The quasi 2 day wave response in TIME-GCM nudged with NOGAPS-ALPHA

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Abstract

The quasi 2 day wave (QTDW) is a traveling planetary wave that can be enhanced rapidly to large amplitudes in the middle and lower thermosphere (MLT) region during the northern winter post-solar period. In this study, we present five case studies of QTDW events during January and February 2005, 2006 and 2008–2010 by using the Thermosphere-Ionosphere-Mesosphere Electrodynamics-General Circulation Model (TIME-GCM) nudged with the Naside Operational Global Atmospheric Prediction System-Advanced Level Physics High Altitude (NOGAPS-ALPHA) Weather Forecast Model. With NOGAPS-ALPHA introducing more realistic lower atmospheric forcing in TIME-GCM, the QTDW events have successfully been reproduced in the TIME-GCM. The nudged TIME-GCM simulations showed good agreement in the NOGAPS-ALPHA mean state data and the horizontal wind model below the mesopause; however, it has large discrepancies in the tropics above the mesopause. The zonal mean zonal wind in the mesosphere has sharp vertical gradients in the nudged TIME-GCM. The results suggest that the parameterized gravity wave forcing may need to be retuned in the assimilative TIME-GCM.

Introduction

The quasi 2 day wave (QTDW) is one of the prominent planetary wave modes in Earth’s mesosphere and lower thermosphere (MLT) region. The quasi 2 day wave response in TIME-GCM is similar with our results. Certainly, the resolution of this question is an important topic for future work but beyond the scope of the present study. The zonal mean wind from the nudged TIME-GCM has an unrealistic eastward jet sitting in the thermosphere tropics.

Motivation

The zonal mean zonal wave number 3 in the auroral summer, as well as westward propagating zonal wave number 3 and 4 (NW3 and NW4) in the boreal summer. This is similar with our results. Certainly, the resolution of this question is an important topic for future work but beyond the scope of the present study.

Method

In this study, we utilize TIME-GCM version 1.5 with double resolution, a spatial grid of 2.5° in latitude and longitude, and 97 log pressure levels with vertical resolution of one quarter of a scale height. The model runs also assume a low geostrophic activity condition with cross-tidal potential ~ 30 kV and hemispheric power ~ 8 GW. The daily and 90 day average K solar radiation values are 70, which represents the solar minimum condition. The model time step is 30 s.

Following the method introduced by Lu et al. (2013), we conduct a one-way coupling between NOGAPS-ALPHA and TIME-GCM from the stratosphere to the mesosphere by equations (1)-(4).

\[ V_{\text{no}}(\lambda, \phi) = V_{\text{time}}(\lambda, \phi) \cdot \left[ 1 - \left( V_{\text{time}}(\lambda, \phi) / V_{\text{no}}(\lambda, \phi) \right) \right] \]

\[ V_{\text{time}}(\lambda, \phi) = \left( V_{\text{no}}(\lambda, \phi) - V_{\text{no}}(\lambda, \phi) \cdot \left( 1 - \frac{\lambda}{\lambda_{\text{max}}} \right) \right) \cdot \left( 1 - \frac{\phi}{\phi_{\text{max}}} \right) \]

\[ \left( \frac{\lambda}{\lambda_{\text{max}}} \right) = \left( \frac{\phi}{\phi_{\text{max}}} \right) \]

\[ \left( \phi_{\text{max}} \right) = \left( \phi_{\text{max}} \right) \]

Zonal Mean State of Nudged TIME-GCM

- These results can serve as benchmarks for the nudged TIME-GCM.
- The mesospheric hot latitudes have a relatively strong eastward jet and warmer in nudged TIME-GCM.
- It is apparent that the nudged TIME-GCM has a better agreement in mesospheric latitudes than standard TIME-GCM runs.
- However, the nudged TIME-GCM has a notable discrepancy with the HW3 hindcast in the tropics.
- One potential reason for these discrepancies is that the gravity wave parameterization needs to be retuned for the presence of soundings.
- Another concern is the continuous forcing on the general circulation, which has not been investigated in previous studies.

Results

The situation for QTDW in the TIME-GCM model is a critical factor, because the zonal mean zonal wind in the Northern Hemisphere in our TIME-GCM simulations might be due to the stronger eastward wind in the mesosphere. The zonal behavior in model is a critical factor, because the zonal mean zonal wind in the Northern Hemisphere in our TIME-GCM simulations might be due to the stronger eastward wind in the mesosphere. The zonal behavior in model is a critical factor, because the zonal mean zonal wind in the Northern Hemisphere in our TIME-GCM simulations might be due to the stronger eastward wind in the mesosphere.

Discussion

Finally, it is also interesting to note that SSWs have also been reproduced in the TIME-GCM nudged with NOGAPS-ALPHA, although the peaks in the Northern Hemisphere were only 4–5 K. The corresponding QTDW events obtained from the SABER observations show similar interannual variation to the model at 80 km. Interestingly, there were weak QTDW peaks at 100 km in the Northern Hemisphere, which were not seen in the TIME-GCM simulations, though the peaks in the Northern Hemisphere were only 4–5 K. One hypothesis for the underestimation of the QTDW W3 amplitudes in the Northern Hemisphere in TIME-GCM is the overestimation of the zonal mean zonal wind in the Northern Hemisphere (Chang et al., 2011a). There is an apparent contradiction between the model results and the observations. The zonal behavior in model is a critical factor, because the zonal mean zonal wind in the Northern Hemisphere in our TIME-GCM simulations might be due to the stronger eastward wind in the mesosphere. The zonal behavior in model is a critical factor, because the zonal mean zonal wind in the Northern Hemisphere in our TIME-GCM simulations might be due to the stronger eastward wind in the mesosphere.

Summary

In this research, we report a novel method of nudging the TIME-GCM with the output from a data driven weather forecast model, NOGAPS-ALPHA. Although this approach achieves our main goal in this research of reproducing a realistic QTDW response in a TIME-GCM simulation without resorting to artificially large forcing at the model lower boundary, it is not without its limitations. The main difference in mean state between TIME-GCM and NOGAPS-ALPHA might be due to the different gravity wave parameterizations used in the two models. This suggestion follows that of Maute et al. (2011) who nudged the TIME-GCM with WACCM-X (L16/GEOS-5) WACCM-X with 116 height levels and specified Meteorology from the Goddard Earth Observing System Data Assimilation System version 3 (GEOS-3) up to 35 km and also produced sharp vertical gradients in the zonal mean zonal wind at the low-latitude region. This is similar with our results. Certainly, the resolution of this question is an important topic for future work but beyond the scope of the present study.