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

ACTUARIES CLIMATE INDEX
INDICE ACTUARIEL CLIMATIQUE

CLRS
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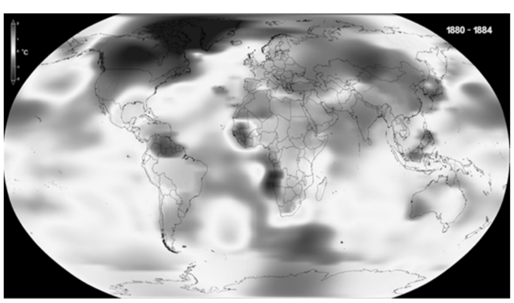
Why do we need a climate index?

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



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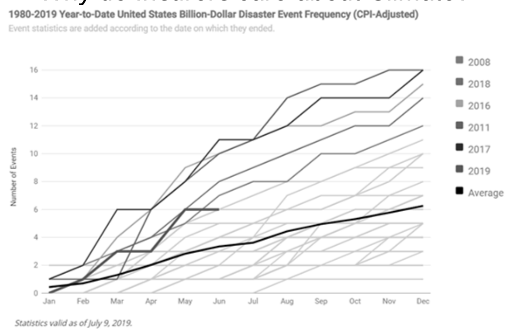
Why do Insurers care about Climate?



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

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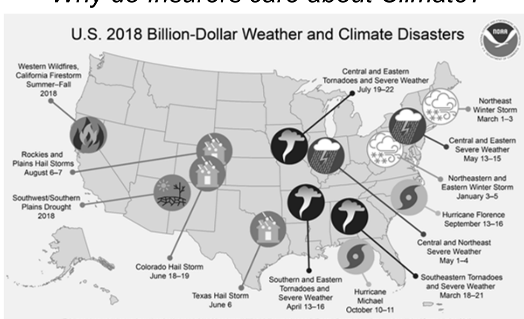
Why do Insurers care about Climate?



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.

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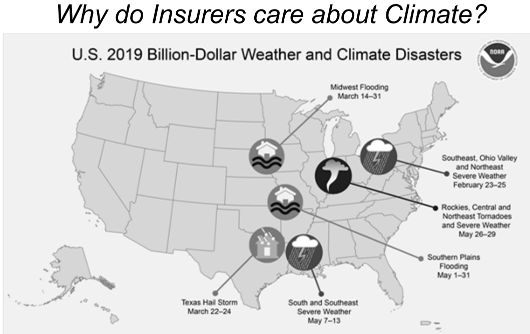
Why do Insurers care about Climate?



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

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Background of the

ACTUARIES CLIMATE INDEX

HTTP://ACTUARIESCLIMATEINDEX.ORG/HOME/

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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

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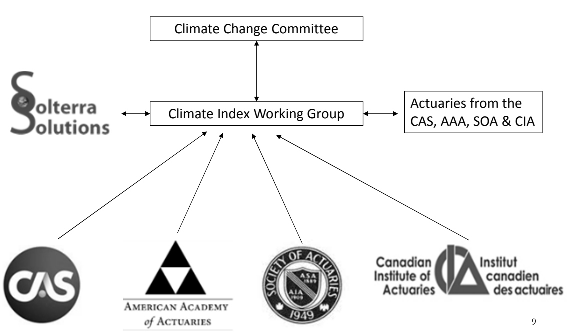
WHICH NORTH AMERICAN INSURANCE ACTUARIES GOT TOGETHER?



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Regions and Components of the ACI

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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

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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

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6 ACI Components

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

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

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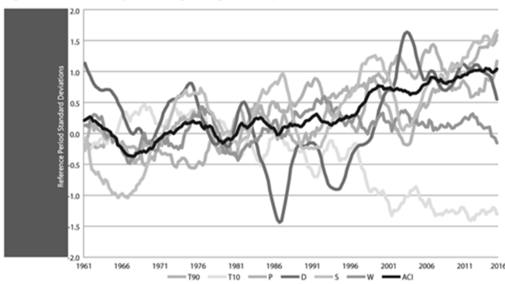
Overall ACI and components

Source: Executive Summary

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



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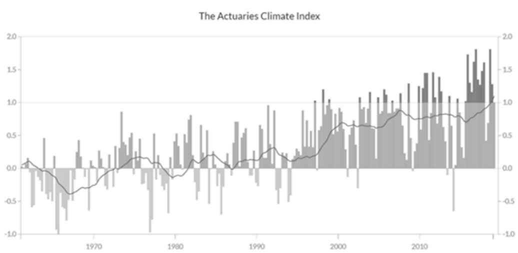
ACI by season

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



U.S. and Canada Combined

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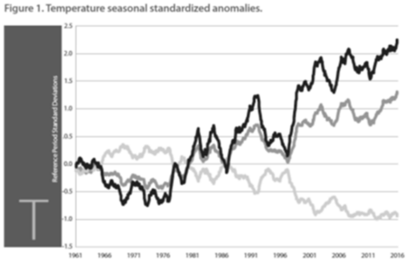
Temperature – T90 and T10

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

Figure 1. Temperature seasonal standardized anomalies.



- 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

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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 $T10_{std} = 1/2(\Delta TX10/\sigma_{ref}(TX10) + \Delta TN10/\sigma_{ref}(TN10))$

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Precipitation – P and D

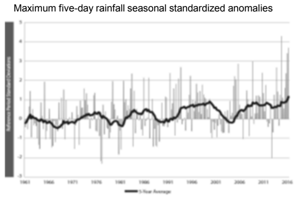
Maximum rainfall over any five consecutive days in the month converted to standardized anomalies

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

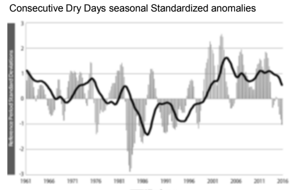
Maximum number of consecutive days in a year with less than 1mm of daily precipitation

Monthly values are linear interpolation of annual values

Maximum five-day rainfall seasonal standardized anomalies



Consecutive Dry Days seasonal Standardized anomalies

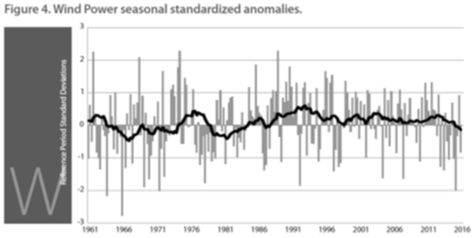


Wind – W

Daily wind speed converted to Wind Power WP
WP = (1/2)ρw³
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.



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Sea Level – S

Use measurements from tide gauges located at over 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)

Figure 5. Sea Level seasonal standardized anomalies.

Standardized Anomaly used as component

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

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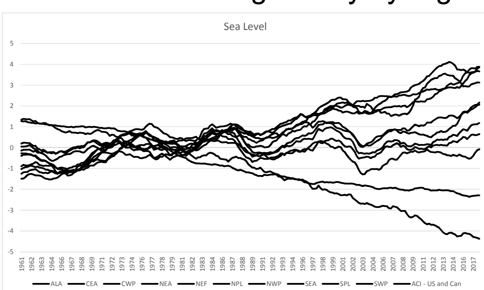
Sea Level – changes vary by region



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

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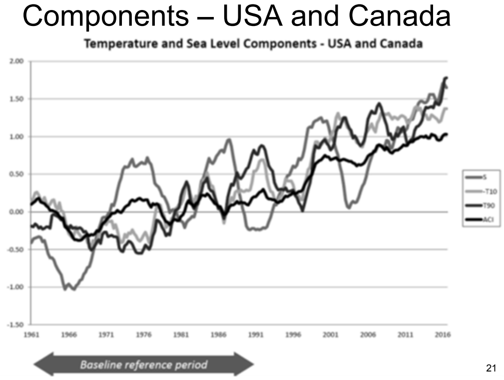
Temperature and Sea Level Components – USA and Canada



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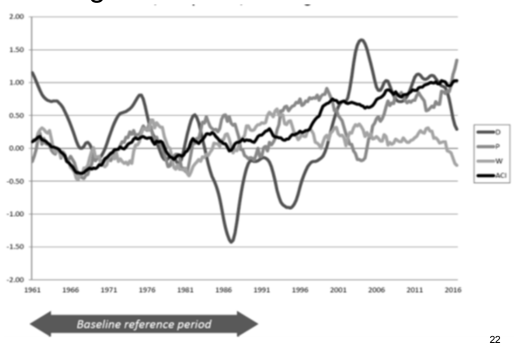
Wind Power, Precipitation, and Drought – USA and Canada



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US and Canada Region, The ACI – Summer 2001

View an animation of 5-year moving average values:

http://actuariesclimateindex.org/maps/

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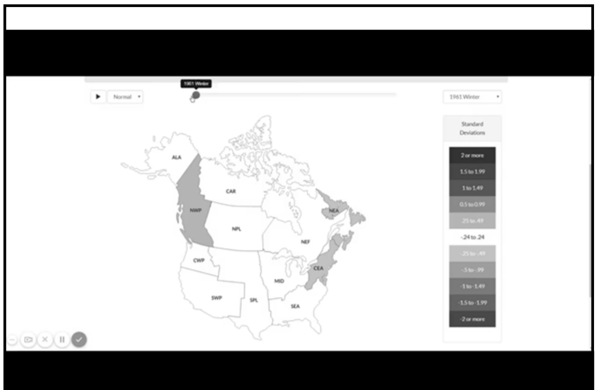

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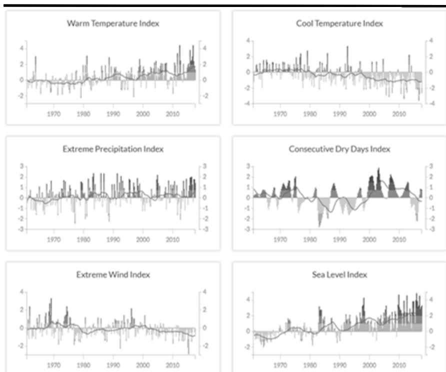
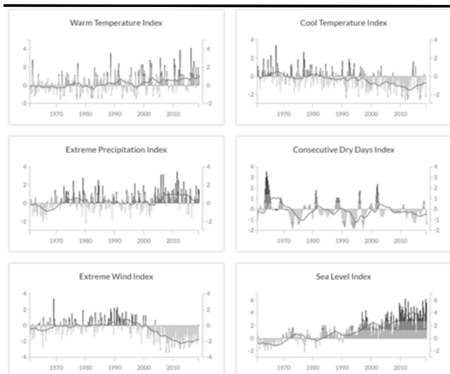
Continental USA - ACI Components – **Seasonal**

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



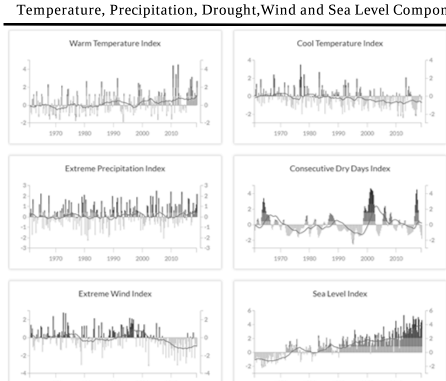
Central East Atlantic - ACI Components –**Seasonal**

Temperature, Precipitation, Drought,Wind and Sea Level Components



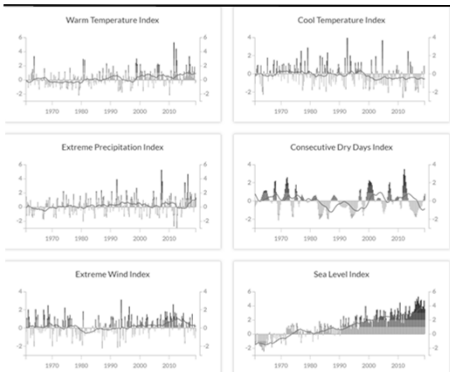
Southeast Atlantic - ACI Components –**Seasonal**

Temperature, Precipitation, Drought,Wind and Sea Level Components

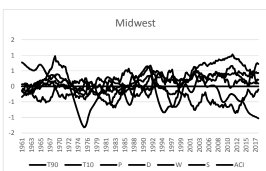


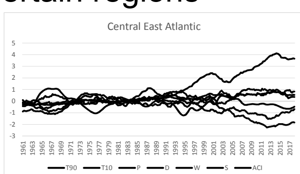
Southern Plains- ACI Components –Seasonal

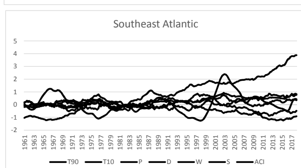
Temperature, Precipitation, Drought,Wind and Sea Level Components

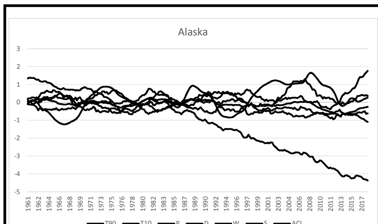


Certain components are more important in certain regions

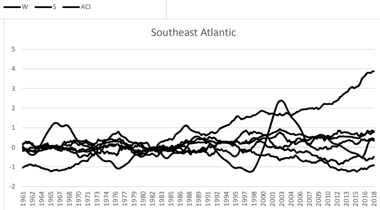




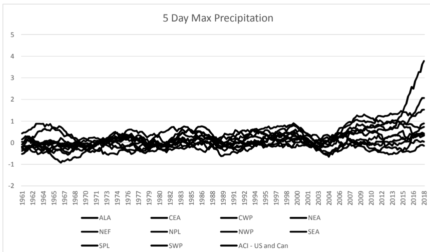




Note Sea Level Rise AK vs. SEA



Comparing Regions for 5 Day Max Precipitation



NWP pulls upward, SWP and CWP downward

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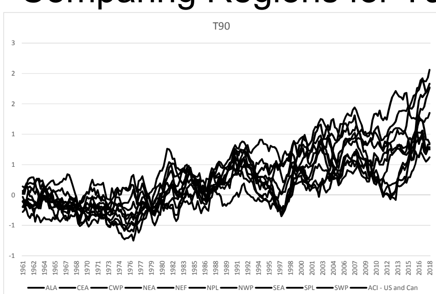
Comparing Regions for T90



SWP and AK high

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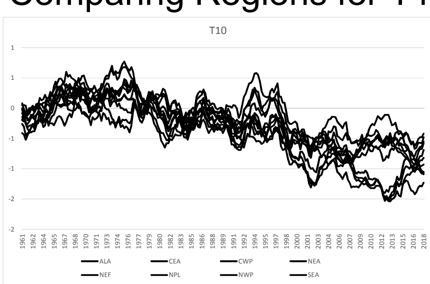
Comparing Regions for T10



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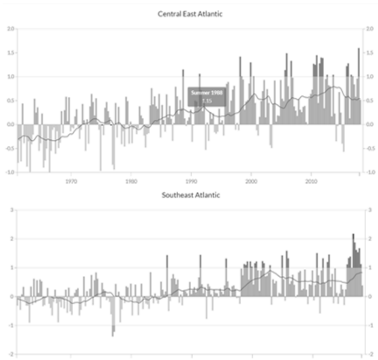
How do Regions Compare?



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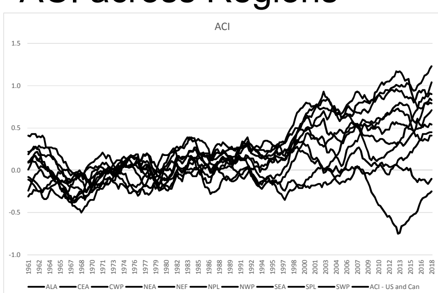
ACI across Regions



AK and NPL below 0; CWP NEF below 0.5

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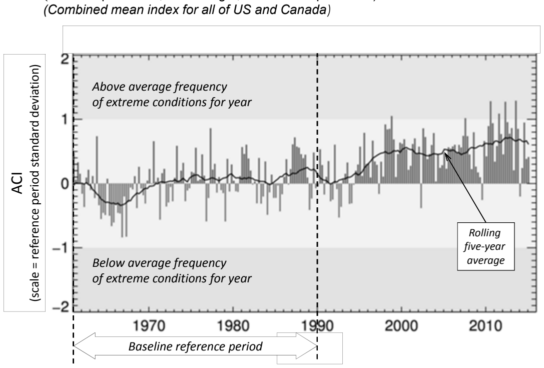
The Actuaries Climate Index (ACI) shows that the frequency of extreme weather has increased

(More frequent heat, rain/drought, and less frequent cold)
(Combined mean index for all of US and Canada)



Actuaries Climate Risk Index

- "How much damage is done to life and property when the distribution of environmental events differs from those observed during a reference period, 1961-1990?"
- ACRI will measure correlation of economic and human losses by peril to the relevant climate variable
- Goal: produce index especially useful to actuaries and insurance professionals
- Version 1.0 - Under review by sponsors

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ACRI adjusts for exposure and correlates to losses

- Uses SHELDUS (Spatial Hazard Events and Losses Database for the United States largely built with NOAA data) data for U.S. and Major Storms Disaster Database for Canada
- Canadian database limited number of events so version 1.0 of the ACRI will be 7 regions of U.S. only
- ACRI version 1.0 will quantify impacts on property losses, to be followed in future versions with similar framework for mortality and morbidity
- Expresses losses in $ or %, with each month of each year for each region separate observation
- Neutralized impact of inflation, exposure, region, and seasonality changes

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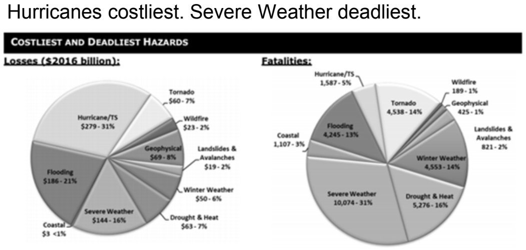
SHELDUS (Spatial Hazard Events and Losses Database for the United States) data summary 1960-2016

Hurricanes costliest. Severe Weather deadliest.



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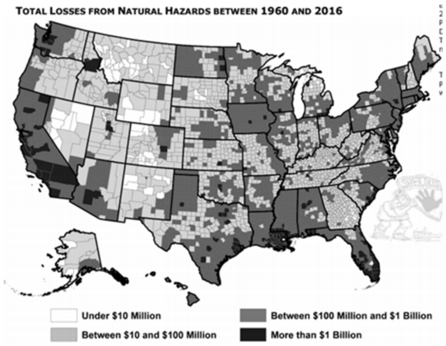
Economic Impact of Natural Hazards

SHELDUS data https://cemhs.asu.edu/sites/default/files/Summary_1960_2015_0.pdf



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Purpose and Use of ACRI

- The Actuaries Climate Risk Index (ACRI) provides an actuarial perspective on past socioeconomic impacts of extreme or moderately extreme environmental conditions.
- General Public: means to understand to what extent extreme climate events and their increasing frequency have been correlated with economic losses
- Public Policymakers: provides measure useful in leveraging the costs of prevention and mitigation policies
- Public and Private Decision-Makers: base for planning the capacity to assume larger risks associated with changes in environmental conditions
- Actuaries: insight into risks potentially associated with extreme climate events

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ACRI - caveats

- Losses due to extreme weather events are large and increasing
- Much of increase in loss is due to increasing exposure (wealth and population)
- Estimates of loss due to extreme weather are imprecise
- Imprecise results may be useful

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Types of models relating extreme climate events to socioeconomic harm

- Catastrophe models – routinely used by insurers to estimate the property insured losses which are likely to occur as a result of natural disasters such as hurricane, earthquake, flood etc.
- Integrated models used by IPCC
- Social cost of carbon models – used by Interagency Working Grouup on Social Cost of Greenhouse Bases to provide metrics for evaluating environmental regulations based on economic damage done by increasing levels of greenhouse gases
- Disaster risk index for United Nations Development Program – to assess the number of deaths resulting from natural catastrophes

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Loss = f(Risk Exposure, Environmental conditions, Geography, Season)

- In order to minimize noise and maximize utility of index and control for variability of independent variables
  - Adjusted for inflation using constant 2016 dollars
  - Adjusted for seasonality by calculating monthly
  - SHELDUS data from NOAA
    - includes data by county
    - 18 categories of losses
    - For each date and location of loss an estimate of property damage, crop damage, lives lost, and injuries is made
    - Problems: concerns about completeness of reporting events (especially prior to 1996) and loss estimates (lower than III numbers when both available)
  - Risk exposure – estimated by population, number of housing units and median house price (due to availability)
  - Environmental conditions – follow ACI
  - Geography – calculate each region separately

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Calculating ACRI – for each region

Start with

$$\text{Loss} = \text{I} * \text{Exposure}^{e} * \text{Precipitation}^{p} * \text{Low Temperature}^{l} * \text{High Temperature}^{h} * \text{Wind}^{w}$$

Taking the natural log of both sides of the equation does not change the equality and produces an equation estimable by linear regression:

$$\text{Ln(Loss)} = \ln(\text{I}) + e*\ln(\text{Exposure}) + p*\ln(\text{Precipitation}) + l*\ln(\text{Low Temperatures}) + h*\ln(\text{High Temperatures}) + w*\ln(\text{Wind})$$

Loss: Property losses in dollars for a particular region in a particular month;
I: Intercept which scales losses to account for factors other than those included in the model;
Exposure: an estimate of the property value at risk in a given region in a given month;
Precipitation (Rx5Day): the maximum 5-day precipitation in the month;
Low Temperatures (T10): the change in frequency of colder temperatures below the 10th percentile, relative to the reference period of 1961 to 1990;
High Temperatures (T90): the change in frequency of warmer temperatures above the 90th percentile, relative to the reference period of 1961 to 1990;
Wind: Daily average wind speed measurements are converted to wind power, which is proportional to the cube of the wind speed. Wind Power is used because impacts from high winds (i.e., damages) have been shown to be more closely related to the cube of wind speed. The procedure used for temperatures is followed, by finding the 90th percentile of wind power for each month or season and subtracting the 90th percentile of wind power for that month over the reference period.
e, p, l, h, w: If statistically significant, these are the exponents corresponding to the independent variables, and reflect the sensitivity of loss to changes in these variables.

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Calculating ACRI - pooled

- Estimate parameters for each region-month 1961-2016. Use dummy variables for intercepts and slopes to pool the region-months into a single equation and use backwards regression (90% confidence level) to identify statistically significant parameters.
- Pooled cross-sectional model produced r-squared of 0.63 and adjusted r-squared of 0.62 and Durbin-Watson statistic of 1.76.
- Re-estimated equation with consistent adjusted covariance matrix
- Precipitation is the most important factor driving the results while Wind ranks second in importance.
- There is still significant unexplained variation.
- Included variables might also be capturing effects of excluded variables correlated with included variables – exposure could reflect non-exposure related issues such as completeness of data.
- Excluded variables might be significant – Sea level to be added in future versions

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Calculating ACRI - complications

- Hard to calculate what losses would have been had environmental conditions not been unusual
- Difficult to control for exposure – not only value changes, but also resilience
- Don't want artefactual bias (non-linearity of our estimating equations builds upward artefactual bias into estimating method)

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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

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Comparing ACI and ACRI to other climate information out there

Looking at ways to view climate distributions

Best ways to use reference years

Thanks to Steve Kolk of Kolkulations LLC

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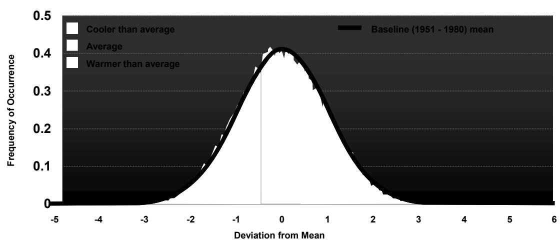
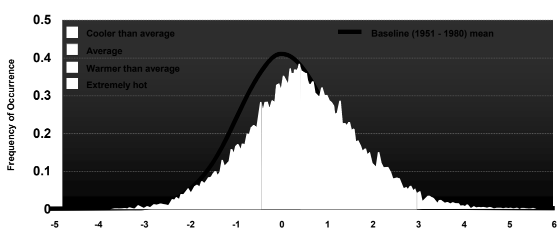
Summer Temperatures Have Shifted

- 1951 – 1980



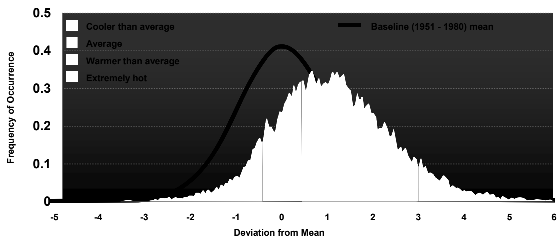
Source: NASA/GISS; Hansen, et al., "Perceptions of Climate Change," Proc. Natl. Acad. Sci. USA 10.1073, August 2012 – Updated 2016

- 1983 – 1993



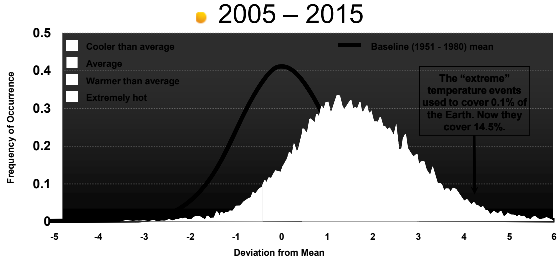
Source: NASA/GISS; Hansen, et al., "Perceptions of Climate Change," Proc. Natl. Acad. Sci. USA 10.1073, August 2012 – Updated 2016

- 1994 – 2004



Source: NASA/GISS; Hansen, et al., "Perceptions of Climate Change," Proc. Natl. Acad. Sci. USA 10.1073, August 2012 – Updated 2016

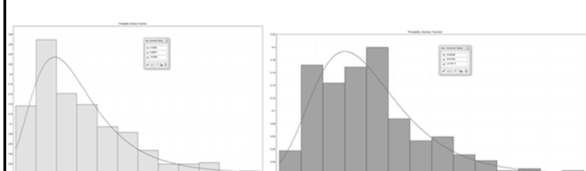
- 2005 – 2015



Source: NASA/GISS; Hansen, et al., "Perceptions of Climate Change," Proc. Natl. Acad. Sci. USA 10.1073, August 2012 – Updated 2016

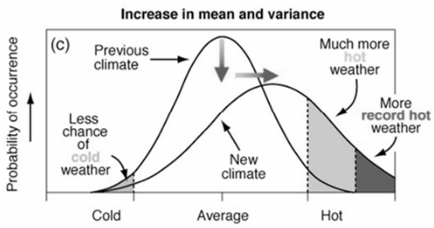
Distribution of T90 Standard Anomalies
Southeast Atlantic (SEA) Region

BASE YEARS **WARMING YEARS**



The blue fitted curves, Generalized Extreme Value curves, **give better curve-fits to the T90 Anomaly distributions**

Climate Impact #3: INCREASE IN MEAN AND VARIANCE



Source: Solterra Solutions: *Determining the Impact of Climate Change on Insurance Risk and the Global Community Phase 1: Key Climate Indicators*

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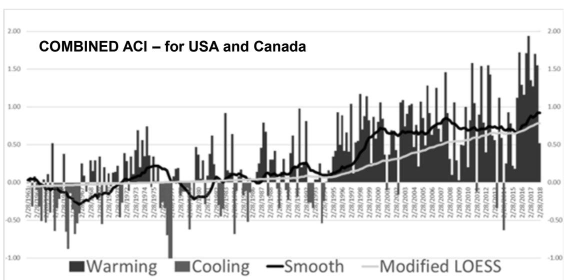
Take advantage of Reference Years



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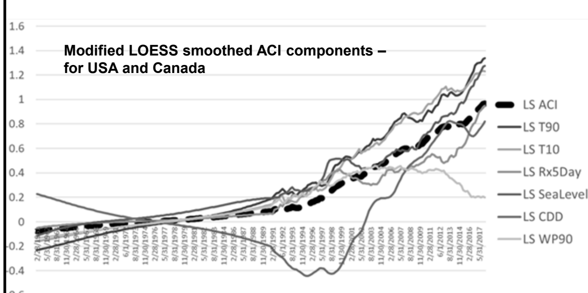
Mod. LOESS Smoothing reveals underlying climate change signals



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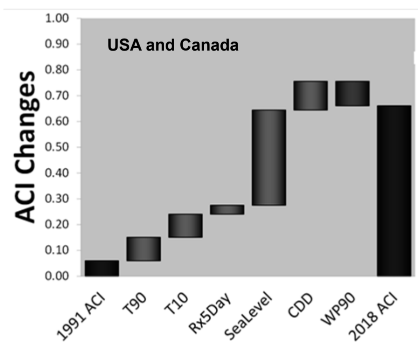
Climate Change BY ACI COMPONENT!



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ACI Resources

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BEYOND THE ACI AND ACRI

ACTUARIES AND CLIMATE CHANGE RISK

Beware of non-catastrophic events:

- 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

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QUESTIONS?

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