GPM-GEO STORM: Characterization of global storm structures using satellite sensors.

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Spaceborne radars—most notably, the launch of the Global Precipitation Measurement (GPM) Dual-Frequency Precipitation Radar (DPR) in 2014—have, over the past decade, enabled a comprehensive understanding of global rainfall distribution, intensity, and variability. Several studies (e.g., Liu et al., 2007; Houze et al., 2015) have exploited these radar measurements to derive storm-specific characteristics from radar reflectivity profiles (Liu et al., 2008; Li et al., 2019), offering valuable insights into precipitation patterns. However, little attention has been paid to the diversity in spatial structures of precipitating cloud systems (PCSs) and their geographic distribution.

While the GPM-DPR provides infrequent, high-quality snapshots of PCS structures, high-frequency geostationary (GEO) satellite multispectral VIS/IR imagery allows for continuous monitoring of cloud formation, development, and decay. It is important to note that the VIS/IR signals measured by GEO sensors in cloudy regions depends exclusively on the optical and thermal properties of the cloud top. Consequently, no direct information about the distribution and concentration of solid and liquid hydrometeors within the cloud is available; such details must instead be inferred from cloud-top properties, texture, and temporal evolution. Over time, distinctive cloud features observed in VIS/IR imagery—such as enhanced V-features (Brunner et al., 2007), overshooting tops (Jurkovic et al., 2015; Setvak et al., 2013), and above-anvil cirrus plumes (Bedka et al., 2018)—have been linked with reports of severe weather at the surface.

The proposed master thesis project will investigate the spatial structures of PCSs worldwide, using GPM DPR observation in synergy with GEO VIS/IR imagery. The project will be divided into four distinct phases, with each phase building upon the previous one to achieve a comprehensive analysis and understanding of PCS structures and their geographic distribution. Throughout the project, the student will work with large satellite datasets, employ various analytical techniques, and further develop their programming skills.

Storm Identification and Characterization using GPM DPR

The student will begin by identifying precipitating clouds and storms captured by the GPM DPR. To achieve this, they will use the GPM-API software developed at LTE, which supports data reading, manipulation, feature extraction, and visualization. The task involves developing a database (GPM-STORM) that summarizes and characterized precipitation events with key storm-related metrics, such as integrated rain volume, maximum reflectivity, area, and cloud height above defined thresholds.

Unsupervised Classification of GPM DPR Storm Structures

Initially, the manually derived storm features stored in the GPM-STORM database will be clustered using the Self-Organizing Map algorithm, grouping together storm events with similar characteristics. Optionally, advanced representation learning algorithms may be employed to extract additional storm features directly from GPM DPR profiles, potentially enhancing the classification of storm structures.

Exploratory Analysis of GPM DPR Storm Structures

The student will investigate the geographic distribution of the classified storm structures, examining whether the horizontal structure of storms can be used to infer phenomena such as hail occurrence, lightning activity, vertical storm characteristics, or other microphysical processes.

Storm detection and classification using GEO VIS/IR imagery.

In the subsequent phase, the student will utilize the GPM-GEO dataset, which collocates GEO VIS/IR imagery and derived cloud products onto GPM DPR swath scans, to assess how some types of PCSs structures observed by GPM DPR correspond to cloud-top patterns in GEO VIS/IR imagery.
For instance, the focus may be on hail-generating storms, identifying distinctive GEO VIS/IR features associated with them. Depending on the available time, the project might also include developing a hail detection classifier for GEO imagery or exploring the integration of lightning activity data to better locate the core updraft regions of the PCSs.

Objectives

- Development of a database characterizing the precipitation events captured by GPM DPR
- Unsupervised classification of GPM DPR PCSs
- Analysis of the geographic distribution and variability of PCSs
- Hail storms characterization with the synergistic use of GEO VIS/IR imagery and GPM DPR data
- (Optional) Development of a hail detection algorithm for GEO VIS/IR imagery

Requirements

- Good programming skills in python
- Interest in precipitation, remote-sensing, machine learning and GIS

References

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