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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.

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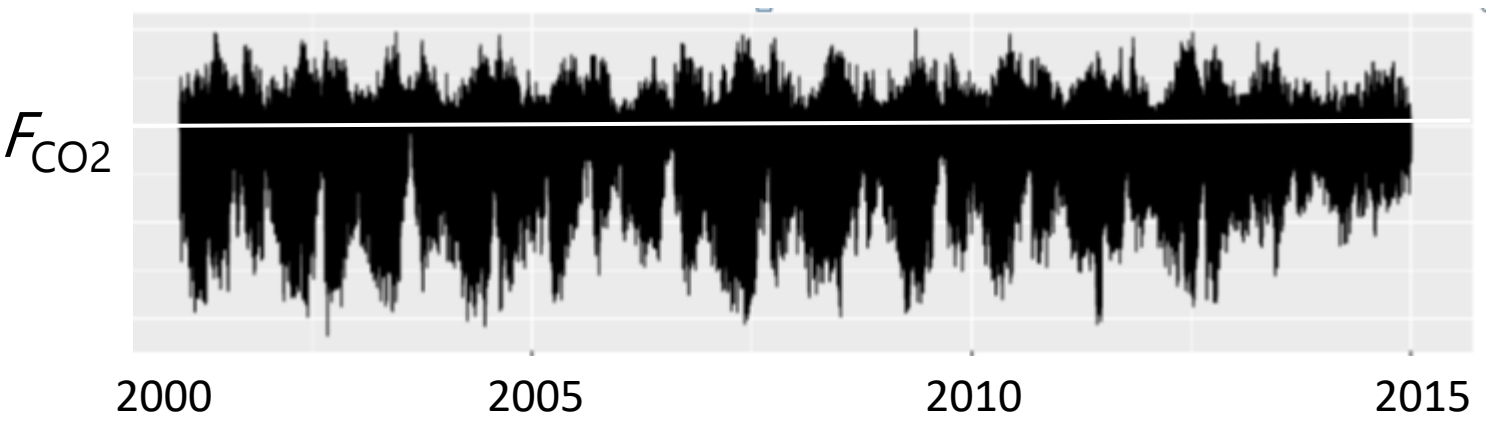
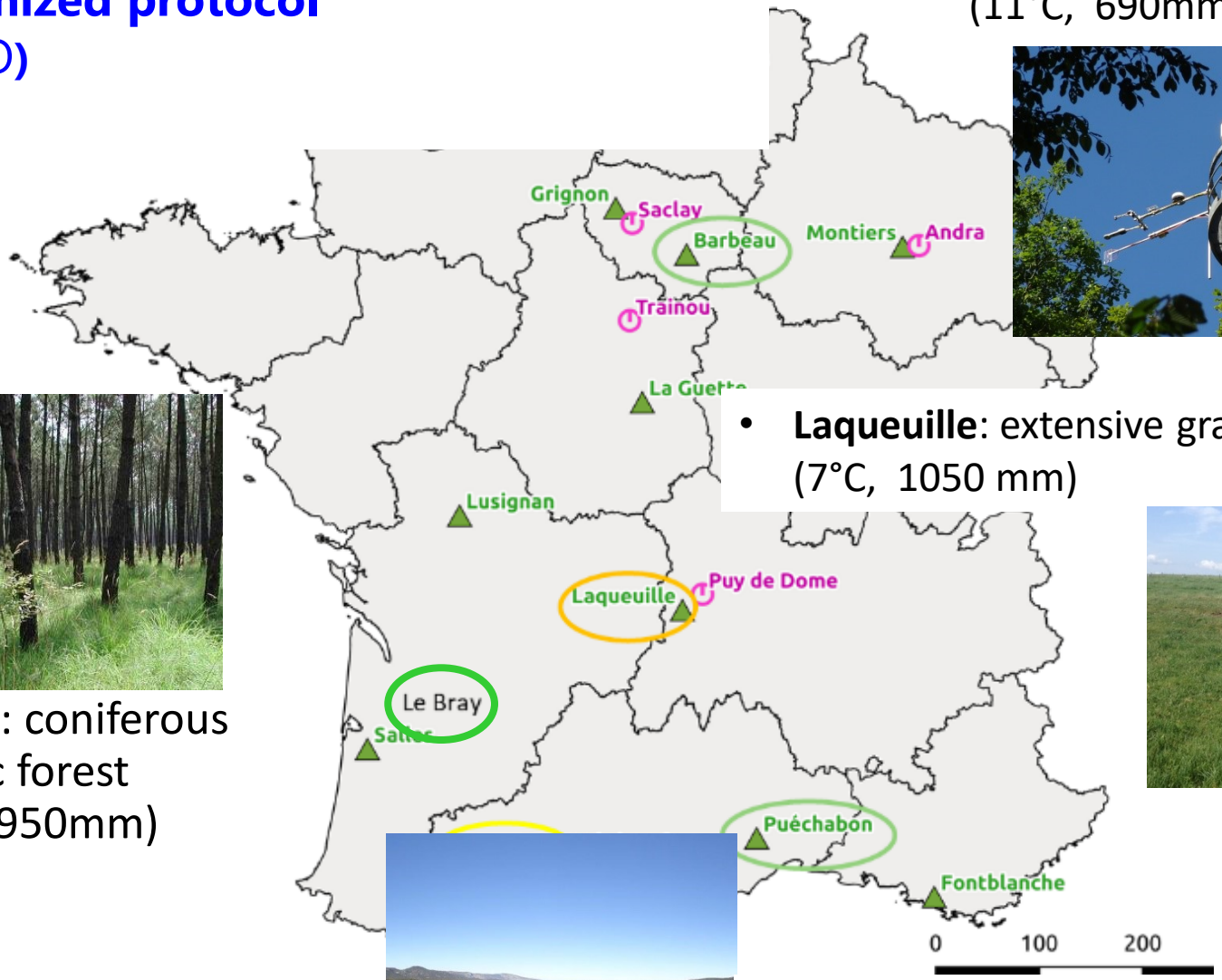
1996 - 2035



At half the way: what is still to be achieved ?

Sites with minimal management
Data filtered & processed using homogenized protocol
(EddyPRO)

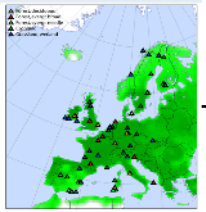
- **Barbeau** : old growth mixed broadleaved forest (11°C, 690mm)



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

- **Le Bray**: coniferous Atlantic forest (13°C, 950mm)

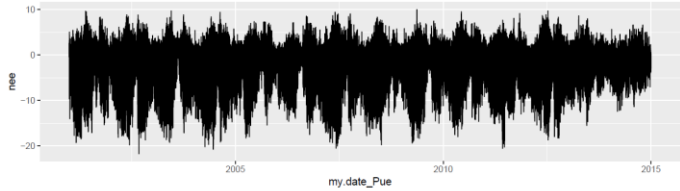
- **Puechabon**: old-growth evergreen Quercus coppice (14°C, 910 mm)



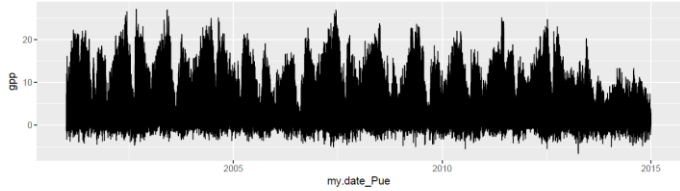
Time series analysed

Puechabon

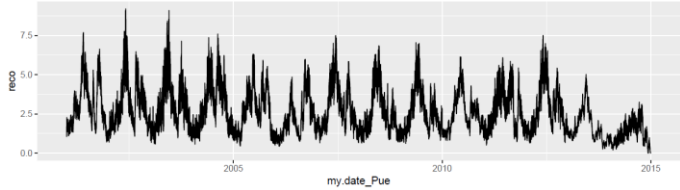
F_{CO2}



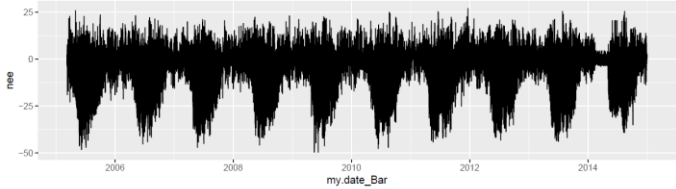
GPP

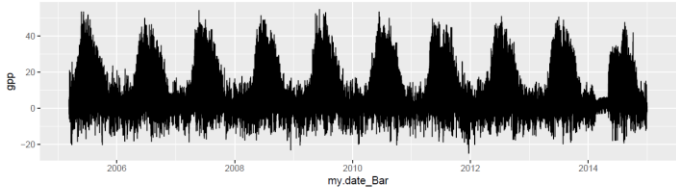


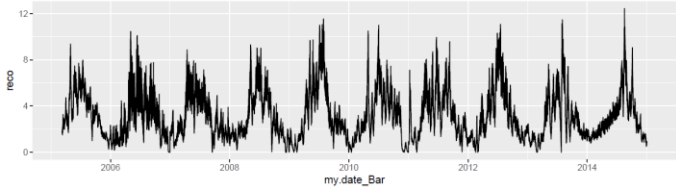
R_{ECO}



Barbeau

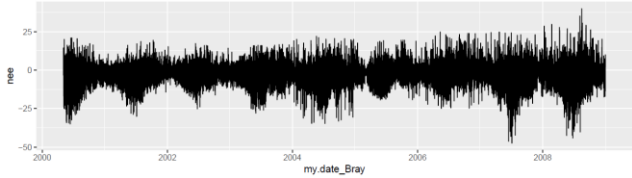




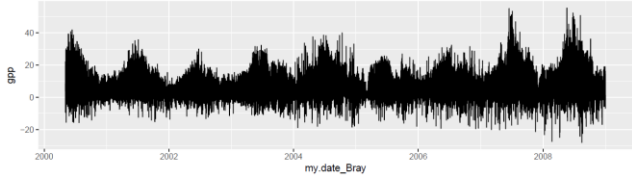


Le Bray

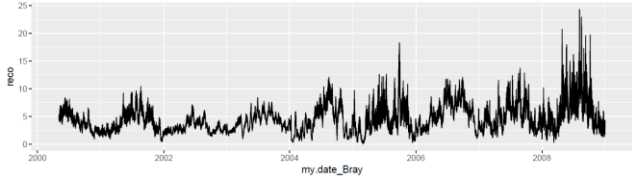
F_{CO2}



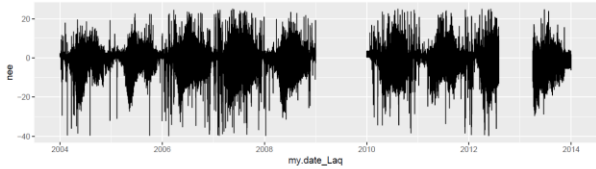
GPP

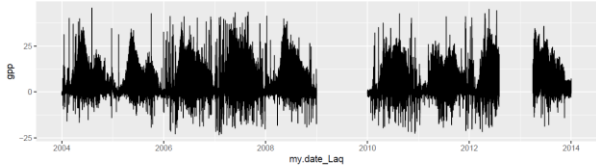


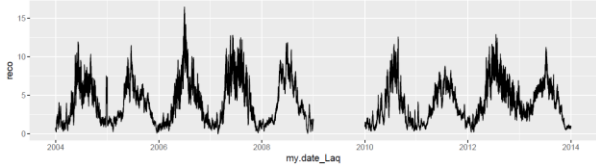
R_{ECO}



Laqueuille





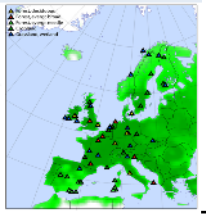


What fluxes are telling us so far ?

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

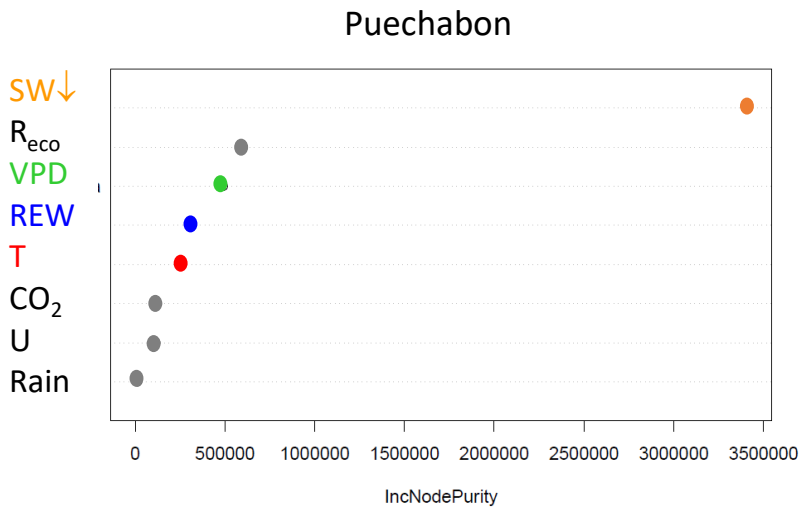
Torrence C & Compo GP, 1998
Stoy et al. 2005, 2009
Vargas et al. 2010, 2011
Fares et al. 2013

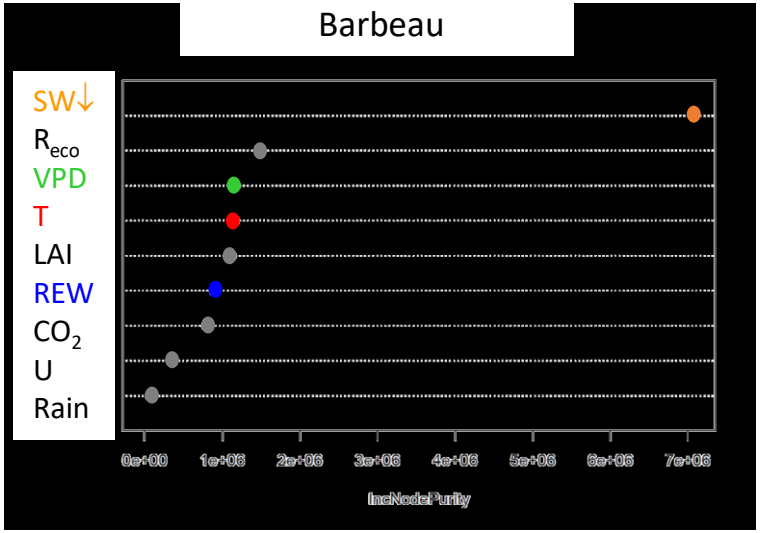
⇒ 3. Inferential statistics (linear/non linear regression analysis)

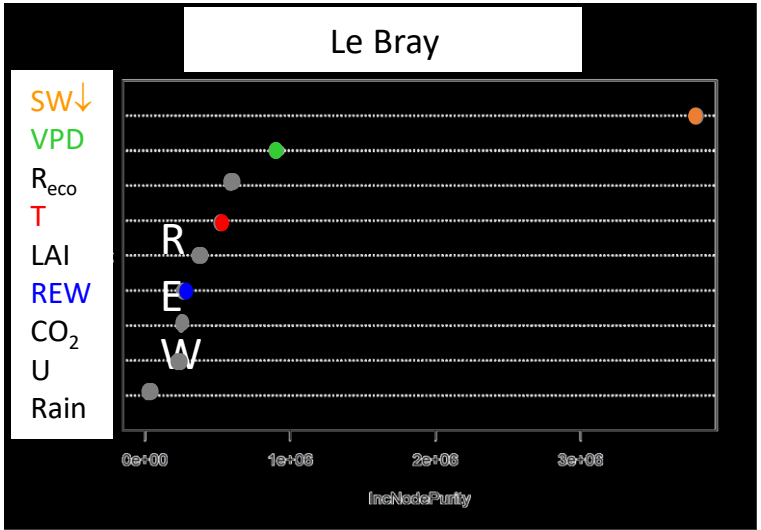
⇒ 4. Low frequency trends. Detection, attribution.

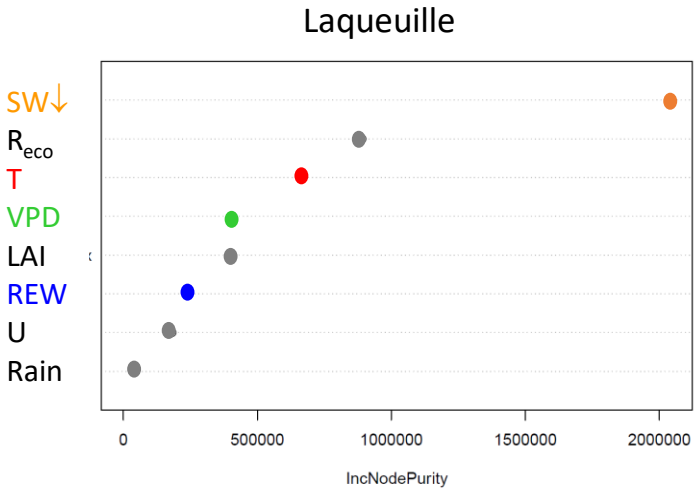
1. Classification of environmental factors : ecosystem photosynthesis (GPP)

- Random forest analysis at 1/2h time scale





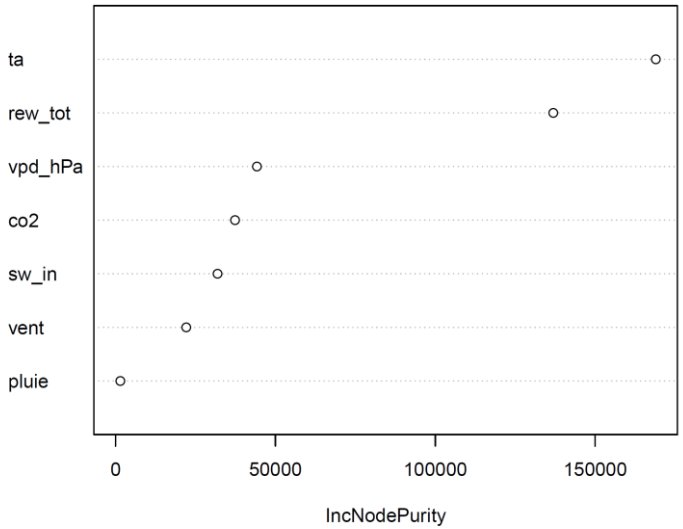




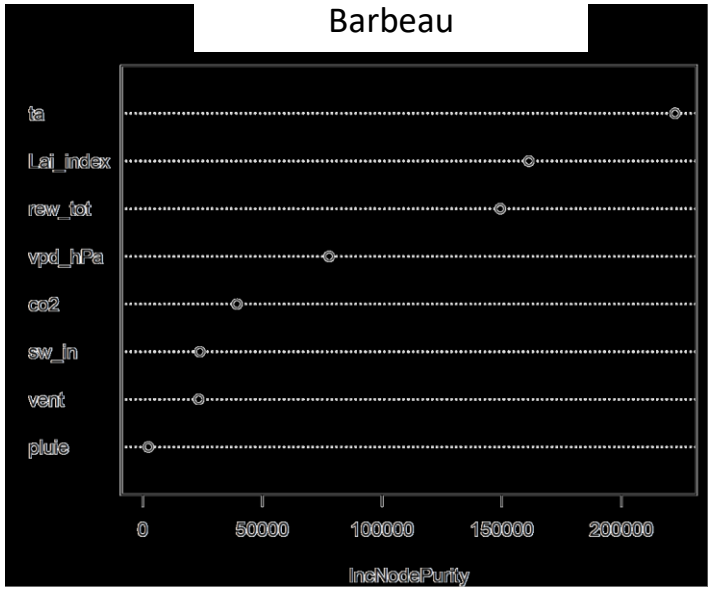
1. Classification of environmental factors : ecosystem respiration (R_{ECO})

- Random forest analysis at 1/2h time scale

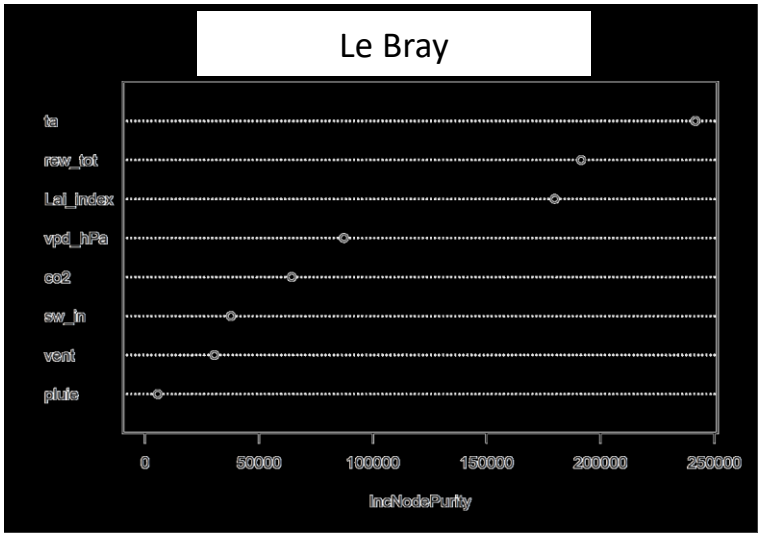
Puechabon



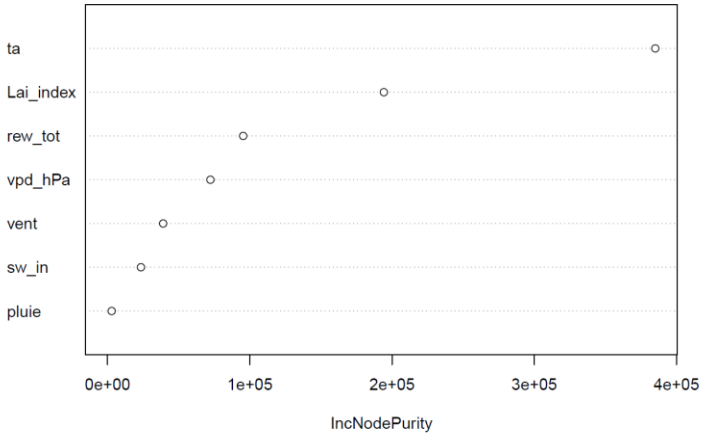
Barbeau



Le Bray



Laqueuille



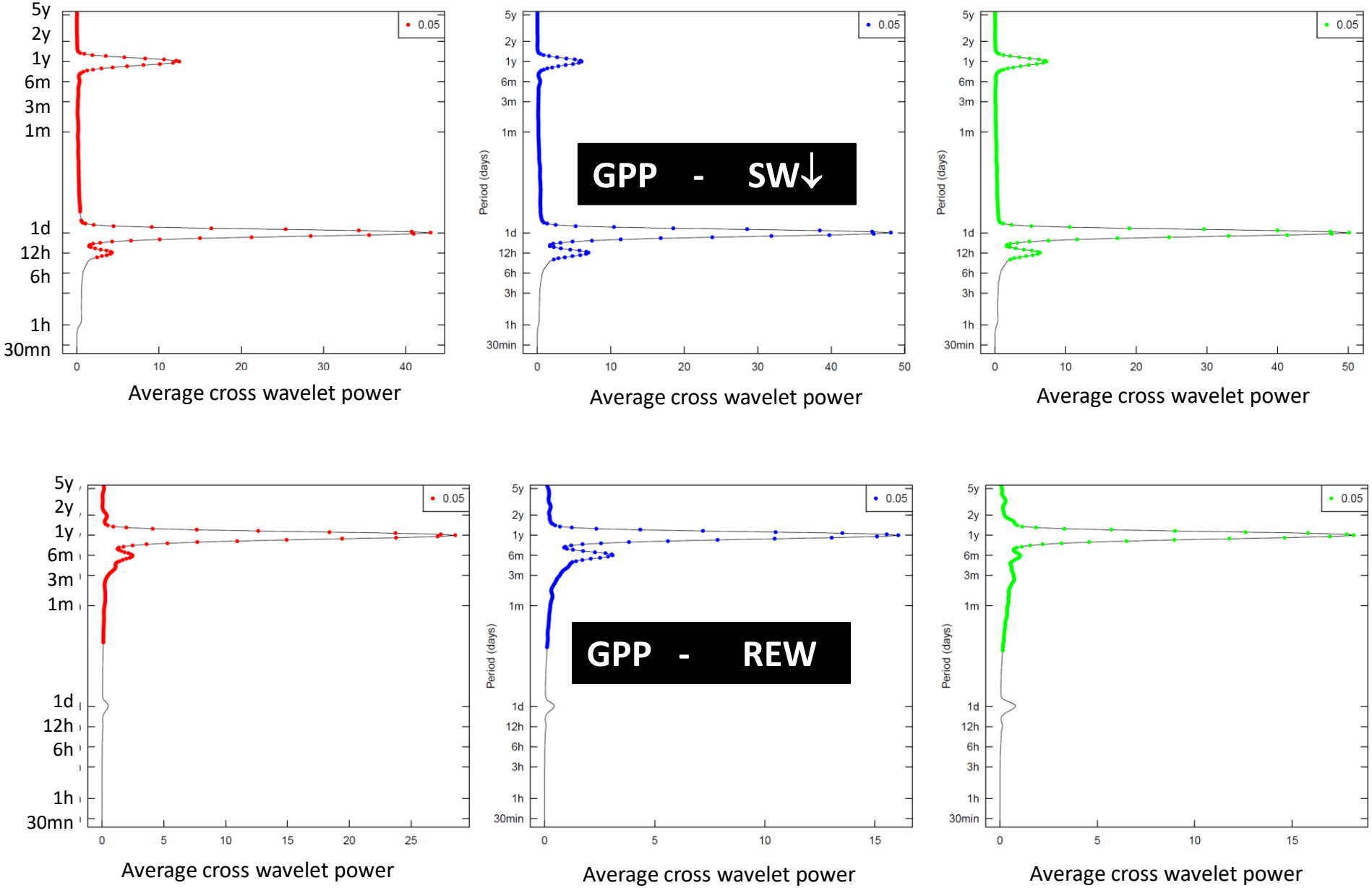
2. Continuous time series analysis

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)

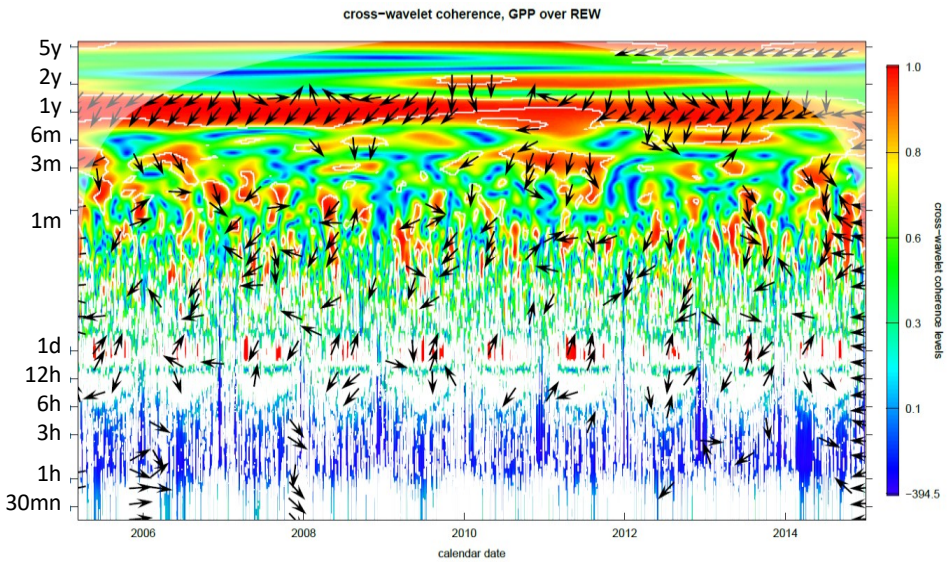
Cross correlograms of GPP, SW↓ and Soil Water (REW)

Barbeau | Puechabon | Le Bray

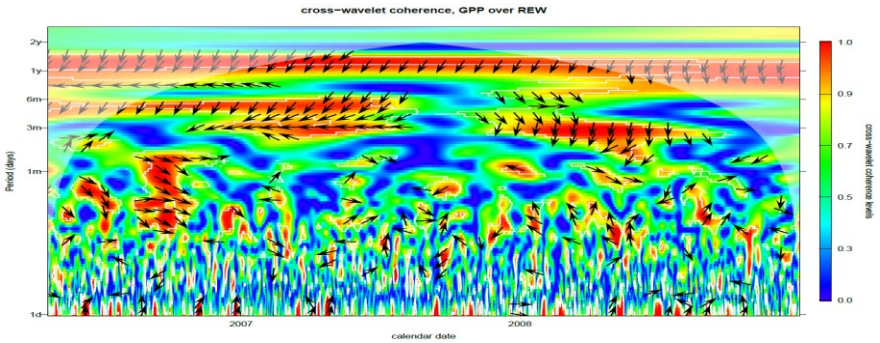


Selected scalograms: GPP - REW

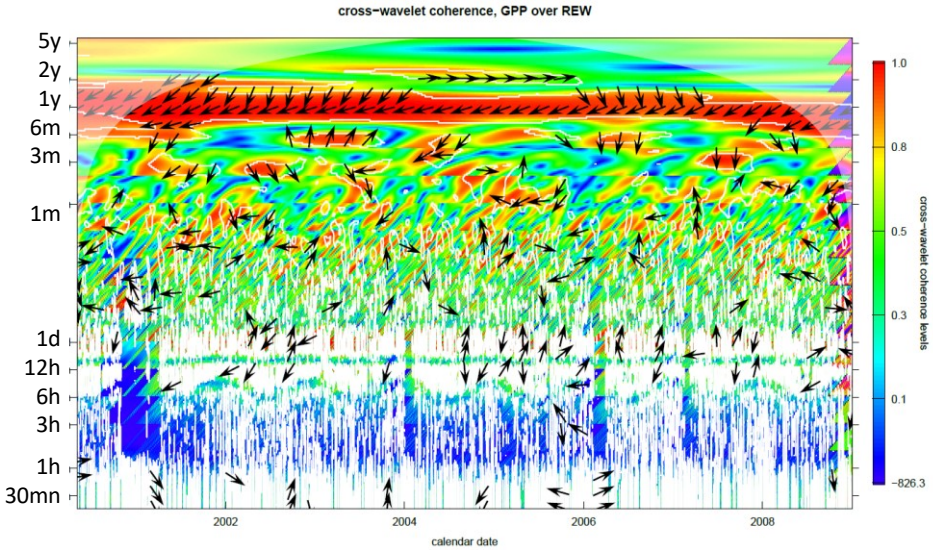
Temperate deciduous broadleaf forest (FR-Fon)



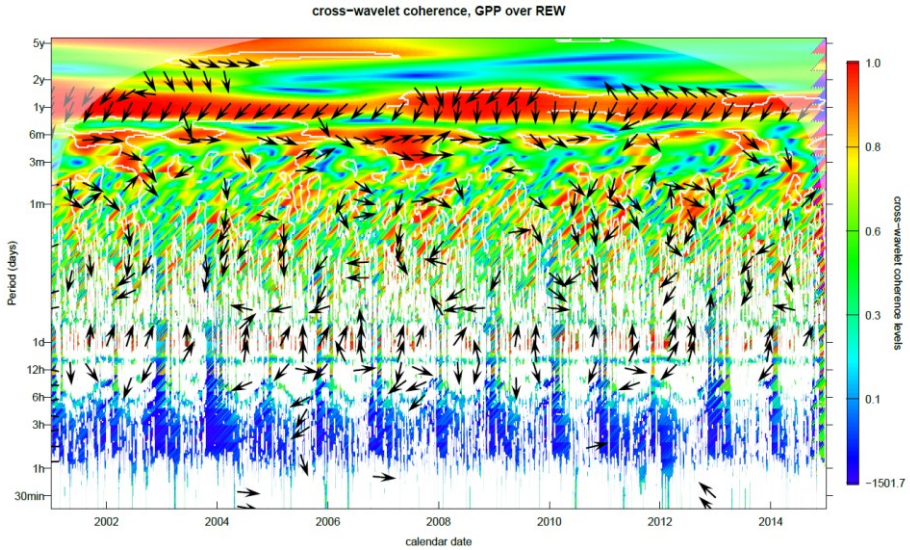
Extensive grassland (FR-Laq)



Temperate coniferous forest (FR-LBr)

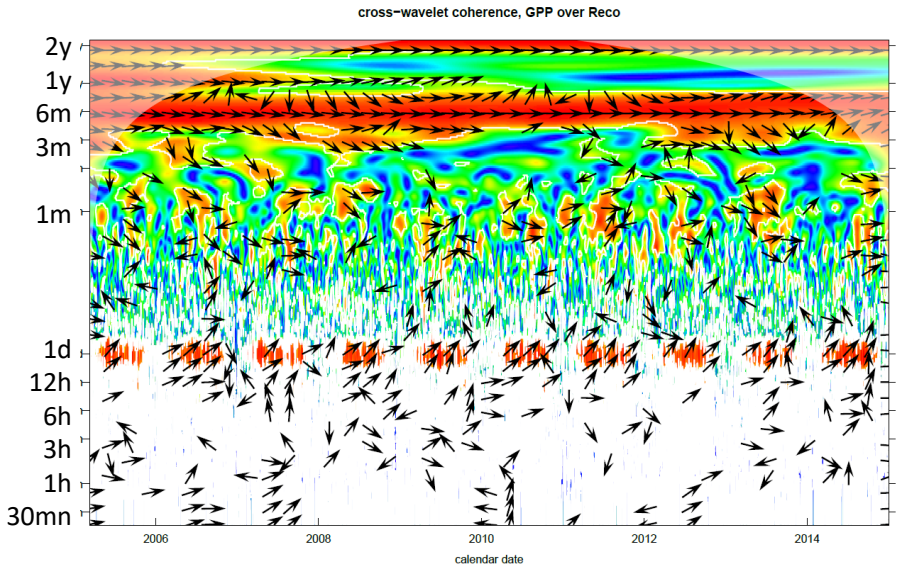


Mediterranean evergreen broadleaf forest (FR-Pue)

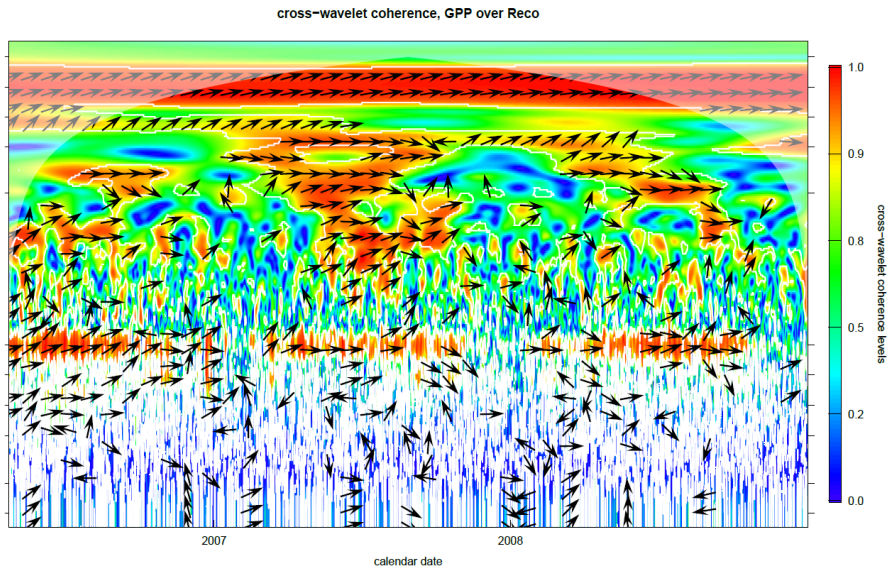


Selected scalograms: GPP - R_{ECO}

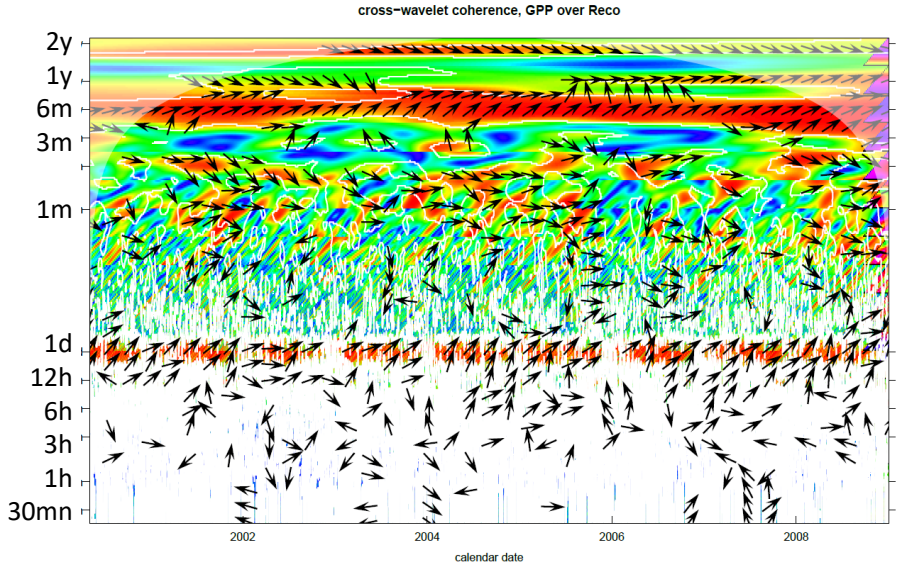
Temperate deciduous broadleaf forest (FR-Fon)



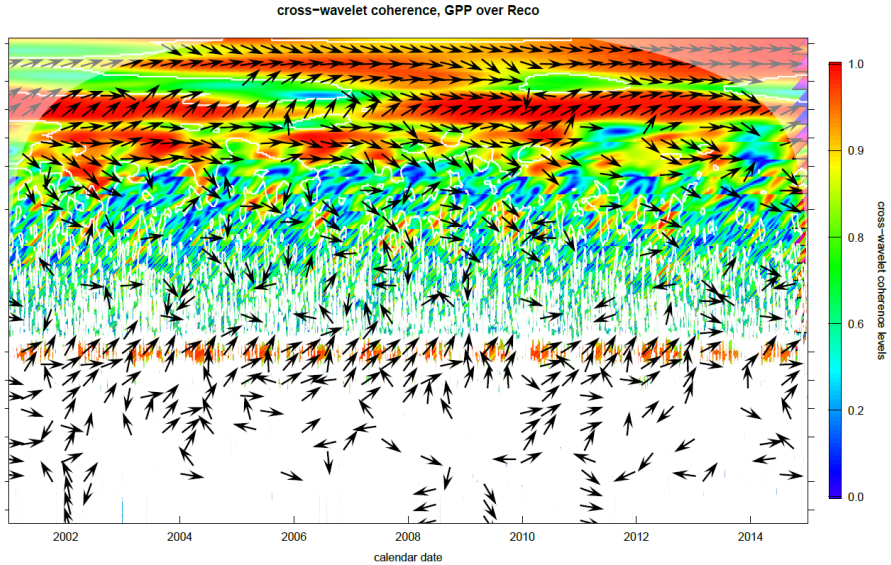
Extensive grassland (FR-Laq)



Temperate coniferous forest (FR-Bra)



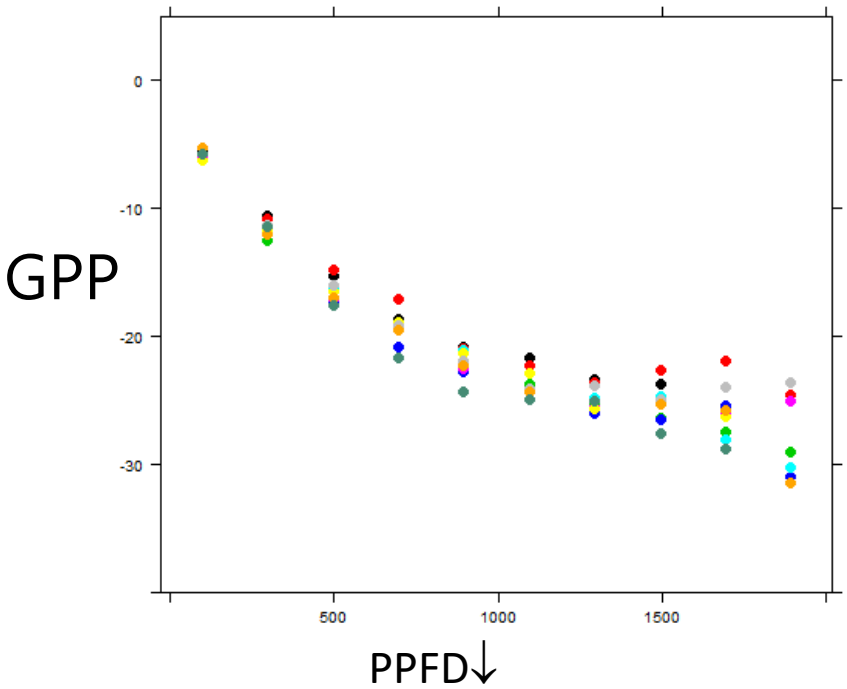
Mediterranean evergreen broadleaf forest (FR-Pue)



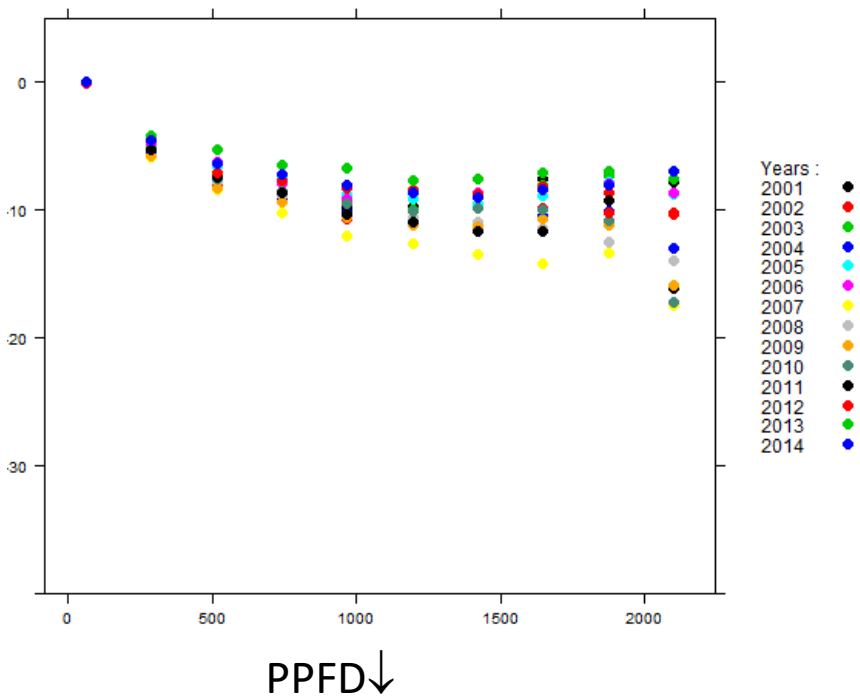
3. Regression analysis: GPP response to environmental parameters: PPFD↓

CESEC Project overview (2015-2017)
Moreaux et al. 2018, ADEME report

Temperate deciduous forest (FR-Fon)



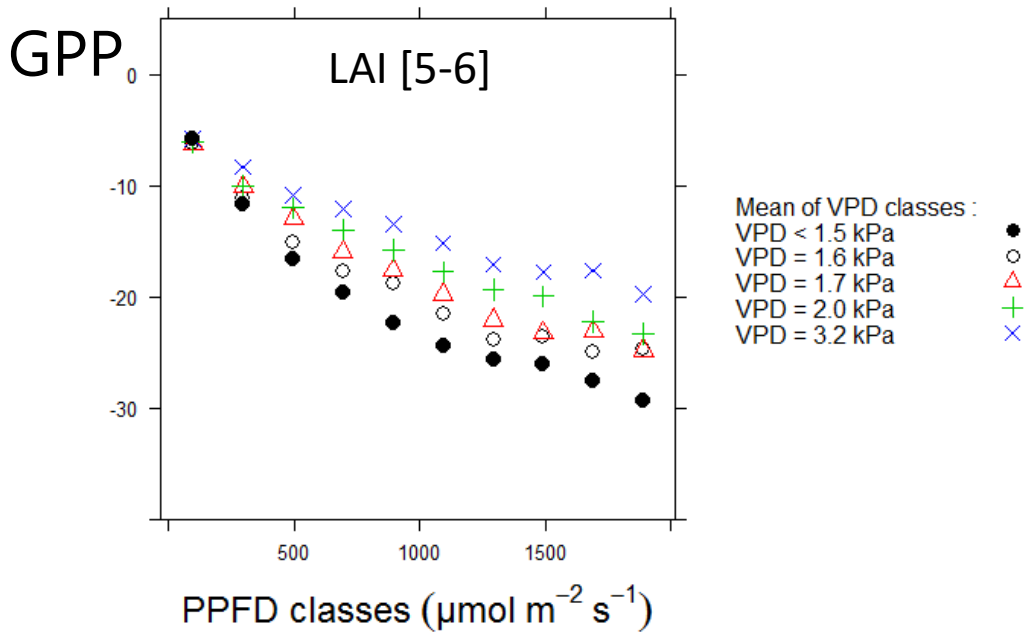
Mediterranean evergreen forest (FR-Pue)



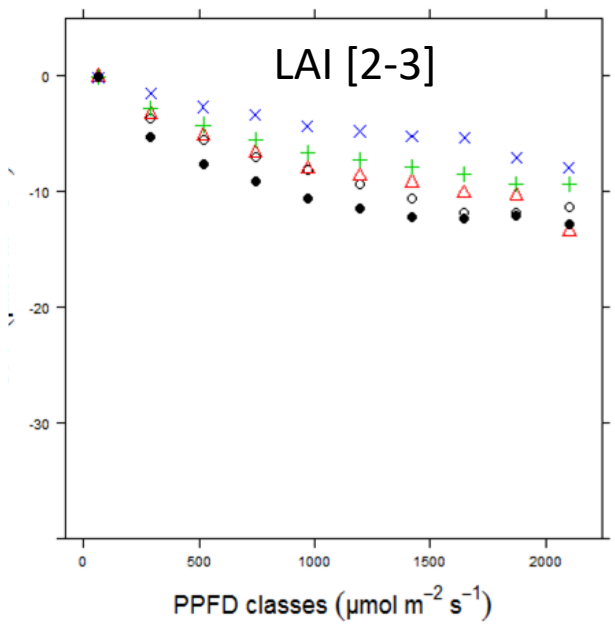
Similar response of ecosystem photosynthesis/LAI to PPFD among sites and between years.

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

Temperate deciduous forest (FR-Fon)



Mediterranean evergreen forest (FR-Pue)

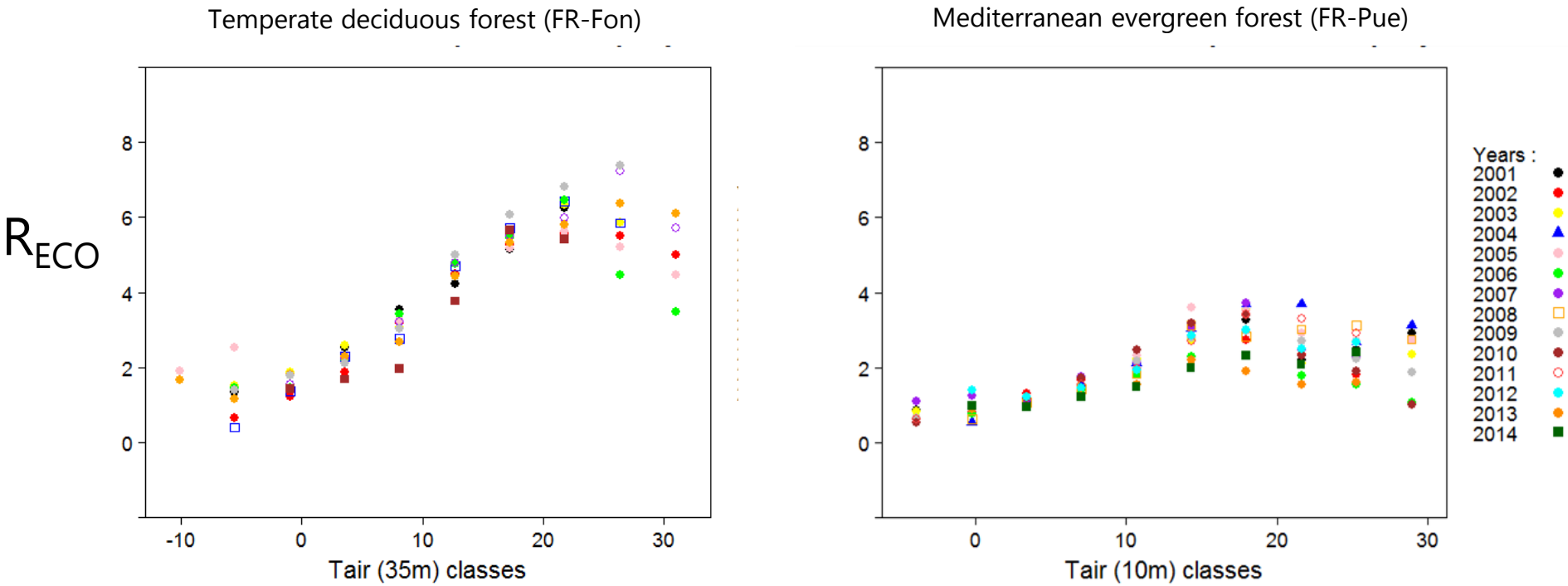


The response of ecosystem photosynthesis/LAI to PPFD x VPD is similar among sites.

CESEC Project overview (2015-2017)
Moreaux et al. 2018, ADEME report

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

CESEC Project overview (2015-2017)
Moreaux et al. 2018, ADEME report



Same response of ecosystem respiration to temperature among sites and between years.

3. Time series re-analysis: naive conclusions

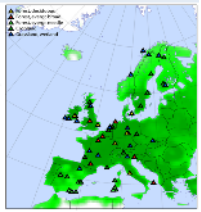
Large similarities among all sites - years.

- Photosynthesis correlated with:

SW↓ > Air VPD > { Air Temperature (Fr-Laq FR-LBr); Soil water (Fr-Fon, Fr-Pue) }

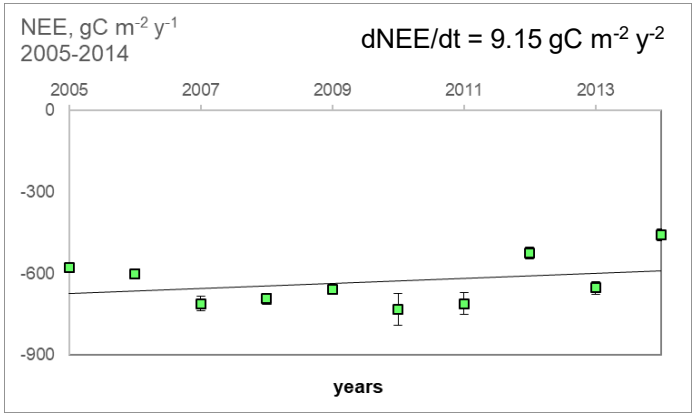
- Respiration correlated with:

Temperature > Air VPD > soil water content

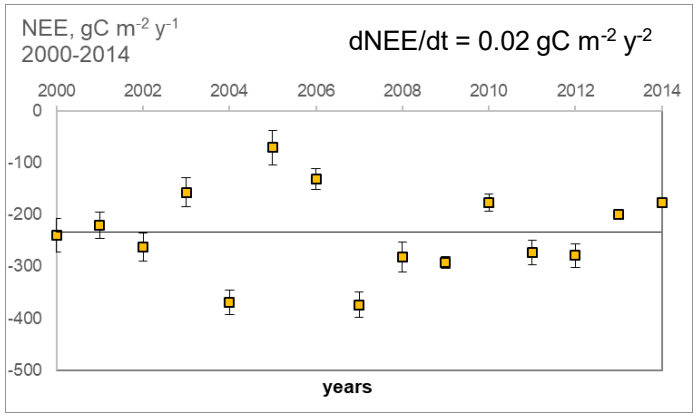


4. Low frequency changes

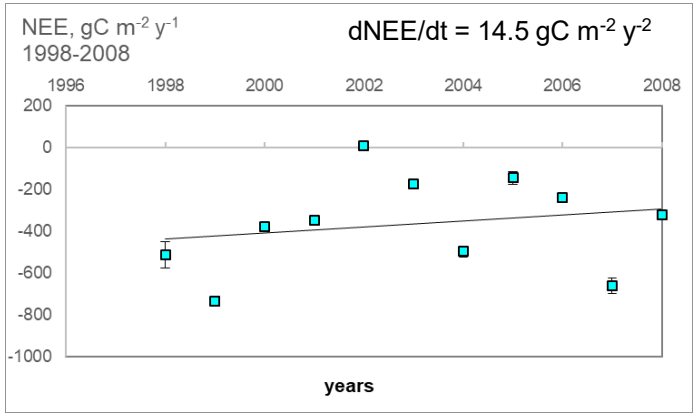
FR-Fon

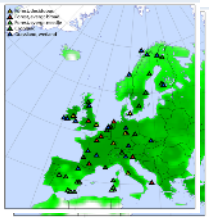


FR-Pue



FR-LBr

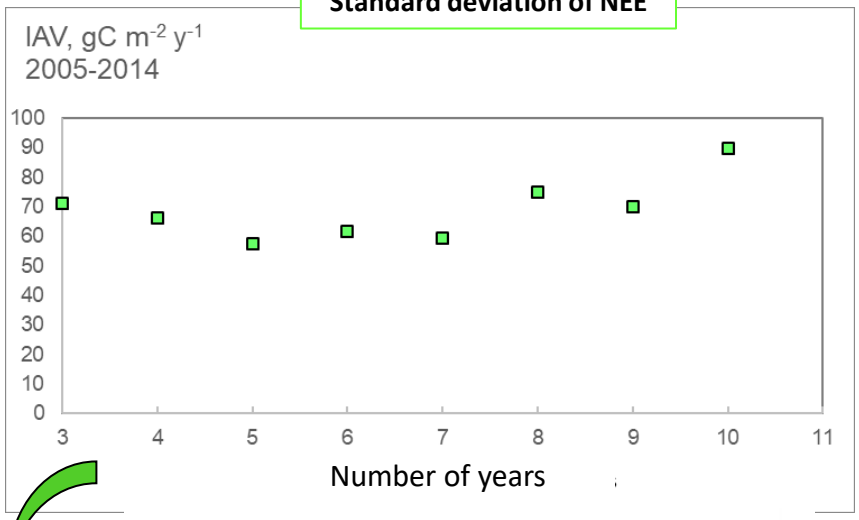




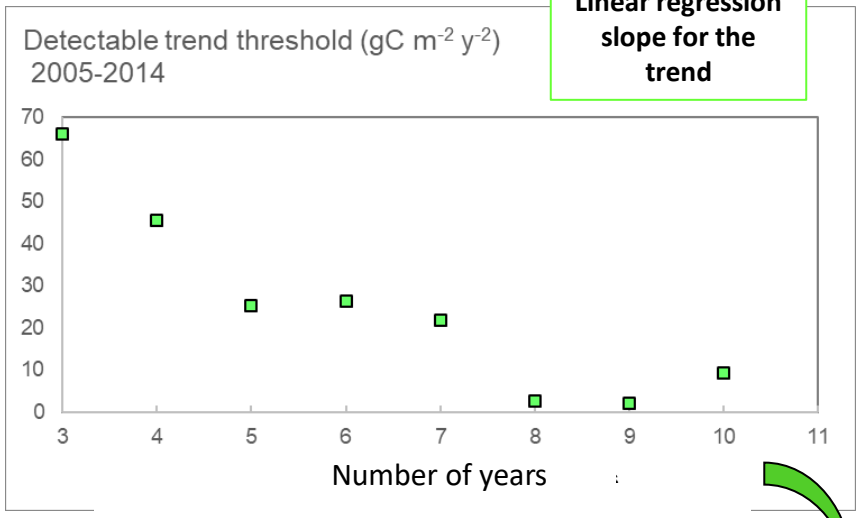
4. Low frequency changes: are they significant ?

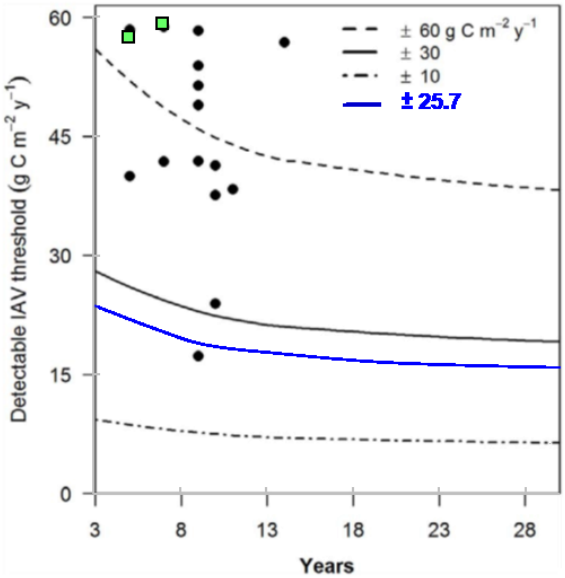
Longterm trend analysis: **Example of Barbeau: FR-Fon** after *Baldocchi et al. 2018*

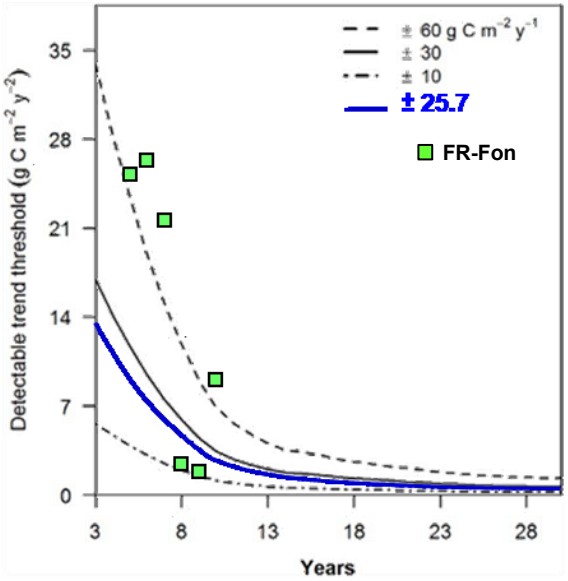
Standard deviation of NEE

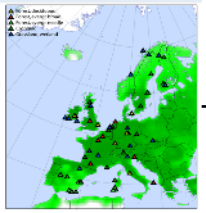


Linear regression slope for the trend

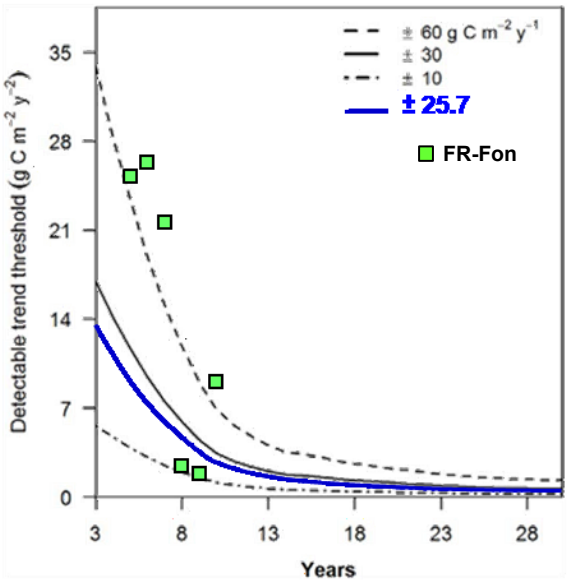


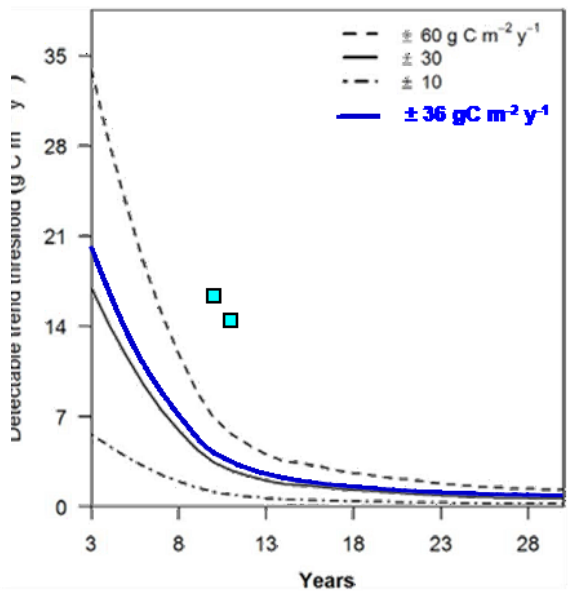


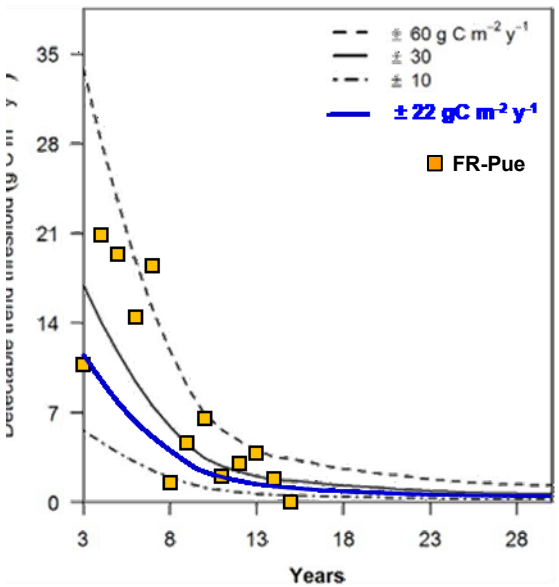




4. Low frequency changes: are they significant ?







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↓, 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 ?

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  - 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.

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- 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)