# Canonical Biplot as a tool to detect microclimates in the inner and outer parts of El Salvador Church in Seville, Spain

A.C. Iñigo[a],*, J. García-Talegón[b], V. Vicente-Palacios[c], S. Vicente-Tavera[c]

[a]Instituto de Recursos Naturales y Agrobiología de Salamanca, IRNASA/CSIC, Salamanca, Spain.

[b]Departamento de Geología de la Universidad de Salamanca, Salamanca, Spain.

[c]Departamento de Estadística de la Universidad de Salamanca, Salamanca, Spain.

*Correspondence to: A.C. Iñigo, Instituto de Recursos Naturales y Agrobiología de Salamanca (IRNASA-CSIC), c) Cordel de Merinas 40-52, 37008 Salamanca. Tel.: (+) 34 923 219606. Fax: (+) 34 23 219609. E-mail: adolfo.inigo@irnasa.csic.es

## Abstract

The present study was carried out on the Salvador Church (Seville, Spain) during its last restoration intervention. Relative humidity and temperature data from the sensors located on the inner and outer parts of the church were analyzed to characterize different microenvironments. The church was built mainly of calcarenite from the Puerto de Santa Maria and the crypts, vaults, and upper parts of the walls were made of adobe bricks partially covered in plaster. In order to monitor the climatic variances between different locations, Canonical Biplot has been applied. The results obtained showed that in all seasons there were differences between the external climate and the internal microclimates. In the interior sites there were dissimilarities between the sensors located in different positions, which were greater during the summer months and less obvious in winter, autumn and spring. The differences observed explain, to a large extent, the deterioration of the different materials, depending on their location.

*Keywords*: Microclimate, historical building, building materials, decay, Canonical Biplot, Cultural Heritage.

## 1. Introduction

El Salvador Church is an 18th century temple located in the historical city center of Seville (Spain). It is a monument that combines Baroque style with renaissance and neoclassical elements. The space where it is located was previously occupied by a baroque temple (17th century) that collapsed before it was completely built, by the Ibn Adabbás Mosque (9th century), the first mosque of Seville, and also by different Roman and Visigoth buildings. Some of these remains are still conserved today.

This monument has been in constant restoration since its opening in 1712. The deterioration of the church has been conditioned by the intrinsic properties of the materials used in its construction (Iñigo et al., 2000; Vicente, 1994; Figueiredo et al, 2007) and by environmental conditions (Camuffo, 1998). These environmental conditions, in turn, have been determined by the general climate of the area, but above all by the microclimates that are generated within the building (Tapete et al., 2014; Sanchéz-Moral et al., 2014; D'Agostino et al, 2013; Merello et al., 2013; Garcia-Talegon et al., 2006; Török and Hajpal, 2005; Iñigo and Vicente-Tavera, 2002; Tricio and Viloria, 2002; Iñigo and Vicente-Tavera, 2001; Vicente, 1996; Winkler, 1997).

Seville is considered to have a continental Mediterranean climate, characterized by very hot and dry summers and mild winters. According to the Spanish State Weather Agency (AEMET), the average daily temperature is 18.6 ºC, where temperatures can reach values below 0 °C during 4 days per year (http://www.tutiempo.net).

The objective of the present work was to identify different microclimates within this church and to associate these with the deterioration detected in the interior of the building.

## 2. Experimental

*2.1. Sensing system configuration and architecture.*

Seven individual sensors were installed in the interior of the church, with 2 channels for recording temperature and relative humidity. The sensors were distributed according to Fig. 1, within the following locations: sensor 1(✹), crypt, -2 meters (m) from ground level, northeast; sensor 2(✹), crypt, -2 meters (m) from ground level, center; sensor 3(✹), crypt, -2 meters (m) from ground level, southwest; sensor 4(✳), first floor, +4 m from ground level, southwest; sensor 5(✶), clerestory, +13 m from ground level, southwest; sensor 6(✳), first floor, +4 m from ground level, northeast and sensor 7(✶), first floor, +13 m from ground level, northeast. The data collected on the exterior temperature and relative humidity were recorded by a weather station (✪) located on the south terrace of the monument, at a height of 22 meters above ground level (Fig. 1).

The values of relative humidity and the exterior environmental temperature of the building were measured with a STH-S331 sensor connected to a METEODATA-3016CM data collection station (henceforth "climate station") equipped to record the mean data of the variables collected hourly. Likewise, the relative humidity and the environmental temperature of the interior of church were determined with seven autonomous "smart" sensors (Data-Logger TESTO, 175 model) programmed to obtain the means of the variables collected every 2 hours. All sensors were kept in the original positions over the entire study period, see Fig. 1.

The time period included within the study was from 5 April 2006 until 29 July 2008. The data collected made up a matrix comprised of 20,215 rows and 2 columns (exterior relative humidity and exterior temperatures) and another matrix of 10,166 rows and 14 columns (7 with the interior relative humidity and 7 with the interior temperatures).

*2.2. Presence of different pathologies in the building.*

Using the ICOMOS nomenclature, 2008, the following pathologies have been observed (deteriorations/alterations/weathering): a) the presence of fissures and scaling in both the calcarenite forming the outer wall and in the gypsum plaster covering the bricks as well as the calcarenite (Figs. 2a, 2b), b) in other areas of the upper outer part of the monument, blackened and black crusts are also observed (Fig. 2c), c) a colony of kestrels, which is a protected animal, still remains and their excrement causes soiling and biological colonization (Fig. 2c), d) in the crypt there are adobe bricks darkened (discolouration) and differential erosion (loss of components and of matrix) (Figs. 2d, 2e) and e) in the crypt and interior of the church showing signs salt efflorescence and possible salt crust on the columns (Figs. 2f, 2g).

*2.3. Statistical methodology*

Initially, there were two data matrices available: one referring to the data collected every hour by the external climate station, on relative humidity and temperature, which contained 2 columns and 20213 rows; and another matrix, containing 14 columns and 10164 rows, which referred to the data collect every 2 hours by sensors located inside the building.

In order to analyze the variation between the different sensor locations, and given that there were 16 time series (8 sensors with 2 recordings each - temperature and relative humidity - over the course of approximately two years) we divided the data according to the season, months, and the corresponding year of when it was collected during the study period.

The daily component was divided into periods of 6 hours (0-6, 6-12, 12-18 and 18-24). This component (by hours) was used for searching for any apparent differences.

Taking the above into account, there are 8 available matrices (4 for temperature and 4 for relative humidity):

Autumn - 4 columns (0-6, 6-12, 12-18 and 18-24) and 1432 rows, divided into 48 groups.

Winter - 4 columns (0-6, 6-12, 12-18 and 18-24) and 1448 rows, divided into 48 groups

Spring - 4 columns (0-6, 6-12, 12-18 and 18-24) and 2152 rows, divided into 72 groups.

Summer- 4 columns (0-6, 6-12, 12-18 and 18-24) and 1696 rows, divided into 56 groups

The statistical analysis was performed using the multivariate technique Canonical Biplot. This is complementary to the MANOVA analysis (Multivariate Analysis of Variance), but includes all of the characteristics of the Biplot method (Gabriel, 1971, 1972 and 1995), which is aimed at discriminating the set of groups of previously established populations. This technique was later developed and completed (Galindo, 1986; Amaro et al., 2004; Vicente- Villardón, 2016) and applied to the field of cultural heritage conservation (Iñigo et al., 2013, 2014 and 2017; García-Talegón et al., 2013, 2016).

The Canonical Biplot used in this work improves and increases knowledge on other multivariate techniques previously employed (Principal Components Analysis) for this purpose (Merello et al., 2014).

The results are summarized on several factorial planes, where the variables are represented as vectors that start out from a hypothetical origin and the means of the different groups as stars surrounded by confidence circles in the same reference system. If two variables are represented with a very small angle, then the variables are highly correlated, and are inversely correlated if they are opposite. Additionally, if the angle is close to perpendicularity, their correlation is minimum. When projecting all of the star markers perpendicularly onto the directions of any of the variables, the order of the projections in the direction of those variables is equivalent to the value that the population means take on for that variable. If two confidence circles are projected perpendicularly on one of the variables and the intervals of both projections do not overlap, this is tantamount to saying that there are differences between both means (Students' t test) (Iñigo et al., 2014); the amplitudes of the circles will depend on the determined significance, α (MSD, Bonferroni corrections, etc.). In our applications the Bonferroni correction has been used, which depends on the number of groups to be compared in each season. These interpretations are subject to a series of measurements of the quality of representation for the different planes (inertia absorption of the planes, the goodness of the projections of the measurements on the variables for the dimensions selected, etc.). In this work confidence circles have not been introduced in the graphs because they make it difficult to interpret the differences.

In our case, there are 4 variables (4 daily time periods) and different groups of relative humidity and temperatures, differentiated according to their location (sensors), month and year. A differential analysis was carried out with respect to the various seasons (relative humidity and temperature analysis). For each season, the analysis was standardized by taking the means of both exterior and interior relative humidity and temperature references, within the established time periods and according to the months and years.

The nomenclature used was the following: TXYZ for temperatures and HXYZ for the relative humidity, where X indicates the different locations in the interior of the church (1, 2, 3, 4, 5, 6 and 7) and the exterior (e). Y refers to the month, which will change according to the season in the following manner: Autumn (October = O, November = N and December = D), Winter (January = J, February = F and March = M); Spring (April = A, May = M, and June = J) and Summer (July = J, August = A and September = S). Z indicates the year in which the data was collected at the different locations (6 = 2006, 7 = 2007 and 8 = 2008).

As an example of interpretation, the main plane of the temperature analysis during autumn was used as a reference, as shown in Fig. 3. In this graph, the stars correspond to the averages of the groups of temperatures in the different locations, different months and years during autumn. These averages should be surrounded by circles of confidence, but in our case to interpret two possible comparisons, the exterior temperature during December 2007 (TeD7) was taken and compared to that of the location of sensor 1 during the same month and year. (T1D7). In this graph, if we compare the differences in the variable of the first 6 hours (0-6), when projecting the circles on the direction of said variable, it is observed that the intervals generated do not overlap. This is interpreted as the presence of differences between both temperatures. If these same groups are compared during the last 6 hours of the day (18-24), the two projections overlap, indicating there are no differences between both groups for this variable.

This interpretation should be generalized to all possible comparisons between the outside in front of the crypt, outside in front of the inside of the church, inside the church in front of the crypt and at different heights inside the church. All of this is extrapolated to each of the stations, both for temperature and relative humidity.

To better visualize all of the comparisons, each main plane has been repeated three additional times in each of the figures. The label for each section is the following: section (b) The Exterior versus the Crypt; (c) The Exterior versus the Interior of the Church; and (d) The Interior versus the Crypt.

The differences between heights inside the church can be determined between sensors 4-5 and 6-7, which can be analyzed in sections a, c and d.

In order to help detect all the possible differences mentioned, specific tables have been introduced for the temperatures and relative humidity during each season.

## 3. Results

### *3.1. Temperature Analysis*

Table 1 shows the overall results of the different Canonical Biplots. As can been observed in all of the analyses the lambda (Wilks) values were $p<0.001$, indicating that the variation among the different groups actually did exist, and the principal factorial plane absorbed more than 95% of the total inertia.

The analysis of the various factorial planes of the four seasons (Figs. 4, 5, 6 and 7) showed that there were differences between the exterior positions as compared to the positions within the interior of the church and crypt; although the differences within the latter two were not that clear. The results of the specific analyses were the following:

a) Autumn

The main plane shown in Fig. 4 coincides with the example given of the interpretation of the statistical method. As shown in Fig. 4a, the following differences were observed after comparing the exterior with the interior positions of the church and crypt during the months of the different years (Table 2):

- The exterior compared to the positions of the crypt: there were differences in all months and years, and in November 2006, December 2007 and in position 1 in November 2007 during the first twelve hours of the day, Fig. 4b.
- The exterior compared to the positions of the interior of the church: there were differences in all months and years, except in November and December of 2006 in the first twelve hours of the day, Fig. 4c.
- The positions of the crypt compared to the interior of the church: there were only differences in December 2006 among all of the positions, Fig. 4d.
- No differences were found between locations at different heights within the interior of the church.

b) Winter

Fig. 5a shows the results after comparing the recorded values, among the months and years, of the exterior and the interior of the church and crypt.

- Differences were detected in all months and years, except for February 2007, where in the crypt differences were only detected within the first twelve hours of the day (Table 3 and Fig. 5b and Fig. 5c).
- The differences between the interior of the church and the crypt were less clear (Table 3 and Fig. 5d), with differences being detected in January 2007 but not in January 2008. Also, differences were detected in February 2007, but only in position 1 during February 2008.

- In March of 2007 and 2008, there were only differences at locations 5 and 7 (Table 3).
- In addition, there were differences in the interior of the church at different heights between positions 4 and 5 in March of 2008 (Table 3).

c) Spring

- In figure 6a, differences were observed between the positions of the sensors on the exterior with those of the crypt and interior of the church, but these differences were unclear. As shown in Fig. 6b, when comparing the exterior position with the positions within the crypt, the differences that appeared were not clearly specific to certain months and years. In this sense there were differences in April 2007, May 2006 and 2008 and June 2008. The remaining comparisons between months and years only detected differences in the last twelve hours of the day (Table 4).
- In April of all of the years analyzed differences were observed between the exterior and interior temperature of the church (Fig. 6c). However, during the hotter months, such as May and June, the behavior was different. Furthermore, clear differences were found in May 2007 and in June 2006 and 2007. However, in May 2006 and June 2008 there were only differences at positions 5 and 7 and at 4 and 6, only during the last twelve hours of the day. Also, in May of 2008 there were differences detected at positions 4 and 6, but at positions 5 and 7, differences were only observed during the first twelve hours of the day (Table 4). The two latter differences were caused by the different heights where the sensors were located.

- In Fig 6d, differences were observed among the positions within the crypt and the interior of the church during the warmer months (May and June) of all the years considered. The differences observed in April were varied greatly, depending on the year and the position of the sensors. Thus, in 2006 there appeared to be clear differences, but in the other two years the differences detected were only found among the positions within the crypt and the positions located higher up within the interior of the church (sensors 5 and 7) (Table 4).
- No differences were found among the positions located at different heights in the interior of the church, except during June 2006, at positions 6 and 7 (Table 4).

d) Summer

Differences were appreciated, as shown in figure 7a, between the sensors positioned on the outside of the church and those located in the crypt and on the interior, but are unclear.

- In Fig 7b, differences were also clear between the exterior position and the positions within the crypt, except during September 2006 and August 2007, where differences were only found during the last twelve hours. The comparisons between the exterior and the interior of the church showed clear differences at all of the positions, except at position 6 in July 2006, which was only observed during the last twelve hours of the day, Fig 7c. In Fig. 7d, clear differences between the temperatures recorded within the crypt and the interior of the church can been seen, (Table 5).

- Differences were found among the positions of the sensors located at different heights within the interior of the church during the hottest months of July and August, but not in September. In the month of July, there were differences in all years, except for 2008, which only presented differences between positions 4 and 5 in the first twelve hours of the day. In August, the differences that were found depended on the year. Thus, in 2006 there were differences between positions 4 and 5 and in between 6 and 7 but only in the first twelve hours of the day. In 2007, there were differences found during the first twelve hours of the day between positions 4 and 5 (Table 5).

*3.2. Relative Humidity Analysis*

The analysis performed on the data obtained during the four seasons had very similar structures. Within the values obtained for relative humidity there were clear differences between the crypt and the interior and exterior of the church. Table 1 shows the overall results of the different Canonical Biplots. As can be observed in all of the analyses the lambda (Wilks) values were $p<0.001$, indicating that differences between the diverse groups did actually exist, and that the principal factorial plane absorbed more than 95% of the total inertia.

The results of the analyses based on the four seasons were the following:

a) Autumn

As shown in Fig. 8a, the relative humidity in the interior of the church and crypt appear separated from the exterior relative humidity. The statistical differences between these positions were not clear. The differences found between the exterior and the interior of the church and the crypt, when comparing the months of the different years, were the following (Table 6):

- The exterior compared to the positions inside the crypt, Fig. 8b, showed differences were found in the months of October 2006. In October 2007, differences were found during the last twelve hours of the day. In November and December 2006 there were differences, except in position 1 which showed differences only during the last twelve hours of the day. In November 2007 there were differences, except in positions 1 and 3, which showed differences only during the last twelve hours of the day. In December 2007 there were differences, except in positions 2 and 3, which showed differences only during the last twelve hours of the day.

- The exterior compared to the position in the interior of the church, Fig. 8c, in November 2006 and 2007 and December 2006 there were only differences in the first twelve hours of the day. In October 2006 there were differences during the first twelve hours of the day, except at position 6. In October 2007 there were differences during the first twelve hours of the day, except at position 7. In December 2007 there were differences, except in positions 4, 5 and 6, which showed differences only during the first twelve hours of the day.

- The interior of the church compared to the crypt, Fig. 8d, overall differences in relative humidity were detected, being greater in the crypt. There was a slight interaction detected between both positions in 2007 (H4D7, H5D7, H6D7 and H7D7) and 2006 (H4N6, H5N6, H6N6, H7N6 and H6O6). After comparing the months of the different years, differences were detected in all months of 2006, and November 2007 in all positions. In October 2007, only differences were found in positions 4 and 5 and in positions 6 and 7 during the last 12 hours of the day. In December 2007, there were no differences in sensor 1 within the crypt with respect to the positions inside the church. In sensor 2 there were differences, except in position 7, and in 3 there were differences with respect to position 4 and positions 5 and 6 in the last 12 hours of the day. The location of sensor 1 was close to the entrance of the crypt coming off from the interior of the church near from 6 and 7.

- No differences were found between locations at different heights within the interior of the church.

b) Winter

In Fig. 9a it can be seen that the relative humidity of the interior of the church and the crypt appeared separated from that of the exterior, although the statistical differences were not clearly appreciable.

Upon comparing the relative humidity of the exterior of the church with the positions of the interior and the crypt, during the winter months of the various years, the following differences were observed (Table 7):

- The exterior compared to the positions inside the cript, Fig. 9b, showed differences that were observed in February 2008 and March 2007. In January and February of 2007 there were differences in positions 2 and 3 and in position 1 only during the last 12 hours of the day. In January 2008 there are differences in position 1 and positions 2 and 3 only during the last 12 hours of the day. In May 2008 there are differences in position 2. In position 1, differences only exist during the first 12 hours of the day and in position 3 during the last 12 hours of the day.

- The exterior compared to the positions of the interior of the church, Fig. 9c, showed differences in January 2007 and 2008 in all positions during the first 12 of the day, except for position 7 in January 2008. On the other hand, in May 2007 and 2008 there were only differences in positions 6 and 7 in the last 12 hours of the day.

- The interior of the church compared to the crypt, Fig. 9d, there were overall differences, which were greater within the crypt. There was a slight interaction detected between both positions during 2007 (H4F7, H5F7, H6F7 and H7F7) and 2008 (H4J8, H6J8 y H7J8) that corresponded to the interior positions of the church during February and January, respectively. These differences increased from January to March. After comparing the months of the different years, differences were observed in February and March of all of the years and in January 2007. In January 2008 there were only differences in positions 2 and 3, except in position 7 (see Table 7). No differences were found in position 1, as this sensor was located the nearest away from the entrance of the crypt from the interior of the church.

- No differences were found between locations at different heights within the interior of the church.

c) Spring

Similar to what was observed during winter, as seen in Fig. 10a, the relative humidity of the interior and the crypt appeared separated from that of the exterior. However, the statistical differences between the positions were not clear. The differences observed when comparing the different spring months were the following (Table 8):

- The exterior compared to the positions located within the crypt, Fig 10b, showed that in April 2006, May 2006 and 2007 and June 2006 and 2008 differences were observed in all months and years. In May 2008 and June 2007 differences were detected in position 3, while in 1 and 2 differences were only detected during the last 12 hours of the day. In April 2008, differences were detected in positions 2 and 3 and only in position 1 during the last 12 hours of the day.

- The exterior compared to the positions of the interior of the church, Fig 10c, showed that differences were detected in the month of April during all three years and May 2007 and 2008 during the first twelve hours of the day. In June of all the three years and in May 2006 the differences were not particularly clear (see Table 8). These last months exhibited an erratic behavior from spring to summer.

- The interior of the church compared to the crypt, Fig 10d, overall differences were observed for relative humidity, which were greater in the crypt. A slight interaction was detected between both positions during 2007 (H4A7, H6A7 and H7A7) and 2006 (H4A6, H5A6, H6A6 and H7A6), Fig 10a, that corresponded to the positions located inside the church. Upon analyzing the comparison between the months of the three years, differences were detected in all cases.

- No differences were found between locations at different heights within the interior of the church.

d) Summer

As shown in Fig. 11a, the relative humidity inside the church and within the crypt appears to be separated from the exterior relative humidity and the statistical differences in this case are much clearer. The differences found after comparing the months of the different years were the following (Table 9):

- The exterior compared to the positions within the crypt, Fig 11b, there were differences in all months and years.
- The exterior compared to the positions within the interior of the church, Fig 11c, showed there were differences during the last twelve hours of the day in all months and years, except for September 2007 at positions 4, 5 and 7, which showed differences during the first twelve hours of the day.
- The interior of the church compared to the crypt, Fig 11d, overall differences were observed in relative humidity, being greater in the crypt.
- Between positions located at different heights in the interior of the church: no differences were observed between positions 4 and 5. In addition, at positions 6 and 7, differences were only detected in the first twelve hours of the day of August 2007.

*3.3 Relationship between the different pathologies of the monument and the different microclimates observed..*

The results of temperature and relative humidity showed clear climatic differences between the exterior and interior sensors. Also, differences were detected during all seasons between the crypt and the interior of the church (Tables 2, 3, 4, 5, 6, 7, 8 and 9). In summer, differences between temperature and relative humidity could be established among the sensors located at different heights in the interior of the church (Tables 5 and 9). After analyzing the differences in the various stations, we are able to deduce the following: thermoclasty is more severe on the exterior than in interior positions within the crypt and church during all seasons of the year.

The presence of fissures and scaling in both the calcarenite forming the outer wall and in the gypsum plaster covering the bricks as well as the calcarenite (Fig. 2.a, 2b) is caused by the different coefficients of expansion between the components of the calcarenite (quartz clasts, calcite fossils, and calcite cement), as well as with covering plaster which can produce landslides and cracks. In other areas of the upper outer part of the monument, blackened and black crusts are also observed (Figs 2c) that expand and contract with the diurnal cycles of heat / cold (thermoclastia). Due to the microclimates generated within the different orientations of the building, a colony of kestrels, which is a protected animal, still remains and their excrement causes soiling and biological colonization (Fig. 2c).

In gereral, less pronounced temperature differences are detected between the crypt and interior locations of the church, with the temperatures being lower in the crypt due to more humid conditions (the water table of the Guadalquivir river emerges at the level of the crypt as well as an ancient creek, previous to remains found from Islamic and even Roman times) (Fig 2d). Thermoclasty is less noticeable between these two locations.

The differences in relative humidity are not as clear as the differences observed between temperatures. These differences are not global. When analyzing the differences between the exterior and interior positions, it is observed that there are locations in which there are no differences, except in summer. Between the interior locations and the crypt there are generally observed differences. This means that there is much more humidity in the crypt, which causes the adobe bricks to be darkened (discolouration) and differential erosion (loss of components and of matrix) (Figs 2d, 2e). The humid atmosphere also gives rise to the phenomena of capillary absorption in the crypt and interior of the church, the latter showing signs salt efflorescence and possible salt crust on the columns (Figs 2f, 2g).

The effect of locations at different heights in the interior of monument is very small and is detected mainly during summer temperatures, in addition there being no marked signs of pathologies/ alterations/deteriorations.

This confirms that the decay of the different materials used in the construction and subsequent interventions of this church will continue to deteriorate depending on the microclimates to which they are exposed.

## 4. Conclusions

After applying the Canonical Biplot to the results of all the temperature and relative humidity data collected from the different locations, it can be concluded that:

a) Three different environments were distinguished in all of the seasons analyzed (exterior, interior of the church and crypt).

b) On the outside of the monument there are more sudden changes in temperature and in the crypt greater relative humidity is observed by the water table of the Guadalquivir river emerges at the level of the crypt as well as an ancient creek.

c) The greatest differences in temperature and relative humidity were detected in summer. In winter the differences were much smaller and in spring and autumn the behavior was intermediate between the two previous seasons.

d) These different environments, which have an effect on the building, can explain the varying degrees of deterioration of the materials used in the construction and posterior interventions within the different parts of the building.

**Acknowledgements**

The authors are grateful for the funding received by the Ministry of Education and Science, within the project CGL2007-62168 (FEDER), and the Ministry of Science and Technology of Spain, project MAT2010-20660.

**References**

Amaro, I. R., Vicente-Villardón, J. L., and Galindo-Villardón, M. P. 2004. ANOVA Biplot para arreglos de tratamientos con dos factores basado en modelos lineales generales multivariantes. Interciencia, 29:26-32.

Camuffo, D. 1998. Microclimate for Cultural Heritage, Vol. 23 (Developments in Atmospheric Science). Amsterdam: Elsevier Science BV.

D'Agostino, D., P. Congedo, and R. Cataldo, 2013. Microclimatic assessment and modelling for salt crystallization control in the crypt of The Duomo of Lecce (South Italy). In Proceedings of Science and Technology for the conservation of Cultural Heritage, ed. M. A. Rogerio-Candelera, M. Lazzari, and E. Cano, 21-24. London: Taylor & Francis Group.

Figueiredo, C. A. M., L. Aires-Barros, M.J. Basto, R.C. Graça, and A. Maurício, 2007. The weathering and wetherability of Basílica da Estrela stones, Lisbon, Portugal. In Proceedings of Building stone decay from diagnosis to conservation, ed. R. Prikryl, and B. J. Smith, 99-107. London: The Geological Society (special publication).

Gabriel, K. R. 1971. The biplot-graphic display of matrices with applications to principal component analysis. Biometrika, 58:453–467.

Gabriel, K. R. 1972. Analysis of meteorological data by means of canonical decomposition and biplots. J. Appl. Meteorol., 11:1071–1077.

Gabriel, K. R. 1995. Manova biplots for two-way contingency tables. In Proceedings of Recent Advances in Descriptive Multivariate Analysis, ed. W. Krzanowsky, 227–268. Oxford: Clarendon Press.

Galindo, M. P. 1986. Una alternativa de representación simultanea: HJ-Biplot. Qüestiió, 1:13-23.

Garcia-Talegon, J., M. González-Sánchez, A. C. Iñigo, S. Vicente-Tavera, and V. Rives, 2006. Microenvironments in the inner and outer of the Zamora Cathedral. In Proceedings of Heritage, weathering & conservation, ed. R. Fort, M. Alvarez-de Buergo, M. Gomez-Heras, C. Vazquez-Calvo, 1, 457-461. London: Taylor & Francis Group plc.

García-Talegón, J., A. C. Iñigo, and S. Vicente-Tavera, 2013. Canonical Biplot as tool to detect microclimates in the inner and outer parts of Salamanca Cathedrals. In Proceedings Science and Technology for the Conservation of Cultural Heritage, ed. M. A. Rogerio-Candelera, M. Lazzari, E. Cano, 59-62. Taylor & Francis Group, London.

García-Talegón, J., Iñigo, A. C., and Vicente-Palacios, V. 2016. A laboratory simulation of desalting on calcareous building stone with wet sepiolite, Environ. Earth. Sci., 75:925-932.

http://www.tutiempo.net/clima/Sevilla_San_Pablo/83910.htm

ICOMOS (ISCS). (2008). Illustrated glossary on stone deterioration patterns. International Council on Monuments and sites: <https://www.icomos.org/publications/monuments_and_sites/15/pdf/Monuments_and_Sites_15_ISCS_Glossary_Stone.pdf>.

Iñigo, A. C., Rives, V., and Vicente, M. A. 2000. Reproducción en cámara climática de las formas de alteración más frecuentes detectadas en materiales graníticos, en clima de tendencia continental. Mat. Construcc., 50(257):57–60.

Iñigo, A. C., and Vicente-Tavera, S. 2001. Different degrees of stone decay on the inner and outer walls of a Cloister. Build. Environ., 36:911-917.

Iñigo, A. C., and Vicente-Tavera, S. 2002. Surface-inside (10 cm) thermal gradients in granitic rocks: effect of environmental conditions. Build. Environ., 37:101-108.

Iñigo, A. C., García-Talegón, J., Vicente-Tavera, S., Martín-González, S., Casado-Marín, S., Pérez-Rodríguez, J. L., and Vargas-Muñoz, M. 2013. Colour and ultrasound propagation speed changes by different ageing of freezing/thawing and cooling/heating in granitic materials. Cold. Reg. Sci. Technol., 85:71-78.

Iñigo, A. C., García-Talegón, J., and Vicente-Tavera, S. 2014. Canonical Biplot statistical analysis to detect the magnitude of the effects of phosphates crystallization aging on the color in siliceous conglomerates. Color. Res. Appl., 39(1):82-87.

Iñigo, A. C., García-Talegón, J., Vicente-Tavera, S., Casado-Marín, S., and Martín-González, S. 2017. Multivariate analyses of soluble salts responsable for pathologies in granites of the Roman Aqueduct of Segovia, Spain. Inter. J. Conser. Sci., 8(1):59-66.

Merello, P., M. C. Perez, J. Perez-Miralles, F. J. Garcia-Diego, A. Fernandez- Navajas, and M. Zarzo, 2013. Basic descriptive statistical methods for monitoring and evaluation of microclimates in Cultural Heritage. In Proceedings of Science and Technology for the conservation of Cultural Heritage, ed. M. A. Rogerio-Candelera, M. Lazzari, and E. Cano, 11-14. London: Taylor & Francis Group.

Merello, P., F. J. García-Diego, and M. Zarzo, 2014. Diagnosis of abnormal patterns in multivariate microclimate monitoring: A case study of an open-air archaeological site in Pompeii (Italy). Sci. Total Environ., 488–489:14-25.

Sanchéz-Moral, S., S. Cuezva, E. García- Antón, A. Fernandez-Cortes, J. Elez, D. Benavente, J. C. Cañaveras, V. Jurado, M. A. Rogerio-Candelera, and C. Saiz-Jimenez. 2014. Microclimatic monitoring in Altamira Cave: Two decades of scientific projects for its conservation. In Proceedings of The conservation of subterranean Cultural Heritage, ed. C. Saiz-Jimenez, 139-144. London: Taylor &Francis Group.

Tapete, D., F. Fratini, B. Mazzei, E. Cantisani, C. Riminesi, R. Manganelli Del Fà, B. Sacchi, O.A. Cuzman, L. Scaletti, M.G. Patrizi, and P. Tiano. 2014. Methodological approach to monitor Roman Catacombs: Experience in the Catacombs of St. Mark, Marcellian and Damasus, Rome, Italy. In Proceedings of The conservation of subterranean Cultural Heritage, ed. C. Saiz-Jimenez, 51-58. London: Taylor &Francis Group.

Török, A., and Hajpal, M. 2005. Effect of temperature changes on the mineralogy and physical properties of sandstones. A laboratory study. Journal for Restoration of Buildings and Monuments, 4:211-218

Tricio, V., and R. Viloria, 2002. Microclimate study of a historical building. In Proceedings of Protection and Conservation of the Cultural heritage of the Mediterranean Cities, ed. E. Galán, and F. Zezza, 67-70. Lisse: Swets & Zeitlinger BV.

Vicente, M. A. 1994. La piedra, un valioso recurso natural. Fronteras de la Ciencia y la Tecnologia, 6:50-54.

Vicente, M. A. 1996. Summary of Project STEP-CT90-0101, Granitic materials and historical monuments: study of the factors and mechanisms of weathering and application to historical heritage conservation. In Proceedings of Degradation and conservation of granitic rocks in monuments, ed. M. A. Vicente, J. Delgado-Rodrigues, and J. Acevedo, 4-44. Brussels: European Commission Directorate-General XII.

Vicente-Villardón, J. L. 2016. MULTBIPLOT: Multivariate Analysis using Biplots, Departamento de Estadística. Universidad de Salamanca. (http://biplot.usal.es), (accesed 06.02.16).

Winkler, E. M. 1997. Stone in Architecture. Properties, durability. Berlin: Springer.

**Figure captions**

Fig. 1: Plane and elevation of El Salvador Church of Seville where the different internal sensors and meteorological station are located.

Fig. 2: The decay in the different materials used in the construction of El Salvador Church: a) and b) fissures and scaling in both the calcarenite forming the outer wall and in the gypsum plaster covering the bricks as well as the calcarenite, c) blackened and black crusts. A colony of kestrels and their excrement causes soiling and biological colonization, d) and e) the adobe bricks darkened and with differential erosion and f) and g) salt efflorescence and possible salt crust on the columns.

Fig. 3: Example of interpretation main plane of the temperature analysis during autumn.

Fig. 4: Canonical Biplot, temperature in autumn: a) Global, b) Exterior compared to the crypt, c) Exterior compared to the church interior and d) Crypt compared to the church interior.

Fig. 5: Canonical Biplot, temperature in winter: a) Global, b) Exterior compared to the crypt, c) Exterior compared to the church interior and d) Crypt compared to the church interior.

Fig. 6: Canonical Biplot, temperature in spring: a) Global, b) Exterior compared to the crypt, c) Exterior compared to the church interior and d) Crypt compared to the church interior.

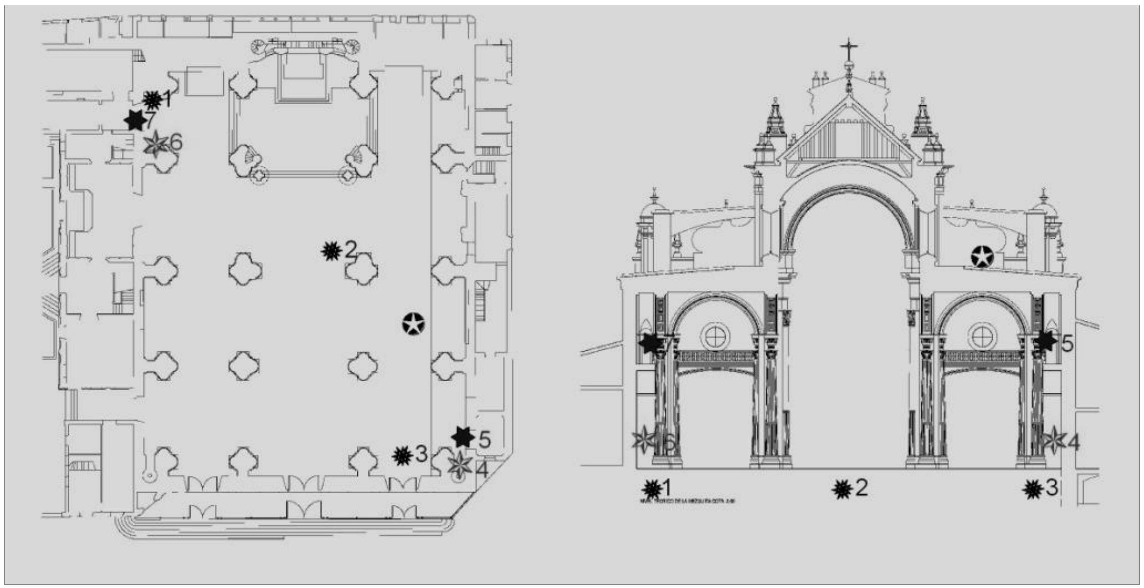
Fig. 7: Canonical Biplot, temperature in summer: a) Global, b) Exterior compared to the crypt, c) Exterior compared to the church interior and d) Crypt compared to the church interior.

Fig. 8: Canonical Biplot, relative humidity in autumn: a) Global, b) Exterior compared to the crypt, c) Exterior compared to the church interior and d) Crypt compared to the church interior.

Fig. 9: Canonical Biplot, relative humidity in winter: a) Global, b) Exterior compared to the crypt, c) Exterior compared to the church interior and d) Crypt compared to the church interior.

Fig. 10: Canonical Biplot, relative humidity in spring: a) Global, b) Exterior compared to the crypt, c) Exterior compared to the church interior and d) Crypt compared to the church interior.

Fig. 11: Canonical Biplot, relative humidity in summer: a) Global, Exterior compared to the crypt, c) Exterior compared to the church interior and d) Crypt compared to the church interior.

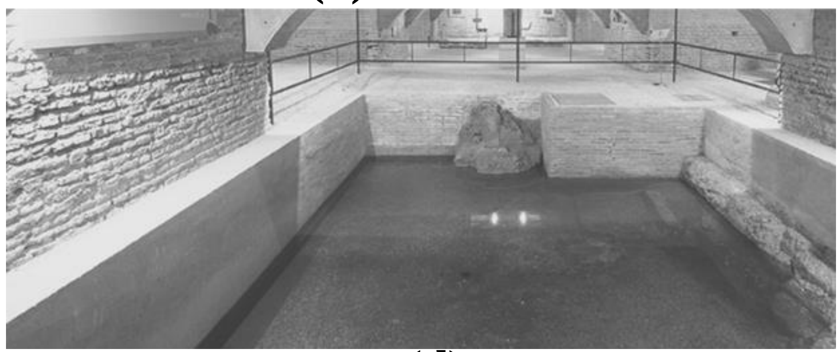


1
7
6
2
3
5
4
1
2
3
5
6
4

(a)

(b)

(c)

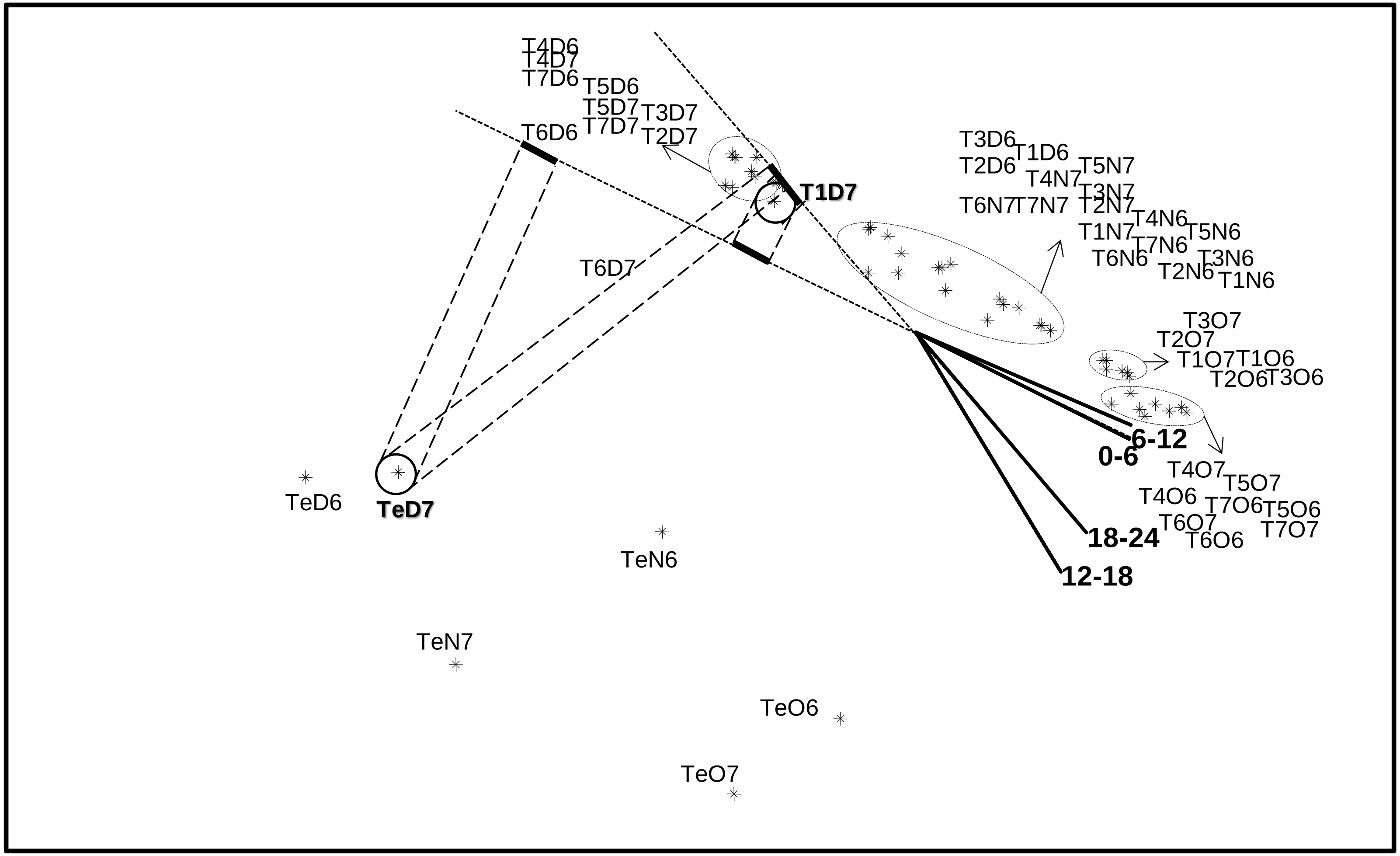


(d)

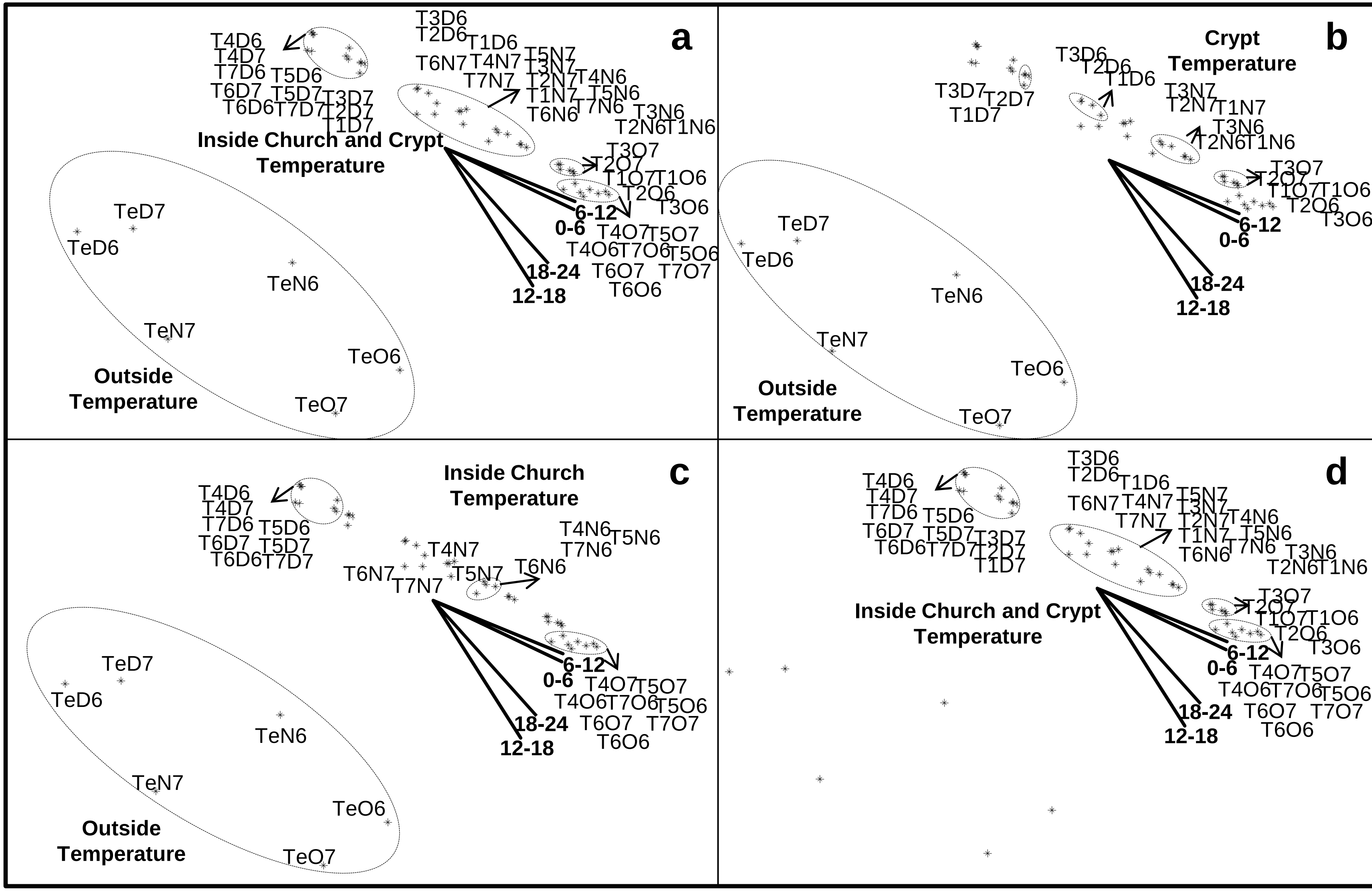
(e)

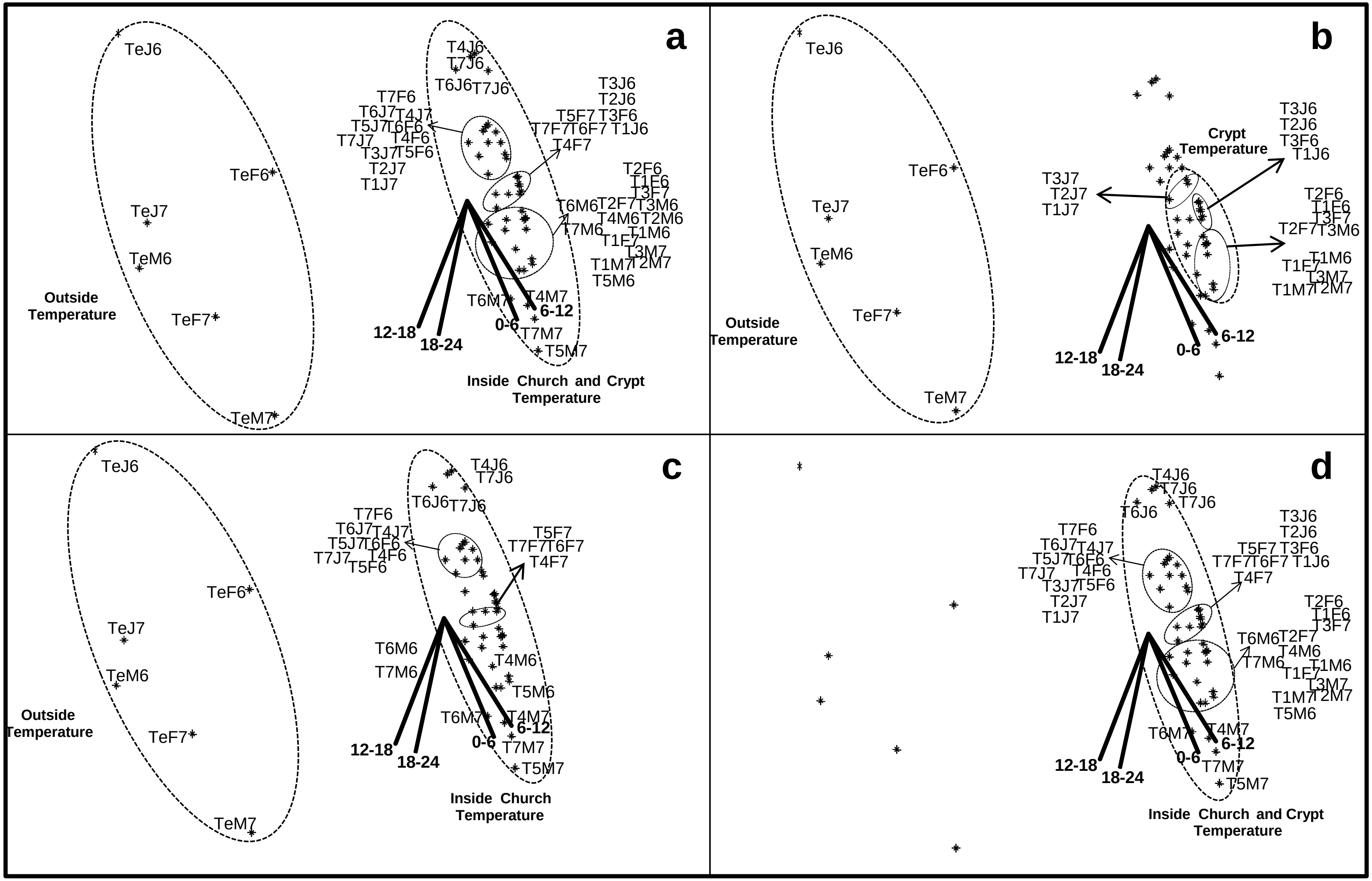
(f)

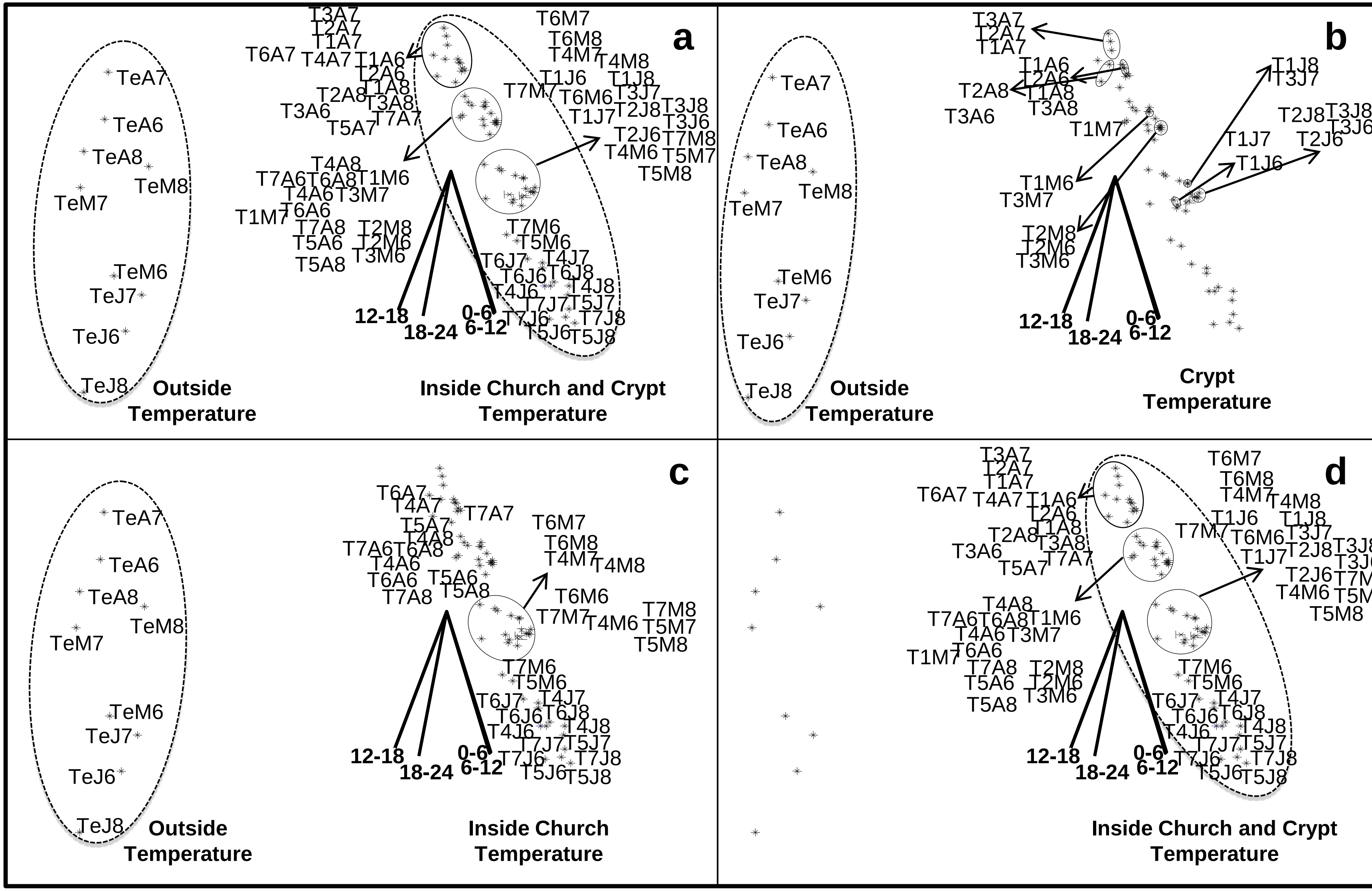
(g)

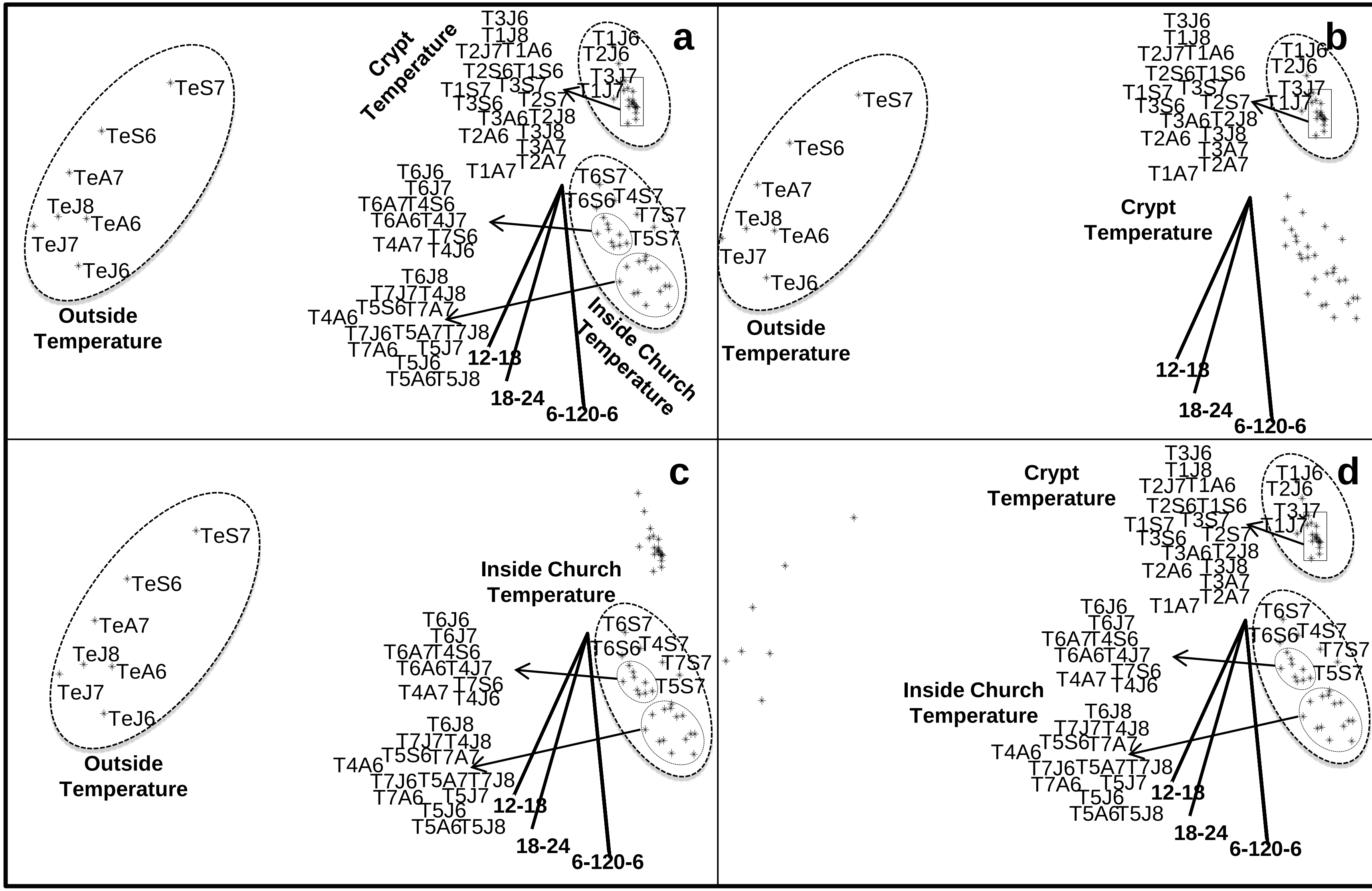


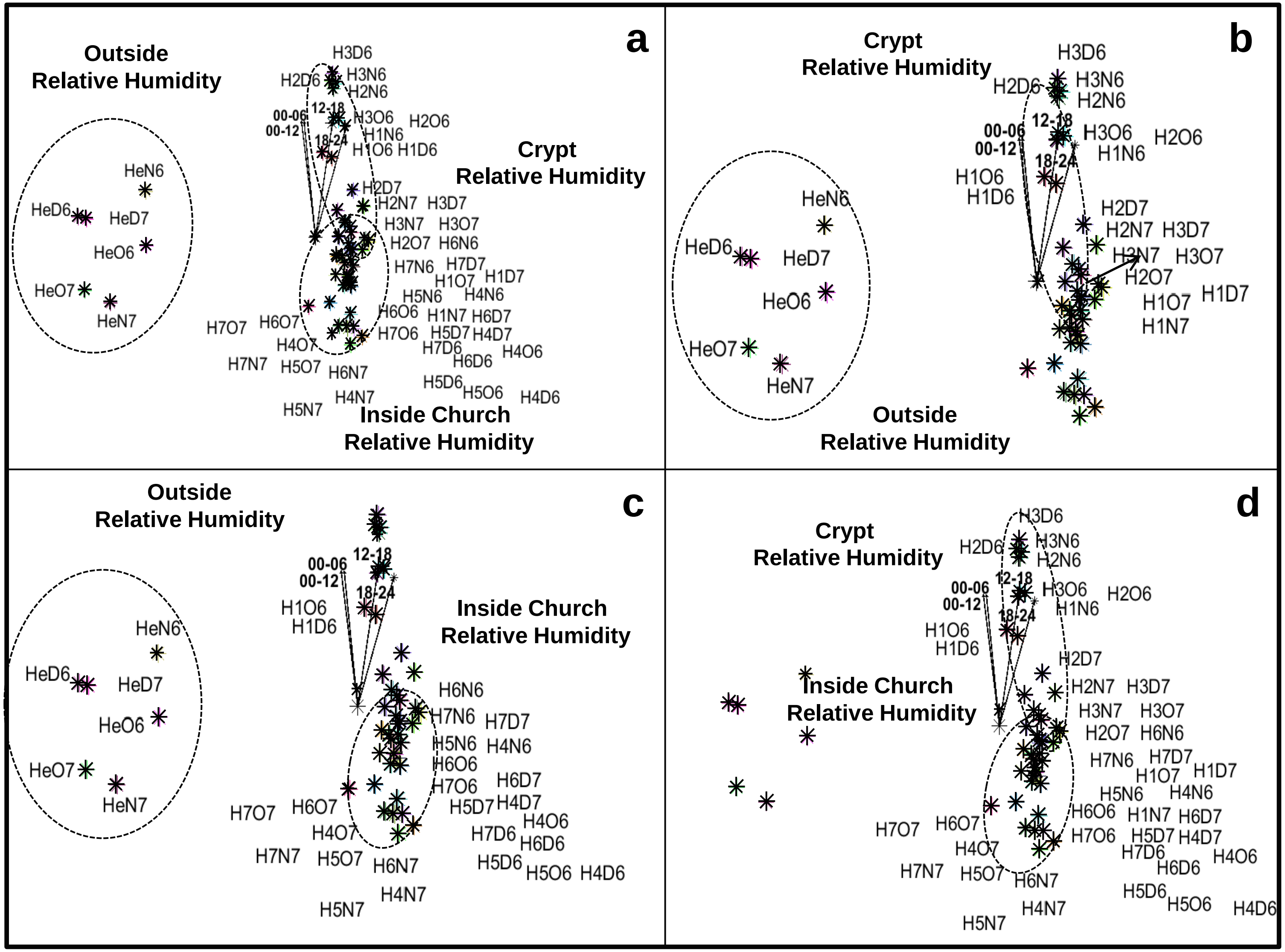
T4D6
T4D7
T7D6
T5D6
T5D7
T7D7
T3D7
T2D7
T6D6
T1D7
T3D6
T2D6
T1D6
T4N7
T5N7
T3N7
T2N7
T6N7
T7N7
T4N6
T5N6
T1N7
T7N6
T6N6
T3N6
T2N6
T1N6
T6D7
T3O7
T2O7
T1O7
T1O6
T2O6
T3O6
6-12
0-6
T4O7
T5O7
T4O6
T7O6
T5O6
T6O7
T7O7
T6O6
18-24
12-18
TeD6
TeD7
TeN6
TeN7
TeO6
TeO7

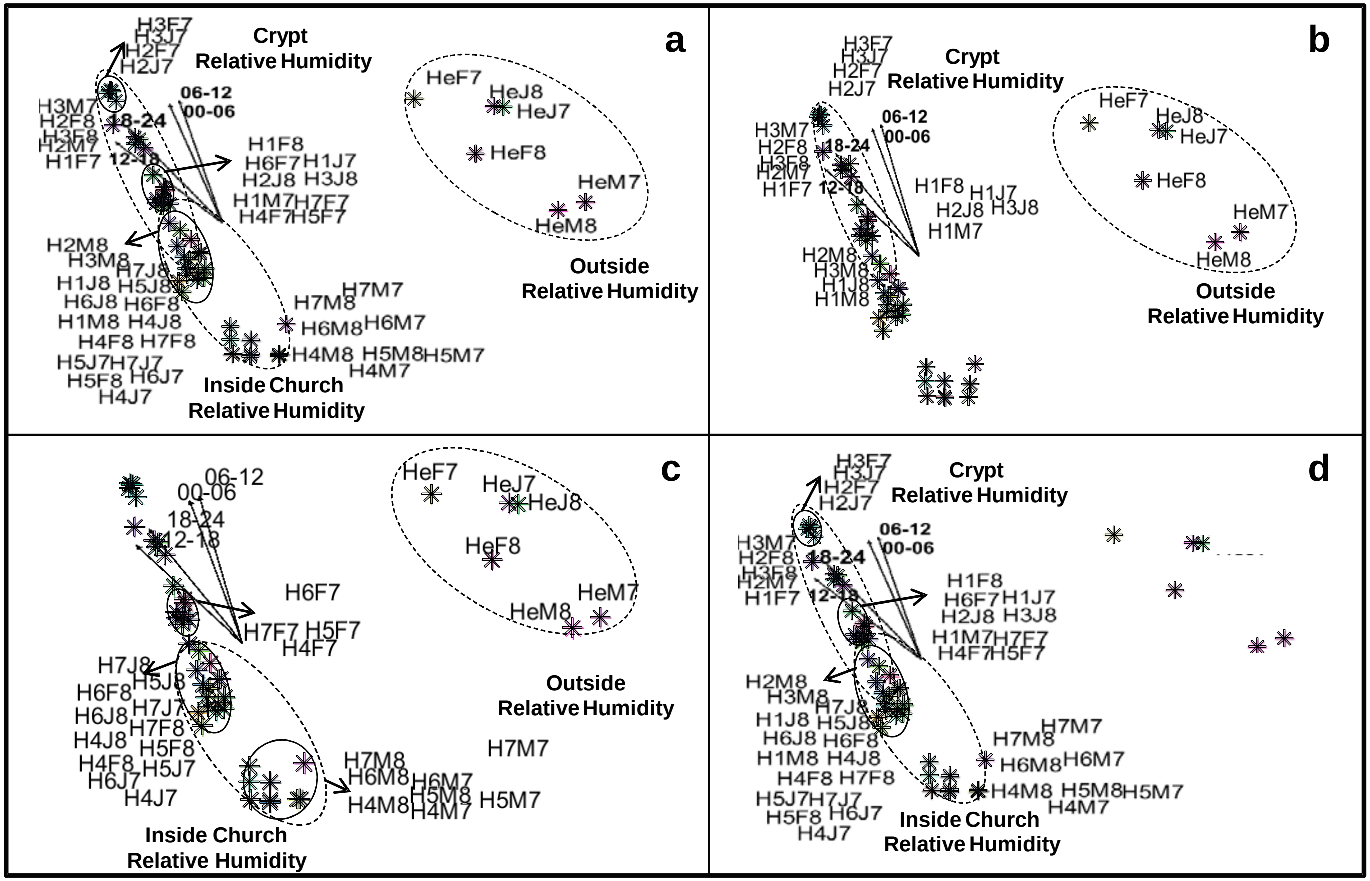

a
T4D6
T4D7
T7D6
T6D7
T6D6
T5D6
T5D7
T7D7
T3D7
T2D7
T1D7
T3D6
T2D6
T1D6
T6N7
T4N7
T7N7
T5N7
T3N7
T2N7
T1N7
T6N6
T4N6
T5N6
T7N6
T3N6
T2N6
T1N6
Inside Church and Crypt
Temperature
T3O7
T2O7
T1O7
T1O6
T2O6
T3O6
6-12
0-6
T4O7
T5O7
T4O6
T7O6
T5O6
T6O7
T7O7
T6O6
18-24
12-18
TeD7
TeD6
TeN6
TeN7
TeO6
TeO7
Outside
Temperature
b
Crypt
Temperature
T3D6
T2D6
T1D6
T3D7
T2D7
T1D7
T3N7
T2N7
T1N7
T3N6
T2N6
T1N6
T3O7
T2O7
T1O7
T1O6
T2O6
T3O6
6-12
0-6
18-24
12-18
TeD7
TeD6
TeN6
TeN7
TeO6
TeO7
Outside
Temperature
c
Inside Church
Temperature
T4D6
T4D7
T7D6
T6D7
T6D6
T5D6
T5D7
T7D7
T4N7
T6N7
T7N7
T5N7
T6N6
T4N6
T7N6
T5N6
6-12
0-6
T4O7
T5O7
T4O6
T7O6
T5O6
18-24
T6O7
T7O7
12-18
T6O6
TeD7
TeD6
TeN6
TeN7
TeO6
TeO7
Outside
Temperature
d
T4D6
T4D7
T7D6
T6D7
T6D6
T5D6
T5D7
T7D7
T3D7
T2D7
T1D7
T3D6
T2D6
T1D6
T6N7
T4N7
T7N7
T5N7
T3N7
T2N7
T1N7
T6N6
T4N6
T5N6
T7N6
T3N6
T2N6
T1N6
Inside Church and Crypt
Temperature
T3O7
T2O7
T1O7
T1O6
T2O6
T3O6
6-12
0-6
T4O7
T5O7
T4O6
T7O6
T5O6
18-24
T6O7
T7O7
12-18
T6O6

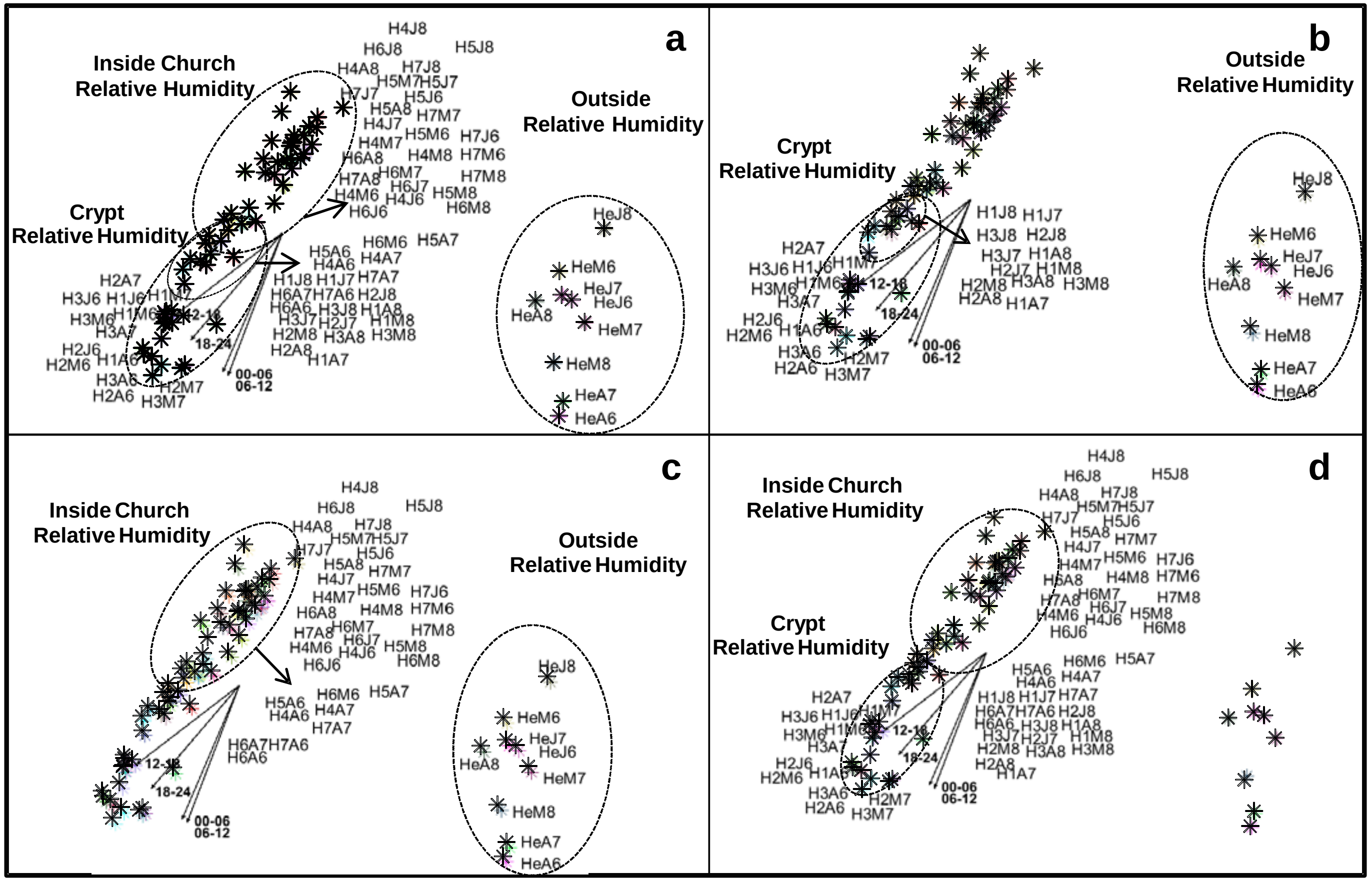

a
b
c
d
TeJ6
TeF6
TeJ7
TeM6
TeF7
TeM7
Outside Temperature
Inside Church and Crypt Temperature
Inside Church Temperature
Crypt Temperature
0-6
6-12
12-18
18-24
T4J6
T7J6
T6J6
T7F6
T6J7
T4J7
T5J7
T6F6
T7J7
T4F6
T3J7
T5F6
T2J7
T1J7
T3J6
T2J6
T3F6
T1J6
T5F7
T7F7
T6F7
T4F7
T2F6
T1F6
T3F7
T6M6
T2F7
T3M6
T4M6
T2M6
T7M6
T1M6
T1F7
T3M7
T1M7
T2M7
T5M6
T6M7
T4M7
T7M7
T5M7


a
T3A7
T2A7
T1A7
T6A7
T4A7
T1A6
T2A6
T1A8
T2A8
T3A8
T3A6
T7A7
T5A7
T4A8
T7A6
T6A8
T1M6
T4A6
T3M7
T1M7
T6A6
T7A8
T2M8
T5A6
T2M6
T3M6
T5A8
T6M7
T6M8
T4M7
T4M8
T1J6
T1J8
T7M7
T6M6
T3J7
T3J8
T1J7
T2J8
T3J6
T2J6
T7M8
T4M6
T5M7
T5M8
T7M6
T5M6
T6J7
T4J7
T6J6
T6J8
T4J6
T4J8
T7J7
T5J7
T7J6
T7J8
T5J6
T5J8
12-18
18-24
0-6
6-12
TeA7
TeA6
TeA8
TeM8
TeM7
TeM6
TeJ7
TeJ6
TeJ8
Outside Temperature
Inside Church and Crypt Temperature
b
T3A7
T2A7
T1A7
T1A6
T2A6
T2A8
T1A8
T3A8
T3A6
T1M7
T1J8
T3J7
T2J8
T3J8
T3J6
T1J7
T2J6
T1J6
T1M6
T3M7
T2M8
T2M6
T3M6
12-18
18-24
0-6
6-12
TeA7
TeA6
TeA8
TeM8
TeM7
TeM6
TeJ7
TeJ6
TeJ8
Outside Temperature
Crypt Temperature
c
T6A7
T4A7
T7A7
T5A7
T4A8
T7A6
T6A8
T4A6
T6A6
T5A6
T7A8
T5A8
T6M7
T6M8
T4M7
T4M8
T6M6
T7M7
T4M6
T7M8
T5M7
T5M8
T7M6
T5M6
T6J7
T4J7
T6J6
T6J8
T4J6
T4J8
T7J7
T5J7
T7J6
T7J8
T5J6
T5J8
12-18
18-24
0-6
6-12
TeA7
TeA6
TeA8
TeM8
TeM7
TeM6
TeJ7
TeJ6
TeJ8
Outside Temperature
Inside Church Temperature
d
T3A7
T2A7
T1A7
T6A7
T4A7
T1A6
T2A6
T1A8
T2A8
T3A8
T3A6
T5A7
T7A7
T6M7
T6M8
T4M7
T4M8
T1J6
T1J8
T7M7
T6M6
T3J7
T1J7
T2J8
T3J8
T3J6
T2J6
T7M8
T4M6
T5M7
T5M8
T4A8
T7A6
T6A8
T1M6
T4A6
T3M7
T1M7
T6A6
T7A8
T2M8
T5A6
T2M6
T3M6
T5A8
T7M6
T5M6
T6J7
T4J7
T6J6
T6J8
T4J6
T4J8
T7J7
T5J7
T7J6
T7J8
T5J6
T5J8
12-18
18-24
0-6
6-12
Inside Church and Crypt Temperature


a
Crypt Temperature
T3J6
T1J8
T2J7T1A6
T2S6T1S6
T1S7 T3S7
T3S6 T2S7
T3A6T2J8
T2A6 T3J8
T3A7
T1A7 T2A7
T1J6
T2J6
T3J7
T1J7
TeS7
TeS6
TeA7
TeJ8
TeA6
TeJ7
TeJ6
Outside Temperature
T6J6
T6J7
T6A7T4S6
T6A6T4J7
T4A7 T7S6
T4J6
T6S7
T6S6 T4S7
T7S7
T5S7
T6J8
T7J7T4J8
T4A6 T5S6T7A7
T7J6T5A7T7J8
T7A6 T5J7
T5J6
T5A6T5J8
12-18
18-24
6-120-6
Inside Church Temperature
b
Outside Temperature
Crypt Temperature
c
Inside Church Temperature
Outside Temperature
d
Crypt Temperature
Inside Church Temperature


a
Outside Relative Humidity
Crypt Relative Humidity
Inside Church Relative Humidity
HeN6
HeD6
HeD7
HeO6
HeO7
HeN7
H3D6
H2D6
H3N6
H2N6
00-06
00-12
12-18
18-24
H3O6
H2O6
H1N6
H1O6
H1D6
H2D7
H2N7
H3D7
H3N7
H3O7
H2O7
H6N6
H7N6
H7D7
H1O7
H1D7
H5N6
H4N6
H6O6
H1N7
H6D7
H7O7
H6O7
H7O6
H5D7
H4D7
H4O7
H7D6
H6D6
H4O6
H7N7
H5O7
H6N7
H5D6
H5O6
H4D6
H4N7
H5N7
b
c
d


a
Crypt
Relative Humidity
H3F7
H3J7
H2F7
H2J7
H3M7
H2F8
H3F8
H2M7
H1F7
18-24
12-18
06-12
00-06
H1F8
H6F7
H1J7
H2J8
H3J8
H1M7
H7F7
H4F7
H5F7
H2M8
H3M8
H7J8
H1J8
H5J8
H6J8
H6F8
H1M8
H4J8
H4F8
H7F8
H5J7
H7J7
H5F8
H6J7
H4J7
H7M8
H7M7
H6M8
H6M7
H4M8
H5M8
H5M7
H4M7
Inside Church
Relative Humidity
HeF7
HeJ8
HeJ7
HeF8
HeM7
HeM8
Outside
Relative Humidity
b
Crypt
Relative Humidity
H3F7
H3J7
H2F7
H2J7
H3M7
H2F8
H3F8
H2M7
H1F7
18-24
12-18
06-12
00-06
H1F8
H1J7
H2J8
H3J8
H1M7
H2M8
H3M8
H1J8
H1M8
HeF7
HeJ8
HeJ7
HeF8
HeM7
HeM8
Outside
Relative Humidity
c
06-12
00-06
18-24
12-18
H6F7
H7F7
H5F7
H4F7
H7J8
H5J8
H6F8
H6J8
H7J7
H7F8
H4J8
H5F8
H4F8
H5J7
H6J7
H4J7
H7M8
H6M8
H6M7
H4M8
H5M8
H4M7
H7M7
H5M7
Inside Church
Relative Humidity
HeF7
HeJ7
HeJ8
HeF8
HeM7
HeM8
Outside
Relative Humidity
d
Crypt
Relative Humidity
H3F7
H3J7
H2F7
H2J7
H3M7
H2F8
H3F8
H2M7
H1F7
18-24
12-18
06-12
00-06
H1F8
H6F7
H1J7
H2J8
H3J8
H1M7
H7F7
H4F7
H5F7
H2M8
H3M8
H7J8
H1J8
H5J8
H6J8
H6F8
H1M8
H4J8
H4F8
H7F8
H5J7
H7J7
H5F8
H6J7
H4J7
H7M8
H7M7
H6M8
H6M7
H4M8
H5M8
H5M7
H4M7
Inside Church
Relative Humidity


a
Inside Church Relative Humidity
Crypt Relative Humidity
Outside Relative Humidity
12-18
18-24
00-06
06-12
b
Crypt Relative Humidity
Outside Relative Humidity
12-18
18-24
00-06
06-12
c
Inside Church Relative Humidity
Outside Relative Humidity
12-18
18-24
00-06
06-12
d
Inside Church Relative Humidity
Crypt Relative Humidity
12-18
18-24
00-06
06-12

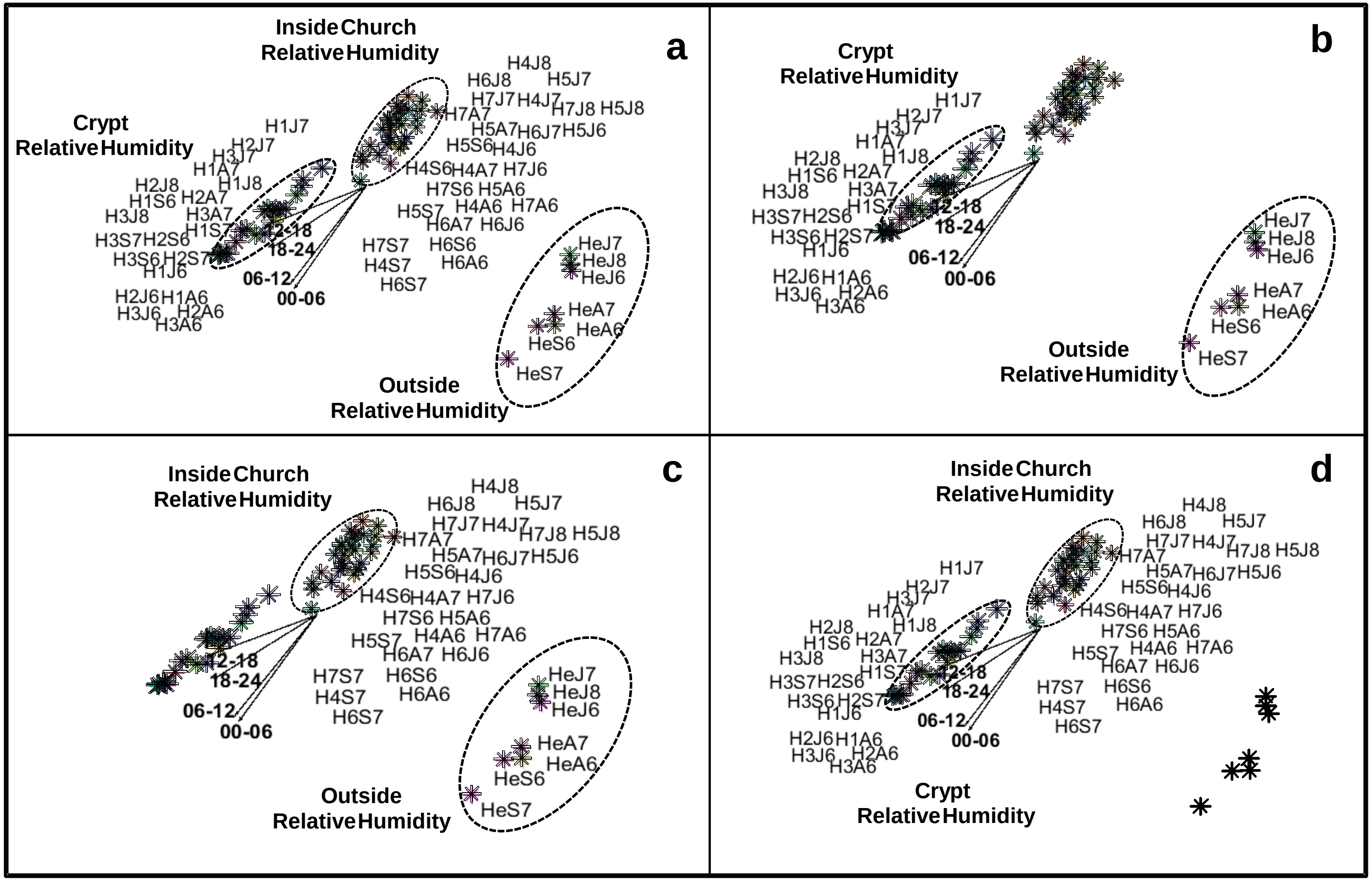

a
Inside Church Relative Humidity
Crypt Relative Humidity
Outside Relative Humidity
H4J8 H6J8 H5J7 H7J7 H4J7 H7J8 H5J8 H7A7 H5A7 H6J7 H5J6 H5S6 H4J6 H4S6 H4A7 H7J6 H7S6 H5A6 H5S7 H4A6 H7A6 H6A7 H6J6 H7S7 H6S6 H4S7 H6A6 H6S7
H1J7 H2J7 H3J7 H1A7 H2J8 H1J8 H1S6 H2A7 H3J8 H3A7 H1S7 H3S7 H2S6 H3S6 H2S7 H1J6 H2J6 H1A6 H3J6 H2A6 H3A6
12-18 18-24 06-12 00-06
HeJ7 HeJ8 HeJ6 HeA7 HeA6 HeS6 HeS7
b
Crypt Relative Humidity
Outside Relative Humidity
H1J7 H2J7 H3J7 H1A7 H2J8 H1J8 H1S6 H2A7 H3J8 H3A7 H1S7 H3S7 H2S6 H3S6 H2S7 H1J6 H2J6 H1A6 H3J6 H2A6 H3A6
12-18 18-24 06-12 00-06
HeJ7 HeJ8 HeJ6 HeA7 HeA6 HeS6 HeS7
c
Inside Church Relative Humidity
Outside Relative Humidity
H4J8 H6J8 H5J7 H7J7 H4J7 H7J8 H5J8 H7A7 H5A7 H6J7 H5J6 H5S6 H4J6 H4S6 H4A7 H7J6 H7S6 H5A6 H5S7 H4A6 H7A6 H6A7 H6J6 H7S7 H6S6 H4S7 H6A6 H6S7
12-18 18-24 06-12 00-06
HeJ7 HeJ8 HeJ6 HeA7 HeA6 HeS6 HeS7
d
Inside Church Relative Humidity
Crypt Relative Humidity
H4J8 H6J8 H5J7 H7J7 H4J7 H7J8 H5J8 H7A7 H5A7 H6J7 H5J6 H5S6 H4J6 H4S6 H4A7 H7J6 H7S6 H5A6 H5S7 H4A6 H7A6 H6A7 H6J6 H7S7 H6S6 H4S7 H6A6 H6S7
H1J7 H2J7 H3J7 H1A7 H2J8 H1J8 H1S6 H2A7 H3J8 H3A7 H1S7 H3S7 H2S6 H3S6 H2S7 H1J6 H2J6 H1A6 H3J6 H2A6 H3A6
12-18 18-24 06-12 00-06

**Table 1: Overall results of the different Canonical Biplots.**

| | Temperature Analysis | | Relative Humidity Analysis | |
|---|---|---|---|---|
| Seasons | lambda (Wilks) | inertia (%) | lambda (Wilks) | inertia (%) |
| Autumn | 62.46 | 95.17 | 33.24 | 95.75 |
| Winter | 35.89 | 96.52 | 36.26 | 98.32 |
| Spring | 51.11 | 96.09 | 33.72 | 97.94 |
| Summer | 54.78 | 97.93 | 41.69 | 98.86 |

**Table 2: Temperature differences in automn season.**

| Month Year | Outside-Cript Outside-Inside | | | | | | | | Cript-Inside Inside-different heights | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | H1 | H2 | H3 | H4 | H5 | H6 | H7 | | H4 | H5 | H6 | H7 |
| O6 | Ext | Y | Y | Y | | | | | H1 | N | N | N | N |
| | Ext | | | | Y | Y | Y | Y | H2 | N | N | N | N |
| | | | | | | | | | H3 | N | N | N | N |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |
| O7 | Ext | Y | Y | Y | | | | | H1 | N | N | N | N |
| | Ext | | | | Y | Y | Y | Y | H2 | N | N | N | N |
| | | | | | | | | | H3 | N | N | N | N |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |
| N6 | Ext | a | a | a | | | | | H1 | N | N | N | N |
| | Ext | | | | a | a | a | a | H2 | N | N | N | N |
| | | | | | | | | | H3 | N | N | N | N |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |
| N7 | Ext | a | Y | Y | | | | | H1 | N | N | N | N |
| | Ext | | | | Y | Y | Y | Y | H2 | N | N | N | N |
| | | | | | | | | | H3 | N | N | N | N |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |
| D6 | Ext | Y | Y | Y | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | a | a | a | a | H2 | Y | Y | Y | Y |
| | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |
| D7 | Ext | a | a | a | | | | | H1 | N | N | N | N |
| | Ext | | | | Y | Y | Y | Y | H2 | N | N | N | N |
| | | | | | | | | | H3 | N | N | N | N |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |

Y = Difference, N = No difference, a = Difference in the first twelve hours of the day and b = Difference in the last twelve hours of the day.

**Table 3: Temperature differences in winter season.**

| Month Year | Outside-Cript Outside-Inside | | | | | | | | Cript-Inside Inside-different heights | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | H1 | H2 | H3 | H4 | H5 | H6 | H7 | | H4 | H5 | H6 | H7 |
| J7 | Ext | Y | Y | Y | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | Y | Y | Y | Y | H2 | Y | Y | Y | Y |
| | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |
| J8 | Ext | Y | Y | Y | | | | | H1 | N | N | N | N |
| | Ext | | | | Y | Y | Y | Y | H2 | N | N | N | N |
| | | | | | | | | | H3 | N | N | N | N |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |
| F7 | Ext | a | a | a | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | Y | Y | Y | Y | H2 | Y | Y | Y | Y |
| | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |
| F8 | Ext | Y | Y | Y | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | Y | Y | Y | Y | H2 | N | N | N | N |
| | | | | | | | | | H3 | N | N | N | N |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |
| M7 | Ext | Y | Y | Y | | | | | H1 | N | Y | N | Y |
| | Ext | | | | Y | Y | Y | Y | H2 | N | Y | N | Y |
| | | | | | | | | | H3 | N | Y | N | Y |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |
| M8 | Ext | Y | Y | Y | | | | | H1 | N | Y | N | Y |
| | Ext | | | | Y | Y | Y | Y | H2 | N | Y | N | Y |
| | | | | | | | | | H3 | N | Y | N | Y |
| | | | | | | | | | H4 | | Y | | |
| | | | | | | | | | H6 | | | | N |

Y = Difference, N = No difference, a = Difference in the first twelve hours of the day and b = Difference in the last twelve hours of the day.

**Table 4: Temperature differences in spring season.**

| Month Year | Outside-Cript Outside-Inside | | | | | | | | Cript-Inside Inside-different heights | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | H1 | H2 | H3 | H4 | H5 | H6 | H7 | | H4 | H5 | H6 | H7 |
| | Ext | b | b | b | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | Y | Y | Y | Y | H2 | Y | Y | Y | Y |
| A6 | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |
| | Ext | Y | Y | Y | | | | | H1 | N | Y | N | Y |
| | Ext | | | | Y | Y | Y | Y | H2 | N | Y | N | Y |
| A7 | | | | | | | | | H3 | N | Y | N | Y |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |
| | Ext | b | b | b | | | | | H1 | N | Y | N | Y |
| | Ext | | | | Y | Y | Y | Y | H2 | N | Y | N | Y |
| A8 | | | | | | | | | H3 | N | Y | N | Y |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |
| | Ext | Y | Y | Y | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | b | Y | b | Y | H2 | Y | Y | Y | Y |
| M6 | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |
| | Ext | b | b | b | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | Y | Y | Y | Y | H2 | Y | Y | Y | Y |
| M7 | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |
| | Ext | Y | Y | Y | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | Y | a | Y | a | H2 | Y | Y | Y | Y |
| M8 | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |
| | Ext | b | b | b | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | Y | Y | Y | Y | H2 | Y | Y | Y | Y |
| J6 | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | Y |
| | Ext | b | b | b | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | Y | Y | Y | Y | H2 | Y | Y | Y | Y |
| J7 | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |
| | Ext | Y | Y | Y | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | b | Y | b | Y | H2 | Y | Y | Y | Y |
| J8 | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |

Y = Difference, N = No difference, a = Difference in the first twelve hours of the day and b = Difference in the last twelve hours of the day.

**Table 5: Temperature differences in summer season.**

| Month Year | Outside-Cript Outside-Inside | | | | | | | | Cript-Inside Inside-different heights | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | H1 | H2 | H3 | H4 | H5 | H6 | H7 | | H4 | H5 | H6 | H7 |
| J6 | Ext | Y | Y | Y | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | Y | Y | b | Y | H2 | Y | Y | Y | Y |
| | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | Y | | |
| | | | | | | | | | H6 | | | | Y |
| J7 | Ext | Y | Y | Y | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | Y | Y | Y | Y | H2 | Y | Y | Y | Y |
| | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | Y | | |
| | | | | | | | | | H6 | | | | Y |
| J8 | Ext | Y | Y | Y | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | Y | Y | Y | Y | H2 | Y | Y | Y | Y |
| | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | a | | |
| | | | | | | | | | H6 | | | | N |
| A6 | Ext | Y | Y | Y | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | Y | Y | Y | Y | H2 | Y | Y | Y | Y |
| | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | a | | |
| | | | | | | | | | H6 | | | | a |
| A7 | Ext | b | b | b | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | Y | Y | Y | Y | H2 | Y | Y | Y | Y |
| | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | a | | |
| | | | | | | | | | H6 | | | | N |
| S6 | Ext | b | b | b | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | Y | Y | Y | Y | H2 | Y | Y | Y | Y |
| | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |
| S7 | Ext | Y | Y | Y | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | Y | Y | Y | Y | H2 | Y | Y | Y | Y |
| | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |

Y = Difference, N = No difference, a = Difference in the first twelve hours of the day and b = Difference in the last twelve hours of the day.

**Table 6: Relative humidty differences in autumm season.**

| Month Year | Outside-Cript Outside-Inside | | | | | | | | Cript-Inside Inside-different heights | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | H1 | H2 | H3 | H4 | H5 | H6 | H7 | | H4 | H5 | H6 | H7 |
| | Ext | Y | Y | Y | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | b | b | N | b | H2 | Y | Y | Y | Y |
| O6 | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |
| | Ext | b | b | b | | | | | H1 | Y | Y | b | b |
| | Ext | | | | a | a | a | N | H2 | Y | Y | b | b |
| O7 | | | | | | | | | H3 | Y | Y | b | b |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |
| | Ext | b | Y | Y | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | a | a | a | a | H2 | Y | Y | Y | Y |
| N6 | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |
| | Ext | b | Y | b | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | a | a | a | a | H2 | Y | Y | Y | Y |
| N7 | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |
| | Ext | b | Y | Y | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | a | a | a | a | H2 | Y | Y | Y | Y |
| D6 | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |
| | Ext | Y | b | b | | | | | H1 | N | N | N | N |
| | Ext | | | | a | a | a | Y | H2 | Y | Y | Y | N |
| D7 | | | | | | | | | H3 | Y | b | b | N |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |

Y = Difference, N = No difference, a = Difference in the first twelve hours of the day and b = Difference in the last twelve hours of the day.

**Table 7: Relative humidty differences in winter season.**

| Month Year | Outside-Cript Outside-Inside | | | | | | | | Cript-Inside Inside-different heights | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | H1 | H2 | H3 | H4 | H5 | H6 | H7 | | H4 | H5 | H6 | H7 |
| | Ext | b | Y | Y | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | a | a | a | a | H2 | Y | Y | Y | Y |
| J7 | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |
| | Ext | Y | b | b | | | | | H1 | N | N | N | N |
| | Ext | | | | a | a | a | N | H2 | Y | Y | Y | N |
| J8 | | | | | | | | | H3 | Y | Y | Y | a |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |
| | Ext | b | Y | Y | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | N | N | N | N | H2 | Y | Y | Y | Y |
| F7 | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |
| | Ext | Y | Y | Y | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | N | N | N | N | H2 | Y | Y | Y | Y |
| F8 | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |
| | Ext | Y | Y | Y | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | N | N | b | b | H2 | Y | Y | Y | Y |
| M7 | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |
| | Ext | a | Y | b | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | N | N | b | b | H2 | Y | Y | Y | Y |
| M8 | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |

Y = Difference, N = No difference, a = Difference in the first twelve hours of the day and b = Difference in the last twelve hours of the day.

**Table 8: Relative humidty differences in spring season.**

| Month Year | Outside-Cript Outside-Inside | | | | | | | | Cript-Inside Inside-different heights | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | H1 | H2 | H3 | H4 | H5 | H6 | H7 | | H4 | H5 | H6 | H7 |
| | Ext | Y | Y | Y | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | a | a | a | a | H2 | Y | Y | Y | Y |
| A6 | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |
| | Ext | b | b | Y | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | a | a | a | a | H2 | Y | Y | Y | Y |
| A7 | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |
| | Ext | b | Y | Y | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | a | a | a | a | H2 | Y | Y | Y | Y |
| A8 | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |
| | Ext | Y | Y | Y | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | a | N | b | b | H2 | Y | Y | Y | Y |
| M6 | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |
| | Ext | Y | Y | Y | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | a | a | a | a | H2 | Y | Y | Y | Y |
| M7 | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |
| | Ext | b | b | b | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | a | a | a | a | H2 | Y | Y | Y | Y |
| M8 | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |
| | Ext | Y | Y | Y | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | a | a | b | a | H2 | Y | Y | Y | Y |
| J6 | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |
| | Ext | b | b | b | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | a | a | N | N | H2 | Y | Y | Y | Y |
| J7 | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |
| | Ext | Y | Y | Y | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | b | N | b | b | H2 | Y | Y | Y | Y |
| J8 | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |

Y = Difference, N = No difference, a = Difference in the first twelve hours of the day and b = Difference in the last twelve hours of the day.

**Table 9: Relative humidty differences in summer season.**

| Month Year | Outside-Cript Outside-Inside | | | | | | | | Cript-Inside Inside-different heights | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | H1 | H2 | H3 | H4 | H5 | H6 | H7 | | H4 | H5 | H6 | H7 |
| J6 | Ext | Y | Y | Y | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | b | b | b | b | H2 | Y | Y | Y | Y |
| | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |
| J7 | Ext | Y | Y | Y | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | b | b | b | b | H2 | Y | Y | Y | Y |
| | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |
| J8 | Ext | Y | Y | Y | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | b | b | b | b | H2 | Y | Y | Y | Y |
| | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |
| A6 | Ext | Y | Y | Y | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | b | b | b | b | H2 | Y | Y | Y | Y |
| | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |
| A7 | Ext | Y | Y | Y | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | b | b | b | b | H2 | Y | Y | Y | Y |
| | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | a |
| S6 | Ext | Y | Y | Y | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | b | b | b | b | H2 | Y | Y | Y | Y |
| | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |
| S7 | Ext | Y | Y | Y | | | | | H1 | Y | Y | Y | Y |
| | Ext | | | | a | a | b | a | H2 | Y | Y | Y | Y |
| | | | | | | | | | H3 | Y | Y | Y | Y |
| | | | | | | | | | H4 | | N | | |
| | | | | | | | | | H6 | | | | N |

Y = Difference, N = No difference, a = Difference in the first twelve hours of the day and b = Difference in the last twelve hours of the day.