Hygrothermal Evaluation of a Museum Storage Building Based on Actual Measurement and Simulations

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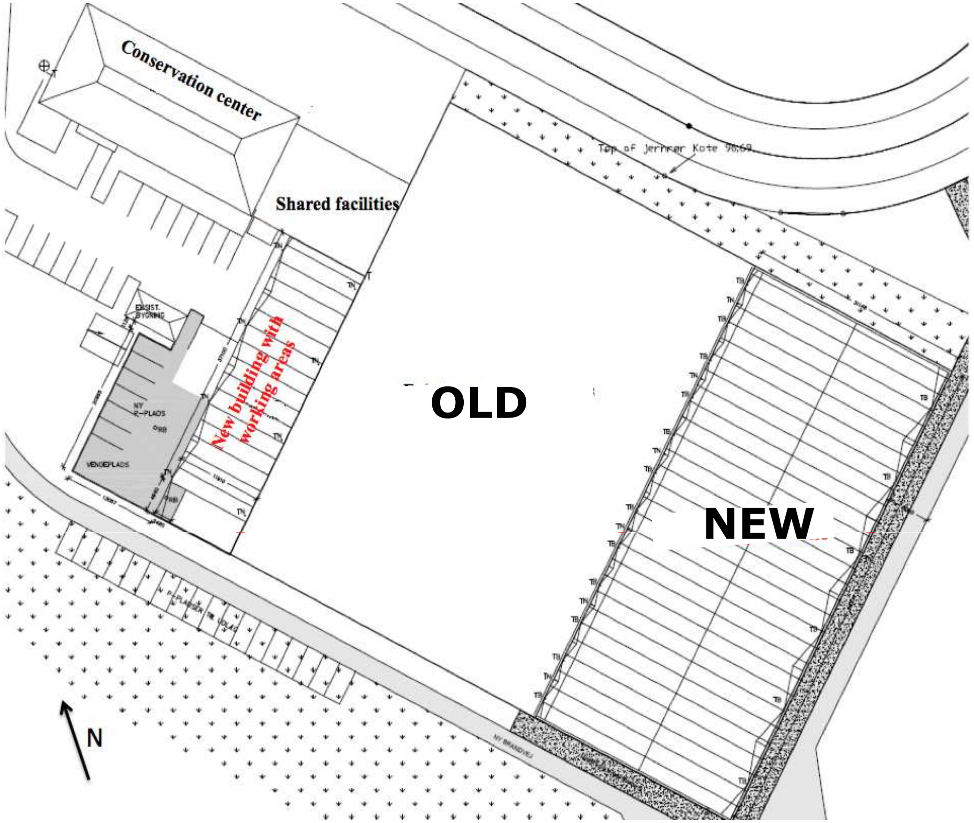
Presentation overview

1. Theoretical background
2. Description of building
3. Scopes of analysis
4. Methodology
5. Building modelling
6. Results analysis
7. Conclusion

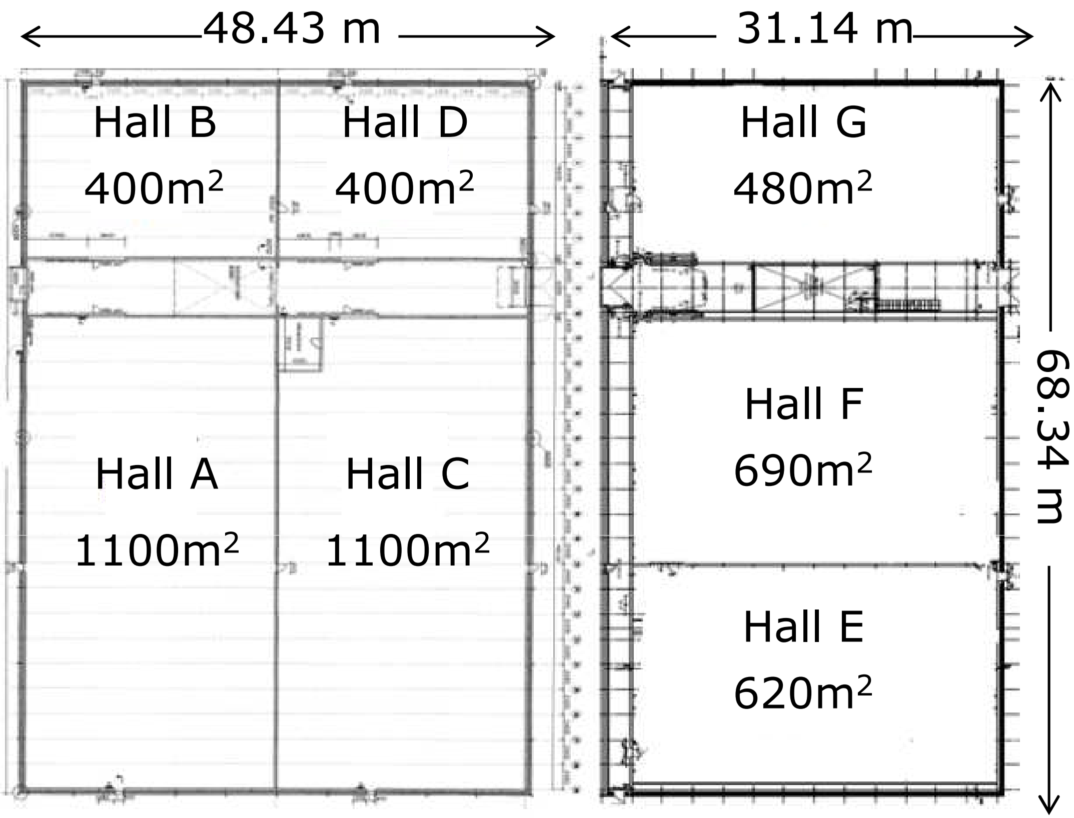
Description of the examined building



Vejle museum storage building

- Shared storage facility
- The storage facilities are consisted of an old (2005) and a new part (2012)
- Apart from the storage space, Vejle museum storage includes a conservation center, offices and working areas for the staff
- Supporting facilities (e.g. packing room, cold store, freeze disinfection compartment)

Description of the examined building



Floor plan of the OLD (left) and the NEW (right) part of Vejle museum storage facilities

- ➢ Airtightness
- • 0.04 ACH old part
- • 0.01 ACH new part
- ➢ No windows
- ➢ Thick walls
- ➢ Uninsulated floor
- ➢ No heating/cooling systems
- ➢ Conc. Dehumidification
- • 00:00 – 06:00 old part
- • 00:00 – 03:00 new part
- ➢ Sufficient insulation

- ➢ Indoor climate
- • RH 50% (±5%), T: 7 to 18 ° C (Desired T: 12 to 14° C)

Scopes of the analysis

- Illustrate how model for a large Museum magazine can be set up and analyzed
- Compare simulation model with measurements
- Investigate building's behavior in terms of temperature levels

Methodology

General building modelling with **IDA ICE** & **BSim** software using **actual weather data**

→

Evaluate the indoor climate in terms of temperature levels (predicted vs measured temperatures)

Problem : IDA ICE and BSim allow **1D** approach, while thermal interaction between building indoor environment and the soil below is a **3D** interaction

Modelling of the foundations with the **HEAT2** software

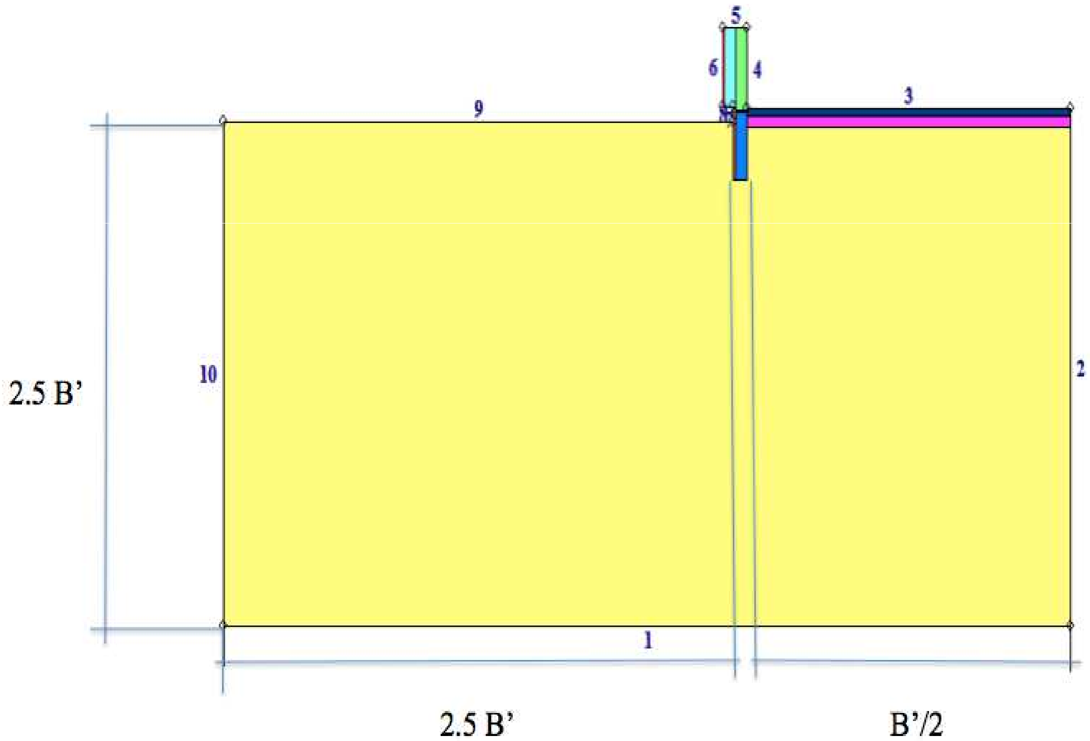
→

Study the heat exchange through the ground

Building modeling

➢ Develop a **HEAT2 model** for the investigation of the heat exchange through the ground

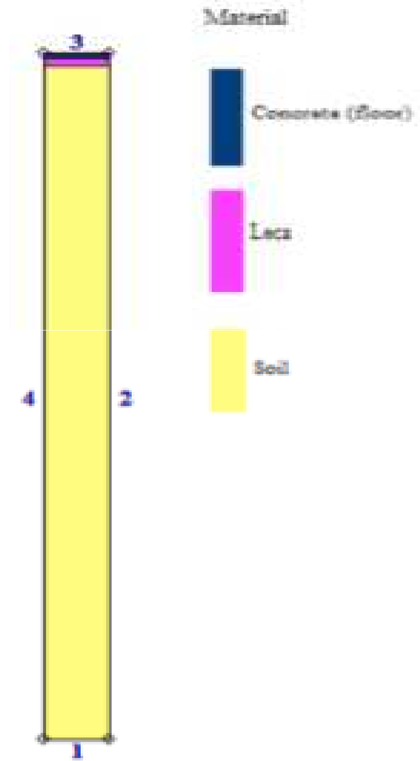
- **3D** ⇨ **2D** ⇨ UNI EN ISO 13370: $B' = \dfrac{A}{\frac{1}{2}P}$



- Using the **HEAT2** software the heat flow through the ground is calculated for the 2D model
- The simulation time interval is 10 years
- Only results of the last year of simulations will be used

Building modeling

- **2D ➡ 1D**
  - The calculated heat flow from the 2D model is used to specify the soil thickness of the 1D model



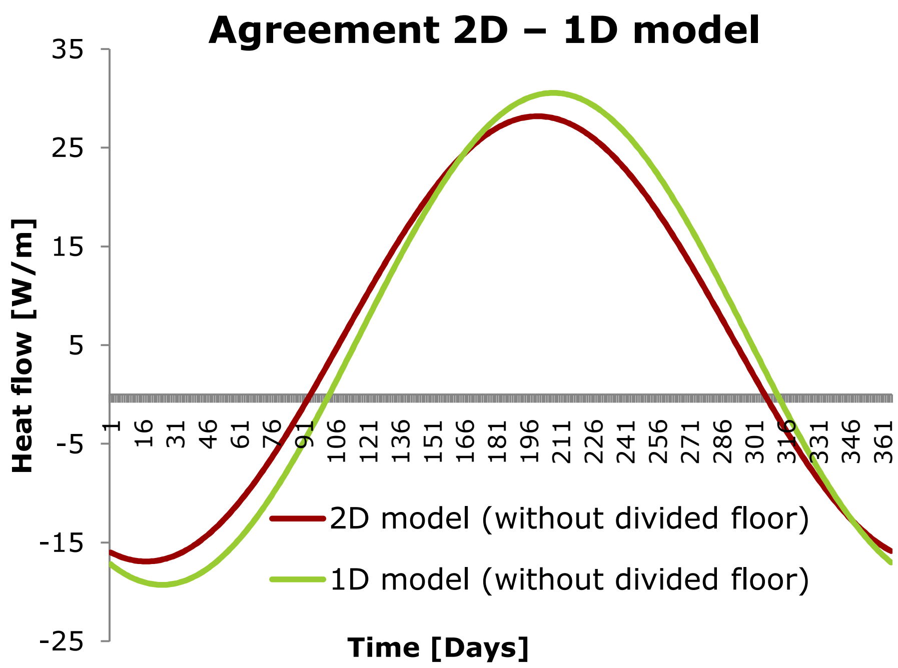
$$q_{\text{floor 2D}} = q_{\text{floor 1D}}$$

$$q_{floor} = U_{floor} \times \Delta T \Rightarrow U_{floor} = \frac{q_{floor}}{\Delta T}$$

$$U_{floor} = \frac{1}{R_{si} + \frac{d_{concrete}}{\lambda_{concrete}} + \frac{d_{LECA}}{\lambda_{LECA}} + \frac{d_{soil}}{\lambda_{soil}} + R_{se}} \quad [\frac{W}{m^2K}]$$

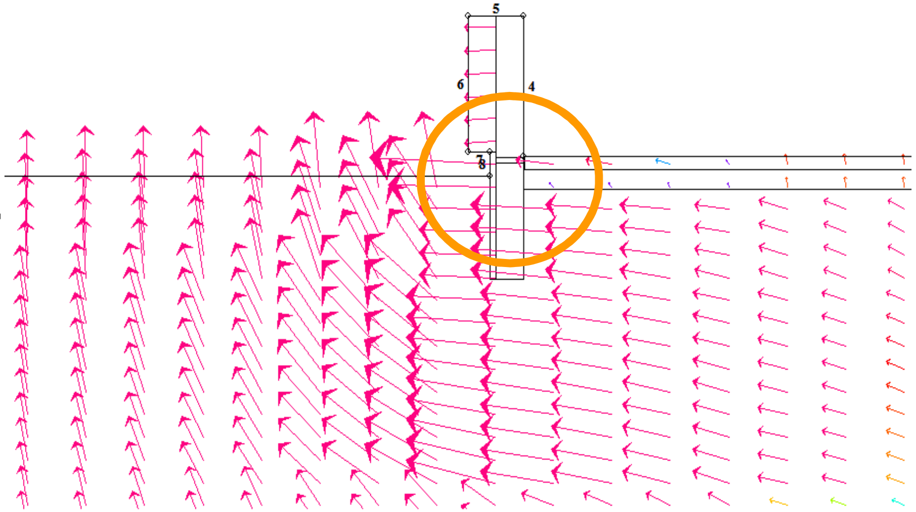
- Soil thickness should be precisely calculated in order to provide the same heat flow as the 2D model

Building modeling



- Equal average heat flow
- **Amplitude** difference (>10%)
- **Phase shift**

- Area close to the foundation is more vulnerable to outdoor weather conditions
- Less time to reach equilibrium with outdoor conditions

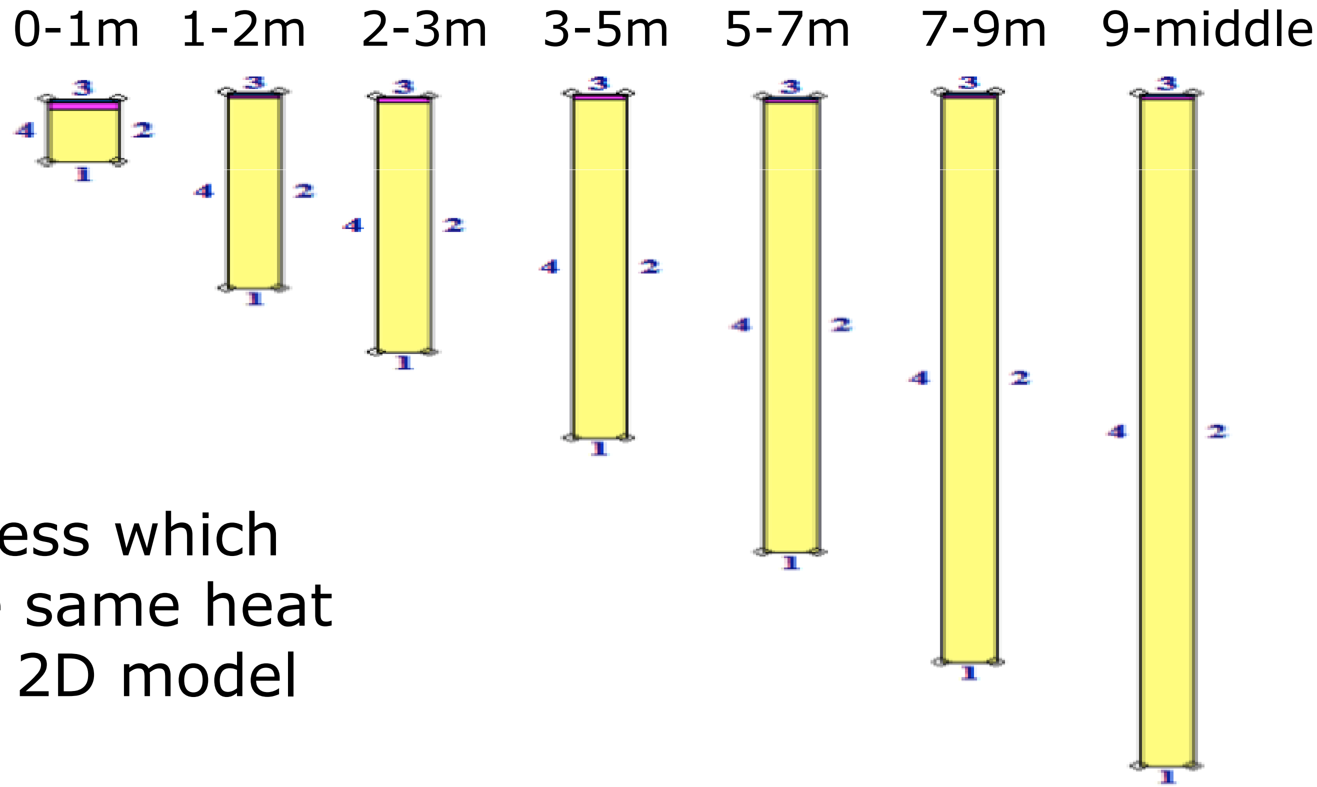


Building modeling

➢ Solution based on the UNI EN ISO 13370 suggestion:

The ground has to be subdivided in such way that the subdivisions are smaller near the edge of the floor and gradually increasing in size to much larger near the truncation planes

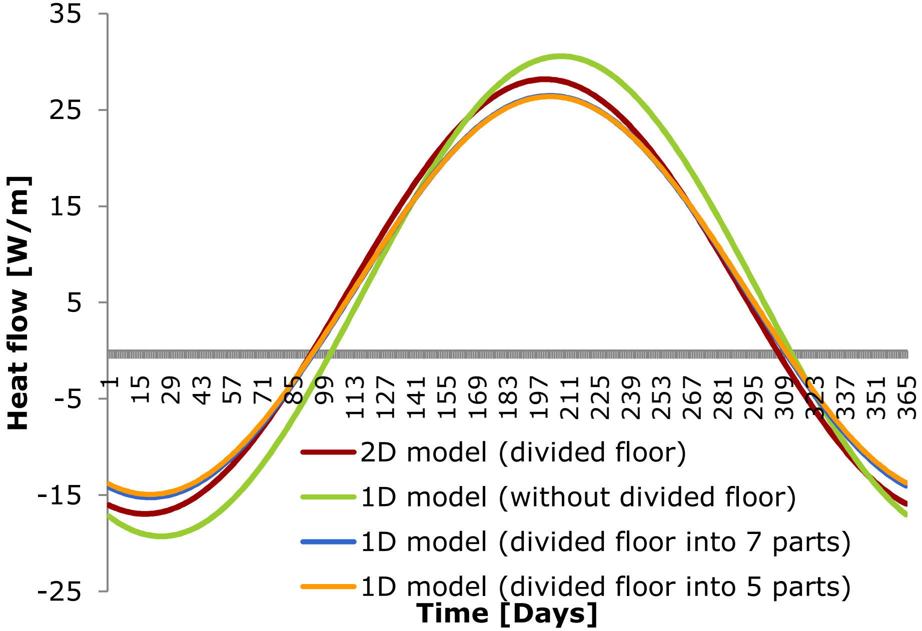
Distance from Outside:



Soil thickness which provides the same heat flow as the 2D model

Building modeling

Agreement 2D – 1D model (divided floor)

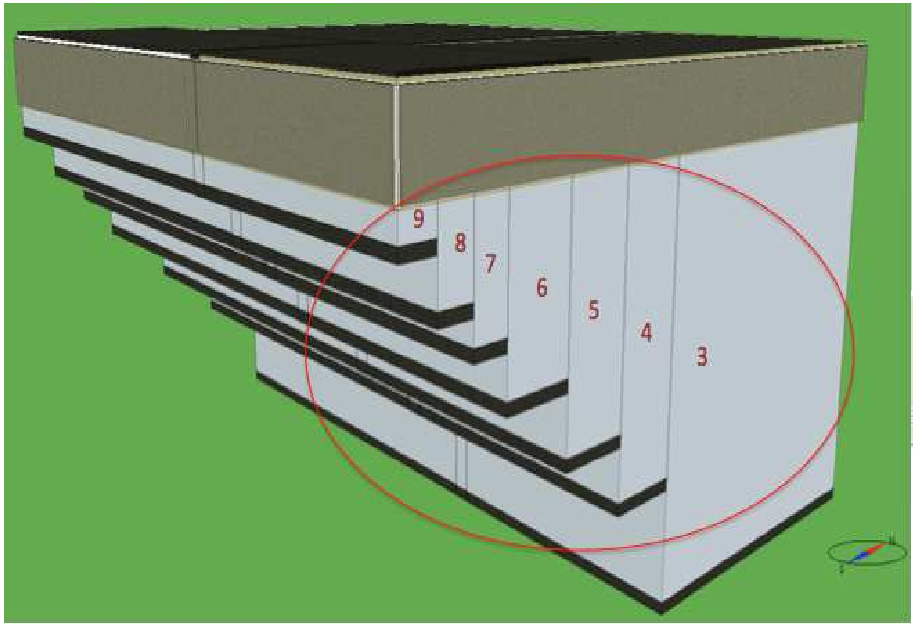


- **Amplitude** difference is improved:
  - 8.4% for 5 parts
  - 7.5% for 7 parts
- **Phase shift** is corrected:
  - Slight difference between 2D and 1D models (divided floor)

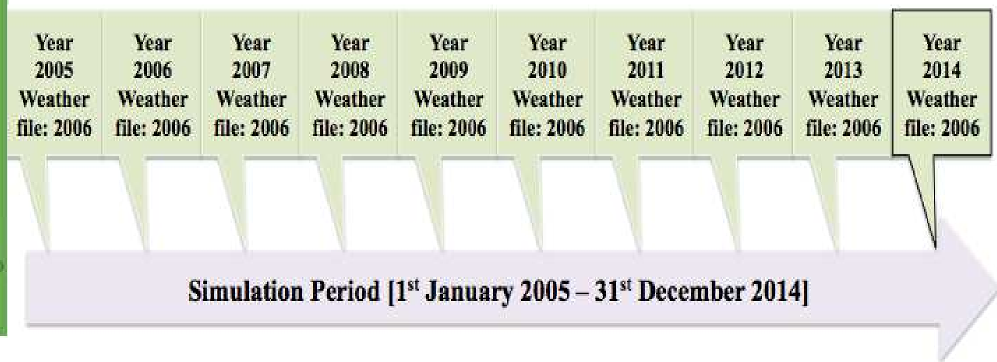
- Develop two different HEAT2 models for each building part
  - B′ is calculated for the entire floor area independent from construction and material composition
  - Heat losses are distributed proportional to the fraction of the outside perimeter of the two zones

Building modeling

- IDA ICE & BSim model **before** the expansion
  (only the old storage 2006 – 2011)
- IDA ICE & BSim model **after** the expansion
  (old and new storage 2012 – 2013)

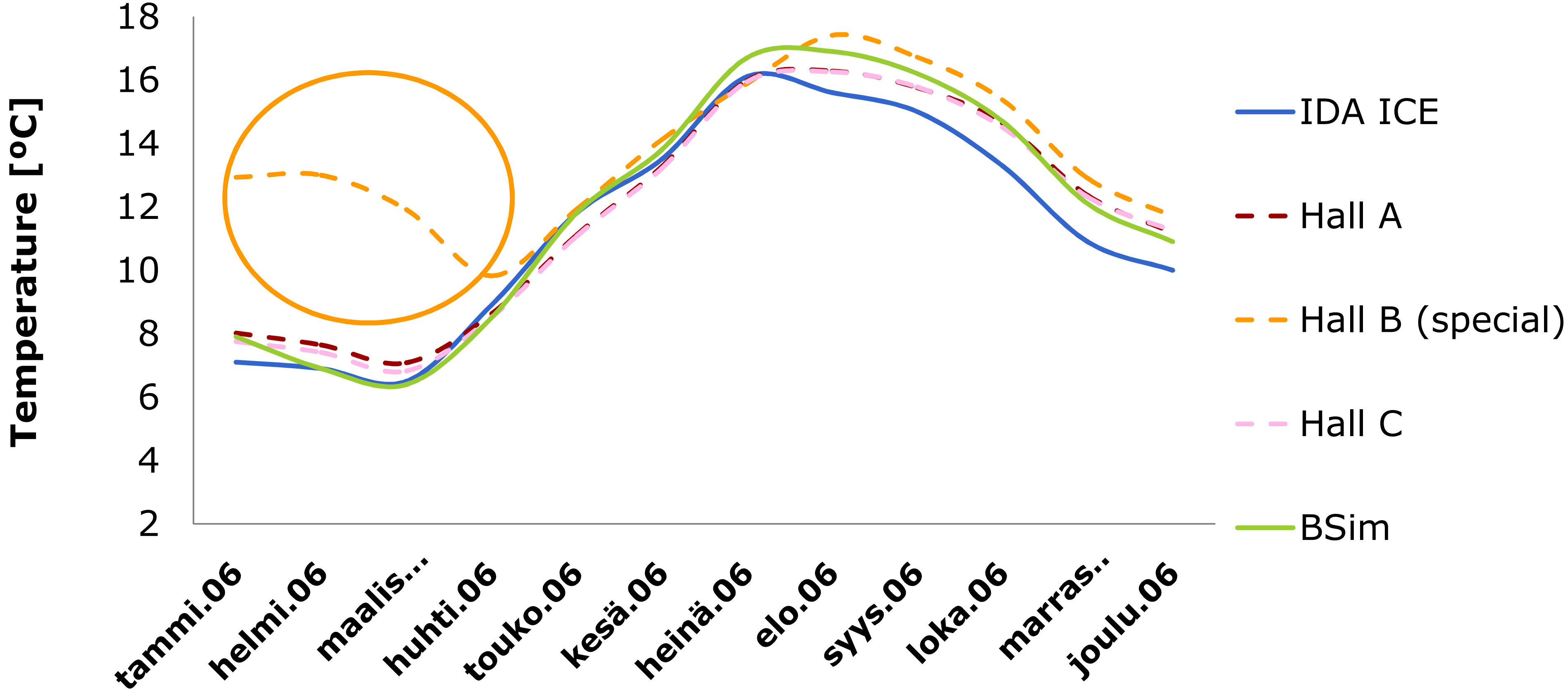


- Simulate the model with a 10 year dynamic start up phase in order the indoor climate to be stabilized



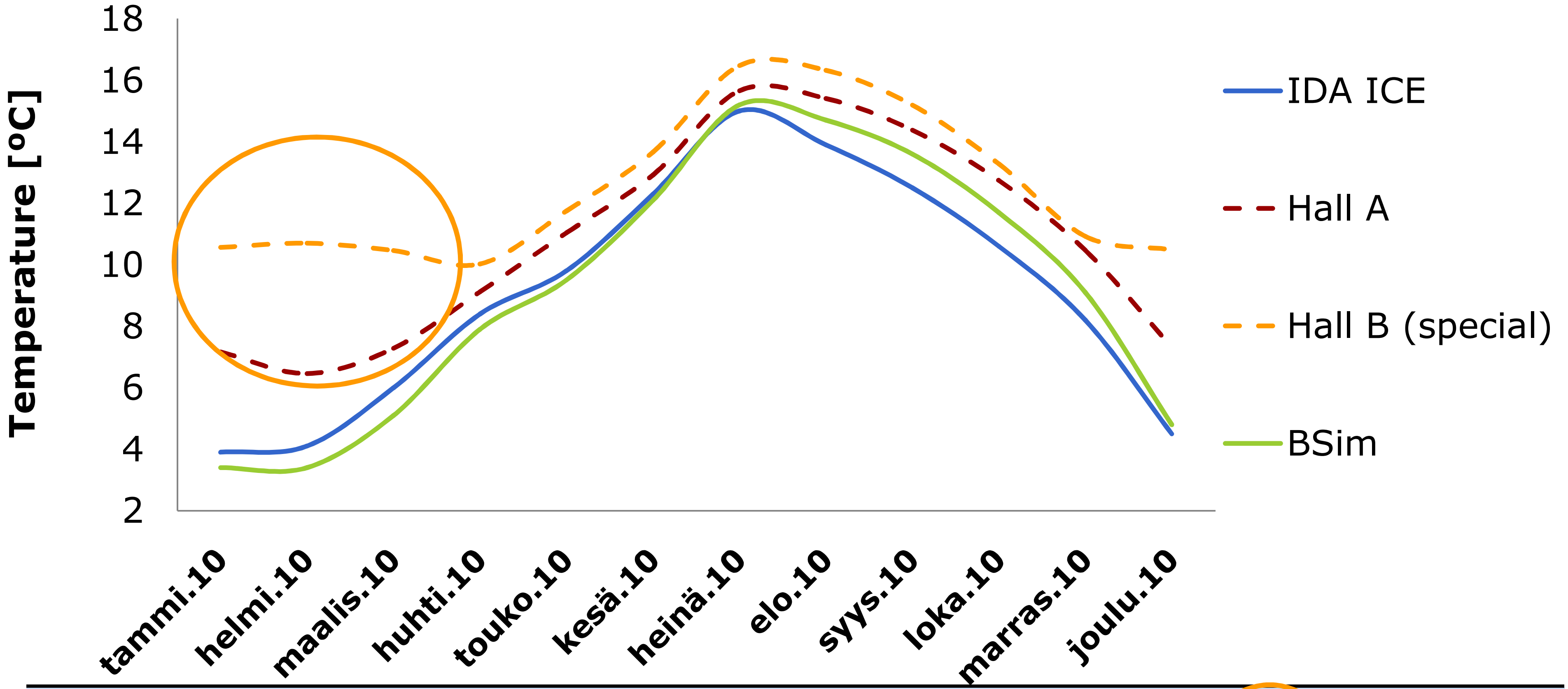
Results analysis

Predicted & measured temperature in the OLD STORAGE during 2006



Results analysis

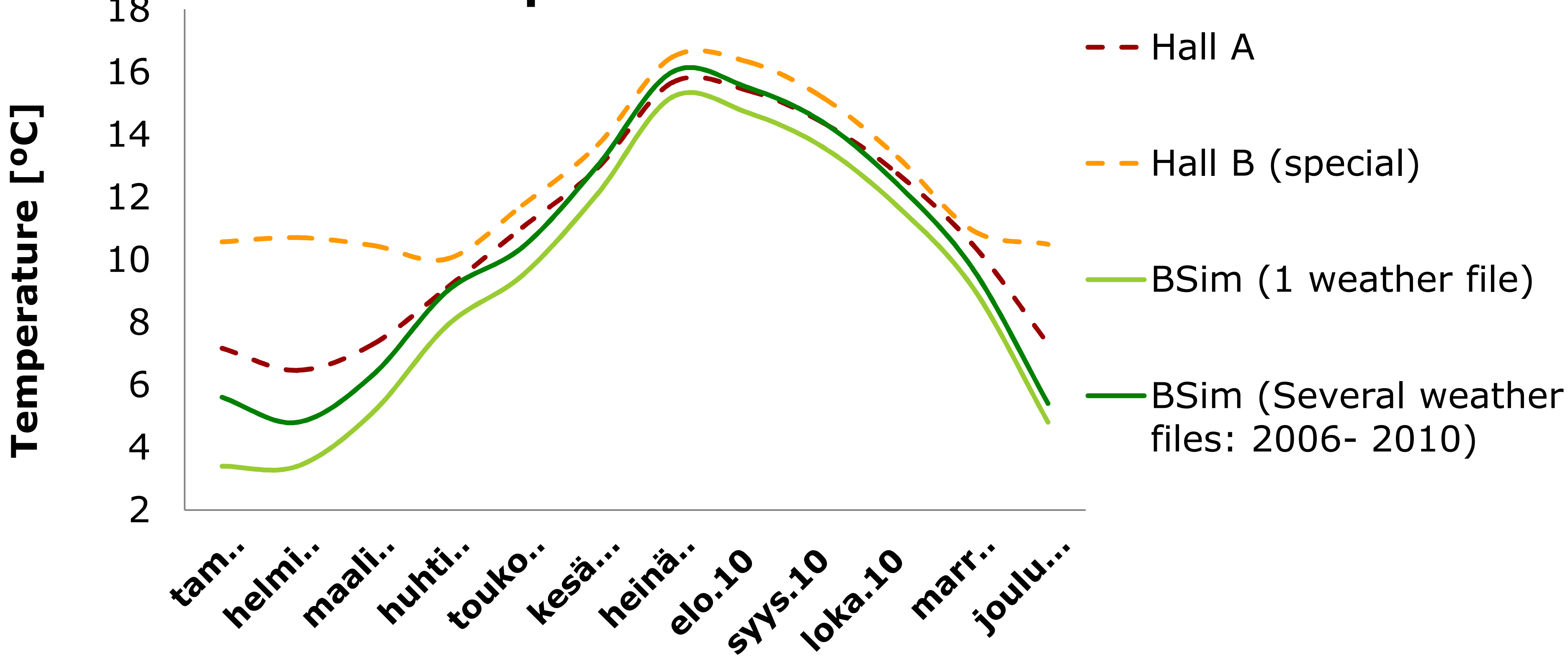
Predicted & measured temperature in the OLD STORAGE during 2010



Year	2006	2007	2008	2009	2010	2011
Average T [ºC]	9.1	9.1	9	8.5	6.5	8.6

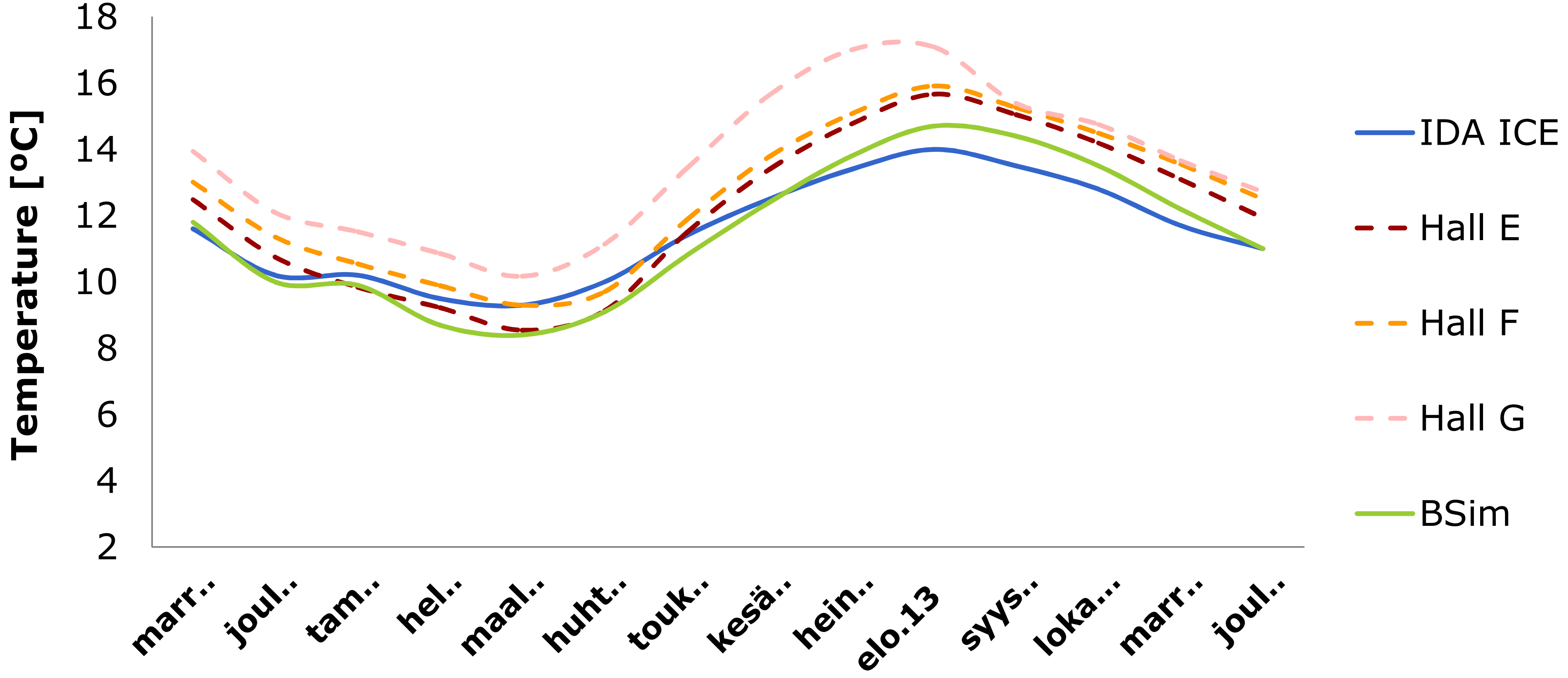
Results analysis

BSim results for the OLD STORAGE before and after the use of several weather files in a single simulation process for 2010



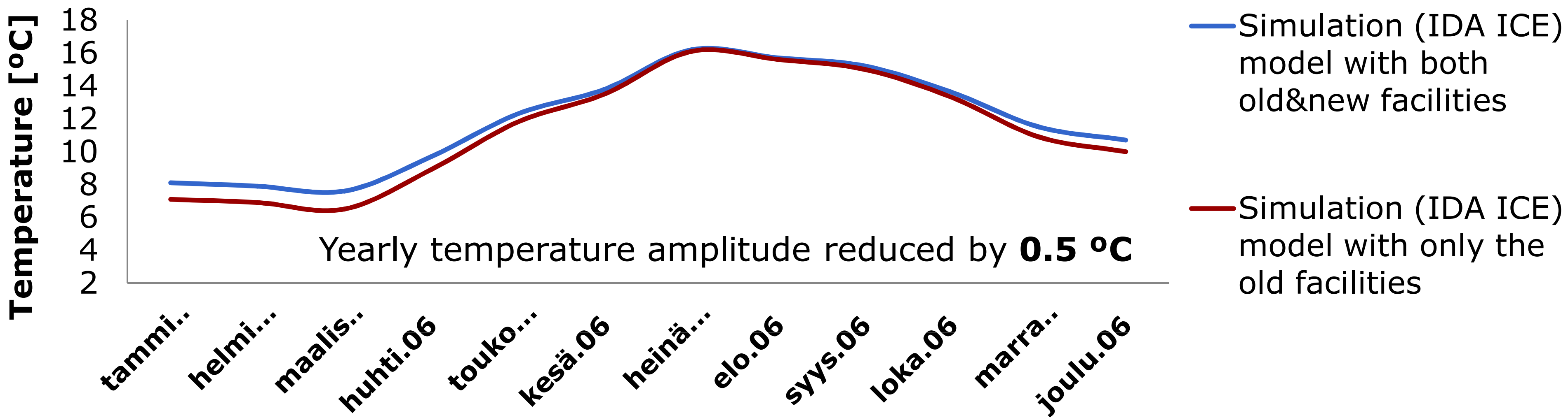
Results analysis

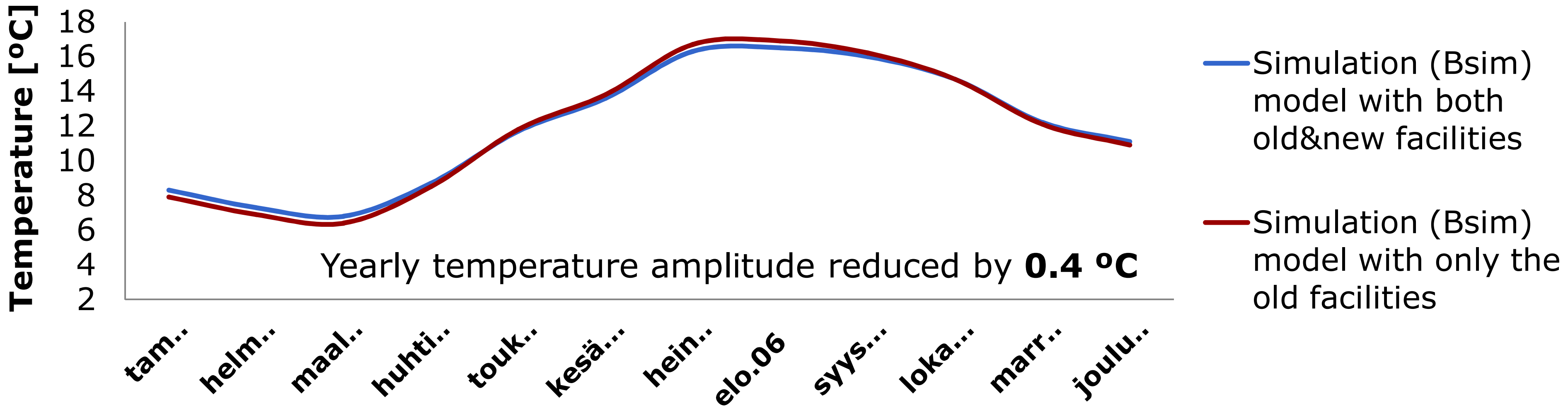
Predicted & measured temperature in the NEW STORAGE during 2012 - 2013



Results analysis

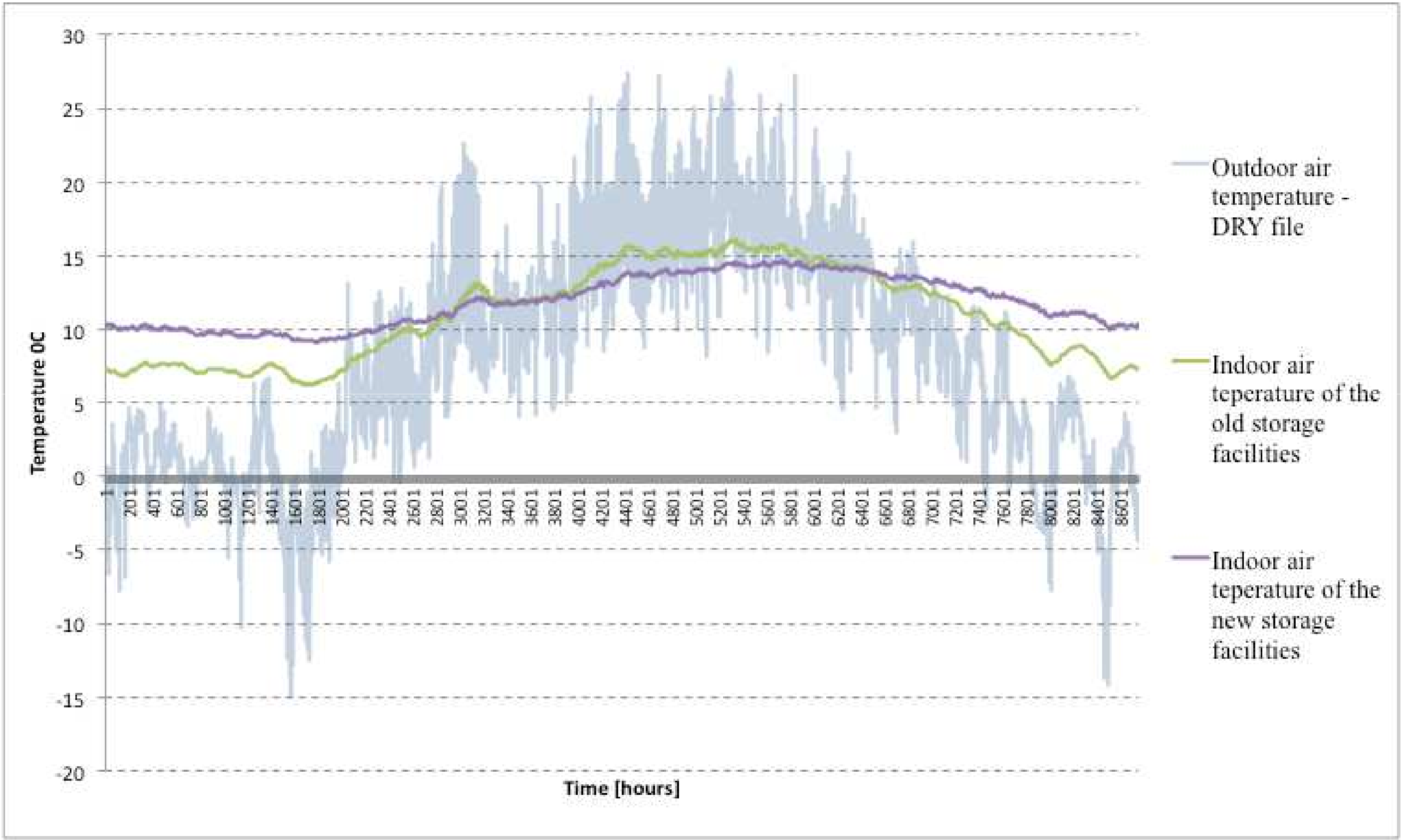
Temperature within the OLD STORAGE before and after the expansion (IDA ICE & BSim results)





Results analysis

Hourly values for indoor and outdoor air temperature



Results analysis

Required dehumidification load to maintain RH at 50%

Dehumidification load=Infiltration+People moisture-Exfiltration

Month	Infiltration [kg/month]		Exfiltration [kg/month]		People Moisture [kg/month]		Dehumidification [kg/month]	
	OLD	NEW	OLD	NEW	OLD	NEW	OLD	NEW
January	2658	468	2317	482	1.38	5.52	342	-9
February	2417	425	2064	425	1.20	4.80	353	5
March	2417	425	2255	463	1.26	5.04	163	-32
April	3332	587	2579	477	1.32	5.28	754	115
May	4429	780	3099	535	1.38	5.52	1330	250
June	5492	967	3211	543	1.20	4.80	2283	428
July	6686	1177	3765	608	1.38	5.52	2923	574
August	6415	1129	3841	629	1.32	5.28	2576	505
September	5446	959	3489	602	1.26	5.04	1958	362
October	4785	842	3199	591	1.38	5.52	1588	257
November	3214	566	2642	528	1.26	5.04	573	43
December	2827	498	2388	501	1.32	5.28	440	2
Sum [kg/year]	**50118**	**8822**	**34851**	**6385**	**15.66**	**62.64**	**15283**	**2500**
Sum [kg/year/m^2]	**15.7**	**4.3**	**10.9**	**3.1**	**-**	**-**	**4.8**	**1.2**

Conclusions

- Good agreement between simulation and measurements
- Weather conditions of the previous years affect the indoor environment of the following years
- The expansion of Vejle museum storage with the new section benefits the indoor climate of the old building part
- The increased airtightness of the new part results in lower need for dehumidification as well as it minimizes the detrimental effect of paint on walls' moisture buffer contribution


Thank you!