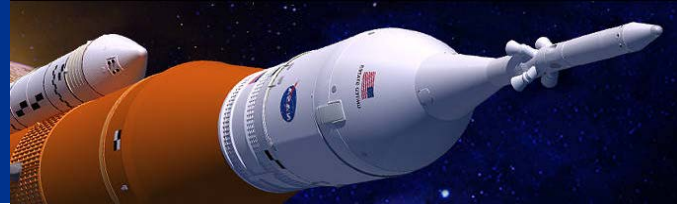


Mars-Global Reference Atmospheric Model:

Current Upgrade Activities and Potential New Data Products



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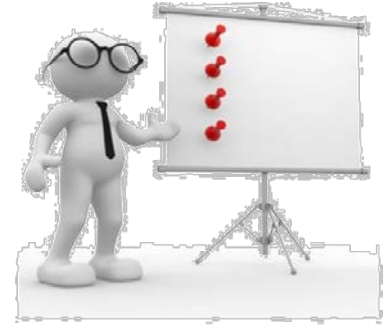
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Agenda

1. GRAM Introduction
2. Current Mars-GRAM data
3. GRAM Funding
4. Sample of potential updated Mars-GRAM data
5. Potential benefits of data assimilation to Mars-GRAM
6. Questions



What Is a GRAM?

- GRAM stands for Global Reference Atmospheric Model.
- Queries datasets of atmospheric parameter values.
- Standalone operation or can be embedded in trajectory codes.
- Includes 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, etc.
- Offers dispersion generation for Monte Carlo analyses.
- Designed to be engineering models, not scientific models.
 - Provide expected ranges of conditions, not prognostic forecasts.
 - Statistics based, not physics based.

NASA GRAM Models

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



GRAM Applications

GRAMs are used to support all mission program phases for launch vehicles, spacecraft, and payloads.

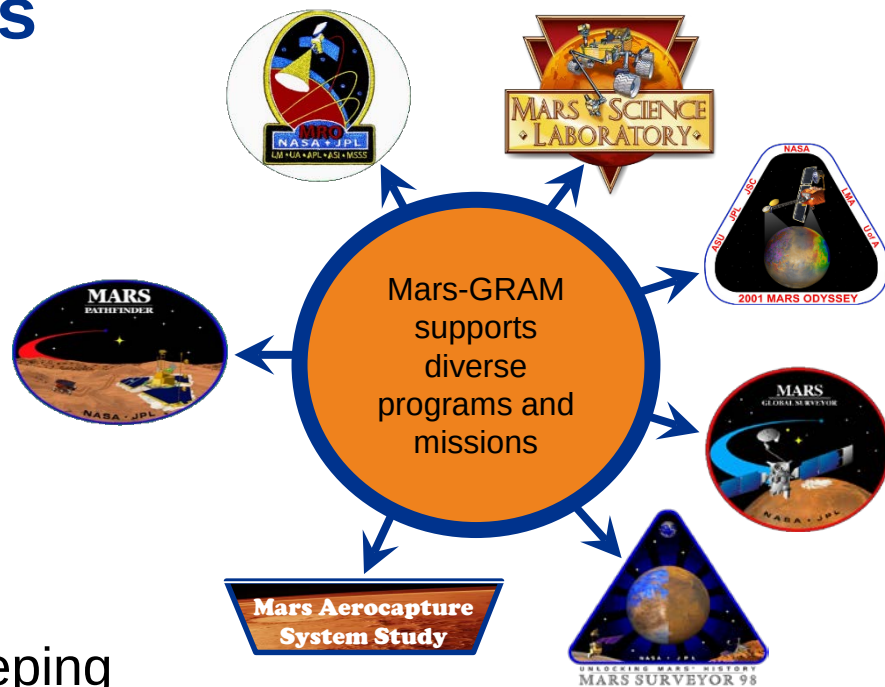
- Concept development
- Requirements specification
- Hardware design
- Verification and test
- Deployment
- Operations
- Post-mission analysis



Mars-GRAM Applications

Mars-GRAM supports a wide range of analyses:

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



Current Mars-GRAM Datasets

Mars-GRAM uses several different datasets to define conditions in the Mars atmosphere. The various datasets have their own gridding schemes for independent variables. The current primary climatology data come from two sources:

1. NASA Ames Research Center (ARC); Mars Climate Modeling Center:
Mars General Circulation Model (MGCM)
2. Steve Bougher; University of Michigan (UM): Mars Thermospheric
General Circulation Model (MTGCM)

The current climatology data were generated around the year 2000.

Current Mars-GRAM Data Formats

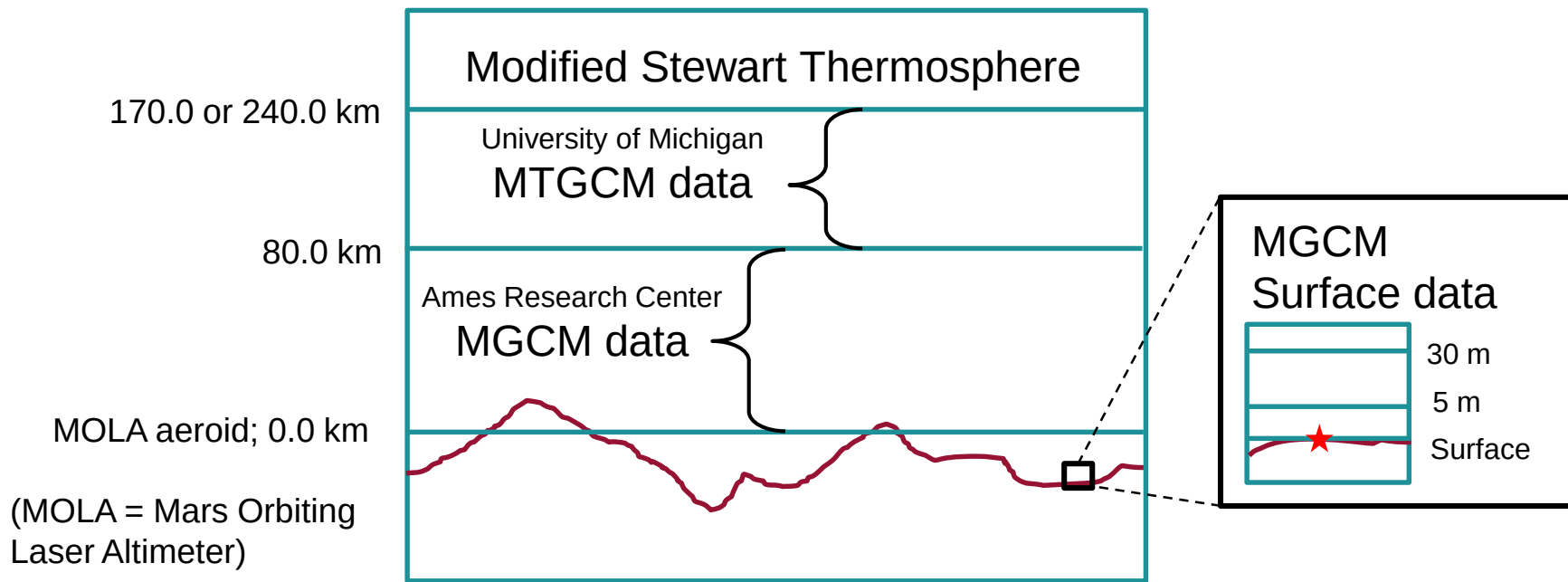
Mars-GRAM climatology data reside in text files that are converted offline to binary files for ingest by the model. Temperature (T), Pressure (P), Density (D), and Zonal (U) and Meridional (V) Wind values are expressed as five tidal coefficients:

1. Zonal/diurnal mean values
2. Amplitude of 1/sol tide
3. Phase of 1/sol tide
4. Amplitude of 2/sol tide
5. Phase of 2/sol tide

Note: Original delivered data files were not retained, and it is unknown if tidal coefficients were provided or computed locally.

Current Mars-GRAM Data Characteristics

Altitude regimes and data domains:



Current MGCM Surface Data Characteristics

Independent variables	Range	Increment
Ls	30 to 360 degrees	30 degrees
Latitude	-90 to 90 degrees	7.5 degrees
Longitude	9 to 360 degrees	9 degrees
Height	0, 5, 30 m above topographic surface	
Dust OD	Uniform values 0.3, 1.0, 3.0 TES* values Derived from TES mapping years 1, 2	

Dependant variables	Zonal/diurnal tidal coefficients
Temperature	Mean (K); amplitudes (K), phases (degrees)
Zonal and meridional wind	Mean (m/s); amplitudes (m/s), phase (degrees)

* TES = Thermal Emission Spectrometer

Current MGCM 0-80 km Data Characteristics

Independent variables		Range	Increment
Ls		30 to 360 degrees	30 degrees
Latitude	Thermodynamics	-90 to 90 degrees	7.5 degrees
	Kinematics	-86.25 to 86.25 degrees	7.5 degrees
Height	Uniform dust cases	0 to 80 km	5 km
	TES dust cases	-5 to 10 km	1 km
		15 to 80 km	5 km
Dust OD	Uniform values	0.3, 1.0, 3.0	
	TES values	Derived from TES mapping years 1, 2	

Dependant variables		Zonal/diurnal tidal coefficients
Temperature		Mean (K); amplitudes (K), phases (degrees)
Pressure	Uniform dust cases	Mean (PA); amplitudes (% mean), phases (degrees)
	TES dust cases	Mean (PA)
Density	Uniform dust cases	Mean (g/m^3)
	TES dust cases	Mean (g/m^3); amplitudes (% mean), phases (degrees)
Zonal and meridional wind		Mean (m/s); amplitudes (m/s), phase (degrees)

Current MTGCM Data Characteristics

Independent variables		Range	Increment
Ls		30 to 360 degrees	30 degrees
Latitude		-87.5 to 87.5 degrees	5 degrees
Height	Uniform dust cases	80 to 170 km	5 km
	TES dust cases	80 to 240km	5 km
Dust OD	Uniform values	0.3, 1.0, 3.0	
	TES values	Derived from TES mapping years 1, 2	
Solar activity (F10.7 flux)	Uniform dust cases	Low(70), medium(130) [at Earth radius]	
	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 Additional Data 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	

GRAM Funding

- 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).

Current Funding Program Has Three Goals

- 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 GRAM developers, users, and model providers.
 - Provide greater conference outreach.
 - Prioritize and expedite response to bugs and user requests for new capabilities.

New Funding Program 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 |

New Mars-GRAM Data

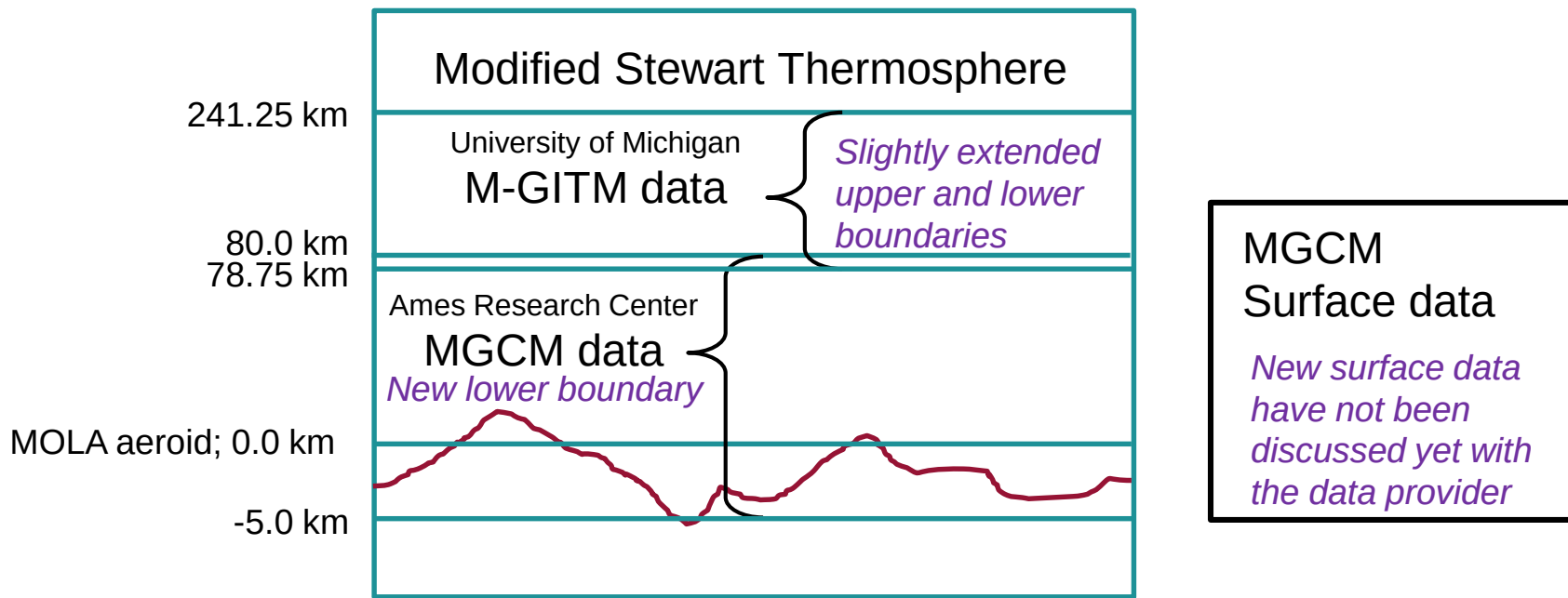
- Discussions are underway with the original climatology data providers (ARC and UM) to acquire new data from the latest versions of their respective models.
- Both providers have delivered samples of their latest outputs for evaluation.
- MGCM has undergone significant evolution over the ~18 years since the original Mars-GRAM data delivery was made.
- MTGCM model has been completely replaced by the Mars-Global Ionospheric Tropospheric Model (M-GITM).
- Discussions with data providers regarding the number of cases to be provided, and their associated specifications, are ongoing.

New Mars-GRAM Data Formats

- Sample MGCM output files are provided in netCDF format.
- Sample M-GITM output files are provided in text “datacube” format.
- Both sets of outputs contain explicit 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 application of standard deviations may be appropriate.
- M-GITM output files are instantaneous “snapshots” of the planet, meaning different longitudes show outputs for different local times. Thus, multiple runs will be necessary to get diurnal variability.

New Mars-GRAM Data Characteristics

Altitude regimes and data domains:



Vertical coverage of new climatology data.

New MGCM Data Characteristics

Independent variables	Range	Increment
Ls	90 to 360 degrees	90 degrees
Latitude	-85 to 85 degrees	5 degrees
Longitude	-180 to 174.5	6 degrees
Height	-5 to 10 km	1 km
	15 to 80 km	5 km
Dust OD	MY24 dust climatology map; Montabone et al (2015)	
Time of Sol	16 values/sol, exact times vary by longitude	

Dependant variables	Units
Temperature	K
Pressure	PA
Zonal and meridional wind	m/s

New M-GITM Data Characteristics

Independent variables	Range	Increment
Ls	Unspecified with data delivery	
Latitude	-87.5 to 87.5 degrees	5 degrees
Longitude	2.5 to 357.5 degrees	5 degrees
Height	78.75 to 241.25 km	2.5 km
Dust OD	Unspecified with data delivery	
Time of Sol	One/latitude; varies by latitude	
Solar activity (F10.7 flux)	Unspecified with data delivery	

Dependant variables	Units
Neutral Temperature	K
Pressure	PA
Zonal and meridional wind	m/s

Additional Data Update Plans

Additional datasets	Update plans
Albedo	No new datasets have been identified
Zf height (1.26 nbar level)	No new datasets 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

Other datasets (science observations, other climate model outputs, vehicle operational engineering measurements, MADA results, etc.) are being evaluated and will be added as deemed appropriate to supplement the standard climatology.

How Mars-GRAM Could Benefit From MADA

- Replace and/or supplement modelled climatology data.
 - Combines 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.
 - Higher temporal fidelity.
 - Implicit correlations between observed parameters.
 - 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.

My Goals For Today, Tomorrow and Beyond:

- Contribute support to MADA workshop and process development.
- Deliver a high quality engineering analysis tool as the next Mars-GRAM update (MG-2020?) using the best available climatology data.
- Promote Mars-GRAM usage within NASA, academia, commercial entities, and other governments seeking to explore the red planet.
- Facilitate updates for the other planetary GRAMs, and develop additional GRAMs for new destinations.
- In some semi-distant future, sit on my front porch rocking chair, watching streaming video of humans walking on another world and know that I had some tiny part of that grand adventure.

Questions

