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

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

- **Le Bray**: coniferous Atlantic forest (13°C, 950mm)
- **Puechabon**: old-growth evergreen Quercus coppice (14°C, 910 mm)
- **Laqueuille**: extensive grassland (7°C, 1050 mm)
- **Barbeau**: old growth mixed broadleaved forest (11°C, 690mm)
Time series analysed

Puechabon

Barbeau

Le Bray

Laqueuille
What fluxes are telling us so far?

A naïve reanalysis of CO$_2$ fluxes over the past 18 years

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)

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

- Random forest analysis at 1/2h time scale

![Puechabon](image1)

![Barbeau](image2)

![Le Bray](image3)

![Laqueuille](image4)
1. Classification of environmental factors: **ecosystem respiration ($R_{ECO}$)**

- Random forest analysis at 1/2h time scale
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)

Extensive grassland (FR-Laq)

Temperate coniferous forest (FR-Bra)

Mediterranean evergreen broadleaf forest (FR-Pue)
3. Regression analysis: GPP response to environmental parameters: PPFD↓

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↓

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):**
  - \( R_{ECO} \) vs. \( Tair \) (35m) classes

- **Mediterranean evergreen forest (FR-Pue):**
  - \( R_{ECO} \) vs. \( Tair \) (10m) classes

**Same response of ecosystem respiration to temperature among sites and between years.**
Large similarities among all sites - years.

• Photosynthesis correlated with:

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

• Respiration correlated with:

\[
\text{Temperature} > \text{Air VPD} > \text{soil water content}
\]
4. Low frequency changes

\[ \frac{d\text{NEE}}{dt} = 0.02 \text{ gC m}^{-2} \text{ y}^{-2} \]

\[ \frac{d\text{NEE}}{dt} = 9.15 \text{ gC m}^{-2} \text{ y}^{-2} \]

\[ \frac{d\text{NEE}}{dt} = 14.5 \text{ gC m}^{-2} \text{ y}^{-2} \]
4. Low frequency changes: are they significant?

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

- **IAV, gC m\(^{-2}\) y\(^{-1}\)**
  - Standard deviation of NEE
  - 2005-2014
  - Number of years

- **Detectable trend threshold (gC m\(^{-2}\) y\(^{-2}\))**
  - Linear regression slope for the trend
  - 2005-2014
  - Number of years
4. Low frequency changes: are they significant?

Temporal trends across sites: significant but not consistent
Few thoughts to share together

• Climate drivers of CO₂ 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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