Typhoons in the Philippine Islands, 1566-1900

Ricardo García-Herrera*, Pedro Ribera +, Emiliano Hernández * and Luis Gimeno **

* Dto Física de la Tierra II, Facultad de Ciencias Físicas, Universidad Complutense de Madrid, Ciudad Universitaria, 28040 Madrid, Spain.

+ Dto de Ciencias Ambientales, Universidad Pablo de Olavide, Carretera de Utrera, km 1, 41013 Sevilla, Spain.

** Dto de Física, Universidad de Vigo. Facultad de Ciencias de Ourense. As Lagoas s/n. 32004. Ourense. Spain

Abstract

Within the last years the population and the value of the properties in Tropical Cyclone (TC) prone areas 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 involved timescales, the instrumental records have demonstrated too short to provide a complete picture. Thus, documentary and other paleoclimatological techniques have been used to reconstruct TC occurrence. This has been mostly made in the Atlantic Basin, while in the Pacific basin less attempts have been made. The aim of this paper is to provide a high-resolution chronology of typhoons and intense storms occurring in the Philippines Islands and their vicinity for the period 1566-1900.

The original work was made by the Spanish Jesuit, Miguel Selga, 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, of them 533 are reported as *typhoons,* the rest being considered as tropical storms. For each of them the landfalling location and the track (when sufficient information is available) have been drawn. This chronology should be considered as an indispensable step towards the determination of a final and complete typhoon record over the Western Pacific Basin.

Introduction

In recent years, social interest in tropical cyclones has grown steadily. This has been due to a number of factors, above all being changes occurred in the tropical cyclones (TC) prone areas. Greater urbanization has lead to increasing and older populations and, dramatically increasing value of properties (Díaz and Pulwarty, 1997), specially concentrated in the Mexican Gulf and Western Pacific areas.

This social awareness has been accomplished by an increase in the scientific interest, due to the evidences that big scale oscillations, such as El Niño-Southern Oscillation (ENSO; Diaz 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, ENSO impact is not uniform in the different tropical basins; a warm ENSO episode can lead to increased frequency, as in the South Pacific and in the North Pacific between 140ºW and 160ºE, while in the North Atlantic, the Australian region and the

Northwest Pacific west of 160ºE, it is associated to lower frequencies (Landsea, 2000). An east phase QBO seems to reduce the 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 to more frequent TC (Sobel and Maloney, 2000). Additionally, tropical cyclones exhibit great variability, with significant millennial, multidecadal and interannual scales (Liu and Fern 2000a, Landsea 1996, Elsner and Bossak, 2001).

Since there is a relatively short record of hurricane incidence when compared with the involved timescales, a growing interest in reconstructing the behavior of storms and hurricanes for pre-instrumental and even prehistorical times has risen in the recent years, up to the point that a new discipline, called paleotempestology is growing.

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 (Millás 1968). The Spanish were quickly aware of the impact of hurricanes in the Caribbean area and promptly adopted the term *huracán* from the Carib language to describe the phenomenon. In the sixteenth century for example Fernandez de Oviedo wrote: *'Huracán, in the language of this island, 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-[1]). 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), Millás (1968), Salivia (1950), Neumann *et al* (1993), Rappaport and Fernández-Partagás (1997) and Fernández-Partagás and Díaz (1996) provide a comprehensive view of the information that can be obtained from such sources.

In the other basins less work has been done. However, Chinese documentary sources can provide the longest historical records of tropical cyclones, as has been recently shown by Chan and Shi (2000) and Liu et al (2001). Using these sources, they have been able to elaborate a 1000 years high resolution typhoon chronology for the province of Guandong. German historical records have also been used to reconstruct topical cyclones in the Marshall Islands, (Spennemann and Marschner, 1994), but they only trace back until 1840.

Other techniques have also been applied to reconstruct tropical cyclones, such as the use of sedimentary records (Liu and Fearn, 1993, 2000b; Donnelly 2001) or dendrochronology (Doyle and Gorham, 1996). These may have coarser resolution than the historical sources, but may provide records as far back as 5000y B.P.

This paper analyses the typhoon chronology of the Philippines elaborated in 1935 by the Spanish Jesuit Miguel Selga (1935). The next section

[1] AGI Indif. Gral. 108 -BIB. L.A. Siglo XVI stands for a manuscript kept at the Archivo

provides a brief account of Selga and the Jesuits meteorological activities in the Philippines. Then, the chronology is described; the sources are discussed in section 4, the paper ends with the discussion.

Miguel Selga

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 Ms478)[2]. There he provides a vivid description of more than 6 pages of *baguíos* (the native word for typhoons*).* '..*The indians of this area call Baguio to this type of hurricane, which in other part and in the East Indies are called typhoons. And all this means a very strong tempest. There use to be in these islands so numerous and so strong that neither Virgilio in his Eneid, nor Ovidius in his Ponto, nor any other poet that I have read reaches by one thousand miles to describe their rigors or their strength. We see them very often and we suffer*

General de Indias (AGI) with signature Indif. Gral. 108 -BIB. L.A. Siglo XVI.

[2] AMN Ms478 stands for a manuscript kept at the Archivo del Muso Naval (Madrid) with signature Ms478

so much, that even after experiencing them it seem impossible to believe. To say it briefly, when one of those baguíos runs (usually one of two every year), neither the trees are safe in the center 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 associated winds.

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 Company 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 area (Manila, Havana, Shanghai, mostly) made that different members of the Company such as B. Viñes, J. Algué and C.E. Deppermann produced some of the first and more interesting studies on tropical storms (Udias, 1996). The chronology presented in this paper is part of this tradition of rigorous scientific work made by the Jesuits.

The chronology

The typhoons chronology elaborated by Selga was originally published in 1935 by the Philippine Weather Bureau, with 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 analyzed up to now (Bankoff, 2003). This paper analyses its part C, described by the author as *'.. an abridged enumeration of the storms and typhoons as described by old chroniclers or described by contemporary documents'.* It really covers the period 1566-1900, because there is only one reference to a typhoon prior to this date. The information of this early typhoon, dated in 1348 comes from the diary of the classical Arab traveler, Ibn Batuta, and it can 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 landfalling point or the affected area. In some occasions the source where the information was obtained is also given. 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), in the rest month and year are provided. Thus, it is a high resolution chronology. As a previous step, a database with the complete chronology has been built. It contains for every reported typhoon/storm information on date and landfalling location. The textual complete description is also included. It can be freely obtained at http://www.ucm.es/info/tropical.

The nature of these reports varies considerably, depending on the date and the amount of available information. Thus, very succinct reports can be found, as that corresponding to the typhoon on November 1-3, 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 November 1, 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 to infer the intensity of the event only in these very detailed reports, but not in a general way. So, in many cases one needs to trust Selga judgment. In some cases, the report is accompanied by instrumental observations.

Table 1 shows all the cases when instrumental observations are provided. It can be seen that the pressure readings vary between 749.3 mm Hg (on board of the *Scales by Castle* on Sept 1809) and 631.7 mm Hg (in Koshun, Formosa on June 1898). Figure 1 shows their distribution according to the Saffir-Simpson Scale. Its interpretation must be cautious; firstly, because this scale is of limited use in the Western Pacific basin (Simpson and Riehl,1981), and secondly, because the reported values do not correspond to the minimum associated to every particular TC, but to the available measurements in each case. However, it can be seen that all are contained in the range of tropical storms and hurricanes and can help in the process of assessing the intensity of every particular TC.

Of the total 533 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 431 to the second half of the 19th. Figure 2 shows the annual frequency of the typhoons and typhoons+storms for the periods 1566-1715 (fig 2a), 1716-1865 (Fig 2b) and 1866-1900 (2c). Superimposed is the average annual frequency of typhoons and tropical storms landfalling in the Philippines (continuous line). This value has been computed for the 1945-2000 period from the UNISYS hurricanes database (http://weather.unisys.com/hurricane/w_pacific). The annual 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; 0.31 for Philippines landfallings), as compared with an average of 4.68 for the instrumental period. Since the 1860s, the figure shows a dramatic increase. This value is higher than the landfalling average, but lower than the total for the Western Pacific (28.07). Thus, for the period prior to 1865, the chronology seems to underestimate the real frequency of landfalling typhoons in the Islands.

The main explanation for this 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 Philippines 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 out of the Philippines (see figure 5). Some examples help to demonstrate it: thus the typhoon on October 12-17 1889, which is referred as : *'A typhoon appeared in*

the China Sea NW of Luzon, moved to WNW and entered the continent NE of Hong Kong'. Similarly, for September, 9-16, 1891, it is quoted as: *'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'*.

Table 1 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 come from Manila, 23 from the rest of the Islands, 29 from other locations outside the Islands, and, remarkably, 21 from different ships while traveling in the area.

Thus, during the 1865-1900 period, the record should be considered as indicative of the total typhoon incidence in the W-P basin. In fact, if the Philippine landfalling typhoons are extracted from the chronology, the average value is 5.44, which is comparable to the instrumental period.

To evaluate the predominant time scales involved in these series, a wavelet analysis has been performed according to the methodology described by Torrence and Combo (1998). Only the landfalling instrumental series (fig 3a) and the series corresponding to the period 1566-1864 (figure 3b) show significant values. In the first case the significant periodicities are in the 3, 8 and 10-12 years bands, while in the second, the 8-12 and 16 years are the most significant. In both cases, it can be seen that they are limited to certain periods (1965-1975) during the modern records and 1620-1640 and 1740-1770 for the historical record), with most of the series free of any significant periodicity.

The monthly distribution has also been computed for the three series. Figure 4 shows the relative frequencies for the 1566-1864 Selga (S1), 1865-1901 (S2), the Unisys Philippine landfalling 1945-2000 (UP). In order to permit a direct comparison among the three 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), September (S2) and August (UP). The approximate trajectories of the typhoons for different subperiods in the different months is shown in figure 5. February is the month with less typhoons, while August, September and October are characterized by the highest typhoon occurrence. It is also evident the expansion of the observatories reporting typhoons to Manila since 1865, and specially from the mid 1880s. A chi-square test shows that the monthly relative frequency distribution does doe not differ in any of the three series (S1, S2, UP) at $p<0.01$.

Sources of the chronology

It is interesting to analyze the sources used by Selga when constructing his Chronology. Unfortunately, he does not cite his sources in an identifiable way, rather, he quotes: (p. 3) *'Part C gives an abridged enumeration of the storms and typhoons as described by old chroniclers or reported in contemporary documents. 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'.

However, in 90 records a source is explicitly cited. They have been included in table 2. It can be seen that in 59 cases a primary sources is cited, while 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 with ship incidences, mostly letters of the Governors referred to the Manila Galleon, the main connection of the Philippines with Mexico, and which had an enormous importance for the life of the colony (Schutz, 1939). Another 20 references come from church documents, mostly Jesuits letters. The rest is a miscellaneous of administrative documents.

Of the secondary sources, the most used are the Piddington maps and the History of the Philippines by Rev. Father Pedro Murillo. The Piddington maps are included in a classic book titled *The sailors handbook for the law of storms* and written by Henry Piddington (1876). He was the first to use the term "cyclone" to refer to the tropical weather phenomenon we now call hurricanes or typhoons. He was the president of the Marine Courts at Calcutta in the mid-19th century. The *History of Philippines* (Murillo, 1749) was written by a Jesuits and provides a comprehensive account of the Jesuits activities in the Archipelago during the period 1616-1716.

It is interesting to note that only in 3 cases the documentary evidences correspond to the period after 1850, which reinforces the idea that during the last period, the data come mostly from direct observations, either in the

Philippines or in the vicinities. The descriptions become more systematic and start to include instrumental values, mostly barometer readings.

The assessment of the accuracy of the reports is not easy to make. However, we have some proof that it was made 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 in García et al 2001. It has been found that 8 of them (marked with * in the table) were referenced correctly, 2 (marked with ** in the table) had not been found in the previous work and one (marked with *** in the table) showed a dating problem in Selga. He dates this typhoon as occurring in 1603, while the documents kept in the Archivo de Indias in Spain (refs AGI Mex 25, N62) show that it really happened in 1602. So, the references seem reasonably accurate.

The British sources have also been checked. Thus, we have examined the original reports of the *Cygnet, Antelope* and *Centurion*, cited in table 2. All of them use the term *storm* which was only used for very severe wind conditions. The *Centurion* report also includes the term *hard gales*, which can be assimilated to Beaufort Force 10. In the case of the *Cygnet,* they describe the ship sailing under *bare poles* (with no sails at all), which was only done at Beaufort force 10 or higher. Thus, all the three reports are compatible with typhoon strength winds.

Since 1850 the reliability seems to increase, since they are based on direct observations from the main observatory, the secondary Philippine network and

the connected observatories, as has been pointed out when referring the previous table. Additional references can also be traced in the Spanish Archives. Thus, the typhoon which occurred in January 17-26th 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.

Discussion

Selga Chronology is an invaluable starting point to obtain 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 can not be considered a complete chronology for the whole period, but the results of this paper suggest that since 1865, it provides a rather complete picture of the landfalling occurrences in the Philippines.

The results for the previous sections suggest that, though incomplete, the series provides accurate information and exhibit similar variability to present day climatology, as evidenced in the wavelet analysis and 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 of anomaly in the location of the Pacific monsoon trough (García et al

2001), being displaced southward of its climatological location. Previous studies (Harr and Elsberry 1995) suggest that weak monsoon trough conditions are associated with decreased tropical cyclone activity in the Western North Pacific basin. Thus, the detected anomaly in this interval should be compatible with a lower than average TC frequency. However, this is a mere suggestion, since the series cannot be considered as complete.

The second part of the series (1865) shows values well above the present-day climatological mean, as can be seen in figure 2c. So, we think that it should be considered as an 'exhaustive' catalogue of intense storms, rather than typhoons. It also contains a significant number of typhoons affecting the whole Western Pacific Basin.

The obtention of a complete chronology in the Western pacific should require a multidisciplinary approach, combining different techniques. For the historical period an intensive search of the available documentary sources should 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 them have been identified, apart for 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 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.

Acknowledgements: This paper was partially supported by the Risk Prediction Initiative, under grant RPI02-2-009. The authors wish 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. Two anonymous reviewers provided useful suggestions that improved the original manuscript.

Bibliography

Baldwin, M.P., L.J. Gray, T.J. Dunkerton, K. Hamilton, P.H. Haynes, W.J. Randel, J.R. Holton, M.J. Alexander, I. Hirota, T. Horinouchi, D.B.A. Jones, J.S. Kinnersley, C. Marquardt, K. Sato, and M. Takahashi. 2001. The Quasi-Biennial Oscillation, Reviews of Geophysics, 39, 179-229.

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

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. Of Climatol.* 20, 183-190

Díaz H.F. and V. Markgraff (eds), 2000. El Niño and the Southern Oscillation. Cambridge University Press. Cambridge, pp. 496.

Díaz H.F. and R.S. Pulwarty (eds). 1997. Hurricanes. Climate and Socioeconomic Impacts. Springer. Berlin, 292pp.

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

Doyle, T.W., Gorham, L.E., 1996. Detecting hurricane impact and recovery from tree rings. In Tree Rings, Environment, and Humanity, J.S. Dean, D.M. Meko, and T.W. Swetnam, Eds., Radiocarbon, Tucson, AZ, 405-412.

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

Elsner J.B, K.-b Liu and B. Kocher. 2000. Spatial Variations in Major U.S. HurricaneActivity: Statictics and a Physical Mechanism. *J. of Climate,* 13, 2293-2305.

Elsner J.B. and B. H. Bossak. 2001. Secular Changes to the ENSO-U.S. Hurricane relationship. *Geophysical Research Letters,* 28, 4123-4126.

Fernández-Partagás, J. and Díaz, H.F. 1996. *A Historically Significant Revision of Atlantic Tropical Cyclone Frequency 1851 to 1890*. Final Report Supplement, ERL-NOAA Report 40 RANR 503516.

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. Met. Soc.,* 82, 2435-2455.

Gray, W.M. 1984. Atlantic seasonal hurricane frequency: Part I: El Niño and 30mb quasibiennial oscillation frequencies. *Mon. Wea. Rev.,* 112, 1649-1648.

Harr, P.A. and R.L. Elsberry. 1995. Large-Scale Circulation Variability over the Tropical Western North Pacific. Part I: Spatial Patterns and Tropical Cyclone Characteristics. *Mon. Wea. Rev.* 123, 1225-1246.

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 H.F. Díaz and V. Markgraf (eds.), El Niño and the Southern Oscillation. Cambridge University Press, U.K., 496 pp.

Landsea, C.W., N. Nicholls, W.M. Gray, & L.A. Avila. 1996. Downward trends in the frequency of intense Atlantic hurricanes during the past five decades. *Geophysical Research Letters,* 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. 2000. Holocene History of catastrophic Hurricanes landfalls along the Gulf of Mexico Coast Reconstructed from coastal lake and marsh sediments, in Z.H. Ning and K. K. Abdollahi (eds.) Current Stresses and Potential Vulnerabilities: *Implications of Global Change for the Gulf Coast Region of the United States.* Franklin Press. 223pp.

Liu, K-b., and M.L. Fearn. 2000b. Reconstructions of prehistoric landfall frequencies of catastrophic hurricanes in northwestern Florida from lake sediment records. *Quaternary Research* 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. Ass. Am. Geographers,* 91, 453-464.

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

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

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

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 Manila: En la Imprenta de la Compañia de Jesus, por Nicolas de la Cruz Bagay, 1749

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

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 Fernández-Partagas, J. 1997. History of the Deadliest Atlantic Tropical Cyclones since the Discovery of the New World in Hurricanes: In H.F. Díaz and R.S. Pulwarty eds. *Climate and Socioeconomic Impacts*. Berlin: Springer.

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

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

Simpson, R.H. and H. Riehl (1981): The Hurricane and Its Impact. Louisiana State Univ. Press, Baton Rouge 398 pp.

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

Sobel A. H., and E.D. Maloney. 2000. Effect of ENSO and the MJO on Western North Pacific Topical Cyclones. *Geophysical Research Letters,* 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- Albury, NSW.: The Jonstone Centre of Parks, Recreation and Heritage, Charles Sturt University.

Tannehill, I.R. 1940. *Hurricanes: Their Nature and History.* Princeton, NJ: Princeton University Press.

Torrence C. and Compo, G.P. 1998. A practical guide to wavelet analysis. *Bull. Amer. Meteor. Soc.*, 79(1), 62-78.

Udías A. 1996. Jesuits' Contribution to Meteorology. *Bull. Am. Met. Soc.*, 77, 2307-2315.

Udías A., 2003. Searching the Heavens and the Earth. The History of Jesuit Observatories. Astrophysics and Space library. Kluwert Academic Publishers (In press)

Figure captions.

Figure 1: Distribution of the typhoons intensity according to the Saffir-Simpson Scale for those typhoons with instrumental measurements available.

Figure 2: The annual frequency of the typhoons for the periods 1566-1715 (A), 1716-1865 (B) and 1866-1900 (C). Superimposed the average annual frequency of typhoons landfalling in the Philippines during the instrumental period (dotted line).

Figure 3: Wavelet power spectra (Morlet wavelet with a characteristic frequency of 6) of the typhoons landfallings in the Philippines for (a) 1945-2001 and (b) 1564-1864. Ordinates indicate the Fourier period (years). Bottom axis is time (years). Shaded contours are at normalized variances of 0.5,1,2,5 and 10. The black contour encloses regions of greater than 90% confidence level for a white-noise process. Cross-hatched areas are contaminated by 0-padding of the time series at its extremes (reduced variance) and should be cautiously interpreted.

Figure 4: Normalized monthly typhoons landfalling in the Philippines for 1564-1864, 1865-1900 and 1945-2000 (unisys).

Figure 5: Typhoons trajectories for 1564-1864 (a), 1865-1882 (b) and 1883-1900 (c).

Table captions:

Table 1: Instrumental observations of the Selga Chronology (year, month, pressure and location).

Table 2: Reported sources of the Selga chronology (day, month, year and source).

TABLE 1

YEAR	MONTH	Pressure (mm Hg)	LOCATION
1797	June	736.0	Macao?
1804	Oct 1	680	Russian corvettes *Nadicjada* and *Neva*
1809	Sept	749.30	Logbook of *Scalesby Castle* (Piddington)
1810	Sept	741.68	on board of *Winchelsea* (Piddington)
1812	Sept	740.41	On board of *Werford* (Piddington)
1838	Dec 18-19	740	Camarines or Albay
1848	Dec 13-14	748.79	Manila
1858	Aug 18-19	744.5	On board of *Novara*
1862	June	726.44	Macao
1865	Nov 7-12	742.64	Manila
1865	Dec 15-17	747.32	Manila
1866	April	745.62	Manila

1867	Sept 20-26	737.30	Manila
1868	Nov 20-24	747.47 740.00	Manila Bayomborg
1870	Nov 3	714.00 743.52	Tuguegarao Albay
1871	June	746	Naga
1871	Sept 29	711	Naga
1873	Sept 27	740.41	Marianas
1873	Oct 28	716	Masbate
1874	Sept 3-4	730.9	Port of Vigan
1874	Sept 21-22	724	Port of Vigan
1874	Sept 28	739	Sto.Domingo Basco
1875	Oct 24-31	744.21	Brig Progreso Manila Bay
1879	Nov 19-21	713.00	E.Mindoro
1880	Oct 18-22	727.60	Manila Bay
1881	May	741	Steamship *Elguin*

1881	Aug 9-14	723.0	On board steamer *Friederic* 29.6ºN,128ºE
1881	Aug 19-20	742.0 746.0	Baler
1881	Aug 24-28	747	Zikawei
1881	Sept 5-8	736.59	Tainanfu Formosa
1881	Sept 27 - Oct 6	717.50	Steamer *Fleurscastle*
1881	Oct 10-14	718.9	Steamship *Oaklands,* near Pratas
1882	Sept 27 - Oct 6	728.0	Steamer *Tanais*
1882	Oct 18-22	See 1880	
1882	Oct 23-27	726.43	Bark *Caridad*
1883	April	732.10	Taganaan
1883	Oct 28-31	747.8	Manila
1885	July	723.6	Steamship
1885	Aug 18-26	724.5	*Ocksan*
1886	Sept 5-9	716.0	Steamer *Killarnay* at 21ºN,128ºE

			21ºN,128ºE
1886	Oct 14-18	731.51	Steamship *Proponti*
1887	May	721.00	Brig *Alic Bowe*
1887	July	728.8	Nagasaki
1887	Sept 5-9	720	Sea at 20.5ºN and 119ºE
1890	Sept 28 - Oct 3	738.05	Region of Albay
1890	Nov 7-13	742.85 741.9	Tabaco Streamship *Mount Hebron*
1891	Sept 19-25	745.8	Aparri
1891	Oct 27-28	736.0	Guam
1893	Sept 10-12	746.5 717.28	Aparri South Cape, Formosa
1893	Sept 28 – Oct 3	705.0	Cabragan Viejo and others
1894	Aug 1-12	728.2 743.7	Hamamatsu Japon? Nemuro?
1894	Sept 15-18	736.8	S.Isidro
1894	Sept 16-25	742.4	Macao

1894	Sept 30 – Oct 6	740.2	S.Fdo Union
1894	Nov 8-11	730.3	Aparri
1895	January	729.4	Yap
1895	July	713.0	Nagasaki
1895	Aug 28-Sep 9	717.7	Sep 7th Kagoshima
1895	Sept 13-19	731.0	Takow, Formosa
1895	Oct28 – Nov 2	733.3	Tuguegarao
1895	Nov 18-22	730.6	Guam
1896	July	733.0	Hongkong
1896	Sept 28 – Oct 7	726.4	Steamer *Strathllam* 23ºN and 112ºE
1896	Oct 19-20	742.65	Aparri
1897	Sept 9-18	729.5	Haichow?
1897	Oct 7-16	710.00	Guiam, Samar
1898	28May- 5 june	722.9 741.6 631.7	Laoang (N Samar) Albay Koshun (Formosa)

1898	July	742	Hainan
1898	Aug 13-16	725.6	Kagoshima
1898	Oct 1-3	723.7	Transport *Siam*, near NE Luzon
1899	July 2-10	727.9 717.2 728.5	Naha Oshima Nagasaki
1899	July 15-26	735.8 736.6 739.0 733.0	Naha Shangai Tokio Choshi
1899	July 31-Aug 6	725.1	Taichu Formosa
1899	Aug 15-22	715.9	Koshum
1899	Oct 3-8	721.4 715.8	Steamship *Columbia* Steamship *Ketat*

Table 2

Day	Month	Year	Source
1	May	1601	Report of the galleon *Santo Tomás* *
24	May	1621	Report of the frigate *Buen Jesús*
29	May	1654	Report of the Galleon *
	May	1709	Jesuit report?
19	May	1753	Report of the galleon *Nª Sª de Guadalupe or Mexicana* **
11	July	1603	Letter of the Governor on the Galleon ***
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 *
	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	August	1568	Report from the fleet of Felipe Salcedo
21	August	1602	Report of the Galleon *
20	August	1606	Report of unknown ship towards Japan
2	August	1620	Report of the Galleon *S. Nicolás* *
	August	1629	Governor report on the Galleon *
5	August	1639	Report of the Galleon **
23	August	1708	Report from a Portuguese ship
22	August	1720	Report Jesuit letter

10	August	1783	Report of the packet *Antelope* of the East India Company
	August	1793	Report of the Recolect Fathers
	August	1832	Piddington map
11	August	1848	Report of the French ship *La Bayonnaise*
18	August	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 Nª Sª de la Concepción, referred in the *Sucesos en Filipinas* *
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 *SouthSea 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

			China
27	Oct.	1599	Report of historian Fr. Chirino S.J.
5	Oct.	1649	Shipwreck of the Galleon *Nª Sª de la Encarnación* *
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, Occidental 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

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

Figure - 1

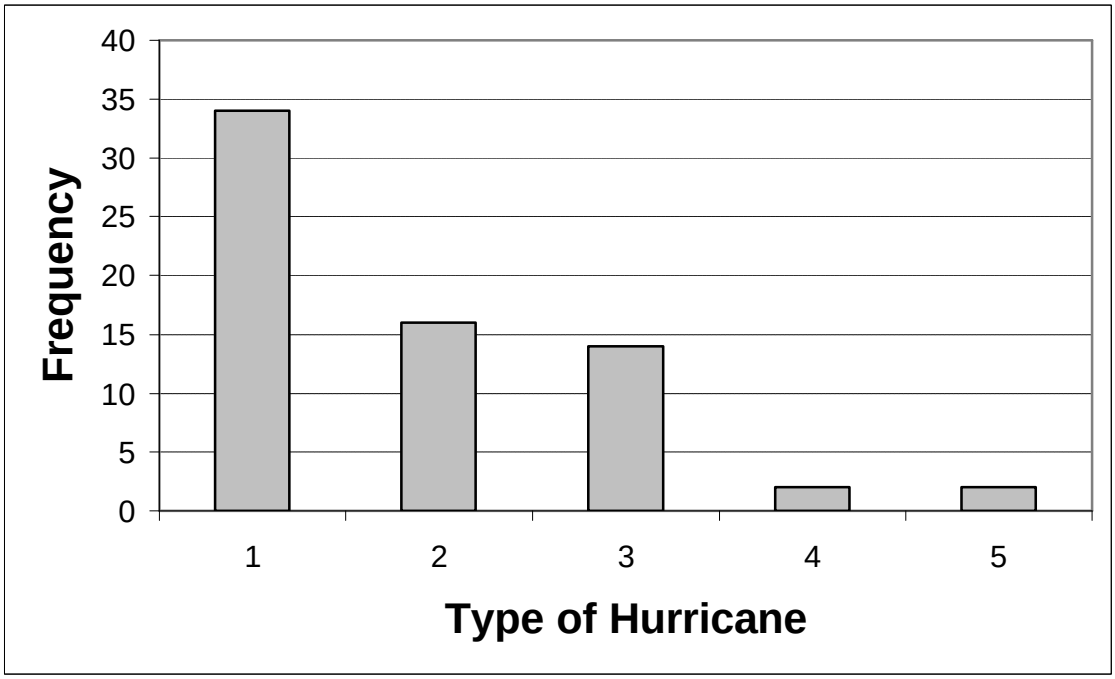


Figure - 2

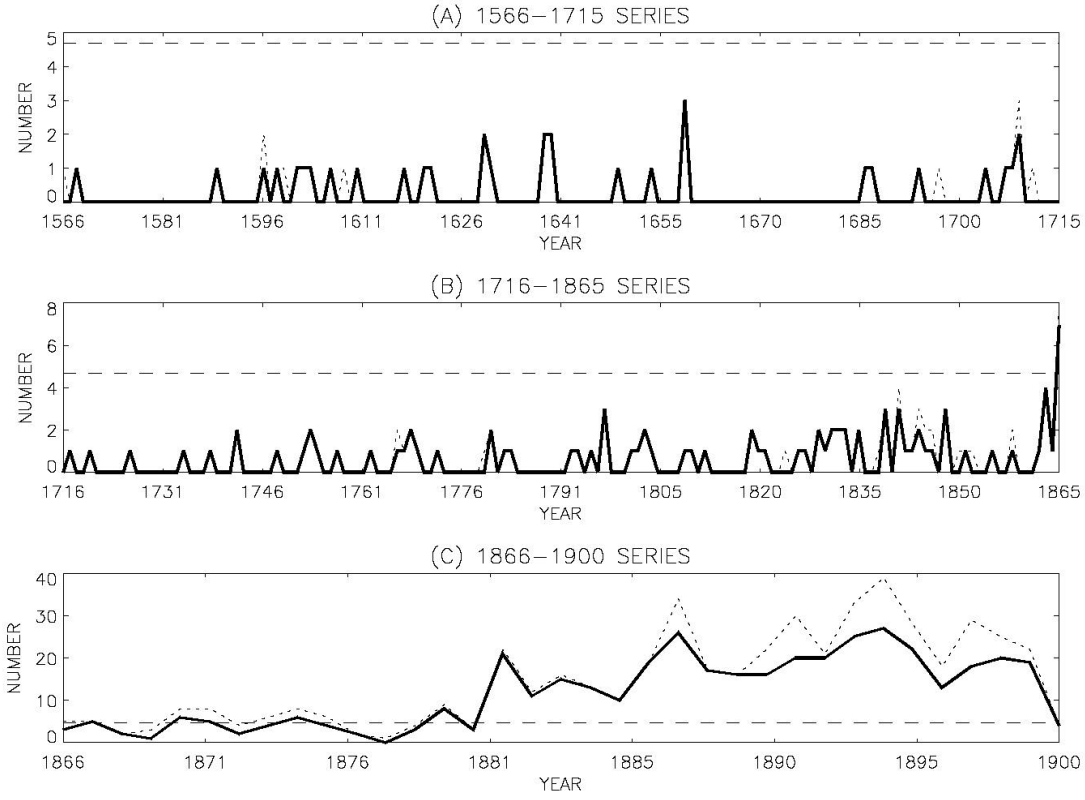

(A) 1566–1715 SERIES
NUMBER
YEAR
1566
1581
1596
1611
1626
1641
1655
1670
1685
1700
1715
(B) 1716–1865 SERIES
NUMBER
YEAR
1716
1731
1746
1761
1776
1791
1805
1820
1835
1850
1865
(C) 1866–1900 SERIES
NUMBER
YEAR
1866
1871
1876
1881
1885
1890
1895
1900

Figure – 3

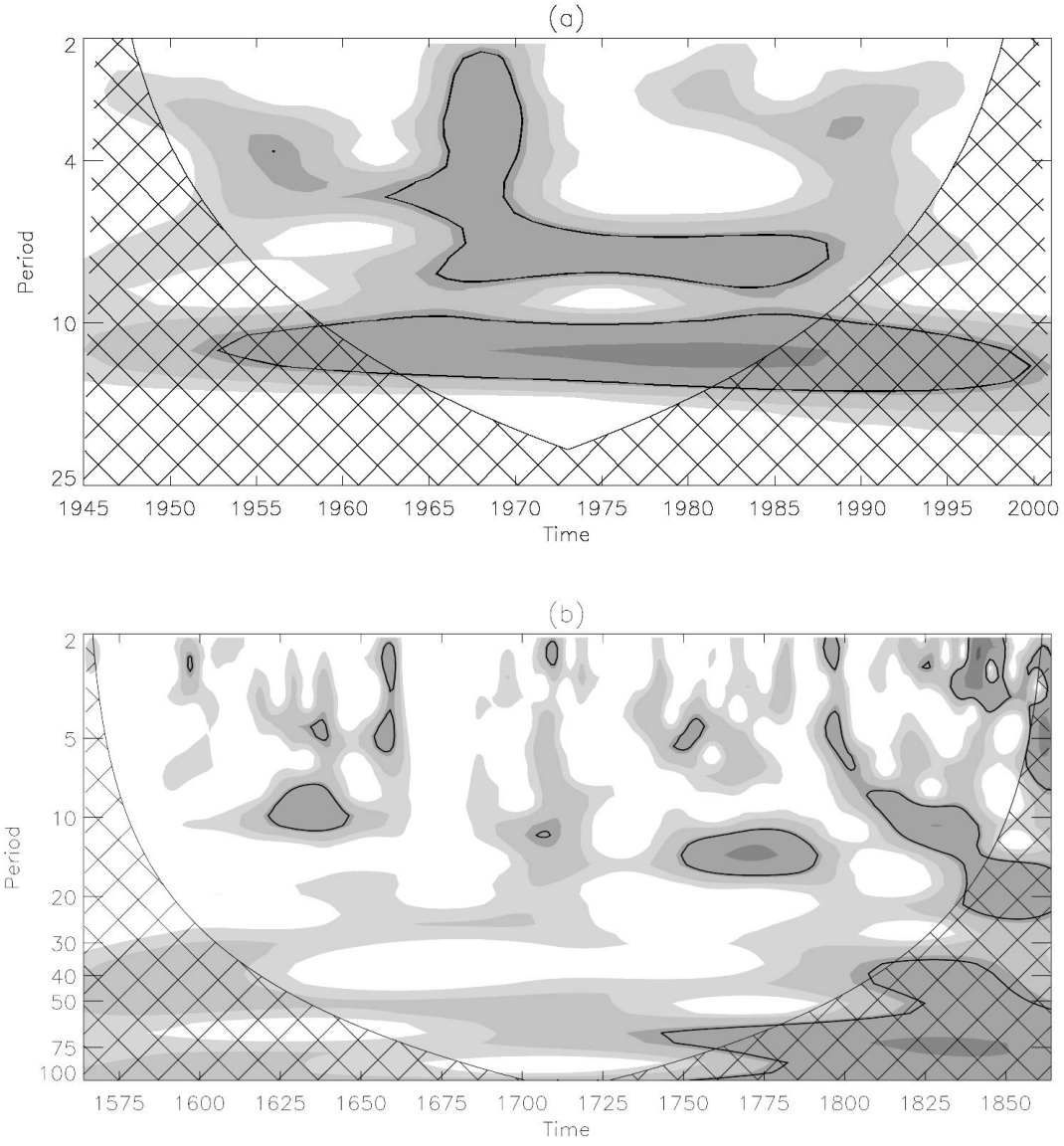

(a)
Period
2
4
10
25
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Time
(b)
Period
2
5
10
20
30
40
50
75
100
1575
1600
1625
1650
1675
1700
1725
1750
1775
1800
1825
1850
Time

Figure – 4

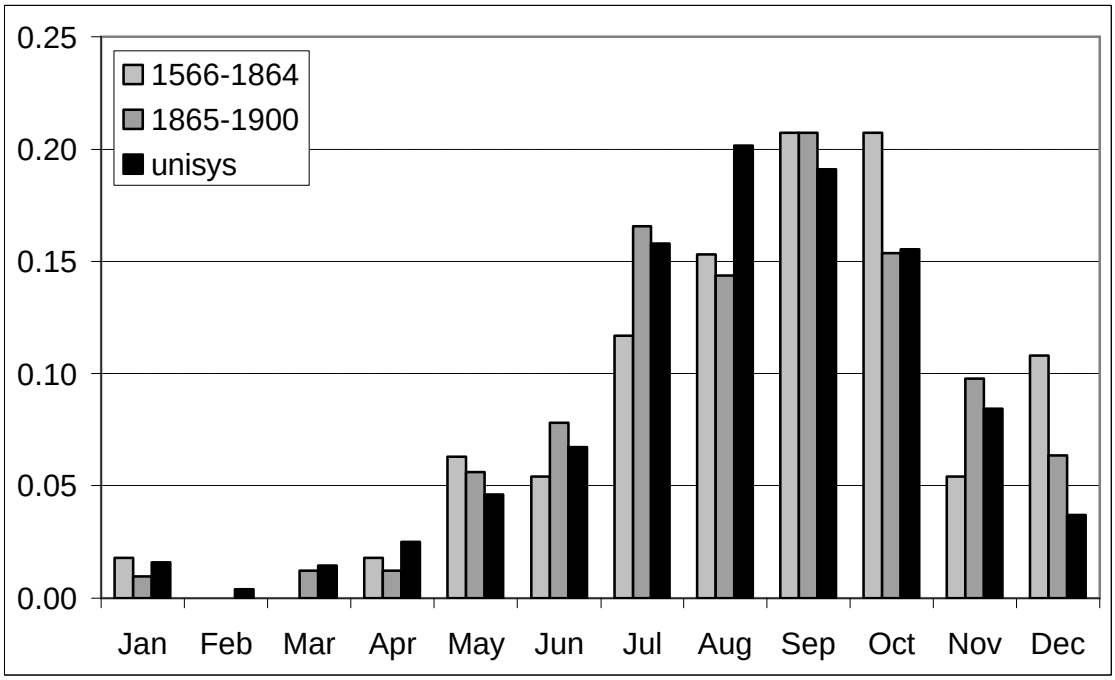
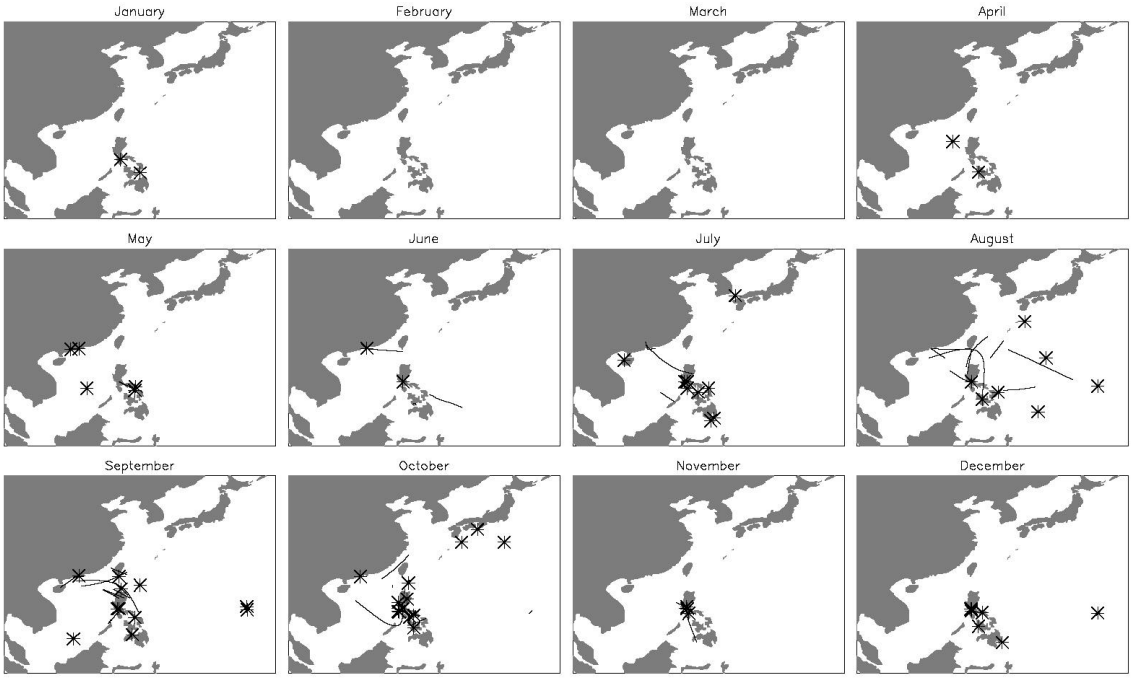
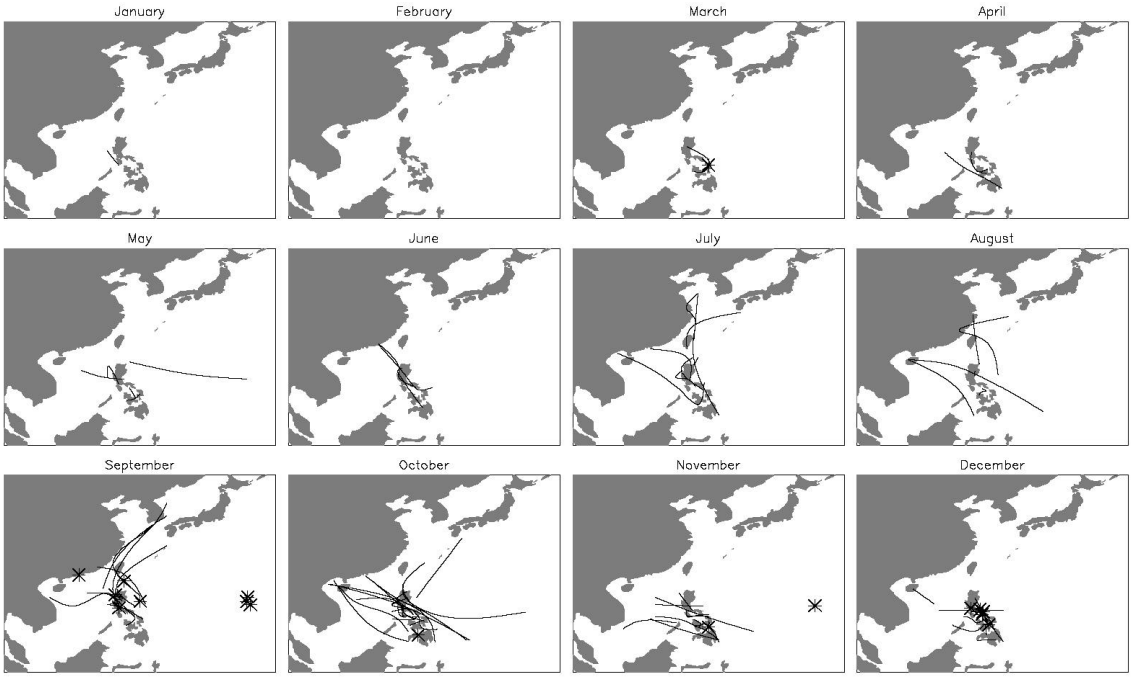

0.25
0.20
0.15
0.10
0.05
0.00
1566-1864
1865-1900
unisys
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Figure – 5

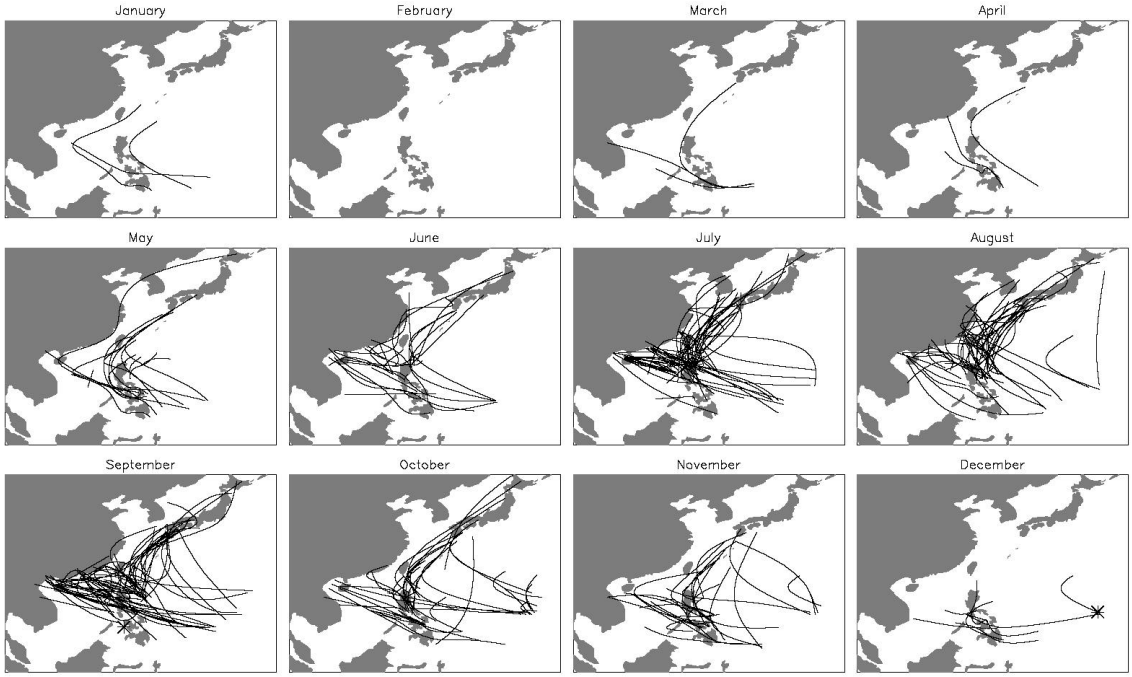
A


January
February
March
April
May
June
July
August
September
October
November
December

B


January
February
March
April
May
June
July
August
September
October
November
December

C


January
February
March
April
May
June
July
August
September
October
November
December