January 2020, regarding https://www.atmos-chem-phys-discuss.net/acp-2019-870

Final author comments for acp-2019-870

from Jonas Hagen (jonas.hagen@iap.unibe.ch) on behalf of the authors.

Dear Editor,

Based on your comments we made some minor changes to the manuscript.

Editor: there are two minor technical correction that remain to be taken care of before publication. I think your changes concerning the first two comments of referee 2 did not change the fact that the sentences are misleading. Therefore, I have the following two suggestions for rephrasing:

Page 2, L14: Isn't it easier to just write: "Satellites with a sun-synchronous orbit, as for example Aura MLS, overpass each location at two local times a day." or even better ".....twice a day". Then you could also add the equator crossing times which are usually given as reference.

Authors: The referenced sentence is: "Satellites with a sun-synchronous orbit, for example Aura MLS, overpass each location exclusively at two local times which are specific to the latitude of this location."

Admittedly, this sentence is a bit abstract. In our opinion it gives a very short and concise picture of the sun-synchronous orbits and their relation to tidal studies: If one gathers all measurements from e.g. MLS for one location (area with some extent in practice) they only contain measurements from two local times, that is one from the ascending orbit and one from the descending orbit.

Aura orbits Earth roughly 15 times per 24 hours and whether there are two measurements per day (or more or less) that intersect with the chosen area depends on its extent. For mid-latitudes and an area of roughly 400 km width (approx. ground based radiometer field of view), it is true, that there are two measurements per day. This might be more in polar regions (where orbits are closer together) or less in tropical regions (where orbits are more spread), again depending on the chosen area. However, all measurements no matter how many, always have been taken at one of two local times specific to the latitude of the location (with a small tolerance) and this is relevant for tidal studies.

Thus we would rather not include the suggestion of the Editor and prefer our general statement that is not specific to ground based radiometry and areas of specific size.

Editor: Page 2, L15: Here it is not clear to which satellites this sentence refers to. I guess you mean the former ones, the non sun-synchronous ones. Did I understood that correct, that for these you need the linear tide model to accomplish the tidal studies on shorter timescales. In that case you could simply change the sentence as follows: "Nevertheless, the global coverage of the former satellites enables tidal studies on a shorter timescale under the assumption of a linear tidal model (Ortland, 2017).

Yes this is correct. We will swap the sentences so that it is clear that this method only applies to satellites with a general orbit and point out the exception right after that. (See changes.)

Best regards,
Jonas Hagen

(Following pages contain a marked-up manuscript version with changes highlighted. Only changed pages are included.)

the dissipation altitudes. Ultimately, tides in the stratosphere and mesosphere region can affect weather phenomena like for example the diurnal cycle of tropical rainfall (Woolnough et al., 2004; Sakazaki et al., 2018).

Due to the global nature of atmospheric tides, they have been studied over decades using models (Lindzen, 1971; Forbes and Wu, 2006; Wang et al., 2016) or global observations from satellites (Oberheide et al., 2009; Häusler et al., 2010; Pancheva and Mukhtarov, 2011). Considering the observational results Oberheide et al. (2011) introduced a climatology based model of atmospheric tides covering the most relevant diurnal and semi-diurnal tidal modes at altitudes between 80 km to 400 km. While atmospheric tides are well understood and modeled (Hagan et al., 1999) on a global and seasonal scale, very little is known about tides on a local and sub-seasonal scale.

Tides in the temperature field have been extracted from satellite observations (Sakazaki et al., 2012; Forbes and Wu, 2006; McLandress et al., 1996; Oberheide et al., 2009) and have been compared to different reanalysis data sets by Sakazaki et al. (2018) from the stratosphere to the lower mesosphere. Satellites, however, often need several weeks to sample a full diurnal cycle for a specific location due to their orbit and therefore are not capable to resolve tidal variations at short timescales. The global coverage nevertheless enables tidal studies on shorter timescales also for instruments on these satellites under the assumption of a linear tide model (Ortland, 2017). Satellites with a sun-synchronous orbit, for example Aura MLS, overpass each location exclusively at two local times which are specific to the latitude of this location ~~. The global coverage nevertheless enables tidal studies on shorter timescales also for instruments on these satellites under the assumption of a linear tide model (Ortland, 2017)~~and thus their ability to resolve tides is limited.

Ground based measurements of tides in the temperature field have been performed by day-light-capable lidars for the stratosphere by Kopp et al. (2015); Baumgarten and Stober (2019) and from meteor radar temperatures (Stober et al., 2008) in the mesosphere and lower thermosphere (MLT) region. Meteor radar and MF-radar observations are also suitable to obtain tides in the wind fields (Portnyagin et al., 1993, 2004; Merzlyakov et al., 2009; Jacobi, 2012; Wilhelm et al., 2019). Current lidar instruments are able to measure inertial gravity waves in the wind field on short timescales (Baumgarten et al., 2015) and are thus in theory also suited for the observation of atmospheric tides, but the necessity of clear sky conditions reduces the availability of long term observations drastically and no observations of atmospheric tides are available to date.

Rogers et al. (2016) derived the local solar time variation of wind at 95 km altitude by integrating a 5 year data set from different ozone radiometers. Rocket soundings of the tides in the wind and temperature field have been performed by Lindzen and Chapman (1969) up to the upper stratosphere but have never been repeated again.

Note that no observations of tides in the wind field for the stratosphere and lower mesosphere have so far been performed.

This leaves reanalysis data with high temporal resolution like ERA5 and MERRA-2 as the only source for the wind field in studies about atmospheric tides. These products typically depend on satellite measurements and, thus, tides in upper atmospheric region are poorly constrained. Recent findings by Sakazaki et al. (2018) suggest that for the temperature field, differences between the different reanalysis and measurements are systematic in amplitude (approx. 1 K or 50 % above 40 km for northern mid-latitudes, more in tropics) and the spread between the reanalysis is quite large in the lower mesosphere (0.3 K to 1 K at approx. 60 km for northern mid-latitudes).