First of all, we would like to thank the referee for the insightful and constructive comments. In our revised version of the manuscript we tried to address all hei/his comments and suggestions in order improve the robustness of the analysis and the clarity of the interpretation.

In the following, we respond to each reviewer's comment by referring to line numbers of the revised non-tracked version, when not differently indicated.

Reviewer 2

General Comment: This study integrated the windthrow observations from aerial photointerpretation and field survey and compared the results with remote sensing indexes and total damaged wood reported in the FORESTORMS database. Their work provides a specially-explicated storm-affected area which is helpful to improve the modeling framework on simulating storm damage in the Earth system model.

We thank the reviewer for her/his positive comment. Inspired by your comments (3 and 4), we decided to expand in the revised version a series of potential applications of FORWIND. They include challenging topics such as forest vulnerability modelling, scaling relations of wind damages, remote sensing-based monitoring of forest disturbances, representation of uproot and break trees in large-scale land surface models and hydrogeological risks associated to wind disturbances. We believe that this new material further improves the manuscript and may facilitate the use of FORWIND in multiple scientific disciplines and contexts.

1. *The damage rate within a storm-affected area can be also found in this data synthesis. However, I could not access any further information about this information. I found that it is very important to reveal the relationship between the degree of damage and affected area among various tree species, such as needle-leaved forests or broadleaf forests, from the model development point of view. I thus recommended that the authors report the relationship between the damage rate and storm-affected area in this dataset.*

   According to the reviewer’s comment, we have explored the relationship between the degree of damage and affected area for different plant functional types.

   <u>**Action taken:**</u>

➔ In order to evaluate the relationship between the degree of damage and affected area, we estimated, for each record, the cover fractions of different plant functional types (PFTs) including broadleaves deciduous (BrDe), broadleaves evergreen (BrEv), needleleaf deciduous (NeDe) and needleleaf evergreen (NeEv). Cover fractions were retrieved from the annual land cover maps of the European Space Agency’s Climate Change Initiative (ESA, 2017) (ESA-CCI, <u>https://www.esa-landcover-cci.org/</u>). Degrees of damage of each record are then spatially averaged over the sampled interquartile range of affected areas using a bin size of 0.25 ha. The spatial averages are computed separately for each PFTs utilizing their cover fractions as weights. Quadratic polynomial functions are finally used to fit the observations and retrieve the relationship between the degree of damage and affected area for the considered PFTs.

Results show that all considered PFTs have generally higher degree of damage for wind disturbance with small spatial extent (Fig. 4a). This may reflect a better delineation of small affected areas when the damage are typically higher and homogeneous. Furthermore, the emerging declining scaling relations could suggest a potential dampening effect of wind severity thanks to a higher landscape heterogeneity in large areas compared to more homogeneous patterns in small forest patches.

Model fitting shows reasonably good performances with R^2 ranging between 0.84 and 0.9 across the PFTs (Table 6). NeEv have generally higher degree of damage compared to the other PFTs. For this biome, the emerging relationship between the degree of damage and affected area is characterized by a prevalent quasi-monotonic pattern. The relationships found for the other PFTs show a stronger link between degree of damage and affected area compared to NeEv, particularly over the range with larger samples (affected areas < 2 ha, Fig. 4b) as visualized by steeper slopes of the fitting functions. For BrDe, BrEv and NeDe a prominent parabolic pattern emerges distinctly driven by records with large spatial extents and relatively high degree of damage.

We stress that the above example is an oversimplification of the relationships observed in nature. More sophisticated fitting functions and more objective metrics of severity could be employed to better capture the scaling relations of the degree of damage. Therefore, the approach described should not be considered as a reference methodology but only as an informative application to explore the usefulness of the FORWIND database.

We have described the above-mentioned method and results in the revised version and added one new figure and one new table to synthesize main findings and list model parameters and fitting performance.

➔ Furthermore, we have included in the revised version of the manuscript, an example on how FORWIND can be used to improve the parameterization of land surface models in representing wind disturbances.

2. *Along with this discussion, the authors may/can introduce the section of data comparison by analyzing their dataset and other remote sensing indexes by using different thresholds for accessing, justifying, or distinguishing the windthrow damage.*

We agree with the reviewer’s comment on the potential of remote sensing data to detect/attribute wind disturbances as well as to quantify the corresponding forest damages.

Previous attempts to detect and attribute wind disturbances from remote sensing data were mostly hampered by the limited number of sampled wind-affected areas available for training/testing classification algorithms. In this respect, FORWIND – given the high number of records – represent a unique source to improve classification performances over large scales and quantify wind impact. For instance, FORWIND could be used to evaluate what remote sensing indexes (or other auxiliary features) and thresholds are more appropriate to identify wind disturbances and assess their damages. Such applications, however, pose a series of challenges. Distinguishing the changes in spectral signature due to wind disturbances from those driven by human forest management or quantifying the spatial and temporal dynamics of exposed biomass are just a couple of critical issues that should be addressed in order to retrieve reasonable estimates.

Action taken:

➔ We have included a new section reporting an example of the use of FORWIND to classify wind-affected areas. The presented approach in the revised version should not be considered as reference methodology but as example of a potential application of FORWIND. We believe that the development of more dedicated modelling frameworks are out of the scope of this work. The major novelty of our analysis consists in having collected and harmonized more than 80,000 forest areas damaged by wind into a consistent Pan-European geospatial dataset. This is the result of a unique joint effort of 26 research institutes and forestry services across Europe. We provide FORWIND as a freely accessible product to the scientific community. We leave to the potential user the opportunity to design and develop appropriate classification tools and assessments of wind disturbances. We hope that the reviewer understand our point of view.

The work made by the authors is not trivial and I support the publication of this study in ESSD. Before publishing this work, I have a few specific comments listed below:

We thank the reviewer for her/his positive comments. In the following lines, we have tried to respond to its remaining comments.

3. *P5L435L: Please explain the reason for using a 500 m2 clear cut area to identify the wind damage due to Gudrun in 2005. Besides, the storm Gudrun caused a super huge damage area which required several years to clean the damaged forests.*

Aerial photointerpretation or field survey aimed to specifically delineate wind disturbances associated to Gudrun are not available. However, the use of forest clear-cuts as proxy for wind-affected areas is reasonable because the morning after the storm all normal felling activity stopped and moved to storm damaged areas (Swedish Forest Agency, personal communication). Therefore, area subject to wind disturbances recorded in FORWIND have been retrieved by intersection of the 2005 registered forest clear-cuts between 2005-01-07 and 2005-12-31 larger than 500 m^2 with the spatial delineation of the Gudrun storm (Gardiner et al., 2010). The initial fixed threshold of 500 m^2 was chosen because that value represented the threshold for which forest owners are obliged by law to communicate any clear-cuts. After a closer investigation with the Swedish Forest Service, we decided to remove such threshold in our database (revised version), in order to include smaller areas affected by wind.

4. *P8L248: The authors argue that a possible reason for underestimating the damaged wood volume/biomass may due to the uncertainty of initial biomass within the FORWIND identified the storm-affected area. The authors should provide the number of mean biomass for the FORWIND identified storm-affected area. Otherwise, I think the uncertainty for estimating the damaged wood volume/biomass due to windthrow might originate from missing interpretation of aerial photos.*

We believe that the reviewer may have misunderstood our validation exercise. We try to clarify the rationale, by referring to the two experiments reported in the text (a and b in the following lines).

a) In a first experiment, we derived, for each of the events considered, estimates of damaged GSV using the GlobBiomass dataset (Santoro et al., 2018). Such values are derived under two different scenarios: 1) accounting for the record-specific degree of damage, and 2) assuming 100% degree of damage for all records. Such values are then compared with damaged GSVs reported in FORESTORMS. This comparison shows a substantial underestimation of GSVs in FORWIND compared to FORESTORMS estimates (Fig. 3e). We pointed out that "any deviations of the mapped GSV from the true forest state are inherently translated into our damaged GSV estimates". Therefore, any errors in the GlobBiomass product are reflected in our estimates of damaged GSVs. In particular, the GSV map refers to the year 2010, therefore it is very likely that it largely reflects the biomass conditions following, rather than preceding, the windstorm events (all the five events considered in this validation exercise occurred before 2010).

b) In order to solve the above-mentioned issue, we performed an additional validation exercise. To this aim, we derived country-scale estimates of average GSVs for the year 2000 (pre-event conditions) from the State of Europe's Forest (FOREST EUROPE, 2015). We then derived the damaged GSVs by rescaling Forest Europe-derived GSVs based on the area affected by wind disturbances (from FORWIND) and the tree height in such areas (please, note the integration of tree height to incorporate a comment from reviewer 1). For such estimates of damaged GSVs we assumed 100% degree of damage. Finally, these damaged GSVs are compared with those estimates derived from FORESTORM as in the previous exercise. As we assume a 100% degree of damage, damaged GSVs reported over the x-axis in Fig. 3f reflect exactly the mean biomass located in those areas affected by wind disturbances. Therefore, the information requested by the reviewer is already reported in our results of the second experiment (b). Results of this experiment are largely in agreement with previous estimates and show a substantial underestimation of damaged GSVs in FORWIND compared to FORESTORMS estimates. We recognize that FORWIND could miss some wind damage occurrences for instance due to incorrect detection of wind disturbances from aerial photointerpretation, as correctly pointed out by the reviewer, or difficulties to map inaccessible areas through ground survey. However, according to the institutions responsible for the data acquisition, the forest areas affected by the windstorm events considered in this validation exercise were exhaustively mapped. We therefore argue that a possible source of error may be associated to the FORESTORM database. Estimates of forest damages from FORESTORM originate from different sources and are collected by multiple actors. Hence, the loss figures should be viewed in light of their potential biases, including a possible overestimation of the true impacts.

<u>Actions taken:</u>

- ➔ We have clarified this in the revised version.
- ➔ As already mentioned, according to the institutions responsible for the data acquisition, the wind disturbances recorded in FORWIND exhaustively represent the damaged forest areas caused by those specific events. However, some known damaging wind events are currently missing in the database. Such missing events do not affect the validation exercise shown in figure 3. However, in order to provide a more comprehensive assessment of the representativeness of FORWIND, we derived for each country the ratio between the number of sampled wind events and the number of all wind events occurred which are known to have caused forest damages. The number of known damaging wind events is derived by summing up the number of distinct events recorded in FORESTORM and FORWIND during the 2000-2018 period. Therefore, the temporal representativeness ranges between 0 (all known wind disturbances are missing in FORWIND) and 1 (all known wind disturbances are included in FORWIND). Estimates of representativeness range between 0.13 and 1 among the countries included in FORWIND, with an average value of 0.67 at Europe level (see table 5). However, when also countries currently missing from FORWIND are accounted for the average representativeness decreases to 0.37. These values should be viewed with caution as the estimated number of total damaging wind events resulting from FORWIND and FORESTORM could likely deviate from the effective ones. Future efforts should be aimed to populate FORWIND with those damaging wind events actually missing. This has been described in the revised version and a dedicated table has been added (Table 5).

5. *P10L299: Please check the citation of the study made by Bonan and Doney (2018) for the implementation of a windstorm effect in land surface models.*

   <u>Action taken:</u>

- ➔ We have removed the referenced study and cited later in a more appropriate context.

6. *Please add a space between texts and parentheses.*

   The issue was due to the setup of the plug-in used for citations and bibliography.

   <u>Action taken:</u>

- ➔ We have fixed the problem in the revised version.