Actuarial Weather Extremes Series: Quarterly Global Warming Report

Catastrophe and Climate

Patrick Wiese, ASA

July 2025

Global Warming Trends through June 2025

This report presents a statistical analysis of global warming trends. The report is updated every three months to reflect the latest data. The data source for the analysis is ERA5, produced by the European Centre for Medium-Range Weather Forecasts (ECMWF). For the period from January 1960 through June 2025, Figures 1A and 1B show the 12-month trailing average of global average air temperature and global average sea surface temperature (SST), respectively. Air temperature is averaged across the earth's entire surface, while average SST excludes latitudes north of 60N and south of 60S (an approach that is commonly used by climate scientists to compute average SST).

12-MONTH TRAILING AVERAGE OF GLOBAL TEMPERATURE FROM JANUARY 1960 TO JUNE 2025

Figure 1A. Air Temperature (F)

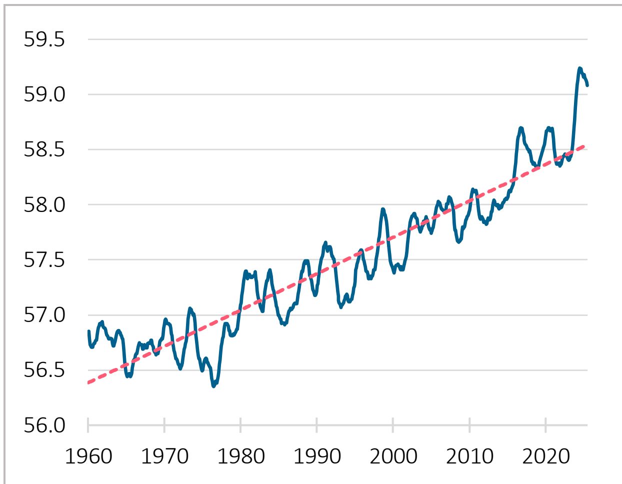
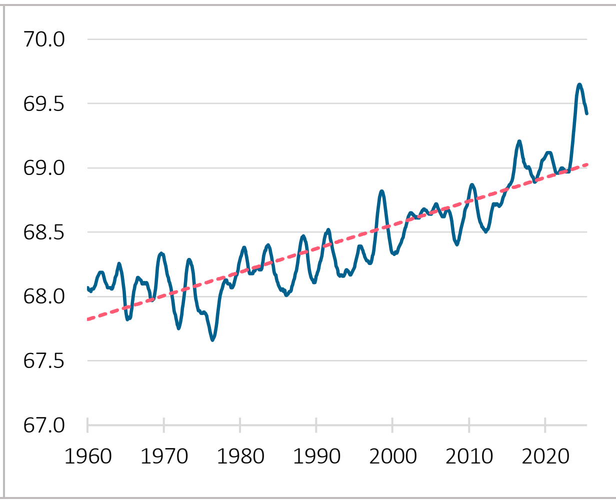


Figure 1B. Sea Surface Temperature (F)



Figures 1A and 1B reveal strong long-term warming trends. Using linear regression, the estimated long-term trend is +0.33F per decade for air temperature, and +0.18F per decade for SST.

Figures 2A and 2B present the same data as in Figures 1A and 1B but focus solely on the period from June 2022 to June 2025. The graphs reveal that the 12-month trailing averages of air temperature and SST rose steadily from January 2023 through June 2024. For both air temperature and SST, a peak was reached in June 2024 (reflecting data from July 2023 through June 2024). Since then, the 12-month trailing averages have declined slightly, but remain near their record highs.

12-MONTH TRAILING AVERAGE OF GLOBAL TEMPERATURE FROM JUNE 2022 TO JUNE 2025

Figure 2A. Air Temperature (F)

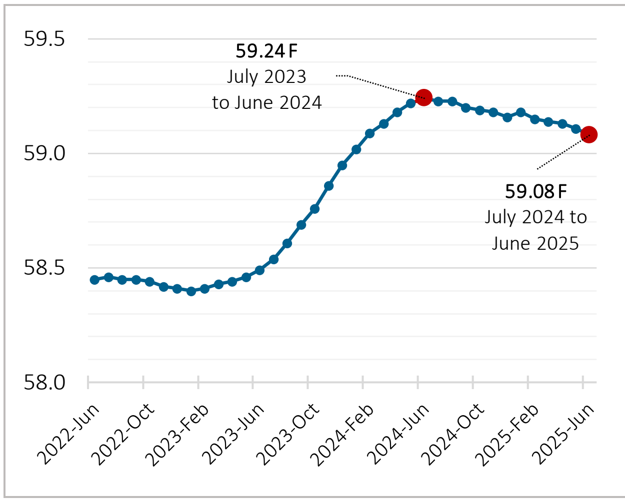


Figure 2B. Sea Surface Temperature (F)

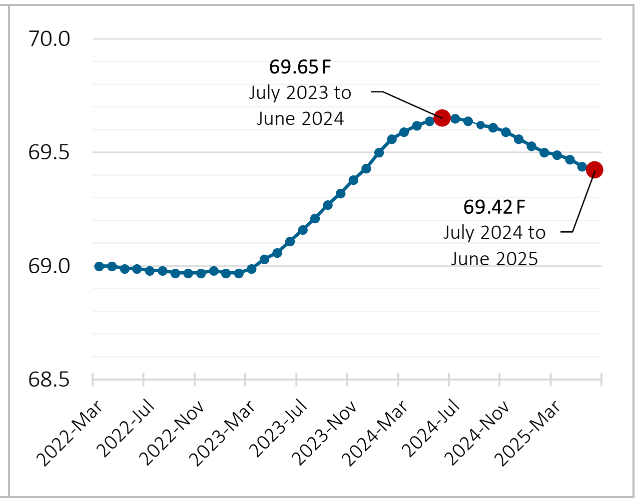
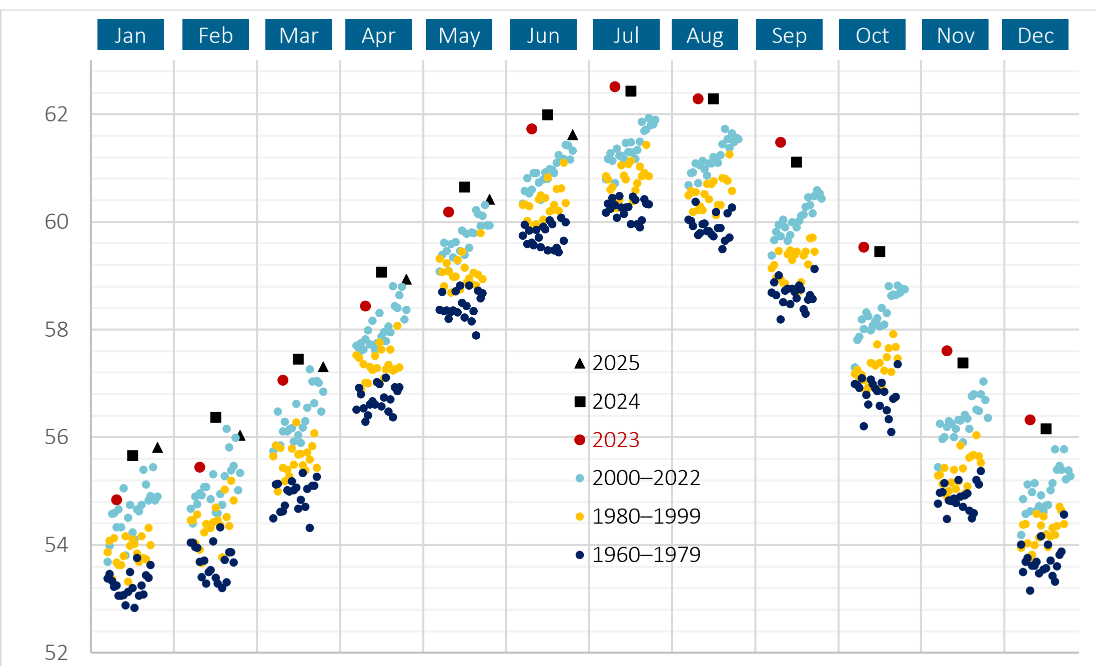


Figure 3 shows global average air temperature for each separate month (as opposed to the rolling 12-month averages show in Figures 1 and 2). Record-high monthly temperatures occurred in 13 consecutive months, from June 2023 to June 2024, and again in January 2025. In the most recent quarter (April to June 2025), the global average temperature is slightly below record-high levels.

Figure 3

GLOBAL AVERAGE AIR TEMPERATURE (F) BY MONTH



In 2023 and 2024, record-high global temperatures occurred in 13 consecutive months. Thus far in 2025, global average air temperature is slightly below its prior record-highs.

It is worthwhile to briefly explain the seasonal cycle of global average air temperature that is apparent in Figure 3. This seasonality may seem counterintuitive given that, on a global level, the earth receives about the same total amount of solar energy per day throughout the year. When the northern hemisphere experiences fall and winter, the southern hemisphere experiences spring and summer, and vice versa. Less daylight in one hemisphere is counterbalanced by more daylight in the opposing hemisphere. This suggests that global average temperature should remain roughly constant from one month to the next. However, the northern hemisphere contains over two-thirds of the earth's land mass, and, in general, land heats up more quickly than does water in response to a given influx of solar energy. Consequently, global average temperature carries a strong signature of the northern hemisphere's seasonal temperature changes.

Air and Sea-Surface Temperature Anomalies

In the parlance of climate scientists, temperatures defined relative to their corresponding long-term averages are "temperature anomalies." The anomalies in Figures 4A and 4B are defined relative to 1960–2019 averages. The figures present anomalies of four temperature metrics: (1) air temperature averaged across the entire surface of the earth, (2) air temperature over land areas, (3) air temperature over oceans, bays, and lakes; (4) and sea surface temperature (SST). To better illustrate long-term trends, Figure 4A shows anomalies averaged across trailing 60-month periods. The final 60-month period runs from July 2020 through June 2025. Figure 4B focuses solely on the period from June 2023 to June 2025 and uses a 12-month averaging period rather than 60 months. The final 12-month period captured in Figure 4B runs from July 2024 to June 2025.

TRAILING AVERAGE OF GLOBAL TEMPERATURE ANOMALIES

Figure 4A. Anomalies Averaged Across Trailing 60 Months (F)

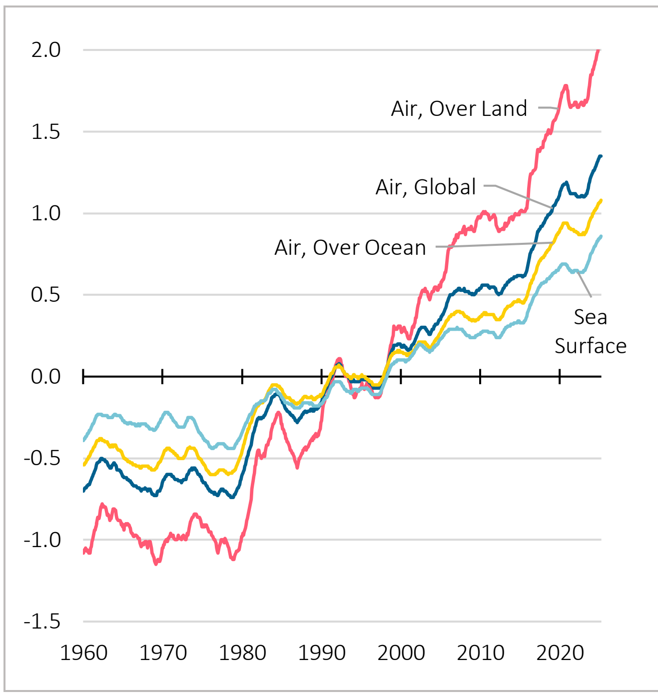


Figure 4B. Anomalies Averaged Across Trailing 12 Months (F)

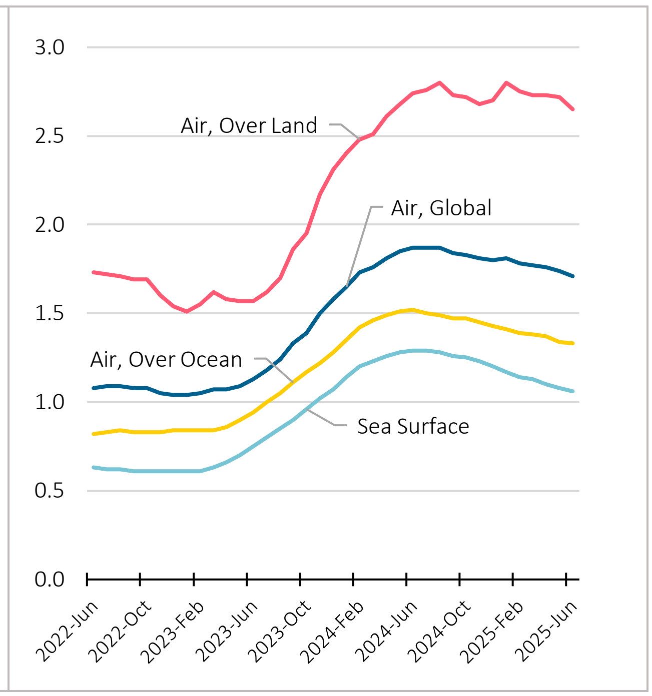


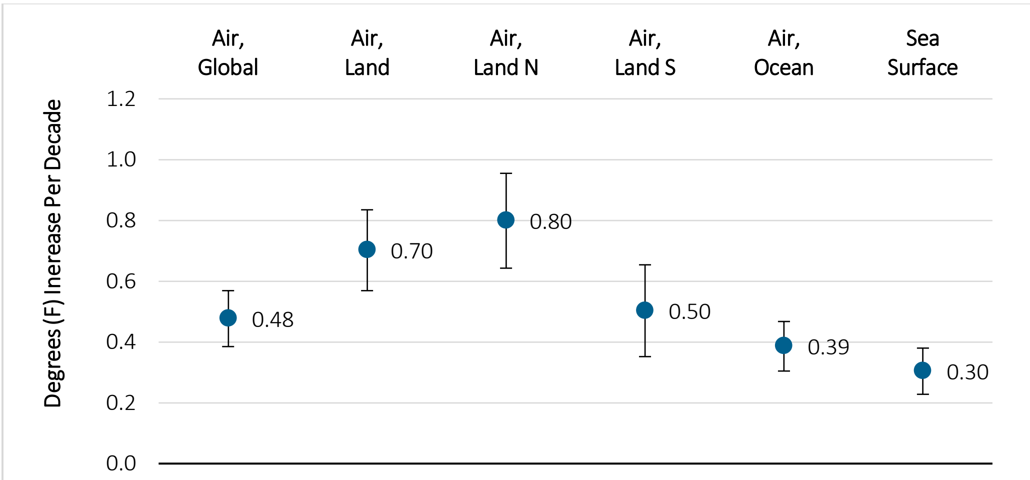
Figure 4A reveals that global average air temperature has risen faster than average SST, and air temperature over land has risen faster than air temperature over oceans. Figure 4B reveals that 12-month trailing average anomalies climbed steadily upwards from June 2023 to June 2024, before declining slightly thereafter.

Warming Trends Estimated Using the Most Recent 30 Years of Data

To estimate warming trends for air temperature and SST, linear regressions were run across the most recent 30 years of data. A period of 30 years is long enough to cancel-out short-term climate cycles such as El Nino and La Nina which can influence global temperatures[1]. The slope of each regression line provides an estimate of the rate-of-warming. Figure 5 shows the best estimate for each slope, as well as the 95% confidence interval.

Figure 5

ESTIMATED WARMING TREND FOR THE 30-YEAR PERIOD FROM JULY 1995 TO JUNE 2025



Average air temperature is increasing at a faster rate than sea surface temperature, and the northern hemisphere is warming at a faster rate than the southern hemisphere.

Note: Best estimates for trends are represented by blue dots, while the vertical bars represent 95% confidence intervals. “Air, Land” is air temperature averaged across all land areas, while “Air, Land N” and “Air, Land S” capture solely the land areas in the northern and southern hemispheres, respectively. “Air, Ocean” is air temperature across all bodies of water. “Sea surface” is the average water temperature across the surface of oceans and other bodies of water.

The results in Figure 5 indicate that average air temperature is increasing at a significantly faster rate than SST, and that air temperature over land is increasing at a faster rate than air temperature over water. Lastly, with respect to air temperature over land, the northern hemisphere is warming at a faster rate than the southern hemisphere.

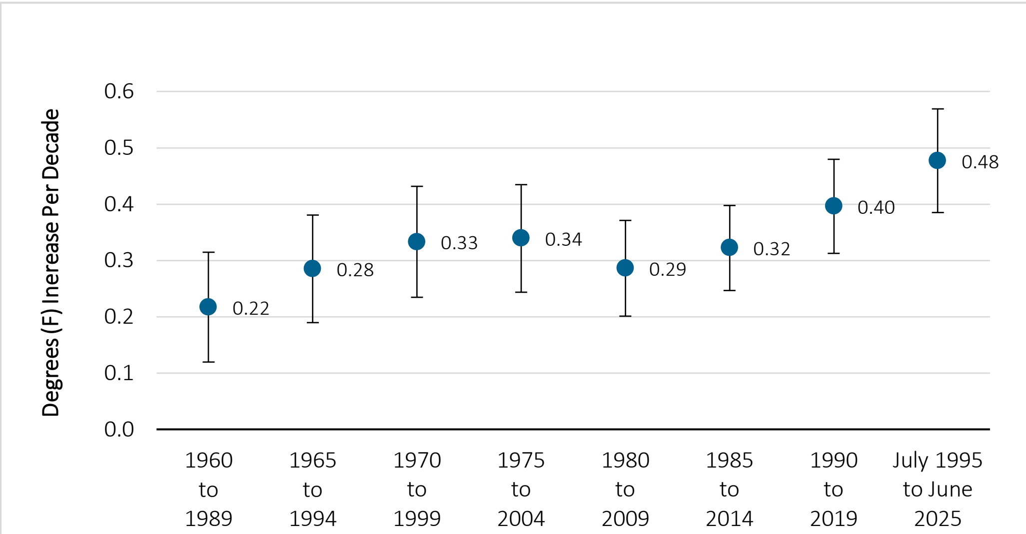
[1] El Nino and La Nina are components of a climate oscillation that is associated with variations in wind speed and sea-surface temperature over the topical Pacific Ocean. These variations, in turn, can affect global weather. A summary of this phenomenon is available here: https://en.wikipedia.org/wiki/El_Ni%C3%B1o%E2%80%93Southern_Oscillation

Is Global Warming Accelerating?

To assess whether the rate of global warming is changing over time, linear regressions were run across the following overlapping 30-year periods: 1960 to 1989, 1965 to 1994, 1970 to 1999, 1975 to 2004, 1980 to 2009, 1985 to 2014, 1990 to 2019, and July 1995 to June 2025 (the most recent 30-year period in the dataset). Focusing on global air temperature, the estimated warming trend for July 1995 to June 2025 is 0.48F per decade, which is greater than the rate for any prior 30-year period captured in Figure 6.

Figure 6

GLOBAL AIR TEMPERATURE: ESTIMATED WARMING TREND FOR OVERLAPPING 30-YEAR PERIODS



The estimated warming trend for the most recent 30-year period is 0.48F per decade, which is greater than the rate for any prior 30-year period.

The graph's vertical bars represent 95% confidence intervals for the warming trend. The blue dot at the center of each vertical bar indicates the "best" estimate produced by the regression.

Interactive Temperature Maps Are Available Online

The analysis presented thus far in this report has focused on global average temperatures. The results summarize the macro-level state of the planet but provide no information about temperature in specific regions. Therefore, a Tableau map was created to visualize air temperature data for each ERA5 grid point, and is accessible online:

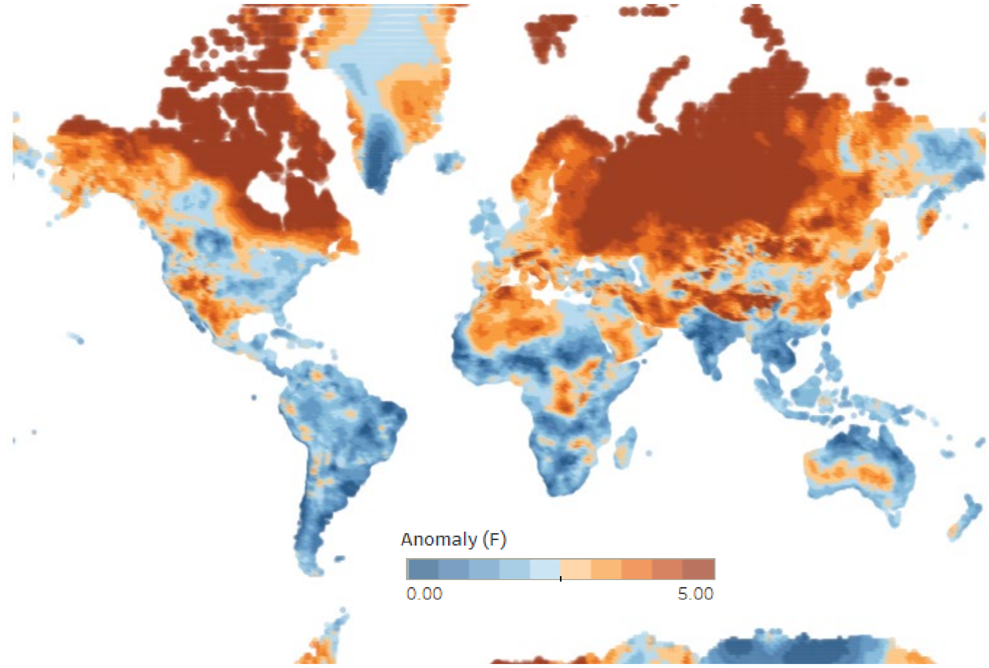
https://public.tableau.com/views/TemperatureAnomalies_17135526296080/Map?:langu age=en-US&publish=yes&:sid=&:display_count=n&:origin=viz_share_link

The map depicts air temperature anomalies computed using a 1960-to-2019 reference period. A toggle switch facilitates the selection of any of several different recent periods which can be compared against the reference period. For example, Figure 7 was produced by selecting the period from July 2024 to June 2025. The figure reveals that for the 12 months from July 2024 to June 2025, most of Canada, northern Europe, and Russia were more than 4F above the corresponding historical averages from 1960 to 2019.

Note that the anomalies in Figure 7 were calculated separately for each ERA5 grid point. For example, consider the grid point at 39N 77W, which is located just outside of Washington DC. During the 1960 to 2019 reference period, this location experienced an average temperature of 56.0F, according to ERA5 data. From July 2024 to June 2025, its average temperature was 58.3F, which equates to an anomaly of 2.3F (the difference between 58.3F and 56.0F).

Figure 7

AVERAGE TEMPERATURE FOR JULY 2024 TO JUNE 2025, MINUS THE AVERAGE FROM 1960 TO 2019 (F)



For much of Canada, northern Europe, and Russia, the average temperature from July 2024 to June 2025 was more than 4F above the corresponding average from 1960–2019.

Methodology for Computing the Worldwide Average Temperature

ERA5 grid points are evenly spaced with respect to degrees latitude and longitude, but they are not evenly spaced when measured in miles or kilometers. As one approaches the poles, lines of longitude converge, reducing the distance between grid points. Consequently, an unweighted global average across grid points would result in the overweighting of data near the north and south poles. The standard remedy used by climate scientists – and the approach used for the analysis presented in this report – is to weight each data point by the cosine of its latitude. At the equator, the resulting weight is 1.0; at 45 degrees north or south, the weight is 0.71; at 60 degrees north or south, the weight is 0.50, declining rapidly to zero as one approaches either pole. This decline counterbalances the increasing density of grid points near the poles, resulting in an even spatial weighting across the surface of the earth.

About The Society of Actuaries Research Institute

Serving as the research arm of the Society of Actuaries (SOA), the SOA Research Institute provides objective, data-driven research bringing together tried and true practices and future-focused approaches to address societal challenges and your business needs. The Institute provides trusted knowledge, extensive experience and new technologies to help effectively identify, predict and manage risks.

Representing the thousands of actuaries who help conduct critical research, the SOA Research Institute provides clarity and solutions on risks and societal challenges. The Institute connects actuaries, academics, employers, the insurance industry, regulators, research partners, foundations and research institutions, sponsors, and non-governmental organizations, building an effective network which provides support, knowledge, and expertise regarding the management of risk to benefit the industry and the public.

Managed by experienced actuaries and research experts from a broad range of industries, the SOA Research Institute creates, funds, develops and distributes research to elevate actuaries as leaders in measuring and managing risk. These efforts include studies, essay collections, webcasts, research papers, survey reports, and original research on topics impacting society.

Harnessing its peer-reviewed research, leading-edge technologies, new data tools and innovative practices, the Institute seeks to understand the underlying causes of risk and the possible outcomes. The Institute develops objective research spanning a variety of topics with its strategic research programs: aging and retirement; actuarial innovation and technology; mortality and longevity; diversity, equity and inclusion; health care cost trends; and catastrophe and climate risk. The Institute has a large volume of topical research available, including an expanding collection of international and market-specific research, experience studies, models and timely research.

Society of Actuaries Research Institute
8770 W Bryn Mawr Ave, Suite 1000
Chicago, Illinois 60631
www.SOA.org