What fluxes are telling us so far ? A naïve reanalysis of CO2 fluxes over the past 18 years

Virginie Moreaux, Paul Berbigier, Daniel Berveiller, Jean-Marc Bonnefond, Christophe Chipeaux, Nicolas Delpierre, Olivier Darsonville, Eric Dufrene, André Granier, Richard Joffre, et al.

HAL Id: hal-02790285
https://hal.inrae.fr/hal-02790285

Submitted on 5 Jun 2020

1996 - 2035

F_{CO2}

2000 2005 2010 2015
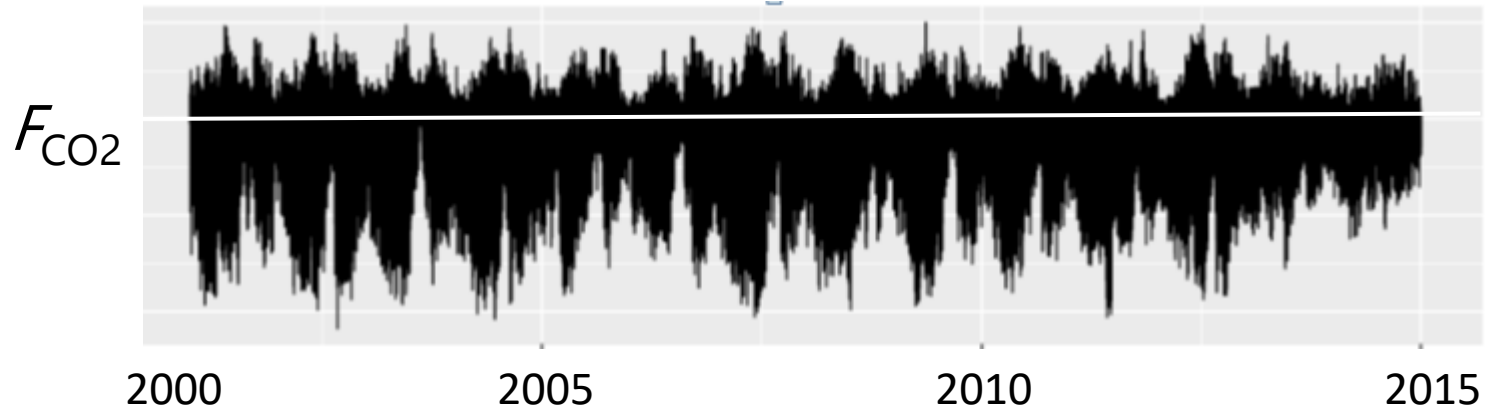
At half the way: what is still to be achieved ?
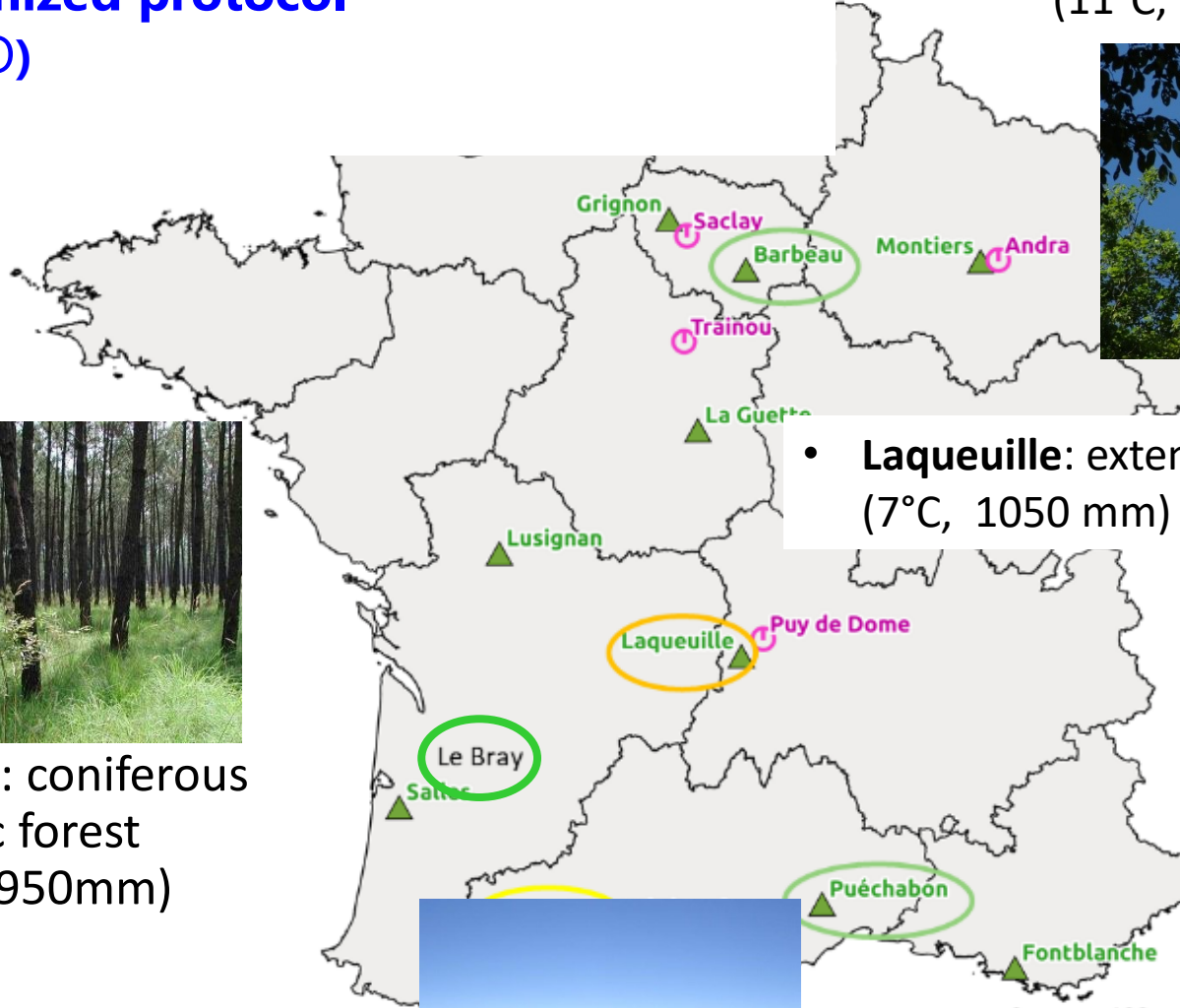
**Sites with minimal management
Data filtered & processed using
homogenized protocol**
(EddyPRO**)**

- **Barbeau** : old growth mixed broadleaved forest (11°C, 690mm)

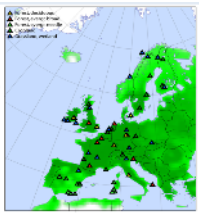- **Laqueuille**: extensive grassland (7°C, 1050 mm)

- **Le Bray**: coniferous Atlantic forest (13°C, 950mm)
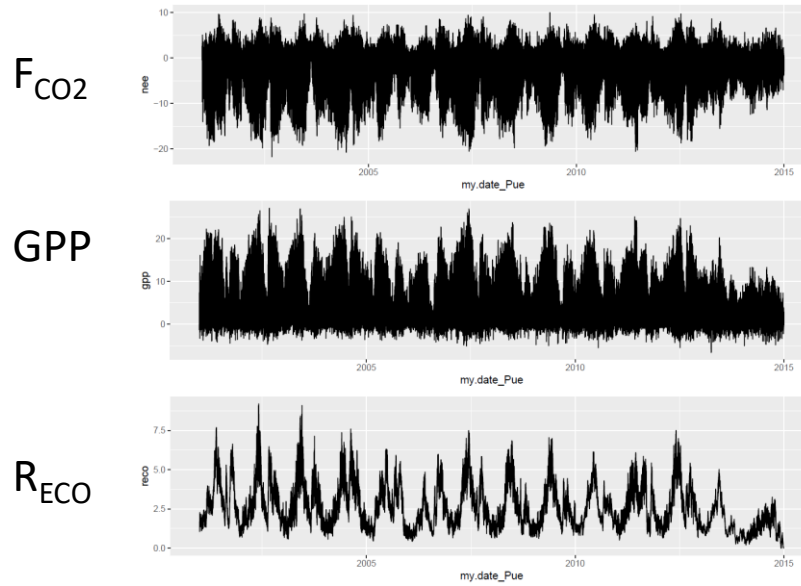
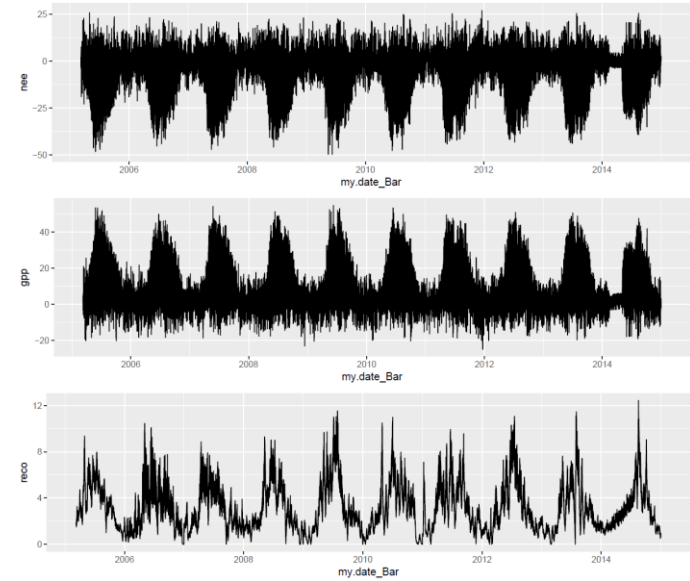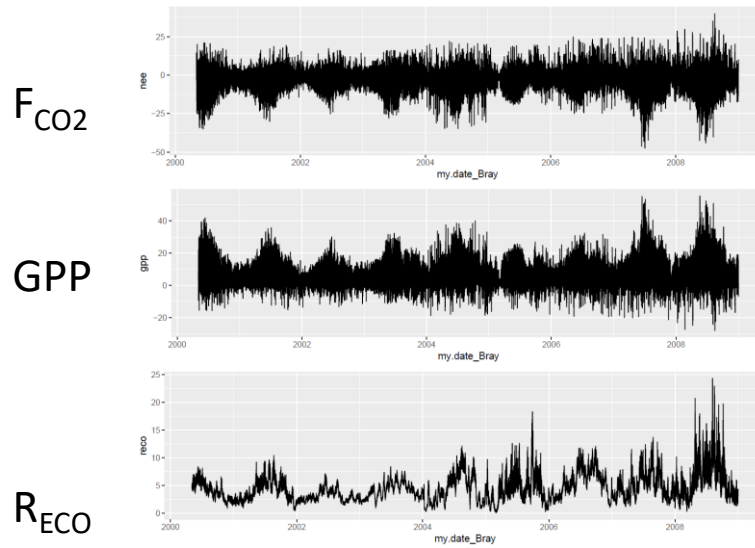- **Puechabon**: old-growth evergreen Quercus coppice (14°C, 910 mm)

Grignon
Saclay
Barbeau
Montiers
Andra
Trainou
La Guette
Lusignan
Laqueuille
Puy de Dome
Le Bray
Salles
Puéchabon
Fontblanche

0   100   200

Time series analysed
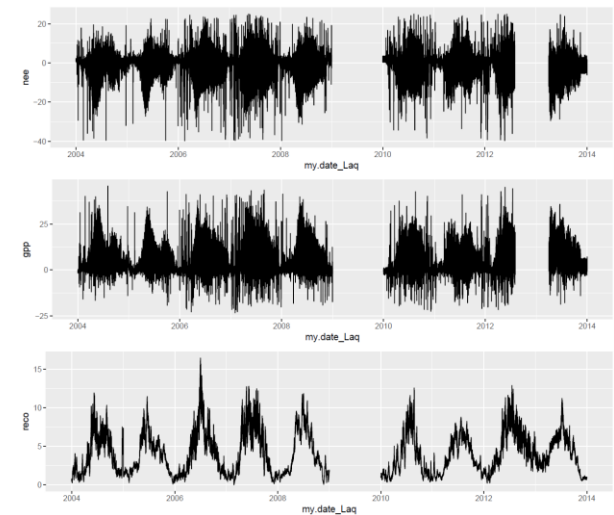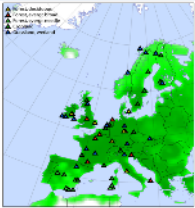
What fluxes are telling us so far ?

A naïve reanalysis of CO_2 fluxes over the past 18 years

Berbigier P., Berveiller D., J.-M. Bonnefond, Chipeaux C., Delpierre N., Darsonville O., Dufrene E., A. Granier Joffre R., Klump K., Lafont S., Limousin J-M., Longdoz B., Loustau D., Ourcival J.-M., Piquemal K., Pontailler J.-Y., Rambal S. , Soussana J.-F.

Moreaux V.

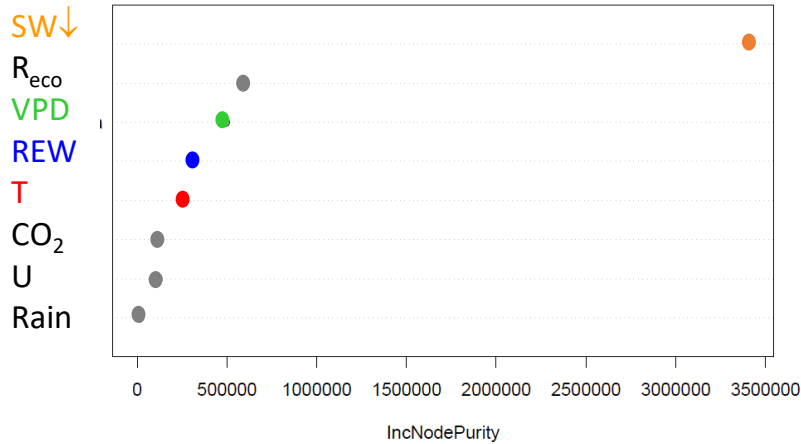# CO$_2$ fluxes and environmental factors across sites and frequency-time scales

⇒ 1. High frequency classification approach: Random Forest analysis (Breiman, 2001)

⇒ 2. Across frequency domain: Cospectra analysis with wavelet theory

Torrence C & Compo GP, 1998
Stoy et al. 2005, 2009
Vargas et al. 2010, 2011
Fares et al. 2013

⇒ 3. Inferential statistics (linear/non linear regression analysis)
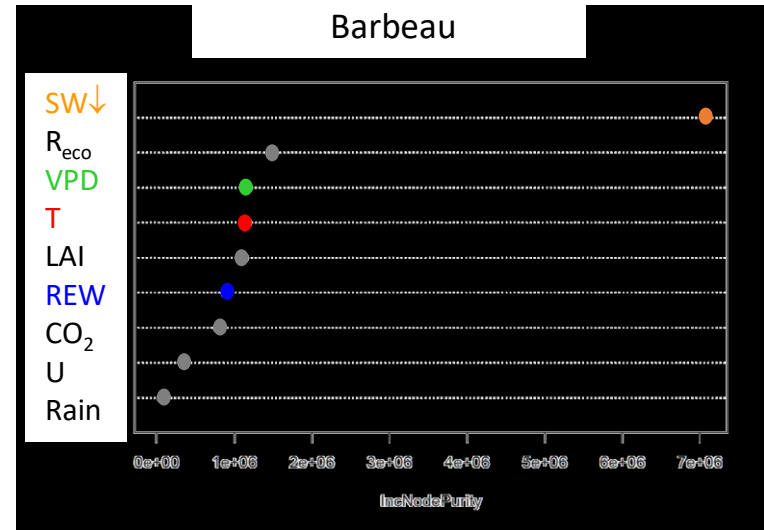
⇒ 4. Low frequency trends. Detection, attribution.
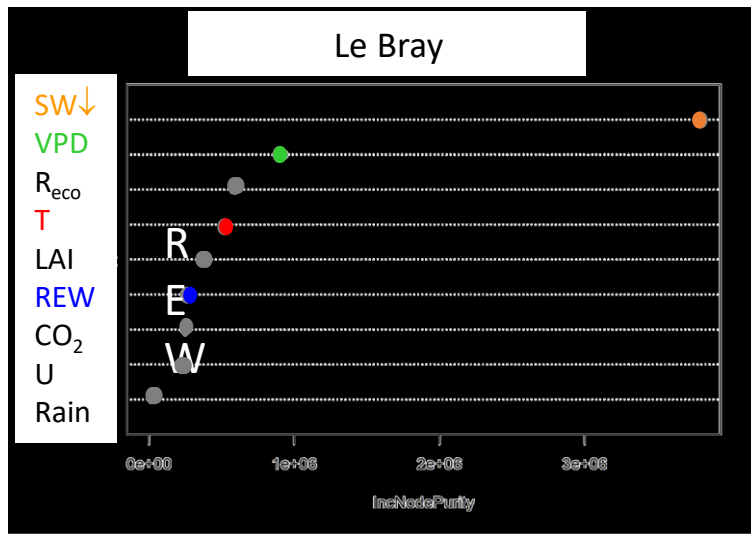
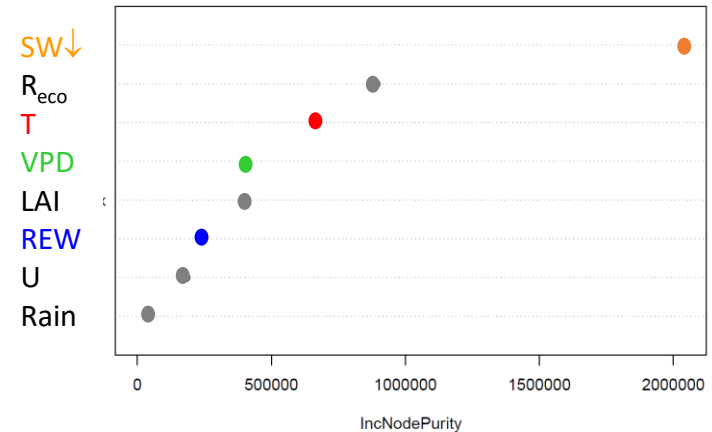- Random forest analysis at 1/2h time scale

Puechabon

Barbeau

Le Bray

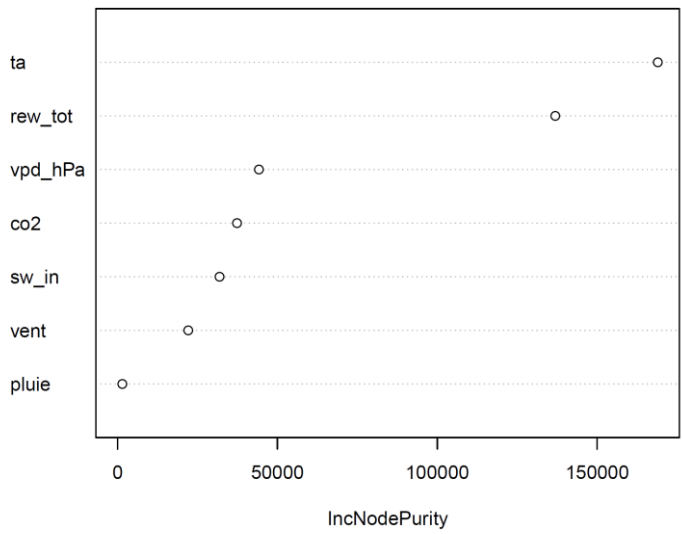Laqueuille

1. Classification of environmental factors : [ecosystem respiration (R_ECO)](#)

- Random forest analysis at 1/2h time scale

Puechabon
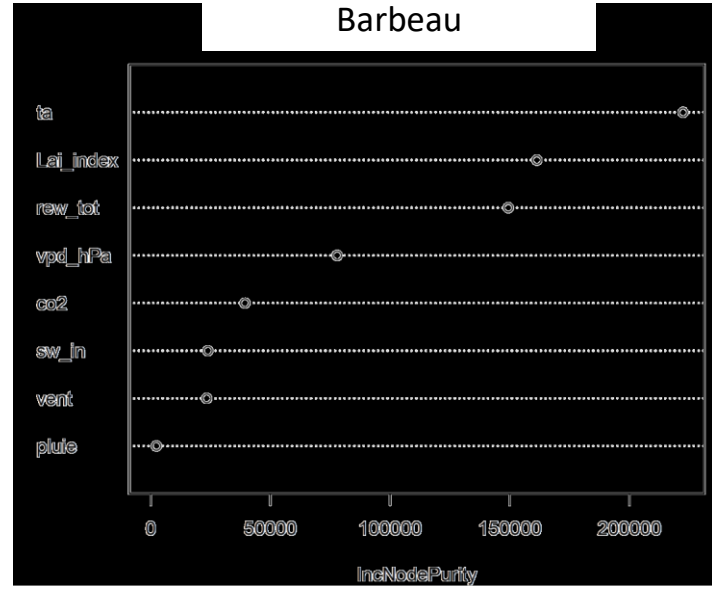

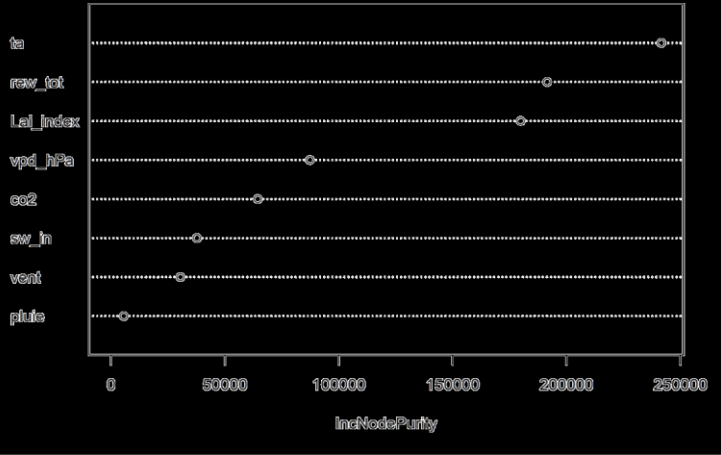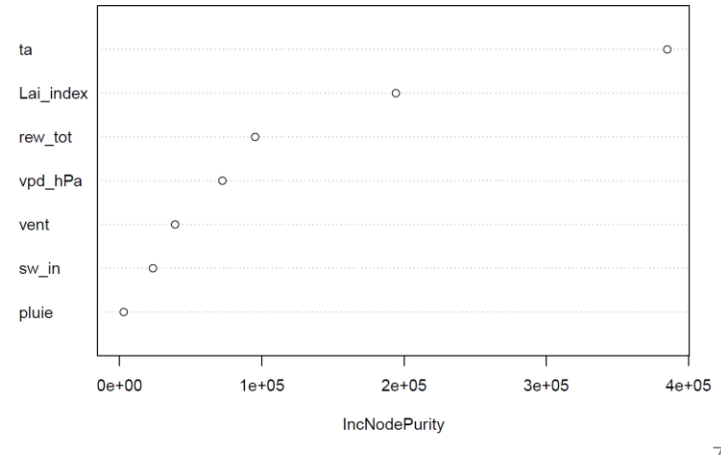Barbeau

Le Bray

Laqueuille

2. Continuous time series analysis

Wavelet analysis: scalogram and average cross-coherence graphs

- Appropriate to nonstationary and heteroscedastic time series

- Single and cross-spectra in time or frequency domains

- Assess synchrony and phasing (advance/delay between signals at given frequencies)

Cross correlograms of GPP, SW↓ and Soil Water (REW)
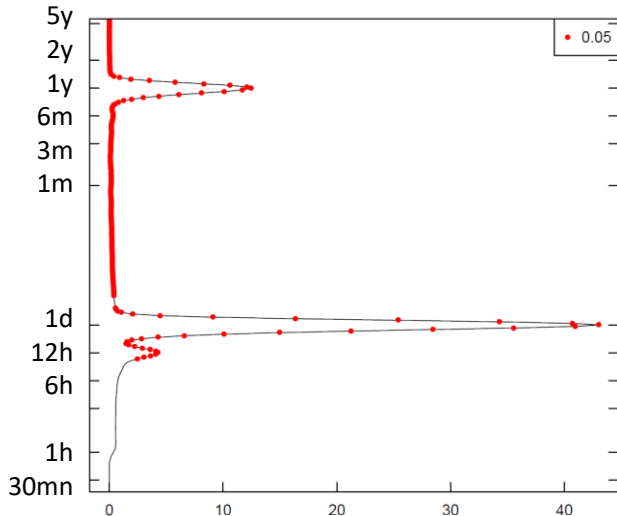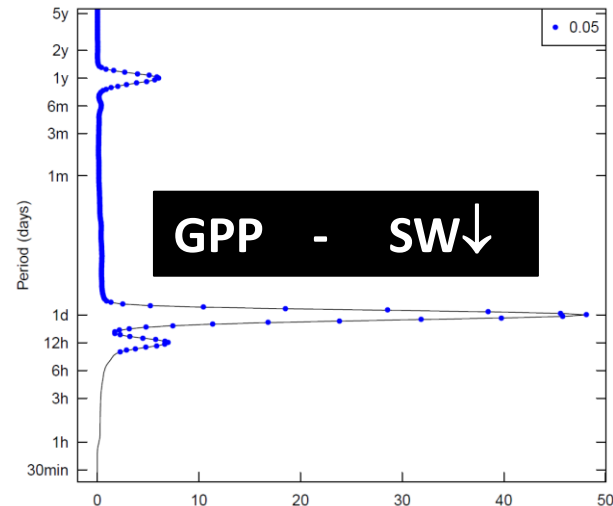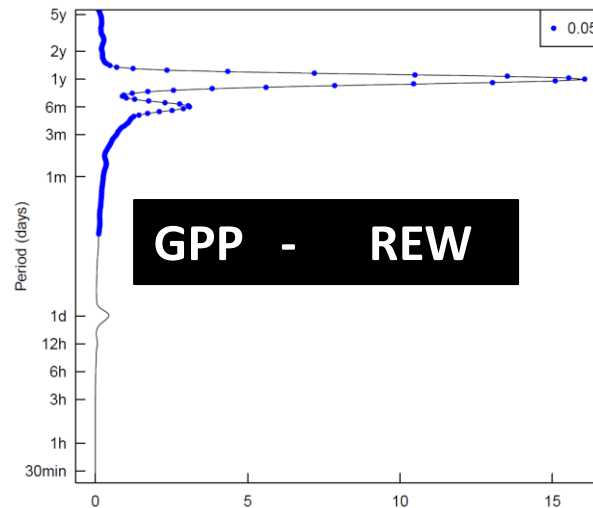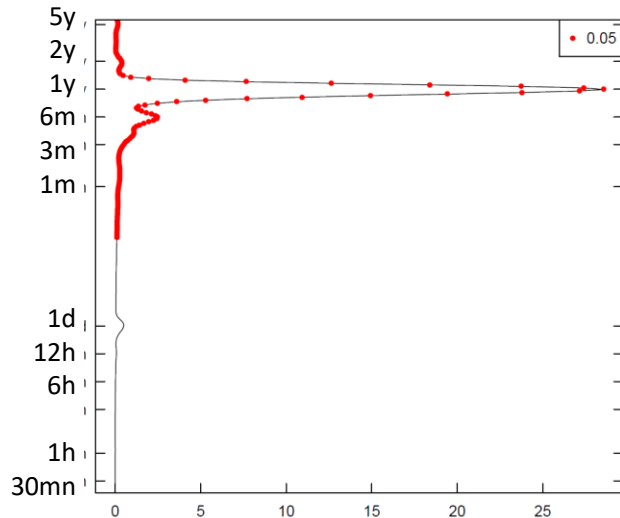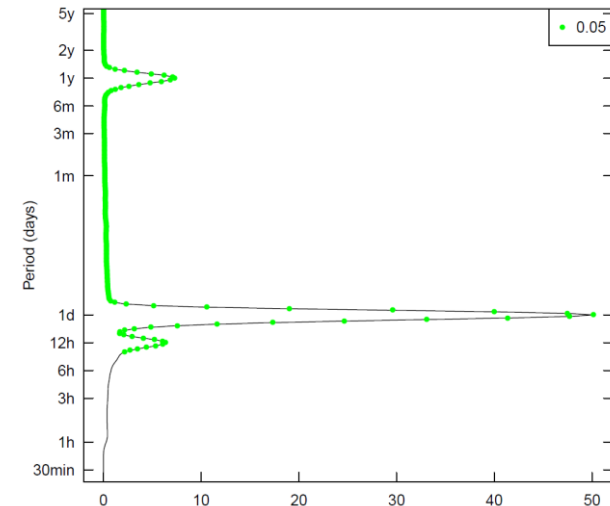
Selected scalograms: GPP - REW

Temperate deciduous broadleaf forest (FR-Fon)

Extensive grassland (FR-Laq)
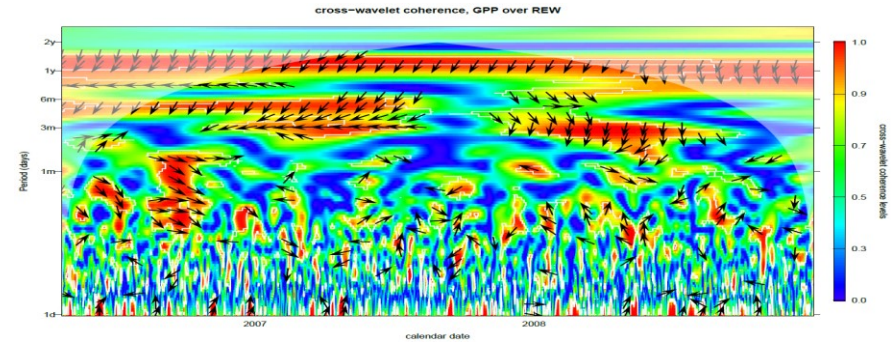
Temperate coniferous forest (FR-LBr)
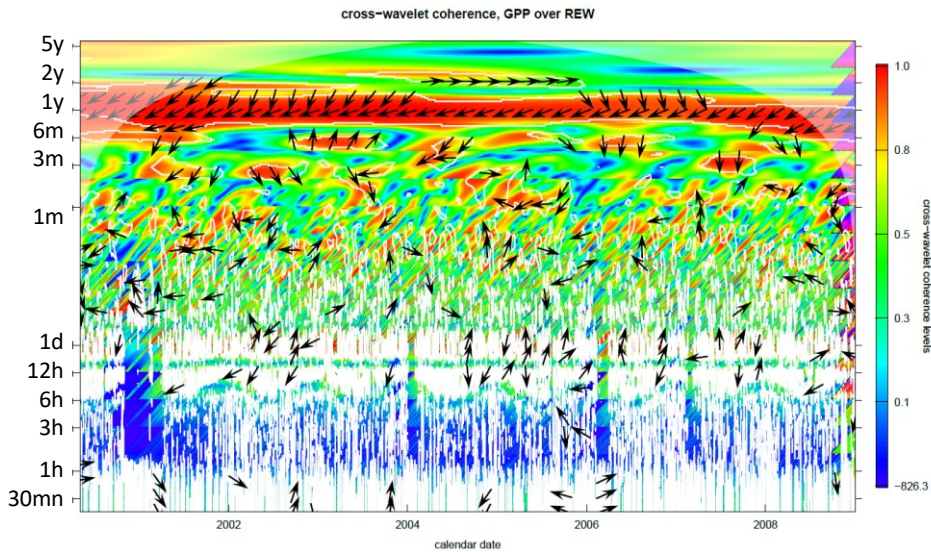
Mediterranean evergreen broadleaf forest (FR-Pue)
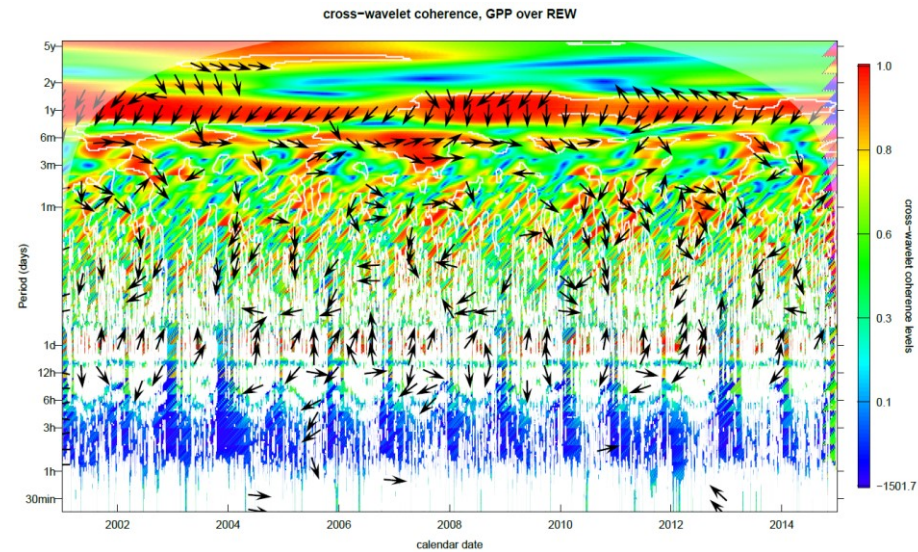
Selected scalograms: GPP - R$_{ECO}$

Temperate deciduous broadleaf forest (FR-Fon)

cross-wavelet coherence, GPP over Reco
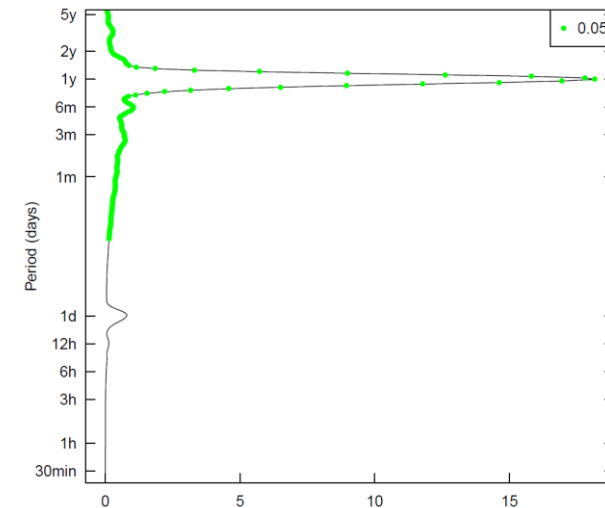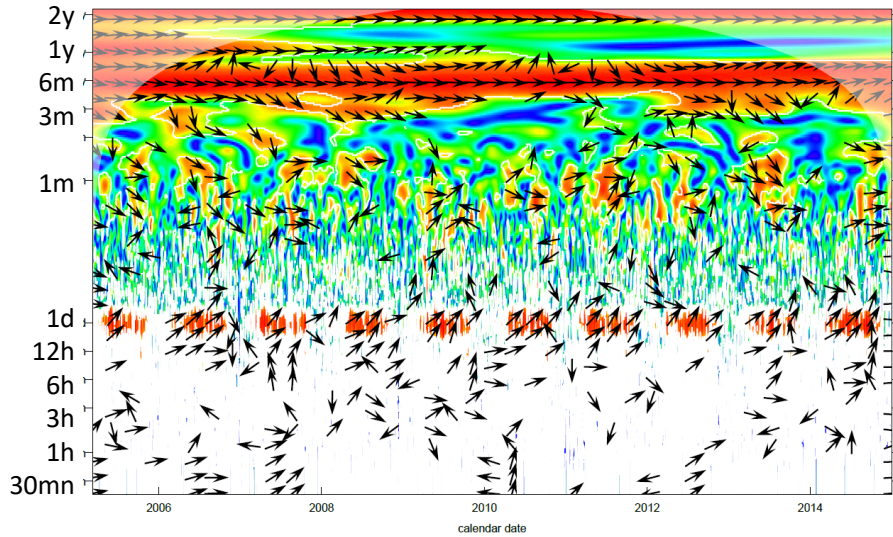
Extensive grassland (FR-Laq)

cross-wavelet coherence, GPP over Reco
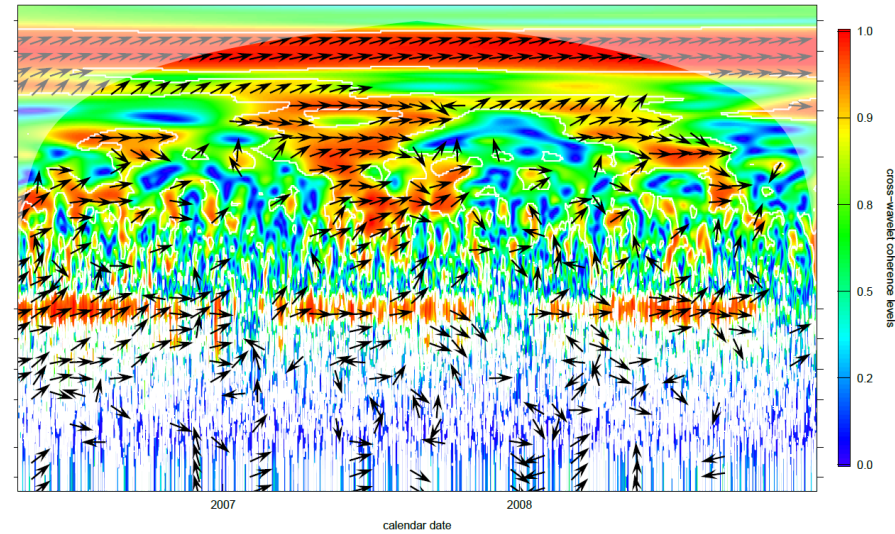
Temperate coniferous forest (FR-Bra)

cross-wavelet coherence, GPP over Reco
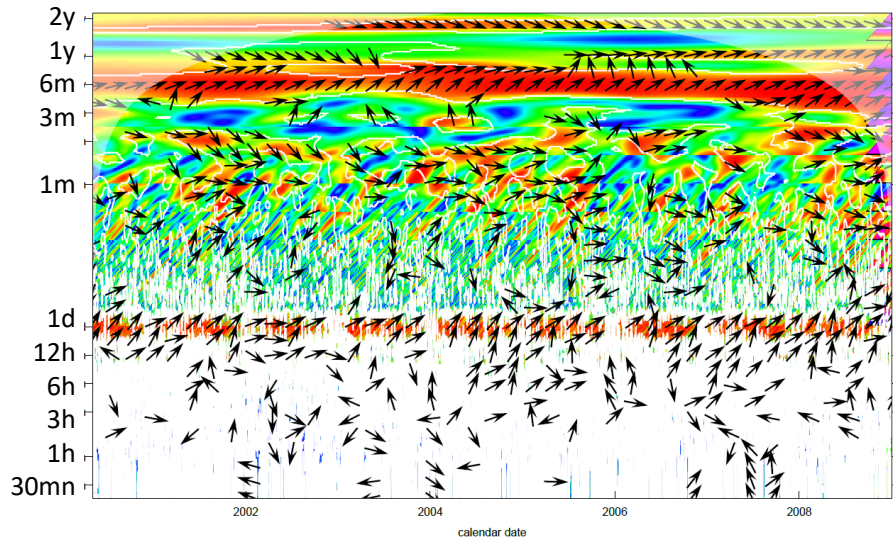
Mediterranean evergreen broadleaf forest (FR-Pue)

cross-wavelet coherence, GPP over Reco

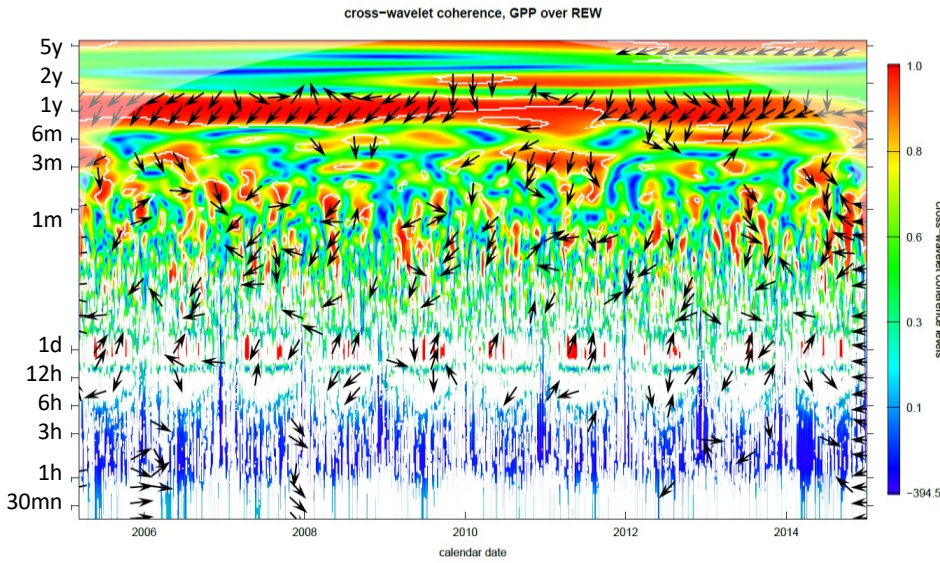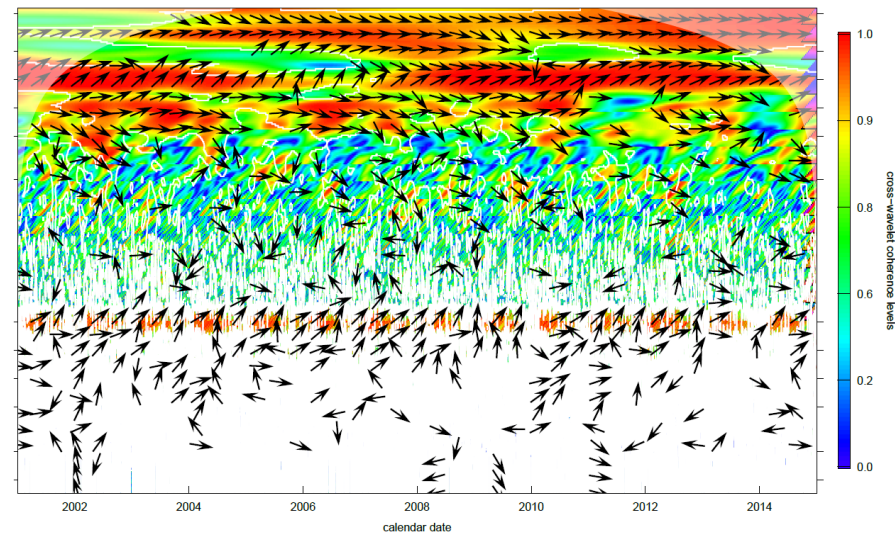# 3. Regression analysis: GPP response to environmental parameters: PPFD↓

Temperate deciduous forest (FR-Fon)

Mediterranean evergreen forest (FR-Pue)

GPP
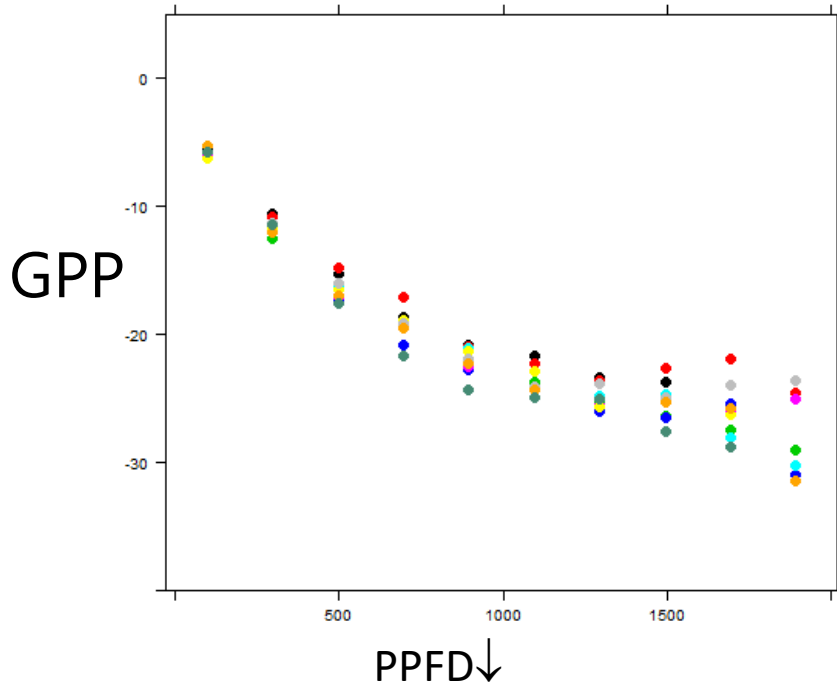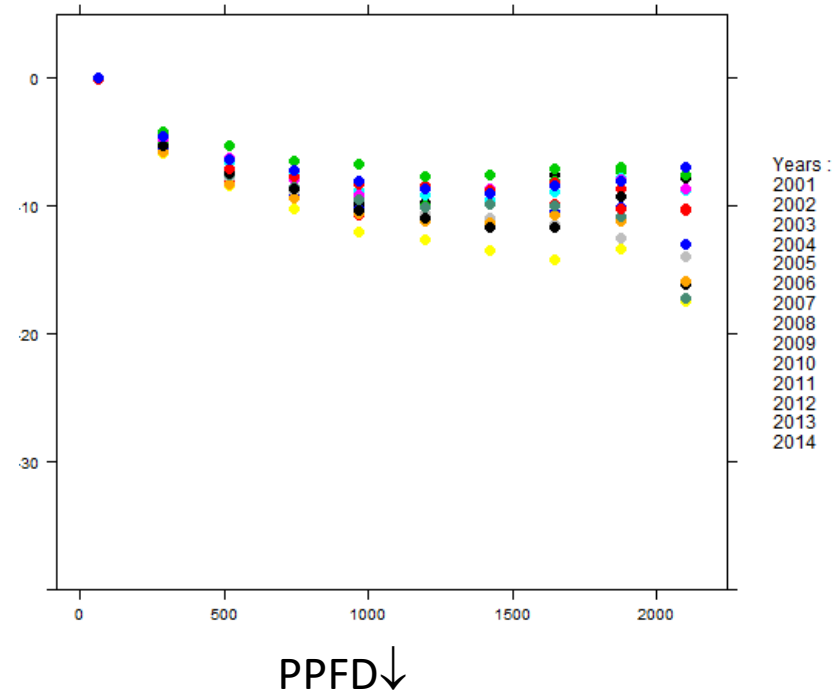
PPFD↓

PPFD↓

Similar response of ecosystem photosynthesis/LAI to PPFD among sites and between years.

3. Regression analysis: GPP response to environmental parameters: PPFD↓

Temperate deciduous forest (FR-Fon)

Mediterranean evergreen forest (FR-Pue)

GPP

LAI [5-6]

LAI [2-3]
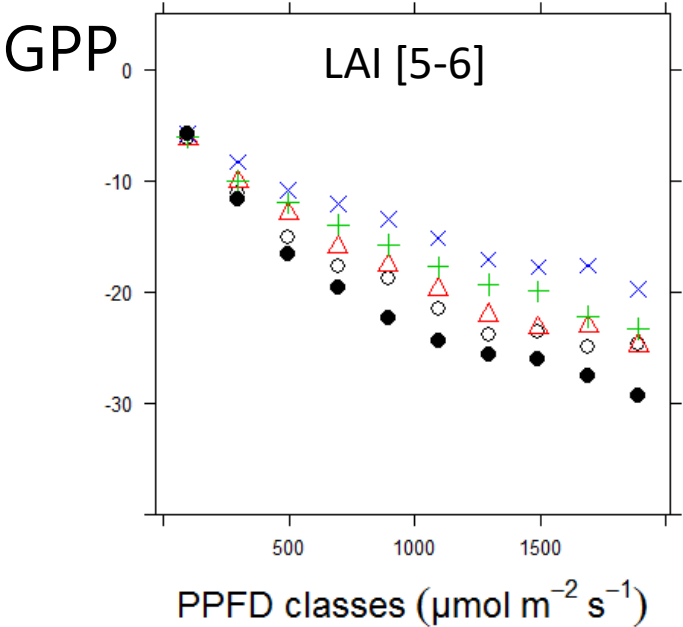
Mean of VPD classes :
VPD < 1.5 kPa   ●
VPD = 1.6 kPa   ○
VPD = 1.7 kPa   △
VPD = 2.0 kPa   +
VPD = 3.2 kPa   ×

PPFD classes ($\mu mol\ m^{-2}\ s^{-1}$)

PPFD classes ($\mu mol\ m^{-2}\ s^{-1}$)
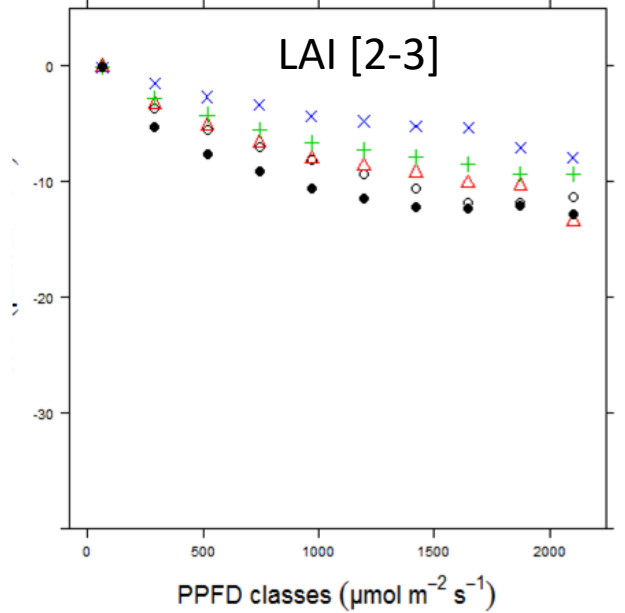
The response of ecosystem photosynthesis/LAI to PPFD x VPD

is similar among sites.

3. Regression analysis: R_{ECO} response to temperature

Temperate deciduous forest (FR-Fon)

Mediterranean evergreen forest (FR-Pue)

Years :
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014

R_{ECO}

Tair (35m) classes

Tair (10m) classes
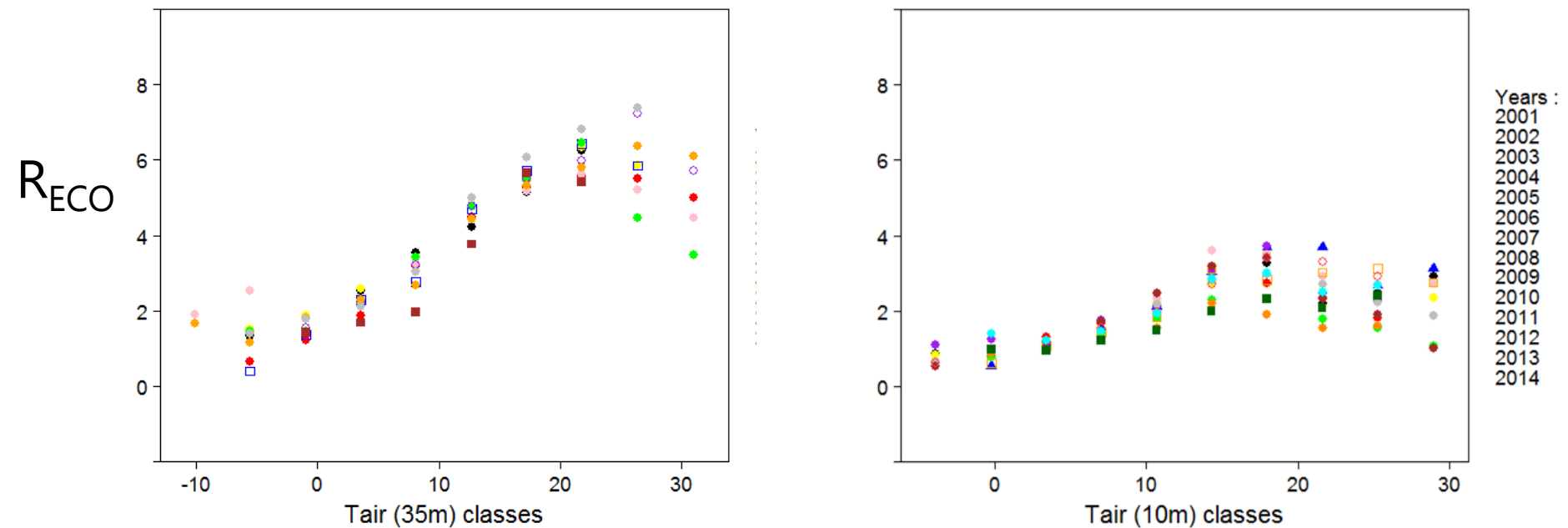
Same response of ecosystem respiration to temperature among sites and between years.

Large similarities among all sites - years.

- Photosynthesis correlated with:

$$SW\downarrow \; > \; Air\;VPD \; > \qquad \begin{cases} \text{Air Temperature (Fr-Laq FR-LBr)} \\[1em] \text{Soil water} \qquad \text{(Fr-Fon, Fr-Pue)} \end{cases}$$

- Respiration correlated with:

Temperature > Air VPD > soil water content

4. Low frequency changes

FR-Fon

NEE, gC m^{-2} y^{-1}
2005-2014

dNEE/dt = 9.15 gC m^{-2} y^{-2}

FR-Pue

NEE, gC m^{-2} y^{-1}
2000-2014

dNEE/dt = 0.02 gC m^{-2} y^{-2}

FR-LBr

NEE, gC m^{-2} y^{-1}
1998-2008

dNEE/dt = 14.5 gC m^{-2} y^{-2}
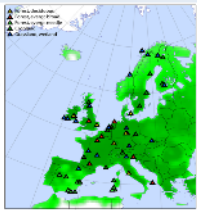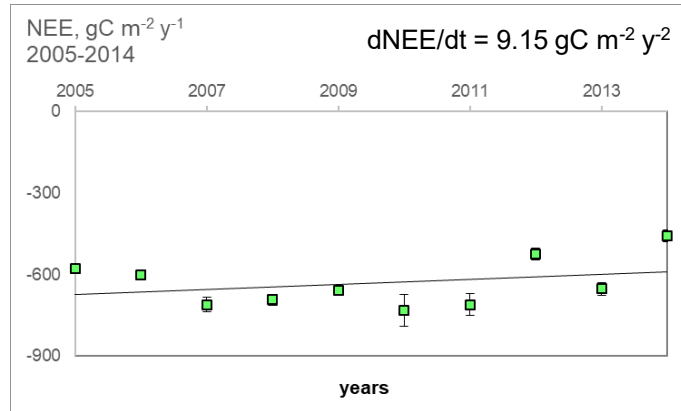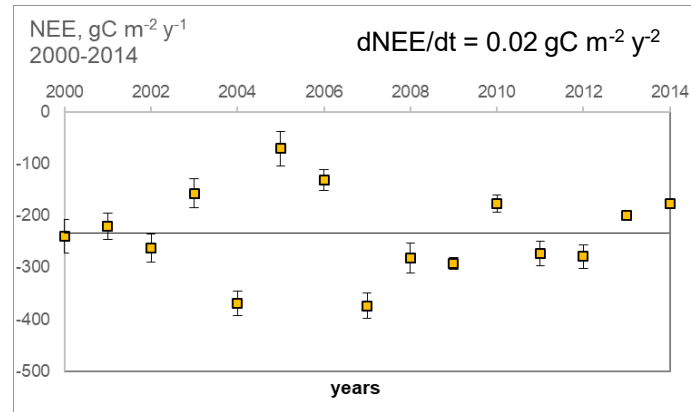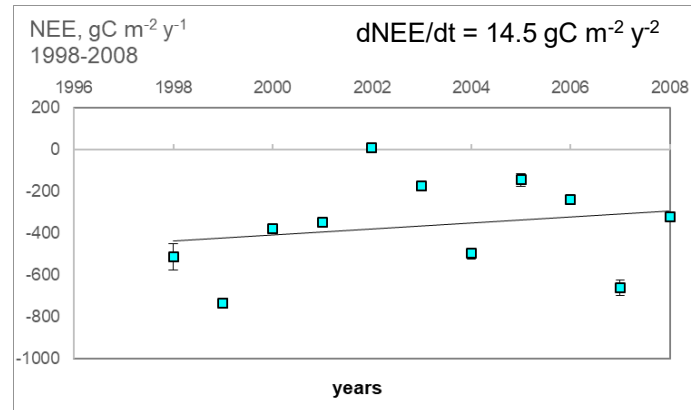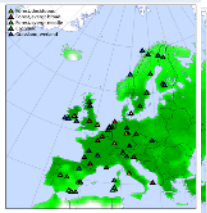
4. Low frequency changes: are they significant ?

Longterm trend analysis: **Example of Barbeau: FR-Fon**   after *Baldocchi et al. 2018*

Standard deviation of NEE

Linear regression slope for the trend

IAV, gC m^{-2} y^{-1}
2005-2014

Number of years

Detectable trend threshold (gC m^{-2} y^{-2})
2005-2014

Number of years
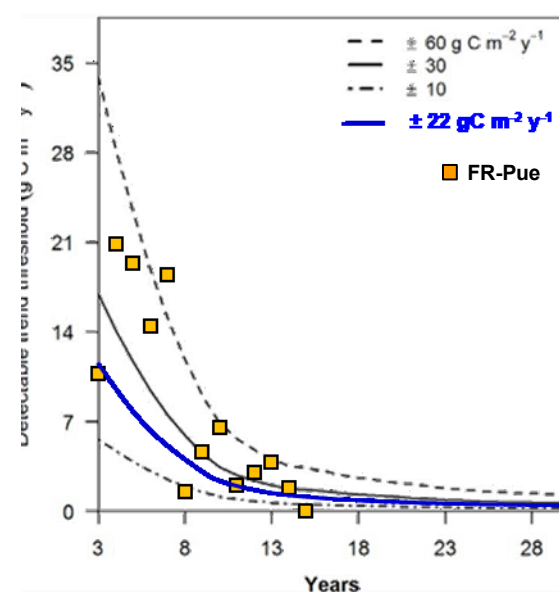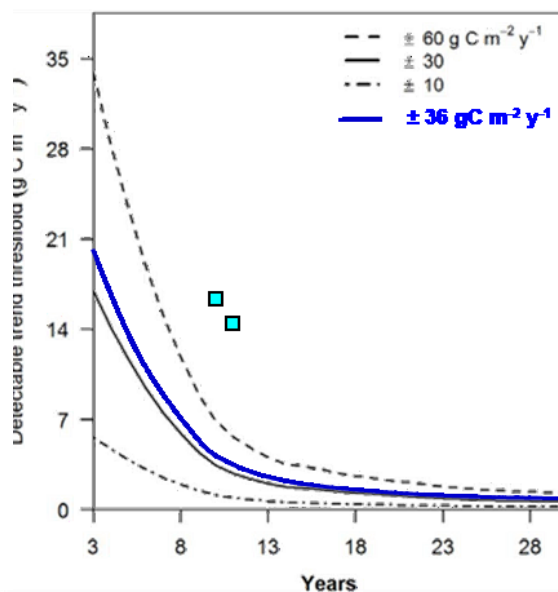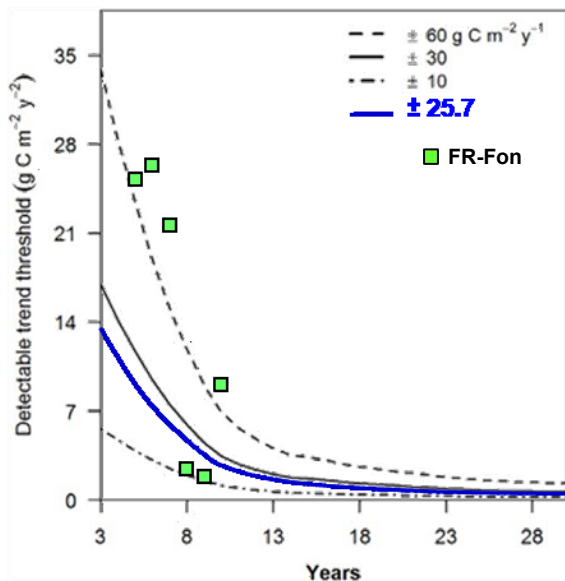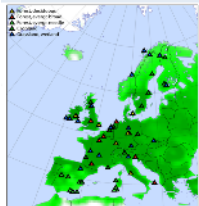
Temporal trends across sites: significant but not consistent

Few thoughts to share together

- Climate drivers of CO_2 exchanges are strikingly similar among a range of ecosystems
  - SW$\downarrow$, Tair, Soil Water, air water vapour saturation deficit

- Respiration is coupled more tightly with GPP in ecosystems with lesser biomass and soil carbon stocks
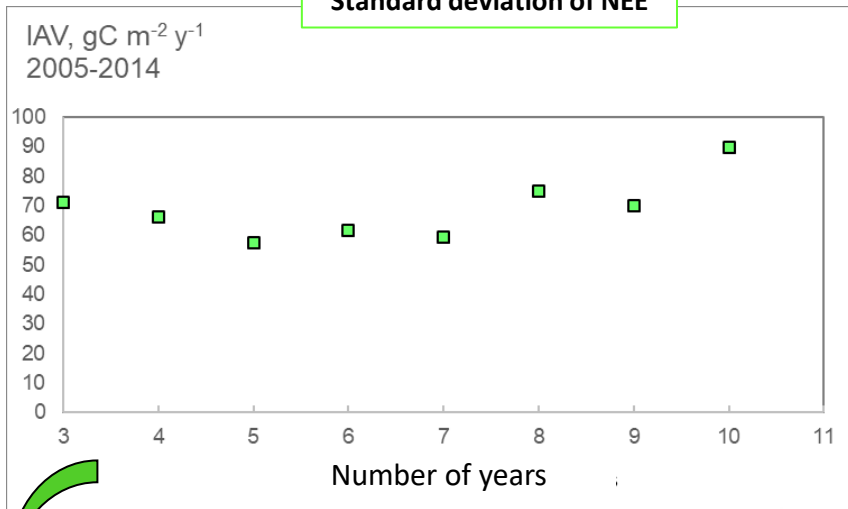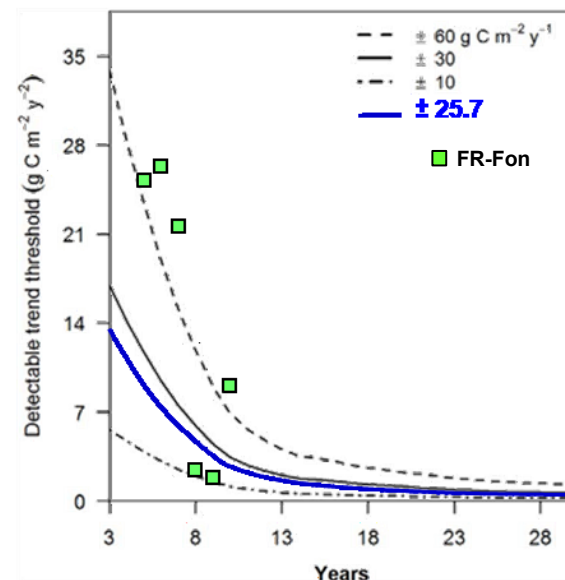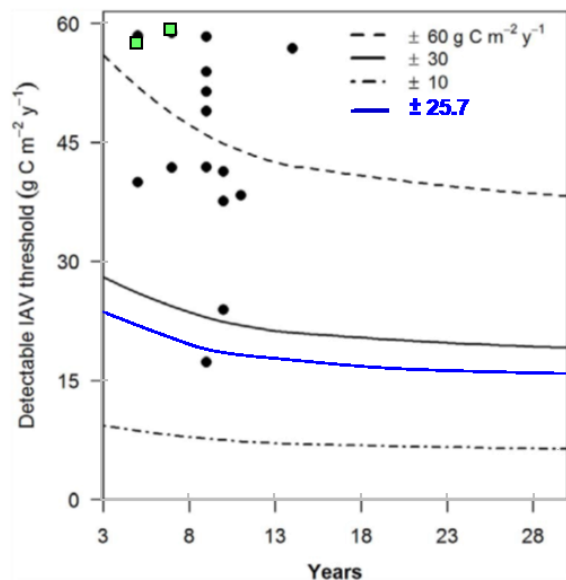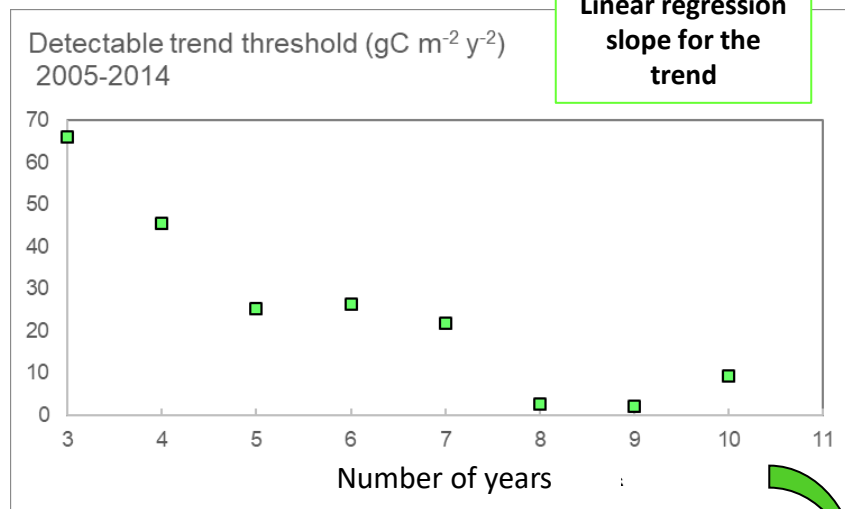 - Faster transfer of C from foliage to soil
  - Larger fraction of autotrophic respiration

- Cumulative effects of drifting variables (e.g. CO2) are barely visible.
  - Uncertainty and lack of temporal consistency still too large
  - Confounding effects (growth, age,…) are dominant

- Obtained time series so far:
  - numerical analysis of fluxes data say little about ecosystem functioning
  - long for scientists but short for the ecosystems !

And few thoughts for future research

From naive statistical correlations to causal attribution of biogeochemical fluxes:

- Transform ecosystem stations, « Flux towers » into terrestrial biogeochemical observatories where :

  - Monitoring of environmental drivers completed (Ozone, Ndeposition, …)

  - Fluxes measurements can be better ascribed to processes

- In-depth, knowledge-guided time series investigations

- Develop plant growth processes modelling !!

  Plant growth drives photosynthesis !

  But what is driving plant growth ?

Acknowledgements

- Sites :
  - Berbigier P., J.-M. Bonnefond, Chipeaux C., Loustau D.
  - Berveiller D., Delpierre N., Dufrene E., Pontailler J.-Y.,
  - Darsonville O., Falcimagne R., Klump K., Soussana J.-F.
  - Cuntz M., Granier A., Gross P., Lily J.-B., Longdoz B.
  - Joffre R., Limousin J-M., Ourcival J.-M., Piquemal K., Rambal S.
  - Buysse P., Cellier P., Loubet B.
  - Brut A., Ceschia E., Tallec T.

- Data analysis:
  - Moreaux V., Brut A., Delpierre N., Dufrene E.,Klump K., Lafont S., Limousin J.-M., Longdoz B., Loubet B., Loustau D., Tallec T.

- CESEC project: Cross-comparison of Reco and GPP in response to environmental parameters: synthesis over French forest ecosystems (ADEME)

- RINGO project: Long term trends and variability on carbon fluxes: uncertainties and detection ability of heterogeneous network. (H2020 / INFRAIA, TASK 3.5)