Northwest Pacific typhoons documented by the Philippine Jesuits, 1566–1900

Ricardo García-Herrera,[1] Pedro Ribera,[2] Emiliano Hernández,[1] and Luis Gimeno[3]

Received 5 April 2006; revised 21 July 2006; accepted 5 December 2006; published 22 March 2007.

[1] In recent years, the population and the value of properties in areas prone to tropical cyclone (TC) have increased dramatically. This has caused more attention to be placed on the characterization of TC climatologies and the identification of the role that factors such as the main teleconnection patterns may play in TC variability. Due to the timescales involved, the instrumental records have proven too short to provide a complete picture. Thus, documentary and other paleoclimatological techniques have been used to reconstruct TC occurrence. This has been done mostly for the Atlantic basin, whereas in the Pacific basin, fewer attempts have been made. The aim of this paper is to provide a high-resolution chronology of typhoons and intense storms occurring in the Philippine Islands and their vicinity for the period 1566–1900. The chronology is based upon the writings of the Spanish Jesuit Miguel Selga, who produced the original work at the beginning of the 20th century. The sources, reliability, and completeness of the chronology are examined critically. A total of 652 events are included, 524 of which are reported as typhoons, the rest being considered as tropical storms. For each of these classes, the landfall location and the track (when sufficient information is available) have been drawn. This chronology is an indispensable step toward a final and complete typhoon record in the western Pacific basin.

Citation: García-Herrera, R., P. Ribera, E. Hernández, and L. Gimeno (2007), Northwest Pacific typhoons documented by the Philippine Jesuits, 1566–1900, *J. Geophys. Res.*, *112*, D06108, doi:10.1029/2006JD007370.

1. Introduction

[2] In recent years, social interest in tropical cyclones (TCs) has grown steadily. This has been due to a number of factors, above all changes that have occurred in areas prone to TCs. Greater urbanization has lead to increasing populations and dramatically rising value of properties [*Díaz and Pulwarty*, 1997], especially concentrated in the Gulf of Mexico and western Pacific areas.

[3] This social awareness has been accompanied by an increase in scientific interest due to the evidence that large-scale oscillations, such as El Niño-Southern Oscillation [ENSO; *Díaz and Markgraff*, 2000], Quasibiennial Oscillation [QBO; *Baldwin et al.*, 2001], North Atlantic Oscillation [NAO; *Hurrell*, 1995], or the Madden-Julian Oscillation [MJO; *Madden and Julian*, 1994], may play a fundamental role in TC occurrence. However, the impact of ENSO is not uniform in the different tropical basins; a warm ENSO episode can lead to increased TC frequency, as in the South Pacific and in the North Pacific between 140°W and 160°E, whereas in the North Atlantic, the Australian region, and the northwest Pacific west of 160°E, ENSO is associated with lower TC frequencies [*Landsea*, 2000]. An east phase QBO seems to reduce the TC activity in the Atlantic basin, but the mechanism is not completely clear [*Gray*, 1984]. The NAO does not seem to impact the frequency but the trajectories of the Atlantic hurricanes [*Elsner et al.*, 2000]. The role of the MJO seems to be relevant in the Pacific basin, with an active MJO phase associated with more frequent TC [*Sobel and Maloney*, 2000]. Additionally, TCs exhibit great variability, with significant millennial, multidecadal, and interannual scales [*Liu and Fearn*, 2000a; *Landsea et al.*, 1996; *Elsner and Bossak*, 2001].

[4] There is a relatively short record of hurricane incidence when compared with the timescales involved. There has been, in recent years, a growing interest in reconstructing the behavior of storms and hurricanes for preinstrumental and even prehistorical times to the point that a new discipline, called paleotempestology, is growing.

[5] Previous works have tried to reconstruct hurricanes in the past, mostly from documentary sources. In the Atlantic basin the first records come from the earliest years of the Spanish Colonies. There seems to be little doubt that Christopher Columbus experienced at least two hurricanes, one in 1495 and the other in 1502 [*Millas*, 1968]. The Spanish were quickly aware of the impact of hurricanes in the Caribbean area and promptly adopted the term "hur-

[1]Departamento Física de la Tierra II, Facultad de Ciencias Físicas, Universidad Complutense de Madrid, Ciudad Universitaria, Madrid, Spain.
[2]Departamento de Sistemas Físicos, Químicos y Naturales, Universidad Pablo de Olavide, Carretera de Utrera, Seville, Spain.
[3]Departamento de Física, Universidad de Vigo, Facultad de Ciencias de Ourense, Ourense, Spain.

0148-0227/07/2006JD007370

acán'' from the Carib language to describe the phenomenon. In the 16th century, for example, Fernandez de Oviedo wrote: ''Huracán, in the language of this island (The Island is Hispaniola, currently Haiti/Dominican Republic.), is precisely defined as a very excessive storm or tempest but being in reality nothing more than a very great wind with heavy and intense rainfall'' (AGI Indif. Gral. 108—BIB. L.A. Siglo XVI-7 (References to manuscript sources in the *Archivo General de Indias* or other archives are denoted by the initials of the archive, such as AGI, followed by the name of the section of the archive where the manuscript is located and the signature identifying the ''legajo,'' or bundle, to which the manuscript belongs. See Appendix A for details about the main archives in Spain.)). Since then, countless documents have been produced containing information on hurricanes in the Atlantic basin. The studies by *Poey* [1862], *Tannehill* [1940], *Ludlum* [1963], *Dunn and Miller* [1964], *Millas* [1968], *Salivia* [1950], *Neumann et al.* [1993], *Rappaport and Fernández-Partagas* [1997], *Fernández-Partagas and Díaz* [1996], and *Chenoweth* [2006] provide a comprehensive view of the information that can be obtained from such sources.

[6] In other ocean basins, less work has been done. However, Chinese documentary sources can provide the longest historical records of TCs, as has been shown by *Chan and Shi* [2000] and *Liu et al.* [2001]. Using these sources, they have been able to construct a 1000-year, high-resolution typhoon chronology for the province of Guandong. German historical records have also been used to reconstruct tropical cyclones in the Marshall Islands [*Spennemann and Marschner*, 1994], but they only traced back up to 1840.

[7] Other techniques have also been applied to reconstruct TCs, such as the use of sedimentary records [*Liu and Fearn*, 1993, 2000b; *Donnelly et al.*, 2001] or dendrochronology [*Doyle and Gorham*, 1996]. These have coarser resolution than the historical sources, but may provide records as far as 5000 years B.P.

[8] This paper analyzes the 1566–1900 period of the typhoon chronology of the Philippines published in 1935 by the Spanish Jesuit Miguel *Selga* [1935]. The next section provides a brief account of the meteorological work of Selga and the Jesuits in the Philippines. Then, the sources are discussed, and the chronology is described. The paper ends with a discussion.

2. Miguel Selga

[9] Miguel Selga (1879–1956) was a Spanish Jesuit who had studied astronomy at Harvard University and became the last Spanish director of the Manila Observatory during the period 1926–1946 [*Udías*, 2003]. The Jesuits had settled in the Philippines during the last decades of the 16th century and played a very active role as missionaries. This was accompanied by a high interest in the natural history of the islands. The intense tropical storms soon attracted their interest due to the damages that impacted their lives and properties. Thus, as early as in 1668, the Jesuit Fr. F. I. Alzina wrote, after more than 30 years of experience in the islands, the *Natural History of the Visayas Islands* (AMN (AMN stands for Archivo del Museo Naval.) Ms478). There he provides a vivid description of more than six pages of ''baguíos'' (the native word for typhoons).

> . . .The indians of this area call this type of hurricane Baguio, which in other parts and in the East Indies are called typhoons. And all this means a very strong tempest. These used to be in these islands so numerous and so strong that neither Virgil in his Eneid, nor Ovid in his Ponto, nor any other poet that I have read comes close by one thousand miles to describing their rigors or their strength. We see them very often and we suffer so much, that even after experiencing them it seems impossible to believe. To put it briefly, when one of these baguíos runs (usually one or two every year), neither the trees are safe in the midst of the mountains, nor the animals in the caves, nor the men in their houses, nor the beasts in their middens, nor even the worms in their dens. . .

The complete text provides a detailed description not only of the impacts of the storms but also of the type of winds associated with them.

[10] This interest in meteorology, and the absence of other scientific institutions, made the Jesuits the pioneer meteorologists in the Philippines and other places of the Far East and Latin America [*Udías*, 1996]. This work continued until 1773, when the Jesuit order was suppressed, but was resumed in 1814 when it was restored. In fact, the Jesuits founded the Manila Observatory in 1865, and by 1900, they had developed a network of 72 secondary meteorological stations, which grew continuously until World War II, when the Manila Observatory was destroyed. In 1946, when the Philippine Weather Bureau was established, the Jesuit observatory ceased its meteorological activity [*Udías*, 2003]. The location of different Jesuit observatories in tropical areas (Manila, Havana, and Shanghai) mainly made it possible for different members of the order, such as B. Viñes, J. Algué, and C.E. Deppermann, to produce some of the first and most interesting studies of tropical storms [*Udías*, 1996]. The chronology presented in this paper is part of this tradition of rigorous scientific work carried out by the Jesuits.

3. Sources of the Chronology

[11] It is interesting to analyze the sources used by Selga when constructing his chronology. Unfortunately, he does not cite them in an identifiable way; rather, he writes [*Selga*, 1935, p. 3]:

> Although the catalogue of historical typhoons represents many hours of painstaking search in libraries and reading of books in various languages, no claim is made that the catalogue is complete or altogether free from inaccuracies; additions and corrections will be welcome.

[12] However, in 90 of the records, a source is explicitly cited. Those have been included in Table 1. It can be seen that in 59 cases, a primary source is cited, whereas in the rest, a secondary one has been used. When the nature of the documents is considered, it can be seen that 32 of them are related to ship incidents, mostly letters of the governors referring to the Manila Galleon, the main link between the Philippines and Mexico, which had an enormous importance to the life of the colony [*Schutz*, 1939]. Another 20 references come from church documents, mostly Jesuits letters. The rest is a miscellany of administrative documents.

[13] The most frequently used secondary sources are the Piddington maps and the History of the Philippines by Rev.

Table 1. Reported Sources of the Selga Chronology (Day, Month, Year and Source)[a]

Day	Month	Year	Source
1	May	1601	Report of the galleon *Santo Tomás*[b]
24	May	1621	Report of the frigate *Buen Jesús*
29	May	1654	Report of the Galleon[b]
	May	1709	Jesuit report?
19	May	1753	Report of the galleon *N^a^S^a^ de Guadalupe or Mexicana*[c]
11	July	1603	Letter of the Governor on the Galleon[d]
15	July	1659	Jesuit report
3	July	1686	Report of the English pirate William Dampier
3	July	1694	History of the Philippines by Rev. Father Pedro Murillo
10	July	1704	History of the Philippines by Rev. Father Pedro Murillo
	July	1717	Jesuit report
23	July	1726	Report of the Galleon[b]
	July	1780	Piddington map and letter of Mr. Webb, captain of an English ship
	July	1835	Piddington map
	July	1841	Piddington map
1	July	1846	Jesuit report
	July	1852	Jesuit report
15	Aug.	1568	Report from the fleet of Felipe Salcedo
21	Aug.	1602	Report of the Galleon[b]
20	Aug.	1606	Report of unknown ship towards Japan
2	Aug.	1620	Report of the Galleon *S. Nicolás*[b]
	Aug.	1629	Governor report on the Galleon[b]
5	Aug.	1639	Report of the Galleon[c]
23	Aug.	1708	Report from a Portuguese ship
22	Aug.	1720	Report Jesuit letter
10	Aug.	1783	Report of the packet *Antelope* of the East India Company
	Aug.	1793	Report of the Recolect Fathers
	Aug.	1832	Piddington map
11	Aug.	1848	Report of the French ship *La Bayonnaise*
18	Aug.	1898	Report of the Austrian frigate *Novara*
18	Sept.	1596	Letter of Gov. Tello on the loss of the Galleon *S. Felipe*
20	Sept.	1638	Loss of the Galeon N^a^ S^a^ de la Concepción, referred in the *Sucesos en Filipinas*[b]
26	Sept.	1687	Report of the English pirate Dampier on board of the *Cygnet* of London
	Sept.	1707	History of the Philippines by Rev. Father Pedro Murillo
23	Sept.	1742	Report of Lord Anson's *Centurion*
30	Sept.	1762	Report of Admiral Cornish on board of *South Sea Castle*
27	Sept.	1779	Sesion de Definitorio de la Corporación Recoletana
15	Sept.	1802	Shipwreck of the *Nautilus* of Calcuta
	Sept.	1803	Piddington map
	Sept.	1809	Piddington map
	Sept.	1810	Piddington map
	Sept.	1812	Piddington map
	Sept.	1819	Piddington map
	Sept.	1820	Piddington map
	Sept.	1826	Historical records of Lumban?
	Sept.	1830	Chronicles of the time?
	Sept.	1839	Historical records of Lumban?
	Sept.	1842	Parochial archives of Las Piñas, Rizal province
1	Sept.	1848	Report of Vice Admiral Julien de la Gabiere on board of *Bayonnaise*
23	Sept.	1855	Report of educated person who had lived for many years on the Marianas, published on 1870?
	Oct.	1566	Logbook of *S. Jerónimo*
3	Oct.	1596	Report of the Galleon *S. Felipe*
4	Oct.	1598	Letter of Fr. Diego Abuarte O.P. on a private expedition to China
27	Oct.	1599	Report of historian Fr. Chirino S.J.
5	Oct.	1649	Shipwreck of the Galleon *N^a^ S^a^ de la Encarnación*[b]
18	Oct.	1711	History of the Philippines by Rev. Father Pedro Murillo
23	Oct.	1766	French translation made by the astronomer Le Gentil of a letter of the governor of the province of Albay to the Fiscal in Manila
23	Oct.	1767	Le Gentil report while at Manila
2	Oct.	1795	Letter of the Governor-General to the Duke of Alcudia
	Oct.	1797	Report of the shipwreck of the Galleon *S. Andrés*, made by the historians José Montero y Vidal and Zúñiga
	Oct.	1801	Report in the parochial archives of Bacolod, Western Negros
	Oct.	1804	Report of the Russian admiral Krusenstern on board of the corvettes *Nadicjada* and *Neva*
	Oct.	1819	Piddington map
	Oct.	1821	Piddington map
17	Oct.	1821	Report of the corvette *Fidelidad*
26	Oct.	1827	Report of the Governor-General

Table 1. (continued)

Day	Month	Year	Source
16	Oct.	1829	Report of the Regente, ship of the East India Company
	Oct.	1832	Piddington map
	Oct.	1833	Piddington map
28	Oct.	1838	Report of the Governor of Marianas to the Governor of Philippines
28	Oct.	1843	Letter of the Rector of the Royal seminary of S. Carlos to the Archbishop of Manila
7	Oct.	1844	Letter of the Governor of Philippines
	Nov.	1608	Edifying Letters of the Jesuits Missionaries
1	Nov.	1610	Annual Litterae of the Province of Philippines by Fr. Gregorio López
10	Nov.	1638	*Sucesos de Filipinas*, probably written by Juan López S.J.
25	Nov.	1659	History of the Philippines by Rev. Father Pedro Murillo
1	Nov.	1742	Manuscript dated 1743 and written in Manila
	Nov.	1780	Biography of Fr. Juan Huy de los Santos, a Chinese Dominican
1	Nov.	1824	Letter of the Governor of Philippines
	Nov.	1841	Piddington map
3	Nov.	1845	Books of the parochial archives of Imus, Cavite
8	Nov.	1858	A suit instituted in the court of Manila
11	Dec.	1734	A manuscript which narrates the principal events that took place in Balayan, Batangas
4	Dec.	1748	History of the Philippines by Rev. Father Pedro Murillo
	Dec.	1752	Certificate of death from the parochial books of Sariaya
3	Dec.	1754	Edifying letters
8	Dec.	1766	Le Gentil report
18	Dec.	1833	Letter of the Governor-General
13	Dec.	1838	Letter of the Governor-General
	Dec.	1865	Letter of the Governor of Burias

[a]The references to the Galleon included in this chronology have been checked against the documents used in the work of *García et al.* [2001].
[b]They were referenced correctly.
[c]They had not been found in the previous work.
[d]A dating problem in Selga.

Father Pedro Murillo. The Piddington maps are included in a classic book titled *The Sailors Handbook for the Law of Storms*, written by *Piddington* [1876], the president of the Marine Courts at Calcutta in the mid-19th century. He was the first to use the term ‘‘cyclone’’ to refer to the tropical weather phenomenon we now call hurricanes or typhoons. The *History of the Philippines* [*Murillo*, 1749] was written by a Jesuit and provides a comprehensive account of the Jesuits’ activities in the archipelago during the period 1616–1716.

[14] An assessment of the accuracy of the reports is not easy to make. However, we have some proof that they were written with special care. In a previous work [*García et al.*, 2001], original records of the Manila Galleon kept in Spanish archives were used to infer changes in the circulation on the Pacific during the 17th and 18th centuries. The references to the Galleon included in this chronology have been checked against the documents used by *García et al.* [2001]. It has been found that eight of them (footnote a in Table 1) were referenced correctly, two (footnote b in Table 1) are not found in the previous work, and one (footnote c in Table 1) showed a dating problem with Selga. He dated this typhoon as occurring in 1603, whereas the documents kept in the Archivo de Indias in Spain (AGI Mex 25, N62) showed that it really happened in 1602. Thus, the references seem reasonably accurate.

[15] The British sources cited in the chronology have also been checked. Thus, we have examined the original reports of the ships *Cygnet*, *Antelope*, and *Centurion* cited in Table 1. All of them used the term ‘‘storm,’’ which was only used for very severe wind conditions. The *Centurion* report also includes the term ‘‘hard gales,’’ which is comparable to Beaufort force 10 (about 50 knots) winds. In the case of the *Cygnet*, the source describes the ship sailing under ‘‘bare poles’’ (with no sails at all), which was only done at Beaufort force 10 or higher. Thus, all three reports are compatible with typhoon strength winds.

[16] Starting around 1850, the reliability of the reports seems to increase. Most of the reports come from direct observations from the main observatory, the secondary Philippine network, and the associated observatories (more details are provided below); only in three cases are from documentary sources. In fact, during this last period, the descriptions become more systematic and start to include instrumental values, mostly barometer readings.

[17] Additional references can also be traced in the Spanish archives. Thus, the typhoon that occurred in 17–26 January 1895, and according to Selga destroyed the island of Yap, is described in a document of almost 400 pages in the Archivo Central de la Marina (ACM 3618, 79) in the Judicial Causes section. This document includes all the administrative actions and procedures taken by the Spanish military courts in affairs related to the damages produced by this typhoon.

4. Chronology

[18] The typhoon chronology constructed by Selga was originally published in 1935 by the Philippine Weather Bureau, under the title *Catalogue of Typhoons 1348–1934* as an addenda of the *Charts of Remarkable Typhoons in the Philippines 1902–1934*. It has not been fully examined up to now [*Bankoff*, 2003]. A previous paper [*Ribera et al.* 2005] analyzed the most recent part of the chronology (1901–1934), which includes mostly direct instrumental observations made by the Manila Observatory and its

Table 2. Instrumental Observations of the Selga Chronology (Year, Month, Pressure, and Location)

Year	Month	Pressure, mm Hg/hPa	Location
1797	June	736.0/981.0	Macao?
1804	1 Oct	680/906.4	Russian corvettes *Nadicjada* and *Neva*
1809	Sept	749.30/998.7	Logbook of *Scalesby Castle* (Piddington)
1810	Sept	741.68/988.6	On board of *Winchelsea* (Piddington)
1812	Sept	740.41/986.9	On board of *Werford* (Piddington)
1838	18–19 Dec	740/986.3	Camarines or Albay
1848	13–14 Dec	748.79/998.1	Manila
1858	18–19 Aug	744.5/992.3	On board of *Novara*
1862	June	726.44/968.3	Macao
1865	7–12 Nov	742.64/989.9	Manila
1865	15–17 Dec	747.32/996.1	Manila
1866	April	745.62/993.8	Manila
1867	20–26 Sept	737.30/982.7	Manila
1868	20–24 Nov	747.47/996.3	Manila
		740.00/986.3	Bayomborg
1870	3 Nov	714.00/951.7	Tuguegarao
		743.52/991.0	Albay
1871	June	746/994.3	Naga
1871	29 Sept	711/947.7	Naga
1873	27 Sept	740.41/986.9	Marianas
1873	28 Oct	716/954.4	Masbate
1874	3–4 Sept	730.9/974.2	Port of Vigan
1874	21–22 Sept	724/965.0	Port of Vigan
1874	28 Sept	739/985.0	Sto. Domingo Basco
1875	24–31 Oct	744.21/992.0	Brig Progreso
			Manila Bay
1879	19–21 Nov	713.00/950.4	E. Mindoro
1880	18–22 Oct	727.60/969.8	Manila Bay
1881	May	741/987.7	Steamship *Elguin*
1881	9–14 Aug	723.0/963.7	On board steamer *Friederic*, 29.6°N, 128°E
1881	19–20 Aug	742.0/989.0	Baler
		746.0/994.3	
1881	24–28 Aug	747/995.7	Zikawei
1881	5–8 Sept	736.59/981.8	Tainanfu
			Formosa
1881	27 Sept–6 Oct	717.50/956.4	Steamer *Fleurscastle*
1881	10–14 Oct	718.9/958.2	Steamship *Oaklands*, near Pratas
1882	27 Sept–6 Oct	728.0/970.3	Steamer *Tanais*
1882	23–27 Oct	726.43/968.3	Bark *Caridad*
1883	April	732.10/975.8	Taganaan
1883	28–31 Oct	747.8/996.7	Manila
1885	July	723.6/964.5	Steamship
1885	18–26 Aug	724.5/965.7	Ocksan
1886	5–9 Sept	716.0/954.4	Steamer *Killarnay* at 21°N,128°E
1886	14–18 Oct	731.51/975.0	Steamship *Proponti*
1887	May	721.00/961.0	Brig *Alic Bowe*
1887	July	728.8/971.4	Nagasaki
1887	5–9 Sept	720/959.7	Sea at 20.5°N and 119°E
1890	28 Sept–3 Oct	738.05/983.7	Region of Albay
1890	7–13 Nov	742.85/990.1	Tabaco
		741.9/988.9	Streamship *Mount Hebron*
1891	19–25 Sept	745.8/994.1	Aparri
1891	27–28 Oct	736.0/981.0	Guam
1893	10–12 Sept	746.5/995.0	Aparri
		717.28/956.1	South Cape, Formosa
1893	28 Sept–3 Oct	705.0/939.7	Cabragan Viejo and others
1894	1–12 Aug	728.2/970.6	Hamamatsu Japon?
		743.7/991.3	Nemuro?
1894	15–18 Sept	736.8/982.1	S. Isidro
1894	16–25 Sept	742.4/989.5	Macao
1894	30 Sept–6 Oct	740.2/986.6	S. Fdo Union
1894	8–11 Nov	730.3/973.4	Aparri
1895	January	729.4/972.2	Yap
1895	July	713.0/950.4	Nagasaki
1895	28 Aug–9 Sep	717.7/956.6	7 Sept, Kagoshima
1895	13–19 Sept	731.0/974.3	Takow, Formosa
1895	28 Oct–2 Nov	733.3/977.4	Tuguegarao
1895	18–22 Nov	730.6/973.8	Guam
1896	July	733.0/977.0	Hong Kong
1896	28 Sept–7 Oct	726.4/968.2	Steamer *Strathllam*, 23°N and 112°E
1896	19–20 Oct	742.65/989.9	Aparri
1897	9–18 Sept	729.5/972.3	Haichow?
1897	7–16 Oct	710.00/946.4	Guiam, Samar

Table 2. (continued)

Year	Month	Pressure, mm Hg/hPa	Location
1898	28 May–5 June	722.9/963.5	Laoang (N Samar)
		741.6/988.5	Albay
		631.7/842.0	Koshun (Formosa)
1898	July	742/989.0	Hainan
1898	13–16 Aug	725.6/967.1	Kagoshima
1898	1–3 Oct	723.7/964.6	Transport *Siam*, near NE Luzon
1899	2–10 July	727.9/970.2	Naha
		717.2/956.0	Oshima
		728.5/971.0	Nagasaki
1899	15–26 July	735.8/980.7	Naha
		736.6/981.8	Shanghai
		739.0/985.0	Tokio
		733.0/977.0	Choshi
1899	31 July–6 Aug	725.1/966.5	Taichu Formosa
1899	15–22 Aug	715.9/954.2	Koshum
1899	3–8 Oct	721.4/961.6	Steamship *Columbia*
		715.8/954.1	Steamship *Ketat*

associated network, acting as the Philippines' meteorological agency [*Udías*, 2003]. As shown below, the records for the period analyzed in this paper come mostly from historical reports, included in part C of Selga's catalogue, which is described by the author as "…an abridged enumeration of the storms and typhoons as described by old chroniclers or described by contemporary documents." In practice, this really covers the period 1566–1900 because there is only one reference to a typhoon prior to 1566. The information of this early typhoon, dated to 1348, comes from the diary of the classical Arab traveler Ibn Batuta, and it should be considered anecdotal. The catalogue is structured monthly, providing for every month a list of typhoons, ordered chronologically and with a report, which usually includes the dates of occurrence and the landfall point or the affected area. A total of 652 events are included; of them, 533 are reported as typhoons. For the rest, the term "storm" or "depression" is mostly used. In 606 cases (93% of the total), the identification includes complete dating (day, month, and year); for the rest, only month and year are provided. Thus, it is a high-resolution chronology. As a first step, a database with the complete chronology was built. It contains for every reported typhoon/storm information on date and landfall location. The complete textual description is also included. It can be freely obtained at http://www.ucm.es/info/tropical.

[19] The nature of these reports varies considerably, depending on the date and the amount of available information. Thus, very succinct reports can be found, such as that corresponding to the typhoon of 1–3 November 1893: "A typhoon appeared to the SE of Manila and partially filled up, entering the Archipelago, continuing westward as a depression." On the other hand, there are very vivid and detailed reports, such as that from 1 November 1742. In a manuscript dated 1743 and written in Manila, we read the following account:

> On All Saints' Day of the last year, 1742, we experienced such a storm as never before had been seen in Manila. It caused the greatest destruction to the churches and houses of the Society of Jesus. In our church, some arches were damaged. The big window of the choir with its frame was forced in; the rain rushed in and the church was so full of water that mass could not be said on some of the altars the next day. The corridors of many houses were destroyed, and in a word, there is scarcely a roof in Manila that is not damaged

The analysis of these reports allows one to infer the intensity of the event only in these very detailed reports, but not in a general way. Therefore in many cases, one needs to trust Selga's judgment. In some cases, the report is accompanied by instrumental observations.

[20] Table 2 shows all the cases for which instrumental observations are provided. It can be seen that the pressure readings vary between 749.3 mm Hg (on board of the ship named *Scalesby Castle* in September 1809) and 631.7 mm Hg (in Koshun, Formosa, in June 1898; Formosa is the old Portuguese name for Taiwan). Figure 1 shows their distribution according to the Saffir–Simpson Scale. To fit the intensity of TCs to Saffir–Simpson categories, we have used the minimum central pressure entry from the table contributed by Chris Landsea and available at http://www.aoml.noaa.gov/hrd/tcfaq/D1.html. The interpretation of Figure 1 must be cautious; first, because the Saffir–Simpson scale is of limited use in the western Pacific basin [*Simpson and Riehl*, 1981], and second, because the reported pressure values do not correspond to the minimum associated with every particular TC, but to the measurements available in each case. However, it can be seen that all are within the range of tropical storms and hurricanes and can help in the process of assessing the intensity of every particular TC.

[21] Of the total 524 typhoons included in this chronology, the distribution is as follows: 4 correspond to the 16th century, 23 to the 17th, 35 to the 18th, 40 to the first half of the 19th, and 422 to the second half of the 19th. Figure 2 shows the annual frequency of the typhoons and typhoons + storms for the periods 1566–1715 (Figure 2a), 1716–1865 (Figure 2b), and 1866–1900 (Figure 2c) identified in the whole western Pacific area. The first two periods are of identical length to simplify the display, but the last period is shorter because of the much more detailed record of typhoons compared to the previous periods. The annual

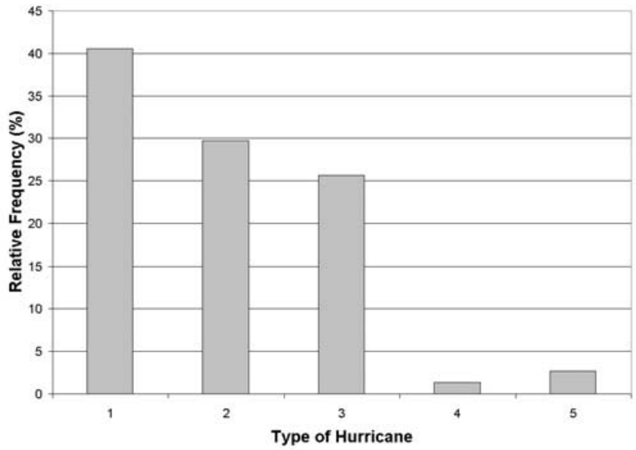

Figure 1. Distribution of the typhoons intensity according to the Saffir–Simpson scale for those typhoons with instrumental measurements available (the Saffir–Simpson hurricane scale is a 1–5 rating based on the hurricane's present intensity. It is mainly based in wind speed, and it is used to give an estimate of the potential property damage and flooding expected from a landfalling hurricane).

frequency of typhoons and storms shows a small range of variability until 1865, with an average frequency of 0.38 (0.44 for T + S). Between 1877 and 1887, the annual frequency of identified typhoons shows a dramatic increase, reaching as many as 20 typhoons and more than 30 typhoons plus storms per year after 1880. From 1887 until 1900, there is noticeable interannual variability in the number of typhoons, but without a clear trend and with an average close to 20/30 [typhoons/(typhoons + storms)]. These values are only slightly different than modern average annual frequency for the western Pacific. According to *Yumoto and Matsuura* [2001], between 1951 and 1999, the annual number of typhoons plus storms formed in the whole Western North Pacific (WNP) basis is about 28, and the number of typhoons (those storms with velocity higher than 33 m/s) is about 15. In recent years, if only those typhoons and storms crossing through the Philippines are counted, the mean annual numbers are reduced to about 5 typhoons and 10 storms plus typhoons. Thus, for the period prior to 1865, the chronology clearly underestimates the real frequency of typhoons in the western Pacific area.

[22] Therefore the Selga series has two different changes (one more evident in 1865 and a smaller one in 1880, only for typhoons making landfall in the Philippines). The explanation for the first and most important change seems to be the formal establishment of the Manila Observatory in 1865. This produced an increase and standardization of the observations, the development of a network of secondary observations covering most of the Philippine territory, and the interchange of information with other observatories of the area, such as Zikawei (near Shanghai and also run by the Jesuits), Hong Kong, or Japan. This can be corroborated in the chronology as an increase during this period of the references to locations outside the Philippines. Some examples help to demonstrate the point: thus the typhoon of 12–17 October 1889, which is cited as "A typhoon appeared in the China Sea NW of Luzon, moved to WNW and entered the continent NE of Hong Kong." Similarly, for

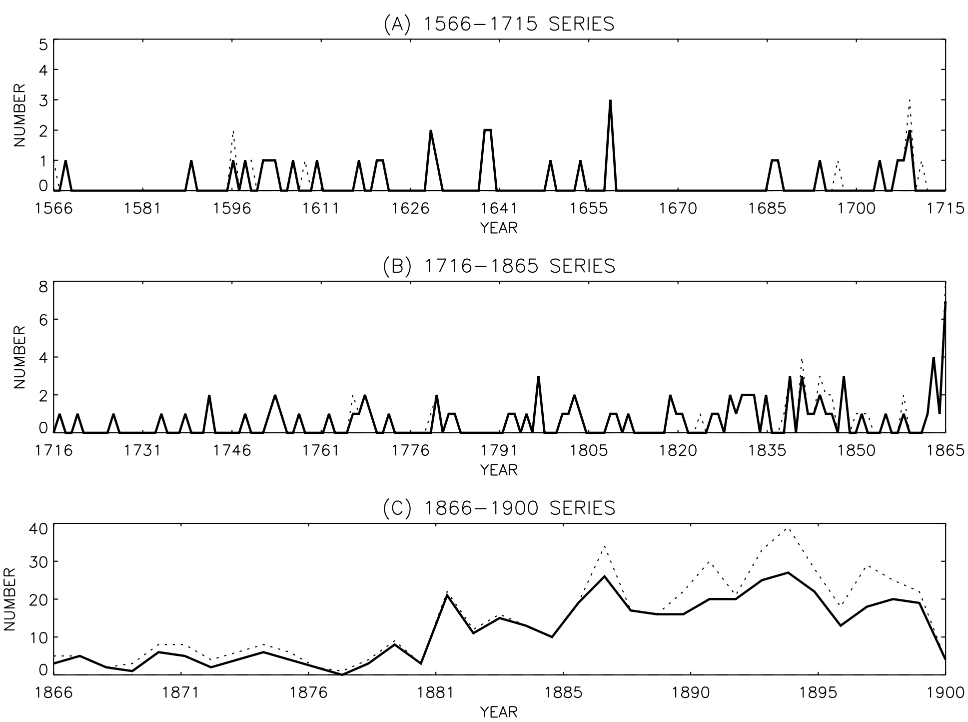

Figure 2. Annual frequency of the tropical storms over the northwest Pacific for the periods (a) 1566–1715, (b) 1716–1865, and (c) 1866–1900 (solid line: only typhoons; light dotted line: all the tropical storms).

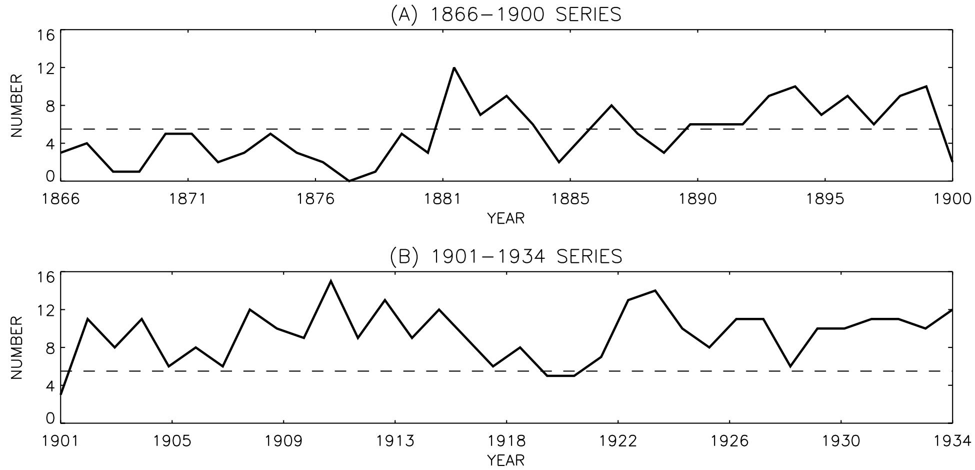

Figure 3. Annual frequency of typhoons landfalling in the Philippines for the period (a) 1866–1900 and (b) 1901–1934.

9–16 September 1891, the citation reads: "Appearing NE of Luzon, the typhoon, moving in a WNW direction, approached S Formosa and recurved to the NE; then it followed the coast of Japan bordering the Japan Sea and finally crossed Hokkaido to the ENE."

[23] Table 2 also illustrates the effective working of the meteorological network in the Philippines and interchange with other observatories. Thus, of a total of 82 pressure readings, 7 came from Manila, 23 from the rest of the islands, 29 from other locations outside the islands, and, remarkably, 21 from different ships traveling in the area.

[24] However, the origin of Selga's sources suggests that the highest representativity of the chronology should be for typhoons making landfall in the Philippines. Figure 3 shows the annual frequency of the typhoons making landfall in the Philippines for 1866–1900 and 1901–1934 (Selga's chronology). There is a slight increase in the number of identified typhoons making landfall in the Philippines from the first to the second period. Therefore the average for the period 1866–1900 is about 5.5 landfalling typhoons per year (dashed line in Figures 3a and 3b). It is observed that the annual number of typhoons is lower than this value for almost all the period 1866–1881 and higher, with the exception of only 3 years for the period 1880–1900. Finally, it is interesting to notice that both numbers are slightly different than the annual mean number of typhoons reaching the Philippines per year obtained for the 1951–1999 period with data from the "Joint Typhoon Warning Center Best Track Data" (Data from the "Naval Pacific Meteorology and Oceanography Center" (https://metoc.npmoc.navy.mil/jtwc/best_tracks/wpindex.html)). This could be due to the extension of the area reporting typhoons included in Selga's Chronology toward South China, Korea, and Japan, especially the data from the very late 19th century and the 20th century.

[25] The monthly distribution has also been computed for the four series. Figure 4 shows the relative frequencies for the Philippine landfalling typhoons extracted from the Selga Chronology in the period 1566–1864 (S1) and 1865–1900 (S2), and from the "Joint Typhoon Warning Center Best Track Data" in the period 1951–1999 (U1), as well as the monthly distribution of typhoons in the whole WNP area for this same period (U2). In order to permit a direct comparison among the four distributions, they have been normalized by dividing the number of typhoons in a given month by the total number of typhoons during the whole period. It can be seen that all of them show a minimum incidence in February; however, they peak at different months: September and October (S1 and U2), September (S2), and August (U1). A chi-square test shows that the monthly relative frequency distributions are significantly different ($p < 0.05$). It also shows that the discrepancy is due to three months (August, November, and December). If we remove them, there are no significant differences among the four series at $p < 0.05$. Additionally, when comparisons are performed two by two, it is observed that only S2 (1865–1900) and U1 (instrumental, whole WNP area) show a statistically differ-

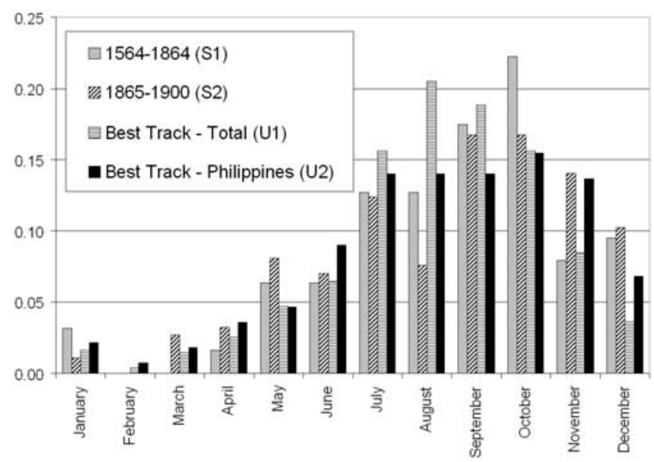

Figure 4. Normalized monthly typhoons for the typhoons landfalling in the Philippines in 1564–1864 (S1), in 1865–1900 (S2), in the whole Western North Pacific basin (U1), and landfalling in the Philippines in the 1951–1999 period (U2) (data for the recent period from the "Joint Typhoon Warning Center Best Track Data").

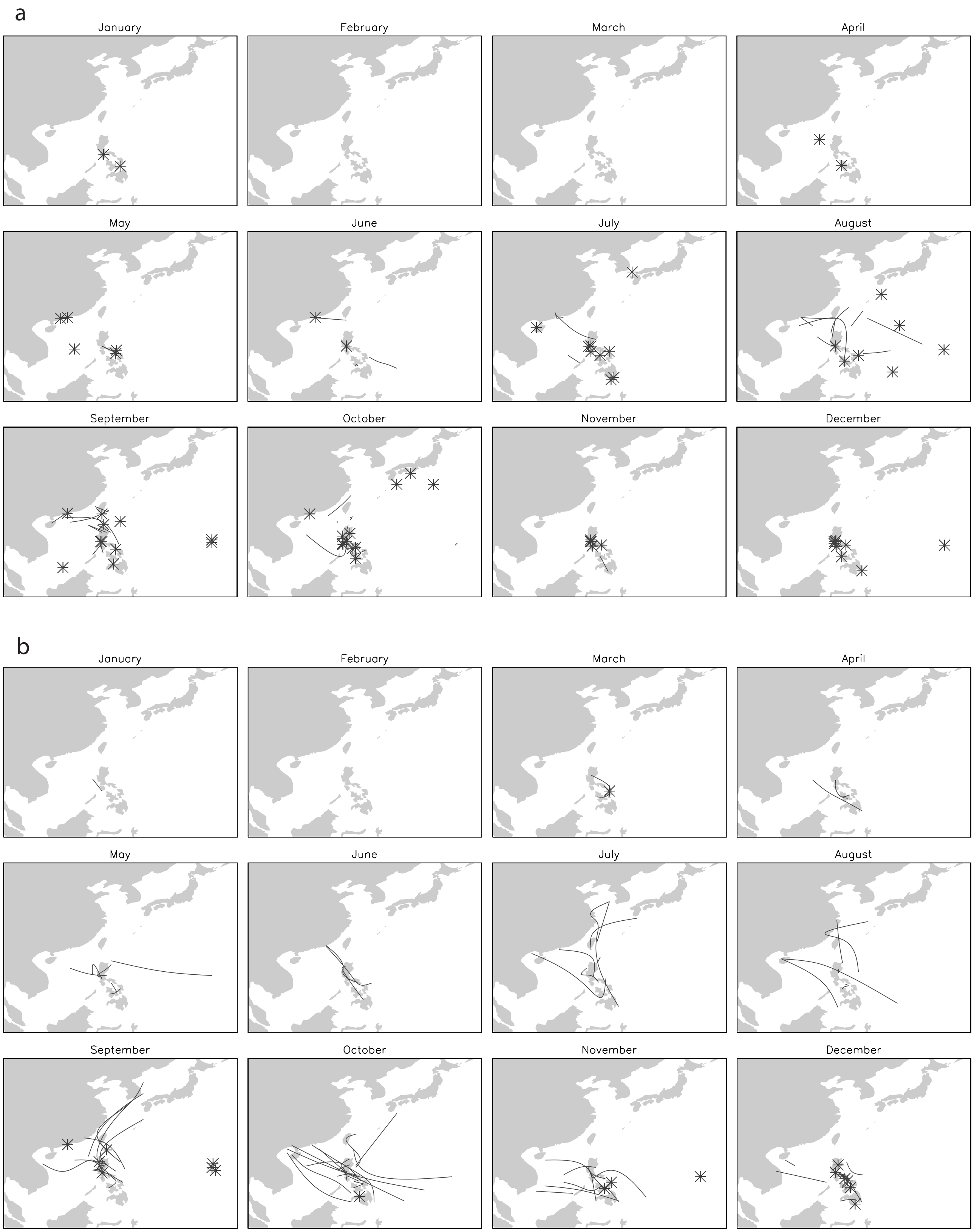

Figure 5. Typhoons trajectories identified by Selga for (a) 1564–1864, (b) 1865–1882, and (c) 1883–1900.

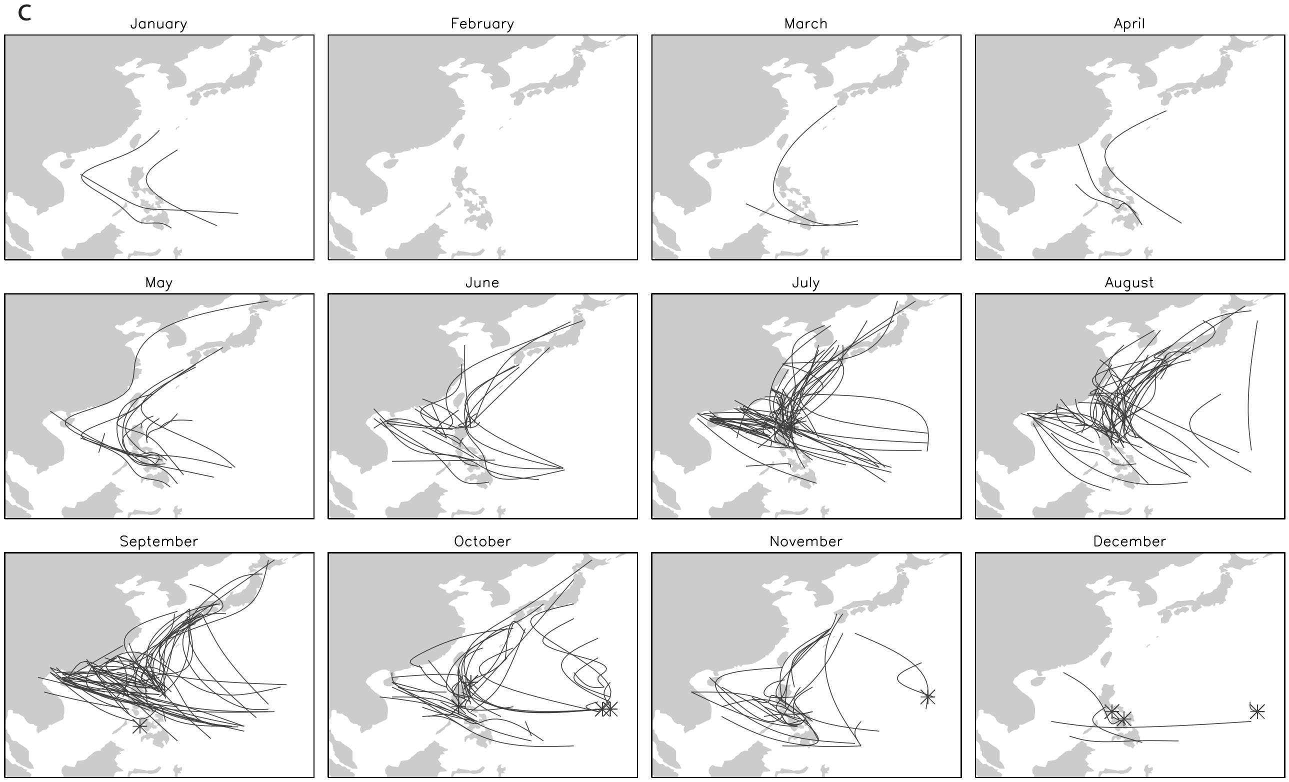

Figure 5. (continued)

ent distribution ($p < 0.05$), and, once again, differences are mainly due to August, November, and December.

[26] The approximate trajectories of all the typhoons identified by Selga for different subperiods in the different months are shown in Figure 5. They have been computed as "best guess" after applying a spline method using the available points for every storm. Some cases are well documented and have as much as seven different locations, whereas other cases have been documented only at one location.

5. Discussion

[27] Selga's Chronology is an invaluable starting point for obtaining a complete typhoon chronology in the Pacific. It provides high-resolution and reliable information on a total of 652 typhoons and tropical storms in the western Pacific area. It cannot be considered a complete chronology for the whole period, but the results of this paper suggest that since 1865, and especially since 1880, it provides a rather complete picture of the landfalling occurrences in the Philippines.

[28] The results for the previous sections suggest that, though incomplete, the series provides accurate information and exhibits similar variability to the present-day climatology, as evidenced in the monthly distribution. The series shows two main periods with no records of typhoons: 1568–1589 and 1659–1686. There is not enough information to properly evaluate if they correspond to a period of low typhoons incidence or if they just reflect the lack of appropriate records. However, the second interval partly coincides with a period when the location of the Pacific monsoon trough was inferred to be anomalous [*García et al.*, 2001], being displaced southward of its climatological location. *Liu et al.* [2001] showed an increased frequency of typhoons making landfall in the Guandong province of China for the second half of the 17th century. Therefore the lack of records during this second period could be reflecting a change in the TC trajectories in the western Pacific. However, this is a mere suggestion since the series cannot be considered as complete.

[29] The compilation of a complete TC chronology for the western Pacific would require a multidisciplinary approach, combining different techniques. For the historical period, an intensive search of the available documentary sources would be required. Previous works have identified archives with relevant sources, as is the case for the Chinese coast [*Liu et al.*, 2001]. In Spain, a number of archives have been identified. Apart from the local archives in the Philippines, a number of Spanish archives contain abundant information on the Spanish colonial administration in the islands. The most relevant of these are *Archivo General de Indias*, *Archivo del Museo Naval*, *Archivo Central de la Marina*, and *Archivo Histórico Nacional*. The combined use of these and additional sources will allow to continue the pioneering work made by Selga.

Appendix A: Main Archives in Spain with Documents Relevant to Climate Reconstruction More Details in the Work by *Garcia et al.* [2001] and Style of Their References

[30] The *Archivo General de Indias* (General Archive of the Indies; AGI, http://www.mcu.es/jsp/plantillaAncho_wai.jsp?id = 61&area = archivos) keeps most of the documents from the colonial administration of Spanish America

and the Philippines. It was founded in the late 18th century, during the reign of Carlos III, who decided to join scattered collections of documents, as well as material previously stored in the National Archive at Simancas, in Valladolid. He chose the *Lonja de Mercaderes* (Merchants' Meeting House) of Seville to house the new collection. The building had served previously as headquarters of the commercial and administrative activities between Spain and the New World during the 17th and early 18th centuries. The collection now contains over 80 million pages of original writings, encompassing all aspects of military, commercial, and cultural relations between Spain and its American colonies. It is divided into sections, according to their administrative origin, and roughly corresponds to former units of the Spanish administration, such as *Justicia* (Justice), which contains most of the records from the different courts or *Contaduría* (Account), dealing with the financial administration documents. *García et al.*'s [2001] Table 1 shows the current organization of the AGI, together with the number of "legajos," or manuscript bundles, contained in each section and the range of dates covered. Each legajo consists of a group of related documents and averages some 1500–2000 manuscript pages.

[31] The *Archivo del Museo Naval* (Archive of the Naval Museum, AMN, http://www.museonavalmadrid.com/Archivo) is a military archive, the main historical archive of the Spanish Navy. It was created in 1930 collecting in the museum the manuscripts and maps from the previous *Depósito Hidrográfico* (Hydrographic Deposit) that had been receiving logbooks and reports from different naval missions and expeditions since the end of the 18th century. Then it was completed with documents from other collections, such as the *Real Compañía de Guardamarinas* (Royal Company of Navy Cadets). The oldest documents are dated in the 10th century, but most of the collections correspond to the 18th and 19th centuries.

[32] The organization of the archives, according to administrative criteria, makes the search of climatic information a complex task since, usually, several sections must be searched in order to abstract all the evidences from a certain area and period of time.

[33] **Acknowledgments.** This paper was partially supported by the Risk Prediction Initiative, under grant RPI02-2-009. The authors wish to thank F. Koek for providing a copy of the original Selga paper. A. Udías discussed enthusiastically part of the manuscript and provided material to understand the Jesuits' role in the meteorological observations in the Philippines. D. Wheeler and C. Wilkinson provided records of the English logbooks. Three anonymous reviewers provided useful suggestions that improved the original manuscript.

References

Baldwin, M. P., et al. (2001), The Quasi-Biennial Oscillation, *Rev. Geophys.*, *39*, 179–229.

Bankoff, G. (2003), *Cultures of Disaster: Society and Natural Hazards in the Philippines*, p. 256, Routledge Curzon, London.

Chan, J. C. L., and J. E. Shi (2000), Frequency of typhoon landfall over Guandong Province of China during the period 1470–1931, *Int. J. Climatol.*, *20*, 183–190.

Chenoweth, M. (2005), Reassessment of historical Atlantic tropical cyclones, *Clim. Change*, in press.

Chenoweth, M. (2006), A reassessment of historical Atlantic basin tropical cyclone activity, 1700–1855, *Clim. Change*, *76*, 169–240, doi:10.1007/s10584-005-9005-2.

Díaz, H. F., and V. Markgraff (Eds.) (2000), *El Niño and the Southern Oscillation*, p. 496, Cambridge Univ. Press, New York.

Díaz, H. F., and R. S. Pulwarty (Eds.) (1997), *Hurricanes. Climate and Socioeconomic Impacts*, 292 pp., Springer, New York.

Donnelly, J. P., et al. (2001), 700 year sedimentary record of intense hurricane landfalls in southern New England, *Geol. Soc. Am. Bull.*, *113*, 714–727.

Doyle, T. W., and L. E. Gorham (1996), Detecting hurricane impact and recovery from tree rings, in *Tree Rings, Environment, and Humanity*, edited by J. S. Dean, D. M. Meko, and T. W. Swetnam, pp. 405–412, Radiocarbon, Tucson, AZ.

Dunn, G. E., and B. I. Miller (1964), *Atlantic Hurricanes*, Louisiana State University Press, Baton Rouge.

Elsner, J. B., and B. H. Bossak (2001), Secular changes to the ENSO–U.S. hurricane relationship, *Geophys. Res. Lett.*, *28*, 4123–4126.

Elsner, J. B., K.-B. Liu, and B. Kocher (2000), Spatial variations in major U.S. hurricane activity: Statistics and a physical mechanism, *J. Clim.*, *13*, 2293–2305.

Fernández-Partagás, J., and H. F. Diaz (1996), Atlantic hurricanes in the second half of the nineteenth century, *Bull. Am. Meteorol. Soc.*, *77*(12), 2899–2906.

García, R. R., H. Díaz, R. García-Herrera, J. Eischeid, M. R. Prieto, E. Hernández, L. Gimeno, F. Rubio, and A. M. Bascary (2001), Atmospheric circulation changes in the tropical Pacific inferred from the voyages of the Manila galleons in the 16th–18th centuries, *Bull. Am. Meteorol. Soc.*, *82*, 2435–2455.

Gray, W. M. (1984), Atlantic seasonal hurricane frequency. Part I: El Niño and 30mb quasibiennial oscillation frequencies, *Mon. Weather Rev.*, *112*, 1649–1688.

Hurrell, J. W. (1995), Decadal trends in the North Atlantic Oscillation: Regional temperatures and precipitation, *Science*, *269*, 676–679.

Landsea, C. W. (2000), El Niño/Southern Oscillation and the seasonal predictability of tropical cyclones, in *El Niño and the Southern Oscillation*, edited by H. F. Díaz and V. Markgraf, 496 pp., Cambridge Univ. Press, New York.

Landsea, C. W., N. Nicholls, W. M. Gray, and L. A. Avila (1996), Downward trends in the frequency of intense Atlantic hurricanes during the past five decades, *Geophys. Res. Lett.*, *23*, 1697–1700.

Liu, K.-B., and M. L. Fearn (1993), Lake-sediment record of late Holocene hurricane activities from coastal Alabama, *Geology*, *21*, 793–796.

Liu, K.-B., and M. L. Fearn (2000a), Holocene history of catastrophic hurricanes landfalls along the Gulf of Mexico Coast reconstructed from coastal lake and marsh sediments, in *Current Stresses and Potential Vulnerabilities: Implications of Global Change for the Gulf Coast Region of the United States*, edited by Z. H. Ning and K. K. Abdollahi, 223 pp., Franklin Press, Baton Rouge.

Liu, K.-B., and M. L. Fearn (2000b), Reconstructions of prehistoric landfall frequencies of catastrophic hurricanes in northwestern Florida from lake sediment records, *Quat. Res.*, *54*, 238–245.

Liu, K.-B., C. Shen, and K.-S. Louie (2001), A 1000-year history of typhoon landfalls in Guandong, southern China, reconstructed from Chinese historical documentary records, *Ann. Assoc. Am. Geogr.*, *91*, 453–464.

Ludlum, D. M. (1963), *Early American Hurricanes, 1492–1870*, American Meteorological Society, Boston.

Madden, R. A., and P. R. Julian (1994), Observations of the 40–50 day tropical oscillation—A review, *Mon. Weather Rev.*, *122*(5), 814–837.

Millas, J. C. (1968), *Hurricanes of the Caribbean and Adjacent Regions, 1492–1800*, Academy of the Arts and Sciences of the Americas, Miami.

Murillo, P. (1749), Historia de la provincia de Philipinas de la Compañía de Jesus: Segunda parte que comprehende los progresos de esta provincia desde el año de 1616 hasta el de 1716, En la Imprenta de la Compañia de Jesus, por Nicolas de la Cruz Bagay, En Manila.

Neumann, C. J., B. R. Jarvinen, C. J. McAdie, and J. D. Elms (1993), *Tropical Cyclones of the North Atlantic Ocean, 1871–1992*, NOAA Historical Climatology Series 6-2, Asheville, NC.

Piddington, H. (1876), The sailors handbook for the law of storms, London.

Poey, A. (1862), Table chronologique de quatre cents cyclones, Paris, 66 pp.

Rappaport, E. N., and J. Fernández-Partagas (1997), History of the deadliest Atlantic tropical cyclones since the discovery of the New World in hurricanes, in Climate and Socioeconomic Impacts, edited by H. F. Díaz and R. S. Pulwarty, Springer, New York.

Ribera, P., R. García-Herrera, L. Gimeno, and E. Hernández (2005), Typhoons in the Philippine islands 1901–1934, *Clim. Res.*, *29*, 85–90.

Salivia, L. A. (1950), Historia de los temporales de Puerto Rico (1508–1949), p. 146, S. Juan.

Schutz, W. L. (1939), *The Manila Galleon*, 453 pp., E.P. Dutton & Company, New York.

Selga, M. (1935), *Charts of Remarkable Typhoons in the Philippines 1902–1934. Catalogue of Typhoons 1348–1934*, 55 pp., Manila Weather Bureau, Manila.

Simpson, R. H., and H. Riehl (1981), *The Hurricane and Its Impact*, 398 pp., Louisiana State Univ. Press, Baton Rouge.
Sobel, A. H., and E. D. Maloney (2000), Effect of ENSO and the MJO on western North Pacific tropical cyclones, *Geophys. Res. Lett.*, *27*, 1739–1742.
Spennemann, D. H. R., and I. C. Marschner (1994), Stormy years: On the association between the El Niño/Southern Oscillation phenomenon and the occurrence of typhoons in the Marshall Islands, report to the Federal Emergency Management Agency, Region IX, San Francisco, The Jonstone Centre of Parks, Recreation and Heritage, Charles Sturt University, Albury, NSW.
Tannehill, I. R. (1940), *Hurricanes: Their Nature and History*, Princeton Univ. Press, Princeton, NJ.
Udías, A. (1996), Jesuits' contribution to meteorology, *Bull. Am. Meteorol. Soc.*, *77*, 2307–2315.
Udías, A. (2003), *Searching the Heavens and the Earth. The History of Jesuit Observatories*, 369 pp., Springer, New York.
Yumoto, M., and T. Matsuura (2001), Interdecadal variability of tropical cyclone activity in the western North Pacific, *J. Meteorol. Soc. Jpn.*, *79*, 23–35.

R. García-Herrera and E. Hernández, Departamento Física de la Tierra II, Facultad de Ciencias Físicas, Universidad Complutense de Madrid, Ciudad Universitaria, 28040 Madrid, Spain. (rgarciah@fis.ucm.es)

L. Gimeno, Departamento de Física, Universidad de Vigo, Facultad de Ciencias de Ourense, As Lagoas s/n, E-32004, Ourense, Spain.

P. Ribera, Departamento de Sistemas Físicos, Químicos y Naturales, Universidad Pablo de Olavide, Carretera de Utrera, km 1, 41013 Seville, Spain.