Measurement of Air Exchange Rates from Daily Cycle of Ambient CO_2

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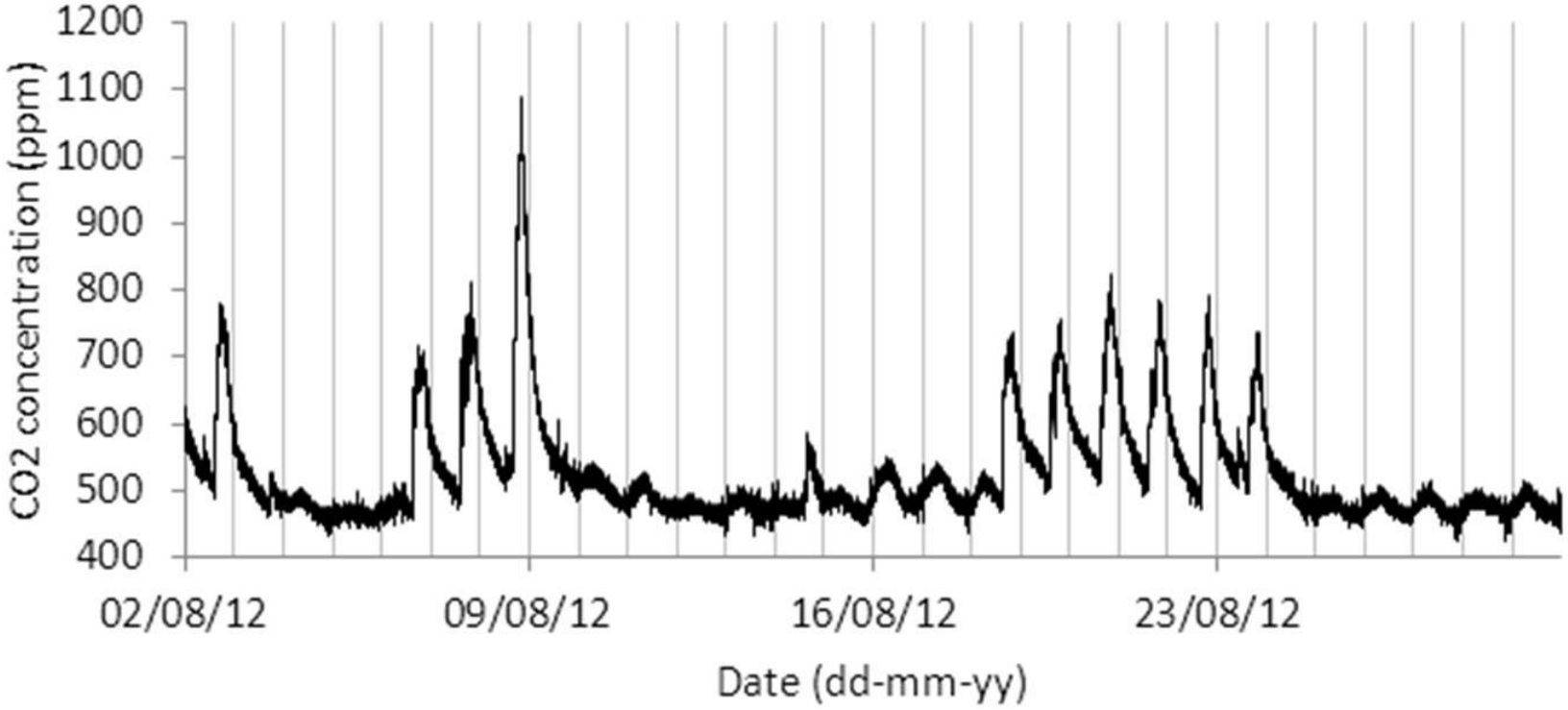
POPH

QUADRO DE REFERÊNCIA ESTRATÉGICO NACIONAL PORTUGAL 2007.2013

UNIÃO EUROPEIA
Fundo Social Europeu

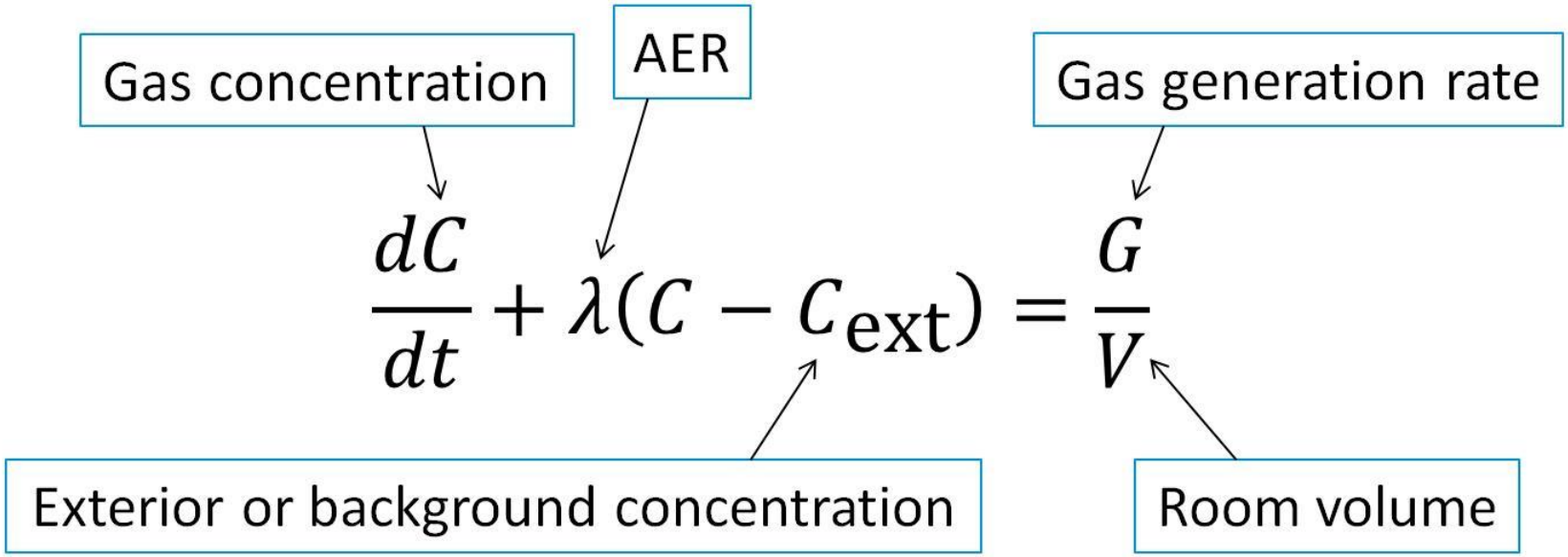
Background

- Tracer gas concentration profiles can be used to determine Air Exchange Rates (AERs)



Background

- Governing equation:

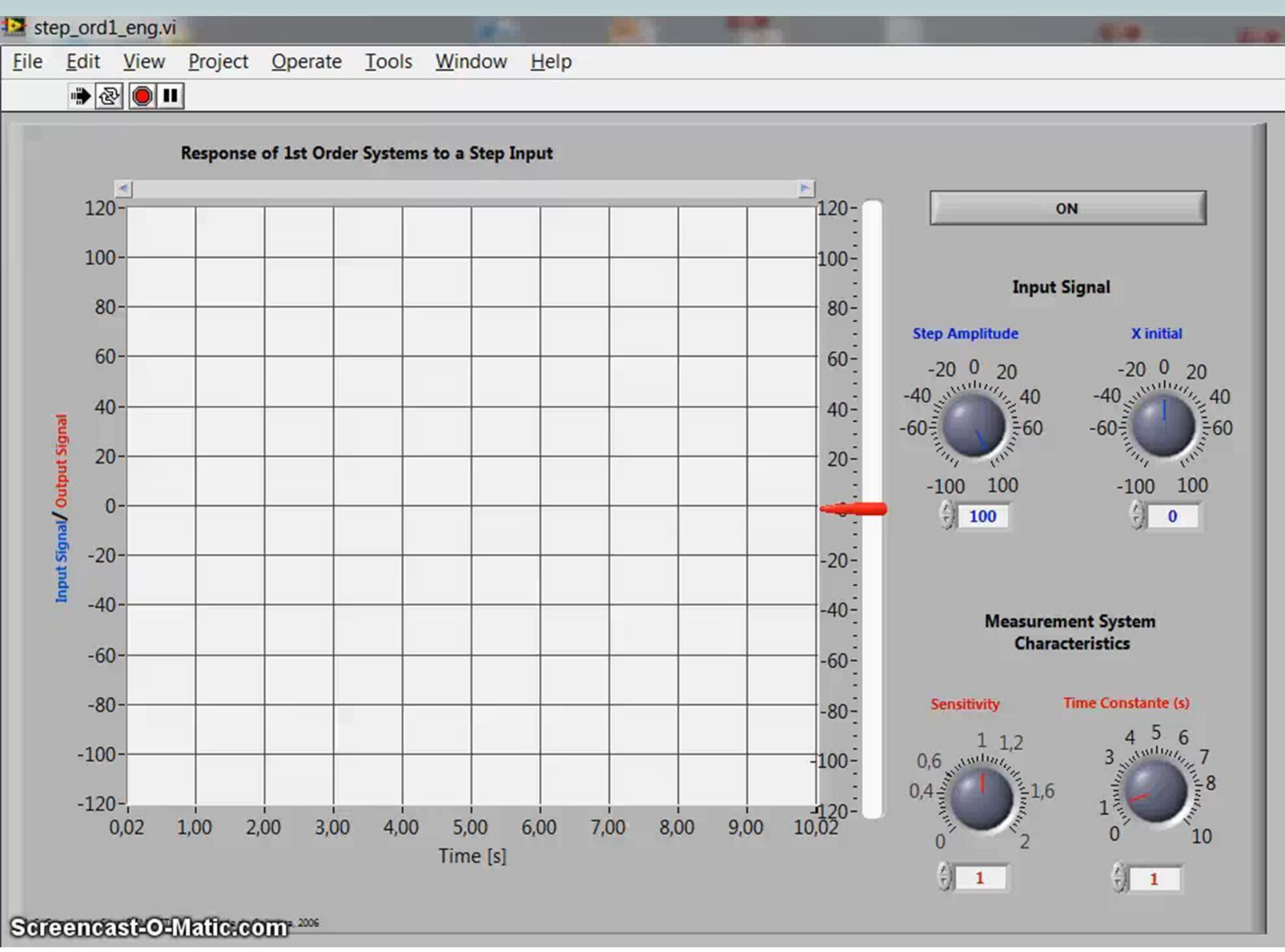


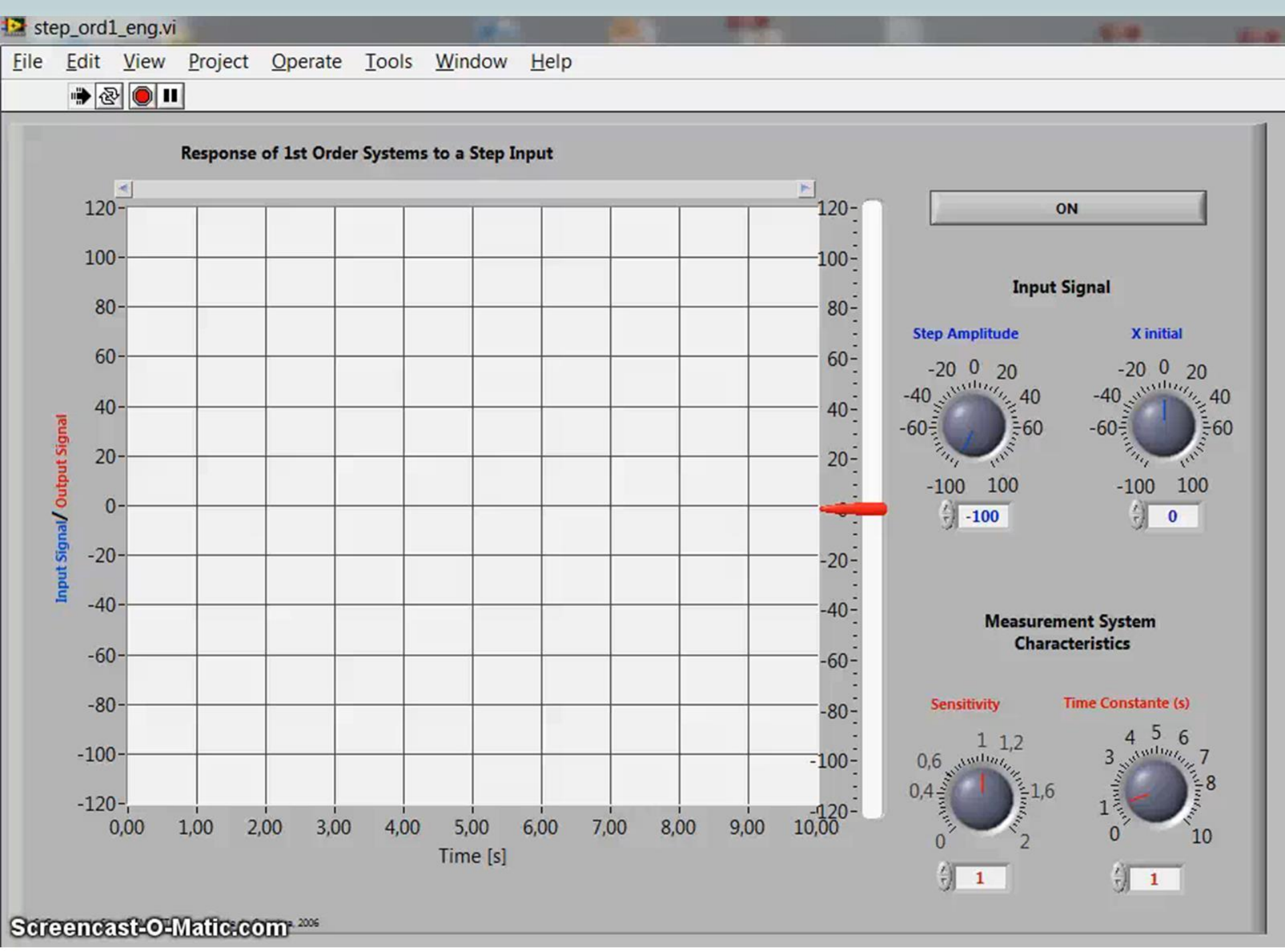
Background

- For constant λ, solution is:

$$C(t) - C_{\text{equi}} = \left(C(t_0) - C_{\text{equi}}\right) e^{-\lambda t}$$

Equilibrium concentration


step_ord1_eng.vi
File Edit View Project Operate Tools Window Help
Response of 1st Order Systems to a Step Input
Input Signal/ Output Signal
Time [s]
0,02 1,00 2,00 3,00 4,00 5,00 6,00 7,00 8,00 9,00 10,02
ON
Input Signal
Step Amplitude
X initial
100
0
Measurement System Characteristics
Sensitivity
Time Constante (s)
1
1
Screencast-O-Matic.com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-100
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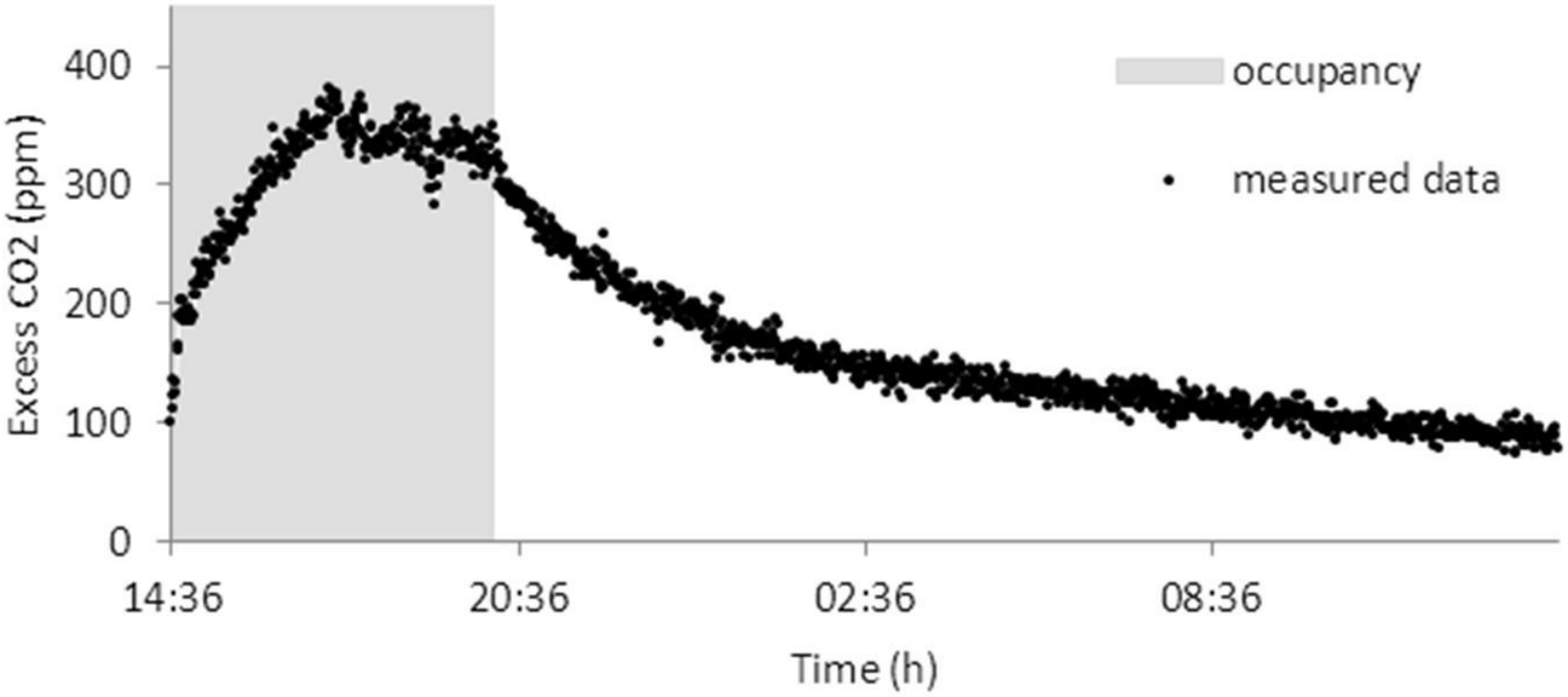
1
1
Screencast-O-Matic.com

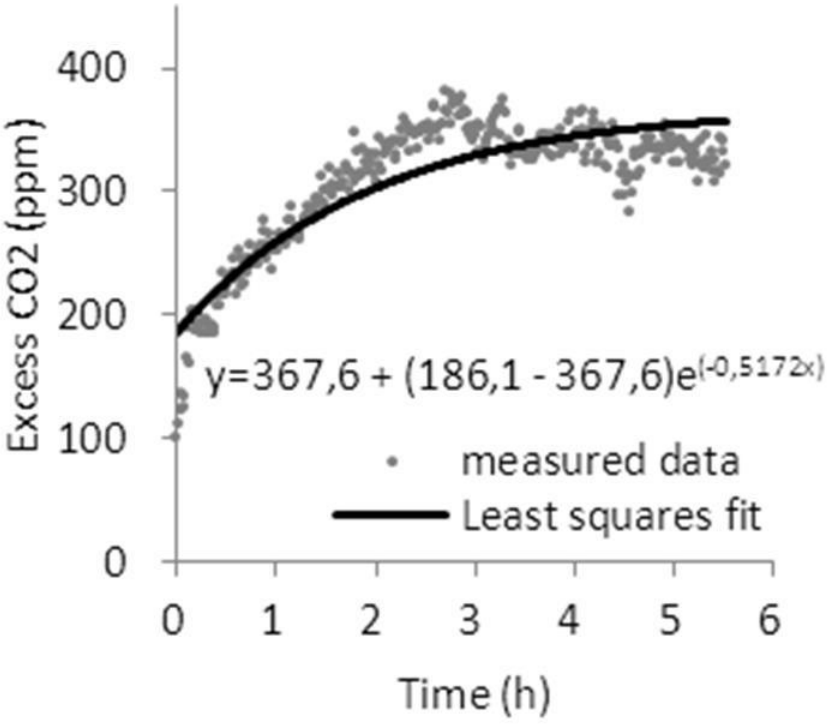
Conventional analysis techniques

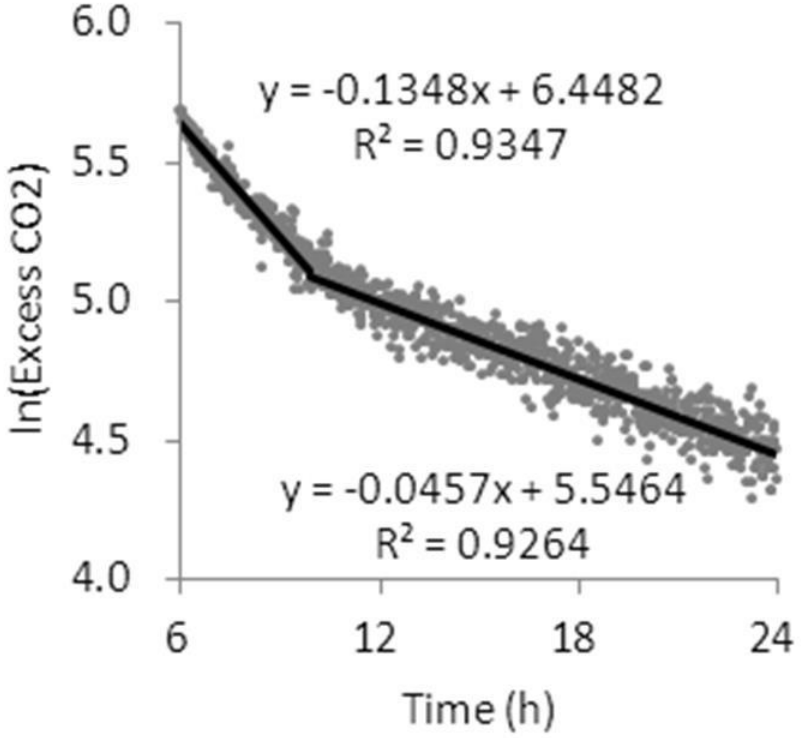
- Metabolic CO_2 as a tracer gas:



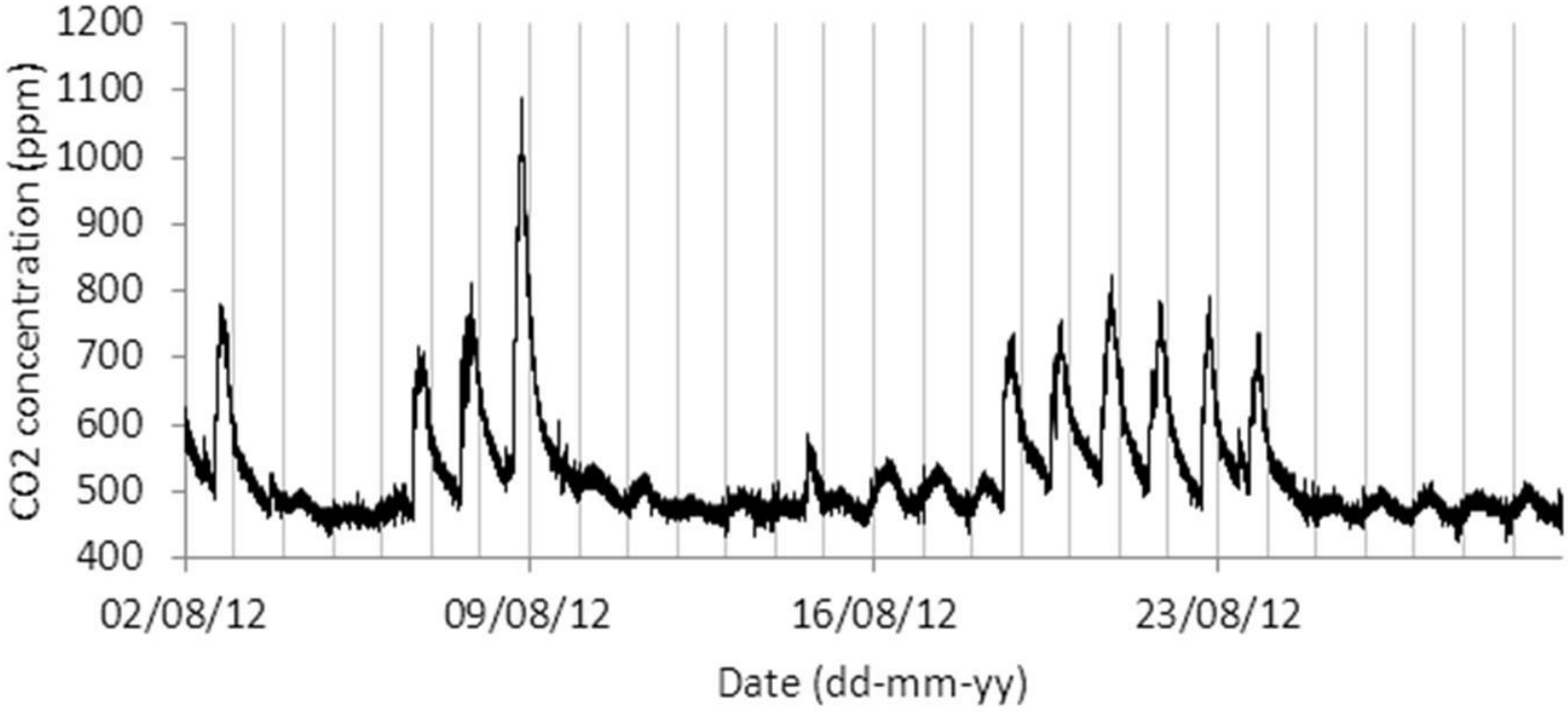
Conventional analysis techniques

- Fitting the exponential solution using the LS method:





Ventilation rate time series from tracer gas time series?



Time variant formulation

- What if λ is allowed to vary continuously in time?
- Typically the situation found in natural ventilation…
- …also in DCV systems

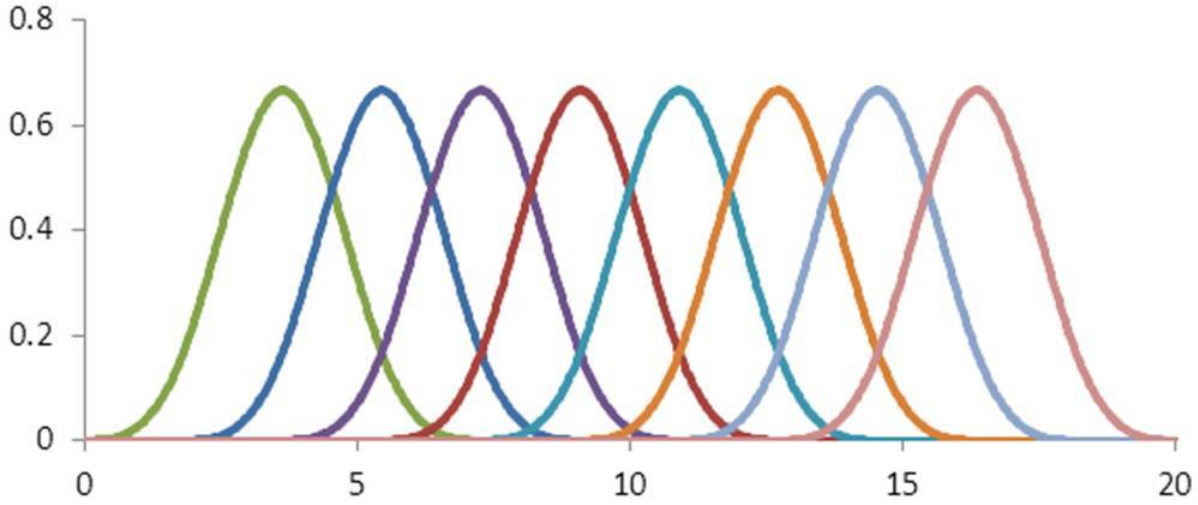
Time varying AER

$$\frac{dC}{dt} + \lambda(t)(C - C_{\text{ext}}) = \frac{G}{V}$$

Time variant formulation

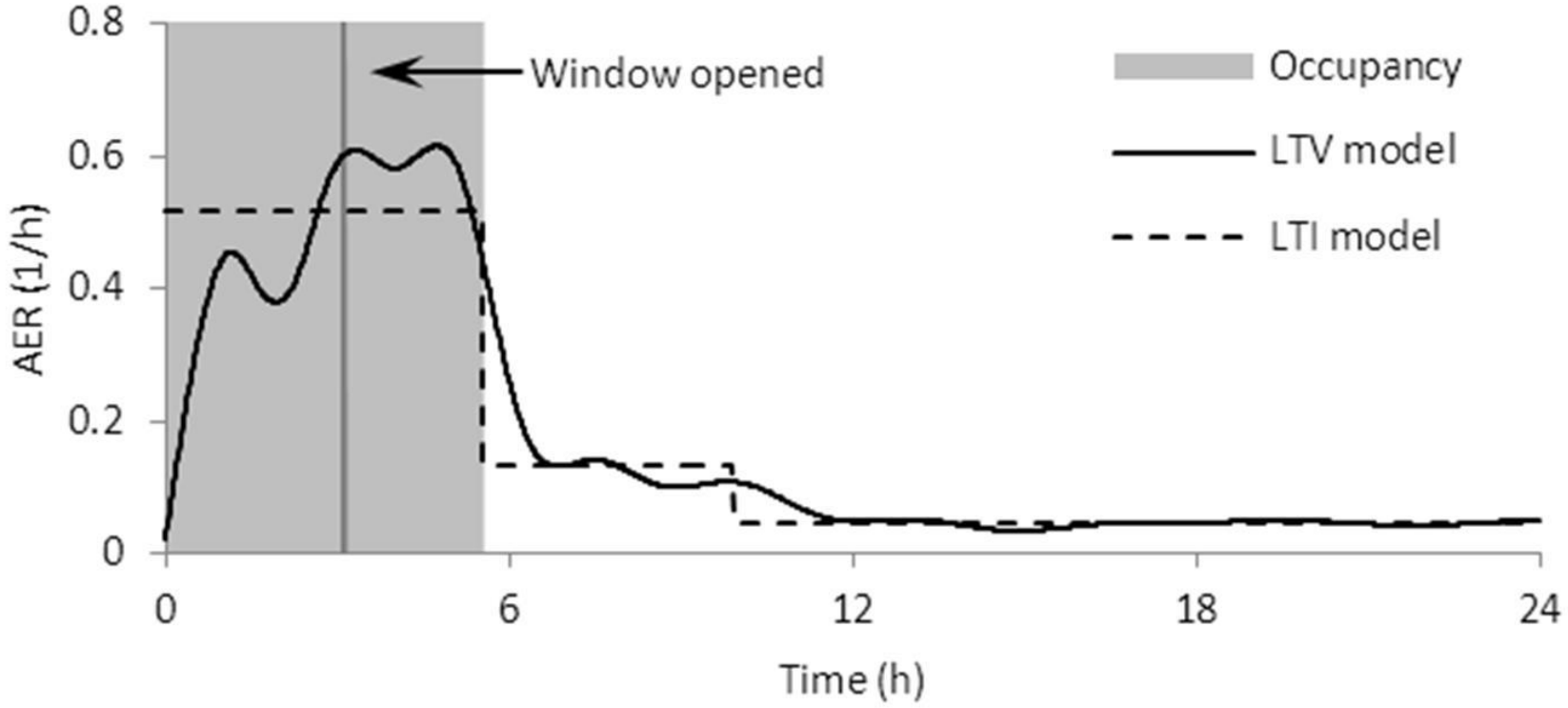
- Approximate $\lambda(t)$ by a linear combination of basis functions:

$$\lambda(t) = \sum a_m \phi_m(t)$$

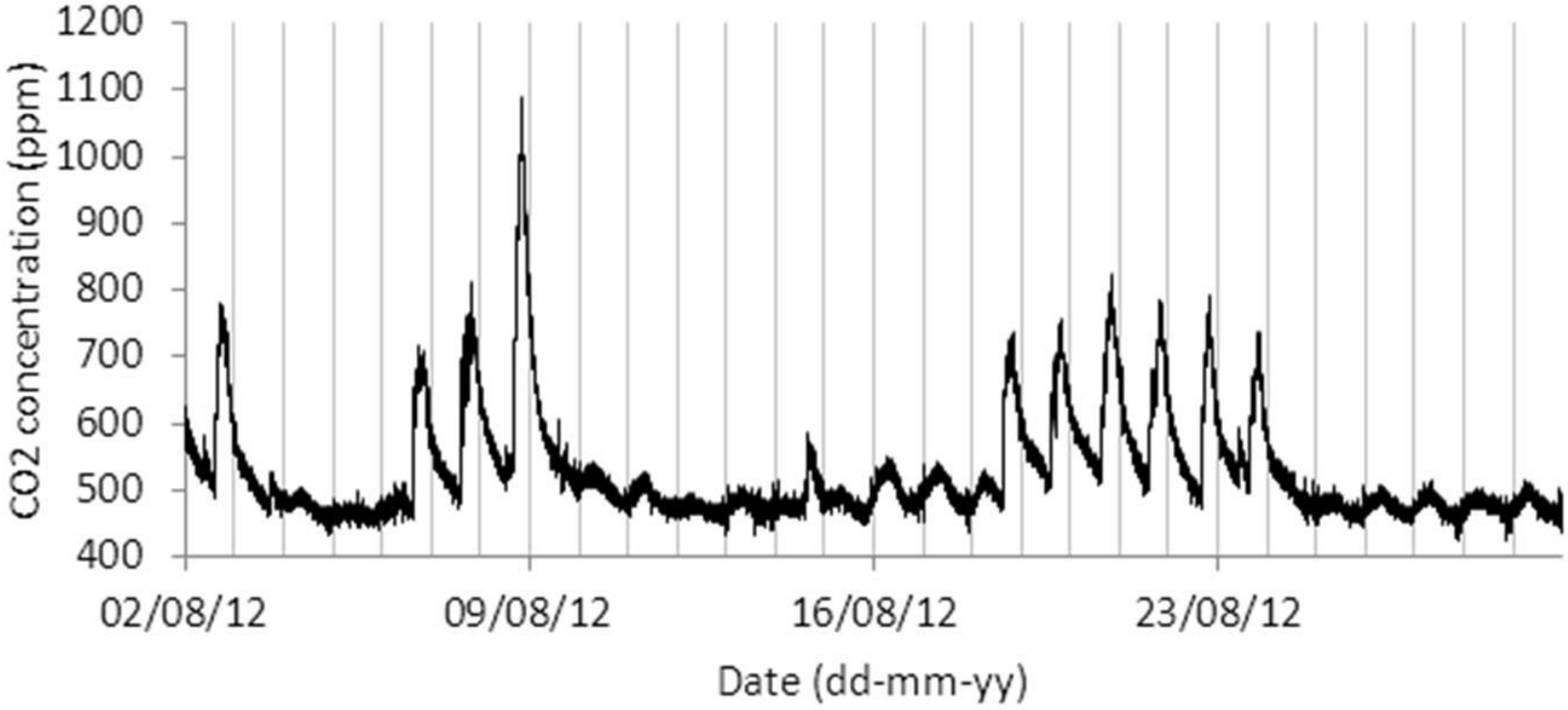


Time variant formulation + collocation of cubic splines:

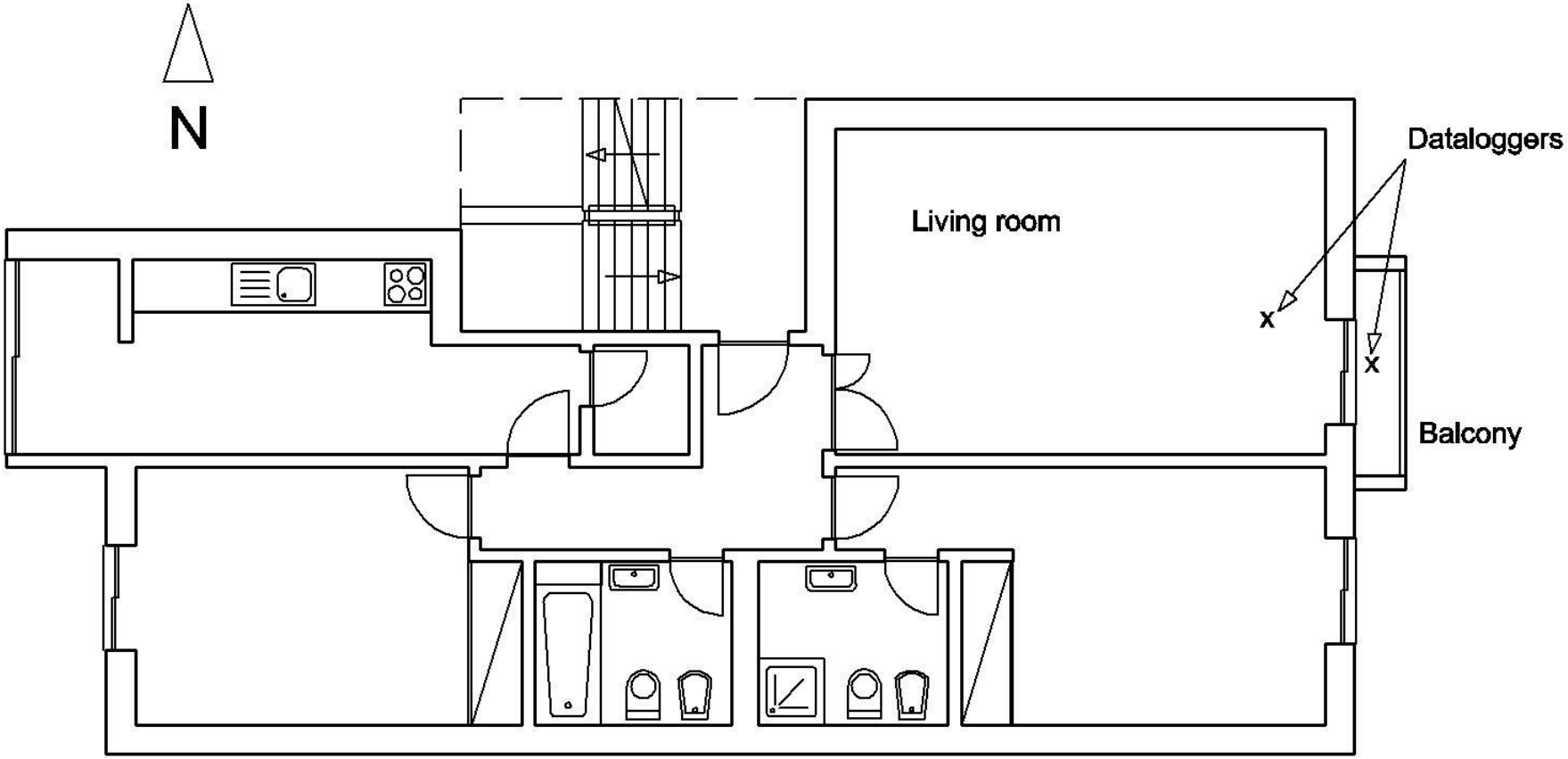
J Dias Carrilho, S Batterman and M Gameiro da Silva. *Estimating Time Varying Air Exchange Rates*, presented at CLIMA 2013, Prague



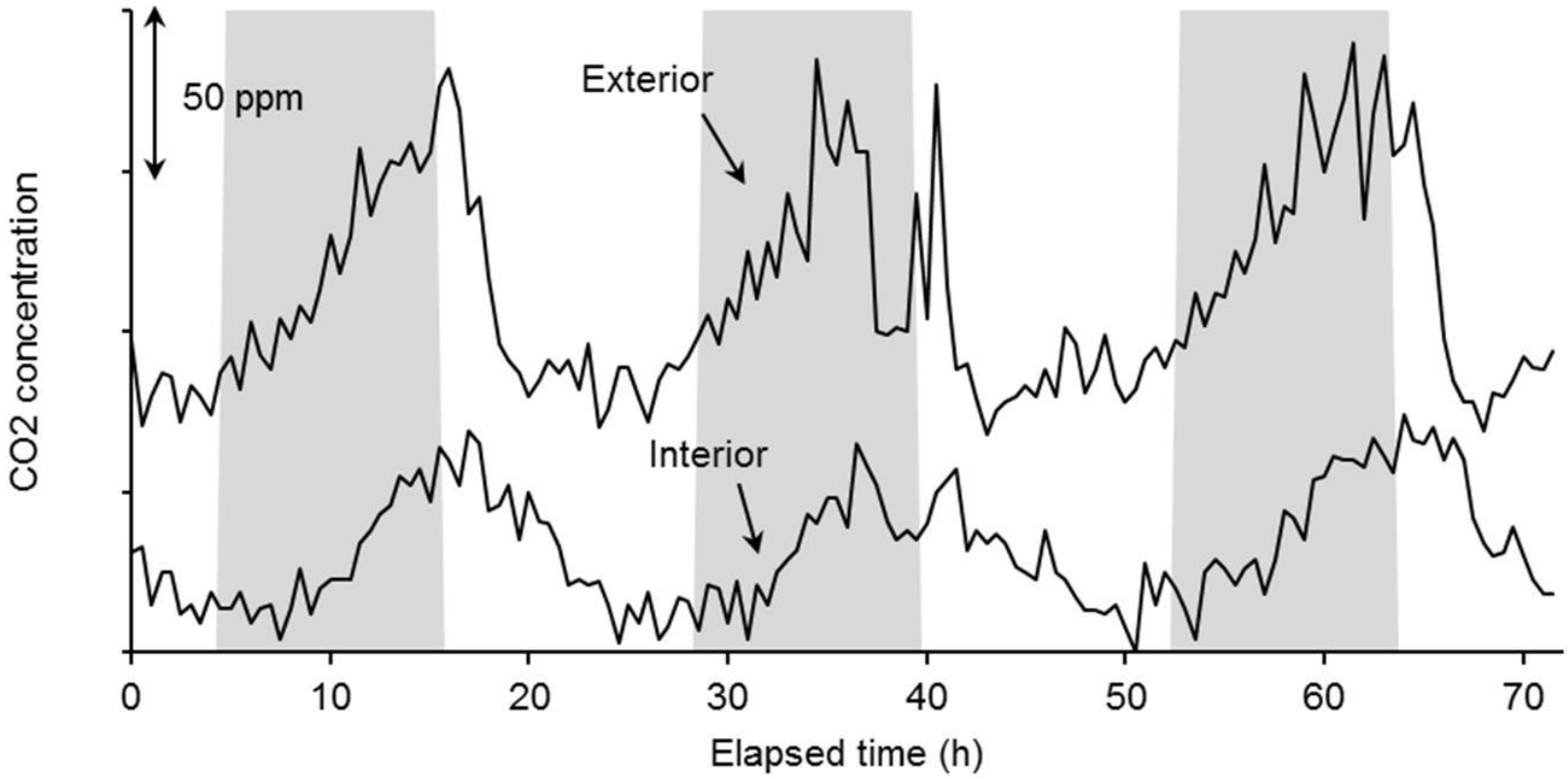
What about days without occupancy?



Trying out ideas...



Inside concentration follows outside concentration like a first order system!



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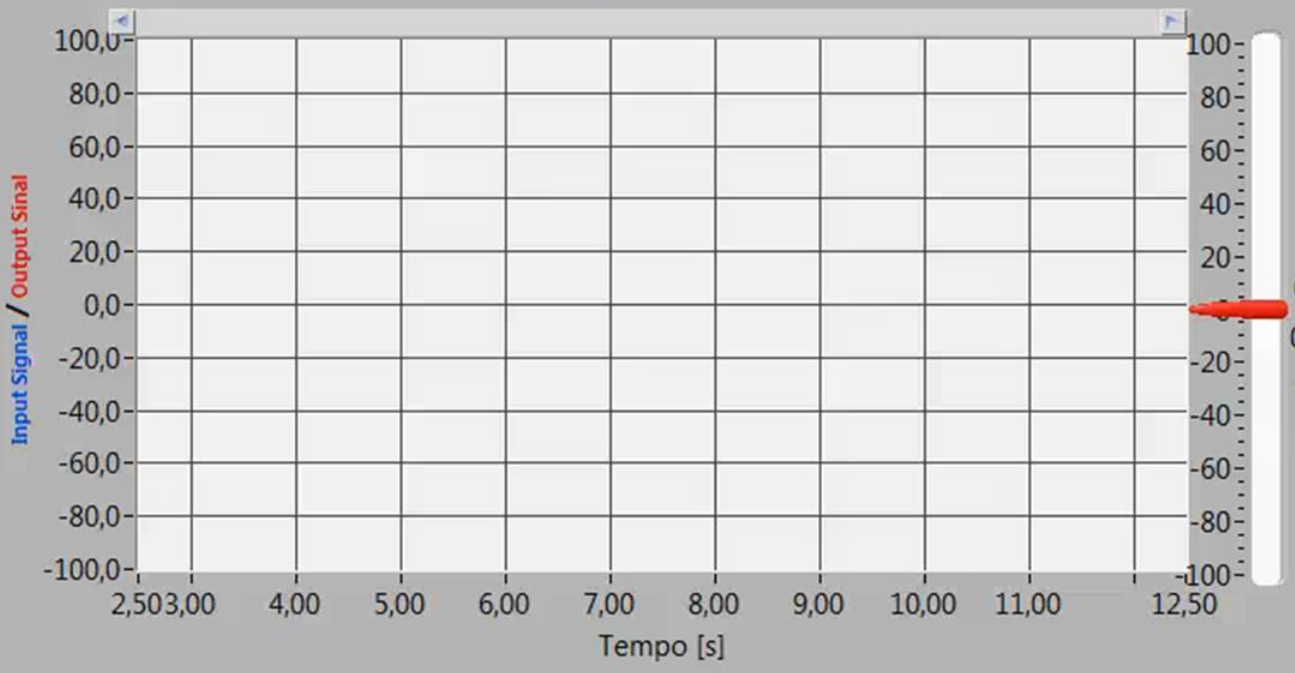
Response of Zero and 1st Order System to a Periodic Input



Input Signal

Frequency (Hz)

0,5

Amplitude

50

Caractheristics of do Measurement System

Sensitivity

1

Time Constant (s)

0,1

Phase angle 0,0 degrees

Time delay 0,00 s

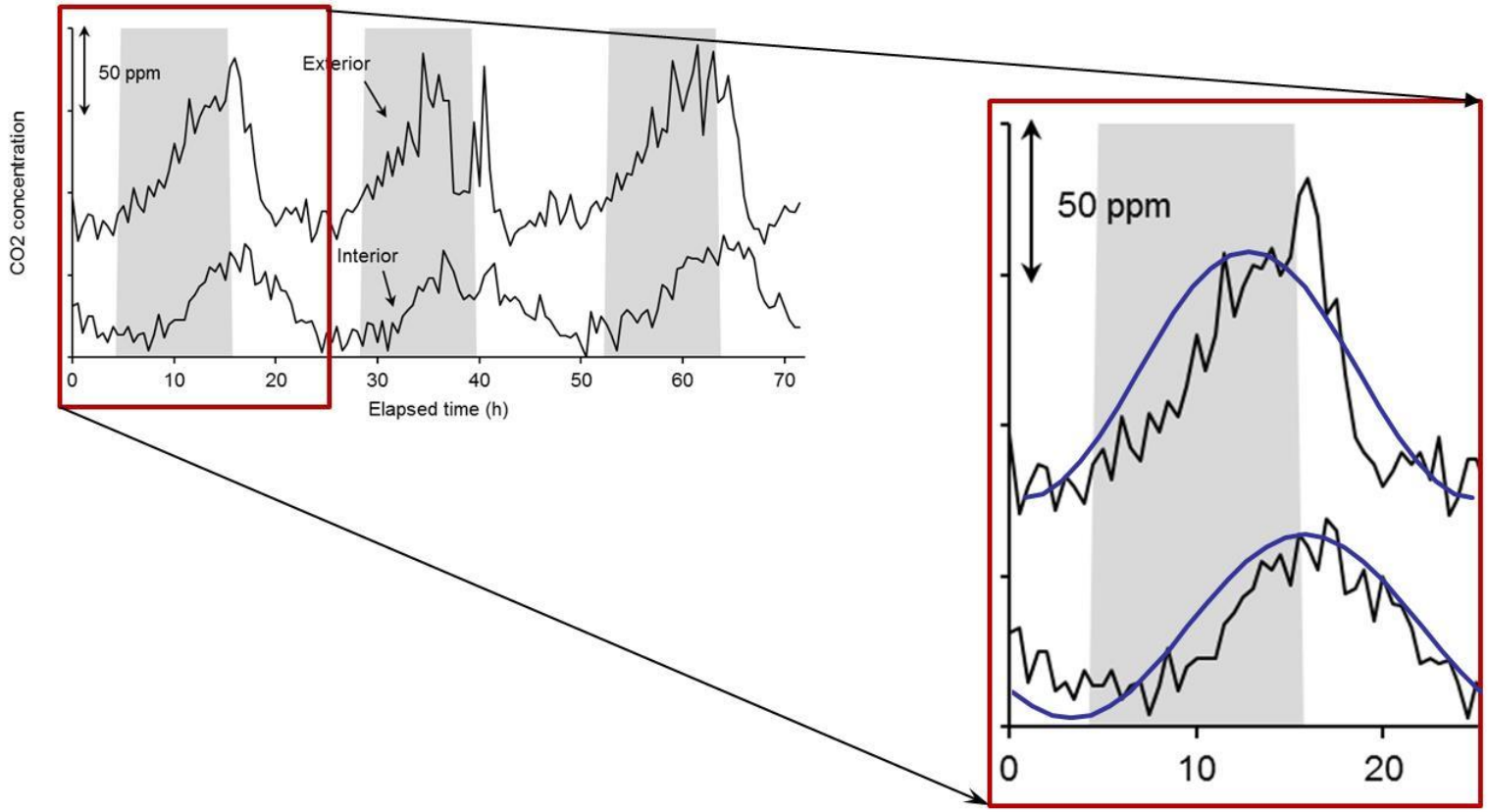
Amplitude ratio 0,00

ON OFF

M.C. Gameiro da Silva DEM-FCT, Universidade de Coimbra, 2006

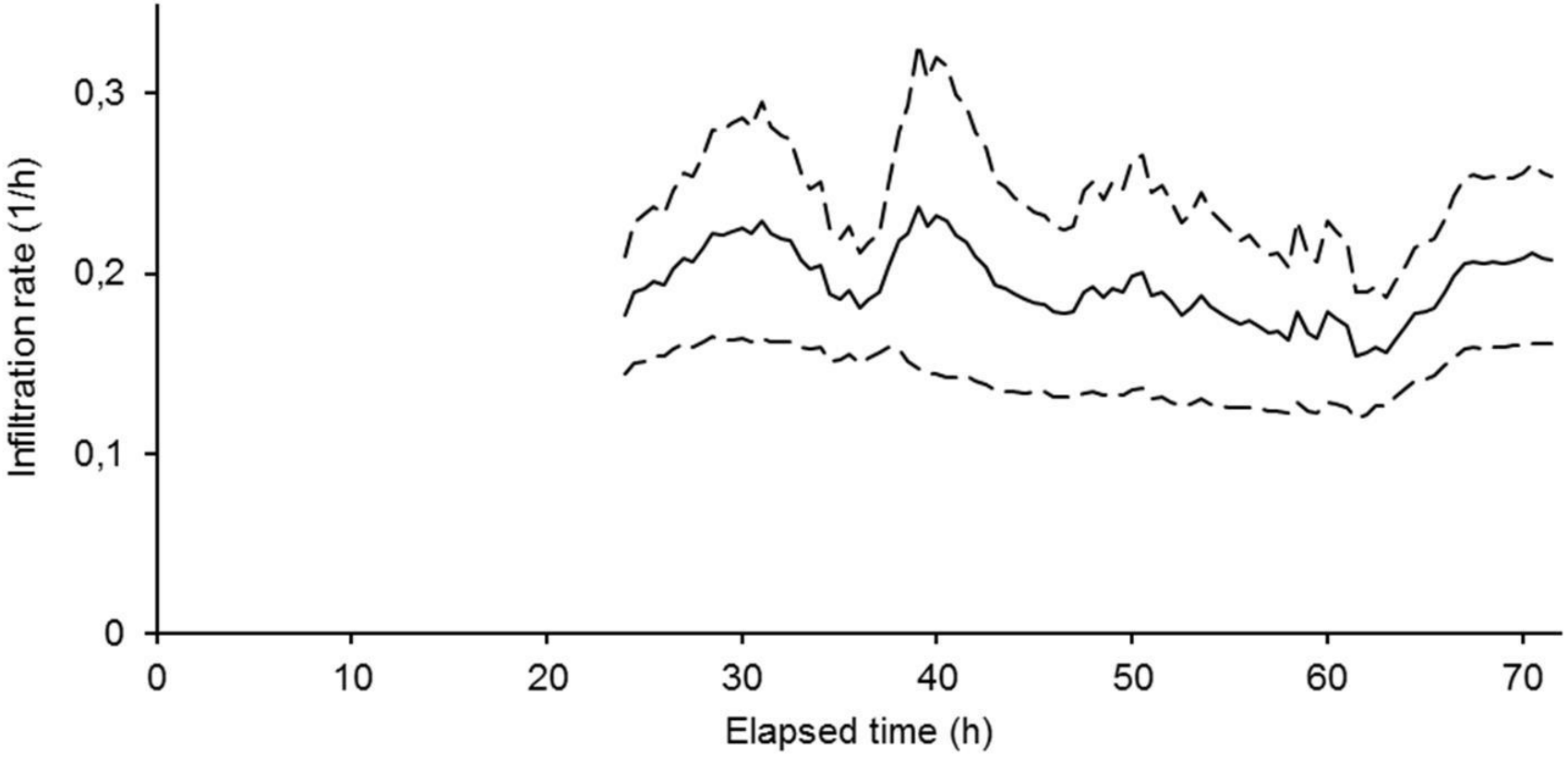
Compute 24h moving average AER from Input/Output relation of a first order system

Dias Carrilho, J., Mateus, M., Batterman, S., Gameiro da Silva, M., Measurement of infiltration rates from daily cycle of ambient CO_2, 35th AIVC conference, Poznan, September 2014.



Preliminary results

Dias Carrilho, J., Mateus, M., Batterman, S., Gameiro da Silva, M., Measurement of infiltration rates from daily cycle of ambient CO_2. Accepted for publication in *International Journal of Ventilation* (2016).



J Dias Carrilho, M Mateus, S Batterman and M Gameiro da Silva. *Air Exchange rates from atmospheric CO2 daily cycle*, Energy and Buildings, 92 (2015) 188-194

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journal homepage: www.elsevier.com/locate/enbuild

Air exchange rates from atmospheric CO_2 daily cycle

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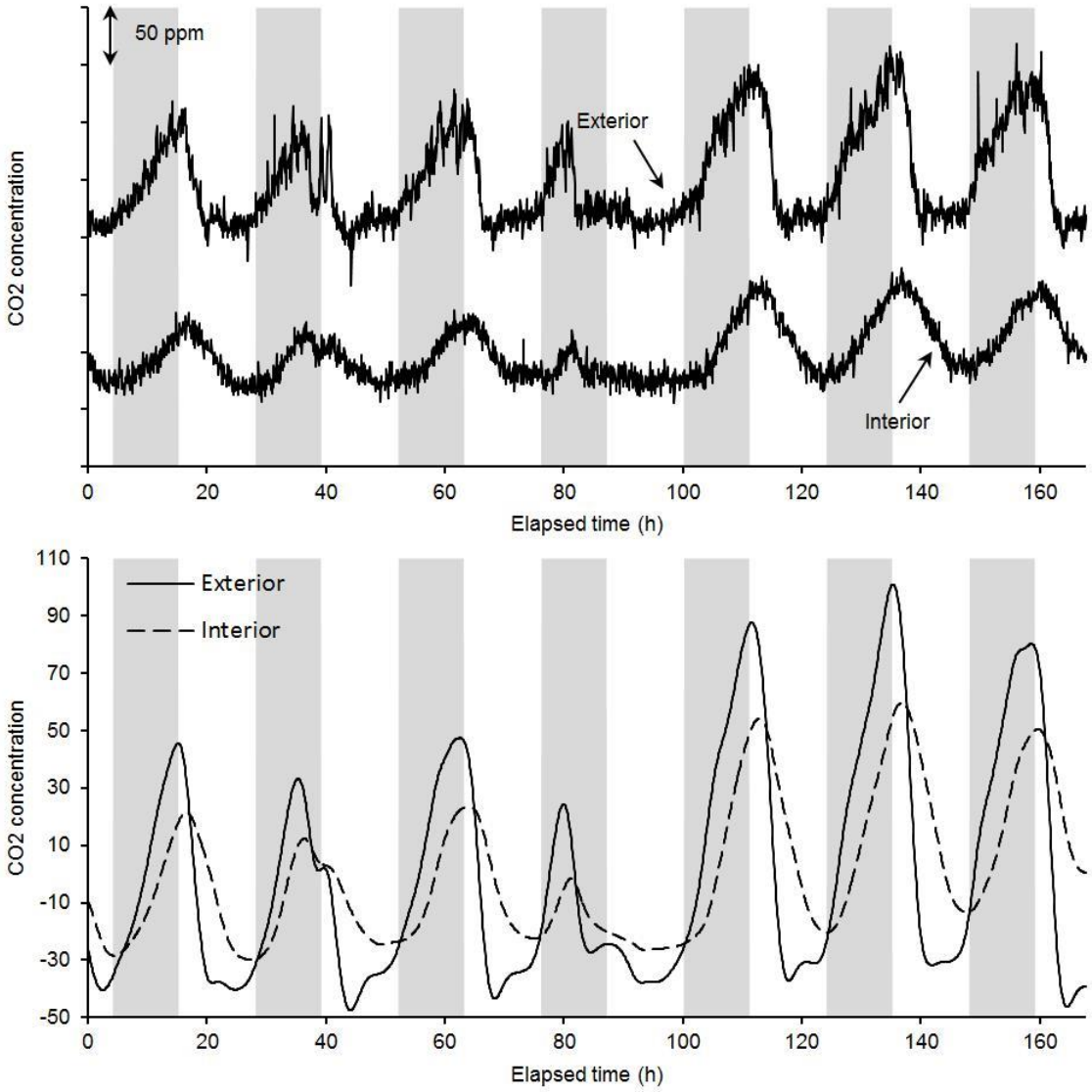
Hilbert transform

ABSTRACT

We propose a new approach for measuring ventilation air exchange rates (AERs). The method belongs to the class of tracer gas techniques, but is formulated in the light of systems theory and signal processing. Unlike conventional CO_2 based methods that assume the outdoor ambient CO_2 concentration is constant, the proposed method recognizes that photosynthesis and respiration cycle of plants and processes associated with fuel combustion produce daily, quasi-periodic, variations in the ambient CO_2 concentrations. These daily variations, which are within the detection range of existing monitoring equipment, are utilized for estimating ventilation rates without the need of a source of CO_2 in the building. Using a naturally-ventilated residential apartment, AERs obtained using the new method compared favorably (within 10%) to those obtained using the conventional CO_2 decay fitting technique. The new method has the advantages that no tracer gas injection is needed, and high time resolution results are obtained.

Preliminary results



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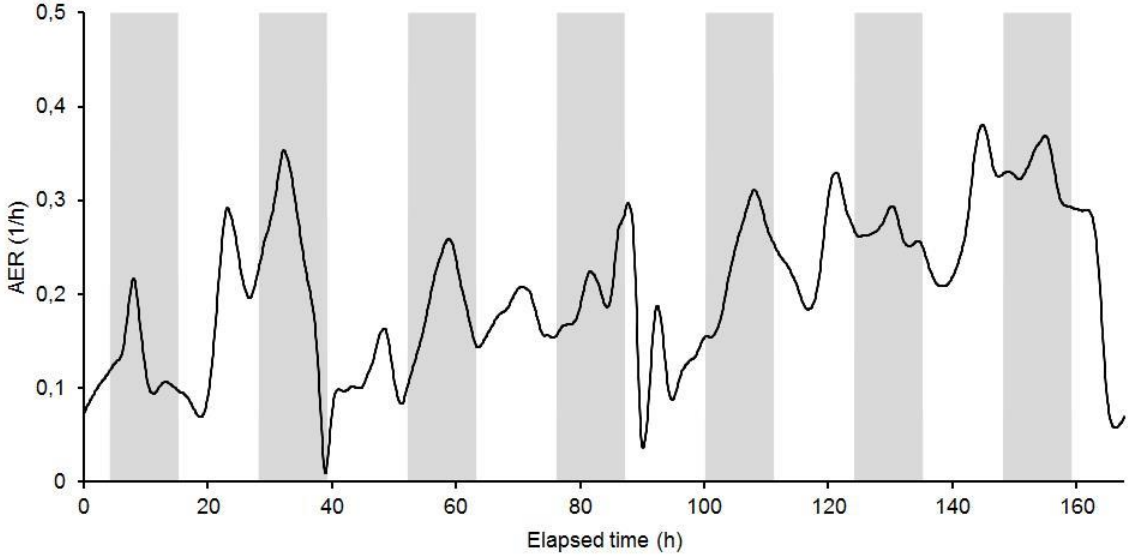

	Phase 1 AER (1/h)		Phase 2 AER (1/h)	
Sample	sample mean	sample standard deviation	decay regression	standard deviation of regression residuals
1	0.24	0.03	0.19	0.05
2	0.12	0.03	0.31	0.08
3	0.18	0.02	0.16	0.04
4	0.12	0.02	0.28	0.13
5	0.28	0.05	0.19	0.08
6	0.33	0.04	-	-
Mean of sample mean	**0.21**	-	**0.23**	
Standard deviation of sample mean	0.08	-	0.06	

Current work

- Experimental validation of the new method against constant concentration method
- Finish writing the thesis

Conclusion

- Developed new tracer gas technique for estimating time-varying AERs
- No need for tracer injection!
- Potentially works with any detectable tracer present in the surface atmosphere
- Preliminary, proof-of-concept results look reasonable
- Further (current) work on experimental validation

Thank you

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