Debating the *domus ecclesiae* at Dura-Europos: the Christian Building in context

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Creation of daylight simulations

The daylight simulations presented here were executed on models of M8-A, the residence that eventually became the Christian Building at Dura-Europos, before and after it was architecturally adapted. We developed these models using the floor plans and isometric projections of the structure's extant remains, in addition to the descriptions and photographs included in the excavation reports and material contained in the Dura-Europos excavation archive at the Yale University Art Gallery.[1] The computer-aided design software package Rhinoceros 3D (Rhino CAD), was used to render the structure before and after the renovation in three dimensions.

We did not utilize the reconstructed sectional elevations drawn by the expedition's architect Henry Pearson when they featured details that the archaeological evidence did not substantiate.[2] In instances when Carl Kraeling's descriptions and Henry Pearson's projections did not align with each other or the archaeological evidence, their reconstructions were omitted, adjusted, or amended based on the material evidence available. For example, Pearson's plan of the Christian Building after its adaptation tentatively suggests there was second low window at the east end of Room 4's north wall identical to the one at the west end, but the east end of the wall was not preserved to such a height to say for certain, so it was omitted.[3]

Likewise, the uneven preservation of the building meant that ceiling heights of Rooms 4, 5, and 6 could be more confidently established than those of the rooms at the eastern end of the structure, on the basis of both Kraeling's descriptions and several excavation photos,

[1] Excavation reports of Dura's Christian Building include *P.R. 5*, 238–88; *F.R. 8.2*. We are grateful to Lisa Brody for allowing us to access and study the Dura-Europos excavation archive at the Yale University Art Gallery.

[2] On these details, see, for example, the subsection entitled "The question of residential use: the 'Upper Room' and the roof" in the main article.

[3] *F.R. 8.2*, Plan V; YUAG, neg. dura-fc3-01 shows the preservation of the east end of Room 4's north wall. If there was a window here, as Pearson hypothesized, the lighting effect over the dais described at the end of the main article would have been all the more intense.

Suppl. Fig. 1. *Photograph of the south end of the canopy of font in Room 6, showing joists of later ceiling. (Dura-Europos Collection, YUAG, neg. Dura-I682b-01, courtesy YUAG.)*

which showed the depressions where the ceiling joists were secured into the mudbrick (see Suppl. fig. 1). Kraeling had tentatively hypothesized on the basis of the width of the portico's two columns that the ceiling level may have varied between rooms, with Rooms 8, 2, and 3 possibly having lower ceilings than the western rooms.[4] Yet, without more of the eastern portion of the structure preserved, the thickness of the column drums alone does not allow us to make this determination. As such, we constructed the roof at a consistent height throughout. This was the most conservative way to reconstruct the ceiling height, as a lower ceiling height in any of the rooms would have intensified the light refracting off the courtyard and thus also the results of the simulation. Because the windows along the west wall of Room 4 faced out onto Tower 17 and the city's fortification wall to the west of the structure, we also included these constructions in the model.

The ClimateStudio plugin suite for RhinoCAD made it possible to execute daylight simulations of the models.[5] Using its graphical user interface, the simulation was customized to take into account the unique reflectance properties of the materials with which the

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[4] *F.R. 8.2*, 9–13.

[5] We are grateful to the University of Toronto's John H. Daniels Faculty of Architecture, Landscape, and Design; the Yale School of Architecture; and the University of Manchester School of Environment, Education and Development for providing us with various equipment and software to develop and execute these models and simulations.

Christian Building was constructed. It was critical to define a material's reflectance properties, but this was challenging as ancient building materials are not modeled as often as modern ones. The Christian Building was mostly constructed out of mud-plastered mudbrick, and in certain cases it received an additional coating of a light-colored plaster. The two windows at the west end of Room 4 had gypsum panels. Because the visual material properties of many of these materials have not been widely studied or discussed, such as mud-plastered mudbrick, it was necessary to aggregate data on the reflectance properties of other forms of similar construction material.

Once the material settings had been inputted, the models were georeferenced and the parameters of the simulation were set to reflect the period that the two phases of the structure were in use. A date-specific sky using an EnergyPlus Weather File location environment file containing such information as direct normal irradiance, diffuse horizontal irradiance, and time zone data was produced. Using ClimateStudio's interface, we then translated this data into a virtual sky for the period in question and pinpointed the sun location, light intensity, and atmospheric reflectance properties.

There are three types of daylight simulations provided in this article: annual radiation, point-in-time illuminance, and cumulative yearly illuminance. Annual radiation simulations (Suppl. fig. 4a–b) represent the amount of sunlight a given surface is exposed to over the course of a year. This is measured in kilowatt-hours per meter squared (kWh/m^2), a non-International System of Units (SI) measure that quantizes the amount of radiant solar energy a surface is exposed to for every hour. The false color on the annual radiation simulations reflects the mean cumulative radiation values that particular surface received on an average day in the year. The scale for the annual simulations provided in this article is 0-1,000 kWh/m^2. The point-in-time illuminance simulations (Figs. 9a–11b; Suppl. figs. 16a–20b) visualize the distribution and intensity of daylight at a specific moment in time. They are measured in Lux (lx). In the International System of Units (SI), Lux is a unit of illuminance used to measure the number of lumens per meter squared. The false color on the point-in-time illuminance simulations reflects the level of light intensity or "illumination" that falls on a certain surface. The scale for the point-in-time illuminance simulations in this model is 0–300 lx. We have provided point-in-time simulations for July and January as these represent the months at which there is the most and least direct sunlight, respectively. Cumulative yearly illuminance simulations (Figs. 7a–8b; Suppl. Figs. 3a–b) represent the mean of the illuminance readings for every hour within the year. They provide an aggregate view of the distribution and intensity of daylight for an average day in the year. This is also measured in lx. The false color represents the aggregate illumination on a particular surface. For the cumulative yearly simulations, which visualize changes to the illuminance in the courtyard, the scale is 0–1,500 lx. For the cumulative yearly illuminance simulations, which focus on the interior of the rooms, the scale is 0–300 lx. The annual radiation and the cumulative yearly illuminance represent aggregated data, while the point-in-time illuminance are snapshots.

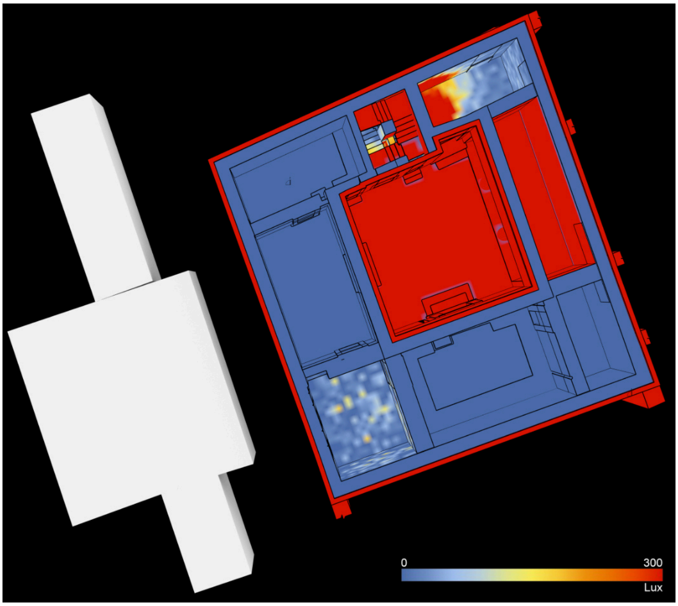
The different scales and colors of the simulations reflect the unique nature of the data they visualize. Since the annual radiation renders visualize exposure over time in kWh/m^2, those renders feature a different set of false colors than the point-in-time illuminance and cumulative yearly illuminance, which visualize the intensity and distribution of light in lx. The exterior surfaces of structures receive more sunlight than their interiors. As such, the 0–15,000 lx scale is helpful for visualizing changes in the illumination of exterior surfaces, while the 0–200 lx scale provides a nuanced picture of how the illumination within the interior of the building's rooms changed. The 0–1,000 kWh/m^2 shows changes the exposure of surfaces in the interior and the exterior of the building.

The simulations were run with the building's roof on and the so-called Upper Room included in the model. We have provided several cut views of the simulations order to enable readers to see the illumination within the building's rooms.

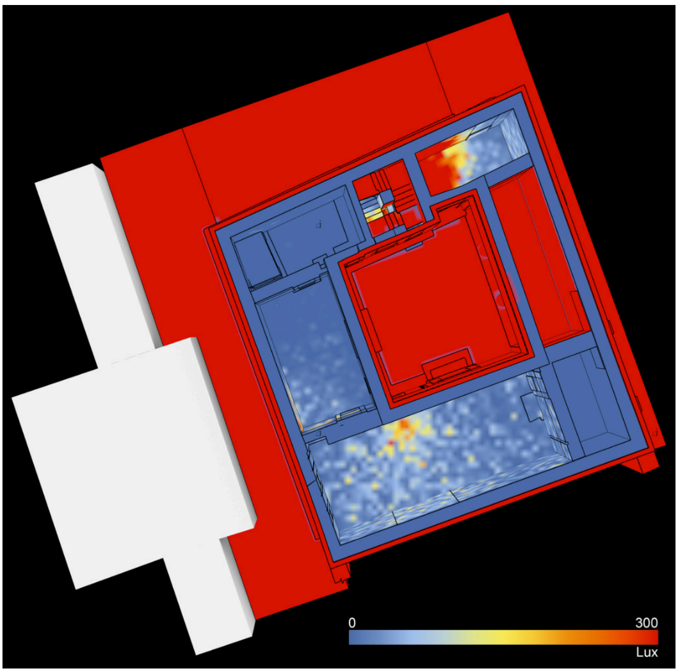
References

P.R. 5 Rostovtzeff, M. I., ed. 1934. *The Excavations at Dura-Europos Conducted by Yale University and the French Academy of Inscriptions and Letters. Preliminary Report of Fifth Season of Work, October 1931–March 1932*. New Haven: Yale University Press.

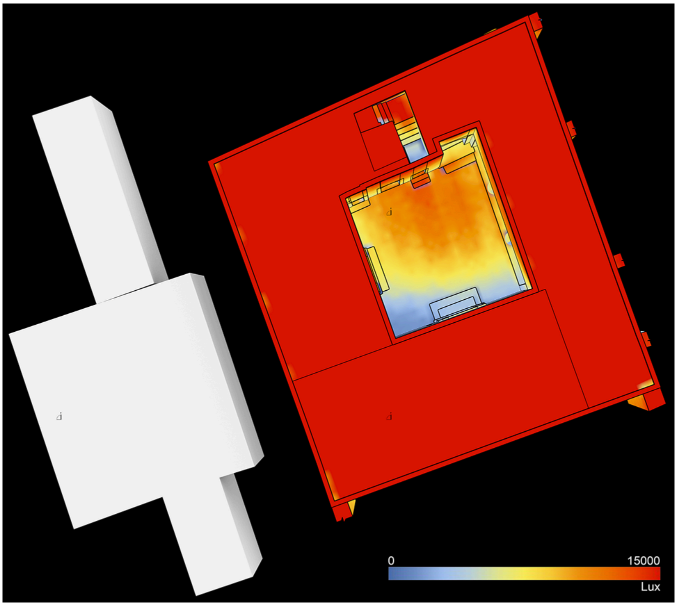
F.R. 8.2 Kraeling, C. H. 1967. *The Excavations at Dura Europos Conducted by Yale University and the French Academy of Inscriptions and Letters, Final Report 8, Part 2. The Christian Building*. New Haven: Yale University Press.



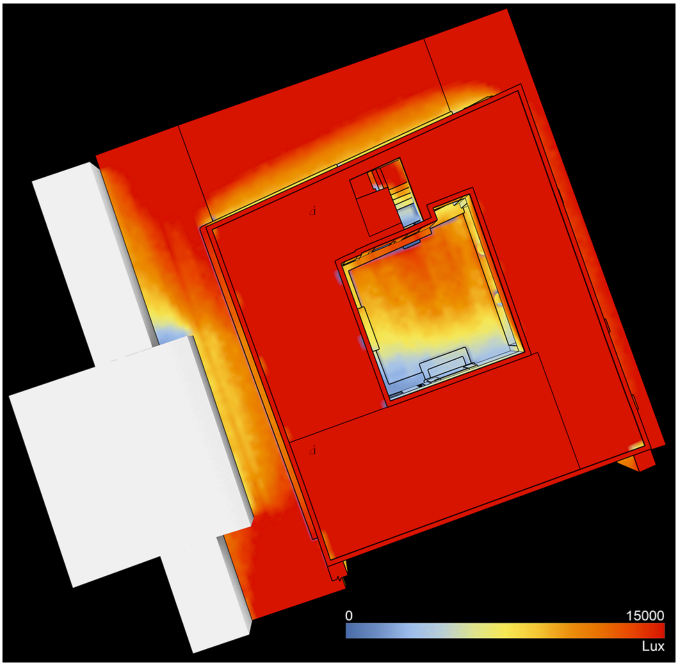
Suppl. Fig. 2a. *Point-in-time illuminance simulation of the Christian Building (M8-A) before adaptation (orientation is to true north; render parameters: July 243 CE, 1450 hours, windows open and doors closed; scale: 0–300 lx). (C. Leon Angelo and J. Silver.)*



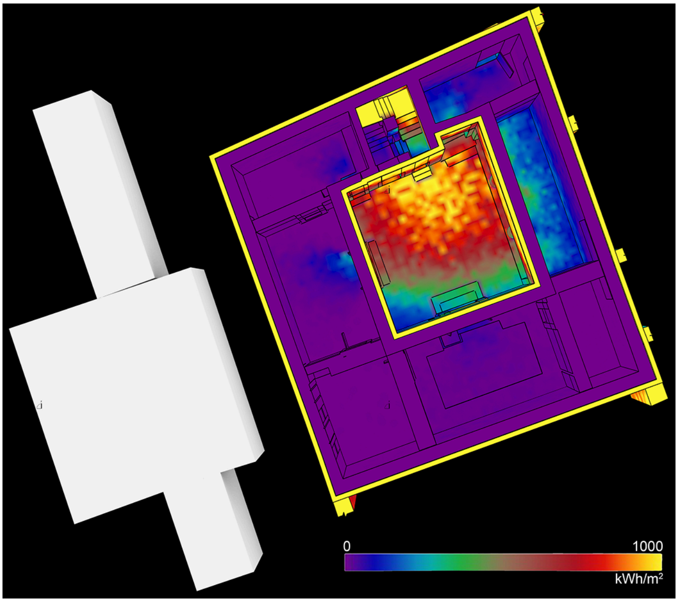
Suppl. Fig. 2b. *Point-in-time illuminance simulation of the Christian Building (M8-A) after adaptation (orientation is to true north; render parameters: July 253 CE, 1450 hours, windows open and doors closed; scale: 0-300 lx). (C. Leon Angelo and J. Silver.)*



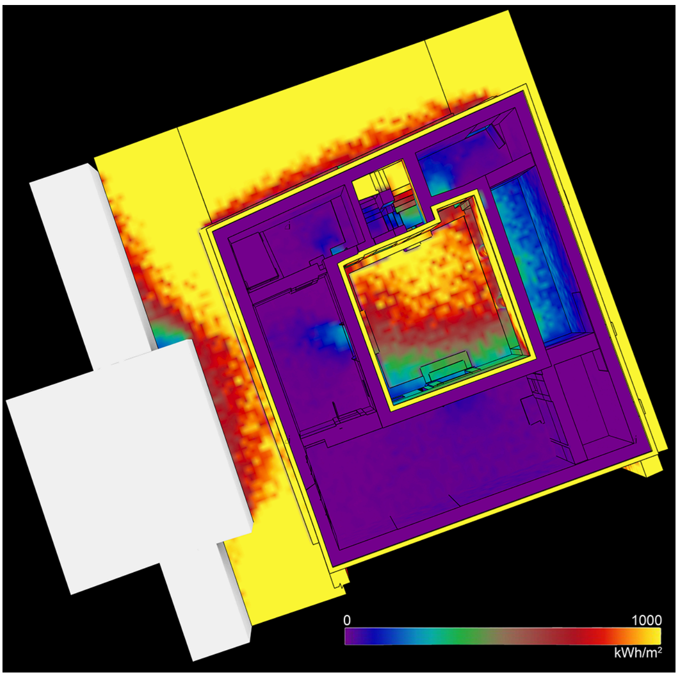
Suppl. Fig. 3a. *Cumulative yearly illuminance simulation of the Christian Building (M8-A) before adaptations; view of the courtyard (orientation is to true north; render parameters: 243 CE; scale: 0–1,500 lx). (C. Leon Angelo and J. Silver.)*



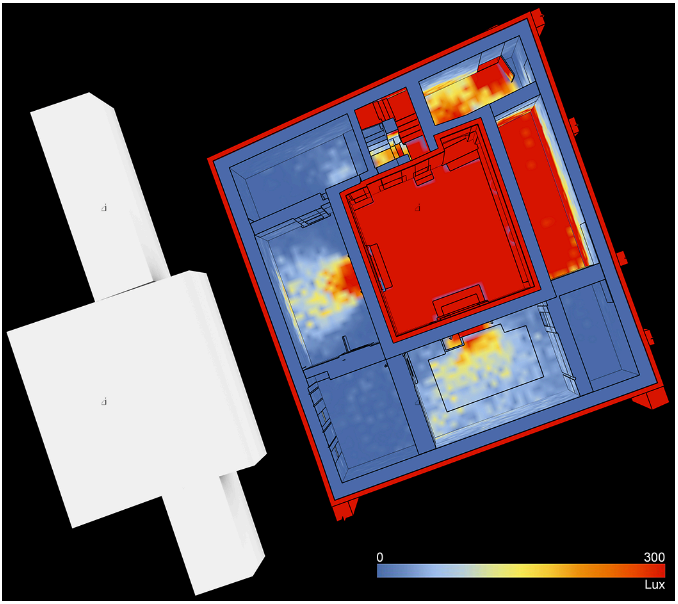
Suppl. Fig. 3b. *Cumulative yearly illuminance simulation of the Christian Building (M8-A) after adaptations; view of the courtyard (orientation is to true north; render parameters: 253 CE; scale: 0–1,500 lx). (C. Leon Angelo and J. Silver.)*



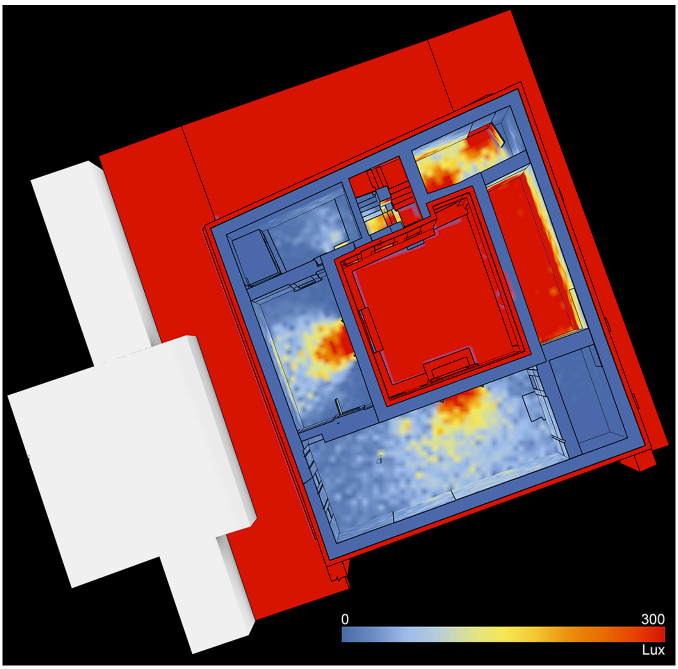
Suppl. Fig. 4a. *Annual radiation simulation render of the Christian Building (M8-A) before adaptation, showing average radiant exposure of surfaces (orientation is to true north; render parameters: 243 CE; windows and doors open; scale: 0–1,000 kWh/m²). (C. Leon Angelo and J. Silver.)*



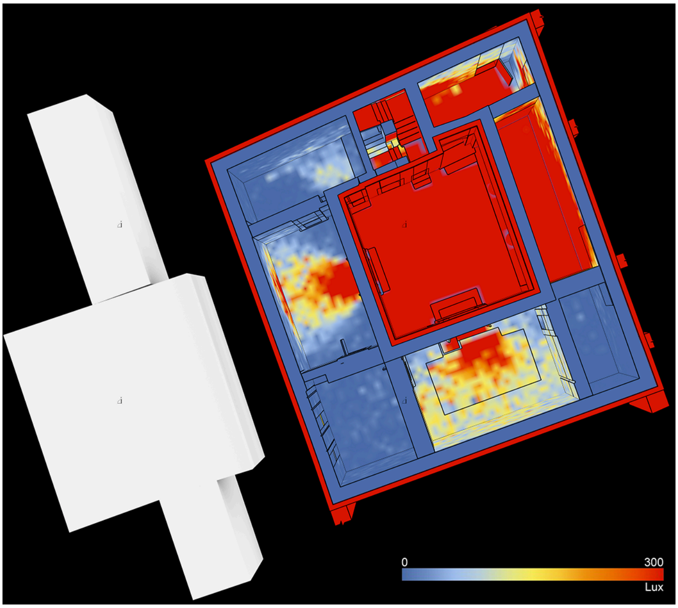
Suppl. Fig. 4b. *Annual radiation simulation render of the Christian Building (M8-A) after adaptation, showing average radiant exposure of surfaces (orientation is to true north; render parameters: 253 CE; windows and doors open; scale: 0-1,000 kWh/m²). (C. Leon Angelo and J. Silver.)*



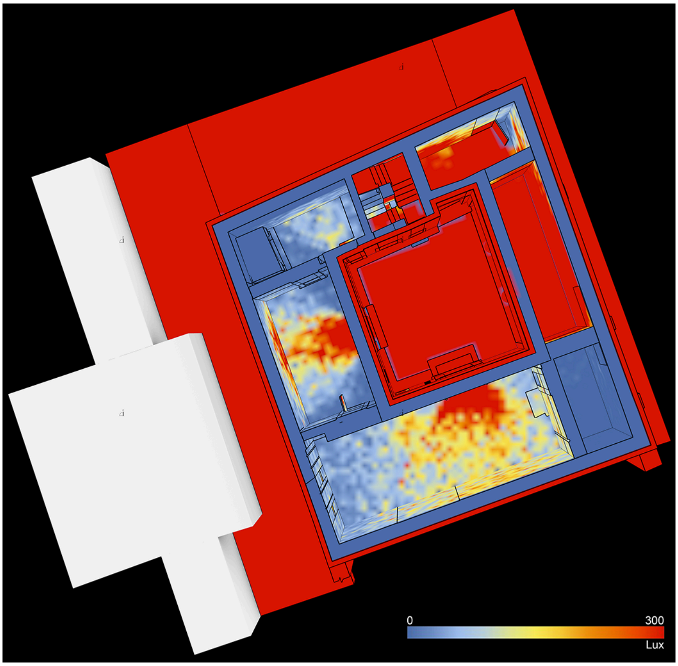
Suppl. Fig. 5a. *Point-in-time illuminance simulation of the Christian Building (M8-A) before adaptation (orientation is to true north; render parameters: January 243 CE, 1530 hours, windows and doors open; scale: 0–300 lx). (C. Leon Angelo and J. Silver.)*



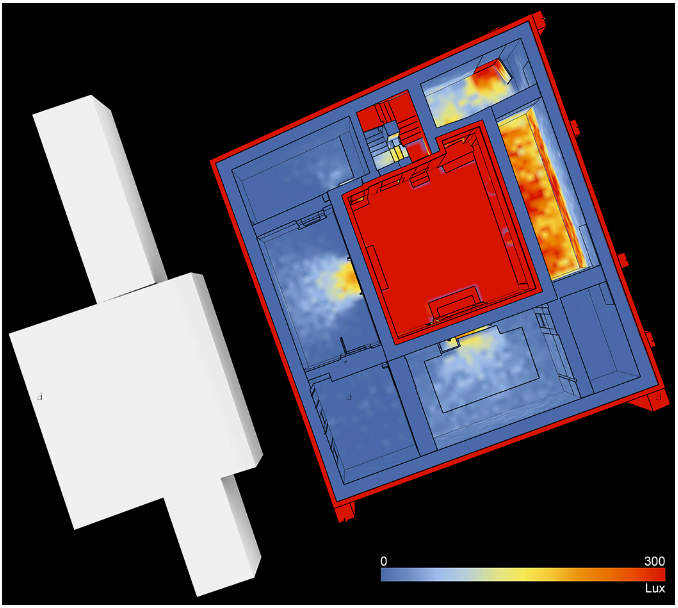
Suppl. Fig. 5b. *Point-in-time illuminance simulation of the Christian Building (M8-A) after adaptation (orientation is to true north; render parameters: January 253 CE, 1530 hours, windows and doors open; scale: 0–300 lx). (C. Leon Angelo and J. Silver.)*



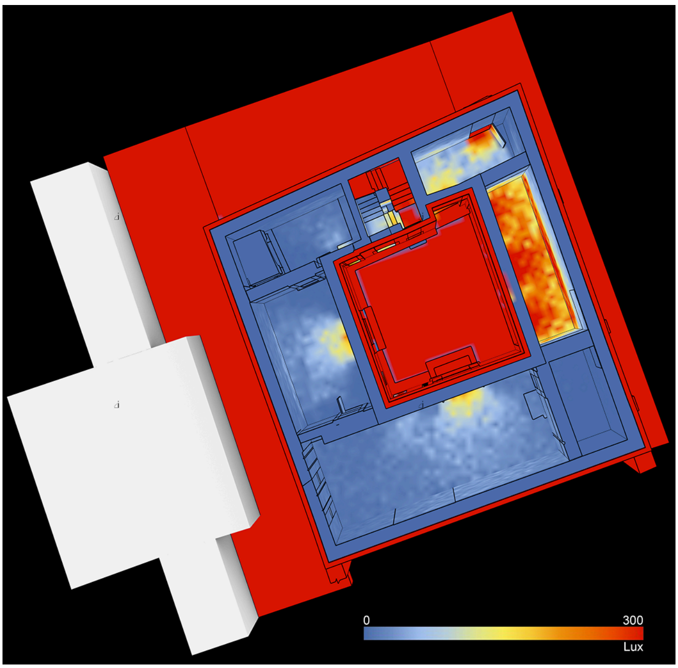
Suppl. Fig. 6a. *Point-in-time illuminance simulation of the Christian Building (M8-A) before adaptation (orientation is to true north; render parameters: July 243 CE, 1630 hours, windows and doors open; scale: 0–300 lx). (C. Leon Angelo and J. Silver.)*



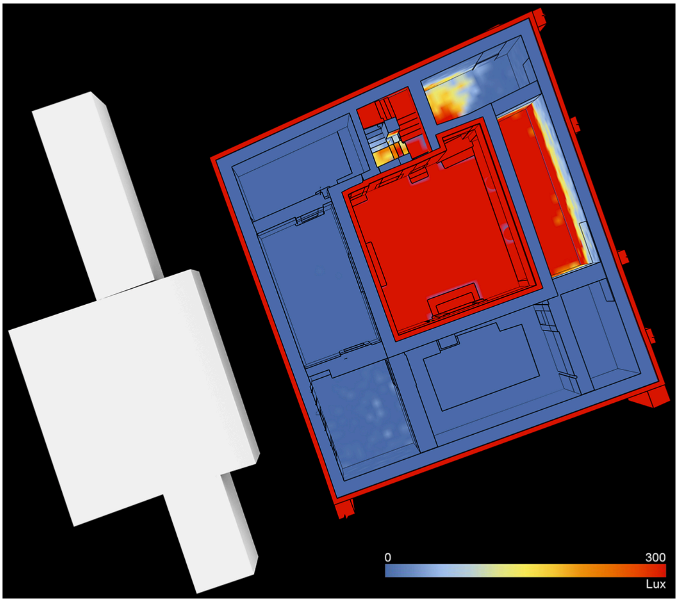
Suppl. Fig. 6b. *Point-in-time illuminance simulation of the Christian Building (M8-A) after adaptation (orientation is to true north; render parameters: July 253 CE, 1630 hours, windows and doors open; scale: 0–300 lx). (C. Leon Angelo and J. Silver.)*



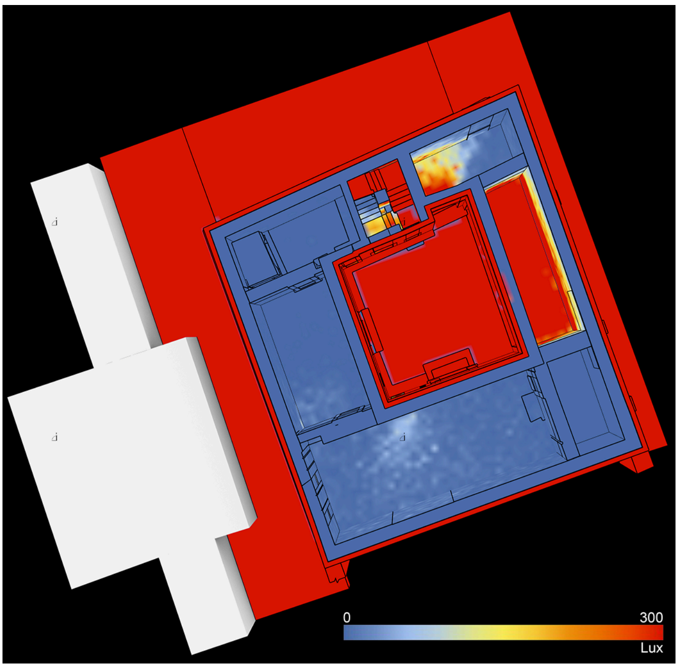
Suppl. Fig. 7a. *Point-in-time illuminance simulation of the Christian Building (M8-A) before adaptation (orientation is to true north; render parameters: January 243 CE, 1630 hours, windows and doors open; scale: 0–300 lx). (C. Leon Angelo and J. Silver.)*



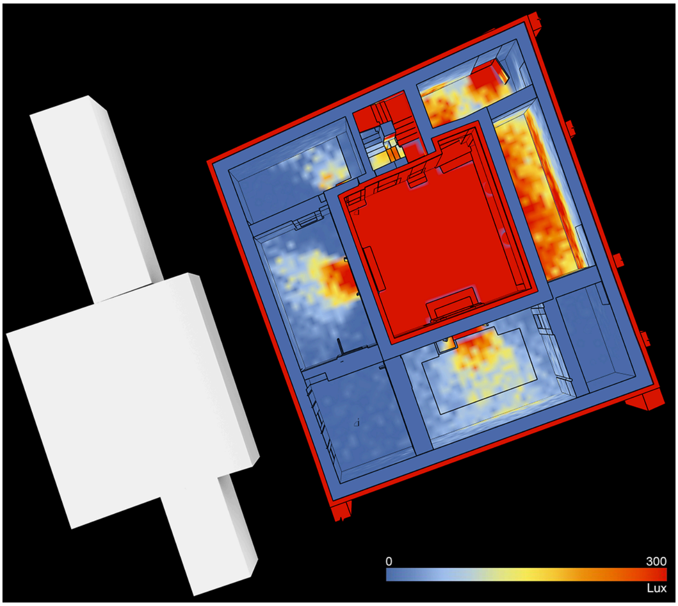
Suppl. Fig. 7b. *Point-in-time illuminance simulation of the Christian Building (M8-A) after adaptation (orientation is to true north; render parameters: January 253 CE, 1630 hours, windows and doors open; scale: 0–300 lx). (C. Leon Angelo and J. Silver.)*



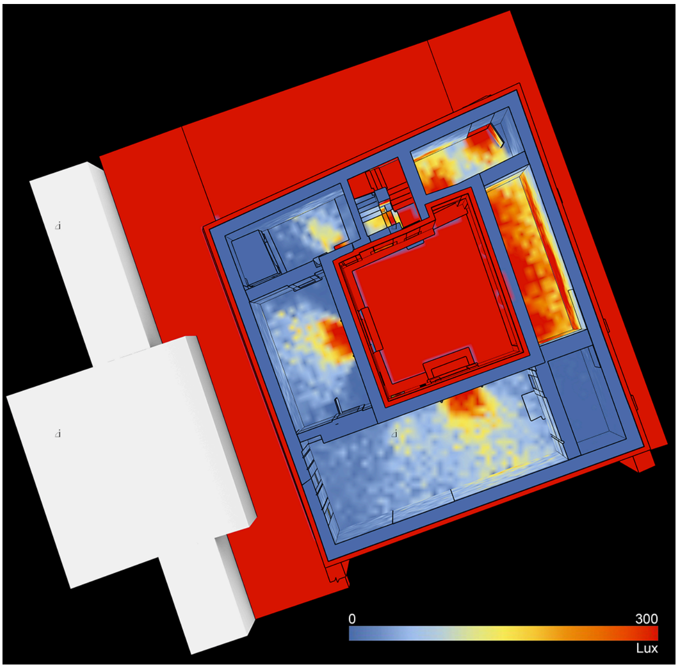
Suppl. Fig. 8a. *Point-in-time illuminance simulation of the Christian Building (M8-A) before adaptation (orientation is to true north; render parameters: January 243 CE, 1530 hours, windows open and doors closed; scale: 0–300 lx). (C. Leon Angelo and J. Silver.)*



Suppl. Fig. 8b. *Point-in-time illuminance simulation of the Christian Building (M8-A) before adaptation (orientation is to true north; render parameters: January 253 CE, 1530 hours, windows open and doors closed; scale: 0–300 lx). (C. Leon Angelo and J. Silver.)*



Suppl. Fig. 9a. *Point-in-time illuminance simulation of the Christian Building (M8-A) before adaptation (orientation is to true north; render parameters: January 243 CE, 0748 hours, windows and doors open; scale: 0–300 lx). (C. Leon Angelo and J. Silver.)*



Suppl. Fig. 9b. *Point-in-time illuminance simulation of the Christian Building (M8-A) after adaptation (orientation is to true north; render parameters: January 253 CE, 0748 hours, windows and doors open; scale: 0–300 lx). (C. Leon Angelo and J. Silver.)*