Atmos. Chem. Phys. Discuss., 6, S1424–S1430, 2006
www.atmos-chem-phys-discuss.net/6/S1424/2006/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Observations of lunar tides in the mesosphere and lower thermosphere at Arctic and middle latitudes" *by* D. J. Sandford et al.

Anonymous Referee #1

Received and published: 28 June 2006

General Comments: This paper contains valuable measurements of the 12.42-h lunar tide over the UK and the Arctic. A convincing argument for the presence of this tidal component in the vicinity of the stronger solar semidiurnal tide is presented and careful analysis proceeds from there. (Although not discussed in the paper, the duration of the data intervals used in both a superposed epoch analysis and a least squares fit analysis are large enough to ensure that leakage of the solar semidiurnal tide into lunar tidal results is negligible.) The data sets are of high enough quality to yield interesting results including, in the case of the Arctic observations, height profiles of the amplitude and phase. A good discussion of the results is included (although comments on improvements to this discussion are listed below). The data are compared to

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observations by other workers and to model results.

The paper makes an important contribution to our knowledge of the lunar tide and is thus of a scope and quality that warrants inclusion in ACP.

Specific comments: Although the height range attributed to the Castle Eaton data is probably about right, the justification for its selection using the GSWM is not convincing. The GSWM tells us much about atmospheric tides, but it cannot be said to represent the atmosphere with enough precision to define a height range in this way. Arguments based on echo height distribution measurements made by height resolving systems at a similar frequency would be more effective.

When the lunar phase results are introduced (around page 4651), the authors use 'h' as a unit. Presumably this is lunar hours, however, most readers would take it to mean solar hours. The authors should either be specific about their unit whenever it is used (Eg. use 'Lh' or similar) or make a note at the beginning of this section defining their terms. (The labels in the figures are clear in this regard.)

The vertical wavelength comparison near the end of 4653 and the start of 4654 is confusing. The comments in the discussion do not seem to correlate with the values in table 1. For example, it is noted that the observed phase sometimes increases with height yielding a negative vertical wavelength. There are no such observed values in table 1. From my interpretation of table 1, the absolute difference between observed and modelled vertical wavelengths is greater than 116 (km?) from May to August. In the other months this difference is less than 21. Of these, the difference is negative for September to November (model>obs) and positive elsewhere (obs>model). Please redraft stating what 'match reasonably well' means and clarifying the point about negative vertical wavelengths.

A consequence of the authors' comments about the presence of two peaks in the spectrum pictured in Figure 1b (at 1.9323 and 1.9350 cycles per day: periods of 12.420 and 12.403 hours respectively) has not been accounted for in the analysis. The au-

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thors note that an annual modulation of the lunar tide (which can be represented as the product of two frequencies, an annually varying modulation function and a 'carrier' at the lunar tide frequency) is interpreted by the periodogram as two separate frequencies (ie. is equivalent to two separate peaks when constructed from the sum of two superposed waves). The modulation is related to the frequency difference which they show yields a period of one year. However, invoking this effect also implies a change in the carrier frequency: the time series that is modulated at the difference frequency will have a carrier at the average of the above frequencies. The monthly segments of the time series that they fit to thus contain oscillations at the average frequency rather than the M2 frequency of 1.9323 cycles/day. Therefore, the least squared fit should have been carried out using a period of 12.412 hours (the period of the average frequency) instead of the 12.420 hours the authors used. The consequences of this on the analysis will likely be only a small attenuation of the results and could be ignored. However, the authors should note both of the consequences of their 'beating' hypothesis in their discussion.

In the discussion of Fig 8 (4654l11 onwards) it is said that the agreement is 'quite good in summer'. My reading of Fig 8 is that, other than at 80 km, the agreement is terrible in summer! Are we talking about the same figure? The summer zonal and meridional phases near 85 km are also very similar (when they should differ by a quarter of a perid) suggesting the data quality is poor at that height and time. (Unsurprisingly, the amplitude is small.) Perhaps for Figure 8, phase values associated with small amplitudes should be removed.

When data from other stations are compared to the present observations, (starting with those from Collm on 4655,) the authors should reassure the readers that the time base is generally applicable at all longitudes. A statement like 'Note that, for the migrating lunar tide, the time of maximum in lunar hours is invariant with longitude.' or equivalent should be included.

The section relating to solar and lunar semidiurnal tidal variability should be rewritten to

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improve its clarity (from 4657l6: 'However, ...' onwards). The argument could be made more clearly by noting that, if the propagation conditions are the source of the variability, then they are likely to affect the solar and lunar migrating tides in similar ways. If source variations are the cause of semidiurnal solar tidal variation, then seasonal variations are likely to differ. It should also be noted that the seasonal variation of the semidiurnal tide at high latitudes is partly due to the combination of non-migrating modes (and their relative phases) that are present at that longitude. There is some evidence for non-migrating semidiurnal tidal components at high southern latitudes (Forbes et al. GRL V22 3247 1995; Murphy et al. JGR V108 4241 2003)

Other corrections: - 4646l4 - the authors refer to a maximum occurring 'around mid-winter...' but do not specify whether this is hemispheric specific. They should add the term 'local' or 'northern', whichever is appropriate.

- 4646l17 onwards - radar description. It is very instructive to include the radar's operating frequency as this can give the reader some insight into the height response function.

- 4646l19 - insert 'narrow' between 'a' and 'beam'

- 4646l25 - change 'of meteors.' to 'of meteor echoes at the radar's operating frequency.'

- 4646l25 - The reference to Muller et al (1995) should include a comment as to which of the radars described there is the one referred to as Castle Eaton in this paper.

- 4648l7 - Lunar time should be defined here.

- 4648l17 - suggest replace 'considered' with 'compared'

- 4649 eq (1) - what does the 'q' refer to and the time unit 't' needs to be specified. (The frequency being in cycles per day and then divided by 24 suggest it is in hours but the reader should not have to infer this.)

- 4649l13 Suggest delete '-see Sects...' or replace '-see' with 'in'.

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- 4649l23 Insert ’solar’ between ’local’ and ’time’.

- 4650l4 - ’12h’ should be ’12.420h’ or ’12 lunar hours’

- 4650l15 insert ’observed’ after ’shows that the’

- 4651l7 change ’and indicates’ to ’and, for the northern hemisphere, indicates’

- 4651l25 - Insert ’together’ after ’averaged’.

- 4652l8 - The term ’grouped’ is ambiguous. Perhaps the authors mean ’vector averaged’?

- 4652l25&26 change ’around’ to ’from’ and change ’and in’ to ’to’.

- 4653l2 - Do the authors really mean ’$>$1m/s’ here? My reading would suggest it should be ’$<$2m/s’.

- 4653l11 change ’particular’ to ’northward or eastward ’.

- 4653l15 - Please define what is meant by uncertainty here. There are too many significant figures present in the number representing this ’uncertainty’.

- 4654l27 insert the sentence ’Zonal and meridional values have been averaged.’ or equivalent.

- 4654l13 - insert ’generally’ between ’differences’ and ’$<$’.

- 4654l15 - a lag of ’˜7h’ could also be a lead of ˜5h and would suggest a better agreement.

- 4657l4 - insert ’wind’ between ’zonal’ and ’and’.

- 4657l16 A reference for this non-linear mixing should be included at the end of this sentence. (Suggest Teitelbaum and Vial [1991, JGR V96 A8 p14169])

- 4663 (Table 1) No units are given for the values in this table.

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- 4667 (Fig 3) - The horizontal axis should be labelled in months because the authors refer to it in terms of months.

Technical corrections: - The authors often parenthesize references incorrectly when they are being used as nouns within their sentences. (I.e. '(Sandford 2006) present a study of lunar tides.' should be ' Sandford (2006) present a study of lunar tides.') Examples of this occur at 4645l6; 4646l25; 4647l4; 4648l17; 4648l24; 4659l14.

- Parentheses should be placed around '1994' in 4650l14; 4652l21

- 4646l9 The word 'model' on this line does not seem to belong. It should be deleted or changed.

- 4650l12 - ;'standard deviation divided...' is a clumsy way of expressing the error in the mean. I suggest you use mathematical symbols.

- 4651l19 insert an 's' after 'phase'

- 4654l19 insert an 's' after 'display'

- 4655l8 delete the 's' at the end of 'middles'

- 4657l3 insert an 's' after 'effect'

- 4657l6 delete 'the' after 'However,'

- 4657l15 change 'the planetary' to 'a planetary'

- 4657l25 insert 'the' between 'near' and '16'

- 4658l12 change 'has' to 'have'

- 4659l8&l9 change 'For' to 'The' and change 'these show' to 'show'. Add a comma after 'behaviour'.

- 4659l29 insert a space into 'maybe' ('may be')

- 4661l24&30 - Is the 'k' in 'Km' capitalized in the original title?

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- Caption fig 1 - you refer to 17 years of data and 16 years elsewhere

- Caption fig 5 ’form’ should be ’from’

- Caption fig 6,7&8 - change ’model results’ to ’results’

- Figure 3 - The phase plot is truncated: the upper error bar for month 5 is missing.

Interactive comment on Atmos. Chem. Phys. Discuss., 6, 4643, 2006.