The Characteristics of TLE-producing Thunderstorms

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Since the first sprite observation in 1989 by J.R. Winckler above a northern Minnesota mesoscale convective system (MCS), a focus of many investigations has been determining the characteristics of tropospheric lightning discharges that induce sprites, and in turn, what types of storms give rise to these relatively rare events. This paper will review the current state of our knowledge. A virtual menagerie of transient luminous events (TLEs) above convective storms has since been documented. Two major classes of TLEs can be described: (a) those originating from clouds tops (blue starters, blue jets, gigantic jets, upward lightning), and (b) those induced in the mesosphere and lower ionosphere by tropospheric lightning in storms below (sprites, halos, elves, trolls, etc.) After a decade of intensive measurements above U.S. High Plains storms, sprite measurements are now being obtained systematically over different geographic and meteorological regimes on a systematic basis by the Sprite Net camera system, and on an ad hoc basis, by operators of sensitive surveillance systems. The first class of TLEs have been extremely difficult to study due to their rarity, lack of apparent direct connection to lightning discharges and RF signatures, and occurrence above severe storm systems. Limited evidence suggests that they occur over both ocean and landmasses, and may be found above vigorous, deep convective storms, possibly with tropopause-penetrating domes. Two recent serendipitous observations of gigantic jets above storms in Mexico and Missouri are reviewed. An example of true upward lightning has been captured above a Japanese thunderstorm. The second and more common classes of TLEs are being observed worldwide. Video observations have documented storms over other portions of the U.S. (the Rocky Mountains, northern plains, midwest and the east coast) as well as providing the first ground imagery of sprites above central African MCSs. New remote sensing techniques are revealing that impulse charge moment change is proving a robust predictor of those CG lightning strokes with a high probability for sprite production. Detailed case studies from MCSs showing the relationship between storm structure, 3-D total lightning distributions and sprite production will be summarized. Large stratiform precipitation regions within intense MCSs remains a favored location for sprite parent lightning. However, as video monitoring becomes more widespread, occasional exceptions are expected to be found in systems as diverse as Gulf Stream convection, intense Great Lakes snow squalls, embedded convection within intense winter cyclones, hurricane outer rain bands and eye walls, etc. This summary draws on the collaborations with many institutions including but not limited to Colorado State University, MIT, Duke, Stanford, the University of Oklahoma, and the Université Paul Sabatier.