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SOME CLIMATIC ALTERATIONS RECORDED IN SOUTH AMERICA DURING THE LAST 7000 YEARS MAY BE EXPOUNDED BY LONG-TERM EL NIÑO LIKE CONDITIONS

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In the Southern Hemisphere the climate of the tropical continental regions bordering Eastern Pacific and Eastern Atlantic Oceans is presently influenced by sea surface temperature particularly cold for tropical oceans. Nevertheless, during El Niño events, the cold coastal waters of Northern Peru (Humbold Current) are replaced by warm waters. This change leads to important anomalies of rainfalls and wind pattern in South America. During the strong 82-83 El Niño event the disturbances were generated by two main processes (1):
-modification of the Walker circulation due to a shift toward the Pacific ocean of the convection zone, normally centred on Amazonia, which promoted anomalously heavy rainfalls in Northern Peru and deficient rainfalls in Amazonia and Bolivian Altiplano.
-blocking situation of polar frontal systems, in a zone extending from South Peru to South Brazil, related to an enhancement of the subtropical jetstream. This situation provoked anomalously high rainfalls in the blocking zone and droughts northward, as well as a modification of the wind pattern, and consequently of the wind-driven littoral dynamic, in the central part of the Brazilian Coast.
In 1984, one year after the Pacific warm event, an intense warm event affected the Eastern Tropical Atlantic.

Inversions of longshore sand transport direction during the last 5000 years in Rio Dôce coastal plain (19°S Brazil).

On a sandy coast the long-term longshore transport direction depends on the orientation of efficient swells (those responsible for the resulting transport). When, as on the Brazilian coast, fossil beach ridges exist, their geometry reflects the past longshore sand transport and then the past orientation of swells and wind pattern. Detailed analysis of the geometry of the fossil beach ridges series in the Rio Dôce coastal plain points out several inversions of the longshore sand transport direction during the last 5100 years (2). These inversions persisted during tens to hundreds of years. In 1983 the same kind of inversion of the longshore transport direction occurred on a sandy beach near Salvador (13°S) (3). During this year the blocking situation of frontal systems related to El Niño event makes Northeastern swell more efficient than the Southeastern ones that, in fall and winter, normally reach this region and determine the longshore sand transport direction.

The Rio Dôce coastal plain study provides the following information:
-before 5100 years BP, the absence of beach ridges does not allow to infer any longshore transport direction;
-between 5100 and 3900 years BP, seven times running, the longshore sand transport that normally is northward reverses southward; it would mean that, seven times running, the frontal systems causing southeastern swells were blocked in the south of the study area;
-between 3900 and 3600 years BP the direction of longshore sand transport cannot be determined in consequence of a relative sea level rise;
-between 3600 and 2800 years BP the longshore transport was continuously northward; the southeastern swells were permanently efficient without any long duration blocking situation of frontal systems;

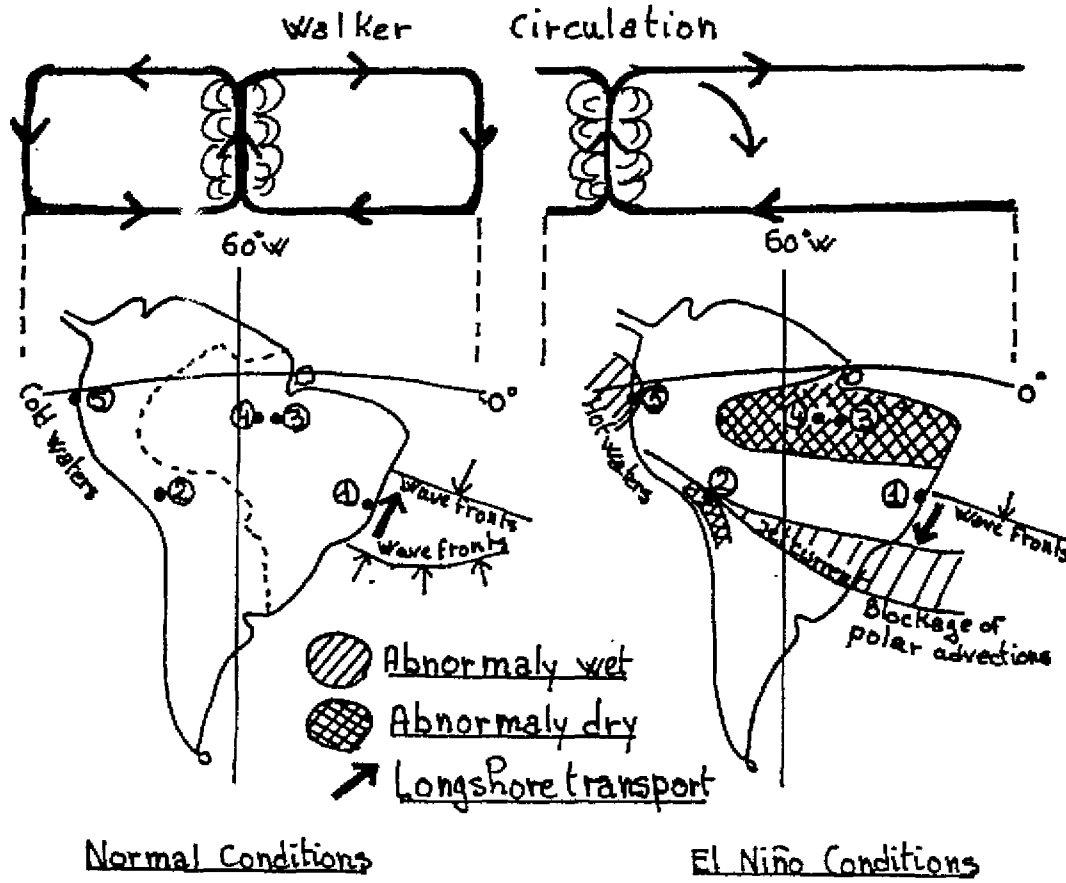

Fig.1 Perturbations engendered by El Niño Phenomenon in several countries of South America. (1) Doce river outlet; (2) Titicaca lake; (3) Carajas Lake; (4) Xingu River; (5) Chira and Piura Rivers.

-between 2800 and 2500 years BP, the direction of longshore sand transport cannot be determined in consequence of a relative sea level rise;
-between 2500 and 0 years BP, three times running (2200+200, 1300+200 and an undefined most recent age), the longshore transport reversed southward. It indicates that, three times running, the southeastern swells do not reach this region and that, consequently, the frontal systems were blocked in the South.
As El Niño phenomenon generates indirectly short-term inversions of sand transport direction, it seems possible to associate periods of anomalous sand transport direction recorded in the Rio Dôce coastal plain with long duration period of El Niño-like conditions (4). These periods may represent a permanent blocking situation of the frontal systems, as well as an high frequency succession of blocking situations during long time intervals.
If the hypothesis is true we may think that the past long duration El Niño-like conditions would have, in South America, the same effects than the 82-83 El Niño event.

Paleoclimatic conceptual model.

On the basis of the observed teleconnection between inversion of longshore transport direction in the central part of the Brazilian coast and the 83 El Niño event, a conceptual model of the effects of long duration El Niño-like conditions can be elaborated. This model has to consider the data we get and to foresee the data we ignore. If, during the last 7000 years, long periods of El Niño-like conditions occur their should exhibit in Amazonia, Bolivian Altiplano, and Northern Peru the same climate anomaly than during 82-83 El Niño:
-Before 3900-3600 years BP (Numerous periods of blocking situation) a succession of drier periods in Amazonia and Bolivian Altiplano , a succession of wetter periods in Sechura Desert (Northern Peru).
-Between 3900-3600 and 2800-2500 years BP (no blocking situations), no dry periods in Amazonia and Bolivian Altiplano and, on an average, a wetter climate; no wet periods in Sechura desert and, on an average, a drier climate.
-Between 2800-2500 and 0 years BP (three recorded periods of blocking situation), at least three drier periods in Amazonia and Bolivian Altiplano and at least three wetter periods in Sechura Desert.

Confirmation of the conceptual model hypothesis.

To confirm this hypothesis we use the information supplied by the fluctuations of water level in Titicaca lake, variations of the pollen rain and of sedimentary fluxes in an Eastern Amazonian lake, variations of Rio Xingu discharge also in Eastern Amazonia and variations of sand supply at Rio Piura and Rio Chira outlets in Sechura Desert.

Fluctuations of the Titicaca lake water level during the last 7000 years.

The paleodepth reconstructed by Mourguiart (5) using a transfer function on present and fossil ostracode fauna indicates that the lake, that had reached rapidly its lowest level around 7500 years BP did not rise again regularly:
-before 3900 years BP (several long duration blocking situations), the water level has fluctuated around a position considerably lower than the present one (-18 m in the small lake); as, on an average, the lake level had not lowered during this period, it was not a permanent dryness but a succession of droughts;
-between 3900 and 3000 years BP (no long duration blocking situation) the water level rose markedly (to -6m in the small lake) as a consequence of a wetter climate;

-after 3000 years BP (at least three long-duration blocking situations) the water level remains lower than the present one, with 4 or 5 periods of abrupt water level lowering, two of them being dated around 2300 and around 1300 years BP. These periods correspond to a drier episodes.

Variation of pollen rain and sedimentary fluxes in a lake of Serra dos Carajas (Eastern Amazonia).

Palynological (6) and sedimentological (7) studies were realized on a core collected in a lake situated on a narrow plateau surrounded by the Amazonian rain forest. Palynological data reveal that, during the last 60.000 years, four periods of forest regression were evidenced by a strong decrease in arboreal pollen percentage. The last one, between 7000 and 4000 years BP, is completely different from the other ones, being characterized by the absence of savanna pollens and by low sedimentary fluxes. Moreover, between 6000 and 4000 years BP, the percentage of arboreal pollens is dominated by *Piper*, a median strata rain forest pioneer vegetation, reaching 40% of the total pollen sum while it represented only a few percents during the Pleistocene dry phases. The absence of savanna pollen, the low erosion revealed by low sedimentary fluxes and the permanence of rain forest pioneers do not indicate such a dry climate as during the Pleistocene dry periods but the existence of some conditions limiting the forest development. During this interval abundant small charcoal fragments appeared in the sediment showing the occurence of periods favorable to fires. This stage is also characterized by the presence of sponger spicules of only one species (*Corvomeyenia thumi*) adapted to episodic dryness showing a bad development of mature forms (gemoscleres). This leads to the conclusion that the forest regression is not due to permanent dryness but to a succession of dry periods. After 4000 years BP the percentage of *Piper* and non arboreal pollens decreases drastically with regard to arboreal pollens. The succession of high strata arboreal pioneer elements after this age suggests climatic fluctuations but the low sedimentation rate precludes their detailed study.

Rio Xingu Discharge Variations (Eastern Amazonia) during the last 2500 years.

This lack of information in Carajas for the recent period can be improved by archeological studies (8) on a "Sambaqui" (anthropogenic shell accumulation) whose base is a few meters below the mean level of the Xingu river. This study shows that three periods of settlement occur during low stages of the river level. These periods lasted tens of years and were interrupted by drowning phases, due to higher levels of the river, around 2200, 1200 and 850 years BP. These data indicate the existence of three dry periods, which correspond to site settlement, during the last 2500 years in Eastern Amazonia.

Variation of sandy outputs of Rio Piura and Chira during the last 5000 years.

During the last 5000 years a discontinuous sandy sedimentation occur close to the Rio Piura and Rio Chira outlets, in Sechura Desert, Northern Peru. These discontinuous deposits are related to discontinuous outputs of the rivers. Such outputs can only be explained by long duration rainy periods, the sand volume concerned being too much important to be transported, even by strong floods, during only a few months. Studies of these morphological features reveal the presence of two generations of deposits separated by a zone without any sand bodies (9). Despite the absence of precise chronology it seems possible to relate:

-the first generation of sandy deposits to the period before 3900 years BP , when several long duration blocking situations occurred (several El Niño-like conditions periods);
-the zone without sand bodies to the period between 3900-3600 and 2800-2500 years BP where there was not any long duration blocking situation (no El Niño-like conditions period);
-the second generation of sandy deposits to the period after 2800-2500 years BP when few long duration blocking situations occurred (few El Niño-like conditions periods).

Conclusions

Variations in longshore sand transport direction on the central Brazilian coast lead to the setting up of a paleoclimatical model linking these variations to long duration periods (tens to hundreds of years) of El Niño-like conditions. The frequency of these occurrences have changed during the last 7000 years: very frequent before 3900-3600 years BP, absent between 3900-3600 and 2800-2500 years BP and not very frequent after 2800-2500 years BP. The available paleoclimatic data in other regions where there is a strong teleconnection between climatic anomalies during present-day El Niño events (Bolivian Altiplano, Amazonia and Northern Peru) confirm fairly well the model hypothesis. On other hand the Pacific El Niño events generate, one year later or so, similar warm events in the eastern Tropical Atlantic Ocean (10). The periods of intense and high frequency El Niño events should engender intense and high frequency Atlantic warm events. The observed variations of vegetation in Pointe Noire region (Congo) during the Holocene (11) may be explained by warm conditions in the Eastern Tropical Atlantic related to El Niño-like situations. Studies of these past teleconnections at a global scale may provide new ideas to understand some climatic variations in other parts of the world.

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