Integration of Mars Global Surveyor Observations of the 25MY Global Dust Storm on Mars: Implications for Atmospheric Modeling

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Mars Global Surveyor (MGS) monitoring of the 25MY (2001) global dust storm (GDS) has yielded an unprecedented wealth of data on the initiation and growth of the most of a major dust event, allowing for the juxtaposition of temperature and dust optical depth (opacity) fields with visual imagery to enable a more comprehensive assessment of storm development. Here we present NASA/Ames General Circulation Model (GCM) results that relate the simulated circulation, atmospheric temperature, and aerosol distribution to the available observations in an effort to better understand the underlying dynamics of the initiation and growth of the 25MY GDS. We also present the creation of a synthetic (composite) dust opacity dataset to supplement missing or unreliable TES retrievals. We are using this new dataset as input into the NASA/NOAA Mars GCM. Results will be presented elsewhere.

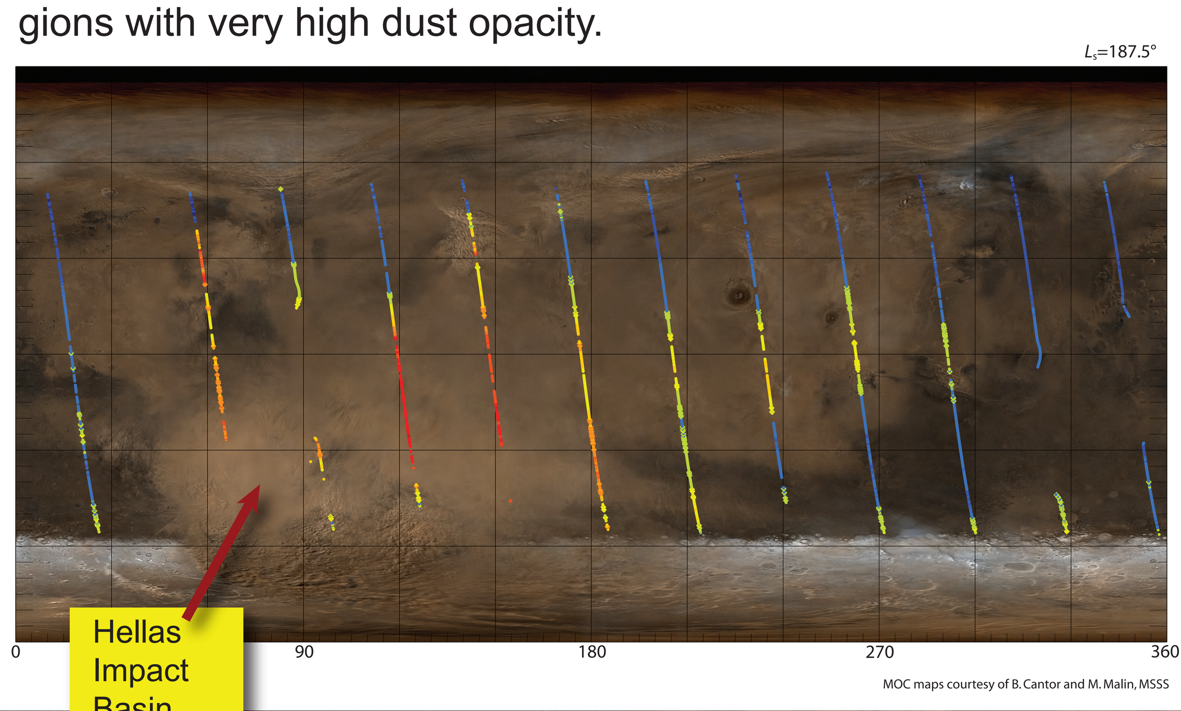
Objectives

- Combine and examine a synthesis of MGS observations of the 25MY GDS to better characterize its development and to investigate which components of the general circulation were involved in storm onset and evolution.
- Produce best possible description of the evolution of column optical depth and regions of active dust lifting based on a synthesis of all available data.
- Produce synthetic datasets of dust opacity to provide better constraints/bases for future modeling

Datasets

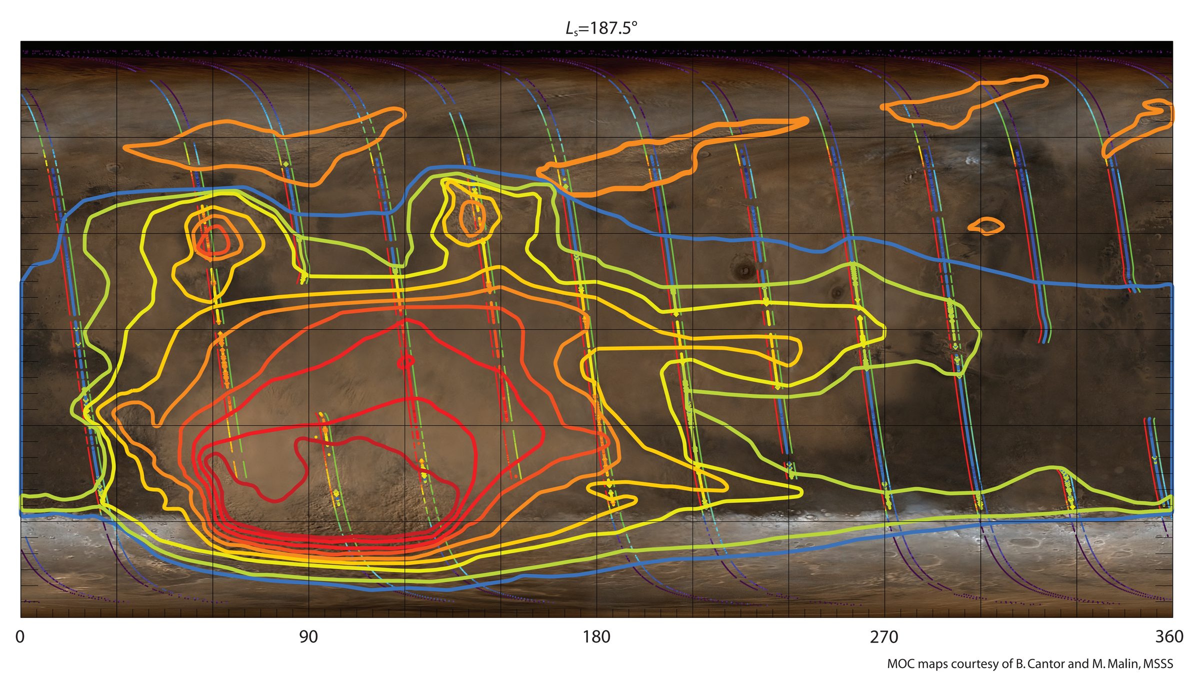
- Mars Orbiter Camera (MOC) daily global maps (Mike Malin and Bruce Cantor)
- Thermal Emission Spectrometer (TES) measurements of atmospheric temperature and 9 µm dust opacity (Phil Christensen and Mike Smith)
- MGS Limb temperature measurements (Mike Smith)
- Mars Horizon Sensor Assembly (MHSA) measurements of middle atmosphere temperatures. (Terry Martin & Jim Murphy)

Known limitations of TES dust opacity observations result in significant spatial gaps in data, especially at high latitudes and in regions with very high dust opacity.



Synthetic dust opacity maps

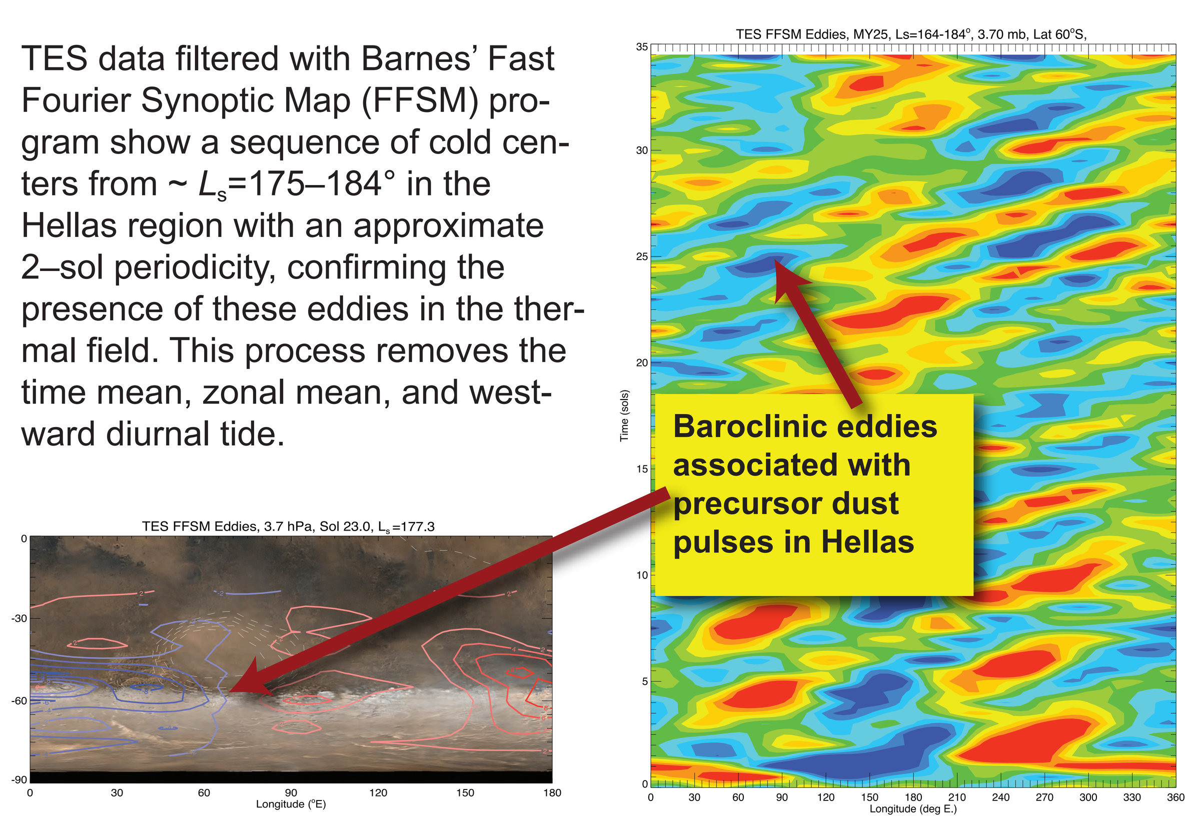
We supplement TES opacity estimates with MOC imagery, surface-air temperature contrasts, and interpretive extrapolation to construct a detailed description and gridded dataset of the initiation and growth of the dust event.

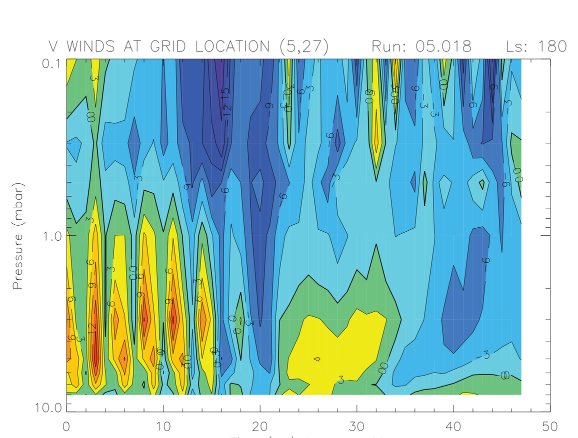


Precursor phase (L_s=176.2–184.4°)

- MOC observations indicate that the initial regional storm in Hellas developed following a series of local storm activity with ~ 2 - 3 sol periodicity (Cantor 2006).

TES data filtered with Barnes' Fast Fourier Synoptic Map (FFSM) program show a sequence of cold centers from ~ L_s=175–184° in the Hellas region with an approximate 2–sol periodicity, confirming the presence of these eddies in the thermal field. This process removes the time mean, zonal mean, and westward diurnal tide.





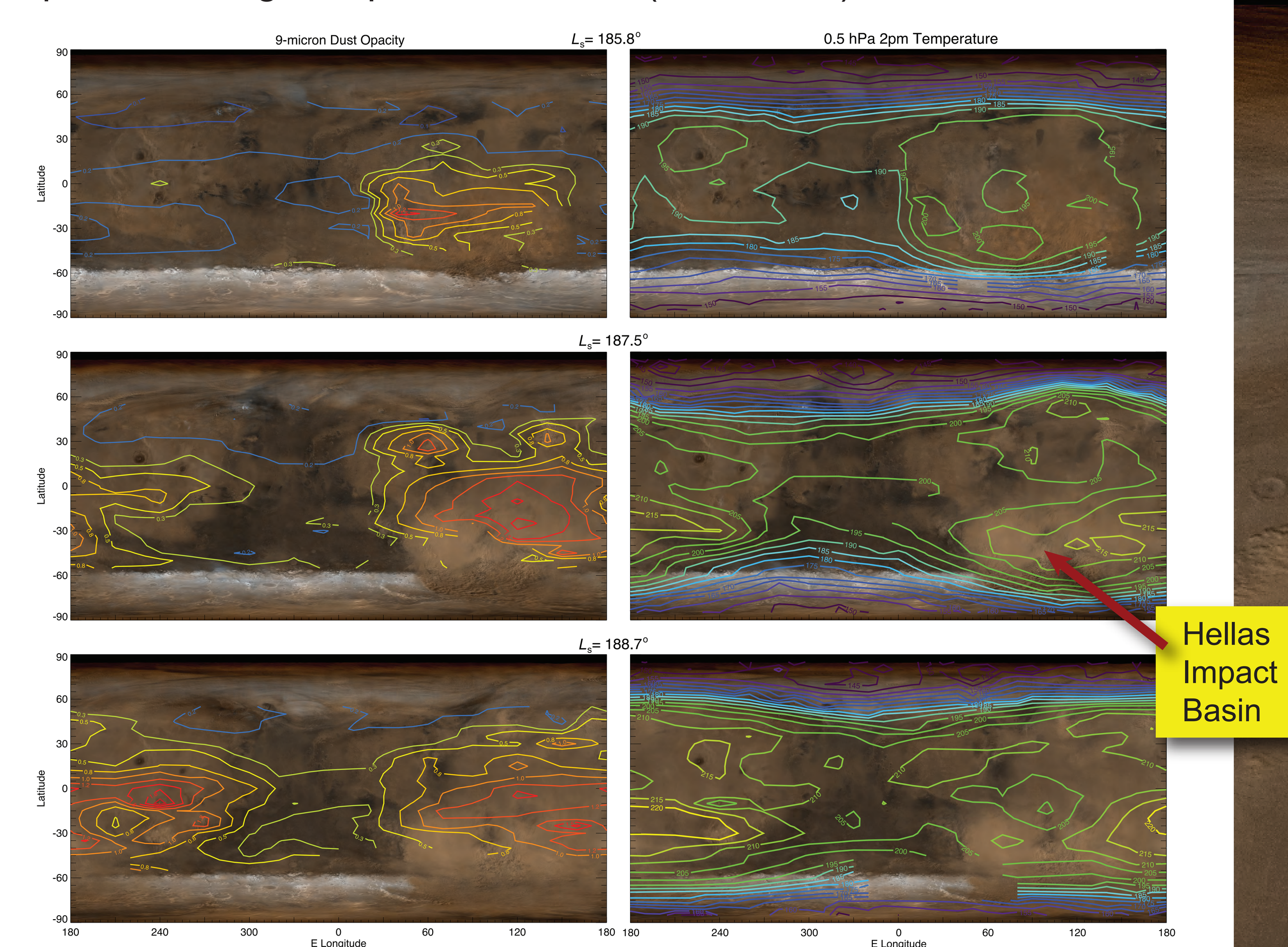
NASA-Ames GCM simulations* of the daily average value of the meridional wind oscillate with a period of ~ 2 sols, appearing to capture this behavior.

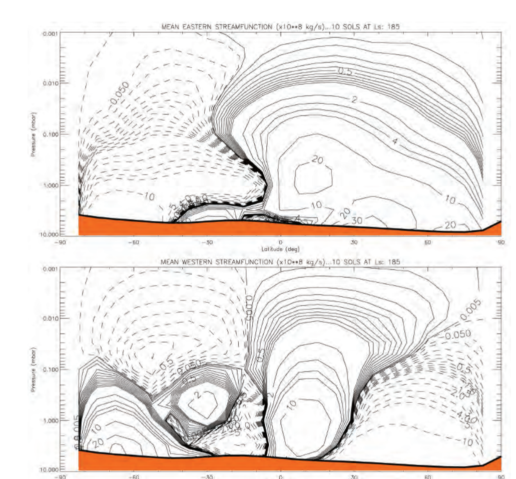
Sol-avergaged meridional wind shows the depth of the disturbance. The pattern significantly changes when the regional storm expands out of Hellas.

*not using new, synthetic dust opacity

Expansion phase (L_s=184.7-200.3°)

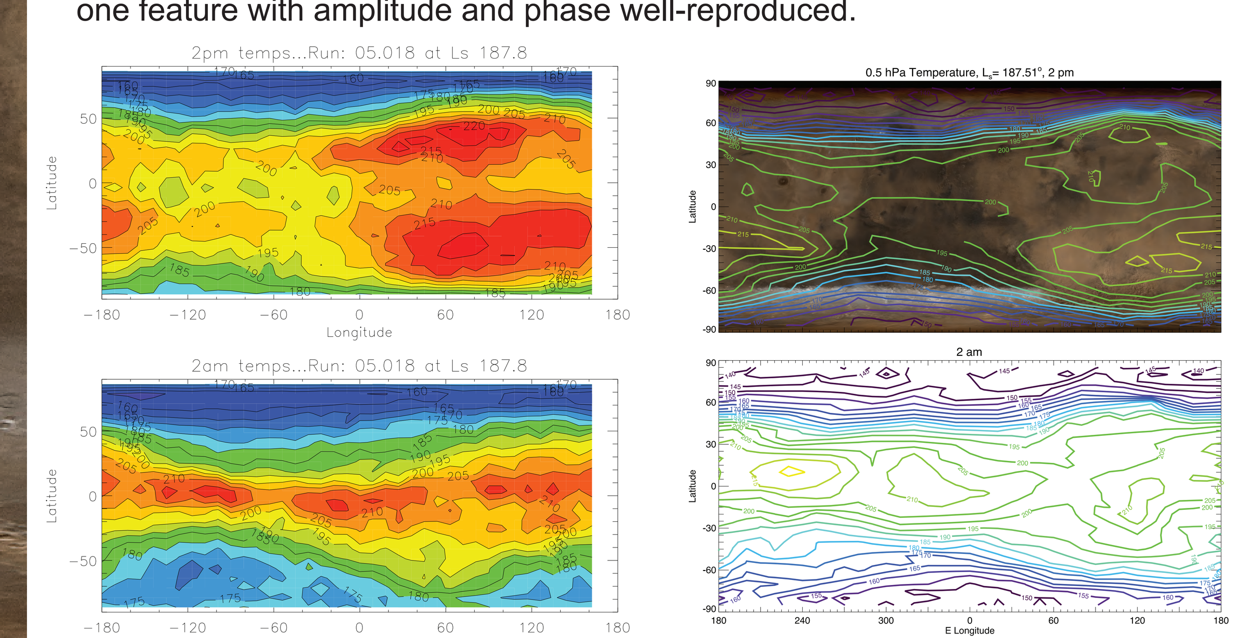
MOC imagery with TES 2pm temperatures superimposed show that by L_s=187.5°, the lifted dust in the Hellas sector had led to the development of a large-amplitude quasi-stationary wave one feature in the temperature field from .11 mb to .83 hPa, with a peak-to-trough amplitude of ~30K (at 0.5 hPa).





NASA-Ames GCM simulations of the mass stream function based on 10 sols of data from Ls=185 show a significant difference in the strucutre of the Hadley circulation. Dust forcing in Hellas is perturbing the circulation, resulting in a longitudinally dependent disturbance: in the eastern hemisphere, a symmetric Hadley cell extends from the equator to each pole – stronger and broader than usual. Sinking motion associated with the descending branch causes compressional heating.

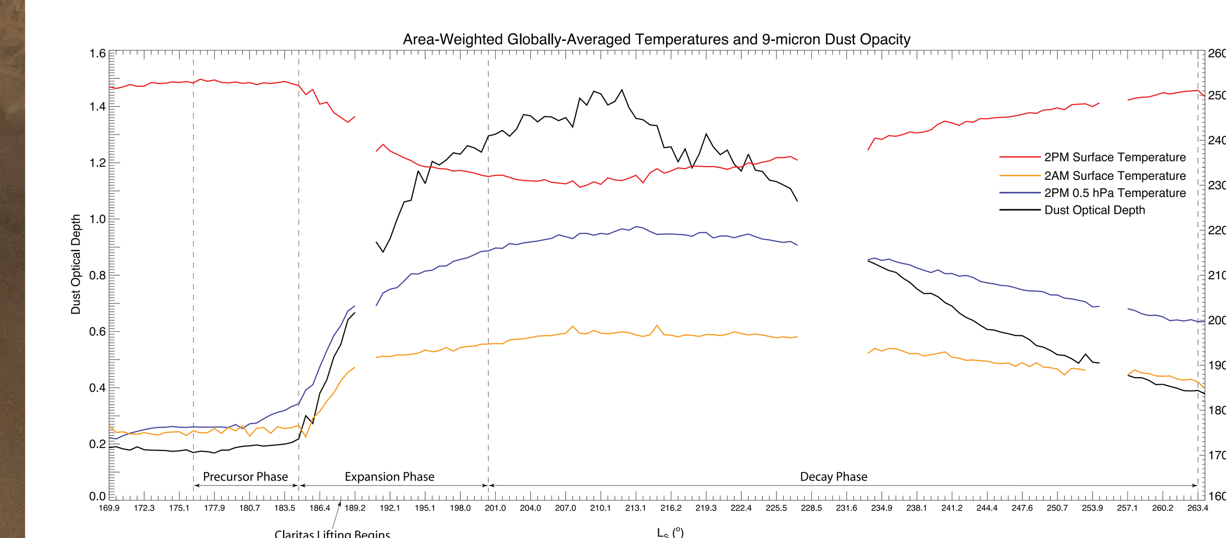
NASA-Ames GCM simulations of the temperature field (left) capture the wave-one feature with amplitude and phase well-reproduced.



Working Hypothesis

A superposition of traveling baroclinic eddies, thermal tides, and topographically-enhanced cap-edge circulation triggered the Hellas regional storm. Westerly winds carried the dust eastward into a longitude sector where a wave-one stationary wave pattern advected the dust southward over the polar cap. As the dust reached higher altitudes in this longitude sector, the subsequent heating over a deep part of the atmosphere amplified the wave-one stationary wave exciting a Rossby wave train that propagated into the opposite hemisphere.

Shortly after the wave-one reached its maximum amplitude, dust lifting began in the Syria-Claritas region, a development possibly related to enhanced thermal tides and the propagating Rossby wave train. Lifting in this region, which was the major source of atmospheric dust, may have been sustained by enhanced tides augmented by upslope/downslope flows. Zonal mean westerlies and the mean meridional circulation affected the largely eastward movement of dust during storm onset, and eventual northward and global dispersion.



Future work

- Conduct simulations and model validation with various synthetic dust opacity datasets (horizontal & vertical distribution)
- Identify high and low confidence regions and perform sensitivity tests
- Create *n*-dimensional dataset with various quantities that suggest possible dust cloud height, such as *dT/dz, dT/dt,* & stability
- Develop model logic to recognize areas with missing data and make appropriate assumptions for supplementation

References

Cantor, B. A., 2007: MOC Observations of the 2001 Mars planet–encircling dust storm. *Icarus*, **186**, 60–96

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