PACKING AND TRANSPORTING CONSIDERATIONS - THE HOLY MONASTERY OF ST. CATHERINE IN SINAI.

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Art in Transit continues to be a controversial area of scientific interest. Modern transport and packing techniques are constantly being ameliorated following the relentless progress and proliferation of exhibition activity worldwide. There are numerous published papers on artefacts damaged during transport and the main causes have been shock (e.g. caused by case toppling), vibration, mishandling and climatological changes (primarily in temperature and humidity). Panel paintings on wood are part of a broader category of hygroscopic materials that are susceptible to variations in humidity and temperature. The requirements for safely transporting and displaying such artefacts between different climate zones are complicated. One of these cases is the Monastery of St. Catherine on the foot of Mount Sinai in Egypt. The paper examines the parameters related to the packing and transport of such an idiosyncratic collection with a particular emphasis on the levels of relative humidity (RH) and temperature (T) for the duration of the transport, as were recorded during actual flights.

1. View of the Holy Monastery of Saint Catherine in Egypt, from the northwest

THE MONASTERY AND THE COLLECTION

The Holy Monastery of St. Catherine is the oldest active Christian Monastery in existence (*Pic. 1, 2*). For over seventeen centuries it has been one of the world's greatest centers of religious pilgrimage and holds a unique collection of important religious and historical artefacts (Forsyth/Weitzmann, 1965; Evans, 2004). The


2. View of the miniature town within the fortress

Monastery and its church are among the finest surviving representative examples of Byzantine architecture, housing collections of priceless Byzantine religious art encompassing mosaics and murals, icons, oil paintings, paintings on wax, textiles, books and manuscripts, fine sacerdotal ornaments, marbles, enamels, chalices, reliquaries and other priceless works of art spanning for over fifteen centuries. The monastery is well known for its legendary collection of illuminated manuscripts and early printed books –second largest and most important collection after that of the Vatican. Nonetheless, St. Catherine's houses a unique collection of icons with important and representative pieces from all eras of Byzantine Art. Thanks to its isolated location, rare and unique encaustic panels from the sixth and seventh centuries survived the ravages during the period of Iconoclasm, when thousands of images used in religious worship were destroyed (Wietzmann, 1976). It should be remembered that the Monastery has been an important crossroads since antiquity and at times maintained strong contacts with Byzantine emperors, the western aristocracy and the papacy, as well as Muslim leaders (Evans/Wixom, 1997). The diverse cultures of these pilgrims and rulers are reflected in the Monastery's vast icon collection, which includes a number of important encaustic as well as other types of icons, which came from workshops in Egypt and Sinai, Palestine, Georgia, Syria, Cappadocia, Constantinople, Crete, Cyprus, Southern Italy and the under Venetian rule islands of the Aegean.

Parts of this collection have been included in eleven international exhibitions around Europe and the United States since 1997, when a small group of icons left the Monastery's premises for the first time. Through careful study of the exhibitions' history (Androutsopoulos, 2005), it was made evident that all institutions that have hosted exhibitions with Sinai artefacts, have endeavoured to take all the necessary precautions as to their safe transport and display. However, the approach and methods that were implemented each time were different.

Paintings on wood panels are reputedly amongst the most environmentally sensitive objects of art (Hoadley, 1978; Knut, 1999). The remote location of the monastery and the distinctive, arid atmosphere pose a great challenge to the practicalities of safe packing and transport in different climate zones around the world. Identifying the characteristics of the prevailing conditions within the monastery's premises is essential in order to have a better understanding of the climate under which the artefacts have been preserved and acclimatized over the centuries. It is rare that the dry climate of St. Catherine's matches those of the borrowing institutions. In order to ensure environmental continuity, which is the guiding principle in preventive conservation (Cassar, 1995), it is crucial that the environment during travel and display should be similar to the one prevailing at the monastery. Any disruption comprises a great threat to the dimensional stability of panel paintings and all other hygroscopic materials that comprise the artefacts of the collection (Kamba, 1993; Ashley-Smith, 1994).

CLIMATE

The climate of the Sinai desert is distinctive and can be very inhospitable but, at the same time, it has played a pivotal role in the preservation of the monastery's collection. It is characterized by extremes in temperature with severe cold in the winter and sweltering heat in the summer. This highly idiosyncratic climate zone has been St. Catherine's locale for many centuries. The Monastery had recorded ambient temperature and humidity levels over the course of some three years but no systematic analysis of this material had ever been made. A careful assessment of the existing digital and analogue records revealed patterns unique to the Sinai and provides a clearer picture of the actual climate behavior inside the Church, an outdoor covered area adjoining the church, inside the small museum and the library.

The following statistic analysis is a result of the assessment of digital and analogue records from different devices (thermohygrographs, digital thermo hygrometers, data loggers and more). In order to perform a comparative study, data had to be uniformed and transferred to an MS Excel spreadsheet. Minimum and maximum RH and T values for the three different locations are included in *Table 1*, along with the average values for a whole year – apart from the library where the monitoring period did not span a full year. Data pertinent to the Church and the outdoor covered area adjoining the church have been recorded by data loggers (HoboPro2) that were set to record RH (%) and T (˚C) values every fifteen minutes. As regards the set of data pertaining to the library, an electronic, rotating drum thermohygrograph was used to record analogue data in the form of tracings on scaled paper-charts. Hence, the laborious task of copying raw data from the paper charts onto a MS Excel spreadsheet – copying one value every two hours – could not be avoided. A total of more than 7,500 values of RH (%) και T (˚C), were copied; a figure that appears minute when compared to the one recorded by the Hobo devices (over 60,000 for a full year). For the aforementioned reasons, the comparative approach can only be considered as indicative (*Fig. 4, 5, 6*).

3. The monastery from above (Google Earth).

4. Satellite view of the monastery (Google Earth).

It is the mountainous location and high altitude of the Monastery (*Pic. 3, 4*) that causes the climate to vary considerably even from other locations across the peninsula. Extremes in temperature and relative humidity are recorded throughout the entire year. The latter remain quite low, with the greatest part (62%) confined in the range of 10-30% RH. The ambient temperature was only recorded to exceed the upper limit of 30˚C in five single occasions during the whole year and for a short period of time (0.3% of the total monitoring period) during the summer months. Monthly temperature variations do not exceed ±10˚C whereas the mean average of relative humidity variations is about ±18%. Despite the extremes of the recorded relative humidity values, covering a range between (2%-85%), the year average does not exceed 27%, a 'relatively' low percentage (*Fig. 1*).

The indoor conditions within the Monastery's ramparts are greatly affected by the prevailing dry climate. The church, lying in the heart of the monastery, is built of granite stone, whereas the library is a reinforced cement building with three external walls and no means of controlling the ambient conditions, situated on the top floor of a three-storey building along the south wall of the monastery. Although the Church is open to visitors for three hours in the morning (09.00-12.00) the Library is scarcely accessed. The overloading of monuments by visitors has been the subject of recent studies e.g. at the Notre-Dame Cathedral in Paris (Boyer, 2000), the Sistine Chapel in Rome (Camuffo/Bernardi, 1986/1991). As regards the church of St. Catherine church, the indoor conditions are not seriously affected by the daily access (during visiting or service hours), with variations of no more than ±6% RH. The greatest percentage of the readings (84%) falls between 10-30%. More specifically 44% of the time the RH fluctuates in the range of 20-30%, while 40% of the monitored data is in the range of 10-20%. The RH was only recorded as exceeding the upper limit of 45% in six single occasions during the whole year and just for a couple of hours in total (0.4% of the total monitoring period). These are likely to have been times of rainfall, which is rare in the Sinai (*Fig. 2)*.

The library room proves to have the most constant levels of RH with the greatest part (82%) limited in the range of 15-30%. There is only one sole occasion during which the RH levels were recorded over 33%, which was when heavy rain was noted, according to the hand notes on the paper charts). It should be noted that the recording device was calibrated during the monitoring period and for this reason, data may present some margin of error. However, it is the rate of fluctuations that is more interesting than the actual values of RH and T (Erhardt/Mecklenburg, 1994; Erhardt et.al., 1995) (*Fig. 3)*. There is no equipment for controlling the climate inside the library; thus, the prevailing conditions are the unique result of the interaction between the outdoor conditions and the room with its contents. Even more recent records from an ongoing monitoring with data loggers reveal even lower – and surprisingly, equal – average values (17%) for the time periods from April to June and July to September (Father Justin, 2006). The library data could also be considered representative of the conditions of the icon storage room, which is located immediately below the library and was not assessed during the course of this research.

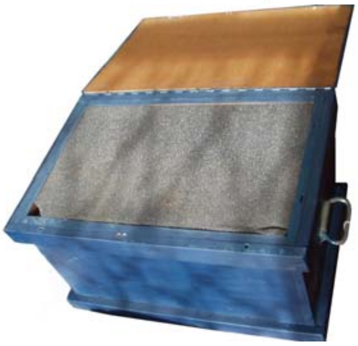
Panels that have travelled to past exhibitions come, for the most part, from the church, while many of them are stored in the icon gallery and the different sacristies. In 2001, a new environment for more than 35 icons and 20 books and manuscripts and other religious artefacts was introduced with the opening of a museum within the citadel. The initial aim was to make the collection more accessible to the secular public. This enchanting, low-ceilinged museum, adjoining one of the monastery's sixth century stone walls, is in fact the result of a successful renovation of one of the old sacristies, made possible with the contribution and consultancy of Greek and American scholars representing renowned institutions and organisations. The museum itself has the ambience of a treasury, and is divided into seven small rooms with controlled, subdued lighting. Maintenance is excellent, and conditions are maintained using modern equipment and monitored by thermo-hygrographs and digital thermo hygrometers, both inside and outside the display cases. The average ambient RH is maintained in the range of 25-35% with 45% being the upper limit. Frequent visits during different seasons and a more systematic monitoring – using Gemini data loggers – for two consecutive weeks during the summer (*Fig. 9)*, attest that the climate conditions are maintained quite stable, with the exception of the variations that are recorded during morning visiting hours. Contrary to the church, the levels of RH inside the museum appear to rise as a result of the presence of visitors (*Fig. 7, 8*). Each time the museum opens at 09.30 in the morning, temperature surprisingly seems to fall, something that could be caused by the intense function of the air-conditioning system during these hours. Apart from that, relative humidity and temperature in the museum prove to be even more constant (RH ±10% - T ±4°C) than those in the library and the church, with the two latter areas being slightly drier and colder. This was partly expected since the monitoring period for the museum was during one of the warmer months of the year. Almost all the artefacts in the museum are displayed in airtight cases of high quality and it is safe to assume that the conditions inside the cases are even more constant that the ones recorded in the different rooms. This was verified by systematic inspections of the monitoring instruments within the cases, with the RH falling between 25 ±5% and T at 18 ±2°C.

PACKING AND TRANSPORT

For the past forty years, the transportation of works of art comprises an individual scientific field of activity and study. Since 1969, important work has also been published by the ICOM-CC Working Group, under the name of *Care of Works of Art in Transit.* Directors, curators, registrars, museologists as well as conservators, scientists and transportation experts have contributed to the work of the Group through various papers that have offered a better understanding and evaluation of practices and standards in travelling exhibitions, not only from the conservation aspect but from the museological point of view as well. Despite the rapid increase of exhibition activity worldwide, it is evident that with increasing travel, the works of art are subject to greater deterioration than when they remain static in their designated environment. At least there, the changes of the conditions are more predictable, than those that can potentially be experienced by the artwork during transit. Insurance claims are only made when visible damage occurs during loan, but in many cases, the damage — for example a weakening in the structure — may not be apparent initially, but is certain to manifest itself at a later date, when it is unlikely that it will be traced back to its real cause.

The incentive for this research was given by an alleged damage that appears to have been caused due to a temporary loan, namely, the dimensional change in the wooden panel of an icon of Spanish origin, depicting St. Catherine[1]. It is a beautiful late work of Italianising Gothic in which Saint Catherine appears represented in the classical form of Western art, standing, crowned, with the instrument of her torment, the spiked wheel, and the palm leaf of victory that signifies her rank as a martyr. While there are no precise, accessible records of the dimensions, the loan agreement sets the RH for the five-month display at 50-60%, inside the case. Although these values have come to be regarded as the optimum for the preservation of wood, they appear to be the cause of distortion in certain categories of hygroscopic materials. Changes in the dimensions of hygroscopic materials are caused by the reaction of the materials trying to establish equilibrium with their new environment. It is worth mentioning that the performance of RH and T inside a closed case is very particular and has been the subject of many papers (Toishi, 1959/1963; Thomson, 1964; Stolow, 1966).

The dimensional stability of hygroscopic material has been principally associated with the effects of both R.H. and T (Mecklenburg et.al., 1998; Michalski, 1991; Stevens, 1961). In reality, changes in the Equilibrium Moisture Content - E.M.C. are directly related to the dimensional stability of wood and all hygroscopic materials. Hackney's (1987) groundbreaking work ascertains that a constant RH is not enough to ensure dimensional stability, as temperature variations can form another effective and direct cause of the transposition of water from or into the wood and eventually resulting in dimensional change. Changes in dimensions of all potential hygroscopic materials constituting an icon (wood, organic glue, size, fabric, paper) are particularly dangerous and known to lead to cleavage, shrinkage, splitting, cracking, craquelure and losses of the paint layers and various kinds of torsion and distortion (ICOM, 1955; Stamm, 1970; Berger, 2000).



5, 6. The MDO plywood crate constructed at the monastery is screwed shut, and has a lid attached to the base with an aluminum piano hinge across the top. Although the crate was not lined, a Plastazote layer (Cross-linked closed cell polyethylene nitrogen expanded foam) of 20mm was used between the lid and the base as an air and vapour barrier. Similar pieces of foam were also used in the inner case. The exterior was coated with three layers of blue acrylic paint to reduce the effects on moisture absorption by the plywood panels of the crate.

TRANSIT

Although the monastery has sent icons to eleven exhibitions, no one monitored the conditions during transit. It seemed possible to replicate such a transit, and this is the relevance of the data presented below. At Sinai, a Medium Density Overlay – plywood crate (MDO - 20 mm-thick panels) was constructed (*Pic. 5, 6*) to replicate the crates with double casing used by the MET for the 2004 exhibition.[2] The crate's volume (520 mm x 380 mm x 340 mm) was calculated at less than 0.05 m^3 and although the interior was not adequately lined, it contained a smaller and thinner plywood case with a volume of 0.027 m^3. Blank wooden panels of pinewood that had been acclimatised to the monastery's natural environment were used as specimens for the transit. Panels were packed inside the crate using different types of foam and plastic for insulation. Data loggers, placed in different parts within the crate recorded (at 10-minute intervals) relative humidity and temperature behavior during the long drive from Sinai to Cairo and on the flight from Sinai to Athens. Subsequently, the crate was shipped to Durham City, in the northern United Kingdom, where it was opened at the university laboratory under controlled conditions. Changes along the tangential direction of the wooden panels are presented in *Table 3*. Changes could have been more accentuated if the transit period was longer, e.g. in case of an overseas transport.

On the 24th of June, the aircraft was flying at an average altitude of 11,500 meters with an average ground speed of 890 km/h and a median outside temperature of -57°C. The duration of the flight from Heathrow to Eleftherios Venizelos airport in Athens was approximately three hours, during which the temperature in the cargo hold, as recorded using the data logger, dropped by 3°C whilst the RH was maintained at fairly constant levels (64 ±2%), slightly higher than the levels recorded upon packing (*Fig. 10)*. In reality, the RH was seen to decrease during take off and increase on landing (dotted circles), in keeping with published data (Saunders/Clarke, 1990). It should be noted that the data logger was kept in suitcase transported in the cargo hold. On the contrary, during the transport by train, the small rise in temperature levels (+3˚C) was followed by a 5% rise in the relative humidity levels According to relevant publications, the RH in the cargo area is in the region of 19-25% while the temperature never drops below 10-5°C (Toishi, 1967; Merrill, 1988; Saunders/Clarke, 1990). A common understanding is that the RH, depending upon the length of flight and temperature, is usually stabilised during the course of the flight to a level slightly lower than it was prior to take-off (Saunders, 1991). This was verified throughout all the monitored flights. Allowance should be made for a slight discrepancy between actual conditions in the cargo hold and conditions inside the plastic suitcase, on the flight from London to Athens.

Similar behaviour was recorded during the flight from Athens to Cairo (28/06/2005), with the data loggers having been placed, once more, in a plastic suitcase (*Fig. 11*). In Athens, at the time of packing, the RH and T were recorded at 44% and 23˚C respectively. During this short, two-hour flight, the recorded small decline in temperature was followed by a small drop in RH levels. Shortly upon arriving in Cairo, the unavoidable, six-hour, overland journey to Sinai began. The rise in temperature, as the sun was rising over the peninsula, was accompanied by a rise in RH levels, with the data loggers remaining in the plastic suitcase. At 11.00 (UK time) the data loggers were taken out of the suitcase with an RH of 48% and were placed in a well-ventilated indoor location, a few meters from the Monastery. Ten minutes later, the logger recorded a remarkable drop in RH levels, with a reading at 21%. Subsequently and for the rest of the day, levels of RH were recorded to stabilise around 22 ±1%. Both the plastic suitcase and its content (mainly clothing) comprised a packing system which managed to retain the initial percentage of RH that was recorded upon packing in Athens. More specifically, after this 10-hour transport from Athens to Sinai, the levels of RH, responding to the rise in temperature, were only recorded to rise about 5%, despite the arid climate of the region.

A different behaviour was observed within the transport crate during the overland journey from Sinai to Cairo (*Fig. 12*) and from Cairo to Athens by plane (*Fig. 13)*. Downloaded data demonstrates convincingly that with the right packing method and materials, the RH does not present major variations. It has been proven, firstly empirically and later mathematically, that if the temperature rises within a sealed case with a certain amount of wood present[3], then the

RH will automatically rise and vice versa (Toishi, 1959/1961; Thomson, 1964; Stolow, 1966). However, during this particular transit, the levels of RH were not recorded to respond to the total rise in temperature (+10˚C) during the overland journey. This clearly indicates a change in the E.M.C of the hygroscopic material, as the latter absorbs the changes in temperature in order to retain the RH constant. It is worth noting that although the RH is initially recorded as being constant, a different behaviour is noticed due to the small decrease in temperature (-4˚C) (*Fig. 12-14)*. In reality, the small drop in RH does not exceed 3%. It would be further interesting to record the RH response to a more abrupt and prolonged drop of temperature.

7. The second wood specimen along with a data logger, tape sealed in polyethylene plastic and placed in the polyurethane foam core box that is also tape-sealed, using thermic tape.

OBSERVATIONS - CONCLUSIONS

Silica gel and other similar buffering agents have been highly recommended as an efficient way of mitigating RH variations during transit (Toishi, 1958; Thomson, 1964; Stolow, 1981; Staniforth, 1984). However, given the small volume of air in packing cases and that all icons are made of moisture-absorbing materials, the use of silica gel or other desiccants is usually unnecessary, expensive and impractical and can even prove dangerous in some cases. In practice, a constant RH during transit (although it could be misleading as to the effects on the dimensional stability of the enclosed materials) can be achieved without the addition of moisture absorbing materials like silica gel. Earlier, Kamba (1993) observed that wood enclosed with little air and without any moisture buffering materials is more dimensionally stable than wood enclosed with a buffering material, such as Art-Sorb. This is also verified by the data collected during transit, although the transportation crate and packaging materials that were used are considered basic. In fact, no shock-absorption or sufficient thermal-protection materials were used. Conditions proved to be more constant for specimen B (*Fig. 14)* which was placed in the inner case after having been wrapped in tissue paper and subsequently tape-sealed in polyethylene plastic along with a data logger and naturally a small amount of air. This was then placed in a tape-sealed polyurethane foam core box (*Pic. 7*).

Some scholars have rejected the use of tape-sealed polyethylene plastic as a moisture protection barrier during transit as in many cases it appeared to cause condensation (Stolow, 1963/1981). However, condensation can only occur under very specific conditions and can be avoided if, upon arrival at the destination, the crates are left in the room where they will be unpacked for an average of 24 hours to allow the internal temperature to come into equilibrium with the ambient conditions (Saunders/Clarke, 1990; Richard et. al., 1991).

Evidently, the more efficient the thermal buffering of the crate is, the longer this period will need to be[4].

Special vigilance should be given to the time of packing and unpacking of the artefacts in transit and the conditions of the room in which they take place, for the object can be exposed to far greater changes in RH and T, than any change during transit. Especially in the case of touring exhibitions, where the artefacts are repeatedly packed and unpacked, there is a clear risk of their being exposed to RH and T changes greater than the ones experienced throughout the transportation. Human presence causes changes in the atmosphere of a closed area, and should be taken into consideration. Equal vigilance should be given to the storage of the crates and all packaging material for it has been proven that the RH of the air enclosed in the crate will dominate during transport, even when the external conditions are not necessarily kept constant. Therefore, storing the crates under humid conditions will certainly affect their performance during transit, and the usually higher RH and lower T conditions can be detrimental to the artefacts.

To ensure the optimal preservation of the collection, it is essential that every movement be planned meticulously, and no loan should be agreed without a full assessment of the condition of each item as well as potential environmental and security risks during transit. Good documentation is also necessary before and after the conclusion of each exhibition (Stolow, 1981a). Condition reports, accompanied by high quality photographs (including photographs made with raking light), should thoroughly record and evaluate the physical condition of each item as well as changes that occur as it moves from one venue to another. Particular attention should be given to devising the condition report forms, so that they oblige the conservator to cover all pertinent categories. Detailed measurement of the dimensions are vital, but weighting each object could also prove to be helpful in assessing the change in the water content of the hygroscopic materials constituting the artwork in transit. Over the years, a number of private transportation companies specialised in the handling and transport of art exhibitions, have been established. Although best practices are being pursued, it is evident that there are no unified standards for packing and transporting of works of art. The initiative by the European Committee for Standardization (Comité Européen de Normalisation) to draft standards in this interdisciplinary field will hopefully further improve the quality of transport and packing of cultural property.

His Eminence Archbishop Damianos and the Holy Council of the Fathers have felt that circulating actively venerated parts of the invaluable St. Catherine's collection of the monastery of St. Catherine in international exhibitions is one of the ways the monastery's treasures have been gradually made more accessible to the secular public of all persuasions. At the same time, it is the Monastery's responsibility to preserve its collection for posterity. Fortunately, all the institutions that have hosted temporary exhibitions with Sinai artefacts have acknowledged and respected the historical, spiritual, and artistic value of the collection, and have endeavoured to take all the necessary precautions pertinent to safe transport and display.

From its earliest history, Sinai was the most isolated of all Christian pilgrim shrines. Generations of monastics passed their lives there in vast solitude, maintaining the cycle of daily services, and caring for the icons and manuscripts that were a part of their spiritual heritage. That isolation came to an end less than forty years ago, and today Sinai daily receives vast numbers of visitors. Members of the community have felt that it is essential to perpetuate venerable spiritual traditions in the midst of these changed circumstances. But at the same time, it is also important to share this heritage and educate others in its significance, and this has led them to participate in international exhibitions. If this is not done with care, icons and manuscripts that have survived for centuries in the Sinai desert could quickly be destroyed. But it does seem possible to achieve this goal, conservators working together with the members of the community, informing their decisions, helping them to safeguard their collections and achieve this noble ideal.

FIGURES

FIGURE 1

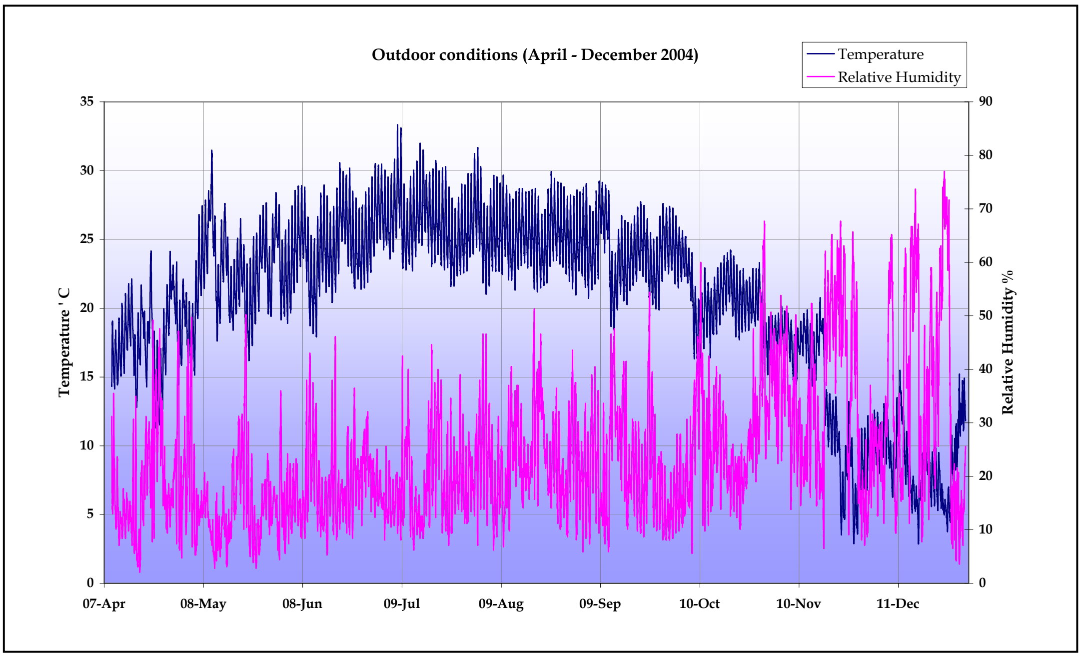


FIGURE 2

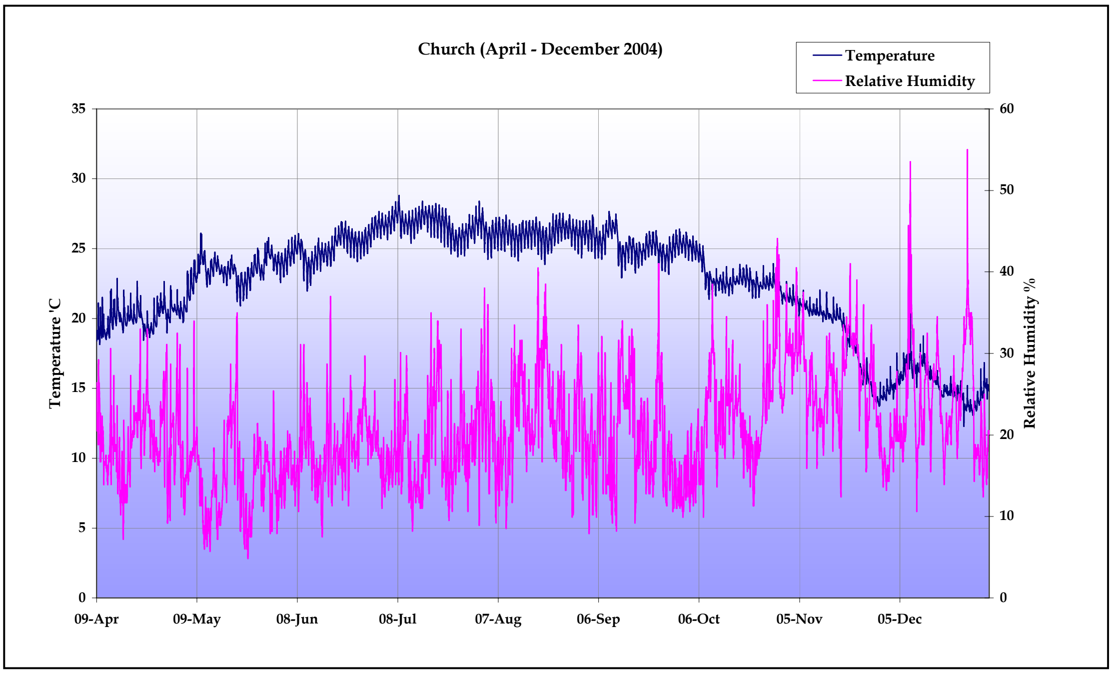
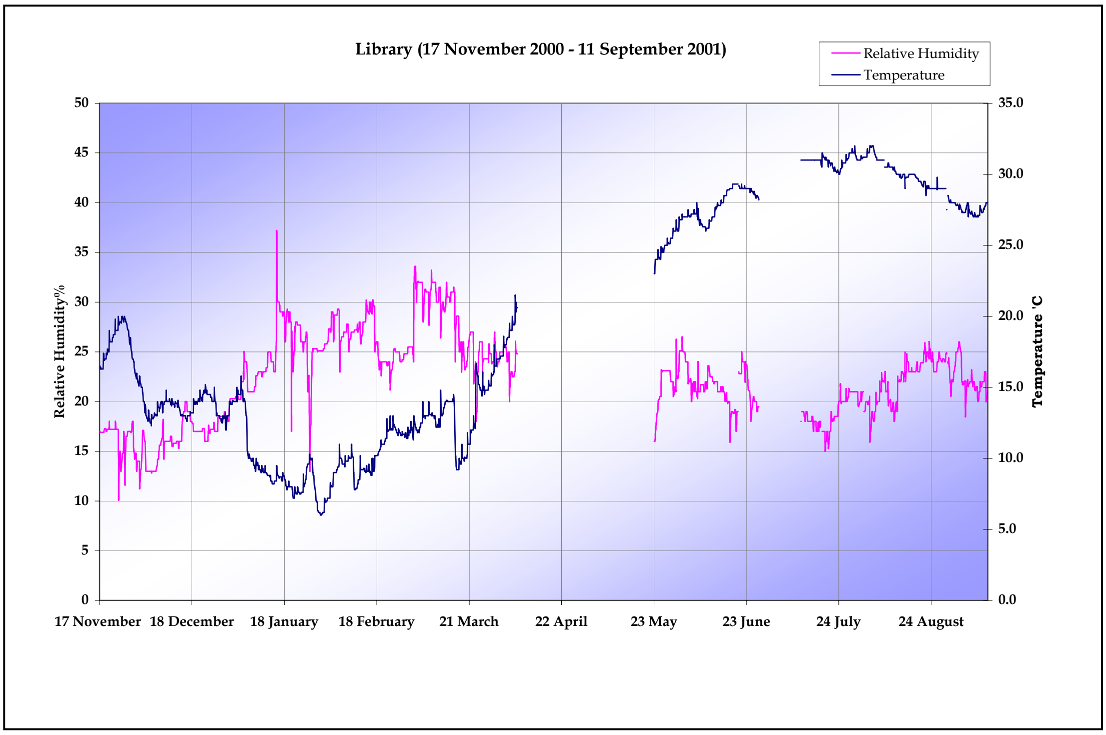


FIGURE 3



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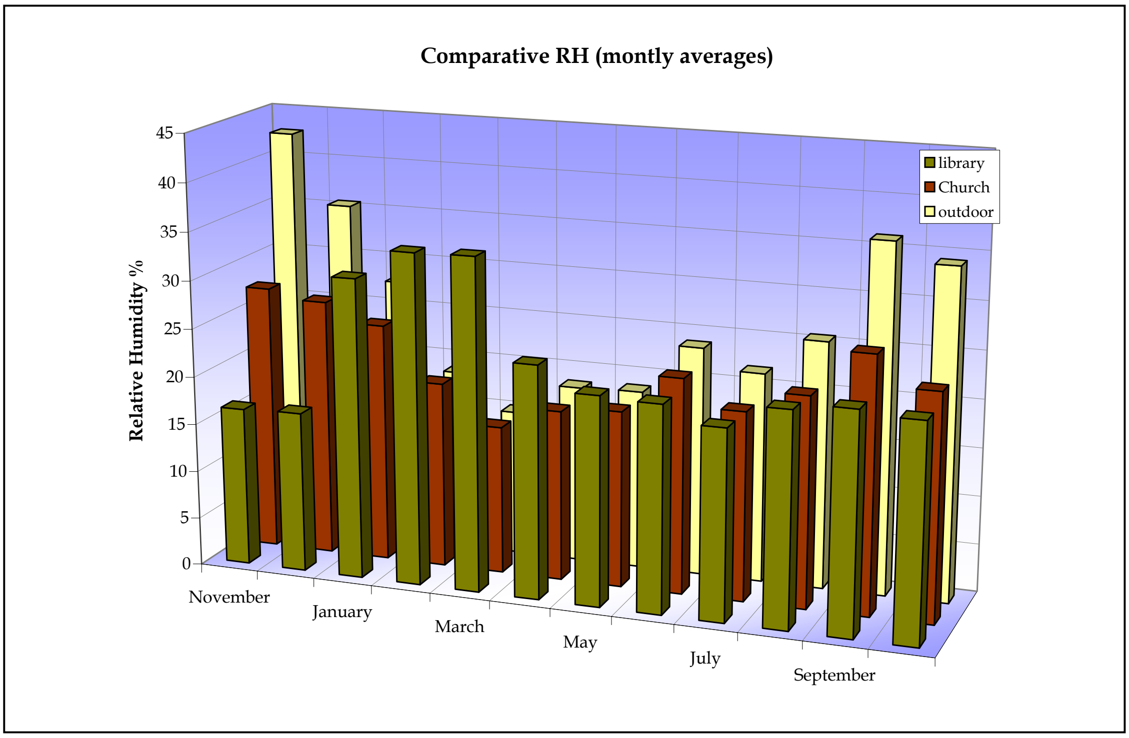

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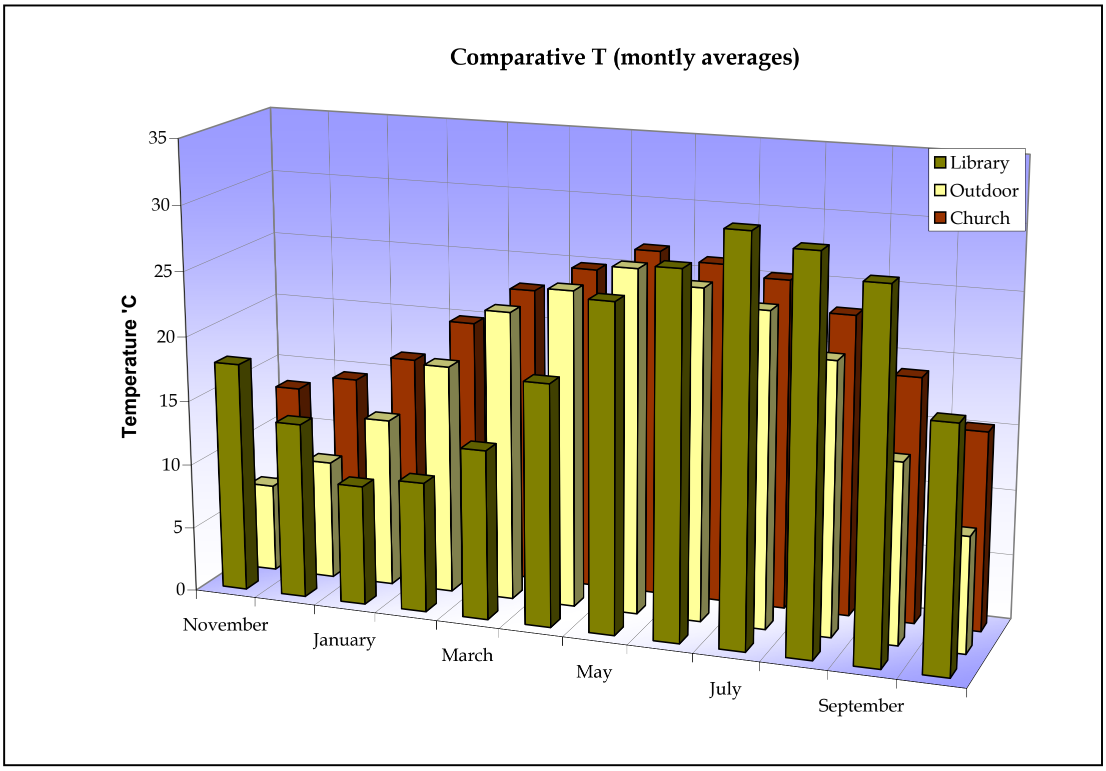

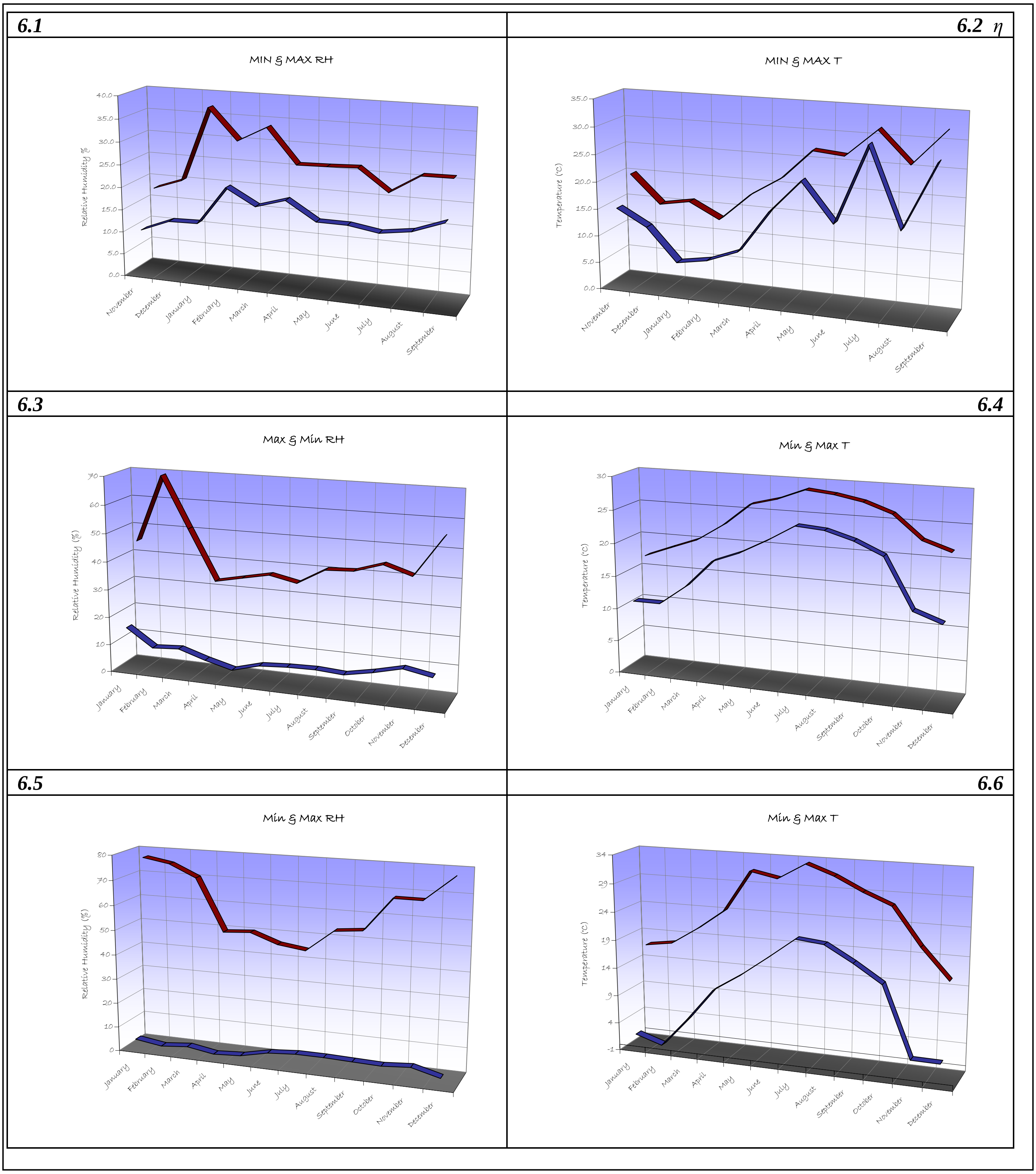
6.1
MIN & MAX RH
Relative Humidity %
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November December January February March April May June July August September
6.2
MIN & MAX T
Temperature (°C)
35.0 30.0 25.0 20.0 15.0 10.0 5.0 0.0
November December January February March April May June July August September
6.3
Max & Min RH
Relative Humidity (%)
70 60 50 40 30 20 10 0
January February March April May June July August September October November December
6.4
Min & Max T
Temperature (°C)
30 25 20 15 10 5 0
January February March April May June July August September October November December
6.5
Min & Max RH
Relative Humidity (%)
80 70 60 50 40 30 20 10 0
January February March April May June July August September October November December
6.6
Min & Max T
Temperature (°C)
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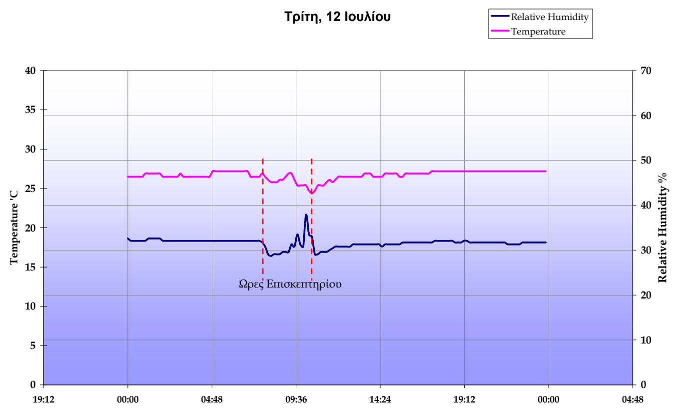
January February March April May June July August September October November December

FIGURE 6

FIGURES 7, 8, 9

7.



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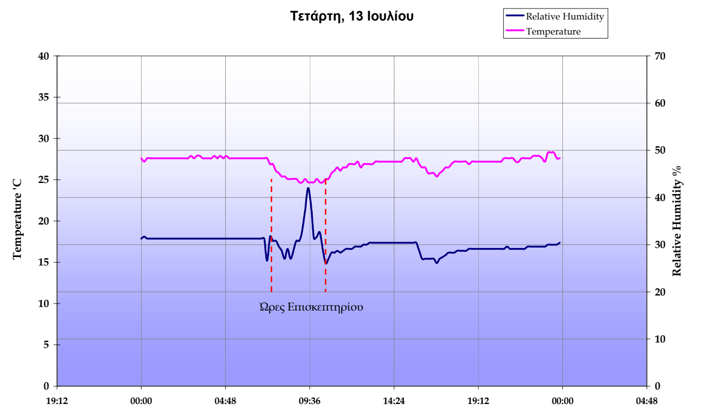

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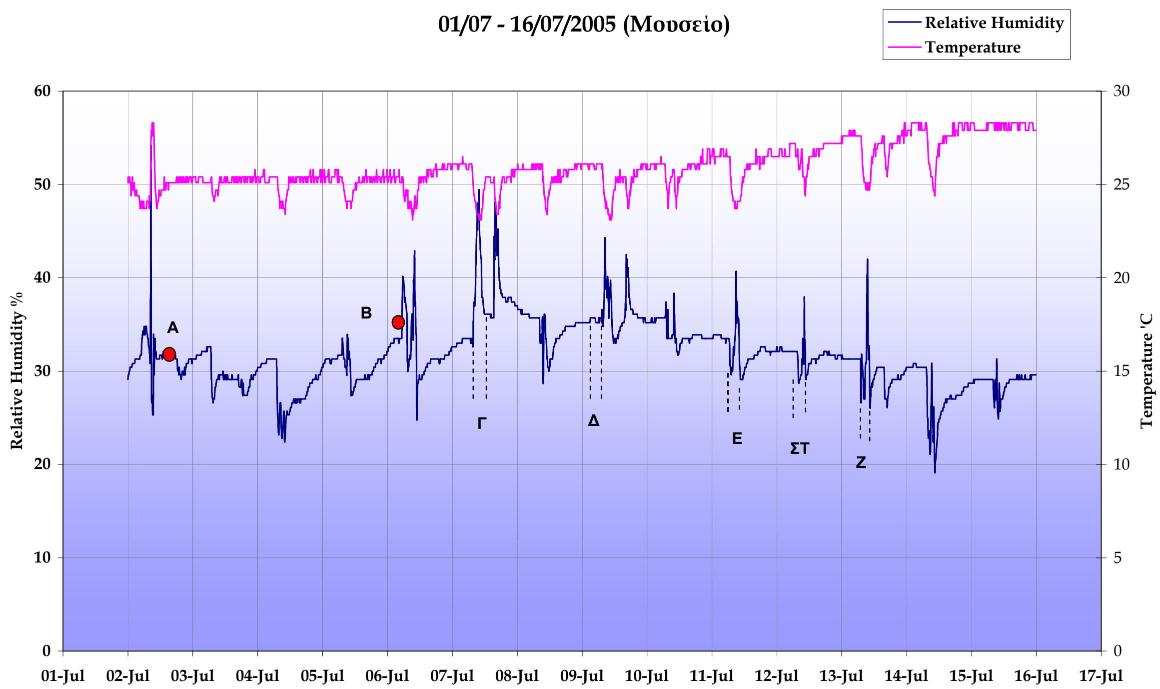

TABLES

TABLE 1. Maximum, minimum and average values of relative humidity and temperature inside the church, the library andoutdoors. Although the average RH value of the library might appear slightly increased, one has to bear in mind that data in the library do not cover a full year. Consequently one would normally expect the average RH to be in the range of 20-22%, taking the two missing -and relatively dry- months of April and May into account.

TABLE 2. Maximum, minimum and average values of relative humidity and temperature, as were recorded by the Gemini data logger, which was placed inside the museum for two weeks.

TABLE 3. Dimensional changes of wood specimens transported form Sinai to Durham and consequently to Athens. The dimensions refer to the width of the wooden panels (along the tangential direction) and all measurements were carried out using digital callipers. No change in thickness was observed.

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FIGURES

FIGURE 1. Relative humidity and temperature behaviour of the outdoor environment in the monastery's premises, from April to December 2004. Although the temperature is maintained above 18-20°C for most of the time, many extremely low temperature values, especially during winter, reduce the yearly average value. It is the location of the monastery in the area of the highest mountains in Egypt that causes such extreme weather variations, in comparison with other sites across the Sinai Peninsula.

FIGURE 2. Relative humidity and temperature behaviour inside the church, as recorded by the Hobo device (April – December 2004). Seasonal changes are obvious by focusing on the temperature's broader monthly fluctuation. By studying open days separately, it is proved that the effects of visitors do not cause the RH to increase over 35%, with the majority of the values limited between 10-30%.

FIGURE 3. Relative humidity and temperature behaviour in the library, processed data from paper-chart-records of a drum-thermo-hygrograph. There are obvious gaps, especially one from the 6th of April to the 13th of May, for which there are no records, as the paper charts failed to be replaced. However, the graph clearly demonstrates

the overall seasonal behaviour of the ambient environment in the library, where there is no equipment for controlling the conditions.

FIGURES 4, 5. Bars of monthly average relative humidity (Fig. 4) and temperature (Fig. 5) values in the church, library and outdoors. It has to be reminded, though, that only the church and outdoor data-sets are from the same year (2004) whereas the library was monitored during 2000-2001. Inside the Narthex of the church the monthly average RH does not fluctuate more than ± 5%. As far as the library is concerned the monthly average RH is even more constant (±2%) with the exception of the first three months of the beginning of the year where the RH was around 30% (difference could be caused be due to calibration of the device.

FIGURE 6.1 Maximum and minimum monthly average relative humidity values in the library.

FIGURE 6.2 Maximum and minimum monthly average temperature values in the library.

FIGURE 6.3 Maximum and minimum monthly average relative humidity values in the church.

FIGURE 6.4 Maximum and minimum monthly average temperature values in the church.

FIGURE 6.5 Maximum and minimum monthly average relative humidity values outdoors.

FIGURE 6.6 Maximum and minimum monthly average temperature values outdoors.

FIGURE 7. Relative humidity and temperature variations during Tuesday 12 June 2005. The effect of the presence of visitors during morning visiting hours is evident.

FIGURE 8. Relative humidity and temperature variations during Wednesday 13 June 2005. The effect of the presence of visitors during morning visiting hours is evident.

FIGURE 9. Relative humidity and temperature behaviour, as recorded by data loggers that were placed in different areas inside the museum for two weeks (2 – 16 July 2005). Point A (02/07 - 12.30) defines the beginning of the monitoring when the logger was placed in the first room of the museum whereas point B is when the logger was moved to

the second room where the encaustic icons are displayed. The highlighted time-periods refer to the morning visiting hours.

FIGURE 10. Transportation by train and airplane as monitored on the 24th of June 2005. It should be noted that the data logger was kept in plastic suitcase transported in the cargo hold. The duration of the flight from Heathrow to Eleftherios Venizelos airports was approximately three hours, during which the temperature in the cargo hold, as recorded using the data logger, dropped by 2°C whilst the RH was maintained at fairly constant levels around 63±0.8% . The overall effect of the journey from Durham to Athens was a rise in RH, with variations in temperature ranging from 22.5°C to 26.5°C. RH levels appear to stabilise soon after the check in at the airport (14.00) but the flight, scheduled for 16.30. was postponed to 18.00.

FIGURE 11. Relative humidity and temperature variation inside the plastic suitcase as recorded during the two-hour flight from Athens to Cairo and the six-hour overland journey from Cairo to Sinai. The chart demonstrates the remarkable drop of the RH (almost by 30%) the minute the data logger was removed from the suitcase, although the internal temperature had already begun to come into equilibrium with the external conditions. The logger was placed in one of the monastery's workshops, a few meters from the fortress, with readings of RH 21% and T 28˚C.

FIGURE 12. On July 17th, the RH within the shipping crate was maintained fairly constant throughout the whole duration of the overland journey from Sinai to Athens. Small, sudden fluctuations (less than ±1%) are noted during the road journey to Cairo, as the temperature rises significantly (10˚C). These are probably due to the attempt of the internal RH to follow the rise of the T while the wood specimen is acting as a buffer.

FIGURE 13. On July 18th, the RH was maintained constant throughout the duration of flight from Cairo to Athens. Although the temperature varies significantly, the RH fluctuations are minor, especially according to the second data logger which was placed inside the polyethylene wrap (Fig. 14).

FIGURE 14. Relative humidity and temperature variations within the tape-sealed polyethylene wrap. It appears the RH of the air trapped inside the polyethylene is maintained at a constant level throughout the whole duration of the journey from Sinai to Athens. Small, sudden fluctuations (less than ±1%) are noted during the road journey to Cairo, as the temperature rises. These are probably due to the attempt

of the internal RH to follow the rise of the T while the wood specimen is acting as a buffer.

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[1] This rare altarpiece, painted by Martí de Vilanova and offered in 1387 to the monastery by Bernat Maresa, ‘Catalan consul' to Damascus, is evidence of the special bond between the Crown of Aragon and the monastery (Carbonell/Cassanelli, 2003).

[2] The crate could not have been constructed without the invaluable help of Father Daniel and the monastery’s gifted carpenter.

[3] Thomson’s (1964) theory and practical trials both indicated that, in a closed case, for wood in excess of about 100g per 100litres of air, the change in RH will not exceed about one-third of the temperature change and will be in the same direction. However, this was challenged in later years through numerous experimentations.

[4] The rate by which the interior temperature changes, following variations of the external T, is mainly determined by the case’s size and shape, the rate of air transfer, the thickness of the case walls, the heat capacity of the contents, and the thermal conductivity of the case and packaging materials. Increasing thermal insulation and making the case more airtight are methods of extending a case’s temperature *half-time* and thus reducing the rate by which it is affected by the external T (Richard et.al., 1991). The *temperature half-time* is frequently used to describe the rate of temperature change inside a packing case and is defined as the amount of time that is required for the case to reach one-half the difference between the original interior-case temperature and exterior-case temperature.