Daylight measurement in Milan

Tiziana Poli[1], Luca Pietro Gattoni[1], Daniele Zappalà[2], Roberto Gottardi[2]

[1] BEST Department, Politecnico di Milano, Milan, Italy
[2]OMD, Milano Duomo Meteorological Observatory, Milan, Italy

ABSTRACT: In Climate Sensitive Buildings attention is often focused on thermal performance. This is done forgetting that illuminance and luminance distribution in daylight interiors not only affects the acceptance of architectural spaces [visual well-being] but above all the energy balance in the building [for example wide and transparent surfaces might cause excessive light resulting in glare and high thermal loads in summertime].
Regarding lighting aspects, the parameter for evaluating the natural light availability in an environment is the Daylight Factor. This parameter depends on the geometry of the environments, the dimensions and positioning of fenestration, the optic properties of the surfaces. The aim of this document is to define the real sky conditions in Milan, in fact the illuminance in a given point in a building depends on the value of outside illuminance for a given DF.

Keywords: daylight, illuminance measurement, sky conditions

1. INTRODUCTION

In the building industry a great number of subjects require greater precise knowledge of the environmental context, specifically climate, supported by the constant widespread measurement over time of specific measures.
Planning and management decisions connected with energy efficiency, inhabitant's well-being and more in general with a wide range of performances provided by the building, for which the environment represents a major sensitive element, can be taken with greater awareness and efficacy thanks to the availability of climate data.
"Good" design and "good" functioning of the building and its component parts are strictly related to the surrounding conditions. The building and the conditions that result inside it strictly depend on the interaction of numerous environmental agents.
Planning connected to outdated statistical data (non updated historical series) or incomplete data or which are irrelevant to the specific situation cannot lead to making energy efficient buildings. Hence the need to have updated and significant data available and, therefore, to create a network of stations dedicated to urban meteorology. The assessment of the sky conditions in the city of Milan is the first chance to weigh its specificity.

2. METEOLAB: A STATION FOR THE MEASUREMENT OF RADIOMETRIC AND PHOTOMETRIC DATA

2.1 Description
MeteoLab is a station for the measurement of the main climate parameters and its significance is strictly related to its location. The station is located near Milan town centre (within the area that is most commonly defined as "heat island" with all the consequent implications) on the roof of one of the tallest buildings of the Politecnico university campus (Fig. 1). The measurement field is totally free (no shadows coming from nearby buildings) and the urban factors are not mitigated or changed by the height.

Figure 1: MeteoLab. Some instruments for irradiance measurement. Data correctness is ensured by various instruments (same typology) working in synchronism

The significance of the location is also connected to the direct relationship between MeteoLab, the OMD measurement station located in the town centre and the stations located in the city outskirts (data comparison).

A precise climate profile of the city can be defined through this sequence or network (especially with respect to temperature changes and wind direction and speed).

Station management, which is subject to constant implementation of instruments and periodical instrumentation checks and calibrations, and climate data processing are in the hands of OMD and the Building EnvelopeGroup of the BEST Department of the Politecnico di Milano.

MeteoLab features the following measurement sensors:
- 1 shadow band;
- 2 data logger (BABUC – ABC);
- 6 illuminance sensors
- 5 irradiance sensors;
- Dry Bulb Temperature and Wet Bulb Temperature;
- Wind speed sensor and wind direction sensors.

2.2 Data measured

MeteoLab was set up to measure radiometric and photometric data but a series of other measurements have been added to these that are necessary to precisely characterise the climate context. The following data are measured:
- global horizontal illuminance;
- diffuse horizontal illuminance;
- global vertical illuminance in the four cardinal directions (North, East, South and West);
- global horizontal irradiance;
- diffuse horizontal irradiance;
- air temperature;
- relative humidity;
- wind speed, direction and frequency.

3. METHODOLOGY

This paper's objective is that of characterising Milan's light climate and of weighing the significance of the sky condition for various periods in the year in relation with the illuminance value a parameter able to affect directy the significance of daylight factor defined by the national technical codes [2].

Below is a summary of the development stages of the research project:
- definition of the typical reference year with respect to radiometric and photometric data;
- significance of the selected year with respect to a historical series (radiometric data);
- characterisation of the light climate in the Milan context (processing measured photometric data).

4. CLIMATIC ANALYSIS

4.1 Reference for Data Base
- Three canonical hours (8, 14, 19) cloud cover observations at Milano Duomo Meteorological Observatory;
- Global and indirect solar radiation data (W/m^2,) with acquisition rate of 10 minutes, measured at Milano Politecnico University;
- Horizontal illuminance data (kLux), with acquisition rate of 10 minutes, measured at Milano Politecnico University;
- Monthly average temperature values measured at Milano Duomo Meteorological Observatory.

4.2 Time period choice

Because of the clear bond between solar radiation and seasons, we decided to analyse a period of one year, since December 2004 up to November 2005, according to the following correspondence:

Winter – December, January, February
Spring – March, April, May
Summer – June, July, August
Autumn – September, October, November

4.3 Meteorological analysis of the period

The 2005 year can be divided into a first more steady part, with monthly average values higher than climate averages and a second hardly unsettled part, with big oscillations about average values.

Table 1: Monthly average daily temperature values measured at Milano Duomo Meteorological Observatory.

PERIOD	YEARS 61-90	YEAR 2005
Jan	3	4,1
Feb	5,3	4,5
Mar	9,3	10
Apr	13,4	13,1
May	17,8	**20,2**
Jun	21,7	**24,5**
Jul	24,5	25,6
Aug	23,3	23
Sep	19,7	20,5
Oct	14	14,3
Nov	8	7,7
Dec	3,8	2,9

1961-1990 are the thirty years adopted by I.P.C.C. (Intergovernmental Panel on Climate Change) as reference. In Table 1 we can especially remark the big shifting in months of May and June, with differences of 2 – 3 °C in comparison with seasonal averages. The meteorological conditions hard variability, recorded during the year, produces a same wide variation in the solar radiation and lightness measured values.

In order to study the possible anomaly during the analysed period, we made a comparison between reference values, issued by CNR [3] and solar radiation data measured at Milano Politecnico University. From the text, daily average energy values (kWh/m^2) are been represented in Table 2.

Table 2: Daily average energy values (kWh/m^2)

PERIOD	Politecnico	CNR	Difference
Jan	1,7	1	0,7
Feb	2,4	1,8	0,6
Mar	3,7	3,1	0,6
Apr	4,3	4,6	-0,3
May	6,5	5,7	0,8
Jun	7	6,3	0,7
Jul	6,4	6,6	-0,2
Aug	5,2	5,5	-0,3
Sep	3,6	4,1	-0,5
Oct	2,2	2,4	-0,2
Nov	1,3	1,1	0,2
Dec	1,1	0,9	0,2

We can remark the shifting in the first six months (exception month of March), caused by the hard steadiness of the weather, corresponding to a bigger solar energy availability during the 24 hours. The second part of the year, more unsettled and rainy, is marked by a smaller solar energy availability.

5. RESULTS

In the following figures main results of processed data are presented. First of all a statistical analysis of illuminance data measured during the working hours (8 ÷ 19) is showed in Fig. 2. It can be noticed clearly the difference in intensity between the wintertime and the summertime: as example 10 klux is exceeded only 40% in winter (45% in autumn) and 75% in summer and spring; 50 klux is still exceeded 30% of time during summer while in winter these values cannot be reached with high frequency.

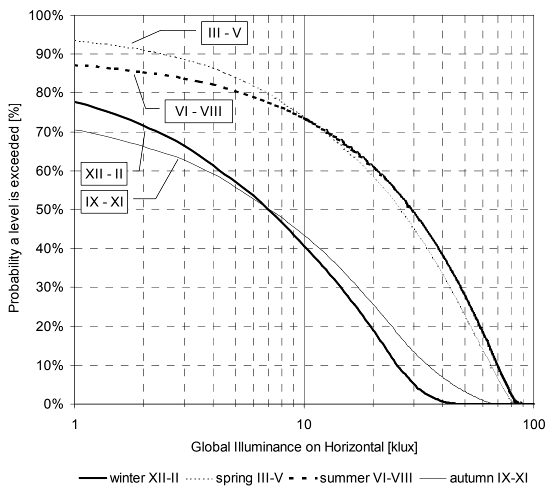

Figure 2: Distribution frequency of Global illuminance on horizontal for different seasons. Analysis for working hours (8-19)

- As next step it clould be useful to combine this seasonal differences with the sky conditions. A simple visual approach, based only on available radiometric and photometric data from MeteoLab, is proved in Fig. 2 and Fig. 3: all measured illuminace data are plotted over the so called “Sky ratio” (or “Diffuse ratio” corresponding to diffuse irradiance / global irradiance).

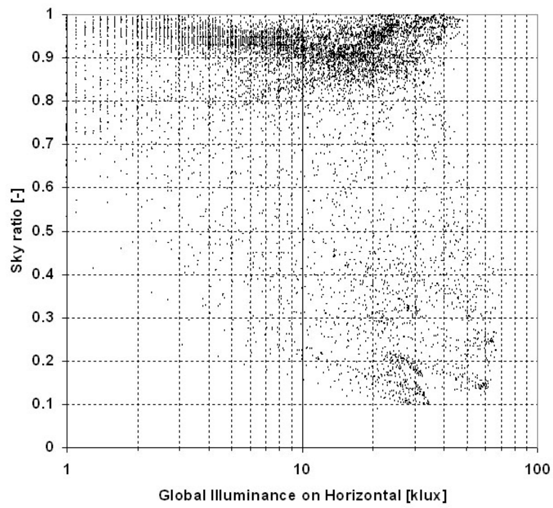

Figure 3: Plot of measured data for wintertime (IX – II) over the Sky ratio (diffuse irradiance / global irradiance).

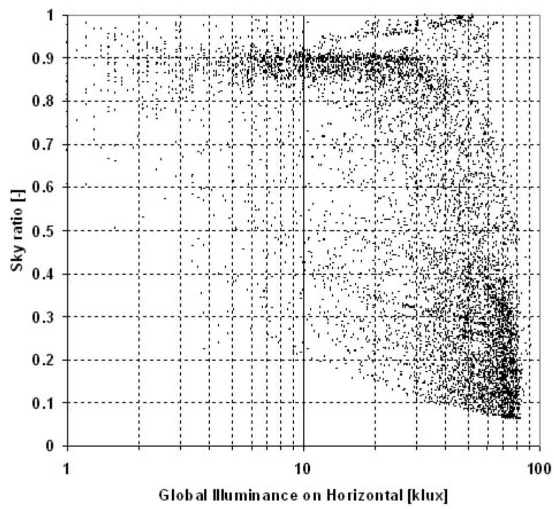

Figure 4: Plot of measured data for summertime (III – VIII) over the Sky ratio (diffuse irradiance / global irradiance).

Such a parameter is strongly related to the clearness index. Nevertheless in the following diagrams it is not possible to connect directly the illuminance value with the exact sky condition because other factors can have a strong influence on the diffuse ratio parameter. Even if limited, the first impressions taken from Fig. 2 and Fig. 3 can be confirmed from futher more accurate analysis:

- a winter season (from September to February) dominated by cloudy days but showing a not negligeable percentage of clear sunshine hours (see also Fig. 9 limitetd to measured data at 14:00); a summer season (from March to August) with a great variation of conditions ranging from clear sky to highly covered sky.

Fig. 5, Fig. 6 and Fig. 7 show an attempt to establish a relationship between illuminance, irradiance (both measured at MeteoLab) and sky condition derived from visual cloud cover observations (from Milano Duomo Meteorological Observatory).

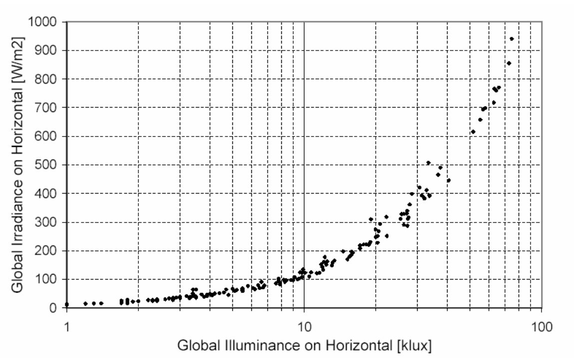

Figure 5: Plot of global illuminance over global irradiance for clear sky conditions at 8:00, 14:00 and 19:00 hours (cloud cover observations).

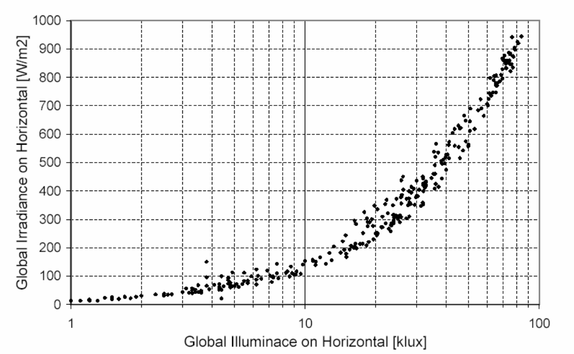

Figure 6: Plot of global illuminance over global irradiance for intermediate sky conditions at 8:00, 14:00 and 19:00 hours (cloud cover observations).

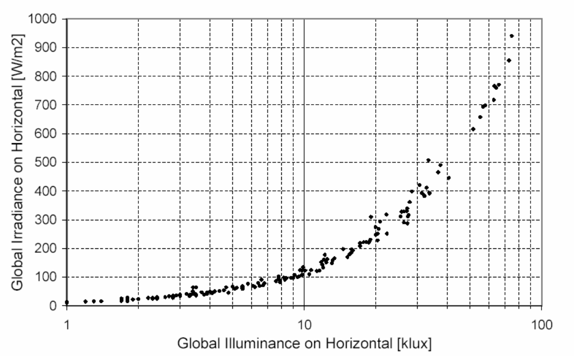

Figure 7: Plot of global illuminance over global irradiance for cloudy sky conditions at 8:00, 14:00 and 19:00 hours (cloud cover observations).

Despite to a great scattering of data along the curve (sign of a strict relationship between irradiation and illuminance) it is possible to notice a concentration of illuminance values according to sky conditions: greater number of dots for higher values of illuminace with clear sky (Fig. 5) the opposite with a prevailing covered conditions (Fig. 7).

A further interesting investigation is represented by the variation of illuminance values during the whole year once more in relation with the observed sky condition. Single values (dots) and trend lines are illustrated in Fig. 8 (14:00 hour), Fig. 10 (8:00 hour) and Fig. 11 (19:00 hour). In the case of midday hour a more detailed report is presented showing the mean value for each season in dependance of sky condition (Tab. 3) and the frequency distribution of such a conditions (Fig. 9).

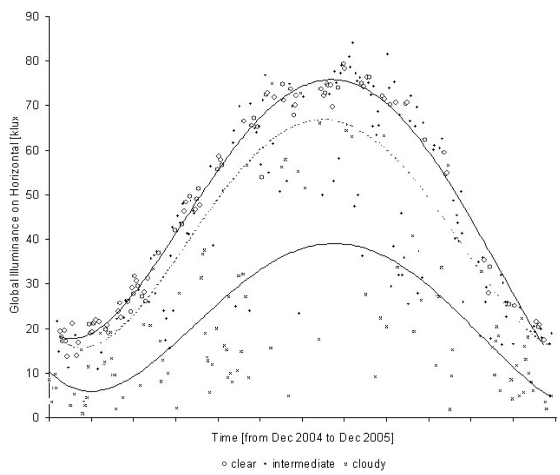

Figure 8: Variation of Illuminance on horizontal plane during a whole year. Values measured at 14:00 hours and splitted according to the sky conditions (cloud cover observations).

Table 3: Period average illuminance value at 14:00 hour (klux) according to the sky conditions

PERIOD	CLEAR	INTERMEDIATE	CLOUDY
XII - II	22,9	24,0	10,2
III - V	59,9	51,6	25,0
VI - VIII	72,8	61,2	39,9
IX - XI	33,0	32,0	13,7

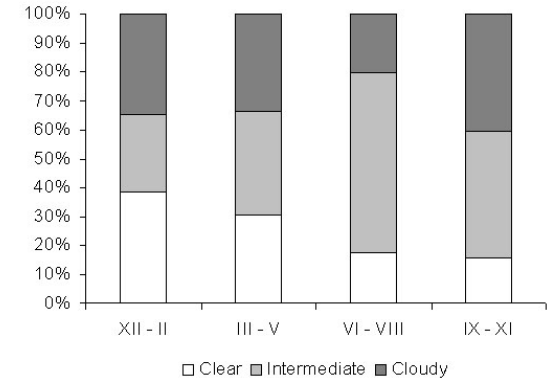

Figure 9: Distribution of sky contiditions (cloud cover observations) in different seasons at 14:00 hour.

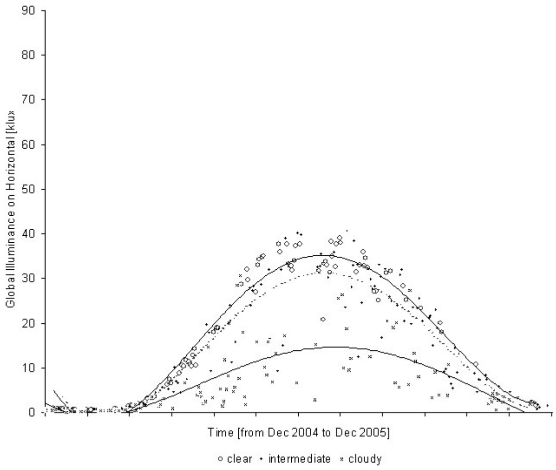

Figure 10: Variation of Illuminance on horizontal plane during a whole year. Values measured at 8:00 hours and splitted according to the sky conditions (cloud cover observations).

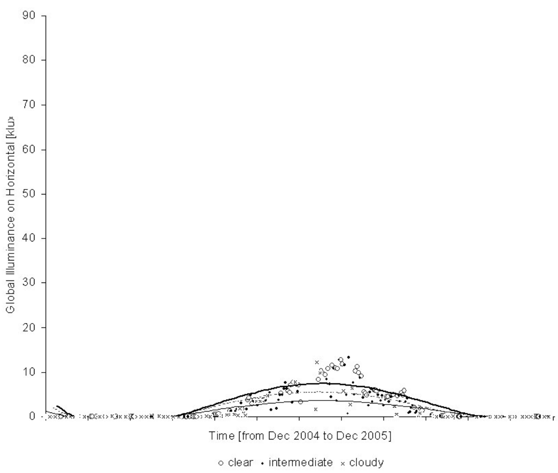

Figure 11: Variation of Illuminance on horizontal plane during a whole year. Values measured at 19:00 hours and splitted according to the sky conditions (cloud cover observations).

6. FINAL CONSIDERATIONS

The aim of this paper is to present the results of a first complete year of measurements from MeteoLab, a daylight station located at Politecnico University in Milano. Correlation of the illuminance on the horizontal plane with observed sky condition, from Milano Duomo Meteorological Observatory, and irradiance values, from MeteoLab, are also presented. The authors judge the analysis presented here as a first step into the definition of daylight climate for the city of Milan and its suburbs.

A further development of the research project, with the support of the existing and recent studies in this field, is oriented to the definition of standard sky models to be applied to the city of Milan that can measure the variability of real sky conditions.

Possible fallouts of these studies are connected to the development of new building codes or calculation methods (or to update the existing ones) in order to consider in a more detailed way the climate charcteristic of the city of Milano.

The availability of reliable daylight data at the design stage is necessary to use calculation methods and simulation tools in order to make prediction of building performances close as much as possible to the real behaviour of the built environment.

REFERENCES

[1] http://idmp.entpe.fr/
[2] UNI 10840, Light and lighting, School rooms General criteria for the artificial and natural lighting, March 2000
[3] Consiglio Nazionale delle Ricerche - “Dati per la progettazione edile ed impiantistica”, February 1982