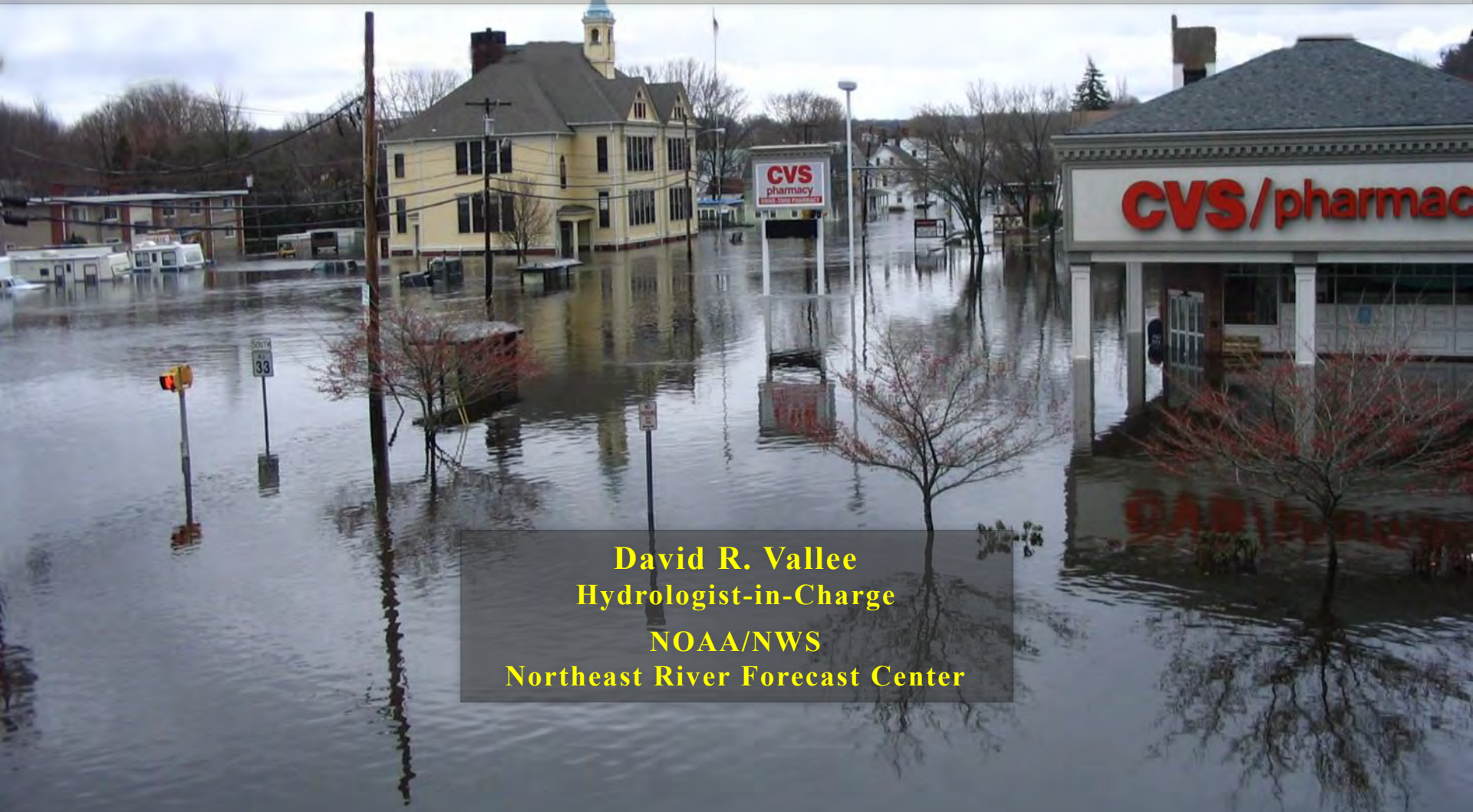
# Climate Trends in Connecticut and Its Impact on Storm and Riverine Flood Behavior




**David R. Vallee**
**Hydrologist-in-Charge**
**NOAA/NWS**
**Northeast River Forecast Center**

# Outline

- From a “Practitioner’s Perspective”
- Touch upon some of our major flood events of the past 10 years
  - Part I: Big Rainstorms & High Impact Floods
  - Part II: Coastal Storms & Sea Level Rise
- How may a changing climate be impacting flood behavior
  - “Accumulation of Ingredients” – not one single “source”
- The challenge ahead of us?

# We've been a little busy these past 10 years!

## *The face of changing flood behavior…*


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

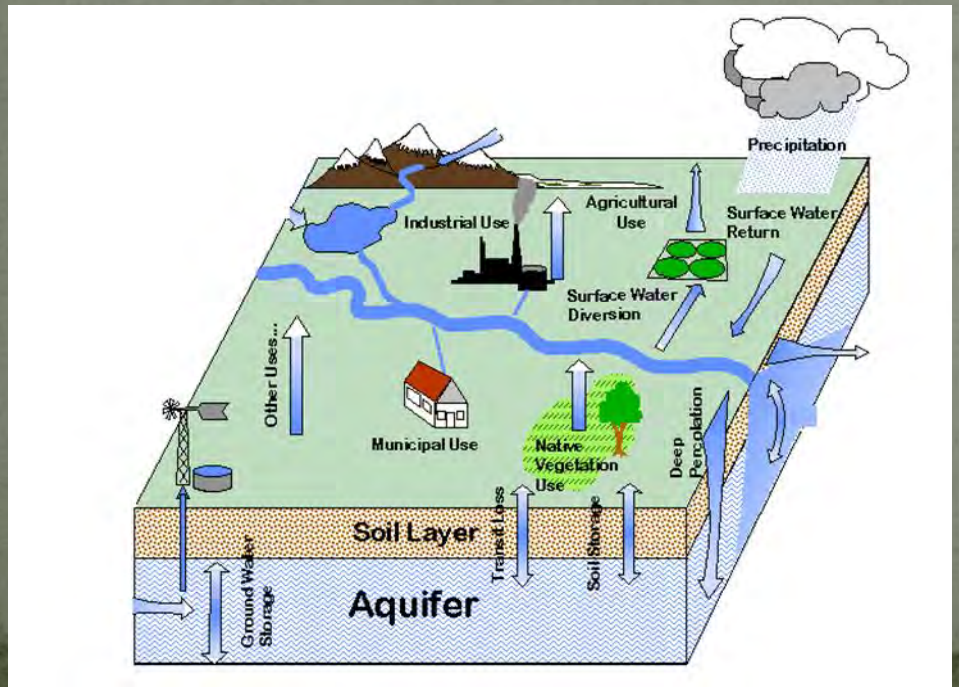
St-Jean-sur-Richelieu, Quebec, Canada, 5/6/11
Photo: AP//Canadian Press, R. Remoirz

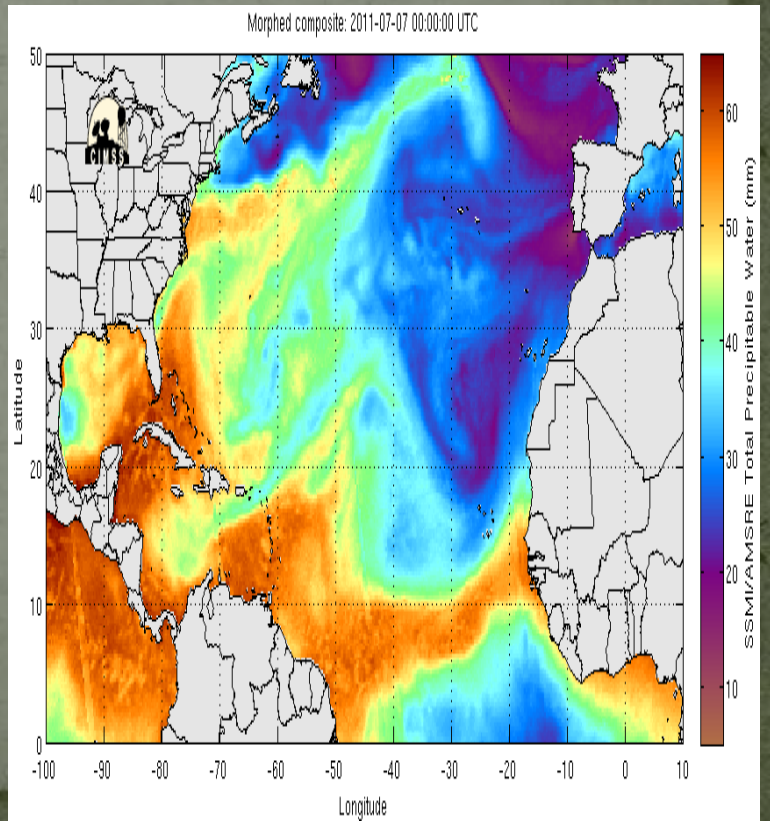

Providence Street – West Warwick, RI at 1030 am Wednesday 3/31/10

Damage along Schoharie Creek, Prattsville, NY – T.S. Irene, Photo: J. Vielkind / Times Union

# Is there a common theme to recent floods?

- Several:
  - Slow moving weather systems – a blocked up atmosphere
    - Related to loss of artic ice cover
    - Multiple events in close succession or one big slow moving storm
  - Results in saturated antecedent conditions before "main event"
  - Each fed by a "tropical connection"
    - Plumes of deep moisture



# The Changing Climate

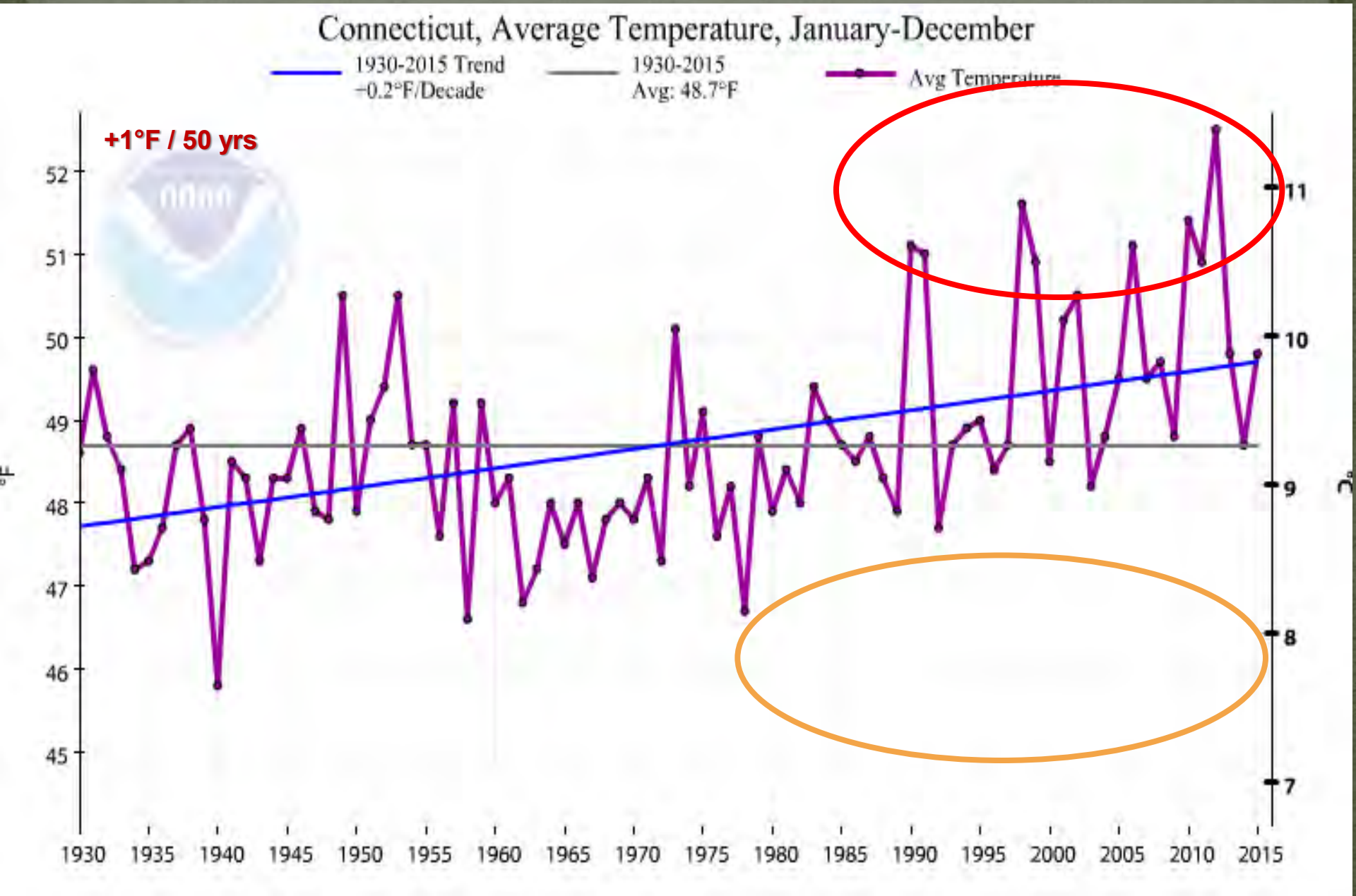
- Common themes across New England and Connecticut:
  - Increasing annual precipitation
  - Increasing frequency of heavy rains
  - Warming annual temperatures
  - Shift in precipitation frequency
- Trend toward increased flood magnitude and/or frequency
  - Most pronounced where significant land use change and/or urbanization has occurred
  - More pronounced in smaller river basins

Residents are rescued from their homes by boat along flooded Pawcatuck River , Westerly RI, on March 30, 2010. Photo: www.theday.com


Major flooding along Route 7 from the Housatonic River in New Milford, CT on March 11, 2011. Source: Ctcameraeye.com

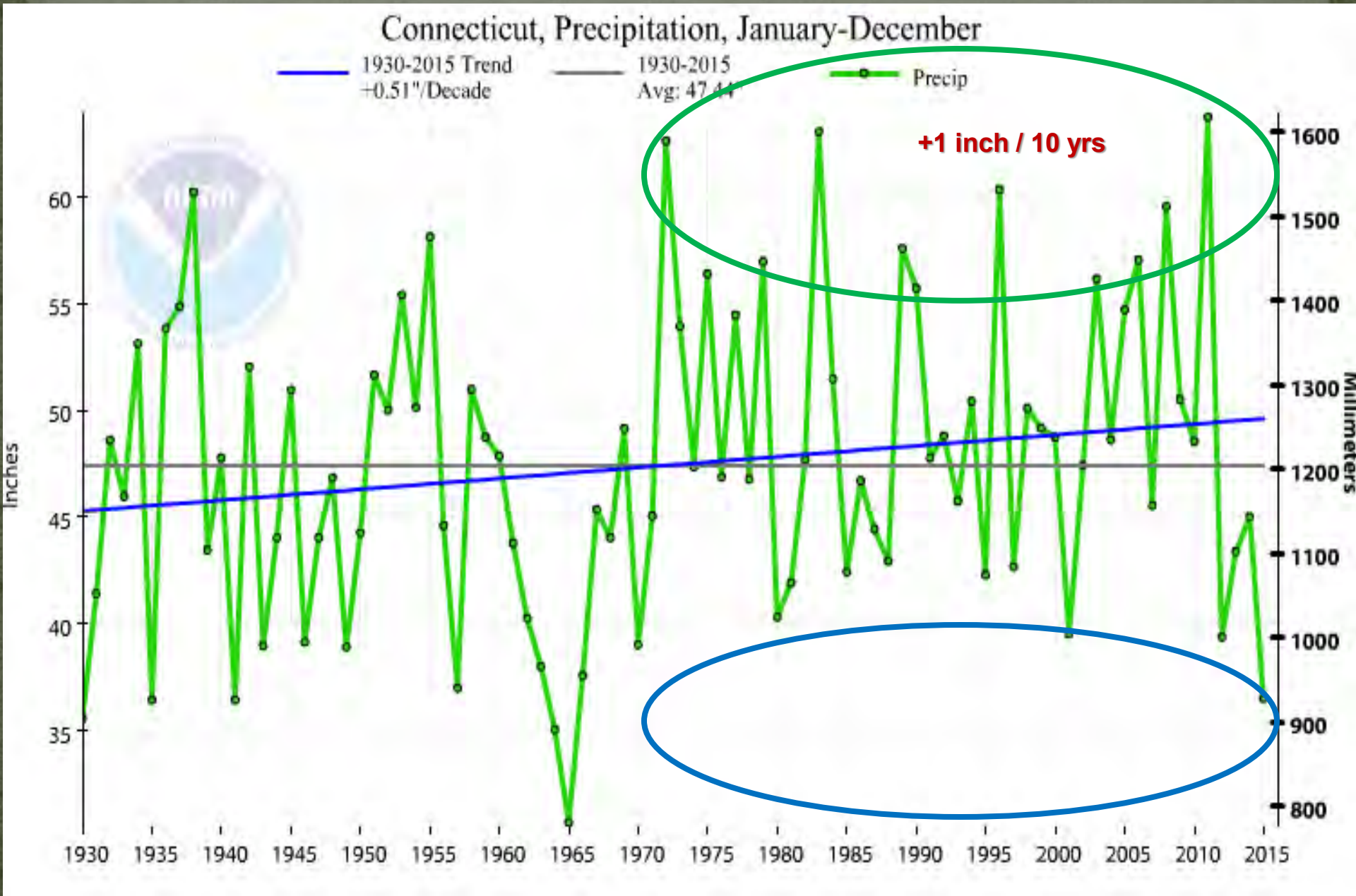
# A Look at Temperature Trends

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



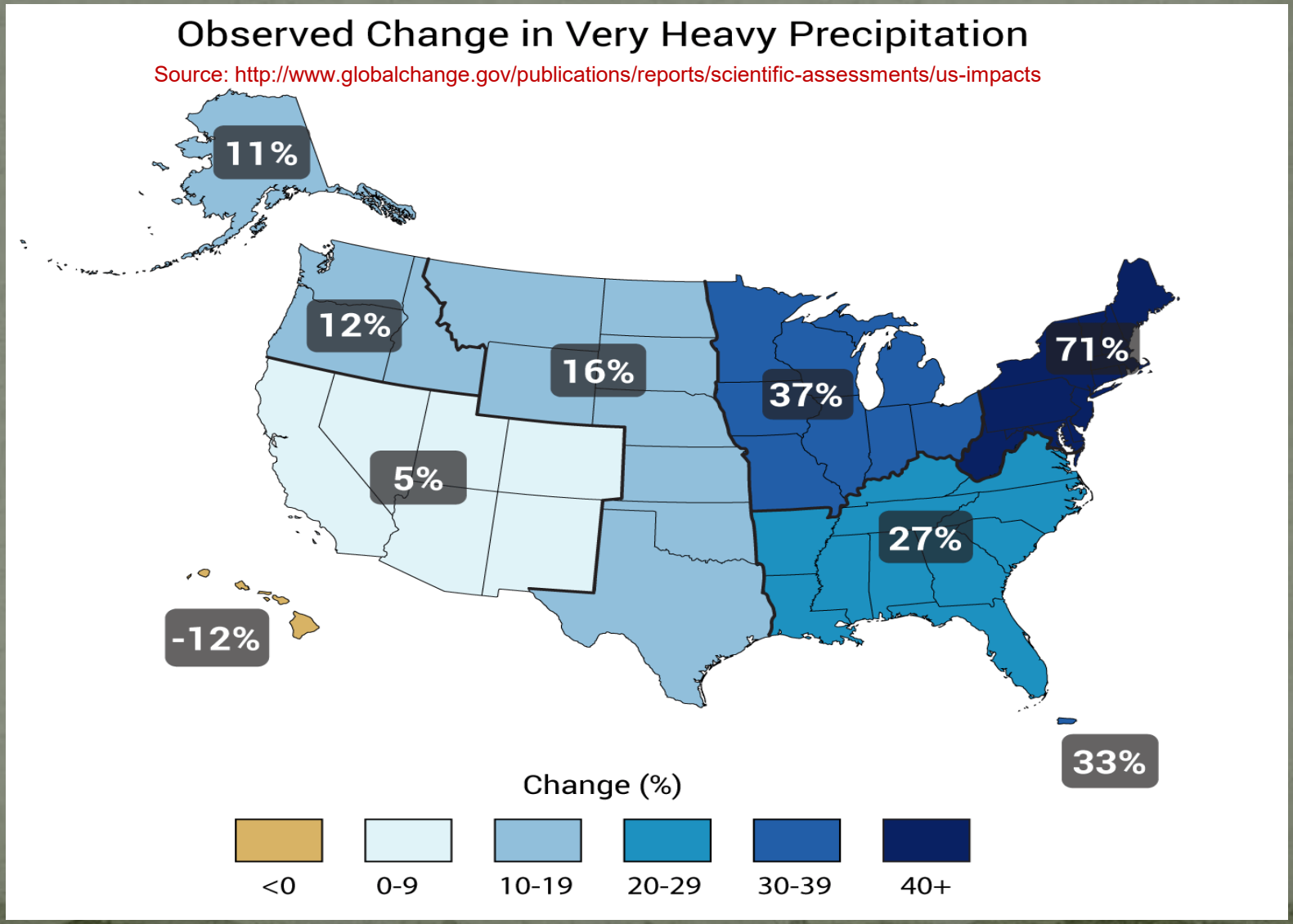
# A Look at Precipitation Trends

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



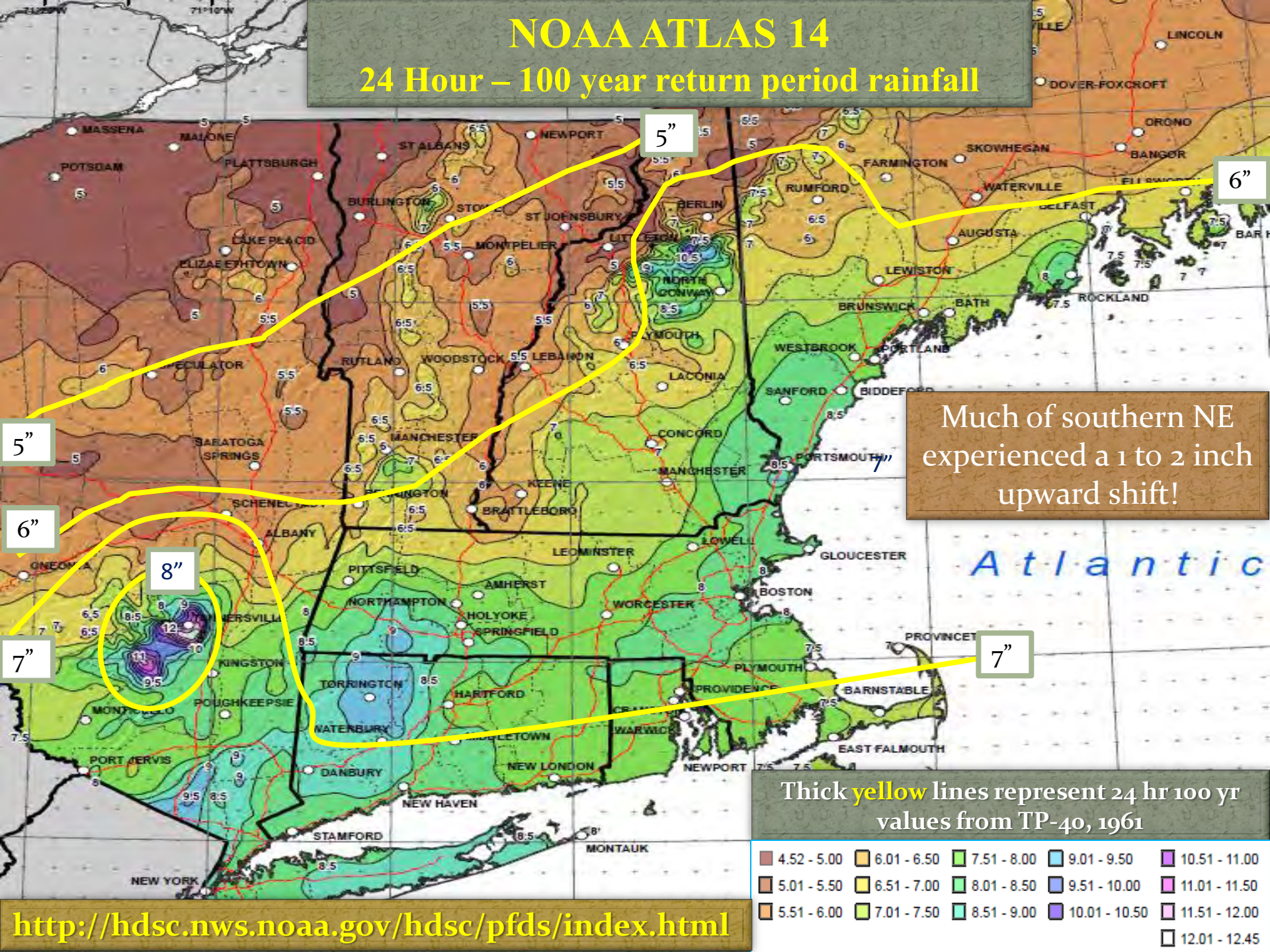
# Change in Precipitation Patterns

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).



# NOAA ATLAS 14

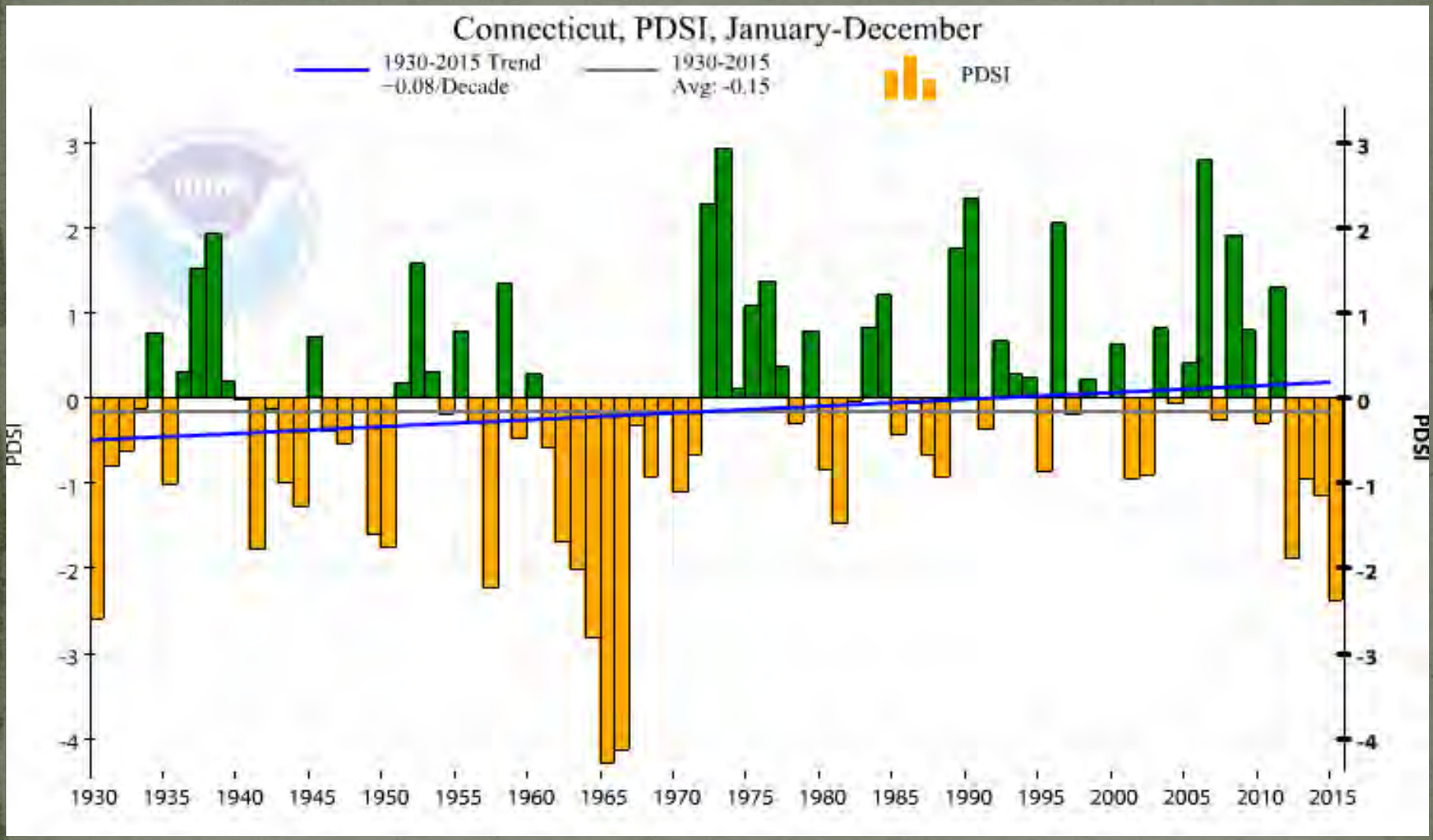
## 24 Hour – 100 year return period rainfall




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

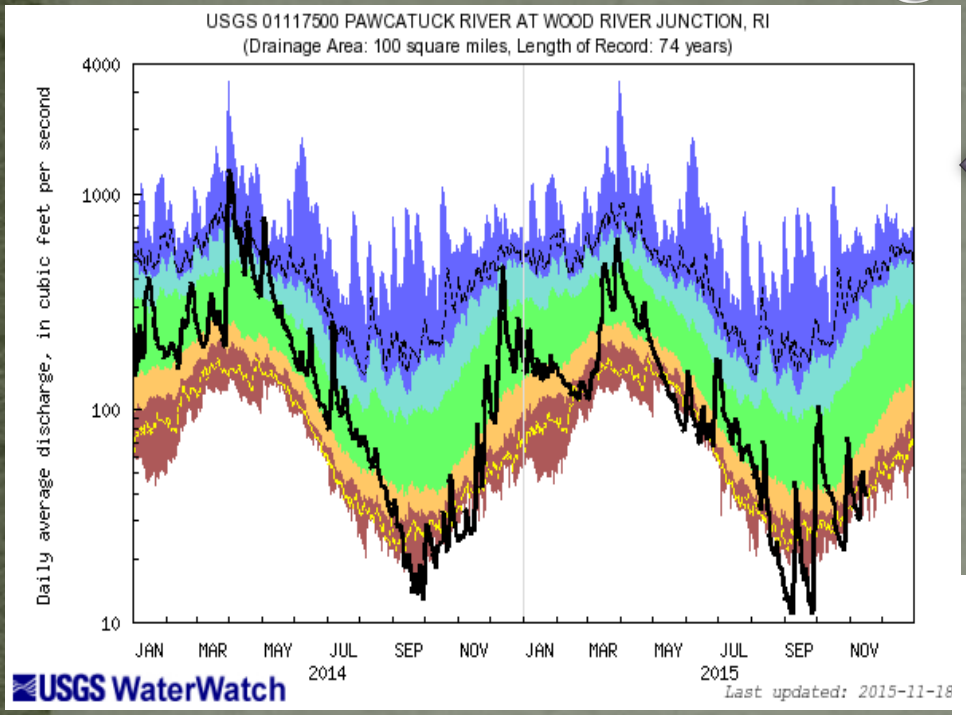
# Changes in the Palmer Drought Index

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



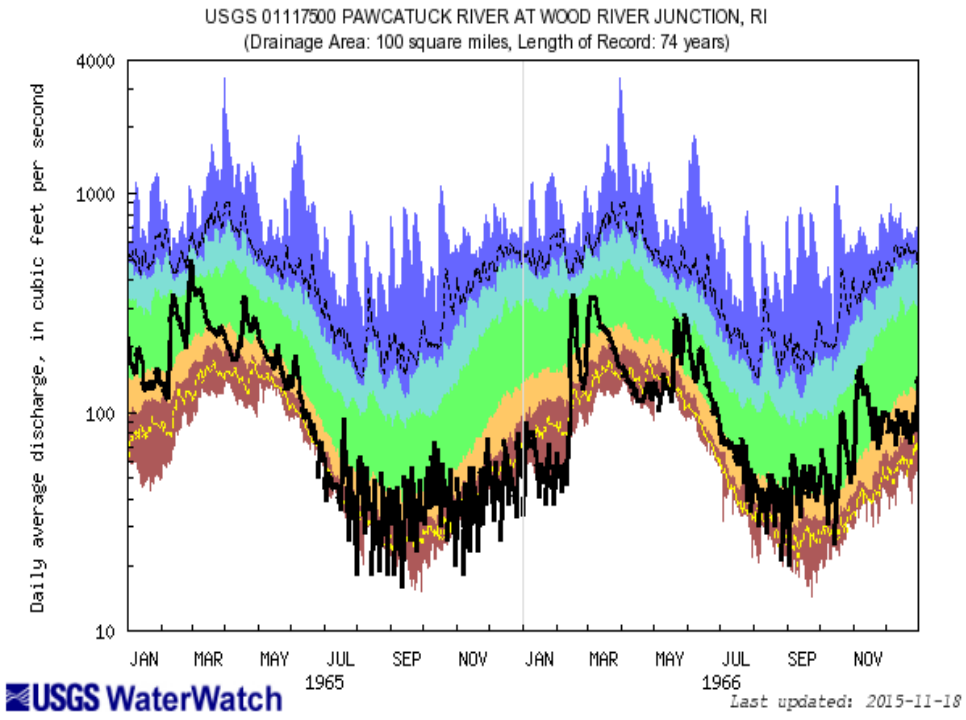

Since the late 60s, signature of less frequent & shorter dry periods and longer, more frequent and intense wet periods

# Closer look at drought characteristics




- Short/intense drought episodes:
  - 2014 and 2015
- Record daily flows
  - Exceeding minimums during the 1960s drought!
  - But…very short duration with long periods of significant recharge if not flood volumes

- Droughts of yesteryear:
  - 1964-66
- Prolonged record lows
  - Not as "record" as today's low minimum flows
  - But far longer in duration with little significant recharge



# Trends in Flood Frequency:
## *Smaller watersheds feeling the effects first*

- Changes in frequency/magnitude
- Part land use/urbanization
  - Compounded by encroachment in the floodplain
- Part changing climate
- Larger basins & those with flood control haven't seen as noticeable a shift
  - Greater capacity to handle more rain
  - Greater capacity to control releases
- Northern and western parts of the state are seeing the most dramatic increase in flooding
  - Same area where 100 year rainfall has shifted dramatically

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

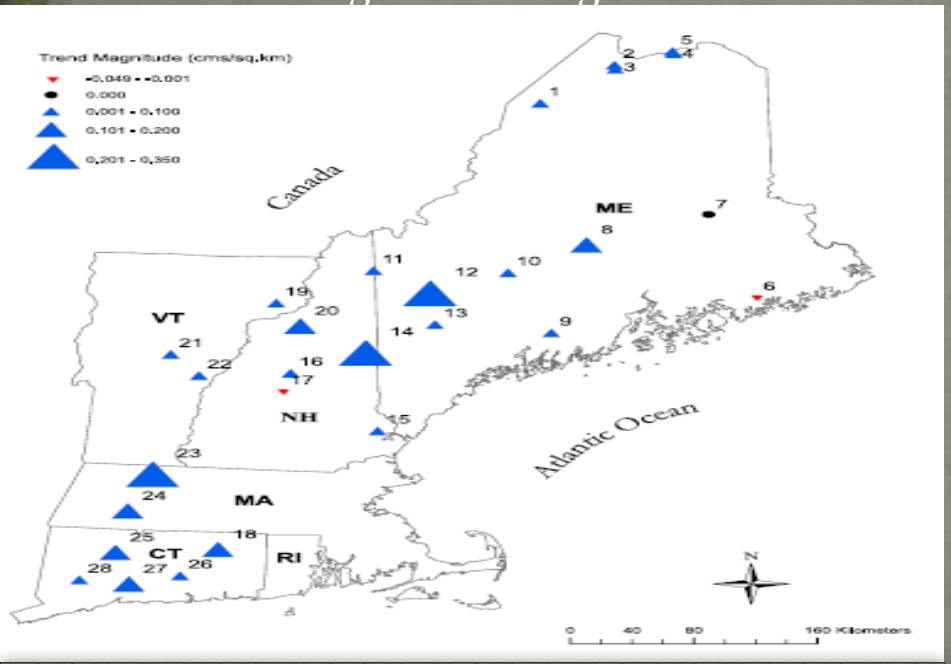
Moderate flooding along Connecticut River , April 1st, 2010. Photo: NBC Connecticut

# Instantaneous peak flows

## Mathias Collins – NOAA NFMS

### 2009 study of 28 watersheds with minimal human influences

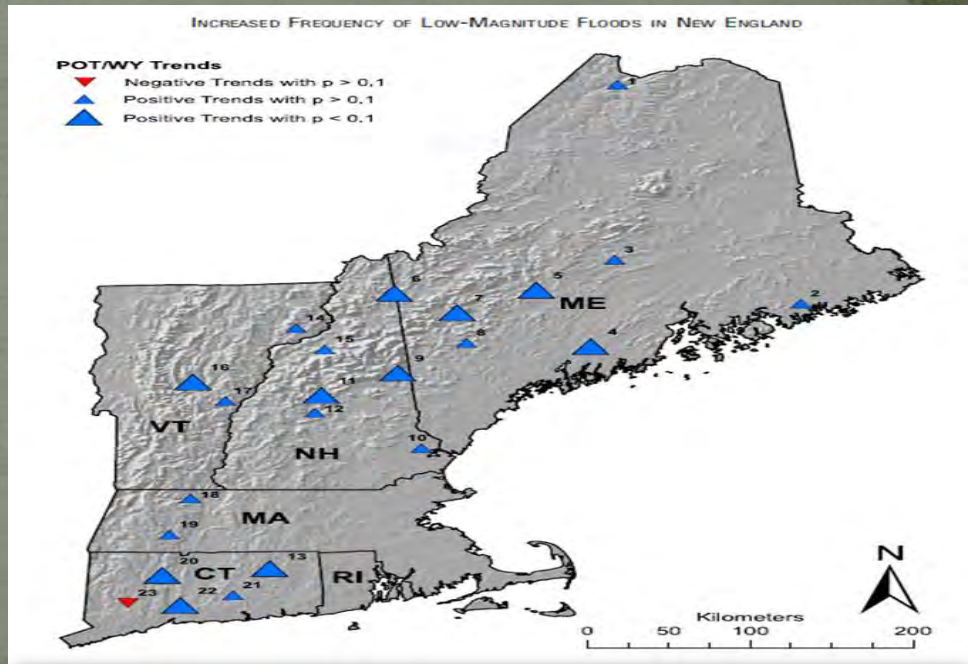
- Results indicate basins in central and western Maine experienced increased peak annual flows
  - Strongest statistical trends noted by the large blue triangles




**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.***

### 2011 study of 23 watersheds with minimal human influences

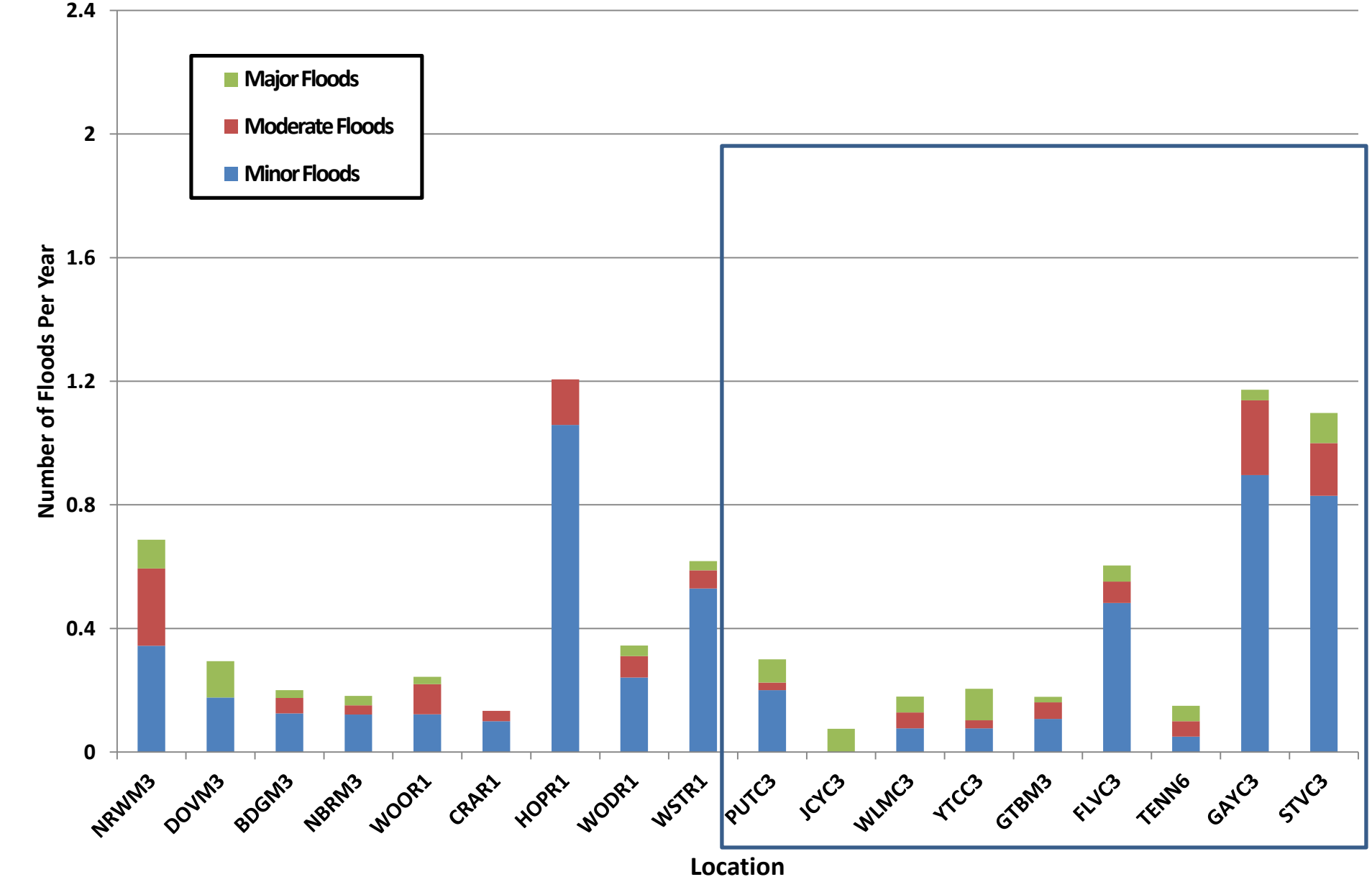
- Examined peaks over defined thresholds per water year
- More frequent flooding at 22 of 23 locations
- Increasing flood magnitude at 17 of 23 locations




**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.***

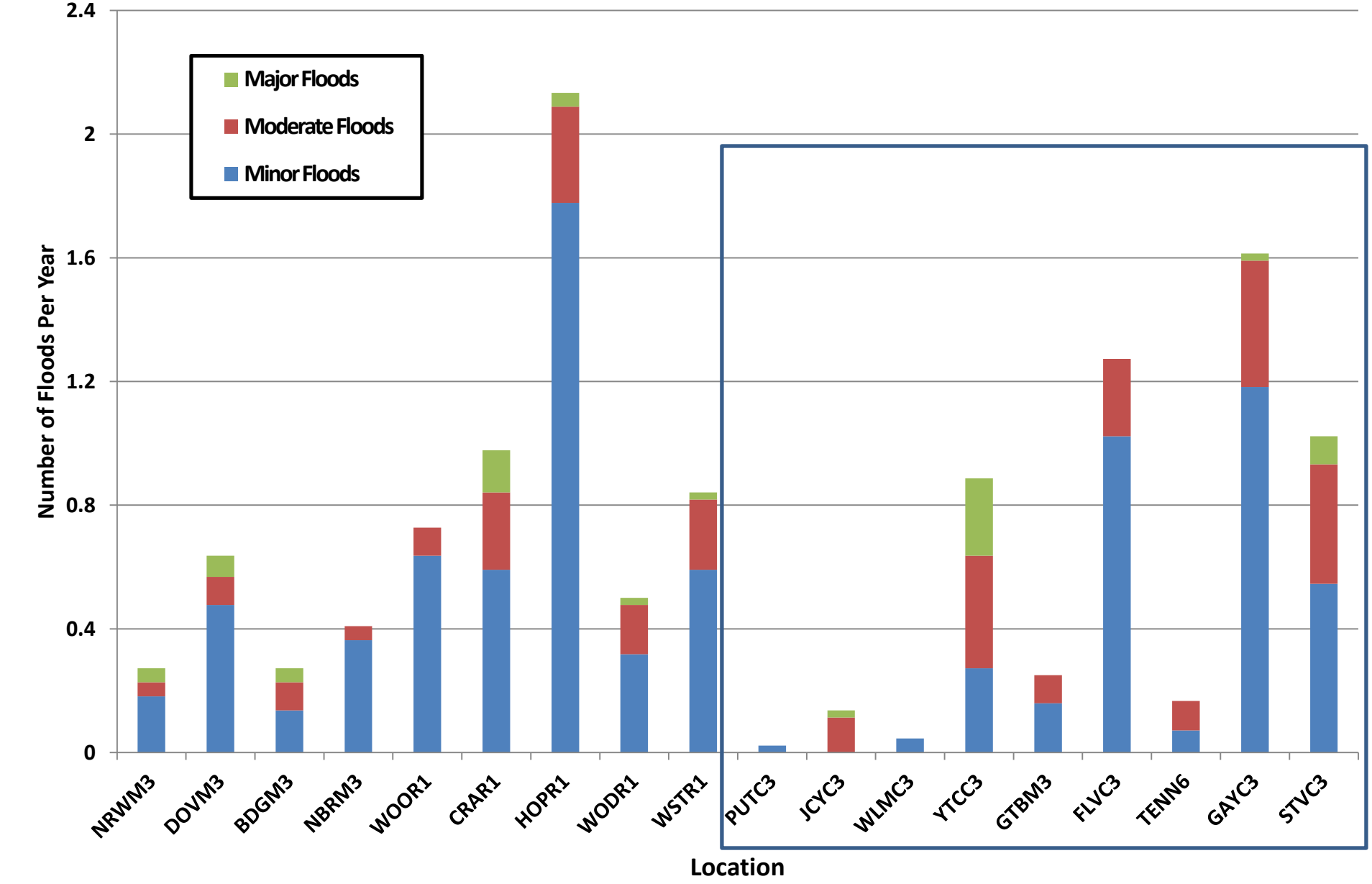
# Southern New England River Basin Normalized Number of Minor, Moderate, and Major Floods Prior to 1970

Data provided by USGS science for a changing world



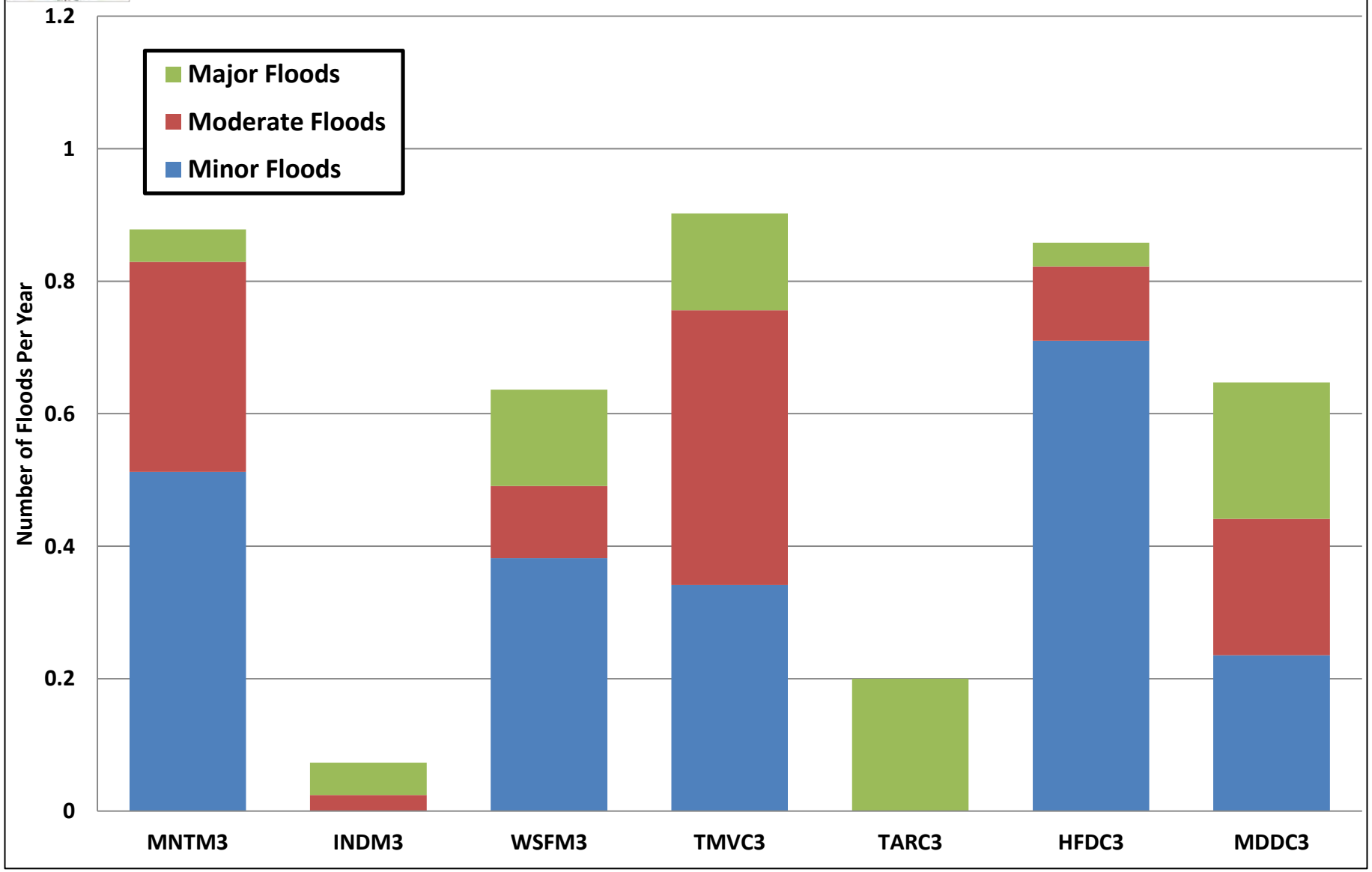
# Southern New England River Basin Normalized Number of Minor, Moderate, and Major Floods from 1970-2013

Data provided by USGS science for a changing world



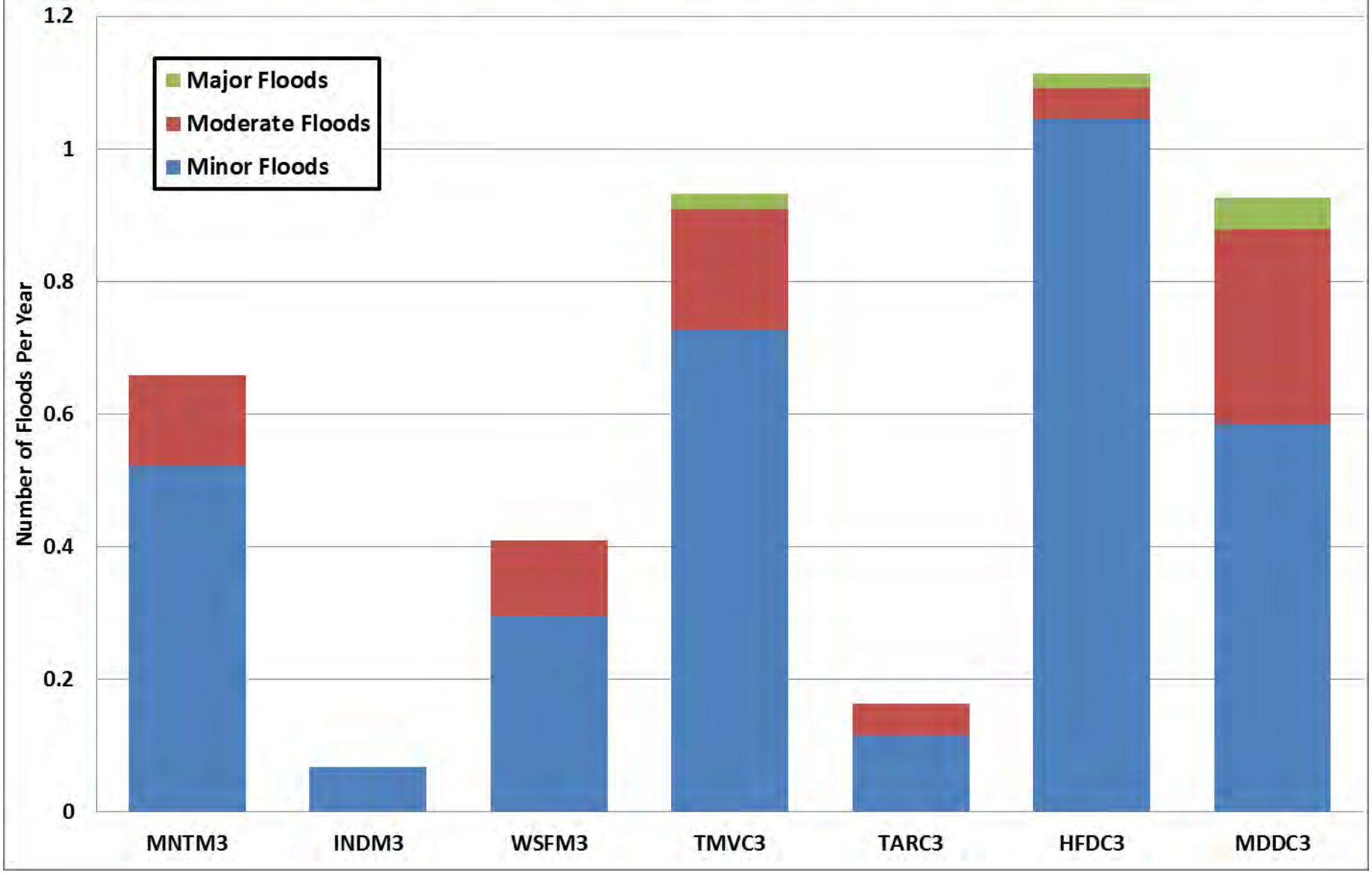
# Lower Connecticut Basin Normalized Number Of Minor, Moderate, & Major Floods Per Year Prior to 1970

Data provided by USGS science for a changing world



# Lower Connecticut Basin Normalized Number Of Minor, Moderate, & Major Floods Per Year from 1970 - 2013

Data provided by USGS science for a changing world



# Part II:
# Coastal Impacts

# Consider The 2011 and 2012 Seasons:

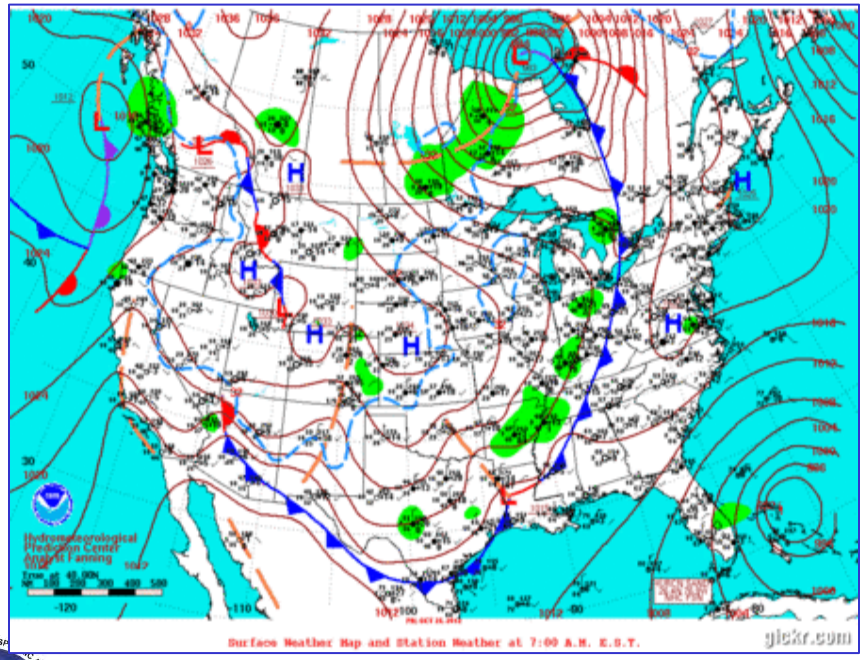
IRENE

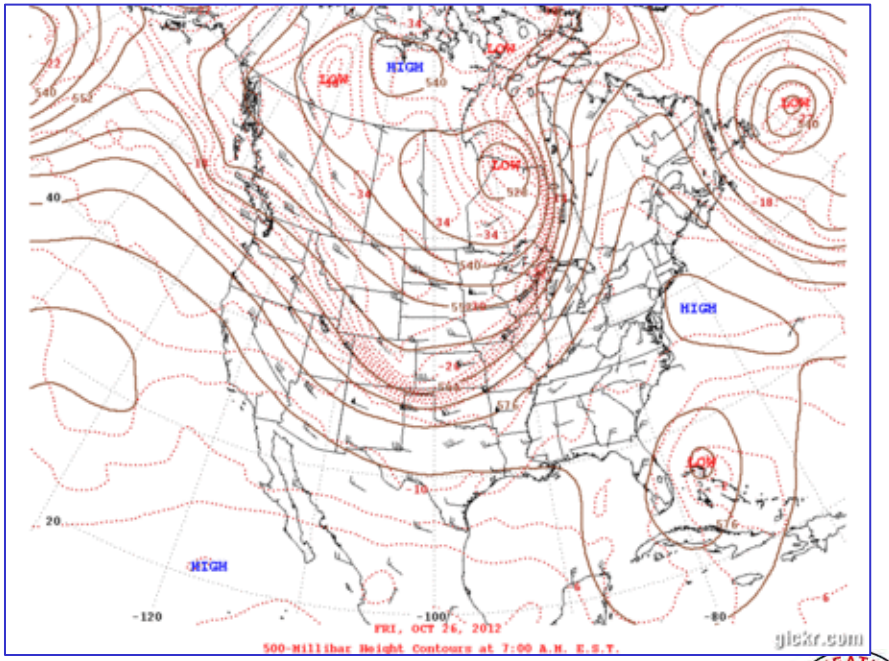
SANDY

- **Irene: Widespread wind damage & power disruption in the east & devastating flooding rains in the west**
  - "It's all about the wind and rain!"
- **Sandy: Significant coastal flooding but with less wind and little if any rain**
  - "It's all about the coastal flooding!"

# Sandy: A Perfect Storm of Sorts

- **Formed in the western Caribbean**
  - Not at all unusual for late October
- **Encountered a very deep trough of Low Pressure in the eastern United States and very strong High Pressure moving southward from the Canadian Maritimes**
  - A winter-type dual jet stream set up (classic for a New England Hurricane)
  - Captured Sandy & blocked her attempt to race out to sea

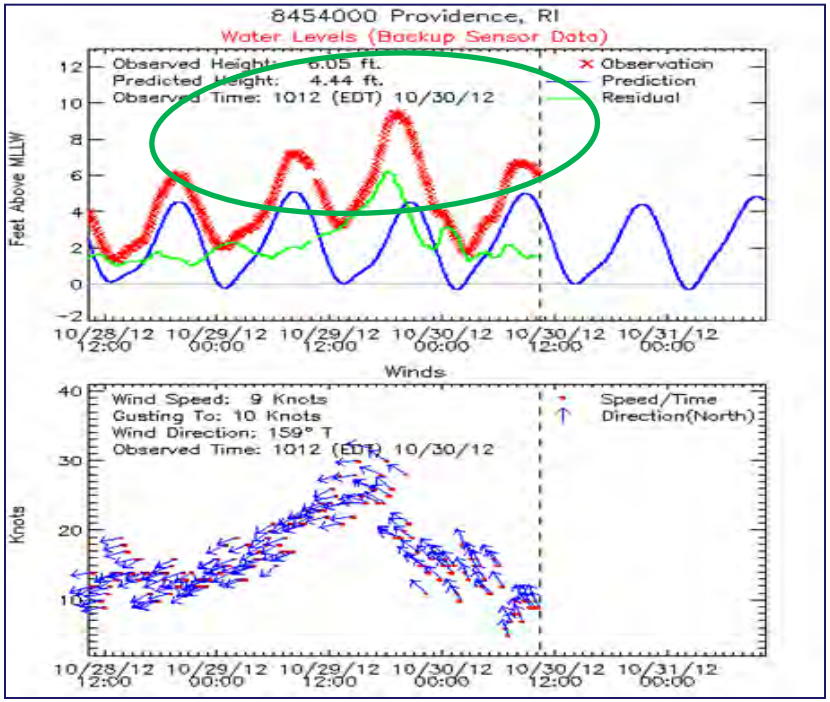


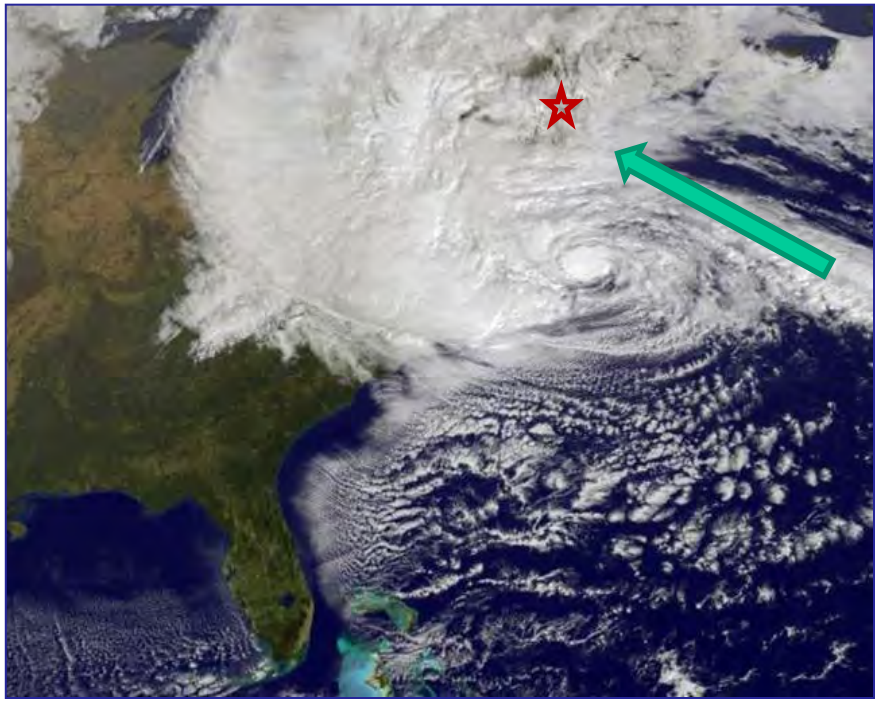



# Long Duration Southeast Fetch

## *Damaging Waves, Multiple Tide Cycles & a 4-5 ft Storm Surge*

- **Southeast swells built on 2 days of southeast winds were driven right into the south coast of RI**
  - Impacted Multiple Tide Cycles – worst of which was Monday night
  - 15-30 foot seas resulted in relentless pounding surf which first weakened then obliterated the 6-10 foot dunes along parts of the coast
  - Storm surge of 4-5 feet atop a “middle-of-the-road” astronomical tide produce a total water level (storm tide) of 9.6 feet;  One foot shy of Hurricane Bob in ’91
  - What she lacked in intensity she made up for in duration!



# Tropical Storm Irene's Coastal Damage

- Significant damage across western Connecticut coastline
  - Significant coastal flooding – from a 3 to 6 foot storm surge
  - Seventeen highway bridges destroyed by rampaging waters
  - Rockslides blocked dozens of other roadways
  - New Haven Rail Line reported 24 washouts, six landslides, one 5-car derailment

Cosey Beach, East Haven, Connecticut
Photo courtesy of TWC/Storify

East Haven, Connecticut

Photos courtesy of C. Zuraw, CT Post

Fairfield, Connecticut

# Hurricane Sandy's Coastal Damage

- Large damaging waves over multiple tide cycles
- Highest tide coincides with highest onshore winds
- Sends storm surge of several feet up the coastal rivers

Milford, Connecticut
Photo: M. McLoughlin/Reuters

Plum Bank Road, Old Saybrook
Photo: Stephen Dunn/Hartford Courant

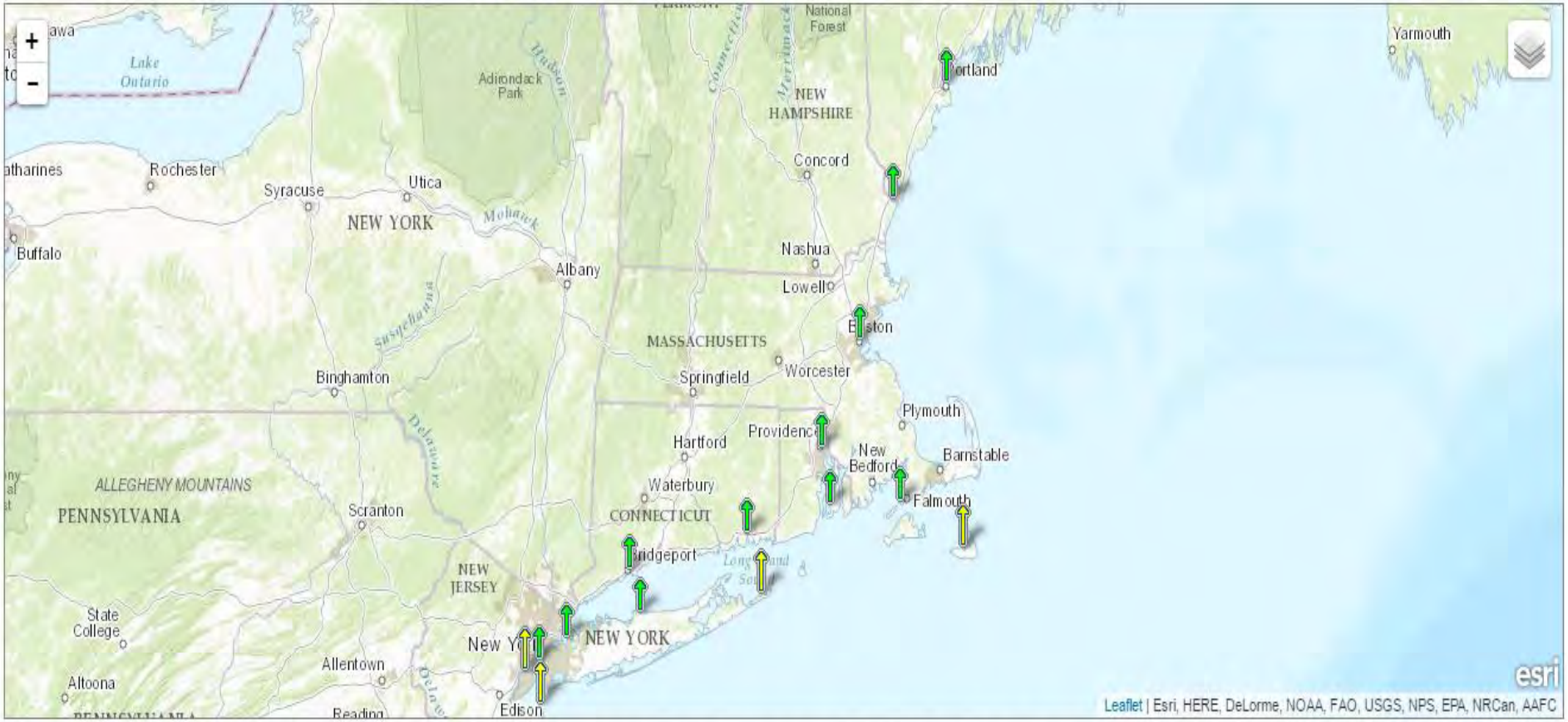
Milford, Connecticut
Photo: CNN

# Sea Level Trends

http://tidesandcurrents.noaa.gov/sltrends/index.shtml

East Coast | West Coast | Gulf Coast | Alaska | Hawaii | Global

View in Google Earth

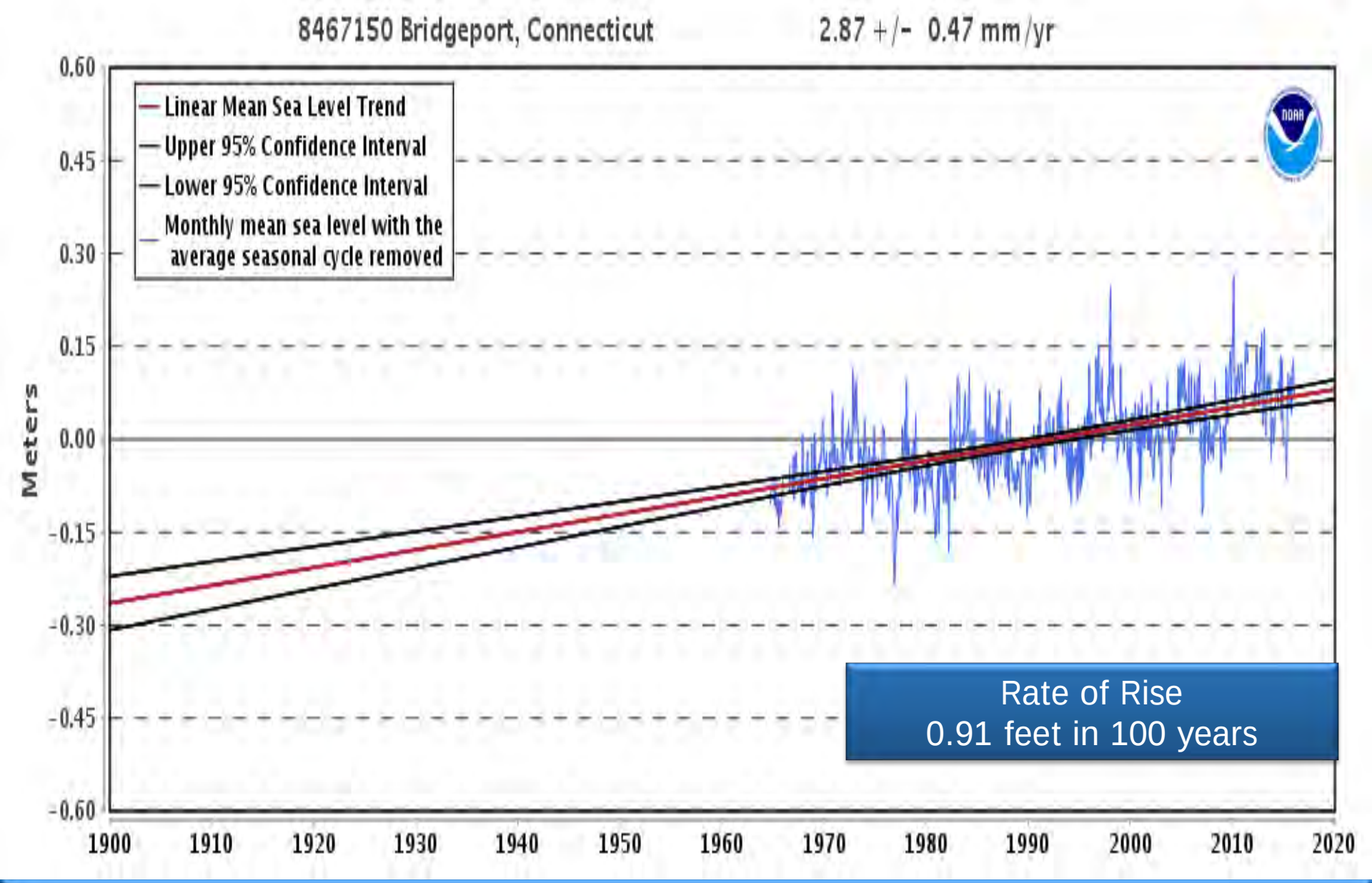



*The map above illustrates regional trends in sea level, with arrows representing the direction and magnitude of change. Click on an arrow to access additional information about that station.*

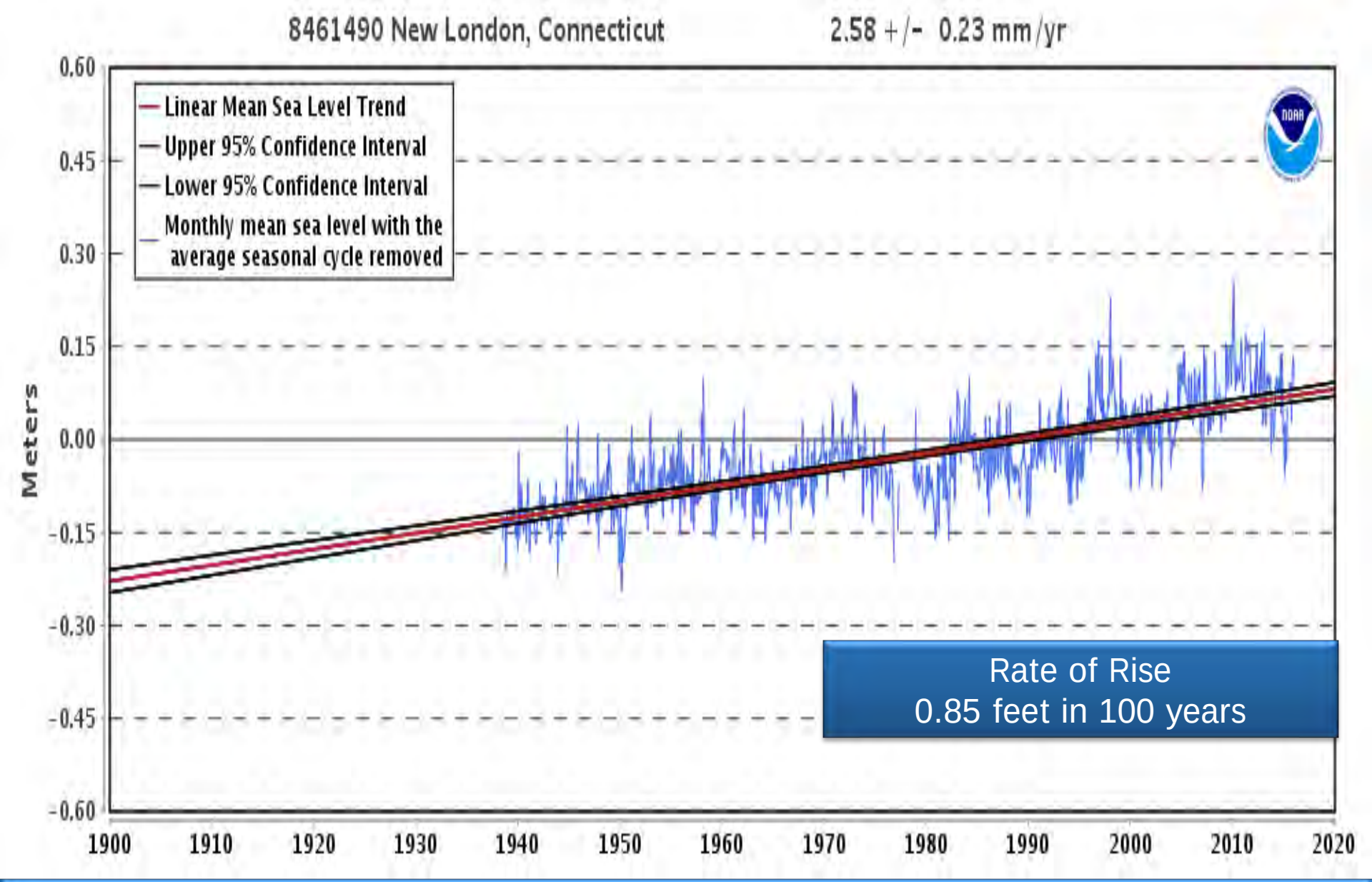
## Sea Level Trends

mm/yr (feet/century)

| | | | |
|---|---|---|---|
| 15 to 21 (5 to 7) | 6 to 9 (2 to 3) | -3 to 0 (-1 to 0) | -12 to -9 (-4 to -3) |
| 12 to 15 (4 to 5) | 3 to 6 (1 to 2) | -6 to -3 (-2 to -1) | -15 to -12 (-5 to -4) |
| 9 to 12 (3 to 4) | 0 to 3 (0 to 1) | -9 to -6 (-3 to -2) | -18 to -15 (-6 to -5) |




**The mean sea level trend is 2.87 millimeters/year with a 95% confidence interval of +/- 0.44 mm/yr based on monthly mean sea level data from 1964 to 2014 which is equivalent to a change of 0.91 feet in 100 years.**




**The mean sea level trend is 2.58 millimeters/year with a 95% confidence interval of +/- 0.23 mm/yr based on monthly mean sea level data from 1938 to 2014 which is equivalent to a change of 0.85 feet in 100 years.**

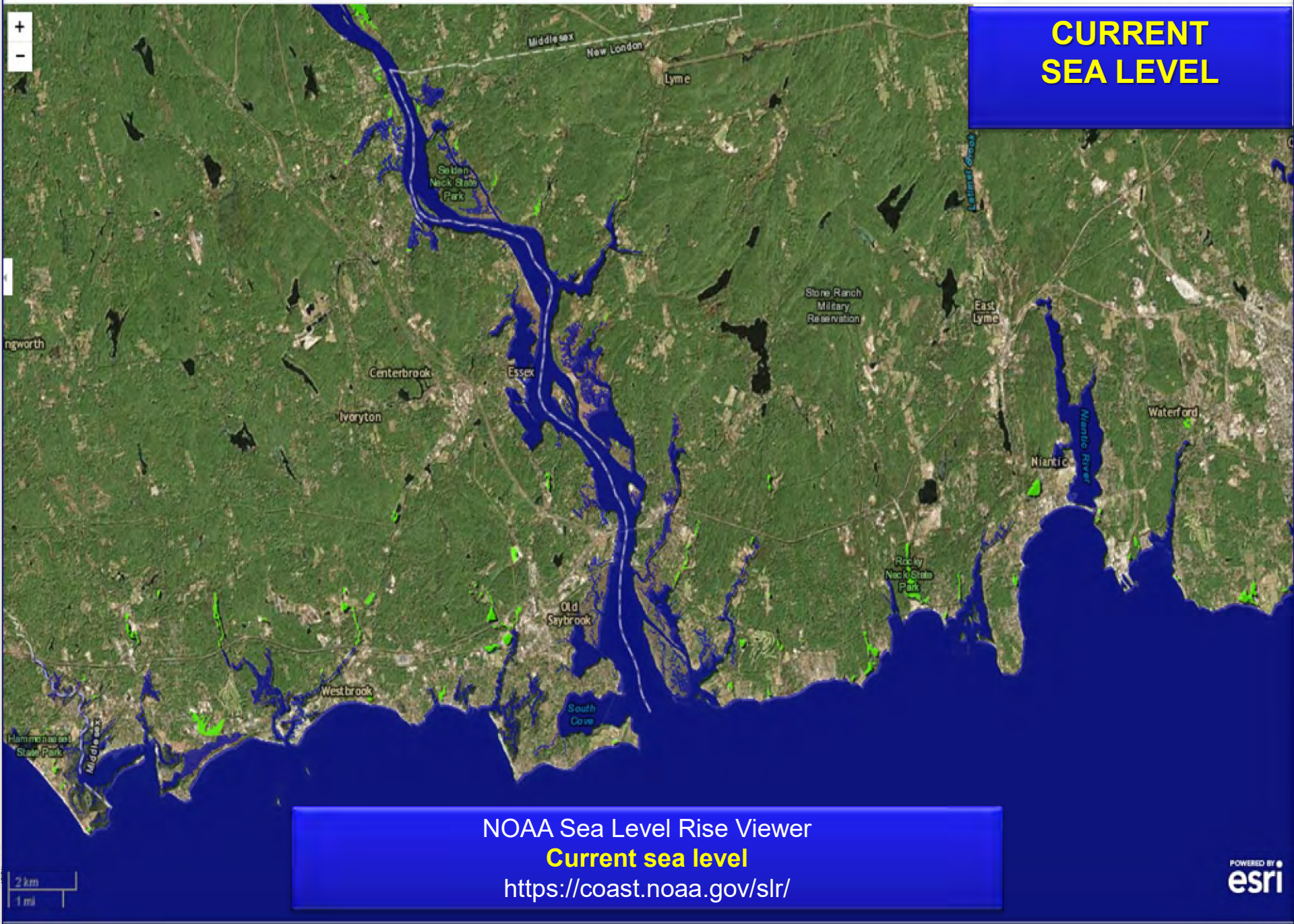
# Frontal Erosion 1939-2012 - Browning Cottages, Moonstone Beach, RI

# Superstorm Sandy - Browning Cottages

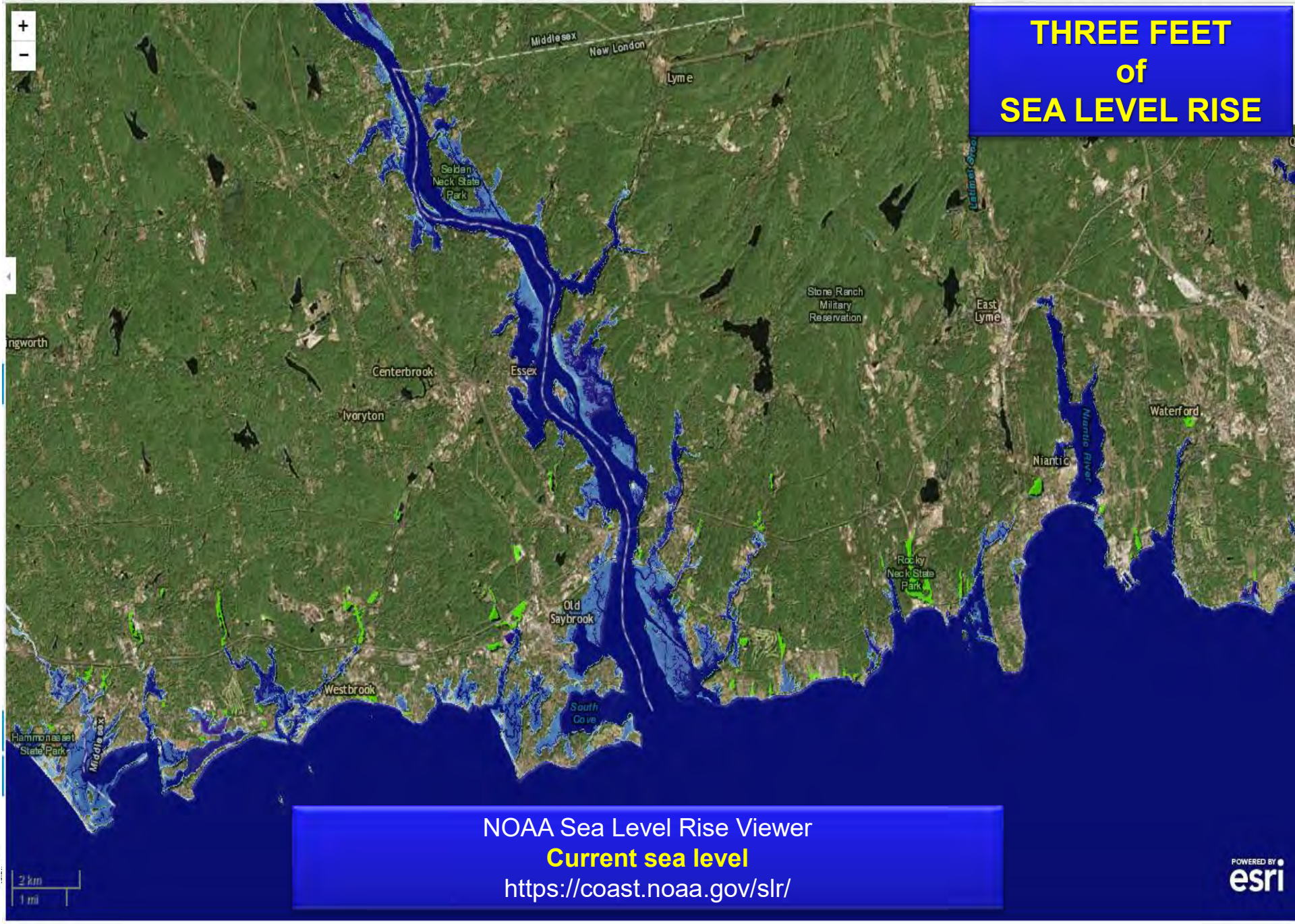
30 Oct 2012

http://fema.maps.arcgis.com/home/webmap/viewer.html?webmap=

Sea Level Rise and Coastal Flooding Impacts



Sea Level Rise and Coastal Flooding Impacts

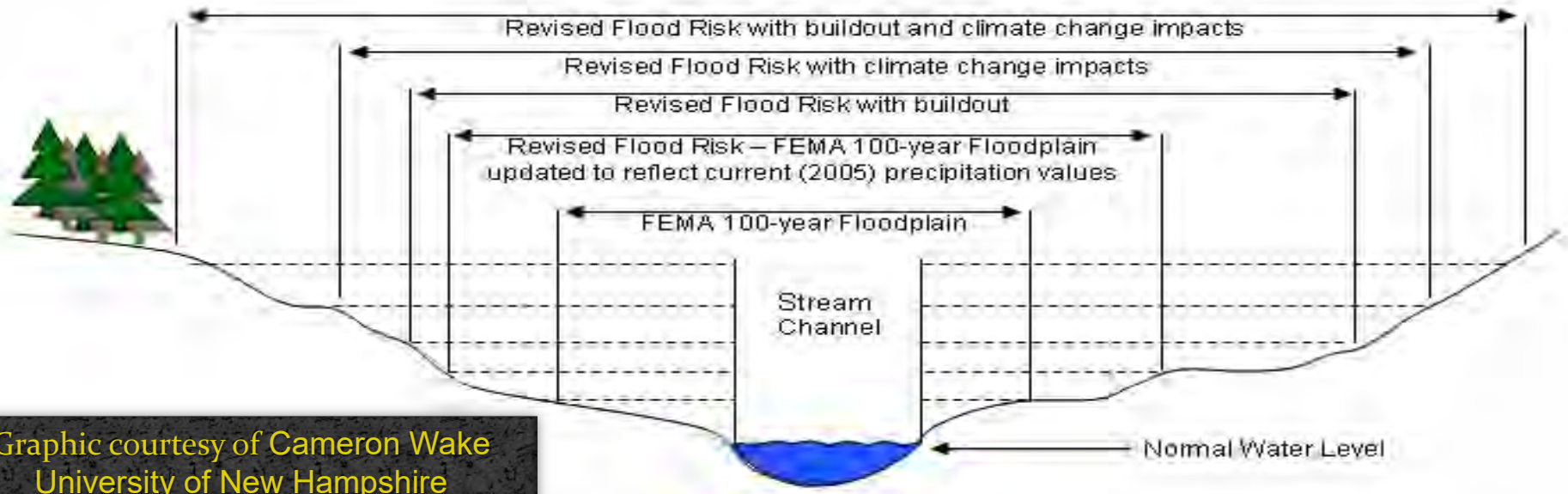


# Summary

- The Northeast U.S. 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
  - Smaller watersheds & those with significant urbanization and/or land use change are most vulnerable to increased river & stream flooding
- Continued sea level rise combined with intense coastal storms has renewed the coastal flood threat
  - A weaker category of storm is now capable of producing inundation once limited to the more intense hurricanes and coastal storms

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

- Floodplain,  land use, infrastructure, dam spillway requirements, drainage requirements, storm water management, 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

# Climate Trends in Connecticut and Its Impact on Storm and Riverine Flood Behavior

David R. Vallee
Hydrologist-in-Charge
NOAA/NWS
Northeast River Forecast Center

Flooding along the Housatonic River following Lee, Sept 8, 2011.