Storm duration analysis using TITAN

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Introduction

The Queensland Cloud Seeding Research Program was conducted to assess the viability of using hygroscopic seeding to enhance precipitation. The Queensland project and other past hygroscopic seeding experiments have observed longer durations in seeded clouds. The objective of this study is to identify what factors are most strongly related to storm duration as a first step toward understanding how, aside from these factors, hygroscopic seeding may prolong storm duration.

Data and Methods

The data used in this study were collected from the Mt Stapylton radar near Brisbane, Australia over two austral summer seasons (November through February of 2007-2008 and 2008-2009) during the Queensland CSRP.

The data were analyzed using the Thunderstorm Initiation, Tracking, Analysis, and Nowcasting (TITAN) algorithm which identified and tracked storms based on four user-defined thresholds:
- Minimum Reflectivity: 35 dBZ
- Minimum Duration: 3 radar volume scans (18 minutes)
- Minimum Volume: 10 km^3
- Maximum Volume: 750 km^3

Once the cells were identified, TITAN computed storm-specific properties such as duration, maximum and mean reflectivity, volume and echo top height. These properties were then statistically correlated with duration.

Initial Statistics and Correlations

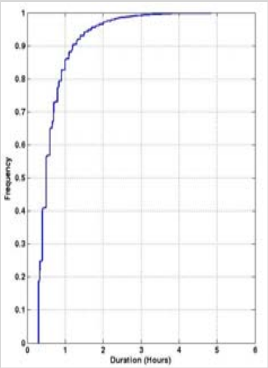

Figure 1: Cumulative frequency distribution of storm duration

Table 1: Population Statistics

Population Statistics	
Mean Duration (Hours)	0.70
Max Duration (Hours)	12.50
Number of Tracks	18704
Tracks > 4 hours	69

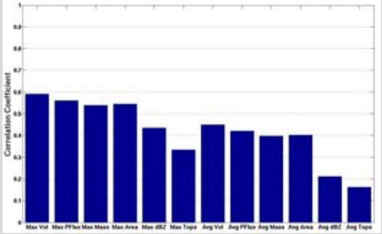

Figure 2: Bar plot of TITAN storm properties correlated with duration

- Roughly 84% of storms lasted 1 hour or less (Fig. 1)
- Nearly 100% of storms lasted less than 4 hours
- Maximum volume was the most correlated TITAN storm property with a correlation of 0.59 (Fig. 2)

Case Studies

- Analyzed 39 randomized seeding cases from the QCSRP
- Looked at the effects of storm mergers, boundary interactions, environmental conditions, and terrain
- Categorized each case by its storm evolution type based on the number of pulses and the type of TITAN track

Pulse – defined as relative peak in maximum reflectivity height
Simple TITAN track – single cell, without mergers or splits
Complex TITAN track – made up of multiple simple tracks that merged together or split during the lifetime of the TITAN track

Three storm evolution types:
Single Pulse Storm – simple TITAN track with one precipitation cycle
Multi-Pulse Storm – simple TITAN track (did not merge with other cells) that had one or more pulses in maximum reflectivity height
Complex Storm - complex TITAN track that had one or more cell mergers

Table 2: Statistics of duration and volume for each storm evolution type

Storm Evolution Type	Number of Cases	Mean Duration (hours)	Standard Deviation	Maximum Duration (hours)	Mean Volume (km^3)	Maximum Volume (km^3)
Single Pulse	10	0.36	0.07	0.50	56.78	154.41
Multi-Pulse	10	0.78	0.36	1.50	87.29	405.84
Complex	19	1.87	1.01	4.40	264.69	666.14

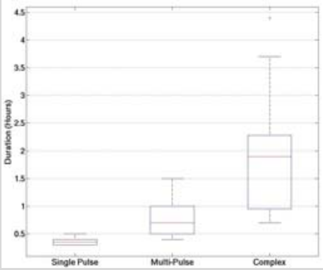

Figure 3: Box and Whisker plot of duration for each storm evolution type

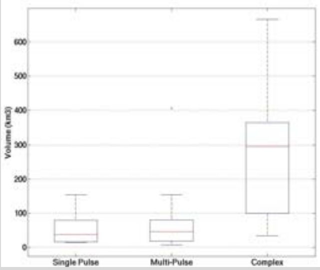

Figure 4: Box and Whisker plot of maximum storm volume for each storm evolution type

- There are distinct differences in storm duration between the different storm evolution types (Fig. 3)
- The complex cases had larger volumes than the other two types because the single cells merge into large, complex systems (Fig. 4)

Single Pulse Case – Cell 529 on 23 January 2009

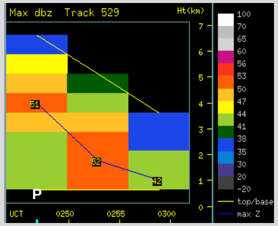

Figure 5: Time height plot of for Cell 529 during its TITAN track lifetime

- The storm is already mature and dissipating by the time it is identified as a cell by TITAN (Fig. 5)
  - o Echo top height and maximum reflectivity height decrease throughout the TITAN track lifetime
- Maximum reflectivity is below 50 dBZ when maximum reflectivity height is at the lowest levels of the storm
  - o This is termed the **"rainout"** period

Multi-Pulse Case – Cell 307 on 07 December 2008

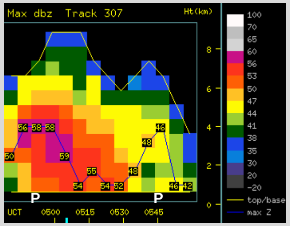

Figure 6: Time height plot of Cell 307 during its TITAN track lifetime

- Two pulses in echo top height and maximum reflectivity height that occur at the same time (Fig. 6)
- Reflectivity values during the first rainout period are above 50 dBZ
  - o This may lead to stronger outflow and a subsequent pulse

Complex Case – Cell 691 on 27 January 2009

- There are three pulses in maximum reflectivity height while echo top height does not change much (Fig. 7)
- The second pulse occurs in association with a cell merger
- Again, maximum reflectivity during the first two rainouts was above 50 dBZ

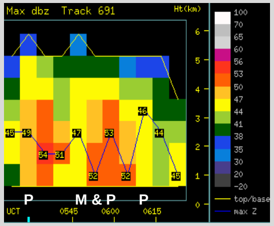

Figure 7: Time height plot of for Cell 529 during its TITAN track lifetime

Conclusions

Maximum storm volume was highly correlated with duration
- This relationship is evident in the complex cases, which had the largest volumes and longest durations of the seeding cases

Storm evolution type was related to duration
- Of the randomized seeding cases, the longest lasting storms had one or more cell mergers
  - o Also, pulses in maximum reflectivity height tended to occur in association with a merger in a complex track
- Multi-pulse storms lasted longer than the single pulse storms
  - o Additional pulses typically occurred after higher reflectivity rainouts
  - o Reflectivity value of the final rainout was usually below 50 dB

Future Work

- Further analysis of the effects of environmental conditions and terrain
- Analysis of updraft and downdraft structure with dual Doppler radar data
- Analysis of droplet size and concentrations with polarimetric radar data

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