

THE IMPACT OF MESOSCALE PROCESSES ON THE ATMOSPHERIC CIRCULATION OF MARS

Thesis by

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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*

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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.

Table of Contents

List of Figures	x
List of Tables	xiii
Chapter 1: Introduction	1
Bibliography	12
Chapter 2: The Mean Meridional Circulation of the Martian Atmosphere	16
2.1 Introduction	16
2.2 Data	19
2.3 Investigative Approach	23
2.4 The Mean Meridional Circulation at the Equinoxes	31
2.5 The Mean Meridional Circulation at the Solstices	37
2.6 An Alternative Approach to the Analysis of Kinematic Coupling	48
2.7 Summary	49
Bibliography	51
Chapter 3: Convective Instability in the Martian Middle Atmosphere	58
3.1 Introduction	58
3.2 Data and Analysis	60
3.3 Results	73
3.4 Discussion	87
3.5 Summary	101
Bibliography	104
Chapter 4: The Vertical Distribution of Dust in the Martian Atmosphere during Northern Spring and Summer	112
4.1 Introduction	112
4.2 Data and Basic Analysis	116
4.3 A New Scheme for Representing Martian Vertical Dust Distributions	125
4.4 Results	148
4.5 Discussion	153
4.6 Summary	165
Bibliography	168
Chapter 5: The High Altitude Tropical Dust Maximum	175
5.1 Introduction	175
5.2 Comparison of MCS Vertical Dust Profiles with Simulations of Active Lifting and Transport	179
5.3 The Longitudinal Structure of the HATDM	183
5.4 Possible Causes of the HATDM	192
5.5 Summary	218
Bibliography	219
Chapter 6: Water Ice Clouds Over the Martian Tropics during Northern Summer	227
6.1 Introduction	227
6.2 Data and Methods	228
6.3 Results	230
6.4 Discussion	238
Bibliography	242
Chapter 7: Reflections on Martian Mesoscale Meteorology from a Global Climate Modeler	245
7.1 Introduction	245

7.2 A Review of Modern Mesoscale Phenomena	246
7.3 Historical and Geological Significance	255
Bibliography	258

List of Figures

<i>Number</i>	<i>Page</i>
2.1 Population of bins used for zonal averaging.....	21
2.2 Zonal average temperature at the equinoxes and solstices.....	24
2.3 Estimated zonal wind at the equinoxes and solstices	25
2.4 Dust density-scaled opacity at the equinoxes and solstices.....	26
2.5 Water ice density-scaled opacity at the equinoxes and solstices.....	27
2.6 Upwelling and downwelling at the equinoxes.....	33
2.7 Possible kinematic coupling regimes at the equinoxes	35
2.8 Upwelling and downwelling at northern winter solstice.....	39
2.9 Possible kinematic coupling regimes at northern winter solstice.....	43
2.10 Upwelling and downwelling at northern summer solstice	44
2.11 Possible kinematic coupling regimes at northern summer solstice.....	47
3.1 Seasonal variability in longitudinal sampling of retrieval dataset	65
3.2 An example of a dry instability in the middle atmosphere.....	68
3.3 Monte Carlo simulation results.....	70
3.4 An example of a significant instability	72
3.5 Thermal and stability structure at northern summer solstice.....	74
3.6 Distribution of $CAPE_{MA}$ in zonal averaging bins	76
3.7 Minimum zonal average $\Gamma(p < 50 \text{ Pa})$	78
3.8 Pressure at which the minimum zonal average $\Gamma(p < 50 \text{ Pa})$ occurs	79
3.9 Zonal average $CAPE_{MA}$	80
3.10 Variability in the stability structure	82
3.11 $CAPE_{MA}$ near the north pole before the 2007 global dust storm.....	84
3.12 Minimum zonal average $\Gamma(p < 50 \text{ Pa})$ and pressure of occurrence near the north pole.....	85
3.13 Zonal average $CAPE_{MA}$ near the north pole	86
3.14 Wave-like perturbations in the stability structure near the north pole before the 2007 global dust storm.....	90
3.15 Estimated zonal wind	93
3.16 Seasonal variability in nightside zonal average temperature	96
3.17 Differences in zonal average temperature at 0.1 Pa between MY 28 and MY 29	98

4.1 Seasonal variability in longitudinal sampling of retrieval dataset and R^2 for the fitting of zonal average dust profiles	120
4.2 Dust distribution at northern summer solstice compared with a fixed dust prescription	128
4.3 Histogram of altitudes at which density-scaled opacity maxima occur relative to the lower limit of the profile	129
4.4 Example Conrath parameter inversion	131
4.5 Example fits of zonal average profiles using new fitting scheme.....	135
4.6 Schematic of fitting scheme and interpretive parameters.....	142
4.7 Seasonal and latitudinal variability in low-level dustiness.....	145
4.8 Seasonal and latitudinal variability in pulse dustiness	146
4.9 Seasonal and latitudinal variability in cutoff height.....	147
4.10 Seasonal and latitudinal variability in pulse height.....	149
4.11 Seasonal and latitudinal variability in pulse thickness	150
4.12 Seasonal and latitudinal variability in cutoff length.....	152
4.13 Seasonal variability in the nightside and dayside dust distributions in the northern tropics	156
4.14 Zonal average $CAPE_{CO_2}$ near the south pole	160
5.1 The zonal average dust distribution at the solstices.....	180
5.2 Map views of average nightside dust density-scaled opacity around northern summer solstice on sigma levels.....	184
5.3 Longitudinal dust distributions near the northern tropic around northern summer solstice	186
5.4 Longitudinal dust distributions near the northern tropic around the middle of northern spring.....	187
5.5 Longitudinal dust distributions near the northern tropic around the middle of northern summer.....	188
5.6 Longitudinal dust distributions near the northern tropic at around $L_s=145^\circ$	189
5.7 Nightside orbit cross-section showing thick high altitude dust and water ice hazes.....	194
5.8 Seasonal variability in the dust distribution over martian volcanoes.....	201
5.9 Results of Mars Pathfinder dusty parcel simulation.....	206

5.10 Sensitivity of the level of neutral buoyancy predicted by Mars Pathfinder dusty parcel simulation to initial vertical velocity and parcel mass mixing ratio	212
6.1 Nightside zonal average temperature and water ice mass mixing ratio during northern summer of MY 29	231
6.2 Population of bins used for zonal averaging during northern summer of MY 29	232
6.3 Nightside and dayside zonal average temperature and water ice mass mixing ratio during northern summer of MY 28	234
6.4 Population of bins used for zonal averaging during northern summer of MY 28	235
6.5 Longitudinal variability in the water ice distribution along the northern tropic	236
6.6 Longitudinal variability in the water ice distribution along the equator	237
7.1 Zonal average dust distribution during the later stages of the 2007 global dust storm	249

List of Tables

<i>Number</i>	<i>Page</i>
4.1 Results of Mie scattering simulations to test the sensitivity of Q_{ext}/r_{eff} in the MCS A5 channel to particle size	124
5.1 Environmental temperature profile used for the single column model simulations of dust heated convection	207
5.2 Parameters for the single column model simulations of dust-heated convection.....	208