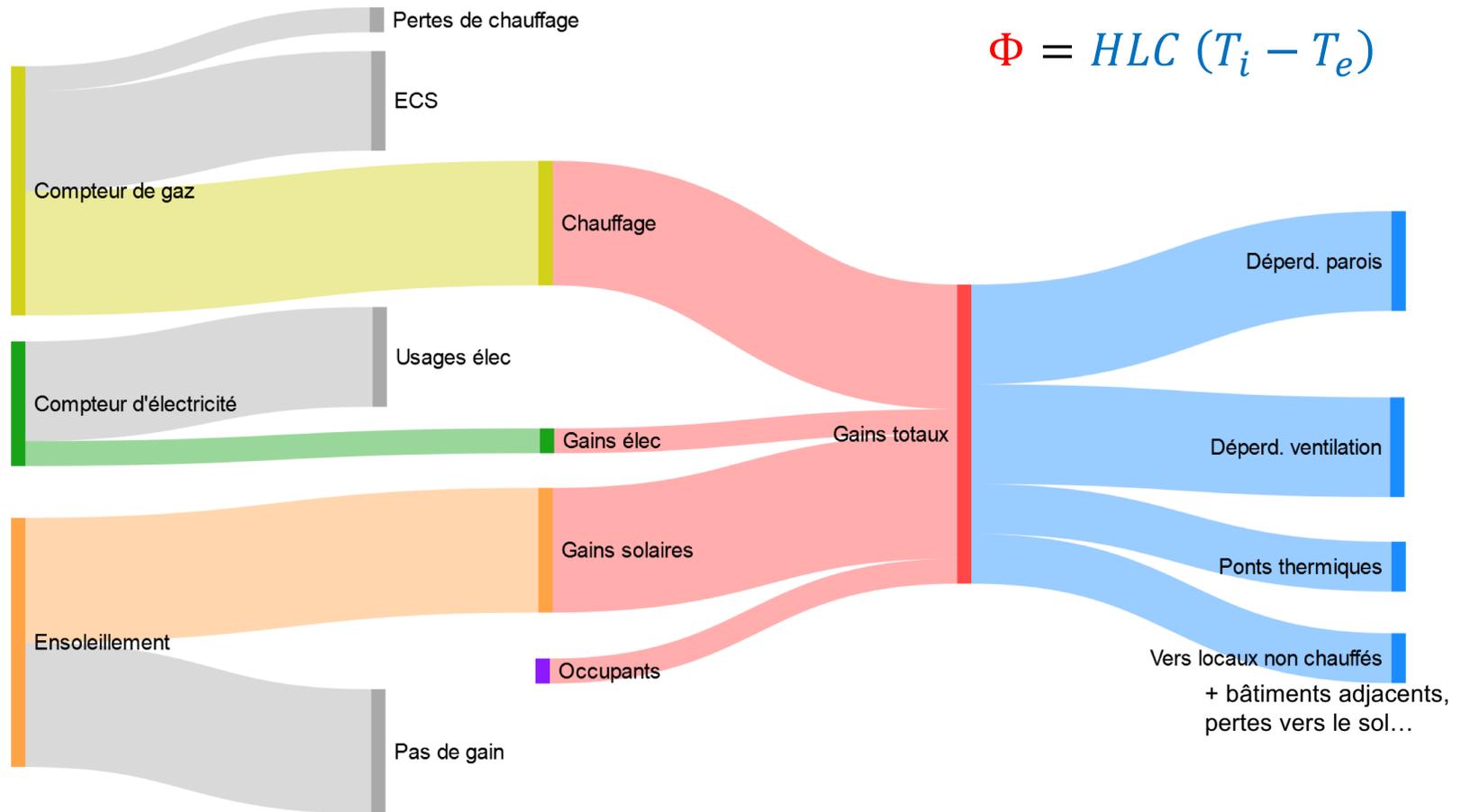


Journée thématique IBPSA France 2019 – Mesure des performances énergétiques des bâtiments
23/05/19

Evaluation en site occupé

Simon Rouchier, LOCIE / Université Savoie Mont-Blanc

Site occupé : pourquoi c'est compliqué



Site occupé : pourquoi c'est compliqué

Contraintes de mesure

- Impossible d'imposer un protocole
- Estimation des gains réels
- Mesures de température
- Exigence de non-intrusivité
- Multi-zone ?

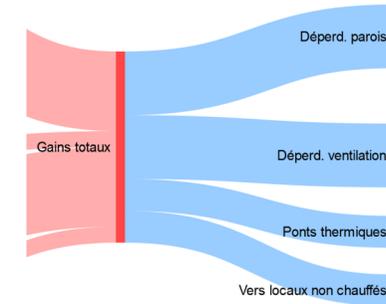
Influence de l'occupant

- Ouvrants et volets
- Charges internes

MAIS

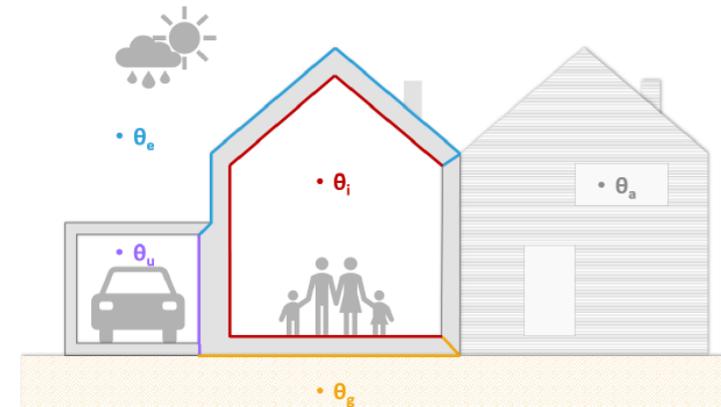
- Temps de mesure plus long
- Plus de choix de modèles

Qu'est-ce qu'on caractérise ?



$$HLC = HTC + H_v$$

$$HTC = H_{tr}^e + H_{tr}^g + H_{tr}^u$$

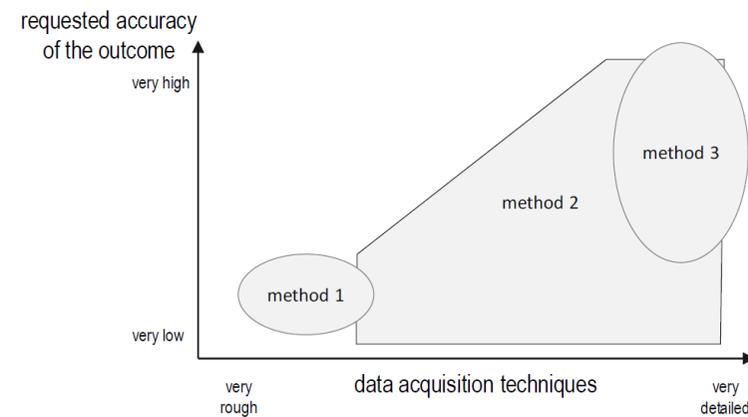
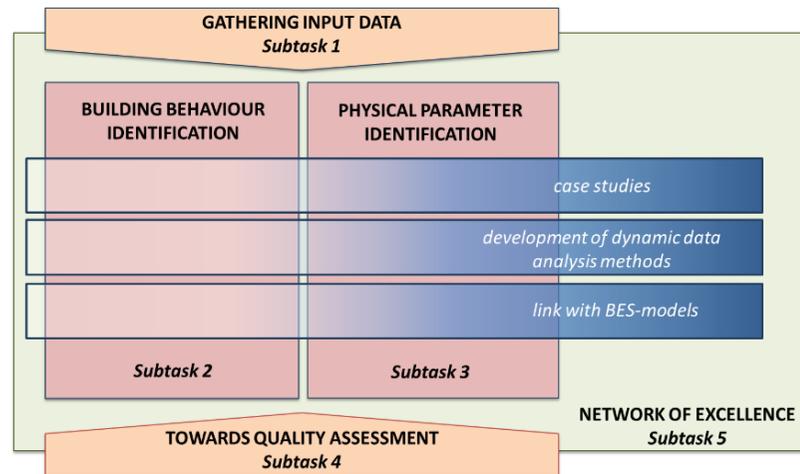




Energy in Buildings and
Communities Programme

IEA EBC Annex 71

Building performance assessment based on in-situ measurements



The current project aims to make the step towards **monitoring in-use buildings** to obtain reliable quality checks of daily building construction practice to guarantee that designed performances are obtained on site.

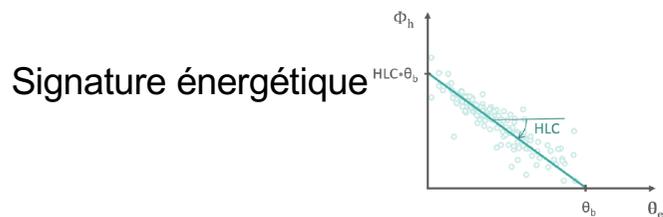
To achieve this global aim, the current research proposal has two main objectives:

1. Support the development of replicable characterisation and quality assurance methodologies embedded in a statistical and building physical framework to characterise and assess the **actual energy performance of buildings**.
2. **Disaggregate** the building energy use to its three main sources: building fabric, systems and users.

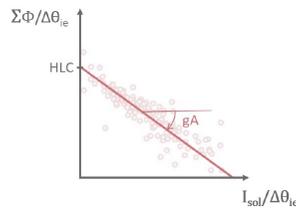
Estimation de paramètres physiques

Les modèles

Moyenne simple
$$HLC = \frac{\sum(\Phi + gA I_{sol})}{\sum(T_i - T_e)}$$



Régression linéaire
$$\Phi = HLC (T_i - T_e) - gA I_{sol}$$



Modèles autorégressifs et modèles d'état

$$\begin{aligned} \mathbf{x}_{t+1} &= \mathbf{F} \mathbf{x}_t + \mathbf{G} \mathbf{u}_t + \mathbf{w}_t \\ \mathbf{y}_t &= \mathbf{C} \mathbf{x}_t + \mathbf{v}_t \end{aligned}$$

Les mesures

$$\Phi, T_i, T_e, I_{sol}$$

$$\Phi, T_e$$

$$\Phi, T_i, T_e, I_{sol}$$

$$\Phi, T_i, T_e, I_{sol}$$

La précision

?

?

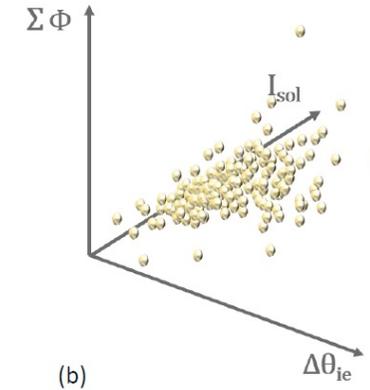
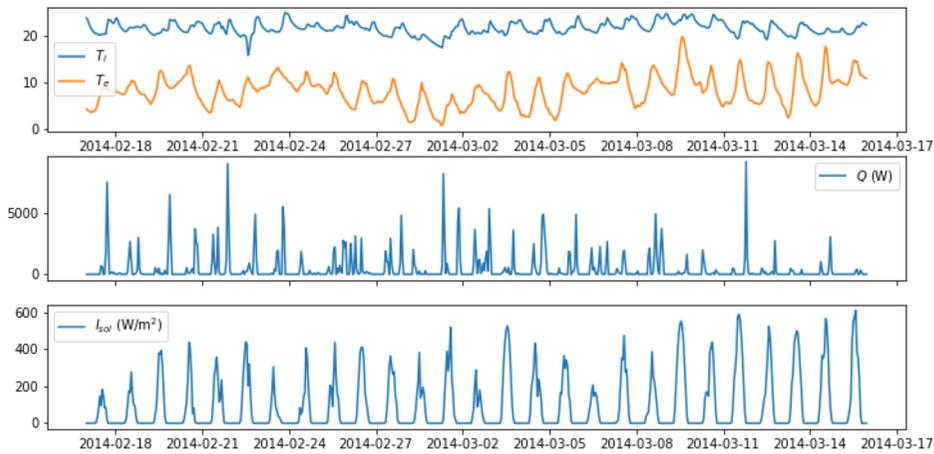
?

?

Régression linéaire

$$\Phi = HLC (T_i - T_e) - gA I_{sol}$$

$$y = a_1 x_1 + a_2 x_2 + b$$



OLS Regression Results

```

=====
Dep. Variable:          Q      R-squared:          0.831
Model:                 OLS    Adj. R-squared:     0.817
Method:                Least Squares  F-statistic:        61.45
Date:                  Mon, 04 Feb 2019  Prob (F-statistic):  2.24e-10
Time:                  16:27:48  Log-Likelihood:     -184.40
No. Observations:     27      AIC:                372.8
Df Residuals:         25      BIC:                375.4
Df Model:              2
Covariance Type:      nonrobust
=====

```

	coef	std err	t	P> t	[0.025	0.975]
x1	56.6144	8.556	6.617	0.000	38.992	74.236
x2	-3.0645	1.164	-2.632	0.014	-5.463	-0.666

```

=====
Omnibus:                0.223  Durbin-Watson:      2.577
Prob(Omnibus):          0.895  Jarque-Bera (JB):   0.423
Skew:                   0.079  Prob(JB):           0.809
Kurtosis:               2.408  Cond. No.           19.2
=====

```

Modèle d'état (continu)

$$\dot{\mathbf{T}}(t) = \mathbf{A}(\theta) \mathbf{T}(t) + \mathbf{B}(\theta) \mathbf{u}(t) + \mathbf{w}(t)$$

$$\mathbf{y}(t) = \mathbf{C}(\theta) \mathbf{T}(t) + \mathbf{v}(t)$$

Modèle d'état (discret)

$$\mathbf{x}_{t+1} = \mathbf{F} \mathbf{x}_t + \mathbf{G} \mathbf{u}_t + \mathbf{w}_t$$

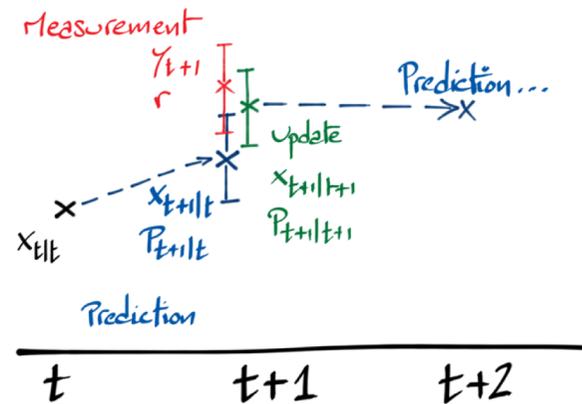
$$\mathbf{y}_t = \mathbf{C} \mathbf{x}_t + \mathbf{v}_t$$

Erreurs de modèle et de mesure

$$\mathbf{w}_t \sim N(0, \mathbf{Q})$$

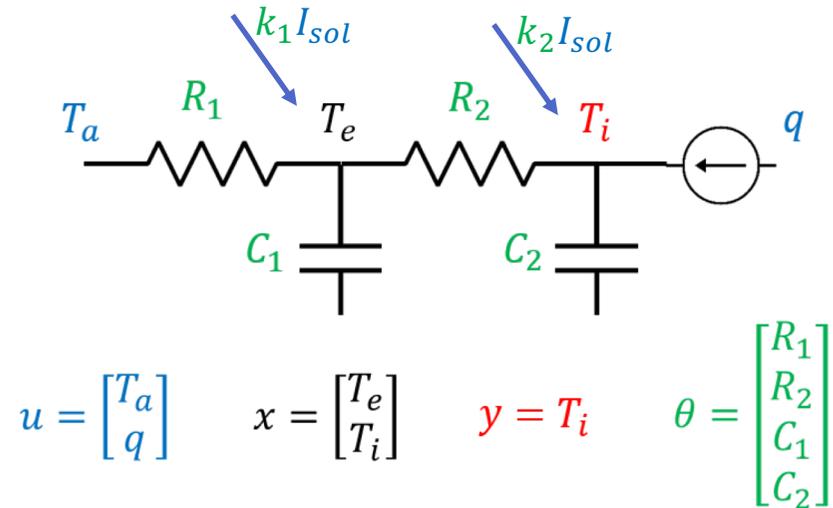
$$\mathbf{v}_t \sim N(0, \mathbf{R})$$

Filtre de Kalman pour la prédiction



Vraisemblance

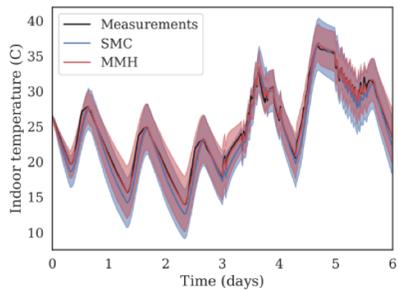
$$-\ln L_y(\theta) = \frac{1}{2} \sum_{t=1}^N \ln |\Sigma_t(\theta)| + \frac{1}{2} \sum_{t=1}^N \epsilon_t(\theta)^T \Sigma_t(\theta)^{-1} \epsilon_t(\theta)$$



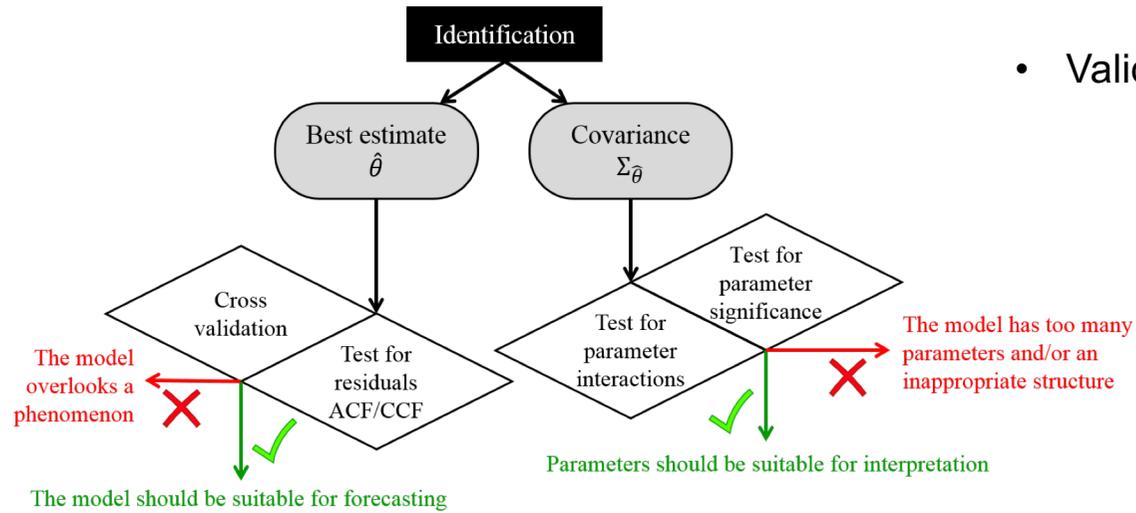
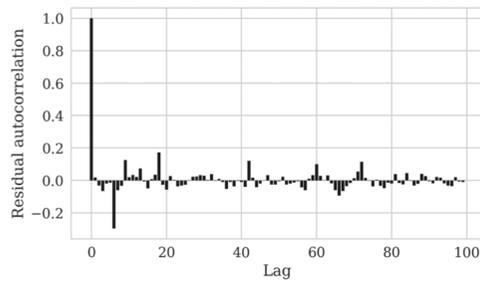
Validation : que dit l'Annexe 58 ?

- Validation du modèle

Modèle calibré vs. mesure

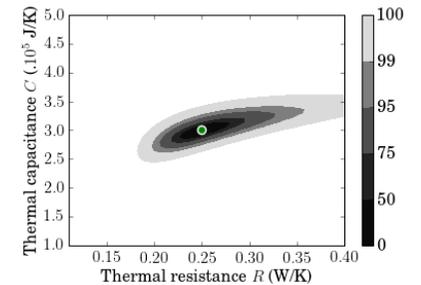
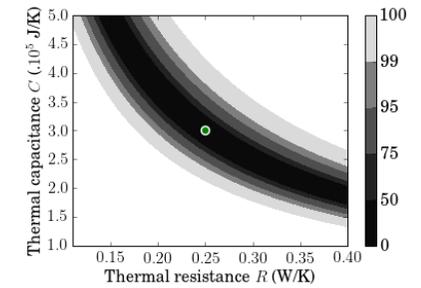


Autocorrélation des résidus



- Validation des paramètres

Profile likelihood

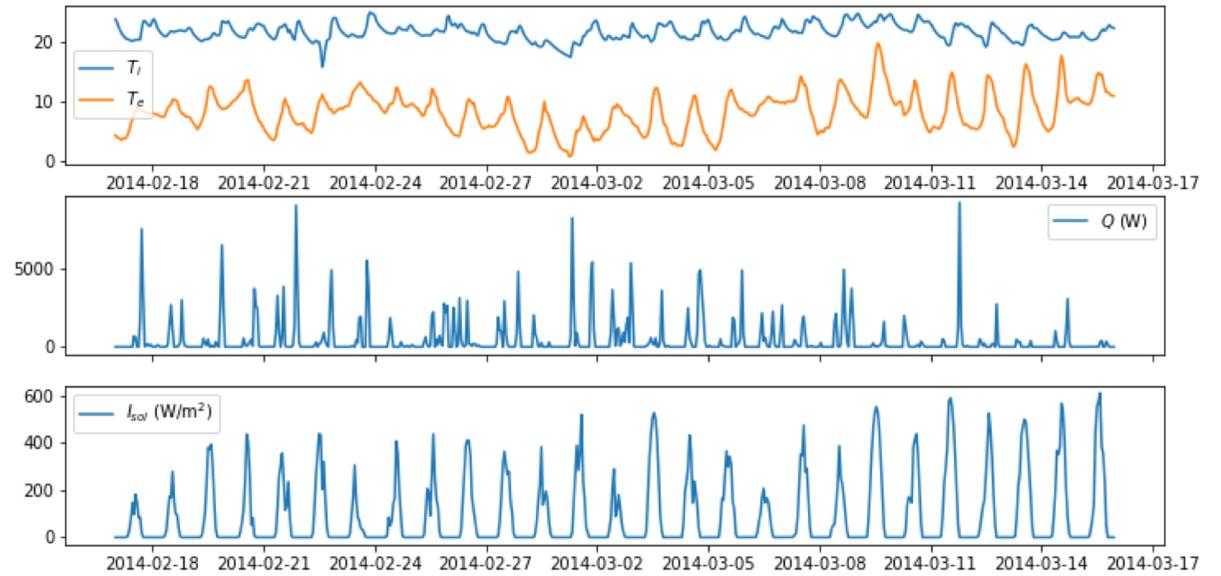


Estimation de paramètres physiques

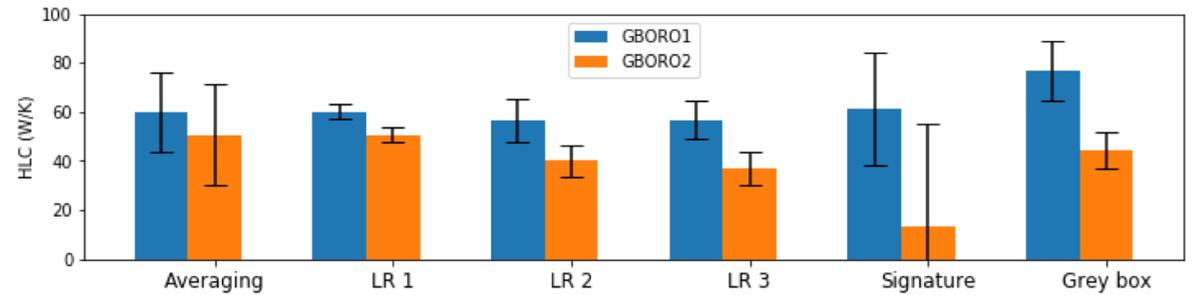
Annexe 71 : exercice commun



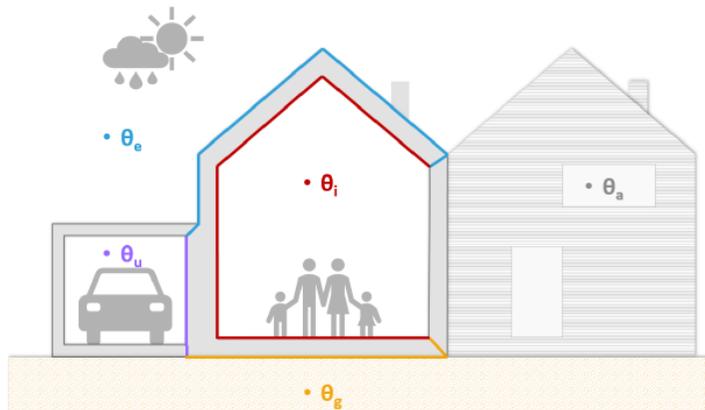
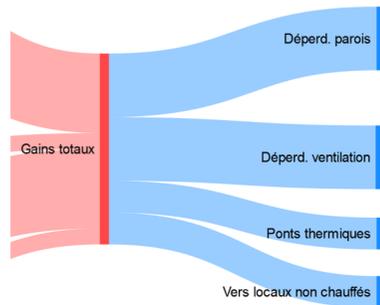
Mesures



Résultats



Désagrégation des déperditions



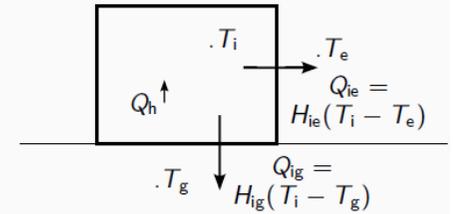
Heat balance

$$Q_h = (H_{ie} + H_{ig})T_i - H_{ig}T_g - H_{ie}T_e$$

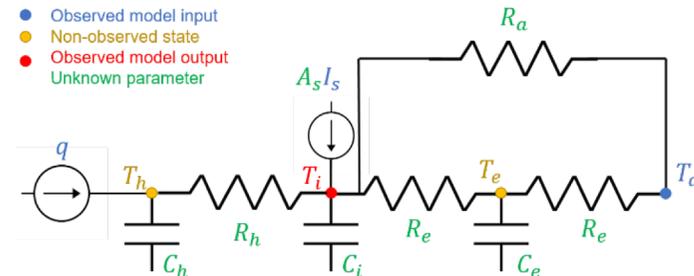
Model for regression

$$Q_h = \beta_1 T_i + \beta_2 T_g + \beta_3 T_e$$

However, T_i and T_g , are both constant, cannot be separated! Combine them:



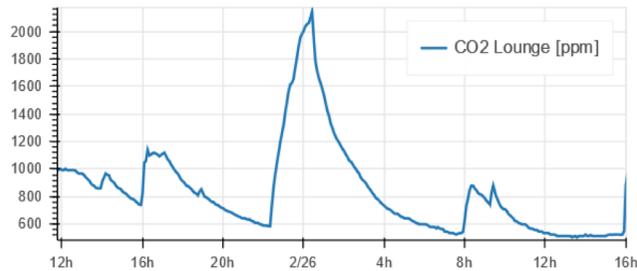
Known	Unknown	Regression model	Identifiable prm.
	T_i, T_g	$Q_h = \mu + \beta_1 T_e$	$H_{ie} = -\beta_1$
T_i	T_g	$Q_h = \mu + \beta_1 T_e$	$H_{ie} = -\beta_1$
T_g	T_i	$Q_h = \mu + \beta_1 T_e$	$H_{ie} = -\beta_1$
T_i, T_g		$Q_h = \mu + \beta_1 T_e$	$H_{ie} = -\beta_1$ $H_{ig} = \frac{\mu - H_{ie} T_i}{T_i - T_g}$



- Observed model input
- Non-observed state
- Observed model output
- Unknown parameter

Désagrégation des déperditions : le CO2 comme gaz traceur

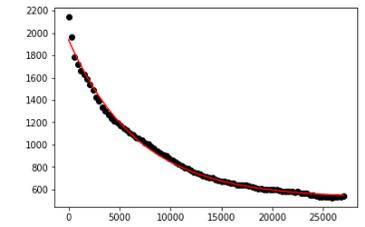
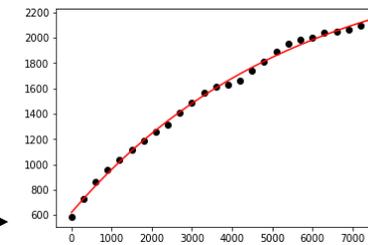
- Ajustement par morceaux sur la mesure de CO₂



$$(c - c_{\infty}) = (c - c_0)e^{-nt}$$

$$c_{\infty} = \frac{1}{n} (\sum_i n_i c_i + p_c) \text{ asymptote}$$

$$n = \sum_i n_i \text{ total air change rate}$$



$$n = 0.65 \text{ (1/h)}$$

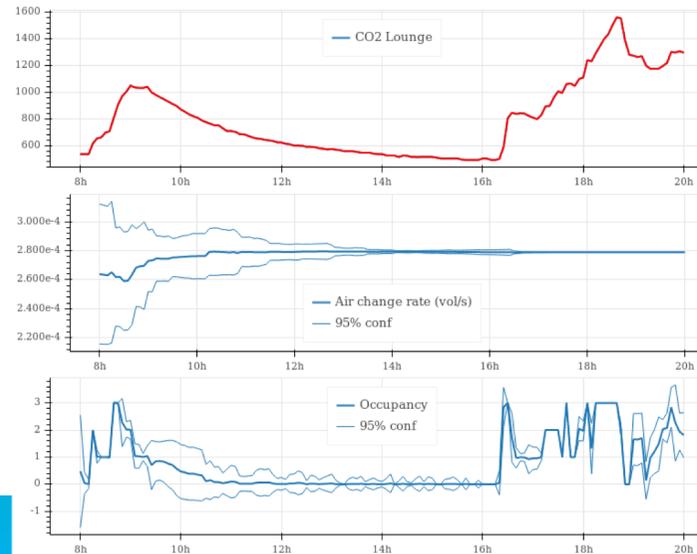
$$c_{\infty} = 2681 \text{ ppm (2.74 people)}$$

$$n = 0.53 \text{ (1/h)}$$

$$c_{\infty} = 520 \text{ ppm (0.05 people)}$$

- Méthodes plus systématiques

- Modèle d'état pour le CO₂
- Mesure directe de l'occupation
- Modèle à commutation

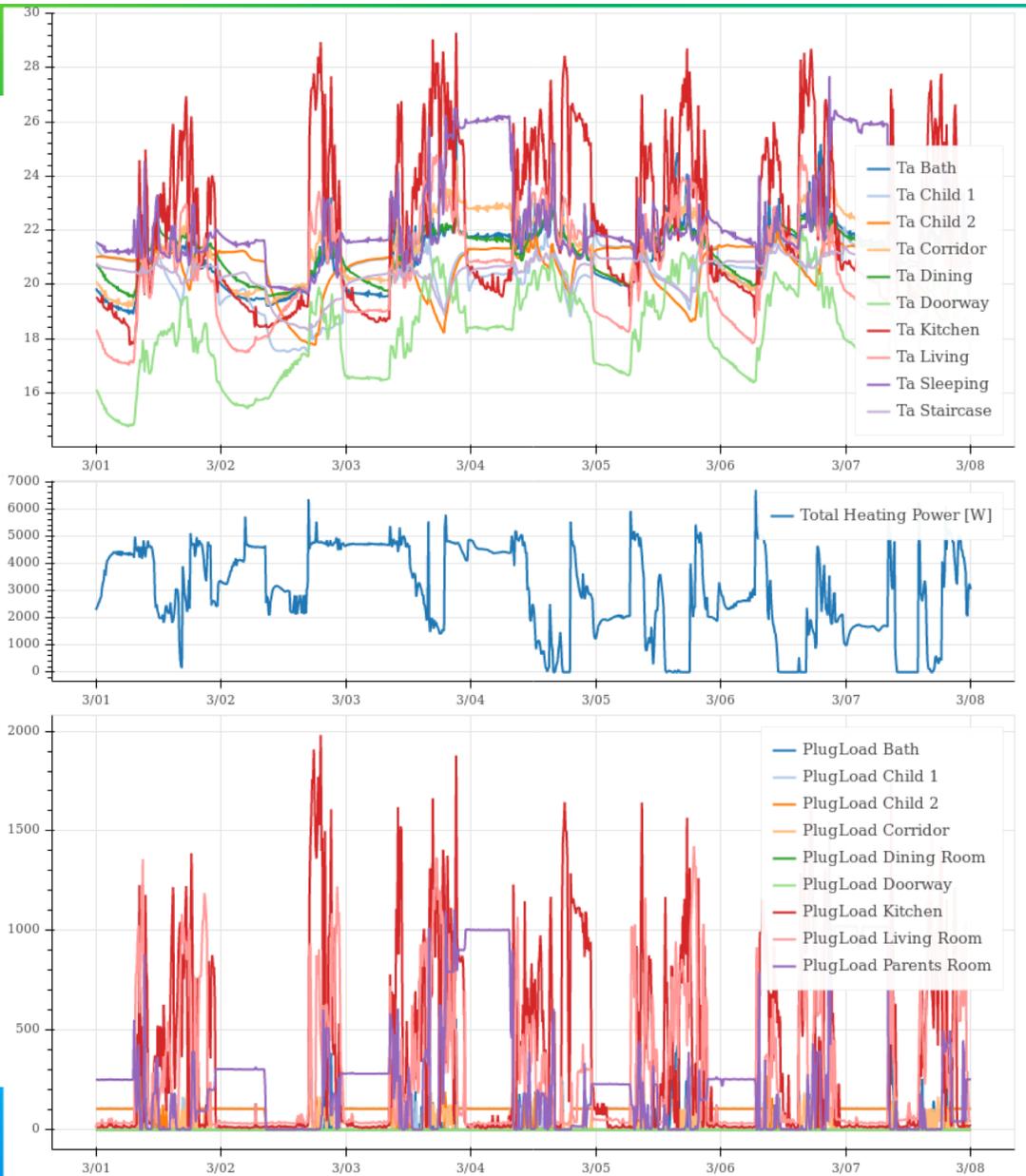


Détection de défauts



Modèles utilisés

- ARX
- ARIMA
- RC
- Random Forest



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