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The Kinetic Energy Spectrum of horizontal motions in the Mars General Circulation Model

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Abstract

Assimilated Mars GCM data is used to investigate the kinetic energy spectrum of the martian atmosphere. This preliminary study only focuses on a T31 resolution energy spectrum. The results validate Kolmogorov's theory for two-dimensional turbulence, and show unfamiliar features from terrestrial ones. Potential research can be made available, especially if running at higher resolutions (comparison with data from ground instruments on Mars, i.e. the REMS instrument on NASA's Curiosity rover) or focusing on different levels in the atmosphere (i.e. interaction between features of different scales).

1. Introduction

The kinetic energy spectra (KES) [1] of the terrestrial atmosphere is subject to intense research [1][2] for the fruitful information it offers, to the theoretical studies of general circulation models (GCMs) [3], as well as the understanding of the rich observational data we continuously collect. A detailed discussion and an inventory of GCMs are provided in J.N. Koshyk et al, 1999 [1]. Kolmogorov's theory [4] for two-dimensional turbulence can be used to describe the physical processes which generate the pattern of the spectra. According to the theory, energy is cascaded to the larger scale features (smaller wave numbers) relative to the energy input, whereas enstrophy is cascaded to the smaller scale features.

Mars GCM (MGCM) assimilation is a more recent development, hence many of the studies we have for Earth's atmosphere, including a systematic investigation of the KES, have just become feasible for this new environment. We provide here a detailed survey of the KES for a MGCM assimilation averaged over a period of 1800 sols (2.69 martian years), spanning from the middle of martian year 28 to the beginning of 31.

2. Mars General Circulation Model

The model used in this study is a recent version of the joint LMD and UK assimilation MGCM. It is based on an adiabatic, multi-level, primitive-equation atmospheric model which uses a spherical geometry with representation of the fields at each level as a truncated series of spherical harmonics. The code was compiled for an initial T31 resolution.

3. Kinetic Energy Spectra

The KES is computed from the spectral coefficients for vorticity and divergence produced by the MGCM on a two martian-hour basis. This approach offers the possibility of a highly accurate separation of the total KES into it's Eddy and Zonal Mean components (Figure 1). Both Earth and Mars KES manifest the same features as predicted by Kolmogorov theory, however, there is a noticeable difference between the the planets.

We find a different wave number at which energy is infused by baroclinic instability. Usually for Earth this occurs at $k = 8$, while on Mars this value is at roughly $k = 6$; a rather expected result considering the lower solar radiation Mars receives in comparison. The greatest discrepancies appear near the end of the viscous dissipation wave number, suggesting that a higher resolution run should offer more information on the behaviour of small scale dissipation. An interesting aspect is observed at the larger scale (low wave number) zonal mean KES. The zonal wind speeds reach $20m/s$ at $k = 2$, suggesting the presence of dust storm activity in the time interval chosen.

Finally, we point out that the KES also varies in time and vertical levels, with variations in slope in the global scale. This is common in many observations and GCMs for Earth's atmosphere. Any theory for the atmospheric KES requires a sophisticated description of the dynamics and forcing mechanisms of the atmosphere.

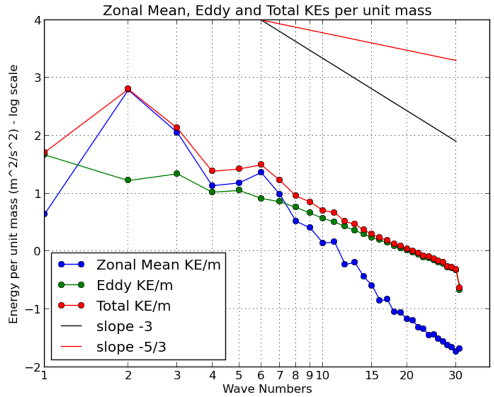

Figure 1: The Zonal Mean, Eddy and Total Kinetic Energy Spectra with added slopes of -3 and -5/3 for reference, to account for the energy and enstrophy regimes. This is a log-log plot.

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