<u>Reply to Review 1 (RC1)</u>

The paper reports a study of vertical aerosol fluxes and vertical concentration profiles in the marine boundary-layer. Three different approaches are used to estimate fluxes using helicopter-based measurements and results are compared. I believe that the topic is interesting and there are elements of innovation especially because the MBL is not frequently studied with these approaches and available information is limited in current scientific literature. I also believe that even if the different methods have relatively large uncertainties, results could give useful insights in the exchanges of particles in the marine boundary layer. The topic is suitable for the Journal.

A few aspects should be made more clear in a revision step as mentioned below.

We thank the reviewer for his comments and suggestions. We reply below to each point in italic font.

Lines 50-57. Probably it could also be mentioned the work at Mace Head regarding fluxes focused on sea spray.

We agree that valuable studies regarding sea spray fluxes have been carried out at Mace Head. In the revised version, we add references to the work by Geever et al (2005), de Leeuw et al. (2011) and Ovadnevaite et al. (2014) in the list of examples.

We added the following sentence: 'Results from sea spray emission studies are published in e.g., Geever et al. (2005); de Leeuw et al. (2011) and Ovadnevaite et al. (2014).'

And these references:

Geever, M. C., D. O'Dowd, S. vanEkeren, R. Flanagan, E. D. Nilsson, G. deLeeuw, and *Ü. Rannik* (*2005*), *Submicron sea spray fluxes*, *Geophys. Res. Lett.*, *32*, L15810, doi:*10.1029/2005GL023081*.

de Leeuw, G., E. L Andreas, M. D. Anguelova, C. W. Fairall, E. R. Lewis, C. O'Dowd, M. Schulz, and S. E. Schwartz (2011), Production flux of sea spray aerosol, Rev. Geophys., 49, RG2001, doi:10.1029/2010RG000349.

Ovadnevaite, J., Manders, A., de Leeuw, G., Ceburnis, D., Monahan, C., Partanen, A.-I., Korhonen, H., and O'Dowd, C. D.: A sea spray aerosol flux parameterization encapsulating wave state, Atmos. Chem. Phys., 14, 1837–1852, https://doi.org/10.5194/acp-14-1837-2014, 2014.

Line 99. Better to say less demanding or less difficult rather than less serious.

Changed to 'less demanding'.

There is a confusion of time resolution (that should be in s) and frequency (in Hz), for example in line 112 or in Table 1.

We agree, thank you for pointing out the inconsistency use of these terms. We make the following changes:

Line 73: "limited time resolution" instead of "low time resolution"

Line 113: "time resolution of 0.1 s" instead of "time resolution of 10 Hz"

Line 136: "with high measurement frequency" instead of "at high time resolution"

Line 146: "with 1 s time resolution" instead of "with 1 Hz resolution"

Table 1 (third entry): "Typical measurement frequency" instead of "Time resolution"

In line 112 there is just the difference between sampling frequency (10 Hz) and time resolution of the instrument (1 s or 1 Hz). That means we sampled faster than the real resolution of the instrument is.

See above.

Line 113. How have been done the correction for aerosol losses? For this is usually necessary to have a measurement of size distribution.

Yes, particle losses depend on the particle size. We measured the size resolved particle losses through the diffusion dryer and calculated the losses through the inlet system. The result of both was a size-dependent function of particle losses, which can of course not be applied to a CPC measurement of total particle number concentration. Thus, the mean value for particles between 20 and 100 nm was chosen and applied to the data.

We modified the sentence to: 'Aerosol number concentrations are corrected for losses in the inlet system using a mean factor for diameters between 20 and 1000 nm that has been determined experimentally and for variations in the sample flow due to pressure changes.'

Lines 116-119. This pendulum motion was seen on meteorological measurements?

Yes, it was visible in the wind measurements of all three coordinates, and therefore treated with a spectral band-stop filter as mentioned in the manuscript.

It could be useful to discuss how the magnitude of fluxes compare with measurements in different environments that could help the reader to make more sense of the large uncertainties and of the role of counting errors. They seems to be significantly lower than those observed in urban areas but likely larger or comparable with those observed in polar regions.

We report typical particle number fluxes of 10^4 - 10^6 m^{-2} s^{-1}. This is several orders of magnitude lower than urban particle number fluxes. Typical urban particle number fluxes measured by eddy covariance with CPCs are up to 10^9 m^{-2} s^{-1}, e.g. in Manchester, London, Edinburgh, Gothenburg (Martin et al. 2009), 0.9 x 10^9 m^{-2} s^{-1} in Edinburgh (Dorsey et al. 2002). Kurppa et al. (2015) report a median value of 0.18 x 10^9 m^{-2} s^{-1} in Helsinki, and Conte et al. (2021) report median values of 0.21 x 10^9 m^{-2} s^{-1} in Lecce and 0.04 x 10^9 m^{-2} s^{-1} in Innsbruck.

In non-urban areas, typical aerosol number fluxes above tall vegetation are up to 0.1 – 0.2 x 10^9 m^{-2} s^{-1} (e.g. Buzorius et al. 2000; Held and Klemm 2006). Flanagan et al. (2005) report *particle number fluxes of the order of 10^9 to 10^{10} m^{-2} s^{-1} during nucleation events at the Irish Atlantic coastline.*

In contrast, particle number fluxes observed in the Arctic Ocean are one to two orders of magnitude smaller than the fluxes reported in this study. Nilsson and Rannik (2001) report median particle number fluxes of 1 x 10^4 m^{-2} s^{-1} above open leads and ice floes, and 25 x 10^4 m^{-2} s^{-1} above the open sea. Held et al. (2011) report particle number fluxes up to 3 x 10^4 m^{-2} s^{-1} above open leads and ice floes in the Central Arctic Ocean.

Buzorius, G., Rannik, Ü., Mäkelä, J.M., Keronen, P., Vesala, T., Kulmala, M., 2000. Vertical aerosol fluxes measured by the eddy covariance method and deposition of nucleation mode particles above a Scots pine forest in southern Finland. Journal of Geophysical Research 105, 19905–19916.

Conte, M., Contini, D., Held, A., 2021. Multiresolution decomposition and wavelet analysis of urban aerosol fluxes in Italy and Austria. Atmospheric Research 248, 105267. doi.org/10.1016/j.atmosres.2020.105267

Dorsey, J.R., Nemitz, E., Gallagher, M.W., Fowler, D., Williams, P.I., Bower, K.N., Beswick, K.M., 2002. Direct measurements and parameterisation of aerosol flux, concentration and emission velocity above a city. Atmospheric Environment 36, 791–800.

Flanagan, R.J., Geever, M., O'Dowd, C.D., 2005. Direct Measurements of new-particle fluxes in the coastal environment. Environ. Chem., 2005, 2, 256–259.

Held, A. and Klemm, O., 2006. Direct measurement of turbulent particle exchange with a twin CPC eddy covariance system. Atmos. Environ. 40, S92-102.

Held, A., Brooks, I.M., Leck, C., and Tjernström, M., 2011. On the potential contribution of open lead particle emissions to the central Arctic aerosol concentration. Atmos. Chem. Phys. 11, 3093-3105.

Kurppa, M., Nordbo, A., Haapanala, S., Järvi, L., 2015. Effect of seasonal variability and land use on particle number and CO2 exchange in Helsinki, Finland. Urban Climate 13, 94-109. https://doi.org/10.1016/j.uclim.2015.07.006

Martin, C.L., Longley, I.D., Dorsey, J.R., Thomas, R.M., Gallagher, M.W., Nemitz, E., 2009. Ultrafine particle fluxes above four major European cities. Atmospheric Environment 43 , 4714-4721. https://doi.org/10.1016/j.atmosenv.2008.10.009

Nilsson, E.D., Rannik, Ü., 2001. Turbulent aerosol fluxes over the Arctic Ocean: 1. Dry deposition over sea and pack ice. Journal of Geophysical Research 106, 32125–32137.

Median values are used instead of averages for gradient and MLG approach. Is there a reason? I mean did authors verified that it is better compared to the more widely used average values?

In a few cases, extreme values that may bias the arithmetic mean values occurred. Therefore, we used the more robust median values.

Line 223. Better airborne.

Changed to airborne.

Caption of Table 2. It is needed a subscript in zP.

Thanks for the hint, we changed it accordingly.

Considering that uncertainties are often quite large and in several instances also the sign of flux could be ambiguous, it would be useful an effort to summarise in the conclusions what can be concluded and what needs further studies regarding particle exchanges in the MBL. It would also be useful to conclude, if possible, what is the more suitable calculation approach for fluxes in the conditions studied.

It is not possible to conclude from this study what is the most suitable calculation approach. The only conclusion is written in the coclusion section: Observed entrainment flux could supply in the order of 30-40 particles/cm3 per hour to the MBL.