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.

To cite this version:
Virginie Moreaux, Paul Berbigier, Daniel Berveiller, Jean-Marc Bonnefond, Christophe Chipeaux, et al.. What fluxes are telling us so far? A naïve reanalysis of CO2 fluxes over the past 18 years. Assemblée Générale ICOS France, Dec 2018, Paris, France. 21 p. hal-02790285
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)

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

• **Laqueuille**: extensive grassland (7°C, 1050 mm)
Time series analysed

- **Puechabon**
  - $F_{CO2}$
  - GPP
  - $R_{ECO}$

- **Barbeau**
  - $F_{CO2}$
  - GPP
  - $R_{ECO}$

- **Le Bray**
  - $F_{CO2}$
  - GPP
  - $R_{ECO}$

- **Laqueuille**
  - $F_{CO2}$
  - GPP
  - $R_{ECO}$
What fluxes are telling us so far?

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

CO\textsubscript{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

![Graphs showing IncNodePurity for different sites (Puechabon, Barbeau, Le Bray, Laqueuille)]
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\(\downarrow\) and Soil Water (REW)

Barbeau

Puechabon

Le Bray

Average cross wavelet power

Average cross wavelet power

Average cross wavelet power

GPP - SW\(\downarrow\)

GPP - 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)**

**Temperate coniferous forest (FR-Bra)**

**Extensive grassland (FR-Laq)**

**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)

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]

Mean of VPD classes:
- VPD < 1.5 kPa
- VPD = 1.6 kPa
- VPD = 1.7 kPa
- VPD = 2.0 kPa
- VPD = 3.2 kPa

LAI [2-3]

PPFD classes (μmol 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)**

![Graph showing the relationship between $R_{ECO}$ and Tair (35m) classes for the temperate deciduous forest (FR-Fon).]

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

![Graph showing the relationship between $R_{ECO}$ and Tair (10m) classes for the 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:
  
  \[
  SW \downarrow \quad \text{Air VPD} \quad \begin{cases} \text{Air Temperature (Fr-Laq FR-LBr)} \\ \text{Soil water (Fr-Fon, Fr-Pue)} \end{cases}
  \]

- Respiration correlated with:
  
  \[
  \text{Temperature} \quad \text{Air VPD} \quad \text{soil water content}
  \]
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

IAV, gC m² y⁻¹
2005-2014

Detectable trend threshold (gC m² y⁻²)
2005-2014

Low frequency changes: are they significant?

Number of years after Baldocchi et al. 2018
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 ?
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:

• 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)