Reply to Anonymous Referee #1

(https://doi.org/10.5194/angeo-2019-140-RC1, 2019)

Authors thank the Reviewer for her/his positive comments and suggestions. Please note that point by point replies are given below in blue. We sincerely hope that the revised manuscript is now clear and concise.

The paper by Uma Das et al. presents a tidal analysis based on COSMIC temperature data derived during the years 2009 and 2010. The analysis uses the least-square fitting technique concerning the zonal wave number, the longitude, and considering a mean, a diurnal, semidiurnal and terdiurnal tidal as well as a stationary planetary wave component. The data is divided into two groups containing four micro satellites each with a third group containing all 6 satellites as comparison. The present study focuses on the investigation of different lengths of data sets and thus, their influence on each tidal component according to their generation, variability and potentially produced aliasing effects. The findings are relevant especially for the satellite community because they give evidence to new interpretation possibilities regarding the nature of tides in the Earth's atmosphere.

The paper is well written, the methods are adequately described and the results are properly discussed, therefore a publication in AnnalesGeophysicae is highly recommended (Thank you). But nevertheless, some major and minor concerns should be addressed as indicated below before publishing.

Specific comments:

1) In the introduction the authors mentioned that a short-term variability from satellite data cannot be retrieved due to the local time coverage at one particular location, which takes several tens of days (Page 2, line 33-34). In general this statement is true, but nevertheless, there are attempts to derive a short-term variability using the deconvolution method for non-migrating tides or by combining satellite data with ground-based measurements. For a comprehensive overview please add some information about this in the introductory part (for this see e.g.: Oberheide et al., 2002; Pedatella et al.,2016).
Ans: Authors thank the Reviewer for providing these important references. They are now discussed in the revised manuscript in Section 1 (Introduction).

2) The classification of the different groups (G1 and G2) seems to be somehow oversampled because 50% of the data is in both groups. The similarity of the results from the different groups is not really surprising when almost the same data is used for each group (G0 contains all six data sets). Perhaps, it is worth to add some information about the exact amount of data from each satellite in form of a table or something like that?
The following figure shows the data availability of the number of profiles available at various latitudes from each of the COSMIC satellites. This figure will be given in a Supplementary Section of the paper.

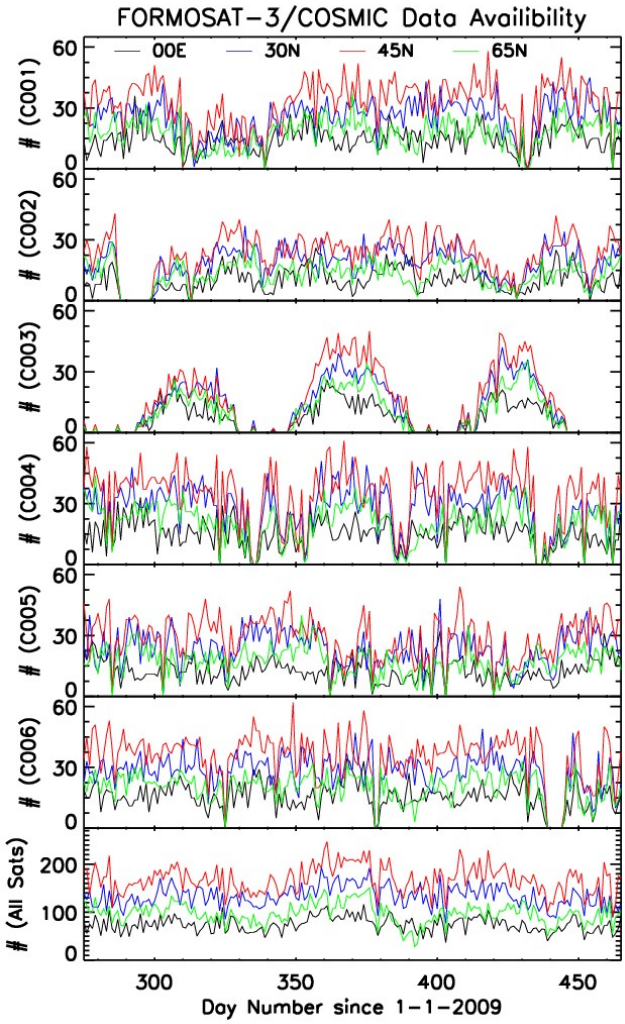


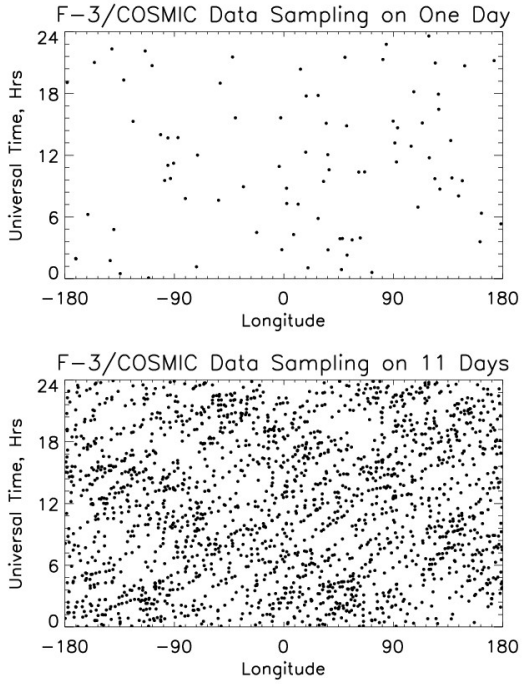
Figure S1: Number of profiles available over equator, 30N, 45N and 65N, from each of the COSMIC satellites C001 to C006. The last panel shows data available from all satellites taken together.

3) Page 4, line 96: What is meant with the statement: "This non-uniform and patternless sampling is in a way supportive to the current study"? Even if there would be a pattern sampling, by knowing this, it would be also possible to distinguish between such a pattern and a real geophysical variation of a tidal signal. Please clarify the meaning with some arguments.

Ans: The non-uniform and pattern-less spatial and temporal sampling is in a way supportive to the current study to characterise the variability of tides in the middle atmosphere as we have used the method of least squares fitting. So, aliasing effects are reduced.

4) Page 4, line 126: "the phase sampling is uniform on any given day for all waves". The reviewer does not see this in Fig. 1 as just the phase of the DW1 component is shown here. In addition to this, perhaps misleading, statement, it seems to be a contradiction to the comment in the beginning about the non-uniform sampling (see point 3). Uniform suggests a complete sampling for each season. This seems to be not true, especially for the winter months. Please rethink about both statements and rewrite them.

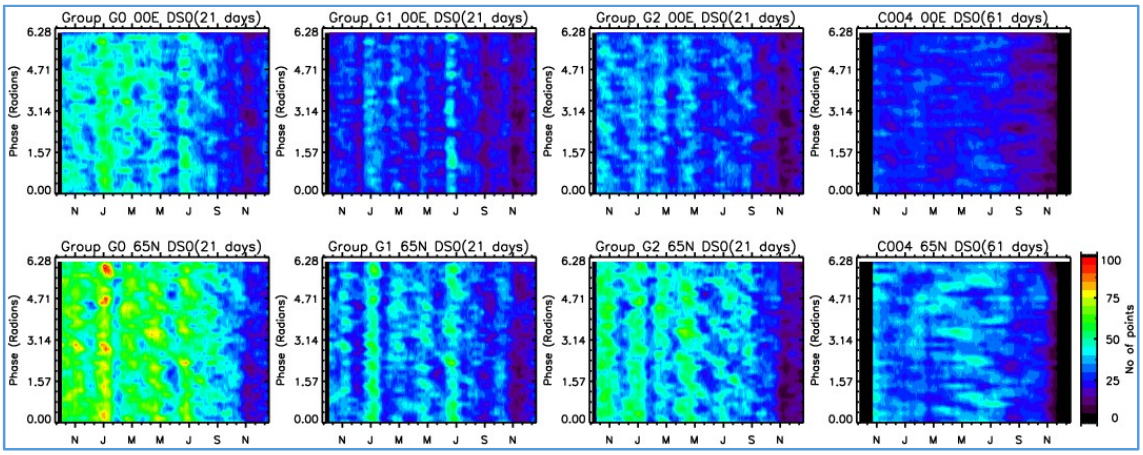
Ans: COSMIC sampling of the atmosphere is irregular in space and time [Please refer to Figure 1 of Pirscher et al., 2010]. The same can be seen in figure below, which shows the sampling in longitude-UT space for one day and 21 days.

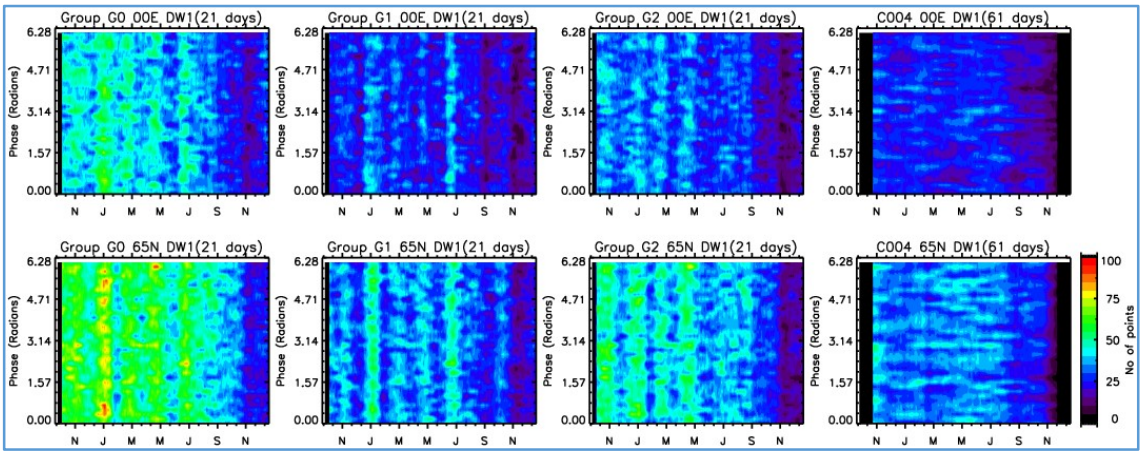


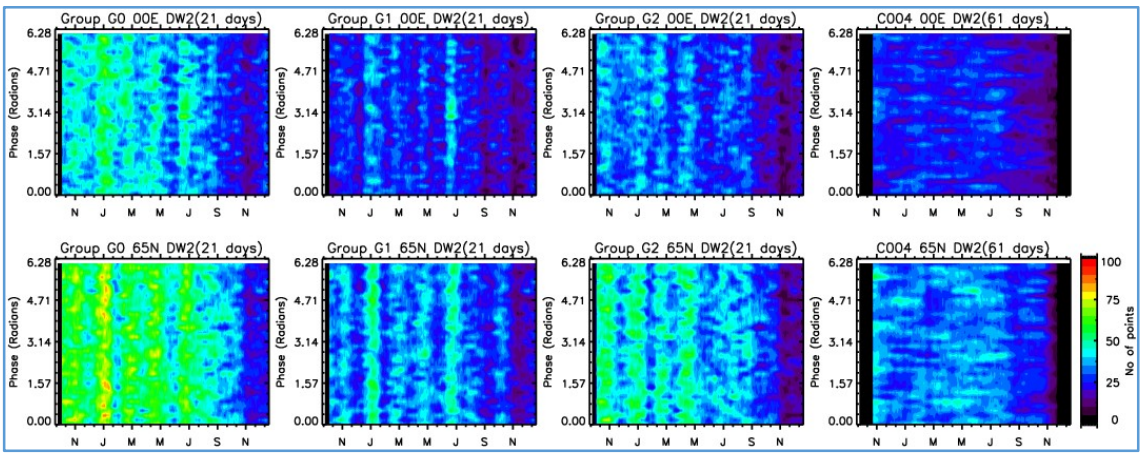
Thus, the information in line 96 is correct. These observations, on the other hand sample the different waves at various phase points. We extracted the phase information of each wave as $2\pi ft+2\pi s\lambda$, where f is frequency and s is wave number of the wave, t is time (UT) and λ is longitude of observation, which is plotted in Figure 1.

Here we would like to draw the attention of the Reviewer towards an error in the figure. Figure 1 actually shows phase sampling distribution of the DS0 Wave. Title was mistakenly written as DW1. We have corrected the figure to show DW1 phase sampling distribution in the revised manuscript.

We show here the phase sampling distribution of all the three tides.





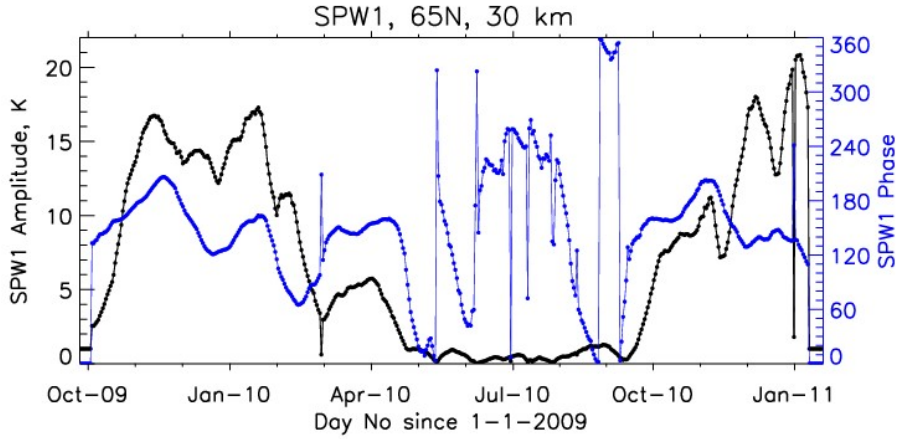


On inspection it can be seen that, phase on any given day, i.e., a vertical slice of any panel in these plots, is reasonably uniform, as mentioned in line 126.

5) Fig. 2: Why there is no amplitude signal for the DW1 tide visible between 15 and 45_ N/S? From the theoretical point of view, one would assume that there is a strong signal at the equator which slowly decreases towards the pole. Are the values really zero here or are they not determined? This is not clear from the colormap of the colorbar.
Ans: The amplitudes of DW1 between 15 and 45°N/S are indeed negligible and below 0.5 K, as determined from COSMIC temperature data. It may be noted that these results are for 30 km.

This is also verified with published literature. Figure 1 of Sakazaki et al., 2018 (ACP) shows that DW1 has amplitude of 1 K over equator at 30 km and is below 0.6K at other latitudes as seen in satellite and reanalysis datasets (SABER,JRA-55, JRA-55C, JRA-55AMIP, MERRA-2, MERRA, ERA-Interim, and CFSR). DW1 amplitudes of 3 to 3.5 K are observed between 15 and 45 N/S at higher altitudes of 50 km. Figure 3 (First Row, Second Column) of Hagan and Forbes 2003, shows that GSWM amplitude of DW1 is 1 K over equator at 50 km. Hence comparisons with published literature proves the current results.

6) Page 7, line 190/191: “with no phase change”. This reviewer is not convinced about this statement. From Fig. 5 it is clearly visible that the phase is changing between maxima of amplitudes.



Ans: The phase of SPW1 is varying between 100 and 200 degree longitude between maxima, as seen on the above figure. Thus the phrase is modified as 'with small phase change'.

7) The nonlinear interaction of the SPW1 and the migrating diurnal tide as a potential generation mechanism of the DW2 and DS0 tidal component was also investigated by Lieberman et al., 2015. Although this study is focused in the MLT region, it is worth to discuss the results here (page 9, line 241/242) because the authors also used SABER data and derived a day-to-day variability of the tidal components. They also made a numerical investigation of their correlation and found that the interaction is a potential source of the non-migrating tidal components. Their findings contradict an aliasing effect as origin for the non-migrating tidal components. Please enhance the discussion according to this.

Ans: Authors thank the Reviewer for suggesting this reference. It is discussed in the revised manuscript.

"Lieberman et al (2015) discuss DW2 variation over equatorial mesopause region and the mechanism of generation is proposed that stratospheric SPWs over mid and high latitudes are ducted upward and equatorward that interact with equatorial DW1 and thereby generate DW2 over the mesoapuse region. DS0 is not quite discussed by Lieberman et al (2015)."

8) COSMIC data show significant tidal variabilities over times less than a month. Unfortunately, the data is limited to stratospheric altitudes, and therefore a comparison to other data sets can hardly be made as they are often done for the MLT region due to larger tidal amplitudes at these altitudes. However, there are a few studies which investigate the tidal variability also in the stratosphere, which should also be mentioned in the discussion (e.g., Baumgarten et al., 2018, Baumgarten and Stober et al., 2019). Both studies show a huge variability of the diurnal tide which origin was not finally determined, but nevertheless, they used also global tidal fields to distinguish between migrating and non-migrating tides. Their results also show a negligible non-migrating tidal contribution if an intermittency is allowed in the analysis which supports a potential aliasing effect as origin for the non-migrating tidal components.

Ans: Authors thank the Reviewer for suggesting this reference. These are discussed in the revised manuscript.

"Baumgarten and Stober (2019) derived short term tidal variability in the altitude range from 30 to 70 km using temperature derived from lidar observations at Kühlungsborn (54°N, 12°E), a mid latitude station. The diurnal tide (consisting of all wavenumbers) in temperature and winds was extracted from lidar data and compared with DW1 component of temperature

and winds from Modern-Era Retrospective analysis for Research and Applications, Version 2 (MERRA-2). It was shown that the local tidal fields are dominated by the migrating diurnal and migrating semidiurnal tides and that other components are negligible. This indicates that the non-migrating components may have very little contribution and thus supports the current study that the observed non migrating tides could be possibly due to aliasing."

Minor/Technical comments:

- Page 1, line 10: sun ! Sun
Ans: Corrected

- Citations should follow the Ann. Geophysicae standard, so please use the command ncitet or ncitep if latex is used or "()" instead of "[]" for references.
Ans: Corrected

- Please add a short summary of the structure of the manuscript at the end of the introduction. For a reader it is much better if a statements about what follows is given there.
Ans: Summary added as follows.
"The paper is organised as follows. Section 2 describes the FORMOST-3/COSMIC data used, satellite sampling and phase space of the various wave components. Data analysis method of least square fitting is described briefly in Section 3. Tidal characteristics and associated aliasing are described in Sections 4 & 5, respectively, and the results are discussed and summarised in Section 6."

- This reviewer suggests to integrate Section 2.1 into Section 2 or Section 2.1 should get an own Section number. In general, it is not likely to write a subsection if just one subsection is existing.
Ans: Both sections are combined and renamed as 'Data and Sampling'.

- Page 4, line 109: in to ! into
Ans: Corrected

- Page 4, line 123: What is meant by "viz."? Please clarify.
Ans: 'viz'means 'namely'. It is replaced in the revised manuscript.

- Page 4, line 124: "the total phase of the important wave component DW1 are investigated" must be "is investigated"
Ans: Corrected

- Page 4, line 126: "data points reduced" should probably be "data points are reduced"
Ans: Corrected

- Page 5, line 1: "the period investigated" please clarify which period this is (Nov. 2009-Sept. 2010) as this should be stated somewhere here in the data section.
Ans: The period of study is October 2009 to December 2010. It is specified in the revised manuscript.

- Page 5, section 3: To be complete here an explanation for the different variables is needed for the reader.

Ans: Added

- Page 5, line 144: How is “with minute differences” determined? The results show small differences between the three groups, but they are not in the range of minutes. If it is meant that the flightpath of the six micro satellites have a temporal difference of a few minutes, then it becomes not clear from the statement written in the manuscript.
Ans: ‘minute’ here means extremely small. To avoid confusion, it is replaced.

- Page 5, line 145: “strong semi-annual variation is observed” The statement should be weakened. The semi-annual variation is visible, but the annual variation is much stronger (the difference here is larger than 30 K, while the difference for the semiannual variation is less than 10 K).
Ans: Modified as suggested.

- Page 5, line 149: Just a thought (there is probably no action required): Is it possible that the band like structure around the equator has something to do with the geomagnetic equator because there is a more or less anti-correlation between both?
Ans: There is no relation with the geomagnetic equator.

- Page 6, line 161: The strongest differences occur not only during winter, also during autumn.
Ans: It is actually during winter and spring. It is corrected in the revised manuscript.

- Page 6, line 172: “are overestimated by C004, particularly in the high latitudes”. This statement is not quite correct, the overestimation occurs only in high latitudes, not above the equator. Please modify the sentence.
Ans: Modified as suggested

- Page 6, line 173: “due to the effect of smoothening as more data was used” It is not clear why this is the explanation. Does C004 contain more data than the other satellites?
Ans: Yes, C004 has more data (±30 days), while G0,G1,G2 consider ±10 days data. This is mentioned in Section 3, Analysis.

- Page 6, line 184: Could the authors estimate also the vertical wavelength of the other two tidal components? Probably this is not easy, but at least some sentence about the relation to other tidal components would be helpful.
Ans: From Figure 4, it is difficult it conclusively comment upon the vertical wavelength of the other tidal components, and so we have not added anything in this regard.

- Page 7, line 200: The amplitude of the SSW is not seen in the figure, therefore the formulation should be changed.
Ans: It is a typographical error. It has to be SPW and corrected in the revised version.

- Page 10, line 257 and 258: “Showed” is the past tense of “show”, but here the authors have to write the past participle which is “shown”.
Ans: Corrected as suggested.

References:

Baumgarten, K., Gerding, M., Baumgarten, G., and Lübken, F.-J. (2018), Temporal variability of tidal and gravity waves during a record long 10-day continuous lidar sounding, Atmos. Chem. Phys., 18, 371–384, https://doi.org/10.5194/acp-18-371-2018.

Baumgarten, K. and Stober, G. (2019), On the evaluation of the phase relation between temperature and wind tides based on ground-based measurements and reanalysis data in the middle atmosphere, Ann. Geophys., 37, 581–602, https://doi.org/10.5194/angeo-37-581-2019.

Oberheide, J., Hagan, M. E., Roble, R. G., and Offermann, D. (2002), Sources of nonmigrating tides in the tropical middle atmosphere, J. Geophys. Res., 107(D21), 4567, doi:10.1029/2002JD002220.

Pedatella, N. M., Oberheide, J., Sutton, E. K., Liu, H.âˇARˇ L., Anderson, J. L., and Raeder, K. (2016), Short term nonmigrating tide variability in the mesosphere, thermosphere, and ionosphere, J. Geophys. Res. Space Physics, 121, 3621– 3633, doi:10.1002/2016JA022528.

Lieberman, R. S., Riggin, D. M., Ortland, D. A., Oberheide, J., and Siskind, D. E. (2015), Global observations and modeling of nonmigrating diurnal tides generated by tideâˇARˇ planetary wave interactions, J. Geophys. Res. Atmos., 120, 11,419– 11,437, doi:10.1002/2015JD023739.

Ans: Authors thank the Reviewer for providing the above references. They are all now discussed in the revised manuscript.