Interactive comment on “Temporal and spatial variability of Icelandic dust emission and atmospheric transport” by Christine D. Groot Zwaaftink et al.

Anonymous Referee #1
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RC: The authors present results from a muli-annual (27 years) study assessing the capability of the Lagrangian model FLEXPART to capture the Icelandic atmospheric dust life-cycle. Thereby, dust emission fluxes are estimated using FLEXDUST. Results of their study were further discussed regarding its interannual variability; results at high resolution were validated against measurements for the year 2012. The manuscript is well structured and a nice read. However, I do have some comments I would like the authors to address.

Authors: Thank you for your review.

2.1 Model description

(1) In the subsection FLEXDUST you describe how dust sources were implemented in the model. You state that lower friction velocities and large soil fractions were assigned to dust hot spots as identified by Arnalds et al. (2016). I am wondering whether these dust host spots occur due to enhanced levels of sediment supply or due to higher frequencies of stronger winds (maybe also channelled by orography).

Authors: The dust hot spots are known to be frequently active. Arnalds et al. (2016) ascribed this mostly to enhanced sediment supply, but also strong wind frequencies and soil properties (weaker winds can mobilize particles). Even without higher frequencies of stronger winds this already leads to larger dust emissions. To our knowledge no research has been published so far on strong wind frequency in dust hot spots.

(2) Can you spend some more words on how FLEXPART and FLEXDUST coexist respectively intertwine as this remains somewhat diffuse. As far as I understand FLEXDUST is used to estimate dust emission fluxes based on ECMWF forecast analyses at 0.2deg horizontal grid spacing. The calculated emission fluxes are then read into FLEXPART and transported whereby FLEXPART is driven using the ERA-Interim reanalysis at 1deg horizontal grid spacing. Why were two different atmospheric data sets chosen to drive the models rather than using consistently ECMWF forecast analyses for both but on a different horizontal grid?

Authors: Indeed FLEXPART and FLEXDUST are separate models. Our description of the simulation setup was obviously confusing. We always used the same ECMWF data for FLEXDUST and subsequent FLEXPART simulations. The high-resolution data were used for one year of model testing, whereas ERA-Interim data were used for the long-term simulations.
Changes: We changed the simulation descriptions in section 2.2 to clarify this.

(3) How is dust deposition respectively removal parameterized? Please add some explaining words. Is wash-out and scavenging due to rain and clouds considered as particle removal processes?

Authors: Yes, these processes are considered, as we mentioned in our manuscript: “In FLEXPART, simulated dust particles are influenced by gravitational settling, dry deposition and in-cloud and below-cloud scavenging (Grythe et al., 2016).“ Deposition processes are described in detail by Grythe et al. (2017) and for interpretation of the current study it suffices to know that these processes were included, we therefore choose to give a reference rather than a description. However, we added one sentence to explain a little better how removal processes are treated in FLEXPART: "Dry deposition is treated using the resistance method (Stohl et al., 2005), wet deposition distinguishes between liquid-phase and ice-phase scavenging (Grythe et al., 2016). "

(4) Simulation setup (section 2.2): As the input meteorological fields were available at a grid with a 0.2deg horizontal grid spacing, but dust emission fluxes were estimated on a grid with 0.01deg horizontal grid spacing, can you explain if there has been any upscaling or interpolation method applied, please? Is topography taken into account for the upscaling?

Authors: There was no upscaling involved for the meteorological fields, we use the 0.2 and 1.0 degrees grid values for the respective simulations. The surface type maps however, were available on a much higher resolution. Even though we use coarser-resolution wind fields, we can clearly define where dust emission occurs and this will give better initial conditions for Lagrangian modelling of particle trajectories. Notice that this method takes advantage of the Lagrangian nature of FLEXPART which is, in principle, independent of the resolution of the meteorological fields and thus can ingest emission data at any resolution.
Changes: We now comment on this in section 2.2.

3. Results and discussion
(5) In section 3.2.1, numbers of days of active dust emission are provided as fraction per annum. How do these numbers of days compare to seasons? Some additional sentences presenting and discussing the seasonal distribution of dust emission events, transport and deposition can help here to draw a more thorough picture of the Icelandic atmospheric dust life-cycle - and eventually imply further mechanism controlling interannual variability.
Authors: Modelled dust emission in Iceland is largest in winter/early-spring.
Changed: We added this to section 3.2.1.

(6) Is there any explanation why the NAO has no significant correlation with dust emission in Iceland?
Authors: It appears that the NAO index does not control dust storm frequency in Iceland. This was also concluded by Dagsson-Waldhauserova et al. (2014). Although we did not look at this in more detail, possible explanations may be found in increased precipitation or storm occurrence during seasonal snow cover.

(section 3.2.2)
(7) As stated in section 3.2.2, the NAO has no significant impact on dust emission. However, why is the NAO used as measure describing Aeolian transport and deposition patterns (section 3.3)? May topography has an important and maybe dominating impact on the transport direction here?
Authors: We hypothesised that even though emission is not linked to NAO, the transport patterns might be. For instance, pollution transport from Europe into the Arctic is strongly controlled by the NAO (Eckhardt et al., 2003). If dust would reach the south-east of Iceland where wind patterns (and thus transport patterns) correlate strongly with NAO, this might result in a correlation nonetheless. Even though no correlation was found, we think it is important to show this, as this was not clear a priori. Topography could be important as well as we also discuss in section 3.3 but we cannot explain this explicitly because we do not study transport pathways of specific regions.
Changes; We extended the discussion in section 3.2.2.

(8) How is the dust vertically distributed? Is there any significant dependency between dust deposition region and transport height or mixing depth into the boundary layer over source regions that can be concluded from the FLEXPART simulations? An enlarged discussion on dust transport pattern and deposition regions is desirable in order to clarify the conditions under which Icelandic dust is transported far beyond its source region. Furthermore, the results may vary with season as the predominance of meteorological situations (e.g. occurrence of precipitation, cloud formation) and atmospheric circulation patterns changes.

Authors: This is an interesting discussion, yet in our simulations we do not split dust from different source regions and we saved only limited data on the vertical distribution of dust. The modelled vertical distribution of Icelandic dust is limited. Global averages show that over 40% of suspended Icelandic dust is at altitudes less than 1000 m above the surface, thus probably within the atmospheric boundary layer. In averaged concentration fields only 6 % of suspended dust is situated at altitudes above 5000 m. Dust from the Hagavatn region has been observed at altitudes of 2 km and in LOAC (Renard et al., 2016a,b) vertical distributions dust reaches altitudes of 1 km during a dust-precipitation event in 2013 (not published).
Changes: We comment on the vertical distribution in section 3.3.

(9) Can the hypothesis by Meinander et al. (2016) that "Icelandic dust may have a comparable or even larger effect on the cryosphere than soot" be confirmed by the presented study?
Authors: This study confirms that Icelandic dust is likely to have an effect on the cryosphere and especially on the glaciers in Iceland, as can be concluded in combination with the results of Wittmann et al. (2017). However, this study was not set up to test this particular hypothesis and we would need to consider the complete cryosphere and include snowpack modelling influenced by soot as well as dust, and radiative transfer modelling. This may be a topic of further research.