ANALYSIS OF THE SUNDIAL OF PREVEZA

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The sundial of Preveza as shown in Figure 1, is fixed on the south face of the clock tower of the town, see Figure 2. The enigma of the dial was already treated but it was not resolved completely [4]. Therefore, in this article I shall have a new look at the geographical latitude, peculiarities of the time scales, and probable dating, and shall argue why the dial serves only as decoration.

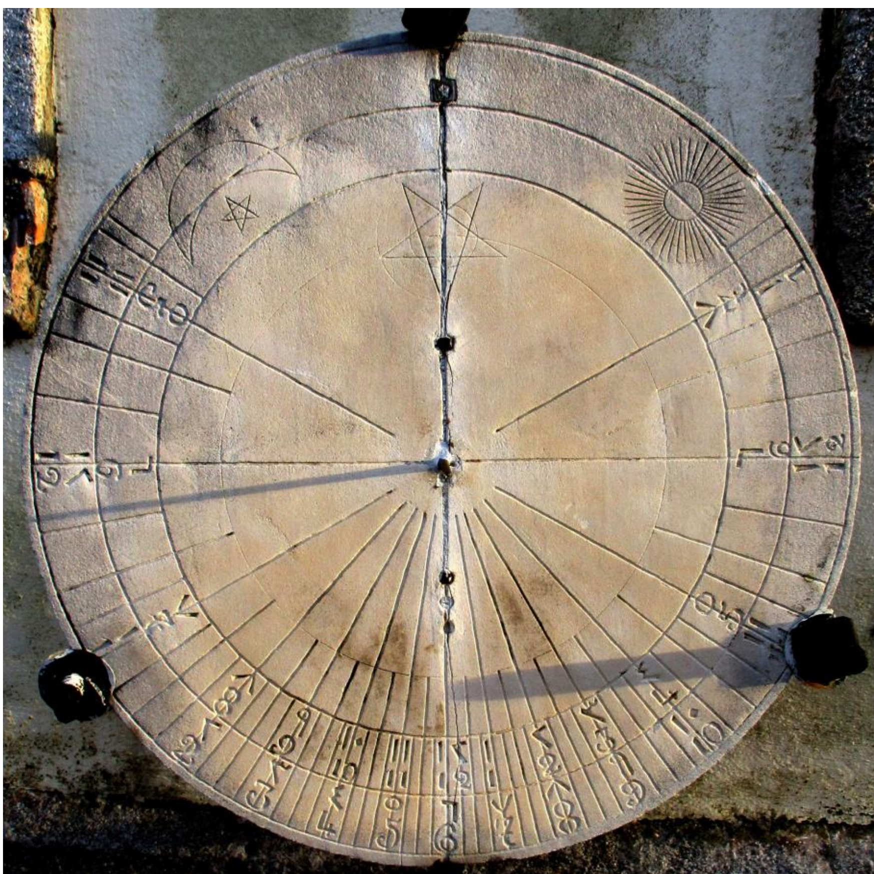

Fig. 1. Ottoman sundial fixed on the south face of the clock tower in Preveza, located in northwestern Greece. Photo: Nikos D. Karabelas, [1].

Fig. 2. Venetian clock tower in Preveza; the dial is fixed below the two small windows as decoration. Photo: [2].

Fig. 3. Detail of the fractured and repaired meridian line of the dial. Photo: Nikos D. Karabelas.

Characteristics of the dial

A closer look at Figures 1 and 3 shows the following features:

- Furniture: At the top, above of the star, the meridian points to the north; the sun’s symbol marks the ante-meridian part of the dial face; the symbol consisting of a five-pointed star and crescent moon, marks the post-meridian part of the dial face (in 1844 it was officially adopted for the Ottoman national flag [3]).
- The outer time scale extends from one to eleven and indicates noon with number six.
- The inner time scale extends from seven to five and indicates noon with number twelve.
- South facing horizontal type: The meridian line is the axis of symmetry for the a.m. and p.m. hour lines and is located below the equinoctial line. This face has 15 hour lines. A south facing vertical dial would have only 13 hour lines, i.e. its indication range is always limited to 12 hours.
- Polar pointing style: The intersection point of all hour lines is the foot of the style; therefore, it cannot be the position of a pin gnomon.
- Indication of equinoctial hours: Temporal or seasonal hours would require a pin gnomon (nodus).
- Division marks between hour lines from 11 / 5 to 1 / 7: They equal approximately a quarter of the difference between two hour line angles.
- Division marks between hour lines from 1 / 7 to 11 / 5 and from 1 / 7 to 11 / 5: They are spaced unequally apart.
- Shadow casting: The shadow comes from a vertical rod located at the center of the dial. It is not known who installed the rod [7].

- Holes along the meridian line: There are clearly discernible one hole above and three holes below the dial's center partly containing metallic residues. These relics, inclusive of the rod in the dial's center, verify several vain attempts to get a functioning dial; but this was in principle impossible.
- Fracture formation along the meridian line: The fracture is obviously a consequence of improper drilling of the holes and/or too many holes.

Symbols and formulae used

<u>Symbols</u>

δ : Sun's declination.

τ : Hour Angle. τ is 0° at midday; positive values west of the meridian.

φ : Geographic latitude.

ε : Obliquity of the Ecliptic.

Λ : Ecliptic length.

<u>Formulae</u>

Half daylight length:

$$\tau_0 = arccos(-tan\,\varphi\,tan\,\delta) \tag{1}$$

Horizontal time line angle [8]:

$$s = arctan(sin\,\varphi\,tan\,\tau) \tag{2}$$

Sun's declination depending on the ecliptic position [9]:

$$\delta = arcsin(sin\,\varepsilon\,sin\,\Lambda) \tag{3}$$

Intended location for the dial

<u>Setup for solution</u>

It is assumed that the hours 11 / 5 and 1 / 7 tally with the solstices. ε was calculated to be 23.452° on December 31st, 1899 (see also [7]).

Calculated location

Relation (1) with $\delta = -23.452°$ and $23.452°$, respectively, and $\tau_0 = 75°$ (hours 11 / 5) and 105° (hours 1 / 7), respectively, yields the geographical latitude φ as 30° 49′ 15.6″ N, i.e. Egypt (Alexandria is at 31° 13′ N, Cairo at 30° 3′ N; Preveza had trade connections with Alexandria [7]).

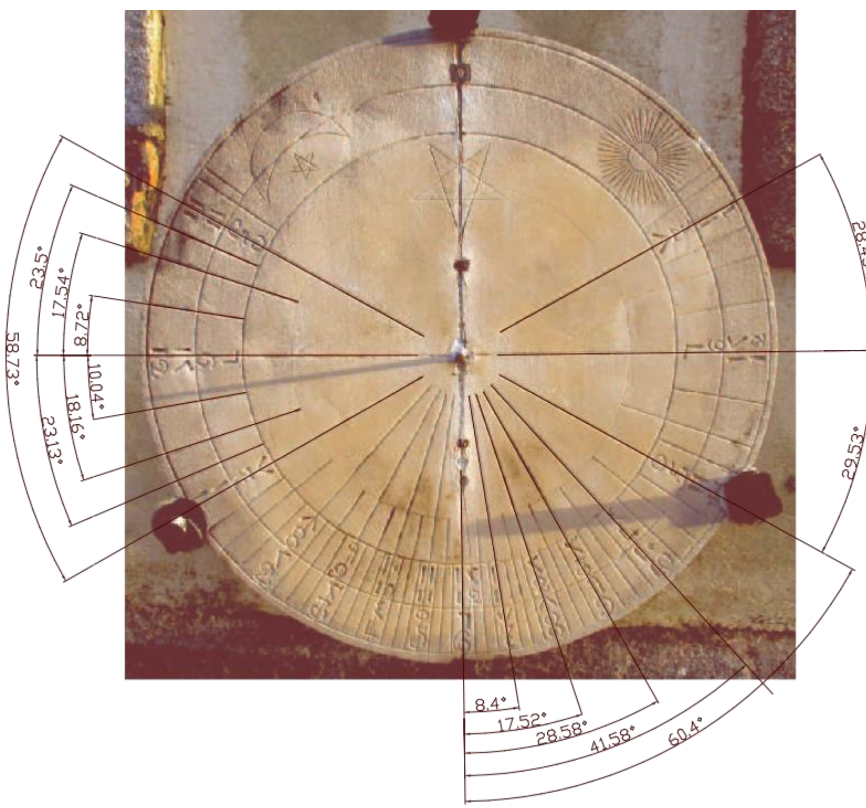

Fig. 4. Measurement of time line angles. Photo: Nikos D. Karabelas.

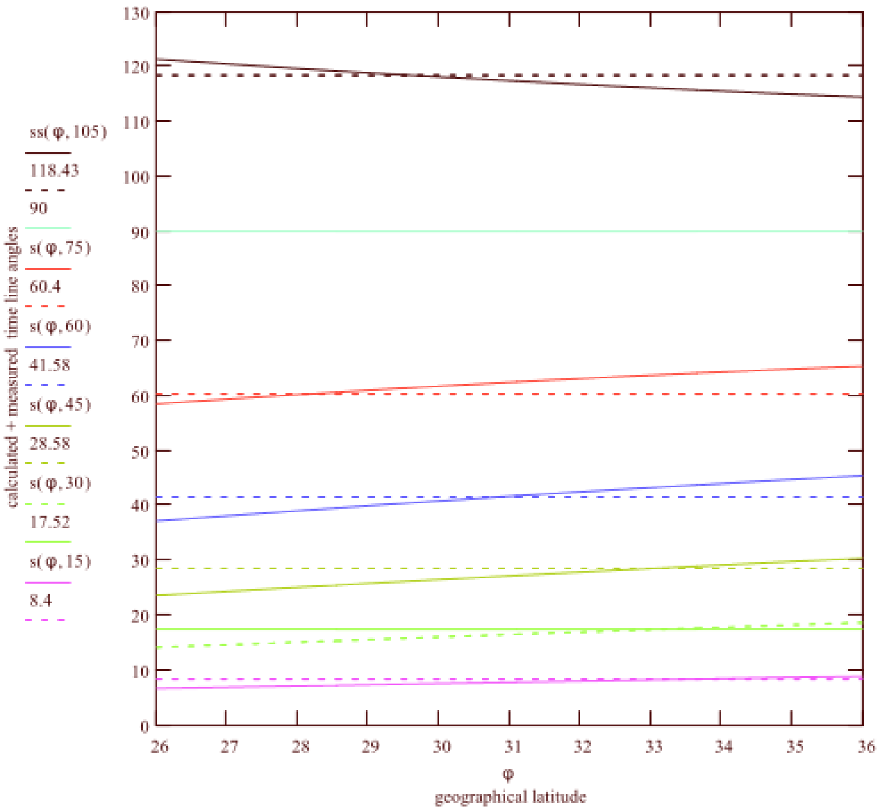

Fig. 5. The values for the parallel lines came from Figure 4; the slanting lines were calculated with relation (2). The latitude values at the intersection points of each line pair are sought, see Table 2.

Validation of location

Two methods will be used:

- Comparison between measured and calculated time line angles, see Table 1.
- Determining the intersection points between the graphical representation of measured time line angles and relation (2) as function of variable geographical latitude values and constant hour angles, see Figure 5 and Table 2.

Table 1. Comparison of measured and calculated time line angles. The measured values mes come from Figure 4; the calculated values cal result from relation (2), φ = 30.820698°. Deviation Δ = (mes / cal – 1) × 100%.

Outer Scale	7	8	9	10	11	12	1
Inner Scale	1	2	3	4	5	6	7
Hour Angle	15°	30°	45°	60°	75°	90°	105°
mes	8.4°	17.52°	25.58°	41.58°	60.40°	90°	118.43°
cal	7.82°	16.48°	27.13°	41.59	62.39	90°	117.61°
Δ (%)	7.46	6.32	−0.71	−0.02	−0.19	0	0.70

Table 2: Latitude values at the intersection points between the parallel straight lines (measured time line angles) and slanting lines (calculated time line angles) in Figure 4.

Hour Angle	105°	75°	60°	45°	30°	15°	Mean Latitude
Latitude	29.74°	28.02°	30.77°	32.77°	32.87°	32.84°	31.17°

Conclusion

The deviations in Table 1 are tolerable and the mean latitude in Table 2 is very near to the location calculated above. Hence $\varphi = 30.820698°$ will be used for further calculations.

Time line angles between the solstices

Setup for solution

The short hour lines between 1 / 7 and 11 / 5 correspond with ecliptic lengths. That means that the shadows cast at sunrise and sunset indicate the seasons as well as their corresponding points in time.

Validation of hour line angles

Figure 6 shows that beyond Λ = 60° the curve δ = f(Λ) becomes smooth. In the range 0° ≦ Λ ≦ 60°, the sun's declination values, and therefore the hour line angles, will be found by trial and error in relation to the measured values in Figure 4, see Table 3.

Table 3. Comparison between measured and calculated time line angles. The measured values mes come from Figure 4; the calculated values cal result from relations (3), (1) and (2), φ = 30.820698°. The deviation Δ = (mes / cal – 1) × 100%.

mes	8.72°	17.54°	23.5°	
mes	10.04°	18.16°	23.13°	
mean *mes*	9.38°	17.85°	23.31°	29.36°
Ecliptic length	20°	40°	60°	90°
Sun's declination	7.82°	14.82°	20.16°	23.452°
Hour Angle	94.70°	99.08°	102.65°	105.00°
cal	9.12°	17.33°	23.66°	27.61°
Δ	2.85%	3.00%	-1.49%	6.34%

Conclusion

The deviations in Table 3 are tolerable.

Graphical representation

The drawing in Figure 6 was calculated with relations (1) to (3) using the parameters τ = ±15°, 30°, 45°, 60°, 75°, 90°, 105°, φ = 30° 49′ 15.6″, ε = 23.452°, and Λ = 0°, 20°, 40°, 60°, 90°.

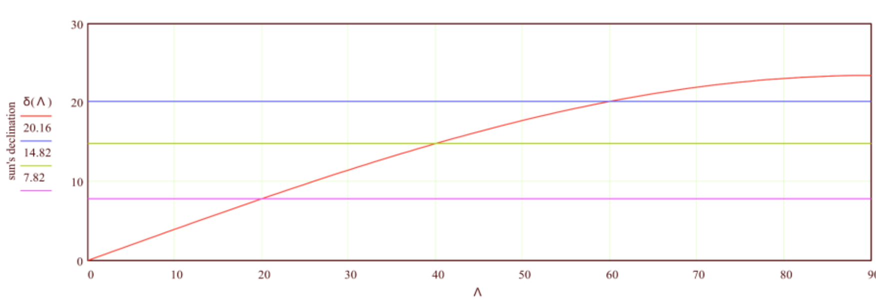

Fig. 6. Graphical representation of relation (3), ε = 23.452°. Resulting declination values are shown by the parallel lines.

Reading the Ottoman sundial

The following quotations (in principle relating to mechanical clocks) will have to be the basis for the comprehension of the two hour scales' different numerical sequences.

The terms *alla Turca* and *alla Franga*

> *The most commonly used hour system in the Ottoman Empire throughout the nineteenth century counted hours from sunset to sunset (gurub), hence the term gurubi saat, which was at least as common in official correspondence as the now better-known alla turca saat. This latter term, which literally means Turkish-style clock or Turkish-style hour, began to be widely used only during the second half of the nineteenth century to distinguish the indigenous hour system from the European one (known as alla franga saat) –* A. Wishnitzer.[1] [5]

Hour systems in the nineteenth-century Ottoman Empire

> *There were different ways of reading clocks in the nineteenth-century Ottoman Empire. First, there was the old scheme of "seasonal hours," which was based on sundials. According to this system, the day and the night were each divided into twelve units that stretched and contracted as the relation of day and night changed throughout the year. According to this scheme, for example, high noon is always six o'clock and sunset is always twelve o'clock, but in summer every day hour would be longer than a night hour.*
>
> *As mechanical clocks became more widespread and accurate in the eighteenth century, people within the elite began to rely on the equal hours of their timepieces in preference to the old seasonal hours. Clocks would be set every day at sunset and run two circles of twelve hours until sunset the following day. It was this system of clock hours counted from sunset that came to be known as "Turkish*

[1] [*alla franga saat* translates to *French Clock* or *French Hours*. Ed.]

time," or alaturka saat (lit. Turkish clock or hour). It is important to note that the shift to equal hours was slow and gradual, and that the system of seasonal hours had not disappeared by the end of the century and even beyond. For many people seasonal hours continued to form the most important frame of reference and mechanical clocks were therefore only rough indicators of the "real time." Around the midcentury, a third way of reading clocks began to spread, especially in commercial circles, among minority communities, and in some governmental agencies. This was the European mean-time system, according to which two rounds of equal hours were counted from noon until noon the following day. This system came to be known as "European time," or ala franga saat in Ottoman Turkish – A. Wishnitzer. [6]

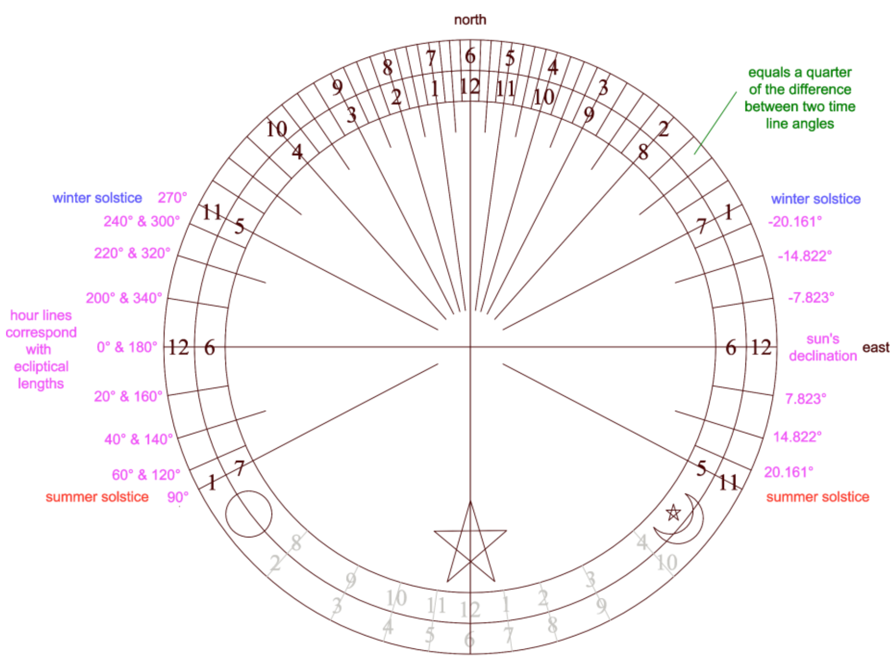

Fig. 7. Drawing of the dial face according to Figure 1, with added explanations and grey-colored hour numerals to make the hour scales more complete. For simplicity, only Western Arabic Numerals are used and positioned as shown.

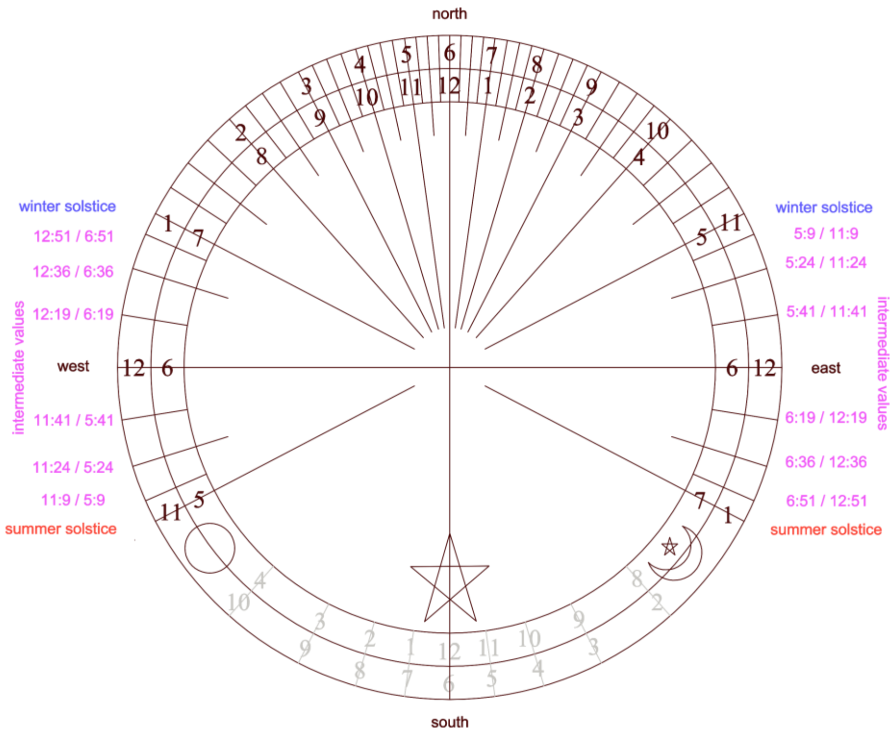

Fig. 8. Drawing of the dialface with the correct sequence of numerals for counting the hours of the day alla Turca on the outer scale and alla Franga on the inner scale, with added intermediate values in hours and minutes between the solstices and grey colored hour numerals for making the time scales more complete. For simplicity, only Western Arabic Numerals are used and positioned as shown.

<u>Outer hour scale</u>

In Figure 7, solar noon on the outer hour scale is six o'clock. Counting starts at the equinoctial sunset (twelve o'clock is zero o'clock), but is contrary to the sun's movement. That means that the numerals were carved incorrectly, namely mirror-image with respect to the east-west line. The correct sequence of numerals for counting the hours of the day *alla Turca* is shown in Figure 8.

<u>Inner hour scale</u>

For Figure 7's inner hour scale, solar noon is twelve o'clock. The counting starts at midnight (twelve o'clock is zero o'clock), but runs contrary to the sun's movement. That means that the numerals were carved incorrectly, namely mirror-image with respect to the east-west line. The correct sequence of numerals for counting the hours of the day *alla Franga* is shown in Figure 8.

Creator of the dial

Elias Vasilas, a Prevezan philologist, scholar, and local historian, wrote, in 1953, that the sundial was put on the Venetian clock tower in 1865 by Osman effendi, "a renowned mathematician and astronomer", who had also installed the mechanism of the second (mechanical) clock of the tower." [7]

Nikos Karabelas wrote in 2017 that "during the same period there was a kadi (an official in the Ottoman Empire) in Preveza, named Osman effendi, famous for his education, prudence, and brilliant character." With the information at hand, Karabelas "cannot suggest that the two persons are identical, even though this seems most probable." [7]

What could be the reason that a mathematician and astronomer put this dial on Preveza's Venetian clock tower? It was a malfunctioning one, in that although he had designed it correctly, the stonemason had not chiseled the hour scales correctly. Nevertheless, the dial had such a beautiful appearance that he could not throw it away!

The dial's plate is limestone, of medium density [7]; it may be the limestone Epirus Beige, which is quarried in Preveza's surrounding province, Epirus.

Acknowledgement

I am most grateful for the valuable information that I have received from Nikos D. Karabelas.

Final remarks

The whole story of the sundial of Preveza is most probably the following; the historical facts are quoted from [7]:

Preveza, until 1912, was under the rule of the Ottoman Empire, as well as Egypt. Many Epirots (people from the province of Epirus) had moved to Alexandria for a better life. (By the way, there is still a small but thriving Epirot community in Alexandria.) Presumably in the second half of the nineteenth century, a member of the Alexandria community ordered from the mathematician and astronomer Osman effendi in (his home town) Preveza, a horizontal sundial with polar pointing style for the equinoctial hours' indication both *alla Turca* and *alla Franga*, as was usual in Preveza at that time. Osman effendi accepted this order and designed the dial. After the dial was finished, he must have noticed that the hour scales were carved as mirror images with respect to the east-west line. He made the best of this unfortunate situation by fixing the sundial on the Preveza clock tower in 1865.

The sundial embodies very clearly then, that "errare humanum est"!

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References and Notes

[1] https://commons.wikimedia.org/wiki/File:Preveza%27s_vertical_sundial_1865.jpg. This file is licensed under the Creative Commons Attribution 4.0 International.

[2] https://commons.wikimedia.org/w/index.php?=File:1750_Preveza_The_Venetian_Clock.jpg&oldid464416505. This file is licensed under the Creative Common License BY-SA/3.0/GR/DEED.DE.

[3] https://en.wikipedia.org/wiki/Ottoman_Empire.

[4] Nikolopoulos, R. L. Kellogg: Sundials for Starters – a Preveza sundial mystery. The Compendium, vol. 25, no. 2, June 2018, pp. 1-7.

[5] Wishnitzer: Reading clocks, alla Turca: time and society in the late Ottoman Empire. The University of Chicago Press, (2015). xi.

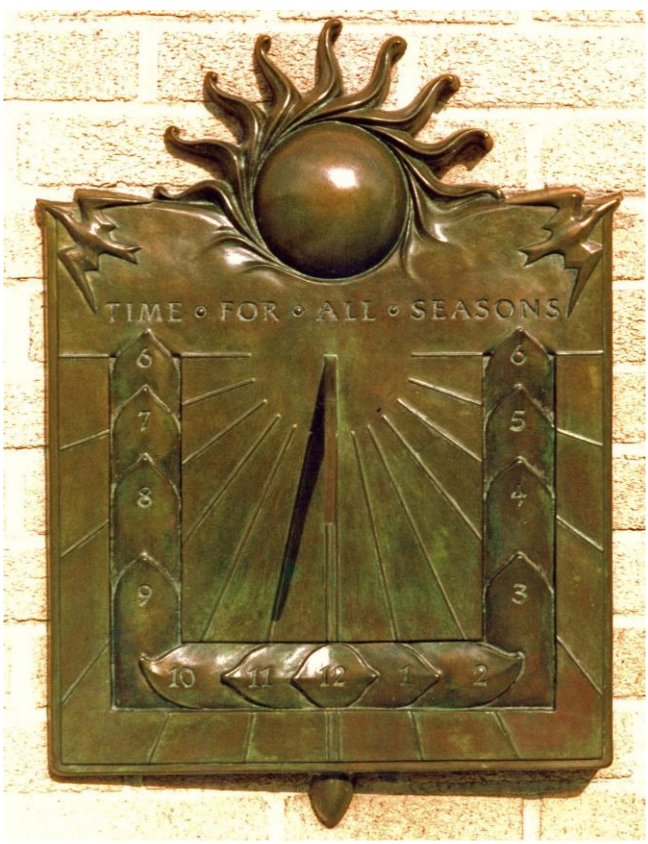
[6] Wishnitzer: Reading clocks, alla Turca: time and society in the late Ottoman Empire. The University of Chicago Press, (2015). Introduction 14.

[7] Emails from Nikos D. Karabelas, president of Actia Nikopolis Foundation, Preveza, Greece. I had contacted him after the mathematical analysis had been finished, therefore I have not replaced the value of the obliquity of the ecliptic.

[8] O. Feustel: The calculation of declining and inclining sundials - an unusual approach. The Compendium, vol. 21, no. 2, June 2014, pp. 35-39, relation 23 using face's inclination i = 90°, and face's declination d = 0°.

[9] D. Yallop, C. Y. Hohenkerk: Astronomical Phenomena. Explanatory Supplement to the Astronomical Almanac, edited by P. Kenneth Seidelmann. University Science Books, Sausalito, CA, 1992, p.485.

FROM THE REGISTRY



#609. Cast bronze vertical dial at a church in Wilmington, Delaware.