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Orientations of colonial churches in the Philippines and the island of Guam

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Abstract:
The orientation pattern of the apses of 98 colonial Catholic churches in the Philippine archipelago (16th–19th centuries) and three in Guam (Mariana Islands, 17th century) has been studied and found not to follow the canonical eastward alignment toward sunrise of Roman Catholic churches built before the Council of Trent. No relationship has been identified between orientation and religious factors such as founding orders or dedications, nor have consistent patterns been observed across most islands. Instead, geographical and environmental factors appear to have influenced church layout, this is more clear in Luzon. Naves were generally oriented to avoid the northeast–southwest monsoon axis; inland churches followed local valleys and rivers, while coastal churches were typically arranged perpendicular to the shoreline, with facades facing the sea perhaps to improve ventilation in accordance with Spanish colonial planning rules. Possible solar alignments related to feast days were explored, and although not statistically significant, several notable cases were identified for further study.

Keywords: Church Orientation; Urban Layout; Philippines; Guam; Spanish Colonialism

Introduction

The orientation of religious buildings has been an essential and differentiating element in a wide variety of cultural and historical contexts. In many cases, its relationship to the position of the celestial bodies has been interpreted as a connection to the celestial order and, ultimately, as an enhancer of sacred meaning. Roman authors such as Vitruvius (in *De Architectura* V, 5) indicated that, in pagan temples, worshippers should face east, the geographical point from which the gods would come. Early Christian authors such as Origen, Clement of Alexandria, and Tertullian, as well as Isidore of Seville in his Etymologies, also speak of the importance of praying toward the east, as it is from there that Jesus Christ will return at the end of days (McCluskey, 2015; Urrutia-Aparicio et al., 2021).

Studies dedicated to the measurement of the orientation of the apse and the analysis of its distribution in pre-Romanesque (4th to 11th centuries; González-García & Belmonte, 2015) and Romanesque (11th to 13th centuries; Urrutia-Aparicio et al., 2021) churches on the Iberian Peninsula show an almost absolute concentration towards the area of the horizon where the sun rises throughout the year and whose extreme points are defined by the summer solstice (far north) and the winter solstice (far south), which we call the arc of the sunrise which, at the average latitude of the Iberian Peninsula, occupies about 64°, 18% of

the circle of the horizon. However, Urrutia-Aparicio (2023) in a study on the orientation of 122 cathedrals and co-cathedrals in Spain and Portugal built between the 11th and 21st centuries, find a clear variation in the distribution of orientations before and after the Council of Trent, held in 1563. While the apses of churches built before that date show a strong concentration towards the solar arc, those built after that Council clearly relax this tendency, greatly increasing the fraction of buildings oriented away from the solar arc. According to Urrutia-Aparicio (2023), this flexibility may have its origin in the instructions on the construction of churches issued by Cardinal Carlos Borromeo at the said Council and published in 1577 (Borromeo, 2000[1577]), which, although still recommending an orientation towards the east, also allows for adaptation, if this is not possible, to the availability of space, environmental conditions or the geometry and orientation of the pre-existing urban layout.

Since at least the 17th century, and mainly in the Anglo-Saxon world, it has been hypothesized that the dispersion shown by the orientation of churches within the arc of the solar sunrise is due to the alignment of their apse towards the sunrise on the day of the patron saint of the temple or its foundation date. However, several recent systematic works indicate that this practice was not as common as previously thought (McCluskey, 2007; Hinton, 2010). On the other hand, in some temples it has been confirmed not only their orientation towards the sun on relevant dates but also the production of striking solar illumination phenomena in their interior and not necessarily related to the exact moments of sunrise or sunset (Ataoguz, 2015; Benfer, 2013). For example, in the Cathedral of Santiago de Compostela the illumination of the figure of the apostle occurs moments before sunset on dates close to the equinoxes or on July 25, the day of St. James the Apostle (Vilas Estévez & González-García, 2016). Mendoza (2005, 2025) has studied several examples of extraordinary illumination phenomena inside churches in Californian missions (built by Spanish monks between the late 18th and early 19th centuries) on solstices or dates of liturgical importance. Detecting these phenomena, if they are not known to the temple community, requires a spatial analysis of various architectural elements, such as the relative position of openings with respect to the ornamental elements of the altar or the side chapels, as well as continuous monitoring of possible illumination patterns throughout the year. Another way to carry out this type of study is through the application of photogrammetry and computerized analysis of solar illumination, such as that carried out by Luengo & Luengo (2019) in the interiors of Spanish baroque churches.

There are also studies on the orientation patterns of Catholic churches built from the 15th century onwards in various territories that were or still are under Spanish sovereignty outside the Iberian Peninsula and the Balearic Islands. In the Canary Islands, orientation patterns vary from island to island. For example, while in Fuerteventura the majority of churches (68%) follow the canonical pattern, that is, their apse faces east (Muratore & Gangui, 2020), in Lanzarote a significant proportion face north-northeast, possibly to avoid

the winds that blow mostly from that direction (Gangui et al., 2016). Another particular case is that of La Gomera, where many churches are arranged along the axes of the ravines that define the intricate topography of the island (Di Paolo & Gangui, 2020).

In the American continent, we also have studies dedicated to the orientation of colonial church complexes, and it is common to find patterns quite different from the canonical one towards the east. In Jesuit churches, both in northwestern Mexico and eastern Bolivia, distributions are observed without significant concentrations towards any particular area of the horizon (Gangui, 2020; Di Paolo et al., 2021). Another example, still to be clarified, is the case of the churches of the Guarani Jesuit missions, which show a preference towards the south, perhaps to avoid the direct entry of sunlight into the interior and prevent overheating (Giménez Benítez et al., 2018).

The orientation of colonial churches in the Philippines is a little-studied but potentially interesting topic, as it is one of only two countries in Asia (along with East Timor) where Catholicism is the majority religion, and where it has a huge number of religious buildings built since the 16th century. Only a few authors have made rather brief comments on the general orientation of some particular buildings or groups of buildings in the archipelago. For example, Legarda (1960), in his study of almost four dozen colonial churches of the Ilocos Region (northwest Luzon), says that “an overwhelming majority of churches … have their facades on the west or toward the sea”. Luengo Gutiérrez (2014) comments on the possible reasons for the orientation of several churches in Rizal province, near Manila, and the need for a monographic study on the question of church orientation in the Philippines. He remarks that "perhaps the answers should be sought in the geomantic practices of the Sangleyes, most likely the builders of the buildings, rather than in Catholic reasons." He also suggests the possibility that it might be due to following, in some way, the general orientation of the adjacent coastline. In a later paper, Luengo Gutiérrez (2021) also discusses the general orientation of the various colonial churches of Intramuros of Manila (most of which have now disappeared) and their adaptation to the urban layout.

To date, the only published work focused entirely on the orientation of churches in the Philippines is the brief report by Ambrosio & Hermosa, published in 2021 in the proceedings of a national Physics conference (Ambrosio & Hermosa, 2021). These authors compiled data on 98 Roman Catholic churches (cathedrals) built from the 16th century to the present day, that is, including temples built before and after the Spanish colonial period, and measuring their orientation using Google Earth images. Their main result is that the buildings do not follow the canonical pattern toward the rising sun; in fact, only 22% are oriented in that direction, consistent with a random distribution. They also found no correlation between their orientation and the rising sun on the date of the patron saint of the churches. In this work, we aim to conduct a study similar to that of Ambrosio & Hermosa, but more complete, considering, among other aspects, the topography of the local horizon

surrounding each church, allowing us to obtain more precise solar orientations. Another difference with the work of Ambrosio & Hermosa (2021) is that we limited our sample to churches built within the Spanish colonial period of the islands, from the 16th to the 19th centuries.

The sample of colonial churches used

Our sample is based on 98 churches from various islands in the Philippine archipelago and three from Guam, the main island of the Mariana Islands, built during the time when these archipelagos were under Spanish sovereignty. During most part of the Spanish colonial period, the Philippines and Mariana Islands were under the authority of the Viceroyalty of New Spain from the 17th to the early 19th century. Although administrative and financial support for both territories was largely managed from Mexico during that period, day-to-day governance in the Mariana Islands was carried out through the Captaincy General of the Philippines, headquartered in Manila. Therefore, both territories were closely linked administratively throughout the colonial period. The number of churches in the Philippines in our sample happens to coincide with that of Ambrosio & Hermosa (2021), who select the temples to study from the Wikipedia entry entitled: "List of cathedrals in the Philippines" (https://en.wikipedia.org/wiki/List_of_cathedrals_in_the_Philippines). However, our sample and that of Ambrosio & Hermosa (2021) only have 10 temples in common, a very small number, so both samples can be considered basically different. The churches in common are those we name in Table 1 as Bacolod, Boac, Dipolog, Jaro, Malolos, Manila Cathedral, Manila Pasig, Tuguegarao Cathedral and Vigan. In their brief work, Ambrosio & Hermosa (2021) do not publish a table of results, so we cannot compare our measurements with theirs for the same temples.

The Philippine churches of our sample were selected from (a) the list of Baroque churches compiled on Wikipedia, which includes the group of temples designated as World Heritage Sites by UNESCO in 1993 (https://en.wikipedia.org/wiki/List of Baroque churches in the Philippines), (b) the list of colonial churches in the National Culture Treasures catalog compiled by the National Commission for Culture and the Arts of the Philippines (https://en.wikipedia.org/wiki/List of National Cultural Treasures in the Philippines), and (c) a recent monograph on heritage churches in the Cagayan River Valley (Galván Guijo, 2022). From the above sources, the book by Alarcon (1991), and various additional Internet pages (such as the one titled The Old Churches, (https://www.theoldchurches.com) we obtained the most likely construction date of their first stone structure, dedication and the religious order that built them. It should be noted that in the vast majority of colonial Philippine churches, the first temple after the foundation was built with perishable materials and it is not usually recorded in documentary sources whether the stone building followed the orientation of the previous temple so, strictly speaking, the date indicated in Table 1 will generally correspond to an upper limit to the date in which the orientation of the church was established. Luzon is the island with the most churches in the sample: 66. Panay Island

is a distant second with seven, Bohol with six, Mindanao with five, Cebu with three, and Batan and Negros with two each. Capul, Leyte, Marinduque, Panglao, Romblon, Samar, and Siquijor islands each have one church. Figure 1 shows maps of the Philippine archipelago and the island of Guam showing the locations of the churches studied.

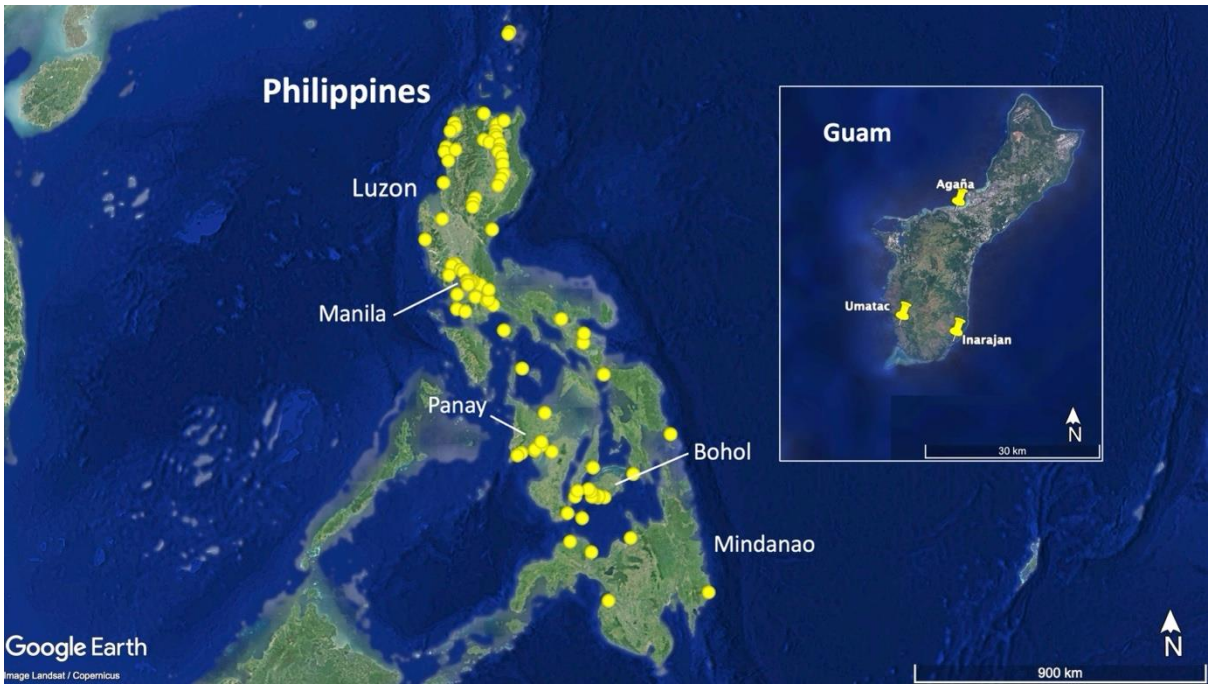


Figure 1. Maps of the Philippine archipelago and the island of Guam showing the location of the churches studied. In the case of Guam, the name of the town where the churches are located is included, and for the Philippine archipelago, the name of the main islands and the location of Manila are also indicated. Images obtained and modified from Google Earth Pro.

Methodology

The orientation of the nave of each church is obtained from the highest contrast and resolution set of images available in the historical imagery library of the web application Google Earth Pro (https://www.google.com/earth/about/) corresponding to the area where the church is located. The azimuth is measured with the angle measurement tool of the application by drawing the line that passes through the major axis of the temple nave (Figure 2). Along this line, we can distinguish two directions: the one defined from the facade towards the apse (where the apse points) and the reverse direction (where the facade points). In our case, we consider the direction in which the apse points (the reverse direction is obtained simply by adding or subtracting 180°). The azimuth adopted for each church was obtained using the following procedure: the azimuths were measured in the seven best available satellite images (best resolution and contrast). From these seven measurements, the highest and lowest values of azimuth were removed, leaving five values from which the mean and standard deviation (dispersion) were calculated. The mean value was then adopted as the representative azimuth for the church. This procedure was successfully applied to 80 of the churches in the sample. For the remaining churches, a

minimum of seven images of sufficient quality could not be found, so a smaller number of measurements were used to calculate the mean, without eliminating the maximum or minimum values in order not to end up with too low a number of measurements. Six suitable images were found for ten churches and between three and five images for the remaining eleven temples.

The average standard deviation for the set of azimuths measured for the sample of churches is only 0.3°, which demonstrates that convergence problems and parallax of each image have a fairly limited effect on the quality of the measurements. Several previous studies (Rodríguez-Antón et al., 2017; Escacena Carrasco et al., 2021) have estimated that the azimuths measured with Google Earth Pro can be considered reliable with a margin of error of $\pm 1°$ when compared with on-the-ground measurements. Although this value is higher than the typical dispersion we find for a given church, we prefer to assume the latter value for our results in order to be conservative and to account for a certain level of human error (which is unquantifiable) in church construction.

Using Google Earth Pro application, we obtain additional data for each church: (a) minimum distance to the nearest coastline; (b) information on whether the nave is aligned with the urban layout surrounding the church; (c) disposition of the major axis of the nave with respect to the coast (whether parallel, perpendicular, or oblique); and (d) for churches with a nave perpendicular to the coast, information on whether the apse points toward the coast or inland. Regarding to (b), we were able to verify that none of the churches studied are isolated, that is, they are all located within a population center. Tables 1 and 2 show the most relevant data from the sample of churches studied in the Philippines and Guam, respectively. Figure 3 shows the orientation diagram of their apses. Each diagram also includes the range of azimuths where the sun rises or sets throughout the year (the solar arc). We can see how a large proportion of the Philippine churches and all those in Guam show orientations outside this arc, a result already obtained by Ambrosio & Hermosa (2021) in the case of the Philippines.

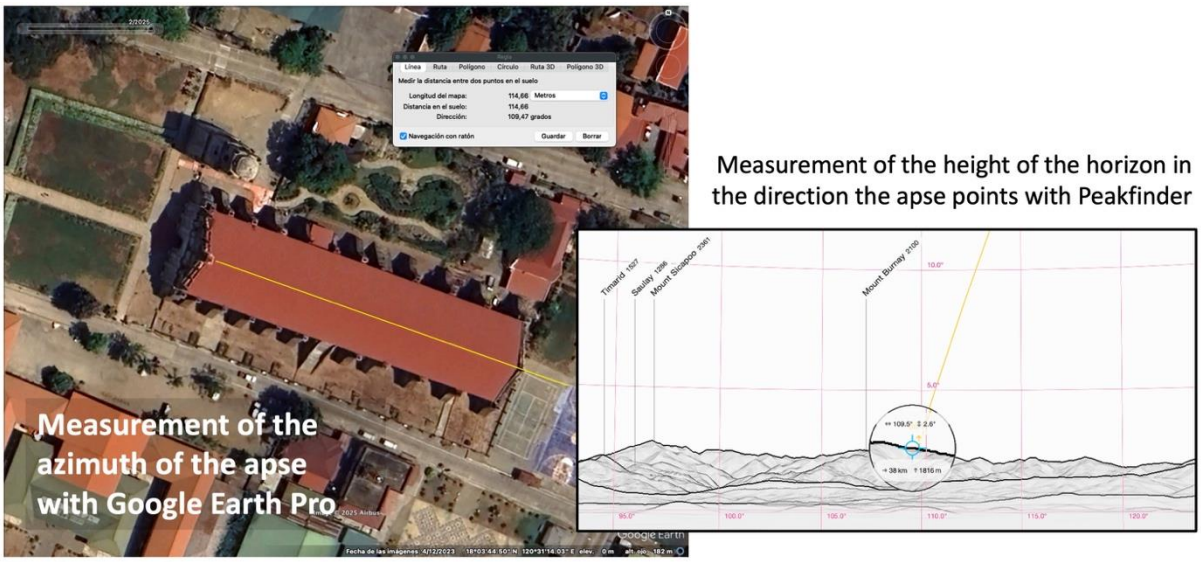


Figure 2. Left: Example of determining the azimuth of a church nave (Paoay, Luzon) using the angle measurement tool on a satellite image in Google Earth Pro. Right: Example of measuring the angular height of the local horizon point toward which the apse of the church points using the Peakfinder internet application. Images obtained from Google Earth Pro and the Peakfinder application.

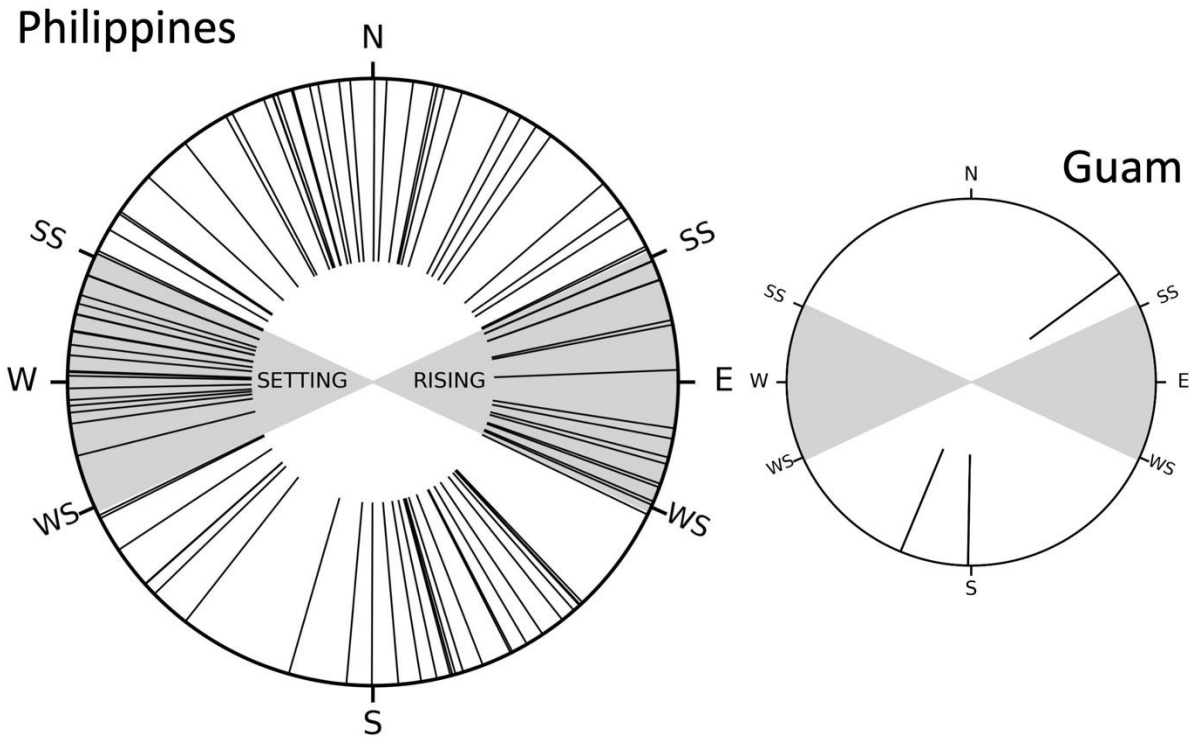


Figure 3. Distribution of orientations (azimuths) of the apses of churches measured in the Philippines (left) and Guam (right). Each line corresponds to a different church. The circles cover the 360° of the horizon. The cardinal points and the positions of the possible extremes of sunrise and sunset are indicated, limited by the summer (SS) and winter (WS) solstices. The gray circular sectors show the azimuth ranges where sunrise (east) or sunset (west) can

occur throughout the year, these are one degree wider at each end to account for the error assumed in azimuth).

In churches oriented within the solar arc, it is possible to check whether the apse (or facade) is pointing toward the sunrise or sunset on a given date, such as the festival associated with the dedication of the church. To do this correctly, we must consider that the horizon will not generally be flat and that, because the daily path of the sun across the sky is oblique (with an angle dependent on latitude), the azimuth of the point where sunrise or sunset occurs above the horizon will be different depending on whether it occurs over the sea, for example, or on a mountain (it is important to note that this correction was not considered by Ambrosio & Hermosa 2021). Therefore, in addition to measuring the azimuth toward which the apse or facade points, we must obtain the height of these points above the local horizon (Fig. 2). Since it was impossible for us to visit the churches, we obtained an approximate reconstruction of the local horizon using the web application Peakfinder (https://www.peakfinder.org), which generates panoramas of the topographic profile visible from a given point on the Earth's surface (providing the geographic coordinates of the churches obtained from Google Earth Pro) from 3D relief map. Peakfinder is valid for any location worldwide between 80° north and 80° south latitude and uses digital models from the NASA Shuttle Radar Topography Mission (SRTM) and European Digital LiDAR Terrain Models (DTMs), as well as various geographic information system (GIS) data sources. The 3D map resolution reaches several tens of meters, so the profiles returned are somewhat smoothed compared to the real-world terrain, but highly reliable in most cases, except for very steep or closely spaced profiles. With Peakfinder we measure the height of the point of the horizon towards a given orientation is facing. Using the pair of angles—azimuth and height—we can determine the declination of the celestial body that rises or sets in the area of the horizon toward which the apse or facade of each church points. Considering an error of ±1° in azimuth and ±0.5° in height, we obtain a range of declination values compatible with each orientation. In Table 3, we show the values obtained for these three angles in both directions of orientation, but only for churches whose associated declination range is compatible with the solar position at some point during the year. For these churches, we show the date ranges in which solar coincidence occurs. In general, each orientation compatible with a solar position has two assigned date intervals. This is because the sun follows a cyclical movement, moving from north to south and vice versa throughout the year, passing through the same point twice, except at the solstices. Therefore, churches that show an orientation with a single date interval do so because the declination band encompasses one of the solstices.

Table 1. Data on churches in the Philippines. The azimuth indicates the orientation of the apse. The penultimate column provides the distance from the nearest coastline.

No.	Locality	Island	Zone[a]	Dedication	Date	Order[b]	Azimuth (°)	Dist. (km)	Additional Data[c]
1	Ivana	Batanes	-	St. Joseph the Worker	1795	Dom.	78.2	0.08	A/Pe/F

2	Mahatao	Batanes	-	St. Charles Borromeo	1787	Dom.	141.6	0.01	A/O
3	Baclayon	Bohol	-	Immaculate Conception	1727	Jes.	7.6	0.04	A/Pe/F
4	Dimiao	Bohol	-	St. Nicholas of Tolentino	1810	Jes.	243.3	0.1	A/Pa
5	Loay	Bohol	-	Most Holy Trinity	1822	Aug.	283	0.3	A/Pa
6	Loboc	Bohol	-	St. Peter	1638	Jes.	164.3	4.6	A/I
7	Loon	Bohol	-	Our Lady of the Light	1780	Aug.	303.7	0.37	A/Pe/NF
8	Maribojoc	Bohol	-	Holy Cross	1798	Aug.	228.3	0.09	A/Pe/NF
9	Capul	Capul	-	St. Ignatius of Loyola	1781	Jes.	136.6	0.1	A/Pa
10	Boljoon	Cebu	-	Our Lady of the Patronage	1783	Aug.	286.7	0.05	A/Pe/F
11	Cebu City	Cebu	-	Santo Niño	1735	Aug.	290.6	0.36	A/Pe/F
12	Dalaguete	Cebu	-	St. William of Aquitaine	1802	-	272.1	0.13	A/Pe/F
13	Maasin	Leyte	-	Our Lady of the Assumption	1771	Aug.	268.8	0.15	A/Pa
14	Alcala	Luzon	Cag.	St. Philomena	1881	Dom.	255.9	46.7	A/I
15	Alicia	Luzon	Cag.	Our Lady of Atocha	1849	Dom.	344.8	68	A/I
16	Bacarra	Luzon	NW	St. Andrew	1702	Aug.	115.9	5.5	A/I
17	Balayan	Luzon	Cen.	Immaculate Conception	1749	Jes.	332.5	0.76	A/Pe/F
18	Baler	Luzon	Cen.	St. Louis of Toulouse	1735	-	341.7	0.73	A/Pa
19	Bambang	Luzon	Cag.	St. Catherine of Siena	1772	Dom.	266.6	72.4	A/I
20	Bantay	Luzon	NW	St. Augustine	1691	Aug.	98.8	5	A/I
21	Barasoain	Luzon	Cen.	Our Lady of Mount Carmel	1871	Aug.	290.7	11.5	A/I
22	Bayombong	Luzon	Cag.	St. Dominic	1773	Dom.	26.4	75.8	A/I
23	Betis	Luzon	Cen.	St. James the Apostle	1770	-	295.1	24.3	A/I
24	Buguey	Luzon	Cag.	St. Anna	1705	Dom.	355.7	0.2	NA/Pe/NF
25	Bulacan	Luzon	Cen.	Our Lady of the Assumption	1630	Aug.	35.7	5.8	A/I
26	Cabigan	Luzon	Cag.	St. Paul	1624	Dom.	271.9	42.8	A/I
27	Cainta	Luzon	Cen.	Our Lady of the Light	1707	Jes.	340.8	4.9	A/I
28	Calamba	Luzon	Cen.	St. John the Baptist	1859	Fra.	158.9	1.8	A/I
29	Calasiao	Luzon	NW	St. Peter and St. Paul	1731	Dom.	348.0	7.4	A/I
30	Cauayan	Luzon	Cag.	Our Lady of the Pillar	1741	Dom.	170.9	68.5	A/I
31	Daraga	Luzon	S	Our Lady of the Patronage	1772	Fra.	264.2	4.8	A/I
32	Dupax	Luzon	Cag.	St. Vincent Ferrer	1773	Dom.	17	70	A/I
33	Enrile	Luzon	Cag.	Our Lady of Snows	1877	Dom.	282.9	48.5	A/I
34	Gamu	Luzon	Cag.	St. Rose of Lima	1726	Dom.	275.1	62.6	A/I
35	Gattaran	Luzon	Cag.	St. Catherine of Alexandria	XVII	Dom.	196.0	30.5	A/I
36	Iguig	Luzon	Cag.	St. James the Apostle	1765	Dom.	162.8	43.4	A/I
37	Lal-lo	Luzon	Cag.	St. Dominic	1602	Dom.	70.3	15.7	A/I
38	Laon	Luzon	Cen.	St. Dominic	1605	Dom.	271.2	1.4	A/Pe/F
39	Liliw	Luzon	Cen.	St. John the Baptist	1620	Fra.	149.7	16.3	A/I
40	Lubao	Luzon	Cen.	St. Augustine	1614	Aug.	2.6	12.5	A/I
41	Magsingal	Luzon	NW	St. William the Hermit	1827	Aug.	110.3	3.3	A/I
42	Majayjay	Luzon	Cen.	St. Gregory the Great	1622	Fra.	152.8	28	A/I
43	Malaueg	Luzon	Cag.	St. Raymond of Peñafort	1617	Dom.	228.2	64	A/I
44	Malolos	Luzon	Cen.	Immaculate Conception	1734	Aug.	164.9	11	A/I
45	Manila Binondo	Luzon	Cen.	Our Lady of the Most Holy Rosary	1614	Dom.	57.2	1.5	A/Pe/F[c]
46	Manila Cathedral	Luzon	Cen.	Immaculate Conception	1591	Sec.	137.4	0.9	A/Pa
47	Manila Makati	Luzon	Cen.	Our Lady of Grace	1601	Aug.	137.2	6.3	NA/I
48	Manila Malate	Luzon	Cen.	Our Lady of Remedies	1591	Aug.	70.2	0.19	A/Pe/F
49	Manila Parañaque	Luzon	Cen.	St. Andrew	1638	Aug.	153.2	0.3	NA/O
50	Manila Pasig	Luzon	Cen.	Immaculate Conception	1575	Aug.	105.7	4.4	A/I
51	Manila Quiapo 1	Luzon	Cen.	St. John the Baptist	1767	Sec.	13.6	2.3	A/I
52	Manila Quiapo 2	Luzon	Cen.	St. Sebastian	1630	Aug.	295.7	2.5	A/I
53	Manila San Agustin	Luzon	Cen.	St. Augustine	1587	Aug.	138.8	0.8	A/Pa
54	Manila San Juan del Monte	Luzon	Cen.	Holy Christ /Holy Cross	1601	Dom.	66.4	6.1	A/I
55	Manila Santa Ana	Luzon	Cen.	Our Lady of the Abandoned	1720	Fra.	175.2	3.7	A/I
56	Manila Santa Cruz	Luzon	Cen.	Our Lady of the Pillar	1688	Jes.	165.3	1.3	A/Pa
57	Manila Tondo	Luzon	Cen.	Holy Child	1611	Aug.	64.0	0.8	A/Pe/F
58	Maragondon	Luzon	Cen.	Our Lady of the Assumption	1611	Jes.	279.8	3.3	A/I

59	Masinloc	Luzon	Cen.	St. Andrew	1713	Aug.	113.9	0.06	A/Pe/F
60	Minalin	Luzon	Cen.	St. Monica	1764	Aug.	340.9	18.6	A/I
61	Namacpacan	Luzon	NW	St. Catherine of Alexandria	1690	Aug.	300.2	0.5	A/O
62	Nassiping	Luzon	Cag.	St. Catherine of Siena	1755	Dom.	12.3	41.2	A/I
63	Paete	Luzon	Cen.	St. James the Apostle	1646	Fra.	87.7	0.6	A/Pe/F
64	Pakil	Luzon	Cen.	St. Peter of Alcantara	1732	-	79.1	1	A/O
65	Pamplona	Luzon	Cag.	St. Peter of Verona and St. John Nepomucene	1614	Dom.	243.9	4.5	A/I
66	Paoay	Luzon	NW	St. Augustine	1694	Aug.	109.6	4.4	A/I
67	Piat	Luzon	Cag.	Our Lady of Piat	1732	-	339.0	65.4	A/I
68	Quipayo	Luzon	S	Immaculate Conception	1616	Fra.	265.5	3	A/I
69	Santa Maria	Luzon	NW	Our Lady of the Assumption	1765	-	185.0	3.1	A/I
70	Sarrat	Luzon	NW	St. Michael and St. Monica	1779	Aug.	104.4	13.5	A/I
71	Taal	Luzon	Cen.	St. Martin of Tours	1755	Aug.	66.5	1.4	A/Pe/F
72	Tabaco	Luzon	S	St. John the Baptist	1844	Sec.	344.5	0.9	A/Pa
73	Tanay	Luzon	Cen.	St. Ildephonsus of Toledo	1773	Fra.	344.5	0.9	A/Pa
74	Tayabas	Luzon	Cen.	St. Michael the Archangel	1600	Fra.	304.2	13.4	A/I
75	Tayum	Luzon	NW	St. Catherine of Alexandria	1803	Sec.	54.7	28	A/I
76	Tuguegarao Cathedral	Luzon	Cag.	St. Peter	1761	Dom.	0.3	45.3	A/I
77	Tuguegarao Ermita	Luzon	Cag.	St. Hyacinth	1704	Dom.	11.6	45.3	A/I
78	Tumauini	Luzon	Cag.	St. Matthias	1783	Dom.	353.6	47.7	A/I
79	Vigan	Luzon	NW	St. Peter and St. Paul	1641	Aug.	113.2	4.8	A/I
80	Boac	Marinduque	-	Immaculate Conception	1792	Jes.	277.1	3.2	A/I
81	Caraga	Mindanao	-	Holy Saviour of the World	1877	Aug.	167.9	0.08	A/Pe/NF
82	Dipolog	Mindanao	-	Our Lady of the Most Holy Rosary	1894	Jes.	100.8	0.97	A/Pe/F
83	Jasaan	Mindanao	-	Immaculate Conception	1887	Jes.	180.2	0.43	A/Pe/NF
84	Jimenez	Mindanao	-	St. John the Baptist	1892	Aug.	279.6	1.3	A/Pe/F
85	Tamontaka	Mindanao	-	Immaculate Conception	1879	Jes.	312.6	6.6	A/I
86	Bacolod	Negros	-	St. Sebastian	1876	Aug.	29	0.76	A/Pa
87	Bacong	Negros	-	St. Augustine	1866	Aug.	285	0.13	A/Pe/F
88	Barotac Nuevo	Panay	-	St. Anthony of Padua	1876	Aug.	32.4	8.9	A/I
89	Dumangas	Panay	-	St. Augustine	1887	Aug.	146.2	4	A/I
90	Jaro	Panay	-	Our Lady of Candles	1864	Dom.	217.9	3.7	A/I
91	Miagao	Panay	-	St. Thomas of Villanueva	1787	Aug.	225.7	0.4	A/O
92	Molo	Panay	-	St. Anna	1831	Sec.	63.4	1.3	A/Pa
93	Panay	Panay	-	St. Monica	1774	Aug.	331.2	5.7	A/I
94	San Joaquin	Panay	-	St. Joachim	1859	Aug.	236.4	0.11	NA/Pa
95	Dauis	Panglao	-	Our Lady of the Assumption	1863	Aug.	349.6	0.05	A/Pe/NF
96	Romblon	Romblón	-	St. Joseph	1726	Aug.	262.1	0.17	A/O
97	Guiuan	Samar	-	Immaculate Conception	1718	Jes.	322	0.08	A/Pa
98	Lazi	Siquijor	-	St. Isidore the Laborer	1884	Aug.	49.1	0.42	NA/Pa

[a] Zones defined in Luzon: Cag.: Cagayan; NW: Northwest; Cen.: Center; S: South.

[b] Religious orders that founded each church: Dom.: Dominicans; Jes.: Jesuits; Aug.: Augustinians; Fra.: Franciscans; Sec.: Seculars.

[c] Alignment with respect to the surrounding urban network: A: aligned, NA: not aligned. If the church is at a distance > 1.5 km from the nearest coast: I: inland. If the church is at a distance $\leq$ 1.5 km from the nearest coast: Pe: nave perpendicular to the coastline, Pa: nave parallel to the coastline, O: nave oblique with respect to the coastline. If the nave is perpendicular to the coastline: F: faces the coast, NF: faces away from the coast.

Table 2. Data on churches of Guam (Mariana Islands). The azimuth indicates the orientation of the apse. The penultimate column provides the distance from the nearest coastline.

No.	Locality	Dedication	Date	Order	Azimuth (°)	Dist. (km)	Additional Data[a]
99	Agaña	Sweet Name of Mary	1670	Jesuits	181	0.33	A/Pe/F
100	Inarajan	St. Joseph	?	Jesuits	202.5	0.09	NA/Pa
101	Umatac	St. Dyonisius	1769	Jesuits	53.5	0.07	NA/Pe/F

[a] See note c of Table 1.

Table 3. Azimuth, height, declination and solar calendar dates corresponding to the points on the horizon to which the churches point whose orientations are compatible with the solar arc.

No.	Locality	Apse				Facade			
		Azimuth (°)	Height (°)	Dec. (°)	Range of dates	Azimuth (°)	Height (°)	Dec. (°)	Range of dates
1	Ivana	78.2	9.5	14.23	25/4–1/5 & 12/8-18/8	258.2	0.3	-11.15	20/10-26/10 & 16/2-22/2
5	Loay	283.0	0.4	12.82	21/4-27/4 & 16/8-22/8	103.0	0.4	-12.85	25/10-31/10 & 11/2-17/2
10	Boljoon	286.7	22.0	18.86	11/5-18/5 & 26/7-3/8	106.8	-0.1	-16.69	5/11-12/11 & 31/1-7/2
11	Cebu City	290.6	2.7	20.70	17/5-22/5 & 16/7-26/7	110.6	0.0	-20.37	21/11-2/12 & 11/1-22/1
12	Dalaguete	272.1	5.2	2.86	25/3-31/3 & 10/9-15/9	92.1	0.5	-2.07	23/9-29/9 & 12/3-17/3
13	Maasin	268.8	1.5	-0.99	15/3-20/3 & 23/9-28/9	88.8	1.8	1.43	16/9-22/9 & 21/3-26/3
14	Alcala	255.9	1.1	-13.26	10/2-16/2 & 26/10-1/11	75.9	0.6	13.51	14/8-20/8 & 23/4-29/4
16	Bacarra	115.9	2.2	-23.89	10/12-2/1	295.9	-0.2	24.28	14/6-28/6
19	Bambang	266.6	1.2	-3.05	10/3-15/3 & 26/9-1/10	86.6	0.8	3.37	10/9-15/9 & 26/3-1/4
20	Bantay	98.8	3.1	-7.56	26/2-3/3 & 8/10-13/10	278.8	-0.1	-0.66	28/8-2/9 & 9/4-14/4
21	Barasoain	290.7	0.8	20.15	16/3-24/3 & 20/7-28/7	110.7	0.4	-20.08	20/11-30/11 & 13/1-23/1
23	Betis	295.1	2.3	24.82	-	115.1	0.2	-24.39	18/12-24/12
26	Cabigan	271.9	1.3	2.08	23/3-28/3 & 13/9-18/9	91.9	3.5	-0.86	23/9-28/9 & 15/3-20/3
31	Daraga	264.2	5.2	-4.49	6/3-11/3 & 1/10-6/10	84.2	0.3	-0.21	4/9-10/9 & 2/4-7/4
33	Enrile	282.9	2	12.82	21/4-27/4 & 16/8-22/8	102.9	1.8	-11.89	22/10-29/10 & 14/2-20/2
34	Gamu	275.1	1.2	5.11	1/4-5/4 & 7/9-12/9	95.1	1.1	-4.67	2/10-7/10 & 6/3-11/3
37	Lal-lo	70.3	1.1	18.92	12/5-19/5 & 25/7-2/8	250.3	1.0	-18.51	15/11-21/11 & 21/1-28/1
38	Laon	271.2	4.2	2.13	23/3-28/3 & 13/9-18/3	91.2	0.4	-1.19	24/9-29/9 & 15/3-19/3
41	Magsingal	110.3	15.2	-14.10	25/1-1/2 & 12/11-18/11	290.3	0.2	19.28	24/7-1/8 & 13/5-20/5
48	Manila Malate	70.2	0.8	19.28	13/5-20/5 & 23/7-1/8	125.2	-0.1	-19.36	18/11-25/11 & 17/1-26/1
50	Manila Pasig	105.7	0.9	-15.10	3/2-9/2 & 1/11-8/11	285.7	0.7	15.28	8/8-14/8 & 28/4-5/5
54	Manila San Juan del Monte	66.4	1.2	23.07	1/6-11/7	246.40	0	-23.00	1/12-11/1
58	Maragondon	279.8	1.2	9.70	13/4-18/4 & 24/8-30/8	99.8	0.5	-9.50	12/10-19/10 & 21/2-26/2
59	Masinloc	113.9	5.1	-21.56	19/11-3/12 & 9/1-24/1	293.9	-0.1	22.85	30/5-13/7
63	Paete	87.7	5.6	3.55	27/3-1/4 & 10/9-15/10	267.7	0.6	-2.20	26/9-1/10 & 12/3-17/3
64	Pakil	79.1	18.3	14.49	27/4-3/5 & 11/8-17/8	259.1	1.4	-10.32	18/10-23/10 & 19/2-24/2
66	Paoay	109.6	2.4	-17.91	25/1-1/2 & 9/11-17/11	289.6	0.5	18.61	26/7-3/8 & 10/5-18/5
68	Quipayo	265.5	0.7	-4.33	8/3-13/3 & 2/10-8/10	85.5	1.6	4.66	7/9-13/9-30/3-4/4
70	Sarrat	104.4	3.5	-12.62	12/2-18/2 & 24/10-30/10	284.4	0.1	13.54	13/8-19/8 & 24/4-30/4
71	Taal	66.5	1.3	23.08	1/6-12/7	246.5	-0.2	-23.05	1/12-11/1
79	Vigan	113.2	3.2	-21.17	15/11-1/12 & 11/1-27/1	293.2	-0.1	21.92	3/7-19/7 & 25/5-11/6
80	Boac	277.1	-0.2	6.74	4/4-9/4 & 3/9-9/9	97.1	2.0	-6.53	4/10-9/10 & 5/3-10/3
82	Dipolog	100.8	3.2	-10.26	18/2-23/2 & 18/10-24/10	280.8	-0.1	10.60	22/8-28/8 & 15/4-21/4
84	Jimenez	279.6	4.0	10.02	13/4-19/4 & 24/8-30/8	99.60	0.5	-9.50	15/10-22/10 & 20/2-25/2
87	Bacong	285	5.3	15.59	30/4-7/5 & 6/8-13/8	105.0	0.7	-14.77	31/10-6/11 & 5/2-11/2
96	Romblon	262.1	9.3	-5.70	5/3-10/3 & 4/10-10/10	82.1	6.3	8.98	10/4-16/4 & 27/8-2/9

Results and discussion about the churches of the Philippines

Some orientation patterns

Regarding the results for the Philippines, we find that only 16.3% of temples are oriented within the arc defined by the solar rises (see Figure 3). Ambrosio & Hermosa (2021) find a

not very different fraction: 22%. If we had a completely random sample of orientations between 0° and 360°, the percentage of these contained within the arc of the solar rises at the average latitude of the Philippines (14.5°), which occupies a width of 48.6°, would be 13.5%. As we can see, the distribution of orientations of Philippine temples is consistent with a random pattern. Although the general conclusion for the entire sample of churches is that they are oriented in a seemingly random way, we performed a more detailed analysis by separating the temples into subsets according to different criteria to check if there is any of those subsets that deviate from the purely random pattern. Firstly, we began by separating the churches according to their construction date, which falls between the end of the 16th century and practically the entire 19th century. As already mentioned in the introduction, Urrutia-Aparicio (2023), studying the orientation of cathedrals and co-cathedrals in the Iberian Peninsula, found a clear variation in the distribution of orientations in churches built before and after the Council of Trent, held in 1563. While those built before that date tend to be oriented following the canonical pattern, those built after the Council show a more random distribution. It should be noted that the earliest churches founded in the Philippines are at least from 1565, so the relaxation of the prescription on the orientation towards the east would already have been in force when the first Philippine stone churches were built. It should be noted that most Philippine churches were initially built with perishable materials (wood, reeds), so the date of construction of the first stone building of each church could strictly correspond to an upper limit of its foundation. This is the case, for example, of the Minor Basilica of the Santo Niño de Cebu, the first church founded in the Philippine archipelago, initially built of wood in 1565, although the first stone building, located on the same site, was not started until 1735. Another added complication is that, in any case, we have no absolute certainty whether the orientation of the new stone version of the temple maintained the same orientation as the previous more fragile one. In fact, as Galende (1987: 57) indicates, in the first stone reconstruction of the Minor Basilica of the Santo Niño de Cebu, the leader of the works, Father Juan de Albarrán, decided to reorient slightly the building for logistical and urban planning reasons.

Although, as we have just seen, the Philippines do not have any churches built before the Council of Trent, we have represented the orientation of the apses based on the century of construction of the first stone structure of each temple (Figure 4). The percentage distribution of the 98 churches is as follows: 5.1% (5 buildings) built in the 16th century, 25.5% in the 17th century, 43.9% in the 18th century, and 25.5% in the 19th century. The percentage of temples that, with a random distribution of orientations, would have their apse facing the sunrise is 13.5%. Only the groups of temples built in the 16th and 17th centuries have higher percentages, reaching 40% for the 16th century and 24% for the 17th century. Although the percentage is quite high in the first group, the small number of temples it contains renders the result scarcely statistically significant. For the later centuries, the percentage is even lower than expected for a random distribution: 11.6% for 18th-century temples and 8% for 19th-century ones. Since the percentage of sunrise-oriented

apses in 17th-century churches is slightly higher than in later centuries, it results to be quite similar to that obtained by Ambrosio & Hermosa (2021) for their sample of colonial and post-colonial cathedrals. Therefore, we consider there is not sufficient evidence to support the use of the pre-Tridentine canonical orientation pattern even in the earlier Philippine churches.

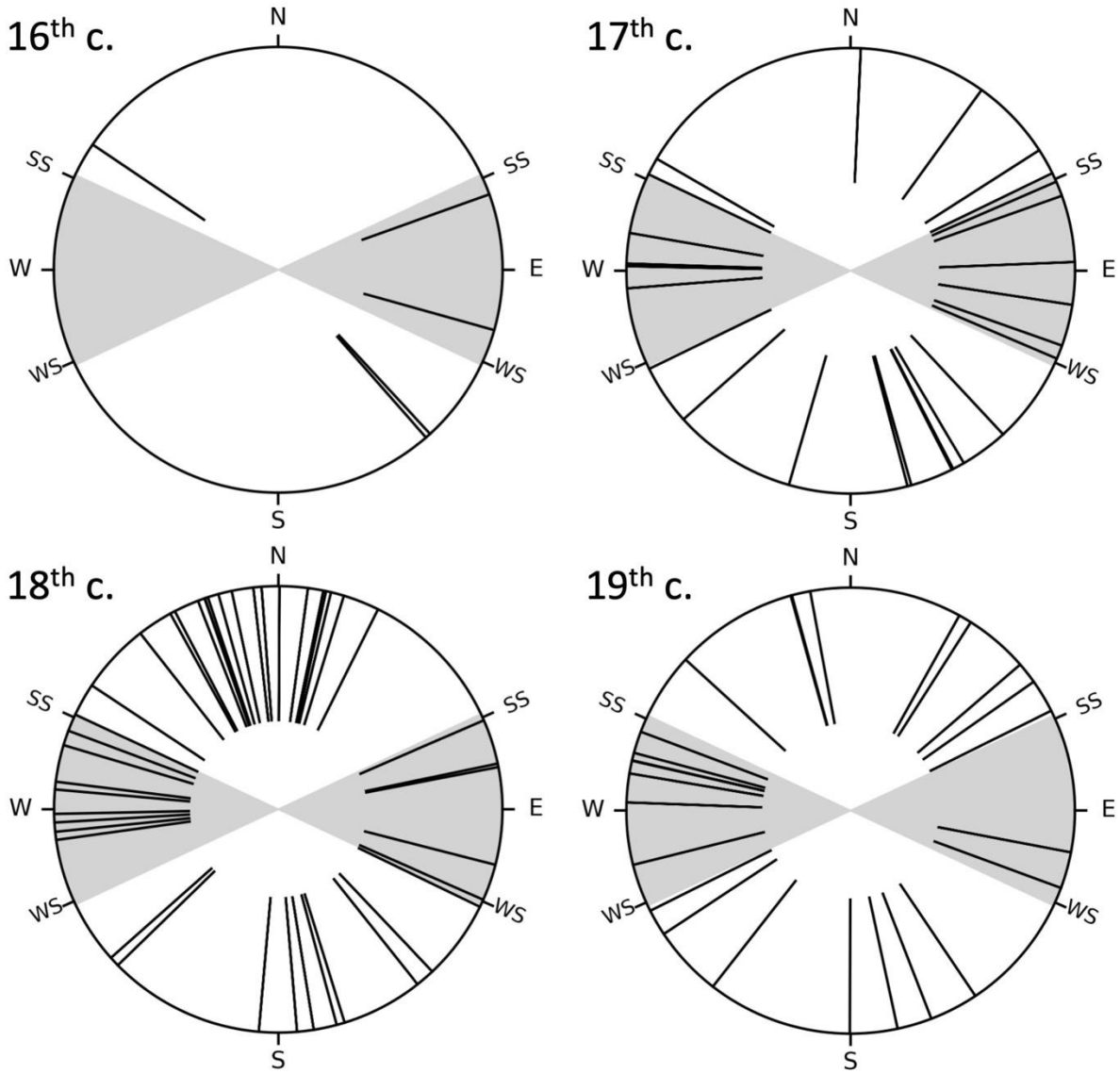


Figure 4. Distribution of orientations of the apses of Philippine colonial churches built in the 16th, 17th, 18th, and the 19th centuries.

The dedication to which it was built and the religious order that founded it are two important cultural elements of a Catholic church. According to the data available for our Philippine churches, 39.8% were founded by Augustinians, 26.5% by Dominicans, 13.3% by Jesuits, 9.2% by Franciscans, and 5.1% by secular clergy (we have no data for the remaining 6.1%). When the orientations of each of the five groups mentioned are represented separately, their distribution is clearly random. Among the 98 churches, we have 57 distinct

dedications, and only three are repeated in at least five churches: St. John the Baptist in five, St. Augustine in seven, and the Immaculate Conception in ten. We found no particular pattern among the churches dedicated to any of these dedications. For the 20 devotions that have two or more temples dedicated to him/her, we also do not find any singular orientation pattern except, perhaps, in the group dedicated to St. Andrew. Of the three churches dedicated to this saint, two of them, Bacarra and Masinloc, located on the west coast of northern Luzon, have a very similar orientation of their apse: 296° and 294° respectively, although, as will be discussed in the next subsection, only Masinloc could be related to the sunrise on the day of the celebration of St. Andrew.

The distribution of temple orientations according to the island in the Philippine archipelago where they are located also shows no notable peculiarities. As already mentioned in the previous section, the majority of Philippine temples (67%) are concentrated on Luzon, while only six islands have more than two buildings. The only exception appears to be Cebu (Figure 5b), where the three colonial churches studied are oriented within a fairly narrow azimuth range. In the distribution of orientations on the island of Luzon (Figure 5a) we can see a larger concentration around the cardinal points and a fairly clear absence of temples with their axes at intermediate angles with respect to the cardinal axes. Interestingly, this pattern of orientations is qualitatively similar to that obtained by Ambrosio & Hermosa (2021) for their sample of Philippine cathedrals—where the fraction of temples in Luzon relative to the whole archipelago is lower than in our sample—, but not as evident in the distribution we found for our sample of colonial churches throughout the archipelago (Figure 3a).

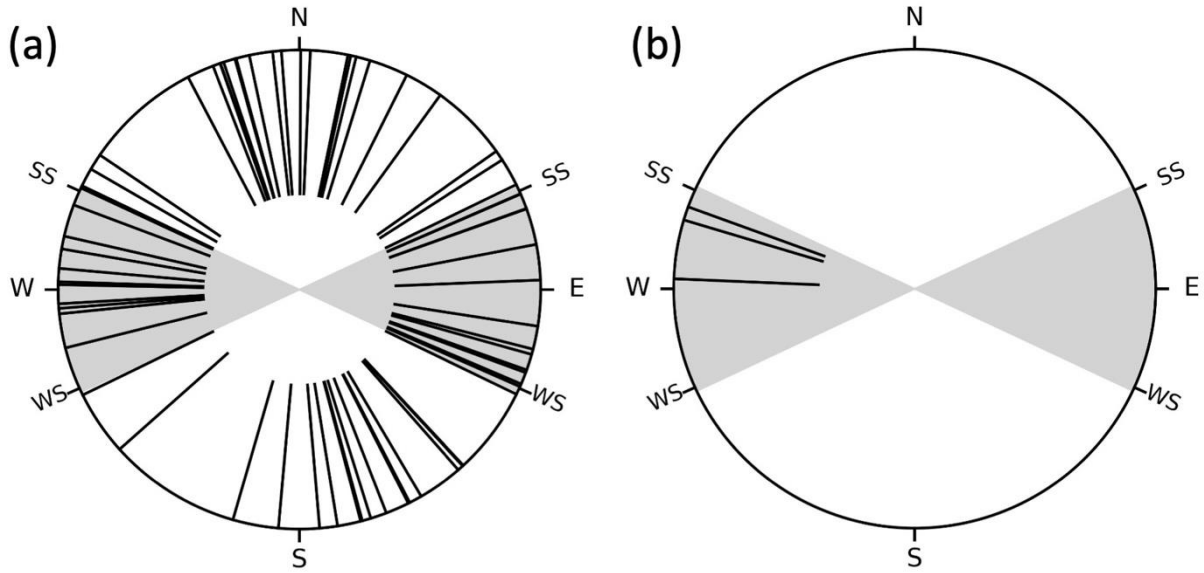


Figure 5. Distribution of orientations of the apses of colonial Philippine churches located in the island of: (a) Luzon, (b) Cebu.

Something that we have learned in this study is that all churches of our sample are located within towns or villages of varying size; that is, none is isolated. Moreover, 94.9% of them are well aligned with respect to the grid defined by the road and street system and the layout of the surrounding buildings, demonstrating that the founding of settlements and churches were interrelated events, planned by the colonial authorities to concentrate the native population and promote its Christianization and Hispanicization (the so-called *reducciones*; e.g. Sánchez Fuertes, 2020). Only three buildings (Buguey, Lazi, and San Joaquin, all coastal) are somewhat rotated (no more than about 25°) with respect to the surrounding urban layout, while two of the churches located on the outskirts of Manila (Makati and Parañaque) are located in an area of complex urban layout where there are no well-defined axes of symmetry.

It is well known that during the settlement and founding of new towns and villages after the incorporation of territories, the Spanish Empire applied certain rules on the organization and orientation of the urban layout collected in what is known as the Laws of the Indies (*Leyes de Indias*). They were promulgated by different monarchs such as the Laws of Burgos, promulgated by the Catholic King Ferdinand II in 1512, the New Laws, issued by King Charles I in 1542, the ordinances of King Philip II of 1573 and the compilation issued in 1681 by King Charles II. For example, in the ordinances of King Philip II of 1573 (the closest to the time of the first settlements in the Philippines) it is recommended that urban layouts be laid out according to a main plaza surrounded by the most important buildings and from which streets laid out in a grid, oriented according to the climate to take advantage of the prevailing winds and ensure ventilation, mainly in warm climates. Regarding churches, the ordinances of 1573 indicate that they should be located in prominent places, visible from the entire city and preferably oriented towards the east following the Christian tradition. It is also indicated that, in the case of coastal settlements, the church should be clearly visible from the sea (Cuesta Domingo, 1994). In principle, these regulations can provide clues to explain the location and orientation of at least some Philippine churches, as they relate them to the geometry of the urban landscape and to geographic and environmental factors.

The island of Luzon

Since Luzon is the largest island and has the largest concentration of colonial churches, we can best analyze and distinguish whether geographic and environmental factors may have influenced their orientation patterns. To do so, we began by conducting an analysis based on different geographic areas. We have defined four zones that encompass several present-day regions of the Republic of the Philippines: (a) the northwest zone, which includes the Ilocos and Cordillera regions; (b) the Cagayan Valley zone, which corresponds to the Cagayan Valley Region; (c) the central zone, which encompasses the Metro Manila area (National Capital Region) and the Central Luzon and Southern Mainland Tagalog regions; and (d) the southern zone, corresponding to the Bicol Region. The number of churches in each zone is 10 in the northwest, 20 in the Cagayan Valley, 33 in the center (13 of which are

in Metro Manila), and 3 in the south. The distribution of orientations of the churches in each area of Luzon is shown in Figure 6.

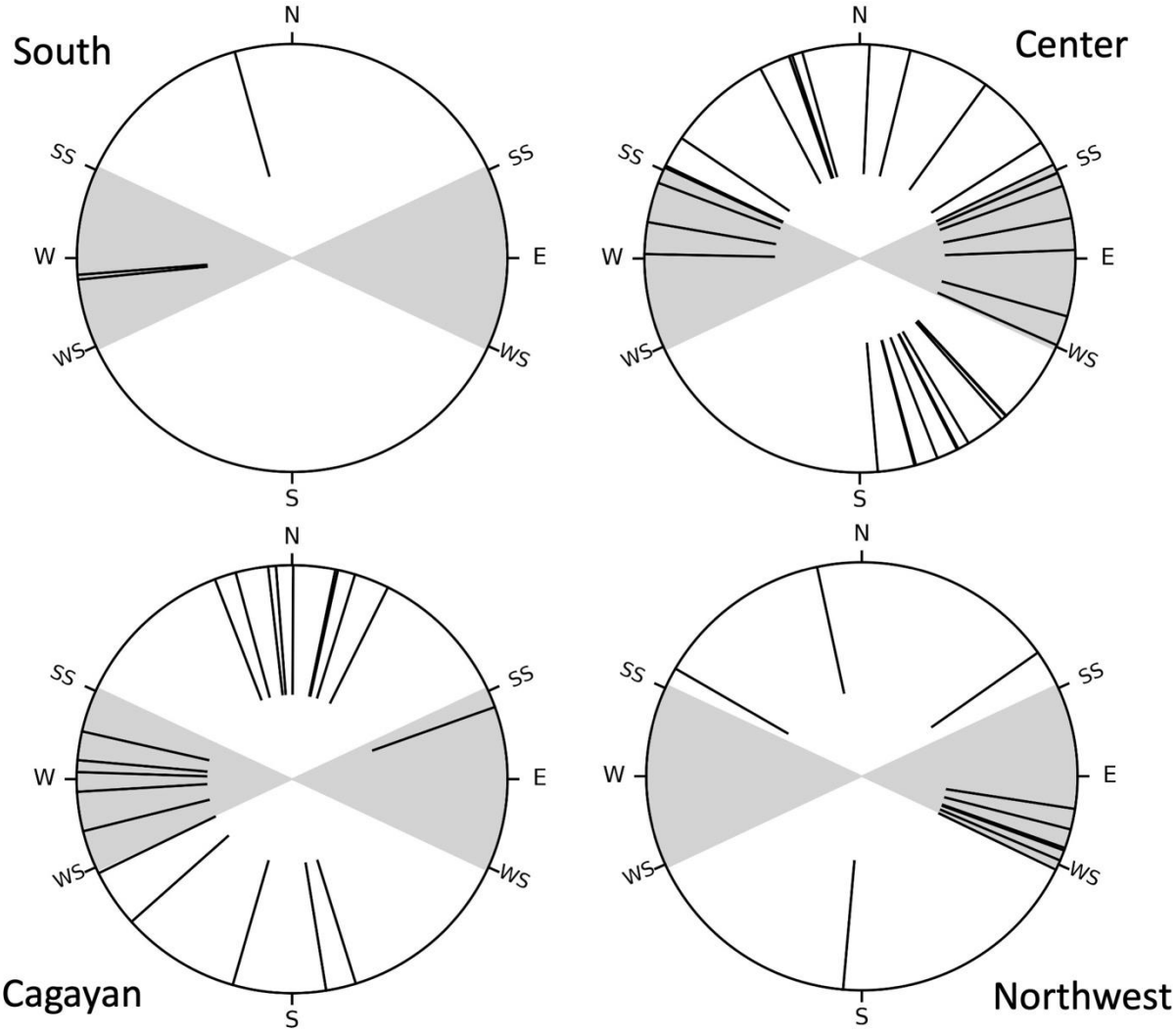


Figure 6. Distribution of orientations of the apses of churches on the island of Luzon according to the geographical area where they are located: south, central zone, Cagayan Valley and northwest.

Starting in the southern zone of Luzon, we can see that two of the three churches, Daraga and Quipayo, display a very similar orientation (264° and 265.5° respectively). Both are Franciscan foundations, and this motive could perhaps be behind their orientation, as will be discussed in the next subsection. The central zone shows a wide dispersion of orientations, but there is a striking total absence of churches with apses oriented towards the southwest quadrant, and also a low proportion in the opposite northeast quadrant. This fact may be related to the direction of the prevailing winds in the area: the northeast monsoon (*Amihan*) is marked by cool, dry winds that blow during the dry season (November

to April), and the southwest monsoon (*Habagat*), generally more dangerous and bringing intense rains along with warm, humid winds that can even become typhoons (June to October). Therefore, it is reasonable that church naves tend to be oriented perpendicularly to reduce the building's exposure to these monsoons, especially their facades. On the other hand, the churches of the Cagayan Valley seem to show a certain tendency to orient themselves in a north-south direction (with a larger concentration towards the north) and towards the west. We believe this pattern could be related to the geographic layout of the valley, which runs from south to north, like the river (the longest in the Philippines) that gives the region its name and defines the main axis of land communications in the area. The secondary accumulation of westerly orientations could be due to buildings arranged perpendicular to the main road axis. Finally, the distribution of orientations of the temples in the northwest zone shows a clear accumulation, with six of the buildings (Bantay, Bacarra, Magsingal, Paoay, Sarrat, and Vigan, all of Augustinian foundation) pointing to a narrow range of azimuths, between 99° and 116°, within the arc defined by the solar rises and around the winter solstice. This group of churches are located on a basically rectilinear coastal strip 78 km long—lying west of the mountain range called Cordillera Central—and at a very similar distance from the coast, between 3.3 and 5.5 km (except for Sarrat, which is 13.5 km away). Using the angle measurement tool of Google Earth Pro, we can estimate the average azimuth of the coastal zone between the southernmost (Vigan) and northernmost (Bacarra) churches in the group, obtaining an approximate angle of 17°. The perpendicular to this line to the east has an azimuth of 107°, very similar to the average value of the orientation of the aforementioned group of six churches: 109°, indicating that the axis of the nave of these buildings is basically perpendicular to the coast. Considering that the facades of the temples point in the opposite direction to the apse, we believe that a simple and utilitarian explanation for the orientation pattern presented by this group is that they were built with their facades pointing towards the sea (favoring ventilation by the local sea breeze) in this case towards the west-northwest (between 178° and 296°), which would partly avoid the humid southwest monsoon winds by being placed perpendicular to it.

The coastal churches

To test whether Philippine churches tend to face the sea, as suggested by the temples in northwestern Luzon and the comments of Legarda (1960) on the Ilocos Region cited in the introduction, we will analyze whether this holds true by considering all Philippine churches near the coast. Figure 7 shows a histogram representing the number of churches located in intervals (bar widths) of 0.5 km from the coast. We also consider the shoreline of the extensive Bay Lagoon in central Luzon, where we have several churches located in towns situated on the shore of said lagoon, such as Calamba, Tanay, Paete and Pakil. In Figure 7, we can see that the distribution increases significantly towards the coast and that a distance of 1.5 km or less can be a reasonable criterion for distinguishing churches that can be classified as coastal from the inland ones. Of the 98 churches, applying this criterion, 43 are coastal (43.9%, the orientations of their facades are shown in Figure 8a), and of these, 23

have the nave perpendicular (their azimuth does not differ by more than 15° to the nearest coastline), which corresponds to the 53.5% of coastal churches. In the majority of this last group, 17 of them, their facades face the sea (73.9% of the churches perpendicular to the coast). As we can see, we have found a significant pattern in the orientation of Philippine coastal churches. This pattern is observed primarily in all the churches on the islands of Batan and Cebu and in a significant portion of the churches in central Luzon, although only in three of the thirteen in the Manila area (Binondo, Malate, and Tondo). It should be noted that this group does not include the six churches in northwestern Luzon studied previously. Although they show orientations toward the sea, they are located at distances somewhat greater than 1.5 kilometers from the nearest coastline.

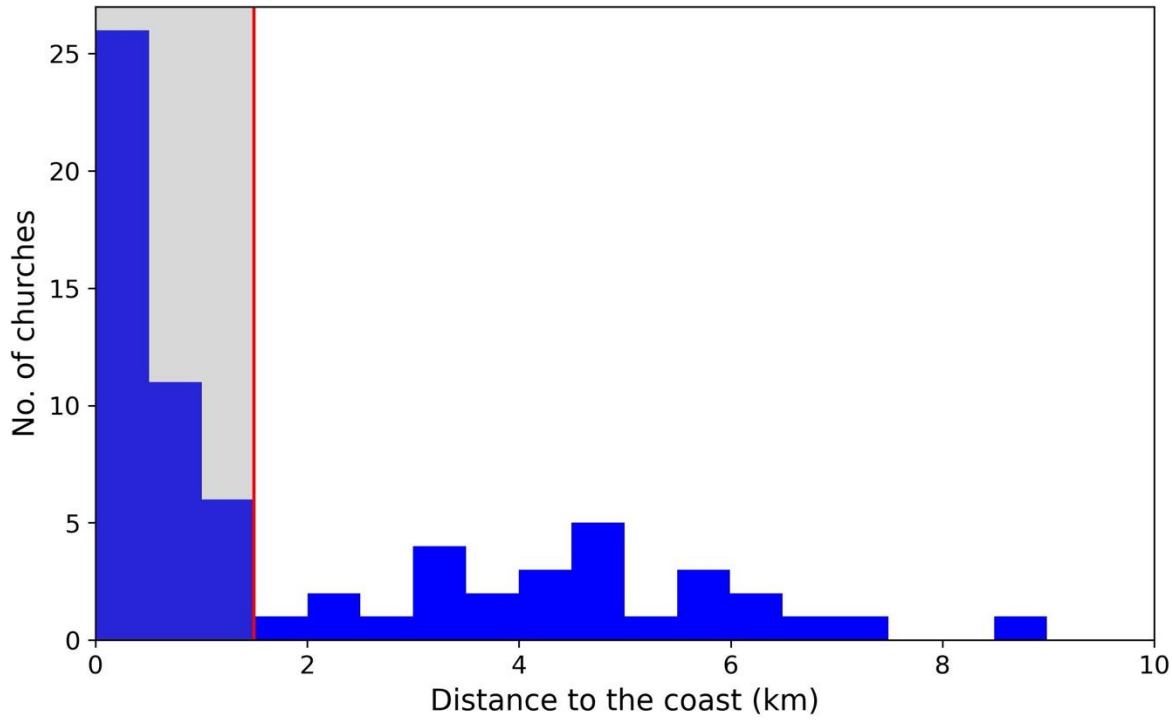


Figure 7. Histogram of the distribution of the distance from the coast of the Philippine churches in the sample. The total sample is not included; only those located up to a maximum distance of 10 km. Only 28 of the 98 temples (28.6%) are outside the represented distance range The church located furthest from the coastline is 75.8 km away.

In Figure 8a, we can see that the facades of 43 coastal churches in the Philippines, which are distributed in a fairly homogeneous and random manner, although showing a lower proportion in the north-northeast and south-southwest sectors, perhaps avoiding the direction of the monsoon winds, which are dominant not only in Luzon but in the rest of the archipelago. However, as shown in Figure 8b, the facades of 17 coastal churches whose nave is perpendicular to the coast and its entrance points towards the sea, show a very curious distribution, since fourteen of them (a very significant 82.4%) are located within the solar arc, both towards the east and the west, which means that the orientation of these

churches tends to be around the east-west axis. This fact could be due to two reasons: on the one hand, to be located in a direction approximately perpendicular to the monsoon winds and for geographical reasons, since a good number of the islands that make up the Philippine archipelago are distributed in a dominant north-south direction and their morphology tends to be elongated in that direction, as is the case of Luzon, the island that houses the most colonial churches.

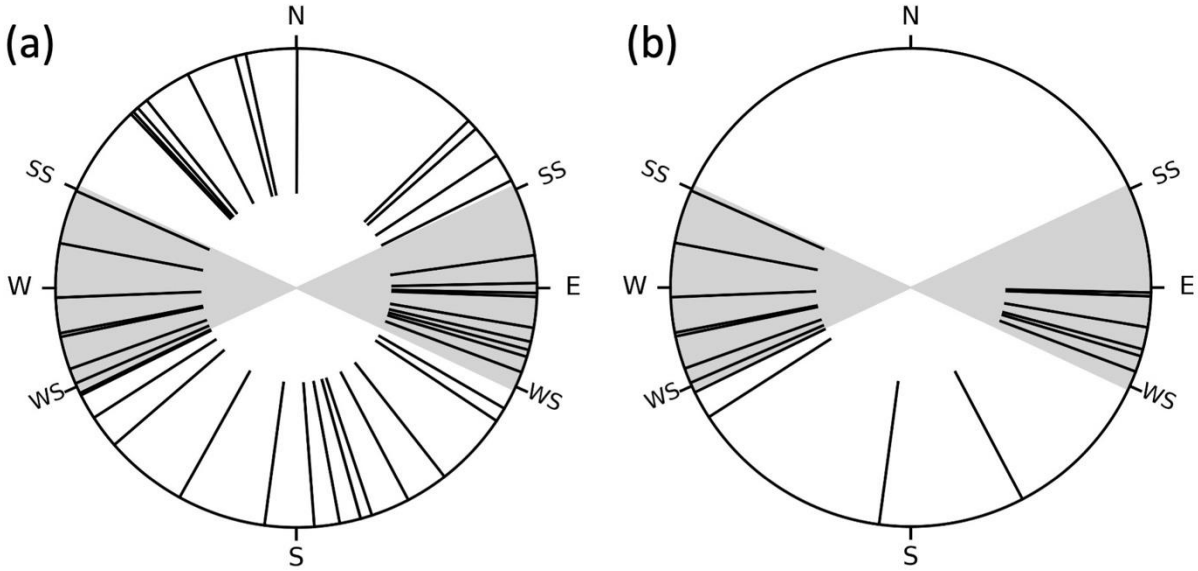


Figure 8. Distribution of orientations of the facades of Philippine churches: (a) located less than 1.5 km from the nearest coastline; (b) subset of the temples included in (a) but with their nave perpendicular to the coastline and their facade pointing towards the sea.

Churches in and around colonial Manila

Of the thirteen churches located in the Greater Manila area, eight are within the confines of colonial Manila and its adjacent neighborhoods. These are: Manila Cathedral and San Agustin Church in Intramuros; the churches of Binondo, Quiapo 1 and 2, Santa Cruz, and Tondo, in the historic neighborhoods north of the Pasig River; and Malate Church, on the coast and south of the river. As we can see in Figure 9, the two temples located in Intramuros display a very similar orientation (since the street layout in this area is drawn in a grid) with their apses pointing southeast. The orientation of the streets and naves of the churches is clearly parallel to the defensive wall of the Spanish city core, which, in turn, follows the general orientation of the coastline. The three churches located outside the city walls closest to the coast: Binondo, Malate, and Tondo have their naves perpendicular to the coast and their entrances facing the sea, while the rest of the churches, located further inland, have a variable orientation because they are located in areas with more complex street layouts determined by the variable arrangement of the meanders of the Pasig River. In some ways, the results of our work for Manila are similar to those obtained in another colonial capital, such as Rio de Janeiro (Brazil). Silva et al. (202X) conducted a study of the churches built in this city between the 17th and 19th centuries, finding that, although some

temples show a certain tendency to be oriented easterly, most follow the urban layout and local topography, indicating that practical, strategic, and even defensive concerns played a more significant role than merely symbolic or astronomical ones.

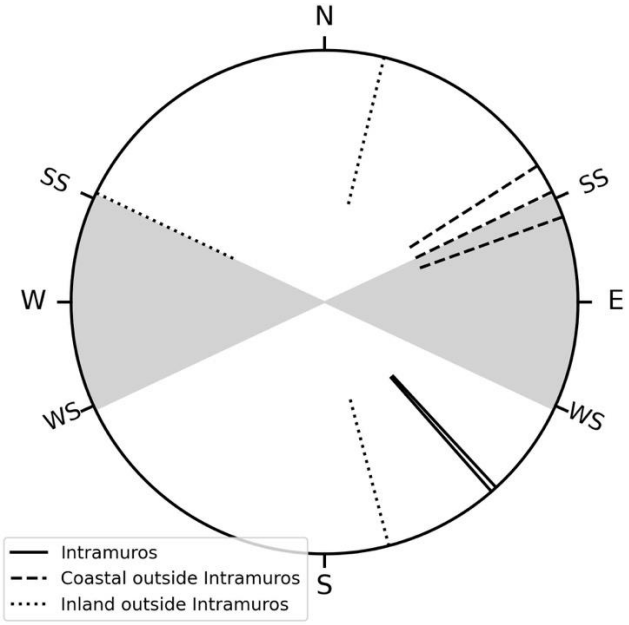


Figure 9. Distribution of the orientations of the apses of churches located in colonial Manila. Different lines are used to distinguish buildings located within Intramuros and those located outside Intramuros, near the coast or inland (although near the meanders of the Pasig River).

Churches oriented to solar risings or settings on festivals or important dates

Thirteen churches in our sample (13.3%) show orientations of their apse or facade toward sunrises or sunsets above the local horizon on the feast days of their respective dedications or on dates that could have special significance in each particular case. This result is consistent with what was expected by chance alone (10%), taking into account the error in measuring the azimuth and the fact that we considered both sunrises and sunsets. On the other hand, we have not found published or online references to such orientations with possible solar significance in any Philippine church, although we cannot rule out the existence of local or exclusively oral sources in some cases, which would require a field study that, for now, is beyond our possibilities. In any case, we think likely that some of the orientations found were deliberate and formed part of the construction plan of the temple, so the following examples would merit future study. In the following, we briefly describe the churches included in Table 3 where we have found relationships with festival dates, distinguishing whether these are orientations defined by their apses or their facades, considering the local horizon and assuming an error of $\pm 1°$ in azimuth and 0.5° in height, that propagates in a typical error of about $\pm 1.1°$ in declination.

a) Orientation defined by the apse.

- Ivana (Batan Island, Batanes province, St. Joseph the Worker, 1795, Dominicans): The azimuth corresponds to the sunrise between April 25 and May 1. Precisely, May 1 is the town's main festival dedicated to the patron saint according to the Catholic liturgical calendar. However, the feast of St. Joseph the Worker was instituted by Pius XII as late as 1955, so this relationship is likely simply coincidental.
- San Juan del Monte (Luzon, central zone, Manila, Holy Christ/Holy Cross, 1600, Dominicans): this church was originally dedicated to San Juan del Monte (St. John the Baptist), whose feast day was and still is celebrated on June 24. Later, during the 17th century, the church's main focus shifted to the Holy Christ or the Holy Cross, whose feast day is commemorated on May 3. The apse of the church is oriented towards the sunrise between June 1 and July 7, aligning with the sunrise on the summer solstice and the feast of St. John the Baptist. Furthermore, the facade of the church is also oriented towards the sunset on the winter solstice (from December 1 to January 11) and, therefore, with the Christmas season.
- Masinloc (Luzon, central zone, Zambales province, St. Andrew, 1713, Augustinians): The apse faces the rising sun between November 19 and December 3, including November 30, the feast day of the patron saint and the date of the *Binabayani* festival, the most important annual celebration in the town.
- Paete (Luzon, central zone, La Laguna province, St. James the Apostle, 1646, Franciscans): The apse points to a fairly high area close to the horizon (the slope of Mount Humarap) where the sun rises between March 27 and April 1, right over the place where, since 1676, three crosses (*Tatlong Krus* in Tagalog) have stood, the destination of a very popular local pilgrimage that takes place during Holy Week, especially on Good Friday. Considering that the dates of Holy Week vary from one year to the next, Good Friday can fall between March 20 and April 23, so the orientation of the apse could be considered a representative intermediate period of Holy Week. Measuring the azimuth of the line connecting the church and *Tatlong Krus* (perfectly identifiable in satellite images) on Google Earth Pro we obtain 88.3° and using the local horizon provided by Peakfinder we find that it corresponds exactly to the position of the sunrise on April 3. That was precisely the date of Good Friday in 1676, the year in which, according to the references, *Tatlong Krus* was built. In view of these coincidences, we believe it likely that the solar relationship between the orientation of the church and the location of *Tatlong Krus* was deliberate.
- Paoay (Luzon, northwest zone, Ilocos province, St. Augustine, 1694, Augustinians): The apse points toward the sunrise from November 9 to 17. This date range includes November 13, which, although not a local festival, is important to the Augustinians, as it commemorates all the saints and blessed

who have belonged to the order throughout history. This commemoration was approved by Pope Innocent XII in 1694.

- Quipayo (Luzon, southern zone, Camarines Sur province, Immaculate Conception, 1616, Franciscans): The apse faces the setting sun between October 2 and 8, which includes October 4, the day of the celebration of St. Francis of Assisi, founder of the Franciscan order. There is no evidence that this latter date is celebrated in the town. The apse of the Daraga Church (discussed below), also Franciscan and located in the same area of Luzon 82 km away, is also oriented toward this celebration.
- Vigan (Luzon, northwest zone, Ilocos Sur province, Conversion of St. Paul, 1790, Augustinians): the apse of this cathedral is oriented toward the sunrise between January 11 and 27, close to the winter solstice. That interval of dates includes the main festival of Vigan, celebrated on January 25 commemorating the Conversion of St. Paul.

b) Orientation defined by the facade.

- Bantay (Luzon, northwest zone, Ilocos Sur province, St. Augustine, 1590, Augustinians): the facade faces the setting sun between August 28 and September 2. August 28 corresponds to the celebration of St. Augustine of Hippo and one of the town's main festivals as it is its patron saint.
- Boljoon (Cebu Island, Central Visayas, Our Lady of the Patronage, 1783, Augustinians): The facade of the temple is oriented to the sunrise between November 5 and 12, which coincides with the feast of the patron saint and the *Bolho* festival, celebrated on the second Saturday of November and which can occur between the 7 and 13 of that month depending on the year.
- Cebu City (Cebu Island, Central Visayas, Minor Basilica of the Santo Niño): This was the first church founded in the Philippines by Andres de Urdaneta, an Augustinian priest, in 1565, although the current stone building dates from 1735. The door faces the sunrise between January 11 and 22. The most important festival in the city is the *Sinulog* festival, dedicated to the Santo Niño, one of the largest religious celebrations in the Philippines and held on the third Sunday of January, between January 15 and 21 depending on the year, a range of dates perfectly consistent with that indicated by the orientation of the facade.
- Daraga (Luzon, southern zone, Albay province, Our Lady of the Gate, 1772, Franciscans): Church oriented on two interesting dates. The facade faces the rising sun between September 4 and 10, which includes September 8, the town's most important festival, dedicated to its patron saint, while the apse faces the setting sun between October 1 and 6, which includes October 4, the feast day of St. Francis of Assisi, founder of the Franciscan order. There is no evidence that this last date coincides with a special celebration in the town, so we consider the result of the facade to be the most relevant in this case.

- Malate (Luzon, Manila District, central zone, Our Lady of Remedies, 1680, Augustinians): the facade faces the setting sun between November 18 and 25. The parish's most important celebration is on the third Sunday of November, dedicated to the image of Our Lady of Remedies, which can occur between November 15 and 21 depending on the year, coinciding perfectly with the range of dates indicated by the facade's orientation.
- Pakil (Luzon, central zone, La Laguna province, St. Peter of Alcantara, 1732, secular): the facade of the building points to the area of the western horizon where the sun sets between October 18 and 23, which includes October 19, the date of the patron saint and main festival of the town.

Potential orientations with the sun at low height above the horizon

In this subsection we discuss four churches in which we speculate that some type of illumination phenomenon may occur inside the nave through an existing or hypothetical opening on the commemorative dates of the patron saint, due to the orientation of the apse or the facade of the building, when the sun is at a low height above the horizon (no higher than 20°) but not coinciding with sunrise or sunset. The meaning of this part of the analysis, evidently quite speculative, should be understood as an indication for future on-site checks, considering the current or previous arrangement of the different structural elements (openings, windows, side chapels) of the temples.

- Bacarra (Luzon, northwest zone, Ilocos Norte province, St. Andrew, 1590, Augustinians): The setting sun on November 30 (day of the patron saint) is aligned with the direction that defines the apse when it is still in the sky at an altitude of between 6.5° and 11°. There could be some kind of interior illumination phenomenon on that date if there were an opening in the apse, which does not appear to exist based on current photographs of the interior of the church.
- Magsingal (Luzon, northwest zone, Ilocos Sur province, St. William the Hermit, 1827, Augustinians): the original church was built in 1676 but was destroyed in an earthquake in 1723 but shared the same orientation, as indicated by the ruins of the older building located just a few dozen meters to the north. The apse of the church is oriented towards the sunrise between January 25 and February 1, but on February 10, the date of the patron saint and main festival of Magsingal, the Sun aligns with the axis of the apse when it is between 11° and 14° degrees high. There does not appear to be an opening in the apse at present; it is also unknown whether there was one in the former building, which is now in ruins.
- Taal (Luzon, central zone, Batangas province, St. Martin of Tours, 1755, Augustinians): this is the largest Catholic church in Asia, the nave is almost 90 m long and up to 28 m tall. The apse is oriented towards the sunrise on and around the summer solstice, while the facade faces the sunset between December 1 and January 11, thus perfectly encompassing the winter solstice. Before sunset on

November 11, the feast day of the patron saint and one of the most important city festivals, the sun aligns with the axis of the facade when is at a height of between 14° and 19.5°. It is important to note that the facade of this church has 10 large windows arranged in two rows of five at two different heights, so it is quite possible that lighting phenomena could occur on that date or even on other dates of interest. We estimate that the sun, at an altitude of approximately 15.5°, could illuminate the apse (located about 90 meters horizontally) from an opening 25 meters high on the facade. We believe this church warrants an in-depth on-site study of the annual solar illumination patterns in its interior.

The curious orientation of the apse of the Manila Cathedral

The construction of Manila Cathedral began in 1581, in wood (the stone building was built in 1591), on a plot of land reserved by the city's founder, Miguel Legazpi (Díaz-Trechuelo Spínola, 1959:226). The temple is dedicated to the Immaculate Conception. Although, as mentioned above, the southeast orientation of its apse is very far from the solar arc, inspection of the local horizon surrounding it with the Peakfinder application provided a curious fact, since the azimuth band corresponding o its orientation includes the central part of the crater of the Banahaw volcano, 2,170 m high and located 80 km away, the highest mountain above sea level visible from the capital. The Banahaw crater has a width of just 1.5° and an angular height of 1.2°, making it a small topographic feature. This volcano, along with nearby Makiling, is one of the mountains considered sacred by the Tagalogs since pre-Hispanic times (Sanz Elorza, 2024), especially for its numerous natural and geographical formations, which, according to tradition, served as dwelling places for invisible beings and forces. Since the 17th century, Spanish authorities have recorded references to numerous popular pilgrimages to the Banahaw caves to perform rituals associated with animistic practices. Today, it still holds great importance in popular religiosity, as some groups consider the mountain an *axis mundi* on par with the Holy Land (Arceta, 2020). On the other hand, we would like to mention that another of the first churches in the Manila area, the Parañaque Cathedral, located near the coast and about 10 km south of Intramuros, dedicated to St. Andrew and built by the Augustinians, shows its apse also oriented southeast, but in this case, toward the summit of Makiling Volcano (located 46 km away), as we have seen, another of the sacred mountains of the island of Luzon since pre-Hispanic times. According to legend, a female spirit benefactor of nature (*diwata* or *engkanto*) lived on this volcano, who in colonial times came to be called *Maria Makiling*. Although this correspondence between the orientation of the apses of the cathedrals of Manila and Parañaque with two volcanoes sacred to the Tagalogs could be perfectly coincidental, it is nonetheless suggestive, as it could indicate, by way of speculation, a certain syncretic concession (and favoring assimilation) on the part of the Catholic hierarchies of the first Spanish settlers towards the predominantly animist population of the Manila area, gestures common in other earlier Spanish colonial contexts such as, for example, Christianization

after the conquest of Mexico (Iwaniszewski, 1999; Martz de la Vega & González Morales, 2021).

Colonial Churches of Guam

We have only considered three churches in Guam: The Dulce Nombre de Maria (Sweet Name of Mary) Cathedral in Agaña, the island's capital, and the churches of St. Dyonisius in Umatac (ruins) and St. Joseph in Inarajan, which we know were founded by the Jesuits in the 17th century, when the conquest and colonization of the island took place. According to data compiled from Guampedia (https://www.guampedia.com/), the Agaña Cathedral was built of coral stone in 1670 in its current location. The original St. Dyonisius Church was built in 1681 although the stone structure was not built until 1769, the ruins of this structure is what we measured since the current building was built in 1939 about 150 m to the east. The St. Joseph Church in Inarajan was founded in 1680 and maintains its original location, although we do not know when its first stone structure was erected. As we can see in Figure 3 and Table 2, all of Guam's churches have their apses oriented away from the solar arc, and none follow the canonical pattern. All are located very close to the sea; the Agaña Cathedral and St. Dyonisius Church have their facades pointing toward the adjacent coastline, in the case of Agaña, quite exactly toward the geographic north. The location with respect to the coast is more difficult to determine in the case of St. Joseph Church, as it is located on a small peninsula and surrounded by water on three sides. The best manner to describe its layout is as parallel to the general coastline of the area. In short, the churches of Guam appear to share with most coastal churches in the Philippine archipelago a layout in which their facades are oriented toward the sea.

Conclusions

The analysis of the orientations of 98 and three colonial churches in the Philippines and the island of Guam (Mariana Islands), respectively, built between the 16th and 19th centuries, is presented. The sample of temples does not follow the canonical orientation pattern toward sunrise. There is no correlation between the distribution of orientations and other purely religious factors such as the order that founded the church or the dedication to which it was built. Nor do we find any specific patterns on the different islands where we have measured more than two churches, except perhaps on the island of Cebu. A geographical analysis of the churches on the island of Luzon (which accounts for 67% of the sampled churches) suggests several trends: (a) churches tend to avoid aligning their naves with the northeast-southwest axis (the dominant direction of the monsoon winds); (b) in the inland Cagayan Valley, churches tend to be oriented parallel or perpendicular to the general direction of the valley and the river that gives it its name; (c) in coastal or near-coastal areas, naves tend to be arranged perpendicular to the coast and, for the most part, with their facades facing the ocean. This last characteristic seems quite common in the rest of the Philippine archipelago, as well as on the island of Guam in the Marianas. However, in the Philippines, this orientation pattern seems to avoid the direction of the monsoon winds. The alignment of

the facade toward the coast favors ventilation of the buildings, as recommended by the layout and construction standards for new settlements in the Spanish Empire.

The possible orientation of the apse or facade of the temples toward solar risings or setting on the dates of their dedication or of special particular interest in each case has also been explored. Although the percentage of cases found is not significantly higher than mere chance, we found some particular cases that could be quite plausible and would merit further investigation, preferably on-site. The most notable cases are those of the churches of Paete, Daraga or San Juan del Monte (in Manila) and, due to its special importance, that of the Minor Basilica of the Santo Niño of Cebu, the oldest place of Catholic worship in the Philippines, whose facade is oriented toward sunrise on the date of the *Sinulog* festival, dedicated to the Santo Niño of Cebu, the most important religious celebration in the Philippines apart from the major universal Catholic celebrations such as Christmas and Easter. Another possible case of interest is that of the Minor Basilica of Saint Martin of Tours in Taal, the largest Catholic church in Asia, where there could be solar illumination phenomena through the large windows of its facade on the date of the feast of its patron saint.

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