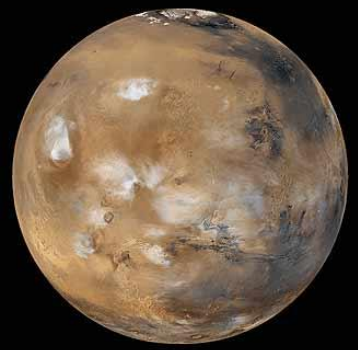
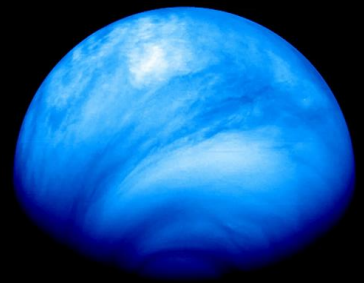
Mars and Venus Global Reference Atmospheric Model (GRAM) Updates





Hilary L. Justh

Planetary GRAM Lead
Natural Environments Branch (EV44)
NASA Marshall Space Flight Center
Hilary.L.Justh@nasa.gov

42nd COSPAR Scientific Assembly
14 - 22 July 2018, Pasadena, CA

What are the GRAMs?

- The Global Reference Atmospheric Models (GRAMs) are engineering-level atmospheric models applicable for engineering design analyses, mission planning, and operational decision making
  - Provide mean values and variability for any point in atmosphere
  - Include seasonal, geographic, and altitude variations
  - Outputs include winds, thermodynamics, chemical composition, and radiative fluxes
  - Integrates numerous data sets into a seamless composite climatology
  - Used by engineering community because of the need to simulate realistic dispersions; can be integrated into high fidelity flight dynamic simulations of launch, entry, descent and landing (EDL), aerobraking and aerocapture
- GRAMs are not forecast models
- GRAMs are available through the NASA Software Catalog: https://software.nasa.gov/

GRAM Progress

- MSFC Natural Environments Branch has been developing and upgrading GRAMs since 1974
- Earth-GRAM 2016 has been released in C++
- Current versions of the following GRAMs are written in Fortran:

  Mars-GRAM 2010 — Venus-GRAM 2005 Rel. Oct 2009

  Titan-GRAM 2004 — Neptune-GRAM 2004
- GRAM Virtual Workshop - September 21, 2017
  - GRAM developers gave overview presentations for each of the GRAMs
  - Attended by GRAM developers, GRAM users, planetary atmospheric modelers, and other interested parties to discuss the future of the GRAMs (at least 76 known attendees)
  - Identified and prioritized GRAM development work
  - Workshop presentations and report are available upon request from Hilary Justh
  - Another GRAM Workshop is planned for the future (Date TBD)

GRAM Upgrade Funding

- Over the past decade, GRAM upgrades and maintenance have depended upon inconsistent and waning project-specific funding
- Hilary Justh (MSFC) and Alicia Cianciolo (LaRC) co-authored a Directed Work Package that was submitted to NASA HQ on March 3, 2017
  - Focused on funding to maintain and update the GRAMs
- NASA Science Mission Directorate (SMD) has agreed to provide funding support in Fiscal Years 2018 and 2019 to upgrade the GRAMs
  - Decision based upon the Directed Work Package and the findings of the GRAM Virtual Workshop

Objectives

- The funding for the GRAM Upgrades aims to achieve three primary objectives:
  - Upgrade atmosphere models
    - Update the atmosphere models in the existing GRAMs
    - Establish a foundation for developing GRAMs for additional destinations
  - Modernize the code
    - Develop a new framework that transitions the original Fortran code to C++
    - Take advantage of the object-oriented capabilities of C++
  - Socialize plans and status to improve communication between users, modelers, and developers

Model Upgrade Task

- Determine which models have upgrades currently available and prioritize model upgrades
  - Mars: Mars Global Ionosphere-Thermosphere Model (M-GITM) and Mars Global Circulation Model (MGCM)
  - Venus: Venus International Reference Atmosphere (VIRA), Venus Thermospheric General Circulation Model (VTGCM), Venus General Circulation Model (VGCM), and Venus-Global Ionosphere-Thermosphere Model (V-GITM)
- Identify and obtain planetary mission atmospheric data and analysis, that is available and appropriate, to use as the basis for verification and validation of the GRAMs
  - Mars: MSL EDL Instrument (MEDLI) data from Mars Science Laboratory (MSL) and Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight) Dust Storm Models
  - Venus: Earth observation data of Venus, Venus-Express data, and Akatsuki data

Model Upgrade Task Continued

- Hold discussions with atmospheric model data providers
  - Determine status and format of data
  - Discuss strategies, options and approaches for implementing data
  - Establish a standard process for updating atmospheric model data
- Compare existing and new models to flight and observed data
- Implement model data into the GRAMs
- Add the highest resolution topography available/reasonable to each of the GRAMs
  - Mars: Increase the resolution of the Mars Orbiter Laser Altimeter (MOLA) aeroid data (Currently 1/2 by 1/2 degree lat-lon resolution) that is in Mars-GRAM
  - Venus: Implement solid body and Magellan topography in Venus-GRAM

Code Upgrade Task

- Understand existing code and software framework
  - Identify common elements between the GRAMs
  - Consider advanced GRAM features
- Develop a stand-alone C++ framework that simplifies model updates, integration, testing and maintenance
- Test new stand-alone framework
- Develop trajectory code interface
- Adapt new framework to develop other stand-alone GRAMs
- Initiate software release procedures

Model Socialization Task

- Socialize the status of the upgrades
- Advocate and promote the continued use of the GRAMs in proposals and projects
- Attend and present at advisory group meetings, workshops and conferences
  - Outer Planets Assessment Group (OPAG) – February 2018
  - Mars Exploration Program Analysis Group (MEPAG) – April 2018
  - 15th International Planetary Probe Workshop - June 2018
  - 42nd COSPAR Scientific Assembly - July 2018
  - Flight Mechanics TDT Face to Face Meeting – August 2018
  - Mars Atmosphere Data Assimilation Workshop - August 2018
  - International Venus Conference - September 2018

GRAM Upgrade Team

- Project Manager: Alicia Cianciolo (LaRC)
- Atmosphere Modeling Lead: Hilary Justh (MSFC)
- Lead Code Architect: Jim Hoffman (LaRC)
- Mars-GRAM Developer: Dr. Lee Burns (MSFC)
- Earth-GRAM Developer: Patrick White (MSFC)
- User Representative: Richard Powell (LaRC)

Recent Activities

- Titan-GRAM conversion to C++ has begun
  - Considered to be the GRAM of medium complexity
  - Dragonfly Mission to Titan one of two finalists for New Frontiers Program
- Organizing and hosting ongoing meetings with planetary modelers, mission data providers, and experts to determine new data sets that are available to upgrade existing planetary GRAMs (Mars, Venus, Titan, and Neptune-GRAM) and to develop new planetary GRAMs (Saturn, Uranus, and Jupiter-GRAM)
- Addressing isostatic equilibrium questions pertaining to the GRAMs
- Completing the following comparison studies:
  - Comparing Mars-GRAM outputs to Mars Science Laboratory (MSL) Entry Atmosphere Reconstruction
  - Comparing Earth-GRAM outputs to Modern-Era Retrospective analysis for Research and Applications (MERRA-2) data

Conclusions

- GRAMs are a critical tool set that influences mission selection and decisions
- Funding provided by the NASA SMD is vital to address current limitations and accomplish GRAM developmental goals
- Updates to the existing planetary GRAMs and development of new planetary GRAMs are planned with release dates TBD
- The GRAM Upgrade Team gratefully acknowledges support from the NASA SMD

Back-up Slides

GRAM Upgrade Team Tasks

- Project Manager: Alicia Cianciolo (LaRC)
  - Responsible for coordinating tasks, managing funds and SMD reporting
  - Attend regular progress meetings with Upgrade Team
  - Support MSFC, as needed, to obtain new data sets from planetary modelers and mission data providers
  - Connect with GRAM users to ensure requirements for this task are relevant
  - Attend conferences and meetings as needed to advocate and inform leadership of task progress and status
- Atmosphere Modeling Lead: Hilary Justh (MSFC)
  - Maintain regular progress meetings with all task participants and the Project Manager
    - Determine and distribute tasks
    - Share progress on task requirements and key schedule elements
  - Work with planetary modelers and mission data providers, in collaboration with the Project Manager and the GRAM Code Developers, to obtain and implement new data sets for the planetary GRAM code upgrades
  - Implement any new data sets into Venus, Neptune, and Titan-GRAM
  - Research possible development of Uranus and Saturn-GRAM
  - Validate models with available flight and/or observation data
  - Responsible for the transfer and acceptance of GRAM code redesign by LaRC to MSFC Natural Environments Branch
  - Attend conferences and meetings to inform and advocate for the GRAM models

GRAM Upgrade Team Tasks Continued

- Lead Code Architect: Jim Hoffman (LaRC)
  - Facilitate discussions required to define the scope of the code redesign with the Upgrade Team
  - Work with Upgrade Team to define code requirements
  - Work with Project Manager to ensure requirements for the upgrade task are met
  - Work with members of the MSFC Natural Environments Branch to ensure they understand the new code's functions and architecture
  - Deliver the new GRAM codes to MSFC Natural Environments Branch
- Mars-GRAM Developer: Dr. Lee Burns (MSFC)
  - Work in collaboration with the Project Manager and the Atmosphere Modeling Lead to obtain and implement new data sets from planetary modelers and mission data providers for Mars-GRAM
  - Validate models with available flight and/or observation data
  - Attend appropriate conferences and meetings to inform and advocate for the GRAM models
- Earth-GRAM Developer: Patrick White (MSFC)
  - Work in collaboration with the Project Manager and the Atmosphere Modeling Lead to obtain and implement new data sets from planetary modelers and mission data providers for Earth-GRAM
  - Validate models with available flight and/or observation data
  - Attend appropriate conferences and meetings to inform and advocate for the GRAM models
- User Representative: Richard Powell (LaRC)
  - Serve as the liaison between GRAM users and developers
  - Provide recommendations to the GRAM Upgrade task team