

Microclima in ambienti di conservazione

(Tracciati estratti dai libri di testo di A. Bernardi e D. Camuffo)

1. Rappresentazione dei parametri microclimatici (temporale, spaziale)
2. Parametri significativi per il monitoraggio microclimatico
3. Analisi comparativa di tracciati e mappe microclimatiche

Microclima in ambienti museali

1. Rappresentazione dei parametri microclimatici (temporale, spaziale)
2. Parametri significativi per il monitoraggio microclimatico
3. Analisi comparativa di tracciati e mappe microclimatiche

Tracciati temporali

- Simultanei in punti diversi dello spazio
- Ciclo riscaldamento/condiz.
- Inerzia termica del pavimento

Uffizi: sala del Pollaiuolo

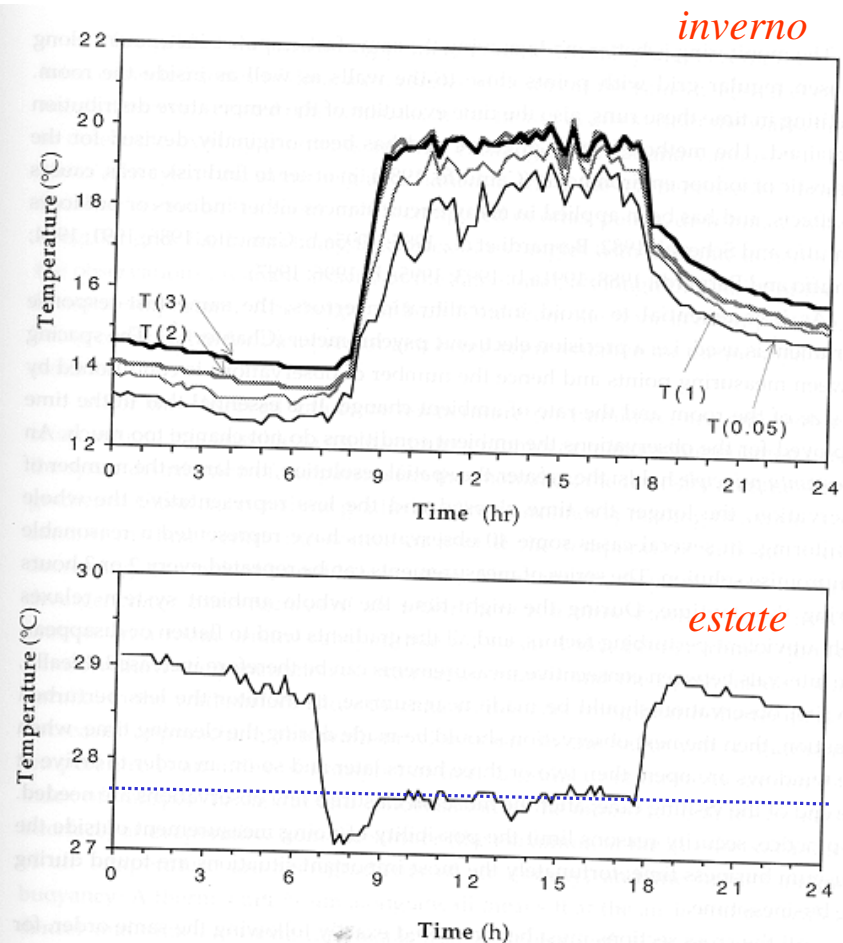


Fig.1.12 (a) Abrupt rise and drop of temperature in winter (18 February 1997), when the heating system is turned on in the morning and off in the evening. Measurements respectively taken at 0.05, 1, 2, 3 m from the floor. During the daytime the air is well mixed above 2 m, and the temperature is the same. (b) In summer (11 August 1992), similar step changes are generated by the air conditioning system, but the air is well mixed and the curves at the different heights are practically indistinguishable. For this reason only one has been reported. The Pollaiuolo and the Giotto rooms, Uffizi Gallery, Florence.

Tracciati temporali

- **Microclimi separati**

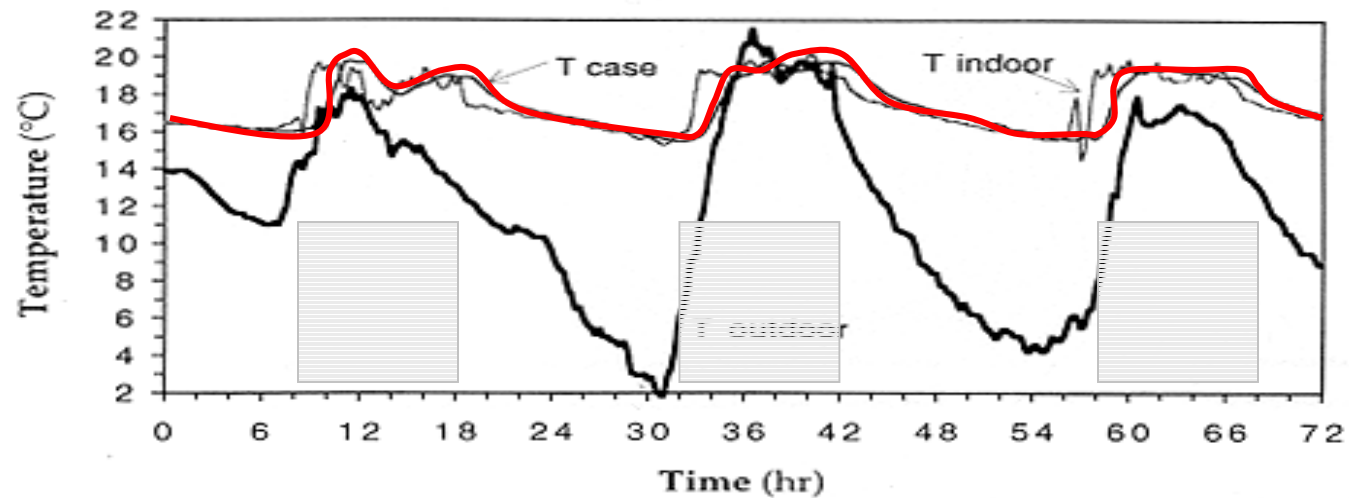


Fig.1.8 Comparison between the outdoor temperature, the indoor value and the temperature inside a show-case. Pollaiuolo Room, Uffizi Gallery, Florence, 11 to 13 March 1997.



Uffizi: sala
del
Pollaiuolo

Tracciati temporali

- *damping della teca*
- *attenzione all'illuminazione delle teche*

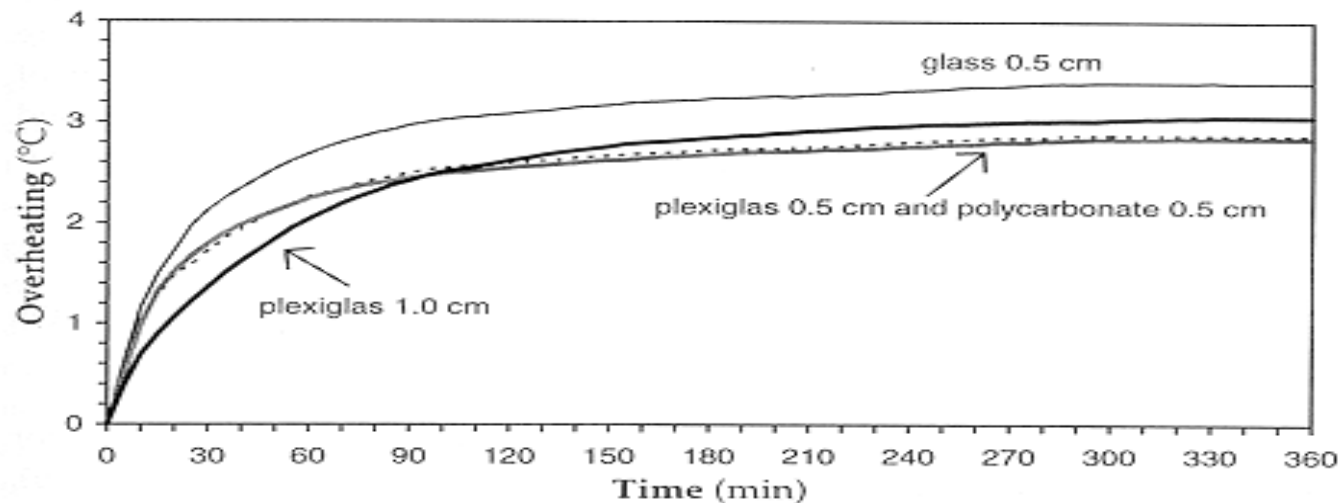
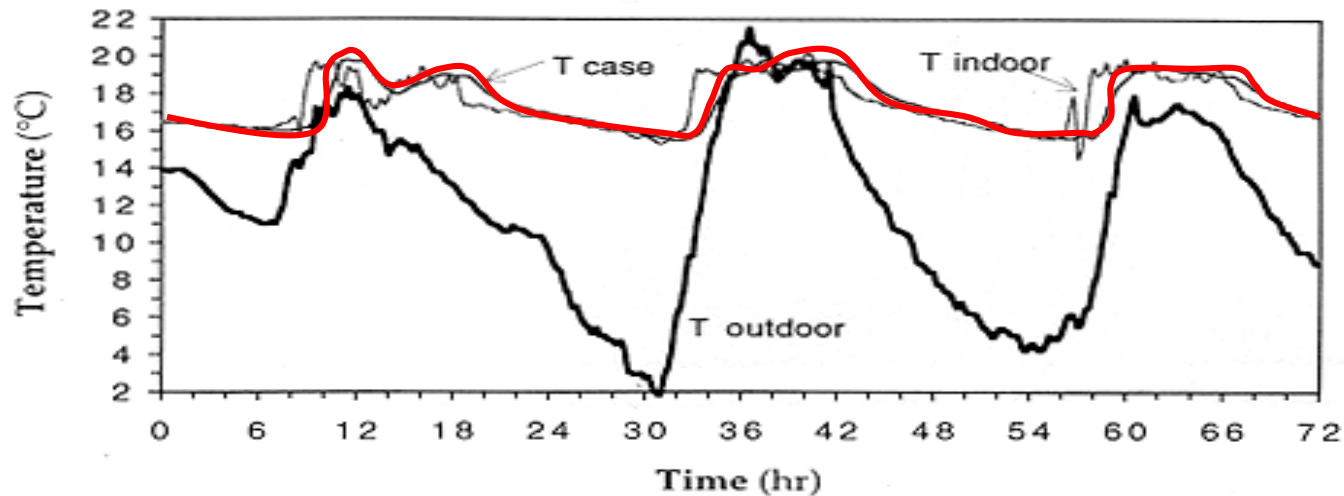


Fig.1.9 Overheating, as a consequence of the green-house effect, of show cases made of: glass, plexiglas, polycarbonate. The cases are lighted with 500 lux from a tungsten incandescence lamp.

Tracciati temporali

- **Microclimi locali**

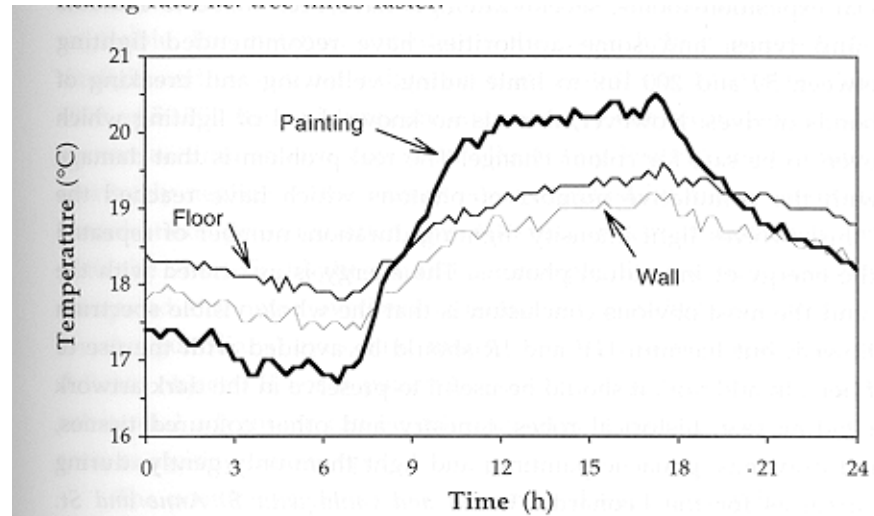


Fig.4.6 Heating of the panel painting the *Madonna d'Ognissanti* by Giotto (Uffizi Gallery, Florence) compared with the wall and floor temperature. The 3 February 1993.



Uffizi: sala di
Giotto,
Madonna
d'Ognissanti

Tracciati temporali

- **Tavola lignea**
- **Effetto dell'illuminazione**

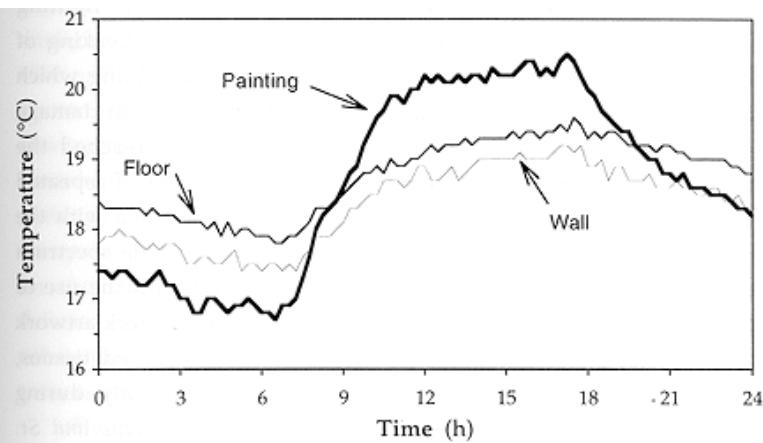
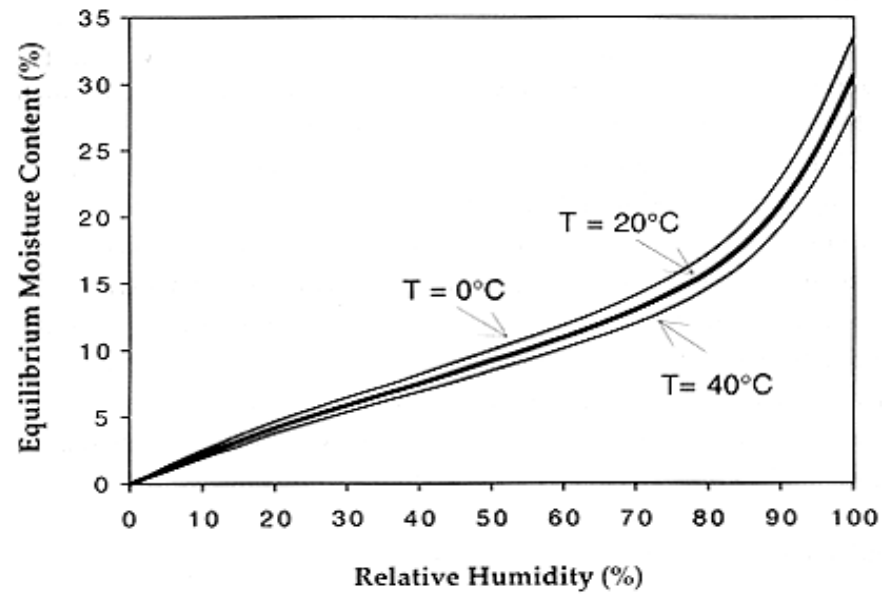
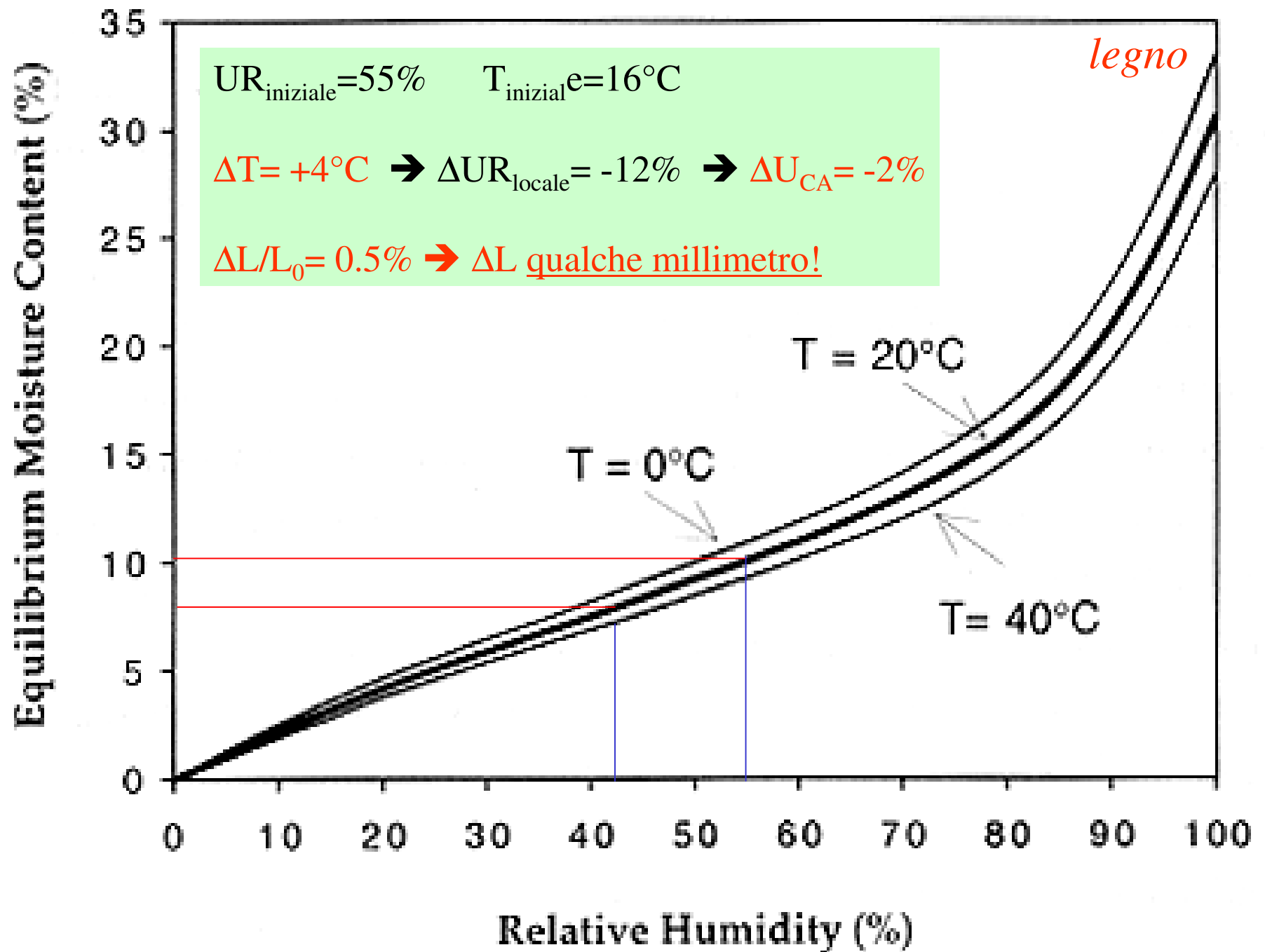


Fig.4.6 Heating of the panel painting the *Madonna d'Ognissanti* by Giotto (Uffizi Gallery, Florence) compared with the wall and floor temperature. The 3 February 1993.





Tracciati temporali

- **Damping dei muri**

S. Maria Maggiore

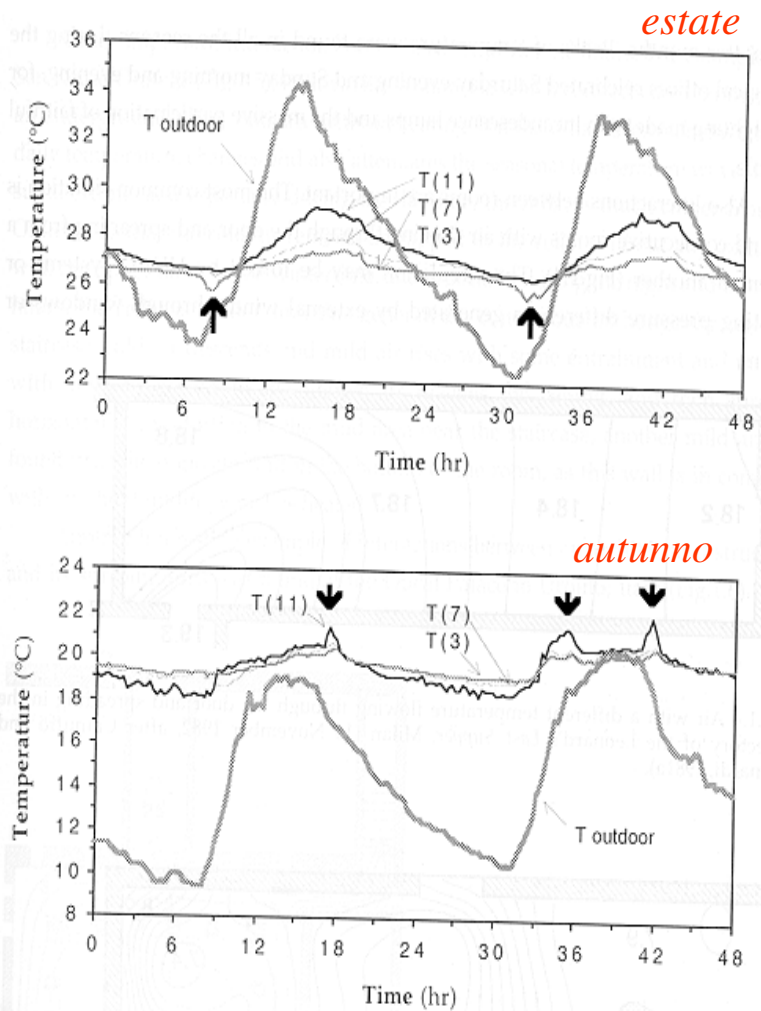
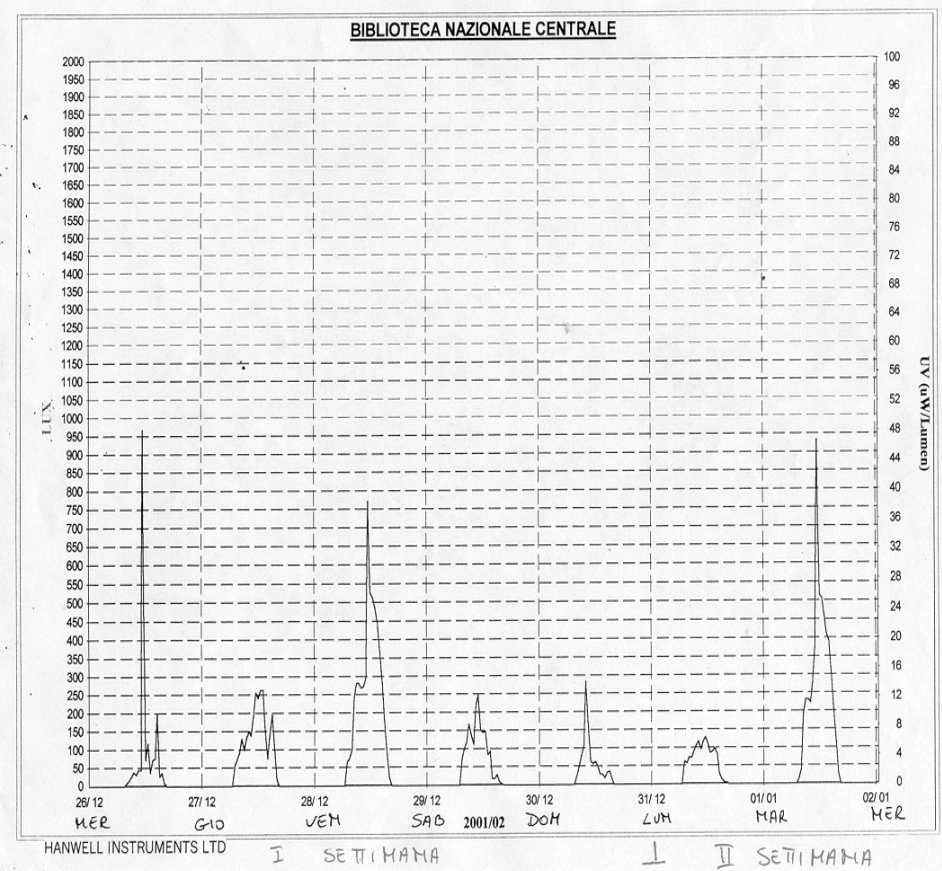
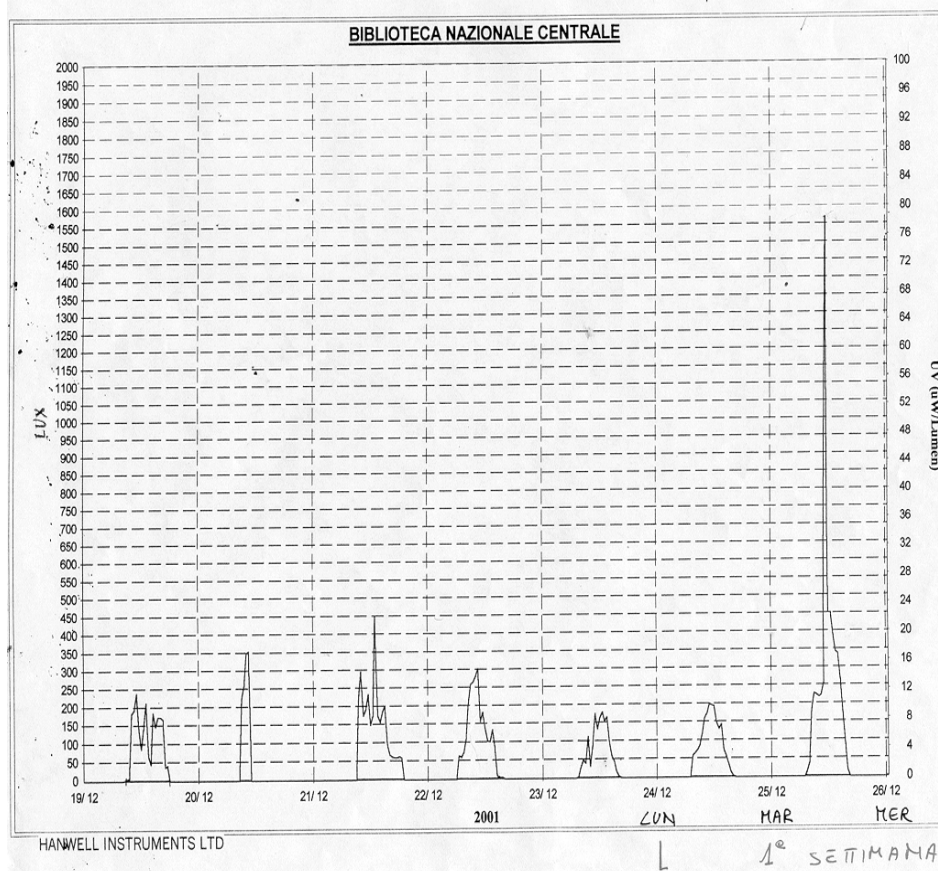


Fig.1.3. External and internal temperature (measured at the heights 3, 7 and 11 m) in the Basilica of S. Maria Maggiore, Rome, in summer (top) and autumn (bottom). The thick walls are very effective in damping out the external daily cycle, and in autumn the heat accumulated during the hot season makes the internal temperature higher than the external average value. Cold air entering through the door is visible at the 3 m level at the opening in the morning (upward arrows in the summer example, 9 to 10 August 1996), and a rise of temperature is visible during the liturgical offices on Saturday evening and Sunday (downward arrows in the autumn example, 19 to 20 October 1996).

Tracciati temporali

- **Diverso controllo dei valori di illuminamento naturale e artificiale**

Nazionale



Tracciati temporali

- **Fluttuazioni rapide (controllo efficiente)**

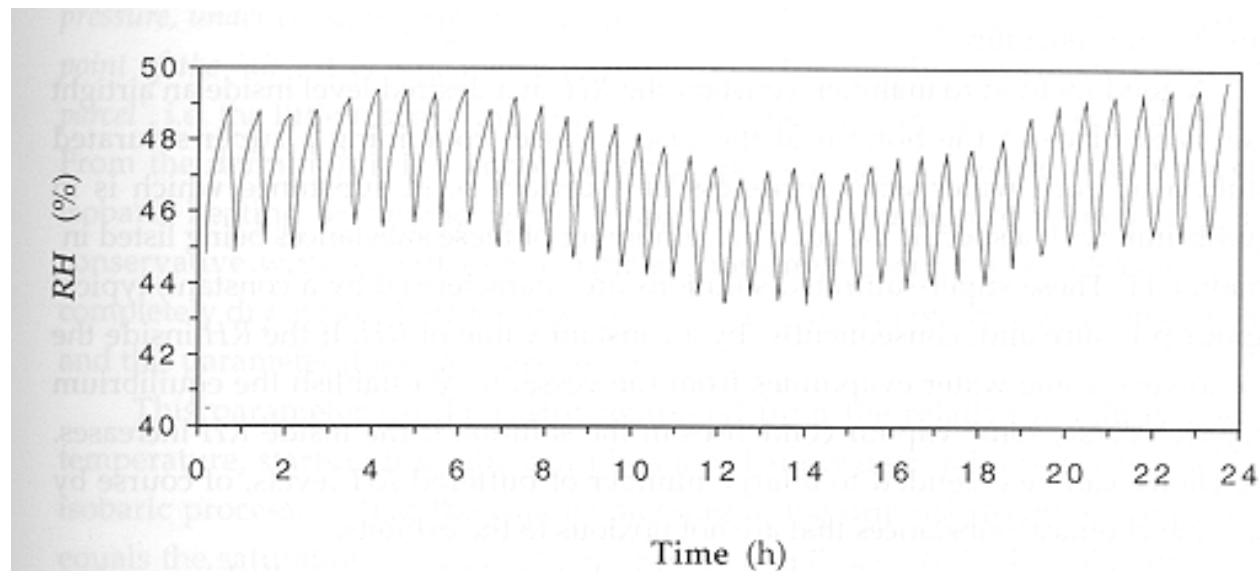


Fig.2.15. Fluctuations in relative humidity (RH) generated by a sophisticated controlling system, which controls this variable within two stated limits, i.e. the span $45 \leq RH \leq 50\%$. (Private Gallery of Modern Paintings, Parma, February 1996).

Tracciati temporali

- **Effetto dei tubi dell'acqua calda**

Chiesa di Colle Santa Lucia

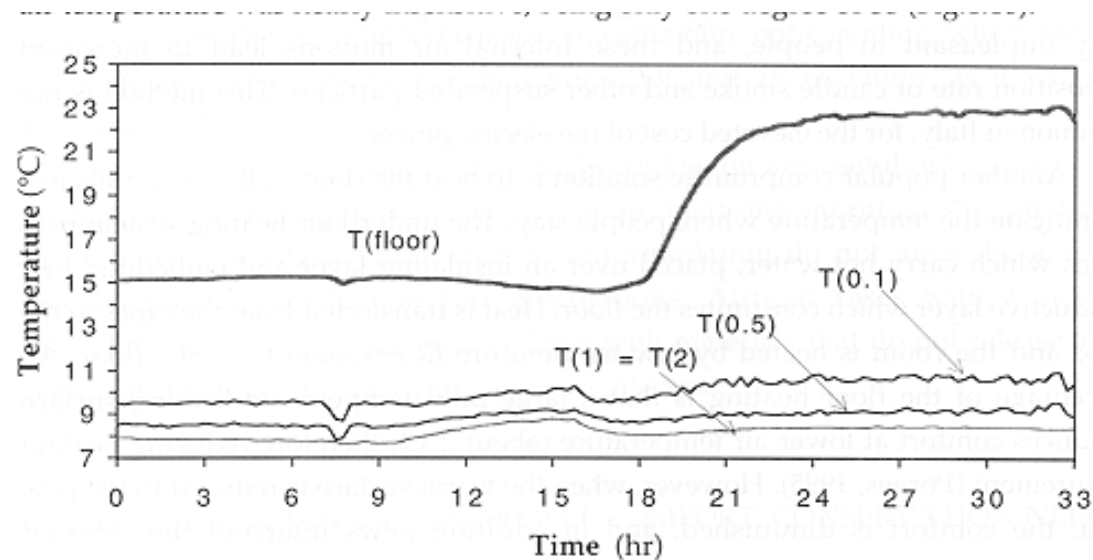


Fig.1.10 Floor and air heating in the church of Colle S. Lucia (Italian Dolomites) from 16 January 1997 at 00.00 to the next day at 9.00. Floor temperature (thick line) and air temperature at 0.1; 0.5 and 1 m; the measurement at 2 m shown the same temperature found at 1 m. The sharp rise in floor temperature in the afternoon of the 17th is due to the rise of hot water in the underfloor pipe from 30° to 60°C. The air heating from 10.00 to 17.00 of the 16th is due to the external sunshine and warming.

Mappe spaziali

- Simultanee ad istanti diversi
- Isolinee

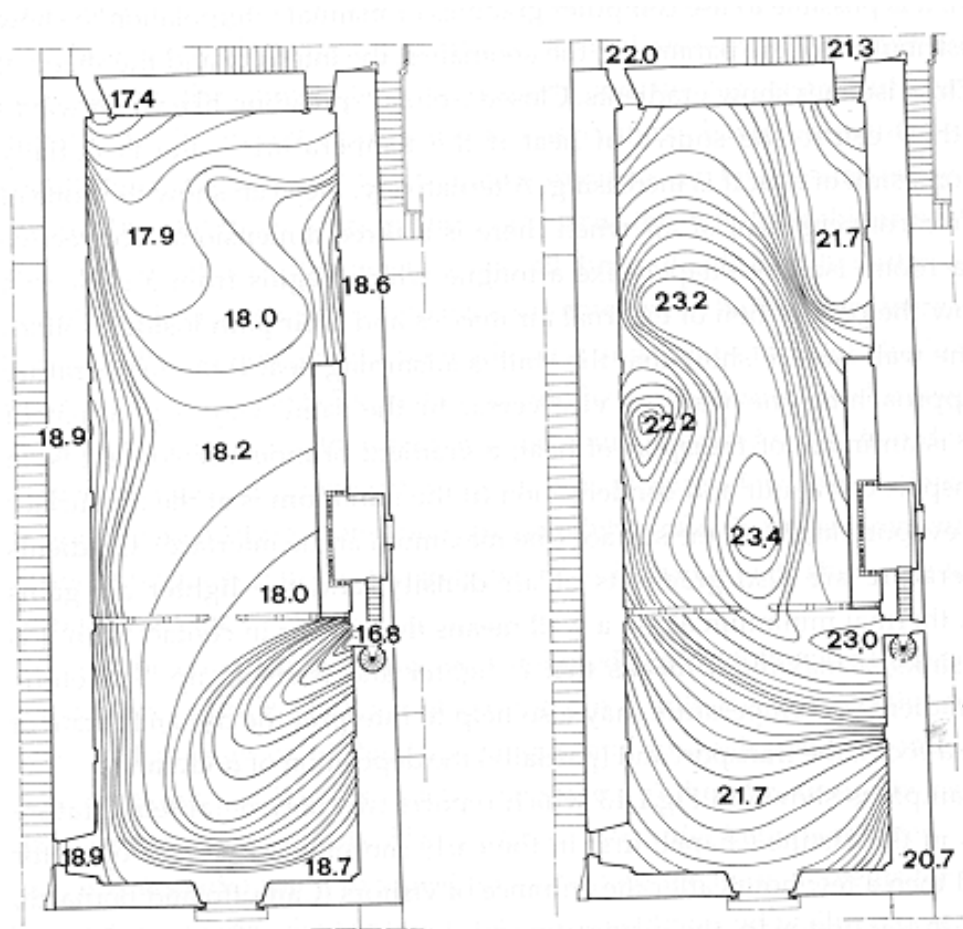


Fig.1.13 Air temperature (°C) in a horizontal cross section of the Sistine Chapel when it is opened for cleaning (a) and after the entrance of visitors (b). (7 May 1983, after Camuffo and Bernardi, 1986, reprinted by permission of the *Bollettino dei Musei e Gallerie Pontificie*).

Sistina



Mappe spaziali

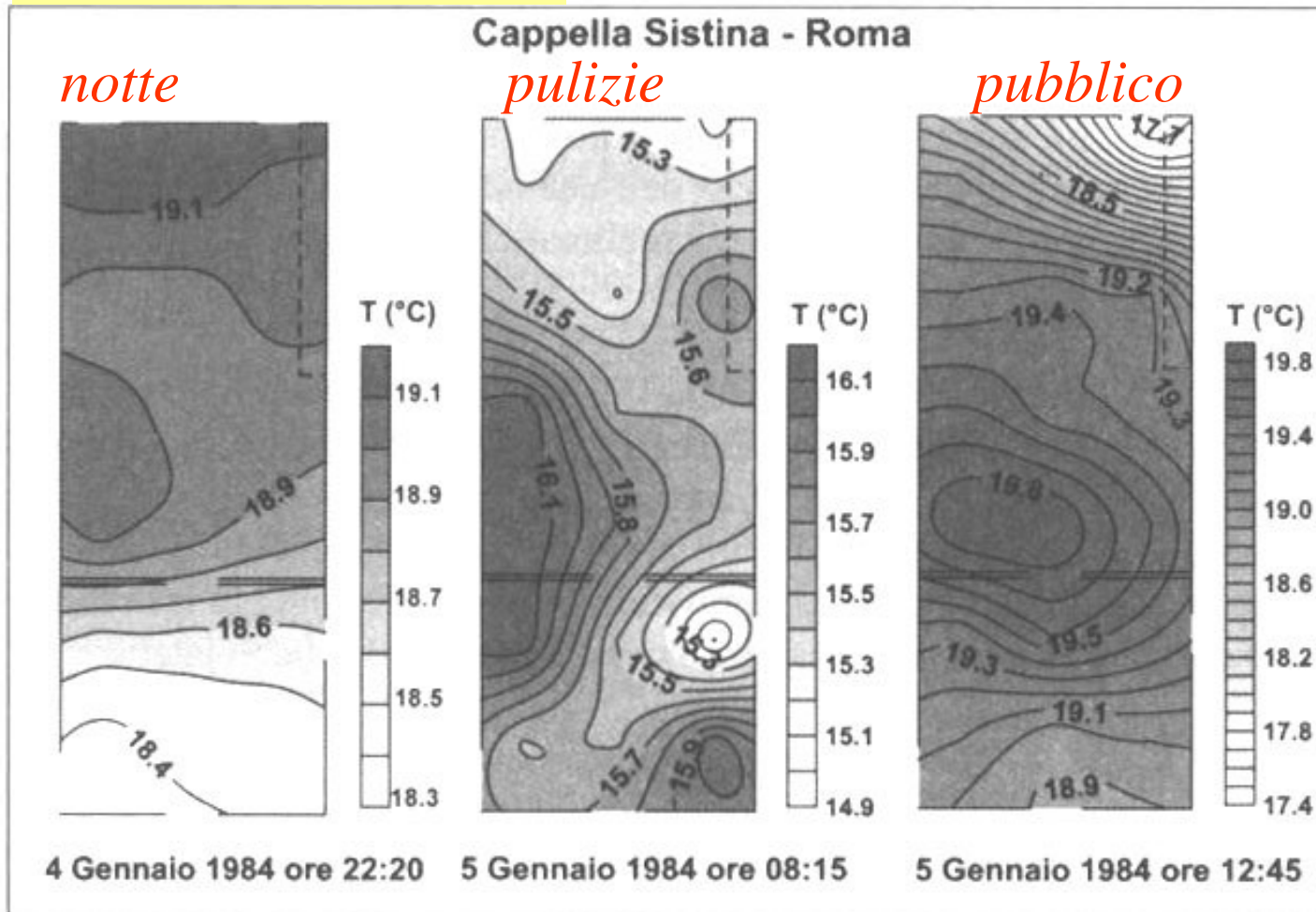


Figura 1.- Sezioni orizzontali della Cappella Sistina a Roma con la rappresentazione delle isolinee relative alla temperatura in tre momenti della giornata: di notte (ore 22:20) si osserva una distribuzione abbastanza omogenea; nelle prime ore del mattino (ore 08:15) si notano i massimi lungo le pareti e i minimi dovuti alle immis- sioni di aria più fredda dalle porte aperte durante le pulizie; in presenza di pub- blico (ore 12:45) sono evidenti marcati massimi termici al centro della sala.

Mappe spaziali

- Cross section
- Stratificazioni e flussi d'aria

Cappella degli Scrovegni

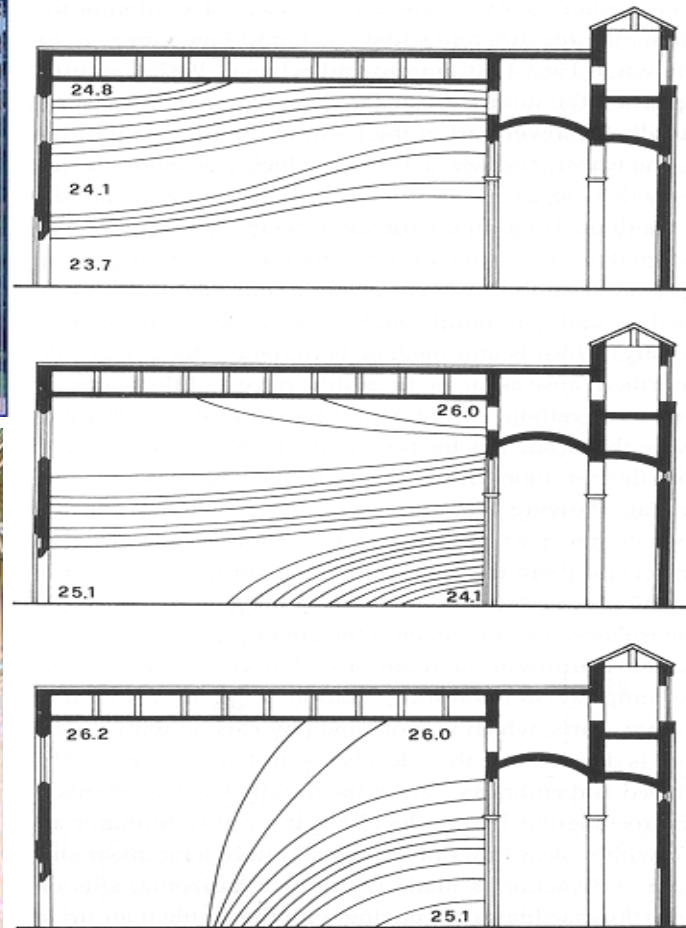


Fig.1.14 Vertical cross sections of the Giotto Chapel, in the summertime. (a) In the early morning (8 a.m., the 9 July 1977) cold air penetrates through the door and above the cold layer the warm air remains entrapped. (b) At mid-morning (11.30 a.m., the 8 July 1977) external air penetrates through the door, and has a density intermediate between the cold tongue near the floor on the apse, and the warm air entrapped aloft. (c) In the early afternoon (14.25, the 9 July 1977), the hot floor generates mixing and isothermy in the front part of the nave; after a transition zone in the middle of the Chapel the air in the apse remains unaffected and thermally stratified. (After Camuffo and Schenali, 1982, reprinted by permission of the *Bollettino d'Arte*).

Mappe spaziali

Sainsbury

- **Scarsa inerzia termica degli edifici moderni**

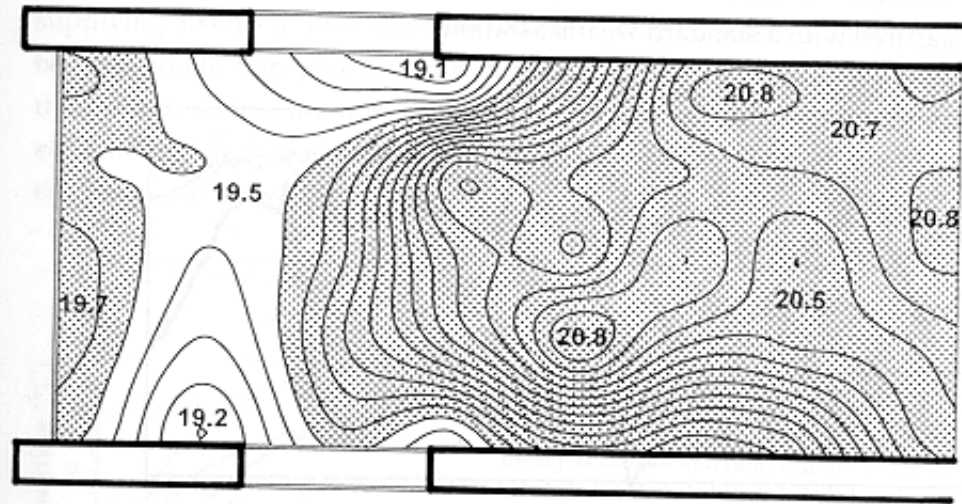


Fig.1.7 Horizontal cross section of the Sainsbury Centre for Visual Art, Norwich (U.K.), showing the temperature distribution. Modern buildings, made of metal and glass, do not benefit of the inertia of the thick wall, and the microclimate is conditioned by heat exchanges and forced mixing, but fans are not sufficient to obtain a very homogeneous temperature distribution. The 9 December 1996 at 16.30.

Mappe spaziali

Cenacolo

- **Flussi d'aria**

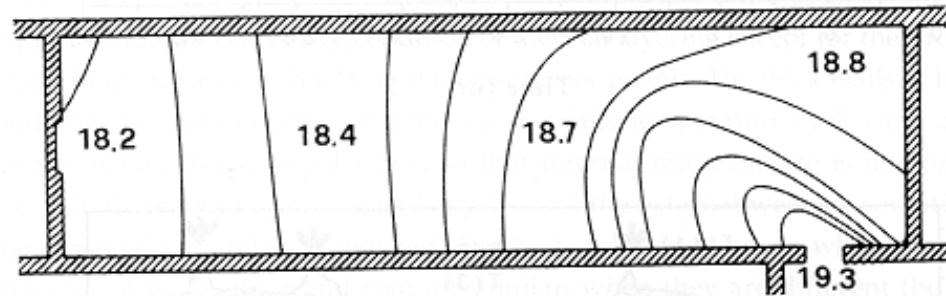


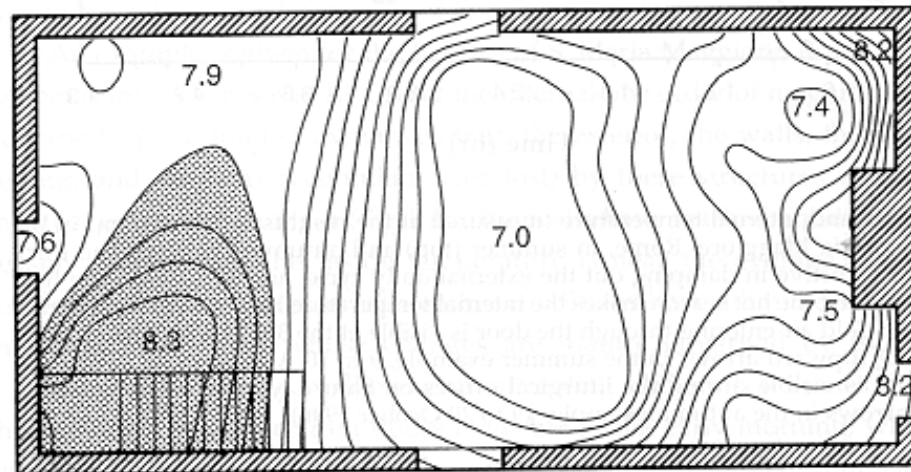
Fig.1.4 Air with a different temperature flowing through the door and spreading in the refectory of the Leonard's *Last Supper*, Milan (14 November 1982, after Camuffo and Bernardi, 1981a).



Mappe spaziali

Oratorio di S. Rocco

- **Flussi d'aria**



T (°C)

Fig.1.5 Interactions between different floors in the S. Rocco Oratory, Padova. In the winter, mild air rises from the cellar through the staircase, spreading in the Oratory. In the bottom of the room (i.e. the right of the map), the wall is milder, being contiguous with another, heated building (18 January 1996).

Microclima in ambienti museali

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Principali parametri microclimatici monitorati

• Temperatura	T	$[^{\circ}\text{C}]$
• Umidità relativa	UR	$[\%]$
• Mixing ratio (rapporto di mesolanza)	MR	$[\text{g/kg}]$
• Umidità specifica	US	$[\text{g/kg}]$
• Distanza dal punto di rugiada	DPS	$[^{\circ}\text{C}]$
• Illuminamento	E	$[\text{lx}]$
• Componente uv (rapporto $\mu\text{W/lm}$)	UV	$[\mu\text{W/lm}]$

Mixing ratio (rapporto di mescolanza) MR [g/kg]

$$MR = \frac{m_v}{m_{aria}}$$

$$[MR] = g / kg$$

- **Non dipende da:** T
 V
 P
 δQ
- **Varia in presenza di :** **condensazione**
evaporazione
miscelamento con altre masse d'aria

Umidità specifica US [g/kg]

$$US = \frac{m_v}{m_{aria} + m_v}$$

$$[US] = g / kg$$

- **Non differisce molto da MR (<1%)**

Distanza dal punto di rugiada DPS [°C]

$$DPS = T - T_R$$

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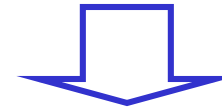
Nota

1. Max valore di MR ad una data T:

$$MR_s(T) = \frac{m_{v,s}(T)}{m_a}$$

2. Si dimostra(*) che :

$$UR(T) = \frac{MR}{MR_s(T)}$$



Se T è costante in tutto l'ambiente, si troverà:

- una corrispondenza diretta di massimi e minimi tra le mappe di UR e MR (US);
- una corrispondenza inversa di massimi e minimi tra le mappe di UR e DPS;

$$^{(*)}UR(T) = \frac{U}{U_s(T)} = \frac{m_v / V}{m_{v,s}(T) / V} = \frac{MR}{MR_s(T)}$$



Uffizi: sala
di Giotto

Uffizi: sala di Giotto

- **Nota: piccole variazioni di T**

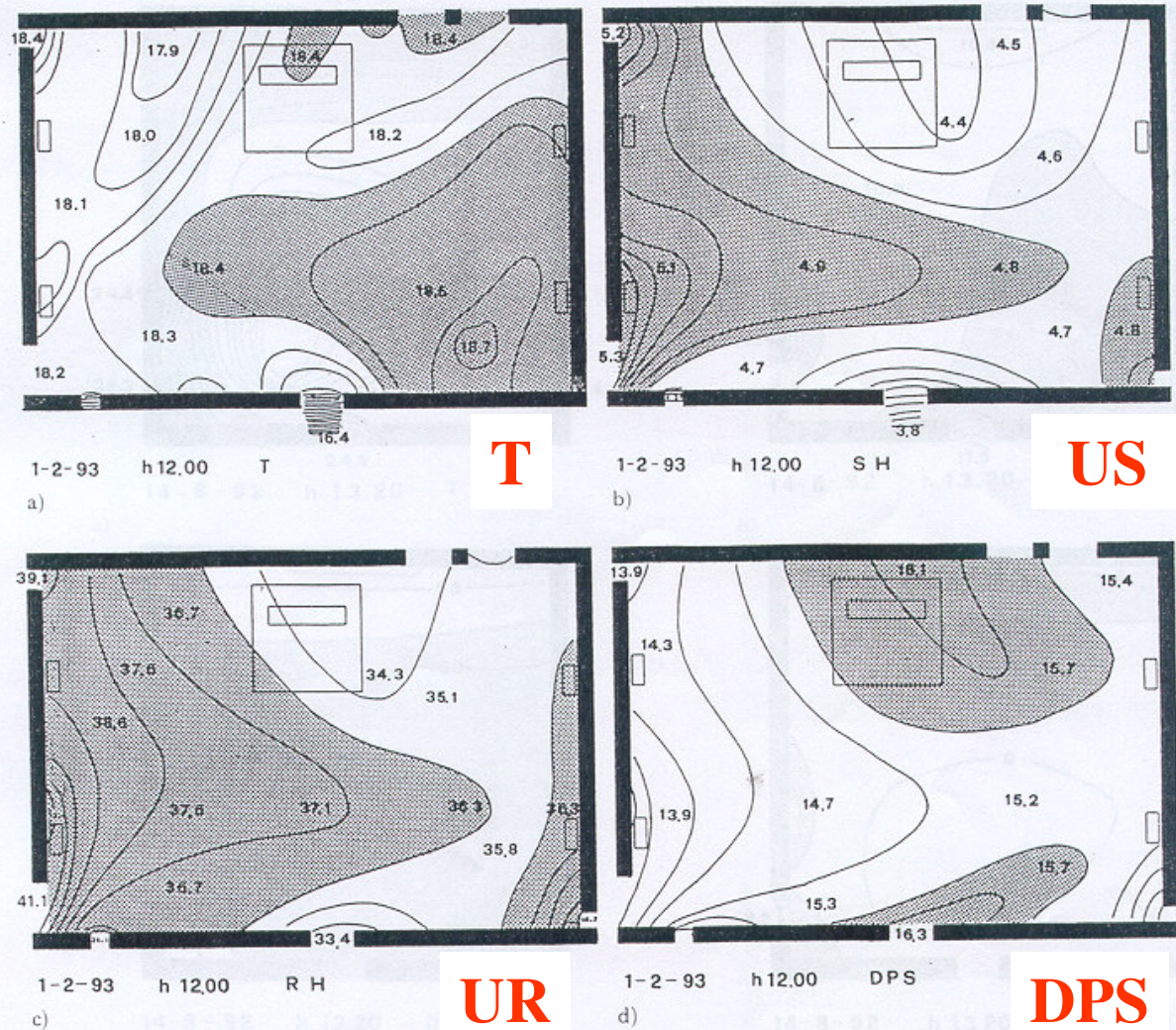


Fig. 2 - Horizontal cross section of the distribution of: (a) temperature T (°C), (b) specific humidity SH (g/kg); (c) relative humidity RH (%) and (d) dew point spread DPS (°C), at 12.00 on 1/2/1993.





Uffizi: sala
di
Leonardo

Uffizi: sala di Leonardo

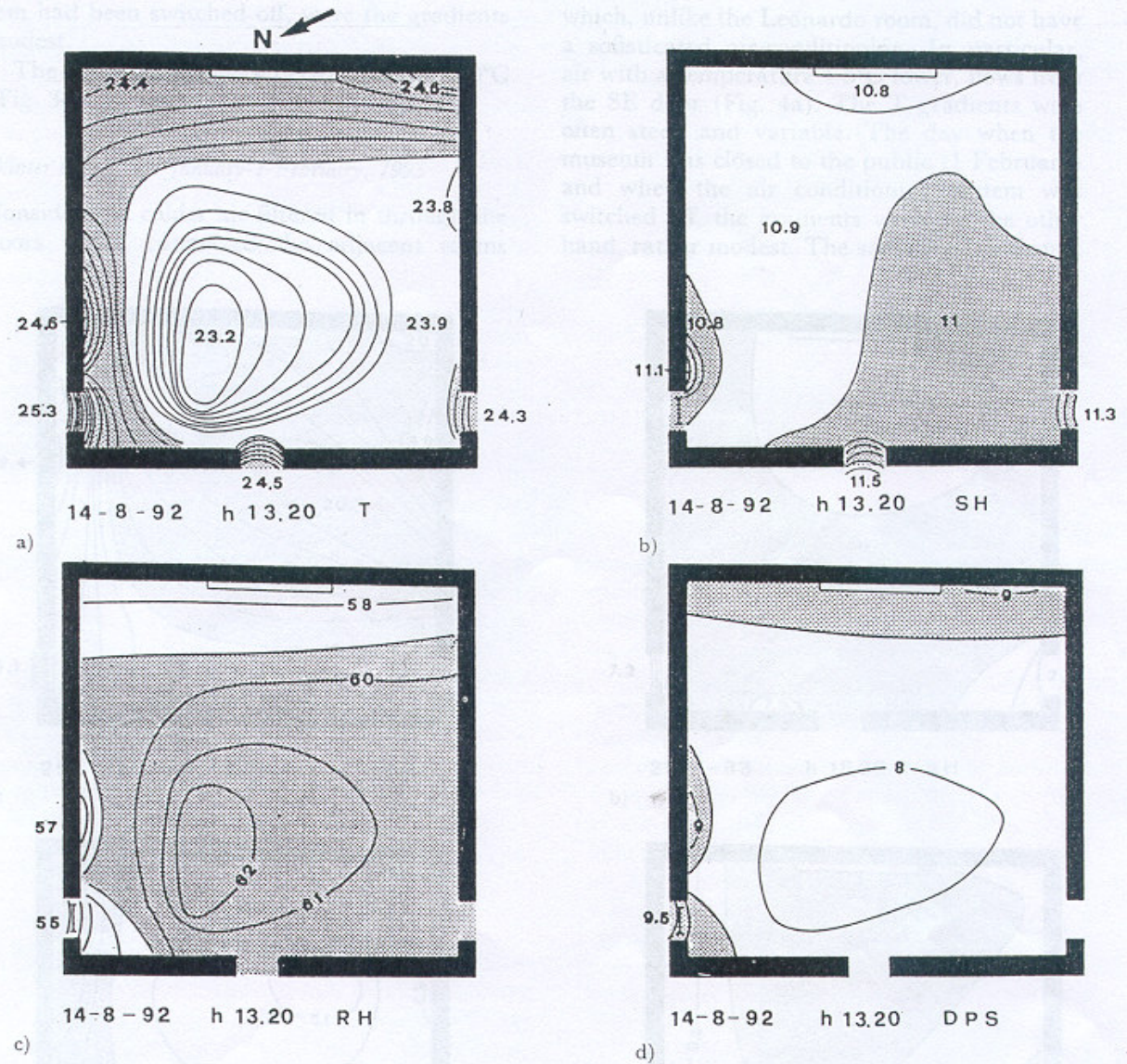


Fig. 3 – Horizontal cross section of the distribution of: (a) temperature T (°C), (b) specific humidity SH(g/kg); (c) relative humidity RH (%) and (d) dew point spread DPS (°C), at 13.20 on 14/8/1992.



Chiesa di Rocca Pietore

- **Variazioni di UR legate a variazioni di T**

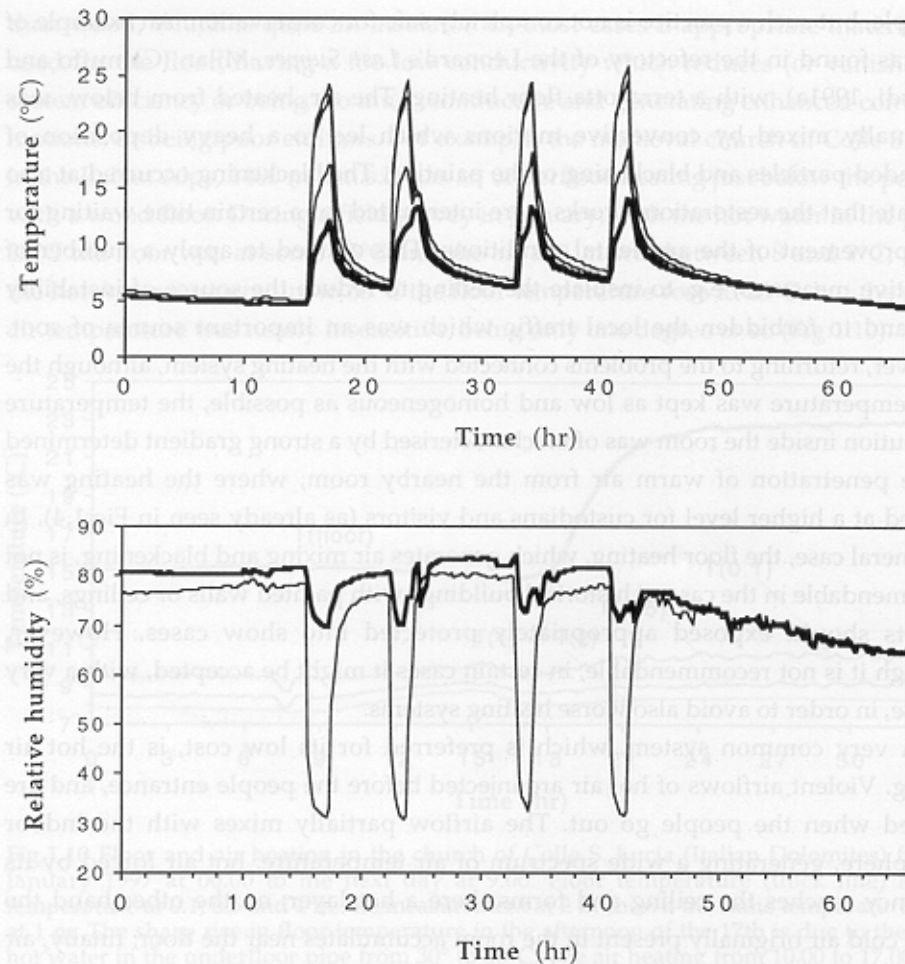


Fig.1.11 (a) Sudden heating and cooling, and strong atmospheric layering, generated by a hot air heating system inside the Church of Rocca Pietore, Italian Alps. The indoor air temperature measurements were taken at the heights 1, 2, 3, 4 m. The measurement at 1 m is evidenced with a thick line, followed by the others with maximum temperature increasing with height. The values monitored at 3 and 4 m are very similar. The figure reports data from 24 to 26 December 1996, and the peaks correspond to the heating for the Eve and Christmas celebrations. (b) Relative humidity variations caused by the above temperature changes at 1 m (thick line) and 4 m (thin line).

Louvre: Salon Carré

- **Massimi di UR e MR e minimi di DPS corrispondono minimi : $T \sim \text{cost}$**

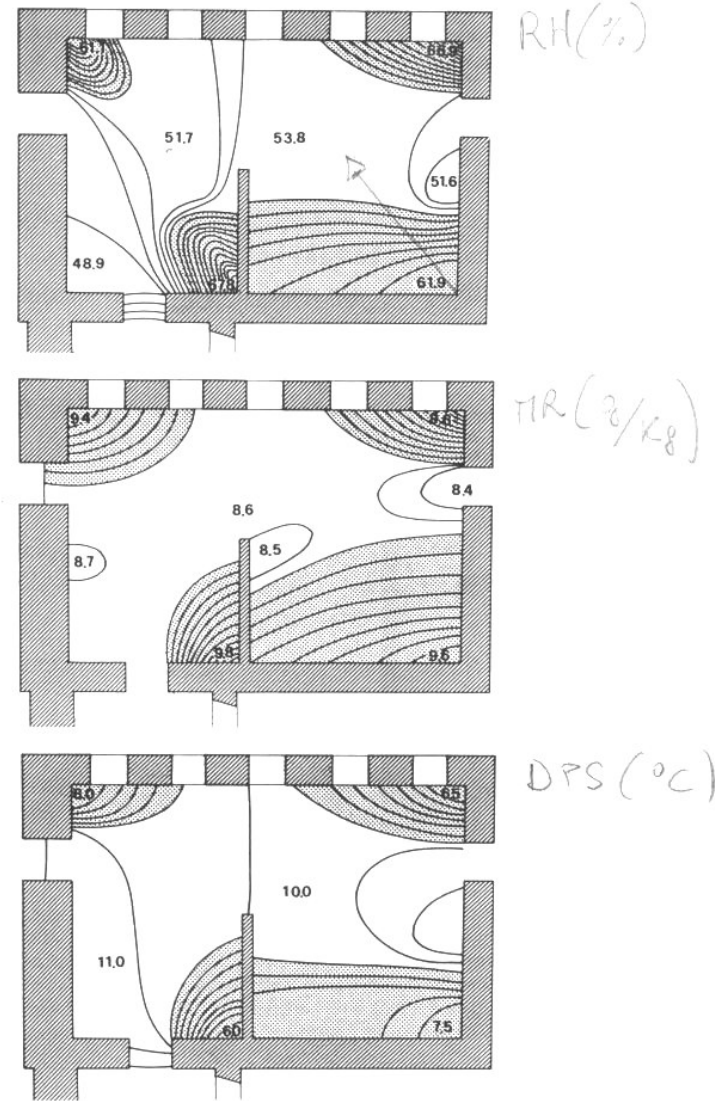


Fig.2.5 Micro-mapping in a horizontal cross section of the *Salon Carré*, Louvre Museum, Paris, showing clouds of moisture (evidenced with shading) diffusing into the room, which are generated by humidifiers. Four active humidifiers are placed in corners of the room. Others are in stand-by position. This situation is here described by means of three parameters, in order to gain familiarity with different representations, i.e.: (a) relative humidity (RH, %); (b) mixing ratio (MR, g/kg); (c) dew point spread (DPS, °C). The clouds of moisture appear as local maxima of RH or MR, and minima of DPS. (21 February 1995).

Uffizi: sala di Giotto

- UR determinata da US (umidificatori)

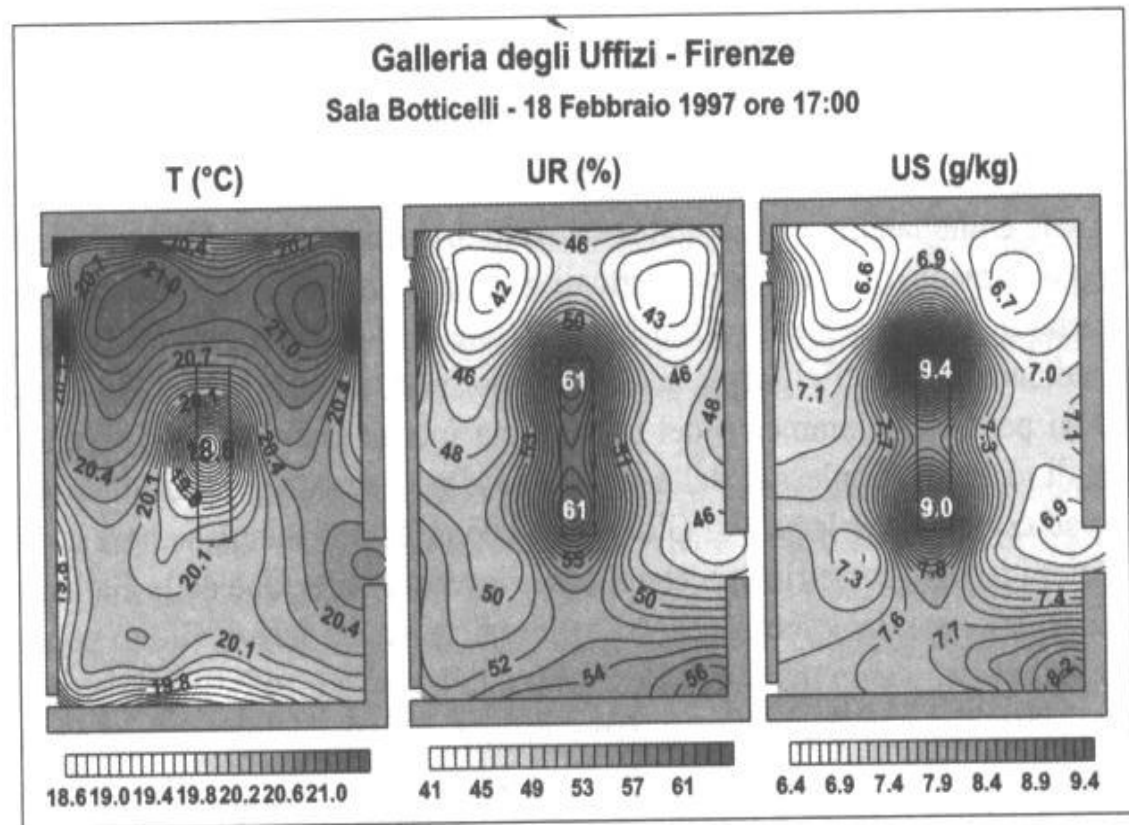


Figura 12.- Sezioni orizzontali della Sala Botticelli della Galleria degli Uffizi a Firenze con la rappresentazione delle isolinee relative alla temperatura, all'umidità relativa e all'umidità specifica. Si notino i marcati gradienti in corrispondenza degli umidificatori posti al centro della sala.



Koninklijk Museum

- **UR determinata da T (radiatori)**

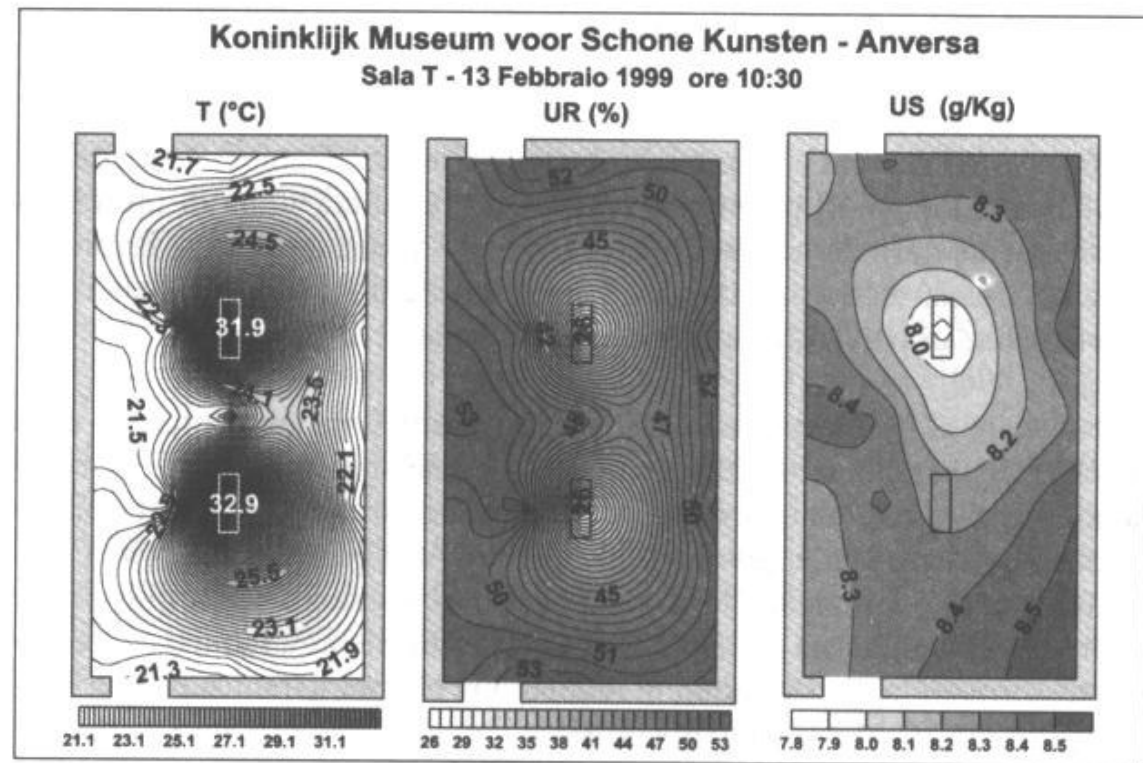


Figura 11.- Sezioni orizzontali della Sala T del Museo di Anversa con la rappresentazione delle isolinee relative alla temperatura, all'umidità relativa e all'umidità specifica. Si notino i massimi in corrispondenza dei termosifoni posti al centro della sala.