Why some positive cloud-to-ground flashes trigger upward lightning and why some do not?
An investigation based on high-speed video, electric field measurements and lightning mapping array data

Carina Schumann¹, Marcelo Magalhães Fares Saba¹, Jeferson Alves¹, Tom A. Warner², Rachel I Albrecht³, John H. Helsdon Jr.²

¹Electricity Atmospheric Group - INPE - National Institute for Space Research
²Dept. of Atmospheric and Environmental Sciences, South Dakota School of Mines and Technology, Rapid City, SD, United States
³CPTEC, INPE - National Institute for Space Research
carina.schumann@gmail.com

Abstract
Observations of upward lightning from tall objects have been reported since 1939. Interest in this subject has grown recently, some of it because of the rapid expansion of wind power generation. Also, with the increasing number of tall buildings and towers, there will be a corresponding increase in the number of upward lightning flashes from these structures. Reports from recent field observations are beginning to address the nature of upward lightning initiation, but much still needs to be learned. Examples are studies of upward lightning from towers in winter thunderstorms in Japan (Wang and Takagi, 2010; and Lu et al., 2009) and summer thunderstorms in Europe (Miki et al., 2005; Flache et al., 2008; and Diendorfer et al., 2009; Zhou et al., 2011) and in North America (Mazur and Ruhnke, 2011; Hussein et al., 2011; Warner, 2011, and Warner et al., 2011). Upward lightning can be initiated when another cloud-to-ground lightning (mostly positive) occurs near the tower (Wang et al., 2010, Mazur and Ruhnke, 2011, Warner et al., 2012 and Zhou et al., 2012). Sudden changes in the electric field generated by the preceding discharge may be responsible for the initiation of upward leaders. In some cases, intracloud discharges can also initiate upward leaders. During the summers of 2012, a combination of high-speed video and standard definition video were used to record upward lightning flashes from multiple towers in Sao Paulo, Brazil and Rapid City, South Dakota USA. This study shows electric field measurements of positive lightning which did and did not trigger upward lightning flashes. Some cases of upward lightning were also analyzed with lightning mapping array (LMA) data.

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LMA: Leaders over the tower
Cases during 4 thunderstorm days  
Upward Leader
+CG: 53 cases  9 cases
IC: 34 cases  1 case
-CG: 12 cases  None

Leader passing over the tower  
Peak Current (kA)  
Height (km)  
Distance (km)

Flash duration?  
Continuing current?  
Static electric field?

+CG flashes that had negative leaders passing over the tower