THE IMPACT OF MESOSCALE PROCESSES ON THE ATMOSPHERIC CIRCULATION OF MARS

Thesis by

Nicholas Gray Heavens

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Maxima pars uatum, pater et iuuenes patre digni,
decipimur specie recti. Breuis esse laboro,
obscurus fio; sectantem leuia nerui
deficiunt animique; professus grandia turget;
serpit humi tutus nimium timidusque procellae;
qui uariare cupit rem prodigialiter unam,
delphinum siluis adpingit, fluctibus aprum.

The vast majority of poets, both the laureate
And the young ones some day laurelworthy,
We all are deceived by the appearance of right.
I strive to be succinct, yet I become obscure.
My mind and nerves fail in the pursuit of eloquence.
Turning epic, I merely might appear swollen.
Or fearful of such storms I could creep along
Safely upon well-trodden ground.
Since he who wants to remake a world
With overweening genius often paints
A dolphin burrowing in the woods
Or a boar at play in the rolling waves.

Quintus Horatius Flaccus, *Ars Poetica*

Acknowledgements

When I first arrived at Caltech in June of 2005, I discovered that the Registrar's Office still had my contact information from when I was admitted as an undergraduate and that the Registrar was willing to make an initial value guess of June 2010 for my graduation date. It now appears that my choice to give Caltech a second chance and the Registrar's estimate were both correct. But I do maintain that if there has been any ease or celerity in the course of my graduate career, it was not my doing.

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Abstract

The study of the modern martian atmosphere is (1) a key to the climate of Mars's past; (2) useful for comparison with other terrestrial planets such as the Earth; and (3) can support hazard analysis and weather forecasting for future exploration and habitation of the planet. Recently, it was found that middle atmospheric downwelling near the south pole during southern winter is much more vigorous than predicted by most Mars general circulation models. This underestimate may be due to models erroneously representing the radiative forcings in the atmosphere due to aerosol and/or the mechanical forcings due to wave breaking. Errors of this kind would influence middle atmospheric dynamics and likely would result from incomplete understanding of lower atmospheric processes such as dust transport. Here, retrievals of vertical profiles of temperature, pressure, dust, and water ice from the Mars Climate Sounder (MCS) on Mars Reconnaissance Orbiter (MRO) are used to characterize the atmospheric circulation of Mars and its forcings. First, I consider the annual cycle of the thermal structure and aerosol distributions of the lower and middle atmosphere and investigate the degree of coupling between the lower and middle atmospheric mean meridional circulations. To evaluate the role of wave breaking, I look for local convective instabilities in the martian middle atmosphere: a key indicator of saturating vertically propagating waves such as the gravity waves and the thermal tides, which are important sources of wave drag in the Earth's mesosphere. I then characterize the vertical distribution of dust and its approximate radiative effects during northern spring and summer and show there is usually a maximum in dust mass mixing ratio at ~15—25 km above the tropics, which is not currently simulated by models. Next, I evaluate the relative importance of dust storm activity, pseudo-moist convection due to the solar heating of dust, orographic effects, and scavenging by water ice clouds in producing this maximum. Finally, I show that published models underestimate the thickness and altitude of water ice clouds in northern summer.

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