Tidal Signatures in the Extended Canadian Middle Atmosphere Model

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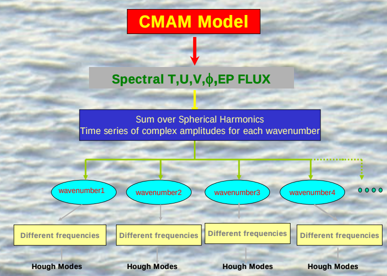
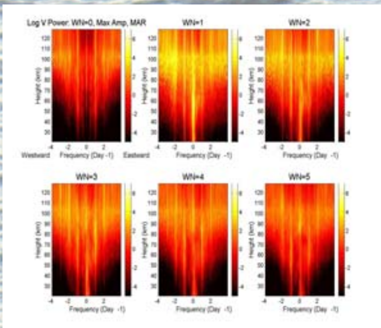
Abstract

Migrating and non-migrating tidal components are among the dominant dynamical features in the mesosphere and lower thermosphere in model runs of the Extended Canadian Middle Atmosphere Model (CMAM). Although the migrating diurnal tide is the dominant component, other components are significant and in mid and high latitudes are as large or larger than this component. Spectral analyses of the diurnal, semidiurnal and terdiurnal signatures of the wind and temperature fields (sampled every three hours) from one year of a multiple year run show eastward and westward propagating components with wavenumbers as high as 5 to be present. Comparison of these results with satellite analyses show the tidal field in the extended CMAM to be reasonably realistic. Analysis of a separate run with a sampling interval of 5 minutes indicates that tidal harmonics up to at least 4 /day contribute. Appropriate treatment of these components will be one challenge that data assimilation in the mesosphere will need to meet.

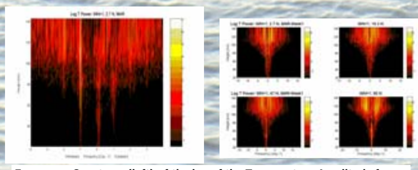
Treatment of Model Data





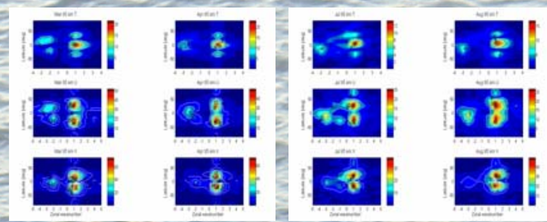
Frequency Spectrum for wavenumbers 0 to 5 for the meridional wind during March. Note the presence of harmonics of 1/day at all wavenumbers. While the strength of the tidal components decreases with wavenumber there are still components with large amplitudes at high wave numbers. What will be observed in the atmosphere is a superposition of these various components.

CMAM Tidal Components



Frequency Spectrum (left) of the log of the Temperature Amplitude for WN=1. Note the presence of the harmonics of 1/day.

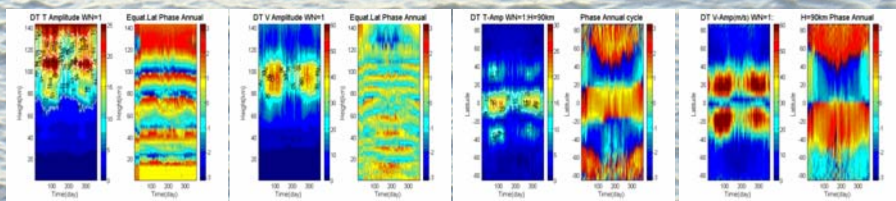
Similar plots (right) but for different latitudes and a saving interval of 5 minutes demonstrating the fall off of amplitude with wavenumber.



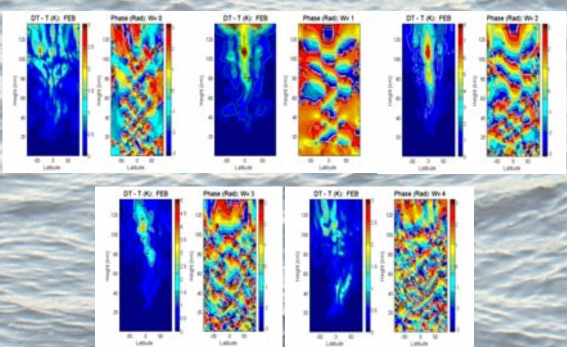
Latitude/wavenumber (-5 to5, westward positive in these plots) plots of T, u and v at 95 km for March, April, June and July. Note the change in structure with month and parameter.

Variability of the Tidal Amplitudes

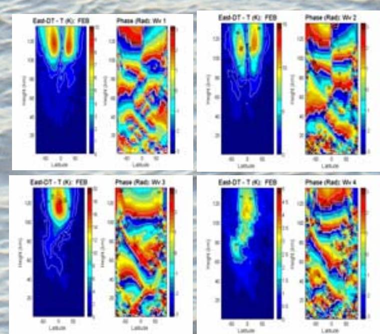
The figures to the right provide time series of the amplitude of the migrating diurnal tide over a year. The first two panels show variation of the amplitude as a function of height and time close to the equator and the last two panels show the amplitude variation as a function of latitude and time at a height of 90 km. Amplitude variations in the temperature and meridional wind are displayed. The latitudinal structure of these two variables is different. There is a strong seasonal variation in the amplitude of this tide with maxima at equinoxes and minima at solstices. In addition there is strong shorter term variability which shows up more strongly during solstices.



Structure of the Various Components

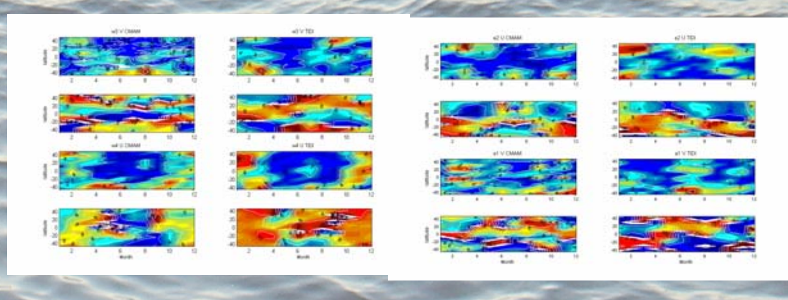


The structure and amplitude of the various components varies with wavenumber and season. Here we illustrate this variability by showing wave 0 to 4 diurnal temperature components during the month of February of the model run. Although the westward wave 1 component has the largest amplitude (~25 K) the eastward wave 2 and 3 components have maximum amplitudes of 15 and 20 K respectively and hence are of a similar strength. Single station tidal analyses have typically assumed that they observe a single component above their station. This analysis suggests that what is actually observed is the superposition of a number of different wavenumber components with different amplitudes.

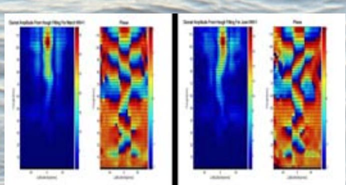


Comparison with Observations

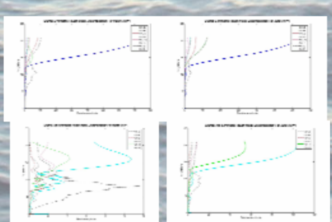
The figures below (from Du et al., 2007, JASTP, in press) show a comparison between the CMAM semidiurnal tidal structures and the equivalent components calculated from TIDI winds. In each case the left panel provides the CMAM results and the right panel provides the TIDI results. The top and third rows show the amplitudes and the second and fourth rows the phase. Apart from e1, the structures are quite similar indicating that the CMAM results are realistic. Comparisons between the diurnal components (not shown) also show that CMAM and TIDI results have similar seasonal strucutures

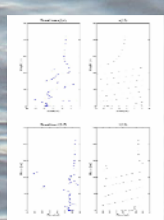


Modal Structures



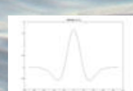
These figures illustrate the effect of modes on the structure of the diurnal migrating tide. Above, March and June amplitude and phase plots of this components show that the structure and amplitude changes with season. The amplitude is small in June and the tide is less symmetric about the equator. As noted by McLandress [1997, JASTP] this structural difference arises because the heating is less symmetric during solstices and the gravest asymmetric mode is excited more strongly at this time. The variation in structure with height arises as a result of interference effects between the two modes which have differing wavelengths. In this case it appears appropriate to consider each mode to have a separate identity as they both have well defined wavelengths and height variations. This conceptual framework is not always appropriate as the structure of components can be distorted as they propagate through background wind fields and additional Hough modes can appear to be excited. (Figures from Dave MacKenzie's Master's thesis, 2006.)





Antisymmetric

Symmetric



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