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

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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

HAL Id: hal-02790285
https://hal.inrae.fr/hal-02790285
Submitted on 5 Jun 2020

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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

\( F_{CO2} \)

\( GPP \)

\( R_{ECO} \)

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

\begin{itemize}
\item Puechabon
\item Barbeau
\item Le Bray
\item Laqueuille
\end{itemize}
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)

Temperate coniferous forest (FR-Bra)

Extensive grassland (FR-Laq)

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

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.

CESEC Project overview (2015-2017)
Moreaux et al. 2018, ADEME report
3. Regression analysis: $R_{ECO}$ response to temperature

Temperate deciduous forest (FR-Fon) vs. Mediterranean evergreen forest (FR-Pue)

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

- Respiration correlated with:
  
  \[ \text{Temperature} > \text{Air VPD} > \text{soil water content} \]
4. Low frequency changes

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 m\(^{-2}\) y\(^{-1}\)
2005-2014

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

Number of years

Number of years

Detectable IAV threshold (g C m\(^{-2}\) y\(^{-1}\))

Detectable trend threshold (g C m\(^{-2}\) y\(^{-2}\))

3 8 13 18 23 28

Years

3 8 13 18 23 28

Years

± 60 g C m\(^{-2}\) y\(^{-1}\)
± 30
± 10
± 25.7
± 60 g C m\(^{-2}\) y\(^{-2}\)
± 30
± 10
± 25.7

FR-Fon
4. Low frequency changes: are they significant?

Temporal trends across sites: significant but not consistent
• 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)