Changes in extreme precipitation in Vermont

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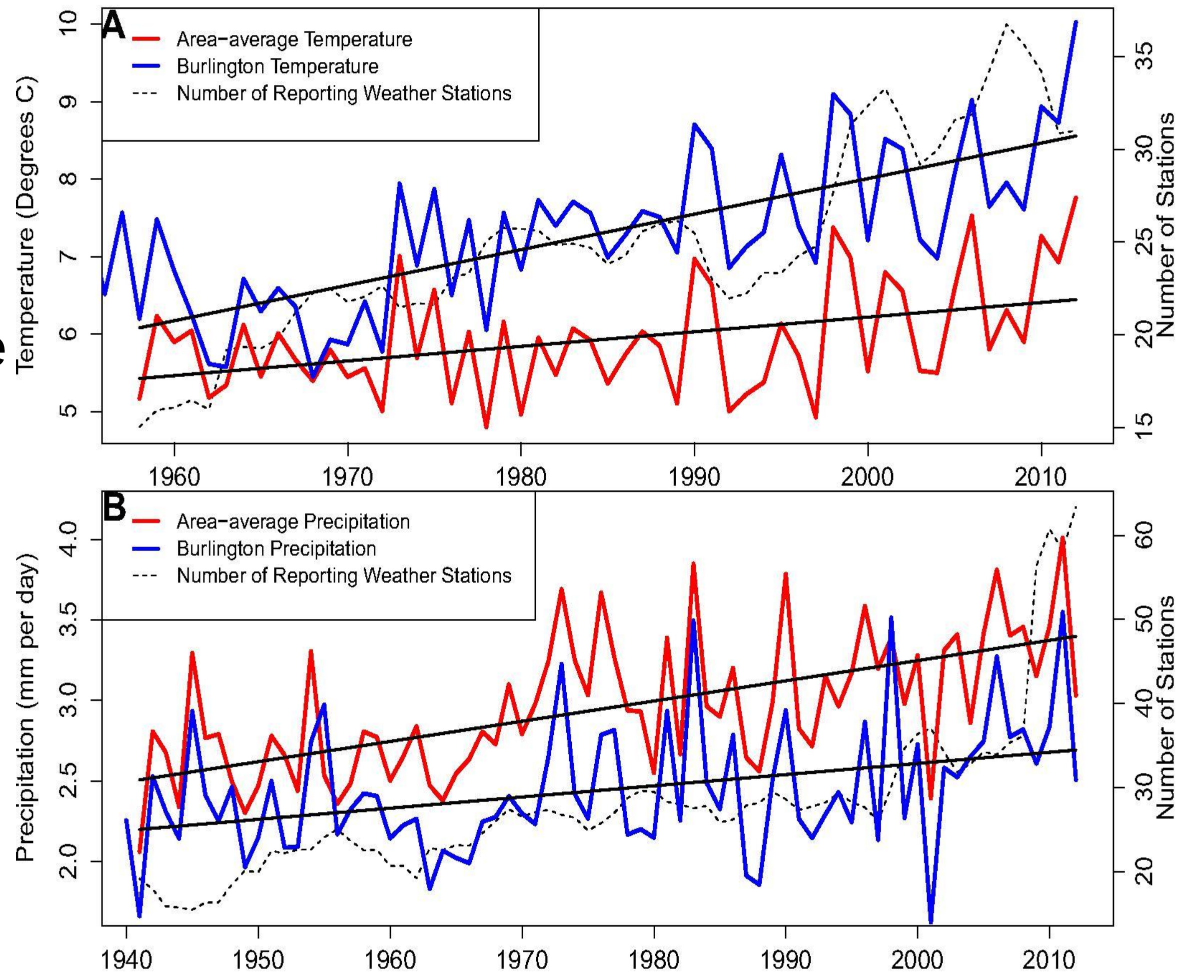
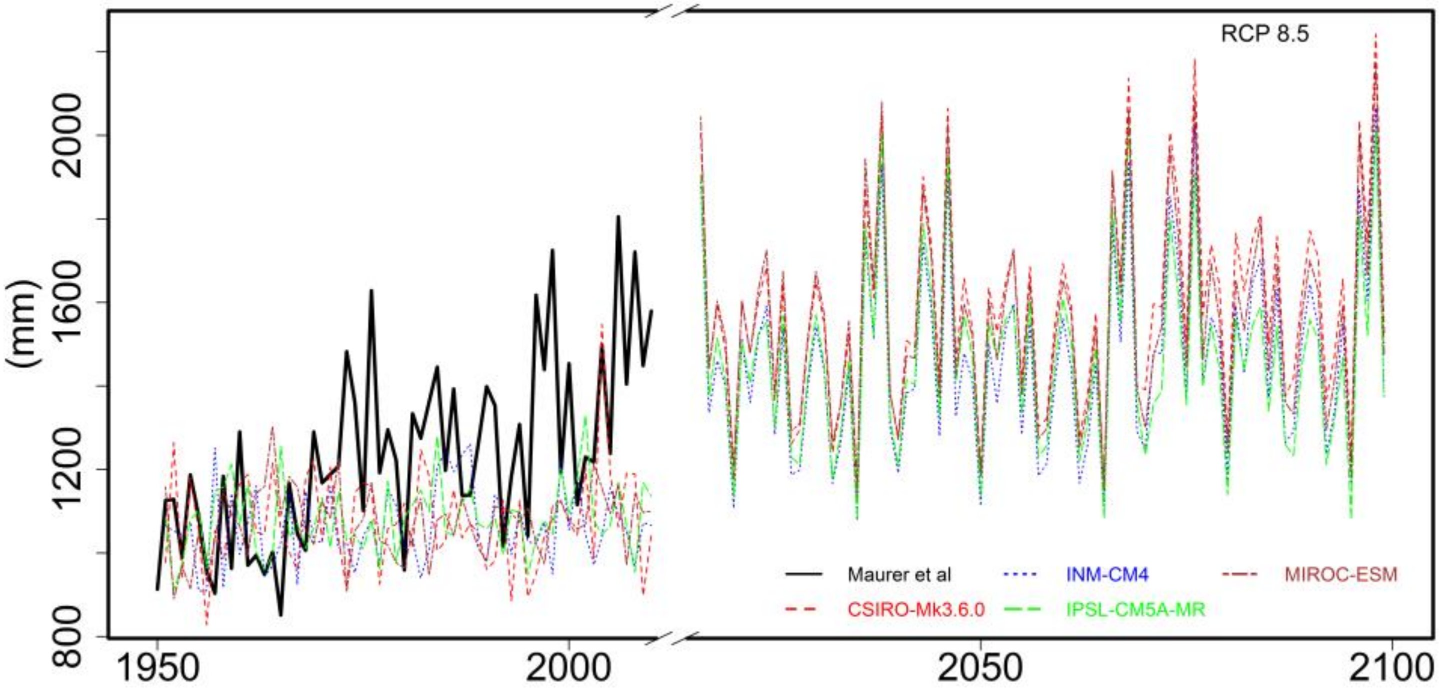
Historical Records

- Temperature:
  - +0.19 ^{o}C/decade
- Precipitation:
  - +0.12 mm/dy/decade



Limited GCM use for extremes analysis without additional steps: results from delta method for statistical downscaling



Use of extreme value statistics.

$$P_t \sim GP(\mu(t,a,b), \sigma(t,a,b), \xi)$$

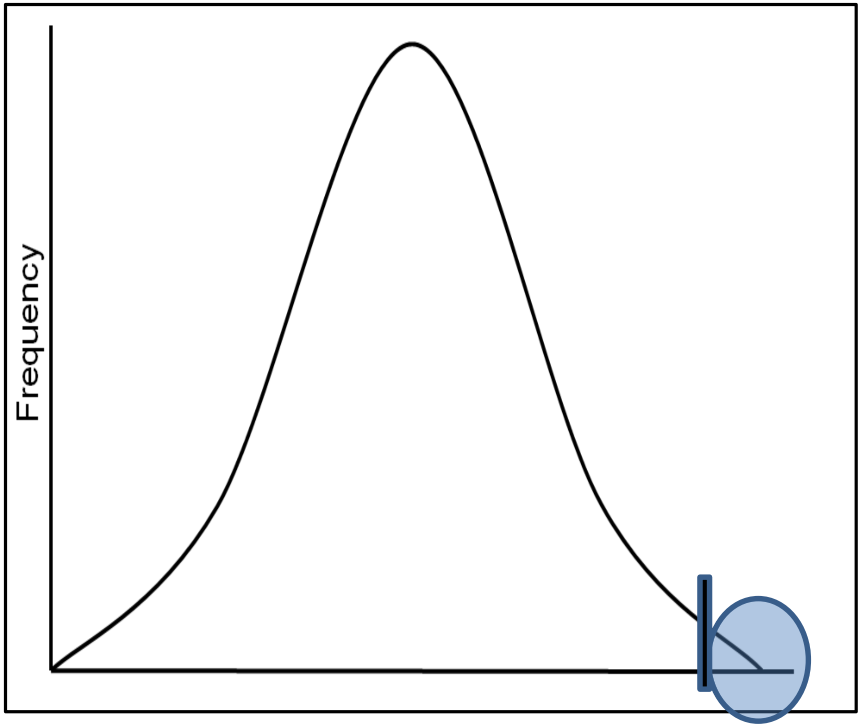
Shape parameter

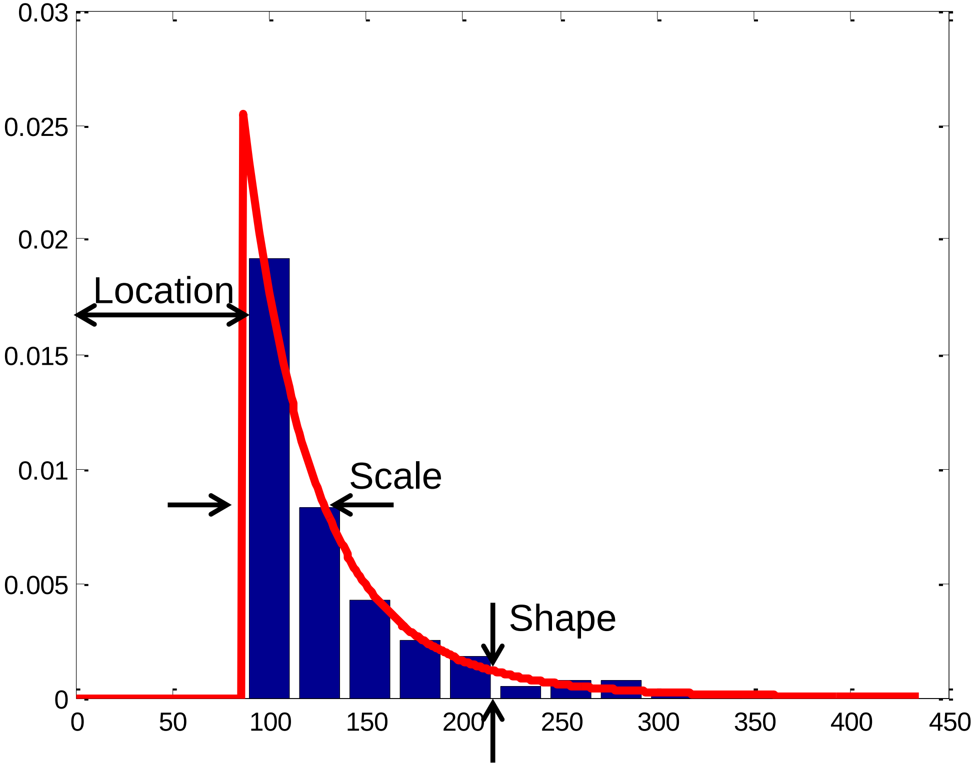
Peak over threshold precipitation

Location parameter
Covariates:
t: time (for trend)
a, b: climate indices
e.g. NAO, AO

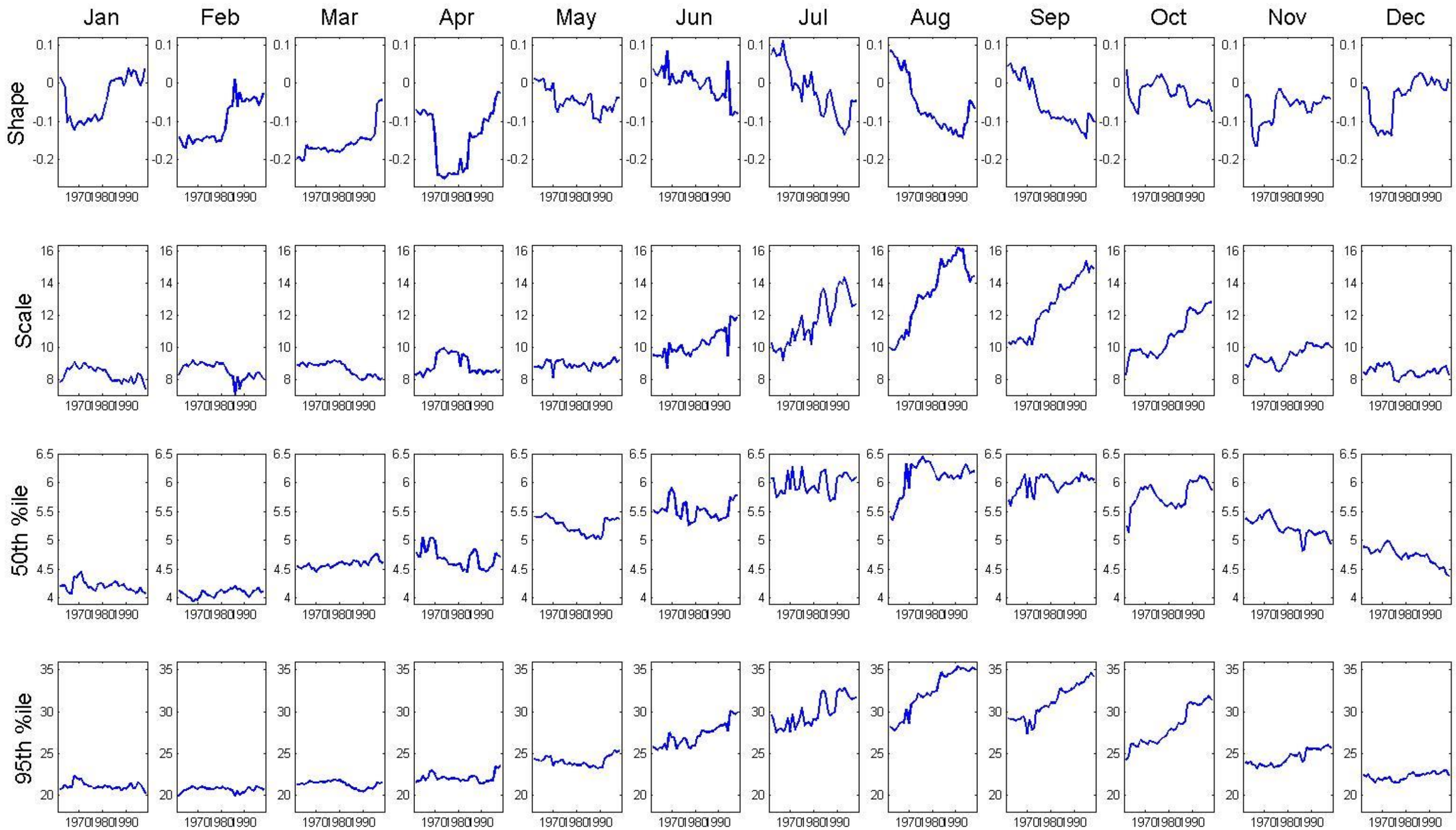
Scale parameter
Covariates:
t: time (for variability)
a, b: climate indices
e.g. NAO, AO

- Fitting the Pareto distribution to extreme values

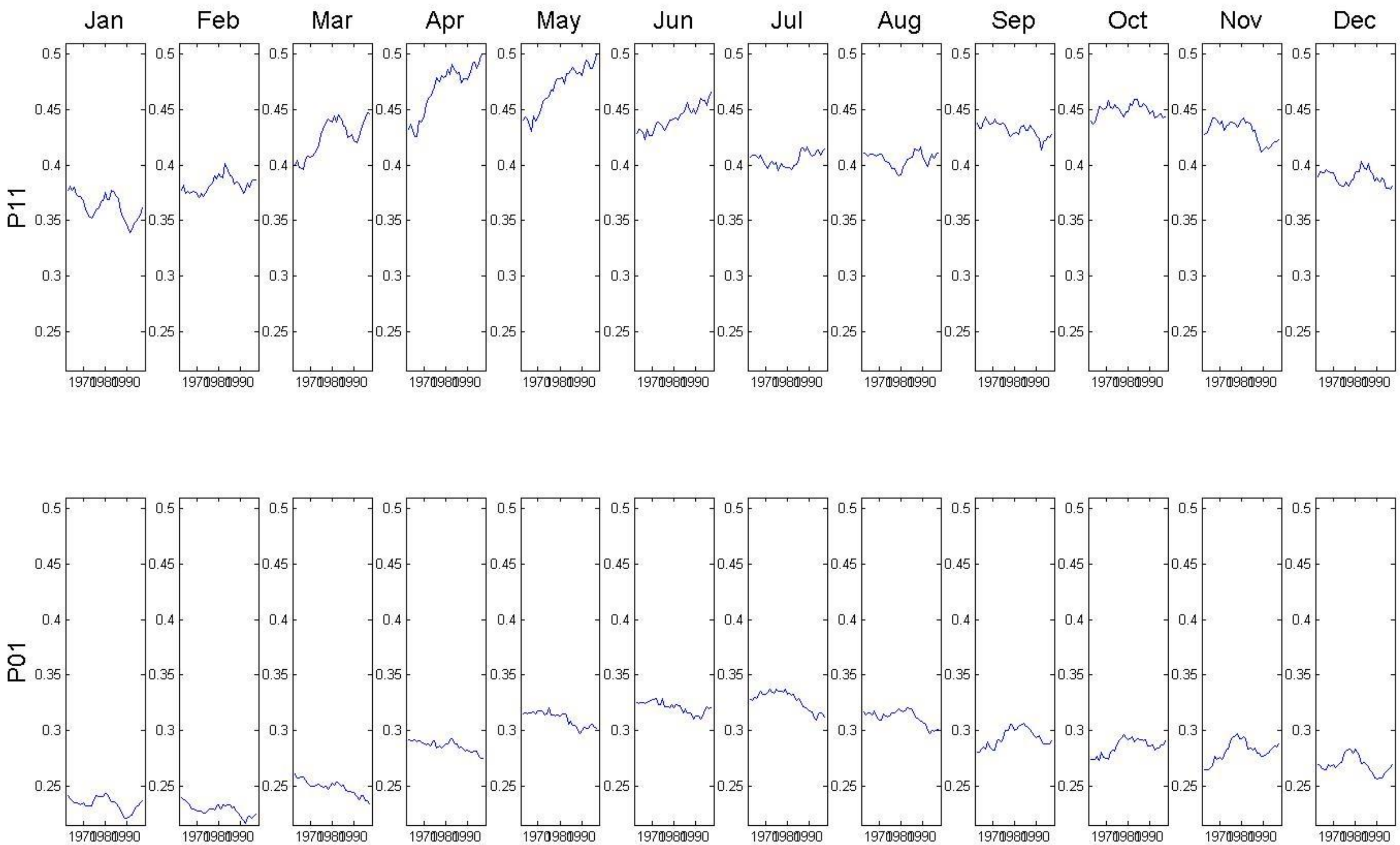




Seasonality of Generalized Pareto Distribution parameters, and percentiles: higher extreme daily precipitation in summer

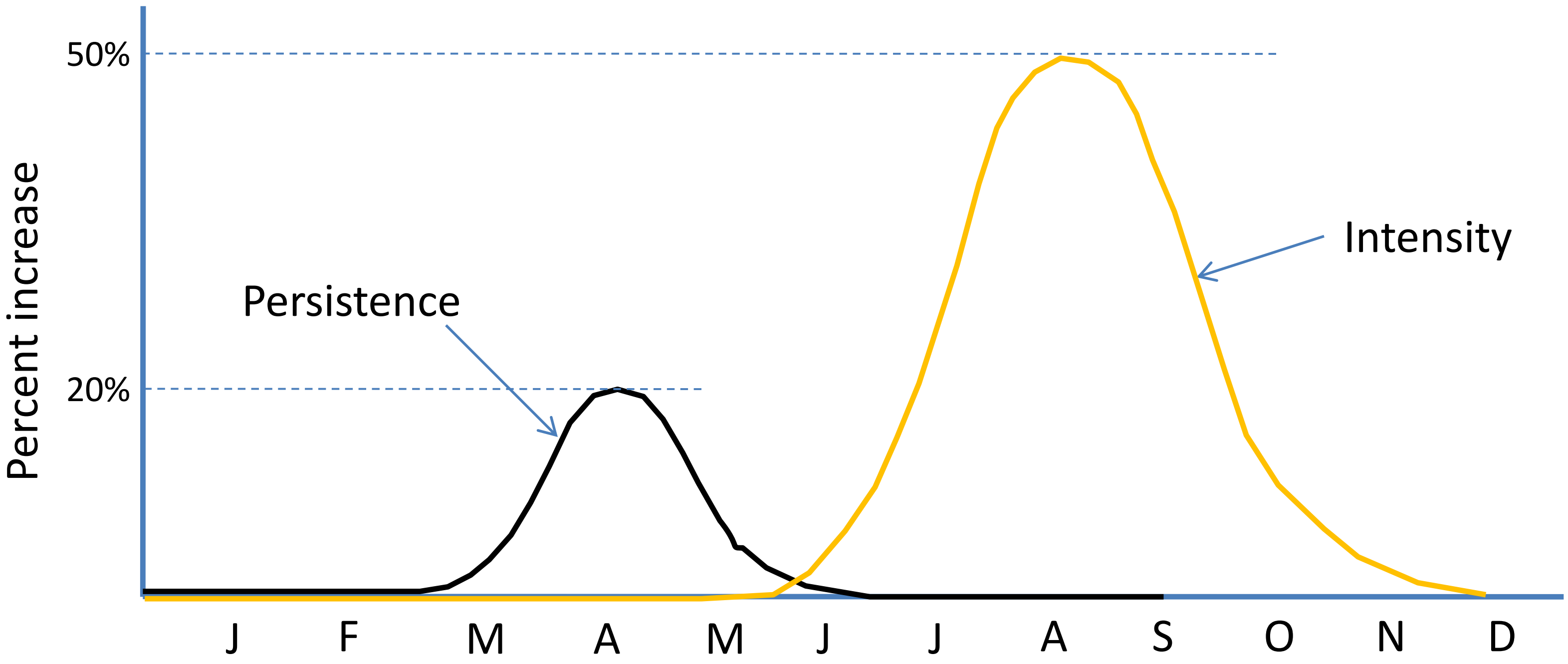


Seasonality of Markov chain parameters: increased persistence in spring?

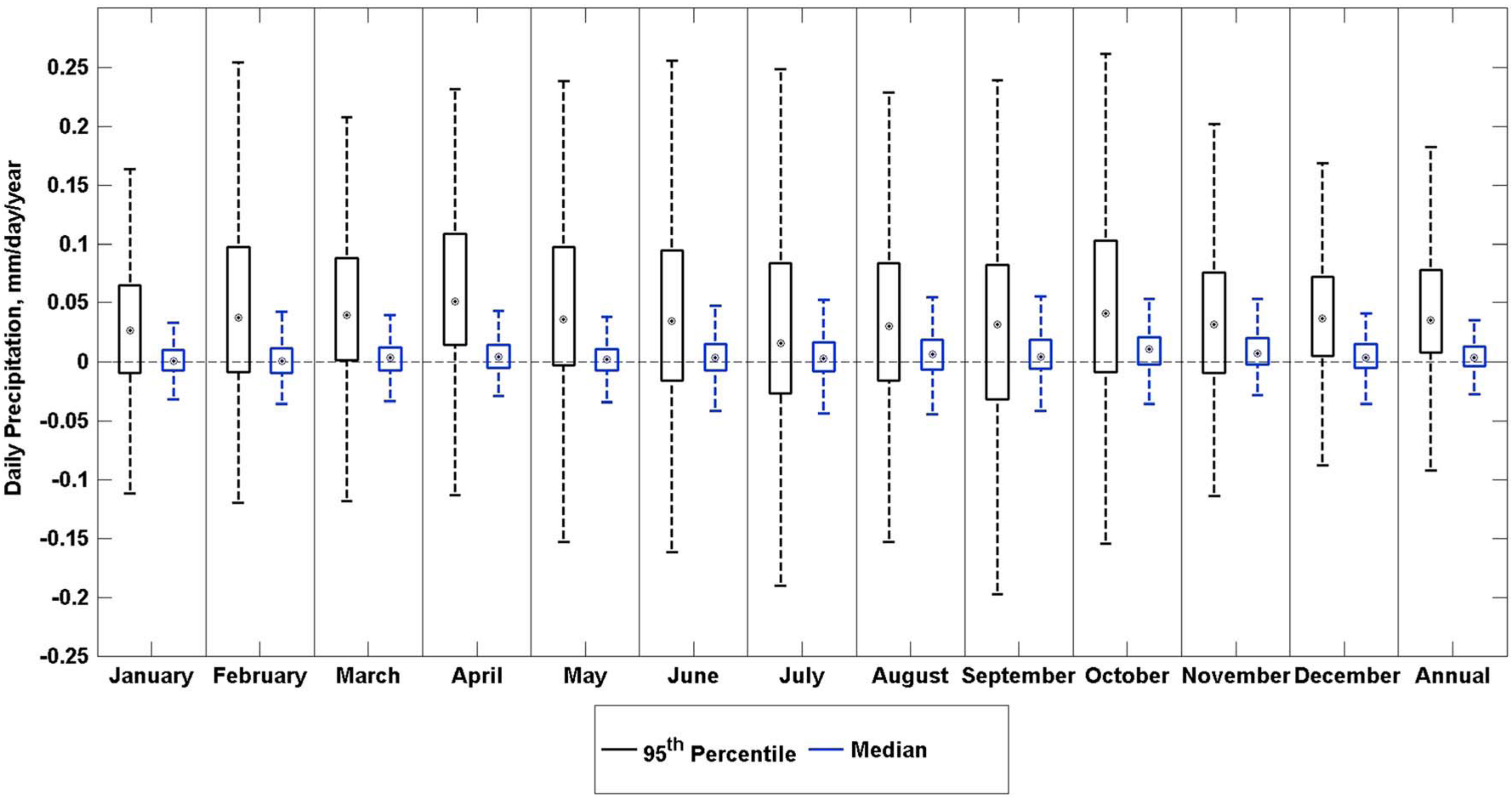


Spring precipitation is becoming more persistent, and summer precipitation is becoming more intense

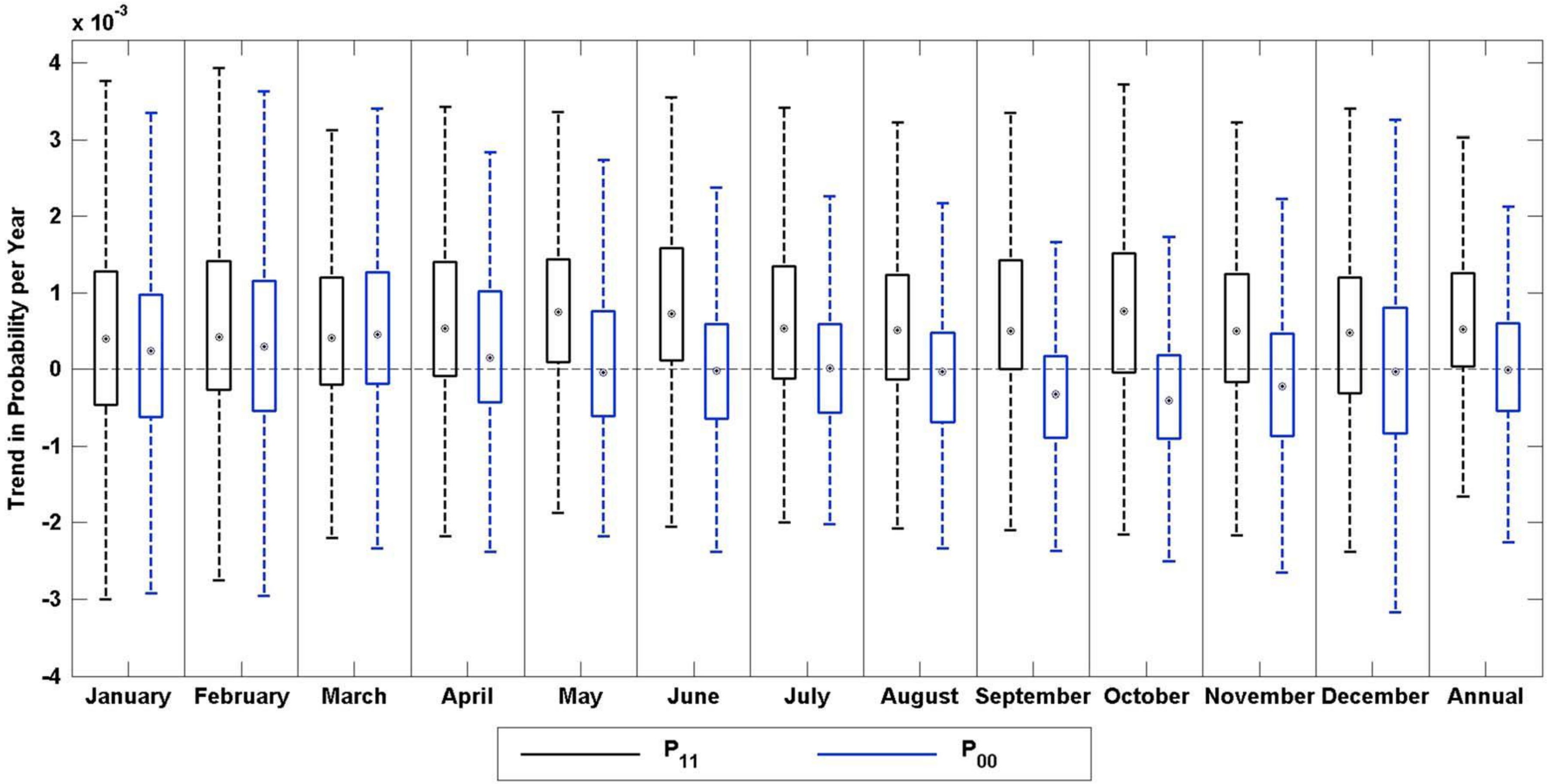
Percentage increases since 1948 at Burlington Airport



Precipitation trends over all Northeast meteorological stations (USHCN)



Trends in Markov Chain parameters show increased precipitation persistence in Northeastern US



AGU PUBLICATIONS

Geophysical Research Letters

RESEARCH LETTER

10.1002/2015GL063124

Key Points:

- Precipitation in the northeastern United States is becoming more persistent
- Precipitation in the northeastern United States is becoming more intense
- Observed trends constitute an important hydrological impact of climate change

Supporting Information:

- Figure S1
- Table S1

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Characterization of increased persistence and intensity of precipitation in the northeastern United States

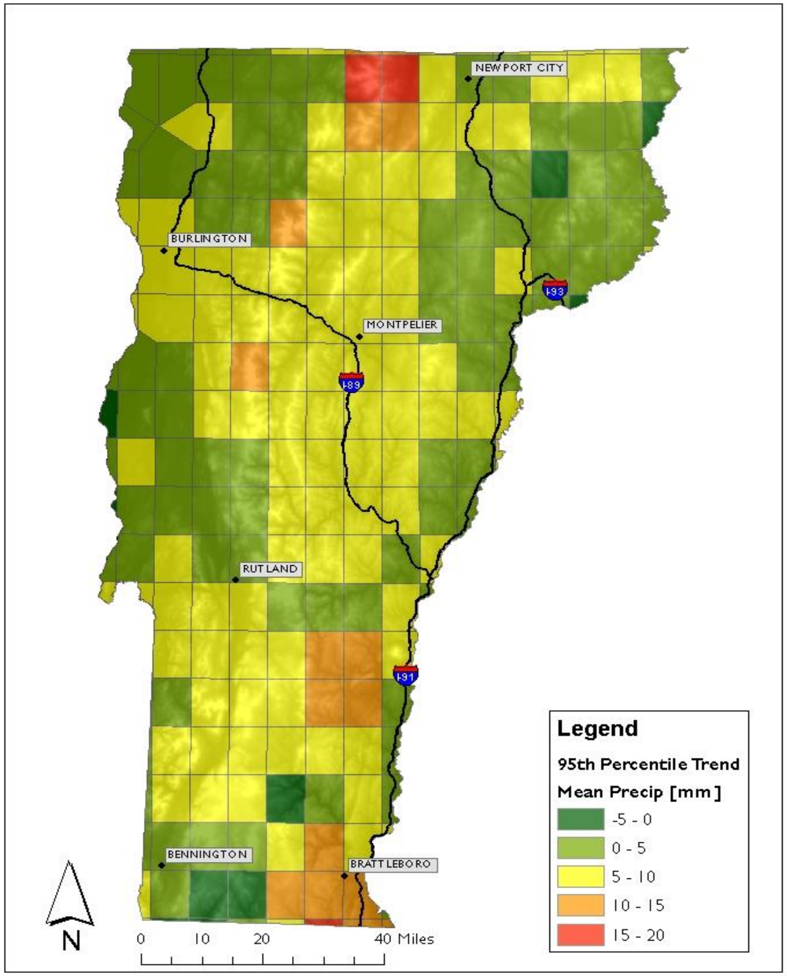
Justin Guilbert[1], Alan K. Betts[2], Donna M. Rizzo[1], Brian Beckage[4], and Arne Bomblies[1]

[1]School of Engineering, University of Vermont, Burlington, Vermont, USA, [2]Atmospheric Research, Pittsford, Vermont, USA, [3]Department of Plant Biology, University of Vermont, Burlington, Vermont, USA

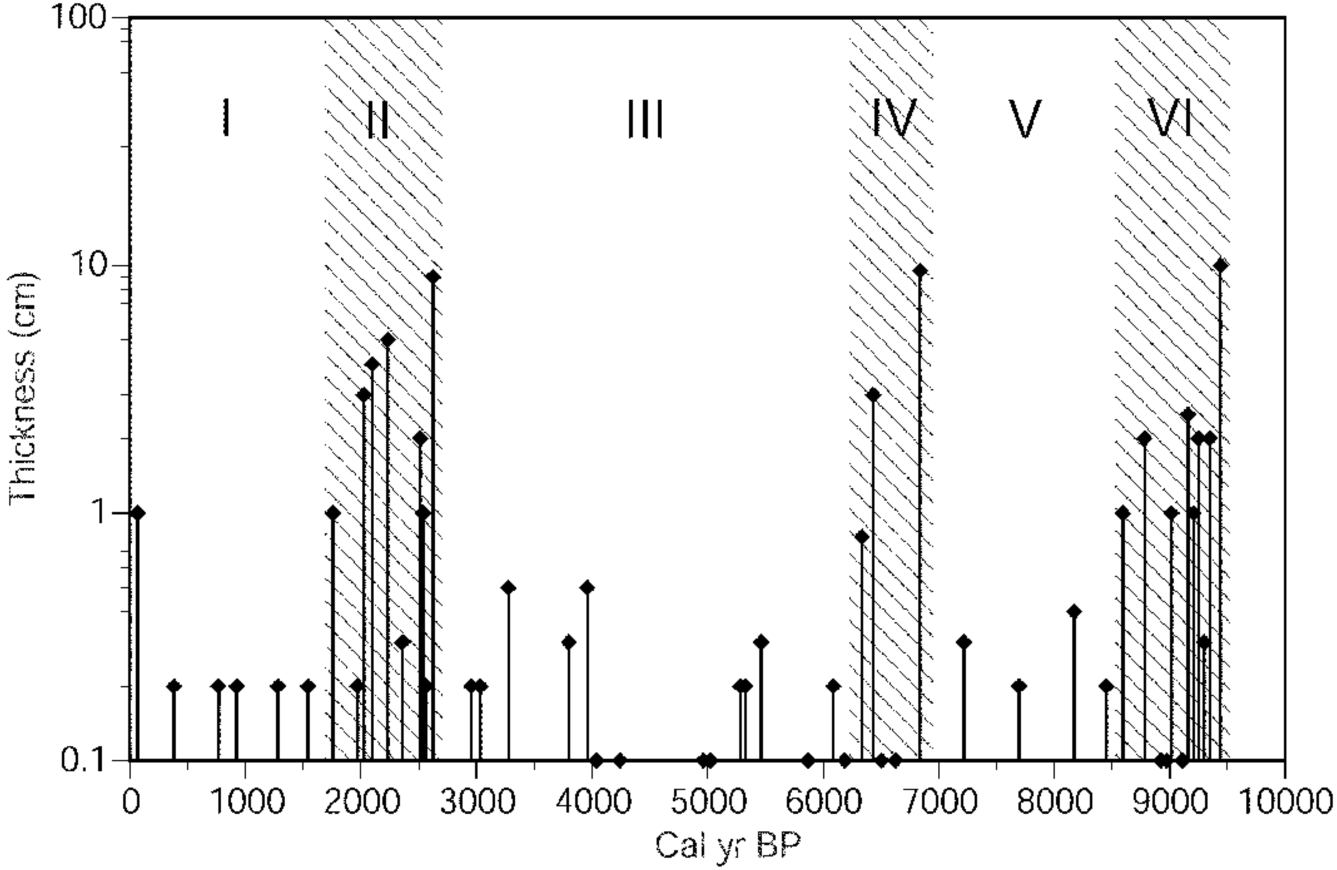
Abstract We present evidence of increasing persistence in daily precipitation in the northeastern United States that suggests that global circulation changes are affecting regional precipitation patterns. Meteorological data from 222 stations in 10 northeastern states are analyzed using Markov chain parameter estimates to demonstrate that a significant mode of precipitation variability is the persistence of precipitation events. We find that the largest region-wide trend in wet persistence (i.e., the probability of precipitation in 1 day and given precipitation in the preceding day) occurs in June (+0.9% probability per decade over all stations). We also find that the study region is experiencing an increase in the magnitude of high-intensity precipitation events. The largest increases in the 95th percentile of daily precipitation occurred in April with a trend of +0.7 mm/d/decade. We discuss the implications of the observed precipitation signals for watershed hydrology and flood risk.

Spatial View

95th Percentile Precipitation Trend



A paleoclimate perspective: lake sediment cores from Ritterbush Pond, Vermont. No clear connection of extremes with Little Ice Age, Medieval Warm Period, or 8200 cal BP drying event from Greenland cores.

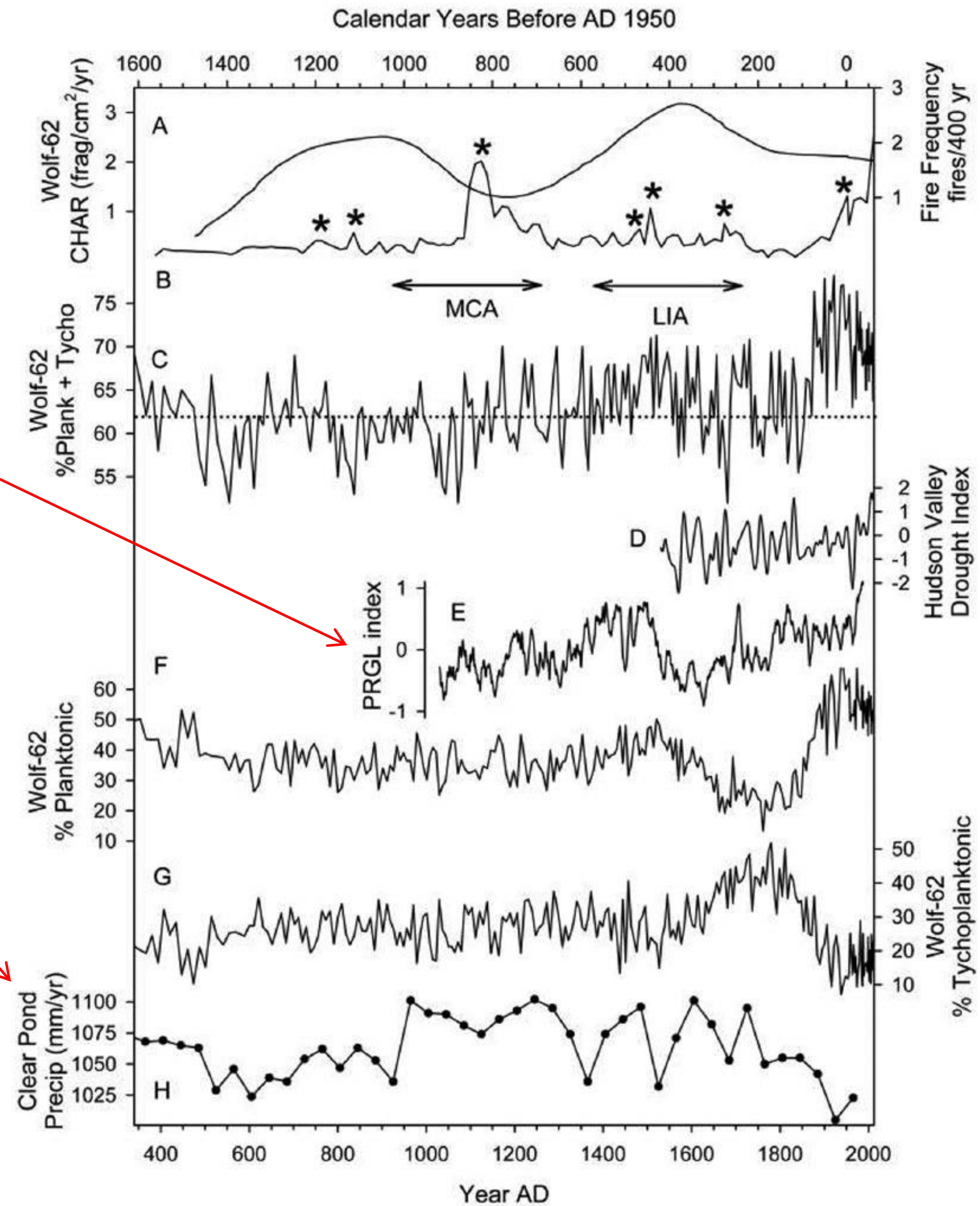


From: Brown S, Bierman P, Lini A, Davis PT, and Southon J (2002) Reconstructing lake and drainage basin history using terrestrial sediment layers: analysis of cores from a post-glacial lake in New England, USA. *Journal of Paleolimnology* **28**:219-236.

And from the Adirondacks, a more recent study

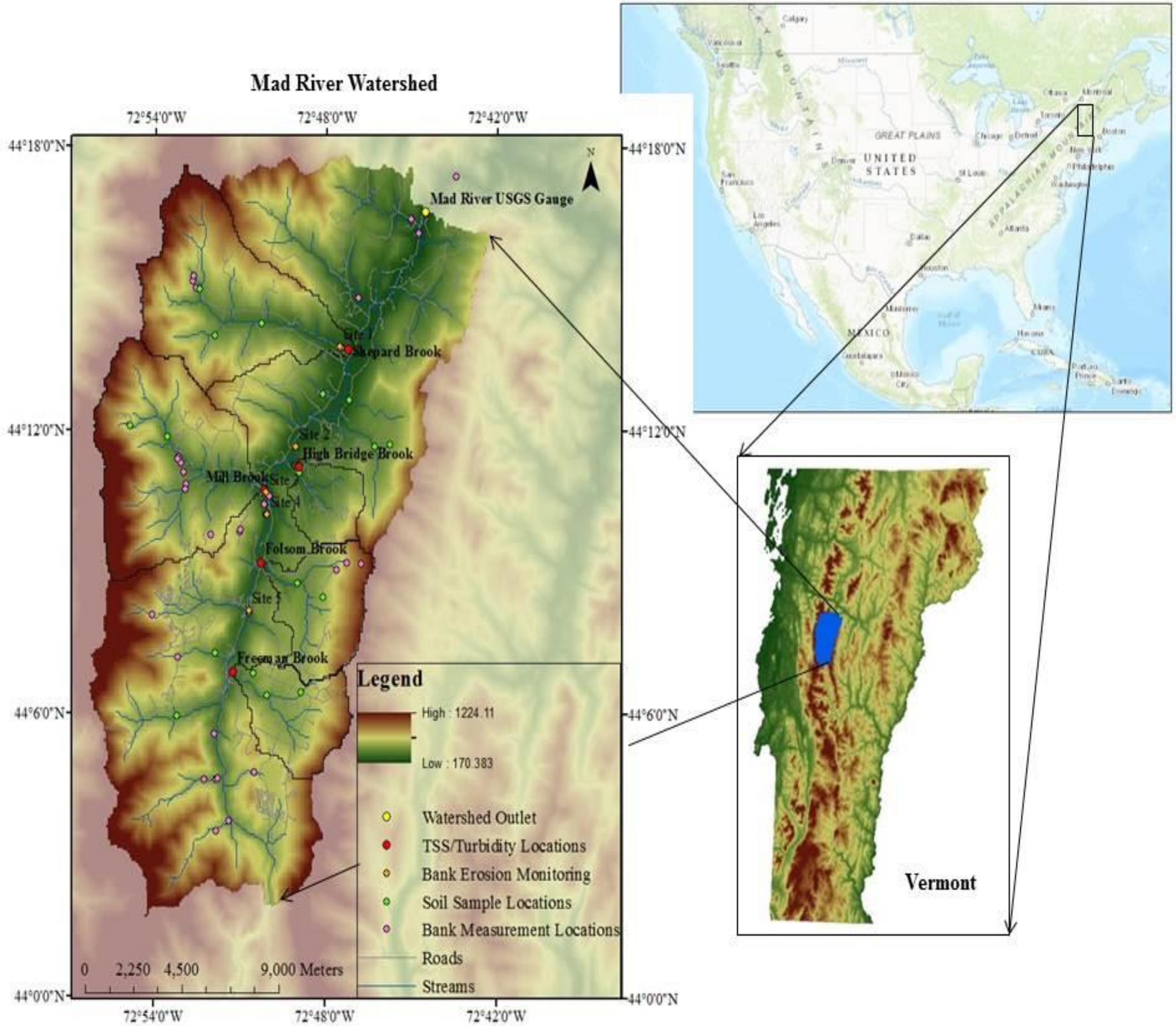
Regional rainfall index

Deduced annual precipitation

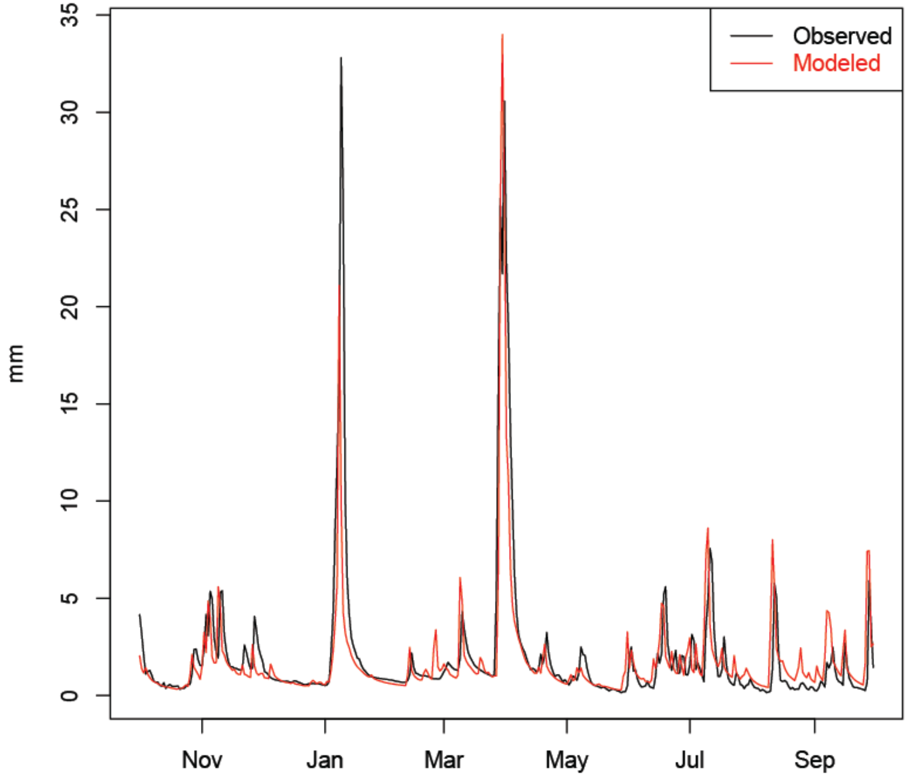


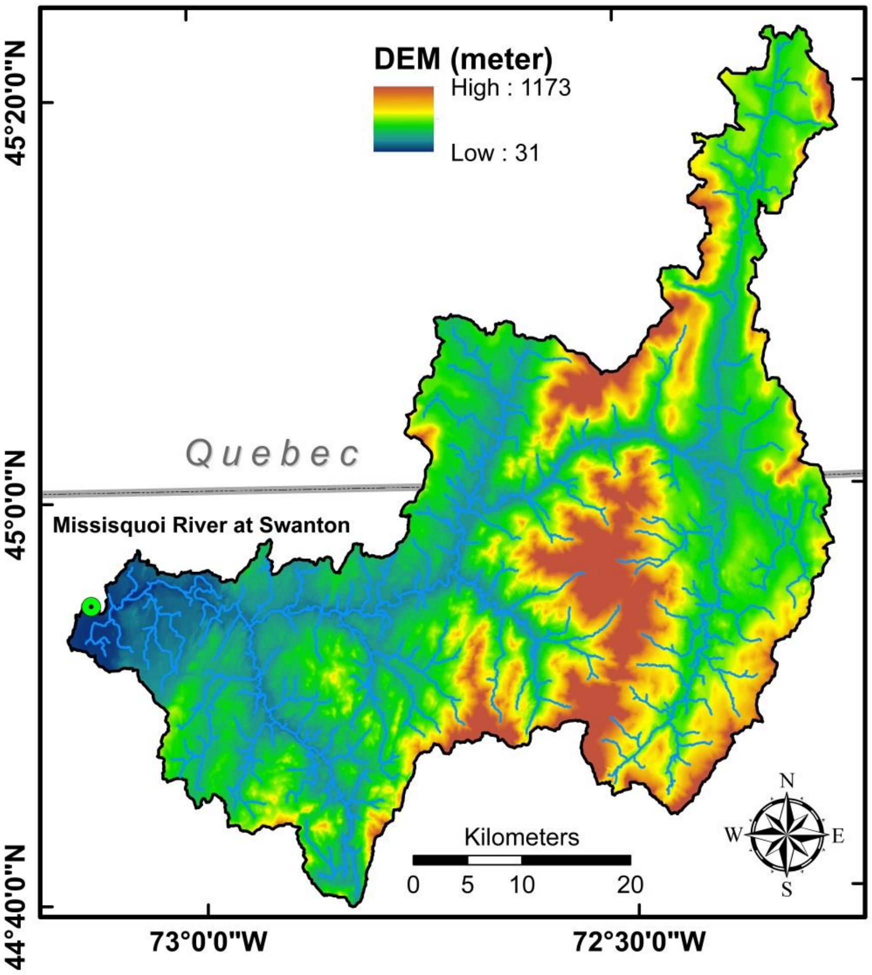
From: Stager JC, Cumming BF, Laird KR, Garrigan-Piela A, Pedersen N, Wiltse B, Lane CS, Nester J, and Ruzmaikin A (2016) A 1600-year diatom record from Wolf Lake, New York. *The Holocene*

Site: Mad River Watershed, Vermont

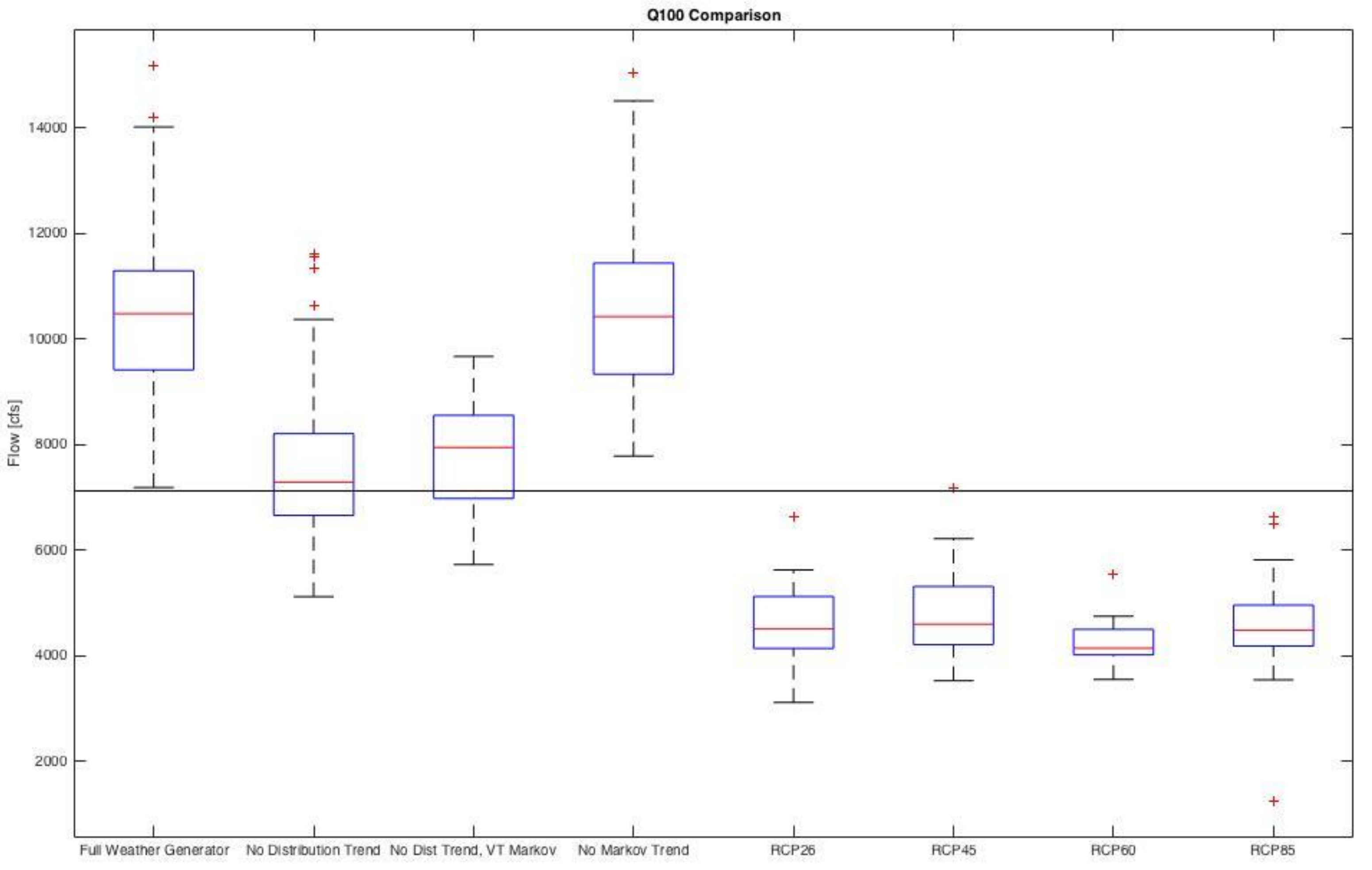


1997-1998 Water Year Observed and Simulated Runoff

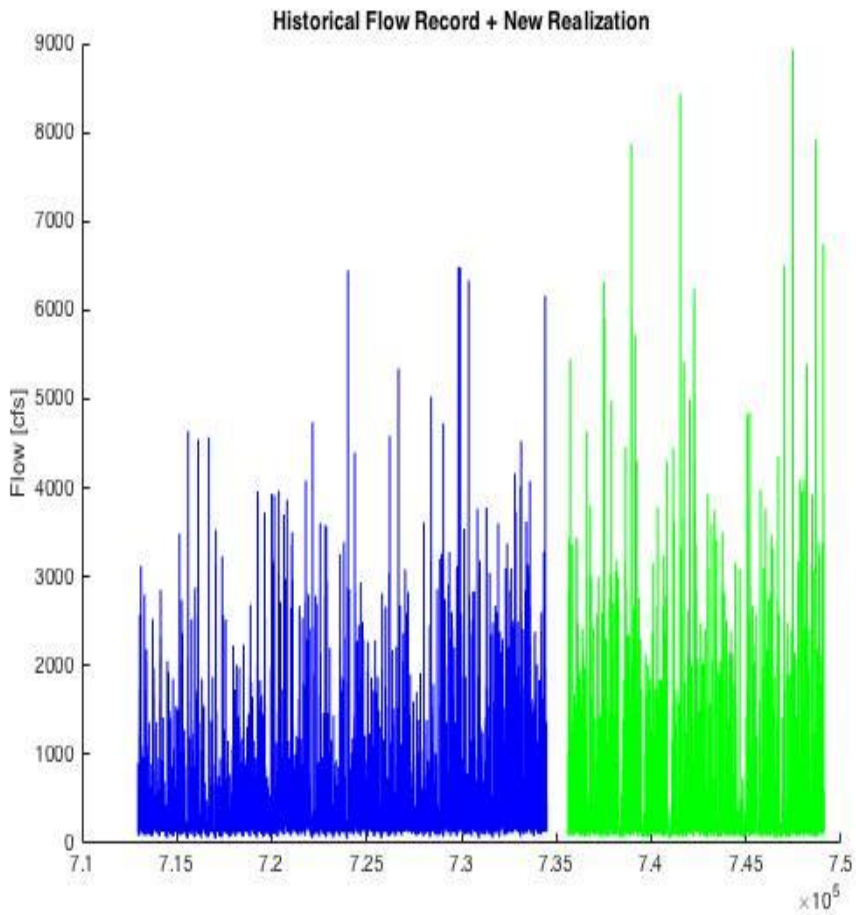




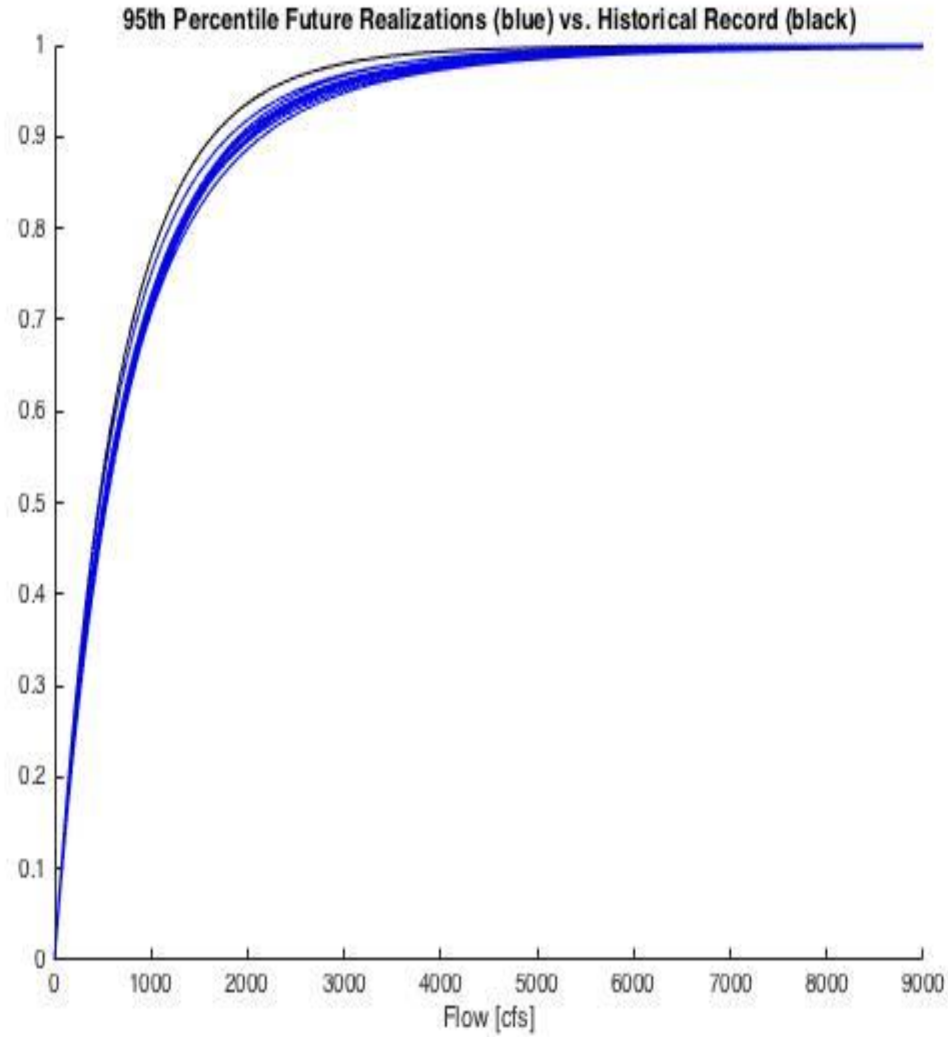
Results from weather generator applied to Mad River, central Vermont.
100-year flows at Moretown gauge for year 2050:



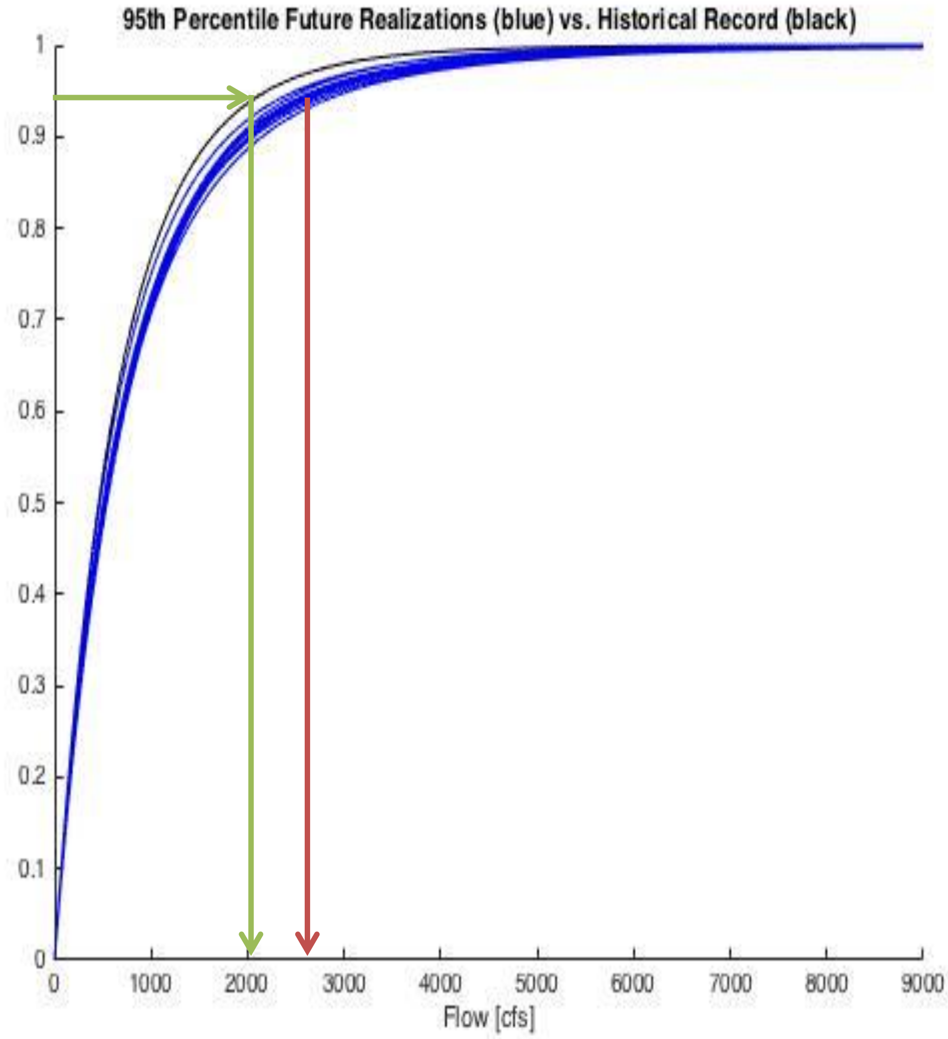
Future Streamflows



Flow Distributions



Change Factor



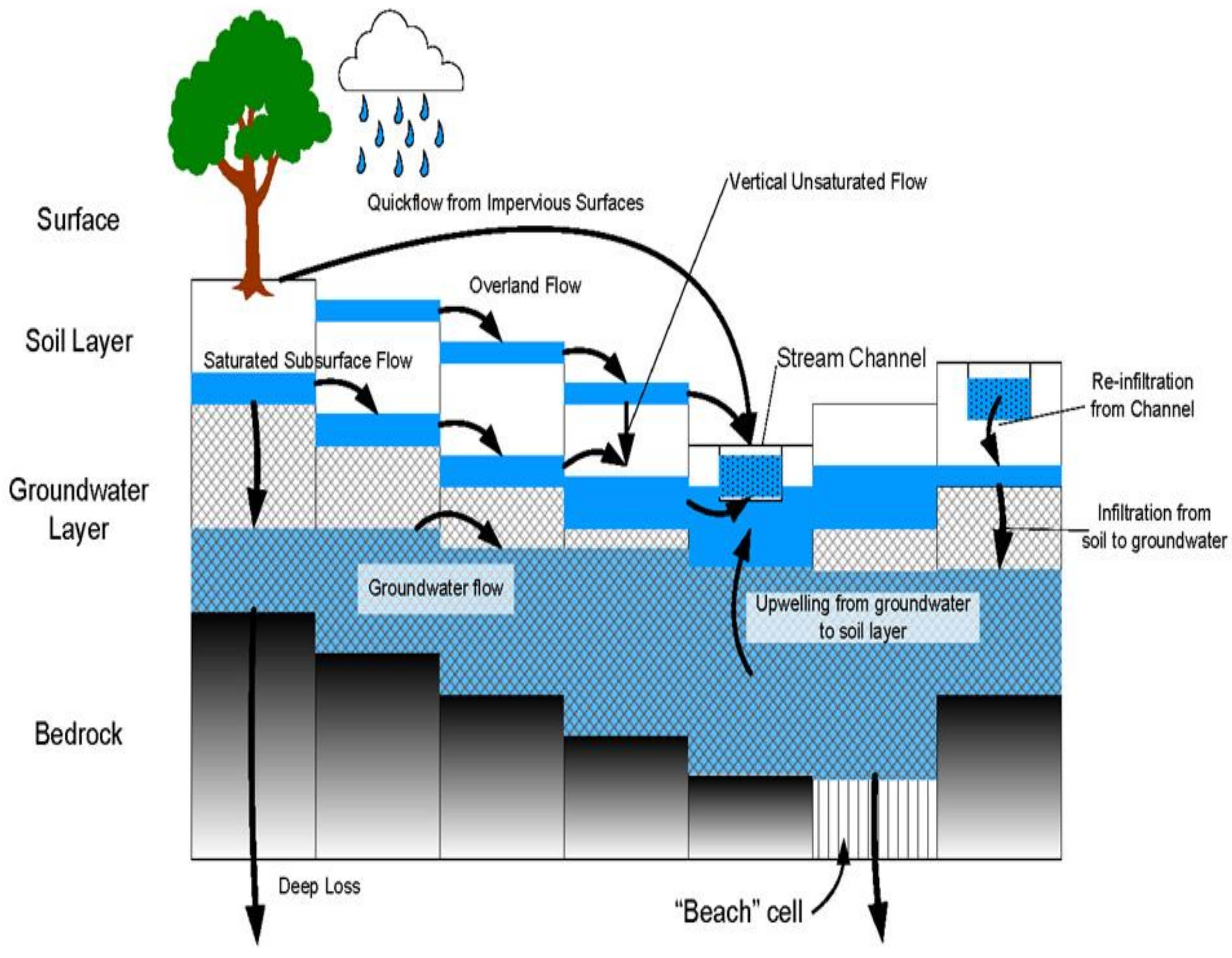
Sediment is one of primary ways nutrients are transported to receiving waters

Large amounts of sediment mobilized by

- Overland erosion
- Road erosion
- **Streambank erosion/failure**

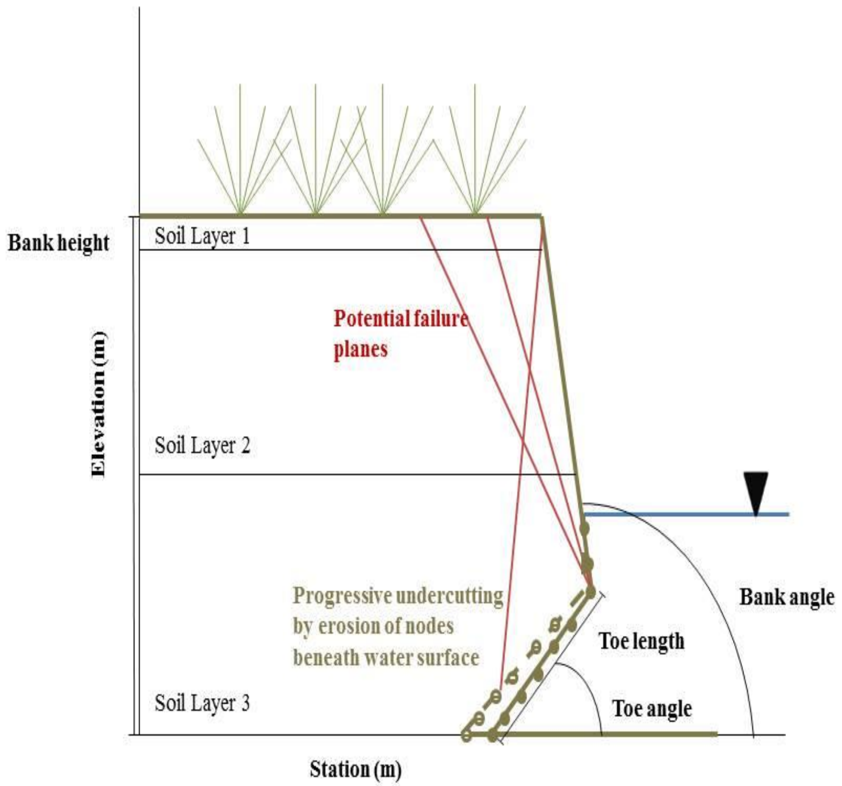
(2012) State of the Lake Report, Lake Champlain Basin Program.

Distributed Hydrology Soil Vegetation Model (DHSVM)



BSTEM: Geotechnical Analysis

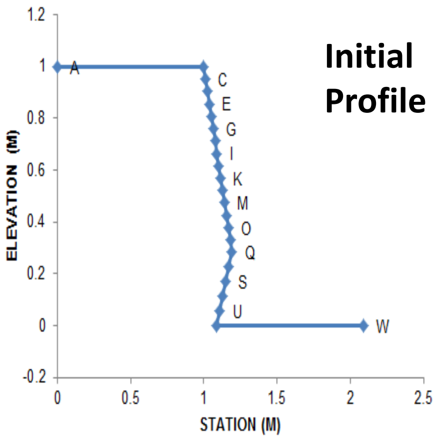
$$\text{Factor of Safety } (F_s) = \frac{\textit{Resisting Forces}}{\textit{Driving Forces}}$$

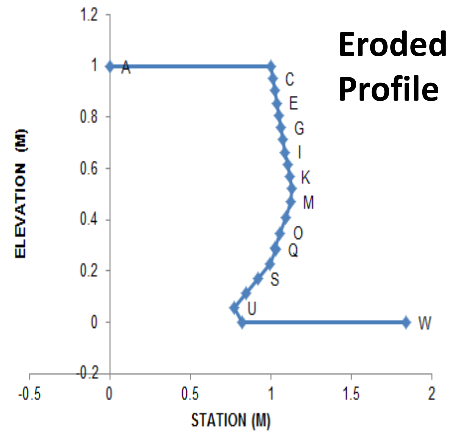


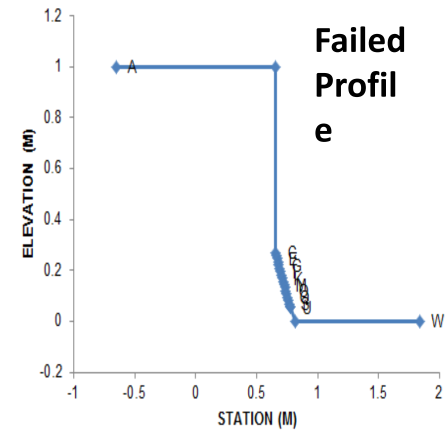
Resisting Forces
Soil strength
Vegetation
Reinforcement
Matric suction

Driving Forces
Bank angle
Weight of bank
Water in bank

BSTEM: Toe Erosion





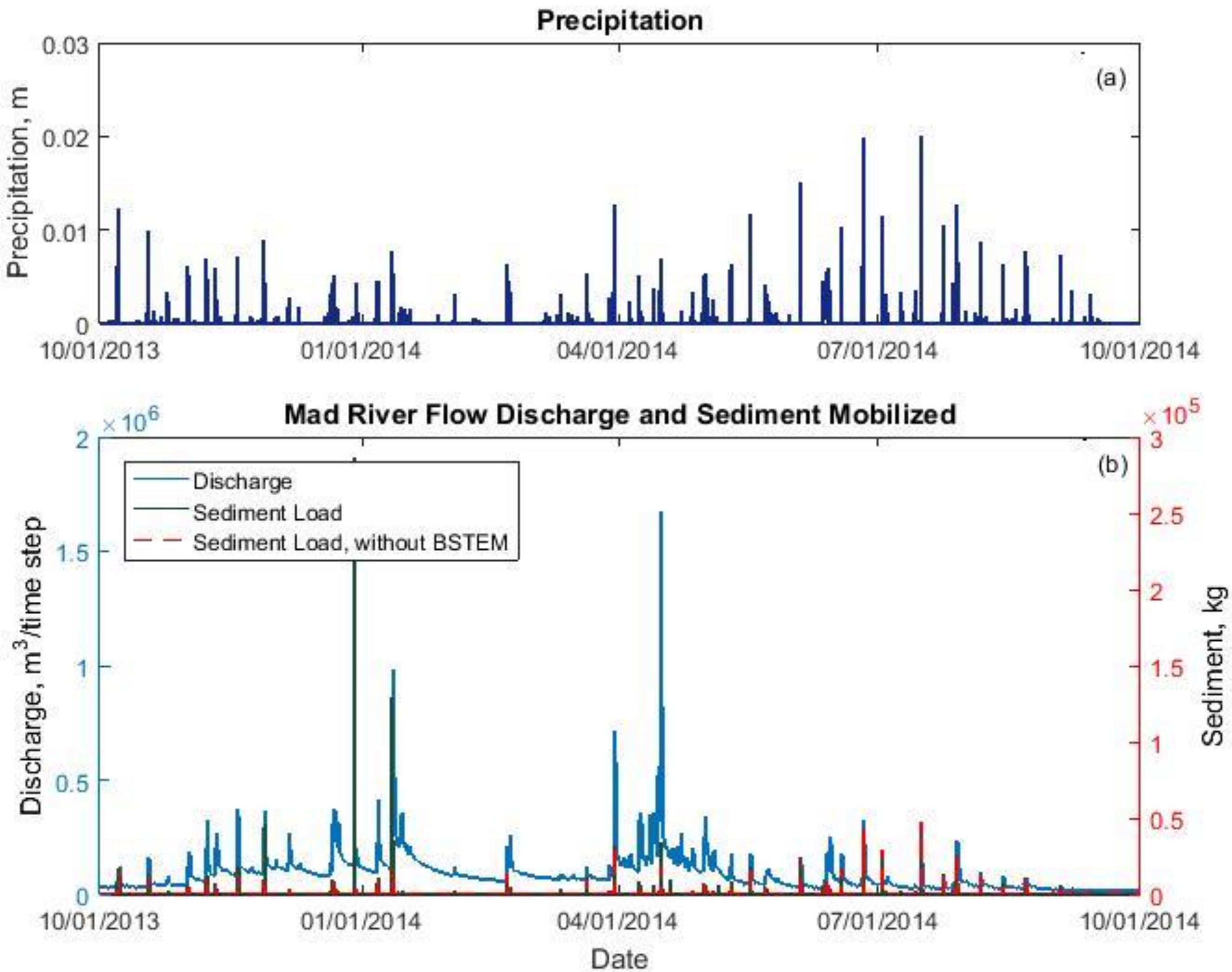


Climate change, hydrology, new challenges

Image credit: Vermont Watershed Management Division

Image credit: Vermont Agency for Natural Resources

Image credit: Vermont Watershed Manageme



Precipitation
(a)
Precipitation, m
0.03
0.02
0.01
0
10/01/2013
01/01/2014
04/01/2014
07/01/2014
10/01/2014
Mad River Flow Discharge and Sediment Mobilized
(b)
×10^6
×10^5
Discharge
Sediment Load
Sediment Load, without BSTEM
Discharge, m^3/time step
Sediment, kg
2
1.5
1
0.5
0
3
2.5
2
1.5
1
0.5
0
10/01/2013
01/01/2014
04/01/2014
07/01/2014
10/01/2014
Date

AGU PUBLICATIONS

Water Resources Research

RESEARCH ARTICLE

10.1002/2016WR019143

Key Points:

- Coupled model more inclusively represents suspended sediment mobilization in a watershed by including stream bank erosion and failure
- Modeled sediment using new approach improves suspended sediment representation at high flows in a test watershed
- Inclusive modeling of sediment mobilization will be important for simulating watershed response to climate shifts and land use change

Supporting Information:

- Supporting Information S1

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Citation:
Stryker, J., B. Wemple, and A. Bomblies (2017), Modeling sediment mobilization using a distributed hydrological model coupled with a bank stability model, *Water Resour. Res.*, *53*, 2051–2073, doi:10.1002/2016WR019143.

Modeling sediment mobilization using a distributed hydrological model coupled with a bank stability model

J. Stryker[1], B. Wemple[2], and A. Bomblies[1]

[1]School of Engineering, University of Vermont, Burlington, Vermont, USA, [2]Department of Geography, University of Vermont, Burlington, Vermont, USA

Abstract In addition to surface erosion, stream bank erosion and failure contributes significant sediment and sediment-bound nutrients to receiving waters during high flow events. However, distributed and mechanistic simulation of stream bank sediment contribution to sediment loads in a watershed has not been achieved. Here we present a full coupling of existing distributed watershed and bank stability models and apply the resulting model to the Mad River in central Vermont. We fully coupled the Bank Stability and Toe Erosion Model (BSTEM) with the Distributed Hydrology Soil Vegetation Model (DHSVM) to allow the simulation of stream bank erosion and potential failure in a spatially explicit environment. We demonstrate the model's ability to simulate the impacts of unstable streams on sediment mobilization and transport within a watershed and discuss the model's capability to simulate watershed sediment loading under climate change. The calibrated model simulates total suspended sediment loads and reproduces variability in suspended sediment concentrations at watershed and subbasin outlets. In addition, characteristics such as land use and road-to-stream ratio of subbasins are shown to impact the relative proportions of sediment mobilized by overland erosion, erosion of roads, and stream bank erosion and failure in the subbasins and watershed. This coupled model will advance mechanistic simulation of suspended sediment mobilization and transport from watersheds, which will be particularly valuable for investigating the potential impacts of climate and land use changes, as well as extreme events.