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Climatic variability related to El Niño in Ecuador – a historical background

K. Arteaga, P. Tutasi, and R. Jiménez

Faculty of Natural Science, University of Guayaquil. Guayaquil, Ecuador

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Abstract. This paper reports on an investigation into the chronology of El Niño/Southern Oscillation (ENSO) events, during the period from the arrival of conquistadores in Ecuador in 1532 until the year 1900. A number of probable El Niño events and drought years can be dated from anecdotal reports of significant rainfall and drought in the equatorial region.

The evidence of ENSO has been documented from early reports in the South America archives. A large number of books and articles have been reviewing from the Ecuadorian archives to obtain information on El Niño events that have occurred over the past centuries. This information is based on evidence obtained from the equatorial region, where strong and very strong El Niño events clearly separate the northern part of the Ecuadorian coast from the southern region, the normally rainy season specially from west-central to the south coast of Ecuador, as well as the drought years, reported in this region which is climatologically and oceanographically different from the moist Northern coast of Ecuador. Given the normal occurrence of rains in the southern coast of Ecuador, it is reasonable to expect that at least some of the major rainy seasons would be recorded in local chronicles and publications. This information has been compared with reports obtained from Peru.

Relative strengths of events are based on such considerations as wind and current effects on travel times of ancient sailing ships, degree of physical damage and destruction, amounts of rainfall and flooding, human disease epidemic, mass mortality of endemic marine organism, rises in sea temperatures and sea levels, effects on coastal fisheries.

This paper is the first survey of the historical sources concerned the rainfall and drought in Ecuador. In the course of this investigation we also noted some extended periods of time, near decadal or longer over the past records, when the amount and/or strength of El Niño and its resulting effects appeared to represent significant long-term climate changes.

Correspondence to: R. Jiménez
(rjimenez@interactive.net.ec)

1 Introduction

Studies of the Southern Oscillation, the El Niño phenomenon and their associated effects throughout the global atmosphere have proliferated over the last two decades (Rasmusson and Wallace, 1983; Philander, 1990; Changnon, 2000; Nash, 2002).

Observational investigations have largely concentrated on fairly recent periods with relatively abundant data (Grove and Chappell, 2000; D'Aleo, 2002). Naturally, curiosity has also developed about the chronology of El Niño/ Southern Oscillation (ENSO) events in the more-distant past. A number of recent papers have addressed this issue or have proposed methods to do so (Díaz and Markgraf, 2000; Caviedes, 2001).

The El Niño phenomenon was defined in Ecuador as well as in northern Peru, as a combination of anomalously warm sea temperature, stronger than usual southward coastal current, high rainfall and floods (Philander, 1990). An early approach to this issue was given by Hamilton and Garcia (1986) to ENSO events and their associated midlatitude teleconnections. In successive works (Quinn et al., 1987; Quinn and Neal, 1992), Quinn proposed a chronology sequence of El Niño events covering the last four and a half centuries, with an individual strength evaluation and confidence rating of every episode.

Quinn's sequences were initially based on documentary reports of significant rainfall in the normally dry coastal areas of northern Peru. Quinn et al. (1987) have been considered the major reference for most studies of variability in ENSO recurrence and intensity.

However, a close re-examination of the same documentary data used by Quinn, and/or additional documents, from Peru and southern Ecuador by Ortlieb (2000) showed some doubts regarding the real occurrence of these reconstructed El Niño events, and proposed a revised chronological sequence of historical El Niño events based upon (mainly) Peruvian evidence.

Most of the past ENSO events were dated from reports of significant rainfall in coastal areas of northern Peru, and more recently in Chile (Ortlieb, 1994; Ortlieb et al., 1995) and Argentina (Prieto, 1994).

In Ecuador past ENSO events have been scarcely mentioned (Quinn et al., 1987; Ortlieb, 2000, 2002) although documentary records exist, considering that it is one of the regions most affected by the catastrophic consequences of El Niño, since early time of Spanish colonization. Ortlieb (2000) pointed out that further investigations into the documentary record of southern Ecuador should be encouraged.

ENSO event reconstruction in coastal Ecuador was based on evidence obtained in the region from the west-central to the south coast of Ecuador, where heavy rainfall seems to be correlated with El Niño occurrences. This region is climatologically similar to northern Peru, with seasonally dry equatorial forests.

El Niño in coastal areas of southern Ecuador, is thus primarily based on written reports of rainfall excess and associated manifestations. The climatic information within the various archival and documentary sources includes: (1) direct dated descriptions and accounts of catastrophic extreme or damaging, and hence noteworthy climate events such as droughts or floods. (2) anecdotal observations of contemporary climate conditions, such as the early or late arrival of the dry or rainy season and long-lasting periods of any season. The unusually dry or wet conditions had implications in the agricultural communities. Other category of documentary sources included indirect evidence, where the reporting of climate event per se was not the main purpose of the document. This category might include references of harvest gains or losses, disputes over changes in availability of an access to water sources, human diseases, and epidemics mass mortality in communities.

2 Historical data analysis

The sources of information used in this work consist of documents of varied origin: published books, newspaper reports articles and unpublished archives and review studies on past El Niño in Ecuador and elsewhere.

This compilation it is not complete, as far as published and unpublished material is concerned. Any improvement of the El Niño chronology should come from research into unpublished data archives of "*Actas Capitulares"* which recorded the "*Cabildo"* (Municipal Council) activities in the colonial city of Guayaquil. Most the climatic records found deal with adverse economic consequences of droughts and floods.

The reconstruction of paleometeorological situations from documentary sources is necessarily speculative. River floods, exceptional thunderstorm or intense and prolonged rainy or dry seasons are elements of information that have been used to infer the occurrence of former El Niño events. In most cases, past El Niño studies from Peru (Quinn et al., 1987; Ortlieb, 2000) and elsewhere (Ortlieb et al., 2002) have been compared with documentary sources from Ecuadorian bibliography and national archives. Ortlieb (2000) has pointed out that reports of climate anomalies or meteorological conditions from different regions of Peru, specially neighboring countries would provide satisfactory and precise criteria for the reconstruction of El Niño or La Niña conditions.

These data reconfirm or may also provide contradictory interpretations of the occurrence of El Niño events. In some cases, reports on drought in southern Ecuador may be used to infer that no El Niño event occurred. In fact, there are much closer similarities between El Niño manifestations with an area that encompasses southern Ecuador and northern Peru, than between northern and southern Peru (Ortlieb, 2000).

Coincidentally, strongest former events are those which are commented upon as catastrophic phenomena not only in Ecuador or Peru, but elsewhere. However, in some few cases reports of climate anomalies were documented as strong or very strong events in Ecuador, and only as moderate events in Peru. This might be related to El Niño's large variability in terms of intensity, location and season of occurrence (Philander, 1990).

3 El Niño impacts in southern Ecuador

Previous studies (Quinn et al., 1987; Otlieb, 2000) included some reports of El Niño events for southern Ecuador (Table 1). The Ecuadorian sequence proposed here, is inferred from historical data gained from the Ecuadorian bibliography and local archives from the area of Guayaquil.

The amount of anomalous rainfall and river flooding in the southern coast of Ecuador and northern Peru remains the most reliable indicator of the strength of the El Niño events (Ortlieb, 2000). According to present meteorological data the catastrophic consequences of the El Niño in Ecuador are concentrated in this region. Based on instrumental data of the past decades (Philander, 2004), it thus appears that droughts, anomalous precipitation episodes or river floods in the southern coast of Ecuador can be used to predict El Niño conditions.

The chronicler Jose de Acosta (1590) reported in 1578: "*... heavy rainfall and northerly wind in Guayaquil, similar climatic situation reported in Trujillo, Peru...*" (Quinn et al., 1987).

In "*Actas del Cabildo"* of Guayaquil reported: "*... abundant rains and Guayas River flood in May 1696...*" (Estrada, 1977).

The President of the "*Real Audiencia de Quito*" Dionysio de Alsedo and Herrera (1741) was a prominent geographer, he described: "*...the unusual rainy season, in Guayaquil where the excess of rains caused river floods of the region during December 1729 to April 1730...*".

Mario Cicala reported in his journey from Guaranda to Guayaquil: "*... the devastation of the roads, landslides, the continuos rains during thirteen days and the floods, affected communications between Guayaquil and the main cities of the interior of the country in 1748...*" (Gómez and Arosemena, 1997a).

Table 1. El Niño events in Ecuador and Peru between 1546 and 1900 according with Quinn et al. (1987), Ortlieb (2000), and new records for Ecuador.

Reports from Peru by Quinn, Neal & Antunez (1987)	Reports from Ecuador by Quinn *et al.*, (1987) and Ortlieb (2000)	New records
Peru	Ecuador	Ecuador
1552 S	-	-
1567 S	-	-
1568 S	-	-
1574 S	-	-
1578 VS	-	1578 VS
1607 S	-	-
1614 S	-	-
1618 S	-	-
1619 S	-	-
1624 S	-	-
1652 S	-	-
1671 S	-	-
1687 S	-	-
1688 S	-	-
1696 S	1696 S/ M	1696 S
1701 S	-	-
1707 S	-	-
1708 S	-	-
1720 VS	-	-
1728 VS	-	-
-	-	1729 S
-	-	1730 S
1740 M	-	1740 *
1747 S	-	-
-	-	1748 S
-	-	1754 *
1761 S	-	-
-	-	1767 S
1784 M	1784 M/M	1784 S
1785 M	1785 S/ M	1785 S
-	-	1790 VS
1791 VS	-	1791 VS
-	-	1797 *
1803 S	1803 S/S	1803 S
1804 S	1804 S/S	1804 S
1814 S	-	-
1817 M	1817 M/M	1817 S
1818 M	1818 M/M	1818 S
1819 M	1819 M/M	1819 S
1820 M	1820 M/M	1820 S
1821 M	1821 M/M	1821 S
1824 M	1824 M/M	1824 S
1825 M	1825 M/M	1825 S
1828 VS	1828 VS/VS	1828 S
-	-	1829 S
-	-	1841 S
-	-	1842 *
-	-	1843 S
1844 S	1844 S/S	1844 S
1845 S	1845 S/S	-
1846 S	1846 M/	-
-	-	1853 *
-	-	1854 S
-	-	1855 *
-	-	1856 *
-	-	1861 S
-	-	1862 S
1864 S	1864 S/S	1864 S
1867 M	-	1867 *
1868 M	-	1868 *
-	-	1869 *
1871 S	-	-
1877 VS	-	1877 VS
1878 VS	-	1878 VS
1880 M	-	1880 *
-	-	1881 S
1884 S	-	-
1888 M	-	1888 S
1889 M	-	1889 S
1891 VS	-	1891 VS
1897 M	-	1897 *
1899 S	-	1899 S
1900 S	-	-

Juan Pío Montufar y Frasco mentioned floods of Babahoyo and Daule Rivers during the rainy season in 1754 (Gómez and Arosemena, 1997).

Cicala mentioned: "*...thunderstorm, windstorms, hailstorm and severe rains and floods at the latitude of Guayaquil, affected the city and the Gulf of Guayaquil in 1767...*" (Gómez and Arosemena, 1997a).

In 1784–1785 the effects of the torrential rains in southern coast of Ecuador were quite spectacular, mainly with interruption of communications between Guayaquil and Quito. This issue was address by Cap. Miguel de Olmedo who proposed to the President of "*Real Audiencia de Quito*" the construction of new roads, useful during the rainy seasons. There were reports that during the rainy season of 1784–1785 torrential downpours caused floods of the Daule and Balzar Rivers affecting agricultural activities in the region, and resulted in disease outbreaks causing migration of the rural communities to the villages (Laviana, 1999).

The Spanish navigator, explorer and thinker Alejandro Malaspina (1885) wrote: *"... In May 1790 arrived to Callao, Peru, they anchorage in the port during four months due to the torrential rains affecting Peru. In September 20, going northward arrived to Guayaquil in October...*" Malaspina described: "*...the intensity and direction of the northerly winds and the continuation of rains in the region...*" In November they sailed to Panama and reported: "*constant and heavy rains off Cape San Francisco in the Ecuadorian coast...*" These anomalous climatic descriptions in this part of the year in Peru and Ecuador was in tune with the powerful ENSO episode of 1791 (Grove, 1998; Caviedes, 2001).

A compilation of several authors "El Viajero Universal" reported severe thunderstorms, heavy rains day and night, and a flood of Guayas River during the rainy season in 1797 (Gómez and Arosemena, 1997a).

Documentary reports accounted for strong rains in southern Ecuador which lasted seven months, between 1803 and 1804. The floods affected numerous villages and agricultural activities (Hamerly, 1987; Spruce, 1996)

Historical climatology records also include investigations into the vulnerability of past economies and societies. Hamerly (1987) in his work described severe floods affecting crops and the economy in southern Ecuador in the years of: 1817–1818, 1818–1819, 1819–1820, 1820–1821. Although at the present time we do not have enough historical records of these years, we included this reference considering that those years were also reported by Quinn et al. (1987) and Ortlieb (2000) as moderate events of El Niño in Peru.

There is diverse evidence related outbreaks of several waterborne diseases with climatic anomalies forced by ENSO events. Diseases involving mosquitoes and rodents may cluster after extreme events, especially flooding in association with ENSO events (Epstein, Peña and Racedo, 1995); and in Ecuador and Peru epidemics of malaria appear related to flooding associated with El Niño occurrence (McMichael and Haines, 1997).

Hamerly (1987) accounted torrential rains in 1824–1825, where some rivers changed their courses and were flooding,

with consequences on the outbreak of a yellow fever epidemic. Hamerly also reported heavy rains of 1828-1829, with the outbreak of malaria which affected communities of the city of Guayaquil.

Theodore Hartweg a British botanist, visited Guayaquil in 1841, and he reported torrential rains which affected the normal activities of the city (Acosta, 1976).

Estrada (1977) also mentioned in 1841, strong rains and floods which caused delayed in the publication of the newspaper *La Balanza* which had to transferred to be Quito.

During the rainy season of 1843–1844 floods of the Guayas River were reported, as well as plague of mosquitoes, insect pest and epidemics of yellow fever.

Pedro José Huerta (1947) documented outbreak in Guayaquil of yellow fever in 1842–1843. He wrote: "*...In March 1943, a flood of Guayas River brings misery and an epidemic of yellow fever to the city...*". There were other diseases mingled in, so it was hard to come up with a precise number. But in all, it was thought, up to 56 000 people of the city of Guayaquil may have been stricken by the mosquitoe-borne illness, and of these as many five thousand people died.

Hamerly (1987) reported epidemic diseases of yellow fever in the rainy seasons of the years of 1740, 1842–1844, 1853–1856, 1867–1869, 1877–1878 and 1880. These epidemics were endemic in the region. In recent El Niño years, outbreaks of this disease were reported in Ecuador, the mosquitoe *Aedes aegiypti* was the vector that carries both the yellow fever and dengue fever viruses (Nash, 2002).

In 1854, Ida Pfeiffer an explorer that visited the region of Guayaquil reported severe precipitations and floods (Gómez and Arosemena, 1998).

The traveler Friederik Hausserak visited Guayaquil in 1861. He described floods in the city and epidemics of fever and dysentery. The communications with the interior of the country were interrupted (Gómez and Arosemena, 1998).

The botanist Dr. Richard Spruce (1996) during his visit to the Province of Guayaquil refers the heavy rains and floods in the desert of Chanduy during March 1862.

The Scientific Spanish Expedition (1862–1866) visited Guayaquil in August, 1864. At that time the city of Guayaquil had tweny thousand people. One of the Naturalist of the expediton, Manuel Almagro wrote: "*...In Guayaquil the high temperatures and the heavy rains during the last seven months caused plagues of insects...*". And Francisco Martínez, mentioned: "*...Most of the roads were interrupted by torrential rains, river flooding, landslides in the road between Guayaquil and Quito...*" (Miller, 1983).

Dr. Theodore Wolf (1892) refers to the unusual year of 1877. The summer months (dry season) lasted only two months. The rainy season lasted up to July and in September it started to rain again, so people talked about "**the three continued rainy seasons**".

Pedro Carbo (1881) recommended after 15 months of rain during 1877–1878 the dredging of the Guayas River due to problems caused by the accumulation of sediments that affected the supply of fresh-water and the flooding of the city.

In 1881, the Newspaper "8 de Septiembre" reported more than one thousand deaths in Santa Elena, Manglaralto, Chanduy and Colonche during April–June, 1881 caused by yellow fever epidemics.

Wolf also reported strong rains, storms with thunders and lightnings during the years of 1888 and 1889, and heavy precipitations in 1891.

The Italian naturalist Enrico Festa (1993) visited Ecuador in 1896 and he arrived to Guayaquil in 1897, and he reported strong thunderstorms and rains along the Ecuadorian coast in 1897. Quinn et al. (1987) also reported a moderate El Niño event in Peru in that year.

The Newspaper "*El Grito del Pueblo*" published in Guayaquil reported during January to May of 1899: "*...the rainy season had been very strong in all the Ecuadorian coast, with the rise of the Colimes, Babahoyo, San Pablo, Caracol, Chone, Vinces, Jubones and other rivers of the coast. The great increase of these rivers produced floods in the nearby towns. Some have been in danger of disappearing under the water like Guaylala, Puentecito, Clotillat, Borbones y El Guabo.*

The crops were also affected as in the areas of Guaranda, where almost all the products have been destroyed; in Portoviejo the harvest has been scarce due to a plague of worms; in Pasaje and Machala large extensions of farm land have been damaged by the floods. Communication between cities has been interrupted, leaving then isolated from the rest of the country "*...In this rainy season it has been raining everyday in Guayaquil. Streets are flooded and the population is living underwater life fish. The city is lacking the most important products for their survival...*".

4 Discussion

Ortlieb (2000) had pointed out that determination of the strengths of past El Niño events is a demanding task. Without precise knowledge of the spatial extension of El Niño with emphasis in northern Peru manifestations, it is hazardous to attempt to make a fair determination of the strengths of the events. Consequently it is natural that subjective elements are involved in the classification of events.

The same author suggested that the evaluation of the intensities of former events should involve a wider regional analysis of meteorological impacts that include the countries neighboring Peru. In recent work Ortlieb et al. (2002) assumed this task, incorporating documentary data mainly from Bolivia, Argentina, Chile and some case from Ecuador.

In this paper we made a contribution with information of past El Niño events in Ecuador and this contribution must be considered as a first step, to the climatic anomalies which may be linked to El Niño conditions. In documentary data 47 events of El Niño were reported for Ecuador, 28 events coincided with El Niño years in Peru and 19 are new records for Ecuador. Some of these events have been categorized strong (S) or very strong (VS) for Ecuador, according with the revised documents, although some of these years were mentioned by the previous authors as moderate (M). This

inconsistency is interpreted as related to the differences of impact of El Niño in Ecuador and, Peru, or may be due to the emphasis of some the chroniclers in their reports. In some cases insufficient data (noted as "*" in the table) were registered. This chronology will be completed when more documents will be revised.

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