Dear Dr. Pohl,

Thank you for your review of our manuscript. Please find in the following our responses to your comments. We repeated your comments in bold and you can find our response in italic.

1 Main comments:

I missed a discussion on the relevance of storms as a sediment transport mechanism on the seafloor. What about other sediment transport processes such as seafloor currents (e.g. tidal, thermohaline, hyperpycnal flows, river discharges etc.) and sediment gravity flows (e.g. slides or turbidity currents likely to be triggered by storm events)? To which water depth can a storm event affect the seabed? Typically, the storm-weather wave-base is located at 150 200 m, and sediments below this base are unaffected. Could the authors explain how storms can transport sediment across the seafloor? In the rock record, storm deposits (Hummocky cross-stratification) indicate mainly reworking of sediment on the seafloor, rather than lateral transportation.
It is a known issue that during strong storm activity, amber is beach-combed. In this study, we focus on high-density MP particles. We assume for this reason that there should be a comparable behaviour of these MP particles and amber. The cited articles underline this assumption. As there is a source of amber in the Baltic Sea, we assume that there are also locations which accumulate MP. A 3-D ocean model is used here with terrain-following vertical coordinates. It is capable to simulate the mentioned sea-floor currents. River discharges are defined from a climatology, but without MP load, as we are interested in the resuspension of particles from the seabed. A simulation over one month, suggests that only strong wave activity during the storm event produced sufficiently high bed-shear stresses to transport the MP particles. This corresponds to the experiences from the amber hunting community. High shear stresses are neccessary to transport the particles in suspension. The water depth still affected by waves depends on the wave length. The Baltic Sea is relatively shallow with the result that larger parts of the seafloor can be affected by wave activity.

The sediment transport model could be explained clearer. I struggle to understand what this model is doing exactly. How wromas the bed shear stress calculated and what are the assumptions for these calculations? What type of movement is simulated at the seabed (oscillatory water motion by waves or unidirectional flow)? What are the values of the calculated shear stress and do these make sense when comparing to field and laboratory measurements? I think the outreach of the paper would increase significantly if it becomes clearer to non-experts what this model is doing. In particular as this paper will be of high interest and relevance for readers from other research fields. I cannot evaluate the atmospheric models, as this is not my field of expertise.
We will add an appendix to the manuscript explaining the sediment transport model more in detail. It is a 3-D model, which calculates the concentrations in each model grid cell. An empirical formula for the estimation of the combined shear stress of waves and currents at the sea-floor is used. The initiation of motion is calculated by the Shields curve, settling velocity of the particles is simplified and based on the Stokes formula.

The used criterion for the movement or suspension of sediment is not clear. The Shields curve describes the initiation of movement of sediment on the bed, which means transportation as bedload. There exist additional curves to estimate the threshold for suspension of sediment (e.g. (Bagnold, 1966; van Rijn, 1993; Nino et al., 2003)). Could the authors be more specific which criterion they used and why? Also, the Shields criterion describes the movement of particles under unidirectional flow. How would this translate through to oscillatory water motion, as caused by wave movement?
An empirical formulation is used to estimate the combined impact of currents and waves in terms of an effective bottom stress. Details including the formulas can now be found in an added appendix section.

Assumptions and limitations of the model should be discussed. The authors specifically state all assumptions and simplifications in their calculations, but I was missing a discussion on how these assumptions (e.g. spherical particles) might affect the results and conclusions.

The spherical shape of the particle will influence its settling velocity. Waldschläger and Schüttrumpf (2019) discuss the impact of the shape on the settling velocity. There is also an impact of biofilms, which affect the weight of the particles. Our aim was to quantify in how far the uncertainty from the metocean conditions affect the transport. The simulations showed a strong impact on the amount of transported material, but not on the location where erosion and deposition takes place. This finding should persist if adapting the parameters to more realistic ones, affecting the amount of transported material and the specific location for a specific size class. The uncertainty is taking into account by driving the model chain with an ensemble of the atmospheric model. The uncertainty in the parameters like the settling velocity or critical bed shear stress could also be taken into account, by defining several fractions covering the uncertain range of the specific parameter. This is possible as there is no interaction between the fractions.

2 Comments made while reading the manuscript:

Page 1, line 7: Can you mention to which depth these surface waves would reach down the water column?
Interaction of the wave with the seafloor takes places in depth less than half the wave length. The dominant wavelength is between 20 m and 70 m and can reach up to 130 m (Kriauinien, J., Gailiuis, B. and Kovalenkovien, M. 2006. Peculiarities of sea wave propagation in Klaipeda Strait, Lithuania. BALTICA 19: 20-29.).

Page 1, line 13-15: Would this also depend on the ocean depth? Maybe you mean this with bathymetry? I suggest to specifically mention that the ocean depth plays a major role in whether or not particles on the seafloor can be resuspended due to increased surface wave intensity.
With uncertainty, the uncertainty in the representation of the storm is meant. At a fixed position, the amount of eroded or deposited material is affected differently depending on the particle properties. Ocean depth at this location is important, but also in the vicinity of the location, which influences waves and currents. This is meant by bathymetry.

Page 2, line 2-3: Could you back this up with a reference? At least in deep-marine sedimentology, sediment transport models still have issues and results often do not match observations.
The sediment transport model is based on the work of Sassi et al. (2015), we add this reference. We assume that for the task of identifying areas of interest for empirical quantification of MP accumulation, uncertainties in the transport models are acceptable.

Page 2, line 8-9: Who assumes that? What about other sediment transport processes such as seafloor currents or sediment gravity flows?
We add references which stress the importance of extreme events for sediment erosion.

Page 2, line 16-20: Could you please be more specific here. The Shields curve would give you the critical shear stress at which particles would start to move as bedload. Other curves describe the initiation of suspension (e.g. (Bagnold, 1966; van Rijn,1993; Nino et al., 2003)). Also, this diagram estimated the critical shear stress with a unidirectional flowing current. It is not clear to me how this would translate through to oscillatory water motion, as caused by wave movement.
Details are now given in an added appendix session.

Page 2, line 20: How have you calculated the shear stress exerted on the seabed due to wave motion of the sea surface?
Details are now given in an added appendix session.

Page 7, line 3-7: This needs more explanations. These sentences are difficult to understand.
These sentences describe properties of the GETM model which reduce undesired numerical mixing. Numerical mixing leads to an unrealistically high diffusion of transported concentrations, reducing the peak concentrations and overestimating the area in which tracers spread. We add an explanatory sentence stating this.

Page 7, line 9: What is the difference between wave and current induced bed (shear) stress? I guess this relates back to my comment on page 2, line 16-20.
GETM simulates the ocean currents on a 3-D mesh. The current induced bed shear stress is based on this current. Wave data are externally provided from the simulation done with WAVEWATCHIII. Wave induced bed shear stress is calculated based on theses wave data. Both stresses are added also taking their non-linear interaction into account. Details are now given in the appendix.

Page 7, line 10: Does this mean that the wave induced oscillatory motion of the water at the seafloor is neglected? Looking at ancient storm deposits in the rock record, oscillatory motion appears to be a dominant sedimentary process.
With the latter, the maximum combined wave- and current-induced bed stress is meant. This is based on an empirical formula as mentioned before. So, oscillatory motion is taken into account.

Page 7, line 10-13: It is not clear to me what this means. If this is important, it should be explained. If not, these sentences might be removed from the manuscript.
For the regional ocean model in this study, initial conditions and lateral boundary conditions are needed. Starting from initial conditions which do not agree with the meteorological data will cause adjustment effects at the very beginning which may produce unrealistically high currents. This statement says how the conditions are at the beginning of the simulation and what goes in and out at the border of the model domain. This is a necessary information and citation.

Page 7, line 15: Sea surface elevation = water level?
Correct. In line 16, water level is used.

Page 8, line 9: Why did you chose these particular grain-size range? What about particles between 10 and 200μm?
We used the same sizes as in the study for the North Sea from Stuparu et al. (2015). It is not a range, these are two discrete fractions, and it is computationally expensive to add more fractions. Our purpose is a support for measurement campaigns and particles of above 300μm are easier to sample.

Page 9, line: 17: Please amend to: Figure 7c-f.
Figure a is the deterministic run (without stochastic perturbations of the model physics in the atmospheric part). Figure b serves as a comparison with a publicly available atmospheric dataset.

Page 9, line 19-21: Was there a predominant current direction? Could you indicate this direction in figure 7? Could this current explain the pattern of erosion and deposition (i.e. erosion on northeast and deposition on southwest dipping slopes)? Would this pattern change if the direction of the storm surge is different?
Currents in the Baltic Sea are in long-term driven by a thermohaline circulation leading to cyclonic currents, but intermittently can be changed and even reversed by wind. This also controls transport direction of the suspended material and consequently deposition areas. An entirely different storm realization could therefore also change erosion deposition patterns, but we see that this effect plays a minor role in our simulations, i.e. meteorological uncertainty is not that strong. We state the main current direction in the caption of the figure but do not add it e.g. as arrows not to mix it up with the wind direction shown in other figures.

Page 9, line 22-24: I think it is very important to state that surface waves can only redistribute sediments and plastics to a certain water depth. Storms are important for the MP distribution in coastal areas and shallow seas (e.g. large areas of the Baltic Sea), but apparently play a minor role in the distribution of MPs on the seafloor for most parts of the worlds oceans (below the storm weather wave base). I would think that MPs are frequently remobilized by storms and thus get transported until they are deposited below the storm weather wave base. Here water depth is too deep and plastics cannot longer be remobilized by storms. This would suggest that MP concentrations are probably highest just below the storm weather wave base.
We agree with this speculation but we could not demonstrate this in this model study. As it is known from amber, there must be a stock on the seafloor affected under storm conditions. Our assumption is that there is a comparable behaviour with MP. This assumption is based on other scientific studies, and the identification of potential deposition areas with the model can help to support measurement campaigns whose outcome could

validate the model runs.

Page 9, line 24-26: What about changes in the wind direction?
They are taken into account by the ensemble approach. The stochastic perturbations of the model physics provoke slightly different developments of the storms in the different members, not only in intensity, also in the track of the storm. This was one of the principial ideas of this study, to see if this variability in the location of the storm affects also the location where erosion and deposition appears.

Page 10, line 5: Why is the color scheme in figure 9b c different compared to figure 7 8? This is confusing and makes a comparison difficult.
Figure 9 is for the 10 μm fraction and figures 7 and 8 for the 330 μm fraction. The range of values is different (0 to 1.2) for figure 9 and (0 to 2.5) for figure 7 and 8.

Page 10, line 12: Again, why where these grain-size classes chosen? Wouldnt it make more sense to spread the size classes more evenly in between the two end-members (10 and 300μm)?
Based on the fractions as in Stuparu et al. (2015). The model can simulate only the transport of discrete size fractions. For one measurement method used in the project, 300 μm was the lower limit for the sampling. With 330 μm, we are 10% above of this lower limit.

Page 11, line 5-9: I think I finally understood that you model both, oscillatory motion and unidirectional flow. Is this correct (see my comment on page 7, line 10)? How high are the calculated bed shear stresses ?
These vary between zero and 0.090 $N\ m^{-2}$, strongly depending on water depth.

Page 12, line 1-2: Does atmospheric forcing mean the generation of a unidirectional current at the seabed? If yes, what is the current velocity and how did you account for interactions with the bathymetry?
The 3-D regional ocean model with 1 n.m. resolution applied in this study simulates the ocean currents close to the seafloor. A 3-D regional ocean model (GETM) is used, which has terrain following vertical coordinates. It calculates the U and V components of the current at each model timestep for each grid cell. The model is driven by the atmospheric data, but also includes river discharges and is driven at the open boundary with the North Sea by lateral boundary conditions of a North Sea ocean model.

Page 14, line 1-2: What about sediment transport mechanism other than storm induced movements? Tidal currents for example. Although tidal currents are not very strong in the Baltic Sea, they play a significant role in the North Sea. Storms may also trigger sediment gravity flows such as turbidity currents which could transport MPs on the seafloor (Pohl et al., 2020). Also seafloor currents due to thermohaline circulation can transport and redistribute MPs (Kane et al., 2020). I think other processes should be discussed.
As figure 12 suggests, strong wave activity plays the pre-dominant role for erosion and though for the transport in suspension. Our aim was not to quantify which are the pre-dominant processes leading to the transport of MP. We wanted to investigate in how far the uncertainty in a weather forecast would affect the transport behaviour of sediment and MP. Tidal currents play a role in the Danish Straits only but the interior of the Baltic Sea is non-tidal. Turbidity currents cannot be represented in our model since the concentration of suspended matter has no influence on seawater density in the model. Thermohaline circulation, on the other hand, is fully taken into account. We add the missing processes to the discussion of the study's limitations.

Page 14, line 2: This is an interesting point. Could the authors be more specific on how these budget methods would work?
The same question was asked by Reviewer 1 so we give the same answer. A budget method relates (a) input and (b) output of a quantity to (c) changes in its mass, e.g. inside an area of interest. If two of the three values are known, the third one can be determined. The purpose of our study is a potential support for the planning of measurement campaigns. To be able to create a map of the sea-floor with MP concentrations, a better knowledge of concentrations entering the Baltic Sea is necessary. We assume a homogeneous distribution over the sea-floor. This is sufficient to see where potential erosion and deposition could take place. For a more realistic simulation, knowledge about the amount of material inside the Baltic Sea would be necessary. Then, the model could run for a longer period, and should approximate the distribution on the sea-floor. The

error in the approximation will be size- and density dependent.

Page 15, line 12-13: The authors use in their model only spherical particles, although most MPs have more complex shapes (angular and oblate fragments, fibers etc.). I fully understand that the simulation of more realistic shapes would add another level of complexity, or might be even impossible to model as we dont fully understand the hydrodynamics for these complex shapes (Khatmullina and Chubarenko, 2019). However, the authors should mention possible deficiencies of the model due to the assumption of spherical particles. Nevertheless, I think these models are crucial for understanding MP distributions and the assumption of spherical particles is a good starting point.
Our aim was to study the effect of the uncertainty in the representation of storms on the transport of MP particles. This kind of uncertainty is, as far as we know, neglected in other studies. The simplifications of the model have of course impacts on the transport behaviour, as unknown particle shapes will add even more uncertainty.

Page 15, line 15-16: I dont understand this sentence. Size difference in what? MPs? Sediment? Could the authors please rephrase and make this clearer?
Will be rephrased.

Page 15, line 18-20: Only because they have the same settling velocity? I think that this is too simple.
The correlations in figure 13 shows the connection between a sediment particle and a ligther but larger MP particle. Enders et al. (2019) showed such a relation based on measurements.

Page 15, line 31-32: This is only valid for shallow waters above the storm weather wave base.
Yes, but the Baltic Sea is relatively shallow.

Page 16, line 10-13: This is very interesting! Could these models predict particular microplastic sinks on the seafloor? To which water depth would storms affect the seafloor distribution of MPs?
Yes, such models should be applicable for this task. The model can predict potential sinks of MP, under the condition that material is available. We assumed a homogeneous distribution of MP over the entire Baltic Sea and we do not have river loads or beach accumulation (as a sink) taken into account. The model predicts areas which are sensitive to a potential deposition. The water depth affected by waves is half of the wavelength, which goes up to 130m in the Baltic Sea, but will strongly dependent on wind direction and especially fetch.

1 Appendix A: Mathematical description of the particle sinking and erosion model

Sinking velocity of the particles is initially calculated by the Stokes formula,

$$w_{Stokes} = \frac{gD^2}{18\nu}\frac{\rho_p - \rho_w}{\rho_w} , \quad (1)$$

where g is the gravitational acceleration, D is the particle diameter, ν is the kinematic viscosity of water, and ρ_p and ρ_w are the densities of the particle and the water. To correct for larger particles whose sinking velocity would be overestimated by the Stokes formula, a Newtonian correction is applied by an iterative algorithm:

- A Reynolds number is calculated as $Re = 0.64 w_{sink} D/\nu$.
- A relative drag coefficient is derived from this Reynolds number as $C_D = 18.5/Re^{0.6}$ following Perry and Chilton as cited by[Khalaf, 2009].
- The updated velocity is calculated as $w_{sink} = \sqrt{\frac{4gD}{3C_D}\frac{\rho_p - \rho_w}{\rho_w}}$

which can be understood as a weighted geometric mean between the two velocities w_{Stokes} and ν/D. This correction makes large particles sink slower than the Stokes formula suggests. We, however, erroneously applied the correction also to the small particles where it resulted in an undesired upward correction. This has no effect on particle erosion but accelerates redeposition, which may even lead to an underestimation of the influence of meteorological uncertainty for the small particles in our study.

Erosion takes place when the actual shear stress exceeds the critical shear stress. To determine the critical shear stress, we follow the Shields curve in its version which was corrected by [Soulsby, 1997]. First, we calculate the dimensionless particle diameter D_*, which relates the particle diameter D to a viscosity-determined length scale, following [Rijn, 1984]:

$$D_* = \sqrt[3]{\frac{g}{\nu^2}\frac{\rho_p - \rho_w}{\rho_w}} D , \quad (2)$$

where ν is the kinematic viscosity of water, ρ_p is the particle density and ρ_w is the water density. Then we calculate the critical shields parameter for non-cohesive grains, θ_{cr} (also dimensionless), following [Soulsby, 1997] as cited by [Ziervogel and Bohling, 2003],

$$\theta_{cr} = \frac{0.3}{1 + 1.2D_*} + 0.055 * (1 - e^{-0.02D_*}) . \quad (3)$$

The critical shear stress can then be calculated as

$$\tau_{cr} = gD(\rho_p - \rho_w)\theta_{cr} . \quad (4)$$

The actual shear stress is calculated from the wave-induced and the current-induced shear stress, τ_w and τ_c. The current-induced shear stress itself, however, is also modified

diameter (μm)	density (kg m^{-3})	sinking velocity (mm s^{-1})	critical shear stress (N m^{-2})
10	1275	0.15	0.006210895
330	1275	8.14	0.045142586
10	1400	0.20	0.009277999
330	1400	10.98	0.062337737

Table 1: Sinking velocities and critical shear stress in the model at 10°C.

the wave field, as it changes the bottom drag coefficient according to the DATA2 formula given by [Soulsby, 1997],

$$\tau_m = \left(1 + 1.2\left(\frac{\tau_w}{\tau_c + \tau_w}\right)^{3.2}\right)\tau_c \,, \tag{5}$$

where τ_c is the shear stress induced by the current in the absence of waves. Both of them are combined depending on the angle α between currents and waves,

$$\tau^2 = \tau_w^2 + \tau_m^2 + 2\tau_w\tau_m\cos(\alpha) \,. \tag{6}$$

If the actual shear stress exceeds the critical one, the deposited material gets resuspended with first-order kinetics, i.e. proportional to its mass in the sediment pool.

The actual values for sinking velocities and critical stresses depend on temperature since it influences sea water viscosity. Values for 10°C are presented in Table 1.

References

[Khalaf, 2009] Khalaf, H. K. (2009). *The theoretical investigation of drag coefficient and settling velocity correlations.* PhD thesis, Nahrain University, Nahrain, Iraq.

[Rijn, 1984] Rijn, L. C. v. (1984). Sediment transport, part II: suspended load transport. *Journal of hydraulic engineering*, 110(11):1613–1641. Publisher: American Society of Civil Engineers.

[Soulsby, 1997] Soulsby, R. (1997). *Dynamics of Marine Sands.* Thomas Telford Publishing, London.

[Ziervogel and Bohling, 2003] Ziervogel, K. and Bohling, B. (2003). Sedimentological parameters and erosion behaviour of submarine coastal sediments in the south-western Baltic Sea. *Geo-Marine Letters*, 23(1):43–52.