Aerosol effects in different types of precipitating clouds in the Amazon

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MOTIVATION

Purpose: Analyse precipitating clouds and its microphysics over Amazon region. The analysis is focused on observed cloud and precipitation properties in different atmospheric and vegetation cover conditions provided by aerosol optical depth (AOD) and normalized difference vegetation index (NDVI) using TRMM-PR and MODIS information. Special issues:

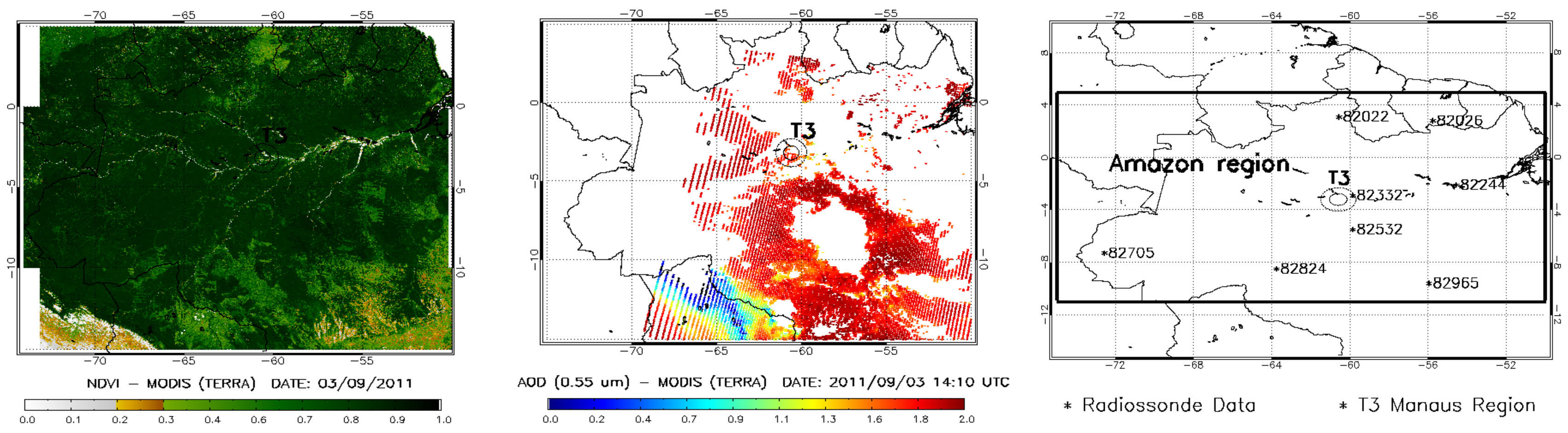
- Observe the precipitating clouds properties (i.e. rain rate - RR, liquid water path - LWP and ice water path - IWP) using TRMM-PR data version 7 (Iguchi et al., 2000; Kirstetter et al., 2013);

- Observe precipitating clouds properties for warm (wrc), stratiform (str) and cold convective (cnv) clouds which are separated using Schumacher and Houze (2003) cloud classification for TRMM-PR radar;

- Analyse the relationship between LWP and IWP (calculated using Carey and Rutledge (2000) method) in function of AOD and NDVI values retrieved from MODIS sensor onboard TERRA satellite (Remer et al., 2005; Didan and Huete, 2006);

DATA AND METHODS

-Moderate-Resolution Imaging Spectroradiometer (MODIS) onboard TERRA satellite



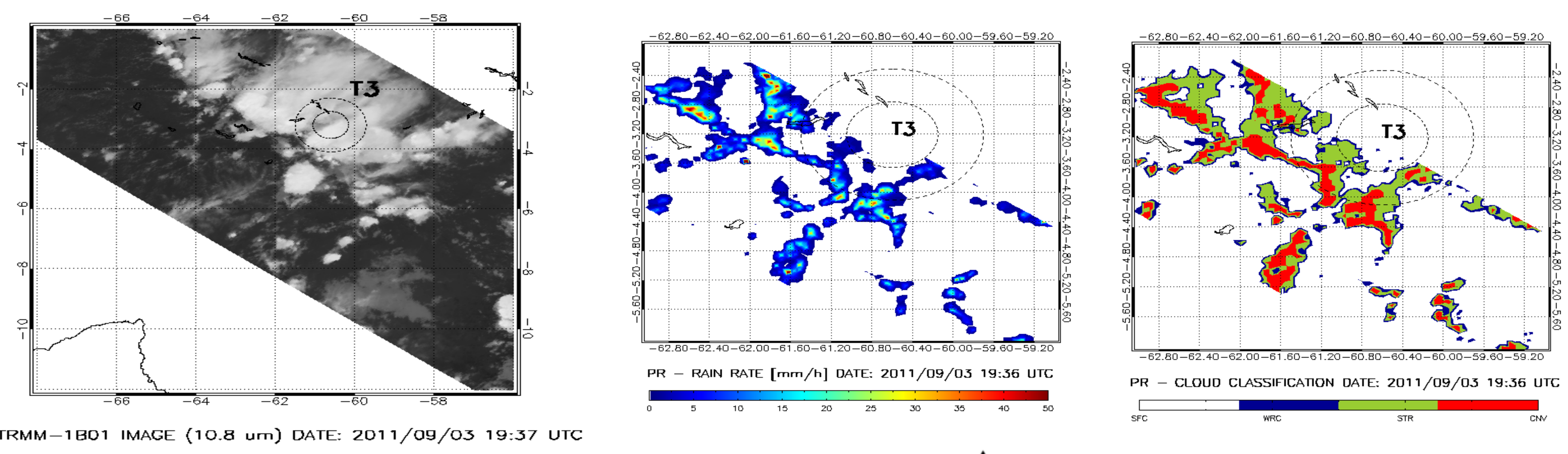
Period: September-December (2004-2013) (dry to wet season)

NDVI data: 16 days composite (MOD13A2*.hdf); pixel: 1 km x 1 km

AOD data: Daily passages (MOD04_L2*.hdf); pixel: 10 km x 10 km

Radiossonde data: 12 UTC for all stations

-Precipitation Radar onboard Tropical Rainfall Measuring Mission satellite



Period: September – December (2004-2013)

Precipitation Radar data: 2A25; 2A23; pixel: (5 km x 5 km)

Methods

- The MODIS AOD pixel information is considered the same for all day. Only the pixels not surrounded by cloud pixels are considered.
- The NDVI pixel information is considered for the date available and next 15 days.
- The PR-TRMM pixels analysis is performed in the cases where all pixel area is inside the AOD pixel area.
- The PR-TRMM samples are analysed for different AOD and NDVI ranges divided per percentiles as showed at Fig.1.

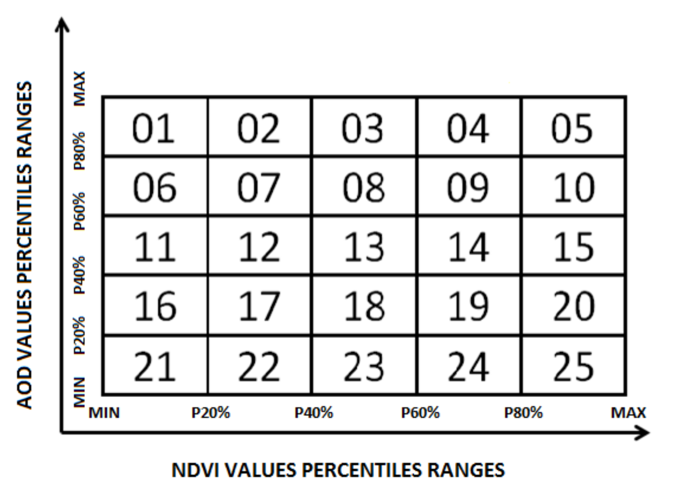


Figure 1- PR-TRMM profiles analisys according to AOD and NDVI sample percentiles ranges.

RESULTS

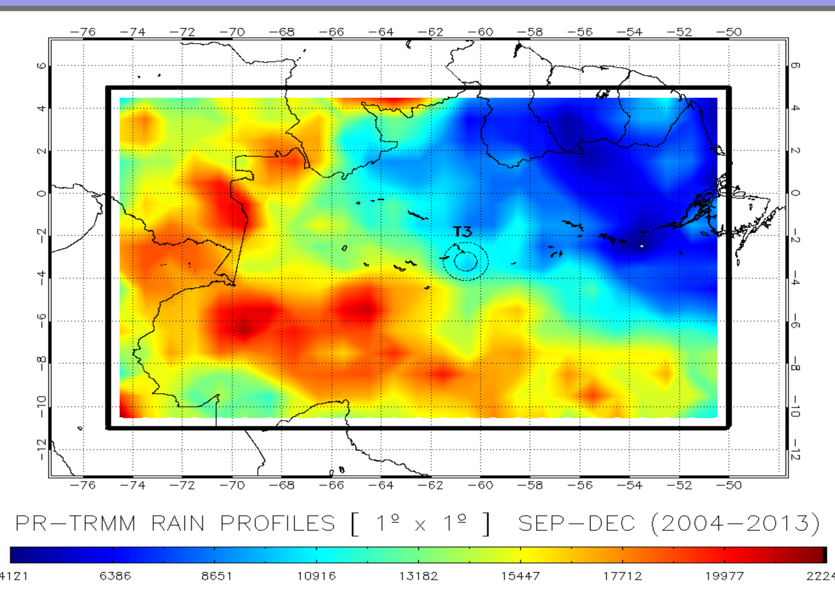


Figure 2- Spatial distribution on the number of PR-TRMM rain profiles used.

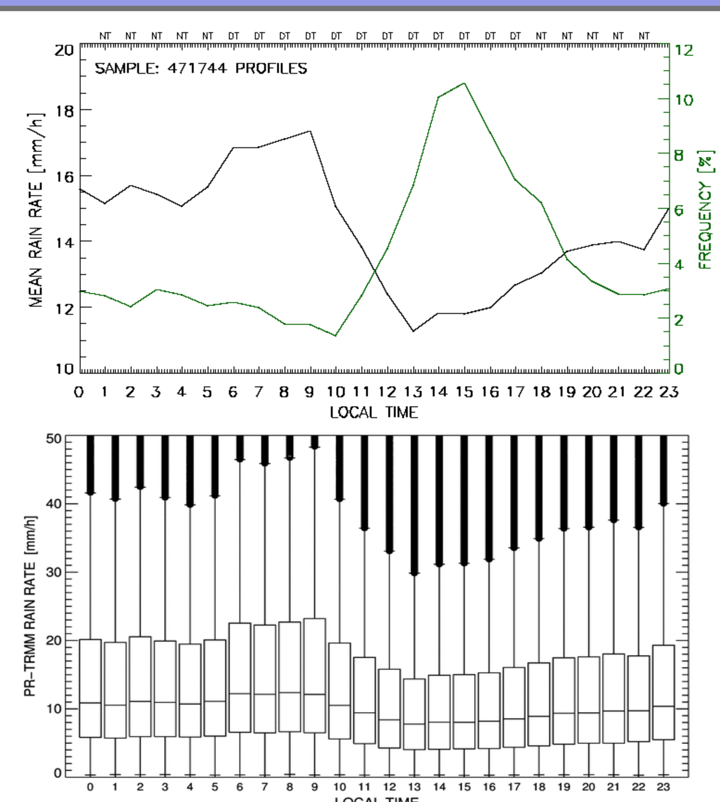


Figure 4- Diurnal Variation of average rain rate and boxplot distribution when convective rainfall is detected for Amazon region.

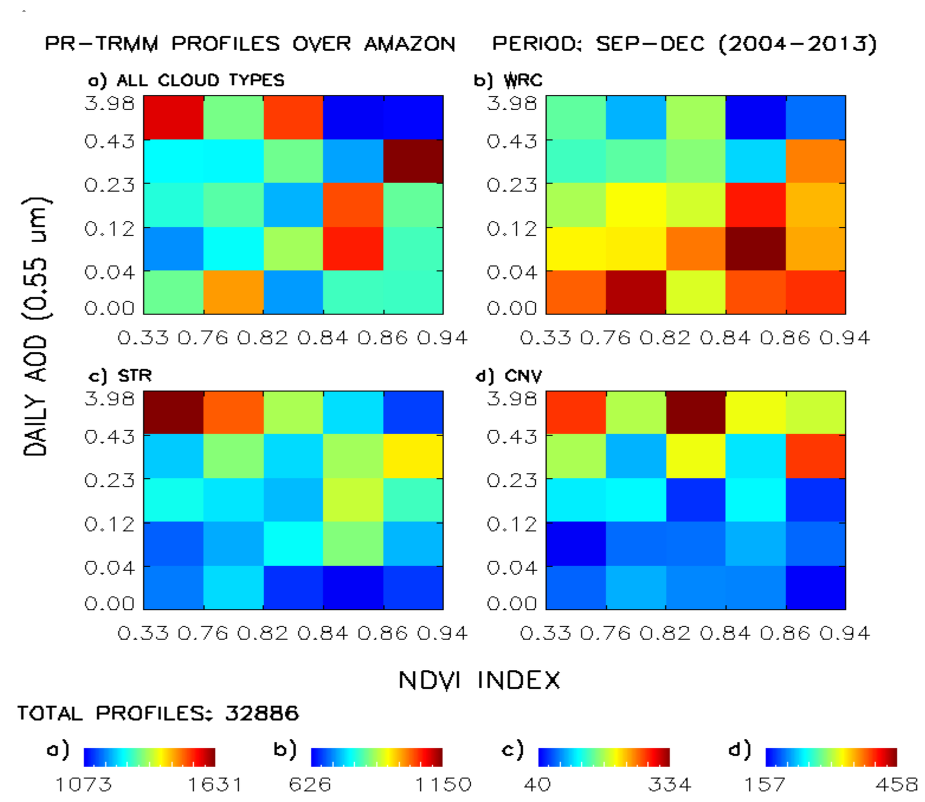


Figure 3- Number of PR-TRMM rain profiles observed for different AOD and NDVI ranges for: a) all cloud types (wrc, str and cnv), b) wrc, c) str and cnv.

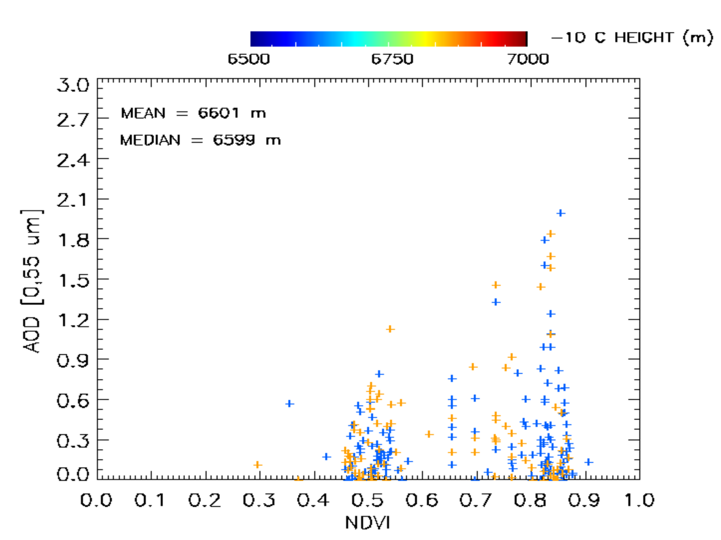


Figure 5- Height of cloud ice phase (-10 °C) as a function of AOD and NDVI values for 243 12UTC radiosondes data over Amazon region.

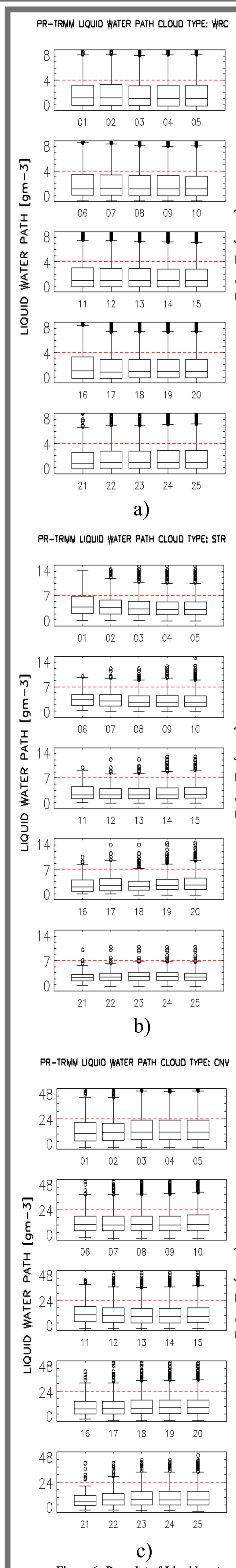


Figure 6- Box-plot of Liquid water path for a) warm clouds (wrc), b) stratiform clouds (str) and c) convective clouds (cnv). The cases are defined at Fig 3.

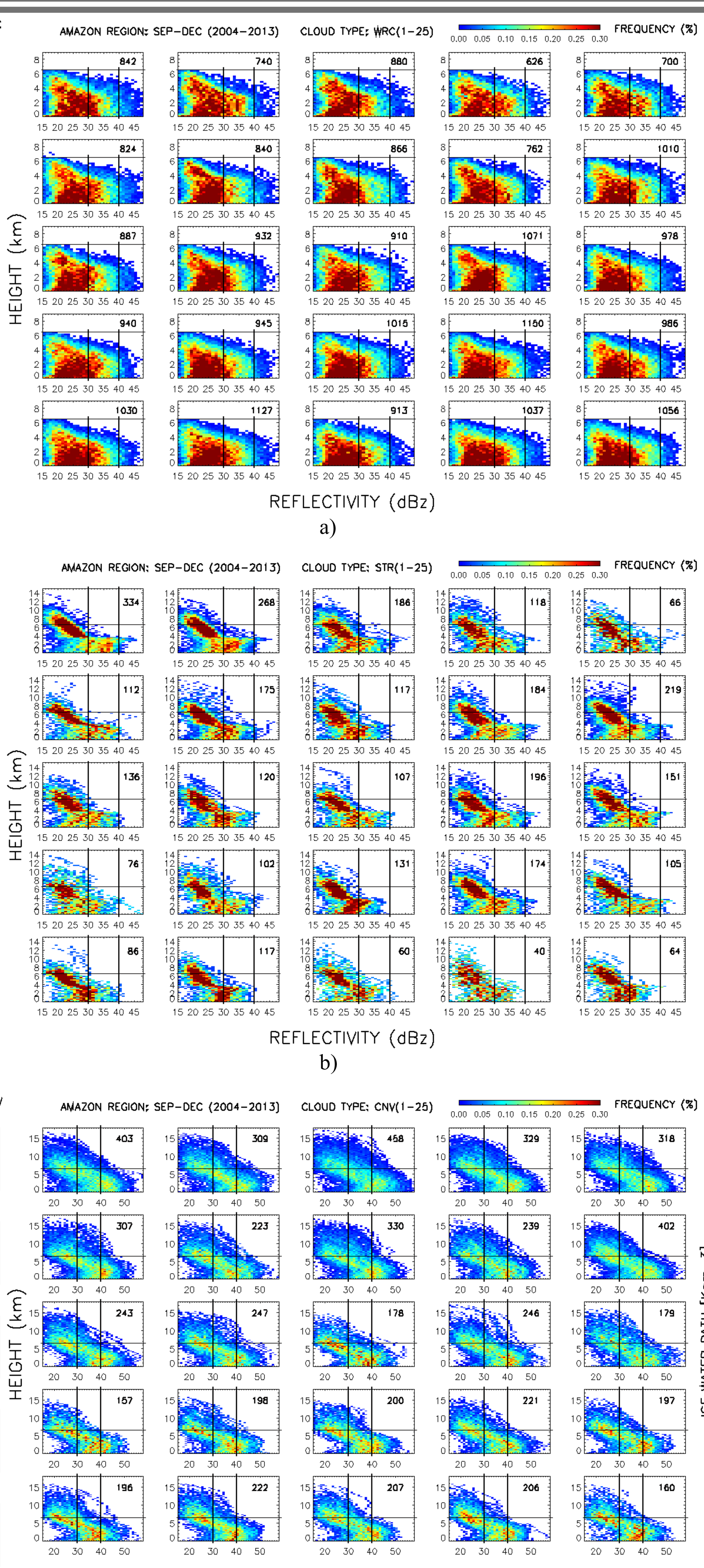


Figure 7- Probability density functions of reflectivity-by-altitude for all cases with PR-detected surface rain rate for a) warm clouds (wrc), b) stratiform clouds (str) and c) convective clouds (cnv). The plots are divided according aerosol optical depth (AOD) and normalized vegetation differential index (NDVI) percentiles range defined at Fig 3. The probability is normalized, i.e., it is the number of occurrences per 1 dBZ per 250 m, divided by all occurrences in all reflectivity and height bins, and expressed as a percentage. The total number of occurrences is shown in the upper-right corner of each plot. Vertical lines are drawn at 30 and 40 dBZ, and horizontal line at 6.5 km height (freezing level, ~ -10 °C).

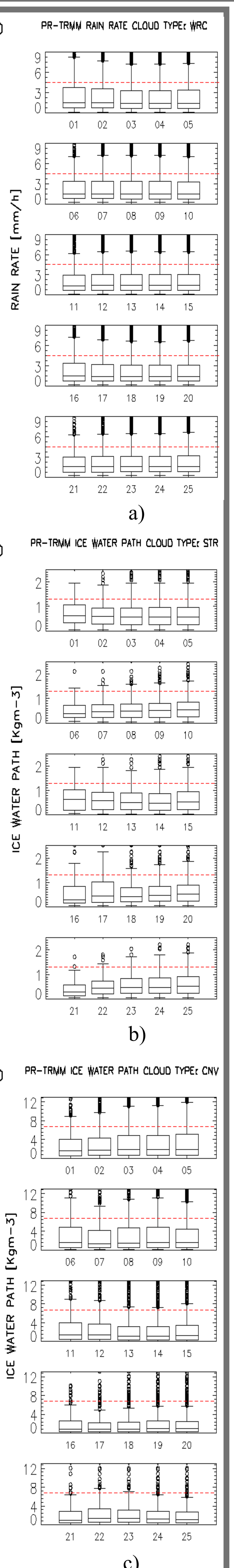


Figure 8- a) box-plot of rain rates for warm clouds (wrc). b) box-plot of ice water path for stratiform (str). c) idem for convective clouds. The cases are defined at Fig 3.

RESULTS

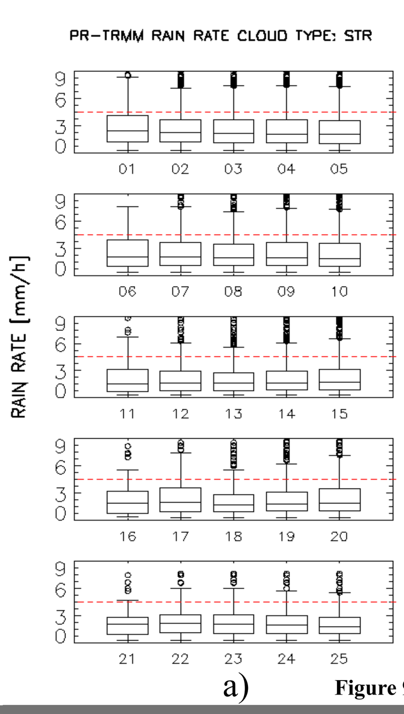
✓ At Amazon region PR-detected surface rain rate (RR) occurs mainly during afternoon (Fig. 4). It is in agreement with previous studies which supports the importance role of solar heating for atmospheric instability generation at this region;

✓ For cleaner environment the number of convective and stratiform clouds are significantly lower than at polluted ones (Fig 3.). The opposite pattern is observed for warm rain clouds.

✓ PR-detected higher RR and LWP in warm clouds for higher AOD values (Figs. 6a. and 8a.). No significant differences in RR were observed for NDVI index variation.

✓ For stratiform precipitating clouds higher RR are observed for higher AOD values (Fig. 9-a.). For polluted cases (1-5) higher LWP, IWP and RR are observed for lower NDVI values (Figs 6-b, 8-b and 9-a). For cleaner cases (21-25) higher IWP are observed for higher NDVI values.

✓ For convective precipitating clouds higher LWP, IWP and RR are observed for higher AOD values (Fig. 9-b). The LWP, IWP and RR shows higher values for higher NDVI ranges at majority cases (Figs 6-c, 8-c and 9-b).



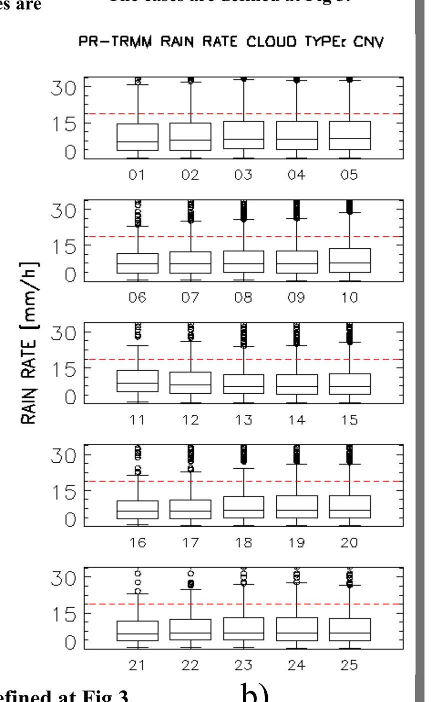


Figure 9- a) box-plot of rain rates for stratiform clouds (str). b) idem for convective clouds (cnv). The cases are defined at Fig 3.

CONCLUSIONS

✓ For warm clouds (wrc) the results suggest that the highest values of rain rate observed for higher AOD values is related to the enhancement of colision and coalescence processes. The explanation for this pattern could be related to cloud drops reaching precipitating drop size and growing in function of a high concentration of small droplets.

✓Str clouds are originated from cnv clouds and observed mainly at a high CCN environment (as showed at Fig.3). In these cases the increase in Bowen ratio at deforested areas (lower NDVI values) lead to the enhancement of updrafts at clouds and more water vapor available for cloud drops generation. The results observed for deforested areas (profiles 1 at Figs. 6-8. b-c) shows different distribution patterns of LWP and IWP. Lower values are observed for cnv clouds in comparison to forested areas (profiles 4-5 at Figs. 6-8. b-c), while the opposite is observed for str clouds.

✓These results suggests that at polluted environments over deforested areas cnv clouds tends to generated smaller drops at cloud warm phase of development than over forested areas. At forested areas the drops grows more and fastly due to lower water vapor competition. At cold phase riming/accretion processes decreases at deforested areas due to the lower availability of large drops and LWP, generating a higher population of small ice particles with lower density than at over forested cases. On the other hand, str clouds at deforested areas has aggregation processes intesified due to the transport of more ice particles from convective phase, generating higher IWP, LWP and RR than at forested areas.

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