Ice Breakup in Three Alaskan Rivers

Identification

1. Description

This regional feature highlights the annual date of river ice breakup for three rivers: the Tanana River at Nenana, Alaska, the Yukon River at Dawson City, Yukon Territory, Canada (the first town upstream from the Alaskan border), and the Kuskokwim River at Bethel, Alaska. These data are available from 1917 (Tanana), 1896 (Yukon), and 1924 (Kuskokwim) to present. The date of ice breakup is affected by several environmental factors, including air temperature, precipitation, wind, and water temperature. For example, a recent comparison with satellite measurements of freeze/thaw conditions at ground level (basically a way of measuring surface temperature) showed a close correlation between regional temperature conditions and actual Tanana River breakup dates (Kim et al., 2017). Tracking the date of ice breakup over time can provide important information about how the climate is changing at a more localized scale. Changes in this date can pose significant socioeconomic, geomorphic, and ecologic consequences (Beltaos & Burrell, 2003).

2. Revision History

May 2014:	Feature published.
June 2015:	Updated feature with data through 2015.
August 2016:	Updated feature with data through 2016.
April 2021:	Updated feature with data through 2020; added the Kuskokwim River.
July 2022:	Updated feature with data through 2022.
December 2024:	Updated feature with data through 2024.

Data Sources

3. Data Sources

This feature presents the annual ice breakup data collected as part of the Nenana Ice Classic, Yukon River Breakup, and Kuskokwim Ice Classic competitions. The Nenana Ice Classic is an annual competition to guess the exact timing of the breakup of ice in the Tanana River. Since its inception in 1917, the competition has paid more than $15 million in winnings (Nenana Ice Classic, 2024). Similar betting traditions occur with the Yukon River in Dawson City, where ice breakup dates have been recorded since 1896, and the Kuskokwim River in Bethel, where breakup dates have been recorded since 1924.

4. Data Availability

All of the ice breakup data used are publicly available:

- **Tanana River.** Data from 1917 to 2024 come from the National Snow and Ice Data Center, which maintains a comprehensive database at: https://doi.org/10.5067/CAQ58H42LQY2. Breakup dates for this river and several other Alaskan rivers are also archived by the National

Weather Service (NWS) Alaska-Pacific River Forecast Center at: www.weather.gov/aprfc/breakupDB.

- **Yukon River.** Data from 1896 to 2024 are maintained by Mammoth Geospatial and are available at: www.yukonriverbreakup.com/statistics.
- **Kuskokwim River.** Most data from 1924 to 2024 were retrieved from the NWS Alaska-Pacific River Forecast Center database at: www.weather.gov/aprfc/breakupDB. The Kuskokwim Ice Classic website displays a calendar of breakup dates at: http://iceclassic.org/historical-data. This calendar was used to fill a gap in the NWS database for 1966. Three years—1933, 1939, and 1965—were missing from both data sources.

Methodology

5. Data Collection

To measure the exact time of ice breakup, residents in Nenana, Dawson City, and Bethel use tripods placed on the ice in the center of the river. This tripod is attached by a cable to a clock on the shore, so that when the ice under the tripod breaks or starts to move, the tripod will move and pull the cable, stopping the clock with the exact date and time of the river ice breakup. In Nenana, the same wind-up clock has been used since the 1930s. Prior to the tripod method, observers watched from shore for movement of various objects placed on the ice. Dawson City also used onshore observers watching objects on the ice during the early years of the competition. For more information about these competitions, see: www.nenanaakiceclassic.com, www.yukonriverbreakup.com/statistics, and http://iceclassic.org.

6. Derivation

Figure 1 plots nine-year moving averages for the annual ice breakup dates for each river. For some years, the original data set included the exact time of day when the ice broke, which could allow dates to be expressed as decimals (e.g., 120.5 would be noon on Julian day 120, which is the 120th day of the year). Some other years in the data set, however, did not include a specific time. Thus, for consistency, EPA chose to plot and analyze integer dates for all years (e.g., the example above would simply be treated as day #120).

Some data points were provided in the form of Julian days. In other cases where data points were provided in the form of calendar dates (e.g., May 1), EPA converted them to Julian days following the same method that was used to calculate Julian days in the original data set. By this method, January 1 = day 1, January 2 = day 2, etc. The method also accounts for leap years, such that April 30 = day 120 in a non-leap year and day 121 in a leap year.

To smooth out some of the variability in the annual data and to make it easier to see broad patterns in the time series, EPA did not plot annual breakup dates but instead calculated nine-year moving averages (arithmetic means) for each river. EPA chose a nine-year period because it is a commonly used temporal averaging method and is consistent with other EPA climate change indicators. Average values are plotted at the center of each nine-year window. For example, the average from 1990 to 1998 is plotted at year 1994.

EPA used endpoint padding to extend the nine-year smoothed lines all the way to the end of the analysis period for each river. For example, if annual data were available through 2024, EPA calculated nine-year smoothed values centered at 2021, 2022, 2023, and 2024 by inserting the 2020–2024 average into the equation in place of the as-yet-unreported annual data points for 2025 and beyond. EPA used an equivalent approach at the beginning of each time series.

No annual data points were missing in the periods of record for the Tanana and Yukon Rivers. Three years of data (1933, 1939, and 1965) were missing for the Kuskokwim River, but averages could still be calculated and plotted during these periods using all available years of data within the nine-year averaging window. This feature does not attempt to portray data beyond the time periods of observation.

7. Quality Assurance and Quality Control

The method of measuring river ice breakup ensures that an exact date and time is captured. Furthermore, the heavy betting tradition at all three locations has long ensured a low tolerance for errors, as money is at stake for the winners and losers.

Analysis

8. Comparability Over Time and Space

River ice breakup dates have been recorded annually for the Tanana River since 1917, for the Yukon River since 1896, and for the Kuskokwim River since 1924, using a measuring device or other objects placed on the river ice at the same location every year. This consistency allows for comparability over time.

9. Data Limitations

Factors that may impact the confidence, application, or conclusions drawn from the data are as follows:

1. While the record of river ice breakup dates is comprehensive, there are no corresponding environmental measurements (e.g., water conditions, air temperature), which limits one's ability to directly connect changes in river ice breakup to changes in climate.

2. Other factors, such as local development and land use patterns, may also affect the date of ice breakup. The three locations featured here, however, are fairly remote and undeveloped, so the ice breakup dates are more likely to reflect natural changes in weather and climate conditions.

10. Sources of Uncertainty

This regional feature is likely to have very little uncertainty. The measurements are simple (i.e., the day when the ice starts to move at a particular location) and are collected with a device rather than relying on the human eye. Measurements have followed a consistent approach over time, and the competitive nature of the data collection effort means it is highly visible and transparent to the community, with low tolerance for error.

11. Sources of Variability

Natural climatic and hydrologic variations are likely to create year-to-year variation in ice breakup dates. For a general idea of the variability inherent in these types of time series, see Magnuson et al. (2000) and Jensen et al. (2007)—two papers that discuss variability and statistical significance for a broader set of lakes and rivers.

12. Statistical/Trend Analysis

EPA calculated long-term trends in river ice breakup for each river by ordinary least-squares linear regression to support statements in the "Key Points" text. All three long-term trends were statistically significant at a 95-percent confidence level:

- Kuskokwim regression slope, 1924–2024: -0.076 days/year ($p = 0.01$)
- Tanana regression slope, 1917–2024: -0.082 days/year ($p < 0.001$).
- Yukon regression slope, 1896–2024 -0.062 days/year ($p < 0.001$).

All three of these regressions are based on Julian dates, so they account for the influence of leap years (see Section 6 for more discussion of leap years). These regressions are also based on integer values for all years. As described in Section 6, some of the available data points included time of day, but others did not, so the graph and the regression analysis use integer dates for consistency.

References

Beltaos, S., & Burrell, B. C. (2003). Climatic change and river ice breakup. *Canadian Journal of Civil Engineering*, *30*(1), 145–155. https://doi.org/10.1139/l02-042

Jensen, O. P., Benson, B. J., Magnuson, J. J., Card, V. M., Futter, M. N., Soranno, P. A., & Stewart, K. M. (2007). Spatial analysis of ice phenology trends across the Laurentian Great Lakes region during a recent warming period. *Limnology and Oceanography*, *52*(5), 2013–2026. https://doi.org/10.4319/lo.2007.52.5.2013

Kim, Y., Kimball, J. S., Glassy, J., & Du, J. (2017). An extended global Earth system data record on daily landscape freeze–thaw status determined from satellite passive microwave remote sensing. *Earth System Science Data*, *9*(1), 133–147. https://doi.org/10.5194/essd-9-133-2017

Magnuson, J. J., Robertson, D. M., Benson, B. J., Wynne, R. H., Livingstone, D. M., Arai, T., Assel, R. A., Barry, R. G., Card, V., Kuusisto, E., Granin, N. G., Prowse, T. D., Stewart, K. M., & Vuglinski, V. S. (2000). Historical trends in lake and river ice cover in the Northern Hemisphere. *Science*, *289*(5485), 1743–1746. https://doi.org/10.1126/science.289.5485.1743

Nenana Ice Classic. (2024). *Nenana Ice Classic 2024 brochure*. www.nenanaakiceclassic.com/brochures