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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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

\( F_{CO2} \)

\( GPP \)

\( R_{ECO} \)

Le Bray

\( F_{CO2} \)

\( GPP \)

\( R_{ECO} \)

Barbeau

Laqueuille
What fluxes are telling us so far?

A naïve reanalysis of CO₂ fluxes over the past 18 years


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)

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

- Random forest analysis at 1/2h time scale
1. Classification of environmental factors: \textit{ecosystem respiration} ($R_{ECO}$)

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

**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)**

**Mediterranean evergreen forest (FR-Pue)**

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

- Photosynthesis correlated with:

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

- Respiration correlated with:

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

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

\[ \frac{\mathrm{d} \text{NEE}}{\mathrm{d}t} = 14.5 \, \text{gC m}^{-2} \text{y}^{-2} \]

\[ \frac{\mathrm{d} \text{NEE}}{\mathrm{d}t} = 9.15 \, \text{gC m}^{-2} \text{y}^{-2} \]
4. Low frequency changes: are they significant?

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

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

- **Detectable trend threshold (gC m$^{-2}$ y$^{-2}$) (2005-2014)**
- **Number of years**
- **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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