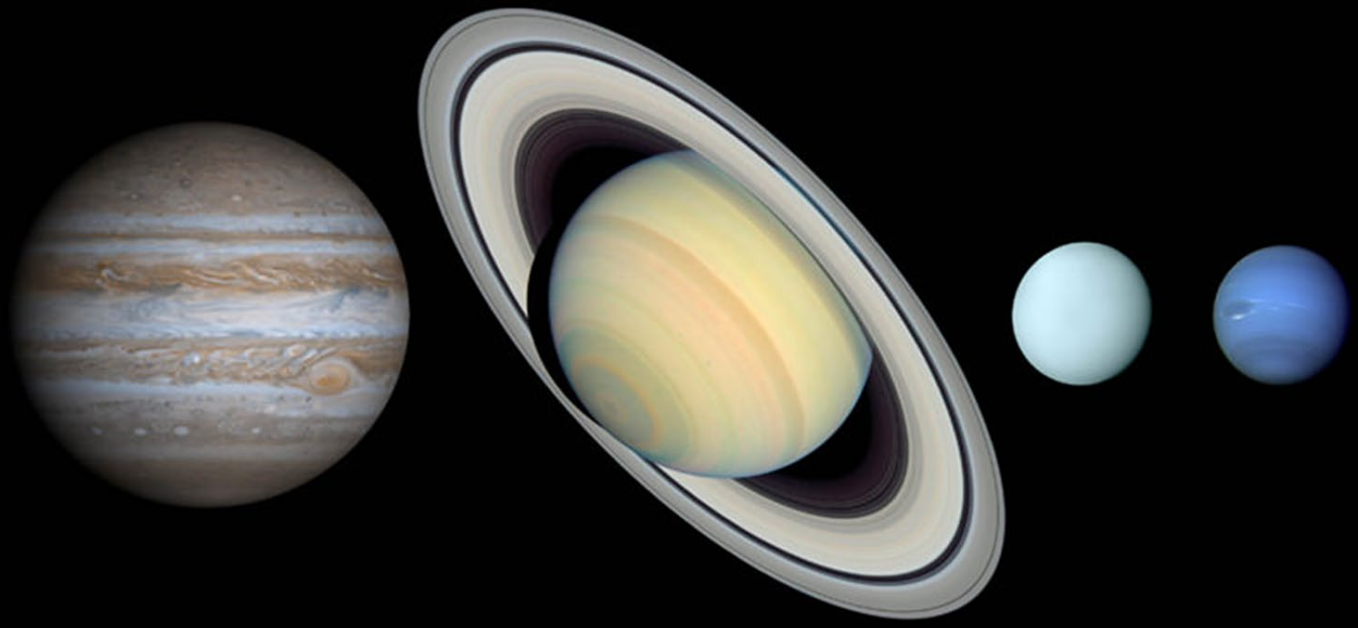
Outer Planet Global Reference Atmospheric Model (GRAM) Upgrade Status



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GRAM Overview

- Global Reference Atmospheric Model (GRAM) estimates mean values and statistical variations of atmospheric properties for Earth, Mars, Venus, Titan, Neptune, Uranus, and Jupiter
- Outputs include atmospheric density, temperature, pressure, chemical composition, radiative fluxes (for Mars-GRAM), and wind components along a user-defined path
  - Includes seasonal, diurnal, geographic, and altitude variations
- Widely used by the engineering community because of their ability to create realistic atmospheric dispersions
- Can be integrated into high fidelity flight dynamic simulations of launch, entry, descent and landing (EDL), aerobraking and aerocapture
- Not a forecast model

GRAM Upgrades

- The GRAMs have been rearchitected from Fortran to a common object-oriented C++ framework called the GRAM Suite
  - Contains a common GRAM library of data models and utilities as well as planet specific code
- GRAM ephemeris has been upgraded to the NASA Navigation and Ancillary Information Facility (NAIF) Spacecraft Planet Instrument C-matrix Events (SPICE) toolkit (version N0066)
- Speed of sound calculations have been improved within the GRAMs
- Released User Guides for all GRAMs and a Programmer's Manual
- GRAM Suite Version 1.4 contains the rearchitected Neptune, Titan, Venus, and Mars-GRAMs, the rearchitected and updated Earth-GRAM, and the new Uranus and Jupiter-GRAM
- Available through the NASA Software Catalog https://software.nasa.gov/software/MFS-33888-1

New Outer Planet GRAMs

- Uranus-GRAM atmospheric data is from the NASA Ames Research Center (ARC) Uranus Atmospheric Model[1,2]
  - Based on Voyager radio science, Infrared Interferometer Spectrometer and Radiometer (IRIS), and Ultraviolet Spectrometer (UVS) data from the Voyager 2 fly-by of Uranus that occurred on January 24, 1986[3,4,5]
  - Includes atmospheric density, pressure, temperature, and chemical composition (helium, hydrogen, and methane)
  - Does not include wind data
- Jupiter-GRAM atmospheric data is based on Galileo probe Atmospheric Structure Instrument (ASI) data from Seiff et al.[6]
  - Includes atmospheric density, pressure, and temperature
  - Does not include chemical composition or winds

Summary

- GRAMs are frequently used toolsets and vital in assessing effects of atmospheres on interplanetary spacecraft during the program life cycle process
- Releases of the GRAM Suite, upgrades of the existing outer planet GRAMs, and development of new outer planet GRAMs are continuing
  - Established Titan-GRAM Working Group
  - Contracted with Johns Hopkins University Applied Physics Laboratory to develop Dragonfly atmospheric profile for use in Titan-GRAM upgrade
  - Saturn-GRAM currently under initial stages of development
  - Ongoing discussions with modeling groups within NASA and academia regarding status of their models
  - Ongoing discussions with planetary mission teams to determine potential mission support by the GRAM team, utilization of collected atmospheric data, and needed GRAM upgrades

References

1. Allen Jr., G.A.; Marley, M.S.; and Agrawal, P.: “Uranus Atmospheric Model for Engineering Application”, Paper Presented at the 11th International Planetary Probe Workshop, Abstract #8023, Pasadena, CA, June 16-20, 2014.
2. Allen Jr., G.A.; Marley, M.S.; and Agrawal, P.: “Uranus Atmospheric Model for Engineering Application”, Paper Presented at the Workshop on the Study of the Ice Giant Planets, Abstract #2001, Laurel, MD, July 28-30, 2014.
3. Lindal, G.F.; Lyons, J.R.; Sweetnam, D.N.; Eshleman, V.R.; Hinson, D.P.; and Tyler, G.L.: “The Atmosphere of Uranus: Results of Radio Occultation Measurements with Voyager 2,” Journal of Geophysical Research, Vol. 92, No. A13, pp. 14,987-15,001, December 30, 1987.
4. Herbert, F.; Sandel, B.R.; Yelle, R.V.; Holberg, J.B.; Broadfoot, A.L.; Shemansky, D.E.; Atreya, S.K.; and Romani, P.N.: “The Upper Atmosphere of Uranus: EUV Occultations Observed by Voyager 2,” Journal of Geophysical Research, Vol. 92, No. A13, pp. 15,093- 15,109, December 30, 1987.
5. Bishop, J.; Atreya, S.K.; Herbert, F.; and Romani, P.: “Reanalysis of Voyager 2 UVS Occultations at Uranus: Hydrocarbon Mixing Ratios in the Equatorial Stratosphere,” Icarus, Vol. 88, pp. 448-464, 1990.
6. Seiff, A., et al.: “Thermal structure of Jupiter's atmosphere near the edge of a 5-μm hot spot in the north equatorial belt,” *Journal of Geophysical Research*, Vol. 103, No. E10, pp. 22,857-22,889, 1998.