

9th Nordic Symposium on Building Physics, Tampere, Finland

Computational modelling of the impact of climate change on the indoor environment of a historic building in the Netherlands

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Where innovation starts

Introduction (1)

Future climate change threatening cultural heritage in Europe until 2100:

- Increased risk of inland flash floods
- More frequent coastal flooding and increased erosion
- More frequent heat waves
- Shifting of climatic zones
- More frequent extreme weather events



**Climate
for Culture**



Introduction (2)

Prediction of future climate change on regional scale:

UN IPCC Emission scenarios



Global climate models

Providing large-scale and initial boundary conditions

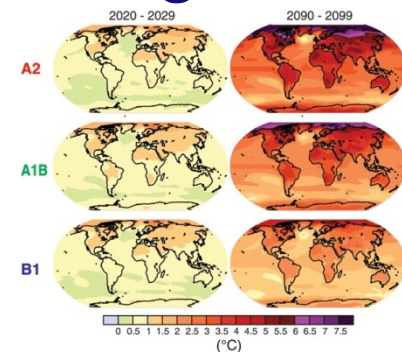


3D high resolution regional climate models

Similar to numerical weather forecasting models

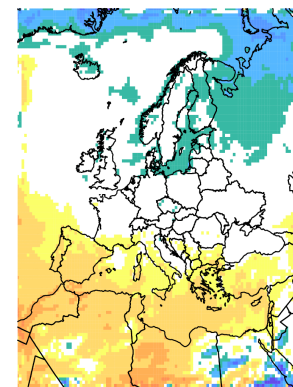


Regional climate change models



Source:
IPCC

change in total precipitation [%]:
2071 to 2100 - 1961 to 1990: REMO/A1B-3 0.44

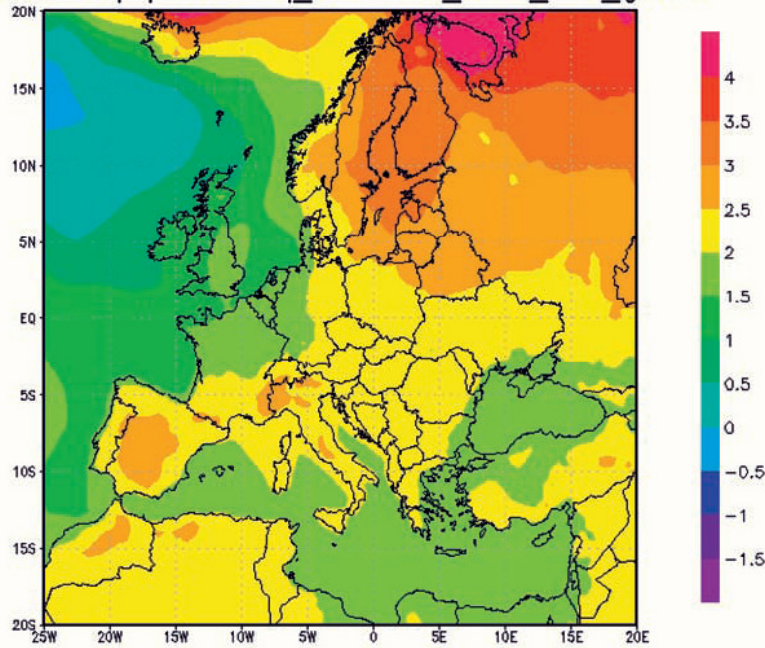


Source:
Max Planck Institute
of Meteorology, Hamburg

Introduction (3)

Future climate change in Europe until 2100:

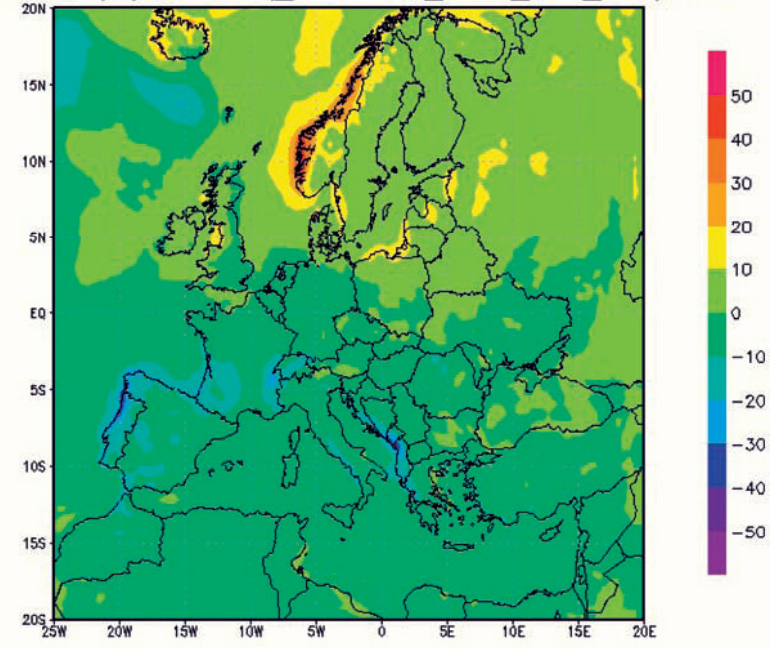
|2070-00|-|1960-90|_514-513_YEAR_167_gradC



GrADS: COLA/IGES

2010-02-16-20:04

|2070-00|-|1960-90|_514-513_YEAR_260_mm/mon



GrADS: COLA/IGES

2010-02-16-20:05

Annual near surface air temperature [°C] and total precipitation [mm/month]
for the time period 2070-2100 compared to 1960-1990
(Jacob and Podzun, 2010)

Case study

Amerongen Castle

- 17th century castle in The Netherlands
- Unheated and heated rooms



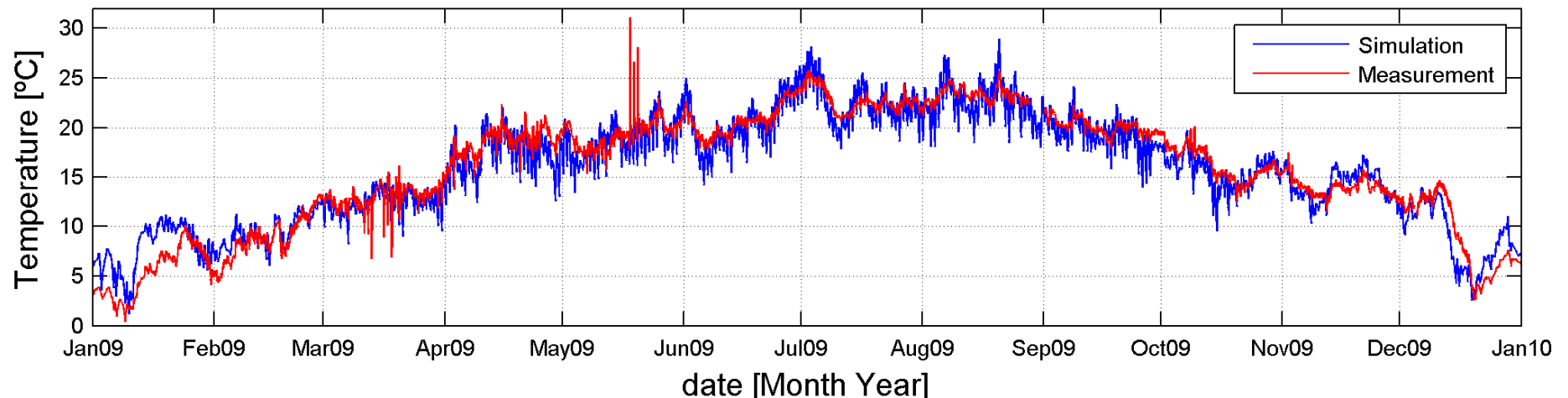
Hygrothermal modelling (1)

Hygrothermal building simulation

- Comparison HAMBase simulation and on-site measurements



Building 1; Validation; Room 3



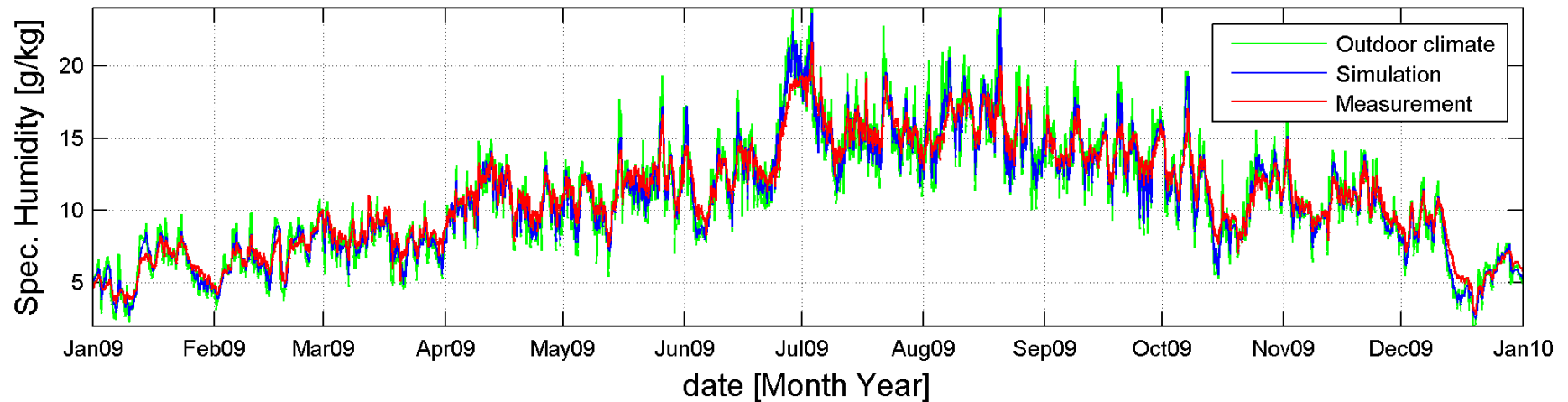
Hygrothermal modelling (2)

Hygrothermal building simulation

- Comparison HAMBase simulation and on-site measurements



Building 1; Validation; Room 3



Damage risk assessment (1)

Indoor climate measurements

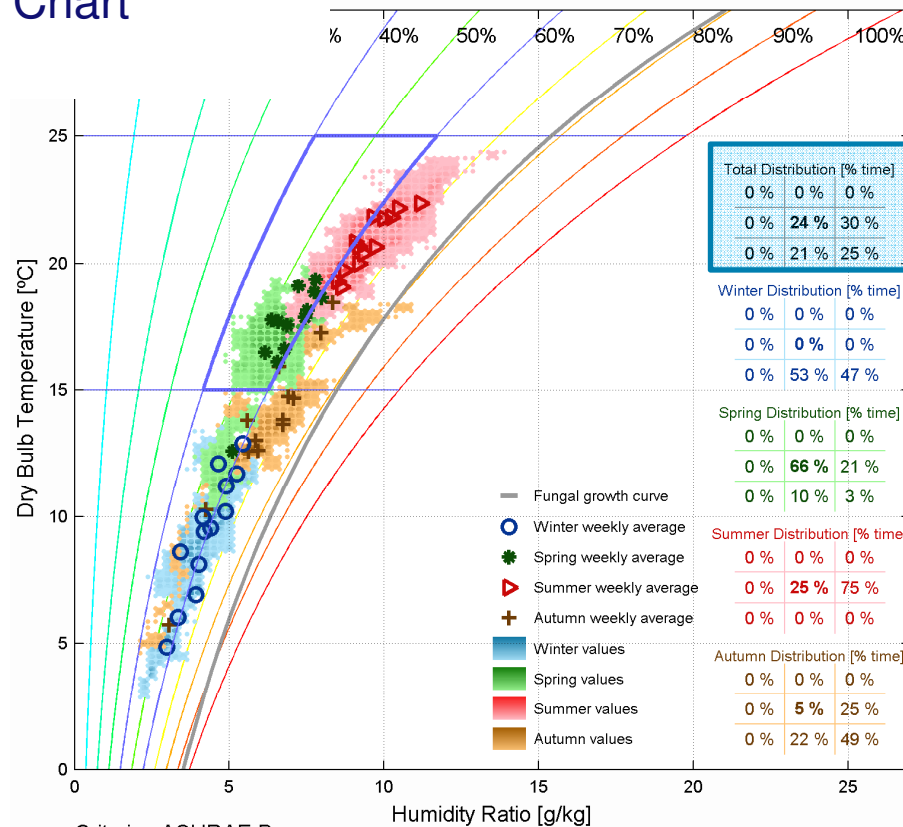
- Climate Evaluation Chart
- ASHRAE Class B

$T_{\min} = 15\text{ }^{\circ}\text{C}$
 $T_{\max} = 25\text{ }^{\circ}\text{C}$
 $\text{RH}_{\min} = 40\%$
 $\text{RH}_{\max} = 60\%$

$\Delta T/\text{hour}_{\max} = 5\text{ }^{\circ}\text{C}$
 $\Delta T/\text{day}_{\max} = 5\text{ }^{\circ}\text{C}$
 $\Delta \text{RH}/\text{hour}_{\max} = 10\%$
 $\Delta \text{RH}/\text{day}_{\max} = 10\%$

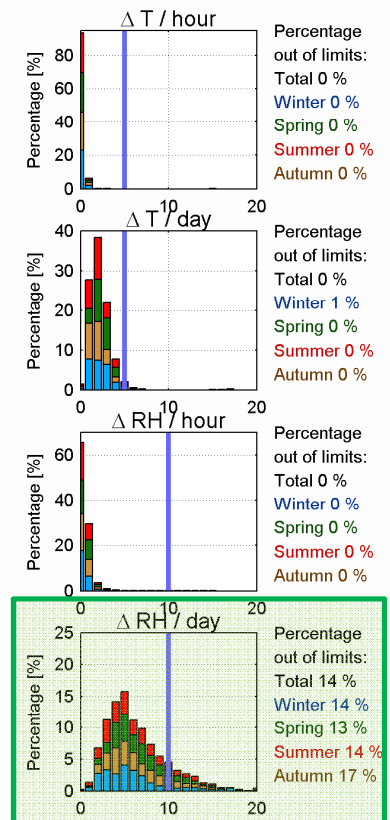
Castle of Amerongen, Bentinckkamer

01-Jan-2009 to 01-Jan-2010



Criteria : ASHRAE B

min T = 15 °C max T = 25 °C $\Delta T = 5\text{ }^{\circ}\text{C}/\text{h}$ $\Delta T = 5\text{ }^{\circ}\text{C}/\text{d}$
 min RH = 40 %RH max RH = 60 %RH $\Delta \text{RH} = 10\text{ \%RH}/\text{h}$ $\Delta \text{RH} = 10\text{ \%RH}/\text{d}$

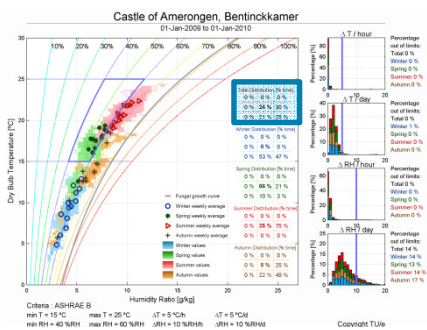


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Damage risk assessment (2)




Indoor climate measurements

- Climate Evaluation Chart



Total Distribution [% time]

0 %	0 %	0 %
0 %	24 %	30 %
0 %	21 %	25 %

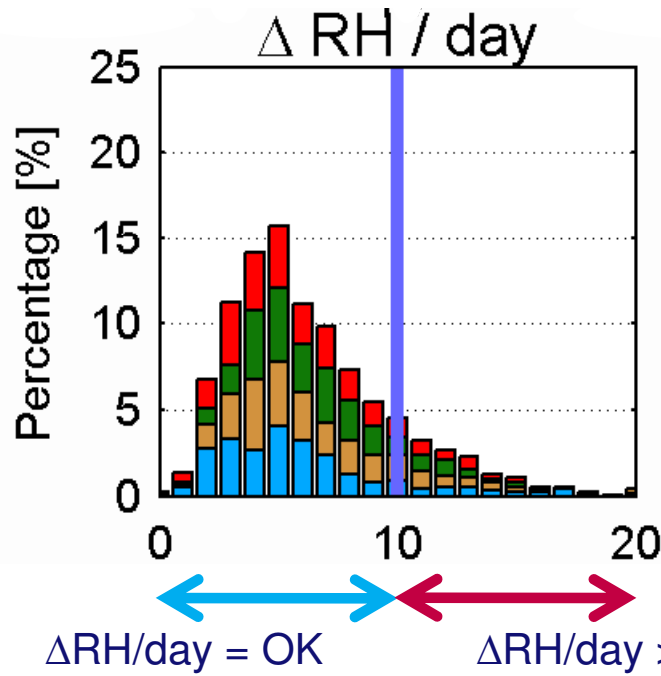
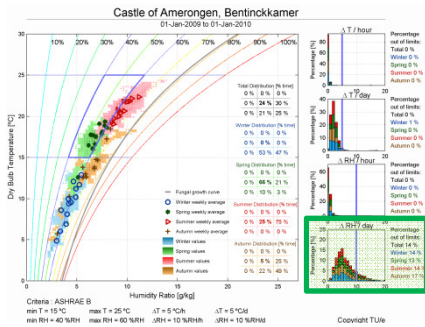
 $T > T_{max}$
 $T = OK$
 $T < T_{min}$

 $RH < RH_{min}$
 $RH = OK$
 $RH > RH_{max}$

Damage risk assessment (3)

Indoor climate measurements

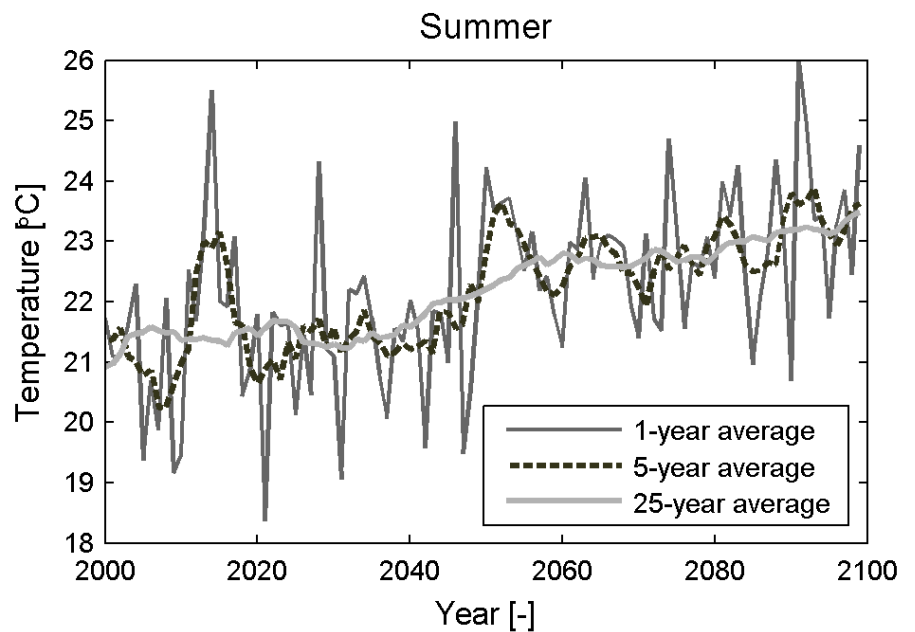
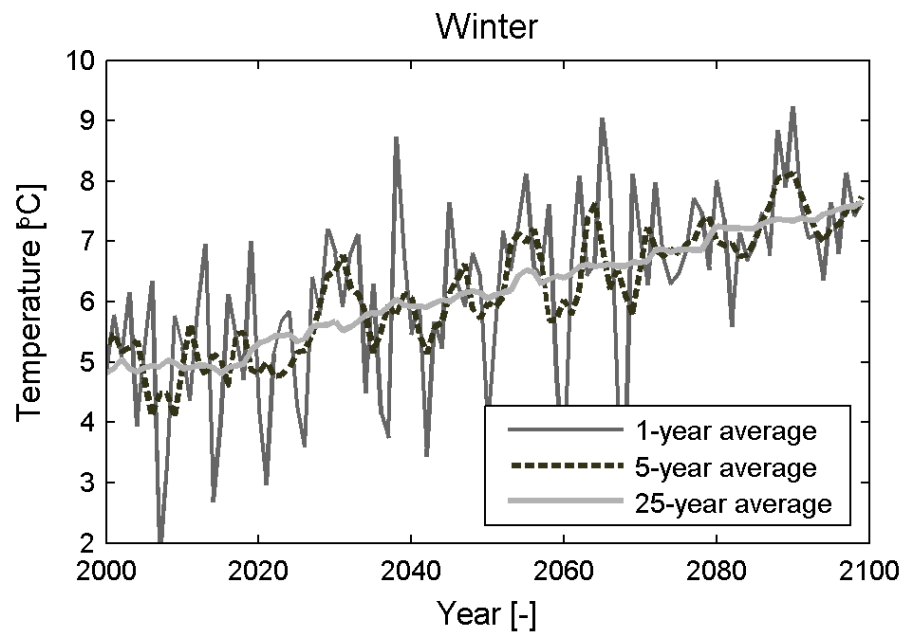
- Climate Evaluation Chart



Percentage out of limits:
 Total 14 %
 Winter 14 %
 Spring 13 %
 Summer 14 %
 Autumn 17 %

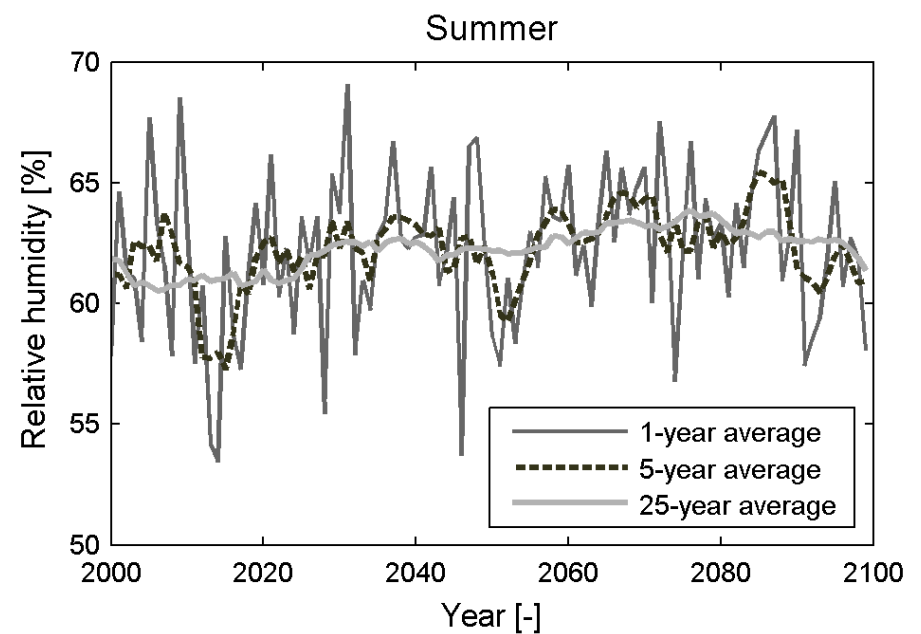
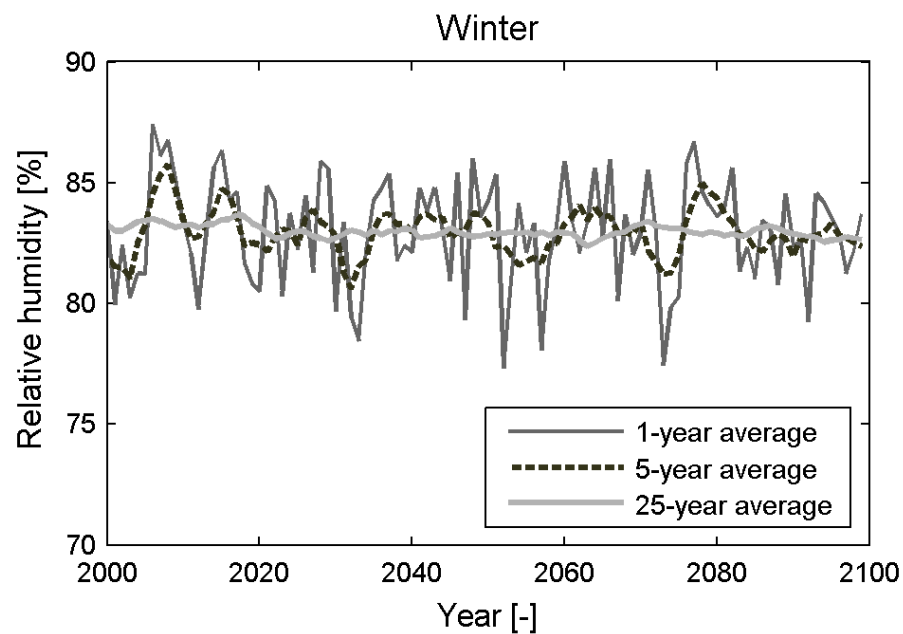
Results (1)

Seasonal mean indoor temperature in an unheated room from 2000 until 2100



Results (2)

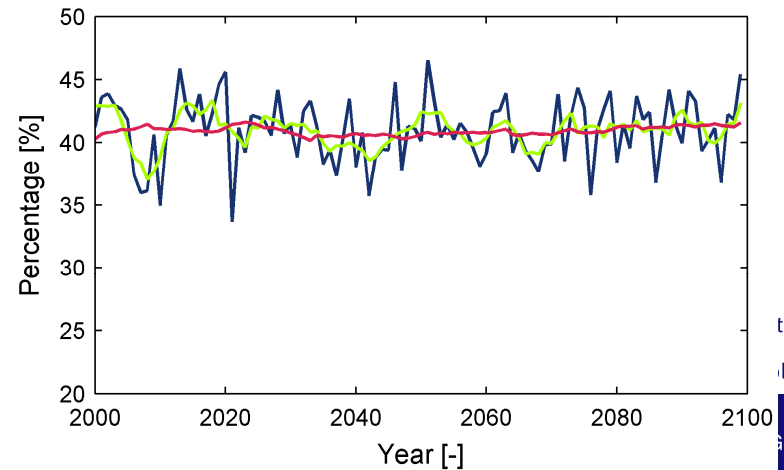
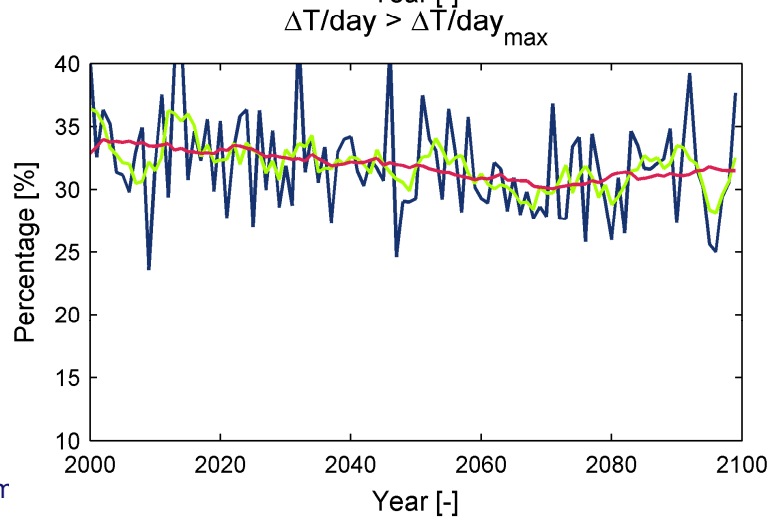
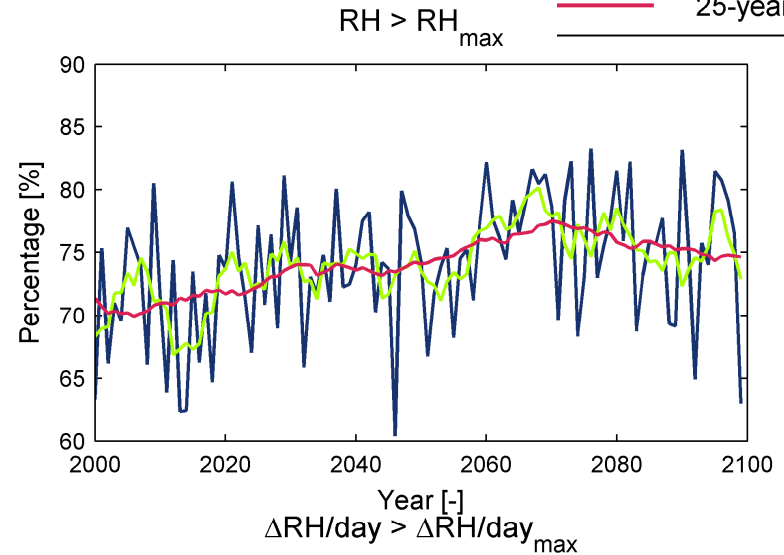
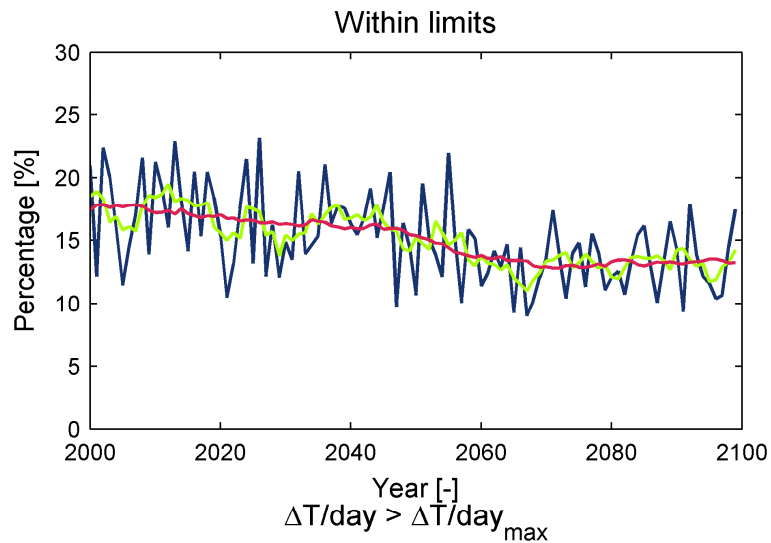
Seasonal mean indoor relative humidity in an unheated room from 2000 until 2100



Results (3)

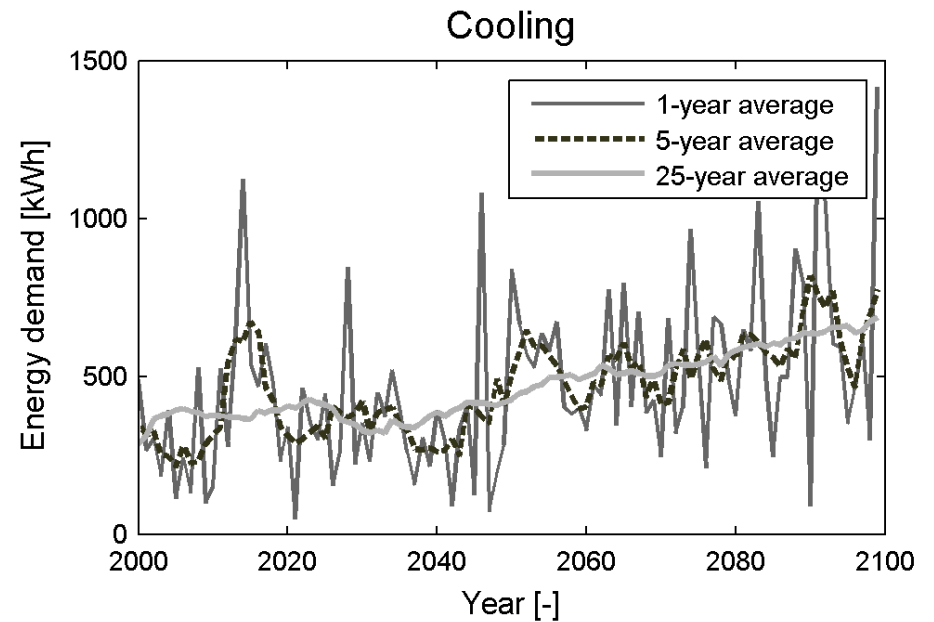
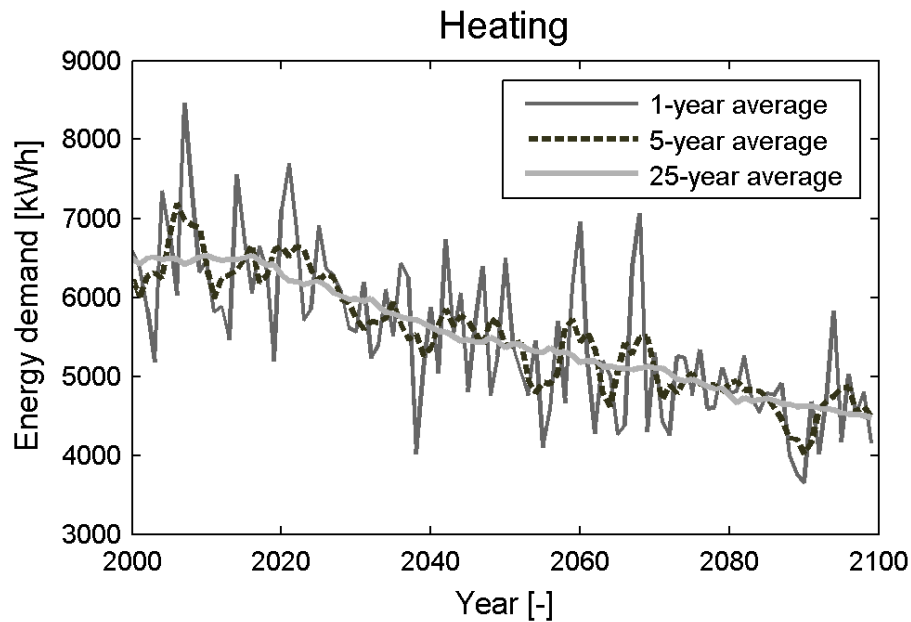
Assessment based on ASHRAE Class B

- 1-year average
- 5-year average
- 25-year average



Results (4)

Annual energy demand for heating and cooling in a heated room from 2000 until 2100



Conclusion

Preliminary results for this case study in The Netherlands:

Unheated rooms:

- Significantly increasing indoor temperature
- Slightly increasing relative humidity
- No major impact of climate change on hourly and daily fluctuations of temperature and relative humidity

Heated rooms:

- Considerable reduction of energy demand for heating
- Slight increase of energy demand for cooling

Recommendations

To achieve more general results:

- **More case studies will investigated**
- **Outdoor climate scenarios will be varied for different greenhouse gas emissions scenarios**
- **Outdoor climate scenarios will be varied for different locations throughout Europe**

Thank you for your attention



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