A Python-based Radar Data Processing System for the NASA GPM Ground Validation Program

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November 24, 2022

Abstract

The science community's progression toward Python as a primary programing language, facilitated NASA's Global Precipitation Measurement (GPM) Ground Validation (GV) Program to develop a Python-based radar processing system, GVradar. GVradar consists of two modules: Dual-Polarimetric Quality Control (DPQC) and dual-polarimetric precipitation product generation (dp_products). Both modules take full advantage of the open-source Python Atmospheric Radiation Measurement (ARM) Radar Toolkit (Py-ART) and Colorado State University's Radar Tools (CSU Radar Tools). Within DPQC, parameter threshold gate filters are utilized to identify and remove non-precipitating echoes based on freezing level, beam height, or by user defined sector. Additional DPQC capabilities include unfolding of Differential Phase (Φdp), Specific Differential Phase (Kdp) retrieval, velocity de-aliasing, and application of calibration offsets. Precipitation products generated with CSU Radar Tools include HIDRO Rain Rate (RC) and Hydrometeor Identification (FH). Additional products include GPM-GV's mass weighted mean diameter (D_m) and normalized intercept parameter (N_w). D_m and N_w retrievals were computed from empirical equations using disdrometer derived Zdr data obtained during GPM field experiments. The recommended method of executing GVradar is to use a user designated parameter dictionary, however the code will run with default settings. The use of a dictionary allows the user to optimize QC thresholds, specify fields to generate, and select output and plotting options. The ability of GVradar to retrieve sounding data from the Rapid Refresh (RAP) model allows DPQC to be applied and dp_products to be generated in near real-time. NASA's Dual Polarimetric (NPOL) radar is currently using GVradar to display data in near real-time. GPM-GV developed GVradar as a user-friendly open-source radar processing tool that is freely available to the scientific community.

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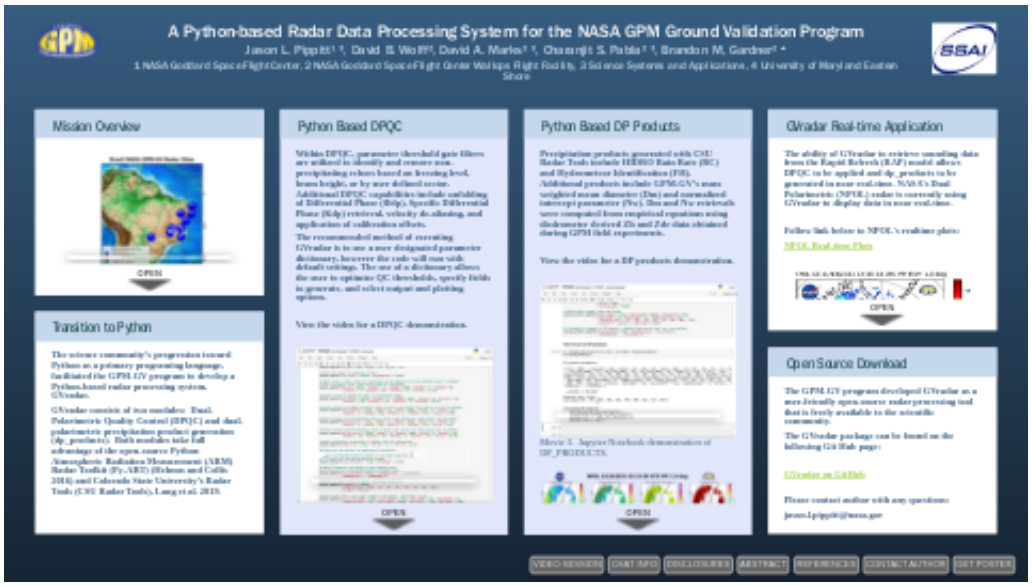

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PRESENTED AT:

MISSION OVERVIEW

[VIDEO] https://res.cloudinary.com/amuze-interactive/video/upload/vc_auto/v1638824137/agu-fm2021/F2-C2-1C-E0-FD-72-9D-43-07-FA-B5-FF-50-4F-F3-09/Video/GV_maps_anim_ucwtak.mp4

Movie 1. NASA GPM-GV radar sites. Maps of all, CONUS, Brazilian, and Pacific sites are shown.

The Global Precipitation Measurement (GPM) Mission satellite an international mission led by NASA and JAXA was launched from Tanegashima, Japan on February 27, 2014. The GPM Ground Validation (GV) program established an extensive network, consisting of over 90 dual polarimetric (DP) weather radars. They are located in different meteorological regimes to identify biases between ground observations and satellite retrievals, to assess the physical basis for uncertainties, and to improve both ground and space-based retrievals of precipitation. Remote sensing by ground radars is a key element in bridging the space and time gap between satellite observations and in-situ surface instrumentations such as rain gauges and disdrometers.

GPM-GV program developed an IDL algorithm based on Ryzhkov et al. 1998, that uses DP parameters to quality control (QC) radar data (DPQC), Pippitt et al. 2013. Additionally an IDL based algorithm was developed to calculate DP rainfall products, Pippitt et al. 2015.

TRANSITION TO PYTHON

The science community's progression toward Python as a primary programing language, facilitated the GPM-GV program to develop a Python-based radar processing system, GVradar.

GVradar consists of two modules: Dual-Polarimetric Quality Control (DPQC) and dual-polarimetric precipitation product generation (dp_products). Both modules take full advantage of the open-source Python Atmospheric Radiation Measurement (ARM) Radar Toolkit (Py-ART) (Helmus and Collis 2016) and Colorado State University's Radar Tools (CSU Radar Tools), Lang et al. 2019.

PYTHON BASED DPQC

Within DPQC, parameter threshold gate filters are utilized to identify and remove non-precipitating echoes based on freezing level, beam height, or by user defined sector. Additional DPQC capabilities include unfolding of Differential Phase (Φdp), Specific Differential Phase (Kdp) retrieval, velocity de-aliasing, and application of calibration offsets.

The recommended method of executing GVradar is to use a user designated parameter dictionary, however the code will run with default settings. The use of a dictionary allows the user to optimize QC thresholds, specify fields to generate, and select output and plotting options.

View the video for a DPQC demonstration.

[VIDEO] https://res.cloudinary.com/amuze-interactive/video/upload/vc_auto/v1638562547/agu-fm2021/F2-C2-1C-E0-FD-72-9D-43-07-FA-B5-FF-50-4F-F3-09/Video/DPQC_z1pudp.mp4

Movie 2. Jupyter Notebook demonstration of DPQC.

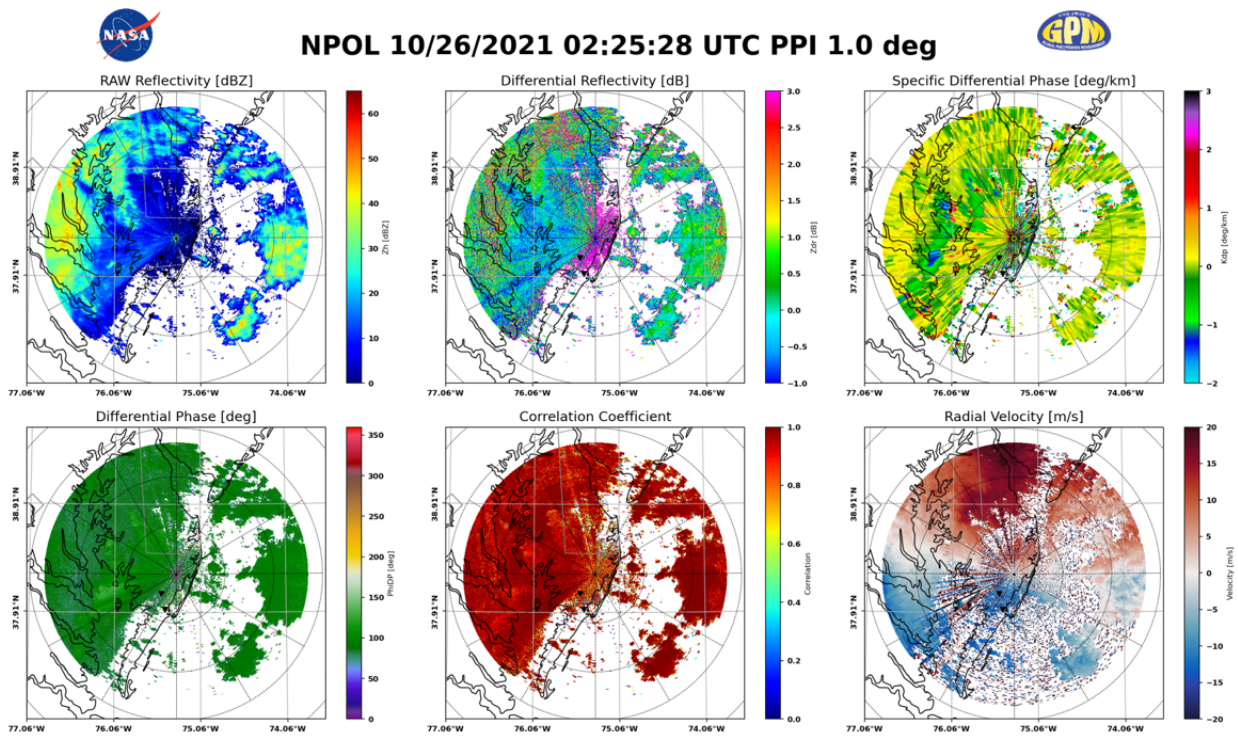

Fig 1. Raw plots of Reflectivity (DZ), Differential Reflectivity (DR) , Specific Differential Phase (KD). Differential Phase (PH), Correlation Coefficient (RH), and Velocity (VR).

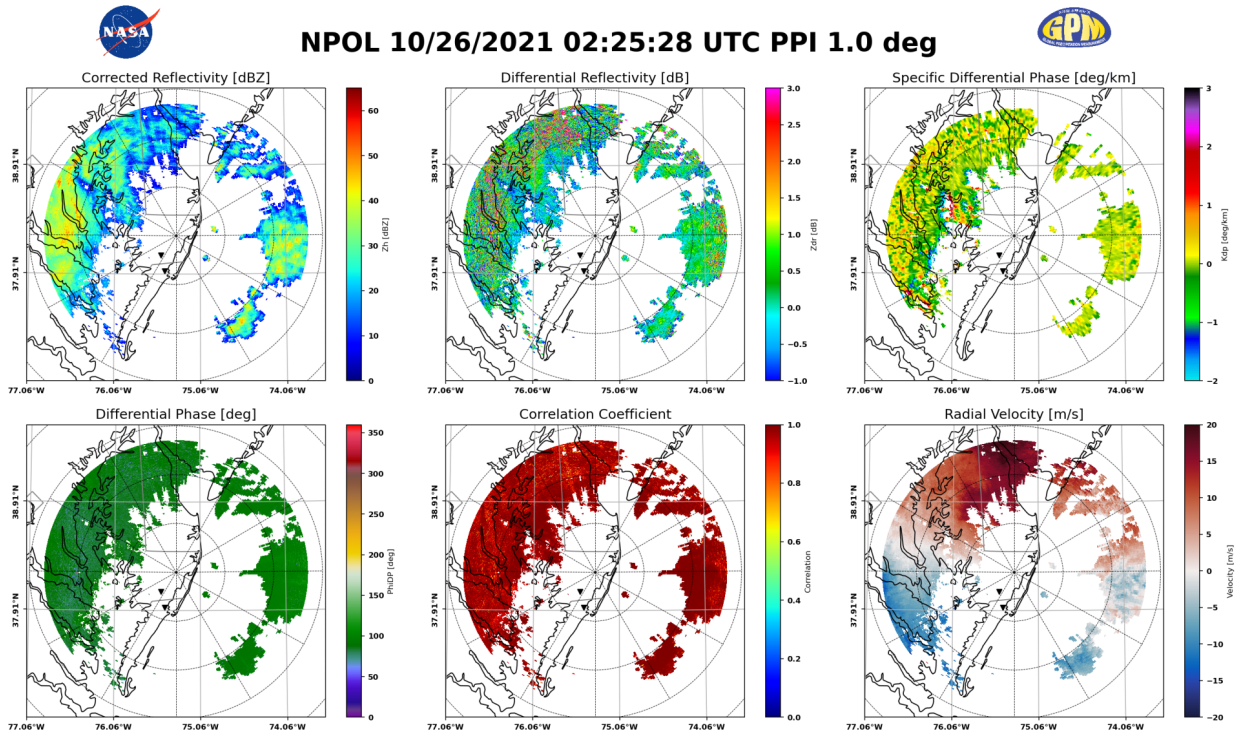

Fig 2. Quality Controlled plots of Reflectivity (CZ), Differential Reflectivity (DR) , Specific Differential Phase (KD). Differential Phase (PH), Correlation Coefficient (RH), and Velocity (VR).

PYTHON BASED DP PRODUCTS

Precipitation products generated with CSU Radar Tools include HIDRO Rain Rate (RC) and Hydrometeor Identification (FH). Additional products include GPM-GV's mass weighted mean diameter (Dm) and normalized intercept parameter (Nw). Dm and Nw retrievals were computed from empirical equations using disdrometer derived Zh and Zdr data obtained during GPM field experiments.

View the video for a DP products demonstration.

[VIDEO] https://res.cloudinary.com/amuze-interactive/video/upload/vc_auto/v1638562463/agu-fm2021/F2-C2-1C-E0-FD-72-9D-43-07-FA-B5-FF-50-4F-F3-09/Video/DPproducts_roiwnh.mp4

Movie 3. Jupyter Notebook demonstration of DP_PRODUCTS.

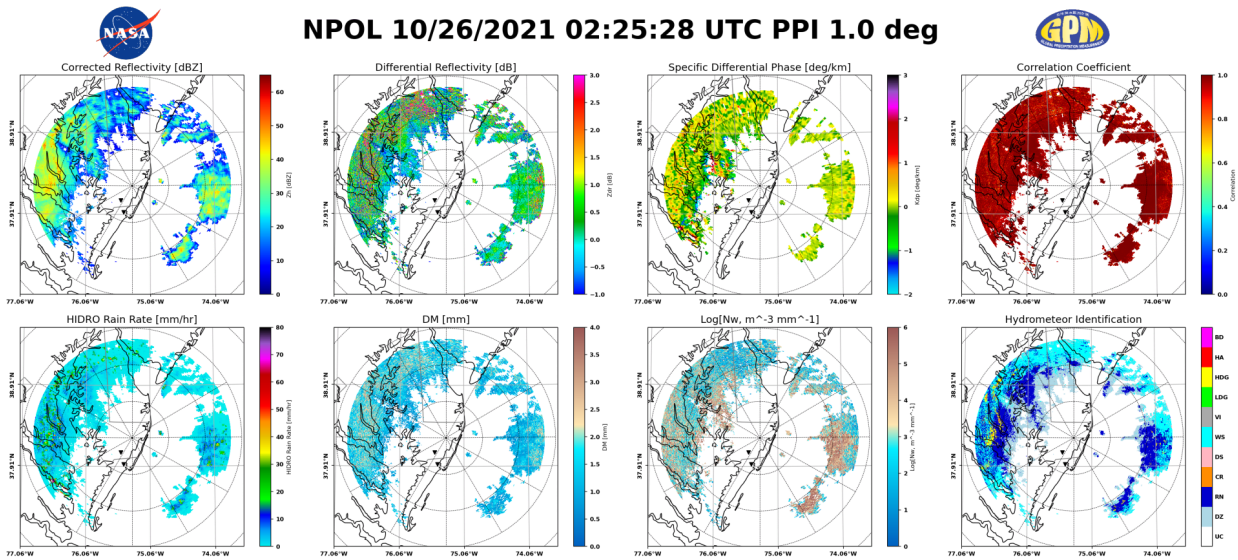

Fig 1. Top row: Quality Controlled plots of Reflectivity (CZ), Differential Reflectivity (DR) , Specific Differential Phase (KD) and Correlation Coefficient (RH). Bottom row: Plots of calculated DP products HIDRO Rain Rate (RC), Mass Weighted Mean Diameter (DM), Normalized Intercept Parameter (NW), and HID (FH).

GVRADAR REAL-TIME APPLICATION

The ability of GVradar to retrieve sounding data from the Rapid Refresh (RAP) model allows DPQC to be applied and dp_products to be generated in near real-time. NASA's Dual Polarimetric (NPOL) radar is currently using GVradar to display data in near real-time.

Follow link below to NPOL's realtime plots:

NPOL Real-time Plots (https://wallops-prf.gsfc.nasa.gov/Radar/NPOL/NPOL_realtime.php)

[VIDEO] https://res.cloudinary.com/amuze-interactive/video/upload/vc_auto/v1637237069/agu-fm2021/55-AE-6B-43-FE-9B-7B-21-E7-8B-87-89-E5-00-6D-60/Video/NPOL_PPI_CZ_2021_1112_g5mlhy.mp4

Movie 4. Example of NPOL real-time Quality Controlled Reflectivity movie from 11/12/2021.

GVradar facilitated the GPM-GV program to develop a real time rainfall accumulation product.

[VIDEO] https://res.cloudinary.com/amuze-interactive/video/upload/vc_auto/v1638826834/agu-fm2021/F2-C2-1C-E0-FD-72-9D-43-07-FA-B5-FF-50-4F-F3-09/Video/NPOL_211005-211006_vdbeon.mp4

Movie 5. NPOL rainfall accumulation map from an event on 10/05/2021 to 10/06/2021 with 3 localized heavy rainfall cells.

OPEN SOURCE DOWNLOAD

The GPM-GV program developed GVradar as a user-friendly open-source radar processing tool that is freely available to the scientific community.

The GVradar package can be found on the following Git Hub page:

GVradar on GitHub (https://github.com/jlpippitt/GVradar)

Please contact author with any questions:

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DISCLOSURES

We would like to thank the GPM Wallops Precipitation Research Facility engineers (Mike Watson, Gary King, Carl Schirtzinger, Brian Lowe) and technician staff for installing, calibrating, and maintaining ground precipitation platforms. This research is funded by Dr. Scott Braun (NASA GPM Project Scientist).

ABSTRACT

The science community's progression toward Python as a primary programing language, facilitated NASA's Global Precipitation Measurement (GPM) Ground Validation (GV) Program to develop a Python-based radar processing system, GVradar. GVradar consists of two modules: Dual-Polarimetric Quality Control (DPQC) and dual-polarimetric precipitation product generation (dp_products). Both modules take full advantage of the open-source Python Atmospheric Radiation Measurement (ARM) Radar Toolkit (Py-ART) and Colorado State University's Radar Tools (CSU Radar Tools). Within DPQC, parameter threshold gate filters are utilized to identify and remove non-precipitating echoes based on freezing level, beam height, or by user defined sector. Additional DPQC capabilities include unfolding of Differential Phase (Φdp), Specific Differential Phase (Kdp) retrieval, velocity de-aliasing, and application of calibration offsets. Precipitation products generated with CSU Radar Tools include HIDRO Rain Rate (RC) and Hydrometeor Identification (FH). Additional products include GPM-GV's mass weighted mean diameter (D_m) and normalized intercept parameter (N_w). D_m and N_w retrievals were computed from empirical equations using disdrometer derived Zdr data obtained during GPM field experiments. The recommended method of executing GVradar is to use a user designated parameter dictionary, however the code will run with default settings. The use of a dictionary allows the user to optimize QC thresholds, specify fields to generate, and select output and plotting options. The ability of GVradar to retrieve sounding data from the Rapid Refresh (RAP) model allows DPQC to be applied and dp_products to be generated in near real-time. NASA's Dual Polarimetric (NPOL) radar is currently using GVradar to display data in near real-time. GPM-GV developed GVradar as a user-friendly open-source radar processing tool that is freely available to the scientific community.

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Ryzhkov, A. V., and D. S. Zrnić, 1998: Polarimetric rainfall estimation in the presence of anomalous propagation. J. Atmos. Oceanic Technol., 15, 1320–1330, https://doi.org/10.1175/1520-0426(1998)015<1320:PREITP>2.0.CO;2 (https://doi.org/10.1175/1520-0426(1998)015%3C1320:PREITP%3E2.0.CO;2).