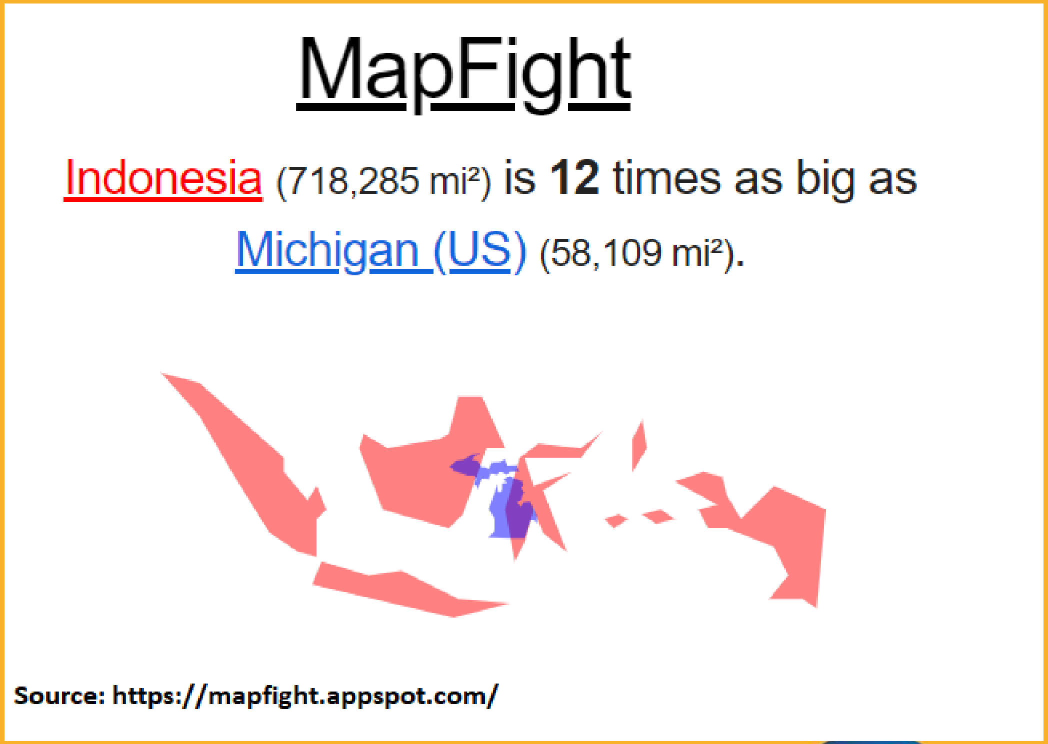
Measuring Climate Change: The Actuarial Climate (and Climate Risk) Indices

ACTUARIES CLIMATE INDEX
INDICE ACTUARIEL CLIMATIQUE

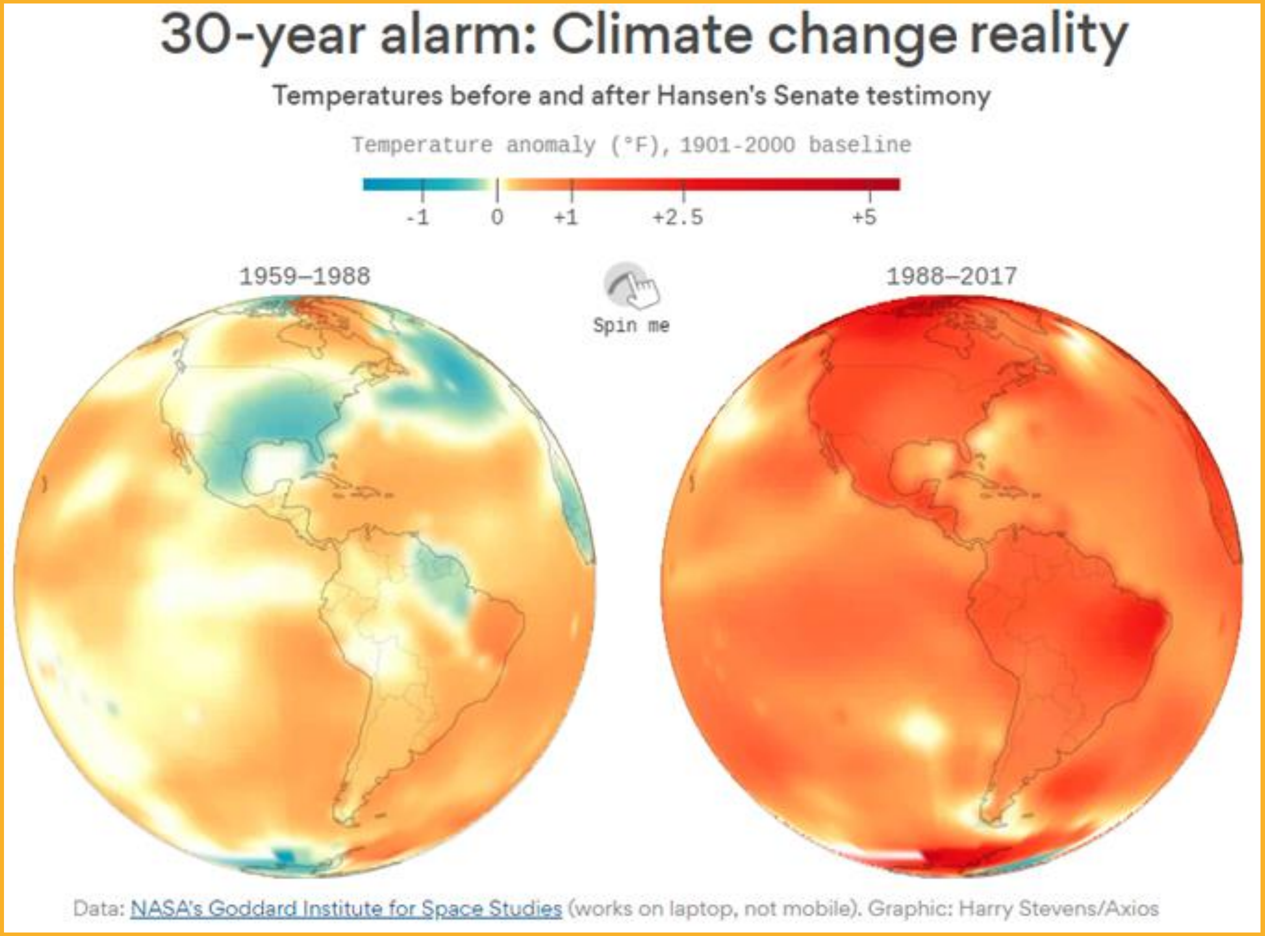
Indonesia Actuarial Conference
19 Oktober 2018

Steve Kolk, ACAS, MAAA

My Home –versus- Indonesia

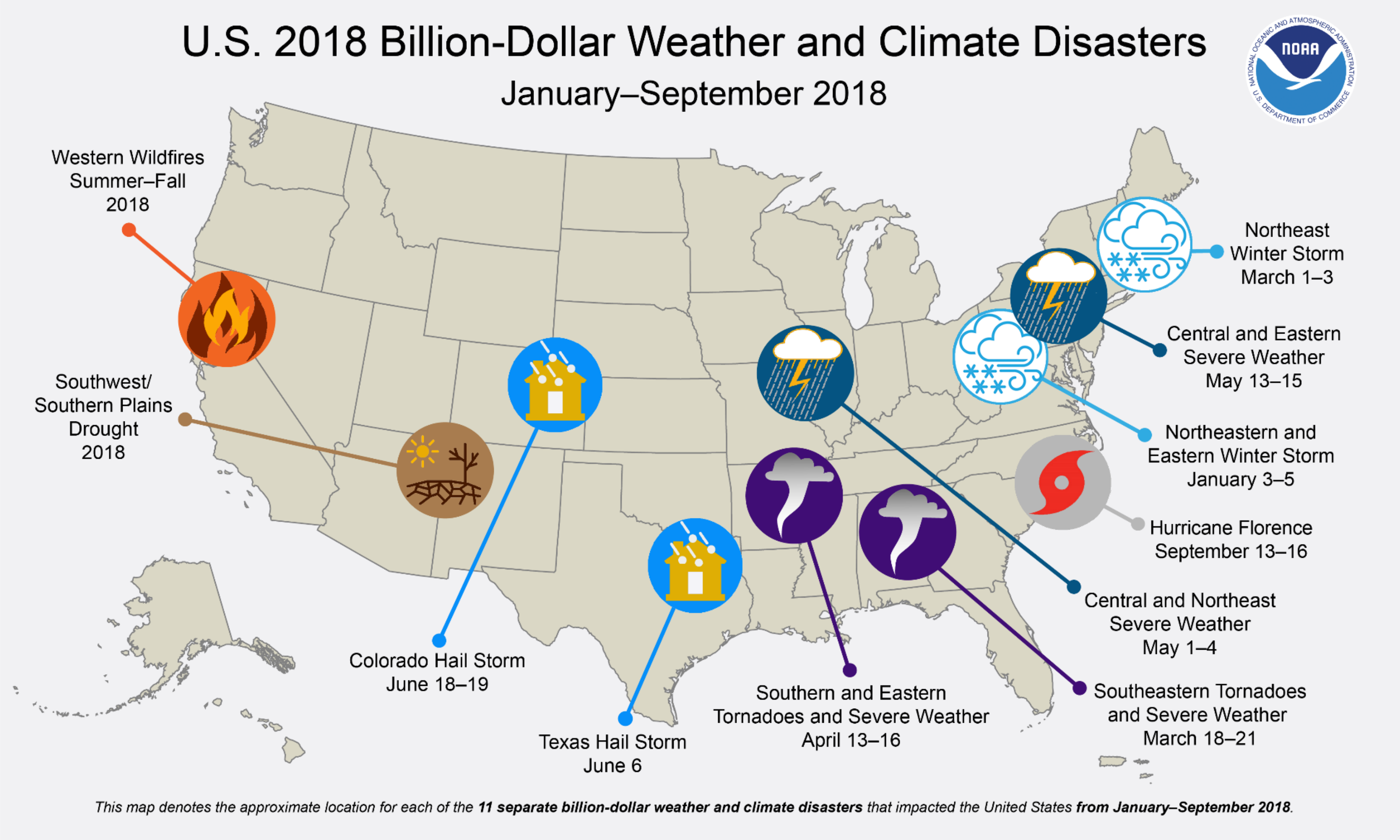


A bit of history: *Why bother about Climate?*



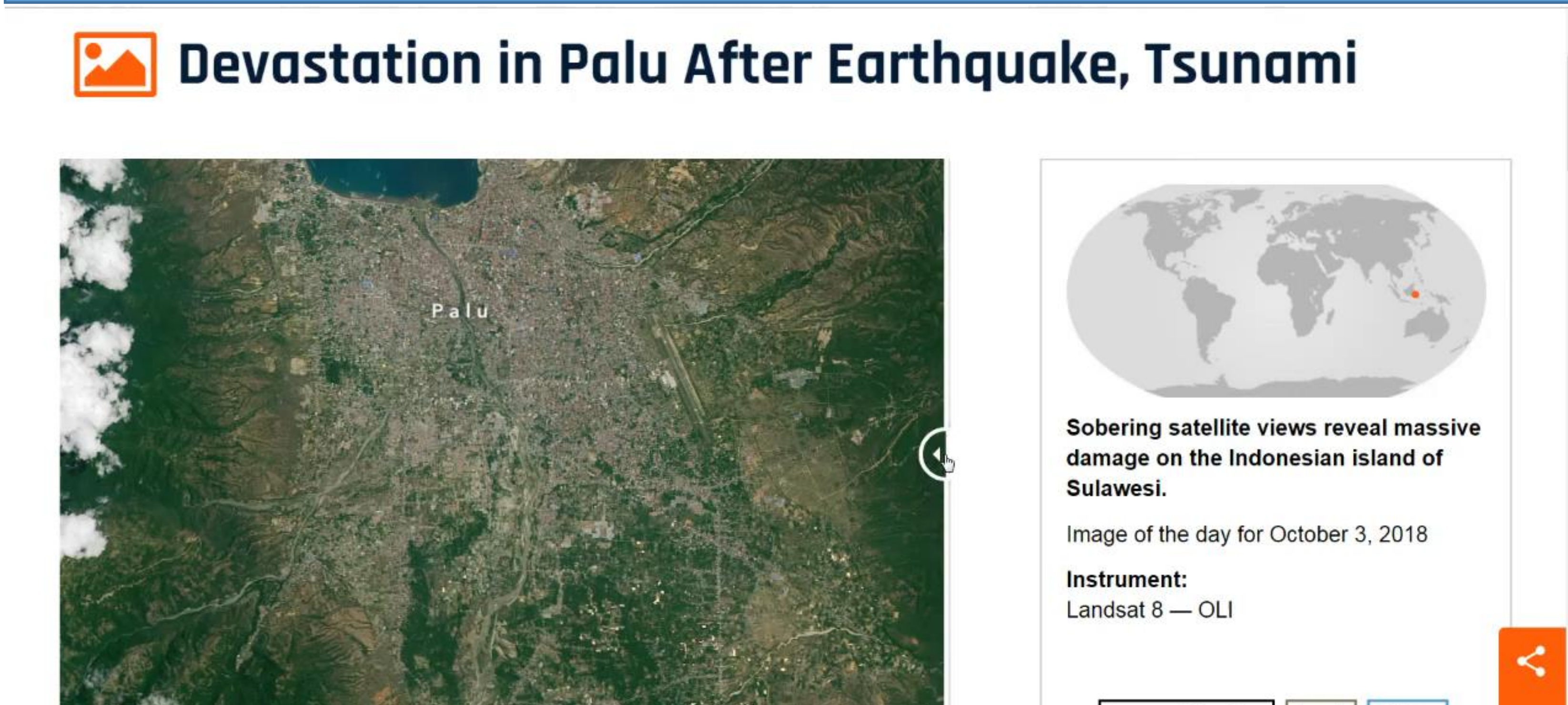
See animated version at: https://www.axios.com/newsletters/axios-am-cf3fa944-b946-42cd-8d11-26013a990398.html

Why should Insurers care about Climate?



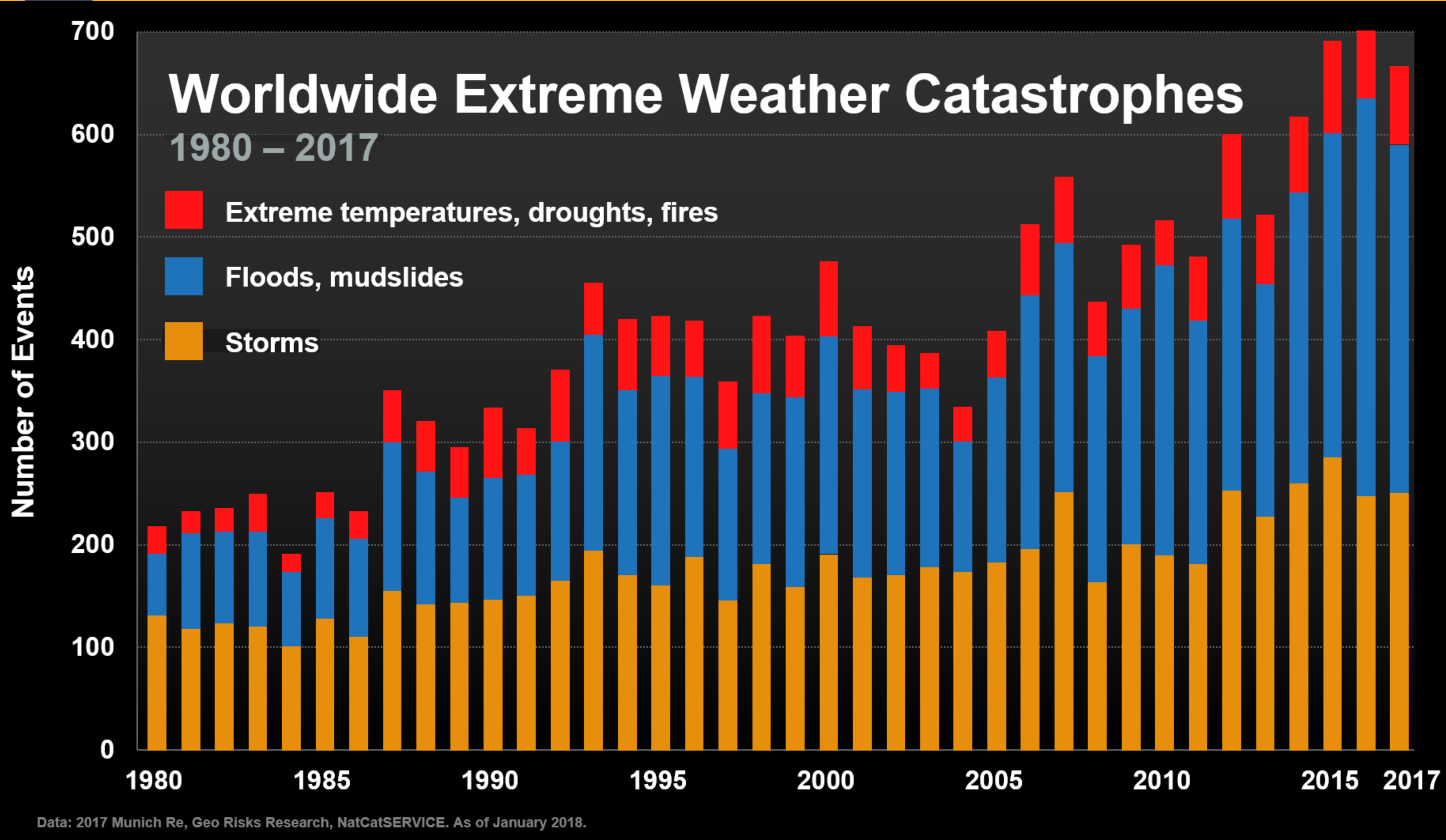
Source: https://www.ncdc.noaa.gov/billions/ accessed 10/11/18

Palu – Before and after the Tsunami

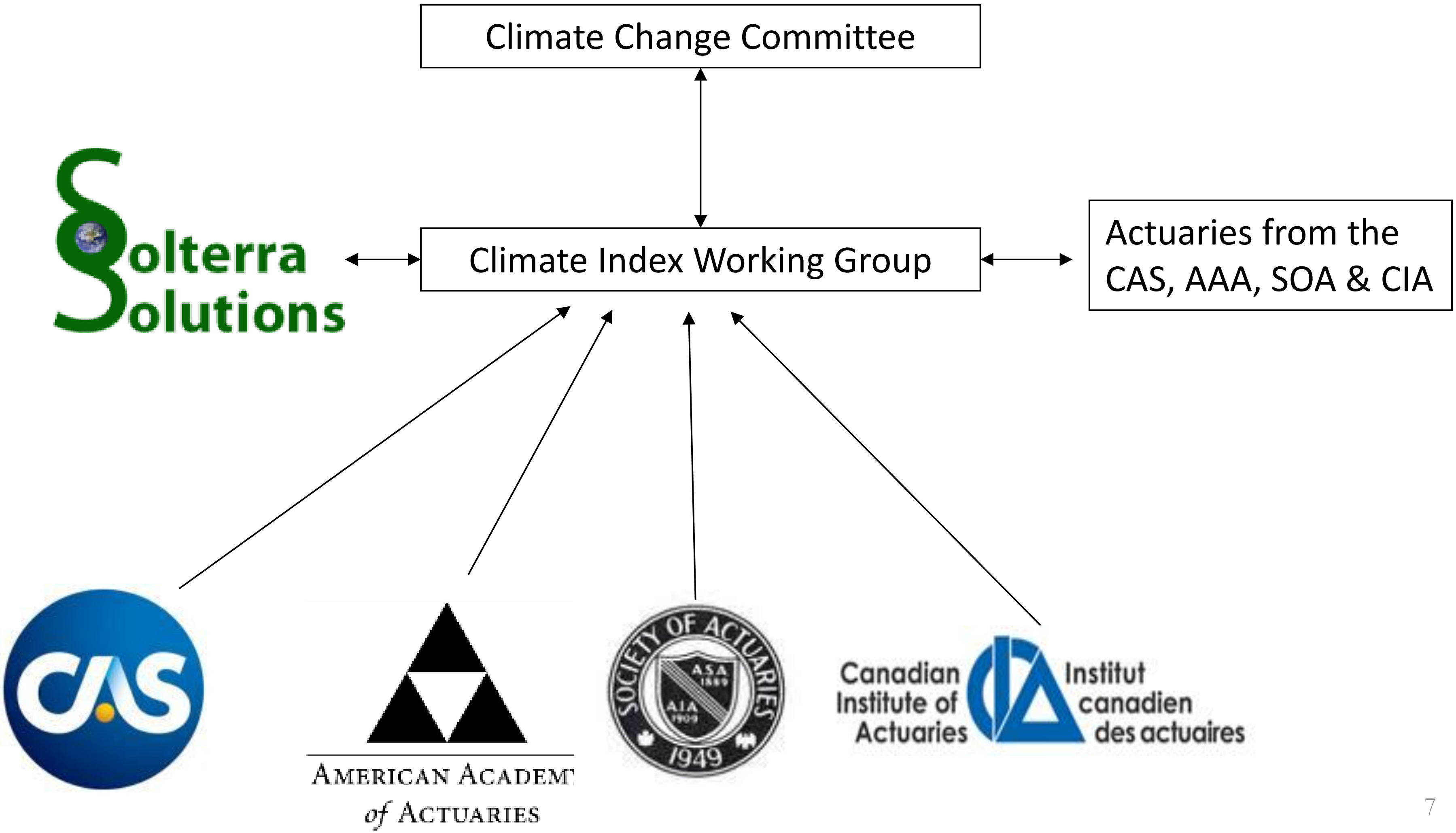


https://earthobservatory.nasa.gov/images/92836/devastation-in-palu-after-earthquake-tsunami?src=eoa-iotd

Why should Insurers care about Climate?



WHICH NORTH AMERICAN INSURANCE ACTUARIES GOT TOGETHER?



Actuaries Climate Index – Goals – WHAT? WHEN?

- 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

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COMPONENTS OF THE ACI

ACTUARIES CLIMATE INDEX

ACI Basics: 1) WHERE? 2) HOW? 3) WHAT?

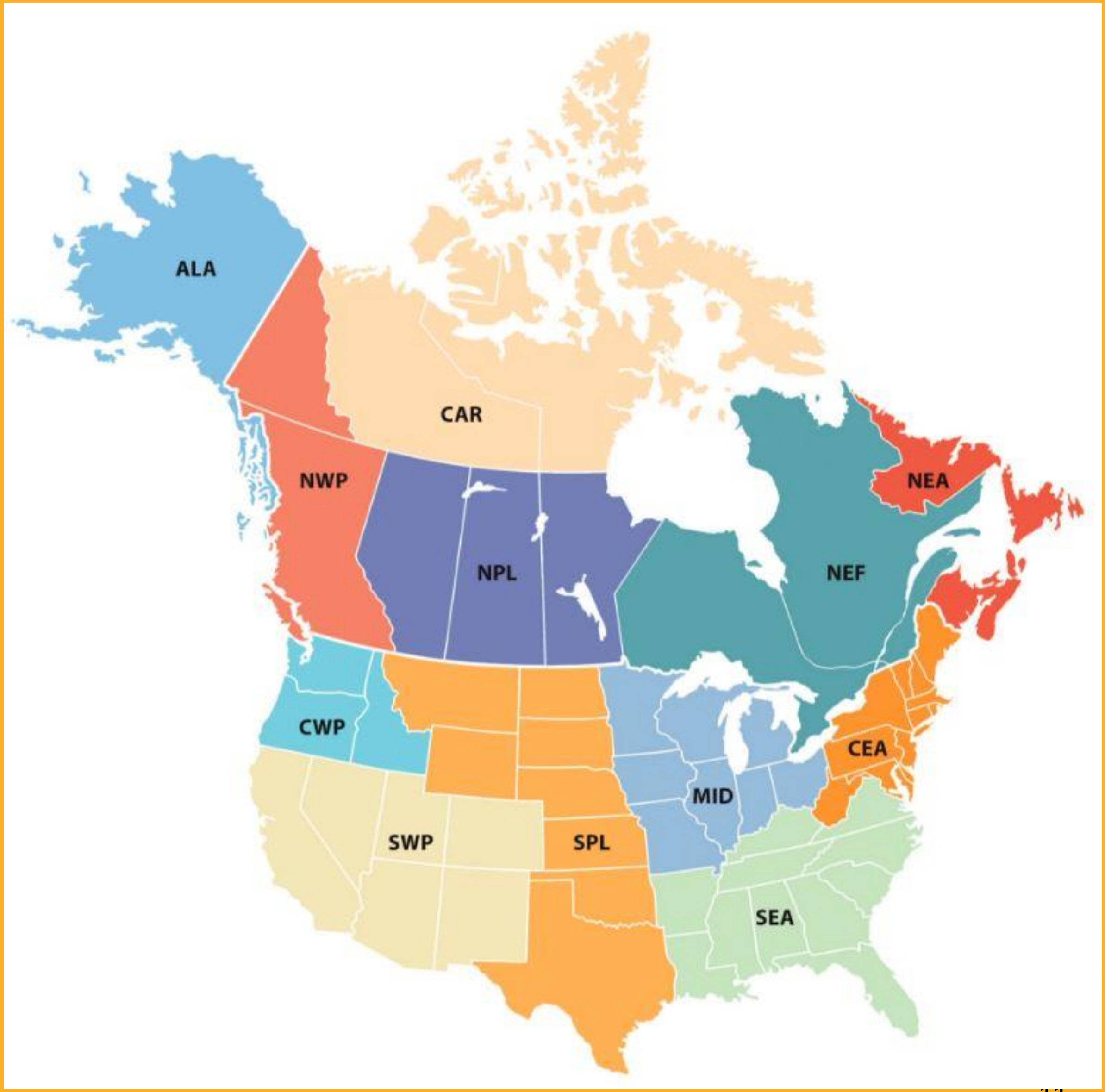
1) **Indices are for big Climatological Regions**
2) **Indices focus on "frequency of severity" (f-s)**
   - "How often is the temperature in a given month at or above the 90th percentile?"
   - The 90th percentile is based on the 1961-1990 reference period
   - Other indices tend to focus on change in the average over time, but it is the frequency of extreme weather that matters to us
3) **Indices are a simple averages of grid data within each climate region from six f-s variables**
   - High temperature
   - Low temperature
   - Heavy precipitation
   - Lengthy drought
   - High wind
   - Elevated sea level (for ocean coast regions only)

ACI Climate Regions

Region

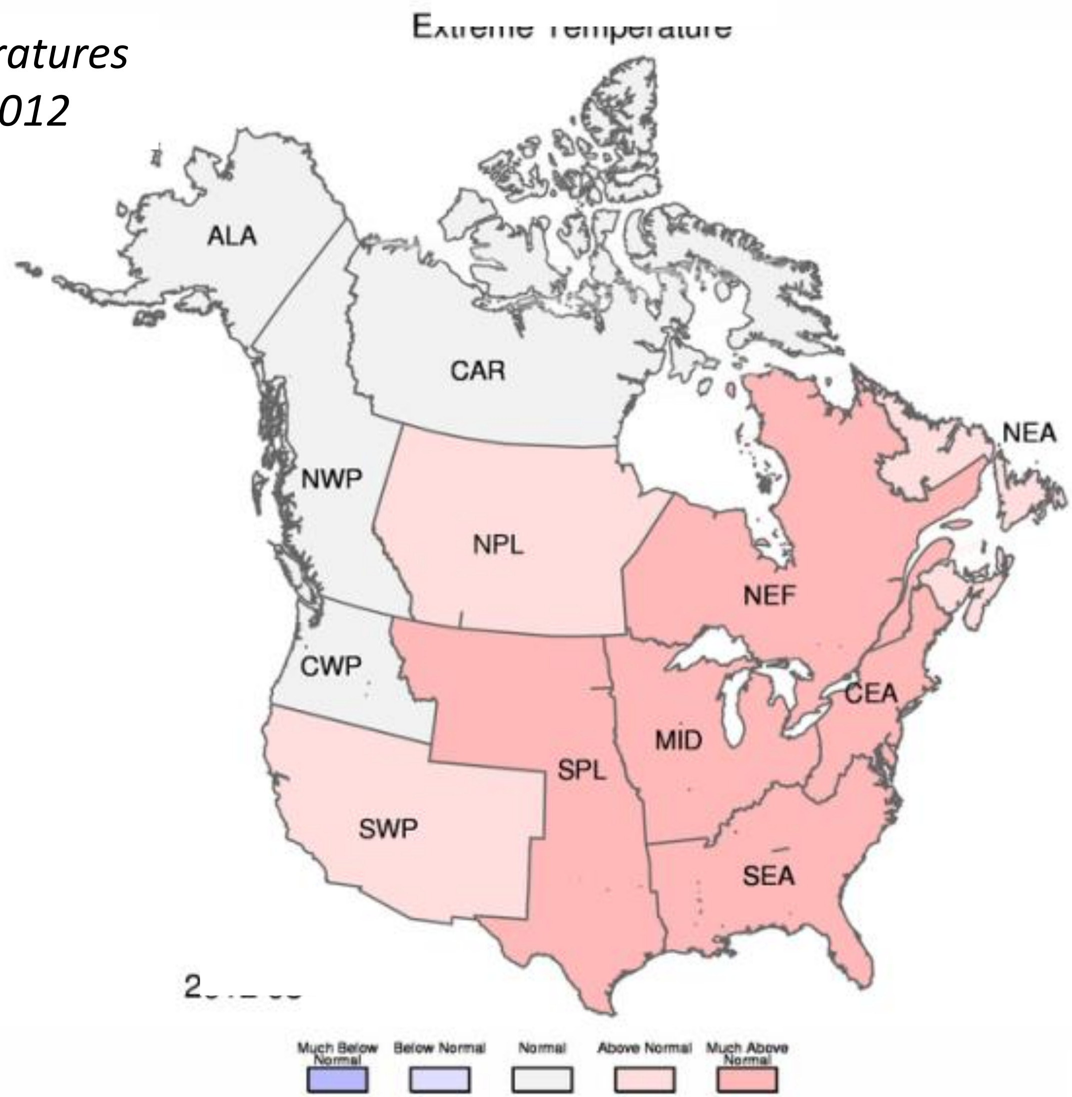
Region Name

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



ACI data is colorized to show heat extremes in red hues and cold extremes in blue hues

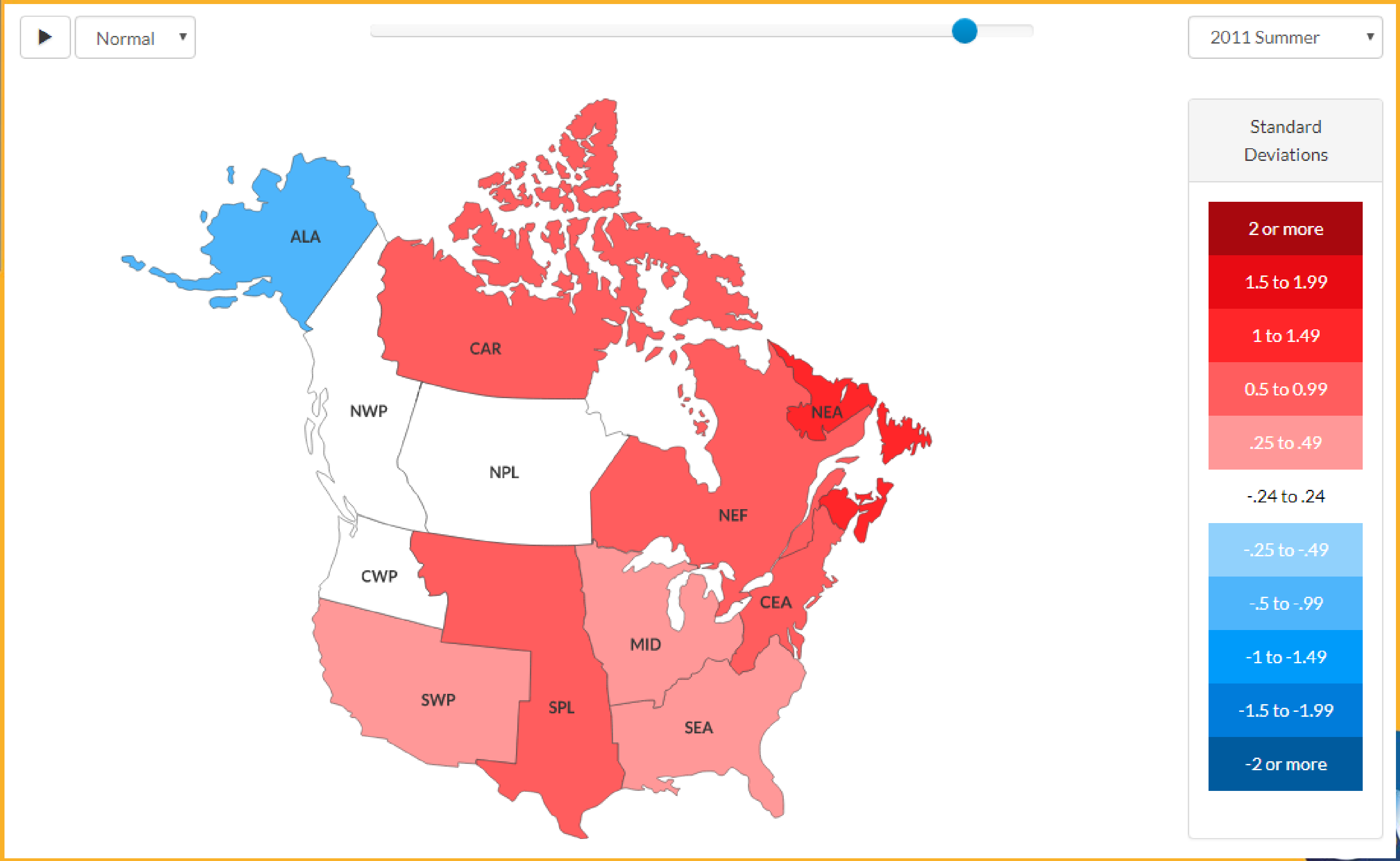
Frequency of Extreme Temperatures of a Hot Month - March, 2012

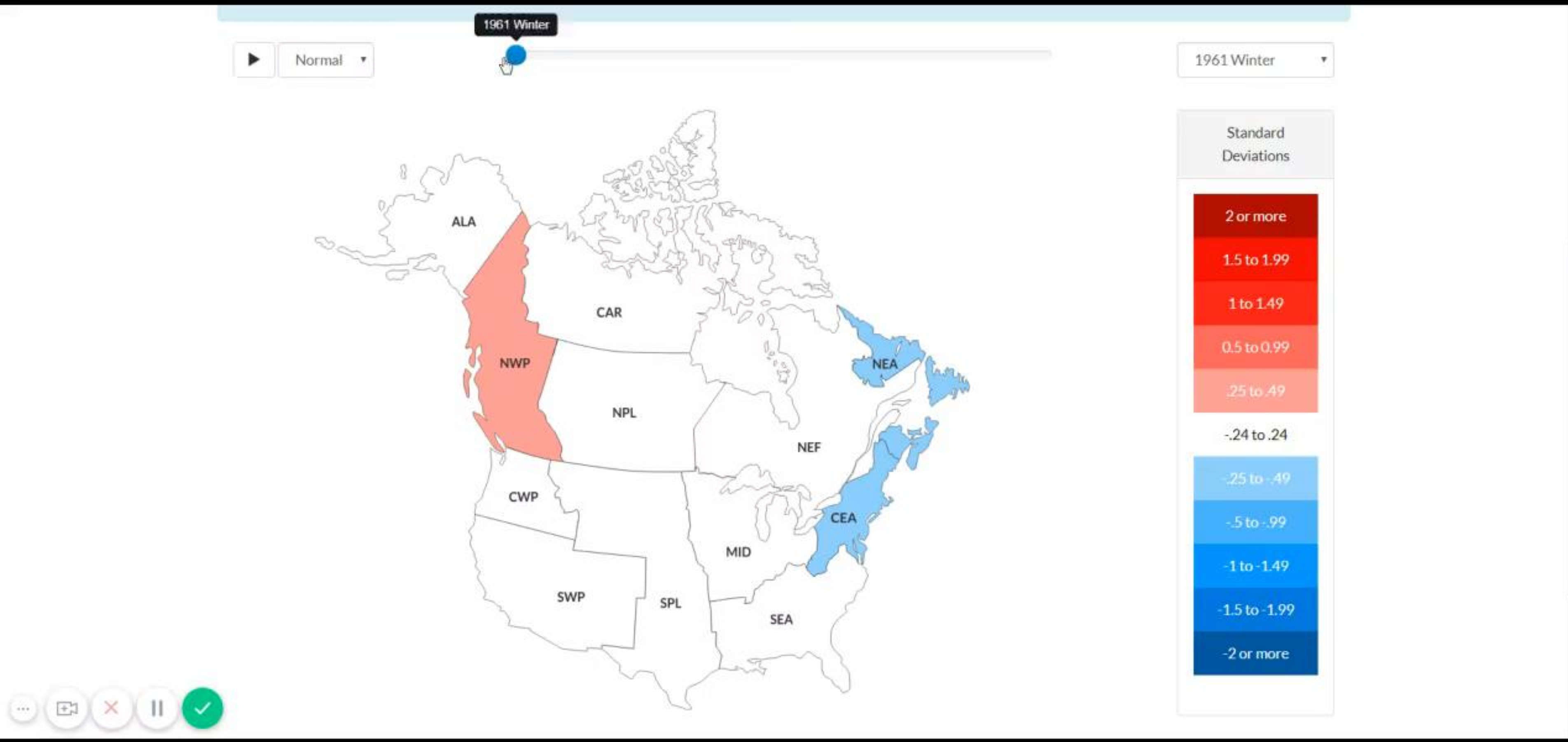


US and Canada Region, The ACI – Summer 2001

View an animation of 5-year moving average values:

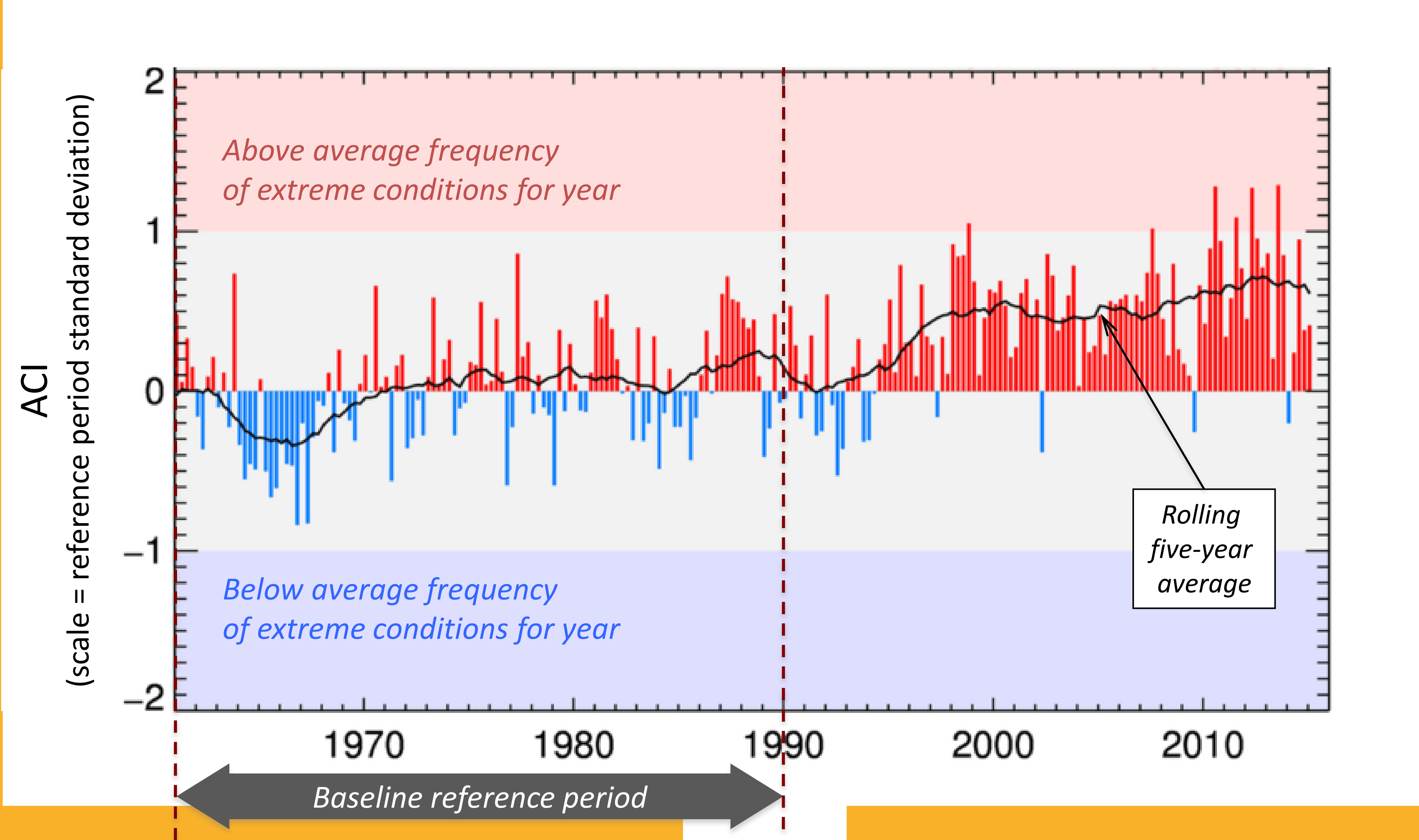
http://actuariesclimateindex.org/maps/




1961 Winter
Normal
1961 Winter
ALA
CAR
NWP
NPL
NEA
NEF
CWP
CEA
MID
SWP
SPL
SEA
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

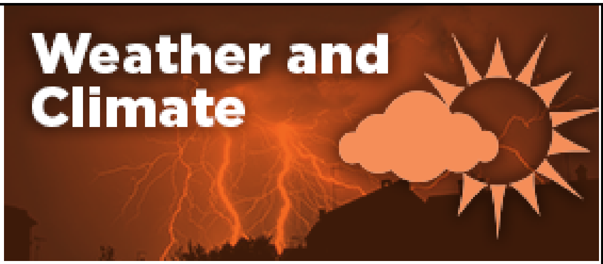
The Actuaries Climate Index (ACI) shows that the frequency of extreme weather has increased

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



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

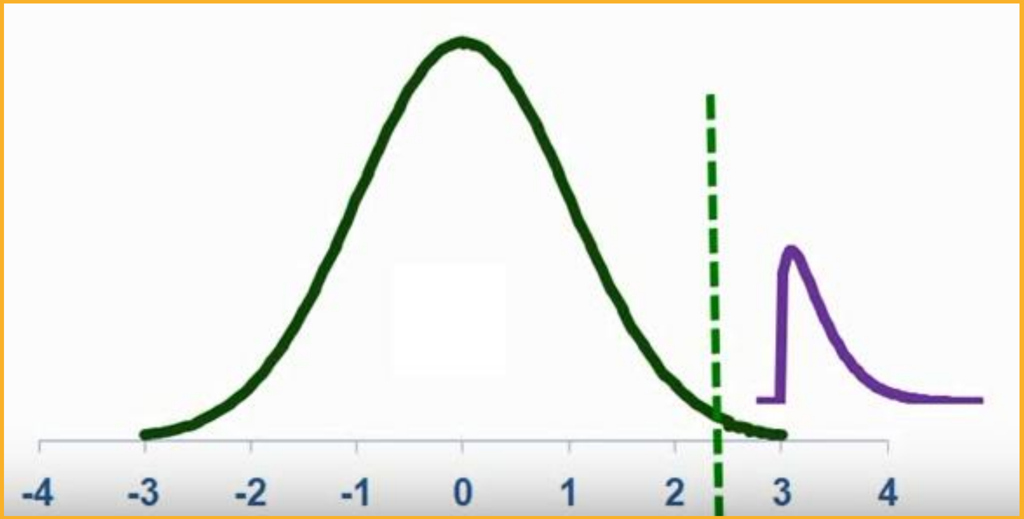
Selected A.C.I. Climate Change Indicators

		
• 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
	• WIND	

THE ACI FOCUSES ON "FREQUENCY OF SEVERITY"

WHAT IS THAT?

- Extreme Temp:
  - VERY HOT or
  - VERY COLD
- Extreme Precip:
  - VERY WET or
  - VERY DRY
- EXTREME WIND
- RISING SEAS

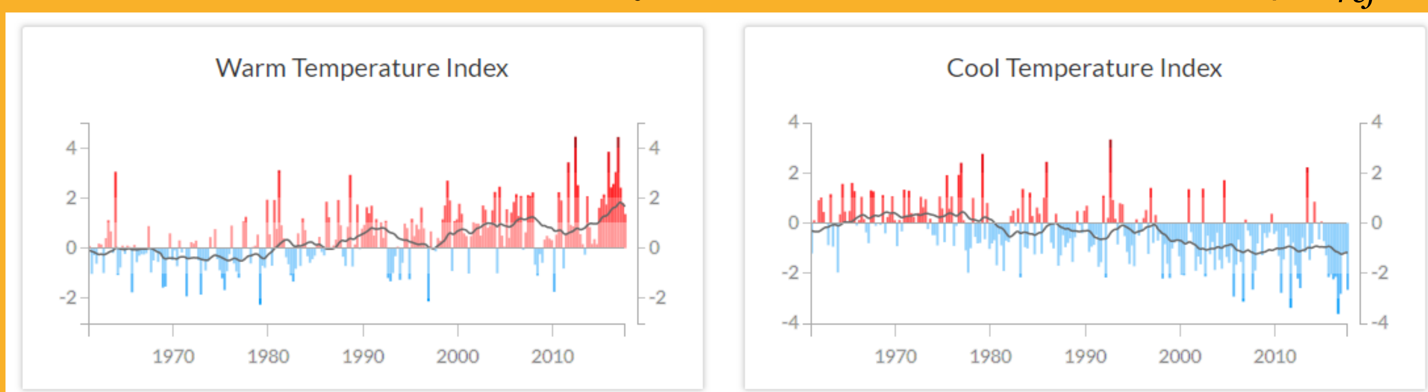


***THE A.C.I MEASURES EXTREMES* WITH**

"CHILD DISTRIBUTIONS"

Extreme Temperature: VERY HOT or VERY COLD

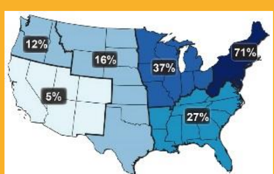
- Global Historical Climatological Network (GHCN) – global, land station-based, gridded dataset, daily from 1950-present (GHCN-Daily)
- GHCNDEX indices* based on the above:
  - TX90 = 90%ile warm days
  - TN90 = 90%ile warm nights
  - TX10 = 10%ile cold days
  - TN10 = 10%ile cold nights
- The average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

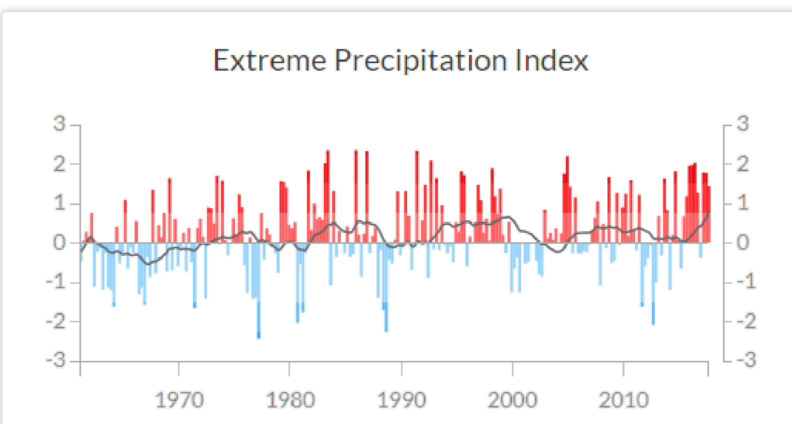


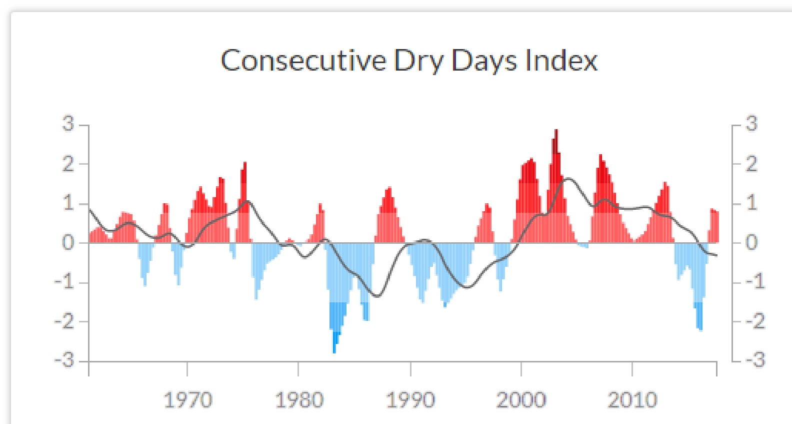
* Produced as part of the CLIMDEX project by the Climate Change Research Centre, at The University of New South Wales, Australia.

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
  - $D' = \Delta CDD \ / \ \sigma_{ref}(CDD)$

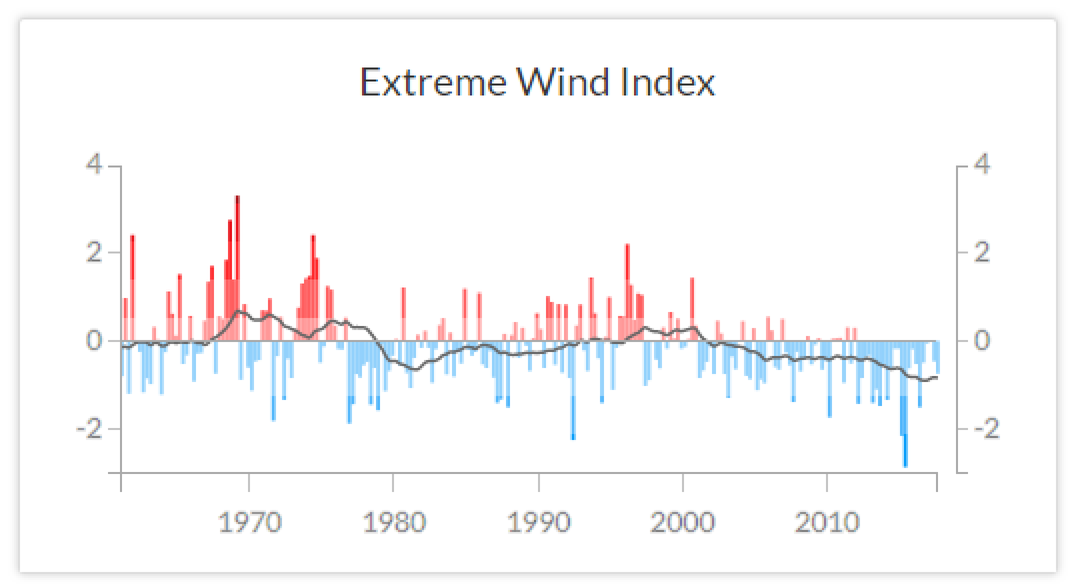






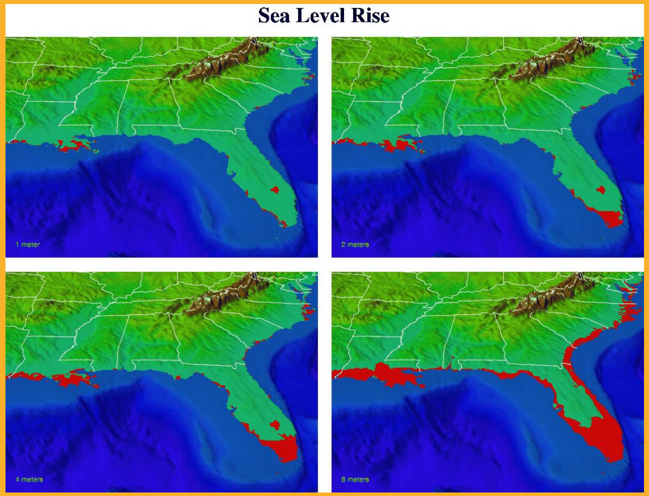
Wind Power Index: EXTREME WINDS

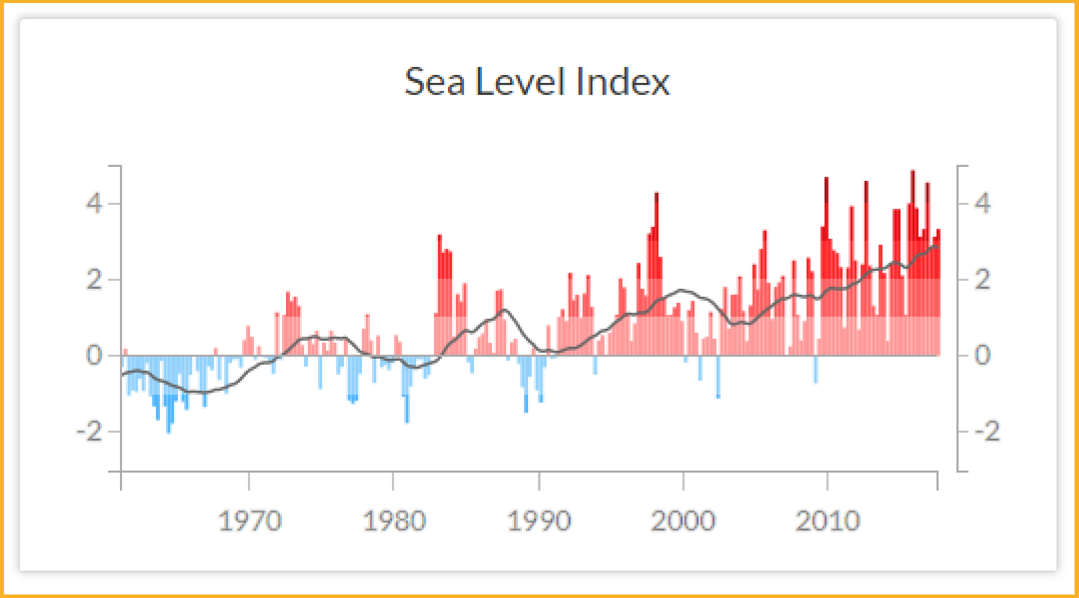
- Index derived from NOAA Earth System Research Laboratory data:
  - Daily mean wind speeds
  - WP = (1/2)*ρ*w³
    Where ρ is air density, w is daily mean wind speed
- $W' = \Delta WP90 / \sigma_{ref}(WP90)$
  - Where WP90 is the monthly frequency of the 90th percentile or higher of daily wind power



Sea Level Index

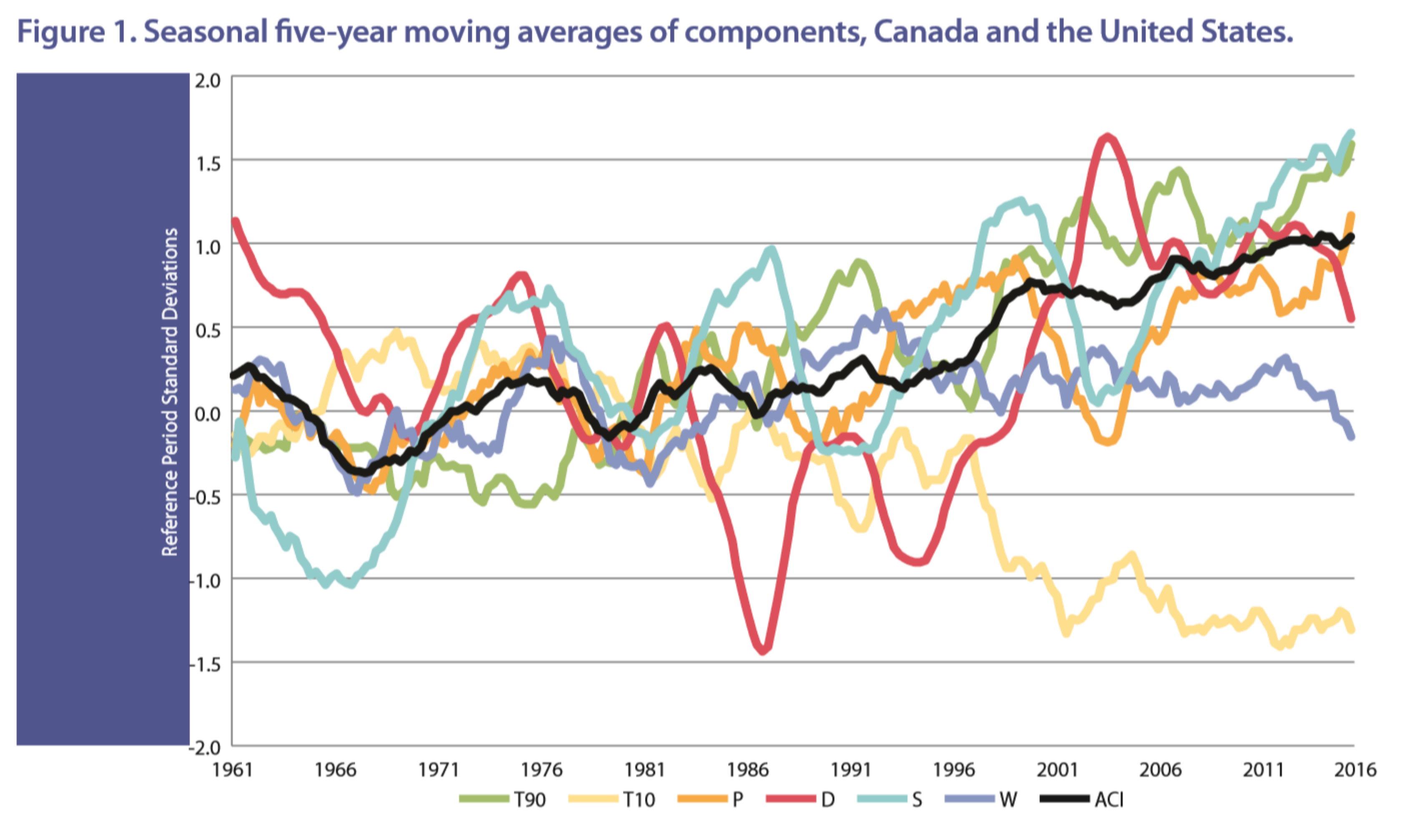
- At tide gauge stations along US and Canada coast
  - Data provided by Permanent Service for Mean Sea Level (PSMSL), part of the UK's National Oceanography Center
  - Data matched to grids used for other variables
    - Index reflects portion of each region represented by coastal grids
  - Land movements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





Overall ACI and components

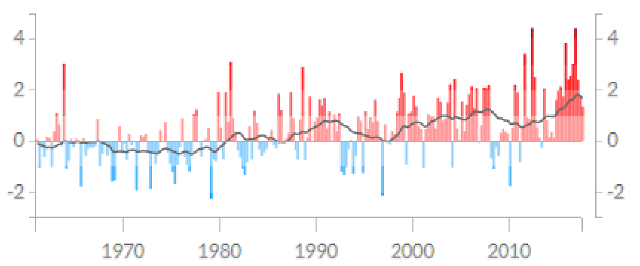
Source: Executive Summary



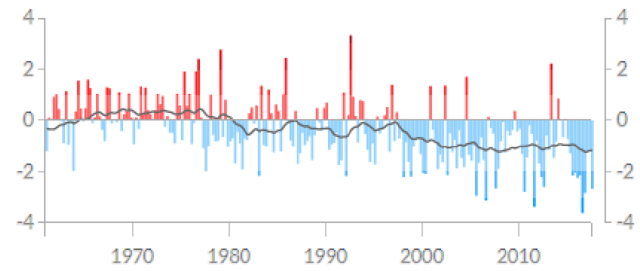
Continental USA - ACI Components – **Seasonal**

Temperature, Precipitation, Drought,Wind and Sea Level Components

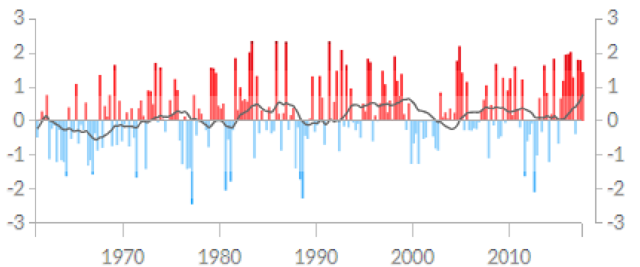
Warm Temperature Index



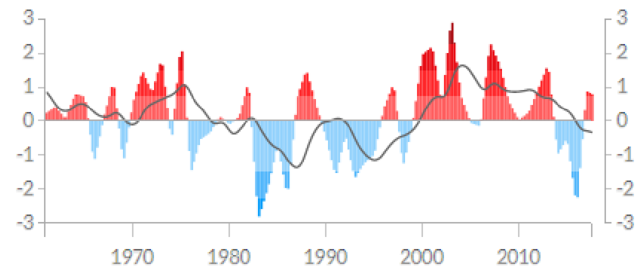
Cool Temperature Index



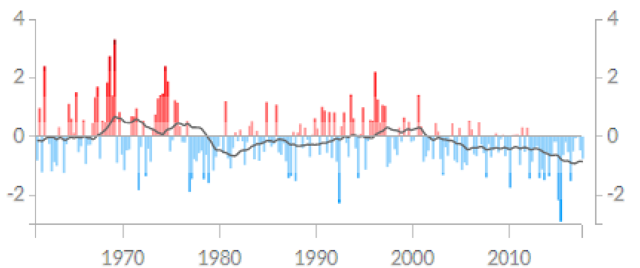
Extreme Precipitation Index



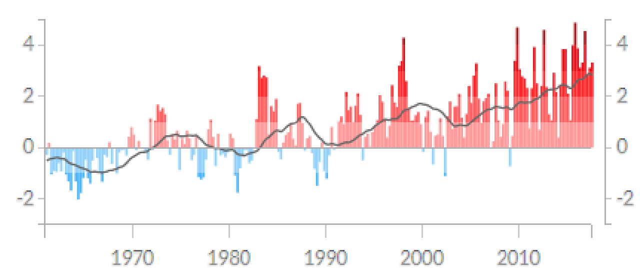
Consecutive Dry Days Index



Extreme Wind Index

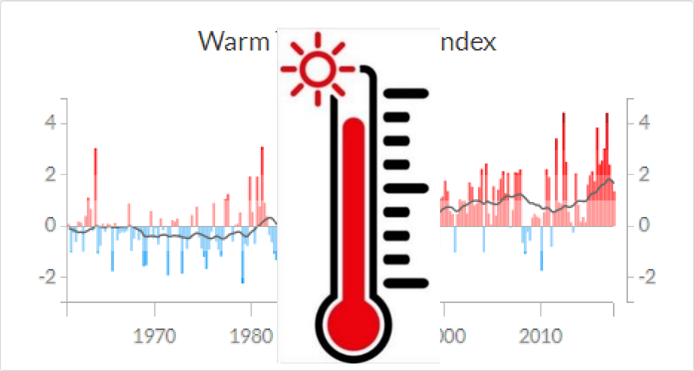


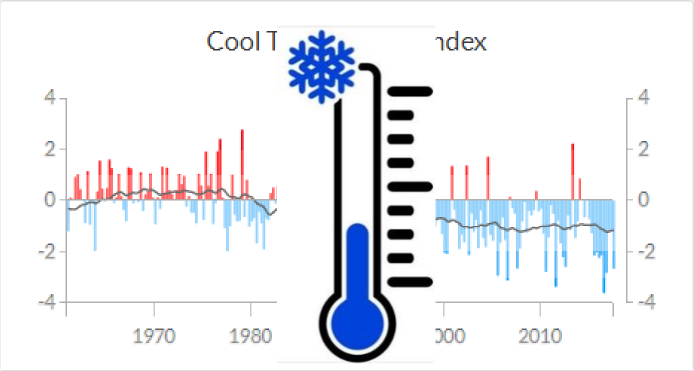
Sea Level Index

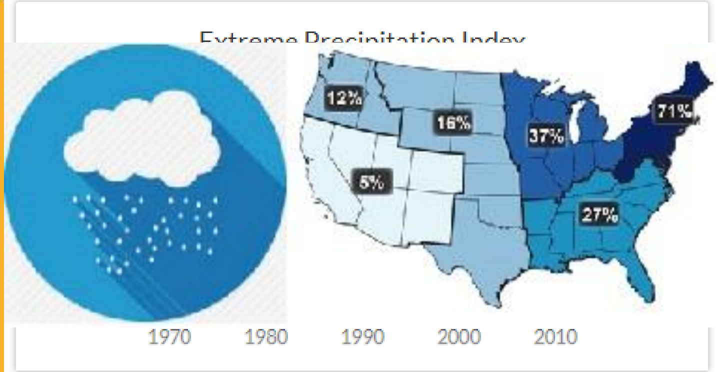


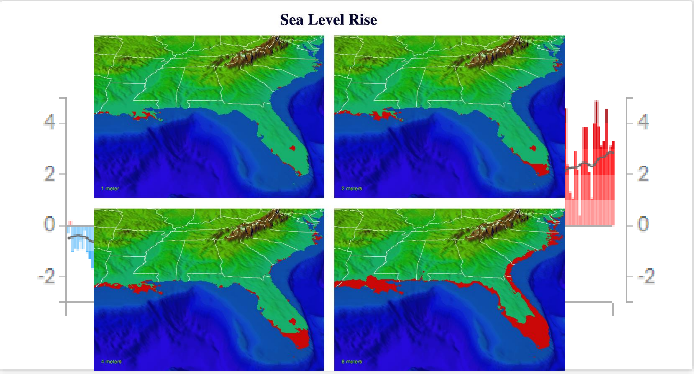
Continental USA - ACI Components – Seasonal

Temperature, Precipitation, Drought,Wind and Sea Level Components





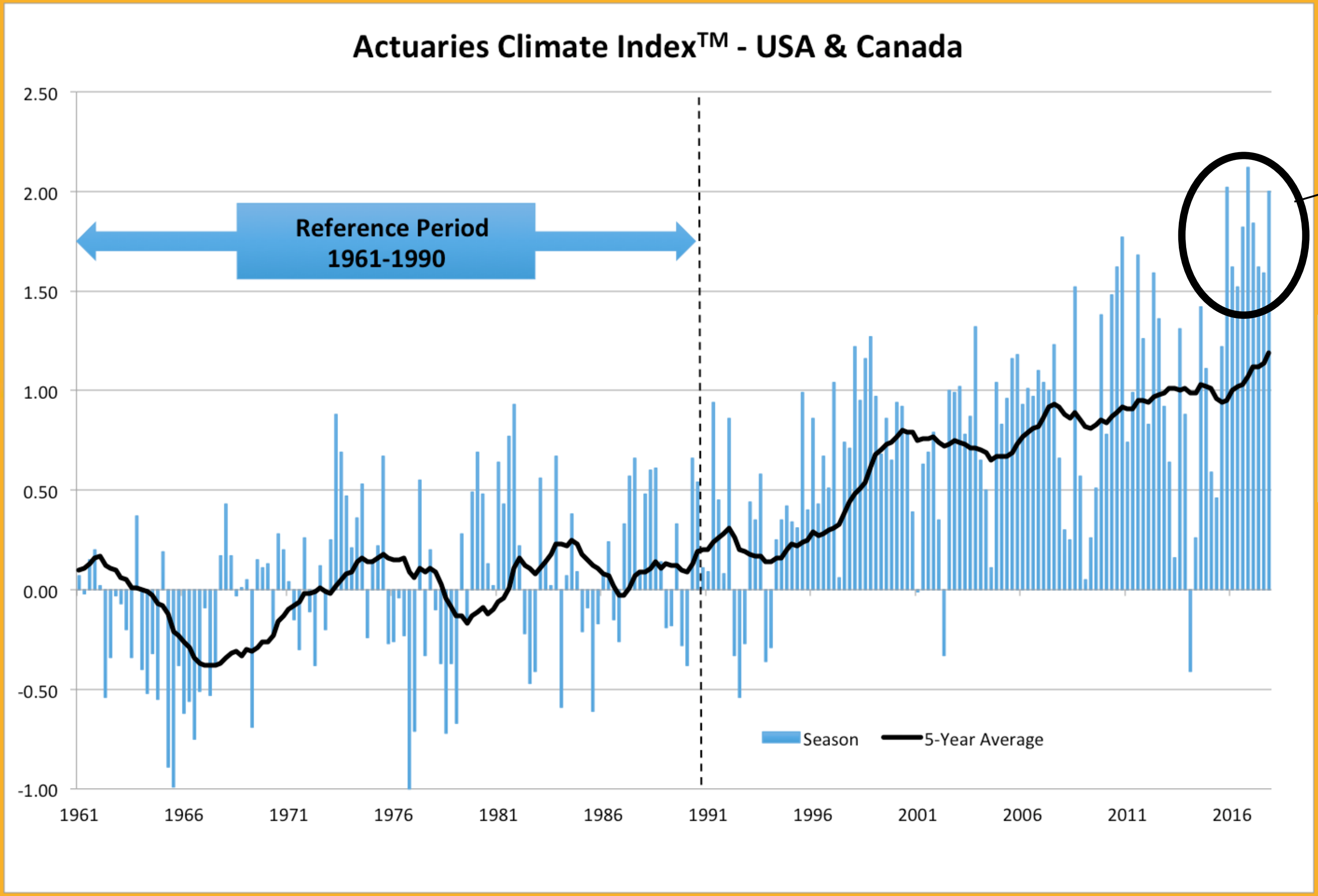




ACI – additional details

- 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 would be volatile
- To enable combining the six indices together, the index values are converted to standardized anomalies:

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



The overall ACI has been above 1.5 for eight quarters in a row.

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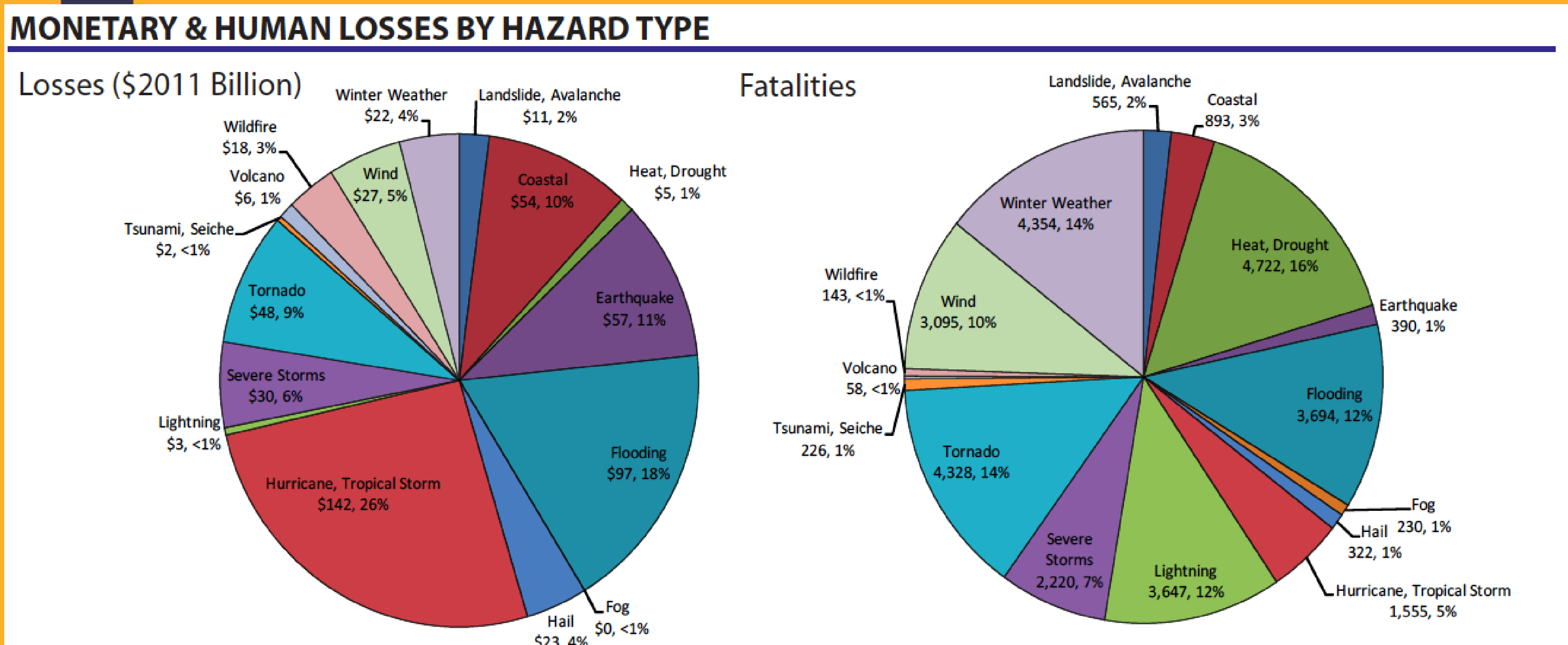
CURRENT WORK of the Climate Change Committee

ACTUARIES CLIMATE RISK INDEX

SHELDUS Data Summary 1960-2011



Source: I HELDUS/docs/Su

ACRI – Very Preliminary Regression results by region and peril

Region	Heat	Flood	Drought	Wildfire	Wind	Weight
US-CEA	✓	✓	✓	Mean	✓	18.6%
US-SEA	✓	✓	Mean	Mean	✓	21.3%
US-MID	Mean	✓	✓	Mean	✓	18.7%
US-SPL	✓	✓	✓	✓	✓	11.0%
US-SWP	✓	✓	Mean	✓	✓	16.6%
US-CWP	Mean	✓	Mean	Mean	✓	3.6%
US-ALA	No	CWP	No	Mean	CWP	0.2%
C-NEA	Mean	Mean	Mean	Mean	✓	0.7%
C-NEF	Mean	✓	Mean	Mean	NEA	6.2%
C-NPL	Mean	✓	Mean	SPL	NEA	1.8%
C-NWP	Mean	Mean	Mean	Mean	NEA	1.3%
C-CAR	No	No	No	No	No	n/a

✓= statistically significant; Mean = Mean of other region's parameters used; No = No index; Otherwise, region name of proxy region

ACRI Roll Out

Next Steps – 2018?

Finish formulation of ACRI 1.0

Peer Review & ACRI Finalization:

- ACRI Climate Relationships to Losses, Injuries and Fatalities, as many as time permits
- Guidance for how to use the relationships

Future Steps – 2019?

Releases alongside ACI, perhaps annually

Development of ACRI 2.0

Periodic articles in actuarial magazines

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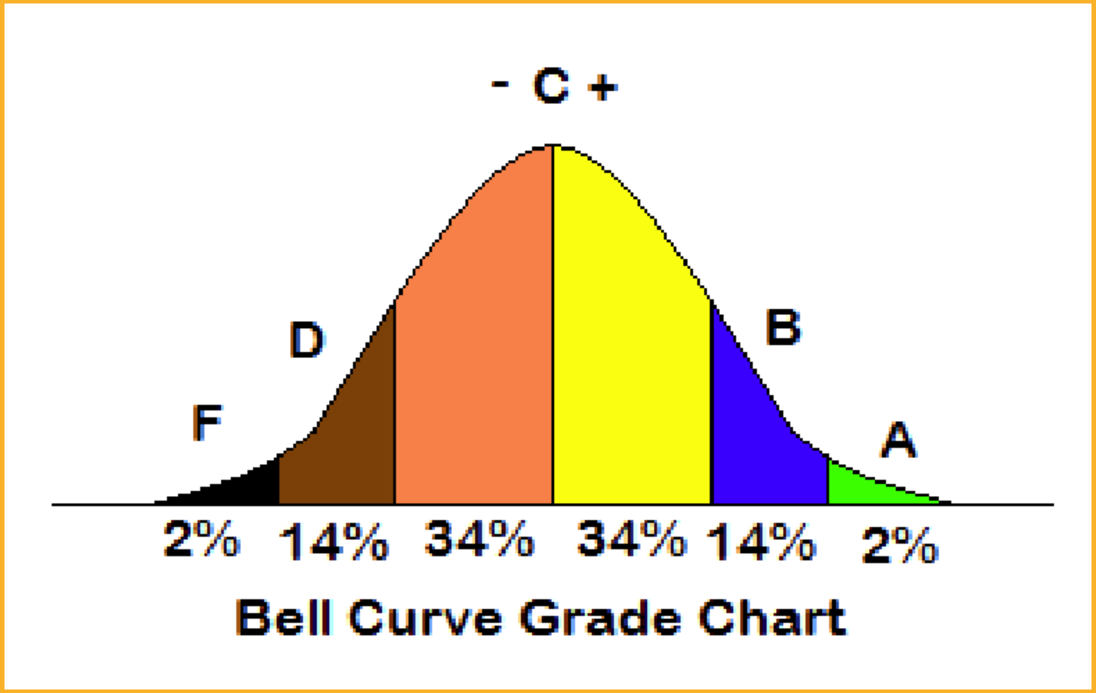
HOW COULD WE USE THE ACI AND THE ACRI

Potential Uses, Further R & D

- Potential uses
  - Inform actuaries and the insurance industry
  - Compare weather and climate
  - Climate Reference models for General Insurance companies
  - Need to integrate climate trends into rating
  - Need for the increased risk to be reflected in risk management
  - Potential need to reassess eligibility and availability
- Adding regions
  - Had preliminary talks recently with IFoA in UK
  - Also in discussion with Australian actuaries
  - Will other actuarial organizations join us?
- Call paper program after launch
- Funded research

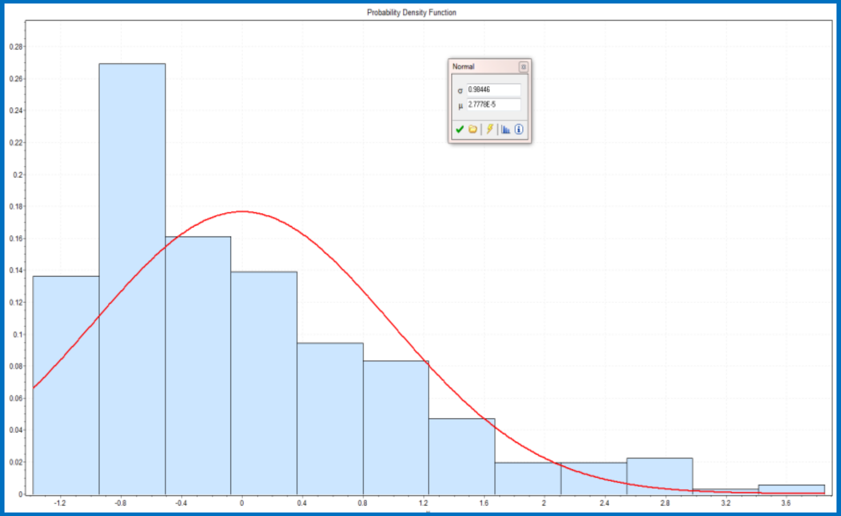
SOME EARLY CLIMATE RISK BSERVATIONS

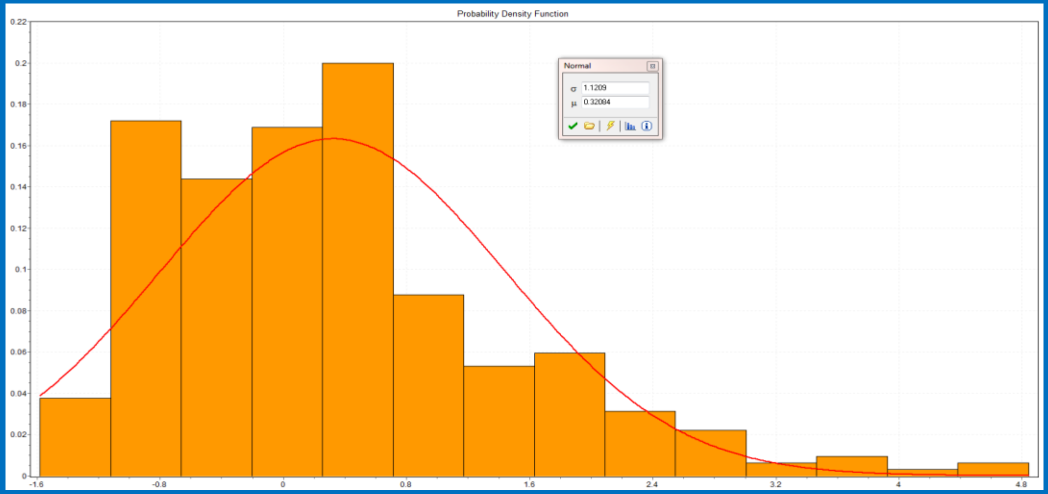
Grading on the Standard Normal Curve



Distribution of T90 Standard Anomalies
Southeast Atlantic (SEA) Region

BASE YEARS **WARMING YEARS**

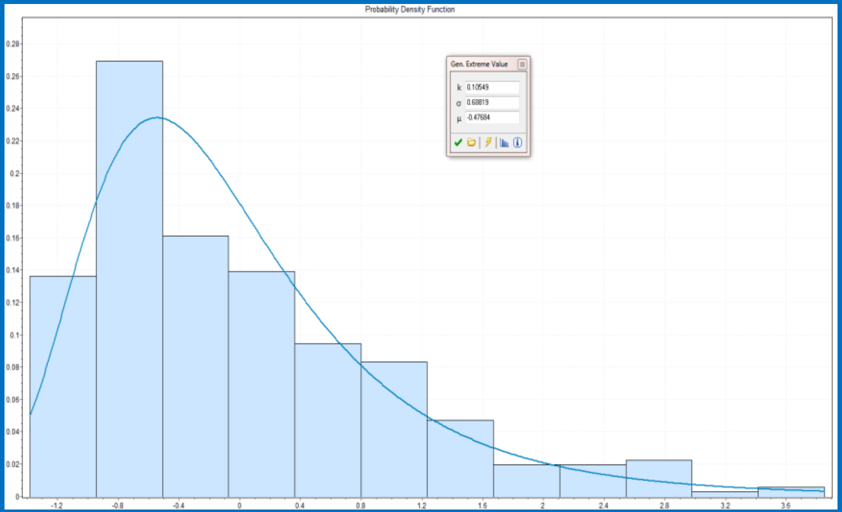


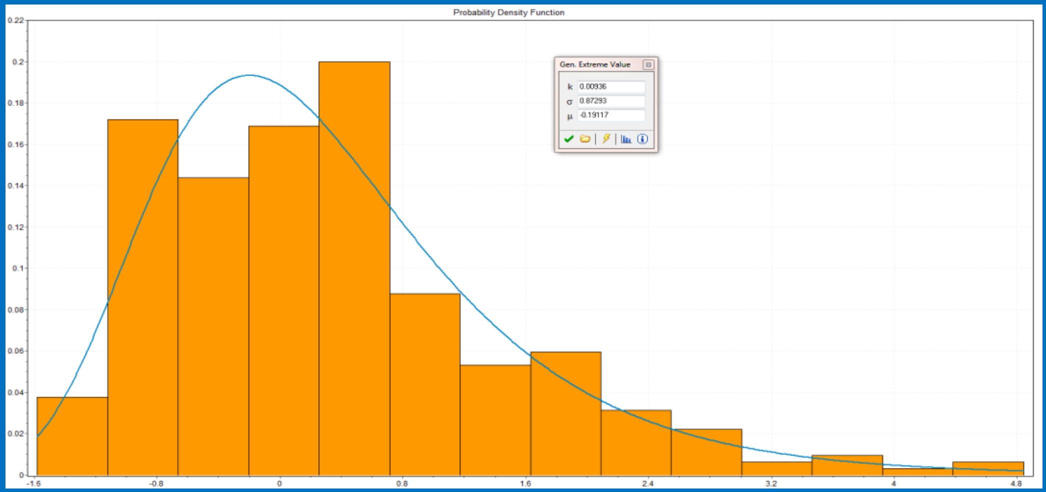


The red fitted curves, standard Normal distributions, are poor curve-fits to the T90 Anomaly distribution

Distribution of T90 Standard Anomalies
Southeast Atlantic (SEA) Region

BASE YEARS **WARMING YEARS**





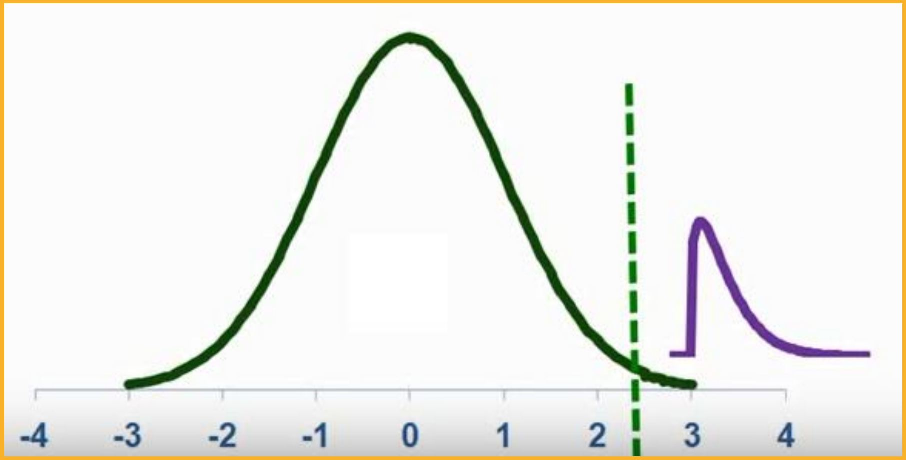
The blue fitted curves, Generalized Extreme Value curves,

give better curve-fits to the T90 Anomaly distributions

Measuring Extremes

EXTREME VALUE THEORY (E.V.T.)

= The theory of the analysis of rare and extreme events.



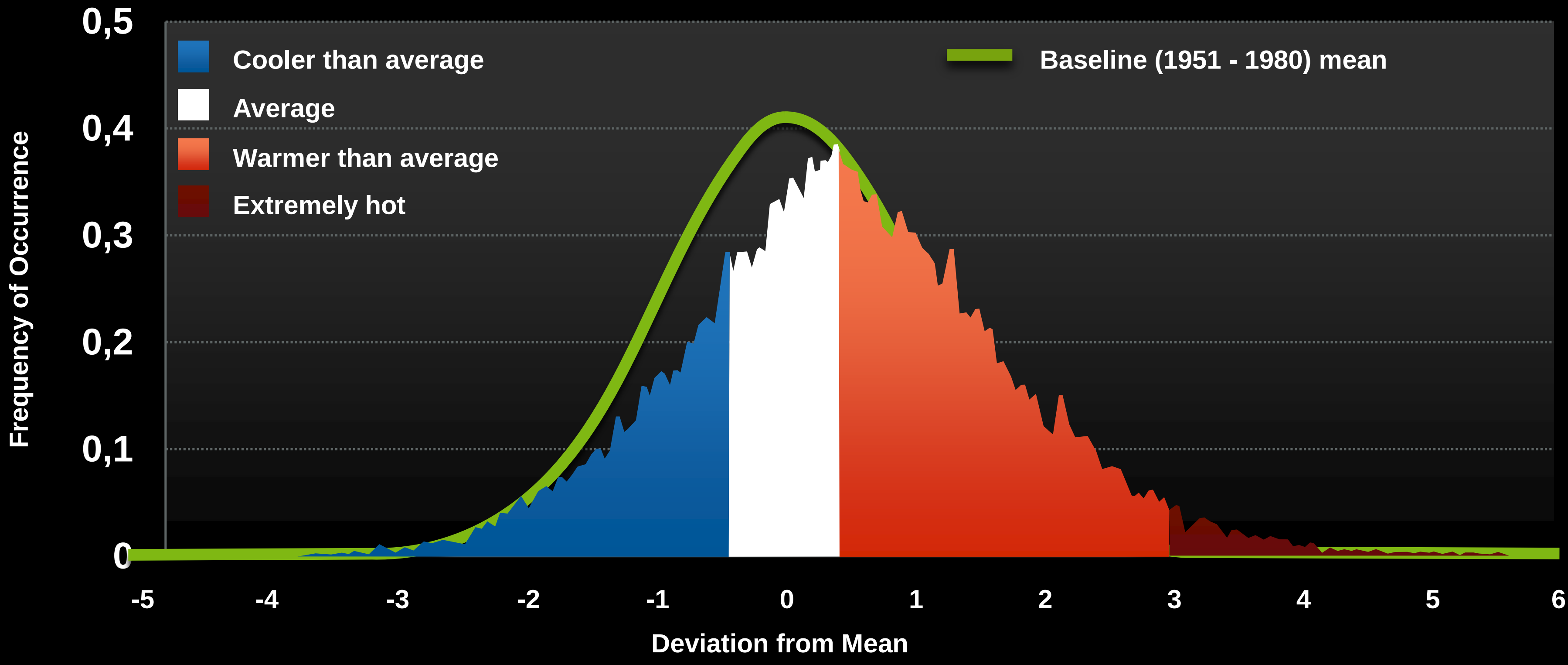
- Extreme value analysis (EVA) refers to the use of extreme value theory (EVT) for analyzing data where interest is in rare, or low probability, events (e.g., annual maximum precipitation, temperature excesses over a very high threshold, wind speeds exceeding a high threshold, etc.).
- Not all high-impact events fall under the category of EVA, but typically the events under consideration also have a high impact on human life, economic stability, infrastructures, the environment, etc.

Summer Temperatures Have Shifted

1951 – 1980

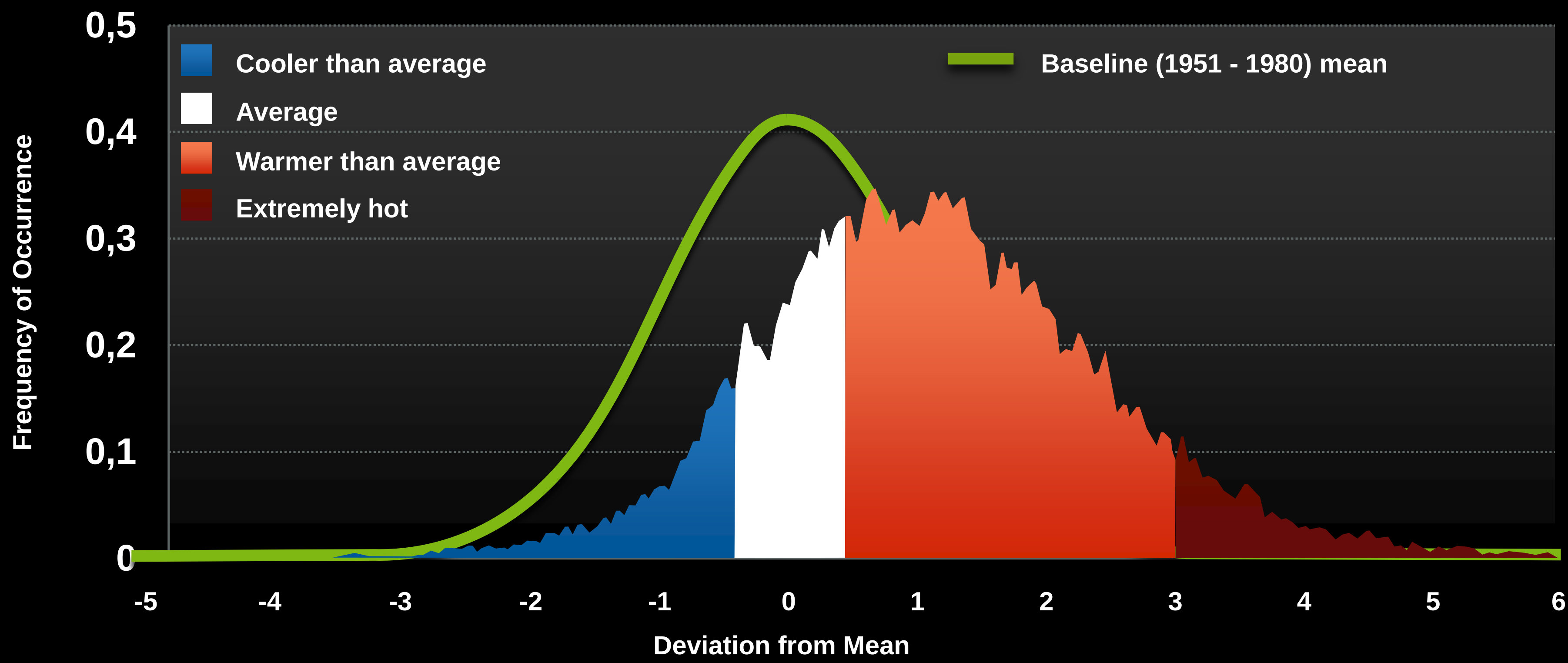
Source: NASA/GISS; Hansen, et al., "Perceptions of Climate Change," Proc. Natl. Acad. Sci. USA 10.1073, August 2012 – Updated 2016

1983 – 1993

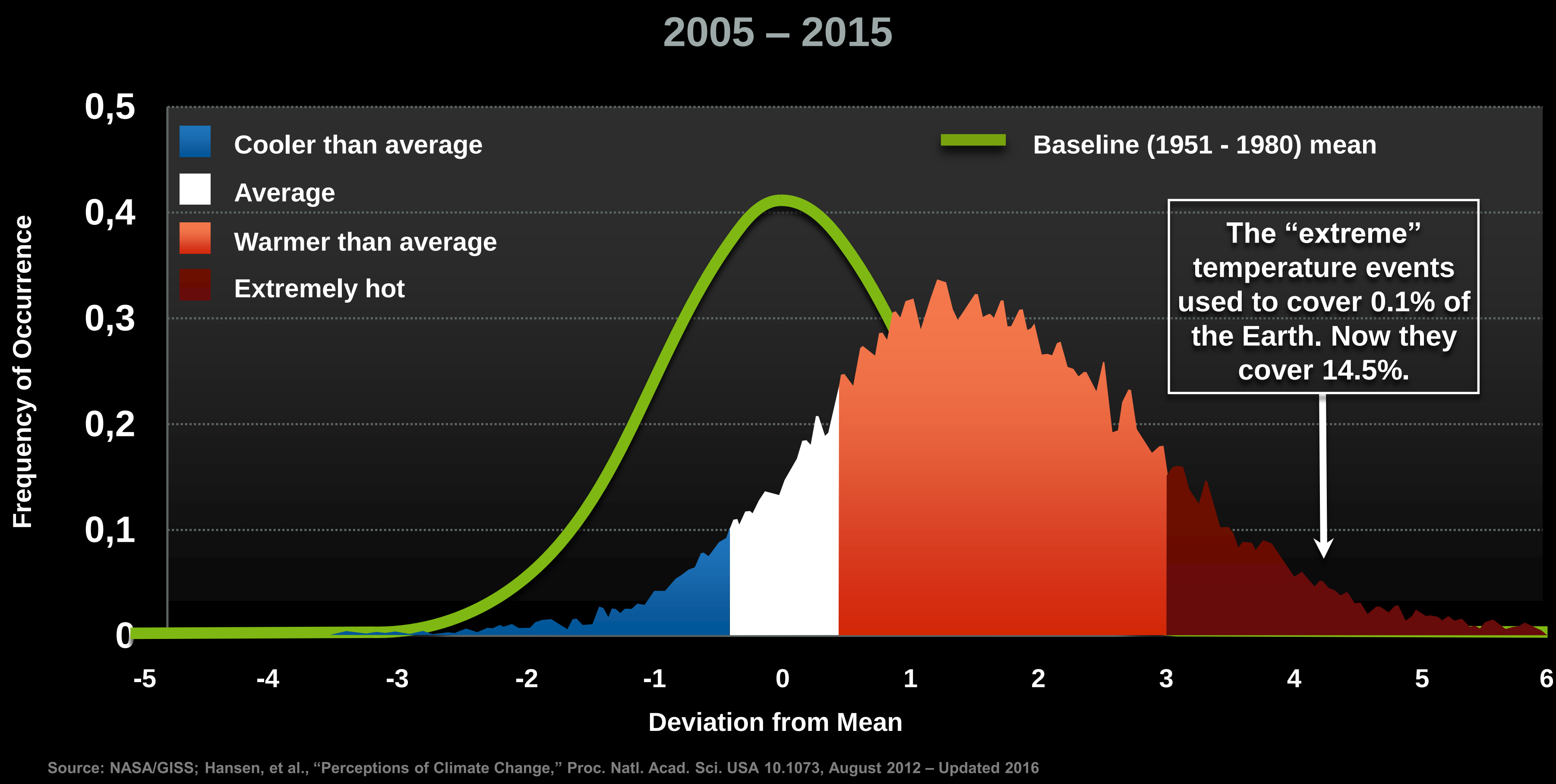


Source: NASA/GISS; Hansen, et al., “Perceptions of Climate Change,” Proc. Natl. Acad. Sci. USA 10.1073, August 2012 – Updated 2016

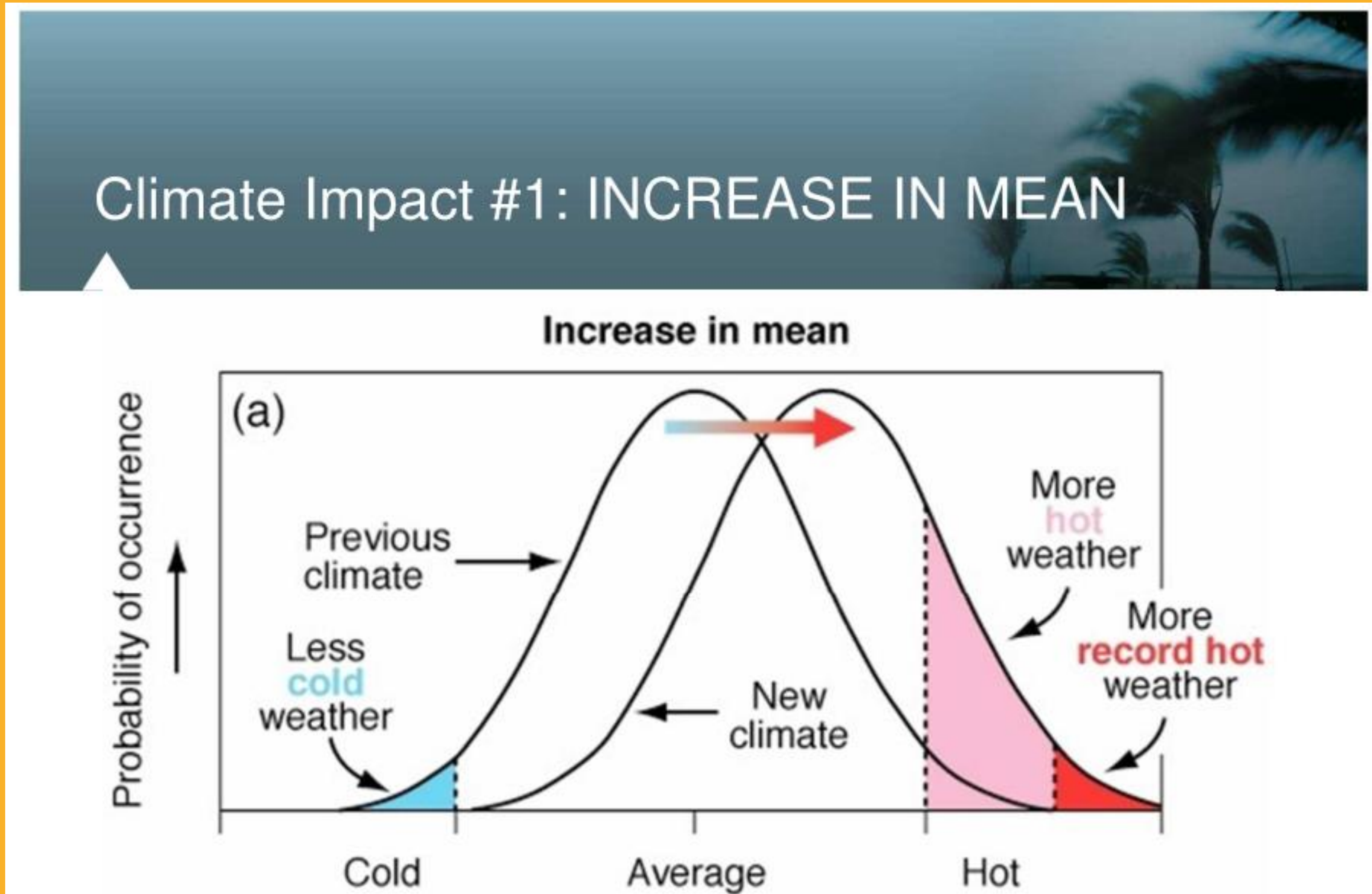
1994 – 2004



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

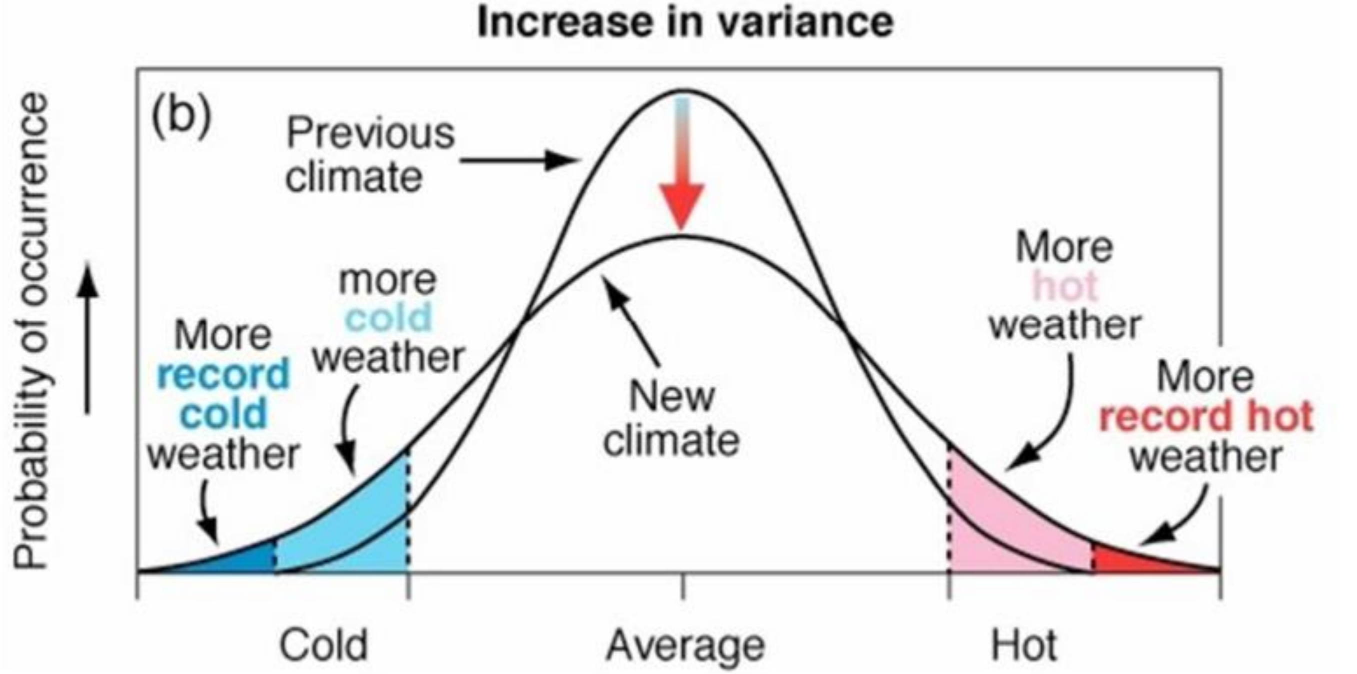


2005 – 2015
Cooler than average
Average
Warmer than average
Extremely hot
Baseline (1951 - 1980) mean
The “extreme” temperature events used to cover 0.1% of the Earth. Now they cover 14.5%.
0,5
0,4
0,3
0,2
0,1
0
Frequency of Occurrence
-5
-4
-3
-2
-1
0
1
2
3
4
5
6
Deviation from Mean
Source: NASA/GISS; Hansen, et al., “Perceptions of Climate Change,” Proc. Natl. Acad. Sci. USA 10.1073, August 2012 – Updated 2016



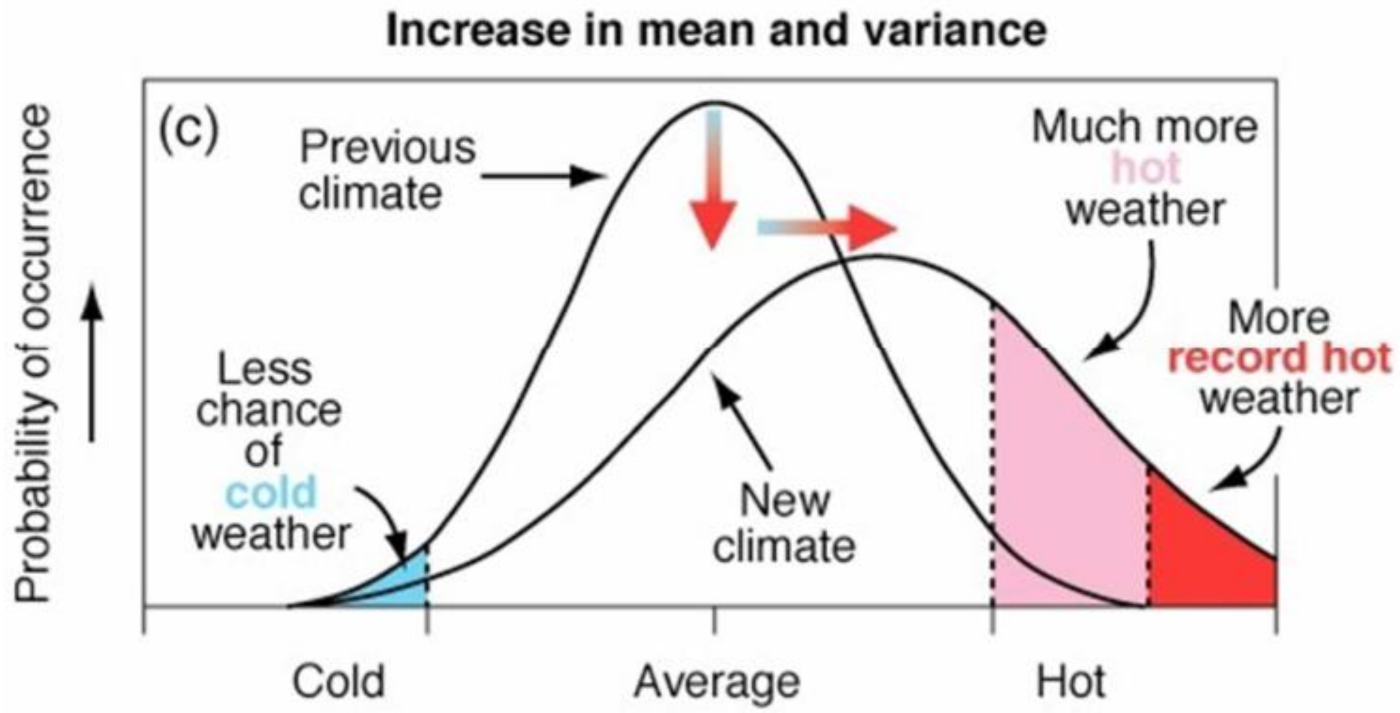
Source: Solterra Solutions: *Determining the Impact of Climate Change on Insurance Risk and the Global Community Phase 1: Key Climate Indicators*

Climate Impact #2: INCREASE IN VARIANCE



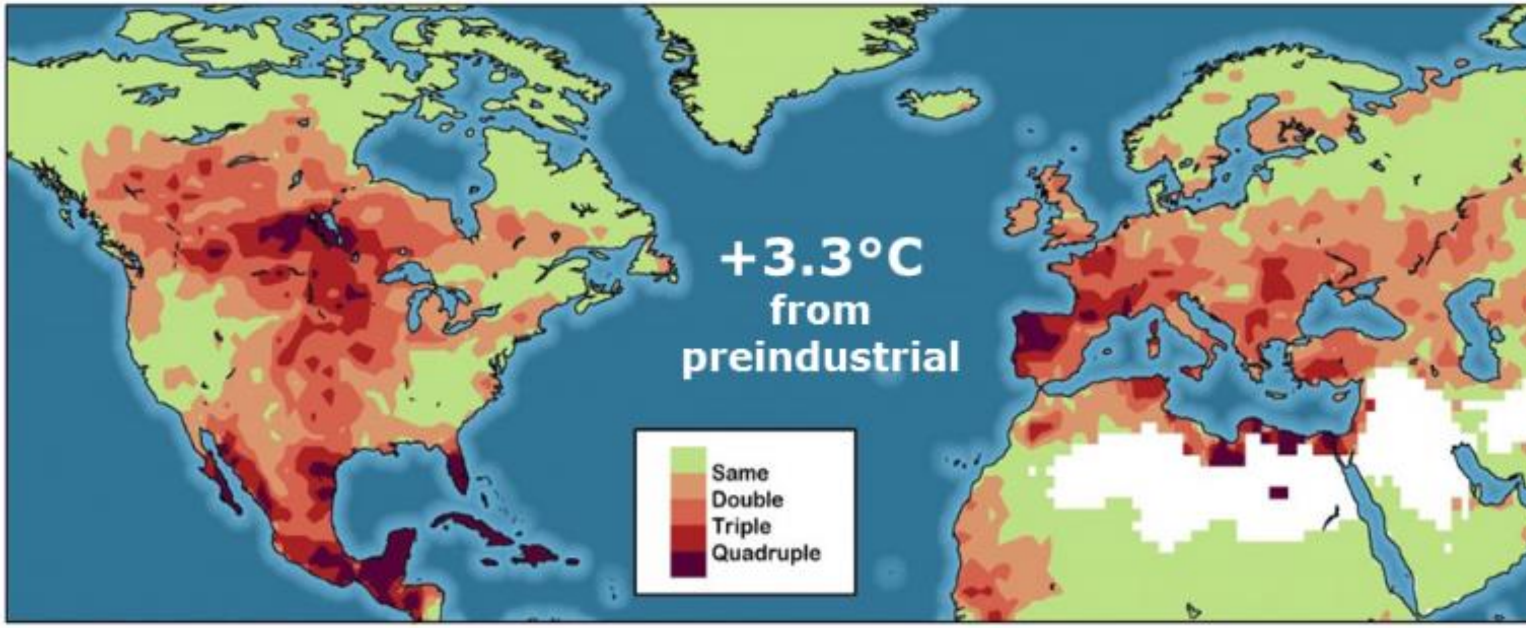
Source: Solterra Solutions: *Determining the Impact of Climate Change on Insurance Risk and the Global Community Phase 1: Key Climate Indicators*

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*

Increase in summer drought



Change in the likelihood of summer season drought (defined as a once in ten years event for the late 20th century) by the end of the 21st century, according to multi-decade simulations with the operational model of the European Centre for Medium-range Weather Forecasts (ECMWF) based on the A1b scenario of the IPCC.

Floods and Droughts in a Changing Climate – Now and the Future
April 29th, 2011 Paul A. Dirmeyer
Center for Ocean-Land-Atmosphere Studies
Calverton, Maryland

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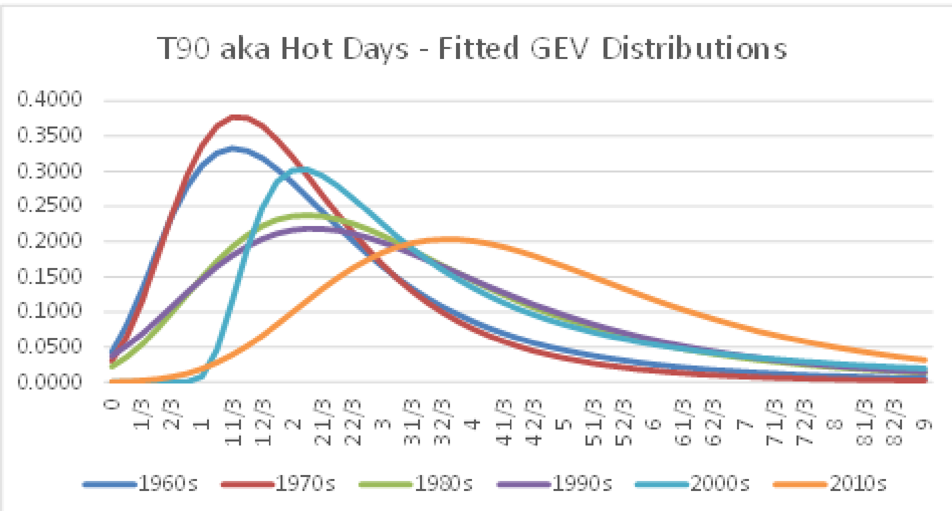
T90 AKA "HOT DAYS" DIST'NS AND TRENDS

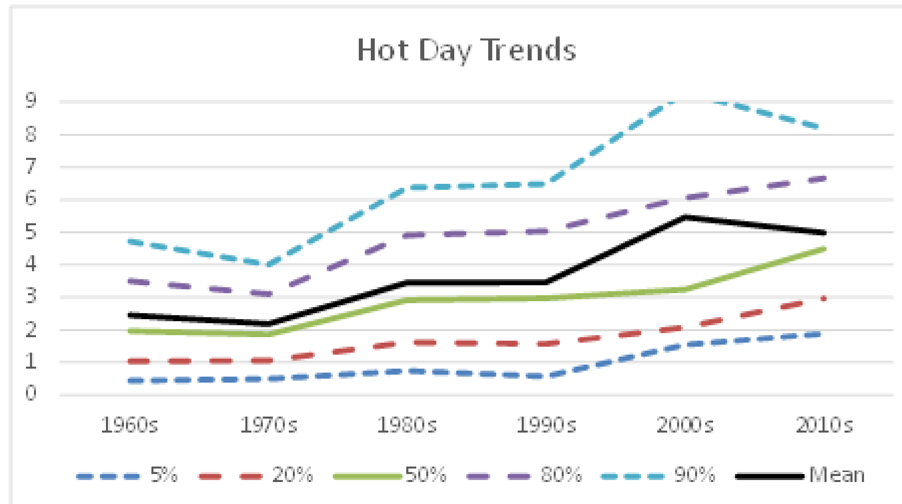
Southeast Atlantic Region - MAY THRU SEPT

Decade	1960s	1970s	1980s	1990s	2000s	2010s
k	0.19159	0.11146	0.12254	0.07525	0.5927	0.06069
s	1.1256	0.97925	1.5609	1.6893	1.4058	1.8142
m	1.5488	1.5043	2.3387	2.3515	2.6682	3.8169
Mean	2.46	2.19	3.45	3.46	5.46	4.98
Std Dev'n	6.05	4.72	7.67	7.65	#VALUE!	7.44
C.V.	246.2%	215.3%	222.1%	220.9%	#VALUE!	149.4%

Average Hot Days (Days)

	1966	1975	1985	1995	2005	2014
Avg Hot Days	2.5	2.2	3.5	3.5	5.5	5.0





RELATIVE SEA LEVEL TRENDS

ea level trends , with arrows representing the direction and magnitude of change. Click on an arrow to access additional

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SOME PARADIGM SHIFTS FROM THE EARLY EXPLORATIONS To Consider:

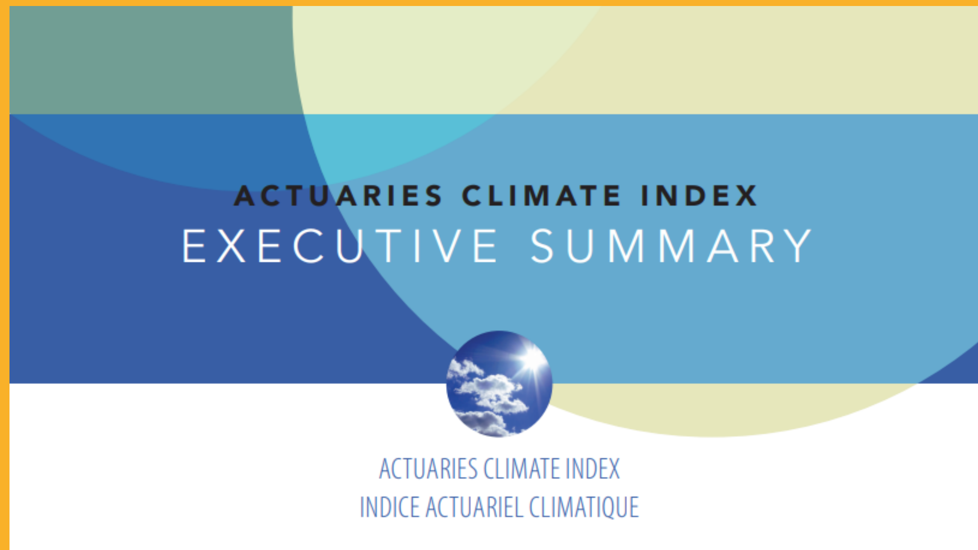
Situation	Helpful Paradigm Shift
Short-term looks (1, 2, or 3 years) won't reveal how extremes are changing.	Use longer forecast time periods: Decade and longer periods reveal shifting extremes
East and West Coast Sea Level Rise is dramatically different. Eastern USA shores' SLR rising fastest.	Think "Glocal": Take **Global** looks, and **localize** them.
Global warming is stirring up more extremes.	Use monthly ACI data for select months by region to see extreme temp. changes
Distributions of extremes can change in three ways (1) only the mean changes, (2) only the variance changes, or (3) both the mean and the variance changes.	Extreme Value Theory offers three flexible, max stable extreme value distributions. They are reasonable tools to use to smooth data and make forecasts.
Other changes will arise.	KEEP THE STORIES IN THE NUMBERS. Dialogue with a variety of professions to best understand how climate is changing.

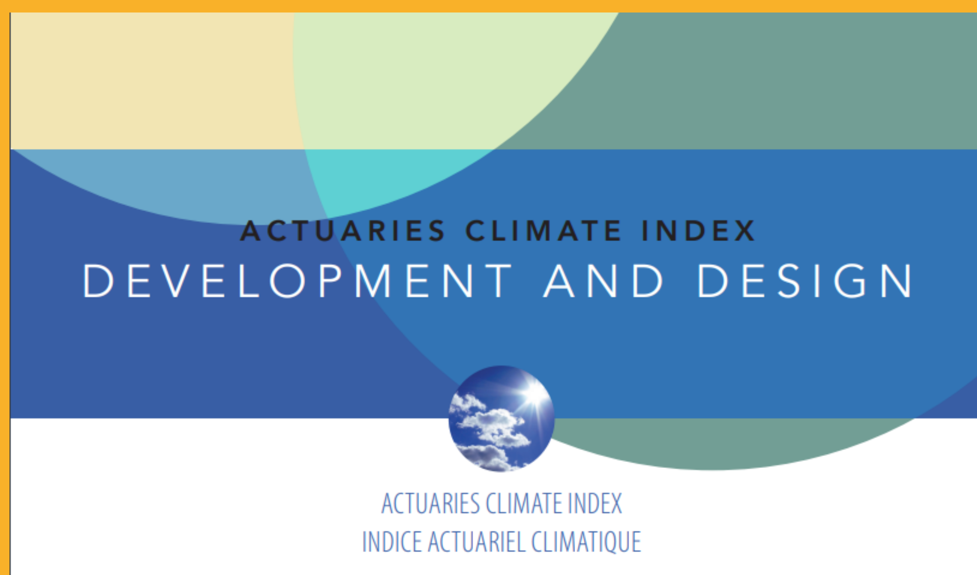
Websites and Logo

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

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

ACI Resources





Index Resources

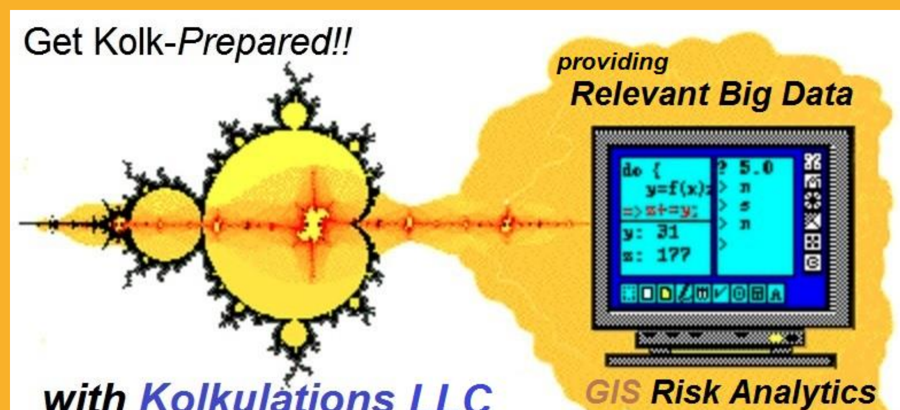
- Donat, M. G., et al. 2013. Global land-based datasets for monitoring climatic extremes. Bulletin of the American Meteorological Society, July, 997-1006, doi:10.1175/BAMS-D-12-00109.1.
- Hansen J., et al. 1998, A Common Sense Climate Index: Is Climate Changing Noticeably? PNAS, 95, 4113-4120.

- Peduzzi, P., et al. 2009, Assessing global exposure and vulnerability towards natural hazards: the Disaster Risk Index. Natural Hazards and Earth System Sciences, 9, 1149-1159.

- Solterra Solutions, Determining the Impact of Climate Change on Insurance Risk and the Global Community, Phase I: Key Climate Indicators, November 2012. Available at: www.casact.org/research/ClimateChangeRpt_Final.pdf

- Data sources:
  - GHCNDEX: www.climdex.org
  - GHCN-Daily: www.ncdc.noaa.gov/oa/climate/ghcn-daily/
  - Sea Level: www.psmsl.org/data/obtaining/
  - Wind: www.esrl.noaa.gov/psd/data/gridded/datancep.reanalysis.html
  - Economic Losses: http://webra.cas.sc.edu/hvriapps/sheldus_setup/sheldus_login.aspx http://www.publicsafety.gc.ca/cnt/rsrcs/cndn-dsstr-dtbs/

QUESTIONS?



Steve Kolk, ACAS, MAAA
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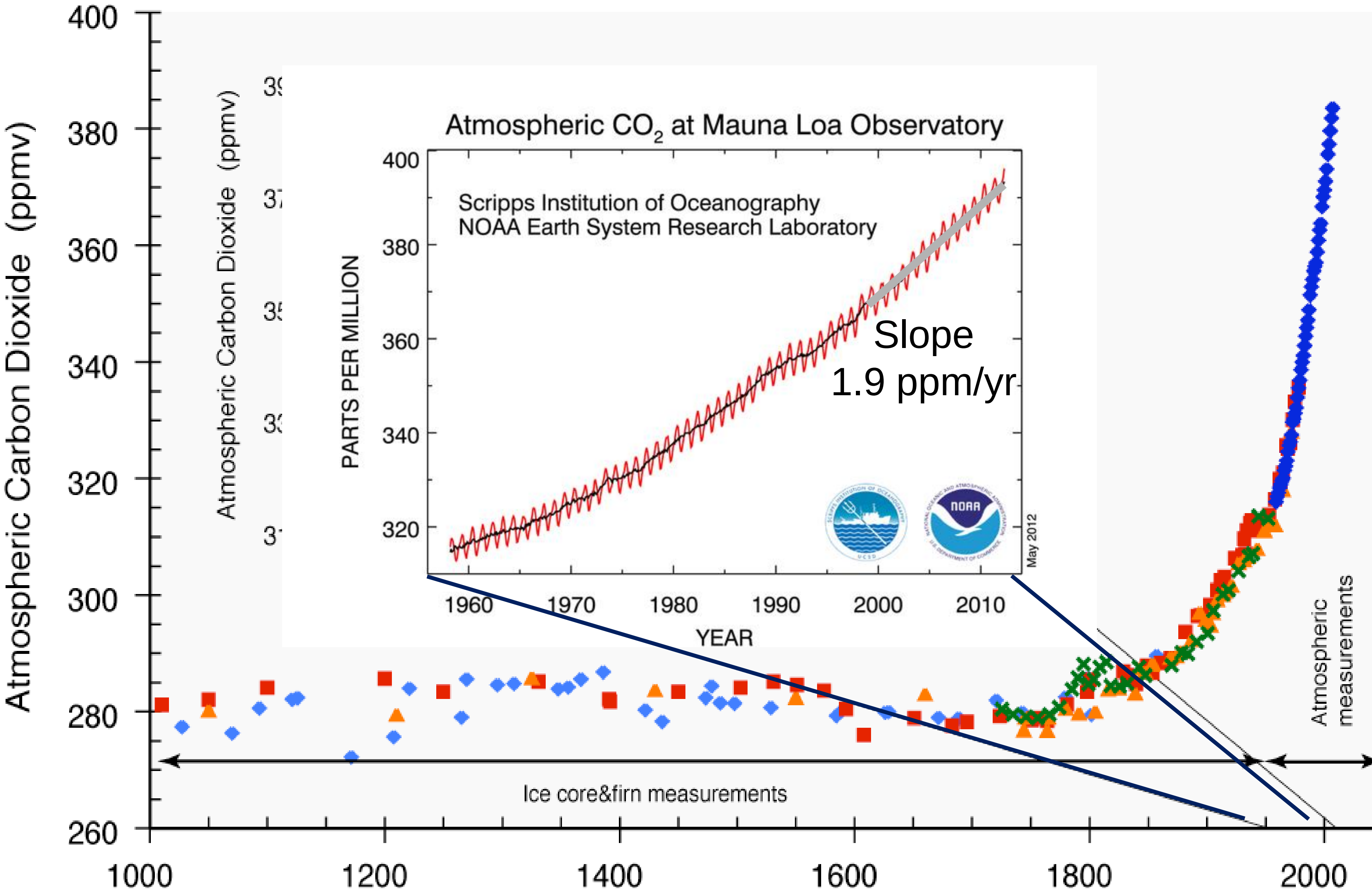
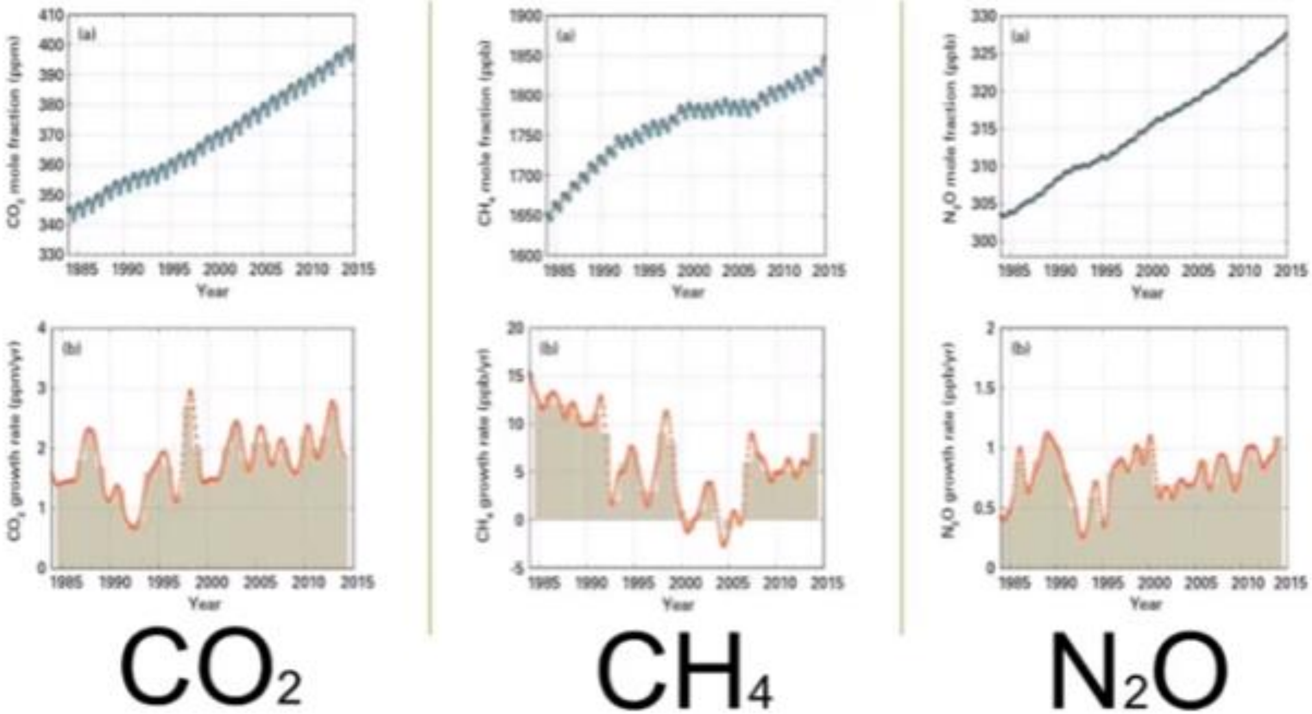
(810) 522-0256

Atmospheric CO_2 was steady for at least 1,000 years before the industrial revolution.

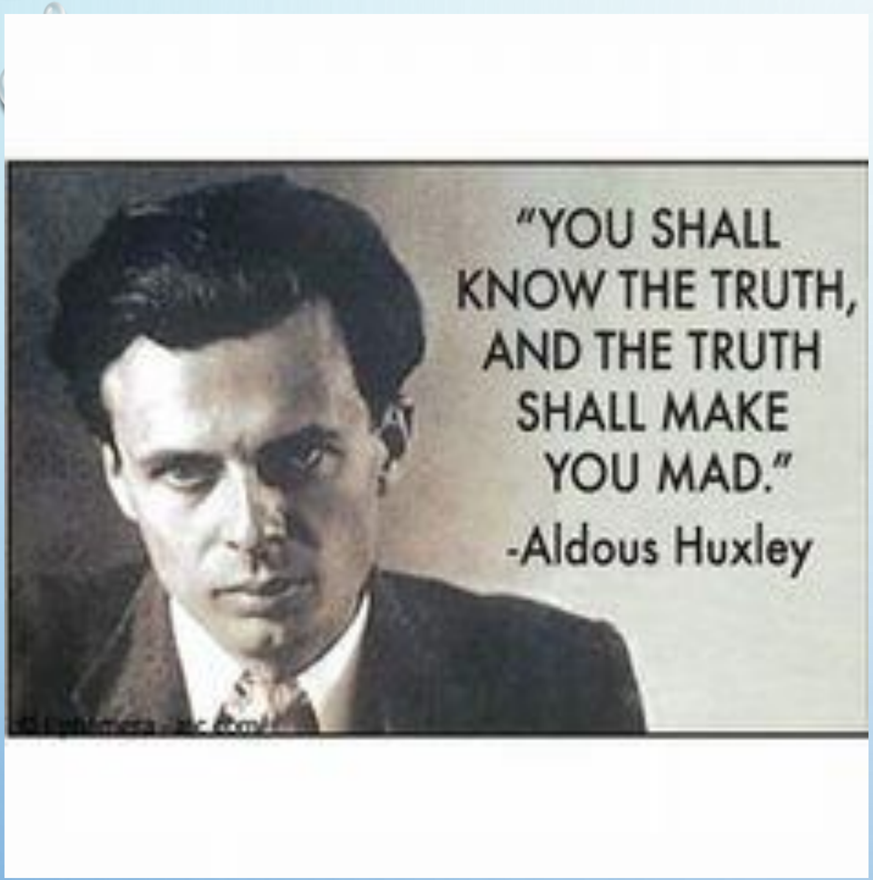


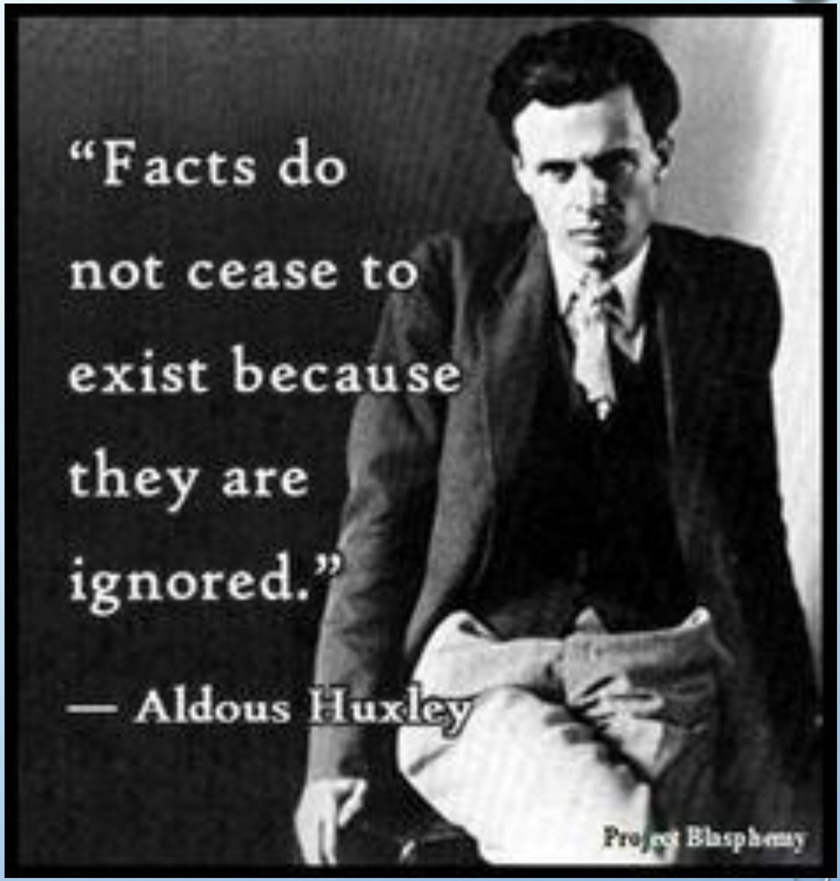
Courtesy Chris Sabine, NOAA PMEL

2014 Concentrations of main greenhouse gases in the atmosphere

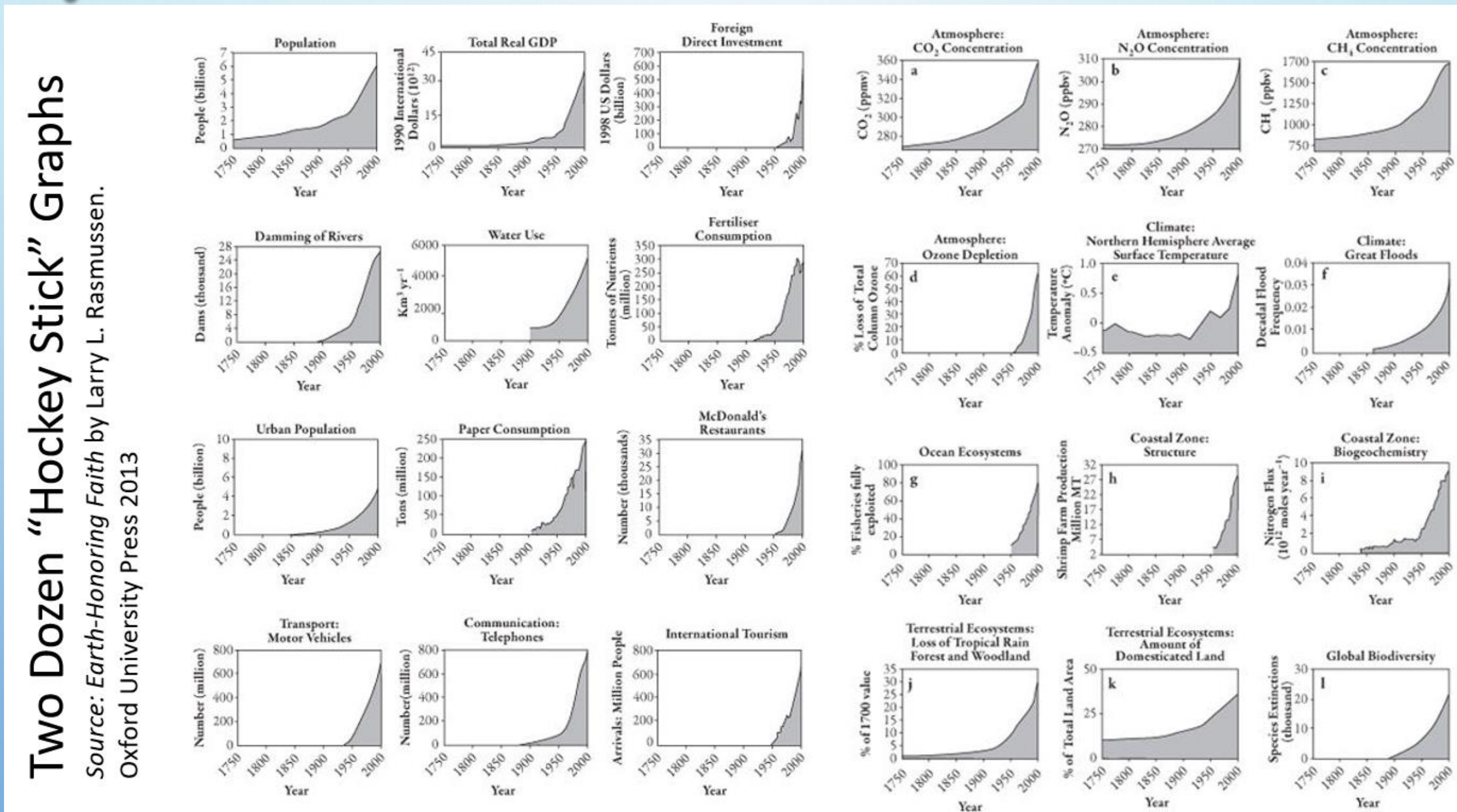


Source: WMO Global Atmosphere Watch


"YOU SHALL KNOW THE TRUTH, AND THE TRUTH SHALL MAKE YOU MAD."
-Aldous Huxley


"Facts do not cease to exist because they are ignored."
— Aldous Huxley
Project Blasphemy

WHY IS THERE SCIENTIFIC CONSENSUS?



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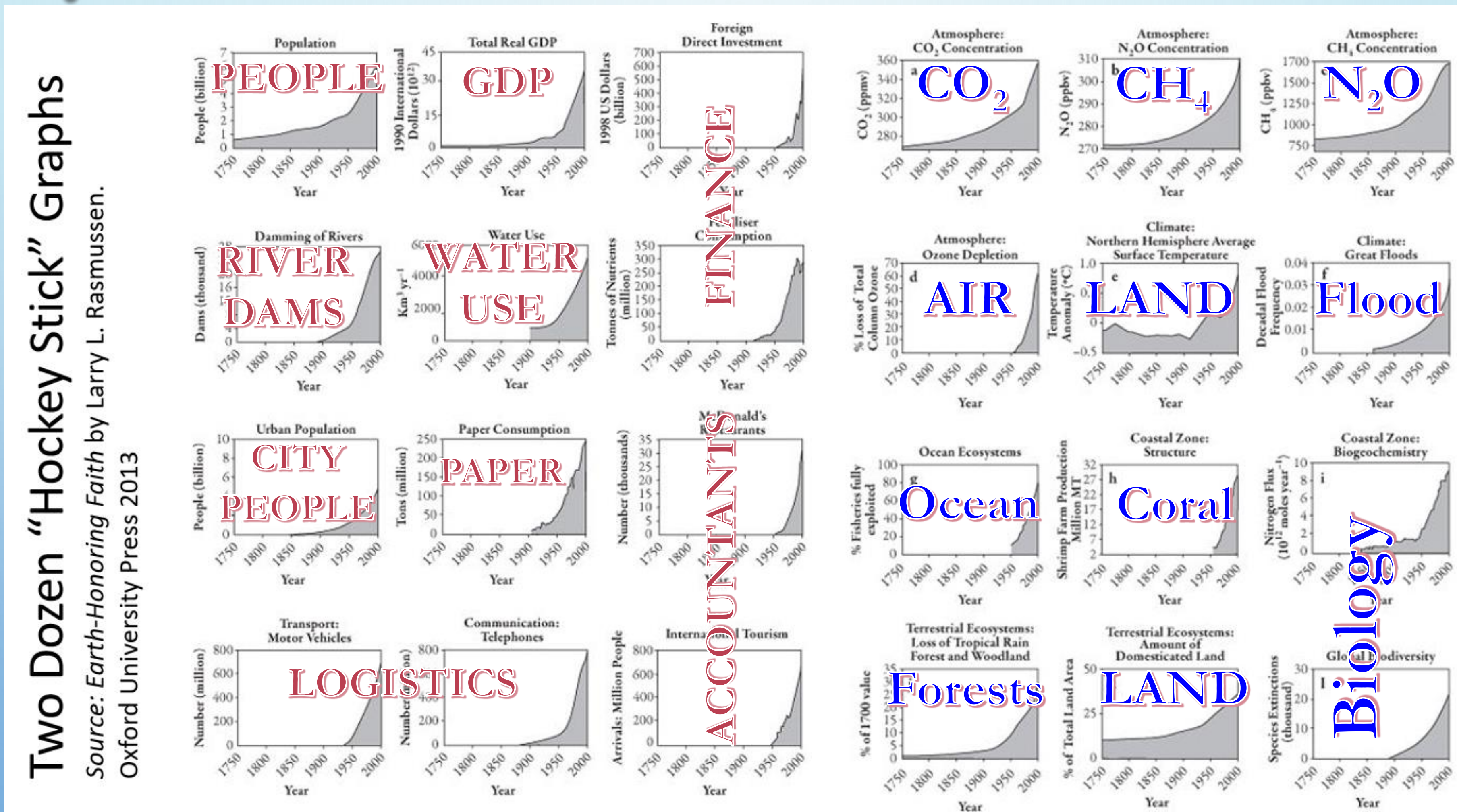

WHY IS THERE SCIENTIFIC CONSENSUS?

When professionals look back thru two centuries of history, in every direction their facts trend & spike like the Hockey-Stick graph