Developing a reliable predictor of lightning initiation and cessation through radar analysis

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I. Project Overview

- ***Purpose:*** to develop a reliable tool for the forecasting of lightning initiation and cessation in thunderstorms through the use of Weather Surveillance Radar-1988 Doppler (WSR-88D) reflectivity data
- Several previous studies have examined lightning forecasting with radar reflectivity (Table 1), but limited by various reasons:
  - Number of locations
  - Number of cells
  - Cloud-to-ground (CG) flashes only
  - Lightning initiation only

Table 1. Results from previous studies of lightning forecasting with radar reflectivity.

Study	Num. of Cells	Location	Criteria		POD	FAR	CSI	Lead Time
			Reflectivity	Isotherm				
Buechler and Goodman (1990)	20	FL, AL, NM	40 dBZ	-10	1.00	0.20	0.80	4-33 minutes
Michimoto (1991)		Japan	30 dBZ	-20				5 minutes
Hondl and Eilts (1994)	23	FL	10 dBZ	-10	1.00	0.18	0.82	15 minutes
Gremillion and Orville (1999)	39	FL	40 dBZ*	-10	0.84	0.07	0.79	7.5 minutes
			25 dBZ	-15	0.84	0.24	0.67	14.8 minutes
Vincent et al (2003)	50	NC	35 dBZ	-10	1.00	0.41	0.59	17.5 minutes
			40 dBZ	-15	0.86	0.31	0.63	11.0 minutes
Wolf (2006)	1,100	FL, GA	40 dBZ	U-10**	0.96	0.11	0.86	n/a
Clements and Orville (2008)	37	TX	30 dBZ	-10				16.14 minutes
Mosier (2009)****	65,399	TX	30 dBZ	-20			0.71	16.9 minutes***

*Met for two consecutive scans
**Updraft -10°C isotherm
***For 30 dBZ at -10°C isotherm
****Information from this table provided by Matt Mosier (2009)

- ***Goal:*** to produce the most comprehensive climatological survey (several locations, numerous cells) of storm characteristics during the initiation and cessation of total lightning: CG and intracloud (IC) flashes
  - Melbourne (Kennedy Space Center)
  - Huntsville
  - Dallas
  - Oklahoma City
  - Houston?

III. Case Study and Preliminary Results

- A case study was analyzed in order to provide a quick look into the overall structure and evolution of a single storm cell through time and space
- **Location:** Melbourne, Florida
  Date: June 25, 2007
  Time: 18:09-20:16 UTC
- Focus on cell which initiated northwest of Kennedy Space Center LDAR (Fig. 4)
- Timeline of events (Fig. 5):
  - ***Cell initiation***: 18:09Z
    - Defined by first 30 dBZ reflectivity in cell
  - No lightning (IC or CG) when:
    - 30 dBZ reaches -10, -15, and -20°C levels
    - 35 dBZ reaches -10, -15, and -20°C
    - 40 dBZ reaches -10 and -15 °C
  - ***Lightning initiation***:
    - IC: 18:38Z
      - 40 dBZ between -15 and -20 °C
    - CG: 18:42Z
      - 40 dBZ at -15°C
  - ***Lightning cessation***:
    - CG: 19:44Z
      - 30 dBZ at -10°C
    - IC: 19:48Z
      - 30 dBZ at -10°C (or slightly below)
  - ***Cell cessation***: 20:16Z
    - Defined by last 30 dBZ reflectivity in cell

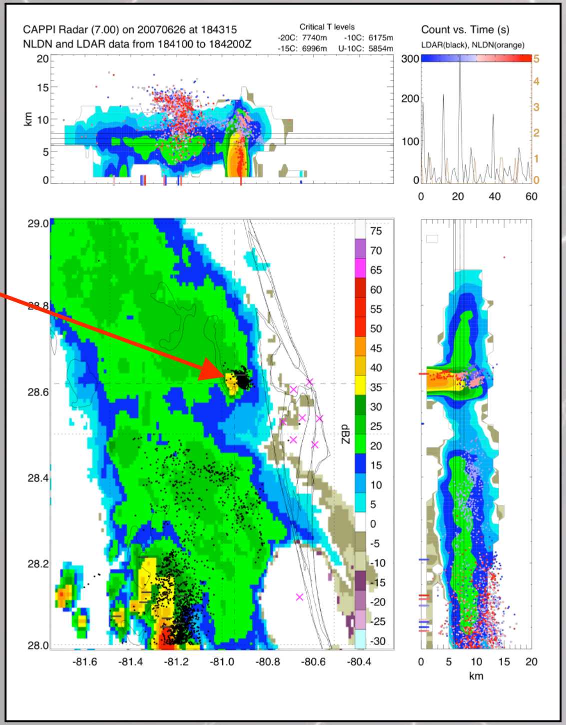

Fig. 4: A CAPPI radar scan at 7 km constant elevation at 18:43:15Z (CG initiation). NLDN and LDAR data are from 1841 to 1842Z. In all plots, radar data is shaded, NLDN (CG) data are plotted in +'s or -'s according to lightning polarity, and LDAR data are plotted with small dots. Top left panel plots the vertical cross-section of the data at 28.63°N, bottom right panel plots the vertical cross-section of the data at 80.9°W. On both cross-section plots, NLDN and LDAR data are color-coded according to time (blue is old, red is new), critical temperature levels are plotted with solid lines, and the 7 km level is plotted with a dashed line. Top right panel plots count vs. time (seconds) of LDAR data (black) and NLDN data (orange).

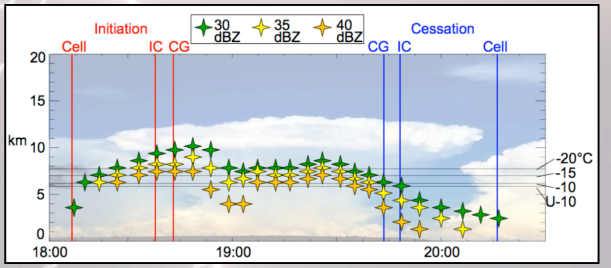

Fig. 5: Timeline of events as described in text to the left. Initiation events denoted in red, cessation events denoted in blue. Time is in UTC on abscissa, height is in km on ordinate.

- **Applying the CAPPI-SCIT algorithm**
  - In order to automate the tedious process of tracking each cell's radar reflectivity signature at IC and CG lightning initiation and cessation, the CAPPI-SCIT algorithm was run on this case. Figure 6 is a sample plot resulting from the algorithm run on this case

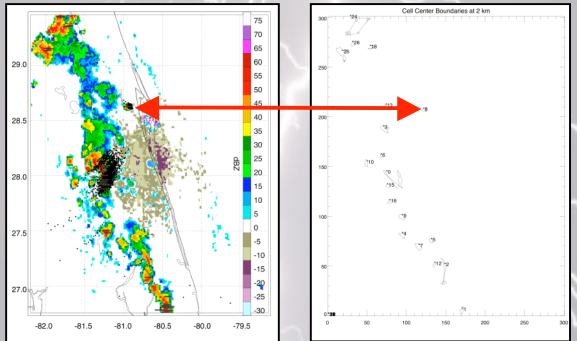

Fig. 6: Image on left is CAPPI radar scan at 2 km height with LDAR (-'s and +'s) and NLDN (dots) data from 18:43 to 18:44Z overlaid. Image on right is a CAPPI-SCIT plot of cell center boundaries at 2 km with cell numbers. Note that the position of cell number 8, the cell in question, matches well with the position of the cell on the left (red arrow).

II. Data and Methods

- **Lightning**:
  - National Lightning Detection Network (NLDN) (Fig. 1)
    - CG lightning only using VLF detection

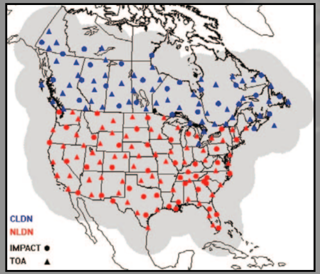

Fig. 1: The red symbols represent the NLDN, composed of 106 sensors. The blue symbols represent the Canadian Lightning Network (CLDN), composed of 81 sensors. (Orville, 2008)

- Lightning Detection and Ranging (LDAR) (Fig. 2) or Lightning Mapping Array (LMA)
  - Total lightning (CG + IC) in 3D using VHF detection

Fig. 2: An example of an LDAR sensor located in Houston. Photo taken by Orville, 2009.

- **Soundings**
  - Radiosonde data for temperature levels (-10, -15, -20°C; -10°C updraft)
  - Averaging performed if no upper air station at site
    - e.g. Melbourne (MLB) weighted from Tampa (TBW) most heavily, then Jacksonville (JAX), then Miami (MFL)

Fig. 3: Upper air stations near Melbourne (MLB) include JAX, TBW, and MFL.

- **Radar**
  - Level II radar data from WSR-88D sites
  - Converted to Cartesian and Constant Altitude Plan Position Indicator (CAPPI) format
- **CAPPI-SCIT algorithm**
  - Modified version of Storm Cell Identification and Tracking (SCIT) developed by Mosier, 2009
  - Allows for automation and maximizes number of cells that can be tracked
  - Calculates vertically integrated liquid (VIL) and volumetrically integrated ice (VII) for each cell

IV. Next Steps/Future Work

- Correlate total lightning (NLDN and LDAR data) with cells identified by CAPPI-SCIT algorithm
- Identify characteristics of each cell at time of lightning initiation and cessation, i.e. 30, 35, 40 dBZ at -10,-15,-20, -10°C updraft, levels; VIL; VII
- **Utilize *dual-polarization radar* data to more accurately determine ice and liquid composition in storms

V. Acknowledgments

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