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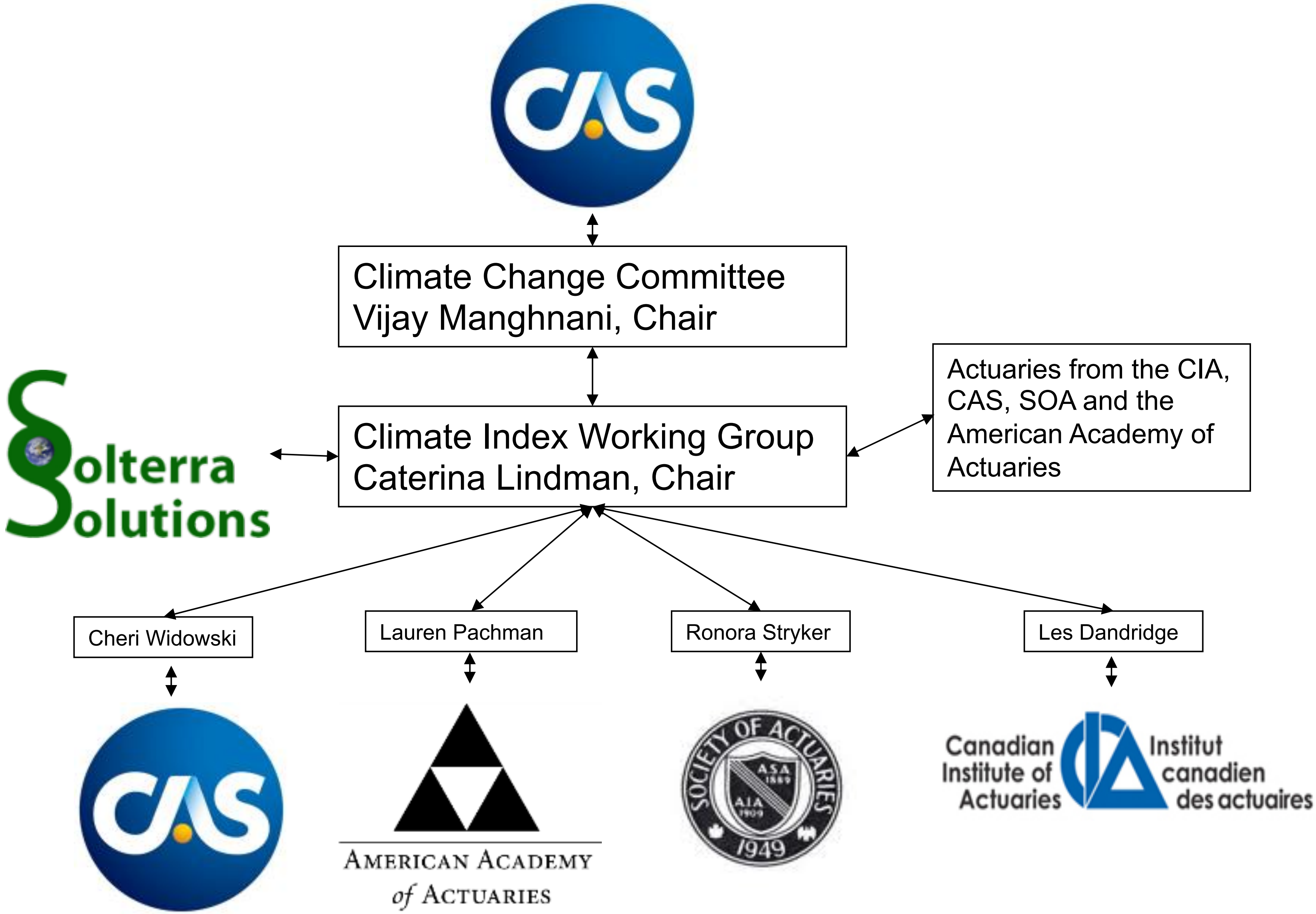
Actuaries Climate Index

Vijay Manghnani, Doug Collins, and Caterina Lindman



Climate Change Committee
Vijay Manghnani, Chair
Climate Index Working Group
Caterina Lindman, Chair
Actuaries from the CIA, CAS, SOA and the American Academy of Actuaries
Solterra Solutions
Cheri Widowski
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American Academy of Actuaries
Society of Actuaries
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Canadian Institute of Actuaries
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Actuaries Climate Index

- Resources: Solterra Solutions and CIWG
- Timing: August 2013 to 2014
- Goals:
  – Easy to understand, but not simplistic
  – Compelling
  – Serves and educates the public
  – Promotes our profession

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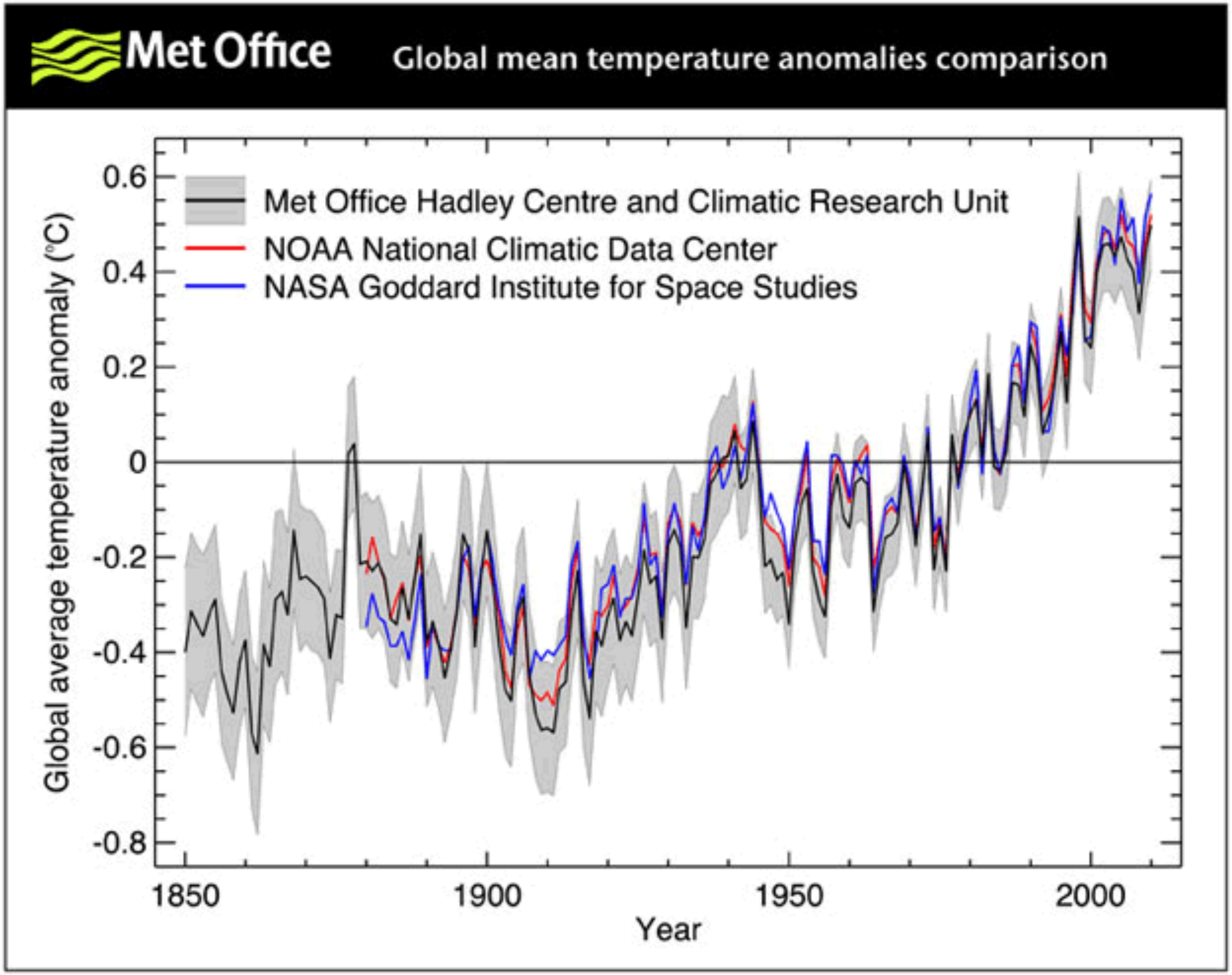

Met Office
Global mean temperature anomalies comparison
Met Office Hadley Centre and Climatic Research Unit
NOAA National Climatic Data Center
NASA Goddard Institute for Space Studies
Global average temperature anomaly (°C)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
1850
1900
1950
2000
Year

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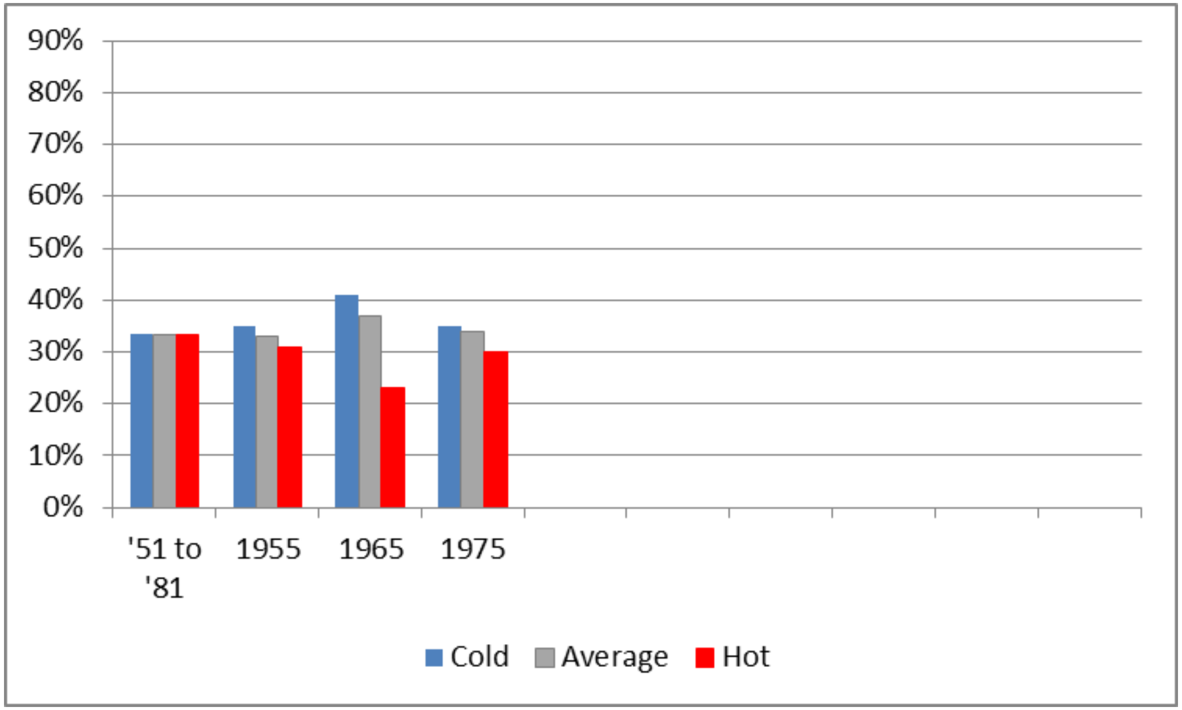
Temperatures

One way to illustrate temperatures is by using a die.

Source: Hansen, Sato and Ruedy, 2012, "The perception of climate"

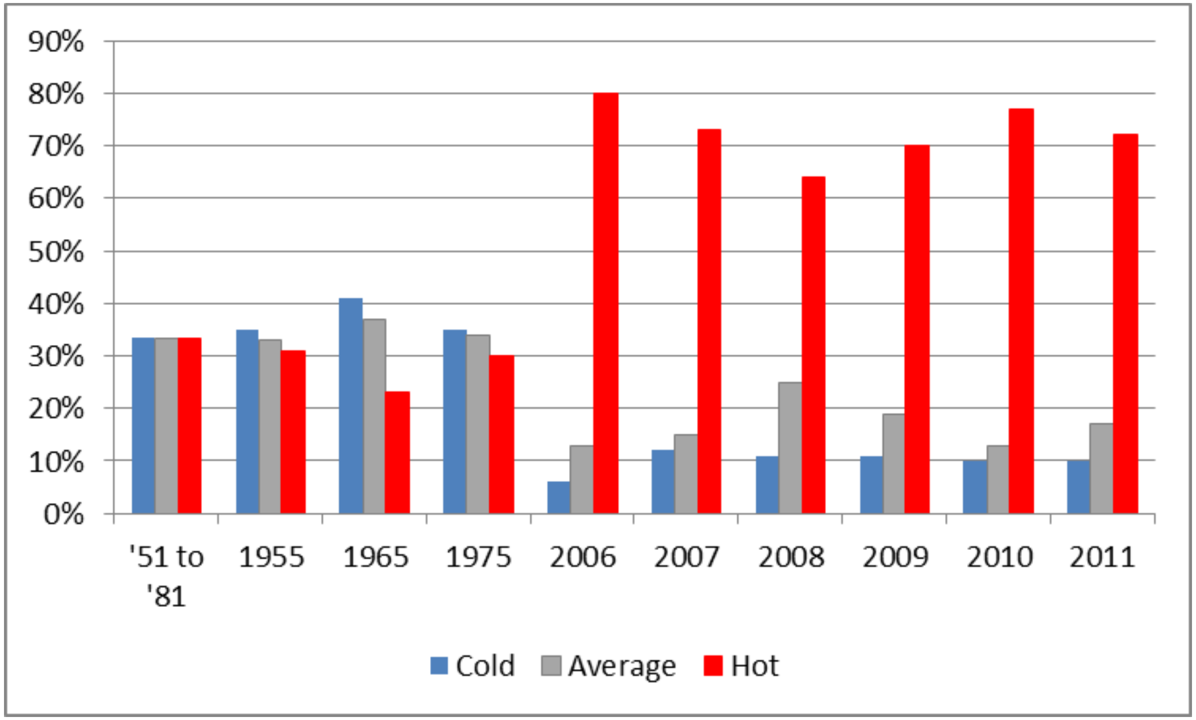
Summer Temperatures

Probability of Cold, Average and Hot Temperatures during the reference period (2/6 Cold, 2/6 Average, 2/6 Hot)



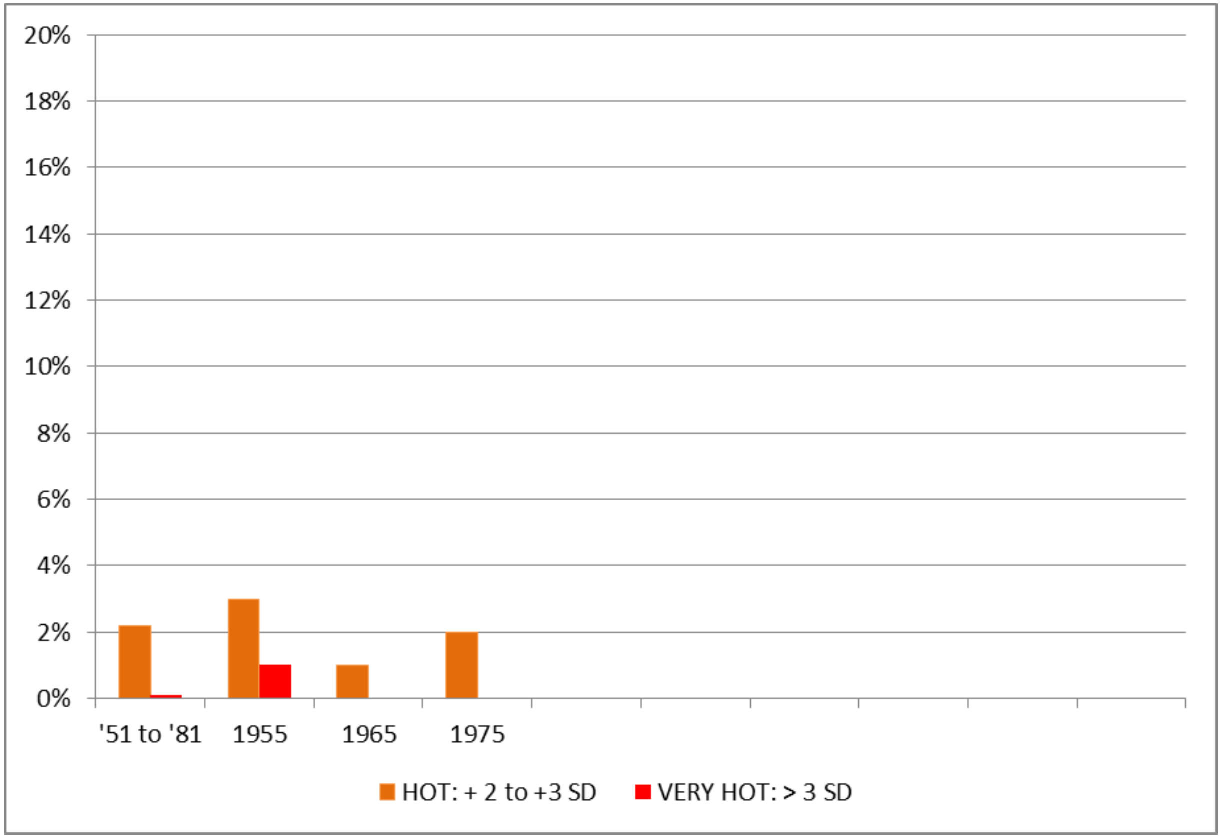
Summer Temperatures

Probability of Cold, Average and Hot Temperatures is changed
(2/6 Cold, 2/6 Average, 2/6 Hot becomes 1/6 Cold, 1/6 Average, 4/6 Hot)



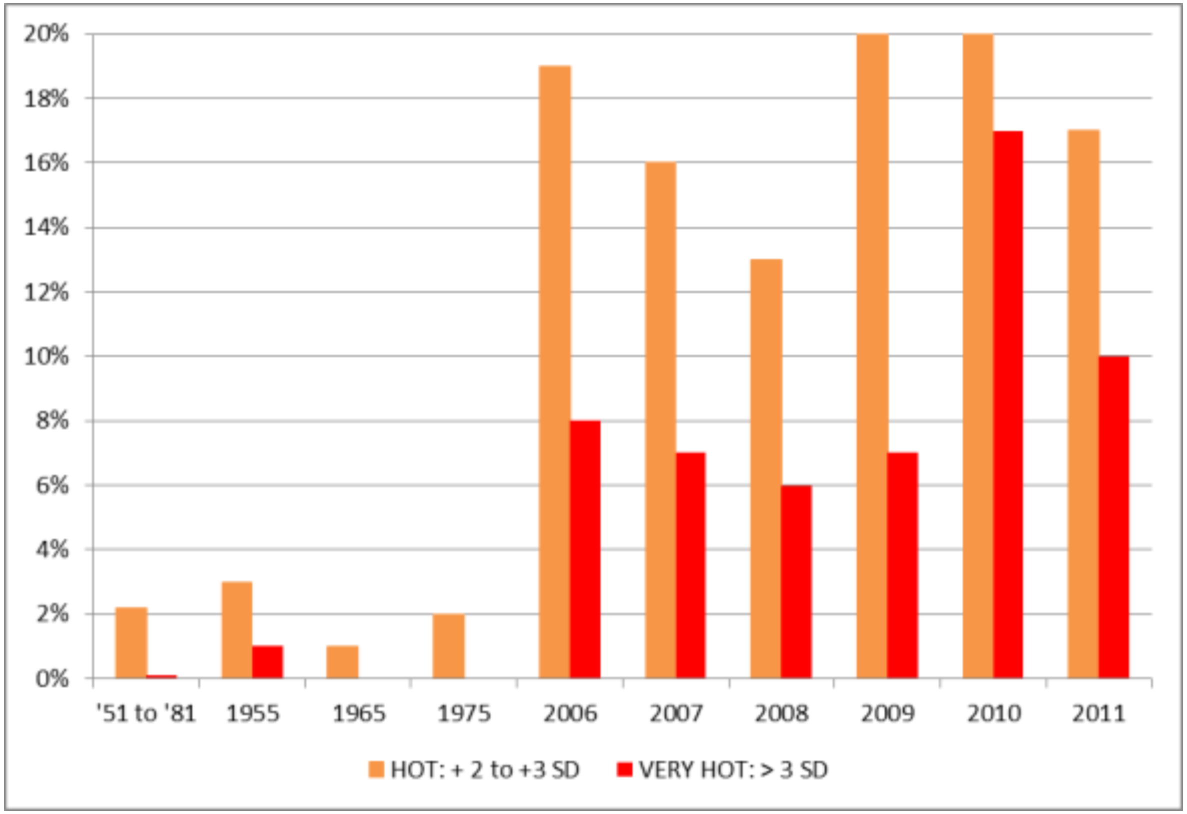
Summer Temperature Extremes

Frequency of Summer temperatures more than 2 or 3 Standard deviations above the norm in the base period:



Summer Temperature Extremes

Frequency of Summer temperatures more than 2 or 3 Standard deviations above the norm:



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130 Years of Global Warming in 30 Seconds

http://videosift.com/video/NASA-130-Years-of-Global-Warming-in-30-seconds

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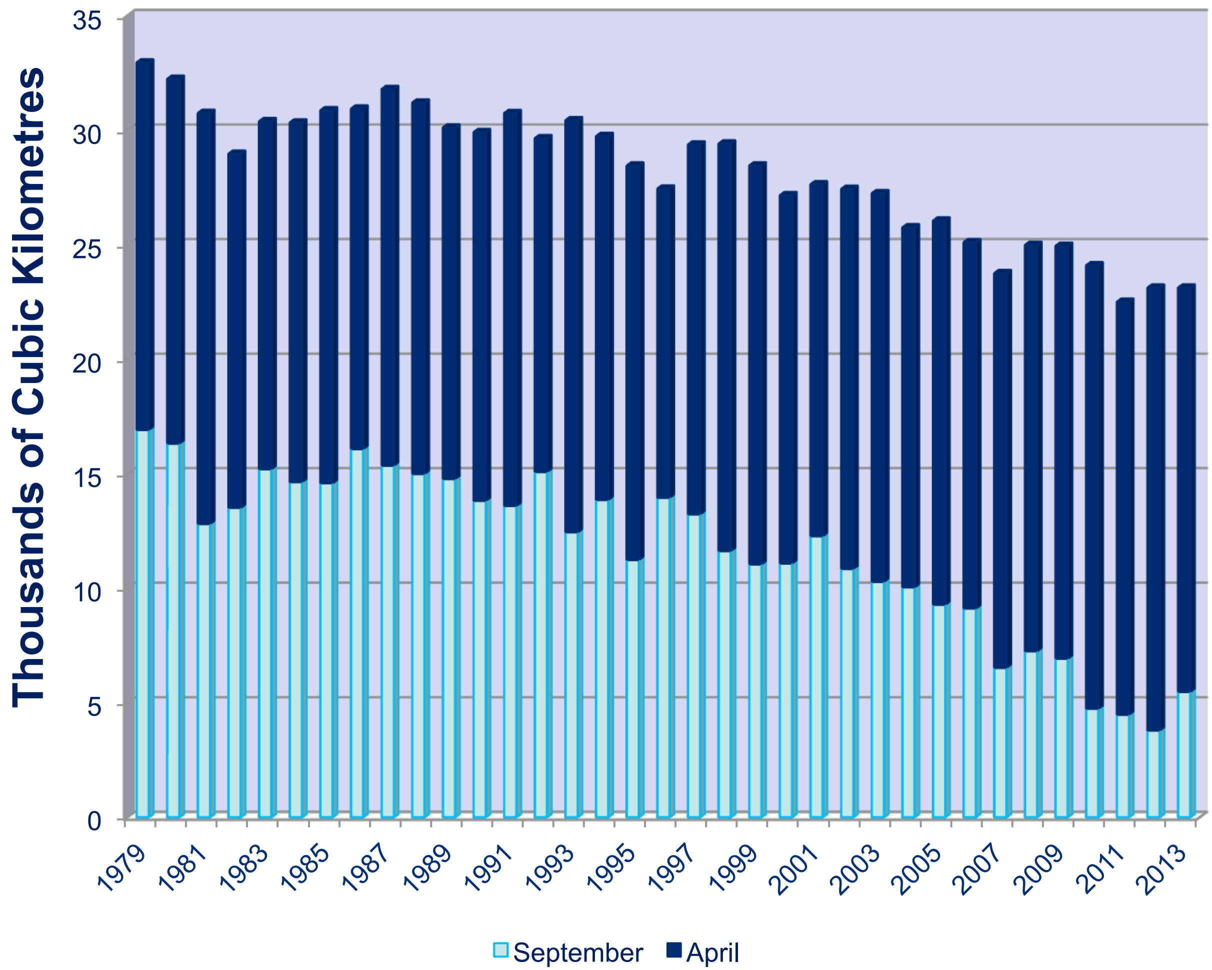
Arctic Sea Ice Volume

Source: Pan-Arctic Ice Ocean Modeling and Assimilation System: PIOMAS



Polar Vortex –

A message from the U.S. Science Advisor

http://www.dailymotion.com/video/x19hmpi_global-climate-change-dr-holden-whitehouse-expert-explains-polar-vortex_news

ACI Basics

- Initial focus US and Canada
  - Hope to gradually add other parts of world where good data is available
  - Publish index and related information on web
- Focus on measuring frequency and intensity of extremes rather than averages
- 6 initial variables we are contemplating: temperature, precipitation, drought, soil moisture, wind, sea level – all by 2.5°grid (275km x 275km at equator)

Temperature Data

- 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

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

Percentiles are based on the number of days exceeding the 90th percentile value (or lower than the 10th percentile value) using the base period 1961-1990.

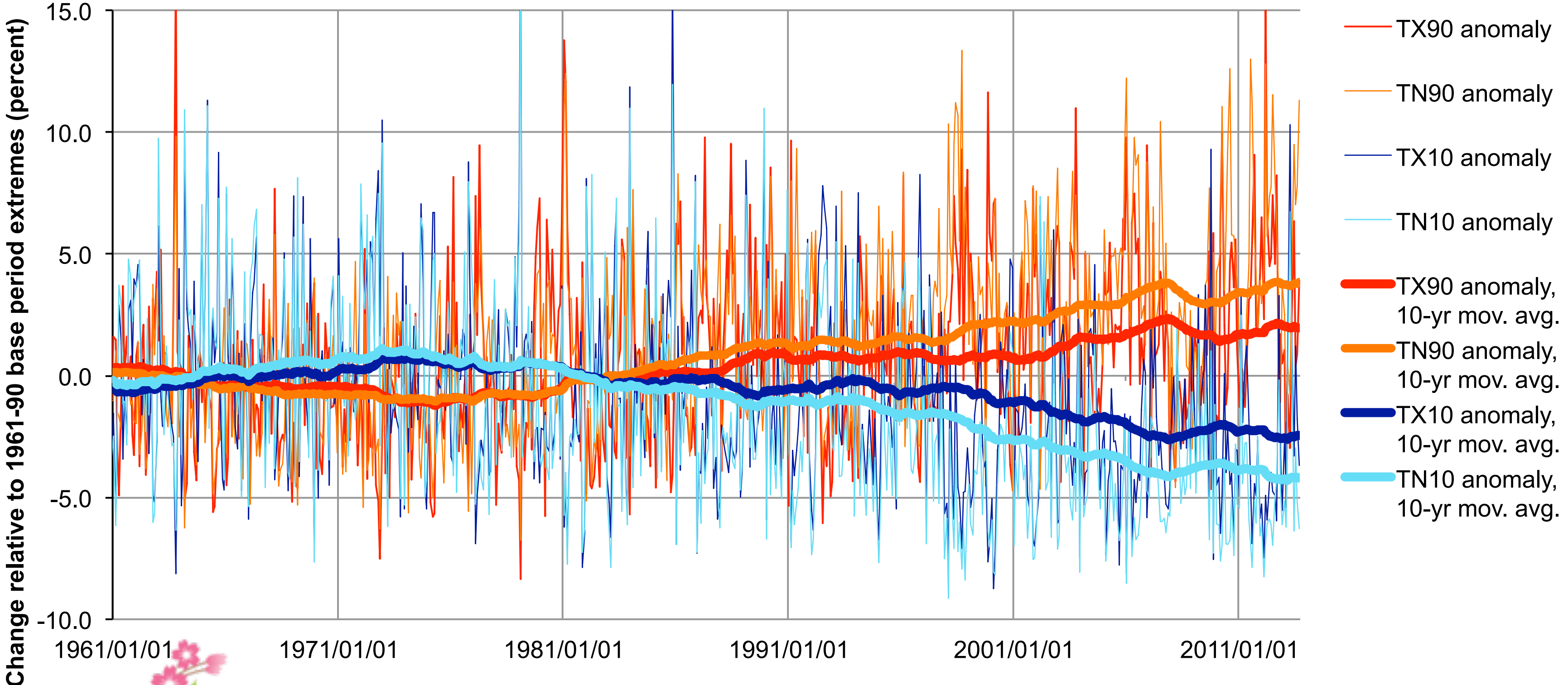
Extreme Temperature Index

- Change relative to 1961-1990 base
- Composite index, Tx = T90 – T10 =

  0.5 x (TX90 + TN90) – 0.5 x (TX10 + TN10)
- The average of % anomalies relative to the base:
  - Average of warm days and warm nights (T90); minus
  - Average of cold days and cold nights (T10)
  - Standardized anomaly (T10' similar):

$$T90' = \Delta T90 / \sigma_{ref}(T90)$$

Day & Night Temp Extremes



TX and TN for US and Canada

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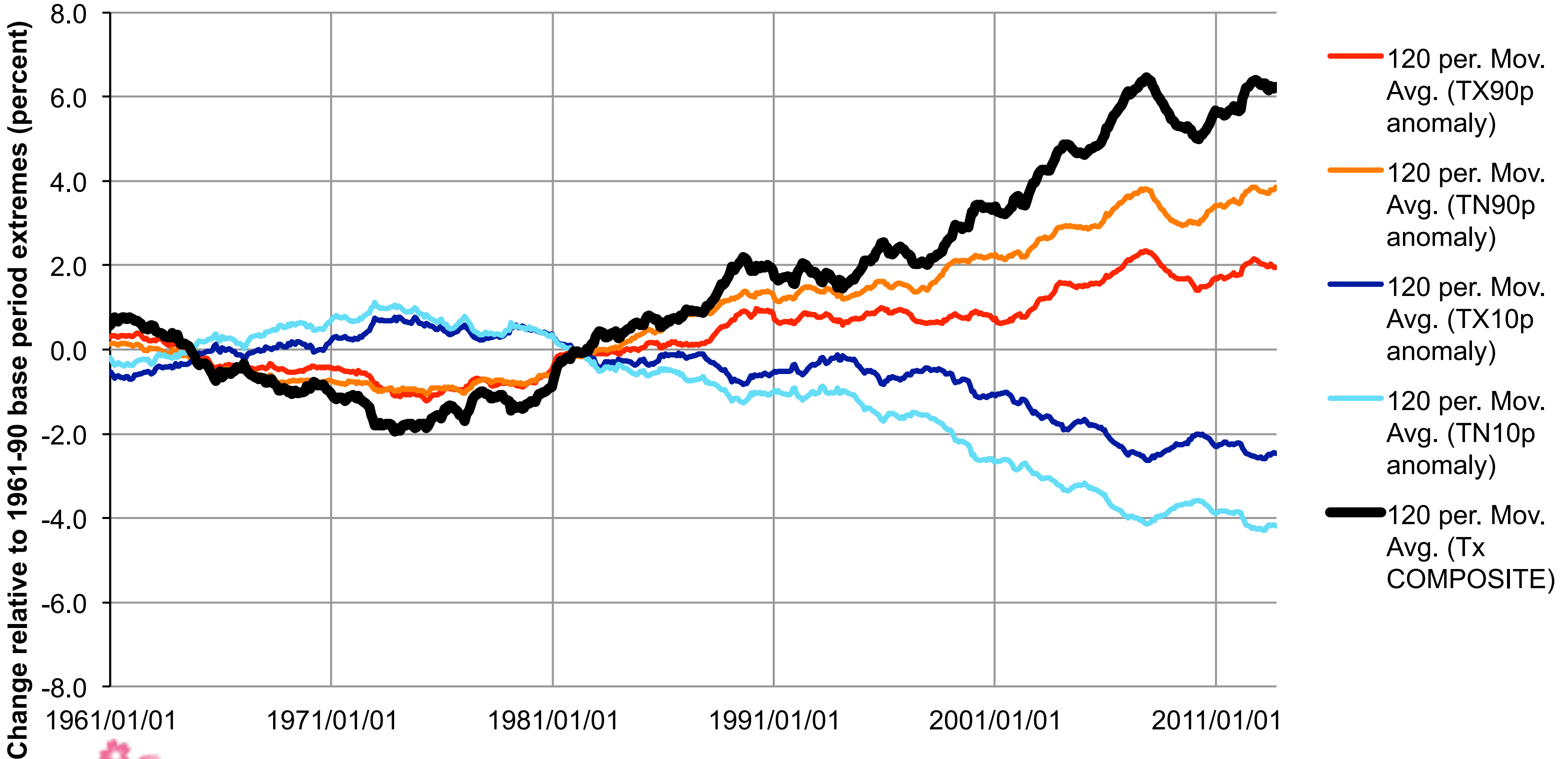
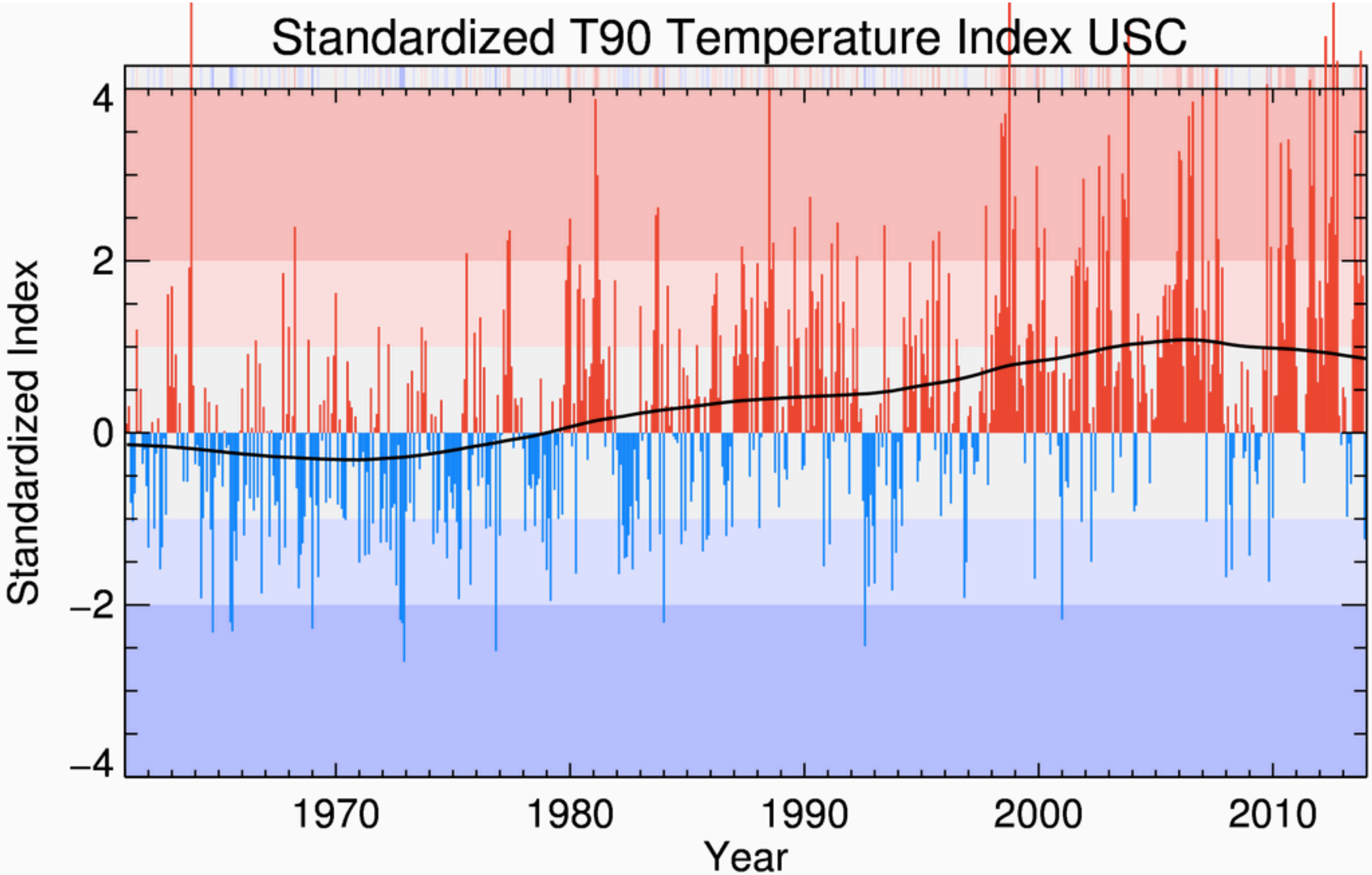
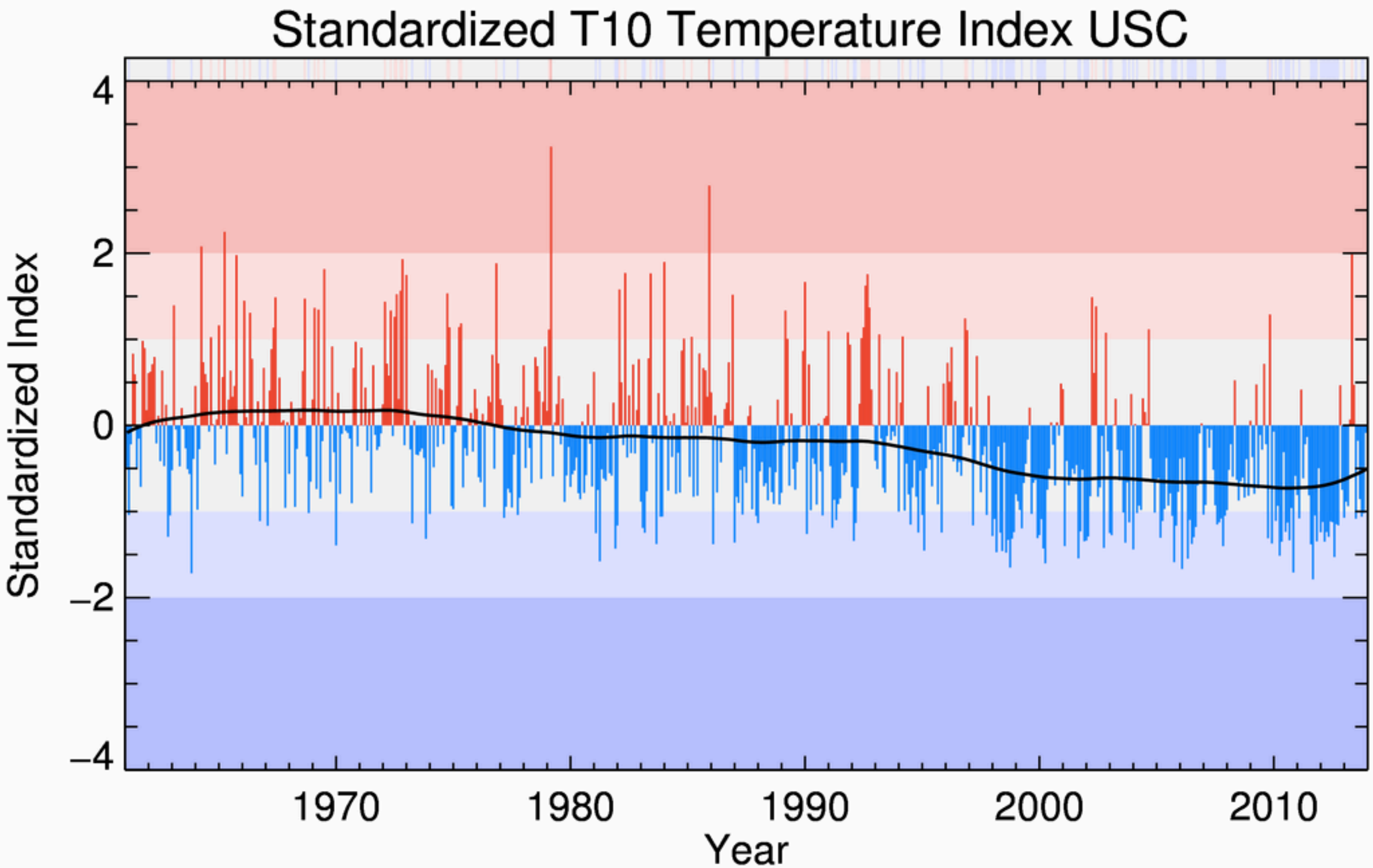
Day & Night Temp Extremes



Tx and its components, US and Canada


Standardized T90 Temperature Index USC
Standardized Index
4
2
0
−2
−4
1970
1980
1990
2000
2010
Year


Standardized T10 Temperature Index USC
Standardized Index
4
2
0
−2
−4
1970
1980
1990
2000
2010
Year

Extreme Precipitation Index

- GHCNDEX, using monthly maximum five-day precipitation data
- Precipitation index, Px =

  $[(Rx5day - Rx5day_{ref}) \ / \ Rx5day_{ref}] \times 100\%$

  Where the reference period is again 1961-90
- Standardized: $Px' = \Delta Px \ / \ \sigma_{ref}(Px)$

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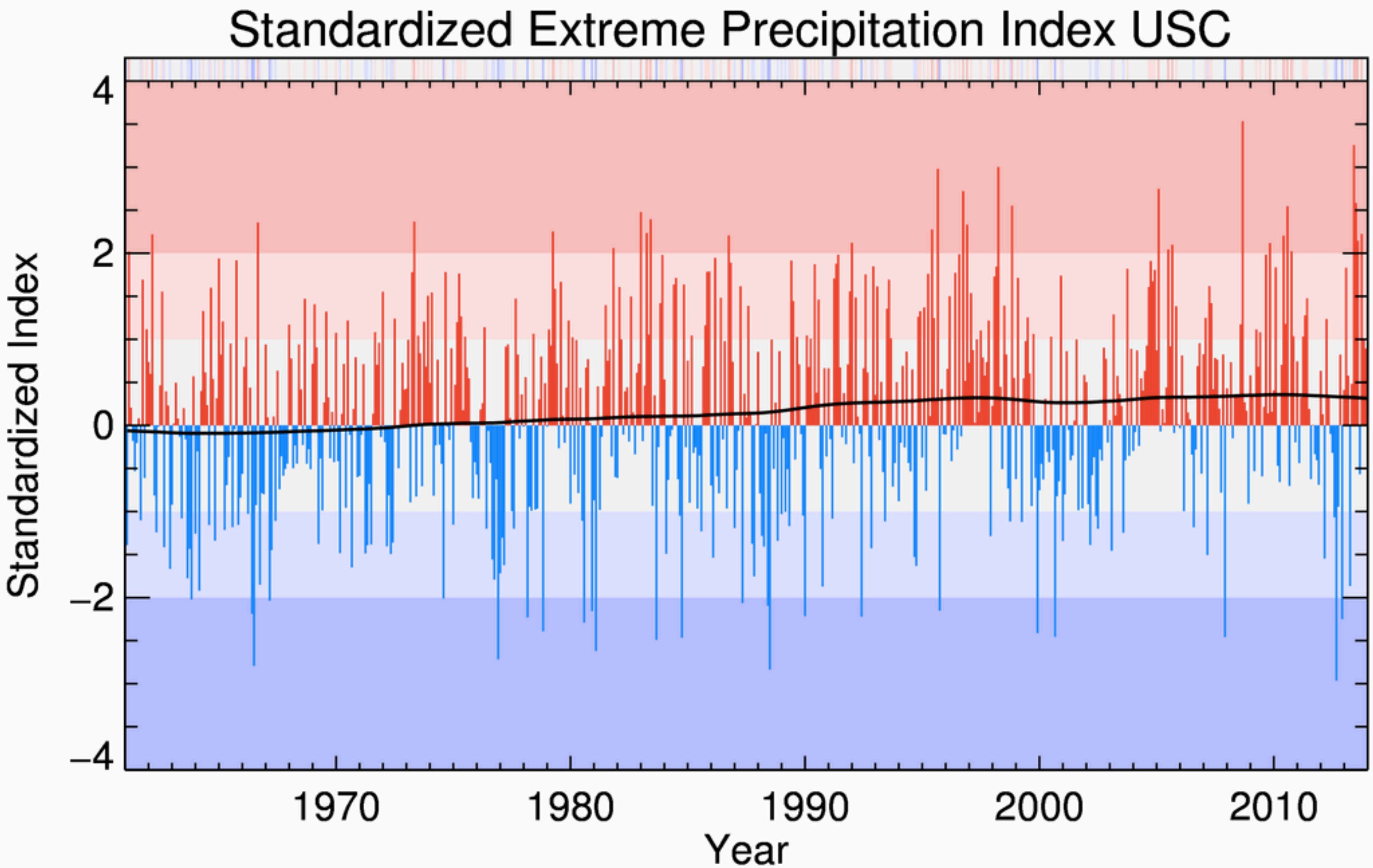
Standardized Extreme Precipitation Index USC
Standardized Index
4
2
0
−2
−4
1970
1980
1990
2000
2010
Year

Drought Index

- GHCNDEX, consecutive dry days (CDD)
  - Max days/year with <1mm precipitation
- Drought index = 1 value of CDD/year
  - Linear interpolation to obtain monthly
  - % anomaly relative to 1961-1990
- $Dx = 100\% * [(CDD - CDD_{ref})/CDD_{ref}]$
  - $Dx'\ std = \Delta Dx / \sigma_{ref}(Dx)$

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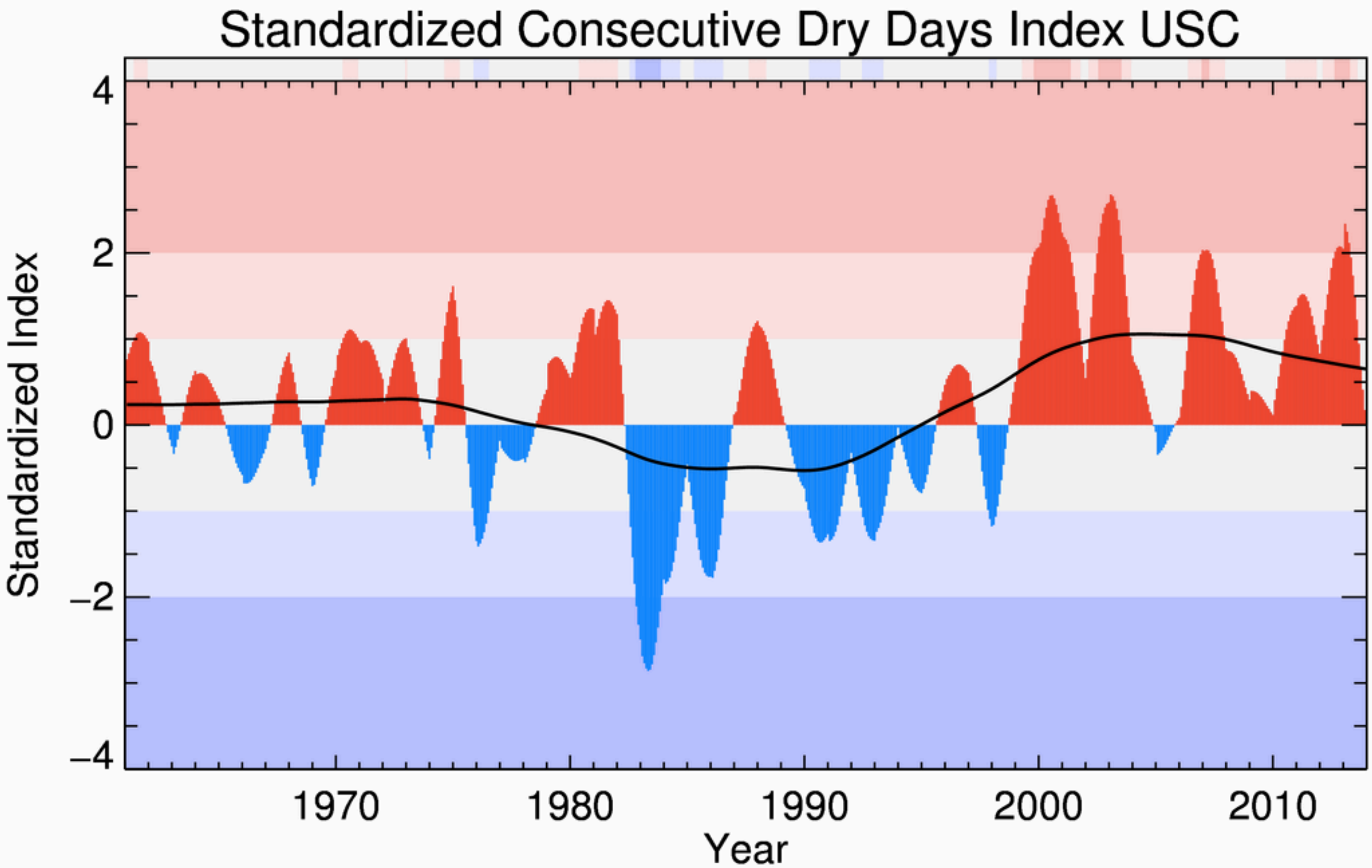
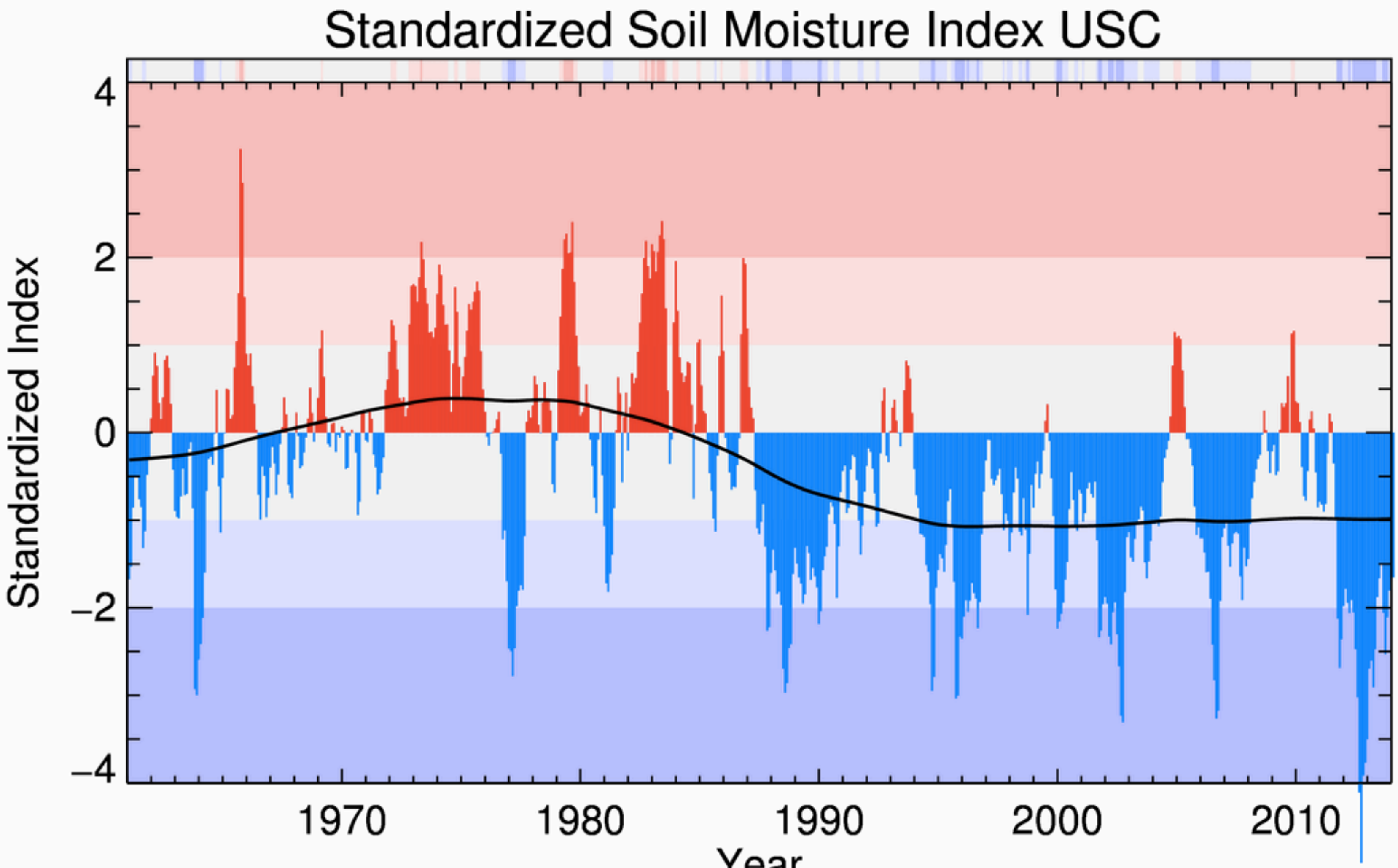


Standardized Consecutive Dry Days Index USC
Standardized Index
4
2
0
−2
−4
1970
1980
1990
2000
2010
Year

Soil Moisture Index

- Index derived by NOAA Earth System Research Laboratory from:
  - Monthly precipitation and temperature
  - Soil properties
  - Local evaporation rate
  - Water balance model
- $M = 100\% * [(SM90 - SM90_{ref})/SM90_{ref}]$
  - $M'\ std = \Delta M / \sigma_{ref}(M)$



Standardized Soil Moisture Index USC
Standardized Index
4
2
0
−2
−4
1970
1980
1990
2000
2010
Year

Wind Power Index

- Index derived from NOAA Earth System Research Laboratory data:
  - Daily mean wind speeds
  - WP = $(1/2)*\rho*w^3$

    Where ρ is air density, w is daily mean wind speed
- $Wx = 100\% * [(WP90 - WP90_{ref})/WP90_{ref}]$
  - Where WP90 is the 90th percentile of daily wind power, calculated monthly
  - $W'std = \Delta Wx / \sigma_{ref}(Wx)$

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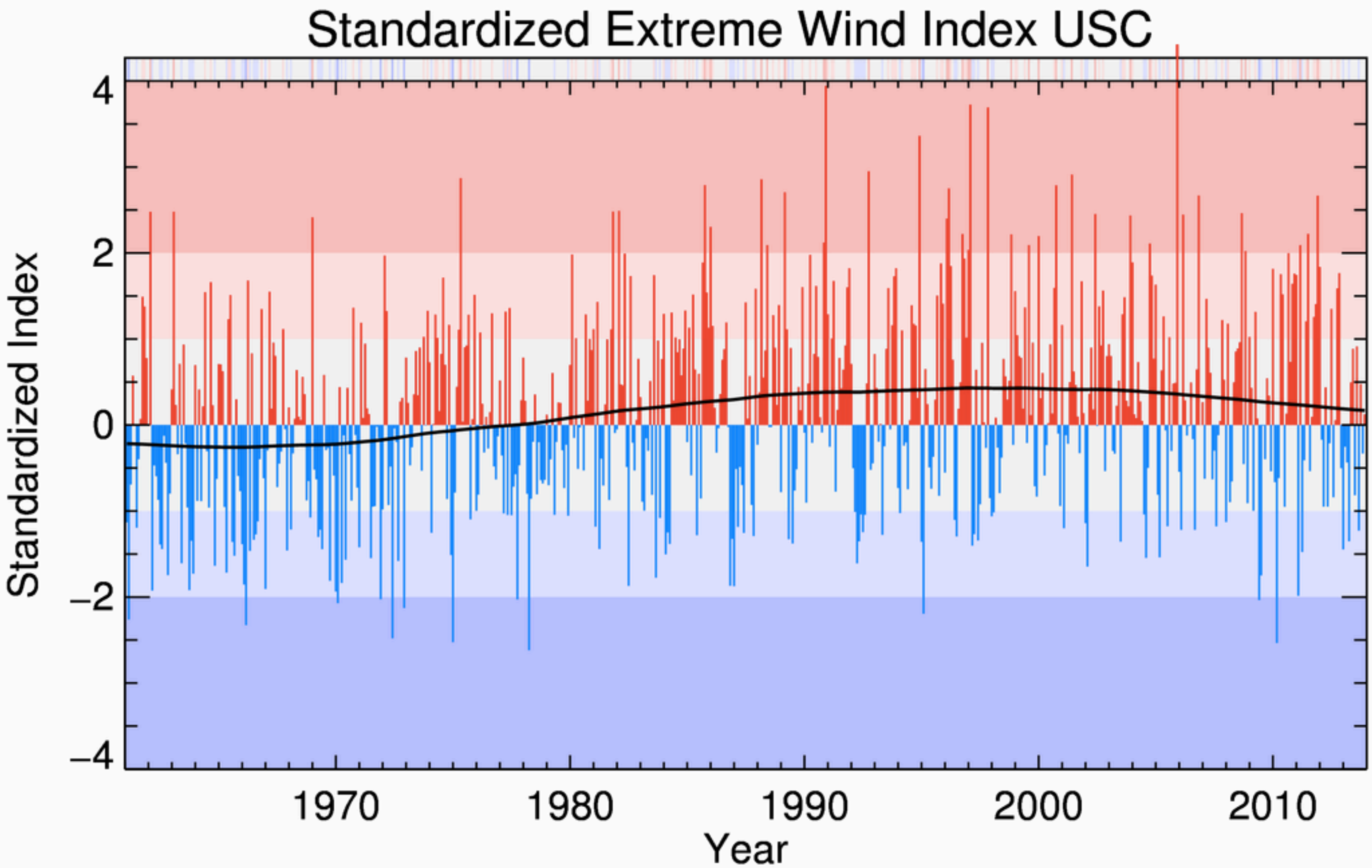

Standardized Extreme Wind Index USC
Standardized Index
4
2
0
−2
−4
1970
1980
1990
2000
2010
Year

Sea Level Index (S)

- At tide gauge stations along US and Canada coast
  - Data provided by Permanent Service for Mean Sea Level (PSMSL), part of the UKs National Oceanography Center
    - Data will be matched to grids used for other variables
- S' std = $\Delta S / \sigma_{ref}(S)$

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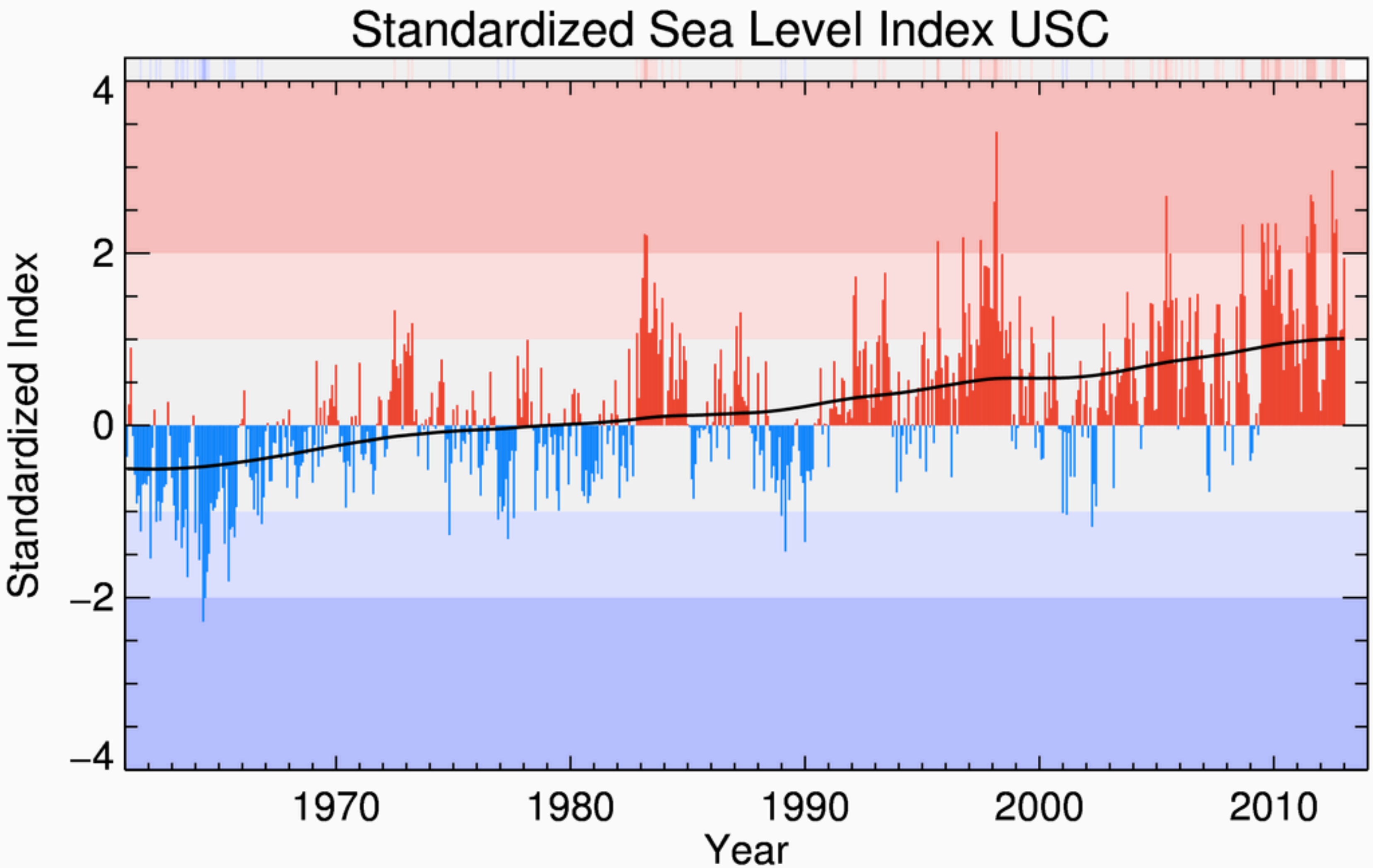
Standardized Sea Level Index USC
Standardized Index
4
2
0
−2
−4
1970
1980
1990
2000
2010
Year

Composite ACI Index

Several options were considered:

1) *Unweighted sum of individual components*

   ACIusum = Tx + Px + Dx + M + Wx + S

2) *Unweighted average of individual components*

   ACIuavg = (*Tx + Px + Dx + M + Wx + S*) / 6

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Composite ACI Index

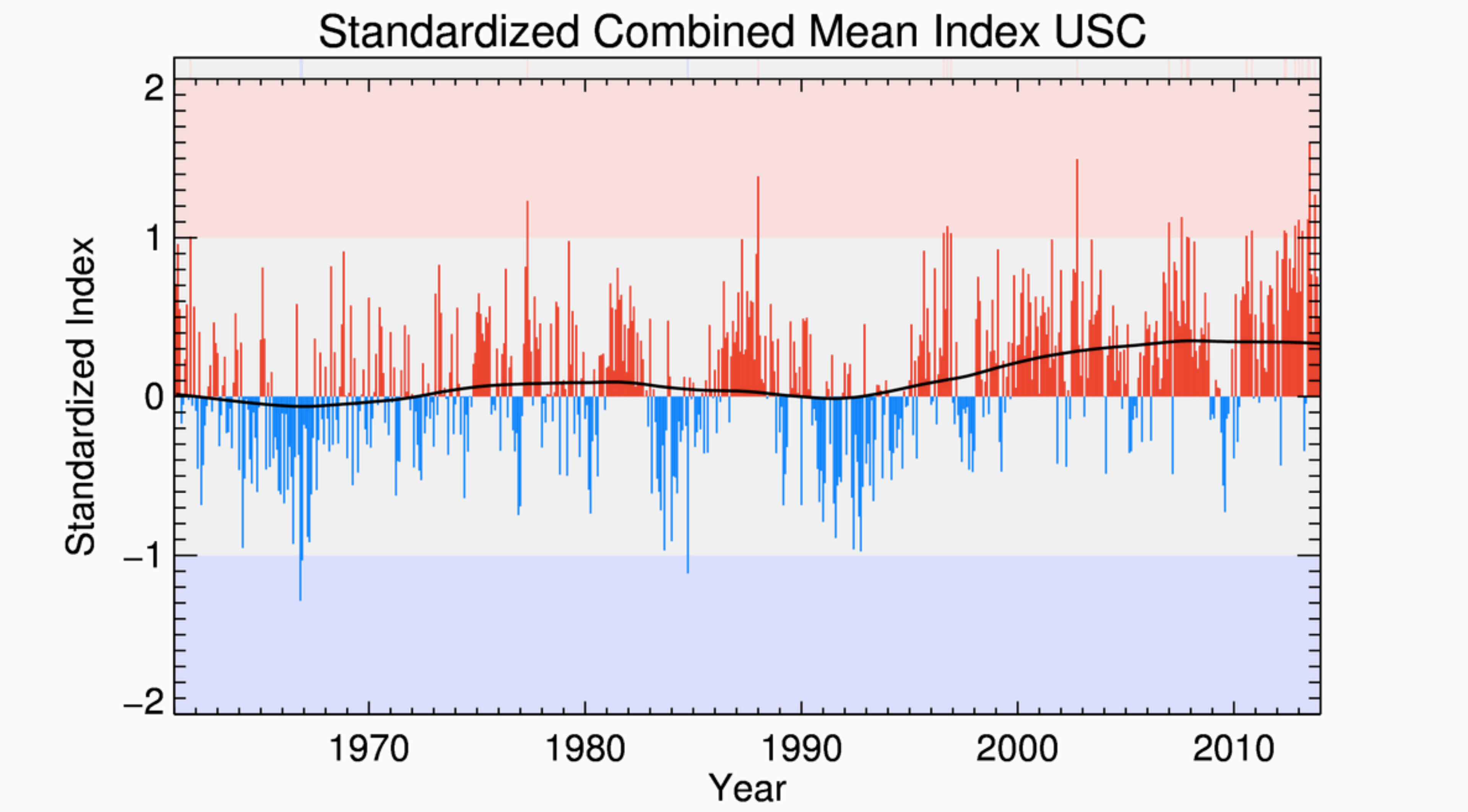
3) Weighted average of individual components

$$ACIwavg = [Tx + Px - Dx + M + 2Wx + S] / 6$$

4) Unweighted average of standardized anomalies

$$ACIstd = (T90'std - T10'std + Px'std + Dx'std + M'std + Wx'std + S'std) / 7$$

Actuaries Climate Index



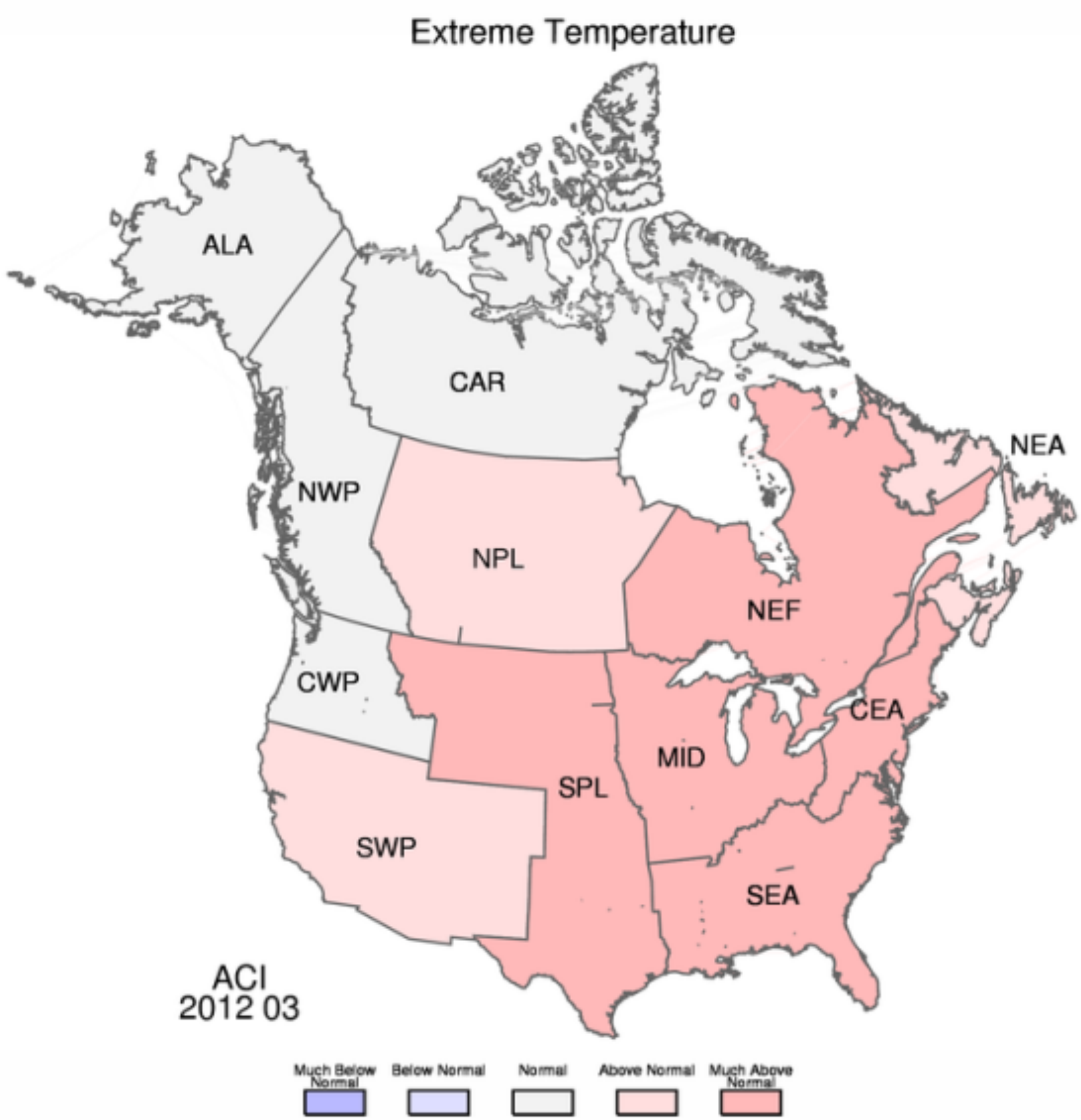
Possible Specialized Sub-Indices

- Warm and wet: $\text{mean}(Tx' + Px' + M' + S')$
- Warm and dry: $\text{mean}(Tx' + Dx' - M')$
- Wet: $\text{mean}(Px' + M' + S')$
- Drought: $\text{mean}(Dx' - M')$
- Storminess: $\text{mean}(Px' + Wx')$

ACI Communication

- Quarterly press releases
- Website
  - Charts of index components and composite indices
  - Maps of variation by 12 regions
  - Commentary in English and French
  - Links to related information

Website Prototype



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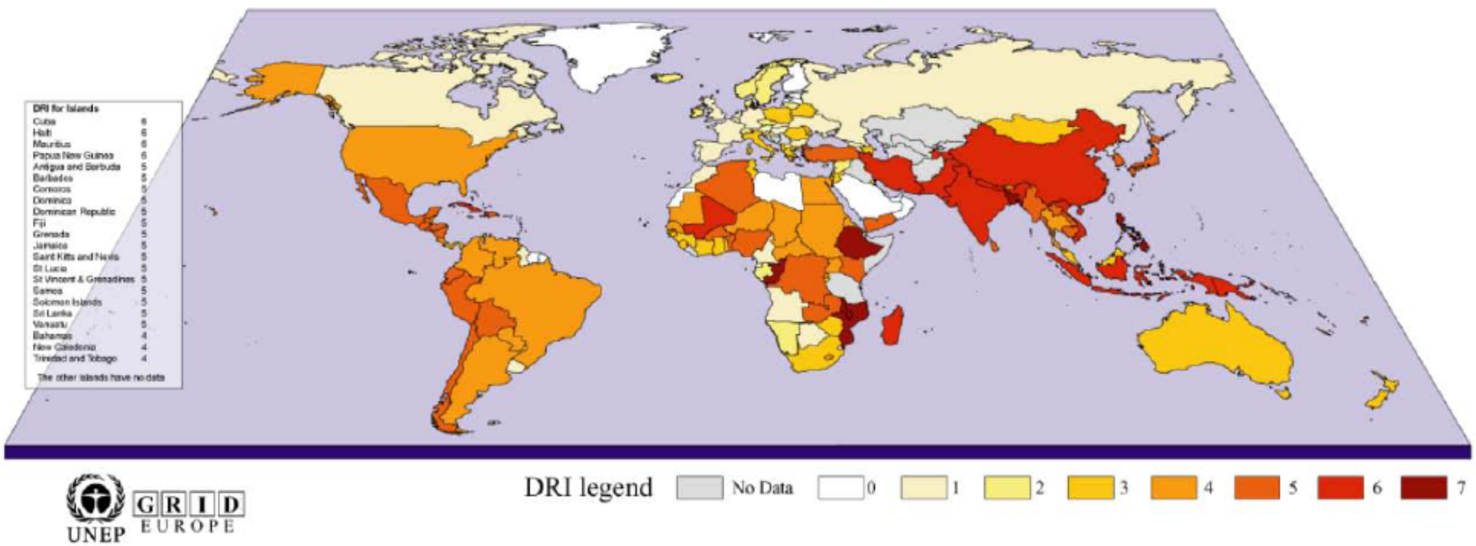
Actuaries Climate Risk Index

- Combine components of ACI with exposure measures (population, property values) to produce ACRI
  - Add Vulnerability and Exposure by product line/region to create a risk index
  - Create a composite risk index by product line or by region
  - Same time period and grids as ACI
- Goal is to produce an index especially useful to the insurance industry
  - ACI rollout Summer/Fall 2014
  - ACRI rollout late 2014

Creating a Risk Index

The Climate index will be extended to a Risk Index by adding Vulnerability and Exposure components.

The Disaster Risk Index (DRI)



$$K = C\, f(H)\, g(P)\, s(V),$$

$$K = C \times (PE)^{\alpha} \times V_1^{\alpha 1} \times V_2^{\alpha 2} \times V_3^{\alpha 3} \times \ldots$$

$$\ln(K) = \ln(C) + \alpha \ln(PE) + \alpha_1 \ln(V_1) + \alpha_2 \ln(V_2) + \ldots$$

Peduzzi et al. 2009: A Mortality Risk Index for Cyclones, Earthquake and Floods

K: Risk Index, H: Hazard, P: Assets, PE: Potential Exposure, V: Vulnerability parameters

Climate Impact by Line of Business

- Composite Index by Product Line can be created based on an understanding of the relative impact of various climate driven natural hazards.
- Examples :
  - Property Climate Risk = f(Floods, Tropical Cyclone, Extra-tropical Cyclone Indices, Sea Level Rise)
  - Crop Climate Risk = f(Floods, Heat waves and Drought)

Hazards	Timeframe	Property (individual and commercial lines)	Engineering (EAR, CAR*)	Marine	Agricultural (crop and livestock)	Motor own damage	Aviation and space	Contingency risks (cancellation of event)	Life and health	Liability
Floods, storm surge	5-10 years	slightly negative	fairly negative	slightly negative	slightly negative	slightly negative	slightly negative	fairly negative	slightly negative	fairly negative
	10-30 years	fairly negative	highly negative	fairly negative	fairly negative	fairly negative	slightly negative	highly negative	slightly negative	highly negative
Storms, flash floods	5-10 years	fairly negative	fairly negative	fairly negative	slightly negative	fairly negative	slightly negative	fairly negative	slightly negative	slightly negative
	10-30 years	highly negative	highly negative	highly negative	fairly negative	highly negative	fairly negative	highly negative	slightly negative	fairly negative
Heatwaves and drought	5-10 years	slightly negative	slightly negative	slightly negative	fairly negative	slightly negative	slightly negative	slightly negative	slightly negative	slightly negative
	10-30 years	slightly negative	fairly negative	slightly negative	highly negative	slightly negative	fairly negative	fairly negative	fairly negative	fairly negative
Less frost and cold weather	5-10 years	generally positive	generally positive	generally positive	generally positive	generally positive	no	fairly negative	generally positive	no
	10-30 years	generally positive	generally positive	generally positive	generally positive	generally positive	no	highly negative	generally positive	no
Rising sea levels	5-10 years	slightly negative	slightly negative	no	no	no	no	no	no	fairly negative
	10-30 years	fairly negative	fairly negative	slightly negative	slightly negative	no	no	no	no	highly negative
Tropical cyclones	5-10 years	fairly negative	fairly negative	slightly negative	slightly negative	slightly negative	slightly negative	fairly negative	no	fairly negative
	10-30 years	highly negative	highly negative	slightly negative	fairly negative	slightly negative	slightly negative	highly negative	no	highly negative
Extratropical storms	5-10 years	fairly negative	slightly negative	no	slightly negative	slightly negative	no	slightly negative	no	slightly negative
	10-30 years	highly negative	fairly negative	slightly negative	slightly negative	slightly negative	no	fairly negative	no	fairly negative
Melting of polar icecaps	5-10 years	no	no	highly negative	slightly negative	no	no	no	no	slightly negative
	10-30 years	slightly negative	slightly negative	highly negative	slightly negative	no	no	no	no	fairly negative

* EAR = Erection All Risks, CAR = Contractors All Risks

- generally positive
- no
- slightly negative
- fairly negative
- highly negative

Source: "Globe of Natural Hazards", Munich Re, 2009

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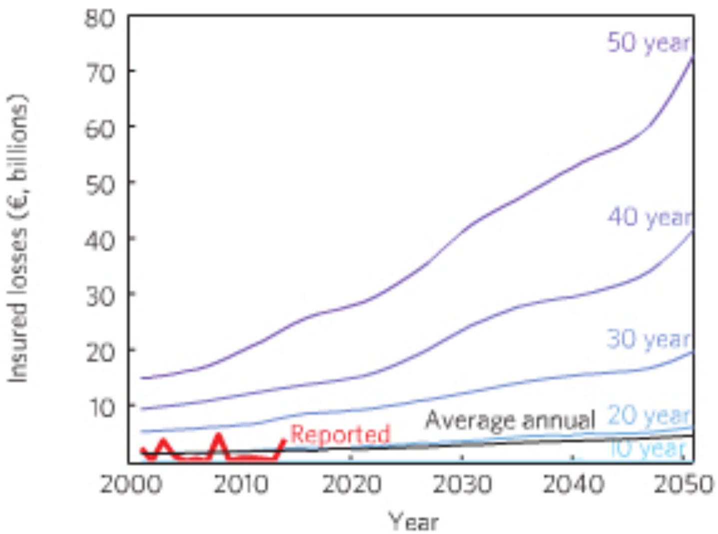
Common Climate Change Risk Perceptions

- **Perception #1: Significant Climate Change is too far in the future**
  - **Inference**: "Impacts beyond the corporate time horizon, so adopt a wait & watch approach"
  - **Reality**: Some impacts may be more imminent than they appear



- Insured European Flood damage expected to quadruple by 2050 - under current infrastructure (Jongman et al, 2014)
- An implied 5-10% annual trend
- The severity of extreme events (volatility) increases faster with time than the projected average annual loss

Similar studies are projecting Climate Change impacts on Hurricane Damage (Emanuel et al 2011), Sea level rise (Climate Central 2012) and global freshwater floods (Botzen 2013) in the not so distant future.

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Common Climate Change Risk Perceptions

- **Perception #2:** **Climate Change will be gradual**
  - Inference: "The underlying change in the hazard will be baked into rates based on loss experience, especially for short tailed lines"
  - Reality: This is not always true..

		Underying Mean Trend			
		0%	0.50%	1%	2%
Underlying Volatility Trend	0%	0.0%	-2.4%	-4.5%	-7.9%
	5%	-0.9%	-3.3%	-5.1%	-8.4%
	10%	-3.0%	-5.1%	-7.0%	-9.9%

Trend Impact on Hypothetical P/L

1. Book of business that has an underlying trend in its mean and volatility
2. Loss cost is updated each year based on the most recent 10 yr historical experience
3. Trend in either mean or volatility causes an P/L shortfall in the long run
4. The emergence of the trend impact depends on the signal to noise (S/N) ratio. For certain perils, such as, Temperature and Precipitation the S/N ratio is high. For some other perils, such Tropical Cyclones, the S/N ratio is positive but modest.

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Common Climate Change Risk Perceptions

- **Perception #3: Catastrophe Models adequately handle climate change risks**
  - Reality: Catastrophe models are important tools, but their out-of-the-box use doesn't attempt to address climate change

- **Perception #4: Too much uncertainty** to make concrete decisions
  - Inference: Ambiguity implies low confidence in the relative likelihood among a range of future scenarios. Primary uncertainty in climate change risk will be large.
  - Reality: This is true. Deep uncertainty in Climate Change is a real challenge. However, the risk is real and material, and is ignored at our own peril.

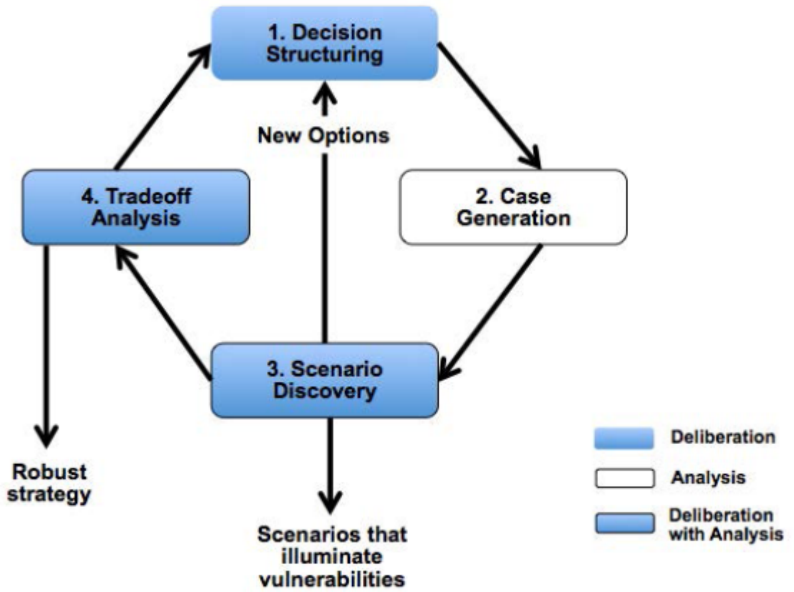
Risk Management under Climate Change

- Traditional Risk Management paradigms may be limited under climate change
- Risk Management methods need to adapt to climate change.
  - Move from **optimization** to **robustness**
  - Intelligent use of climate and catastrophe risk models
  - Underwriting and Capital allocation: Adopt an explicit "**Climate Change Ambiguity Aversion load**"?
  - Explore reinsurance and primary underwriting **strategies that will embrace the uncertainty** in the frequency of weather extremes and global aggregation of risks.
  - Adopt Investment strategies that diversify climate risks
- Actuaries Climate (Risk) Index is a tool in this adaptation process
  - Provides a uniform framework to calibrate perceptions with reality
  - Quantifies climate change impacts on specific books and business
  - Helps monitor and project climate change impacts

Robust Risk Management

A multi-year Cat Reinsurance purchase decision
Robust Decision Example

1. Uncertainty in climate projections imply a range of outcomes/scenarios are possible
2. Use CAT model to create scenarios (events) – ignore the probability of events
3. Use data mining or structural models to cluster scenarios to a subset of alternate scenarios
4. Evaluate Net positions and recoveries under various structuring options
5. Choose the structure that is resilient under multiple scenarios (no attempt to relatively rank scenarios)
6. Structure deals that allow for explicit mid-term recalibration as new information becomes available



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Actuaries Climate (Risk) Index in Rate Making & Risk Management

1. Integrate AC(R)I as parameters into predictive models
    - Capture climate sensitivity in underlying hazard
    - Capture both historical and projected trends explicitly
2. ACRI can complement catastrophe risk models and enhance the incorporate of climate change in CAT risks
3. ACRI parameters can be used to create and assess future robust decision making scenarios
4. ACRI can be used to calculate the Climate Change “Uncertainty or Ambiguity” load in pricing and capital management
5. Regional and line of business ACRI can be used for portfolio diversification and strategic decisions

Resources for Further Learning

Yale Forum on Youtube: Short, Compelling Videos http://www.yaleclimatemediaforum.org/yale-climate-media-forum-on-youtube/

Books:

Hansen, James	Storms of my grandchildren
McKibbon, Bill	Eaarth
Monbiot, George	Heat
Nordhaus, William	The Climate Casino
Kolbert, Elizabeth	Field Notes from a Catastrophe
Weaver, Andrew	Generation Us

Movies: Chasing Ice; Greedy, Lying Bastards; Revolution; The Last Reef.

Reports: Climate Change and Resource Depletion, the Challenges for Actuaries. Resource and Environment Group, 2010 (UK Institute of Actuaries)

Websites: American Association for the Advancement of Science: www.whatweknow.aaas.org

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

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/
Soil Moisture: www.esrl.noaa.gov/psd/data/gridded/data.cpcsoil.html
Sea Level: www.psmsl.org/data/obtaining/
Wind: www.esrl.noaa.gov/psd/data/gridded/datancep.reanalysis.html

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Questions or Comments

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