Proposal (at no-cost) to NASA Precipitation Measurement Missions

Brazilian Ground Validation Activities for GPM: Understanding the Physical Processes of Intense Precipitation Events

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1. Introduction and Rationale

Climate change is increasing the frequency of extreme events over the globe (IPCC, 2012). The number of victims and the damage these events are very high. The extreme weather events may be related to drought or excessive rain. This proposal will address this second type of event, precipitation extremes and severe weather. The statement of the problem is basic and simple: how to measure and describe the physical processes of extreme events
There are several types of intense precipitation events, some are typical severe systems produced by mesoscale convective systems (MCS), and others are related to less intense rain rate, but continuous generating large amount of total rainfall in few days, this last one very frequent near cost. These two types of rainfall events this project will be focusing,

Mesoscale Convective Systems (MCS) are usually associated with severe weather events such as hail, heavy precipitation on the surface, high winds and even tornadoes. The understanding of the physical processes and the microphysical structure of rainfall associated with these kinds of systems and how GPM retrievals are describing them is a major topic cover in this proposal.

On the other hand, clouds with little ice formation or without ice phase (or where the ice layer is not directly related with precipitation) are very common, especially in the tropical region. Clouds with warm rain (as the main rainfall process) can be associated to orographic clouds, early stages of cumulus nimbus, stratus, stratus cumulus, or even cumulus congestus that have the entire life cycle within the warm phase. This kind of clouds occur in northeastern Brazil and recent analyses using the TRMM/PR, indicate that warm clouds (classified as shallow convection) represents more than 80% of precipitating events during the rainy season (May-September) in the coastal region of Brazil from 10ºS to 5ºS (Araujo, 2015). Those systems can produce large amount of rainfall while they do not lead to a significant brightness temperature depression on PMW sensors and they are often classified as “no rain” by the screening procedure.

In this proposal, severe events are defined as those with high rain rate and/or occurrence of hail and/or high wind gusts and/or high frequency of electric discharges and/or accumulated precipitation greater than 100 mm over three days. Several tools are used to understand the physical processes inside the clouds: ground sensors, radar and lightning detection networks. Satellites also could be used if polar or equatorial platforms equipped with MW sensor (i.e. GPM constellation) overpass the study region during those severe events

The main goal of this proposal is to describe the physical process of the intense rainfall events and propose a methodology to describe the physical properties using satellite remote sensing data and evaluate how the retrieval techniques employed by GPM are adequate to describe these rainfall systems.

Measuring precipitation and GPM ground validation activities is also an important aspect of this proposal. In order to achieve the expected accuracy of all GPM products, several field campaigns in different precipitation regimes are carried out around the globe. These campaigns and regimes range from the Light Precipitation Validation Experiment (LPVEx; Helsinki, Finland, fall-winter 2010, partnered with CloudSat) to the Mid-latitude Continental Convective Clouds Experiment (MC3E; Ponca City, OK, April-May, 2011, partners DOE-ARM) among others. In this context, The SOS-CHUVA (Sistema de Observação e Previsão de Tempo Severo, in Portuguese) field campaign (Apr 2016-Dec 2017) will provide ground precipitation datasets supporting physical validation of satellite-based precipitation retrieval algorithms. The GV measurements site include a X-band dual-polarimetric radar, radiometer observations, and a very high temporal and spatial ground-based disdrometer and raingauge network as a core instrument and measurement complement. On the other hand, radar and gauge measurements in Ceara State, located in the northeastern part of Brazil, on the Atlantic coast will also help to support physical validation processes of warm clouds

2. Scientific Aspects and Objectives

The use of multi-frequency dual-polarimetric radars is a requirement to achieve the level of accuracy for GPM. The knowledge about the use of this type of radar in Brazil is limited and there is a clear need to expand the knowledge in applied research and make it useful to society. This proposal aims to employ this type of radar data and satellite information to develop knowledge to reduce the impact of weather disasters associated with the occurrence of extreme events on the society.

The main objective of this proposal is to understand the evolution of microphysical properties of clouds when modify to become intense precipitation events and predict these changes based on conceptual models and provide ground precipitation datasets supporting physical and direct validation of satellite-based GPM precipitation retrieval algorithms.

Several specific objectives are underlined:

- Develop a ground-based precipitation dataset (radar, gauges, disdrometers, radiometer, etc.) to support GPM direct and physical based ground validation activities.
- Adapt and improve tracking tools to understand the evolution of microphysical properties of clouds.
- Study the occurrence of lightning and how this electric activity is linked with severe weather.
- Develop different conceptual models of storm evolution according MCS characteristics (stratiform, shallow and deep convection) using different remote sensing techniques (radar, satellite, lightning, etc.).

3. International Research Efforts

a) RELAMPAGO (Remote sensing of Electrification, Lightning, And Mesoscale/microscale Processes with Adaptive Ground Observations, translates to lightning flash in Spanish and Portuguese) is a project proposed to the US National Science Foundation and NASA/NOAA to bring US resources to the field to observe convective storms that produce high impact weather in the lee of the Andes mountains in Argentina and southern Brazil. It will also involve significant contributions from Argentina (CONICET), Brazil (CNPq and FAPESP), and Chile (CONICYT), as well as universities across the region, Argentina's national meteorological service (Servicio Meteorológico Nacional, SMN) and Brazil's space agency (INPE) that governs Brazil's weather and climate prediction service (CPTEC).

b) CACTI (Clouds, Aerosols, and Complex Terrain Interactions) is a ($7.4 million) funded project to study orographic clouds and their representation in multi-scale models for 15 Aug 2018 – 31 Mar 2019. It will involve the AMF-1 cloud-aerosol-radiation observatory, the Mobile Aerosol Observing System (MAOS), the CSAPR-2 precipitation radar, and a surface meteorological network. It will also bring intensive airborne observations during RELAMPAGO through the deployment of the G-1 aircraft.

4. National Research Efforts and Experimental Design

SOS-CHUVA (Sistema de Observação e Previsão de Tempo Severo, in Portuguese) this field campaign will be carried out between April 2016 and December 2017. The radar X-band dual-polarization radar will be installed in Campinas, state of São Paulo. The radar is installed in partnership with the CEPAGRI in Campinas university (UNICAMP). This radar will make volumetric scans every 10 minutes on a regular basis. This scan will include vertical scan offset correction (ZDR), zero checking and RHI (Range-Height Indicator) in specific directions perpendicular and transverse the preferential convection propagation direction in that region. In the case of special events the radar will be operated by performing systematic RHI's of a system under development to study the evolution of microphysics in high resolution. A third scanning will scan GPM passage. In this case, RHI scanning will be carried out on the same direction of the satellite overpass and in the same direction to the satellite swath.

Three disdrometers are installed in the vicinity of the radar: one close to the radar, a second one at 10 km and the third at Luiz de Queiroz College of Agriculture (ESALQ) – 50 km. These are two Parsivel and one Joss. The disdrometers are used to determine the distribution of droplets on the surface. Two network with10 raingauges each one are installed on the radar region for adjustment and calibration of the precipitation estimates. The Embrapa at Jaguariuna, ESALQ at Piracicaba and UNICAMP at Campinas are the main experiment site. A network of Hail Pads is being installed in the vicinity of the radar in an approximate number of 20. The Hail Pad lets you know the occurrence of hail and determine hail size. Lightning measurements, polarity and intensity will be obtained through BrasilDat network. A network with six field mills are installed at ESALQ that will relate electrification with the microphysics of clouds.

Finally, three GPS sensors will be installed for indirect measurement of integrated water vapor content in order to study the increases of integrated content before the extreme events that are associated and penetration of moisture convergence lines. See below a description of all instruments installed in SOS CHUVA.

5. Proposed Activities

Perform ground validation activities for X-band Dual Pol radar in Campinas using the statistical analysis and display program for GPM validation network geometry-matched DPR and GV data sets.

Analyze the evolution of thunderstorms using dual polarization radar data and multichannel satellite observations. Develop a conceptual model of thunderstorm electrification life cycle (from convective initiation to first CG flash), in order to describe, throughout the storm evolution, specific microphysical characteristics of the vertical structure and the dynamics of mesoscale circulation.

Evaluates the differences between storms with different type of lightning (i.e., cloud-to-ground positive and negative lightning and intracloud lightning) in terms of surface rainfall and microphysical vertical profiles.

Evaluate the relationship between the microphysical proprieties estimated by X-band radar and total lightning from GLM (GOES-R). This work could open a perspective to the use the total lightning from GLM sensor as auxiliary information to retrieve the convective core of the MCS and its microphysical properties.

Perform and compare DSD from GPM/DPR and disdrometer in SOS-CHUVA field campaign in order to assess the uncertainties in DSD models employed in Ku- and Ka-band dual-wavelength radar retrievals.

Identify the formation, growth and size of hail inside storm clouds using the X-band dual-pol radar and associate the occurrence of this phenomenon with polarimetric variables. Validate PMW satellite-based techniques (i.e., Ferraro et al., Cecil et al) to extend radar coverage. An extensive hail-pad network will be installed near Campinas to evaluate the occurrence and size of hail

6. Development Team

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Equipamentos e Sítios do SOS CHUVA

UNICAMP

Radar Banda X dual POL Selex

With dual polarization as a standard feature, the magnetron based system is a fully fledged high-end weather radar system, which delivers high quality data for a large variety of applications. The METEOR 50DX can be used for regional campaigns in hydrological forecasting and scientific research, as a gap-filler in existing meteorological networks or to fulfil general meteorological functions in the X-Band range.

MP3000 – Radiômetro de MIcroondas

Measurement: 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 Barometric Pressure). Temperature, relative, cloud liquid water, water vapor profiles. Time-resolution: 2-6 minutes.

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. It is a highly reliable system suitable for use in remote and extreme environments, requiring minimal maintenance and is well adapted for long term unattended operation. Statistically stable drop size distributions can be derived within a few seconds due to the size of the scattering volume. 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.

Parsivel Disdrometer

Ott Inc. PARSIVEL Optical Laser Disdrometer, 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. A fast signal processor uses the raw data to calculate the type of precipitation as well as the amount and intensity of the precipitation, the visibility in precipitation, the kinetic energy of the precipitation and the equivalent radar reflectivity. Optical precipitation measuring instrument for rain quantity and intensity as alternative to conventional collecting rain gauges.

GPS (Global Positioning System)

A dual-frequency receiver for scientific applications, created specifically for reference stations and other high precision applications, with a capacity to collect the following observables GPS L1 C/A, L2C, L1 e L2 with its 24 available channels. To measure integrated water vapor by using atmosphere delay concept.

Field Mills – Moinho de Campo

Atmospheric electric fields have been measured for decades by electric field meters nicknamed "field mills". Traditional field mills employ a spinning metal rotor (vane) electrically connected to Earth ground, placed between the external field and stationary metal sense electrodes. The grounded spinning rotor alternately shields and exposes the sense electrodes from the electric field to be measured, resulting in a modulation of the induced charge on the sense electrodes. Typically, a pair of charge amplifiers converts the modulated charge into AC voltages that are synchronously rectified and filtered to form a low-frequency voltage proportional to the low-frequency (≤10 Hz) electric field. easured for decades by electric field meters nicknamed "field mills". Traditional field mills employ a spinning metal rotor (vane) electrically connected to Earth ground, placed between the external field and stationary metal sense electrodes. The grounded spinning rotor alternately shields and exposes the sense electrodes from the electric field to be measured, resulting in a modulation of the induced charge on the sense electrodes. Typically, a pair of charge amplifiers converts the modulated charge into AC voltages that are synchronously rectified and filtered to form a low-frequency voltage proportional to the low-f.

Veja o relatório técnico do instrumento.

Pluviômetro - Tipping Bucket Rain Gauge

The design uses a proven tipping bucket mechanism for simple and effective rainfall measurement. The bucket geometry and material are specially selected for maximum water release, thereby reducing contamination and errors. Catchment area of 200 cm2 and measurement resolution of 0.1 mm meet the recommendations of the WMO.

Hail Pad – Detector de Granizo

Hail pads reveal where hail falls and at what intensity during a hailstorm. Since hail is solid and often heavier than rain, it leaves dents or "footprints" on the surface of hail pads. Because hail falls over large distances, and the intensity/size of the hail varies over these distances, it wouldn't be helpful to simply study a small area during a hailstorm. In order to cover more distance, you need more hail pads. Hail pad can measure the number, size, and orientation of hailstones.

CTC – ESALQ

1. Tipping Bucket Rain Gauge (as described above)
2. GPS (as described above)
3. Field Mill (as described above)
4. Parsivel (as described above)
5. Hail Pad
6. Flux Tower e Estação de Superfície

Medidas dos fluxos turbulentos de momentum, calor sensível, latente e dióxido de carbono usando a técnica de correlação de vórtices. Os instrumentos (anemometro sonico e analisador de gases infravermelho IRGA da firma Campbell Scientific) são coletados a uma taxa de amostragem de 20 Hz e calculados os fluxos on line. Os equipamentos estão em uma torre de 10 metros de altura com os seguintes sensores; Topo da torre 10mts anemômetro YOUNG, A 08mts sistema de Fluxo de CO^2 e um CNR4 com o sistema de fluxo com 1 anemômetro sônico 3D da Campbell,Temperatura e Umidade e Pressão coletados em um CR3000. A 2mts teremos mais um sensor de temperatura e umidade do ar. Da parte de medidas de solo temos ; sensor de umidade do solo PR1 com 06 níveis , 05 sensores de temperatura do solo e duas placas de fluxo de calor do solo. Um Pluviômetro. Além do CR3000 para coleta de dados de Fluxo de CO^2 teremos outro CR23x para coleta de dados de Baixa frequência sendo então duas caixas para abrigar os data loggers e uma caixa para o sistema de energia com baterias e fonte para alimentação do sistema.

EMBRAPA Meio Ambiente - Jaguariúna

1. Tipping Bucket Rain Gauge (as described above)
2. GPS (as described above)
3. Field Mill (as described above)
4. Parsivel (as described above)

5. Hail Pad
6. Joss-Waldvogel Acoustic Impact Disdrometer Model RD 80

The Distromet disdrometer (model RD-80) measures the character and amount of liquid precipitation . The main purpose of the disdrometer is to measure drop size distribution, which it captures over 20 size classes from 0.3mm to 5.4mm, and to determine rain rate. Disdrometer results can also be used to infer several properties including drop number density, radar reflectivity, liquid water content, and energy flux. Rain that falls on the disdrometer sensor moves a plunger on a vertical axis. The disdrometer transforms the plunger motion into electrical impulses whose strength is proportional to drop diameter. Data are collected once a minute.

Bacia de Contrôle

1. Tipping Bucket Rain Gauge (as described above)
2. GPS (as described above)
3. Field Mill (as described above)
4. Parsivel (as described above)
5. Hail Pad

Usina de Contrôle

1. Tipping Bucket Rain Gauge (as described above)
2. GPS (as described above)
3. Field Mill (as described above)
4. Parsivel (as described above)
5. Hail Pad (as described above)
6. Hail Pads – Voluntários – vários (ideal um a cada 4x4 km2)
7. File Mills – 6 estações