Midwinter suppression of baroclinic storm activity on Mars: observations and models

Conference or Workshop Item

Midwinter suppression of baroclinic storm activity on Mars: observations and models

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Abstract

We present results from assimilated analyses of observations from the Mars Global Surveyor Thermal Emission Spectrometer showing evidence for a regular suppression of baroclinic circumpolar storm activity in both hemispheres of Mars around winter solstice. General circulation model simulations are then used to elucidate the structure and possible causes of this suppression, for which the local 'Eady growth rate' appears to be a good predictor.

1. Introduction

Baroclinic instability and intense traveling wave activity on Mars is well known to occur in "storm zones" [1] close to the edge of the advancing or retreating polar ice cap. Such activity usually sets in during Martian fall and continues until the onset of the summer season when large-scale instability mostly ceases as the atmosphere is no longer baroclinically unstable. The stormy season is typically characterized by large-scale, zonally-propagating waves with zonal wavenumbers *m = 1-3*, the lower wavenumber modes typically penetrating to considerable altitude though may also be surface-intensified.

Observations suggest that this eddy activity does not persist uniformly throughout the autumn, winter and spring seasons, but appears to die down quite consistently within 10-20 sols or so either side of the winter solstice. This midwinter 'solsticial pause' appears to be a sufficiently consistent feature of each winter season in both hemispheres to be regarded as a significant feature of Martian climatology, and could affect a variety of aspects of Martian meteorology including global heat and momentum transport, occurrence of dust storms etc.

A somewhat similar phenomenon has also been documented for the Earth (e.g. [2]), especially in relation to seasonal variations in the north Pacific storm tracks. The cause of this phenomenon is still not well established, though suggested mechanisms include the effects of enhanced barotropic shear (the so-called 'barotropic governor' [3] and interactions with topography over central Asia.

In this presentation we examine evidence for this phenomenon in the assimilated record of Martian climate from the Thermal Emission Spectrometer on board the Mars Global Surveyor mission (MGS-TES), in conjunction with the UK version of the LMD-Oxford-OU-IAA Mars GCM [4,5]. This is further corroborated in other evidence from seasonal variations in the incidence of local and regional dust storms that owe their origin to circumpolar baroclinic storms. We also discuss the extent to which this 'solsticial pause' phenomenon is reproduced in stand-alone atmospheric models and present results of some simulations to test a number of hypotheses for its dynamical origin on Mars.

2. Observational evidence

The UK Mars reanalysis dataset comprises a synoptic record of Martian global meteorology obtained from MGS-TES retrievals of atmospheric temperature and dust optical depth, assimilated into the UK version of the LMD-Oxford-OU-IAA Mars GCM [4]. The reanalysis was conducted using a version of the Analysis Correction sequential estimation scheme [6] and results in a complete synoptic record of Martian weather and atmospheric circulation at the model resolution of T31 (equivalent to a horizontal resolution of approximately 5^o x 5^o in latitude and longitude) and 25 vertical σ levels from the surface to around 120 km altitude, sampled every 2 hours during the three Mars Years (MY) 24-26.

Figure 1 presents a summary of baroclinic eddy activity during all three Mars years in this record, and shows the standard deviation of transient eddy

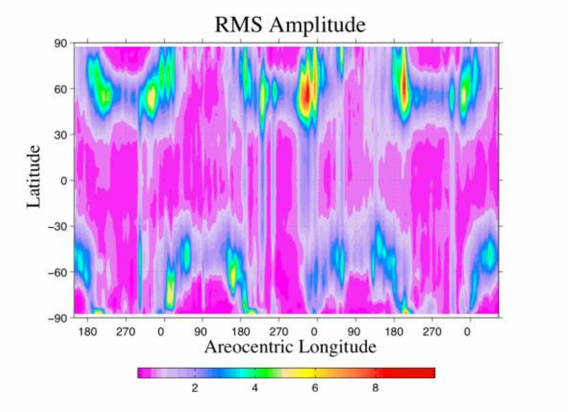

Figure 1: Standard deviation of transient eddy temperature at the 4 hPa level as a function of latitude and areocentric longitude (L_s), as represented in the UK Mars reanalysis dataset for MY24-26.

temperature as a function of latitude and time (areocentric longitude) at the 4 hPa level, where eddy activity is relatively strong. This clearly illustrates the onset and migration of baroclinic storms during autumn towards the equator and then polewards in spring. In both the northern and southern hemisphere, however, there is a clear lull in eddy activity around, or shortly after, the winter solstices. This is reproduced remarkably clearly every year, despite interannual variations in dust loading and other factors.

This tendency for reduced storminess around solstice is also apparent in the incidence of dust storms. Statistics for the seasonal frequency of dust storms obtained by Cantor et al. (2010) show a clear absence of high latitude storms around winter solstice in the north. A similar absence of activity is also evident in the occurrence of condensate cloud features associated with frontal storms (Cantor et al. 2010).

3. Model studies

The clear occurrence of such a solsticial pause in baroclinic activity is a strong feature of Martian climatology that should be reproduced in general circulation model simulations of Martian weather and climate. In practice, however, models seem to vary in the extent to which they exhibit this phenomenon.

The underlying mechanism behind this phenomenon appears to be subtle and is affected by a number of factors, including the presence or absence of radiatively active water ice clouds. The local "Eady growth rate",

$$\sigma = 0.31 \frac{f}{N} \frac{\partial \bar{u}}{\partial z} \qquad (1)$$

appears to form a good correlation with the strength of baroclinic activity, indicating that that the pause has a clear dynamical origin from a modulation of the baroclinic environment of the circumpolar storm zone. Further aspects of this will be discussed in the presentation.

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