Review of “Uncertainty of Antarctic sea ice concentration using passive microwave retrievals in the marginal ice zone” by Marta Stentella et al.

The MS is describing the simulated sensitivity of the Bootstrap algorithm sea ice concentration estimates to snow-ice-ocean surface parameters simulated with SMRT for sea ice and PARMIO for open water in the MIZ - Antarctica. There are two cases with two first-year sea ice profiles (one in summer conditions and one in winter) and the simulated brightness temperatures are tuned by varying each of the snow-ice-ocean surface parameters (LWC, SGS…) until a match is made with observations. The default surface parameter values and range of variability are picked from the literature without specific reference.

The authors thank the referee for their careful reading of the manuscript. The comments raised several important points that have helped us improve the manuscript, as detailed in the point-by-point responses below. We will address these in the revised version, both in the analysis and in the written presentation.

Some things are unclear and needs to be specified, for example, judging from the plots, the sea ice concentration algorithm, which is used, is the frequency mode bootstrap, i.e. the part of the bootstrap algorithm normally used over open water. Is that correct?

**RC1.1** Yes, we use the Bootstrap algorithm in frequency mode (BF).

The primary aim of this study is to assess the order of magnitude of the impact that surface-property variability has on brightness temperatures in the marginal ice zone (MIZ), particularly at low sea-ice concentrations (SIC < 80%), where the ocean contributes strongly to the mixed-pixel signal. Our focus is therefore on the low-concentration regime, where retrieval sensitivities differ significantly from those in consolidated pack ice. We recognise that this framing was not emphasised clearly enough in the manuscript. Since our aim is to study how surface-property variability propagates into retrieval uncertainty in this low-SIC regime, we use Bootstrap as a representative algorithm rather than comparing multiple algorithms, which we considered out of the scope of the study. This frame will be more clearly stated in the next version.

We will revise the text to clarify our motivation:

“ This study focuses on the low concentration regime, where the ocean contributes strongly to the mixed-pixel signal, leading to a signature that differs substantially from that of the consolidated ice pack. Accordingly, for the purpose of this case study, we chose to work with the Bootstrap algorithm in frequency mode (BF) as it performs comparatively better in regions dominated by open water (Andersen et al., 2007; Ivanova et al., 2015). “

Further clarification is in the revised background section (RC2.3).

The range over which the snow-ice-ocean parameter is varied has a large impact on the magnitude of the SIC variability. The handle on the parameter variability and the initial profile is very loose and therefore the magnitude of the SIC variability is very uncertain. I would suggest either to constrain the snow-ice-ocean parameter variability with models or observations or both.

**RC1.2** Our approach is close to the reviewer's suggestion. More precisely, a key challenge in constraining these parameters more tightly is the limited availability of observational data providing statistically robust, circumpolar-scale measurements, particularly for the Antarctic MIZ, where snow properties, salinity profiles, and thin-ice characteristics remain sparsely and unevenly observed. Additionally, the microwave emission models restrict the representation of the medium, and matching measurements to meaningful parameters is often a challenge, for instance for the grain size.

Given these limitations, our approach has been to use parameter values informed by the available studies and by the knowledge within our team as initial, physically-reasonable, starting points before tuning them on the background observations and before assessing how variability in these values propagates into SIC uncertainties. For example: Soriot 2022 paper is about the Arctic region but it served as a starting point for the initial snowpack configuration and many snowpack parameters fall within the range presented in Massom 2001.

We generally chose relatively broad parameter ranges to capture the expected physical variability across the Antarctic region considered. As shown in Figures 2,3, the modeled brightness temperature variability is comparable to the observed variability, suggesting that the parameter ranges are sufficiently representative without being excessively broad. However, some degree of subjectivity is implied in the analysis, because of the current state of observations where data remains sparse. An example of the limitations imposed by observational availability is the value the model required for the optical radius. Further discussion on the choice of the radius parameter is provided in the response to RC2.5.

We will add a reference column in Table 1 to list the references for the parameters chosen as starting input for the forward modelling approach as in:

Table 1. Physical properties of the snowpack input in the SMRT model for warm and cold seasons. 'Value REF'is the reference value most representative of seasonal observations. The 'Min'and' Max 'Max'columns define the parameter range used in the sensitivity analysis, with references provided for the range bounds where available.

| Parameter | Layer | Summer | Winter | Min | Max | Reference |
|---|---|---|---|---|---|---|
| *Winded snowpack* | | | | | | |
| Thickness (m) | SP | 0.05 | 0.1 | 0 | 0.2 | Massom (2001) |
| Density (kg m$^{-3}$) | SP | 300 | 370 | 310 | 450 | Massom (2001) |
| Temperature (K) | SP | 269.15 | 273.00 | 259.15 | 273.15 | Massom (2001) |
| Radius (m) | SP | 0.0001 | 0.00007 | 0.00005 | 0.0004 | — |
| Salinity (ppt) | SP | 1 | 1 | 0 | 3 | Lewis et al. (2011) |
| Liquid water fraction | SP | 0 | 0.005 | 0 | 0.04–0.1 | Nicolaus (2009) |
| *Depth hoar* | | | | | | |
| Thickness (m) | DH | 0.03 | 0.01 | 0 | 0.1 | Lewis et al. (2011) |
| Density (kg m$^{-3}$) | DH | 200 | 250 | 200 | 300–345 | Massom (2001) |
| Temperature (K) | DH | 273.15 | 273.15 | 263.15 | 273.15 | — |
| Radius (m) | DH | 0.0002 | 0.0003 | 0.0002 | 0.0005 | — |
| Salinity (ppt) | DH | 5 | 5 | 0 | 8 | Worby & Massom (1995) |
| Liquid water fraction | DH | 0.01 | 0.02 | 0 | 0.04–0.1 | — |
| *Snow ice* | | | | | | |
| Thickness (m) | SI | 0.1 | 0.02 | 0 | 0.3–0.4 | Lewis et al. (2011) |
| Density (kg m$^{-3}$) | SI | 400 | 400 | 200 | 760–800 | Lewis et al. (2011) |
| Temperature (K) | SI | 273.15 | 273.15 | 269–270.15 | 273.15 | Lewis et al. (2011) |
| Radius (m) | SI | 0.0004 | 0.0004 | 0.0001–0.0002 | 0.0005–0.0006 | — |
| Salinity (ppt) | SI | 5 | 5 | 3 | 20–30 | Jutras et al. (2016) |
| Liquid water fraction | SI | 0.02 | 0.03 | 0.001 | 0.4 | Jutras et al. (2016) |
| *Sea ice 1* | | | | | | |
| Thickness (m) | $SI_1$ | 0.1 | 0.05 | 0 | 0.1 | — |
| Density (kg m$^{-3}$) | $SI_1$ | 915 | 915 | — | — | — |
| Temperature (K) | $SI_1$ | 269.15 | 269.15 | 268.15 | 271.15 | — |
| Radius (m) | $SI_1$ | 0.000002 | 0.000002 | — | — | — |
| Salinity (ppt) | $SI_1$ | 8 | 8 | 6 | 11 | Jutras et al. (2016) |
| *Sea ice 2* | | | | | | |
| Thickness (m) | $SI_2$ | 0.95 | 0.95 | — | — | — |
| Density (kg m$^{-3}$) | $SI_2$ | 915 | 915 | — | — | — |
| Temperature (K) | $SI_2$ | 271.15 | 271.15 | — | — | — |
| Radius (m) | $SI_2$ | 0.000002 | 0.000002 | — | — | — |
| Salinity (ppt) | $SI_2$ | 3 | 3 | — | — | Jutras et al. (2016) |

Different sea ice concentration algorithms have different sensitivities to snow-ice-ocean variability (e.g. Tonboe et al. 2022) and for other commonly used algorithms (e.g. NT, NT2, ASI…), the sensitivity response may be different. I would suggest either to include more algorithms or to make this a case study for the Bootstrap algorithm.

We will explicitly state that this is a case study, together with an explanation of the choice of the Bootstrap algorithm (more details in answer RC1.1).

The atmosphere (in addition to windspeed) is somehow included in the simulations, but the SIC variability due to water vapor and cloud liquid water is not quantified. At 36GHz and at low concentrations this is non-negligible. Anyway, a description of what is going on with the atmosphere is needed.

**RC1.3** In the revised manuscript, we will therefore include the suggested sensitivity analysis. For this we'll use ERA5 reanalysis data for varying atmospheric profiles across different circumpolar locations for the two seasons, and update the text accordingly, including the contextualization within existing literature. To this end, we will use the PyRTlib model that is connected with SMRT, allowing us to inject ERA5 profiles smoothly.

There will be a new section in the revised manuscript: **Section 3.3 Atmosphere simulation**

“This work employs two different atmospheric models for different analysis. We use the PARMIO model to simulate a clear-sky atmosphere. PARMIO relies on an analytical atmospheric formulation, with constant relative humidity which is used to compute absolute humidity and water vapour content at each atmospheric layer. The absorption is calculated layer by layer according to the model’s built-in vertical profile. This configuration does not include any varying humidity field or additional atmospheric variability.

The second atmosphere we employ is simulated with the PyRTLib package (Larosa et al. 2024) embedded in SMRT , which enables the simulation of observations, under non-scattering Rayleigh approximation for the selected radiometer. For the atmospheric vertical profile it extracts meteorological data from the ERA5 reanalysis (Hersbach et al., 2020) including pressure, air temperature, water vapor ( specific and relative humidity), cloud liquid and ice water and ozone prescribing the date, latitude and longitude of interest. These data are used to estimate the propagation parameters in SMRT by selecting the R20 gas absorption model, which is based on recent field and laboratory experiments (Makarov 2011, Meshkov and De Lucia 2007),and provides recently updated gas absorption characteristics, particularly for water vapour and oxygen.”

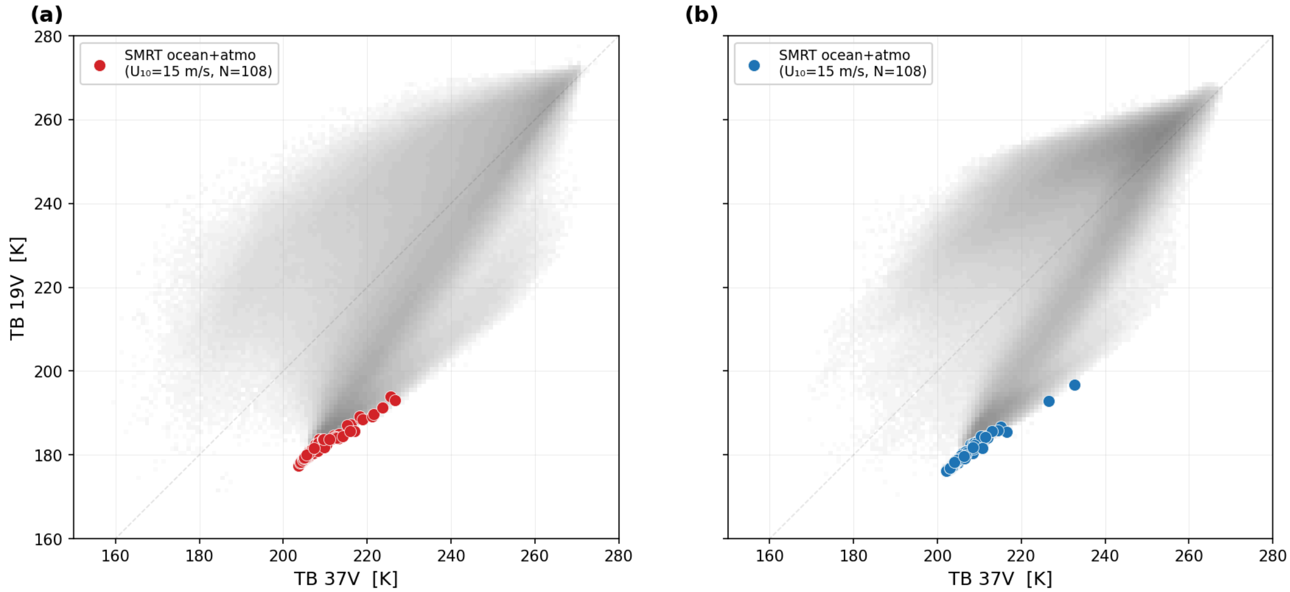
**Section 3.5.4 SIC Sensitivity to the atmosphere**

“To sample the atmospheric variability throughout the warm and the cold season, profiles are extracted at a regular spatial grid of longitudes spaced every 60° (6 points) and latitudes at −60°, −65° and −70°S (3 points), spanning the latitude band 60°–70°S. Temporally, profiles are sampled every 10 days within the warm season (that for the scope of this analysis we define as January–February 2022) and cold season (June–July 2022), yielding 6 dates per month and 108 profiles per season.

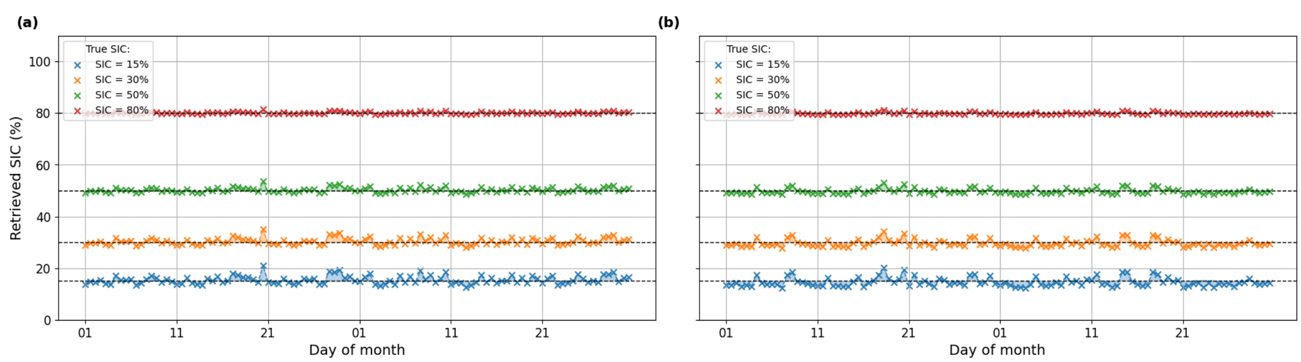
With SMRT we impose the atmosphere over the ocean. We considered the output from the PARMIO model when deactivating PARMIO clear-sky atmosphere as the surface contribution. We model the ocean as a specular reflector (*make_reflector* in SMRT), whose temperature is set to the SST, 271.25K and 273.15K respectively for the cold and the warm season and where the emissivities are derived from PARMIO output at wind speed of 15 $ms^{-1}$ , consistently with the ocean simulation described in Section 3.2. The atmosphere object modelled with the *pyrtlib_era5_atmosphere* is overlaid at the top at the ocean medium by means of the *make_transparent_volume* function in SMRT.

The sensitivity of SIC retrievals to different atmospheric profiles is assessed as described in Sect. 3.5.1. In this case, the observations (P points in step 2) correspond to open ocean grid cells over which different atmospheric profiles are applied.”

**Results section:** A new section will be added to the Results and Discussion of the revised manuscript. Here, we present only preliminary results to illustrate our response to the referee's suggestion.




(a) Brightness temperature signatures in the 19V–37V space for 108 atmospheric profiles selected as described in Sect. 3.5.4 (warm season), superimposed on the open ocean simulation at 15 m/s wind speed. Sea ice and ocean brightness temperature observations from AMSR2 correspond to the warm season.
(b) Same as (a) for the cold season.




(a) SIC retrieved for different atmospheric profiles selected as in Sect. 3.5.4 for the warm season. True SIC values (15%, 30%, 50%, 80%) are represented with horizontal lines. Data points are coloured by SIC and shown for atmospheres at different times and location.
(b) Same as 9a) for the cold season.

One of the major components of the SIC uncertainty in the MIZ is the resampling uncertainty (Tonboe et al., 2016; Lavergne et al., 2019). You also use a resampled dataset and part of the uncertainty in those data are due to this resampling uncertainty and part due to geophysical noise (that you simulate). It is not clear if the observed TB variability has an influence on the snow-ice-ocean parameter range of variability in T1, but you are only characterizing part of the 'uncertainty' with the simulations. I think that you should mention that.

**RC1.4** This limitation will be further discussed and clarified in the Discussion section. In the present study, geophysical noise is represented by the variability of brightness temperatures around the open-ocean and 100 % SIC tie points. We do not explicitly address additional sources of uncertainty related to spatial smearing, such as those introduced by the resampling of satellite swath data onto a fixed grid or by footprint mismatches between frequency channels, as described for example by Lavergne2019. (Further details in the new background section in answer RC2.3).

I think that some references are missing from the reference list, some suggestions are given below.

**RC1.5** During manuscript preparation, several references were removed but we agree that the suggested literature is highly relevant, and we will incorporate these references in the revised version of the manuscript. Further details are in answer RC2.2.

Specific comments:

I suggest to change the title, for example: "Sensitivity of the Bootstrap SIC to surface parameters in the Antarctic MIZ"

**RC1.6** We will revise the title and change it to: "Sensitivity of the Bootstrap sea ice concentration to surface parameters in the Antarctic marginal ice zone using passive microwave retrievals".

P1, L3: delete "global"

**RC1.7** We will do it.

P2, L40: Three surface types are assumed, first-year ice, multiyear ice and open water. New-ice and bare ice does not fit the ice-line. Please clarify.

**RC1.8** In the revised version of the manuscript we will make explicit this consideration about the signature of thin ice:

"As discussed by Comiso (1995) in the description of the Bootstrap algorithm in frequency mode, the radiometric signature of new and thin ice formed in the marginal ice zone typically falls below the OA line, occupying an intermediate region between the open-water and thick-ice signatures ."

P3, L83: replace "pure ice" with "100% ice", and in general 'pure water' with 'open water'.

**RC1.9** We will do it.

P3, L86: add after “properties”: “or the fraction of new-ice within the resolution cell.”

**RC1.10** We will add it, together with a reference to the new ice type modelled in the revised version of the manuscript (new sensitivity analysis in answer 2.7).

P4, L88: Is the water tie-point adjusted daily? Please clarify.

**RC1.11** In the current version of the manuscript, both the water and ice tie points are shown with respect to a single-date observational background, which may lead to the ambiguity that this model parameterization aims to represent a daily tie-point varying within the season. In the revised version, we will update the figures to include observational backgrounds constructed from multiple dates. Specifically, for each season - the warm season (December to February) and the cold season (June to August) - dates are selected at 15-day intervals over the period 2012–2024, yielding 96 dates per season. For each date, the ascending orbit of the satellite passage is selected, providing brightness temperatures in vertical polarisation at 19 GHz and 37 GHz. This multi-date background allows us to demonstrate that the chosen circumpolar parameterization for both the cryospheric and ocean components is representative of the typical surface conditions observed across the season considered. The AMSR2 observations background serves, therefore,  as a sanity check for the seasonal snowpack parametrization, rather than for a parametrization of the daily dynamic tie point, which is not addressed in this study.

We will rephrase line 87-88 to: ‘The Bootstrap algorithm, among others, adjusts the tie points and the 100\% SIC line on a daily basis to account for seasonal and meteorological variability  to account for the variability that depends on season and the meteorological conditions (Comiso, 2013).’

P4, L91: why do you have empty sections?

**RC1.12** The appearance of consecutive headings is due to the nested structure of the document, conforming to the Copernicus template.

P4, L114: It is unclear if there is a relationship between salinity, temperature and brine volume? I think that there should be.

**RC1.13** In the current version of the manuscript, salinity, temperature, and brine volume fraction are varied independently in the sensitivity analysis. This choice was motivated by two reasons: first, to isolate the specific contribution of each parameter to the passive microwave signature; and second, because the empirical relationship between brine volume fraction and temperature (Leppäranta & Manninen, 1988) -which uses coefficient from Cox and Weeks (1983)- introduces its own uncertainty . However, following the reviewer's suggestion, and given the particular sensitivity of the passive microwave signature to the brine volume distribution, especially in the top layer of thin ice,  we will include, in the revised manuscript, a dedicated sensitivity analysis for each of the three parameters (salinity, temperature, and brine volume fraction), fixing the remaining two in each case. This will be described in section 3.5.2, together with updating Table 2 showing the values assumed by the physical parameters and the relative references.

Line 181: “The sensitivity analysis for the thin ice component quantifies the impact of different thin ice fractions characterised by having different temperature profiles, salinity profiles or brine volume fractions, on the total SIC. We compare the 'true' SIC at the standard SIC levels (15%, 30%, 50%, 80%), derived from the linear combination of tie-point brightness temperatures, with the SIC retrieved when thin ice of varying characteristics constitutes fractions of 0, 0.15, 0.30, 0.50, 0.80, and 1.00 of the total ice area, mixed with the thick first-year ice tie point defined in Section 3.5.1.

In the temperature sensitivity experiment, the dark nilas is represented by three layers of total thickness 0.05 m and with salinity fixed to 17 PSU throughout (mid value in bulk density for the 0.05m thick newly formed ice (Kovacs 1996 , Weeks and Lee 1962). The top-layer temperature is swept from 260 K to 270.25 K in steps of 1 K, while the bottom layer is held at 271.25 K  and the intermediate layer temperature is interpolated linearly between the two boundary values. The brine volume fraction is fixed, in the three layers, at its value computed at 271 K (near-freezing temperatures characteristic of ice in the first hours after formation) following Leppäranta & Manninen (1988).

In the salinity sensitivity experiment , the temperature profile is fixed (269, 270, 271)K and the brine volume fraction is again computed through Leppäranta & Manninen (1988) at a fixed temperature of 271K. The bulk salinity is varied for the range in Table 2.

Finally, for the brine volume fraction sensitivity experiment  the temperature profile (269, 270, 271)K in the three layers and the salinity of 17 PSU are held constant  throughout the analysis. We then prescribed a fraction volume in the range 0.03 to 0.2, uniform in the three layers, where 0.05-0.07 represents the lower percolation threshold (Cox and Weeks 1988) and and 0.20 is a maximum value for nilas reported in Petrich and Eicken (2016). ”

| Parameter | Reference value | Min | Max | Reference |
|---|---|---|---|---|
| **NILAS** | | | | |
| Total thickness (m) | 0.05 | – | – | Petrich & Eicken (2017) |
| Layer thicknesses (m) | 0.02, 0.01, 0.01 | – | – | – |
| Density (kg m$^{-3}$) | 920 | – | – | – |
| Radius ($\mu$m) | 2 | – | – | – |
| Microstructure model | Sticky hard spheres | – | – | – |
| Stickiness parameter | 100 | – | – | – |
| Top-layer temperature (K) | 265 | 260 | 270.25 | Notz and Worster (2007) |
| Middle-layer temperature (K) | 270 | – | – | Notz and Worster (2007) |
| Bottom-layer temperature (K) | 271.25 | – | – | – |
| Top-layer salinity (PSU) | 17 | 10 | 25 | Kovacs (1996); Weeks & Lee (1962) |
| Middle-layer salinity (PSU) | 8 | 5 | 13 | – |
| Bottom-layer salinity (PSU) | 16 | 9 | 25 | – |
| Brine volume fraction | – | 0.05 | 0.20 | Cox & Weeks (1988); Petrich & Eicken (2017) |
| **GREASE ICE** | | | | |
| Thickness (m) | 0.002 | – | – | – |
| Temperature (K) | 271.25 | – | – | Mielke et al. (2021) |
| Radius ($\mu$m) | 100 | – | – | Mielke et al. (2021) |
| Salinity (PSU) | 32 | – | – | Mielke et al. (2021) |
| Inclusion shape | Random needles | – | – | – |
| Liquid water fraction | – | 0.60 | 0.80 | Mielke et al. (2021) |
| **SLUSH** | | | | |
| Temperature (K) | 271.25 | – | – | – |
| Radius ($\mu$m) | 100 | – | – | – |
| Salinity (PSU) | 32 | – | – | – |
| Thickness (m) | 0.10 | 0.02 | 0.30 | – |
| Liquid water fraction | 0.20 | 0.15 | 0.80 | – |

P5, L118: Please explain why you have a microstructure model with hard spheres and then you use the IBA for computing the scattering. Is that consistent?

**RC1.14** It is consistent, as demonstrated in Picard et al. 2022, IBA can be combined with any microstructure with explicit autocorrelation function to describe the snow microstructure (Matzler and Wiesman, 1999), including the sticky hard spheres. In Picard et al. 2018, the authors demonstrate close equivalence between IBA and DMRT when using this microstructure.

P5, L124: why this set-up and why 13PSU and 0.05m? please provide some references or explanation.

**RC1.15** We will add the references (Table 2, RC1.13), used at the initial step of the forward model approach, with the limitation outlined in answer RC1.2; for the thin ice, a new parameterization will be introduced in the revised manuscript to include three layers and have a more realistic representation of the temperature gradient.

P5, L135: What other atmospheric contributions other than wind?

**RC1.16** In the revised version of the manuscript we will include ERA5 atmospheric profiles in the model that will therefore prescribe vertical profiles of pressure, air temperature, water vapor ( specific and relative humidity), cloud liquid and ice water and ozone. This will be described in the sensitivity analysis conducted over different atmospheric profiles as in answer RC1.3.

P5, L143: This is unclear… you only include datapoints with SIC >15%? And what do you use it for?

**RC1.17** We will correct the mask selection and update its description in the manuscript: "We applied a mask to the dataset to select the sea ice area and a limited portion of adjacent open ocean. The mask was created using the sea ice concentration (>0%) corresponding to the date under analysis for the warm and cold seasons, and extending it for 100 Km"

T1: please provide some specific references to these values. I guess that they are static when they don't have a min and max?

**RC1.8** Yes, the values are static when the range is not specifically listed, this will be stated more clearly in the revised manuscript "In cases where a parameter is assigned a minimum and maximum value, its range is sampled using 21 evenly spaced values, corresponding to a uniform increment across the full range. Otherwise, the parameter is kept constant." As noted in the response to RC1.2, we will provide additional references within the constraints outlined above.

P7, L157: Several of these parameters are closely correlated, e.g. brine volume and temperature, they will never vary independently. Please explain.

**RC1.9** The objective of this work is to decouple these variables to quantify each parameters' contribution. As noted by the referee the brine volume fraction plays a particularly relevant role in the PM signature (Kwok et al 2006) for nilas, we included therefore a sensitivity analysis as in RC1.13.

F1: P should be half way between 'O' and the intersect with the ice line if 'P' represents 50%, but it is not. Is it just a sketch? There is some confusion between the ice tie-point 'A' and the ice line 'I' in the figure caption. I think that you should include both the multiyear and first-year ice ('A') tie-points in the plot.

**RC1.10** The point P is the result of the simulation for 50% SIC and falls, therefore, half way to between the point O and the intersection with the ice line. We are unsure why P does not look in the middle, but it is. We'll try to change the green colour used for the intercept point I which will be changed to red.

Given the focus on the MIZ we did not model the multi-year ice in this study, we will explain this more carefully in the revised manuscript and we will rephrase the caption of this figure to avoid the confusion the referee pointed out.

T2: Please explain: 'Water substrate – True'? Please use sea ice terminology.

**RC1.11** The substrate in the SMRT simulation is the lower boundary conditions for the radiative transfer equation. In this case we impose the ocean beneath the ice. This will be removed from the table and clarified in the text: "In the sea ice simulations, the boundary condition for the radiative transfer equation is imposed by activating the "water substrate" for the lowest layer in SMRT, which represents the ocean beneath the ice."

P15, L242: delete 'existing'

**RC1.12** We will do this.

Suggested references:

Lavergne, T., Sørensen, A. M., Kern, S., Tonboe, R., Notz, D., Aaboe, S., Bell, L., Dybkjær, G., Eastwood, S., Gabarro, C., Heygster, G., Killie, M. A., Brandt Kreiner, M., Lavelle, J., Saldo, R., Sandven, S., and Pedersen, L. T.: Version 2 of the EUMETSAT OSI SAF and ESA CCI sea-ice concentration climate data records, The Cryosphere, 13, 49–78, https://doi.org/10.5194/tc-13-49-2019, 2019.

Tonboe, R. T., Eastwood, S., Lavergne, T., Sørensen, A. M., Rathmann, N., Dybkjær, G., Pedersen, L. T., Høyer, J. L., and Kern, S.: The EUMETSAT sea ice concentration climate data record, The Cryosphere, 10, 2275–2290, https://doi.org/10.5194/tc-10-2275-2016, 2016.

Tonboe, R., Nandan, V., Mäkynen, M. P., Pedersen, L. T., Kern, S., Lavergne, T., Øelund, J., Dybkjar, G., Saldo, R., & Huntemann, M. (2022). Simulated Geophysical Noise in Sea Ice Concentration Estimates of Open Water and Snow-covered Sea Ice. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 15, 1309-1326. https://doi.org/10.1109/JSTARS.2021.3134021.