Climate Trends in Southeast New York and Their Impact on Flood Frequency

Southeast New York Stormwater Conference

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Northeast River Forecast Center

 Record flooding along the Mohawk River in Rotterdam, NY, August 2011 following Irene. Photo from AP.

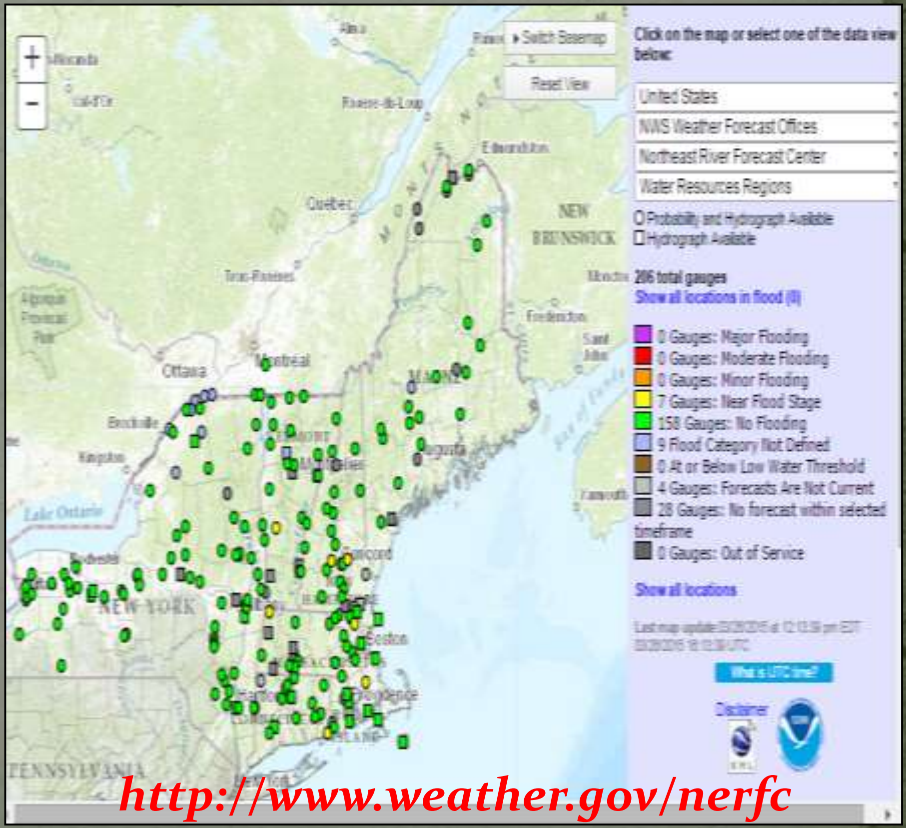
Overview of today's presentation

- Part I: A bit about the Northeast River Forecast Center & how we go about the business of river and water resource forecasting
- Part II: Our changing climate
  - Warm, wetter, more frequent extreme precipitation events, and changes in river flood frequency & magnitude
- Part III: New water resource services
  - From hours to years
  - From Summit to Sea / Tree Top to Bedrock

NOAA/NWS's Northeast River Forecast Center

Our Mission:

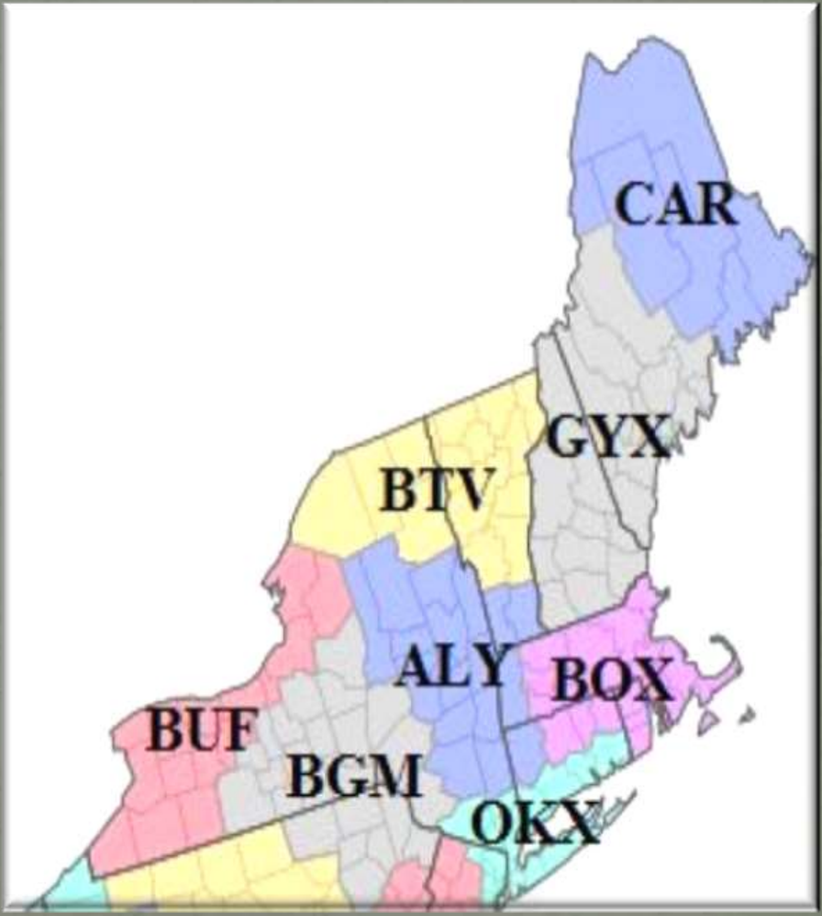
To provide our nation with river, flood and water resource forecasts for the protection of life and property and the enhancement of the national economy



http://www.weather.gov/nerfc

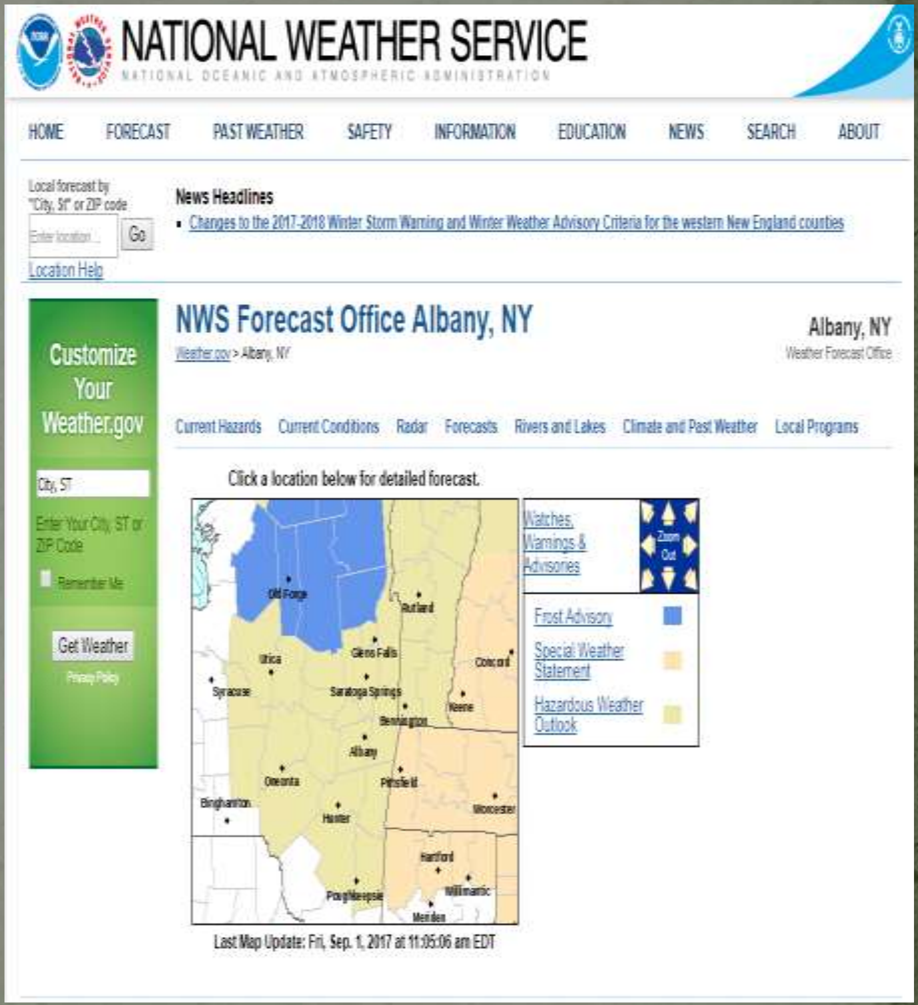
Weather Forecast Office
New York/New England Service Areas

- WFO Caribou, ME
  - Northeast Maine counties
- WFO Gray, ME
  - Southwest Maine and all of New Hampshire
- WFO Burlington, VT
  - Northern 2/3rds of VT
- WFO Albany, NY
  - Srn 1/3 of VT, Berkshire, MA, Litchfield, CT
- WFO Taunton, MA
  - Rest of MA, all of RI, and the northern 2/3rds of CT
- WFO Upton, NY
  - All coastal CT Counties
- WFO Binghamton, NY
  - Finger Lakes region
- WFO Buffalo, NY
  - Buffalo Creeks, Genesee and Black



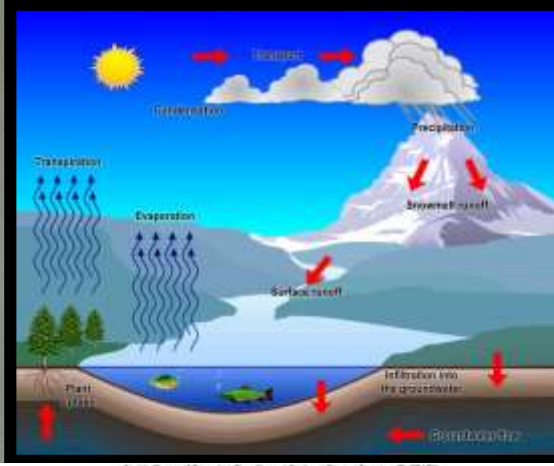
Weather Forecast Office Responsibilities

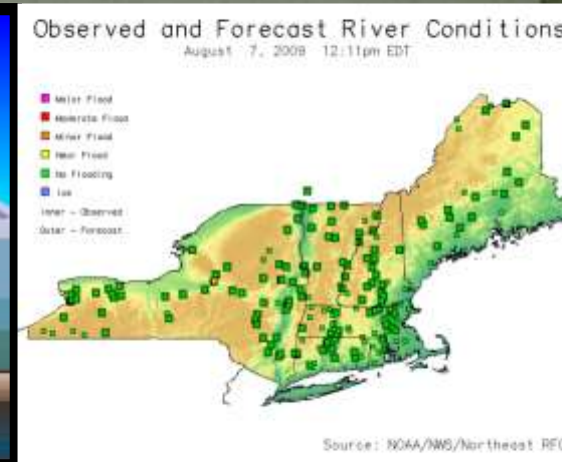
- Watch/Warning responsibilities
  - Coordinate final adjustments to RFC forecasts for warning issuances
  - Issue and coordinate all watches/warnings with local interests
    - Flood/Flash Flood
    - Drought/Water Resource
    - Hydrologic Outlooks
  - Define forecast service requirements
  - Establish flood stages and impact statements for forecast points
  - Work with RFC on developing modeling requirements
- Provide Decision Support Services to the Decision Makers in the region

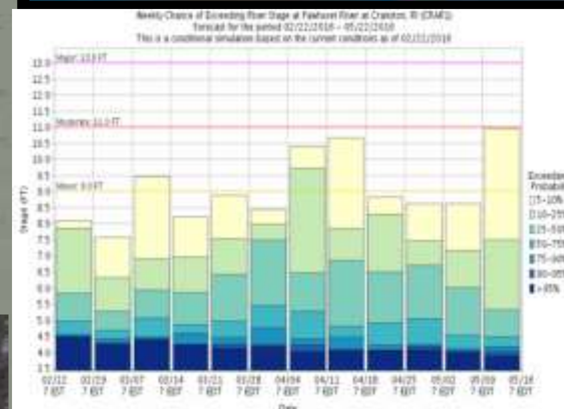


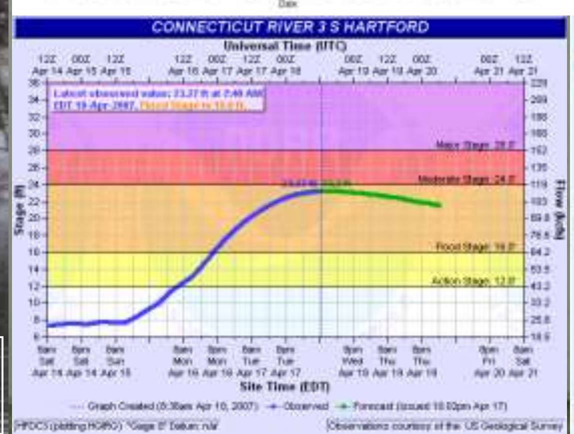
River Forecast Center Responsibilities

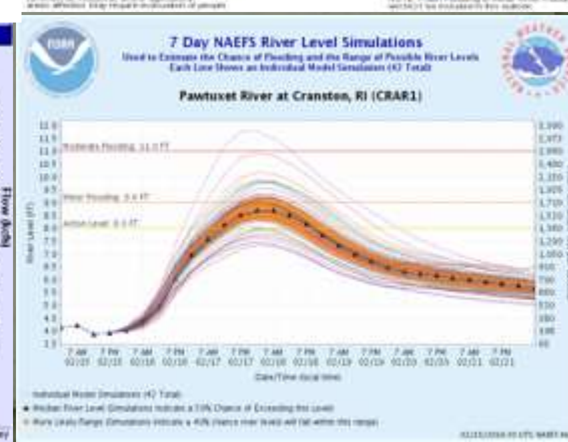
- Calibrate and implement a variety of hydrologic and hydraulic models to provide:
  - River flow and stage forecasts at 180 locations
  - Guidance on the rainfall needed to produce Flash Flooding
  - Ensemble streamflow predictions
  - Ice Jam and Dam Break support
  - Water Supply forecasts
  - Partner 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.

Our changing climate:

- From a “Practitioner’s Perspective”
- Rainfall/Temperature trends
- Changes in flood & drought behavior
- Challenges going forward

A few caveats

- Neither Ed nor I are climate scientists!
  - We are practitioners
- We have the benefit of living in this part of the country – i.e.: *we are locals!*
  - 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!

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 10 years!

Job Security in the face of changing flood behavior!!

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

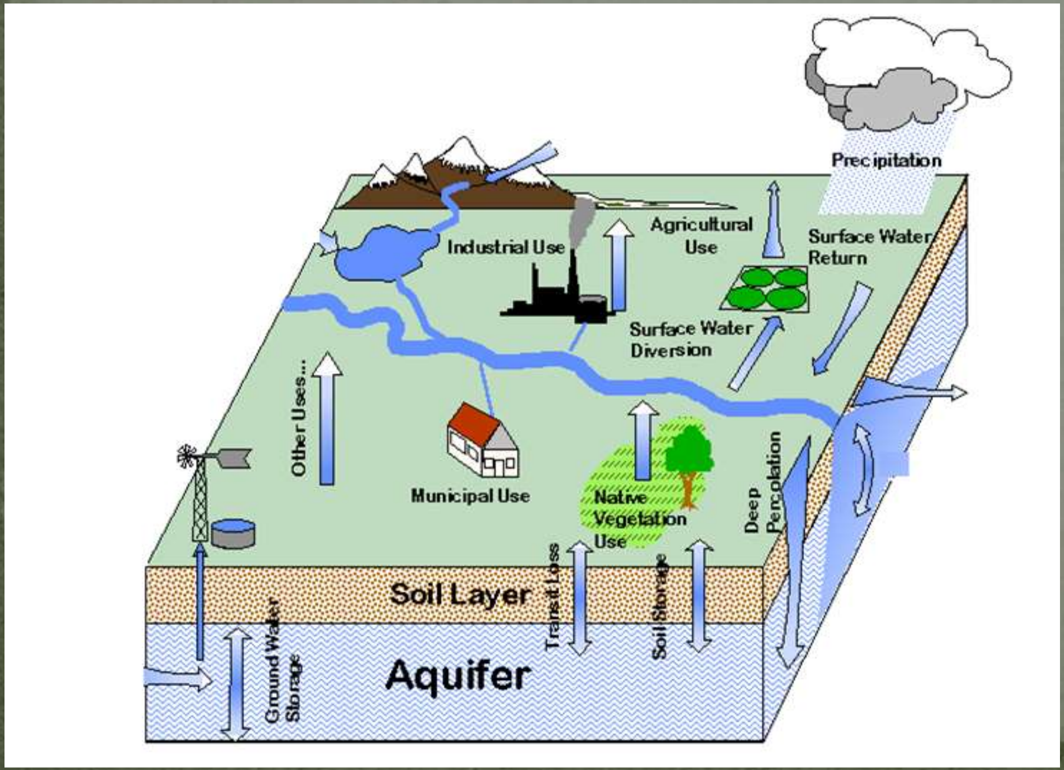
Providence Street – Warwick, RI at 1030 am Wednesday 3/31/10

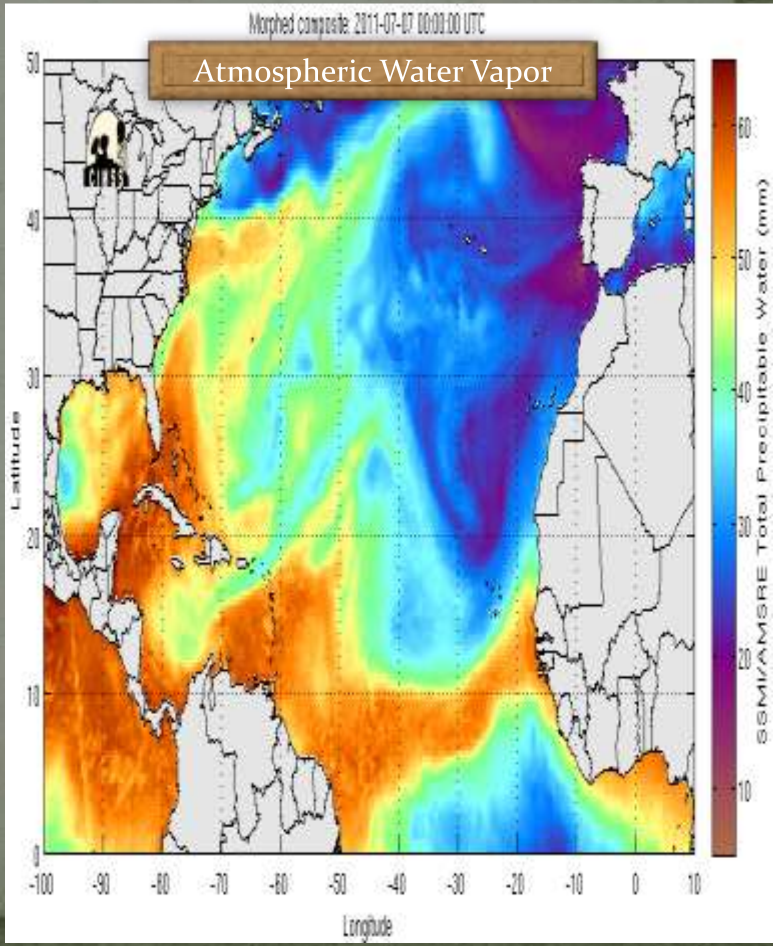
Home washed off its foundation on the Schoharie Creek, Prattsville, NY – Tropical Storm Irene

Record Flash Flooding in Utica, NY, July 1st, 2017
Photo courtesy of Jill Reale (WKTV)

Is there a common theme to recent ?

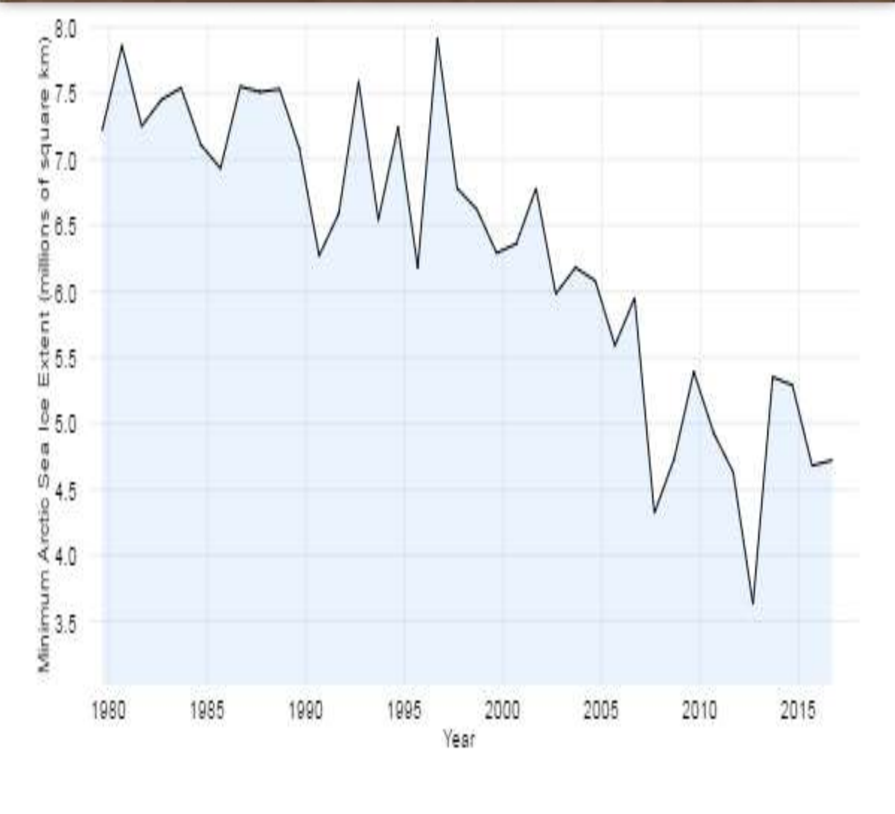
- Several:
  - Slow moving weather systems – a blocked up atmosphere
  - Multiple events in close succession or 1 or 2 slow movers
  - Resulted in saturated antecedent conditions
  - Each fed by a "tropical connection"
    - Plumes of deep moisture





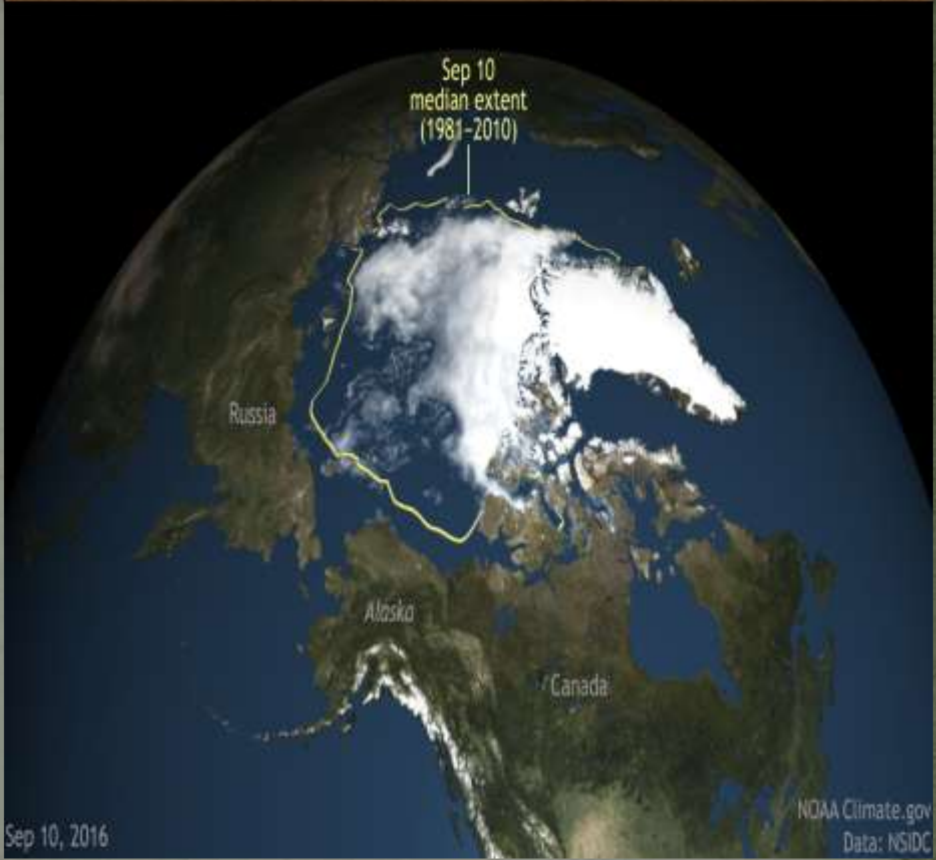
A warming planet and shrinking Arctic Sea ice

September Minimum Sea Ice Cover 1979-2016



This graph shows the average area covered by sea ice during September each year. Minimum sea ice extent has decreased 12% per decade since 1979. Data provided by the National Snow and Ice Data Center.

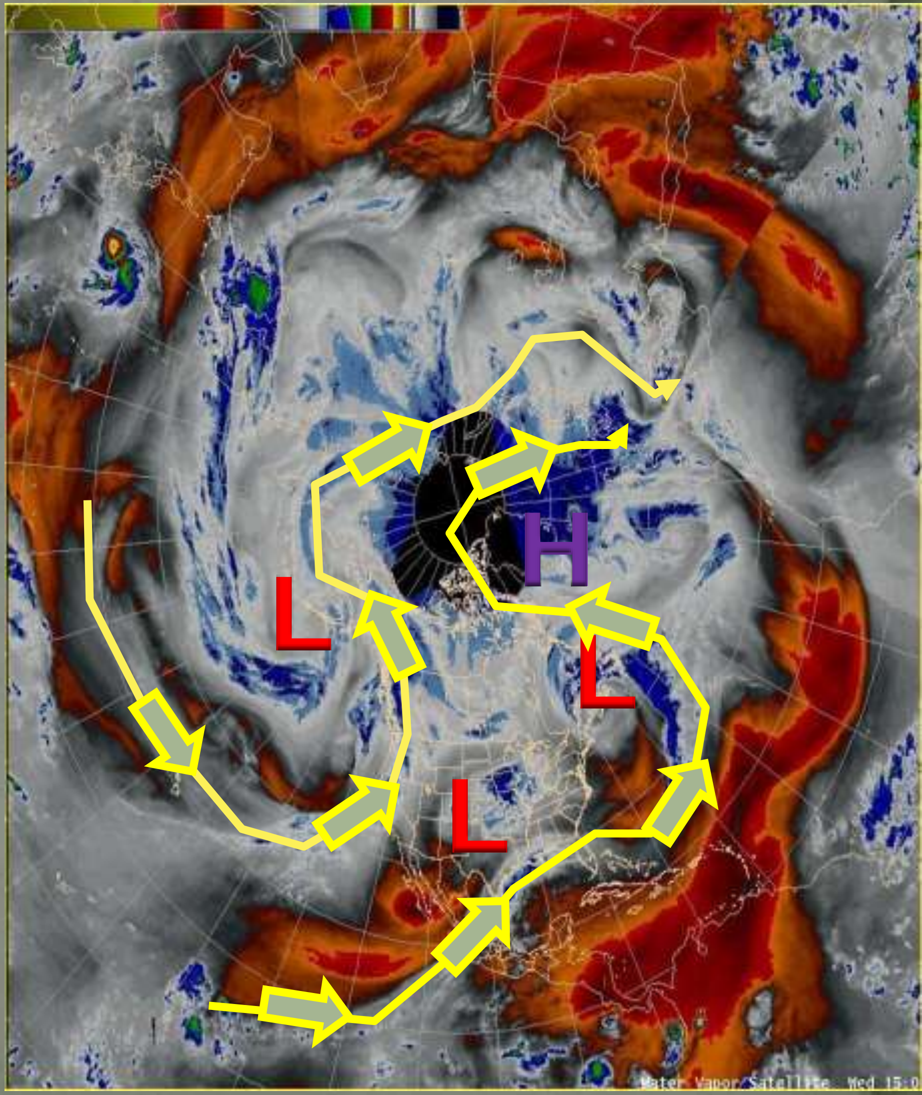
2016 Arctic Sea Ice Summer Minimum



Arctic sea ice concentration on the date of the 2016 minimum extent, September 10, 2016. NOAA Climate.gov image based on NOAA and NASA satellite data from NSIDC.

Is there a plausible "Climate Hypothesis"?

- Modest changes in air & sea temperatures = atmosphere can hold more moisture
  - The region 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

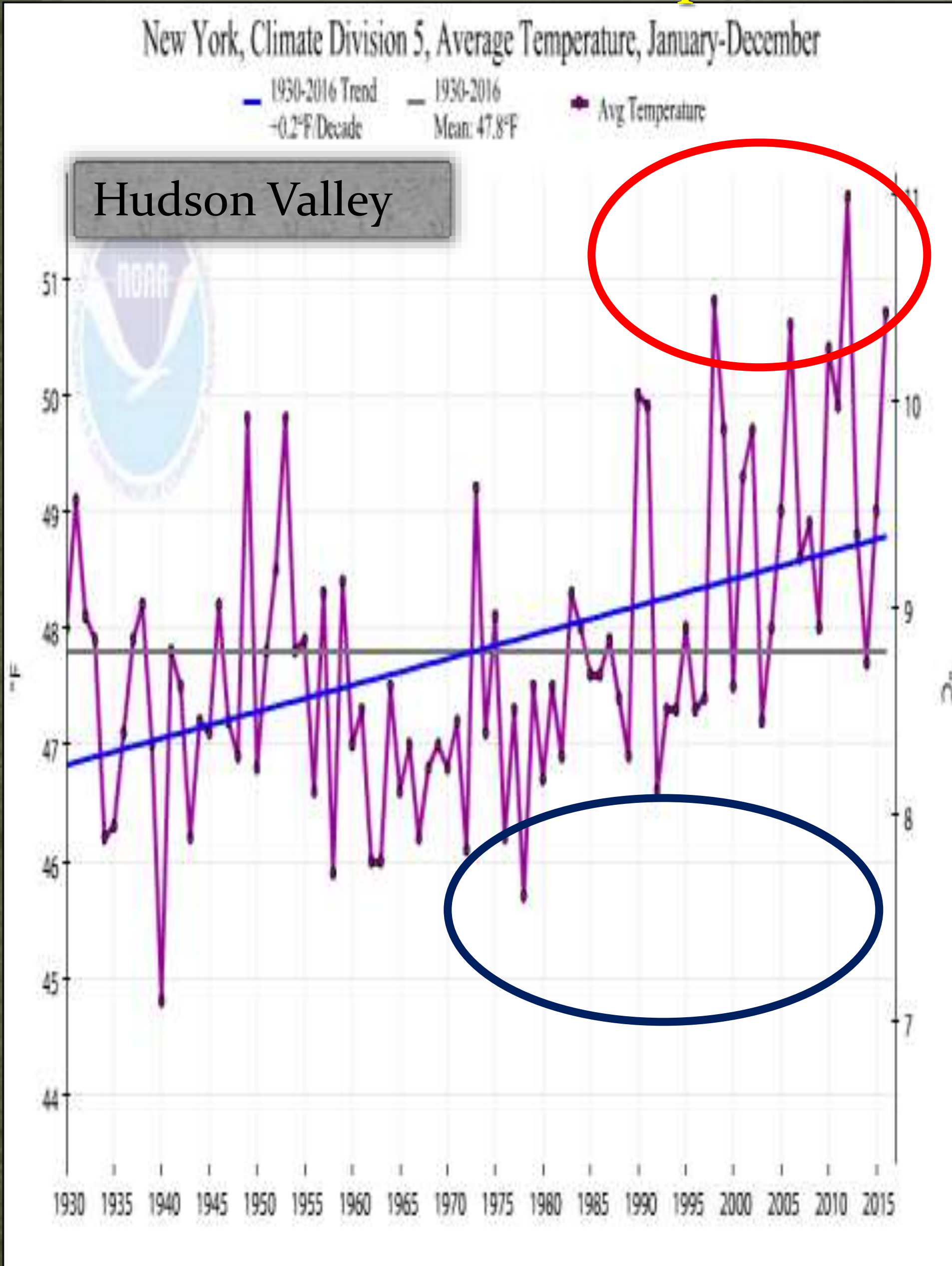
- Common themes across New England:
  - Increasing annual precipitation
  - Increasing frequency of heavy rains
  - Warming annual temperatures
  - Wildly varying seasonal snowfall
- Shift in precipitation frequency (50, 100 yr – 24 hr rain)
- For smaller (<800 sq mi) basins – trend toward increased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

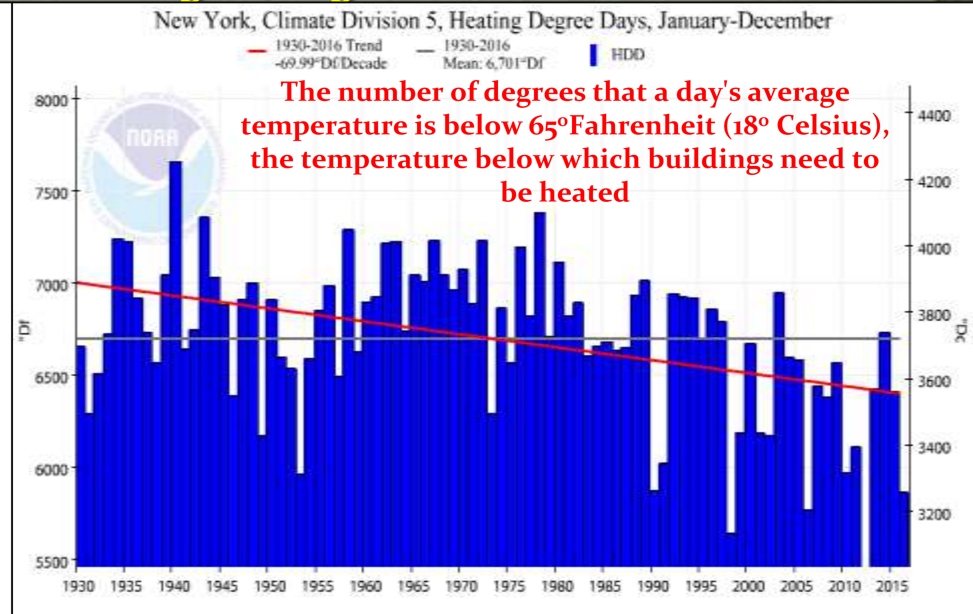
Record flooding during Tropical Storm Irene, Catskills Region of NY. Photo: catskillstreams.org

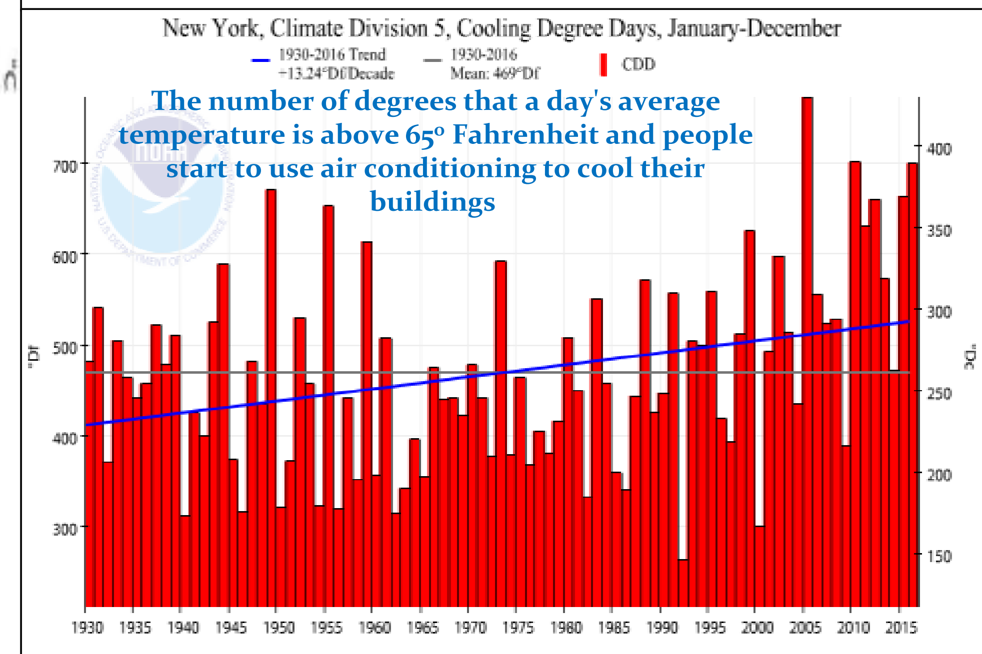
Record flash flooding, Islip, LI from 13 inches of rain. August 13th, 2014. Photo: Ed Betz, Newsday

A Look at Temperature Trends

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

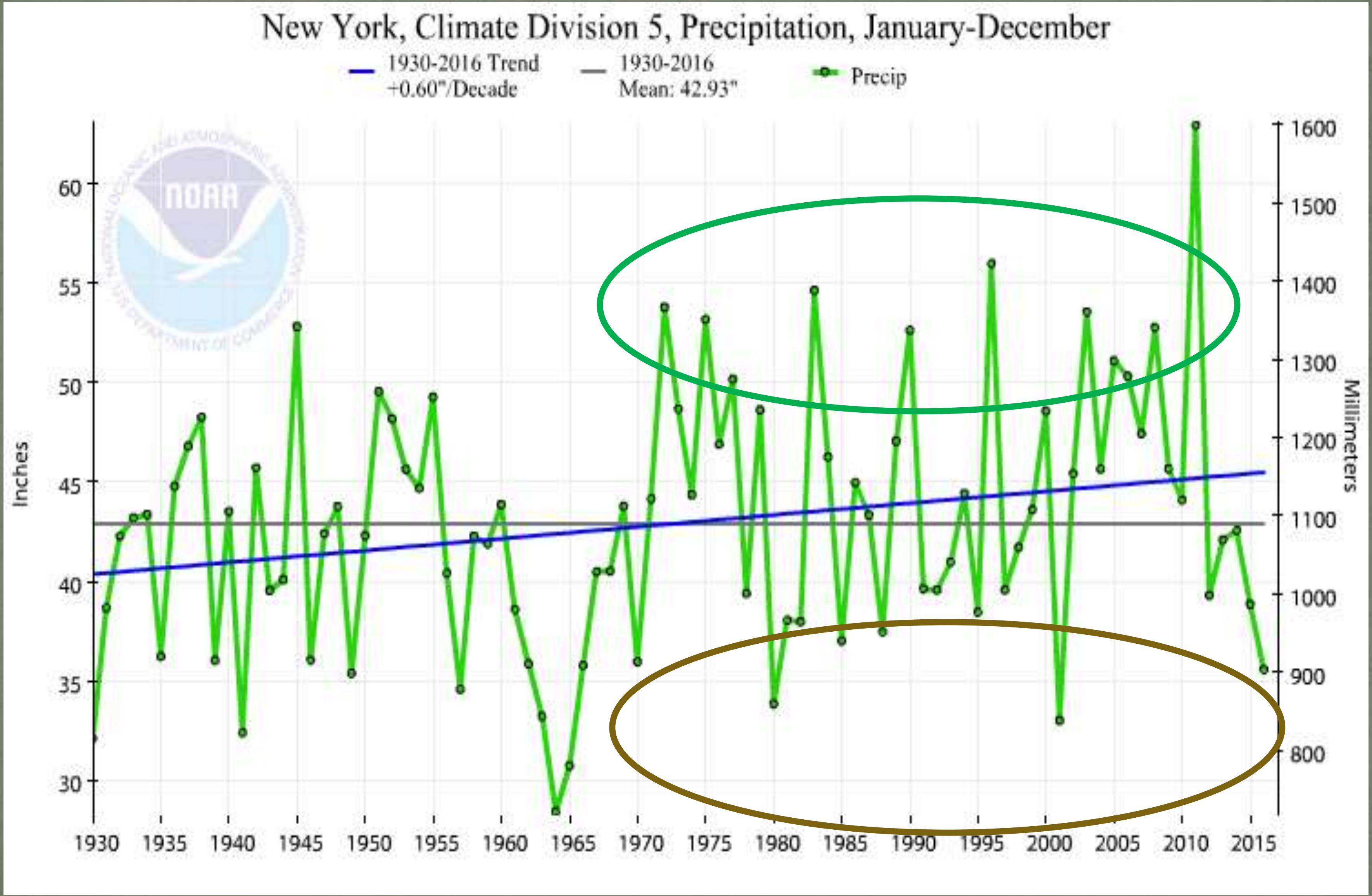






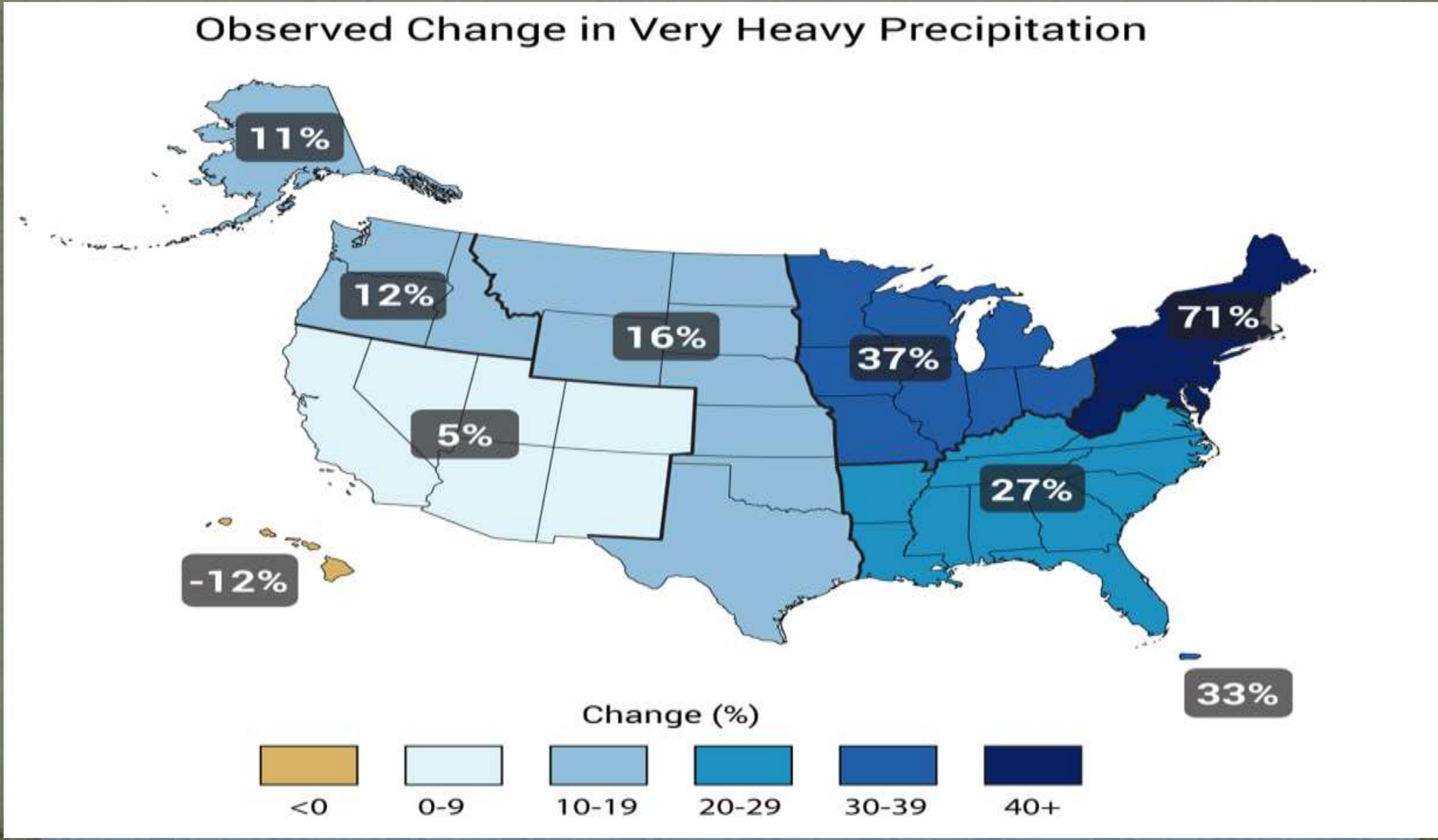
A Look at Precipitation Trends

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



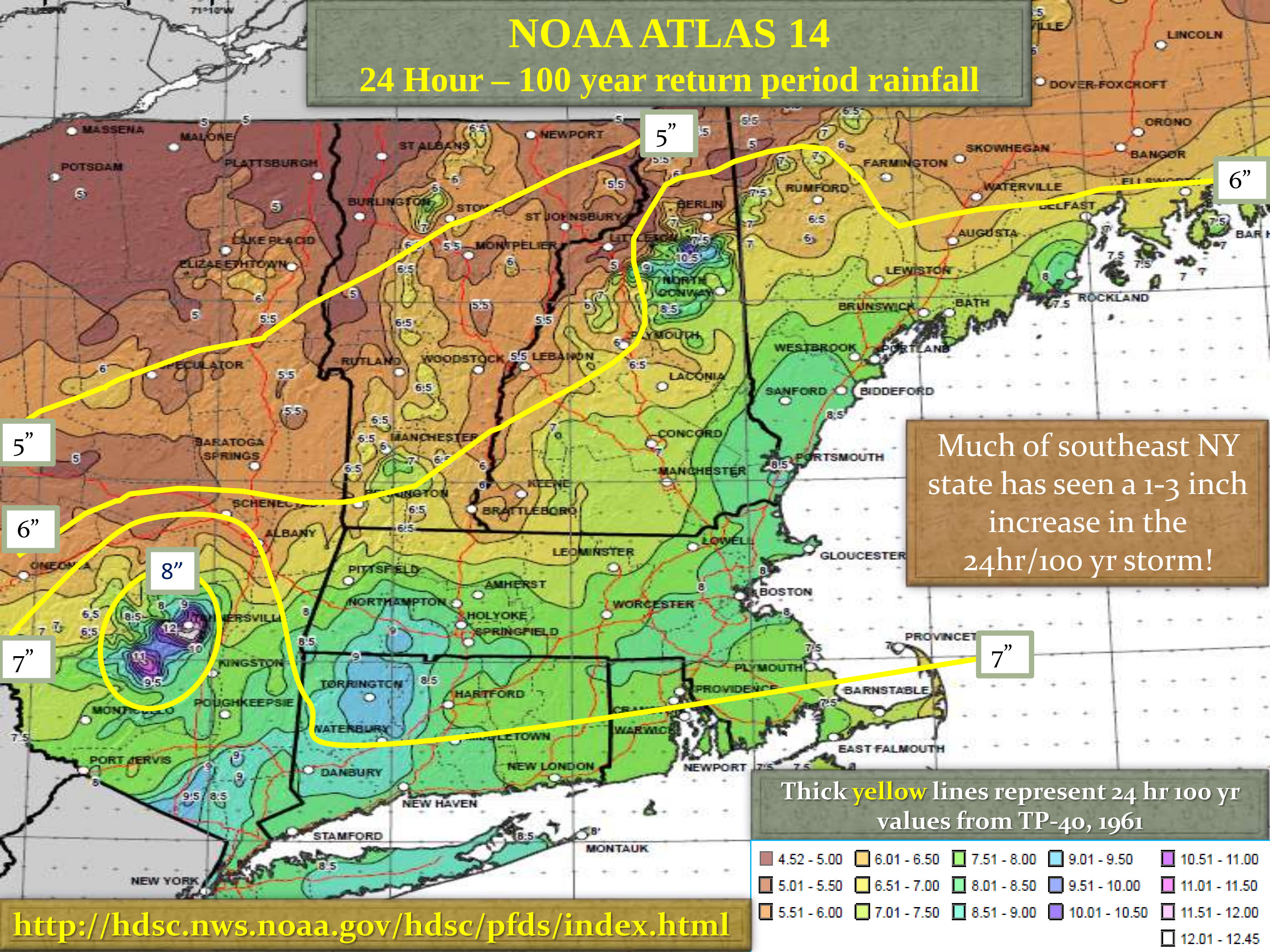
Change in frequency of Heavy Precipitation

- Intense precipitation events (the heaviest 1%)
- Used to average 4-6 days a year of >1" of rain or more
- Today we are averaging nearly 10-12 days!



Source: http://www.globalchange.gov/publications/reports/scientific-assessments/us-impacts

NOAA ATLAS 14
24 Hour – 100 year return period rainfall



Much of southeast NY state has seen a 1-3 inch increase in the 24hr/100 yr storm!

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

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

…But you cannot design for everything!

Example: August 13th, 2014 – Islip, NY – Rainfall 11 inches/3 hours

AMS-based precipitation frequency estimates with 90% confidence intervals (in inches)[1]

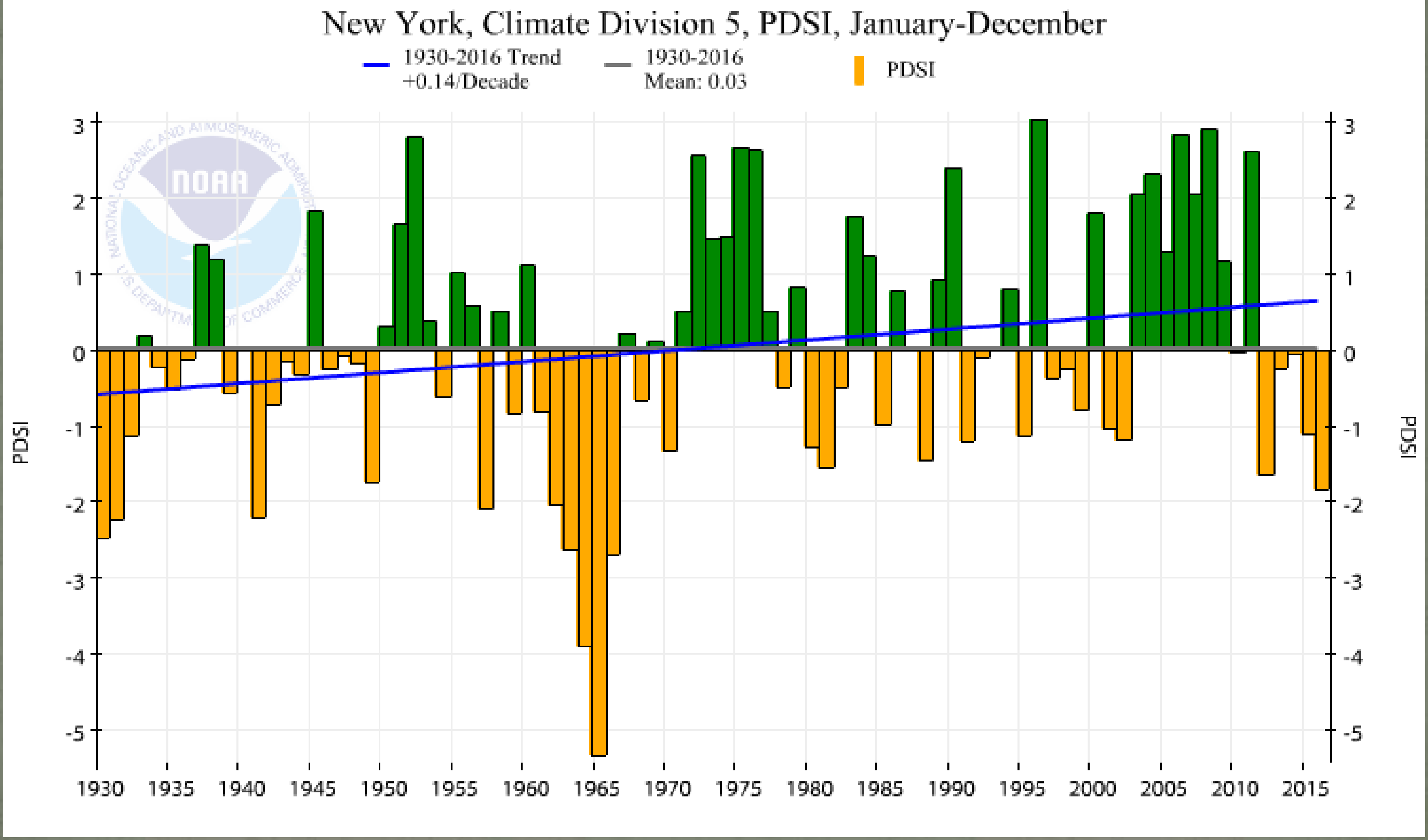
Duration	Annual exceedance probability (1/years)								
	1/2	1/5	1/10	1/25	1/50	1/100	1/200	1/500	1/1000
5-min	**0.400** (0.312-0.507)	**0.544** (0.423-0.693)	**0.654** (0.505-0.836)	**0.798** (0.597-1.06)	**0.907** (0.666-1.23)	**1.02** (0.727-1.42)	**1.16** (0.784-1.65)	**1.36** (0.880-1.98)	**1.51** (0.953-2.23)
10-min	**0.566** (0.442-0.719)	**0.771** (0.599-0.981)	**0.926** (0.715-1.18)	**1.13** (0.846-1.50)	**1.29** (0.944-1.74)	**1.44** (1.03-2.02)	**1.65** (1.11-2.33)	**1.92** (1.25-2.80)	**2.13** (1.35-3.15)
15-min	**0.666** (0.520-0.846)	**0.907** (0.705-1.15)	**1.09** (0.842-1.39)	**1.33** (0.995-1.77)	**1.51** (1.11-2.05)	**1.69** (1.21-2.37)	**1.94** (1.31-2.74)	**2.26** (1.47-3.29)	**2.51** (1.59-3.71)
30-min	**0.938** (0.731-1.19)	**1.28** (0.992-1.63)	**1.53** (1.19-1.96)	**1.87** (1.40-2.49)	**2.13** (1.56-2.88)	**2.39** (1.71-3.34)	**2.73** (1.84-3.86)	**3.18** (2.06-4.63)	**3.53** (2.23-5.22)
60-min	**1.21** (0.942-1.53)	**1.65** (1.28-2.10)	**1.98** (1.53-2.53)	**2.42** (1.81-3.21)	**2.75** (2.02-3.72)	**3.08** (2.20-4.31)	**3.52** (2.37-4.98)	**4.11** (2.66-5.97)	**4.55** (2.88-6.72)
2-hr	**1.60** (1.26-2.02)	**2.21** (1.73-2.79)	**2.67** (2.08-3.39)	**3.28** (2.47-4.32)	**3.74** (2.76-5.02)	**4.20** (3.01-5.83)	**4.80** (3.25-6.74)	**5.59** (3.63-8.08)	**6.19** (3.93-9.09)
3-hr	**1.86** (1.47-2.33)	**2.58** (2.02-3.24)	**3.12** (2.44-3.94)	**3.84** (2.90-5.03)	**4.38** (3.24-5.86)	**4.93** (3.54-6.80)	**5.63** (3.81-7.87)	**6.55** (4.27-9.43)	**7.25** (4.61-10.6)
6-hr	**2.35** (1.86-2.93)	**3.25** (2.57-4.06)	**3.93** (3.09-4.93)	**4.84** (3.67-6.29)	**5.52** (4.11-7.32)	**6.20** (4.48-8.50)	**7.08** (4.82-9.83)	**8.24** (5.39-11.8)	**9.12** (5.82-13.3)
12-hr	**2.87** (2.30-3.55)	**3.95** (3.15-4.90)	**4.76** (3.77-5.93)	**5.84** (4.46-7.55)	**6.65** (4.98-8.78)	**7.47** (5.43-10.2)	**8.55** (5.84-11.8)	**9.97** (6.54-14.1)	**11.1** (7.07-15.9)
24-hr	**3.34** (2.69-4.10)	**4.64** (3.72-5.71)	**5.62** (4.48-6.95)	**6.92** (5.32-8.90)	**7.90** (5.96-10.4)	**8.88** (6.52-12.1)	**10.3** (7.04-14.1)	**12.1** (7.96-17.0)	**13.5** (8.65-19.3)
2-day	**3.72** (3.02-4.54)	**5.31** (4.29-6.48)	**6.50** (5.22-7.98)	**8.09** (6.28-10.4)	**9.28** (7.07-12.2)	**10.5** (7.78-14.3)	**12.3** (8.47-16.8)	**14.7** (9.72-20.6)	**16.6** (10.7-23.5)
3-day	**4.01** (3.26-4.86)	**5.72** (4.64-6.96)	**7.02** (5.66-8.58)	**8.74** (6.81-11.2)	**10.0** (7.68-13.1)	**11.3** (8.46-15.4)	**13.4** (9.23-18.1)	**16.1** (10.6-22.4)	**18.1** (11.7-25.7)
4-day	**4.27** (3.49-5.16)	**6.05** (4.92-7.34)	**7.40** (5.98-9.01)	**9.18** (7.18-11.7)	**10.5** (8.09-13.7)	**11.9** (8.90-16.1)	**14.1** (9.70-19.0)	**16.9** (11.2-23.5)	**19.1** (12.3-27.0)
7-day	**4.98** (4.09-5.99)	**6.84** (5.60-8.24)	**8.24** (6.70-9.98)	**10.1** (7.95-12.8)	**11.5** (8.89-14.9)	**12.9** (9.72-17.4)	**15.2** (10.6-20.5)	**18.3** (12.1-25.3)	**20.6** (13.3-28.9)
10-day	**5.67** (4.68-6.79)	**7.58** (6.23-9.10)	**9.02** (7.36-10.9)	**10.9** (8.61-13.8)	**12.4** (9.56-15.9)	**13.8** (10.4-18.5)	**16.1** (11.2-21.6)	**19.2** (12.8-26.4)	**21.5** (13.9-30.0)
20-day	**7.79** (6.47-9.26)	**9.85** (8.15-11.7)	**11.4** (9.37-13.6)	**13.5** (10.6-16.7)	**15.0** (11.6-19.0)	**16.6** (12.4-21.7)	**18.7** (13.1-24.8)	**21.5** (14.4-29.3)	**23.6** (15.3-32.7)
30-day	**9.57** (7.98-11.3)	**11.7** (9.76-13.9)	**13.4** (11.1-16.0)	**15.6** (12.3-19.1)	**17.2** (13.3-21.5)	**18.9** (14.0-24.3)	**20.8** (14.6-27.4)	**23.3** (15.6-31.6)	**25.2** (16.4-34.8)
45-day	**11.8** (9.88-13.9)	**14.1** (11.8-16.6)	**15.8** (13.1-18.8)	**18.1** (14.4-22.1)	**19.9** (15.4-24.7)	**21.6** (16.0-27.5)	**23.3** (16.5-30.6)	**25.6** (17.2-34.6)	**27.3** (17.8-37.5)
60-day	**13.7** (11.5-16.0)	**16.1** (13.4-18.9)	**17.9** (14.9-21.1)	**20.3** (16.1-24.6)	**22.1** (17.1-27.2)	**23.9** (17.7-30.2)	**25.5** (18.0-33.3)	**27.5** (18.6-37.1)	**29.1** (19.0-39.9)

>11"

Changes in the Palmer Drought Index

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

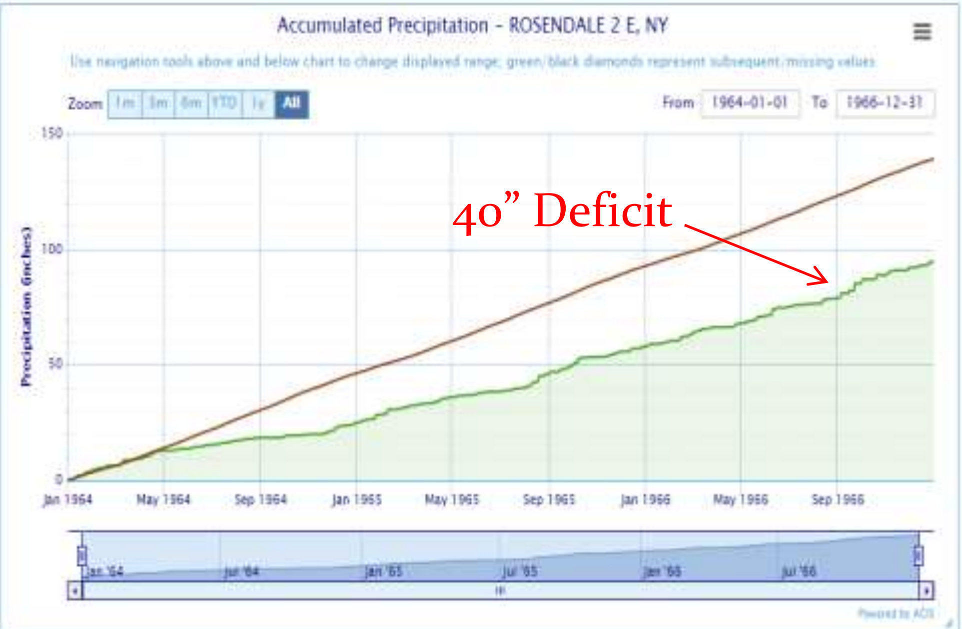
The Palmer Drought Severity Index (PDSI) uses readily available temperature and precipitation data to estimate relative dryness. It is a standardized index that spans -10 (dry) to +10 (wet). It has been reasonably successful at quantifying long-term drought.

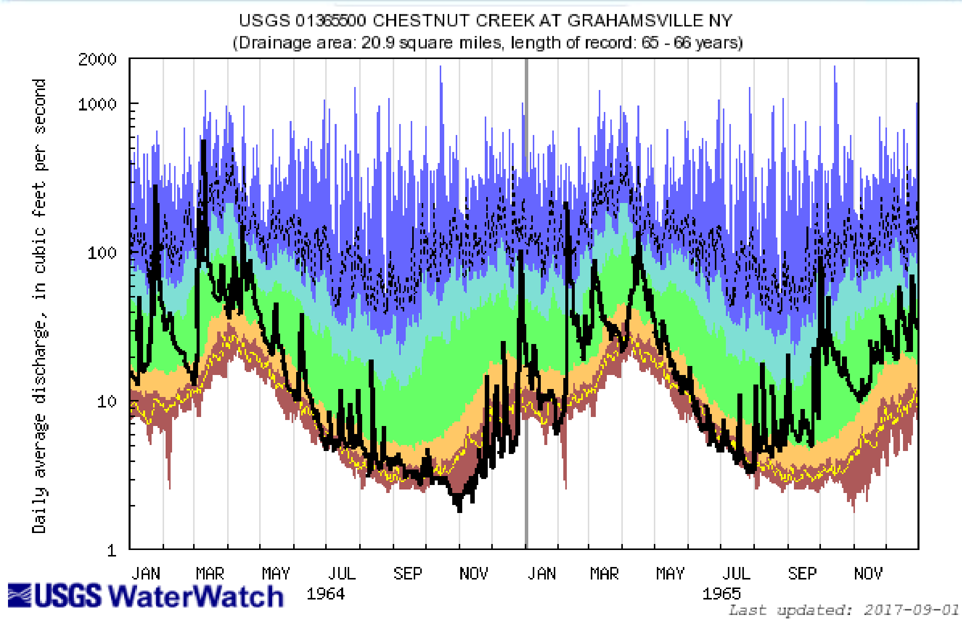


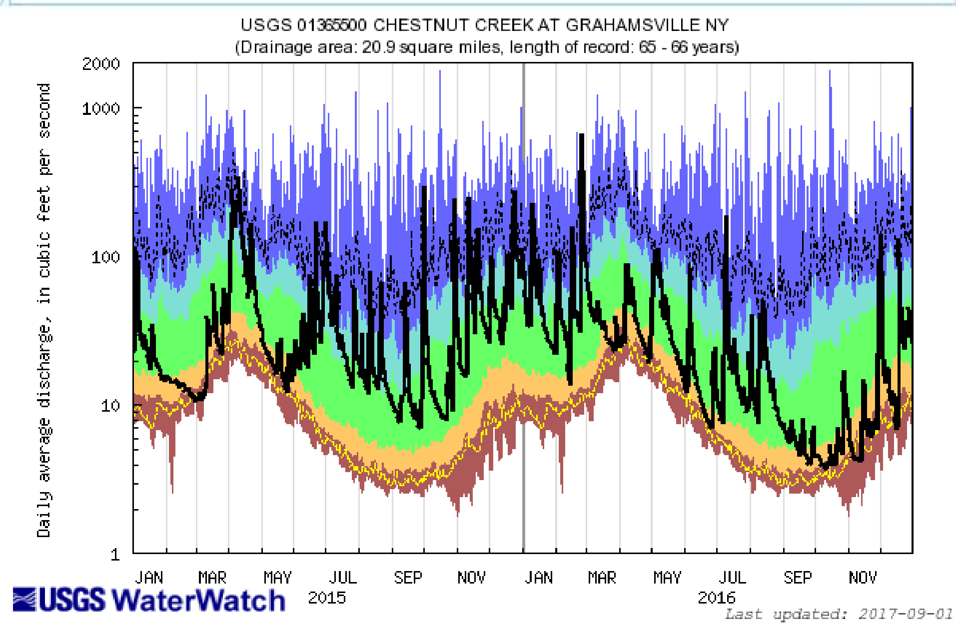
Since the late 60s, similar signature of much shorter, mostly less intense dry periods and longer higher amplitude wet periods

Moving from long duration to short/flash droughts

Southeast New York

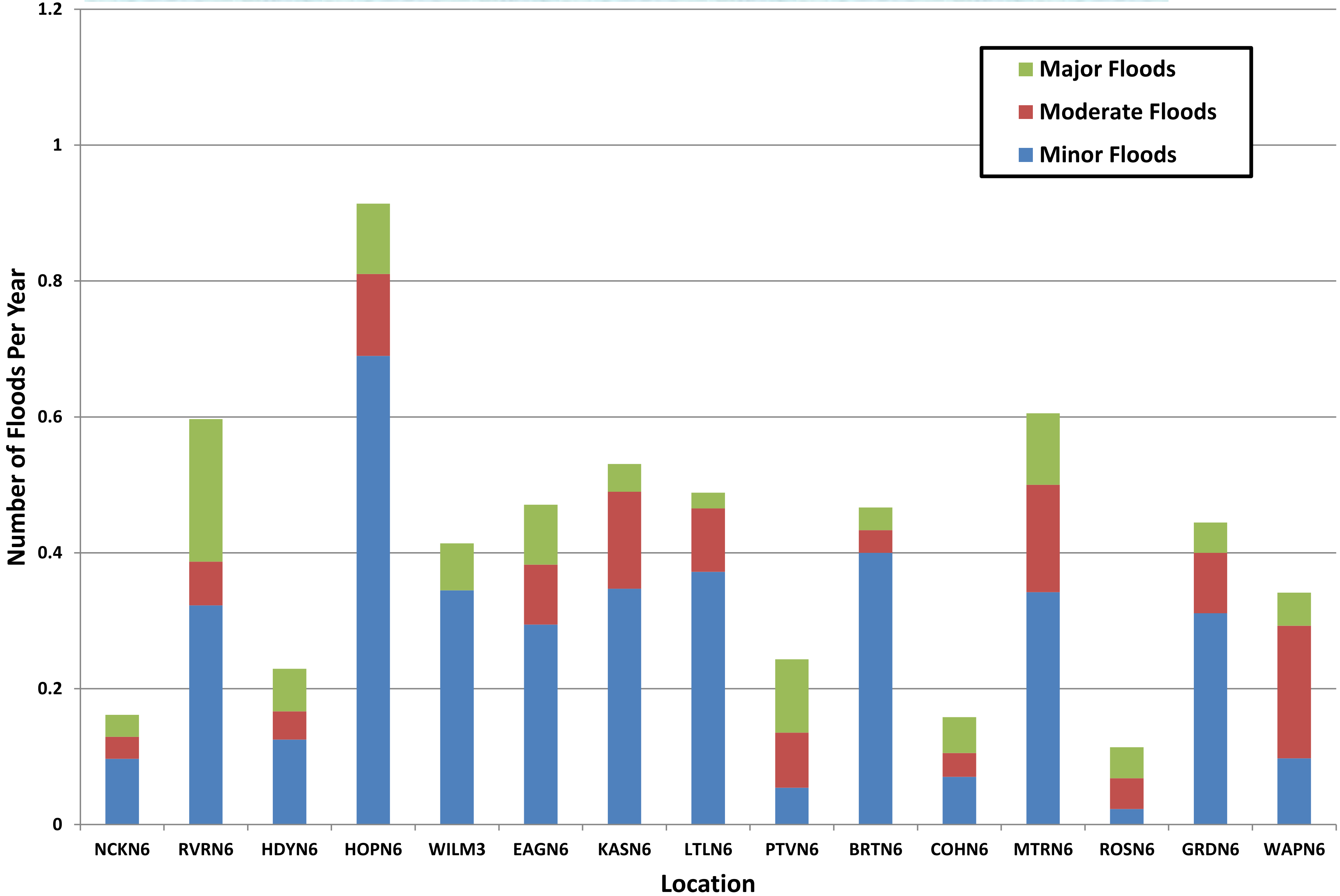






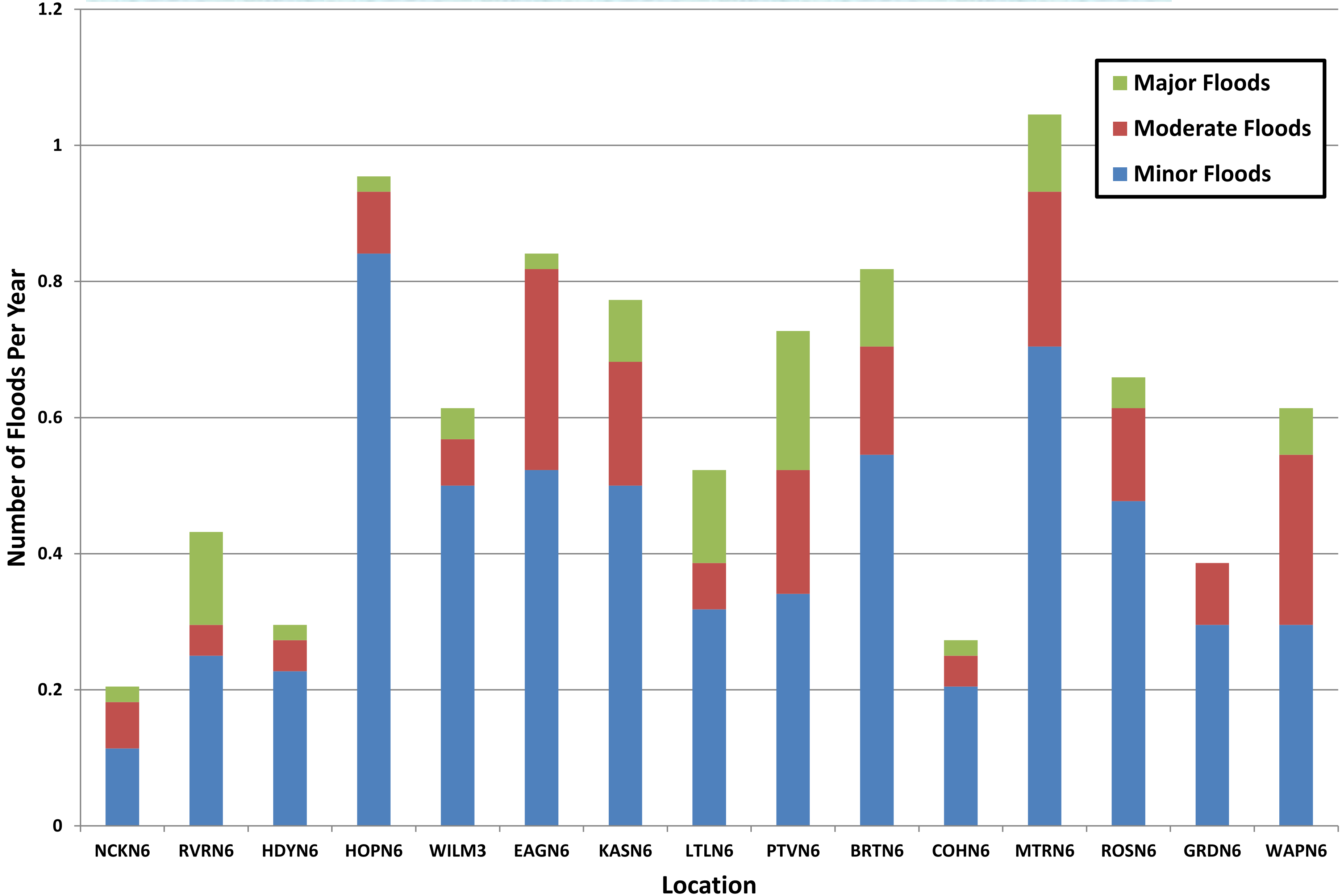
Hudson River Basin Normalized Number of Minor, Moderate, and Major Floods Per Year Prior to 1970

Data provided by USGS science for a changing world



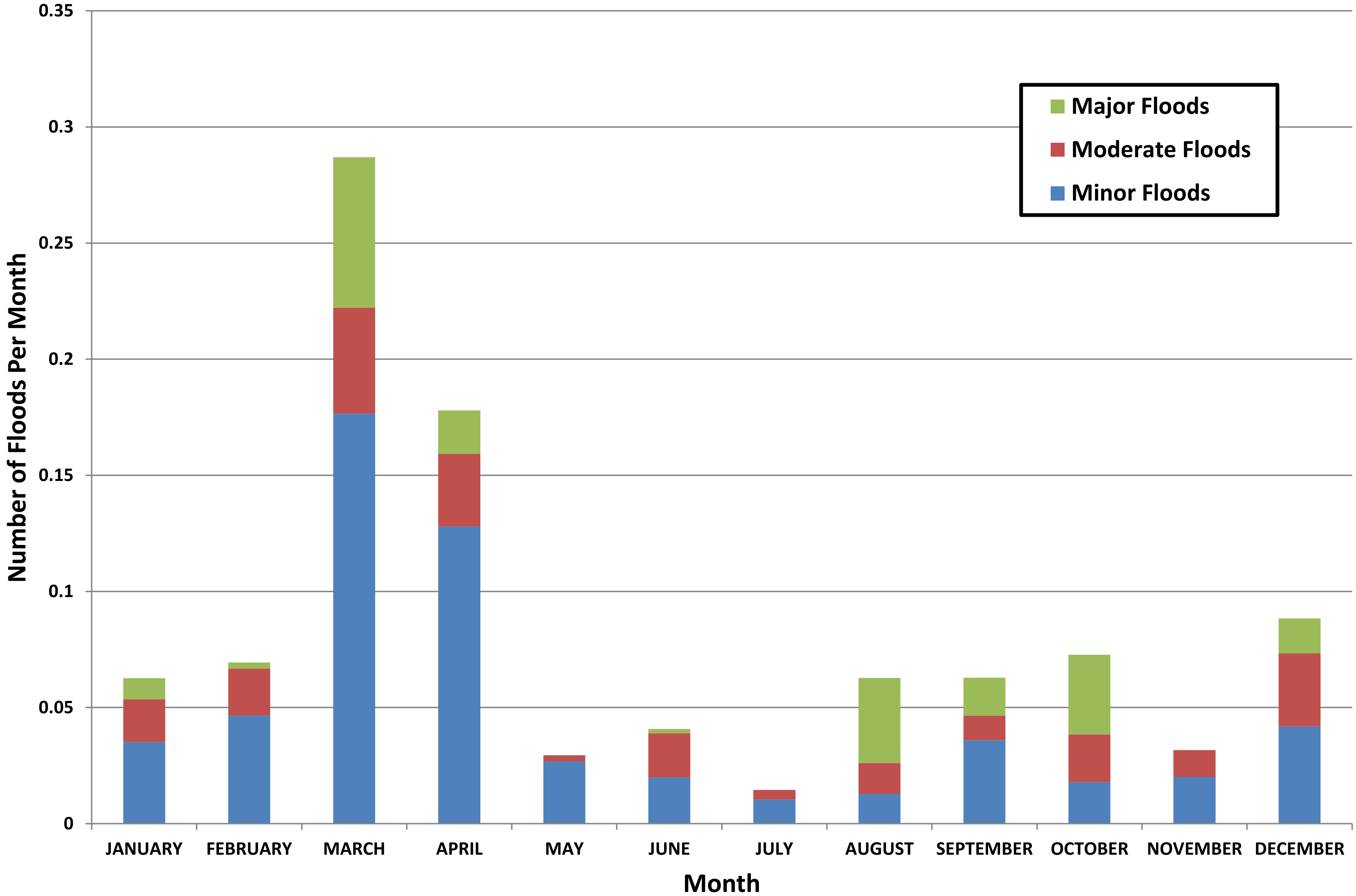
Hudson River Basin Normalized Number of Minor, Moderate, and Major Floods Per Year from 1970 - 2013

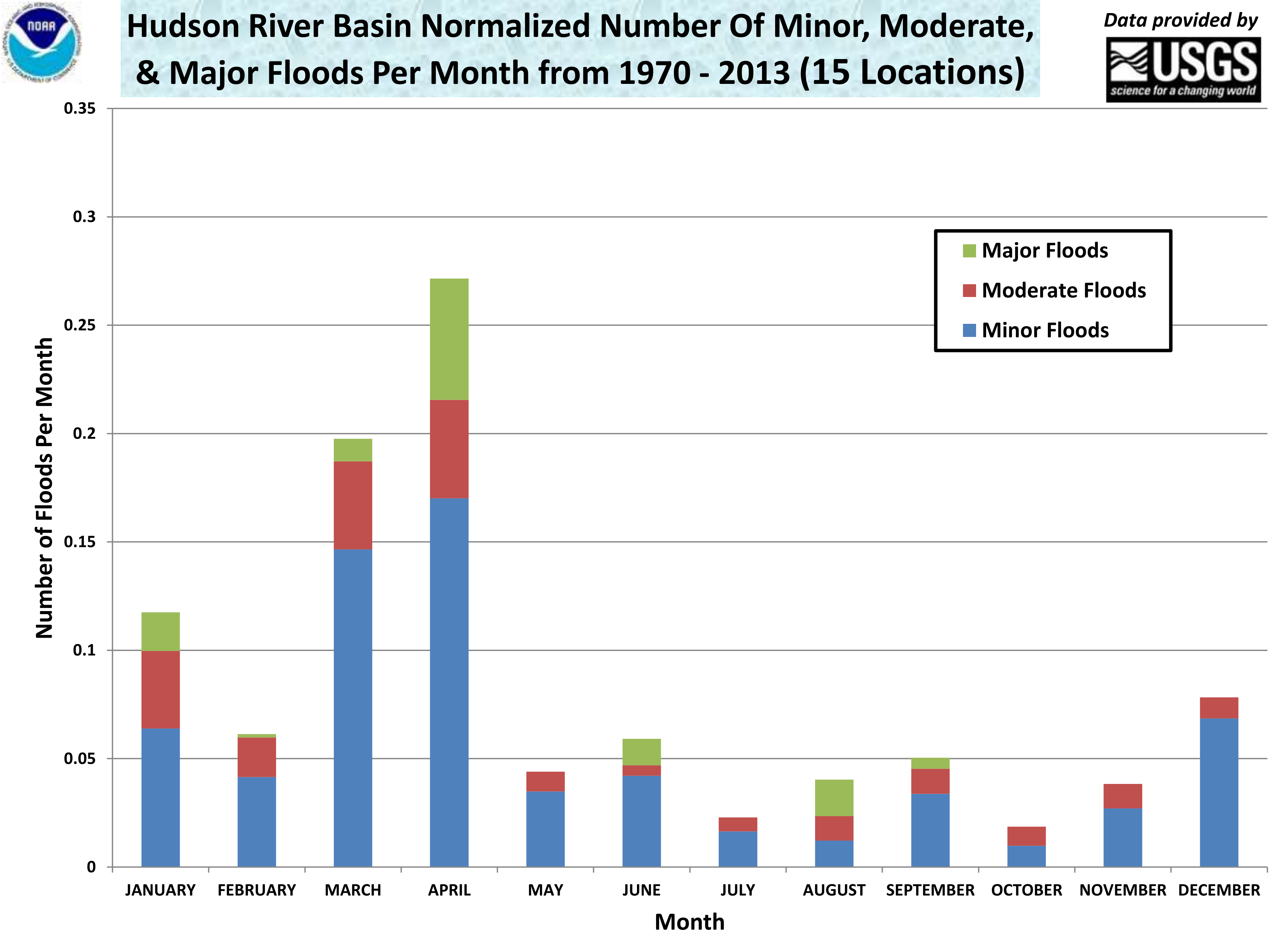
Data provided by USGS



Hudson River Basin Normalized Number Of Minor, Moderate, & Major Floods Per Month Prior to 1970 (15 Locations)

Data provided by USGS science for a changing world




Hudson River Basin Normalized Number Of Minor, Moderate, & Major Floods Per Month from 1970 - 2013 (15 Locations)
Data provided by
USGS
science for a changing world
Number of Floods Per Month
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
Month

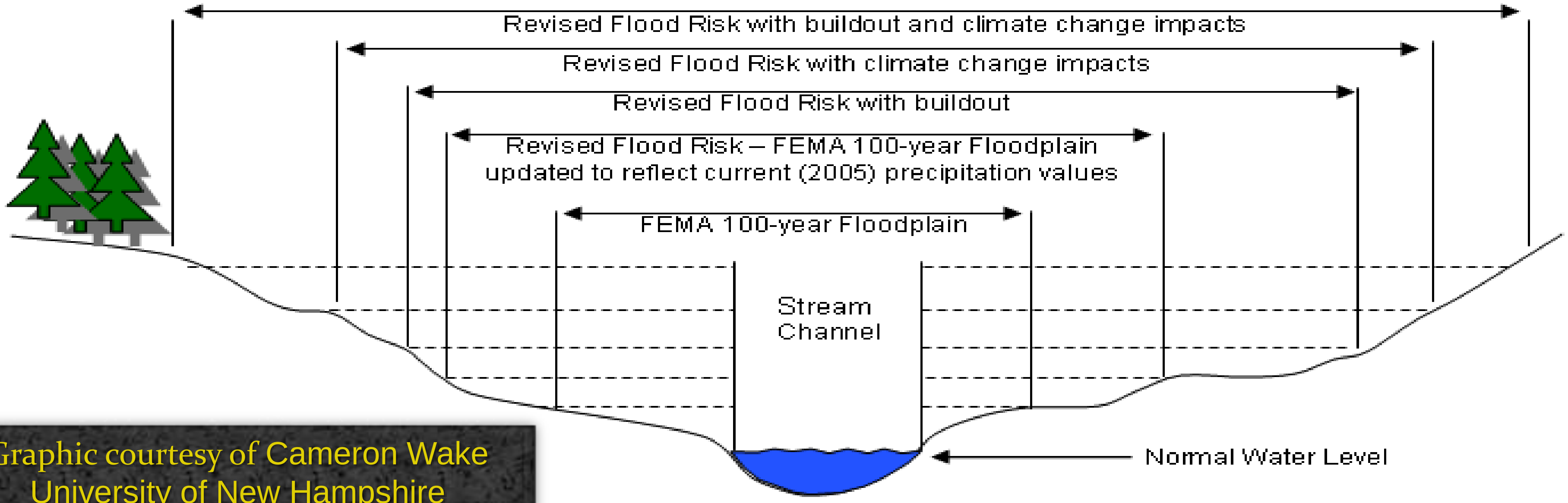
Summary:

- 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
  - Portions of the Hudson valley have experienced a 1 to 3 inch shift upwards in the 100 yr – 24 hour rainfall
- Smaller watersheds & those with significant urbanization are most vulnerable to increased river & stream flooding
- Drought episodes have become shorter in duration and of a "Flash/Rapid Onset" variety

Far reaching implications:

Protect, Adapt or Retreat???

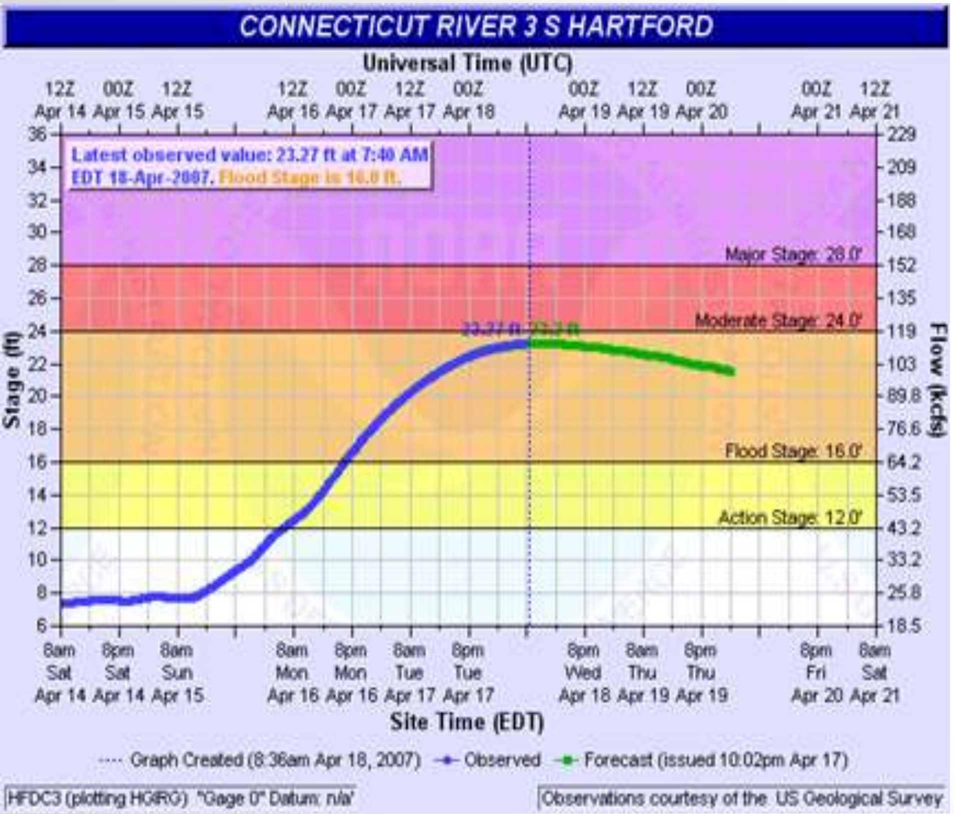
- Floodplain, land use, infrastructure, dam spillway requirements, drainage requirements, non-point source runoff, bridge clearances, "hardening" of critical facilities in the floodplain, property values etc…
- Flood Insurance – work to increase participation
- How much risk are we willing to insure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

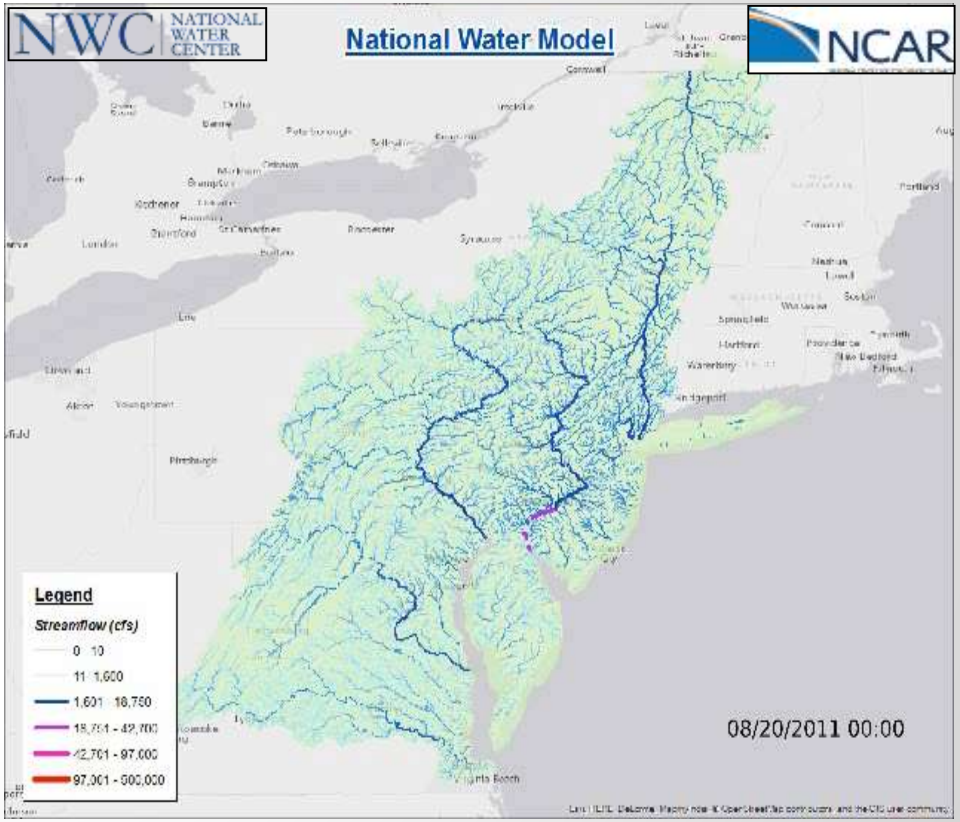


Graphic courtesy of Cameron Wake
University of New Hampshire

A Look At Future Water Prediction Services:

Moving from Point Specific to Street Level Hydrologic Forecasting



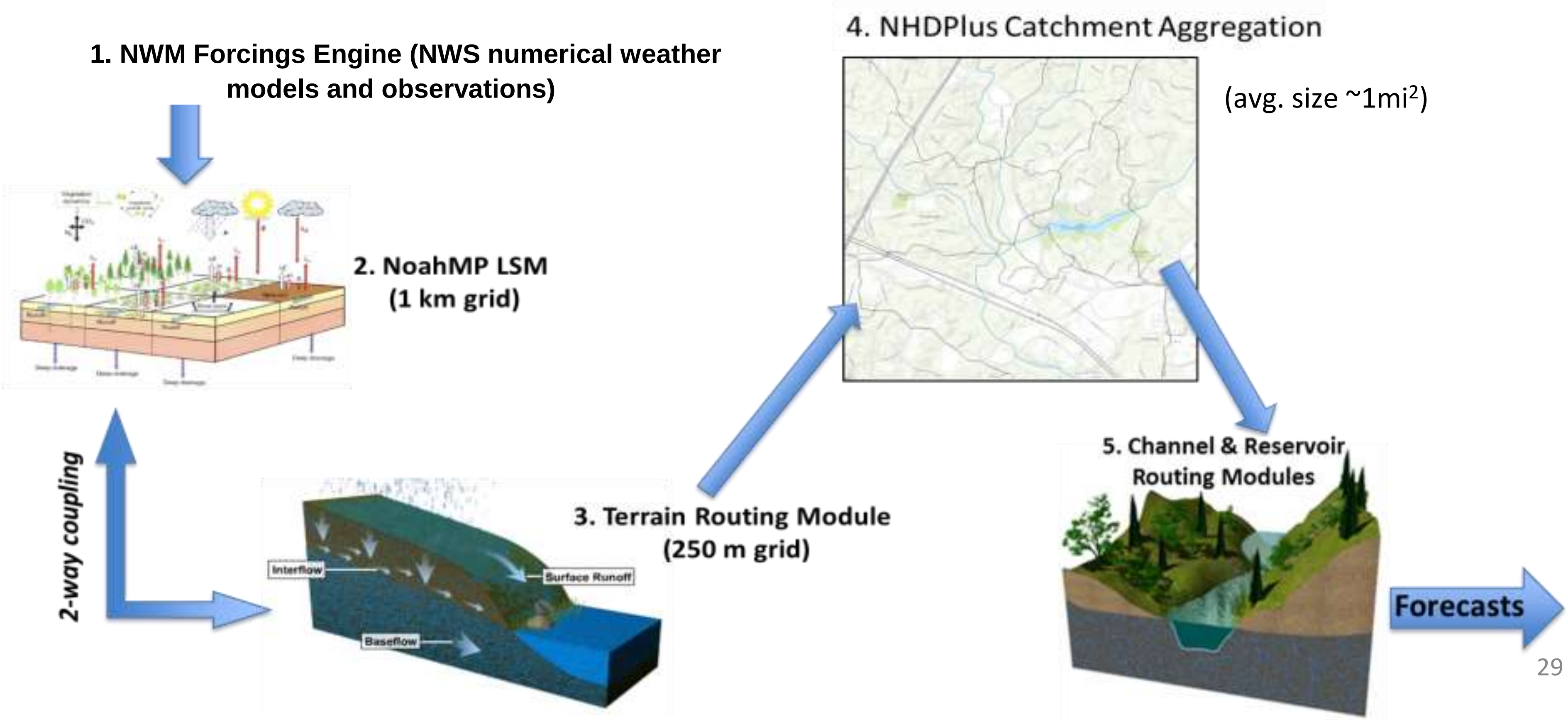


New services to include the Hydrologic Ensemble Prediction System & the new National Water Model

NOAA National Water Model

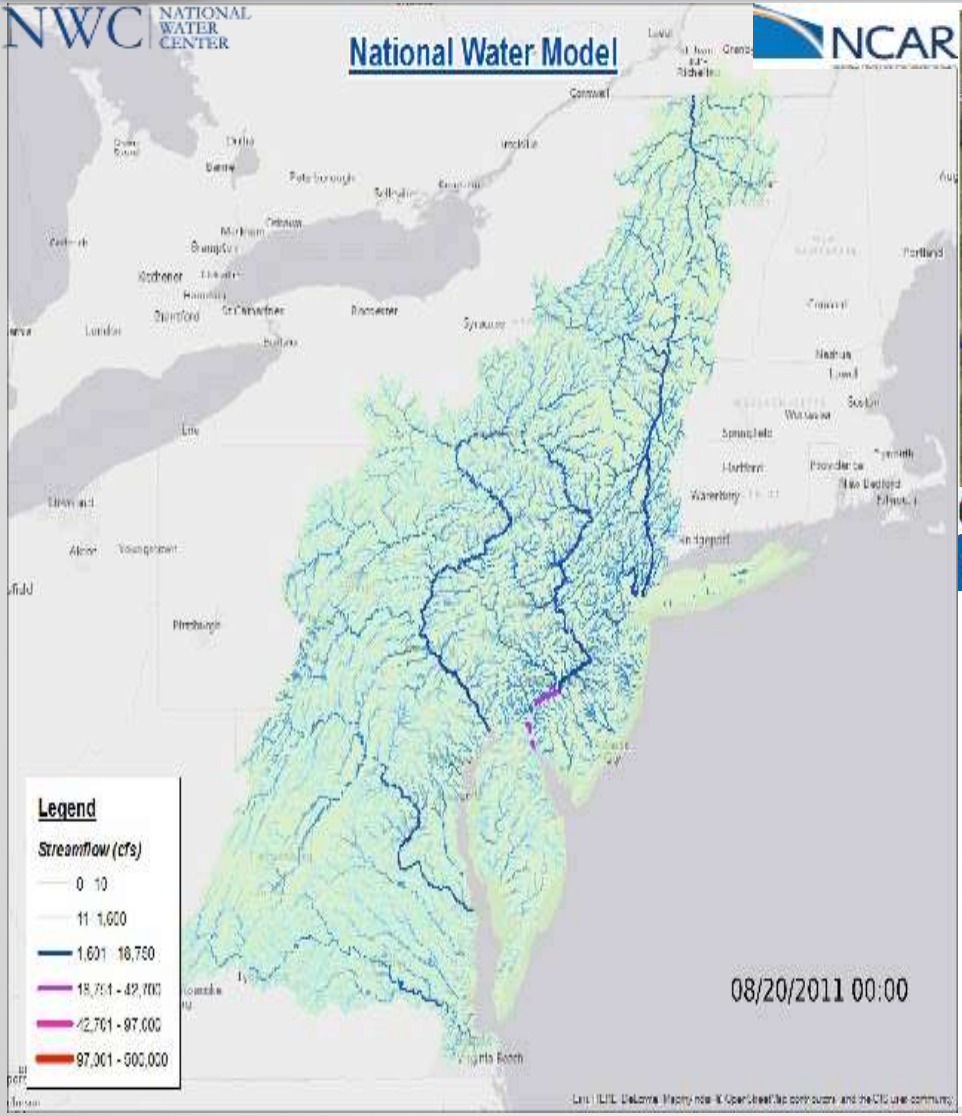
- Implemented in August to provide foundation for sustained growth in nationally consistent operational hydro forecasting
- WRF-Hydro hydrologic core, community-based, ESMF compatible hydrologic modeling *framework* supported by NCAR
- Version 1.0 Goals: Focus on full range of water resources, provide streamflow guidance for underserved locations and spatially continuous national estimates and forecasts of hydrologic states, architecture that supports rapid infusion of new science and data

NWM V1.0 System Flow



But it truly is a matter of scale

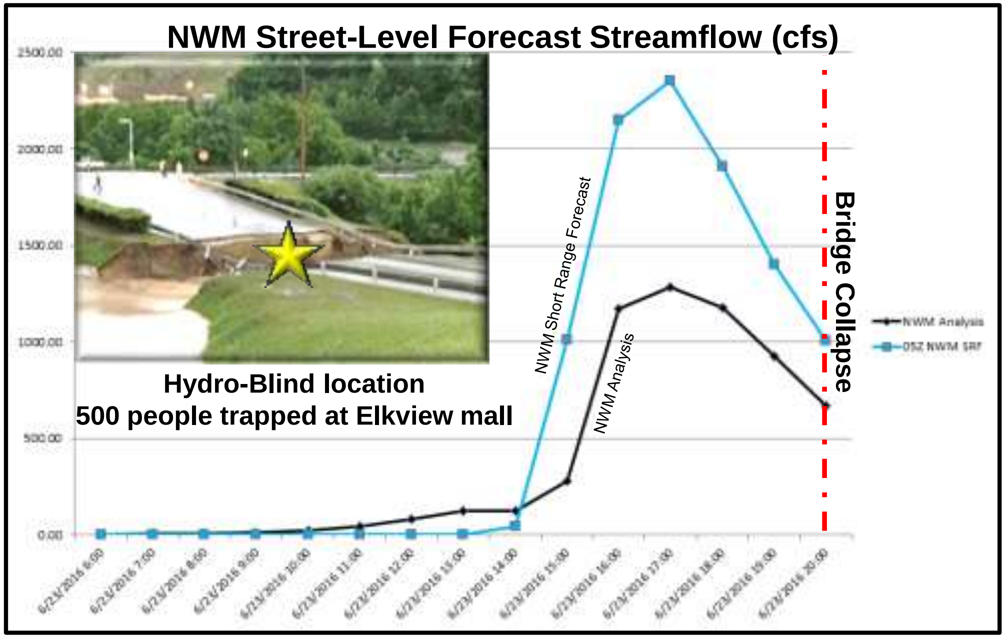
Tomorrow's Scale – 1 km or less!

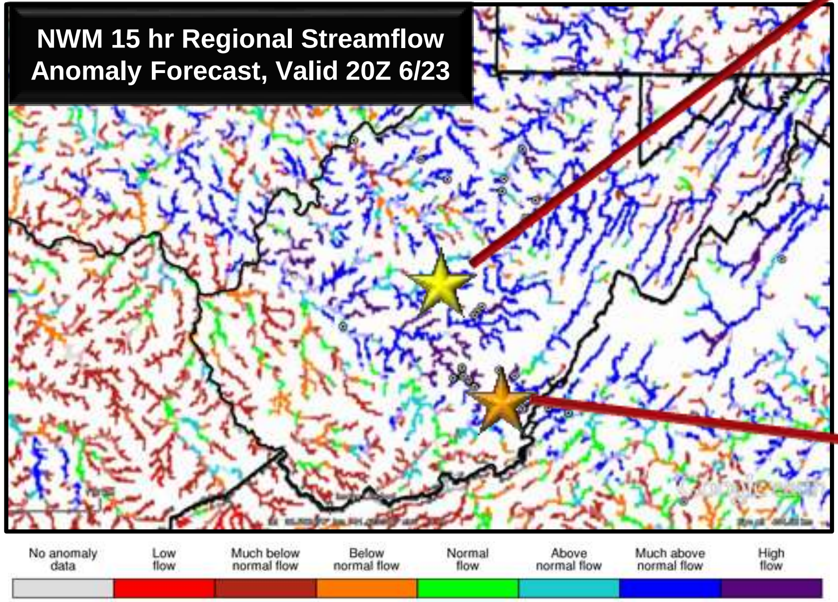


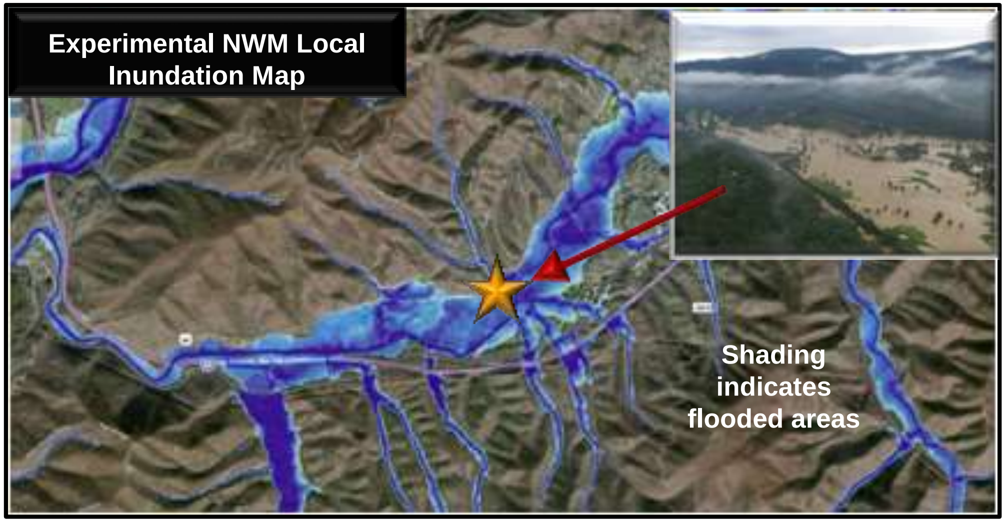
Experimental simulation from the National Water Model

NWM-Based Street Level Hydrologic Prediction Record Setting West Virginia Flood Event, June 23rd 2016

- Thousands of homes damaged or destroyed, $111+ million in FEMA aid
- NWM allows users to drill down from regional to local to street scale
- Information complements hydrologic guidance at existing forecast locations and provides new insight at millions of hydro-blind locations



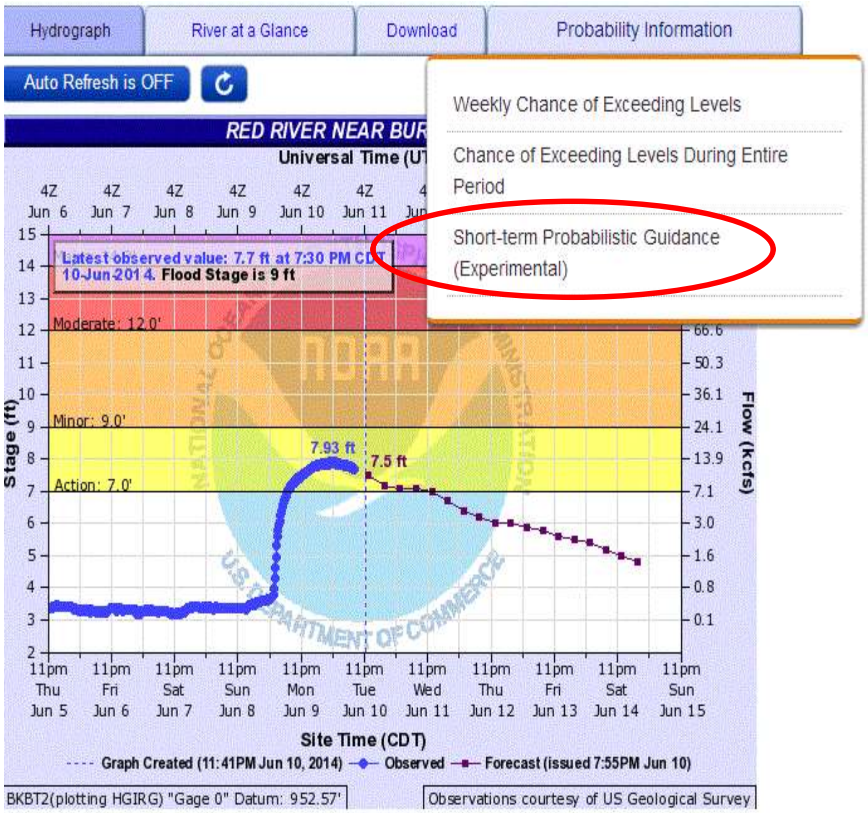


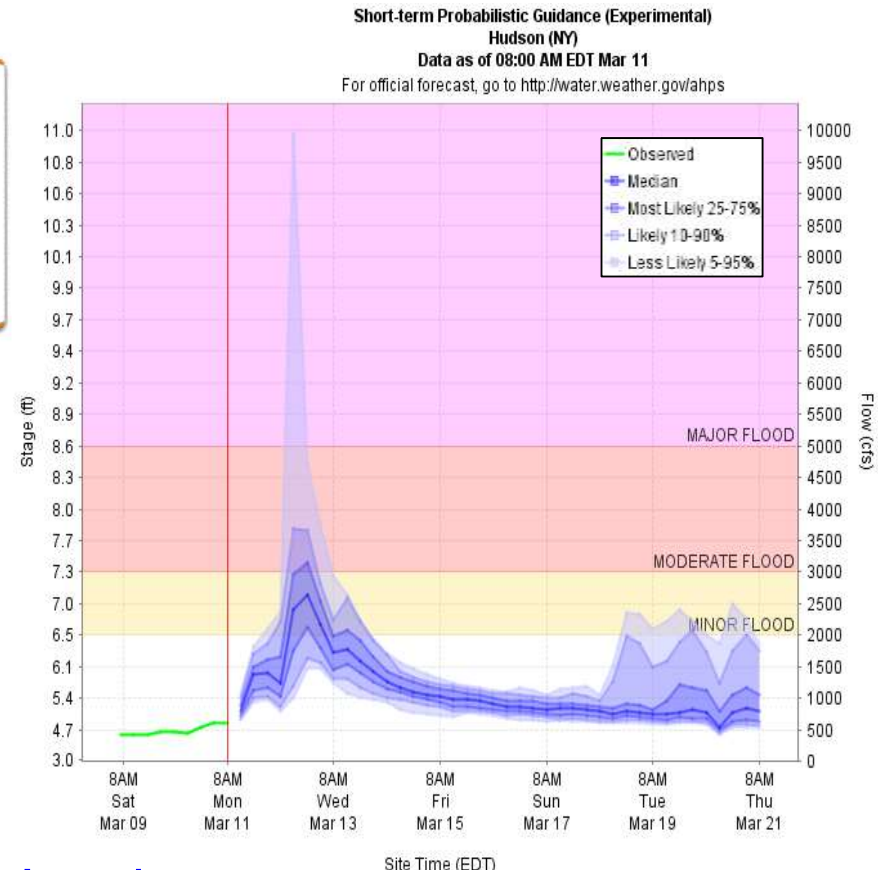


http://www.water.noaa.gov/map

Moving to probabilistic short to long range services

AHPS short-range probabilistic product





See: http://water.weather.gov/ahps/

Climate Trends in Southeast New York and Their Impact on Flood Frequency

Southeast New York Stormwater Conference

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

Record flooding along the Mohawk River in Rotterdam, NY, August 2011 following Irene. Photo from AP.

Questions

- 1. The top 5 warmest years in southeast New York:
  - Occurred prior to 1970
  - Occurred between 1990 and 2016
  - Are spread evenly across the last 100 years
- 2. Annual precipitation in southeast New York is:
  - Decreasing at more than 1 inch per decade
  - Increasing at a rate of about 1 inch every 17 years
  - Staying exactly the same
- 3. Many rivers in the Hudson Valley are:
  - Experiencing more frequent floods in the past 50 years
  - Experiencing less frequent floods in the past 50 years

Answers to Questions

- 1. The top 5 warmest years in southeast New York:
  - Have occurred prior to 1970
  - **Have occurred between 1990 and 2016**
  - Are spread evenly across the last 100 years
- 2. Annual precipitation in southeast New York is:
  - Decreasing at more than 1 inch per decade
  - **Increasing at a rate of about 1 inch every 17 years**
  - Staying exactly the same
- 3. Many rivers in the Hudson Valley have:
  - **Experienced more frequent floods in the past 50 years**
  - Experienced less frequent floods in the past 50 years