U.S. Actuarial Societies & the American Academy of Actuaries' Climate Work

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German Actuarial Association | March 14, 2024

Three Major U.S. Based Actuarial Organizations

American Academy of Actuaries

- Is the voice of the U.S. actuarial profession on public policy
- Maintains the profession's standards and supports the professional disciplinary board
- Defines qualification standards and continuing education requirements

CAS

- Founded in 1914
- A credentialing actuarial organization exclusively focused on P&C (General) insurance
- Conducts research relevant to P&C insurance and actuaries' daily work

Society of Actuaries®

- Current form founded in 1949
- A credentialing actuarial organization focused on all areas of actuarial practice
- Also conducts research relevant to the practice areas

American Academy of Actuaries Climate Change Joint Committee

Papers & Research

- ESG Issue Brief: Basics of Environment, Social, and Governance considerations and how it could affect actuaries' work (risk-brief-ESG.pdf – actuary.org)
- Glossary of Climate-Related Terms (ClimateGlossary_2.pdf – actuary.org)
- (In Progress) Climate Change Data Quality Issues
- (In Progress) Introduction to Attribution Science

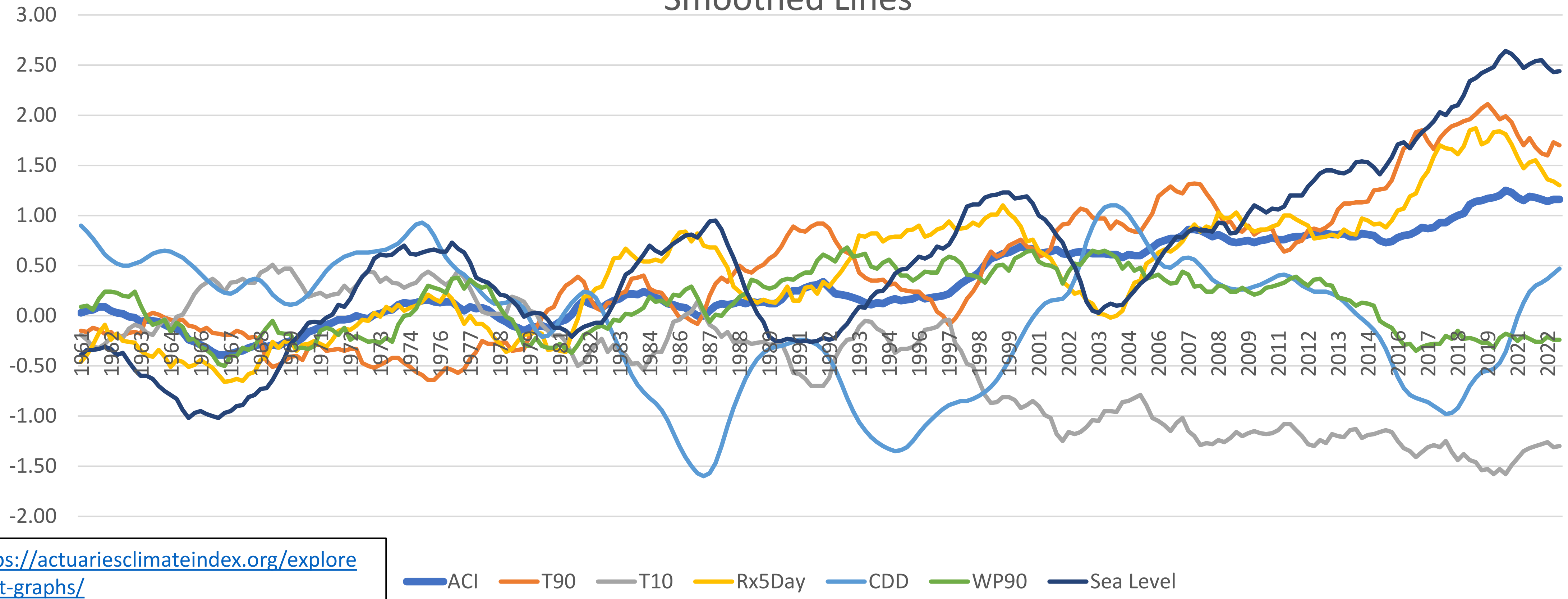
Presentations & Outside Engagements

- Webinar series with NOAA & NSF
- Climate Risk Webinar (PowerPoint Presentation – actuary.org)
- Comment letter to International Sustainability Standards Board (Academy ISSB Comment Letter_Final.pdf – actuary.org)
- Comment letter to Securities and Exchange Commission (Academy Letter to SEC June 17 2022_1.pdf – actuary.org)

The Actuaries Climate Index (ACI) v1.1: Current Construction and A Clue to Challenges

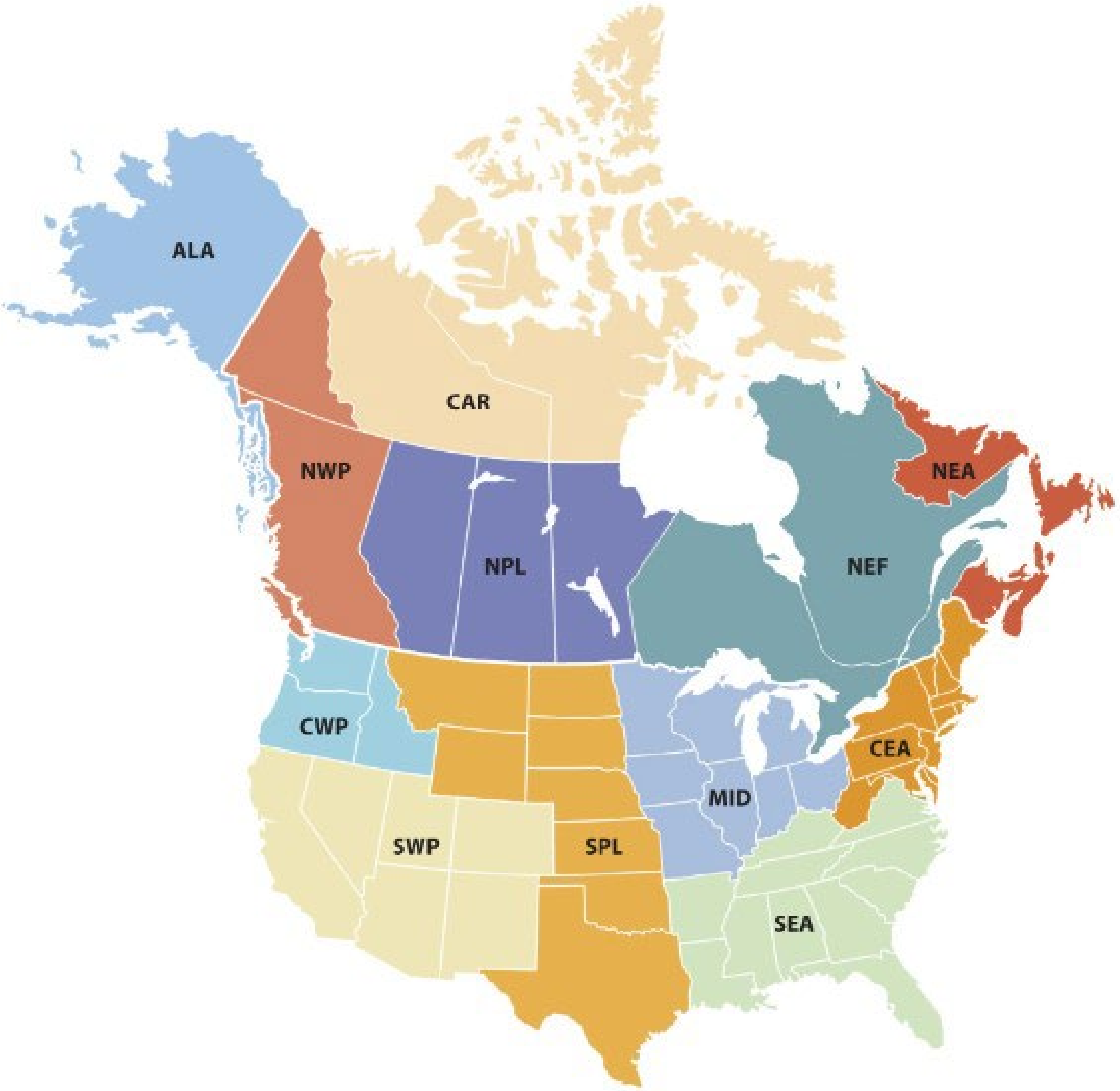
Revising the Actuaries Climate Index Leads to Exploring New Sources of Data

Actuaries Climate Index + Six Components: USA + CAN
Smoothed Lines



Source: https://actuariesclimateindex.org/explore/component-graphs/

ACI Regions:
7 U.S. Regions,
5 Canadian



ALA=Alaska
CAR=Central Arctic (NT, NU)
CEA=Central East Atlantic (CT, DC, DE, MA, MD, ME, NH, NJ, NY, PA, RI, VT, WV)
CWP=Central West Pacific (WA, OR, ID)
MID=Midwest (IA, IL, IN, MI, MN, MO, OH, WI)
NEA=Northeast Atlantic (NB, NS, NL, PE)
NEF=Northeast Forest (ON, QC)
NPL=Northern Plains (AB, MB, SK)
NWP=Northwest Pacific (BC, YT)
SEA=Southeast Atlantic (AL, AR, FL, GA, KY, LA, MS, NC, SC, TN, VA)
SPL=Southern Plains (KS, MT, ND, NE, OK, SD, TX, WY)
SWP=Southwest Pacific (AZ, CA, CO, NM, NV, UT)

Source: https://actuariesclimateindex.org/data/region-definitions/

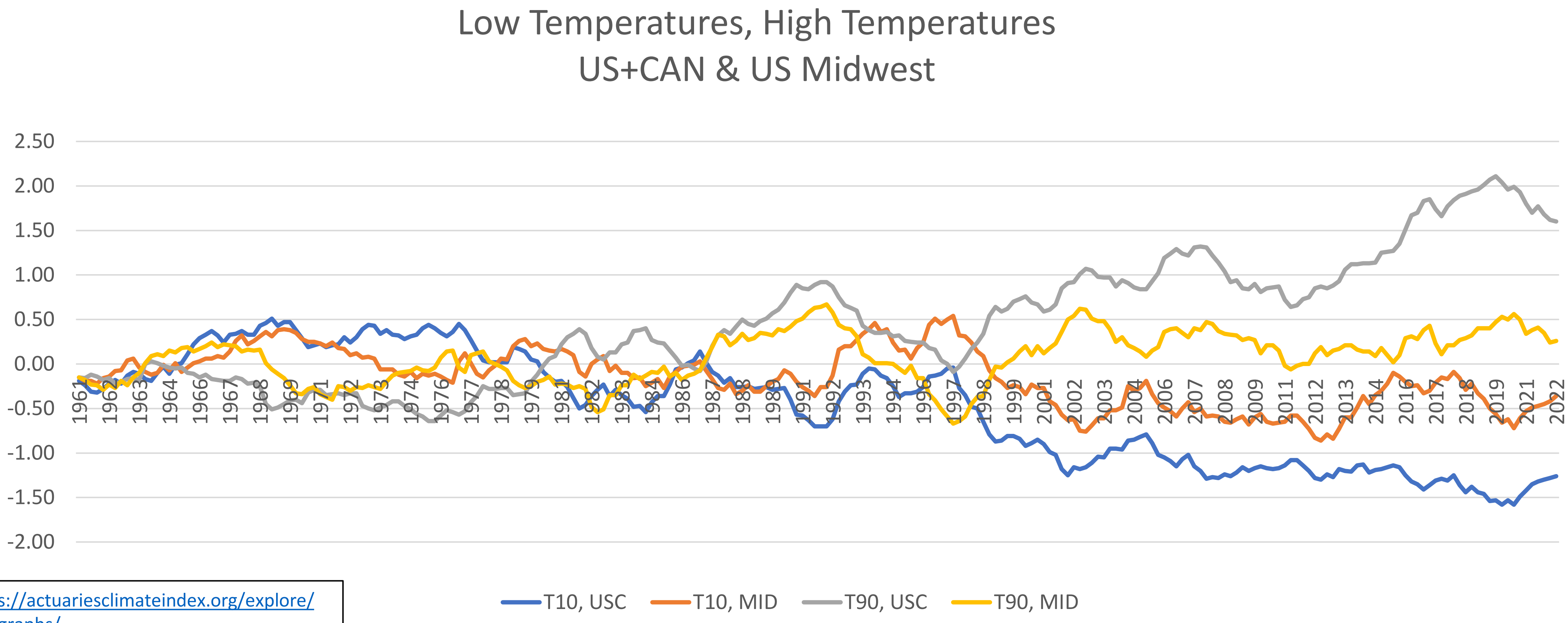
The Measurement of Extremes: High Temperature Illustrated

The High Temperature component is defined as the frequency of temperatures above the 90th percentile relative to the reference period of 1961 to 1990.

1. Calculated for each weather station within a 2.5° x 2.5° grid. Within each grid, values are averaged over the selected weather stations, and within each ACI region, values are averaged over the grids in that region.
2. The difference between each monthly exceedance percentage and the reference period value—for the corresponding month at each grid point is calculated.
3. To normalize values, for each month, regional average differences in exceedance percentages are divided by the standard deviation of those percentages during the corresponding months in the reference period.

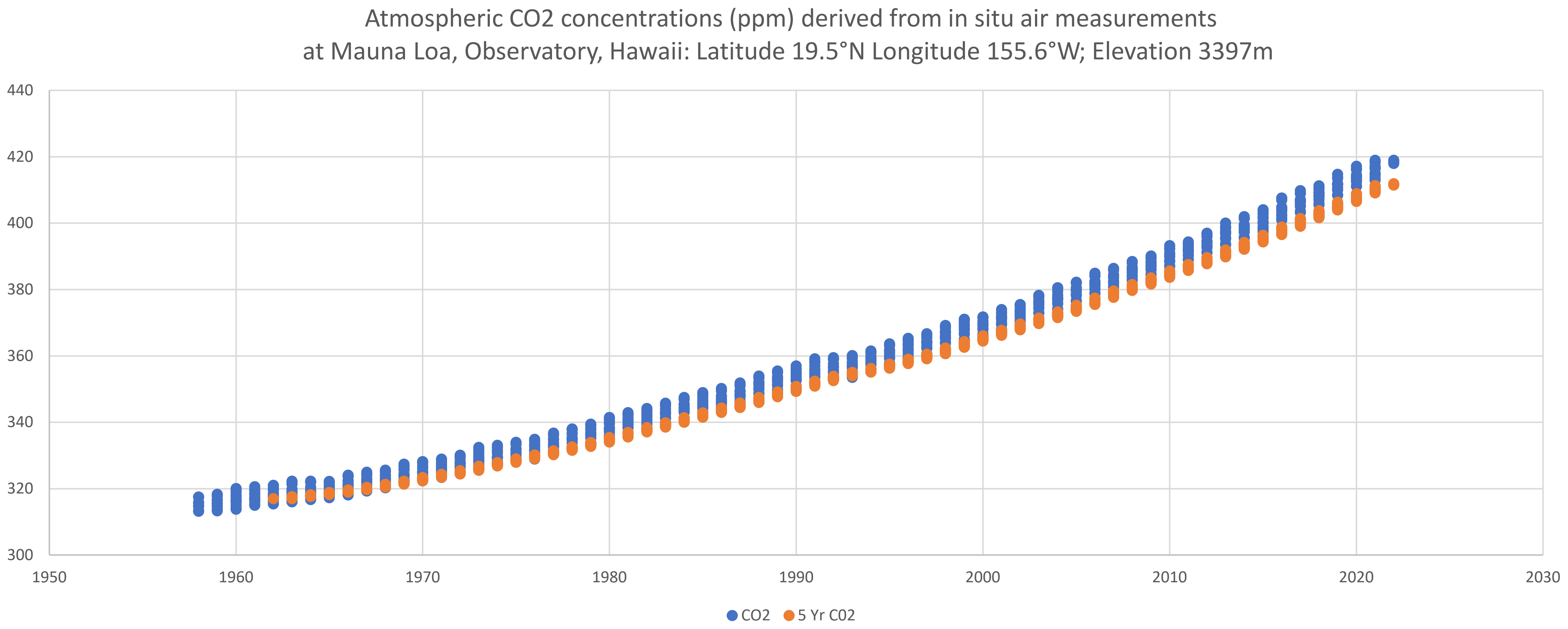
Source of data: GHCNDEX
Source of definition and steps: Actuaries Climate Index: Development and Design

Extreme Temperatures Vary Over Time in North America and the Midwest



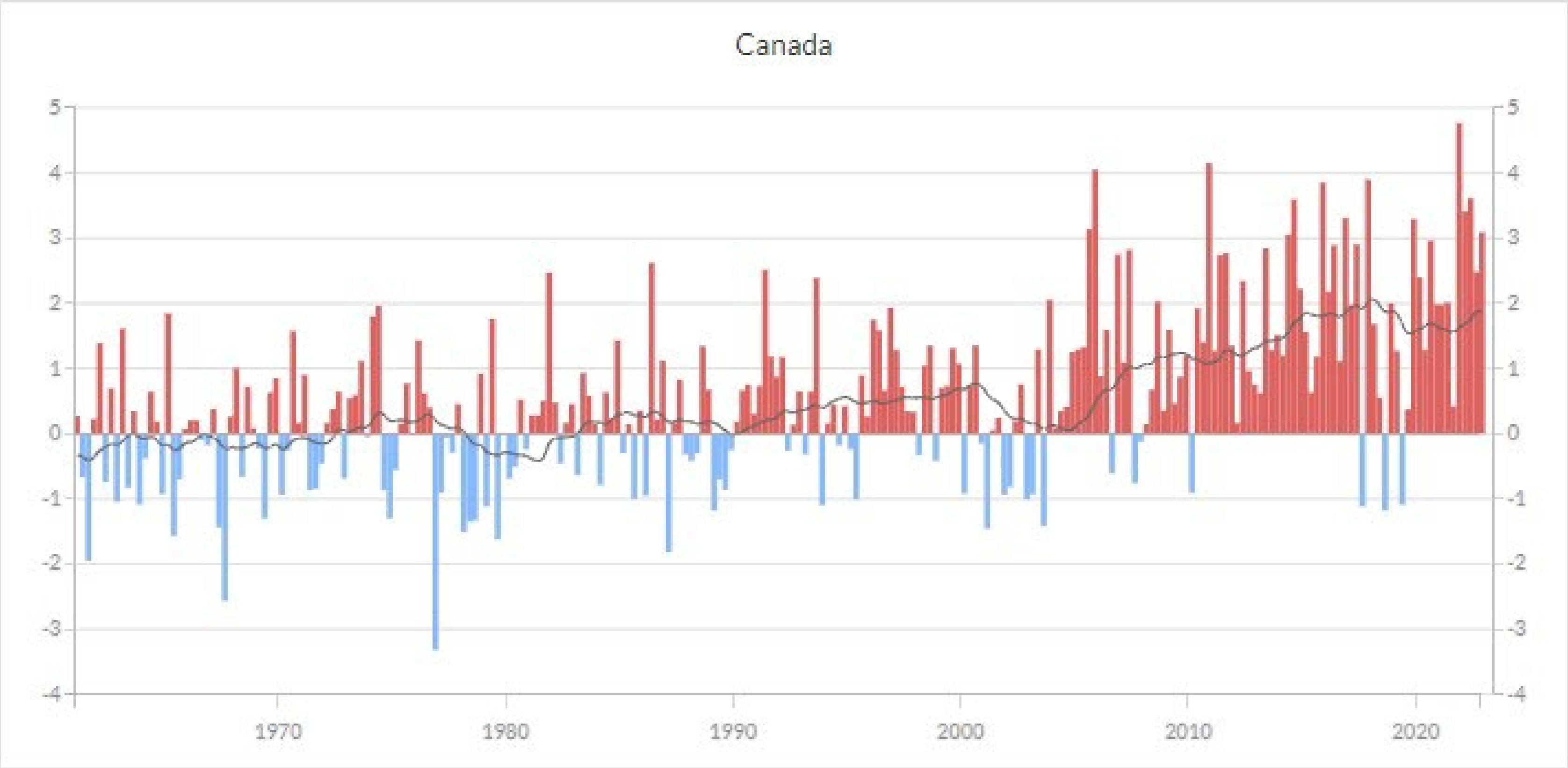
Source: https://actuariesclimateindex.org/explore/component-graphs/

Extreme Temperatures Vary Over Time in North America and the Midwest, More Than Change in CO_2 levels



Challenge With ACI 1.0: Disappearing Weather Stations Affect Index Levels

Extreme Precipitation (Rx5Day) Index for Canada



Source: https://actuariesclimateindex.org/explore/component-graphs/

- 2005–2020: Large increase in extreme precipitation in Canada.
- During this period, large number of weather stations were taken offline in Canada.
- Those taken offline tended to have less precipitation.
- Increase in the index reflected, in part, changes in the reporting stations which produced the data.

Source: https://actuariesclimateindex.org/data/data-disclosure/

Challenges With ACI v1.1 Data

- Completeness of Coverage
- Consistency of Coverage
- Granularity

Number of Weather Stations Available Decreases as Standard for Missing Data Rises

Global Historical Climatology Network (GHCN) Stations: Completeness in Every Decade, 1961–2020

Minimum Percent of Days Reporting in Every Decade	USA: Number of Stations	Canada: Number of Stations
0%	14,936	5,801
10%	3,539	335
20%	3,357	271
30%	3,192	227
40%	3,052	191
50%	2,901	168
60%	2,720	126
70%	2,418	78
80%	2,042	45
90%	1,463	30
100%	81	0

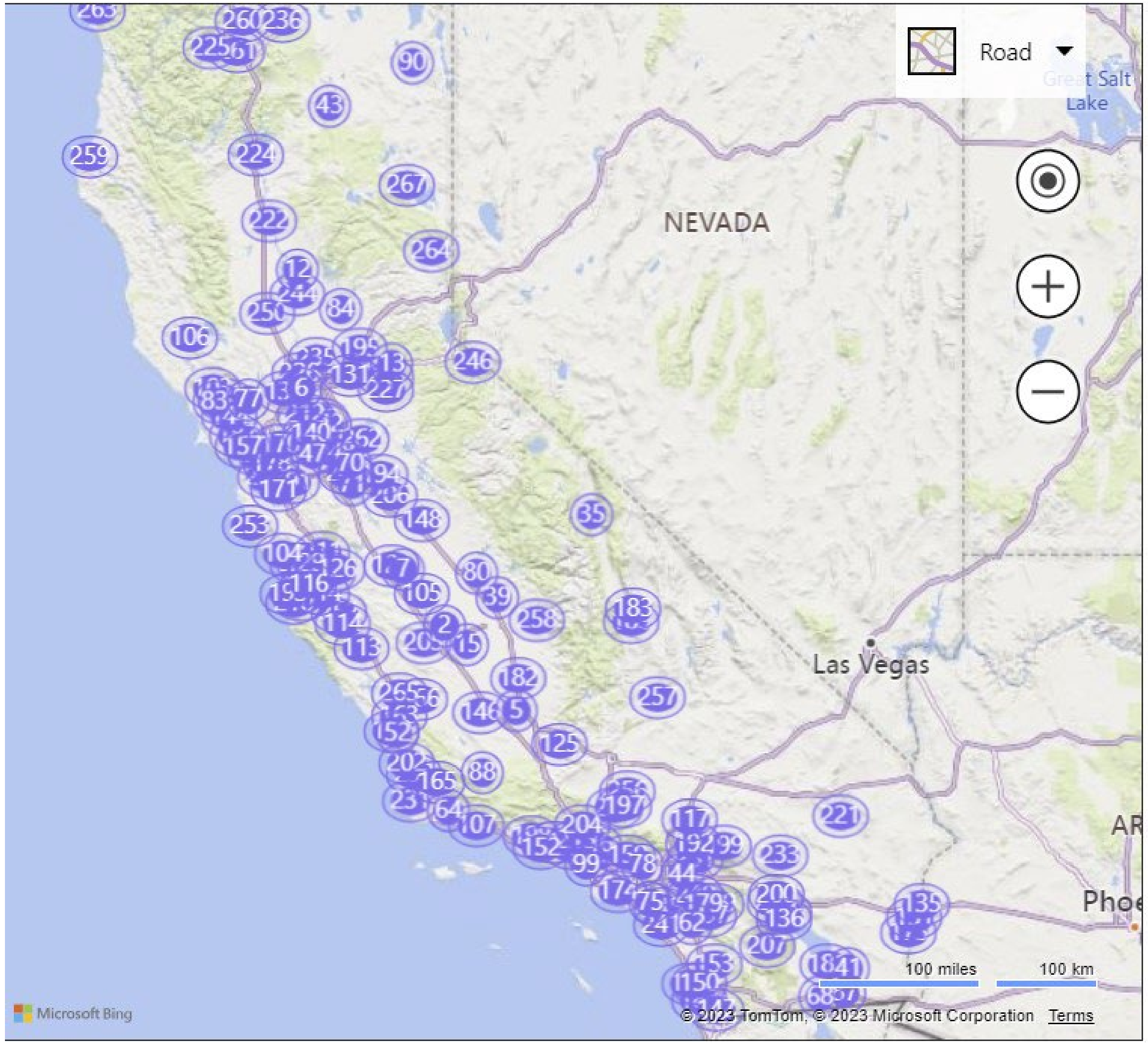
Source: Academy analysis of data obtained from https://www.ncei.noaa.gov/products/land-based-station/global-historical-climatology-network-daily

22 States Have 30+ Persistent Weather Stations

STATE	Number of Stations Reporting 90% of the Days in each Decade	Number of Stations Reporting at least once		STATE	Number of Stations Reporting 90% of the Days in each Decade	Number of Stations Reporting at least once
CA	76	1072		OH	41	213
TX	74	794		MI	40	365
KS	66	260		MN	40	299
WI	65	281		UT	40	517
IA	62	192		SD	39	246
MT	58	610		TN	37	219
NC	50	296		IL	36	249
NE	45	264		NY	36	374
WA	44	386		AR	32	187
CO	43	579		FL	30	284
OR	42	580		ID	30	419

Source: Academy analysis of data obtained from https://www.ncei.noaa.gov/products/land-based-station/global-historical-climatology-network-daily

Challenge of Coverage—What Is Enough?



California has the greatest number of persistent weather stations in the U.S., but still has a large geographical area uncovered.

Source: https://cimis.water.ca.gov/Stations.aspx

ERA5 more granular, more consistent than GHCN stations

Source: Academy analysis of data obtained from https://www.ncei.noaa.gov/products/land-based-station/global-historical-climatology-network-daily ; from https://www.ecmwf.int/en/forecasts/dataset/ecmwf-reanalysis-v5; from https://www.census.gov/quickfacts/fact/table/CA/PST045222; and from https://www.usgs.gov/faqs/how-much-distance-does-a-degree-minute-and-second-cover-your-maps#:~:text=One%20degree%20of%20latitude%20equals,one%2Dsecond%20equals%20101%20feet .

		ERA5	GHCN
Total Number of Reporting Stations or Gridpoints	USA	17,565	65,166
Total Number of Reporting Stations or Gridpoints	CAN	26,980	8,910
90% of Days Reported, 1961-2020	USA	17,565	2,590
90% of Days Reported, 1961-2020	CAN	26,980	120
90% of Days Reported in each Decade, 1961-2020	USA	17,565	1,473
90% of Days Reported in each Decade, 1961-2020	CAN	26,980	31
Grid (Equivalent)	**CA, USA**	**.25° x .25°**	**.75° x .75°***
Grid (Equivalent)	**FL, USA**	**.25° x .25°**	**.75° x .75°***
Grid (Equivalent)	**ID, USA**	**.25° x .25°**	**.86° x .86°***
***Grid Equivalent: Stations at 90% Each Decade, assuming Equally spaced on grid**			

Question: How Do ERA5 Measures Compare to GHCN and Other Station Data?

Unless otherwise noted, on the slides which follow, the source is Academy analysis of data obtained from https://www.ncei.noaa.gov/products/land-based-station/global-historical-climatology-network-daily ; and/or from https://www.ecmwf.int/en/forecasts/dataset/ecmwf-reanalysis-v5.

Prior Literature

- "The results show that ERA5 climate reanalysis data can be used for modelling phenological phases…." [Oses et al., *Sensors*, 2020]

- "The representation of climate in reanalyses varies significantly not only between the different reanalyses but also between the parameters (i.e., the climate indices) and regions." [Keller and Wahl, *Journal of Climate*, 2020]

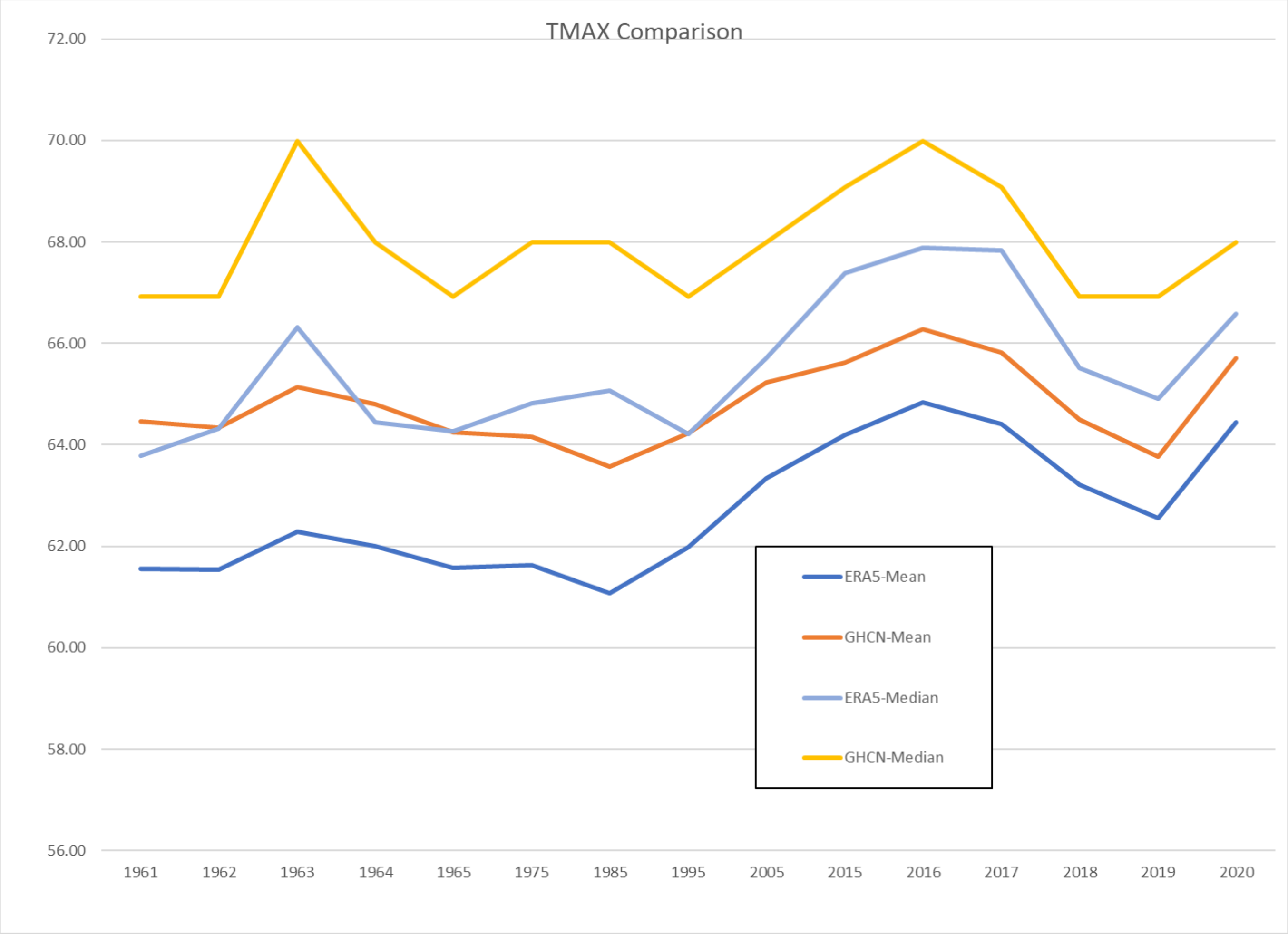
- "[V]ery few have examined how similar they are [reanalysis and observations] in identifying extreme weather event days. Here, we explore this similarity using three reanalysis products: ERA5, ERA5-LAND, and NARR, in terms of the days on which they identify extreme temperature events…. Cold events have a greater match than heat events. ERA5 has the greatest match percentage with station data across the study region." [Sheridan et al., *Geophysical Research Letters*, 2020]

Regressing Station Temperatures Against Those From Nearest ERA5 Gridpoint Show High Correlation

ERA5_TMAX = Alpha + (Beta)*(TMAX_GHCN)				
Year	**Alpha**	**Beta**	**Beta-t-stat**	**RSQ**
1961	-0.75	0.97	2393	0.93
1962	-0.89	0.97	2523	0.94
1963	-1.01	0.97	2566	0.94
1964	-0.75	0.97	2347	0.93
1965	-0.32	0.96	2335	0.93
1975	-0.05	0.96	2270	0.93
1985	0.49	0.95	2260	0.93
1995	1.72	0.94	2005	0.91
2005	1.82	0.94	1967	0.91
2015	3.15	0.93	1841	0.89
2016	2.83	0.94	1848	0.89
2017	2.92	0.93	1771	0.89
2018	3.17	0.93	1866	0.90
2019	2.82	0.94	1896	0.90
2020	3.44	0.93	1708	0.88

ERA5_TMIN = Alpha + (Beta)*(TMIN_GHCN)				
Year	**Alpha**	**Beta**	**Beta-t-stat**	**RSQ**
1961	2.72	0.98	2354	0.93
1962	2.79	0.98	2456	0.94
1963	2.66	0.98	2492	0.94
1964	3.14	0.97	2276	0.93
1965	2.95	0.97	2372	0.93
1975	3.28	0.97	2288	0.93
1985	3.41	0.97	2405	0.94
1995	3.62	0.97	2187	0.92
2005	3.78	0.97	2230	0.93
2015	4.32	0.96	2220	0.92
2016	4.35	0.96	2171	0.92
2017	4.40	0.96	2109	0.92
2018	4.13	0.96	2268	0.93
2019	4.24	0.96	2249	0.93
2020	4.63	0.95	2033	0.91

ERA5 and GHCN Annual Average Temperatures Differ by Level but Move Similarly Over Time



Goodness of Fit for Precipitation-Daily Less Than Temperature or Precipitation-Monthly

1961 - 2020	R^2
ERA5 v GHCN Regression of Daily Values, TMAX	0.93
ERA5 v GHCN Regression of Daily Values, TMIN	0.95
ERA5 v GHCN Regression of Daily Values, PRCP-D	**0.42**
ERA5 v GHCN Regression of Daily Values, PRCP-M	0.74

Trends in Temperature and Precipitation Similar, Not Same, for ERA5 and GHCN

	TMAX Slope: 1961 - 2020		TMIN Slope: 1961 - 2020	
	ERA5	GHCN	ERA5	GHCN
Mean (Daily)	0.00012063	0.00006173	0.00014481	0.00011828
Per Decade	0.44	0.23	0.53	0.43

	PRCP-D Slope: 1961 - 2020		PRCP-M Slope: 1961 - 2020	
	ERA5	GHCN	ERA5	GHCN
Mean (Daily)	0.00000031	0.00000047	0.00000816	0.00001295
Per Decade	0.00	0.00	0.03	0.05

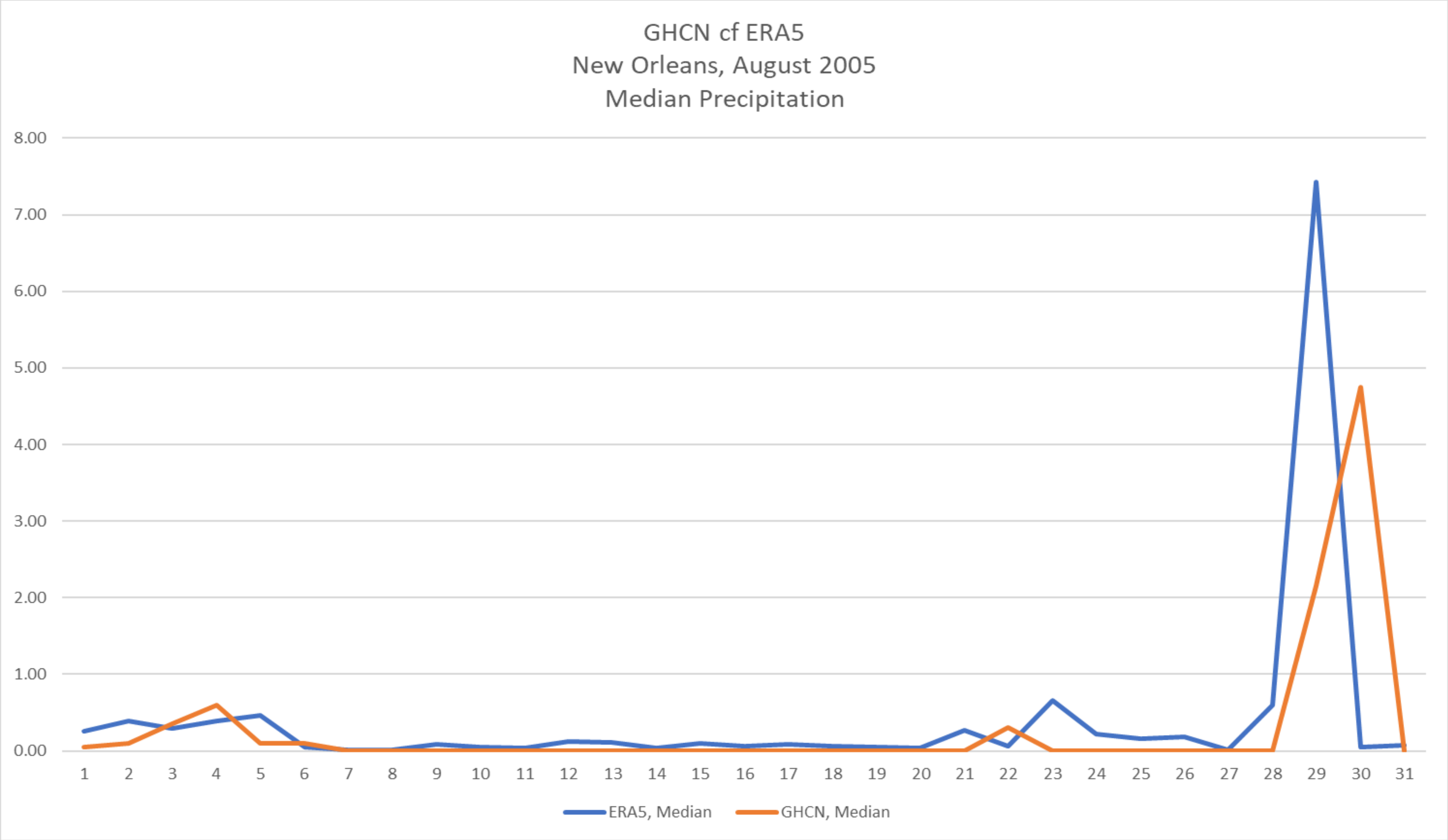
Special Circumstances

Precipitation

Hurricane Katrina, 2005
New Orleans

New Orleans, August 2005
Precipitation Median (6 GHCN Stations, 25 ERA Gridpoints)

ERA5 and GHCN: Similar, but differ by one day on peak



Katrina Summary of Amounts
Peak differs by one day; two-day total very similar

CHARACTERISTIC	ERA5	GHCN	
New Orleans: Average Daily Precipitation August 2005	0.42	0.35	Inches
New Orleans: Average Precipitation August 29th	7.13	3.63	Inches
New Orleans: Average Precipitation August 30th	0.09	3.88	Inches
New Orleans: Average Precipitation August 29th + August 30th	7.23	7.52	Inches

Katrina: E Hammond Station Discrepancies and Problems

STATION_NAME	DATE	Hourly PRCIP
HAMMOND 5 E LA US	20050828 18:00	0.2
HAMMOND 5 E LA US	20050828 21:00	0.1
HAMMOND 5 E LA US	20050829 02:00	0.2
HAMMOND 5 E LA US	20050829 03:00	0.2
HAMMOND 5 E LA US	20050829 04:00	0.5
HAMMOND 5 E LA US	20050829 05:00	0.3
HAMMOND 5 E LA US	20050829 06:00	0.4
HAMMOND 5 E LA US	20050829 07:00	0.4
HAMMOND 5 E LA US	20050829 08:00	0.5
HAMMOND 5 E LA US	20050829 09:00	0.8
HAMMOND 5 E LA US	20050829 10:00	0.8
HAMMOND 5 E LA US	20050829 11:00	0.5
HAMMOND 5 E LA US	20050829 12:00	0.3
HAMMOND 5 E LA US	20050829 13:00	0.4
HAMMOND 5 E LA US	20050829 14:00	0.1
HAMMOND 5 E LA US	20050829 15:00	0.5
HAMMOND 5 E LA US	**20050829 16:00**	0.2
HAMMOND 5 E LA US	**20050901 01:00**	0
HAMMOND 5 E LA US	20050901 09:00	999.99
HAMMOND 5 E LA US	20050901 12:00	999.99
HAMMOND 5 E LA US	20050905 04:00	1.1
HAMMOND 5 E LA US	20050905 06:00	0.1

Sum of Hourly Readings, 8/29/05: 6.1

NAME	DATE	PRCP
HAMMOND 5 E, LA US	8/25/2005	0
HAMMOND 5 E, LA US	8/26/2005	0
HAMMOND 5 E, LA US	8/27/2005	0
HAMMOND 5 E, LA US	8/28/2005	0
HAMMOND 5 E, LA US	**8/29/2005**	**1.95**
HAMMOND 5 E, LA US	**8/30/2005**	**6.69**
HAMMOND 5 E, LA US	8/31/2005	0
HAMMOND 5 E, LA US	9/1/2005	0
HAMMOND 5 E, LA US	9/2/2005	0
HAMMOND 5 E, LA US	9/3/2005	0
HAMMOND 5 E, LA US	9/4/2005	0
HAMMOND 5 E, LA US	9/5/2005	0

Source: https://www.ncdc.noaa.gov/cdo-web/search

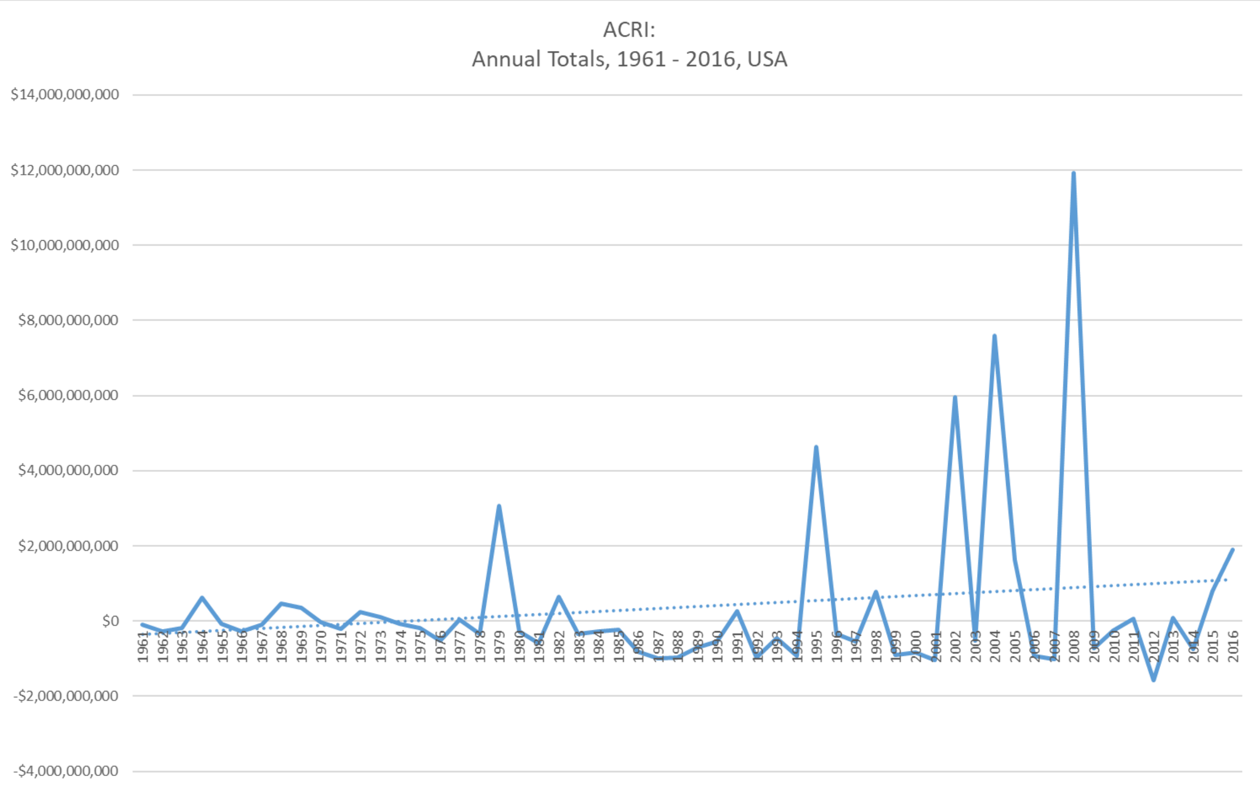
Source: https://www.ncdc.noaa.gov/cdo-web/datasets/PRECIP_HLY/stations/COOP:164030/detail

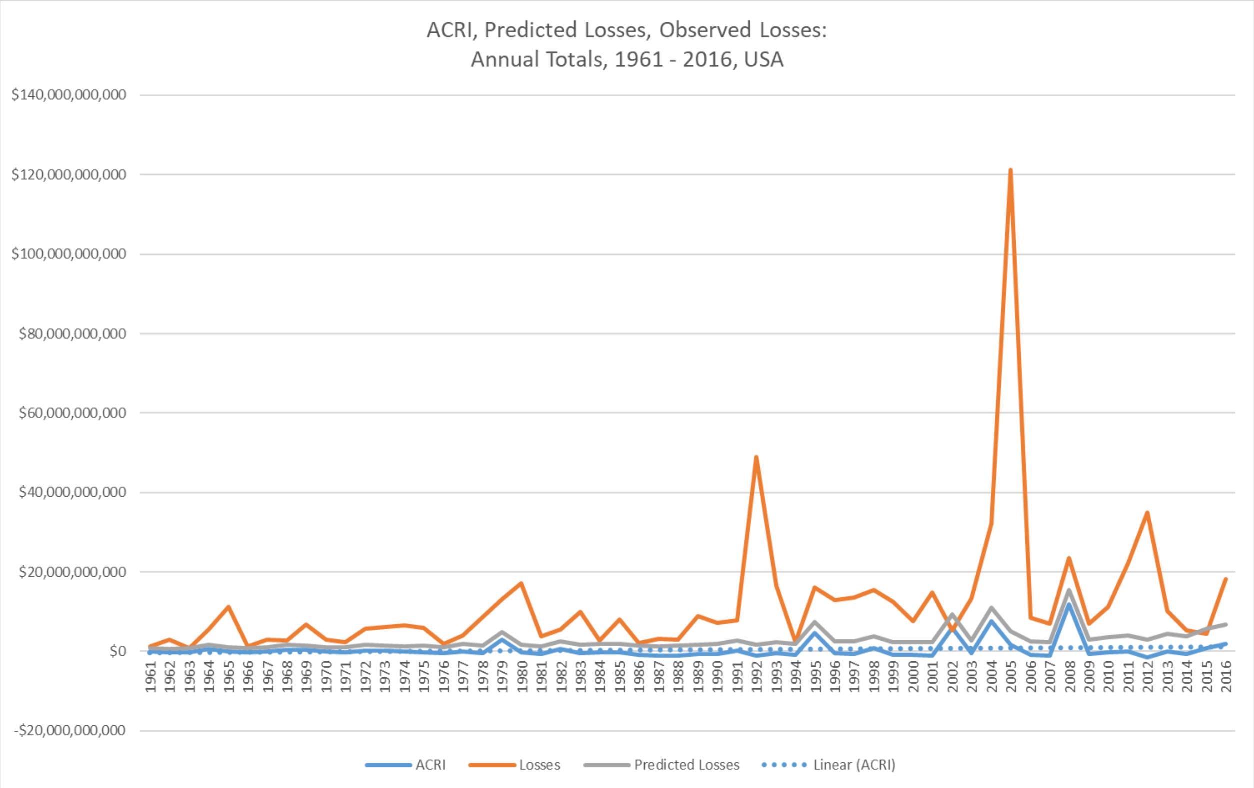
Actuaries Climate Risk Index

Actuaries Climate Risk Index: Preliminary Findings

- Published in January 2020
- Using ACI elements
- Using Sheldus for losses, based on NOAA Storm Events Database
- Loss = f(Risk Exposure, Environmental conditions, Geography, Season)
  - ACRI aimed to measure Losses due to Climate Change, controlling for Risk Exposure, Geography and Season
  - Retrospective
- Preliminary Findings with Challenges recognized

ACRI, Preliminary Findings, Main Results





- Climate change produces increasing losses, 1961-2016
- Since 1991, climate change more often produces sharp increases in losses.

- Losses due to climate change a small proportion of total losses.
- Losses expected with no change in exposure also a small proportion of total losses.

ACRI: Challenges and Potential Improvements

- Granularity: constrained by ACI regions
  - ACI based on ERA5 relaxes those constraints
- Sparseness of data: NOAA Storm data has information on most events, but losses for relatively few. Only flood data reasonably complete.
  - Supplement NOAA data with US Billion Dollar Climate and Weather Disasters data (and comparable Canadian data).
- Modeling of data strained by prior two challenges
  - Consider approximating cat modeling for estimation
  - Consider Extreme Value Theory distributions for loss distributions

Conclusions

Conclusions

- ACI and ACRI can be improved by new data sources.
- Climate elements in ERA5 data will resemble weather station measurements (sometimes more, sometimes less), usually with some attenuation of extremes.
- More granularity not always better in ERA5 measurement; need to identify optimal granularity.
- More granular climate data combined with more robust loss data, and more developed modeling, should provide significant improvements in ACRI.

While new data provides better coverage,
it will still pose challenges.

Questions or comments:

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