Estimation of spatialized turbulent flux on flux towers and its uncertainties.

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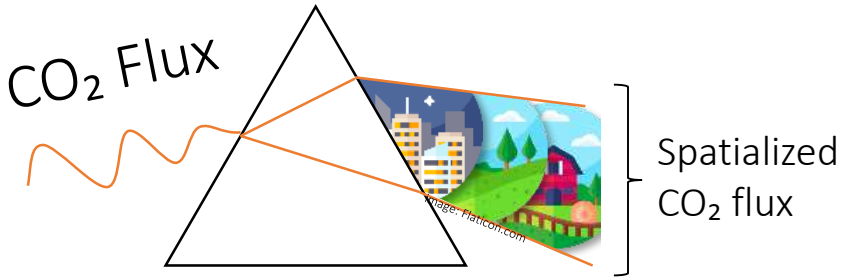
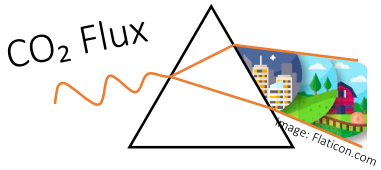
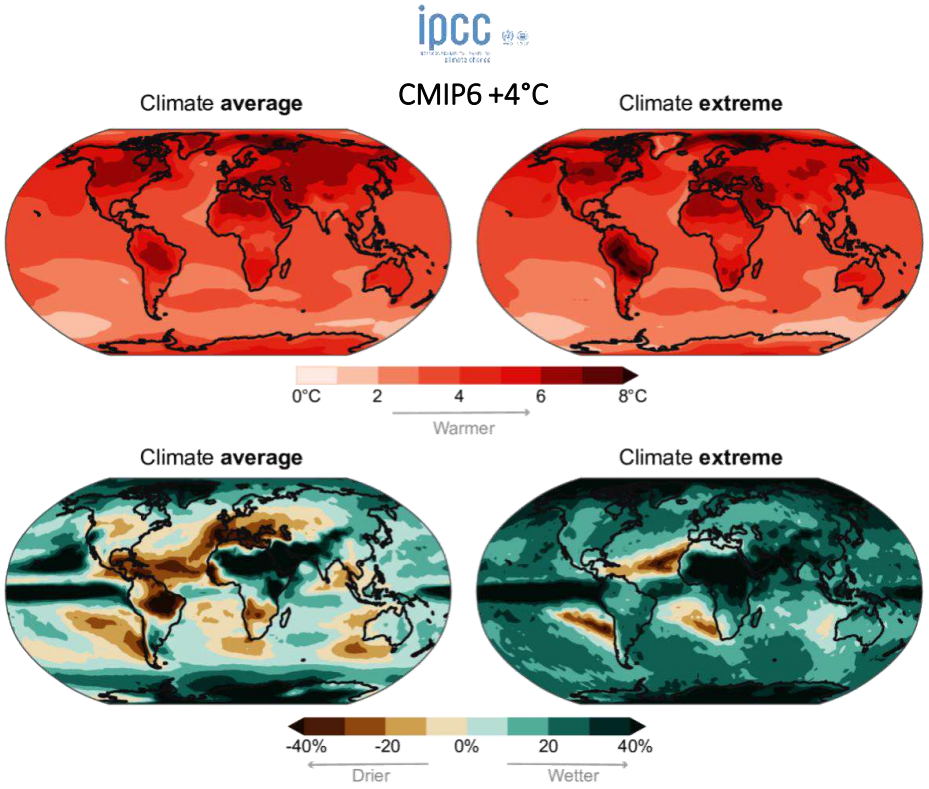
Benjamin Loubet (dir.), Olivier Laurent (co-sup.),
Pauline Buysse, Michel Ramonet





Climate change is now and we need to measure to understand its impacts



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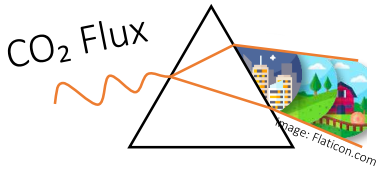

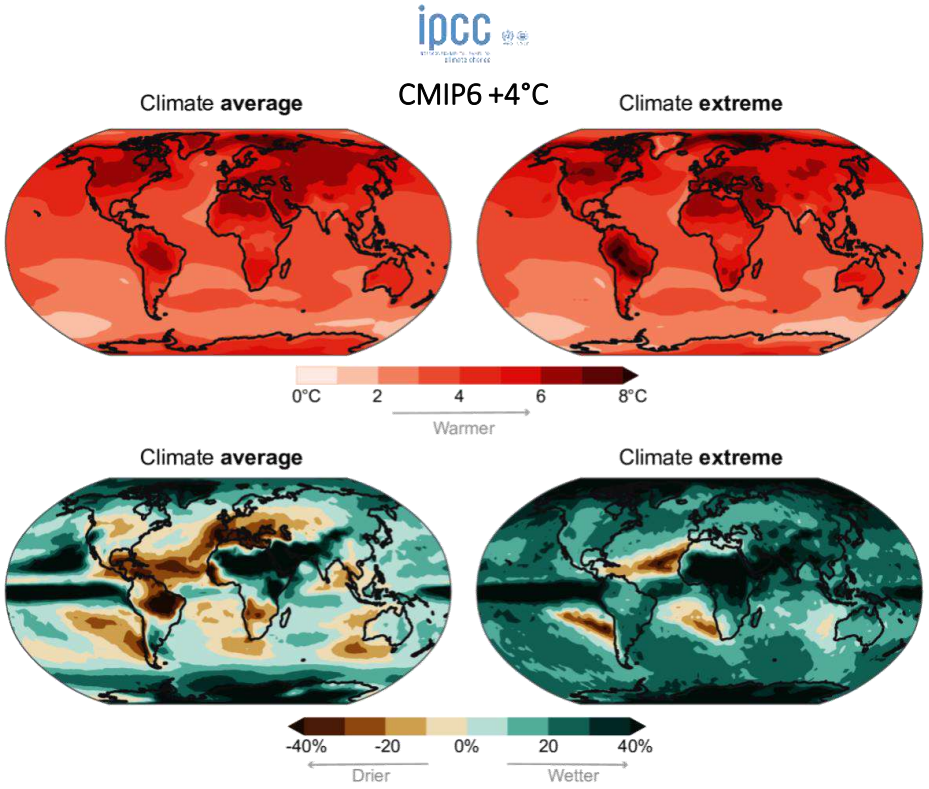

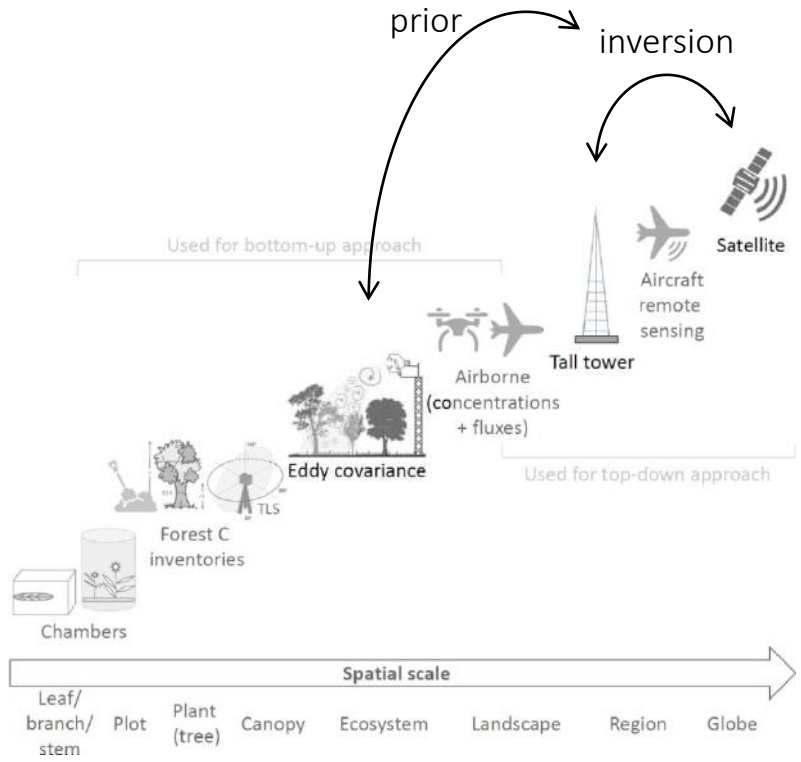

Source: Kalliokoski et al. (2019)

- satellites lack in spatial density
- need to solve vertical profile
- atmospheric data for inversion
- ecosystem data for prior

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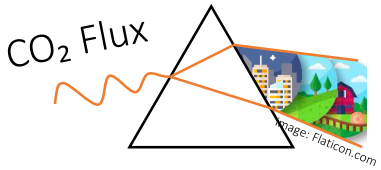

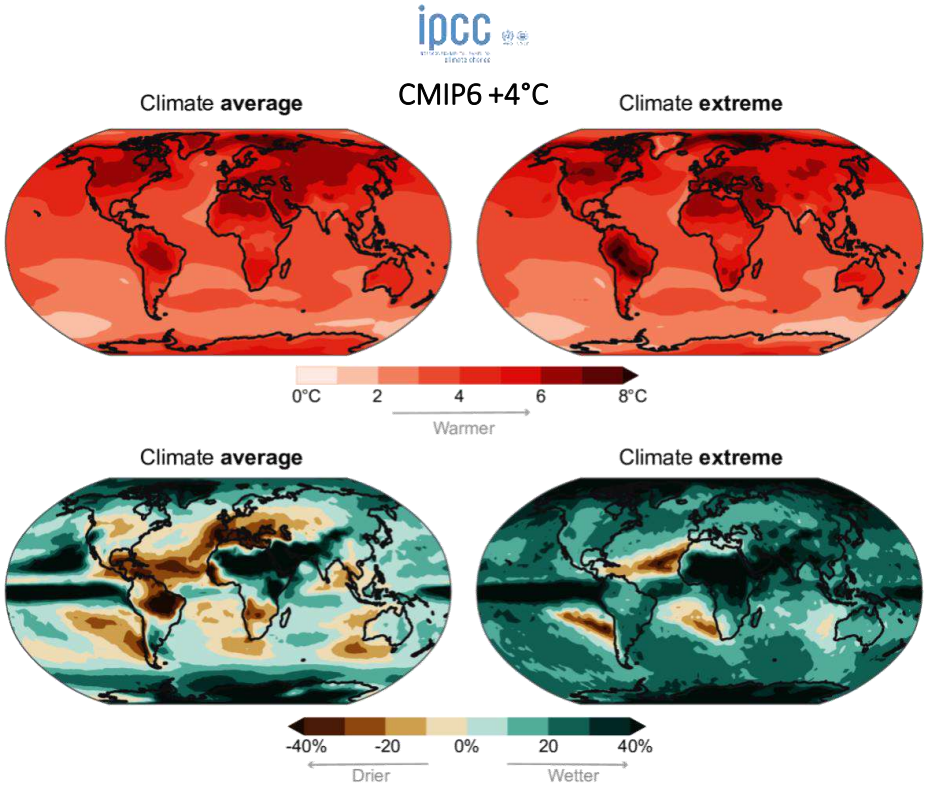

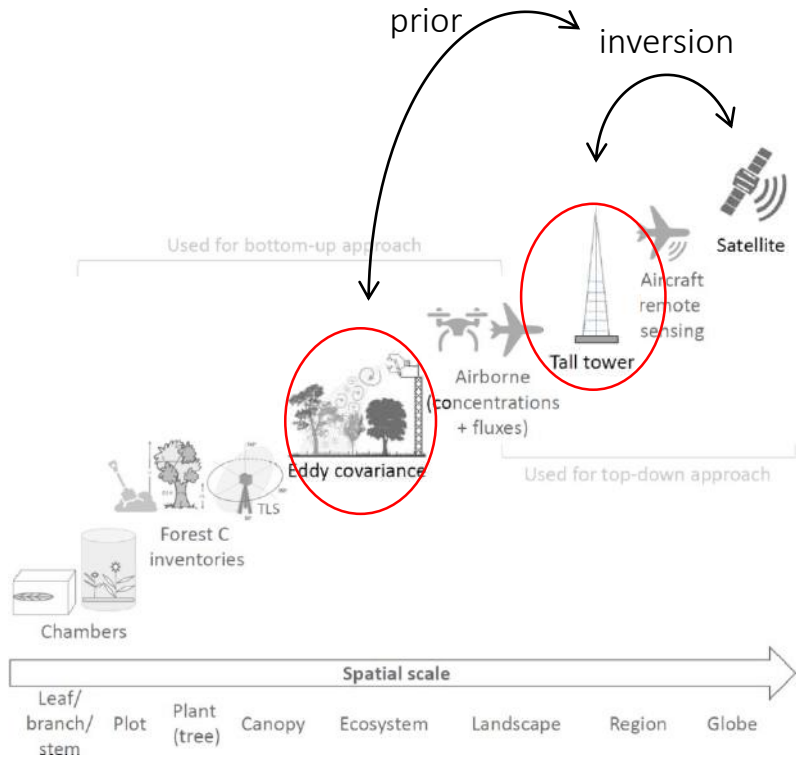

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Goal: improve the prior

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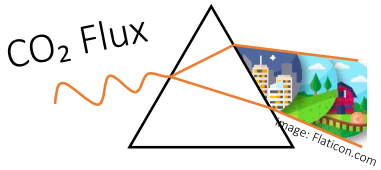
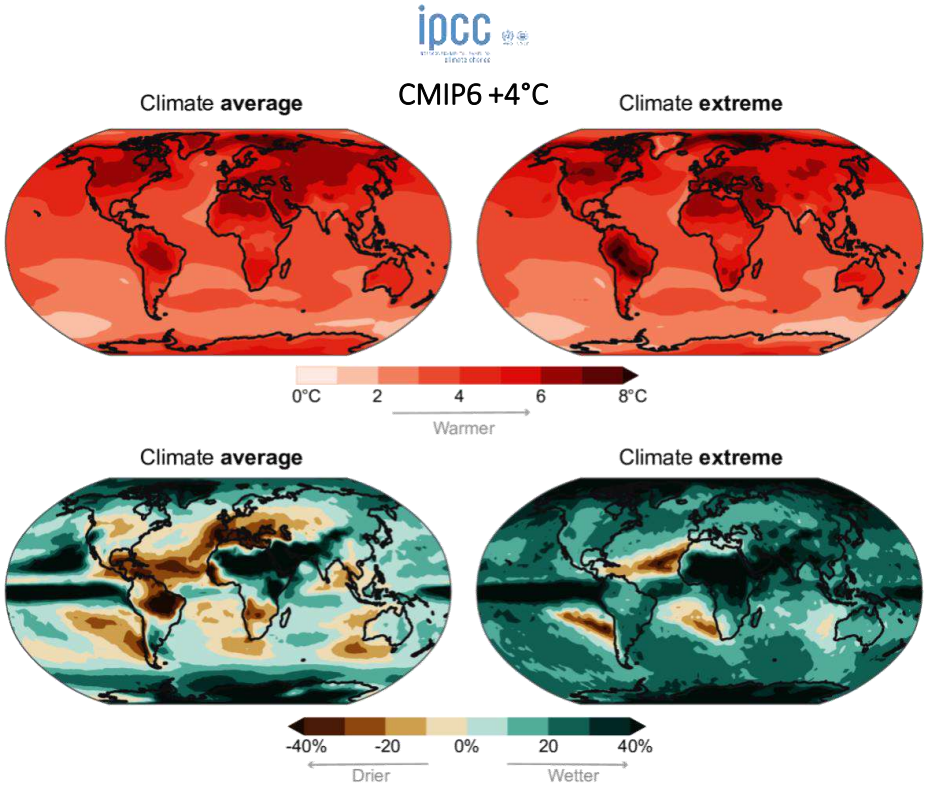
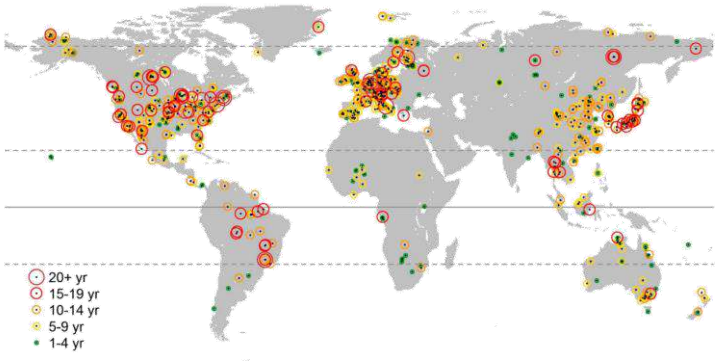
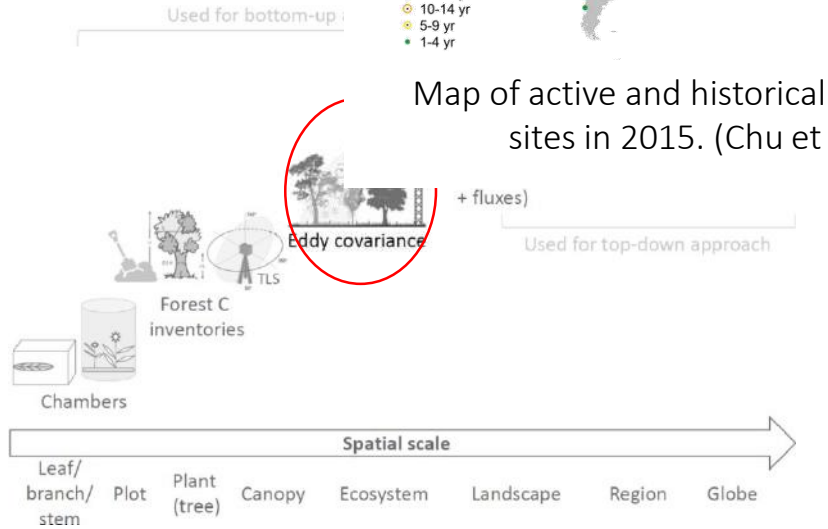




A global network that needs to be more global

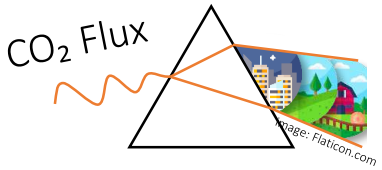


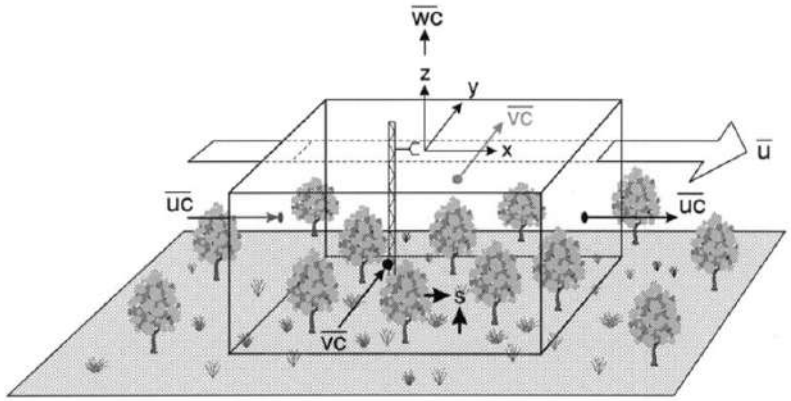
Map of active and historical FLUXNET tower sites in 2015. (Chu et al., 2017)



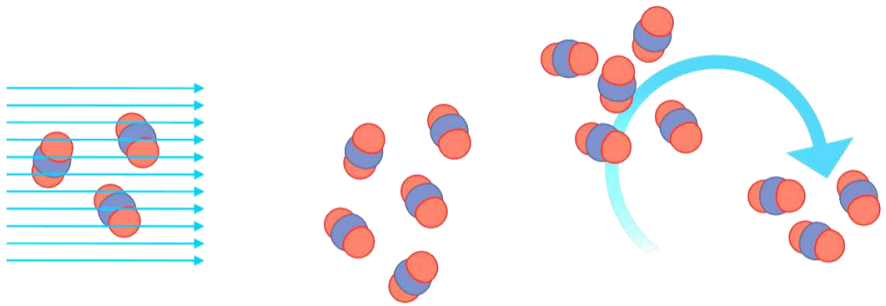
Source: Kalliokoski et al. (2019)

Intuitive explanation on eddy covariance

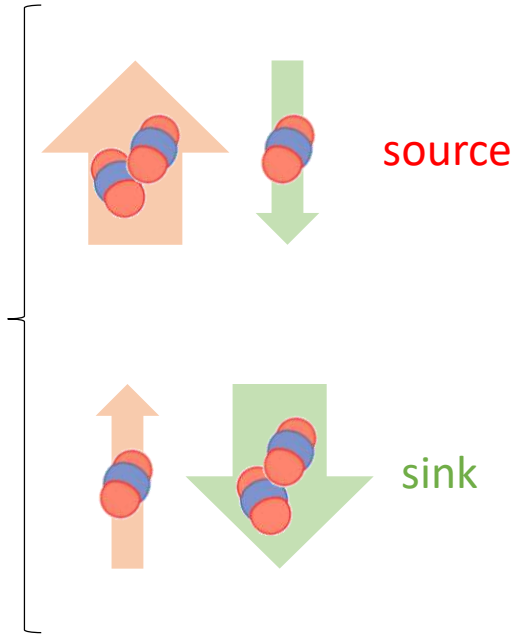




Source: Finnigan et al. (2003)



Source: Burba et al. (2003)



- Assuming a homogeneous terrain and a negligible mean vertical wind component, surface flux can be simplified as the mean variation of a scalar in time (stock flux) and vertical turbulent flux (eddy covariance).
- The flux's source area, footprint, is determined by a transport function which can be estimated using wind conditions at the measurement height. Due to computation efficiency most often backward lagrangian models are used.

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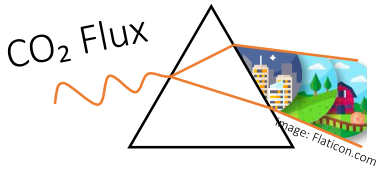

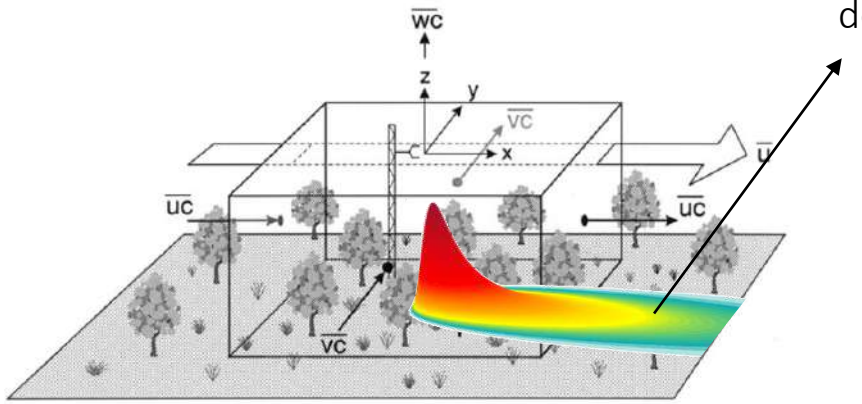

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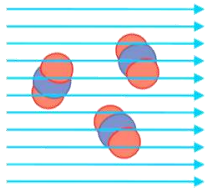
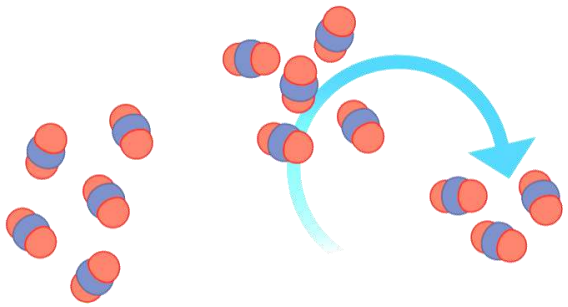
Footprint density





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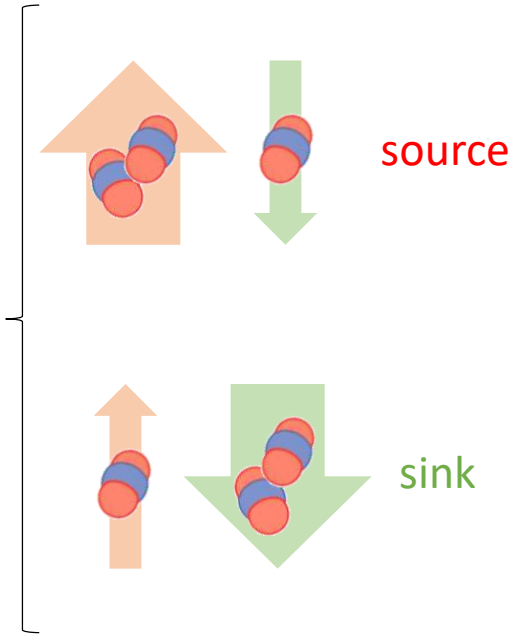

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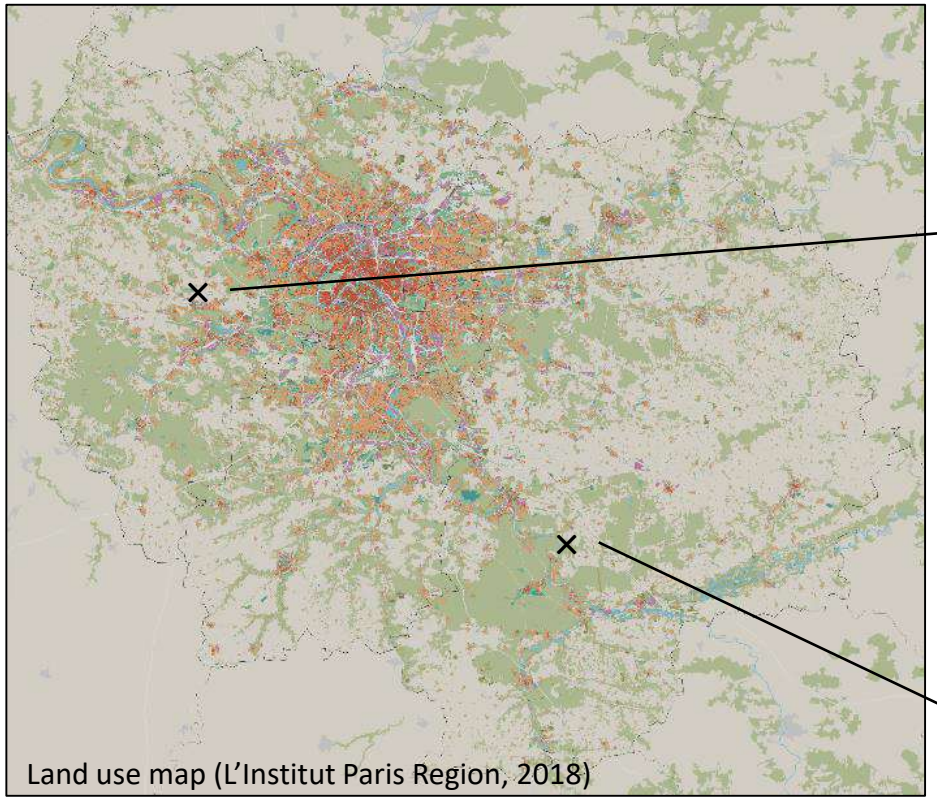
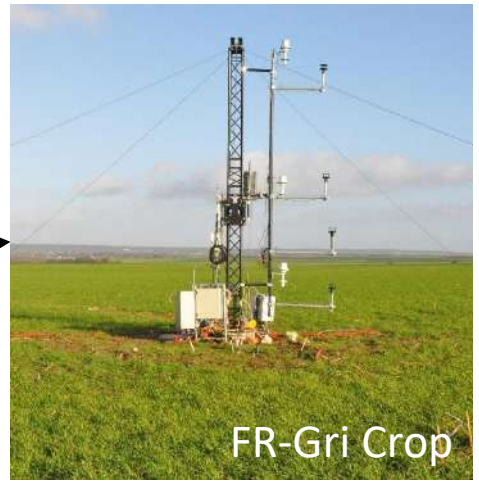
Standard Eddy Towers have one target ecosystem

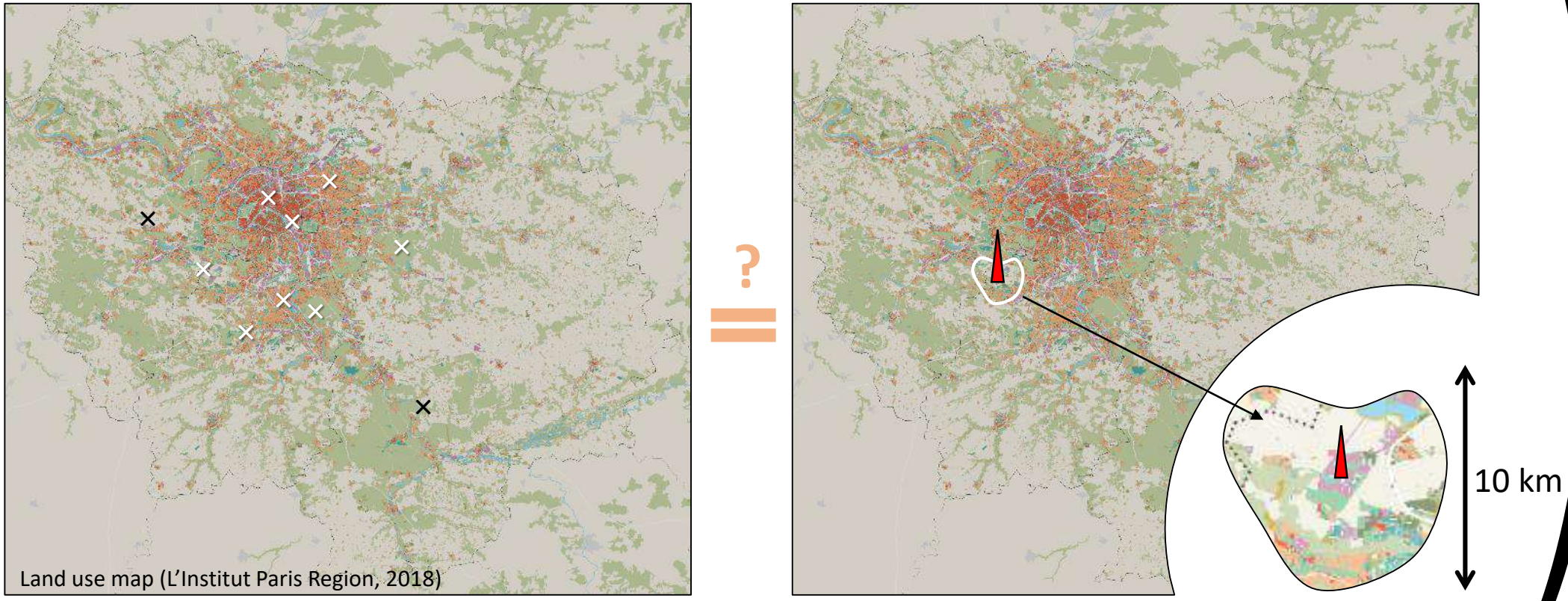




★ Tower

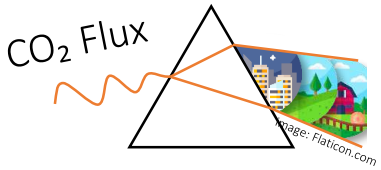
Target area

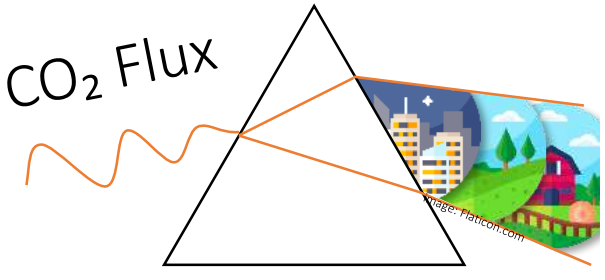
Can we use a tall tower and decompose the contribution of each climate zone?



- A method to attribute fluxes to each land use can be helpful on complex terrains, thus of special interest for urban and tall towers.

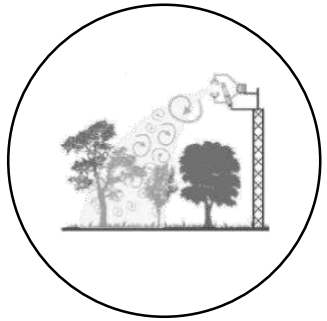
How we plan to do it





Spatialized CO_2 flux

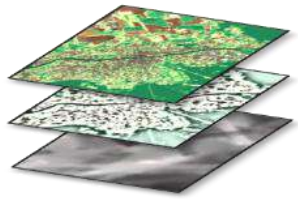
Provide a method for scaling turbulent flux towers measurements using fine resolution remote sensing and inverse modelling.



surface flux

eddy covariance / wavelet

$= f($

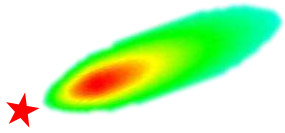


$) \times$

light-efficiency models
inventories

surface model

VPRM /

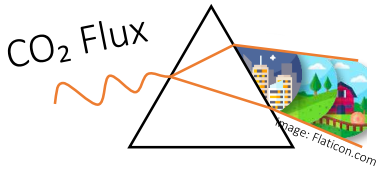


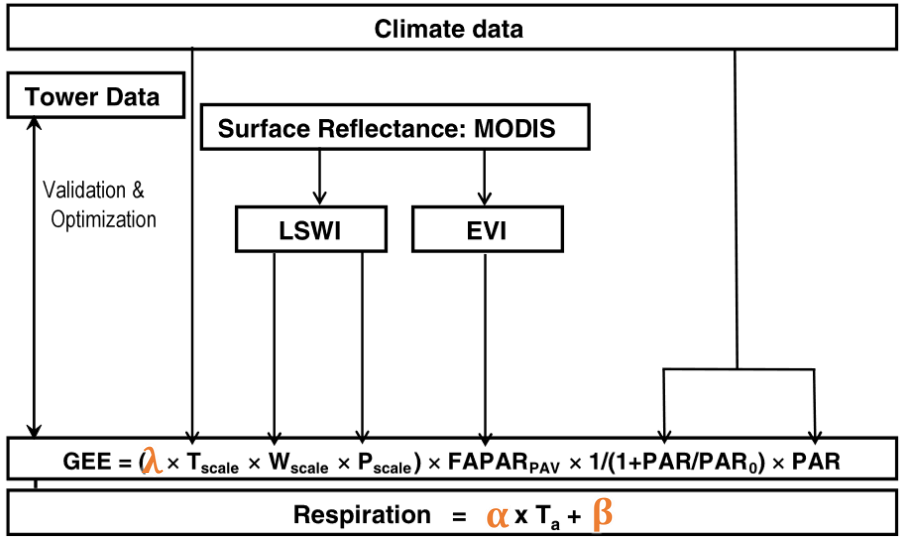
footprint model

10 / 30 min

- First, test in a known site, with minimal anthropogenic influence so to fix the biogenic component which is the most important and complex.

The light-efficiency models used





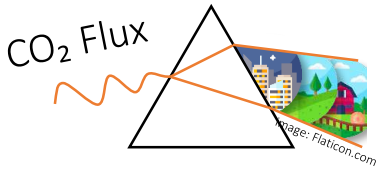
Mahadevan (2008)

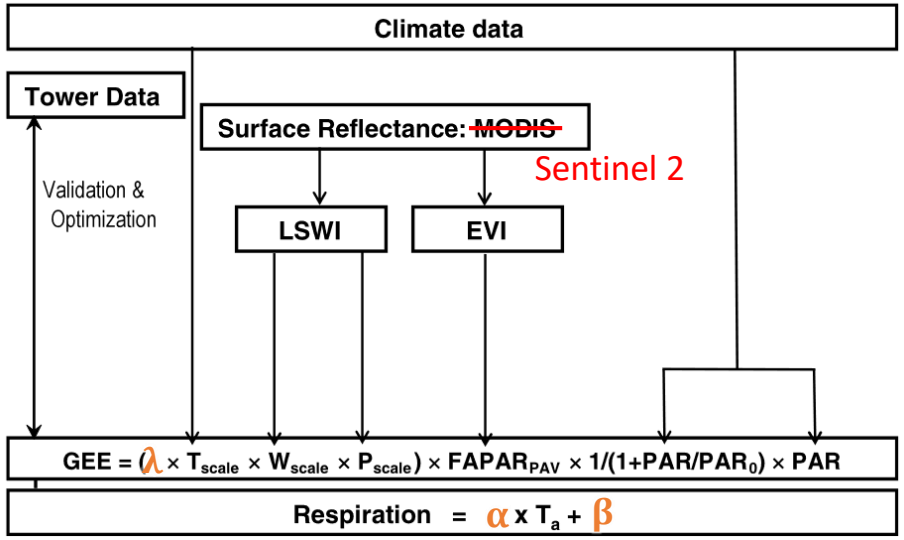
$$\mathrm{GEE} = \lambda \times (temperature\ and\ water\ conditions) \times proxy\ to\ LAI \times light\ sensitivity$$

$$Reco = \alpha \times temperature + \beta$$

- Satellites are expected to bring spatial and temporal resolved information. e.g.: crop growth, fall and grown of leaves in deciduous forests, …

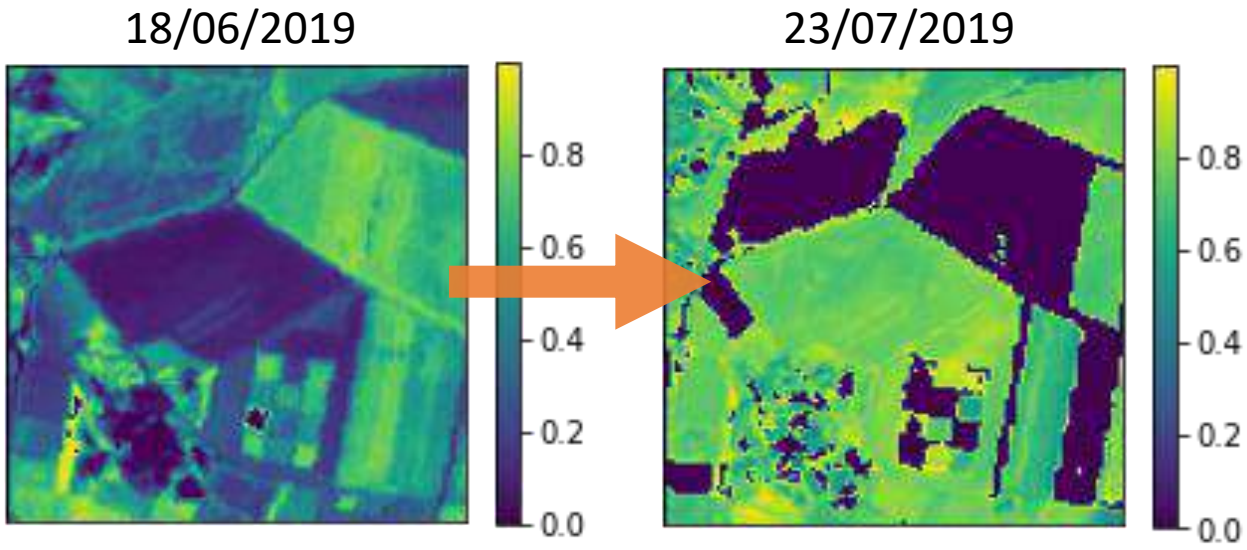
The light-efficiency models used:
some updates





Mahadevan (2008)

EVI (vegetation index)



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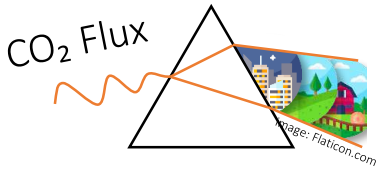


Inversion strategy

Goal:

Find the best parameter (x^a) to move estimation ($H(x)$) towards observation (y°), considering prior knowledge of the system (x^b) and respective uncertainties (R and B).

$$\phi = \frac{1}{2}\left\|x - x^b\right\|_B^2 + \frac{1}{2}\left\|H(x) - y^\circ\right\|_R^2$$

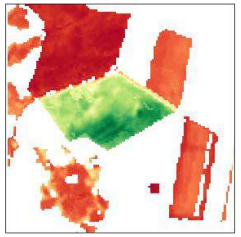
$x^a = x$, given $\min(\phi)$

where x: parameters to be optimized (by pixel)

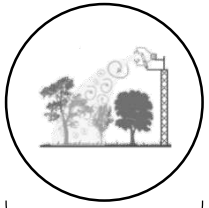
$$x^a = x^b + \underbrace{BH^T(HBH^T + R)^{-1}}_{relaxation}\underbrace{(y - Hx^b)}_{innovation}$$

$f(x^a)$

flux map



surface flux



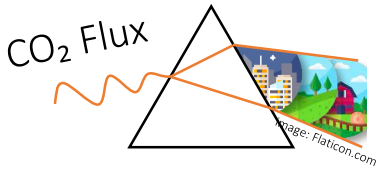
surface model

footprint model

$$= f\left(\right) \times$$

y°

$H(x) = FCO2$



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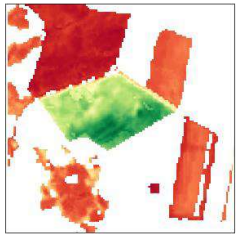
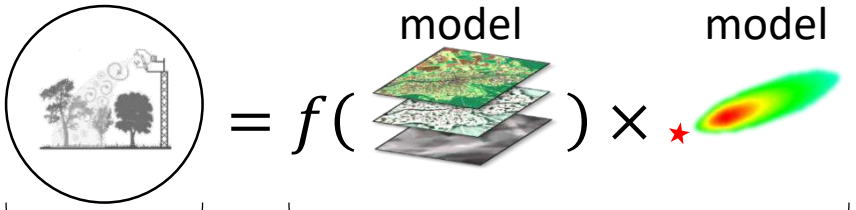


surface flux — surface model — footprint model



$= f($ $) \times$

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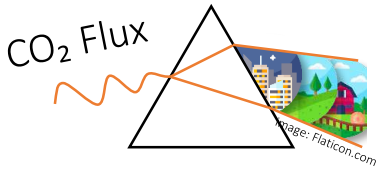

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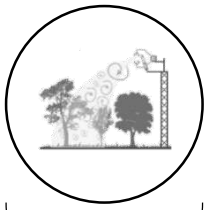
surface flux | surface model | footprint model



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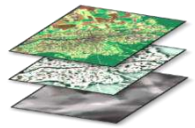

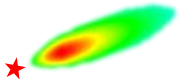

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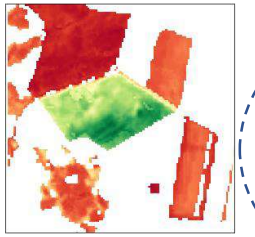
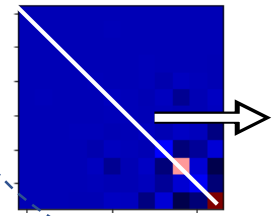
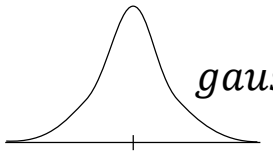


uncertainty

$$A = (B^{-1} + H^T R^{-1} H)^{-1}$$





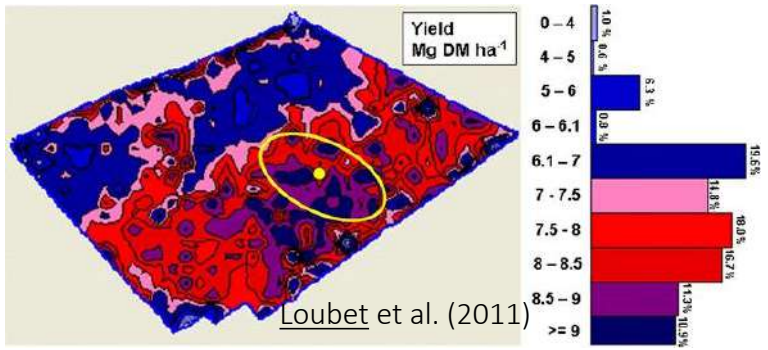
$gaus(\mu, \sigma)$

$x^a_{\lambda,\alpha,\beta,\ldots}$

Sites are rarely completely homogeneous

soil depth and characteristics can have a impact

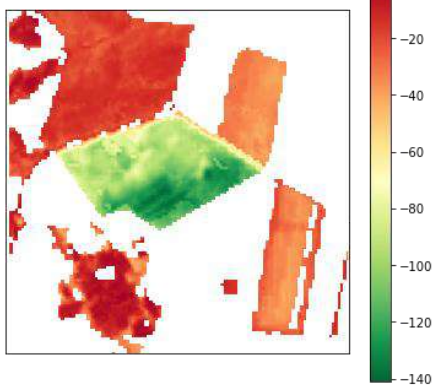
FR-Gri's 2004 yield (barley)



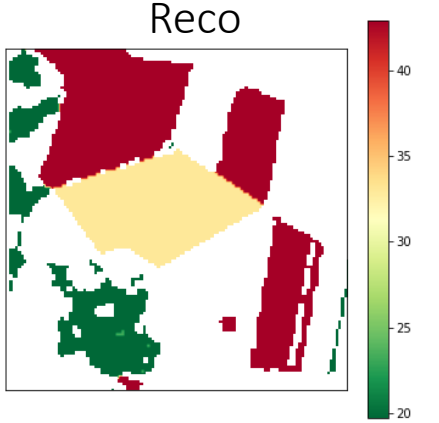
Loubet et al. (2011)

FR-Gri large spatial variability of the yield most probably linked available water content of the field.

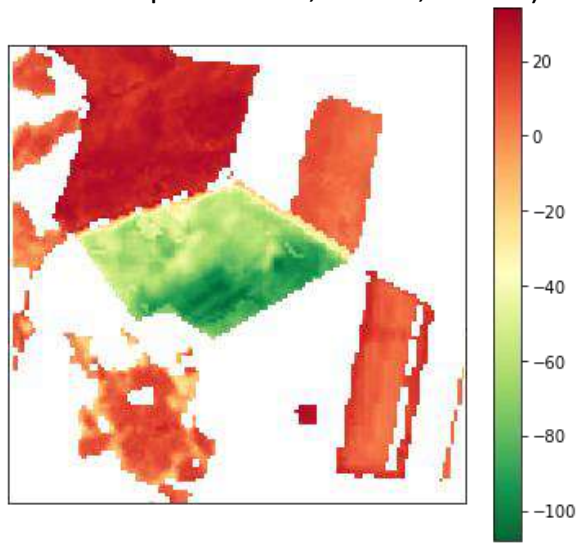
GPP



Reco



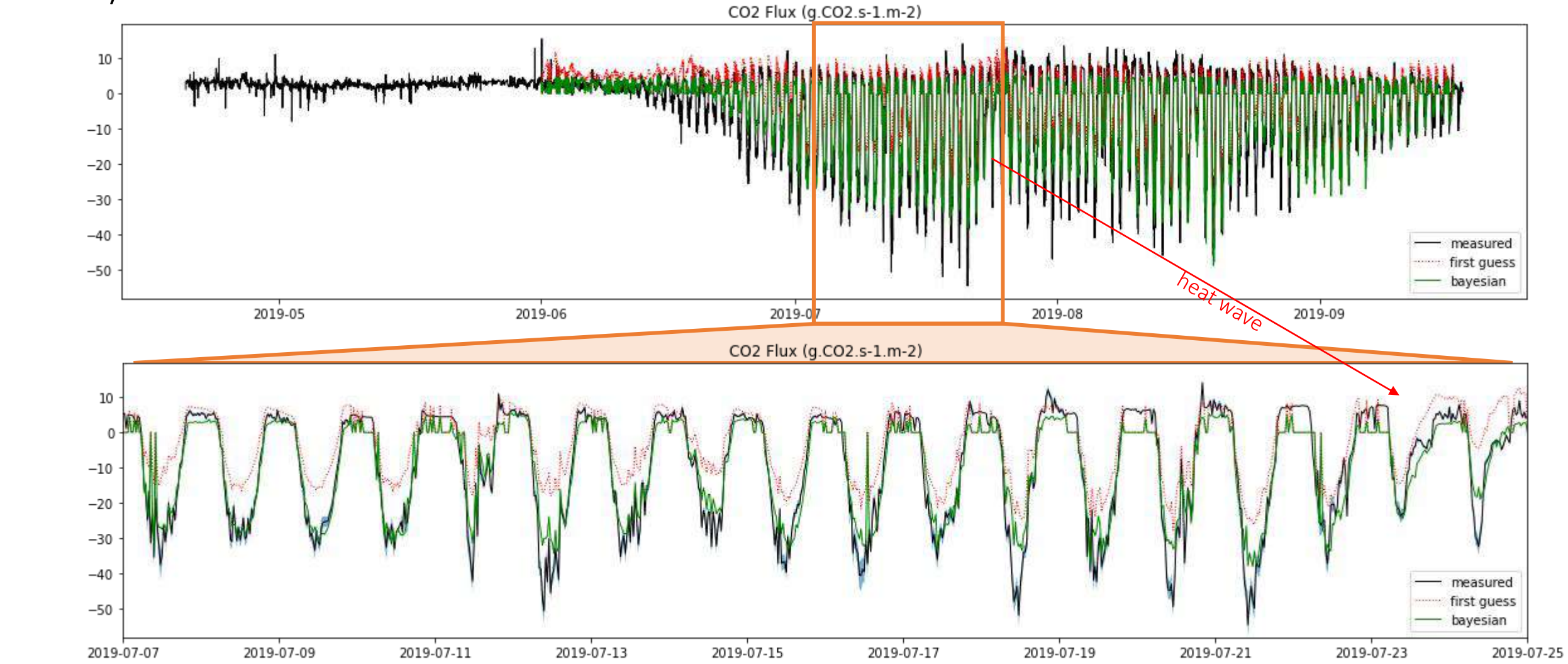
FCO2
(June-Sept. 2019, corn, total)



$10^6 CO_2 s^{-1} m^{-2}$

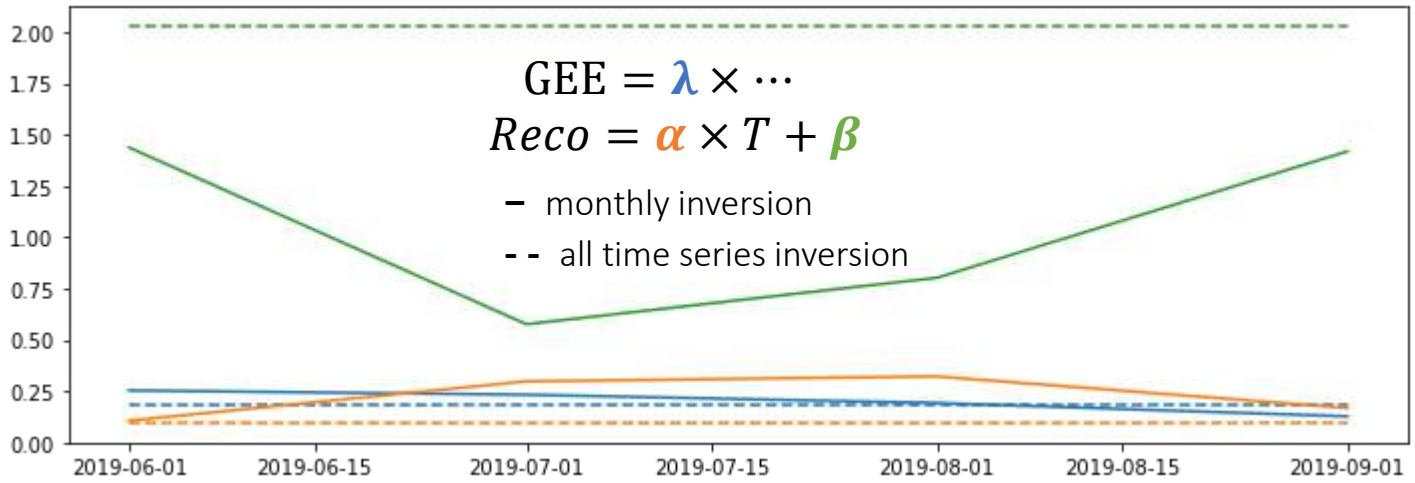
Estimated map shows FCO2 differences on site which spatially correlates with 2004 yield.

Model captures the site dynamics

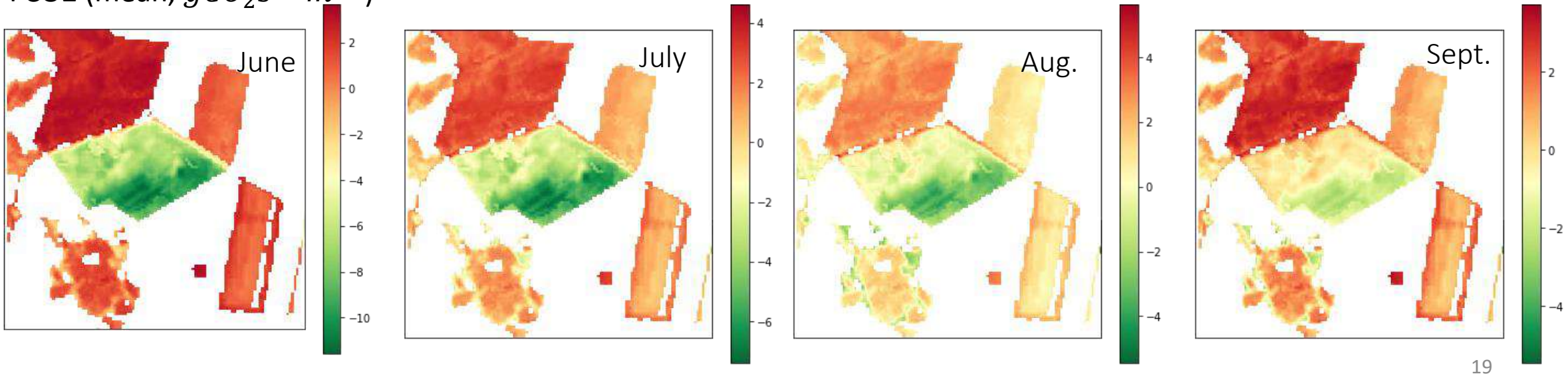


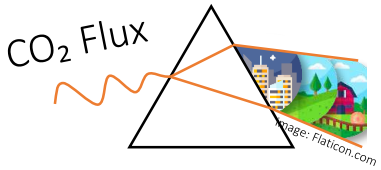
Monthly runs show varying parameters

- Smooth decline in GPP response (↓–). Crop less response to climatic variables and/or EVI saturation.
- Increase in respiration response to temperature during July-August (↑–), but w/ compensation (↓–). Possibly indicating other factors role (water for instance).



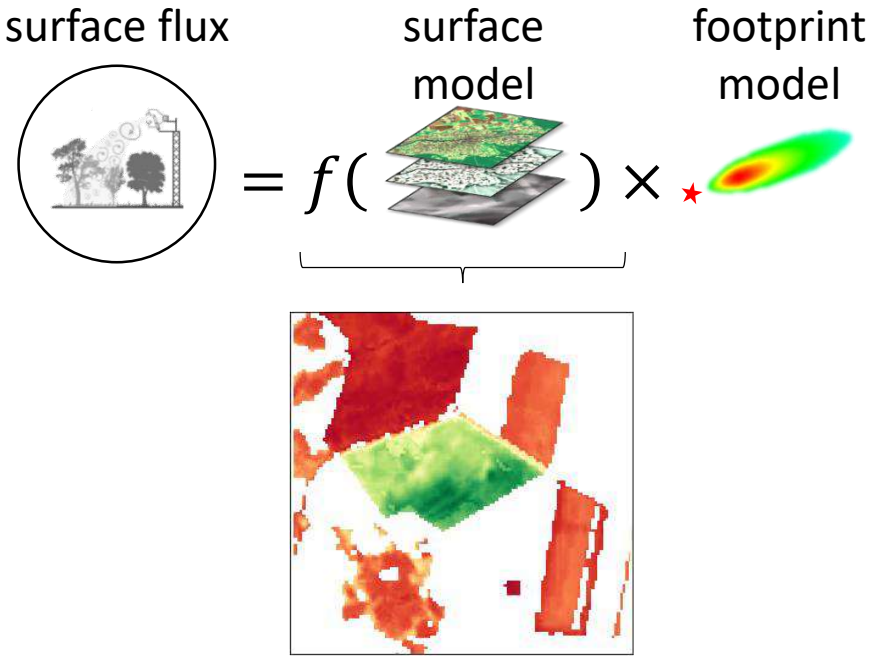
FCO2 (mean, $gCO_2 s^{-1} m^{-2}$)

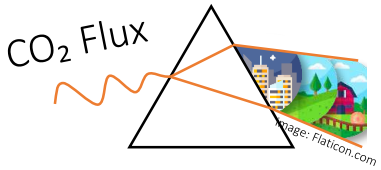




Keep in mind

- Surface model allows retrieving spatialized flux, and inversion framework helps calibrate it;
- 2019 flux map are spatially correlate with 2004 yield, indicating soil and underground water availability play a significant role on the carbon flux;
- GPP response to environmental variables decreases when monthly calibrated, possibly linked to phenology.
- Increase in respiration response to temperature during July-August but with parameter compensation. Possibly indicating other factors play a role (water for instance).

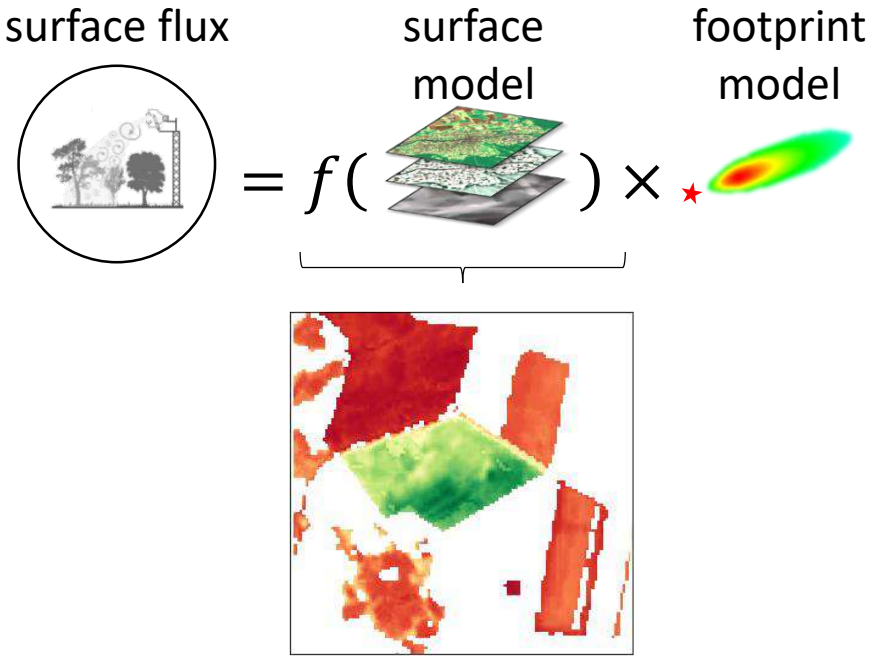




Keep in mind

- Surface model allows retrieving spatialized flux, and inversion framework helps calibrate it;
- 2019 flux map are spatially correlate with 2004 yield, indicating soil and underground water availability play a significant role on the carbon flux;
- GPP response to environmental variables decreases when monthly calibrated, possibly linked to phenology.
- Increase in respiration response to temperature during July-August but with parameter compensation. Possibly indicating other factors play a role (water for instance).

- Study must be done using different years (2019 maize, 2020 wheat, 2021 rapeseed) and different sites (crops, forests, grasslands);
- Validating using biomass and soil carbon stock data resolved in time and space;
- Ever-improving satellite resolution will demand increasing precision on surface measurements; We are currently working on decreasing time averaging (to narrow down source areas and increase precision), and on decreasing gap filling (to increase number of data points);




Thank you for
your attention!