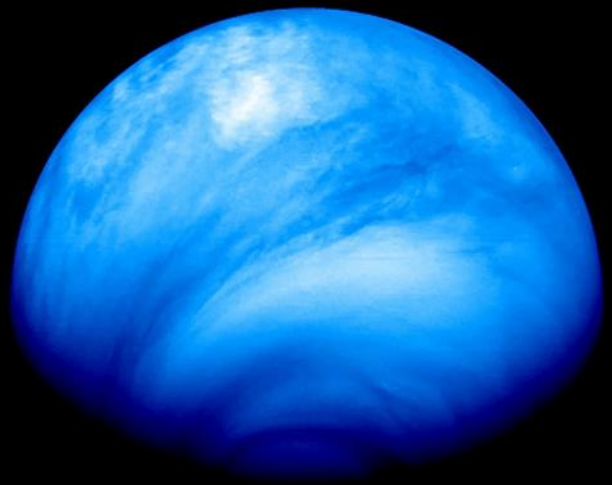
Venus Global Reference Atmospheric Model Status and Planned Updates



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Venus-GRAM

- Venus Global Reference Atmospheric Model (Venus-GRAM) is an engineering-level atmospheric model developed by MSFC that is widely used for diverse mission applications including:
  - Systems design
  - Performance analysis
  - Operations planning for aerobraking, Entry, Descent and Landing, and aerocapture
- One of a family of GRAMs including Earth, Mars, Titan and Neptune
- Is not a forecast model
- Outputs include density, temperature, pressure, wind components, and chemical composition
- Provides dispersions of thermodynamic parameters, winds, and density
- Optional trajectory and auxiliary profile input files
- Has been used in multiple studies and proposals including NESC Autonomous Aerobraking and various Discovery proposals
- Released in 2005

Venus-GRAM Atmosphere (0 - 250 km)

- From the surface to 250 km, Venus-GRAM atmosphere model is based on the Venus International Reference Atmosphere (VIRA).
- Lower atmosphere: 0 - 100 km
  - VIRA data depends on height and latitude.
- Middle-atmosphere: 100 - 150 km
  - VIRA data depends on height and local solar time (LST = 0 or LST = 12 Venus hours).
- Upper-altitude: 150 - 250 km
  - VIRA data depends on height and solar zenith angle.
- Venus-GRAM ensures smooth variation between height regions by averaging values at the two transition heights (100 km and 150 km).
- The original version of VIRA in Venus-GRAM includes Pioneer Venus Orbiter and Probe data as well as Venera probe data, but does not include a solid planet model, nor a high resolution gravity model.

Venus-GRAM Thermosphere (250 – 1000 km)

- The Venus-GRAM thermosphere (250 - 1000 km) is based on a MSFC-developed model.
- Model assumptions:
  - VIRA conditions and constituents at 250 km are used as lower boundary values
  - Constant (exospheric) temperature is assumed above 250 km (exospheric temperature = local VIRA temperature at 250 km)
  - Hydrostatic conditions are computed separately for each constituent (diffusive separation)
  - Total pressure is computed from constituent partial pressures
  - Mass density is computed from constituent number densities

Venus-GRAM Data Upgrades

- Several Venus atmosphere models and data sources are available that can be utilized to update Venus-GRAM:
  - Updated VIRA model in work
  - Earth observation data of Venus
  - Venus Express data
  - Magellan surface and gravity field data
  - Development of a Venus Global Ionosphere-Thermosphere Model (V-GITM)

Venus-GRAM Capability Upgrades

- Convert model code from Fortran to C++.
  - Object oriented code offers additional options not previously available.
- Identify high priority items that would enable mission modeling that is not currently available. Examples include:
  - Incorporating a higher resolution topography model for probe mission analysis.
  - Utilizing Venus Express data to build sets of auxiliary profiles for representation of mean atmospheric conditions in Venus-GRAM.
  - Characterizing observed atmospheric variability and update perturbation models for density, temperature, and winds in Venus-GRAM.

Proposed GRAM Maintenance Tasks

- Maintain consistent support and maintenance across all GRAM versions
- Establish formal communication between GRAM users and developers; monitor shortcomings, expand capability, and fix bugs
- Establish formal and continuous relationship between GRAM developers and model providers to ensure regular model updates
- Establish a regular process/call for proposals that allows NASA to procure models developed outside of the agency
- Incorporate surface and orbiting data, correlated where possible, into GRAM global circulation and dispersions models
- Work with international missions to obtain and incorporate atmosphere relevant data sets
- Evaluate additional features (e.g. destination specific uncertainty models, mesoscale model accommodation and interfaces)
- Document and present updated GRAM comparisons to recently acquired data sets

Path Forward

- 2016 New Frontiers Announcement and 2018 Discovery Announcement include Venus as a target destination.
- Sustained funding opportunities are being sought and are necessary to maximize the contribution an updated Venus-GRAM can make to the mission planning phases of proposals.
- Plan to host a virtual workshop for users, developers, modelers, and mission managers to identify and prioritize tasks required to upgrade all GRAMs.