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TITLE: "Solar Cycle/Seasonal Variations of H, D, H_2 and He Distributions and Escape on Mars as Determined by the Mars Thermosphere General Circulation Model (MTGCM)"

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University of Michigan
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I. Summary of Research and Activities

This 1-year NASA Planetary Atmospheres Grant was made to Dr. Bougher after the proposal of the same name (above) was rejected for full 3-year funding. Instead, the NASA Program Manager (Dr. John Hillman) provided this 1-time "close-out" funding to Dr. Bougher until a new NASA Planetary Atmospheres full proposal could be submitted, reviewed, and funded. Such a full proposal was submitted, reviewed, and funded 1-year later.

This [redacted] of "close-out" funding was used to accomplish a small fraction of research tasks originally proposed. In particular, Dr. Bougher chose to focus upon 2-topics: the impact of the Mars thermospheric circulation (during solstice conditions) upon helium distributions and winter polar night temperatures [Bougher et al., 2003; 2004; Keating et al., 2003].

The Mars Thermosphere General Circulation Model (MTGCM) was exercised for Ls = 90 (aphelion) solar minimum, and Ls = 270 (perihelion) solar maximum conditions. Simulated MTGCM outputs (i.e. helium density distributions) were compared to those previously observed for Earth and Venus. Winter polar night bulges of helium are predicted on Mars, similar to those observed on the nightside of Venus and in the winter polar regions of Earth [Bougher et al., 2003]. A poster on this research was presented at the European Geophysical Society Meeting (EGS) in 2003 (see attached summary of this poster). This research paves the way for what might be expected in the polar night regions of Mars during upcoming aerobraking and mapping campaigns.

Lastly, Mars thermosphere (~100-130 km) winter polar warming was observed at high Northern latitudes during the perihelion season, but not at high Southern latitudes during the opposite aphelion season [Keating et al., 2003]. Presumably, the Mars thermospheric circulation is responsible for the dynamically controlled heating needed to warm polar night temperatures above radiative equilibrium values. Again, MTGCM simulations were conducted for Ls = 90 and Ls = 270 conditions; polar temperatures were examined and found to be much warmer at Northern high latitudes (perihelion) than at Southern high latitudes (aphelion), similar to Mars aerobraking datasets [Keating et al., 2003; Bougher et al., 2004]. The Mars thermospheric circulation is found to be stronger during perihelion solstice conditions than during aphelion conditions, owing to both stronger seasonal solar and dust heating during Mars perihelion. An invited talk was given at the Spring AGU 2004 on this research [Bougher et al., 2004]. A forthcoming GRL paper was drafted on this same topic [Bougher et al., 2005], but not submitted before the termination of this 1-year grant.

II. Conference Talks on Funded Research

Bougher, S. W. and R. G. Roble, "Helium as a Tracer of the Terrestrial Planet Upper Atmosphere Dynamics: Predictions for Mars", Geophysical Research Abstracts, Vol. 5, 01542, 2003.

Bougher, S. W., J. H. Waite, Jr., T. Majeed, and J. R. Murphy, "Responses by the Mars and Jupiter Upper Atmospheres to External Forcings: Contrasts for TGCM Simulations", Invited, EOS Trans. AGU, 85 (7), Joint Assembly Supplement, Abstract #SA51B-05, 2004.

III. Publication (in Process)

Bougher S. W., J. M. Bell, J. R. Murphy, M. A. Lopez-Valverde, and P. G. Withers, "Polar Warming in the Mars Lower Thermosphere: Seasonal Variations Owing to Changing Insolation and Dust Distributions", to be submitted to GRL, 2005.

IV. Added Reference

Keating, G. M. et al., "Brief Review on the Results Obtained with the MGS and Mars Odyssey 2001 Accelerometer Experiments", Int'l Workshop: Mars Atmosphere Modeling and Observations", Granada, Spain, January 13-15, 2003.

V. Summary of EGS Poster (see Attached)

Geophysical Research Abstracts, Vol. 5, 01542, 2003

HELIUM AS A TRACER OF TERRESTRIAL PLANET UPPER ATMOSPHERE DYNAMICS : PREDICTIONS FOR MARS

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The comparative approach to planetary problems is becoming increasingly fruitful as new information from various planet atmospheres is assimilated. In particular, Earth, Venus and Mars upper atmosphere observations and modeling studies over the past 35-years provide a useful platform for addressing similar processes in other planetary environments.

It is well known from thermospheric studies that light species (e.g. H, He) are efficiently redistributed about Venus and Earth by the global scale thermospheric circulation patterns that prevail. These observed helium distributions in fact can be used as a first order tracer of the seasonal thermospheric wind patterns on these two planets. For Earth, large winter bulges of helium are observed by satellite drag and mass spectrometer data (Keating and Prior, 1968; Reber et al., 1968; Mayr et. al., 1978). For Venus (a slow retrograde rotating planet), a helium bulge is observed on the nightside, consistent with a combined subsolar-to-antisolar plus retrograde superrotating zonal flow (e.g. Niemann et al.. 1980; Bougher et al., 1997). Likewise, we anticipate that helium will serve as first order tracer of the Mars thermospheric circulation. We present new Mars Thermospheric General Circulation Model (MTGCM) simulations that provide predictions of the expected helium distribution in the Mars upper atmosphere over 100 to 300 km. A winter polar helium bulge is anticipated which could dominate total densities above about 300 km. This seasonal feature could impact spacecraft drag if orbits pass through the winter polar night region (e.g. Mars Reconnaissance Orbiter).

Data are needed to confirm these MTGCM predictions and measure the global scale wind patterns at Mars. The impact of exospheric return flow upon the Mars helium distribution remains to be estimated.

Table 1. SOLAR CYCLE AND SEASONAL VARIATIONS OF HELIUM AT MARS

Ls (F10.7-cm FLUX)	ALTITUDE (km)	LST=6 (NT/DY RATIO)	SLT = 15 (NT/DY RATIO)
	PERIHELION/SMAX		
270 (200)	200	500	400
	180	450	316
	160	450	316
	140	180	133
	120	30	15
	APHELION/SMIN		
90 (70)	200	80	70
	180	78	63
	160	78	63
	140	70	60
	120	38	30

CONCLUSIONS AND SUMMARY

- **Global scale thermospheric wind effects on light species are pronounced for Venus and Earth.**

– Winter helium bulges in the Earth thermosphere (solstices)

– Nightside helium bulge (at equator) in the Venus thermosphere.

– Wind-induced diffusion of light species driven by large scale winds.

– Strength of circulation and magnitude of bulges vary with solar cycle.

– Superimposed SS-AS and RSZ wind components at Venus are confirmed by changing location of helium bulge on the nightside. Good tracer of the circulation.

- **Simulated MTGCM thermospheric circulation yields pronounced winter polar helium bulges as well:**

– Solstice circulations are the strongest; bulge magnitudes are the largest.

– Solstice (Ls = 90) driven bulges (NT/DY) reach 70-80x (at 200 km).

– Solstice (Ls = 270) driven bulges (NT/DY) reach 400-500x (at 200 km).

– Perihelion/SMAX bulges are largest; aphelion/SMIN bulges are smallest.

– Magnitude of bulges can be used as constraint on wind magnitudes.

– Position of bulges can be used as constraint on wind patterns.

- **Mars winter polar night bulges determine that helium surpasses atomic oxygen above 250 km in the thermosphere, affecting mean mass and density:**

– Will impact drag calculations for Mars spacecraft above 250 km.

– Important for MRO Mission for Primary Science Orbit planning.

- **Mechanisms to reduce NT/DY helium ratio at Mars :**

– Helium escape fluxes (global average is already included)

– Helium exospheric return flow (temperature and density dependent)