

## Observations of Winter Sprites in the Eastern Mediterranean: Results from the 2006-2008 ILAN Campaigns

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The ground-based ILAN (Imaging of Lightning And Nocturnal flashes) campaigns concentrated on optical and electromagnetic measurements of TLEs associated with winter thunderstorms in the eastern Mediterranean. We report the results of three observation campaigns conducted during the 2006-8 winter seasons. We observed thunderstorms near the eastern coast of the Mediterranean Sea from 3 different sites (Tel-Aviv, Mitzpe-Ramon and Jerusalem). In 25 out of 50 different nights during the 3 years we detected >100 events from ranges of 250 to >500 km. Sprites were found to be produced by active cells with a vertical dimension of 5-7 km and cloud top temperature  $\sim -40^\circ\text{C}$ , embedded in a much larger matrix of stratiform precipitating cloudiness. This configuration closely resembles the conditions for winter sprites reported in the Hokuriku region of Japan. Synchronized with the optical observations, ELF data (3-3000Hz) were recorded in order to qualify and quantify parameters of the parent lightning discharge associated with the transient optical emissions in the upper atmosphere. The majority ( $\sim 80\%$ ) of optically observed TLEs were accompanied by an intense ELF transient event, caused by lightning discharges with positive polarity. Calculation of the charge moment change showed values of  $1400 \pm 600 \text{ C}\cdot\text{km}$ . Within the accuracy of one video field (20 ms), it was found that the average time delay between the ELF transient of the parent +CG and its associated sprites was 76 ms ( $\pm 34$  ms), with some events delayed  $>120$  ms from the parent lightning, much longer than values reported for summer sprites in the US ( $\sim 10$  ms). The average time delay for columniform sprites was  $65 \pm 26$  ms while for carrot sprites  $80 \pm 32$  ms, similar to results in winter storms in Japan. Furthermore, based on the ELF data, there were no early identifiable precursors to TLEs occurrence in the regional lightning activity that distinguish between sprite producing and non-producing +CGs. The 3-D structure of columniform sprites was investigated with dual observations from two separate sites (Jerusalem and Tel-Aviv), and results show that the elements are arranged in a circular pattern, with radii comparable to the column lengths. A simple model of the mesospheric electric field is used to calculate the predicted diameter of the circle-of-sprites. In the winter 2007/8 campaign attempts for calibrated spectral measurements were conducted, but only few events were recorded.