"Ship-based lidar measurements for validating ASCAT-derived and ERA5 offshore wind profiles"
Rev v3
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Authors response to reviewer comments

We would like to thank the referees once again for their time and effort in reviewing our work. We appreciate their feedback and comments, and we have carefully considered their recommendations and concrete suggestions to enhance and clarify our work.

Below, we addressed the additional referees' comments and reply to them point by point. First, the referee's comment is included in italics and bold font, followed by our answer, and when applicable, we have included an excerpt of the revised version of the manuscript (highlighted in blue).

Ine Wijnant, Referee #2

1. ***Abstract: Text still gives the impression that this work contributes to "accurate characterization of offshore wind resources". Maybe this is true for the Baltic for now, but certainly not for places with wind farm (effects). I suggest this alternative text: Because offshore in-situ wind measurements at turbine operating heights are scarce, ECMWF Reanalysis 5th generation (ERA5) data are often used for offshore wind resource assessments. There are however a few disadvantages of using ERA5: it has a rather course grid spacing which makes it less useful for coastal areas and it does not include wind farm effects, so it can only be used for wind resource assessments in areas without wind farms. This study presents a comprehensive comparison between wind profiles derived from the satellite-based Advanced Scatterometer (ASCAT) ~~satellite observations~~ and ~~the~~ ERA5 ~~reanalysis dataset~~ against ship-based lidar measurements in the Northern Baltic Sea for a period without wind farms. The aim is to investigate the applicability of ship-based lidar measurements for validating these datasets and to better understand the reliability, accuracy and limitations of ASCAT-and ERA5-derived wind statistics for offshore wind characterization at wind turbines operating heights when there are no wind farms. To extrapolate ASCAT observations at sea level to turbine rotating heights, a mean correction of atmospheric stability effects based on ERA5 and a probabilistic adaptation of the Monin-Obukhov similarity theory (MOST) ~~was~~ were implemented. The comparison between the two gridded... etc***
   The aim of the paper is clearly stated in the abstract already "The aim is to investigate the applicability of ship-based lidar measurements for validating these datasets and to better understand the reliability, accuracy and limitations of ASCAT- and ERA5-derived wind statistics for offshore wind characterisation at wind turbines operating heights."

   Additionally, as mentioned in previous review rounds, noted in earlier review rounds, wake effects are not relevant to the objectives or findings of this study. We fully agree with the referee that the validity of our results applies to regions without wind farms, and we have made this clear in the revised manuscript for instance, in the Introduction ("…offshore wind characterisation at wind energy-relevant heights in areas without

wind farms.") and in the Concluding discussion ("…both ERA5 and ASCAT must be approached with caution due to their inherent characteristics, including insufficient spatial resolution and the inability to adequately capture wind farm wake effects…"). In our view, repeating this clarification 3 times more again in the abstract is unnecessary, as wake effects do not factor into the presented results. Moreover, the known limitations of ERA5 in modeling wake losses are already well-known in the literature and do not directly influence the findings in this context. Including several times an explicit statement in the abstract regarding wake effects may suggest they were a central element of the study, although they are not.
The rest of the abstract has been adjusted according to referee suggestions.

2. ***Line 44-45: Each NWP model comes with inherent limitations due to factors like grid resolution, physical modelling, and parameterization choices (e.g. wind farm parametrisations or the lack thereof).***
Corrected.

3. ***Line 46-47: "However, conducting such validation is particularly challenging in deep-water offshore regions, where in situ measurements are sparse.". There are fewer measurements at sea than on land, but I am not convinced there are fewer measurements in deep than in shallow water… what did you base this on?***
We have clarified this in the manuscript. We are referring to the lack of measurements at turbine operating heights in deeper waters, given the high costs and logistical difficulties of deploying mast- and buoy-based systems in these areas: …challenging in deep-water offshore regions, where in situ measurements at wind turbine operating heights are sparse.

4. ***Line 77-79(typo): To the authors' knowledge, this study represents the first comprehensive comparison of vertically extrapolated ASCAT winds ~~profiles~~ (hereafter referred to as ASCAT wind profiles) ~~from 10 m height up~~ to wind turbine operational heights against non-stationary in situ measurements, covering locations near the coast and further offshore. ~~a wide horizontal extent from nearshore to offshore locations.~~***
Corrected.

5. ***Line 80-82: Therefore, this work aims to contribute significantly to a better understanding of the reliability, limitations, and accuracy of satellite measurements derived wind statistics and ERA5 wind data for offshore wind characterization at wind energy-relevant heights in areas without wind farms.***
Corrected.

6. ***Line 87: The discussion of these findings and the main ~~extracted~~ conclusions are included in Sections 4 and 5, respectively.***
Corrected.

7. ***Line 89-91: This section describes the three datasets used in this work. In addition, the methodology used for processing the different 90 datasets is explained in detail ~~detailed~~, as well as the methodology to extrapolate ASCAT winds and the collocation approach used for their comparison against the ship-based lidar measurements.***

Corrected.

8. ***Line 104: The campaign took place from 28 June 2022 ~~to~~ until 21 February 2023***
Corrected.

9. ***Line 105: … ship-based lidar system was used with ~~This is composed by~~ a vertical profiling Doppler lidar WindCube WLS7v2, …***
Corrected.

10. ***2.1 Ship based lidar measurements: I still miss info on the accuracy of the measurements from the WindCube WLS7v2 in this section. Also what you added in lines 567-573(answer to my question 16) is not really info on accuracy. So you assume (or know? reference?) that the accuracy of a ship-based lidar with motion recorder is comparable to the accuracy of a floating lidar? Add in section 2.1: the accuracy of a ship-based lidar with motion recorder is (assumed to be) similar to the accuracy of a floating lidar. According to Dhirendra et al (2016) this is 3.1%-4.2% for heights of 92m in the wind speed range 4m/s-16m/s (pg 15 TNO report -DOWA validation against offshore mast and LiDAR measurements | Report | Dutch Offshore Wind Atlas).***
It is difficult to include specific uncertainty values to ship-based lidar systems, as their non-stationary nature hinders direct comparisons with reference measurements typically used for uncertainty quantification (as stated in the Introduction …before ship-mounted profiling lidar systems can become a generally accepted alternative …, specific challenges need to be overcome, such as the validation of these data against reference measurements and the quantification of the associated uncertainty). The main sources of uncertainty in ship-based lidar measurements are (1) the intrinsic lidar measurement uncertainty, (2) the effect of tilting, and (3) the translational motion of the ship. While the first two components are well studied in the context of floating lidar validation, the third is, to our knowledge, not yet fully quantified in the literature, but we expect will not have a great impact. Therefore, we assume that the overall uncertainty of ship-based lidar equipped with a motion compensation system is similar to that of a floating lidar. This assumption is supported by previous studies showing good agreement between ship-based lidar measurements and met mast data from FINO1 (G. Wolken-Möhlmann et al. 2014), as well as by other comparisons between ship-based lidar measurements and independent datasets (Zentek et al. 2018; Rubio et al. 2022; Zhai et al. 2018).
We have clarified this in the conclusion section of the manuscript (rather than in Section 2.1, since the uncertainty of ship-based lidars is discussed in this section). We have also included a citation to the recommended reference (Dhirendra et al. 2016) to provide a quantitative benchmark for floating lidar uncertainty.

11. ***[Line567-573: "Consequently, the mean values derived from lidar measurements may exhibit biases that vary depending on the time slots during which measurements were acquired at particular locations. Additionally, it is acknowledged that lidar measurements, like any other observational data, are subject to inherent uncertainties that may impact the results (Duncanet al., 2019b; Rubio and Gottschall, 2022). Nevertheless, the observed deviations between the lidar measurements and both extrapolated ASCAT and ERA5 significantly exceed the***

magnitude of potential discrepancies attributable to floating lidar uncertainties (at turbine rotor heights roughly 3-4% see section 2.1), which can be up to approximately 2 % with mast-mounted anemometers as lower limit reference (Wolken-Mohlmann et al., 2022)".]
We have added the suggested reference from the reviewer and added the corresponding reference (Dhirendra et al. 2016).

12. ***Line 150: What is a nadir gap?***
The nadir gap is the area directly beneath the satellite's path where no data is collected (see: [The Xynthia Storm by ASCAT](), [Scatterometry | Learning Weather at Penn State Meteorology]()).

13. ***Line 170-172: Despite the application of these quality filters, ASCAT seems to overestimate wind speeds ~~excessively high mean wind speed values were observed in ASCAT grid cells~~ near the coast (as shown later in this report in fig 12), likely due to coastal contamination effects (Stoffelen et al., 2008; Lindsley et al., 2016).***
Corrected.

14. ***Line 179-180: provides hourly estimates of a wide range of atmospheric, land surface and oceanic variables with a 0.25° x 0.25° latitude-longitude grid resolution (31x31 km), covering the period from 1950 to present.***
A resolution of 0.25° × 0.25° does not necessarily correspond to 31 × 31 km, as it depends on latitude. In fact, in the study area, this 31 × 31 km measurement would be significantly smaller. We have, however, included the specific ERA5 resolution in kilometers in the newly added Table 1.

15. ***Line 211-212: So there are two methods for stability correction: mean stability correction and instantaneous stability correction. Compared to the instantaneous stability correction approach, applying the mean stability correction avoids the need to calculate wind speeds under stability …***
Corrected.

16. ***Line 218-221: Another advantage of the ~~Additionally, employing the~~ mean stability correction ~~offers other potential benefits. N~~is that the numerical models used for this method can accurately capture average meteorological conditions over extended periods (Peña and Hahmann, 2012). The stability information of data used for instantaneous stability correction is (generally?) less accurate because the measurements are for a single location or a limited time span. This introduces , ~~whereas the accuracy of instantaneous stability information from these datasets is questionable, introducing~~ additional uncertainty to extrapolated profiles using this instantaneous data (Badger et al., 2012)***
Corrected.

17. ***Line 224-225: ~~Otherwise~~However, a relevant drawback of the mean stability correction is that everything gets averaged out and site-or time-specific information ~~the~~ information ~~provided by~~fromin-situ measurements is not included~~the individual wind speed samples is neglected, masking the potential influence of particular mesoscale effects that modify the average wind profile.~~***

Corrected.

18. ***Line 237: You use ERA5 to derive L and you select values of C that give NPD of 1/L closest to ERA5. Does that mean that all differences between ASCAT and ERA5 at higher levels are mainly due to differences at sea level (or 10m) because the (stability dependent) extrapolation to higher levels is equal?***
    No, because ASCAT values at higher altitudes are derived using the mean stability correction method presented in the paper, while ERA5 values are obtained directly from the model output. Therefore, the differences at higher level will be due to the differences at 10 m plus the methodology to obtain mean values at higher heights, in the case of ASCAT, the mean stability correction approach. This is outlined in Section 3.2 of the paper: The difference in bias observed between 100 m and 10 m in ASCAT and ERA5 can be attributed to two key factors: first, the inherent differences between the datasets at 10 m, and second, the mean stability correction approach applied to extrapolate ASCAT.

19. ***Line 250: In this study, the values for the C± constants have been set to 6 and 4 for the stable and unstable portions, respectively. These values are the same for all ASCAT grid points (both near coast and further offshore) and for the whole period (regardless of e.g. time of day and season).***
    It is clearly stated in this paragraph (couple of lines below) that identical values of C± were applied across all ASCAT grid points: … Furthermore, identical values of C± were applied to all ASCAT grid points.
    Additionally, we believe it is unnecessary to specify that these values were applied throughout the entire study period, as this is an inherent characteristic of the methodology used. The approach involves averaging wind profiles and stability conditions over the study period, meaning that explicitly stating this information does not add further clarity or information.

20. ***Line 309-310: "This situation may lead to coastal contamination and excessively high wind speed retrievals within these grid boxes." Counter-intuitive: land contamination gives an overestimation of the surface roughness and an underestimation of the surface wind. So please explain.***
    This sentence has been removed from the manuscript.

21. ***Line 329: Figure 8 illustrates the differences in wind speed at 100 m height between the collocated and the full campaign approaches.***
    Corrected.

22. ***Line 336-338: "Consequently, the collocated approach in these areas may have insufficient stability information available, potentially introducing a biased representation of the theoretical stability distribution during the campaign period". My old question 28 has not been answered. Too few ASCAT measurements increases uncertainty but does not necessary lead to bias. Maybe the reason is that a higher percentage of land-contaminated ERA5 data are used in the collocated stability correction than the full approach?***
    We have removed this sentence from the manuscript, as we believe the difference in the theoretical distribution derived from the two approaches (collocated and full

campaign) is relation with the ERA5 stability information used is better explained in the lines below: Secondly, the temporal discretization of ASCAT overpasses, occurring at roughly the same time each day, influences the resulting mean stability distribution "seen" by the collocated approach. This is…

23. ***Line 344-347: As can be observed, the more unstable conditions just beforemiddayat Nynäshamn harbour due to land-contamination (red line)"weigh"more in themean stability assessmentif you just consider the collocated periods (orange shadows) instead ofthe full period. ~~collocated approach yields a more variable and unstable mean distribution of the stability conditions near the Nynäshamn harbour (red line),~~ This leads ~~leading~~ to a larger stability correction factor in absolute terms (despite its negative sign at this location), and consequently, to lower wind speeds compared to the full campaign approach, as derived using the equations described in Section 2.4.***
Text corrected according to referee suggestion.

My old question 30 is not sufficiently answered. I can not see in the formulas in 2.4 how a higher negative value of 1/L leads to a larger stability correction (so please explain). And how does a larger stability correction lead to lower wind speeds (and at what level)? Less unstable (more weight to surface friction effect) tends to result in a lower wind speeds at the surface: is that what you mean?
In locations where unstable conditions occur more frequently ($n_{-} > n_{+}$), the mean stability correction factor (Ψ_m^*) will be greater than zero. The higher is the prevalence of unstable conditions, the larger is n_{-}, which in turn leads to an increase in Ψ_m^*. According to Eq. 6, for a given grid point, Ψ_m^* is the only variable that changes, and therefore, the larger frequence of unstable conditions in the correlated approach leads to slightly lower values of the calculated wind speed (U).

The manuscript has been modified for further clarity on this point.

24. ***Line 347-350: This ~~instability~~ unstability at location A is attributed to the coarse resolution of ERA5, resulting in land contamination of the grid box at the harbour location, where ~~the~~ land ~~mask~~ covers 56% of the grid box surface. Therefore, the daily stability cycle ~~profile~~ is more ~~akin~~ similar to that of an onshore site.***
Corrected.

25. ***Line 352: The period of ~~lowest~~ highest unstability then occurs around midday when the surface heating is mostintense.***
Corrected.

26. ***Line 354: ~~As this trend persists, s~~Untability reaches its ~~maximum~~ minimum (the negative value of 1/L closest to 0) in the late evening and stays relatively constant until the following morning.***
Corrected.

27. ***Line 355: In contrast, locations B to E are purely offshore (with a land fraction ~~mask~~ of 0%) and therefore exhibit almost no diurnal cycle because the atmospheric stability is mainly determined by the sea water temperature. There is however a seasonal cycle that was not taken into account. ~~a more stable diurnal cycle of~~***

~~*stability and lower variations throughout the day, due to the presence of a relatively uniform water surface. This leads to*~~

Corrected.

However, we have omitted the sentence "*There is however a seasonal cycle that was not taken into account*." since the seasonal cycle occurring outside the temporal scope of the campaign is not relevant to this study. The mean stability correction approach applied here considers only the stability conditions within the study period, which corresponds to the measurement campaign. Consequently, stability variations outside this period are neglectable, as they do not affect the in-situ measurements nor influence the mean stability conditions calculated for the extrapolation of ASCAT.

28. ***Line 357-359: Finally, ~~location F~~ at Hanko harbour (location F) there is more of a daily stability cycle than offshore, but a lot less than at Nynäshamn harbour (location A). There are two reasons for the difference between Nynäshamn (A) and Hanko (F): (1) The gridbox at Hanko (F) contains a significantly lower land-fraction: 6% compared to 56% at Nynäshamn (A)and (2) with predominantly W-SW winds, the wind at Hanko (F) is mostly from sea to land and at(Nynäshamn(A) is from land to sea. ~~, with a land mask of 6%, presents slightly higher variations in stability during the day compared to the offshore sites but is still relatively steady compared to location A.~~***

    Suggestion from referee included.

29. ***Line 364-367: Given the minimal differences in the wind speeds at 100 m depicted in Fig. 8, and thus the similar wind profiles obtained using both approaches, subsequent sections of this paper will only consider the full campaign approach ~~for the sake of clarity and conciseness. T~~because this approach is expected to provide more representative wind profiles along the complete ship route.***

    Rewritten for clarity.

    Differences between the collocated and full campaign approaches are minimal, as demonstrated by the results. Therefore, for the sake of clarity and conciseness, we have chosen to present only one of them, as comparing both would not yield sufficiently significant differences. This does not imply that no differences exist, but rather that they are small enough to make including both approaches in the subsequent results unnecessary.

30. ***Fig 9: Daily cycle of the stability parameter (1/L) at the six evaluated locations A-F from Fig. 7. All values of 1/L are below zero indicating an unstable atmosphere. Long(itude)18°corresponds to the harbour of Nynäshamn (Sweden)and long(itude) 23°to the harbour of Hanko (Finland). The orange shadows indicate the time periods when ASCAT overpasses are available and are therefore the only time periodsincluded ~~, considered for the stability characterization~~ in the collocation approach.***

    Corrected.

31. ***Line 372-378: As can be observed when comparing the spatial variation shown by the two datasets at 10 m, ERA5 exhibits higher mean wind speeds in the areas farthest from the shore ~~at 10 m~~, but the wind speed near the coast is lower. ~~with a progressive decrease as the coast is approached. However, although ASCAT also shows higher wind speeds in the middle of the basin, the areas closest to shore still~~***

~~present considerably higher values of wind speed compared to ERA5~~. This is because ERA5 has a grid-box size of 31x31km, so part of the selected grid boxes (only grid boxeswith ASCAT data so at 12.5 km from the coast) are still land-contaminated in ERA5(and assume a surface roughness that is toohigh and therefore a 10m wind that is too low).Again, the effect of the prevailing W-SW winds can be seen: the land affects particularly the areas where the wind predominantly blows from land to sea(Swedish coast).Similar effects can be seen at 100m height. ~~This discrepancy occurs because, despite the filtering process for the ASCAT dataset, the coastal contamination still affects ASCAT measurements, leading to excessively high mean values in nearshore areas. The effect of coastal contamination in the ASCAT map is particularly visible in the 100 m height map, where the highest mean wind speeds are located along the perimeter of the region with available data.~~

We have adjusted the manuscript as suggested by the referee. However, we have retained and revised the discussion regarding the ASCAT results. As can be seen in the figure below, ASCAT does exhibit higher 10 m wind speed values near the shore compared to offshore areas. While a detailed evaluation of ASCAT performance is beyond the scope of this study, we believe this pattern may be related to the high density of small inlets in these coastal regions, which could increase water surface roughness and therefore, increase the 10 m ASCAT wind retrievals. At 100 m, this nearshore overestimation suffered by ASCAT is more evident.
We have added and clarified this in the manuscript.

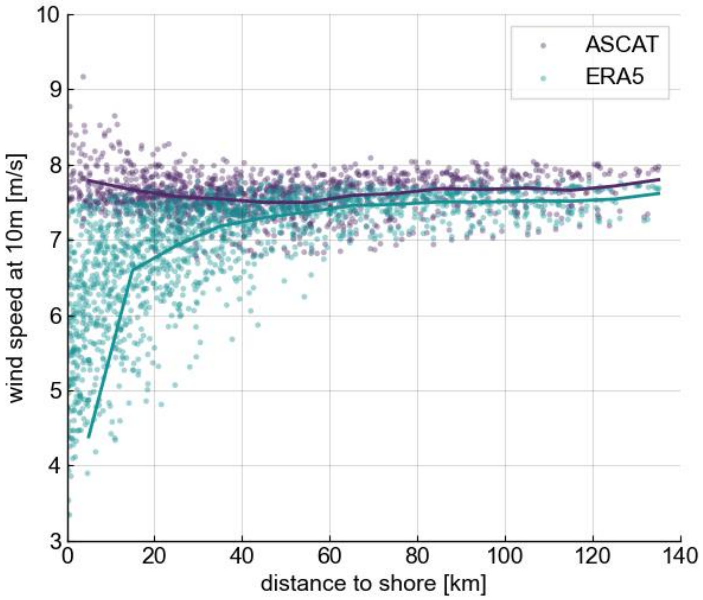

Figure 1: mean ASCAT and ERA5 wind speeds at 10 m depending on distance to shore. Each scatter point represents a point of the ASCAT/ERA5 grid.

32. ***Line 397: ~~As to be expected, b~~Both datasets consistently show higher wind speeds at 100 m than at 10 m height.***
    Corrected.

33. *Line 380-383: For 10m height, tThe ~~overall mean~~ wind speed averaged over all included gridpoints is s at 10 m are 7.61 m s-1 (ASCAT) and 7.15 m s-1 ~~for ASCAT and~~ (ERA5), ~~respectively~~.which means that ~~However, a notable reduction in~~ the ~~mean deviation~~ difference(UASCAT− UERA5) is 0.46 ms-1. When only locations ~~is observed when considering only locations distanced~~ more than 20 km from the shore are included, this difference reduces ~~where the overall mean deviation decreases~~ to approximately 0.16 m s-1. However ~~Conversely~~, only including locations within 20 km from the shore increases the ~~account for a total mean deviation~~ difference ~~of~~ to 0.98 m s-1.*

    Corrected.

34. *Line 386-390: For ~~At~~ 100 m height, the wind speed averaged over all included gridpoints is , ~~the mean wind speed values increase to~~ 9.31 m s-1 (~~for~~ ASCAT)and 8.67 m s-1 (~~for~~ ERA5) and the difference 0.64 m s-1. If only more than 20 km from shore locations are included, the difference is only slightly ~~if the whole area is considered, though the deviation is~~ reduced to 0.43 m s-1.~~when only far-from-shore sites are considered~~ So land-contamination in ERA5 is less relevant at 100 m height than at10 m height, which is what we expect (surface roughness affects wind at lower levels more than at higher levels). The differences between ASCAT and ERA5 at 10 and 100m ~~differing biases between these two datasets at the two heights levels (10 m and 100 m)~~ can be attributed to ~~three~~ two (or one?) key factors: first, the inherent difference between the datasets at 10m (e.g. the gridbox sizes: ERA5 still land-contaminated near the coast, ASCAT not), second, the mean stability correction approach used to extrapolate ASCAT; ~~and finally, as illustrated in Figure 8, the impact of the collocation strategy applied for the theoretical stability characterization.~~*

    Corrected.

35. *Line 396-398: This ~~discrepancy~~ difference between in nearshore areas can be explained by the combination of excessively high wind speeds retrieved by ASCAT due to coastal contamination and ERA5's inability to properly resolve the coastal atmospheric phenomena and small-scale wind flow variations due to its coarse horizontal resolution.*

    Corrected.

36. *Line 398-401: The differences become smaller ~~When~~ moving further offshore and almost negligible at distances further than 40 km from the shore: ~~(more than around 40 km), this discrepancy stabilizes, converging to more consistent estimates away from the influence of land and coastal effects and reaching mean difference values of~~ around 0.2 m s-1 at 10 m height and 0.4 m s-1 ~~400 at 10 m and~~ at 100 m height, ~~respectively~~.*

    Corrected.

37. *Line 417: mean profile bias is consistently positive (indicating ASCAT overestimation compared to the ~~regarding~~ lidar measurements), with the magnitude depending*

    Corrected.

38. ***Line 426: significantly outperforms ASCAT profiles, which overestimates the wind speed ~~exhibit~~ even at 10 m height, highlighting the***
Corrected.

39. ***Line 427-429: "Additionally, it is striking to observe the substantial deviation of the ASCAT stability corrected profiles from the logarithmic profiles, particularly at heights above 50-100 m, as a consequence of a stability distribution that is not representative enough of these specific sites".***
I do not understand want you want to say here. The logarithmic profile represents a wind profile for neutral atmospheric stability. Do you mean that at the harbour sites the ASCAT-profile seems to follow a logarithmic profile up to 50-150m (so no stability correction occurs). What does that mean?
Rewritten for clarity: Furthermore, a significant difference is observed between the ASCAT stability-corrected and logarithmic profiles at harbour locations, particularly above 50-100 m, mainly driven by the introduction of the stability correction factor that leads to higher wind speed estimates compared to the logarithmic profile.

40. ***Line 431: A statistical analysis of the wind speed deviation between ASCAT and ERA5 ~~with regard~~ compared to the lidar observations***
Corrected.

41. ***Line 432-435: "Each box plot is calculated considering the wind speed difference of all the grid boxes with lidar data along the whole route of the ship, but grid boxes closer than 20 km away from the shore have been excluded to minimize the effect of ASCAT coastal contamination in the derived statistics". Why not 30 km to eliminate the land contamination in ERA5 (that you have used for stability correction)? Line 438-439 can go: you already mentioned that you did not use grid points closer than 20k from the coast.***
We have applied a 20 km threshold to ensure consistency with previously presented results, such as those in Fig. 11. Additionally, as observed in Fig. 11, the agreement between ERA5 and ASCAT at 10 m improves significantly after applying the 20 km threshold, indicating that the effects of coastal contamination are largely mitigated (ERA5 grid boxes in the Baltic are about 17 x 31 km). Nevertheless, we have compared the results shown in Fig. 13 using both 20 km and 30 km thresholds. As illustrated in the figure below, the exclusion of additional grid points (from 20 to 30 km distance from coast) has a minimal impact on the statistical comparison presented, probably likely due to their limited number and reduced coastal contamination influence.

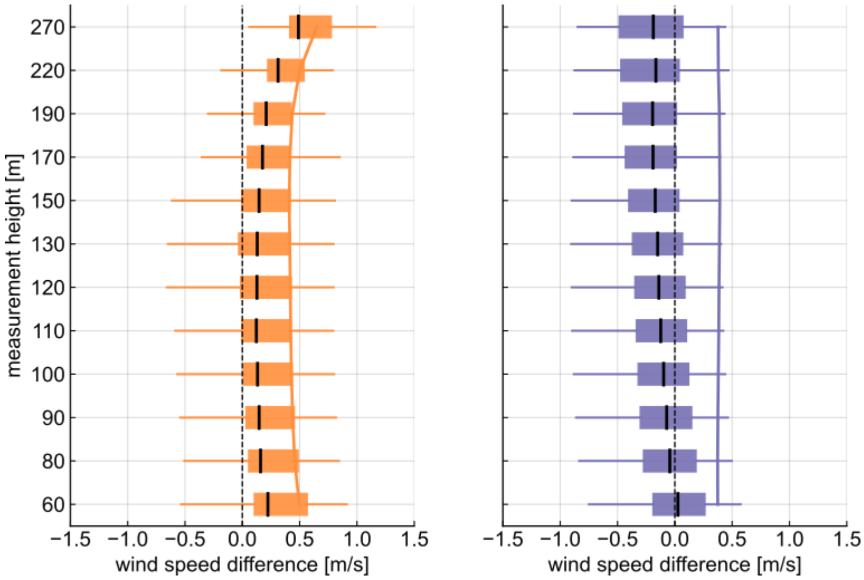

Figure 2: Fig. 13 of manuscript but filtering out grid points closer than 30 km from the coast.

Line 438-439 has been removed as suggested.

42. ***Line 441-443: This indicates that both ERA5 and ASCAT are probably within measurement uncertainty of the lidar measurements for these heights. ~~yield similar performance in this segment of the profile, suggesting that they are both reasonably aligned with the lidar observations in the lower to mid-altitude ranges.~~***
As already mentioned, we are not able to fully quantify the uncertainty of ship-based lidar measurements, and therefore, we cannot confirm if ERA5 and ASCAT deviations are within that range. Instead, the phrasing "reasonably aligned with the lidar observations" was chosen to reflect a qualitative comparison based on observed agreement of the ERA5 and ASCAT with the considered reference dataset, the ship-based lidar, shown in Fig. 13. Additionally, this boxplot includes data from different locations along the ship route, introducing additional variability that likely exceeds the magnitude of the uncertainty attributable to the measurement system.
We have further discussed this issue in the discussion of the paper, where we provide more context on the implications of ship-based lidar uncertainty.

43. ***Line 443-445: ERA5 consistently underestimates the wind speed across the entire profile, with this negative bias becoming increasingly pronounced with altitude and reaching the largest negative mean bias of around 0.2 m s-1 at 270 m, which is (probably) still an insignificant difference with the lidar measurements if you take into account the accuracy of the lidar measurement itself.***
The lidar measurement uncertainty is not the only factor influencing the results presented in Fig. 13. In fact, the spatial variability introduced in the boxplot (as data across different locations along the vessel's route are included) likely exceeds the inherent uncertainty of the lidar system itself. Therefore, we do not consider a mean bias of 0.2 m/s to be negligible, as the total uncertainty in this context is considerably larger due to these additional variability sources.
As already mentioned too (here and in the manuscript), the uncertainty associated with ship-based lidar measurements cannot be fully quantified, and thus it is not

possible to determine whether such a bias falls within the bounds of measurement uncertainty. We believe the current wording accurately emphasizes the consistent underestimation observed throughout the vertical profile without overinterpreting its statistical significance.

44. ***Line 445-446: As opposed to ERA5 ~~Contrarily~~, ASCAT profiles exhibit a persistent overestimation of wind speed relative to the lidar across all heights.This overestimation increases significantly above 170 m.***
Corrected.

45. ***Line 447-450: For ERA5, the IQR is almost the same for ~~remains fairly constant across~~ all heights, with values around 0.5 m s-1, suggesting the quality of ERA5 wind speeds does not depend on height ~~a stable performance across different elevations.~~ In the case of ASCAT, IQR displays a slight decrease with height, highlighting the larger and more consistent overestimation at higher altitudes.***
Corrected.

46. ***Line 451-455:The whiskers analysis provides further insights into the discrepancies between the two datasets. For ERA5, the lower whiskers extend further into negative values as altitude increases, with the larger underestimations reaching approximately -~~1.3~~0.8m s-1at 270 m. ~~Differently~~, ASCAT's whiskers reveal a different pattern:, particularly noteworthy are the upper (positive) whiskers that extend significantly beyond the lower whiskers at ~~altitudes above 170~~270m, illustrating once again the . ~~This observation strikes emphasises again the pronounced~~ tendency for ASCAT to specifically overestimate wind speeds at ~~higher elevations~~ greater heights.***
Corrected.

47. ***Line464-469: Notably, the western area of the ship route (longitude below 18.5 degrees) exhibits the largest errors for both ASCAT-extrapolated and ERA5 winds, with maximum differences up to about 5 ~~exceeding 1~~ m s-1 at all elevation levels. In the eastern area of the ship route, there are maximum differences up to about 4 ms-1. This indicates that wind speed estimation cannot be done accurately enough in ~~these~~ coastal areas using these datasets, first, because of the poor quality of ASCAT in areas closer to the coast, and secondly, due to the ~~insufficient~~ ERA5 grid box size of 31 km, which means that for distances closer than 31 km to the coast the surface roughness in ERA5 gridboxes is overestimated because of land-contamination. This effect will be larger near the harbour of Nynäshamn in Sweden (longitude18°) than near the harbour of Hanko in Finland (longitude23°) because with a prevailing W-SW'lywinds, the wind at Nynäshamn blows mostly from land to sea, advecting 'landsurface roughness contamination'to sea grid points (at Hanko where the wind mostly blows from sea to land, 'watersurface roughness contamination'is advected to land grid points). Also, a fairly course model like ERA5 is ~~ing, which is~~ unable to capture the small-scale wind flow variations in these complex locations and the intricate interactions in the coastal boundary layer influenced by both land and sea.***
Manuscript adjusted according to referee suggestions.

There are no ASCAT-values less than 12.5 km from the coast, so what are those "ASCAT" values in fig 14 for < 12.5 km distance from the coast? See also earlier remark about quality of ASCAT near coast (after quality control and just looking at sites > 12.5 km from the coast).

The distances shown in Fig. 14 are approximate, and the minimum distance from the centre of the grid cells to nearest shoreline is roughly 5 km. Despite being less than 12.5 km, most of the grid box remains over water, which might explain the existence of ASCAT retrievals at these grid points. For improved clarity, we have revised the figure and its label.

48. ***Line 474-475: "It can be noted that, although ERA5 usually underestimates the wind speed, this is more pronounced at higher elevations and in the western part of the ship track".***

    Basically at a coast where there is an abrupt change of the surface roughness an internal boundary layer (IBL) is formed where the flow adjusts to the new surface roughness. This is what affects your results in coastal areas, mainly near the Swedish harbour where the wind mostly blows from land to sea. So why is the underestimation of the wind speed more pronounced at higher levels? I think because the Internal Boundary Layer (IBL) has not reached these heights yet. So basically the wind profile has not adapted to the surface roughness of the sea.
    Internal Boundary Layer (IBL): Internal boundary layer growth following a step change in surface roughness | Boundary-Layer Meteorology . The height of the IBL grows the father away you are from the place where the surface roughness changes (coast). So at the Swedish harbour with a W-SW wind, the wind speed adapts to the lower sea surface roughness in the IBL. The further away from the coast, the higher this IBL.

    Thanks for the clear explanation. This has been now included in the manuscript.

49. ***Line 484-490: "When comparing the two datasets, ERA5 shows a smaller nRMSE in the majority of the studied region, except in the eastern area near the harbour in Hanko. This may be attributed to the differing spatial resolutions of the two datasets. In the east of 22 degrees longitude, the finer resolution of ASCAT mitigates the impact of coastal contamination, enabling it to capture local conditions more effectively and consequently leading to a lower average nRMSE in this region. In contrast, the coarser resolution of ERA5 may be insufficient to adequately represent the average wind characteristics in this area. Conversely, in the western part of the studied area, with features more intricate topography and a higher density of small islets within a few tens of kilometres from the mainland shoreline, ASCAT measurements are more susceptible to coastal contaminated."***

    How significant are the differences that you find in figure 15. Also, I do not think you should put all heights together. At 10m ASCAT is ASCAT, at other heights ASCAT is not ASCAT, but you have used ERA5 data for stability correction. So you can only compare spatial resolutions at 10 m height. Due to land contamination, ERA5 (31 km) will always lose from ASAT (12.5 km) in joined grid points closer than 31 km from the coast. At other heights than 10m you include ERA5 data, so affectively make the spatial resolution courser. The only reason why one location might on average be more land-contaminated than another is prevailing wind direction (if wind blows mostly from sea to land, there is less land-contamination). Please rewrite this (and

the rest of this) section or leave it out. You use the grid box land fraction argument to say that ASCAT is better than ERA5 near the Finnish harbour (I get that) and ERA5 is better than ASCAT near the Swedish harbour (that I think is wrong)???
As suggested by referee, this part has been removed from the manuscript.

50. ***Line 510-513: For the mean stability correction methodology, we had to decide whether we would use the collocated or the full dataset. A disadvantage of the collocated dataset is that the stability information may be biased because ASCAT overpasses only twice a day at roughly the same time. ~~One of the primary limitations of the mean extrapolation technique is the requisite for a comprehensive characterization of the atmospheric stability throughout the comparison period. To address this, we examined the impact of the stability information available on ASCAT profile derivation by comparing two distinct strategies: the collocated and the full campaign approach~~. The collocated and full dataset ~~Both~~ strategies demonstrated remarkable agreement across most of the examined area, resulting in very similar wind speed***
Referee suggestion included, and the rest of the Discussion has been also updated according to referee previous suggestions.
The referee also questions the necessity of having a Discussion section, so we have decided to revise this, and merge both the Conclusion and Discussion into a final section named Concluding discussion, as done in other manuscript published in this journal.

51. ***Conclusion: Not checked. Needs to be adapted after revisions.***
Conclusion revised and merged with Discussion into a single section: Concluding discussion.

Anonymous Referee, Referee #3

1. ***Page 5, Figure 2: Although a height of 100 m is used as the reference height in this study, the hub height of recent wind turbines often exceeds 100 m. It would be helpful to explain why you chose 100 m as the reference height.***
   Thank you for the comment. We have chosen 100m as reference for several reasons. First, 100 m is a widely used standard in wind energy research, primarily due to the height limitations of existing meteorological masts commonly used for validating numerical models and other measurement techniques. Therefore, using this height helps to be consistent with previous studies and facilitates the comparison of our results with existing literature.
   Secondly, while it is true that some recent offshore wind projects have hub heights slightly above 100 m, the difference is not substantial. For example, the global capacity-weighted average hub height in 2023 was approximately 124 m, according to the NREL Offshore Wind Market Report: 2024 Edition (see Offshore Wind Market Report: 2024 Edition). Therefore, 100 m remains within the typical hub height range of many operational offshore turbines and is still representative for slightly higher turbines.
   Finally, we note that the results at 100 m are also representative of nearby heights. As shown in Section 3.3, there are no significant changes across the intermediate height levels, and the trends discussed in Section 3.2 are consistent throughout the vertical profile. While some quantitative differences would be expected between, for example, 100 m and 130 m, the qualitative conclusions remain unchanged.

2. ***Page 20, Figure 20: Since the ERA5 profiles above the surface layer are calculated using the PBL scheme, they exhibited more natural profiles than ASCAT-based dataset profiles as shown in Figure 12. Rather than using surface parameters from ERA5 for the vertical extrapolation of ASCAT, a simpler and potentially better approach might be to combine the surface wind field from ASCAT with wind profiles from ERA5.***
   We appreciate referee suggested approach and recognize it could be a valuable alternative. However, as any other alternative, this approach also introduces additional assumptions that could challenge its potential. For instance, the assumption that ERA5 wind profiles are sufficiently accurate at each location. This is particularly challenging in nearshore areas, where ERA5's coarse spatial resolution often leads to coastal contamination of grid cells.
   While we acknowledge that other methodologies exist and may be promising, they fall outside the scope of this manuscript. Here, we have chosen to focus on the mean stability correction approach for several reasons:
   - The limited duration of the measurement campaign, together with the coarse temporal resolution of ASCAT (approximately two observations per day), results in insufficient data availability for applying data-driven approaches such as triple collocation or machine learning algorithms. SAR measurements were contemplated as an alternative to ASCAT due to their higher resolution and potential better performance in near-shore areas. However, given that SAR's lower temporal resolution (one overpass every couple of days) and the relatively short period of the campaign, we opted for ASCAT in order to maximize the amount of collocated data and ensure the consistency of the statistical metrics evaluated.

- ASCAT provides wind field measurements, while ERA5 are modelled. Therefore, ASCAT winds at 10 m can often be more accurate than ERA5, especially in areas where measurements are unavailable for the assimilation and validation of the model.
- We do use ERA5 stability data due to, again, lack of measurement data available. It is not possible to estimate site-specific stability conditions from on-site measurements across the entire are included in this study and along the ship track, simply because they are scarce.
- The motivation to use the long-term correction approach comes from its potential better performance compared to the instantaneous correction approach. Studies show that while numerical models can capture average meteorological conditions well (Peña and Hahmann 2012), the accuracy of instantaneous stability information from these datasets is less reliable, adding uncertainty to the extrapolated profiles (Badger et al. 2012). Another advantage of the long-term stability correction is that we avoid calculating wind speed for conditions and heights outside the valid range of the MOST model. MOST is tailored to characterize turbulent fluxes within the surface boundary layer (Lange et al. 2004; Högström et al. 2006), but struggles with instantaneous data analysis, especially in stable conditions. The long-term adaptation of MOST, however, remains effective up to turbine operating heights, as it falls within the range where MOST is applicable.

In summary, the approach we used was selected after carefully considering the available data and the limitations of alternative methods. While different techniques may offer specific advantages, their suitability depends on data availability and the specific objectives of the study. We believe our methodology offers a balanced and practical solution for the assessment of ASCAT-based wind profile extrapolation, and their validation against ship-based lidar measurements.

3. ***Additionally, the abstract currently concludes by highlighting the issues with the extrapolation method for ASCAT surface wind speeds. However, it would be more effective to end on a positive description, emphasizing the advantages of ASCAT-based offshore wind resource assessment.***
   This last sentence has been removed from the manuscript so the abstract focuses in introducing the study and presenting the main results.

4. ***Page 25, Line 528–533: It is stated that there is a negative impact up to 40 km from the coast, but this seems rather extensive given the ASCAT data resolution of 12.5 km. This could lead to the impression that this dataset is unusable in near-shore areas. Considering the potential application of ASCAT data, it might be beneficial to examine this issue more carefully.***
   This assertion referred to the comparison between ASCAT and ERA5 has been clarified now. We believe is not only due to ASCAT overestimation in nearshore areas, but also due to ERA5 coarse grid (about 17x30 km in the Baltic Sea region) and coastal contamination of sea grid boxes. This has been clarified in the manuscript: …stabilizing at approximately 0.2 m/s and 0.4 m/s at 10 m and 100 m, respectively, in grid cells beyond 40 km from the coast. These larger nearshore discrepancies can be attributed

to the inherent limitations of both datasets. For ERA5, its coarse spatial resolution leads to land contamination in grill cells near the coast, overestimating the surface roughness, and consequently underestimating wind speeds. Furthermore, ERA5's resolution limits its ability to simulate coastal atmospheric dynamics and small-scale wind flow variations, particularly in areas with abundant small islands and rocky islets, which are especially common in the coastal regions analysed in this study (Dörenkämper et al. 2015; Gualtieri 2021). In contrast, ASCAT tends to overestimate wind speeds in some coastal areas, potentially due to effects such as wave breaking and surface slicks (Johannessen 2005; Kudryavtsev 2005) caused by the large number of small islets that result in excessively high wind field retrievals at 10 m.

5. ***Page 25, Line 524–540: It would be beneficial to describe the relationship between the validation results of ASCAT and ERA5 in this study and previous research. Additionally, instead of listing numerical values in the main text, presenting them in tables would make the information clearer and easier to understand.***
   A couple of references for comparison have been added to the manuscript (This larger overestimation of ASCAT in the coastal areas of the Baltic Sea has also been reported by (Hasager et al. 2020) as well as the better agreement in far from some regions between ERA5 and ASCAT, but an increased bias of around 0.6 m/s in the North Sea's coastal regions, as reported by (Duncan et al. 2019).)
   We have not added a table, but we hope the revised version of this section is now clearer and more accessible to the reader.

Minor comments:

6. ***Page 5, Line 103–104: In Section 2.1, it would be beneficial to include information on the accuracy of the ship-based LiDAR, particularly regarding whether there is any difference in accuracy compared to fixed LiDAR systems.***
   We have included a short discussion and clarification on ship-based lidar uncertainty in the Concluding discussion section of the paper.

7. ***Page 5, Figure 2: It would be more informative if Figure 2 were improved by using a geobubble chart or other visualization methods to plot the data on the map.***
   We opted to include a 2D histogram plot (Fig. 1b) because it allows to display both the temporal and spatial distribution of the lidar measurements. While a geobubble plot might more clearly show the locations with greater or fewer data points, it would not provide information about the time distribution of them, which is an essential characteristic of our ship-based lidar campaign conducted onboard a regularly scheduled ferry boat.
   The 2D histogram might be a less straightforward alternative, but it effectively illustrates both when and where measurements were taken, providing a clearer insight into the dataset's structure. We believe this visualization better supports the interpretation of our results. In addition, Fig. 6 already shows the number of lidar recordings along the ship track.

8. ***Page 6, Line 138–149: It would be helpful to include a comparison table of ASCAT and ERA5 specifications in the Data and Methods section (Section 2).***
   We have included a table indicating the main specifications of these two datasets.

9. ***Page 15, Figures 7 and 9: In Figure 7, points A–F are indicated, but longitude is used in the figure's labeling. It would be better to ensure consistency in notation.***
   Figure 9 legend has been modified to ensure consistency.

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