ABSTRACT: Lightning Image Sensor (LIS), an optical instrument on board of the TRMM satellite, provides total lightning information over the tropics since 1997, which includes the whole Brazil. In this work, the cloud-to-ground (CG) lightning distribution over Brazil is estimated based on a 13-year dataset (1998-2010) of total lightning with 0.5º, 0.25º, and 0.1º resolutions. Instrument detection efficiency and view-time corrections were used to compensate variations due to the diurnal cycle and differential sampling over the equator and tropics. The resulting cloud-to-ground flash density map indicates that Brazil presents regions with distinct lightning activity patterns (South, North and Southeast) which are correlated to distinct meteorological conditions. These meteorological systems are associated with the thunderstorms over different parts of the country, for example, large mesoscale convective systems in the south, small convective systems in the north and a transition area over the southeast part. A more comprehensive analysis is presented in a joint paper during this same conference. Comparison with a previous low-resolution map (1º resolution) helped to evaluate whether the CG lightning patterns remained unchanged when the resolution is increased. On the other hand, the higher resolution reveals some new features not observed in the previous low-resolution map.

INTRODUCTION
The Lightning Imaging Sensor (LIS) is a scientific instrument that is integrated aboard the Tropical Rainfall Measuring Mission (TRMM) Satellite [Christian et al. 1999]. On November 1997, LIS was launched into a low Earth orbit at 350km of altitude, and now, after an orbit boost in 2001, it circles the Earth at an altitude of 402.5km. The orbit inclination is 35º, thus allowing LIS to observe lightning activity in the tropics regions of the globe. The LIS sensor contains an optical staring imager which is used to identify lightning activity by detecting momentary changes in the brightness of the clouds as they are illuminated by lightning discharges. Since the sensor detects only the luminous pulses of lightning events, it cannot discriminate between cloud-to-ground (CG) flashes and intra-cloud (IC) discharges. Thereby, its information corresponds to the total lightning activity observed with an estimate location accuracy (LA) of about 5km and a detection efficiency (DE) of about 90-95% [Mach et al. 2007]. The wide angle lens combined with the 402.5km altitude of the TRMM spacecraft permit the sensor to view a 668km x 668km area of the Earth with a spatial resolution of 4.2km at the nadir. Since LIS travels around the Earth with a velocity greater than 7km s⁻¹, it can monitor individual storm systems for about 92 seconds as it passes overhead. As a consequence, LIS takes about 49 days to sample the 24h of the day for the same point at Earth.

METHODOLOGY
In order to assess CG flash rates using the LIS data, it is required to correct the map for the diurnal variation of LIS DE, which decreases to a minimum of about 70% at noon and reaches a maximum of 88% during the whole night (Boccioppio et al., 2002). Furthermore, since the TRMM satellite has an orbit with 35º latitude inclination, the sampling time near the tropics is significantly higher than over the equator [Christian et al. 2003]. This effect can be clearly observed in Figure 1 which shows an example of the total lightning view time over Brazil for 1997-2007. One can see that over the North region (particularly over the Amazon basin), the total sampling time is almost one third of the sampling time over the South portion of the country. This affects directly the number of lightning events observed by the sensor causing a spatial bias from south to north. More details can be found in Naccarato et al. (2008).

RESULTS AND DISCUSSIONS
Figures 2a, 2b and 2c show the CG flash rate densities (flashes km²⁻¹ yr⁻¹) with 0.5º, 0.25º and 0.1º resolutions, respectively, based on 13 years of LIS measurements corrected by view time and the instrument detection efficiency as described in section 2. In order to estimate the CG flash rate densities values from the total lightning information provided by LIS, the average IC/CG ratio of 1.5 (60% IC and 40% CG) was adopted for the whole country. The ratio was assessed comparing the LIS total lightning data and LF network CG data for two different regions of Brazil: Rondonia State (very close to the Amazon basin) and the Southeastern region (Pinto et al. 2003).

The comparison of Figures 2a, 2b and 2c shows that the increase of the map resolution allows a better identification of particular CG lightning activity patterns in Brazil. However, even with a low resolution map (Figure 2a), we can identify the main areas of high and low CG lightning activity over Brazil. Moreover, decreasing the resolution, it is observed that the CG flash density values also decrease as a result of the smoothing process that cuts off all high variations present in the data.

From Figure 2c, it can be observed that the CG lightning activity over Brazil presented four (among others) major lightning spots: (1) west portion of Rio Grande do Sul State (~12-14 flashes km²⁻¹ yr⁻¹); (2) the west portion of Rio de Janeiro and south of Minas Gerais state (>15 flashes km²⁻¹ yr⁻¹); (3) middle area of Mato Grosso do Sul State (>15 flashes km²⁻¹ yr⁻¹); and (4) large part of the Amazon basin in the northern Brazil. The high CG lightning activity in regions (1) and (3) can be correlated to Mesoscale Convective Systems (MCS) that frequently reach these parts of the country coming from Argentina and Paraguay (Velasco and Frisch 1987). Region (2) is related to the interaction of the sea breeze with the local topography. Region (4) is related to the Amazonian convection and the International Convergence Zone (ITCZ) in the Amazon basin. The lightning patterns over Southeastern Brazil are related to the interaction of outflow fronts with high mountains (Naccarato, 2006) and the effect of the large urban areas (Naccarato et al. 2003; Farias et al. 2008) which are not so evident from LIS. Finally, it is clear that the Amazon basin has a higher CG lightning activity in the north part of Brazil estimated from LIS. Since these CG lightning patterns are related to complex interactions of different meteorological systems (including the ITCZ) and local features of the region, for example, deforestation, biomass burning and topography (Albrecht et al., 2011), the physical explanations are still not well established. A more comprehensive study is presented by Naccarato et al. (2001).

CONCLUSIONS
According to LIS data, there are six regions in Brazil with high lightning activity, with CG flashes rate densities values varying from 12 to 15 flashes km⁻² yr⁻¹: Amazon basin and mid of Tocantins State, west of Rio Grande do Sul State, northwest of Mato Grosso do Sul State, Pará Valley (Southeastern region) and Metropolitan Region of São Paulo. There are also six regions with lower CG lightning activity: Acre, Roraima and Amapá States, northeastern Brazil, north of Minas Gerais State and Espirito Santo State.

Some differences in the CG lightning activity throughout the country cannot be attributed only to dataset limitations, since some regional behaviors are related to different types of meteorological conditions, which interactions are still a matter of discussion.

REFERENCES