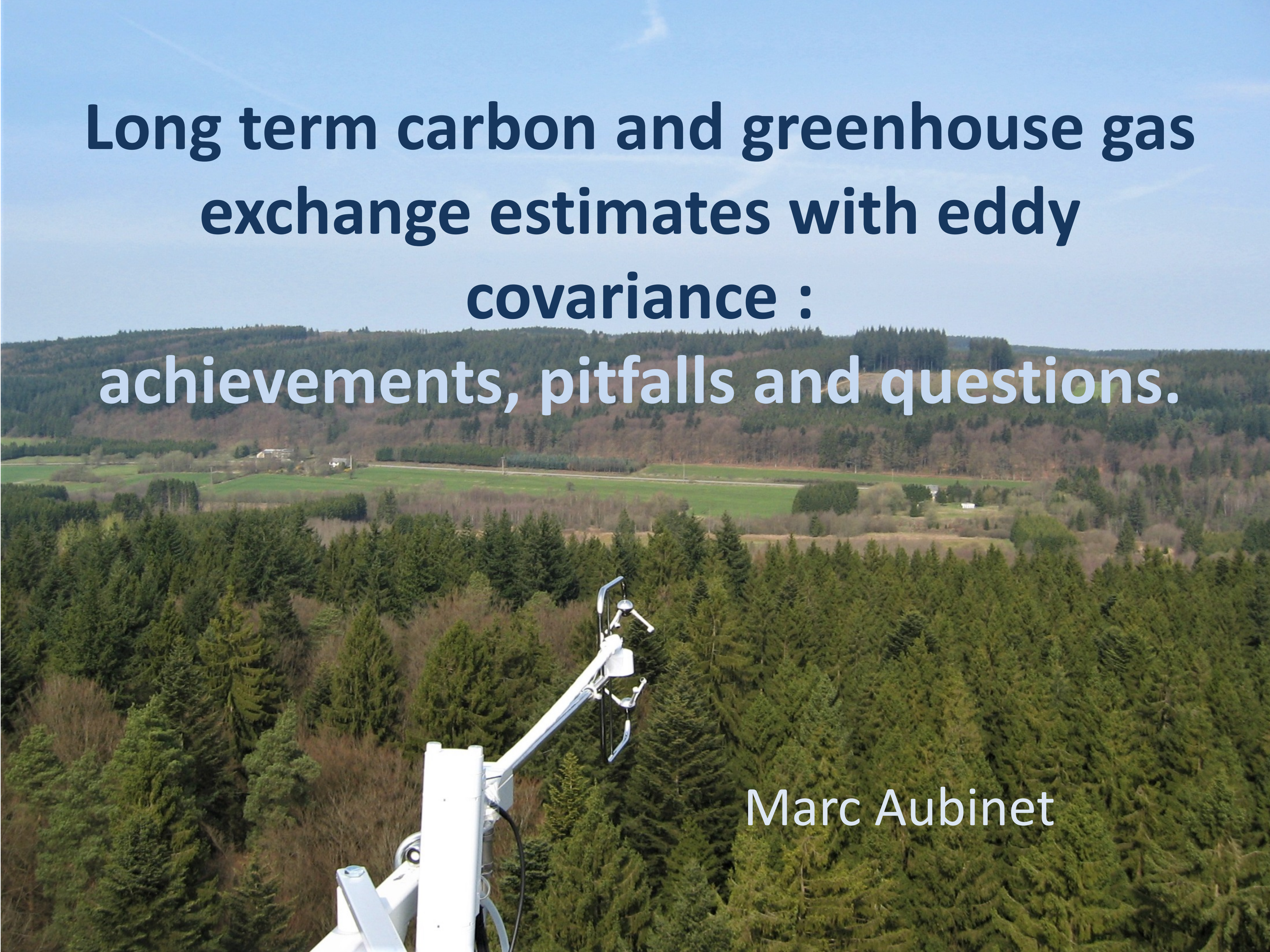
Long term carbon and greenhouse gas exchange estimates with eddy covariance : achievements, pitfalls and questions.

Marc Aubinet



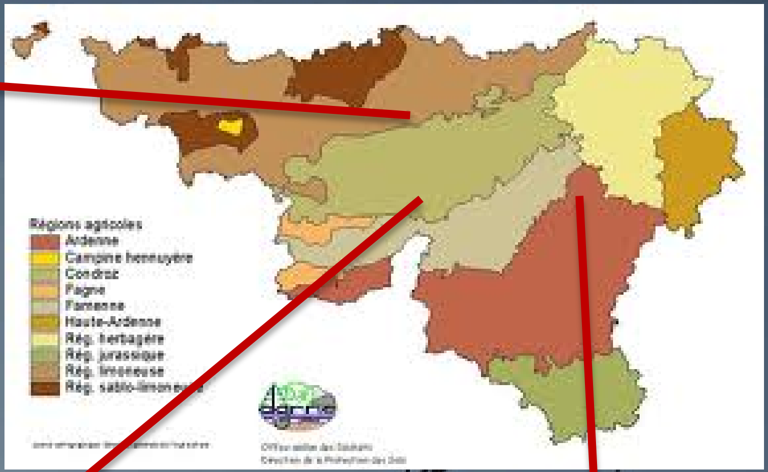
Eddy covariance for dummies

- Measures net fluxes exchanged by surface with atmophere (H_2O, CO_2, CH_4, N_2O, BVOC,…)
- Continuous (every half hour)
- Long term (> 20 years)
- Spatially integrated (1 ha)
- Based on atmospheric turbulence

$\Rightarrow$ High frequency measurements of wind velocity and gas concentration

Eddy covariance sites

Lonzée (LTO)
Crop
Since 2004



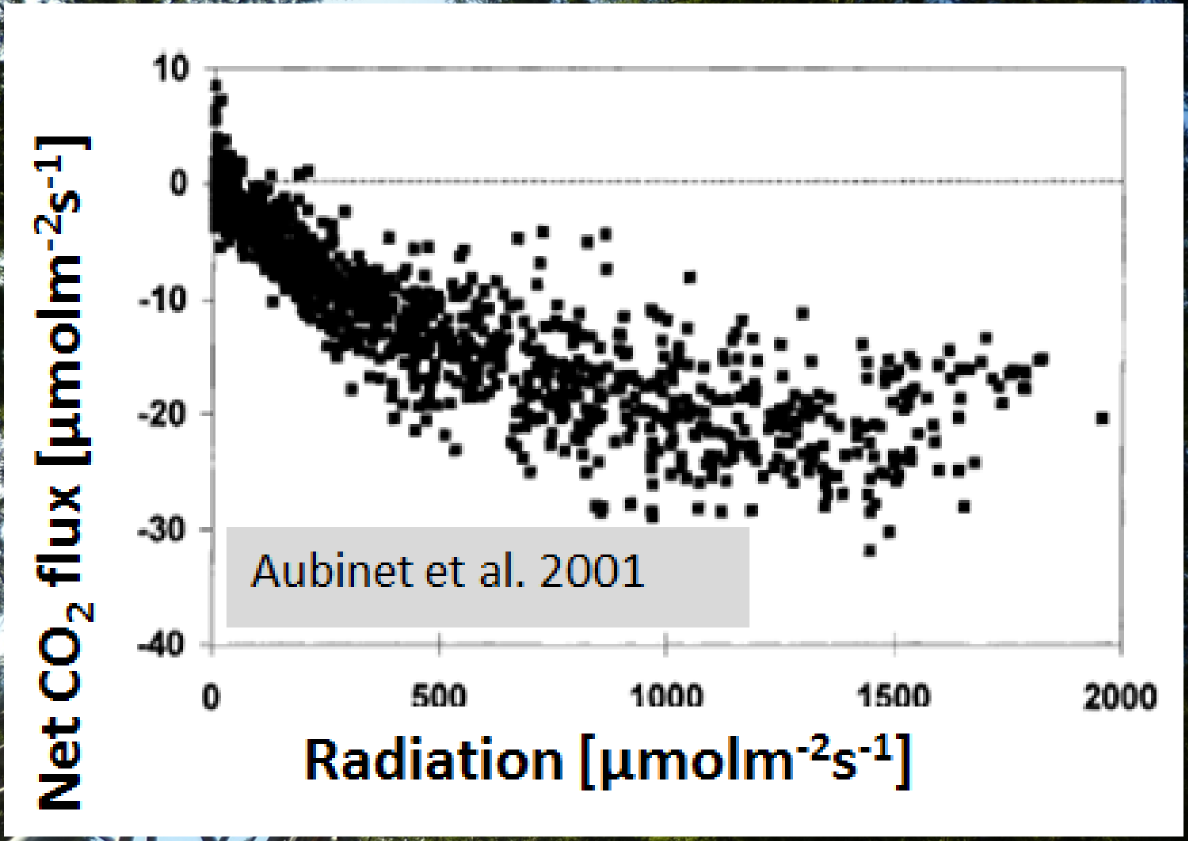
Dorinne (DTO)
Grazed grassland
Since 2010

Vielsalm (VTO)
Forest
Since 1997

Why performing EC measurements ?

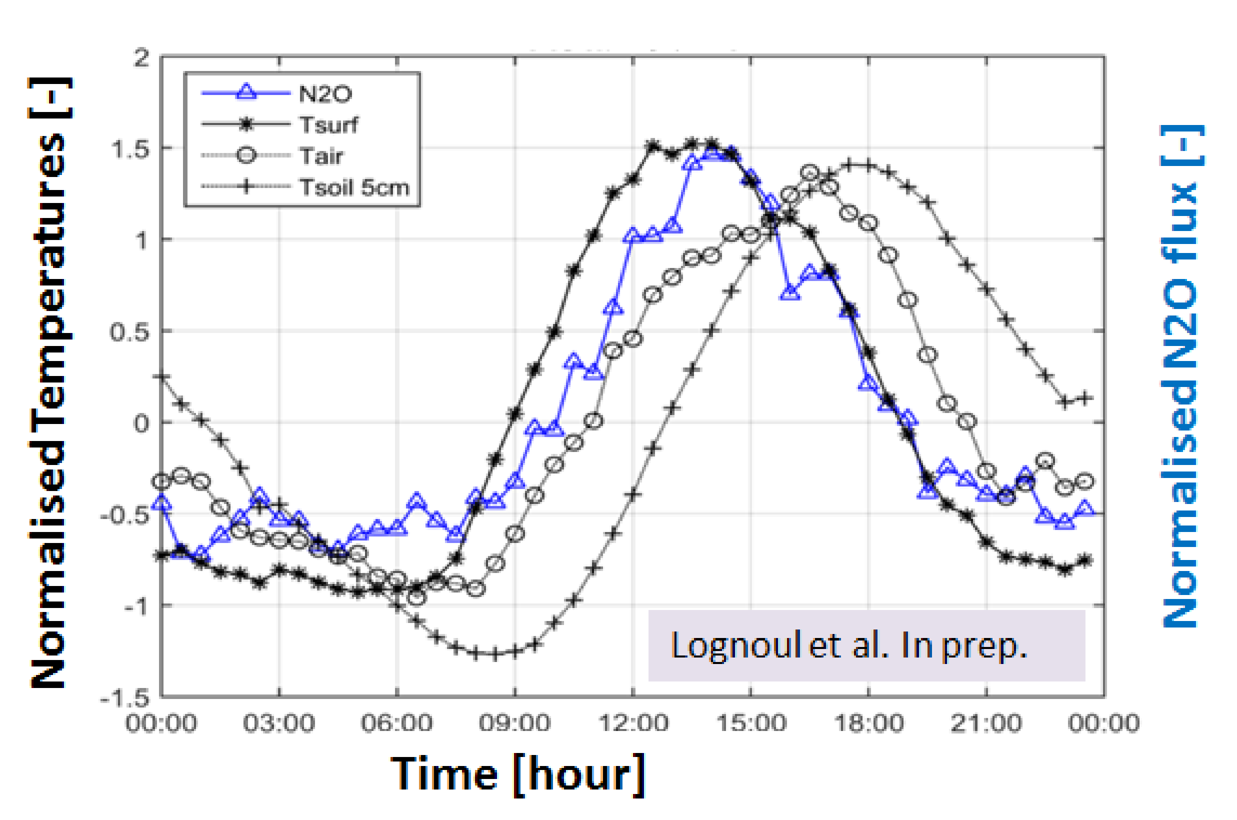
- To obtain flux functional responses (and understand mechanisms);
- To establish budgets;
- To study the impact of extreme events;
- To study the impact of management;
- To follow flux interannual variability;

To obtain flux functional responses



CO_2 Fluxes response to solar radiation

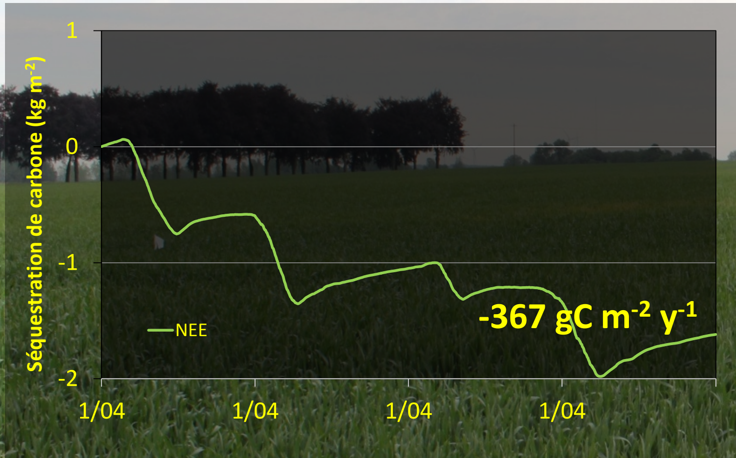
To obtain flux functional responses

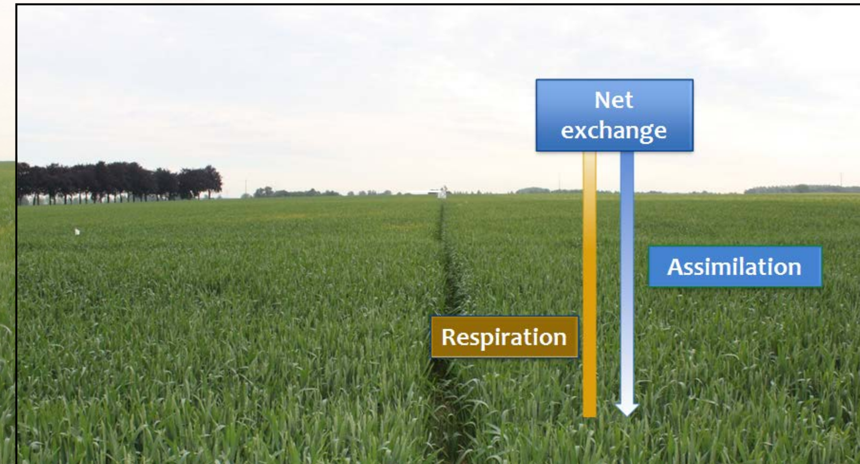


N_2O fluxes are best phased with surface temperature:
⇒ N_2O emission processes occur at the very surface

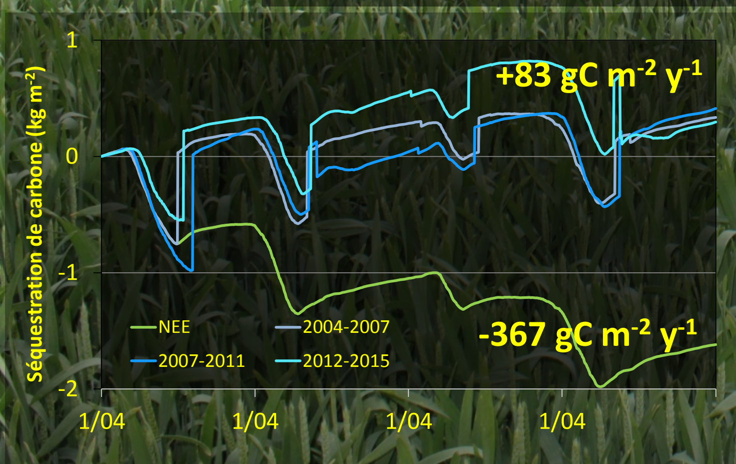
To establish budgets (CO2 and Carbon)

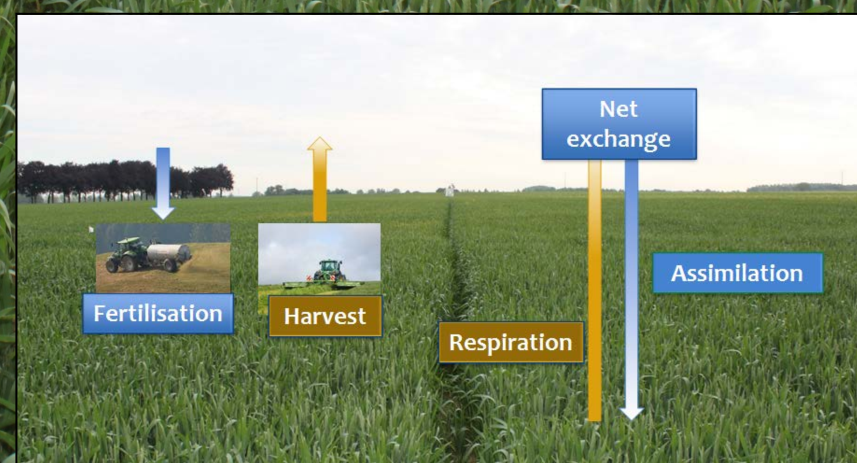
CO_2 budget at LTO (12 Years)





Carbon budget at LTO (12 Years)

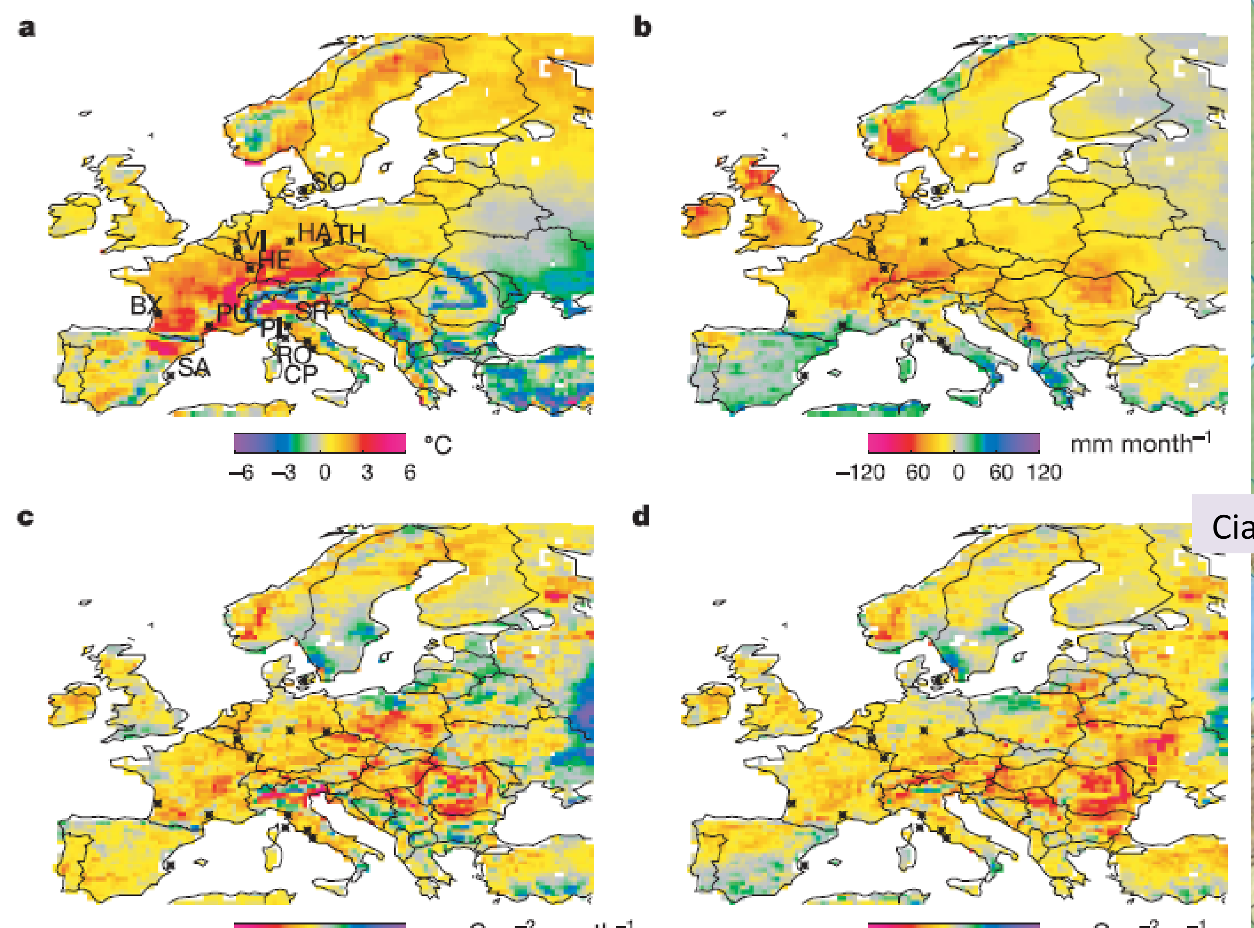




Buysse et al. 2017

To study the impact of extreme events

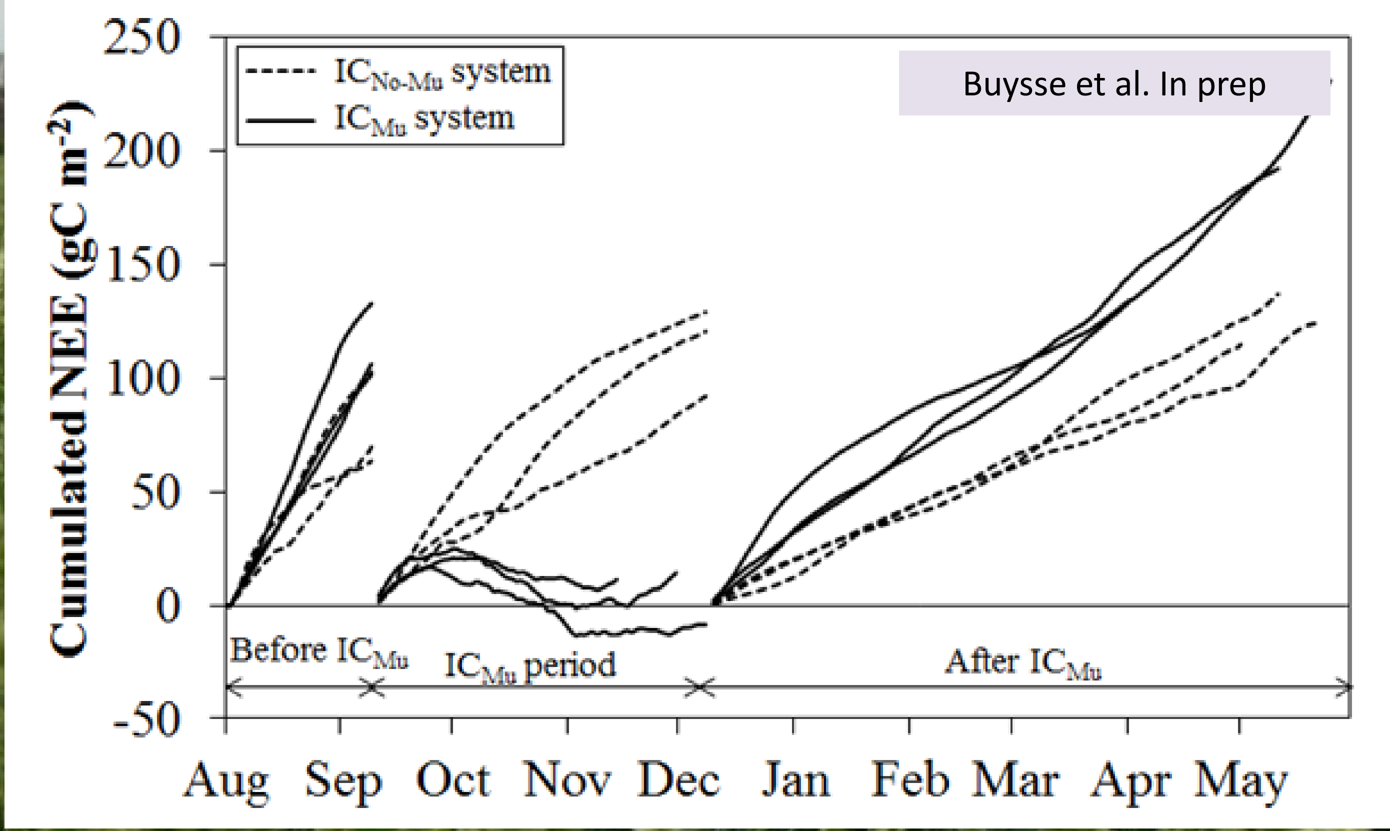
Impact of 2003 heat wave on carbon flux at European scale



Ciais et al. 2005

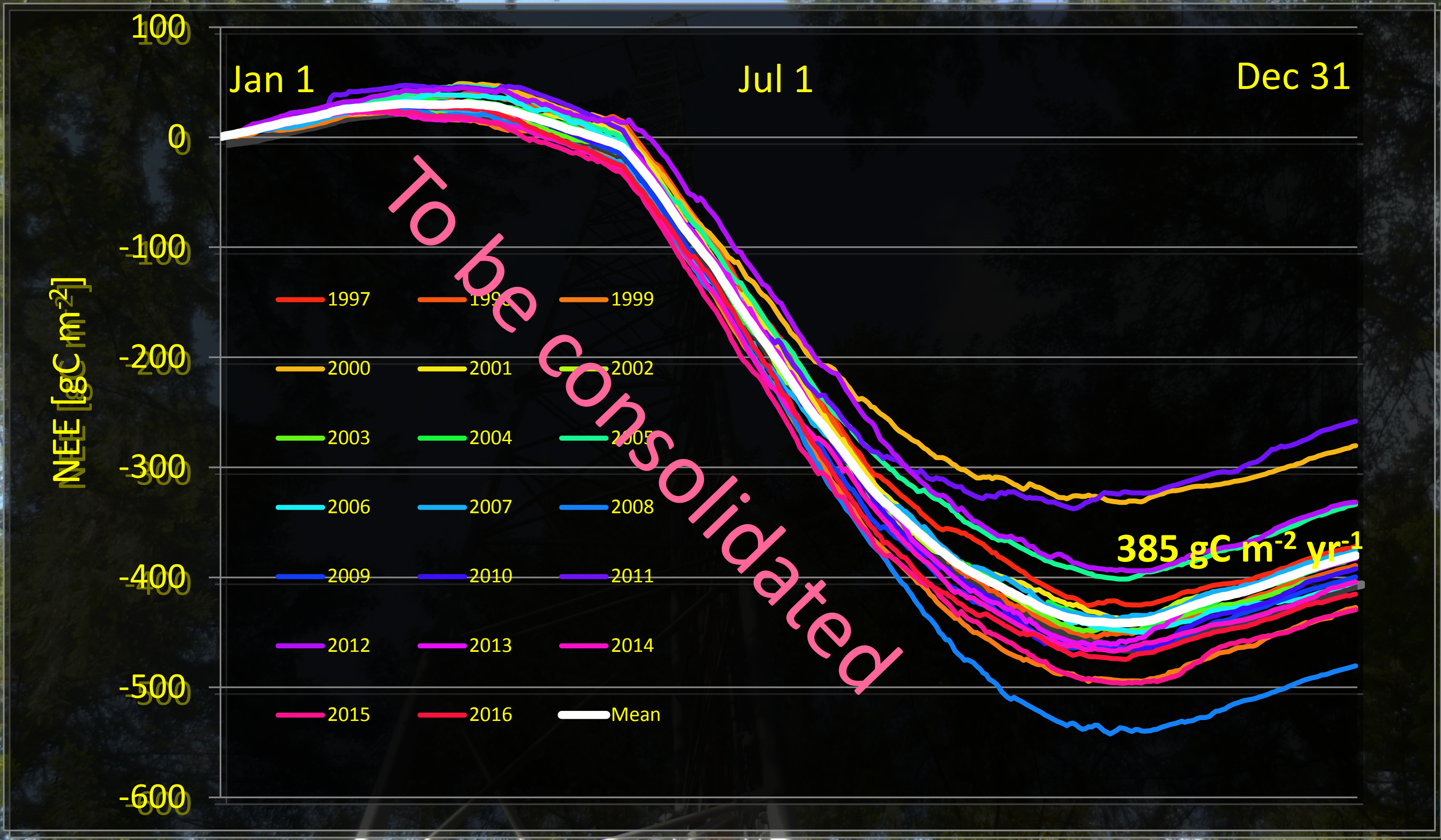
To study the impact of management

Impact on C sequestration of cover crops (6 Years)



To follow flux interannual variability

VTO beech CO2 budget (1996 – 2016)



Aubinet, not published

Pitfails and questions

Is the measurement correctly made ?

Not always : Instrumental errors, breakdowns.

Is the measured flux faithful to the real exchange ?

Not always : physical limitation of the method

Is the studied zone representative of the target zone ?

Not always : varying footprint with climate and set up

⇒Systematic and random errors

⇒Uncertainties

Random errors

- Due to instruments and Stochastic nature of turbulence
- Cannot be corrected *but* impact decreases with the number of measurements

Uncertainties resulting from random errors

Example : Vielsalm TO
(estimated using Richardson DD method)

Relative uncertainty	n	Mean	Median	Min
Half hour	1	173 %	84 %	27%
Day	48	54 %	30 %	11 %
Month	1465	13 %	10 %	6 %
Year	17520	4%		
10 Y	175200	1.5 %		

Typically : 20 gCm^{-2} for one year

Uncertainties resulting from systematic errors

- Systematic error impact ***do not*** decrease with measurement number !

Well identified error | **Physically based correction** | **Proper correction procedure**

No resulting uncertainty

« We know we know »

Uncertainties resulting from systematic errors

- Systematic error impact ***do not*** decrease with measurement number !

Well identified error | **Empirical correction** | **Proper correction procedure**

Quantifiable uncertainty

« We know we don't know »

Uncertainties resulting from systematic errors

- Systematic error impact ***do not*** decrease with measurement number !

Not identified error

No possible correction

No procedure

Unquantifiable uncertainty

« We don't know we don't know »

Need for validation

« We know we know »
Density error

Well identified error	Physically based correction	Proper correction procedure

CRITICAL IN ENCLOSED SYSTEMS !

- WPL correction or instantaneous molar fraction computation

- Requires exact measurement of temperature fluctuations in the IRGA volume !

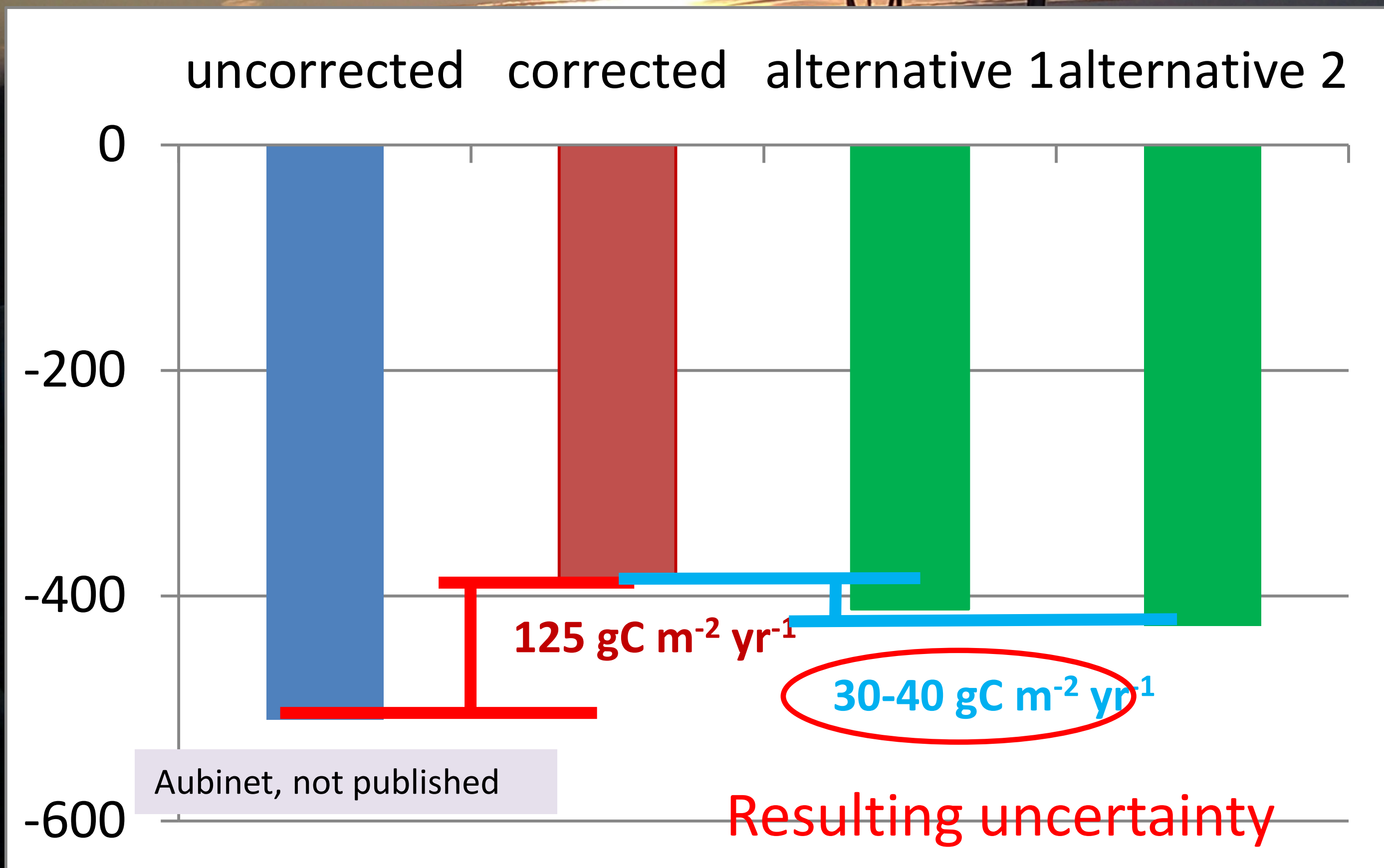
« *We know we don't know* »

Night time error

Well identified error

Empirical correction

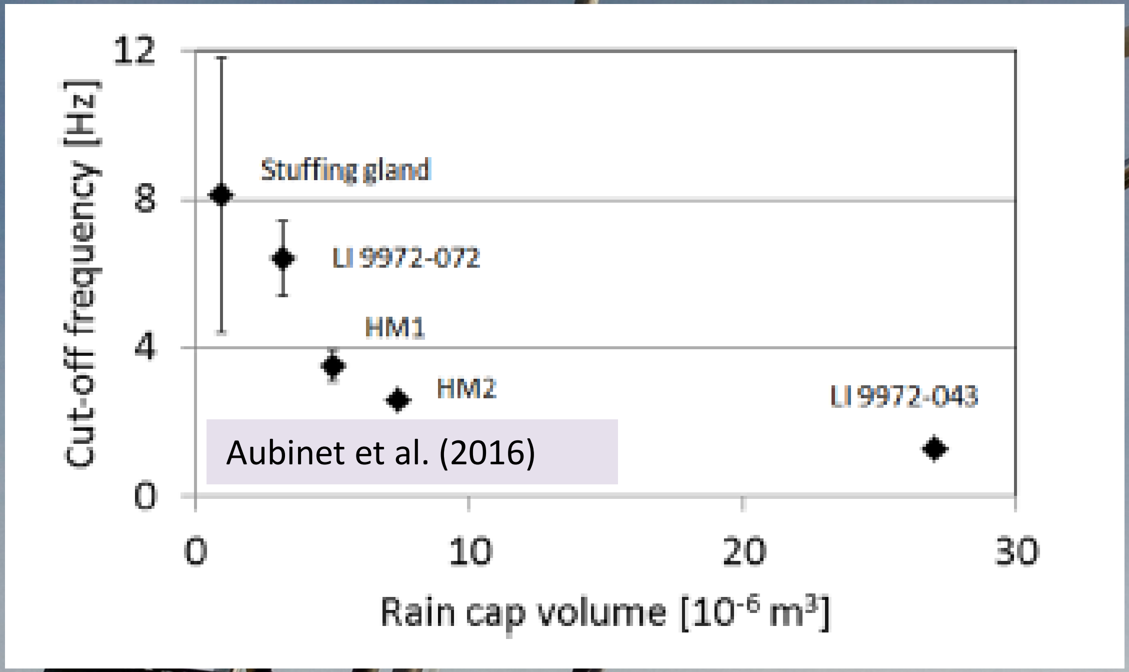
Proper correction procedure



« *We didn't know we don't know* »
High frequency losses by rain cap

Not identified error (before 2016)

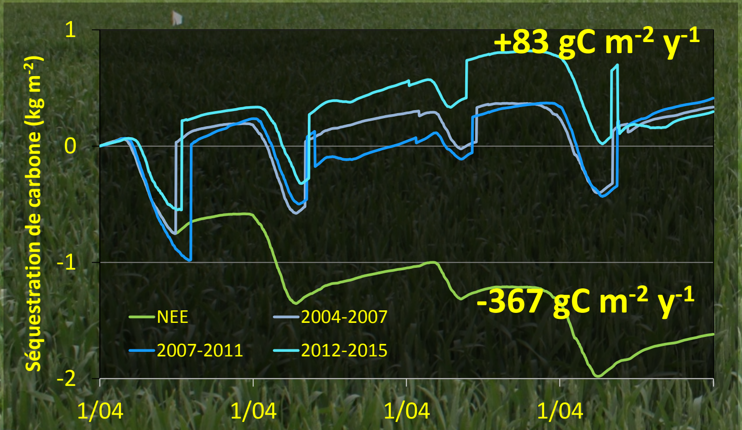
No possible correction



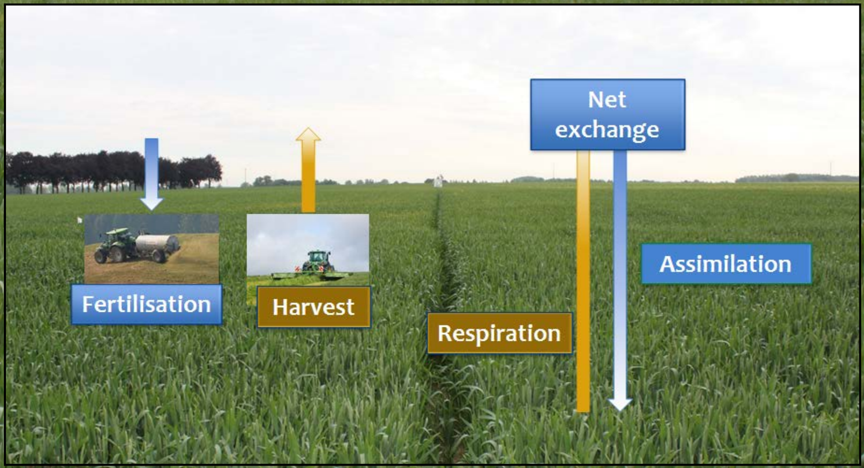
Critical for enclosed path;
Explains some correction inadequacies for closed path ?

« We don't know we don't know (don't we ?)»

Carbon budget at LTO (12 Years)



Buysse et al. 2017



Is a 83 $gC\ m^{-2}\ y^{-1}$ loss it realistic ?

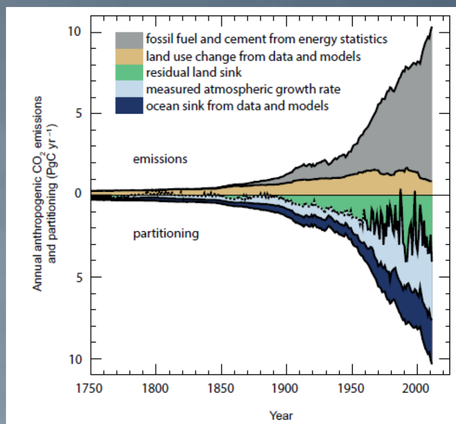
Is there an undetected systematic error ?

Need for validation !

Are uncertainties critical ?

- Budgets
  - Random errors decrease with measurement period length ⇒ not critical
  - Systematic errors don't decrease with measurement period length ⇒ critical

Are we able to detect the vegetation sink ?



Terrestrial Sink : 2.97 GtC/yr.

Vegetated surface : 11 Gha.
Forested surface: 4 Gha.

Average sink : 27 $gCm^{-2}yr^{-1}$ (67 $gCm^{-2}yr^{-1}$ if sink only in forests).

Ideally, systematic uncertainties should not exceed 27 $gCm^{-2}yr^{-1}$.

Are uncertainties critical ?

- Budgets
  - Random errors decrease with measurement period length $\Rightarrow$ not critical
  - Systematic errors don’t decrease with measurement period length $\Rightarrow$ critical
- Comparisons (Interannual variability, extreme events, impacts of management)
  - Random errors significant
  - Systematic errors not critical

Conclusions

Eddy covariance already provided major insights

but

Further credibility of the method relies on continuous methodology improvement and adaptation

Improvement of existing correction procedures (night flux; frequency).

Hunt still unknown systematic errors.

Multiply validation experiments.

Thank you !