Homogeneous data-reprocessing and full synthesis of eddy-flux measurements in French terrestrial ecosytems : 1999 - 2014

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ICOS-France - SNO Tourbières

« The Greenhouse gases cycle: fluxes, regional balances, scenarios and instrumentation»

Tuesday 14th, November 2017

CNRS, Orléans

OUTLINE

1- CESEC project overview

2- Material et Methods

3- Results

4- Conclusion and Perspectives

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1- Project overview

Context and goals

- **CESEC project**: Déterminants des longues séries de mesures d'échanges nets de **C**O_2, vapeur d'**E**au et rayonnement**S** des **EC**osystèmes forestiers, prairiaux et culturaux
  - **Caracterization:** Temporal fluctuations of the **biochemical** (flux CO_2, H_2O, CH_4 and N_2O 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:

ADEME
Agence de l'Environnement et de la Maîtrise de l'Energie

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 CO_2 fluxes (other variables of interest in a close future) : statistical approach

- Sites Cross-comparison

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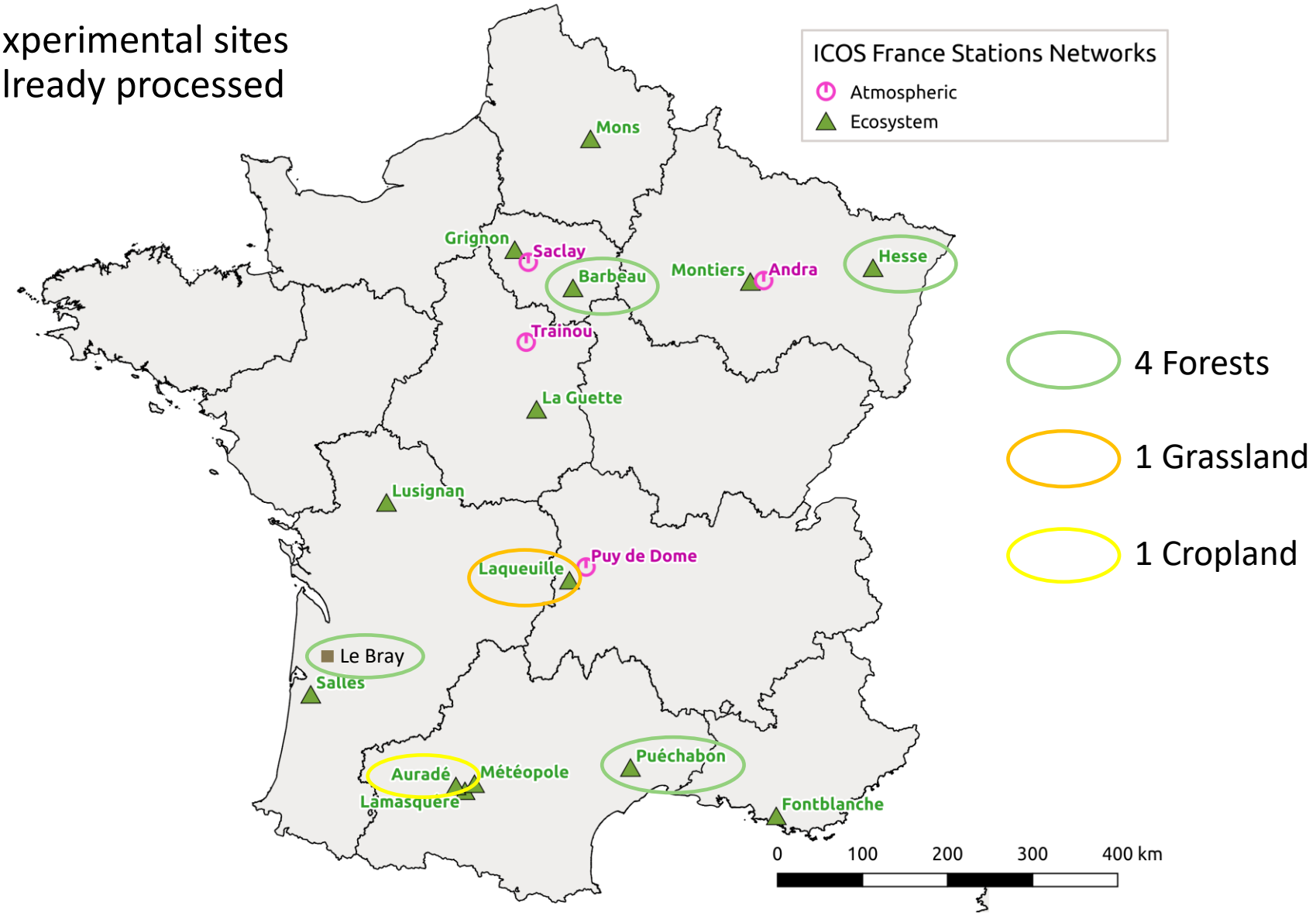
2- Material & Method

- Experimental sites already processed



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

Sites	Ecosystems	Period	Analyzer	Sonic anemometer
Hesse	Deciduous broadleaved	2000-2014	LI-6262	GILL R3
Barbeau	Deciduous broadleaved	2005-2014	LI-7500	GILL HS50
Laqueuille ext	Grassland	2004-2013	LI-7500	GILL R3
LeBray	Coniferous	1999-2002 2003-2008	LI-6262 LI-7500	GILL R2 GILL R2
Auradé	Cropland	2004-2013	LI-7500	CSAT
Puechabon	Evergreen broadleaved	2001-2014	LI-6262	GILL R3

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

- 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 seperations 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
  - Quality check: tests de Mauder et Foken (2004)
  - Statistical test on raw data: Vickers et Marth (1997)
  - Test on rainfall data (open-path Li7500):
  - u* filter: Papale et al. 2006 re-adapted

- Partitioning
  - Ecosystem respiration: Reco (Nightime 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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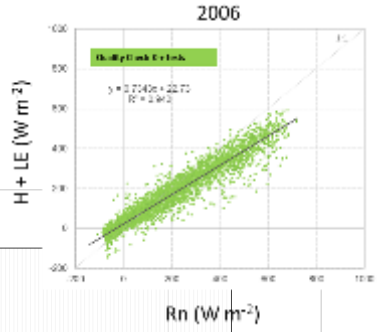
- Synthesis of selected data:

  - Pourcentage based on 17520 (365 days) and 17568 (366 days) half-hourly data

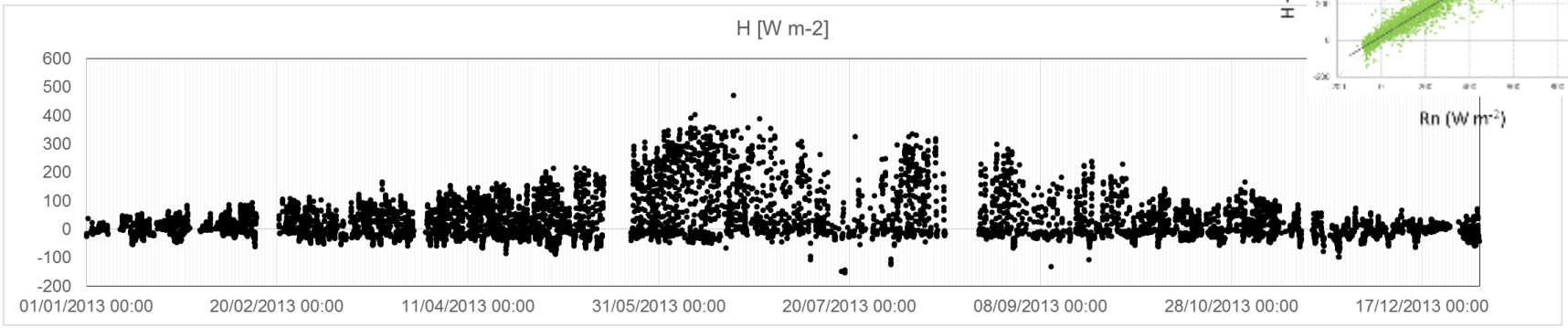
Sites	Ecosystèmes	Période	H	LE	FCO_2
Hesse	Deciduous broadleaved	2000-2014	En cours	En cours	En cours
Barbeau	Deciduous broadleaved	2005-2014	58%	41%	38%
Laqueuille ext	Grassland	2004-2013	53%	40%	41%
LeBray	Coniferous	1999-2008	35%	25%	29%
Aurade	Cropland	2004-2013	47%	36%	37%
Puechabon	Evergreen broadleaved	2001-2014	38%	22%	27%

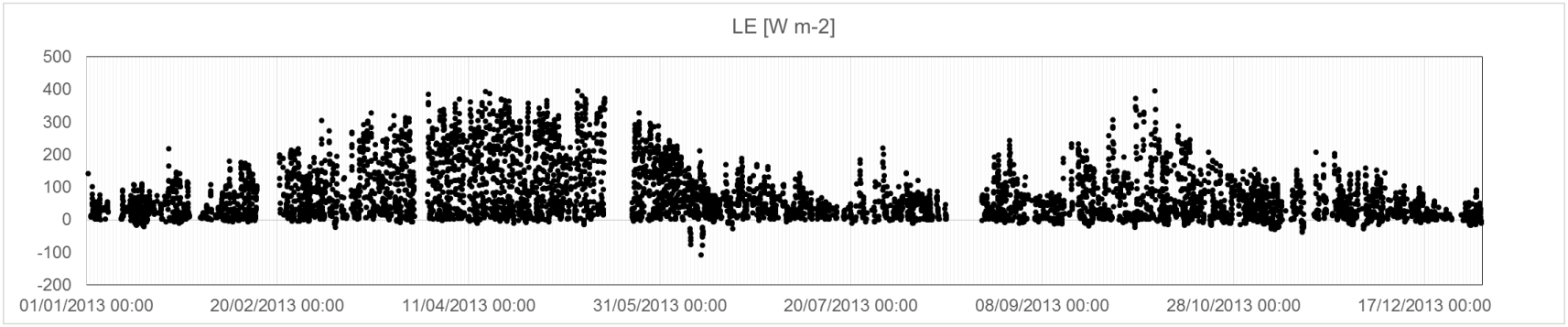
  - Higher impact of u* filtering in forests
  - Higher impact of statistical test filtering for closed-path sensors (6262)

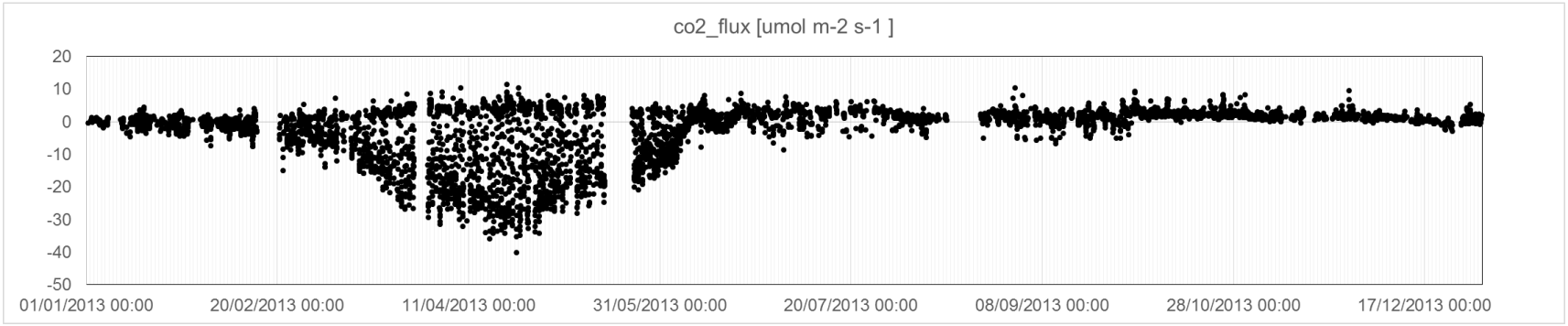
- Homogeneous distribution over the year of the final data selected



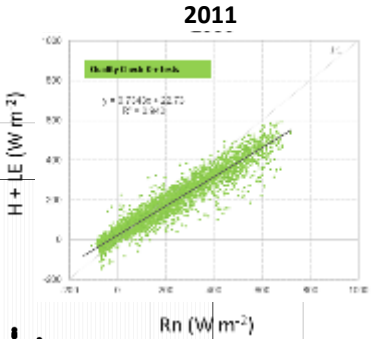
Auradé 2006 : Winter wheat

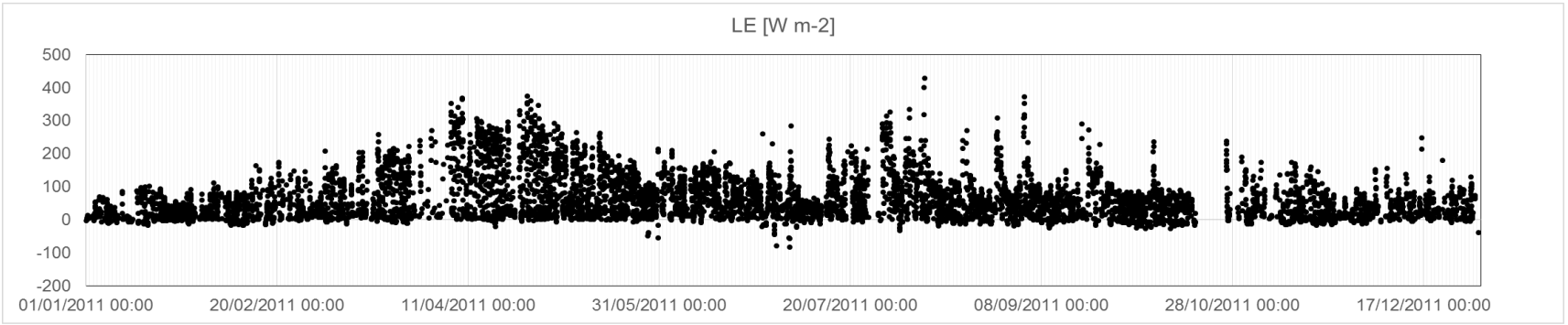


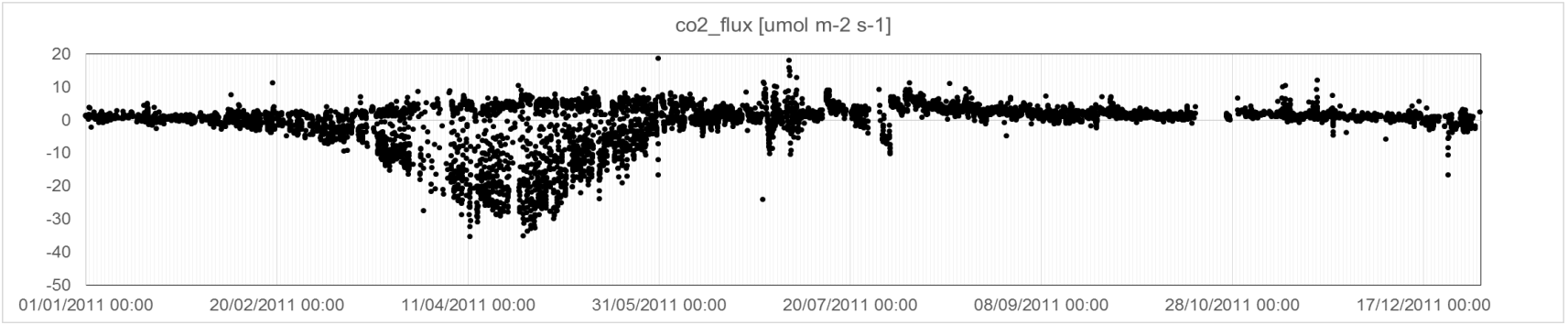




Auradé 2011 : Rapeseed



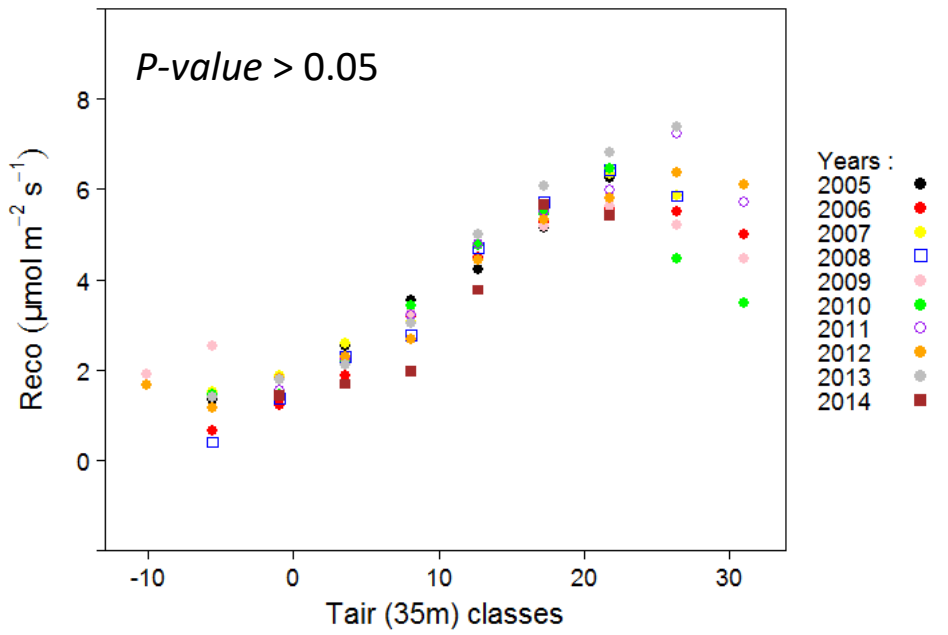




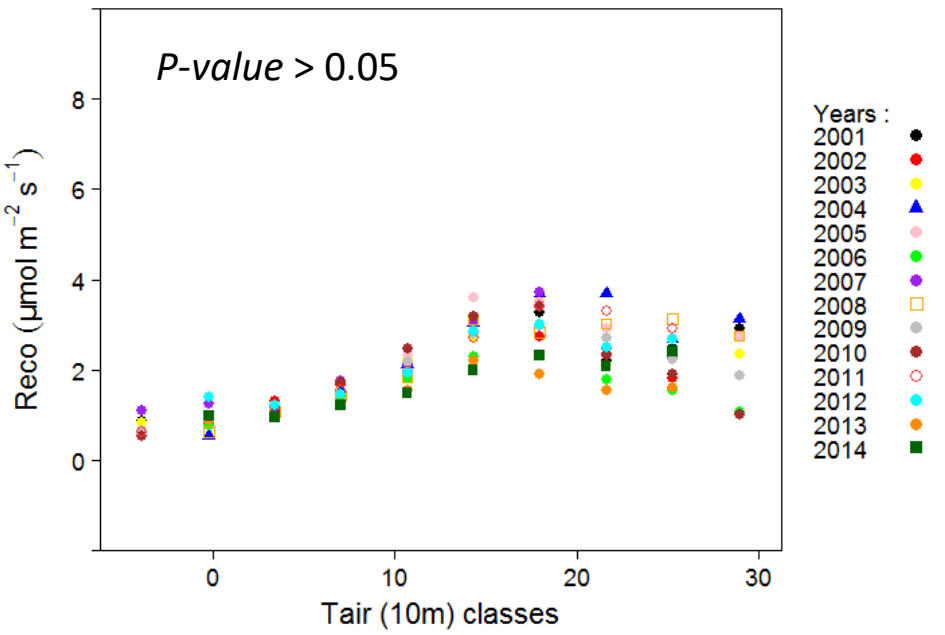
- Cross-comparison of Reco and GPP in response to environmental parameters: synthesis

- Homogeneous trend of Reco in response to Tair

Temperate deciduous forest



Mediterranean evergreen forest



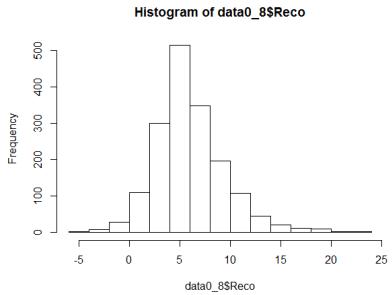
Respiration rates generally increased with increasing temperatures (Tair < 20°C)

Reco limitation at high air temperature Tair > 20°C ⇔ soil inertia

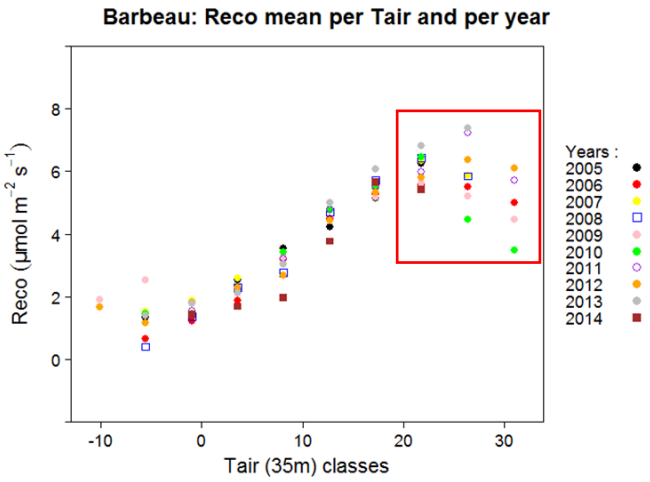
❑ Homogeneous trend of Reco in response to Tair

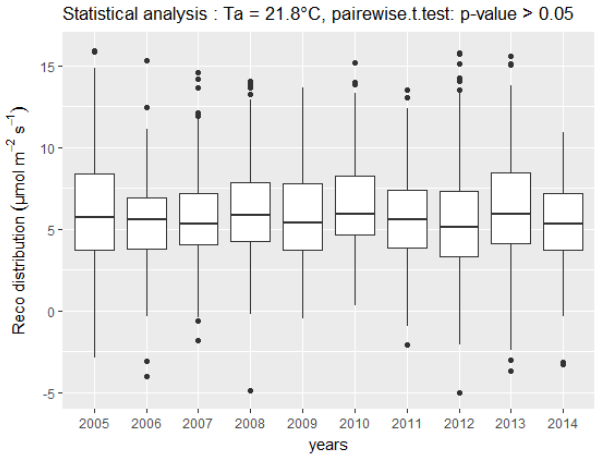
Temperate deciduous forest

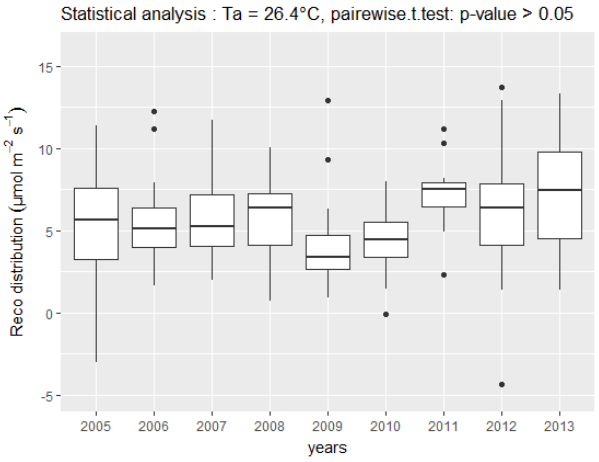
Normality: Kolmogorov-Smirnov test: p-value << 0.05

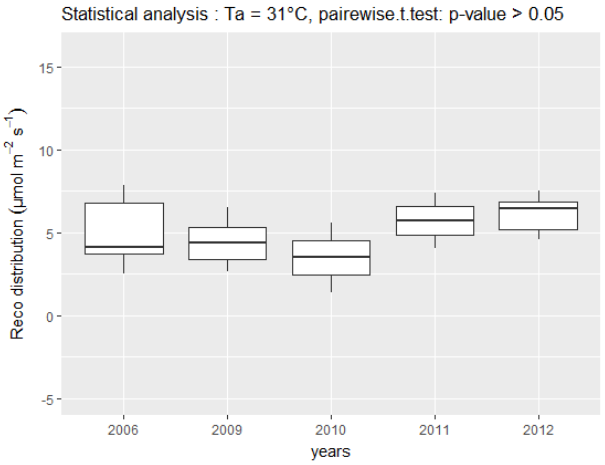


We can regroup the years into each t° class







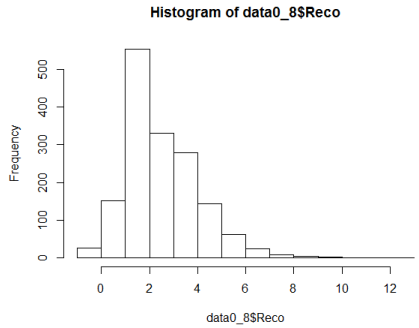


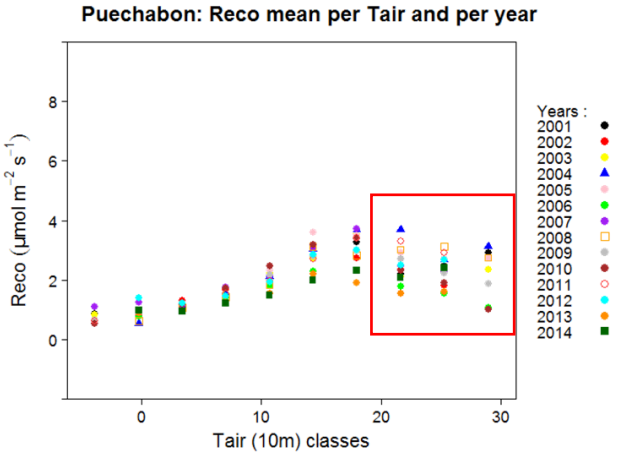
No general trend of Reco in any t° classes throughout 2005-2014 : anova: *p-value* > 0.05

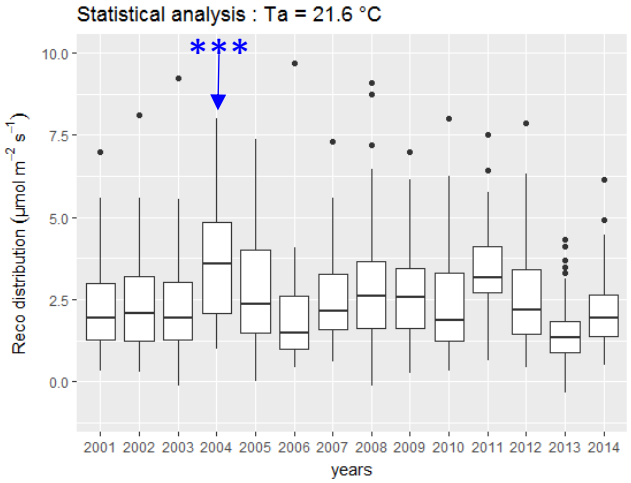
Homogeneous trend of Reco in response to Tair

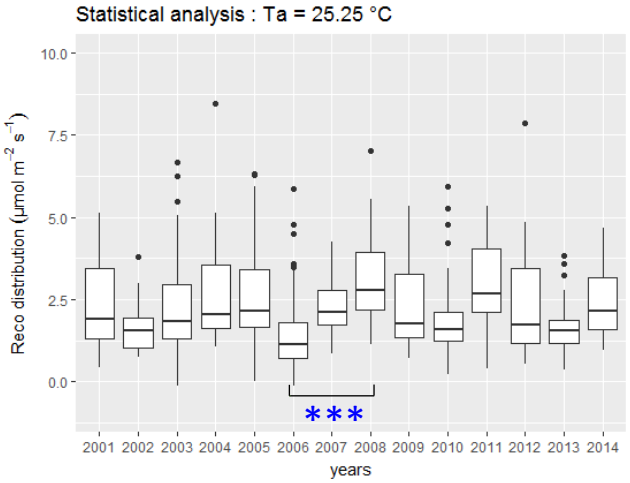
Mediterranean evergreen forest

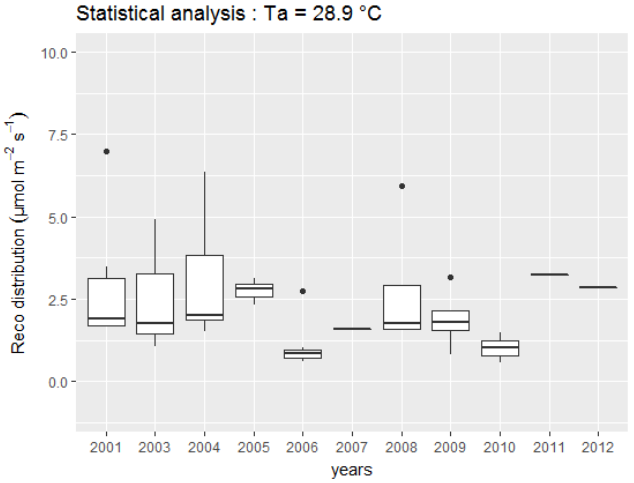
Normality: Kolmogorov-Smirnov test: p-value << 0.05







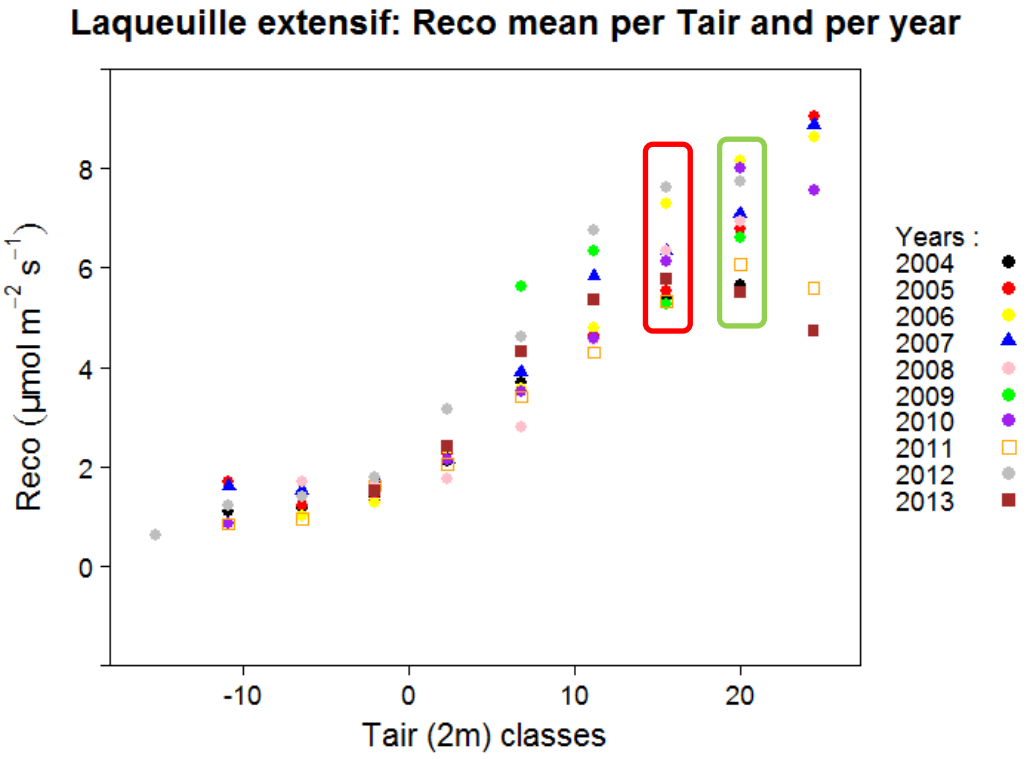


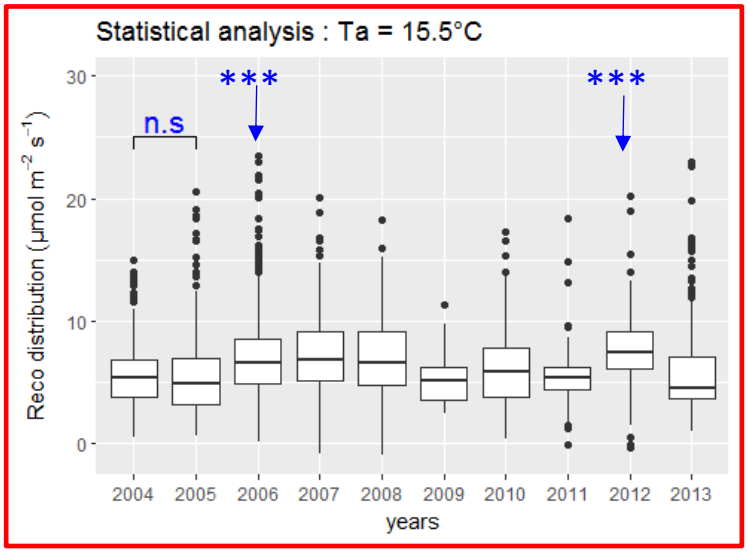


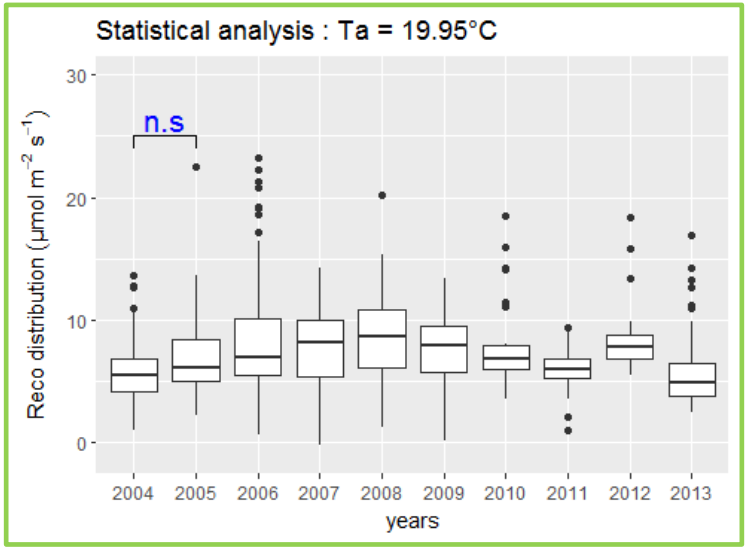
No general trend of Reco throughout 2001-2014 : anova: *p-value* > 0.05

Other sites

Extensive grassland

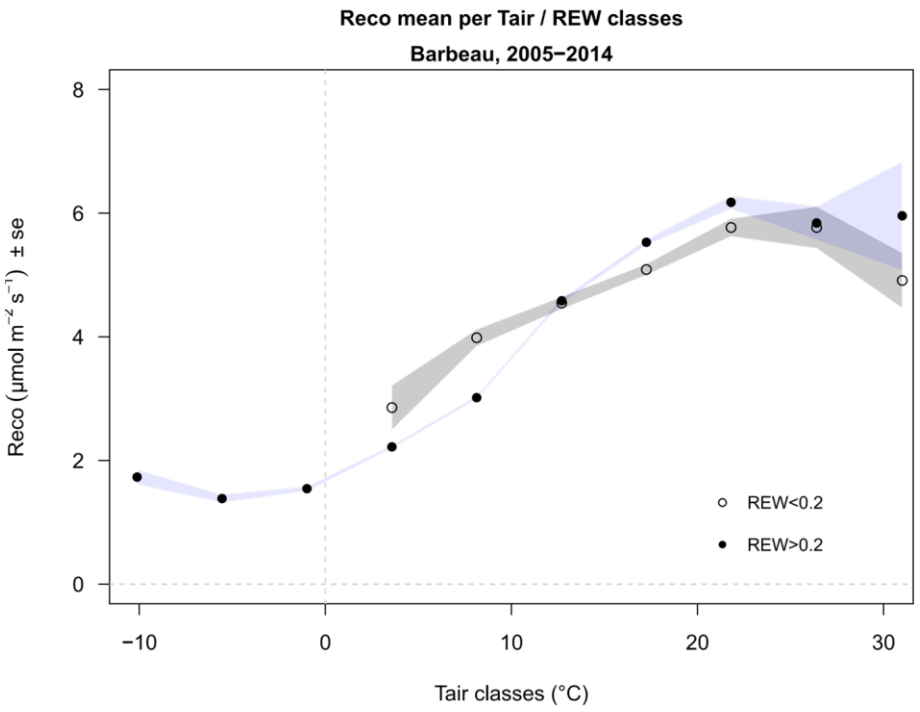




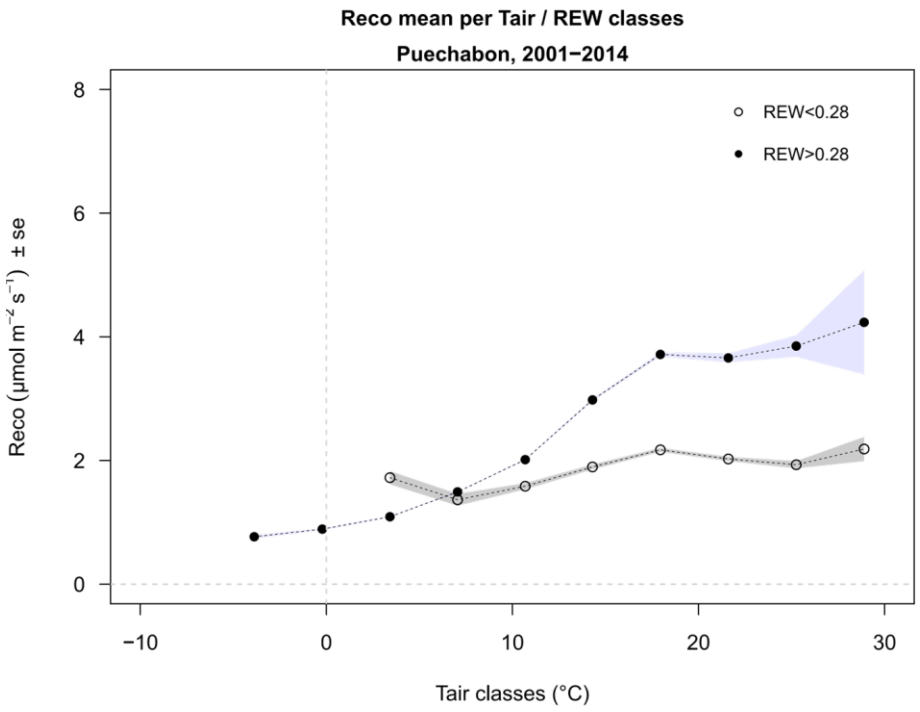


- At the top-35cm surface: different impact of edaphic stress

Temperate deciduous forest



Mediterranean evergreen forest

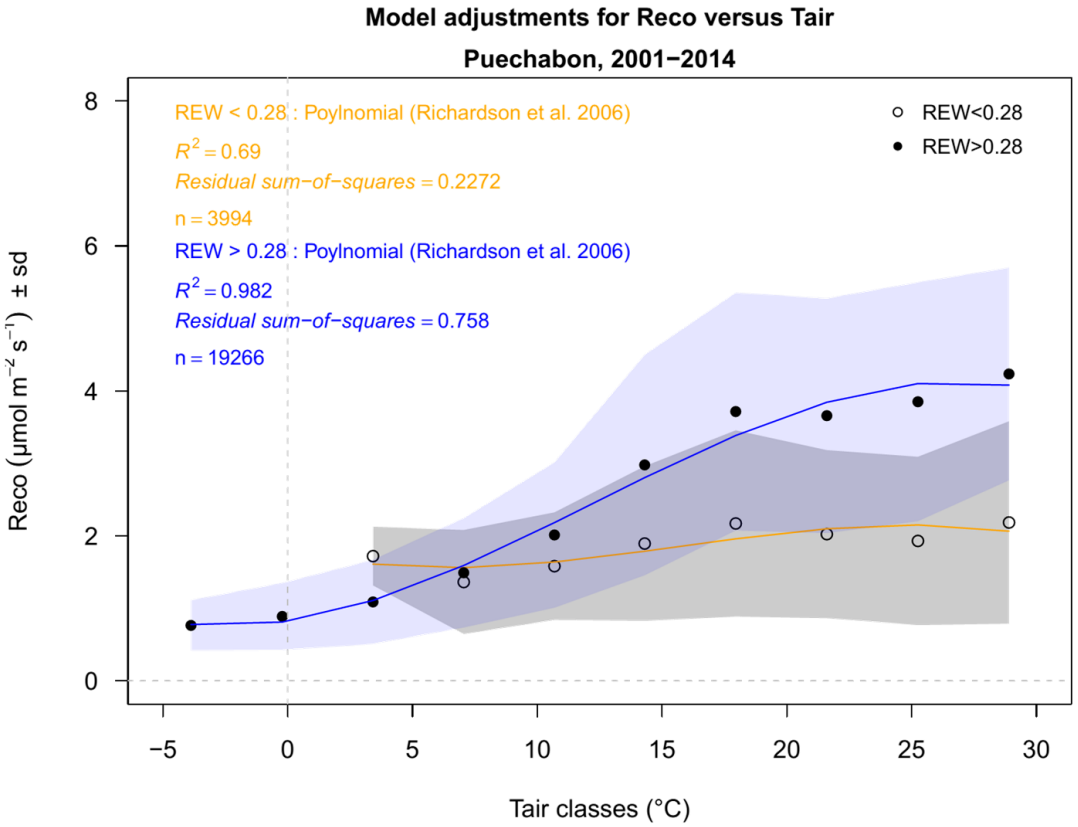


=> No impact of soil water stress (REW) on Reco response to Tair:
Wilcoxon test : *P-value* > 0.05 at high temperatures)

=> Strong impact of soil water stress (REW) on Reco response to Tair:
Wilcoxon test : *P-value* << 0.05 at high temperatures)

Look up table determination

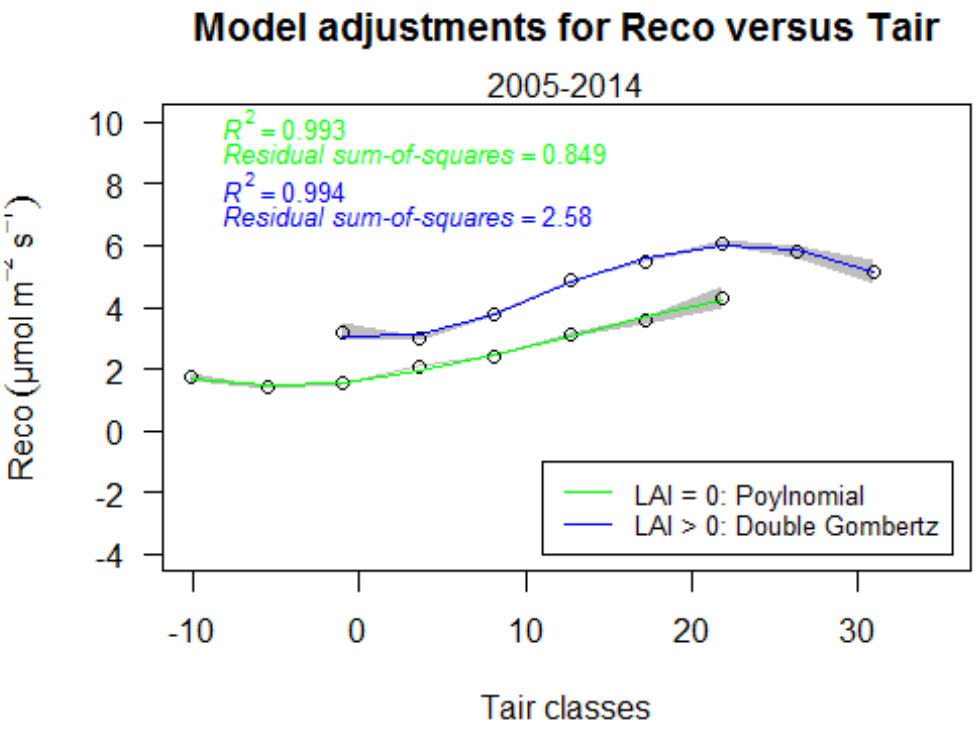
Mediterranean evergreen forest



Two polynomial regressions for Reco extrapolation on daytime data

- Look up determination

Temperate deciduous forest

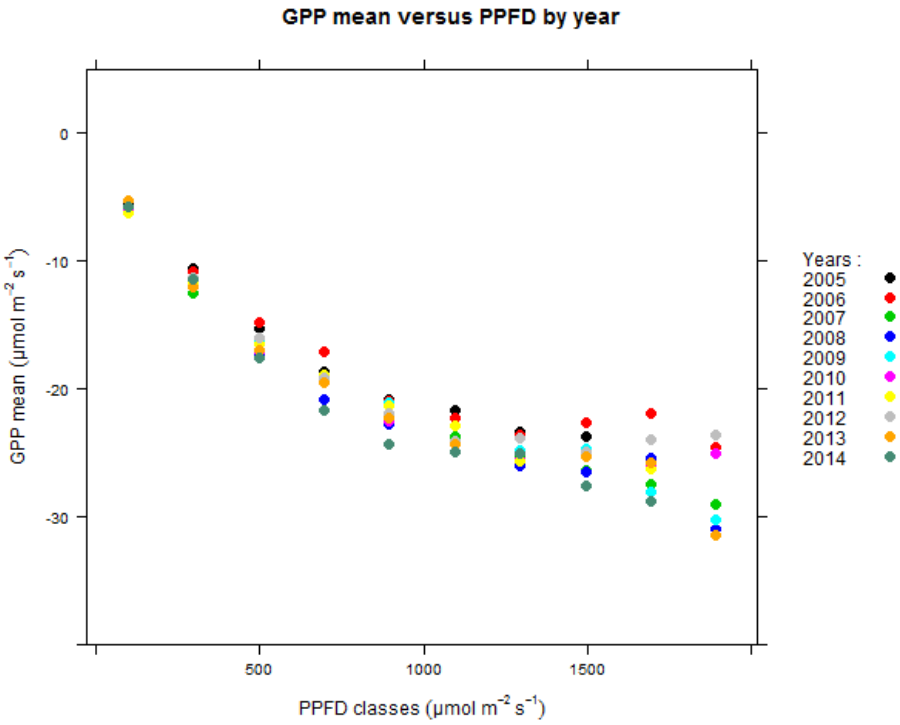


=> LAI impact on Reco response to Tair:
Significant difference by Tair classes (t.test: *p-value* << 0.05)

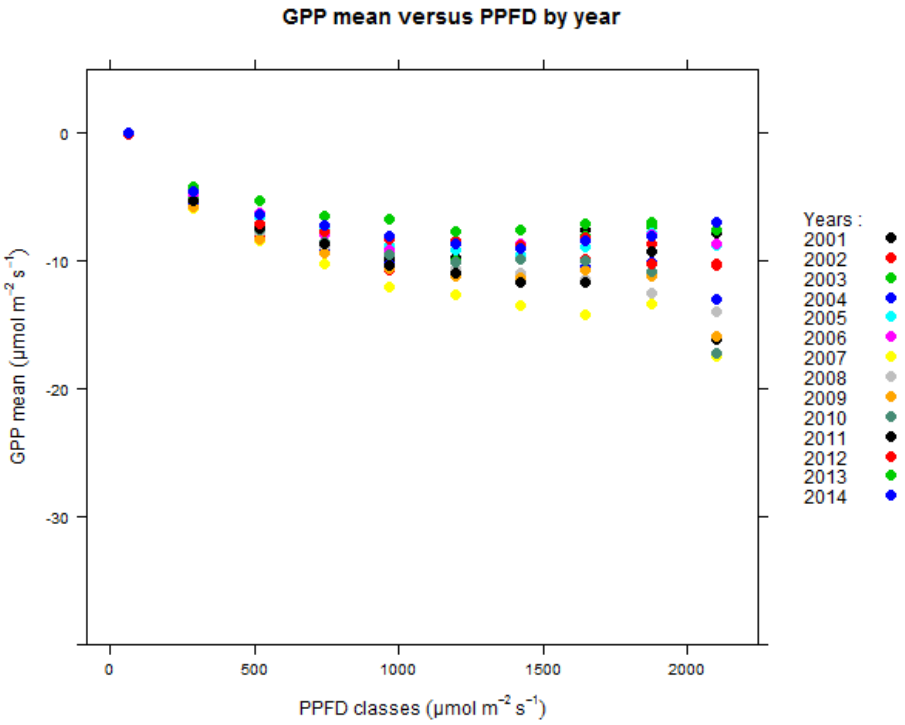
For LAI > 0: non linear adjustment ajustement for GPP computation

GPP analysis

Temperate deciduous forest



Mediterranean evergreen forest

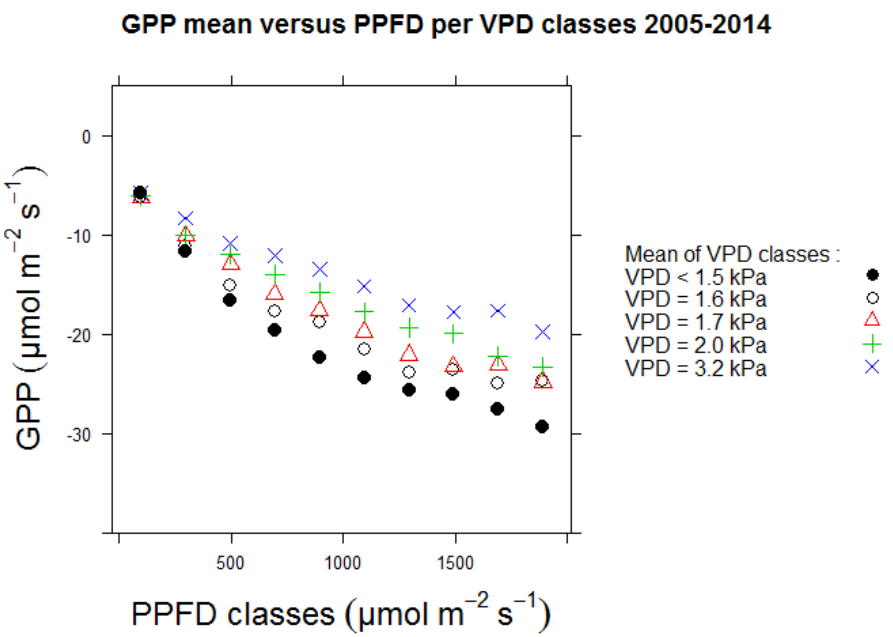


No general trend of GPP response to PPFD throughout 2001-2014 : anova: *p-value* > 0.05

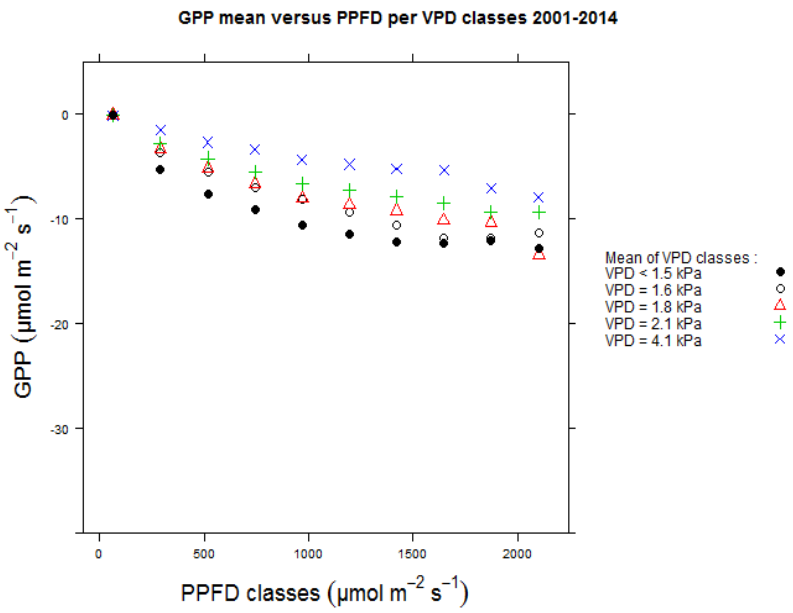
We can regroup the years into each PPFD class

- Environmental factors for GPP determinism

Temperate deciduous forest



Mediterranean evergreen forest

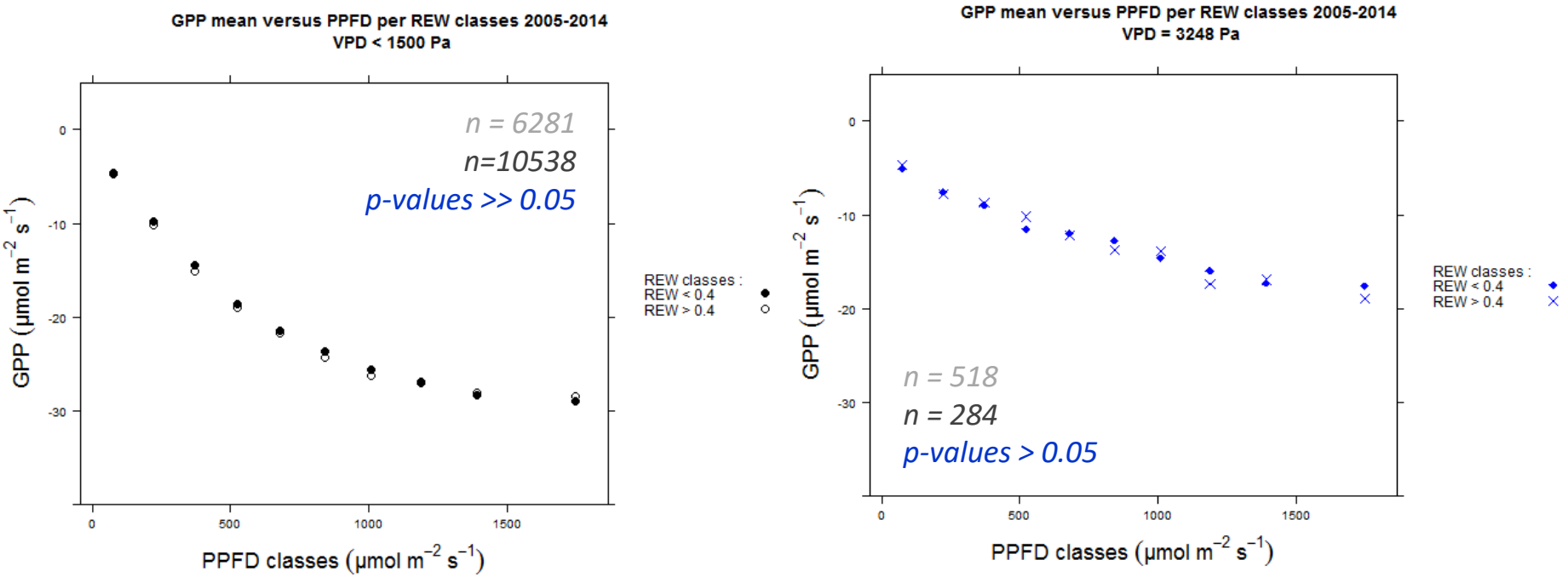


Lower slope and saturation values at high VPD

p-value << 0.5 from PPFD = 200 µmol m^{-2} s^{-1}

Barbeau: Environmental factors for GPP determinism

Temperate deciduous forest



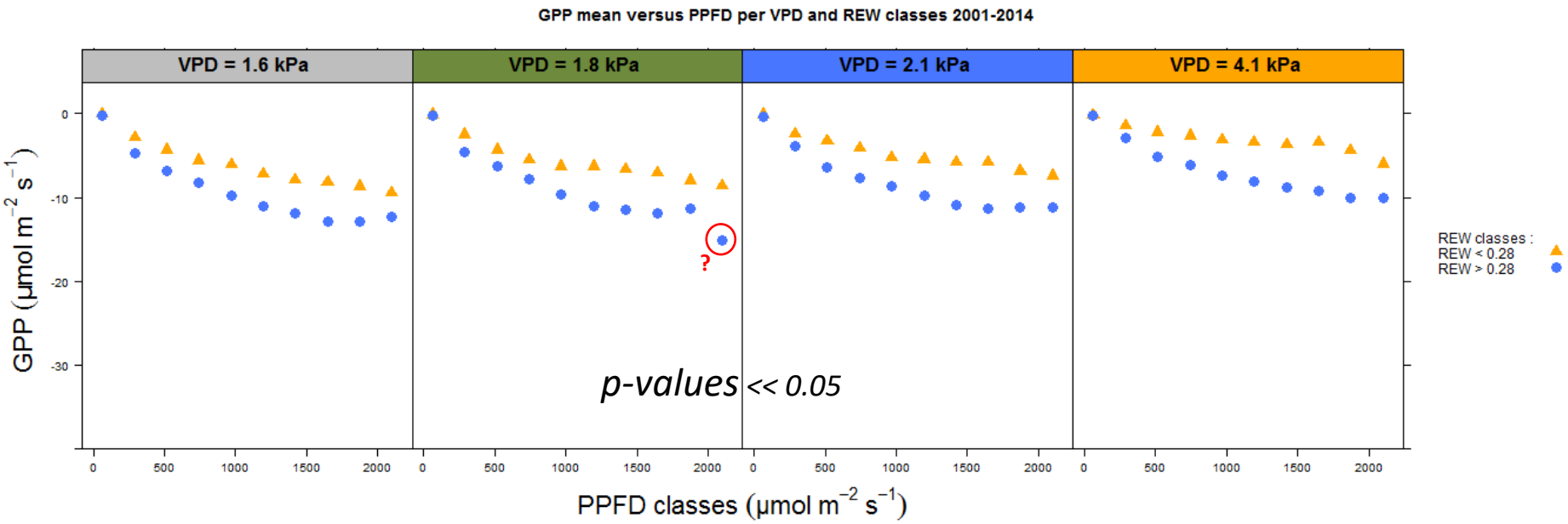
Soil drought (REW < 0.4)

No edaphic stress impact on GPP response to PPFD

Dominant impact of VPD compared to REW

- Puechabon : Environmental factors for GPP determinism

Mediterranean evergreen forest



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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- 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 [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 …

Determinant variables		Reco	GPP	ET	H	Albedo
Atmospheric parameters	Tair	X	X		X	
	CO_2		X			
	VPD	X	X	X		
	PPFD		X			
	Rg			X	X	
	LWsortant	(X)				
	Rn			X	X	X
	Wind			X	X	
Soil parameters	Tsurf	(X)				
	SWCsurf	(X)				X
	REW	X	X	X		
	G					
Vegetation parameters	LAI	X	X	X	X	X
	Species	X	X			
	Technical practices	X	X			X

- Stress parameters :

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

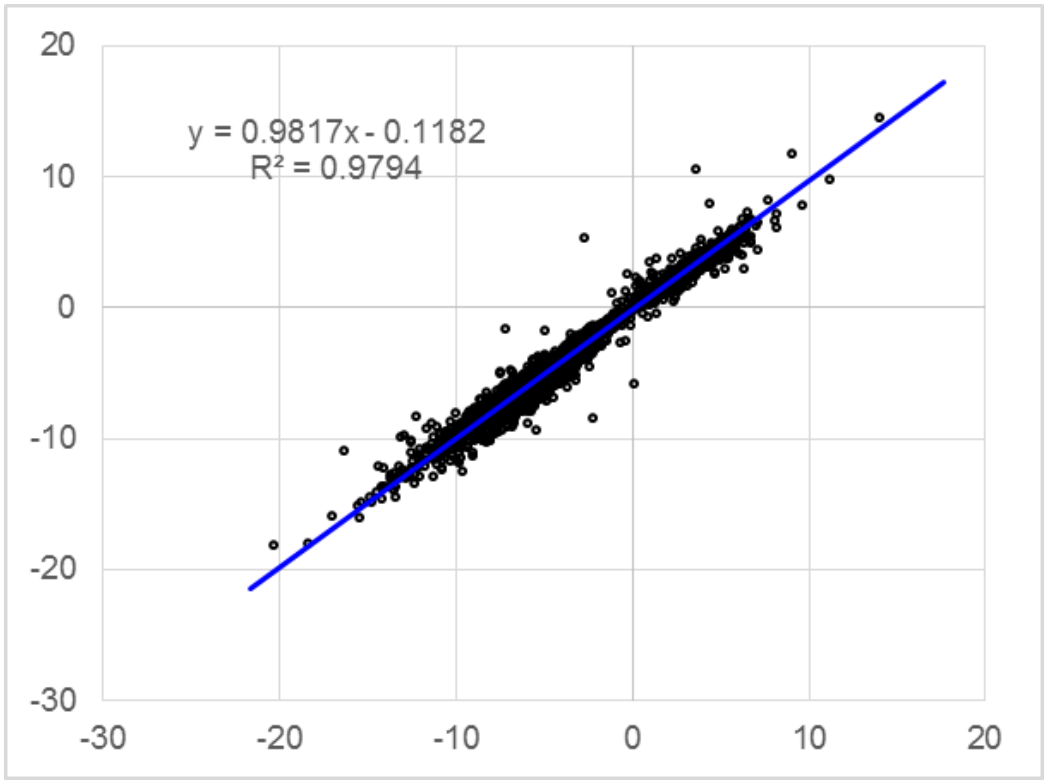
- Vegetation parameters:

- 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)

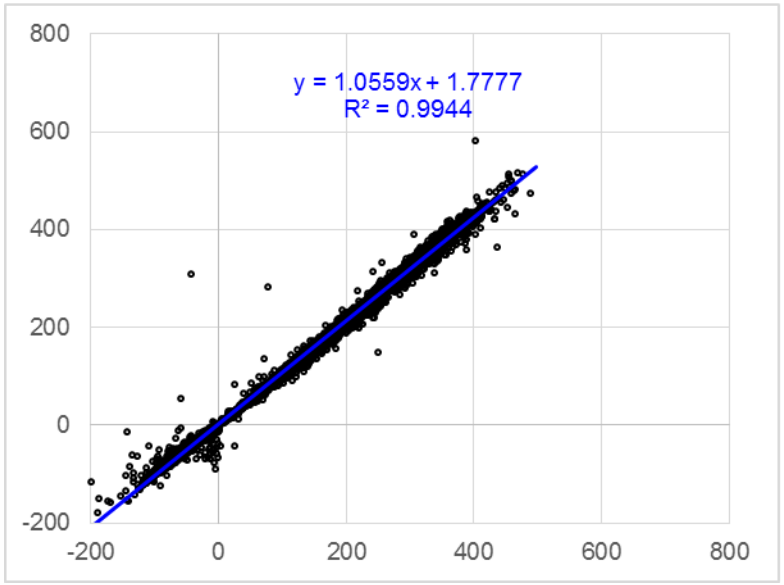


FCO2 IMECC (µmol m-2 s-1)

New processing (CESEC, EddyPro) versus prvious processing (IMECC database)

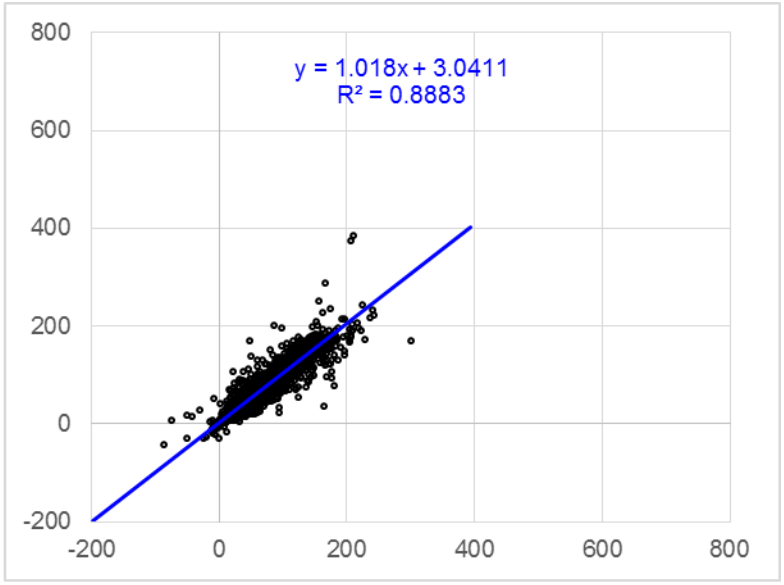
Example :
Puechabon

H CESEC (W m-2)



H IMECC (W m-2)

LE CESEC (W m-2)



LE IMECC (W m-2)

- EddyPro

Sites	Ecosystèmes	Période	Quality Check [1]	Tests statistiques [2]	Météo	Ustar threshold [3] ($m\ s^{-1}$)
Hesse	Décidus	2000-2014	Flag 0	√	×	-
Barbeau	Décidus	2005-2014	Flag 0	√	√	0.252
Laqueuille ext	Prairie	2004-2013	Flag 0	√	√	0.146
LeBray	Conifères	1999-2002 2003-2008	Flag 0	√	× √	0.275
Auradé	Cultures	2004-2013	Flag 0	√	√	0.13
Puechabon	Feuillus persistants	2001-2014	Flag 0	√	×	0.232

1 : Mauder et Foken, 2004

2 : Vickers et Marth,1997: Spikes, Amplitude resolution, drop-outs, absolute limits, Discontinuities, Skweness & Kurtosis (high flag uniquement)

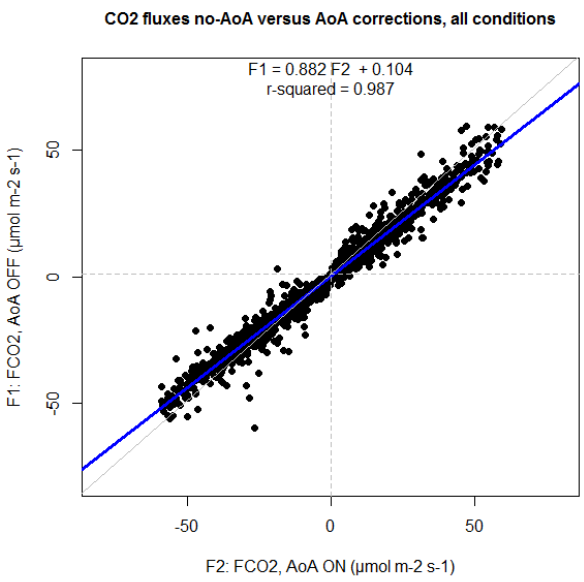
3 : Papale et al. 2006 ré-adapté

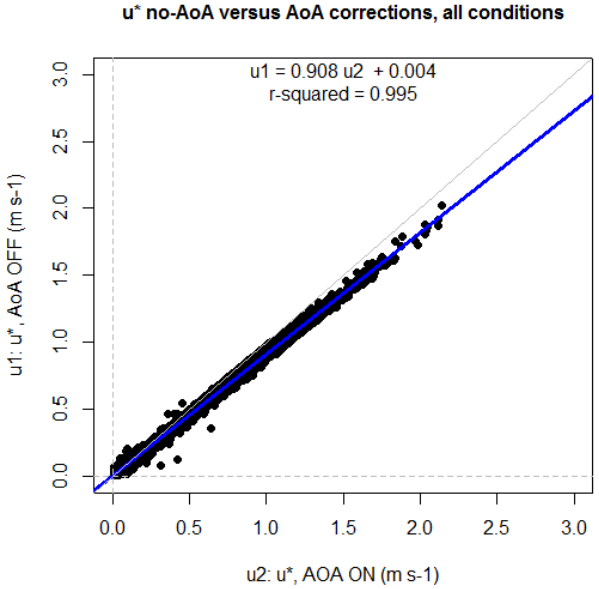
- Impact of Nakai et al. 2006 corrections (GILL R3)
  - Barbeau case study : with and without leaves period

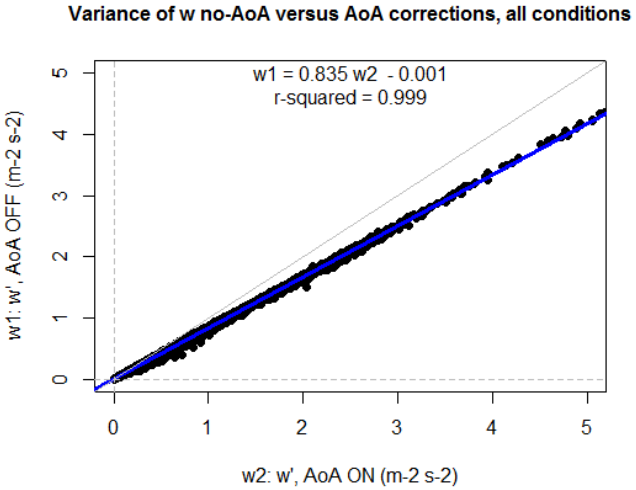
Year	Period	Parameters	With leaves
2005	**mai-juin**	w'	20%
		u*	9%
		H	15%
		LE	14%
		FCO_2	14%
2008	**mai-juin**	w'	21%
		u*	11%
		H	15%
		LE	13%
		FCO_2	12%
2011	**mai-juin**	w'	21%
		u*	9%
		H	16%
		LE	12%
		FCO_2	13%
2014	**aout sept**	w'	21%
		u*	9%
		H	16%
		LE	13%
		FCO_2	13%

Year	Period	Parameters	without leaves
2006	**février-mars**	w'	20%
		u*	9%
		H	15%
		LE	14%
		FCO_2	7%
2009	**février-mars**	w'	20%
		u*	9%
		H	16%
		LE	16%
		FCO_2	11%
2012	**février-mars**	w'	20%
		u*	7%
		H	16%
		LE	12%
		FCO_2	9%
2014	**janv-fév**	w'	19%
		u*	12%
		H	13%
		LE	12%
		FCO_2	12%

Nakai et al. 2006

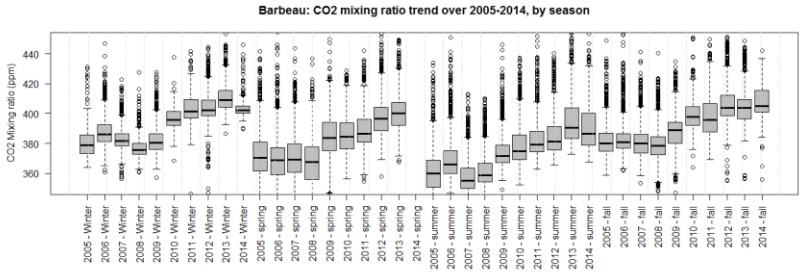


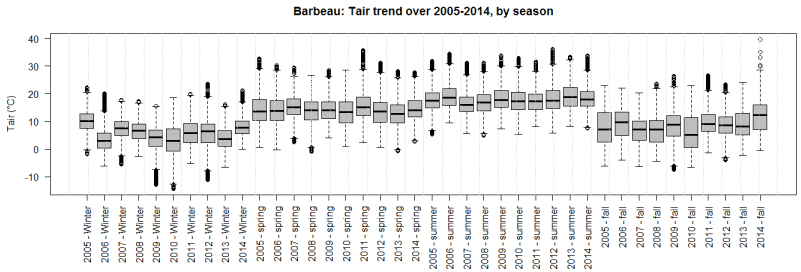


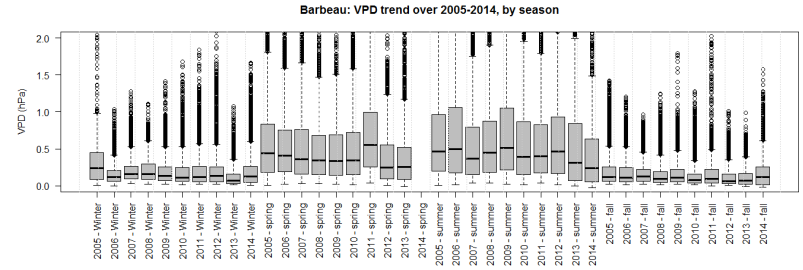


- Long term evolution of environmental parameters

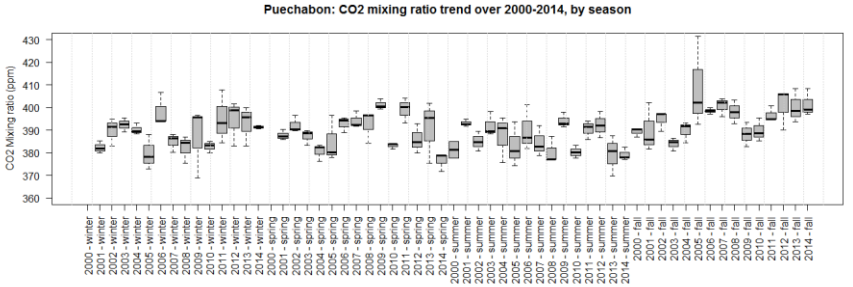
Temperate deciduous forest

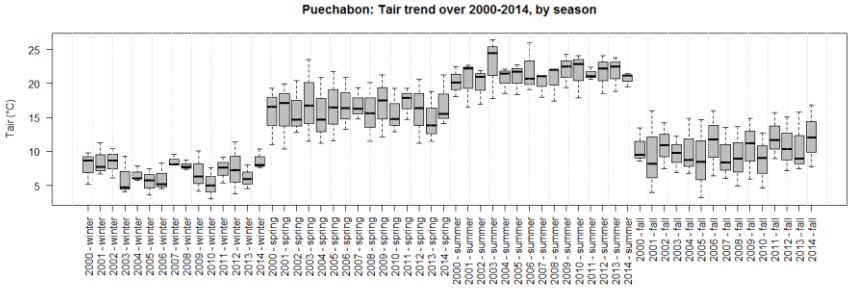


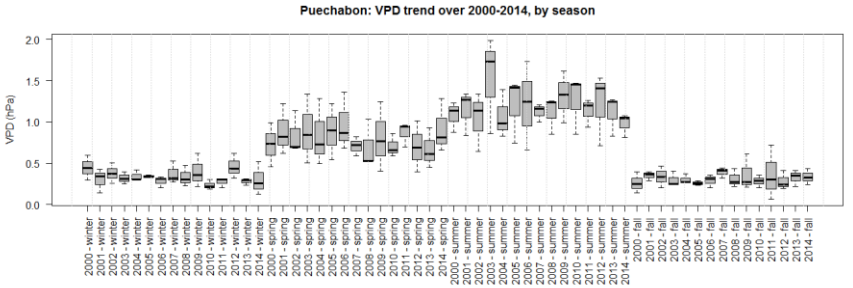




Mediterranean evergreen forest





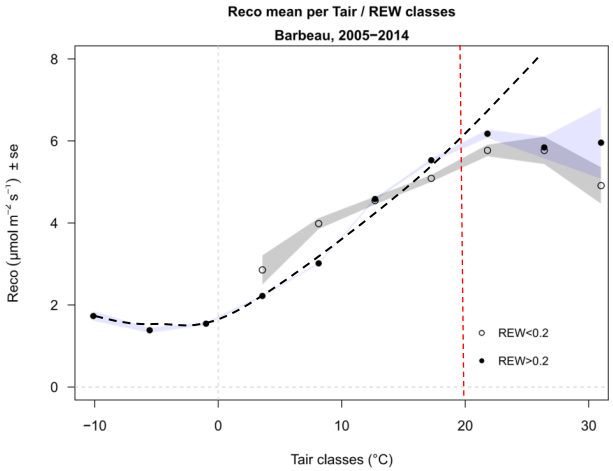


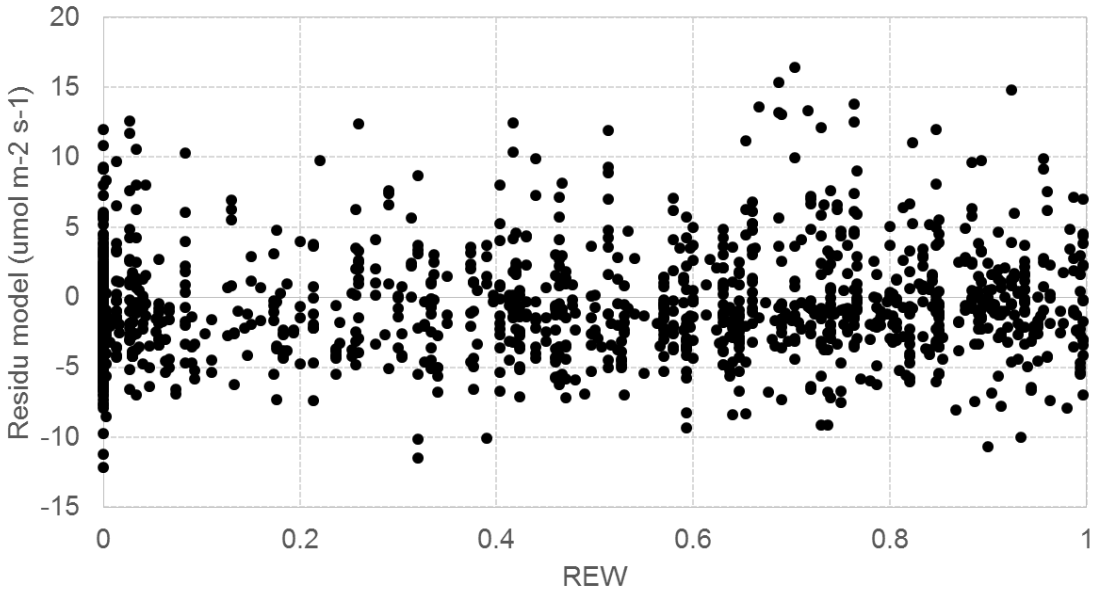
Evolution par année et difference sinificative ou non?

Reco attenuation at high temperature

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

```
#  Formula: data0$Reco ~ Rref * exp(Eo * ((1/(Tref - To)) - (1/(data0$Ta - To))))
#  Parameters:
#        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 ***
#  ---
#  Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```





Reco attenuation at high temperature

- Effet de GPP