SUSTAINABLE PLACES 2021

Sep. 28 - Oct. 1, 2021 | Rome, Italy

IES

iBECOME

29/09/2021

Sustainable Places 2021

Dr. Giovanni Tardioli

This project has received funding from the European Union's Horizon 2020 Programme under Grant Agreement no 894617

iBECOME wants to…

Enable the efficient control of a building

Reduce bills through energy savings and demand response

Improve occupant wellbeing through optimising comfort

Enable additional services such as car sharing

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The iBECOME virtual Building Management System (SaaS)

Data

Monitoring

On-site ICT automated control

ICT

Science

Forecasting Toolbox

Analytics, Insights & Advisory Control

ICT

Services

Retrofit Design & Implementation

Fault Detection, Diagnosis and Maintenance

Optimization

Welfare & Commuting Management

Demonstrating a combination of novel technologies for optimizing buildings energy performance and comfort conditions, while reducing the operational costs

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Our demo sites

Country Crest, Dublin Ireland

Helix, Glasgow, Scotland

Demonstration in Operational Efficiency

Demonstration in Retrofits

San Luigi Scorosoppi, Udine, Italy

World Trade Centre, Grenoble, France

Our first results

Year One Summary

Key Achievements: June 2020 – 2021

IEQ Virtual Sensors

Developed methods that combine simulation and machine learning to predict indoor Environmental Quality, including Thermal Comfort Sensation, Illuminance levels throughout a day and Air Pollutants Concentration with good accuracy.

Automation of Building Energy Model Calibration

Duration of calibration process reduced by 98% and accuracy improved by 27%.

*Tested in specific case studies

Co-Simulation

Calibrated physics-based energy model interacts with Machine Learning Algorithms in cloud simulations to provide predictions of the future building conditions.

Energy Modelling and Insights of Case Study Buildings

Data generated from case study buildings to inform the development of iBECOME services including Fault Detection & Diagnostics and Predictive Maintenance.

An innovative modelling approach based on building physics and machine learning for the prediction of indoor thermal comfort in an office building

Giovanni Tardioli, Ricardo Filho, Pierre Bernaud and Dimitrios Ntimos

29/09/2021

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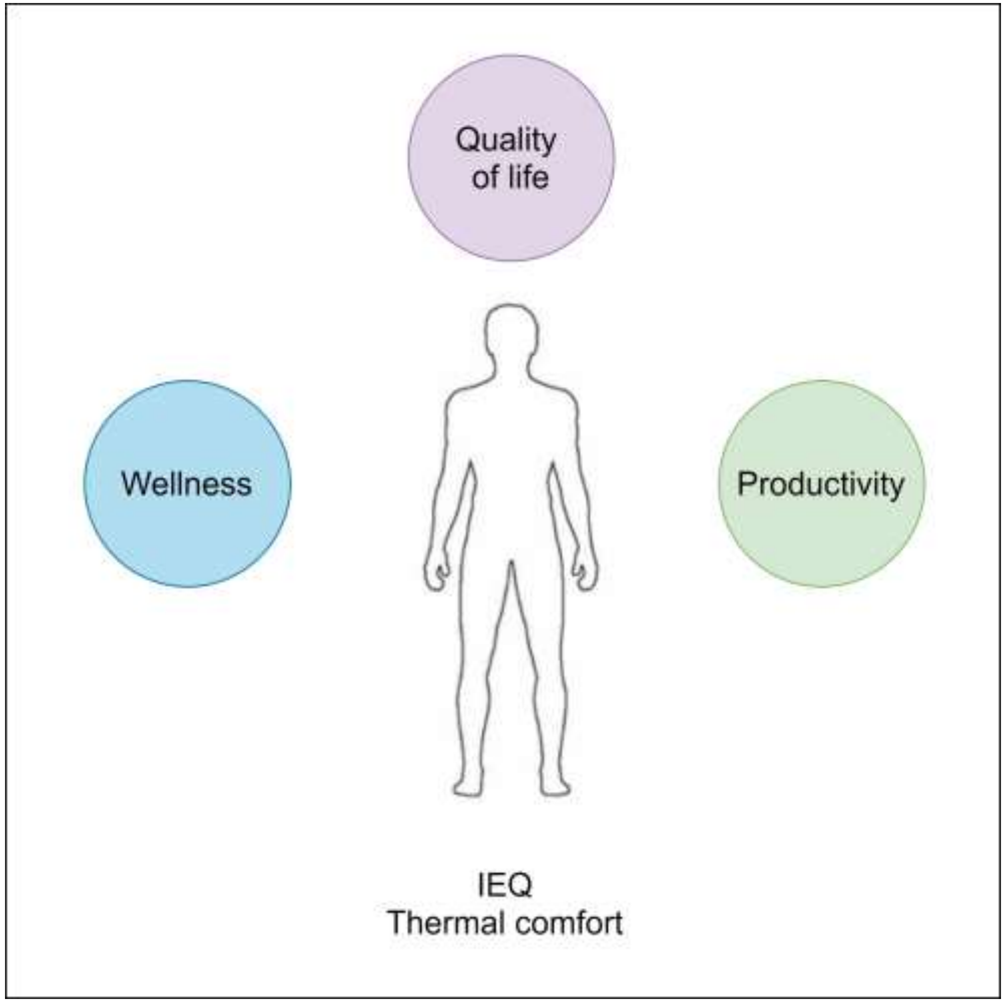
Importance of thermal comfort in office buildings



1/9/90 [1]:

- 1% of the cost is associated to energy
- 9% is associated to building rental costs
- 90% associated to cost of personnel

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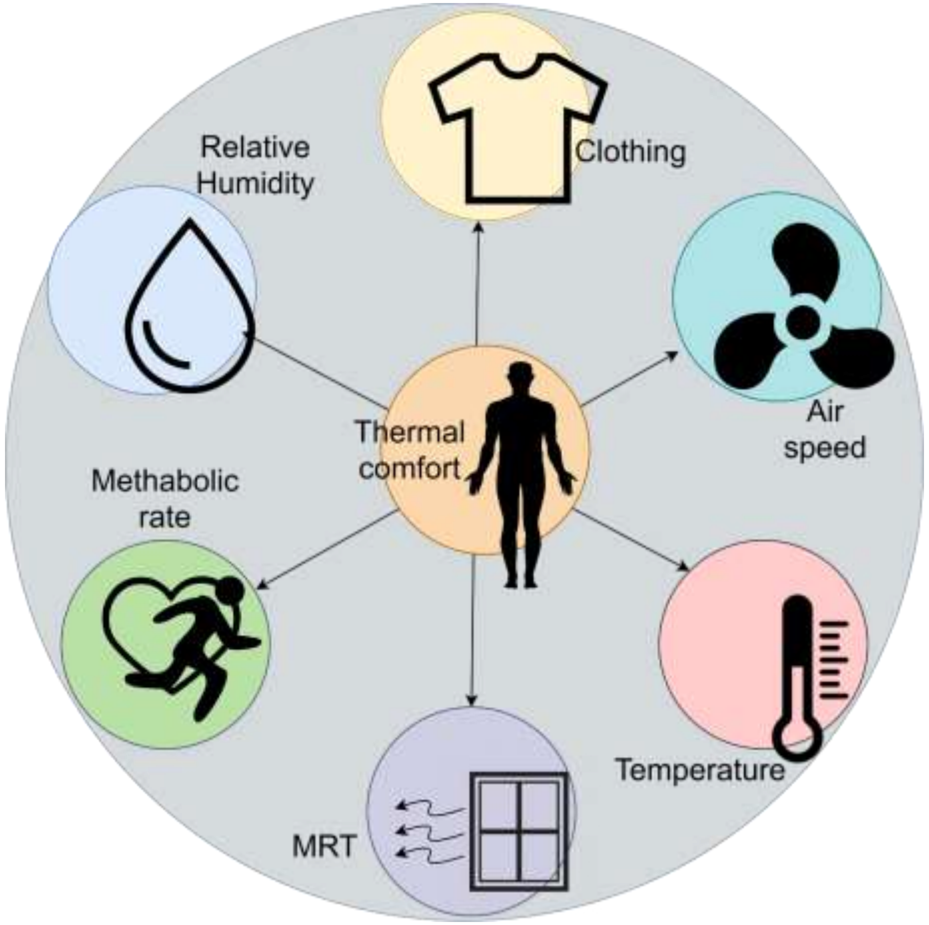
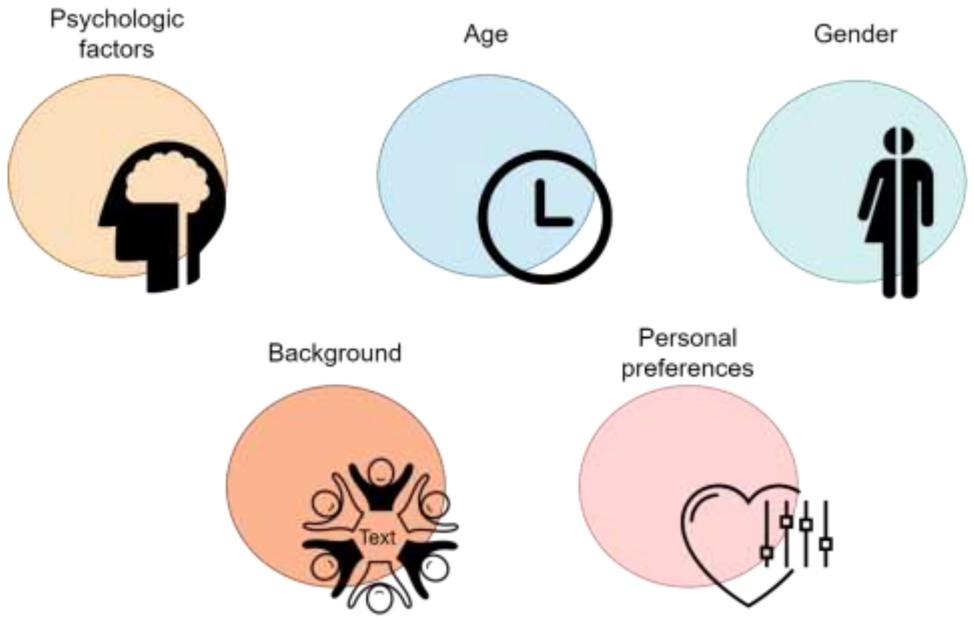
Limitations of current normative methods



Physics-based approach to thermal comfort



Limitations of current physics based methods
PMV and Adaptive method:

- Inability to consider additional important variables
- Accuracy
- Generalisation
- Not tailored for a case study

Alternative/innovative methods (direct feedback + ML)

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Objectives of the paper

- Test the capabilities of ML models when used for predicting thermal comfort votes of occupants in an office building.
- Combine the use of ML model for IEQ evaluation with physics dynamic simulation in a co-simulation environment to generate dynamic predictions of thermal comfort metrics.
- Establish a comparison with traditional normative methods of evaluating thermal comfort.

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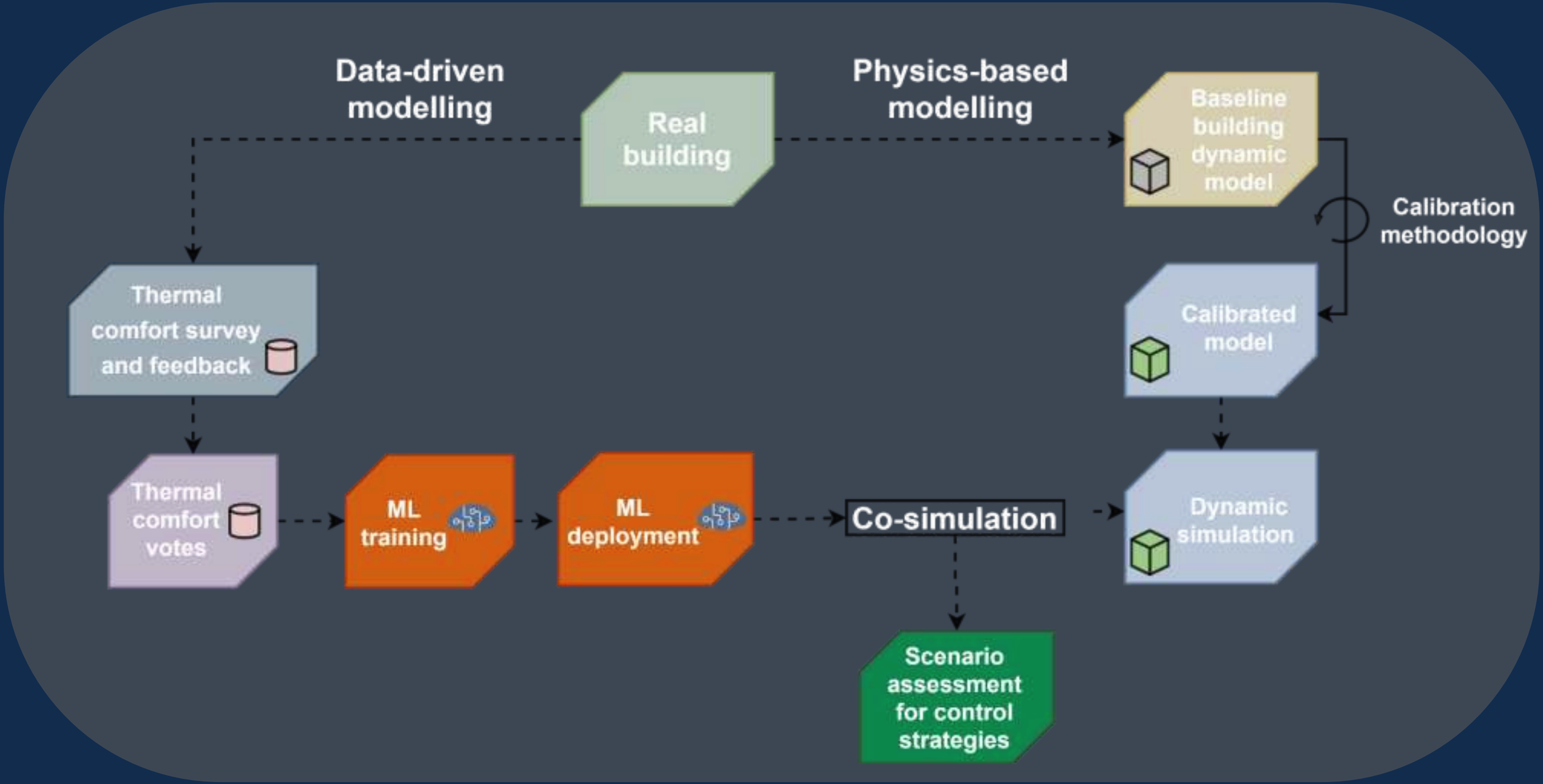
Methodology



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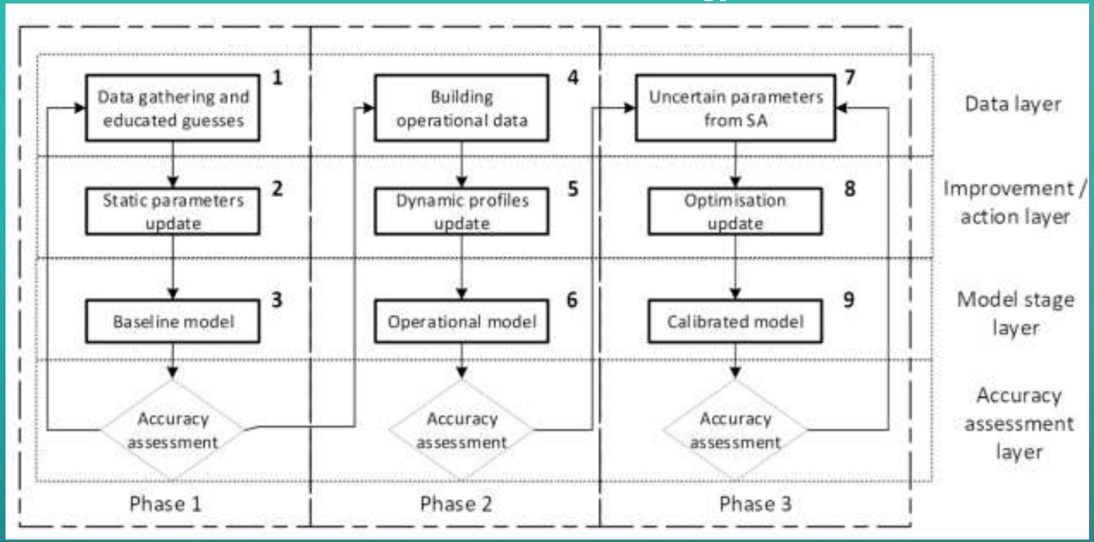
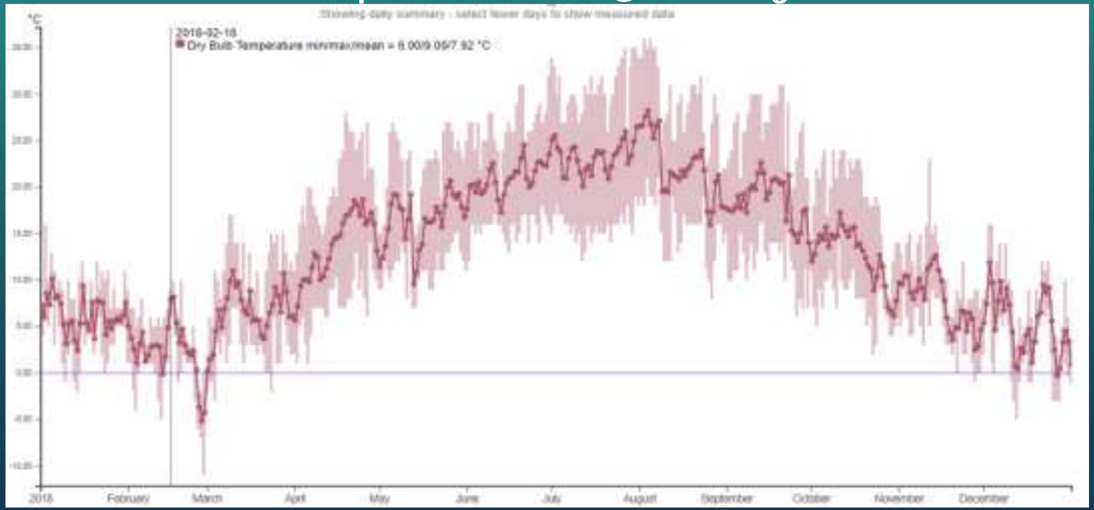
Physics-based modelling

Calibration methodology

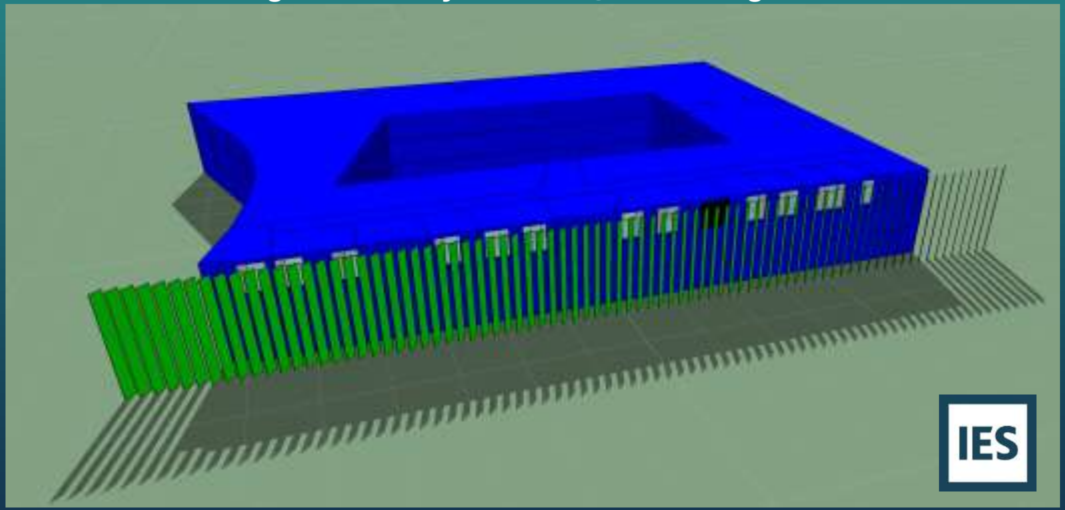


Building case study: Helios @ Le Bourget-du-Lac

External temperature: Helios @ Le Bourget-du-Lac



Building case study: Helios @ Le Bourget-du-Lac



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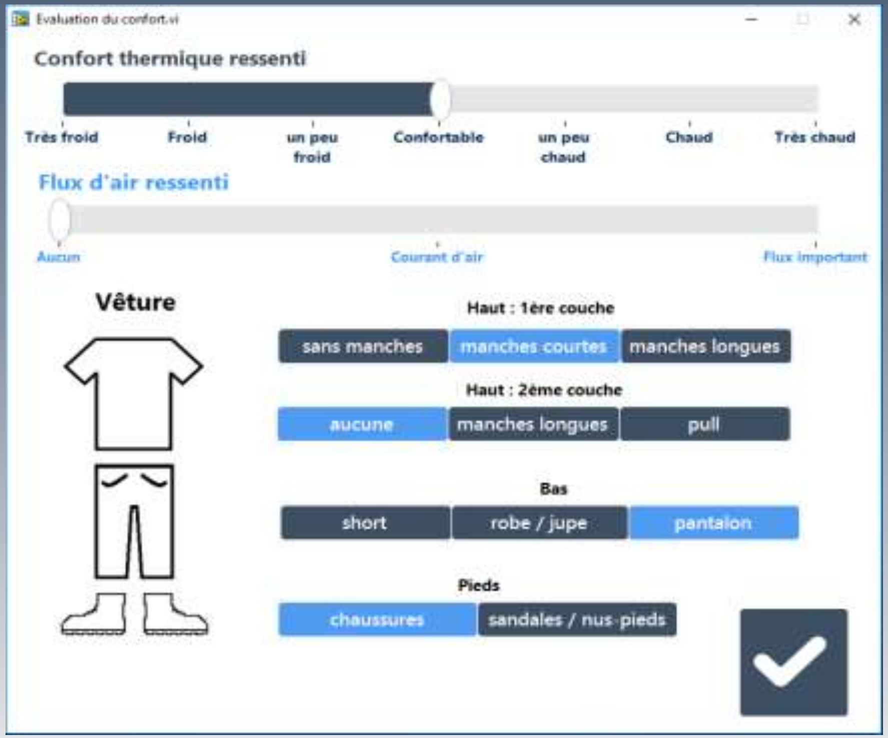
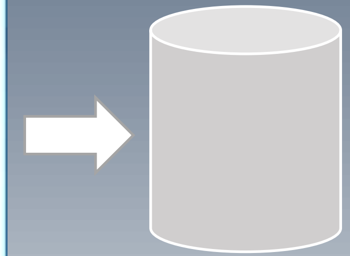
Data-driven modelling

Thermal comfort feedback interface



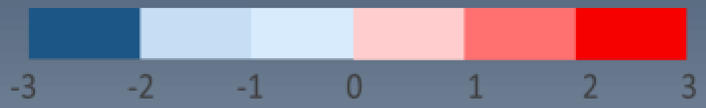


Thermal comfort votes database

Modelling

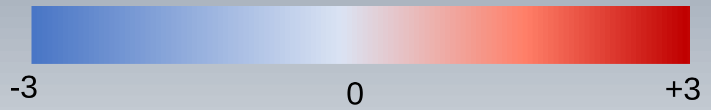
1 Simplified

2 Detailed



ML models:
- K-Neighbors Classifier
- Decision Tree Classifier
- Random Forest Classifier
- Logistic Regression
- Gradient Boosting Classifier

3 Continuous



Bayesian model

$$v = a + bx_1 + cx_2 + dx_3 + e_{x4} + \ldots$$

- a: intercept
- W: b, c, d, e (weights)
- X: x1, x2, x3, x4,... (predictors)

Bayesian formulation

$$P(W|v,X) = \frac{P(v|W,X) \times P(W,X)}{\int P(v,X|W_i)dW_i} \longrightarrow$$

M.C.M.C. (No-U-Turn algorithm)
Non informative priors

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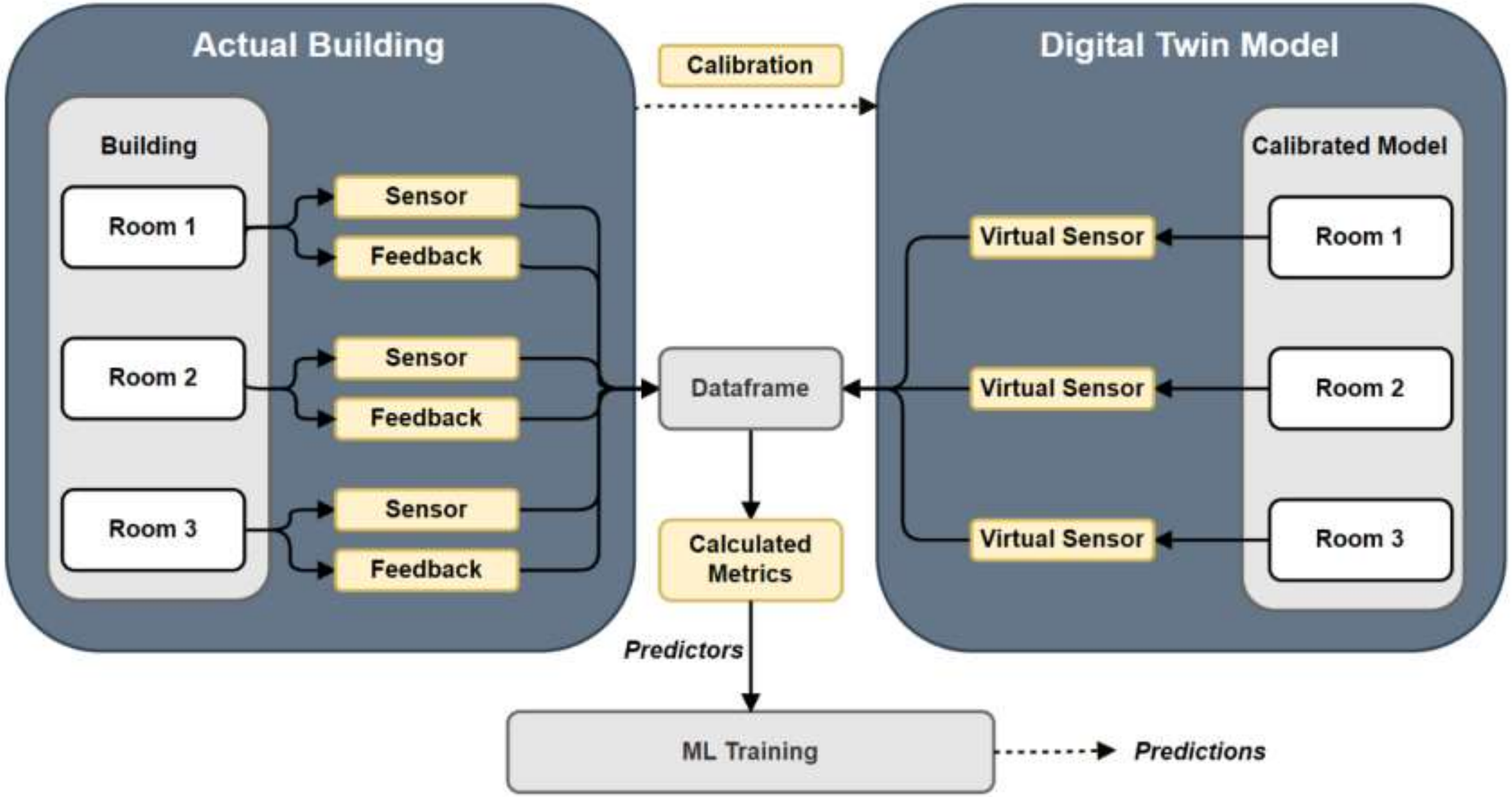
Merging physics and data-driven modelling



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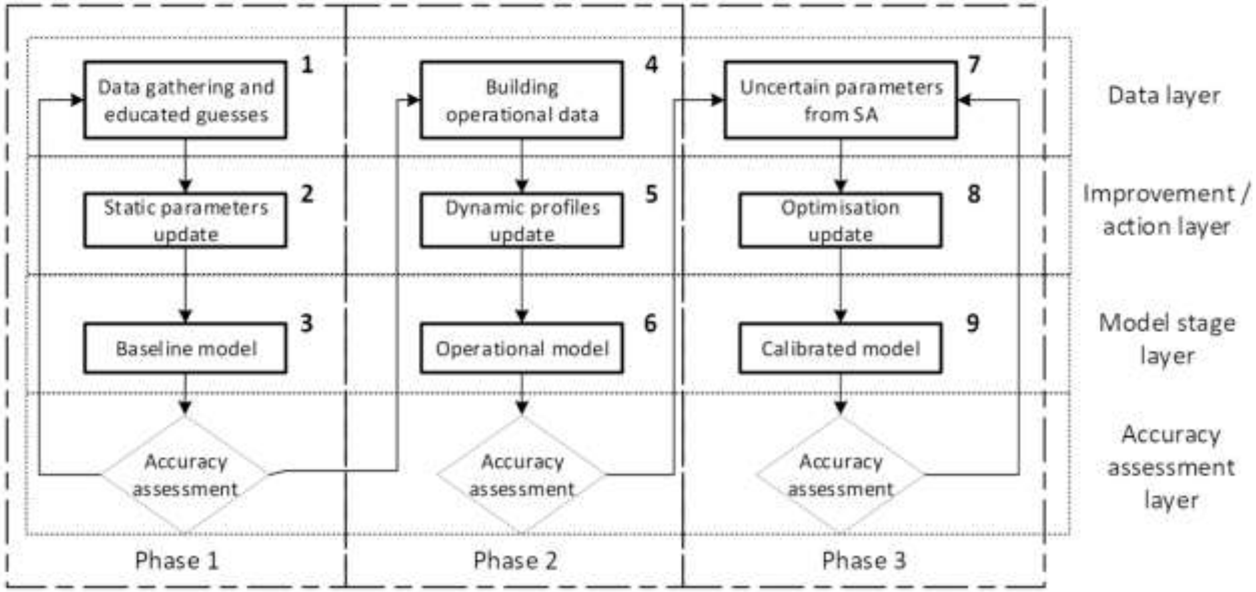
Building physics modelling: calibration



Room	Variable	MAE [℃,PPM]	RMSE [℃,PPM]
3072	Air temperature [℃]	4.1	2.4
3072	CO_2 [PPM]	126.1	83.0
3071	Air temperature [℃]	3.6	1.1
3071	CO_2 [PPM]	186.1	169.9
3033	Air temperature [℃]	1.3	0.7
3033	CO_2 [PPM]	219.2	140.7
3092	Air temperature [℃]	1.3	0.4
3092	CO_2 [PPM]	105.1	20.9

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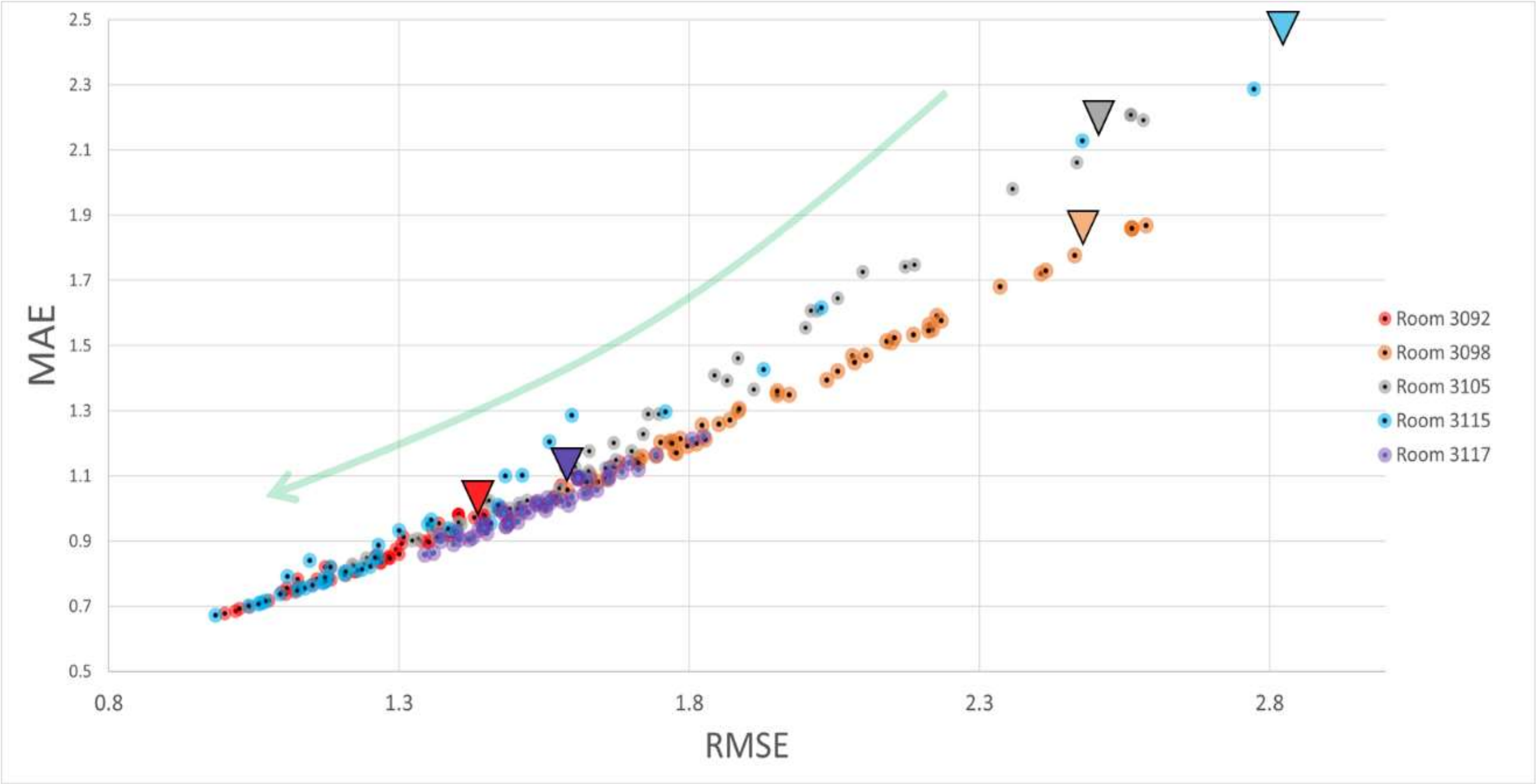
Building physics modelling: optimisation 1/2



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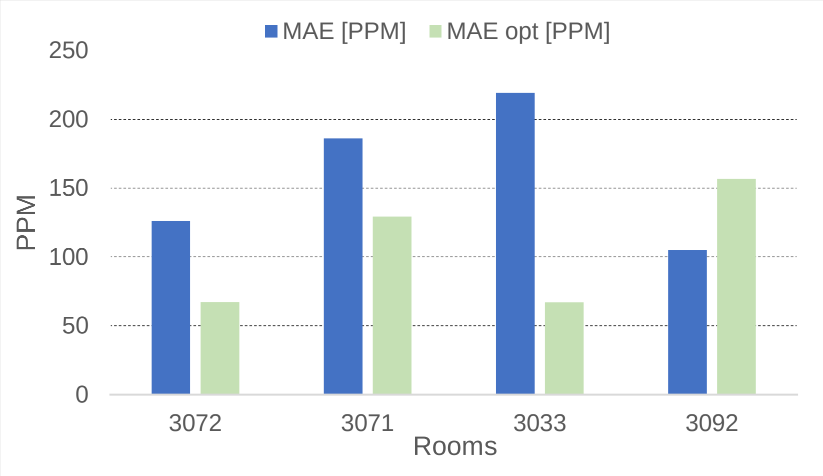
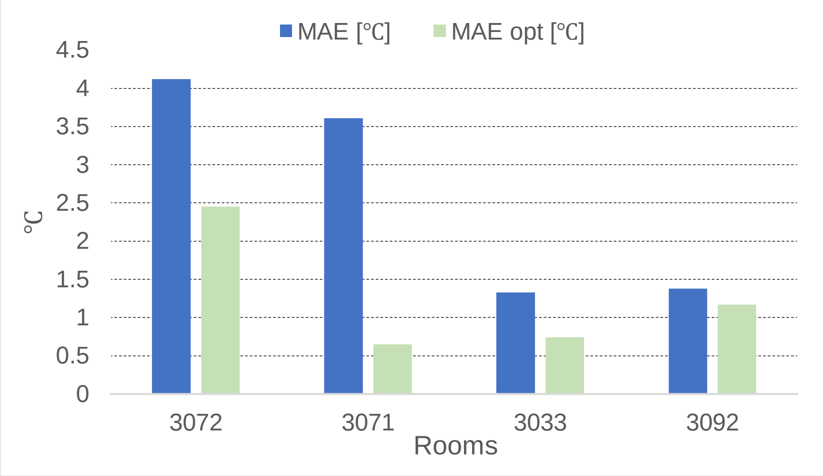
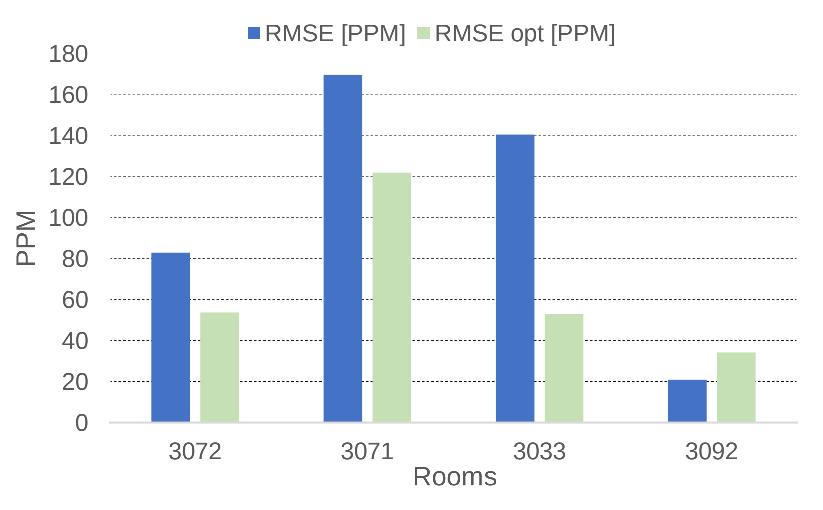
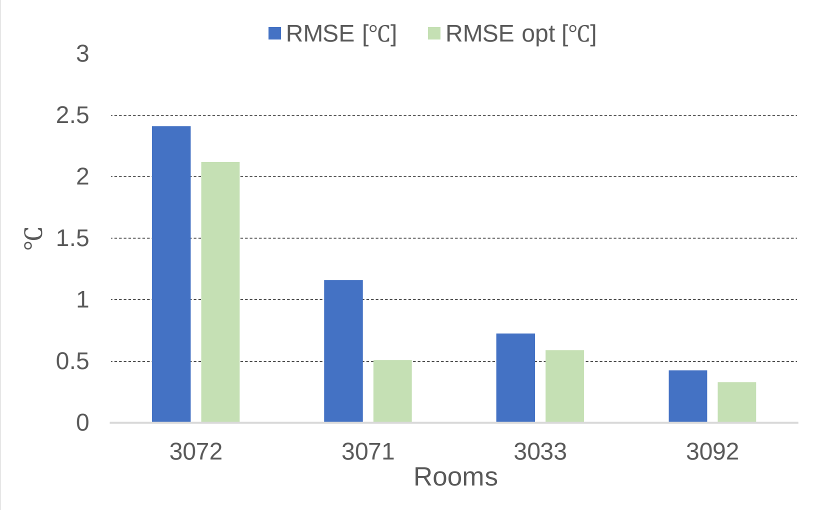
Building physics modelling: optimisation 2/2









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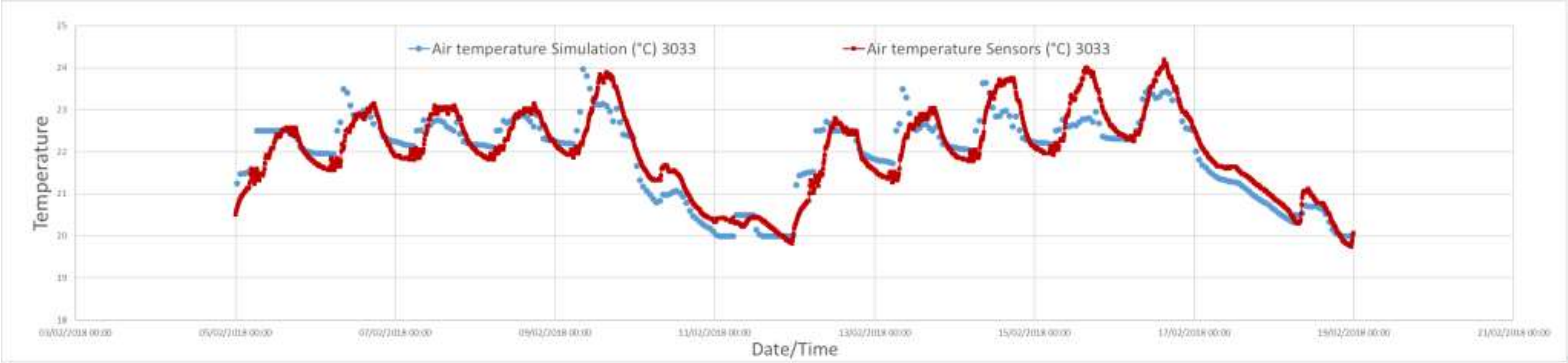
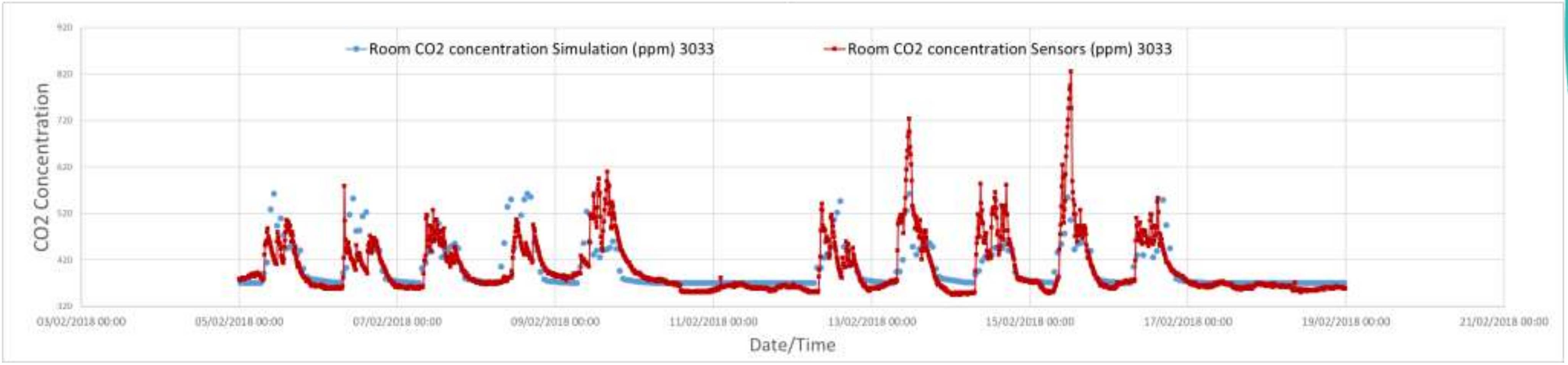
Building physics modelling: optimisation 2/2





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Data-driven modelling: results

Simplified

-3 0 3

ML Classifier	Accuracy
K-Neighbors Classifier	78%
Decision Tree Classifier	79%
Random Forest Classifier	84%
Logistic Regression	77%
Gradient Boosting Classifier	81%

Detailed

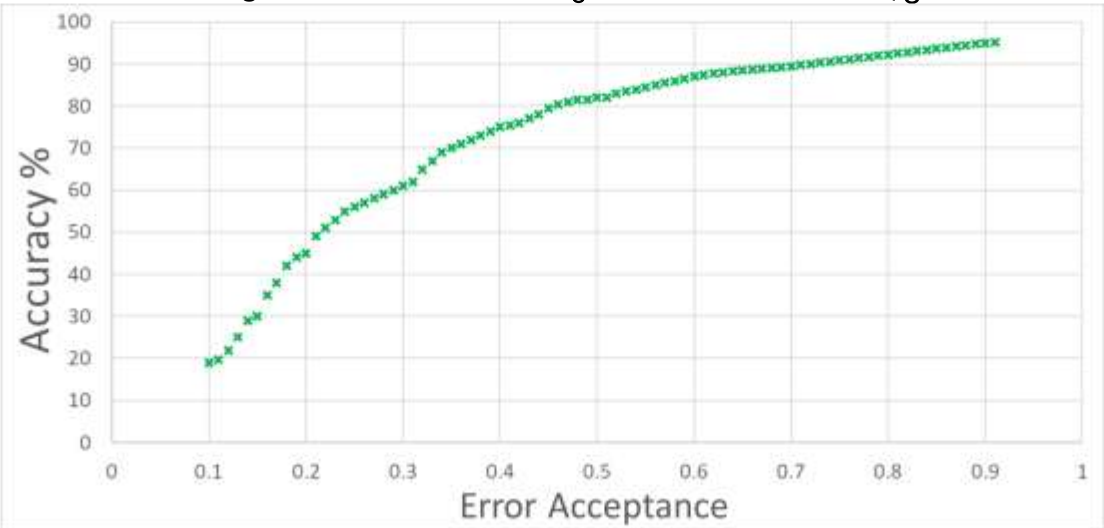
-3 -2 -1 0 1 2 3

ML Classifier	Accuracy
K-Neighbors Classifier	62%
Decision Tree Classifier	56%
Random Forest Classifier	69%
Logistic Regression	62%
Gradient Boosting Classifier	66%

Continuous

-3 0 +3

Bayesian model



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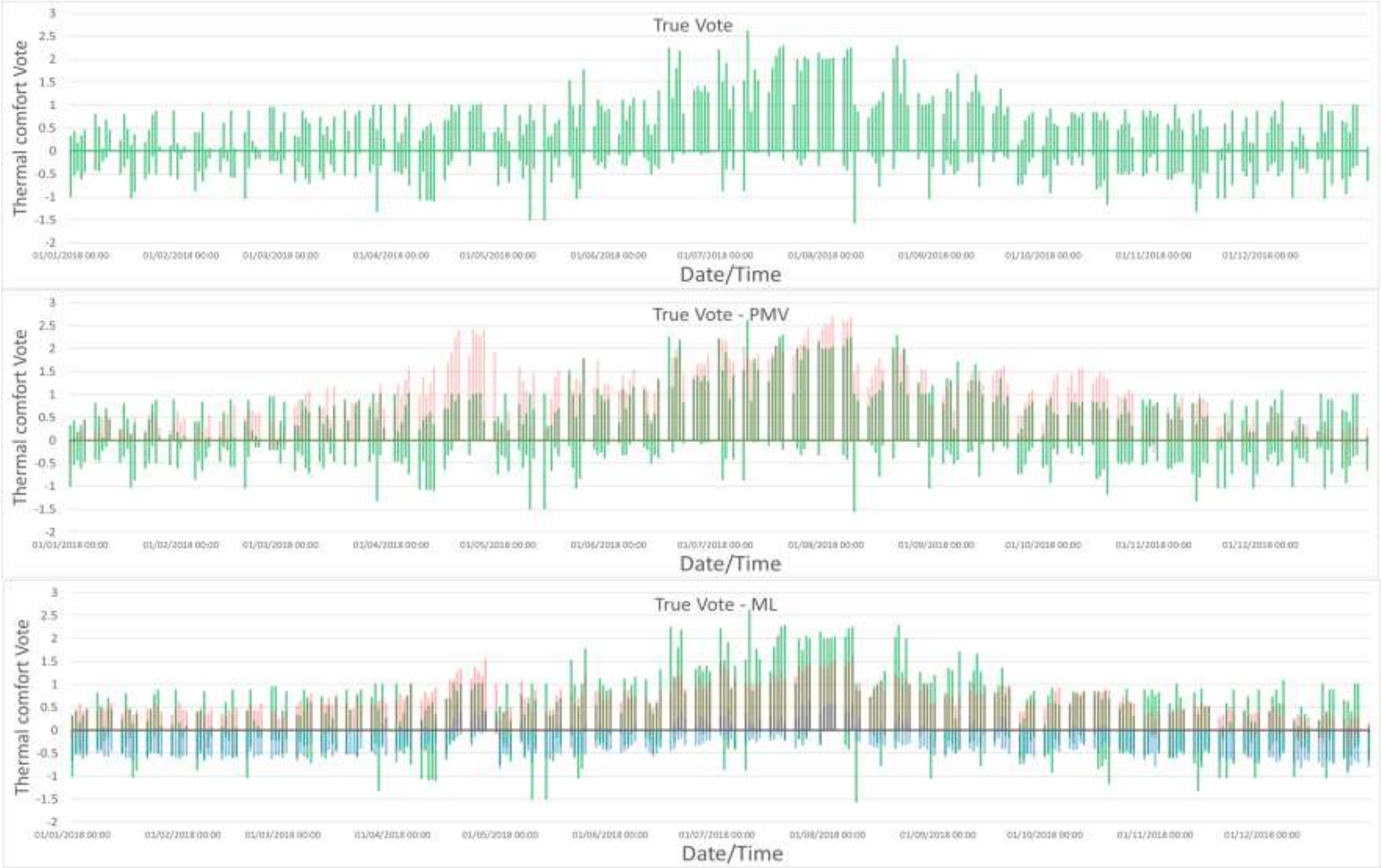
Data-driven modelling: results



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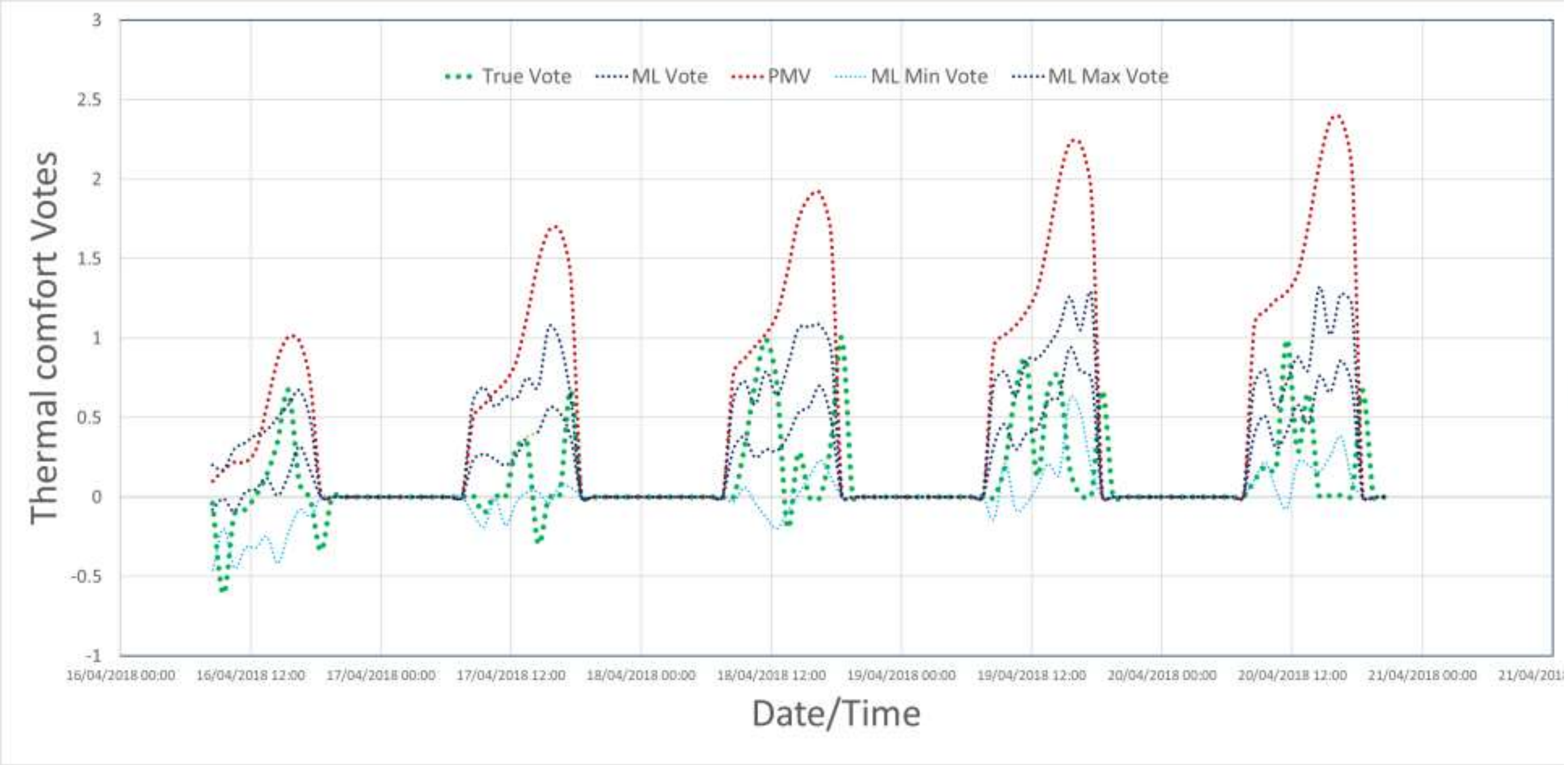
Data-driven modelling: results



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Conclusions

- ML models overcome traditional methods for thermal comfort evaluations. Improve in accuracy of about 25% (compared to PMV)
- Calibrated physics based modelling can be used effectively to augment the set of variables used for training of ML models
- The use of co-simulation strategies between ML and building dynamic simulation provides an innovative methods for scenario evaluation for tailored comfort strategies.

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THANK YOU!

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