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*Supplement of*

# Multi-sensor satellite analysis reveals latitudinal and morphometric controls on ice phenology across 31 000 lakes on the Alaska North Slope

**Alexander L. Nguyen et al.**

*Correspondence to:* Roger J. Michaelides (roger.michaelides@wustl.edu)

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**Supplementary figures**

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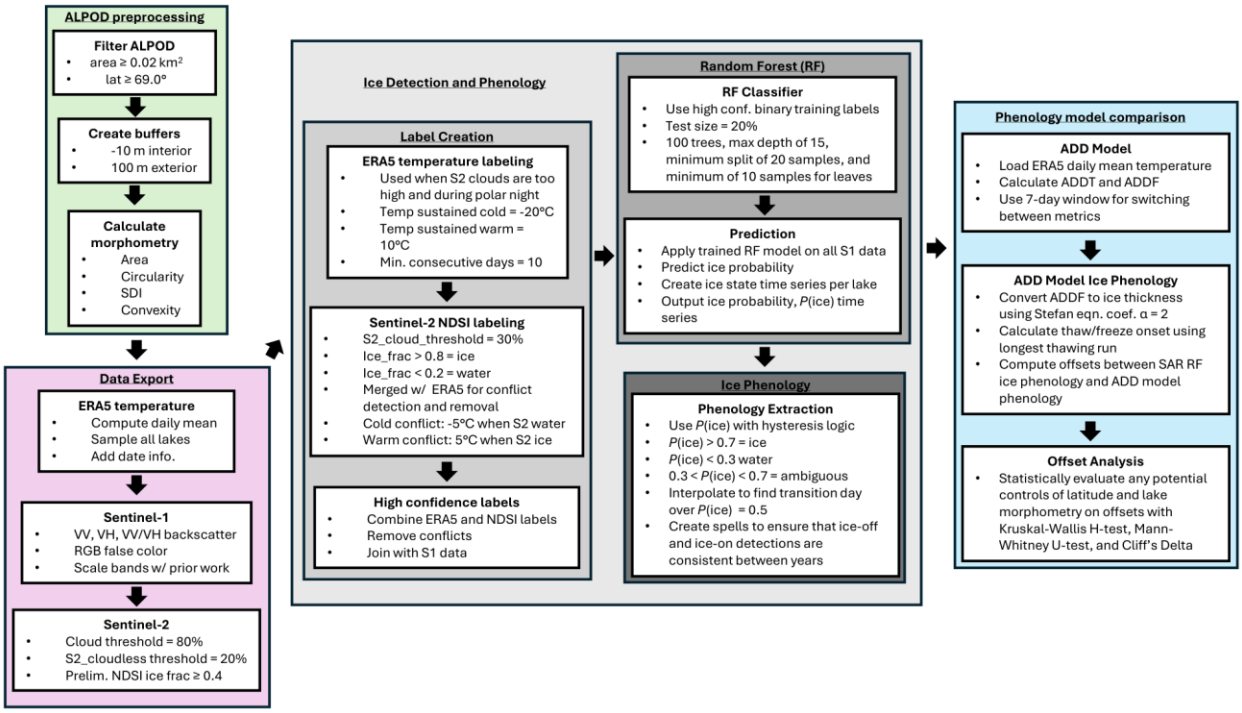



**Figure S1:** Workflow diagram of main processing. Highlighting the ALPOD processing (green box), data exporting (magenta box), ice detection and phenology (gray box), and phenology model comparison (blue box).

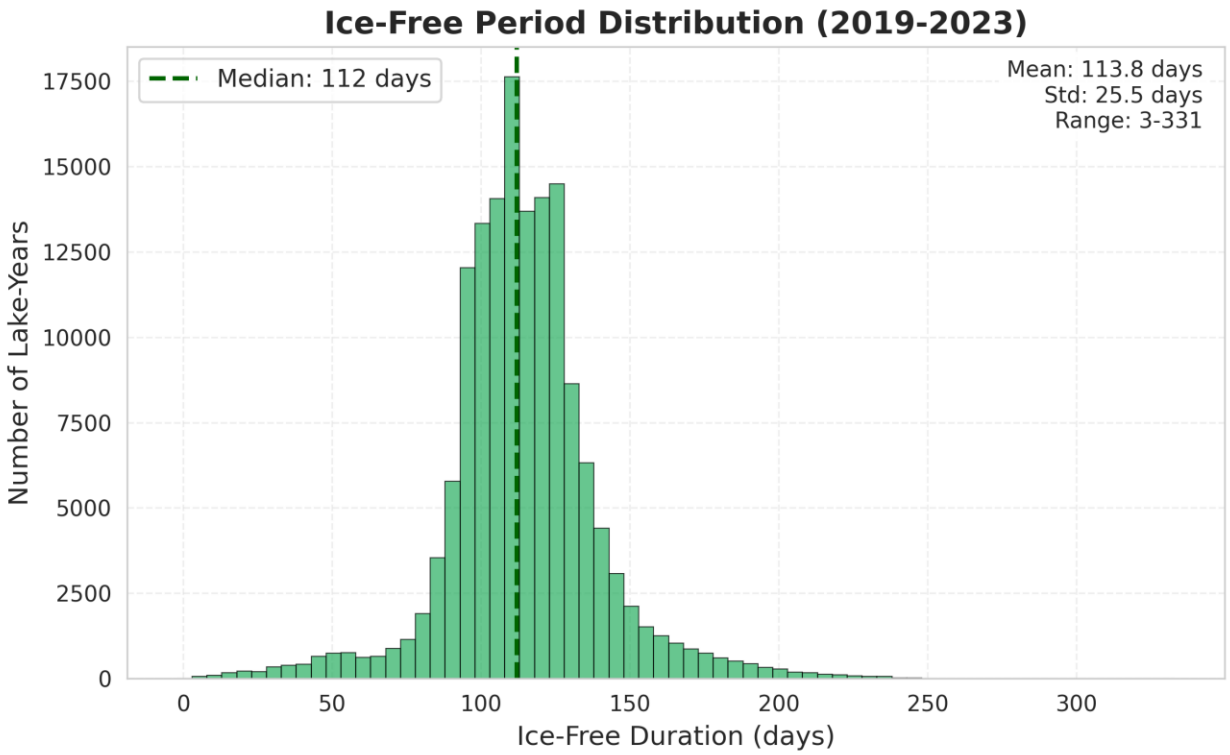



**Figure S2:** SAR RF model-detected ice-free period distribution for the entire 2019 – 2023 time range across all lake-year combinations, where the median (plotted), mean, standard deviation, and range are reported in days.

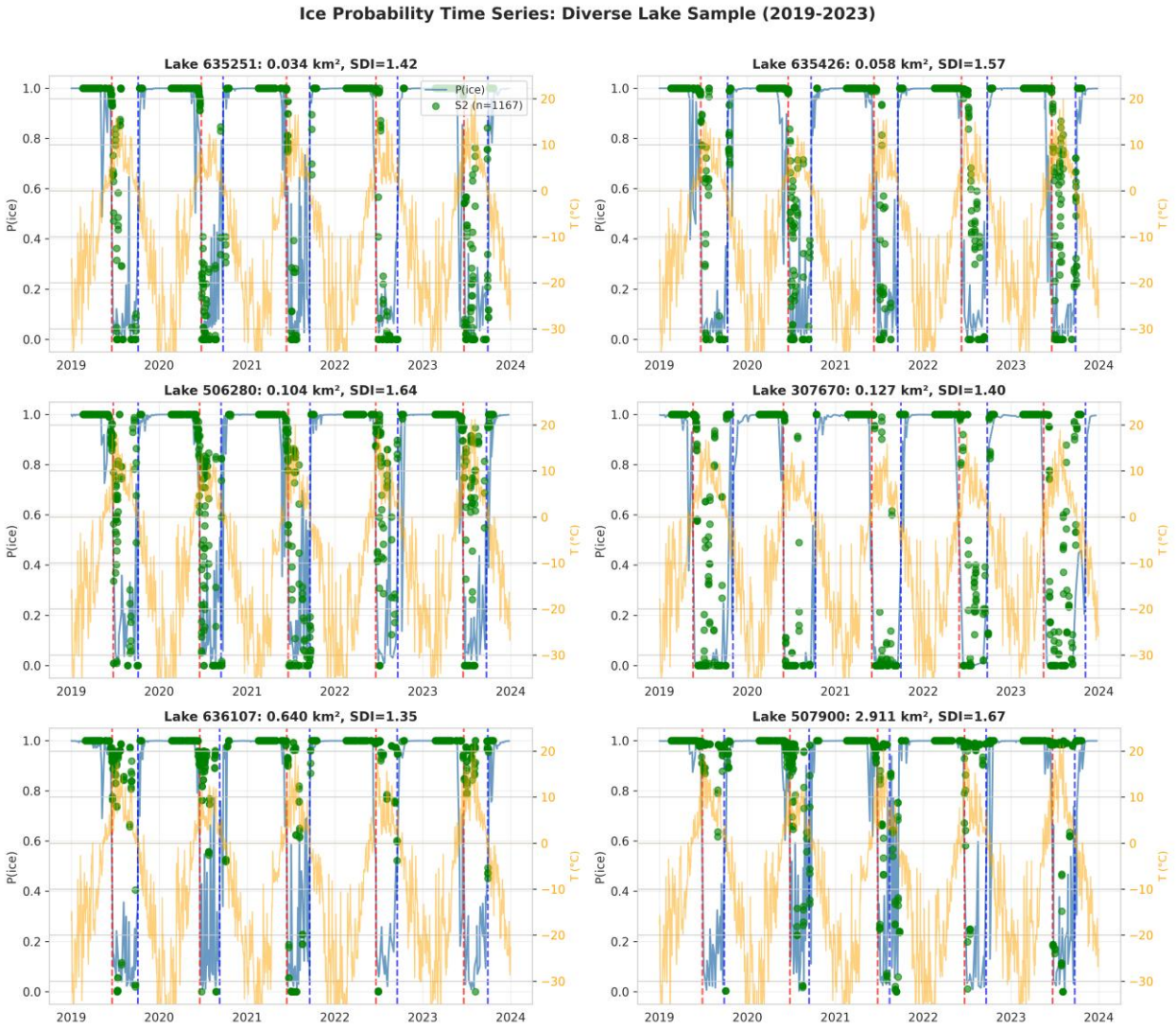



**Figure S3:** Example ice probability time series for six lakes spanning different size classes (Small: < 0.05 km$^2$, Medium: 0.05–0.5 km$^2$, Large: > 0.5 km$^2$) and shoreline complexity (SDI). Blue line: Random Forest ice probability from Sentinel-1; orange line: ERA5 daily temperature; green dots: Sentinel-2 ice fraction. Vertical dashed lines mark detected ice-off (red) and ice-on (blue) dates.

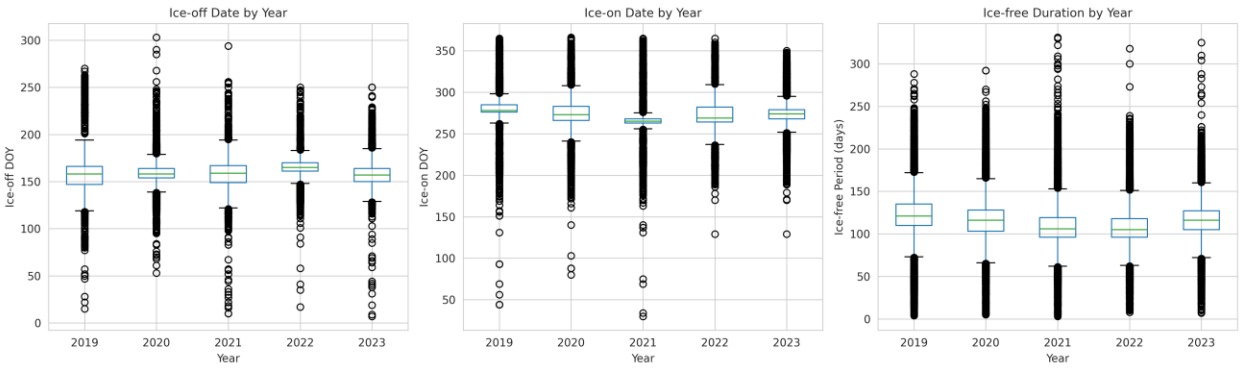



**Figure S4:** Box plots of ice-off dates for phenology-detected lakes each year **(left)**, ice-on dates for each year **(center)**, and ice-free duration (days) for each year **(right)**. Phenology presented here is detected from the SAR RF model.

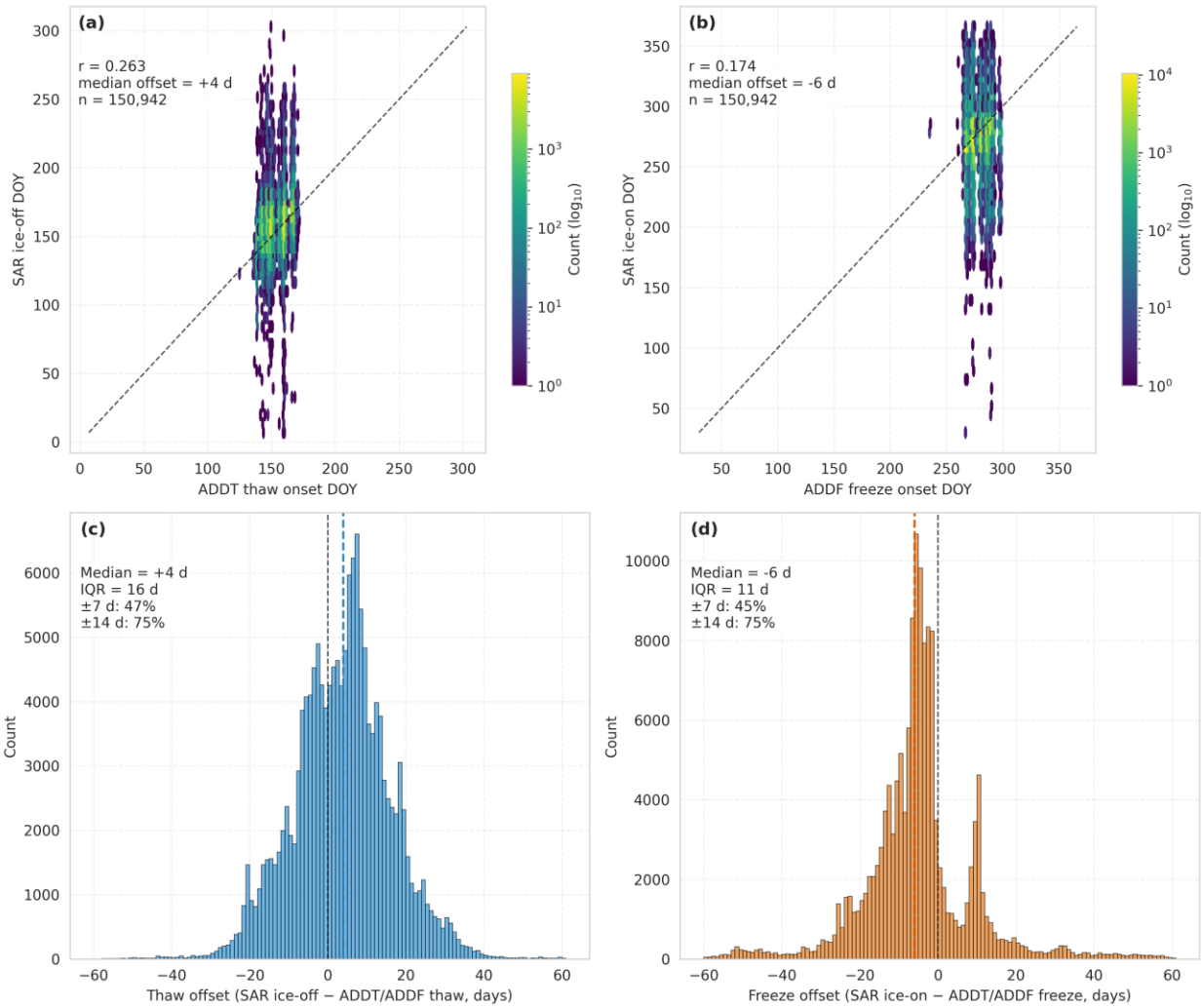



**Figure S5:** Day of year agreement and offset distribution plots. **(a)** ADDT thaw onset vs RF SAR model ice-off (day of year) colored by number of lake-year counts. **(b)** ADDF freeze onset vs RF SAR model ice-on, as in **(a)**. **(c)** Histogram distribution of the thaw offset between RF SAR model ice-off and ADDT thaw onset (days). **(d)** As in **(c)** instead for freeze offset between RF SAR model ice-on and ADDF freeze onset.

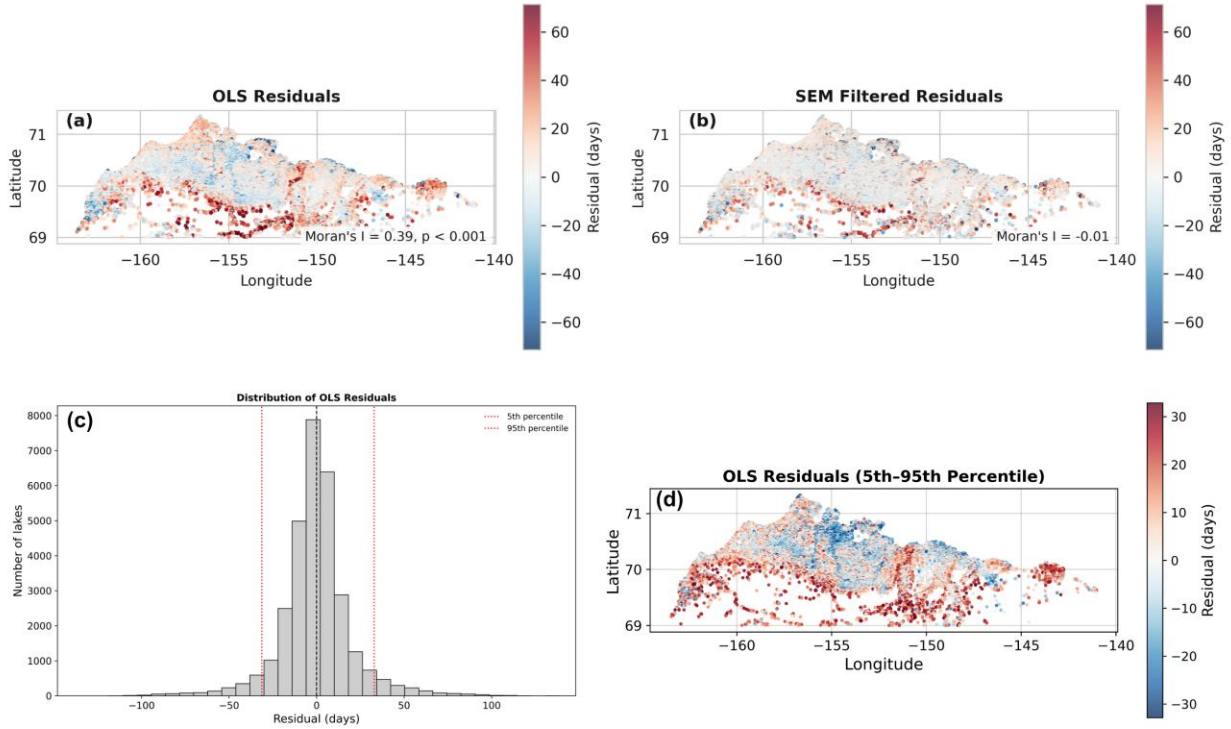



**Figure S6: (a)** OLS residual map and **(b)** SEM filtered residual map, both colored by days along with calculated Moran's I values using the SAR RF model-detected phenology. **(c)** Histogram of OSL residuals, with the 5$^{th}$ and 95$^{th}$ percentiles denoted by the dashed red lines. (d) 5$^{th}$ to 95$^{th}$ percentile of OLS residual map, colored by days.

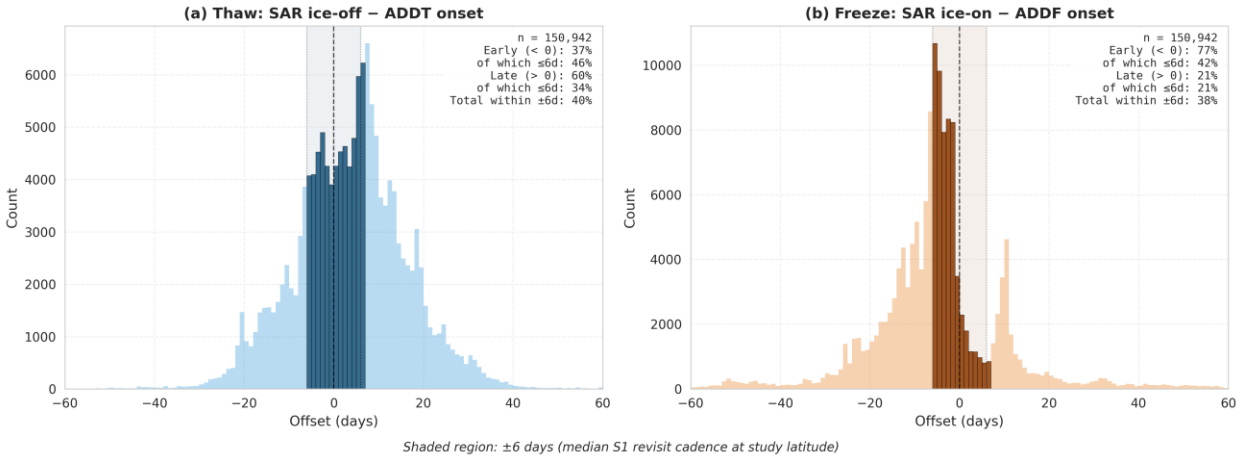



**Figure S7:** Histograms of offsets between RF model detected ice-off date and ADD model onset of thaw date **(a)** and offsets between RF model detected ice-on date and ADD model onset of freeze date **(b)**. Shaded regions indicate the subset of offsets that fall within the SAR revisit temporal resolution. Negative values are where the RF model detects ice-off **(a)** or ice-on **(b)** before the ADD model, and positive values occur where the RF model does so after the ADD model.

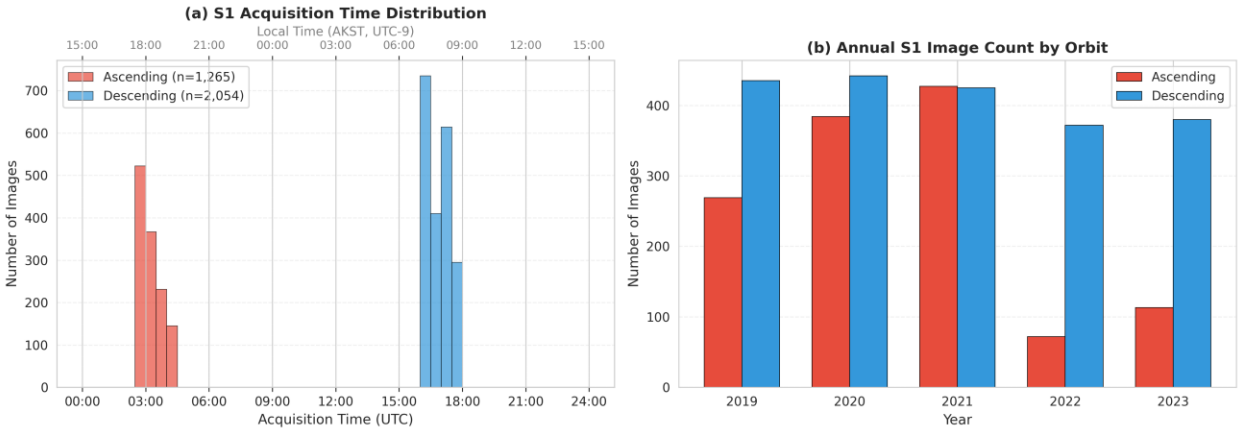



**Figure S8:** Number of Sentinel-1 image information with ascending and descending tracks in red and blue, respectively. **(a)** Acquisition time (in Alaska Standard Time and UTC) distribution for all years of data. **(b)** Number of Sentinel-1 scenes by year and flight direction.

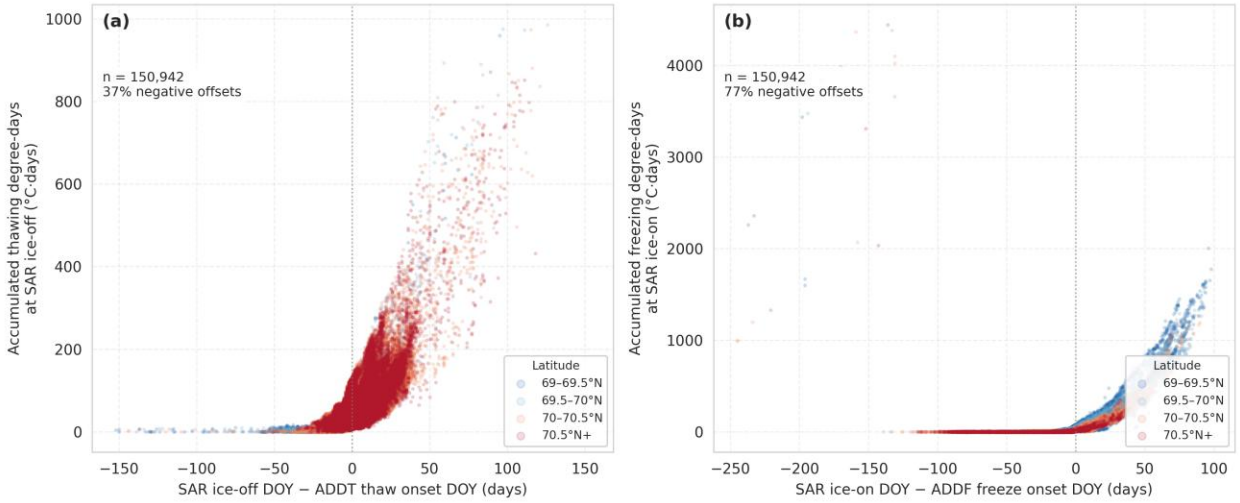



**Figure S9:** Accumulated thawing degree-days (ºC·days) from the ADD model by the time the RF model detected ice-off date occurs vs the timing offset between the RF and ADD models for ice-off date and thaw onset **(a)**. Accumulated freezing degree-days (ºC·days) from the ADD model by the time the RF model detected ice-on date occurs vs the timing offset between the RF and ADD models for ice-on date and freeze onset. Points are colored by latitude bins. Negative values are where the RF model detects ice-off **(a)** or ice-on **(b)** before the ADD model, and positive values occur where the RF model does so after the ADD model.

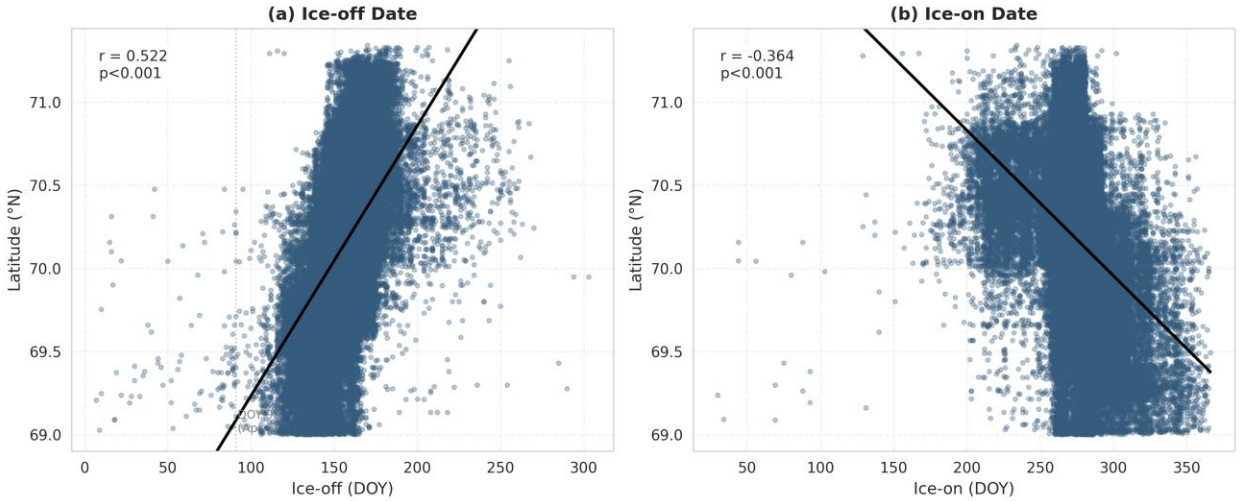



**Figure S10:** Relationship between latitude and ice-off date **(a)**, and latitude and ice-on date **(b)**. The black lines show the linear regression best-fit using the SAR RF model-detected phenology.

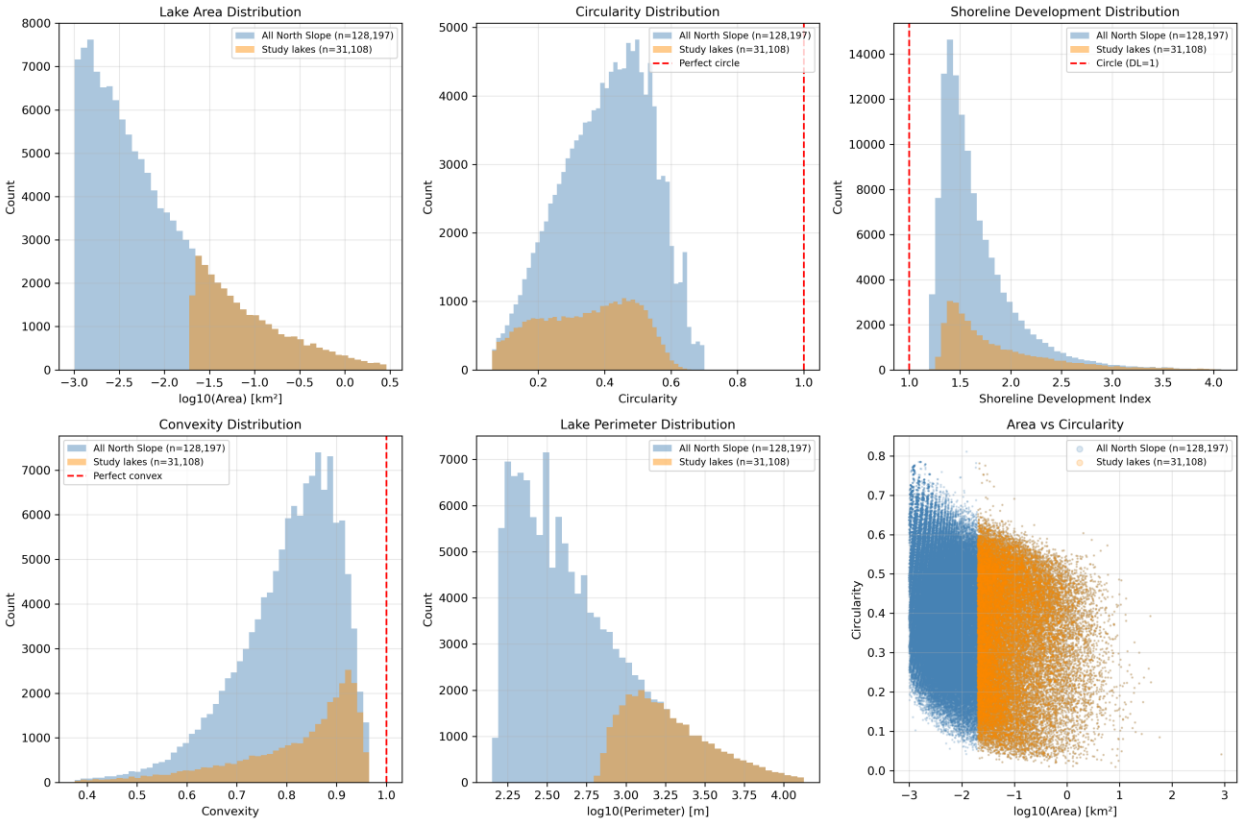



**Figure S11:** Histograms of lake area (km$^2$) for both lakes utilized in this study and all lakes in the study region in the ALPDOD dataset **(top-left)**, circularity **(top-center)**, SDI **(top-right)**, convexity **(bottom-left)**, perimeter **(bottom-center)**, and circularity vs lake area (km$^2$) **(bottom-right)**. Red dashed lines indicate a perfect circle **(top-center)**, a circle **(top-right)** and perfect convexity **(bottom-left)**.

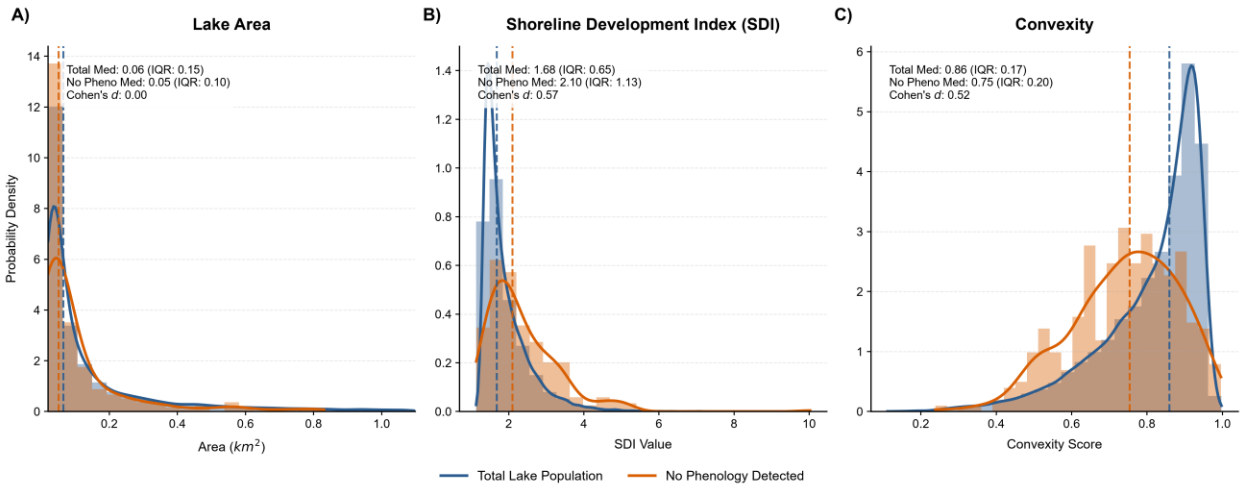



**Figure S12:** Probability density comparison between total lake population and lakes in which no SAR RF model phenology was detected for **A)** lake area, **B)** shoreline development index (SDI), **C)** and convexity.

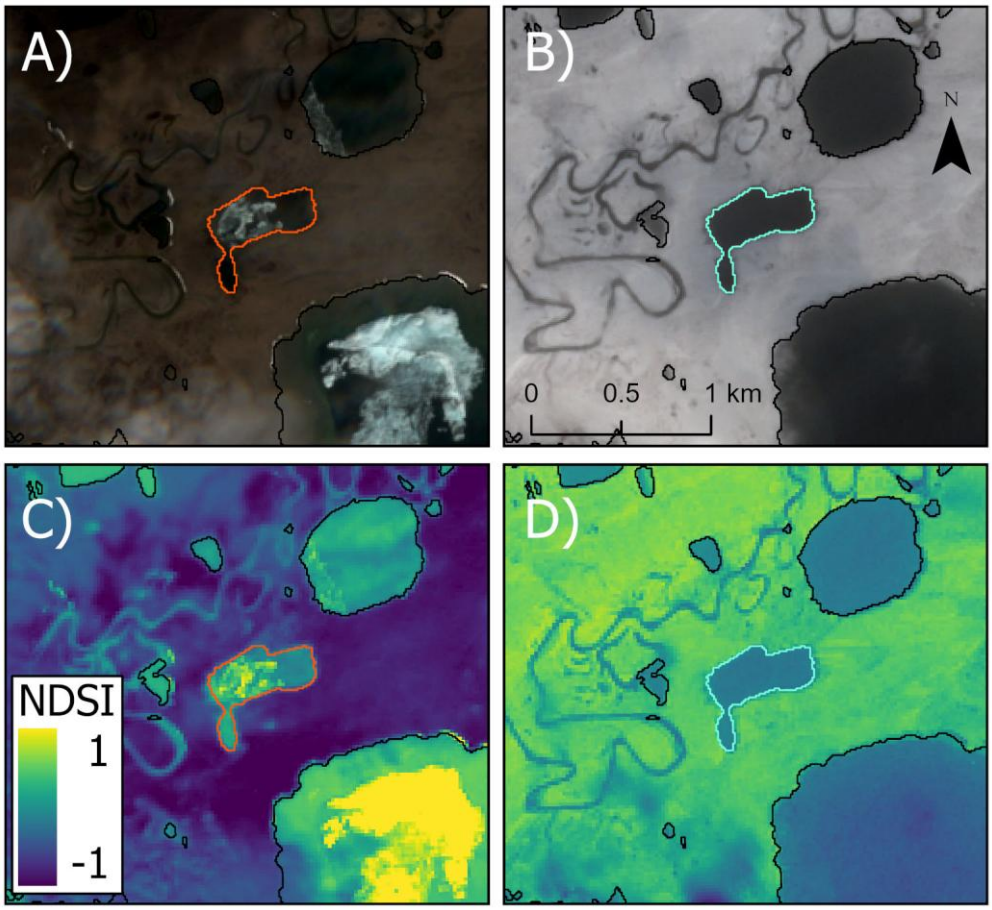



**Figure S13:** Sentinel-2 RGB for Lake ID: 513033 (151.1414 °W, 69.568 °N) on the SAR RF model ice-off date of June 24, 2021 (A) and the ice-on date of September 22nd, 2021 (B), where the randomly-selected lake is highlighted in orange and blue, respectively. C) NDSI for the ice-off date, and D) NDSI for the ice-on date.