Mars-Global Reference Atmospheric Model:

Current Upgrade Activities and Potential New Data Products

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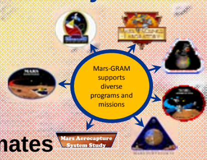
What Is a GRAM?

- GRAM stands for Global Reference Atmospheric Model.
- Queries datasets of atmospheric parameter values.
- Standalone or embedded subroutine operation.
- Robust set of inputs for solar activity, dust optical depth (OD; Mars only), perturbation scaling, optional runtime processes, mission time-lining, variable integration step sizes.
- Offers dispersion generation for Monte Carlo analyses.
- Designed to be engineering models, not scientific models.

Mars-GRAM supports a wide range of analyses:

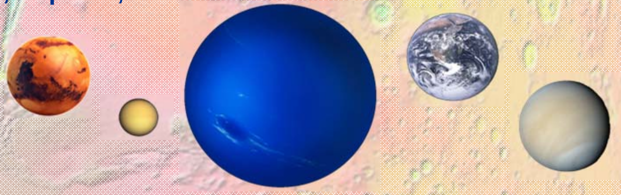
- Aerobraking/Aerocapture operations
- Landing site selection
- Entry system performance
- Thermal design requirements
- Satellite lifetime/station-keeping estimates



GRAMs support all mission phases.

- Concept development
- Requirements specification
- Hardware design
- Verification and test
- Deployment
- Operations
- Post-mission analysis

NASA GRAM Models currently exist for Earth, Venus, Mars, Neptune, and Saturn's moon Titan.



GRAMs are available through the NASA Software Catalog: https://software.nasa.gov/

GRAM development is funded by the NASA Science Mission Directorate (SMD). The funded activities are a joint-venture between the Marshall Space Flight Center (MSFC) and the Langley Research Center (LaRC). Currently on a 2-year funding increment (FY-2018 and FY-2019) to update all GRAM models.

Goal 1: Update all GRAM codes to a common framework.

- Convert all GRAM software from Fortran to C++.
- Standardize and streamline processing and computational flow.
- Accelerate development of GRAMs for new destinations.

Goal 2: Update atmospheric models and climatology data.

- Obtain more recent outputs from existing data sources.
- Explore additional potential data sources (MADA, true observations, etc.).

Goal 3: Improve communication between developers and users.

- Provide greater conference outreach.
- Prioritize and expedite response to bugs and new capability requests.

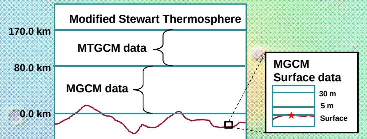
Project Personnel:

Alicia Dwyer-Cianciolo; LaRC:	Program Manager
Hilary Justh; MSFC:	Atmospheric Modeling Lead
Jim Hoffman; LaRC:	Lead Code Architect
Patrick White; MSFC:	Earth-GRAM Developer
Lee Burns; MSFC:	Mars-GRAM Developer
Richard Powell; LaRC:	User Representative

Current Mars-GRAM data:

The current climatology data comes from two primary sources, and was generated ~2000.

1. NASA Ames Research Center: Mars General Circulation Model (MGCM)
2. University of Michigan: Mars Thermospheric General Circulation Model (MTGCM)



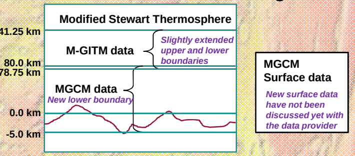
Current Climatology Dataset Characteristics			
Independent variables		Range	Increment
Ls		30 to 360 degrees	30 degrees
Dust OD	Uniform values	0.3, 1.0, 3.0	
	TES values	Derived from TES mapping years 1, 2	
Height	MGCM uniform dust cases	0 to 80 km	5 km
	MGCM TES dust cases	-5 to 10 km	1 km
		15 to 80 km	5 km
	MGCM surface data	0, 5, 30 m above topographic surface	
	MTGCM uniform dust cases	80 to 170 km	5 km
	MTGCM TES dust cases	80 to 240km	5 km
Latitude	MGCM Thermodynamics	-90 to 90 degrees	7.5 degrees
	MGCM Kinematics	-86.25 to 86.25 degrees	7.5 degrees
	MGCM surface data	-90 to 90 degrees	7.5 degrees
	MTGCM data	-87.5 to 87.5 degrees	5 degrees
Longitude	MGCM surface data	9 to 360 degrees	9 degrees
Solar activity (F10.7 flux)	MTGCM uniform dust cases	Low(70), medium(130) [at Earth radius]	
	MTGCM TES dust cases	Low(70), medium(130), high(200) [at Earth radius]	
Dependant variables		Zonal/diurnal tidal coefficients	
Temperature		Mean (K); amplitudes (K), phases (degrees)	
Pressure		Mean (PA); amplitudes (% mean), phases (degrees)	
Density		Mean (g/m^3); amplitudes (% mean), phases (degrees)	
Zonal and meridional wind		Mean (m/s); amplitudes (m/s), phase (degrees)	

Current Auxiliary Dataset Characteristics			
Additional datasets	Independent variables	Range	Increment
Albedo	Longitude	0.5 to 359.5 degrees	1 degree
	Latitude	-89.5 to 89.5 degrees	1 degree
Zf height (1.26 nbar level)	Ls	30 to 360 degrees	30 degrees
	Latitude	-87.5 to 87.5 degrees	5 degrees
	Dust OD	Uniform 0.3, 1.0, 3.0; TES years 1, 2	
TES observed dust OD	Longitude	9 to 360 degrees	9 degrees
	Latitude	-90 to 90 degrees	7.5 degrees
	TES mapping year	Year 1, year 2	
	Ls	30 to 360 degrees	30 degrees
MOLA aeroid height	Longitude	0.25 to 359.75 degrees	0.5 degrees
	Latitude	-89.75 to 89.75 degrees	0.5 degrees
Local topographic height	Longitude	0.25 to 359.75 degrees	0.5 degrees
	Latitude	-89.75 to 89.75 degrees	0.5 degrees
MTGCM height offsets	Ls	30 to 360 degrees	30 degrees
	Dust OD	Uniform 0.3, 1.0, 3.0; TES years 1, 2	

Potential new Mars-GRAM data:

Discussions to acquire new data are underway with the original providers. Both providers have delivered sample data for evaluation. Number and range of cases are being discussed.

- MGCM has undergone significant evolution.
- MTGCM model has been completely replaced by the Mars-Global Ionospheric Tropospheric Model (M-GITM).



- Both datasets contain longitudinal and time-of-sol variability. Thus, computation of tidal coefficients may be unnecessary.
- New MGCM data files contain 10 sols of output per Ls value. Thus, computation and use of standard deviations may be appropriate.
- M-GITM output files are instantaneous "snapshots" of the planet. Thus, multiple runs will be necessary to get diurnal variability.

Sample Updated Climatology Dataset Characteristics			
Independent variables		Range	Increment
Ls	MGCM data	90 to 360 degrees	90 degrees
	M-GITM data	Unspecified with data delivery	
Dust OD	MGCM data	MY24 dust climatology map; Montabone et al (2015)	
	M-GITM data	Unspecified with data delivery	
Height	MGCM data	-5 to 10 km	1 km
		15 to 80 km	5 km
	M-GITM data	78.75 to 241.25 km	2.5 km
Latitude	MGCM data	-85 to 85 degrees	5 degrees
	M-GITM data	-87.5 to 87.5 degrees	5 degrees
Longitude	MGCM data	-180 to 174.5	6 degrees
	M-GITM data	2.5 to 357.5 degrees	5 degrees
Time of Sol	MGCM data	16 values/sol, exact times vary by longitude	
	M-GITM data	One/latitude; varies by latitude	
Solar activity (F10.7 flux)	M0GITM data	Unspecified with data delivery	
Dependant variables		Units	
Temperature		K	
Pressure		PA	
Zonal and meridional wind		m/s	

Auxiliary Dataset Update Plans	
Additional datasets	Update plans
Albedo	No new datastets have been identified
Zf height (1.26 nbar level)	No new datastets have been identified
TES observed dust OD	No plans for new data
MOLA aeroid height	Higher resolution MOLA data; Specific resolution has not been selected
Local topographic height	Higher resolution MOLA data; Specific resolution has not been selected
MTGCM height offsets	Obsolete; no plans to upgrade

Mars-GRAM Could Benefit From Mars Atmosphere Data Assimilation (MADA)

- Replace/supplement modelled climatology data, combining the advantages of empirical data and advanced modeling capabilities. Using initial/boundary conditions derived more closely from actual observations could remove artificiality of dust specifications. GRAM development team would probably retain capability to use updated climatology data in addition to MADA results.
- Allow new capabilities, including higher temporal fidelity, implicit correlations between observed parameters, and more accurate representation of long-term variability.
- Earth-GRAM currently uses a data assimilation product, so experience applying these kinds of datasets is already in-house.