

Reply to reviewer's comments

We correct our manuscript based on reviewer's comments. Because authors pointed out some grammatical issues in the revised parts, the manuscript was checked carefully by us (authors) and native speaker.

Reviewer' comment: line 73: a reader not familiar with DMS chemistry may get the wrong impression that also SO₂ is emitted by marine biogenic activity, which is not true as SO₂ is the major reaction product of DMS in the atmosphere. Please modify this sentence to avoid misunderstandings.

Reply form authors: We agree with the comment from reviewer. We modified the sentence as follows.

Actually, H₂SO₄ in the Antarctic is converted dominantly via photochemical oxidation of dimethyl sulfide (DMS) released from biogenic activity in the ocean, and SO₂ derived from DMS oxidation (e.g., Minikin et al., 1998; Weller et al., 2015; Enami et al., 2017; Jang et al., 2019).

Reviewer' comment: lines 162-165: I am not convinced about the relevance of sea-salt emissions in this context. Although sea spray emissions extend to the ultrafine size range, can they really influence sub-20 nm sizes to interfere with determination of J₅ using equations 5-7? The same issue is related to the statement on lines 330-331.

Reply form authors: As shown in previous work (Hara et al., 2011b), sea-salt particles with less volatility were distributed even in $D_p \leq 20$ nm during winter. Particularly, the number concentrations in ultrafine particles increased remarkably by strong emission of sea-salt aerosols from sea-ice areas under storm conditions during the winter. Details were discussed in Hara et al. (2011b). Because J₅ was estimated using the number of aerosol particles in size bins with range of $D_p = 5-20$ nm in this study, mixing of sea-salt particles during the winter can lead to the false values.

Reviewer' comment: line 173 and later: please be more specific in that D_{pi} is the number mean diameter of the mode (not e.g. mass mean diameter used by those people dealing with particle mass size distributions). Later on, the authors call this same diameter as "modal size", which is confusing. I would recommend keeping with the same term

throughout the paper. The text on lines 204-206 is particularly confusing: the authors should rather state that the number mean diameters of the mode(s) was(were) in the range(s) of xx-yy nm.

Reply form authors: We modified the sentence based on reviewer's comment, as follows.

In equation (9), D_p , n , $D_{p,i}$, σ_i , and N_i respectively denote the particle diameter, mode number ($n = 1-4$), modal size in mode i (i.e., mean diameter of the mode in aerosol number size distributions), modal standard deviation in mode i , and the aerosol number concentrations in mode i .

We keep to use "modal size" in the revised manuscript. Also, the descriptions were modified the sentences in Section 3.1 base on the later comment. The corrected sentences are written in lines of 208-211.

Reviewer' comment: lines 200-201: While the presence of quad-modal distributions is acceptable, I am not quite convinced about the reasoning here. Time-averaging data tends to smoothen details in it, so one would expect to fewer modes in daily-average distributions compared with shorter-average one. Unless the authors have a concrete evidence on their claim, I would recommend them to avoid statements like this, or at least say that this is only one possible explanation causing the difference between their and earlier studies.

Reply form authors: To avoid misunderstanding, the statement was removed in the revised manuscript.

Reviewer' comment: lines 213-214: the claim that particles grow to a few tens of nm immediately after NPF is very strange in this context. Considering the typical growth rates associated with NPF events reported in Antarctica, such growth will take a few hour in minimum, often a few days. "Immediately" is therefore not a proper word here.

Reply form authors: We modified the sentence based on reviewer's comment, as follows.

As demonstrated by Asmi et al. (2010), Kyrö et al. (2013), Järvinen et al. (2013), Weller et al. (2015), Jokinen et al. (2018), and Kim et al. (2019), aerosol particles were grown to a few tens of nanometers after NPF, even in the Antarctic troposphere during summer.

Reviewer' comment: line 229: lower solar radiation sounds like an understatement here. Should one rather say ... in spite of almost total absence of solar radiation....?

Reply form authors: We modified the sentence as follows.

Surprisingly, tri-modal structures were identified even under dusk and polar night conditions during May–August.

Reviewer' comment: Section 3.2: When discussing different air masses, I would recommend keeping the word "air mass" or "air masses" everywhere in the text. Having just words like "MBL" or "continental FT" in the text may cause confusion, as such words usually refer to specific compartments in the atmosphere. For example saying that ...structures were observed in MBL ... (line 264) could be interpreted so that these structures were observed inside the MBL, although the authors mean that they were observed in the air mass type MBL.

Reply form authors: We agree with the comment from reviewer. We change the words like “air masses from continental FT” in the section and others.

Reviewer' comment: line 275: please specify what you exactly mean with the variability of NPF frequency. day-to-day, monthly or year-to-year variability?

Reply form authors: Here, we mean “monthly”. We modified the sentence as follows.

The monthly occurrence (frequency) of the NPF, however, varied greatly at Syowa, Concordia and King Sejong.

Reviewer' comment: line 311-312: Do the authors mean ...CN concentrations and their seasonal variation were...? "Features" is not a proper word here, and it is also unclear whether these features refer to CN or some other quantities discussed in the previous paragraph.

Reply form authors: We changed the sentence as follows.

CN concentrations and seasonal variations were similar to those measured at other

coastal stations (e.g., Weller et al., 2011; Fiebig et al., 2014).

Reviewer' comment: line 366-370: I do not fully agree with this reasoning. Transport of aerosol particle from the BL to the FT is usually rather inefficient, unless there is strong convective activity. Effective turbulent mixing mainly takes place within the BL (even though the BL may grow in height due to such mixing). Condensation sink of sea-salt particle is usually dominated by rather large sea-salt particles, and these are least effectively transported higher up in the atmosphere. In fact, the authors mention a large gradient between the BL and FT for >300 nm around their station (lines 413-415).

Reply form authors: Aerosol enhanced layer in BL and FT induced by rapid vertical mixing of aerosols (probably sea-salts) were observed over Syowa Station immediately after the storm conditions (Hara et al., 2014). This is the direct evidence from the observations. Additionally, sea-salt particles were distributed in ultrafine – coarse ranges during the winter and storm conditions as shown by Hara et al. (2011b). This vertical aerosol mixing is important and interesting in aerosol cycles in the Antarctic. It is true that we and others do not have knowledge of frequency of the vertical mixing events because aerosol observations in the FT under storm conditions have never been made. However, the strong and rapid vertical aerosol mixing can engender large influence on aerosol and atmospheric chemistry in FT. Therefore, the impact of vertical aerosol mixing is one of the future works.

Reviewer' comment: The figure numbering goes wrong after Figure 8. The real figure 9 is not referred to at all in the text, and Figures 10, 11 and 12 are referred to using wrong numbers. There are 2 figures with number S3.

Reply form authors: We check and correct the figure numbers in the text.

Reviewer' comment: The manuscript, especially the newly added text, contains many minor grammatical problems. One frequent problem are missing articles, especially in relation to the words "abundance" and "structure", but also elsewhere in the text. Please check out throughout the paper.

Reply form authors: We checked and corrected carefully typo and grammatical issues in the revised manuscript. Also, the revised manuscript was checked by native English speaker. Also, the grammatical things pointed by reviewer were modified in the revised

manuscript.