Vermont
EPSCoR
Experimental Program to Stimulate Competitive Research

Question 2: Watershed component
“Which alternative stable states can emerge in the watershed and lake resulting from non-linear dynamics of climate drivers, lake basin processes, social behavior, and policy decisions?”


W BRANCH LITTLE R, BINGHAMFALLS
WINOOSKI R, ESSEX JUNCTION
RANCH BROOK, RANCH CAMP
ALLEN BROOK AT VT 2A
LAKE CHAMPLAIN, BURLINGTON
LITTLE R, WATERBURY
LAPLATTE R, SHELBOURNE FALLS
WRIGHTSVILLE DETENTION RESERVOIR
NORTH BRANCH WINOOSKI R
MAD R, MORETOWN
WINOOSKI R, MONTPELIER
NORTH BRANCH WINOOSKI R, MONTPELIER
DOG R, NORTHFIELD FALLS
EAST BARRE DETENTION RESERVOIR
USGS_gauges

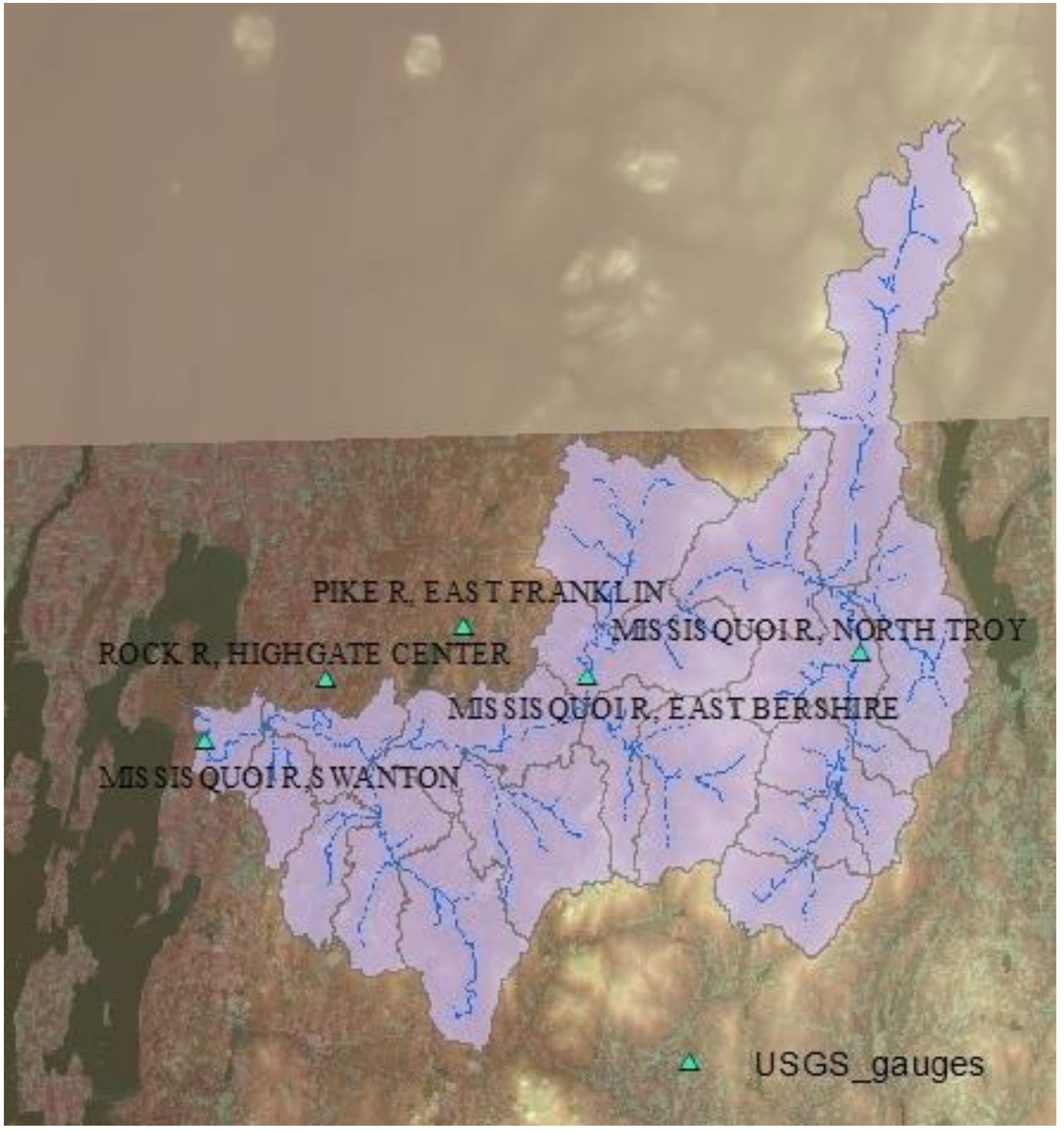
We are taking a SYSTEMS APPROACH to impacts and adaptation studies.

We seek to understand:

1. The watershed/lake system as a complex adaptive system
2. The expected impact of precipitation change on:
    1. Sediment and non-point phosphorus mobilization
    2. Flooding/scouring of channels and floodplains
    3. Natural vegetation and farming practices
    4. Infrastructure

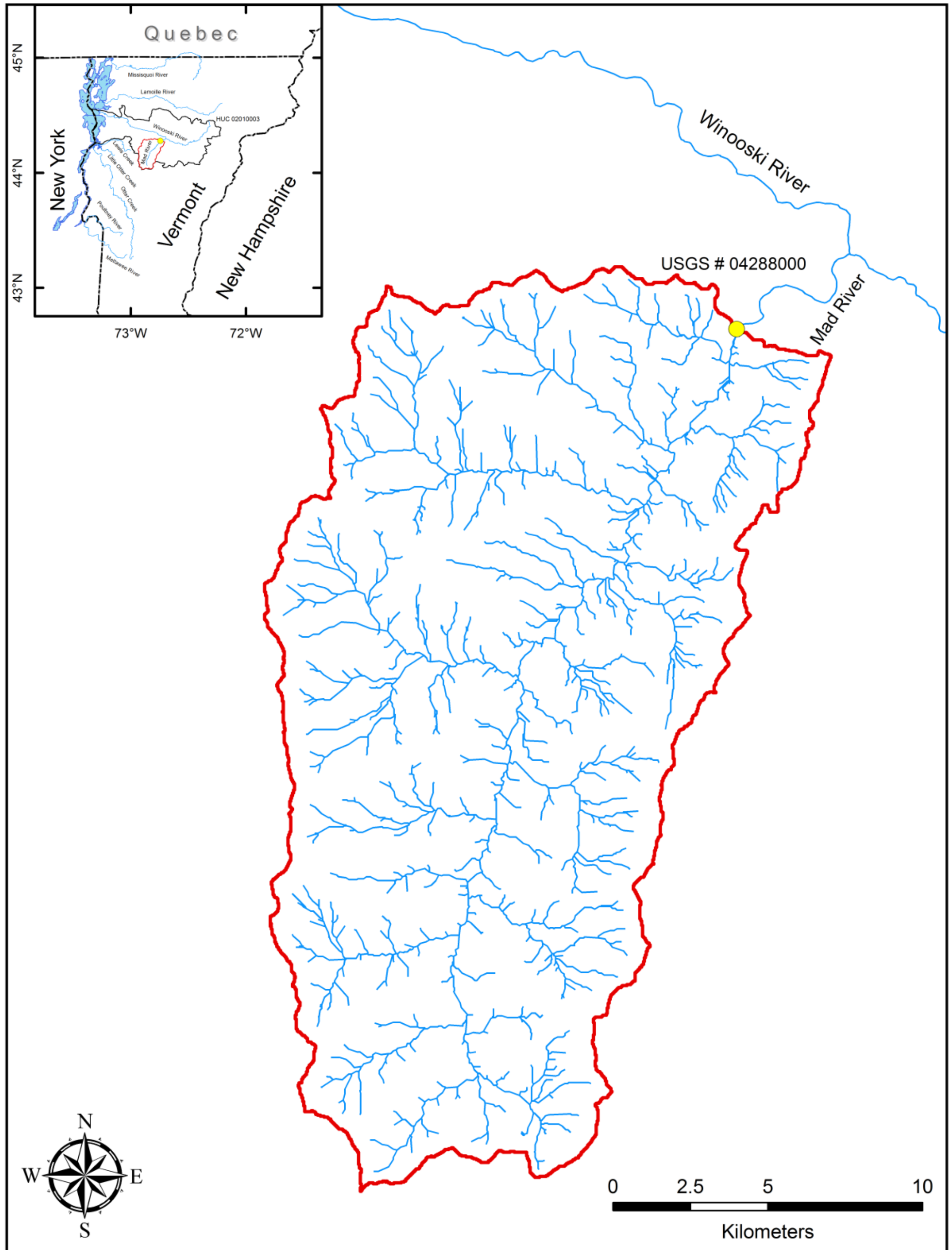
    } Watershed model
3. The expected impact of temperature change on:
    1. Natural vegetation
    2. Frozen ground
    3. Snow/rain ratio

    } Regional Climate Model
4. System resilience to future changes under a variety of scenarios
    1. What variables dominate? (e.g. land use, governance, etc)
    2. What alternative stable states may the watershed take on? (agricultural/ urban, forest succession, healthy channels/impacted,etc)

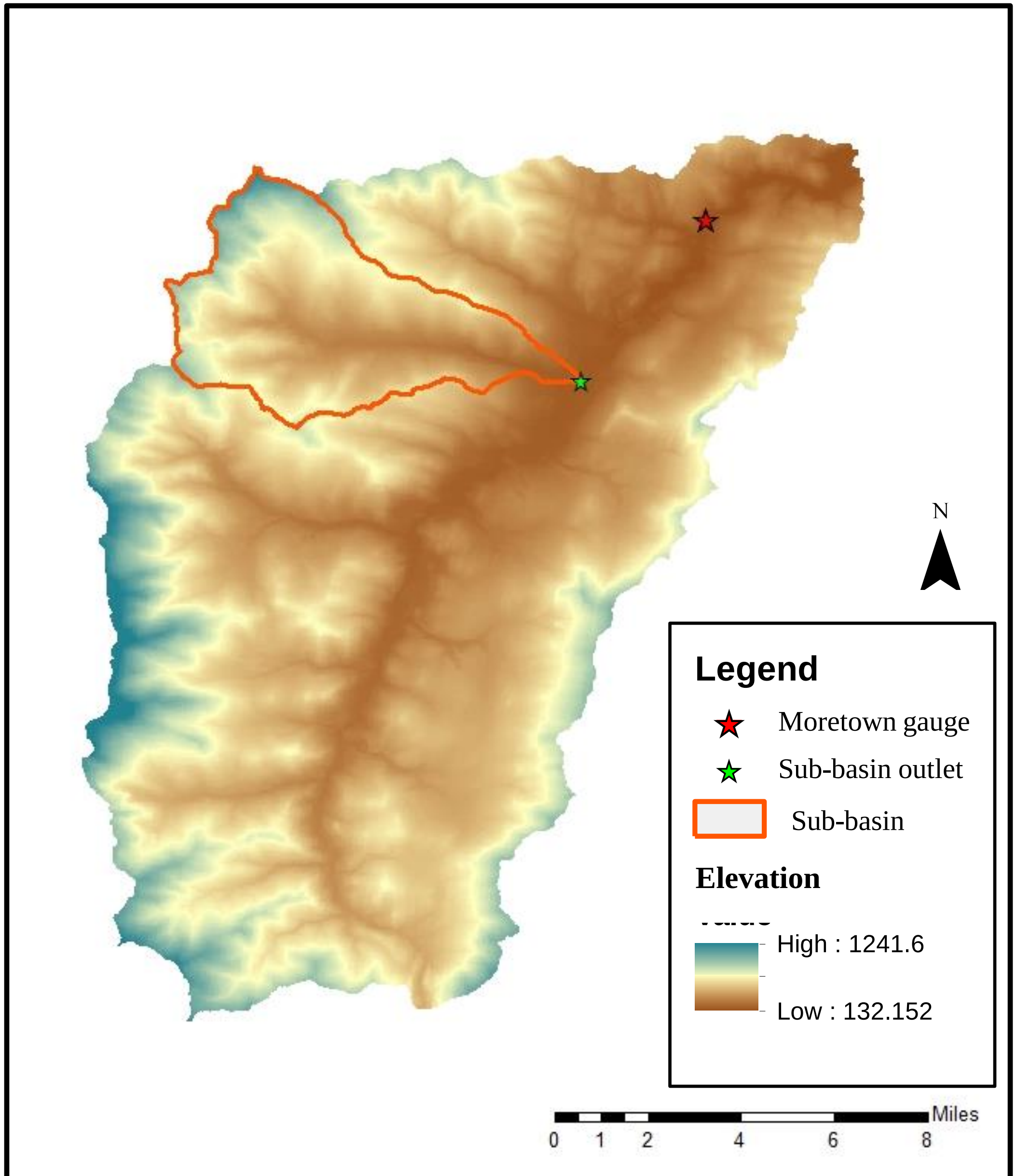

PIKE R, EAST FRANKLIN
MISSISQUOI R, NORTH TROY
ROCK R, HIGHGATE CENTER
MISSISQUOI R, EAST BERSHIRE
MISSISQUOI R, SWANTON
USGS_gauges

Hydrological modeling:

Begin with Mad River watershed

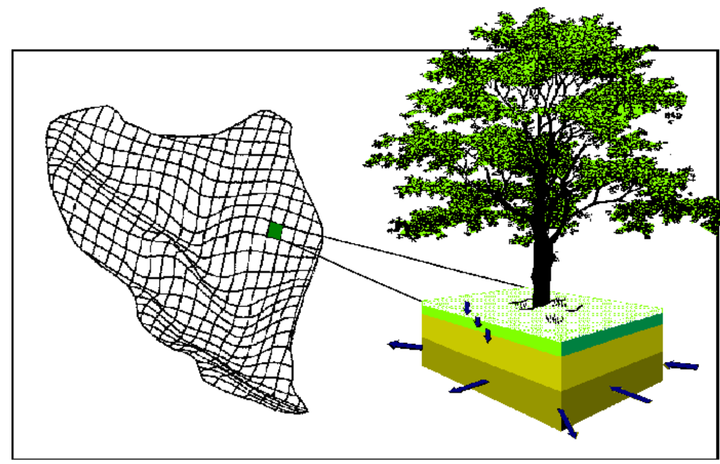


Modeling Efforts on the Mad River Watershed



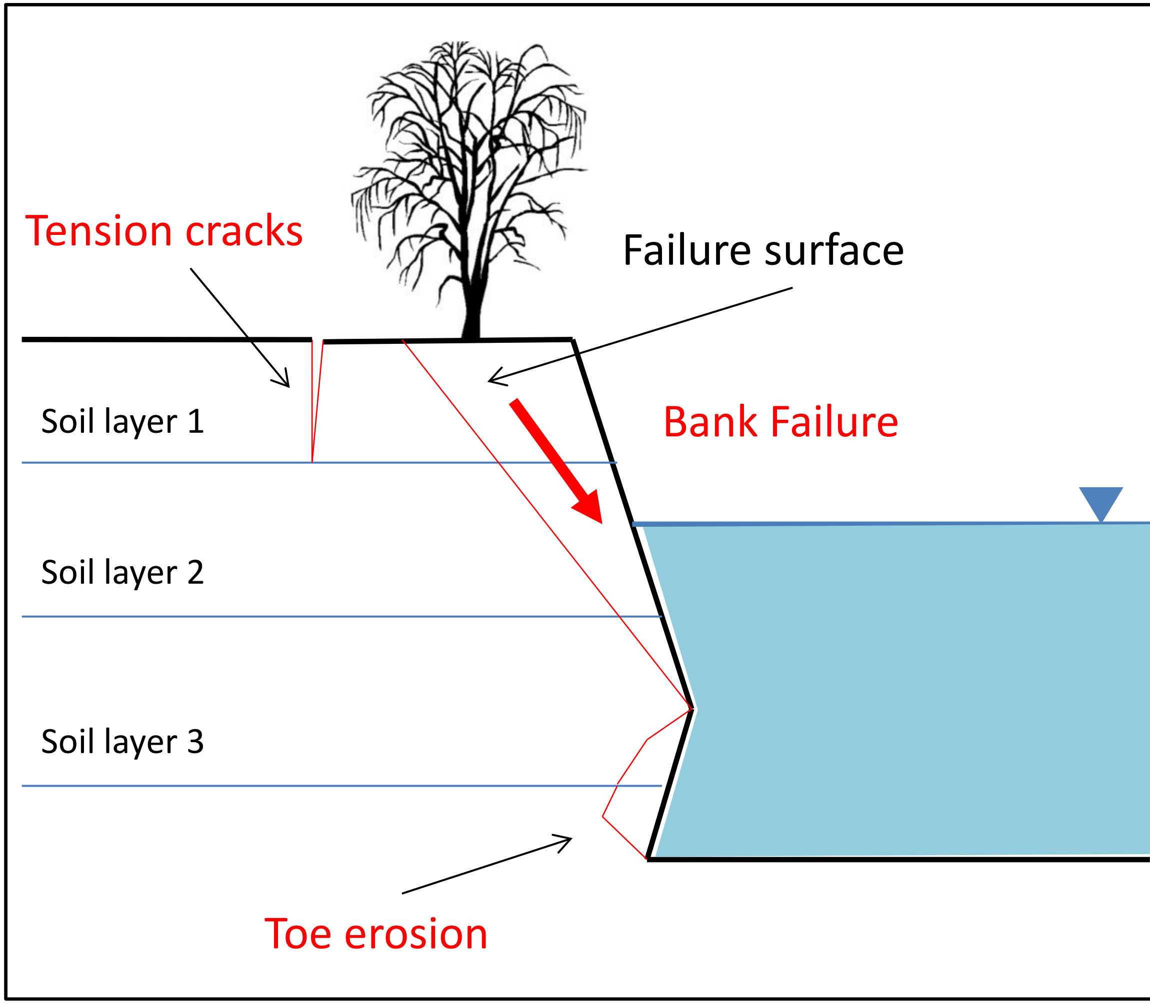
DHSVM – Distributed Hydrology Soil Vegetation Model

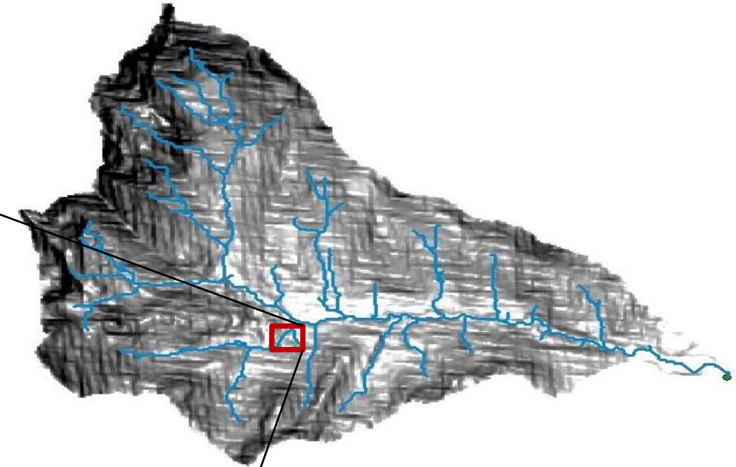
DHSVM explicitly represents the effects of topography, soil, vegetation, and channel networks on water fluxes through a landscape.



Water and energy balances
Surface, subsurface, and channel flow
Sediment transport
Evapotranspiration

DHSVM/BSTEM Model Schematic





Calculated on each segment of channel:

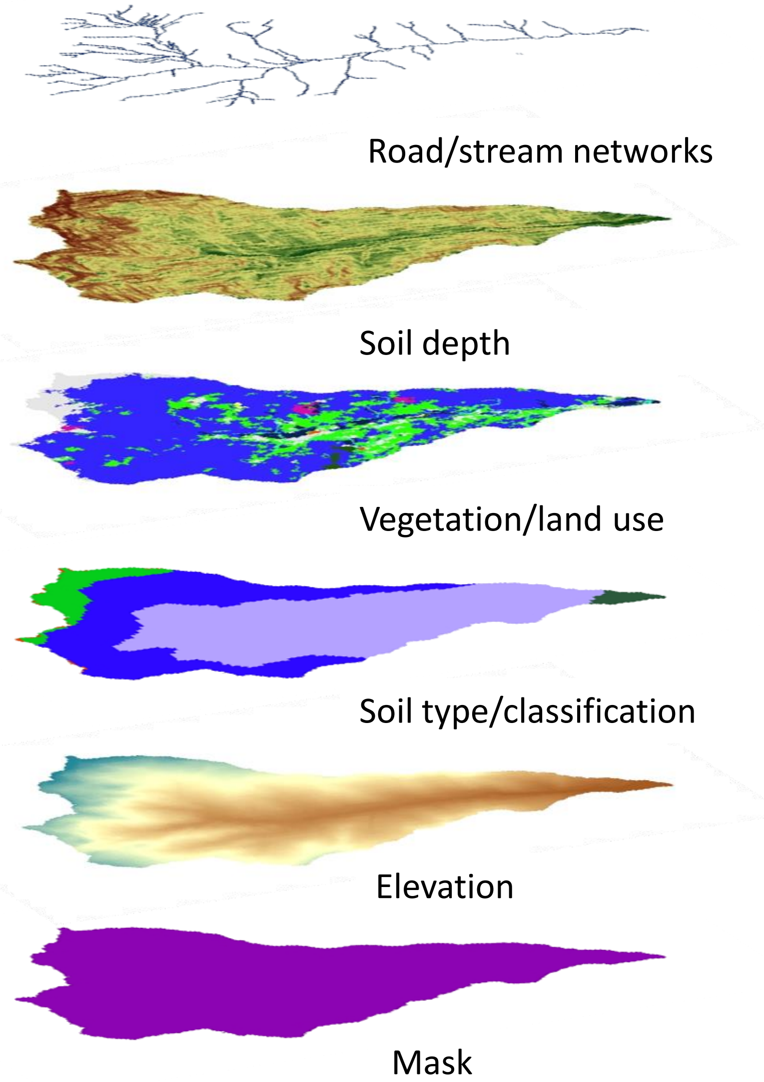
- Toe erosion
- Horizontal planar failure
- Vertical planar failure
- Cantilever failure resulting from tension cracks

DHSVM Inputs

Field-derived Inputs

- Meteorological data :
  temperature, RH, precipitation, shortwave/long-wave radiation, wind speed
- Stream data:
  channel gradient, friction angle, bank angle, bank height, bank toe length, toe angle
- Soil parameters:
  cohesion, saturated unit weight/bulk density, hydraulic conductivity, porosity, grain size distribution, roughness coefficient

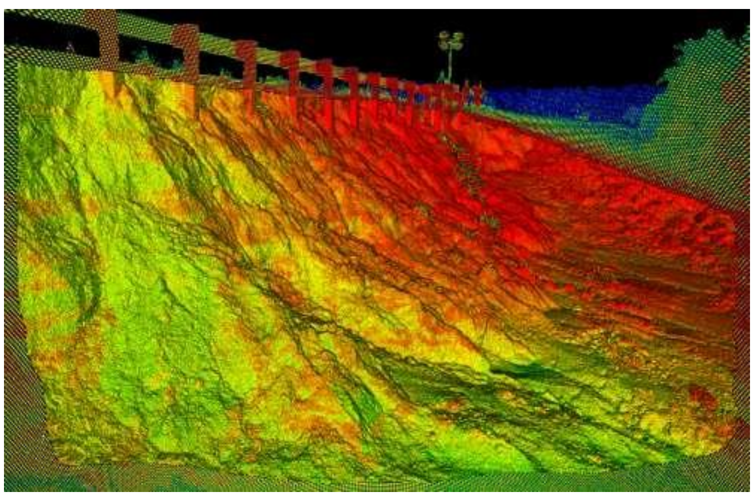
GIS-derived Inputs (for sub-basin)

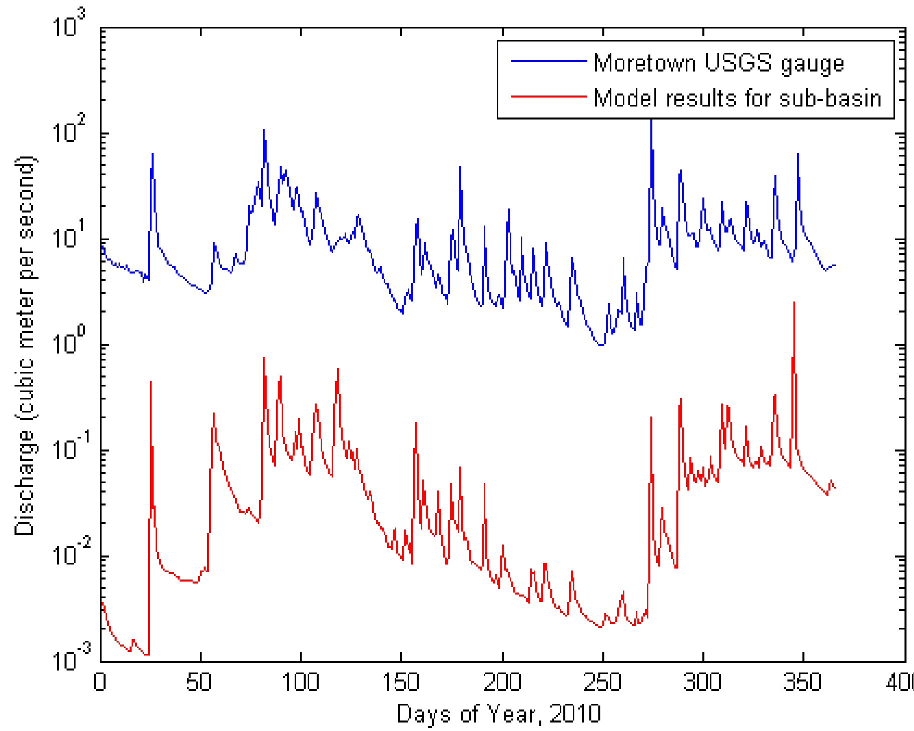


Field Data for Calibration

Models will be calibrated and compared against field measurements take from several locations within watershed.

- Erosion measurements using LIDAR and traditional methods
- Turbidity
- Stream flow
- Water surface profile





Source: U.S. G.S. is using this new technology in select areas of Louisiana, Mississippi and Alabama to map impacts by Hurricane Isaac. (http://gallery.usgs.gov/photos/09_07_2012_dIYk0ONb07_09_07_2012_0)

Future Modeling Work

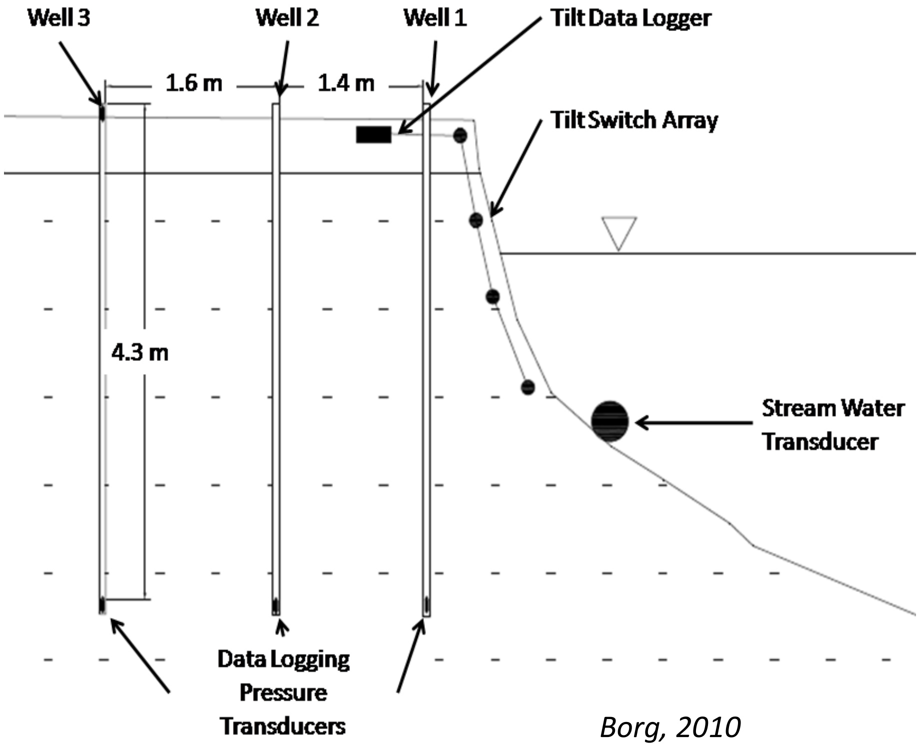
Processes that affect and are effected by changes in stream morphology may also be important in planning for the future of Vermont's rivers and streams systems. Model development will also include representation of feedback mechanisms that play a role in determination of alternate stable states in rivers and streams in Vermont.

- Development of model to include processes related to changing stream morphology
  - Stream incision
  - Deposition of materials
  - Dynamic feedback processes

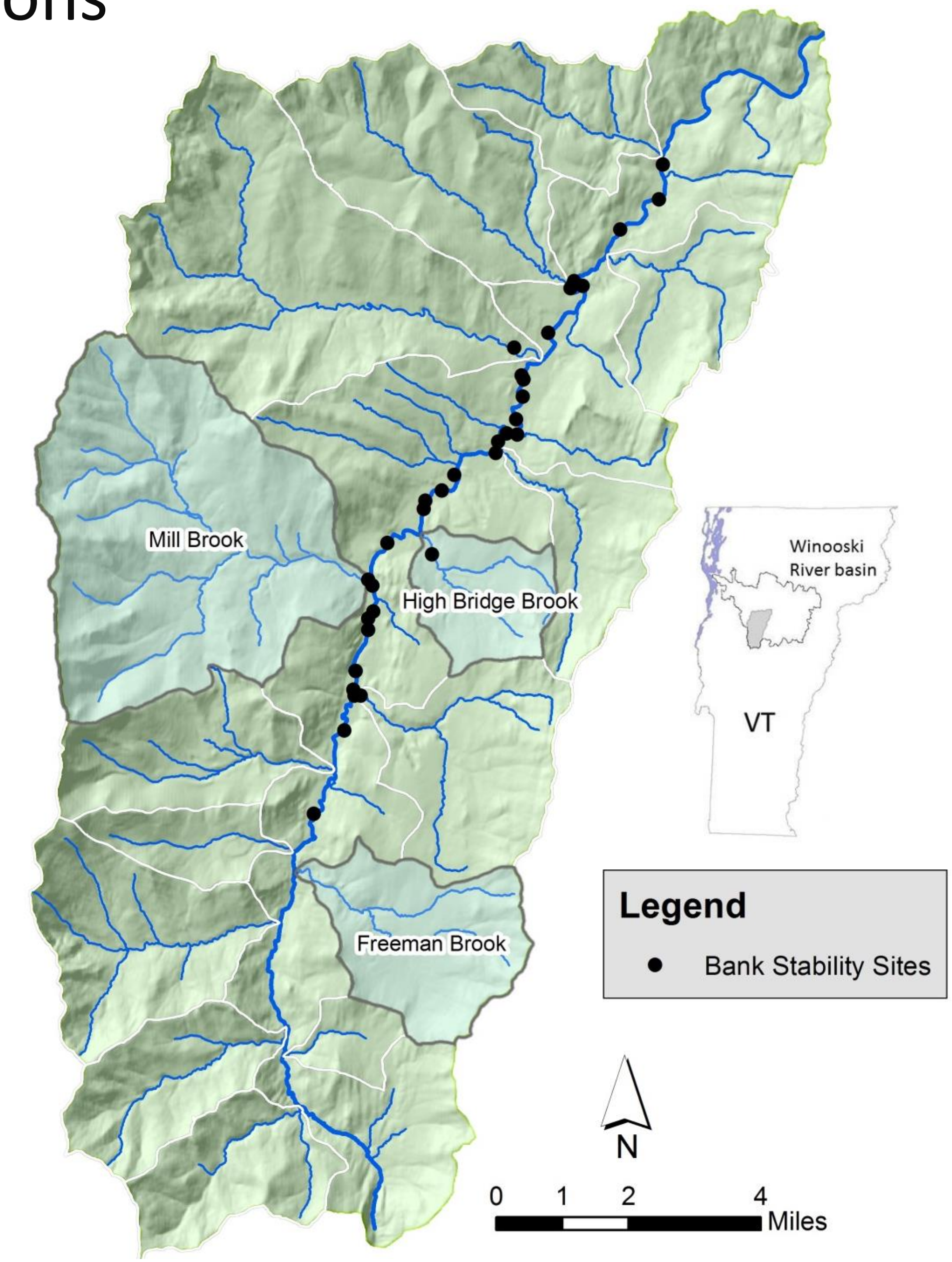
Source: http://vtdigger.org/2011/12/21/river-experts-discuss-impacts-of-irene-and-development-on-rivers/

Source: http://www.vtwaterquality.org/wqd_mgtplan/swms_appC.htm

Streambank stability evaluations

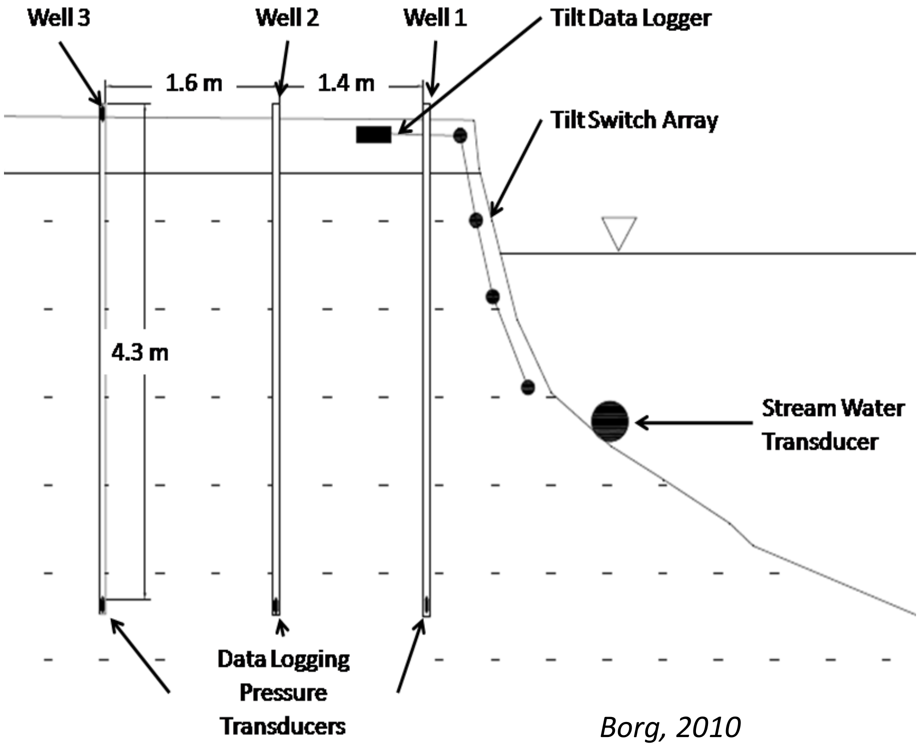


Borg, 2010



- Geotechnical parameters
  (Borehole Shear Test, Jet Test, Grain Size Analysis)
- Hydraulic parameters
  (groundwater and stream levels)
- Survey / Estimate Erosion volumes
  (monumented cross sections, RIEGL USA Model VZ-1000 terrestrial LiDAR scanner)
- Analysis / Modeling (BSTEM)

Streambank stability evaluations



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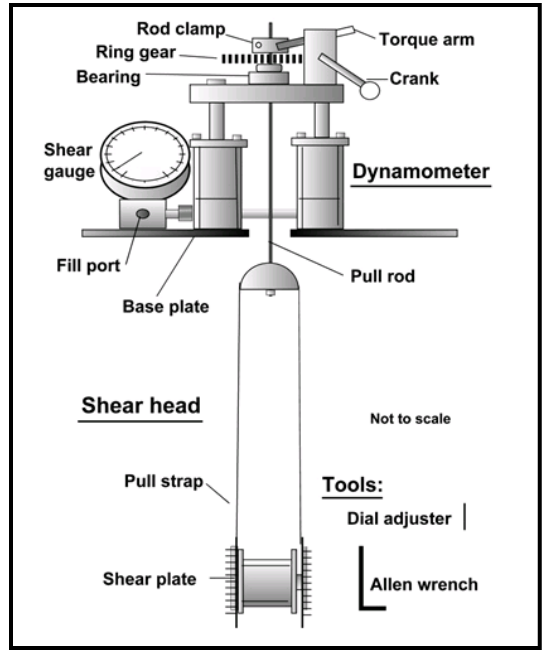

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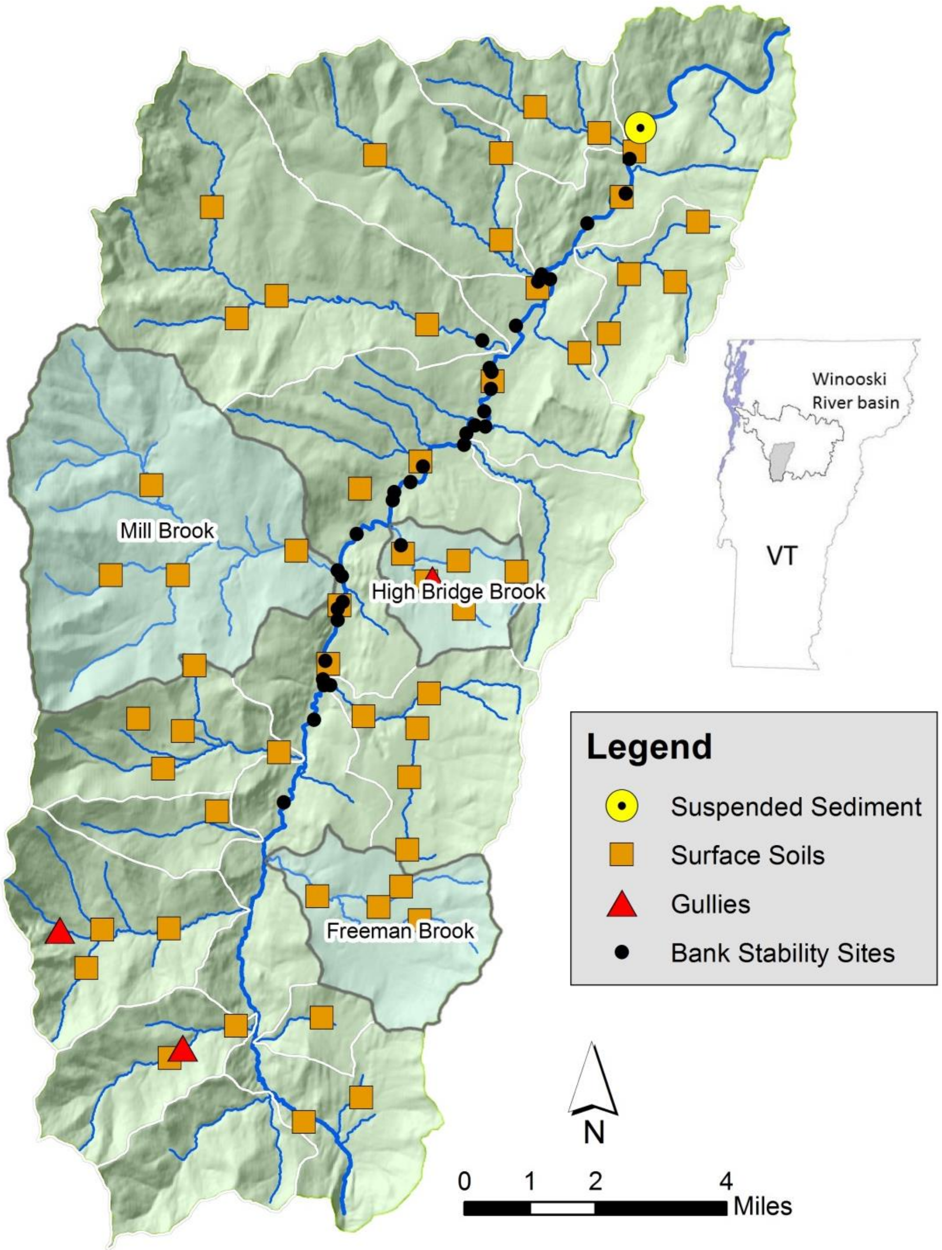
- Analysis / Modeling (BSTEM, DHSVM)



Sediment tracer study

- Discriminate between surface and subsurface sources of suspended sediments in Mad River.
- Validate models of fine particulate flux including process-based (e.g., DHSVM) and data-driven models (e.g., sediment rating curves, artificial neural networks).
- Tracer selection
  - Radionuclides (^{137}Cs, ^{210}Pb)
  - base cations (e.g., Ca, K, Mg, Na)
  - trace metals (e.g., Al, Fe, Mn)
- Site selection
  - Surface soils, stratified by land cover, geologic parent material
  - Eroding Streambanks/ Gullies
  - Suspended sediment
- Un-mixing model – multivariate and Bayesian statistics.

Field Work

RACC PhD (Underwood, Stryker)
NSF Fellowship PhD (Hamshaw)
EPSCoR interns (4+)
CEE Barrett Scholarship interns (2)

- Maintain rain gage, stream gage, turbidity sensor network – including Met station (8 sites)
- Establish stage/discharge rating curves (3 sites)
- Establish TSS / turbidity relationships
  (4 sites; both automated and grab samples, range of flows)
- Instrument streambank monitoring sites
  (10 sites – 2013; additional 10 sites – 2014)
- Sediment sampling for tracer study (80 to 100 sites)

Why are we interested in precipitation extremes?

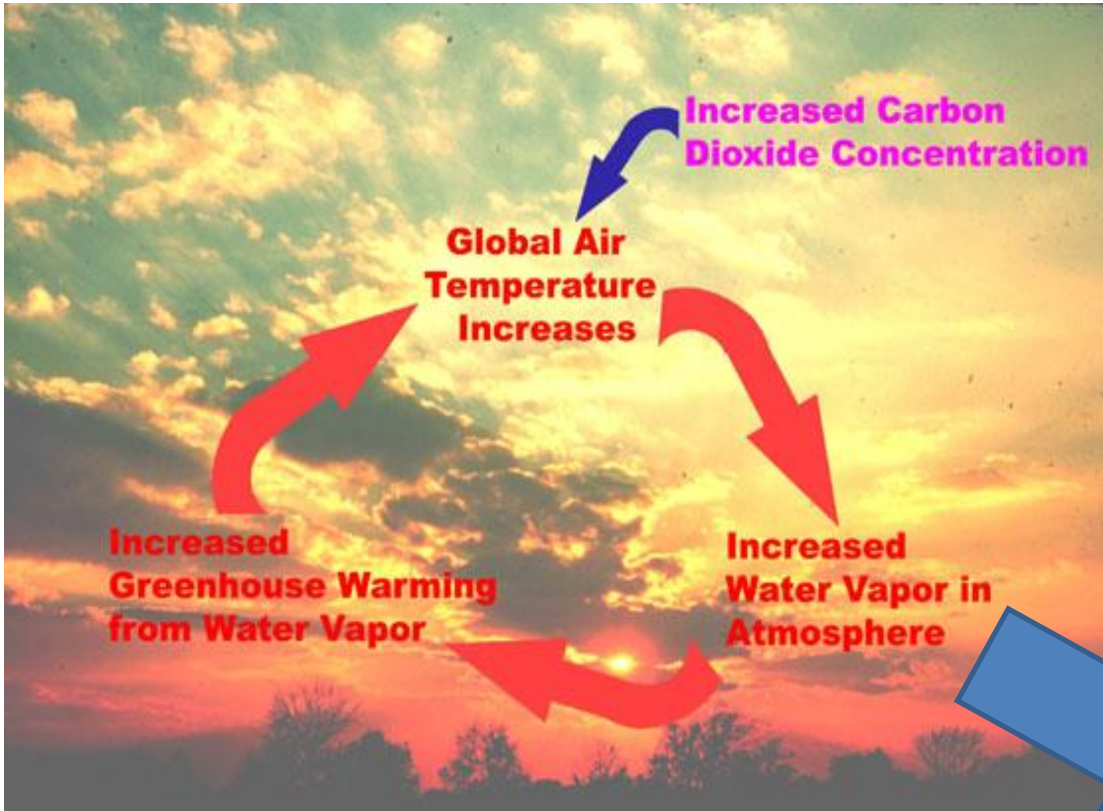
- Increased nutrient delivery to the lake primarily in the form of sediment bound phosphorus
  - Stream bank erosion
  - Overland flow


www.huffingtonpost.com


www.northcountrypublicradio.org

- Increased awareness of frequent extremes
- High infrastructural and environmental consequences

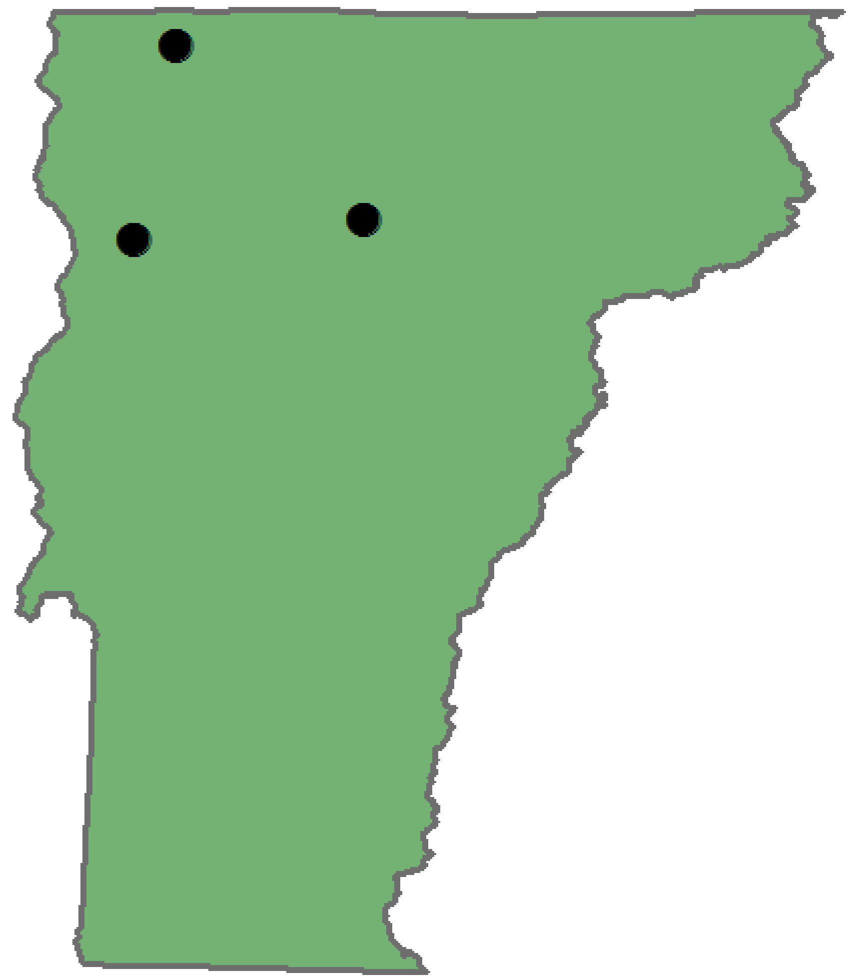
Expected Trends



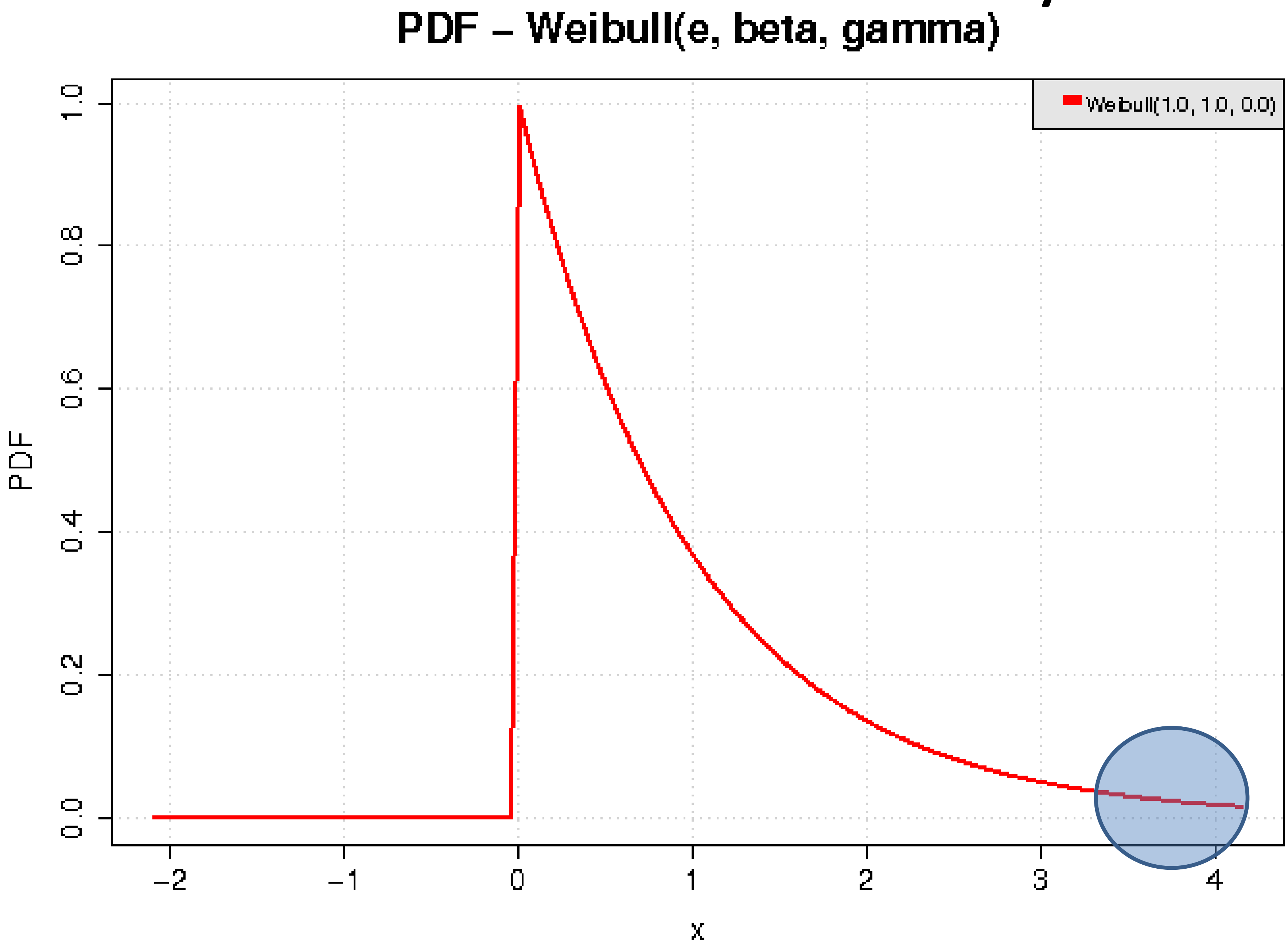
www.nasa.gov

Historical Station Data

- 3 Locations
  - Burlington
  - Morrisville
  - Highgate Falls
- Hourly Data
  - 1948 - 2011



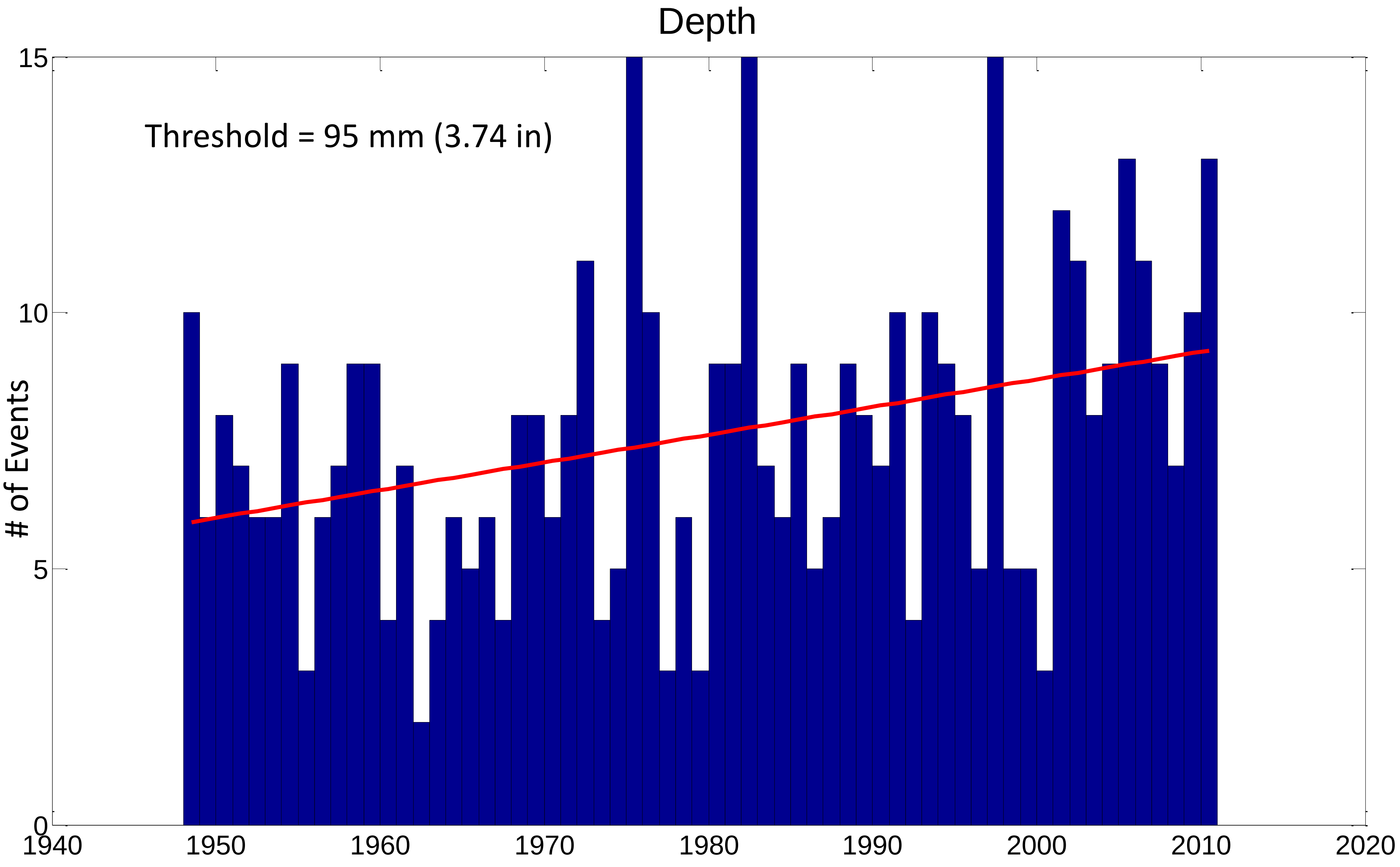
Extreme Value Theory



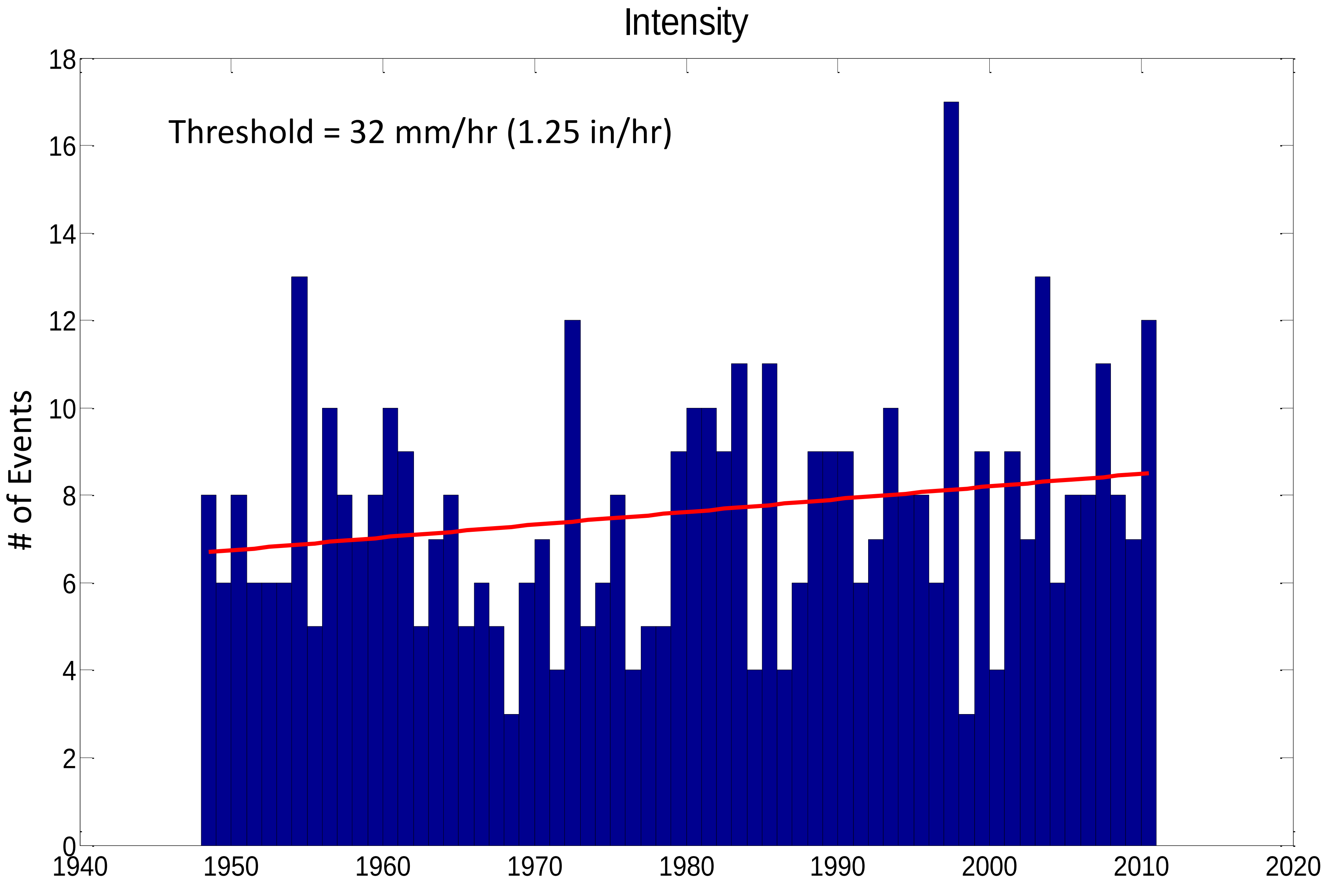
Increase in Extremes?

- Measure of “Extreme”
  - Total depth (millimeters)
  - Maximum intensity (millimeters per hour)

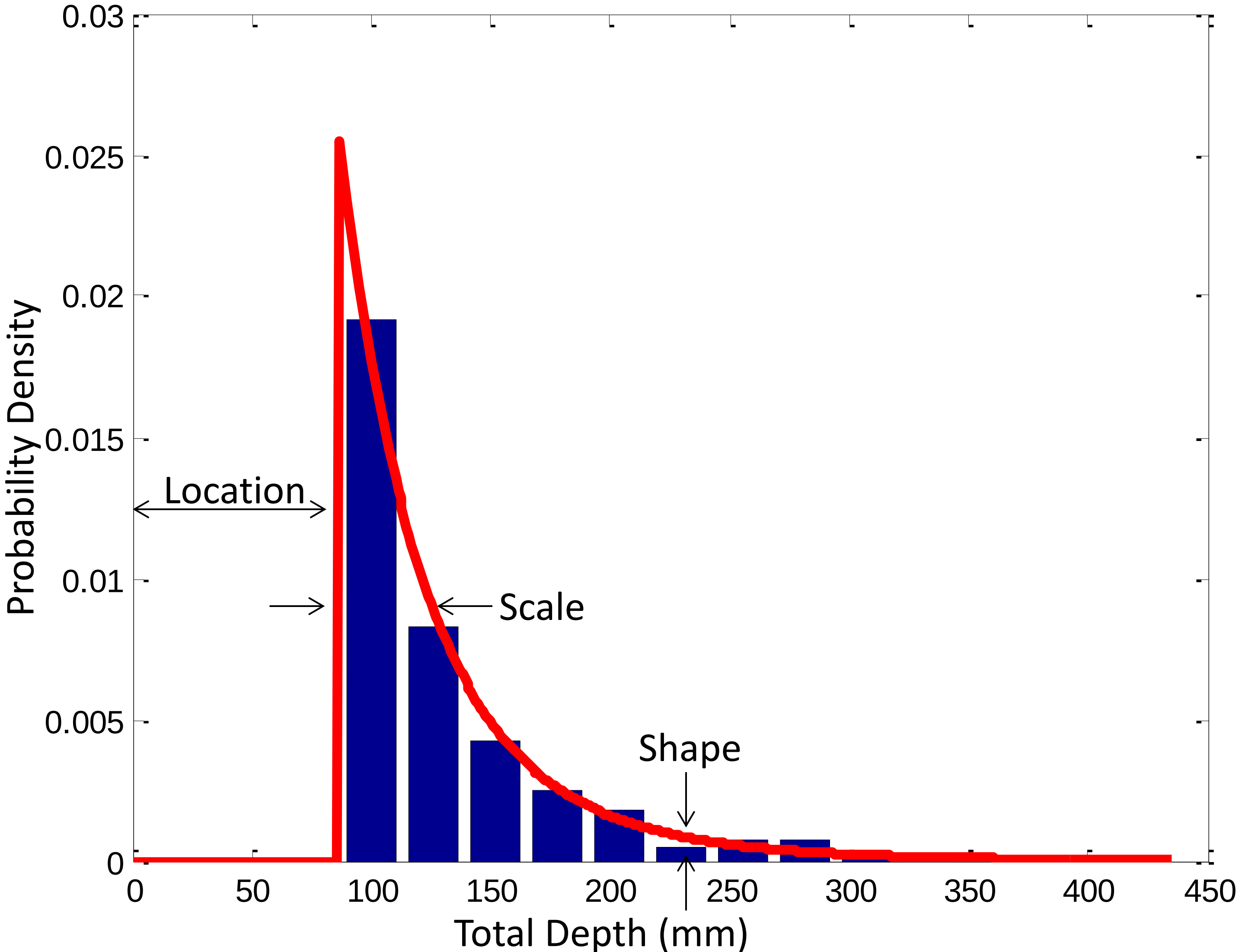
Increase in Extremes?



Increase in Extremes?

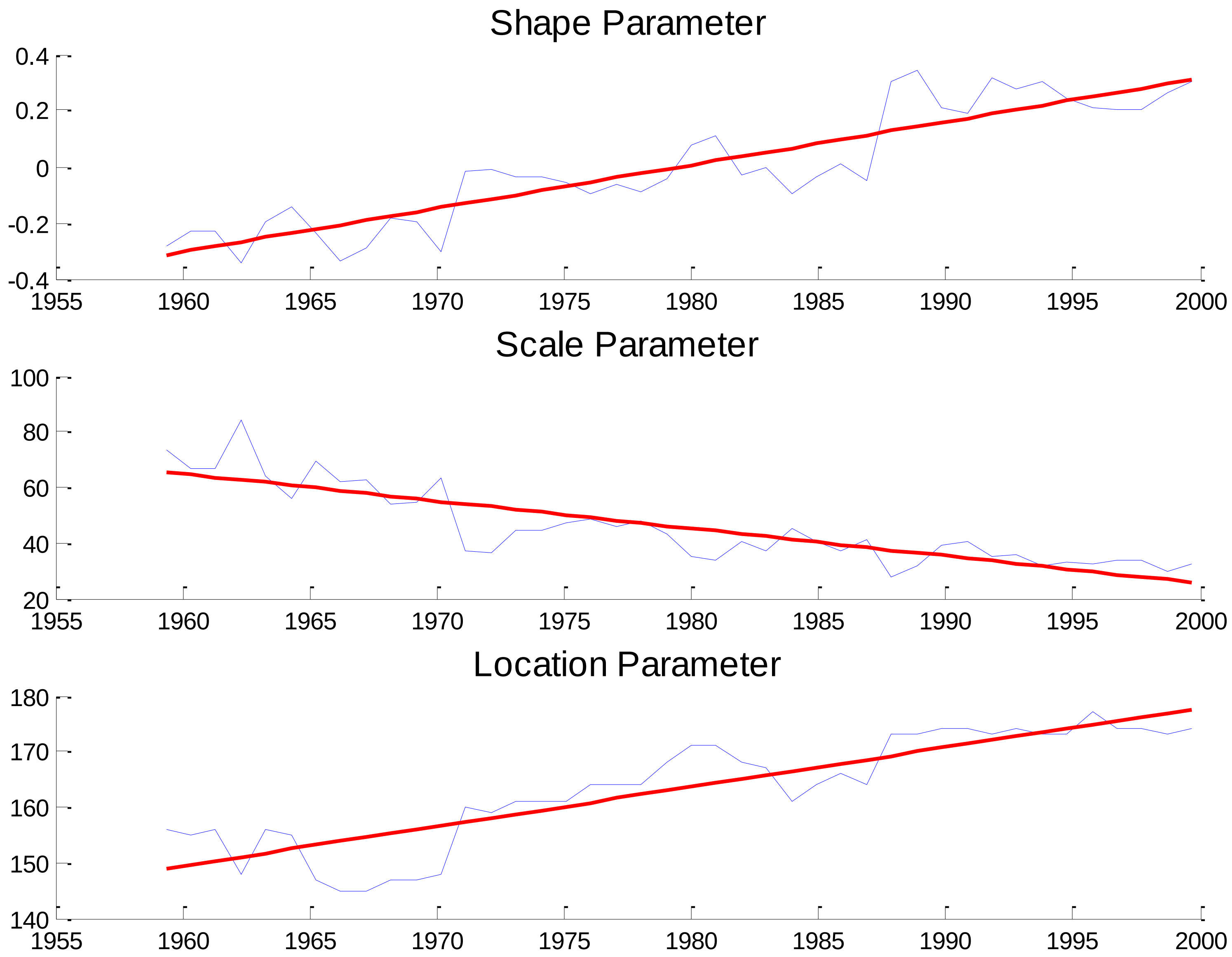


Data Fit to Pareto Distribution



Pareto Distribution Parameters

BTV, 21 yr window, extreme event definition = >99%



Future Work

- Expand to more weather stations to observe if trends are similar
- Extrapolate parameter trends to generate future distributions
- Investigate temporal changes of spatial patterns of rainfall
- Link to watershed model to assess flood risk