A draft solar-climatic and impacts analysis of the proposed complex in Villeray–Saint-Michel–Parc-Extension

OCPM

(Office de Consultation Publique de Montréal)

Mémoire: Projet Immobilier, Les Ateliers Castelnau

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1: R.M.M. Solarch Studio, www.solarchvision.com

March 2014

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Canadian Weather Energy and Engineering Datasets CWEED:
Long term hourly solar radiation and temperature, etc. contains information licensed under the Open Government Licence – Canada.
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A draft solar-climatic and impacts analysis of the proposed complex in Villeray–Saint-Michel–Parc-Extension

1. Montréal's current & future challenges

1.1. According to weather data and considering the impact of a solar-climatic approach in design and planning

Contrary to popular belief, cold and at times cloudy conditions, like those of a Montréal winter, should not be considered a convincing reason to avoid applying and optimizing solar designs in buildings and urban quarters. On the contrary, solar studies and consideration of the sun in architectural and urban design are essential in cities with extreme temperature conditions, whether cold or hot, simply because in many cases, extreme high and low temperature conditions are also sunny (for more detail please compare long-term historical plots on Figures 42 & 46 with Figures 44 & 48, and also see cloud cover and air temperature forecasts for 14 March 2014 on Figures 33-34).

Even in Montréal with winter temperatures between -10°C and -30°C, the availability of hourly direct beam radiation can exceed 750W/m² and sometimes can even reach 1000W/m². In other words, in Montréal the coldest and warmest temperatures most often likely occur on sunny days. This simple fact increases the importance and great benefit of considering the sun, both in planning of buildings as well as the interaction of those buildings with outdoor areas in Montréal (for more information see Figures 41-42 and Figures 45-46 in the appendix).

On the coldest days of winter, the effect of having often abundant direct solar radiation on the building skin (e. g. windows) and in outdoor areas happens to coincide with the increase need for energy for heating. On other winter days, when it is completely cloudy, or when it snows, direct radiation decreases; however, in most of these cloudy cases, the need for benefiting from direct radiation is lower as the air temperature is less cold, often close to 0°C (for more information see Figures 43-44 and Figures 47-48 in the appendix).

A change in the hourly daily temperature associated with solar gains can have a significant effect on the heating and cooling loads of buildings, as well as on the levels of comfort or discomfort in useable spaces inside and outside of buildings. The courtyards, building skin and the HVAC system, can be designed to respond effectively to the general solar-climatic patterns at each location. The issues concerned with the outdoor space, on the other hand, are more related to health and safety, rather than energy loads and operating costs. For instance long episodes of overshadowing in winter conditions can increase the ice build-up in some areas and as a result, increase the danger of damage and injuries as a result of snow accumulations and falling ice.

While some studies suggest a change in general temperature patterns in the past decades, some studies also highlight the fact that as time goes by, Montréal is experiencing sunnier situations since it appears that the average amount of direct beam radiation has been increasing significantly both in summer and winter. And in the case of Montréal, a sunnier situation means not only more warm days with higher air temperatures in summers, but could it also mean more sunny days in winter accompanied by extremely cold air temperatures (The sun and the city of Montréal, 2013), (see Figures 9-10).

"*It is nevertheless important to be reminded of the sun not only as a powerful and perpetual actor in our dynamic atmosphere but also as a basis for figuring out a variety of adaptive solutions that must be identified and followed.*" (Intelligent design using solar-climatic vision, 2014).

Solar-climatic studies during the processes of building skin and urban design can improve many aspects including the potentials and performances in terms of energy production, energy demand, daylight, health, comfort and safety for long periods of time; with the added benefit that most of these architectural rearrangements and improvements do not necessarily increase the construction costs.

To bring and maintain good qualities associated with life-cycle, health, comfort and safety measures, it is therefore essential to:

1. develop a mitigation plan to adapt existing buildings and urban spaces in Montréal to accommodate ongoing changes in local climate and micro-climates variables and to prepare for conditions and scenarios;
2. integrate comprehensively the environmental considerations and weather data details as early as possible in the planning and design processes and also in construction and operation phases.

(Also see Weather Forecast Data an Important Input into Building Management Systems, Poulin, 2013).

1.2. According to OCPM - Montréal Development Plan

According to the OCPM 2014 report on the consultation held on the draft Montréal Development Plan: "*after analysis of all the information, the commission considers that Montréal cannot escape three challenges*". "*Adapting the city to climate changes*" is the first one noted. In response to these three challenges and to different issues, the commission proposed to achieve 5 targets including: 1. a compact and efficient city; 2. an inclusive and supportive city; 3. a city of culture and knowledge; 4. a green city; 5. a thriving city (OCPM-PDM, 2014).

It is also highlighted that: in terms of adapting the city to climate changes: such changes lead to serious problems in terms of public health, life and property safety and pollution – a 20 to 30% increase in the mortality rate was recorded in certain heat islands during the latest heat waves, not to mention the major inconveniences associated with periods of extreme cold; the drop in air quality during smog episodes; the flooding of certain areas of the city in heavy rains; or the pollution of shorelines and waterways resulting from overflows. The commission recommends the adoption of a Montréal climate change, an adaptation plan that would ensure such consistency. Besides, one of the recommendations is to make pedestrian safety and comfort the basic principle of Montréal's approach (OCPM-PDM, 2014).

2. The project (Les Ateliers Castelnau)

2.1. Solar-climatic analysis

The solar-climatic analysis presented here highlights the overshadowing impacts of proposed complex in Villeray–Saint-Michel–Parc-Extension. As a result the attention of the OCPM should be drawn to what appears to be the negative effects that could likely result from the proposed layout of building volume on certain courtyards, pedestrian paths and entry points in this project (see Figures 18-19).

In addition, and as is analyzed, this arrangement of the proposed complex would produce negative effects on the energy efficiency performance of the existing building: “Anciens Ateliers” (see Figures 20-21).

The negative impacts in terms of solar-climatic aspects are illustrated in red, orange and yellow levels. As is presented in the analysis, the proposed arrangement of buildings could most likely lead to the creation of undesirable and unsafe courtyards (notably the court on the north side of the complex) (see Figures 22-23).

Considering the path of the sun as well as the changes in hourly air temperature and solar energy patterns during different months, the performance of each facade during a typical year in Montréal can be studied. The SOLARCHVISION analysis of different facades of this project as well as the interior studies suggest that for each facade of this project different approach can be applied to reduce energy demands and to improve internal thermal/daylight comfort measures for all units within the project (see Figure 14 and Figures 24-25). In this regard the glass areas could most likely be decreased in the north-west and north-east comparing to south-west facades where using large glass areas is recommended (see Figure 15).

It is also necessary to mention that to reduce overheating in summer it is also essential to design and optimize ingenious shading devices for each building orientation namely south-west and north-west as well as south-east facades. Also, to improve the indoor air quality especially in summer, it can be suggested to consider a ventilation corridor on top of the access corridors. As a result, the units could then basically be opened to these corridors to have effective cross ventilation.

In addition to building skin issues, on each floor plan, there are a number of units with no proper daylight; however even by considering this arrangement as the final layout for building masses, more possibilities exist to simply improve the potentials of each unit. For instance it makes sense that the some units become exposed to the sun in winter instead of access corridors (see Fig. 16-17).

In addition to general yearly patterns observed in the Montréal climate databases, information from real-time weather observations and weather forecasts can be used to optimize the daily decisions associated with the building skin and HVAC systems in order to maximize the operational benefits by harmonizing the building’s operations with real time and anticipated weather conditions. (See Fig. 30-34 as well as “Weather Forecast Data an Important Input into Building Management Systems”, Poulin, 2013).

2.2. General recommendations

One of the recommendations from this modest study undertaken is to rethink the arrangement of volumes namely the eastern side. However, to improve the indoor and outdoor qualities of all the spaces developed in this project as well as certain areas which are affected by this particular arrangement of building volumes, different alternatives should be studied. Obviously, a variety of possible modifications as well as rearrangements should be studied to identify a solution that optimally incorporates different architectural as well as environmental aspects.

Considering the huge roof area of this project, the potential to use this space is significant, for example: harvesting of rain water, heating water with solar water heaters, generating electricity with solar panels, installing a green roof or even a rooftop garden. Even in the case where solar thermal collectors, PV panels or other innovative uses are not included in the present proposal or construction of this project, it can be reasonable to expect that such uses be included and evaluated in the planning phase. By providing minimum requirements of such types of systems and in a setting that can accommodate them, such systems could then be reliably provided and installed by the users in future.

In addition, to prepare the required parking stations, instead of using 100% of the land, a more effective solution should be applied for example: developing a two-story parking structure. This is a remarkably important issue for a number of reasons such as creating/maintaining better conditions for planting the trees, reducing urban heat island contributions and also achieving more flexibility for future developments on this site.

An integrated solar approach suggested here is not limited to recommending beneficial application of solar thermal collectors and PVs to building roofs and facades; however, additional studies can also be performed to help developers of this project to optimize the layout and the performance of such building elements, in case the projects contains a number. Meanwhile, a solar-climatic vision can be applied during the whole design process to improve the good effects that a nice project like this, can have on human life time.

It is hoped that along with the request to take into account the solar climatic analysis and impacts considerations, that the OCPM will also ensure the following considerations have also been addressed as part of the overall project plan. These additional considerations could include: how will the buildings and surrounding areas will be able to manage frequent and intense rainfalls, an analysis of how the building and area will contribute to the urban heat island effect, how will snow load and snow clearing be handled, how all accessible spaces near these buildings will be made to be safe to the public no matter what the weather conditions or the season, how the buildings and spaces in that area will be built in order to be able to, as a whole unit, provide maximum benefit and minimum impacts under the exposure to daily and weekly weather condition scenarios and finally, how will the buildings and area handle what are likely changing climate conditions over the next 50-100 years.

3. Solar-climatic vision

3.1. Quotes

"*L'architecture est le jeu savant, **correct** et magnifique des volumes assemblés sous la lumière.*" (Vers une Architecture, Le Corbusier, 1923)

"*If we ever knew exactly where the light was coming from, getting there would be easy.*" (Back to the light, Brian May, 1992)

3.2. Research objectives

In addition to mapping direct and diffuse solar radiation on buildings, and urban surfaces which can be performed by many available tools, architects as well as urban planners always need an analysis to find out the effect of each architectural element on building skin and urban areas in regard to the varied effects of the sun in different cycles (hourly, daily, annual and in decades).

An integration of ingenious passive design as well as application of intelligent active solutions and systems during the architectural design process can simply improve building skin performance and improve significantly the operation of interior building spaces in terms of energy efficiency, daylighting, comfort, health and safety factors. On the other hand, achieving similar results by using advance materials and technologies not only requires an increase in enormous construction costs but also is not possible in theory/practice.

Moreover, the issues concerned with the outdoor spaces can also lead to immediate impacts. Long lasting building volumes need long time horizons. Bearing in mind the fact that there are just a few solutions available to improve the quality and performance of outdoor spaces, the responsibility of the city and decision makers as well as the time allocated to planning, etc. should be long enough so that the designers can comfortably investigate different parameters and impacts from early stages of design and come up with a responsive solution and integrated form.

3.3. Research limits

Though the information in this document presents SOLARCHVISION best practices by March 2014, the information contained in this document could be improved further still. The quality of the analysis in this document was currently limited because of a lack of access to precise 3-dimensional models of the proposed project as well as other building blocks of this neighbourhood. A best effort was applied by the author to assemble a basic model using the 2-dimensional drawing provided in OCPM documents namely document 3.1 (http://ocpm.qc.ca/sites/ocpm.qc.ca/files/pdf/P73/3a.pdf) to illustrate general impacts. Higher quality input information could likely improve the analysis in more detail.

Additional analysis to demonstrate the building skin as well urban solar-climatic performances during the annual cycle e.g. summer and winter analysis is NOT included in this document because of lack of space; however, such analysis would be included during the oral presentation regarding this project at OCPM.

3.4. Future development areas

There are a growing number of initiatives to integrate best practices of sustainable development as early as possible in the urban planning and development. These best practices are increasingly considering the full range of benefits and impacts from renewable energy considerations and these can be extended to projects of all scales, including buildings such as the ones proposed in this project.

It would be reasonable to think that a comprehensive and robust solar climatic analysis with the best quality input data for the 3D landscape could be considered as part of the borough and city sustainable development plans. It would also make sense that borough and City urban planning and zoning bylaws take solar climatic analysis impacts and benefits into account especially for example if seasonal risks like falling ice can be minimized and the safety and comfort of public spaces can be enhanced as a result.

The city and province's public health groups are also increasingly advocating urban design approaches that will if possible reverse or mitigate the negative impacts from the Urban Heat Island effects and from Heat waves. Proper solar climatic analysis as part of the design stage could be applied to ensure the buildings and surrounding spaces are designed to be as comfortable and safe as possible year-round.

Finally urban planners and architects are also updating their professional codes to strive for improved, efficient and sustainable urban designs. Solar climate analysis could be easily considered to be part of this new and sustainable approach in these areas.

The author welcomes further exchanges with the OCPM consultation committee so that additional updates to this type of information and analysis can be shared regarding this project or similar developments for Montréal.

3.5. Acknowledgments

The author would like to acknowledge Environment Canada (EC) for access to weather observation data retrieved from The National Climate Data and Information Archive.

The author also acknowledges the assistance from Mr. Lewis Poulin of the Quebec High Impact Weather Laboratory of Environment Canada for his help in learning more about the availability and application of deterministic and ensemble weather forecast datasets, summarized in part in one of his presentations made at the International Conference for Enhanced Building Operations (ICEBO), Montréal, 2013.

The author thanks the consultation committee of the OCPM for accepting this document. The author extends an open invitation to the committee to contact the author for any further required information or questions they may have regarding this document.

4. Illustrations

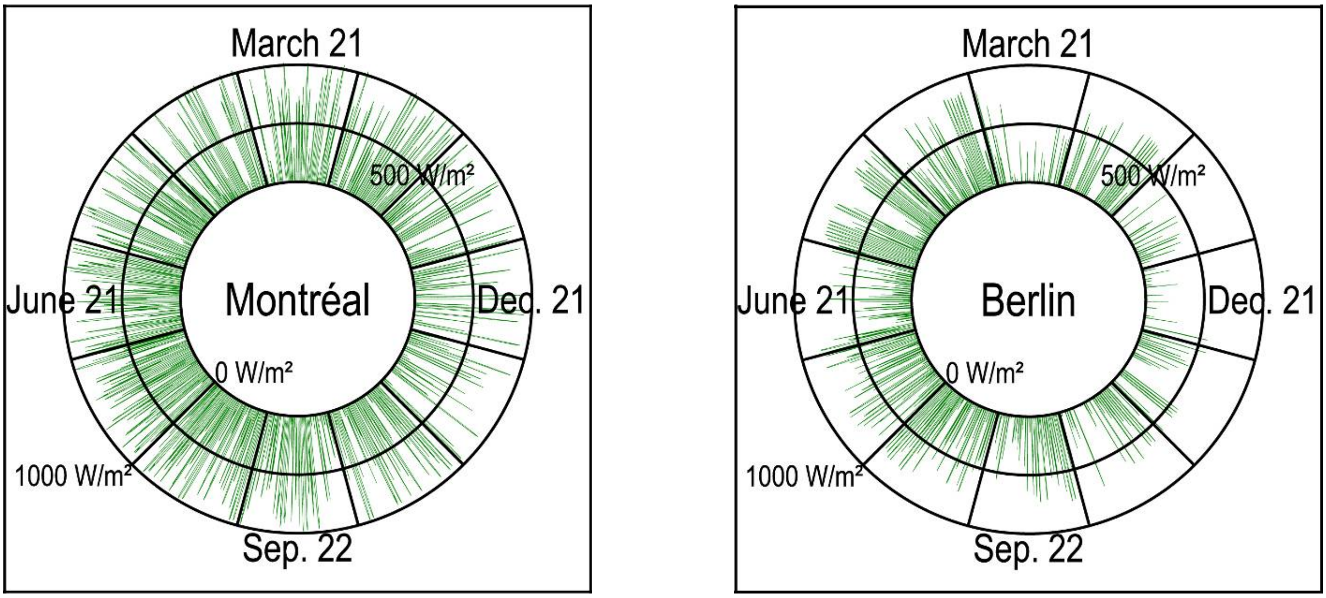
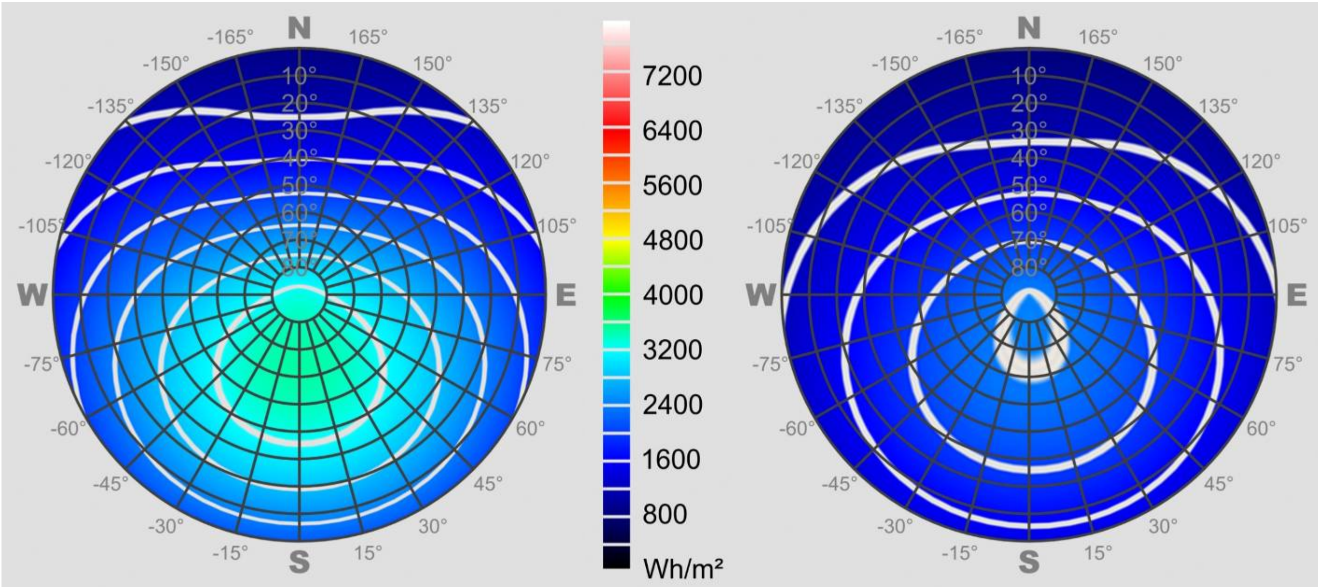


Fig. 1: SOLARCHVISION radial annual plot of hourly direct beam radiation
in typical meteorological year (U.S. Department of Energy TMY files),
(Intelligent design using solar-climatic vision, 2014)



Montréal Berlin

Fig. 2: Differences between the total amount of annual radiation on different orientations and inclinations
in typical meteorological year (U.S. Department of Energy TMY files),
(Intelligent design using solar-climatic vision, 2014)

Potential for active solar strategies in Montréal (Canada) is much higher comparing to those of Berlin (Germany).

In addition potential for passive solar strategies in Montréal (CA) is also significantly high (see Figure 4 on next page). That is because in Montréal not only the amount of solar radiation is high, but also the need to be exposed to the sun is significant (as a result of extremely low temperatures in Montréal, see Figure 3).

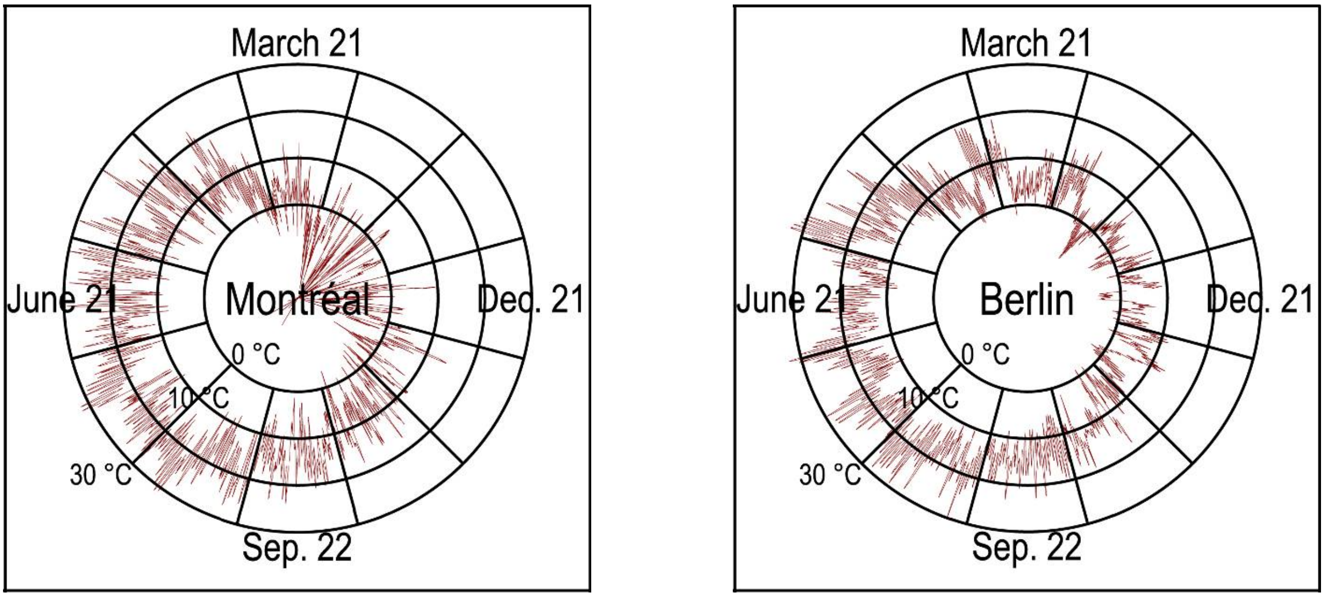


Fig. 3: SOLARCHVISION radial annual plot of hourly temperature
in typical meteorological year (U.S. Department of Energy TMY files),
(Intelligent design using solar-climatic vision, 2014)

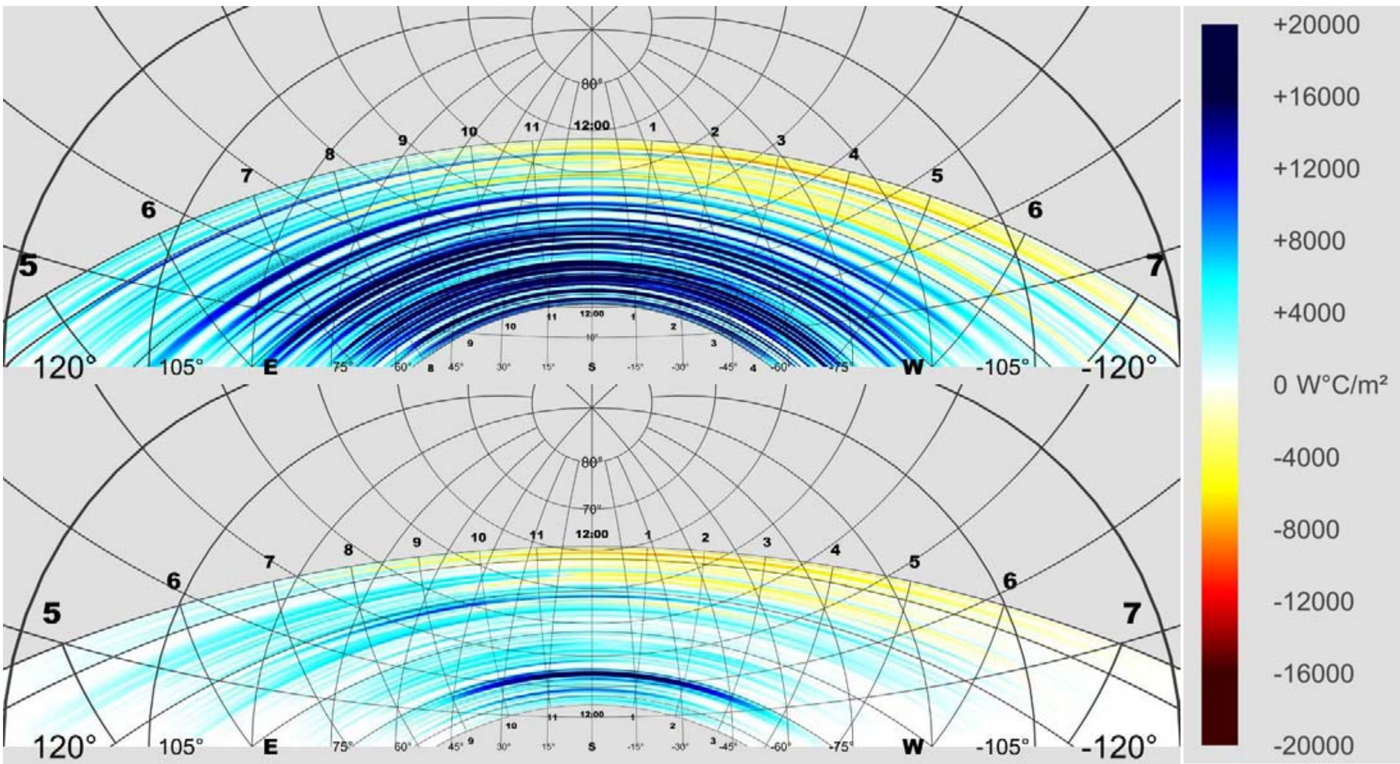


Fig. 4: Differences between the positive and negative effects of direct beam radiation in Montréal (above) and Berlin (below)
in typical meteorological year (U.S. Department of Energy TMY files),
(Intelligent design using solar-climatic vision, 2014)

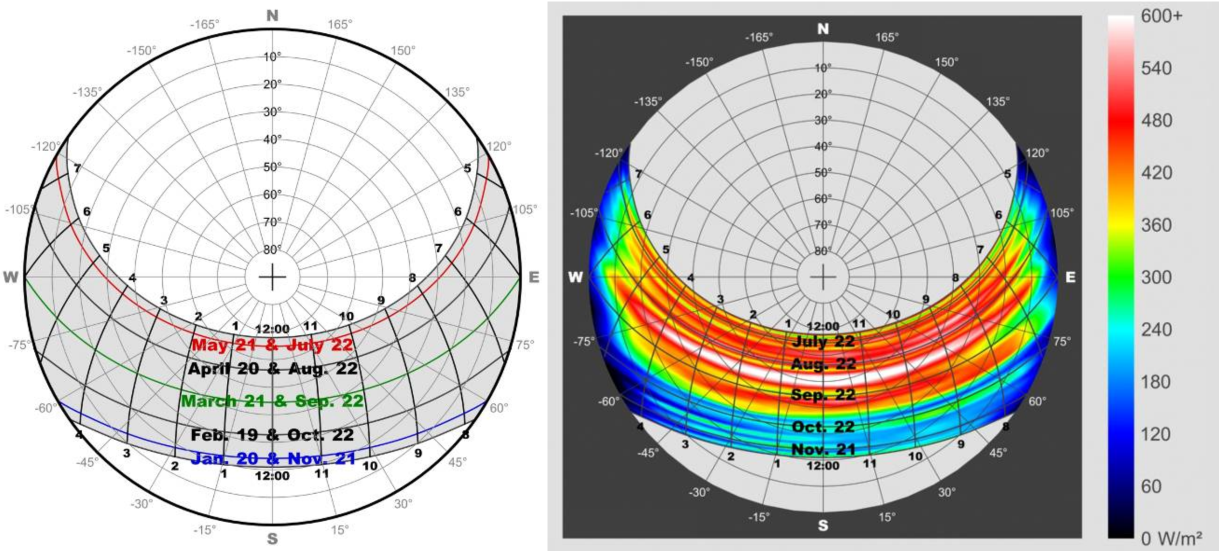


Fig. 5-6: Montréal sun path (left) and average pattern of direct beam radiation between 2001 and 2005 (right)

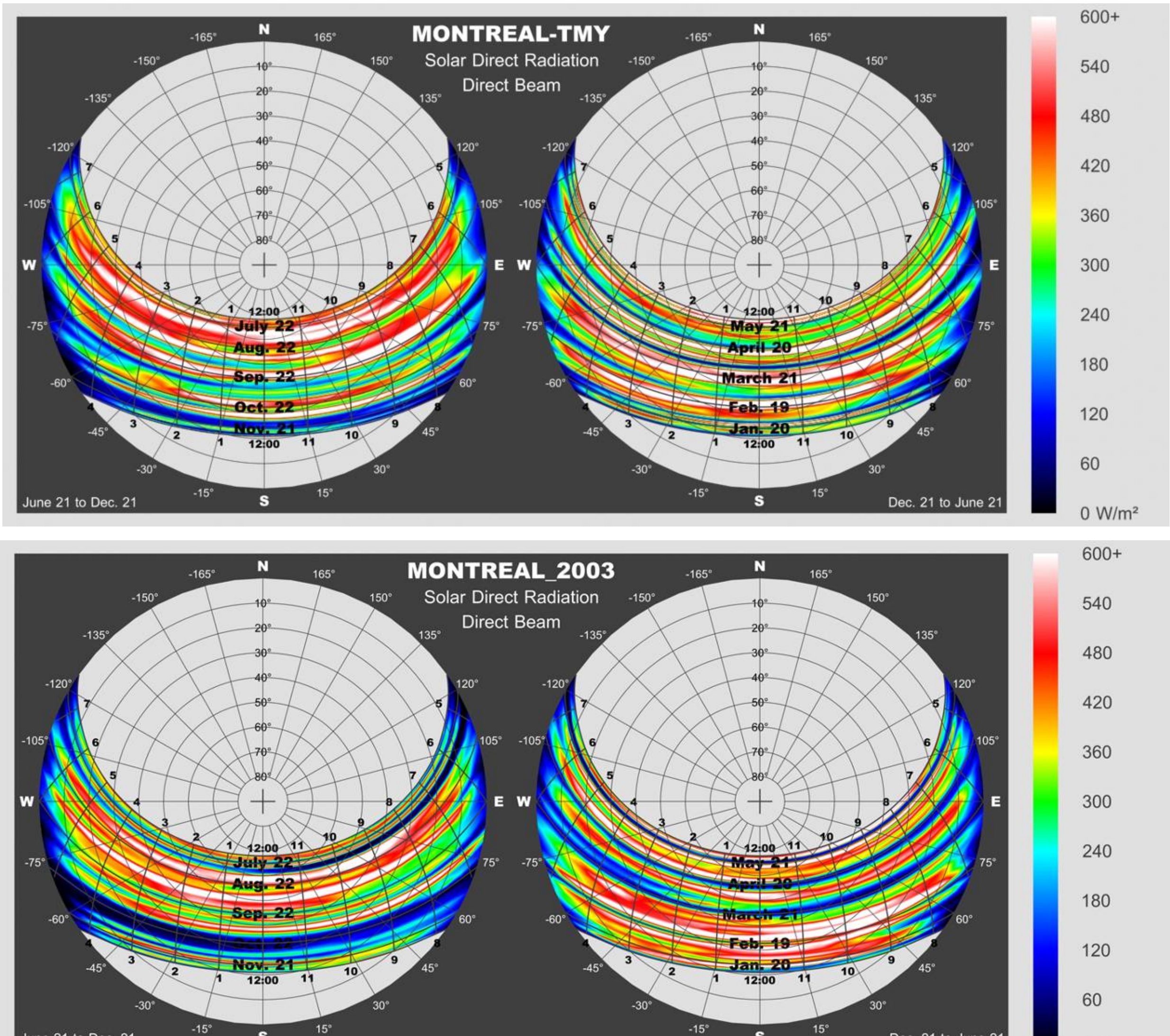


Fig. 7-8: Comparison of pattern of direct beam radiation of Montréal in Typical Meteorological Year (above) and in 2003 as an extreme year (below), left: June 21 to December 21, right: December 21 to June 21

All simillar illustrations between 1953 to 2005, for Montréal could be found at a one-minute video: http://youtu.be/C5PKTbbCN_Q

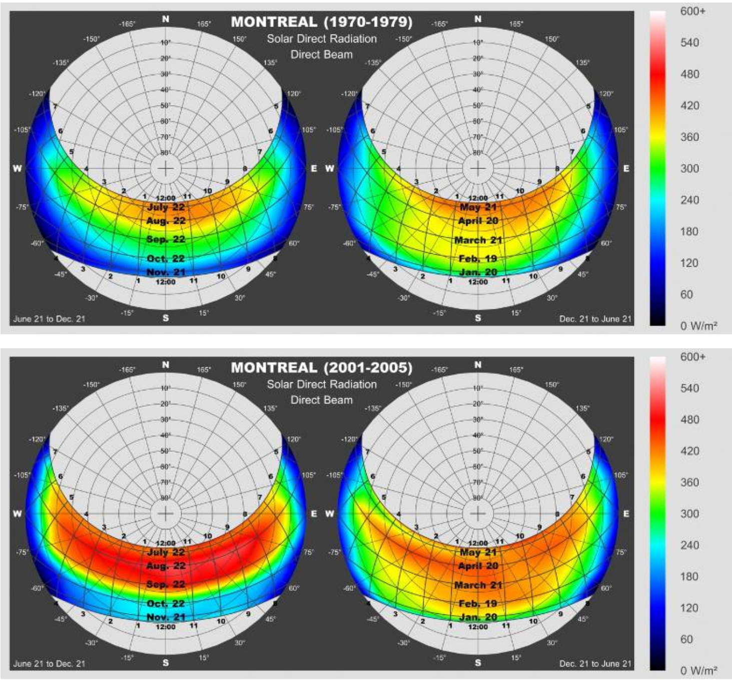


Fig. 9: Changes in direct beam radiation patterns in Montréal,
above: 1970's, below: 2000's,
left: June 21 to December 21, right: December 21 to June 21
SOLARCHVISION standardization based on CWEED

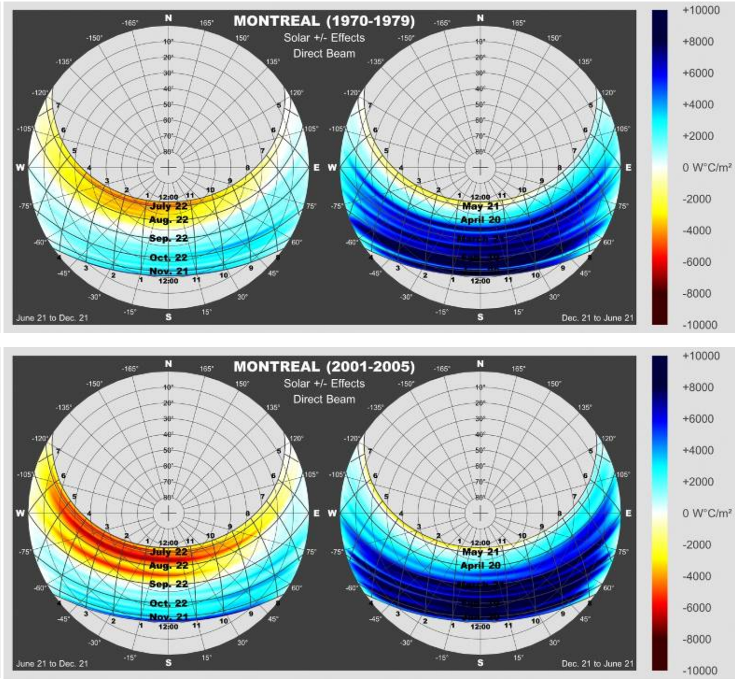
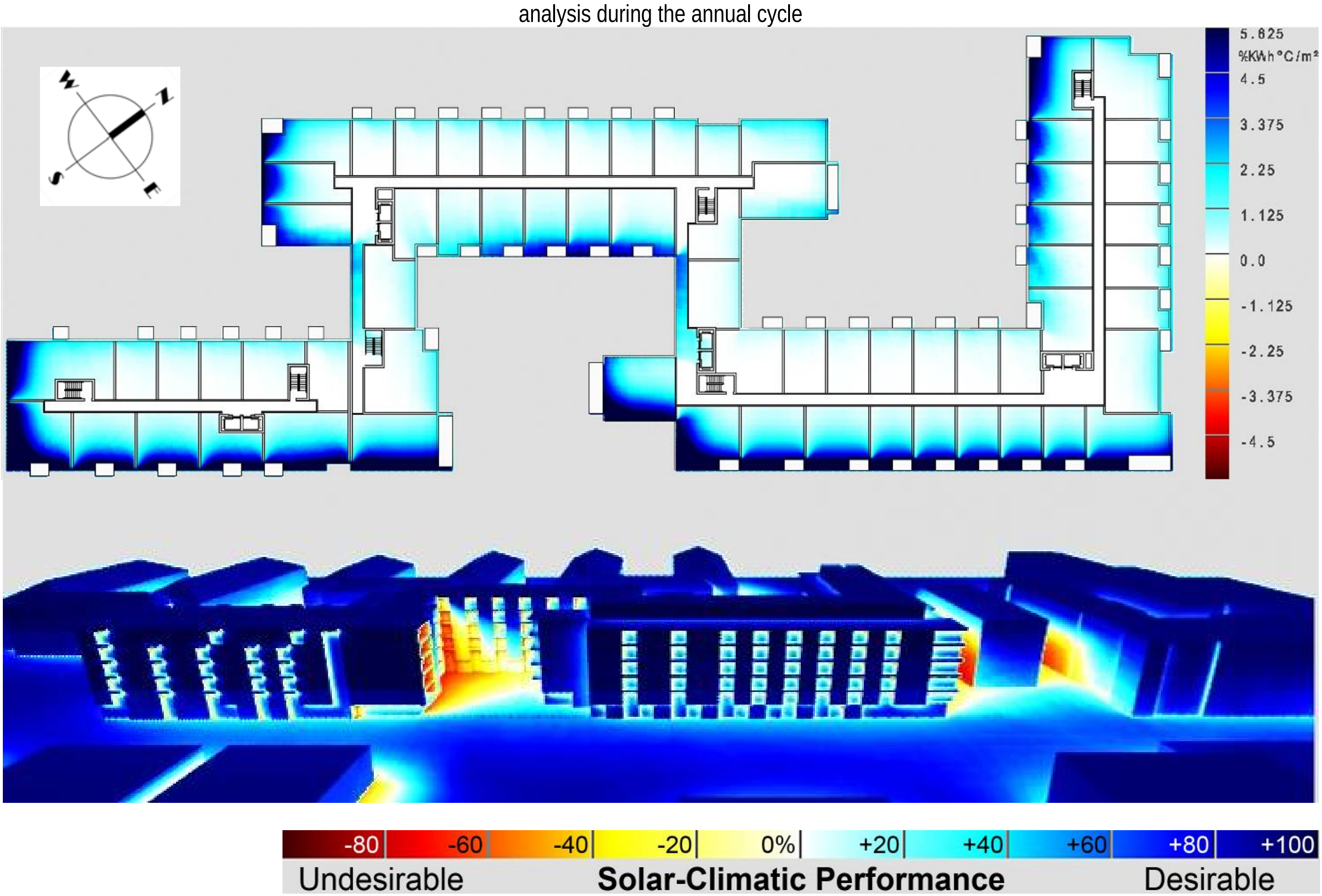


Fig. 10: Changes in positive and negative effects of direct beam radiation in Montréal,
above: 1970's, below: 2000's,
left: June 21 to December 21, right: December 21 to June 21

Fig. 11-12: Proposed typical floor plan and south-east elevation (OCPM, document 3a)

Fig. 13-15: Above: proposed arrangement for complex volumes (OCPM, document 3a), below: SOLARCHVISION indoor and outdoor performance analysis during the annual cycle



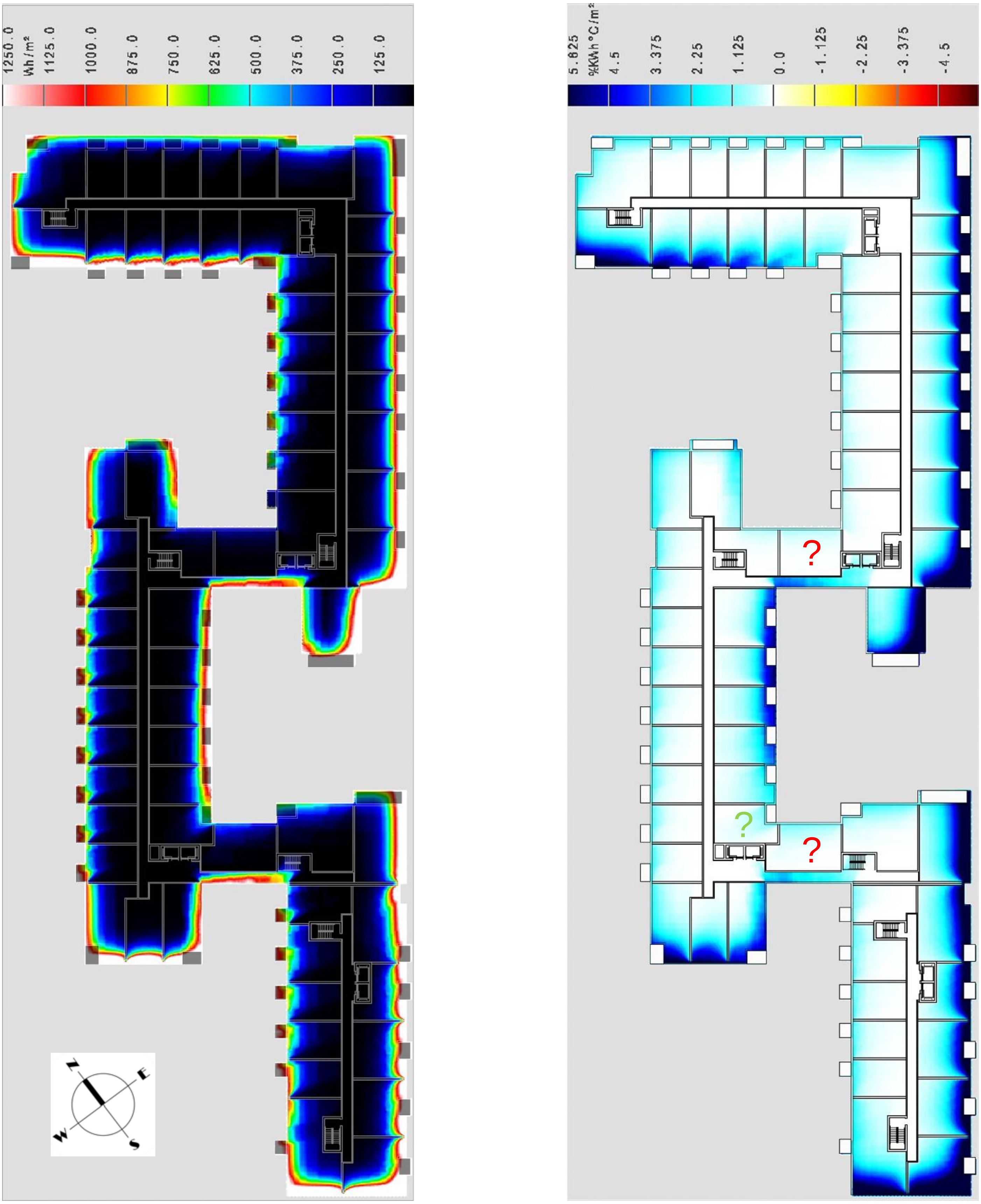


Fig. 16-17: Indoor solar radiation model (left) and SOLARCHVISION analysis (right) during the annual cycle for third floor plan

The red question marks illustrate the units which produce remarkable negative effects on the courtyards (see Fig. 19).
The green question mark illustrates the unit in typical plan that has insufficient daylight/ventilation/view potentials.

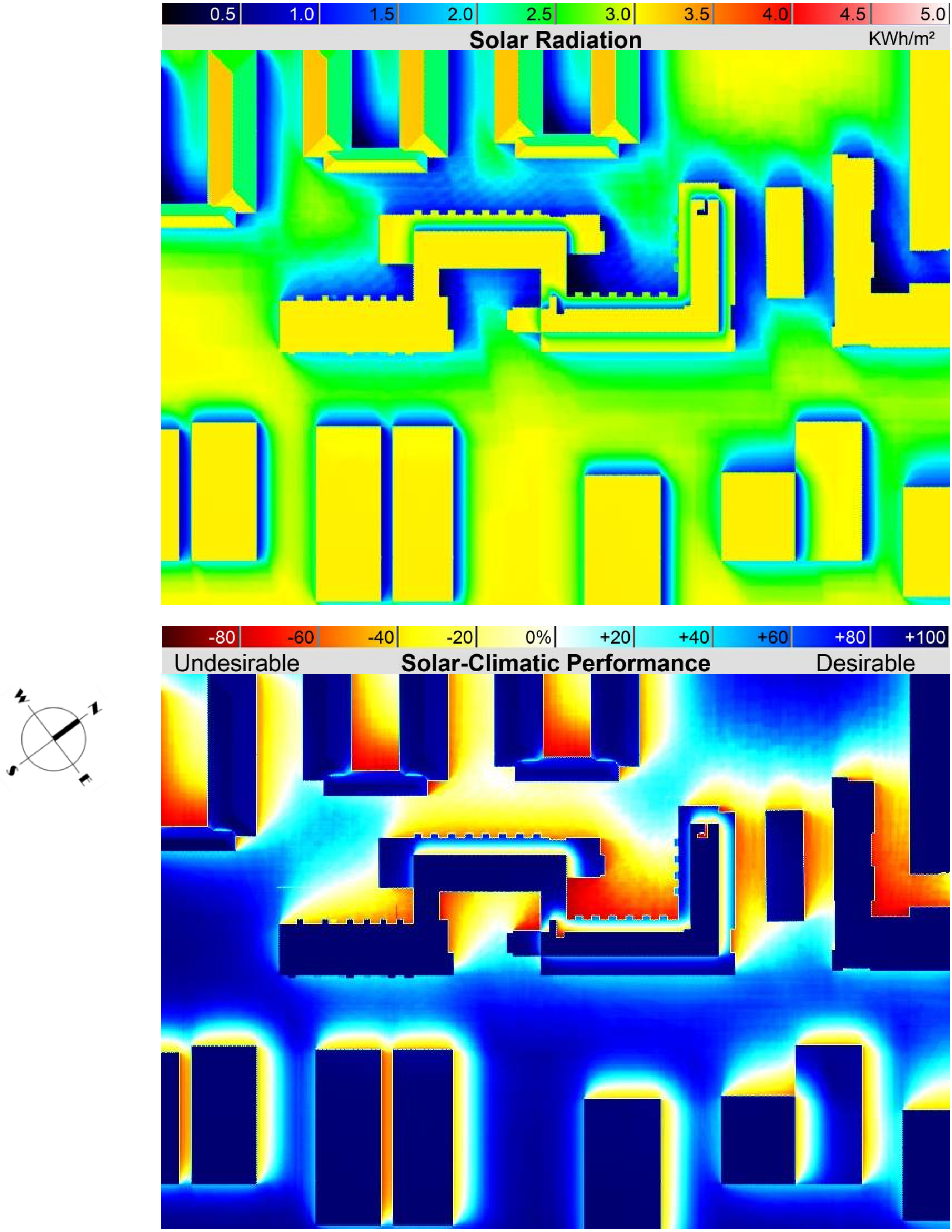
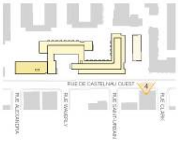


Fig. 18-19: Building skin/urban solar radiation model (up) and SOLARCHVISION analysis (down) during the annual cycle



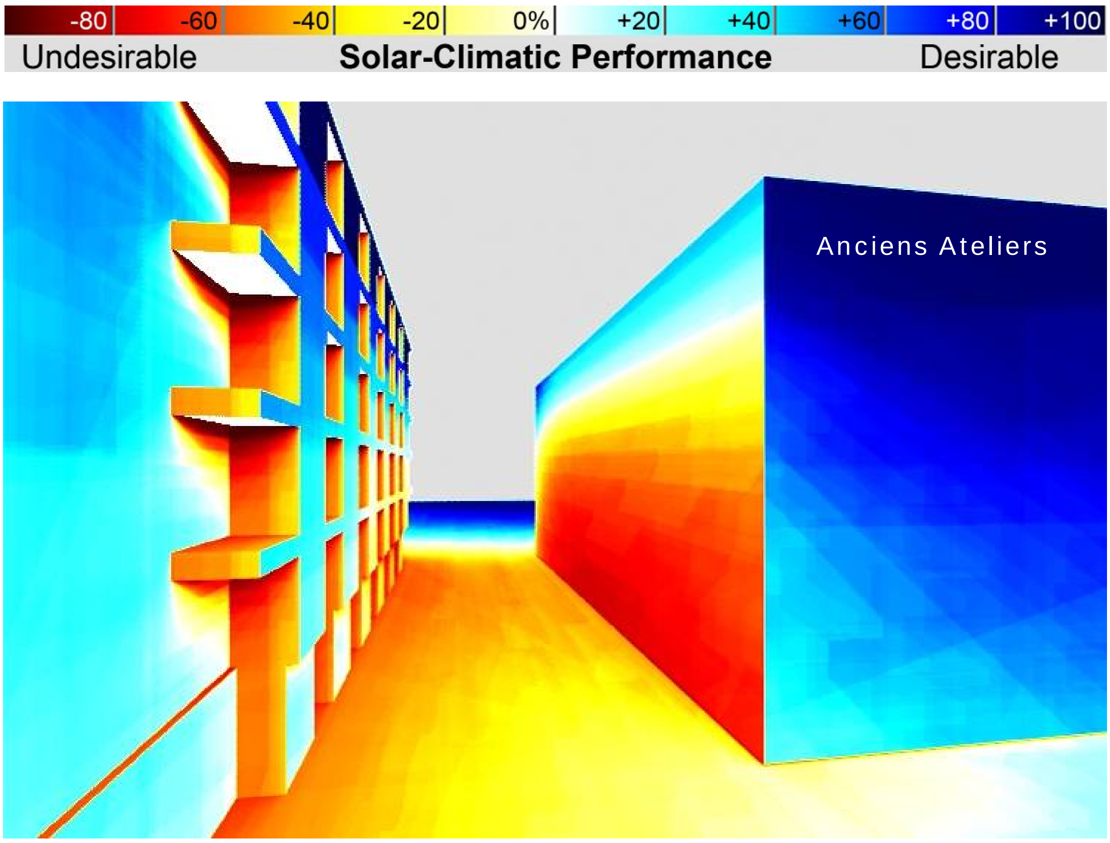
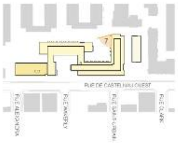


Fig. 20-21: Above: perpective of the north-east side of the project (OCPM, document 3a), below: the negative impact of the proposed new building volume on the old building skin (internal comfort/energy demand) as well as on the urban area (undesirbale/unsafe space) during the annual cycle



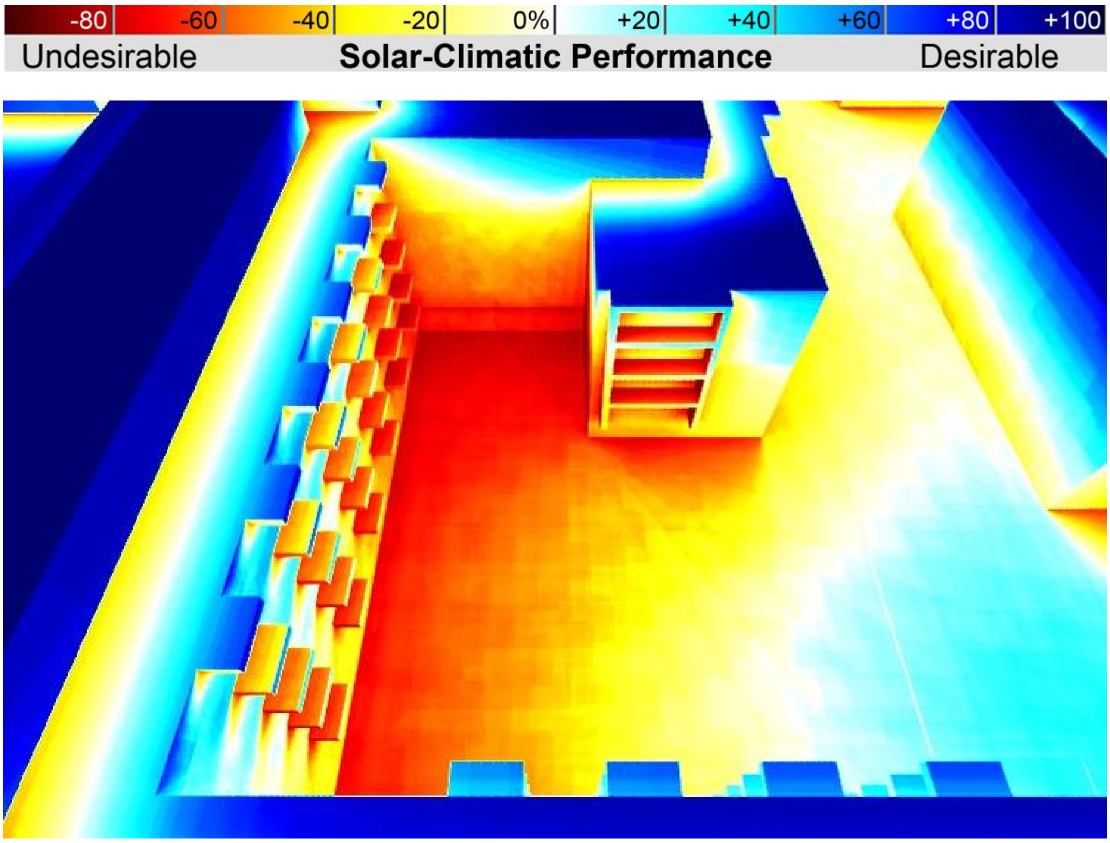


Fig. 22-23: Above: perpective of the north courtyard and entry of the project (OCPM, document 3a), below: the negative impact of the proposed building volume on itself (internal comfort/energy demand) as well as on the open area (undesirbale/unsafe space) during the annual cycle

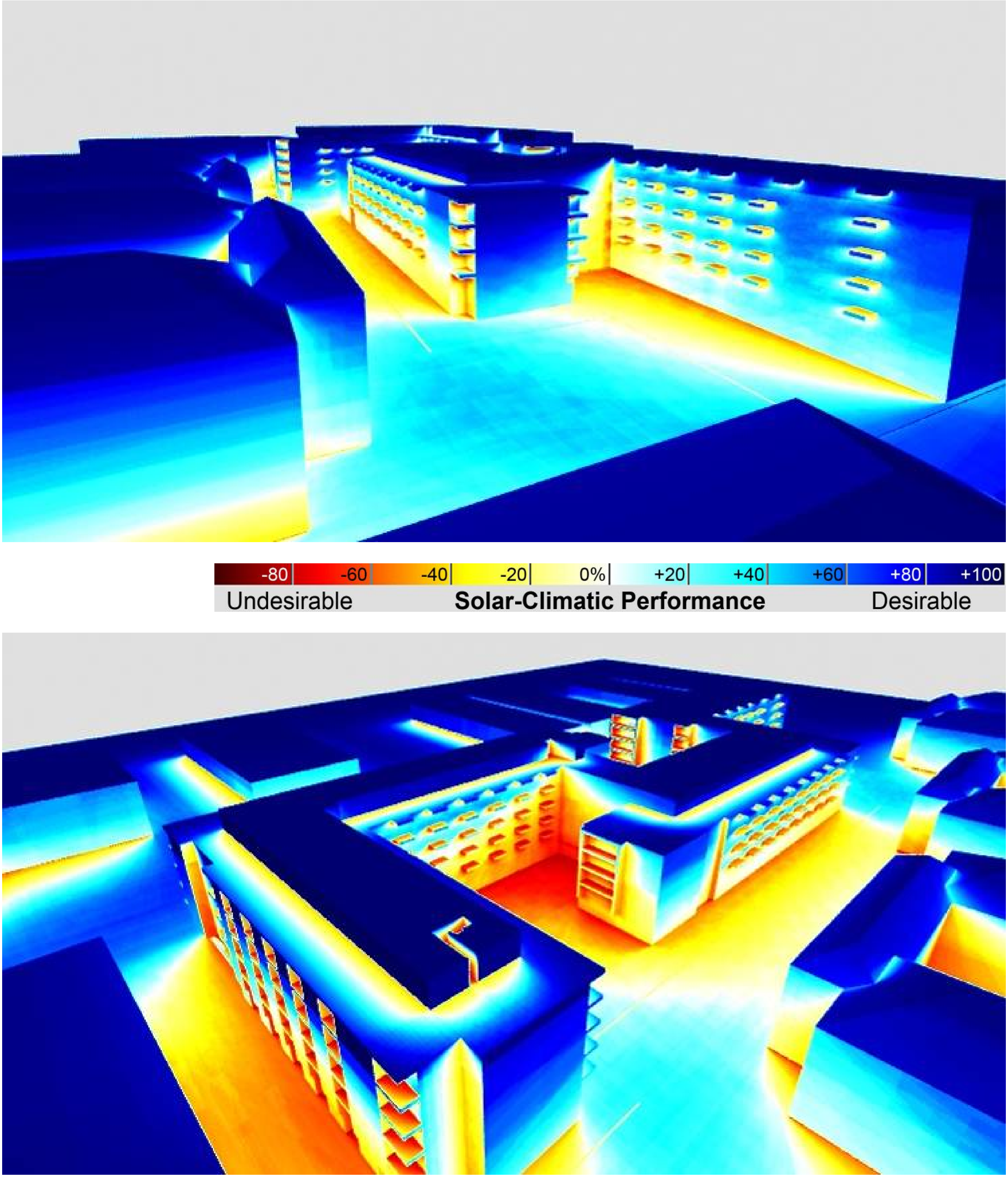


Fig. 24-25: Solar-climatic analysis illustrating positive and negative impacts on building skin and urban levels during the annual cycle

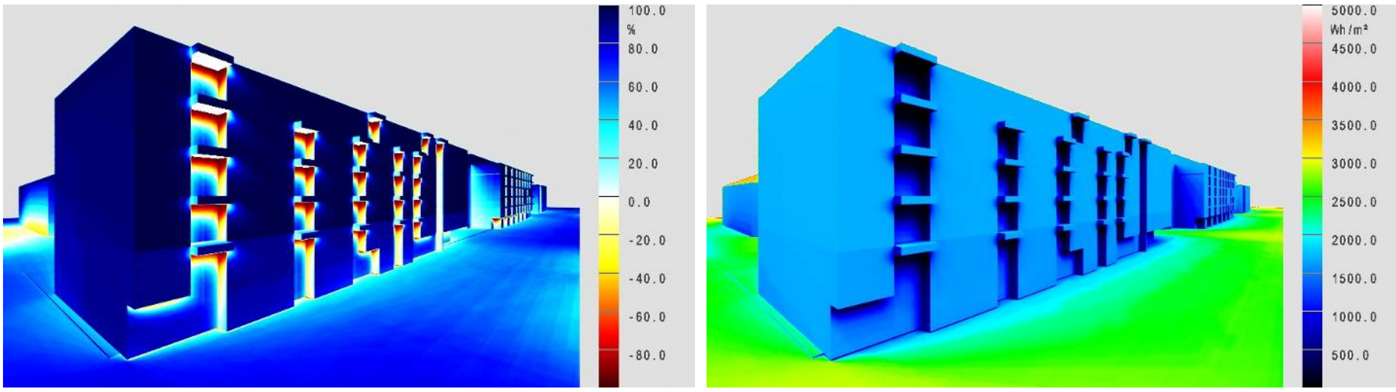


Fig. 26-27: Passive solar-climatic performance analysis (left) and active analysis (solar radiation model) during the annual cycle for the general south-east façade of the project (The building general (south-east) orientation is 55°)

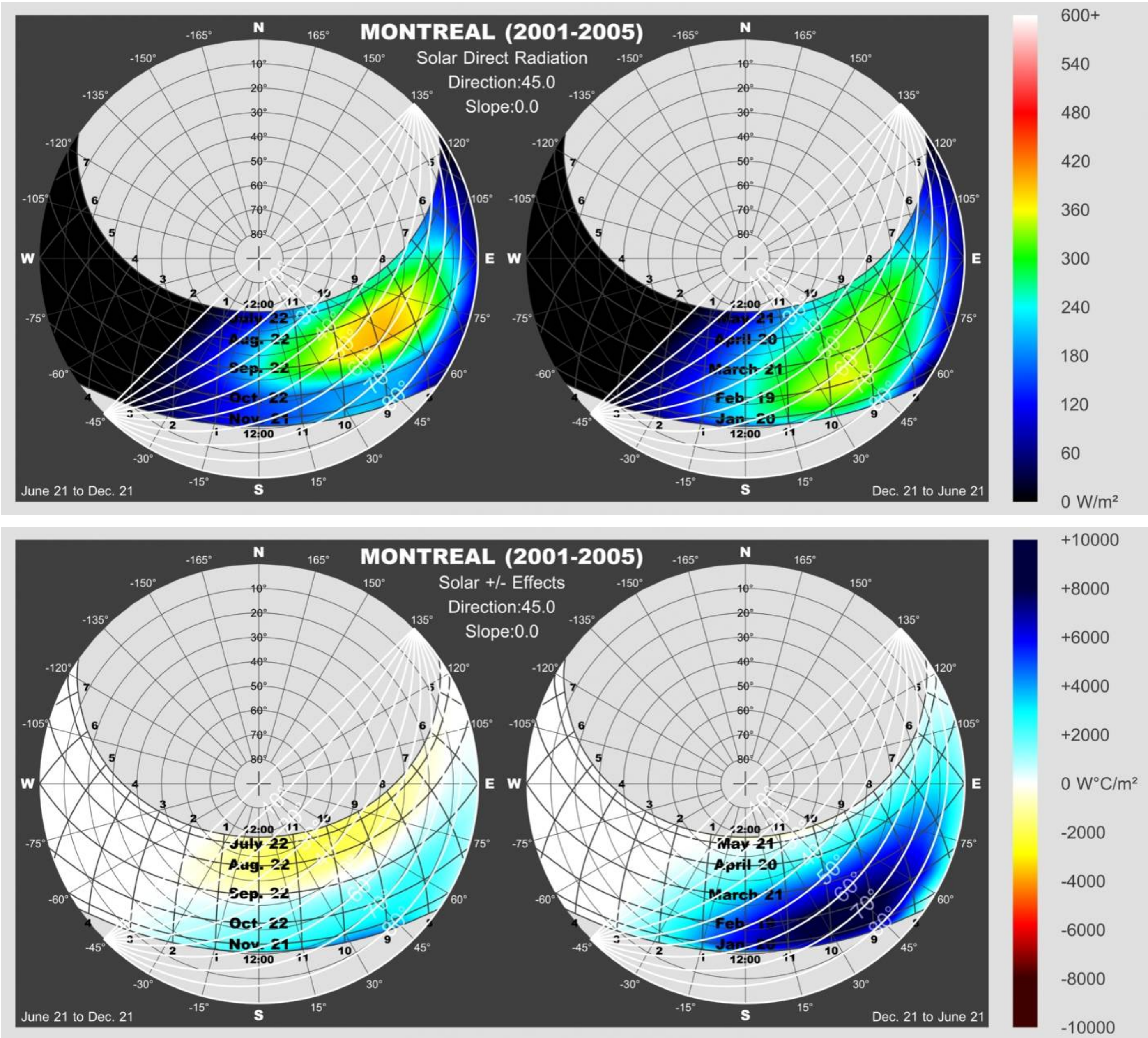
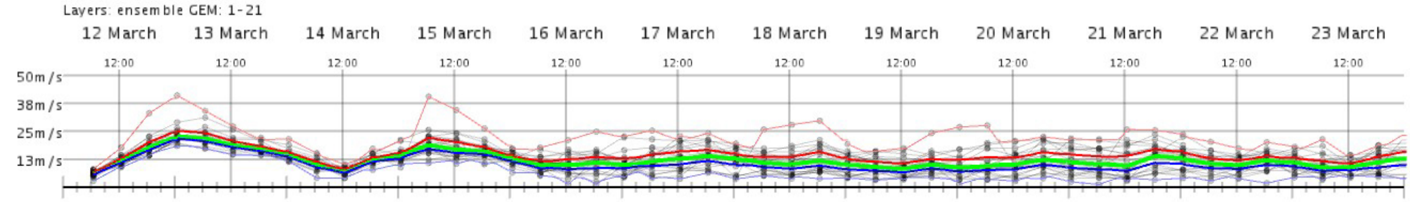


Fig. 28-29: The amount of direct radiation (above) and its positive/negative effects (below) on south-east direction (orientation: 45°) during the annual cycle, left: from June to December, right: from December to June, (based on CWEED information between 2001 and 2005), (The sun and the city of Montréal, 2013)

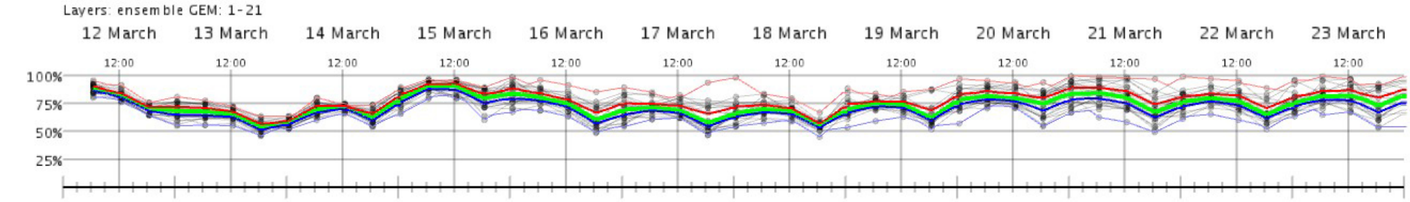
5. Appendix

Plots of 21 members from the Environment Canada's Global Ensemble Prediction System (GEPS).

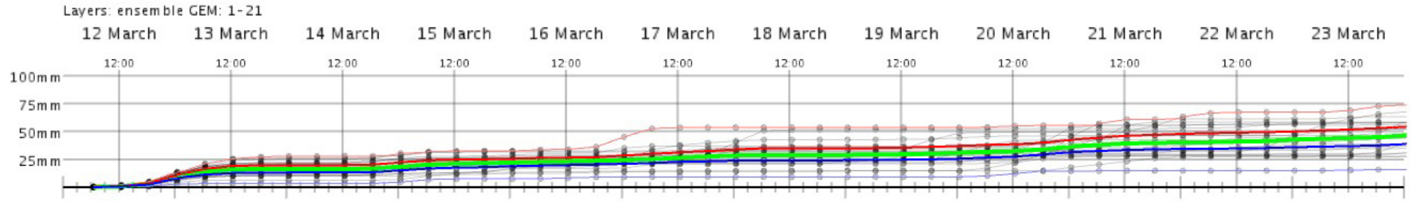
(For more information on these forecast datasets and their applications see "Weather Forecast Data an Important Input into Building Management Systems", Poulin, 2013 available at: http://collaboration.cmc.ec.gc.ca/cmc/cmoi/product_guide/docs/REFcsts/).



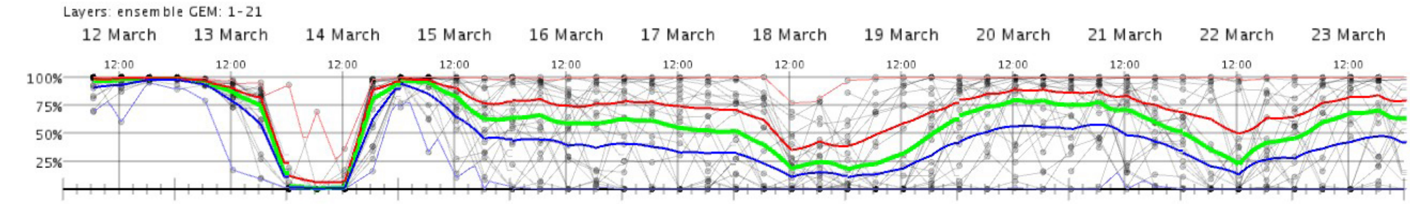
Wind Speed (m/s) at the surface (Vitesse du vent (m/s) à la surface)



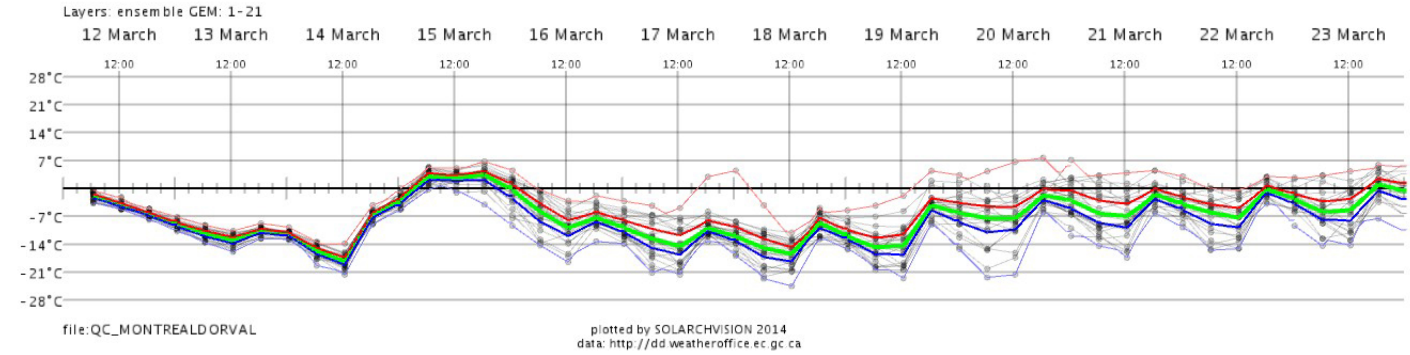
Relative Humidity (%) at the surface (Humidité relative (%) à la surface)



Accumulated Precipitation (mm) at the surface (Précipitations accumulées à la surface (mm))



Total Cloud Cover (%) (Couvert nuageux total (%))

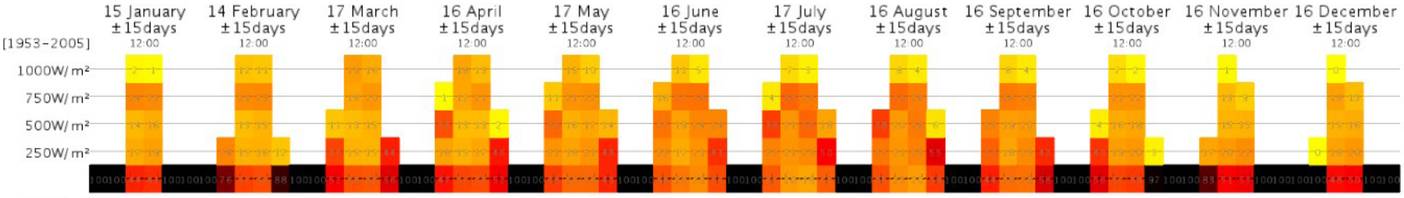


Air Temperature at the surface (°C) (Température de l'air à la surface (°C))

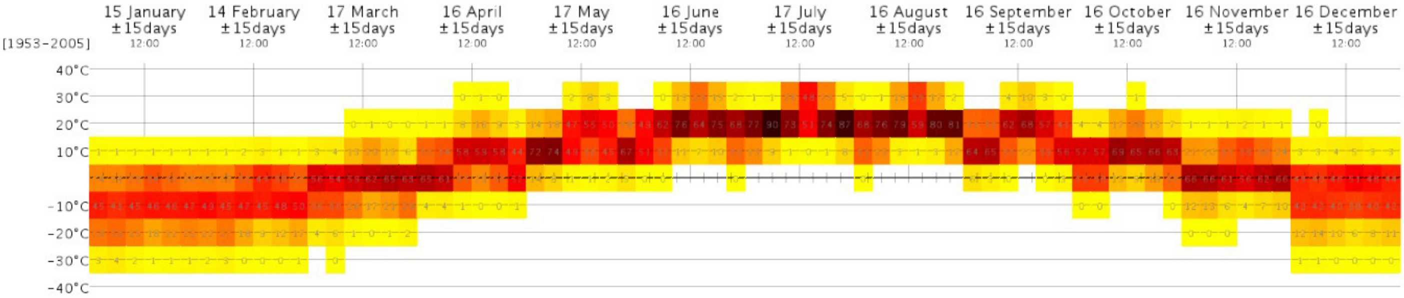
Fig. 30-34: SOLARCHVISION plots of 21 members of Environment Canada GEPS forecast parameters for some of the available forecast parameters. This data is from the XML file produced by the March 12 2014 00Z GEPS model run. Though the original XML data file contains forecast information at 6 hour interval for lead times extending out 15 days, for convenience here only forecast data for the period of March 12 to March 23 are presented. In addition to these 21 members, XML data files contain 21 NCEP members and one deterministic global CMS model which are not presented in the graphs. Data source: Environment Canada website available at: http://dd.weatheroffice.ec.gc.ca/ensemble/naefs/xml/

Highlighted on the plots are: pink line (maximum values), red line (75th percentile*), green line (median*), blue line (25th percentile*) and light blue line (minimum values).

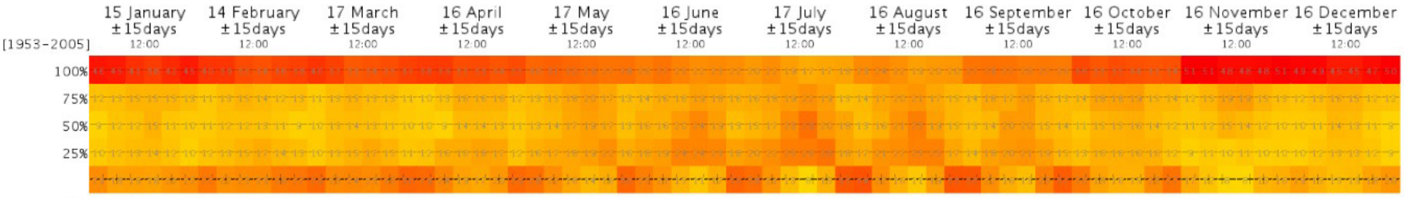
Probabilities in Montréal in different months (1953-2005)



Direct Beam Radiation (W/m²)



Air Temperature (°C)

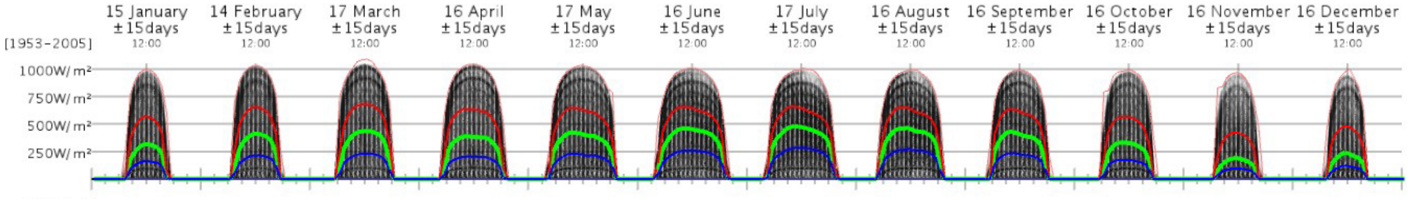


Opaque Sky Cover (%)

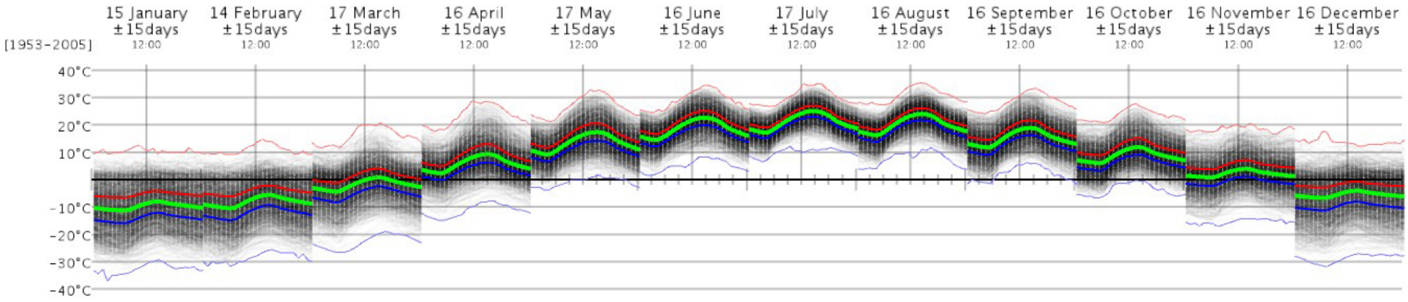
Fig. 35-37: SOLARCHVISION plots with the probabilities of different hourly weather parameters counted in 4-hour intervals during different months of the years between 1953 and 2005 (CWEED).

Within each rounded range and at each interval, darker colors present higher probabilities.

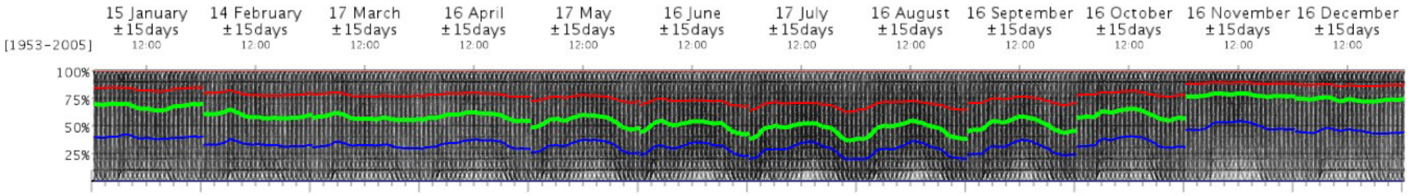
Hourly plots in Montréal in different months (1953-2005)



Direct Beam Radiation (W/m²)



Air Temperature (°C)



Opaque Sky Cover (%)

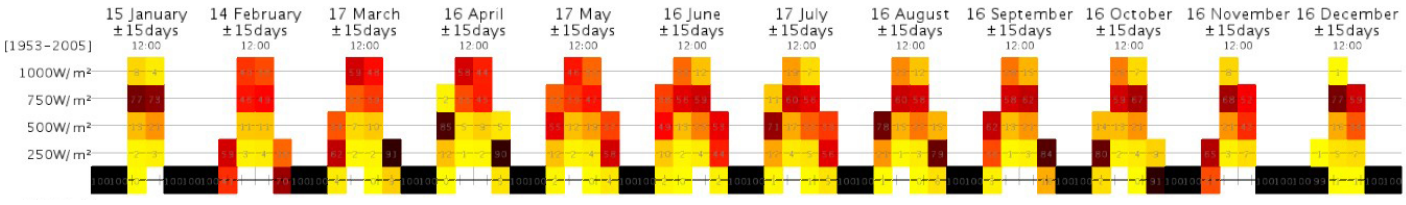
Fig. 38-40: SOLARCHVISION plots of different hourly weather parameters during different months of the years between 1953 and 2005 (CWEED).

Highlighted on the plots are: pink line (maximum values), red line (75th percentile*), green line (median*), blue line (25th percentile*) and light blue line (minimum values).

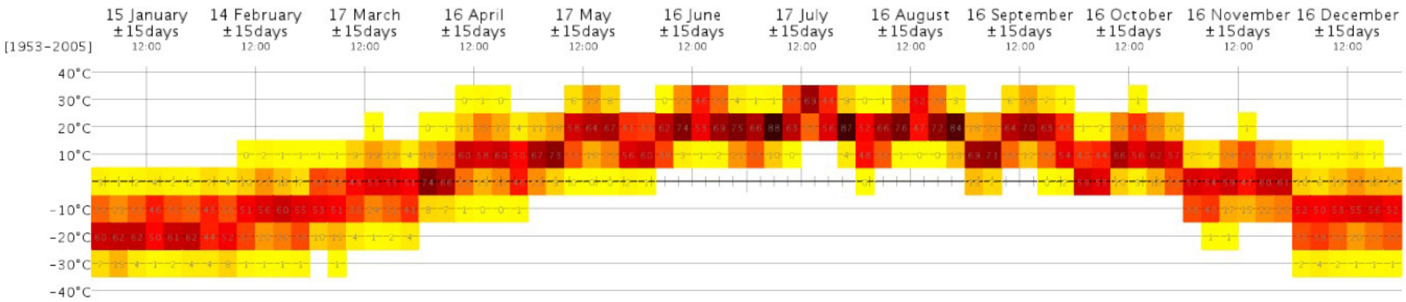
* Following algorithm is applied by SOLARCHVISION tool to calculate different ranges at each interval as median*, 25th percentile* and 75th percentile*. However the results of this method are close to standard methods in most cases; one of the advantages of SOLARCHVISION method is to include all available nodes in the calculation process of these ranges using different linear weight factors. The application of this method is notably essential for standardization of direct beam radiation parameter as is described in more detail the book “Intelligent design using solar-climatic vision”. The following code is developed for Processing programming language (http://processing.org/).

```
int N_Max = 4;
int N_MidHigh = 3;
int N_Middle = 2;
int N_MidLow = 1;
int N_Min = 0;

float FLOAT_undefined = 1000000000;
// it must be a positive big number which is not included in data

float[] SOLARCHVISION_NORMAL(float[] _values) {
      float[] weight_array = {0,0,0,0,0};
      float[] return_array = {0,0,0,0,0};
      int NV = 0; // the number of values without counting undefined values
      float _weight = 0;

      _values = sort(_values);
      for (int i = 0; i < _values.length; i += 1){
            if (_values[i] < 0.99 * FLOAT_undefined) NV += 1;
      }
      if (NV == 0) {
            for (int i = 0; i < _values.length; i += 1){
                  return_array[i] = FLOAT_undefined;
            }
      }
      else{
            for (int i = 0; i < NV; i += 1){
                  if (_values[i] < 0.99 * FLOAT_undefined){
                        _weight = (0.5 * (NV + 1)) - abs((0.5 * (NV + 1)) - (i + 1));
                        weight_array[N_Middle] += _weight;
                        return_array[N_Middle] += _values[i] * _weight;

                        _weight = (i + 1);
                        weight_array[N_MidHigh] += _weight;
                        return_array[N_MidHigh] += _values[i] * _weight;

                        _weight = (NV + 1 - i);
                        weight_array[N_MidLow] += _weight;
                        return_array[N_MidLow] += _values[i] * _weight;
                  }
            }
            return_array[N_MidHigh] /= weight_array[N_MidHigh];
            return_array[N_Middle] /= weight_array[N_Middle];
            return_array[N_MidLow] /= weight_array[N_MidLow];

            return_array[N_Max] = _values[(NV - 1)];
            return_array[N_Min] = _values[0];
      }
      return return_array;
}
```

Clear sky: probabilities in Montréal in different months (1953-2005)



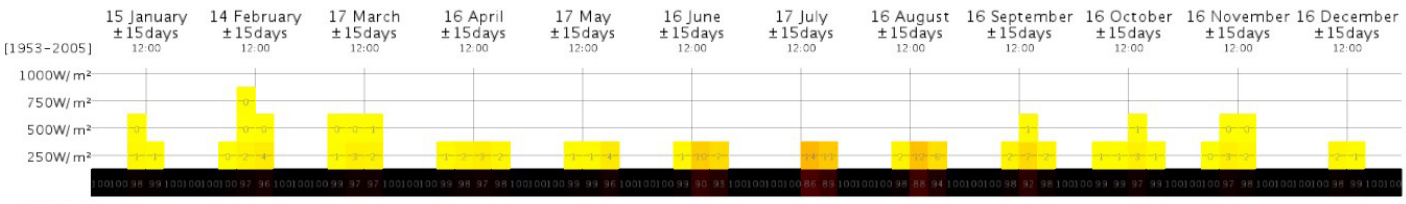
Direct Beam Radiation (W/m²)



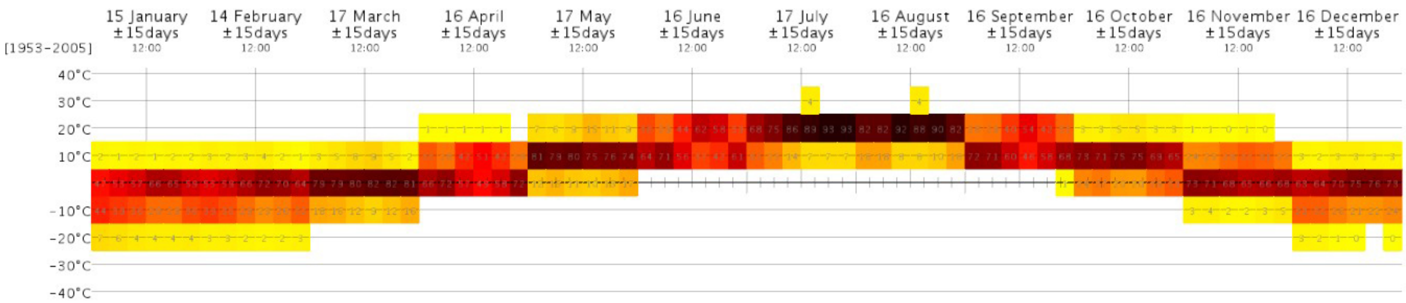
Air Temperature (°C)

Fig. 41-42: SOLARCHVISION plots with the probabilities of different hourly weather parameters in clear sky counted in 4-hour intervals during different months of the years between 1953 and 2005 (CWEED)

Overcast sky: probabilities in Montréal in different months (1953-2005)



Direct Beam Radiation (W/m²)

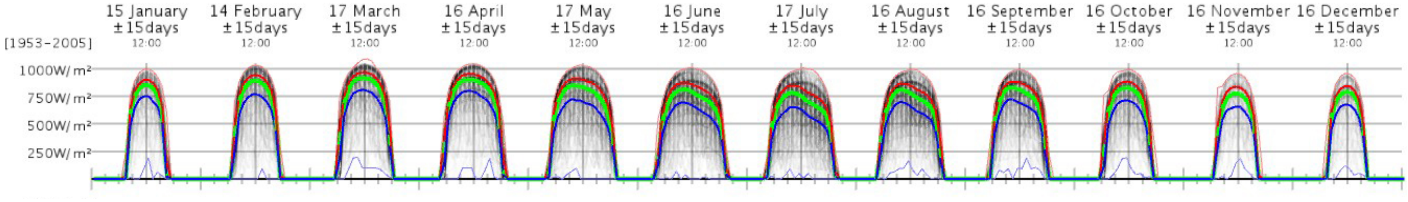


Air Temperature (°C)

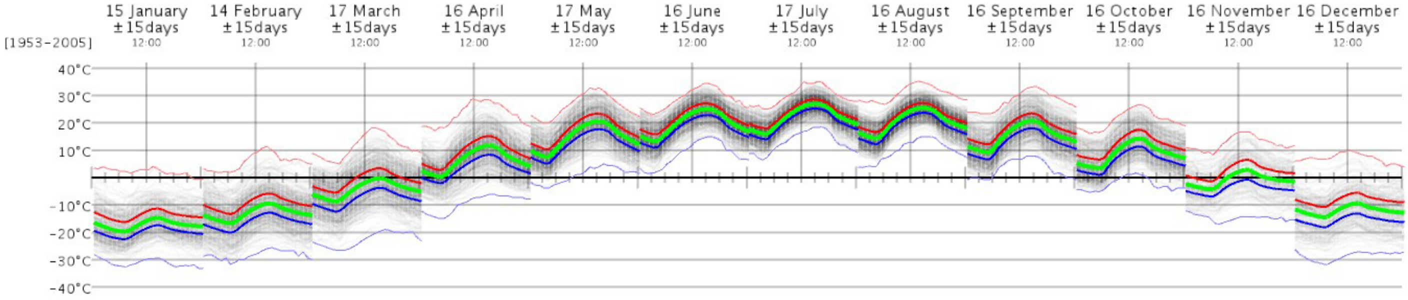
Fig. 43-44: SOLARCHVISION plots with the probabilities of different hourly weather parameters in overcast sky counted in 4-hour intervals during different months of the years between 1953 and 2005 (CWEED)

Within each rounded range and at each interval, darker colors present higher probabilities.

Clear sky: hourly plots in Montréal in different months (1953-2005)



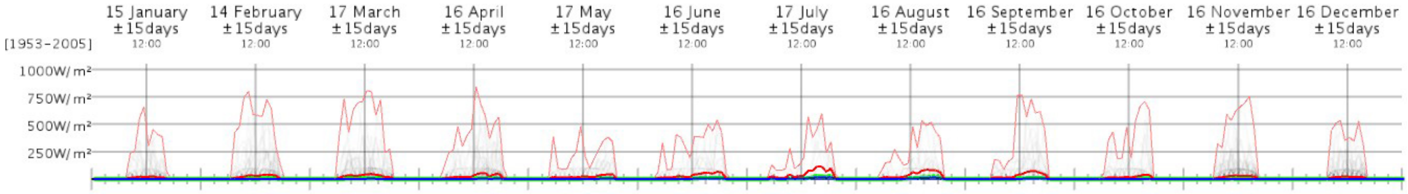
Direct Beam Radiation (W/m²)



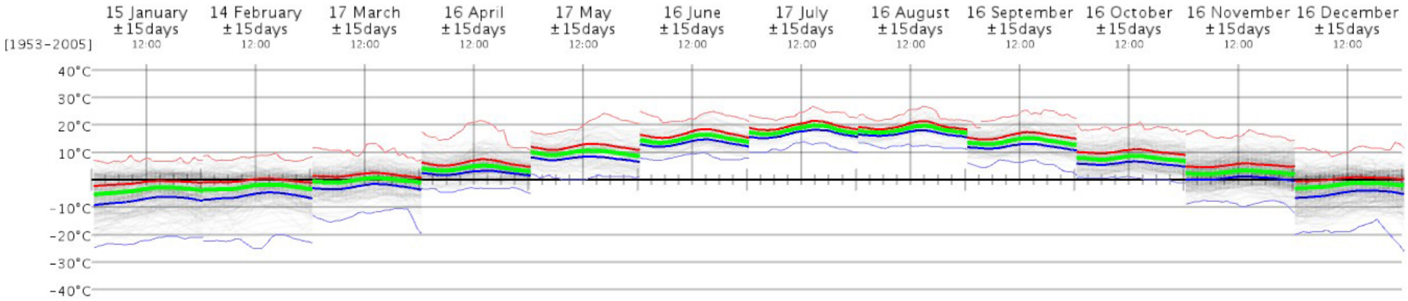
Air Temperature (°C)

Fig. 45-46: SOLARCHVISION plots of different hourly weather parameters in clear sky during different months of the years between 1953 and 2005 (CWEED).

Overcast sky: hourly plots in Montréal in different months (1953-2005)



Direct Beam Radiation (W/m²)



Air Temperature (°C)

Fig. 47-48: SOLARCHVISION plots of different hourly weather parameters in overcast sky during different months of the years between 1953 and 2005 (CWEED).

Highlighted on the plots are: pink line (maximum values), red line (75th percentile*), green line (median*), blue line (25th percentile*) and light blue line (minimum values).