Statewide Riverine Flood Vulnerability Assessment

Emmanouil Anagnostou and Xinyi Shen
Civil and Environmental Engineering, UCONN

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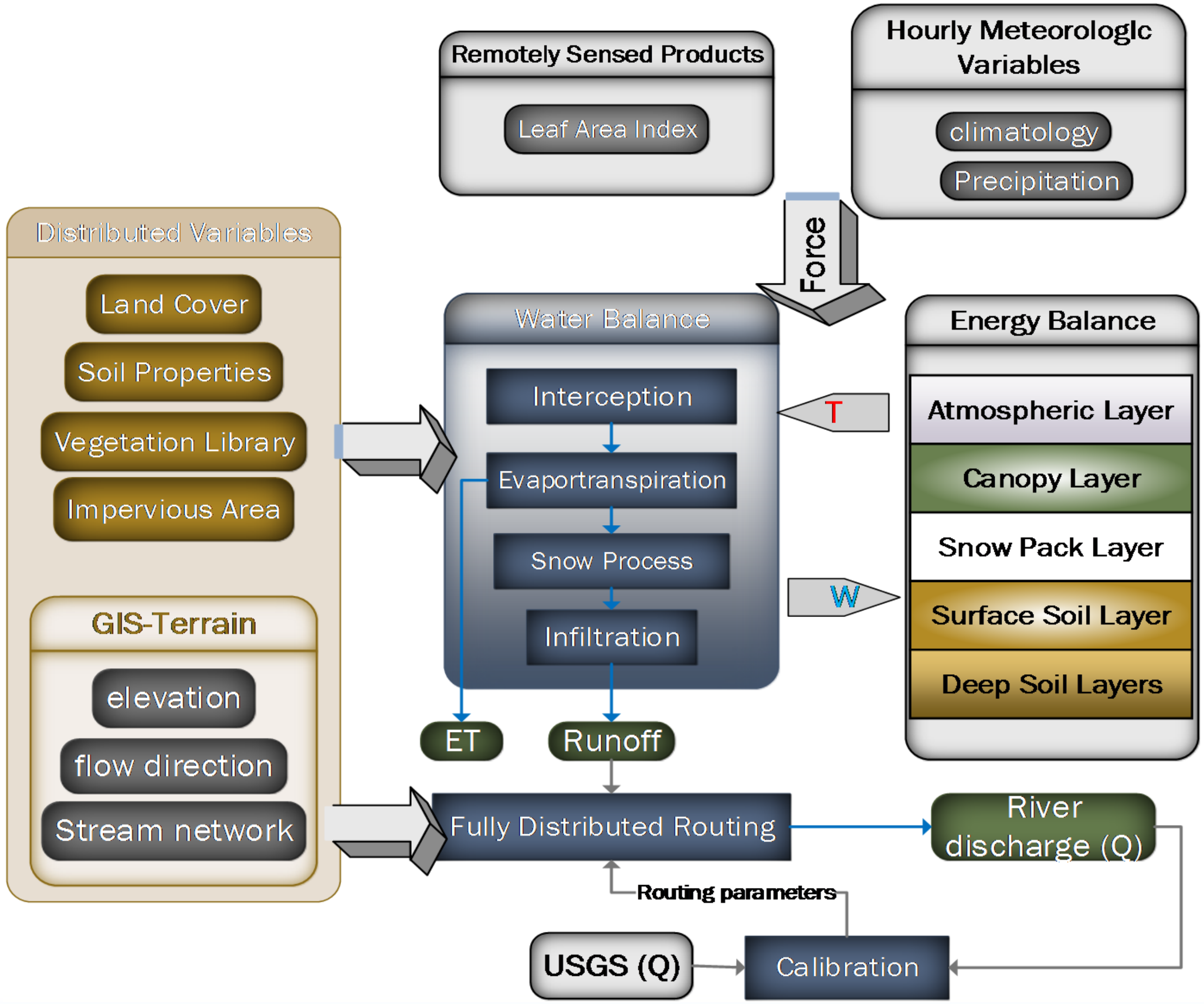
Topics

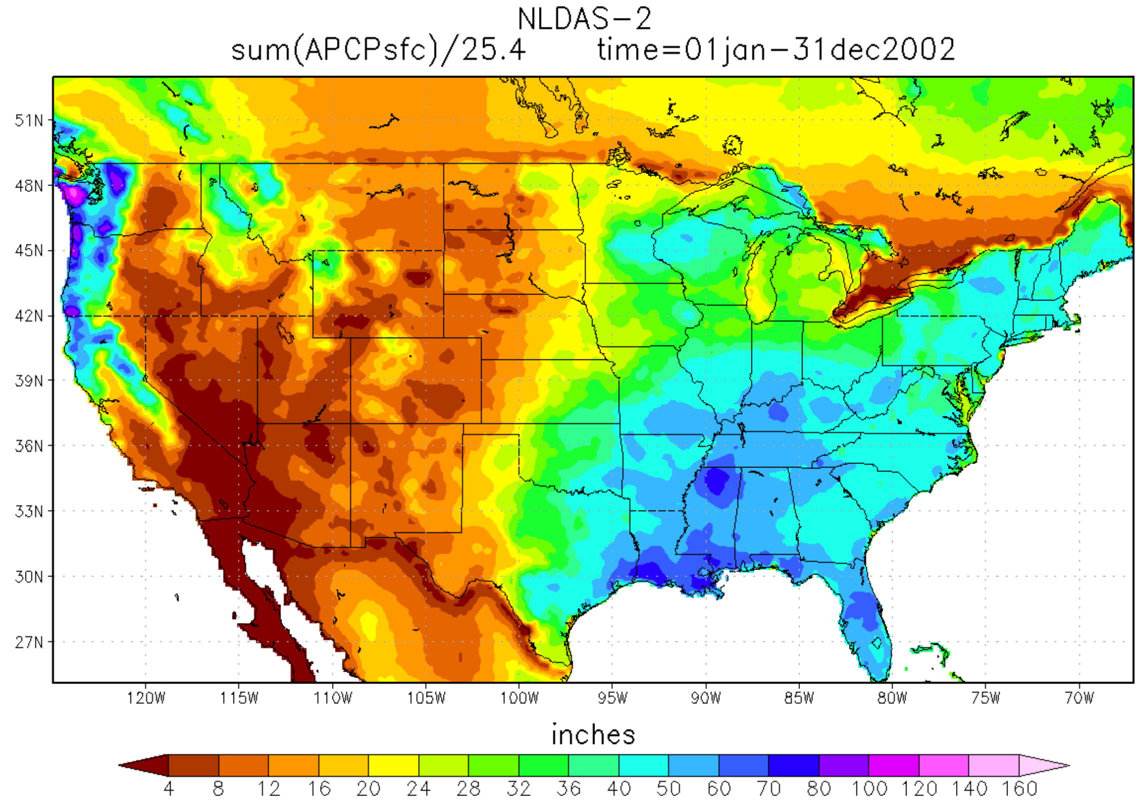
- Flood Frequency Analysis (FFA)
- Flood Vulnerability Analysis
- Flood Risk of Road Crossings
- Regional Flood Frequency (RFFA)
- Flood Inundation Early Warning System

CREST-SVAS
A new numerical modelling framework



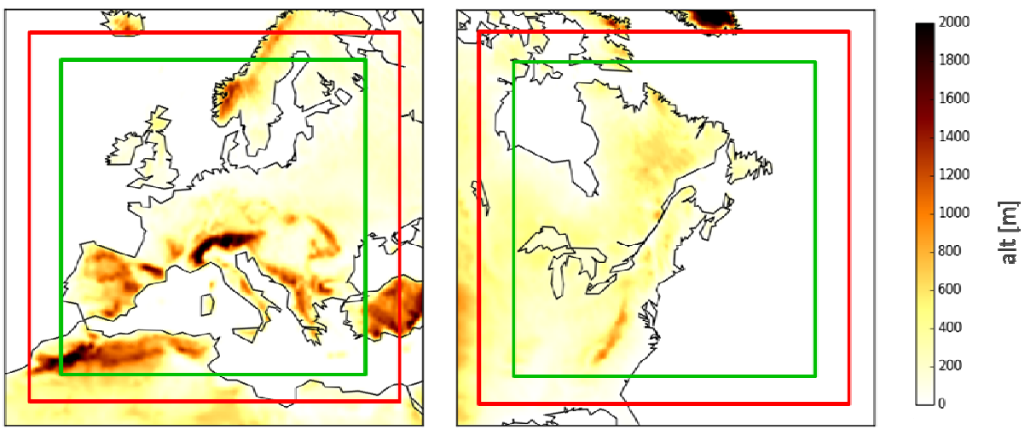
Atmospheric Reanalysis

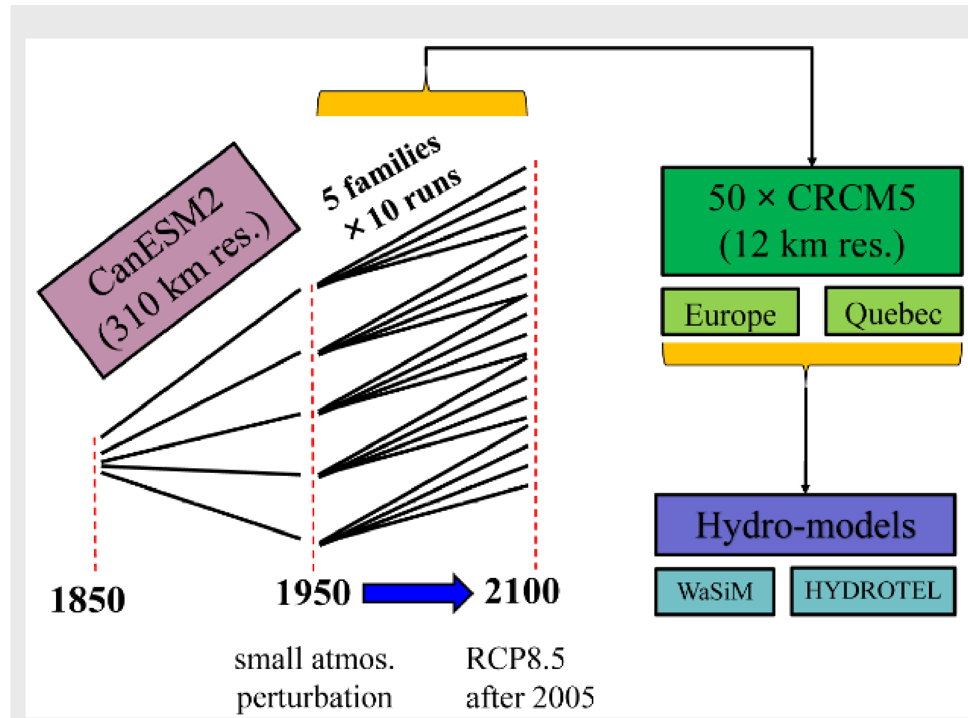
- **NLDAS-2**: North American Land Data Assimilation System (1979-present, 1h/12km)



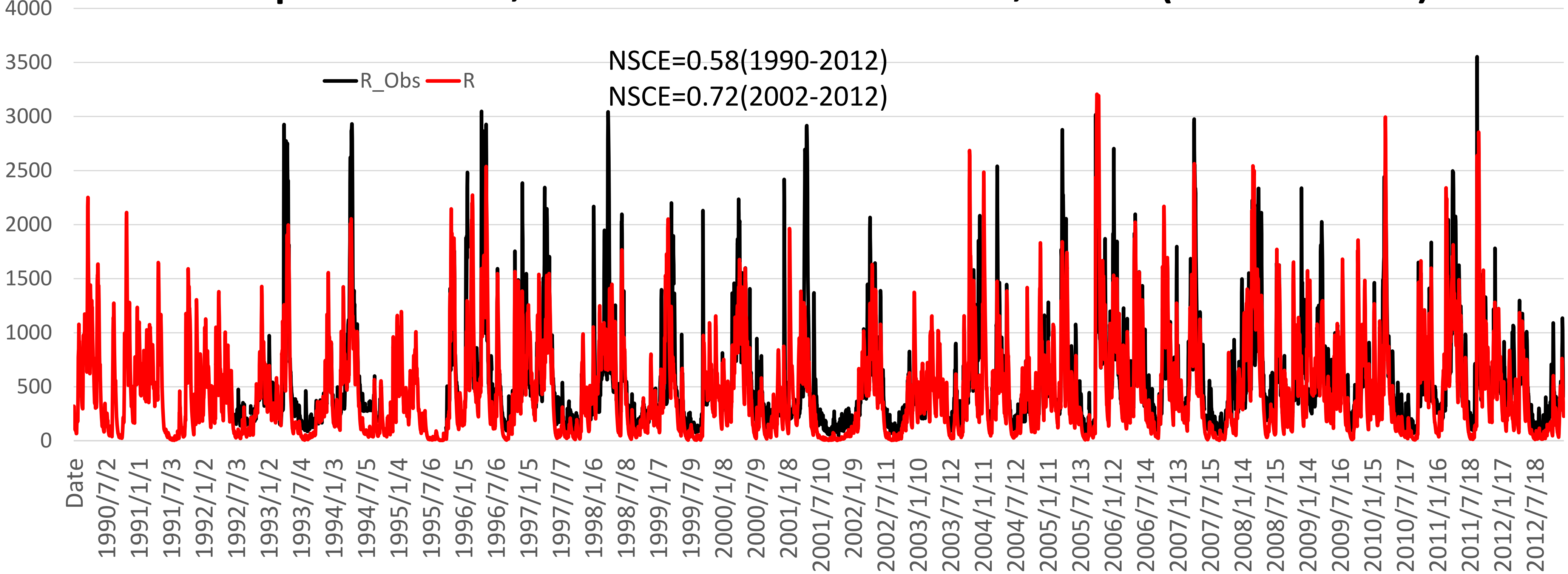
Future Weather Projection

- ClimEX project-150 years reanalysis





Thompsonville, Connecticut River, MA (9660 mi^2)



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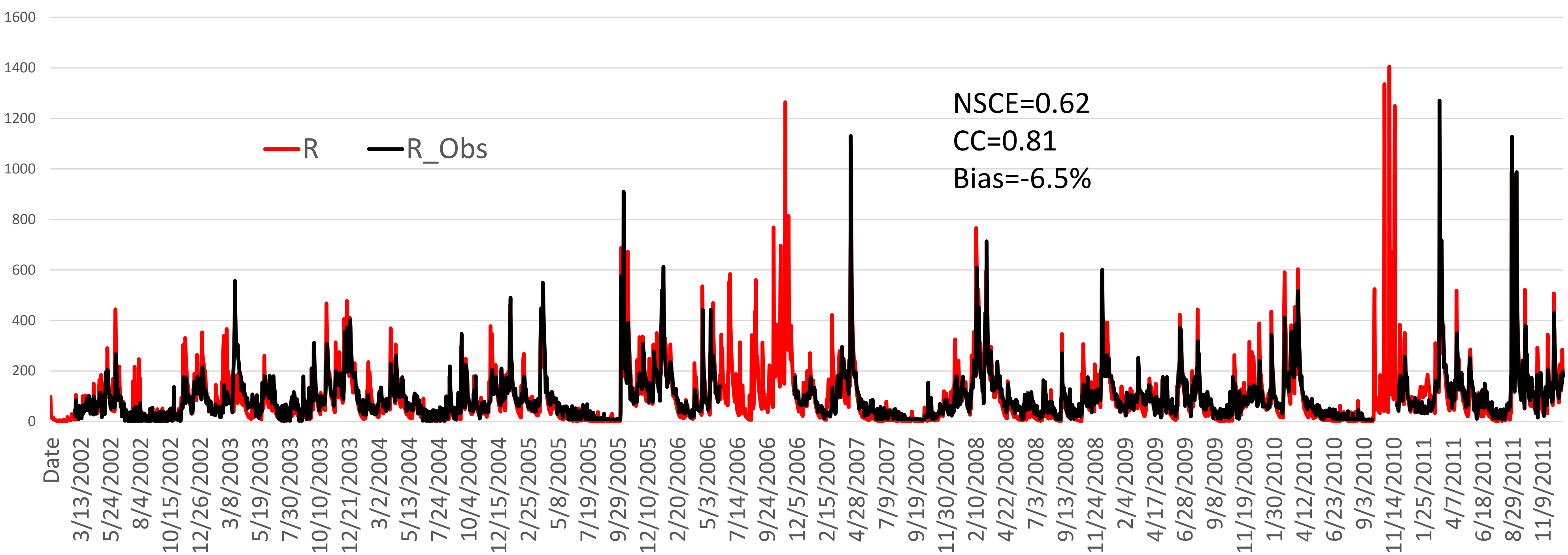
Stevenson, CT, Housatonic River (1544 mi^2)



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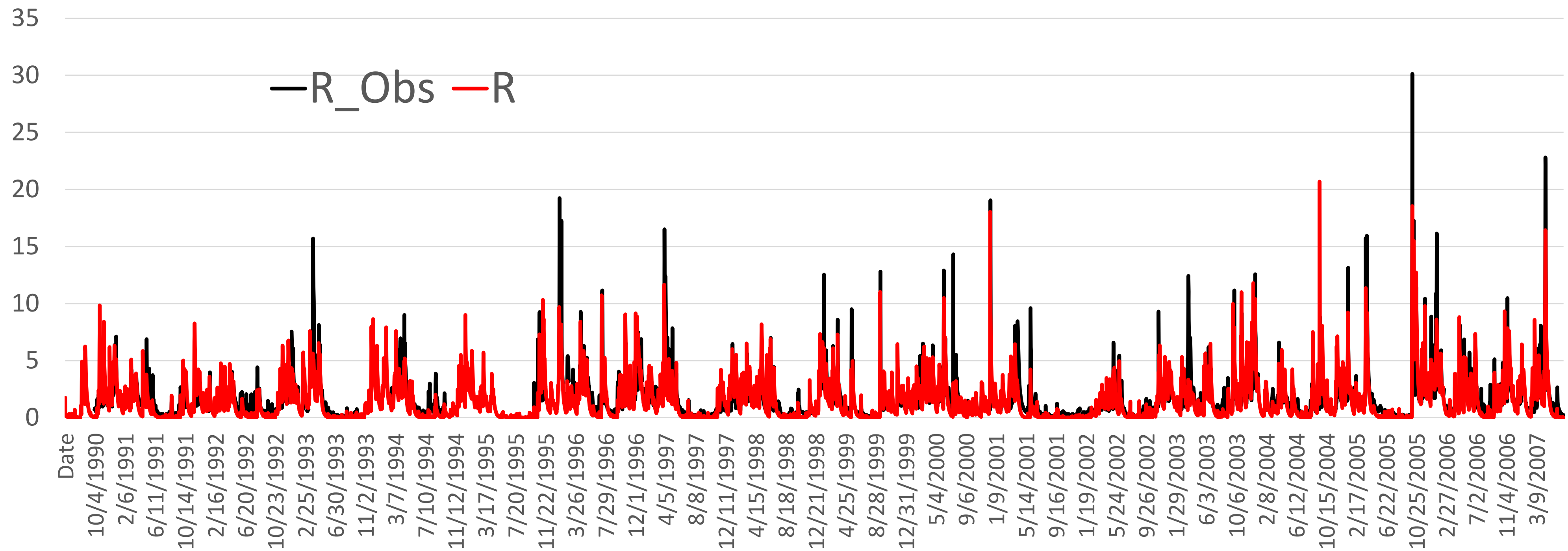
Salmon Kill, CT, Housatonic River (29 mi^2)



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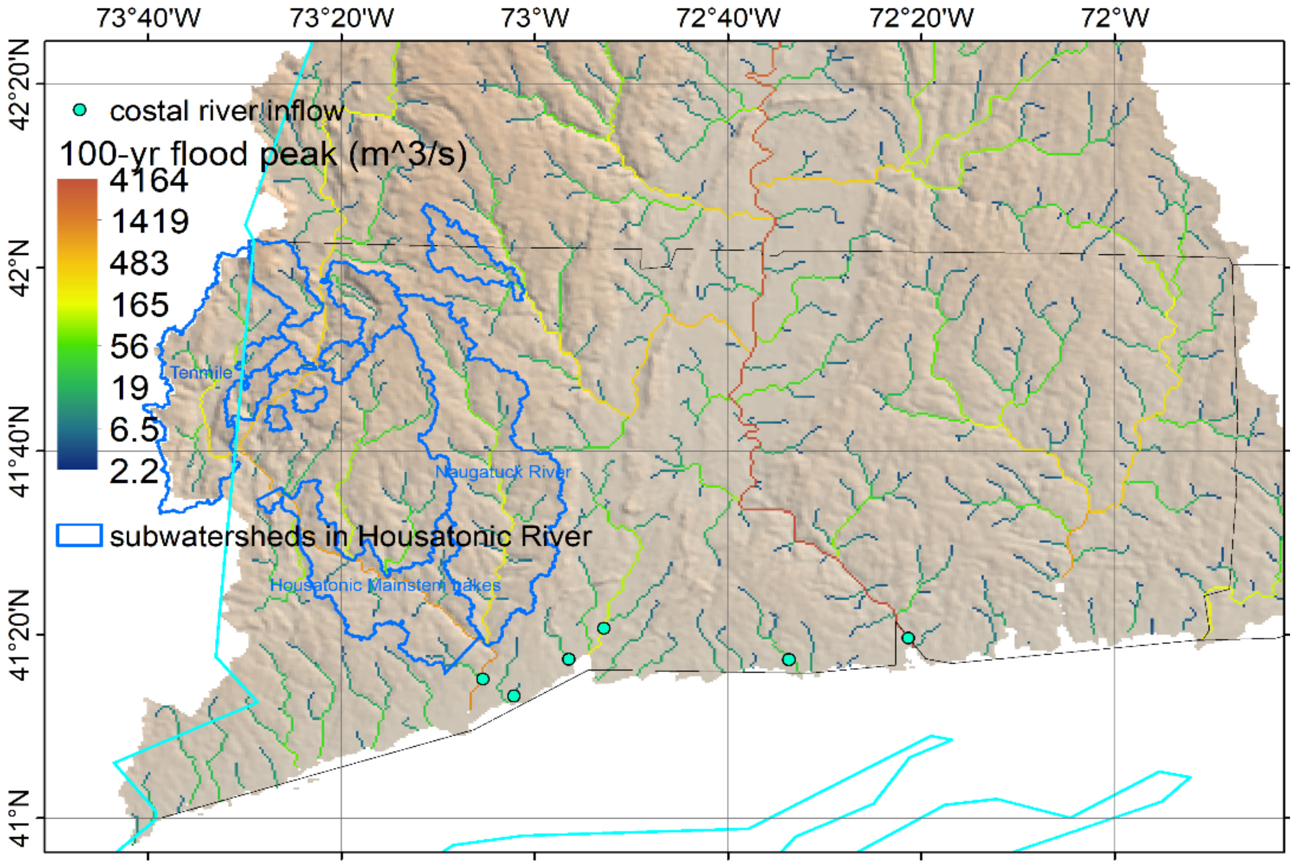
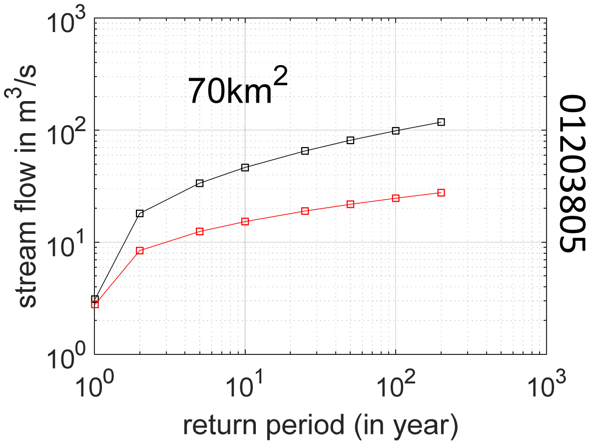
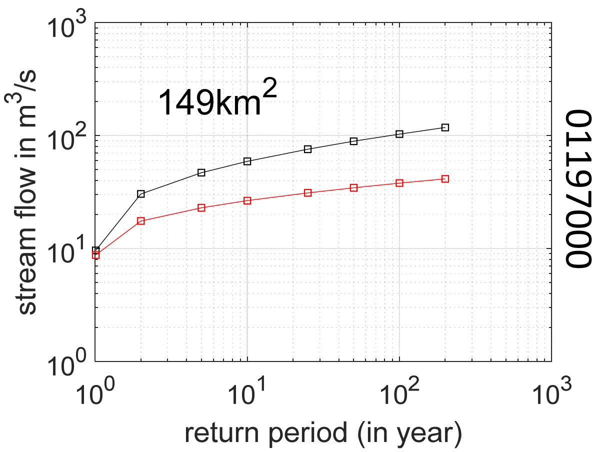
Flood Frequency Maps (2-200-yr) of CT

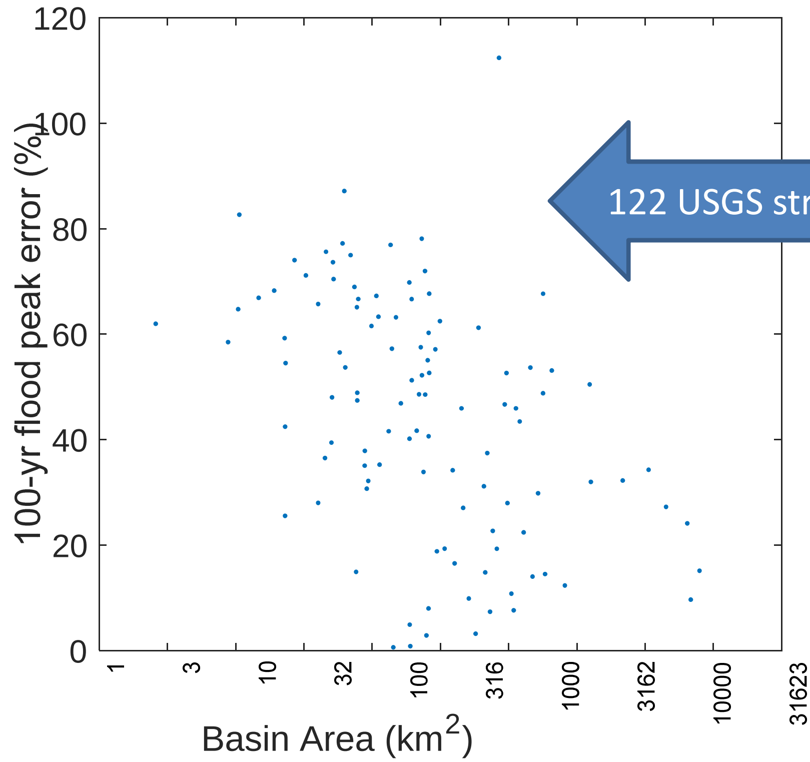


FFA – error analysis

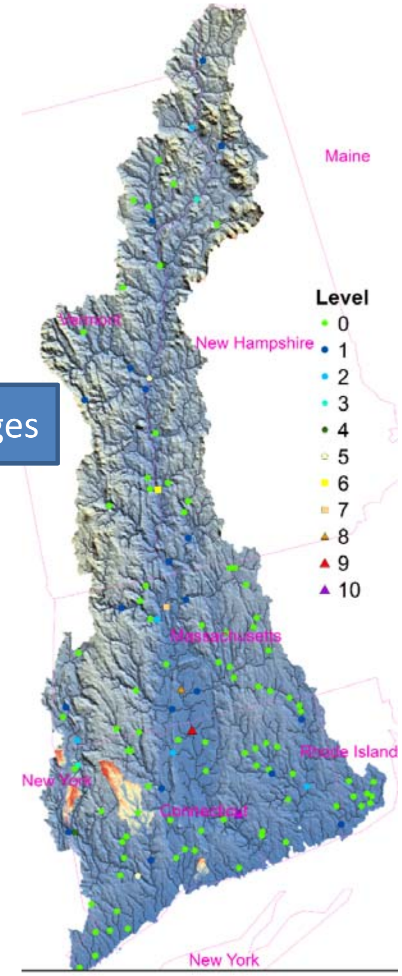
Error=|sim-obs|/obs





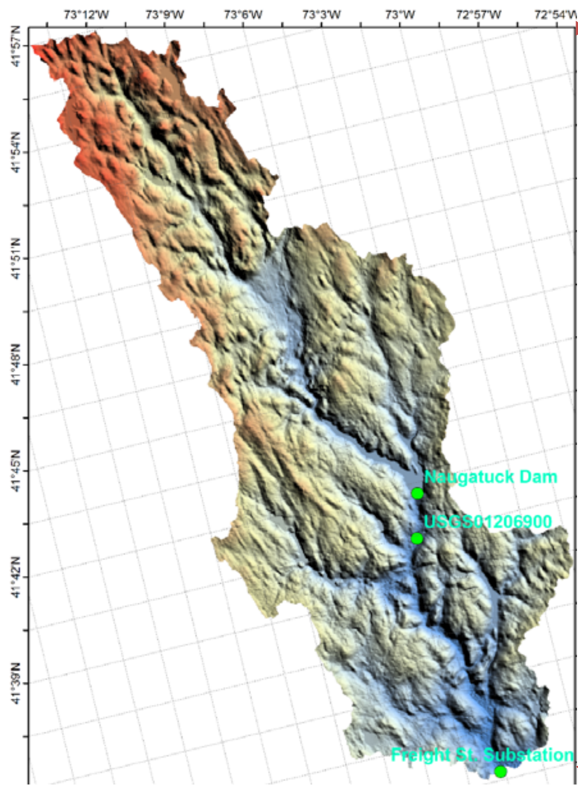


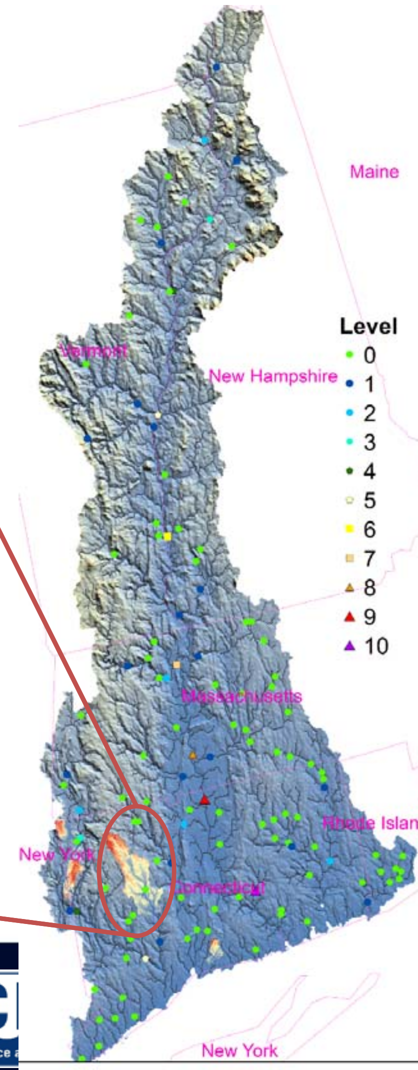
122 USGS stream Gauges



Flood Vulnerability Analysis

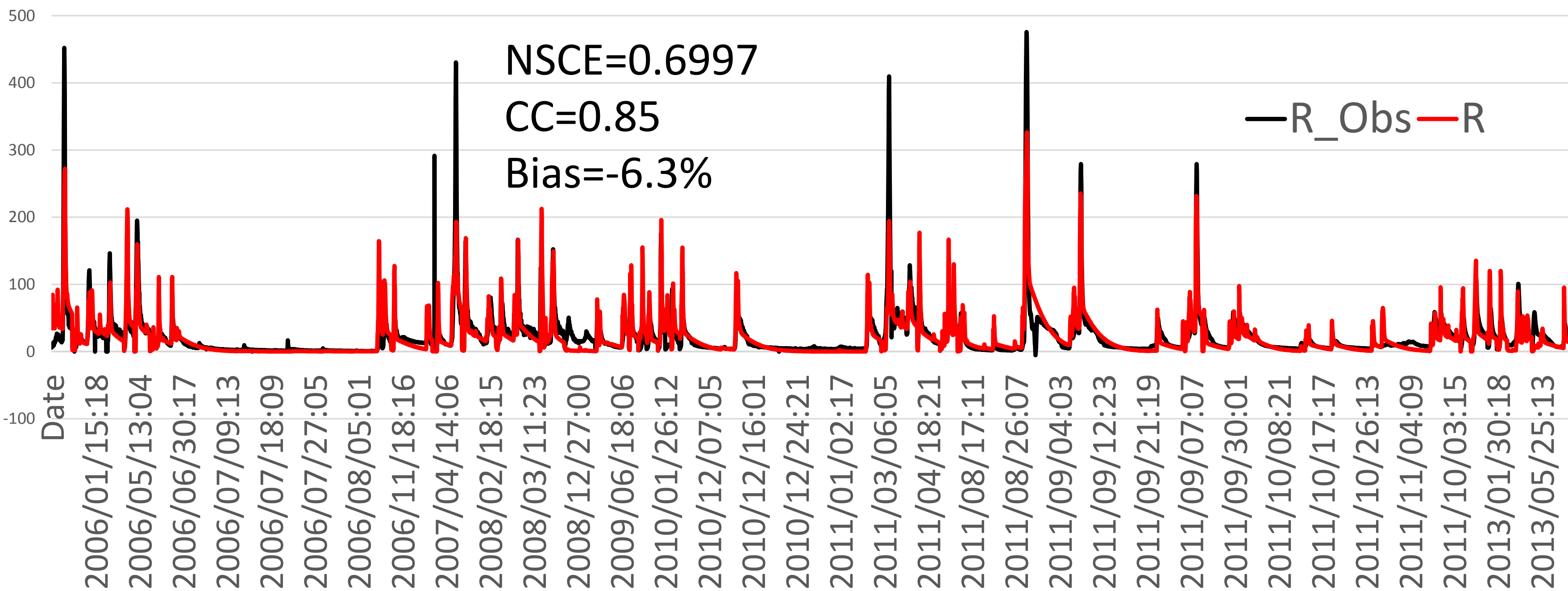
- **Study Area**
  - Naugatuck River
  - Thomaston Dam in the middle of the River
  - Critical Infrastructure at Freight St., Waterbury, CT

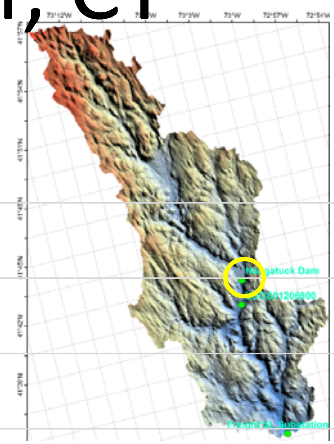




Thomaston Dam inflow, Naugatuck River, CT

45 events , 9/36--calibration/validation (9 years record)





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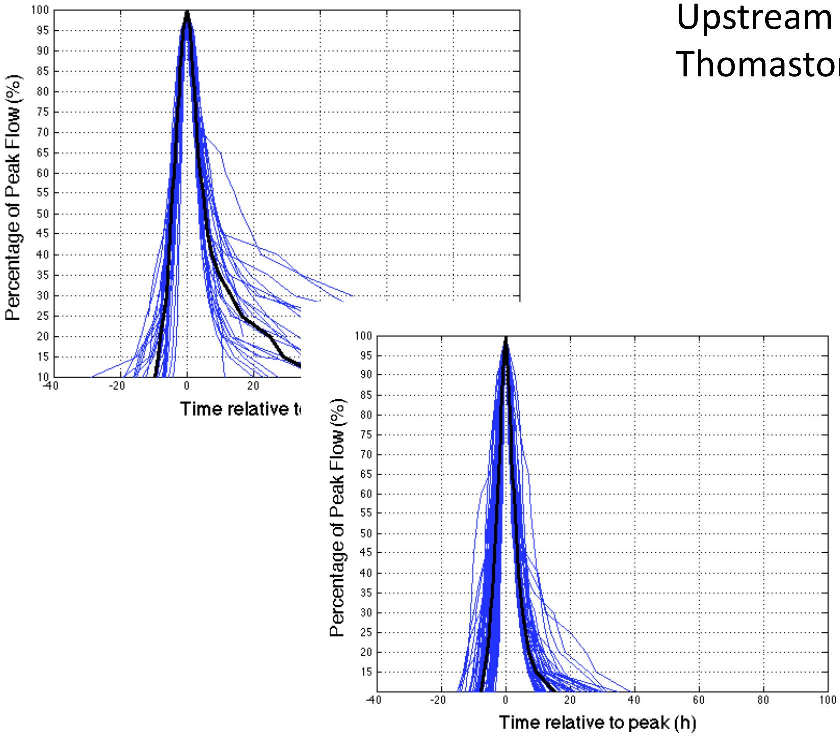
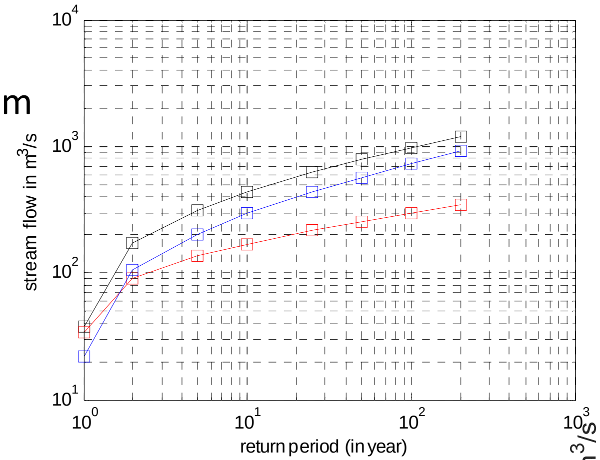
Synthetic Hydrograph

- Timing



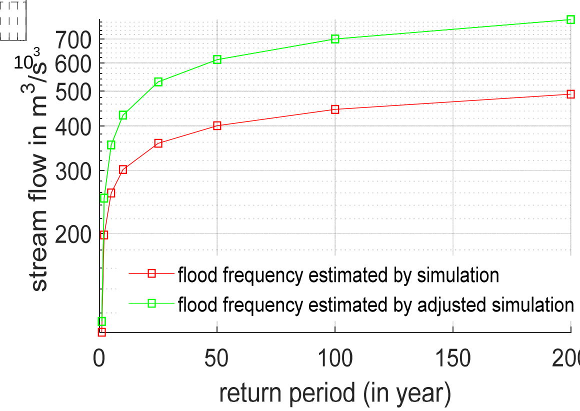
Upstream to Thomaston Dam

- A power-law frequency adjustment



$$r_I^{obs}(p) \approx a\left[r_I^{sim}(p)\right]^b$$

Downstream to Thomaston Dam



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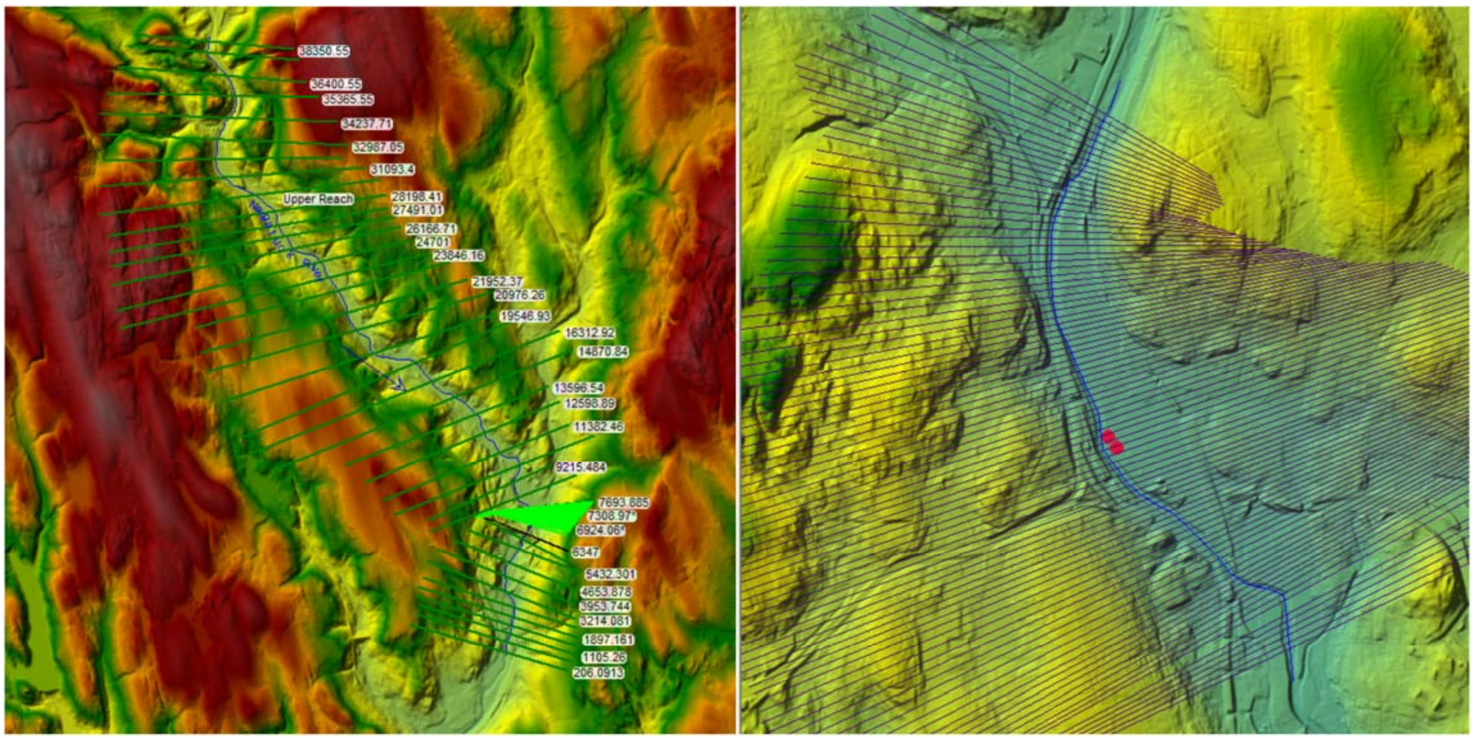
Connecticut Energy Environment

Hydraulic Simulation by HEC-RAS

- River Profiling using LIDAR derived DEM of 1 m resolution



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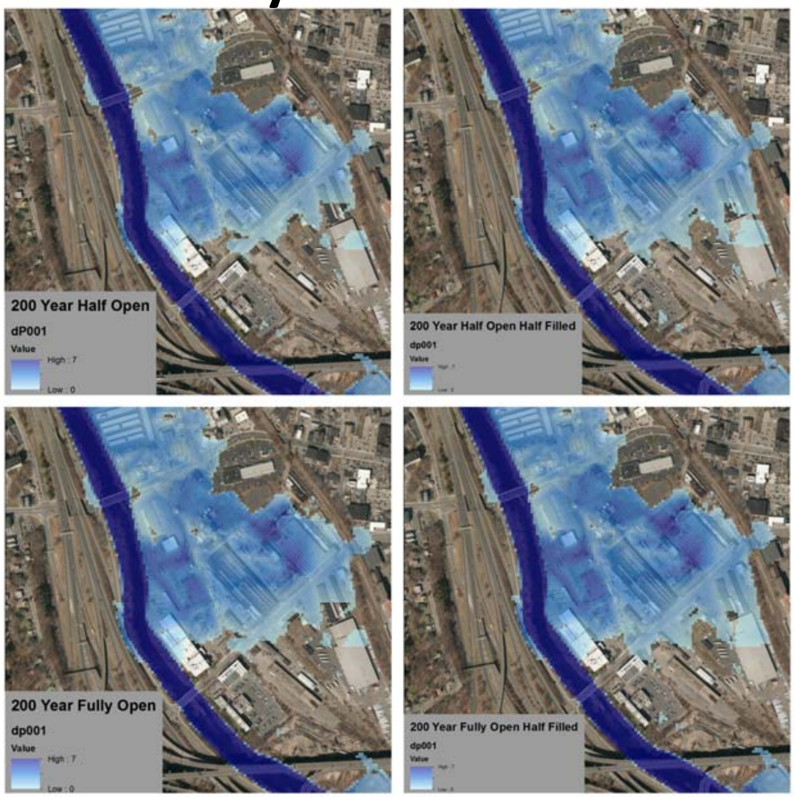
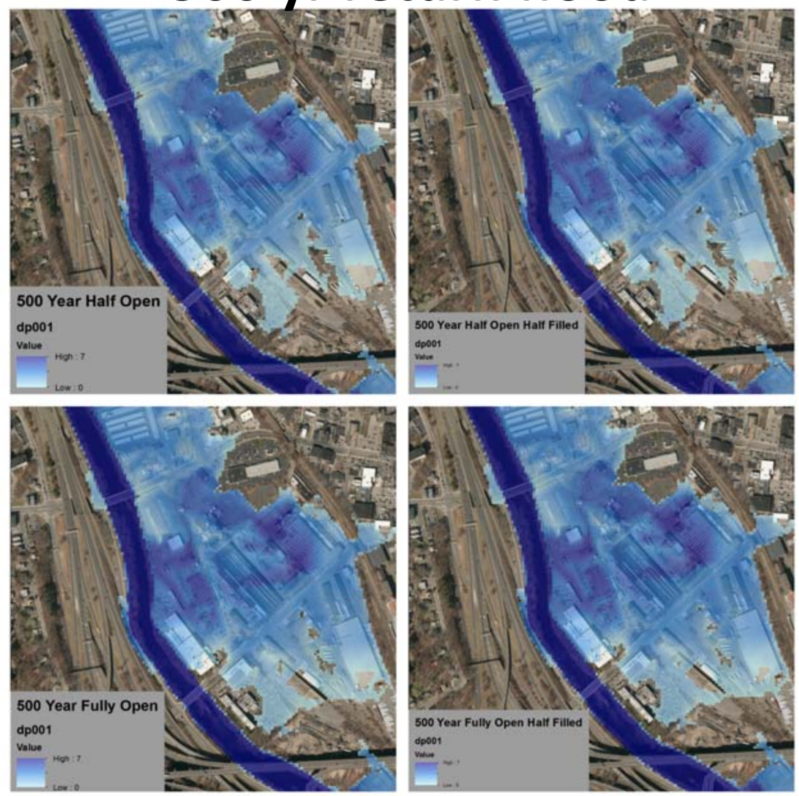
Inundation - different dam operation scenarios

200 yr return flood

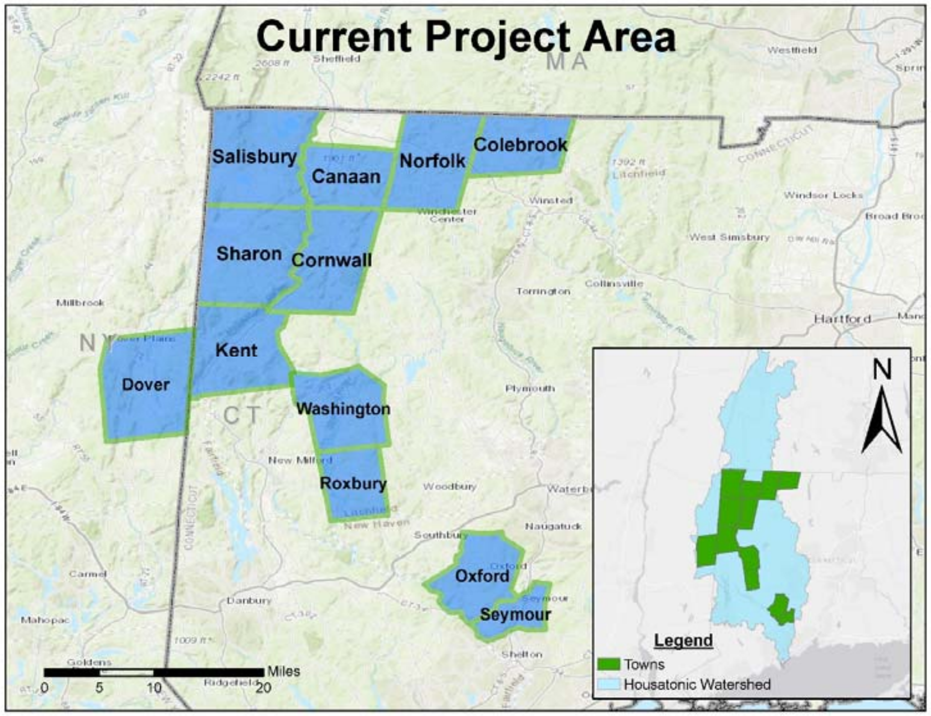


500 yr return flood



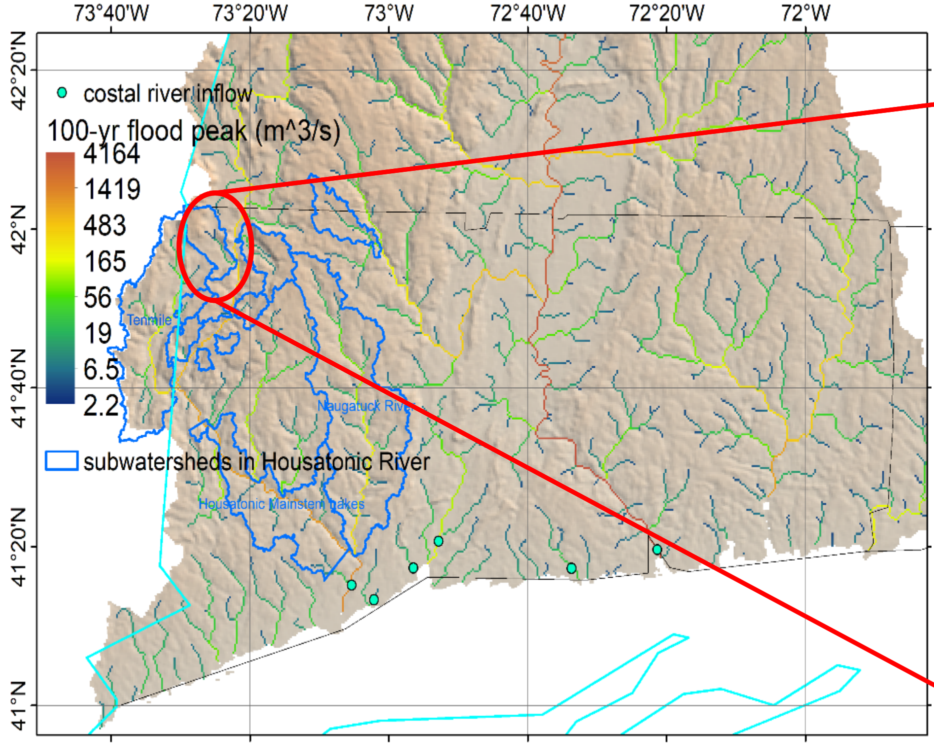
200 Year	Transformer	Building
Closed Dam	1.23	0.00
No Dam	5.72	3.78
Half Open	3.10	1.04
Half Open Half Filled	3.30	1.34
Fully Open	3.33	1.39
Fully Open Half Filled	3.51	1.55
500 Year		
Closed Dam	2.69	0.17
No Dam	6.32	4.38
Half Open	4.01	2.12
Half Open Half Filled	4.20	2.22
Fully Open	4.28	2.57
Fully Open Half Filled	4.63	2.69

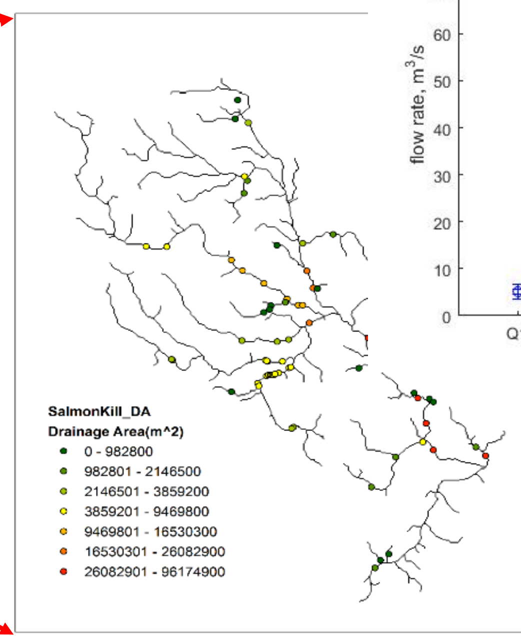
Road Crossing Flood Risk Assessment - Housatonic River

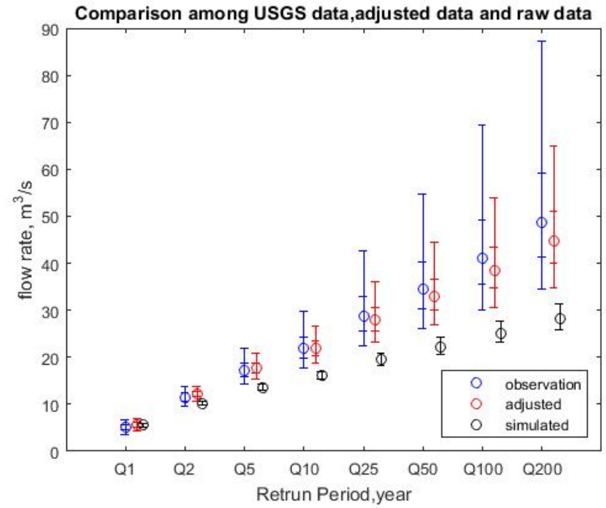


From Michael Jastremski, HVA

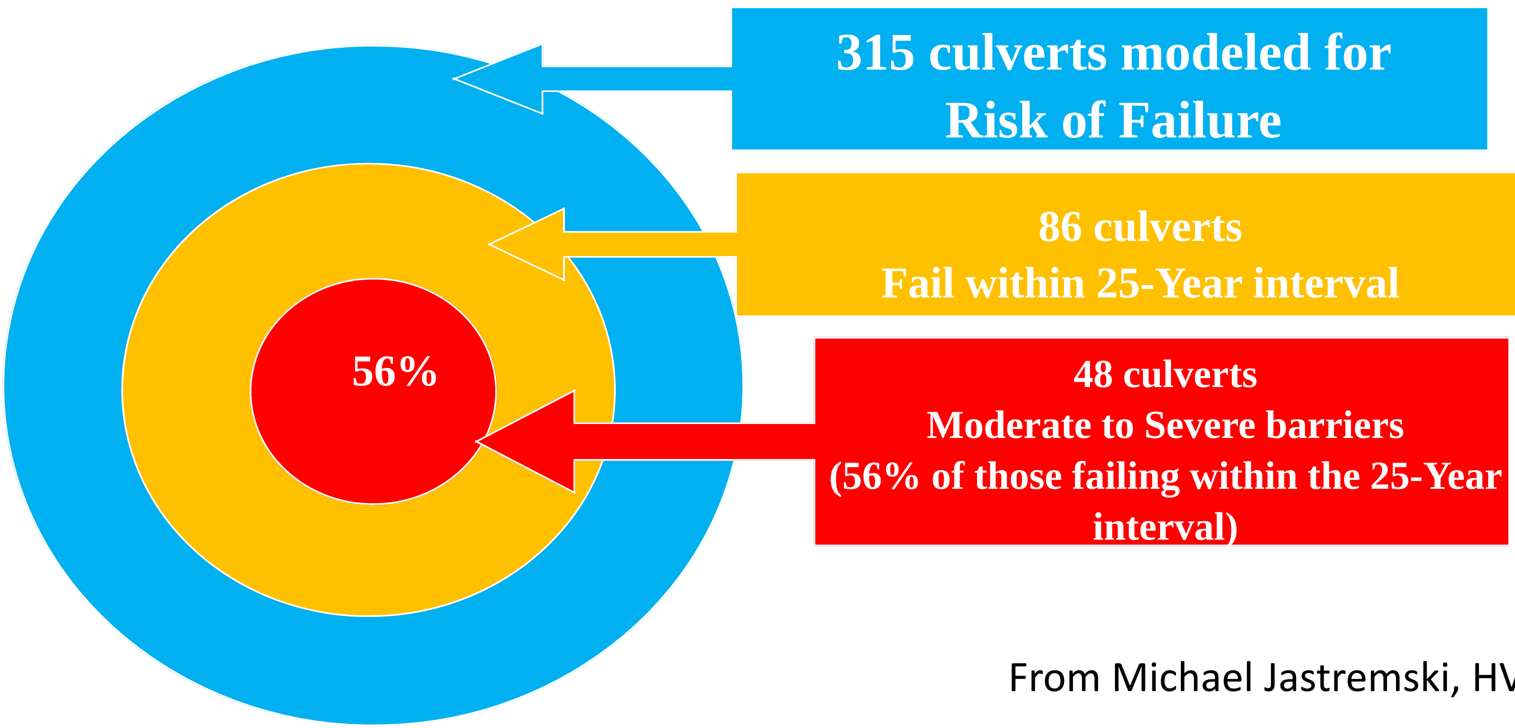
An Example: Salmon Kill watershed







Summary of the Results



From Michael Jastremski, HVA

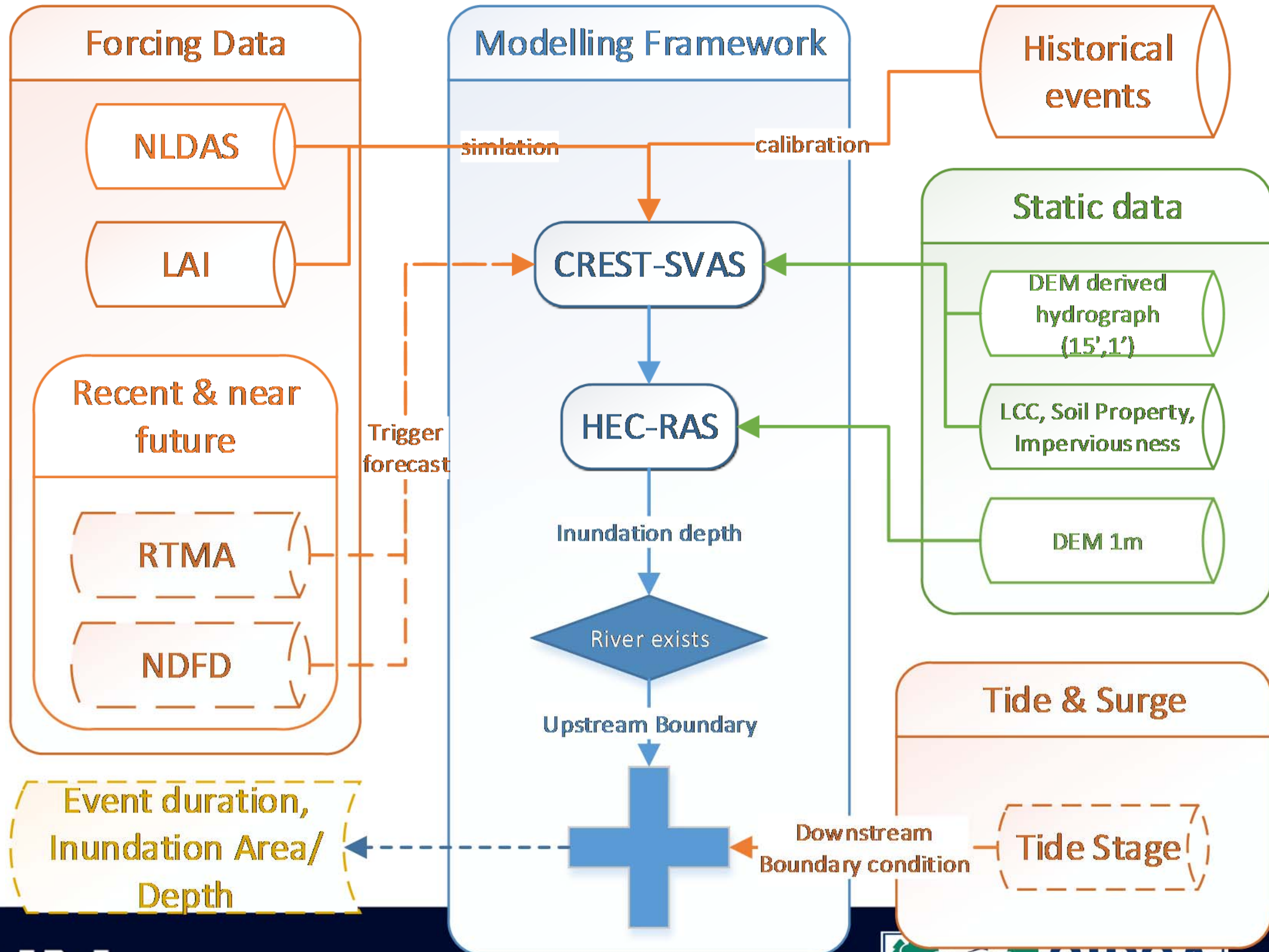
Summary

- A fully-physically based numerical hydrological framework, CREST-SVAS, forced with atmospheric reanalysis has been developed to estimate flood frequency in mid- and northern-latitude basins
- CREST-SVAS has been applied to assess flood-inundation and flood overtopping risks in conjunction with hydraulic models & LiDAR data

Work in progress

- A real-time early warning system of flood vulnerability based on weather-forecasting driven CREST-SVAS, in combination with storm & tide forecasts
- A novel regional flood frequency estimation method combining the strength of CREST-SVAS numerical simulations and USGS network observations

Under development: Real-Time Forecast System



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Slide 21

SX1 This figure needs to be updated according to the new data
Shen, Xinyi, 4/10/2018

RFFA Method

According to IUH theory, the runoff of a basin can be decomposed to that of its sub-basins in the following form,

$$r_o(t) = \sum r_i(t + \tau_i) \qquad (1)$$

Where τ_i stands for the time delay of the i[th] sub basin to the outlet r_o and r_i stands for the runoff of at the outlet and the i[th] sub-basin.

Carrying out Fourier transformation of (1), we have

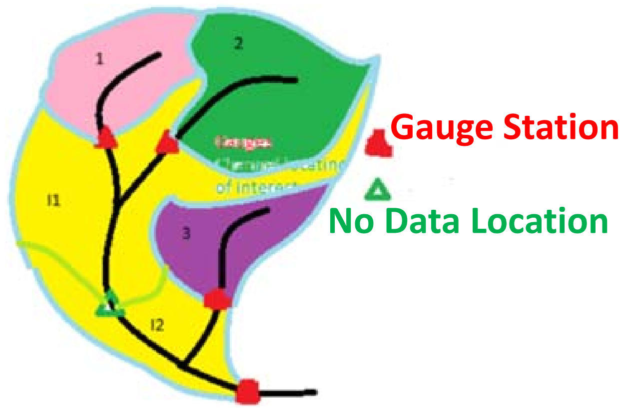
$$R_o(f) = \sum e^{2\pi j \tau_i f} R_i(f) \qquad (2)$$

where $R_o(f)$ is the Fourier transformation of $r_o(t)$ given by equation (3)

$$R(f) = \int_{-\infty}^{\infty} e^{-2\pi j f t} r(t)\,dt \qquad (3)$$

In a general case illustrated by the right Figure, the equation (4) could be derived from equation (2)

$$R_o(f) = R_I(f) + \sum_{i=1}^{3} e^{2\pi j \tau_i f} R_i(f) \qquad (4)$$



In order to solve FFA at no data location, the first step is to solve (4) for τ_{1-3} and $R_I(f)$.

To extend the length of observation data, assuming simulation and observation satisfy a power law relationship

$$r_I^{obs}(p) \approx a(p)\left[r_I^{sim}(p)\right]^{b(p)} \qquad (5)$$

For yellow region, also could use (2) and derive equation (6)

$$R_I(f) = R_{I_2}(f) + e^{2\pi j \tau f} R_{I_1}(f) \qquad (6)$$

Simultaneous equations (4), (5) and (6) in the low frequency range, could solve $a(p)$, $b(p)$ and τ_{1-3} . Finally, RFFA of no data location could be derived from equation (7).

$$r_{LOI}(t) = r_1(t) + \sum_{i=1}^{2} r_i(t + \tau_i - \tau) \qquad (7)$$

RFFA results

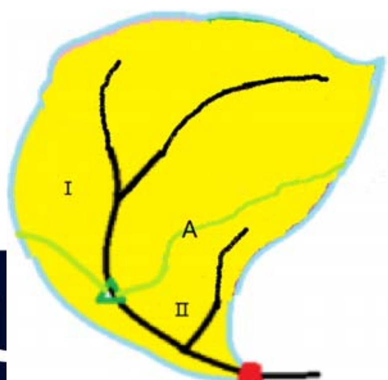
Use daily Obs and Sims data of 7 main station on C.T river

$$r_I^{obs}(p) \approx a(p)\left[r_I^{sim}(p)\right]^{b(p)} \quad (5)$$

$$R_I(f) = R_{I_2}(f) + e^{2\pi j\tau f} R_{I_1}(f) \quad (6)$$

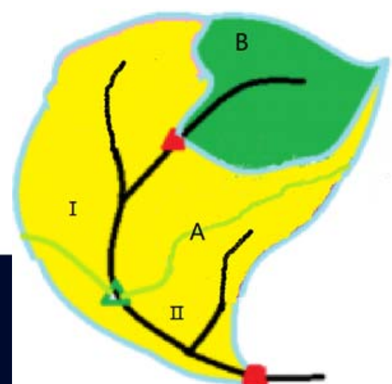
$$r_{LOI}(t) = r_1(t) + \sum_{i=1}^{2} r_i(t+\tau_i-\tau) \quad (7)$$

Scenario Ⅰ Eq(6)

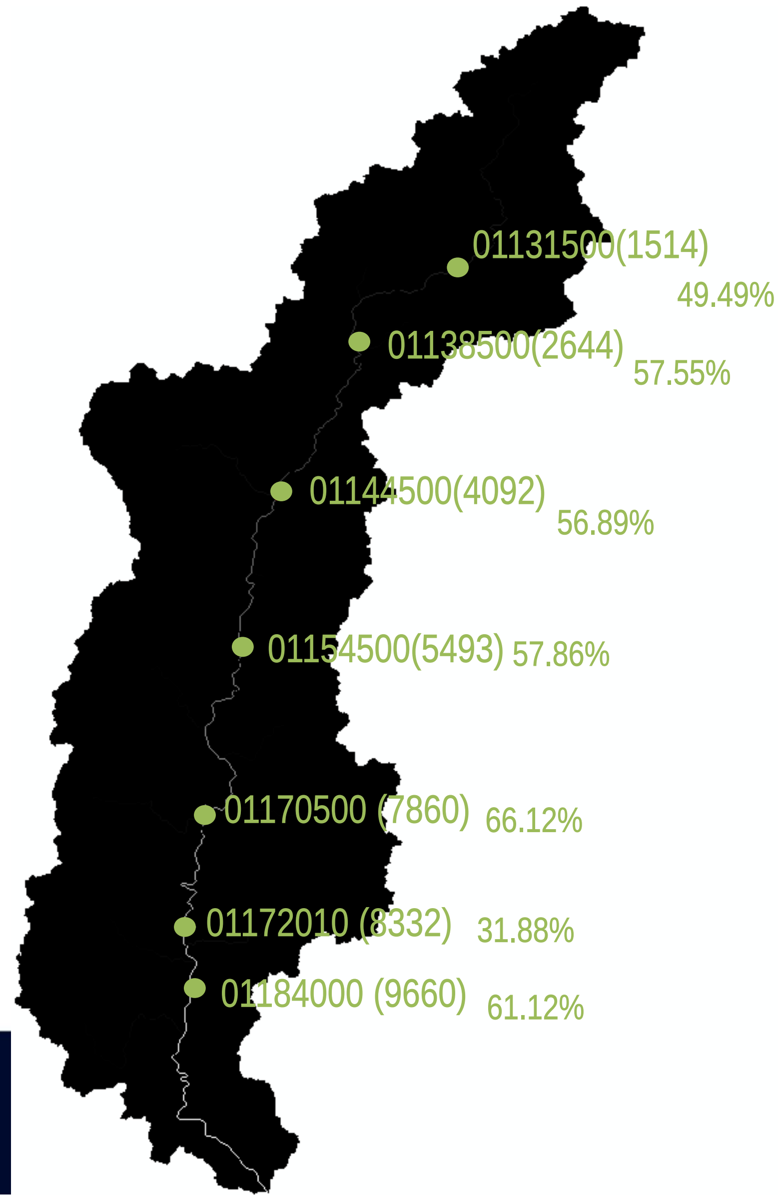


Ⅱ : Ⅰ

Scenario Ⅱ Eq(4),(6)&(7)



Ⅱ : Ⅰ :B



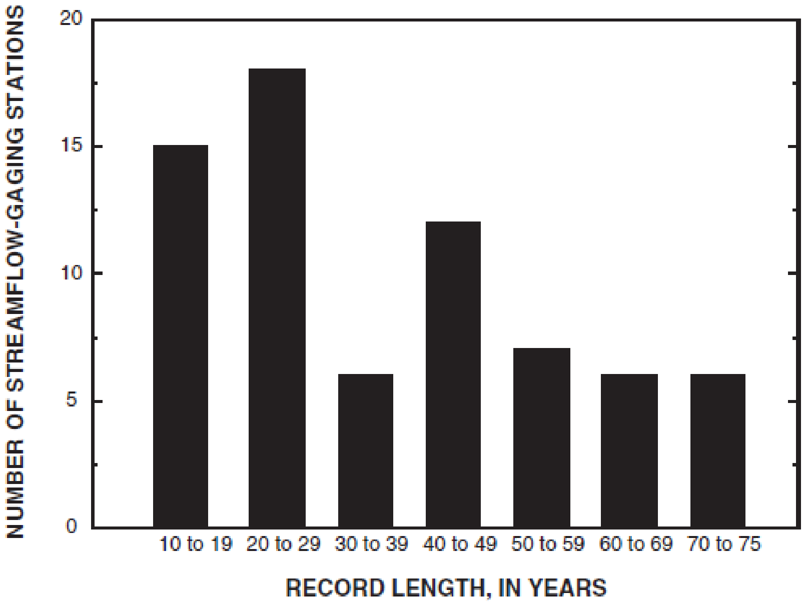
Statistical Approaches

- Average stand errors of streamstats

	2	10	25	50	100	500
CT	31.8	32.7	34.4	35.9	37.6	45.0
NJ	49					63.9
NC	25.0					73.3
OK	31					46

- Large error
- Short record length
- No future projection
- Subjective

Available USGS records in CT (reported in 2004)

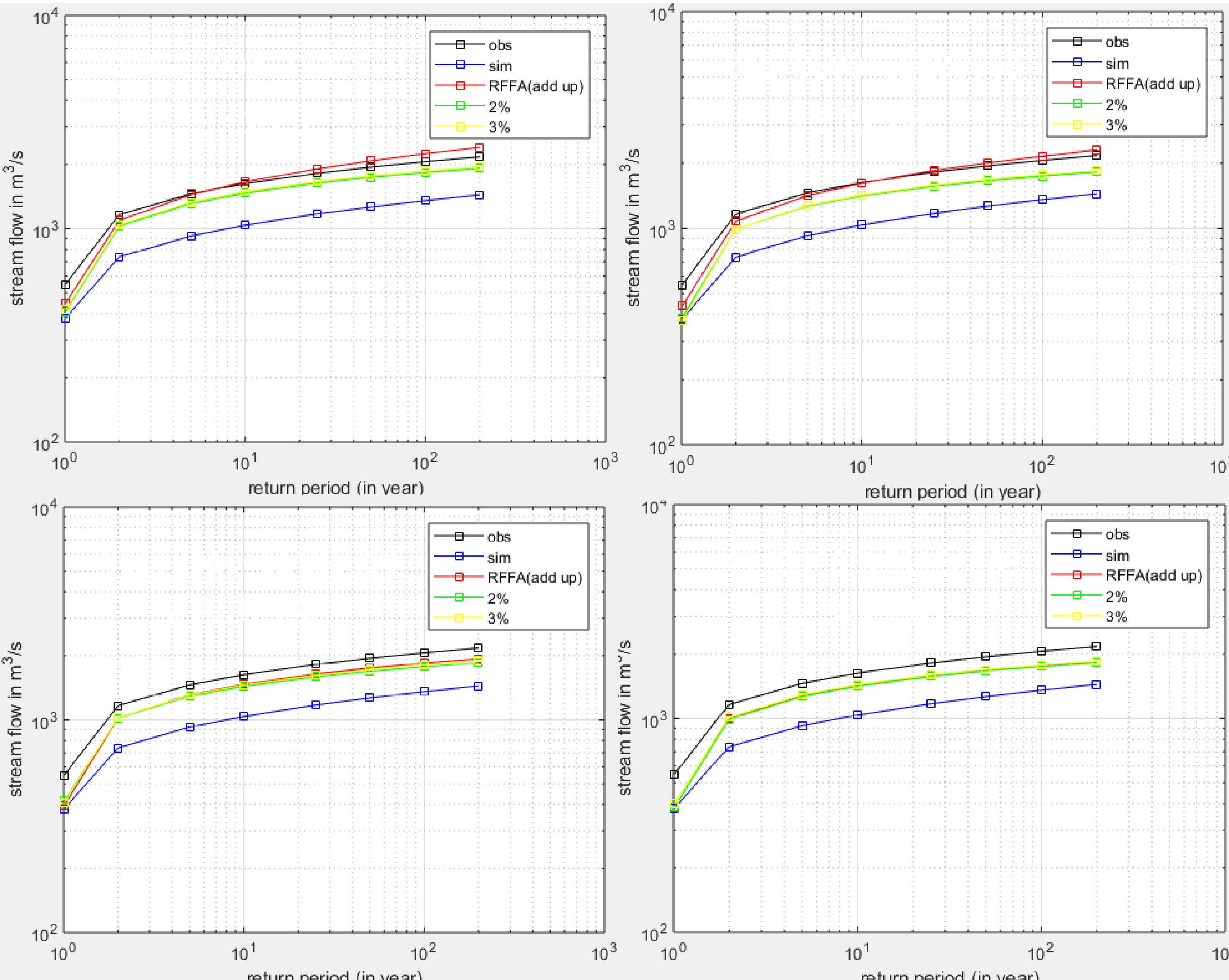


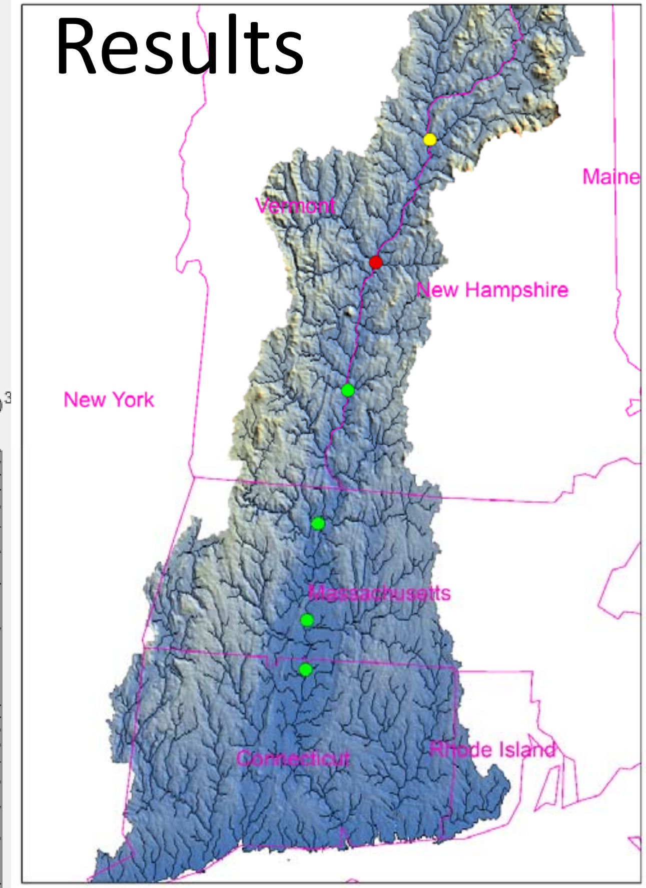
A New RRFA method Under Construction

- Combine the strength of simulation and observation

	Peak biased	Sparsely available	Record Length	Future projection
Simulation	√	×	-1900 (New GLDAS) -1949 (GLDAS) -1979 (NLDAS)	2100
Observation	×	√	-1990	×

Preliminary Results





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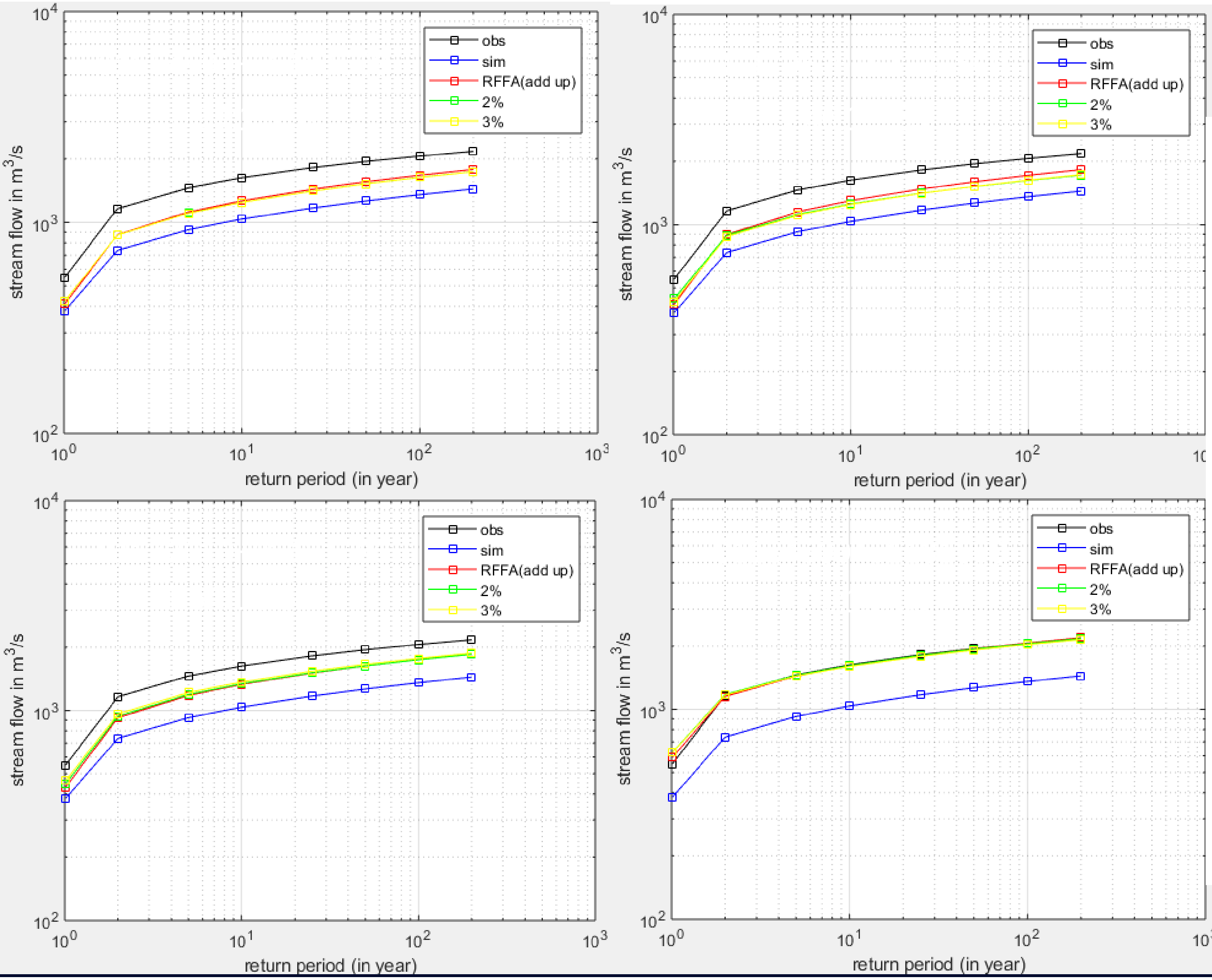
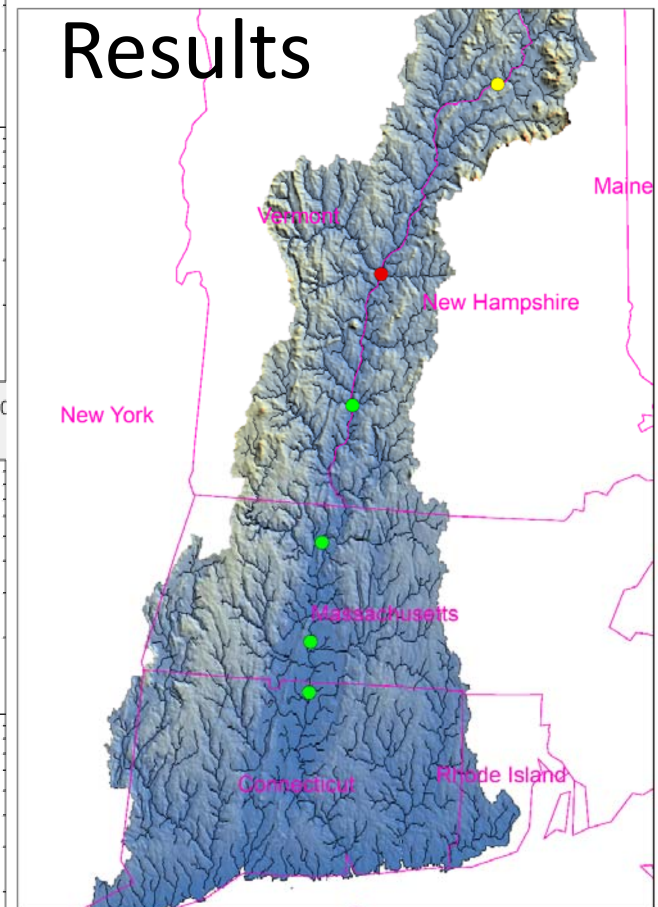
Preliminary Results





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