NATURAL LIGHT MONITORING AND SUSTAINABLE RETROFIT OF CLASSROOMS IN ANTOFAGASTA, CHILE

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Summary

This paper discusses the retrofit process of a classroom located in Antofagasta midtown, in Chile. Climate is desert coast climate, characterized by high solar radiation levels (both beam and diffuse radiation), as well as very high sky luminance (about 12.000 lm/m^2 in the typical sunny day and more than 22.000 lm/m^2 in an overcast sky). Educational buildings in Chile are quite poor in terms of energy efficiency and comfort issues, but Government Agencies like AChEE – Chilean Agency for Energy Efficiency are working on the retrofit of this kind of spaces, because of the importance of education results on the predictable development of the Country. School of Architecture of the Catholic University of the North – UCN, is involved in the energy efficiency policies and research. As result of an internal research project, a case study classroom has been selected, monitored and simulated searching for the optimization of light and thermal performance. Users have been involved with questionnaires and educational results monitoring before the retrofit. Retrofit actions to take have been selected by computational simulation considering the following parameters: intensity and distribution of light, sun penetration profundity and glare probability. Simulation tools used in simulation are Ecotect, Radiance and DaySim. Final retrofit is currently on-going and results expected are an improving of more than 50 % in the ambient quality described with the considered parameters and a general satisfaction of final users. Better educational results of children are also expected as secondary result of the retrofit process.

Keywords: natural light, educational buildings, building simulation

1 Introduction

Educational buildings are only a small part of the entire building sector around the world, but they are very important because of the role that they play in the society. Some investigations indicate that academic results of the students are in direct relationship with the classroom performance [1], [2], [3]. Moreover, the Chilean education sector has been hardly discussed during the last years, with student's request of changes and improvements in the general condition of the educational system of the country.

Academic results of the Chileans are quite poor because of a certain number of factors, such as family, television, bad companies, etc. However, it can be certainly said that educational buildings are often totally inappropriate for listening and concentration, how academic study requires. Even in university classrooms students feel cold or warm depending of the season, light is inhomogeneous, acoustic and ventilation performance are absolutely poor.

The object of this paper is a research developed to contribute to improve the energy efficiency and the comfort of the UCN's classrooms. We focused on natural light use and distribution because of its importance in this climate emplacement. Antofagasta has a very mild climate, with temperature around the 24 degree Celsius during the whole year. Classrooms seem not to have problems in thermal conditions, but solar radiation is very high: the northern desert of Chile is one of the world sites with the mayor levels of beam radiation. In general, we have to protect us from direct solar radiation during all the day and all the year. Cloudiness of the sky is variable during the day; normally the sky is overcast in the morning and clean in the afternoon.

2 Methodology

Literature [4], [5], [6] suggests light values on the work plan of about 500 lux for offices and schools. Glare has to be avoided (both direct and reflected glare). Distribution of light has to be as much uniform as possible. Sun penetration has to be highly avoided in this climate [7], [8]. With these values in mind, we select the classroom to investigate.

Classroom D101 locates in the School of Architecture of the UCN Campus. It has a large window exposed to north (to the sun in this hemisphere). In front of the window a building project small shadows, that are not relevant on the performance. In the morning (from 7 to 9), classroom is protected from direct sun radiation by the school main building and by the mountains, which enclosed Antofagasta city to the sea. From 10 to 15 hours, sun is entering on half zone of the classroom. After 16, a building located on the west project a large shadow and protects the window.

Methodology selected to establish the retrofit objects was:

- First, to do a questionnaire with the objective to understand the prevalent user feelings in the space;
- Second, to monitoring the natural light levels in the classroom during a typical day;
- Third, to do simulations in order to predict the possible behaviour after a retrofit;
- Fourth, to retrofit the classroom;
- Fifth, to do a new questionnaire to the users.

Question included in the questionnaire ask users about the quantity of light, the glare sensation, the light distribution, the colour preference, the thermal sensation and the general agree with this classroom as a space to study. Users are students 20–22 years old, using normally this classroom for the lessons. General response was that light was not uniform, with molesting glare at certain moments. Classroom was described also as little cold, with too much white colour on the walls. Figure 1 shows the classroom aspect before retrofit and the Ecotect model built for simulation studies.

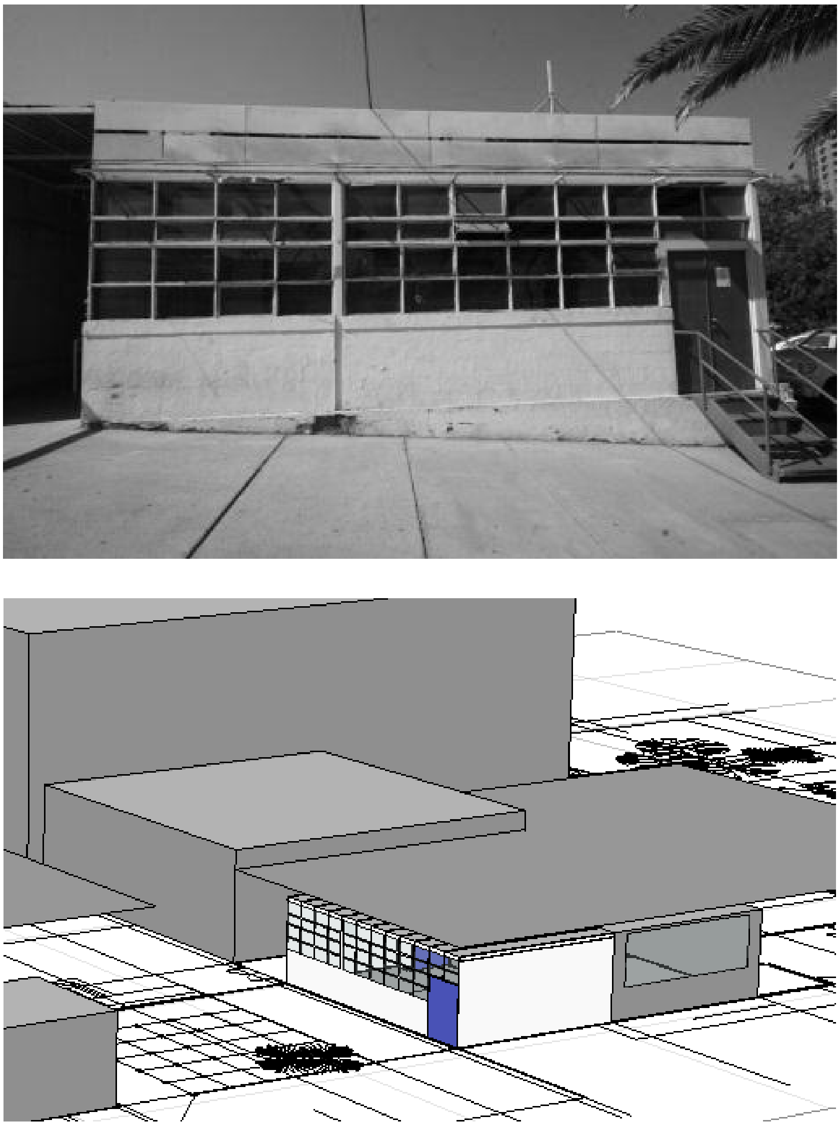

Fig. 1 *D101 Classroom north façade and Ecotect model*

3 Simulation and monitoring results

Monitoring was done during a sunny day and indicates that light values are extremely high, especially between 12 and 14 hours. Classroom was divided in parts and light level was monitored in a plan 600 mm high, where students work. Results shows that light distribution is not uniform: close to the window light levels are 4000 lux at 12.00, 2000 at 14.00, 1500 at 16.00. Far from the window, light levels are 800 lux at 12.00, 600 at 14.00, and 400 at 16.00. We detect also small differences in the same lines. Artificial light, used from 20.00, has a value of 350 lux quite uniform. Figure 2 shows the monitored lighting levels (windows to the right) at 10, 12, 14, 16, 18 and 20 hours.

h 10 ext 16000 lux

446	626	790	1298	2158
582	684	949	1565	2515
664	775	1097	1620	2545
731	803	1211	1613	2594
677	814	1029	1731	2530
	1336	1088	951	

h 12 ext 22500 lux

620	878	1179	2117	4340
825	982	1448	2647	5105
823	1004	1550	2760	5404
973	1075	1840	2520	5180
1010	1208	1650	3204	5570
	1346	1584	2220	

h 14 ext 16000 lux

415	541	672	1031	1630
530	583	766	1210	1900
608	676	903	1316	2075
680	730	1033	1348	2230
652	760	960	1530	2268
	928	1082	1302	

h 16 ext 10375

493	610	678	935	1088
564	580	682	951	1253
610	619	769	987	1357
643	646	832	1001	1375
593	662	807	1168	1435
	862	1013	1243	

h 18 ext 6470

276	318	350	660	792
325	328	384	515	656
341	336	418	547	734
375	366	467	534	752
367	385	455	673	801
	557	660	806	

h 20 ext 1410

56	78	88	132	168
73	80	102	146	194
74	79	106	156	223
81	83	118	145	198
66	77	93	152	200
	94	113	145	

Fig. 2 *D101 monitoring result for 6/12/2012 10–20 hours*

Simulations have been conducted in order to establish better retrofit to undertake, between the following options:

- Curtains, colour white, transparency 40 %
- Eaves on the top of the window, large 60 cm, colour grey
- Eaves on the top of the window, large 60 cm, colour white
- Eaves on the middle of the window, large 60 cm, colour grey
- Eaves on the middle of the window, large 60 cm, colour white

Best results in terms of uniformity and level reduction are achieved with the combination of the two eaves and the curtains. Colour of the eaves seems not to have strong influence on the result. Figure 3 shows the base case situation analysed using Ecotect simulator. Simulation parameters have been inserted according to IBPSA indications [9].

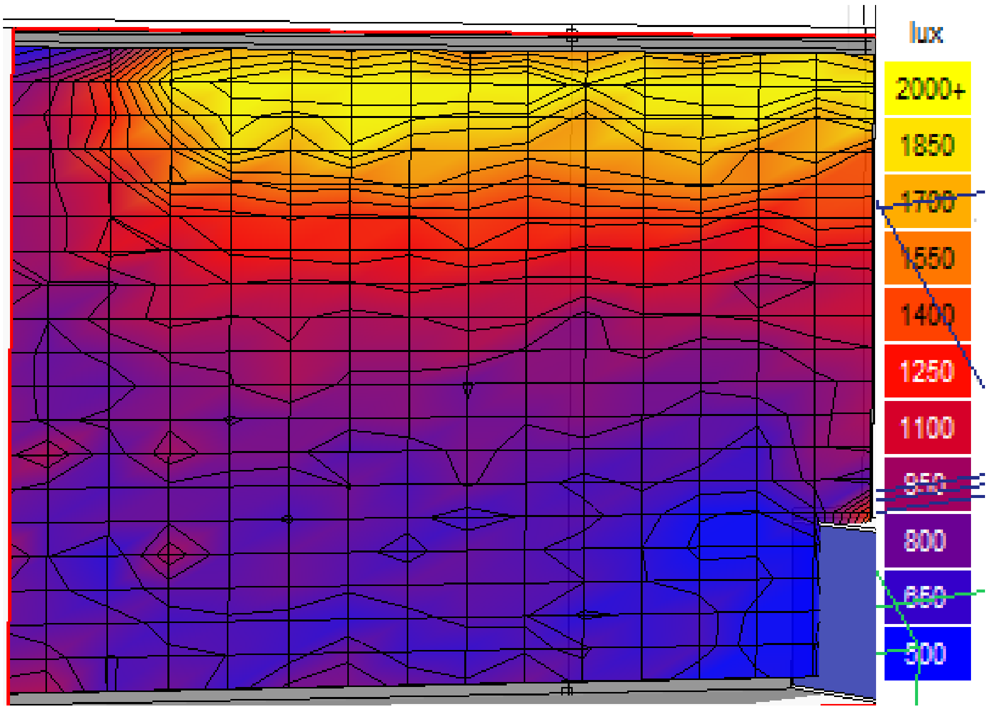

Fig. 3 *Simulation results of the base case*

Figures 4 to 8 show the single action of one of each intervention simulated. It can be notice that only a combination of different intervention can lead to an acceptable result in terms of both uniformity and level of natural light. Especially, the curtain effect is needed to guarantee less than 1000 lux near the window. At the other hand, eaves are needed to establish certain uniformity in light distribution, because of the double effect of protection and deep reflexion of light. Figure 9 show the final application selected: two grey eaves and the curtain.

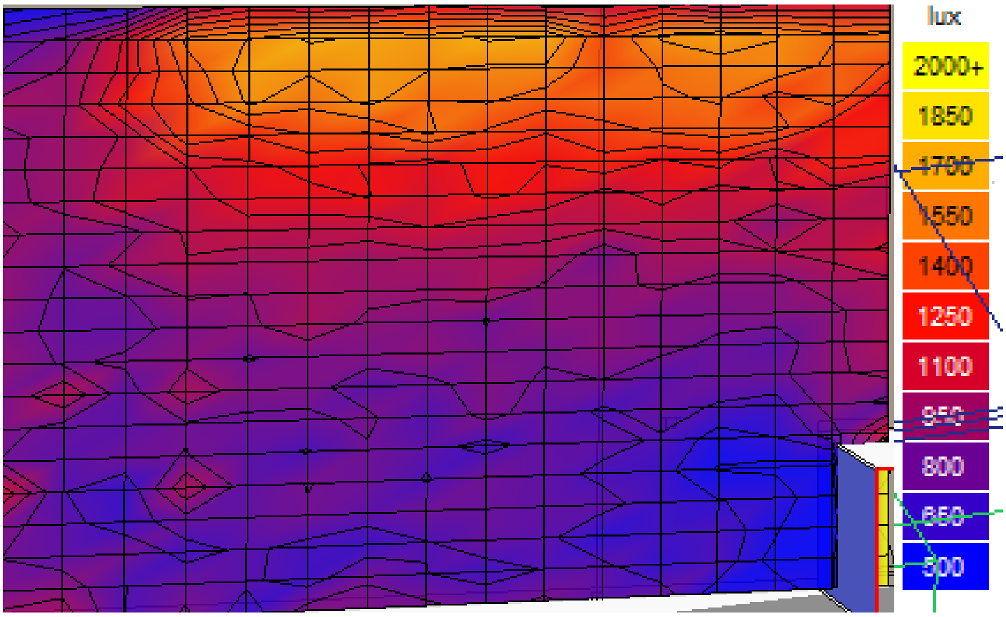

Fig. 4 *Simulation results of the inferior eaves colour withe implementation*

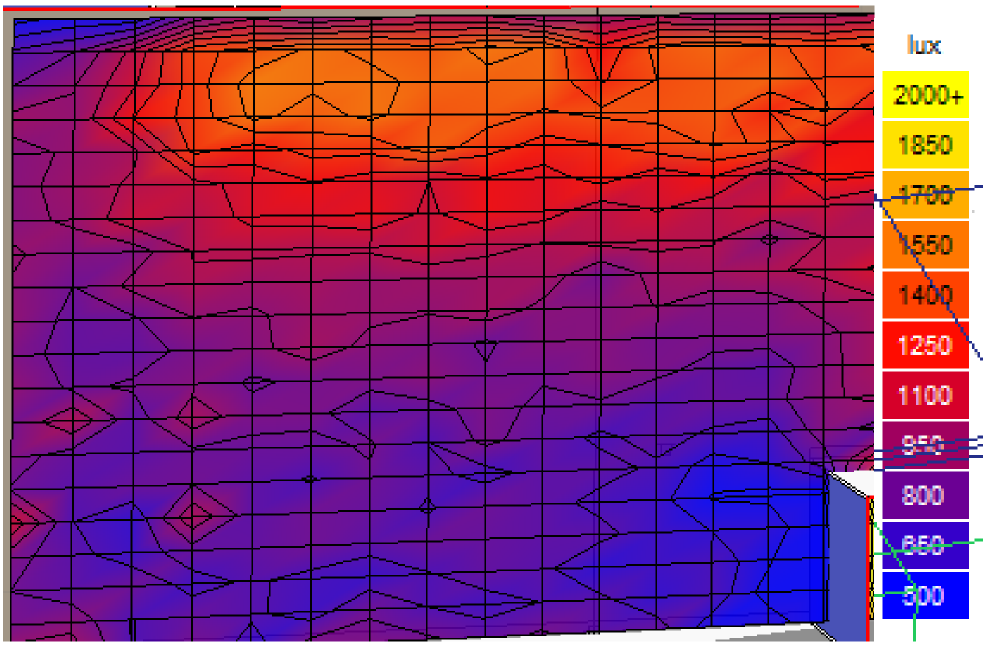

Fig. 5 *Simulation results of the inferior eaves colour grey implementation*

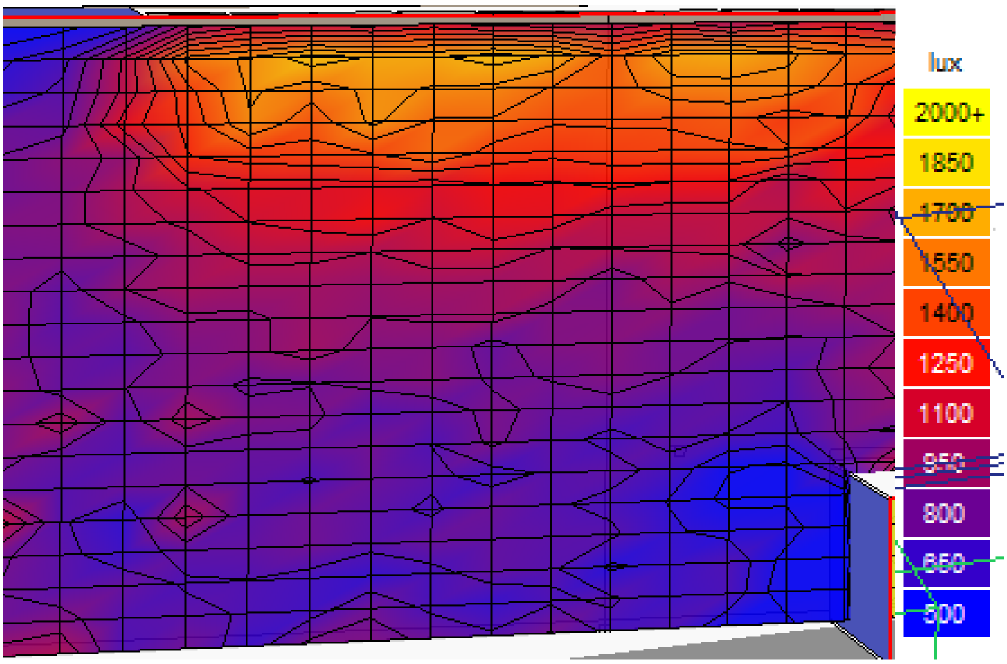

Fig. 6 *Simulation results of the superior eaves colour withe implementation*

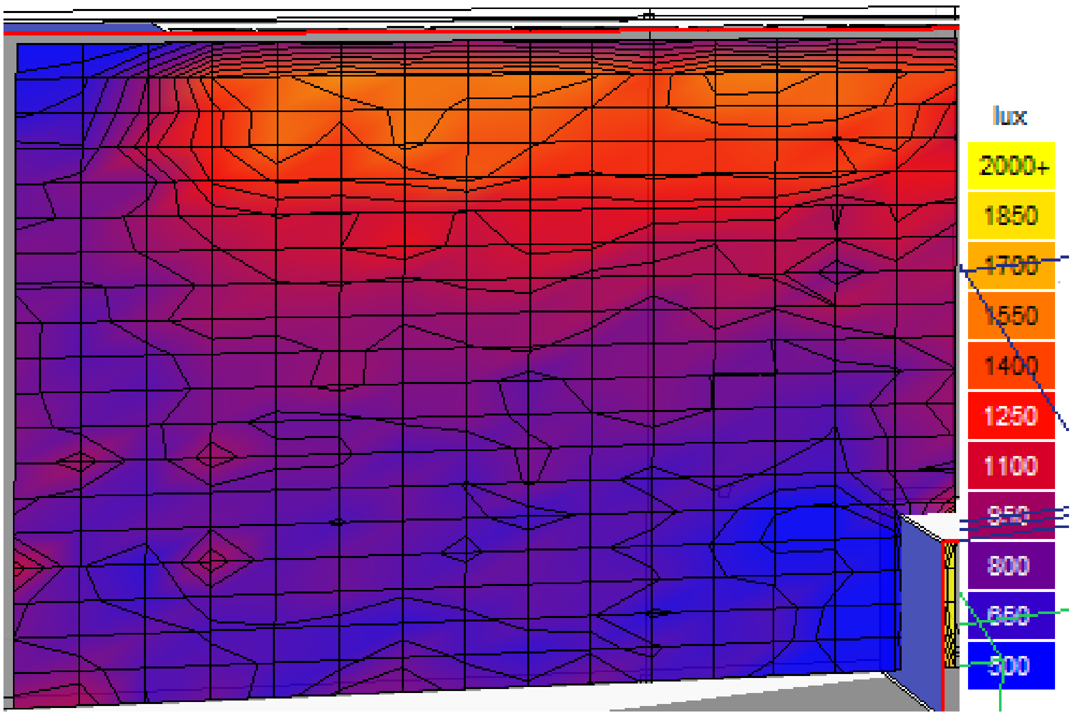

Fig. 7 *Simulation results of the superior eaves colour grey implementation*

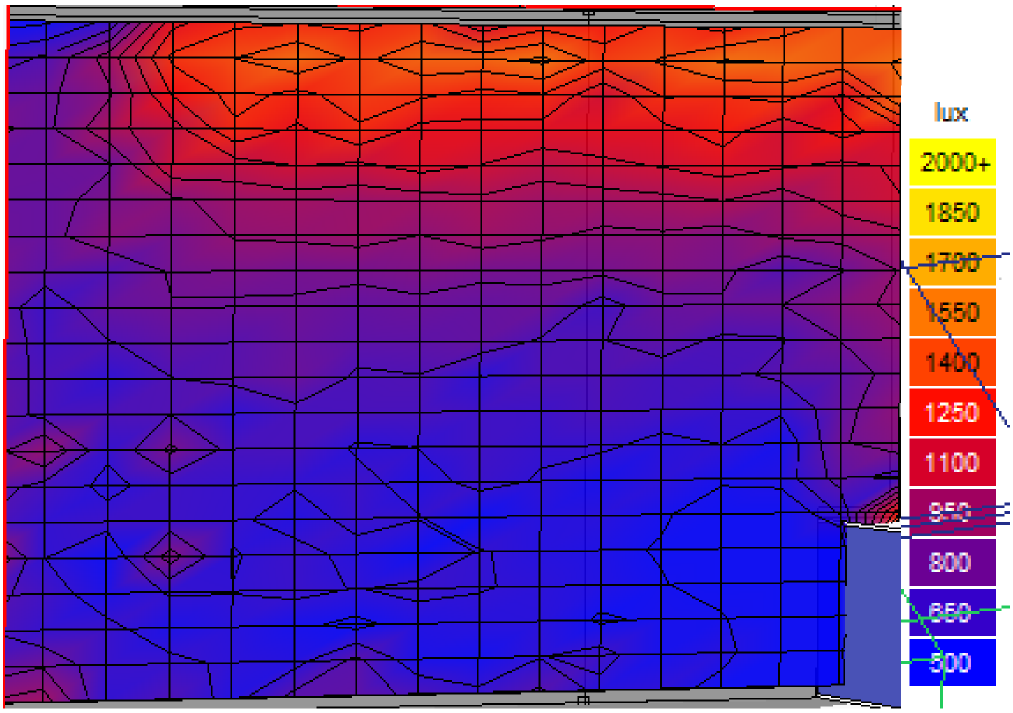

Fig. 8 *Simulation results of the curtain implementation*

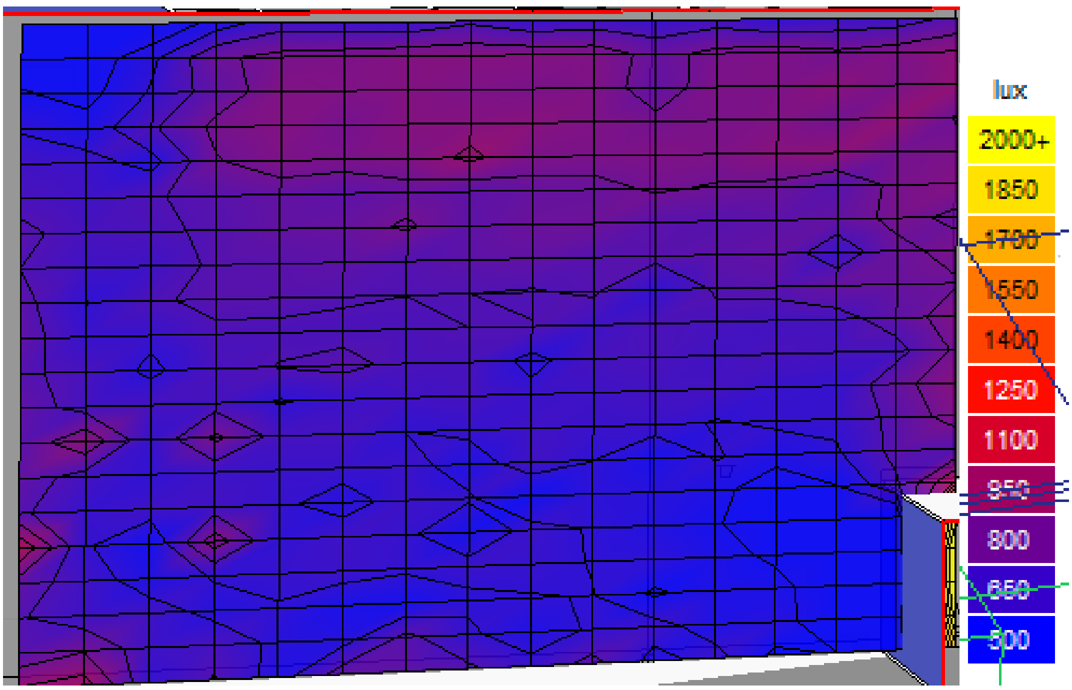

Fig. 9 *Simulation results of the retrofit selected actions (two eaves and curtain)*

4 Conclusions

As simulations indicate, retrofit was done installing two eaves on the big north face window, one on the top and other in the middle. Additionally, a set of double courtains were installed in the interior, one light curtain to reduce light levels up to 40 %, and other curtain, darker, to use the classroom to shows photos or presentations.

After-retrofit monitoring confirms the simulation result: now classroom has light levels about 600–800 lux at 12.00 and 14.00 and 400-500 lux at 10.00 and 16.00 hours. Questionnaire has also been submitted to the students: user satisfaction increases in 50 %.

Relation between comfort sensation and academic results has not been investigated yet. Before the retrofit the approval rate of students was 80 %, it is expected to increase the approval rate to 90 % during this semester. Obviously, one classroom lightening retrofit is insufficient information to be conclusive on this question. However, light values and distribution are now more according to recommended and user's satisfaction improved.

Acknowledgement

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