Lunar semidiurnal tide longitudinal variation observed in SABER temperature

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Introduction

Atmospheric lunar tides are generated in the lower atmosphere primarily as a result of the Moon's gravitational attraction, but also due to the vertical motion of the oceans at the lower boundary of the atmosphere. Although the lunar tidal forcing be well known, changes in background winds and temperature gradients can also affect their propagation through the atmosphere.

Since the lunar tide is excited by a predictable and well-known source, the variability observed in this oscillation must represent responses to the changes in the background atmosphere acting up on the lunar tide. Due to the fact that the source of the lunar tide does not change, the determination of the lunar tide in the MLT is an excellent tool to understand the coupling mechanism between the lower and upper atmosphere. The determination of this oscillation can help us to understand how the middle atmosphere conditions act upon the tide as it propagates upward.

Lunar Tide theory suggests that the migrating components are much larger than the non-migrating ones. However, non-migrating modes are capable of introducing longitudinal variations. So, the non-migrating components must be important for the global distribution of this tide. The existence of non-migrating components might be due to ocean and solid Earth tidal forcing that propagate vertically or due to nonlinear interaction between stationary planetary waves and the migrating modes. In order to study the longitudinal variability of the atmospheric lunar semidiurnal tide ten years of temperature data collected by the TIMED/SABER satellite have been used.

Data Analysis

The data used in this study were the temperature measured by SABER, that is an instrument onboard the TIMED satellite launched in December 2001. However, the SABER instrument began making observations in January 2002. The temperature profiles are retrieved from CO_2 emissions using local thermodynamic equilibrium (LTE) in the stratosphere and non-LTE in the mesosphere and lower thermosphere [for more details see, Mertens et al.,2001].

We use temperature data from 2002 to 2012, in order to study monthly mean amplitudes and phases of the semidiurnal lunar tide. The lunar tide is obtained by performing the least squares fit.

$$\sum_{n=1}^{3} A_n \cos(n\tau + \varphi_n)$$

where $\boldsymbol{\tau}$ denotes lunar local time, n represents sub harmonics of a lunar day, and An and φn are the amplitude and phase, respectively. Solar and lunar local time are related as $\tau = t - \nu$ (t denotes the solar local time and ν is the age of the Moon, a cyclic term which is dependent on the phase of the Moon and where $\nu = 0$ is equivalent to new moon). For this analysis were used a window size of ~ 60 days (combining ascending and descending data together), a grid size of $\pm$ 20° in longitude and $\pm$ 5° in latitude.

Results

Figure 1 shows the zonal average for semidiurnal lunar tide calculated over all period (2002-2012) at 0° (dashed line + x), 20°S (solid line + open circle), 20°N (solid line + filled circle), 40°S (dot-dash line + open square) and 40°N (dot-dash line + filled square) latitude for amplitude (left panel) and phase (right panel). Error bars represent the uncertainties in the calculation plus the variability from year to year for the lunar semidiurnal tide.

The mean amplitude (left panel) grow with height from 20 km to ~110 km, where there are amplitude peaks and above this the peaks begin to decrease. In general, the phase profile showed a downward phase progression with height. It is noticeable that when the amplitudes increase quickly (lower thermosphere region) the phase progression with height is more pronounced. This regular progress of phase provides further confidence that a clear tidal signature has been identified.

The mean amplitude values displayed in Figure 1 were smaller than those reported in previous works because the present analysis uses the entire 10 years data set which was vector averaged to yield mean values. This process can lead to some degree of self-cancellation of the seasonal fluctuations and/or inter-annual variability in the phase eventually present in the data (which is shown by the error bars), in such a way that the wave amplitudes become much lower than if calculated for a single month.

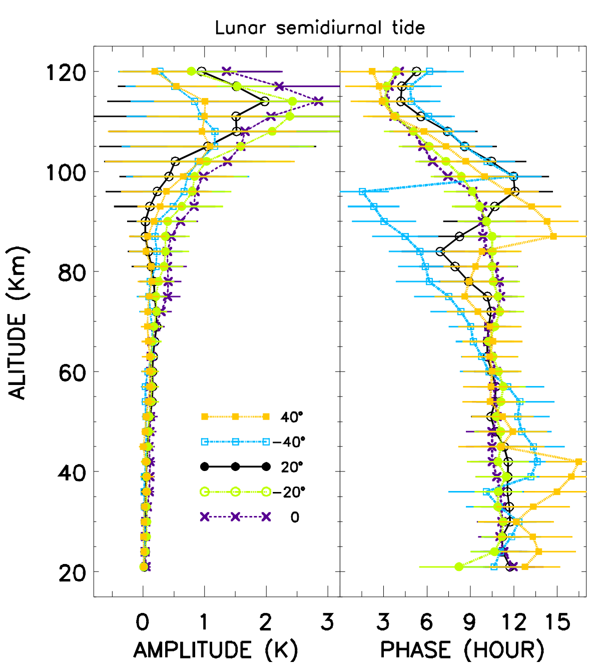

Figure 1 – Vertical mean profile for semidiurnal lunar tide at 0° (dashed line + x), 20°S (solid line + open circle), 20°N (solid line + filled circle), 40°S (dot-dash line + open square) and 40°N (dot-dash line + filled square) latitude.

Figure 2 shows the longitude and latitude variability of the lunar semidiurnal tide amplitude for March, June, September and December at 81, 90 and 108 km.

The lunar semidiurnal tide amplitude exhibited longitudinal and latitudinal variability with season at all of the three shown altitudes. It is clear that the semidiurnal lunar tide exhibits longitudinal variability which would not occur if only the migrating semidiurnal component were present.

The lunar tide amplitude at 108 km in September (in the Northern hemisphere) and December (in both hemisphere) and at 90 km in September (in the Northern Hemisphere) and December (in the Northern Hemisphere) presented four distinct peaks in longitude. These structure might be associated with zonal wave-4 pattern.

The theory of the lunar tide suggests that the migrating components are much larger than non-migrating components. However, non-migrating modes are capable of introducing longitudinal variations. So, the non-migrating components must be important for the global distribution of this tide.

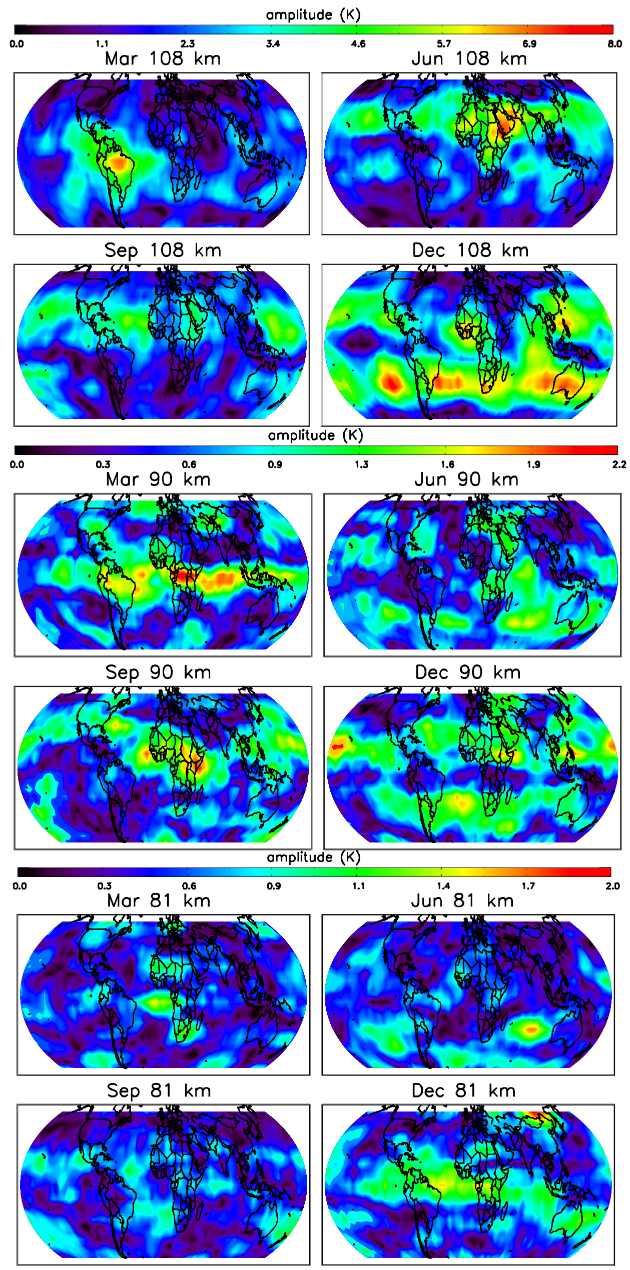

Figure 2 – Monthly average latitude and longitude variability of the semidiurnal lunar tide amplitude in the temperature for March, June, September and December at 81, 90 and 108 km.

Summary

The vector average monthly amplitude over all period demonstrated that the semidiurnal lunar tide has characteristic of vertically propagating wave.

Significant longitudinal variability was also observed in the gravitational tide. This result reveals the existence of non-migrating components in addition to the dominant migrating gravitational tide.

Reference

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