XXVe Congress

Optimising *in situ* networks for the early detection and attribution of environmental effects on European forests

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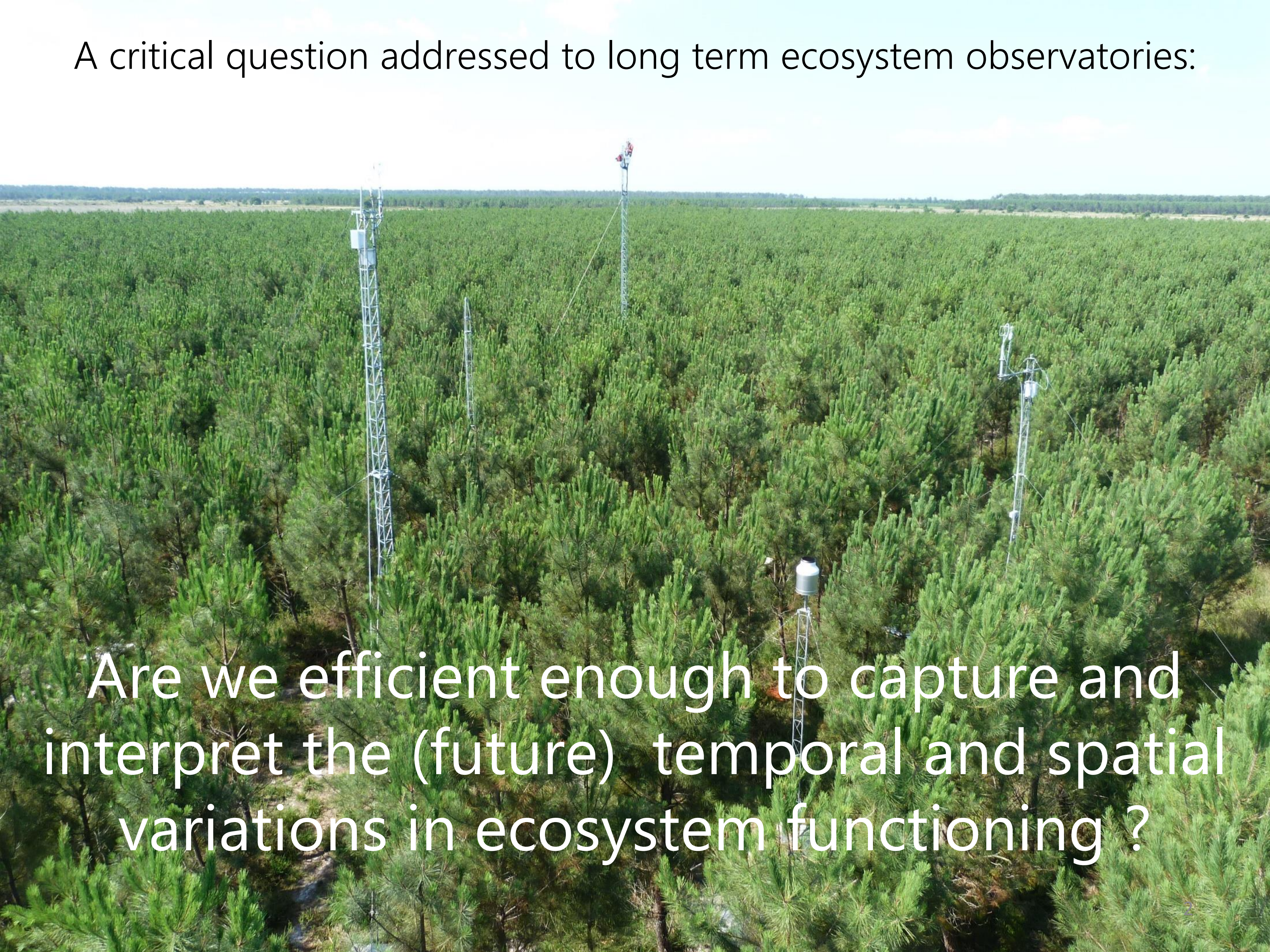

A critical question addressed to long term ecosystem observatories:
Are we efficient enough to capture and interpret the (future) temporal and spatial variations in ecosystem functioning ?

Background

- In addition to dramatic events (e.g. fires, storms, drought, massive defoliation etc.) forest ecosystems are going through discrete and subtle changes due to changes in CO_2 concentration, temperature air water vapour saturation deficit, solar dimming, ozone, nitrogen & sulfur deposition...

(Drought 2019 in fir stands, Jura, France)

- Such impacts are :
    - Mostly non-linear, accumulative (CO_2, N, O_3), or transient (solar dimming, VPD).
    - Interactive:
        - ⇒ antagonistic ($CO_2 \times O_3$),
        - ⇒ synergestic ($CO_2 \times N$, $T \times VPD$)
    - Heterogeneous in temporal and spatial domains
    - Differentiated according to ecosystem type, species.

(Fontainebleau ICOS station credit CNRS)

The ICOS Research infrastructure in brief

(https://www.icos-ri.eu/)

- Launched in 2013 as a large , distributed, European research infrastructure.

- Expected lifetime 20 years

- Includes a network of ecosystem stations monitoring 120 variables using standardised protocols and instruments.








SUMMARY

Assess the sensitivity of *in situ* observation network to environmental impacts in 3 steps :

(1) Quantify the sensitivity of network measurements

(2) Analyse the CO_2 case for 1995-2010 in Europe.

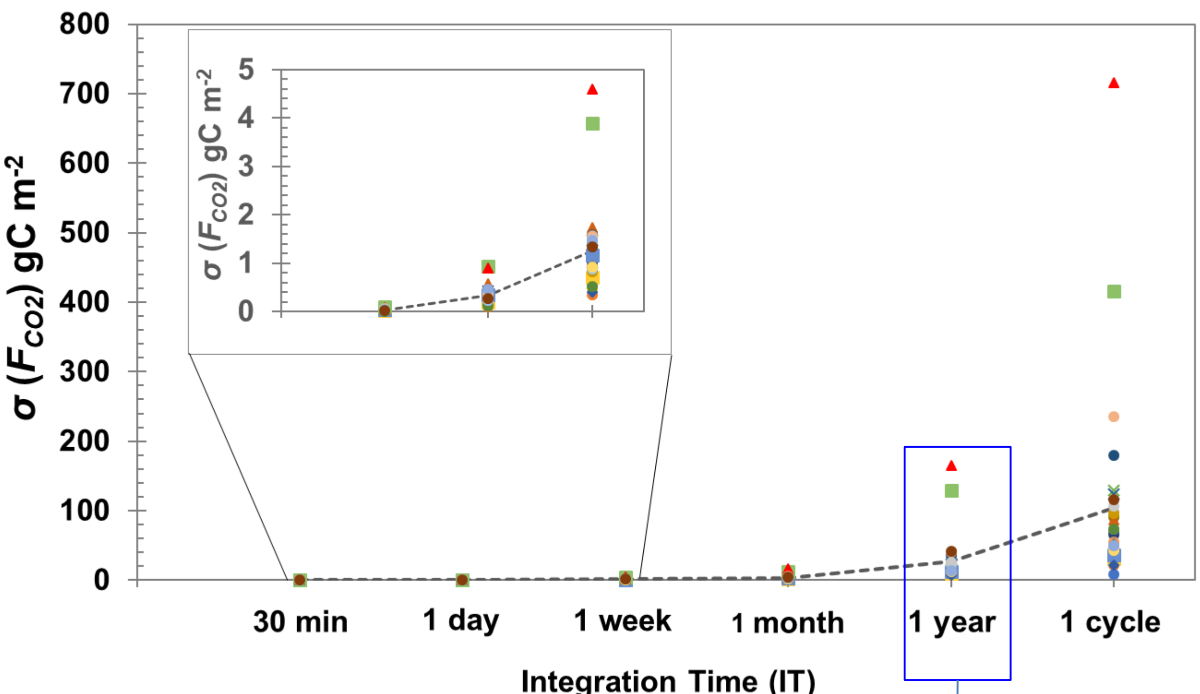
(3) Generalise

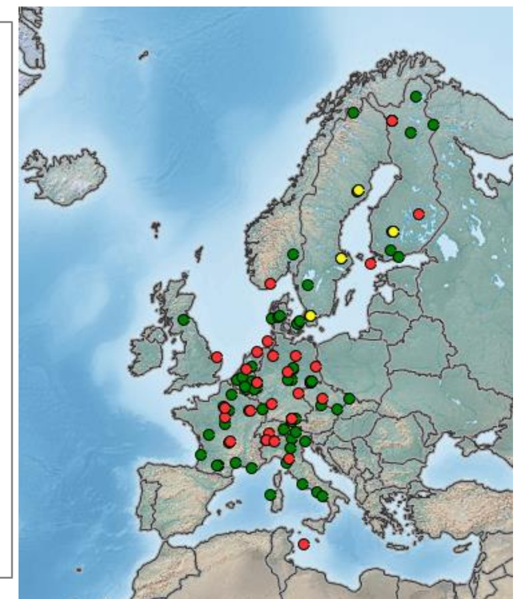
(Puèchabon ICOS station, credit CNRS, France)

1st step. Sensitivity of CO_2 flux measurements

(1). Error in the historical measurements of ICOS stations: F_{CO2} spanning from 30mn to 1 year. (FLUXNET2015 database)

ICOS network within FLUXNET2015 dataset (31 stations): Uncertainty on integrals



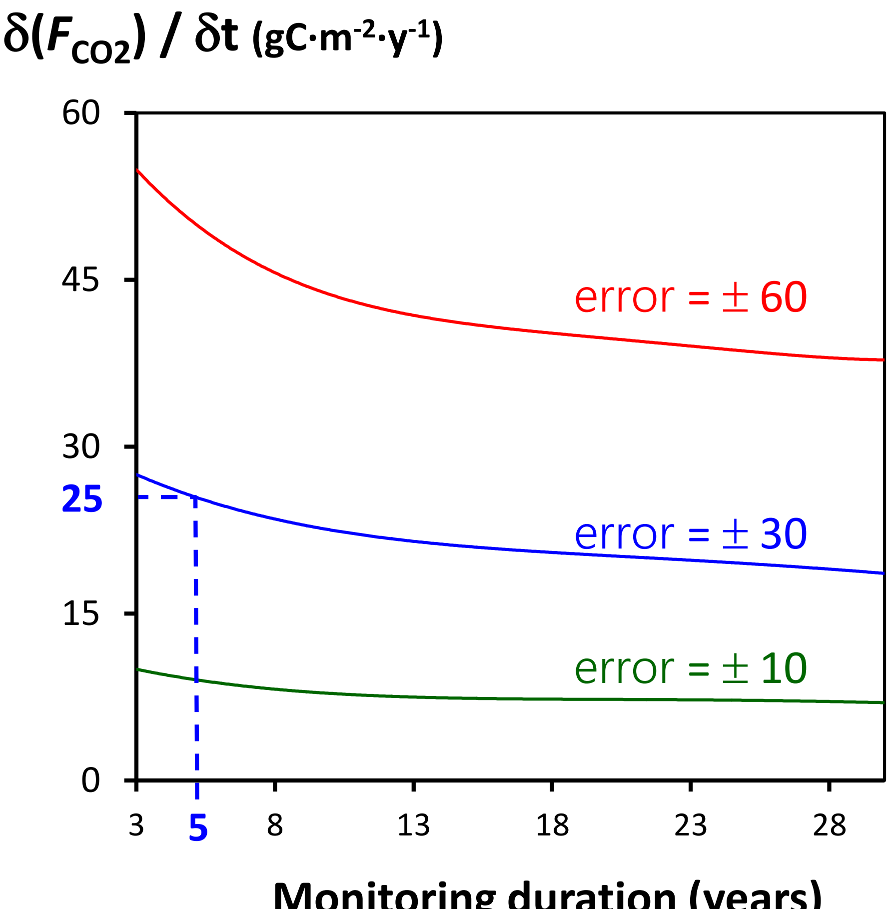


Yearly integral
Mean error = 27.3 gC m^{-2} (about 9%)

RINGO Readiness of ICOS

1st step. Sensitivity of CO_2 flux measurements

(2). Can we detect a difference among years in CO_2 fluxes, $\delta(F_{CO2}) / \delta t$?



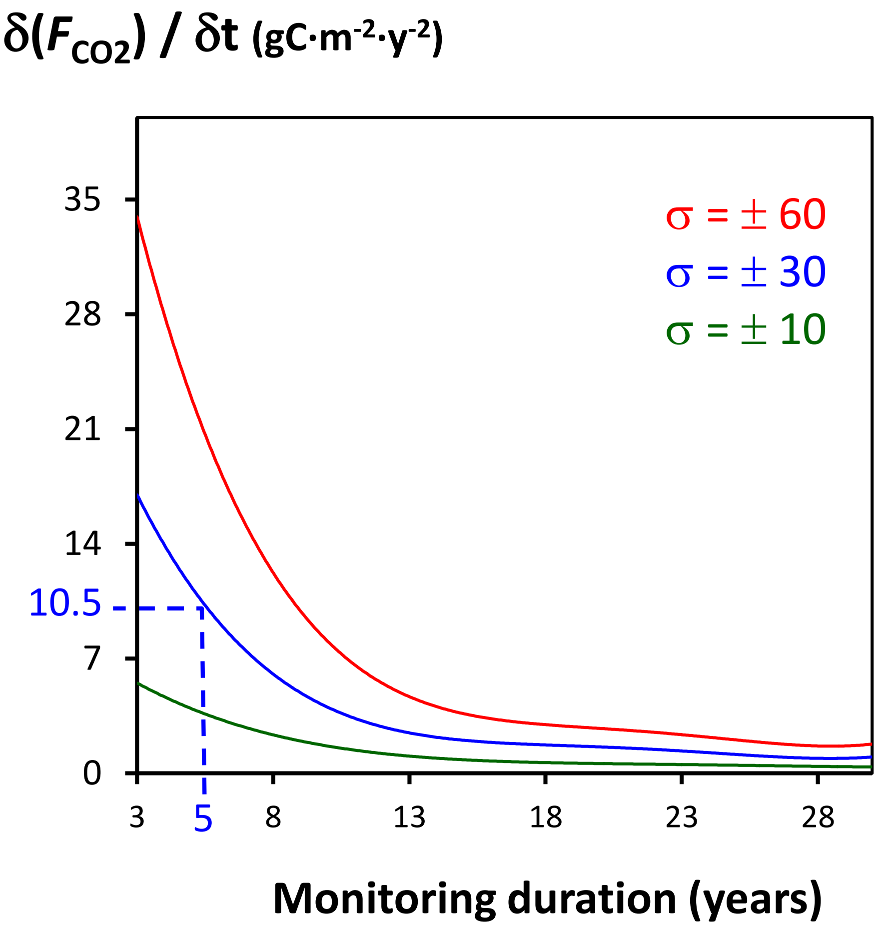
Baldocchi et al. 2018, Monte Carlo analysis.

- The detection threshold decreases with time and accuracy.
- The accuracy is the main determinant of the sensitivity.

1st step. Sensitivity of CO2 flux measurements

(3). Can we detect a continuous shift in CO2 fluxes ?

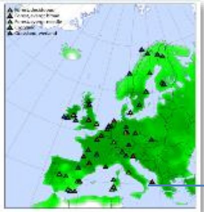
- The linear trend case



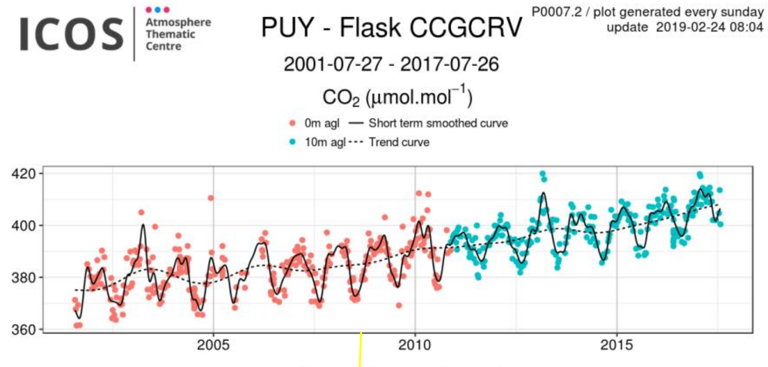
<u>*Baldocchi et al. 2018, Monte Carlo analysis.*</u>

- Temporal consistency of the measurements is assumed
- Duration and accuracy have similar influences.

Ex. For an error of 30gC.m^{-2}.$yr^{-1,}$ 5 years are needed for detecting a 10.5 gC.m^{-2}.yr^{-2} shift



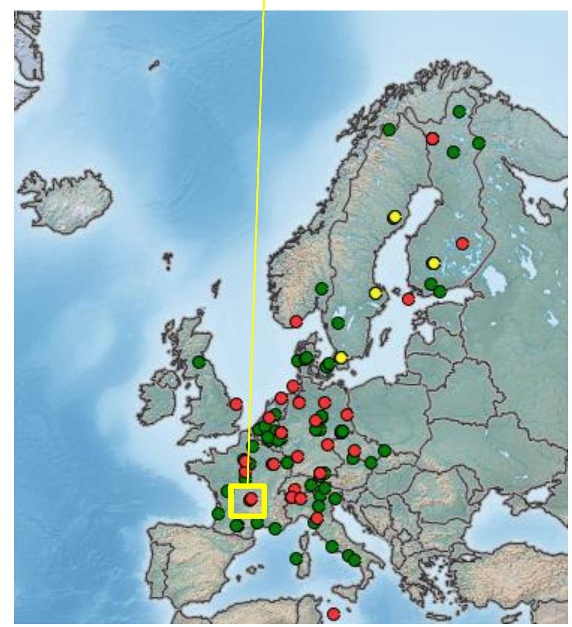
2^{nd} step. Application to detection of the CO_2 effect on ecosystem photosynthesis (GPP)



Simple

- spatially uniform across Europe
- but no control (constant CO_2)
- each station can be considered as a replicate
- increase is continuous and ~monotonous

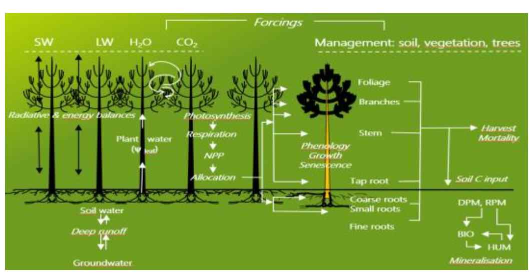
ICOS station networks 2019

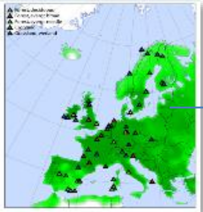


Expected impact

- well documented at leaf / plant levels

- can be simulated by models

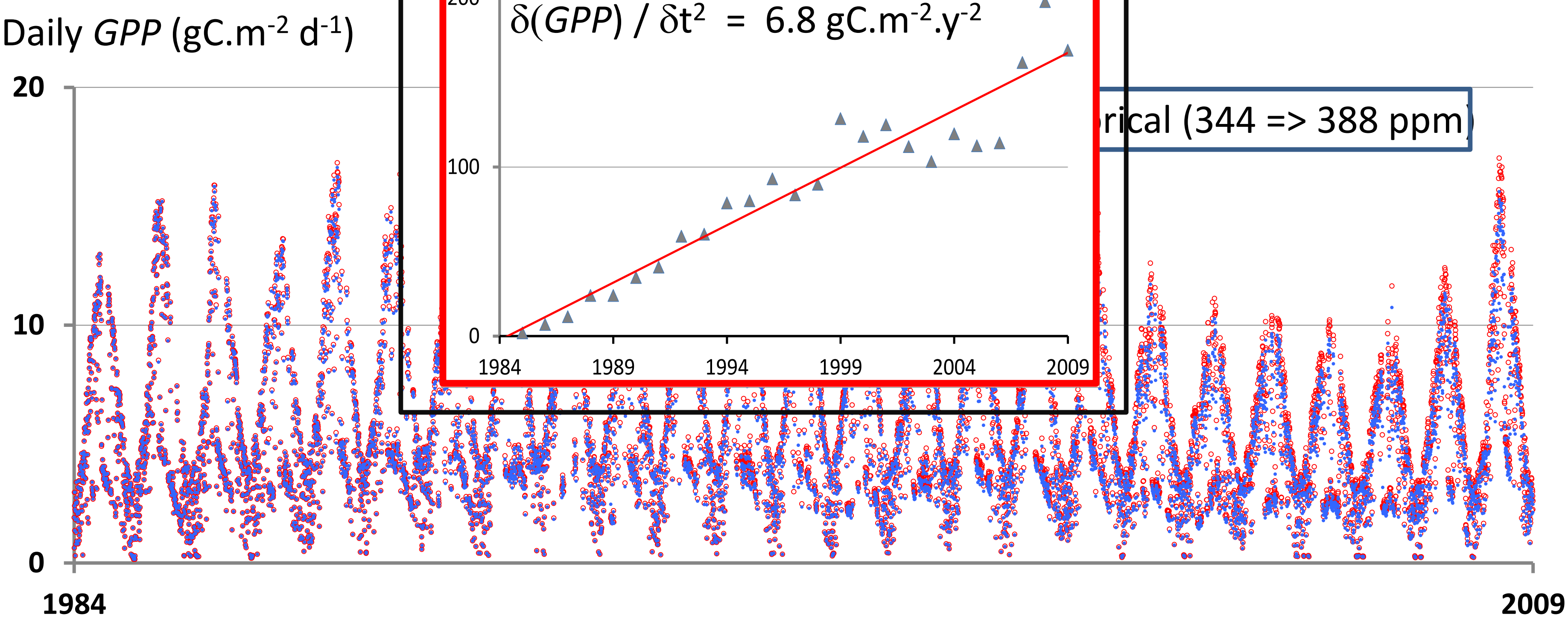




2^{nd} step. Application to the CO_2 effect on GPP

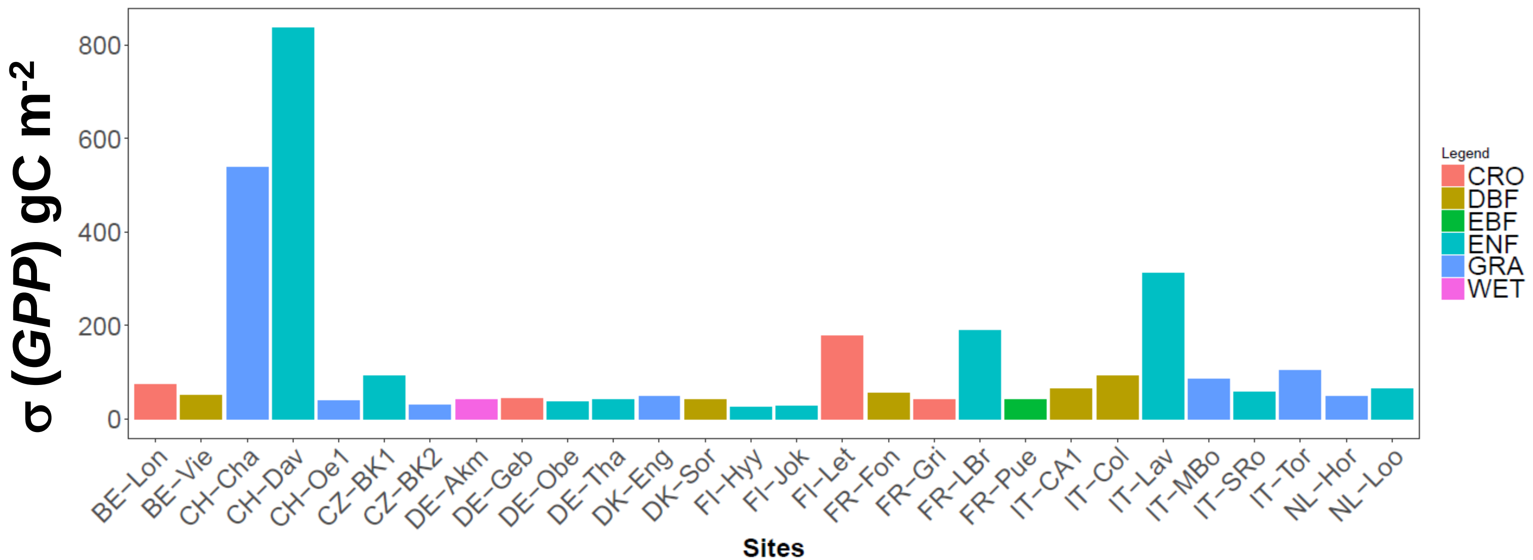
- Simulation of CO_2 impacts on historical measurements.

GPP modelled from 1984 to 2008 at 1) constant and 2) historical CO_2 concentrations (FR-LBr coniferous site)



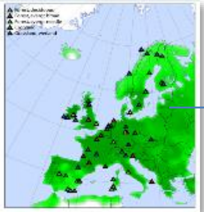
2nd step. Application to the CO_2 effect on GPP

Error in the historical measurements of ICOS stations: annual ecosystem photosynthesis (*GPP*) for 28 ICOS stations.



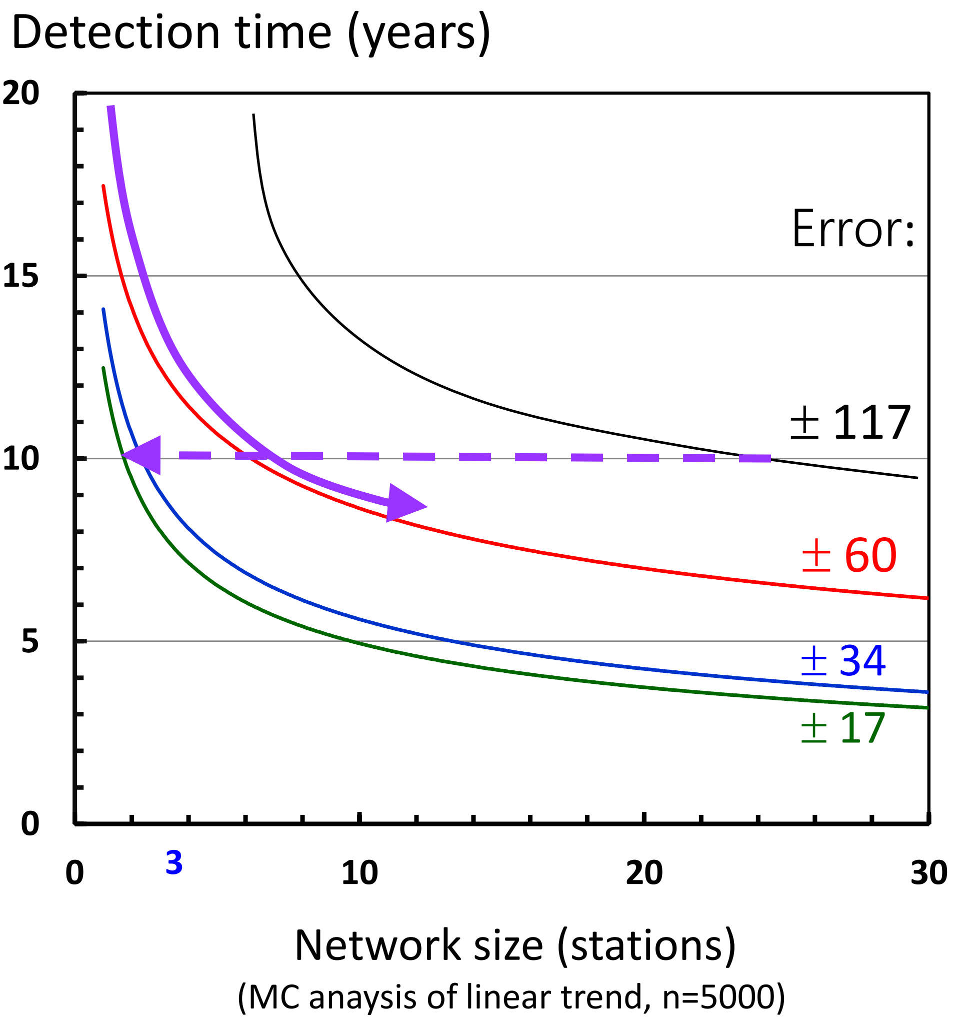
Mean error (*GPP*) = 117 gC m^{-2} yr^{-1} (~ 8%)

RINGO Readiness of ICOS



2^{nd} step. Application to the CO_2 effect on GPP

How long before the CO_2 impact on GPP can be detected ?



Adding stations until 12 reduces the detection time:

- 1 station cannot detect the CO_2 impact after 20 years
- 12 stations need 8 years

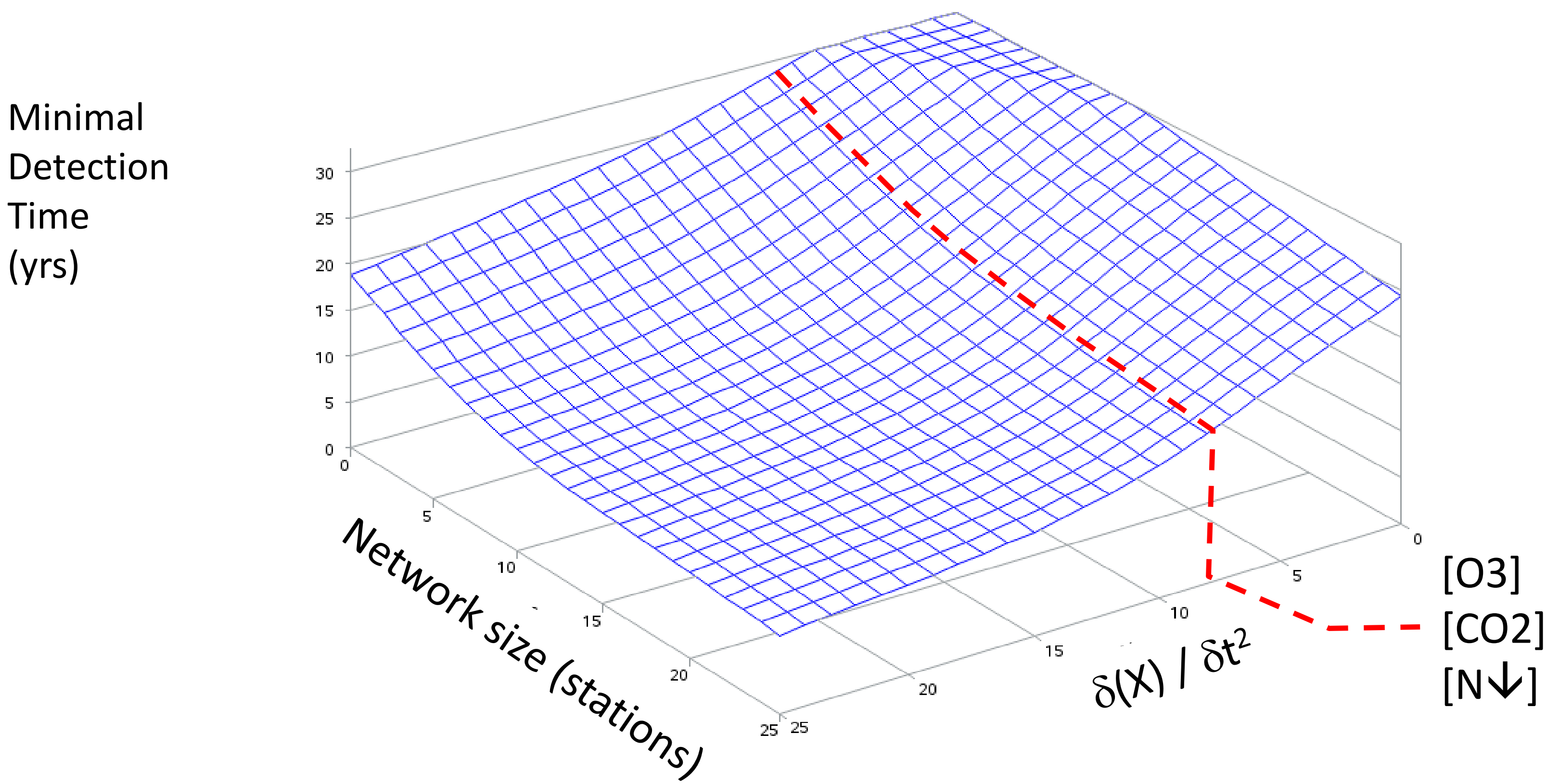
Increased accuracy reduces the network size required

RINGO | Readiness of ICOS

3rd. Generalisation. Designing the optimal accuracy / network size.

Surface of detection for *GPP* = *f*(CO_2)

(error = 75gC.m^{-2} yr^{-1})



Towards optimised *in situ* networks : RINGO | Readiness of ICOS

1. Duration, accuracy and number of ecosystem stations can be optimised

2. Distribution of stations among- and replication within homogenous ecological subdomains are required

3. Interoperability of measurements across networks is critical

   (ICOS, eLTER, ICP, Copernicus products…)

   ecosystem fluxes
   environmental drivers
   canopy structural and physiological features

4. Temporal consistency in measurements is essential


Thanks for your attention

Additional slides