Computational Modelling of the Impact of Solar Irradiance on Chemical Degradation of Painted Wall Hangings in an Historic Interior

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Where innovation starts

Introduction

Study within EU Climate for Culture project

Numerical assessment of climate-induced degradation risks for historic interiors and art objects

Case study: Hofkeshuis, Almelo, The Netherlands

- Series of 18th century oil paintings on canvas, painted in situ
- Lead soap formation: internal marker for the degree of chemical degradation
- Temperature and relative humidity can strongly influence chemical degradation processes of artefacts

Source: Cultural Heritage Agency of the Netherlands

Introduction

Research question

- *Is it possible to derive, for each location on the wall-hangings in the room, a relation between the chemical degradation of the paint and the thermal conditions?*

Results are of importance for decision making in exhibition and storage conditions of oil paintings on canvas
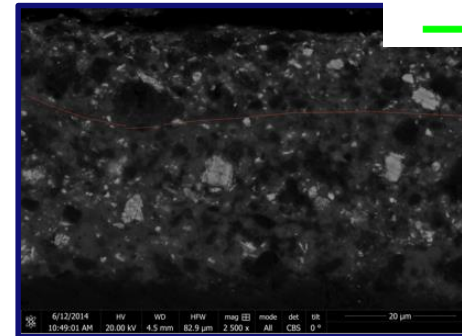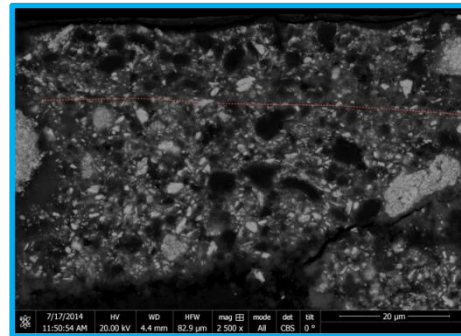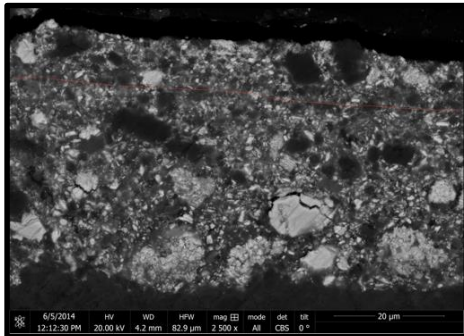

Source: Cultural Heritage Agency of the Netherlands

Analysis of lead soap formation
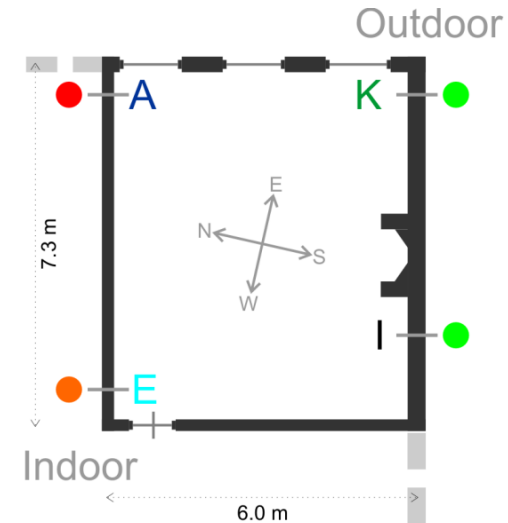
Position K and I: Low degree of saponification:
many lead white particles visible

Position E: Middle degree of saponification:
smallest lead white particles have dissolved

Position A: High degree of saponification:
lead white particles have largely dissolved

Source: University of Amsterdam

Method

- Experimental analysis:
  - Measurements of air and surface temperatures at four positions on north and south canvas
  - Infrared thermography
- Numerical analysis of conductive, convective and radiative heat transfer with Comsol Multiphysics version 4.4

Objective: to analyse minimum, maximum and average air and surface temperatures and temperature fluctuations for each position

20-Sep-2013 09:00
air conditions: 22.4 ºC and 47.8 %

Surface temperatures

18   19   20   21   22   23   24
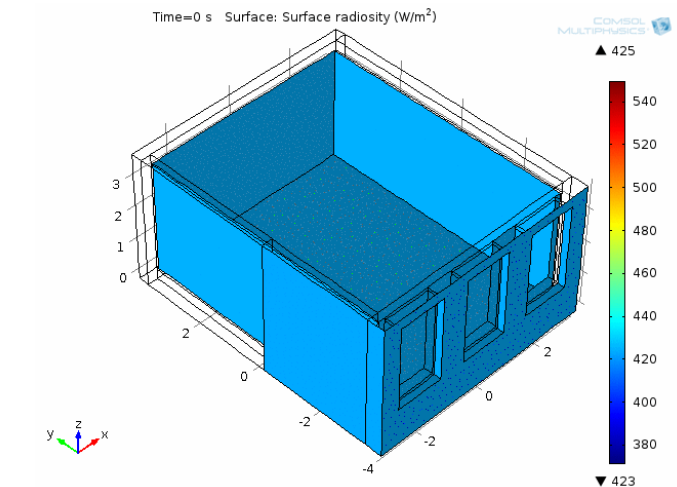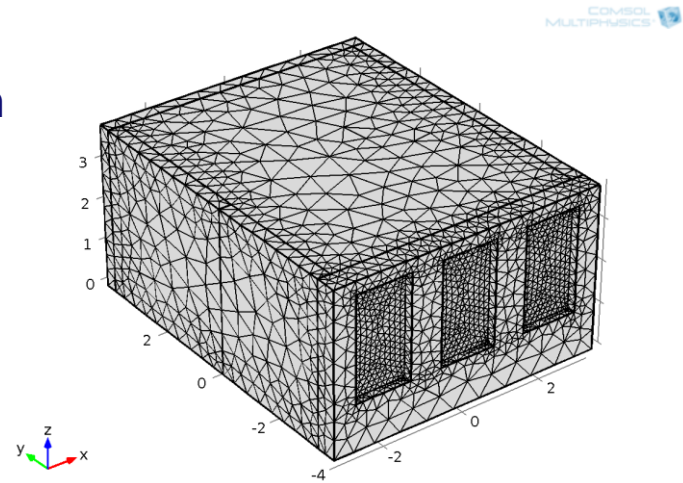Temperature [ºC]
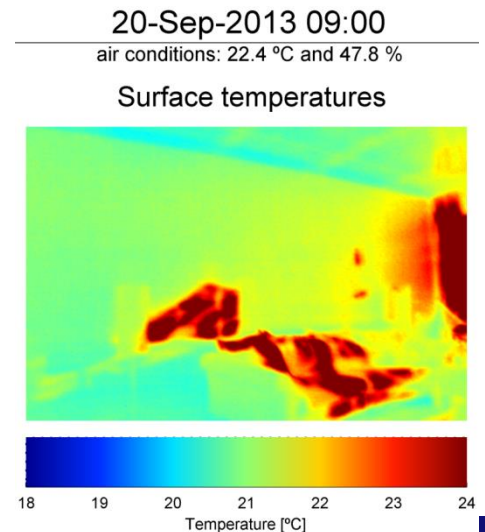
Comsol modelling

Objectives:
1. To calculate local thermal conditions on the north and south canvas
2. To analyse the impact of various boundary conditions such as glazing types, curtains and heat sources in the room.

Comsol physics module: heat transfer with surface-to-surface radiation

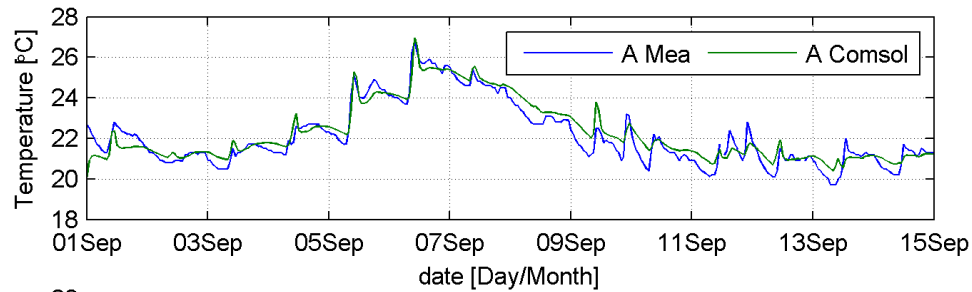Solar position: Latitude: 52.357, Longitude: 6.665, Time zone: 1

Outdoor air temperature, indoor air temperature and solar irradiance are derived from on-site measurements
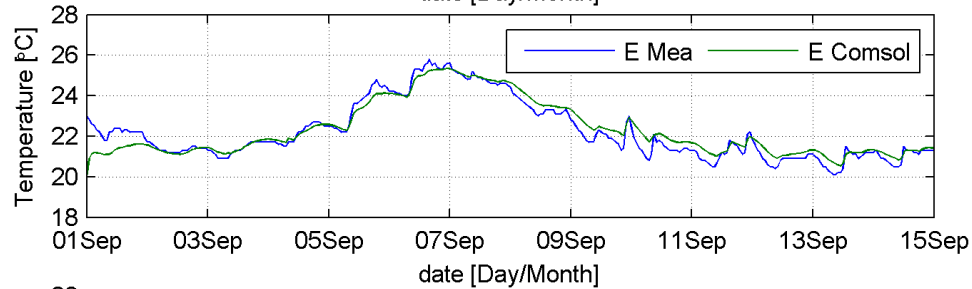
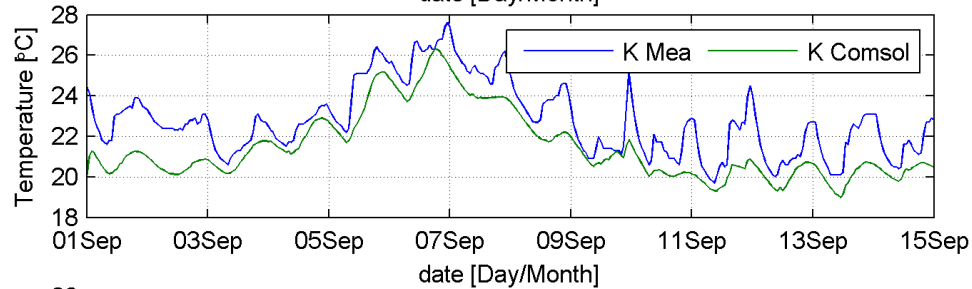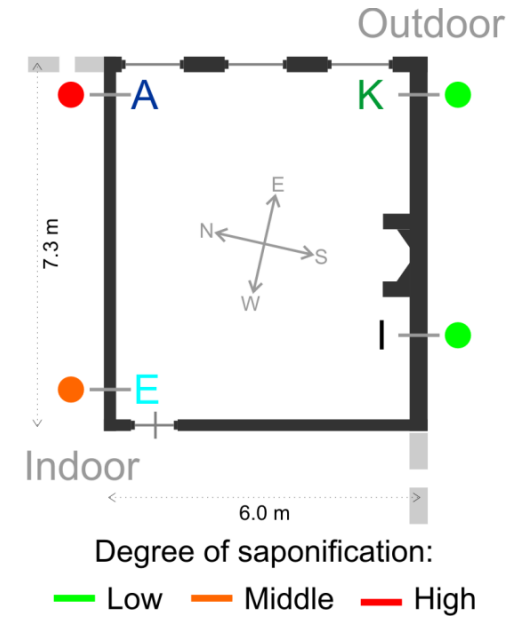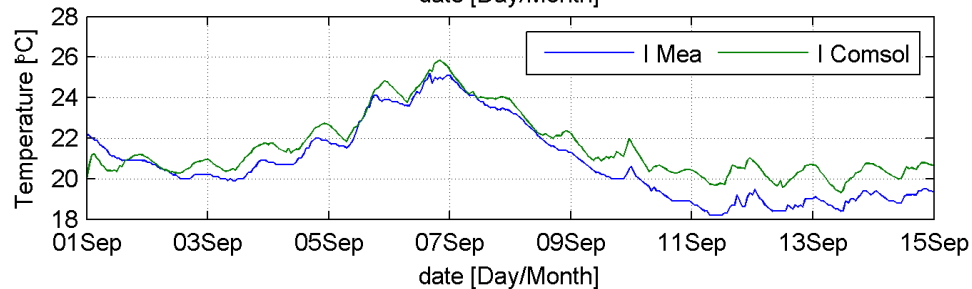Surface emissivity: 0.9

Comsol model validation

Comsol results

Analysis of surface temperatures in July 2013
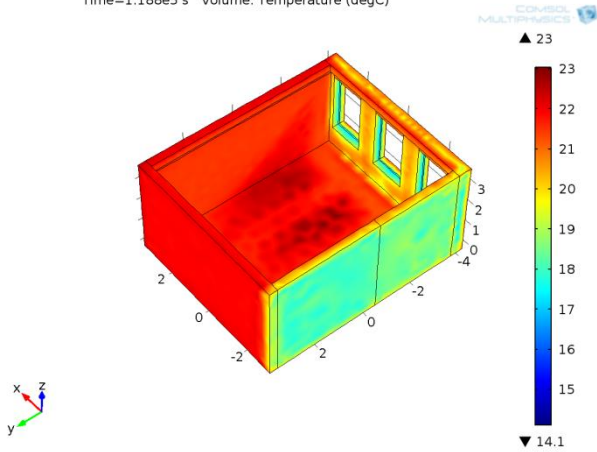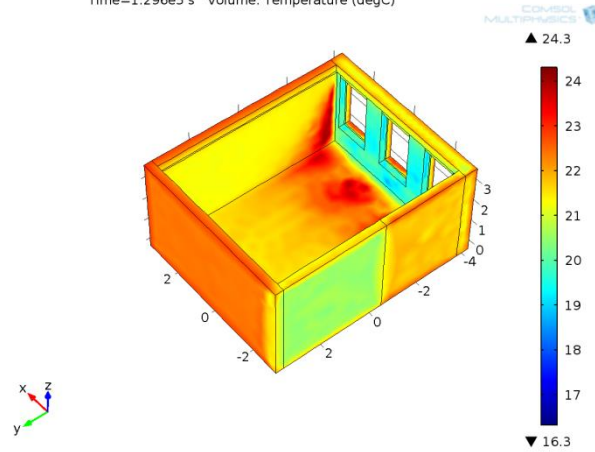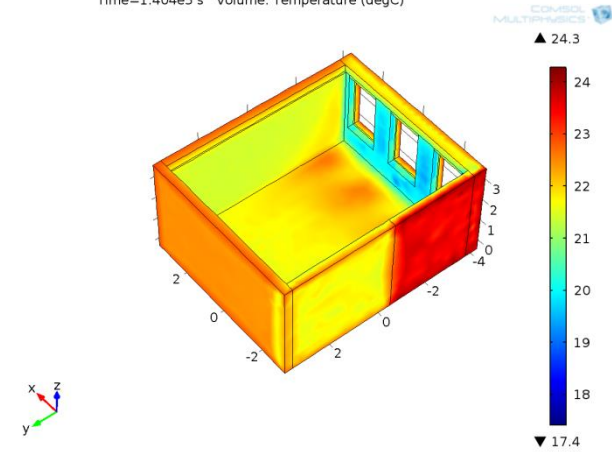
Surface temperature 2 July, 9 a.m.　　Surface temperature 2 July, 12 a.m.　　Surface temperature 2 July, 3 p.m.

Comsol results

Time-averaged surface temperatures in July 2013

Time=1.728e6 s   Surface: timeavg(0,1728000,T) (degC)

North canvas
Maximum temperature
difference: 0.7 °C

Time=1.728e6 s   Surface: timeavg(0,1728000,T) (degC)
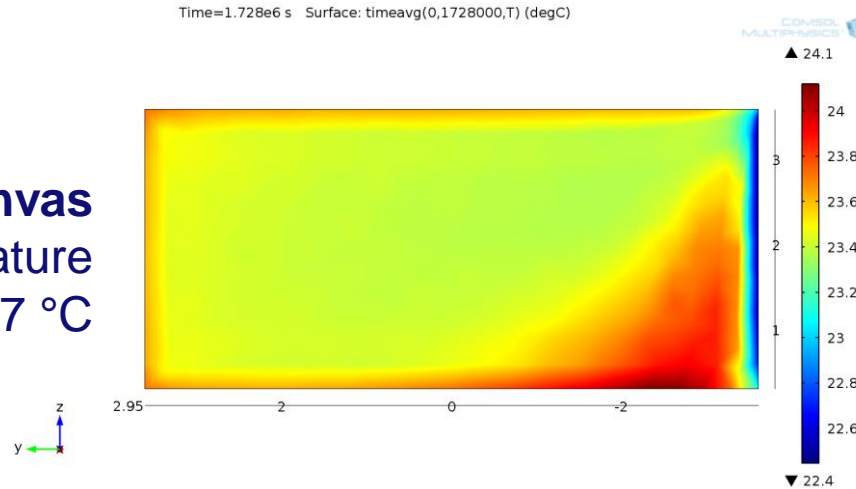
South canvas
Maximum temperature
difference: 0.6 °C
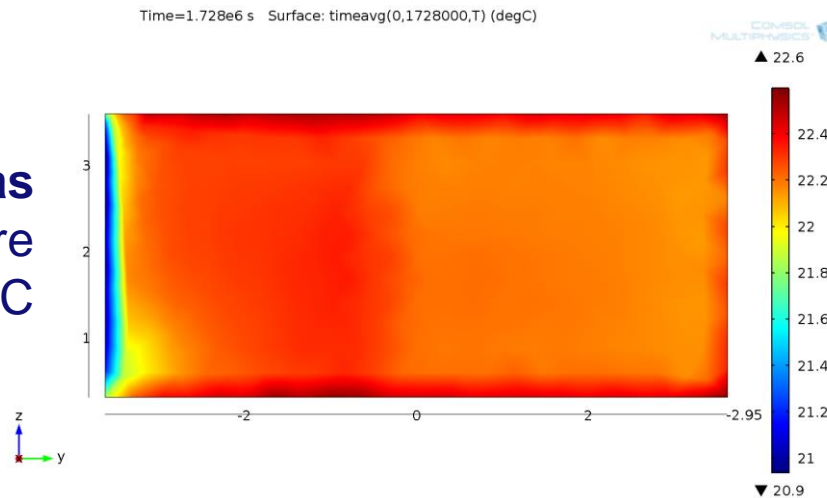
Conclusions and discussion

Conclusions

- Comsol was able to generate an adequate prediction of the surface temperature at several wall positions

- Experimental and numerical analysis suggests small differences between average, minimum and maximum surface temperature at the four positions:
  - Maximum temperature difference north canvas based on IR thermography: ± *4℃*
  - Maximum average temperature difference between north and south canvas based on Comsol model: ± *3℃*

➡ *Could these temperature differences have caused a considerable difference in chemical degradation of the oil paintings?*

Model limitations

- Comsol model could not adequately be validated for position K

- Model assumes well-mixed air, no turbulence model is included to model convective heat transfer accurately

- Some material properties and dimensions are based on estimations

- Only short periods could be analysed due to long calculation time and required computational resources

Thank you for your attention

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