**Supplementary material**

# **Multi-scale satellite observation of the Arctic sea ice: a new insight into the life cycle of floe size distribution**

Byongjun Hwang\*, Yanan Wang\*\*

\*Corresponding author : B.Hwang@hud.ac.uk

\*\*E-mail : Yanan.Wang@hud.ac.uk

**Supplementary Table 1 :** Summary of the range of the floe size distribution derived from previous observations.

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**Supplementary Figure 1 :** Floe number histograms derived from MEDEA imagery data.

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**Supplementary Figure 5 :** Sub-sections of the TX images for scaling.

**SUPPLEMENTARY TABLE 1 – Summary of the range of the floe size distribution derived from previous observations.**

|  |  |  |
| --- | --- | --- |
| Floe size range (d) | Observation | Reference |
| 1 to 100 m | Aerial photograph mosaic (*δ\** ≈ centimetres) | Rothrock and Thorndike (1984); Paget et al. (2001); Inoue et al. (2004); Lu et al. (2008); Steer et al. (2008); Toyota et al. (2006); Toyota et al. (2011); Perovich and Jones (2014); Toyota et al. (2016) |
| 5-10 to 1,000 m | MEDEA images (*δ* = 1 m) | Wang et al. (2016); Stern et al. (2018); Denton and Timmermans (2022) |
| 100 to 1,000 m | Landsat images (*δ* = 30 m) | Rothrock and Thorndike (1984); Toyota et al. (2006); Gherardi and Lagomarsino (2015); Wang et al. (2016) |
| 200 to 3,000 m | TX SM images (*δ* = 1.2-3.3 m) | Hwang et al. (2017); Stern et al. (2018). |
| 900 to 10,000 m | ERS-1 SAR images (*δ* = 100 m) | Holt and Martin (2001) |
| 2,000 to 20,000 m | MODIS images (*δ* = 250 m) | Toyota et al. (2016); Stern et al. (2018) |

\*image resolution

**SUPPLEMENTARY TABLE 2 – Summary of satellite data used in this study and power-law parameters.**

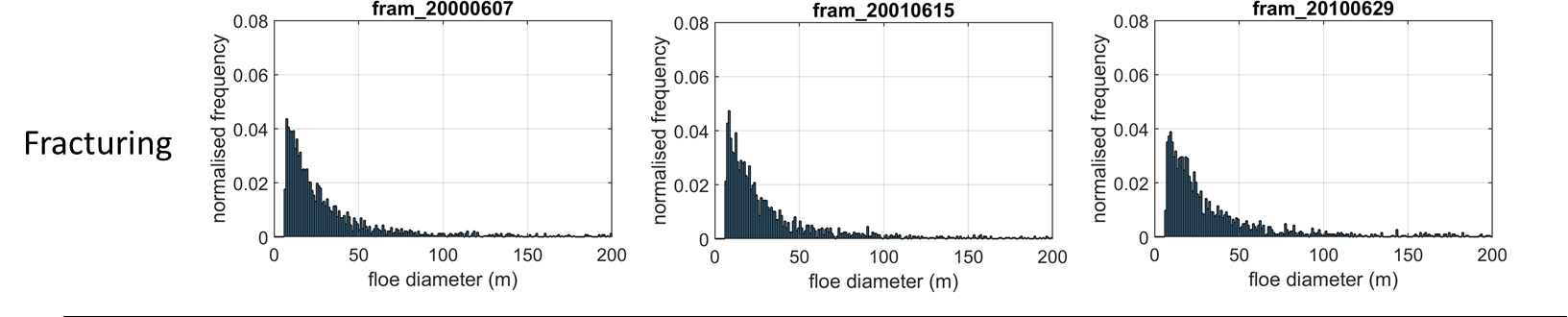
|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Image name and date | Image type | Image size (m) | location | Total number of floes | Power-law range (m) | Power-law exponent α | Number of floes within power-law range | p-value |
| **Fracturing** |  |  |  |  |  |  |  |  |
| TX\_SL\_20200526 | TX SL | 5,256×6,516 | MOSAiC1 | 943 | 27 – 1,000 | 1.97 | 523 | 0.01 |
| TX\_SL\_20200612 | TX SL | n/a\* | MOSAiC2 | n/a | n/a | n/a | n/a | n/a |
| fram\_20000607 | MEDEA | 14,472×12,552 | Fram Strait1 | 2,264 | 24 – 3,000 | 2.07 | 1,074 | 0.84 |
| fram\_20010615 | MEDEA | 16,416×7,440 | Fram Strait1 | 1,962 | 26 – 3,000 | 1.99 | 870 | 0.53 |
| fram\_20100629 | MEDEA | 10,608×5,040 | Fram Strait1 | 1,824 | 31 – 3,000 | 2.05 | 759 | 0.12 |
| **Transition** |  |  |  |  |  |  |  |  |
| fram\_20140707 | MEDEA | 12,388×13,343 | Fram Strait1 | 3,910 | 288 – 3,000 | 2.56 | 147 | 0.16 |
| chukchi\_20060604 | MEDEA | 13,486×17,557 | Chukchi Sea | 5,558 | 172 – 3,000 | 2.54 | 343 | 0.65 |
| chukchi\_20100530 | MEDEA | 7,080×10,944 | Chukchi Sea | 4,101 | 240 – 3,000 | 2.71 | 125 | 0.35 |
| fram\_20100820 | MEDEA | 9,528×10,944 | Fram Strait1 | 4,909 | 252 – 3,000 | 2.78 | 197 | 0.86 |
| chukchi\_20130610 | MEDEA | 8,352×12,960 | Chukchi Sea | 14,537 | 310 – 3,000 | 3.46 | 203 | 0.76 |
| chukchi\_20140610 | MEDEA | 13,008×6,144 | Chukchi Sea | 7,431 | 261 – 3,000 | 3.15 | 183 | 0.34 |
| TX\_SC\_20120624 | TX\_SC | 53,856×48,114 | Chukchi Sea | 2,407 | 300 – 10,000 | 2.44 | 920 | 0.46 |
| TX\_SM\_20180731 | TX\_SM | 16,552x8,327 | Fram Strait2 | 948 | 405-3,500 | 2.66 | 160 | 0.44 |
| **Melt/Wave** |  |  |  |  |  |  |  |  |
| miz02\_20140718 | MEDEA | 6,720×9,168 | MIZ1 | 4,144 | 70 – 2,000 | 2.48 | 776 | 0.21 |
| miz02\_20140730 | MEDEA | 10,352×9,392 | MIZ2 | 6,954 | 69 – 2,000 | 2.42 | 601 | 0.10 |
| miz02\_20140814 | MEDEA | 10,944×7,728 | MIZ3 | 6,682 | 70 – 1,000 | 3.45 | 1,597 | 0.14 |
| TX\_SM\_20140731 | TX\_SM | 30,360×23,232 | MIZ4 | 9,262 | 204 – 6,000 | 2.77 | 1,543 | 0.57 |
| TX\_SM\_20140812 | TX\_SM | 29,832×26,796 | MIZ5 | 11,579 | 298 – 2,000 | 3.82 | 1,373 | 0.14 |
| WV3\_20210428 | WV3 | 2,282×2,354 | Bering Sea | 4,996 | 39 - 400 | 3.29 | 773 | 0.33 |
| miz02\_20140808 | MEDEA | n/a | MIZ6 | n/a | n/a | n/a | n/a | n/a |
| miz02\_20140830 | MEDEA | n/a | MIZ7 | n/a | n/a | n/a | n/a | n/a |
| miz02\_20140913 | MEDEA | n/a | MIZ8 | n/a | n/a | n/a | n/a | n/a |
| TX\_SM\_20140729 | TX\_SM | n/a | MIZ9 | n/a | n/a | n/a | n/a | n/a |
| miz04\_20140802 | MEDEA | n/a | MIZ10 | n/a | n/a | n/a | n/a | n/a |
| miz04\_20140814 | MEDEA | n/a | MIZ11 | n/a | n/a | n/a | n/a | n/a |
|  |  |  |  |  |  |  |  |  |

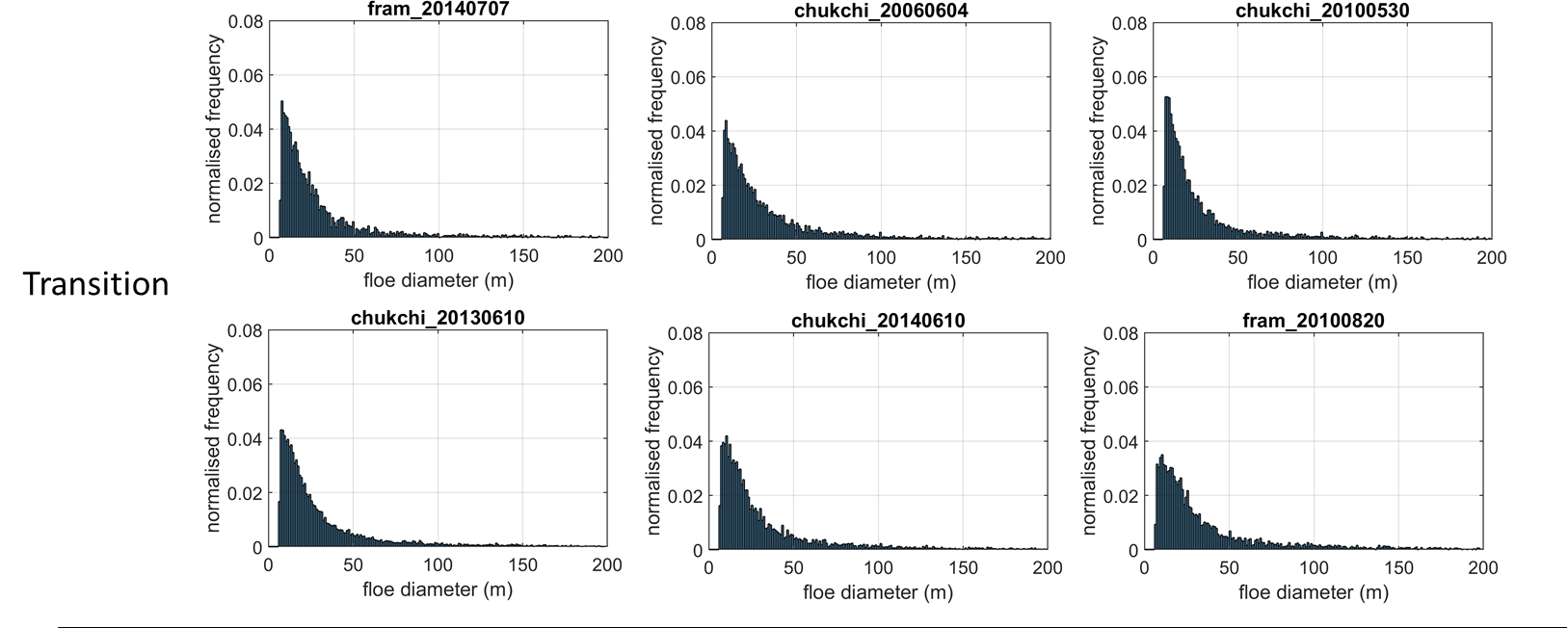
Image type & resolution: TX\_SL = 1.25 m; MEDEA = 1 m; TX\_SC = 8.25 m; TX\_SM = 2.75 m; WV3 = 0.3 m

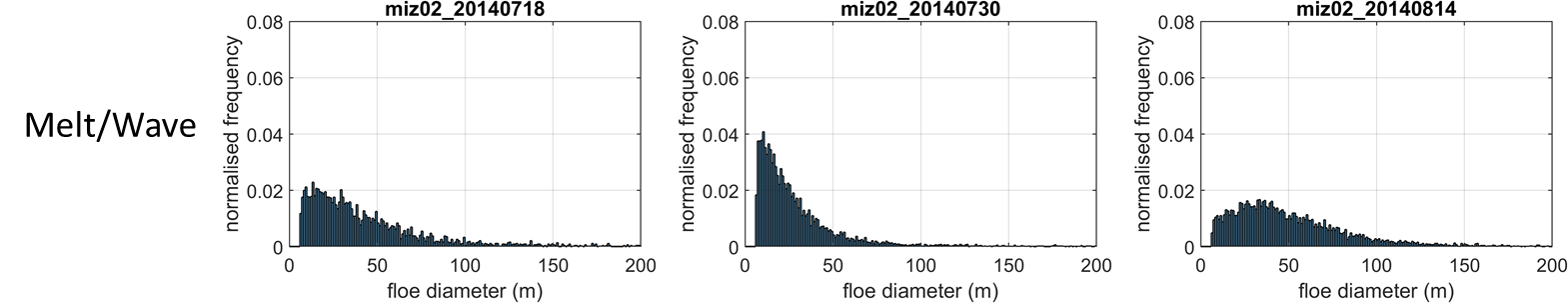
Power-law range: the low cut and high cut to determine the power-law regime using the method by Clauset et al. (2009); p-value: a goodness-of-fit to test whether the data in question represent a power-law distribution (typically considered as power-law when p-value > 0.1); the power-law program obtained from the website https://aaronclauset.github.io/powerlaws/

MOSAiC1: 83.40°N, 8.93°E; MOSAiC2: 82.71°N, 7.95°E; Fram Strait1: 85.00°N, 0.05°E; Fram Strait2: 84.87°N, 6.75°E; Chukchi Sea: 70.00°N, 170.00°W; MIZ1: 74.12N, 150.20W; MIZ2: 74.22N, 149.44W; MIZ3: 74.05N, 153.41W; MIZ4: 74.34N, 149.07W; MIZ5: 74.32N, 151.52W; MIZ6: 74.35N, 150.99W; MIZ7: 74.93N, 153.66W; MIZ8: 75.14N, 150.83W; MIZ9: 74.29N, 149.28W; MIZ10: 74.59N, 149.48W; MIZ11: 74.59N, 149.58W; Bering Sea: 61.98N, 169.93W

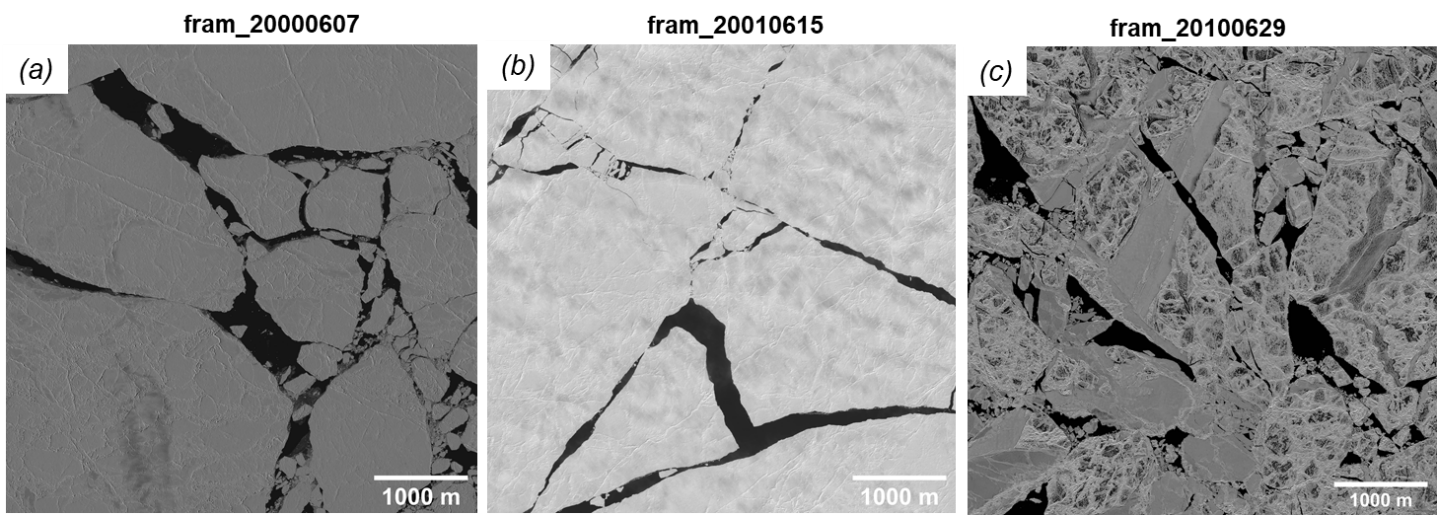
\* n/a - not used to derive the floe size distribution

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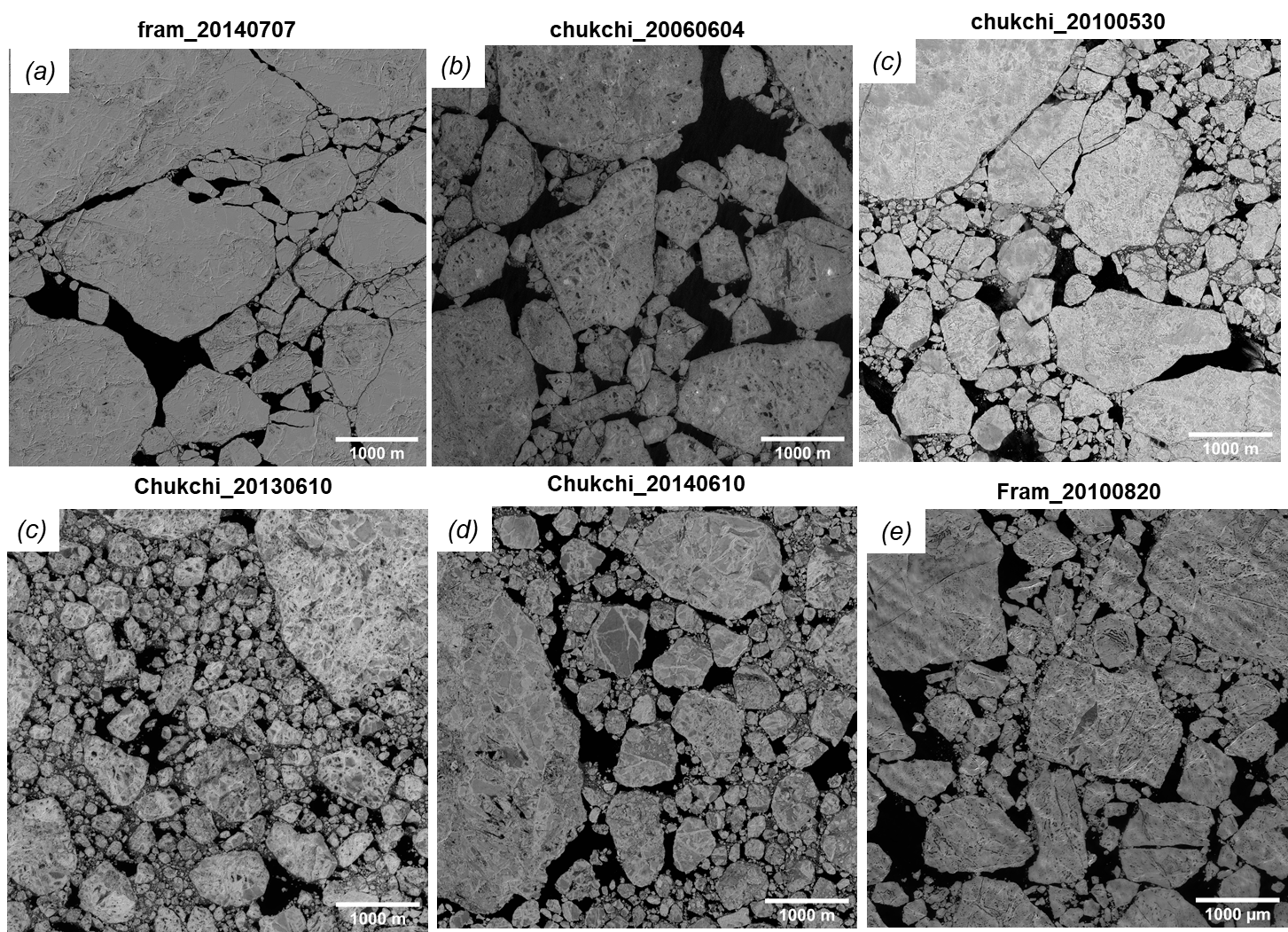
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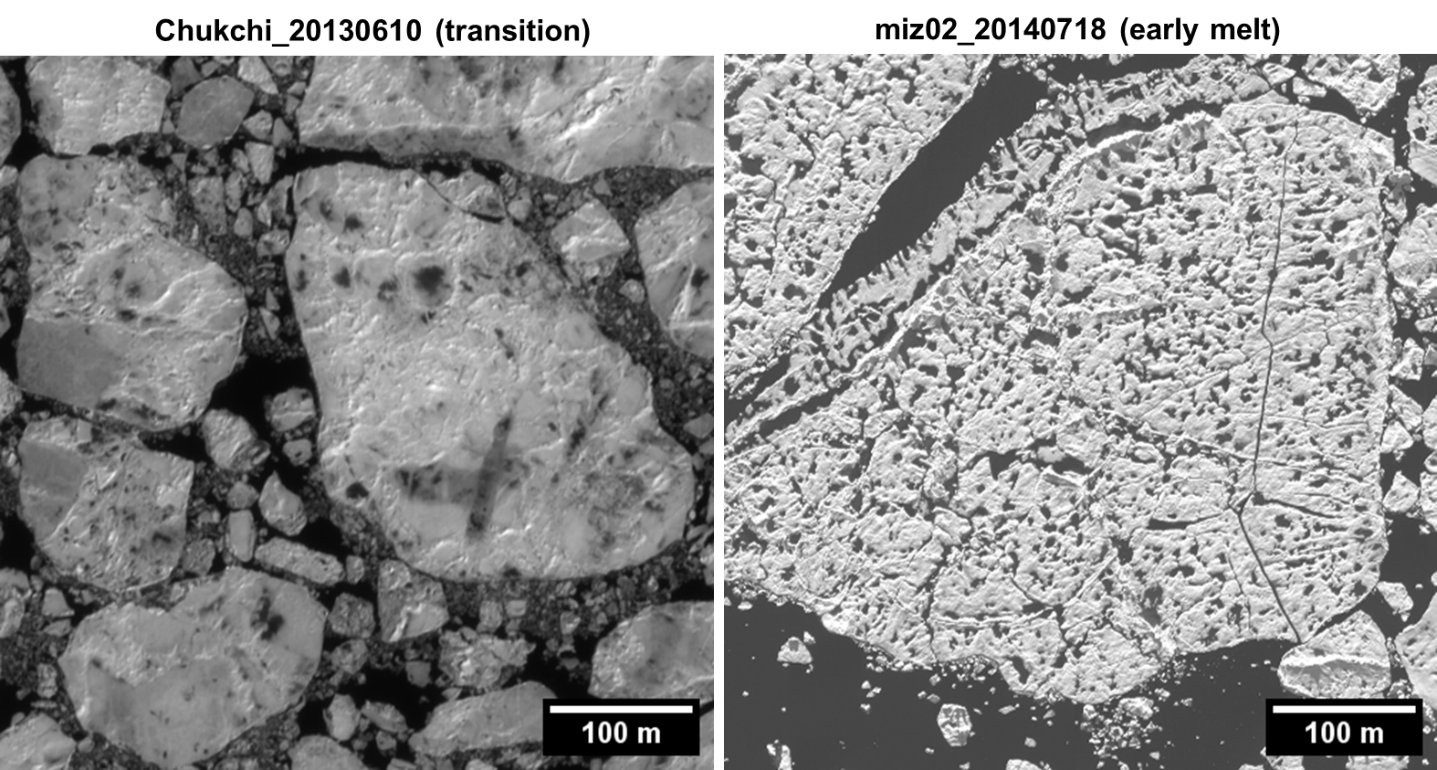
**SUPPLEMENTARY FIGURE 1 – Floe number histograms derived from MEDEA imagery data**. The histograms are shown for three different stages of the life cycle: fracturing, transition and melt/wave.

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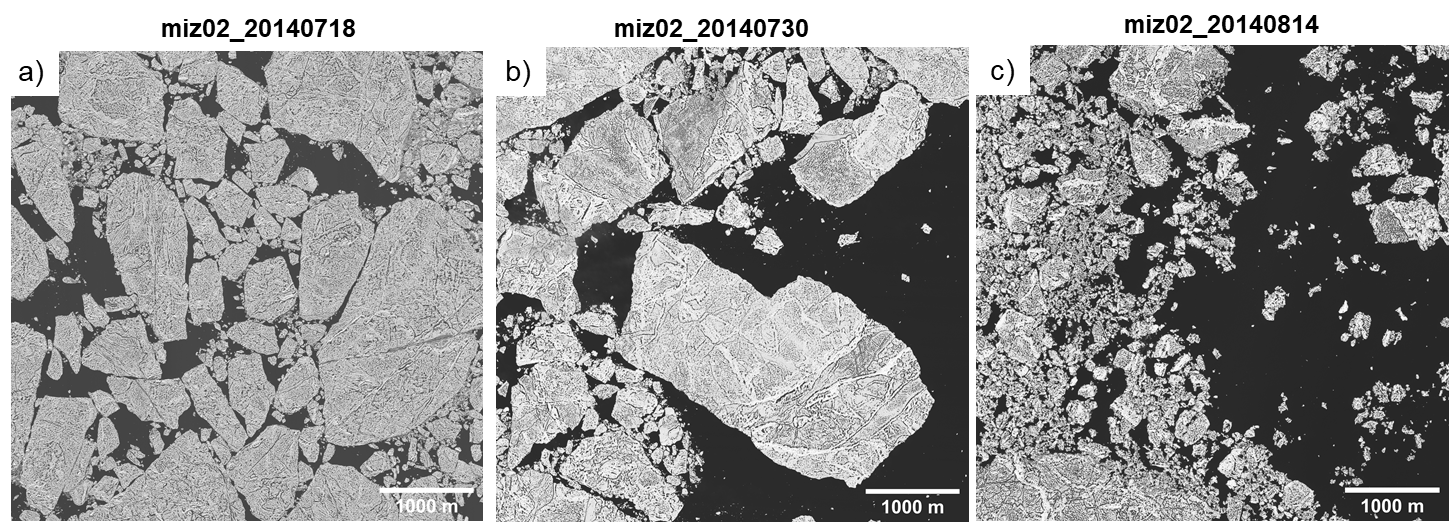
**SUPPLEMENTARY FIGURE 2 – Sub-sections of the MEDEA images for fracturing**. These images represent the ice floe conditions right after the spring breakup (“fracturing”).



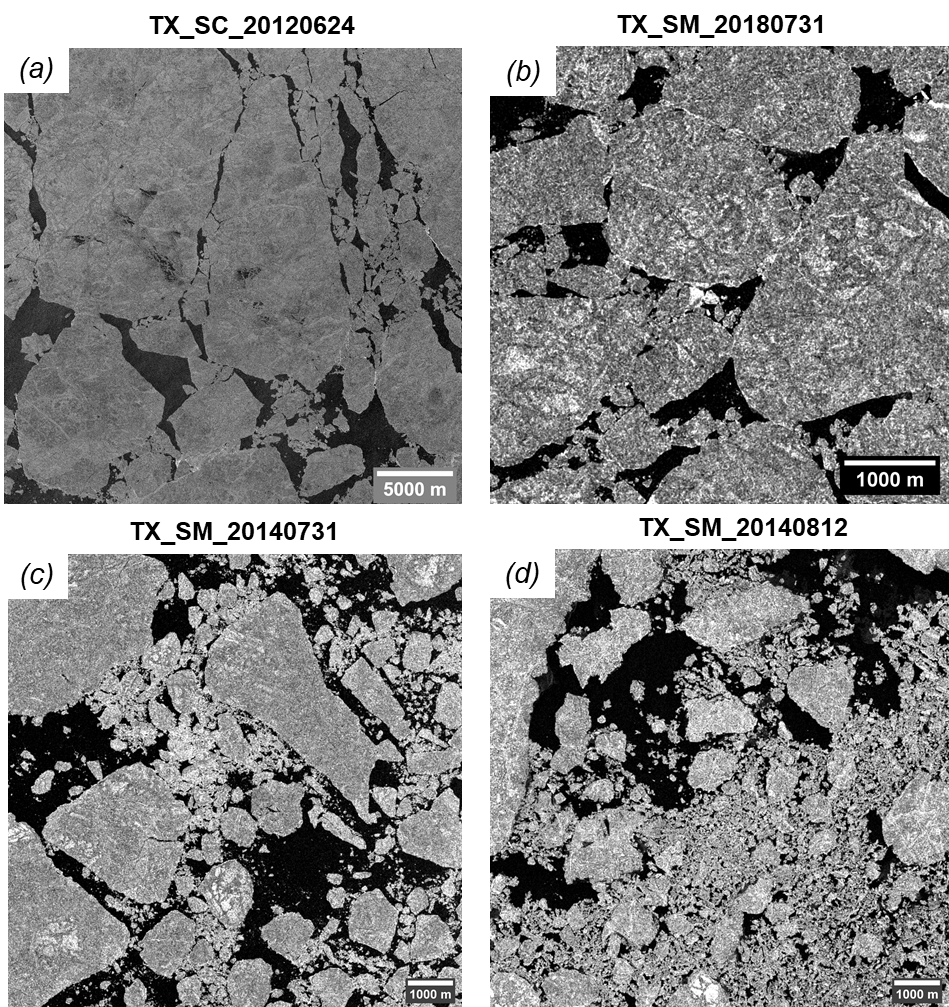
**SUPPLEMENTARY FIGURE 3 – Sub-sections of the MEDEA images for transition**. These images represent the ice floe conditions in transition from fracturing to summer melt. Dynamic ice conditions can cause further floe fragmentation from the initial floe size distribution.



**SUPPLEMENTARY FIGURE 4 – Close-up images showing the difference in surface melt between (left) transition and (right) melt/wave fragmentation. The melt ponds in the Chukchi\_20130610 image (transition) were not well developed, compared to the miz02\_20140718 image (melt/wave), although the power-law exponent of the former is larger.** (The floe size distribution from the Chukchi\_20130610 image shows the power-law regime with the largest exponent (*α* = 3.46) over the floe size range of 310-3,000 m, while the distribution from the miz02\_20140718 image shows the power-law regime a smaller exponent (*α* = 2.48) over the floe size range of 70-2,000 m.)



**SUPPLEMENTARY FIGURE 5 – Sub-sections of the MEDEA images for melt/waves fragmentation**. These images represent the ice floe conditions during the summer melt.



**SUPPLEMENTARY FIGURE 6 – Sub-sections of the TX images used for scaling**.

## Supplementary references

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