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SECAS AND EL NIÑO: TWO SIMULTANEOUS CLIMATICAL HAZARDS IN SOUTH AMERICA

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ABSTRACT. Among the most disastrous climatic hazards affecting both man and the ecology of plants and animals in South America are the *El Niño* of north-western Peru and the *Secas* (droughts) of northeastern Brazil. Even though these phenomena strike the two opposite coasts of South America, a linkage between them seems to exist, for they have appeared simultaneously in some particular years.

In their origin, *El Niño* and the *Secas* depend on the position of the ITC and the subtropical high pressure cells of the Pacific and Atlantic Oceans. While during the summer months of *El Niño* years the ITC advances unusually far southward along the coast of Peru, in the equatorial Atlantic the ITC and the South Atlantic high pressure cell counterbalance by moving northward and remaining almost stationary during the winter months, thus creating a sequence of a dry summer between two already dry winters: a drought year. Nephoanalysis of satellite pictures of normal years suggests that this mechanism is the reason for the simultaneous occurrence of the two events.

The droughts of northeastern Brazil and the *El Niño* phenomenon which occurs along the coast of northern Peru are among the most striking catastrophies which affect the ecological equilibrium of South America. Up to now both have been considered separately, although some kind of relationship seems to exist between the two phenomena as it is suggested by the available climatic records and research which has been done.

A *seca* (drought) may be defined as a rainless or a rain-poor summer between two already dry winters. Since two consecutive drysummersmay alternate with three anyhow rainless winters, such a drought period may extend over three years, and this calamity is referred to as a *grande seca* (Lopes de Andrade, 1948). The consequences of this are not only noticeable by an extraordinary dryness of the *sertao*, but also by the out-migration of numerous rural settlers in order to avoid famine, pests and diseases which are often the alternative for those who stay. In fact, the *secas* are largely responsible for the overall mobility within the area of dense rural population in northeastern Brazil (Brooks, 1971). Combining the information about the areas affected by the *secas* which was provided by the studies of Menezes (1936), Markham (1967) and Brooks (1971) one can delimitate three zones with varying degrees of dryness during a drought period in northeast Brazil (Fig. 1). The core which is located on the lee side of the Planalto de Borborema, extending from the latitudes 6°S to 10°S, is surrounded by a fringe to the west and north where the intensity and frequence of the *secas* is somewhat less than that of the nucleus and it may

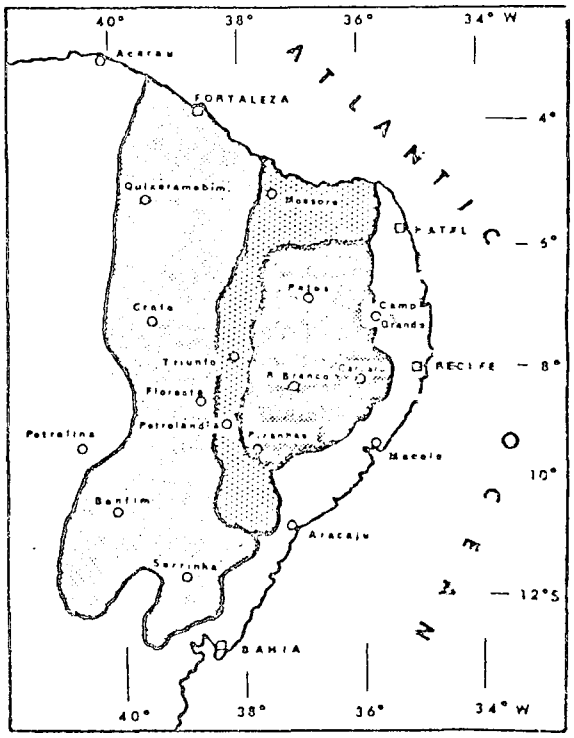

Fig. 1. Areas of northeast Brazil affected to different degrees by the *secas*.

become an area of severe drought during particularly dry years. A further wider fringe area which runs down from Fortaleza to the interior behind Bahia represents the buffer zone between northeastern Brazil and adjacent zones in which the precipitation pattern shows fluctuations in intensity one year to the next, but never the extreme fluctuation of the typical region of the *secas* itself.

Off the coast of Peru, in some particular years, and during the solstice of December, the cold upwelling waters of the Peru Current are covered at the surface by tropical warm waters. Concurrently heavy rains, that will last until March, fall upon the semi-desert environment of northwestern Peru and the western slopes of the Cordillera Occidental (Fig. 2). The *El Niño* phenomenon affects the marine and costal wild life more than it affects man himself. During the summer and fall of such a year the cold water fish migrate farther south because of a lack of plankton in the unusually warm water. Coastal birds that feed on them follow their migration. Exhausted by their long trip down the south coast, thousands of starving guanays (*Phalacrorax bouganvillii*) and cormorans (*Phalacrorax gaimardi*) become

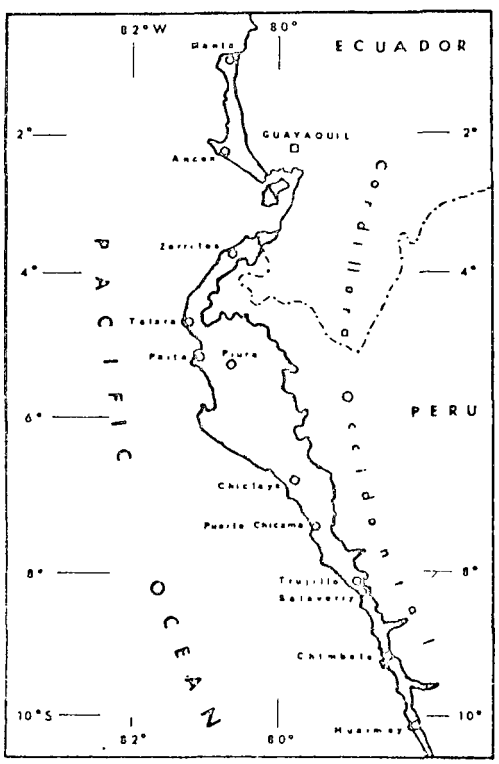

Fig. 2. The coast of Peru and Ecuador affected by the *El Niño* phenomenon.

stranded on the beaches of South Peru and North-Central Chile. Particularly disastrous for the economy of Peru is the disappearance of anchovies, a species which is the main stay of the country's fish meal industry. On the land, the heavy rains swell the commonly dry rivers and flooding occurs in the fertile valley bottoms and many farm houses are inundated (Murphy, 1926). In summary, the classical *El Niño* year is characterized by atmospheric disturbances shown by especially heavy rains during the summer months and ocean current disturbances caused by the unusual southward extension of tropical surface waters overlapping the Peru Current.

THE ANOMALIES OF THE ATMOSPHERIC CIRCULATION OVER THE EQUATORIAL PACIFIC AND ATLANTIC DURING EL NIÑO – SECA YEARS

The characteristic patterns of the atmospheric circulation over the regions affected during *El Niño* and *seca* years have been carefully studied by J. Bjerknes (1961), K. Schutte (1969) and C. G. Markham (1967). Combining their data we may examine both phenomena together during abnormal years and compare them with the pattern of circulation during normal years.

In a normal south-hemispheric summer, the ITC may advance as far as 3° Lat. S, producing short but intense summer rainfall in northeastern Brazil (Markham, 1969). After a short period of dryness during the autumn months (April – May), winter and spring rains from frontal disturbances affect the region, so that only the fall months are rain-free. However, in the years in which the South Atlantic high pressure cell seems to appear especially strong near northeastern Brazil, the ITC is prevented from moving southward during the summer months, and the frontally associated disturbances from the southwest cannot enter northeastern Brazil in the winter. This being so, the region is affected by the following sequence of dry seasons: summer–fall–winter–spring–summer, the classical situation of a common *seca*. If the drought continues through another fall–winter–spring, lasting thus more than two years, the region is under the influence of a catastrophical *grande seca*. The moisture rates, the humidity transport and the conditions of the upper atmosphere during those particular years have not been studied closely by meteorologists. It is therefore rather difficult to explain why the moisture sources are inactive during these years and why the

South Atlantic anticyclone remains in a semi-stationary position over the Brazilian northeast for this long period of time.

For a great part of the South American west coast, the dry southeast winds coming from the South Pacific high-pressure cell and reinforced by the cold waters of the Peru Current are the most important factors for the dry climate of this coast. In Peru during the summer months of normal years, with the retreat of the South Pacific anticyclone and the weakening of the southeast winds, the ITC advances southward (Fig. 3) and moist air invades the Peruvian northwest coast where it causes short, but heavy rainfall. Its intensity decreases rapidly towards the south, so that the coastal stations south of 10°S do not register any amount of precipitation during the summer months. The flow of the Peru Current appears "normal" also.

A typical *El Niño* year in Peru, however, is preceded by a rapid invasion of warm, tropical waters starting at about Christmas (thence the name *El Niño* from the Infant Jesus) and lasting often until the beginning of April. Heavy rains accompany the unusual sothward advance of the ITC which is, in addition, partially responsible for the appearance of the oceanic *El Niño* phenomenon. Alterations in the sea-surface temperatures are quite noticeable as far south as the port of Salaverry, 8°S. For Puerto Chicama, Doberitz (1967) reports that during March, 1925, the water temperature was 7.7°C above the mean monthly average; in March, 1941, it was 3.8°C above average, in February, 1957, 2.7°C above average. In the studies of Wooster (1960) and Bjerkness (1961) it has been shown that the overlapping of the cool water of the Peru Current is not only a result of the invasion of tropical air masses which, for a time, interrupt the upwelling associated with the regularly blowing Southeast Trades but also of the transport of equatorial surface waters. These waters are helped both by an abnormally deep thermocline and the weakening of the southeast Trade Winds. Given these events, the data avilable suggest that the occurrence of an oceanic–meteorological *El Nino* phenomenon requires the concurrence of oceanographic and climatological factors, which may begin to develop a few years before the event itself and involve not only the southern hemispheric patterns of circulation but also those of the northern hemisphere. So we are presented with large-scale changes in the atmo-

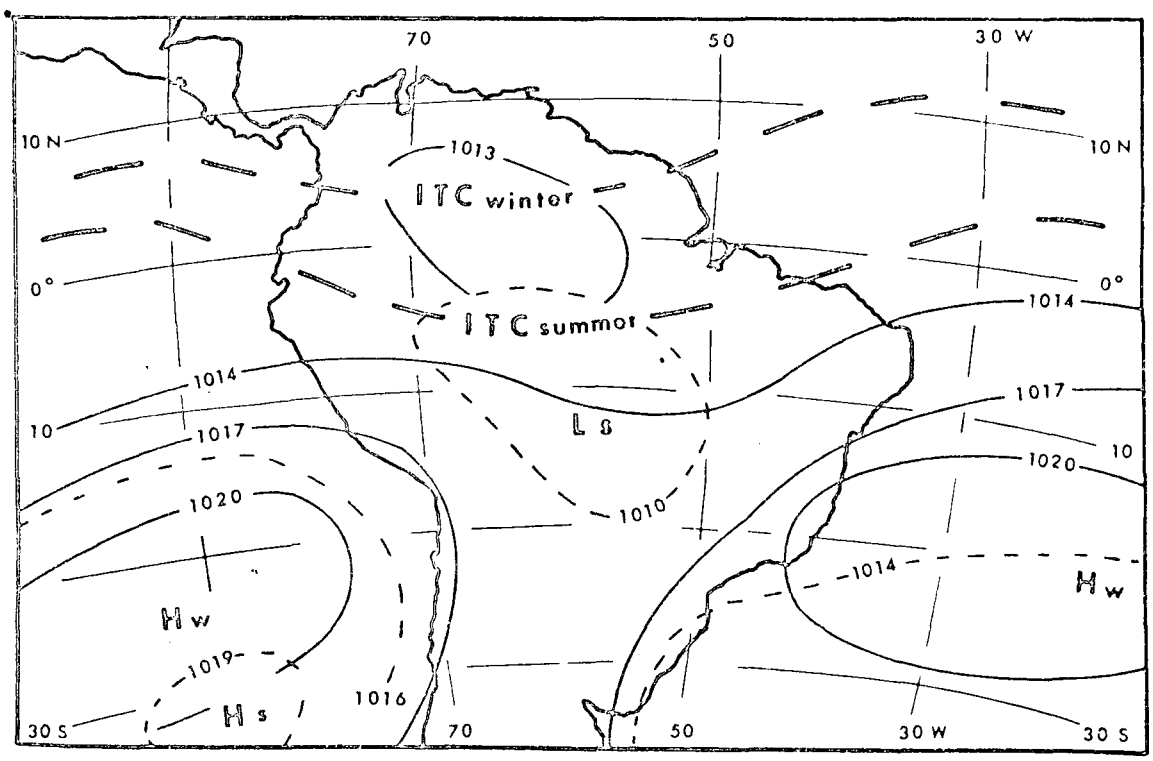

Fig. 3. Average location of the ITC and pressure cells in South America. Continuous isobars: winter months, broken isobars: summer months.

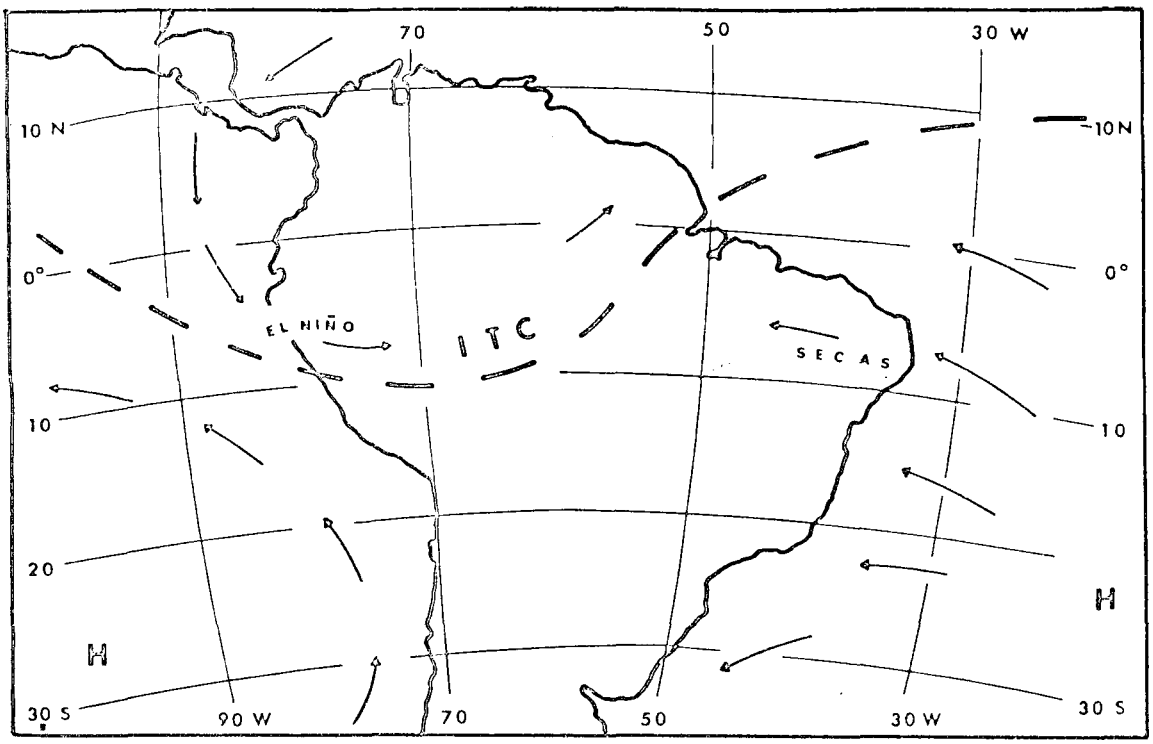

Fig. 4. Typical location of the ITC and South Hemispheric Trade Winds during a classical El Niño-Seca year.

spheric circulation throughout tropical South America. These changes affect the tropical Atlantic and Pacific coasts, but they need not occur during the same year. However, we may hypothesize that the mechanism involved is the same for both coasts.

THE OCCURRENCE OF SECAS AND EL NIÑO YEARS

Because of the terrible impact of both phenomena, records of the years in which they occurred have been kept by the inhabitants of northeastern Brazil and northwestern Peru for centuries. They have been observed scientifically since the end of the last century, and the author has chosen a period of 83 years: 1890–1972 in order to study the frequency of occurrence of the phenomena (Table 1).

In Brazil, and by using the information provided by Lopes de Andrade and Brooks as well as the climatical records of the last 25 years, 13 droughts were counted. Those of the years 1915, 1919 and 1931 are remembered as *grande secas* because they affected the region for more than two years and caused enormous damages in agriculture and stock farming. Those of the years 1891, 1907, 1942 and 1958 were considered as critical, but not as catastrophic *secas*. A cycle of 9–10 years seems to separate one drought from another in the study period. Markham (1967) supports the idea of a eleven years cycle, tying it to the cycle of sunspot activity. Ideally, in order to determine the cyclical occurrence of the phenomena more precisely it should be possible to consider a longer period of time.

On the northwestern coast of Peru, the *El Niño* years have been observed since the 16th century. However, the incompleteness of the meteorological records available for the greater part of the last century makes information dating from before 1890 unreliable. After 1890, extremely accurate measurements of the meteorological and oceanic conditions were taken by the Compañia Administradora del Guano and were used by Schweigger (1959). By evaluating his information we may establish that 11 times the *El Niño* phenomenon appeared between 1890 and 1957. Among them the most disastrous were those of 1891, 1925, 1939-41 and 1957. At this writing (September, 1972) periodicals such as the *Peruvian Times* and the *Christian Science Monitor* are carrying stories that another intensive *El Niño* year has begun and

TABLE 1. SECAS AND EL NINO YEARS DURING THE LAST EIGHT DECADES

Secas: Northeastern Brazil	El Nino: Northwestern Peru
1891	1891
	1899
1900	
1907	
1911	1911
	1912
1915	
1917	1917
	1918
1919	
1923	
	1925
1931	
1932	1932
1938	
	1939
	1940
1941	1941
1942	
	1943
	1951
1952	
1953	1953
1956	
	1957
1958	
1971 !	1972 ! *

Source: Lopes de Andrade (1948), Markham (1967), Schweigger (1959) and Brooks (1971).

is almost ruining the previously flourishing fishing industry of Peru.

If we consider the occurrence of the *El Nino* and the *secas* in terms of the general multiplication rule of probability we find: first, that the possibility of obtaining a *seca* year in Brazil given that Peru is experiencing an *El Niño* year is .461 or 46.1%; and second, that the probability of obtaining an *El Niño* year in Peru given that Brazil is experiencing a drought year is .600 or 60%. These are both very high probabilities given the absolute number of occurrences of *El Niño* and *secas* during the study period. If we assume statistical independence between the *El Niño* and *secas* phenomena we obtain a probability of .018 or 1.8%. Clearly both the phenomena are related to some general mechanism. If we were to consider the simultaneous occurrence of both to cover one year plus or minus another year, then the multiplication scale indicates that it is almost certain that an abnormal year in Brazil will occur with an abnormal year in Peru or vice versa. At present, the exact nature of this mechanism is not known but an attempt at an explanation of it will be presented.

THE TROPICAL CIRCULATION DURING SECAS -- EL NIÑO YEARS

From before we know that the southward shift of the ITC during the south-hemispheric summer months is directly responsible for the rains in northeastern Brazil and southwestern Peru. The position of the ITC in South America can be studied from nephanalyses of photographs released by the meteorological satellites Tiros IX and X (January, 1965 to September, 1968). Its normal location during the summer months (December to March) and during the winter months (June to September) is shown in Figure 3. In the abnormal years the ITC does not reach northeastern Brazil, and anticyclonic conditions prevail throughout the region because of the extraordinary strength and persistence of the South Atlantic high pressure cell (Fig. 4). In the interior part of Brazil, however, the ITC advances much farther south that usual and an even greater part of the coast of South America is affected by this movement. During the summer and winter months of the abnormal years, the core of the South Pacific anticyclone remains at about the same latitude, i.e. 35°S. As a result the southeast winds weaken or disappear even completely along the Peruvian coast, and the frontal depressions which cause the winter rains in Central Chile cannot advance as far north as they usually would (Fig. 4). Studies by the author show that during most *El Niño* years the winter precipitation along the Chilean coast is far below average. This is a clear indication of an abnormal stationary position of the South Pacific anticyclone and its associated wind systems off the coast of Middle Chile in the same year or in those that precede or follow an *El Niño* phenomenon.

Furthermore, we know that on the tropical Atlantic off northeastern Brazil, the South Atlantic anticyclone is blocking the southward advance of the ITC. As a consequence of this stationary situation (or temporary weakening?) of the South Pacific anticyclone the ITC is allowed to move extremely far south on the Pacific side of

the continent. Simultaneously warm tropical water begins to invade the commonly cool environment conditioned by the Peru current. This may happen not only in the *El Niño–seca* year itself, but it may start a couple of years before and may last until a couple of years after these phenomena have hit the respective regions (Bjerknes, 1961). This, then, is the reason why *El Nino* and *seca* years lie so close to each other in the series of years considered here.

Taking into account all these preliminary results, the explanation of both phenomena seems to lie in:

(a) the counterbalance movement of the subtropical high pressure cells at both sides of the continent, which either allows the ITC to advance southward or prevents it, and
(b) in the existence of periodically occurring big changes in the pattern of the general circulation over the tropical and subtropical belts which comprise most of the continental mass of South America.

Furthermore, in the origin of the *El Niño* not only the conditions of the circulation in the eastern South Pacific seem to play an important role but also a great part of the wind system and pressure centers of the North Pacific (Bjerkness, 1961). Coinciding with this is the opinion of Serra (in Trewartha, 1966) that the movement of the ITC along northeastern Brazil is closely related to conditions in the circulation over the southern part of North America and the Caribbean Sea.

We may conclude tentatively that *El Niño* and *secas* are indeed the consequence of the same large-scale variation in the tropical and equatorial circulation, and that the closeness of the years of their occurrence is not just coincidence.

This conclusion has been drawn after studying the available data and comparing the characteristic conditions of normal years with those of abnormal years. Since the last simultaneous *seca* and *El Niño* phenomena occurred between 1956 and 1958, before photographs from meteorological satellites of the tropical part of South America and the adjacent oceans were available, the decisive support of these views will come when both phenomena strike simultaneously again. Might this be the case in 1972–73?

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