Characterization of Convective Precipitation Events Leading to Severe Weather Impacts in Vulnerable Regions of Northern South America

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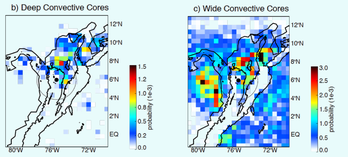
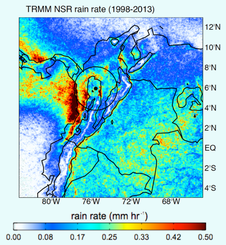
Introduction

The tropical region of South America is unique in weather related importance since it is a place where the ITCZ intersects elevated topography (up to 5,000 m).



Probability of TRMM-PR finding a extreme event for JJA (1998-2013)



The region location favors the occurrence of a maximum in precipitation [1], and to have a large concentration of MCSs [2, 3] producing convective storms exhibiting a different variety of forms [3], which depending on the energetics produce several weather related emergencies.

Objectives and Methodology

- Compile a database of weather related emergencies associated to intense hail, strong wind gusts and flooding to produce an event list to be used for case analysis.
- Use those cases to document the similarities/differences of the horizontal and vertical storm structure using QPE, reflectivity, radial velocity, and polarimetric variables from a C-BAND weather radar.
- Using ERA5 reanalysis data to explore the atmospheric conditions associated to the time of occurrence of those extreme events.

Emergencies related to Severe Weather

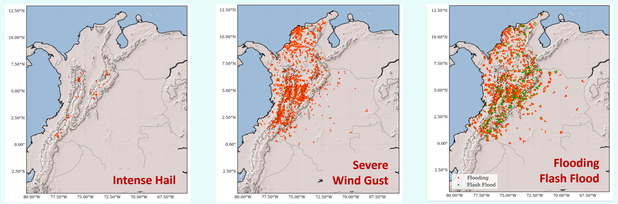
Emergencies were extracted from the National Unit for Risk Management of Disasters (UNGRD) database

- Data obtained for entire Colombian territory and a subset for the Antioquia (ANT) province (area of influence of the C-Band radar).
- Data spans from 2013 to 2018, similar period as the radar database.

Type of emergency	Colombian territory	Antioquia province
Intense Hail	108	39 (19)
Severe wind gust	2703	179 (50)
Flooding	3030	268 (36)

(*) Number of events with report of exact time

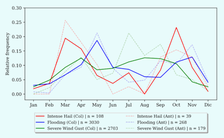
Spatial distribution of weather related emergencies over Colombia



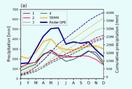
Annual and diurnal frequency distribution

Annual cycle of emergencies have a bi-modal distribution similar to annual cycle of precipitation.

- Hail related emergencies show maxima in March and October, while Flooding peaks in May and November.
- Severe wind gust emergencies have broad peaks in between.



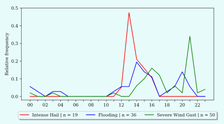
Annual frequency of emergencies for Colombia (solid) and Antioquia region (dotted)



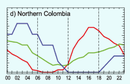
Mean annual cycle of precipitation near Salgar ANT from rain gauges and TRMM 3B42. Taken from [4]

Diurnal distribution skewed towards the afternoon and evening.

- Hail events have a maxima in the early afternoon.
- Flooding peaks in the afternoon and evening.
- Severe wind gusts later than flooding events
- Relationship with type of convective cloud.
- Limited information due a lack of consistent hourly reports.

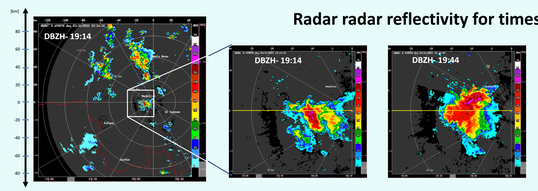


Diurnal frequency of emergencies for the Antioquia region



Diurnal cycle of the frequency of occurrence of Deep cores (red), Wide Cores (green), and Broad Stratiform. Taken from [3]

Intense Hail Event - 2015-03-31

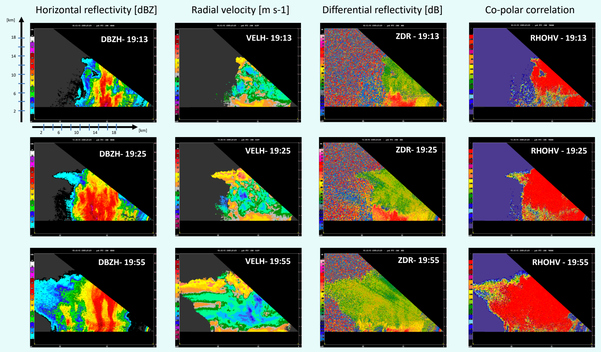


Radar radar reflectivity for times close to the reported emergency

Very localized, relatively small convective storm west of radar site.

- Reflectivity values up to 65 dBZ in concentrated region.
- Similar coverage extension for other hail related emergencies.

Vertical structure



Vertical cross sections across the east–west direction (270°) of the reflectivity field.

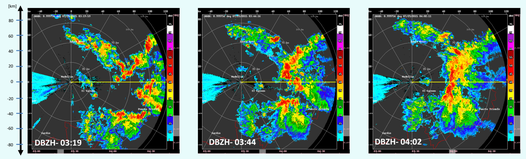
- Tall, convective storm reaching 10 km height with a small horizontal footprint.
- Packets of up to 65 dBZ, with ZDR ~ 0.8 dB and RhoHV < 1,0, indicating presence of hail.
- Strong mid-level winds favoring entrainment of dry air.

Severe Wind Gust Event - 2015-07-29

Radar radar reflectivity for times close to the reported emergency

Widespread convective region that aggregated from several intense cells.

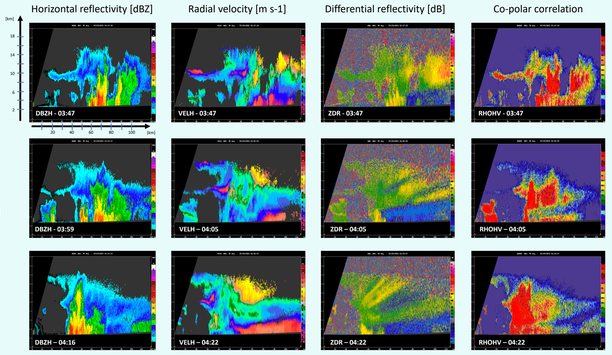
- Several emergencies were reported for the event.
- Similar convective extension was observed for other wind related emergencies.



Vertical structure

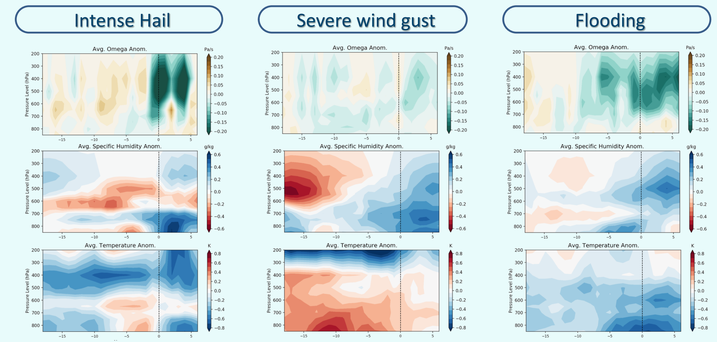
Vertical cross sections across the west–east direction (90°) of the reflectivity field.

- Moderately elevated convective with intense packets in a widespread area.
- Strong mid-level wind in a broad area favoring entrainment of dry air (Rear Inflow Jet from a MCS).
- Mostly liquid rain reaching the surface.



Mean atmospheric conditions

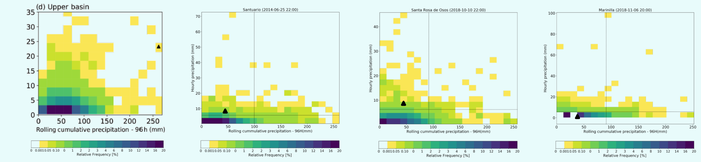
Composite time-height sections of anomaly fields computed from the time close to the occurrence of 19 intense hail events, 50 severe wind gust and 36 flooding related emergencies



- Increased vertical velocity close to the time of the event. Stronger and deeper for hail cases.
- Mid-level layer of below average specific humidity. Possible associated to capping inversion.
- Anomalous warming of the atmosphere for time close to the intense hail event.
- Atmospheric conditions leading to flooding events different, possible related to mixture of conditions.

Cumulative precipitation frequency in case of flooding

Bivariate histogram of the 96h and 1h historical (2014-2019) QPE cumulative precipitation in the area where an specific flooding emergency was reported. The triangle represent the event near the emergency



Salgar, 05/18/2015
Taken from [4]

Santuario, 06/25/2014

S. Rosa de Osos, 10/10/2018

Marinilla, 11/06/2018

- Combined role of most recent and precedent rainfall in modulating the overall conditions of the basin to produce the emergency outcome.
- For most of cases, event around the 75th percentile for 1h, but below 75th of the 96h.
- No single precipitation event was exceptionally large enough to generate the emergency.

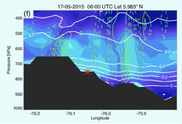
Conclusions

This study compiles a database of weather related emergencies to investigate similarities and differences of the spatial structure of the associated storm.

- Intense hail emergencies have an associated storm structure of deep convection, with very intense characteristic that occurs in localized areas. They maximize early in the wet season and present a peak early in the day. Likely associated to the energetics of the convective cloud.
- Severe wind gust related emergencies are linked to widespread convective storms of the mesoscale convective type that develop intense mid-level flows that favor the generation of intense wind.
- Flooding have a variety of storm structures, maximize later on the wet season and later on the day. Indication of combined role of actual and precedent rainfall events to produce the calamities.

Future work

Conduct WRF modelling experiments to investigate the representation of the observed storm structure and associated environmental conditions during weather related emergencies as the ones studied here



WRF model simulations for the Salgar emergency showing a orographic ascent of moist air, forced by the topographic barrier. Taken from [4]

References

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- [4] Hoyos, C.D. and co-authors. Meteorological conditions leading to the 2015 Salgar flash flood: lessons for vulnerable regions in tropical complex terrain. *Nat. Hazards Earth Syst. Sci.*, **19**, 2635–2665, 2019
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Acknowledgements

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