KEYWORDS: Climate; Climate change; Climate classification/ regimes

ABSTRACT: Adapted from the sports concept of scorigami, the weathergami chart is introduced. Weathergami charts depict the frequency of occurrence of the full range of daily maximum and minimum temperature combinations observed at a location. These charts highlight essential features of climate not evident in traditional representations. A variation of the weathergami chart displays transition frequencies, which describe the likelihood of particular day-to-day changes in maximum and minimum temperatures. Likewise, weathergami anomaly charts reveal characteristics of changing climate not evident in standard time series representations. Several examples are provided, with comparisons to climate descriptions found in popular textbooks.

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corigami, a combination of the words score and origami, is a score that has never
occurred before in a sporting contest (SB Nation 2016). Originally conceived by
sportswriter Jon Bois, scorigami is often depicted via charts and has become a popular
concept among enthusiasts of many different sports (Fig. 1). Scorigami has garnered
particular attention in the U.S. National Football League, where points typically accrue in
increments of two, three, six, and seven. Over 1,000 different final scores have been achieved
since the league’s inception in 1920 (Molski 2023). Legal sports betting establishments
offer longshot odds for a scorigami to occur in a particular contest (Murphy 2022).

The weathergami chart
Inspired by scorigami, we introduce the weathergami chart as a new way to examine the
climate of different locations. The weathergami chart depicts the occurrence frequencies
of all combinations of daily maximum and minimum temperatures observed at a particular
location.

The weathergami chart is analogous to the word cloud, which uses word frequency
visualization to tell a story with textual data (Viégas et al. 2009). Word clouds, also known as
wordles and related to tag clouds, present word frequency data as a visually dynamic graphic
statement with aesthetic combinations of typeface, color, and layout. Word clouds are consid-
ered a form of social visualization: an attractive, compact, public-friendly alternative to detailed
lists, increasingly utilized in mainstream media and education (Hearst and Rosner 2008). The
weathergami chart is similarly designed to visualize climate data in an easily digestible format.

To show real-world examples of weathergami charts, several examples were prepared for
locations with different climate types (Table 1). Daily summary observations from 1950 to
2021 at U.S. Automated Surface Observing System stations (NOAA 1998) were accessed via
the Iowa State University’s Iowa Environmental Mesonet weather server (https://mesonet.agron.
iastate.edu/). Max/min temperature occurrence frequencies were calculated and plotted using
Microsoft Excel.

Examples are shown in Fig. 2. Chicago, Illinois, a midlatitude site frequently impacted by
both polar and tropical air masses, experiences a wide range of both maximum and mini-
um daily temperatures (left column). Chicago’s annual weathergami chart (top panel) thus
features a long, broad swath of max/min temperature combinations. Maximum temperatures
range from very hot (100°F) to very cold (−10°F), with a minimum temperature range of
80° to −20°F. Two areas of somewhat larger max/min temperature frequency are evident,
representing summer and winter conditions. Weathergami charts for these seasons, shown
in the middle and bottom panels of Fig. 2, reveal swathes of observed max/min combinations
that are larger in winter than in summer, indicating that much of Chicago’s annual tempera-
ture variability occurs during winter.

Honolulu, Hawaii, a tropical location in the Pacific Ocean, has a markedly different weath-
ergami chart (Fig. 2, right column). In contrast to Chicago, minimal seasonality in tempera-
ture is evident at Honolulu, with a much smaller annual range of both maximum (70°–90°F)
and minimum (55°–80°F) temperatures. As a result, the weathergami for Honolulu covers
Fig. 1. Major League Baseball scorigami chart (https://scorigami.danaben.net). Scorigami charts are also available for many other sports including basketball, football, hockey, and rugby.
Table 1. Details of weather data utilized.

<table>
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<th>Location</th>
<th>Call ID</th>
<th>Latitude (°N)</th>
<th>Longitude (°W)</th>
<th>Elevation (m MSL)</th>
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<td>87.934</td>
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<tr>
<td>Honolulu</td>
<td>HNL</td>
<td>21.324</td>
<td>157.929</td>
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</tr>
<tr>
<td>Utqiaġvik</td>
<td>BRW</td>
<td>71.283</td>
<td>156.782</td>
<td>9</td>
</tr>
<tr>
<td>San Francisco</td>
<td>SFO</td>
<td>37.620</td>
<td>122.365</td>
<td>2</td>
</tr>
</tbody>
</table>

Fig. 2. Weathergami charts for (left) Chicago and (right) Honolulu. (top) Daily data from 1950 to 2021. (middle) Summers (June–August). (bottom) Winters (December–February).
much less area on the chart, without differing areas of higher frequencies as was noted for Chicago. Rather, much of the reduced chart area exhibits the highest occurrence frequencies, displaying similar characteristics in both summer and winter.

Variability in max/min temperature combination frequency can be quantified with a typical combination frequency (TCF) statistic, defined as the total frequency of all temperature combinations that occurred on at least 0.1% of days during the analysis period (26 days for annual periods; 6 days for seasonal periods). For Chicago the winter TCF was 0.58, indicating that 42% of days (i.e., 1 − TCF) experienced temperature combinations outside the typical range of 30°–40°F for the maximum and 20°–35°F for the minimum. Chicago’s summer TCF was 0.79, indicating that only 21% of days experienced maximum temperature combinations outside the typical range of 75°–90°F for the maximum and 55°–70°F for the minimum. TCF values for Honolulu were 0.97 (summer) and 0.95 (winter), confirming the scarcity of atypical max/min temperature combinations.

A variation of the weathergami chart displays transition frequencies, which describe the likelihood of particular changes to maximum and minimum temperatures from day to day. Transition frequencies for Chicago and Honolulu (Fig. 3) present considerably different patterns. In Chicago, small daily changes from −5° to 5°F in maximum and minimum temperatures are the most common, however extreme daily changes of up to ±30°F have frequently occurred in the 1950–2021 analysis period. The asymmetric lobe of temperature drops exceeding −20°F is likely associated with lake breeze fronts occurring on the western shore of Lake Michigan (Roebber and Gehring 2000). In Honolulu daily max/min temperature changes are much smaller, generally less than ±5°F, although changes up to ±10°F have occurred.

Similar to the weathergami chart, the transition frequency characteristics can be quantified with a typical transition frequency (TTF) statistic, defined as the total frequency with which typical transitions are observed (i.e., the sum of the occurrence frequencies of all squares except those with the lightest blue color). The TTF is 0.64 for Chicago, indicating that 36% of the time, the day-to-day changes in max/min temperatures are outside the common range of −5° to 5°F, consistent with the variable weather of a midlatitude, continental site often in the vicinity of the polar front. The TTF is 0.95 for Honolulu, indicating that daily max/min temperature changes are rarely outside the most frequent range of −5° to 5°F, representing the static weather of a tropical, marine location.

Fig. 3. Transition frequencies for (top) Chicago and (bottom) Honolulu, based on daily data from 1950 to 2021.
A complementary paradigm for describing climate and climate change

Introductory meteorology textbooks typically utilize the climograph (Huschke 1995), which depicts the annual progression of average monthly temperature and precipitation, to characterize a location’s climate. The climograph for Utqiaġvik (formerly known as Barrow), Alaska, an Arctic Ocean coastal site, is an example commonly featured in introductory meteorology textbooks (Fig. 4). Lutgens and Tarbuck (2013) describe Utqiaġvik’s climate as polar tundra (Köppen category ET), with enduring cold and meager precipitation. Ackerman and Knox (2015) explain that the “polar” climate classification requires the mean temperature of the warmest month to be below 50°F (10°C), as this temperature is the minimum necessary for tree growth. Ahrens and Hensen (2019) provide details on Utqiaġvik’s permafrost, describing how above-freezing summer temperatures thaw the topmost soil layer, turning the tundra swampy and muddy. Aguado and Burt (2015) cite Utqiaġvik’s minimum temperatures and strong stability as factors inhibiting precipitation.

Weathergami and transition frequency charts present a complementary paradigm for describing a location’s climate by supplementing the standard climograph with additional information on maximum and minimum daily temperatures, temperature extremes, and daily and seasonal max/min temperature variability. Weathergami charts for Utqiaġvik (Fig. 5, left) depict a broad swath of max/min temperature combinations with concentrated frequencies of around −10°/−20°F (winter) and around 35°/32°F (summer). Winter max/min temperature combinations are much more variable than during summer, with TCF values of 0.57 and 0.83, respectively. The seasonal change in daily max/min temperature variability is further evident in the transition frequency diagrams (Fig. 5, right), with TTF values of 0.64 (winter) and 0.83 (summer).

Weathergami similarly provides a complementary means of visualizing climate change. Time series of summertime monthly temperatures from 1950 to 2021 at San Francisco, California, along the Pacific coast, for example, show increases of around 5°F in both maximum and minimum temperatures (Fig. 6, top). Weathergami anomaly charts for the same period (Fig. 6, middle and bottom) present a somewhat different perspective that reveals characteristics of the temperature changes not evident in the time series. The leftmost region (solid circle) of the weathergami anomalies displays a consistent decrease in occurrence frequency.

Fig. 4. Climograph for Utqiaġvik (formerly known as Barrow), Alaska. Temperature (line, left scale) and precipitation (bars, right scale) for 1950–2021 from the Global Summary of the Month dataset were obtained from the U.S. National Centers for Environmental Information (ncei.noaa.gov).
Fig. 5. (left) Weathergami and (right) transition frequencies for Utqiaġvik (formerly known as Barrow), Alaska.
from the early (1950–79) to the latter (1992–2021) portions of the analysis period. The adjacent warmer region (below and to the right of the solid circle), exhibits a corresponding increase in frequency. This indicates that San Francisco's cooler summer days (days with maximum temperatures of 55°–75°F) are getting warmer, with increases in both daily maximum and minimum temperatures. The right portions of the weathergami charts (dashed circles) indicate

Fig. 6. (top) Time series of monthly summer temperatures at San Francisco, 1950–2021. Weathergami anomalies at San Francisco for (middle) 1950–79 and (bottom) 1992–2021 during summer. Anomalies were determined by subtracting the 1950–2021 max/min temperature frequencies from those during the indicated periods.
a different behavior for San Francisco’s warmest summer days, when maximum temperatures exceed 85°F. During these warmer days the minimum temperatures have increased, while maximum temperatures have not changed in a consistent manner.

Future directions
Weathergami, adapted from the sports concept of scororigami, depicts max/min temperature occurrence frequencies that can highlight essential features of climate data not evident in the classic climograph or time series representations. As such, weathergami has the potential to be an effective framework for the analysis and display of weather and climate data.

Weathergami may be useful in related fields such as climate risk perception and communication (Pidgeon 2012) and climate-smart agriculture (Chandra et al. 2017), where charts could be adjusted or expanded to display precipitation, insolation, or variables representing agricultural or geo-economic factors. The time frames could be altered as well, with weathergami charts displaying monthly or annual combination frequencies. Weathergami charts may also provide a useful means of visualizing forecast quality (e.g., Roebber 2009). Animations of annual anomaly charts such as those in Fig. 6 (middle and bottom) can provide illustrative opportunities to visualize climate change, analogous to the climate spiral animation designed by climate scientist Ed Hawkins (https://climate.nasa.gov/climate_resources/300/video-climate-spiral-1880-2022/). Efforts are planned to utilize weathergami to visualize the climates of diverse locations and to provide an interface where users can make their own weathergami charts.

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Data availability statement. Daily maximum and minimum temperature observations from 1950 to 2021 at U.S. Automated Surface Observing System stations were obtained from the Iowa State University’s Iowa Environmental Mesonet weather server (https://mesonet.agron.iastate.edu/). Monthly average temperature and precipitation data (Global Summary of the Month data set) for 1950–2021 were obtained from the U.S. National Centers for Environmental Information (ncei.noaa.gov).

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