Evaluation of Indoor Climates Using the 'Climate Evaluation Chart'

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ABSTRACT

The indoor climate plays a key-role in relation to sustainable building. Often measured or simulated time series are used for the evaluation of indoor climate performances. Analyzing these data might be a problem due to the lack of proper visualization tools. In this paper, we introduce a new way to visualize long-term (seasonal) and detailed (less than 1 hour) measured or simulated indoor climate data compared to demanded criteria in a single chart: the Climate Evaluation Chart (CEC). Furthermore, the use of CECs is demonstrated by two case studies: (1) Preservation priority. This case comprehends the evaluation of various indoor climate control designs of a famous Dutch museum, in relation to the preservation of paintings. (2) Thermal comfort priority. The thermal comfort in a fully controlled standard office is evaluated in relation to the energy usage. It is concluded that CECs can be quite helpful for analyzing indoor climate data in relation to its criteria. Furthermore, the CEC is implemented in a web application and is public domain.

KEYWORDS

Indoor climate, building physics, visualization tool, psychometric chart, climate demands, building performance simulation

INTRODUCTION

Nowadays, a lot of modern measurement equipment is available to perform different indoor and outdoor climate measurements. Wireless sensors promote measurements on several positions. Also the storage capacity of modern systems is nearly infinite. Therefore the amount of available data has increased drastically. This means that the analysis of indoor and outdoor climates has become more and more complex.

The usual way of plotting time series of measurement data is not the easiest way to analyze the data. Due to the availability of computers, more complicated plots can be displayed. This article introduces the 'Climate Evaluation Chart' (or CEC) as a new way of visualizing measured or simulated data. The layout of the CEC is explained.

Two case studies show the use of the CEC at different occasions. Some conclusions about the CEC are stated. Finally a web interface is described and the name of the web page is given so the whole world can create CECs.

EXPLANATION OF THE 'CLIMATE EVALUATION CHART'

An example of the Climate Evaluation Chart (CEC) is shown in figure 1. In this figure, area 1 displays the title of the graph and the period that is plotted. Region 2 shows the demanded performance on: (1) climate boundaries – maximum and minimum temperature and relative humidity (min T, max T, min RH and max RH) – and (2) climate change rate limits – maximum allowed hourly and daily changes (ΔT/hour, ΔT/day, ΔRH/hour and ΔRH/day).

Area 3 – the basis of the chart – is formed by a standard psychometric chart for air. On the horizontal axis the specific humidity is displayed and on the vertical axis the dry bulb temperature is shown. Also the curves for relative humidity are displayed.

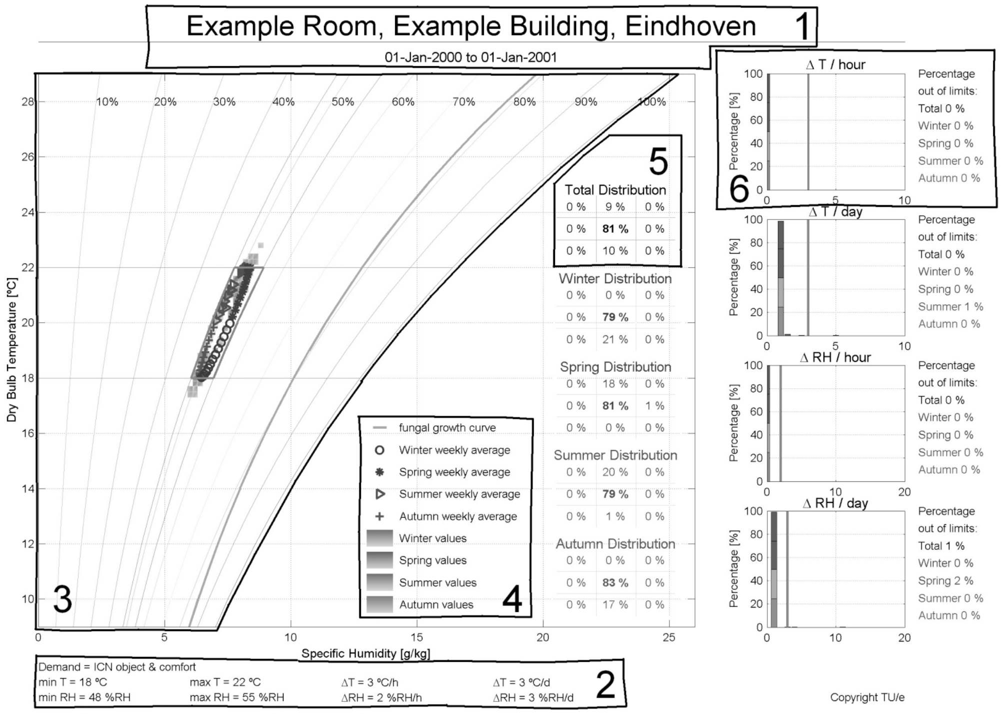

Figure 1: example of a 'Climate Evaluation Chart' (Note: some parts of CEC rely on color).

Area 3 also shows the climate limits (the blue lines) and the measured or simulated climate. This climate is represented by a different color for each season. The saturation of these colors represents the percentage of time of occurrence. Also seasonal weekly averages are displayed. The colors visualize the climate distribution. Area 4 provides the corresponding legend.

Area 5 shows the total percentage of time of occurrence in each of the areas in the psychometric chart (9 areas, marked by the blue lines). In this example, 81% of time the climate is within the climate limits; the area to the top (too hot) occurs 9% of time, the area to the bottom (too cold) occurs 10% of time. The climates in the other 6 regions do not occur. Below the total distribution the same can be found for each season separately.

Area 6 presents the occurrence in percentage of time outside the climate change rate limits. In the example the demand of the maximum allowed hourly change of temperature of 3 (ºC/hour) is shown as a blue line. The distribution per season is provided together with the percentage of time the value is out of limits. In this example, area 6 shows that the hourly temperature change rate is within the limit during the entire period. Below area 6 the same can be found for the other climate change rate boundaries.

USE OF THE CLIMATE EVALUATION CHART

The Climate Evaluation Chart can be used in many different areas of interest. First, a case that focuses on the preservation of paintings is discussed. Second, a case that focuses on thermal comfort is described.

Case 1: preservation priority

Background

In the 1980's, a monument – that has a lot of windows – was adapted to be a museum. A HVAC system was installed in this building and part of the windows were blinded (see figure 2). Some paintings are located in front of these blinded windows. Although the indoor climate is very strict, the paintings begin to show some cracks in the thin layer of paint.

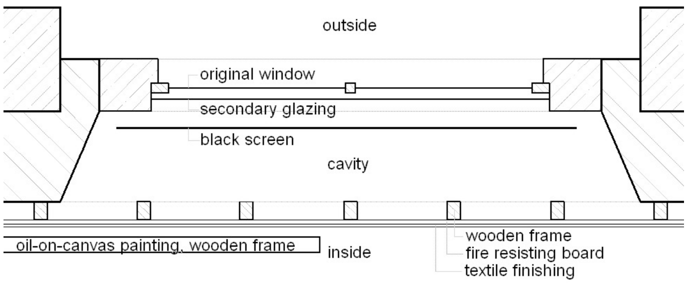

Figure 2: horizontal section of the blinded window.

Measurements and results

Temperature and relative humidity were measured, in between the painting and the textile finishing of the wall, during one year. The result of this measurement is displayed in figure 3. During the summer and autumn period, the temperature near the canvas of the painting reaches 29 ºC. The relative humidity drops to about 35 %. The maximum daily changes in temperature are 10 ºC, in relative humidity more than 20 %.

The cause for the change in temperature is the presence of the blinded window. Solar radiation, which falls onto the black screen, causes the cavity temperature to rise. Only a thin, un-insulated construction separates the cavity from the painting, so also the painting experiences this rise in temperature.

By moving this painting to an internal wall, the cause of possible deterioration of the painting will be limited. Figure 4 shows the measured local climate near an internal wall. The temperature and relative humidity have improved. Also the daily changes in temperature and relative humidity decreased.

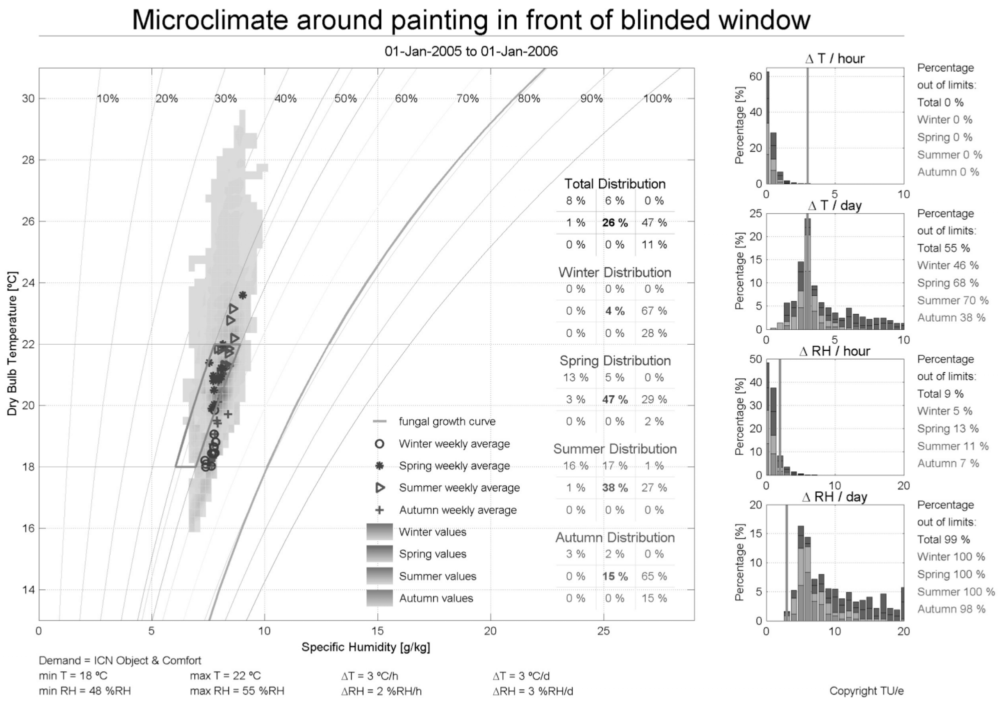

Figure 3: CEC of a painting near a blinded window (Note: some parts of CEC rely on color).

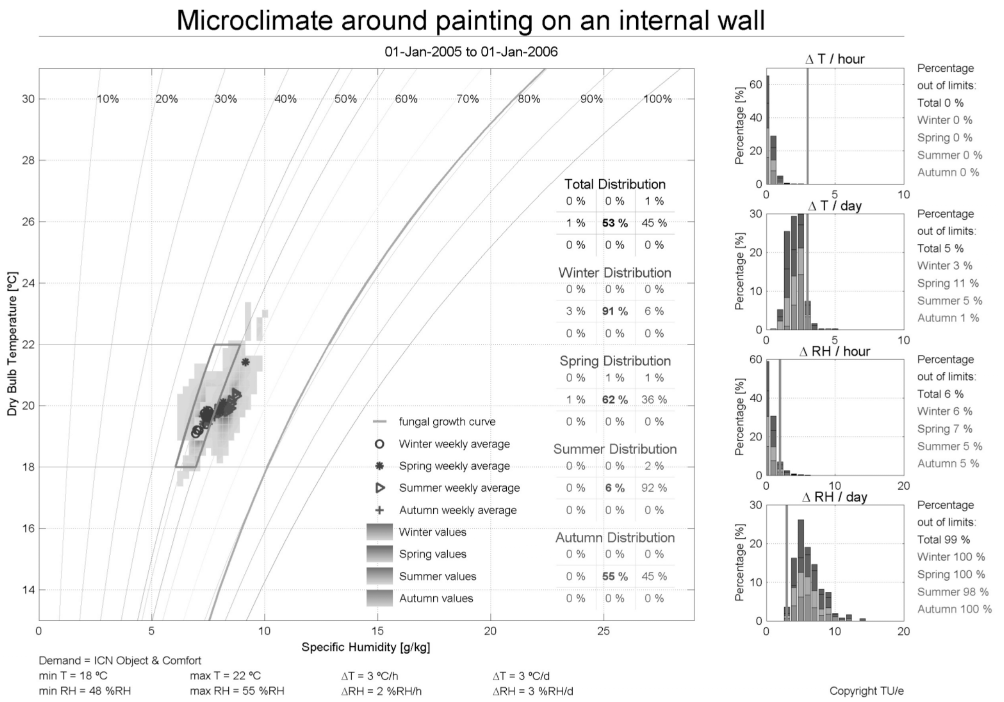

Figure 4: CEC of a painting near an internal wall (Note: some parts of CEC rely on color).

Case 2: thermal comfort priority

Background

The Dutch senate is housed in an ancient office building. This building, built between the 15th and 19th century, has a simple heating system. Due to modern technology many computers – that produce heat – are used in the office spaces. The main problem in the building is the overheating during the summer period.

The Senate building is a monument. This implies that changes to the building should not have any impact on the exterior or the interior of the building. Installing ducts and shafts for air handling systems is simply not possible. So, other solutions should be found.

Measurements and results

Measurements were taken for a period of one summer. These measurements are displayed in figure 5. Because the comfort is only of interest during the opening hours of the office, only the data between 8 AM and 5 PM are displayed. Moreover, the Saturdays and Sundays are not taken into account.

The square shows the comfort area. It is easy to see that the comfort is not as it should be. High temperatures occur. 23 % of the summer period is above the upper limit.

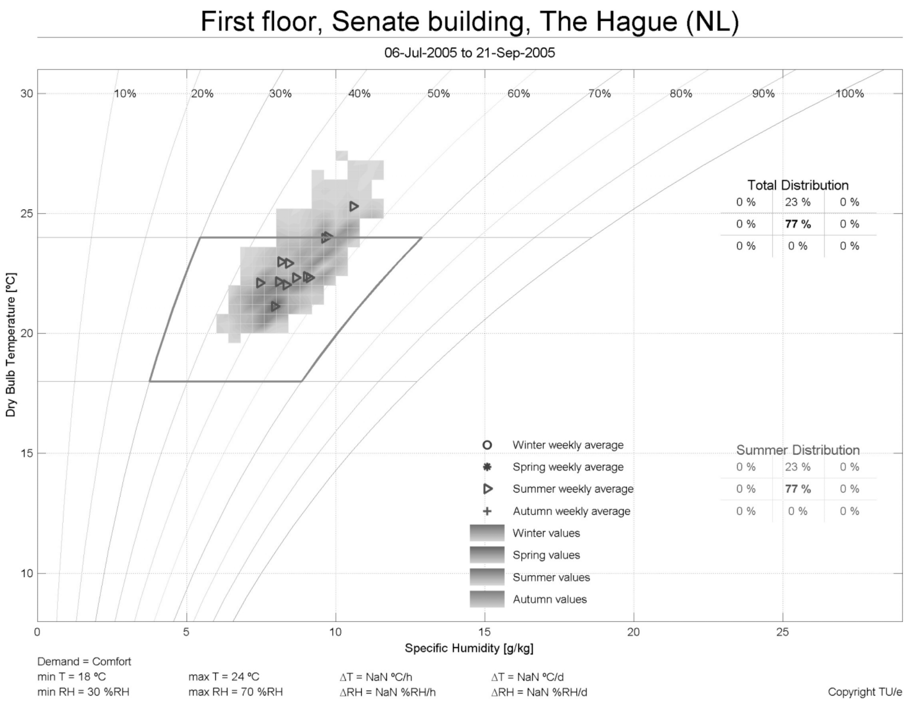

Figure 5: Measurements in the Senate building (Note: some parts of CEC rely on color).

Figure 6 shows the same period of data but now for a simulated indoor climate. Blinds were placed in front of the windows. These blinds already are present on the existing building, but they are hard to operate. An electric system can be added to automatically open and close the blinds. In addition, during the evening and morning period, the ventilation rate is increased to provide free cooling.
The period in which temperatures are too high decreases from 23 % down to 14 %. Note that due to the ventilation extra moisture is added and that the maximum relative humidity of 70 % is exceeded during 15 % of the time.

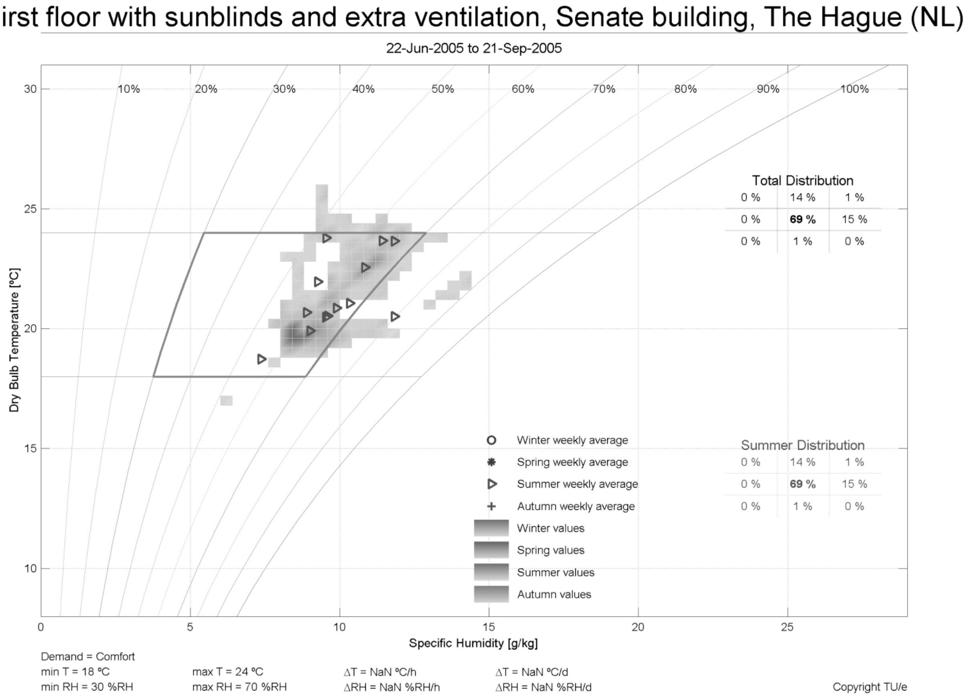

Figure 6: CEC of the Senate building after changes (Note: some parts of CEC rely on color).

CREATION OF CECS USING THE WEB INTERFACE

The Climate Evaluation Chart can also be created using a web interface. On http://sts.bwk.tue.nl/monumenten a link can be found called ‘web applications’. One can upload a text file which contains measured or simulated data. A choice can be made which climate demands to use. Other options are available too, such as temperature range and a fungal growth curve. All of the above is supported through online help.

CONCLUSION

The CEC is easy to use. It is instantly clear what the problem at one certain position in a building is. The CEC makes it easier to compare the data with climate demands.
The CEC does not only show the climate itself. It also shows the derivative of both temperature and humidity. Hourly and daily changes are calculated and compared to a climate demand.
The CEC uses colors to visualize differences in seasons. If a CEC is used on a web page or in a simulation program this is an advantage. But printing it in black-and-white makes it less useful.

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