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AN ANALYSIS OF CLOUD AND RAINFALL DISTRIBUTIONS OVER DEFORESTED AMAZONIA USING TRMM AND GOES MEASUREMENTS

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1 INTRODUCTION

The advent of remote sensing in hydrology presents great opportunities to further our knowledge and understanding of the Earth's dynamic natural system. One such area of interest is the impact of tropical deforestation on global and regional climatic circulation. In this paper, we use data from the Tropical Rainfall Measuring Mission (TRMM) and Geostationary Operational Environmental Satellite (GOES) to study precipitation intensity and shallow cloud patterns over Amazonia under the current state of deforestation.

Recent studies on the impact of large-scale deforestation on climate in the Amazon basin have demonstrated the importance that such land-use changes have on the regional and global scales. General Circulation Model (GCM) simulation results of Amazonian deforestation undertaken by Salati *et al*. (1991) suggested that the equilibrium climate for grassy vegetation in Amazonia would be one of significantly reduced precipitation. Using GCM simulations, Nobre *et al*. (1991) found that when the Amazonian tropical forest was replaced by pasture, there was a significant increase in the mean surface temperature ($\sim$2.5^{o}C), and decreases in the annual evapotranspiration (30%), precipitation (25%) and runoff (20%). The relative decreases in the latter three variables indicated a decrease in the regional moisture convergence. The simulations of Nobre *et al*. (1991) showed that the greatest differences occurred during the dry season. A large-scale ($\sim$2,500 km) simulation of the response of the tropical atmosphere to deforestation undertaken by Eltahir & Bras (1993a) also showed an increase in mean surface temperature and a decrease in precipitation. These results, it was discussed, are competitive, and hence make predictions of resulting runoff highly sensitive to their relative scales.

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McGuffie *et al*. (1995) studied the global-scale climate sensitivity to tropical deforestation using a modified version of the NCAR Community Climate Model coupled with a land-surface hydrology scheme (the Biosphere Atmosphere Transfer Scheme, BATS). Their experiment consisted of replacing the tropical forest in the Amazon, S.E. Asia and tropical Africa with grassland. Their results in Amazonia showed marked decreases in precipitation, evaporation and moisture convergence. They also showed that tropical deforestation impacted the Asian monsoon, as well as climate in the middle and high latitudes.

Recently, studies have been undertaken on the impacts of deforestation on climatic circulation at regional and local scales. A numerical mesoscale circulation model (Penn State/NCAR MM4) was used in conjunction with BATS to study the sensitivity of climate to deforestation at the regional scale ($\sim$250 km.) New parameterizations for rainfall interception and rainfall spatial coverage were developed to aid this study, and are described by Eltahir & Bras (1993b,c.) The modeling exercises of this study showed a decrease in net surface radiation, evaporation and rainfall, and an increase in surface temperature. The model results concurred with observed net radiation over forested and deforested areas (Eltathir & Bras, 1994.)

Looking at the local impacts of land-use change, Rabin *et al*. (1990) used GOES visible and infrared images over Oklahoma and observed that, under weak synoptic forcing, clouds formed earlier over mesoscale-sized areas of harvested wheat than over the actively growing vegetation of adjacent areas. They also observed that shallow clouds were suppressed downwind of small human-made lakes and over areas dominated by heavy tree cover. Following this study, Cutrim *et al*. (1995) a cumulus cloud recognition algorithm that uses GOES visible and infrared image pairs, and applied it twice-daily over Amazonia during August 1988. They found an enhanced frequency of afternoon cumulus clouds over areas where the forest had been cleared.

Rabin *et al*. (1996) used the same cumulus recognition algorithm as the previous paper to study the frequency of cumulus clouds over the central United States for two periods: July 1988, which was a drought year, and July 1987, which is the control. The observed that cumulus clouds occurred more often over lightly vegetated than heavily vegetated surfaces in southern and central Illinois.

The impact of observed deforestation at local scales (∼10 km) on the spatial distribution of rainfall and clouds was studied using the Penn State/NCAR MM5 numerical weather model to a sub-region of Rondonia (Wang *et al*., 2000.) Synoptic forcing was shown to dominate mesoscale circulation during the wet season (December - April). However, during the dry season (May - August) and the break-period (September - November), mesoscale circulation had an impact over the deforested area. An enhancement in low-level clouds was seen, although there was little or no effect on rainfall amounts.

2 OBJECTIVES

The objectives of this study are to determine and quantify the local effect of deforestation on shallow cumulus and rainfall intensity climatologies in the Amazon basin. The goal is to quantitatively validate past observational and numerical studies.

3 DATA & PROCESSING

For this study, shallow cumulus cloud maps are produced three-times daily over the Amazon basin. The shallow cumulus were detected using a modified version of the algorithm first developed by Cutrim *et al*. (1995). The algorithm employs a series of thresholds which must all be met to determine whether a pixel is occupied by a shallow cumulus. Table 1 presents the state that is determined by the threshold, the parameter on which the threshold is applied, and the threshold values.

Rainfall intensities are derived 48 times daily using the Convective Stratiform Technique (CST) with GOES infrared images. The derived rain rates are calibrated a priori with rainrates derived from four months of TRMM Microwave Imager (TMI) data. The reader is referred to Negri *et al*. (2001) for a more detailed treatment of the rainfall intensity retrieval process.

Table 1: Shallow Cloud Detection Algorithm

	Land vs. Cloud	Deep vs. Shallow	Stratus vs. Cumulus	Association to Deep Convection
Parameter	Relative Albedo (%)	Infrared Temperature (K)	Albedo Contrast (%)	Proximity to Deep Convection (km)
Low Threshold	20	280	10	8
High Threshold	100	330	100	N/A

4 PRELIMINARY RESULTS

Shallow cumuli and rainfall intensities were studied over two regions of 200 km to the side. These regions are characterized by a strong contrast in land surface cover: the contrast in one is between the Amazon river and tropical forest, while the other shows a long strip of deforested land flanked by dense tropical forest. Both regions are void of topographical features.

The probability that the shallow cloud density over the forest exceeds that over the contrasting land cover was computed for each month. A Monte-Carlo simulation of a completely spatially random (CSR) cloud field was used to determine the statistical significance of the difference in cloud densities observed over contrasting land surface covers. Figure 1 shows that the difference in shallow cumulus density over the river/forest contrast is statistically significant to a level of 95% for all months studied, whereas that difference is significant only for the month of November 2000 over the region characterized by the forest/deforest contrast. NCEP/NCAR re-analyses were used to study the synoptic meteorological conditions during days of high cloud density contrast (i.e. contrast values that exceed the mean monthly contrast by one standard deviation), and it is observed that the mean mid and lower level winds are significantly weaker when a high contrast in cloud density over differeing land covers is observed (see Figure 2.)

5 PRELIMINARY CONCLUSIONS

The preliminary analyses of shallow clouds over the Amazon basin demonstrates that land cover significantly affects shallow convection. The mean monthly cloud cover density over the surface characterized by water (the Amazon river) is significantly lower than over Forest for all months studied. The mean monthly cloud cover density over the deforested surface is significantly higher than over the forest for the

Figure 1: Probability that Cloud Density over Deforest/River Exceeds/Lags that over Forest

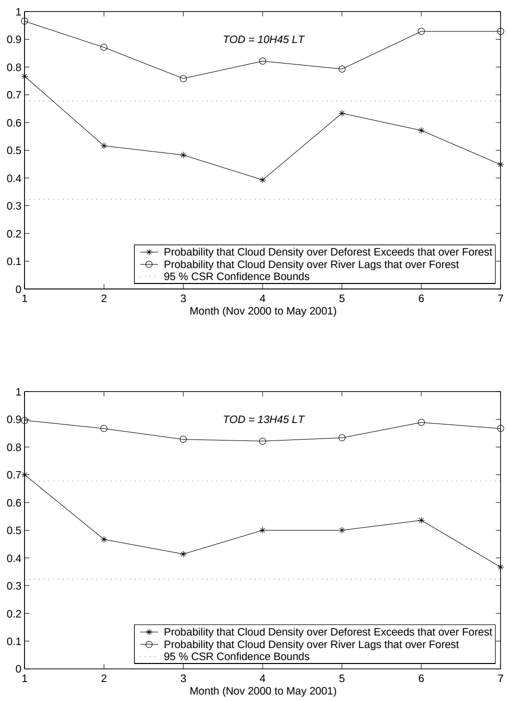
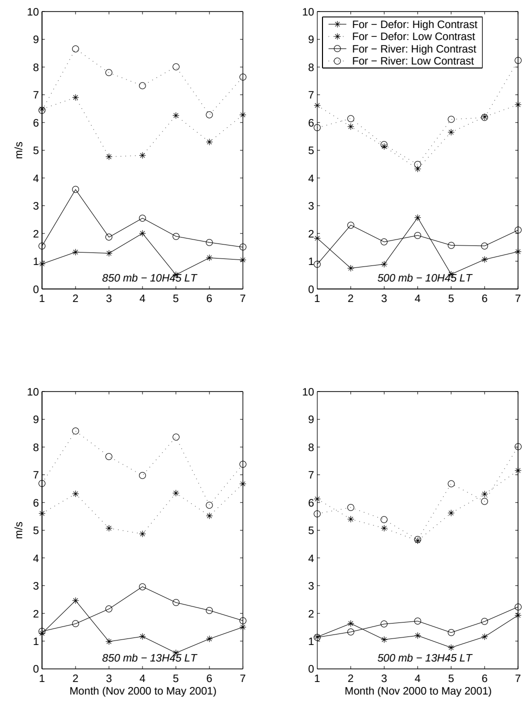


Figure 2: Mean Monthly Wind Speeds: Periods of High vs. Low Cloud Density Contrast



month of November 2000, which is the “break period” between the dry and wet seasons, and is characterized by weak synoptic flow. It is also observed that the higher contrasts in cloud cover densities occur when the mid and lower levels winds are weak.

6 ON-GOING WORK

The process of analyzing GOES data and producing shallow cloud maps over the amazon is on-going. A lenghtier climatology of the shallow clouds will improve our understanding of the impacts of land cover change on local atmospheric circulation under differing synoptic condidtions.

Instantaneous rainrates derived half-hourly (Negri *et al.*, 2001) are being studied over the same two regions in the Amazon to determine whether there is a statistically significant impact of the land cover on rainfall.

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