OUTER PLANET GLOBAL REFERENCE ATMOSPHERIC MODEL (GRAM) UPGRADES. H. L. Justh[1], A. M. Dwyer Cianciolo[2], J. T. Aguirre[3], A. Diekmann[4], J. Hoffman[5], and R. W. Powell[6]. [1]NASA, Marshall Space Flight Center, Mail Code EV44, Marshall Space Flight Center, AL, 35812, hilary.l.justh@nasa.gov, [2]NASA, Langley Research Center, Mail Stop 489, Hampton, VA 23681, alicia.m.dwyercianciolo@nasa.gov, [3]Analytical Mechanics Associates, 21 Enterprise Pkwy., Suite 300, Hampton, VA 23666, john.t.aguirre@nasa.gov, [4]Jacobs Space Exploration Group, 1500 Perimeter Pkwy., Suite 400, Huntsville, AL 35806, anne.m.diekmann@nasa.gov, [5]Analytical Mechanics Associates, 21 Enterprise Pkwy., Suite 300, Hampton, VA 23666, james.hoffman-1@nasa.gov, and [6]Analytical Mechanics Associates, 21 Enterprise Pkwy., Suite 300, Hampton, VA 23666, richard.w.powell@nasa.gov.

Introduction: The Global Reference Atmospheric Model (GRAM) is one of the most widely used engineering models of planetary atmospheres. The GRAM upgrades are being developed by NASA Marshall Space Flight Center and NASA Langley Research Center. This presentation will provide details regarding the upgrades to the existing GRAMs, the development of new GRAMs, and the ongoing objectives, tasks, and milestones related to the GRAM upgrades funded by the NASA Science Mission Directorate (SMD).

GRAM: The GRAMs are engineering-oriented atmospheric models that estimate mean values and statistical variations of the atmospheric properties for numerous planetary destinations. They provide mean values and variability for any point in the atmosphere as well as seasonal, geographic, and altitude variations. GRAM outputs include atmospheric density, temperature, pressure, winds, and chemical composition along a user-defined path. They are extensively used by the engineering community because of their ability to create realistic dispersions. GRAMs have been integrated into high fidelity flight dynamic simulations of launch, entry, descent and landing (EDL), aerobraking and aerocapture. GRAMs are currently available for Earth, Mars, Venus, Neptune, Titan, and Uranus.

Outer Planet GRAM Upgrade Status:

Code Modernization. The outer planet GRAMs have been rearchitected from Fortran to a common object-oriented C++ framework called the GRAM Suite. This new architecture creates a common GRAM library of data models and utilities. The first C++ releases of the rearchitected legacy outer planet GRAMs (Neptune and Titan-GRAM) are straight conversions from the latest Fortran version.

Model Upgrades. The focus of the model upgrade task is to improve the atmosphere models in the existing GRAMs and to establish a foundation for developing GRAMs for additional destinations. The GRAM ephemeris has been upgraded to the NASA Navigation and Ancillary Information Facility (NAIF) SPICE toolkit (version N0066). The calculation of the speed of sound has also been improved in the GRAMs.

In FY20, the GRAM project established a contract with Hampton University to develop empirical global models for Jupiter, Saturn, Uranus, Neptune, and Titan.

Upgraded Outer Planet GRAM Releases. GRAM Suite Version 1.0 was released in May 2020 and contains the rearchitected Neptune-GRAM, including the common GRAM framework and planet–specific code. GRAM Suite Version 1.1 was released in September 2020 and added the rearchitected Titan-GRAM to the GRAM Suite. A User Guide and Programmer's Manual are released with all GRAMs.

New Outer Planet GRAM Releases. New GRAMs have been developed for Uranus and Jupiter. Uranus-GRAM is based on the NASA Ames Research Center (ARC) Uranus Atmospheric Model [1,2] and was released in GRAM Suite Version 1.2 in July 2021. Jupiter-GRAM is based on Galileo probe Atmospheric Structure Instrument (ASI) data from Seiff et al. [3] Saturn-GRAM is also under development. Both Jupiter and Saturn-GRAM will be released in future versions of the GRAM Suite.

Conclusions: GRAMs are vital and frequently used toolsets. Releases of the GRAM Suite, upgrades of the existing planetary GRAMs, and development of new planetary GRAMs are ongoing. Titan-GRAM atmosphere model upgrades will be included in the next phase of GRAM tasks.

References: [1] Allen Jr., G.A. et al. (2014) *11th International Planetary Probe Workshop*, Abstract #8023. [2] Allen Jr., G.A. et al. (2014) *Workshop on the Study of the Ice Giant Planets*, Abstract #2001. [3] Seiff, A. et al. (1998) *JGR*, 103, 22,857-22,889.

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