

ICOS-France - SNO Tourbières
« The Greenhouse gases cycle: fluxes, regional balances, scenarios and instrumentation»

Tuesday 14th, November 2017
CNRS, Orléans
1- CESEC project overview

2- Material et Methods

3- Results

4- Conclusion and Perspectives
1- CESEC project overview

2- Material et Methods

3- Results

4- Conclusion and Perspectives
1- Project overview

- Context and goals
  - **CESEC project**: Déterminants des longues séries de mesures d’échanges nets de CO₂, vapeur d’Eau et rayonnementS des ECosystèmes forestiers, prairiaux et culturaux
    - **Characterization**: Temporal fluctuations of the biochemical (flux CO₂, H₂O, CH₄ and N₂O fluxes) & biophysical (ET, albedo) variables from « ICOS-Ecosystème France » experimental sites for the last 8 to 17 years.
    - **Analysis**: Influence of environmental parameters + Inter-site comparison
    - **Quantification**: impact of potential climatic drifts and extreme events on flux data
    - **Attribution**: potential evolution of fluxes due to natural and/or anthropogenic factors
  - 7 Partners:
    - EEF, INRA Nancy
    - UREP, INRA Clermont-Ferrand
    - ISPA, INRA Bordeaux
    - URP3F, INRA Poitou-Charente
    - ESE, Univ. Paris-Sud/CNRS
    - CESBIO, Univ. P. Sabatier (Toulouse)/CNRS
    - Gx Agro-Bio Tech, Univ. Liège (Belgique)

- Funding:
Working steps

- Obstacle for a comparative analysis: heterogeneity in the raw data processing of the historical eddy-covariance fluxes.

**Goal:** Data harmonization

- Standardized re-processing of the eddy flux computation on a half hourly basis from the high frequency data collected.
- Choice of the software: [EDDYPRO](#)
- Half hourly data selected for analyses on basis of their high quality

- Establishment of Look-up tables for CO₂ fluxes (other variables of interest in a close future) : statistical approach

- Sites Cross-comparison
1- CESEC project overview

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Experimental sites already processed

ICOS France Stations Networks
- Atmospheric
- Ecosystem

4 Forests
1 Grassland
1 Cropland

November 14th, 2017
Acquisition of historical data

Availability of the data by all the partners:

- Eddy-covariance high frequency raw data
- Meteorological and soil measurements
- Above and below ground biomass measurements
- Forest/crop management and practices

<table>
<thead>
<tr>
<th>Sites</th>
<th>Ecosystems</th>
<th>Period</th>
<th>Analyzer</th>
<th>Sonic anemometer</th>
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<td>GILL R3</td>
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</tbody>
</table>

Uniform processing for making possible the cross-comparison of long term flux data

November 14th, 2017
Re-traitements uniformisés:

- Standardization of the corrections applied on fluxes
  - **Angle Of Attack Correction**: Sonic anemometer from GILL:
    - **NO CORRECTIONS CONSIDERED**: The corrections proposed are inaccurate
      - Nakai et al. 2006: Gill R2 et Gill R3 => wrong algorithm
      - Nakai et al. 2012: Gill WindMaster™ et Gill WindMaster™ Pro => wrong algorithm
  - **Spectral Corrections**:
    - Low frequencies: Moncrieff et al. 2004
    - High frequencies:
      - Open-path analyzer: Moncrieff et al. 1997 (analytical method)
      - Closed-path analyzer: Fratini et al. 2012 (tube attenuation and sensors separations considered)
  - **Density Corrections**: WPL, Sensible heat flux from the 7500 : Burba et al. 2008

- **Time lag and Axis rotation for tilt correction**
  - **Time lag**: « Automatic time lag Optimization »
  - **Rotation coefficients**: Planar fit (grasslands and forests) et rotation 2D (croplands)
Post-processing: selection of high quality half hourly data

- Test on rainfall data (open-path Li7500):
  - $u^*$ filter: Papale et al. 2006 re-adapted

Partitioning

- Ecosystem respiration: Reco (Nighttime fluxes: Reichstein et al. 2005)
- Gross Primary Production : GPP (Daytime fluxes: NEE – Reco extrapolated)

Look Up Table approach

- Fluxes in relation to explanatory variables : half hourly time step
- Long term analysis of chronological series
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- Synthesis of selected data:
  - Percentage based on 17520 (365 days) and 17568 (366 days) half-hourly data

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<th>Sites</th>
<th>Ecosystèmes</th>
<th>Période</th>
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<td>38%</td>
<td>22%</td>
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</table>

- Higher impact of u* filtering in forests
- Higher impact of statistical test filtering for closed-path sensors (6262)
3- Results

- Homogeneous distribution over the year of the final data selected

**Auradé 2006 : Winter wheat**
3- Results

Auradé 2011: Rapeseed

![Graphs showing H [W m⁻²], LE [W m⁻²], and co2_flux [umol m⁻² s⁻¹] over time from 01/01/2011 to 17/12/2011.]

November 14th, 2017
- Cross-comparison of Reco and GPP in response to environmental parameters: synthesis
3- Results

Homogeneous trend of Reco in response to Tair

- Temperate deciduous forest
  - Barbeau: Reco mean per Tair and per year
  - $P$-value > 0.05

- Mediterranean evergreen forest
  - Puechabon: Reco mean per Tair and per year
  - $P$-value > 0.05

Respiration rates generally increased with increasing temperatures (Tair < 20°C)

Reco limitation at high air temperature Tair > 20°C $\Leftrightarrow$ soil inertia

November 14th, 2017
3- Results

- Homogeneous trend of Reco in response to Tair

**Temperate deciduous forest**

Normality: Kolmogorov-Smirnov test: p-value << 0.05

We can regroup the years into each t° class

No general trend of Reco in any t° classes throughout 2005-2014: anova: *p-value* > 0.05

November 14th, 2017
3- Results

- Homogeneous trend of Reco in response to Tair

**Mediterranean evergreen forest**

Normality: Kolmogorov-Smirnov test: p-value << 0.05

No general trend of Reco throughout 2001-2014: anova: *p-value* > 0.05
3- Results

- Other sites

Extensive grassland

Laqueuille extensif: Reco mean per Tair and per year

Statistical analysis: Ta = 15.5°C

Statistical analysis: Ta = 19.95°C

November 14th, 2017
3- Results

- At the top-35cm surface: different impact of edaphic stress

**Temperate deciduous forest**

- No impact of soil water stress (REW) on Reco response to Tair: Wilcoxon test: \( P\text{-value} > 0.05 \) at high temperatures

**Mediterranean evergreen forest**

- Strong impact of soil water stress (REW) on Reco response to Tair: Wilcoxon test: \( P\text{-value} << 0.05 \) at high temperatures

November 14\textsuperscript{th}, 2017
3- Results

- Look up table determination

**Mediterranean evergreen forest**

*Model adjustments for Reco versus Tair*

*Puechabon, 2001–2014*

- REW $< 0.28$: Polynomial (Richardson et al. 2006)
  - $R^2 = 0.69$
  - Residual sum-of-squares = 0.2272
  - $n = 3994$
- REW $> 0.28$: Polynomial (Richardson et al. 2006)
  - $R^2 = 0.982$
  - Residual sum-of-squares = 0.758
  - $n = 19266$

Two polynomial regressions for Reco extrapolation on daytime data

November 14th, 2017
3- Results

- Look up determination

Temperate deciduous forest

Model adjustments for Reco versus Tair

- $R^2 = 0.993$
- Residual sum-of-squares = 0.849
- $R^2 = 0.994$
- Residual sum-of-squares = 2.58

=> LAI impact on Reco response to Tair:
   Significant difference by Tair classes (t.test: $p\text{-value} < 0.05$)

For LAI > 0: non linear adjustment ajustement for GPP computation

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3- Results

- GPP analysis

No general trend of GPP response to PPFD throughout 2001-2014: anova: $p$-value $> 0.05$

We can regroup the years into each PPFD class
3- Results

- Environmental factors for GPP determinism

Temperate deciduous forest

Mediterranean evergreen forest

Lower slope and saturation values at high VPD

*p-value* \(< 0.5\) from PPFD \(= 200 \, \mu\text{mol m}^{-2} \text{s}^{-1}\)
Barbeau: Environmental factors for GPP determinism

**Temperate deciduous forest**

Soil drought (REW < 0.4)
No edaphic stress impact on GPP response to PPFD

**Dominant impact of VPD compared to REW**
3- Results

Puechabon: Environmental factors for GPP determinism

Mediterranean evergreen forest

GPP mean versus PPFD per VPD and REW classes 2001-2014

- VPD = 1.6 kPa
- VPD = 1.8 kPa
- VPD = 2.1 kPa
- VPD = 4.1 kPa

$p$-values $<< 0.05$

Soil drought (REW < 0.28)
Edaphic stress impact on GPP response to PPFD

Co-impact of VPD and REW on GPP response to VPD
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4- Conclusion & Perspectives
- Analysis based on 40% on average of flux data for both sites.
- Homogeneous approach for statistical analysis and comparative studies
- First analysis: temperate deciduous and mediterranean evergreen forests
  - No significant long term evolution of Reco and GPP through the studied periods on both sites despite $[\text{CO}_2]$ increase.
  - Look up table:
    - Respiration limitation at high air temperature on both sites (and others)
      - LAI dependency for the temperate deciduous forest (Barbeau)
      - REW dependency for mediterranean evergreen forest (Puechabon)
    - Significant decrease of GPP response to PPFD with VPD increase:
      - Dominant effect of air vapor stress in the temperate deciduous forest
      - Co-impact of atmospheric and edaphic stresses in the mediterranean evergreen forest

- Homogeneous database « pré-ICOS »:
  - Using the standardized methodology for the other sites (Lonzée, Lamasquère, Kourou, laqueuille intensif, Grignon).
  - Similar work for the biophysical variables
  - Build the Look Up Table based on these results and assess different climate scenarii using simple relations.
Thank you
A little bit more ...
### Material & Methods

#### Determinant variables

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#### Stress parameters:

- Atmospheric: Vapor Pressure Deficit : VPD: measured
- Soil: Relative Extractable Water: REW : modelled (GO+, Biljou, SIERRA): threshold REW (0.2, 0.4)

#### Vegetation parameters:

- LAI => vegetation index 0-1 (with or with out leaves, bare soil / cultivated soil)
Nouveau traitement (CESEC, EddyPro) versus ancien traitement (base de données IMECC)

Exemple :
Puechabon

FCO2 CESEC (µmol m⁻² s⁻¹)

FCO2 IMECC (µmol m⁻² s⁻¹)

\[ y = 0.9817x - 0.1182 \]
\[ R^2 = 0.9794 \]
New processing (CESEC, EddyPro) versus previous processing (IMECC database)

Example:
Puechabon

H CESEC (W m⁻²)  LE CESEC (W m⁻²)

H IMECC (W m⁻²)  LE IMECC (W m⁻²)

\[ y = 1.0559x + 1.7777 \]
\[ R^2 = 0.9944 \]

\[ y = 1.018x + 3.0411 \]
\[ R^2 = 0.8883 \]
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<th>Ecosystèmes</th>
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<th>Quality Check 1</th>
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1 : Mauder et Foken, 2004  
2 : Vickers et Marth, 1997: Spikes, Amplitude resolution, drop-outs, absolute limits, Discontinuities, Skweness & Kurtosis (high flag uniquement)  
3 : Papale et al. 2006 ré-adapté
Impact of Nakai et al. 2006 corrections (GILL R3)

Barbeau case study : with and without leaves period

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<th>Parameters</th>
<th>With leaves</th>
<th>Year</th>
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</table>
3- Results

- Long term evolution of environmental parameters

Temperate deciduous forest

Mediterranean evergreen forest

Results

Evolution par année et différence significative ou non?
Reco attenuation at high temperature

- Effet de la réserve en eau extractible REW de surface (0-35 cm)

Formula: \( \text{data0$Reco} \sim \text{Rref} \times \exp(\text{Eo} \times ((1/(\text{Tref} - \text{To})) - (1/(\text{data0$Ta} - \text{To})))) \)

Parameters:

| Parameter | Estimate  | Std. Error | t value | Pr(>|t|) |
|-----------|-----------|------------|---------|----------|
| Rref      | 4.5017    | 0.0327     | 137.66  | <2e-16 *** |
| Eo        | 159.2166  | 4.5808     | 34.76   | <2e-16 *** |

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Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
Effet de GPP

Résidus versus GPP (Tair > 19°C)