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Original mesoscale phenomena in the Martian atmosphere

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Abstract

Mars appears as an excellent laboratory for atmospheric mesoscale processes. The combined modeling + observation fruitful approach provides insights into the dynamics and physics of the Martian atmospheric environment.

1. Introduction

Recent missions to Mars have given new insights on small-scall atmospheric phenomena. Combining modeling to data analysis appears necessary to fully understand the atmospheric physics and dynamics underlying the results of in-situ or orbital Martian exploration. Simulating atmospheric phenomena at horizontal scales below 100 kilometers require the use of specific three-dimensional tools called mesoscale models, which complement global circulation models [5]. In this report, three typical examples are described to demonstrate how mesoscale models help to interpret recent measurements in the Martian atmosphere.

2. Regional variability in boundary layer convection

Mesoscale models can be used at high resolution (< 100m grid spacing) in Large-Eddy Simulations. In idealized conditions simulating an infinite flat plain, turbulent motions responsible for boundary layer mixing in afternoon convective conditions are resolved. Recently, mixing layer depths in various Martian regions were determined through Mars Express radio-occultations [2]. In low latitudes, the Martian convective boundary layer appeared to extend at higher altitudes over high plateaus than in lower plains despite similar surface temperatures. Through Large-Eddy Simulations (cf. Figure 1), it is possible to relates such behaviour with the dominant radiative forcings of the Martian boundary layer [6]. Mars appears in striking contrast with terrestrial arid conditions where sensible heat flux dominates [4]. New scaling laws must be built for the Martian example to account for the turbulent heat flux not being maxi-mum near the surface but a few hundreds meters above it.

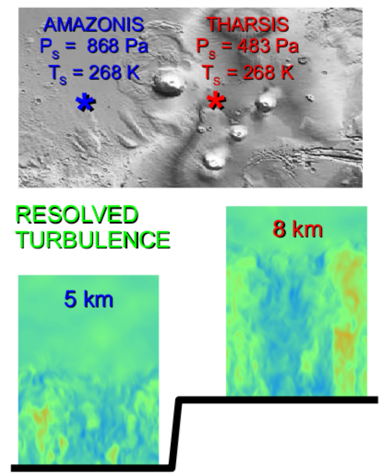

Figure 1: Regional variability of afternoon boundary layer convection. Turbulent vertical velocity is shown through horizontal/vertical section

3. Powerful slope winds and thermal impact

Mesoscale models are suitable tools to describe circulations in the vicinity of Martian topographical obstacles. Novel diagnostics can be derived, such that the fact that nighttime surface temperature over slopes is strongly influenced by mesoscale atmospheric dynamics. An alternate explanation can thus be proposed to account for the 15-20 K surface warmings over the slopes of Olympus Mons observed by Thermal Emission Spectrometer (hitherto believed to be mostly caused by contrasts of surface thermophysical properties, i.e. thermal inertia). Observed nighttime warmings around Olympus Mons are qualitatively and quantitatively reproduced in dedicated mesoscale simulations with uniform surface thermophysical properties (Figure 2). Strong katabatic winds blowing over Olympus slopes warm the atmosphere through compressional heating and enhance sensible heat flux which in turn warms the surface [7]. This phenomenon have strong implications for meteorology and geology: 1. surface temperature measurements might be used to validate predicted slope winds; 2. retrievals of thermal inertia from orbit are impacted over Martian slopes (and not only over Olympus Mons, but also e.g. over low-inertia cratered terrains like Meridiani Terra); 3. slope winds on Mars have a thermal influence on the surface in addition to aeolian erosional effects.

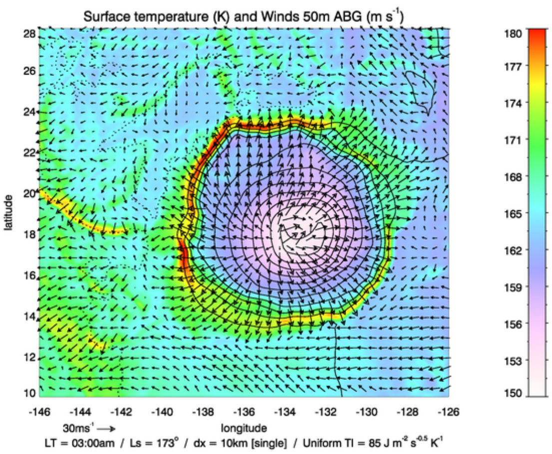

Figure 2: Surface temperature disturbances caused by katabatic winds over Olympus Mons.

4. The need to explore gravity wave activity

Mesoscale models are useful to determine dynamical effects unresolved by global circulation models, despite being crucial in controlling large-scale circulations. This is the case for gravity waves. Seldom observations are available, but observational clues are building up as new missions operate on Mars. For instance, new observations of fluctuations in the 1.27 microns O_2 dayglow emission obtained through Mars Express/OMEGA imaging spectrometry are reminiscent of gravity wave activity [1]. This provides important information to constrain gravity wave activity predicted through mesoscale modelling, which appears in reasonable agreement with those observations. Investigating gravity waves through fine-scale modelling is an important task to determine forcings caused in the higher atmosphere by their propagation and breaking (and to improve the parameterization of these processes in coarser-resolution models). In a different topic, related to other observations carried out by OMEGA, gravity wave might be key to trigger the formation of high-altitude CO_2 clouds, some of which having a possible convective origin that remains to be elucidated [3].

5. Perspectives

Not only the Martian experience would be helpful to prepare future robotic and human exploration of this environment, to yield further comparative planetology elements with the Earth, but it will path the way for studies of small scales processes on other planetary environments such as Titan, Venus, giant planets, ...

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