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On the development of reduced-order models of the Martian atmospheric dynamics

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We present recent progress on the construction of reduced-order models of the Martian atmosphere. This work is motivated by studies that suggest that the dynamics of the Martian atmosphere are more regular than those of the Earth, and an important part of the large-scale variability takes place in a phase space of relatively low dimension.

The technique that we employed is a combination of the Proper Orthogonal Decomposition (POD) and Galerkin methods. Firstly we find the subspace where the most energetic modes evolve by means of the POD. Then, we project the dynamical equations onto that subspace. The original dataset is an assimilation of Mars Global Surveyor/Thermal Emission Spectrometer data into the Oxford Mars General Circulation Model, focusing on a northern hemisphere winter period of around 90 days.

Previous work relied on the assumptions of quasi-geostrophy (QG). However, the limited validity of QG theory on Mars (where the Rossby number Ro ~ 0.2) and the large-scale Martian topographic features require the use of the primitive equations. Hence, we performed a fully three-dimensional vector POD in an energy-measure space. The resulting modes are classified according to their structure and the most dominant frequencies, thereby identifying diurnal and semi-diurnal tides and baroclinic waves.

The models are constructed retaining up to 20 modes since they contain 99% of the total atmospheric energy. The projection of the primitive equations onto the span of these modes produces systems of ordinary differential equations for the spectral coefficients. The response of these systems to different forms of radiative and mechanical forcing is investigated so that the dynamics are realistic while the complexity of the resulting models is not increased.