Optical Properties and Radiative Forcing of Cirrus Clouds in the Central Amazon Forest

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Abstract: Cirrus clouds cover a large fraction of tropical latitudes and play an important role in Earth's radiation budget. Their optical properties, altitude, vertical and horizontal coverage control their radiative forcing, and hence detailed cirrus measurements are of utmost importance. Studies reporting cirrus properties over tropical rain forests like the Amazon, however, are scarce. In this work, we derive the first comprehensive statistics of optical and geometrical properties of cirrus clouds in Amazonia and estimate its radiative forcing. For that, we are using 1 year of ground-based lidar observations in the central Amazon forest, Brazil. The retrieved optical properties were then considered to calculate the cirrus radiative forcing (CRF) and heating rates profiles computed in detail by the libRadtran software package and the approximated Corti and Peter model. The cirrus frequency of occurrence was found to be as high as 88% during the wet season and not lower than 50 % during the dry season, with mean values of cirrus cloud top and base heights, cloud thickness and cloud optical depth were 14.3 ± 1.9 (std) km, 12.9 ± 2.2 km, 1.4 ± 1.1 km, and 0.25 ± 0.46, respectively. With such high frequency of occurrence and altitude over the dark-pristine Amazon forest (albedo $\alpha = 0.12$), these clouds produced a net CRF at the top and bottom of the atmosphere (TOA and BOA) of +14.7 and -3.6 Wm-2, respectively, much more intense than estimated for 3 European sites (0.9, 1 and 1.7Wm-2 at TOA). Optically thicker cirrus in general have grater net CRF, with instantaneous CRF that could reach extremes up(down) to 140(-65) Wm-2 for night(day) time. Together, the vertical profiles with total optical depth with > 0.3 was responsible for about 72%(62%) of the TOA(BOA) net CRF, which mean that a large faction of the CRF is generated by optically thinner cirrus (COD<0.3) that is harder to detect by radars and passive instruments on board of satellites. A clear diurnal cycle of the optical depth was found and shows a minimum around local noon and maximum during late afternoon (~16h LT), associated with the diurnal cycle of precipitation. This result in a mean instantaneous TOA(BOA) net CRF ranging from 1.7(-23) Wm-2 at the afternoon evolving to 47(3.1) Wm-2 at night time. The cirrus clouds produced an approximately constant average increment of about 1.2 K/day in the heating rate vertical profile from 8 to 18km (in-cloud), but with instantaneous values that can reach values higher than 10K/day for portions of the cloud with high IWC.

Keywords: Cirrus; Radiative Forcing; Optical Depth.

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