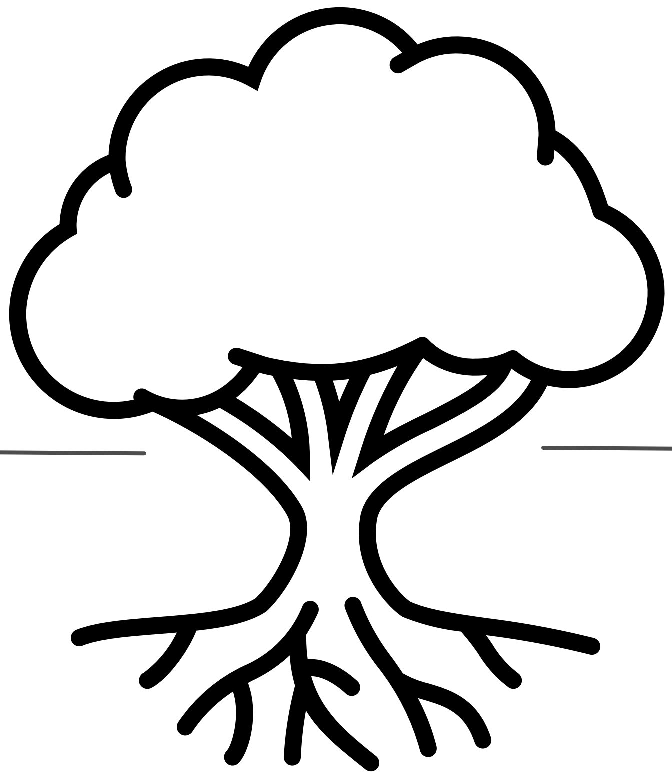
Wavelet analysis as a tool to deduce temporal multi-scale influence of climatic events on a young beech forest CO_2 exchanges

Jonathan Bitton, Catherine Charles, Bernard Heinesch, Matthias Cuntz, Emilie Joetzjer, Bernard Longdoz

Gembloux Agro Bio-Tech, ULiege - BELGIUM

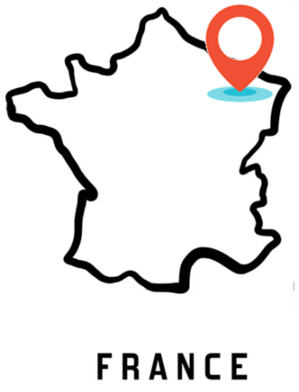


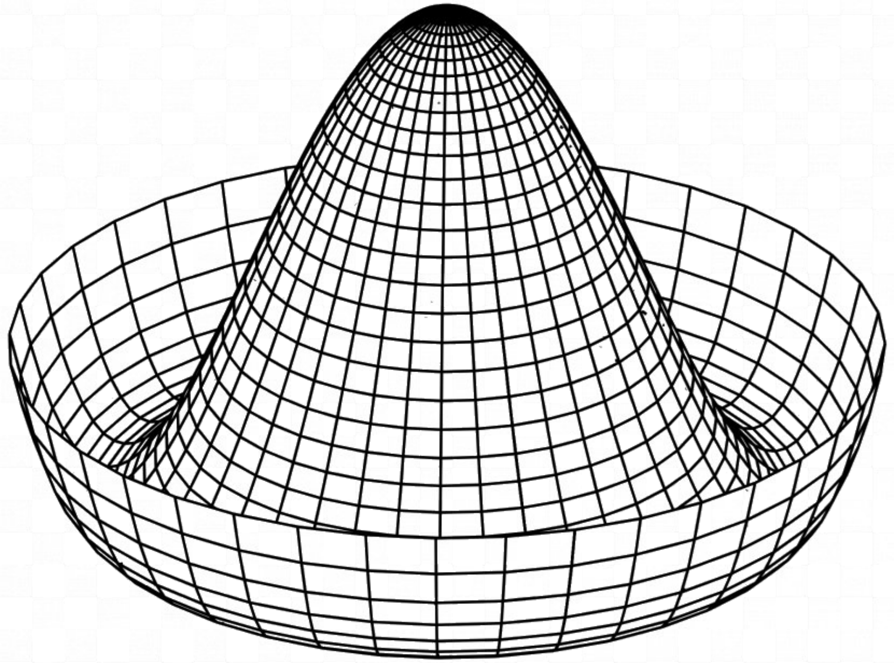
The Site
National forest of Hesse

Study Site

HESSE FOREST:

1. 90% Beech (*Fagus Sylvatica L.*)
2. 57 years-old exploitation
3. Sparse understorey vegetation
4. 20 years of continous 30 min data (2000-2020)





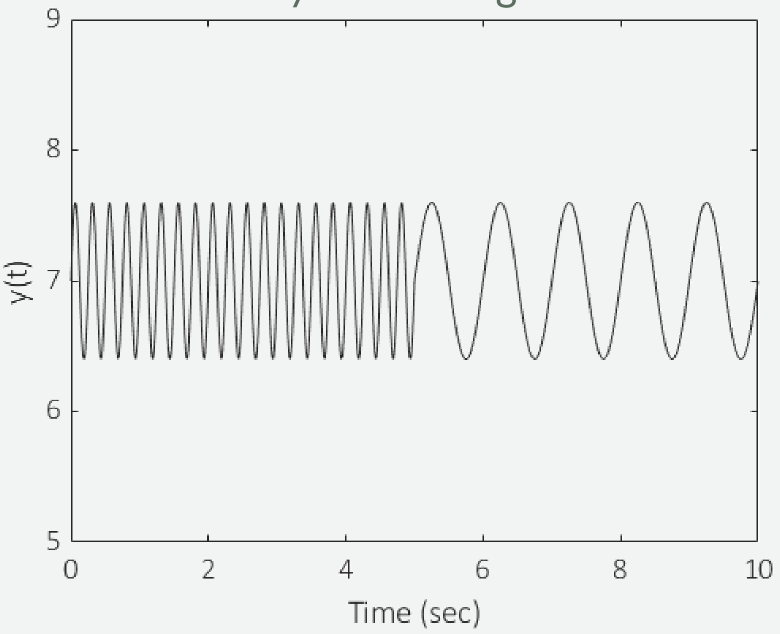
The Tool
Continuous wavelet transform

Continuous Wavelet Transform (CWT)

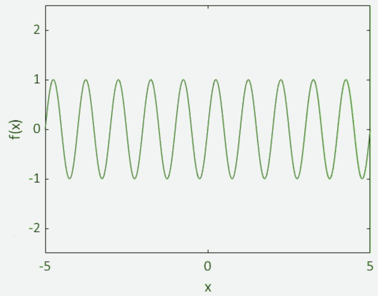
- Pattern detection for non-stationary phenomena
- Multivariate Analyses
- Adapted to large datasets
- Numerous uses in environmental studies

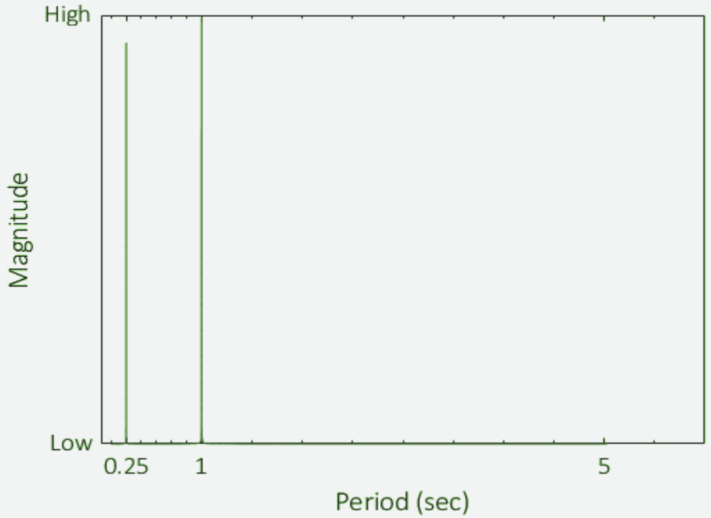
Time-frequency analysis

Synthetic signal :

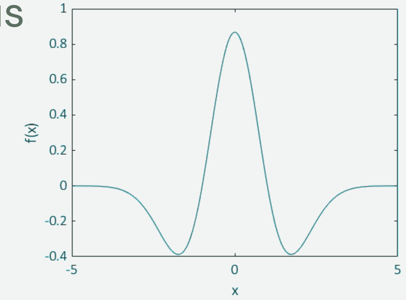


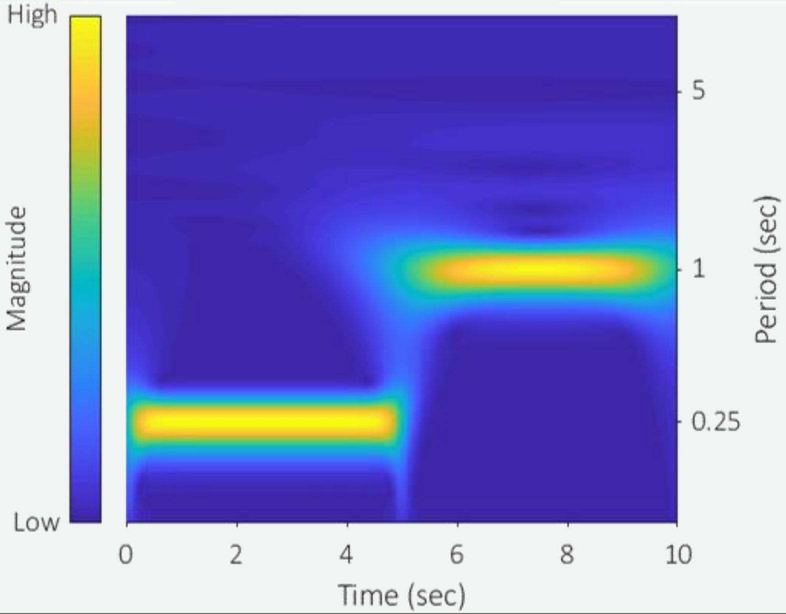
Fourier Transform



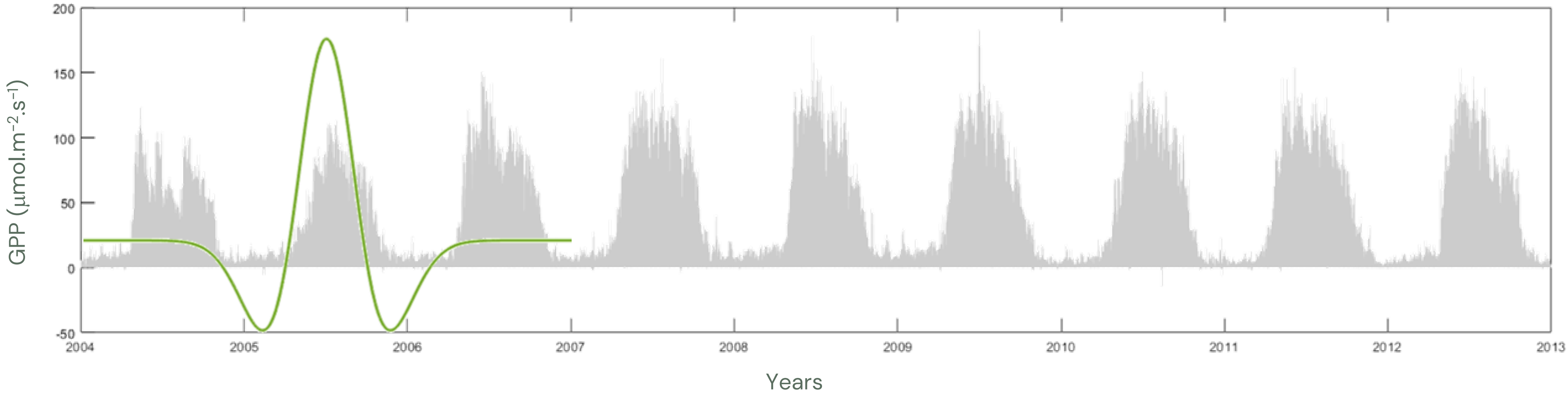


Continuous Wavelet Transform

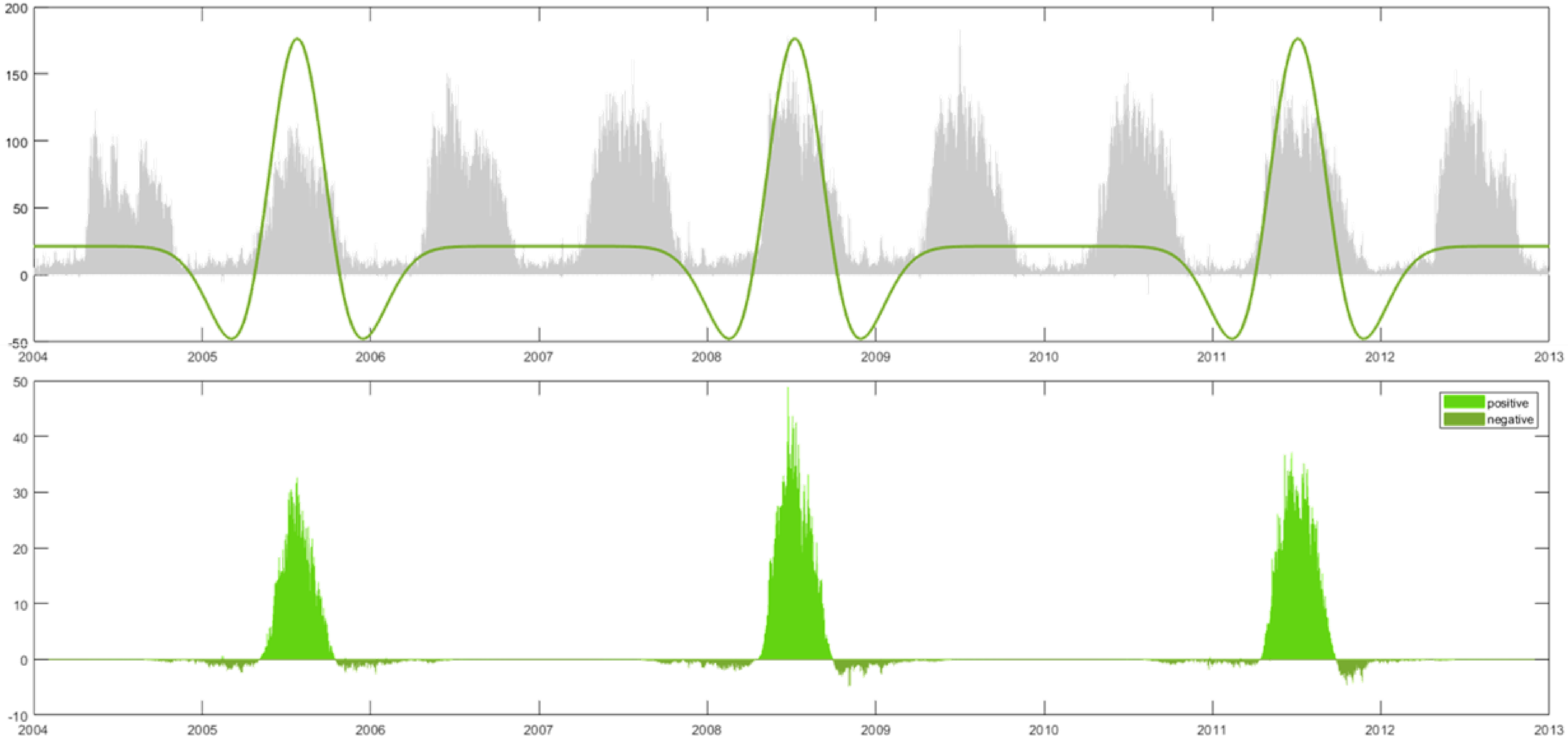




Continuous Wavelet Transform : **How does it work?**

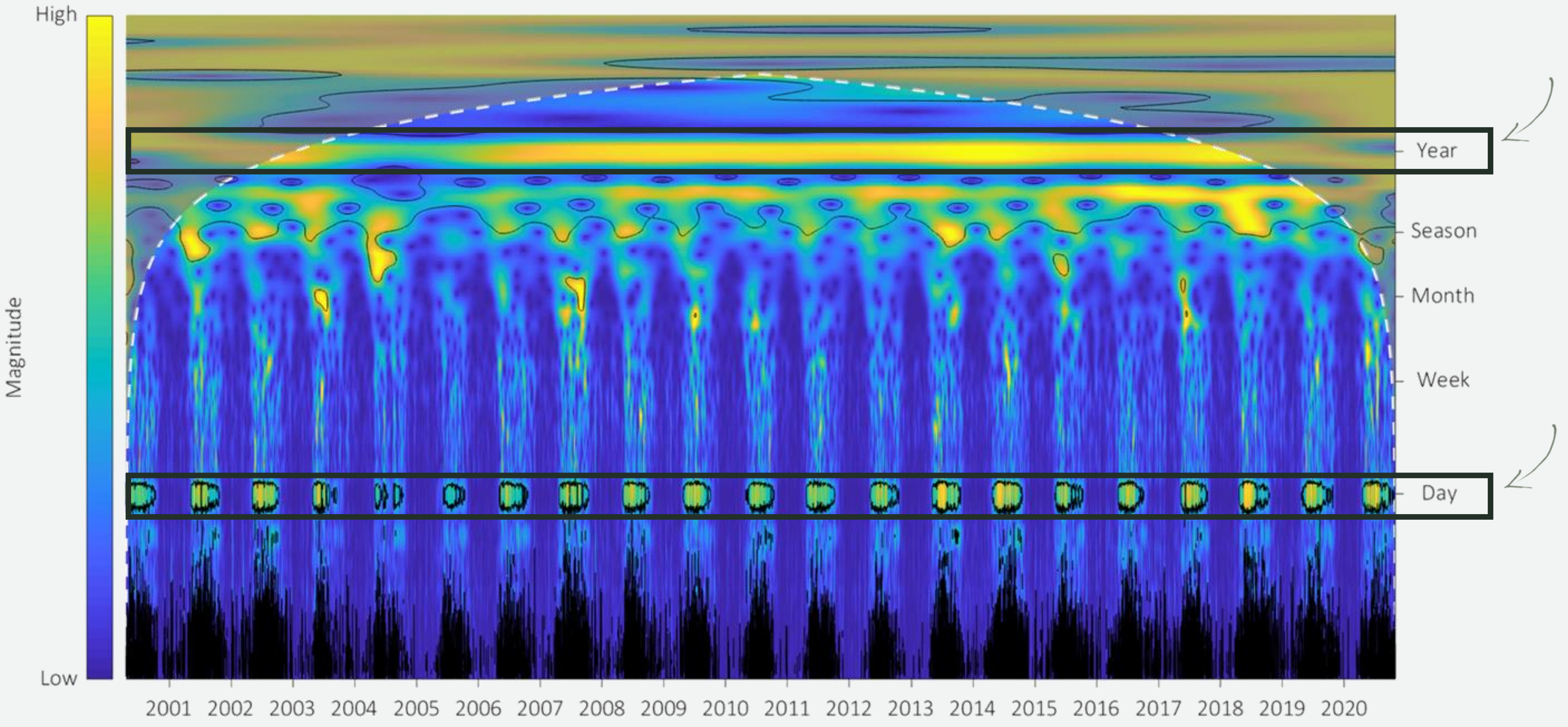


Continuous Wavelet Transform:
How does it work?

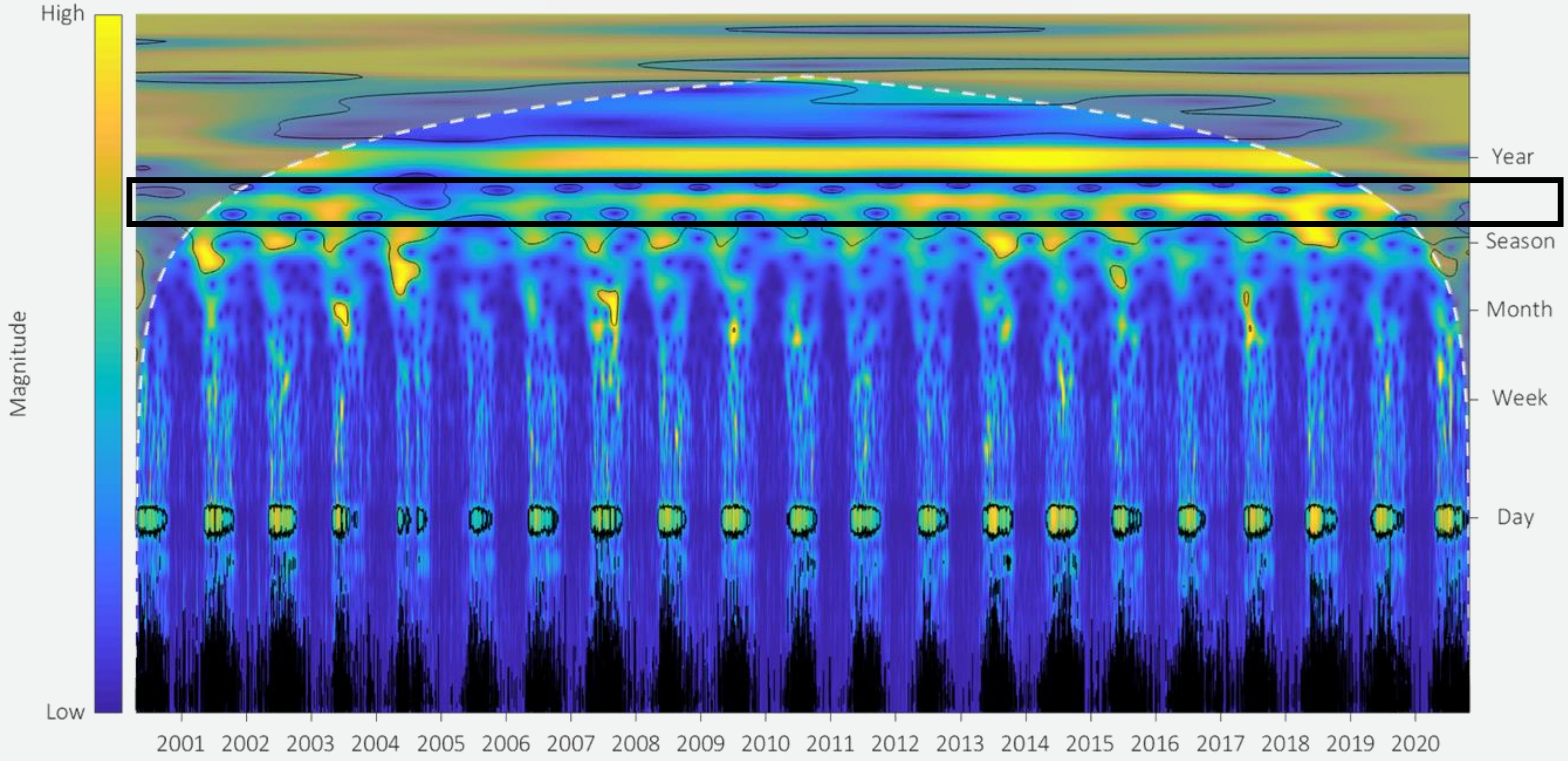


The Study
First Results

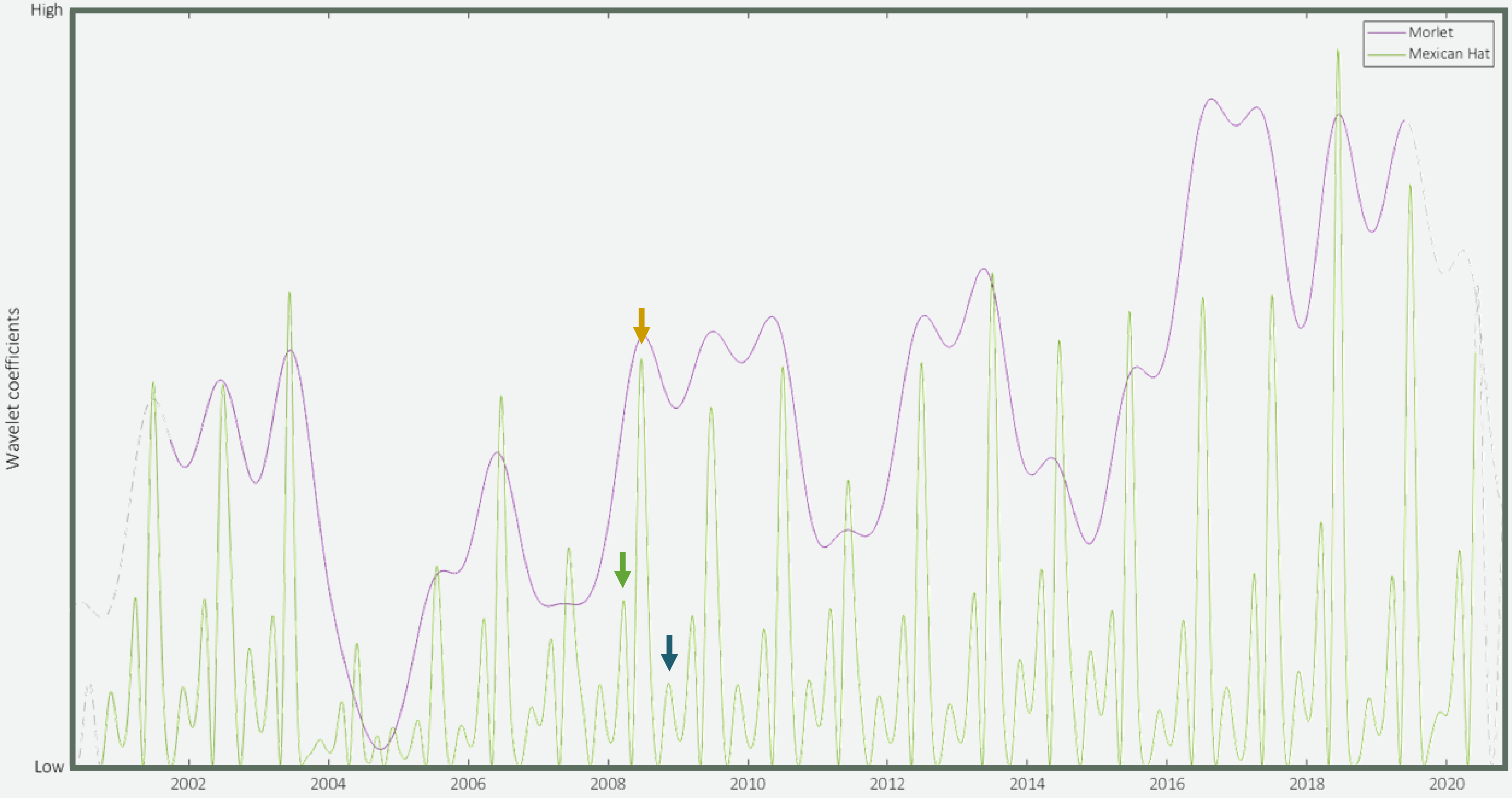
Scalogram of GPP



Scalogram of GPP

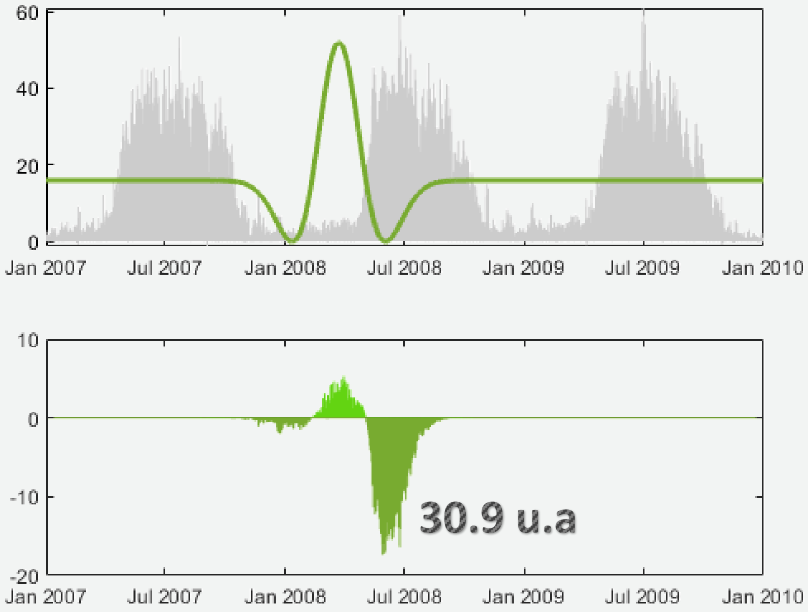


Wavelet coefficients at 6 months



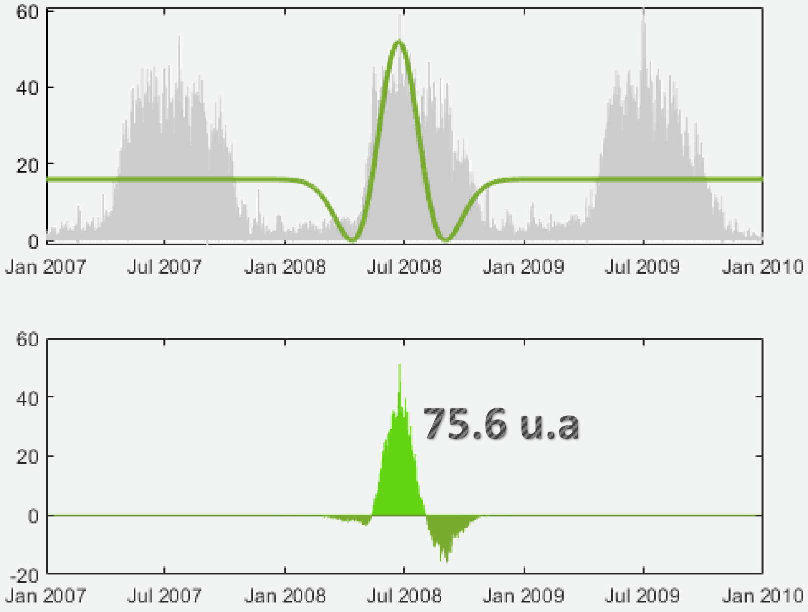
Peaks at 6 months for year 2008

April



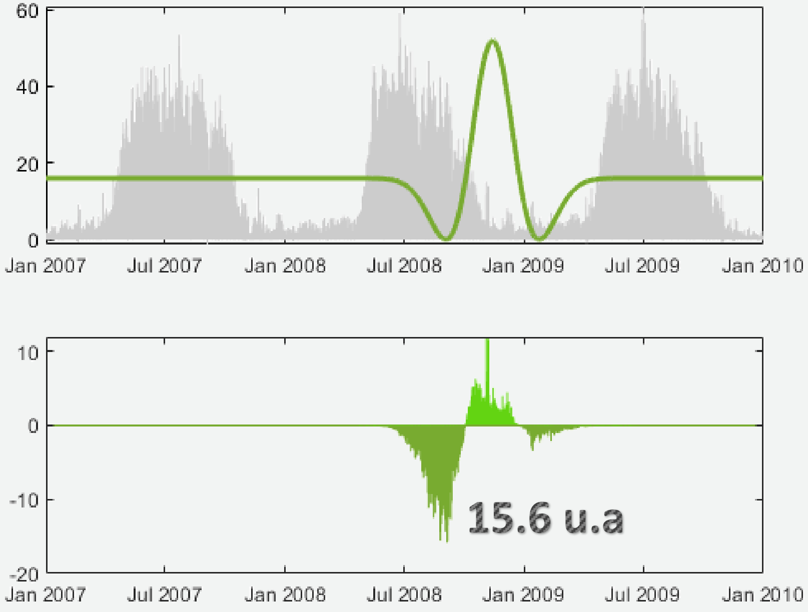
June GPP values

June



June-July GPP peak

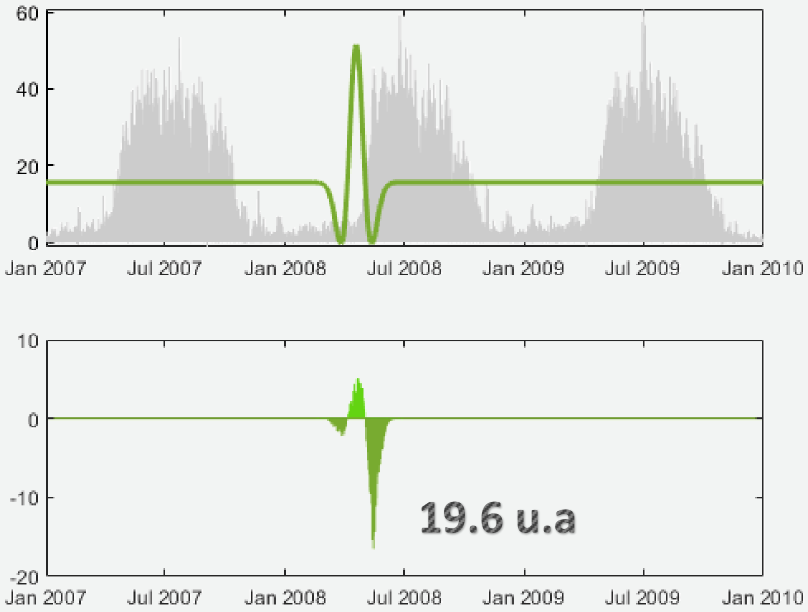
November



August – September GPP values

Peaks at 2 months for year 2008

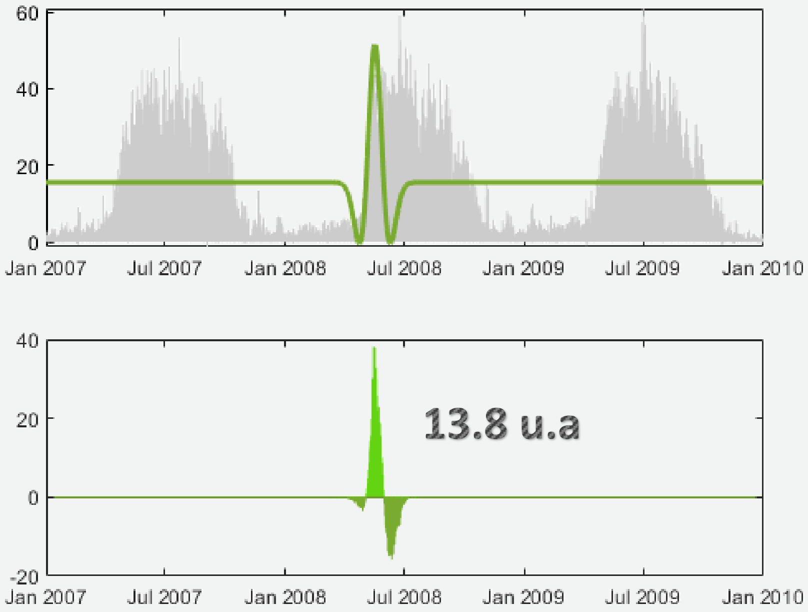
April



Steepness of GPP rise

(bud burst)

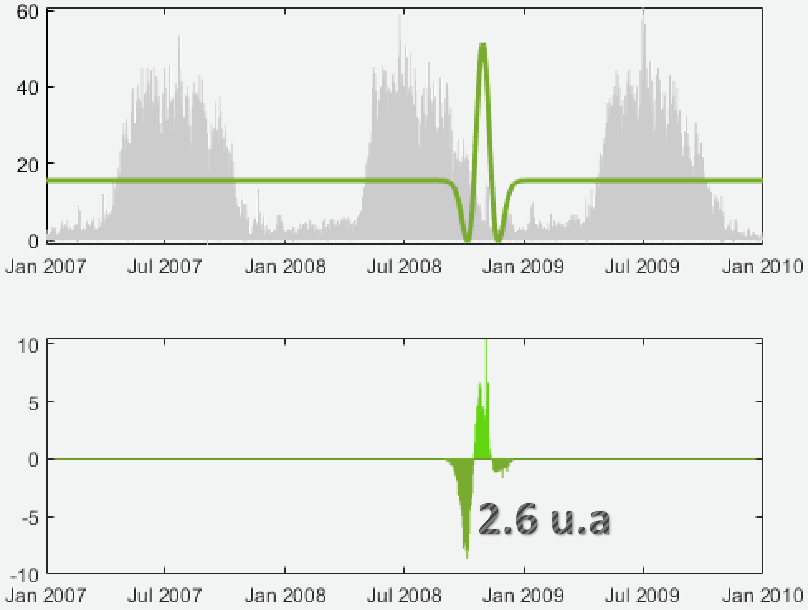
June



Amplitude of june GPP

rise + subsequent drop

November



Steepness of GPP drop

(senescence)

GPP Characteristics across years

	Yearly GPP (bell-shaped curve)	GPP variation to previous year	June GPP values	Steepness of GPP rise (Bud burst)	June-July GPP peak	August – September GPP values	Steepness of GPP drop (senescence)	Importance of August GPP drop
2000			23.72		43.16	14.00	3.01	3.13
2001	116.26		31.48	18.71	71.26	14.85	3.97	4.76
2002	133.93	17.67	31.17	12.69	70.81	22.07	4.59	3.23
2003	78.43	-55.51	28.04	17.12	87.99	5.07	0.80	16.67
2004	33.22	-45.20	12.16	14.50	22.96	7.37	2.02	3.13
2005	47.76	14.54	8.70	0.85	37.23	7.79	1.41	4.76
2006	92.47	44.70	27.59	12.38	68.76	11.15	1.77	6.25
2007	93.52	1.06	23.75	9.10	40.68	15.30	3.91	2.63
2008	110.63	17.10	30.90	19.61	75.56	15.58	2.06	4.76
2009	114.48	3.86	28.06	11.50	66.61	15.33	1.38	4.35
2010	109.87	-4.61	25.55	4.15	74.19	16.21	2.47	4.55
2011	106.88	-2.99	29.43	11.80	53.19	13.25	1.61	4.00
2012	102.45	-4.44	28.14	16.26	74.95	11.77	2.65	6.25
2013	134.53	32.08	32.32	8.76	91.45	20.02	3.68	4.55
2014	154.99	20.47	36.66	6.97	79.08	21.61	1.61	3.70
2015	103.37	-51.62	29.00	12.73	84.41	10.59	1.97	7.69
2016	111.03	7.66	27.27	11.51	87.00	14.83	0.92	5.88
2017	119.12	8.09	35.94	17.15	87.38	17.83	2.56	5.00
2018	144.00	24.88	45.40	17.14	132.81	12.82	3.77	10.00
2019	135.45	-8.56	35.43	7.34	107.84	10.19	1.50	11.11
2020			40.18	13.08	89.20	15.29		5.88

Positive coefficients :

High value

Low value

Negative coefficients :

High value

Low value

GPP drop in August

- 6 potential/available variables : Rg, Tair, P, Ts, VPD and REW

- 3 Indices for duration and intensity of environmental stresses

$$I.REW(i) = \sum_{365} \max\left(0, \frac{0.4 - REW(i)}{0.4}\right)$$

Based on Granier et al., 2007

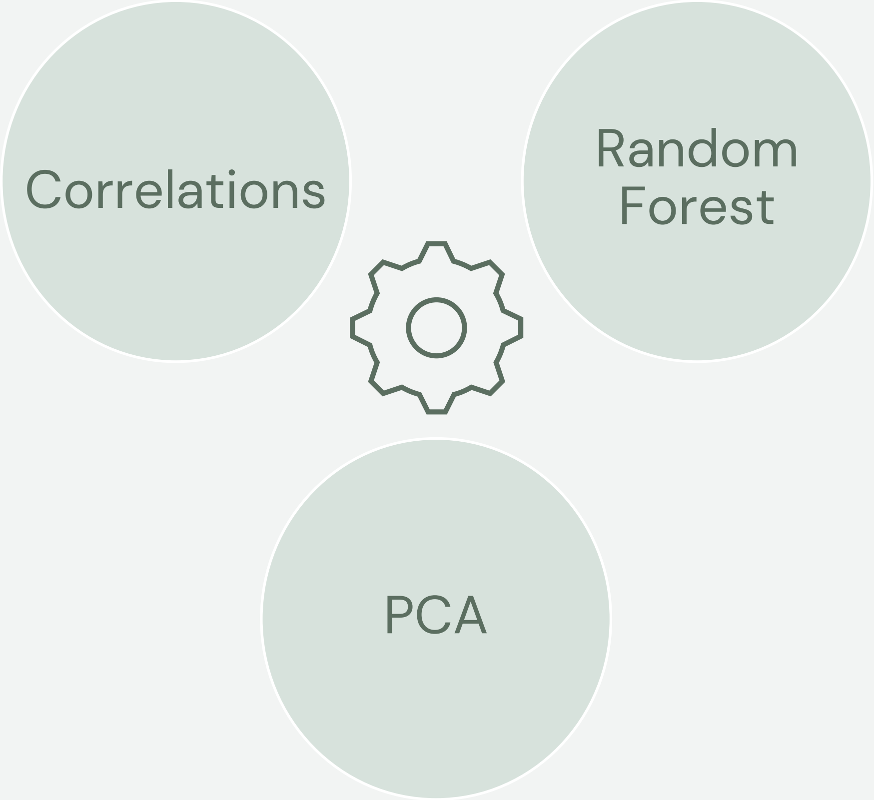
$$I.VPD(i) = \sum_{365} \max\left(0, \frac{VPD(i) - 1.5}{\max(VPD - 1.5)}\right)$$

$$I.Tair(i) = \sum_{365} \max\left(0, \frac{Tair(i) - 25}{\max(Tair - 25)}\right)$$

- 5 time steps : ½ month, month, 2 months, season, year

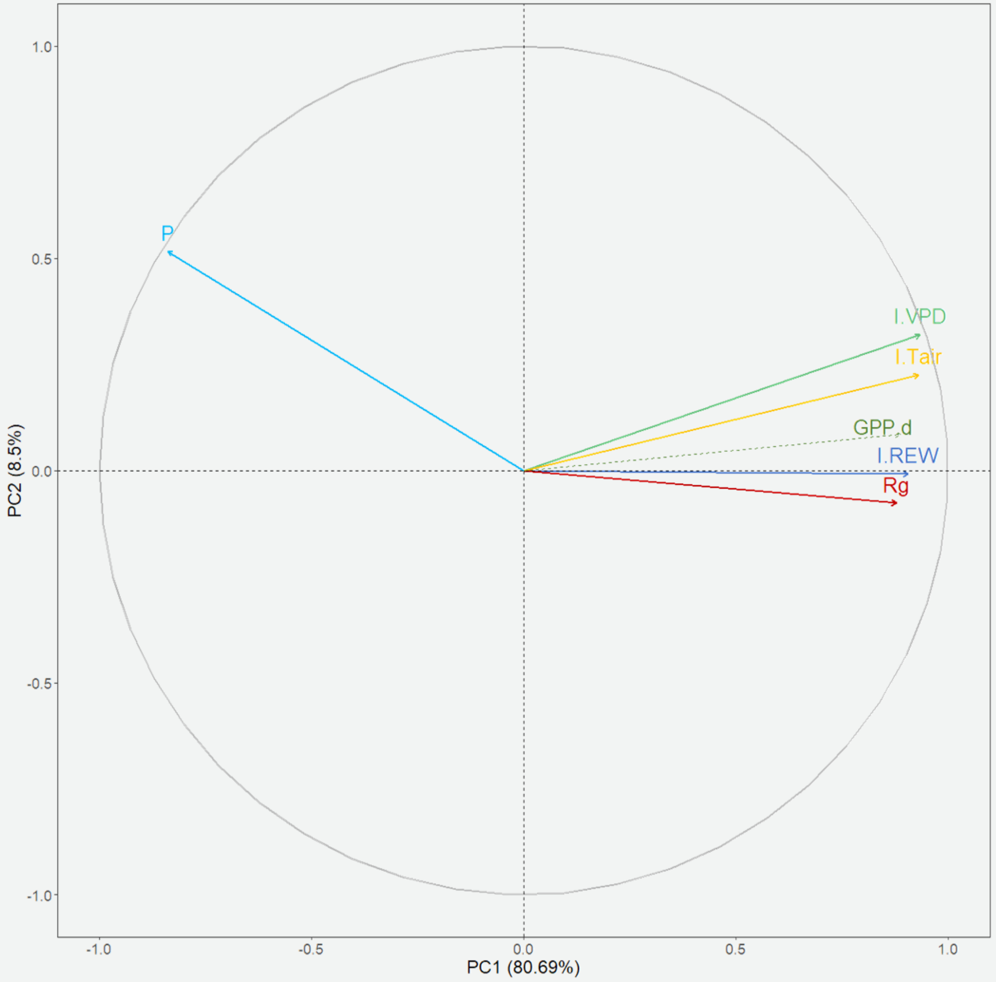
	Importance of August GPP drop
2003	16.67
2019	11.11
2018	10.00
2015	7.69
2012	6.25
2006	6.25
2016	5.88
2020	5.88
2017	5.00
2008	4.76
2001	4.76
2005	4.76
2010	4.55
2013	4.55
2009	4.35
2011	4.00
2014	3.70
2002	3.23
2000	3.13
2007	2.63

GPP drop in August



	Importance of August GPP drop	I.REW	I.VPD	I.Tair	Rg (July-Aug)	P (July-Aug)
2003	16.67	**58.82**	**14.26**	**10.18**	252.74	101.80
2019	11.11	**59.42**	**7.56**	**6.44**	250.16	83.80
2018	10.00	**64.45**	**6.65**	**5.25**	254.03	66.00
2015	7.69	**52.52**	**6.98**	**8.92**	240.23	59.60
2012	6.25	6.94	3.13	3.18	221.23	124.40
2006	6.25	7.29	3.98	3.13	223.61	185.20
2016	5.88	**31.59**	2.08	3.06	239.50	59.40
2020	5.88	**33.50**	**6.06**	**4.70**	240.39	89.20
2017	5.00	22.93	3.21	3.38	215.81	112.20
2008	4.76	5.90	0.44	0.41	208.22	142.00
2001	4.76	13.44	1.62	1.10	229.05	174.80
2005	4.76	16.00	2.22	1.71	210.57	134.20
2010	4.55	0.05	2.10	2.44	218.27	235.20
2013	4.55	12.44	2.52	3.70	245.02	93.60
2009	4.35	0.07	1.17	1.40	228.04	205.80
2011	4.00	0.00	1.55	1.61	210.75	207.20
2014	3.70	11.15	1.79	1.66	201.09	218.40
2002	3.23	1.33	0.79	0.89	195.45	172.40
2000	3.13	0.00	0.70	0.22	203.25	239.20
2007	2.63	0.00	1.45	0.59	199.45	329.20

GPP drop in August



- First dimension : Depletion of soil water reserves
- Second dimension : Air water content, storm events?
- GPP drop mostly driven by Rg (normal behavior) and drought intensity/duration

Conclusions
& Perspectives

Conclusions & Perspectives

- Indicators of photosynthesis patterns across years
- Preliminary results concerning the effect of droughts on GPP
  - Other variables : moment of drought and rainfall
- Other events : thinning

	Yearly GPP (bell-shaped curve)	GPP variation to previous year	June GPP values	Steepness of GPP rise (Bud burst)	June-July GPP peak	August – September GPP values	Steepness of GPP drop (senescence)	Importance of august GPP drop
2005	47.76	14.54	8.70	0.85	37.23	7.79	1.41	4.76
2010	109.87	-4.61	25.55	4.15	74.19	16.21	2.47	4.55
2016	111.03	7.66	27.27	11.51	87.00	14.83	0.92	5.88

Limited to no impact on other indicators !

Thank you for your attention!

Jonathan Bitton
University of Liege, Gembloux Agro-Bio Tech
PhD student in environmental sciences and technologies

Jonathan.bitton@uliege.be