RELAMPAGO – SOS-CHUVA Project

Intensive observation period in São Borja, RS

1 November 2018 – 15 December 2018

1) INTRODUCTION

RELAMPAGO (Remote sensing of Electrification, Lightning, And Mesoscale/microscale Processes with Adaptive Ground Observations, translates to lightning flash in Spanish and Portuguese) is a collaborative project funded by the US National Science Foundation (NSF), National Oceanographic and Atmospheric Administration (NOAA), National Aeronautics and Space Administration (NASA), Servicio Meteorologico Nacional (SMN), Ministry of Science and Technology of Argentina (MinCyT), Province of Cordoba, Brazil (INPE, CNPq, and FAPESP), and INVAP, to observe convective storms that produce high impact weather in the lee of the Andes mountains in Argentina. RELAMPAGO Extended Observing Period will be 1 June 2018 – 30 April 2019, while the Intensive Observing Period will be 1 November – 18 December 2018.

One of the collaborative efforts from Brazil will be the deployment of several instruments in the São Borja region, near the border with Argentina. This instrumentation includes an X-band dual-polarization radar, mobile surface stations, high-frequency soundings, disdrometers, profilers, among others. The site in São Borja was selected to sample the evolution of convection from the Cordoba region to the east throughout the La Plata Basin. Along with the scientific measurements that will complement the RELAMPAGO campaign, another aim of the São Borja campaign is to evaluate the nowcasting tools applied to the Brazilian network and test these tools in an environment that simulates nowcasting operations. The entire nowcasting process, from the pre-convective forecast to the warning, will be tested and validated during the experiment.

GOALS OF THE RELAMPAGO - SÃO BORJA CAMPAIGN:

1) Improve RELAMPAGO measurements in the eastern La Plata region and support operations in Cordoba and Mendoza;

2) Study the evolution of hydrometeors and electrification in MCSs;

3) Cloud-resolving models (CRM) with 1 km scale: control-validation-microphysics tests;

4) Evaluate CRM assimilation radar and lighting from GLM;

5) Test nowcasting algorithms based on dual pol variables;

6) Satellite rainfall estimation: GPM precipitation measurements of intense thunderstorm;

7) Forecast hail size with dual-polarization radar observations;

8) Test surface fluxes in BRAMS model;

9) Evaluate N2, CH4 and ozone and their relationship with rainfall events;

10) Estimate the pre-convective predictability of convective activity and severe weather threat in Brazil.

The next sections describe the instrumentation installed in São Borja for the RELAMPAGO (Sec. 2), the cases of severe storms occurred in the period (Sec. 3) and an overview of the RELAMPAGO field campaign in Argentina (Sec. 4).

2) INSTRUMENTATION

X-band polarimetric radar

Volume scan were done with 17 elevations, with low antenna speed and staggered PRF to improve doppler velocities data quality. Radial resolution of 200 m x 1°. A zenith-pointing scan (a.k.a. bird-bath scan) will be performed at the 17th elevation to be used for ZDR calibration purposes. An internal calibration (zero-check) will be performed after each volume scan. When the radar operates in automatic mode, this volume scan will be performed each 10 minutes as the standard scan. If a storm is detected within radar range the operator can switch the operation to a sectorized RHI scan pointed to the azimuth of choice. It is mandatory that a complete volume scan is performed every full hour (0000 GMT, 0100 GMT etc) as the modelling and data assimilation group will be using this data as input for their models.

Elevation scans (RHI) were done in elevation angle starting at 0° and stopping at 60°, which covers an 18 km storm height at a 10 km distance. The RHIs did not use staggered PRF as Doppler velocities were not the priority for these scans. Radial resolution was 200 m x 0.5°. The average time of a single RHI is 15 seconds. The operator were able to select between 4 types of scan definitions, besides doing a single RHI: a 20°, 45°, 90°, or 180° azimuth sector, with a single RHI each 2° apart for the 20° sector and 5° apart for the other ones. The beginning of each sector was positioned anywhere each 1° in a 360° circle as seen in Fig. 4.3. After every scan sector a 0.5° PPI will be performed to check for new storms and storm motions.

Special GPM operation

When the GPM satellite passed over the São Borja region, special RHIs were performed using the X-band polarimetric radar to help in the GPM precipitation estimates verification. When a DPR overpass (light green lines in the figure 4.5 for Ku and Ka swaths) fitted totally or partially with the radar footprint (distance < 200 km), three special elevation scan (RHI) of 15 seconds each were performed across the GPM path if rain was present in the radar footprint at the time of the closest approach.

Soundings

There were two types of sounding available to launch during the experiment. The older type of sounding (RS92) was launched at 1800 UTC daily, while the new type of sounding (RS41), which has better temporal resolution, was launched in convective events. The decision to launch soundings ahead or near convection was made during the morning briefing and during operations. The methodology was adapted to the physical process that were expected to be sampled. For example, if a quasi-linear convective system was moving towards the experiment area, soundings were launched each 1 hour before and after the gust front passage.

GOES-16 mesoscale scans (rapidscans)

In support of the RELAMPAGO field campaign, the GOES-16 was performing scans with 1 minute interval (when requested) to monitor the convective systems near São Borja. Four rapidscans periods were covering the region:

1) 0300 UTC 13 Nov 2018 to 0300 UTC 14 Nov 2018;
2) 1500 UTC 17 Nov 2018 to 0900 UTC 18 Nov 2018;
3) 0300 UTC 12 Dec 2018 to 1500 UTC 12 Dec 2018;
4) 1800 UTC 14 Dec 2018 to 1200 UTC 15 Dec 2018.

Field Mill

The atmospheric electric field sensor, also known by the acronym EFM (Electric Field Mill) is an electronic device that measures the atmospheric electric field directly above and in the surroundings of the station. Five sensors will be installed in a range of 2 km distance. This sensor detects the cloud electric field and describes the electrification processes inside the clouds. The rain gauge connected to the instrument is tipping buckets having a sampling resolution of 0.254 mm and maximum temporal resolution of 10 s. The link for real-time access to the Field Mill data is http://fieldmill.net/relampago.shtml.

GPS

The GPS receivers are employed to derive the IWV value using TOPCON brand, LEGACY-H model, dual-frequency type. A dual frequency receiver for scientific applications, created specifically for reference stations and other high-precision applications, with the ability to collect the following observable GPS L1 c/a, L2C, L1 and L2 with its 24 channels available. Measuring, indirectly, the integrated water vapor using the concept of atmosphere delay. This equipment is connected to a transmitter of pressure, temperature and humidity PTU300. The PTU300 of the Vaisala incorporates Vaisala BAROCAP: sensors for atmospheric pressure, the Vaissala and a sensor for moisture HUMICAP platinum RTD for temperature.

The zenithal tropospheric delay is obtained by processing the GPS data using GOA-II software using the precise point positioning pos-processed method. The zenithal wet delay is obtained after removing the zenithal hydrostatic delay.

Surface station

Conventional weather station measuring air temperature, relative humidity, atmospheric pressure, speed and wind direction and accumulated precipitation

Five sets of stations will be installed on ground spaced about 2 km to measure, in the convective scale, the electrical, surface atmosphere and integrated water vapor variability. This is the same WRF model scale running in a domain centered at the experiment site.

Parsivel disdrometer

Parsivel Optical Laser Disdrometer is a disdrometer for the classification of the drop spectrum. The device works on the extinction principle and measures precipitation particles using the shadowing effects they cause when they pass through a laser band. Parsivel captures both the size and the rate of fall in detail of the individual hydrometeors and classifies them into a range of 32 classes each. Depending on the measuring interval set, the resulting precipitation spectrum covers a time between 10 seconds and one hour.

Joss disdrometer

The disdrometer RD-80 of Disdromet LTD is a sensor for measurements of raindrops and consists of two units: the sensor, which is exposed to the rain and processor for processing and digitization of analog sensor signals. The sensor turns the mechanical impact moment of a raindrop in an electrical pulse whose amplitude is proportional to this moment.

Sonic anemometer

Wind sensor that uses ultrasonic technology to provide wind speed and direction. The instrument is robust and doesn’t have mobile parts, which reduces maintenance.

Micro Rain Radar (MRR)

The unique and innovative Micro Rain Radar (MRR) is a small, portable and easy to operate. It can be used for now-casting of precipitation ie, it will detect the start of rain from ground level to high above the radar several minutes before the start of rain at ground level. The Micro Rain Radar (MRR) can detect very small amounts of precipitation (below the threshold of conventional rain gauges) detecting drop sizes between 0.25 mm and 4.53 mm. This covers the size range of atmospheric occurring precipitation drops as larger drops in the atmosphere are affected by the air resistance as they fall and will split into smaller drops. The droplet number concentration in each drop-diameter bin is derived from the backscatter intensity in each corresponding frequency bin. In this procedure the relation between terminal falling velocity and drop size is exploited.

Flux tower

The flux tower uses eddy covariance methods to measure turbulent fluxes of momentum, sensible and latent heat and carbon dioxide. An anemometer (YOUNG) is installed at the tower top (10 m height tower). A sonic anemometer and carbon dioxide and water vapor infrared gas analyzer IRGA (Campbell Scientific) and a Radiometer CNR4 are installed at a height of 8 m, together with temperature, humidity and atmospheric pressure. Another sensor of temperature and humidity is installed at 2 m height. In addition, the following instruments are installed at the surface level: soil humidity sensor (PR1, 6 levels); 5 soil temperature sensors; two plates that allow the measurement of soil heat flux; a rain gauge station. The sonic anemometer and gas analyzer collect data with a 20 Hz frequency, and the turbulent fluxes are calculated on-line.

MP3000 microwave radiometer

Surface-based passive microwave and infrared remote sensing at 35 Channels (frequency: 22.00 – 30.00 GHz and 51.00 – 59.00 GHz). Surface sensor (temperature, relative humidity, and pressure). Temperature, relative, cloud liquid water, water vapor profiles. Time-resolution: 2-6 minutes.

Hailpad

The hail detector hailpad is a pad of soft styrofoam material packed in aluminum foil with a support for fixing. Since hail is solid and heavier than rain, it will leave marks or footprints in the surface of the hailpad. From these footprints, the incident hail number, size and orientation can be estimated.

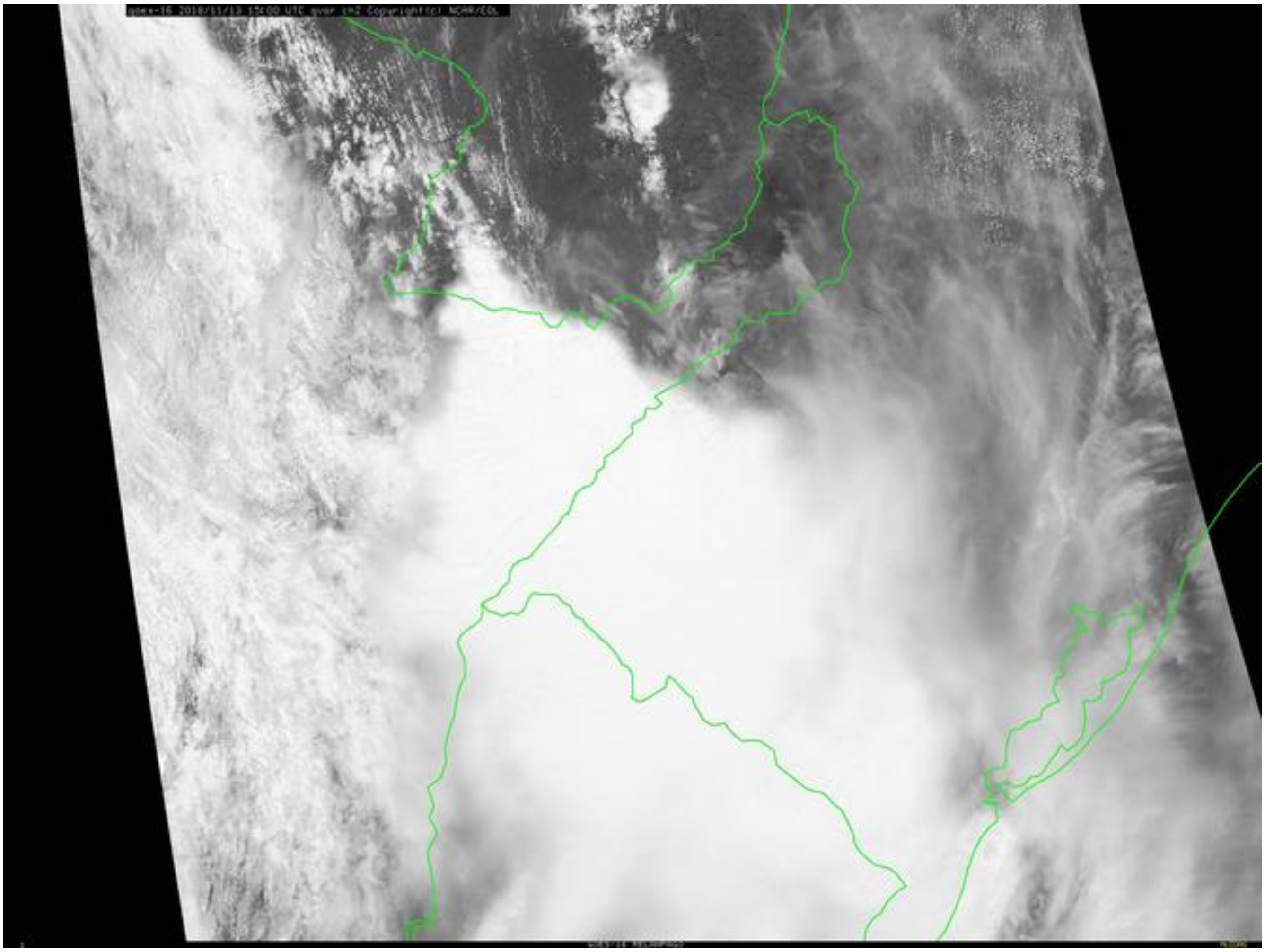
BrasilDAT network for lightning detection

BrasilDAT network is an integrated intra-cloud and cloud-to-ground lightning detection system (total lightning) that combines wide-band sensors and relative dense network deployment of Earth Networks technology. Its deployment started in Dec/2010 and now is composed of 56 sensors covering 11 States of Brazil located at southeast, south, center and part of northeast of the country. The sensors use time-of-arrival (TOA) method of detection and operate in a wider frequency range (from 1Hz to 12MHz). Multiple sensors are used to locate and verify individual strokes adding precision to the system. This network is able to capture the whole waveforms of the radiated signal and differentiate cloud-to-ground strokes from intra-cloud discharges by lining up entire waveforms in cross-correlation.

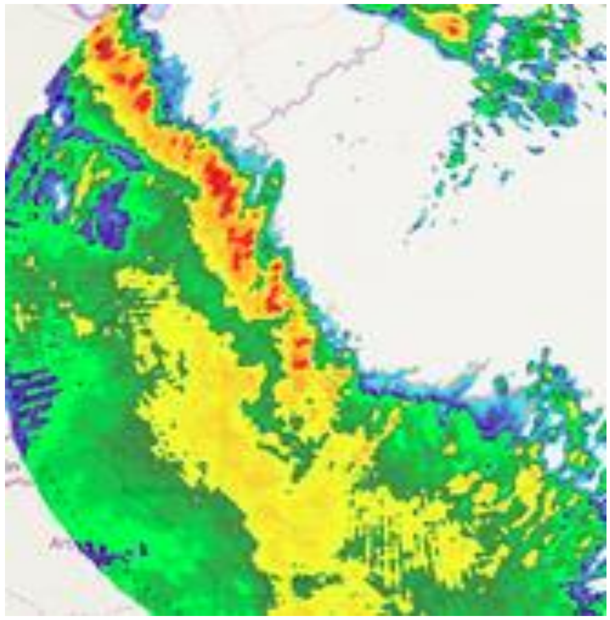
3) CASES WITH INTENSIVE OBSERVATIONS IN SÃO BORJA

13 November 2018

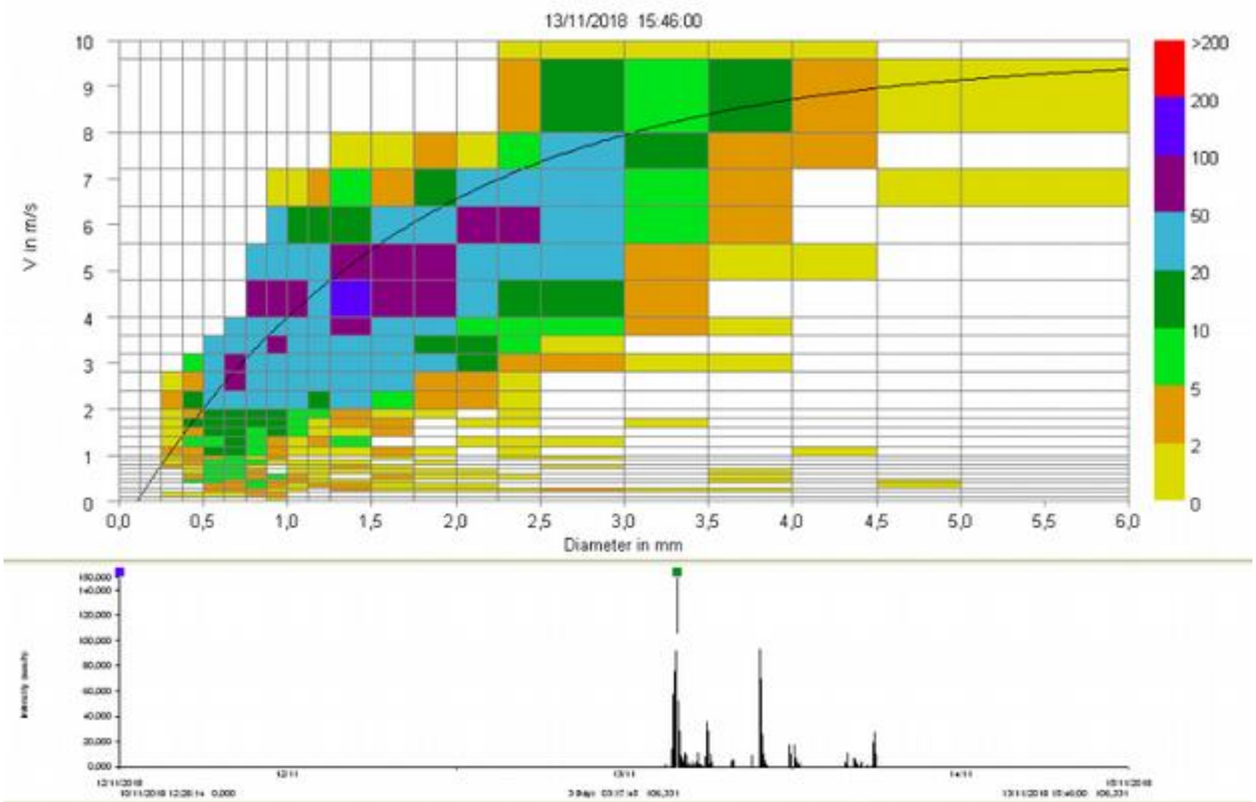
During this day, a pre-frontal quasi-linear convective system affected the São Borja area. This system produce heavy rainfall in a short period of time and wind gusts greater than 60 km/h. The GOES-16 mesoscale sector rapidscan below shows the approximate time of arrival of the system in the São Borja (1500 UTC). The convective activity was mainly located at norwest of the system, close to Argentina - Brazil border.



The Santiago radar image at 1550 UTC are shown below. The quasi-linear convective system had high reflectivity values when it was over São Borja, and the trailing stratiform region is well defined.

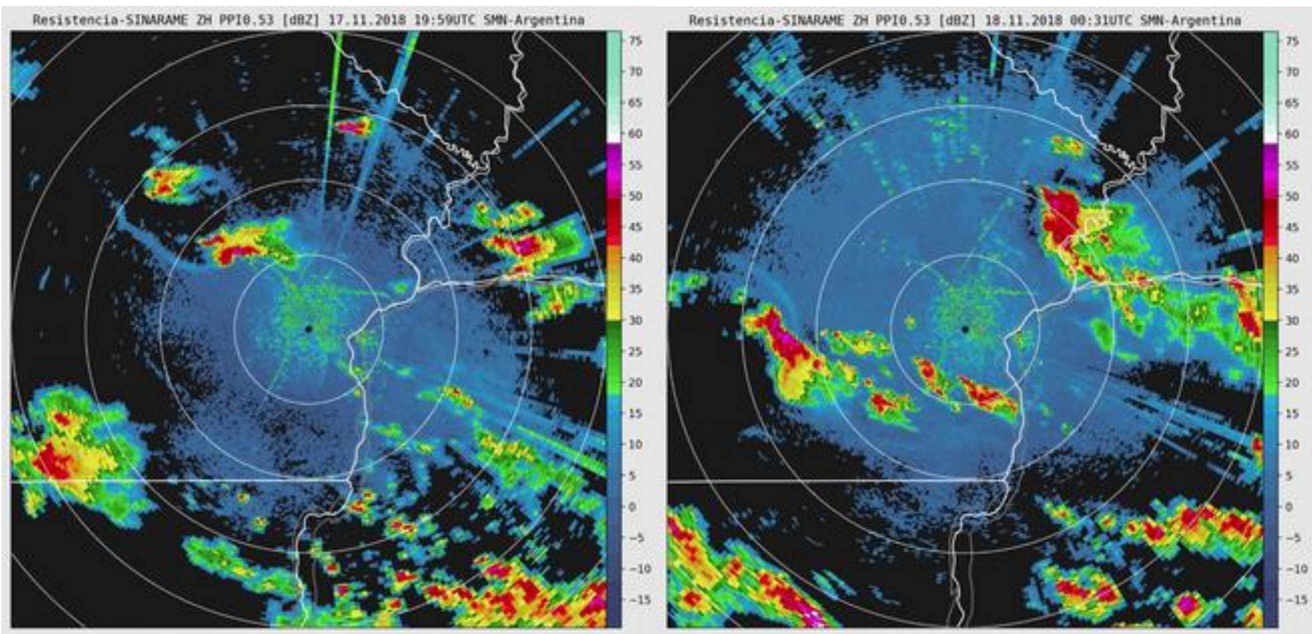


The disdrometer measurements below, when the line passed over São Borja, shows how the distribution of raindrops skew toward the larger diameters when heavy rain occurs.



17 November 2018

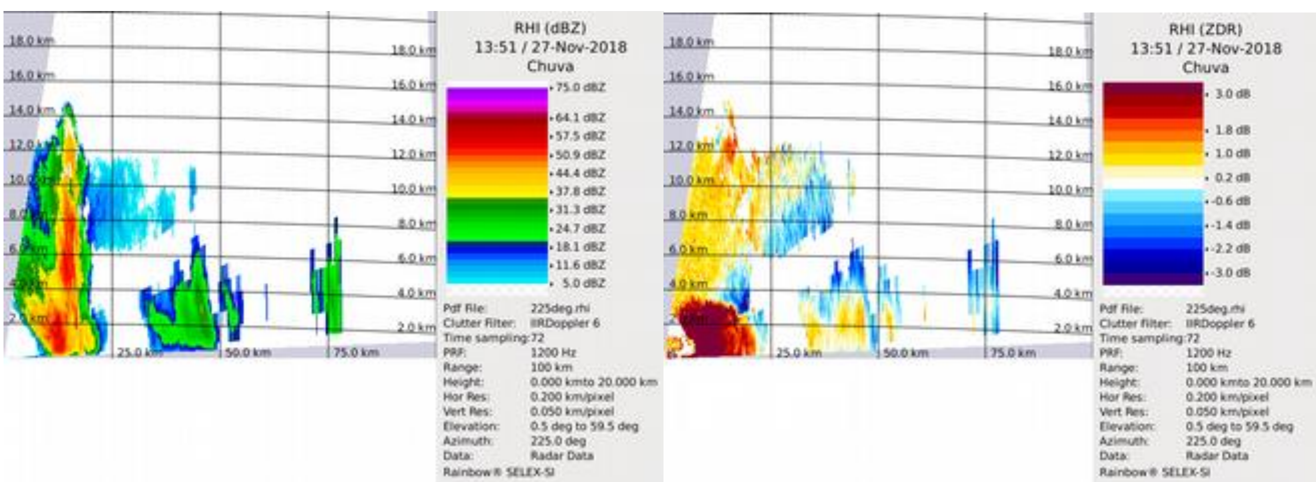
A convective system developed over the São Borja area, causing street flooding in different points in the city (figure below). At approximately 1200 UTC, convective cells developed over northern Argentina and began to produce heavy rainfall in Sao Borja. In the rest of the day, a sequence of convective cores and stratiform regions propagated towards the Rio Grande do Sul state and added to the precipitation totals. Also, some supercells were observed in northeastern Argentina (figures below). The left image shows an anticyclonic supercell and the right a cyclonic one, as seen by the Mercedes, Argentina, C-band radar. The supercells have attendant gust fronts.



27 November 2018

A right-moving supercell formed over southern Paraguai and moved towards São Borja in the morning (figure below). This storm interacted with a group of disorganized storms near the Brazil-Argentina border and caused severe weather ~20 km south of São Borja at nearly 1400 UTC. RHIs of this storm were made starting on the morning. The Civil Defense received watches and warnings for this storm. A damage survey was made by the RELAMPAGO participants.

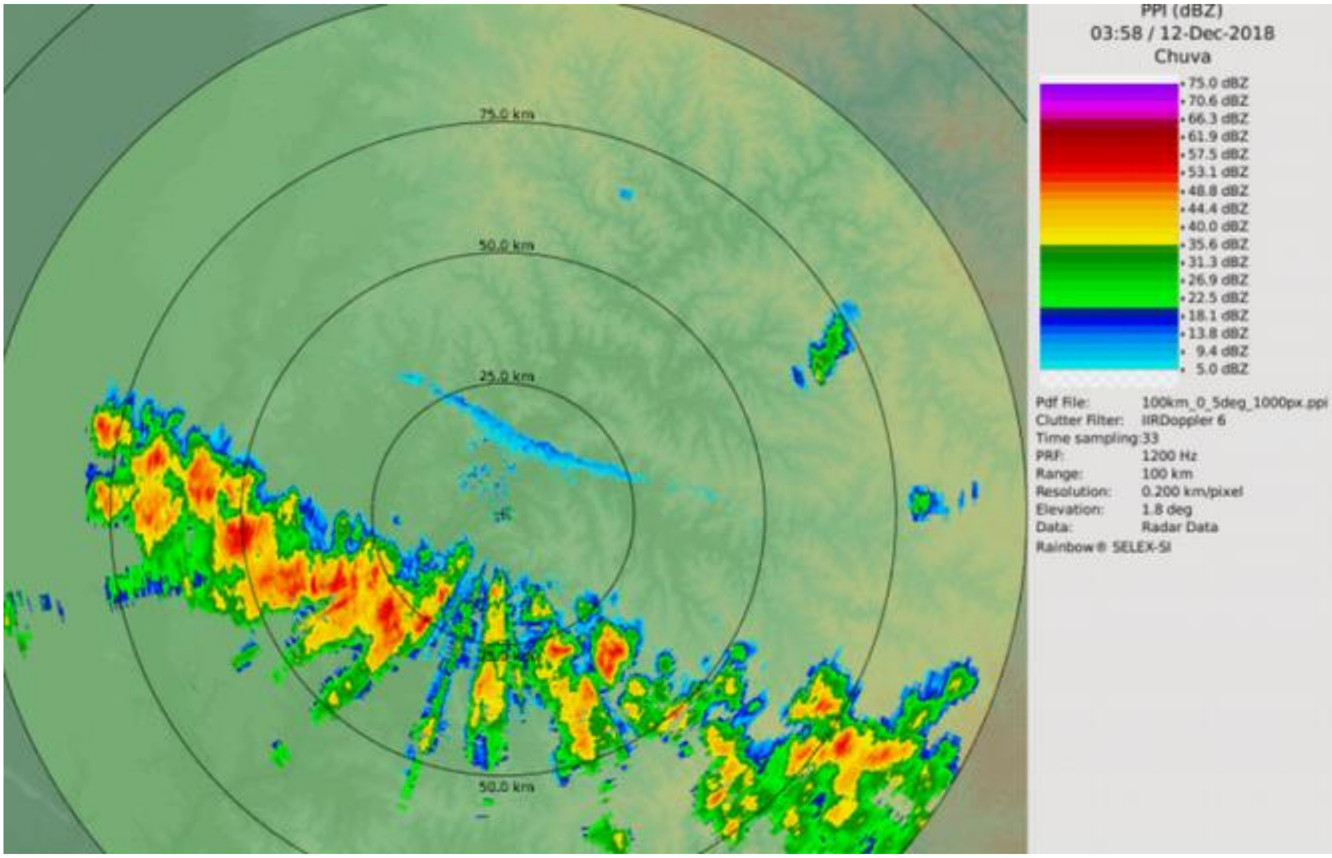
Wind damage photo taken during the survey.



225° RHI of (a) reflectivity factor and (b) ZDR from the X-band radar at 1351 UTC.

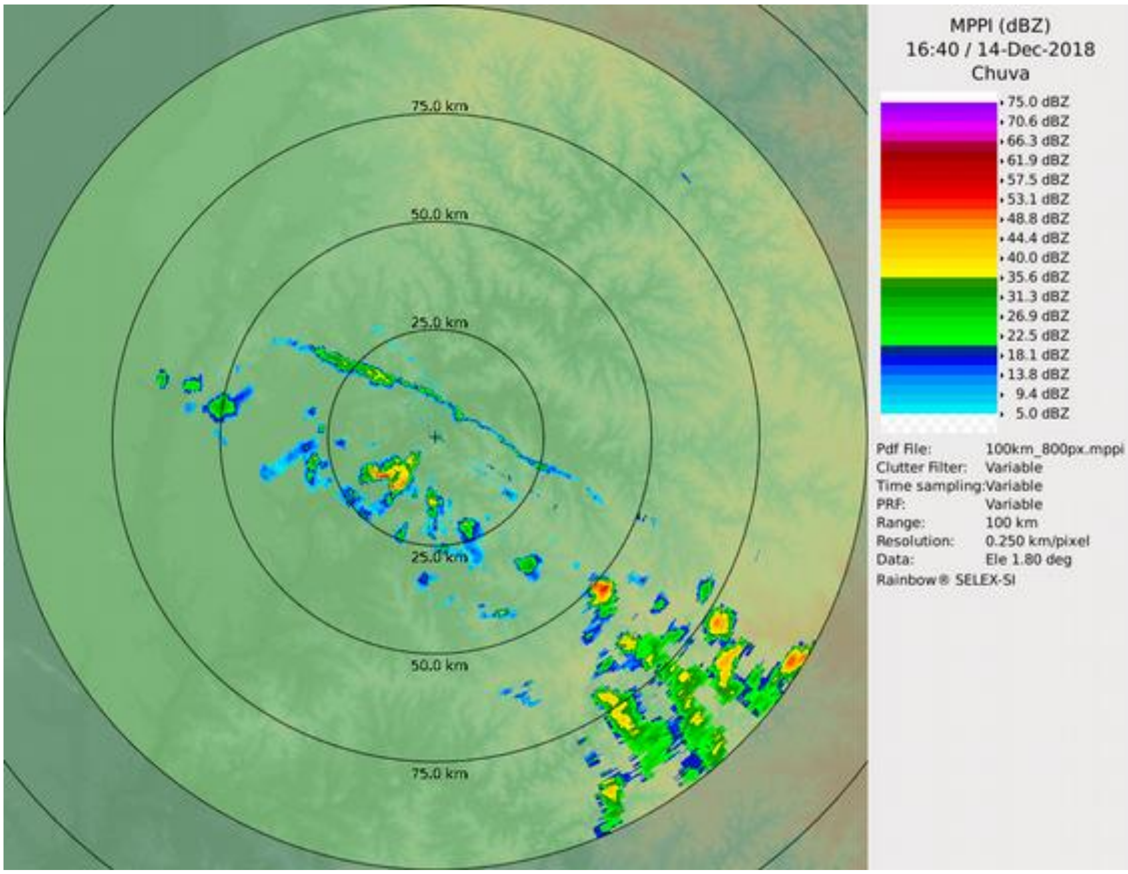
12 December 2018

A quas-linear convective system formed during the night hours and moved towards São Borja. This system propagated a gust front that was well sampled by the X-band radar. Also, soundings were launched before and after the gust front passage, capturing a nocturnal gust front with umprecedented detail in Brazil. Multiple RHIs were made along the strongest cells within the line of convection.



14 December 2018

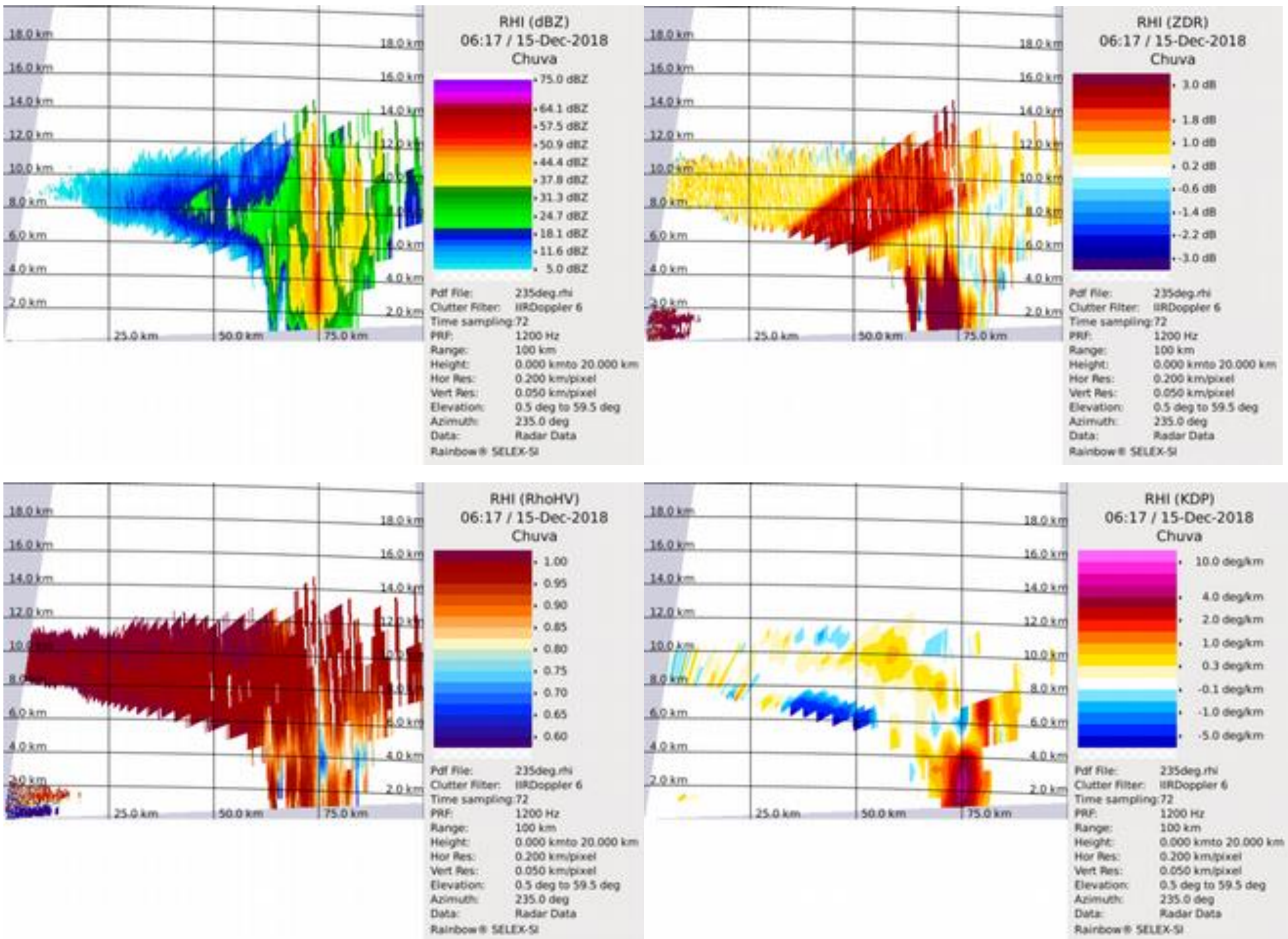
A cold front was moving northwards over Uruguay, while a morning MCS moved slowly over western Rio Grande do Sul state. Some strong wind gusts occurred in cities near the border with Uruguay, but the system lost intensity as it moved towards São Borja. The disorganized squall line caused a pre-squall line gust front that was sampled by the radars (figure below). Also, hourly soundings were launched before and after gust front passage.



1.8° PPI from the X-band radar at 1640 UTC 14 Dec 2018.

15 December 2018

During the night, a cold front approached the region from the south and convection became widespread south of São Borja. Hourly soundings began at ~0600 UTC sampling the pre-convective environment. The GOES-16 rapidscan was operating in the area. The storm system was south of the X-band radar, which allowed continuous sampling through RHIs (group of figures below).



X-band polarimetric radar 235° RHI at 0617 UTC 15 Dec 2018.

4) RELAMPAGO IN ARGENTINA

The intensive observation period in Argentina was organized in three main research topics: Convective Initiation, Severe Weather and Upscale Growth. Each research topic had a principal investigator (PI) that proposed missions bases on the forecast for a given day. The scientific director on duty had to decide which group to favor in the case of conflicting missions. The radar scan strategies, surface observations and sounding launch schedules were adapted to each misson. For each mission, there were several scientific questions that had to be addressed. In total, there were 19 IOP missions.

The instrumentation in the Cordoba region included:

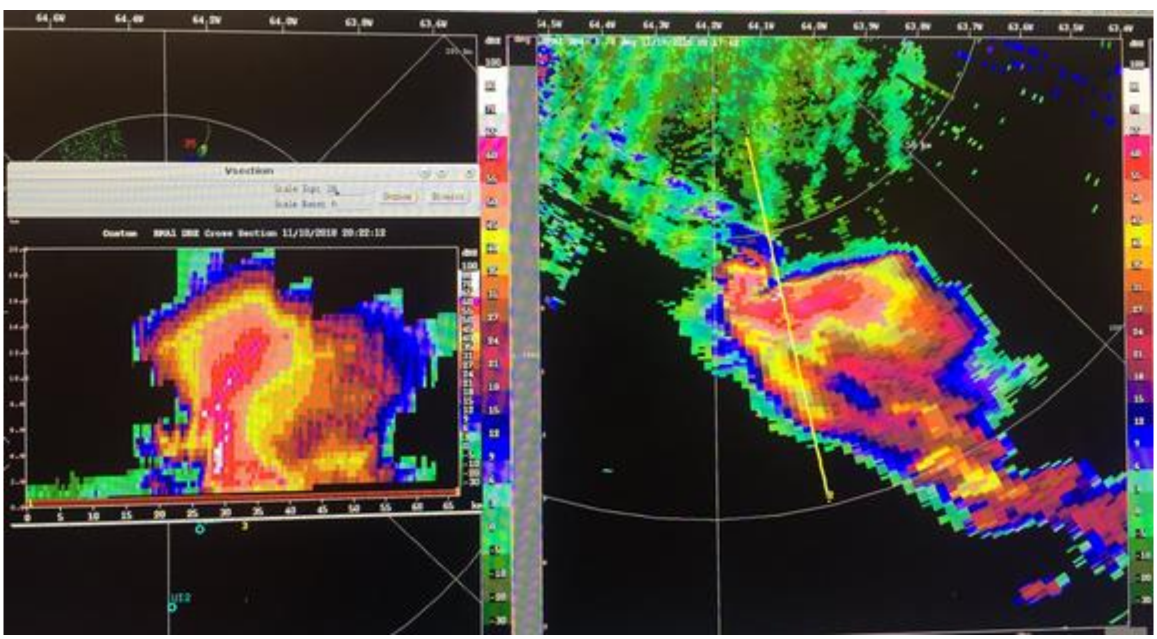
- 3 Doppler On Wheels (DOW) radars: mobile X-band, polarimetric radars installed over trucks. These radars were deployed close to each other in an array that allowed dual-Doppler analysis, i.e., retrieve the 3-dimensional winds from Doppler velocity measurements;

The 3 X-band, polarimetric DOW radars.

- 1 C-band DOW radar: a radar similarto the X-band DOWs, but with a larger antenna that reduces its mobility. This radar was used to make RHIs in the main convective cores;

- 3 fixed C-band radars: the operational radar located in Cordoba and the Colorado University radar were doing volume scans all the time, while the ARM radar located over the mointains was doing RHIs in 360° every 5°;

Two cyclonic supercells with attendant hook echoes sampled by the Cordoba radar on 14 Dec 2018.



Cross section of a supercell storm with top at nearly 18 km above ground level (10 Nov 2018).

- 3 mobile sounding teams: cars with the equipment to launch hourly soundings in the study area;

- 3 fixed sounding stations: these stations launched soundings every day each 6 hours, and in IOP days every 3 hours;

- 3 mobile mesonets: cars equipped with surface sensors of temperature, moisture, pressure and wnids. These cars were fixed, but in some missions were doing transects. Each mesonet is also equipped with 3 PODs, which are small mobile surface stations deployed in strategic locations;

- ARM site: A complete set of instruments to measure several quantities in the atmosphere, such as a wind profiler, moisture profiler, chemical concentrations, lidar, etc;

The ARM site over the Sierras de Cordoba.

- **G-1 airplane**: a research airplane capable of measuring small particles such as cloud droplets and cloud condensation nuclei;

- Mobile hailpad network, 3D hail scanner and drones: the hailpads are styrofoam plates capable of measuring hail sizes and distributions. When possible, the hail stoneswere collected to be scanned by the 3D scanner, and the hail swath was photographed using drones;

Hailpad hit by 4-cm hail on 26 Nov 2018.

Lightning Mapping Array: a group of 11 sensors of lightning flashes at very high spatial and temporal resolution.