Climate Change

What is happening now

What we might expect in the future

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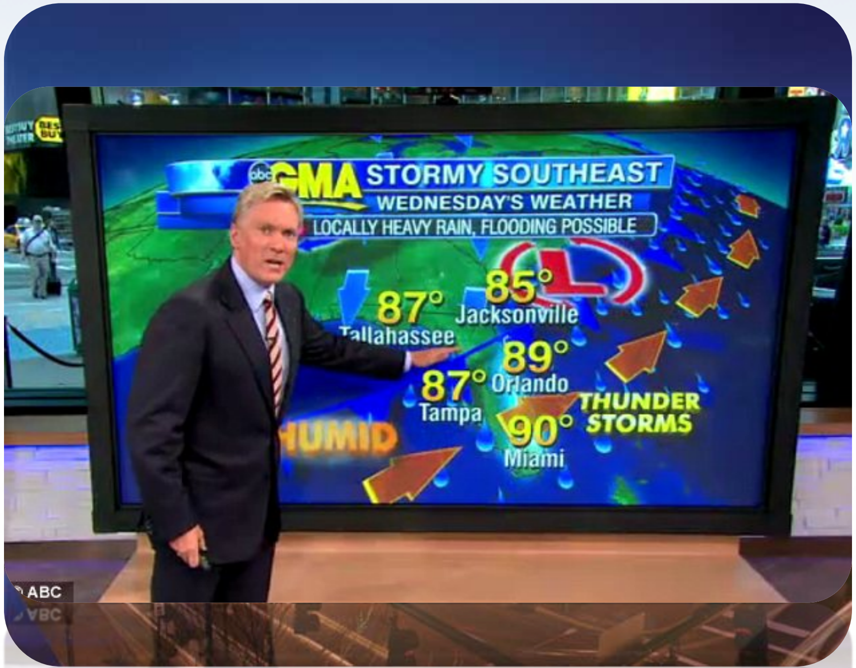
Asheville, North Carolina

The National Climatic Data Center

The world's largest archive of weather and climate data

- NCDC is located in Asheville, North Carolina
- A place of "active retirement" for weather data of many types



http://www.ncdc.noaa.gov/

NCDC Climate Monitoring Branch

About Me

- I'm a meteorologist by training & education
  - Then I got into drought
  - Then I got into local climate
  - Then I got into big-picture climate
- I am, like many people in the field, an "accidental climatologist"
- Meteorology background is only a tiny part of the climate system

Some Resources

- *Bulletin of the American Meteorological Society's* Annual State of the Climate Report:
  - http://www.ncdc.noaa.gov/bams-state-of-the-climate/
- The National Climate Assessment
  - http://globalchange.gov
- Extreme Weather & Climate Paper:
  - Kunkel et al. (2012). Monitoring and Understanding Trends in Extreme Storms: State of Knowledge. Bulletin of the American Meteorological Society
- NCDC's Data (and Climate Monitoring Branch!)

PART 1:
Climate Change versus Climate Variability

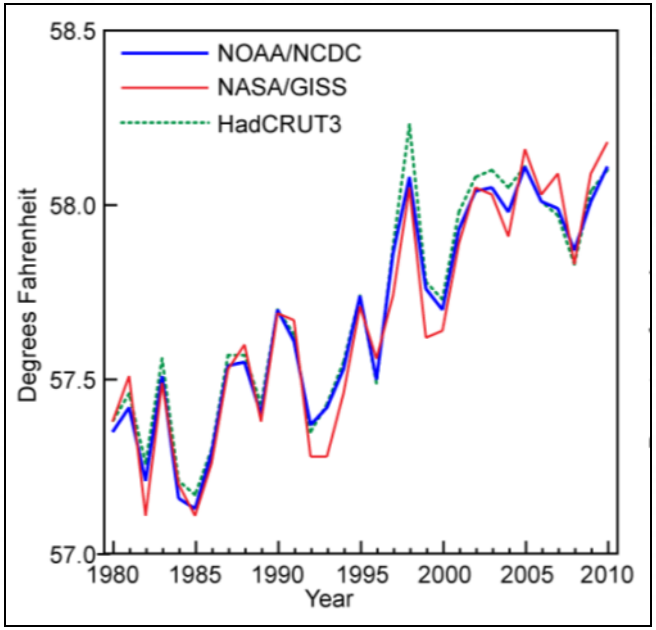
PART 1:

Climate Change ~~versus~~ and

Climate Variability

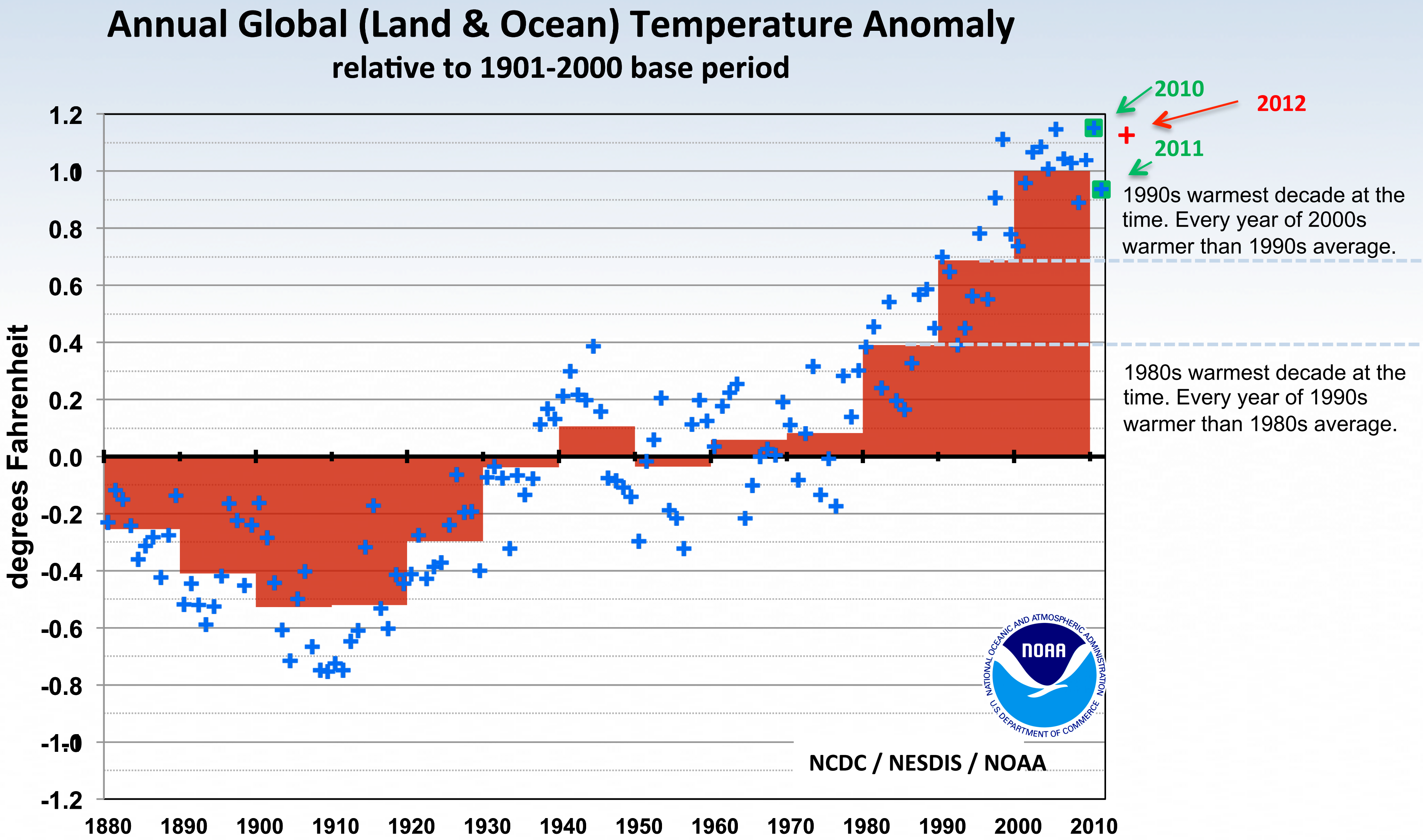
(they coexist)

Weather vs. Climate: *Like the Stock Market*

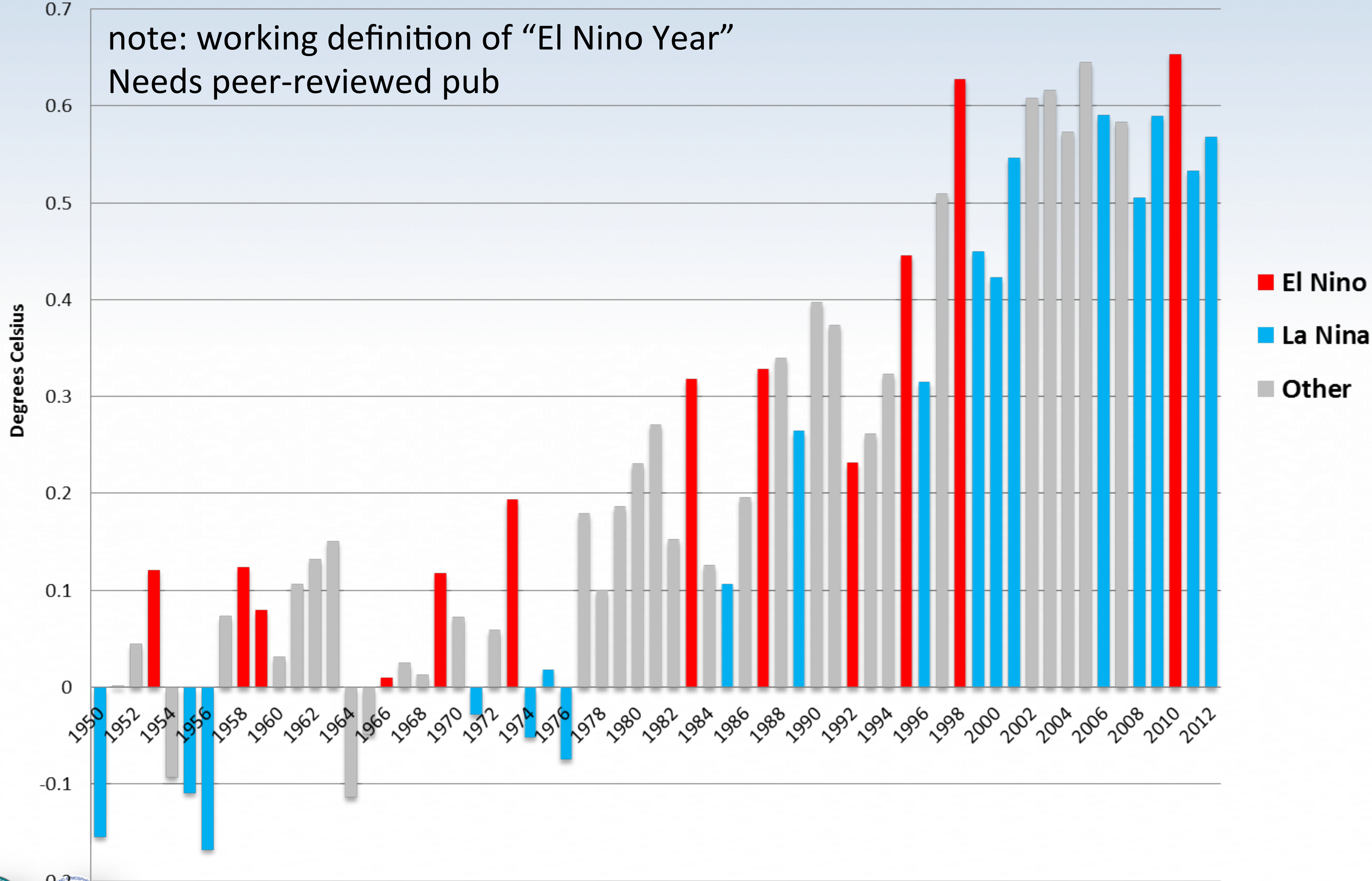


Lots of examples of this in complex systems.
Best place to find them: your life!

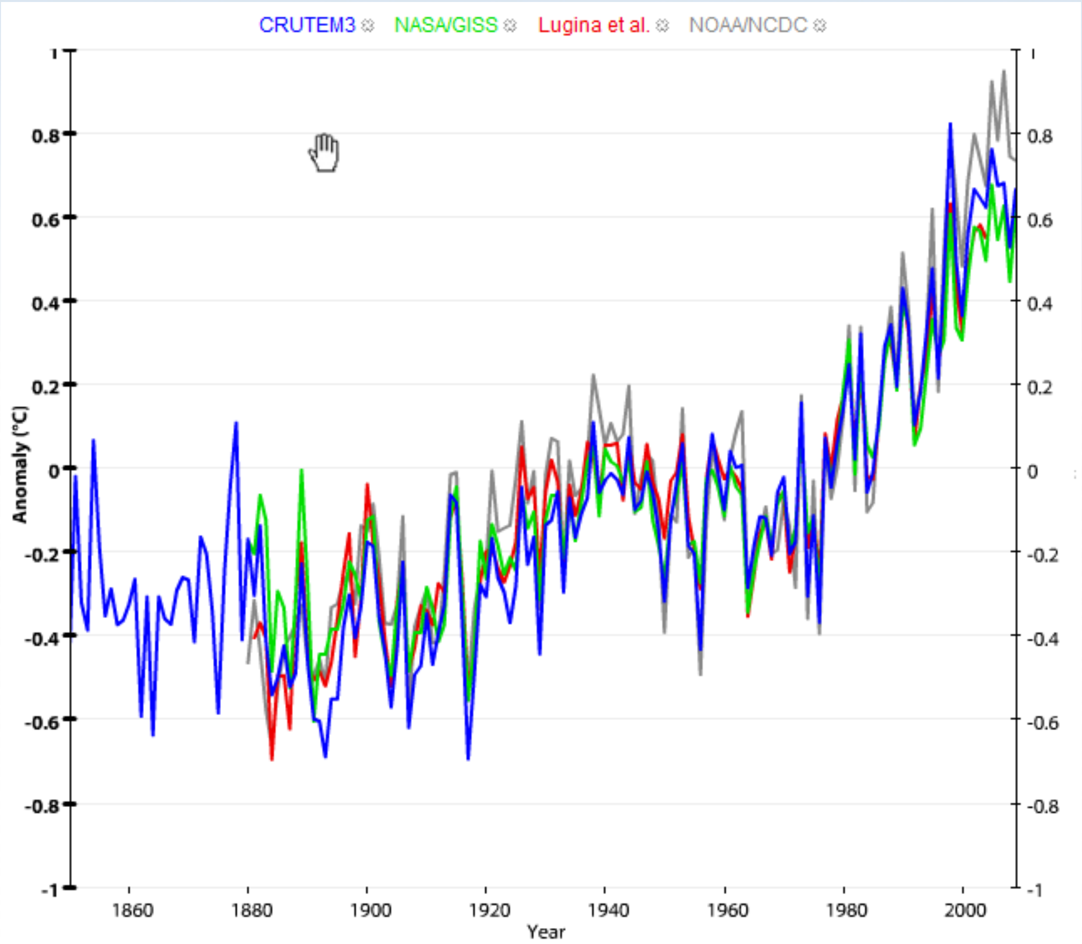
Global Temperature Decadal Average: 1880 - 2009



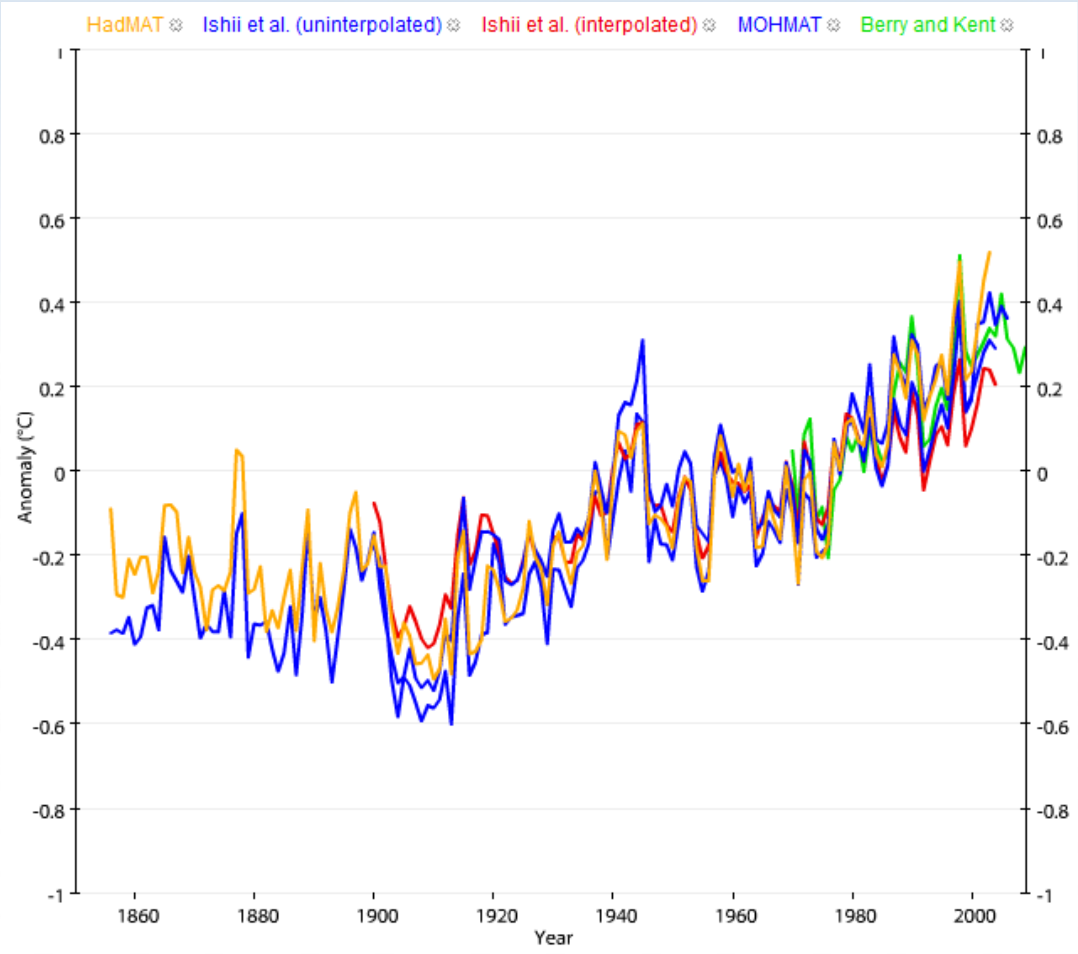
Annual Global Temperature Anomalies
1950 - 2012



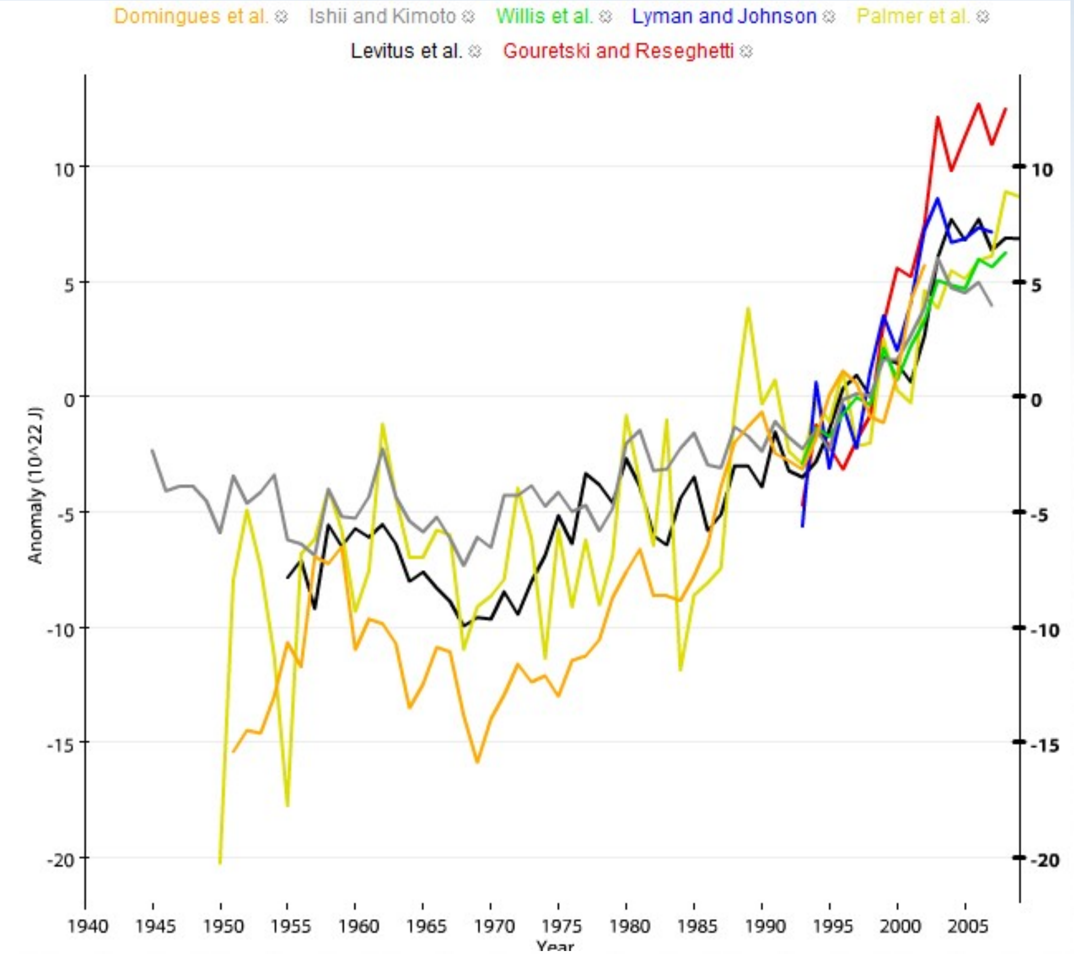
Globally: Temperature over Land



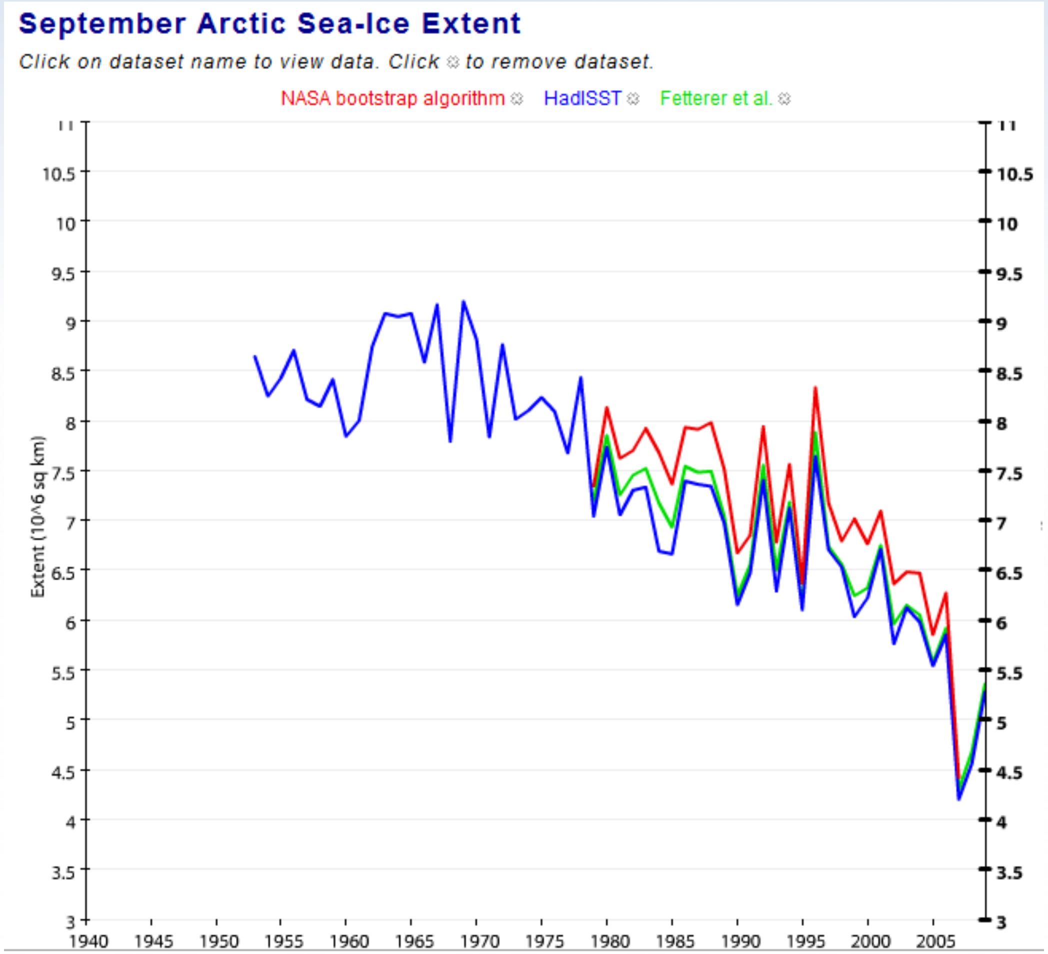
Globally: Temperature over Oceans



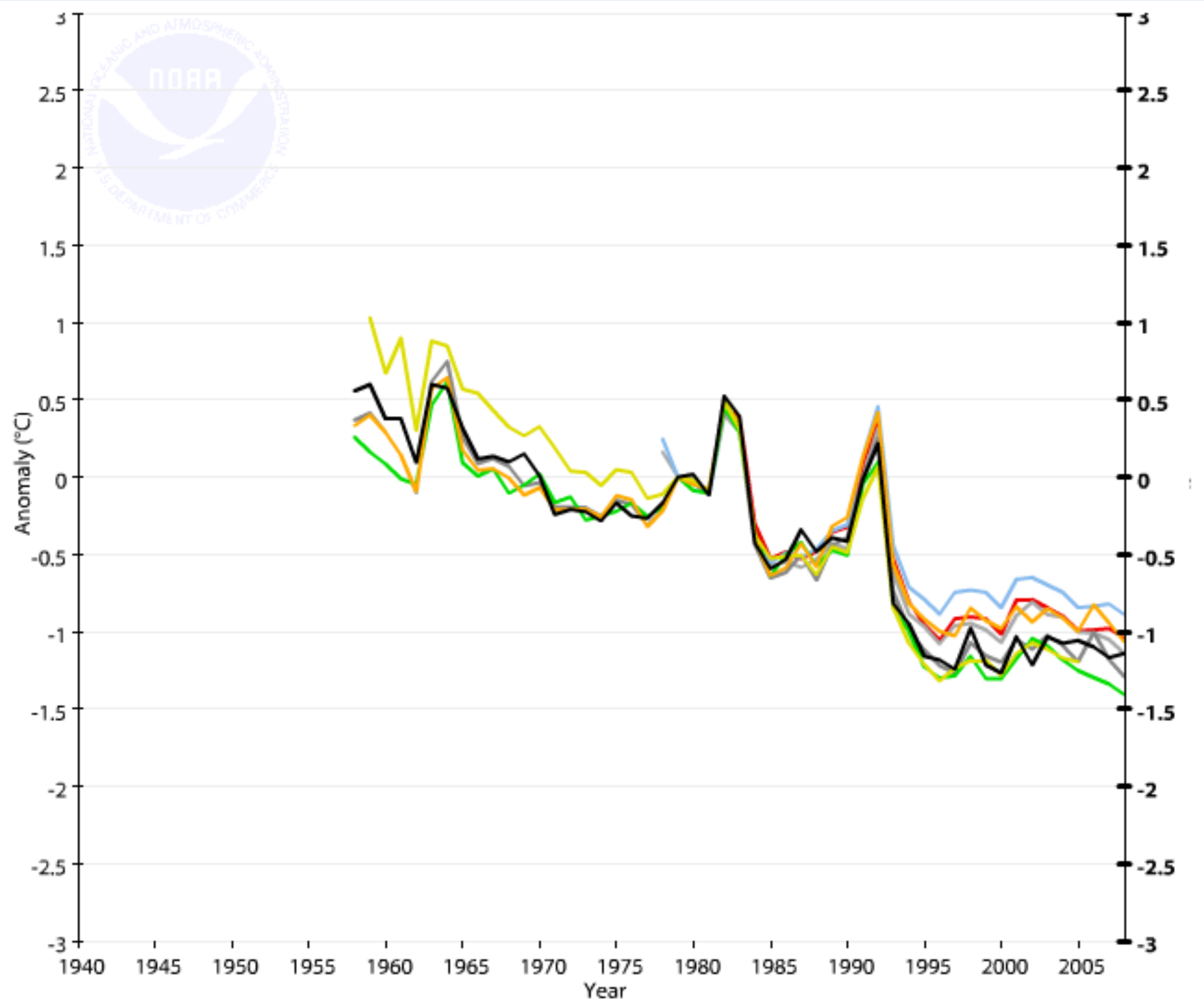
Global Ocean Heat Content
(upper layers)



Northern Hemisphere Sea Ice

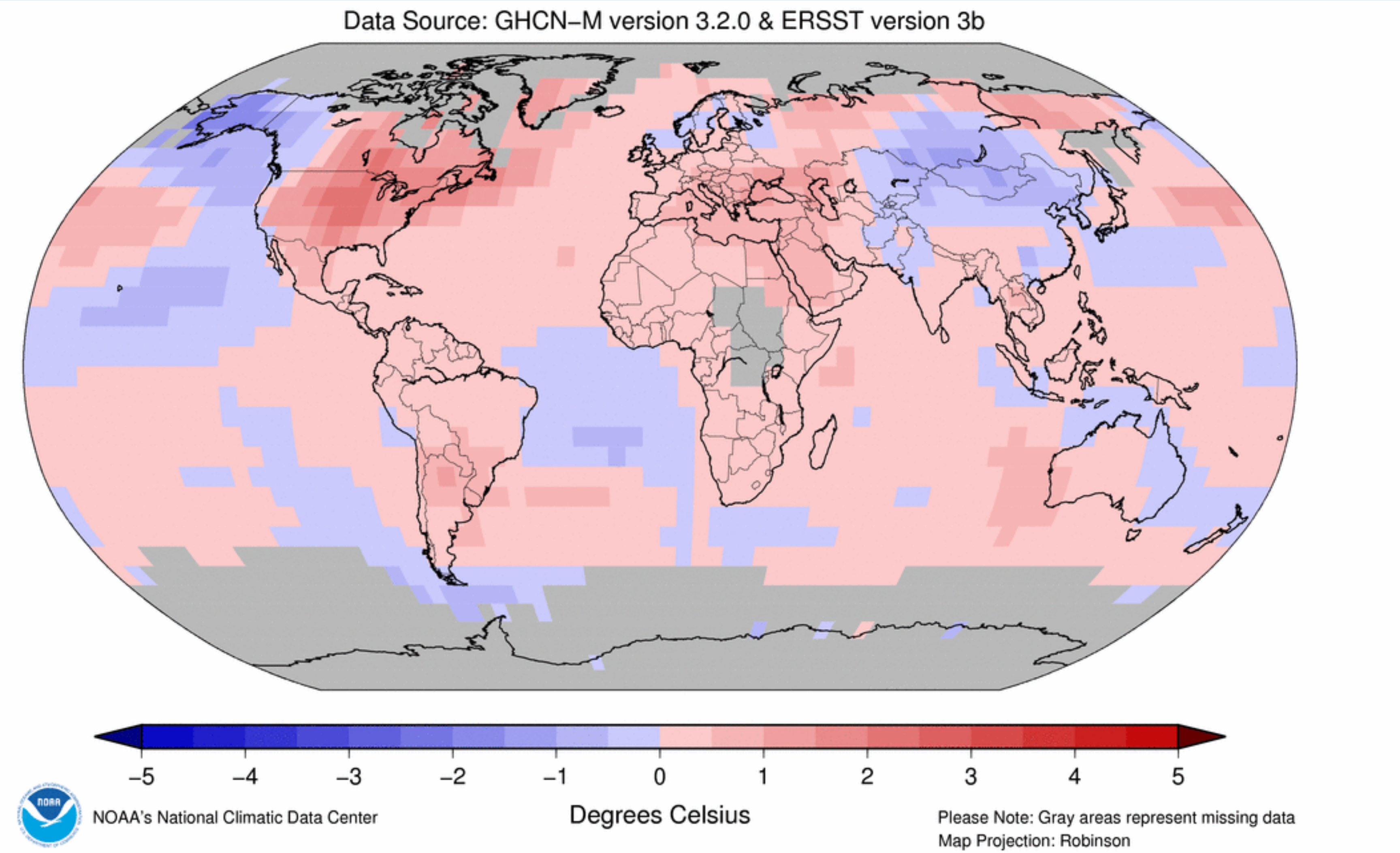


Stratospheric Temperature



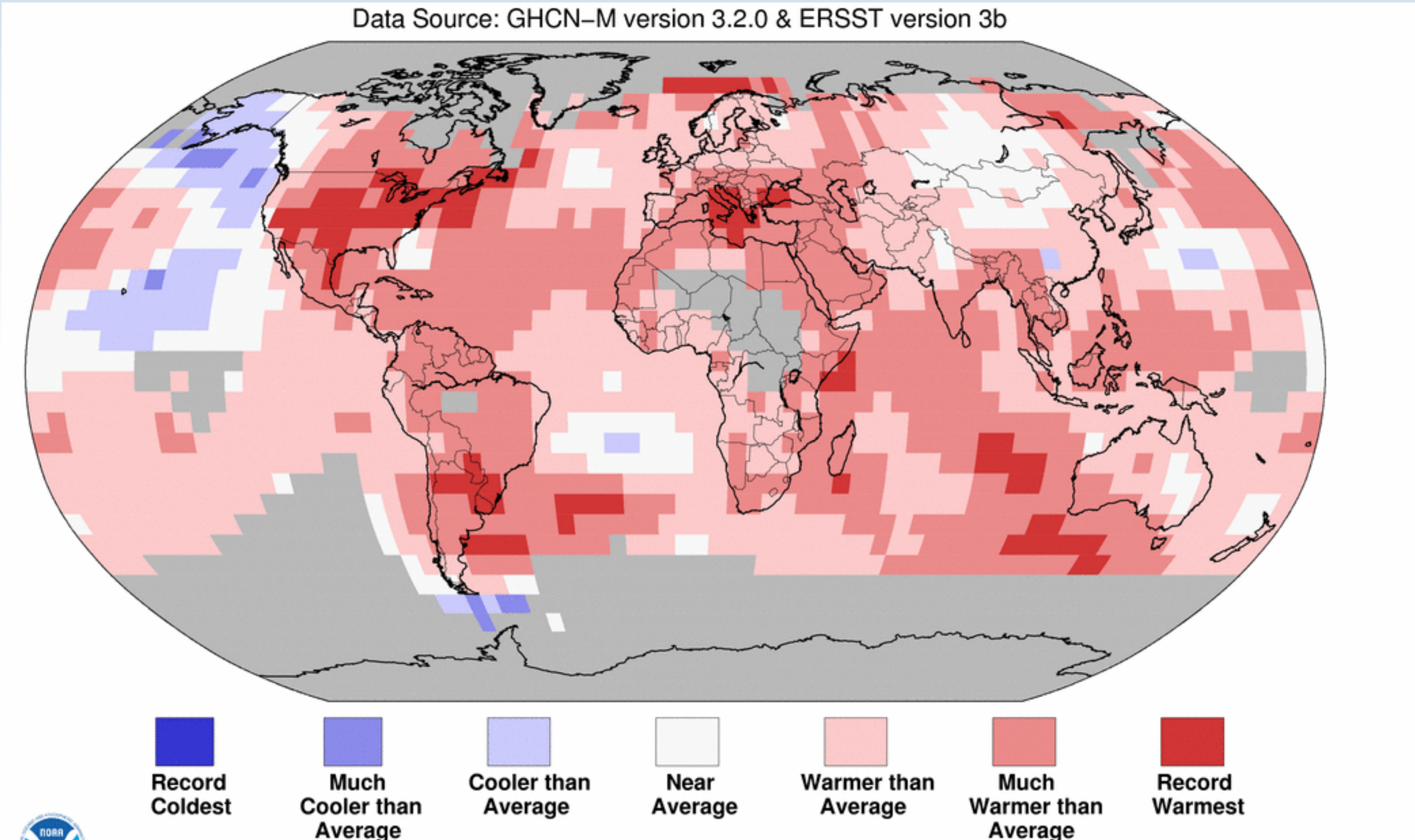
Land & Ocean Temperature Anomalies

Annual 2012 (with respect to a 1981-2010 base period)

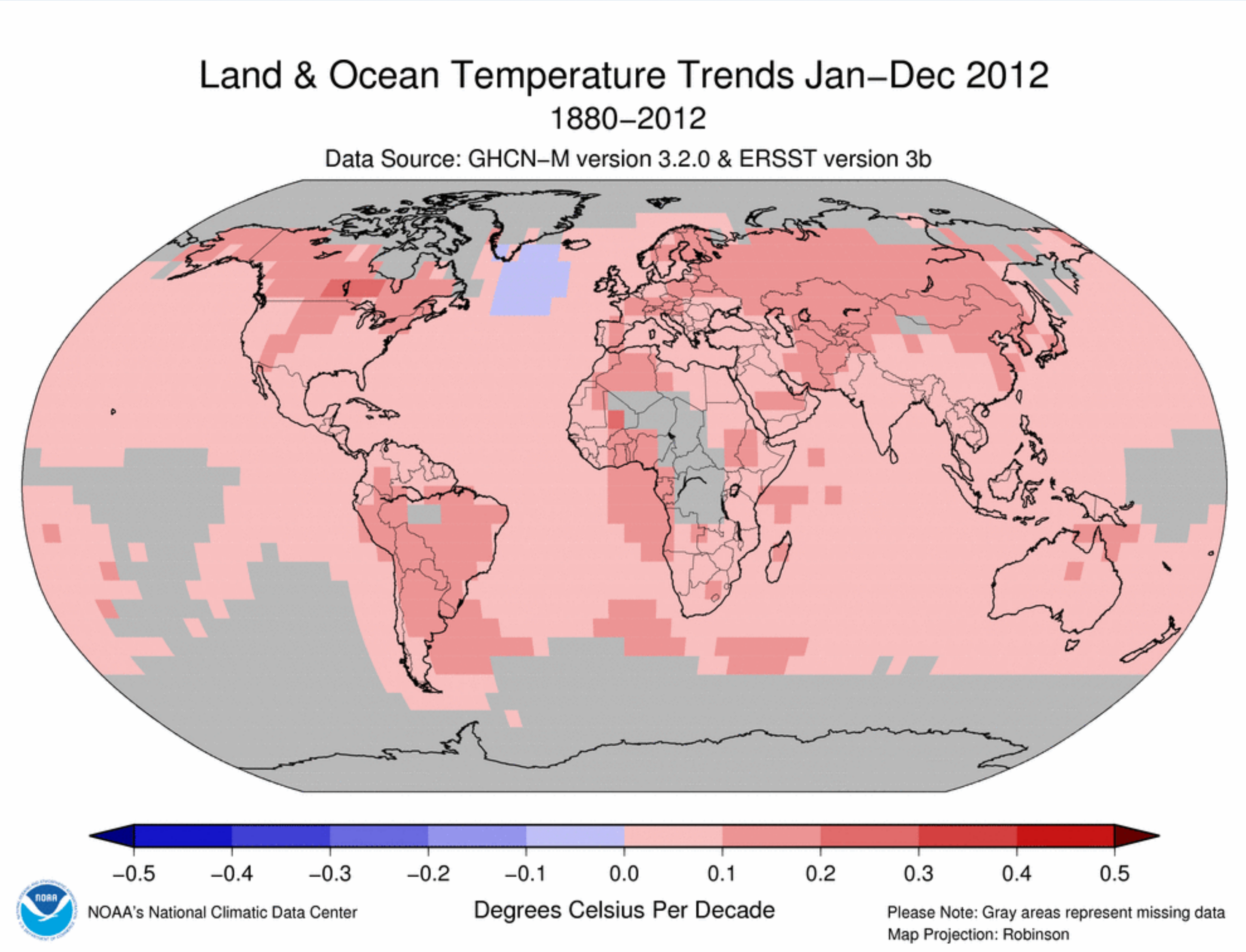


Land & Ocean Temperature Percentiles

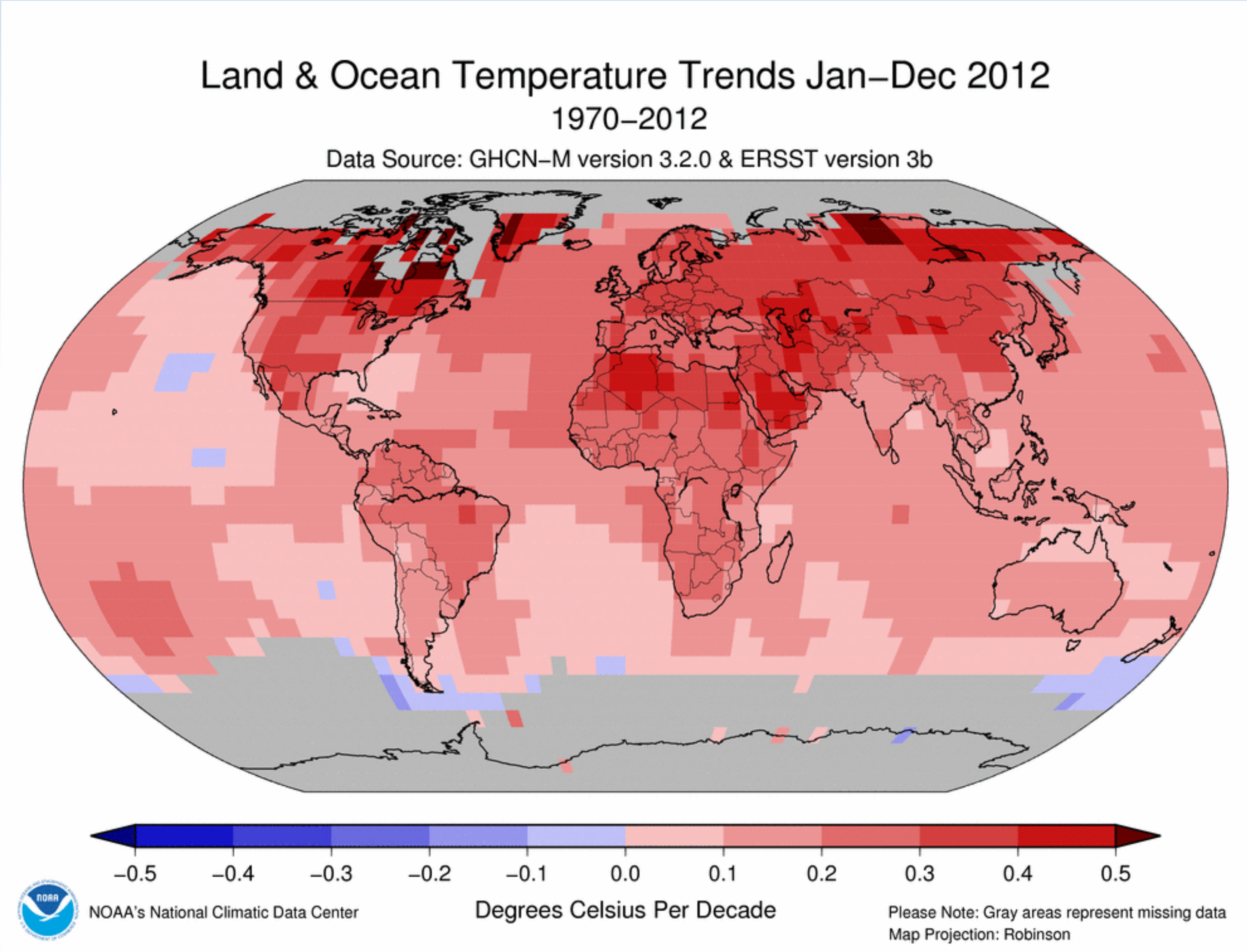
Annual 2012 (grid points with at least 80 yrs on record)



Trends since 1880

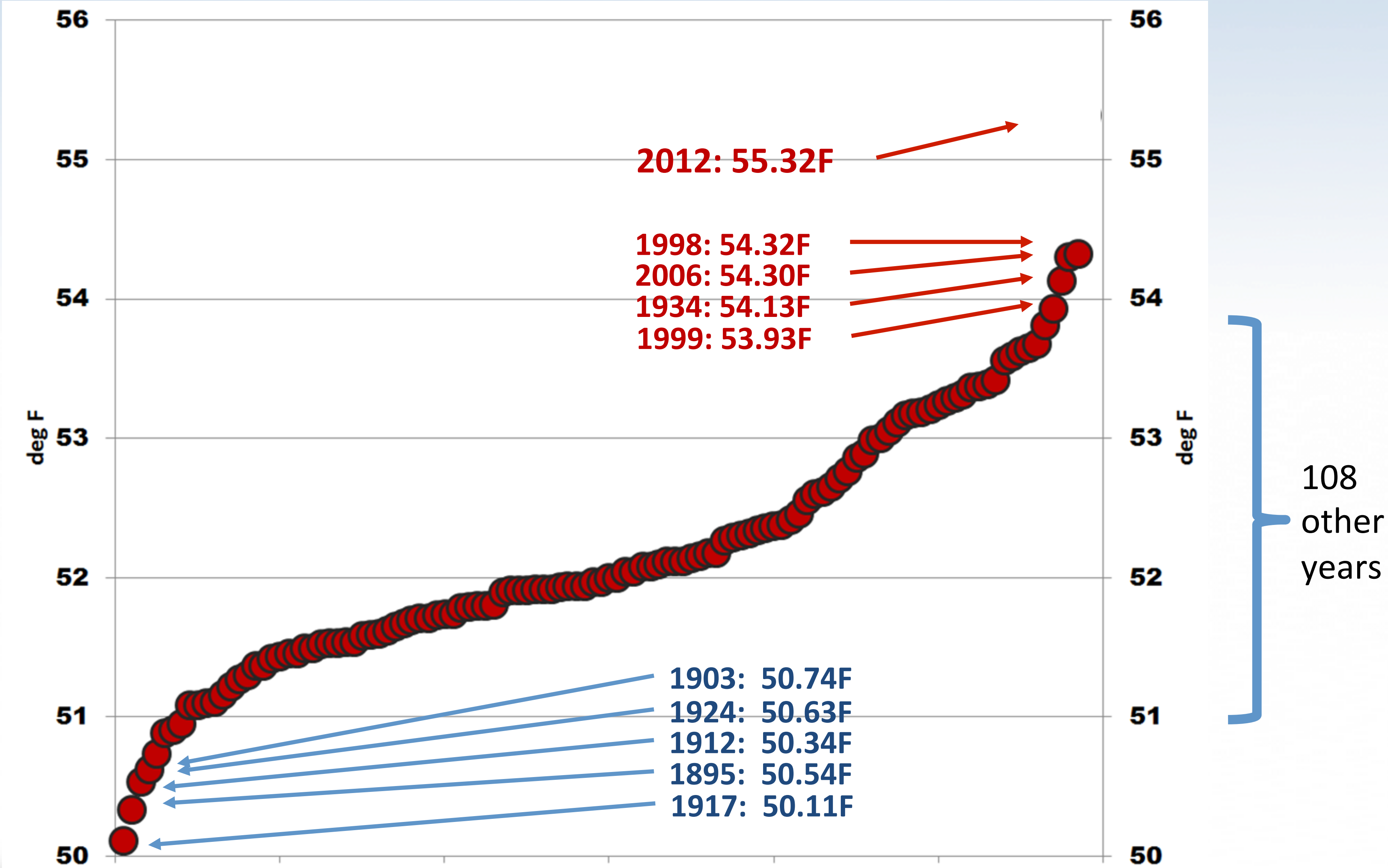


Trends since 1970



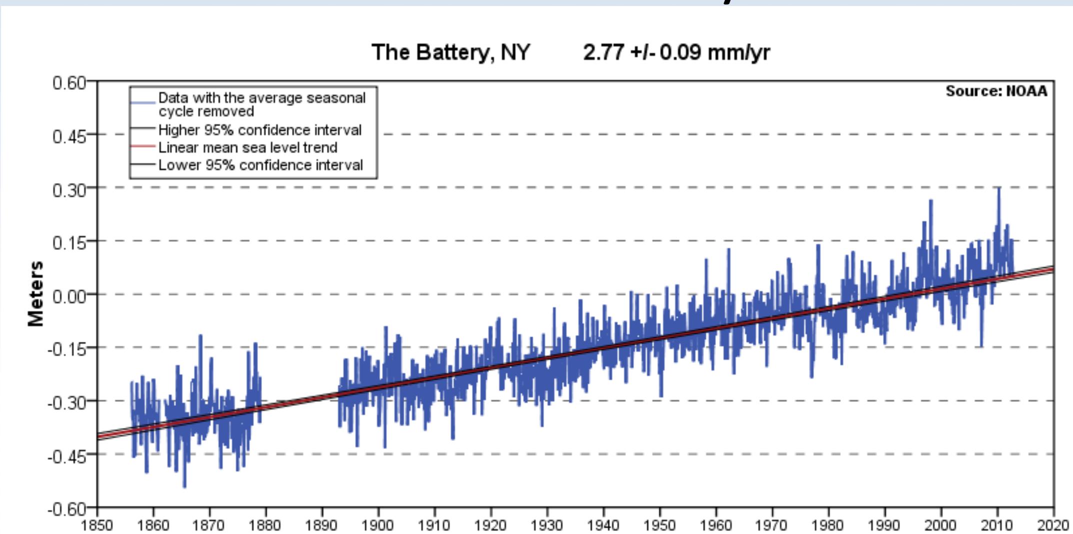
Part 2: Climate Change and Extreme Weather

Warmest Year on Record for the CONUS

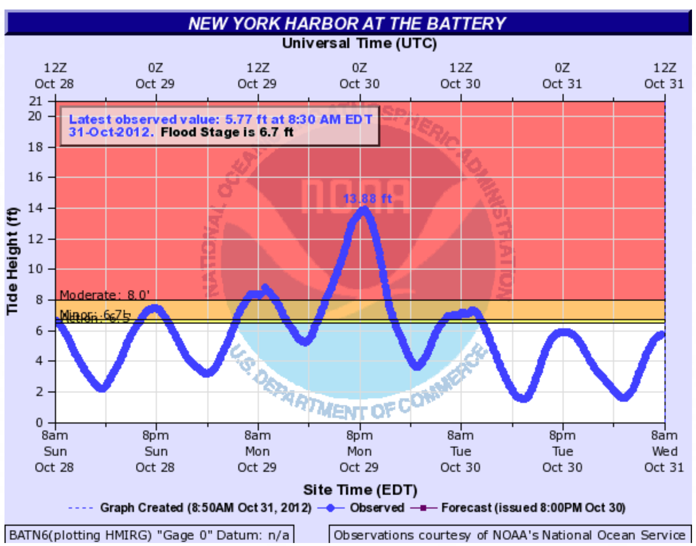


Hurricane Sandy

Sea level rise at the Battery since 1855

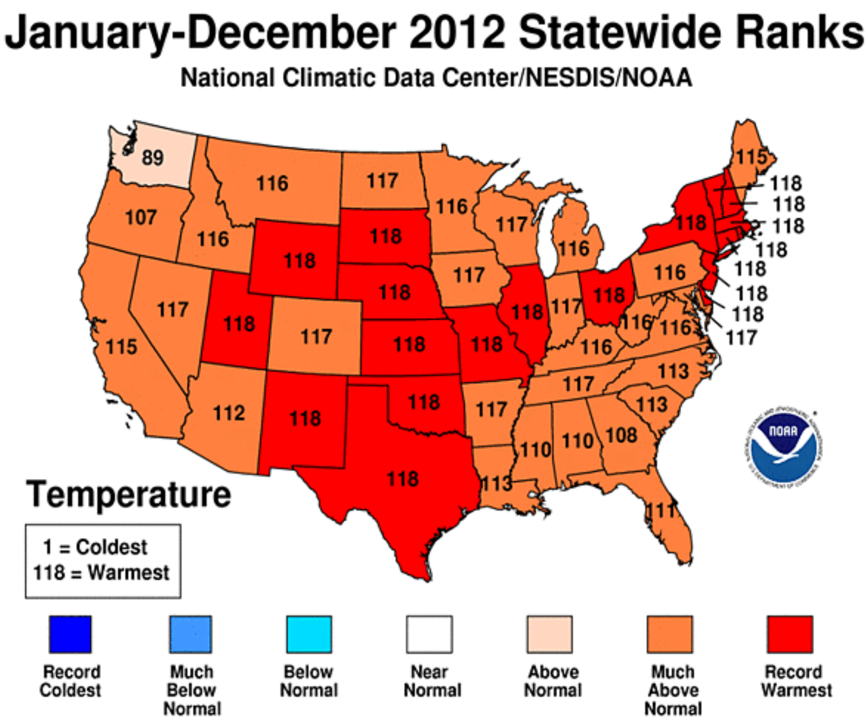


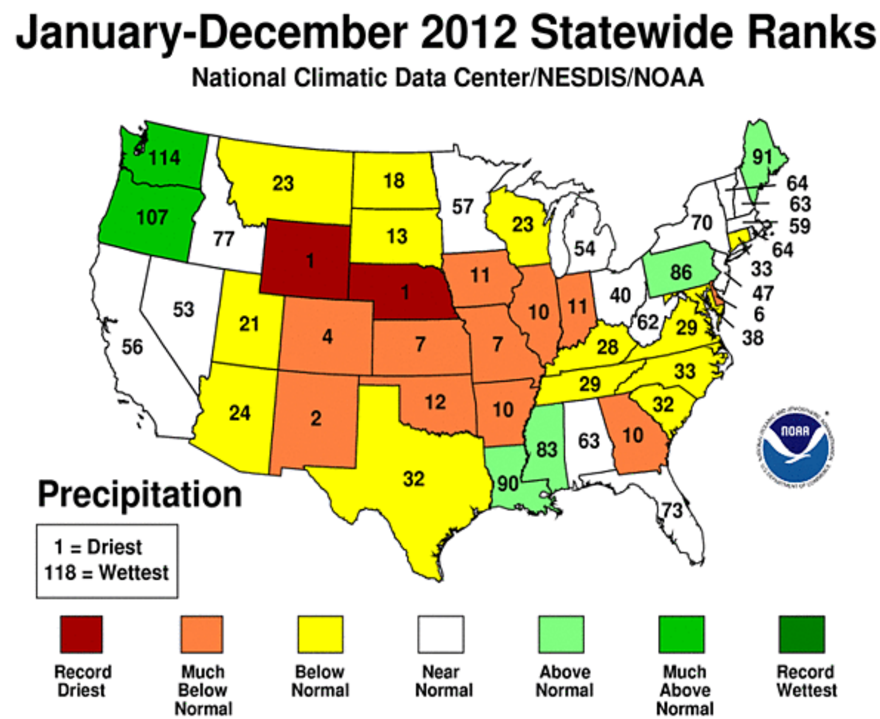
Record flooding during Sandy



Battery Park underpass after Sandy hit

United States Climate Highlights
2012





A Few Notes Before We Start

- Weather is complex
- The intersection of weather and climate is quite complex
- The intersection of extreme weather and climate is stunningly complex
- **Science is Conservative**

Weather ~~versus~~ Climate

- **Weather** is local and short-term. It can change day to day, hour to hour, and even minute to minute.
- **Climate** is what the weather is normally like year to year and decade to decade. Climate is usually measured over periods of about 30 years.

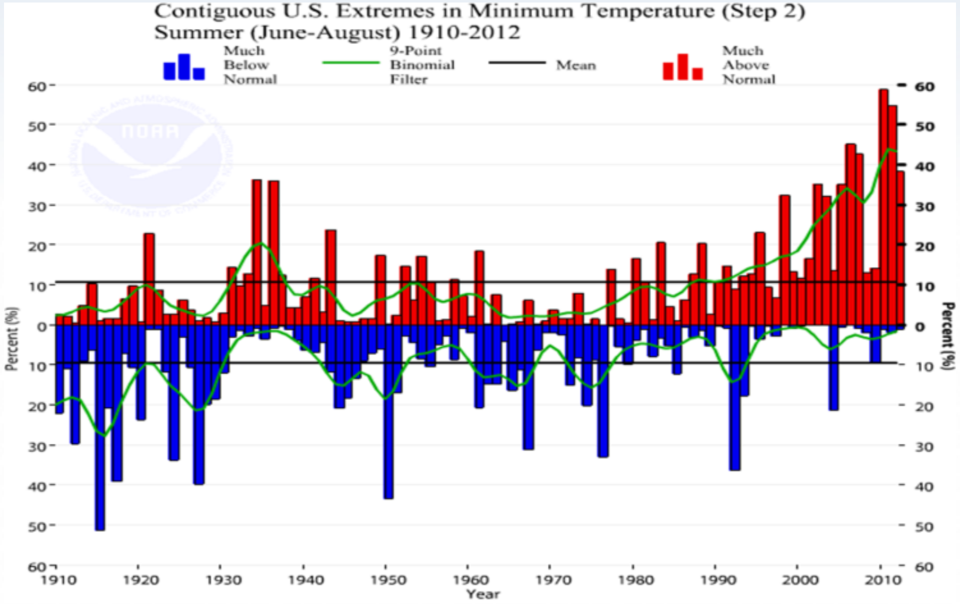
***Climate** tells you what clothes to buy and have in your wardrobe, **weather** tells you what to wear each day.*

Relationship between weather & climate

Literature Review: Stallone et al. (1976)

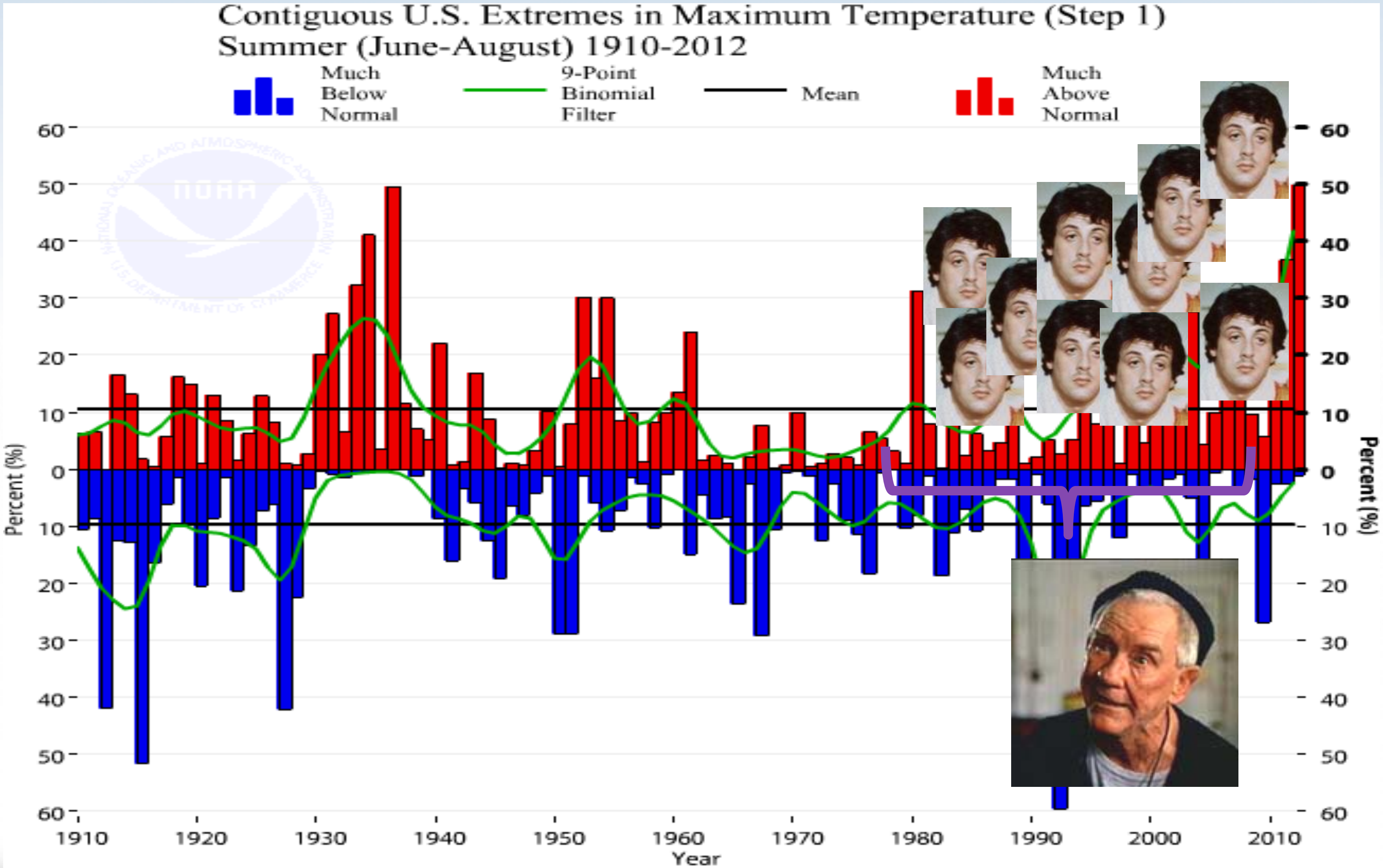
Heat Waves / Extreme Heat

- Heat waves defined in many different ways, depending on affected population
- The data are in great shape in the USA
- The Gist: extreme heat is one of the "easy ones". There will be more extreme heat … and there already is



US Climate Extremes

summer minimum temperatures



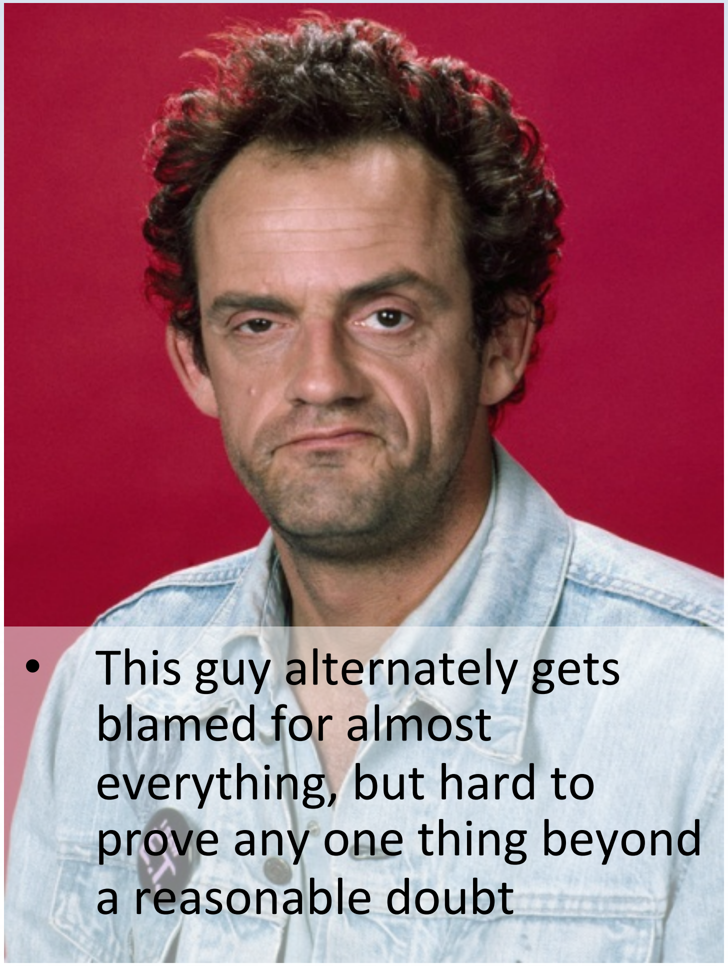
And Again

- Kinda impulsive
- Short attention span
- Very sensitive to his environment
- Prone to occasional extreme behavior, given the "right set of ingredients"
- Forgets quickly, "moves on"
- Let's call this kid weather

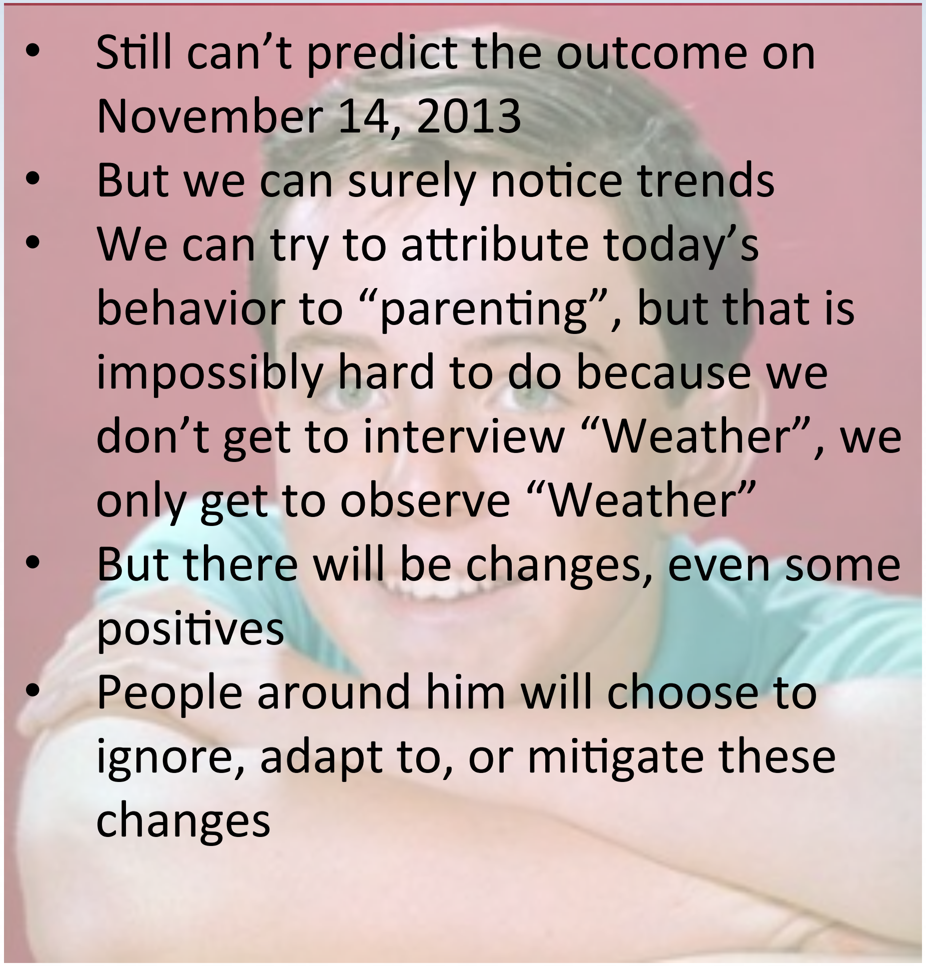
And Again

- Still impulsive
- Still responds mostly to his immediate environment
- Still spends months at a time hanging out with his influential friends “La Nina” and “el Nino”
- But seems to be getting into weird situations more often
- The drivers of his days mostly similar
- The trajectory of his life has changed

And Again



- This guy alternately gets blamed for almost everything, but hard to prove any one thing beyond a reasonable doubt



- Still can’t predict the outcome on November 14, 2013
- But we can surely notice trends
- We can try to attribute today’s behavior to “parenting”, but that is impossibly hard to do because we don’t get to interview “Weather”, we only get to observe “Weather”
- But there will be changes, even some positives
- People around him will choose to ignore, adapt to, or mitigate these changes

Extreme Events

- How we detect, count and measure extreme events has changed, for each event, since the mid-20th Century.

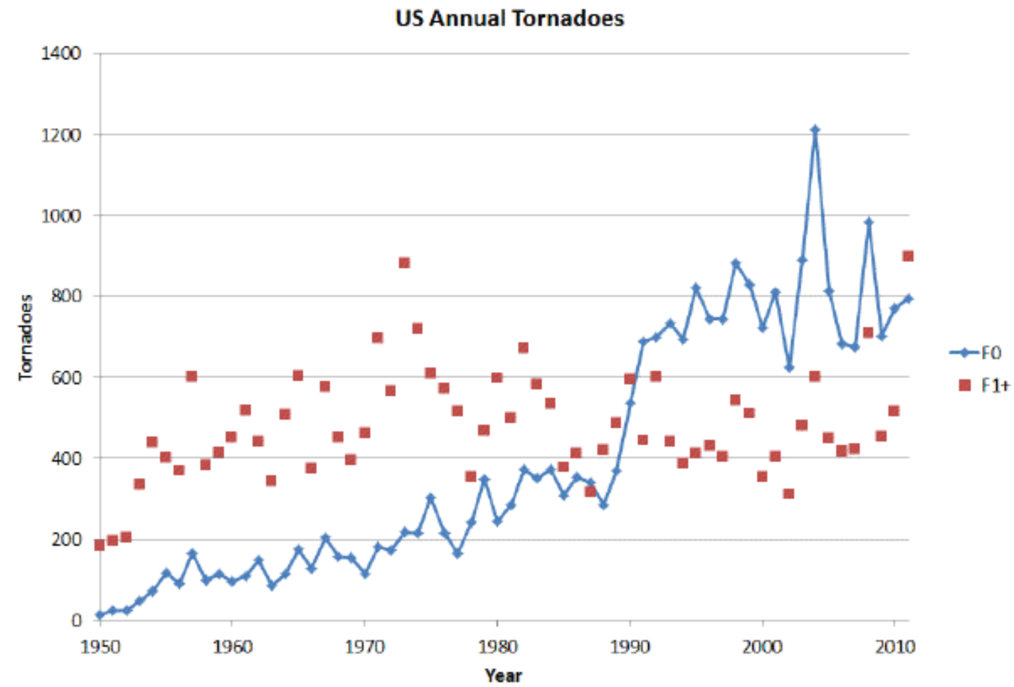


Figure 1. Reported tornadoes in NWS database from 1950-2011. Blue line is F0 tornadoes, red dots are F1 and stronger tornadoes.

Extreme Events

- Extreme events are borne from a set of ingredients.
- Tracking *the* ingredients is very useful!

Violent Local Weather: Ingredients

- Instability

  Several flavors, but generally related to warm, moist air low in the atmosphere, cold, dry air higher in the atmosphere

  High Instability: powerful updrafts

- Wind shear

  Changing of wind speed and/or direction as you go up

  High wind shear: well-organized, long-lived t-storms and related phenomena

- Tornadoes need very high wind shear, generally

Violent local weather: Trends

- Difficult to establish long-term trends because we're so much better at predicting/verifying than we used to be
- The instability ingredient is likely increasing / will increase
- The shear ingredient, in the long term, decrease
- Some issues of scale (long-term trends versus scale of event)

July 23, 2010: Vivian, SD

Image courtesy Aberdeen, SD WFO

Kansas State record Hailstone

Photos from National Weather Service, Wichita, KS WFO. Credits: Frank Kotsch and Melissa McCarter

Hurricanes

- Ingredients
- Warm water
- Supportive shear profile

Hurricanes / TCs

- Still considerable scientific work to be done to determine trends of TC frequency
- Slightly more confidence that TCs will become more intense (on average) in certain basins
- Known: Sea level is rising, this makes the impact of a given TC potentially more destructive

Flooding / Extreme Precipitation

- Ingredients for Extreme Precipitation:
  - Sufficiently moist air
  - Sufficient “lift” or rising motion

Extreme Precipitation

- Another one of the "easy ones"
- Rule of thumb (works often, not always) for general precipitation in a changing climate: wet places/seasons/phenomena get wetter; dry places/seasons/phenomena get drier
- For the most part, the data are in great shape, and support this

Heat Waves / Extreme Heat

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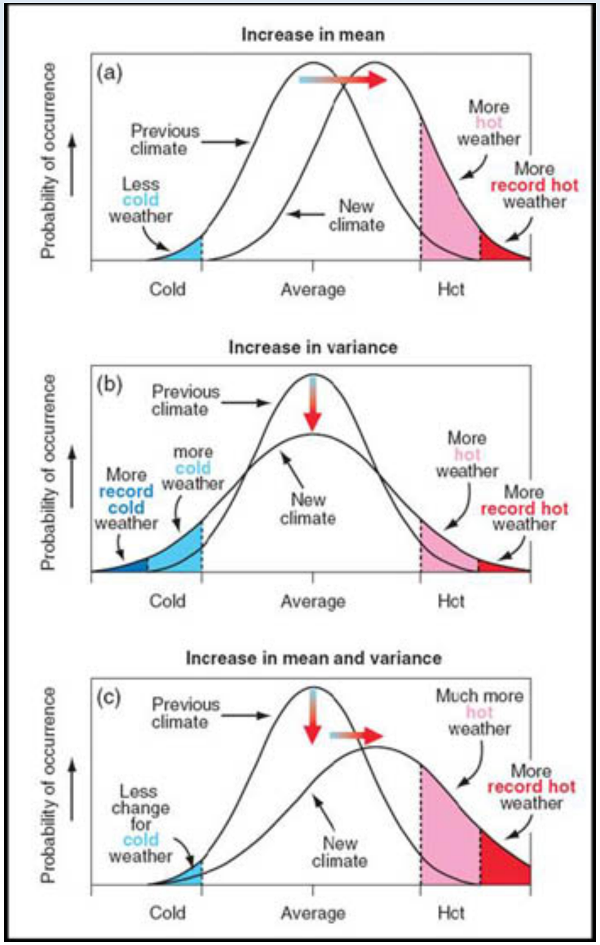

Big picture Climate Extremes since 2010

- Mar 2010: MA NJ RI
- Apr 2010: IL NJ CT RI ME
- May 2010: LA
- Jun 2010: DE LA* MD NC NJ RI VA IA MI
- Jul 2010: DE RI
- Aug 2010: FL* LA*
- Sep 2010: NM MN
- Oct 2010: FL
- Dec 2010: FL GA NV UT
- Apr 2011: IL IN KY NY OH PA WV
- Jun 2011: LA TX NM
- Jul 2011: OK TX
- Aug 2011: AZ CO FL LA NM OK TX NH NJ NY VT
- Sep 2011: OR PA
- Mar 2012: CONUS AR CT GA IL IN IA KS KY MI MN MS MO NE NH NJ NY OH OK PA RI SC SD TN VT WV WI WY CO
- Jun 2012: CO WY FL
- Jul 2012: CONUS VA
- Aug 2012: NV NE WA WY
- Sep 2012: MN MT ND SD
- Oct 2012: DE
- Dec 2012: DE

- 1Q 2010: FL ME NH* VT*
- Spr 2010: CT* MA* ME MI* NH* NJ* NY* RI VT*
- 2Q 2010: CT DE LA MA ME MD NC NH NJ RI VA
- Sum 2010: AL DE FL GA MD MS NC NJ RI SC TN VA WI
- 3Q 2010: FL MA WI
- 4Q 2010: NV FL
- CY 2010: NH* RI* ND
- Spr 2011: IN KY MT NY OH PA VT WA WV WY TX
- 2Q 2011: OR WA TX IN KY MI OH NM
- Sum 2011: LA NM OK TX CT NJ TX
- 3Q 2011: NM TX MD NJ VT
- Aut 2011: OH PA
- 4Q 2011: MA NH RI VT
- CY 2011: CT IN KY NJ NY OH PA
- 1Q 2012: CONUS CT DE IA IL IN KS KY MA MI MN MO ND NH NJ NY OH OK PA RI SD TN VA VT WI WV CT
- Spr 2012: CONUS AL AR CO CT DE GA IA IL IN KS KY LA MA MD MI MN MO MS NC NE NH NJ NY OH OK SC SD TN TX VA VT WI WV WY DE
- 2Q 2012: CO KS AR
- Sum 2012: CO WY FL NE WY
- 3Q 2012: NV WY MS MT NE SD
- CY 2012: CONUS CT DE IL KS MA MO NE NH NJ NM NY OH OK RI SD TX UT VT VA WY NE WY

WARMEST COOLEST
WETTEST DRIEST

Summary

- Climate and weather have, in some ways, a teacher-student, parent-child, coach-athlete relationship
- Climate affects weather outcomes by changing the frequency and nature of how ingredients come together
- We are seeing changes in the mean
- We are seeing changes in certain types of extreme weather