Climate Trends in New England and Its Impact on Riverine Flood Behavior

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Northeast River Forecast Center

Providence Street – West Warwick, RI at 1030 am Wednesday 3/31/10

Outline

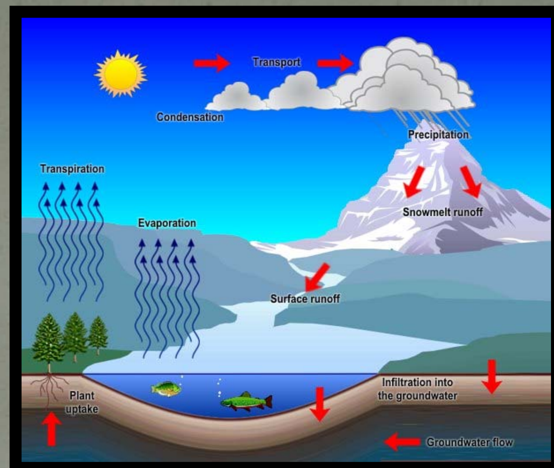
- From a "Practitioner's Perspective"
- Big Rainstorms & Increased River Flooding
- How may a changing climate be impacting storm behavior in the Northeast?
- What does this all mean?

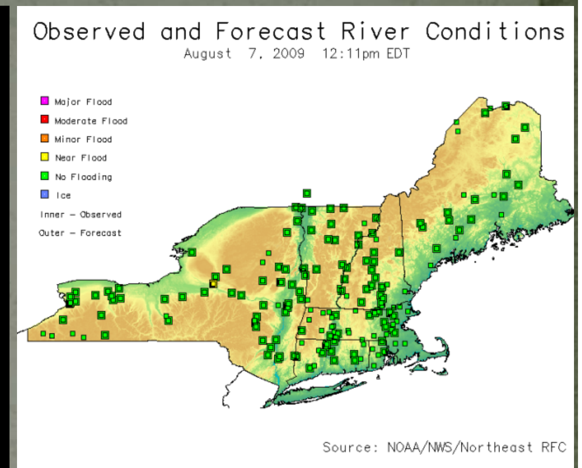
A few caveats

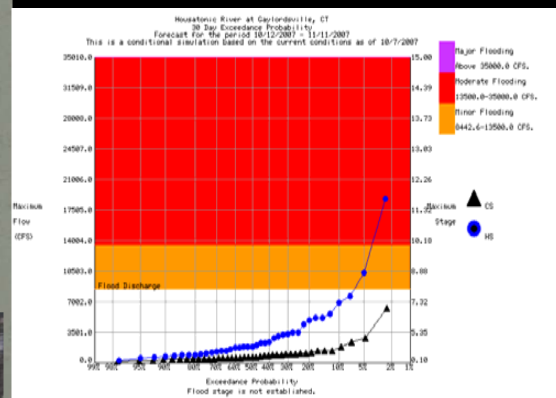
- I’m not a climate scientist!
  - I’m a practitioner
- I have the benefit of living in this part of the country my entire life
  - It’s different now – beyond temps & precip
  - Changes in vegetation, insects, bird life & ***river response***
  - Sea level rise
- The mission: Develop a better understanding of the current regime vs. the old & what that means to how we model our rivers
  - “Accumulation of Ingredients” – not one single “source”
  - Where we are headed: that’s the million $$ question!

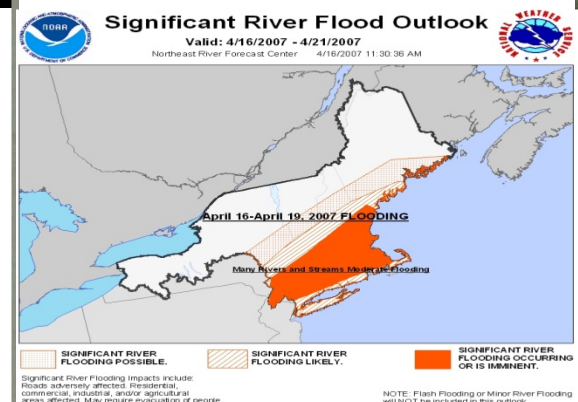
River Forecast Center Responsibilities

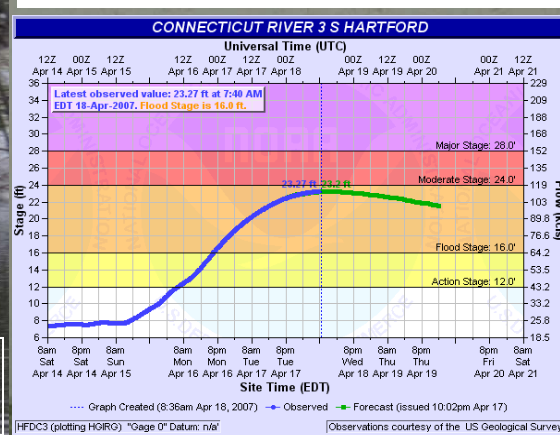
- Calibrate and implement a variety of hydrologic and hydraulic models to provide:
  - River flow and stage forecasts at 180 locations
  - Guidance on the rainfall needed to produce Flash Flooding
  - Ensemble streamflow predictions
  - Ice Jam and Dam Break support
  - Water Supply forecasts
  - Partner with NOAA Line Offices to address issues relating to Hazard Resiliency, Water Resource Services, Ecosystem Health and Management, and Climate Change

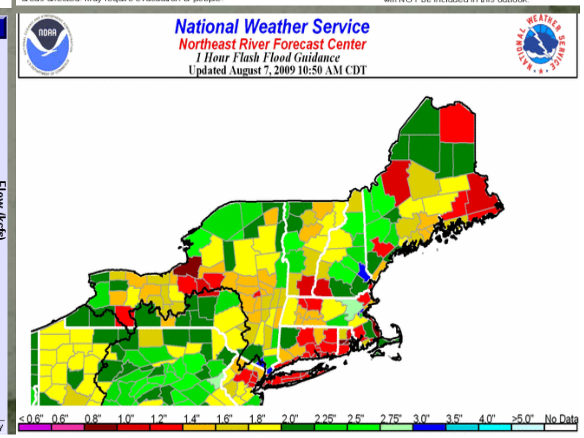












Moderate flooding – Connecticut River at Portland, CT.

My “religious experience”:

Takes on a whole new meaning when it hits your hometown…

Providence Street – West Warwick, RI at 1030 am Wednesday 3/31/10

I've been a little busy these past 8 years!
Job Security in the face of changing flood behavior!!

Record flooding along the Fish and Saint John Rivers – northeast Maine, 4/30/2008

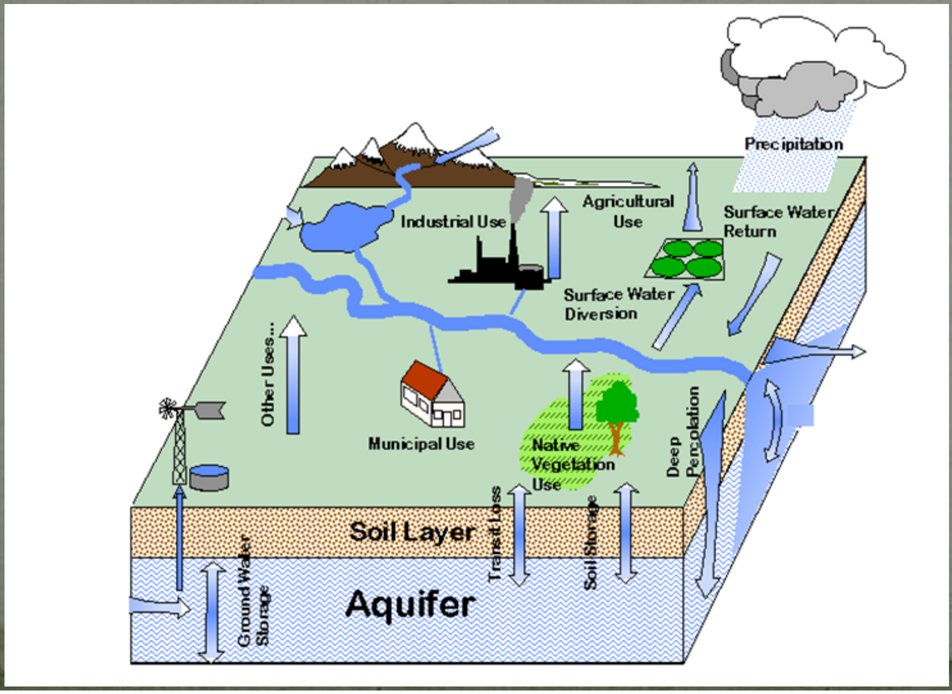
St-Jean-sur-Richelieu, Quebec, Canada, 5/6/11
Photo: AP//Canadian Press, R. Remoirz

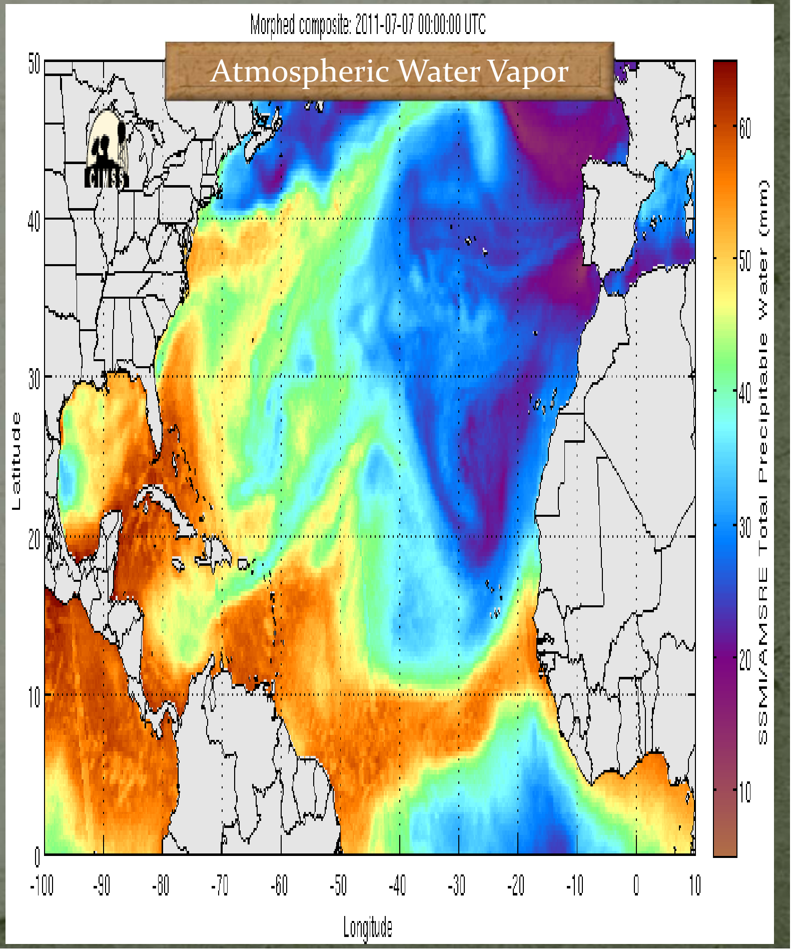
Warwick Mall – Warwick, RI at 2 pm, Wednesday March 31st, 2010

Home washed off its foundation along the Schoharie Creek, Prattsville, NY – Tropical Storm Irene

Is there a common theme to recent ?

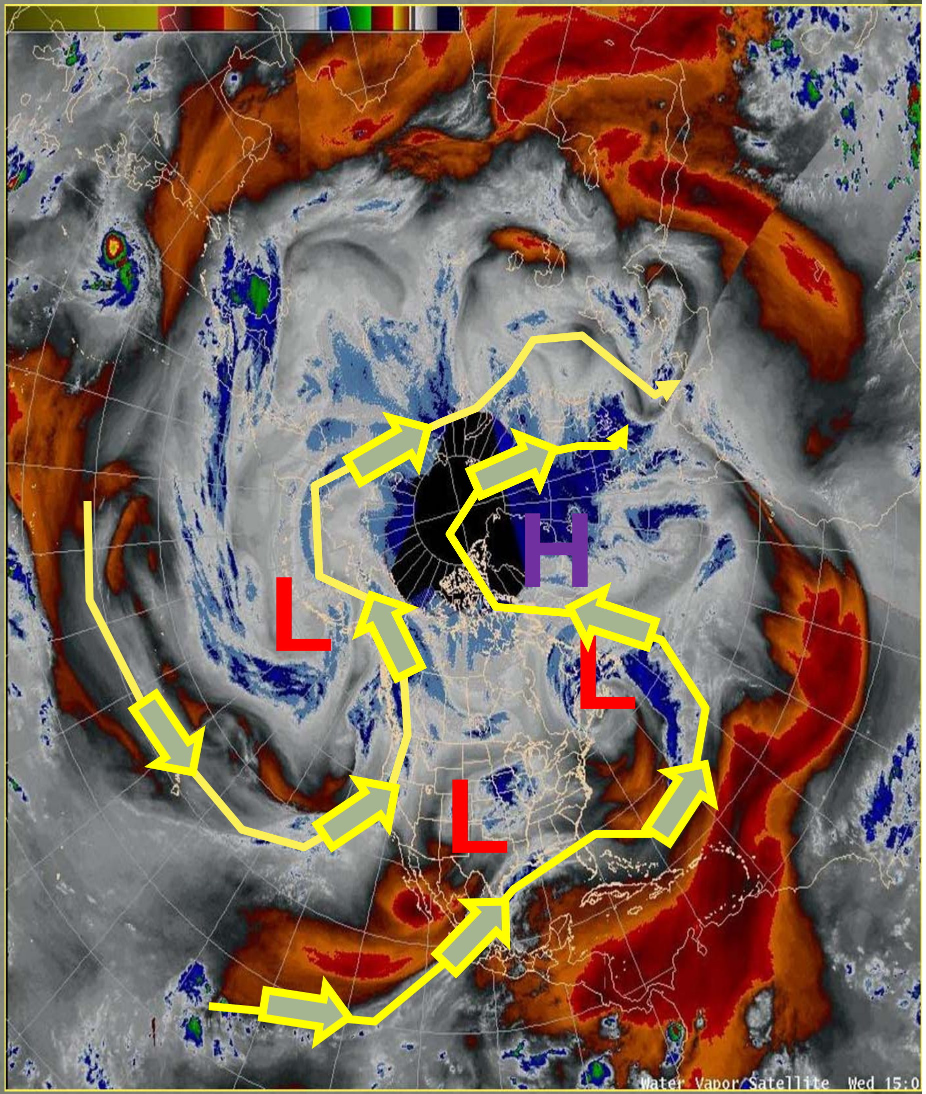
- Several:
  - Slow moving weather systems – a blocked up atmosphere
  - Multiple events in close succession or 1 or 2 slow movers
  - Resulted in saturated antecedent conditions before "main event"
  - Each fed by a "tropical connection"
    - Plumes of deep moisture





Is there a plausible "Climate Hypothesis"?

- Modest changes in air & sea temperatures = atmosphere can hold more moisture
  - New England is in close proximity to the ocean and the Gulf & Atlantic moisture streams
  - Affected by dual storm tracks and blocking high pressure over Greenland
  - These ingredients offer us more "opportunities" to latch onto these plumes
- Reduction of sea ice changes upper level wind flow
  - Blocked up pattern induces slower moving storms or back-to-back-to back events



The Changing Climate

- Common themes across New England:
  - Increasing annual precipitation
  - Increasing frequency of heavy rains
  - Warming annual temperatures
  - Wildly varying seasonal snowfall
- Shift in precipitation frequency (50, 100 yr – 24 hr rain)
- For smaller (<800 sq mi) basins – trend toward increased flood magnitude and/or frequency
  - Most pronounced where significant land use change and/or urbanization has occurred

Moderate flooding – Connecticut River at Portland, CT, April 2007

I-95 in Warwick with submerged Warwick Waste Water Treatment Facility March 31, 2010 – photo from RI ANG)

Trends in U.S. Temperature: Decadal trends and 1991-2012 relative to 1901-1960

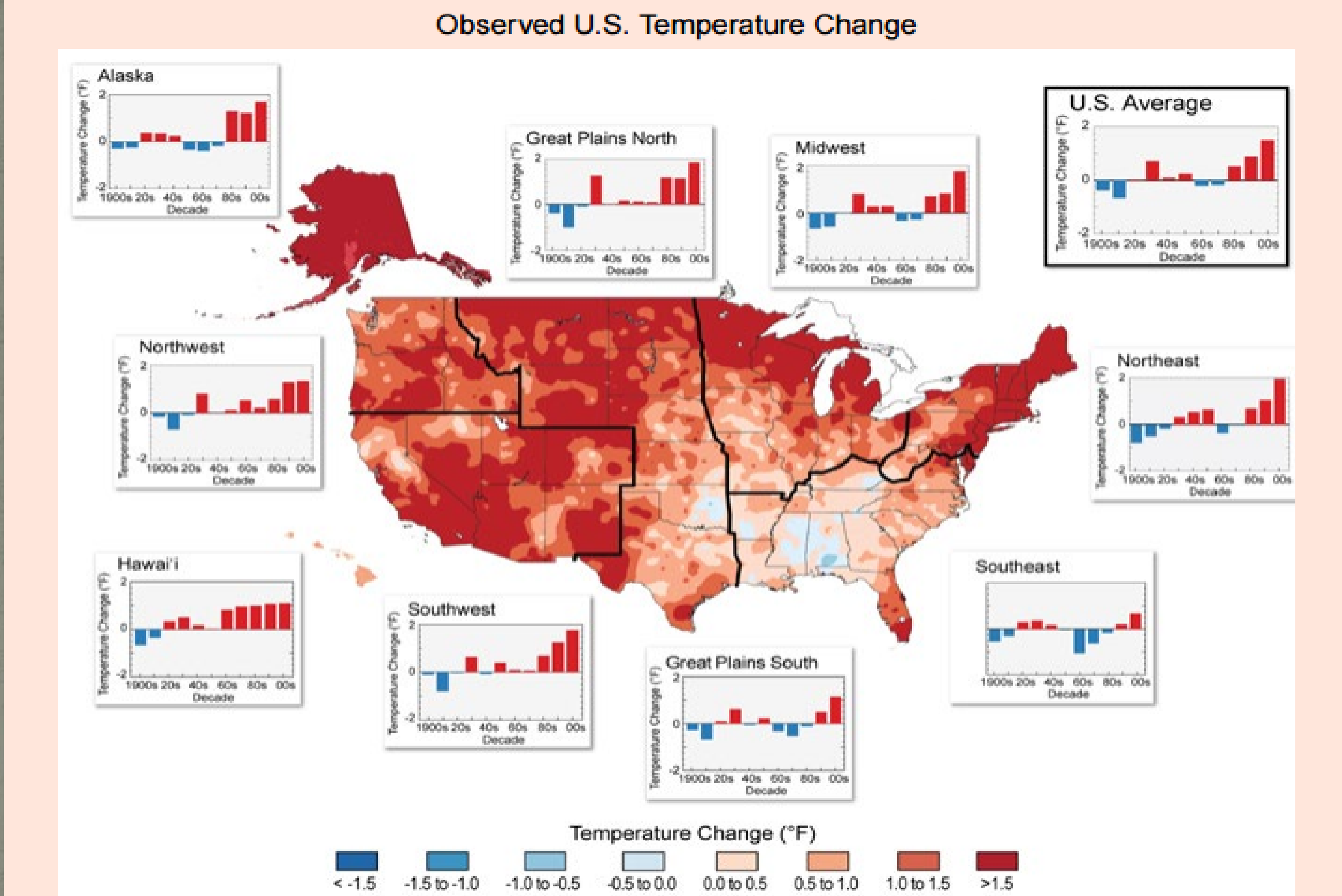
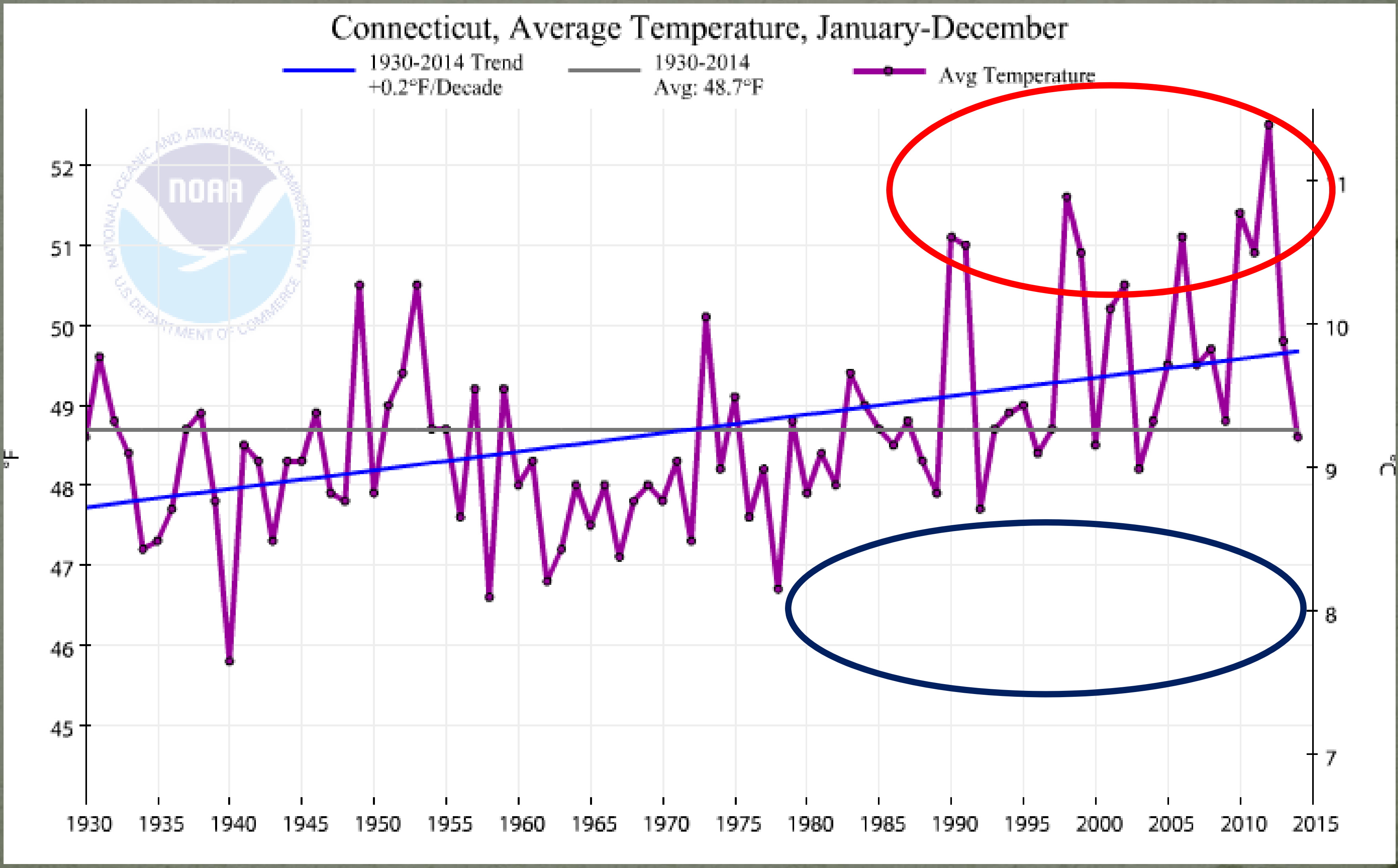


Figure 2.7. The colors on the map show temperature changes over the past 22 years (1991-2012) compared to the 1901-1960 average, and compared to the 1951-1980 average for Alaska and Hawai'i. The bars on the graphs show the average temperature changes by decade for 1901-2012 (relative to the 1901-1960 average) for each region. The far right bar in each graph (2000s decade) includes 2011 and 2012. The period from 2001 to 2012 was warmer than any previous decade in every region. (Figure source: NOAA NCDC / CICS-NC).

Statewide Temperature Trends

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



Statewide Temperature Trends

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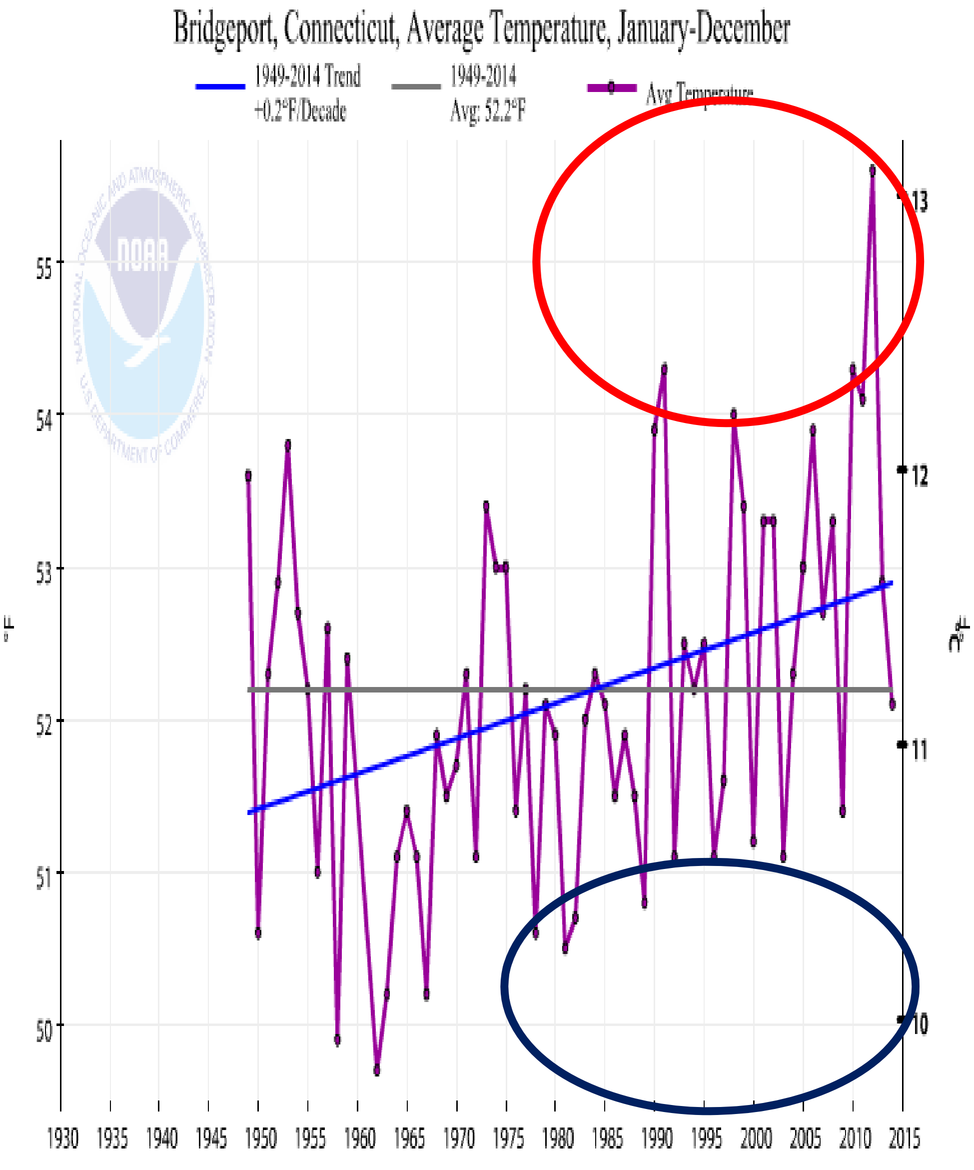
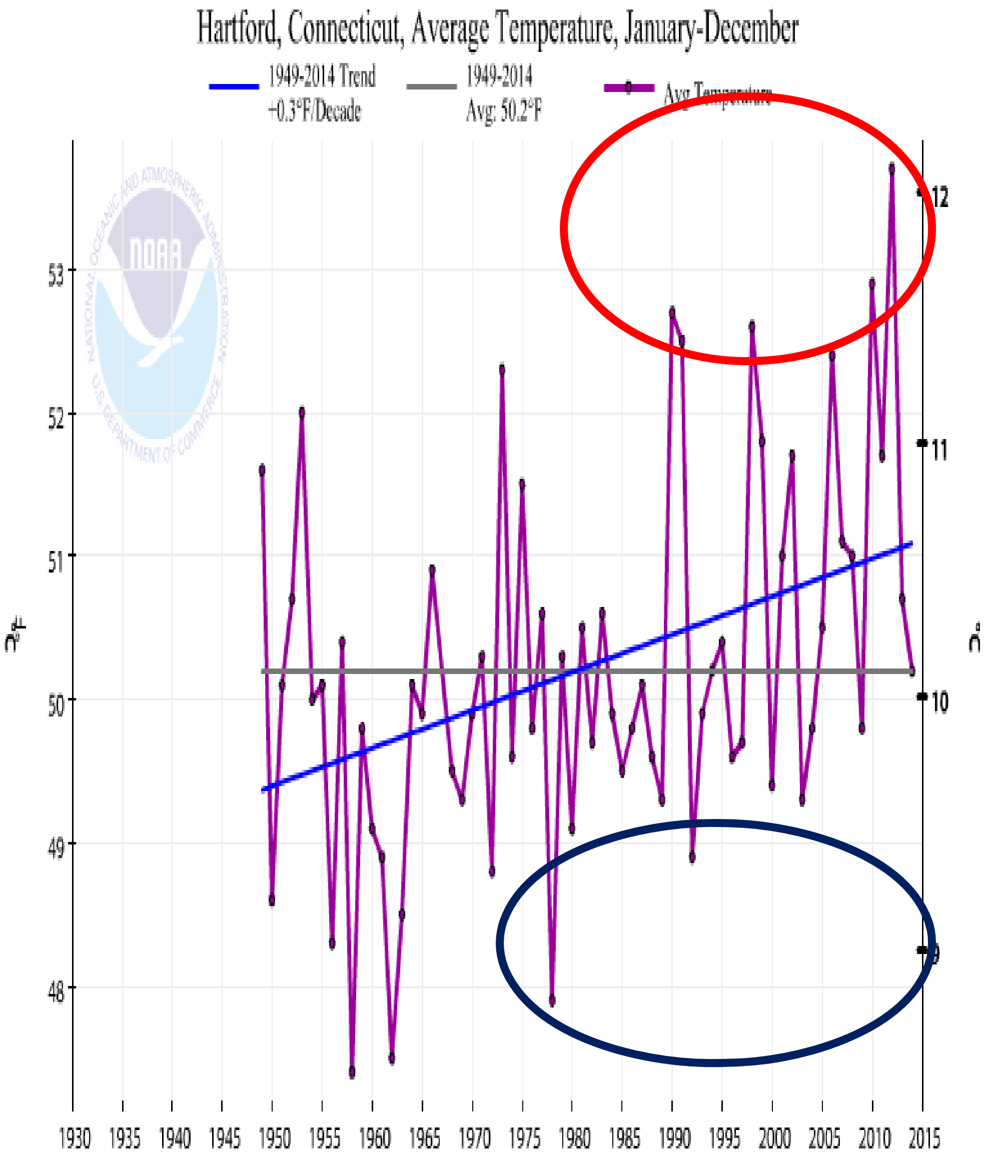




Trends in U.S. Precipitation: Decadal trends and 1991-2012 relative to 1901-1960

Observed U.S. Precipitation Change

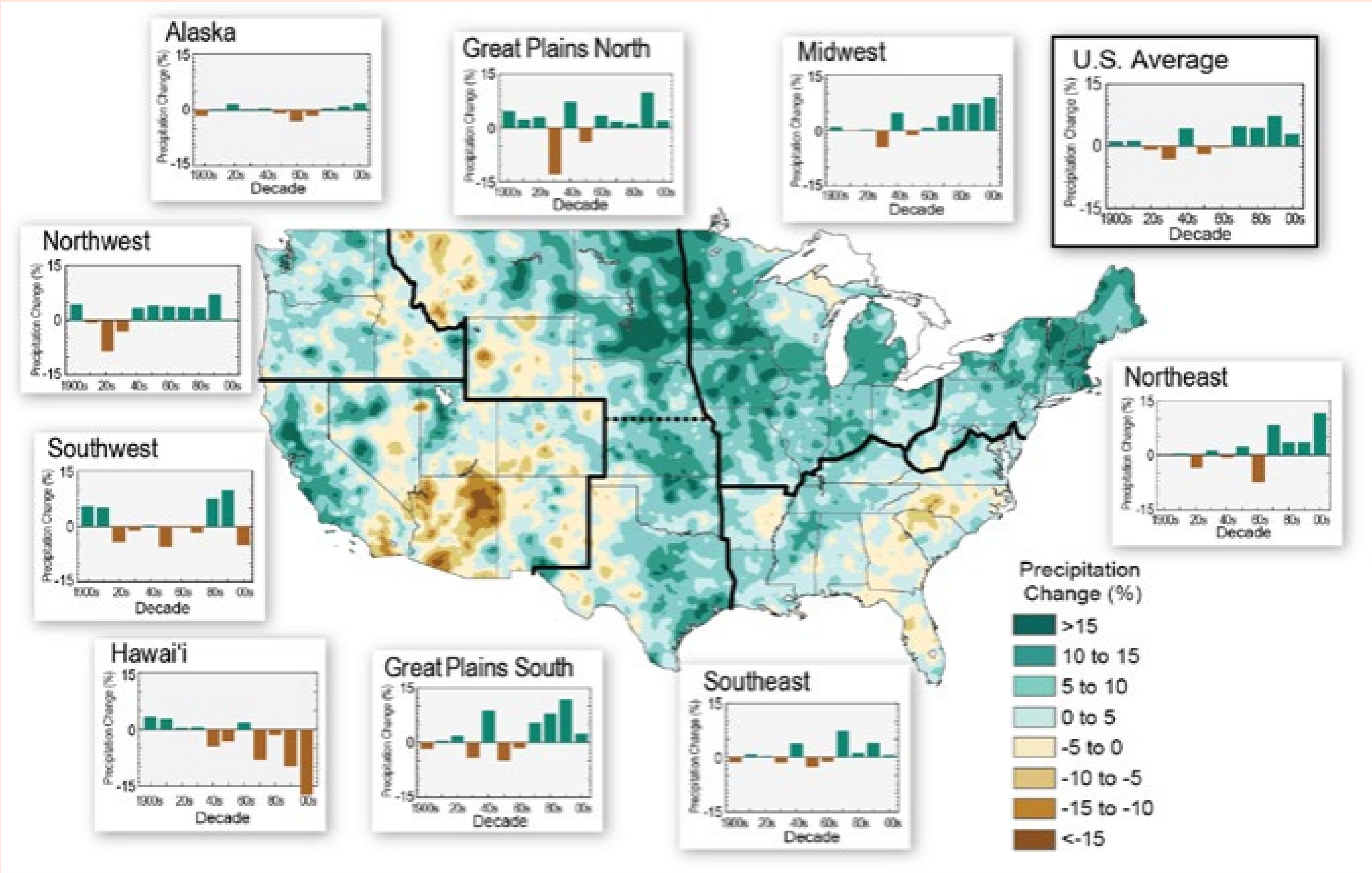
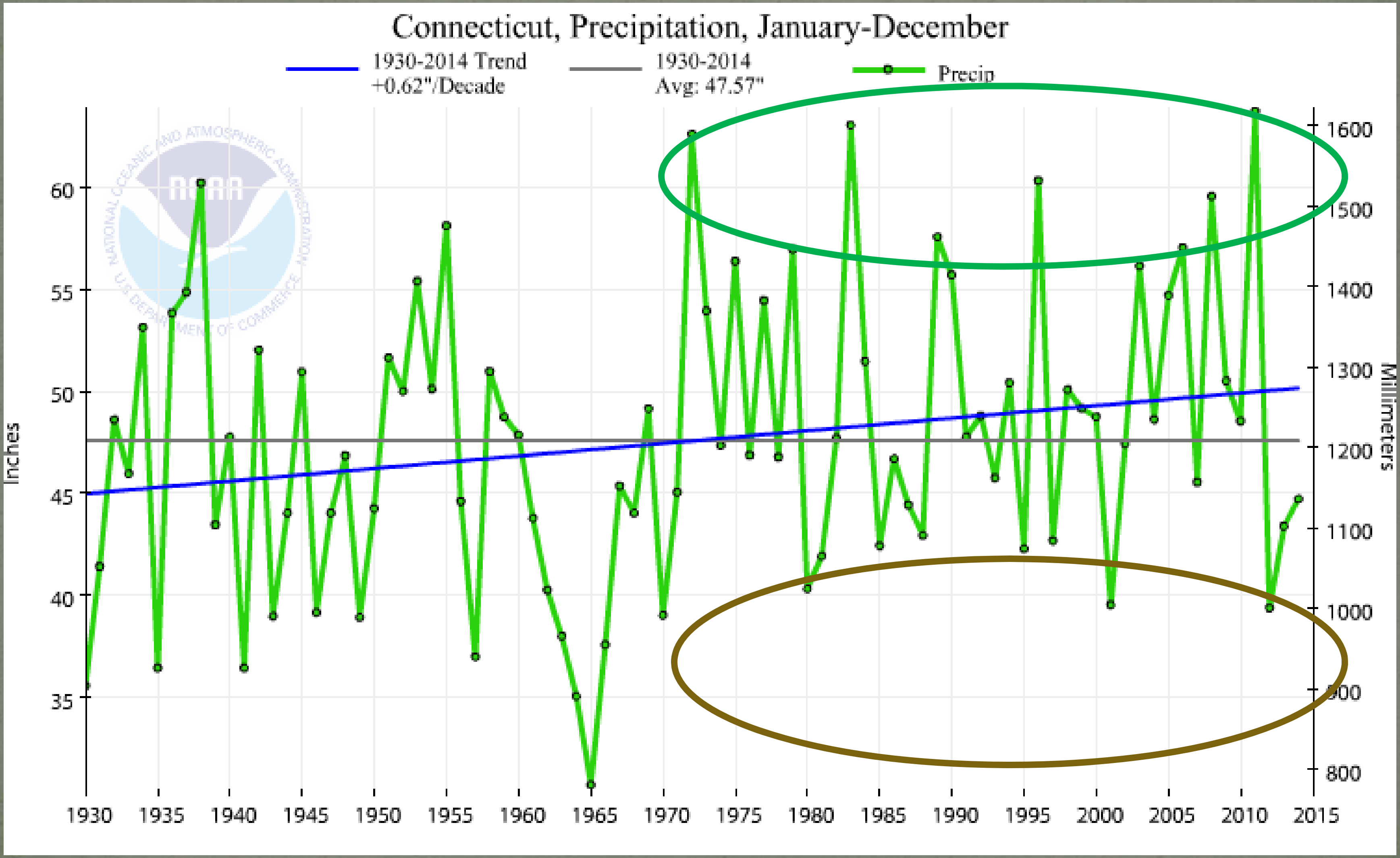


Figure 2.12. The colors on the map show annual total precipitation changes for 1991-2012 compared to the 1901-1960 average, and show wetter conditions in most areas. The bars on the graphs show average precipitation differences by decade for 1901-2012 (relative to the 1901-1960 average) for each region. The far right bar in each graph is for 2001-2012. (Figure source: adapted from Peterson et al. 2013[48]).

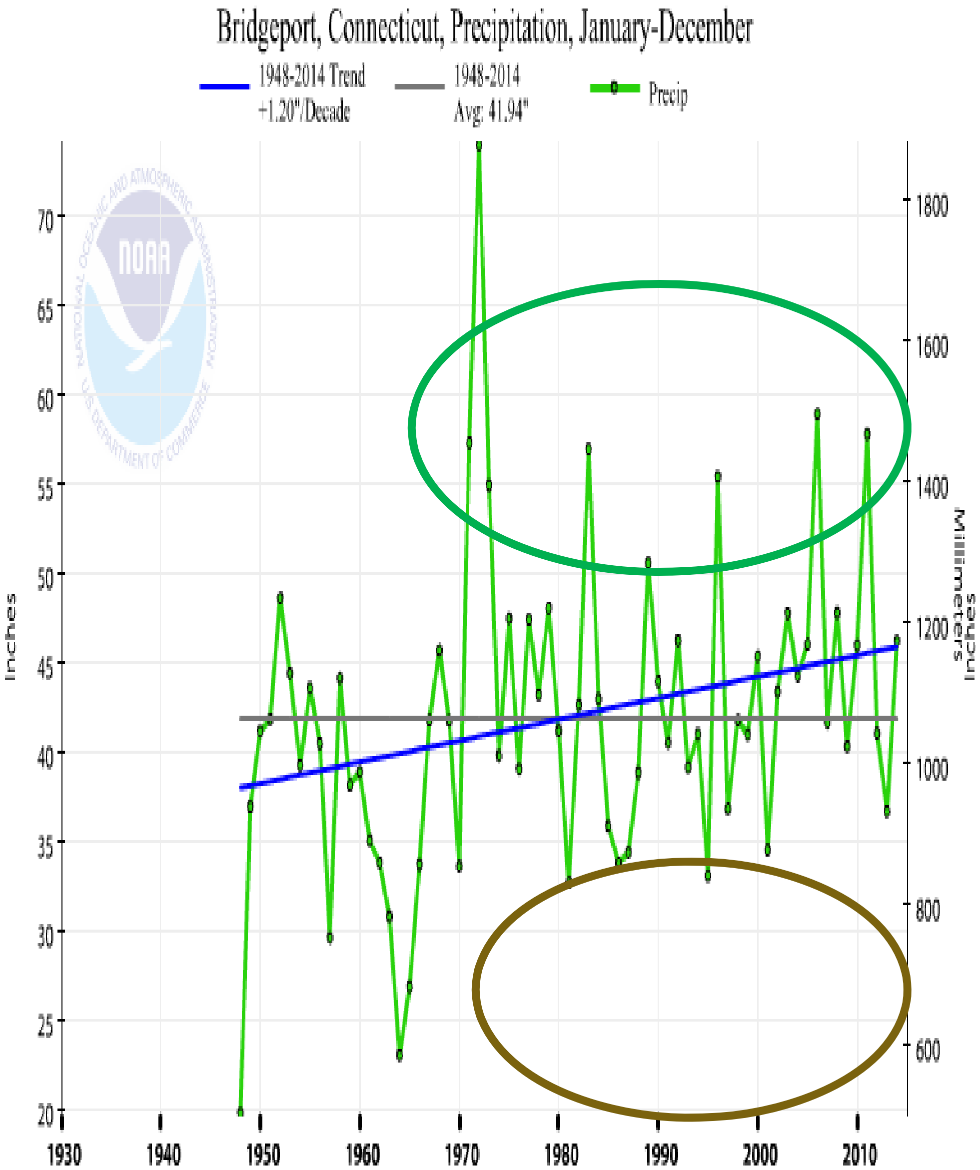
Statewide Precipitation Trends

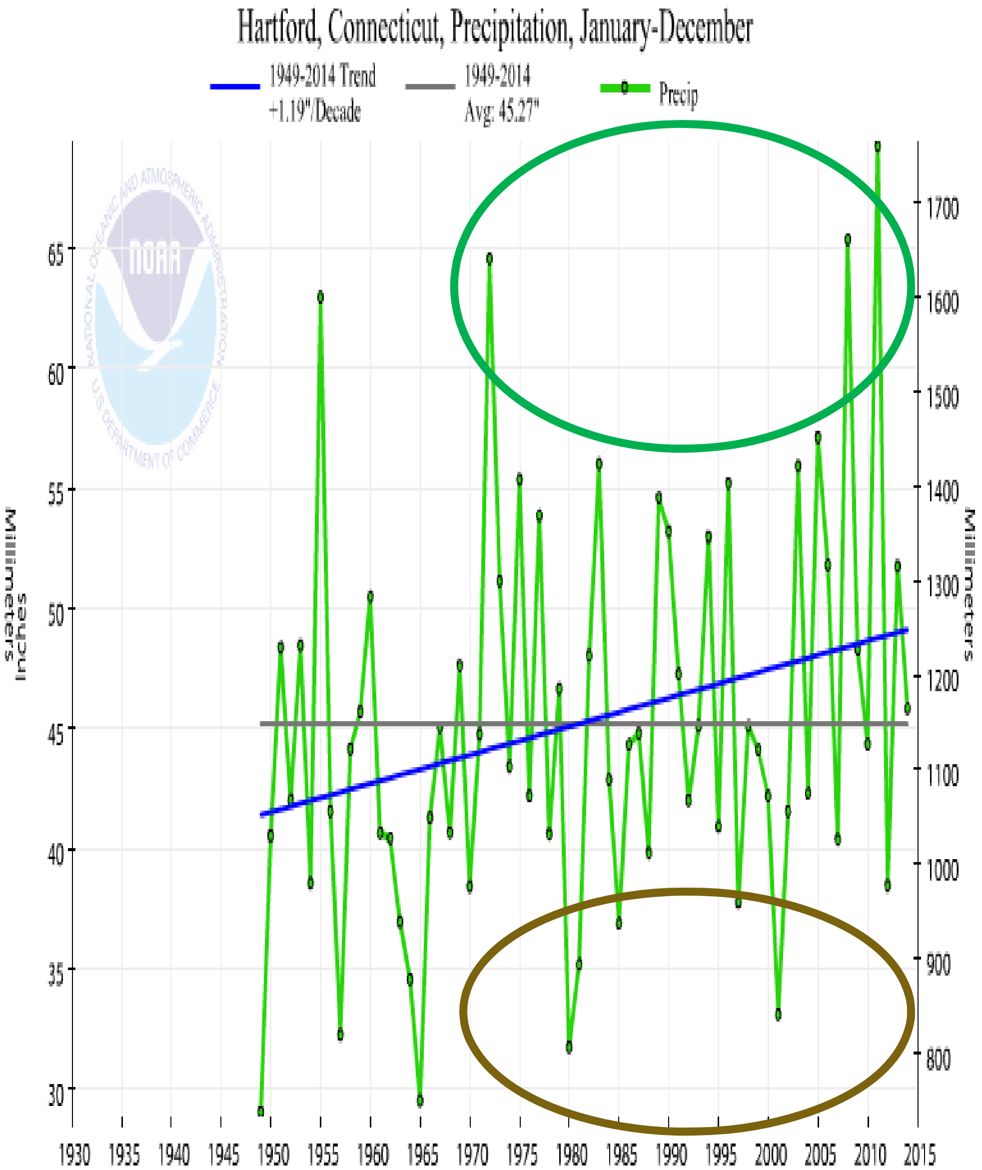
http://www.ncdc.noaa.gov/cag



A Look at Annual Precipitation Trends

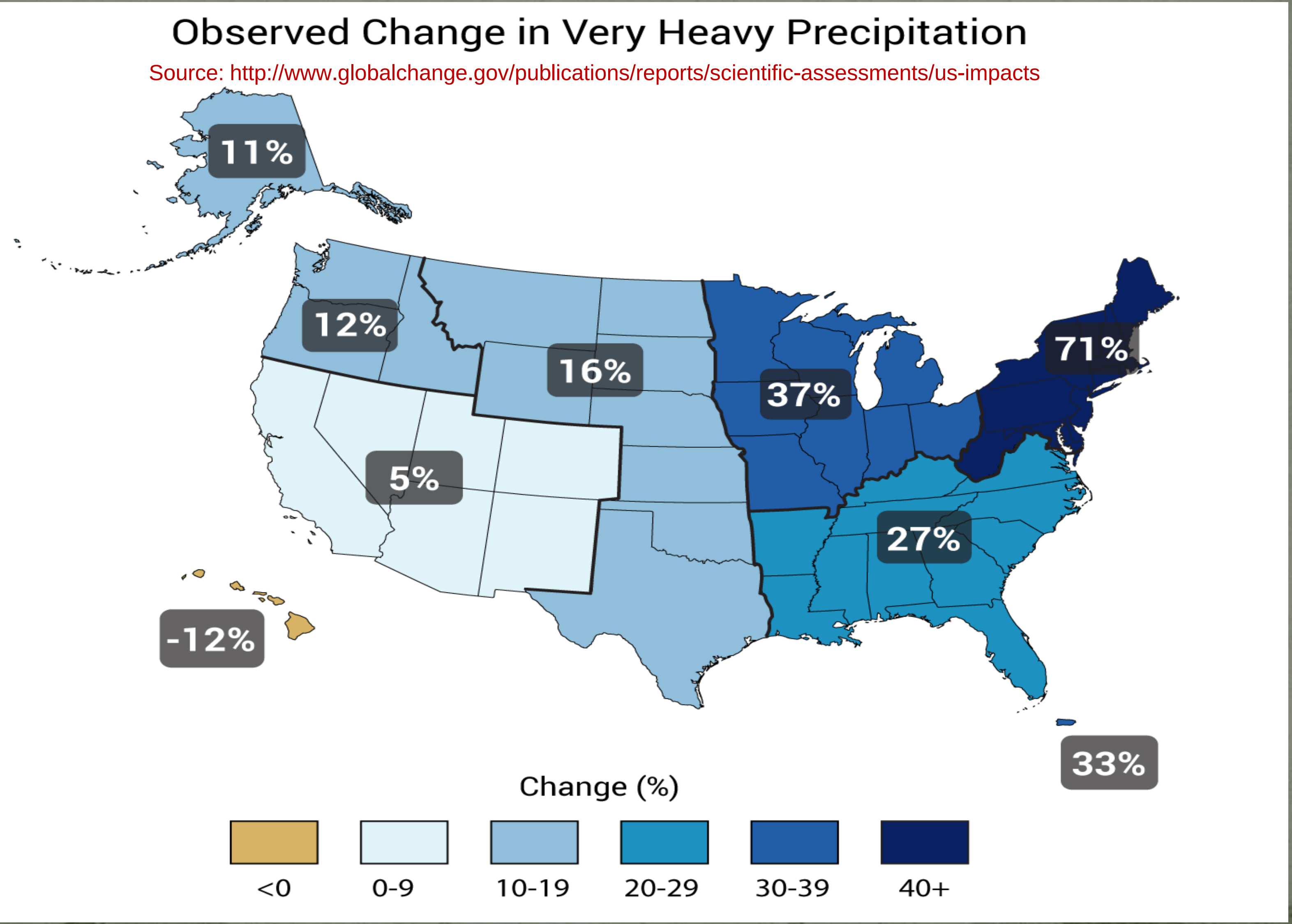
http://www.ncdc.noaa.gov/cag





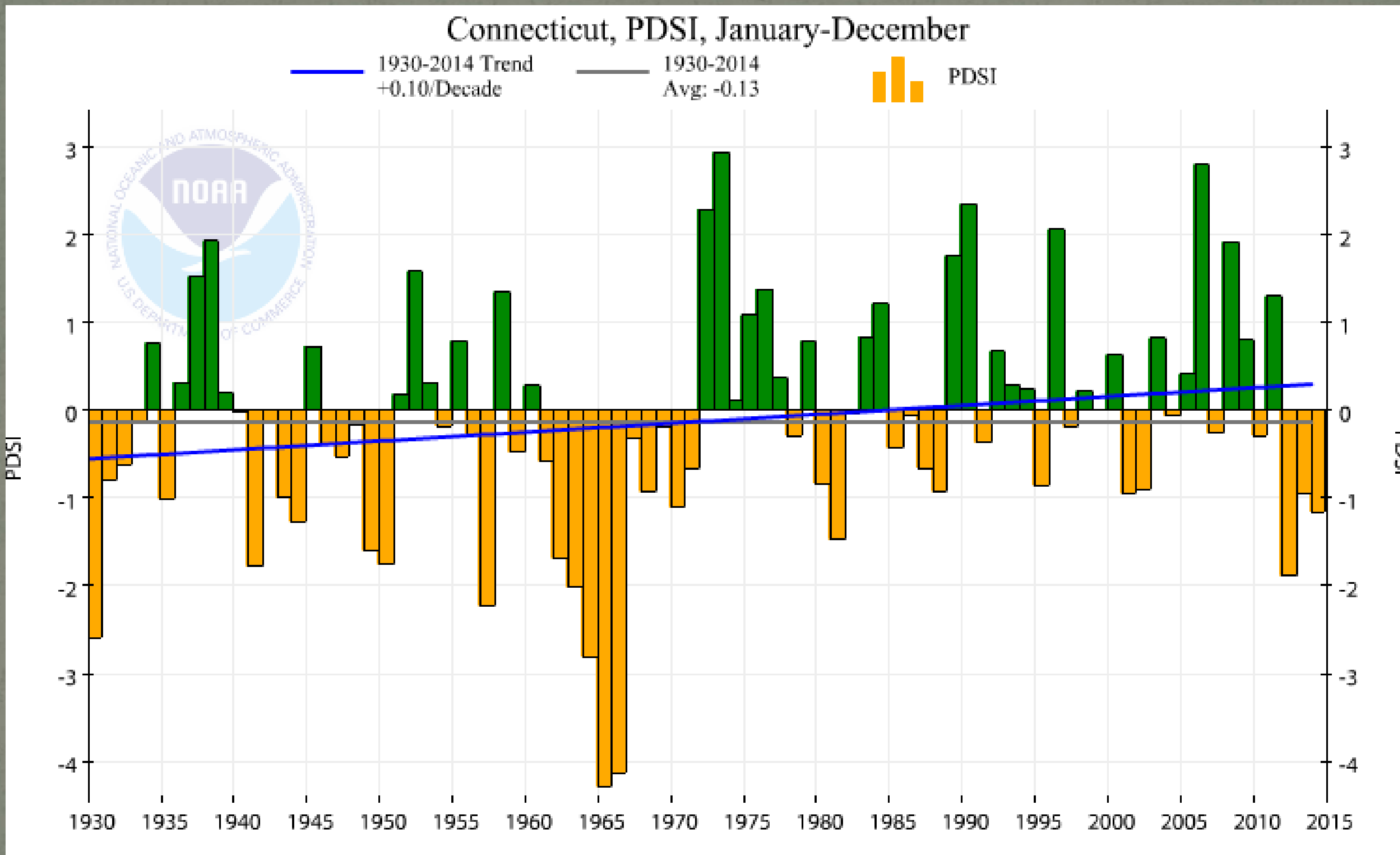
Change in Precipitation Patterns

Intense precipitation events (the heaviest 1%) in the continental U.S. increased by 20% over the past century while total precipitation increased by 7% (1958-2012).



Palmer Drought Severity Index

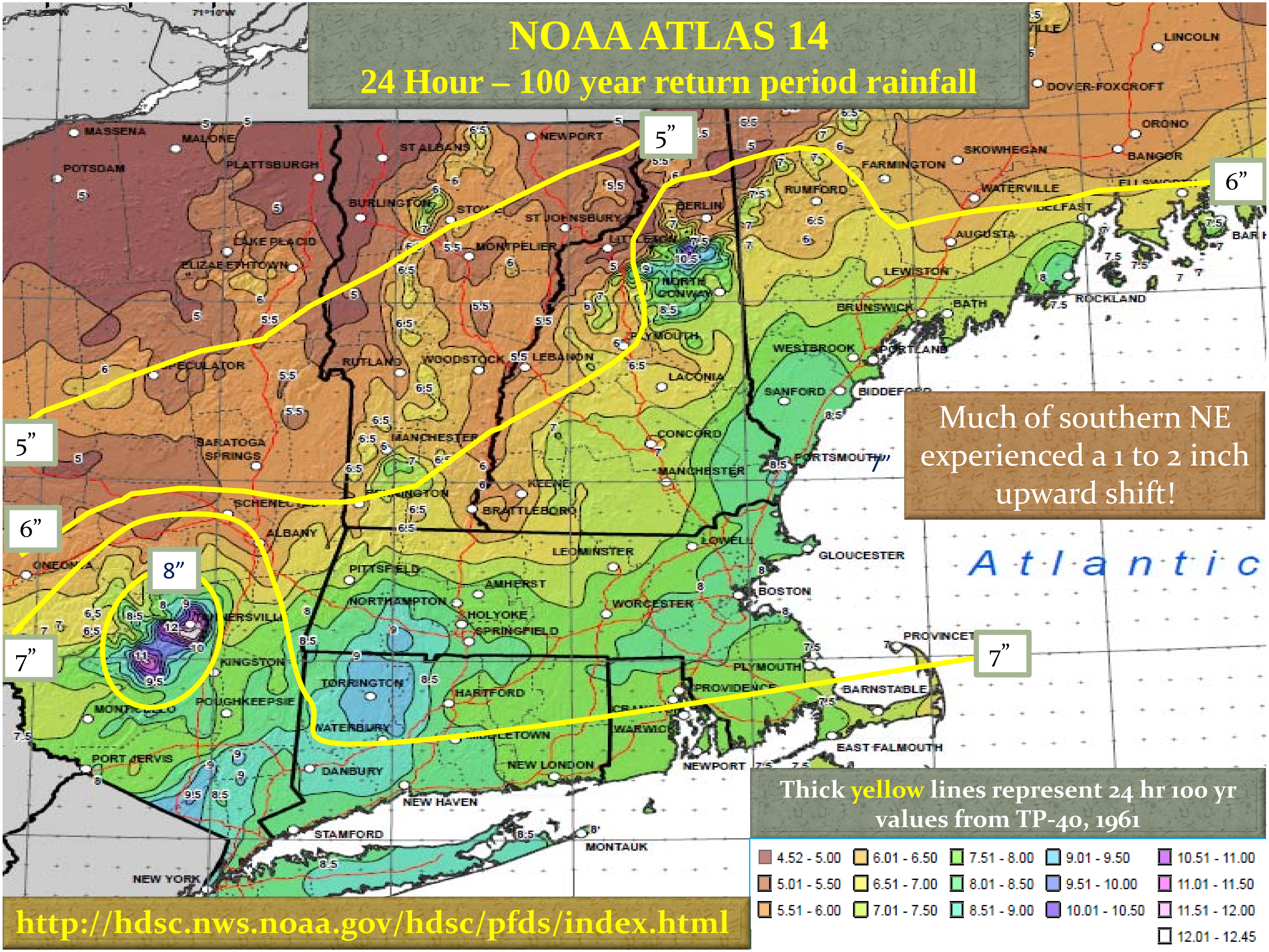
Much wetter & less frequent dry episodes



Since the late 60s, similar signature of much shorter, less intense dry periods and longer higher amplitude wet periods

NOAA ATLAS 14

24 Hour – 100 year return period rainfall



Much of southern NE experienced a 1 to 2 inch upward shift!

Thick yellow lines represent 24 hr 100 yr values from TP-40, 1961

http://hdsc.nws.noaa.gov/hdsc/pfds/index.html

Trends in Flood Frequency:
From the Practitioner's perspective

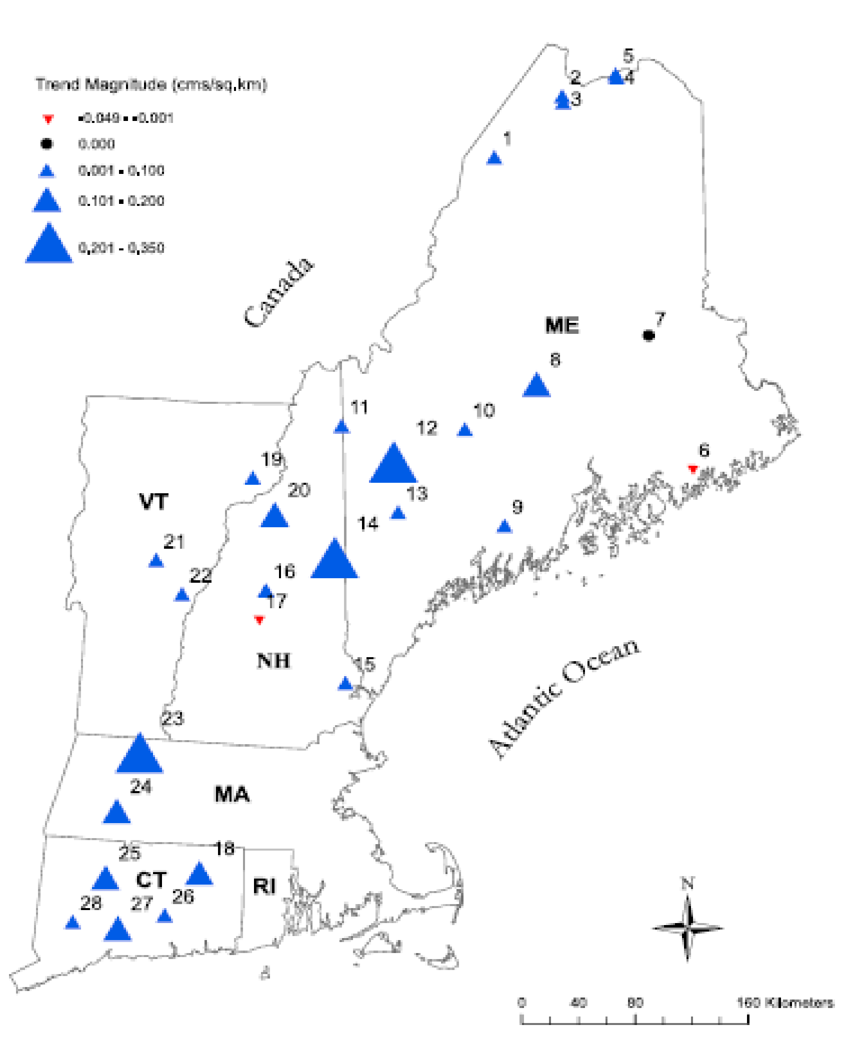
- Small watersheds feeling the effects
  - Changes in frequency/magnitude
  - Part land use/urbanization
    - Compounded by encroachment in the floodplain
  - Part changing climate
- Larger basins with flood control haven't seen as noticeable a shift
  - Most USACE reservoirs are built for 6-8 inch runoff events
  - Greater capacity to handle more rain

Perkins Avenue, Warwick, RI
Tuesday, March 30, 2010

Flooding along the Housatonic River following Lee, Sept 8, 2011.
Photo: A. Driscoll, Connecticut Post

Instantaneous peak flows

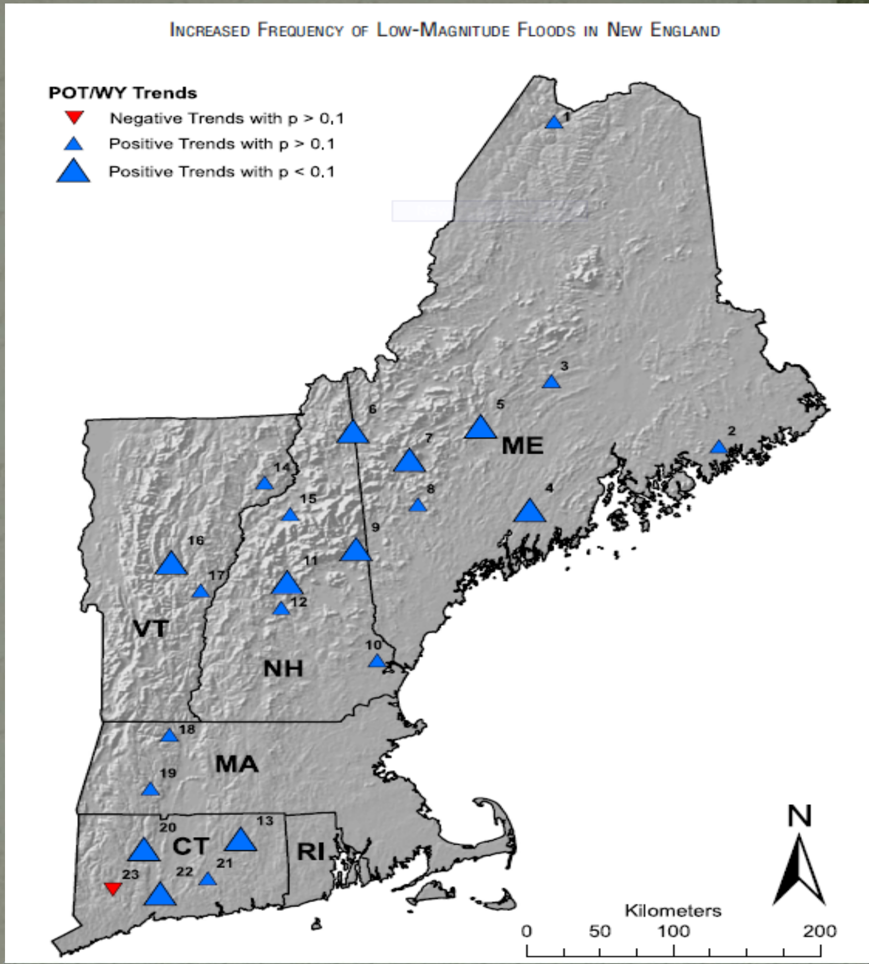
- Mathias Collins – NOAA NFMS – Restoration center
  - 2009 study of 28 watersheds with minimal human influences
  - Results indicate basins throughout much of New England have experienced increased peak annual flows
    - Strongest statistical trends noted by the large blue triangles



Spatial distribution of trend directions & magnitudes for based with minimal human influences.
Reference: *M. Collins, Journal of The American Water Resources Association (JAWRA) April 2009.*

Increased low magnitude floods

- Mathias Collins – NOAA NFMS – Restoration center
  - 2011 study of 23 watersheds with minimal human influences
  - Examined peaks over defined thresholds per water year (direct measure of flood frequency)
  - More frequent flooding at 22 of 23 locations
  - Increasing flood magnitude at 17 of 23 locations

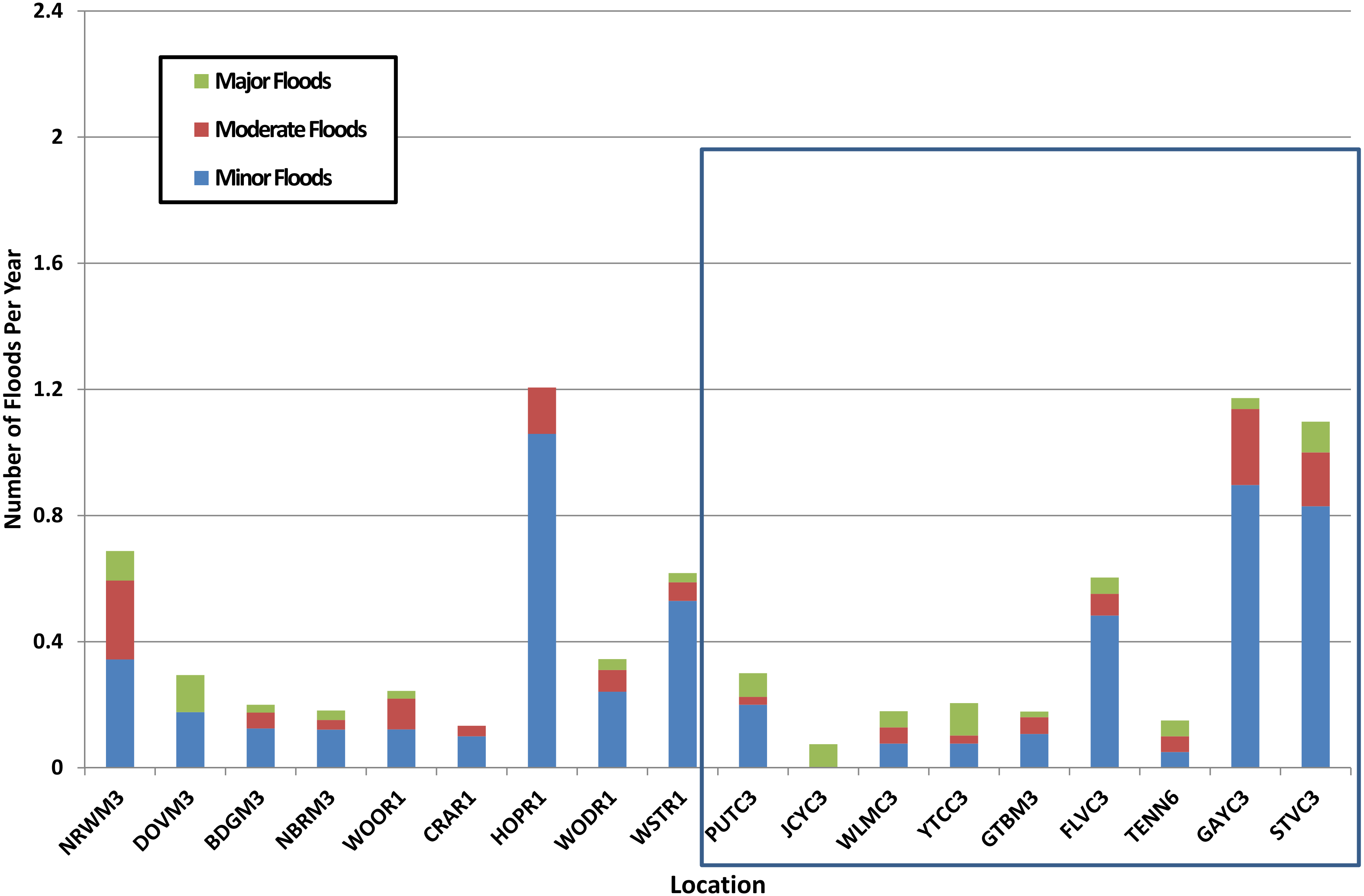


Spatial Distribution of Flood Frequency – as measured by peaks over threshold per water year.

Reference: W. Armstrong, M. ***Collins, and N. Snyder Journal of The American Water Resources Association (JAWRA) April 2011.***

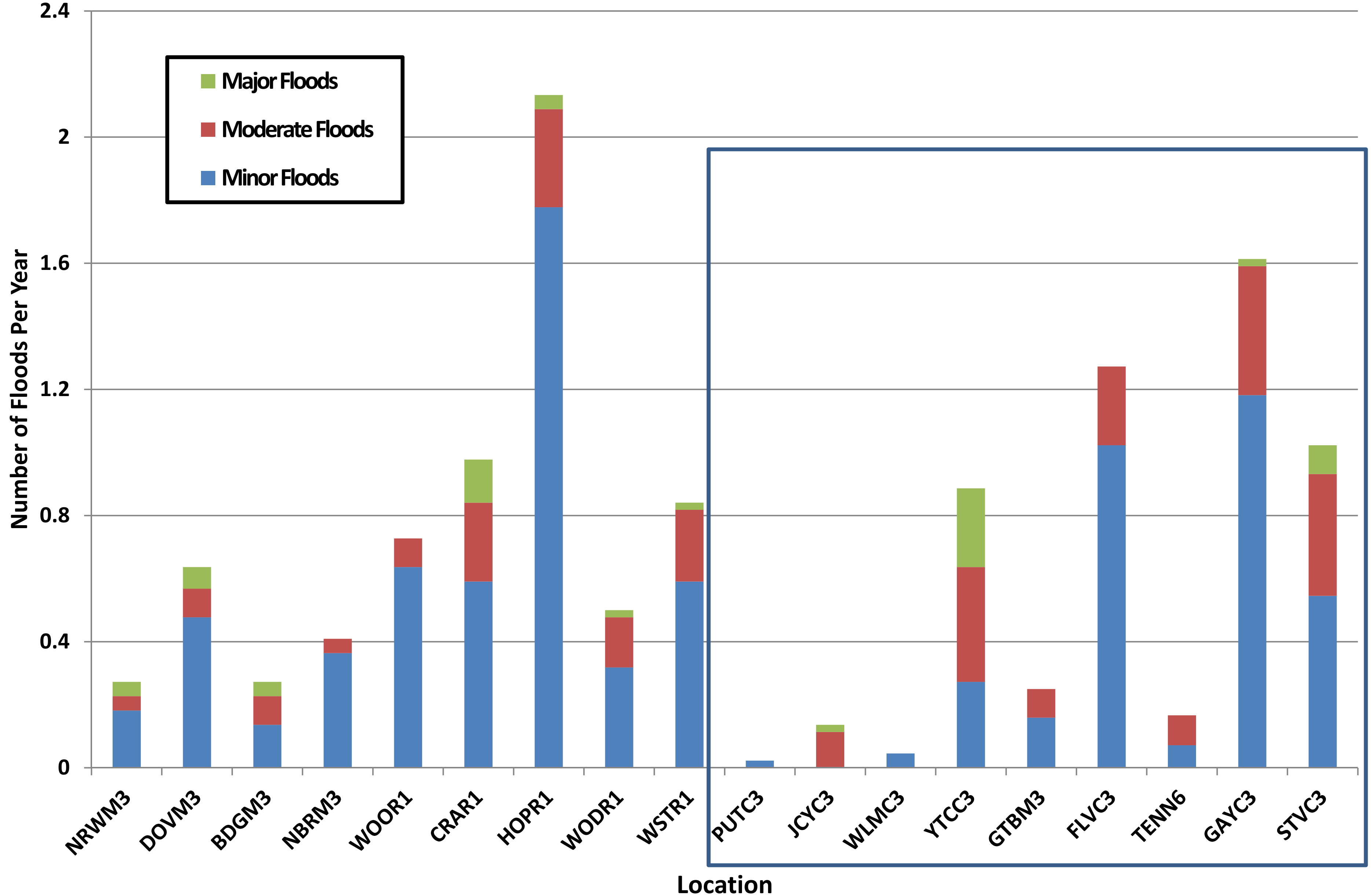
Southern New England River Basin Normalized Number of Minor, Moderate, and Major Floods Prior to 1970

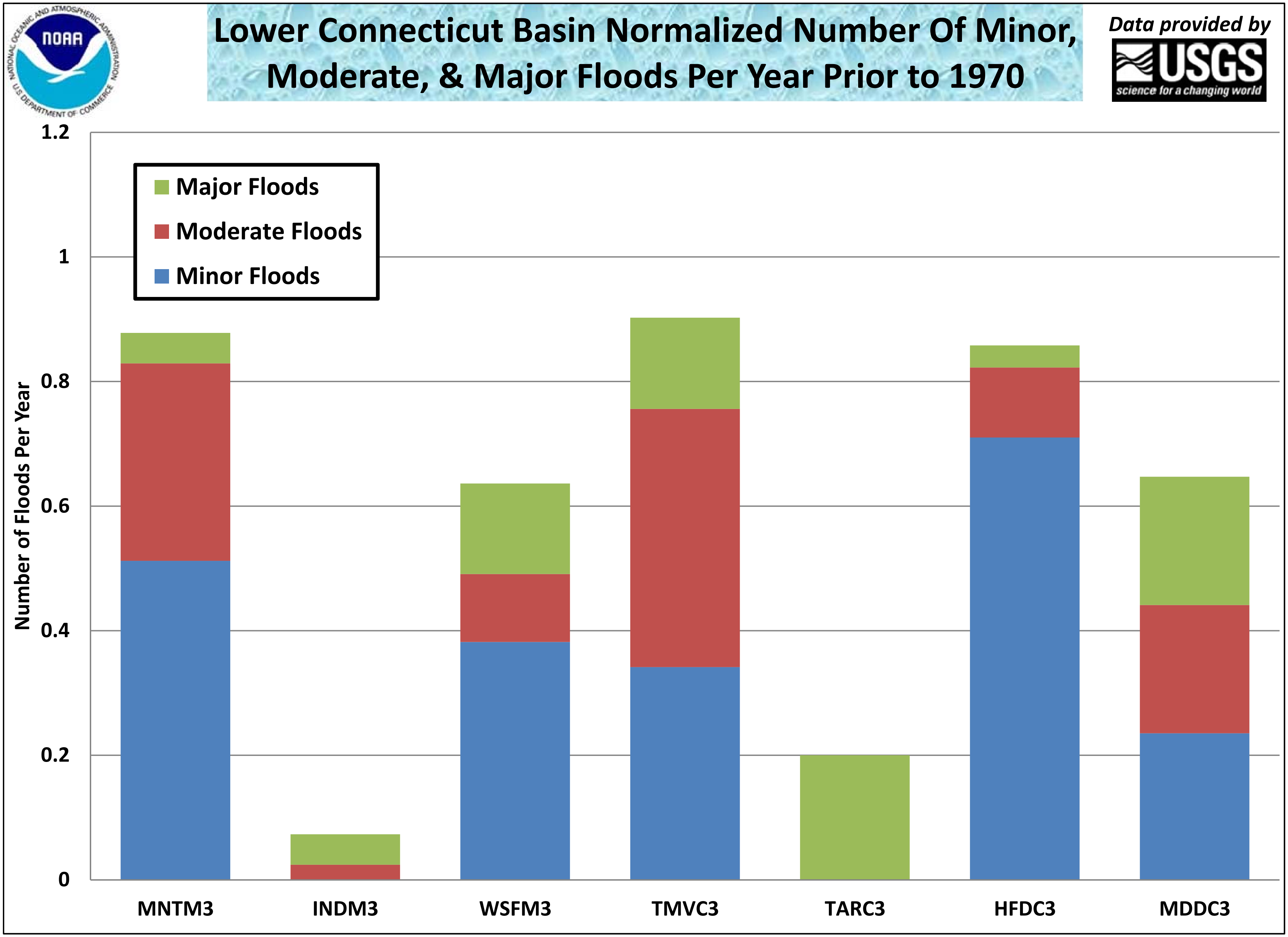
Data provided by



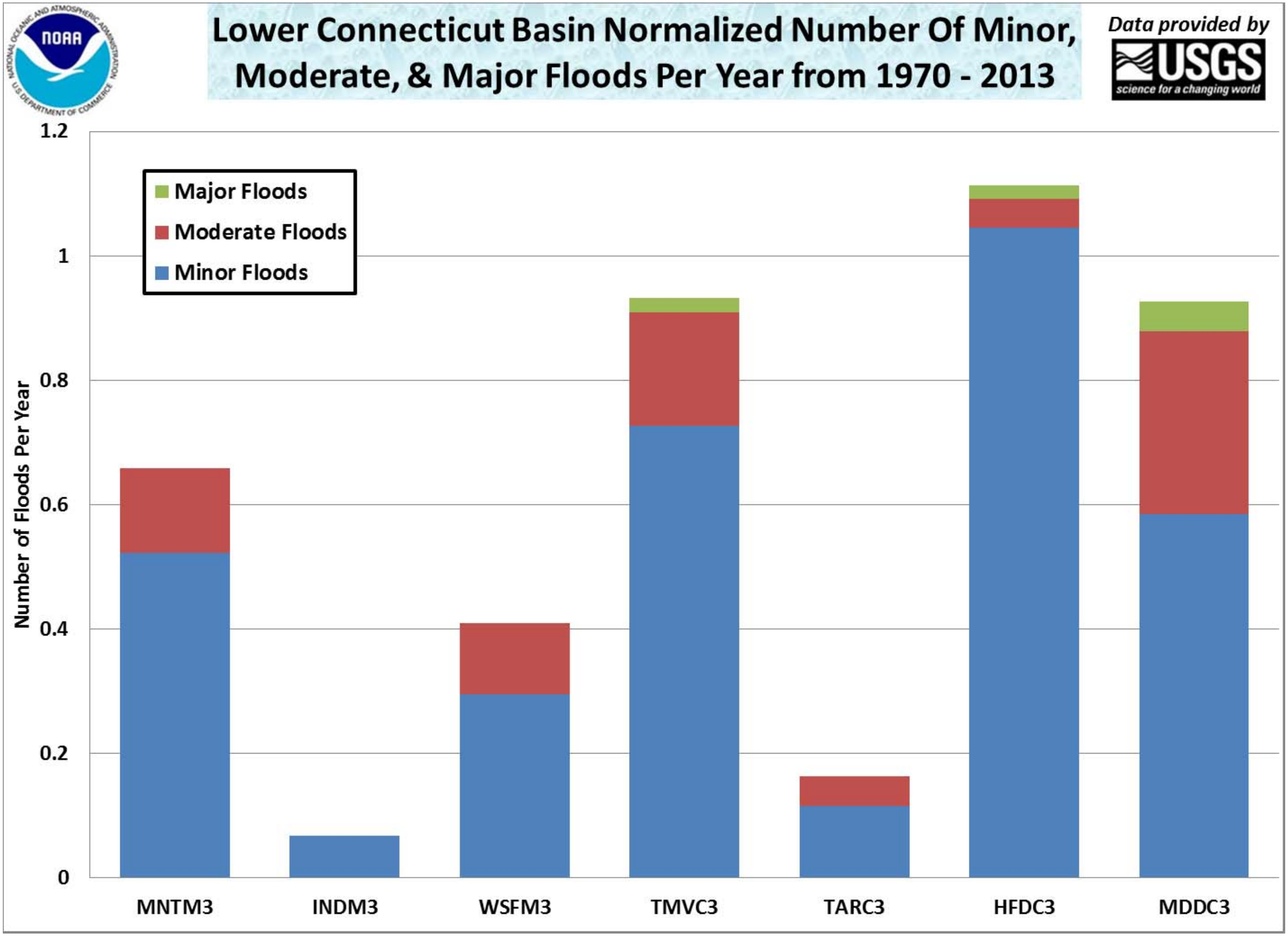
Southern New England River Basin Normalized Number of Minor, Moderate, and Major Floods from 1970-2013

Data provided by USGS

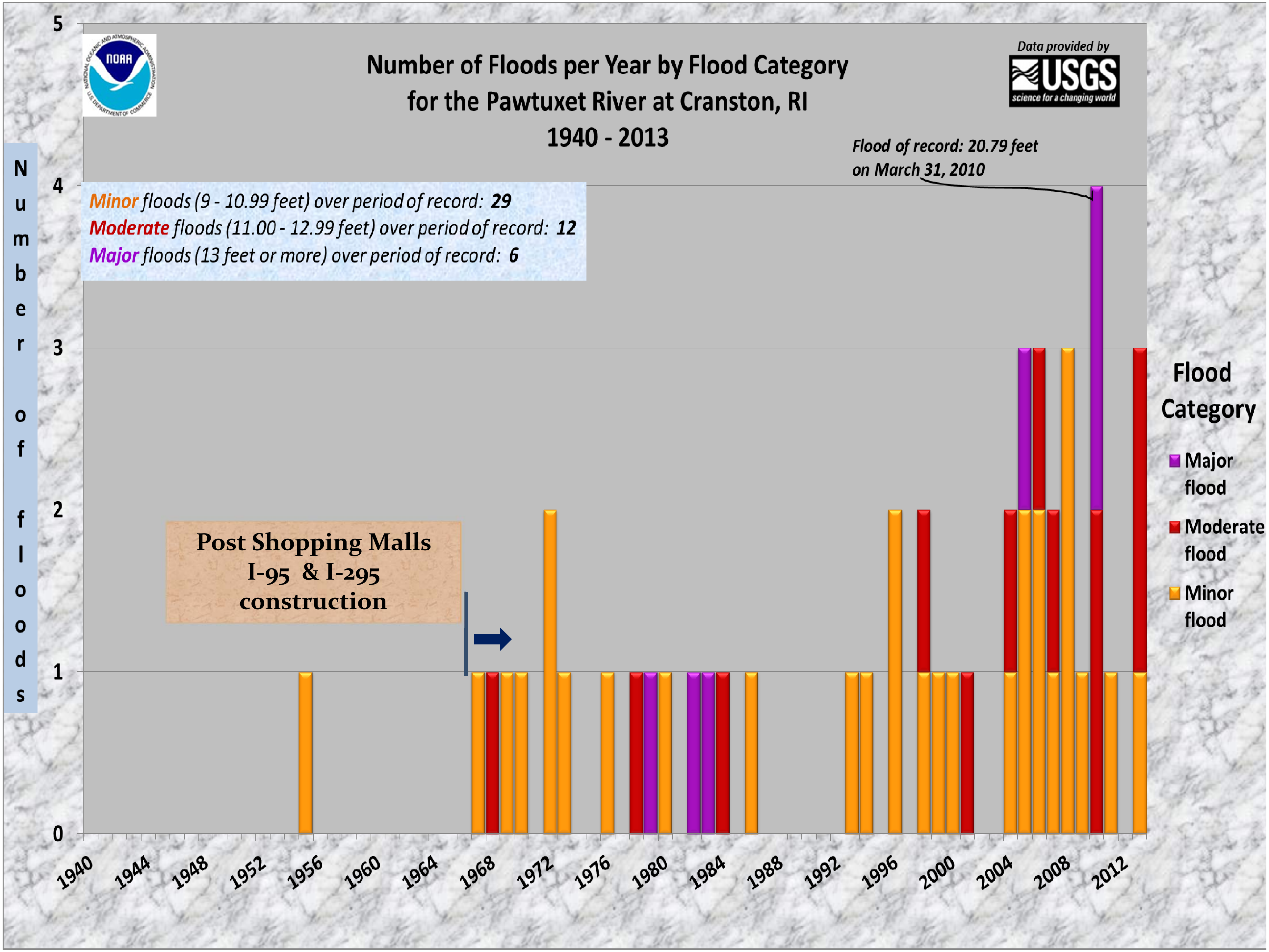




Lower Connecticut Basin Normalized Number Of Minor, Moderate, & Major Floods Per Year Prior to 1970
Data provided by
USGS
science for a changing world
NOAA
Major Floods
Moderate Floods
Minor Floods
Number of Floods Per Year
1.2
1
0.8
0.6
0.4
0.2
0
MNTM3
INDM3
WSFM3
TMVC3
TARC3
HFDC3
MDDC3



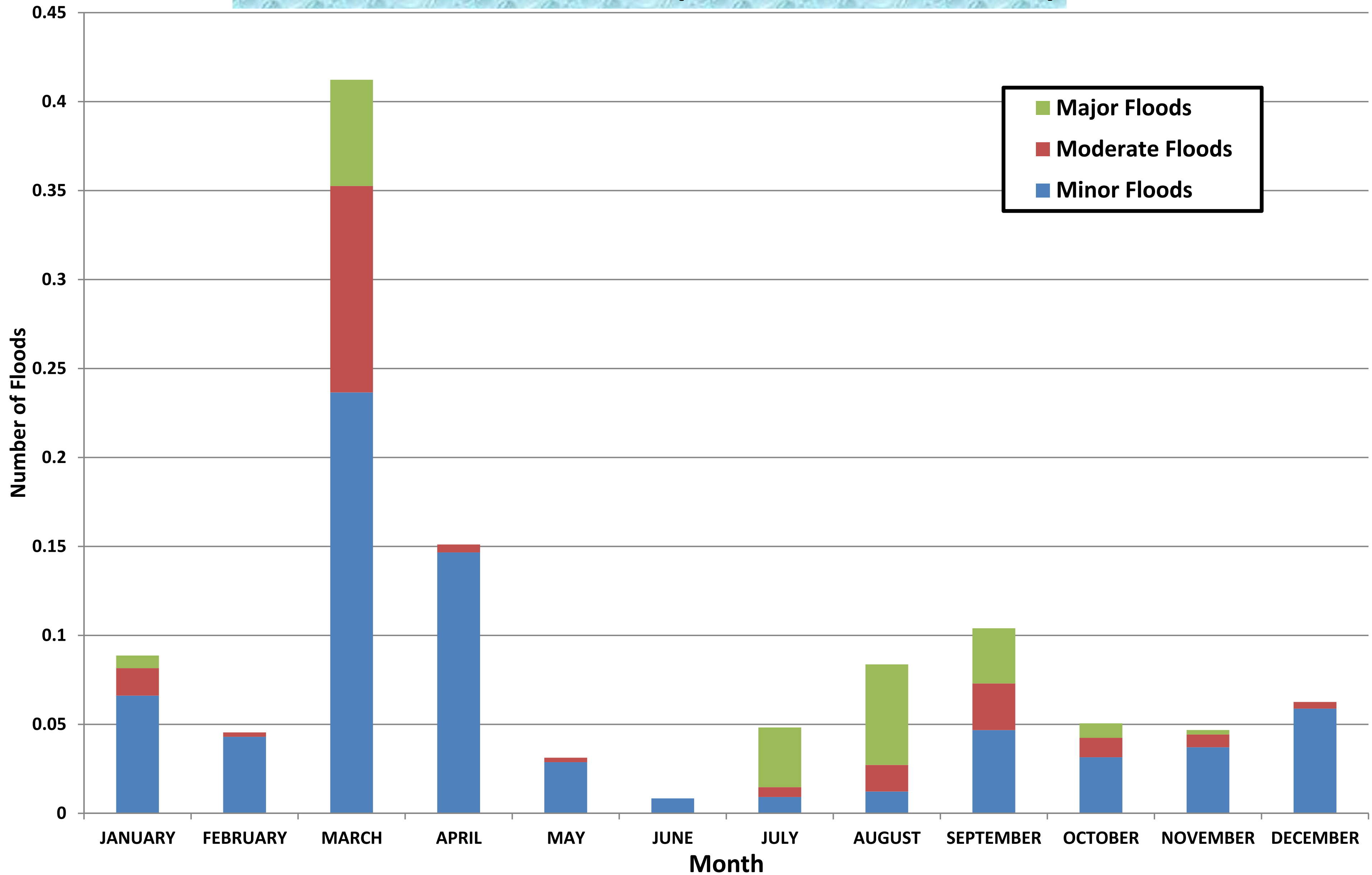
Lower Connecticut Basin Normalized Number Of Minor, Moderate, & Major Floods Per Year from 1970 - 2013
Data provided by
USGS
science for a changing world
Major Floods
Moderate Floods
Minor Floods
Number of Floods Per Year
1.2
1
0.8
0.6
0.4
0.2
0
MNTM3
INDM3
WSFM3
TMVC3
TARC3
HFDC3
MDDC3



Number of Floods per Year by Flood Category
for the Pawtuxet River at Cranston, RI
1940 - 2013
Data provided by
USGS
science for a changing world
NOAA
Flood of record: 20.79 feet
on March 31, 2010
Minor floods (9 - 10.99 feet) over period of record: 29
Moderate floods (11.00 - 12.99 feet) over period of record: 12
Major floods (13 feet or more) over period of record: 6
Post Shopping Malls
I-95 & I-295
construction
Number of floods
Flood Category
Major flood
Moderate flood
Minor flood
0
1
2
3
4
5
1940
1944
1948
1952
1956
1960
1964
1968
1972
1976
1980
1984
1988
1992
1996
2000
2004
2008
2012

Southern New England River Basin Normalized Number of Minor, Moderate, and Major Floods Per Month Prior to 1970 (18 forecast locations)

Data provided by USGS



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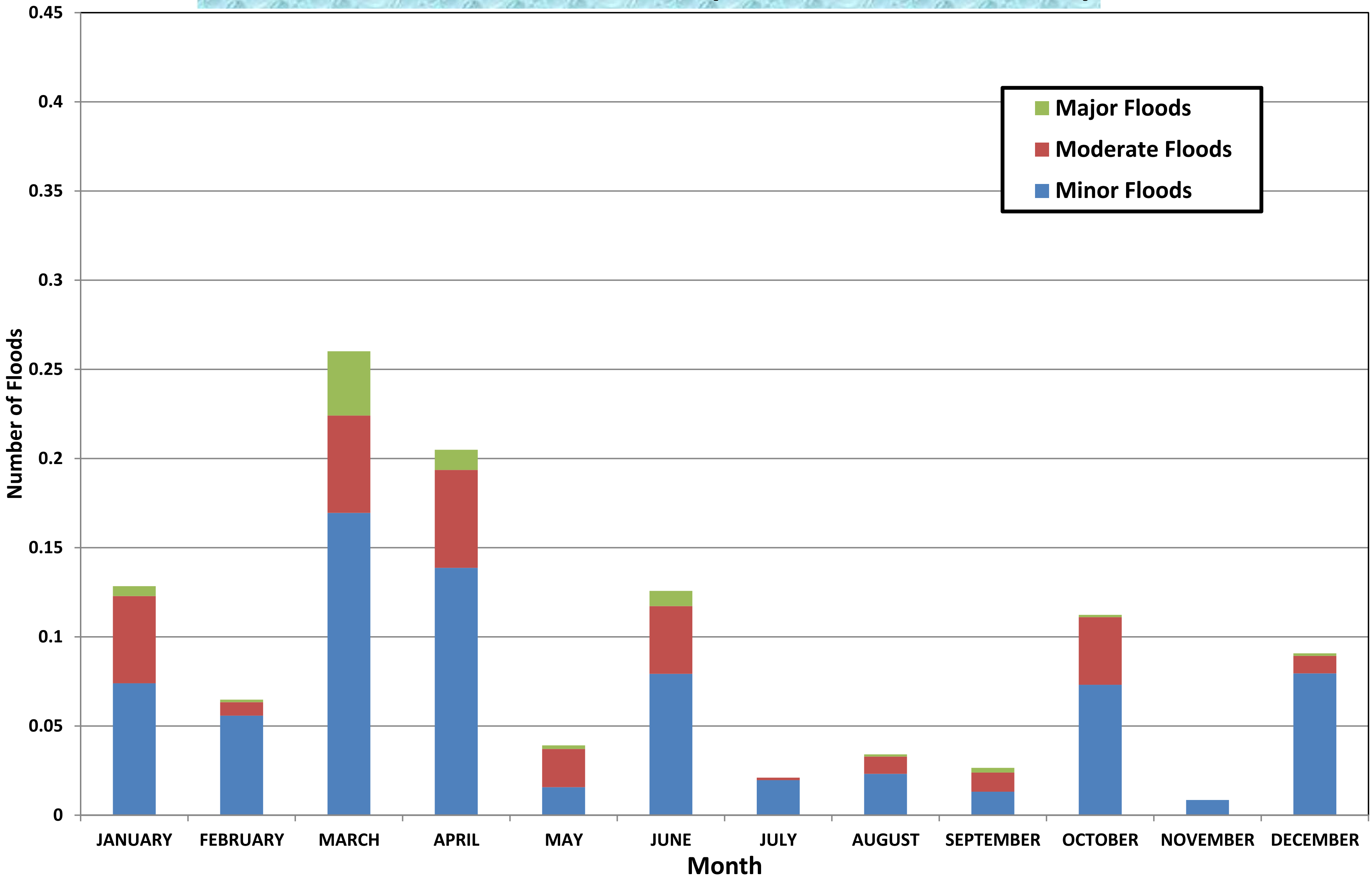
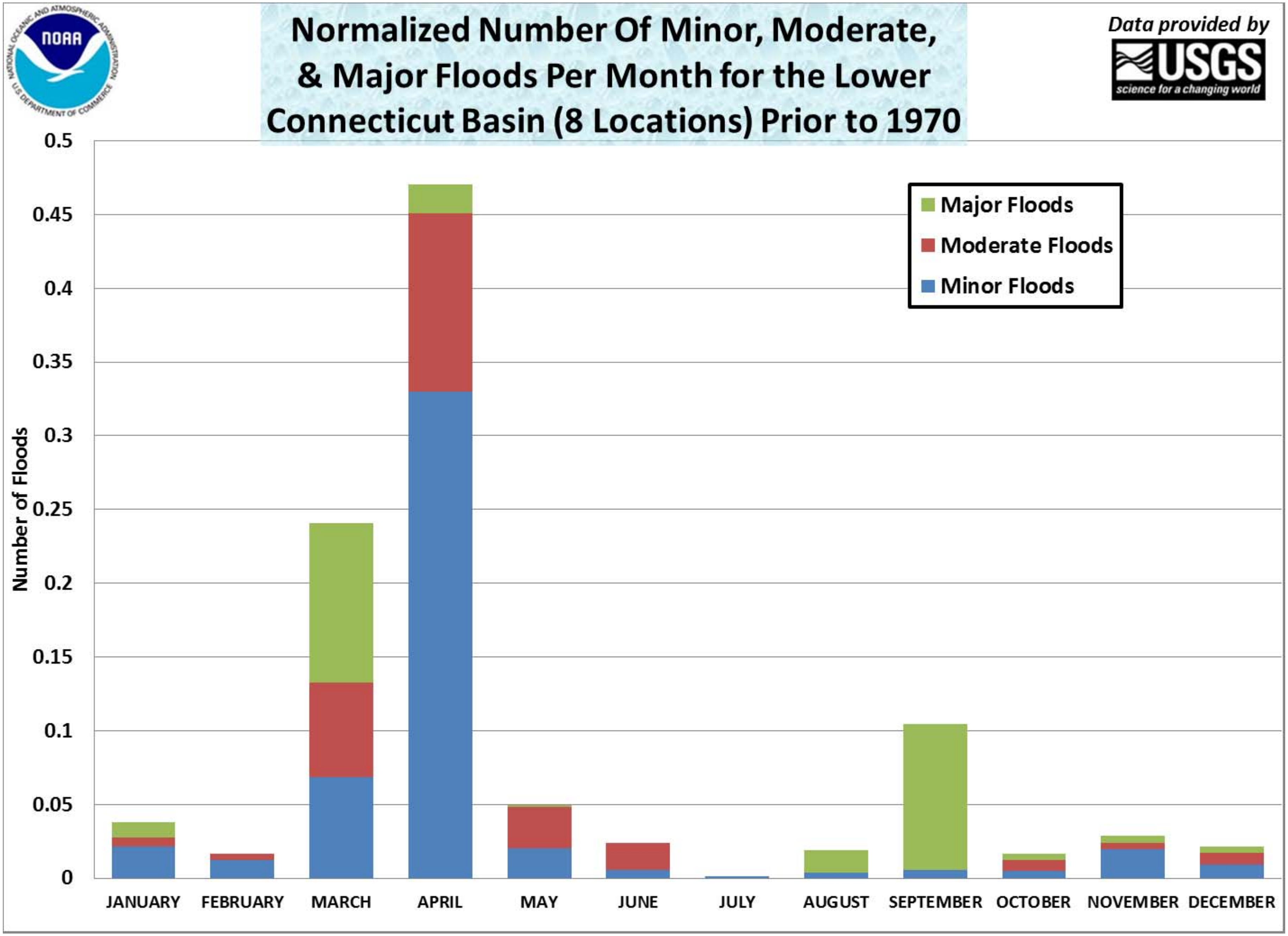
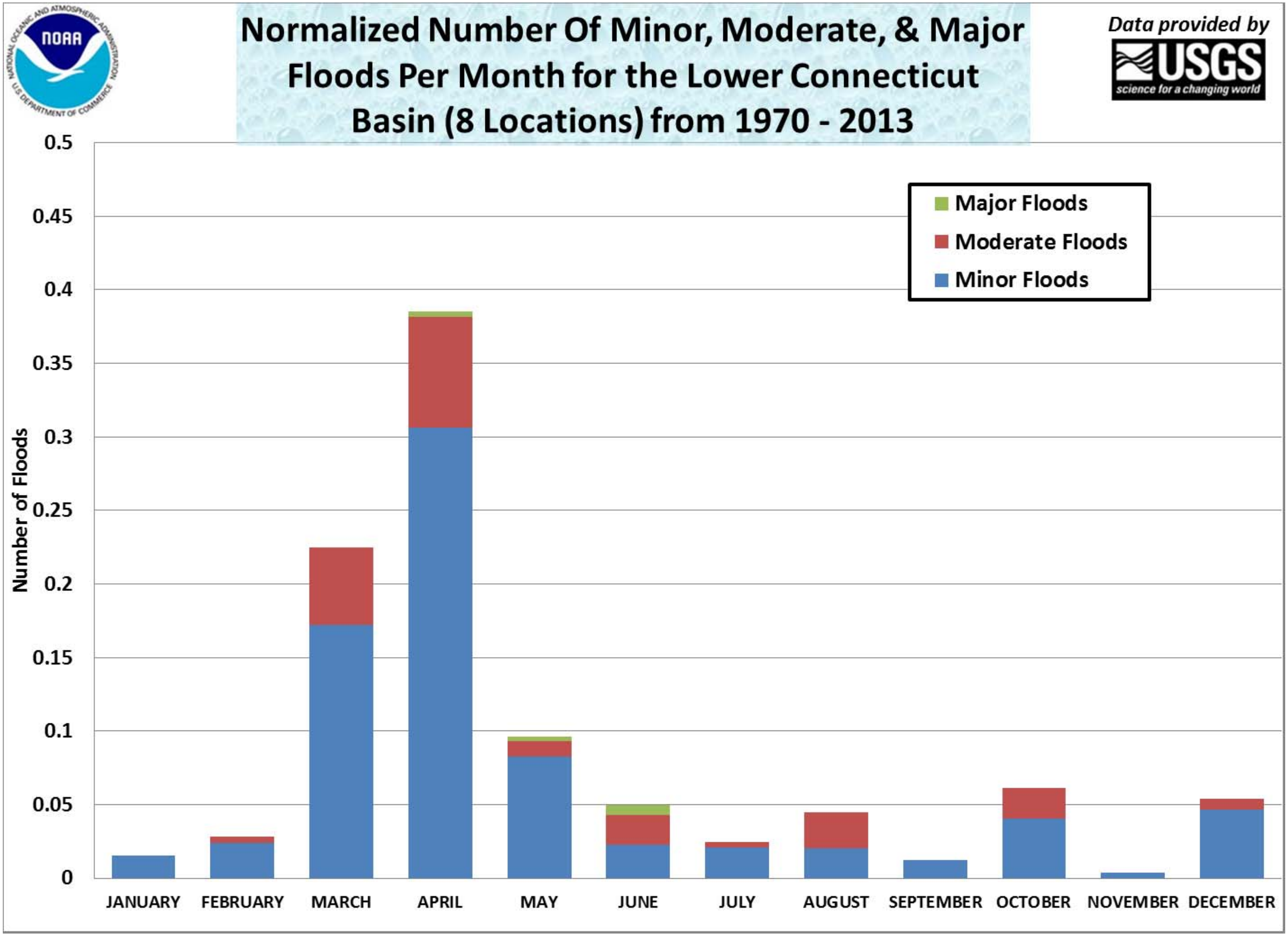




Normalized Number Of Minor, Moderate, & Major Floods Per Month for the Lower Connecticut Basin (8 Locations) Prior to 1970
Data provided by
USGS
science for a changing world
Number of Floods
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Major Floods
Moderate Floods
Minor Floods
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER

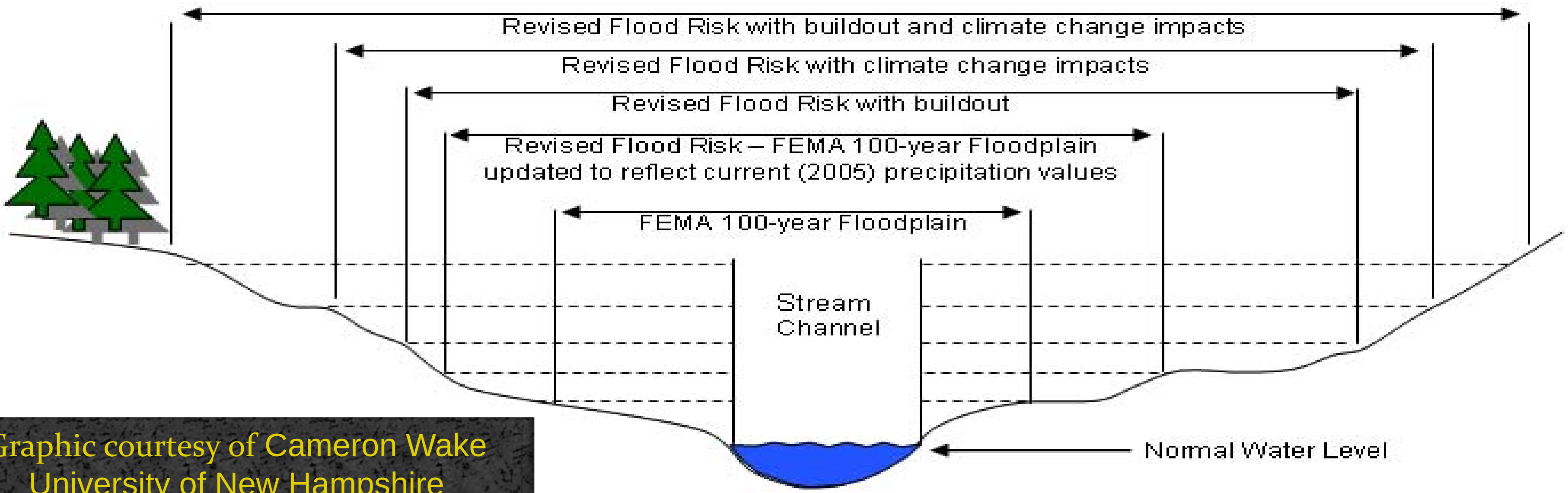

Normalized Number Of Minor, Moderate, & Major Floods Per Month for the Lower Connecticut Basin (8 Locations) from 1970 - 2013
Data provided by
USGS
science for a changing world
NOAA
Number of Floods
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Major Floods
Moderate Floods
Minor Floods
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER

Summary

- The Northeast has become a "hot spot" for record floods & heavy rainfall in the past 10 years
- Noticeable trends include increased yearly rainfall and increased annual temperatures
  - Southeast New England has experienced a 1 to 2 inch shift upwards in the 100 yr – 24 hour rainfall
- Smaller watersheds & those with significant urbanization are most vulnerable to increased river & stream flooding

Far reaching implications:
Protect, Adapt or Retreat???

- Floodplain, land use, infrastructure, dam spillway requirements, drainage requirements, non-point source runoff, bridge clearances, "hardening" of critical facilities in the floodplain, property values etc…
- Flood Insurance – work to increase participation
- How much risk are we willing to insure and accept?



Graphic courtesy of Cameron Wake
University of New Hampshire

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