*Supplement of*

# Seasonal evolution and parameterization of Arctic sea ice bulk density: results from the MOSAiC expedition and ICESat-2/ATLAS

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**Table S1.** Overview of the 12 SIMBAs and 3 SIMBs deployed in the MOSAiC DN.

| Buoy name | Start date (YYYY/MM/DD) | End date (YYYY/MM/DD) | Onset of growth (YYYY/MM/DD) | Initial ice thickness (m) | Initial snow depth (m) | Ice type |
|---|---|---|---|---|---|---|
| SIMBA _T47 | 2019/10/13 | 2020/02/07 | 2020/10/16 | 0.34 | 0.10 | FYI |
| SIMBA _T58 | 2019/10/07 | 2020/07/21 | 2019/11/09 | 0.84 | 0.08 | SYI |
| SIMBA _T62 | 2019/10/29 | 2020/07/27 | 2019/11/02 | 0.80 | 0.20 | SYI |
| SIMBA _T63 | 2019/10/07 | 2020/07/28 | 2019/11/28 | 1.12 | 0.14 | SYI |
| SIMBA _T64 | 2019/10/10 | 2020/08/02 | 2019/11/22 | 1.74 | 0.16 | SYI |
| SIMBA _T65 | 2019/10/07 | 2020/05/30 | 2019/12/08 | 1.32 | 0.14 | SYI |
| SIMBA _T66 | 2019/10/29 | 2020/08/03 | 2019/10/30 | 0.40 | 0.10 | FYI |
| SIMBA _T67 | 2019/11/09 | 2020/08/03 | 2019/11/14 | 1.36 | 0.22 | SYI |
| SIMBA _T68 | 2019/10/05 | 2020/06/05 | 2019/12/05 | 1.81 | 0.17 | SYI |
| SIMBA _T69 | 2019/10/11 | 2020/01/31 | 2019/10/29 | 0.80 | 0.08 | SYI |
| SIMBA _T70 | 2019/10/09 | 2020/08/05 | 2019/10/14 | 0.48 | 0.06 | FYI |
| SIMBA _T72 | 2019/10/09 | 2020/04/27 | 2019/11/02 | 1.00 | 0.14 | SYI |
| SIMB_I1 | 2019/10/05 | 2020/03/15 | 2019/12/17 | 1.20 | 0.17 | SYI |
| SIMB_I2 | 2019/10/07 | 2020/07/30 | 2019/11/10 | 0.80 | 0.12 | SYI |
| SIMB_I3 | 2019/10/10 | 2019/02/03 | 2019/10/10 | 0.30 | 0.06 | FYI |

**Table S2.** Growth rates of sea ice thickness for different buoys from mid-October to mid-April. Note that the statistical test *P*-values are all below 0.001.

| Buoy name | Growth rate of sea ice thickness (m per month) |
|---|---|
| SIMBA _T47 | 0.23 |
| SIMBA _T58 | 0.16 |
| SIMBA _T62 | 0.16 |
| SIMBA _T63 | 0.12 |
| SIMBA _T64 | 0.10 |
| SIMBA _T65 | 0.10 |
| SIMBA _T66 | 0.19 |
| SIMBA _T67 | 0.12 |
| SIMBA _T68 | 0.08 |
| SIMBA _T69 | 0.13 |
| SIMBA _T70 | 0.21 |
| SIMBA _T72 | 0.18 |
| SIMB_I1 | 0.11 |
| SIMB_I2 | 0.17 |
| SIMB_I3 | 0.31 |

**Table S3.** Fitting performance of the ice draft-to-thickness ratio to sea ice bulk density at different spatial scales and sea ice types.

| Spatial scale | Sea ice type | $R^2$ | *RMSE* (kg m$^{-3}$) | Counts |
|---|---|---|---|---|
| 40 m | FYI | 0.92 | 7 | 8538 (48.64 %) |
| | SYI | 0.90 | 8 | 1061 (6.04 %) |
| | MYI | 0.90 | 8 | 7955 (45.32 %) |
| 800 m | FYI | 0.59 | 12 | 1872 (80.45 %) |
| | SYI | 0.76 | 10 | 80 (3.44 %) |
| | MYI | 0.77 | 10 | 375 (16.12 %) |
| 12.5 km | FYI | 0.56 | 8 | 450 (77.45 %) |
| | SYI | 0.92 | 4 | 25 (4.30 %) |
| | MYI | 0.88 | 4 | 106 (18.24 %) |
| 25 km | FYI | 0.45 | 8 | 250 (77.16 %) |
| | SYI | 0.94 | 3 | 20 (6.17 %) |
| | MYI | 0.92 | 3 | 54 (16.67 %) |

**Text S1. Relative contribution of the input parameters**

In order to quantify which input parameters used in Eq. (5) contribute most or least to the total uncertainty in sea ice bulk density, the relative contribution of the input parameters ($RC_{\mathrm{X}}$) was defined as follows:

$$RC_{\mathrm{X}} = \frac{(\frac{\partial \rho_{\mathrm{i}}}{\partial X})^2 \times {\sigma_X}^2}{{\sigma_{\rho_{\mathrm{i}}}}^2} \times 100\% \quad \text{(S1)}$$

where $\sigma_{\rho_{\mathrm{i}}}$ is the uncertainty in sea ice bulk density, $X$ and $\sigma_X$ denote each input parameter and its uncertainty, respectively.

The partial derivatives of sea ice bulk density with respect to each variable are as follows:

$$\frac{\partial \rho_{\mathrm{i}}}{\partial \rho_{\mathrm{w}}} = \left(1 - \frac{h_{\mathrm{f}}}{h_{\mathrm{i}}} + \frac{h_{\mathrm{s}}}{h_{\mathrm{i}}}\right) \quad \text{(S2)}$$

$$\frac{\partial \rho_{\mathrm{i}}}{\partial \rho_{\mathrm{s}}} = -\frac{h_{\mathrm{s}}}{h_{\mathrm{i}}} \quad \text{(S3)}$$

$$\frac{\partial \rho_{\mathrm{i}}}{\partial h_{\mathrm{i}}} = \frac{\rho_{\mathrm{w}} h_{\mathrm{f}} - \rho_{\mathrm{w}} h_{\mathrm{s}} + \rho_{\mathrm{s}} h_{\mathrm{s}}}{{h_{\mathrm{i}}}^2} \quad \text{(S4)}$$

$$\frac{\partial \rho_{\mathrm{i}}}{\partial h_{\mathrm{s}}} = \frac{\rho_{\mathrm{w}} - \rho_{\mathrm{s}}}{h_{\mathrm{i}}} \quad \text{(S5)}$$

$$\frac{\partial \rho_{\mathrm{i}}}{\partial h_{\mathrm{f}}} = -\frac{\rho_{\mathrm{w}}}{h_{\mathrm{i}}} \quad \text{(S6)}$$

where $\rho_{\mathrm{i}}$ is the sea ice bulk density $\rho_{\mathrm{w}}$ and $\rho_{\mathrm{s}}$ represent the seawater and snow bulk densities, respectively; $h_{\mathrm{i}}$, $h_{\mathrm{f}}$, and $h_{\mathrm{s}}$ are the sea ice thickness, total freeboard, and snow depth, respectively.