OBSERVED HISTORICAL LONG-TERM TRENDS IN PRECIPITATION IN THE AMAZON BASIN SINCE THE LATE 1920'S

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ABSTRACT
Rainfall indices were constructed for both northern and southern Amazonia, and together with river data were used to identify possible climate trends in Amazonia. Besides the fact that no systematic long-term trends towards drier or wetter conditions were identified since 1920's, it was observed a 20-year time scale variation of rainfall in northern Amazonia, a similar variation of rainfall in southern Amazonia, an opposite tendency of rainfall in both regions, and an effect of the SO that is stronger in northern Amazonia, and very weak in the southern basin.

1. Introduction

The Amazon basin has experienced increased deforestation in time, and the possible changes in regional and global climate have motivated a host of climate model experiments (Lean and Rowntree 1997). Possible scenarios include a reduction in the precipitation and evaptranspiration rates, and increase in regional air temperatures. However, the southern portions of the basin (which have highest rates of deforestation) actually show increased precipitation model precipitation under deforestation scenarios, which would be opposite to expect. For a review on the results of several experiments using different models, please refer to Fisch et al. (1998), and from ABRACOS studies refer to Gash and Nobre (997).

It is also clear that a variety of human activities can act to modify various aspects of surface hydrologic systems. For example, changes in land cover can significantly affect the surface water and energy balance through changes in net radiation, evapotranspiration, and runoff. However, because of the intricate relationships between the atmosphere, terrestrial ecosystems, and surface hydrological systems, it is still difficult to gauge the importance of human activities in the Amazonian hydrologic cycle.

Previous studies have considered the long term variability of precipitation in Amazonia, either based on the records at individual stations or with several stations with short time series (Marengo 1992, Marengo et al. 1998, Dias de Paiva and Clarke 1995, Chu et al. 1994), as well as discharges of the Amazon rivers and its tributaries (Gentry and Lopez-Parodi 1980, Marengo et al. 1998, Marengo 1995, Guyot et al. 1997). In principle, the discharges of the Amazon river, together with the Negro Solimões, Madeiras and Purus rivers, should show the influence of the rainfall across de basin. In the case of the Solimoes River, the largest affluent of the Amazon, the large volumes of this river may upset the gauging values in lower courses of tributaries, producing with is known as the backwater effect (Meade et al., 1991). This indicates that for some basins, the assumption that the discharges/levels measured on large basins represent the hydrometeorological conditions at those sites is no longer safe. In addition, the availability of worldwide gridded reanalysis (NCEP, ECMWF, NASA-DAO) have allowed assessments of the water vapor transport into Amazonia, and in fact some recent works have shown contradictory results in terms of trends in input moisture into the Amazon basin. For instance, Costa and Foley (1998) have identified a statistically significant decreasing trend in the atmospheric transport of water both into and out to the Amazon basin, based on 20 years (1976-96) of the NCEP reanalysis. On the other hand, Curtis and Hastenrath (1998) have identified statistically significant upward trends of lower tropospheric convergence, upward flow, convergence of atmospheric water vapor transport, and precipitable water over the Amazon basin, based on the analysis of 40 years (1958-97) of the NCEP reanalysis. Thus, rainfall observations are seen as perhaps the only way to infer on the components of the hydrological cycle of the region, and to validate both studies based on global reanalysis and model results.

In this paper, we used the NAR and SAR rainfall indices and streamflow records of the main basins of the Amazon and Tocantins Rivers to explore the long-term variability of the hydrology since the beginning of the century. To assess the direction and the significance of the trends, the statistical test of Mann-Kendall (Marengo et al. 1998) was applied to the time series.

2. Objectives

It is proposed in this research an assessment of trends in precipitation in the Amazon basin, by means of the analysis of long-term rainfall indices for both northern an southern Amazonia, with the intention of validating estimates of the water balance in Amazonia, and the long term variations as depicted by rivers discharges and levels across the basin. This is done in terms to identify any possible climate trend in Amazonia, as results of increased deforestation in the basin.

3. Hydrometeorological data and processing

To examine the long-term mean trends in the hydrometeorological data, annual seasonal discharge and rainfall have been calculated for all the time series. The northern Amazonia rainfall (NAR) and southern Amazonia rainfall (SAR) indices were developed by Marengo (1992), and have been updated and extended in time and spatial coverage. Stations located in northern and southern Amazonia, from which the indices were implemented, are indicated in Fig. 1. These indices are based on the September-August hydrological year since 1928. Sources of rainfall data are the Agencia Nacional de Aguas e Energia Eletrica (ANEEL), the National Climatic Data Center, and the INMET and CPTEC archives. The indices were constructed following Marengo (1992), based on the average of normalized departures of the long term mean for groups of stations with similar annual cycle of rainfall. The NAR and SAR indices were regionalized according to the peak of the rainy season, as NAR-West and NAR-Central, and SAR-West and SAR-East, according to the annual cycle of rainfall and the availability of rainfall stations. Seasonal river discharges used in this study were extracted from the archives of ELETROBRAS, ELETRONORTE, and ANEEL.

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4. Trends in precipitation in the Amazon basin

The NAR (Fig 1a-b) index series since 1928 shows that: a) interannual variations show that ENSO influences are significant more notably the in the northern drainage basin of the Amazon basin, drier during El Niño than la Niña years, b) interdecadal variations indicate that both the central and western part of the northern basin, show positive trends in rainfall between 1940-62, and a negative trend between 1962-82. Both NRA-Central and West show a wet period between 1950-76 [wettest in 1960-74], and also coincides with cool sea surface temperatures (SST) in the equatorial Pacific. Dried periods were observed in 1928-42, 1978-84, and 1990-94 [driest in 1979-83]. The SOI index (Fig. 2c) shows negative rainfall anomalies in years with negative SO index values. Interdecadal time scale variations are found in the rainfall series, with periods of 20-years of successive drier and wetter conditions. This variability seems related to an interdecadal mode of variability of the meridional SST gradient (dipole) and atmospheric circulation over the tropical Atlantic, which also seems applicable to river discharge in northern Amazonia (Marengo et al. 1998). Regarding Northeast Brazil, the variability of both northern NEB (Hastenrath and Greischar 1993, HG in Fig. 3a), and the northern and eastern parts of eastern NEB (Alves et al. 1997, ASRF in Fig. 3b), their variability shows concordance with the SO index series, and also interdecadal time scale variations, different from the 20-years time variations detected in NAR

On the other hand, southern Amazonia (Fig. 4a-b) shows a short wet period in 1930-40, and upwards trends since 1975, while a drier period was found in 1960-72. This variability is characteristic of both the western and eastern parts of southern Amazonia, and seems to be independent of the Pacific SST or ENSO influences, and does not follow variations if rainfall in northern Amazonia.

In addition, river data analysis in northern Amazonia (not shown here) indicate wetter periods in middle 1970's, and 1990, as well as drier periods between 1980-90, consistent with the NAR anomalies in Fig. 2a. Gentry and López-Parodi 1980). Gentry and López-Parodi and Chu have investigated rainfall, river records and convection and have found periods (1962-78 and 1971-92) that have been characterized by high Amazon River levels at Iquitos and increased convection and rainfall in Northwest Amazonia. However, these are short periods that in the context of a long range time scales would look like part of a low-frequency variation, meaning the upward or downward tendencies part of the natural climate variability, rather than effect of climate change.

5. Summary and discussions

In very large drainage basin, such as the Amazon, backwater effect may affect the variations of the discharge/levels series, especially at the Solimoes basin and at the Manaus site. Thus rainfall comes as perhaps the best indicator of hydrologic trends in the region. From the analysis of trends using rainfall indices and river series, it has been shown that no trends towards drier conditions have been detected in Amazonia, as one would expect due to increased deforestation. However interdecadal variations have been observed in rainfall in both northern and southern portions of the basin: (a) northern Amazonia show some associations with the SO variations, and a 20-years time variation in rainfall, (b) southern Amazonia exhibits similar time-variation, and is independent of SO and rainfall variation in northern Amazonia.

6. References

Alves, J., Sousa, E., Repelli, C., Ferreira, N.: 1997, Um estudo da variabilidade pluviometrica no sector leste do Nordeste brasileiro e a influencia do fenomeno El Nino/Oscilacao Sul. *Revista Brasileira de Meteorologia*, **12(2)**, 11-25.

Chu, P.-S, Yu, Z.-P., Hastenrath, S.: 1994, Detecting climate change concurrent with deforestation in the Amazon Basin: Which way has it gone?, *Bull. Am. Met. Soc.*, **75**, 579-583.

Costa, M., Foley, J.: 1998, Long term trends in the hydrologic cycle of the Amazon basin. *Submitted. J. Geophys. Res.*

Curtis, S., Hastenrath, S.: 1998, Trend of upper-air circulation and water vapor over equatorial South America and adjacent oceans. *Submitted Int. J. Climatol*.

Dias de Paiva, E. M. C., Clarke, R.: 1995, Time trends in rainfall records in Amazonia. *Bull. Amer. Met. Soc*. **75**, 579-583.

Fisch, G., Marengo, J., Nobre, C.,1997: Clima da Amazonia. *Acta Amazonica,* **28(2)**, 102-126.

Gentry, A., Lopez-Parodi, J.: 1980, Deforestation and increased flooding in the upper-Amazon, *Science*, **210**, 1354-1356.

Gash, J., Nobre, C.: 1997: Climatic effects of Amazonian deforestation: Some esults from ABRACOS. *Bull. Amer. Met. Soc.*, **78**, 823-830.

Gentry, A., Lopez-Parodi, J.: 1980, Deforestation and increased flooding in the upper-Amazon, *Science*, **210**, 1354-1356.

Guyot, J,-L., Callede, J., Molinier, M., Guimaraes, W., de Oliveira E.: 1997, La variabilite hydrologique actuelle dans le bassin de l'Amazone. *Seminario Internacional Consequencias climaticas e Hidrologicas del Evento El Niño a Escala Regional y local.* Memorias Tecnicas. 26-29 Noviembre Quito, Ecuador. Pp. 285-293.

Hastenrath, S., Greischar, L.: 1993, Further work of Northeast Brazil rainfall anomalies, *J. Climate.*, **6**, 743-758.

Lean J, Rowntree, P., 1997: Understanding the sensitivity of a GCM simulation of Amazonian deforestation to specification of vegetation and soil characteristics. *J. Climate*, **6**, 1216-1235.

Marengo, J.: 1992, Interannual variability of surface climate in the Amazon basin, *Int. J. Climatol.*, **12**, 853-863.

Marengo, J.: 1995, Variations and Change in South American Streamflow. *Clim. Change*, **31**, 99-117.

Marengo, J., Tomasella, J., Uvo, C.: 1998, Long-term streamflow and rainfall fluctuations in tropical South America: Amazônia, Eastern Brazil and Northwest Peru. *J. Geophys. Res.*,**103**, 1775-1783.

Meade, R., J. Rayol, Conceicao, S., Natividade, J.: 1991, Backwater effects in the Amazon river basin of Brazil. *Environ. Geol. Sci.*, **18**, 105-114.

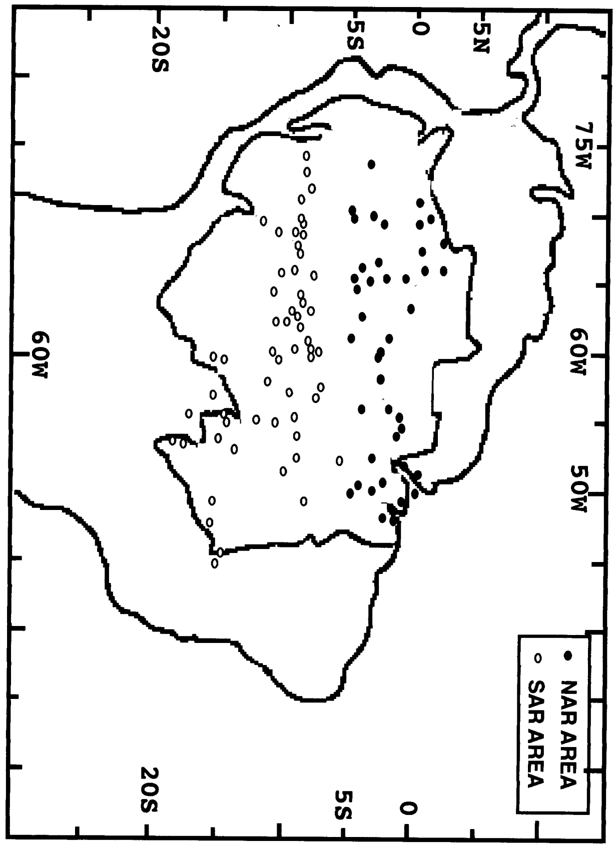

Fig. 1 Location of rainfall stations in Amazonia

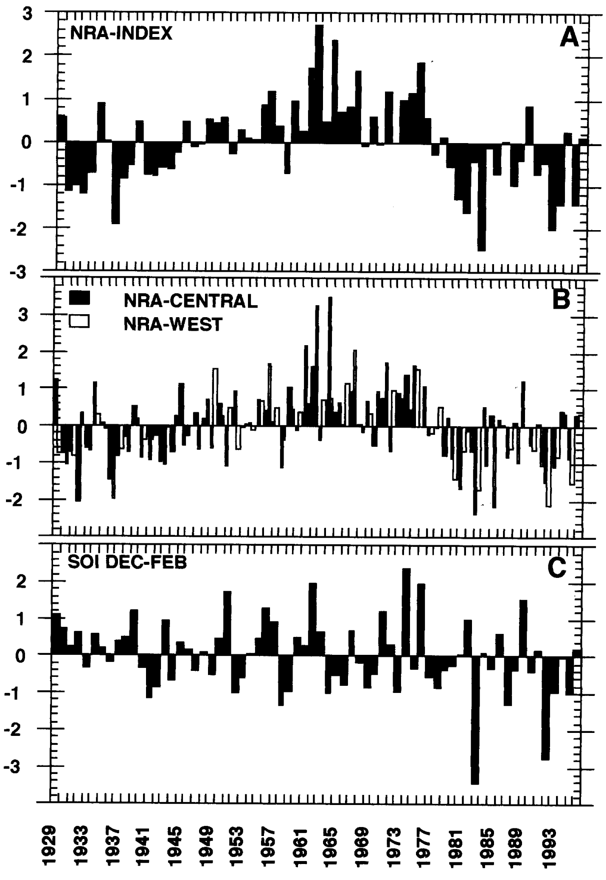

Fig. 2. Variation of NAR index and SO.

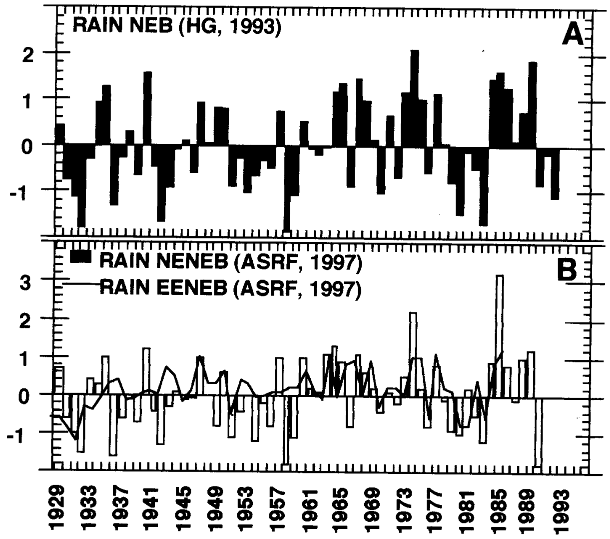

Fig. 3 Variation of rainfall indices in Northeast Brazil.

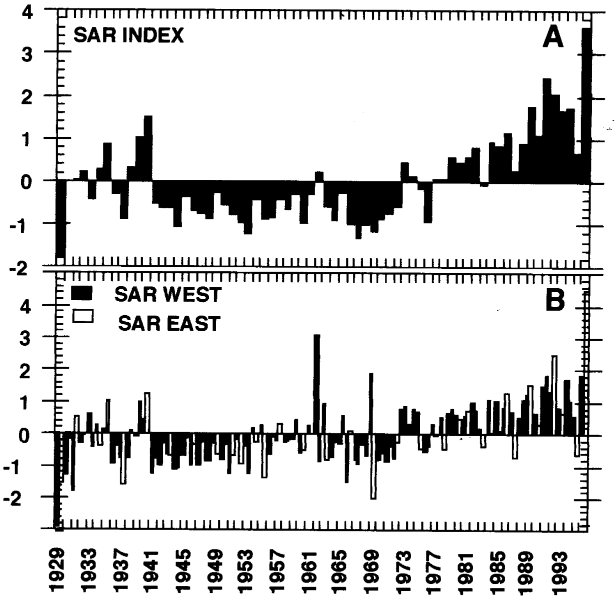

Fig. 4 Variation of SAR index