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## Length estimations of presumed Upward Connecting Leaders in lightning flashes to flat water and flat ground

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**Abstract.** Using video data recorded at 50,000 frames per second for nearby negative lightning flashes, estimates are derived for the length of positive upward connecting leaders (UCLs) that presumably formed prior to new ground attachments. Return strokes were 1.7 to 7.8 km distant, yielding image resolutions of 4.25 to 19.5 m. No UCLs are imaged in these data, indicating those features were too transient or too dim compared to other lightning processes that are imaged at these resolutions. Upper bound lengths for 17 presumed UCLs are determined from the height above flat ground or water of the successful stepped leader tip in the image immediately prior to (within 20  $\mu$ s before) the return stroke. Better estimates of maximum UCL lengths are determined using the downward stepped leader tip's speed of advance and the estimated return stroke time within its first frame. For 17 strokes, the upper bound length of the possible UCL averages 31.6 m and ranges from 11.3 to 50.3 m. Among the close strokes (those with spatial resolution <8 m per pixel), the five which connected to water (salt water lagoon) have UCL upper bound estimates averaging significantly shorter (24.1 m) than the average for the three close strokes which connected to land (36.9 m). The better estimates of maximum UCL lengths for the eight close strokes average 20.2 m, with slightly shorter average of 18.3 m for the five that connected to water. All the better estimates of UCL maximum lengths are less than 38 m in this dataset.

### Keywords:

upward leader, upward connecting leader, upward discharge, lightning attachment

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