Response to Short Comment #1 (Haidong Pan)

We thank Dr Pan for his comments on the paper.

The comments are in bold, our replies are in normal font.

Understanding the long-term changes of tides is important and useful. This paper investigated long-term tidal change in the North Atlantic and discussed a possible underlying mechanism which I think is pretty interesting. I want to provide some suggestions which may further improve this paper.
We thank Dr Pan for this comment.

First, the title of this paper is 'Climate-scale changes of the semidiurnal tide.....', however, the authors only analyzed M2 tide but ignored S2 tide which is also important.
We agree that the paper focus mainly on M2. However, S2 has not been ignored, and has also been analyzed. Results are briefly presented in the paper (but not shown), see line 319-322 of submitted paper: "Results show that S2 amplitude decreases at all the stations located in the North West Atlantic, and in contrast, tends to increase in the North East Atlantic (not shown). The large-scale decrease of S2 observed in the North West Atlantic is consistent with previous studies, e.g. Ray (2006) in the Gulf of Maine. Further investigations should be definitely conducted to extend this work to more constituents."

In addition to, the gravitational forcing of S2, oscillations in barometric pressure, changes in ocean temperature, and onshore-offshore wind have also been argued as contributing to the sea surface variations at the S2 frequency (Feng et al., 2015). The non-gravitational component of S2 is called the radiational tide and its amplitude has been estimated to be 10–18% of the gravitational amplitude, depending on geographical region and the physical parameters concerned (e.g., pressure, wind stress, and/or thermal forcing) (Feng et al., 2015). It seems that S2 tide is more easily influenced by changes of atmospherical circulation than M2 tide. Thus, it is necessary to check whether the changes of S2 tide are similar to North Atlantic Oscillation (NAO) which will prove underlying mechanism proposed by this paper.
We agree that at S2 frequency, there is a combination of gravitational and radiational tide (e.g. Simon, 2013), which is not the case at M2 frequency. For this reason, changes in S2 may have different origins than changes in M2. As mentioned in the paper, S2 decreases at all the stations located in the North West Atlantic, and in contrast, tends to increase in the North East Atlantic. This is different from the observed M2 changes, which is not surprising, for the following reasons. Firstly, S2 response may be different to M2 response, even with similar forcing. For example, Pickering et al. (2017) showed different response to a 2 m sea level rise scenario for M2 and S2 – see Figure 1 (a) and (b) from Pickering et al. (2017). Secondly, some changes in solar radiation could also affect S2 (and not M2). However, this is not in the scope of the paper.

Second, this paper is very similar to Müller (2011) which found the rapid change in semi-diurnal tides in the North Atlantic since 1980. This paper seems to revisit the Müller's work and change 1980 to 1990. The authors need to clearly describe the difference of two papers.
The present paper clearly differs from Müller (2011), and as suggested, we will point out more clearly the differences between the two papers.

The differences between Müller (2011) and the present paper are the following (1) Müller (2011) focuses on shorter records (tide gauges with at least 35 years of data prior to 1980) whereas we focus on longer records (tide gauges with at least 80 years of data, starting before 1930), (2) Müller (2011) show recent changes since 1980, whereas we show that the changes started long before the XXth century, and are not linear (which is consistent with previous studies, e.g. Pouveau et al., 2006; Talke et al. 2014; Talke et al. 2018; Ray & Talke, 2019). (3) Müller (2011) already proposed a possible influence of NAO, but without going further in the description of the physical mechanism (this is mentioned line 269 of the submitted paper), whereas we propose a possible underlying mechanism (effect of large-scale atmospheric circulation). (4) We bring now quantitative insights on the possible influence of NAO, which was mentioned by Müller (2011) on the basis of quantitative criteria (see response to reviewers #1 and #2).

By the way, this paper calculates the post-1990 trend and post-1910 trend to show the rapid change in M2 tide since 1990. I think post-1990 trend is meaningless because the length of post-1990 records is too short. I think that you can calculate the trend of 1910-1990 and post-1910.
Post-1990 records may be considered as long enough to compute trends. Note that the sea levels have been measured by altimeters only since the 1990s, and post-1990 mean sea level rise is estimated at around 3.1 mm/year (Dangendorf et al., 2017; Meyssignac and Cazenave, 2012). However, we agree that trends computed on such a short period have to be interpreted carefully, and this is mentioned lines 221-223 of the submitted paper: “The trends have to be interpreted very carefully as the M2 variations are not linear, and may increase or decrease depending on the years; as a consequence, the estimated trends depend strongly on the period considered to estimate it. The interannual variability also plays an important role, and when substantial, trends can vary depending on the computational period.”

At last, although it seems that M2 variations are similar to NAO, it is very difficult to prove statistical validity since the data are too short. The authors should point out this in the paper.
We went further in the data exploration to link the M2 variations with the NAO. We have now some new insight from the statistical analysis. These new results are detailed in response to reviewers #1 and #2.

Reference:
Feng, X., M. N. Tsimplis, and P. L. Woodworth (2015), Nodal variations and long-term changes in the main tides on the coasts of China, J. Geophys. Res. Oceans, 120, 1215–1232.
Müller, M. (2011), Rapid change in semi-diurnal tides in the North Atlantic since 1980, Geophys. Res. Lett., 38, L11602.