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Analysis of Daylight Control in a Chateau Interior

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Abstract: Assessment of daylighting in the residential hall of a historical chateau is presented. The evaluation is based on both the daylight measurement and simulations. Illuminance levels in the interior were controlled in accordance with requirements for light exposition of light sensitive materials. Valuable paintings and claddings as well as wallpapers and furniture upholstery in the hall are extremely light sensitive and they need to be protected from light damage. The daylight measurements and simulations give an overview of daylight conditions in the annual profile for clear sky conditions and for different levels of window shadings.

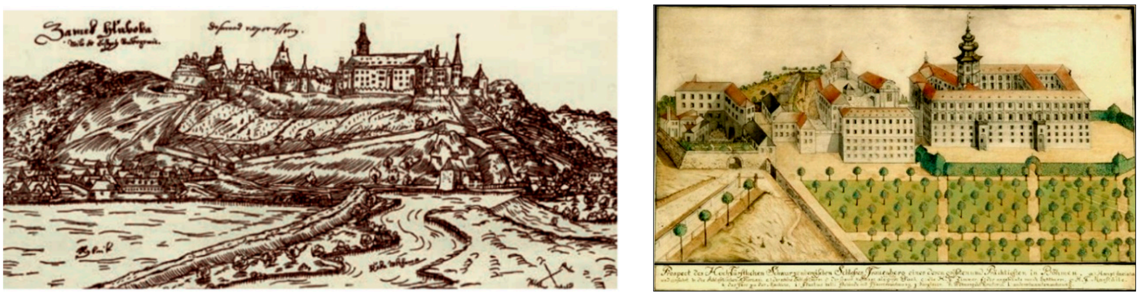
Keywords: historical building; daylight control; light damage; light measurement; daylight simulation

1. Introduction

Daylight is fundamental for visual comfort and indoor climate comfort in buildings. Interiors with plenty of daylight appear to have a positive influence on the occupants' environment [1]. However, in some cases daylight surplus might cause problems for specific buildings [2]. It is in the case of historical monuments where light causes damage of light-sensitive materials and artefacts. In this case, a light control strategy must be considered. The article is focused on evaluation of potential light damage in an architecturally valuable interior. Light environment was analyzed in a hall of a historical protected monument of the chateau Hluboka located on the river Vltava in Czechia (Figures 1–4). The official name of the monument is the State chateau Hluboka nad Vltavou [3].

(a) (b)

Figure 1. Locality of the State Chateau Hluboka nad Vltavou (google map.cz). (**a**) Hluboka locality in the South of Czechia; (**b**) aerial photograph of the chateau.



(**a**) (**b**)

Figure 2. Drawings of the chateau from historical documents (**a**) Veduta of Hluboka chateau by Jan Willenberg, 1602 [4]; (**b**) Prospect of the chateau from the west elevation, unknown author, about 1767 [5].

Figure 3. Photograph of the State Chateau Hluboka nad Vltavou (archive of the National Heritage Institute, Prague).

Figure 4. Photo-gallery of the State Chateau Hluboka nad Vltavou, the elevation with the Morning Salon bay windows [6].

The historical monument was originally founded as a castle in the middle of 13th century on the west bank of the river Vltava as a royal residence. In the 16th century it was rebuilt into the Renaissance chateau. Since 1661 the chateau has been in the ownership of the noble line of the Schwarzenbergs [4,7]. They restored it into the Baroque style in the 18th century. Finally, the castle was rebuilt into the pseudo-gothic style and modernized for a noble residence in the 19th century. The modernized chateau architectural style was influenced by Windsor Castle in England because the then owner, prince Jan Adolf II Schwarzenberg, was an admirer of England culture [8].

The reconstruction exterior and interior works started in 1840 based on the plans by architect Franz Beer and were finished in 1871 with Damasius Deworetzky, designer of the chateau's magnificent interiors [4,7]. The chateau is surrounded with a green park in the English style, and sculptural scenery.

Today the chateau is listed among historical buildings kept by the Czech National Heritage Institute. A part of the chateau is open for public tours. The assessment of the microclimate environment of specific interiors was part of a project supported from the program for applied research and development of national and cultural identity (NAKI) in 2011. After a time-consuming and financially demanding construction and restoration works preceded by a meticulous archive research, nine of the guest rooms were restored to their original appearance [4].

The chateau interior is decorated with woodcarving panels on the walls and ceiling soffits. The most valuable interior decoration is in the eastern residential hall. The hall, located in the eastern wing of the chateau complex, has valuable interiors with original furniture, unique walls and ceiling paneling and wall papers. It also contains valuable paintings. High levels and/or extended exposure to light can irreversibly damage sensitive materials. It is, therefore, important to assess whether this can be considered a problem in particular rooms [9].

Morning Salon

The residential hall is one of the biggest rooms of the first floor with the main windows south east in orientation. Because of the orientation for solar radiation access in morning time, the hall is called the Morning Salon. There are three bay windows in the front peripheral wall and two glazed doors at the side walls close to terraces (Figures 4 and 5).

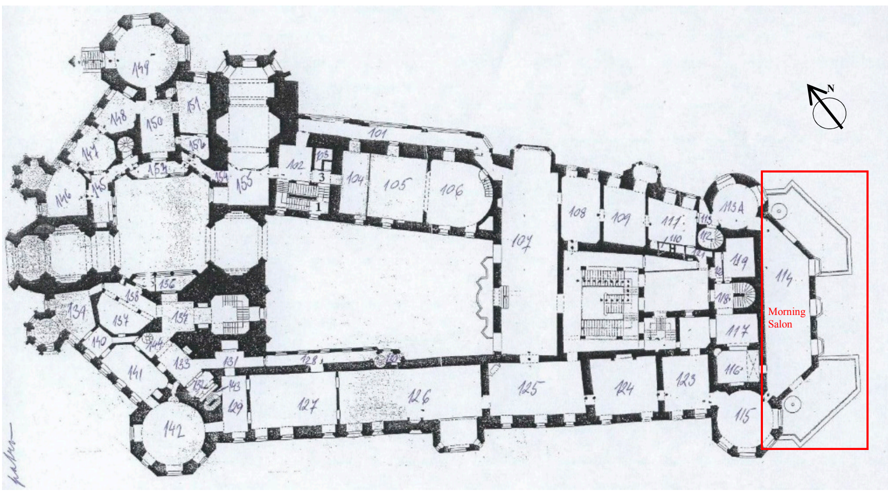


Figure 5. Plan of the first floor of the chateau with the Morning Salon (archive of the National Heritage Institute, Prague).

The salon has preserved original interior decoration from the 19th century [4] such as wooden parquet floors and wall and ceiling paneling of carved chestnut (Figures 6 and 7), stylish furniture with high-quality textiles and valuable oil paintings (Figures 7 and 8). The ceiling is faced with wooden coffered soffit, which is combined with valuable colored wallpapers (Selucká 2012) (Figure 9).

Figure 6. Photograph of the Morning Salon—view to windows (archive of the National Heritage Institute, Prague).

Figure 7. Photograph of the Morning Salon—view to the opposite wall with paintings (archive of the National Heritage Institute, Prague).

Figure 8. The Morning Salon with the original furniture (archive of the National Heritage Institute, Prague).

Figure 9. *Cont.*

Figure 9. Valuable wallpapers of the ceiling decoration (authors' archive).

2. Research Aim

The Morning Salon has been selected for long-term indoor climate comfort controlling [9] and daylight illuminance assessment [10,11]. The main task is to evaluate the influence of the hall daylighting on light-sensitive materials and artefacts. The eastern wing of the chateau is opened for public tours. It means that this part of the chateau is frequently visited. The Morning Salon has a specific location in the chateau. It is situated on the first floor in the east wing. It is illuminated through side-lit bay windows and two glazed doors in side walls. Windows are not shaded by the upper floor overhangs [4]. The internal space of the salon is overheated and exposed to high daylight illuminance because of excessive solar gains through the windows. Especially in mornings, irradiance and illuminance in the salon is very high [9]. The external wall with windows is opposite the internal wall with wood paneling and paintings. Windows have their original shading of external wooden lamellae shutters, and new internal curtains and paper-folded blinds, as well as textile roller blinds, Figure 10. The use of internal blinds and curtains is the commonly recommended solution. However, the blinds are not permanently activated. For that reason, some windows may remain with the binds up [4,9].

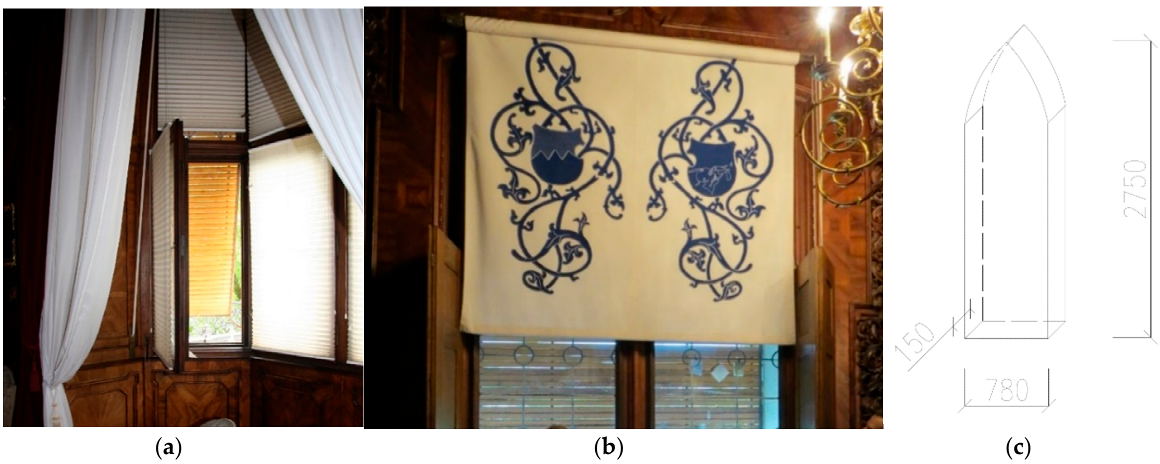


Figure 10. Window and its interior shadings (**a**) internal curtains and paper folded blind; (**b**) textile roller blinds (authors' photo archive); (**c**) window segment dimensions (mm).

3. Light Control Requirements

The interior illuminance level monitored in the salon was compared to the standard requirements for maximal daylight exposition of historically and architecturally valuable interiors. Light as a form of energy has a potential to change materials [12]. This energy causes changes, either through radiant heating or photochemical action [13]. Photochemical changes are irreversible and cannot be rectified by conservation treatment.

Light exposure to such light-sensitive materials as textiles and tapestries, paintings and interior decorations in historical buildings could result into their deterioration or even permanent damage [14]. Many factors influence the light exposition in practical situations, such as light sensitivity and life span of the displays, permitted time for the display and demands for the visibility and visual aesthetic effects [15].

The fundamental dilemma in lighting objects is visibility versus vulnerability [16]. In many cases, indoor illumination on conservation illuminance levels cause poor viewing conditions. Reciprocity law [16] refers to the principle that an object exposed to low light level for extended periods of time will incure as much damage as if exposed to high light levels for brief periods.

Low illuminance levels over a long period of time can have similar effects as intensive light affection for a short period. That is why valuable light-sensitive artefacts have permitted exposition time and limited illuminance level [17,18]. Light level and time of the exposition is 50 lux as a minimum for lighting requirements determined for visibility to humans [16]. The maximal permitted illuminance level for the high light-responsive materials (as silk and highly fugitive colorants, old newspapers etc.) is 50 lux [17]. This level is accepted as a lighting standard for museums. It is the minimum illuminance level required for most people to be able to observe the artwork. Values in lux hours are recommended, not only lux illuminance values.

The requirement for exposure of highly light-responsive materials and artworks is maximal illuminance. This relates to the acceptable amount of deterioration to the level of illuminance on the work and to its duration [2]. Light-sensitive artefacts can be exposed to 50 lux but in the overall annual time limit total light exposition does not exceed 150,000 luxhours [17,18]. The light level of 50 lux is recommended for adequate visibility. It means that in some cases a room with daylight shadings and artificial lighting dimming control is lit for example for 10 lux, but for visitors 50 lux is activated. The mentioned 150,000 lux hour is a limit for the new responsivity category; it means that the object cannot be on continuous display. Lower sensitive materials can be exposed to 200 lux, which corresponds to 600,000 lux hours per year. Also, the spectrum of light is important for the lighting control strategy. Therefore, the above limits of illumination values are considered with the exclusion of UV radiation. However, the UV radiation needs to be taken into consideration in the conservation [19,20]. High-energy light spectrum near UV and visible light [21], mainly in its blue spectral band, has a negative impact on deterioration of light-sensitive materials [22,23].

4. Light Measurements

Monitoring of indoor climate in the Morning Salon has been carried out for many years. Indoor temperature and relative humidity, as well as illuminance and UV radiation, is controlled.

Measurement sensors are located on the mantelpiece of the fireplace opposite the wall with windows, in the middle of the salon (Figure 11). Despite of the lighting control strategy, visible bleaching deficiencies and frail changes on furniture upholstery were found in the salon. For this reason, continual daily illuminance control measurements were taken in period from July to October 2013. Illuminance was measured with a Hanwell ML4000 light sensor.

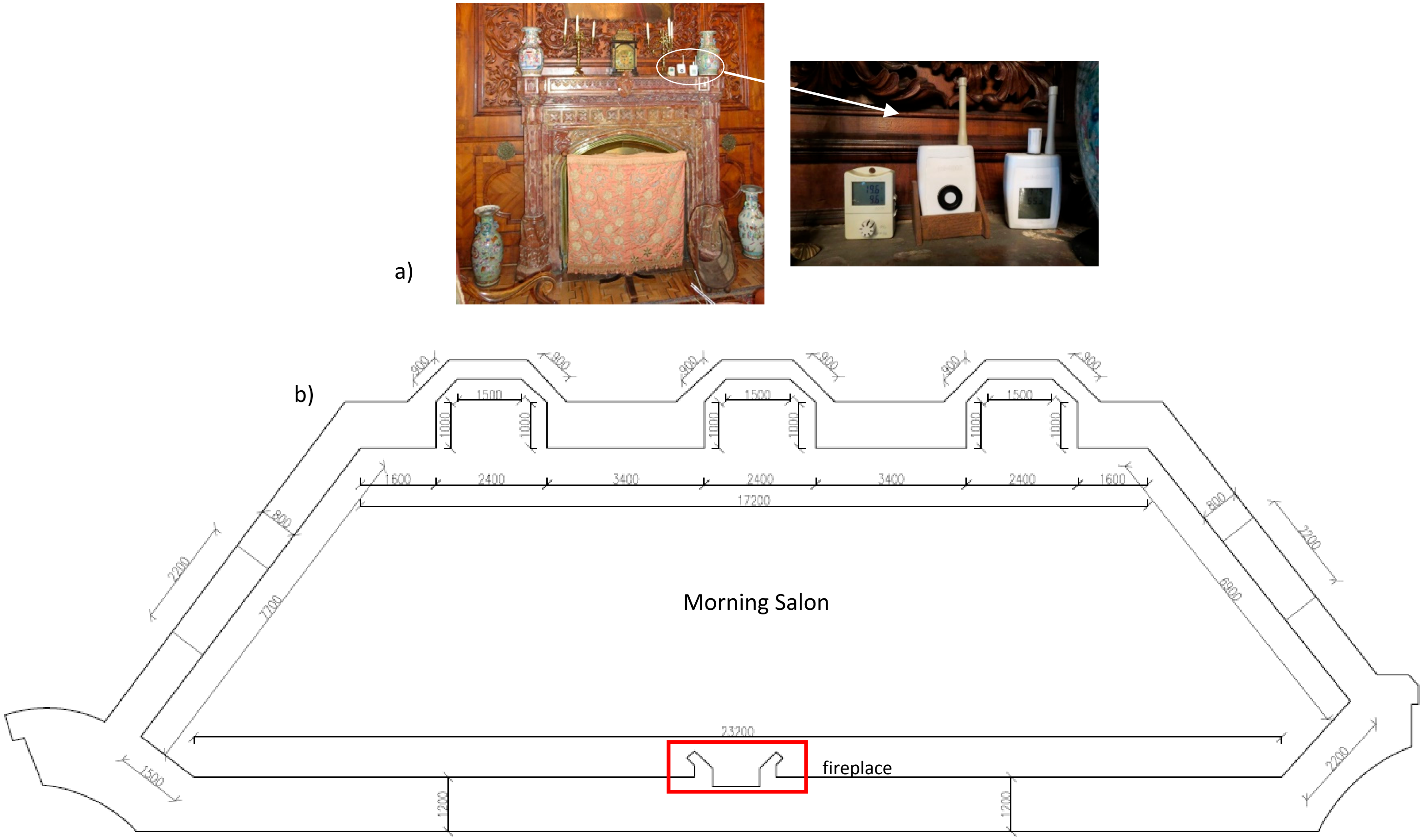


Figure 11. Data-loggers location in the Morning Salon (authors' archive). (**a**) Photograph of the measurement apparatuses installation on the fireplace; (**b**) plan of the Morning Salon.

Illuminance data processing brought important information. Light exposure monitoring in October 2013 showed extremely high light exposition of about 80,000 luxhours [24] (Figure 12).

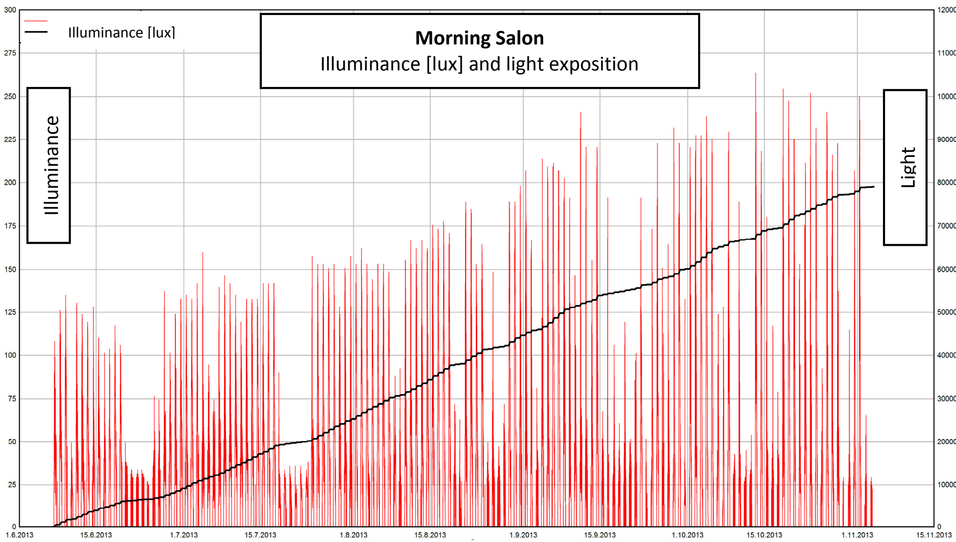


Figure 12. Graph from the data from light measurement in the Morning Salon—illuminance [lux] and light exposition [luxhours] monitoring interval from July to October 2013 [24].

Reasonable explanation of such high values seems to be negligent solar shading activation by the staff. This was confirmed by a test using Light Check light dosimeters, and after a 90-min time exposition very high values were found at the window jambs. High light exposition might be very negative for light-sensitive materials and cause serious and irreversible change and deterioration of quality of the materials such as paintings or upholstery. This finding has led to demands for detailed study of the daylight level in the Morning Salon under different conditions in the annual profile assessment.

Complex measurements using data-loggers with light, UV and temperature sensors ELSEC 765C were done in May 2016. The purpose of the measurement was to find illuminance in two different places of the salon compared to the exterior illuminance, Table 1 and Figure 13.

Table 1. Monitoring of illuminance and UV radiation in the Morning Salon (May 2016).

No	Sensor	Parameter/Unit	Value	Date and Time Setting/Removal	Position in the Salon	Notice
Measurement of Artificial Lighting in the Morning Salon						
1	A	VIS (lx) UV (µW/lm)	2.7 lx 0 (µW/lm)	16 May, 13:30	Window jamb, sensor facing the window (distance 0.79 m) near the oil painting (Figure 13).	Window shaded; lighting of 3 chandeliers with halogen lamps.
2	B	VIS (lx) UV (µW/lm)	12.4 lx 0 (µW/lm)	16 May, 13:30	On the table below the painting near the wall, facing towards windows in distance 7.69 m and 6.65 m Figure 13), position over the floor 0.84 m.	
3	B)	VIS (lx) UV (µW/lm)	14.5 lx 34 (µW/lm)	16 May, 13:30	On the upholstery under the central chandelier, distance 5.95 m from window and vertically 0.73 m over the floor.	
Measurement od Illuminance—Light Reflected from the Wooden Paneling						
1 2	B B	VIS lx VIS lx	22.5 lx 3.7 lx	16 May, 14:00 16 May, 14:00	Sensor facing to the wooden paneling.	Window shaded; lighting of 3 chandeliers with halogen lamps.
3 4	B B	VIS lx VIS lx	24.2 lx 1.8 lx	16 May, 14:00 16 May, 14:00	Sensor facing to the oil painting.	

Table 1. *Cont.*

no	Sensor	Parameter/Unit	Values	Date and Time Setting/Removal	Position in the Salon	Notice
Measurement of Light Transmitted through Windows						
1	C	VIS lx UV	9225/8933/8721 (lx) 776/832/829 (µW/lm)	16 May, 13:50 (partly cloudy sky)	Sensor at the external terrace distance 3.34 m from the window wall, height 14 m from ground level (without covering)	Uncovered sensor, values were measured 3 times.
2	C	VIS lx UV (µW/lm)	7952/7561/7680 (lx) 829/825/836 (µW/lm)	16 May, 13:50 (partly cloudy sky)		Covered sensor—polyethylene transparent box.
3	B	VIS lx UV (µW/lm)	10,698/12,798/12,211 (lx) 904/924/890 (µW/lm)	16 May, 15:00 (partly cloudy sky)	Sensor close to the glass outside of the window (exterior, terrace)	-
4	A	VIS lx UV (µW/lm)	8764/10,070/8543 (lx) 734/714/717 (µW/lm)	16 May, 15:00 (partly cloudy sky)		
-						
Daylight Measurements						
I. External Wooden Shutters—Opened, Internal Textile Roller Blinds Pulled down						
1	A	VIS lx UV (µW/lm)	986 (lx) 327 (µW/lm)	16 May, 14:30 (partly cloudy sky)	At the window jamb, facing the window distance 0.79 m, close to oil painting (Figure 13); no chandelier influence.	No artificial light
2	B	VIS lx UV (µW/lm)	54.2 (lx) 279 (µW/lm)	16 May, 14:30 (partly cloudy sky)	On the table below the painting close to the wall facing towards windows, distance 7.69 m and 6.65 height from the floor 0.84 m.	No artificial light
3	B)	VIS lx UV (µW/lm)	54.2 279	16 May, 14:30 (partly cloudy sky)	On the upholstery below the central chandelier, distance from windows 5.95 m, height above floor 0.73 m.	No artificial light
II. External Wooden Shutters—Pulled down, Internal Textile Roller Blinds up						
1	A	VIS lx UV (µW/lm)	690 336	16 May, 14:30 (partly cloudy sky)	At the window jamb, facing the window distance 0.79 m, close to oil painting (Figure 13); no chandelier influence.	No artificial light
2	B	VIS lx UV (µW/lm)	102 591	16 May, 14:30 (partly cloudy sky)	On the table below the painting close to the wall facing towards windows, distance 7.69 m and 6.65 height from the floor 0.84 m.	No artificial light
3	B)	VIS lx UV (µW/lm)	82.4 340	16 May, 14:30 (partly cloudy sky)	On the upholstery below the central chandelier, distance from windows 5.95 m, height above floor 0.73 m.	No artificial light
III. Windows without Shading (External Shutters Opened, Textile Roller Blinds Are only on the Top of the Windows)						
1	A	VIS lx UV (µW/lm)	4135 (lx) 753 (µW/lm)	16 May, 14:30 (partly cloudy sky)	At the window jamb, facing the window distance 0.79 m, close to oil painting (Figure 13); no chandelier influence	No artificial light
2	B	VIS lx UV (µW/lm)	169 (lx) 788 (µW/lm)	16 May, 14:30 (partly cloudy sky)	On the table below the painting close to the wall facing towards windows, distance 7.69 m and 6.65 height from the floor 0.84 m.	No artificial light
3	B)	VIS lx UV (µW/lm)	184 (lx) 781 (µW/lm)	16 May, 14:30 (partly cloudy sky)	On the upholstery below the central chandelier, distance from windows 5.95 m, height above floor 0.73 m.	No artificial light

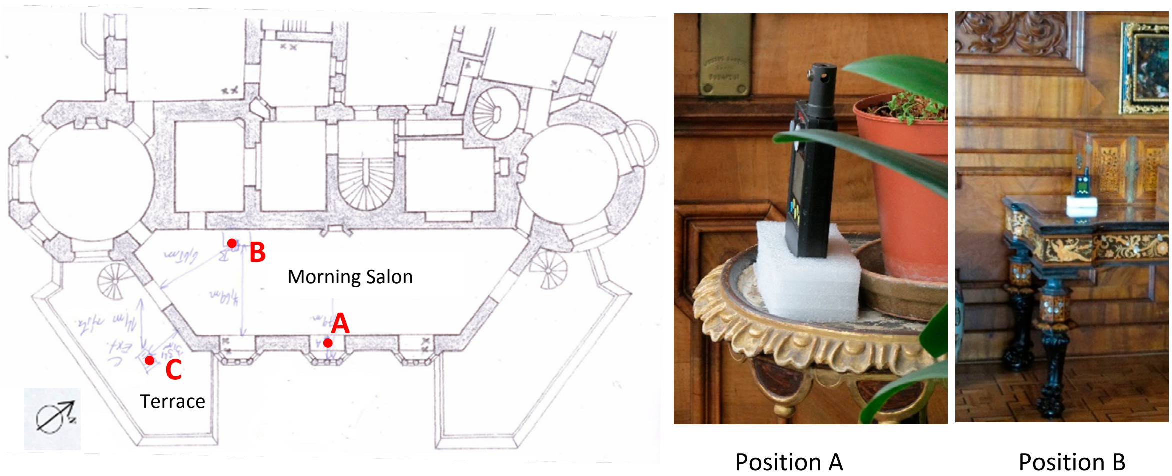


Figure 13. Positions of dataloggers ELSEC 765C for illuminance and UV radiation and temperature measurements in May 2016 (positions A, B and C). Position A—on the central window sill, height 0.9 m; Position B—on the desk next to the fire place, height 0.8 m; Position C—terrace in the middle, the floor level.

Results of the continual measurements of illuminance (lux × 1000), UV radiation power and temperature are shown in Figure 14 for internal values at positions A and B as well as external measurements at position C. It is visible from the graphs that illuminance and temperature increase in the morning. Higher illuminance rise is from about 9:00. Afternoon illuminance is lower because of the salon windows' south-east orientation. The UV radiation power is greatest early in the morning at sun rise and in late afternoon during the sun set. It exceeds the limits of maximal permitted standards [25,26] 75 µW/lm [27] (Thomson, 1978) better 10 µW/lm [28] (Saunders 1989). It points to the fact that the Morning Salon windows should have solar shadings activated all the time in the morning and in the afternoon to protect fading and light damage of the salon interior.

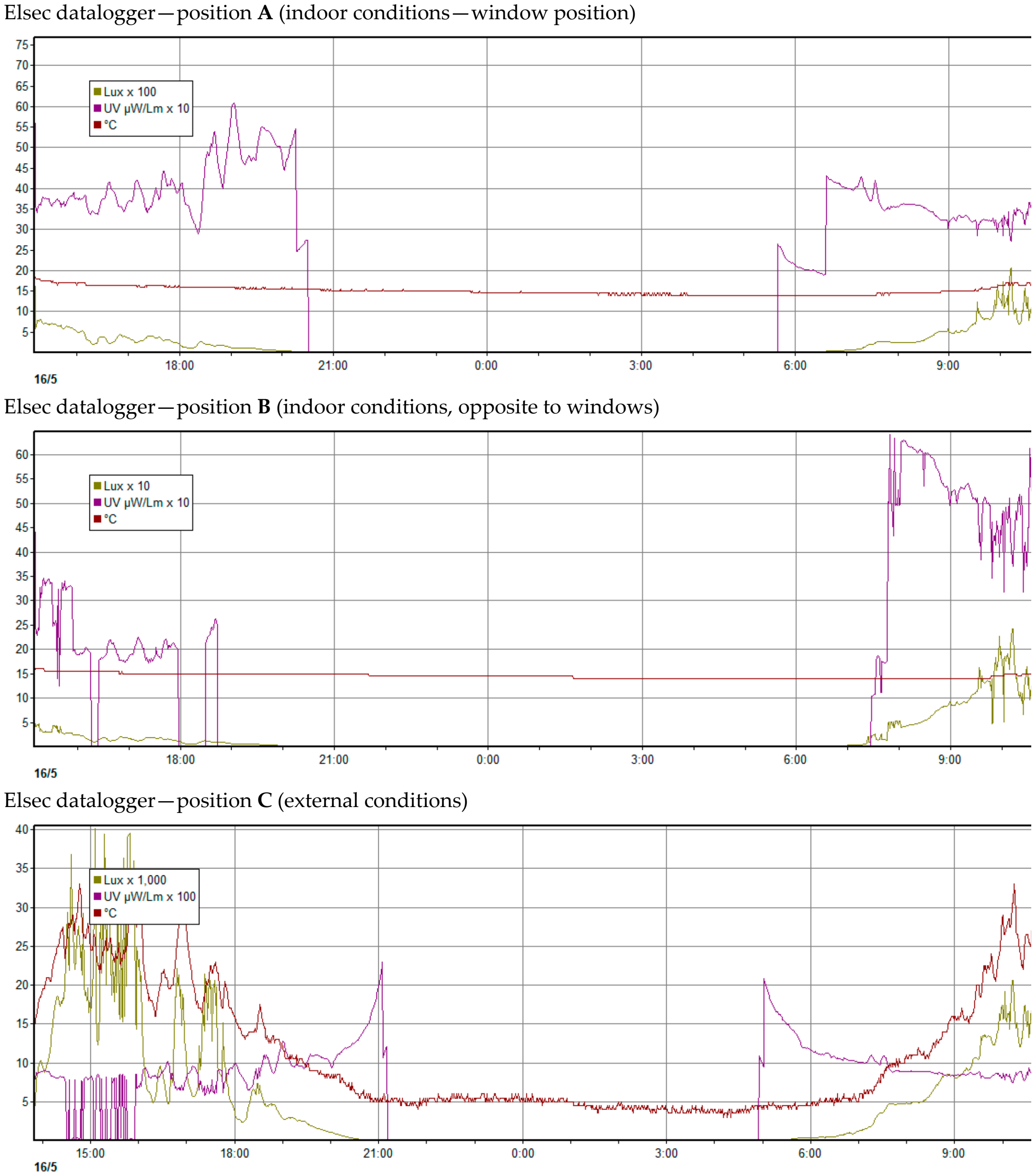


Figure 14. Illuminance, UV radiation and temperature in the Morning Salon (monitored time from 16–17 May 2016).

5. Daylight Simulations

Daylight simulations for different daylight scenarios are assessed. The first assumes the windows are unprotected, and for the second an internal blind is used. The south-east facing windows transmit sunlight in the morning period. This time solar radiation has a low angle of incidence, which results in a high flux of light transmitted indoors. In a location where clear skies predominantly occur in this period of the day, this can exacerbate the problem, and effective measures should be in place to prevent sunlight being admitted.

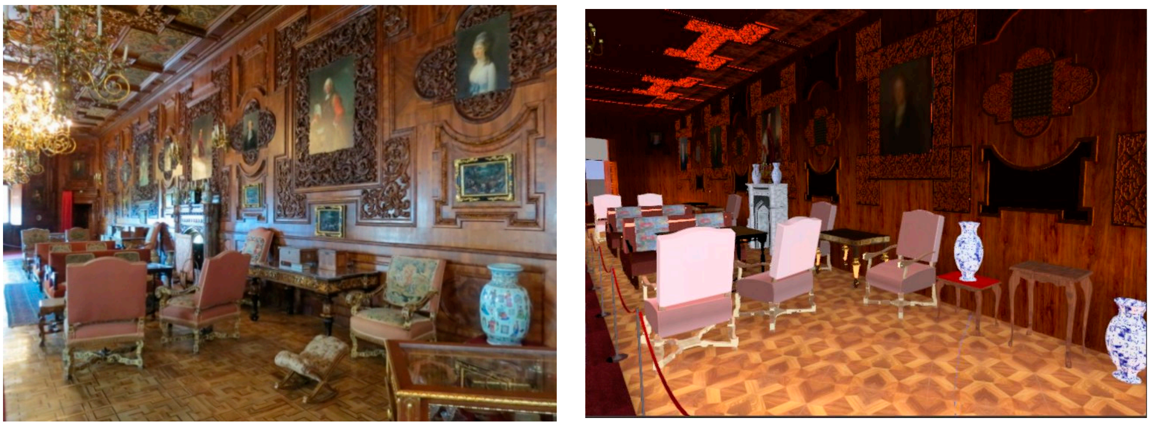
Daylight simulations were completed in software DIALux evo, version 7 [29] (Lighting design software DIALux). A geometric model of the salon is transported from Sketch Up [30] (3D modelling software Sketch-Up). The simulations were carried out for the following conditions of clear sky for the following days: 21 June, 21 March, 21 September and 21 December. Clear sky conditions were selected. The chateau locality is defined: latitude 49.06° (North), longitude 14.44° (East) and altitude 432 m. Simulation outputs are shown for daylight illuminance for daytime between 8:00 and 12:00 in two-hour intervals specified for two design cases as follows:

- firstly, for the salon fully daylit through windows without shading;
- secondly the salon window shadings are activated for variations of 25, 50, and 75 percent of the salon window area.

Parameters selected for the simulations are as follows:

- Light reflectance: internal surfaces: wooden paneling of walls and ceiling soffit 0.3; floor—wooden parquets and carpets 0.3; window frames 0.3; external surfaces: ground 0.3; plaster 0.7; floor of the terrace 0.5.
- Light transmittance: window glass (double glass pane) 0.8; balustrade: 0.5.

Daylight conditions of the CIE clear sky model - cloudless sky for which the relative luminance distribution [31] is as described in ISO 15469:2004 [32]. Date of 21 June were selected for the study for simulation of maximum possible daylight illuminance affecting the Morning Salon area. The salon windows are without shading blinds. Simulation daylighting of the areas compared to the illumination limit of 50 lux are shown in Figures 15–37. Daylight simulation outputs were compared with standard requirements for maximal permitted light exposition in historically protected buildings with architecturally valuable interiors. In accordance with document CIE 157:2004 requirements, the maximal illuminance limit is 50 lux for light exposition to light-sensitive materials as textiles and paintings.



(**a**) (**b**)

Figure 15. View to the wall opposite to windows. (**a**) Photograph; (**b**) DIALux model.

The false color schemes shown in Figures 16 and 17 give an overview of the illuminance in the viewed part of the salon. The light limit of 50 lux is shown in yellow; the orange part is for illuminance between 50 and 100 lux. The red color in the simulations means the places where illuminance level exceeds 100 lux. It means these parts are affected by very high illuminance, which is negative for the light-sensitive interior materials. It is obvious that the wide part of the wall with painting and floor and furniture in the morning time is exposed to very high light limits in case the windows are without shadings. The daylight simulations were completed for the variations with the window shading activation at 25, 50, and 75% (25% unshaded glazed area close to the window sill), simulated for noon (Figure 18).

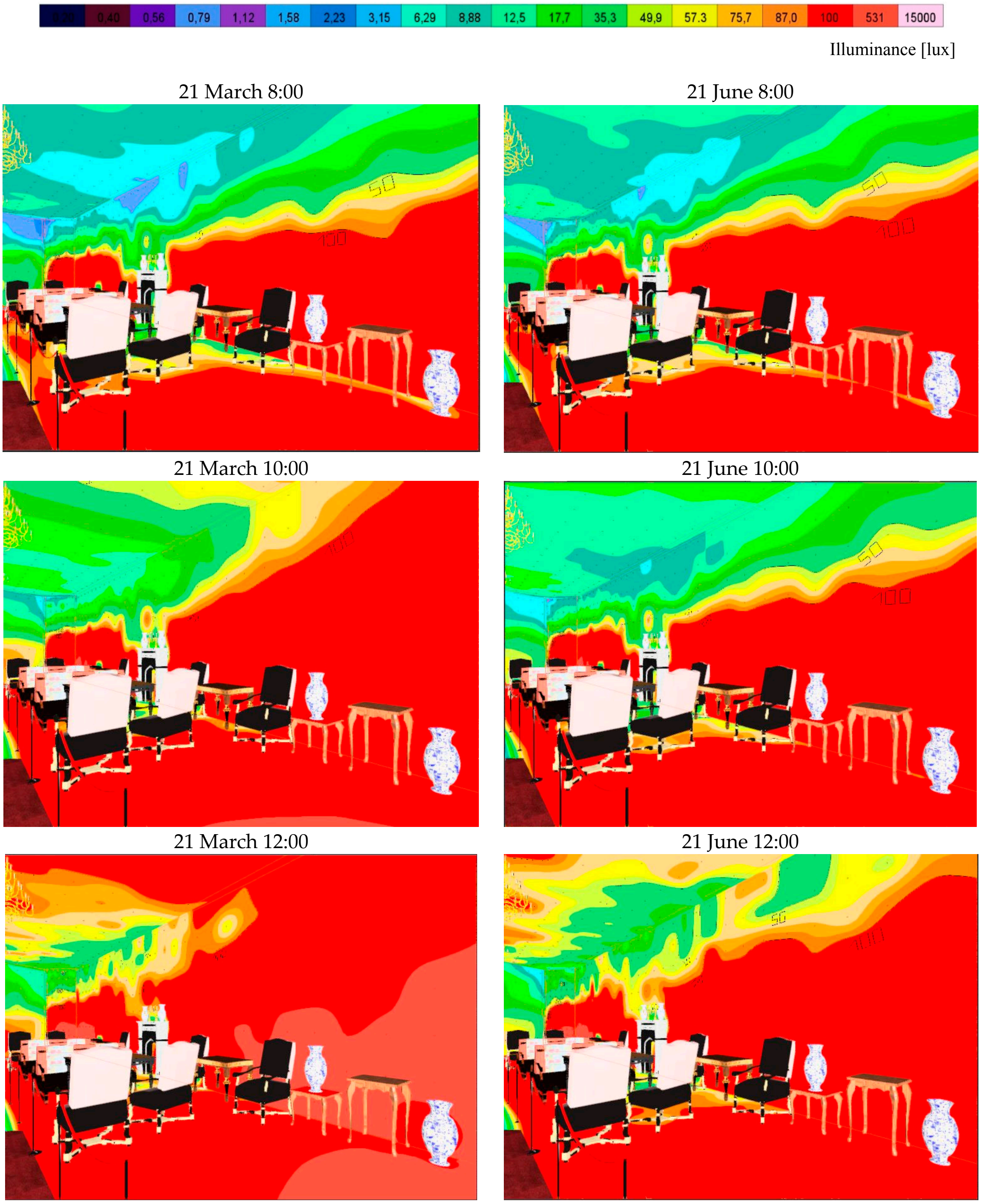


Figure 16. View to the wall opposite to windows—illuminance (lux) levels for 21 March and 21 June.

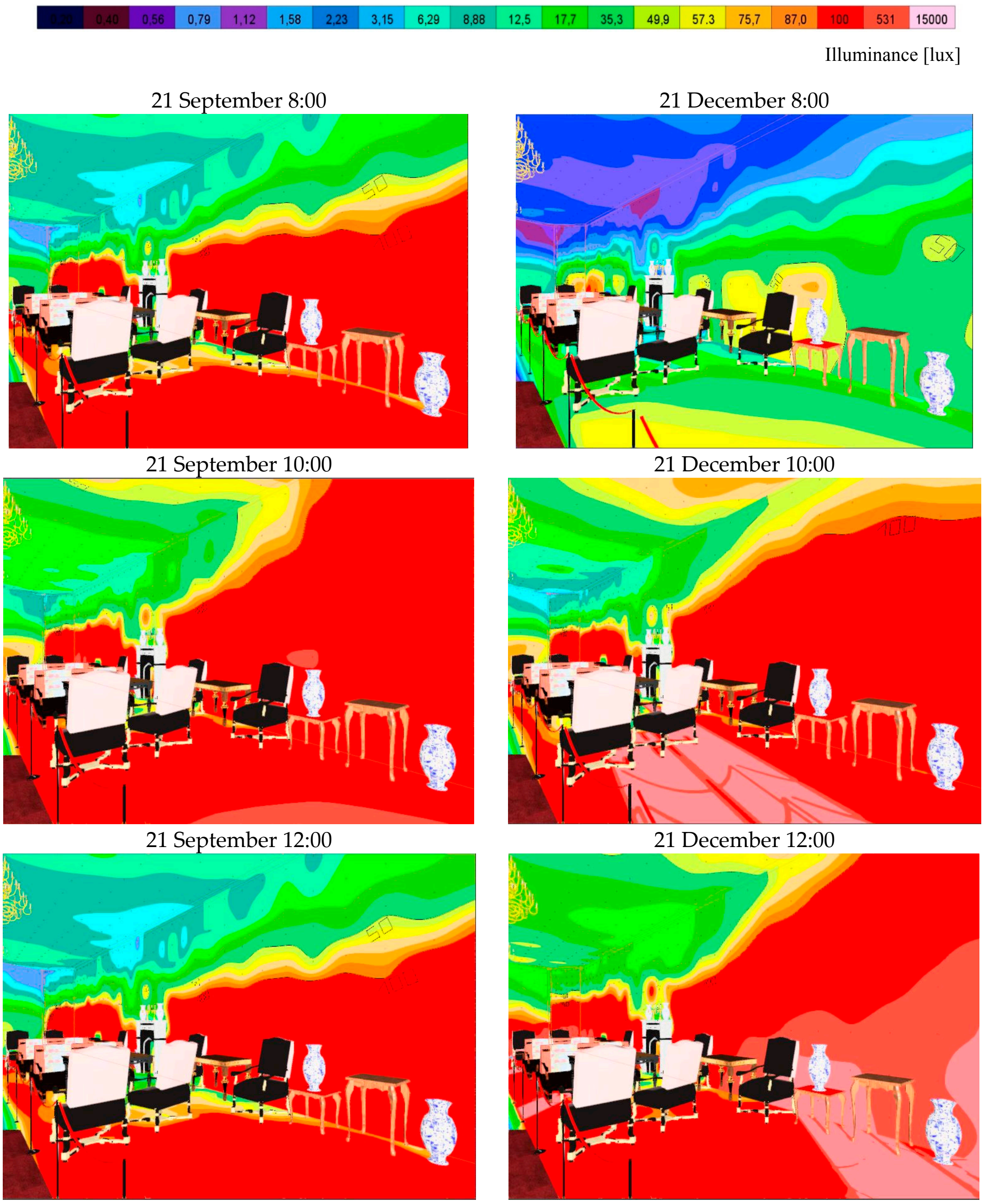


Figure 17. View to the wall opposite to windows—illuminance (lux) levels for 21 September and 21 December.

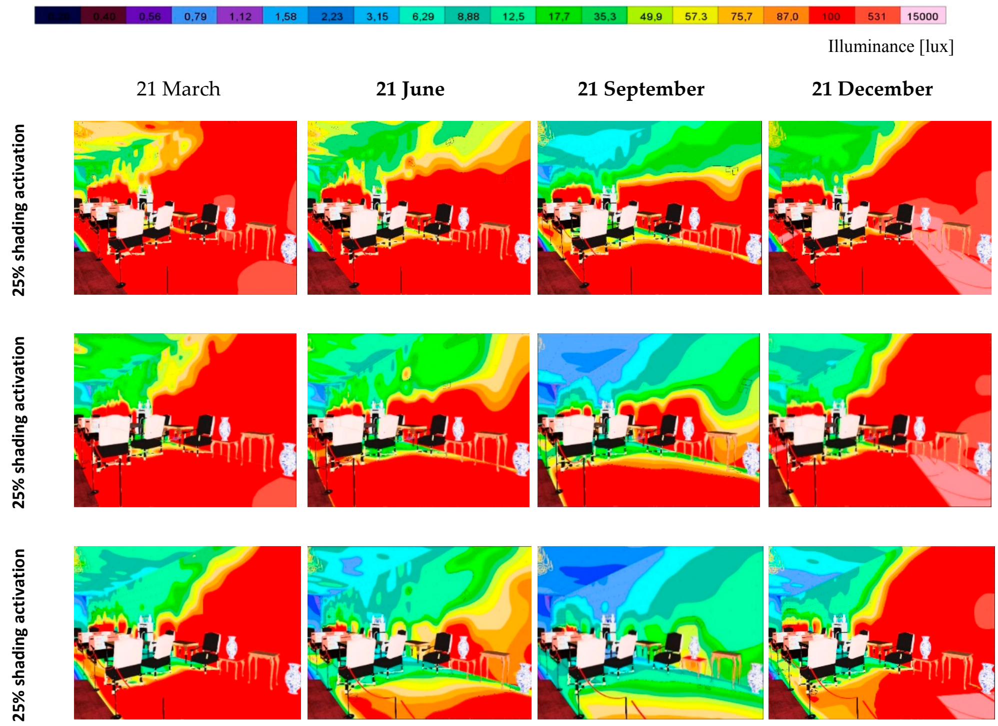


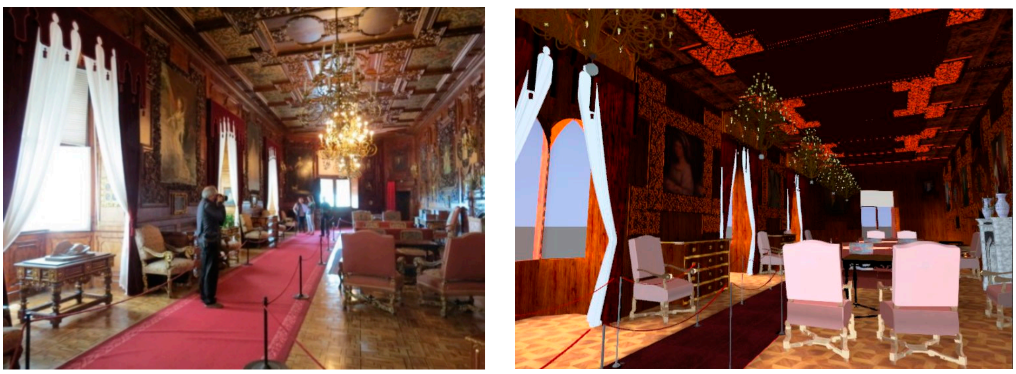
Figure 18. View to the wall opposite windows with shadings activation for 25%, 50% and 75%.

The next simulation outputs are for the view to the salon windows as seen in Figure 19 and in false color illuminance levels in Figures 20 and 21.

The simulations for the view to the windows shows that the high rise of illuminance is between 10:00 and noon. The floor area is highly affected. Ceiling soffit has increased illuminance level from March to June and between September to December. The view to the windows was also simulated for shading activation at 25%, 50%, and 75% (Figure 22).

The following figures show the salon furniture and upholstery in the photograph and 3D model in Figure 23 and in illuminance simulation graphical outputs in Figures 24 and 25.

The area of the furniture location in the middle of the salon is all the time exposed to high illuminance level, as it is seen from the simulations in Figures 24 and 25. This is a problem influencing the quality of textiles of armchairs and sofa upholstery in the salon. The furniture area was also simulated for variations with the window shading activation for 25%, 50%, and 75% shown in Figure 26.



(**a**) (**b**)

Figure 19. View to windows, (**a**) photograph; (**b**) DIALux model.

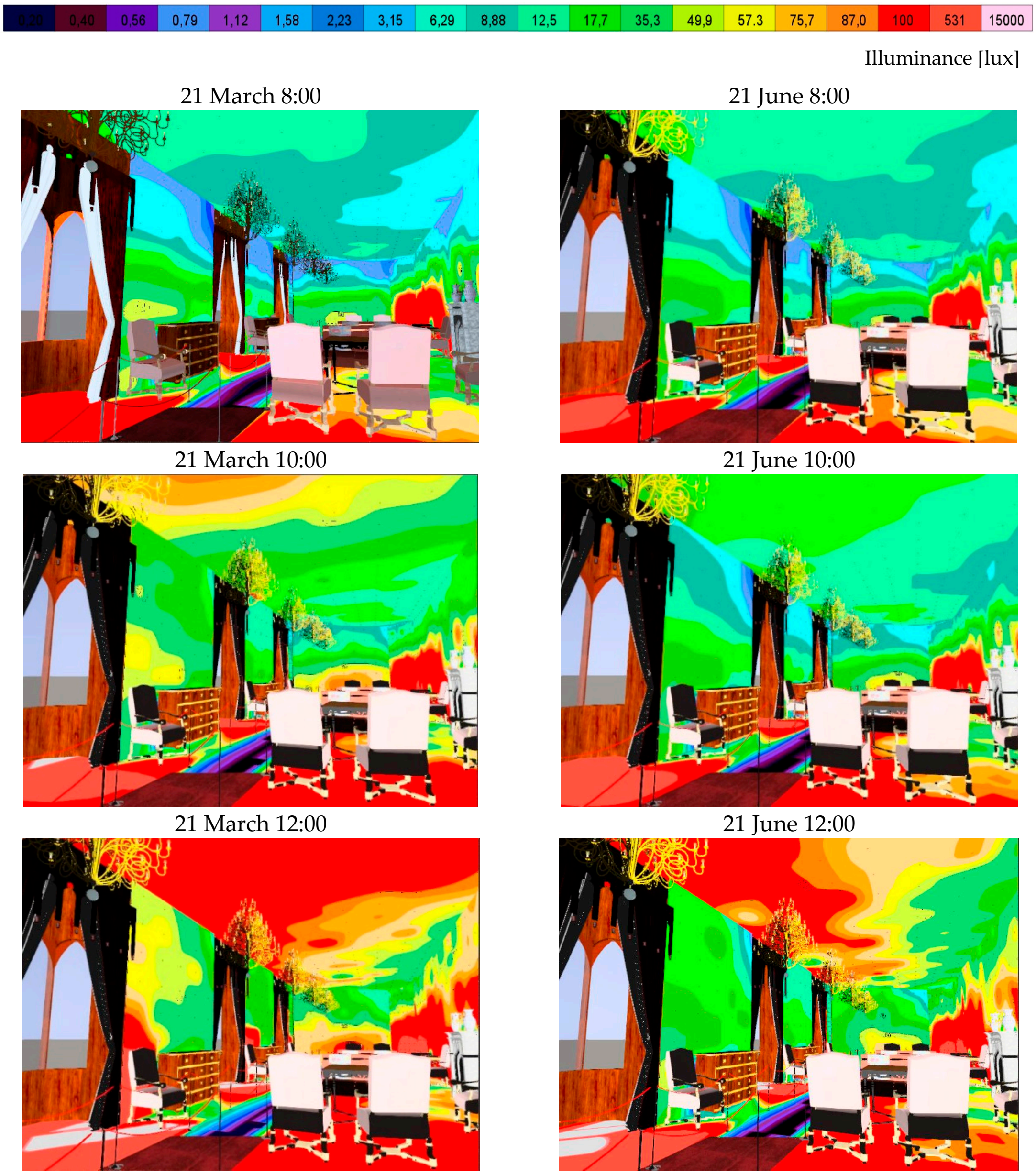


Figure 20. View to window area—illuminance (lux) levels for 21 March and 21 June.

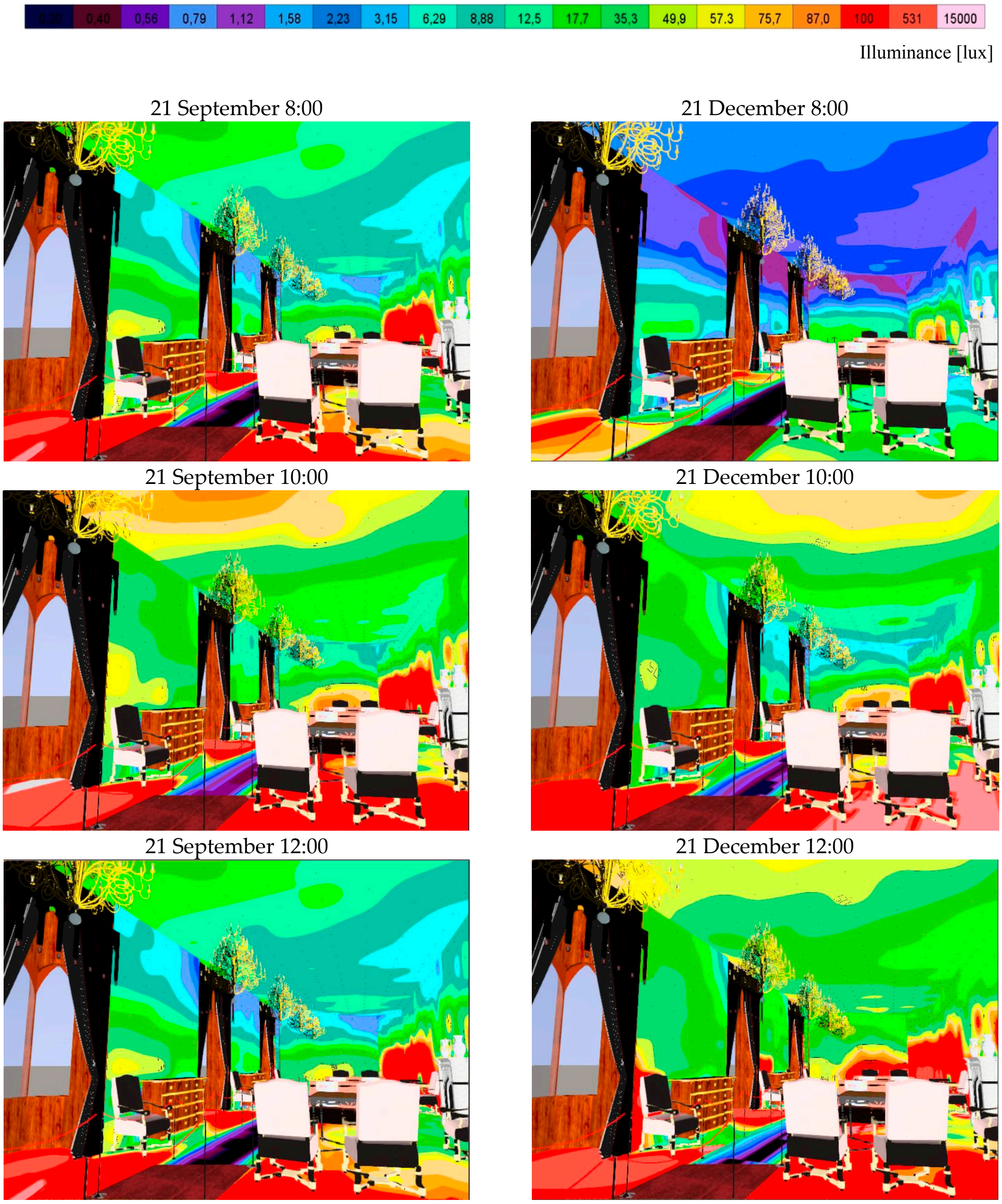


Figure 21. View to window area—illuminance (lux) levels for 21 September and 21 December.

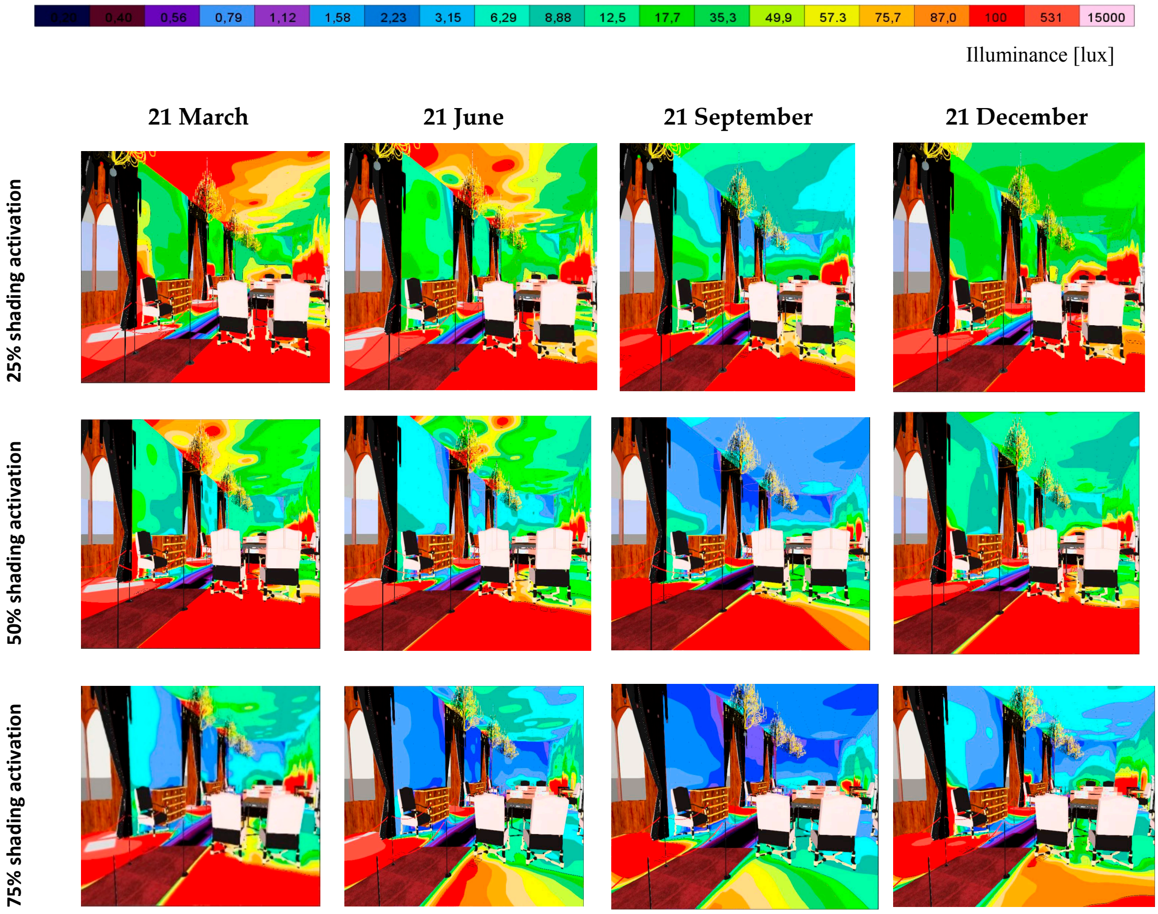


Figure 22. View to the salon with windows shadings activation for 25%, 50% and 75%, illuminance [lux].

(**a**) (**b**)

Figure 23. Furniture, (**a**) photograph; (**b**) DIALux model.

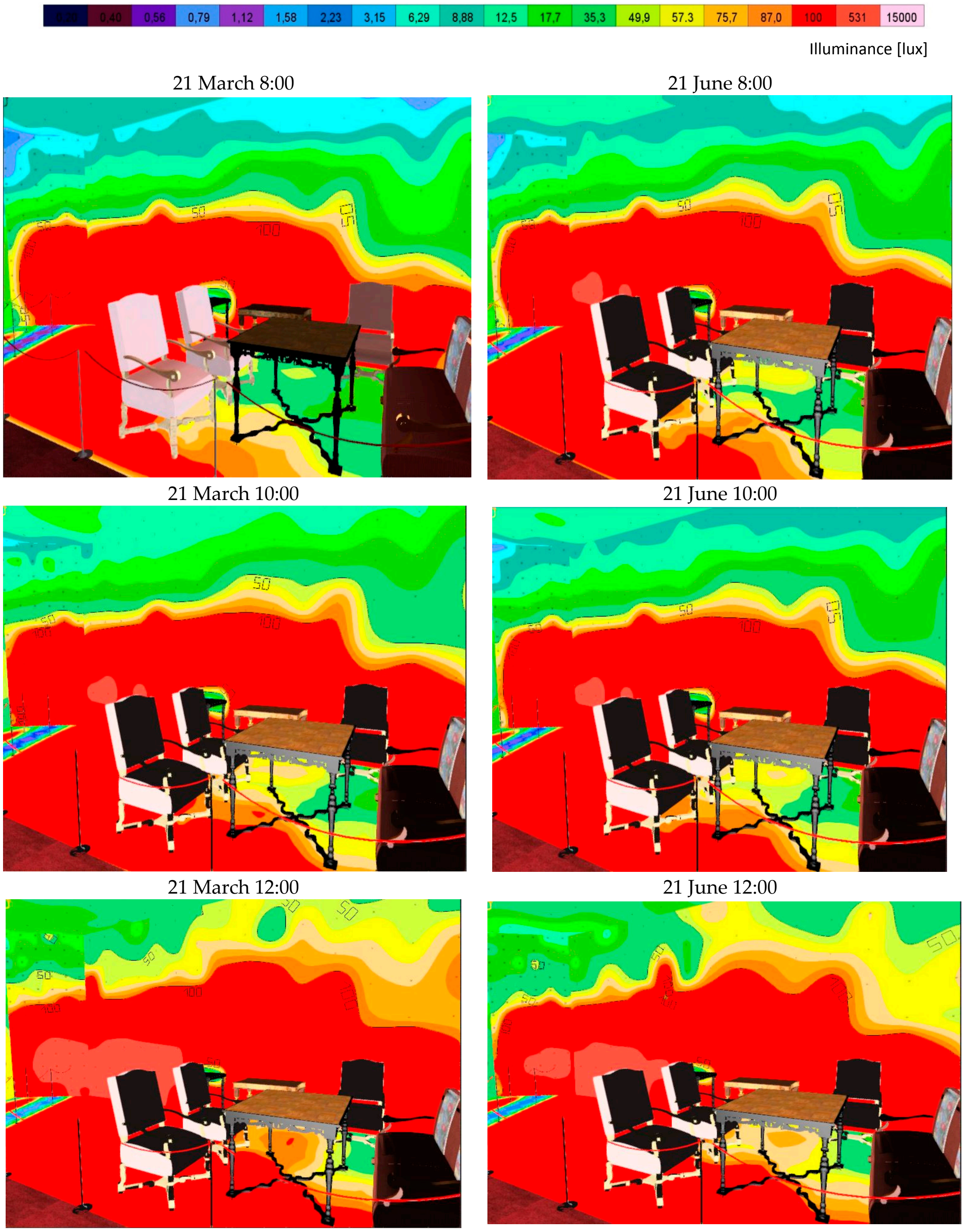


Figure 24. Furniture—illuminance (lux) levels for 21 March and 21 June.

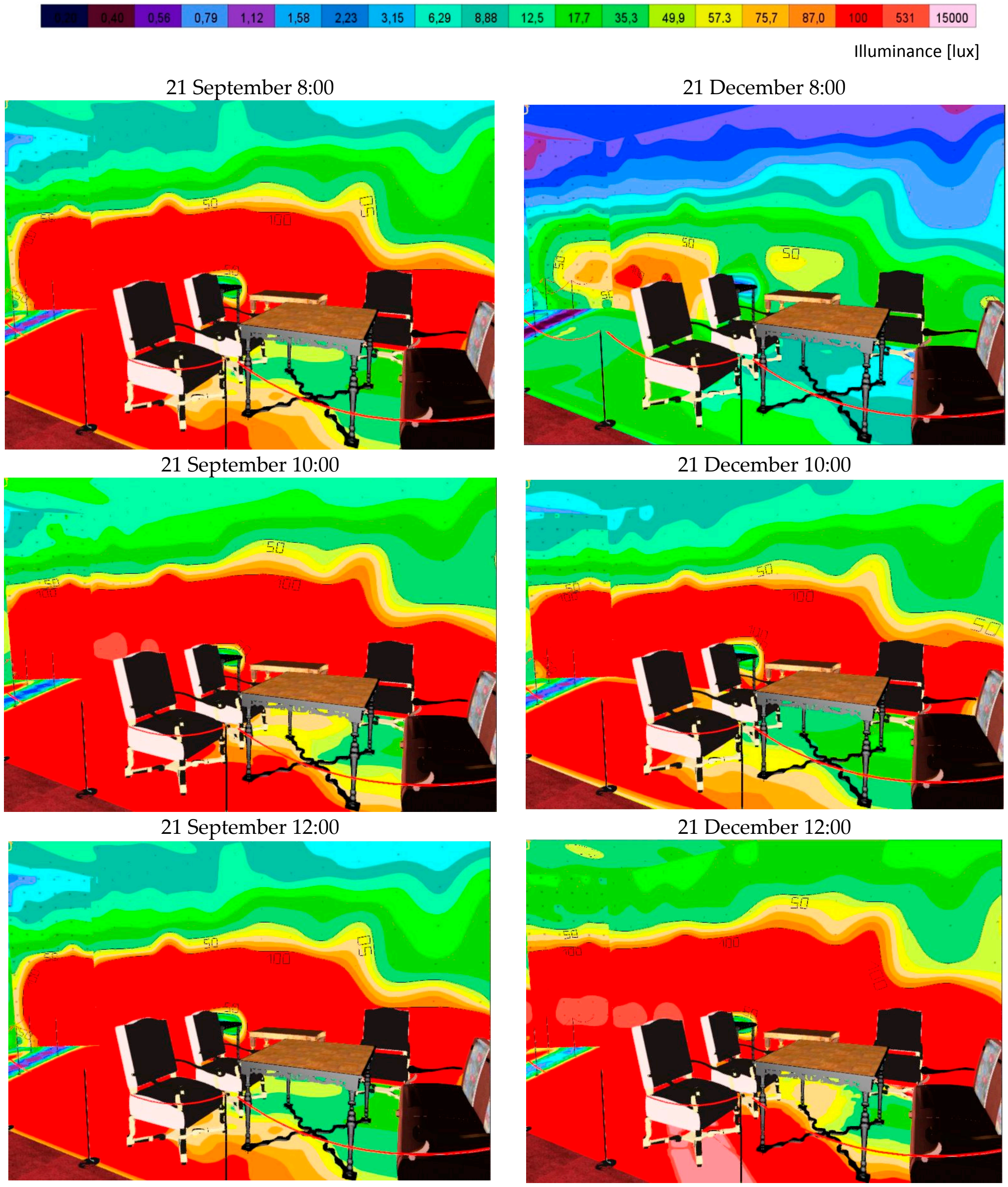


Figure 25. Furniture—illuminance (lux) levels for 21 September and 21 December.

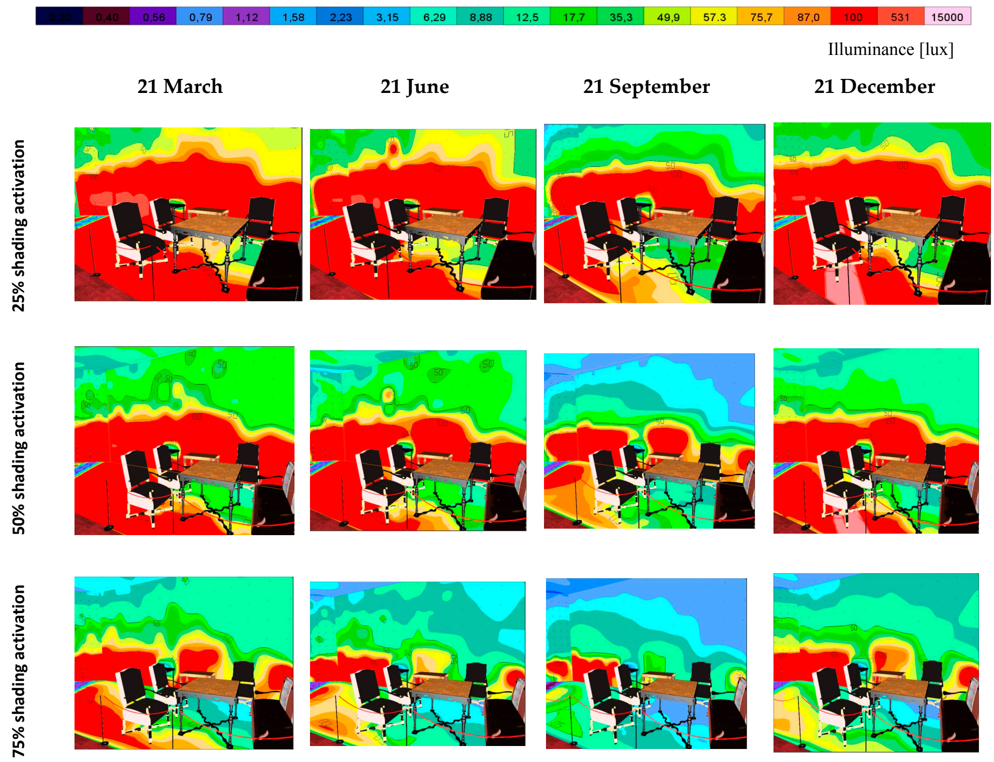


Figure 26. Furniture in the salon with window shading activation for 25%, 50% and 75%.

Valuable oil paintings on the wall opposite the windows are light-sensitive artefacts. The view to the painting from the window side is shown in Figure 27 and in graphical distribution of illuminance levels in Figures 28 and 29.

The area of the painting is overexposed for a substantial part of the year. It represents a high potential damage of painting degradation and color bleaching. The view of the painting was simulated for shading activation at 25%, 50%, and 75%, as shown in Figure 30. The light level on the vertical plane close to the painting (Figure 31) is shown in detailed evaluation in Figures 32 and 33.

Figures 32 and 33 give an overview of the illuminance level of a part of the vertical plane close to the painting is over the 50-lux limit all year except in the early morning time in December. The painting light exposition was also studied for window shading activation at 25%, 50% and 75%, as shown in Figure 34.

(**a**) (**b**)

Figure 27. View to the painting of the chateau possessor, (**a**) photograph; (**b**) DIALux model.

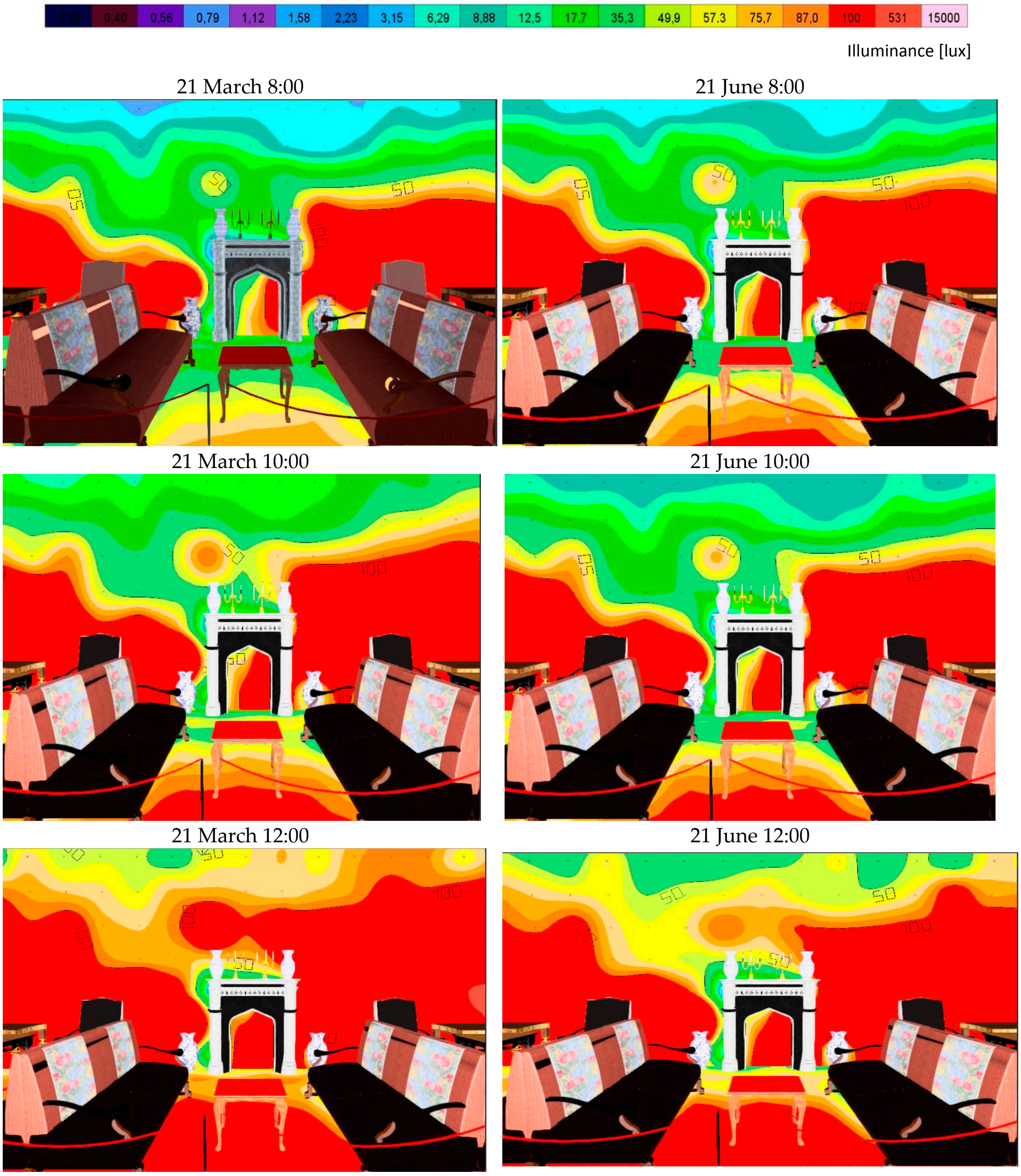


Figure 28. View to the painting—illuminance (lux) levels for 21 March and 21 June.

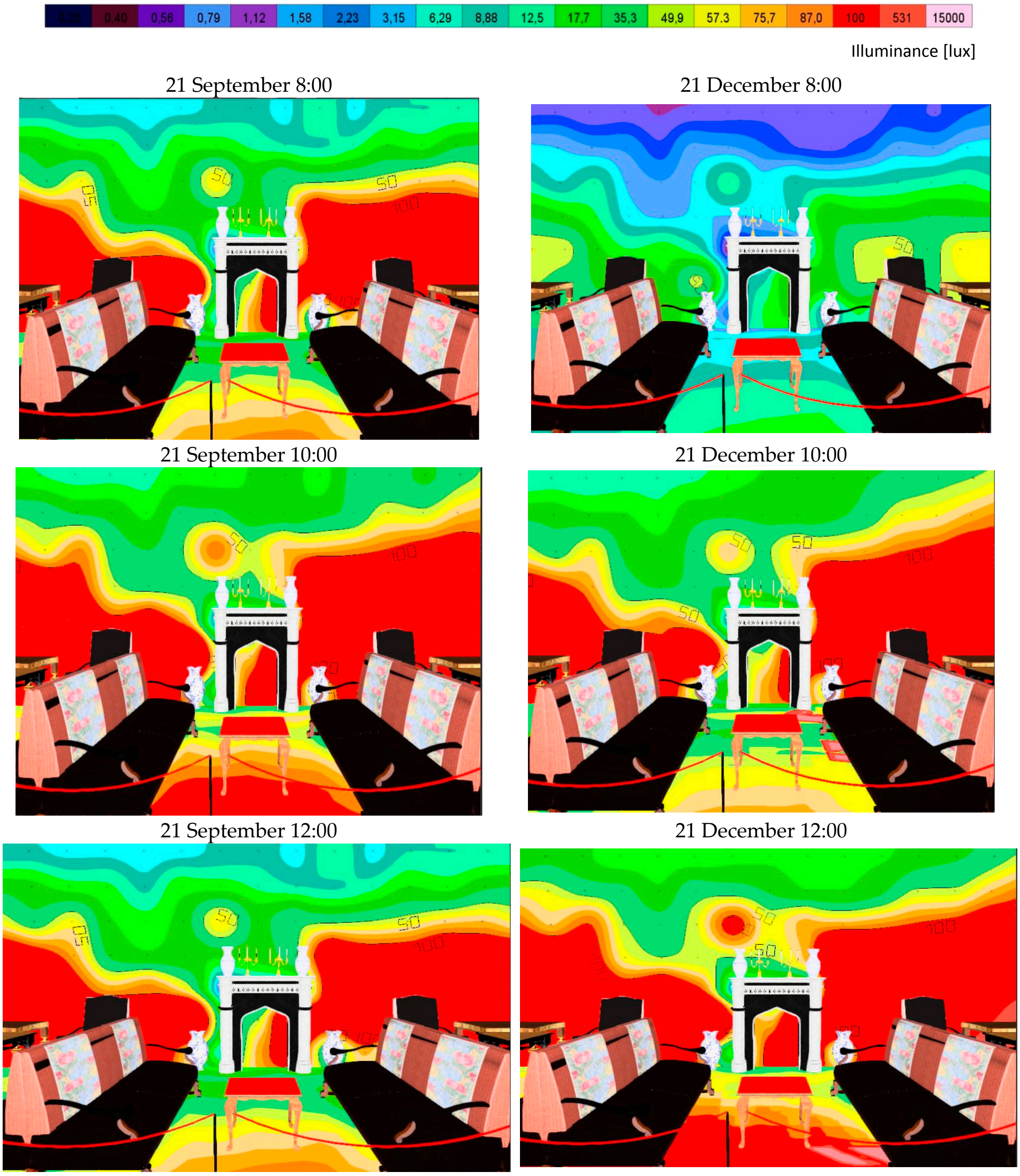


Figure 29. View to the painting—illuminance (lux) levels for 21 September and 21 December.

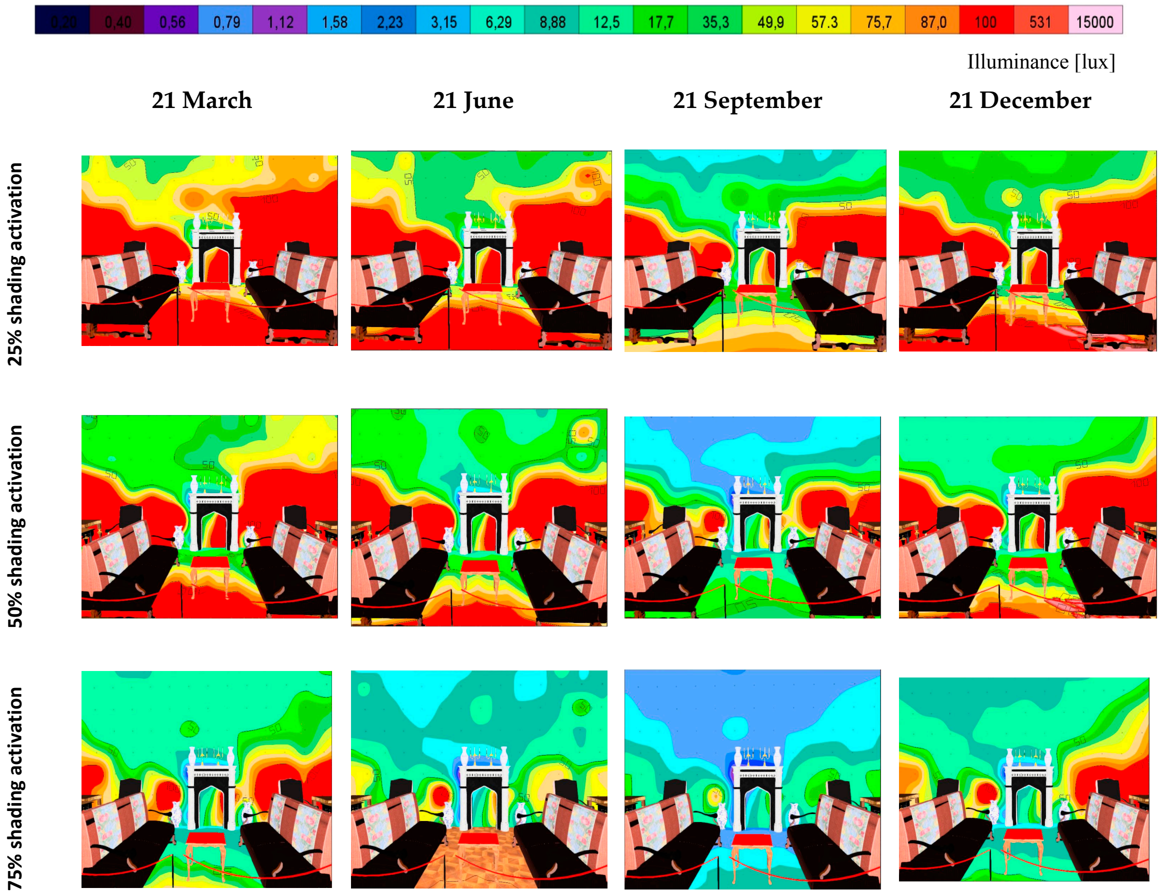
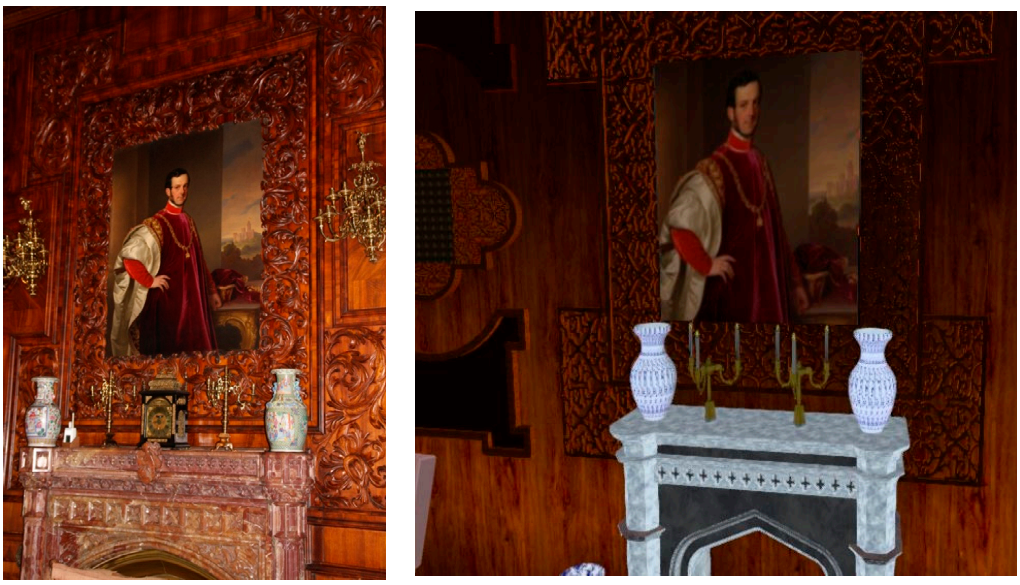


Figure 30. View to the painting simulated for window shading activation for 25%, 50% and 75%.



(**a**) (**b**)

Figure 31. Painting in detail, (**a**) photograph; (**b**) DIALux model.

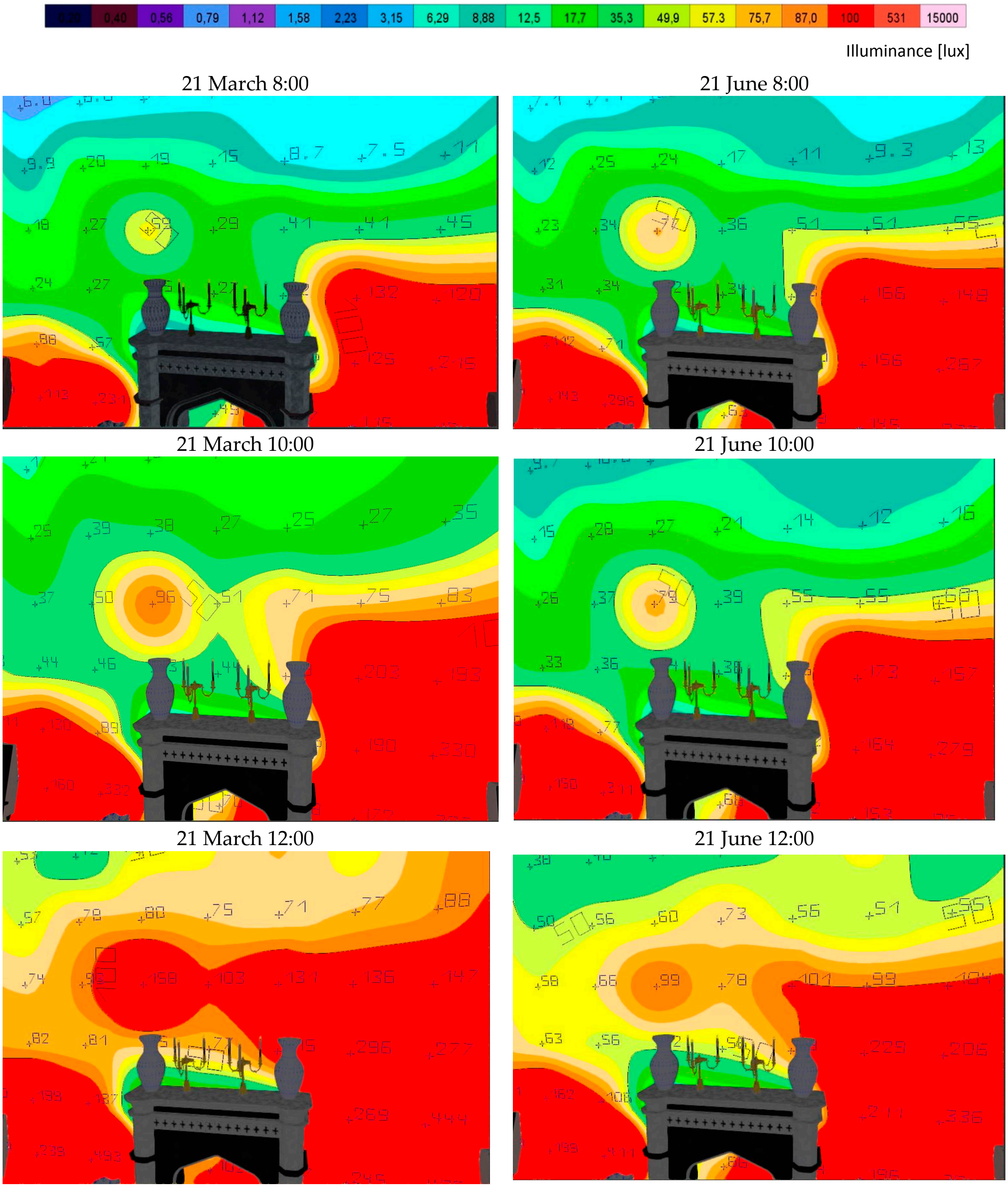


Figure 32. Detail view to the painting—illuminance (lux) levels for 21 March and 21 June.

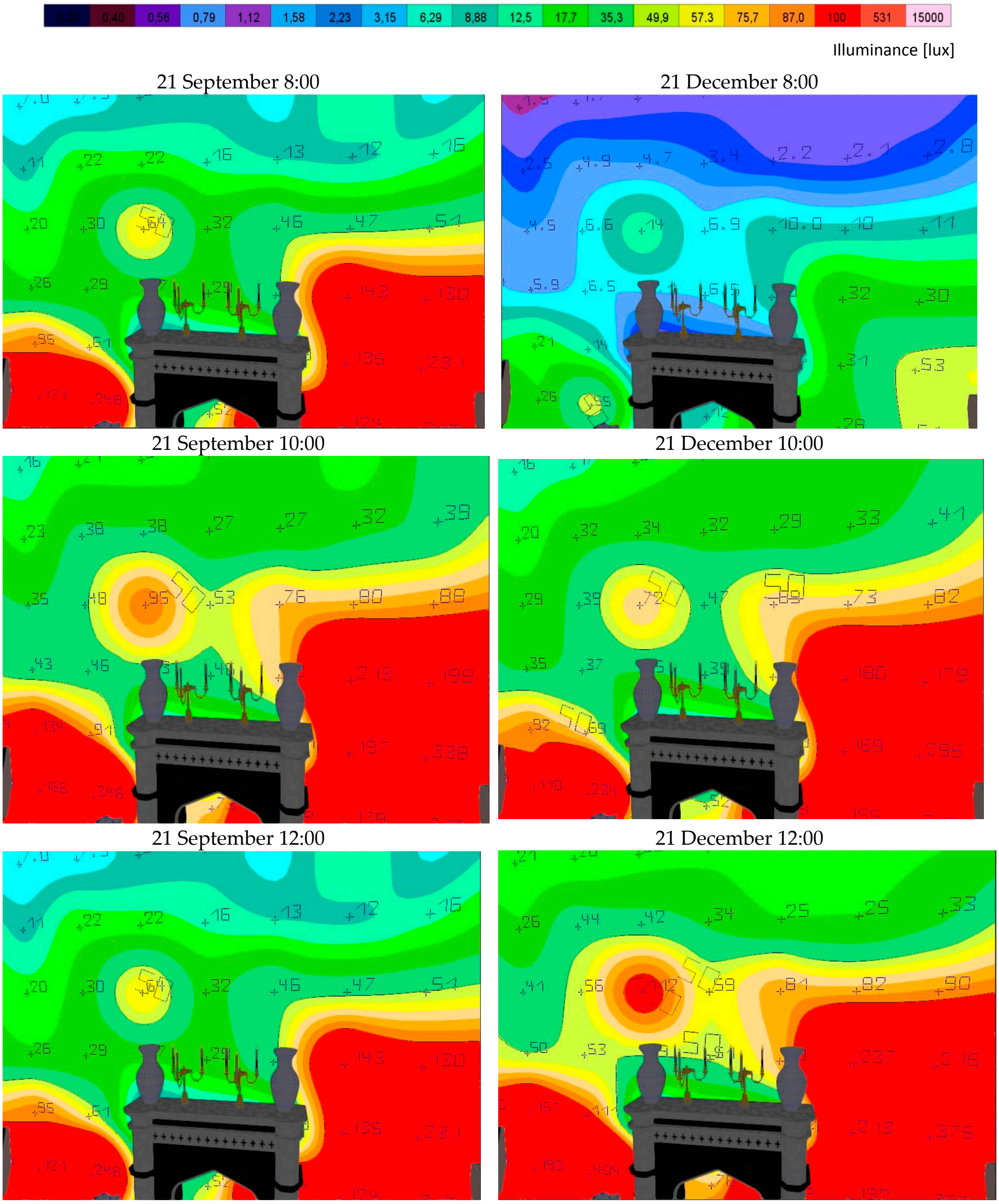


Figure 33. Detail view to the painting—illuminance (lux) levels for 21 September and 21 December.

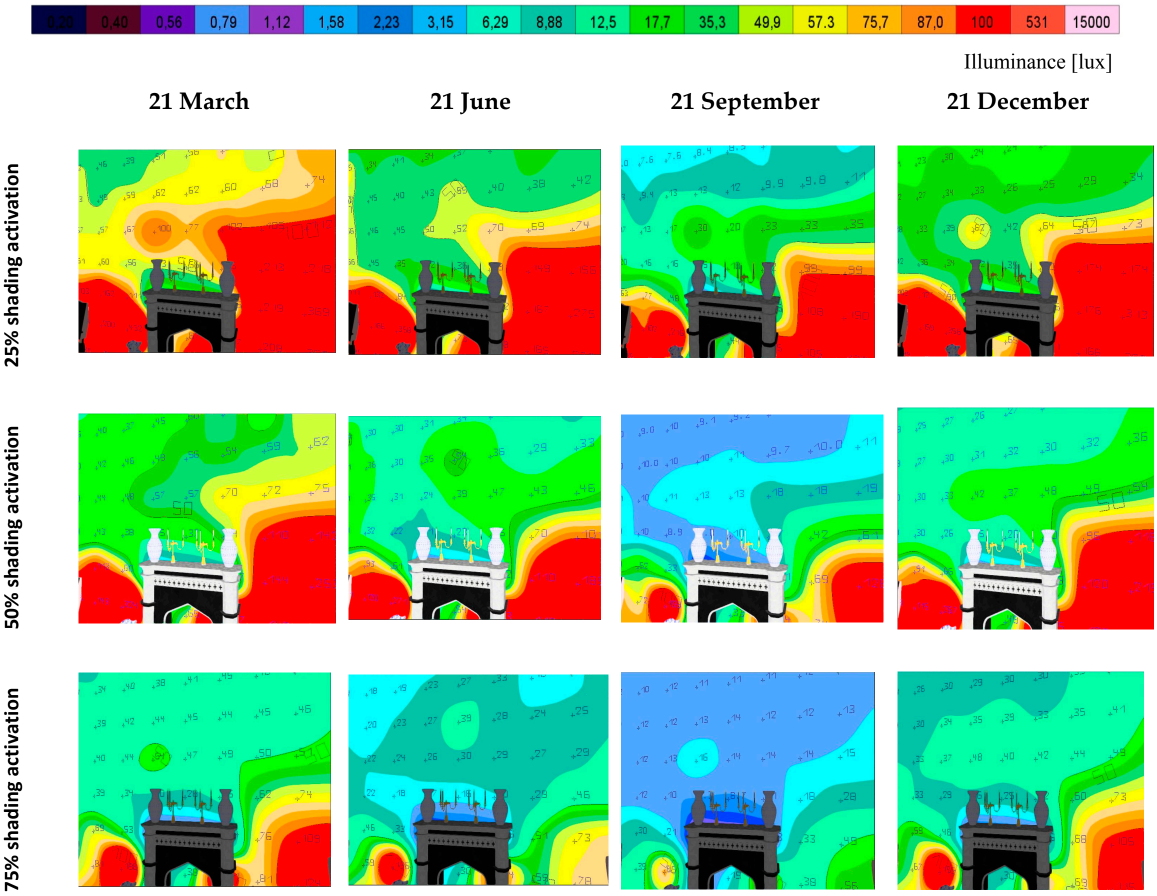
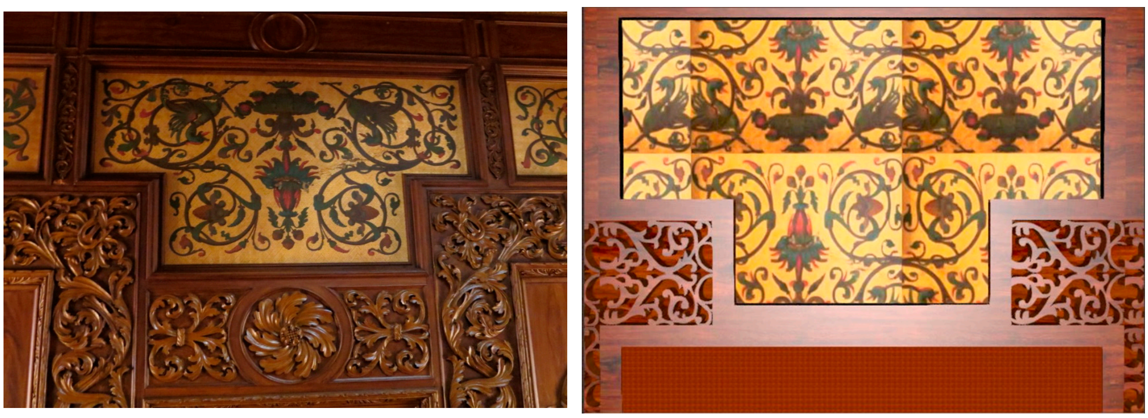


Figure 34. View to the painting simulated for window shading activation for 25%, 50% and 75%.

The extremely light-sensitive material is the original wallpaper on the ceiling soffit, Figure 35. The illuminance on the horizontal plane close to the soffit was simulated for the specified daylight conditions.

The simulation outputs in Figures 36 and 37 show that the wallpapers are exposed to higher illuminance levels in the period of year between March and June at noon. The rest of the year the wallpaper decoration is not damaged because illuminance level close to the ceiling wallpaper surface is not for more than 50 lux.



(**a**) (**b**)

Figure 35. Detail of the ceiling wallpaper decoration, (**a**) photograph, (**b**) DIALux model.

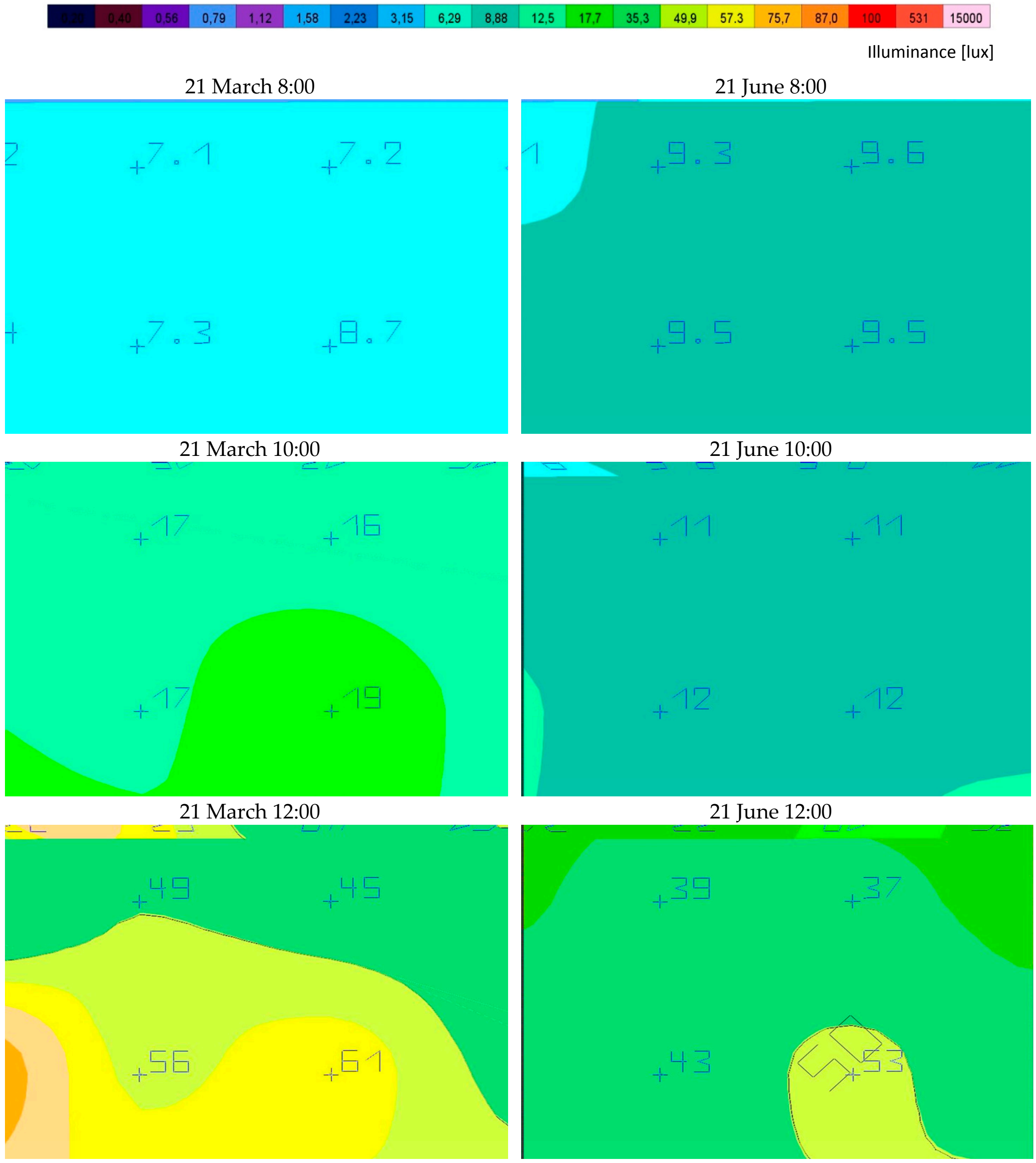


Figure 36. Detail view to the wallpaper—illuminance (lux) levels for 21 March and 21 June.

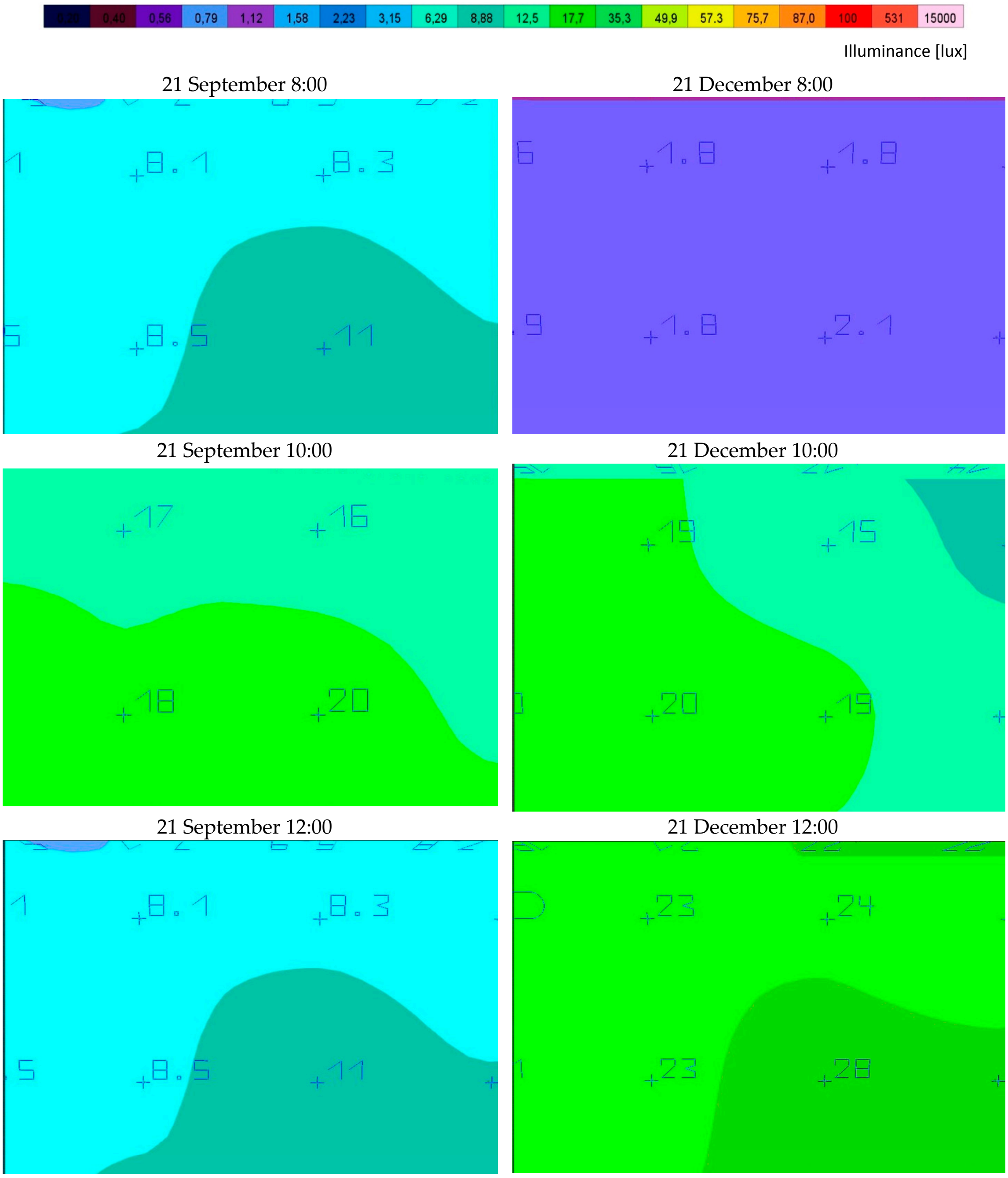


Figure 37. Detail view to the wallpaper—illuminance (lux) levels for 21 September and 21 December.

6. Conclusions

"There is no architecture without light and there can be no building where the presence of natural light, either in part or as a whole, will not benefit those who use it." [2]. The statement is absolutely truthful, and it represents one of topical ideas of building design. Buildings with plenty of daylight positively influence occupants' well-being in an indoor environment. However, in ancient and historical heritage buildings light exposition must be reduced as much as possible to maintain sufficient visibility but minimize damage of light-sensitive materials [33,34]. It appears reasonable that historical monuments and architecturally valuable interiors should have a controlled daylighting strategy [35].

The results presented above of measurements and daylight simulations show that light intensity level in the Morning Salon in many cases exceeds the illuminance permitted for conservation of light-sensitive materials [25]. The daylight illuminance is so high that it always exceeds the 50-lux limit. It is obvious from all simulation outputs. It means that large interior areas are at potential risk of light degradation, mainly in summer and transitional time. Simulations for the 21 December also show high illuminance distribution for winter time. Mainly, the wall with paintings and textiles on historical furniture located in the middle of the salon are affected. Ceiling wallpapers are less damaged than expected.

It appears that mornings represent the period of the salon interior's damage. The most sensitive for light damage are oil paintings on the wall opposite the windows, but original wall paneling and upholstery and textiles are also damaged.

The salon interior and furnishing needs to be protected from the high light intensity and solar gain. Excessive direct solar radiation causes glare discomfort and overheating of indoor climate [36]. It is recommended that strict shading control is maintained. As any automatic shading systems are not permitted in such a historically valuable place, the full-time activation of the rollers and shading blinds is recommended in mornings for the whole year, especially during summer. Full-time activation of the shading blinds, especially in the morning because of the south-east orientation of the Morning Salon is also recommended. Especially at sun rise and then until about 10:00 or 11:00 the Morning Salon should be protected by blinds at 100 percent full blind shading. The Salon should be controlled by at least 75 percent shading activation at noon. In the afternoon, the shading can be reduced, bout the illuminance should be controlled all the time.

If possible, some ultraviolet filters which are known for conservation [37] are recommended. Special protective coatings could be applied to protect the paintings against ultraviolet radiation bleaching [38]. If the historical value of glass panels allows application of special shading systems, these might be completed with transparent spectrally selective glazing [39]. Special glass is used for reduction of transmission of ultraviolet and infrared ranges of solar radiation into the interior. Switchable glazing could solve demands for reduction of daylight transmission in time of intensive solar shining and transparency for diffusive skylight conditions [40]. Nevertheless, selected glazing must not influence the architectural style of the historical monument. In special cases, advanced daylight guiding and redirecting systems can also be applied [41]. All these special system applications must be consulted over with architects and historical monument preservation authorities.

Artificial lighting should also be controlled. Luminaires should contain light sources to supply light intensity for the interior visual scene. Light sources free of the ultraviolet and infrared parts of radiation are preferred. A neutral white color of artificial light seems to be convenient for the lighting the colorful interior [42–44]. Dimming of lamps is recommended in the response to the daylight access for energy efficiency and glare elimination. Luminaires should be movable, to allow flexibility in the artificial lighting scenes in a mixture of direct and indirect light sources to provide uniform lighting with accentuating light spots directed on the artefacts and display items with respect to the protection against damage of light-sensitive materials for optimal balance between exposure and damage.

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