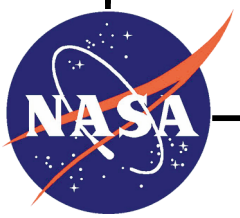
Global Precipitation Mission (GPM)
Ground Validation System
Level 3 Requirements

DRAFT
July 28, 2006

Goddard Space Flight Center
Greenbelt, Maryland 20771



CM FOREWORD

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1. GVS Overview

1.1 Background and Purpose

This specification defines the Level 3 functional and performance requirements for NASA's Global Precipitation Measurement (GPM) mission Ground Validation System (GVS). Overall, the GPM mission has defined a series of scientific objectives which include improvement in predicting terrestrial weather, climate, and hydrometeorology through a better observational understanding of the global water cycle. The purpose of the GPM GVS is rooted in the need for independent and objective evaluation of the precipitation products generated by the GPM mission. For its part, the GVS provides an independent means of evaluation, diagnosis, and ultimately improvement of the GPM spaceborne measurements and precipitation retrievals. These goals are more completely defined as follows:

- Evaluation—Quantify the uncertainties in GPM standard precipitation retrieval algorithms
- Diagnosis—Understand the time and space error characteristics of GPM precipitation products generated by these algorithms, and
- Improvement—Contribute to the improvement of GPM precipitation retrieval algorithms throughout the mission.

Achieving these goals is seen as a necessary step for improved GPM data products and for increased utilization of these products in Global Climate Models (GCMs), Numerical Weather Prediction (NWP) models, and hydrometeorological models for climate and weather forecasting.

1.2 Document Scope

This document sets forth requirements for NASA's GPM GVS including necessary ground validation measurement, data ingest, processing, archiving, and distribution. The entire mission timeline is covered: from pre-launch to the end of the required GPM core and constellation satellite missions.

The structure and functional breakdown of this document are used to organize the requirements only, and should not be interpreted as a physical architecture or allocation. Physical attributes and implementation approaches of the GVS are intentionally omitted from this document.

The GVS requirements presented in this document are traceable to the NASA GPM Level 2 Requirements (see Section 11).

1.3 GVS Definition

The Global Precipitation Measurement (GPM) mission is a partnership between the National Aeronautics and Space Administration (NASA) and the Japanese Aerospace Exploration Agency (JAXA). NASA's Goddard Space Flight Center (GSFC) has the lead management responsibility for GPM mission. The GPM mission definition includes the following elements:

- GPM core satellite carrying the JAXA-provided Dual-frequency Precipitation Radar (DPR) and a NASA-provided, passive GPM microwave imager (GMI)
- A GMI instrument intended for flight on a "constellation" satellite provided by a partner to be determined
- A Precipitation Processing System (PPS) to generate near-real-time precipitation products and a final time series of global precipitation measurements
- A Mission Operations System for the operation of the NASA-provided spacecraft
- A Ground Validation System (GVS), consisting of several system elements employed in the independent validation of the instruments on the GPM core satellite and the associated data products generated from them.

The high-level roles within the GPM mission, and the GVS portions of them, are illustrated in Figure 1-1.

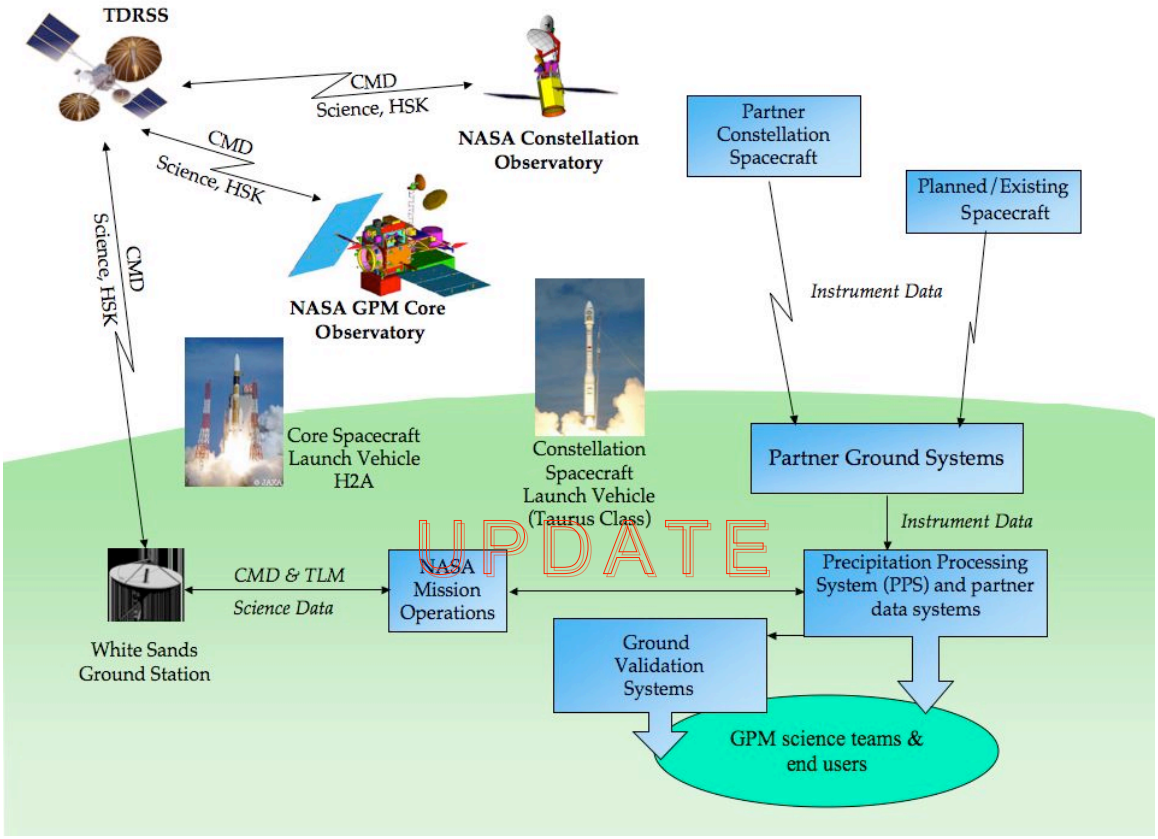

Figure 1-1. GPM Mission Architecture

In meeting its responsibilities, the GVS performs 5 main functions:

- Measurement of atmospheric variables at field sites and associated product generation
- Comparison of satellite and ground measurements

- Modeling of atmospheric fields, simulation of satellite measurements, and retrieval from the simulated data
- Archive and distribution of ground validation products and reports
- Metrics database administration for GPM management analysis of GVS performance.

The operational data flow within the GVS is shown below in Figure 1-2. The requirements associated with the main functions of the GVS are presented in Sections 4 through 8 of this document.

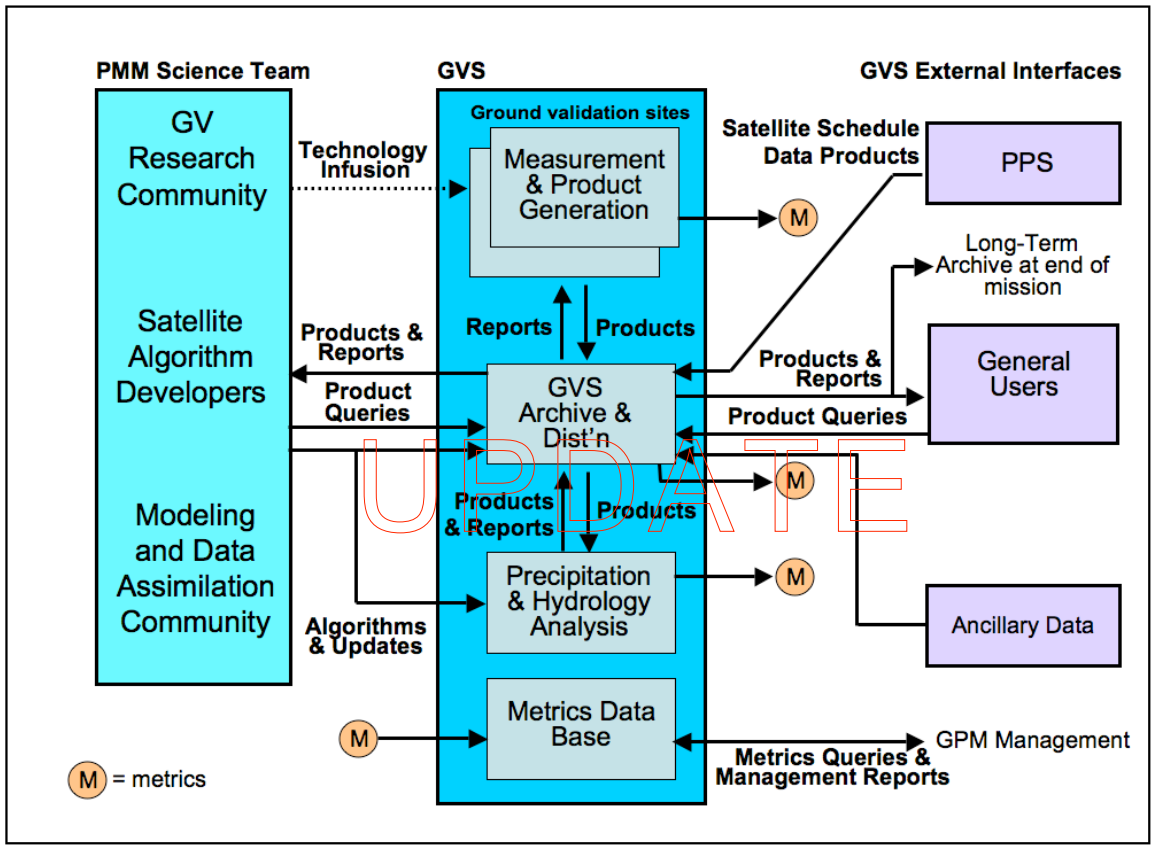

Figure 1-2 GVS Operational Data Flow

1.4 Applicable Documents

The following is considered the controlling documents for this specification:

- NASA GPM Project Level 1 Requirements.
- NASA Global Precipitation Measurement (GPM) Mission (L2) Requirements Document (420.2-REQS-013001A).

1.5 Document Organization

Section 1 of this document provides introduction and background information on the GVS, including an overview of the GVS and its operations. Section 2 defines the overall

GVS requirements. Section 3 defines GVS requirements in the context of external entities and interfaces. Sections 4-8 define requirements for each major functional element of the GVS. Section 9 defines requirements that are specific to the pre-launch and post-launch operational phases of the GVS.

2. GVS Overall Requirements

2.1 General Requirements

GVS0100 **Ready for operations**
The GVS shall be ready for operations at least 6 months prior to the projected launch of the GPM core satellite.

GVS0105 **Operations lifetime**
The GVS shall operate for the minimum required lifetime of the GPM Core and Constellation Satellites.

GVS0110 **Nominal operations**
The GVS shall nominally operate on a 5-day per week, 8-hour per day work schedule, with unattended operations after hours and during holidays.

GVS0112 **Check validity of data received**
The GVS shall check the validity of all data received.

GVS0113 **Check validity of data distributed**
The GVS shall check the validity of all data distributed.

GVS0115 **Observe MAR, NPGs, and GPGs**
The GVS shall observe all applicable NASA/GSFC Mission Assurance Requirements (MAR), NASA Program Requirements (NPRs) and Goddard Project Requirements (GPRs).

GVS0117 **Secure data rights**
The GVS shall secure rights for all data products, reports, documentation and computer code that it makes available for archive and distribution.

GVS0118 **Mange data policies and procedures**
The GVS shall document, archive and distribute its data policies and procedures.

GVS0120 **Conduct pre-operational testing**
The GVS shall support pre-operational testing.

GVS0125 **Conduct maintenance and sustaining engineering**
The GVS shall conduct maintenance and sustaining engineering throughout the period of GVS operations.

GVS0130 **Conduct configuration management**
The GVS shall maintain configuration control, at a minimum over

a. Internal systems and software
b. Data holdings, including products, reports, documentation and computer code
c. External interfaces.

GVS0135 **Safety**
The GVS shall ensure the safety of all system elements and personnel.

2.2 Major GVS Functions

GVS0200 **Conduct Field Measurement and Product Generation (FMPG)**
The GVS shall implement a MPG function to make atmospheric measurements using ground-based instrumentation within view of the NASA GPM core satellite. [Note: see Section 4 for MPG requirements].

GVS250 **Implement Validation Network**
The GVS shall implement a validation network to compare passive microwave and radar satellite data to ground measurements.

GVS0300 **Implement Satellite Simulator Model (SSM)**
The GVS shall implement a SSM function to conduct cross-comparison of ground-based measurements with GPM core and constellation satellite retrieval results.

GVS0400 **Conduct Archive and Distribution (A&D)**
The GVS shall implement an A&D function. [Note: see Section 5 for A&D requirements].

GVS0500 **Implement Metrics Database (MD)**
The GVS shall implement a MD function to manage GVS-related statistics and performance information.

3. GVS Interface Requirements (TBD-49)

GVS0XXX **Interface to PMM Science Team**
The GVS shall...

GVS0XXX **Interface to PPS**
The GVS shall...

GVS0XXX **Interface to General Users**
The GVS shall...

GVS0XXX **Interface to GPM Management**
The GVS shall...

GVS0XXX **Interface to Ancillary Data Providers**
The GVS shall...

GVS0XXX **Interface to Long-Term Archive**
The GVS shall...

4. Field Measurement and Product Generation (FMPG) Requirements

4.1 Overall requirements

GVS0205 **MPG deploy instrumentation capability**
The FMPG shall implement a Deploy Instrumentation capability at NASA ground validation sites for the purpose of making atmospheric measurements.

GVS0210 **MPG generate atmospheric products capability**
The FMPG shall implement a Generate Atmospheric Products capability. The FMPG Generate Atmospheric Products capability shall

a. process ground instrument measurements into products defined Sections 4.3–4.11.

b. Generate documentation for all FMPG products.

GVS0215 **MPG calibration/validation capability**
The FMPG shall implement a Calibration/Validation capability. The FMPG Calibration/Validation capability shall, at a minimum

a. trace the calibration of all ground instrument measurements to a defined standard

b. validate all ground instrument products by comparison with independent observations or proxy measurements

GVS0220 **MPG metrics capability**
The FMPG shall implement a Metrics capability. The FMPG Metrics capability shall, at a minimum, monitor and record

a. ground instrument outage and/or malfunction

b. instrument noise

c. instrument drift

d. instrument spatial accuracy and precision

e. instrument temporal accuracy and precision

f. the quality of all data received from external interfaces

g. process metrics (including error characteristics) for each FMPG product

GVS0225 **MPG local archive capability**
The FMPG shall implement a local archive capability. The FMPG local archive capability shall

a. maintain the integrity of all data collected

b. manage multiple versions of the same data.

GVS0240 **MPG updated instruments and methods**
The FMPG shall permit the introduction of additional or updated instruments and methods.

GVS0245 **MPG product generation time-line**
The FMPG shall generate products within 24 hours of receipt of required input data during nominal operations.

GVS0250 **MPG product distribution time-line**
The FMPG shall make products (including Metrics products) available for distribution within 24 hours of generation during nominal operations.

4.2 FMPG Interface Requirements

GVS0260 **MPG receipt of core spacecraft planning and scheduling data**
The FMPG shall receive GPM core spacecraft planning and scheduling data from the PPS according to the PPS–defined interface.

GVS0265 **MPG receipt of constellation spacecraft planning and scheduling data**
The FMPG shall receive GPM constellation spacecraft planning and scheduling data, and data product subsets, from the PPS according to the PPS-defined interface.

GVS0270 **MPG distribution of metrics data**
The FMPG shall distribute metrics to the Metrics Database.

GVS0275 **MPG distribution of data and data products**
The FMPG shall distribute data and data products to A&D function.

4.3 Product Generation Requirements

4.3.1 Derived Products: products that are interpolated in time or space and/or are based on additional assumptions

GVS-1.05 **X-band scanning radar product Cartesian grid**
The GVS shall generate X-band radar products (defined below) interpolated from polar coordinates to a 3-dimensional Cartesian grid with, at a minimum, the following characteristics:

a. Cartesian grid center located at the X-band scanning radar
b. Cartesian grid extending 30 km in the X,Y (east-west ,north-south) direction from the location of the radar
c. Cartesian grid extending in the Z (vertical) direction from 0.5-18km above ground level
d. Resolution of the Cartesian grid in all dimensions not to exceed the actual radar beam resolution at maximum horizontal range.

Rationale: X-band radar components need to be mapped to a Cartesian grid, since the original polar-coordinate product data are incompatible with requirements for use of the data. The 3-D Cartesian gridded data will be used as input to Satellite Simulation Models (SSM), for validation of Cloud Resolving Models (CRM), and to evaluate the calibration and attenuation correction of the satellite-borne PR/DPR. The domain and resolution of the 3-D grid are driven by the X-band radar characteristics, sampling theory, and product usage.

GVS-1.10 **S-band scanning radar product Cartesian grid**

The GVS shall generate S-band radar products (defined below) interpolated from polar coordinates to a 3-dimensional Cartesian grid with, at a minimum, the following characteristics:

a. Cartesian grid center located at the X-band scanning radar

b. Cartesian grid extending 60 km in the X,Y (east-west ,north-south) direction from the location of the radar

c. Cartesian grid extending in the Z (vertical) direction from 0.5-18km above ground level

d. Resolution of the Cartesian grid in all dimensions not to exceed the actual radar beam resolution at maximum horizontal range.

Rationale: As in GVS-1.10, but for S-band radar.

GVS-1.15 **X-band re-sampled equivalent reflectivity factor product**

The GVS X-band scanning radar shall generate a resampled horizontal and vertical equivalent reflectivity factor (rZ_h and rZ_v in dB) product with, at a minimum, the following characteristics:

a. The rZ_h and rZ_v product shall be resampled to the Cartesian grid defined in Requirement GVS-1.10 for each PPI-volume scan of radar data

b. The rZ_h and rZ_v product shall have an accuracy of 2.0 dB or better for any grid element in the entire resampled radar scan volume.

Rationale: See GVS-1.10. Primarily, X-band reflectivity will be compared to satellite radar reflectivity on a common grid to validate the calibration of each instrument and the effectiveness of the PR/DPR attenuation corrections. It will also be used in computation of rain rates using the traditional Z-R as well as polarimetric relationships. 2 dB is the minimum accuracy required for these purposes.

GVS 1.20 **X-band re-sampled differential reflectivity product**

The GVS X-band scanning radar shall generate a resampled differential reflectivity factor (rZ_{dr} in dB) product with, at a minimum, the following characteristics:

a. The rZ_{dr} product shall be resampled to the Cartesian grid defined in Requirement GVS-1.10 for each PPI-volume scan of radar data.

b. The rZ_{dr} product shall have an accuracy of 0.4 dB or better for any grid element in the entire resampled radar scan volume.

Rationale: See GVS-1.10. Differential reflectivity is needed to estimate Drop Size Distributions, detect the presence of hail, and estimate rainfall using polarimetric parameters.

GVS-1.25 X-band scanning radar specific differential phase product

The GVS X-band scanning radar generate a differential phase (K_{dp} in degrees/km) product with, at a minimum, the following characteristics:

a. The K_{dp} product shall be measured in polar coordinates with an accuracy of 0.3 degrees/km or better over a minimum distance of 3 km for any measurement in the entire radar scan volume where reliable differential propagation phase measurements can be obtained

b. The K_{dp} product shall be generated in polar coordinates re-sampled to the Cartesian grid specified in requirement GVS-1.10.

Rationale: See GVS-1.10. Differential phase is needed to estimate rainfall intensity and accumulation, especially in the presence of hail. It is highly immune to radar calibration errors and partial beam blockage

GVS-1.30 S-band re-sampled equivalent reflectivity factor product

The GVS S-band scanning radar shall generate a resampled horizontal and vertical equivalent reflectivity factor (rZ_h and rZ_v in dB) product with, at a minimum, the following characteristics:

a. The rZ_h and rZ_v product shall be resampled to the Cartesian grid defined in Requirement GVS-1.15 for each PPI-volume scan of radar data

b. The rZ_h and rZ_v product accuracy shall be 2.0 dB or better for any grid element in the entire resampled radar scan volume.

Rationale: See GVS 1.15.

GVS-1.35 S-band re-sampled differential reflectivity product

The GVS S-band scanning radar shall generate a resampled differential reflectivity factor (rZ_{dr} in dB)) product with, at a minimum, the following characteristics:

a. The rZ_{dr} product shall be resampled to the Cartesian grid defined in Requirement GVS-1.15 for each PPI-volume scan of radar data

b. The rZ_{dr} product accuracy shall be 0.4 dB or better for any grid element in the entire radar scan volume.

Rationale: See GVS-1.20.

GVS-1.40 S-band scanning radar specific differential phase product

The GVS S-band scanning radar shall generate a specific differential phase (K_{dp} in degrees/km) data product with, at a minimum, the following characteristics:

a. The K_{dp} product shall be generated in polar coordinates with an accuracy of 0.3 degrees/km or better over a minimum distance of 3 km for any measurement in the entire radar scan volume where reliable differential propagation phase measurements can be obtained

b. The K_{dp} product shall also be generated in polar coordinates re-sampled to the Cartesian grid specified in requirement GVS-1.15.

Rationale: See GVS-1.25.

GVS-1.45 Microwave Profiling Radiometer liquid water content product

The GVS shall generate a vertical profile of atmospheric liquid water content product (in gm/m^3) with, at a minimum, the following characteristics:

a. the liquid water content product shall have a vertical resolution of ≤1 km below a height of 2km AGL and TBD-17 km above a height of 2 km AGL

b. the liquid water content product shall have temporal resolution of ≤ 15 minutes

c. the liquid water content product shall have an accuracy of TBD-1.

Rationale: Vertical profiles of atmospheric liquid water are needed as input to and validation of SSMs, and for validation and initiation of Cloud-system Resolving Models (CRMs). These data will supplement moisture profiles collected by upper air soundings. Accuracies are based on the instrument measurement requirements. Temporal resolution is the minimum required to provide a representative measurement in changing atmospheric conditions.

GVS-1.50 Scanning radar hydrometeor identification product

The GVS shall generate a hydrometeor type product with, at a minimum, the following characteristics:

a. The hydrometeor type product shall generate estimates of the most likely hydrometeor types sampled to a 3-dimensional grid with a horizontal resolution not to exceed the actual radar beam resolution for each PPI-volume scan of radar data

b. The hydrometeor type product shall classify hydrometeors into at least the following types: light rain, moderate rain, heavy rain, rain mixed with precipitation-sized ice, and precipitation-sized ice only (warm season) and low density snow, high density snow, and mixed precipitation (cold season).

Rationale: Knowledge of actual hydrometeor types is needed to model and validate microwave precipitation retrievals and CRM microphysics, and improve active radar attenuation algorithms.

GVS-1.55 Scanning radar median drop diameter product

The GVS shall generate a median drop diameter D_0 product (in mm) with, at a minimum, the following characteristics:

a. The D_0 product shall be sampled to a 3-dimensional grid with a horizontal resolution not to exceed the actual radar beam resolution for each PPI-volume scan of radar data

b. The D_0 product shall have an accuracy of $\leq$0.2 mm.

Rationale: See GVS-1.20 and 1.35. GVS-1.55, 1.60, and 1.65 are related and interdependent. D_0 in combination with number concentration of liquid droplets (GVS-1.65) is needed to make accurate determination of rain rates from radar and to compute attenuation estimates.

GVS-1.60 Scanning radar instantaneous rain rate product

The GVS shall generate a rain intensity product (in mm/hr) with, at a minimum, the following characteristics:

a. The rain intensity product shall be sampled to a 3-dimensional grid with a horizontal resolution not to exceed the actual radar beam resolution for each PPI-volume scan of radar data

b. The rain intensity product shall have an accuracy of ±20%.

Rationale: See GVS-1.55. Rain rate is the primary measured element to be validated in GPM. Rain rate estimates from scanning radar will be one of the validating measurements.

GVS-1.65 Scanning radar number concentration – liquid product

The GVS shall generate a drop number concentration product that estimates of the number of liquid water drops per volume (in m^{-3}) with, at a minimum, the following characteristics:

a. The drop number concentration product shall be sampled to a 3-dimensional grid with a horizontal resolution not to exceed the actual radar beam resolution for each PPI-volume scan of radar data

b. The drop number concentration product shall have an accuracy TBD-2.

Rationale: See GVS-1.55

GVS-1.70 **S and UHF band profiler pair median particle diameter product**
The GVS shall generate a vertical profile of median particle diameter product (in mm) with, at a minimum, the following characteristics:

a. The median particle diameter product shall have a height resolution of TBD-3, starting at TBD-3 and extending to TBD-3

b. The median particle diameter product profiles shall be generated from all available profiler data where reliable estimates can be derived

c. The median particle diameter product shall have an accuracy of TBD-4.

Rationale: The raindrop size distribution can be described by a Gamma function with three parameters: median particle diameter (GVS-1.70), particle concentration (GVS-1.75), and Gamma shape parameter (GVS-180). Using the assumed Gamma function, the DSD can be retrieved from the profiler pair data. Profiler DSD estimates also provide provides an independent measurement directly comparable to GVS-1.55, with a greater height resolution to match with PR and DPR measurements.

GVS-1.75 **S and UHF band profiler pair particle concentration product**
The GVS shall generate a vertical profile of particle concentration product (in m^{-3}) with, at a minimum, the following characteristics:

a. The particle concentration product shall have a height resolution of TBD-5, starting at TBD-5and extending to TBD-5

b. The particle concentration product profiles shall be generated from all available profiler data where reliable estimates can be derived

c. The particle concentration product shall have an accuracy of TBD-6.

Rationale: The raindrop size distribution can be described by a Gamma function with three parameters: median particle diameter (GVS-1.70), particle concentration (GVS-1.75), and Gamma shape parameter (GVS-180). Using the assumed Gamma function, the DSD can be retrieved from the profiler pair data. Profiler DSD estimates also provide provides an independent measurement directly comparable to GVS-1.65, with a greater height resolution necessary to match with PR and DPR measurements.

GVS-1.80 **S and UHF band profiler pair shape parameter product**
The GVS shall generate a vertical profile of a Gamma shape parameter product (in units TBD-7) with, at a minimum, the following characteristics:

a. The Gamma shape parameter product shall have a vertical resolution of TBD-8, starting at TBD-8 and extending to TBD-8

b. The Gamma shape parameter product shall be generated from all available profiler data where reliable estimates can be derived

c. The Gamma shape parameter product shall have an accuracy of TBD-9.

Rationale: The raindrop size distribution can be described by a Gamma function with three parameters: median particle diameter (GVS-1.70), particle concentration (GVS-1.75), and Gamma shape parameter (GVS-180). Using the assumed Gamma function, the DSD can be retrieved from the profiler pair data. Profiler DSD estimates also can help validate precipitation type estimates from scanning radar (GVS-1.60), as well as from PR/DPR.

GVS-1.82 S and UHF band profiler pair vertical air motion product

The GVS shall generate a vertical profile of vertical air motion product (in units m/s) with, at a minimum, the following characteristics:

a. The vertical air motion product shall have a vertical resolution of TBD-23, starting at TBD-23 and extending to TBD-23

b. The vertical air motion product shall be generated from all available profiler data where reliable estimates can be derived

c. The vertical air motion product shall have an accuracy of TBD-24.

Rationale: The rain rate is the mass flux of water passing a reference plane, and the air motion increases or decreases the total mass flux. Air motion can also be used for validation of CRM simulations.

GVS-1.85 Disdrometer particle diameter product

The GVS shall generate a median particle diameter product (in mm) with a temporal resolution of TBD-10 minutes.

Rationale: Disdrometer median particle diameter estimates are needed to provide ground truth measurements for GVS-1.55 and GVS-1.70 and to determine the validity of the Z-R relationships for the active radars.

GVS-1.90 Disdrometer number concentration product

The GVS shall generate a particle concentration product (in number of drops/m^3) with a temporal resolution of TBD-10 minutes.

Rationale: As in GVS-1.85, but for particle number concentrations (GVS-1.65 and 1.75).

GVS-1.95 Disdrometer rain rate product

The GVS shall generate a precipitation rate product (in mm/hr) with a temporal resolution of TBD-10 minutes.

Rationale: As in GVS-1.85. Needed to provide ground truth for GVS-1.60.

GVS-1.100 Disdrometer radar reflectivity product

The GVS shall generate a radar reflectivity product (in dBZ) with a temporal resolution of TBD-10 minutes.

Rationale: Provides ground truth for GVS-1.15/1.120 and 1.30/1.155. Requires GVS-1.85 and 1.90 as inputs.

GVS-1.105 Rain gauge rain rate product

The GVS shall generate a rain gauge precipitation rate product (in mm/hr) with a temporal resolution of TBD-11 minutes.

Rationale: Rain gauge rain rate is needed to validate the remotely-sensed (GVS-1.60) and in-situ derived (GVS-1.95) rain rate estimates, as well as those from the TMI/GMI and PR/DPR.

GVS-1.110 Profiling microwave radiometer temperature profiles product

The GVS shall generate a product consisting of vertical profiles of temperature (in K) with, at a minimum, the following characteristics:

a. The vertical profile of temperature product shall have a vertical resolution of TBD-12, starting at ground level to 10km AGL

b. The vertical profile of temperature product shall have temporal resolution of TBD-13 minutes.

c. The vertical profile of temperature product shall have an accuracy of TBD-14.

Rationale: CRM validation and a supplement to temperature profiles provided by upper air soundings.

GVS-1.115 Profiling microwave radiometer water vapor concentration profiles product

The GVS shall generate a product consisting of vertical profiles of water vapor concentration (in g/m^3) with, at a minimum, the following characteristics:

a. The vertical profile of water vapor concentration product shall estimate water vapor concentration from ground level to 10km AGL

b. The vertical profile of water vapor concentration product shall have a temporal resolution of TBD-15

c. The vertical profile of water vapor concentration product shall have an accuracy of TBD-16.

Rationale: CRM validation and a supplement to temperature profiles provided by upper air soundings.

4.3.2 Measured Products: products generated in the native coordinates of the instrument with no interpolation in time or space

GVS-1.120 **X-band scanning radar equivalent reflectivity factor product**
The GVS X-band scanning radar shall generate a calibrated horizontal and vertical equivalent reflectivity factor (Z_h and Z_v) product (in dB) to an accuracy of ≤1.0 dB for measurements at all ranges and elevations, independent of any attenuation correction.

Rationale: An accuracy of 1.0 dBZ is necessary to provide sufficient accuracy of the rain rate derived from reflectivity, and to match the reflectivity accuracy requirements of the GPM DPR.

GVS-1.125 **X-band scanning radar differential reflectivity product**
The GVS X-band scanning radar shall generate a calibrated differential reflectivity (Z_{dr}) product (in dB) with an accuracy ≤ 0.2 dB independent of any attenuation correction.

Rationale: As in GVS-1.20, but in the native range, azimuth coordinates of the radar.

GVS-1.130 **X-band scanning radar differential propagation phase product**
The GVS X-band scanning radar shall generate a differential propagation phase (Φ_{dp} in degrees) product with an accuracy of ≤3.0 degrees for any measurement in the entire radar scan volume where the radar signal has not been completely attenuated.

Rationale: As in GVS-1.25, but in the native range, azimuth coordinates of the radar. Differential propagation is also used to eliminate ground clutter from the scan.

GVS-1.135 **X-band scanning radar co-polar correlation coefficient product**
The GVS X-band scanning radar shall generate a correlation coefficient product (unitless) of the horizontal and vertical return signal (ρ_{hv}) with an accuracy of ≤0.005 for any measurement in the entire radar scan volume.

Rationale: The correlation coefficient is needed in concert with other measured and derived parameters to help distinguish between precipitation types and to help eliminate ground clutter.

GVS-1.140 **X-band scanning radar linear depolarization ratio product (optional)**
The GVS X-band scanning radar shall generate a linear depolarization ratio (LDR) product (in dB) to an accuracy of ≤1.0 dB (when averaged over distances of 1 km) for both horizontal transmit/vertical receive and vertical transmit/horizontal receive conditions for any measurement in the entire radar scan volume.

Note: the default mode of data collection for the GVS X-band scanning radar will be simultaneous transmission and simultaneous reception (STSR) and depolarization information will not be collected. As required, the GVS X-band scanning radar shall operate in a mode capable of measuring the depolarization ratio (e.g., simultaneous transmit alternate reception – STAR mode).

Rationale: LDR is a good indicator of regions where a mixture of precipitation types occur and can be used as a hydrometeor identification discriminator.

GVS-1.145 X-band scanning radar Doppler radial velocity product

The GVS X-band scanning radar shall generate a Doppler radial velocity product (in m/sec) with an accuracy of +/- 1 m/sec for any measurement in the entire radar scan volume.

Rationale: Single or multiple Doppler wind retrievals will be used to validate CRM kinematic structure.

GVS-1.150 S-band scanning radar equivalent reflectivity factor product

The GVS S-band scanning radar shall generate a horizontal and vertical equivalent reflectivity factor (Z_h and Z_v) product (in dB) with an accuracy of ≤1.0 dB for any measurement in the entire radar scan volume, independent of any attenuation correction.

Rationale: See GVS-1.120.

GVS-1.155 S-band scanning radar differential reflectivity product

The GVS S-band scanning radar shall measure differential reflectivity factor (Z_{dr}) product (in dB) with an accuracy of ≤0.2 dB for any measurement in the entire radar scan volume, independent of any attenuation correction.

Rationale: As in GVS-1.125, but for S-band radar.

GVS-1.160 S-band scanning radar differential propagation phase product

The GVS S-band scanning radar shall measure differential propagation phase (Φ_{dp} in degrees) product with an accuracy of ≤3.0 degrees for any measurement in the entire radar scan volume where the radar signal has not been completely attenuated.

Rationale: As in GVS-1.130, but for S-band radar.

GVS-1.165 S-band scanning radar horizontal-vertical correlation coefficient product

The GVS S-band scanning radar shall generate a correlation coefficient product (unitless) of the horizontal and vertical return signal (ρ_{hv}) for periods of arbitrary length with an accuracy of ≤0.005 for any measurement in the entire radar scan volume.

Rationale: As in GVS-1.135, but for S-band radar.

GVS-1.170 **S-band scanning radar linear depolarization ratio product (optional)**

The GVS S-band scanning radar shall generate a linear depolarization ratio (LDR) product (in dB) to an accuracy of ≤1.0 dB (when averaged over distances of 1 km) for both horizontal transmit/vertical receive and vertical transmit/horizontal receive conditions for any measurement in the entire radar scan volume.

Note: the default mode of data collection for the GVS S-band scanning radar will be simultaneous transmission and simultaneous reception (STSR) and depolarization information will not be collected. As required, the GVS S-band scanning radar shall operate in a mode capable of measuring the depolarization ratio (e.g., simultaneous transmit alternate reception – STAR mode).

Rationale: LDR is a good indicator of regions where a mixture of precipitation types occur and can be used as a hydrometeor identification discriminator.

GVS-1.175 **S-band scanning radar Doppler radial velocity product**

The GVS S-band scanning radar shall generate a Doppler radial velocity product (in m/sec) with an accuracy of +/- 1 m/sec for any measurement in the entire radar scan volume.

Rationale: Single or multiple Doppler wind retrievals will be used to validate CRM kinematic structure.

GVS-1.180 **S-band profiler Doppler spectra product**

The GVS S-band profiler shall generate a Doppler spectra product consisting of relative received power at each Doppler velocity bin.

Rationale: TBD-34

GVS-1.182 **S-band profiler spectral moments product**

The GVS S-band profiler shall generate a spectral moments product consisting of the mean reflectivity, mean reflectivity-weighted Doppler velocity, and velocity variance at each radar range gate.

Rationale: TBD-34

GVS-1.185 **UHF profiler Doppler spectra product**

The GVS UHF profiler shall generate a Doppler spectra product consisting of relative received power at each Doppler velocity bin.

Rationale: TBD-34

GVS-1.186 **UHF profiler precipitation spectral moments product**

The GVS UHF profiler shall generate a spectral moments product consisting of the mean reflectivity, mean reflectivity-weighted Doppler velocity, and velocity variance at each radar range gate.

Rationale: The three velocity parameters are needed to generate the vertical air motion product (see GVS-1.187).

GVS-1.187 **UHF profiler vertical air motion product**
The GVS UHF profiler shall generate an air motion product consisting of a Gaussian shaped function defined with the three parameters of amplitude, mean air motion velocity, and velocity variance at each radar range gate.

Rationale: Vertical air motion from the UHF profiler helps discriminate precipitation type, identify the bright band location, and improve rain rate estimation.

4.4 Instrument Measurement Requirements: X-band scanning radar

GVS-2.05 **X-band scanning radar center frequency**
The GVS X-band scanning radar shall have a center frequency of 9.4 GHz.

Rationale: 9.4 GHz is a nominal center frequency for an X-band radar.

GVS-2.10 **X-band scanning radar minimum and maximum elevation**
The GVS X-band scanning radar shall have a range of elevation look angles from -0.5° to 90°.

Rationale: The stated elevation range is required for the X-band radar to scan, as near as practical, a full 3-D volume to meet requirement GVS-1.05.

GVS-2.15 **X-band scanning radar minimum and maximum range**
The GVS X-band scanning radar shall have a minimum operational range of ≤0.5 km and a maximum operational range of ≥75 km.

Rationale: The stated ranges are required for the X-band radar to scan, as near as practical, a full 3-D volume to meet requirement GVS-1.05, and a hydrologic basin of sufficient size for GPM GV purposes.

GVS-2.20 **X-band scanning radar elevation pointing accuracy**
The GVS X-band scanning radar shall have an elevation pointing accuracy of ≤0.2 degrees.

Rationale: This is a nominal elevation pointing accuracy for a research quality scanning radar. It maintains a beam height error upper limit of ~250m at maximum range, which is the height resolution of the DPR.

GVS-2.25 **X-band scanning radar elevation pointing uncertainty**
The GVS X-band scanning radar shall have an elevation pointing uncertainty of <0.1 degree.

Rationale: See GVS-2.20.

GVS-2.30 **X-band scanning radar azimuth pointing accuracy**
The GVS X-band scanning radar shall have an azimuth pointing accuracy of ≤0.2 degrees.

Rationale: This is a nominal azimuthal pointing accuracy for a research quality scanning radar. It maintains a beam center error upper limit of ~250m at maximum range.

GVS-2.35 **X-band scanning radar azimuth pointing uncertainty**
The GVS X-band scanning radar shall have an azimuth pointing uncertainty of <0.1 degree.

Rationale: See GVS-2.30.

GVS-2.40 **X-band scanning radar range resolution**
The GVS X-band scanning radar shall have a minimum range resolution of ≤50 m for all gates within the minimum and maximum range.

Rationale: The radar data must have sufficient resolution to provide meaningful information on the spatial variability of rainfall and other products.

GVS-2.45 **X-band scanning radar horizontal/vertical resolution**
The GVS X-band scanning radar shall have a half-power beam width of ≤1 degree.

Rationale: This is a nominal beam width for a research quality scanning radar.

GVS-2.50 **X-band scanning radar calibration stability**
The GVS X-band scanning radar shall maintain a Z_h calibration within +/-2 dB.

Rationale: The GVS will have limited support for recalibration of field instrumentation, and precipitation events will occur at random, so the X-band radar needs stable calibration precision. 2 dBZ is the maximum allowable drift to give meaningful reflectivity intercomparisons with PR/DPR and compute rain rates from the ground radar.

GVS-2.55 **X-band scanning radar scan rates**
The GVS X-band scanning radar shall provide a maximum azimuthal (elevation) scan rate of ≤ 36° (4°) sec^{-1}.

Rationale: These rates allow the X-band radar to be scan-synchronized with the S-band radar (or any WSR-88D unit).

GVS-2.60 **X-band scanning radar full volume scan time**
The GVS X-band scanning radar shall be capable of completing a full volume scan within 12 minutes.

Note: A full volume scan shall be defined as a sequence ≥ 2 full azimuth (360°) scans, with each azimuth scan taken at a different elevation between 0° and 90° of elevation.

Rationale: TBD-35

GVS-2.65 **Communications**
The GVS X-band scanning radar shall generate quick-look images at least every 15 minutes and these images will be available to other computers in the local network.

Note: These images will show low-level Plan Position Indicators (PPIs) of radar reflectivity, differential reflectivity, and specific differential phase.

Rationale: An image display generation capability is necessary to locally and remotely monitor the instrument data quality and for weather situational awareness in GV field operations.

4.5 Instrument Measurement Requirements: S-band scanning radar

GVS-3.05 **S-band scanning radar center frequency**
The GVS S-band scanning radar shall have a center frequency of in the range of 2.7 GHz to 2.9 GHz.

Rationale: 2.7-2.9 GHz spans the nominal center frequency range for an S-band radar and the exact frequency must be selected to not interfere with the WSR-88D network radars, assuming the GVS S-band radar itself is not one or more of the WSR-88D systems.

GVS-3.10 **S-band scanning radar minimum and maximum range**
The GVS S-band scanning radar shall have a minimum operational range of ≤1 km and a maximum operational range of ≥150 km.

Rationale: The stated ranges are required for the S-band radar to scan, as near as practical, a full 3-D volume to meet requirement GVS-1.05, and a hydrologic basin of sufficient size for GPM GV purposes.

GVS-3.15 **S-band scanning radar minimum and maximum elevation**
The GVS S-band scanning radar shall have a range of elevation look angles from -0.5° to 90°.

Rationale: The stated elevation range is required for the S-band radar to scan, as near as practical, a full 3-D volume to meet requirement GVS-1.10.

GVS-3.20 **S-band scanning radar range resolution**
The GVS S-band scanning radar shall have a range resolution of ≤75 m for all gates within the minimum and maximum range.

Rationale: The radar data must have sufficient resolution to provide meaningful information on the spatial variability of rainfall and other products.

GVS-3.25 **S-band scanning radar horizontal/vertical resolution**
The GVS S-band scanning radar shall have a half-power beam width of ≤1 degree.

Rationale: This is a nominal beam width for a research quality scanning weather radar and matches the NEXRAD specification.

GVS-3.30 **S-band scanning radar azimuth pointing accuracy**
The GVS S-band scanning radar shall have an azimuth pointing accuracy of ≤0.2 degrees.

Rationale: This is a nominal azimuthal pointing accuracy for a research quality scanning radar. It maintains a beam center error upper limit of ~500 m at maximum range.

GVS-3.35 **S-band scanning radar azimuth pointing uncertainty**
The GVS S-band scanning radar shall have an azimuth pointing uncertainty of <0.1 degree.

Rationale: See GVS-3.30.

GVS-3.40 **S-band scanning radar elevation pointing accuracy**
The GVS S-band scanning radar shall have an elevation pointing accuracy of ≤0.2 degrees.

Rationale: This is a nominal elevation pointing accuracy for a research quality scanning radar. It maintains a beam height error upper limit of ~500 m at maximum range.

GVS-3.45 **S-band scanning radar elevation pointing uncertainty**
The GVS S-band scanning radar shall have an elevation pointing uncertainty of <0.1 degree.

Rationale: See GVS-3.40.

GVS-3.50 **S-band scanning radar calibration stability**
The GVS S-band scanning radar shall maintain a Z_h calibration within 2 dB.

Rationale: See GVS-2.50.

GVS-3.55 **S-band scanning radar full volume scan time**
The GVS S-band scanning radar shall be capable of completing a full volume scan within 12 minutes.

Note: A full volume scan shall be defined as a sequence ≥ 2 full azimuth (360°) scans, with each azimuth scan taken at a different elevation between 0° and 90° of elevation.

Rationale: See GVS-2.60.

GVS-3.60 **S-band scanning radar scan rates**
The GVS S-band scanning radar shall provide a maximum azimuthal (elevation) scan rate of ≤ 36° (4°) sec^{-1}.

Rationale: These rates allow the X-band radar to be scan-synchronized with the X-band radar (or any WSR-88D unit).

GVS-3.65 **Communications**
The GVS S-band scanning radar shall generate quick-look images at least every 15 minutes and these images will be available to other computers in the local network.

Note: These images will show low-level PPIs of radar reflectivity, differential reflectivity, and specific differential phase.

Rationale: An image display generation capability is necessary to locally and remotely monitor the instrument data quality and for weather situational awareness in GV field operations.

4.6 Instrument Measurement Requirements: S-Band Profiler

GVS-4.05 **S-band profiler center frequency**
The GVS S-band profiler shall operate at a fixed frequency in the 2700-2900 MHz radar band.

Rationale: 2700-2900 MHz spans the nominal center frequency range for an S-band radar and a fixed frequency must be selected to not interfere with the GVS S-band scanning radar or the WSR-88D network radars.

GVS-4.10 **S-band profiler bandwidth**
The GVS S-band profiler shall have a signal bandwidth matched to the transmitted pulse length.

Rationale: The returned power will vary with the transmitted pulse length and the bandwidth must be able to accommodate the dynamic range of the signal.

GVS-4.15 **S-band profiler minimum and maximum range**
The GVS S-band profiler shall measure at least 50 dBZ without saturating at a minimum range of 200 meters above the ground. The GVS S-band profiler shall collect observations up to 18 km above the ground.

Rationale: The GPM DPR will provide data coverage from the surface up to 18 km above ground, at 250m height resolution, with a 70 dB range. The S-band profiler must provide matching coverage within reasonable attenuation limits.

GVS-4.20 **S-band profiler antenna (beamwidth)**
The GVS S-band profiler shall have a fixed, vertically pointing antenna with a maximum half-power beamwidth of 2.5 degrees.

Rationale: 2.5 degrees is a nominal half-power beam width for an S-band profiler. It provides a spatial resolution of less than 1 km at maximum vertical range, which allows sub-bin comparisons with the X-band and S-band scanning radars and the DPR.

GVS-4.22 **S-band profiler antenna shroud**
The GVS S-band profiler shall have an antenna shroud.

Note: An antenna shroud greatly reduces the low-angle sidelobes of the antenna.

Rationale: An antenna shroud is needed to get the maximum performance and data quality from the profiler and gain flexibility in instrument location.

GVS-4.25 S-band profiler vertical resolution
The GVS S-band profiler shall have a minimum vertical resolution of 62 m.

Rationale: This resolution allows for good matching with the 125 meter resolution of the GPM DPR at Nadir.

GVS-4.35 S-band profiler minimum reflectivity sensitivity (dBZ)
The GVS S-band profiler shall measure a minimum return of ≤10 dBZ at a range of 10 km.

Rationale: 10 dBZ sensitivity places the S-band profiler below the minimum reflectivity threshold of the PR and DPR.

GVS-4.40 S-band profiler calibration stability
The GVS S-band profiler shall maintain a stable reflectivity accuracy of less than 1 dBZ.

Note: A Joss-Waldvogel Disdrometer (JWD), or its equivalent, will be provided as part of the S-Band profiler equipment to monitor calibration of the profiler. The JWD disdrometer data will be available for other uses, but its primary purpose will be to provide calibration information for the profiler.

Rationale: The GVS will have limited support for recalibration of field instrumentation, and precipitation events will occur at random, so the S-band profiling radar needs stable calibration precision. 1 dBZ matches the reflectivity calibration requirement for the PR/DPR.

GVS-4.45 S-band profiler unambiguous range
The GVS S-band profiler shall have a maximum unambiguous range greater than 18 km.

Rationale: The profiler should match the GPM DPR, which measures up to 18 km in altitude.

GVS-4.47 S-band profiler dwell time
The GVS S-band profiler shall dwell for less than 15 seconds.

Rationale: A complete profile of Doppler spectra and spectral moments will be recorded for each dwell period. These Doppler spectra are used to estimate the Gamma function DSD specified in requirements 1.70 through 1.82.

GVS-4.50 **S-band profiler Nyquist Doppler velocity and spectral resolution**
The GVS S-band profiler shall have a minimum Nyquist velocity ≥16 ms^{-1} and a maximum Doppler spectral resolution (Doppler velocity bin spacing) ≤0.15 ms^{-1}.

Rationale: An unambiguous velocity of 16 ms^{-1} allows fall speeds of all snow and rain, and of hail of up to 20 mm, to be measured in free air.

GVS-4.55 **S-band profiler access to spectra for real time analysis**
The GVS S-band profiler shall make the observed Doppler velocity spectra available for analysis within 15 minutes of the observation.

Rationale: A near-real-time product generation capability is necessary to locally and remotely monitor the instrument data quality and for weather situational awareness in GV field operations.

GVS-4.60 **S-band profiler local archive**
The GVS S-band profiler shall have a local storage capacity with a minimum capacity sufficient to store 30 days of continuous data.

Rationale: The GVS will not be staffed on a 24/7 schedule, and precipitation events will occur at random, so the S-band profiler system must provide its own data collection and storage mechanisms to assure data continuity.

GVS-4.62 **S-band profiler back-up archive**
The GVS S-band profiler shall maintain a back-up copy of all data collected and generated.

Rationale: A local back-up of the profiler data ensures that any loss of data during transportation for off-site archival and analysis would not be catastrophic. Automatic copying of the data from the radar processor to the renewable storage devices will be part of the software.

GVS-4.65 **S-band profiler quick-look image product**
The GVS S-band profiler shall generate a quick-look image product at least once every 15 minutes during instrument operations with, at a minimum, the following characteristics

a. The GVS S-band profiler quick look images shall be available to other computers in the local network

b. The GVS S-band profiler quick look images shall show the three moments (reflectivity, velocity, and velocity standard deviation) as a function of time and height.

Rationale: An image display generation capability is necessary to locally and remotely monitor the instrument data quality and for weather situational awareness in GV field operations.

GVS-4.70 **S-band profiler unattended operations**
The GVS S-band profiler shall operate unattended and shall restart operating without user intervention after a power failure.

Rationale: TBD-38

4.7 Instrument Measurement Requirements: UHF Profiler

The GVS UHF profiler will not be required to meet NTIA Manual of Regulations and Procedures for Radio Frequency Management, RSEC-E Criteria. The bandwidth and antenna requirements of RSEC-E are too restrictive for this instrument. A waiver of the requirements will be needed to obtain frequency authorization.

GVS-5.05 **UHF profiler center frequency**
The GVS UHF profiler shall operate at a fixed frequency of 449 MHz ±0.1 MHz. The operating frequency will be crystal controlled.

Rationale: TBD-39.

GVS-5.10 **UHF profiler bandwidth**
For an 800 ns pulse width with an 80 ns rise time, typical for a 125 m spatial resolution, the necessary bandwidth for the GVS UHF profiler will be 7.1 MHz.

Rationale: TBD-39.

GVS-5.15 **UHF profiler minimum and maximum range**
The GVS UHF profiler radar shall measure at least 50 dBz without saturating at a minimum range of 200 meters above the ground. The GVS UHF profiler shall collect observations up to 18 km above the ground.

Rationale: See GVS-4.15.

GVS-5.20 **UHF profiler horizontal resolution (beamwidth)**
The GVS UHF profiler shall have a maximum half-power beamwidth of 9 degrees.

Rationale: 9 degrees is a nominal half-power beam width for an UHF profiler. It provides a spatial resolution of 3 km at maximum vertical range, which allows bin-bin comparisons with the X-band and S-band scanning radars and the DPR.

GVS-5.25 **UHF profiler vertical resolution**
The GVS UHF profiler shall have a minimum vertical resolution of 125 meters.

Rationale: This is the resolution of the GPM PR at nadir.

GVS-5.30 **UHF profiler minimum reflectivity sensitivity (dBZ)—precipitation**
The GVS UHF profiler shall measure at least 50 dBZ without saturating at a minimum range of 200 meters above the ground.

Rationale: See GVS-4.15.

GVS-5.32 **UHF profiler minimum reflectivity sensitivity (dBZ)—no precipitation**
The GVS UHF profiler shall measure a minimum return of ≤ -15 dBz at a range of 5 km in the absence of precipitation (Bragg Scattering).

Rationale: TBD-40

GVS-5.35 **UHF profiler calibration stability**
The GVS UHF profiler shall maintain a stable reflectivity accuracy of less than 2 dBz.

Rationale: The GVS will have limited support for recalibration of field instrumentation, and precipitation events will occur at random, so the UHF profiler needs stable calibration precision. 2 dBZ is the maximum allowable drift to give meaningful reflectivity intercomparisons with PR/DPR and compute rain rates from the ground radar.

GVS-5.40 **UHF profiler unambiguous range**
The GVS UHF profiler shall have a maximum unambiguous range greater than 18 km.

Rationale: The profiler should match the GPM DPR, which will provide data coverage from the surface up to 18 km above ground.

GVS-5.42 **UHF profiler dwell time**
The GVS UHF profiler shall dwell for less than 30 seconds.

Rationale: A complete profiler of Doppler spectra and spectral moments will be recorded for each dwell period. These Doppler spectra are used to estimate the Gamma function DSD specified in requirements GVS-1.70 through 1.82.

GVS-5.45 **UHF profiler Nyquist Doppler velocity and spectral resolution**
The GVS UHF profiler shall have a minimum Nyquist velocity ≥16 ms^{-1} and a maximum Doppler velocity spectral resolution (Doppler velocity bin spacing) less than 0.15 ms^{-1}.

Rationale: See GVS-4.50.

GVS-5.50 **UHF profiler access to spectra for near real time analysis**
The GVS UHF profiler shall make the observed Doppler velocity spectra available for analysis within 15 minutes of the observation.

Rationale: TBD-41

GVS-5.55 **UHF profiler local archive**
The GVS UHF profiler shall have a local storage capacity with a minimum capacity sufficient to store 30 days of continuous data

Rationale: The GVS will not be staffed on a 24/7 schedule, and precipitation events will occur at random, so the UHF profiler system must provide its own data collection and storage mechanisms to assure data continuity.

GVS-5.57 **UHF profiler back-up archive**
The GVS UHF profiler shall maintain a back-up copy of all data collected and generated.

Rationale: A local back-up of the UHF profiler data ensures that any loss of data during transportation for off-site archival and analysis would not be catastrophic. Automatic copying of the data from the radar processor to the renewable storage devices will be part of the software.

GVS-5.60 **UHF profiler quick-look image product**
The GVS S-band profiler shall generate a quick-look image product during at least once every 15 minutes during instrument operations with, at a minimum, the following characteristics

a. The GVS S-band profiler quick look images shall be available to other computers in the local network

b. The GVS S-band profiler quick look images shall show the three moments (reflectivity, velocity, and velocity standard deviation) as a function of time and height.

Rationale: An image display generation capability is necessary to locally and remotely monitor the instrument data quality and for weather situational awareness in GV field operations.

GVS-5.65 **UHF profiler unattended operation**
The GTS UHF profiler shall operate unattended and shall restart operating without user intervention after a power failure.

Rationale: The GVS will not be staffed on a 24/7 schedule, and precipitation events will occur at random, so the UHF profiler system must provide its own automated restart mechanisms to assure data continuity.

4.8 Instrument Measurement Requirements: Precipitation Gauge and Disdrometer Network

GVS-6.05 **Precipitation gauge network temporal resolution**
Each GVS precipitation gauge shall record data at 1 minute intervals.

Rationale: High time resolution rain gauge accumulation data with negligible time offset between locations is needed to validate instantaneous rain rates from GPM and ground-based radar.

GVS-6.07 **Precipitation gauge network temporal resolution**
The time stamp in each gauge data logger will be accurate to within 1 minute of a standard GPS time measurement..

Rationale: TBD-44

GVS-6.10 **Precipitation gauge 1-minute accuracy**
The GVS precipitation gauges shall have a coefficient of variability of ≤20% when co-located gauges measure rain accumulations for a period of 1 minute at rain rates measured between 1 mm/hour and 100 mm/hour.

Rationale: Gauges need to agree within 20% in their 1-minute values to validate the desired accuracy and precision of the point-measurement, instantaneous, rain rate data over the range of routinely observed rain rates.

GVS-6.15 **Precipitation gauge 5-minute accuracy**
The GVS precipitation gauges shall have a coefficient of variability of ≤15% when co-located gauges measure accumulations for a period of 5 minutes at rates measured between 1 mm/hour and 100 mm/hour.

Rationale: As in GVS-6.10, but with stricter thresholds for 5-minute rain accumulations.

GVS-6.20 **Precipitation gauge 1-hour accuracy**
The GVS precipitation gauges shall have a coefficient of variability of ≤10% when co-located gauges measure accumulations for a period of 1 hour at rates measured between 1 mm/hour and 100 mm/hour.

Rationale: As in GVS-6.10, but with stricter thresholds for 1-hour rain accumulations.

GVS-6.25 **Precipitation gauge calibration precision**
Each precipitation gauge in the GVS rain gauge network shall be within TBD-25 level of precision when compared to a TBD-25 standard.

Rationale: Gauges need to achieve the stated calibration precision for the point measurements to provide useful instantaneous rain rate data for ground validation over the range of routinely observed rain rates.

GVS-6.30 **Precipitation gauge calibration stability**
The calibration precision shall be maintained to within a tolerance of TBD-26 when measured over a time interval of TBD-26.

Rationale: The GVS will have limited support for recalibration of field instrumentation, precipitation gauges will be numerous, and precipitation events will occur at random, so precipitation gauge calibration precision must be stable over the stated time interval.

GVS-6.35 **Precipitation gauge data distribution**
The precipitation gauges will be equipped with recording devices to store data for TBD-27 days. The data will be periodically downloaded from the recording devices and made available over the GVS local network every TBD-27 days.

Rationale: The GVS will not be staffed on a 24/7 schedule, and precipitation events will occur at random, so the precipitation gauge system must provide its own data collection, storage, and delivery mechanisms to assure data continuity.

GVS-6.40 **Disdrometer network**
The GVS disdrometer network shall measure rain drop size spectra as concentration (number of drops/ m^3), rain rate (mm/hour) and reflectivity (mm^6/m^3).

Rationale: The three disdrometer parameters are required for surface validation and intercomparison of the same parameters at higher levels in the atmosphere from remote sensing instrumentation.

GVS-6.45 **Disdrometer drop size measurements**
The GVS disdrometer network shall measure rain drop size spectra in a minimum of TBD-28 levels for rain rates from a minimum of TBD-28 (mm/hour) to a maximum of TBD-28 (mm/hour) with a minimum temporal resolution of 1 minute.

Rationale: High time/magnitude resolution disdrometer drop size data with negligible time offset between sources is needed to validate instantaneous rain rates from GPM and ground-based radar.

GVS-6.50 **Disdrometer accuracy**
The GVS disdrometer network shall make measurements with the following accuracy for a sampling interval of ≤1 minute, a sample of ≤25 drops, and a rain rate of ≥0.5 mm per hour:

a. Rainrate: 8% standard error
b. K_{dp} : 8% standard error
c. Z_h: 1-3 dB
d. Z_{dr} : 0.3-1.4 dB.

Rationale: TBD-42

GVS-6.55 **Disdrometer data distribution**
The disdrometers will be equipped with recording devices to store data for TBD-27 days. The data will be periodically downloaded from the recording devices and made available over the GVS local network every TBD-27days.

Rationale: The GVS will not be staffed on a 24/7 schedule, and precipitation events will occur at random, so the disdrometer system must provide its own data collection, storage, and delivery mechanisms to assure data continuity.

4.9 Instrument Measurement Requirements: Profiling Microwave Radiometer

GVS-7.05 **Radiometer center wavelengths and bandwidths**
The GPM GV profiling radiometer shall operate with 12 channels (5 in the 20-22 GHz band and 7 in the 51-59 GHz band).

Rationale: The specified channels optimize the measurement of the desired temperature and water vapor profiles.

GVS-7.10 Radiometer rain mitigation capability

The GPM GV profiling radiometer shall employ a rain mitigation capability such that temperature and humidity errors will be ≤ 3K and 20%, respectively, in rain rates over the radiometer of 6 mm/hr.

Rationale: The GVS will be attempting to measure atmospheric variables within precipitation events, and rainwater accumulation on the profiling radiometer will greatly degrade the quality of the instrument measurements below the required accuracies unless it is mitigated.

GVS-7.15 Radiometer profiling capability

In the current software, temperature is *oversampled* to 100 m in the vertical below 1 km and then 250 m up to 10 km. Temperature accuracy is around 0.5-1.0 K. Water vapor content is less certain but, is somewhere around 1 g/m^3, lower in the atmosphere. Uncertainty in moisture/temperature can be improved by combining with GOES Sounder data above 4 km or so. The uncertainty in cloud water retrieval isn't clear.
Rationale: TBD-43

GVS-7.20 Radiometer resolution by wavelength

Since most of the retrievals invoke multiple frequencies, not sure I understand what "resolution" refers to here. In general, vertical resolution is best lower down and then gets worse the higher you get as larger layer thicknesses contribute to the signal.
Rationale: TBD-43

4.10 Instrument Measurement Requirements: Rawinsonde

GVS-8.05 Rawinsonde measured variables

The GVS shall generate a rawinsonde product with, at a minimum, the following characteristics:

a. The rawinsonde product shall measure soundings in wind speed (ms^{-1}), wind direction (degrees), temperature (K), pressure (mb), relative humidity (percent), and altitude (m)

b. The rawinsonde product shall measure soundings in ≤2-second-intervals, beginning at the surface

c. The rawinsonde product shall report sounding data either in ASCII in accordance with the Code Form For Temp Rawinsonde Observations in FMH-3 edition FCM-H3-1997, Appendix E-II (i.e., WMO TEMP format FM-35), or in BUFR format.

Rationale: High-time-frequency rawinsonde measurements are required to obtain the best time and space match to the high vertical resolution measurements from the profilers and the PR/DPR. Sounding products in a standard meteorological format will be needed for compatibility with external/user meteorological data analysis and processing systems. Seems too frequent an interval, given instrument lag and average ascension rates of 300 m/min (TBD-31).

GVS-8.10 **Rawinsonde measurement accuracies**

GVS rawinsonde ranges, accuracies, precisions, and resolutions for

a. wind speed
b. wind direction
c. air temperature
d. relative humidity
e. altitude (and/or geopotential height)
f. pressure

shall not exceed those specified in the Federal Meteorological Handbook No. 3 (FMH-3), edition FCM-H3-1997 (http://www.ofcm.gov/fmh3/text/default.htm).

Rationale: Meets minimum industry standard data quality.

GVS-8.15 **Rawinsonde flight capability**

GVS rawinsondes shall be lifted by helium filled balloons of sufficient weight to sample the environment to a minimum pressure of 100 mb.

Rationale: The PR and DPR provide data up to 18 km, which is typically near or above the elevation of the 100 mb isobaric level.

GVS-8.20 **Rawinsonde position tracking**

GVS rawinsondes shall be tracked via Global Positioning Satellite (GPS) capabilities.

Rationale: Industry standard capability.

GVS-8.25 **Rawinsonde independent surface measurements**

Portable instrumentation shall be available at each GVS rawinsonde launch site to verify the rawinsonde surface measurements of temperature and relative humidity.

Rationale: Pre-flight calibration check is necessary due to rawinsonde instrument package variations.

GVS-8.30 **Rawinsonde data quality control**

GVS rawinsonde automated QC procedures shall flag potentially spurious data (e.g., unreasonable lapse rates and winds or moisture biases).

Rationale: Anomalous data in original sounding data is common and must be identified and eliminated by quality control algorithms.

GVS-8.35 **Communications**

Raw and quality-controlled GVS rawinsonde data products for a sounding shall be available over the local computer network within 6 hours of balloon launch.

Rationale: Soundings must be available in a timely manner to initialize cloud models and perform data quality evaluations.

4.11 Instrument Measurement Requirements: Aircraft-Based Measurements (TBD-21)

Microphysics Aircraft:

Vertical resolution- a minimum of 50 m – is this number realistic? Seems like this number needs to be larger to account for stacking of aircraft flight tracks…
Horizontal 100 m (assume 1 second averaging at 100 m/s airspeed).

Variables (Don't think we need to define probe types here- more what we would like to measure)
Ice particle concentrations: 20 microns – 2 cm
Cloud/Rainwater particle concentrations: 2 microns to 8 mm
Horizontal and Vertical velocity: +/- 1 m/s
Temperature/moisture profiling (dropsonde or in-situ flight sampling)
Liquid water content (g/m^3 down to 0.1 g/m^3) includes supercooled water
CCN/IN measurements (concentration, size and type)

Satellite simulator Aircraft

Multi-frequency downward looking radiometers
Multi-frequency scanning polarimetric radar (X, Ka/u, W bands) (gate spacing ≤ 50 m)
Dropsonde ?

4.12 Instrument Deployment Requirements

GVS-10.05 **X-band scanning radar location**
The GVS X-band scanning radar shall be located within 60 km from the GVS S-band scanning radar.

Rationale: The X- and S-band radars must scan a common area within a reasonable range of the attenuation-susceptible X-band radar.

GVS-10.10 **X-band scanning radar deployment capability**
The GVS X-band scanning radar shall have the capability to stop operations, be stored and ready for transportation to an alternate location within TBD-29 days. After transportation to an alternate location, the X-band radar shall be assembled and ready for operations within TBD-29 days.

Rationale: The GVS field sites will change during the limited lifetime of the intensive GPM GV effort, and down time between locations must be minimal.

GVS-10.15 S and UHF profiler co-location

The GVS S-band profiler antenna and GVS UHF profiler antenna shall be located within 20 m of each other and the two systems shall be able to operate simultaneously without interference at this maximum antenna separation.

Rationale: Co-location is necessary for the S-band and UHF profilers to sample the same column of air beginning at the lowest possible altitude.

GVS-10.17 Profiler and scanner co-location

The GVS S-band profiler antenna and GVS UHF profiler antennas shall be located between 30 and 60 km from the GVS scanning S-band scanning radar.

Rationale: : The S-band and UHF profilers must sample a column of air within the 3-D grid volume of the S-band radar but at a sufficient distance for the scanning radar to sample higher altitudes.

GVS-10.20 Precipitation gauge network design (TBD-30)

The GVS precipitation gauge network will have a flexible design to accommodate different site locations and cold vs. warm precipitation. The network shall be designed to measure the variability of precipitation accumulation (mm/hour) within the area of an interpolated radar pixel (defined in requirements GVS-1.05 and GVS-1.10) as well as within a larger area sampled by the scanning radars. The rain gauges will be distributed into clusters (each cluster will be approximately 100 km^2, depending on individual site characteristics) at ranges extending from roughly 30-120 km from the radars (the exact number of clusters with depend on the site location). Data from within each cluster will be used to evaluate the sub-pixel spatial variability of rainfall while the combined cluster data will be used to quantify range errors in the radar precipitation products.

The spatial density of precipitation gauges within each cluster will vary from site to site but will have a minimum of 1 gauge per TBD-30 m^2 (warm precipitation) and 1 gauge per TBD-30 m^2 (cold precipitation) within the area of an interpolated radar pixel.

Rationale: The rain gauge network must capture the sub-pixel variability of precipitation from the ground and space radars.

GVS-10.25 Disdrometer network design (TBD-30)

The GVS disdrometer network will have a flexible design to accommodate different site locations and cold vs. warm precipitation. The network shall be designed to measure the variability of precipitation size characteristics within the area of an interpolated radar pixel(defined in requirements 1.05 and 1.10). as well as within a larger area sampled by the scanning radars. The disdrometers will be embedded within the same rain gauge clusters (defined in requirement 10.20) to evaluate the sub-pixel spatial variability of rainfall characteristics as well as to quantify range errors in the radar precipitation products.

The spatial density of disdrometers within each cluster will vary from site to site but will have a minimum of 1 disdrometer per TBD-30 m^2 (warm precipitation) and 1 disdrometer per TBD-30 m^2 (cold precipitation) within the area of an interpolated radar pixel.

Rationale: See GVS-10.20.

GVS-10.40 Rawinsonde launch configurations

GVS rawinsonde launch locations shall range from a minimum of one (nominal operation periods) to maximum of 4 to 6 during special observation periods. The launch points shall be located in a configuration which provides a sufficient characterization of the environmental for CRM modeling.

Rationale: The spatial variation of the atmospheric vertical profile must be captured for proper model initialization.

GVS-10.45 Rawinsonde launch frequencies

GVS rawinsonde launch frequency at each site shall range from a minimum of 2 per day (nominal operation periods 00 and 12 UTC) to a maximum of 8 per day (00, 03, 06, 09, 12,15, 18, and 21 UTC) during special observation periods.

Rationale: The temporal variation of the atmospheric vertical profile must be captured for proper model initialization and to match up to the PR/DPR overpasses.

5. Validation Network (VN) Requirements

5.1 Overall VN Requirements

<<to be added>>

5.2 Data Ingest

GVS-NM-001 **Acquire WSR-88D data**
The GVS shall acquire full-scan-volume, full resolution WSR-88D Level-II Reflectivity data, over national network.

Note: NEXRAD Level II Reflectivity data come bundled with Velocity and Spectrum Width, so these fields will also be acquired. Once WSR-88D systems are upgraded to dual polarization capability, the format and content of their Level II data will change. Once the upgrade occurs for a given radar, it is expected GVS will need to acquire the following fields, likely bundled: horizontal polarization reflectivity, vertical polarization reflectivity or differential reflectivity, correlation coefficient, linear depolarization ratio, and specific differential phase.

Rationale: Recommendation of the GPM Ground Measurements Advisory Panel, and derived.

Priority: Phase-1

GVS-NM-005 **Acquire TRMM PR data**
The GVS shall acquire TRMM PR 1C-21, 2A-23 and 2A-25 products over the CONUS area.

Rationale: 1C-21 needed for matchup with WSR-88D data as recommended by the GPM Ground Measurements Advisory Panel; 2A-23 is used to populate the national map metadata with fields such as rain type; 2A-25 is used for comparisons with PR/DPR attenuation-corrected data.

Priority: Phase-1

GVS-NM-010 **Acquire GPM DPR data**
The GVS shall acquire GPM DPR (PR-A and PR-U) Level 1C Reflectivity and Level 2 Precipitation products over the CONUS area.

Rationale: Derived from Requirement GVS-NM-005.

Priority: Phase-1

5.3 Data Preprocessing

GVS-NM-101 **Extract WSR-88D metadata**
The GVS shall extract and store nominal volume scan time, volume coverage pattern (VCP), and product, system, and precipitation state information as metadata for each volume scan. (TBD-45)

Rationale: These parameters support the determination of coincident ground and satellite radar data (Reqt. GVS-NM-201, GVS-NM-205), and whether the 88D is detecting significant precipitation and/or severe storms. WSR-88D scans in fixed VCPs of fixed duration, depending on the mode (Clear Air, Precipitation, Storm) of the radar.

Priority: Phase-1

GVS-NM-105 Extract TRMM PR metadata

The GVS shall extract and store the nominal overpass time and other PR product and precipitation state information for each PR overpass covering 20% or more of the ground radar field of view.

Note: The nominal overpass time is defined as the time (year to second) of the closest approach of the satellite subtrack to the ground radar location.

Rationale: Supports determination of coincident data sets and time offsets.

Priority: Phase-1

GVS-NM-110 Extract GPM DPR metadata

The GVS shall extract and store the nominal overpass time and other DPR product and precipitation state information for each DPR overpass covering 20% or more of the ground radar field of view.

Note: The nominal overpass time is defined as the time (year to second) of the closest approach of the satellite subtrack to the ground radar location. Compare/contrast to GPM PPS Level 3 Draft Requirement M12.5.

Rationale: Supports determination of coincident data sets and time offsets.

Priority: Phase-1

GVS-NM-115 Apply automated quality control

The GVS shall apply automated quality control to the GV radar data, and record the applied QC methods and results.

Rationale: This is a major function of the TRMM GV procedures required for utilization of ground radar data, and needs to be included in the GPM GVS processing.

Priority: Phase-1

GVS-NM-120 Apply manual quality control

The GVS shall be able to apply manual quality control to the GV radar data, and record the applied QC methods and results, including:

a. (Accept) the data as-is, overriding any automated QC result

b. Edit and store a manually-corrected version of the product (Accept Corrected)

c. (Reject) the data as bad, overriding any other QC result.

Rationale: This is a major function of the TRMM GV procedures required for utilization of ground radar data, and needs to be included in the GPM GVS processing.

Priority: Phase-1

GVS-NM-125 Maintain QC versions
The GVS shall store the post-QC and original radar data

Note: It is assumed that a database will be used in the implementation of the National Map to store radar data and derived parameters.

Rationale: Derived, facilitates future reprocessing of the ground radar data with improved QC.

Priority: Phase-1

5.4 Data Post-processing and Analysis

GVS-NM-201 Calculate overlap
The GVS shall determine the actual (km^2) and percent areal overlap of the PR (for TRMM) and DPR (for GPM) data coverage with the GR area of coverage within a selected GR range limit.

Rationale: Needed to determine whether the satellite and ground observations are coincident, according to areal overlap thresholds.

Priority: Phase-1

GVS-NM-205 Variable time offset and area overlap thresholds
The GVS shall apply a set of variable time offset and areal overlap thresholds between DPR and GR data as criteria to determine whether the two data volumes are coincident.

Priority: Phase-1/2 (See GVS-NM-401, -403)

Note 1: It is assumed that, in the implementation of the National Map, a default threshold set and any number of user-specified threshold sets will be able to be stored and retrieved for use within the GVS. The results of any coincident data event determination will also be able to be stored in the GVS, with an identifying link to the given threshold set used.

Note 2: A coincident data event is a PR or DPR overpass of a ground radar site which meets the areal overlap threshold, and includes all PR/DPR and ground radar products within the time offset threshold. It is specific to the threshold set used to determine the data coincidence. It may or may not be an active precipitation event.

Note 3: The default minimum areal overlap is a system-defined parameter. Compare/contrast to GPM PPS Level 3 Draft Requirements M12.5, M13.1, and M13.2.

Note 4: Data from more than one product (PPS granule or WSR-88D volume scan) may be coincident. Two adjacent PPS granules may need to be "sewn together" to cover the ground radar area (TBD-46). WSR-88D products should be segmented by, and evaluated for coincidence by the midtimes of, the elevation sweeps in the volume, regardless of which volume scan the sweep is within.

Rationale: This requirement allows exclusion of coincident overpasses from analysis when the areal overlap is too small, or when the time between a ground radar scan and satellite overpass is too large.

GVS-NM-210 Determine fractional area of precipitation

The GVS shall be able to determine the fractional area of precipitation, relative to the range-limit-defined GR area of coverage, and within the DPR/GR overlap area, as detected by: (1) the DPR, (2) the GR, and (3) both the DPR and GR, in common.

Rationale: Needed to determine whether the satellite and ground observations are observing a "rain event."

Priority: Phase-1

GVS-NM-215 Data transformation and interpolation

The GVS shall be able to transform and interpolate GPM PR and DPR product data and ground-based radar (GR) data to a common space/ground grid with, at a minimum, the following characteristics:

d. north (y) east (x) and local vertical (z) oriented 3-dimensional Cartesian grid,

e. grid centered on the ground radar location.

Priority: Phase-1

GVS-NM-220 Reflectivity transformation

GV shall be able to convert reflectivity factor (Z) to and from reflectivity in decibels (dBZ) for interpolation of reflectivity.

Rationale: WRS-88D data comes in dBZ, the transformation algorithms convert to Z to preserve the linearity of the data when re-sampling to the transformed grid.

Priority: Phase-1

GVS-NM-225 Variable parameters for common space/ground grid

The GVS shall use a set of variable parameters to define the map projection, grid spacing, and dimensions of the common space/ground grid (defined by requirement GVS-NM-215).

Note: It is assumed that in the implementation of the National Map a default set and any number of user-specified grid parameter sets shall be able to be stored and retrieved for use within the GVS.

Rationale: Derived.

Priority: Phase-1

GVS-NM-230 Gridded Radar Data Storage

The Cartesian 3-D grids of GR, PR, and DPR data shall be able to be stored in the GVS database with identifying links to the:

a. input radar data source product(s) (directly, or by attributes-in-common),

b. set of parameters (Reqt. GVS-NM-215) used to define the 3-D Cartesian grid,

c. set of parameters (Reqt. GVS-NM-205) used to define data coincidence, and the

d. coincident data event itself, as defined by the coincidence parameters.

Note: Item (c) may be optional if (d) provides the necessary links by association. Item (d) serves to link coincident grids of different data sources to one another.

Rationale: This provides the necessary flexibility in the cross-comparison (matchup) of coincident ground and space radar data under differing comparison criteria, without the need to re-create the grids.

Priority: Phase-1

GVS-NM-235 Grid Metadata

The GVS shall analyze characteristics of data in the 3-D grids and produce descriptive metadata based on these analyses.

Note 1: It is assumed that the metadata elements will be stored in the GVS database with links to the related 3-D grids, and by association, to the matchup radar products from which the 3-D grids are produced. Also, storage retention of the metadata elements in the database will match those of the 3-D grids from which they were derived.

Note 2: Example metadata to be derived from the data in the 3-D grids include:

- Percentage of the horizontal grid area within which precipitation is present, based on a reflectivity threshold, for each vertical level in the 3-D grid
- Percentage of the 3-D grid in which overlapping PR or DPR data are available (partial overlap coverage will be allowed and is likely to be the norm)
- Maximum and minimum vertical grid levels where the bright band occurs within the 3-D grid
- Percent missing data in each level of the 3-D grid
- Type(s) of precipitation (convective, stratiform, etc.) present in the 3-D grid (this in itself may be a 2-D array indicating the

dominant precipitation type in each vertical column of the 3-D grid)

Rationale: Grid metadata are needed to support the analysis and metrics reporting functions in the reflectivity comparison product generation.

Priority: Phase-1/2 (complex parameters like bright band and precipitation type deferred to Phase-2)

GVS-NM-240 Alignment

The GVS shall be able to align DPR and GR 3-D data volumes to achieve a best fit to minimize earth-location and pointing uncertainties in the DPR data.

Rationale: Research by Chandrasekar and others suggests that affine transformation of the input data can reduce errors introduced by uncertainties in the ground- and space-based viewing geometries.

Priority: Phase-2

GVS-NM-245 Attenuation corrections (delete?)

The GVS shall be able to apply instrument- and wavelength-specific attenuation corrections to DPR and GR measured reflectivity.

Note: This requirement can be deleted if we just rely on the PPS to provide the attenuation corrections (operational and algorithm-improvement versions) to the DPR, and the radar processor to provide the same types of attenuation corrections to the GV X-band data.

Priority: Phase-2

GVS-NM-250 Averaging

The GVS shall be able to average 3-D gridded radar data in the vertical and horizontal dimensions.

Rationale: Reference 2.

Priority: Phase-2

GVS-NM-255 Extract vertical profiles

The GVS shall be able to extract vertical profiles from the 3-D Cartesian gridded radar data.

Rationale: Reference 2.

Priority: Phase-2

GVS-NM-260 Exclude selected observations

The GVS shall be able to exclude grid cells from the matchup analysis based on selectable criteria, at a minimum:

a. storm type,

b. reflectivity or reflectivity factor limits

c. presence or absence of a bright band

d. poor correlation of ground and satellite reflectivity fields.

Rationale: There is a need to segregate the matchup data into categories based on these criteria to minimize the within-group variability.

Priority: Phase-2

GVS-NM-301 Reflectivity Comparison Products

The GVS shall be able to perform matchup analysis of reflectivity from satellite and ground radars to produce the comparison product including, at a minimum:

a. Scatter plots of satellite vs. ground radar reflectivity

b. Time series of mean monthly bias of WSR-88D reflectivity relative to PR/DPR

c. Plots of mean ground-satellite reflectivity difference vs. PR/DPR reflectivity category

d. Vertical profiles of mean ground-satellite reflectivity difference.

Priority: Phase-2

GVS-NM-305 Automated QC in Comparison Products

The GVS shall perform quality control with reflectivity comparison product generation to determine, as best as possible, whether there are significant geolocation errors (for PR/DPR reflectivity) or anomalous echoes (anomalous propagation, ground clutter, etc.) from the ground radar.

Note: Where possible errors exceed defined thresholds, the affected 3-D grids will be flagged in the database and excluded from the product results. A summary (Date/time, data type, QC check failed) of excluded grid data will be produced for the default output product and stored in the database as metadata associated with the product. The output display products will indicate, at a minimum, the number of grid pairs excluded from the results due to failure of QC checks.

Rationale: Derived.

Priority: Phase-2

GVS-NM-307 Manual Override QC flags

The GVS shall provide an option to manually override the individual 3-D grid QC flags which result from the automated reflectivity comparison QC checks from a prior product generation run.

Note: This option would be exercised, for example, in the case where the manual override is used to force the inclusion of 3-D grid data otherwise flagged for rejection by automated QC. In that case, the manual override data will be included in the results when the output display product is regenerated.

Rationale: Derived.

Priority: Phase-2

GVS-NM-310 Reflectivity Comparison Product Storage
The GVS shall store scheduled, default reflectivity comparison products as they are completed.

Rationale: Derived.

Priority: Phase-1 (3-D grids); Phase-2 (comparisons)

5.5 Scheduled and Interactive Capabilities

GVS-NM-401 Default parameters for coincident data
The GVS shall use a default set of parameters to define coincident data in routine, scheduled processing.

Rationale: Derived.

Priority: Phase-1

GVS-NM-403 User-defined parameters for coincident data
The GVS shall allow authorized users to create, save, edit and retrieve custom parameter sets, and select a custom set to be applied to determine coincident data in a user-initiated run.

Rationale: Derived.

Priority: Phase-2

GVS-NM-405 Default parameters for common space/ground grid
The GVS shall use a default parameter set for defining the 3-D Cartesian grid in routine, scheduled processing.

Rationale: Derived.

Priority: Phase-1

GVS-NM-405 Default and user parameters for common space/ground grid
The GVS shall allow authorized users to create, save, edit and retrieve custom parameter sets, and select a custom set to be applied to generate 3-D grids in a user-initiated run.

Rationale: Derived.

Priority: Phase-2

GVS-NM-410 Manual Quality Control
The GVS shall provide the capability to display and manually quality control WSR-88D radar data, including the ability to edit the product and override the automated quality control flags to force inclusion and exclusion of the product.

Rationale: Derived.

Priority: Phase-1

GVS-NM-415 Routine Process Initiation
GVS data ingest, preprocessing, automated QC, post-processing, and comparison product creation for the National Map shall be performed automatically, triggered by the availability of new data or scheduled by the system.

Rationale: Derived.

Priority: Phase-1

GVS-NM-420 Non-Routine Process Initiation
Authorized users shall be able to initiate post-processing and comparison product creation on demand and specify all necessary parameters to define the subset of data to process and the products to be produced,.

Rationale: Derived.

Priority: Phase-2

GVS-NM-425 User Access to Standard National Map Data Products
The GVS shall provide to the public an online catalog of reflectivity comparison display products, from which products may be selected, viewed, and downloaded.

Priority: Phase-1

5.6 Performance requirements (TBD-51)

6. Satellite Simulator Model (SSM) Requirements

GVS0420 **SSM integration and test capability**
The SSM shall implement an Integration and Test capability for validation algorithms received from the Precipitation Measuring Missions (PMM) Science Team.

GVS0425 **SSM product generation capability**
The SSM shall implement a Product Generation capability. The product generation capability shall generate validation products on a routine basis.

GVS0430 **SSM metrics capability**
The SSM shall implement a Metrics capability. The SSM metrics capability shall, at a minimum

a. generate data quality statistics for each validation product

b. generate process metrics for each product

c. Generate documentation for all SSM products.

6.1 SSM Operations and Performance Requirements

GVS0450 **SSM product generation time-line**
The SSM shall generate products and reports within 24 hours of receipt of required input data during nominal operations.

GVS0455 **SSM product distribution time-line**
The SSM shall make products (including Metrics products) and reports available for distribution within 24 hours of generation during nominal operations.

GVS0460 **SSM reprocessing time-line**
The SSM shall be capable of reprocessing data products and reports at a rate (TBD-47).

6.2 SSM Interface Requirements

GVS0470 **SSM receipt of PMM Science Team algorithms**
The SSM shall receive algorithms from the PMM Science Team.

GVS0475 **SSM receipt of ancillary data**
The SSM shall receive ancillary data from external sources.

GVS0480 **SSM receipt of data from A&D**
The SSM shall receive data from the A&D.

GVS0485 **SSM delivery of data to A&D**
The SSM shall provide data and reports to the A&D.

GVS0490 **SSM delivery of data to MD**
The SSM shall provide metrics to the Metrics Database.

7. Archive and Distribution (A&D) Requirements

GVS0305 **A&D ingest capability**
The A&D shall implement an Ingest capability to receive data, products, reports, documentation, and computer code.

GVS0310 **A&D archive capability**
The A&D shall implement an Archive capability to store and maintain the integrity of all materials received from external sources.

GVS0315 **A&D search and order capability**
The A&D shall implement a Search and Order capability to provide a user interface to all materials in its archive.

GVS0320 **A&D distribution capability**
The A&D shall implement a Distribution capability to make available all versions of materials in its archive.

GVS0325 **A&D user services capability for PMM Science Team Members**
The A&D shall implement a User Services capability to provide off-line responses to PPM Science Team member inquiries.

GVS0330 **A&D metrics capability**
The A&D shall implement a Metrics capability to generate process metrics.

7.1 A&D Operations and Performance Requirements

GVS0350 **A&D data delivery time-line**
The A&D shall make GVS data available for search and delivery within 24 hours of receipt during nominal operations.

GVS0355 **A&D electronic data delivery**
The A&D shall provide the capability to deliver materials in its archive electronically over the Internet in response to user requests.

GVS0360 **A&D long-term archive**
The A&D shall, at the end of its lifecycle, make all current versions of materials in its archive available for long-term archive by an organization external to the GVS.

7.2 A&D Interface Requirements

GVS0370 **A&D receipt of FMPG data**
The A&D shall receive data products, reports, documentation and computer code from the FMPG.

GVS0375 **A&D receipt of SSM data**
The A&D shall receive data products, reports, documentation and computer code from the SSM.

GVS0376 **A&D receipt of VN data**
The A&D shall receive data products, reports, documentation and computer code from the VN.

GVS0377 **A&D receipt of external data sources**
The A&D shall receive TBD-48 data products, reports, documentation and computer code from the TBD-48 data sources.

GVS0380 **A&D receipt of PPS data products**
The A&D shall receive GPM Core and Constellation data products from the PPS according to the according to the PPS-defined interface.

GVS0385 **A&D delivery of data to SSM**
The A&D shall provide archive materials to the SSM.

GVS0390 **A&D delivery of data to the MD**
The A&D shall provide metrics to the Metrics Database.

8. Metrics Database (MD) Function

GVS0510 **MD ingest capability**
The MD shall implement an Ingest capability to, at a minimum:

a. receive metrics from the FMPG function

b. receive metrics from the A&D function

c. receive metrics from the SSM function

d. receive problem reports from GPM Management

e. receive problem resolution reports from GPM Management.

GVS0515 **MD archive capability**
The MD shall implement an archive capability to store and maintain the integrity of all metrics and problem reports received.

GVS0520 **MD report capability**
The MD shall implement a report capability. The report capability shall, at a minimum,

a. generate pre-defined reports

b. generate user-defined reports.

GVS0525 **MD distribution capability**
The MD shall implement a distribution capability to provide pre-defined and user-defined reports to GPM management.

8.1 MD Operations and Performance Requirements

GVS0540 **MD report delivery time-line**
The MD shall provide user-defined reports to GPM management within 8 hours following the receipt of a valid request.

8.2 MD Interface Requirements

GVS0560 **MD receipt of FMPG metrics**
The MD shall obtain metrics from the FMPG.

GVS0565 **MD receipt of A&D metrics**
The MD shall obtain metrics from the A&D.

GVS0570 **MD receipt of SSM metrics**
The MD shall obtain metrics from the SSM.

9. Operational Phases (TBD-50)

10. Acronyms and Symbols

ACRONYM	DEFINITION
3-D	3-Dimension
A&D	Archive and Distribution
AGL	Above Ground Level
ASCII	American Standard Code for Information Interchange
cm	centimeter
CM	Configuration Management
CMO	Configuration Management Office
CONUS	Continental United States
CRM	Cloud Resolving Model
D_0	Median drop diameter
dB	Decibel
dBZ	Reflectivity in decibels
DPR	Dual-frequency Precipitation Radar
DSD	Drop Size Distribution
FMH-3	Federal Meteorological Handbook, No. 3
FMPG	Field Measurement and Product Generation Function
g	gram
GCM	Global Climate Model
GHz	GigaHertz
GMI	Global Microwave Imager
GOES	Geostationary Operational Environmental Satellite
GPR	Goddard Project Requirement
GPM	Global Precipitation Measurement
GPS	Global Positioning System
GR	Ground Radar
GSFC	Goddard Space Flight Center
GV	Ground Validation
GVS	Ground Validation System
hr	Hour
JAXA	Japanese Aerospace Exploration Agency t
JWD	Joss-Waldvogel Disdrometer
K	Kelvin
K_{dp}	Specific Differential Phase
km	kilometer
L2	Level–2
LDR	Linear Depolarization Ratio
m	Meter
MAR	Mission Assurance Requirements
mb	Millibar
MD	Metrics Database
MHz	MegaHertz

mm	Millimeter
ms^{-1}	Meters per second
NASA	National Aeronautics and Space Administration
NEXRAD	
NTIA	National Telecommunications and Information Administration
NPR	NASA Program Requirement
ns	Nanosecond
NWP	Numerical Weather Prediction
PHA	Precipitation and Hydrology Analysis
PMM	Precipitation Measuring Missions
PPI	Plan Position Indicator
PPS	Precipitation Processing System
PR	Precipitation Radar
QC	Quality Control
RSEC-E	Radar Spectrum Engineering Criteria, Item E
rZ_{dr}	Resampled differential reflectivity factor
rZ_h	Resampled equivalent reflectivity factor horizontal polarization
rZ_v	Resampled equivalent reflectivity factor vertical polarization
s, sec	Second
SSM	Model-Based Analysis
STSR	Simultaneous Transmission and Simultaneous Reception
STAR	Simultaneous Transmission Alternate Reception
TBD	To Be Determined
TRMM	Tropical Rainfall Measuring Mission
UHF	Ultra High Frequency
VCP	Volume Coverage Pattern
VN	Validation Network
WSR-88D	Weather Surveillance Radar - 1988 Doppler
WMO	World Meteorological Organization
Z	Reflectivity Factor
Z_{dr} (rZ_{dr})	Differential reflectivity factor (resampled)
Z_h (rZ_h)	Equivalent reflectivity factor horizontal polarization (resampled)
Z_v (rZ_v)	Equivalent reflectivity factor vertical polarization (resampled)
Φ_{dp}	Differential propagation phase
ρ_{vh}	Correlation coefficient of the horizontal and vertical return signal

11. Requirements Traceability (TBD-52)

12. Work-off Items

Item No.	Description
TBD-1	Accuracy of the liquid water content product GVS-1.45
TBD-2	Accuracy of the drop number concentration product GVS-1.65
TBD-3	Profile vertical extent and resolution of the profiler median particle diameter product GVS-1.70
TBD-4	Accuracy of the profiler median particle diameter product GVS-1.70
TBD-5	Profile vertical extent and resolution of the particle concentration product GVS-1.75
TBD-6	Accuracy of the particle concentration product GVS-1.75
TBD-7	Units for the vertical profile of a Gamma shape parameter product GVS-1.80
TBD-8	Profile vertical extent and resolution of the vertical profile of a Gamma shape parameter product GVS-1.80
TBD-9	Accuracy of the vertical profile of a Gamma shape parameter product GVS-1.80
TBD-10	temporal resolution of the disdrometer particle diameter, number concentration, rain rate and reflectivity products, GVS-1.85 through 1.100
TBD-11	temporal resolution of the rain gauge rain rate product TBD-11
TBD-12	Vertical resolution of the vertical profile of temperature product GVS-1.110.a
TBD-13	temporal resolution of the vertical profile of temperature product GVS-1.110.b
TBD-14	accuracy of the vertical profile of temperature product GVS-1.110.c
TBD-15	temporal resolution of the vertical profile of water vapor concentration product GVS-1.115
TBD-16	accuracy of the vertical profile of water vapor concentration product GVS-1.115
TBD-17	Vertical resolution of the uwave radiometer's liquid water content product for ranges above 2 km, GVS-1.45
TBD-18	CLOSED
TBD-19	CLOSED
TBD-20	CLOSED
TBD-21	Section 4.11 (aircraft measurements) needs additional review
TBD-22	CLOSED
TBD-23	Vertical air motion resolution, start height and max height (GVS-1.82.a)
TBD-24	Vertical air motion product accuracy (GVS-1.82.c)
TBD-25	Rain gauge precision (GVS-6.25)
TBD-26	Gauge calibration stability tolerance and time interval over which the stability is measured (GVS-6.30)
TBD-27	Gauge and disdrometer recording device storage capacity; does this requirement need to be re-written so that it does not preclude real-time delivery of gauge data? GVS-6.35

TBD-28	Specification of disdrometer drop size measurements in terms of minimum resolution of drop size and min/max rain rate GVS-6.45
TBD-29	Shipping and set up time specification for the X-band radar GVS-10.10
TBD-30	Gauge and disdrometer network design and related requirements GVS-10.20
TBD-31	Sounding intervals ≤2-second-intervals seem short GVS-8.05
TBD-32	CLOSED
TBD-33	CLOSED
TBD-34	Rationale for S- and UHF-band profiler Doppler spectral product and spectral moments GVS-1.180 through 1.185
TBD-35	Rationale for X-band full-volume scan time of 12 minutes GVS-2.60
TBD-36	CLOSED
TBD-37	CLOSED
TBD-38	Rationale for S-band unattended operations GVS-4.70
TBD-39	Rationale for UHF center frequency and bandwidth GVS-5.05 and 5-10
TBD-40	Rationale for UHF profiler minimum sensitivity GVS-5.32
TBD-41	Rationale for near-real-time (within 15 minutes) availability of UHF profiler data GVS-5.50
TBD-42	Requirement revision and rationale for disdrometer accuracy specifications in GVS-6.50
TBD-43	Rationale for radiometer profiling capability and wavelength resolution GVS-7.15 and 7.20
TBD-44	Rationale for rain gauge time stamp accuracy GVS-6.07
TBD-45	Scan times may be 5 minutes or more; is there a single time assigned to the entire scan or can time be assigned to each scan element?
TBD-46	Requirement for and/or method of stitching PPS granules to cover ground radar observation areas
TBD-47	SSM reprocessing rate GVS0460
TBD-48	A&D receivables GVS0377
TBD-49	Validation Network interface requirements
TBD-50	Operations phases (Section 9)
TBD-51	Validation Network performance requirements (Section 5.6)
TBD-52	Requirements traceability (Section 11)

OPEN: 44
CLOSED: 8