RADAR AND LIGHTNING CHARACTERISTICS OF MESOSCALE CONVECTIVE SYSTEMS IN SOUTHERN BRAZIL

Cesar Beneti, Augusto J. Pereira, Leonardo Calvetti, Eloa Damian

SIMEPAR - Curitiba - Brazil

In South America, southern parts of Brazil, Paraguay and northeastern Argentina are regions particularly prone to severe weather events (high lightning activity, intense precipitation, hail, flash floods and occasional tornadoes). Most of the precipitation is associated with extra-tropical cyclones, frontal systems and Mesoscale Convective Systems (MCS). However, MCS are specially responsible for a significant amount of the precipitation and severe weather which occur in this area, mainly during spring and summer, but there is a limited knowledge in relation to the characteristics of those storms such as frequency, type, morphology, intensity and location of cloud-to-ground lightning.

In the south of Brazil, agricultural industry and electrical power generation are the main economic activities. This region is responsible for 35% of all hydro-power energy production in the country, with long transmission lines to the main consumer regions, which are severely affected by these extreme weather conditions associated to the MCS events.

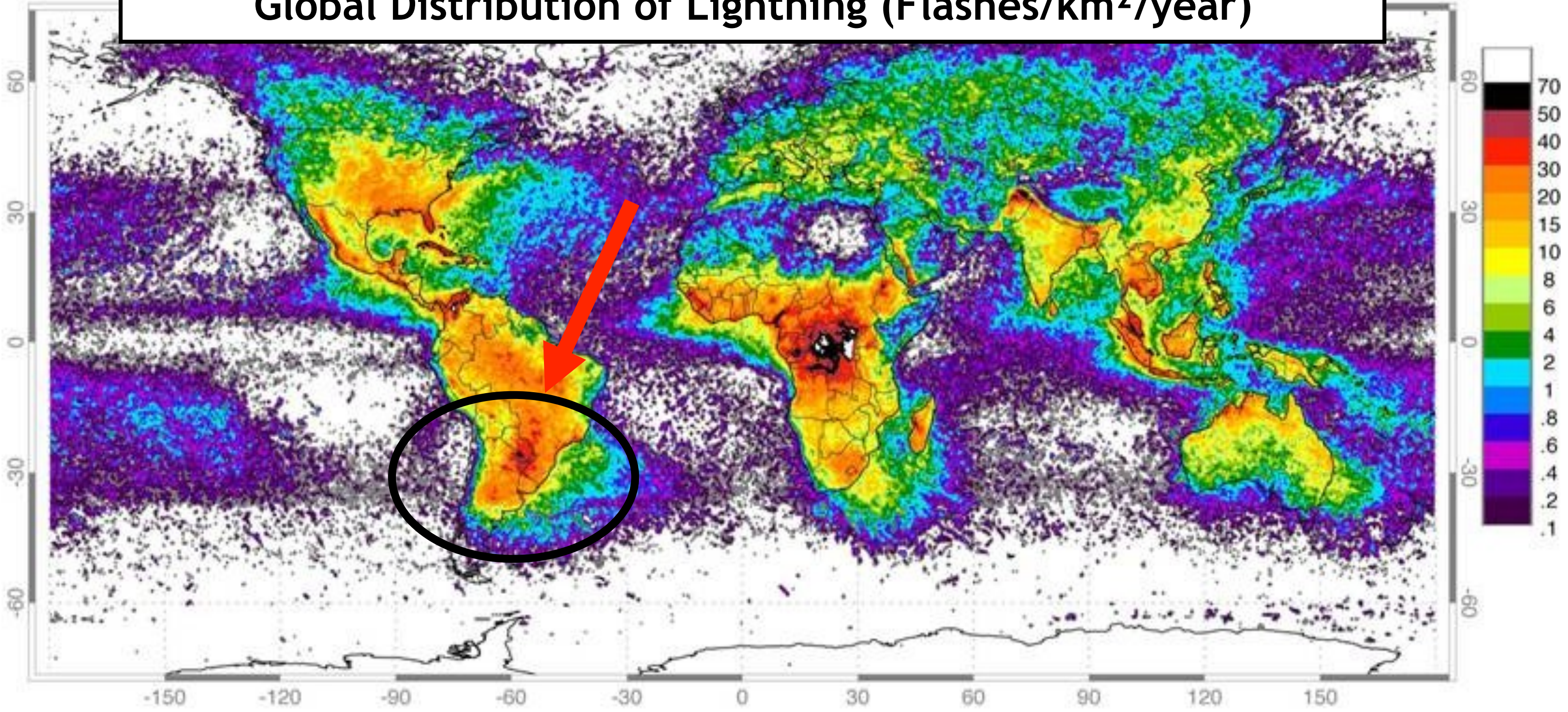
The MCS play an important role on the hydrological cycle and on the incidence of severe weather events, highlighting the importance of improving the knowledge of those weather systems, with the goal of better forecasts.

Mesoscale Convective Systems Seazonal Variation

In South America, MCS occur throughout the year, but they are most frequent during the warm season (spring and summer). Lightning activity is intense in the continent, with maximum in the subtropical region, between Paraguay, northern Argentina and south of Brazil.

Precipitation is well distributed during the year, but Low Level Jets, east of Andes, bring more moisture and convective instability to the region during spring and summer, favouring the frequency of MCS occurrence in this period of the year as observed from the lightning and precipitation seazonal variation.

Global Distribution of Lightning (Flashes/km²/year)



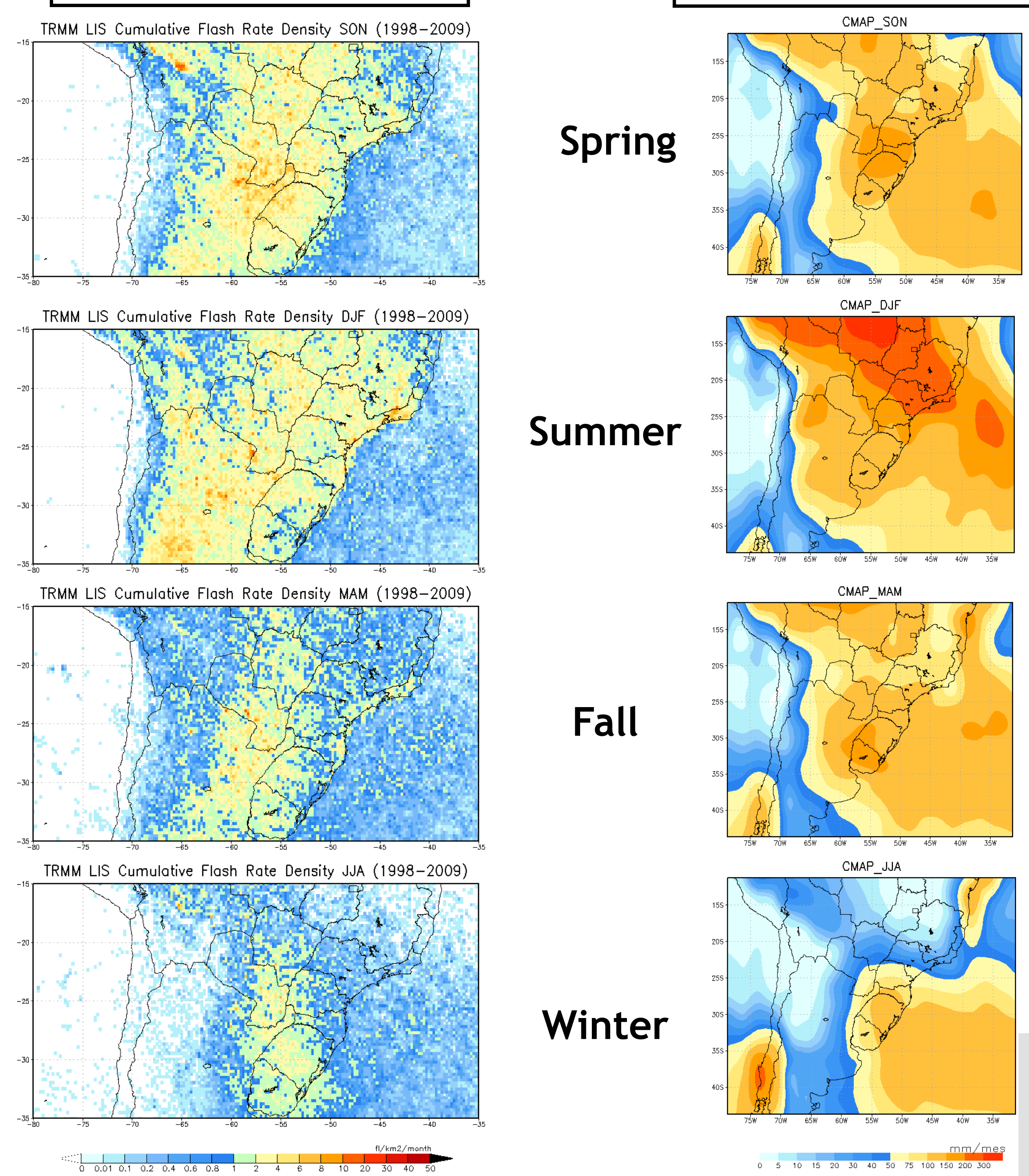
High Resolution Full Climatology Annual Flash Rate
Combined LIS/OTD 1995-2003. (Goodman & Cecil 2002)

Hydrometeorological Monitoring System

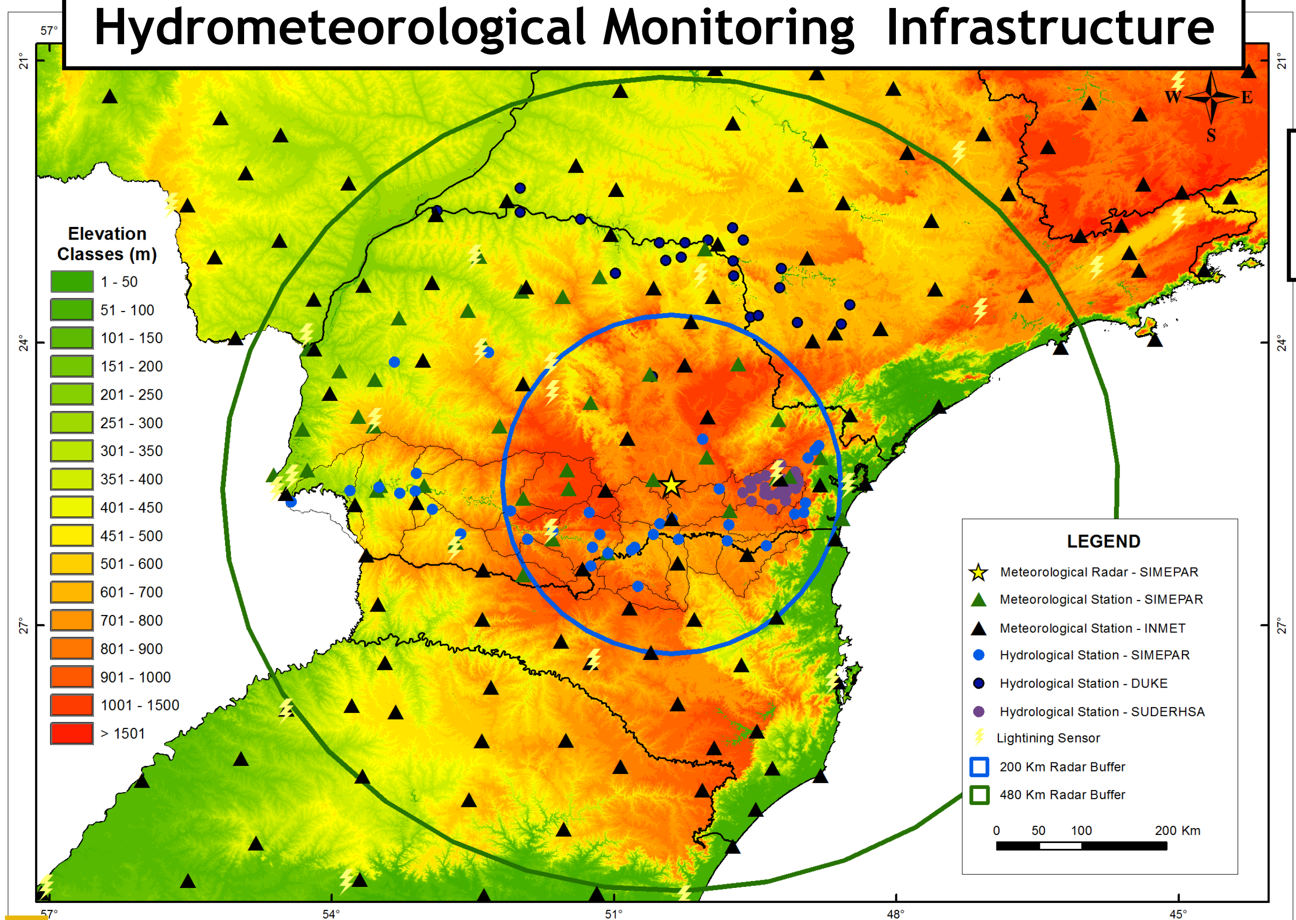
A hydrometeorological system comprising a network of automatic weather stations, S-Band Doppler weather radar, lightning sensors, satellite information in the south of Brazil was used to characterize and evaluate the weather events in the region.

Lightning Incidence Seasonal Variation

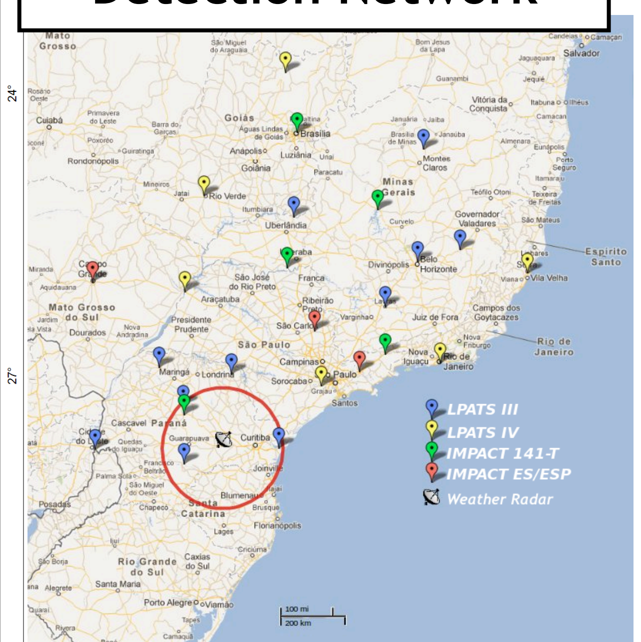
Precipitation Seazonal Variation



Hydrometeorological Monitoring Infrastructure

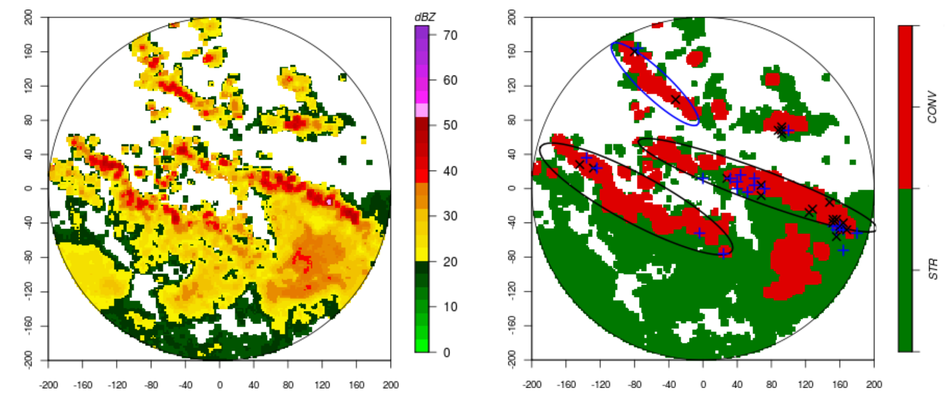


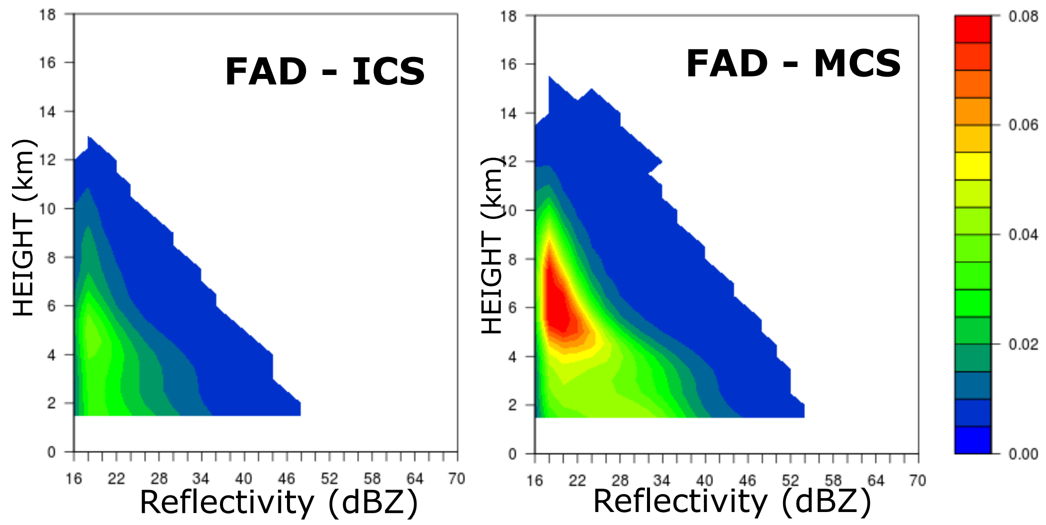
Brazilian Lightning Detection Network



Mesoscale Convective Systems – Radar Characteristics

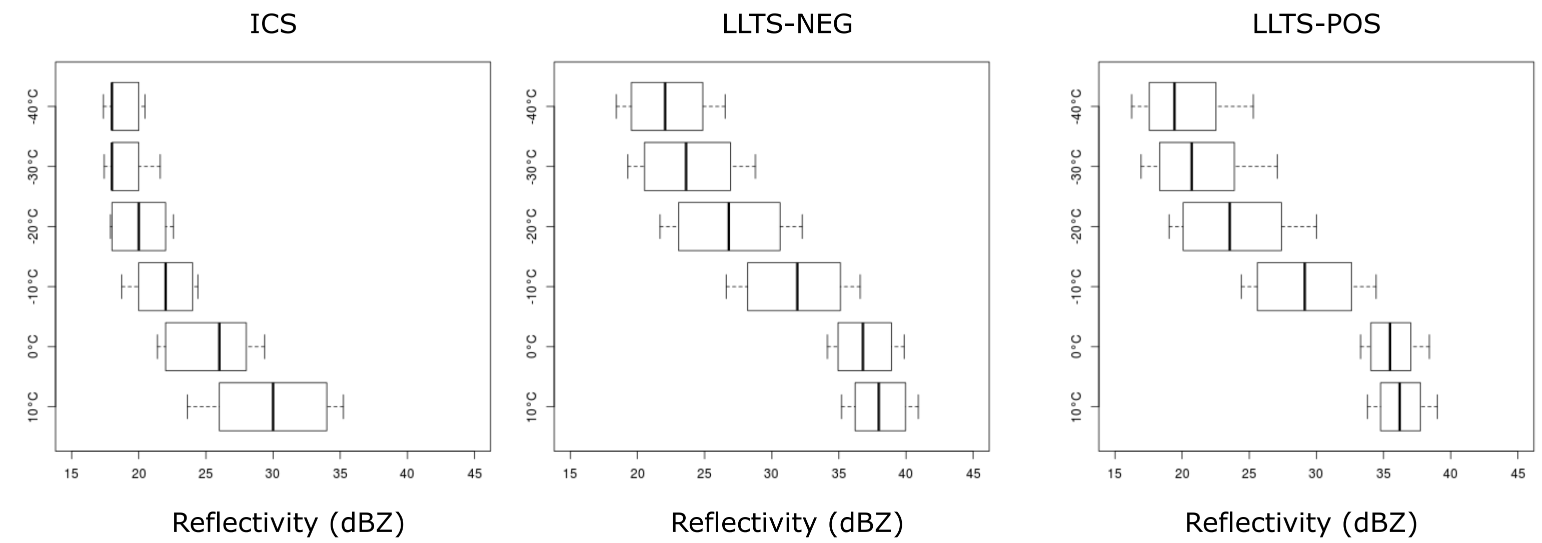
Radar volumetric data were used to identify convective and stratiform precipitation areas associated to MCS, using VIL > 1kg/m^2 and Z > 30dBZ as convective threshold and an ellipsis fitting algorithm to identify MCS larger than 100km.



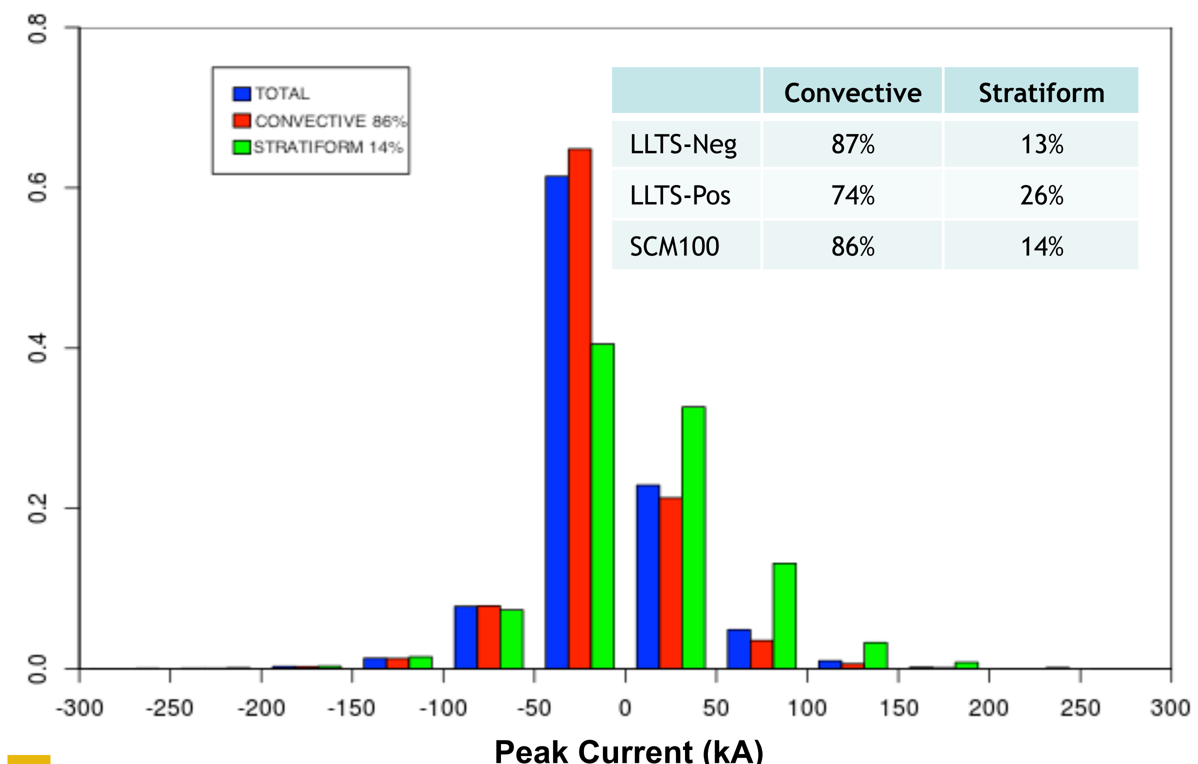


In this analysis, weather radar and lightning data from January 2000 to December 2010 was used. A total of 42% of the days were identified with convective activity, 26% with Isolated Convective Systems (ICS) and 16% with MCS (larger then 100km). Frequency with Altitude Diagrams (FADs) of reflectivity is presented with distinct differences between isolated convection and organized MCS, with higher echo tops and different vertical profiles for MCS.

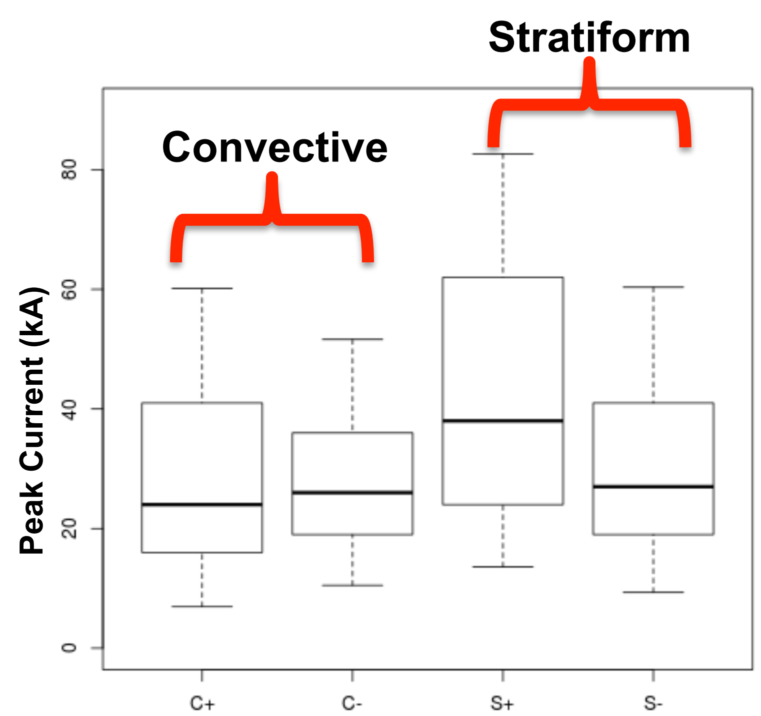
MCS with a leading convective line and trailing stratiform (MCS-LLTS) structure with horizontal extent > 200km is present in 20% of the cases studied. Vertical reflectivity profiles show a mixed phase layer (0 to -10°C) with 30-35dBZ in most cases, and lower Z values above -10°C for those MCS with larger percentage of positive lightning (LLTS-POS) indicating less ice water content in those cases.



Mesoscale Convective Systems – Lightning Characteristics



	Convective	Stratiform
LLTS-Neg	87%	13%
LLTS-Pos	74%	26%
SCM100	86%	14%



Using the algorithm for convective and stratiform separation together with lightning flash data, we were able to analyse the electrical activity in those distinct areas within the MCS. In general, the convective region is the most active (86%) in terms of lightning, even for the events with larger stratiform areas with predominance of positive lightning (LLTS-POS). However, peak current in the stratiform region is higher for both negative and positive lightning flashes when compared to the convective region.

Mesoscale Convective Systems – Precipitation Regimes

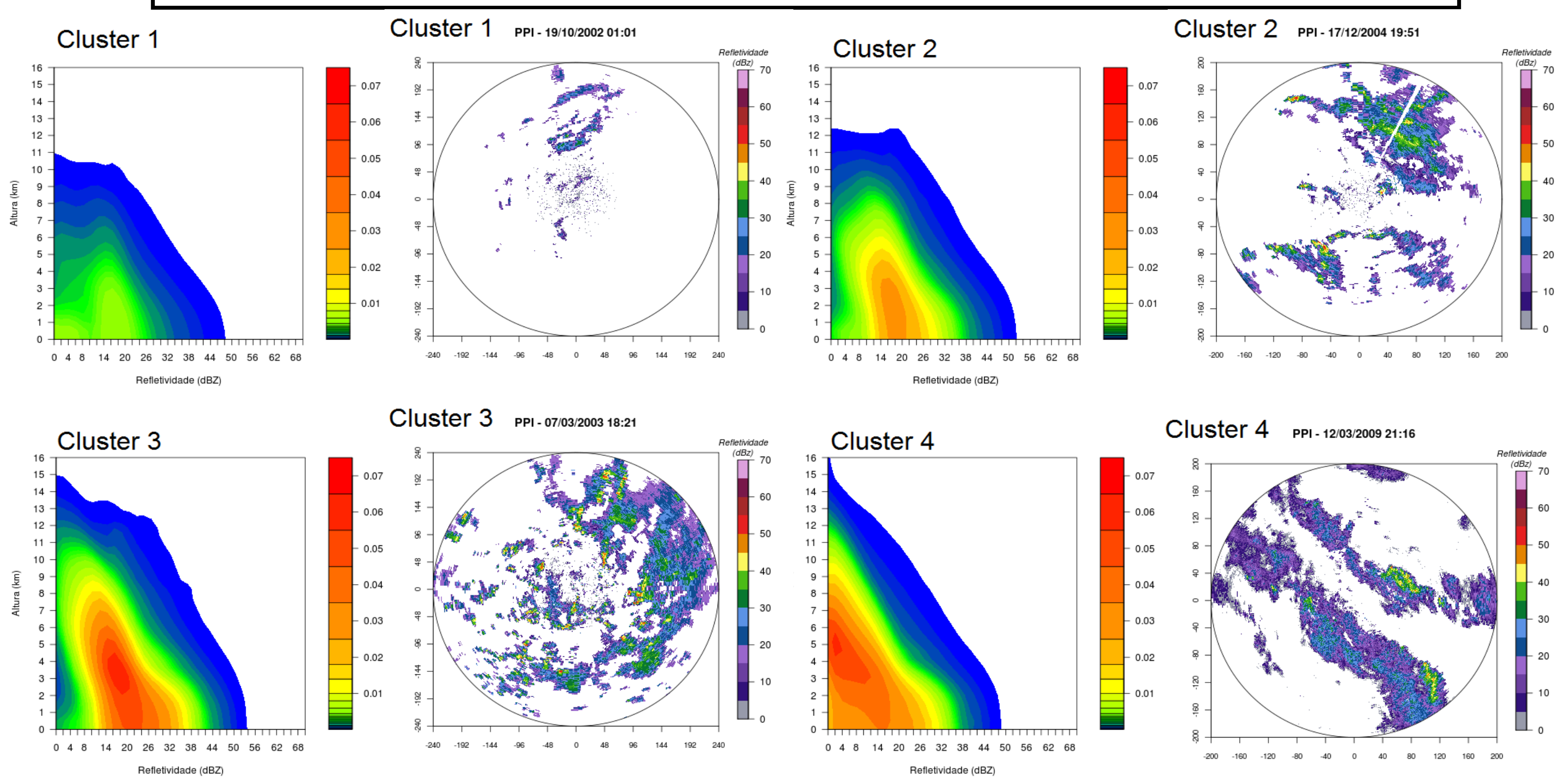
In order to objectively identify possible regime characteristics with lightning and radar data available, a cluster algorithm (KMeans) was applied to Frequency with Altitude Diagrams (FADs) obtained from histograms of the radar reflectivity volumetric data, revealing four major precipitation regimes in the region.

The regimes, or clusters, with 1% or less Total Volume Coverge (TVC) Zeroth and Cluster1, represent 77% of the total radar data and are characterized by small convective cells scattered in the area, with very little electrical activity, when compared to the other regimes.

Cluster2 represent radar echoes formed by isolated convective cells with little or almost no stratiform region. They occur throughout the year, but are more frequent during the warm season (from September to March), with a clear diurnal cycle, with a peak in activity around the early to late afternoon (16 to 22UTC).

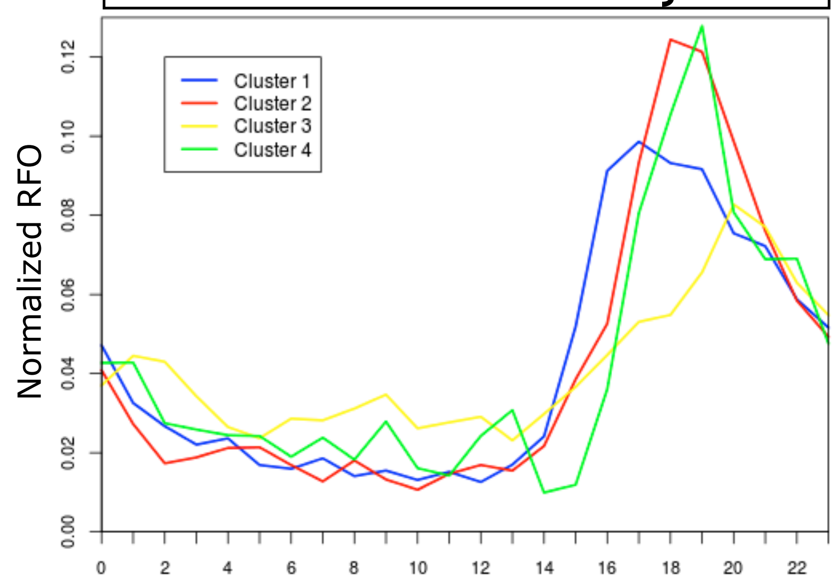
Clusters 3 and 4 represent only 8% of the total sample but generally have TVC of 17% or more, and are accompanied by strong lightning activity. These regimes have high echo top, around 15km, indication of a Bright Band around 3.5 to 5km of height (around 0°C isotherm), and organized convective cells embedded in stratiform area. They are also present throughout the entire year. However, they occur more frequently in late afternoon and early night, from 17 to 02UTC, and are more electrically active in the same period of the day.

Clustering Algorithm (KMEANS) applied to Radar Data Frequency with Altitude Diagrams (FAD)

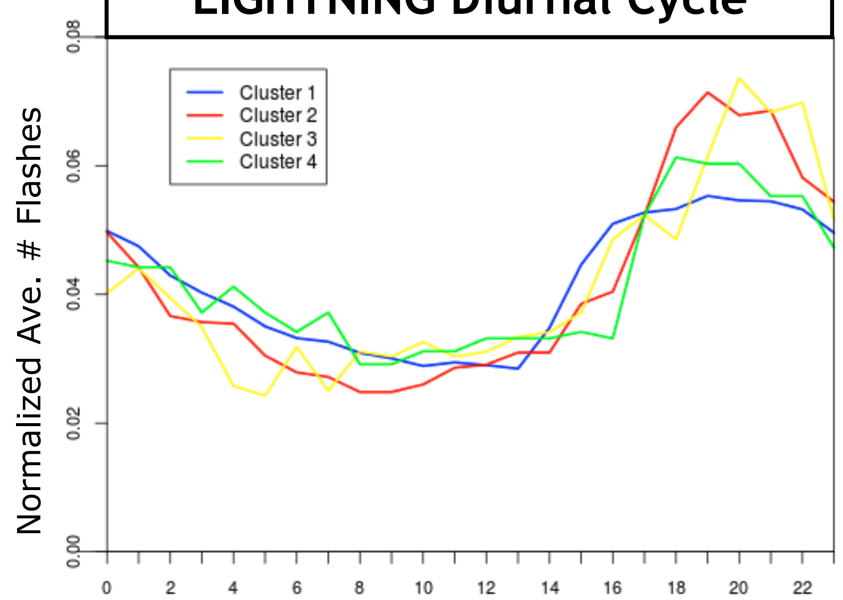


Precipitation Regime	Relative Frequency of Occurrence (RFO)	Total Volume Coverage (TVC)	Average # Negative Flashes	Average # Positive Flashes
Zeroth	27.3%	-	-	-
Cluster 1	49.8%	1%	5	3
Cluster 2	14.7%	8%	43	23
Cluster 3	4.7%	17%	145	34
Cluster 4	3.4%	17%	333	57

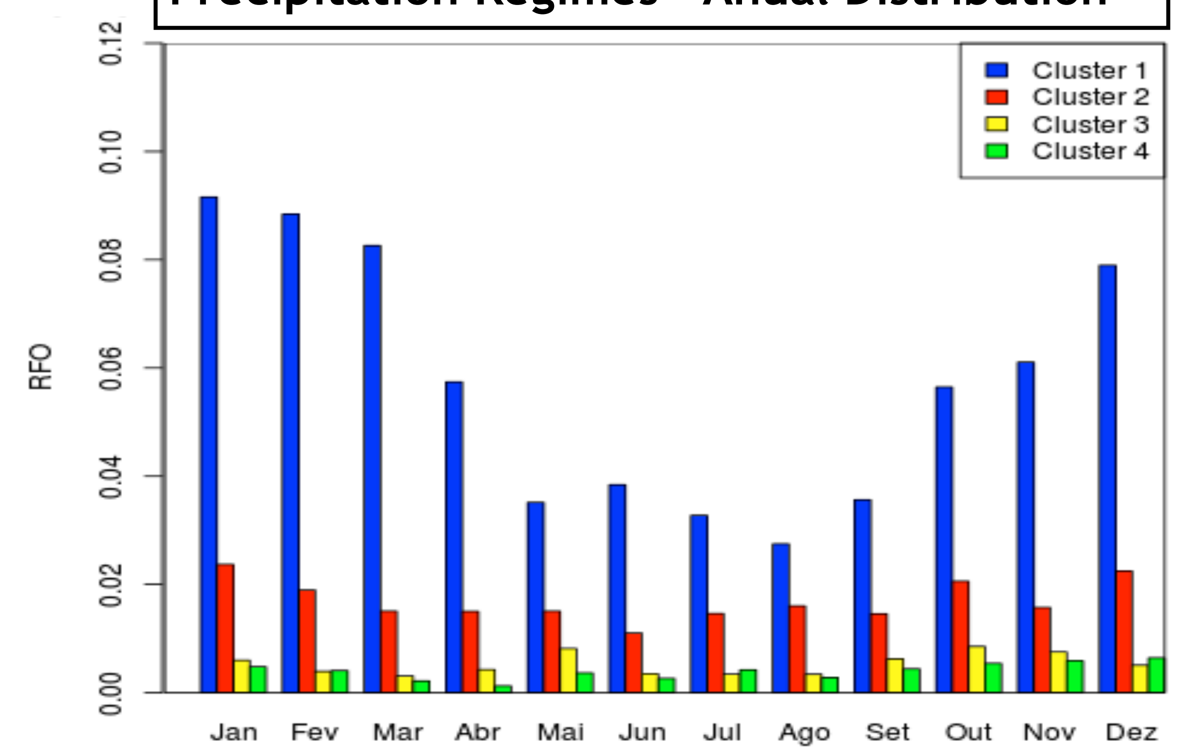
RADAR/FAD Diurnal Cycle



LIGHTNING Diurnal Cycle



Precipitation Regimes - Anual Distribution



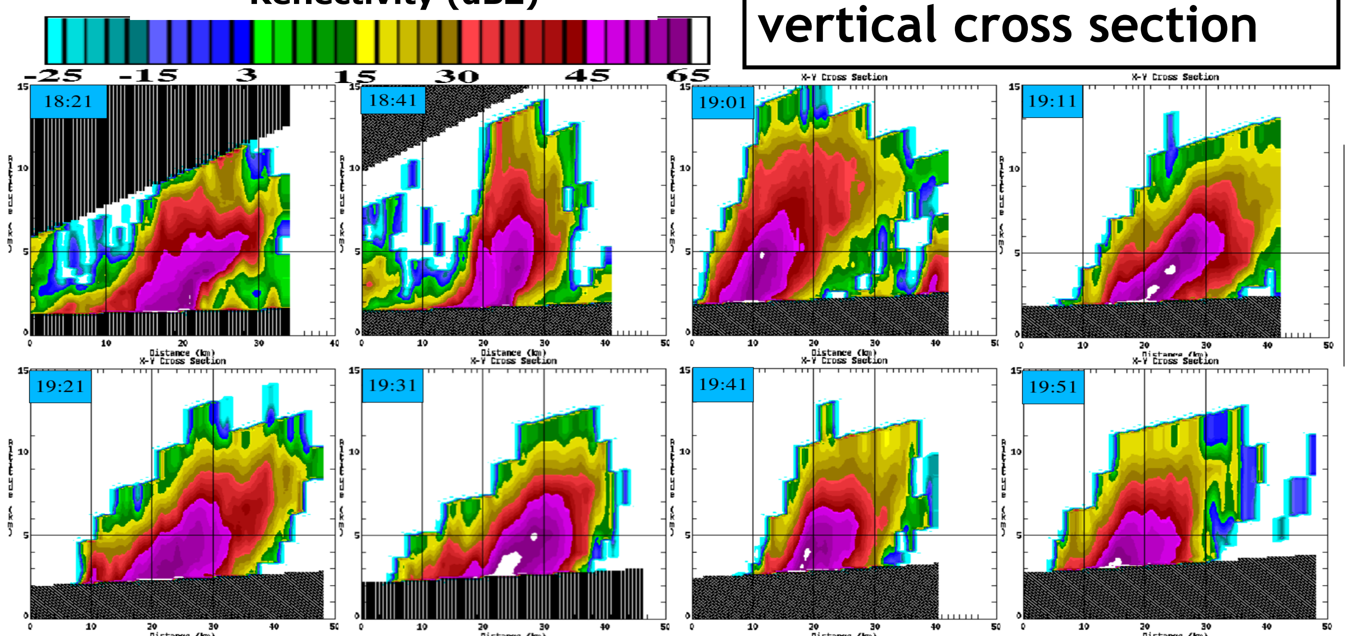
Example of MCS: Hailstorm - July 06th 2003

A pre-frontal environment in the previous day and the fast displacement of the cold front during 06 July 2003 generated conditions for severe weather occurrence in Parana State. This storm caused severe damage in the Curitiba Metropolitan Area (CMA), with accidents in highways, power cuts affecting more than 800 thousand people in the area for more than 6 hour.

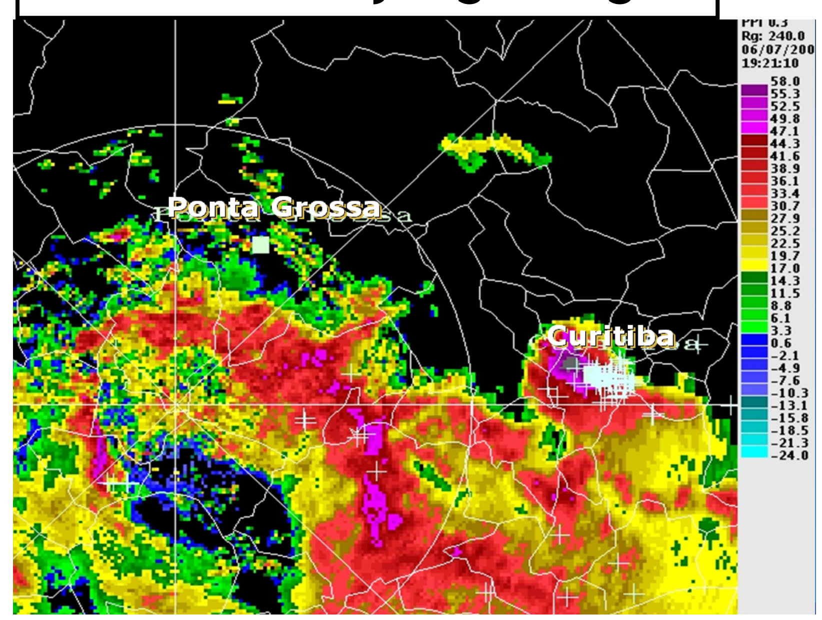
This storm reached CMA around 19 UTC and large amount of hail in less than 30 minutes fell over there. With the hail, flooding followed. Throughout the observation period, strong electrical activity occurred, with reflectivity profile with 40dBZ above -10°C , flash rate 10-20/min, VIL >80kg/m^2, indicating the severe intensity of this storm event.

Hail and flooding in the area

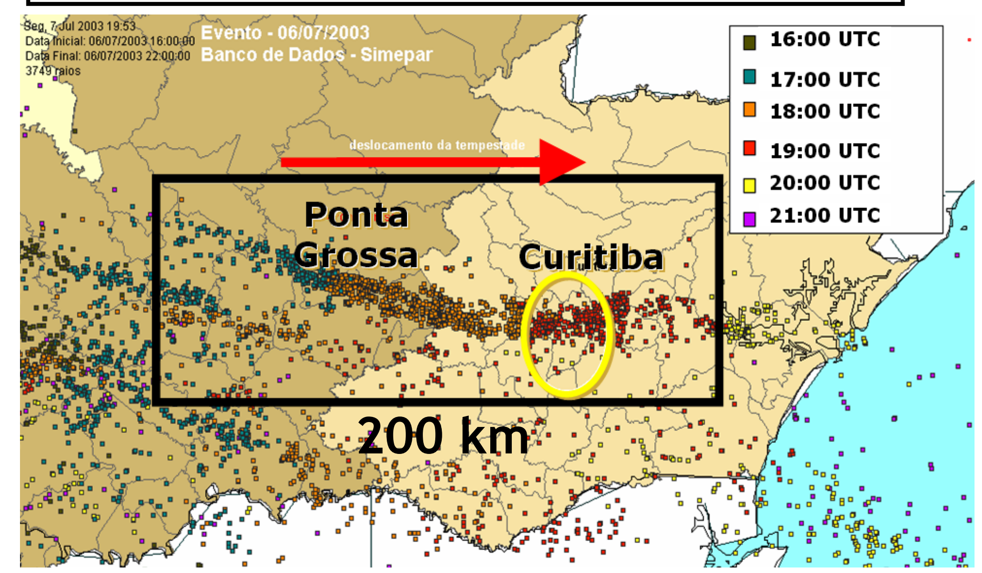
Storm reflectivity vertical cross section



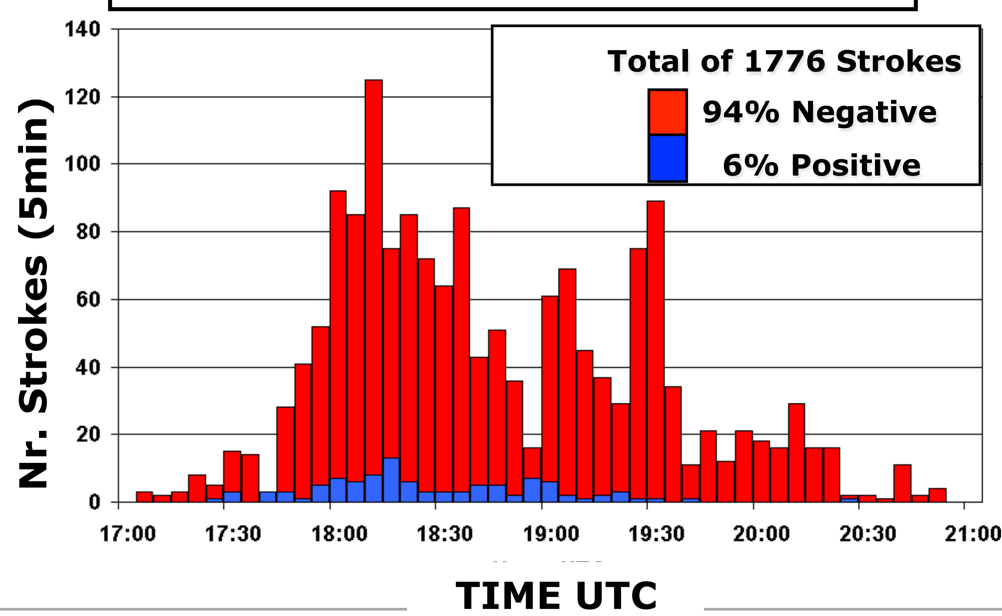
PPI-Reflectivity+lightning



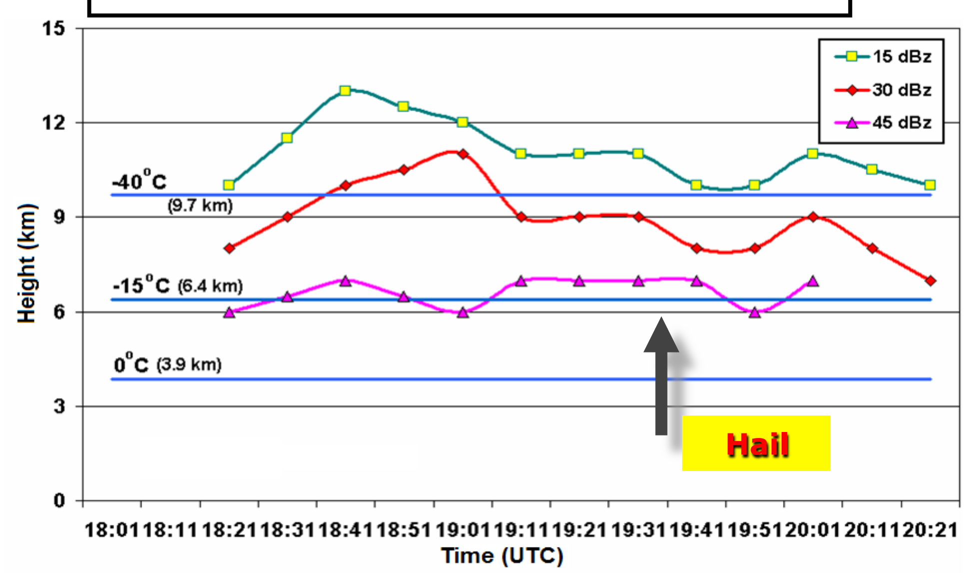
Storm path - lightning observation



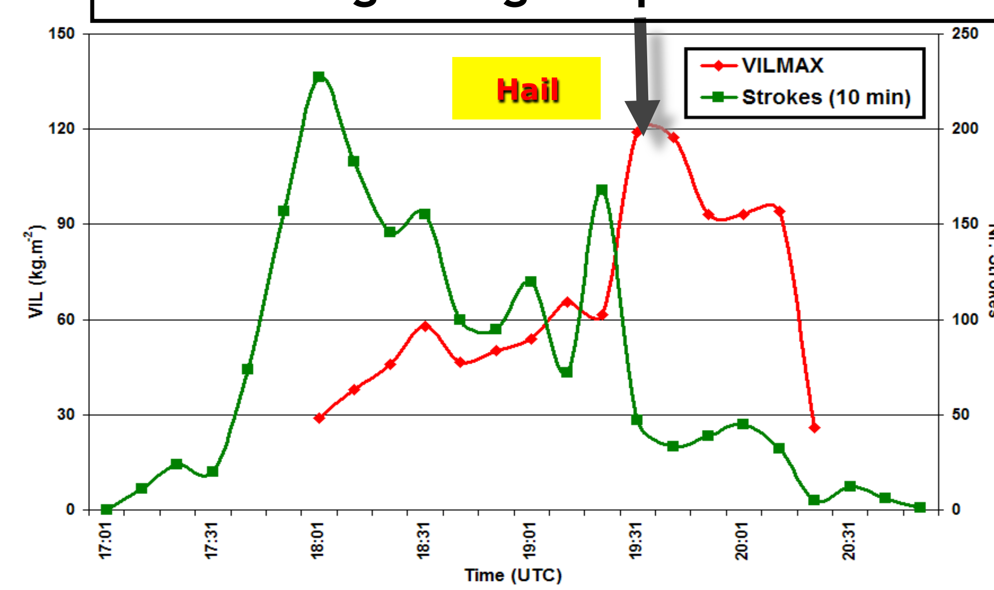
Evolution of lightning activity



Storm reflectivity evolution

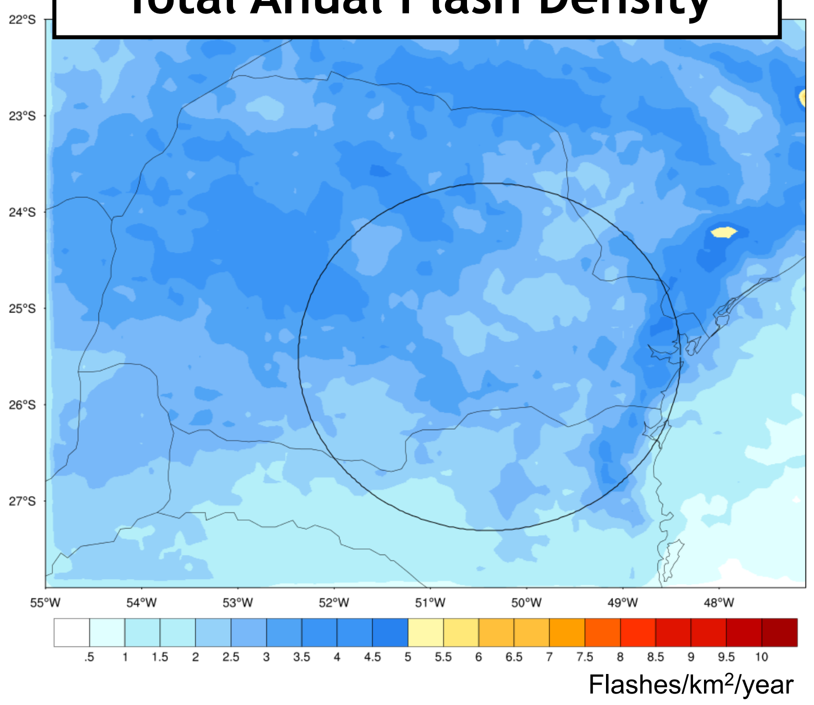


VILMAX+lightning temporal evolution

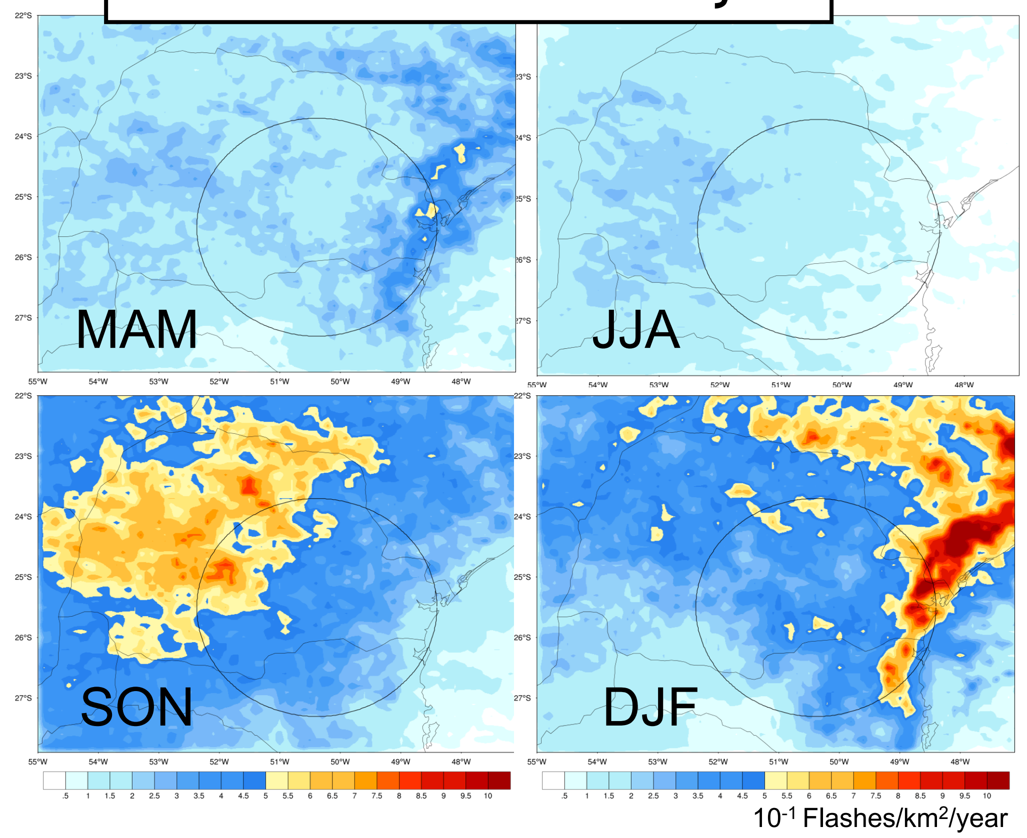


Lightning Density Distribution

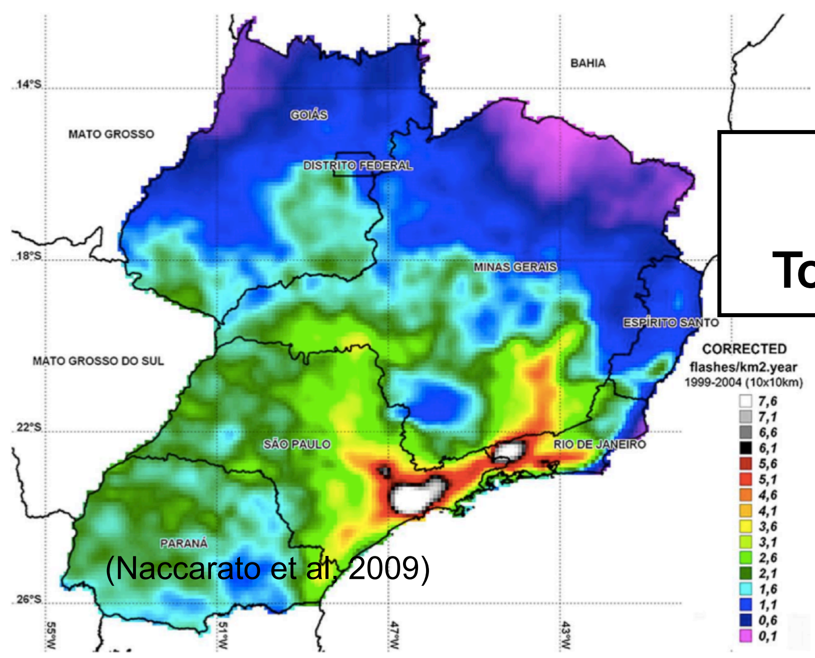
Total Anual Flash Density



Seazonal Flash Density

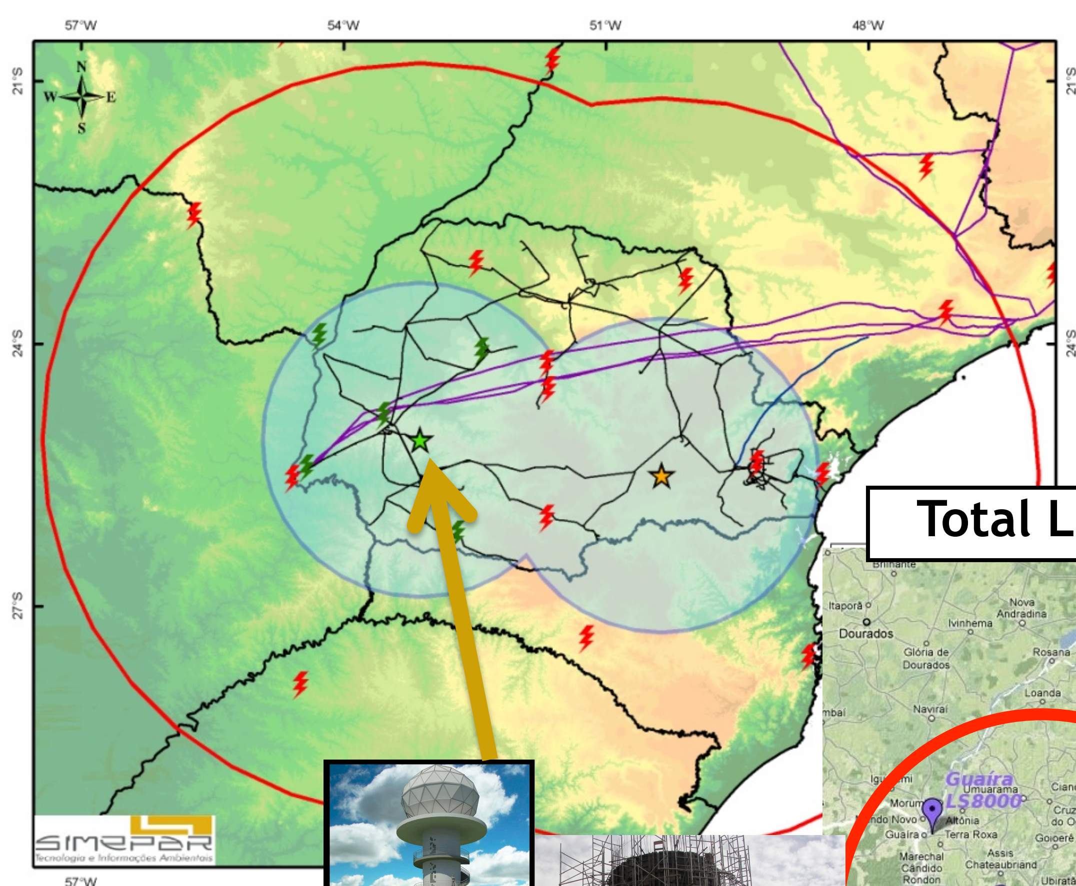


Lightning distribution within the studied area indicates concentration of activity in two main areas. In the east, around 'Serra do Mar' mountain range, with most convective isolated storms during summer, and a second active area to the west plateau, with most of the lightning activity related to the MCS and larger CCM originated in the northern Argentina and Uruguay, moving through this region later in the day. Seasonal variations, with more active spring (SON) and summer (DJF) are a result of the effect of MCS in this region, more than other weather systems (e.g. cold fronts).

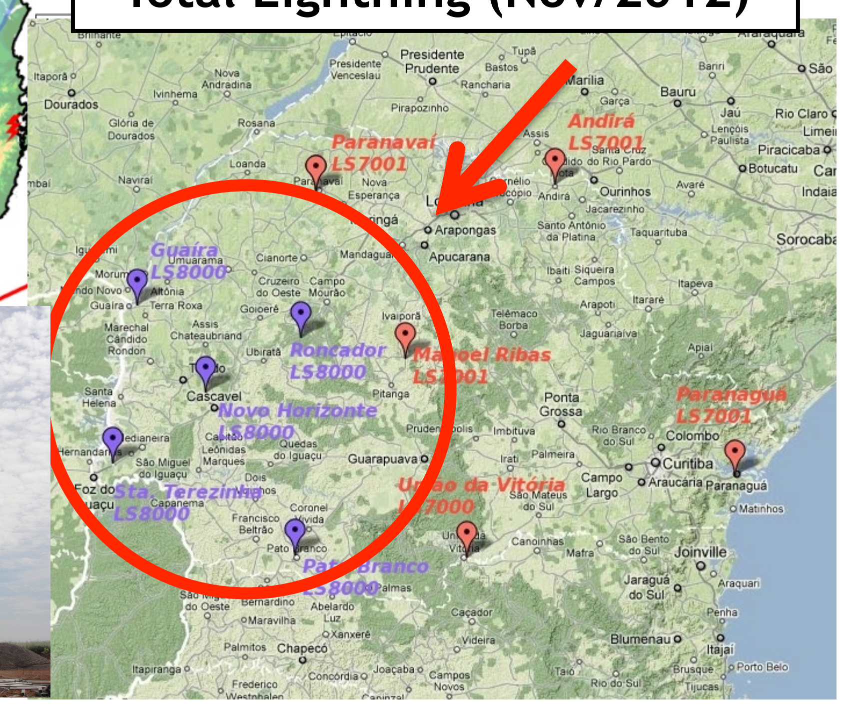


Brazilian Lightning Detection Network

Total Anual Flash Density



Total Lightning (Nov/2012)



S-Band Polarimetric Radar(Aug/2013)

Future Work

The present work show some results of radar and lightning data analysis regarding the occurrence of Mesoscale Convective Systems in the south fo Brazil. With the pursuit of further improvement in the analysis and forecasting of severe weather events in the region, new observation systems (S-band polarimetric radar and total lightning network) will be installed in the region in the near future.