Everything an Actuary needs to know about the Actuarial Climate Index (ACI) and the Actuarial Climate Risk Index (ACRI)

2021 Ratemaking, Product and Modeling Seminar

March 16, 2021

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AGENDA
All About the ACI and the ACRI
Past, Present and Future

PAST & PRESENT: The Actuaries Climate Index (ACI)

  Why? Who? How? When? What?

  Where and When? Video history – North American Regions

PRESENT: The Actuaries Climate Risk Index (ACRI)

FUTURE: Challenges and Next Steps – Possible Enhancements

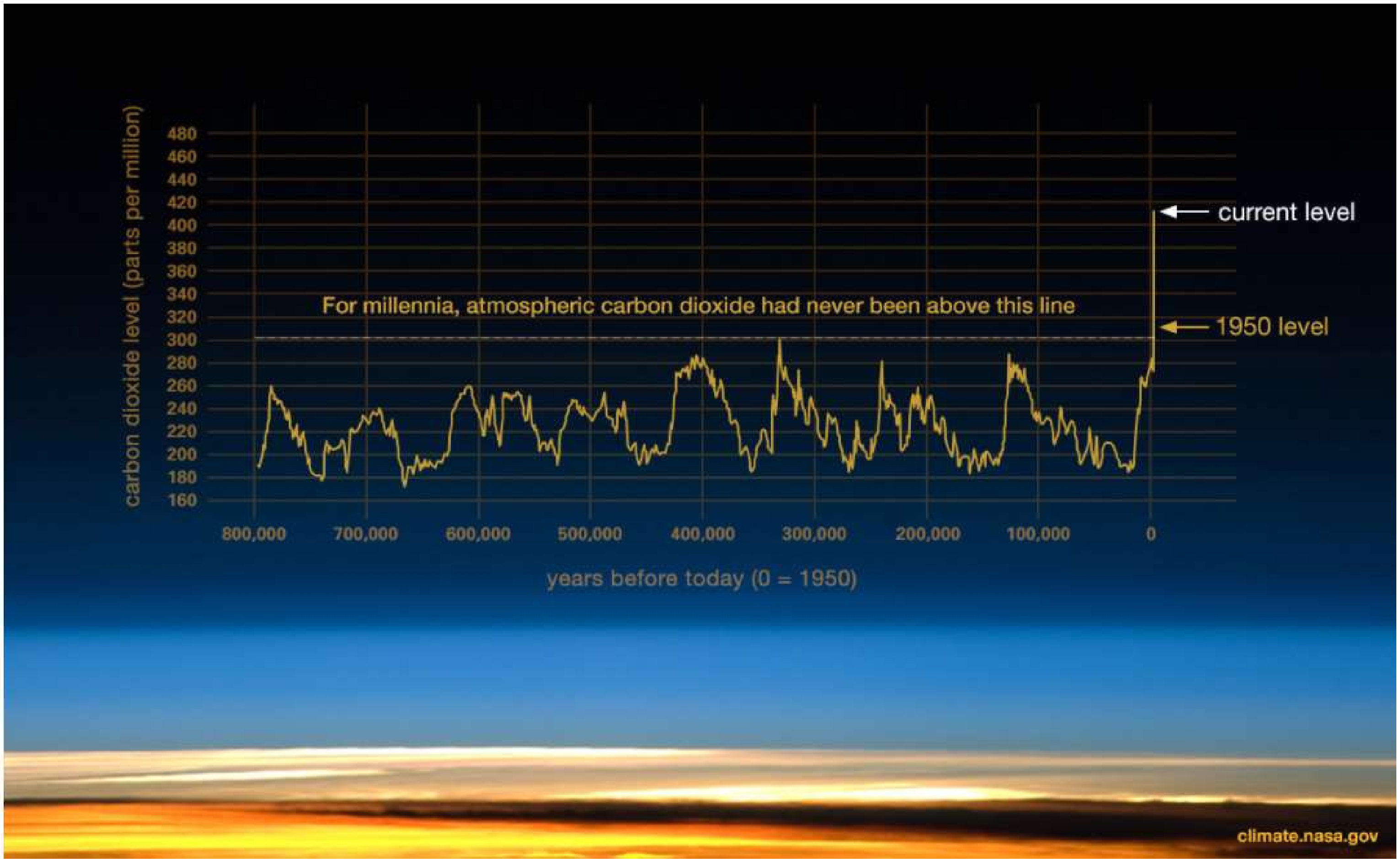
APPENDIX: Even More Details

POLL QUESTION #1

- How familiar are you with the ACI?
  A. Never heard of it before today.
  B. I’ve only read about it.
  C. I’ve visited the ACI website
  D. I’ve downloaded the ACI spreadsheet once.
  E. I love it & download the ACI spreadsheet every quarter

Climate Change: How Do We Know?

https://climate.nasa.gov/evidence/

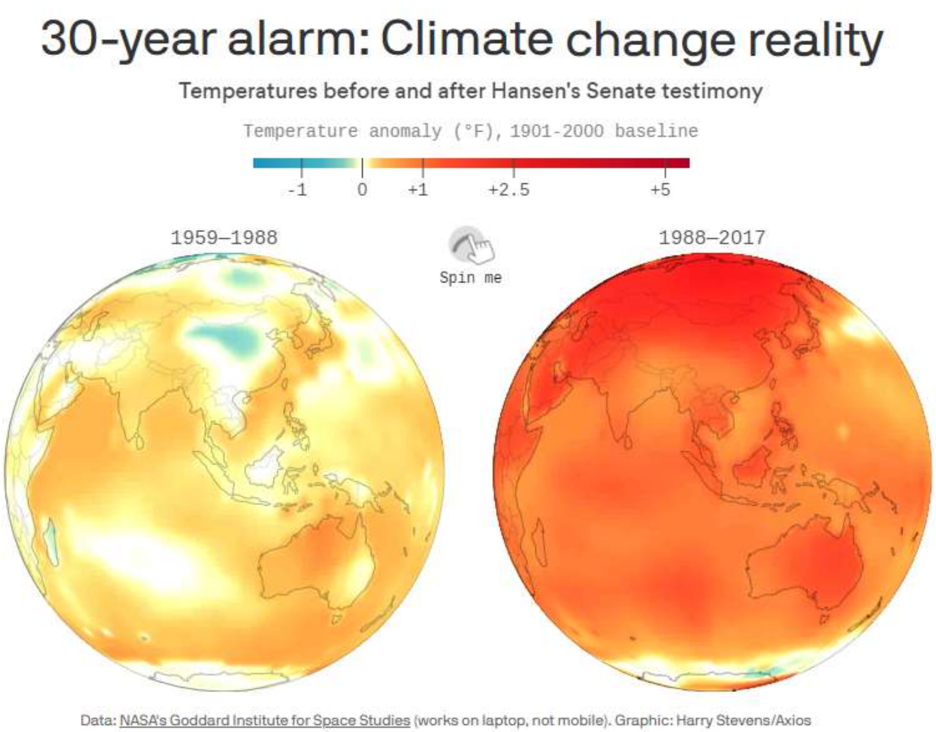


Two Centuries ago – These Scientists Knew

Source: Katherine Hayhoe, Climate Lecture, Calvin University 2021 January Series

Bell Telephone Science Hour - 1958

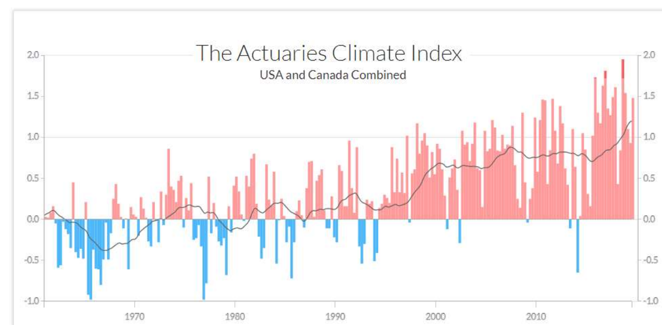
The ACI: Why? and What?



Source: AXIOS Climate Change Deep Dive – June 23, 2019

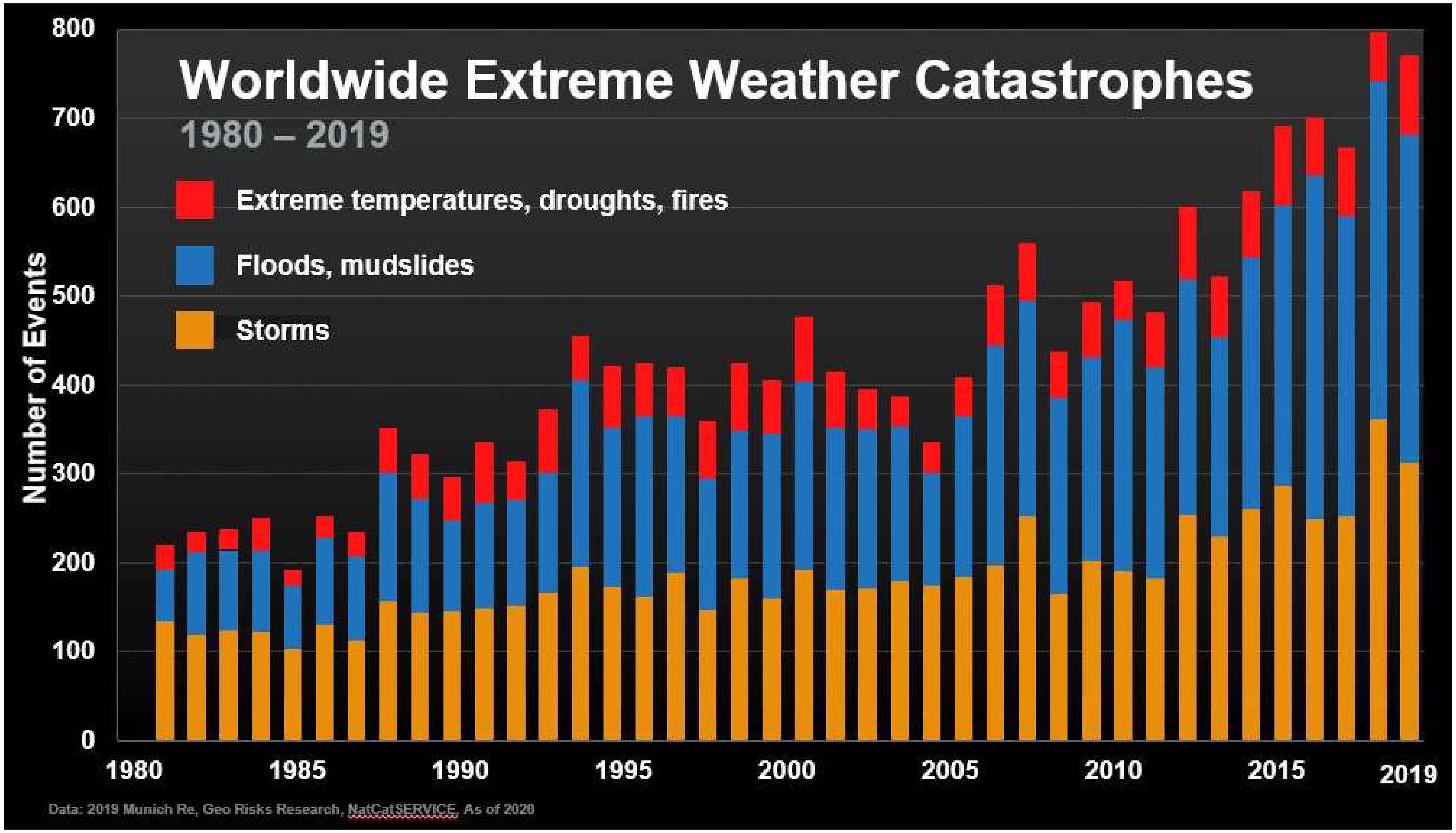
Animated version at: https://www.axios.com/newsletters/axios-am-cf3fa944-b946-42cd-8d11-26013a990398.html

ActuariesClimateIndex.org



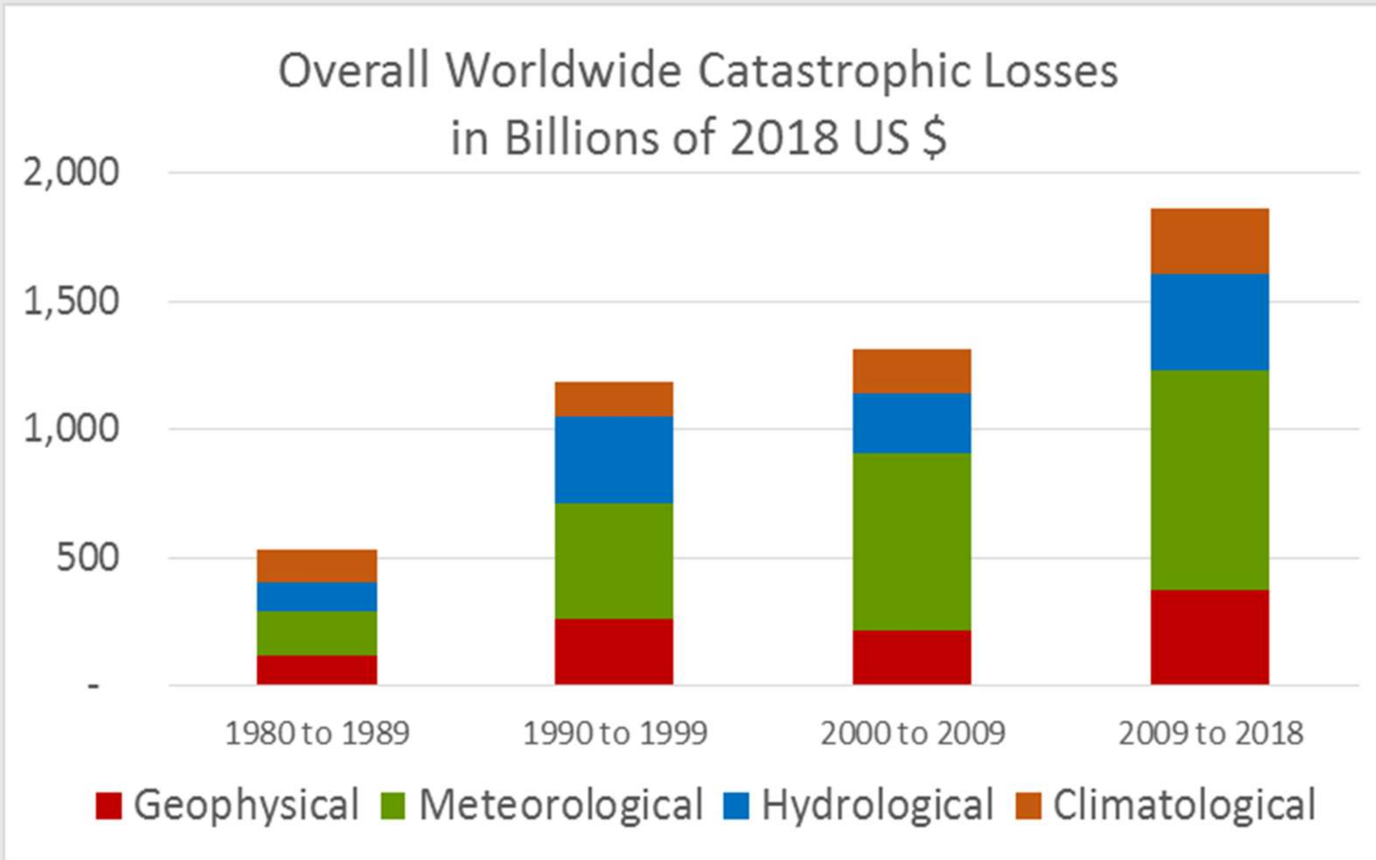
Why Insurers Care

Catastrophic Events have tripled since the 1980s



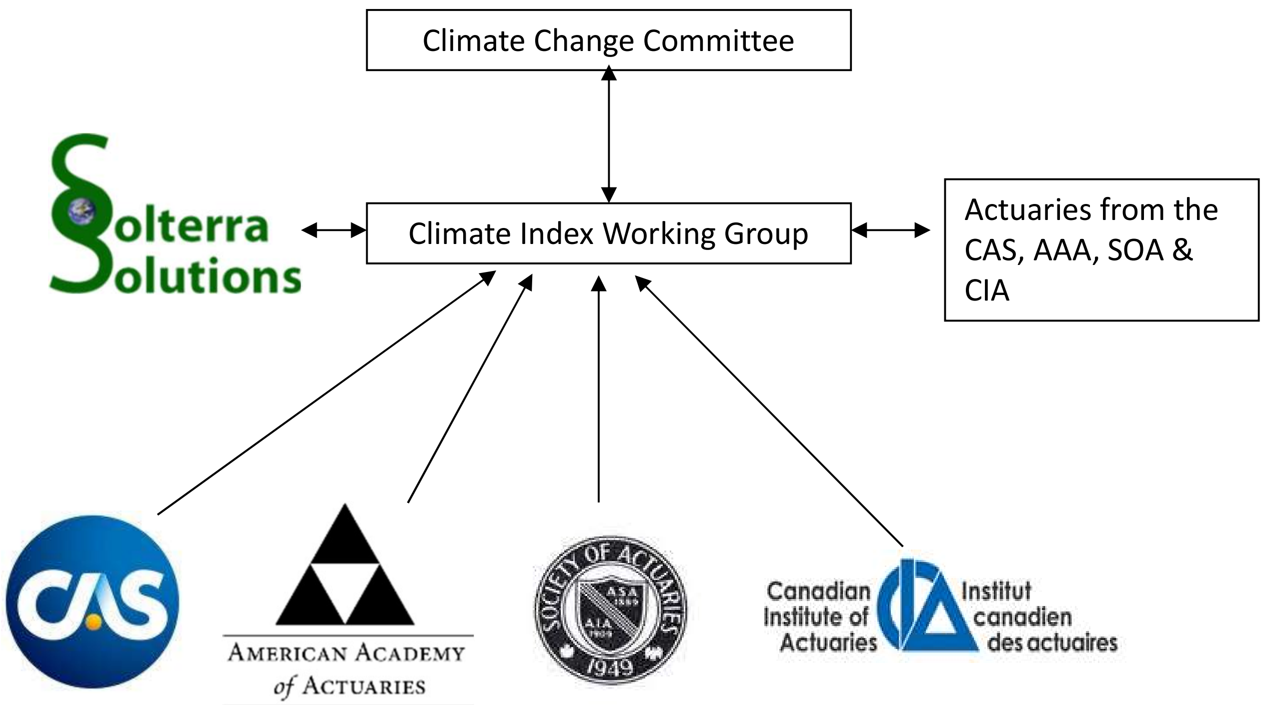
Why Insurers Care

Catastrophic Economic Losses are growing exponentially



Source: https://natcatservice.munichre.com/ accessed March 2019

Structure of Climate Index Development Teams

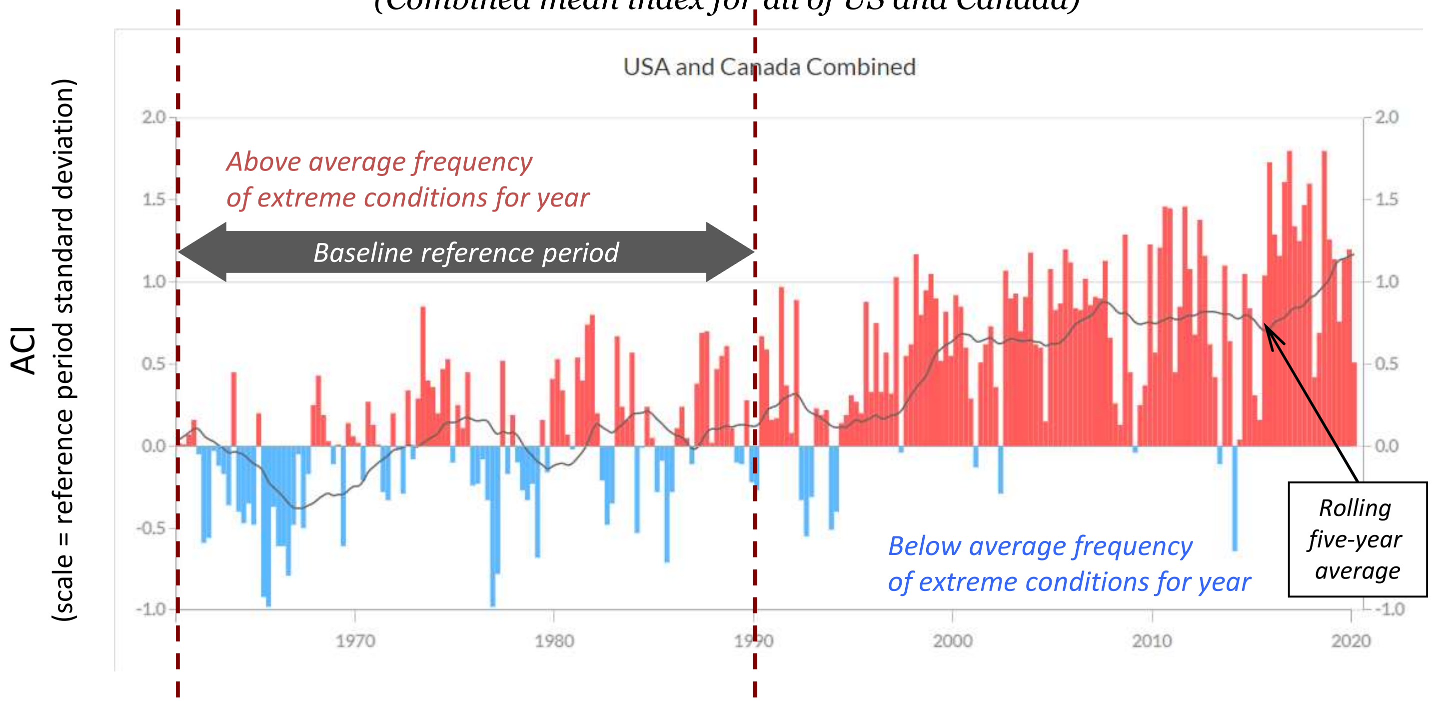


Actuaries Climate Index – Goals

- Create an objective index that measures changes in climate over recent decades
- Educate the insurance industry and the general public on the impact of climate change
- Easy to understand, but not simplistic
- Promote our profession

The Actuaries Climate Index (ACI) measures the increasing frequency of extreme weather

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



EPA.GOV Climate Change Indicators

- Greenhouse Gases Summary
- U.S. Greenhouse Gas Emissions
- Global Greenhouse Gas Emissions
- Atmospheric Concentrations of Greenhouse Gases
- Climate Forcing

- Weather and Climate Summary
- U.S. and Global Temperature
- High and Low Temperatures
- U.S. and Global Precipitation
- Heavy Precipitation
- Tropical Cyclone Activity
- River Flooding*
- Drought

- Oceans Summary
- Ocean Heat
- Sea Surface Temperature
- Sea Level
- Coastal Flooding*
- Ocean Acidity

<table>
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<td>Greenhouse Gases Summary
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<td>WIND</td>
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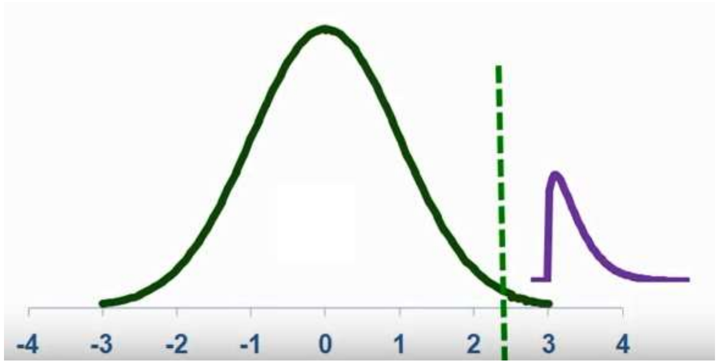
THE ACTUARIES CLIMATE INDEX FOCUSES ON "FREQUENCY OF SEVERITY"

WHAT IS THAT?

- Extreme Temperatures:
  - VERY HOT or
  - VERY COLD
- Extreme Precipitation:
  - VERY WET or
  - VERY DRY
- EXTREME WIND
  - (Wind Power)^3
- RISING SEAS

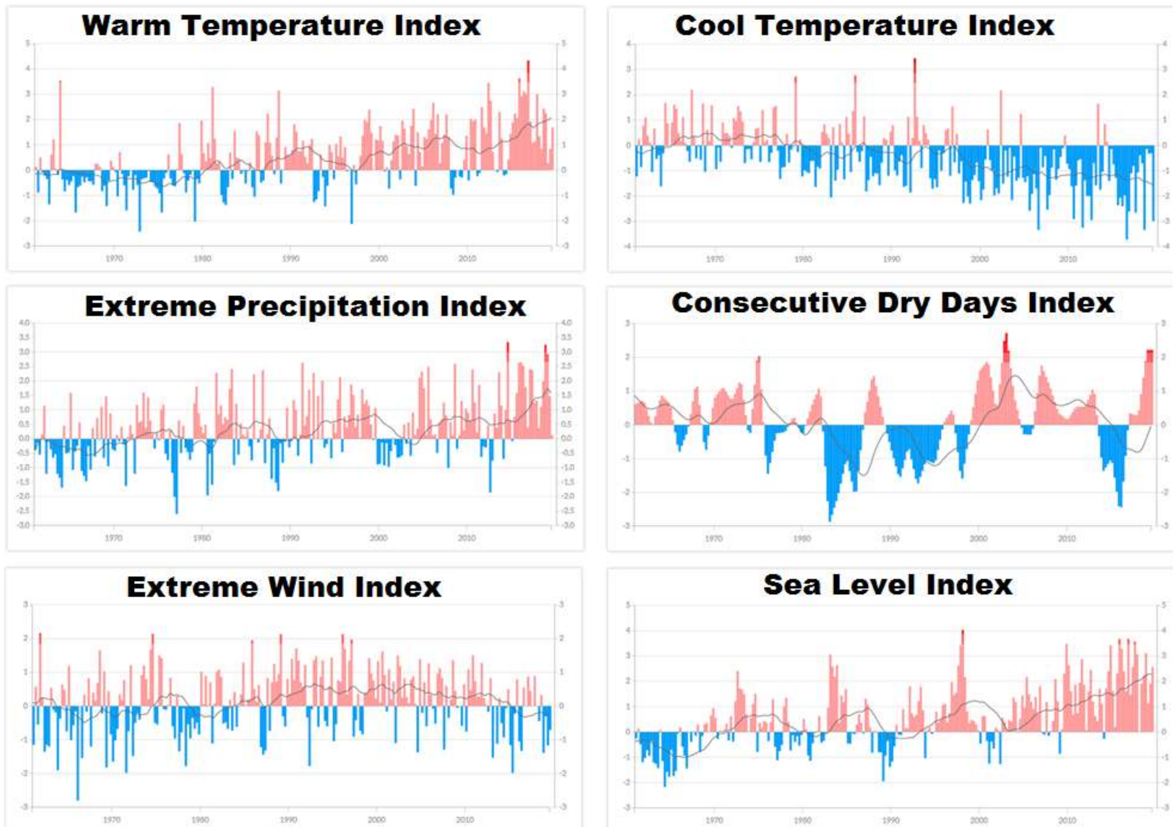


THE A.C.I MEASURES EXTREMES **a.k.a.**

"CHILD DISTRIBUTIONS"

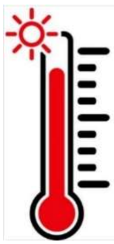
Continental USA - ACI Components – **Seasonal**

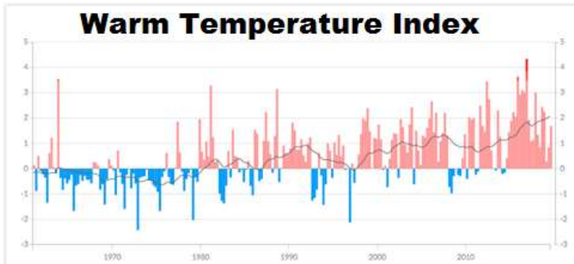
Temperature, Precipitation, Drought,Wind and Sea Level Components

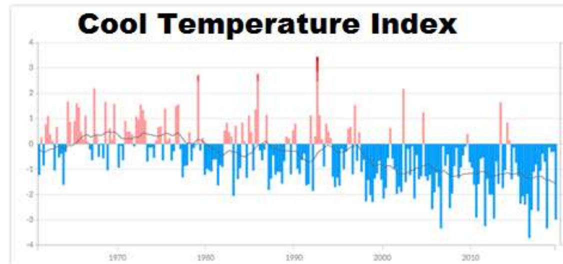


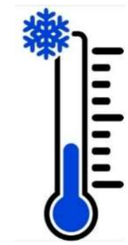
Continental USA - ACI Components – **Seasonal**

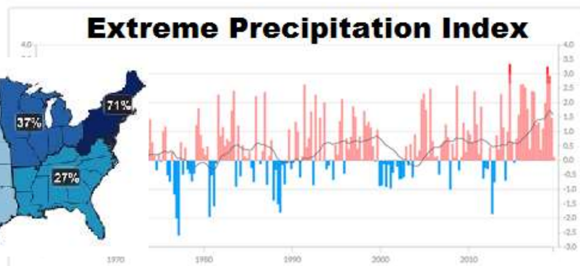
Temperature, Precipitation, Drought,Wind and Sea Level Components

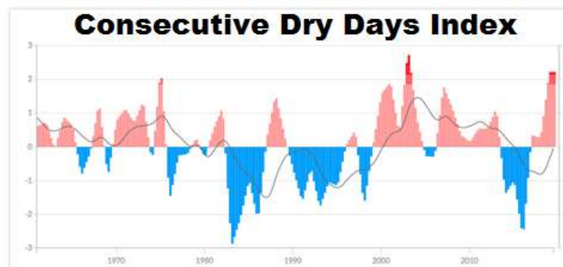


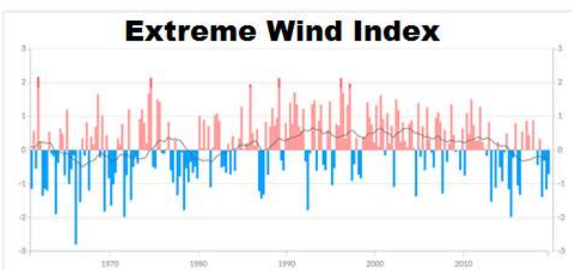


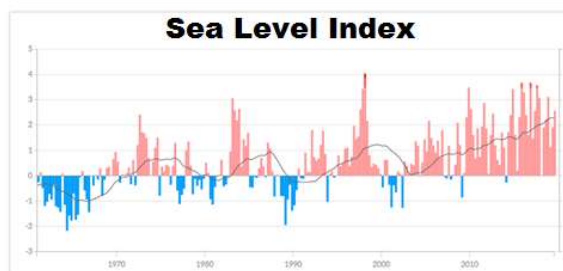


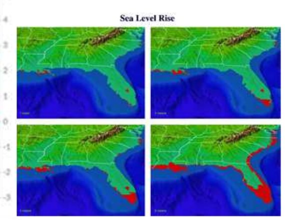






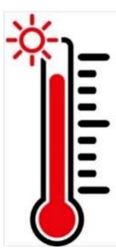


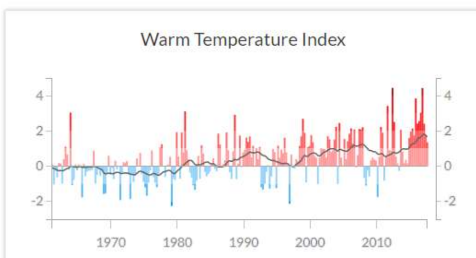


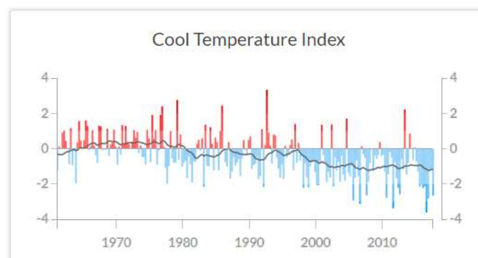


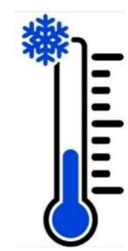
Extreme Temperature: VERY HOT or VERY COLD

- Global Historical Climatological Network (GHCN) – global, land station-based, gridded dataset, daily from 1950-present (GHCN-Daily)
- GHCNDEX indices* based on the above:
  - TX90 = 90%ile warm days
  - TN90 = 90%ile warm nights
  - TX10 = 10%ile cold days
  - TN10 = 10%ile cold nights
- The average of % anomalies relative to the 1961-1990 reference period for T90 and T10:
  - Standardized anomaly (T10′ similar): $T90' = \Delta T90 / \sigma_{ref}(T90)$





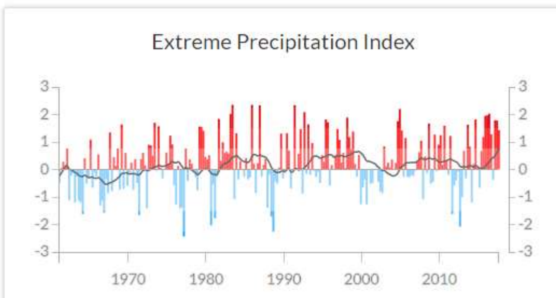


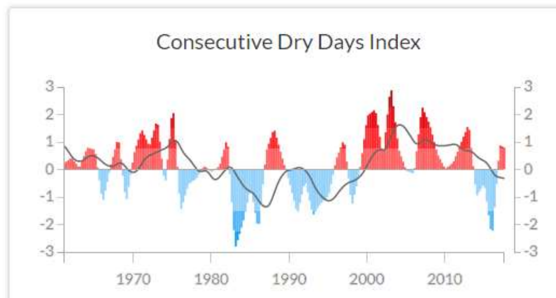


* Produced as part of the CLIMDEX project by the Climate Change Research Centre, at The University of New South Wales, Australia.

Extreme Precipitation Indices:
VERY WET or VERY DRY

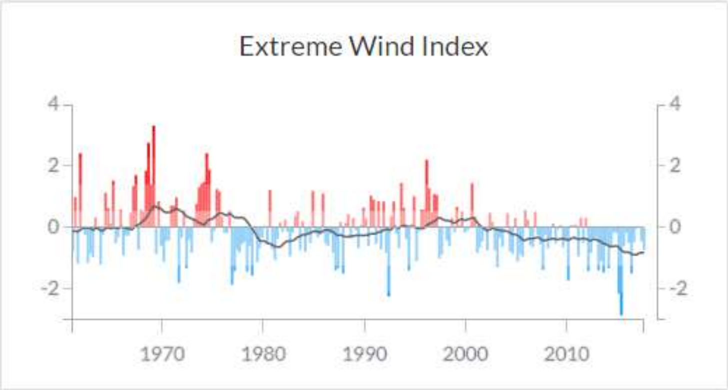
- GHCNDEX monthly maximum five-day precipitation data
  - Heavy precipitation index, $P' = \Delta Rx5day \ / \ \sigma_{ref}(Rx5day)$
- GHCNDEX, consecutive dry days (CDD) = Max days per year with <1mm precipitation
  - Drought index = 1 value of CDD/year
  - Linear interpolation to obtain monthly
  - $D' = \Delta CDD \ / \ \sigma_{ref}(CDD)$





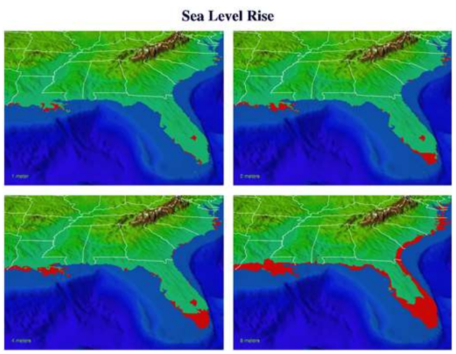
Wind Power Index: EXTREME WINDS

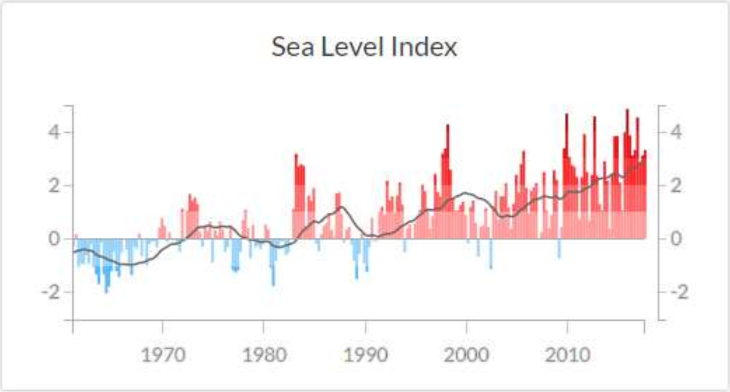
- Index derived from NOAA Earth System Research Laboratory data:
  - Daily mean wind speeds
  - WP = (1/2)*ρ*w³
    Where ρ is air density, w is daily mean wind speed
- $W' = \Delta WP90 / \sigma_{ref}(WP90)$
  - Where WP90 is the monthly frequency of the 90th percentile or higher of daily wind power



Sea Level Index

- At tide gauge stations along US and Canada coast
  - Data provided by Permanent Service for Mean Sea Level (PSMSL), part of the UK's National Oceanography Center
  - Data matched to grids used for other variables
    - Index reflects portion of each region represented by coastal grids
  - Land movements removed from tide gauge measurements to produce index reflecting sea movements only
- $S' = \Delta S / \sigma_{ref}(S)$



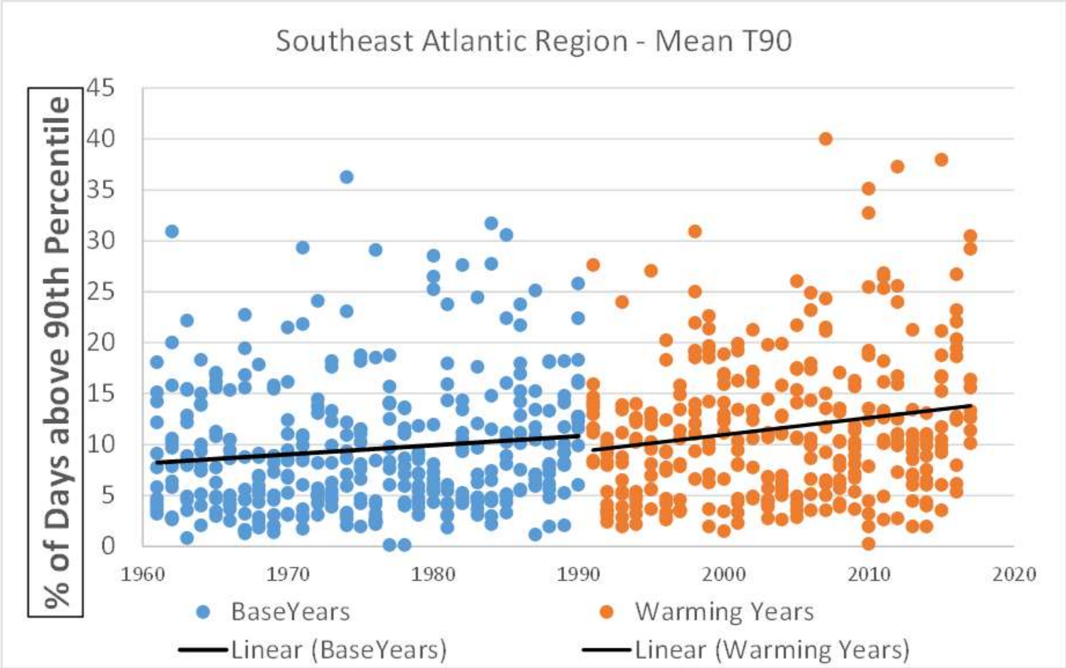


ACI – additional details

- Granularity of data – each variable is available for each 2.5° grid (275km x 275km at equator) in North America
  - While indices can be computed at this granularity, they'd be volatile
- And the six component indices measure different statistics:
  - Hot and Cold Temperatures in **% of extreme days in a month**
  - Rainfall in **inches**
  - Drought in **days**
  - Wind Power in **(Wind Speed)^3**
  - Sea Level in **millimeters**
- To combine these varied measures together, values are converted to **standardized anomalies**:

$$\mathbf{X' = (X - X_{ref}) / \sigma_{ref}(X)} = \Delta X / \sigma_{ref}(X)$$

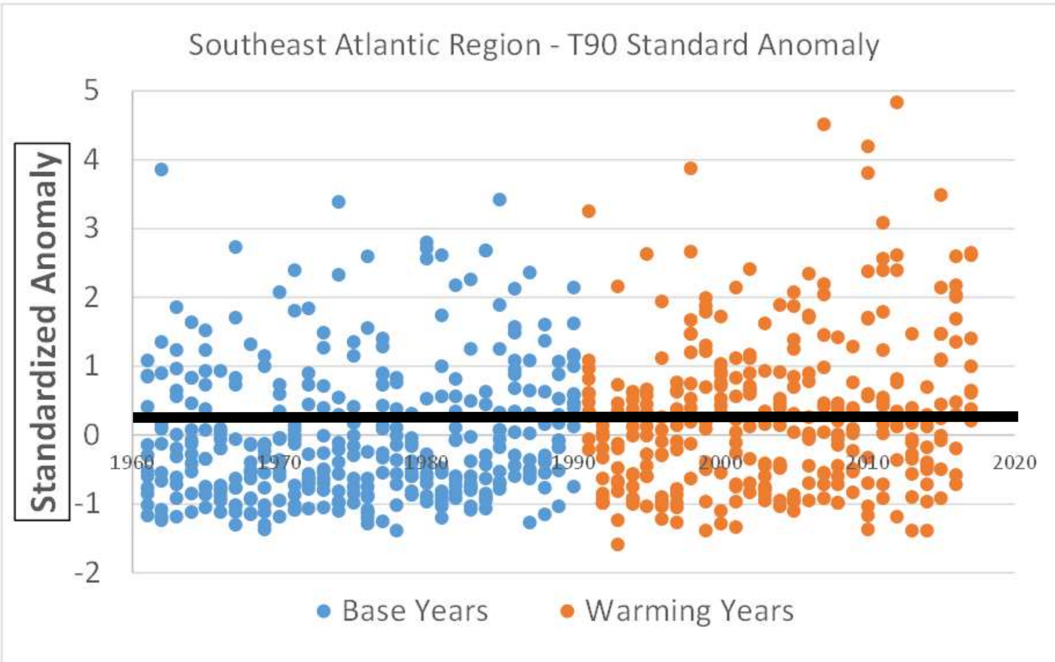
T90 = % of days in a month where max temperature falls above the 90th percentile of a 30-year reference period running from 1961 to 1990



Thanks go out to Patrick Weiss for this illustration

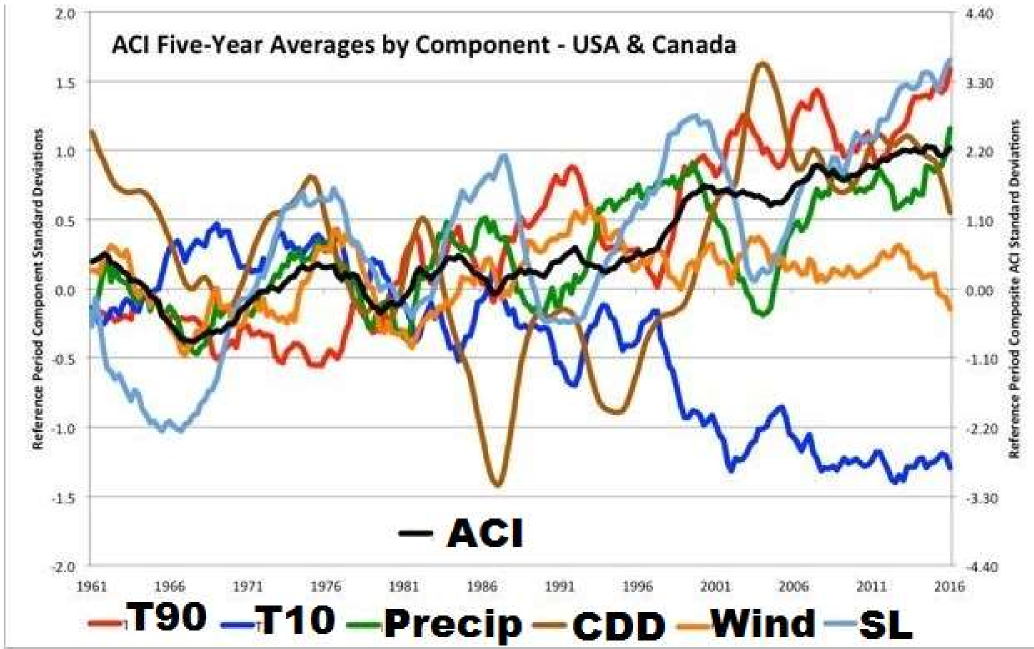
Standardized T90 Anomaly,
BASE YEARS = 30-year period from 1961 to 1990

Same data as prior slide, but
standardized using the reference period's mean and standard deviation



Overall ACI and components

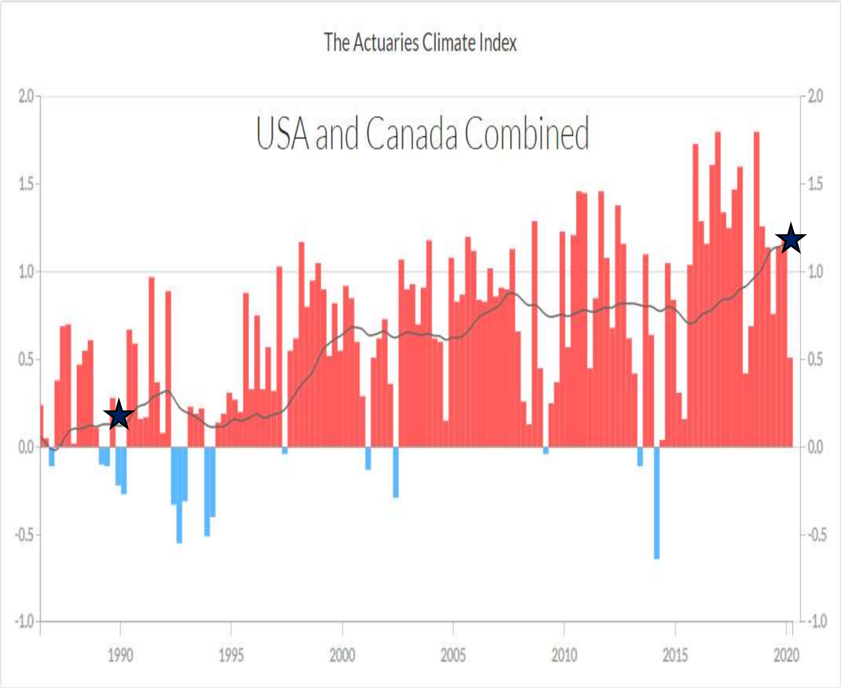
- Unweighted average of standardized anomalies
  - $ACI = (T90' - T10' + P' + D' + W' + S') / 6$

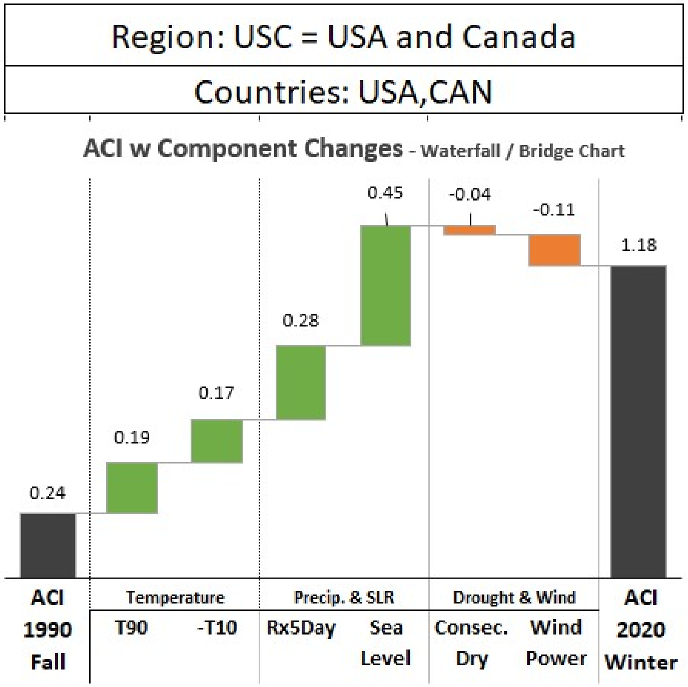


POLL QUESTION #2

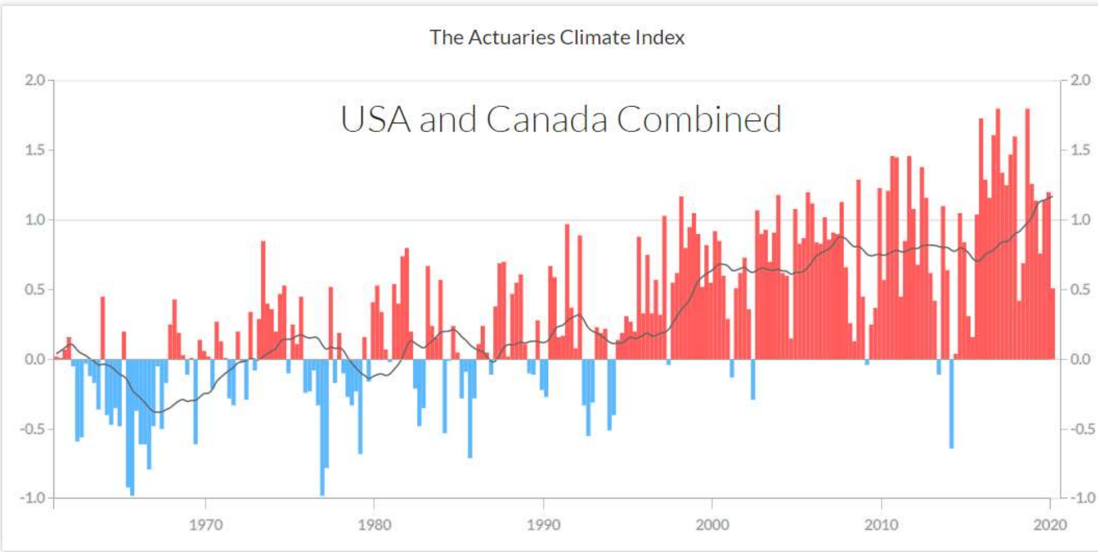
- What is the biggest contributor to the increase in the overall ACI?
  A. T90 = Extreme Warm Temperatures
  B. T10 = Extreme Cold Temperatures
  C. Precip = Extreme Precipitation
  D. CDD = Consecutive Dry Days of Drought
  E. WP90 = Extreme Wind
  F. SL = Sea Level

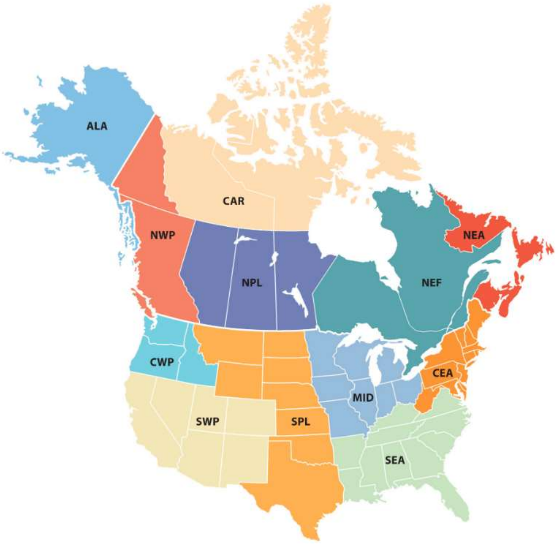
ACI Change: 1990 Fall to 2020 Winter



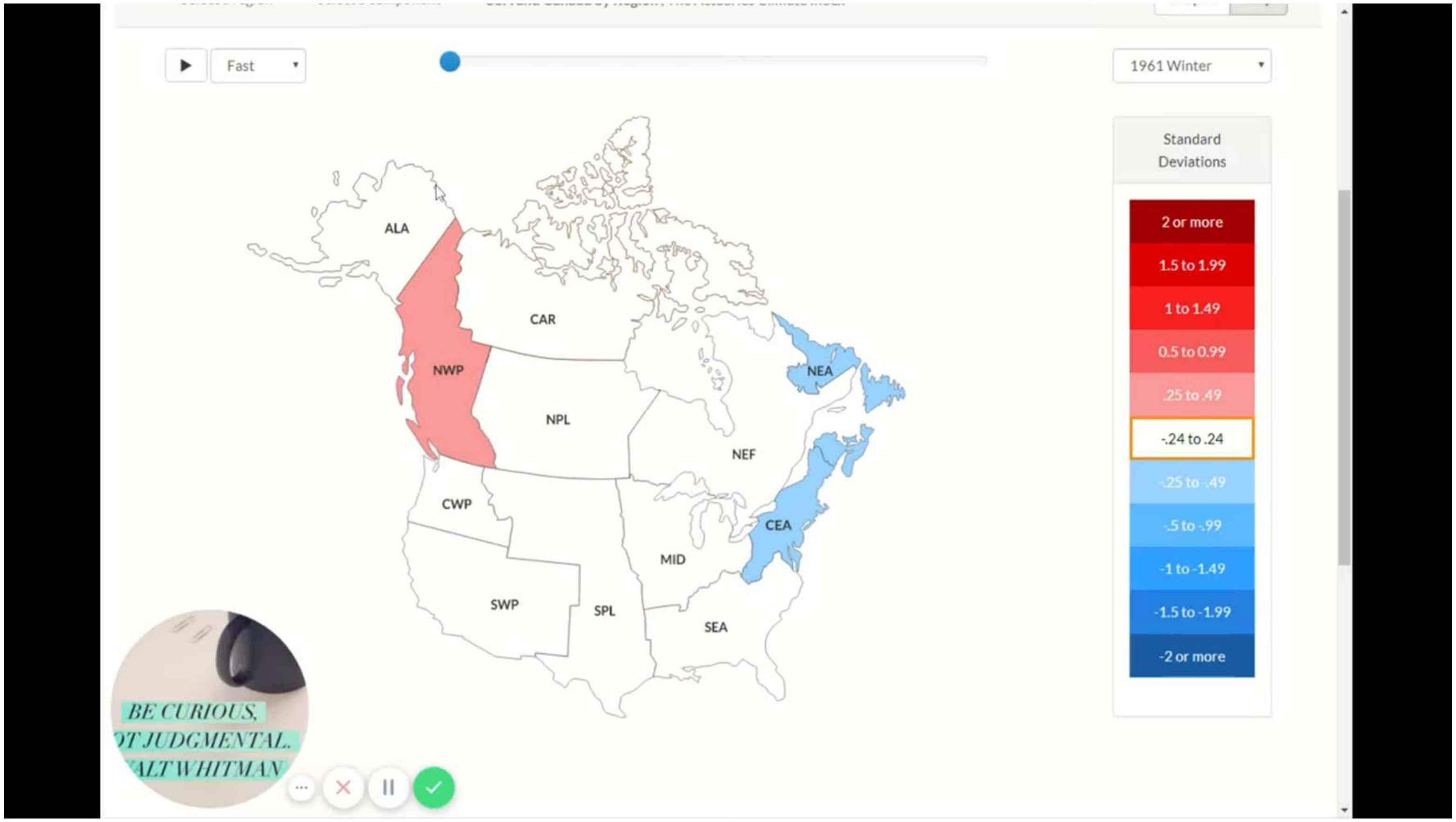


Current ACI – USA and Canada





Dynamic Map of ACI
by Region



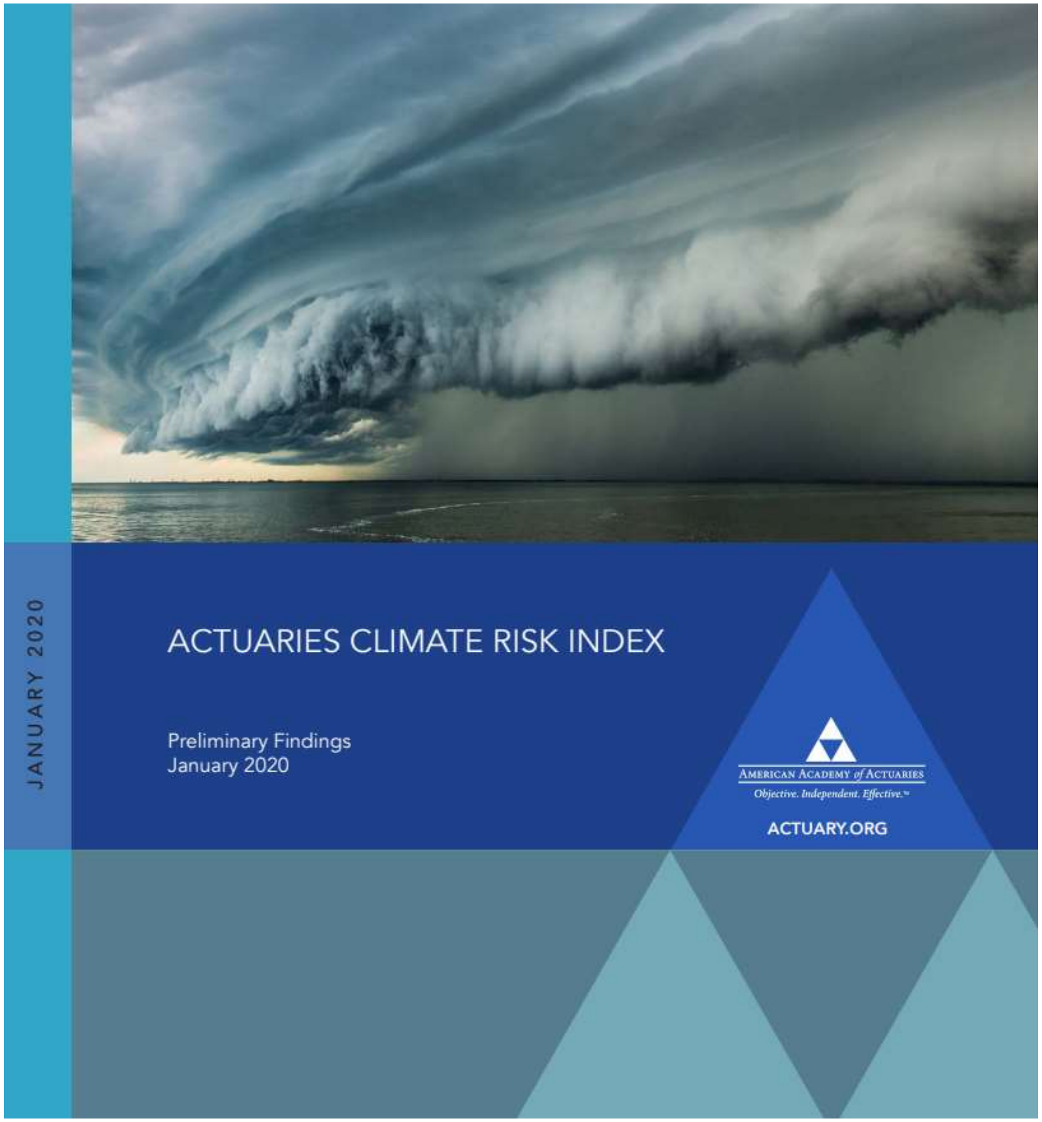
[Source: https://actuariesclimateindex.org/explore/regional-graphs/](https://actuariesclimateindex.org/explore/regional-graphs/)

The ACRI

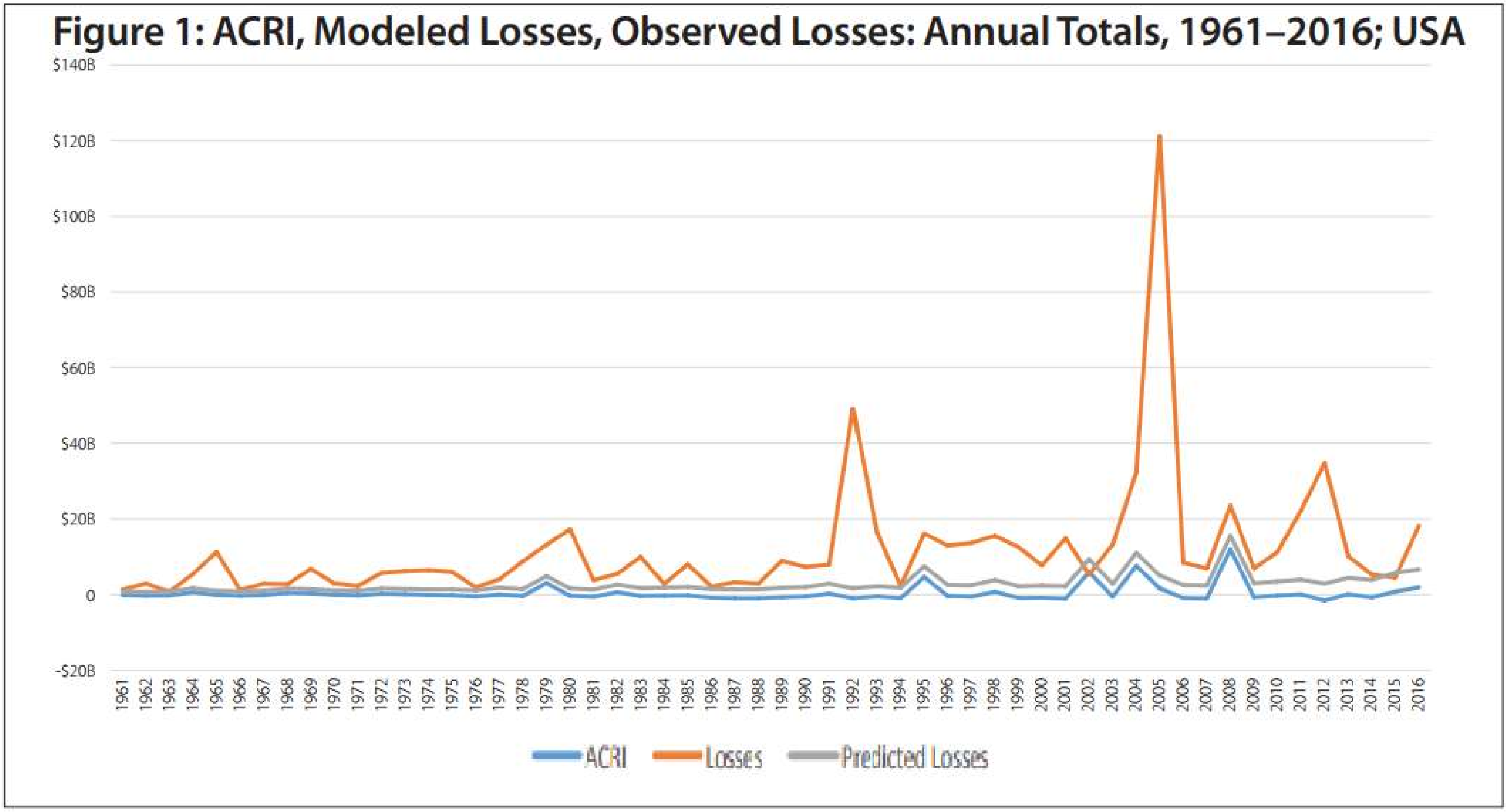
Preliminary Findings

American Academy of Actuaries

January 2020



ACRI - Preliminary US Results
Graphical Findings



ACRI Preliminary Results – Statistical Findings

Table 2: Summary of Parameter Estimates Significant at the 90% Confidence Level
(based on estimates for 84 region-months)

	Statistically Significant	Average Value for Region-Months With Statistically Significant Values	Average Value for All
Exposure	70%	1.84	1.29
Rx5Day	54%	4.13	2.21
T10	12%	1.12	0.13
T90	19%	1.11	0.21
Wind	15%	2.80	0.43

It is worth noting that with an r-squared of 0.62, there is still significant unexplained variation. It is also worth noting that the included variables might also be capturing effects of excluded variables that are correlated with included variables.

ACRI 1.0 – Loss Data Model

$$\text{Loss} = I * \text{Exposure}^{e} * \text{Precip.}^{p} * (\text{Low Temp.})^{l} * (\text{High Temp.})^{h} * \text{Wind}^{w}$$

for a particular region in a particular month
where

Loss: Property losses in dollars

I: Intercept

Exposure: Estimated property value at risk

Precipitation (Rx5day): maximum 5-day precipitation in the month

Low Temp. (T10): the change in frequency of colder temp. below 10th percentile, relative to the reference period of 1961 to 1990

High Temp. (T90): *the change in frequency of warmer temp. above 90th percentile, relative to the reference period of 1961 to 1990*

Wind (WP90): Wind Power above the 90th percentile, determined after daily average wind speed measurements is converted to wind power, which is proportional to the cube of the wind speed.

Statistical Findings – Overall US *versus* Regions

Ln(Loss) = ln(I) + e*ln(Exposure) + p*ln(Precipitation) + l*ln(Low Temperatures) + h*ln(High Temperatures) + w*ln(Wind).

Table 5: R-Squared by Region, Ln(Loss) and Loss in $

Region	ALA	CEA	CWP	MID	SEA	SPL	SWP	Mean	USA
R-Squared, Ln(Loss)	0.22	0.36	0.26	0.50	0.39	0.47	0.32	0.36	0.62
R-Squared, Loss in $	0.00	0.02	0.00	0.07	0.02	0.07	0.14	0.05	0.03

Table 7: R-Squared by Region: With and Without ACI Components

Region	ALA	CEA	CWP	MID	SEA	SPL	SWP	Mean	USA
R-Squared, With ACI	0.22	0.36	0.26	0.50	0.39	0.47	0.32	0.36	0.62
R-Squared, Without ACI	0.16	0.10	0.11	0.26	0.09	0.29	0.12	0.16	0.54
Predictive lift of ACI	0.06	0.26	0.15	0.24	0.30	0.18	0.20	0.20	0.08

ACI 2.0 Possibilities

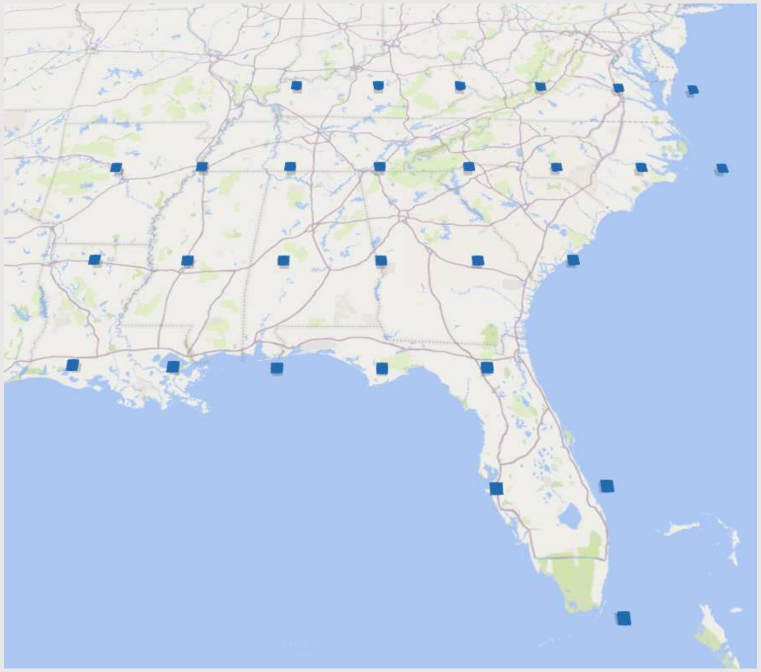
Better reference data for extreme weather and climate analytics

Looking beyond ACI 1.1 to ACI 2.0

DATA & ANALYTICS POSSIBILITIES

- BETTER INPUT: Obtain more granular source data
- DIFFERENT INPUT: Replace/Drop/Add new index components
- BETTER OUTPUT: Compute ACI for smaller areas
- Quantify Historical Climate Trends
- Quantify the Shape of Risk Distributions & How they Change

ACI 1.1 PROBLEM: VERY COURSE DATA

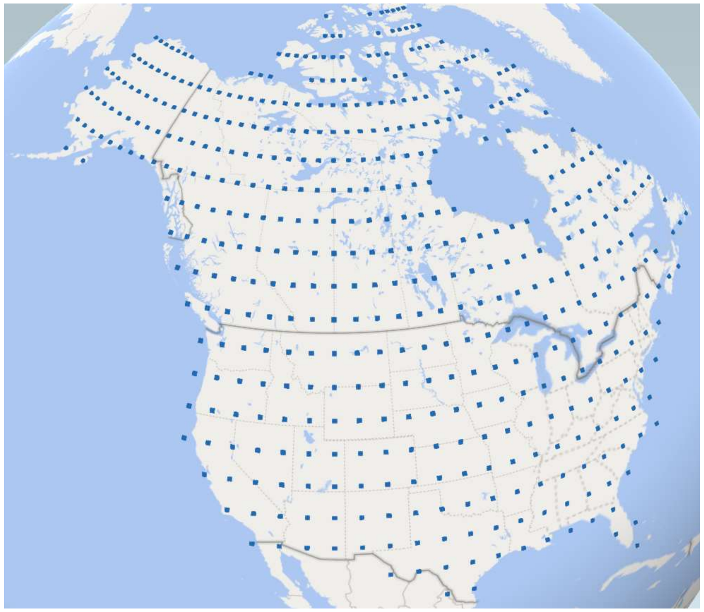


- ACI 1.0 grid points have 2.5^{O} x 2.5^{O} grid USA weather data
- Before looking, we thought there were six (6) Florida grid points
- PROBLEM: Three (3) Florida grid points miss land.
- PROBLEM: 3 other Atlantic ocean grid points miss land.
- SOLUTION: Use finer 1^{O} x 1^{O} gridded data with many more points and/or use weather station data directly.

BETTER GEOGRAPHIC DATA

ACI 1.0 PROBLEM…

COURSE 2.5^{O} GRIDS



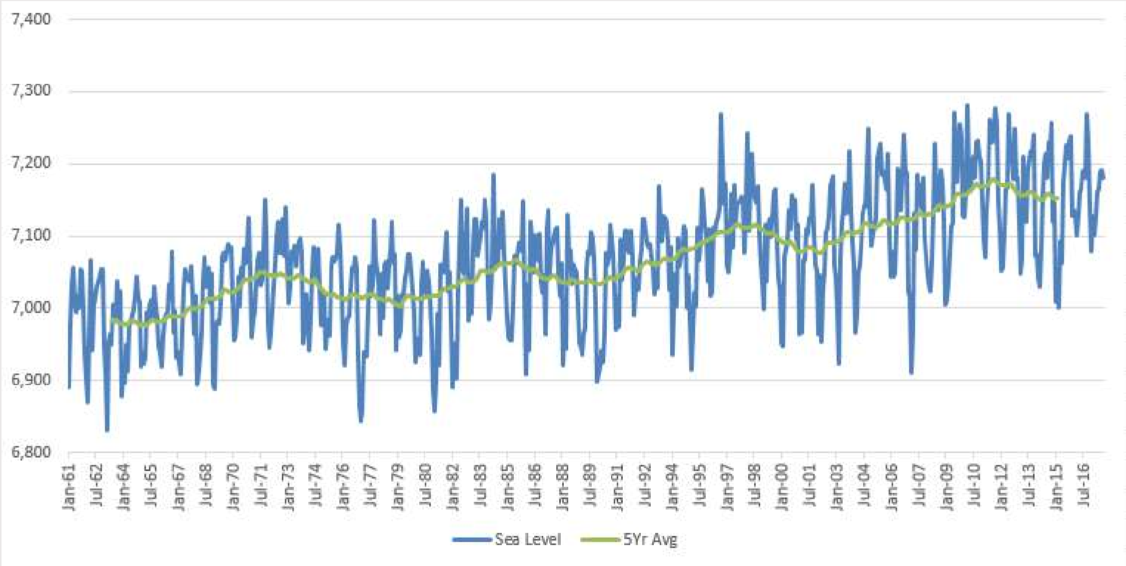
ACI 2.0 SOLUTION

1^{O} GRIDS (OR FINER)

BETTER TEMPORAL DATA

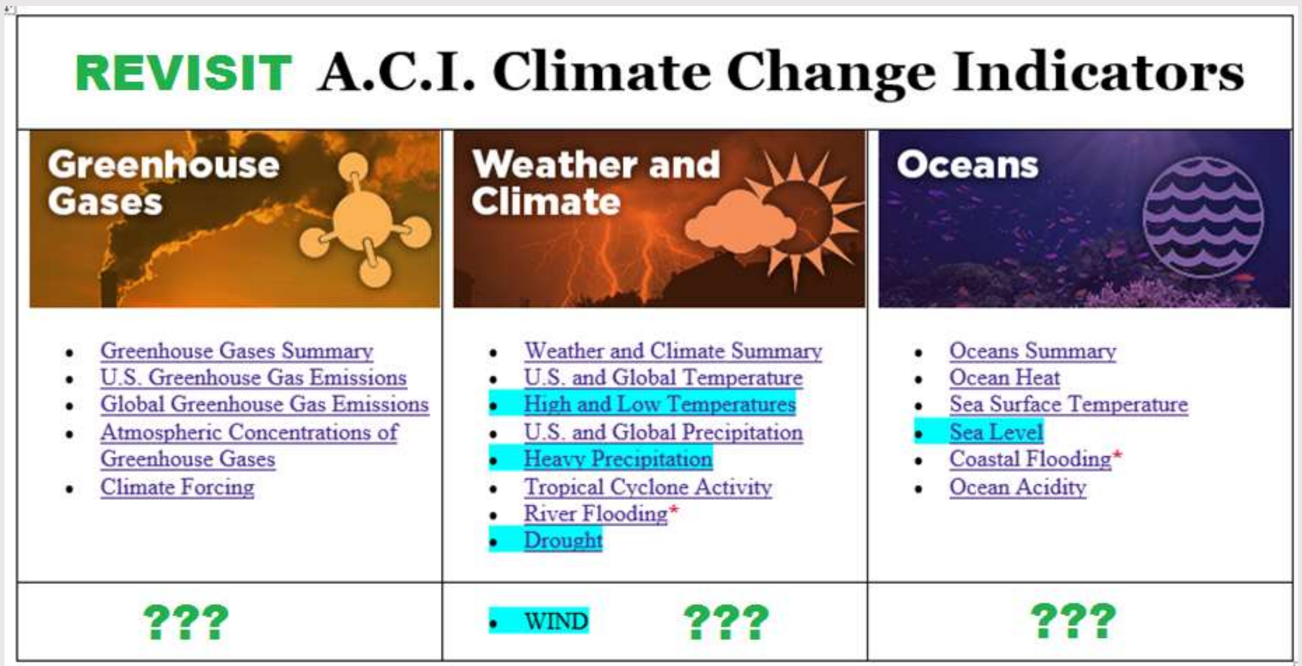
Replace Underlying Seasonal/Monthly time series with Daily/Hourly?

ACI Monthly SEA LEVEL
Central East Atlantic Region
5 Year Average Smoothing



DIFFERENT DATA: *To be determined…*

…maintaining as much continuity with ACI 1.1 as possible



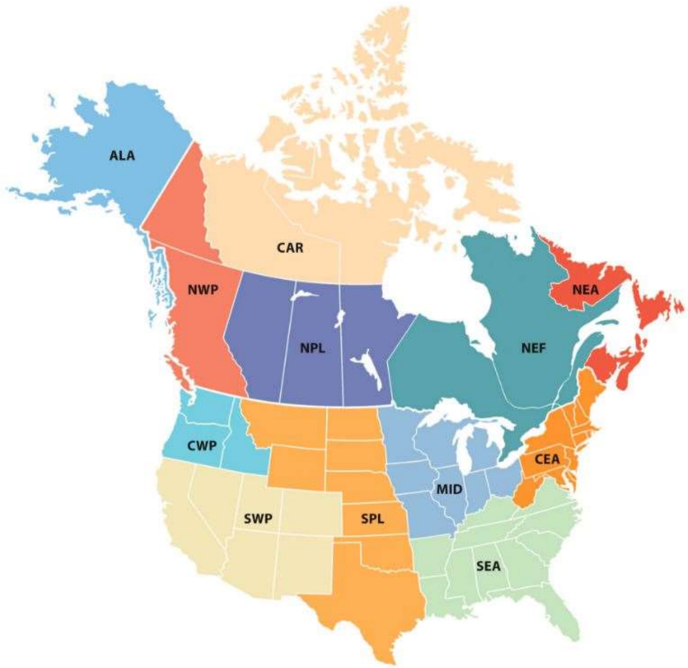
Components being considered to replace CDD Index:

- **Palmer Drought Severity Index (PDSI sc)**
- **Evaporative Index**

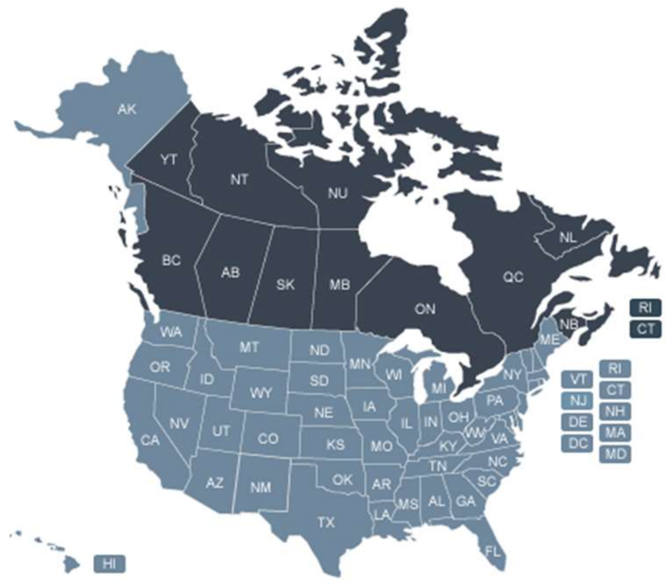
More detailed ERA5 and OCEAN5 instead of GHCN

BETTER GEOGRAPHIC DATA

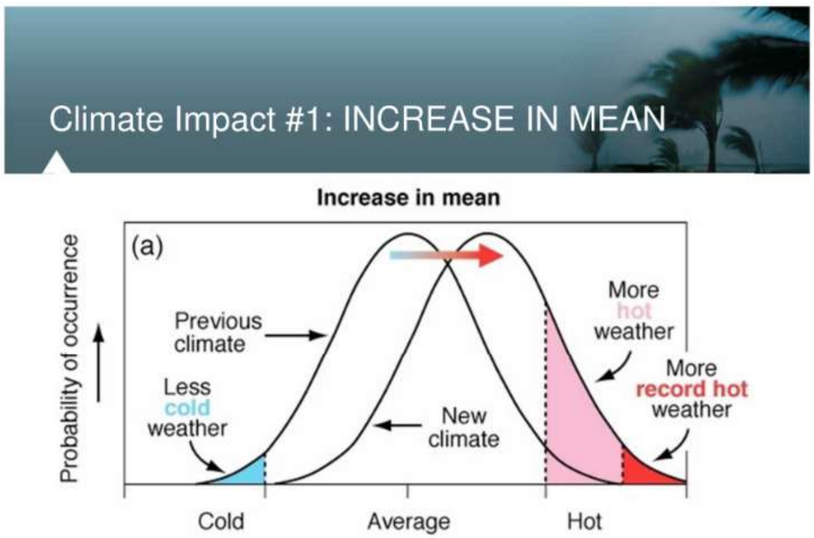
12 Regions, US & Canada

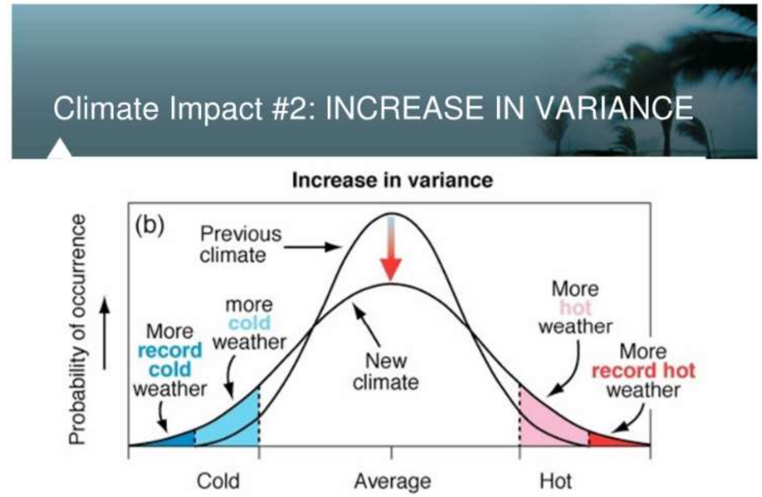


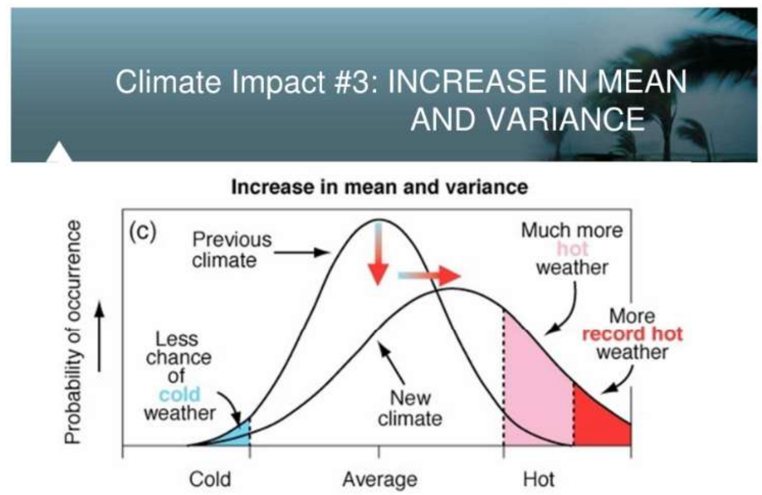
Downscale from regions to State and Provinces



ACI/ACRI CHALLENGE: DISCERN IMPACTS OF CHANGING CLIMATE







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

Illustration of Changing Distribution Mean

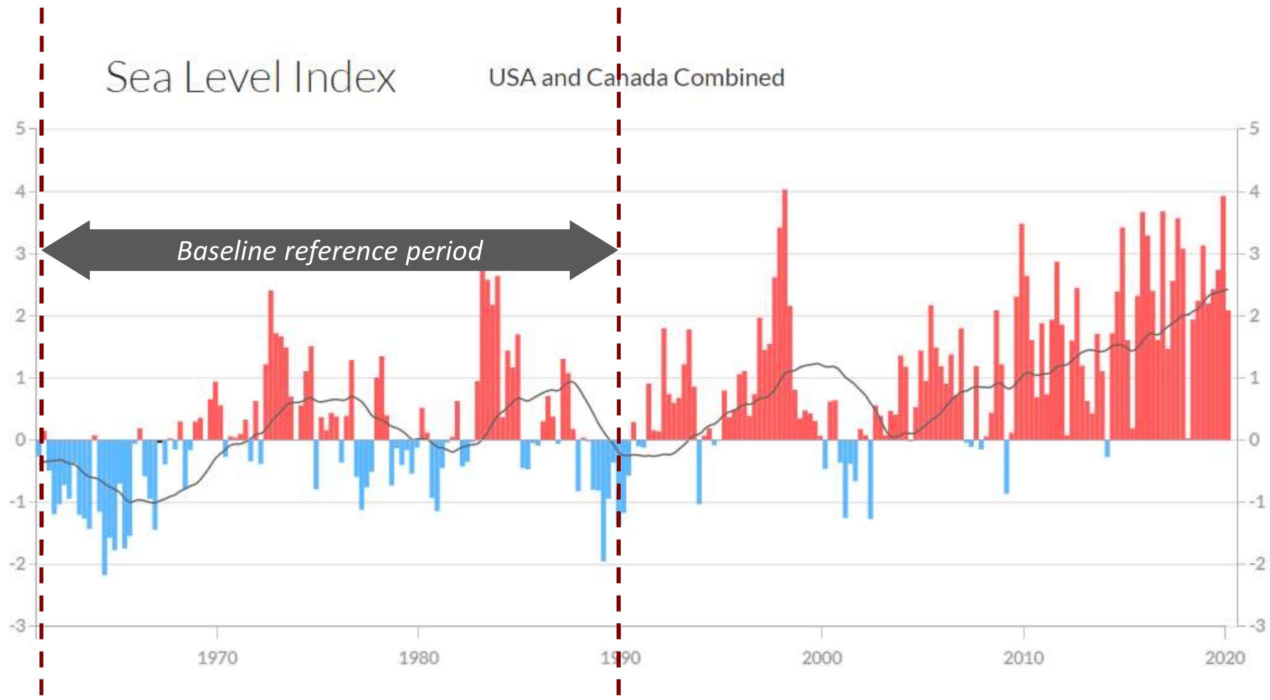
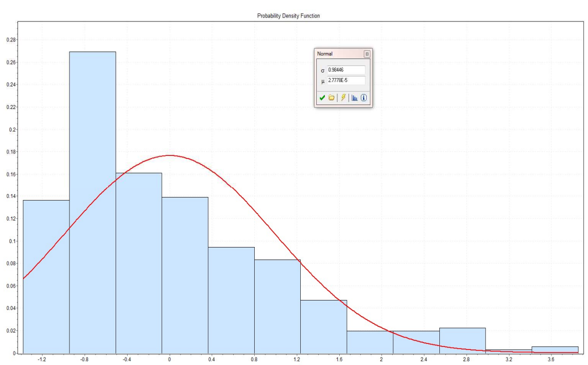
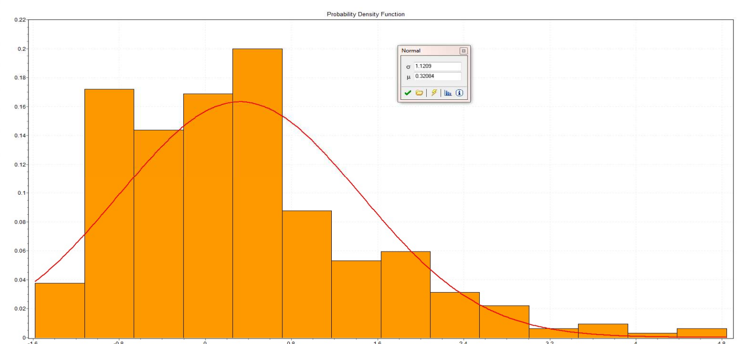


Illustration of Changing Distribution Shape

Distribution of T90 Standard Anomalies
Southeast Atlantic (SEA) Region

REFERENCE YEARS **WARM YEARS**

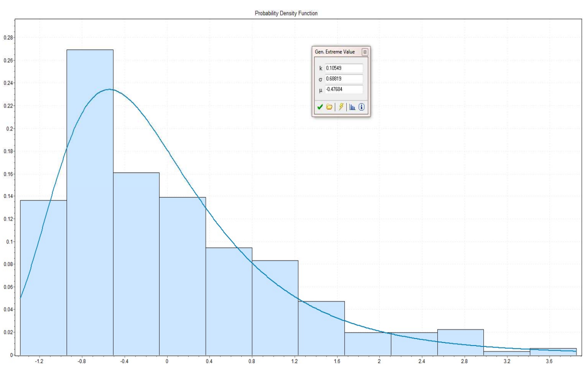




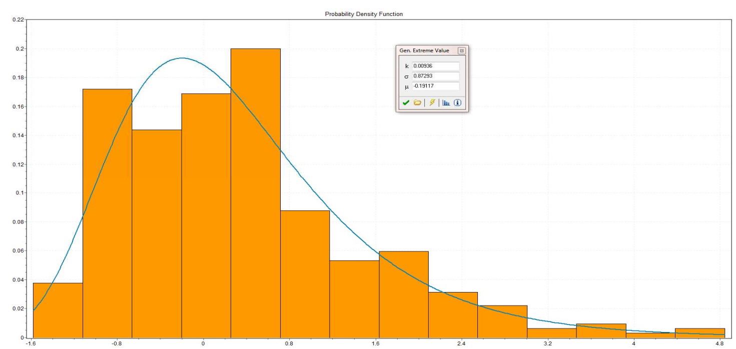
The smooth fitted curve, a standard Normal distribution, is a poor fit to the T90 Anomaly distribution

Distribution of T90 Standard Anomalies Southeast Atlantic (SEA) Region

REFERENCE YEARS



WARM YEARS



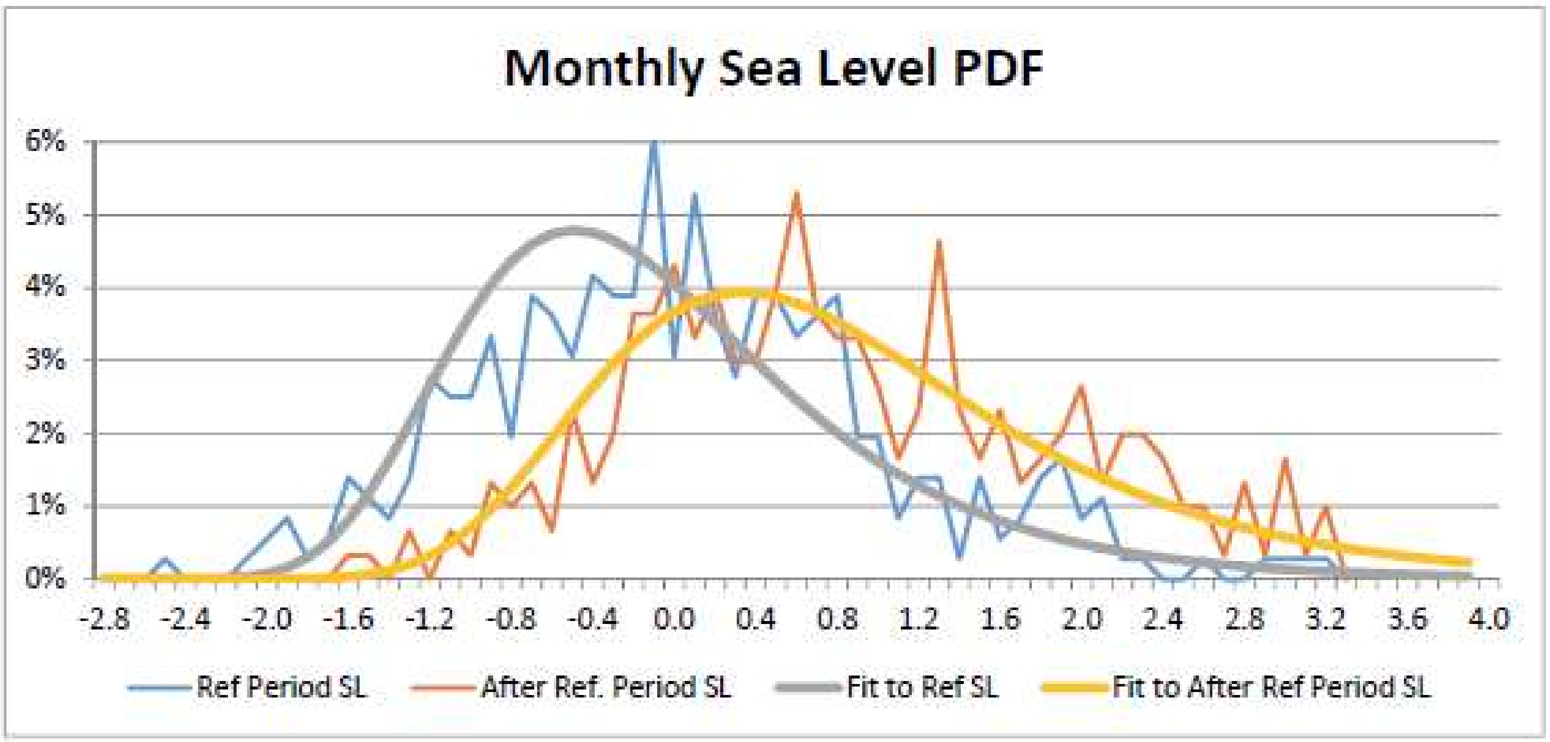
The skewed Generalized Extreme Value curve, fits T90 Anomalies better

CONCLUSION

T90 STANDARD ANOMALY
IS NOT NORMALY DISTRIBUTED,

THE SKEWED
EXTREME VALUE DISTRIBUTION
FITS BETTER

ACI (PSMSL) DATA:
Sea Level Mean and Variance are increasing



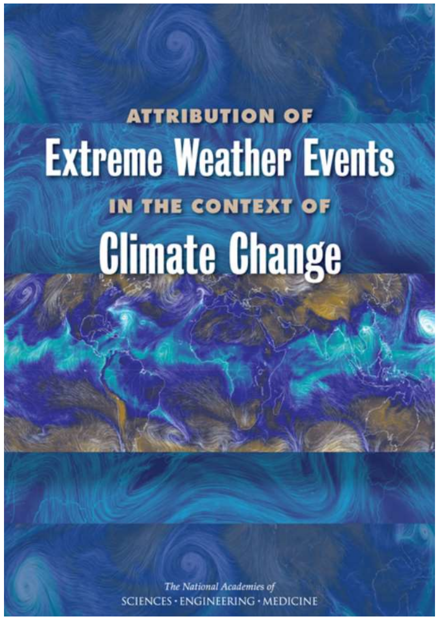
ACI/ACRI 2.0 Possibilities

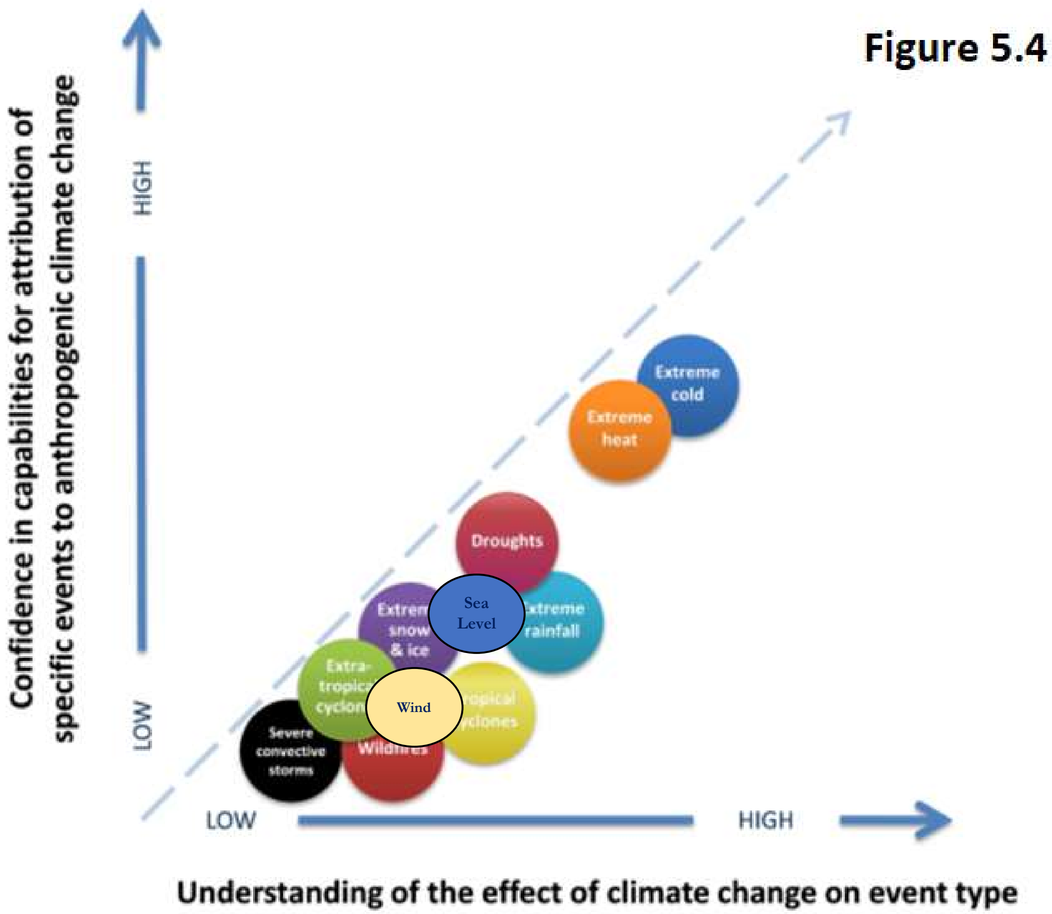
The ACI and it components and ACRI

are tools to use to look for correlations with extreme event losses, injuries and fatalities

ACI/ACRI future: Analyze climate impacts on many types of events

Levels of Confidence and Understanding of HOW Climate affects Natural Hazards





What we can do with the ACI/ACRI tools!

"Climate change is a 'threat multiplier' making worse the problems that already exist."

- Senator John Warner, in testimony before the Senate Foreign Relations Committee as quoted by John Kerry, Secretary of State at Old Dominion University.

CONCLUSION:

BUILD THE ACRI TOGETHER TO GIVE THE WORLD…

RELIABLE (CREDIBLE!) ACTUARIAL EXTREME RISK MEASURES

ACRI Risk multipliers – a tool for sustainable growth measures

Bill Gates – The Grand Challenge of Climate Change

SOURCE: https://www.youtube.com/watch?v=0__6kx-vTO4

QUESTIONS?

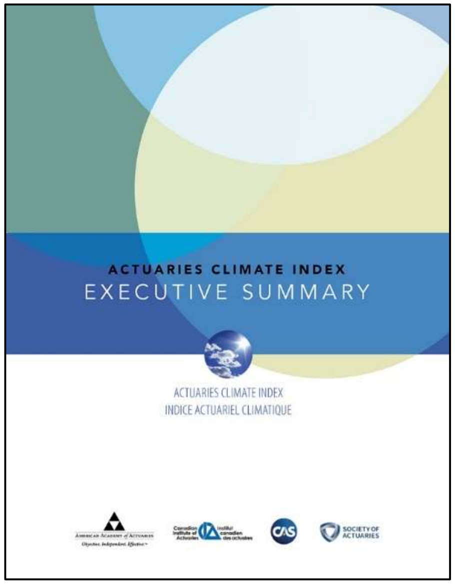
Steve Kolk, ACAS, MAAA
Steve@Kolkulations.com

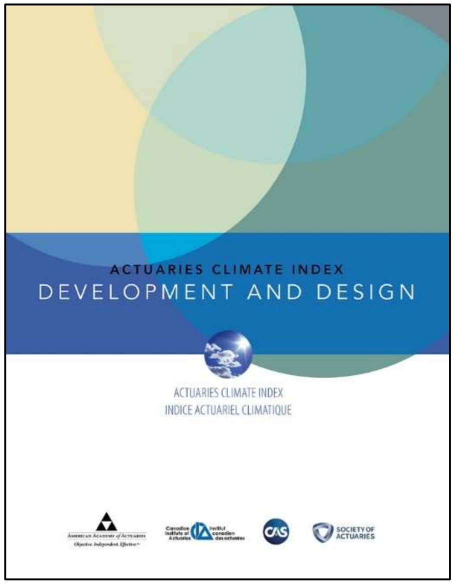
APPENDICES

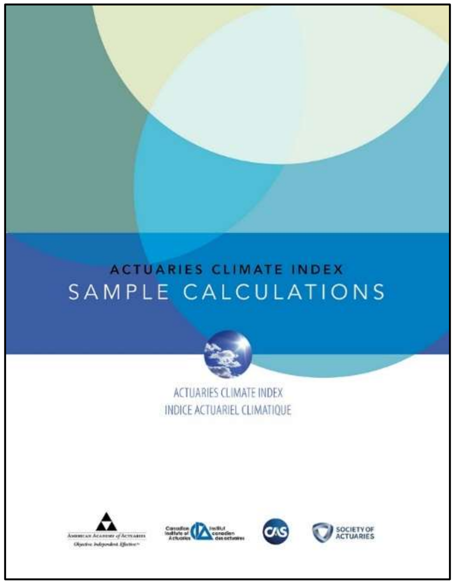
APPENDIX 1

ACI REFERENCES

Three Foundational Documents on the ACI Website







actuariesclimateindex.org

Websites

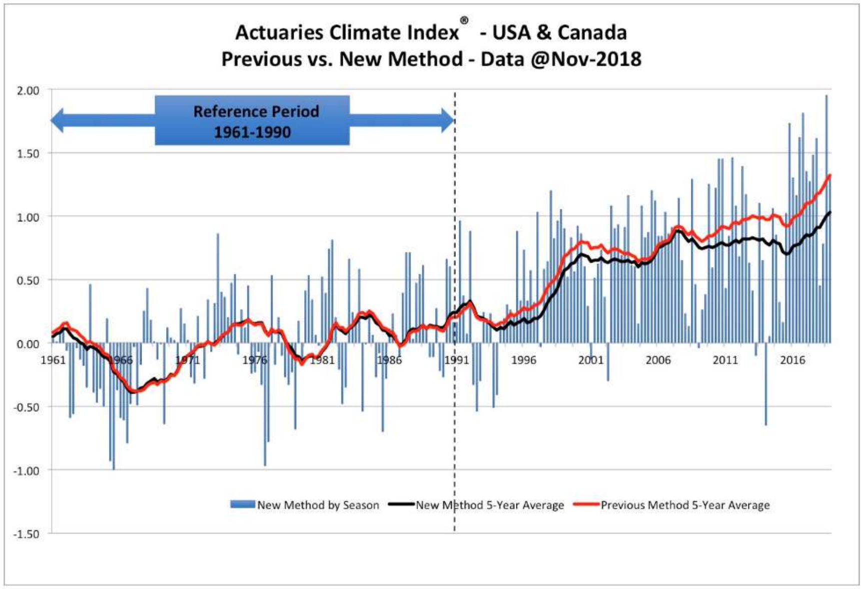
- English
  www.ClimateRiskHub.org and .com
  www.ActuariesClimateIndex.org and .com

- French
  www.CarrefourRisquesClimatiques.org and .com
  www.IndiceClimatiqueActuaires.org and .com

APPENDIX 2

“KNOW THY DATA”
READ ACI DATA DISCLOSURES

Data Disclosure: ACI 1.1 versus ACI 1.0



- PROBLEM: During routine quarterly ACI updates, careful data review revealed a problem.
- CAUSE: Data holes grew, primarily in Canada where station reporting decreased causing an upward bias in the ACI.
- CORRECTION: The ACI 1.0 formula was modified to remove this bias and results were restated as shown here.

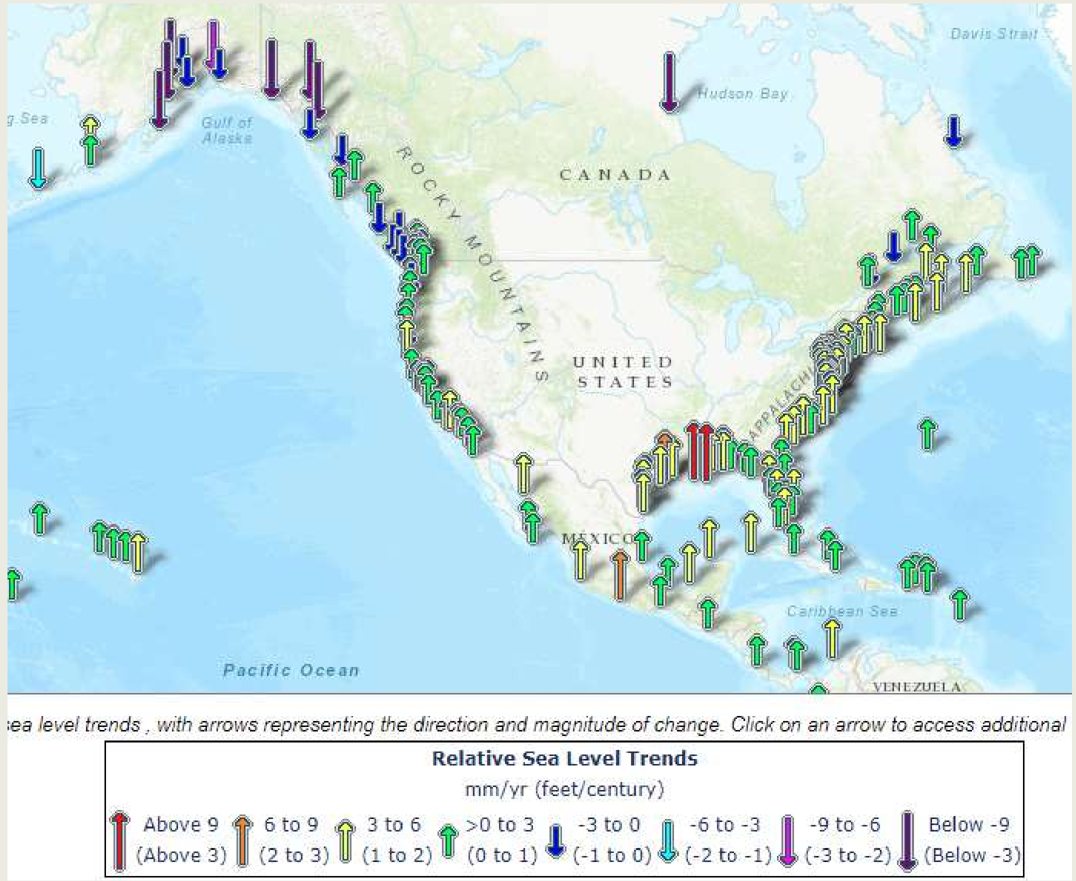
See https://actuariesclimateindex.org/data/data-disclosure/ for details of this and future data releases

APPENDIX 3

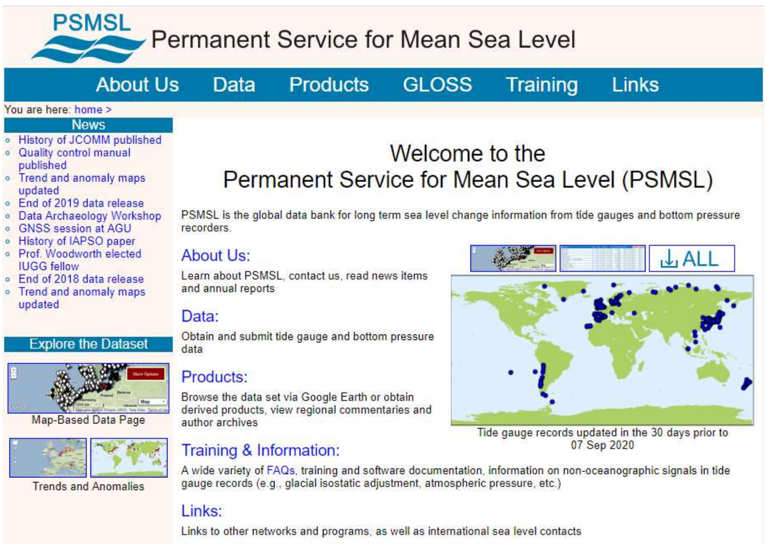
EXTEND ACI WITH EXTERNAL DATA

These
RELATIVE SEA LEVEL TRENDS from NOAA

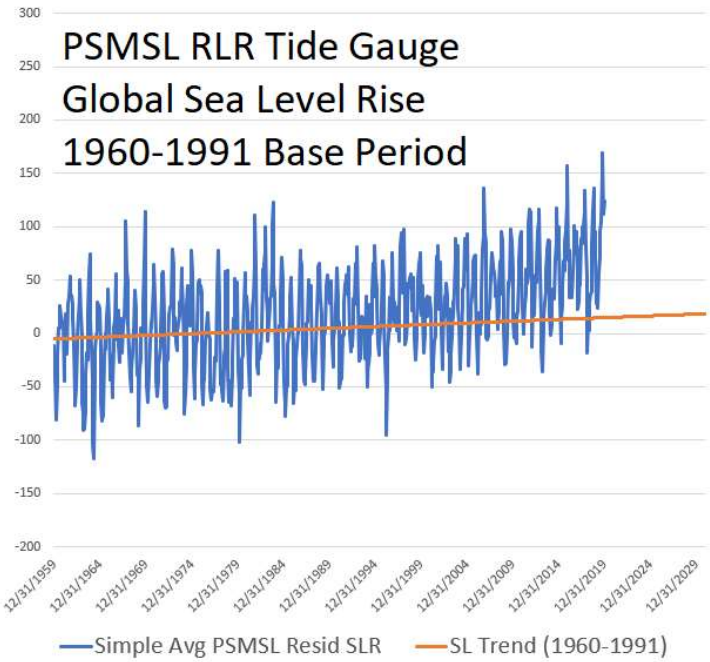
SPURRED EXPLORING PSMSL SLR TREND by LATITUDE
[and LOCATION]

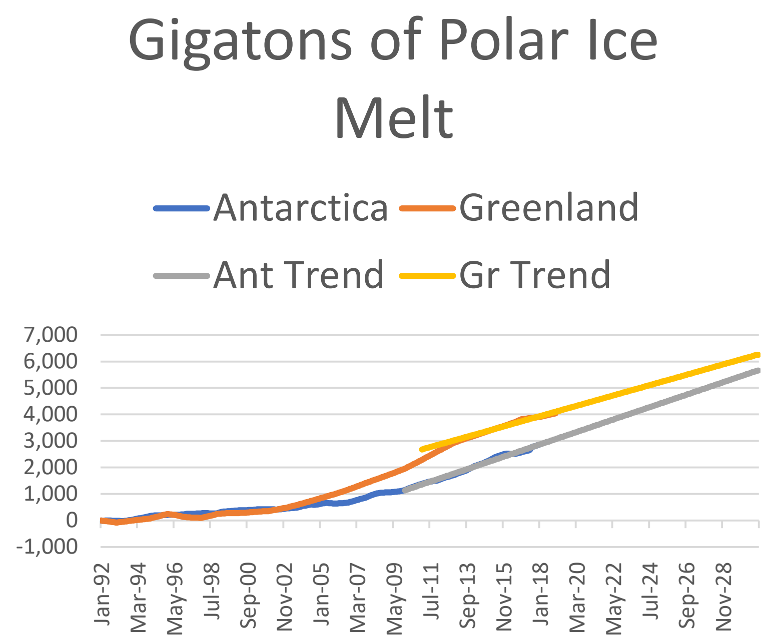


Worldwide Sea Level Rise Forecast?
Blend: [PSMSL SLR] + [IMBIE Ice Melt]

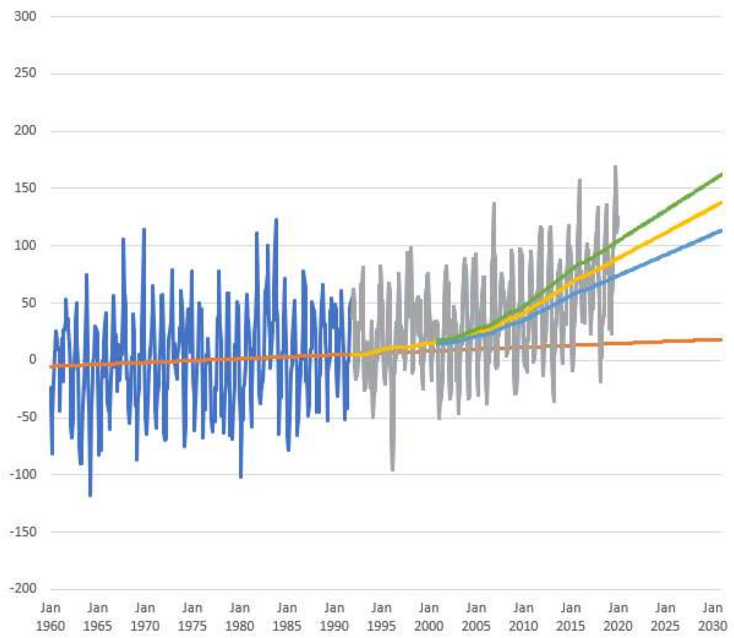


Snapshot Look at the two Data Sources





Blended Global SLR Trend Analysis:
How SLR varies by Latitude & Ocean Basin

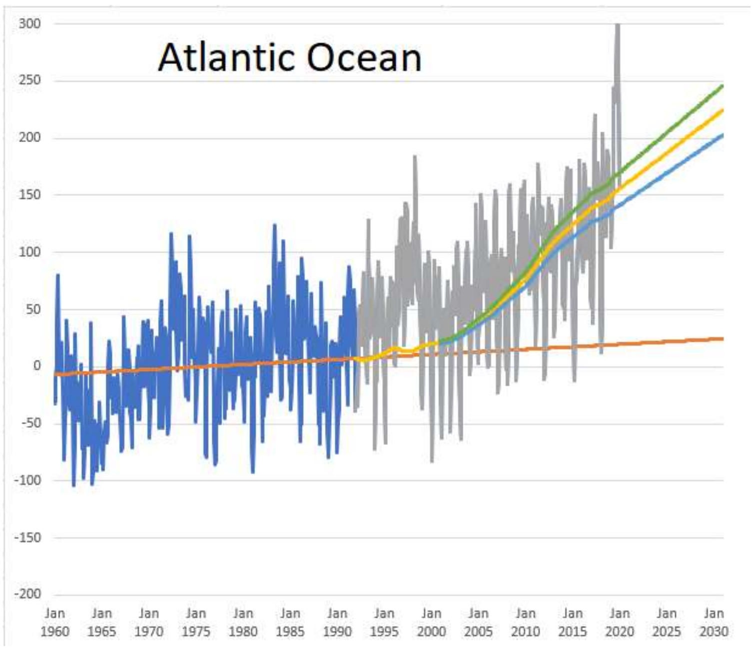


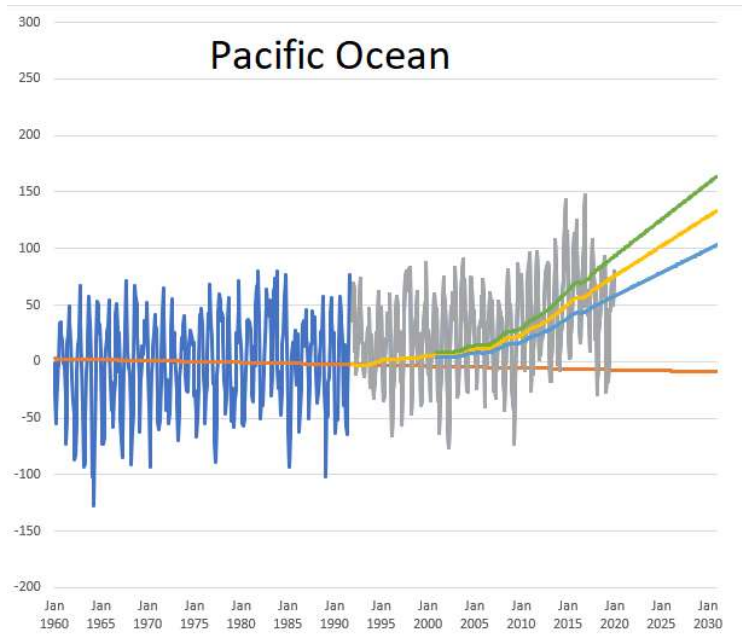
- Two Sea Level Rise equations were fit to over 200 PSMSL RLR tide stations' data*:
  - Simple Linear fits from 1960 to 1992
  - 1992 to 2018 is proportional to IMBIE
    - Greenland Mass loss in N. Atlantic and Arctic
    - Antarctic Mass loss in all other ocean basins
- Classifying the tide stations by Ocean sector (N,S,E,W) and Lat/Lon for analysis
- Combinations are simple averages
- FINDING: **IMBIE Ice Melt data can help quantify Sea Level Rise projections**

*Permanent Service for Mean Sea Level (PSMSL), 2020, "Tide GaugeData", Retrieved September 2020 from http://www.psmsl.org/data/obtaining/.

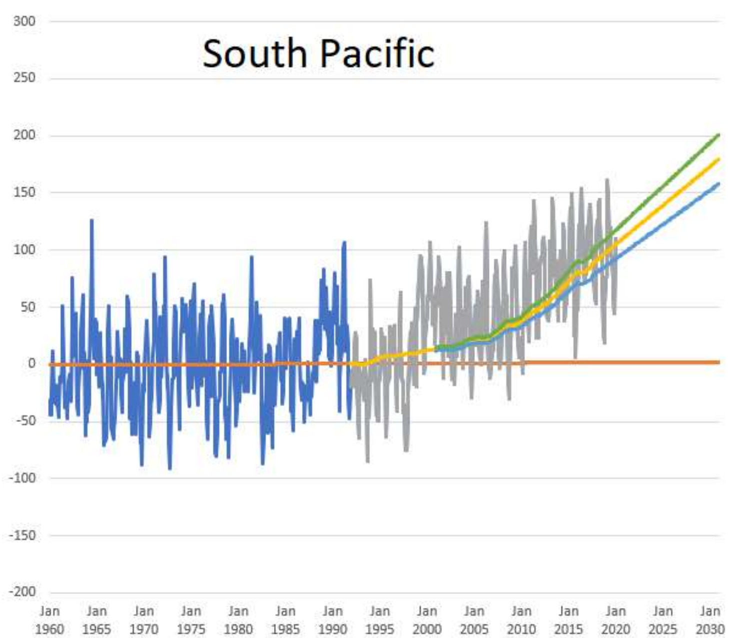
Simon J. Holgate, Andrew Matthews, Philip L. Woodworth, Lesley J. Rickards, Mark E. Tamisiea, Elizabeth Bradshaw, Peter R. Foden, Kathleen M. Gordon, Svetlana Jevrejeva, and Jeff Pugh (2013) New Data Systems and Products at the Permanent Service for Mean Sea Level. Journal of Coastal Research: Volume 29, Issue 3: pp. 493 – 504. doi:10.2112/JCOASTRES-D-12-00175.1.

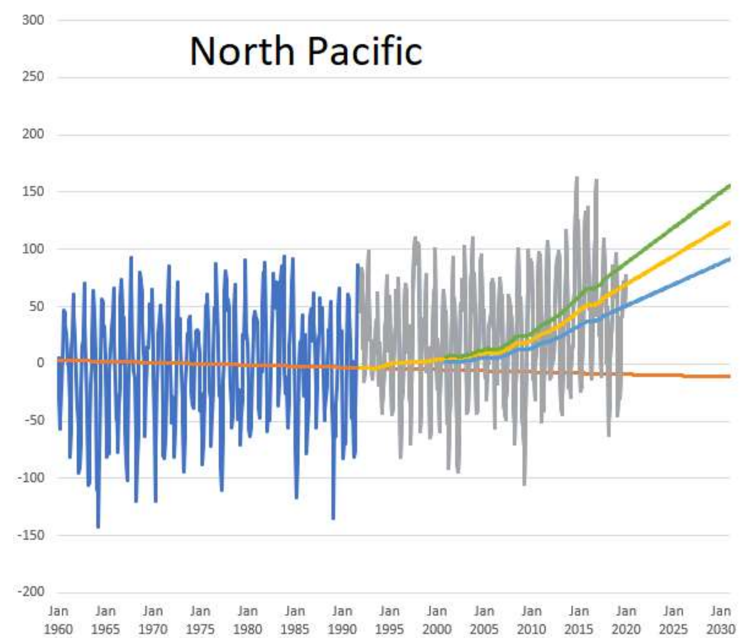
Atlantic SLR > Pacific SLR, sensible because
Greenland Ice Mass Loss > Antarctica Ice Mass Loss





South Pacific SLR > North Pacific SLR because of proximity to Antarctica

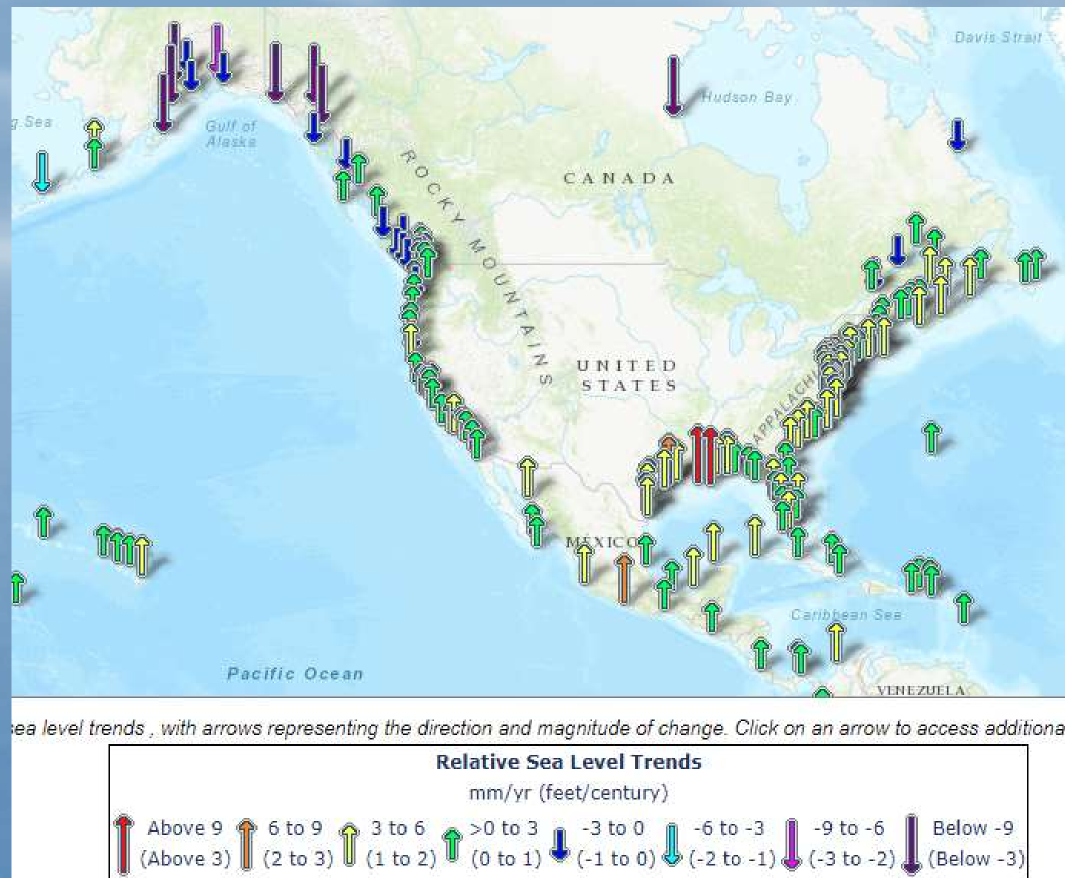




EXPANDING NOAA'S SEA LEVEL TREND ANALYSIS OF NORTH AMERICA…

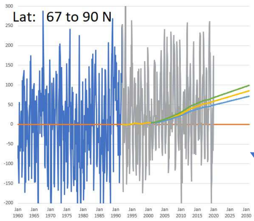
…THROUGH TIME AND AROUND THE GLOBE…

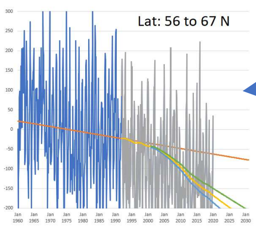
…SHOWS ICE-MELT WATERS MOUND UP AROUND THE EQUATOR AND ARE SQUEEZING EARTH MEASUREABLY

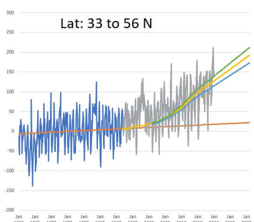


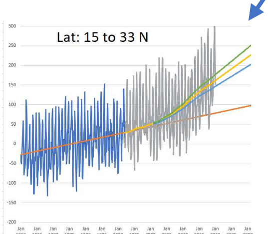
Get Kolk-Prepared!!
with Kolkulations LLC
providing Relevant Big Data
GIS Risk Analytics

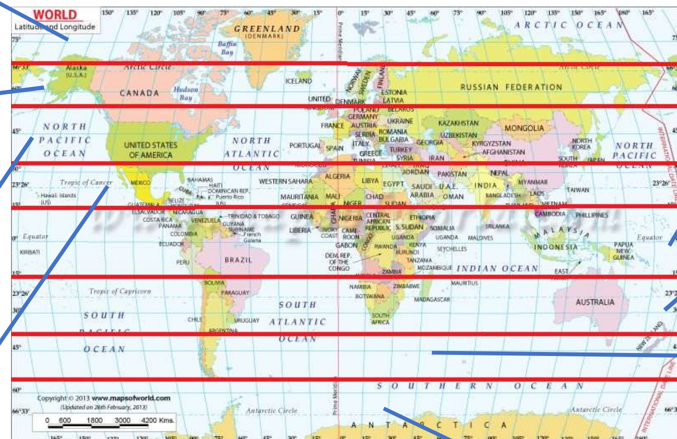
SLR Variation by Latitude

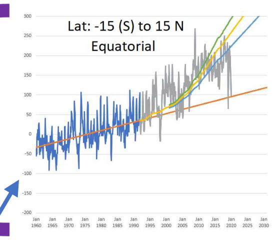


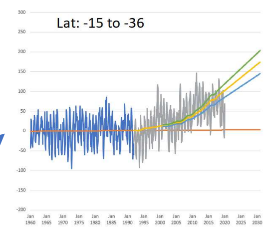


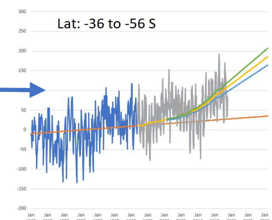


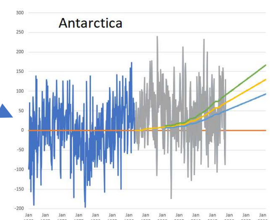












Hypothesis suggested by NOAA map, confirmed:

(a) Sea Level is rising fastest near the equator

(b) More equatorial water is squeezing the globe

(c) Land rebounds between Lat 56 to 67 N making Sea Levels drop. This is most noticeable in Alaska.