

## New records of Atlantic hurricanes from Spanish documentary sources

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[1] Spanish historical documents from the Archivo General de Indias (General Archive of the Indies) have been used to identify Caribbean hurricanes and storms from the sixteenth to the nineteenth centuries. These sources provide previously unrecorded information on hurricanes useful to complete preexisting chronologies and cyclone tracks. Our work adds 10 hurricanes not previously identified, which can now be freely accessed through the World Wide Web. The results suggest that the seventeenth century may have been less active than the sixteenth and eighteenth centuries, with the most active period occurring between 1766 and 1780. Additionally, the study is the first compilation of information about storms (different from hurricanes) in the Caribbean basin.

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### 1. Introduction

[2] It is well known that tropical cyclones exhibit significant variability, on millennial, multidecadal, and interannual timescales [Liu and Fearn, 2000; Landsea et al., 1996; Elsner and Bossak, 2001]. It is not known if anthropogenic global warming with elevated atmospheric moisture levels could be associated with a change in the frequency, intensity, or usual area of occurrence [Intergovernmental Panel on Climate Change, 2001]. The frequency of events is not well known and could increase or decrease. Royer et al. [1998] suggested small, regionally dependent variations. The area of occurrence appears to be a factor that will not be dramatically impacted by anthropogenic global warming influences [Henderson-Sellers et al., 1998]. However, the analysis of historical patterns in tropical cyclone frequency and intensity has not shown any significant trend in the last century, neither in frequency nor in intensity. Bister and Emanuel [2002, p. 26-1] argued that “any climatic change in the thermodynamic potential intensity (PI) of tropical cyclones would affect the intensity distribution of real tropical cyclones,” suggesting that changes in tropospheric temperature due to global warming will contribute to an increment in the PI and consequently in changes in intensity of tropical cyclones. On the other hand, Balling and Cerverny [2003] have recently reexamined duration, seasonal timing, and geographical position of North Atlantic tropical cyclones over the period 1950–2002 finding no trends in any of the parameters, although the 52-year period they examined was not long enough to extract a long-term anthropogenically induced

trend because of the strong interannual and interdecadal variability. However, the apparent disagreement between expected and actual trends suggests the need for extending and improving the available hurricane record. In addition to the clear benefits to climatologists a longer and more complete climatology of hurricanes and storms in the Atlantic will be of interest to insurers, hurricane risk modelers, and emergency managers. A review of the main hurricane impacts and the applicability of hurricanes chronologies is given by Díaz and Pulwarty [1997].

[3] Over the last century, great effort have been made to develop hurricane chronologies in the Caribbean basin. The studies by Poey [1862], Tannehill [1940], Ludlum [1963], Dunn and Miller [1964], Millás [1968], Salvia [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. Most of these works are based on the use of documentary sources from preinstrumental or early instrumental period. Additionally, most of the sources are those kept in the Americas, while less work has been done from sources kept in Europe. In particular, Spanish official documents from the Caribbean region are poorly explored. They represent a rich source of information on hurricanes for the years following the establishment of the Spanish colonies [García-Herrera et al., 2004]. Some of these documents are from as early as the sixteenth century. They usually refer to hurricanes or intense storms and describe damages in terms of lives and property. For Cuba and Puerto Rico, in particular, there are records covering more than 400 years (approximately 1500–1898). This paper describes the first results obtained after a systematic search at the Archivo General de Indias (AGI).

### 2. AGI Documentary Sources

[4] The AGI was established in 1785 by King Charles III and is located in Seville, Spain. It contains the records from the Spanish administration in the (Spanish) American col-

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**Table 1.** Distribution of the Hurricanes Reports According to Type and Period

	Period				Total
	1500–1599	1600–1699	1700–1799	1800–1899	
Landfall reports	105	86	187	14	392
Open sea reports from ships	160	103	137	5	405
Reports from trials	23	11	-	-	34
Total	288	200	324	19	825

onies during the period 1492–1825. The AGI contains more than 8 km of shelves with 44,000 bundles and 80 million folders. The AGI collection is divided into “sections,” each one covering a different area of colonial affairs. A description of the AGI is given by *García et al.* [2001]. Each bundle consists of a group of related documents and averages some 1500–2000 manuscript pages. In the present research, 424 bundles were studied with the aim of detecting hurricanes occurring during the colonial period. The search has been done in the following sections: Santo Domingo (132 revised bundles), México (100), Contratación (Contracts) (41), Indiferente General (General Miscellaneous) (49), and Cuba (38). From the other AGI sections (Patronato (Patronage), Estado (Estate), Justicia (Justice), Correos (Mail), Escribanía, Guatemala, Santa Fe, and Panamá), 64 bundles were studied. This study entailed the reading of tens of thousands of pages. As a result, we have identified a total of 825 reports from 320 bundles with references to meteorological events and/or damage that could have a meteorological origin. These reports come mostly from three types of documents: damage reports from coastal and inland cities and ships and records from trials associated with damage claims. Their distribution is shown in Table 1. The reports were examined for type of described phenomenon, the intensity of damage, and time of year. By combining these criteria, the events were classified as hurricanes, intense storms, and other meteorological events. In particular, we categorized an event as a hurricane instead of a storm when any of the three following criteria was present in a report: (1) the term hurricane was used in the report, (2) great damage was reported, or (3) changing wind direction was included in the report. When the information was contradictory, for example, the term hurricane was used but the wind direction was constant for several days, the event was not considered a hurricane. The term storm includes any event of excessive wind, but the documents do not allow a finer classification, they can be different meteorological phenomenon, including among others not very intense tropical storms, extratropical storms, squall lines, or strong frontal passage episodes.

[5] AGI Patronato 175, ramo (R) (branch) 18, numero (N) 3, provides a vivid description of the hurricane that affected Puerto Rico on 28 and 29 July of 1529 and can be considered an example of type 1:

Information compiled in San Juan of Puerto Rico, in the presence of Antonio de la Gama, resident judge appointed by His Majesty, regarding the damage that a certain hurricane caused there and other matters. Puerto Rico, August the 20th of 1530.

“Noblemen:

Lieutenant Governor and officials of His Majesty in San Juan island, Diego de Cuellar, counsel at law of this city, in the name

of this city ... this last Thursday, counting 28 days of July of this present year, at night the Lord's will was done in sending a storm and a very large hurricane to this city and island that lasted from dusk to daybreak on Friday, and it was so powerful and large that every hut fell down, and also some tile houses collapsed or were blown up to their basements, and the stone houses in the city, and those tile and wooden houses that remained were not available to inhabit, and some of the stone houses ... urgently need to be repaired, and a stone wall of the city hospital fell down to its base, and there were such enormous damages provoked by the hurricane in the city that it will not be rebuilt in twelve or even fifteen years ... and the citizens and the inhabitants of this city are so hopeless that they want to leave and abandon the island, and in fact they will if they were pressed to pay their debts, and then the island would be deserted...”

[6] AGI Patronato 181, R 25 is a good example of a detailed description plentiful of witnesses, up to 12:

Mexico, 5-XI-1552. Sending an information (Veracruz, 27-IX-1552) by request of García de Escalante Alvarado (Major of San Juan de Ulua) on the destruction caused by a hurricane on the second of that month, and testimony of good governance.

“... from the second to the fourth of this present month of September of this present year of 1552 there were in this harbour of San Juan de Ulua and in this city such a great storm and hurricane that five ships, the unloading boats and other caravels from Tabasco were lost, and most of the island houses were stricken down and it ruined the island and caused great damage and some people to drown ... and in this city the river was so overflowed that inundated the whole city and a lot of houses collapsed ... and a lot of merchants and inhabitants houses were lost, and caused great losses in terms of gold pesos and the storm and the hurricane and the river flood were so enormous that nobody remembered something similar for a long time ... it knocked down all the adobe houses and inundated the cellars filled with merchandise and this witness saw in the streets a lot of barrels and oil and pitchers of vinegar and boxes of goods dragged by the flood...”

[7] An example of type 2 can be found in AGI Santo Domingo 180, R 16, N 97, where, even without using the term hurricane, its occurrence can be inferred from the detailed description:

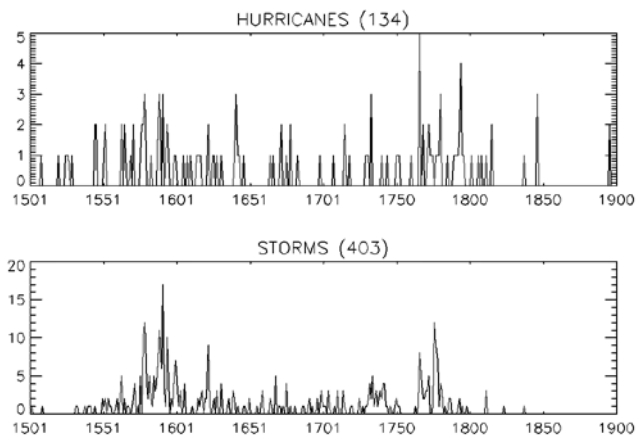
A letter from Diego Guajardo Gajardo, governor of San Martin. San Martin, July the 4th of 1642:

“Recently The Lord's will was pleased by sending, within two months, three enormous storms that ruined everything, and, although hopeless after the second one for having ruined the crops and the cattle, and for having struck down every house and storehouses, and broken most of the tiles, having to save the few remaining cazabe supplies by covering it with blankets and mattresses, having lost more than half, although this time most of the damages were repaired thanks to the most extraordinary management, but when the repairs were almost made, the third storm came as furious, even more than the second, that no more repairs could be made and making everything to fall down, not even a single tree stood up in the isle ... the 14th of September, and during daylight, men had to lay down and cling to the rocks not to be blown by the wind gusts, and even though some of them were dragged far away, it broke nearly ten thousand tiles and now there is no material to repair the storehouses...”

[8] A clear example of type 3 can be found in AGI Mexico 2489, documento (DOC) sin numerar (S/N) (not numbered):

Testimony of Luis Gomez Raposo, accompanying the almiranta's pilot, regarding the convenient departure of the ‘Armada’: San Juan de Ulua, September the 13th of 1678.

“... in the year 1675, having the warning-ship left to Spain from this harbour in the company of three ships, on August the 17th, and having on that trip pleasant breezes and calms, the 29th day of navigation they saw La Habana, on September the 14th, and the day before the arrival, on September the 15th, they were caught in a gale, obligating them to shift back to west being the wind from northwest, and the day after it was the north wind blowing stronger and after midday it was the south wind as



**Figure 1.** Annual frequency of hurricanes and storms obtained from the Archivo General de Indias.

strong as the northern, and since the sea was so stormy and the wind from all directions, the ships could not be driven, so, trying not to sink, they had to haul down the masts, and it lasted for seven days time, and during that time they managed to remain at sea offshore thanks to the variable winds, although they could have been lost if only one wind blew ... and for The Lord's providence the vessel was straightened and they arrived in Campeche, and I was inside one of these vessels and finally I arrived at 29° and two thirds, the chichimecos coast ..."

[9] An example of a storm is found in AGI Mexico 2982, DOC S/N, Mexico 2983, DOC S/N/México, DOC S/N, which contains the description of the strong gale that caused the loss of the merchant vessel *El Nuevo Constante*, its captain Julian Antonio Urcullu, that sailed together with the fleet: La Habana, 1 November of 1766:

The 'El Nuevo Constante' ship left on August the 21st from Veracruz ... since this day, although with variable weather, some sailing could be made, making us to arrive on September the 1st to 25° 40', close to Negrillo. At half past eight at night of this mentioned 1st day, a rapidly increasing strong gale was formed and finally turned into strong hurricane winds and high seas waters, but the ship prevailed ... on Thursday the 4th it was far away from the others ... still during the strong gale, but on that day the ship was found to be taking in water...

[10] A letter from the fleet commander, sir Manuel Antonio de Flores, to Julian de Arriaga, Secretary of the Indies: La Habana, 27 October of 1766:

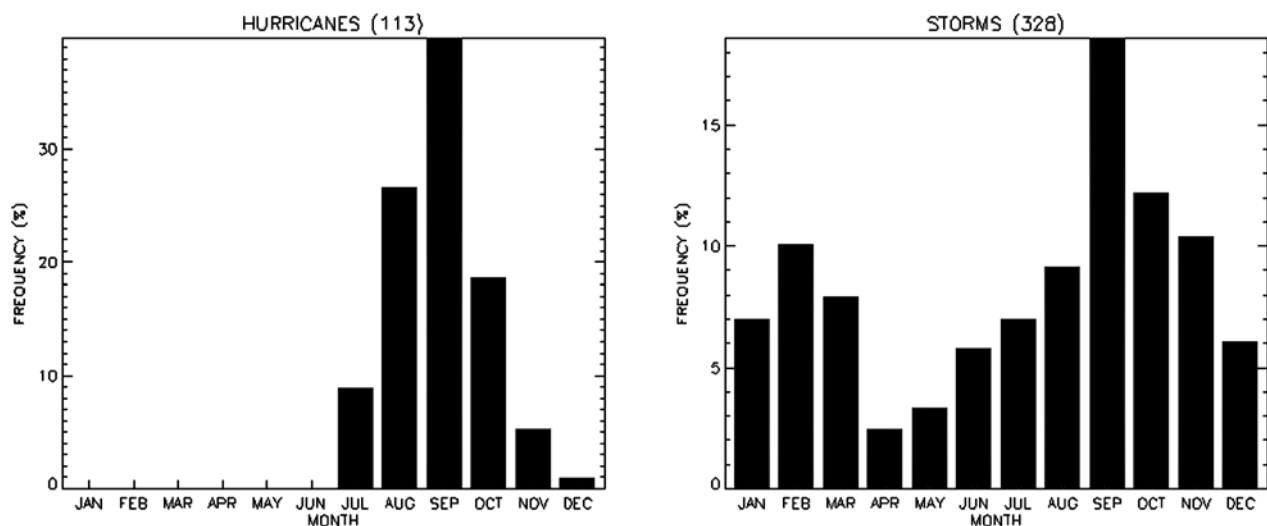
... that on September the 1st being the fleet at 24° and a half latitude, and considering to be at Negrillo longitude, a strong gale from the southeast buffeted the ships, lasting up to the 5th of that same month, making them to cope with the staysail, mizzen sail and mainsail, with the wind always blowing a moderate-gale but never out from the second quadrant; they noticed that the strongest winds came from the southeast, and then the sea calmed down after a copious rainfall ...

It can be noted that the term hurricane is used several times, however, in the description ("with the wind always blowing a moderate-gale but never out from the second quadrant"), it is mentioned that the wind remained always within the same quadrant, which is not compatible with a hurricane occurrence. In this case, this term would indicate a very intense wind but not the existence of a tropical cyclone. Being the late October and the second quadrant, a strong frontal passage is possible.

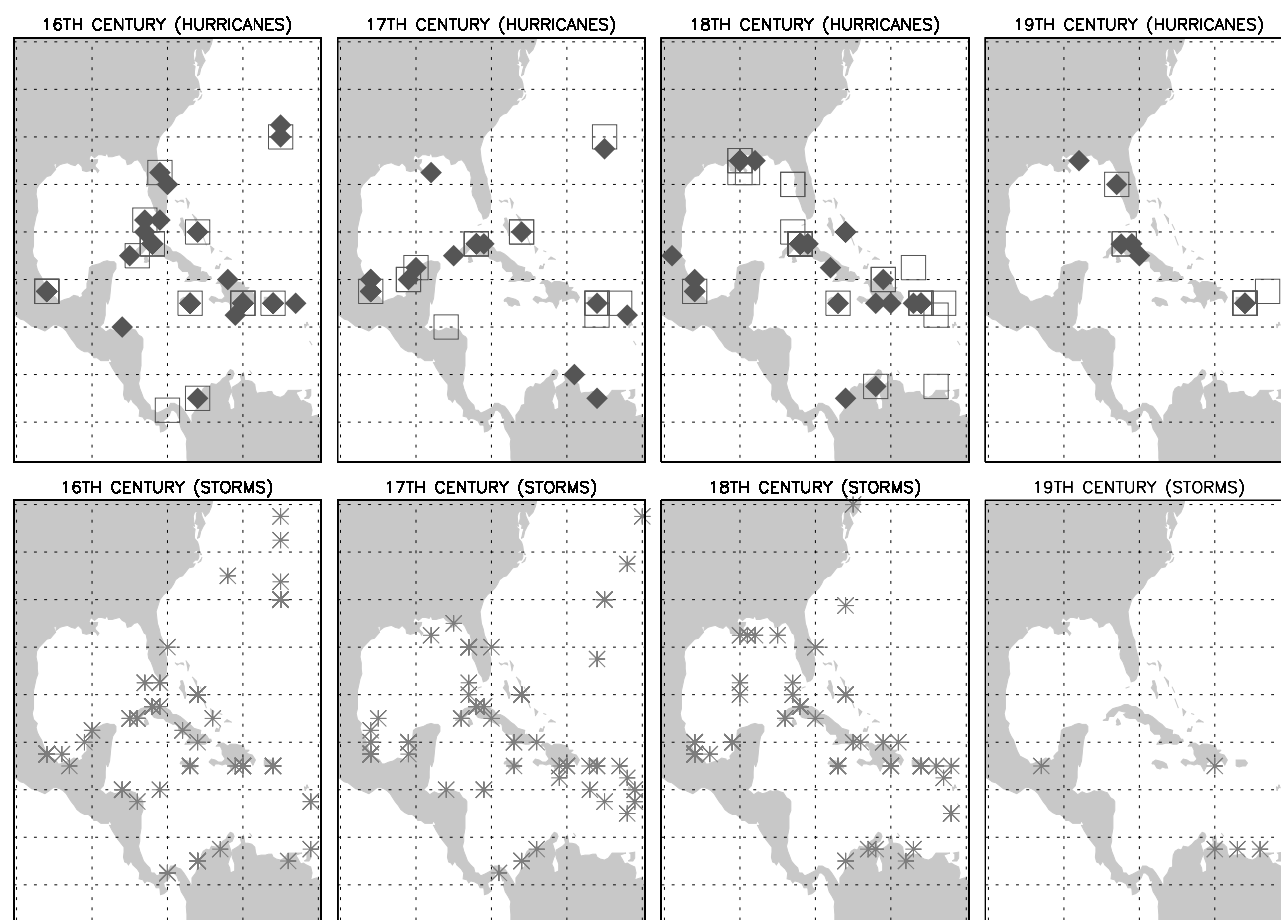
[11] Those reports can be freely accessed from a database available at <http://www.ucm.es/info/tropical/caribbean.html>. For every identified hurricane/storm, it provides date (day/month/year), affected area, landfall point, archival reference of the document, transcription of the report, and its classification as hurricane or storm.

### 3. Results

[12] Among the 825 reports included in our database 134 were considered hurricanes, 403 were classified as storms, and the other 222 were not included in either of the two categories. The annual frequency of hurricanes and storms can be seen in Figure 1. The maximum number of events is detected at the end of the eighteenth century for hurricanes and at the end of the sixteenth century for storms. The total number of events detected in the nineteenth century is very low because Mexico and the other Spanish Caribbean territories became independent at the beginning of that century; Spain retained Cuba and Puerto Rico until 1898. The greatest number of hurricanes occurred in late summer and early fall as expected (Figure 2), although hurricanes



**Figure 2.** Seasonal occurrence of hurricanes and storms.



**Figure 3.** Positions of (top) hurricanes and (bottom) storms from the sixteenth to nineteenth centuries included in the database. Previously recorded hurricanes are marked with a square, while newly reported hurricanes from this paper are denoted with a diamond. Asterisks indicate storm positions.

also were recorded during July, November, and even December (though in this case, there was only one occurrence). In the case of storms (Figure 2), there are two seasonal occurrence maxima, one centered in September and the other centered in mid-February. The September peak is due to tropical cyclones, which justifies the strong correlation between hurricanes and storms. The February peak is associated with winter storms whose meteorological origin differs from tropical cyclones. The small differences in the number of hurricanes and storms between Figures 1 and 2 are due to the absence of information on the complete date of occurrence in some reports (21 hurricane and 75 storm reports have information only about the year of occurrence; thus they cannot be included in the monthly frequencies distribution). Most of the hurricane records (115 out 146) include information on a single point of the hurricane trajectory, 12 include two points, 2 include three points and 1 includes four points. In addition to an event's date of occurrence most reports also have information on one or more location points for the hurricane or storm track (a landfall point, an impacted town, the position of an affected ship, etc.). In fact, this kind of geographical information is available for 93.5% of the analyzed storms (377 of 403) and for 97.0% of the hurricanes (only four cases have no associated position). In Figure 3 we show the known

positions of hurricanes (top) and storms (bottom) from the database for the sixteenth to nineteenth centuries. The information from the reports does not allow us to systematically infer the hurricane intensity, so a further hurricane classification has not been produced.

[13] This work adds a total of 70 hurricanes not included in previous chronologies (Marx [1983], Sandrik and Landsea [2003], Millás [1968], and Fernández-Partagás and Díaz [1996] and references therein). The sixteenth century has the greatest number (34) of previously unrecorded hurricanes. A comparison of chronologies is shown in Table 2. The date, location, and

**Table 2.** Detected Hurricanes in This Work and Comparison With Previous Chronologies<sup>a</sup>

Century	This Work	Coincident With Other Chronologies	Not Referenced in Other Chronologies
XVI	46	12	34
XVII	30	13	17
XVIII	49	30	19
Total	125	55	70

<sup>a</sup>Sources are Marx [1983], Sandrik and Landsea [2003], Millás [1968], Fernández-Partagás and Díaz [1996, and references therein].



**Table 3.** Date, Source, and Main Affected Areas of Hurricanes Not Previously Recorded<sup>a</sup>

Year	Month	Date(s)	Type of Source	Main Affected Area(s)	Landfall Point(s)
1520			AGI Justica 14, N 3	Dominican Republic	
1525			AGI Justica 1005, N 1, R 2	Honduras	Triunfo de La Cruz
1527			AGI Indiferente 421, L 12, IM 69/AGI Indiferente 421, L 12, IM 139-140	Dominican Republic	Santo Domingo
1529	July	28–29	AGI Patronato 175, R 18, N 3	Puerto Rico	San Juan de Puerto Rico
1545			AGI Panamá 235, L 8, IM 270-271	Cuba	Havana
1546			AGI Santo Domingo 868, L 2, F 313 V-314 V	Dominican Republic	
1546		day of San Bartolomé	AGI Santo Domingo 164, N 31	Puerto Rico	San Juan de Puerto Rico
1552	Aug.	28–29	AGI Justica 1029, N 7, R 1	Dominican Republic	Santo Domingo
1552	Sept.	2–4	AGI Patronato 181, R 25	México	Veracruz
1566	Sept.	3–6	AGI Patronato 257, N 1, G 3, R 4, IM 23	Florida	(37.5°N)
1569	Sept.		AGI Patronato 254, N 3, G 3, R 4	Bahamas	Bahamas Channel
1571	Oct.	18–21	AGI Contratación 4803, DOC S/N	Cuba-Jamaica	
1576			AGI Patronato 257, N 1, G 4, R 4	Dominican Republic	Montecristi
1577	Aug.–Sept.		AGI Contratación 5101	Cuba-Jamaica	
1577	Sept.–Oct.	26–8	AGI Contratación 717, N 9		27°–38° N
1578			AGI México 72, R 4, N 51	Dominican Republic	Ocoa
1578	Oct.		AGI Patronato 255, N 2, G 1, R 5	Cuba-Jamaica	Cuba-Jamaica
1579			AGI Indiferente 2676, DOC S/N	Jamaica	Jamaica
1579	Sept.	13	AGI Indiferente 739, N 217, DOC 3	Bermudas	33.30° leagues <sup>a</sup> from Bermuda
1579	Sept.	26	AGI Indiferente 1095, R 25, N 299/AGI Indiferente 1095, R 25, N 304/AGI Indiferente 1095, R 31, N 370	Bermudas	Bermuda
1583	Aug.	19	AGI Santo Domingo 80, N 79 BIS	Dominican Republic	Santo Domingo
1588	Nov.	4–6	AGI Patronato 196, R 21/AGI Santa Fe 62, N 46	Colombia	Cartagena de Indias
1588	Sept.	20	AGI Santo Domingo 127, N 66	Cuba	Havana
1589	Sept.	12	AGI Patronato 254, N 3, G 3, R 4	Bahamas	Bahamas Channel
1589			AGI Contratación 730 A, N 5	Florida	Cape Cañaveral and Santa Elena
1589	Aug.	7	AGI Contratación 5108	Leeway Islands (Lesser Antilles)	
1591	Sept.	21	AGI Santo Domingo 169, FOL 390	Puerto Rico	
1591	Sept.		AGI Santo Domingo 127, N 62	Florida	Las Tortugas
1591	Sept.	24	AGI Contratación 5109	Cuba	
1594			AGI Santo Domingo 24, N 46	Dominican Republic	Santo Domingo
1594		day of San Lucas	AGI Santo Domingo 127, N 202	Cuba	Havana
1595	Aug.	29–30	AGI Santo Domingo 99, R 20, N 190	Cuba	Havana
1599	Sept.	22	AGI Santo Domingo 229, fol130r-130v/AGI Santo Domingo 229, fol 136r/AGI Santo Domingo 229, fol 151r	Florida	San Agustín de la Florida
1605	Sept.	29	AGI Santo Domingo 224, R 6, N 52, DOC 1/AGI Santo Domingo 224, R 6, N 52, DOC 4	Cuba	Sabana Port
1608	Sept.	3	AGI México 351, DOC S/N	México	Veracruz
1622	Sept.	9	AGI Contratación 5101/AGI Contratación 4806, DOC 34	Bermuda	31°N, 150 leagues from Bermuda
1625	Aug.	11–12	AGI Santo Domingo 101, R 3, N 33	Bahamas	Bahamas Channel
1628			AGI México 242 A, N 65	México	Santa María de Cizal (Mérida)
1643	Aug.	20–21	AGI Contratación 5101	Antigua and Barbuda	
1646	Oct.	17	AGI Contratación 5101	Cuba	Los Órganos (Pinar del Río)
1664	Sept.		AGI Santo Domingo 104, R 6, N 55	Cuba	Havana
1666			AGI Santo Domingo 543, fol 52r-53v/AGI Santo Domingo 543, fol 54r-56r/AGI Santo Domingo 543, fol 57r-60v/AGI	Puerto Rico	San Juan
1671	Sept.	22–25	AGI México 2489, DOC S/N	México	Ensenada Mexicana
1672	Sept.		AGI México 2489, DOC S/N	Venezuela > México	Caracas > San Juan de Ulúa
1675	Sept.	15–22	AGI México 2489, DOC S/N	Cuba-México	La Habana- Campeche
1678	Sept.	2–13	AGI México 2489, DOC S/N	México	San Juan de Ulúa
1678	Sept.	14–19	AGI México 2489, DOC S/N	México	San Juan de Ulúa
1683	Oct.	22	AGI Santa Fe 259, FOLS 207-213	Venezuela	Curazao
1698	Dec.	12	AGI México 618, DOC 10	Florida	Bahía Santa María de Galve (Pensacola)
1715	Aug.	26	AGI Mexico 856, DOC S/N	México	Tampico
1729			AGI Santo Domingo 546, DOC S/N	Puerto Rico	San Germán (Mayagüez)

**Table 3.** (continued)

Year	Month	Date(s)	Type of Source	Main Affected Area(s)	Landfall Point(s)
1740	July	11–13	AGI Santa Fe 572	Puerto Rico	San Tomás Island- San Juan de Puerto Rico
1750	Aug.		AGI Contratación 2527, N 5	Bahamas	Bahama Channel
1760	Sept.	7–8	AGI México 2982, DOC S/N	México	Veracruz
1766	Sept. (9)	8	AN MAR/COTE-4/JJ/23		
1766	Oct.	29	AGI México 2982, DOC S/N	Cuba	Puerta de la Punta (Havana)
1766	July	17	AGI México 2973, DOC S/N	Bahamas	Bahamas Channel
1771	Nov.–Dec.	30–1	AGI MÉXICO 2973, DOC S/N	México	Veracruz
1773	Sept.	13–14	AGI Santa Fe 576	Colombia	Riohacha-Cartagena de Indias
1775	Aug.	28–29	AGI Santo Domingo 1211, N 972	Cuba	Havana
1777	Oct.–Nov.	28–4	AGI Cuba 1230, Fols 283r–284	Cuba	Santiago de Cuba
1780	Oct.	17–21	AGI Santo Domingo 1657, N 49/AGI Santo Domingo 1657, N 50	Cuba and Florida	Havana-Pensacola
1789	Aug.	18	AGI Cuba 1232, N 202/Cuba, 1232, N 204	Louisiana	New Orleans
1791	Oct.	25	AGI Indiferente 1559, N 46	Puerto Rico	
1793			AGI Santo Domingo 2612, N 16	Louisiana	Bonnet Caré (New Orleans)
1794	Aug.	10–11	AGI Santo Domingo 2563, N 431/Santo Domingo 2606, N 122/AGI Santo Domingo 2612, N 6/AGI Santo Domingo 2612, N 8	Louisiana	Baton-Batón Rouge and Fuerte de Placaminas (New Orleans)
1794	Aug.	9–10	DOCIMPRESO	Cuba	Havana
1795	July	20	AGI Santo Domingo 2564, N 543	Louisiana	Fuerte de Placaminas- Reducto Borbón (New Orleans)
1796	Aug.	26–27	AGI Santo Domingo 2613, N 40	Louisiana	San Felipe de Placaminas (New Orleans)
1801	Aug.	15–16	AGI Santo Domingo 2618, N 20/AGI Santo Domingo 2618, N 21/AGI Santo Domingo 2618, N 24	Alabama	Panzacola (Mobile)
1808			AGI Santo Domingo 2325, N 122	Puerto Rico	
1811	Oct.	11	AGI Cuba 447, N 76	Florida	Pensacola Bay
1815	Aug.	30	AHN ULTRAMAR 1067, Expediciones 56	Puerto Rico	
1815	Sept.	15	AHN ULTRAMAR 1067, Expediciones 56	Puerto Rico	
1895	Oct.	20–21	AAB SECC Expediciones 408.2	Cuba	Sagua and Sierra Morena (Santa Clara)-Matanzas-Santa Clara

<sup>a</sup>A league is 1/20 of a meridian degree, i.e., 5555 m. Definitions are as follows: V and F, both sides (of a sheet); L, libro (book); FOL, fol, r, v, sheet, both sides; G, general; IM, image; BIS, double numbers in a bundle; AHN ULTRAMAR, Archivo Histórico Nacional Ultramar; AAB SECC, Archivo Museo Alvaro de Bazan, Sección.

archival reference of previously unidentified hurricanes are given in Table 3.

#### 4. Concluding Remarks

[14] This paper summarizes the results of a search for Caribbean hurricanes recorded in Spanish historical sources from the sixteenth to the nineteenth centuries. Though the task is very time-consuming, the results are highly rewarding. They provide information on 70 previously unrecorded hurricanes and offer independent verification on 55 previously reported hurricanes, which confirms the reliability of previous hurricane dating. These records are unique in different senses: (1) The data have been obtained from sources independent from any other currently available; this allows independent cross-checking with other available sources and will contribute to improve statistical forecast of the hurricanes activity. (2) In many cases they are the only remaining record of the reported event.

[15] Thus they help to complete preexisting chronologies and improve the reanalysis of previously known hurricanes. This search in AGI does not produce a comprehensive database during these centuries, however, since the number of investigated documents is homogeneously distributed

along the period 1500–1800; our results (Figure 1) suggest that the seventeenth may have been less active than the sixteenth and eighteenth centuries, with the period between 1766 and 1780 being the most active for hurricanes and storms. It is difficult to draw firm conclusions from this last result because of the existence of possible gaps and other uncertainties in the documentary sources analyzed. However, since we have produced a search not biased in time, it is worth noting the high probability that the interannual variability in the number of Caribbean hurricanes during the study period may be similar to that found in this paper. The annual occurrence of North Atlantic hurricanes is mostly controlled by tropical Atlantic sea surface temperature (SST) (higher SSTs significantly increase the number of hurricanes) and by wind shear (which is dependent on El Niño–Southern Oscillation (ENSO), with more hurricanes occurring during La Niña events than during El Niño events [Goldenberg *et al.*, 2001]). It is difficult to reconstruct SST and ENSO during the sixteenth, seventeenth, and eighteenth centuries, but climate reconstructions indicate that North Atlantic SST increased in the third quarter of the eighteenth century [Delworth and Mann, 2000; Gray *et al.*, 2004] and that there were no moderate, strong, or very strong El Niño events during 1762–1776 [Quinn and Neal, 1992; Dunbar

et al., 1994]. The reconstructions are consistent with the period of highest hurricane occurrence found in this study.

[16] This work shows the values of Spanish archives for the reconstruction of Atlantic hurricanes. The AGI has not yet been completely exhausted. Other archives have been identified with rich collections of documents of hurricane prone areas, such as the Archivo General de la Marina (General Navy Archive), and they should not be ignored when constructing a complete chronology with reliable tracks of Atlantic hurricanes.

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