Recent improvements in estimating convective and stratiform rainfall in Amazonia

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1. Introduction

In this paper we present results from the application of a satellite infrared (IR) technique for estimating rainfall over northern South America. Our main objectives are to examine the diurnal variability of rainfall and to investigate the relative contributions from the convective and stratiform components. We apply the technique of Anagnostou et al (1999). In simple functional form, the estimated rain area A_{rain} may be expressed as: $A_{rain} = f(A_{mode}, T_{mode})$, where T_{mode} is the mode temperature of a cloud defined by 253 K, and A_{mode} is the area encompassed by T_{mode}. The technique was trained by a regression between coincident microwave estimates from the Goddard Profiling (GPROF) algorithm (Kummerow et al, 1996) applied to SSM/I data and GOES IR (11 μm) observations. The apportionment of the rainfall into convective and stratiform components is based on the microwave technique described by Anagnostou and Kummerow (1997). The convective area from this technique was regressed against an IR structure parameter (the Convective Index) defined by Anagnostou et al (1999). Finally, rainrates are assigned to the A_{mode} proportional to (253-temperature), with different rates for the convective and stratiform rain areas.

2. Results

Figure 1 displays a GOES IR image (top) for 1932 GMT 26 Jan 1999 and estimated rainrate (bottom) from this technique, showing the convective (red) and stratiform (green) components. While the technique does not explicitly filter thin, non-raining cirrus cloud, some implicit filtering appears. This is due to the training of the IR technique with microwave rain estimates, which are effective in screening non-raining clouds. As can be seen in Fig. 1, not all clouds defined by 253 K have associated rain estimates.

Figure 2 presents the average rainrate by hour for the four-month period Jan-Apr 1999. The color scale is the same as in Figure 1, except the values range from 1-1000 mm/mon. The major features of this analysis are as follows:

- In the Amazon region, convection begins around 15 GMT in the east (the elevated Mato Grosso plateau) and builds westward across the continent, reaching its maximum extent around 21 GMT.
- A line of convection forms along the northeast coast at about 16 GMT, builds and moves slowly inland. Remnants of this line persist as late at 07 GMT.
- A late evening/early morning maximum is found along the eastern slopes of the Andes Mountains (03-15 GMT).
- Isolated morning maxima (12-15 GMT) maybe be found along the length of the Amazon River.
- An intense morning maximum (09-16) is noted offshore in the Gulf of Panama.

In Figure 3 we display a time series of the estimated total, convective and stratiform rainrates (mm/mon) for three regions. Local time (LT) is determined from the longitude of the center of each region. In the region of the central Amazon (bottom), peak rainfall occurs around 16-17 LT. The convective and stratiform rainfall each comprises about 50% of the total, and the stratiform estimates lag the convective by 1-2 hours. A subset of that region in which radar data were collected during the Large Scale Biosphere-Atmosphere (LBA) experiment is shown in the top figure. Results are similar, except we see the addition of a weaker maximum around 2 LT. The curve for the region in northeast Brazil, near Belem is shown in the middle figure. A very dry morning is followed by a broad duration of rainfall peaking near local midnight.

An interesting representation of the data is shown in Figure 4. In the upper panel we display the difference between infrared estimates at 18 and 06 LT for Jan-Apr, 1999. Morning maxima appear in the blue shades while afternoon maxima appear in red. The bottom panel of Figure 4 displays the difference in the microwave (GPROF) estimates at 18 and 06 local time for Jan-Apr, 1992-97. (Note that this is a 6-year period). Common to both estimates is the alternating pattern of morning/afternoon rainfall as one progresses from the Pacific Ocean northeastward toward the Atlantic Ocean. The mountain/valley circulation of the Andes Mountains is evident, as is the land/sea circulation along the northeast Brazilian coast. The morning rainfall maximum is apparent along the Amazon River and in the Gulf of Panama. The infrared estimates tend to over-estimate the afternoon rainfall in the central Amazon compared to the microwave estimates. More examples of microwave-derived rainfall climatologies may be found in Negri et al (1999).

In Figure 5 we display the mean rainrate (mm/mon) for the 4-month period Jan-Apr. 1999. The top figure shows the GPROF microwave estimates derived from satellite overpasses at 06,08,18 and 20 LT. The IR estimates for the same period are shown in the bottom panel, using estimates only from the hours of the day at which the microwave estimates are available. Note that the sampling is NOT identical. The GOES are sampled every day at the aforementioned hours, while the microwave is sampled about twice every three days. This procedure is an attempt to use the microwave estimates as ground-truth for the IR estimates, since raingage gage estimates are widely scattered and not readily available. The major features of this 4-month rainfall are present in both estimates. One notable exception is the microwave maximum over the water off the northeast coast of Brazil. Since the IR technique was trained over land, it does not perform well over water, where the processes producing the rainfall are not driven by convective heating or topography. We also tend to over-estimate the rainfall in Amazonia, due in large part to a tendency to overestimate the afternoon rainfall. The coastal maximum along northeast Brazil and the Gulf of Panama maximum compare favorably.

3. Conclusions and Future Work

In this paper we presented results from a new technique to estimate tropical, warm-season precipitation. The technique is infrared-only with intrinsic MW calibration (Anagnostou et al, 1999). For Jan. – Apr. 1999 we derived the diurnal cycle of rainfall over northern South America. Delineation of convective and stratiform rainfall was based on an IR "structure" parameter (the Convective Index), also calibrated to the microwave estimates (Anagnostou and Kummerow, 1997). Qualitative comparisons to passive microwave (GPROF) estimates for four-month period were encouraging; i.e. the effects of rivers, topography and local circulations on the rainfall were apparent.

Future work will include:

- Recalibration of microwave/infrared relationships using TRMM data (both the TRMM Microwave Imager and Precipitation Radar).
- Recalibration of convective/stratiform division using latest GPROF algorithm.
- Comparison of results with LBA case studies using TOGA and S-bands radars.

References:

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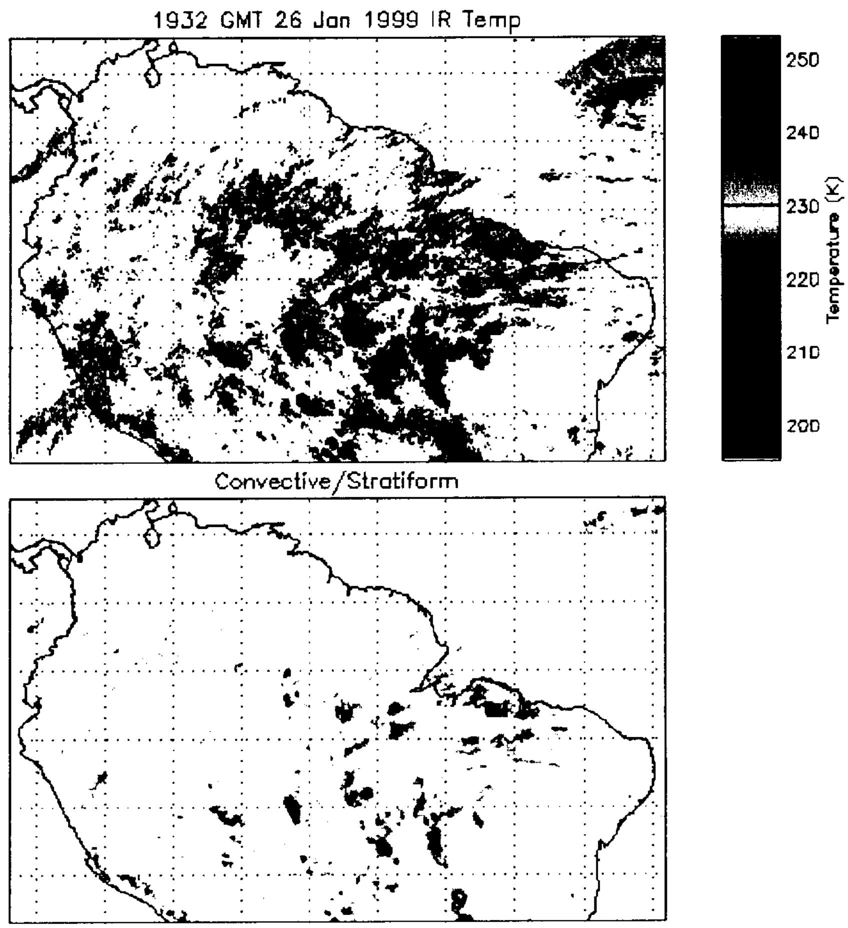

Figure 1: GOES infrared image (top) for 1932 GMT 26 Jan 1999 and estimated rainrate (bottom) from the technique of Anagnostou et al, 1999 showing convective (red) and stratiform (green) components.

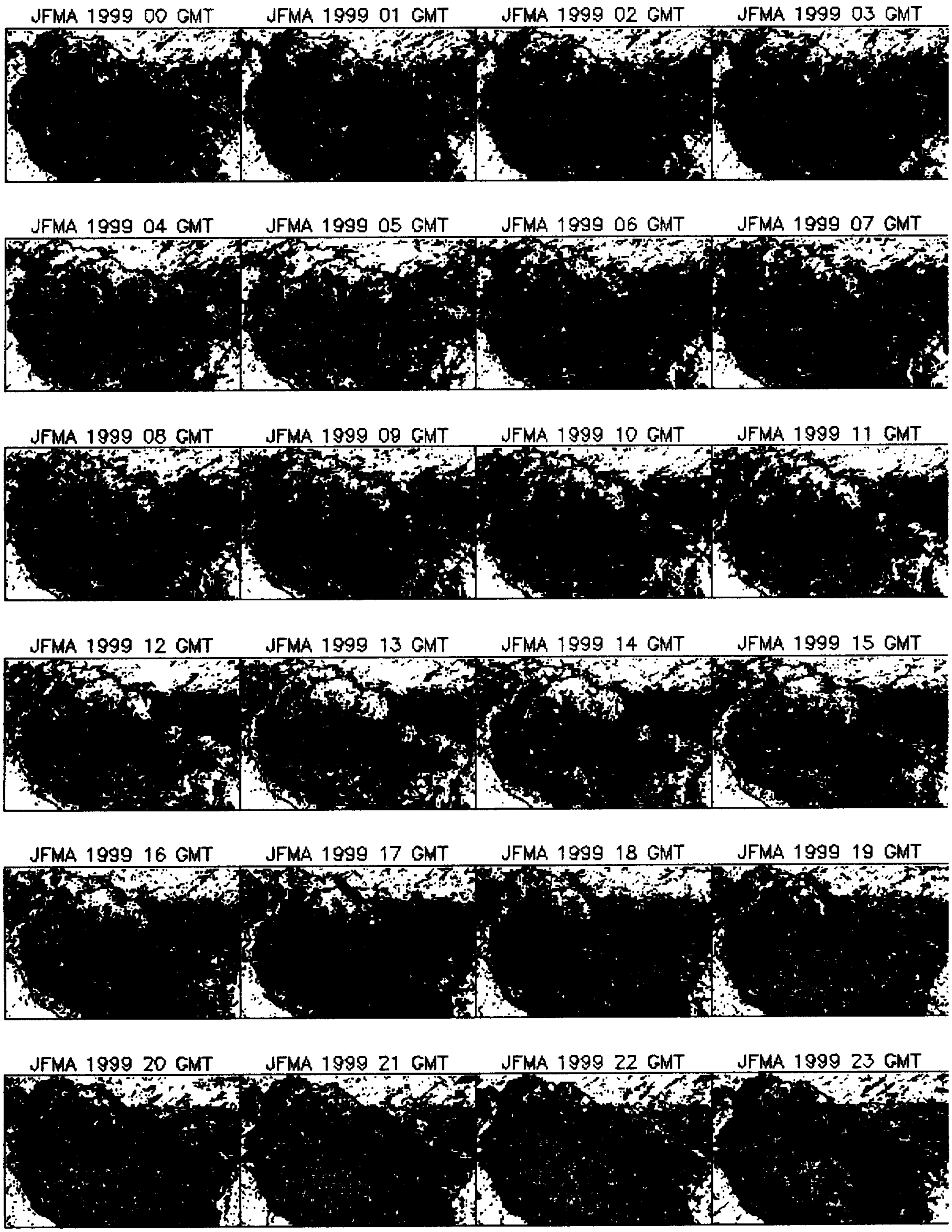

Figure 2: Average rainrate by hour for the four-month period Jan-Apr 1999 from the technique of Anagnostou et al, 1999. Color scale same as in Figure 1, except values range from 1-1000 mm/mon.

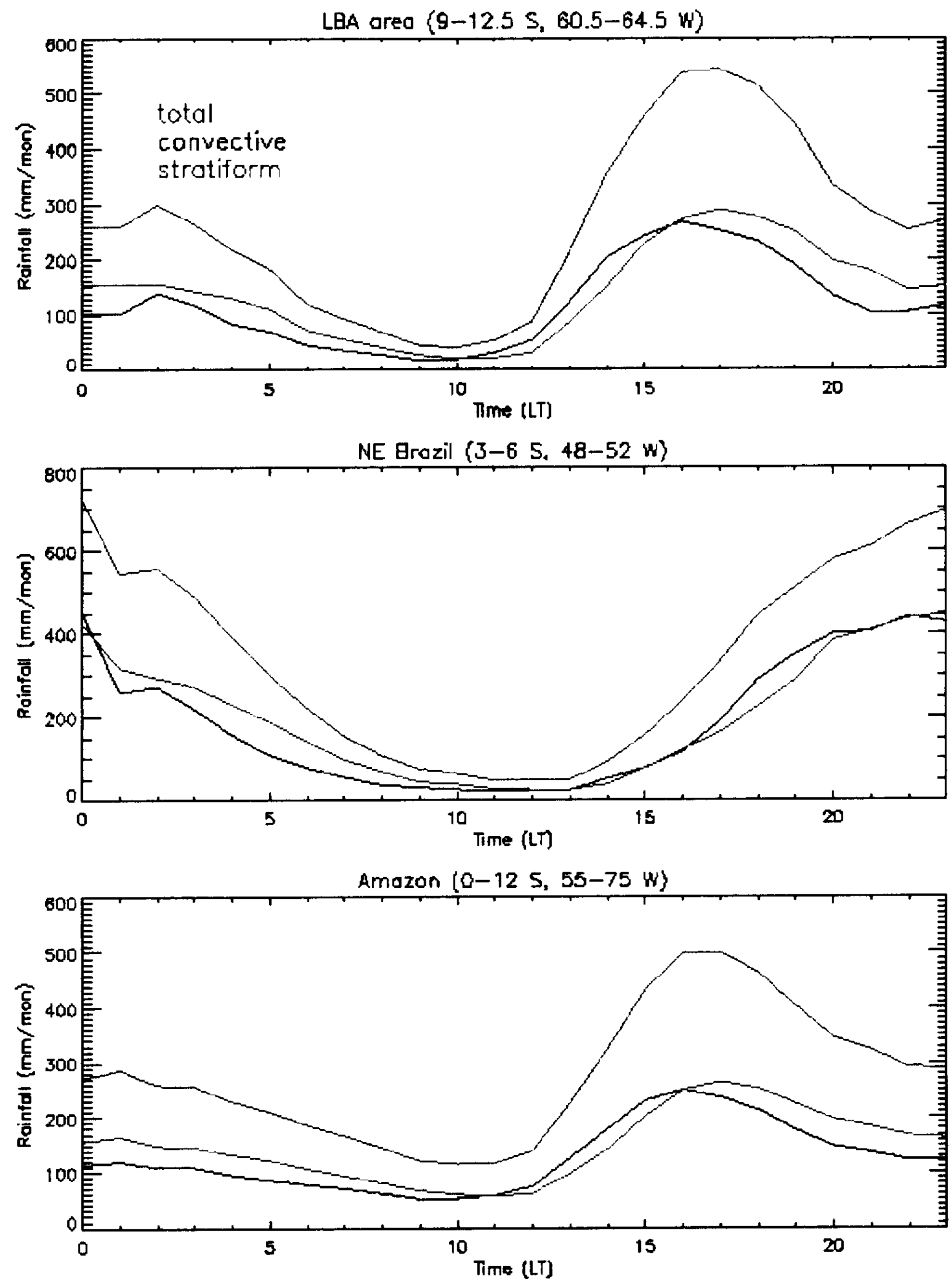

Figure3: Time series of total, convective and stratiform rainrates (mm/mon) for three regions.

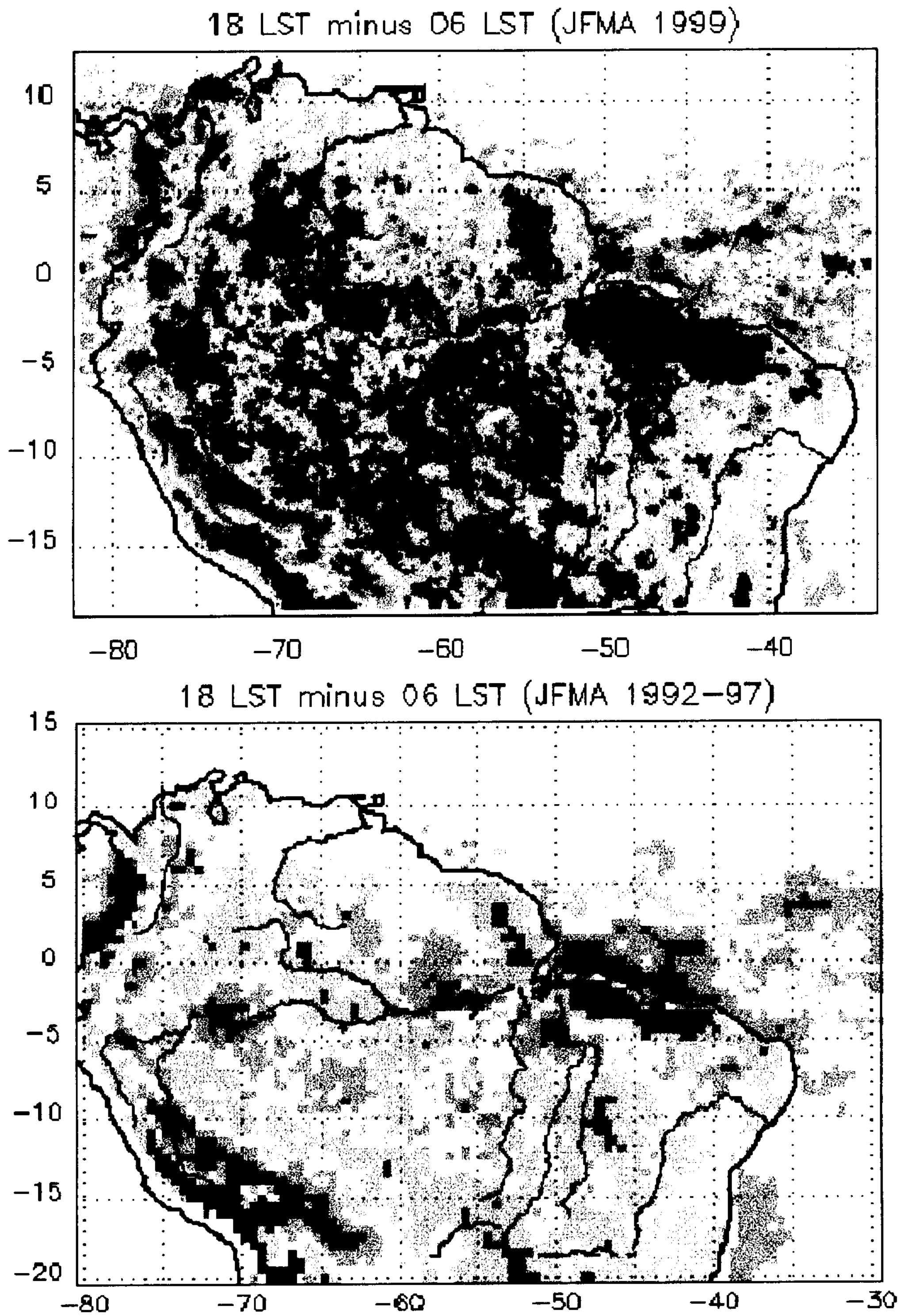

Figure 4: (Top): Difference between infrared estimates at 18 and 06 local time for Jan-Apr, 1999. (Bottom): Difference between microwave estimates at 18 and 06 local time for Jan-Apr, 1992-97. Morning maxima appear in the blue shades, evening maxima in red.

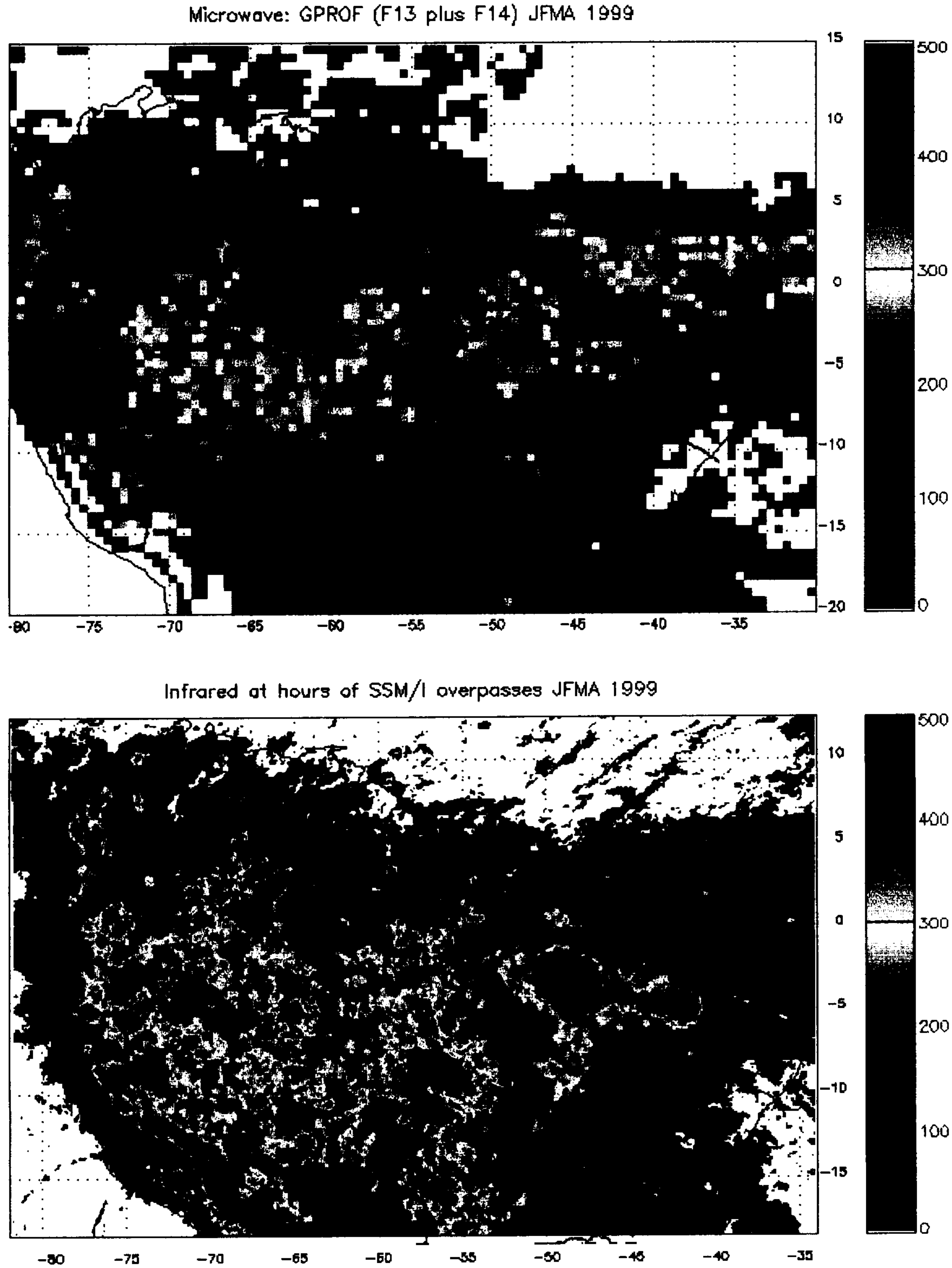

Figure 5: (Top): Microwave estimates of 4-month accumulated rainfall at 06,08,18 and 20 local time. (Bottom): Infrared estimates for the same period, using only the hours that match the microwave sampling. Scale is in mm/mon.