An Introduction to the Actuaries Climate Index® and the Actuaries Climate Risk Index®

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Middle Atlantic Actuarial Club
Columbia, MD – November 20, 2019

An Introduction to the Actuaries Climate Index

ACTUARIES CLIMATE INDEX
INDICE ACTUARIEL CLIMATIQUE

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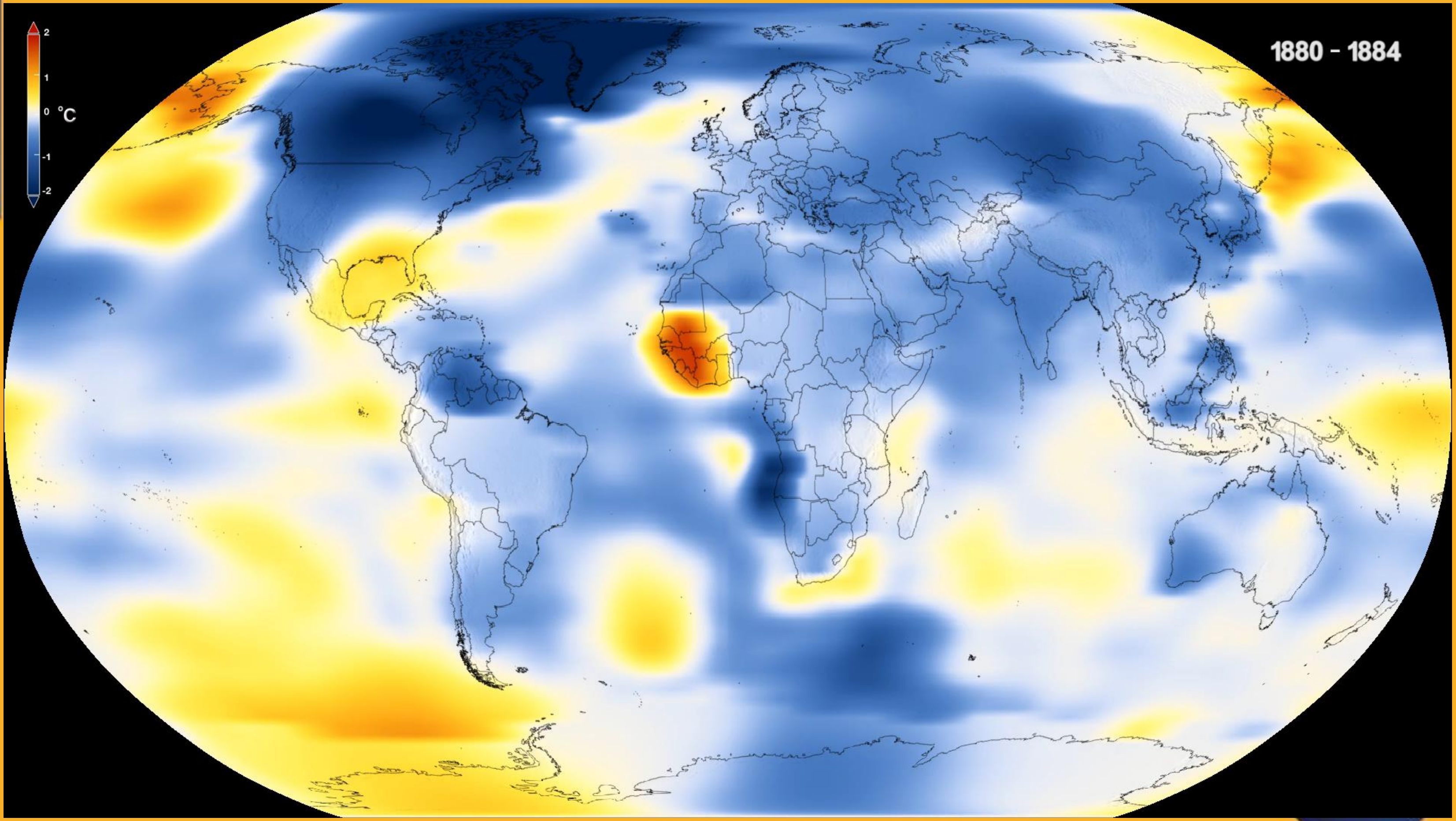
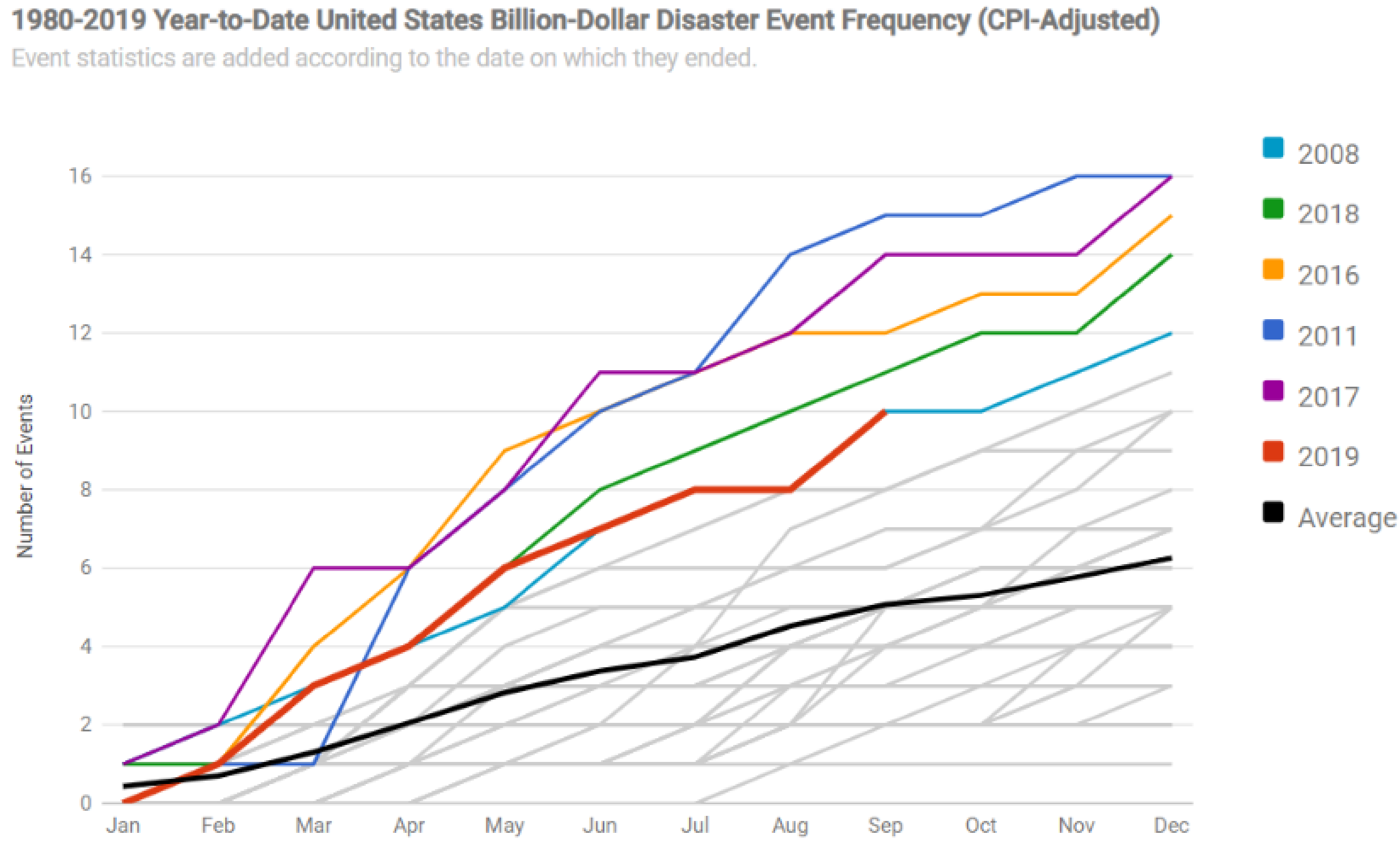
Why do we need a climate index?

NASA's Scientific Visualization Studio. Data provided by Robert B. Schmunk (NASA/GSFC GISS)

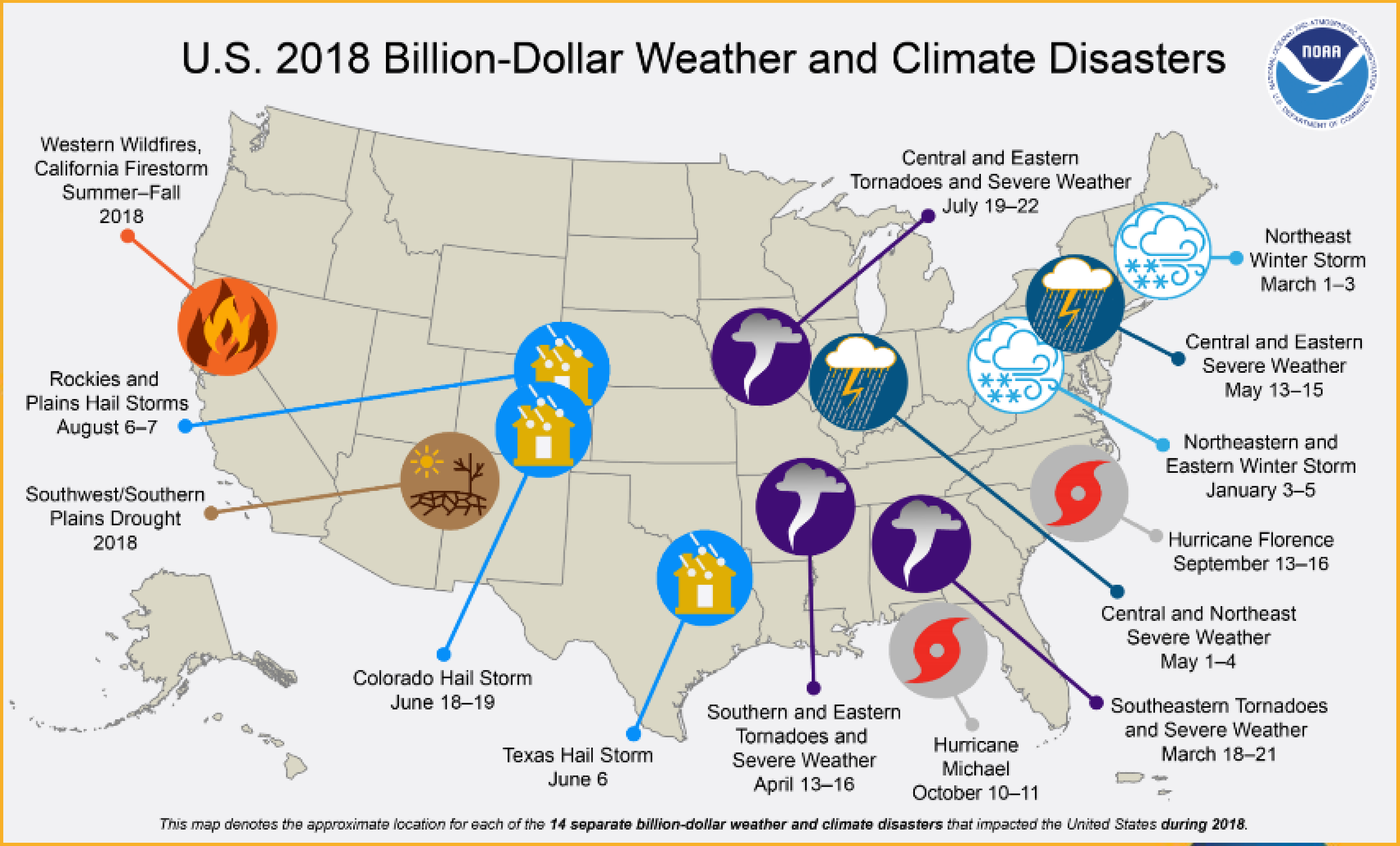


Why do Insurers care about Climate?



Source: https://www.ncdc.noaa.gov/billions/ accessed October 2019

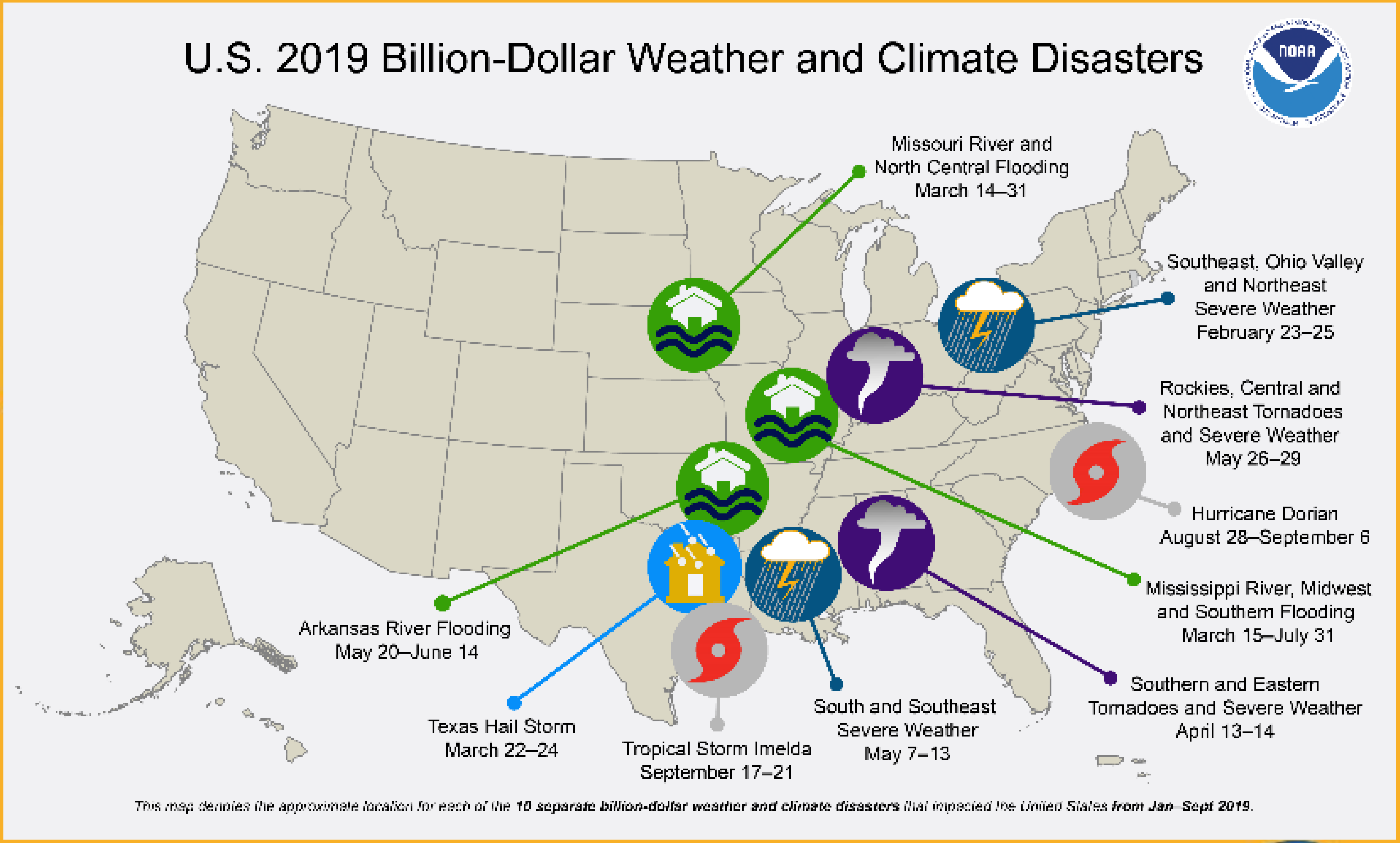
Why do Insurers care about Climate?



Source: https://www.ncdc.noaa.gov/billions/ accessed April 2019

Sources of data include the National Weather Service, the Federal Emergency Management Agency, U.S. Department of Agriculture, National Interagency Fire Center, U.S. Army Corps, individual state emergency management agencies, state and regional climate centers, media reports, and insurance industry estimates.

Why do Insurers care about Climate?



Source: stats https://www.ncdc.noaa.gov/billions/ accessed October 2019

Background of the

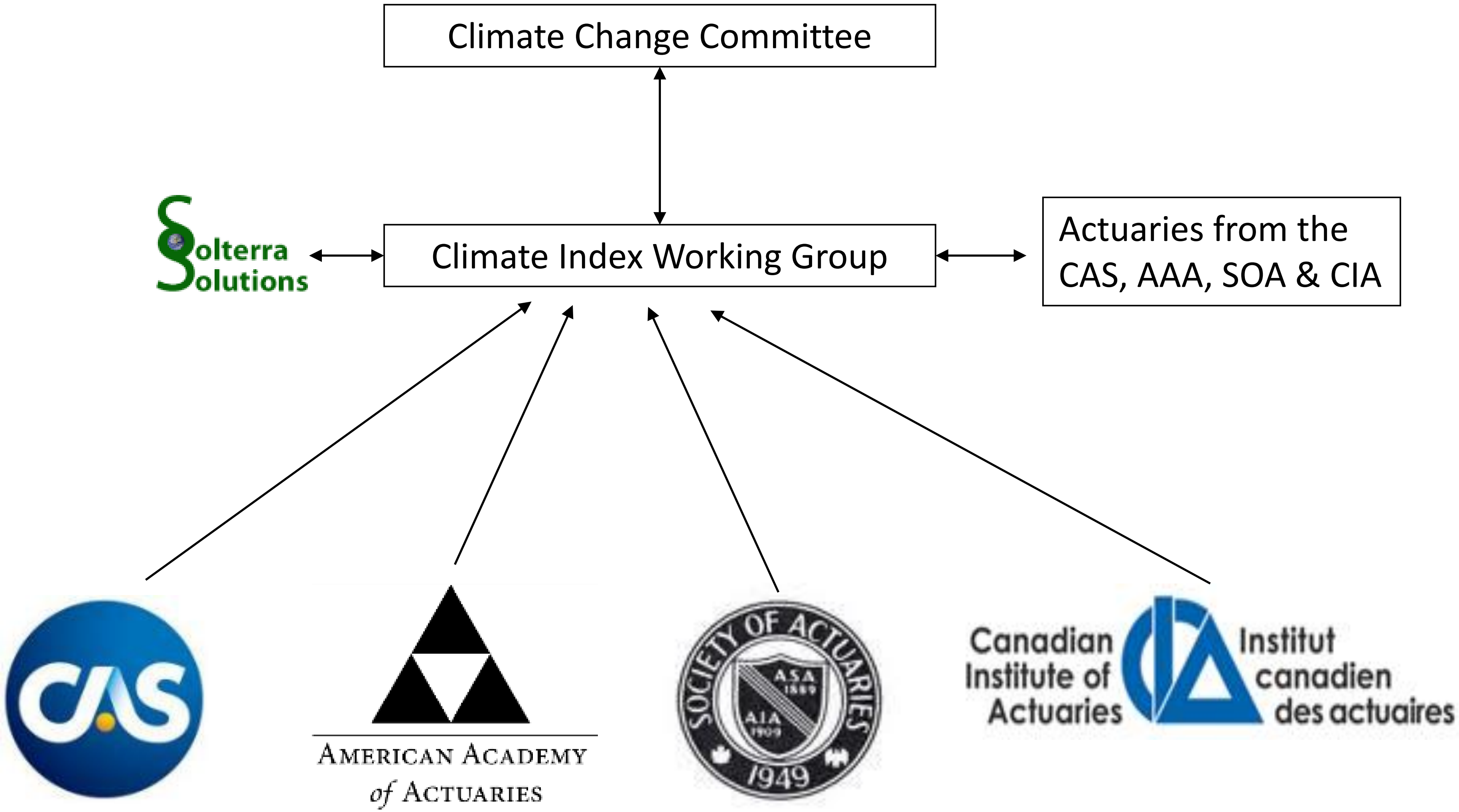
ACTUARIES CLIMATE INDEX

HTTP://ACTUARIESCLIMATEINDEX.ORG/HOME/

Actuaries Climate Index – Goals

- To create objective measure of observations of extreme weather and sea levels
- Inform actuaries, public policymakers, and general public about climate trends
- Provide monitoring tool of climate trends
- Statistically robust, yet easy to understand
- Promote our profession

WHICH NORTH AMERICAN INSURANCE ACTUARIES GOT TOGETHER?



Regions and Components of the ACI

ACTUARIES CLIMATE INDEX
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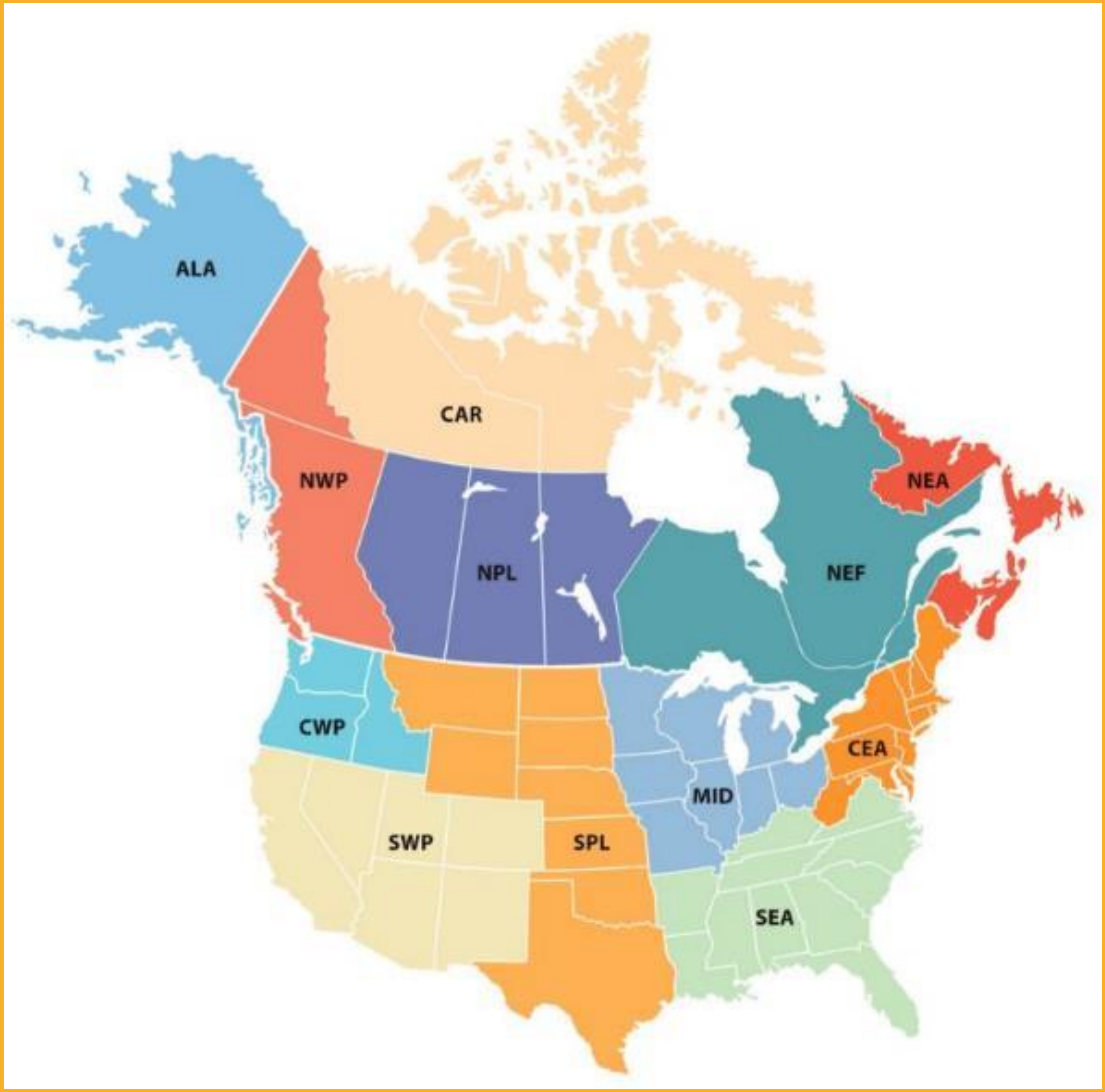
- Indices are for 12 Climatological Regions
- There are 6 components
  - ACI components are of the form:

    $$(x - \mu_{ref}) / \sigma_{ref}$$

  - Each is monthly time series starting 1961
  - Compared to measurements over 30-year reference period 1961-1990
  - Summarized by season
  - 5-year moving average is key metric

12 ACI Climate Regions

Region Name	Region
Central Arctic	CAR
Northeast Atlantic	NEA
Northeast Forest	NEF
Northern Plains	NPL
Northwest Pacific	NWP
Alaska	ALA
Central East Atlantic	CEA
Central West Pacific	CWP
Midwest	MID
Southeast Atlantic	SEA
Southern Plains	SPL
Southwest Pacific	SWP



6 ACI Components

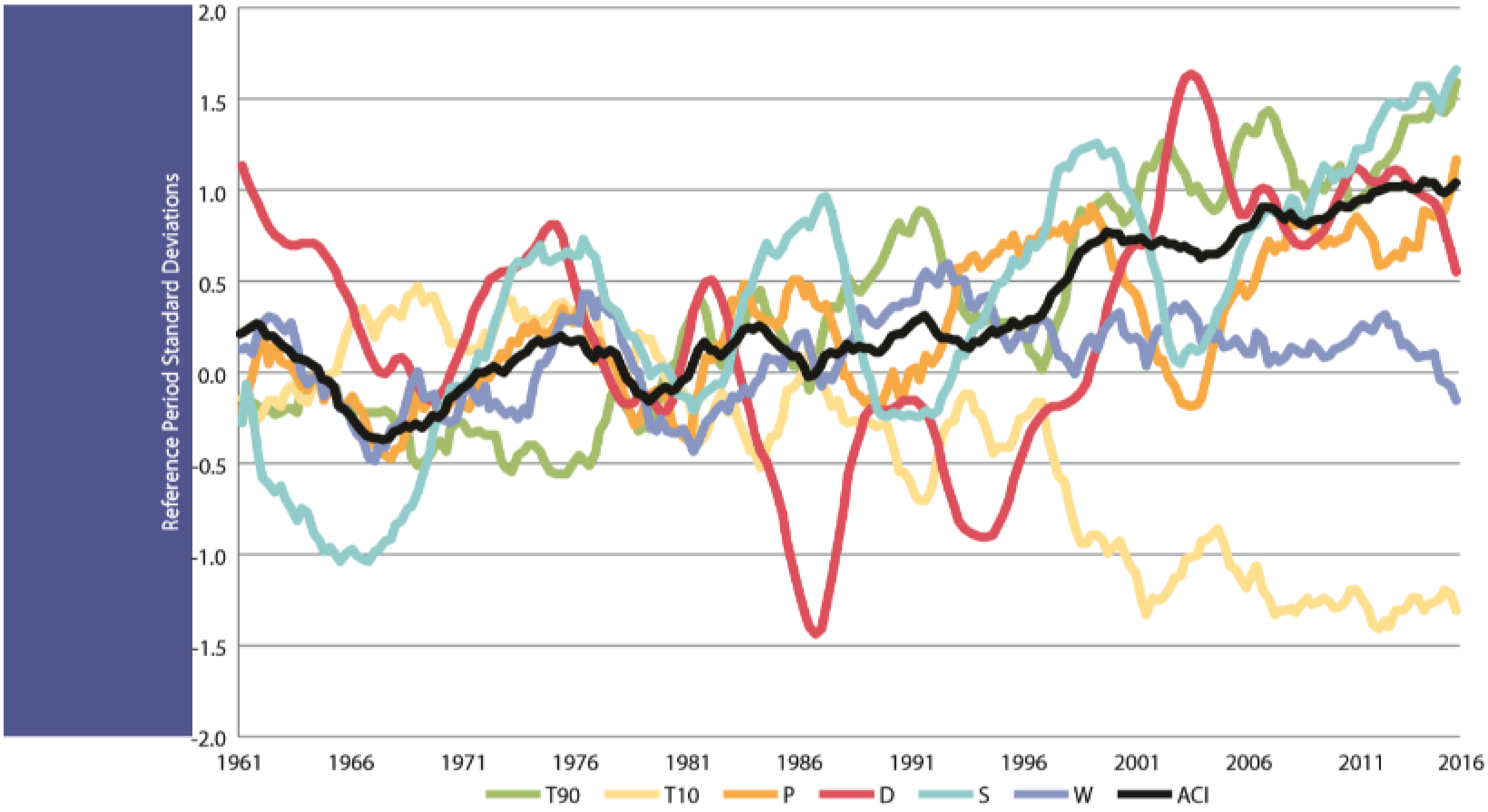
- **T90** – Frequency of temperatures above the 90^{th} percentile
- **T10** – Frequency of temperatures below the 10^{th} percentile
- **P** – Maximum rainfall per month in 5 consecutive days
- **D** – Annual maximum consecutive dry days
- **W** – frequency of wind speed above the 90^{th} percentile
- **S** - Sea level changes

$ACI = (\Delta T90 - \Delta T10 + \Delta P + \Delta D + \Delta W + \Delta S) / 6$

Overall ACI and components

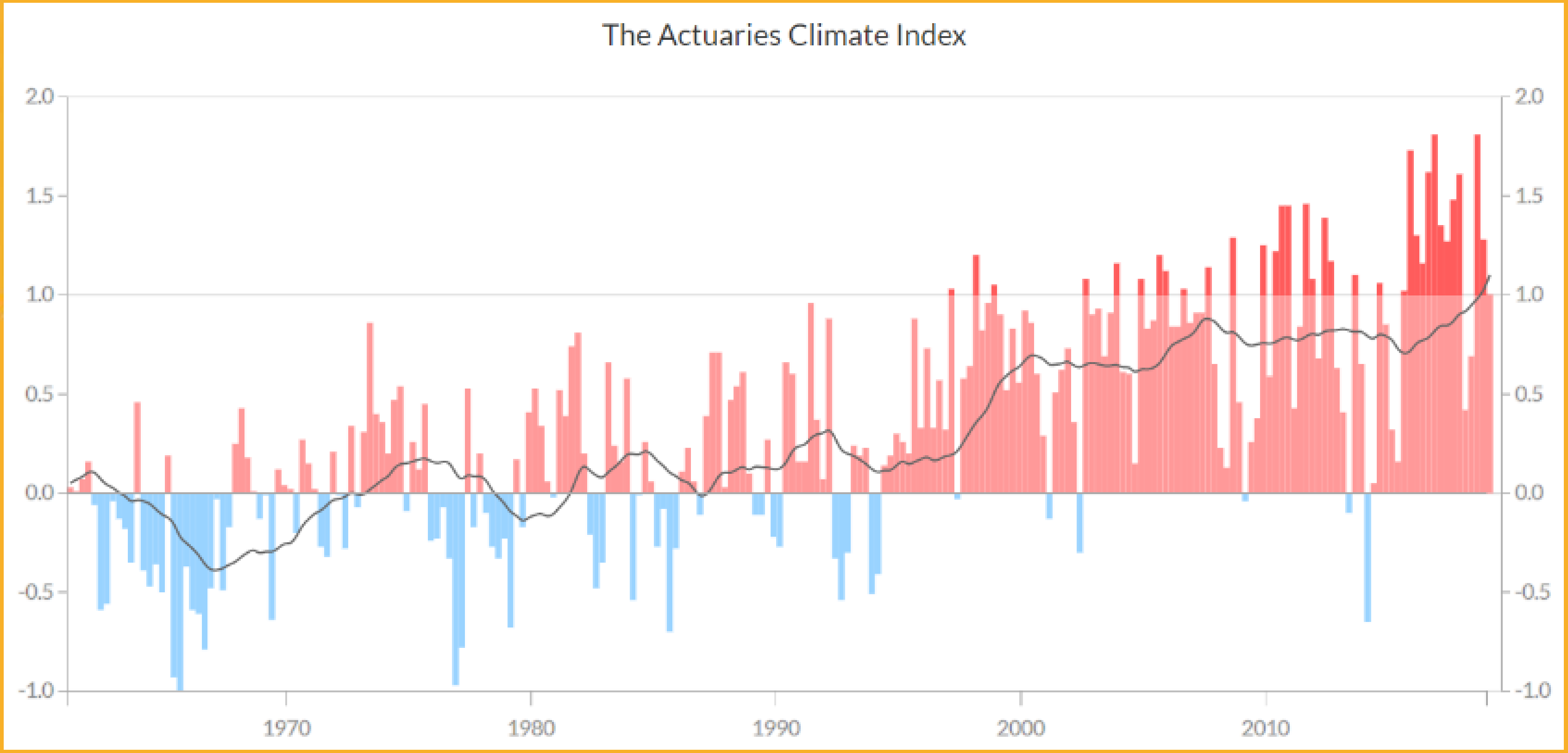
Source: Executive Summary

Figure 1. Seasonal five-year moving averages of components, Canada and the United States.



ACI by season

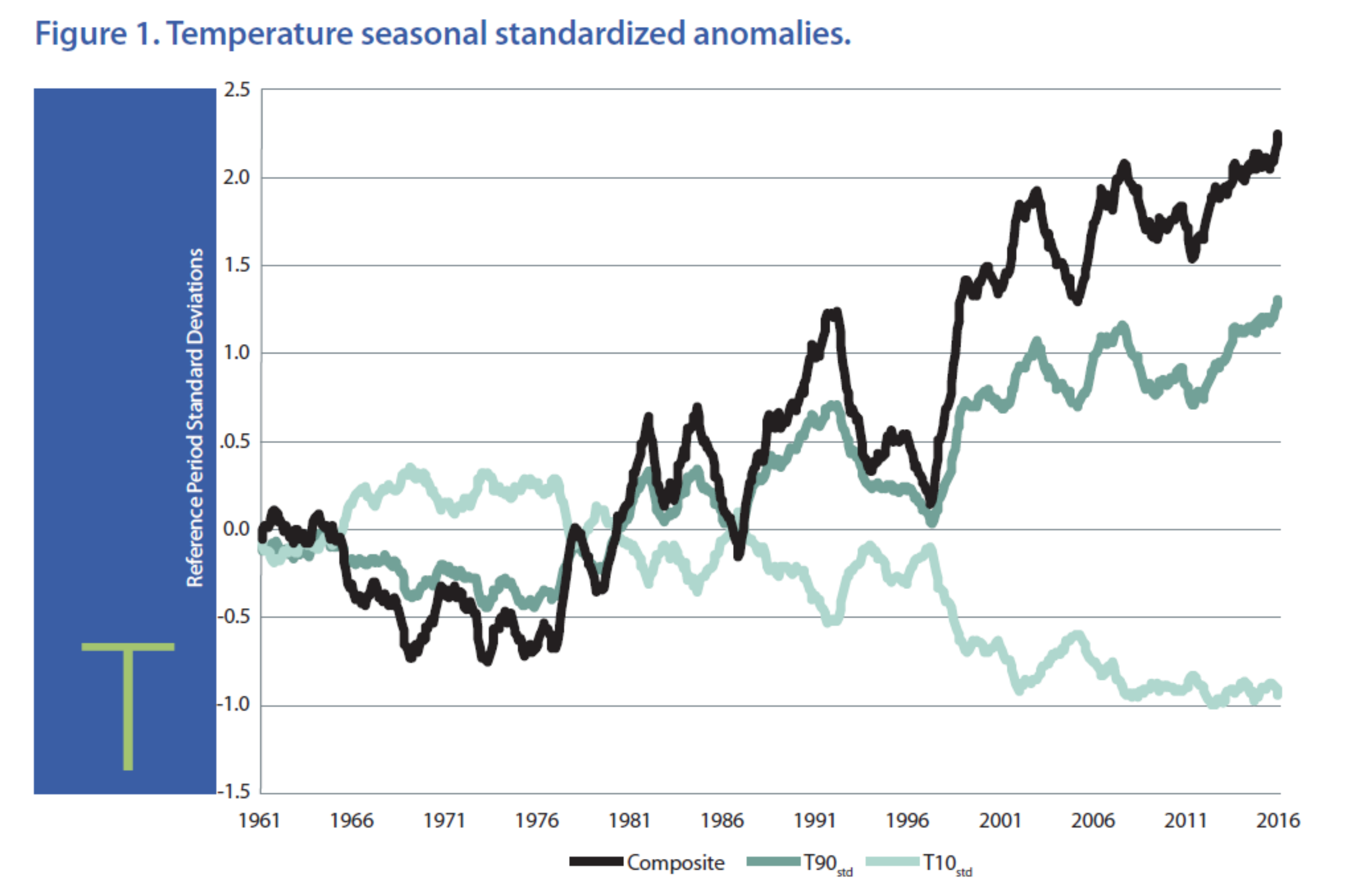
Source: http://actuariesclimateindex.org/explore/component-graphs/



U.S. and Canada Combined

Temperature – T90 and T10

- 2 components – above 90th % and below 10th %



- Monthly frequency of daily maximum (generally daytime) and minimum (generally nighttime) temperatures lying below the 10th and above the 90th percentiles of the probability distribution function (PDF) used

PDF normal

Temperature – T90 and T10

- T90 is calculated for both daily maximum temperatures (TX90) and the daily minimum temperatures (TN90)
  T90 is the average of TX90 and TN90
  Similar for T10, with T10 = (TX10 + TN10)/2
- TX90, TN90, TX10, TN10 come from GHCNDEX, which provides monthly data on a gridded dataset (2.5 degrees latitude and longitude)
- GHCNDEX is from the National Center for Atmospheric Research and the University Corporation of Atmospheric Research, headquartered at the University of Colorado
- Standardized anomaly: compare the change since the reference period, ΔT, to its reference period standard deviation, $\sigma_{ref}(T)$ to measure what level of change in average readings is significant relative to underlying level of variability for each quantity at the region level.
  $T90_{std} = 1/2(\Delta TX90/\sigma_{ref}(TX90) + \Delta TN90/\sigma_{ref}(TN90)$,
  and $T10_{std} = 1/2(\Delta TX10/\sigma_{ref}(TX10) + \Delta TN10/\sigma_{ref}(TN10))$

Precipitation – P and D

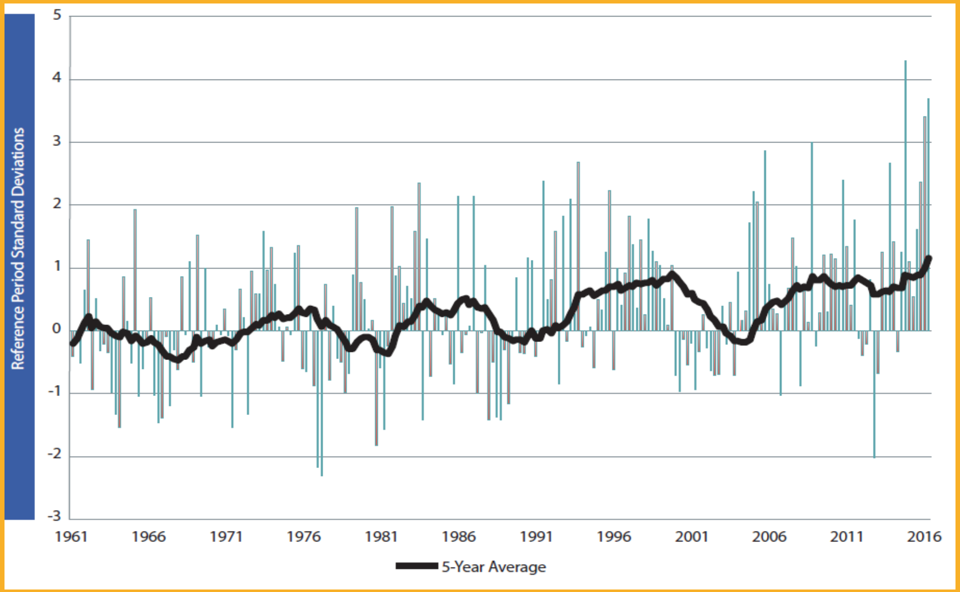
Maximum rainfall over any five consecutive days in the month converted to standardized anomalies

$\Delta P = [(Rx5day - Rx5day_{ref})/Rx5day_{ref}]$

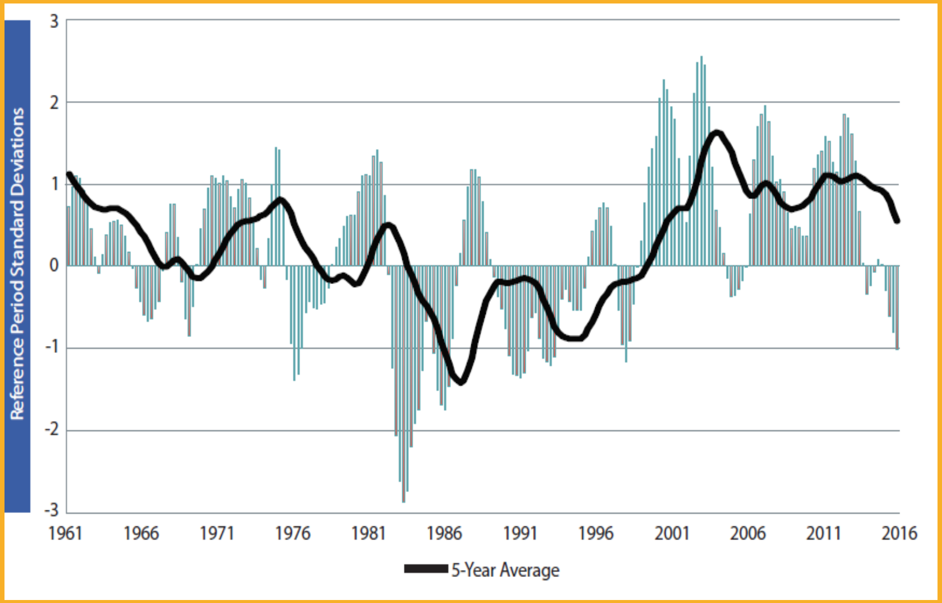
Maximum number of consecutive days in a year with less than 1mm of daily precipitation

Monthly values are linear interpolation of annual values

Maximum five-day rainfall seasonal standardized anomalies



Consecutive Dry Days seasonal Standardized anomalies

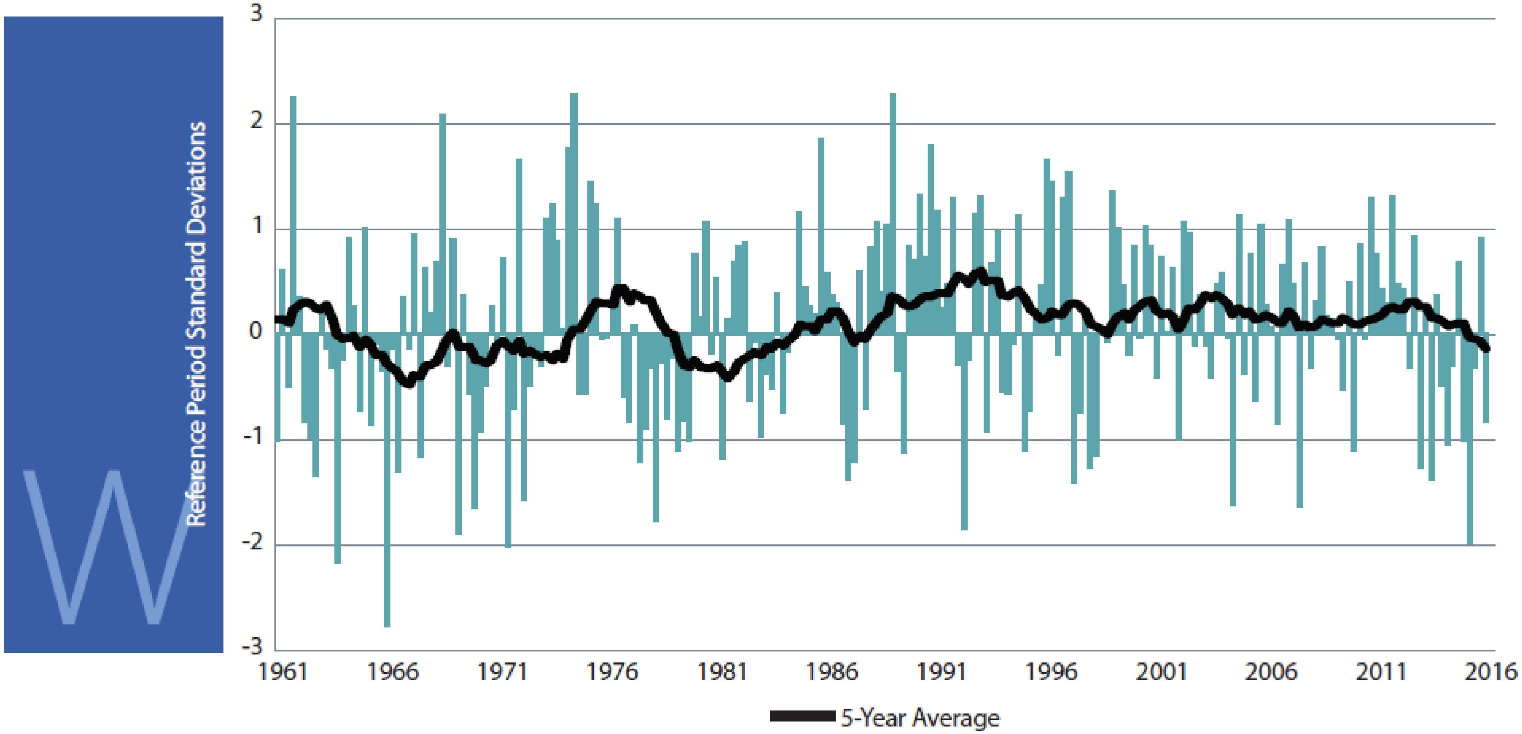


Wind – W

Daily wind speed converted to Wind Power WP
$WP = (1/2)\rho w^3$
Where ρ is air density, w is daily mean wind speed

- Percent Anomaly used as component
- $\Delta W = (\Delta WP90/WP90_{ref})$

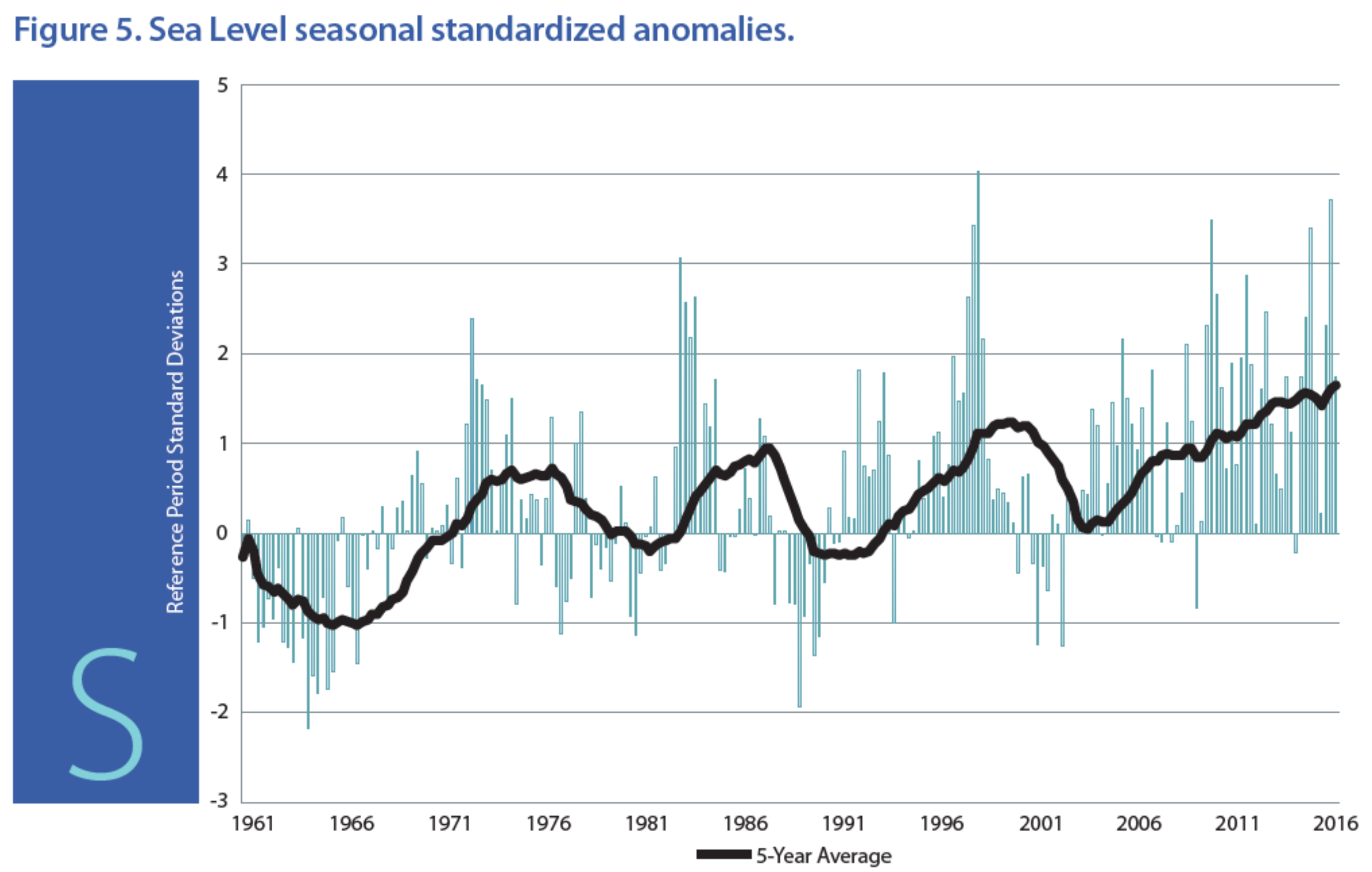
Figure 4. Wind Power seasonal standardized anomalies.



Sea Level – S

Use measurements from tide gauges located at 76 permanent coastal stations

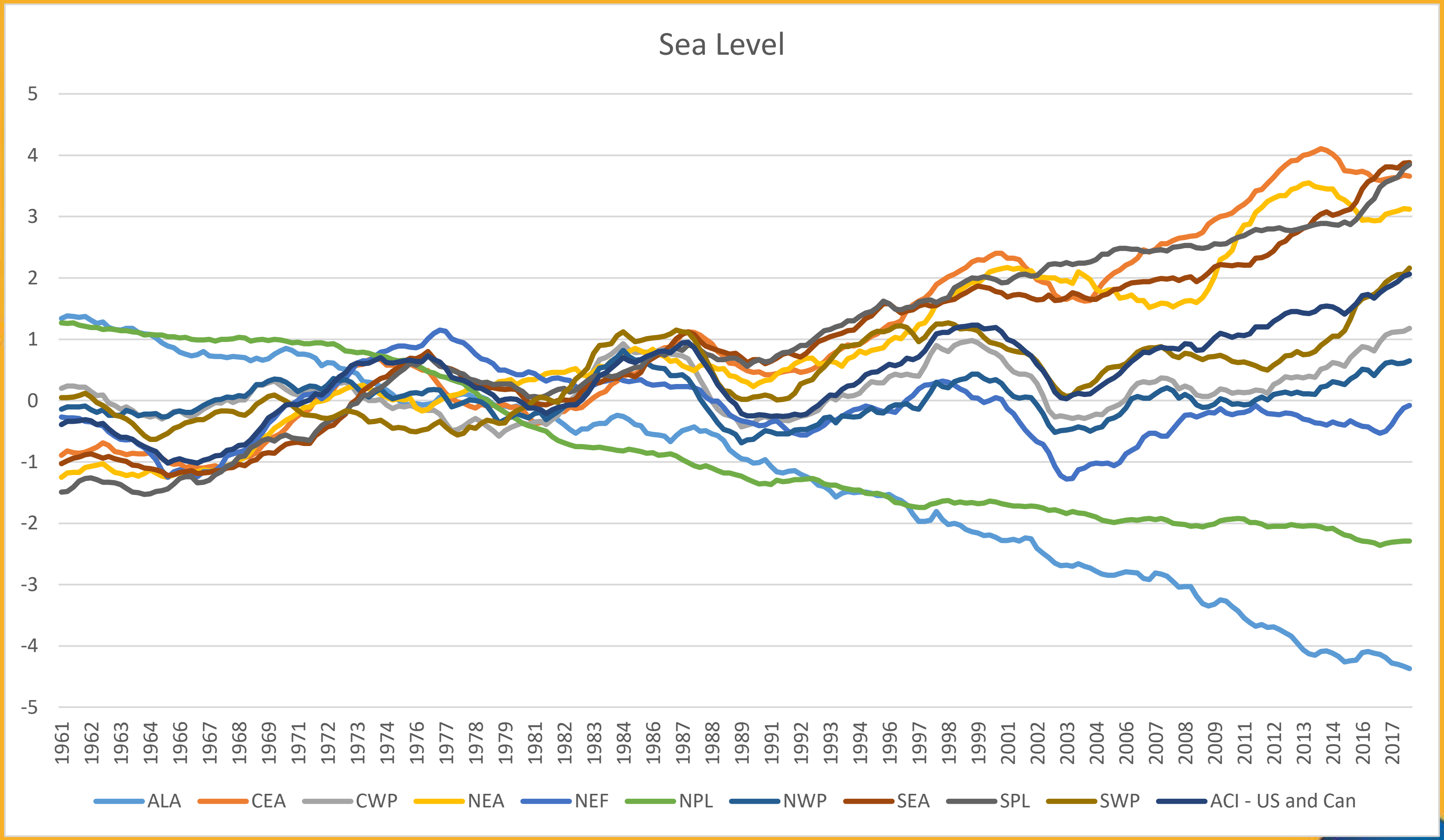
Sea level relative to land (because land may be moving want combined effect of change in level to seas and land)



Standardized Anomaly used as component

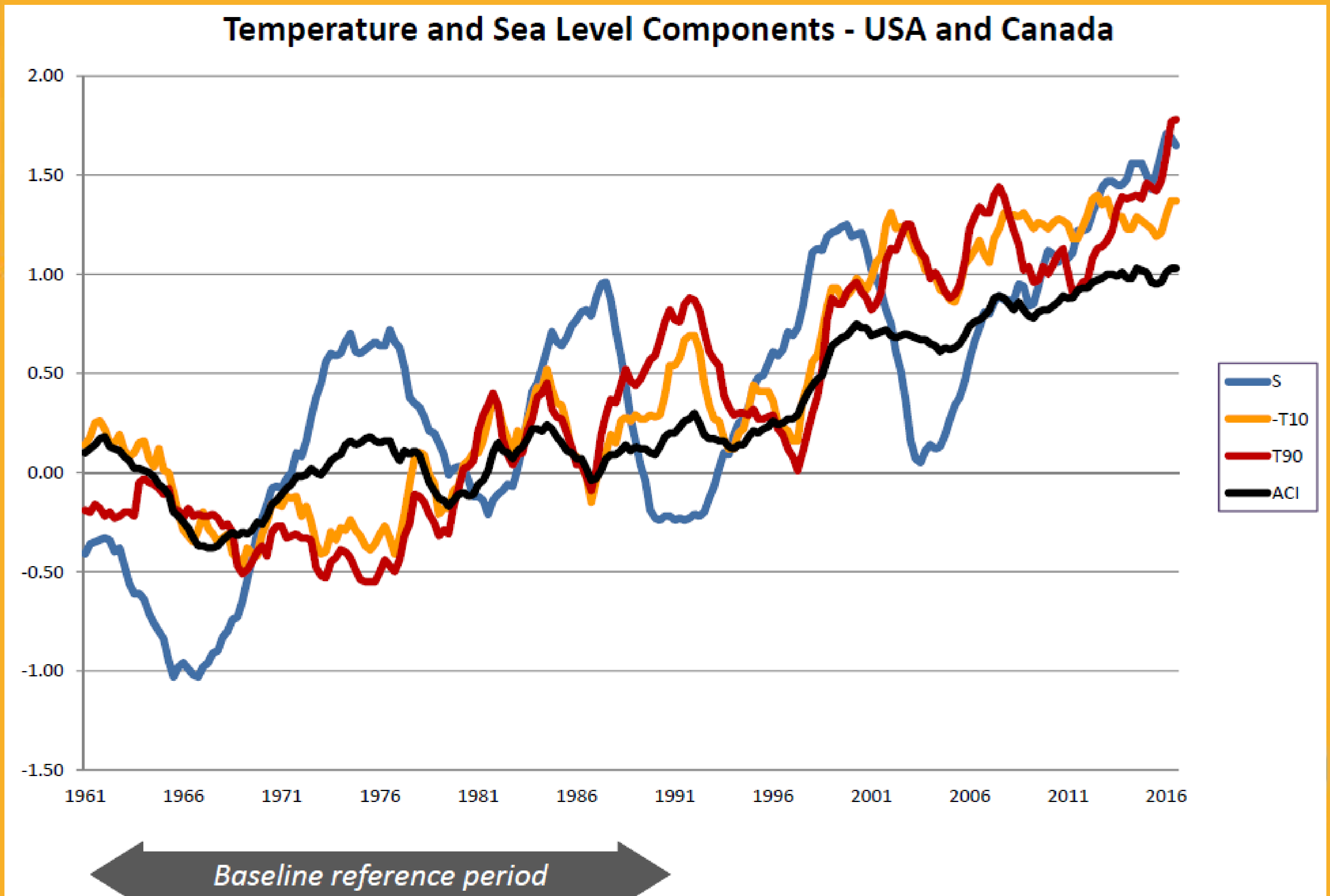
$S_{std} = \Delta S / \sigma_{ref}(S)$

Sea Level – changes vary by region

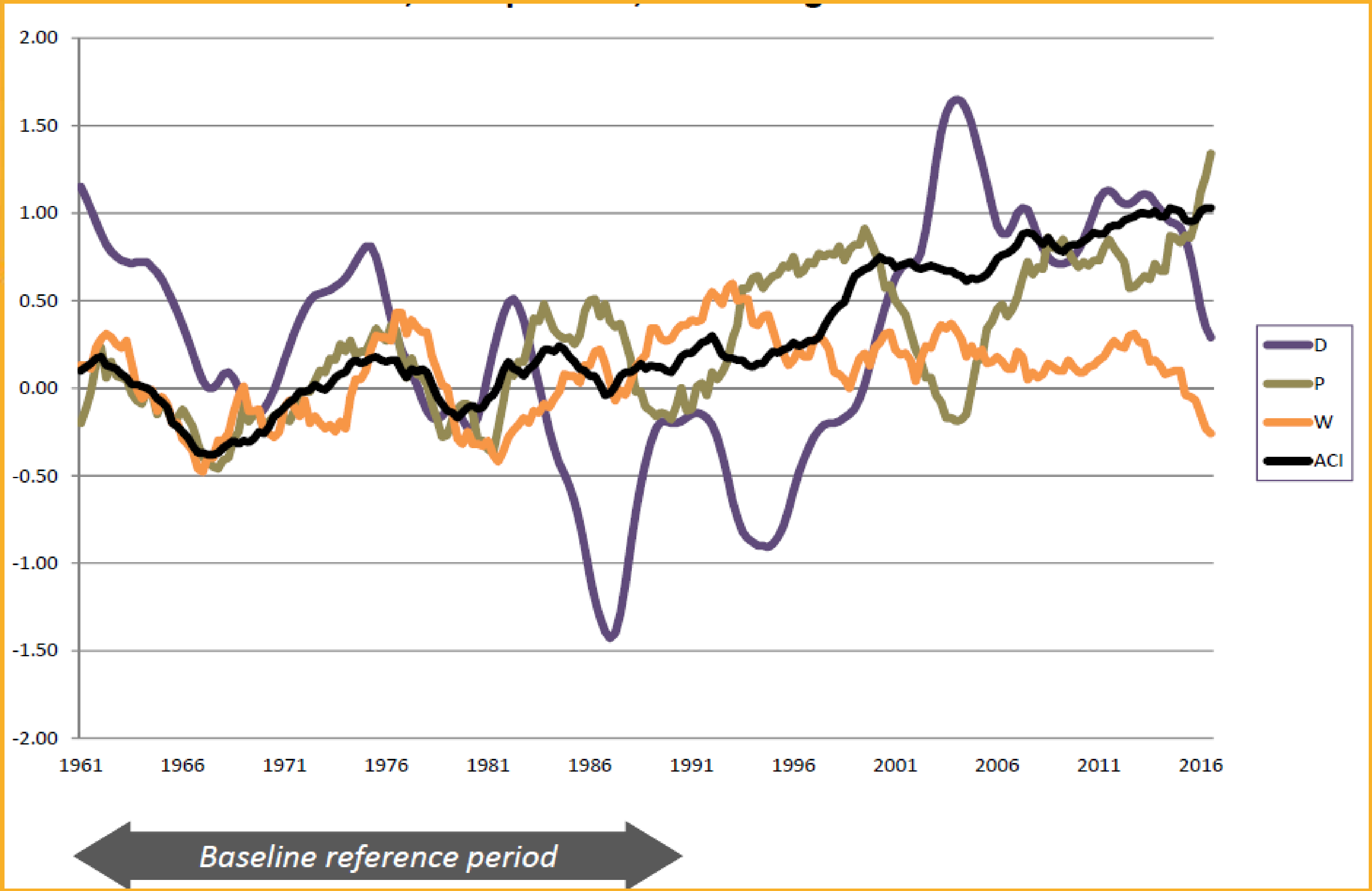


AK and NPL going highly negative while SEA,CEA, SPL, NEA highly positive

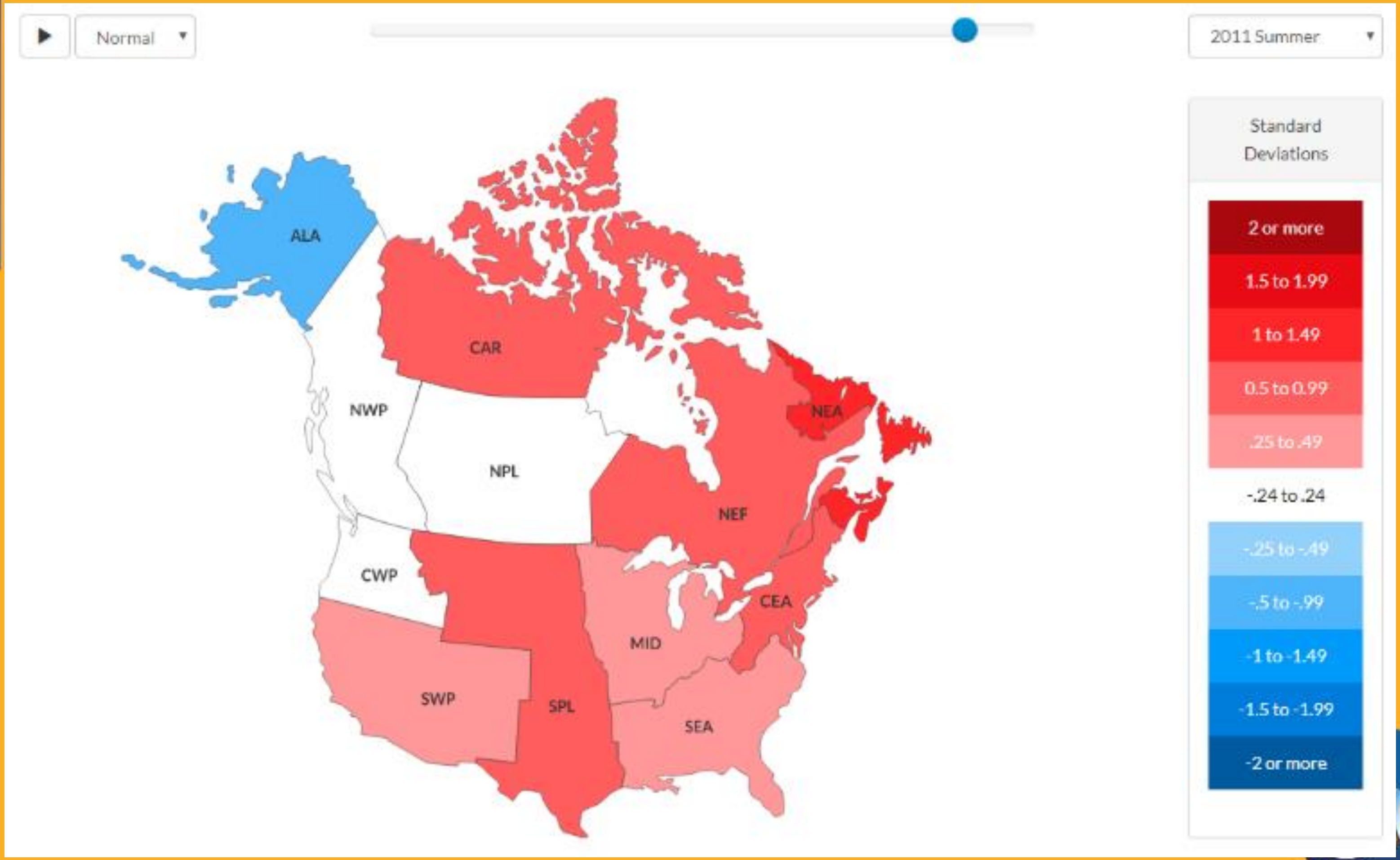
Temperature and Sea Level Components – USA and Canada

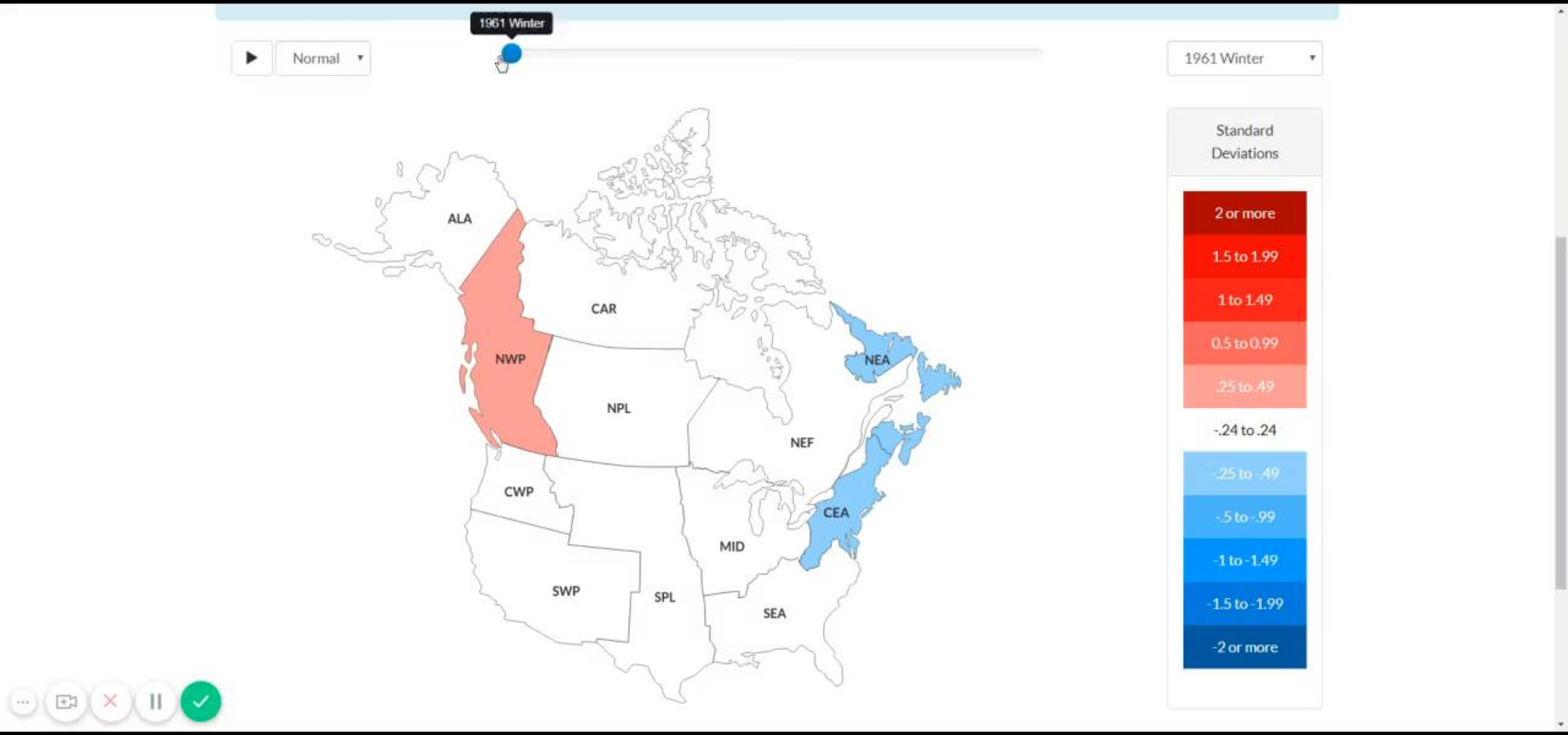


Wind Power, Precipitation, and Drought – USA and Canada



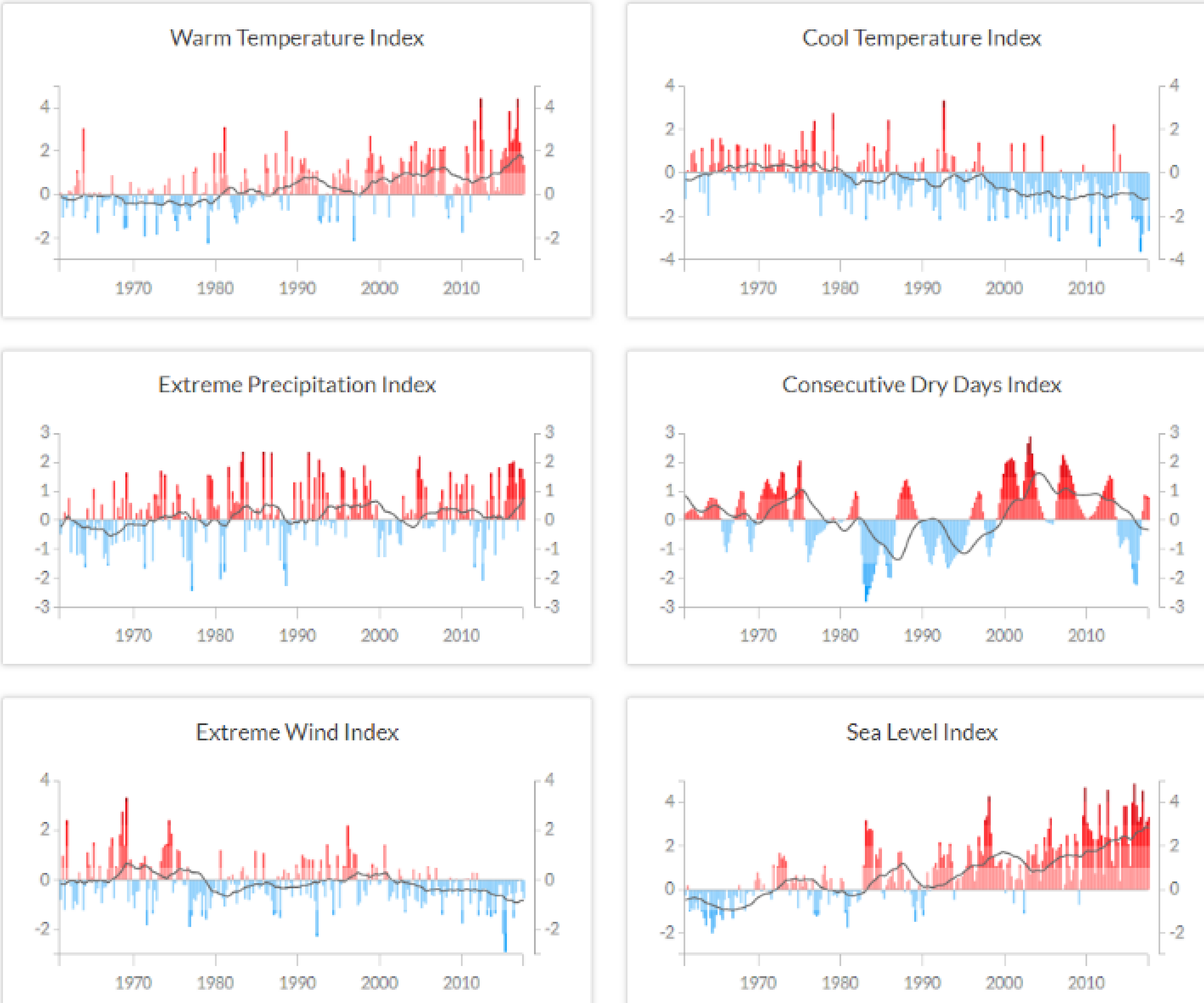
US and Canada Region, The ACI – Summer 2001
View an animation of 5-year moving average values:
http://actuariesclimateindex.org/maps/




1961 Winter
Normal
1961 Winter
Standard Deviations
2 or more
1.5 to 1.99
1 to 1.49
0.5 to 0.99
.25 to .49
-.24 to .24
-.25 to -.49
-.5 to -.99
-1 to -1.49
-1.5 to -1.99
-2 or more
ALA
CAR
NWP
NPL
NEA
NEF
CWP
CEA
MID
SWP
SPL
SEA

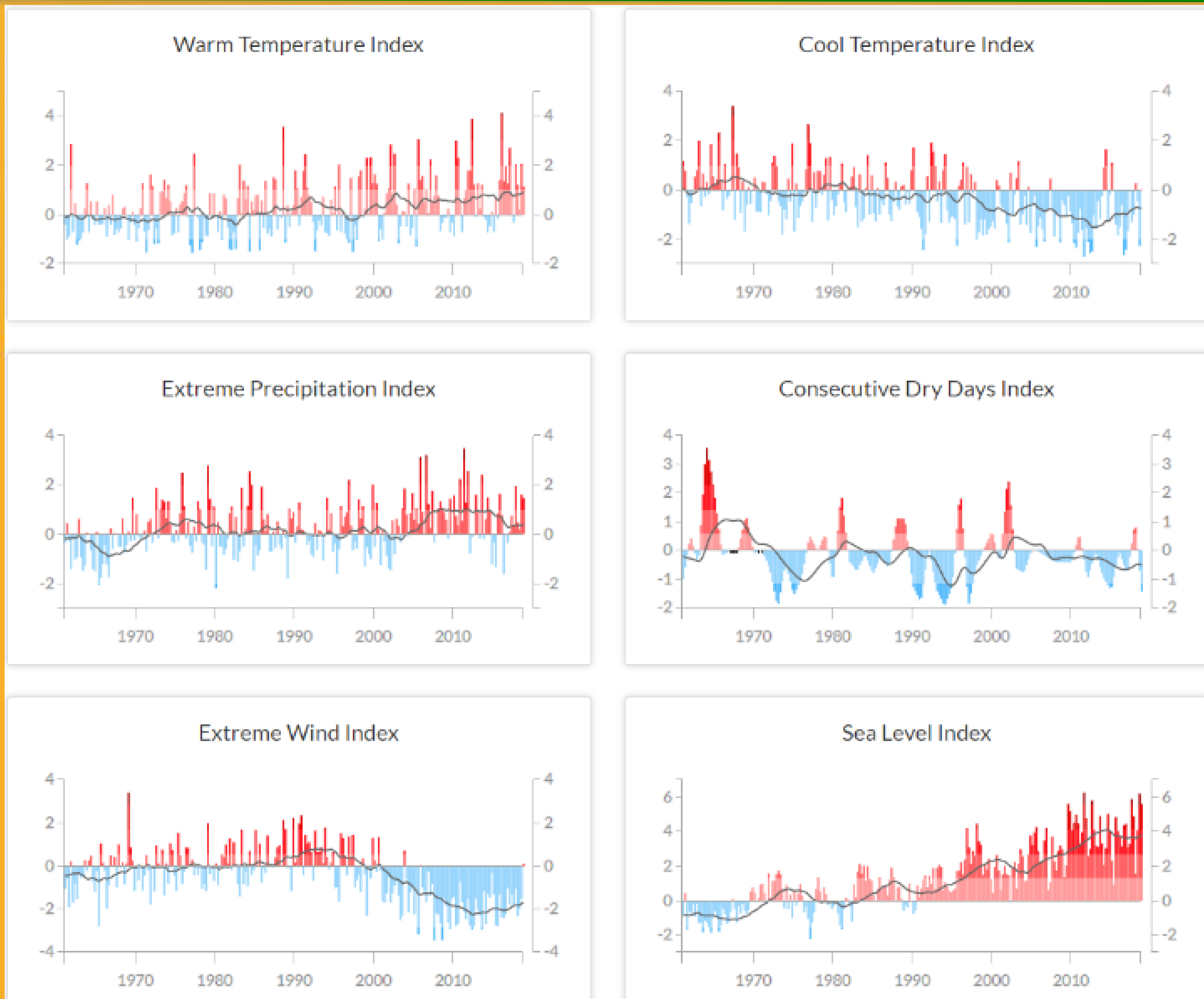
Continental USA - ACI Components – **Seasonal**

Temperature, Precipitation, Drought, Wind, and Sea Level Components



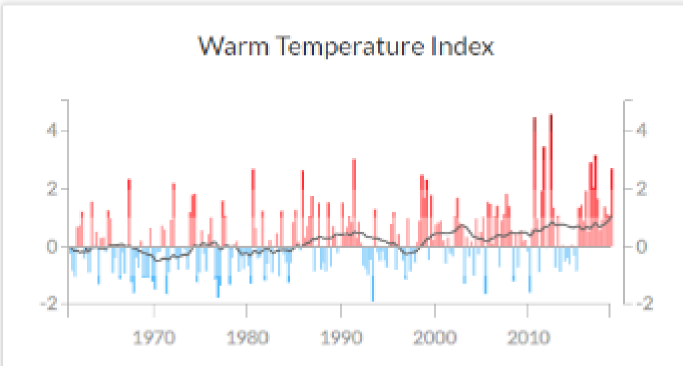
Central East Atlantic - ACI Components –Seasonal

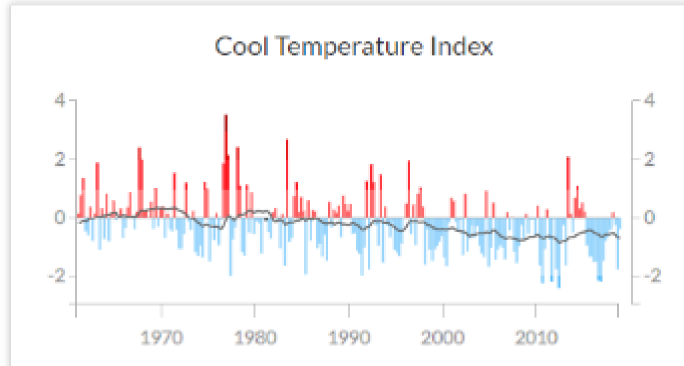
Temperature, Precipitation, Drought,Wind and Sea Level Components

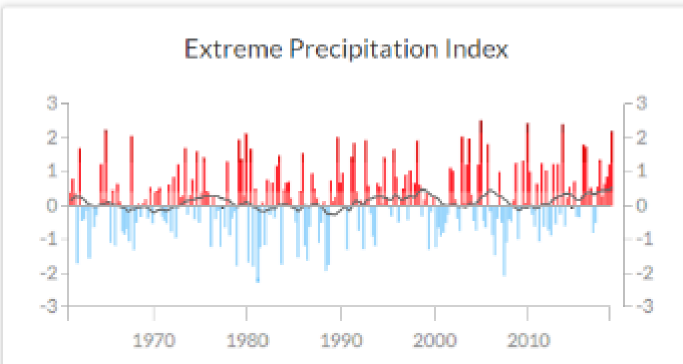


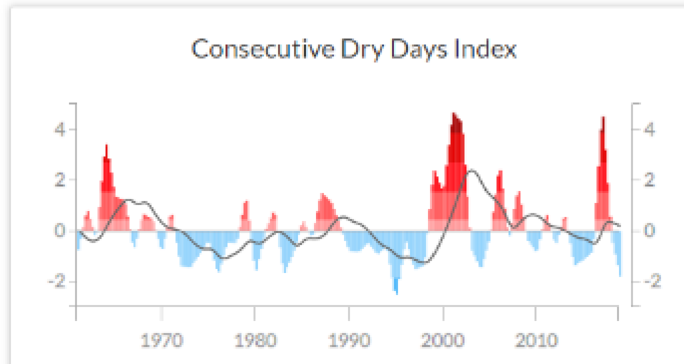
Southeast Atlantic - ACI Components **–Seasonal**

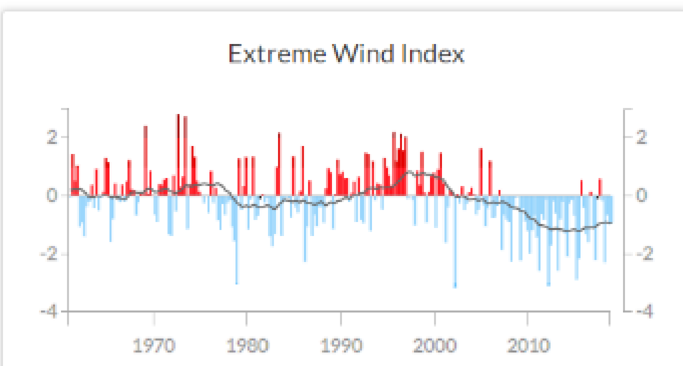
Temperature, Precipitation, Drought,Wind and Sea Level Components

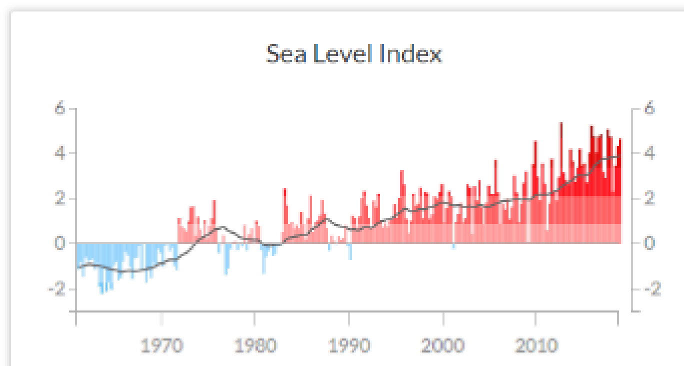




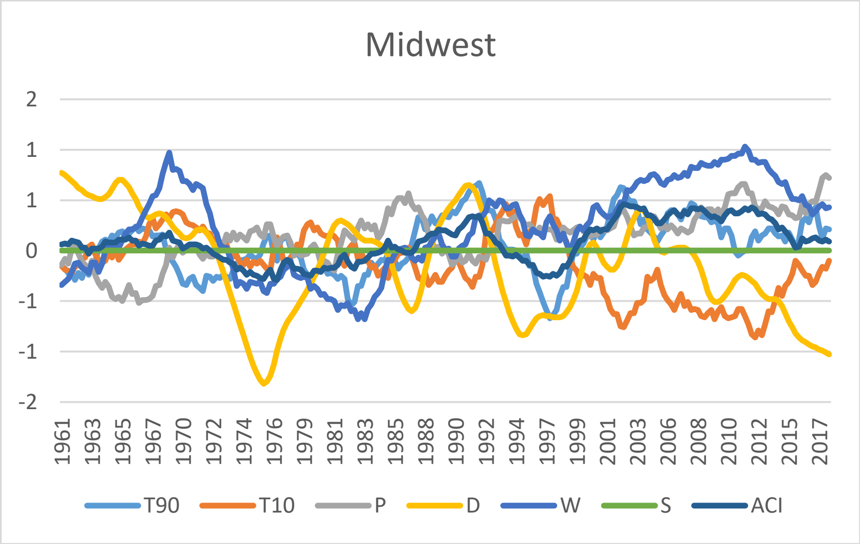


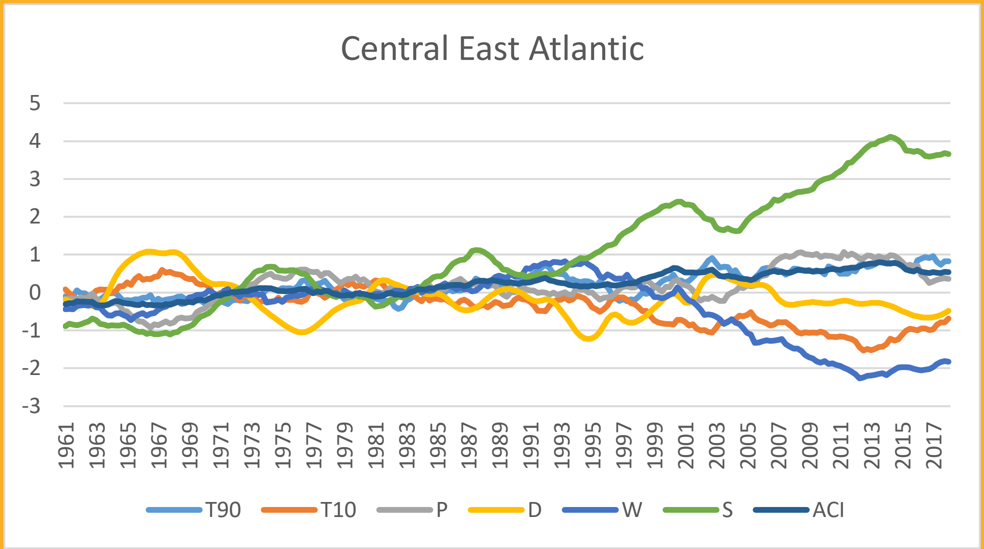


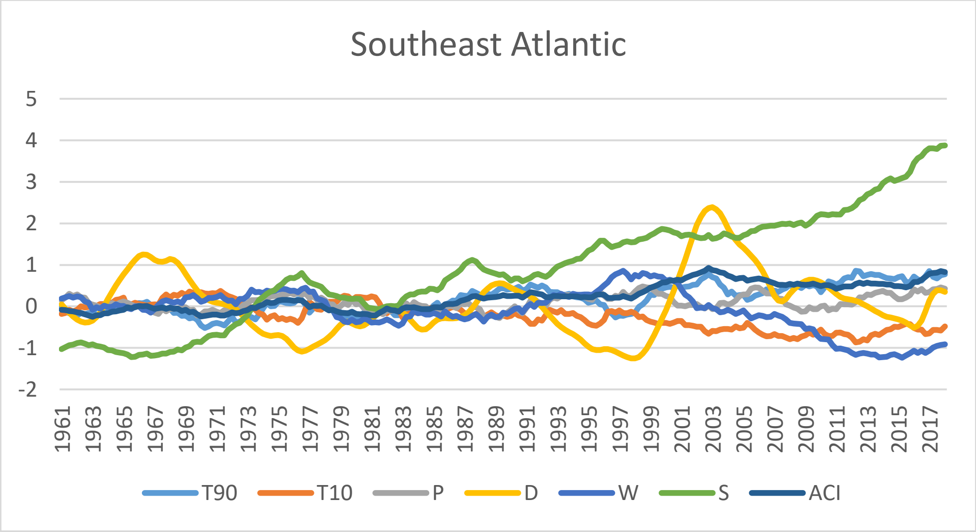




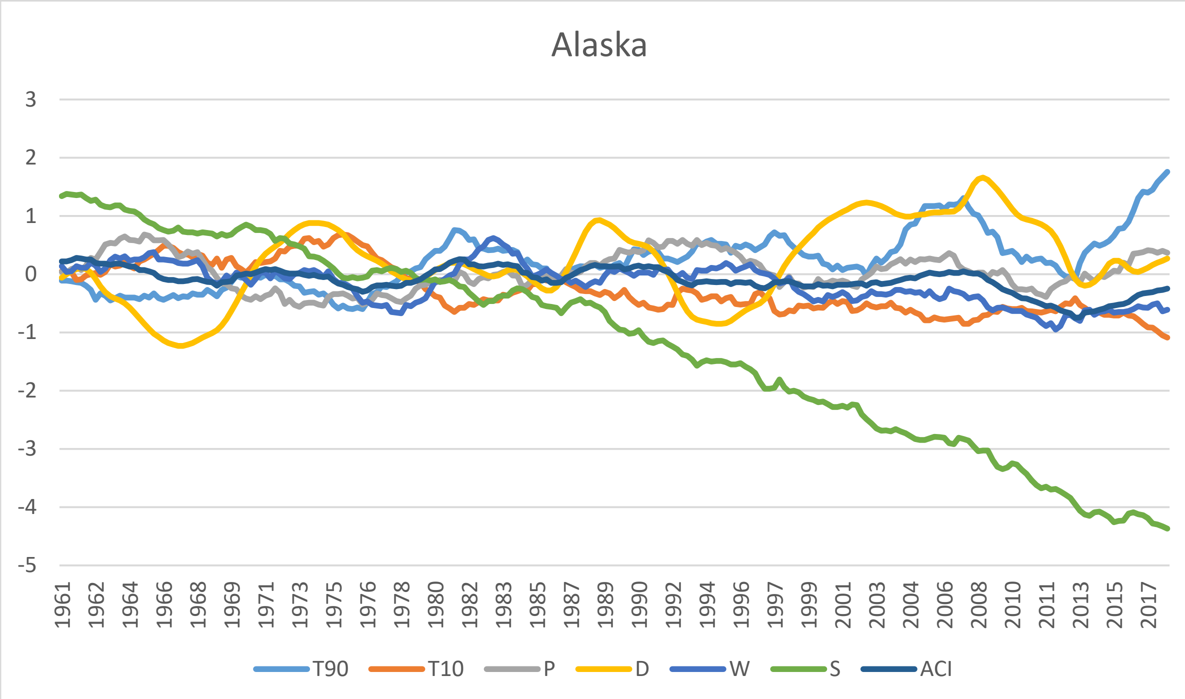
Certain components are more important in certain regions

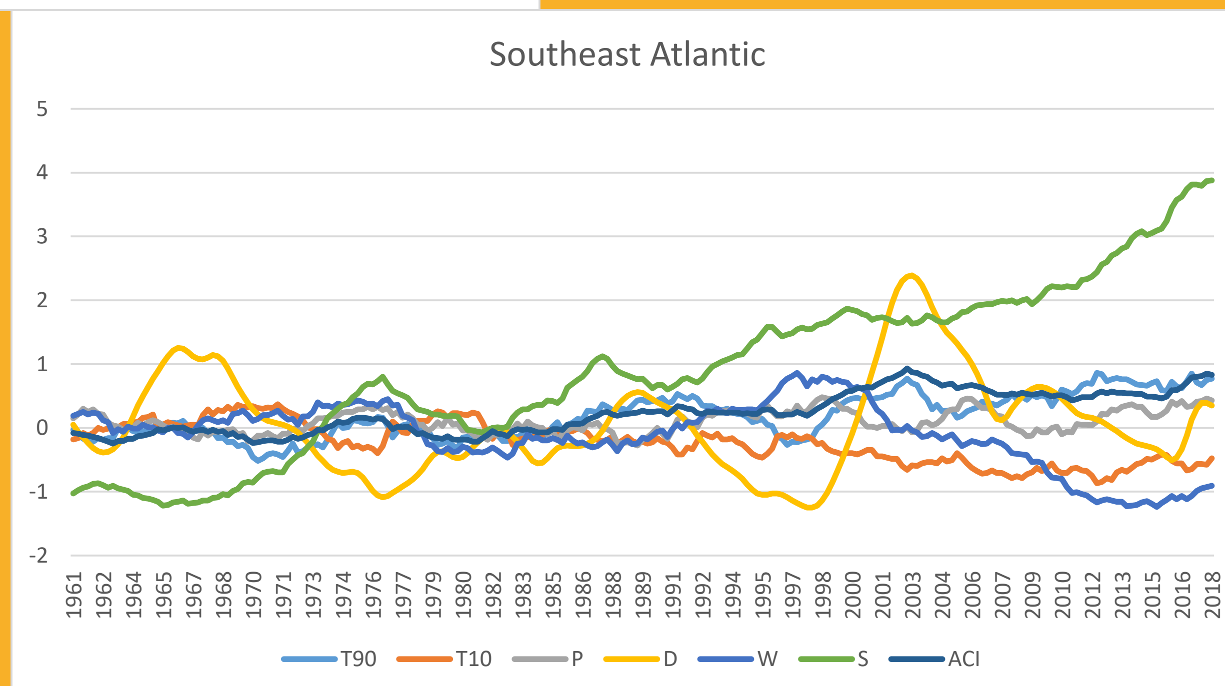




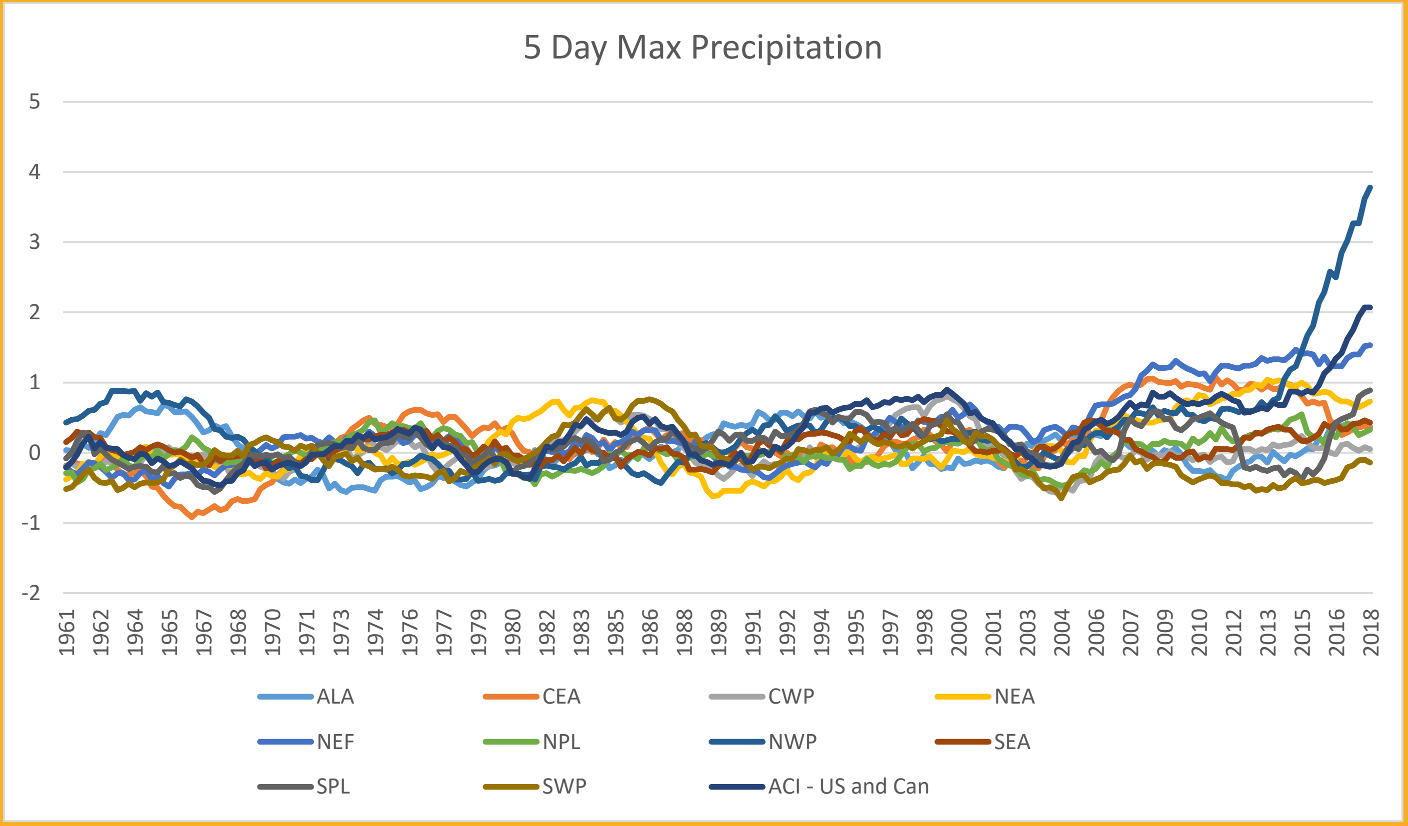


Note Sea Level Rise AK vs. SEA



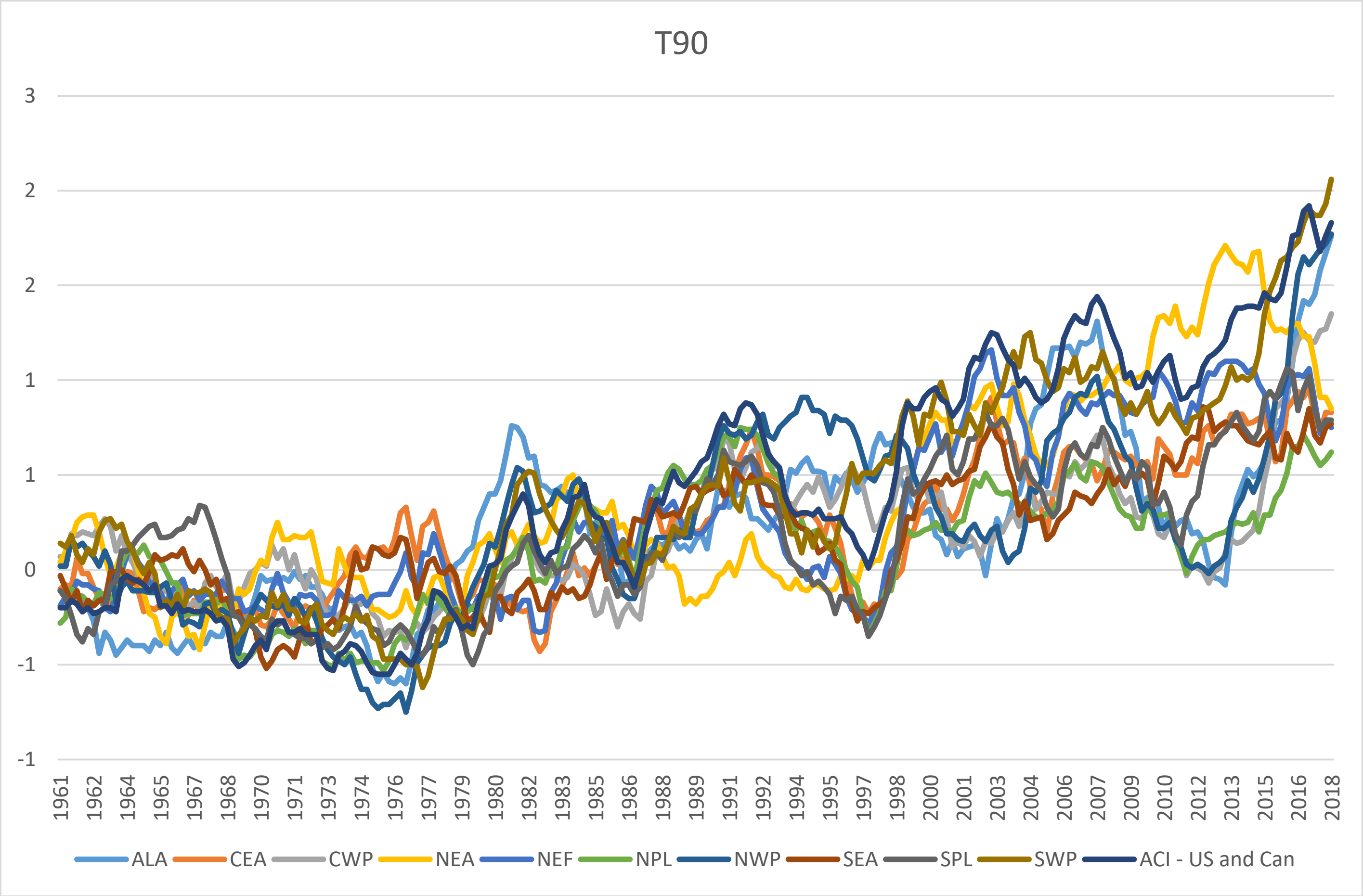


Comparing Regions for 5-Day Max Precipitation



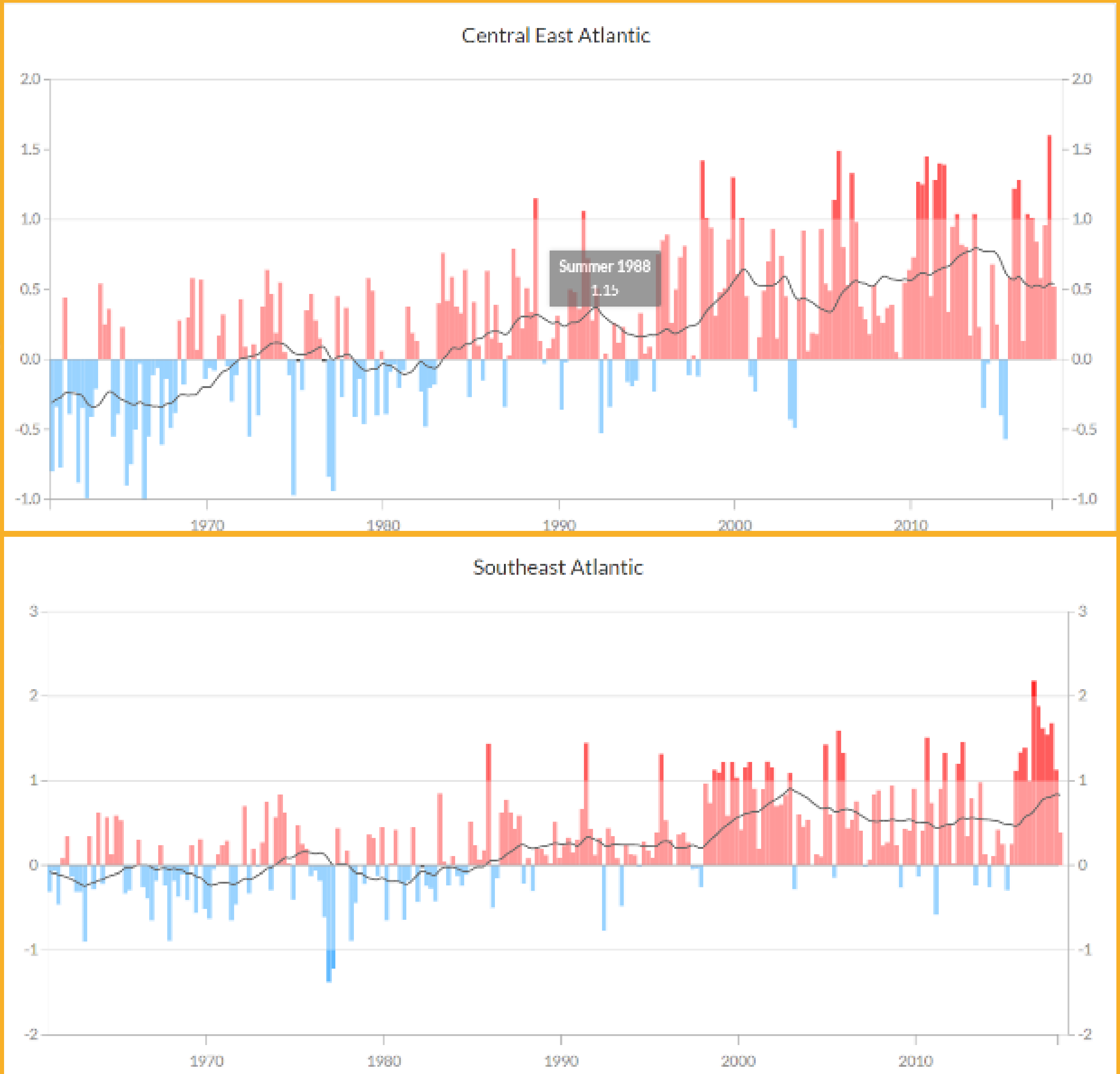
NWP pulls upward, SWP and CWP downward

Comparing Regions for T90



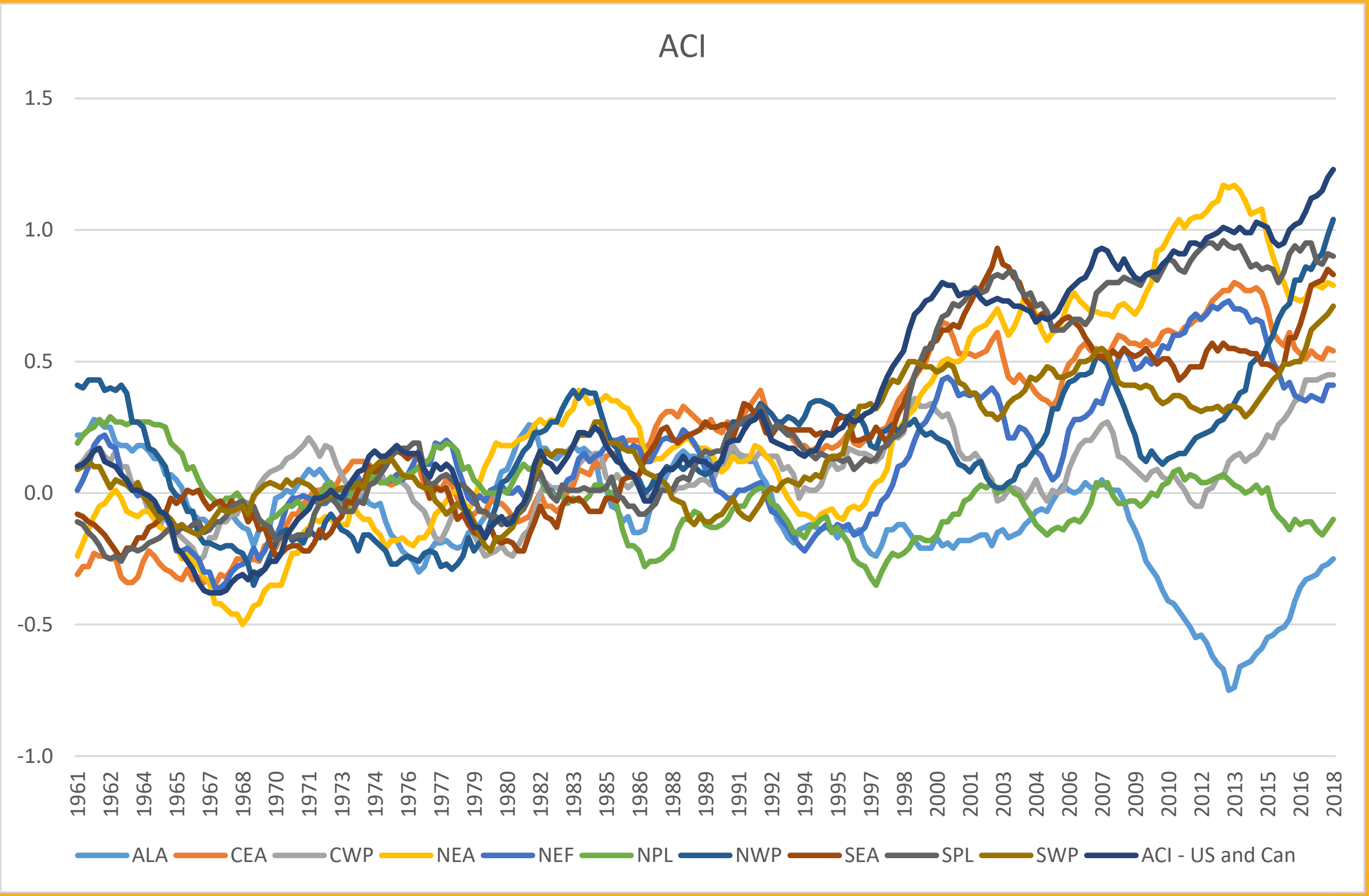
SWP and AK high

How do Regions Compare?



Composite Index

ACI across Regions

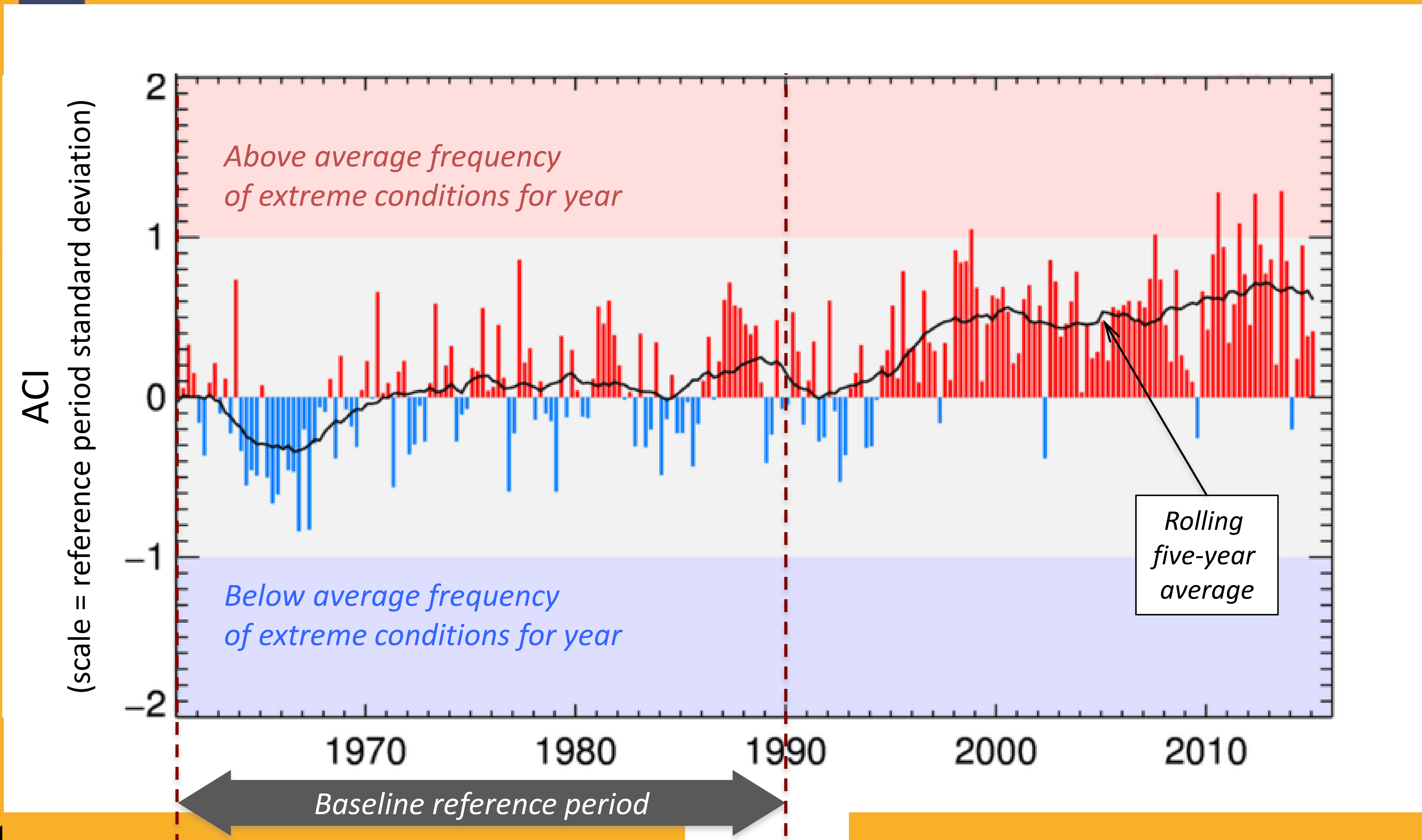


AK and NPL below 0; CWP NEF below 0.5

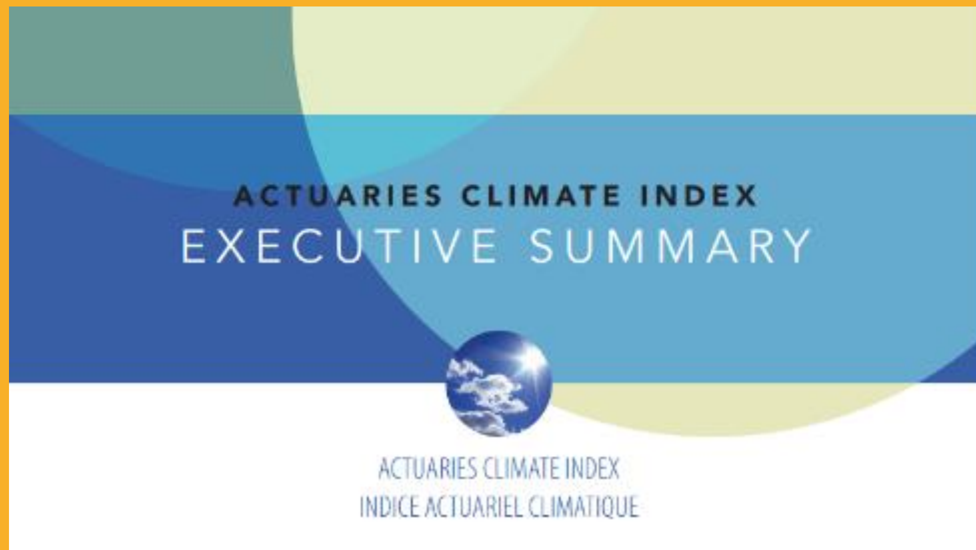
The Actuaries Climate Index (ACI) shows that the frequency of extreme weather has increased

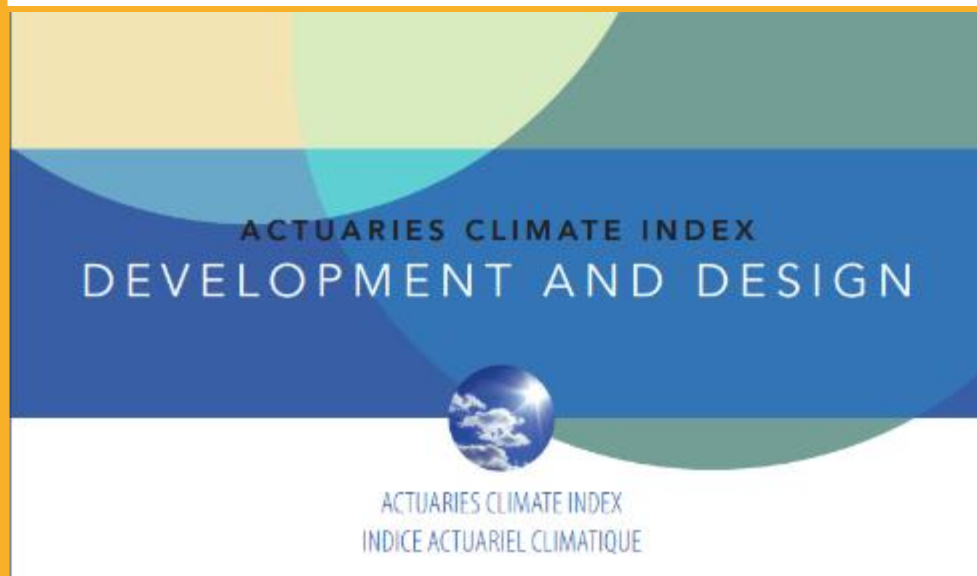
(More frequent heat, rain/drought, and less frequent cold)

(Combined mean index for all of US and Canada)



ACI Resources





Actuaries Climate Risk Index®

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Middle Atlantic Actuarial Club, November 20, 2019; Columbia MD

Actuaries Climate Risk Index® (ACRI)

ACRI—Status Update

- Research update describing version 1.0 of ACRI under review by the sponsoring actuarial associations
- Estimates relationships between the ACI's weather metrics and weather-related losses; derives ACRI from those estimates
- ACRI 1.0 will focus only on the United States due to data limitations for Canada; uses four of six ACI elements (excluding Drought and Sea Level)
- ACRI 1.0 Research Update expected publication December 2019

Spatial Hazard Events and Losses Data for the United States (SHELDUS)

- Loss Data from SHELDUS, Arizona State University
- SHELDUS™ is a county-level hazard data set for the U.S. and covers natural hazards such as thunderstorms, hurricanes, floods, wildfires, and tornados as well as perils such as flash floods, heavy rainfall, etc. The database contains information on the direct losses caused by events (property and crop losses, injuries, and fatalities) from 1960 to present.
- Information primarily derived from NOAA Storm Event Monthly Reports which, since 1996, are included in the NOAA Storm Events database.

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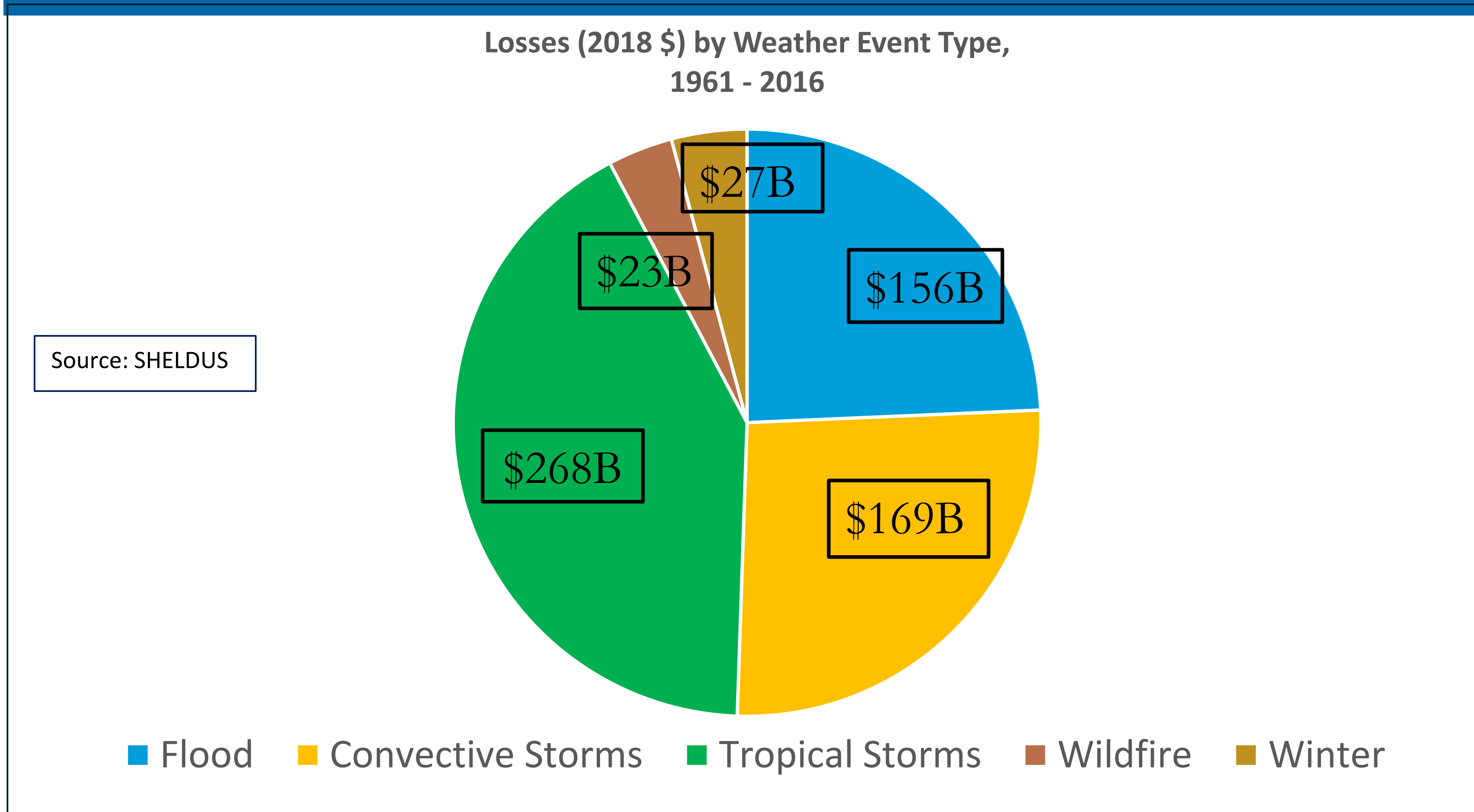
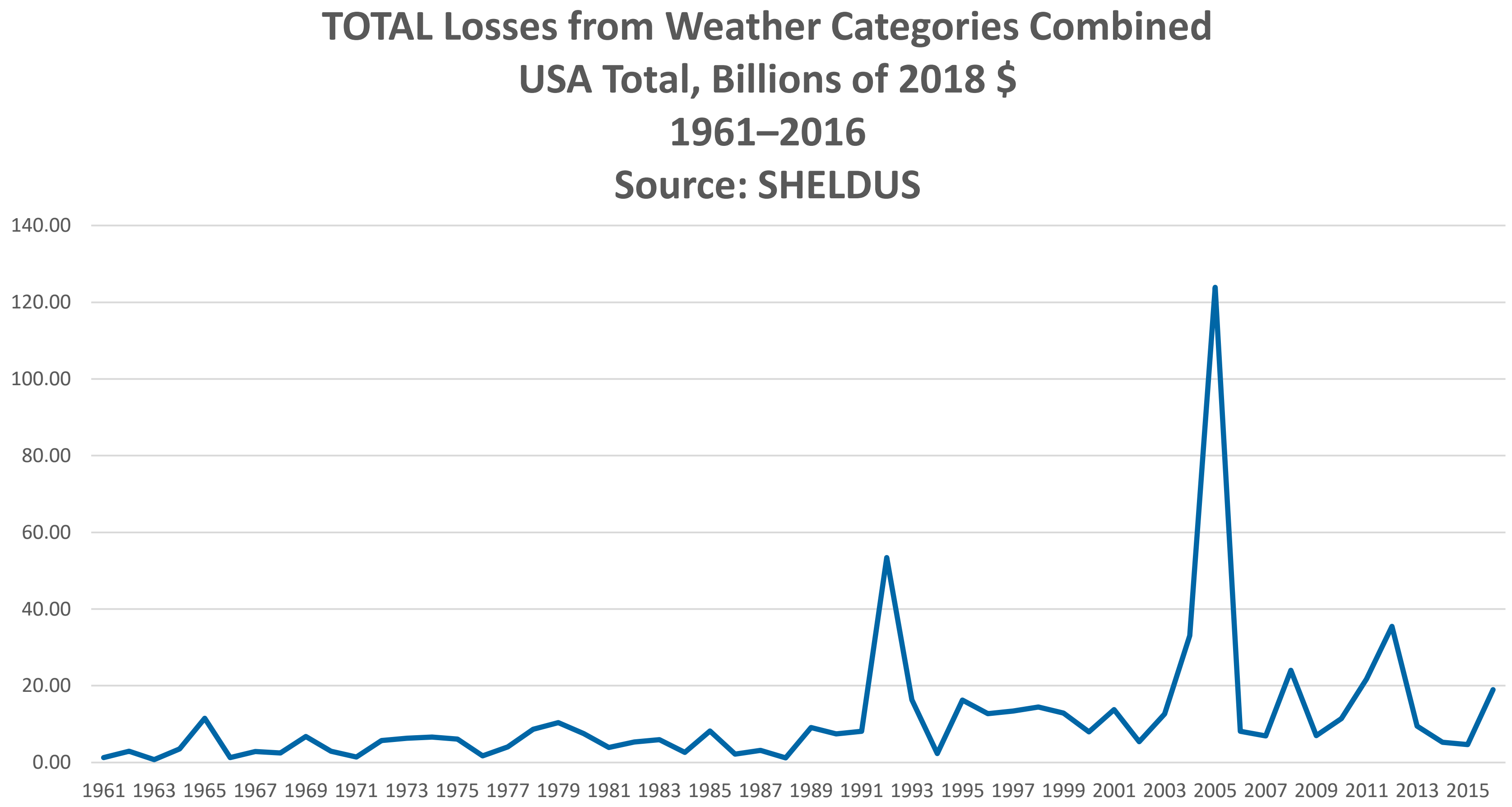
Losses by Weather Categories, 1961–2016



Weather-Related Losses Combined, 1961–2016



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Inherent Difficulty

“Methods used to estimate the potential economic effects of climate change in the United States … and the studies that use them produce imprecise results because of modeling and other limitations but can convey insight into potential climate damages across sectors in the United States.”

GAO 17-720, “Climate Change,” September 2017

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Limited Losses

"Economic costs of extreme weather events have increased over the period 1960–2000. … However, the greatest contributor to increased cost is rising exposure associated with population growth and growing value of assets."

IPCC, 2014: *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects.*

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Statistical Approach to ACRI

- Combine losses from all weather categories
- Fit exponential model of Losses to Set of ACI weather metrics using OLSQ:

$$Losses(\$) = A * T90^{a} * T10^{b} * Precip^{c} * Wind^{d} * Exposure^{e}$$

- Use a pooled, cross-section for Region-Months
- Correct for heteroskedasticity by adjusting covariance matrix (MacKinnon and White)
- ACRI for a region-month equals (predicted losses) – (average, exposure-adjusted predicted losses during reference period)

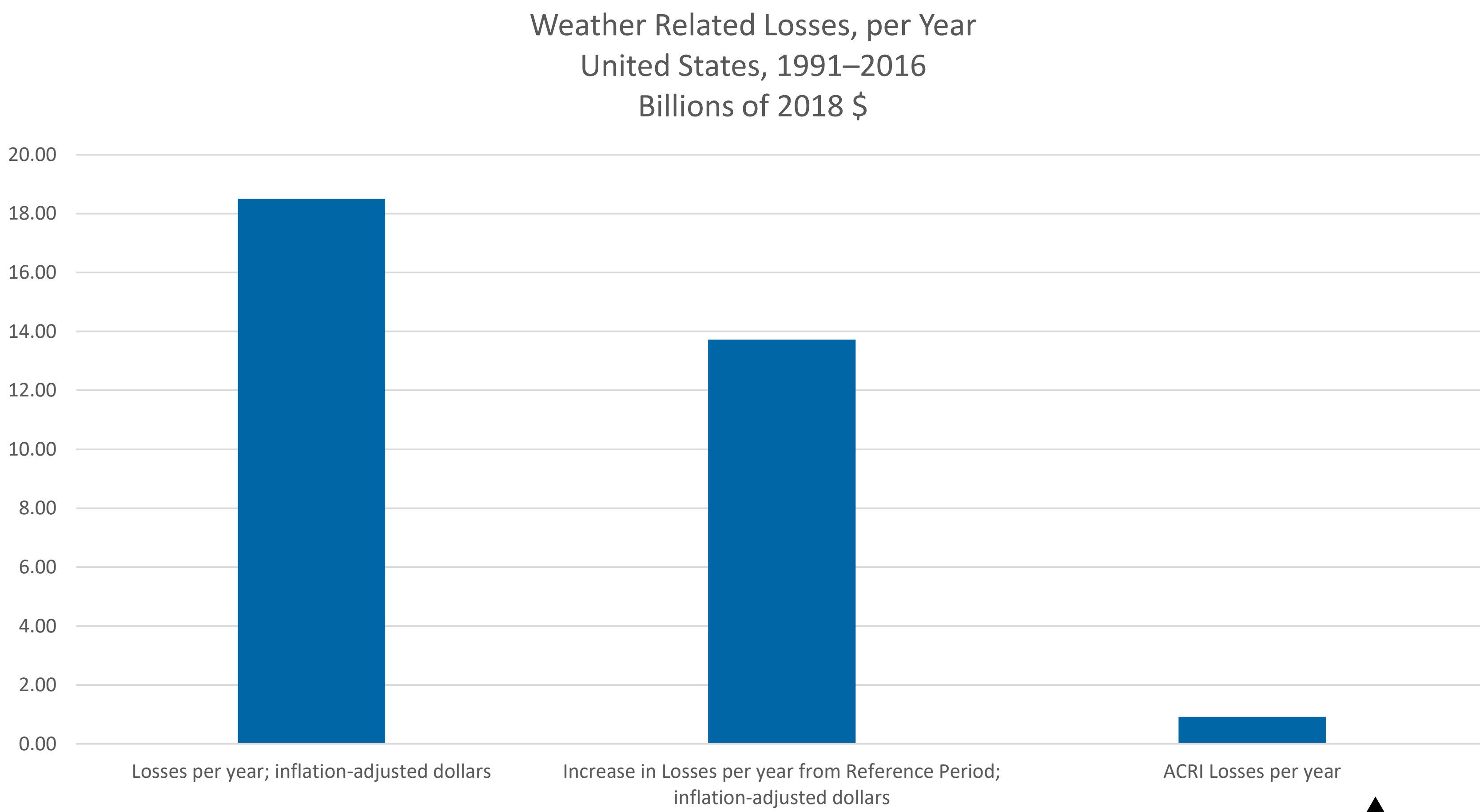
ACRI Losses with Confidence Intervals

ACRI Losses by Region, with Confidence Intervals
(in billions)

	1991-2016	Intrinsic, Lower Limit	Extrinsic, Lower Limit	Intrinsic, Upper Limit	Extrinsic, Upper Limit
USA	$23.78	$15.72	$2.42	$35.98	$45.15
SEA	$22.42	$14.82	$10.90	$33.91	$33.94

- ACRI Best Estimate: ~$1 billion per year in the USA, mostly from the South East Atlantic region
- ACRI (USA) 90% confidence Interval, intrinsic uncertainty: ~$0.5 billion - ~$1.5 billion per year
- Intrinsic 90% confidence interval: uses 90% confidence interval for predicted losses to produce ACRI estimates, capturing uncertainty of parameter estimates
- ACRI (USA) 90% confidence interval, extrinsic uncertainty: ~$0.0 billion - ~2.0 billion
- Extrinsic 90% confidence interval: based on standard errors of 30 estimates of ACRI with synthetic data sets, drawn from pool of actual observations with replacement, capturing uncertainty due to sampling.

Weather-Related Losses per Year, 1991–2016: All Losses, Increase From Reference Period, ACRI



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ACRI: Conclusion

- While others find likely large losses due to changes in weather by end of 21st century, but little loss yet when controlling for changes in exposure, we find small increases in loss likely already occurred, 1991–2016 (~5% of total weather-related losses).
- We also find substantial uncertainty in these estimates.
- Challenges prompting us to version 2.0.

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Further Work

- Working with other organizations to add regions
- Australia recently came out with their own index
- Actuarial Association of Europe working on index
- Less data is available in Asia, but could perhaps have index

BEYOND THE ACI AND ACRI

ACTUARIES AND CLIMATE CHANGE RISK

Beware of non-catastrophic events as well as catastrophic:

- Increased hailstorm frequency
- WC risk with more hot days
- Increased risk to first responders – more severe weather events
- Crop risk – changes as climate changes
- Invasive species – increased risk?
- Loss of natural buffers to flood and wind due to climate change

ACI: Toward Version 2.0

Possible refinements of ACI:

- Additional weather and/or hydrologic elements (e.g., inland water levels)
- Station-level, rather than gridded, data
- Reanalysis data for all but precipitation
- Maximum wind speed, rather than average
- Monthly drought rather than annual
- Improved aggregation to regional and super-regional levels

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QUESTIONS?

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