Detecting Change in Equatorial Regions of Brazil Using Medium Resolution Satellite Imagery

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I. INTRODUCTION

Currently there is an extended international effort to monitor the change in global rain forest and equatorial woodlands. Because of government incentives, land reform, and general population pressures, the natural vegetation in these regions is being replaced by an anthropogenic agricultural mosaic.

Because of frequent cloud cover in these regions, active microwave imagery such as the ERS-1 SAR is preferred over high-resolution visible and near infrared spaceborne sensors for monitoring landscape degradation. Nevertheless, because rain forest and savanna vegetation cover such vast regions, AVHRR and its derivative vegetation indices are frequently used for medium or low-resolution monitoring where comprehensive high-resolution imaging would create unmanageable data volumes, or would be cost prohibitive. Areas showing significant change then become targets for data acquisition with higher resolution sensors such as SPOT or Landsat. In a few cases, expensive airborne sorties may be warranted.

While the cloud cover problem has always been the plague of visible and near-infrared remote sensing in equatorial regions, other problems exist. For example, many types of vegetation, such as primary equatorial forest and its older, degraded, secondary forest counterpart, frequently display very little difference in near-infrared or visible wavelength reflectance. Furthermore, conversion of forest, woodland, and grassland to agriculture is frequently slow and patchy in character. From a remote sensing perspective, this creates mixed pixels which are difficult to classify into a specific vegetation class with any certainty based on visible and near infrared data alone.

Over the past few years, reconstructed scatterometer and radiometer imagery has been used for equatorial forest inventory. This paper presents results of a project to monitor large-area changes in the natural Brazilian landscape which is apparent between 1978 and 1996. The 1978 image originates from the Seasat-A scatterometer (SASS), whereas the 1996 image is reconstructed from recent 1996 NASA (NSCAT) imagery.

II. LAND CONVERSION IN BRAZIL

Deforestation in Brazil is the result of many complex and interrelated processes. The most often cited causes include commercial logging, cattle ranching, farming, gold digging, and road building, but these causes fail to reflect the larger and more complex issues facing the government and people of Brazil which lead to deforestation. Issues of drought, soil fertility, poverty, rapid population growth, rural to urban migration, land reform, foreign debt, energy needs (including hydroelectric and charcoal), and territorial security have all had an influence on the changing use of land in Brazil's rain forest region [1].

Concerted efforts by the Brazilian government in the 1960s and 1970s to develop Amazonia illustrate the interrelated causes of deforestation. Smith (1982) offers three general causes: 1) Geopolitical reasons motivated Brazil to increase settlement in Amazonia to prevent loss of territory and resources to neighboring states and to effectively incorporate the territory into national society. 2) Demographic and economic challenges in the more densely populated coastal regions and in the less developed and drought ridden northeast region prompted the government to view Amazonia as a "safety valve" for Brazil's overpopulated cities and economically depressed regions. 3) The rich resource potential of Amazonia offered Brazil the hope of decreasing its foreign debt and thereby moving into the ranks of the world's more developed countries. To obtain these benefits, Brazil moved its capital to inward oriented Brasilia, launched an extensive road building project which sent soldiers to border states and brought settlers, miners and ranchers to frontier territories such as Rondonia [2].

III. DATA

Satellite scatterometers are active microwave radar instruments originally designed to measure the radar backscatter of the ocean's surface under all-weather conditions. Between June and October of 1978, the Seasat-A scatterometer (SASS) was able to obtain nearly continuous global coverage at a spatial unit cell resolution of 50km until a catastrophic short-circuit in the satellite's electrical system terminated subsequent data acquisition. The two SASS antennas (one on each side of the instrument) were arranged

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at two different azimuth angles. As the satellite orbited, a resolution element on the surface of the Earth was observed first by the forward looking antenna and then by the aft antenna a minute or two later. This produced two sets of co-located, nearly simultaneous observation pairs from two different azimuth angles. The result of this arrangement is a set of vectors – multiple σ_0 measurements made of each cell over an irregular 50-km by 50-km along-track / cross-track sampling grid. By utilizing the overlap in these measurements, SASS data collected over the 99 day period was reconstructed into a single, enhanced resolution image [3]. A reconstructed image for central South America is shown in Figure 1.

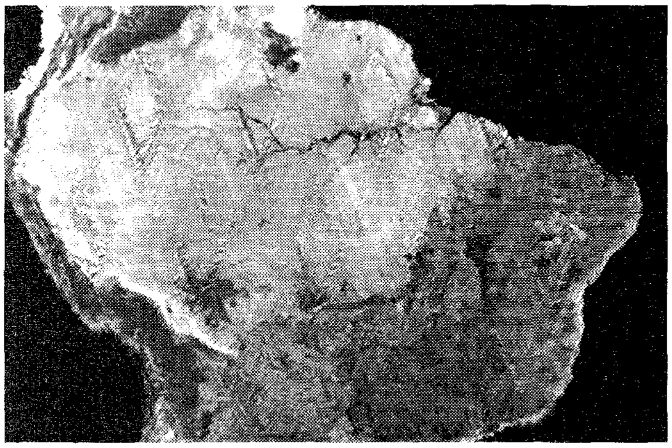

Figure 1: Reconstructed SASS image, 1978.

Launched in August, 1996, the NASA scatterometer (NSCAT) was also designed to measure ocean wind vectors. As discussed elsewhere [4], NSCAT is heavily based on SASS with significant improvements to enhance backscatter measurement accuracy at a spatial resolution of 25 km. Although designed primarily as an ocean-wind instrument, NSCAT data is also collected over land. Resolution enhancements similar to those applied to SASS permit image cell sizes approaching 8 km. An NSCAT composite, covering nearly the same seasonal time period as the SASS composite is shown as Figure 2.

IV. METHODS

In performing change detection with satellite imagery, three methods are popular. The first is simple image subtraction – the image pixels are subtracted on a cell-wise basis, creating and image of difference between the two represented time periods. Alternatively, the two images can be ratioed on a cell-wise basis, and then subjected to a logarithmic transform. The third method involves simple linear regression. The later-date image becomes the dependent variable, while the pixels in the early image are the independent variable. A regression equation is created which best predicts the later-date image values from the early-date values. The residuals remaining after the fit, when displayed on a pixel-by-pixel basis, become the image of change.

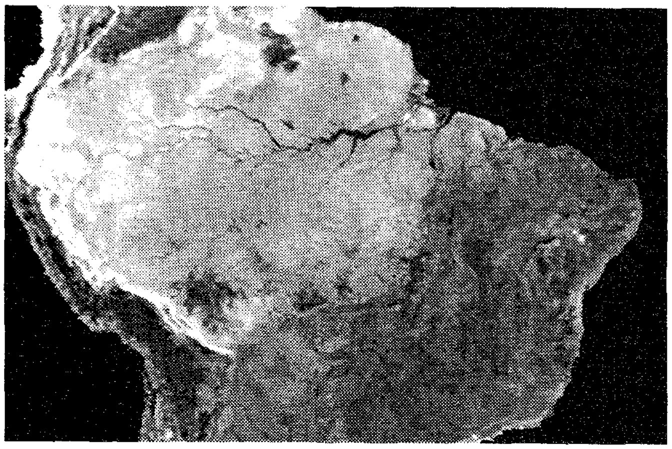

Figure 2. Reconstructed NSCAT image, 1996.

In this study, all three methods were performed to detect large-area change between 1978 and 1996. Since the results produced by the three methods were nearly identical, only the simple image differencing product was used for interpretation.

Primarily because of noise in the reconstructed SASS image, the resulting difference image was quite noisy. To remove the noise, an overall difference image mean and standard deviation were calculated. Only those pixels with differences above or below two standard deviation units were considered as representing substantial change. These pixels were replotted on the 1996 NSCAT image and interpreted. Figure 3 shows those areas of change.

IV. INTERPRETATION

Several trends are easily seen in the image. While most of the Amazon basin appears unchanged, some areas, especially along the frontiers, have clearly been altered. These regions are represented by a “1” on the image. As mentioned previously, several Brazilian government policies encourage this deforestation. One example shown on Figure 3 is in the state of Rondonia, located in the southwestern section of Brazil's Amazon. Brazil Road - 364 was constructed in 1964 to allow more access to the Amazon Basin. BR-364 was widely used in the late 1970s and 1980s as the only means for people of different states to enter Amazonia. As a result, the state of Rondonia has undergone massive deforestation along the road and its side-roads. This same trend can be seen in the states of Para and Maranhao in the southeast corner of Brazil's amazon. These locations generally contain submountainous transitional wet closed forests. When cultivated intensively, they rapidly lose native fertility after three or four seasons. If erosion and compaction of the cultivated area is not too severe, the land reverts to a secondary forest or woodland. Otherwise, the land converts to a wasteland of shrubs, grasses, and noxious weedy species. Cattle ranching has also caused environmental damage in these regions.

Large amounts of change are also evident along Brazil's eastern coast. In these cases, it is the classic Brazilian Atlantic Forest which is suffering from clearance. As coastal states such as Espirito Santo, Bahia, Alagoas, and Pernambuco undergo rapid urban and rural population growth, land-use conversion from forest is inevitable. Example locations are labeled in the image with a "2".

States such as São Paulo and Rio de Janeiro show little change because most of their spatial growth preceded the 1978 Seasat-A flight.

VI. REFERENCES

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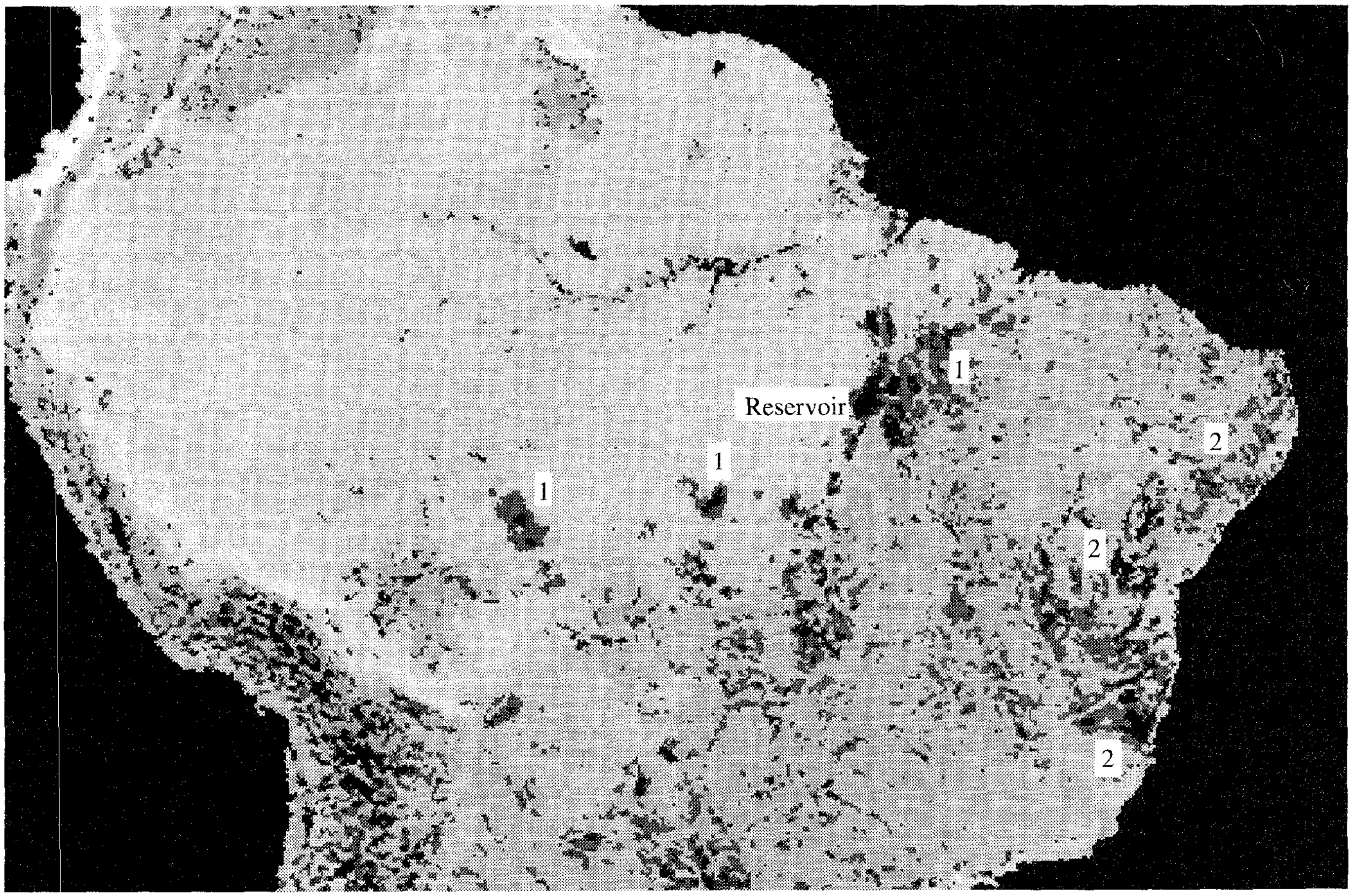

Figure 3. Areas of change within the study area. Areas of severe change in backscatter between the two dates show up as black. Areas of moderately severe change show up as dark gray patches. The areas of change are cast on the 1996 NSCAT image. Areas of apparent change in the Andes Mountains are an artifact of seasonality and the imaging process.