CHARACTERISTICS OF RAINFALL IN THE BRAZILLIAN AMAZON BASIN

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The intent of this paper is to present the hypothesis that the influence of sea surface temperature (SST) on rainfall in the Brazillian Amazon Basin is largely through its influence on onset and end of the rainy season, rather than on rain rates during the rainy season itself.

This work utilizes rainfall data from 431 stations in the Brazillian Amazon Basin, averaged onto a 2.5 degree grid. The analysis is from 1977 to 1996. The average record length is 12 years and of the years with data, 11.8% of the days are reported as missing. The December-February (DJF) climatological total is shown in Fig. 1. There is a gradient toward larger amounts in the southeast, consistent with an annual cycle which follows the sun to an accurate first approximation.

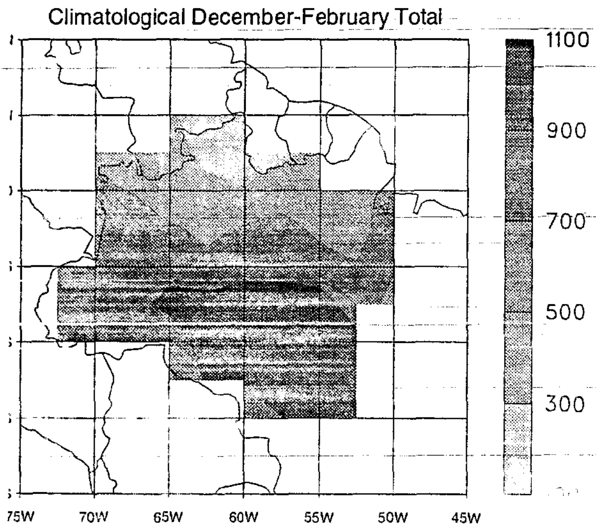

Fig. 1. Climatology of DJF rainfall in millimeters.

Figure 2 shows the simultaneous correlation between DJF SST in Nino 3.4 (5N-5S, 170W-120W) and rainfall. Although one must be careful when using linear correlations because of the non-normality of rainfall, this figure does suggest a relationship between SST and rainfall in the region south of the equator and east of 60E. A regression (not shown) reveals a 100-200 mm deficit in this region associated with a 1 standard deviation increase in SST (~0.8 C).

Onset and end of the rainy season are defined by the following:

$$\sum (R(t) - R(annual))$$

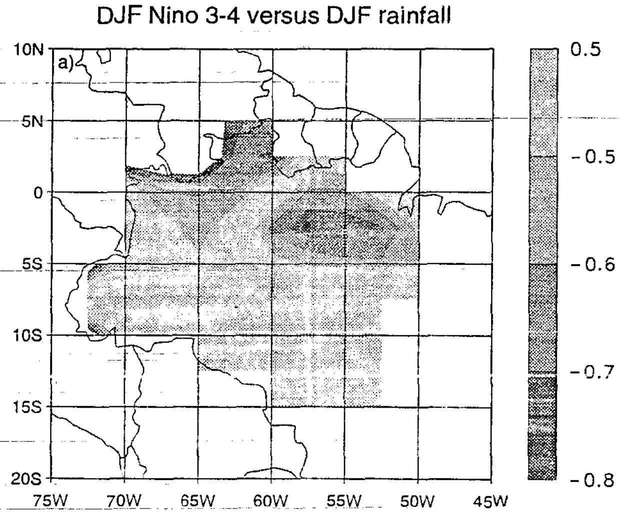

Fig. 2. Simultaneous correlation between DJF SST in Nino 3.4 and gridded rainfall.

where *R(t)* is the daily varying climatology (or single year's daily total) and *R(annual)* is the annual daily average, averaged over the desired stations. The beginning (end) of the rainy season is defined as when rainfall exceeds (is less than) its annual average.

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RAINFALL AND SURFACE PROCESSES IN AMAZONIA DURING THE WETAMC/LBA - AN OVERVIEW

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1. INTRODUCTION

The Large-Scale Biosphere-Atmosphere Experiment in Amazonia (LBA) is designed to generate new knowledge essential to the understanding of the processes within the ecology, hydrology, biogeochemistry and climatology of Amazonia, the impacts of the different land uses on these proceses and the interactions between the Amazonia and the global biogeophysical system of the planet.

The Wet Season Atmospheric Mesoscale Campaign - WETAMC - has a focus on the local effects of deforestation, with its different impacts, as well as on the regional response to the larger scale forcing, within the lines of the LBA. The WETAMC scientists (including Brazilians and Europeans) joined forces with the NASA/TRMM scientists , whereby a major ground validation program within the TRMM, known as TRMM/LBA, was collocated with the WETAMC. The field phase of this campaign took place in the Rondonia state of Brazil (Southwest side of Amazonia) during January and February 1999. TRMM/LBA had a focus on the dynamical, microphysical, electrical and diabatic heating characteristics of tropical convection in the Amazon region. Together, the WETAMC/LBA and TRMM/LBA campaigns represent a major effort to study tropical convection in Amazonia and its relation to the underlying forested and deforested regions.

2. EXPERIMENTAL SETUP

The field campaign design included:

- four radiosonde sites performing 6 - 8 soundings per day,
- three tethered balloon sites;
- 1 forest 60 m micrometeorological tower instrumented with 3 levels ofeddy correlation measurements and vertical profiles of radiation, temperature, humidity and windspeed
- 1 forest 54 m tower instrumented for chemistry measurements, including CO2 flux;
- forest and pasture arrays for temperature and soil moisture and set of rings for soil respiration.
- 1 tethered ballon for atmospheric chemistry measurements,
- 2 pasture towers with profiles, and eddy correlation measurements including CO2 flux,
- 1 pasture tower for atmospheric chemistry measurements,
- 2 wind profiler sodar,
- network of complete AWS;
- a four-station lightning detection network, a network offlat plate antennas,
- a dense raingauge and disdrometer network,
- two Doppler radars (including the NCAR S-pol and the TOGA radar),
- a dual-wavelength profiler from the NOAA/Aeronomy Lab
- U. of North Dakota Citation II Learjet for in-situ sampling of microphysical variables
- the high altitude NASA ER-2 carrying the EDOP radar (ER-2 Doppler, X band radar) and AMPR (Airborne Microwave Profiling Radiometer), a multi-frequency radiometer similarto the SMI instrument on TRMM.

The aircraft operations required also the functioning of a weather forecasting office at Ji-Paraná with access to NWP from CPTEC/INPE and from USP (RAMS 20 km resolution model) used in conjuction with high resolution GOES and airport data.

3. RESULTS

The beginning of the observation period in January wasdominated by widespread rainfall associated to a large scale forcing due to the South Atlantic Convergence Zone episode that lasted for about a week. The TOGA radar screened the associated clouds and measured cloud tops reaching 7-8 km, well above the 0 oC isotherm, but much below the tropopause (at about 17 km). At the same time, CCN counts indicated a very clean atmosphere, at a few tens of CCN m^{-3}. Disdrometers showed rainfall contained very large drops. These features are typical of maritime clouds. As the experiment progressed, the SACZ decayed and we

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had almost a month of rainfall dominated by local convective systems and by travelling mesoscale convective systems (MCS). CCN counts increased at that time. The S-POL, the radar profilers, from the ground, at the TRMM satellite and aboard the ER-2 aircraft discriminated precipitation species, confirmed by in situ measurements with the Citation aircraft mycrophysical measurements in the trailing stratriform region of the MCS. These information identified very large snow particles above the melting layer, with small terminal velocities. Just below the melting layer, large terminal speeds were observed. The Citation aircraft encountered large vertical speeds of updrafts and downdrafts in seemingly not so threatening Cumulus Congestus and Cumulonimbus.

The large scale situation evolved including a westward intrusion of an upper level trough that inhibited Amazonian rainfall in a large area for a day or two. The MCS in the form of long lived squall lines, sometimes originating in the northern coast, progressed throughout the region with some influence in the organization of clouds observed in Rondonia. The growth of MCS from initially small isolated Cb was observed several times. The surface outflow observed through the visible GOES images indicated the very effective auto sustainability of the convective system sometimes leading to long lived MCS.

The surface data collected in the micrometeorological towers show interesting features. At the forest site, mean vertical profiles show differences in the temperature and wind signature of the top of forest (sharp transition in temperature and smoother in the wind). Bowen ration show a large diurnal variation during (from 0.2 in the early morning to 0.5 (before noon) and back to 0.2 in the afternoon.

Radiosonde intercomparison VIZ and VAISALA was performed with 19 soundings. Temperature RMSE is of the order of 0.7C. VIZ profiles are warmer than VAISALA. VIZ specific humidity is wetter than VAISALA. However, there are differences in individual soundings. Wind speed agrees fairly well but differences of the order of 5 m.s^{-1} can be expected. Differences between mixed layer height in forest and pasture are very small during the wet season (of the order of 100 m). Growth of the mixed layer is compared in the forest and pasture in undisturbed and disturbed days. Mixed layer is much lower on the disturbed days. Vertical structure of the mixed layer from the tethered balloon shows thermal structures with large variability of the thermodynamical variables. Spikes in the mixed layer are associated to surface control.

Two sites for chemistry measurements were installed: from January 15 to the end of May.

Measurements included: fine and coarse aerosol composition, black carbon, organic elemental carbon and size distribution (biomass burning tracer) Instrumentation: total particle counter, cloud condensation nuclei measurements with two different techniques, optical properties and a sun photometer (aerosol optical thickness in 5 different wavelengths in the pasture site and in Alta Floresta). Trace gas measurements: O3, NOx, CO, VOC at forest and pasture, precipitation chemistry, TOMS and organic aerosol speciation.

About 50 % of the data have been analyzed so far. Fine particles do not show much diurnal variation but the coarse particle measurements show more variability. The mean diurnal variation indicates an increase early in the morning and a decrease at 2 PM. No major increase is observed during the night. Black carbon indicated an increase during the night. An enhancement of black carbon has been observed (perhaps contamination from cities, coal production). Large increase of BC during the night after 18 PM. Frequent surges of BC during the first 6 hours of the night. The signal is not clearly related to biomass burning. It could be transportation from some other place. What causes the surges in aerosol load during the wet season?

4. CONCLUSION

The challenge to understand the evolution of precipitation, and the effect of deforestation on precipitation, in a tropical continent is posed and the preliminary means to tackle this challenge are given by the WETAMC/LBA and TRMM/LBA data sets.

ACKNOWLEDGEMENTS

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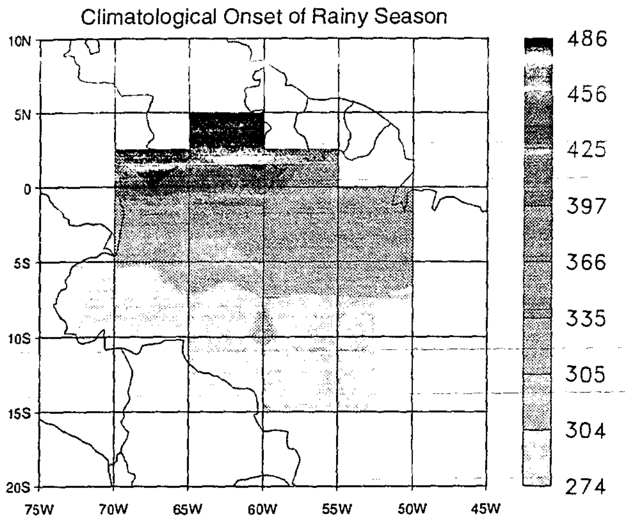

Fig. 3. Climatological onset of rainy season. Scale is in Julian days, by month, starting in October.

The climatological onset of the rainy season, using the above definition, is shown in Fig. 3. The rainy season begins in southern Amazonia in mid-October and progresses northward, with onset in the far north occurring in April. In the region east of 60W and just south of the equator, the rainy season begins in December, suggesting that a late onset will result in a deficit of rainfall in the DJF season, and an early onset will result in an excess. Using seasons defined by the above definition, the correlation between the date of onset and the rainy season total is -0.88, while that between rain rate and the total is 0.55.

Figure 4 shows the correlation between DJF SST and DJF rainfall in the east-central Amazon, the starting date in that region, and the rain rate during the rainy season. The correlations with the seasonal total (Fig. 4a) and onset date (Fig. 4b) both exhibit a similar pattern, with the largest correlations along the equator, east of 150W. The similarity of these patterns suggests that the influence of SST on calendar-season rainfall totals is through its influence on onset date. On the other hand, the rain rate during the (interannually varying) rainy season shows no large correlation with SST (Fig. 4c). These results suggest that once the rainy season has been initiated, east Pacific SST has little role in determining rainfall amounts; its influence is solely through the onset date.

An interpretation of the results presented here is that when SST is warm in the eastern Pacific, the transition of convection from the Northern Hemisphere summer position in the eastern Pacific north of the equator into the Amazon Basin is delayed. Likewise, when SST is warm from May-July in the western Atlantic south of the equator, which is when the rainy season ends in the east-central Amazon, it seems to be associated with a delayed withdrawal of convection there (not shown). These results are consistent with previous studies of the timing of the western Pacific monsoon by Meehl (1987; *Mon. Wea. Rev.*, 27-50) and Joseph et al. (1991; *J. Climate*, 529-538).

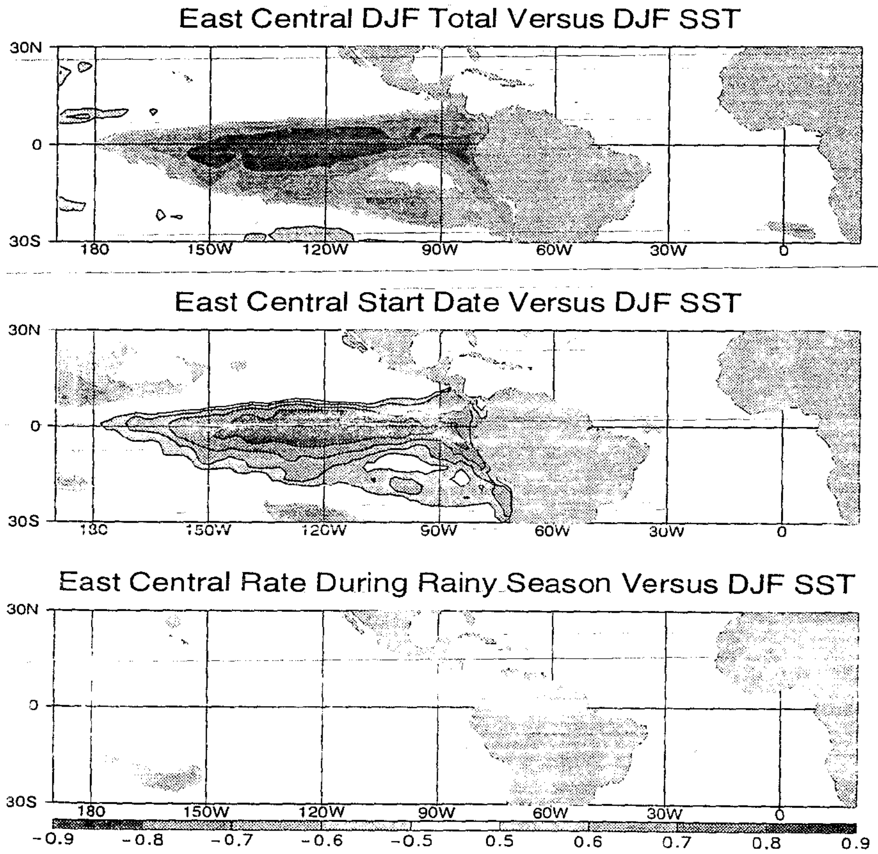

Fig. 4. Correlation between DJF SST and east central amazon a) DJF mean rainfall, b) start date of rainy season, and c) rain rate during rainy season. Positive correlations are both contoured and shaded.