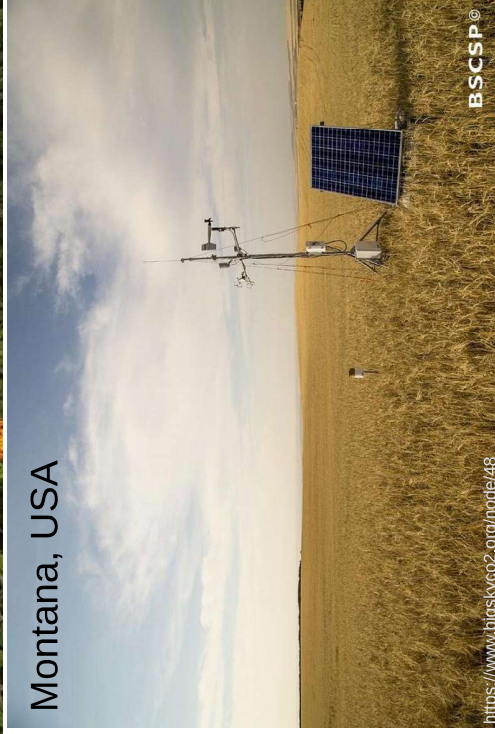
Amazon Tall Tower Observatory, Brazil



SMEAR station, Estonia



Montana, USA

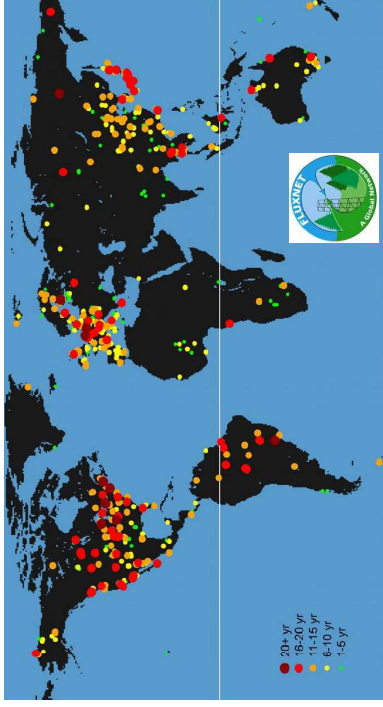


Barrow, Alaska



A complementary way to model natural  
carbon exchange over land

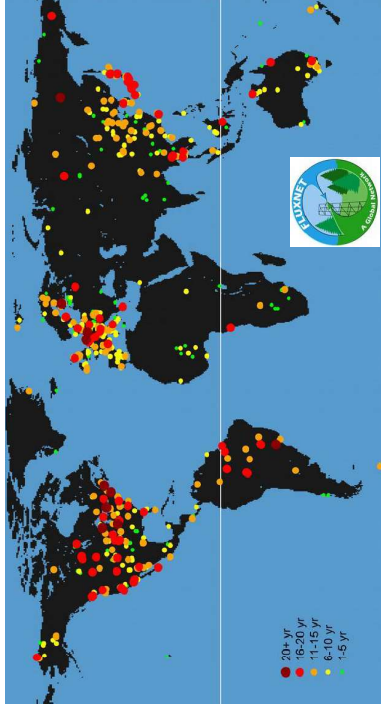
# A complementary way to model natural carbon exchange over land



In-situ eddy-covariance  
carbon fluxes &  
meteorology



# A complementary way to model natural carbon exchange over land

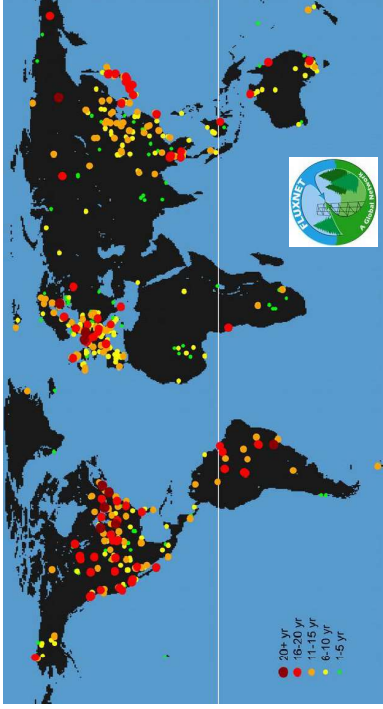


In-situ eddy-covariance  
carbon fluxes &  
meteorology

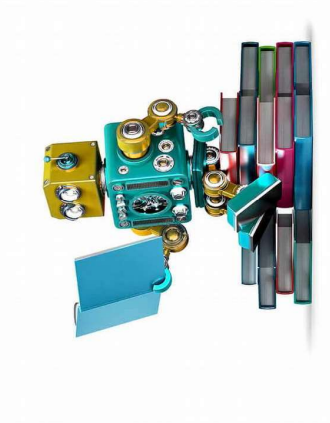


machine learning

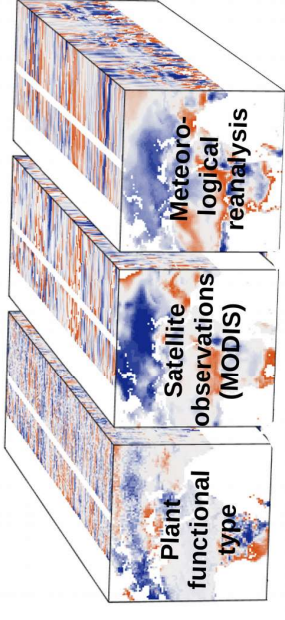
# A complementary way to model natural carbon exchange over land



In-situ eddy-covariance  
carbon fluxes &  
meteorology

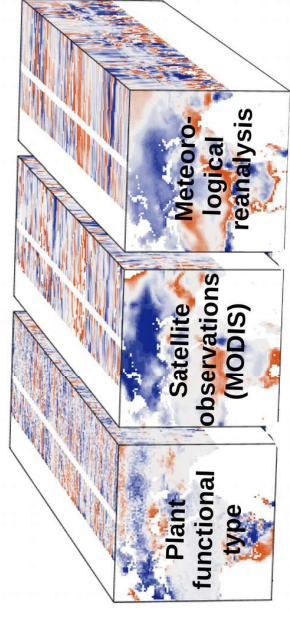
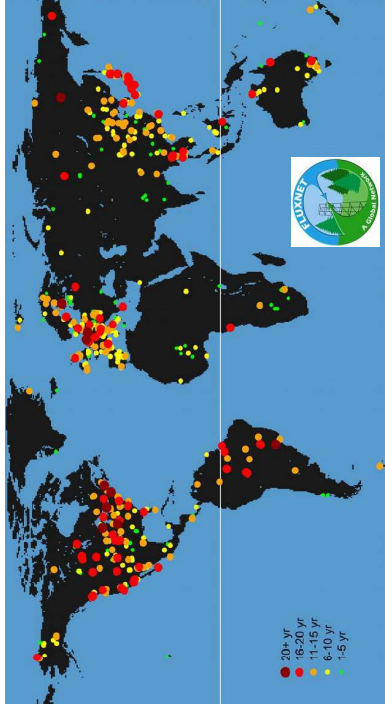


machine learning +



global gridded data sets of  
predictors

# A complementary way to model natural carbon exchange over land



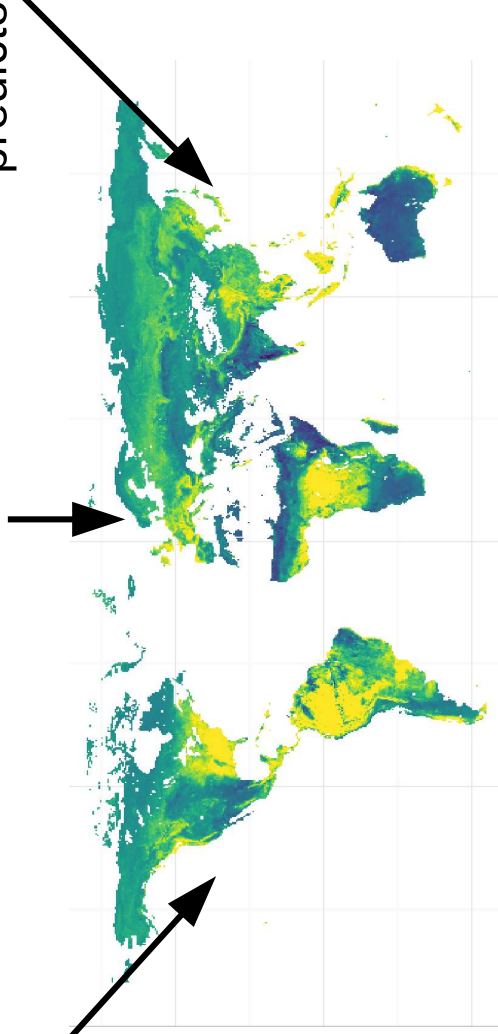
In-situ eddy-covariance carbon fluxes & meteorology

+

machine learning

+

global gridded data sets of predictors

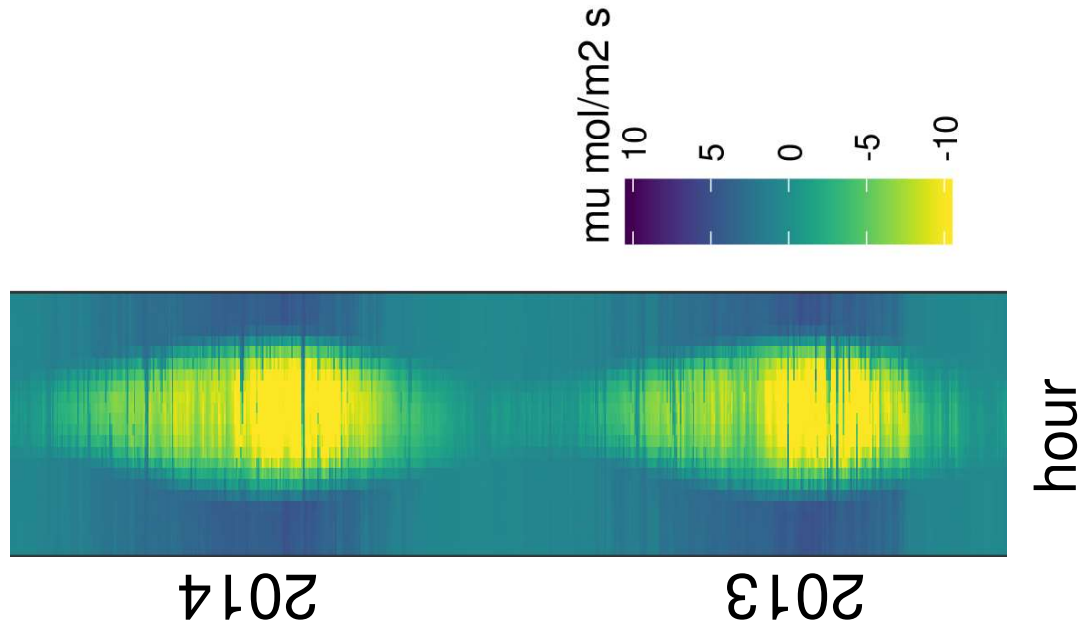


Global gridded estimates of carbon fluxes



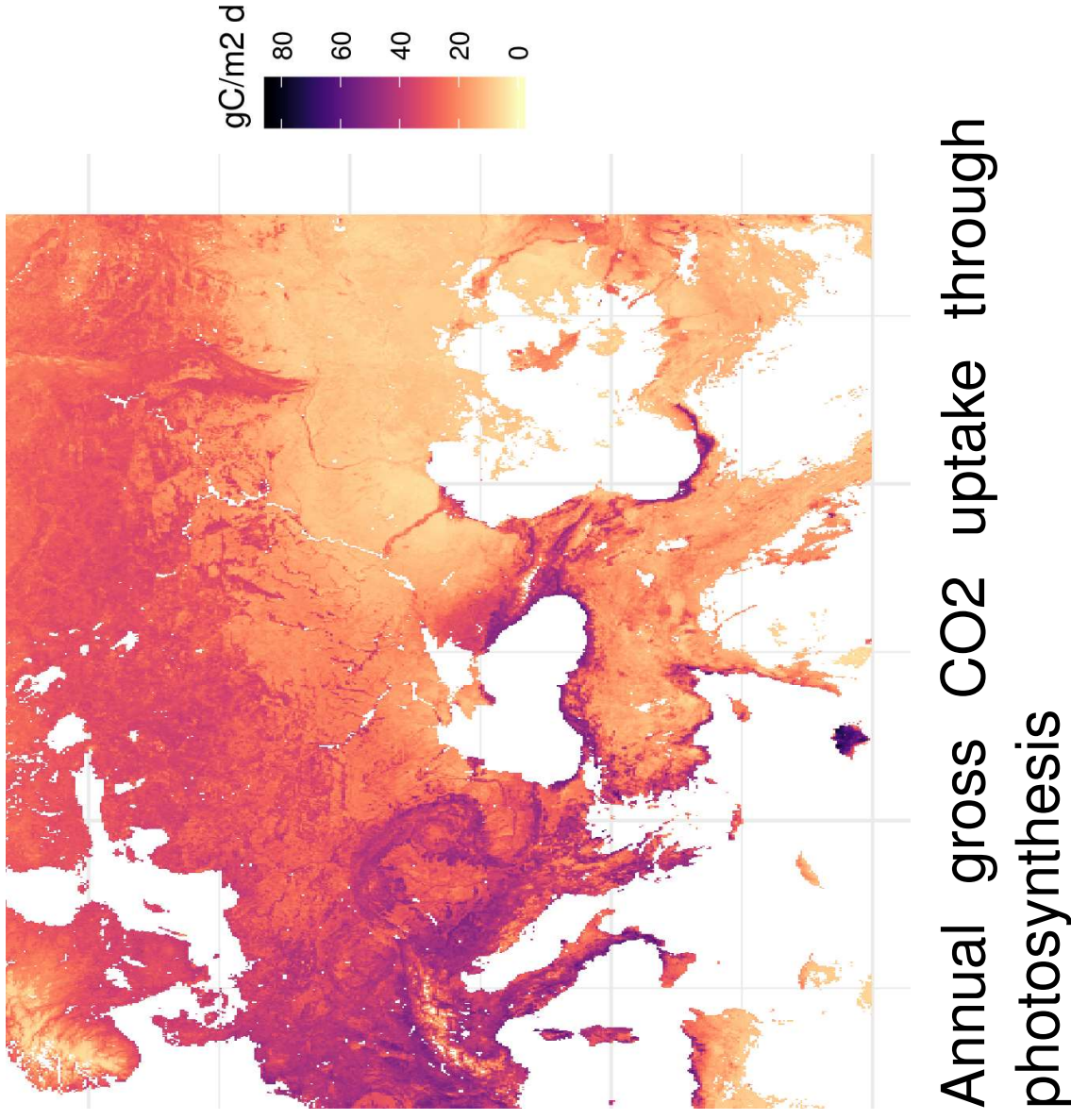
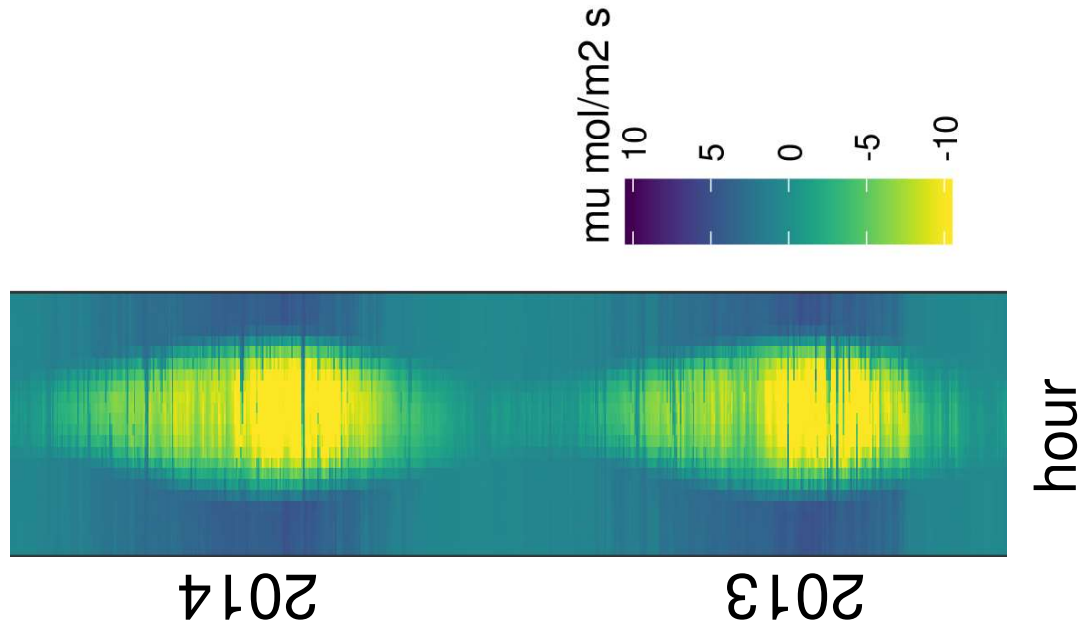
# Simulated carbon fluxes

Net CO<sub>2</sub> uptake in the pixel of Jena/ Germany (hourly):



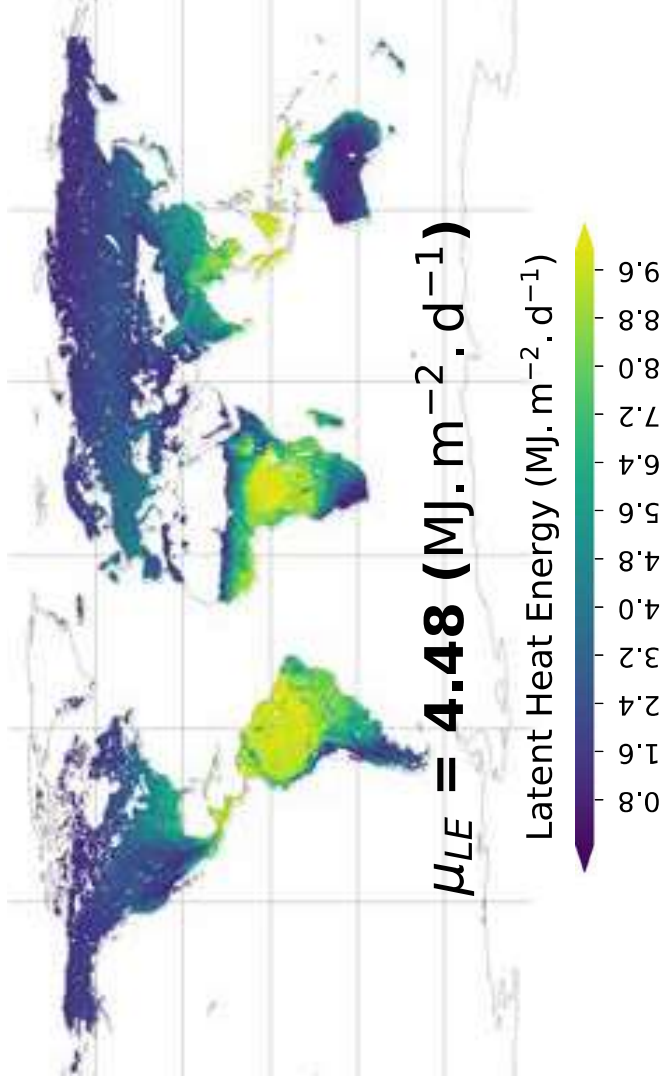
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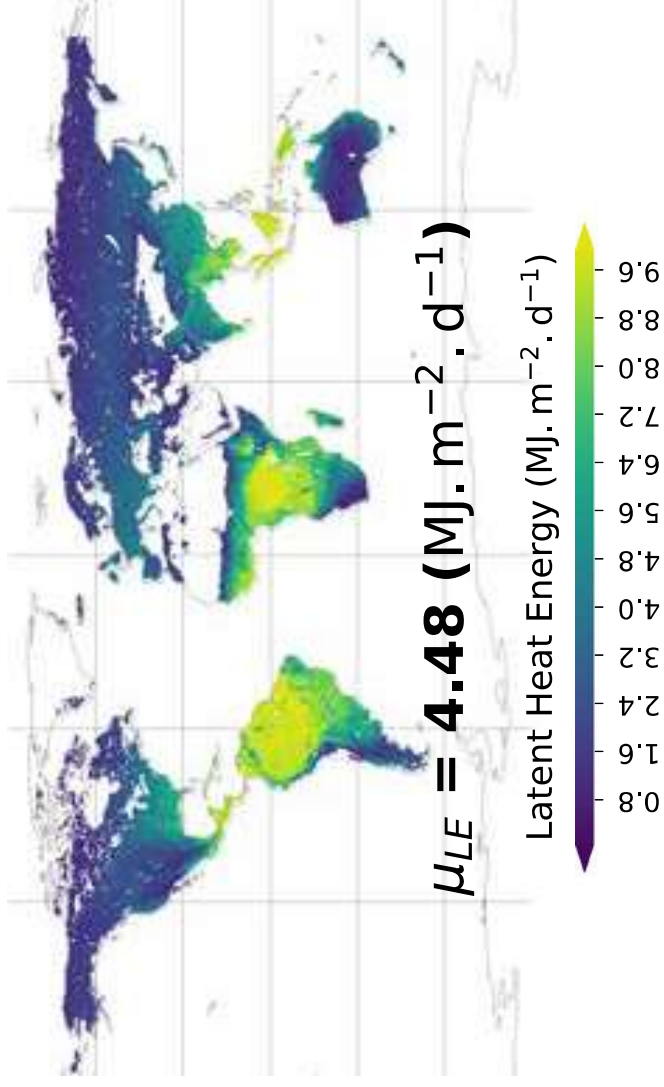
hour

# Simulated energy exchange



Similar for sensible heat and net radiation

# Simulated energy exchange



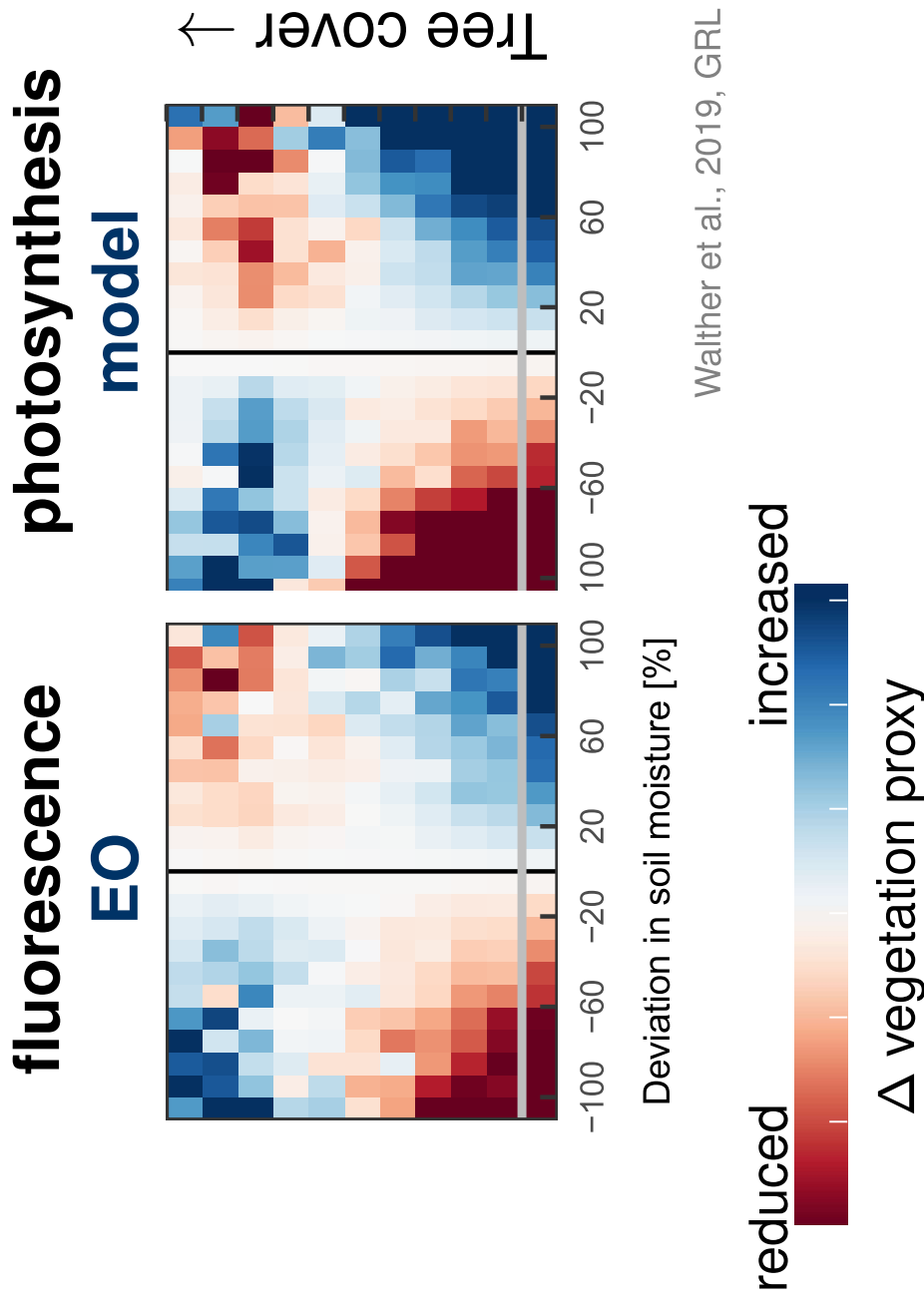
Similar for sensible heat and net radiation

**Robust spatial and seasonal patterns → applications in various fields**

Photosynthesis as  $f(\text{water status, tree cover})$

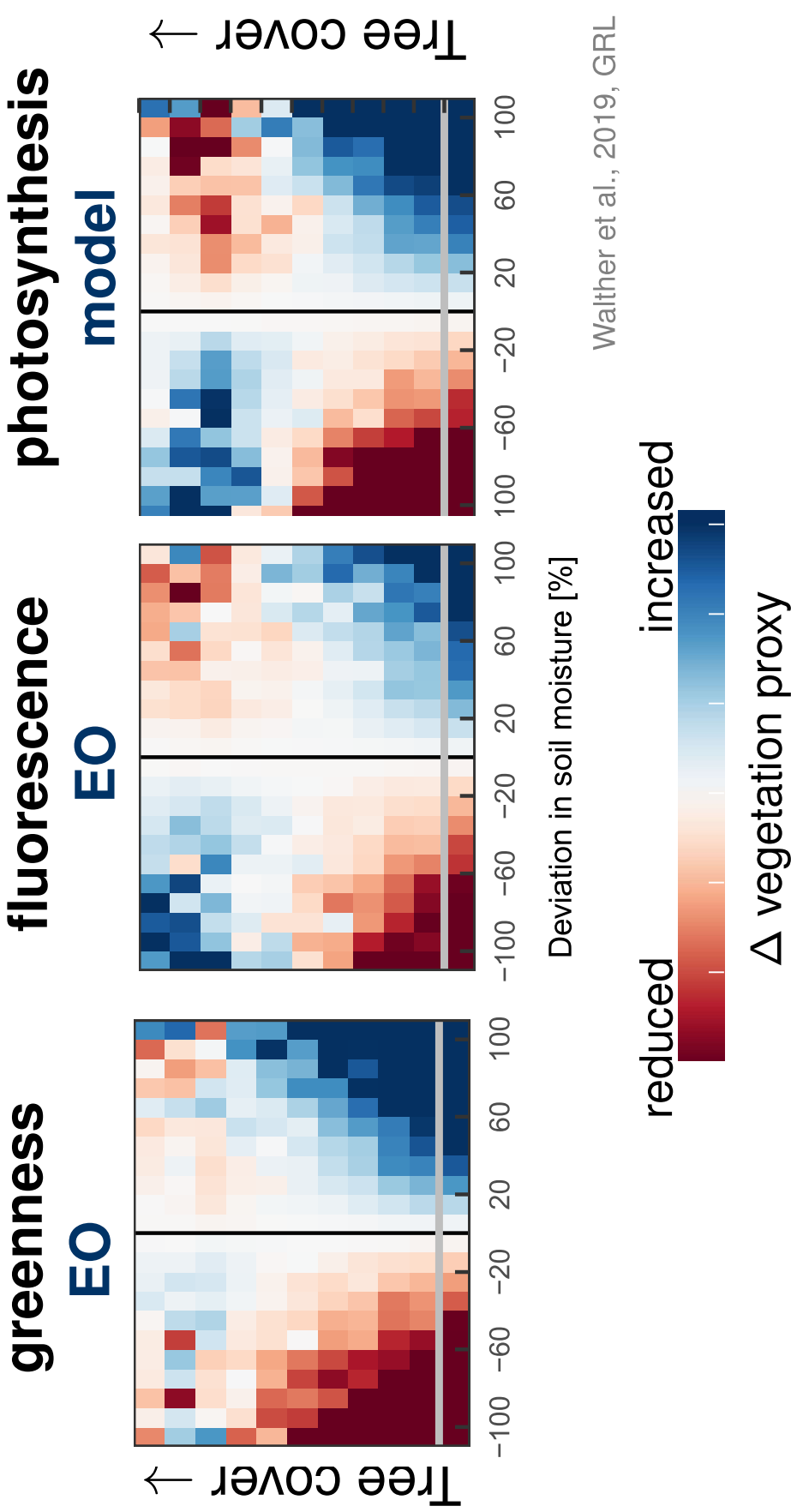


# Photosynthesis as f(water status, tree cover)



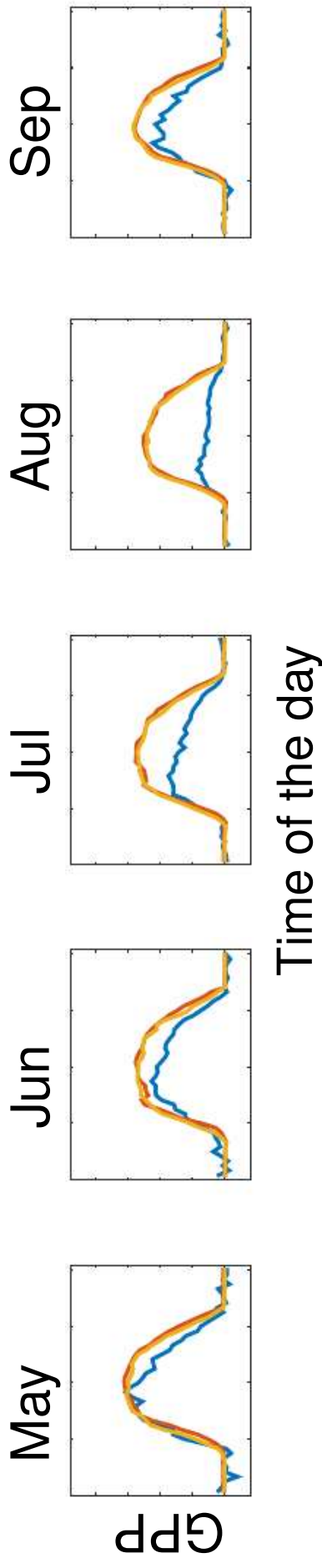
Walther et al., 2019, GRL

# Productivity & greenness decoupled in forests



- **light-driven variability in forests**  
 soil moisture → precipitation → clouds → light → photosynthesis  
 → evapotranspiration → soil moisture

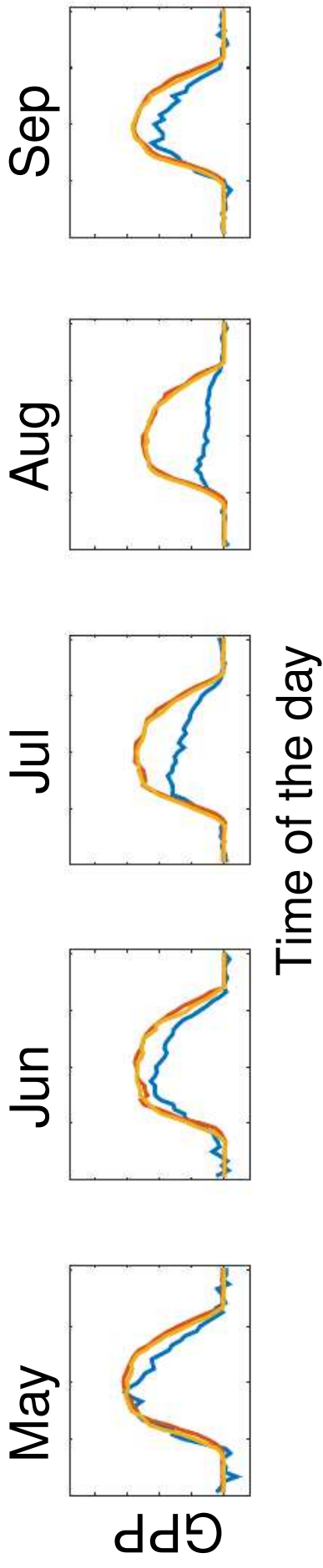
# Drought effects not well represented



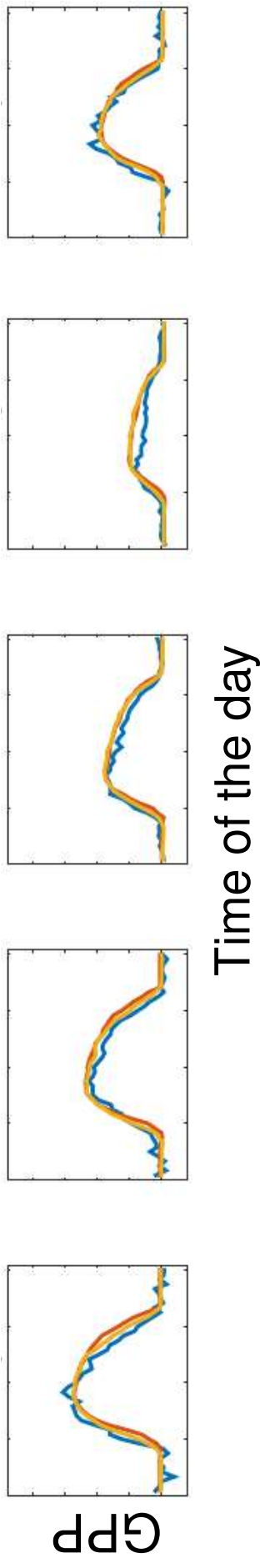
- observation
- modelled with daily predictors
- modelled with daily & halfhourly predictors



# Drought effects not well represented



## Daily GPP as additional daily predictor:



- observation
- modelled with daily predictors
- modelled with daily & halfhourly predictors

Puechabon



A complementary way to model natural land-atmosphere exchanges over land

**incomplete process understanding** of vegetation reactions to environmental conditions and **limited observational** constraints

⇒ do not describe processes in the model but let the algorithm **learn from data** → **dependence on data**



use **insitu** measurements **synergistically** with global spatially explicit **EO** of the state of the land surface and **meteorological reanalysis** data

# Towards high spatial AND high temporal resolution

Number of voxels per 10 years (log)

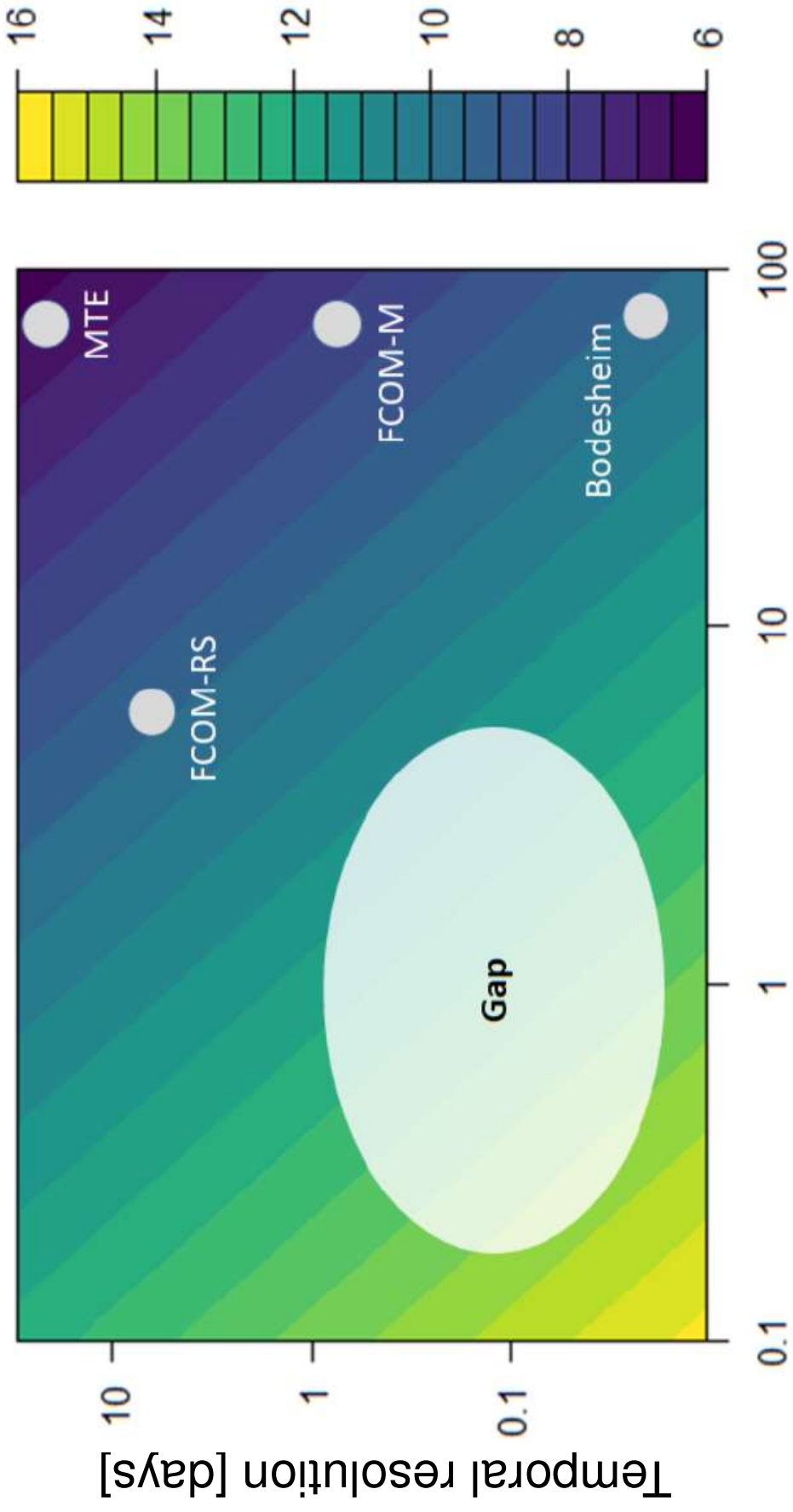


Figure courtesy Martin Jung

# Towards dedicated products

## The approach is data-driven - and data-dependent!

Ongoing efforts for improvements in terms of:

- **Training data:** more sites, more site-years, higher quality
- **!!features, features, features!!** amount and accuracy of **EO-based predictor variables are key:** additional predictors with extensive QC planned
- **machine learning methods** (e.g. memory effects, transfer learning)
- **semi-operational** set-up
- better uncertainty characterization

# Acknowledgements



M. Jung



M. Reichstein



D. Papale



K. Ichii



## Recent News

- FLUXCOM Workshop, 2017 will be held in Jena from 16th - 18th May, 2017.

- Based on a recent study, FLUXCOM GPP sees the imprints of relationships between vegetation and groundwater.

- A study based on FLUXCOM data highlights the compensatory effect of water and temperature on global carbon sink (Jung et al., 2017).

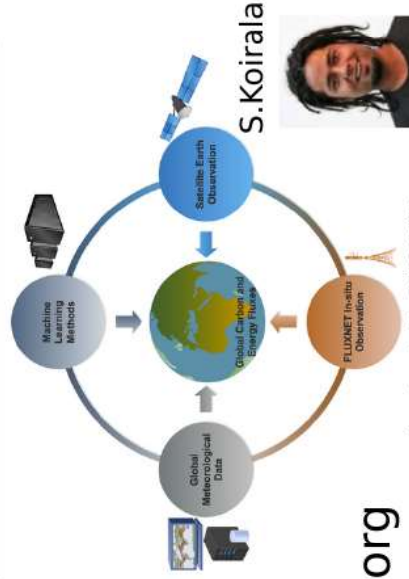
- The cross-validation paper by Tramontana et al. has been published (2016/07).

## "An initiative to upscale biosphere-atmosphere fluxes from FLUXNET sites to continental and global scales"

Several experts joined hands for the collaborative FLUXCOM initiative. We use upscaling approaches based on machine learning methods that integrate FLUXNET site level observations, satellite remote sensing, and meteorological data. Our data products have promising values for assessing biosphere-atmosphere fluxes over large regions, and for evaluating process-based land models.

## Aims

- Creating an ensemble of data products for global carbon and energy fluxes on land
- Understanding and characterizing uncertainties in this upscaling approach



A general overview of the FLUXCOM initiative.

[www.fluxcom.org](http://www.fluxcom.org)

G. Tramontana



C. Schwalm



G. Camps-Valls



F. Gans



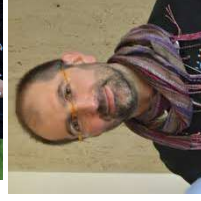
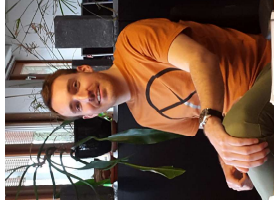
U. Weber





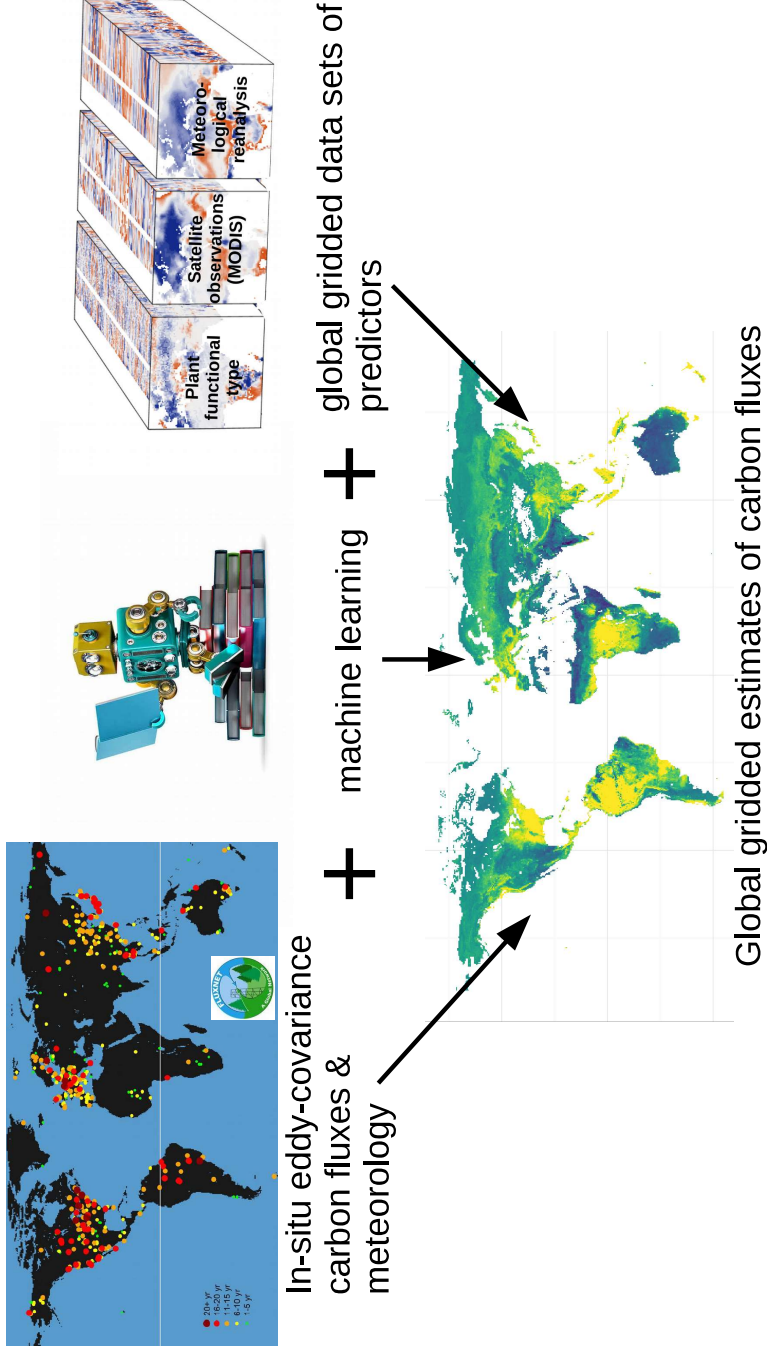
# Acknowledgements

Ongoing efforts by Martin Jung, Sophia Walther, Jake Nelson,  
Ulrich Weber, Mirco Migliavacca, Nuno Carvalhais, Simon  
Besnard, Dario Papale



and others...

# Thank you :)



## questions?

now, coffee break or [swalth@bgc-jena.mpg.de](mailto:swalth@bgc-jena.mpg.de)

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