DYNASTEE

NEWSLETTER ISSUE 2018/10

Foreword

Here is DYNASTEE again with some news on dynamic methods for energy performance analysis.

There are 2 main articles with guidelines for data analysis, from both physical and statistical points of view. Further to that, a practical experience of using grey-box models is reported in a summary paper.

In late summer, there will be 2 distinct intensive training sessions on data analysis, one in Denmark, another one in Almeria, Spain.

And in the frame of Annex 71, DYNASTEE is organising a workshop in Brussels, 11 April, on quality assurance in energy performance assessment by in-situ measurements. More info on http://dynastee.info and in the next newsletter.

The actions of DYNASTEE are since November 2017 co-ordinated through an enlarged steering group composed of: Hans Bloem (INIVE), Luk Vandaele (INIVE), Maria-José Jiménez (PSA CIEMAT), Paul Strachan (ESRU Strathclyde), Matthias Kersken (Fraunhofer), Henrik Madsen/Peder Bacher (DTU), Alex Marshall/Richard Fitton (Salford University) and Staf Roels (KU Leuven)

Pasillo Central Campus Desde Azotea - Venue of Summar School 2018

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Newsletter Editors

Hans Bloem, INIVE

Luk Vandaele, INIVE

Alex Marshall, Salford University

Announcement of the Summer School 2018 - 10 - 14 September, Almeria, Spain

Level 2: “Dynamic Methods for whole Building Energy Assessment”

After 6 very successful editions of the Summer School on *“Dynamic methods for whole building energy assessment”* this time a more advanced level is introduced focusing on the variability aspects of boundary conditions. Pragmatic solutions will be applied to assess thermal characteristics of buildings, based on the material used for the Summer Schools but more advanced in dealing with building physical aspects as well as more complex mathematical and statistical techniques. Specifically the focus will be on:

- Variable climate data from solar radiation and wind
- Analysis problems due to not-measured phenomena
- Whole building energy analysis and model simplification using LORD
- Working in continuous time with CTSM in the R environment.

Exercises will deal with benchmark data that brings the fore mentioned complexity to the front. Three specific cases will be offered to to participants, dealing with increased complexity, e.g. : Conduction only dealing with distributed thermal mass, combined conduction, convection and radiation processes dealing with air gaps and finally closed environments (buildings). See illustrations on next page.

When and where?

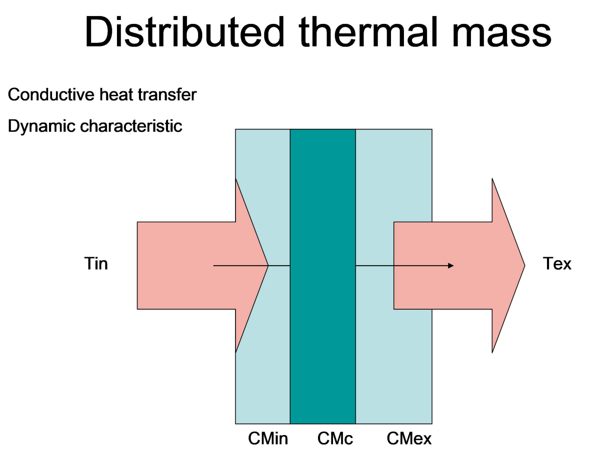
The venue for the Summer School is in Almeria, Spain and takes place from **Monday 10 until Friday 14 September, 2018**.

Detailed information about the presented topics can be found in the announcement that comes available early 2018. The cost for the week-long Summer School is 450 Euro.

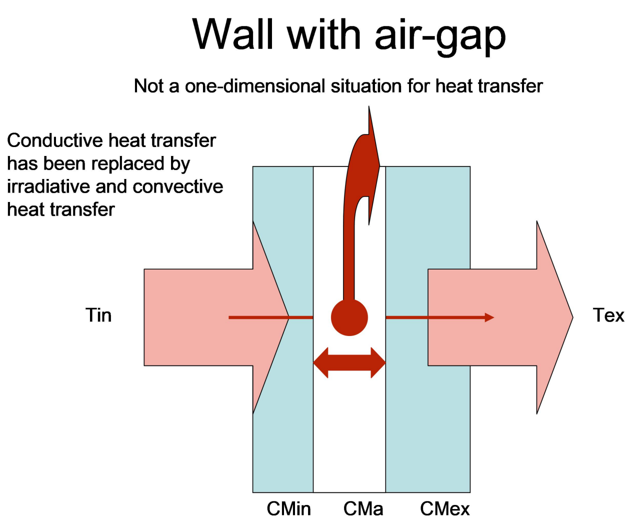
Pre-registration for the Summer School will be possible as from April 2018. More information will become available at www.dynastee.info and can be done by mailing to CIEMAT- PSA. The person to be contacted will be Mrs. Marta Ruiz (e-mail: mruiz.serviciosexternos@psa.es tel.: 0034.950387932).

Objective

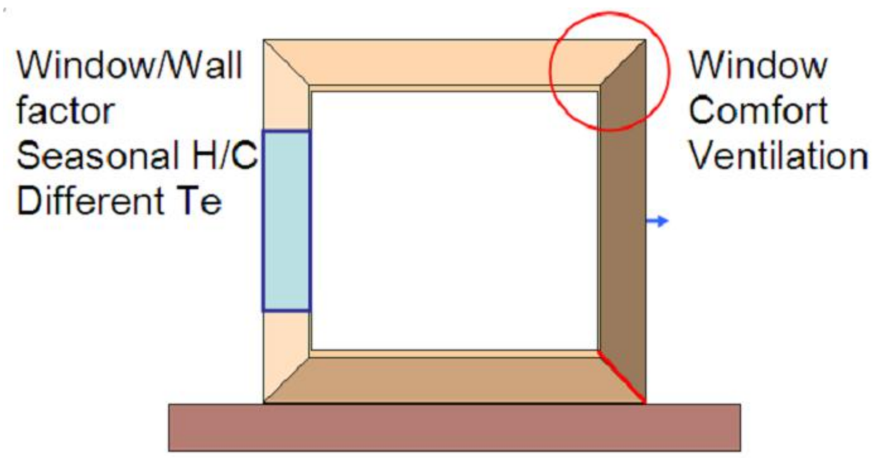
The main purpose of this summer school is to train a methodology for evaluation of measured data. Enthusiastic lecturers will teach methodologies in more than 10 presentations for assessing the heat transfer characteristics of building envelopes as well as whole building using data for hands-on exercises. During this summer course, information on relevant software (like CTSM-R) will be given and software tools (like LORD) will be used in the exercises.



One-dimensional thermal transmission conduction



Thermal transmission by conduction, convection and radiation



Thermal transmission by ventilation, infiltration, conduction, convection and radiation

IEA-EBC Annex 58: Guidelines for data analysis from dynamic experimental campaigns; physical aspects.

Hans Bloem (INIVE), Maria-José Jiménez (PSA CIEMAT)

Analysis and modelling of data obtained from experiments under real climate conditions require special attention to the treatment of the data during all steps of the elaboration process. The interest for these techniques and their application has grown in recent years by industry. This interest has pushed standardisation activities such as CEN/TC 89/WG13 and research initiatives such as IEA EBC Annex 58. In general it concerns numerous observations by measurements at regular interval of physical processes that requires mathematical and statistical techniques for proper assessment of the searched physical parameters. So the main question is: How to get from many observations as input for the mathematical analysis process to one or a few limited output values for reporting?

In that process the accuracy of input data, the propagation of the errors in the calculation process and the required accuracy of the reported value are of high importance. Once data has been produced (raw data), from a dedicated experiment, it is assumed that these data contain all information describing the physical processes that a mathematical model is supposed to analyze.

Two documents have been made available from the IEA-EBC Annex 58 project on http://dynastee.info/data-analysis/overview/

• The document Guidelines_Analysis_BuildingPhysics_A58.pdf focuses on criteria that must be considered to avoid mistakes in pre-processing data and constructing candidate models.

• The document Guidelines_Analysis_StatisticalModelling_A58.pdf presents criteria for selecting the optimal method and model to analyse the available data.

For the case of experimental work and analysis for the energy performance assessment of buildings the physical processes are importantly thermal transfer between a controlled indoor environment and a variable outdoor environment. In principle all these thermal transfer processes are well known physical ones, e.g. conduction, convection and radiation. On many occasions data is produced by people carrying out the technical work of setting up an experiment and controlling the process of data acquisition.

This document in the first part is mainly dealing with physical aspects and specific complexity and problems that may occur due to the experimental conditions. It may be considered as a question: what quality and what information does the data contain for analysis? Minimum steps to carry out data analysis are reported and different alternative analysis approaches are outlined. The document explains how to transfer the main features of the physical system to these modelling frameworks, in order to build candidate models.

Common exercises facilitated the identification of frequently made mistakes leading to unjustified high spread in the results and inaccurate parameter estimates. A case study is presented to facilitate the understanding of some of the recommendations given in this document. The presented case study consists of a round robin test box, designed in the framework of Annex 58. References in this document are given for additional case studies that help to understand the different aspects discussed.

As an introduction some basic information on temperature measurements is given as it is considered as important for a proper analysis of the measured data. The measurement of temperatures and thermal flows is performed by sensors based on the applied physical properties of the sensitive part of it: resistances (PT100), thermo-couples (like Cu-Co) and electronic devices. A correct measurement of the target temperature is required and a closer look will be given within the context of thermal performance of a building corresponding to the transfer of heat through the building envelope.

Radiation is the main source of wrong temperature measurements that give false signals from the sensor and hence false information to the mathematical models about the physical processes. The disturbing radiation may arrive from solar radiation, heat sources such as badly shielded electric heaters and incandescent light bulbs. Shielding of air- and surface temperature sensors is therefore necessary in particular for those that could be hit by solar radiation near to window openings and those sensors that are placed in a space where electric heaters or light bulbs are used. Measured data is supposed to contain all information about the total physical process to be studied. As a consequence it is important also to have knowledge about the phenomena that are part of the physical process but that not could be measured, such as corner effects, air infiltration.

It is assumed that the reader is familiar with basic principles of heat transfer (many text books deal with this topic) and that the reader has some background on measurement techniques that are well described in the literature and standards.

IEA-EBC Annex 58: Statistical guidelines for building energy data

Peder Bacher, Henrik Madsen (DTU)

In many years the wells of data from buildings have become richer and a great potential for extracting useful information has built up. Dealing with this data the challenges are manifold -- in this short post we will touch on the statistical modelling techniques needed. In very general terms one can say, that the basic challenge is to select the best model fitting the observed data, however in doing that, some steps must be considered:

- How to define a model
- How to estimate the parameters in a model
- How to measure the fit of a model and use this to select the best model
- How to extract the information which is useful for the particular application

Indeed, ultimately an applied model should be evaluated on the usefulness of the information it provides for the application it is used for, however that is often not practically possible. Therefore procedures leading to the selection of a suitable model must be formed -- statistics provides the needed techniques. Observed data varies: some of the variation is systematic and some of the variation is random. The statistical techniques enable a mathematical understanding of the systematic relation between observed variables, as well as a mathematical understanding of the random variation. They can be used, both to learn about informative parameters in the models, e.g. the heat loss coefficient of a building, as well as finding models suitable for prediction and control. Most statistical methods can be derived with the principle of maximum likelihood, which provides a clear and transparent methodology for defining models, estimating parameters and measuring the fit of a model to data.

Time series data from building energy systems exhibits naturally strong dynamical relations stemming from the thermal processes of the systems. Luckily, the dynamics can often successfully be described by models for time invariant linear (LTI) systems, on the relevant time resolutions (e.g. hourly values). Statistical models for LTI systems are very well understood. The discrete models for LTI systems are referred to as Auto-Regressive Moving Average with eXogenous input, in short ARMAX, models. Several software implementations exists, like the Matlab system identification toolbox and the R inbuilt function ARIMA and the MARIMA package are recommended. Also useful for modelling of LTI systems are continuous time models, where the dynamical relations between the variables are described by differential equations, hence the model and its parameters have a direct meaning in the context of physics. To facilitate the method of maximum likelihood for continuous time models, thus enabling the entire statistical methodology, the continuous time models must be formulated as stochastic differential equations -- hence a proper description of the random variation is included and the models are called a grey-box models. A very useful implementation for grey-box modelling is available in the R package ctsmr. Further, it is perfectly possible to include time-varying and other non-linear effects in both discrete and grey-box models, even in a non-parametric way -- hence the exact functional relationship is not defined, only some constraints of its shape. This can be carried out for example with base spline or Fourier functions, even while keeping some parts of the model parametric, thus forming a semi-parametric model.

In order to provide statistical modelling procedures, which can be used to extract information about the thermal performance of buildings and their systems, quite some work was carried out in IEA Annex 58. One of the documents, referred to as the IEA Annex 58 statistical guidelines, holds the description a statistical procedure developed to model thermal performance of buildings using simple data, e.g. hourly values of internal and external temperature, heat input and solar radiation. The statistical guidelines provide a procedure for selecting a suitable ARX model and from the selected model to calculate the heat loss coefficient and gA-value. Further, the basics of grey-box modelling for building energy systems are introduced. The guidelines can be downloaded together with examples in R from http://dynastee.info/data-analysis/overview/. The statistical guidelines is a good base for the statistical models and techniques, which will be needed in Annex 71. Time-varying and non-linear phenomena, e.g. caused by occupants, must be modelled in an effective way, where a diurnal curve is included in a discrete model using Fourier series.

Estimation of thermophysical properties from in-situ measurements in all seasons: quantifying and reducing errors using dynamic grey-box methods

Virginia Gori, Cliff Elwell (Physical Characterisation of Buildings Group, UCL Energy Institute, University College London, UK)

Energy and Buildings, 167 (2018) 290–300. https://doi.org/10.1016/j.enbuild.2018.02.048

The use of in-situ measurements and the development of robust data-analysis techniques are key to address the current limited understanding of the as-built energy performance of the building stock and to close the performance gap. A robust characterisation of the thermal performance of buildings from monitored data requires error analysis to evaluate the certainty of estimates. This paper presents a method for the quantification of systematic errors on the thermophysical properties of buildings obtained using dynamic grey-box methods, and compares them to the error estimates from the average method. Different error propagation techniques (accounting for equipment uncertainties) were introduced to reflect the different mathematical description of heat transfer in the static and dynamic approaches.

A solid and a full-fill cavity wall monitored long term were used to test the performance of the methods. The dynamic framework substantially reduced the systematic error at all times of year (even for low internal-to-external average temperature difference), particularly applying a two thermal mass and three thermal resistance (2TM) model, compared to the AM, while providing robust thermophysical estimates (Figure 1). The systematic error estimates were also compared to the application of a uniform error as suggested in the ISO 9869-1:2014 Standard, showing that the latter is generally misrepresentative. The study emphasised that the in-situ characterisation of the thermophysical properties of buildings cannot disregard error quantification even when the estimates may look plausible and in line with literature calculation, as the magnitude of the systematic measurement error may effectively nullify the insights gained. Additionally, dynamic methods may extend the use of in-situ measurements beyond the winter season (or to climatic regions where the average temperature difference is generally low), and be applied for example for quality assurance and informed decision making in support of closing the performance gap.

The Physical Characterisation of Buildings Group investigates the energy performance of buildings as built, applying physics and statistical techniques to both develop novel assessment methods (e.g., heat transfer, ventilation) and derive a greater appreciation of the performance of the built stock.

Recent papers by the PCB group:

Gori V, Marincioni V, Biddulph P, Elwell CA. Inferring the thermal resistance and effective thermal mass distribution of a wall from in situ measurements to characterise heat transfer at both the interior and exterior surfaces. Energy and Buildings 135 (2017) 398–409. https://doi.org/10.1016/j.enbuild.2016.10.043

Love J, Wingfield J, Smith AZP, Biddulph P, Oreszczyn T, Lowe R, Elwell CA. 'Hitting the Target and Missing the Point': Analysis of Air Permeability Data for New UK Dwellings and What It Reveals about the Testing Procedure. Energy and Buildings 155 (2017) 88–97. https://doi.org/10.1016/j.enbuild.2017.09.013

Pelsmakers S, Elwell CA. Suspended Timber Ground Floors: Heat Loss Reduction Potential of Insulation Interventions. Energy and Buildings 153 (2017) 549–63. https://doi.org/10.1016/j.enbuild.2017.07.085

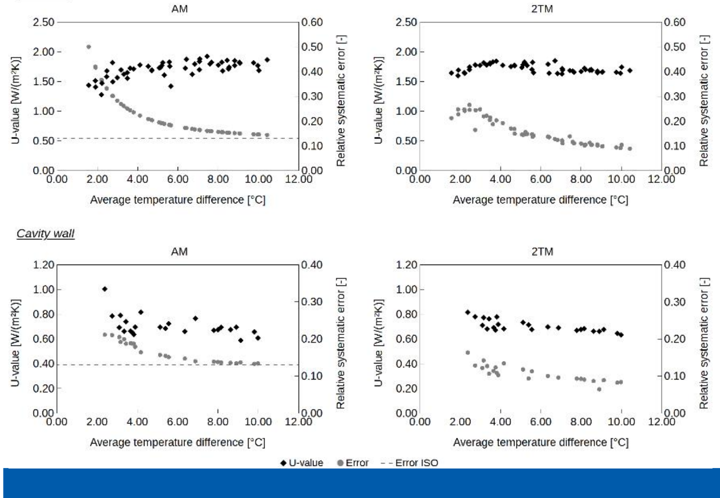


Figure 1: U-value and associated relative systematic error for the average and dynamic method (2TM model) for the solid and cavity wall as a function of the average temperature difference. The uniform error from ISO 9869-1:2014 Standard is also shown

ABOUT DYNASTEE

DYNASTEE stands for: "DYNamic Analysis, Simulation and Testing applied to the Energy and Environmental performance of buildings". DYNASTEE is a platform for exchange of knowledge and information on the application of tools and methodologies for the assessment of the energy performance of buildings. DYNASTEE functions under the auspices of the INIVE EEIG and it is open to all researchers, industrial developers and designers, involved in these items. The EU energy research projects PASSYS (1985-1992) COMPASS and PASLINK created the initial European network of outdoor test facilities, developed test methods, analysis methodologies and simulation techniques. It resulted eventually into the PASLINK EEIG network (1994). The grouping profiled itself as a scientific community of experts on Testing, Analysis and Modelling. In 1998, PASLINK EEIG started a new project PV-HYBRID-PAS on the overall performance assessment of photovoltaic technologies integrated in the building envelope. The use of the outdoor test facilities in several Member States situated in different climates, together with the available expertise on analysis and simulation techniques, offered the ingredients for more successful projects: IQ-TEST (2001), focussing on quality assurance in testing andanalysis under outdoor test conditions as well as evaluation techniques of collected in-situ data. The expertise of the grouping was also offered to other European projects, such as DAME-BC, ROOFSOL, PRESCRIPT, IMPACT and PV-ROOF. In 2005 the EEIG was converted into an informal network that today is known as DYNASTEE. It is offering a network of excellence and should be considered as an open platform for sharing knowledge with industry, decision makers and researchers. It has been very active in supporting projects such as the IEA-EBC Annex 58 and recently the new project IEA-EBC Annex 71 'Building energy performance assessment based on in-situ measurements'.