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Some aspects of climate in Costa Rica using historial data from the XIX century

JORGE A. AMADOR[1]

Center for Geophysical Research and Department of Atmospheric, Oceanic and Planetary Physics (LIAP),
School of Physics, University of Costa Rica, San José, Costa Rica

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RESUMEN

Se presenta una breve reseña histórica, del desarrollo de la meteorología en Costa Rica, en los siglos XVIII y XIX y de las primeras observaciones meteorológicas realizadas en el país. Durante la mayor parte del siglo XVIII, los datos meteorológicos cuantitativos eran escasos y predominó la descripción de los fenómenos atmosféricos. En el primer tercio del siglo siguiente, Rafael F. Osejo ofreció las primeras descripciones y explicaciones del clima local, de inundaciones y de lo que parece ser, incursiones de masas de aire frío en el Caribe de Centro América. El botánico danés, A. S. Oersted realizó observaciones meteorológicas sistemáticas de precipitación y temperatura durante 1846-47 que muestran claramente, lo que probablemente es, la primera descripción cuantitativa de la sequía intra-estival o veranillo en el país. Fuentes documentales del periodo 1830-1890 se refieren algunas veces a caídas de nieve en los picos más altos de Costa Rica. Un análisis sinóptico simple durante las últimas décadas, ayudó a entender el posible origen y la probabilidad meteorológica de tal condición extrema. Como tales condiciones no han sido documentadas científicamente durante las últimas décadas, esto podría ser una posible indicación de un cambio climático desde el siglo anterior, especialmente si se considera la evidencia reciente de un calentamiento en la atmósfera al nivel de los picos altos de las montañas. Datos de temperatura que se encontraban dispersos, tanto en archivos públicos como privados, fueron recolectados de fuentes primarias y secundarias y se sometieron a un control de calidad para construir series de valores mensuales para el periodo 1866-1887. Esta serie de tiempo junto con la del periodo 1888-1899 fue utilizada para estudiar algunos aspectos del clima en la región. Anomalías de temperatura durante el periodo de estudio muestran claramente el calentamiento asociado a los eventos El Niño (incluyendo el de 1876-78 considerado el episodio más intenso de ese siglo) y el enfriamiento en la región posiblemente relacionado con la erupción del Krakatoa en 1883. Los resultados de esta investigación llaman la atención acerca de la importancia del rescate de datos meteorológicos y el uso de fuentes documentales históricas en la reconstrucción de eventos extremos del clima pasado.

1. Introduction

In the recent past, the history of meteorology and meteorological observations in Costa Rica has been practically undertaken solely by local scholars with interest in climate related issues. Very few works have addressed the development of physical sciences in this Central America country in a systematic way. Among them, Coen (1973) presented an interesting account of meteorological phenomena and he also analyzed local folklore relative to climate. Co-authors, Amador et al. (1990), Páez et al. (1990) and Solano et al. (1990), can be quoted probably as one of the few groups to provide, in the last decades, some details and historical facts about the early development of the physical sciences, including meteorological observations and physical interpretations during the colonial period in Costa Rica. In a more recent work, Solano (1999) made a more comprehensive approach to the history and institutionalization process of meteorology in the country, so providing a reference frame to current and future research in the local history of science.

In Costa Rica, until recently, climate change issues, either natural or anthropogenic, were relegated to meteorologists, atmospheric physicists and geophysicists, who were interested in long-term historical observations, to conduct regional climate and climate variability research. The need of a multidisciplinary approach to this problem has become evident, however, when large amounts of documents, archives and historical information have been needed and used to perform data rescue and proper historical interpretation. In this paper the use of the historical and the scientific methods, provided a unique opportunity to reconstruct some aspects of the early history of meteorology in Costa Rica, specially during the XIX century. Besides that, the approach sets the frame to advance in the understanding of the historical context of the first meteorological observations in the country. An effort was also made to gather historical observed data, as much as it has been possible, from national and international documentary sources, in an attempt to provide quantitative evidence of past climate and climate disruptions in this part of the world. In some cases, specially at the turn of the XIX century, qualitative and to

[1]Corresponding author address: Dr. Jorge A. Amador, Centro de Investigaciones Geofísicas, Universidad de Costa Rica, San Jose, Costa Rica. . E-mail : jamador@cariari.ucr.ac.cr

some extent subjective descriptions of meteorological phenomenon and climate predominated (e.g.: see descriptions of Scottish sailor John Cockburn in Meléndez, 1974). This information was cautiously taken, it was studied in its historical context and used to complement (if appropriate) other climate information. Only in very few cases, qualitative or subjective information was discarded on the basis of being not scientifically sound. In other situations, this information guided the research towards challenging questions, such as, it is the case of exploring the possibility of snowfalls, in Costa Rica's highest mountain peaks during the 1800s (e.g., Osejo, 1833; Frantzius, 1868).

This paper gives, in the next section, a brief historical account of the early development of meteorological sciences in the country, and the way in which, the first meteorological observations were carried out, specially during the last two thirds of the XIX century. The influence of immigrants, mainly from European countries, and the contribution of Costa Rica or other Central América nationals to the progress of meteorological concepts and observational network are also discussed. The methods and procedures of analysis are presented in section 3, while the data sources and a discussion about meteorological observations are given in section 4. In part 5 some descriptions of climate related phenomena are presented and analyzed. Meteorological observations of temperature and precipitation for different periods were rescued, collected and in some cases reconstructed, for the purpose of offering an interpretation of past climate and the main climate disruptions for that period in Costa Rica. These results are shown and discussed in part 6. Finally, in section 7, some remarks and the conclusions of this research are presented.

2. A brief history of meteorology and meteorological observations in Costa Rica

During Columbus fourth trip to the Américas in 1502, he got to a small island (Quiribirí) in front of Cariay (nowadays Port Limón) in the Caribbean coast of Costa Rica. After his trip to Costa Rica, chronicles from the epoch tell that relatively few explorers and conquerors visited Costa Rica during the first decades of that century. Possible reasons for this were the inhospitable climate of the Caribbean coast and the ferocious resistance by local natives to be conquered. Gil González Dávila explored the Pacific coast near the Térraba region in 1519. He told of a huge overflowing in which he and his men lost their belongings, and faced difficulties to return to the Central Valley. Floods in this part of Costa Rica are known since then, and are usually associated to storms related to ITCZ northward motion and to indirect effects of Caribbean tropical cyclones. In most chronicles, however, difficulty in interpretation arises, mainly due to lack of reference to season or time of year of phenomenon. According to Meléndez (1974), the Scottish sailor, John Cockburn visited Costa Rica in 1731 and while on travel to Panama, described a four-day storm that prevented him from continuing their trip to the south. During all this period, until almost the end of the XVIII century, qualitative description of meteorological phenomena predominated. Some other visitors and immigrants, who contributed to descriptions of local climate and meteorological phenomena prior to the XIX century, are found in Meléndez (1974) and Solano (1999).

The origin of first meteorological concepts in Costa Rica is closely related to the development of experimental physics at the University of San Carlos (USC) in Guatemala during the second half of the 1700s. Dr. (Fray) José Antonio de Liendo y Goicoechea of the Saint Francis Order, a natural from Costa Rica, who studied in Spain from 1765 to 1767, was among the first to introduce the scientific method of experimental physics in the region at USC. An extended account of Liendo y Goicoechea's contribution to physical sciences in the region is offered by co-authors Amador et al. (1990), Páez et al. (1990) and Solano et al (1990). To accomplish his mission, Liendo y Goicoechea brought books of natural philosophy and basic experimental equipment, which he placed in the central little garden of the monastery in Guatemala City. Liendo y Goicoechea was one of the founders of the "Sociedad de Amigos del País" in 1795, a society for the promotion of local industry, culture, arts, and commerce. The "Sociedad" also sought cultural and scientific independence from Spain.

"La Casa de Enseñanza de Santo Tomás" was created in San José in 1814, as a governmental mean to stimulate local progress through education. This establishment turned to be, in a few years, in an important center for the consolidation of the national culture. The first formal scientific ideas in Costa Rica were introduced at this Institution. Costa Rica experienced, during the first third of the XIX century, the influence of the "Seminario Conciliar de León" located in Nicaragua, as a consequence of the spread of the illustration ideas at the USC in Guatemala. In this context, Br. Rafael F. Osejo, a graduate from the "Seminario" in Nicaragua was appointed as Head of "La Casa de Santo Tomás" in San José. From this Institution and others in which he worked, Osejo contributed greatly to the implantation and diffusion of scientific and meteorological ideas, during his long stay in Costa Rica. Zelaya (1971) offers a comprehensive approach to the other facets of Osejo; the politician, the lawyer and the teacher.

From approximately the 1840s onwards, immigration increased rapidly in the country. Europeans with scientific background studied Costa Rica's fauna and flora and while on travel across the territory made important meteorological observations. Immigrants such as, Danish A. S. Oersted, German born Alejandro Von Frantzius, Fernando Streber, Francisco Kurtze, Karl Hoffman, and Spanish Enrique Villavicencio, among others, made important contributions to meteorology in Costa Rica, by collecting, promoting and exchanging meteorological data. Their efforts conducted the country to

COSTA RICA

Adapted from
La Gaceta Oficial
Gobierno de Costa Rica
(1 March 1878)

SECCION CIENTIFICA.

Observaciones meteorológicas verificadas en la Ciudad de San José.

Término medio de la Temperatura en el mes de Febrero. Termómetro centígrado

7 a. m. 2 p. m. 9 p. m. Término medio en el mes.
19,67 26,38 22,16 22,74

Tempra. mas alta el 9 y 14 del mes á las 2 p. m. 29,00
Tempra. mas baja el 27 del mes á las 7. a. m. 17,50

En el mes de Febrero próximo pasado hubo una Temperatura mas alta, que en el mismo mes de los doce años anteriores.

En el año de 1869 fué el término medio de la Temperatura en Febrero 21,56
y en Febrero de 1866 hubo la Temperatura mas baja en estos 12 años la cual es 19,01

Lluvia. En 4 dias: 2 horas y 15 minutos de duracion.

El viento sopló á las 7 a. m. 19 veces del NE.
Hubo 3 dias de calma.
" " " " ", 2 p. m. 7 " " N.
y 7 veces del NO.
" " " " ", 9 p. m. 14 " " NE.
y 9 veces del E.

Estado de la Atmósfera:
á las 7. a. m. 4 v. claro, 22 v. claro y oscuro y 2 veces oscuro.
á las 2. p. m. 28 veces claro y oscuro.
á las 9. p. m. 19 v. claro y oscuro y 9 v. oscuro.

San José, Marzo 1º de 1878.

F. MAISON.

MEXICO

Adapted from
Diario Oficial
del Gobierno del
Estado de Jalisco
(29 July 1889)

TOMO X. Guadalajara, 1º de Agosto de 1889. NUM. 82

CONDICIONES.

DIARIO OFICIAL
DEL GOBIERNO DEL ESTADO DE JALISCO.

AVISOS.

REDACTOR LIC. MANUEL CORDERO. TIPOGRAFIA DEL GOBIERNO.

OBSERVATORIO ASTRONOMICO Y METEOROLOGICO DEL ESTADO.

JULIO 29 DE 1889.

	A las 7	A las 2.	A las 9	Prom
Termómetro libre	16° 0	28° 5	20° 4	20° 0
Termómetro húmedo	15° 0	21° 4	16° 5	14° 3
Termómetro fijo	18 4	22° 8	23° 5	21 5
Barómetro	63 64	63 54	63 51	63 56
Presión reducida á 0°	63 43	63 28	63 24	63 32
Tensión del vapor	12 93	16 12	12 74	16 29
Humedad	81	54	69	67
Vientos. Dirección	N O	O.	N	
Idem Velocidad	1	0 5	0 5	
Idem Fuerza				
Nubes Clase	CK.	N.	K	
Idem Cantidad	2	6	6	
Idem Dirección	E.	O.	N	
Ozono	1	3 5	1 5	2
		Sombra.	Sol.	
Temperatura máxima		30° 1		
Idem mínima		15° 0		
Oscilación		15° 1		
Lluvia. Principio				
Idem Fin				
Idem Altura				
Evaporación			3 5	

Fig. 1. Typical tables of meteorological observations from a) San José, Costa Rica for February 1878 and b) Observatory of the State of Jalisco, México, for 29 July, 1889.

international meteorological collaboration. Most of the above mentioned immigrants later nationalized and stayed in Costa Rica, many of them until death. The contribution of Costa Rica naturals was of fundamental importance for this achievement. Federico Maison and others from the Oficina de Estadística made systematic observations with

the encouragement and official support of the Costa Rica Government. Through diplomatic channels, Costa Rica Ambassador to Washington, Dr. Manuel M. Peralta established scientific communication with General Albert J. Myer, the Chief of the United States Army Signal Office, leading to the participation of Costa Rica in the First International Meteorological Network in 1877. This Network included 19 different stations, some of which, were located in América (Washington, México City and San José) and the rest in European countries.

Several governmental offices, after the 1860s kept a continuous program to make meteorological observations in different sites for applications to agriculture and road construction. The data complied with international standards according to procedures and observational guides of the period (e.g., Smithsonian Institute Guides, firstly adapted and translated by Jiménez, 1863; a member of the Sociedad Mexicana de Geografía y Estadística, and after that also adapted by Reyes, 1877).

3. Methods and procedures

The combination of two different but complementary methods, the historical and the scientific, provide the framework for this study. Although some descriptions of meteorological phenomena are presented and discussed for the first decades of the 1800s, this work concentrates mainly on the second half of that century. The historical method possesses the practical and theoretical approach to elucidate the main issues involved in the development of the society in Costa Rica during the XIX century and its relationship with the institutionalization process of the meteorological sciences. Some particular historical facts, such as the development of the state concept and the degree of support that was provided to meteorology by different governments, specially after the Independence in 1821, were taken into consideration to understand the progress of meteorology and the reliability that can be put in meteorological observations over the analyzed period. Also the historical method was used to clarify if local practice and meteorology as a scientific discipline, met with international requirements. A comparative historical study between countries in the region threw some light about standards and procedures for meteorological observations during that period. The scientific method was used, as it is customary, to collect, study, analyze and interpret data, meteorological observations, climatic conditions and climate variability that could be associated to a known physical, atmospheric or geophysical phenomena. Some of the documentary sources had explanations and information about extreme meteorological events during the analyzed period (e.g., snowfall in Costa Rica's highest mountain peaks). This information led to an exploration of the possibility of evidence for climate change conditions in the region and to a discussion of meteorological synoptic situations over the Central América region, at altitudes of the order of that of the Irazú Volcano and Talamanca Mountains (both above 3500 m.) in Costa Rica, where such conditions could be met.

4. Data sources and meteorological observations

This research is based mainly on historical primary and secondary data sources for the 1700s and 1800s (Solano, 1999). Limitations on documentary sources were faced from the beginning of the work, specially due to missing and uncatalogued XIX century documentation on public libraries in Costa Rica. Some of the known or unpublished historical sources are held in private hands, which results in problems and limitations of access to meteorological data for some parts of the period 1840-1888. International institutional sources include Instituto Panamericano de Geografía e Historia (IPGH), Archivo General de la Nación, México (AGM), Universidad Nacional Autónoma de México (UNAM) Libraries, Atlantic Oceanographic and Meteorological Laboratory-National Oceanic and Atmospheric Administration (AOML-NOAA) Library and NOAA Library in Silver Spring, Maryland. Main institutional documentary sources in Costa Rica are, Biblioteca Nacional, Museo Nacional, Centro de Investigaciones Geofísicas (CIGEFI), Carlos Monge and Eugenio Tortós Libraries at the Universidad de Costa Rica (UCR), Archivos Nacionales de Costa Rica, and Instituto Meteorológico Nacional of Costa Rica (IMN).

As far as the Costa Rica meteorological data is concern, it complied with international standards and it had a good degree of international diffusion, specially to observatories in Europe. Around the 1860s, the Smithsonian Institute had published a set of recommendations and procedures to make meteorological observations, which were later translated and reproduced by Jiménez (1863) and Reyes (1877). These procedures had been in use in Costa Rica since the creation of the Oficina Nacional de Estadística in 1861 (Gobierno de Costa Rica, 1861). Most of this information appeared almost on a daily basis in La Gaceta Nacional (the Government of Costa Rica Official Newspaper) in an especial scientific section. The observations were taken at 7.00 a.m., 2.00 p.m. and 9.00 p.m. (Gobierno de Costa Rica, 1866). To establish that the procedures were almost the same for different countries in the region, and that these followed those recommended by the Smithsonian Institute, Fig. 1, is presented. This figure shows typical tables of observations taken from La Gaceta Oficial de Costa Rica (1 March 1878) in Fig. 1a, and from Diario Oficial del Estado de Jalisco, the Official Newspaper of the Government of the State of Jalisco, México, for 29 July 1989, in Fig. 1b. In both cases, it can be clearly seen, that the procedures to collect the data did not differ from those recommended by the Smithsonian and other leading scientific institutions of that period.

Besides the above-mentioned data, some climatological reports were published by naturalists in statistical and technical bulletins, and in papers from La

Secretaría de Fomento (Secretary of Development). Temperature information was collected from primary and secondary sources and quality controlled. Monthly temperature values were reconstructed for the period 1866 to 1887 for San José, Costa Rica, using either, climatological data from bulletins and technical reports or daily available values extracted from La Gaceta. In most cases, more than 20 daily values were used to estimate the monthly mean in the usual meteorological sense. Temperature data for the period May 1876 to February 1877 (11 months) could not be found in any of the documentary sources consulted. This time series together with that for the period 1888 to 1899 (available at the IMN), was utilized to study some aspects of climate and climate disruptions during the second half of the XIX century. Some of the meteorological analysis was complemented by the use of data at particular levels from the NCEP/NCAR Reanalysis (Kalnay et al. 1996) and the Comprehensive Aerological Reference Data Set (CARDS) prepared by NOAA-NCDC for the period mid-1940s to 1992.

5. Descriptions of meteorological phenomena and data analysis

Osejo (1833) offered the first known descriptions of Costa Rica's climate in his "Lecciones de Geografía" (Geography Lessons), which he wrote for his students and general public. His "Lecciones de Aritmética" (Arithmetic Lessons), also from 1833, together with the Geography Lessons, is the first book published in Costa Rica. It is interesting to note that this honor did not correspond, as one would have thought, to political or economical issues of that period, specially if it is considered that Costa Rica got its independence from Spain in 1821. Osejo, as it was customary, presents his book in the form of catechism, that is to say, in form of questions and answers.

> "Cuál es el clima de Costa Rica? Es variado, así como su aspecto y por las mismas causas. Contrayéndonos a los puntos habitados y principales Pág. 87- puede asegurar, que el clima es el más bello del mundo conocido, pues que ni es excesivamente frío ni caliente. El Termómetro centígrado designa su temperatura entre el 11º y 24º; pero queriendo hablar de todos los demás puntos ó visitados por la mano agricultora ó pastoril ú ocupados por alguna población se puede asegurar sin temor que recorre el Termómetro todos los grados o desde el de la congelación a arriba y en proporción a la latitud que ocupa" (page 86).

> "(...) y hay varios lugares (a poca distancia de Cartago y otras poblaciones) en donde el frío es tan intenso que frecuentemente amanece helada el agua bien sea la estancada ó la de los riachuelos y aún por lo mismo es de presumir que a poco más de distancia se presente la nieve" (page 87).

The above quotation deals with the climate of Costa Rica. In this respect, Osejo offers a brief and subjective description of this concept, providing evidence of what could possibly be the first meteorological observations with a thermometer in the Central Valley in Costa Rica. Osejo also measured the temperature in different sites in Costa Rica and stated without referring to any particular site, that the thermometer reached in some places the freezing point ("punto de congelación" in Spanish). He also wrote, based on his observations, that snow ("nieve" in Spanish) should fall in places near Cartago (very likely he was referring to the Irazú Volcano). In 1840, John Lloyd Stephens, a special agent of the United States Government in Central América told about his trips to these tropical regions and referred that people living near the volcano often told him of snowfalls over the Irazú during January (Fernández, 1982) ; a winter month that is characterized by frequent low latitude cold air intrusions. Besides the above references; Wagner and Scherzer (1856), German travelers that made a study trip to Costa Rica during 1853 and 1854, indicate about the Irazú volcano the following:

> "La alta cumbre del volcán Irazú, que se halla en el fondo norteño del Valle, (...) está a veces cubierta de nieve en diciembre o enero; (...)" (page 105).

Snowy conditions are again quoted in the description of aspects of climate in the country over the Irazú volcano during the winter months. Also, in the same book, these authors provide a brief dictionary of words used by the native Indians of the Talamanca mountains in Costa Rica, a region where the highest peak in the country, Cerro Chirripó Blanco with over 3800 m., is located. It is interesting to note that these Indians knew about below freezing meteorological conditions, since they had a specific word for snow (ka-ha-na-mo-bel-wi, according to approximate German pronunciation).

In an attempt to identify what sort of synoptic scale circulations may have provided, in the past, the appropriate temperature conditions for snowfalls in Costa Rica, a search for such a situation was conducted using available NCEP/NCAR and CARDS data for the period 1960 to 1995, approximately. First, radiosonde station data for Costa Rica was examined at different levels, specially

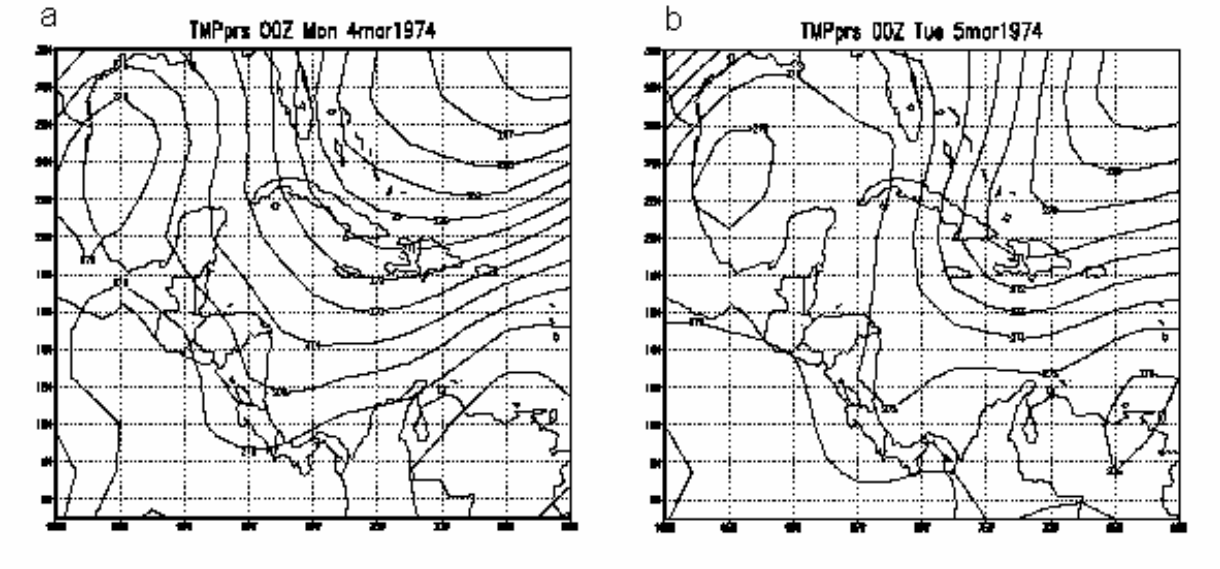


Fig.2. Temperature in Kelvin at 600 hPa for a) 4 March 1974, and b) 5 March 1974.

those at the elevation of the Irazú volcano and Cordillera de Talamanca peaks (near or above 3500 m.). Two cases were found for the winter months where temperature at the 600 hPa (~4100 m.) level reached at some stage values near the freezing point. The first case is for the period 28 February – 5 March 1974 and the second one is 7-12 February 1976. Both situations correspond to southward displacement of cold air masses from the North American subcontinent. Since a complete analysis of these situations is beyond the scope of this paper, findings are shown only for the 600 hPa level for one of the cases, namely that one for 1974. In Fig. 2, the horizontal temperature field over the region of interest for the period 4-5 March 1974 at 600 hPa is presented. As it can be seen in Fig. 2a,b, a kind of mid tropospheric temperature wave was developing over the region with values near or below the freezing point in the Central Caribbean. Over Costa Rica, at 600 hPa, temperature is just above the freezing level (275-276 °K). To complement the above data, actual values of the vertical profile of the temperature using Costa Rica radiosonde station data are shown in Fig. 3. In this figure, it is observed that temperature was indeed near the freezing point at an elevation similar to that of the above mentioned peaks. In this respect, Reanalysis data appears to be quite realistic over Costa Rica. No such snowy conditions are known to have been scientifically documented for any of the situations analyzed.

Results of research carried out about observed evidence of climate changes at high elevation-sites, specially for areas of the Northern hemisphere extra-tropics, indicate that temperature at the mountain regions of the world has increased (see for instance an overview by Beniston et al. 1997). In an earlier work, Díaz and Graham (1996), had focused attention on decadal changes in temperature of tropical regions (specifically changes in tropical freezing heights). They concluded that an increase in tropical sea surface temperatures since the 1970s, have resulted in a mean upward lift of freezing heights on the order of 100 m. This upward displacement of the freezing height corresponds to a temperature increase of approximately 0.5 °C over a 20 year period. Also Díaz and Bradley (1997) found evidence for appreciable differences in mean temperature changes with elevation and high altitude warming during the last decades using instrumental records at a number of mountain tops, primarily in Europe. Data used by Díaz and Bradley (1997) also included some stations in northern South América. Considering the evidence of warming at high altitude peaks, and with the noticeable fact in recent past, that temperatures at levels near 600 hPa, have dropped to around freezing conditions during some of the winter months, the possibility of snowfalls in Costa Rica during the XIX century widens. Such a condition, that is told by chronicles from the epoch, based on descriptions of highly educated people, becomes a likely meteorological situation and a plausible indication of climate change since that century. This aspect also brings the attention about the importance of documentary evidence in the reconstruction of extreme events of past climate.

Osejo (1833) also described the floods that usually occur from November to March in the Caribbean side of Costa Rica. He attributed the cause of the overflowing to cold air associated to strong winds related to more or less intense and continuous precipitation. It is noteworthy to mention that Osejo believed that these floods were caused by winter development conditions and disruptions of these conditions in mid latitudes, an idea that was fully developed many decades after Osejo's explanation. In his own words:

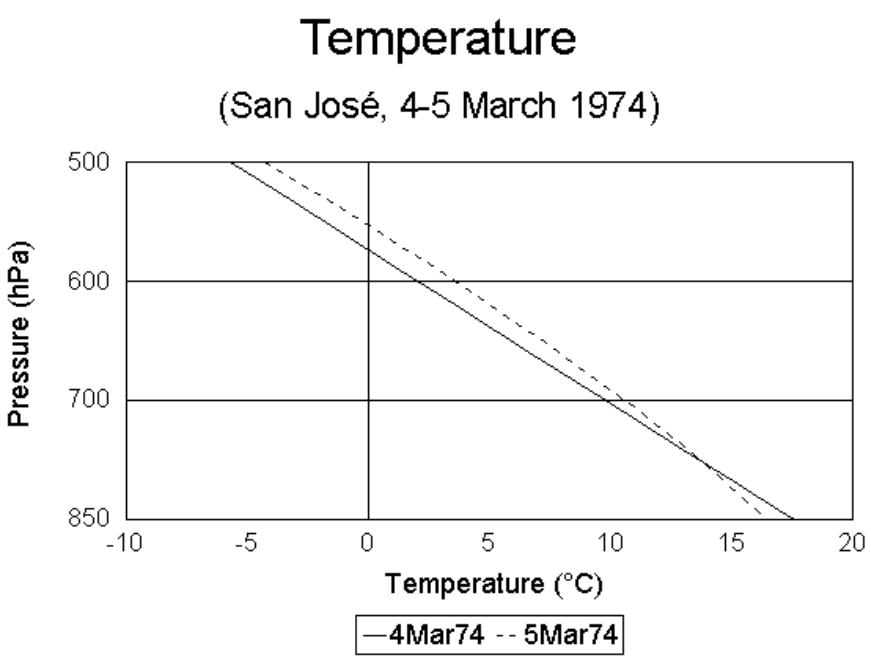


Fig. 3. Vertical profile of temperature (ºC) for San José for the period 4-5 March 1974.

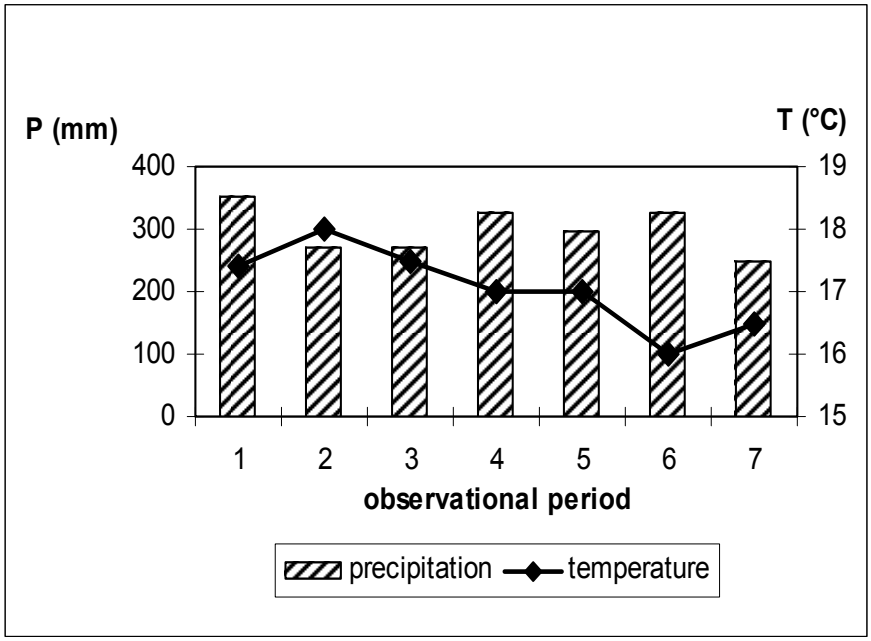
> **"**se sienten en la parte oriental de Costa Rica frío más o menos intenso hasta muchos grados bajo el término de congelación, vientos mas o menos recios, lluvias más o menos fuertes y frecuentes" (page 71).

> ".. Siguiendo en todo la intencidad y progresos del invierno y las alteraciones de la zona templada", (page 72)

In his book, Osejo refers to the "inundaciones del Valle de Matina" (Matina floods) giving a description and explanation of cold air masses reaching the region, and making use of the runoff concept to explain the floods. He also describes, but does not provide a number for, the associated temperature drop. Strong winds, frequent storms and continuous rainfall characterized the event, which had a duration between 24 to 36 hours. This phenomenon would probably correspond to a cold surge intrusion at latitudes as low as 8-10 north, and would be responsible for the Matina floods, which in turn, he considered to be a predictable phenomenon. Osejo also introduced in this book, the concept of geographical water division, made an attempt to give the first broad climate classification of Costa Rica and used the climate concept in urban planning.

> **"**hay un punto llamado Alto de Ochomogo (…) desde el cual notablemente se reparten las aguas o ríos… ¨ , (page 70)

After the Osejo's descriptions and explanations of weather events and climate conditions, national and foreign explorers provided temperature measurements and other descriptive accounts of climate characteristics in different sites of Costa Rica (e.g.: all year round rainfall conditions in northern Costa Rica region). In 1846, Danish botanist Dr. Anders S. Oersted, established in Costa Rica and made systematic meteorological observations during most of his two years stay in the country. Oersted left meteorological evidence to characterize seasonal distribution of precipitation and temperature in the Central Valley of Costa Rica. The precipitation and temperature patterns clearly show, what is probably, the earliest quantitative description of the Mid-Summer Drought (MSD) in the country. Over this region, the rainy season has a bimodal distribution with maxima in June and September-October and a relative minimum in July-August (the MSD). This feature, also called "veranillo" or "canícula", depending on the region where it is experienced, is now known to be part of the seasonal cycle and the evolution of the rainy season over southern Mexico and Central América (Magaña et al. 1999). In Fig. 4, meteorological observations carried out by Dr. A. S. Oersted in San José for the period 15 May to 15 November are shown. As previously described, a minimum in precipitation corresponding to the "veranillo" occurs in July-August; which in Oersted's data reflects during the period 16 June -15 August. As a consequence of less cloudiness during the "veranillo", there should be



1 15 May-15 June
2 16 June-15 July
3 16 July-15 August
4 16 August-15 September
5 16 September-15 October
6 16 October-15 November
7 16 November-15 December

Fig. 4. Meteorological observations of precipitation (P) in mm, and temperature (T) in °C, carried out by Dr. A.S. Oersted in San José, Costa Rica, showing the "veranillo" within the period 16 June – 15 August, 1847.

an increase in mean temperature due to more radiation reaching the surface during that period. This increase can also be observed in Fig. 4, in the temperature data taken by Oersted during the period 15 June - 15 July 1847.

6. Analysis of reconstructed temperature data

As described in section 4, temperature data was collected from a number of different documentary sources, such as La Gaceta Oficial, bulletins from Secretaría de Fomento and other public and private archives (Solano, 1999). Available daily temperature values were carefully treated to avoid transcription errors. A time series of monthly temperature values was constructed for the period 1866-1887. A longer time series for the period 1866-1899 was obtained using data available at the IMN for the period 1888-1899. The monthly values were determined from the daily available temperatures and monthly anomalies for the period were estimated as departures from the 1866-1899 mean monthly temperatures. The results for the period 1866-1899 are shown in Fig. 5, which presents some remarkable disruptions of climate over the region. Firstly, a dramatic warming of the order of more than 2 °C is observed around 1878, which according to Coughlam (1999), is the most intense El Niño episode of the XIX century. Also, from Fig. 5, the El Niño event of 1898-99 is documented, but with a less intense warming than the one previously mentioned.

Over a century ago, on August 23, 1883, an island volcano in Indonesia, the Krakatau ("Krakatoa") exploded with devastating intensity. According to reports from the period, the effects of the explosion were felt on a global scale, and ashes and dust were launched into the upper troposphere affecting incoming solar radiation and disrupting the earth's climate for years. Temperature anomalies for San José, Costa Rica, remarkably show in Fig. 5, an extended period from late 1883 to 1886-87, of anomalously large negative temperature departures, which could be associated to cooling effects of the Krakatau eruption.

7. Remarks and conclusions

A brief historical account of the development of meteorology, specially during the 1700s and 1800s, and the first meteorological observations taken in Costa Rica are presented. Quantitative meteorological data were scarce and descriptive evidence of atmospheric phenomena predominated over most of the XVIII century. The origin of the first meteorological concepts in Costa Rica is closely related to the development of physics at the University of San Carlos (USC) in Guatemala during the second half of the XVIII century. Dr. (Fray) José Antonio de Liendo y Goicoechea, a Franciscan natural from Costa

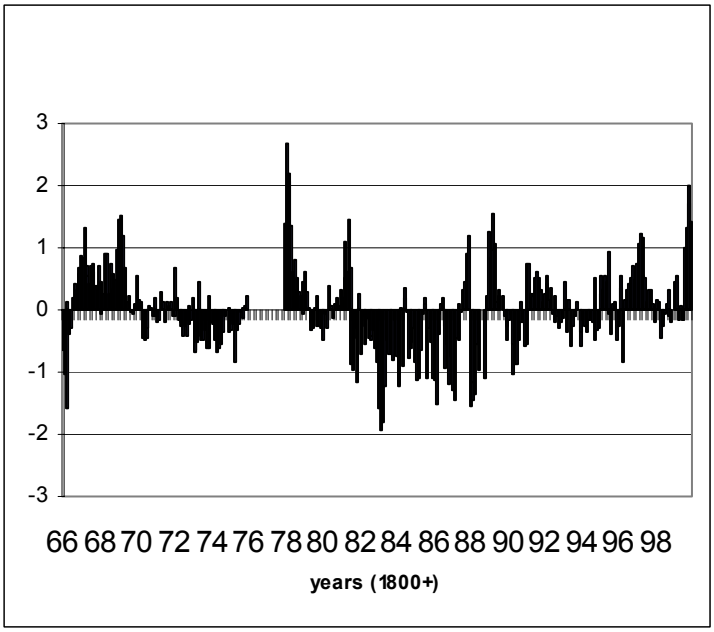


Fig. 5. Temperature anomalies (ºC) for San José, Costa Rica, for the period 1866 – 1899, from the same period mean values.

Rica, played an important role in introducing experimental physics at this Institution. During the first third of the 1800s, a highly educated local teacher, Rafael F. Osejo, provided the first descriptions and explanations of local climate and, of what appears to be, the intrusion of cold air masses in the Caribbean region of Central América. From the mid 1840s onwards, immigrants (mainly from European countries) along with nationals, started to measure mainly temperature at different locations as they traveled and explored Costa Rica territory. In 1846, Danish botanist, A. S. Oersted made systematic meteorological observations, of precipitation and temperature, that clearly showed, what is probably, the earliest quantitative description of the Mid-Summer Drought (MSD) or veranillo in the country. After the 1860s, there was a significant increase of meteorological observations in San Jose, the capital city, which led to the participation of the country in the first International Meteorological Network.

Documentary sources of the period 1830-1890 usually refer to snow falls in the highest mountain tops of Costa Rica. No such conditions are known to have been reported during the last decades. Using NCEP/NCAR Reanalysis and CARDS radiosonde station data, it is shown that in the last few decades, temperatures at levels near 600 hPa, have dropped to around freezing conditions in some cases during the winter months. When recent evidence of ongoing warming at high altitude peaks is considered, snow falls in Costa Rica during the XIX century winter months, as told by chronicles of that period, become a more likely meteorological situation and a plausible indication of climate change since that century.

Before the creation of the National Meteorological Institute in Costa Rica in 1888, several government offices kept a continuous program to measure meteorological data in different sites for applications to agriculture and road construction. Temperature information was collected from primary and secondary sources and quality controlled, and monthly temperature values were constructed for the period 1866 to 1887 for San José. This time series together with that for the period from 1888 to 1899, was used to study some aspects of the climate and El Niño signal in the region, specially during the second half of the XIX century. The monthly temperature values were determined from the daily available temperatures and monthly anomalies for the period were estimated as departures from the 1866-1899 mean monthly temperatures. The temperature anomalies present some remarkable disruptions of climate over the region. A dramatic warming of the order of more than 2 ° C is observed around 1878, which according to Coughlam (1999), is the most intense El Niño episode of the XIX century. Also, from the temperature departures, the El Niño event of 1898-99 is documented, but with a less intense warming than that of 1876-78. The effects of the Krakatau explosion in 1883 were felt on a global scale, and ashes and dust were launched into the upper troposphere affecting incoming solar radiation and disrupting the earth's climate for years. Temperature anomalies for San José, Costa Rica, remarkably show an extended period from late 1883 to 1886-87, of anomalously large negative temperature departures, which could be associated to cooling effects of the Krakatau eruption.

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ABSTRACT

A brief historical account, of the early development of meteorology in Costa Rica, particularly during the 1700s and 1800s, and, of the first meteorological observations taken in the country, is presented. Quantitative meteorological data were scarce and descriptive evidence of atmospheric phenomena predominated over most of the XVIII century. During the first third of the 1800s, Rafael F. Osejo, provided the first descriptions and explanations of local climate, floods and, of what appears to be, the intrusion of cold air masses in the Caribbean region of Central América. Danish botanist, A. S. Oersted made systematic meteorological observations of precipitation and temperature during 1846-47, that clearly showed, what is probably, the earliest quantitative description of the Mid-Summer Drought (MSD) or "veranillo" in the country. Documentary sources of the period 1830-1890 often refer to snowfalls in the highest mountain tops of Costa Rica. A simple analysis of synoptic data for the last few decades helped to understand the possible origin and the meteorological likelihood for such an extreme meteorological situation. Since no such conditions are known to have been scientifically documented during the last decades, this could be a plausible indication of climate change since that century, specially if recent evidence of ongoing warming at high altitude peaks is considered. Temperature information, although very disperse in public and private archives, was collected from primary and secondary sources and quality controlled. Monthly temperature values were constructed for the period 1866 to 1887 for San José. This time series together with that for the period 1888 to 1899, has been used to study some aspects of the climate in the region. Anomalies of temperature during the period of study clearly show the warming associated with some El Niño events (including the 1876-78 episode, the most intense event of the century) and the cooling in the region possibly due to the Krakatau eruption of 1883. The results of this research bring the attention about the importance of meteorological data rescue and the use of documentary historical sources in the reconstruction of extreme events of past climate.

References

Amador J, Páez J, Solano F (1990) Algunos detalles y hechos históricos de los albores de la física en Costa Rica: Parte I. En: Las matemáticas en Costa Rica. Memorias III Congreso Nacional de Matemáticas. Angel Ruiz (ed). Costa Rica, p 349-355.

Beniston M, Díaz HF, Bradley RS (1997) Climate change at high elevation sites: An overview. Clim Change 36:233-251

Coughlam MJ (1999) Reacción del sistema de las Naciones Unidas al episodio de El Niño de 1997-1998. Boletín Organización Meteorológica Mundial 48(3):321-325

Coen E (1973) El folclore costarricense relativo al clima. Revista de la Universidad de Costa Rica, 135:135-145. Universidad de Costa Rica, San José, Costa Rica, 42 pp

Díaz HF, Graham NE (1996) Recent changes in tropical freezing heights and the role of sea surface temperature. Nature 383:152-155

Díaz HF, Bradley RS (1997) Temperature variations during the last century at high elevation sites. Clim. Change 36:253-279

Fernández R (1982) Costa Rica en el siglo XIX. EDUCA, 4ª edición. San José, Costa Rica, 585 pp

Frantzius A (1868) Ensayo de una fundamentación científica de la climatología de Centro América. En: Revista de Archivos Nacionales, 1942. Año VI (1-2). Tr. José Dávila. Imprenta Nacional. Costa Rica, p 32-58

Gobierno de Costa Rica (1861) Creación Oficina Central de Estadística, circular número 27, del 25 de octubre de 1861 por Ministro Francisco María Iglesias. San José, Costa Rica

Gobierno de Costa Rica (1866) Observaciones meteorológicas realizadas en la ciudad de San José. Gaceta Oficial del 30 de junio de 1866 por Fernando Streber. San José, Costa Rica

Jiménez F (1863) Instrucciones para hacer las observaciones meteorológicas (Adoptadas por el Instituto Smithsoniano de Washington y traducidas por la Sociedad de Geografía y Estadística). Boletín de La sociedad mexicana de geografía y estadística, tomo X. Imprenta de Vicente García Torres, calle de S. Juan de Letrán, número 5, 47 pp

Kalnay, et al. (1996) The NCEP/NCAR 40-year reanalysis project. Bull Amer Met Soc 77:437-471

Magaña V, Amador JA, Medina S (1999) The Midsummer Drought over Mexico and Central America. J. Climate 12:1577-1588

Meléndez C (1974) La ilustración en el antiguo Reino de Guatemala. EDUCA. 2ed. Costa Rica, 218 pp

Osejo, RF (1833) Lecciones de Geografía. Imprenta de la Paz, San José, Costa Rica, 15 pp

Páez J, Solano F, Amador J (1990) Algunos detalles y hechos históricos de los albores de la física en Costa Rica: Parte II. En: Las matemáticas en Costa Rica. Memorias III Congreso Nacional de Matemáticas. Angel Ruiz (ed) Costa Rica, 356-369 pp

Reyes V (1877) Instrucciones especiales para hacer las observaciones internacionales simultáneas. Imprenta y Litografía de Ireneo Paz. México, 72 pp

Solano FJ (1999) El proceso de institucionalización de la meteorología en Costa Rica en el siglo XIX. Tesis de Licenciatura en Historia. Universidad de Costa Rica. Costa Rica, 228 pp

Solano F, Amador J, Páez J (1990) Algunos detalles y hechos históricos de los albores de la física en Costa Rica: Parte III. En: Las matemáticas en Costa Rica. Memorias III Congreso Nacional de Matemáticas. Angel Ruiz (ed). Costa Rica, 371-384 pp

Wagner M, Scherzer C (1856) La república de Costa Rica en Centroamérica. Tr. Jorge Lines. Lehmann. Costa Rica, 353 pp

Zelaya C (1971) El Bachiller Osejo. Tomo I y II. Editorial Costa Rica. Costa Rica, 423 pp