Modeling multiple indoor climates in historic buildings due to the effect of climate change

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Where innovation starts

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What is the Effect of Climate Change on Built Heritage?

Buildings as Dynamic Complex systems

Modeling Tools

What can we simulate?

Incorporating Climate change

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Introduction
Climate for Culture Project

- Climate change -> global challenges
- Historic buildings in different parts of Europe
- High resolution climate evolution scenarios
- Coupled with whole building simulation models
- Mapping most urgent risks for specific regions

- Scale problem: building vs. EU regions

Climate for Culture

COOPERATION

TU/e Technische Universiteit Eindhoven University of Technology

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Buildings as Dynamic Complex Systems
What is special on complex systems?

- The whole is greater than the sum of the individual parts

Buildings as Dynamic Complex Systems
What is special on complex systems?

- Butterfly effect: Small parameter variations may produce large variations in the long term behavior of the system.

Importance of BuildCoSy

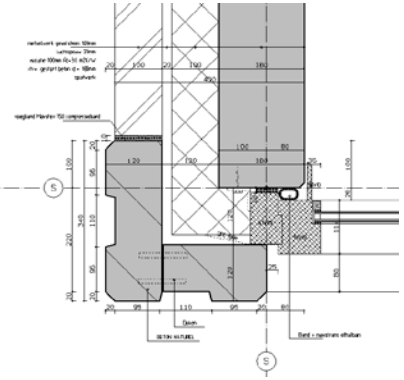
- **Where are the dynamic complex systems at the built environment ?**

Everywhere and on several scales

~ km

~ 10 m

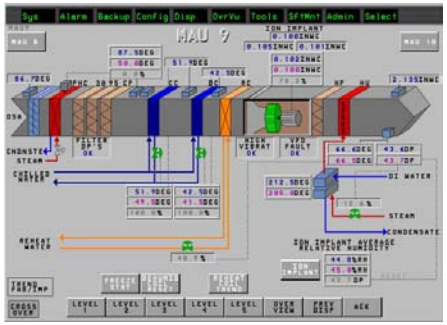
~ 1 m

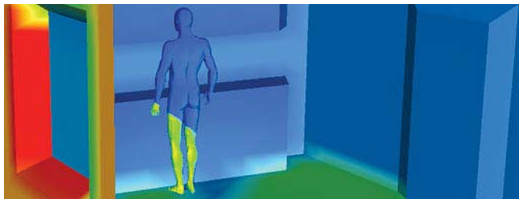


~ mm

Buildings as Dynamic Complex Systems

- **Butterfly effect: Small parameter variations may produce large variations in the long term behavior of the system.**





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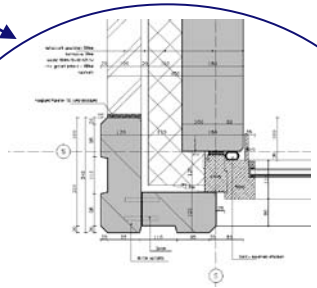
Tools HOW? Modeling based on physics
Using state of art scientific software

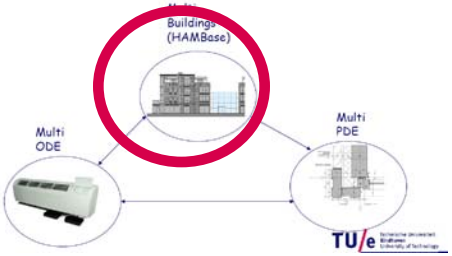
Multi Buildings
'HAMBase'
MatLab

Multi Systems & Control
ODE
SimuLink

Multi Details
PDE
Comsol

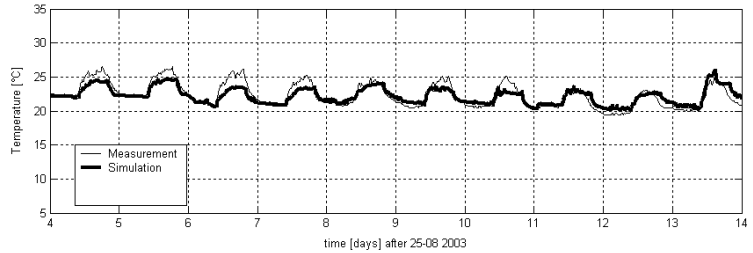


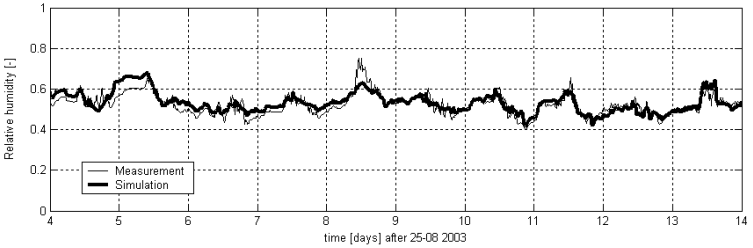
Tools Buildings modeling physics: HAMBase scientific software: MatLab



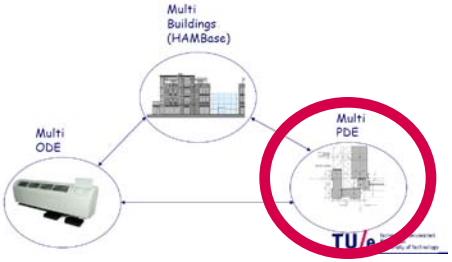
Anne Frank House

Simulation and validation



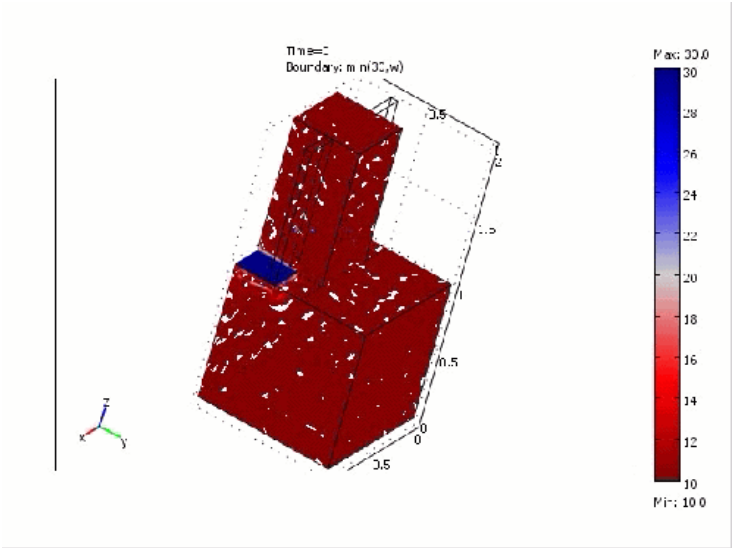


Tools Detail modeling physics: PDEs
scientific software: Comsol

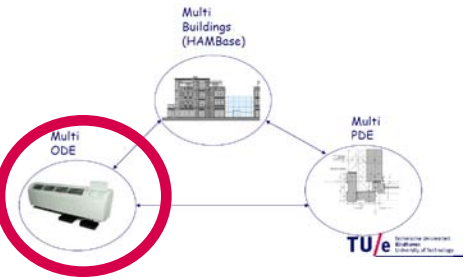


Hunting Logde St. Hubertus

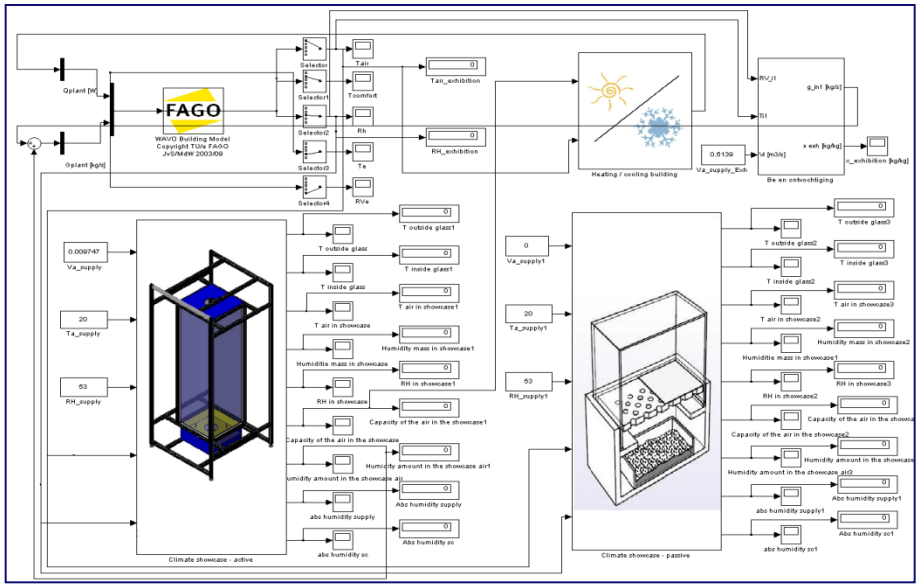
3D Moisture



Tools Systems&Control modeling physics: ODEs scientific software: SimuLink



Building systems failure modeling



Dutch Maritime Museum

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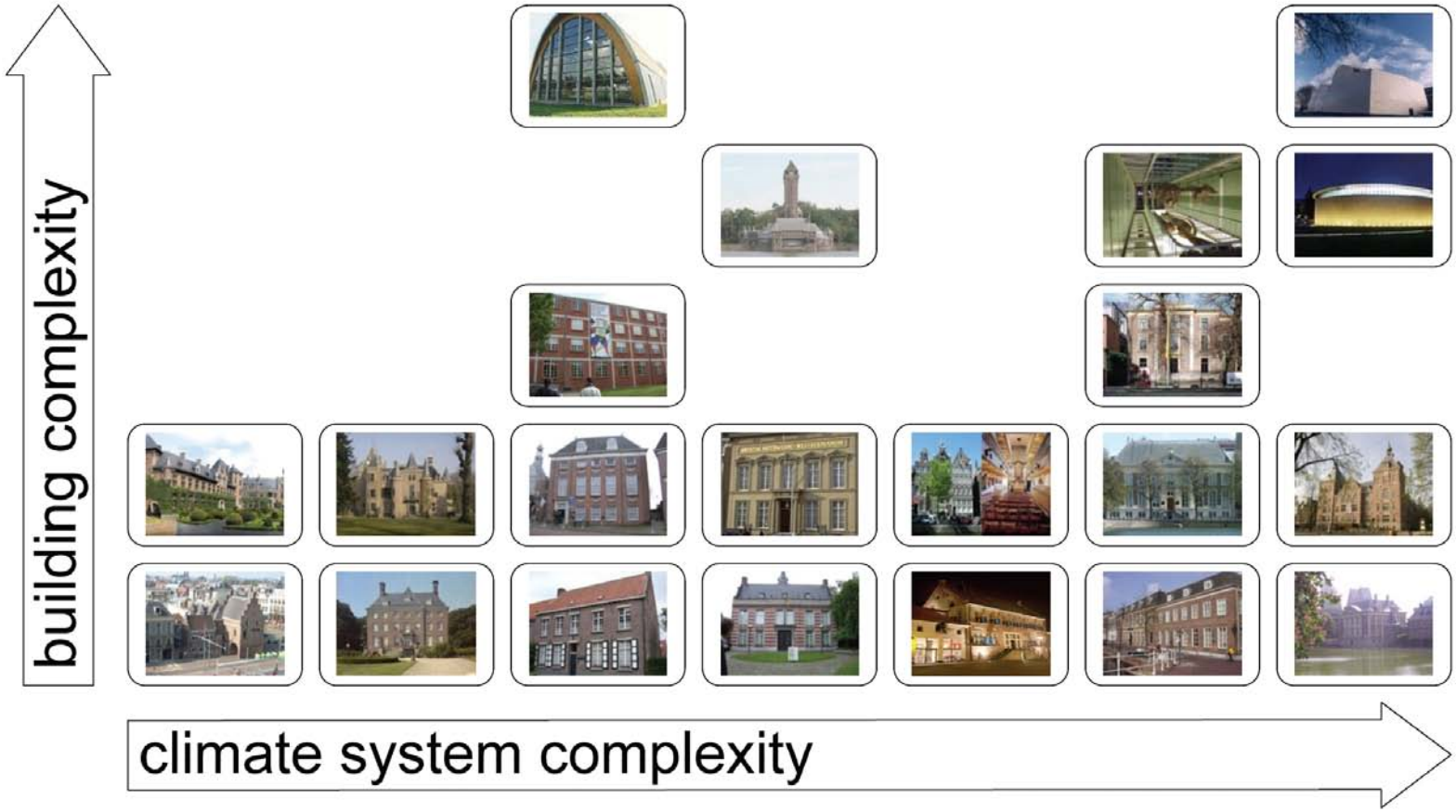
Artificial Climate Data

(1) Meteonorm commercial software
- Reference year
- Available for our models
- Hourly based,
- 8000 locations on earth

(2) EU Climate for Culture project data
- 250 years: period 1850 – 2100
- Not available yet (Max. Plank Institute Jacob et al.)
- Hourly based,
- Any location in Europe

Classification



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New: Multi Buildings model

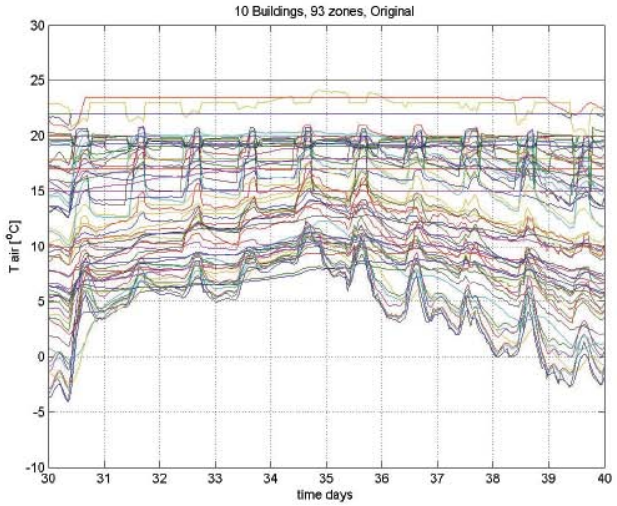
1 Museum Our Lord in the Attic
2005/01/24 - 2006/01/23
2 Castle of Amerongen
2003/10/10 - 2005/12/04 and 2006/02/08 - 2010/02/08
3 Begijnhof Museum
2006/03/15 - 2009/09/15
4 Flipje Museum
2006/01/09 - 2009/01/23
5 Museum The Prison Gate
2003/10/27 - 2005/11/03
6 St Hubert Hunting Lodge
2005/12/13 - 2006/12/01
7 Historical Museum of The Hague
2007/07/03 - 2010/01/01
8 Castle Gaasbeek
2007/11/26 - 2009/03/27
9 Castle Keukenhof
2007/11/05 - 2009/12/08
10 Museum Mesdag
2007/04/16 - 2008/04/18
11 Martena Museum
2008/04/23 - 2009/02/01
12 Mauritshuis
2004/10/20 - 2010/12/31
13 Museum Meermanno
2007/04/23 - 2008/02/14
14 National Museum of Antiquities
2006/12/07 - 2007/12/10
15 Depot Raamsteeg
2008/10/31 - 2009/12/08
16 Nationaal Museum van de Speelkaart
2006/03/15 - 2009/09/15
17 National repository for ship archaeology
2007/12/19 - 2010/01/01
18 Netherlands Maritime Museum Amsterdam
2003/12/23 - 2006/12/31
19 Tropenmuseum
2006/12/19 - 2009/03/12
20 Taxandria Museum
2006/03/15 - 2009/09/15
21 Van Gogh Museum
2007/07/31 - 2009/01/01

Table 3. Details of 11 historic buildings included in the Multi-buildings model

Building Nr. From fig 8	# Zones	# Walls	# Windows	Systems
2	10	66	26	Heating
3	12	80	18	Heating
5	10	77	24	Heating
8	4	21	3	Heating
9	15	205	64	Heating
11	8	51	19	Full airco
12	3	36	7	Free Floating
13	10	46	13	Heating
16	11	86	20	Heating
20	6	52	14	Heating
21	4	56	2	Full airco
total	**93**	**776**	**210**	

Very Useful to compare building indoor climates

T



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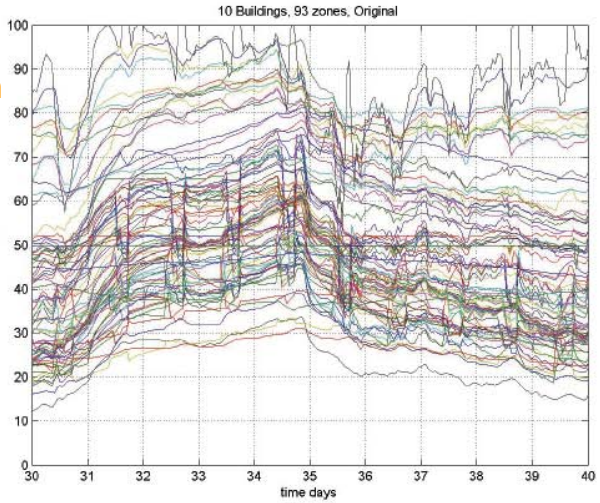
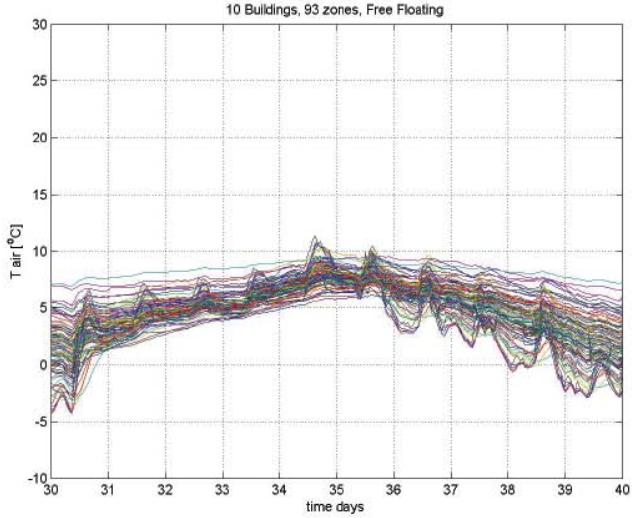


10 Buildings
93 indoor climates
Validated with measurements

Simulation
"AS IS" i.e
With
Heating & Internal sources

T



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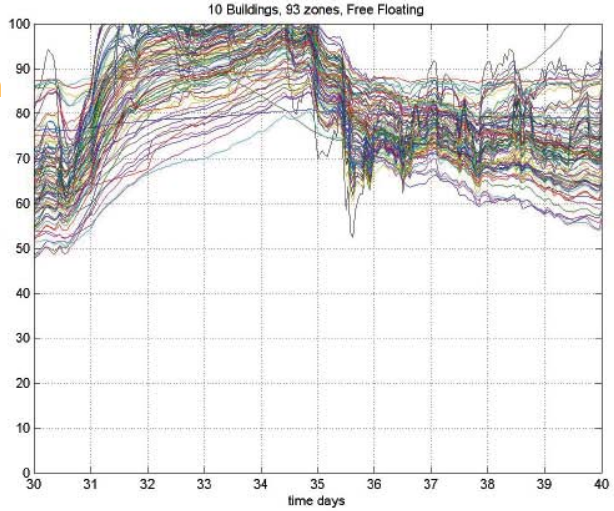

Same
10 Buildings
93 indoor climates

Simulation
"Free Floating"
Without
Heating & Internal sources

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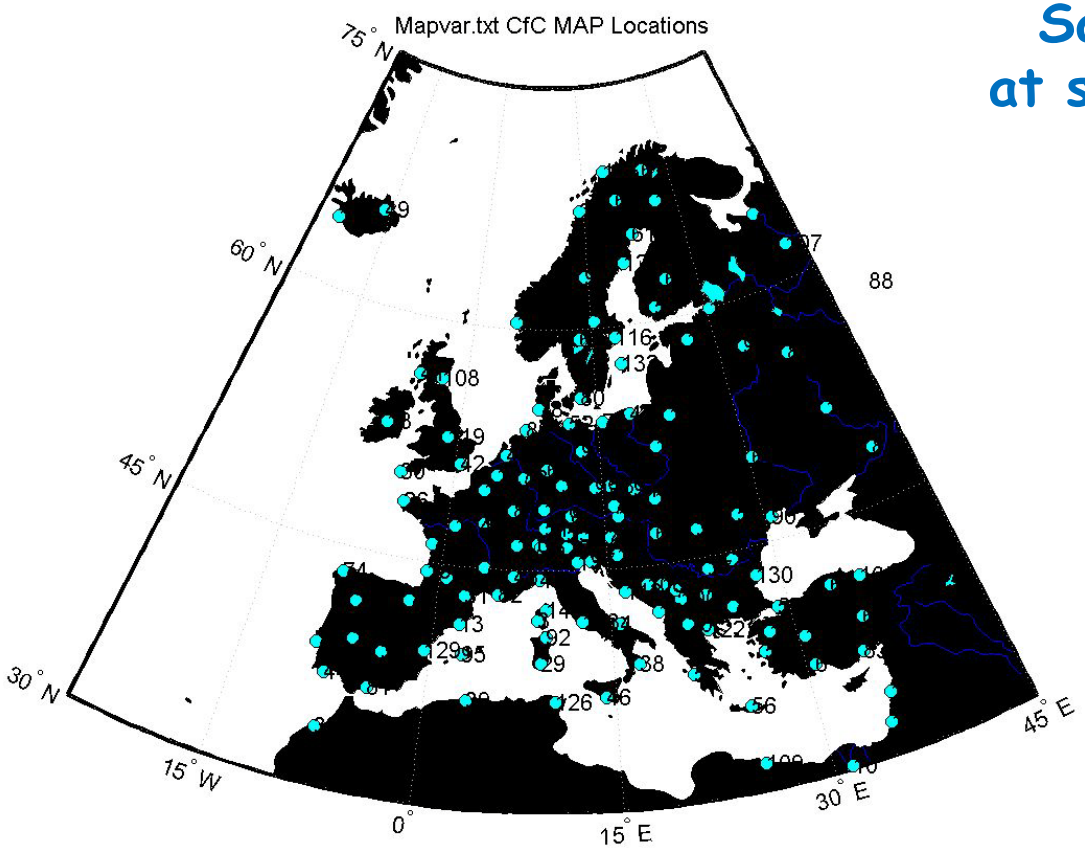
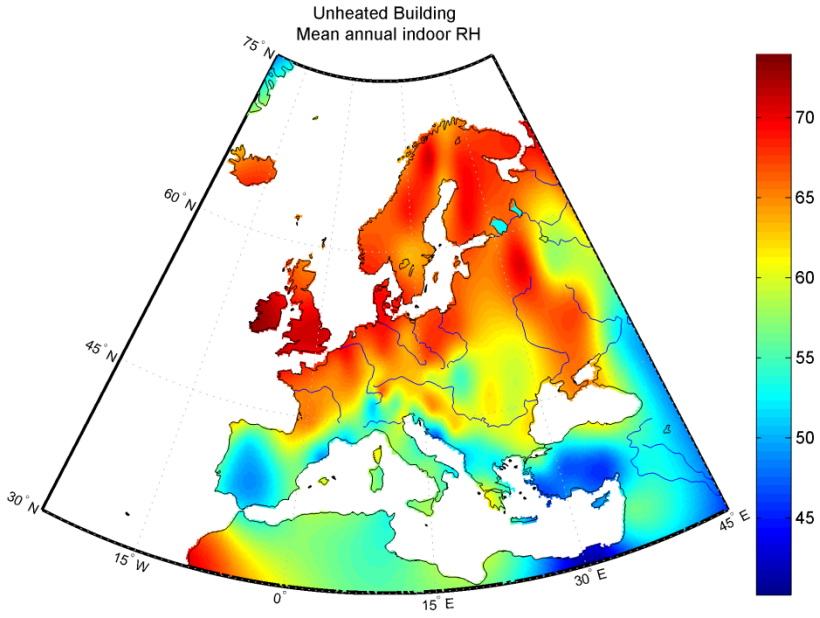
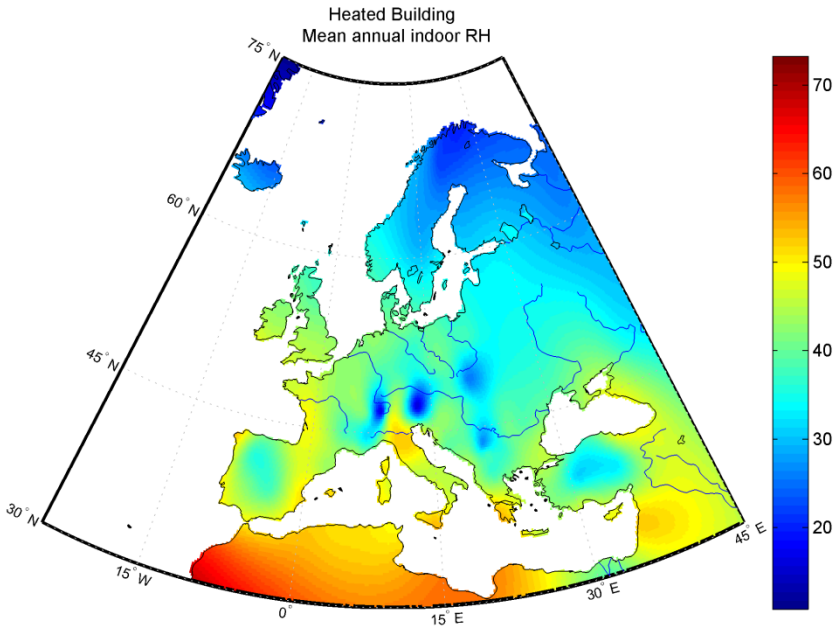
Mapping



Same building placed at several locations over Europe

Mapping
New preliminary results





Conclusion

- **A preliminary method for up-scaling building spatial level models onto a continental level by the following steps:**

(1) Classification of buildings;

(2) simulation of the same type of buildings at several locations spread over Europe;

(3) simulation of the effect of climate change using artificial local climate data sets;

(4) visualization of the results using EU maps.

- **Thank you**
- **Questions?**