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Comment on egusphere-2022-730

Johannes Becherer (Referee)

Referee comment on "Imminent reversal of the residual flow through the Marsdiep tidal inlet into the Dutch Wadden Sea based on multiyear ferry-borne acoustic Doppler current profiler (ADCP) observations" by Johan van der Molen et al., EGUsphere, https://doi.org/10.5194/egusphere-2022-730-RC2, 2022

Review for:

Imminent reversal of the residual flow through the Marsdiep tidal inlet into the Dutch Wadden Sea based on multiyear ferry-borne ADCP observations

Based on a long ferry-born ADCP time series of the Marsdiep tidal inlet the authors demonstrate that the residual flow changed from net outflow to net inflow during the last decades. The authors associate this trend to global warming by correlating the yearly net flow to the annual mean air temperature. A couple of potential mechanisms that could yield this behavior are discussed, where a change in tidal amplitude due to increased stratification in the North Sea is suggested.

The data analysis appears to be done very carefully and the manuscript is well-written and easy to read. The main result of the paper, a major shift from out- to inflow in the Marsdiep, is, taken on its own, already worth publishing and quite interesting to the community. When it comes to the discussion of potential mechanisms behind this trend, I still have a couple of questions (see below). Overall, I suggest this manuscript for publication after some minor revisions.

General Questions/Comments:

The argument that a change in tidal amplitude due to increased North Sea stratification causes the change in residual flow is not entirely clear to me. Normally, the change in tidal range due to stratification is mostly thought to be associated with decreased friction of the semidiurnal tidal constituents (see e.g. Mueller 2012, Graewe 2014). This has to do with

the near-resonance of semidiurnal tides with the inertial period in mid-latitude regions, resulting in frictional boundary layers that can extend way beyond the height of the thermocline. Therefore, an increase in vertical stratification can reduce the boundary drag for semidiurnal tidal components. In theory this should be less pronounced for the diurnal tidal constituent. In this context it is surprising that the only trend you observe is in the O1 tidal constituent. In line 255 you mention that this can be explained by the "day/night heating/cooling cycle". This reasoning is not very clear to me. Maybe you could explain a little bit more, what you mean here.

The correlation to mean air temperature could also suggest other mechanisms. For instance an increase in the baroclinic pressure gradient between the tidal basin and the North Sea. Due to differential heating the tidal basin could become substantially warmer than the open North Sea, yielding a net baroclinic exchange flow (estuarine circulation). However, it is not obvious how this would yield a change in the net volume flow. The warmer water that leaves the system at the surface gets displaced by colder North Sea water in the deep. Given that this is a two-inlet system could this mean that the deeper of the two inlets (Marsdiep?) needs to accommodate more deep inflow to account for the increase in surface outflow through both inlets? I am not sure if this makes any sense. It is just an idea that came to mind while reading this manuscript.

I am missing a discussion on the river run off. Isn't there some runoff from the Ijsselmeer? Could it also be that warmer years are also more dry years with less run off, resulting in less net outflow from the basin? Or is the run-off just too small to explain the change? that should be easy to discuss.

In Line 264 you say "that wind-forcing … is not correlated to the trend observed in the ADCP data". As far as I understand, you only test this for annual mean eastward wind speeds, right? What about strong wind events (storms)? Do you have any way to assess or discuss their potential contribution? You mention in L95 that the ferry does not go during "extreme weather events", could this mean that the observations are biased towards "good weather"? I feel that a brief discussion on the potential effect of storm events could be beneficial.

Minor:

Figure 6: The coloring of the lines makes it difficult to distinguish between different years. Could you potentially use a more contrasting coloring? This is also true for figure 8.

Most figures?: Is there a reason why you plot the x-axis (latitude) in reverse. This was a little bit confusing to me. If you don't want to change this. Can you at least mention explicitly in the caption that you are looking into the tidal basin (or in ebb-direction).

Figure 7. I find the double gyre structure in (b) quite interesting. This seems to hint towards an important contribution from lateral circulation to the tidal residual flow. You discuss this a little bit, however (d) suggests that these lateral circulation cells are weakening, which I don't recall to be discussed in the manuscript. I feel a weakening of the secondary circulation could also hint towards potential mechanisms involved in the change of residual flow and are therefore worth to be discussed or at least mentioned.

Figure7c: What is this giant blue blob in panel (c). Is this an artifact or real? In this context I was wondering how much of your transect averaged trend is governed by these strong outliers (also on the edges of the transect)? Is there a way to quantify their contribution, relative to the seemingly more well behaved transect interior?

Figure 8b: From this figure it seems as if specifically the residual outflow near the surface has decreased in recent years. Could you comment a little bit on that? Could this be related to less fresh water run-off? or decreased estuarine circulation?

Typos:

L166: something is wrong with the figure reference.

References:

Müller, M. (2012), The inï¬uence of changing stratiï¬cation conditions on barotropic tidal transport and its implications for seasonal and secular changes of tides, Cont. Shelf Res., 47, 107–118.

Gräwe et al. (2014), Seasonal variability in M 2 and M 4 tidal constituents and its implications for the coastal residual sediment transport, Geophys. Res. Lett., 41, 5563–5570, doi:10.1002/2014GL060517.