On the Stationarity of Flood Peaks in the Continental US and Central Europe

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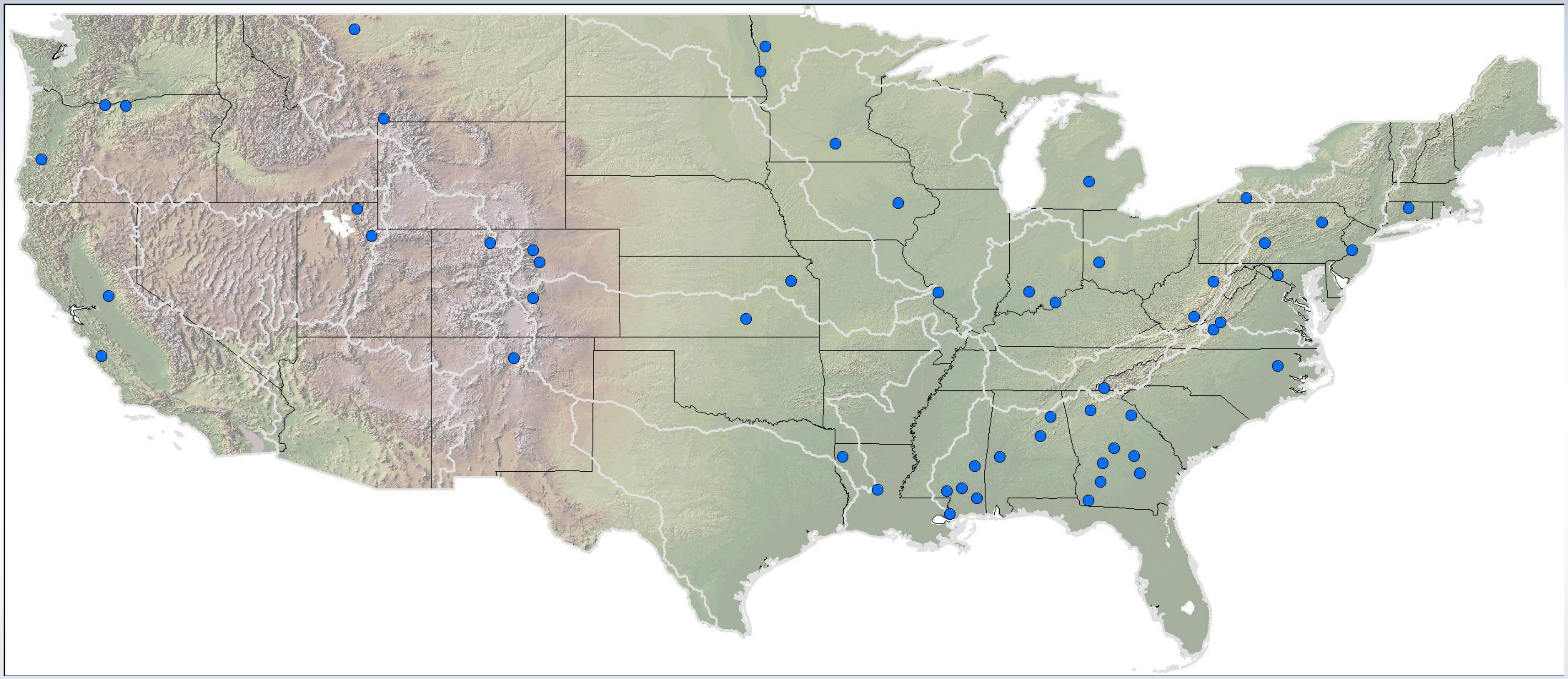
Problem Statement and Objectives

- **There is a large spatial variability in flood hazards over the continental United States and central Europe**
- **Profound anthropogenic changes (e.g., changes in land use / land cover, construction of dams, river engineering)**
- **Projected increasing frequency of extreme rain and flood with human induced climate change**
- **Rapidly changing flood hazards with urbanization**

Central Issues:

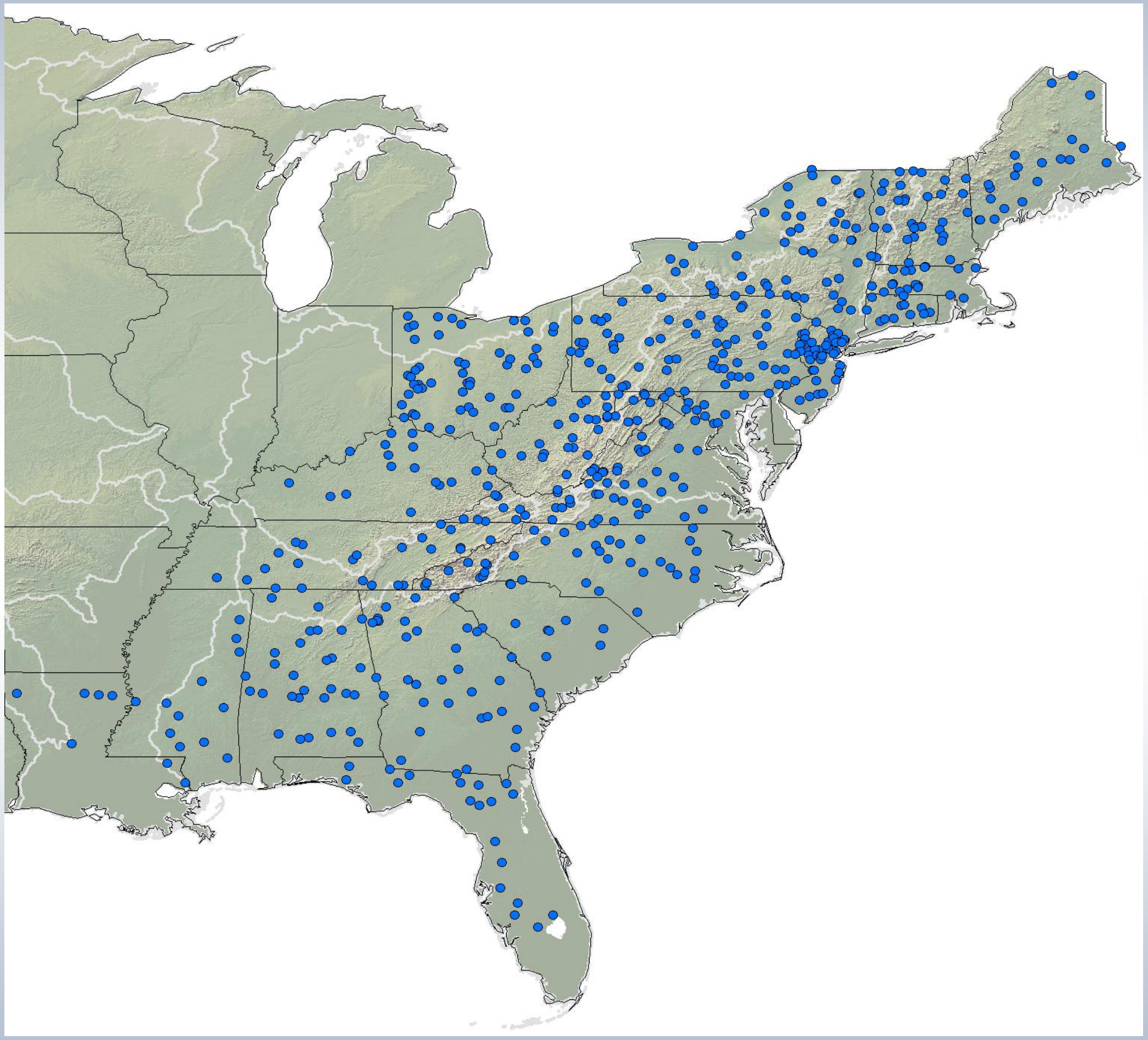
- **temporal non-stationarities of annual flood peaks**
- **changes in frequency of extreme flooding due to climate change**
- **flood hazard assessment in urban environment**
- **“Mixtures” of flood peaks and impact of tropical cyclones on flood peak distributions**

Continental US



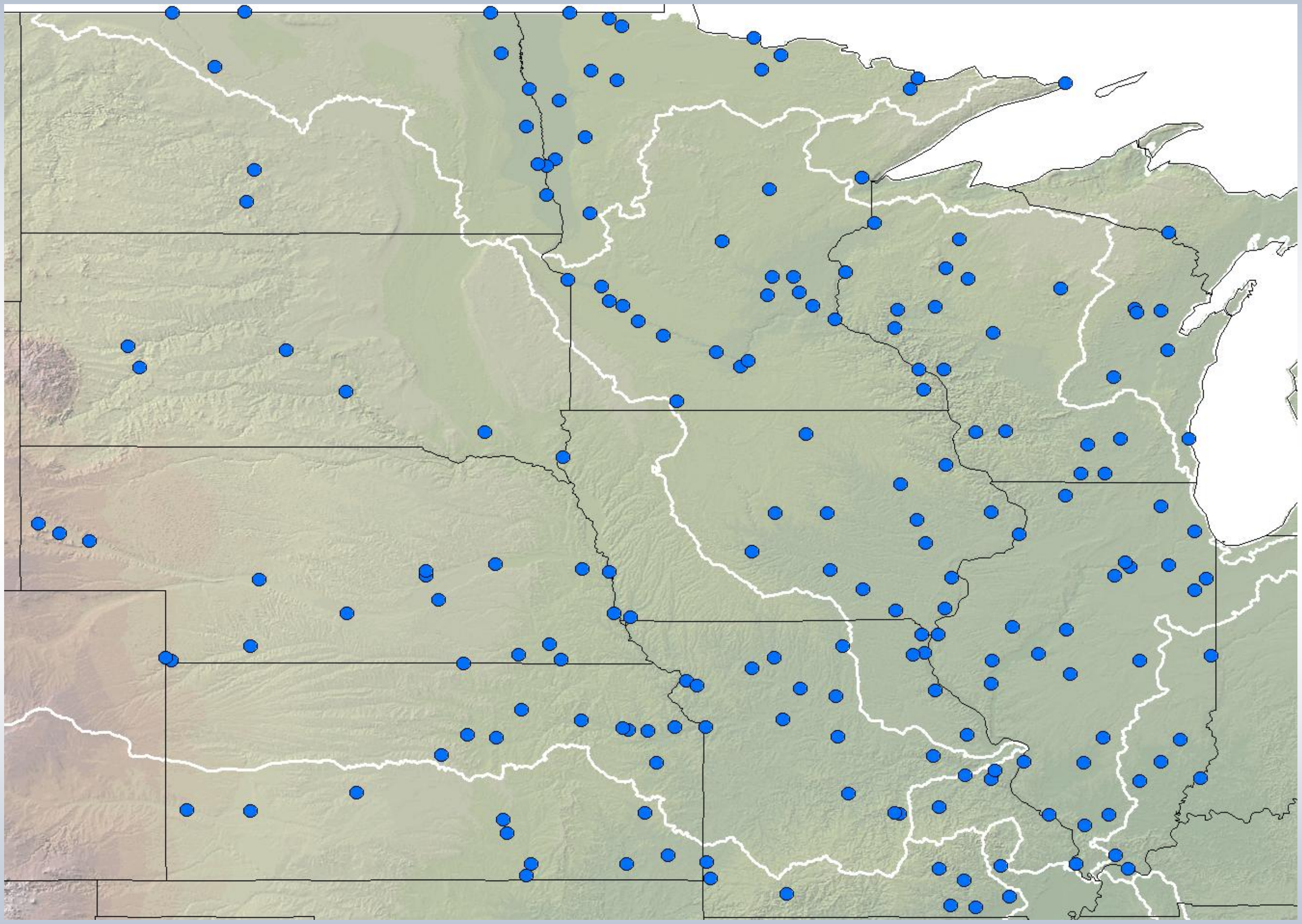
50 USGS streamflow stations with at least 100-year record length of annual maximum peak discharge

Eastern US



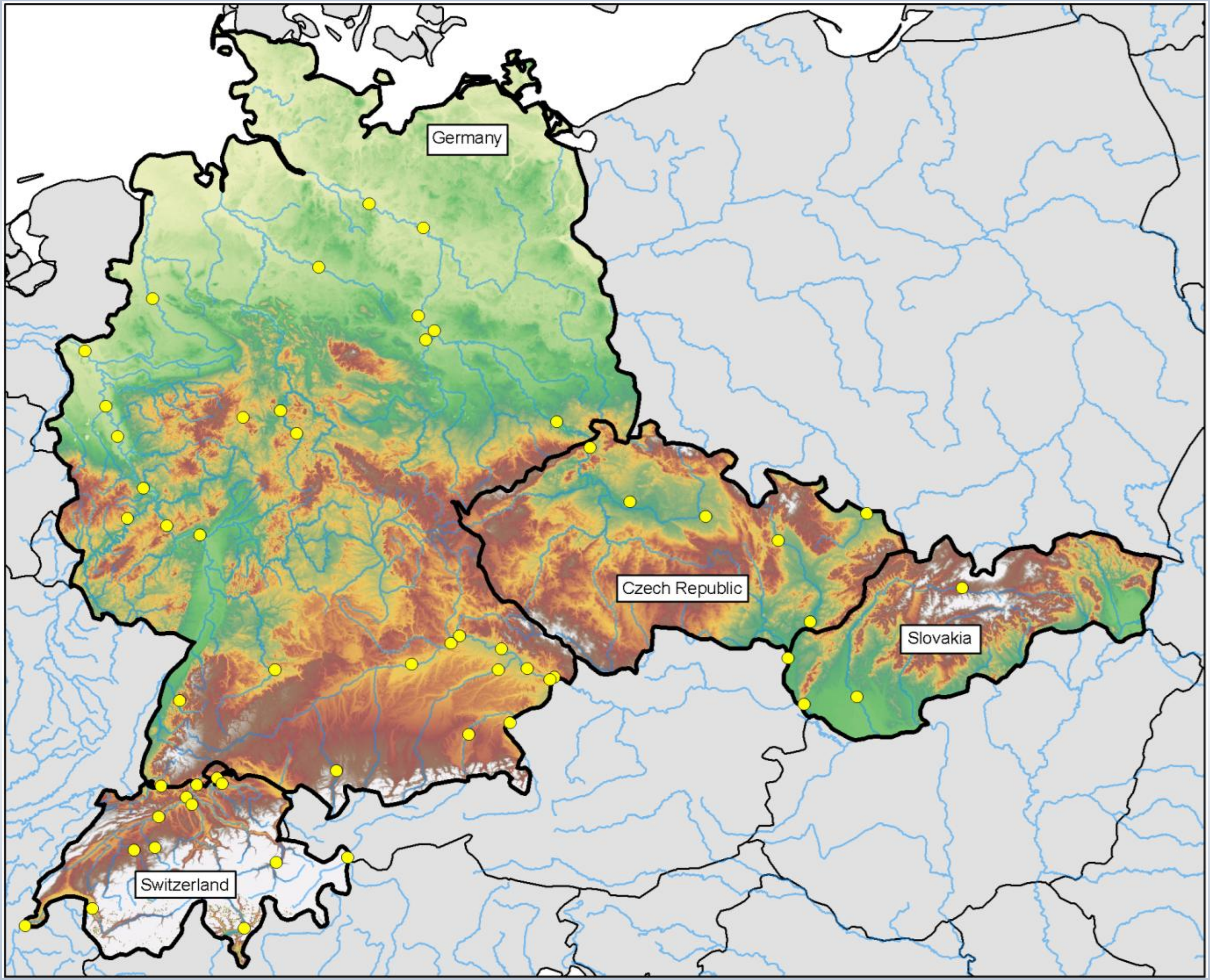
572 USGS streamflow stations with at least 75-year record length of annual maximum peak discharge

Central US



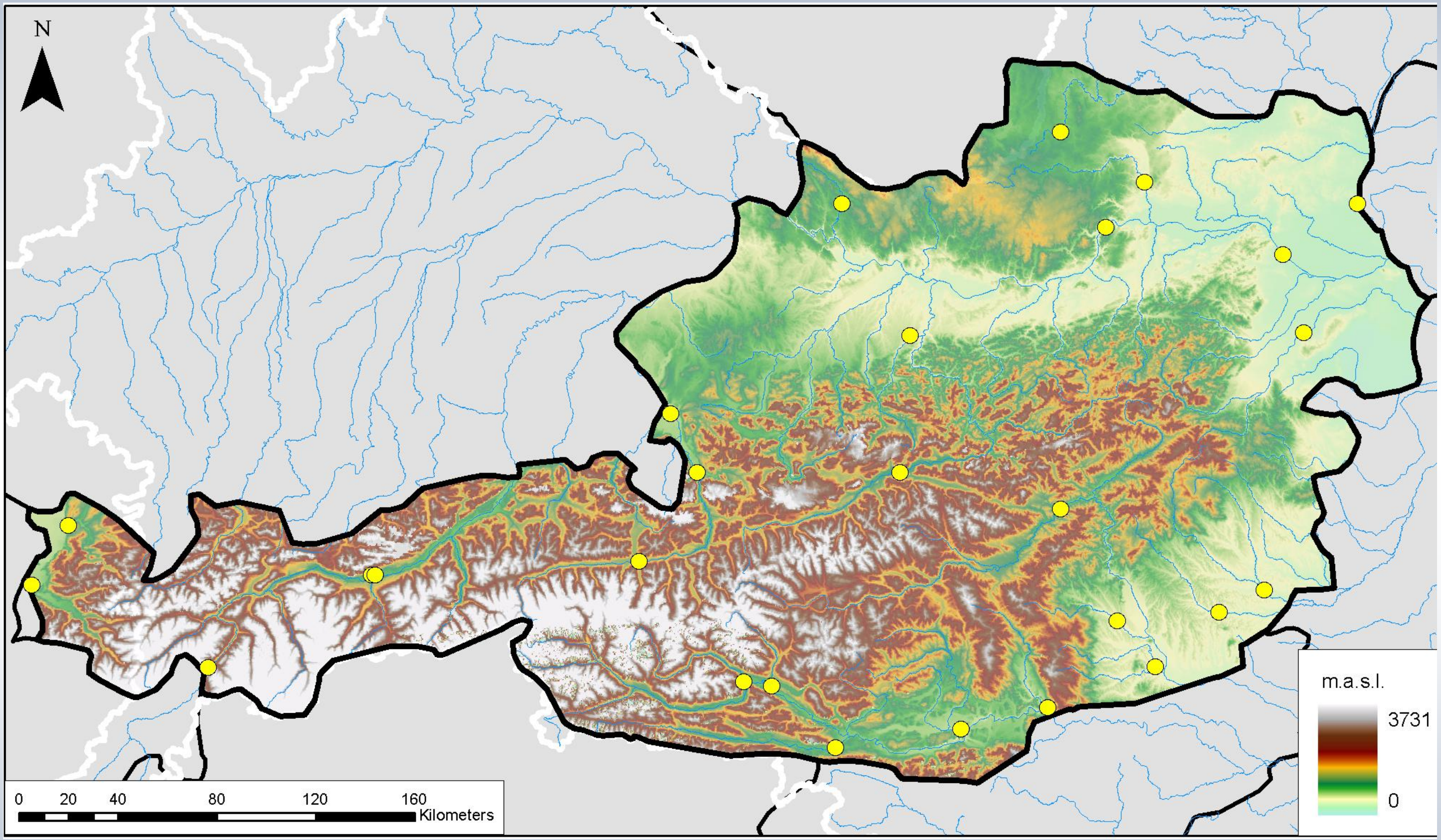
196 USGS streamflow stations with at least 75-year record length of annual maximum peak discharge

Central Europe



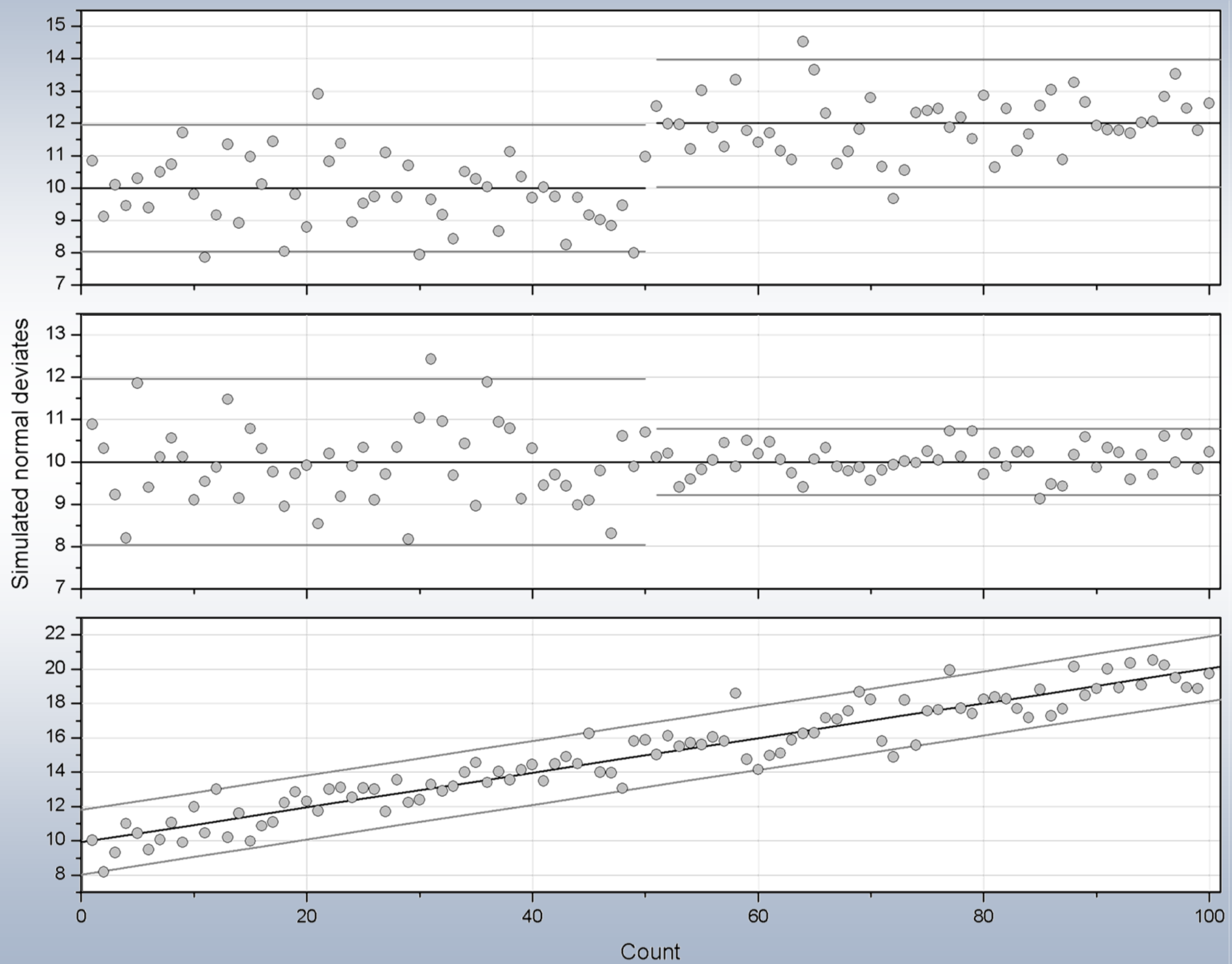
55 streamflow stations with at least 75-year record length of annual maximum daily peak discharge

Austria



27 streamflow stations with annual maximum daily peak discharge from 1951 to 2006 (56 years)

Stationarity

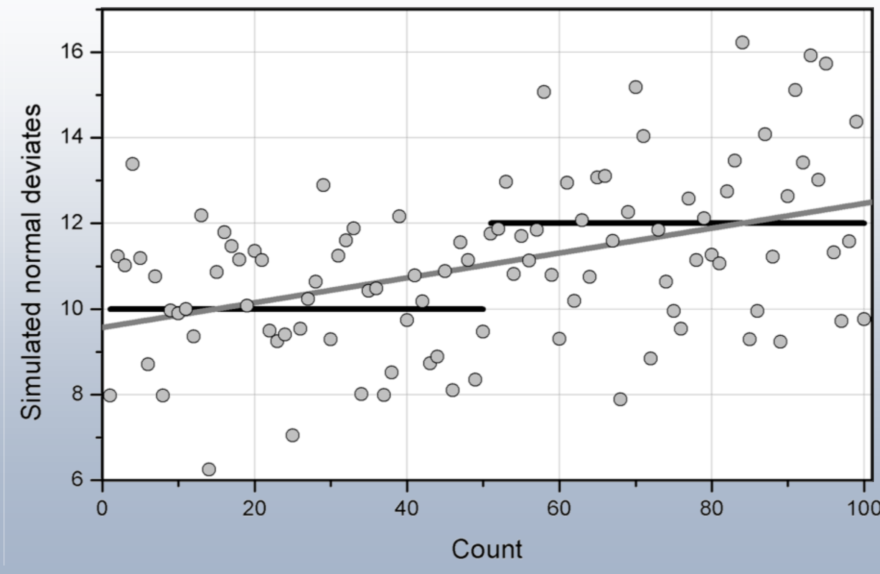


Stationarity

The stationarity of a time series is evaluated by checking for the presence of abrupt and/or slowly varying linear changes over time:

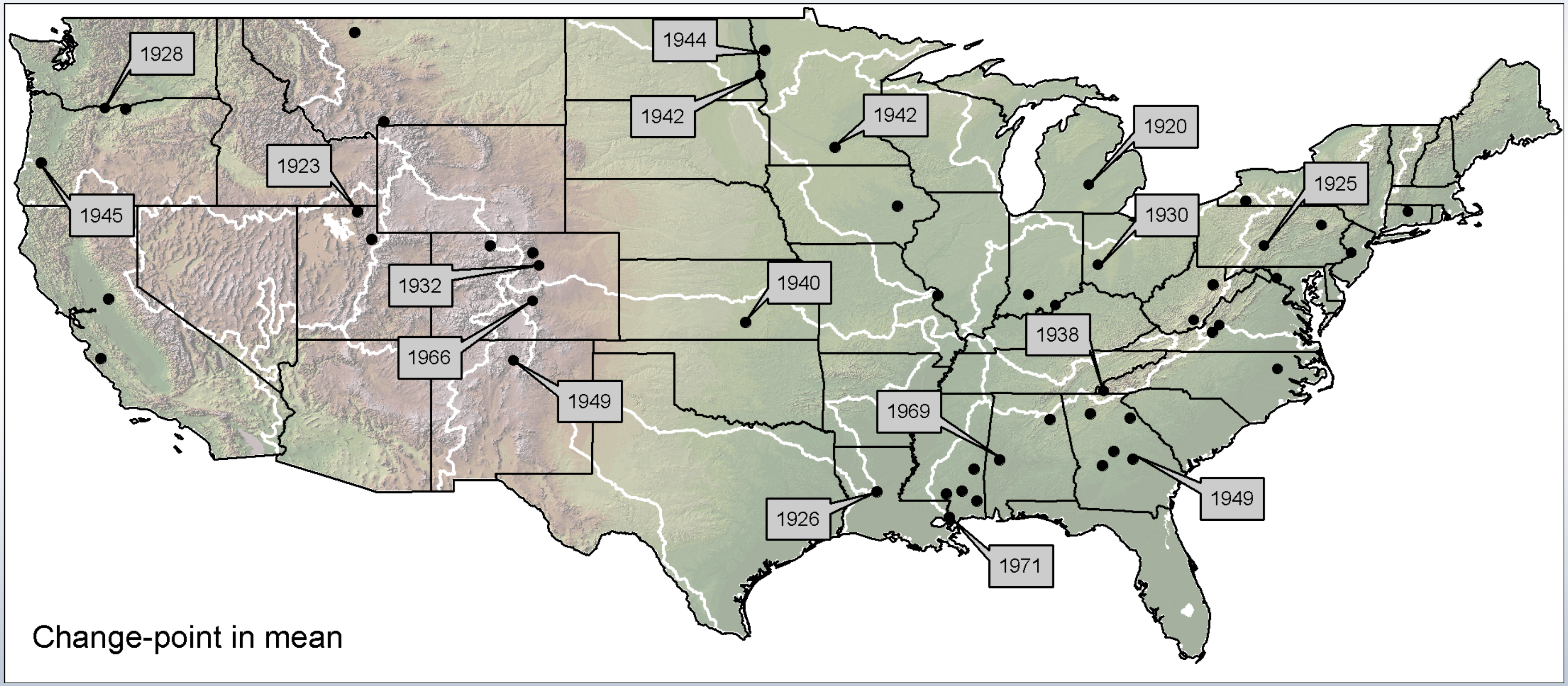
-Change-point (cp) in mean and variance investigated by means of the non-parametric Pettitt test

-Presence of monotonic trends investigated by means of the non-parametric Mann-Kendall and Spearman tests



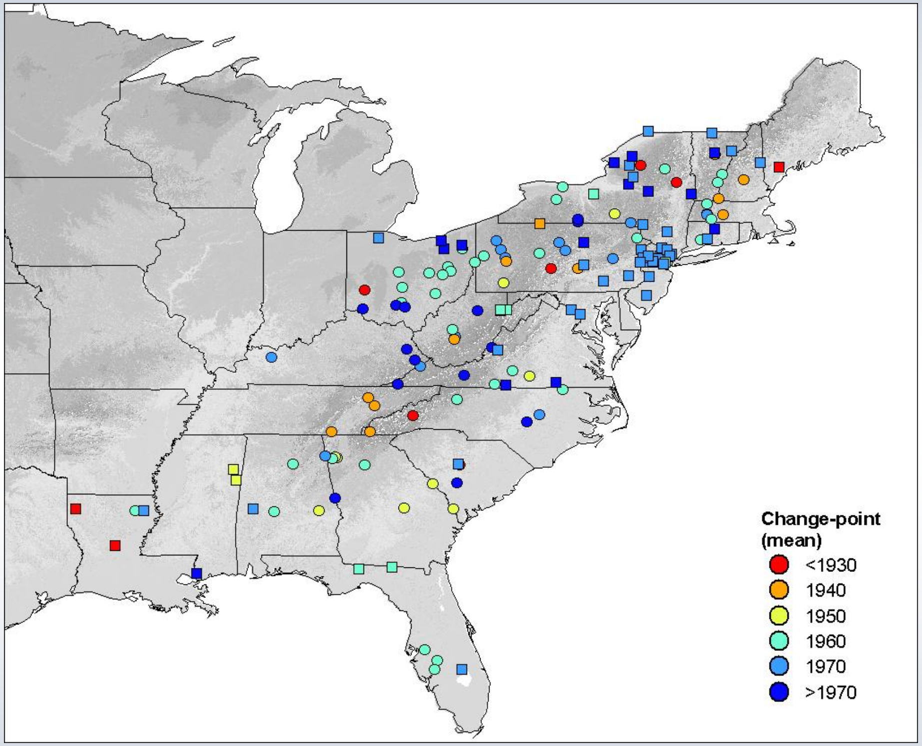
Stationarity: Continental US

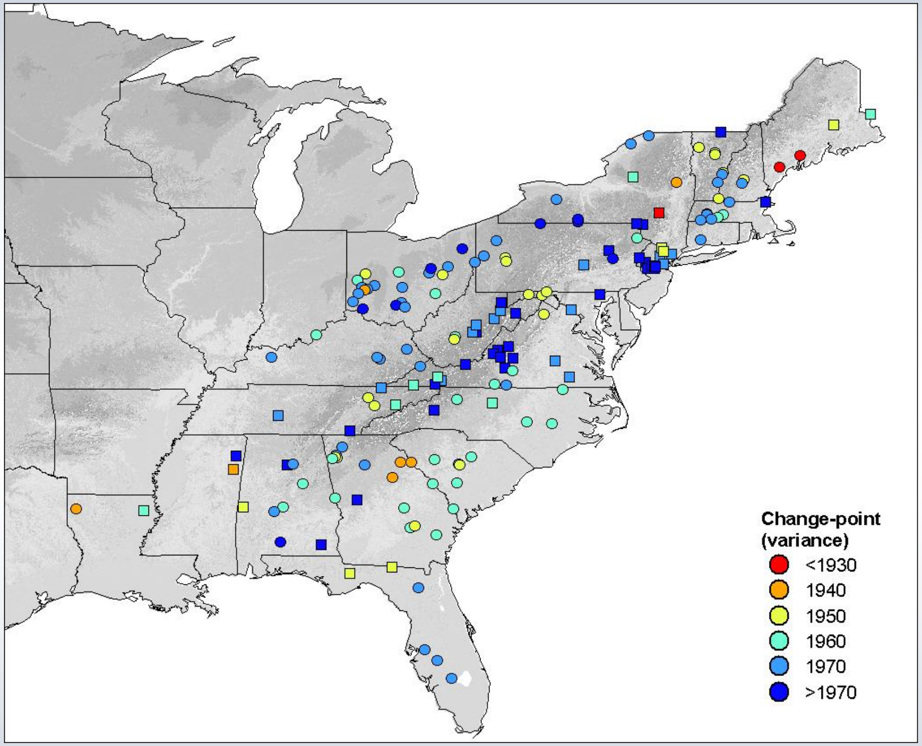
Most of the violations of the stationarity assumption are associated with construction of dams, streamgage relocation, and changes in land use/land cover.



Villarini, G., F. Serinaldi, J.A. Smith, and W.F. Krajewski, On the stationarity of annual flood peaks in the Continental United States during the 20th Century, *Water Resources Research*, 45, W088417, doi:10.1029/2008WR007645, 2009.

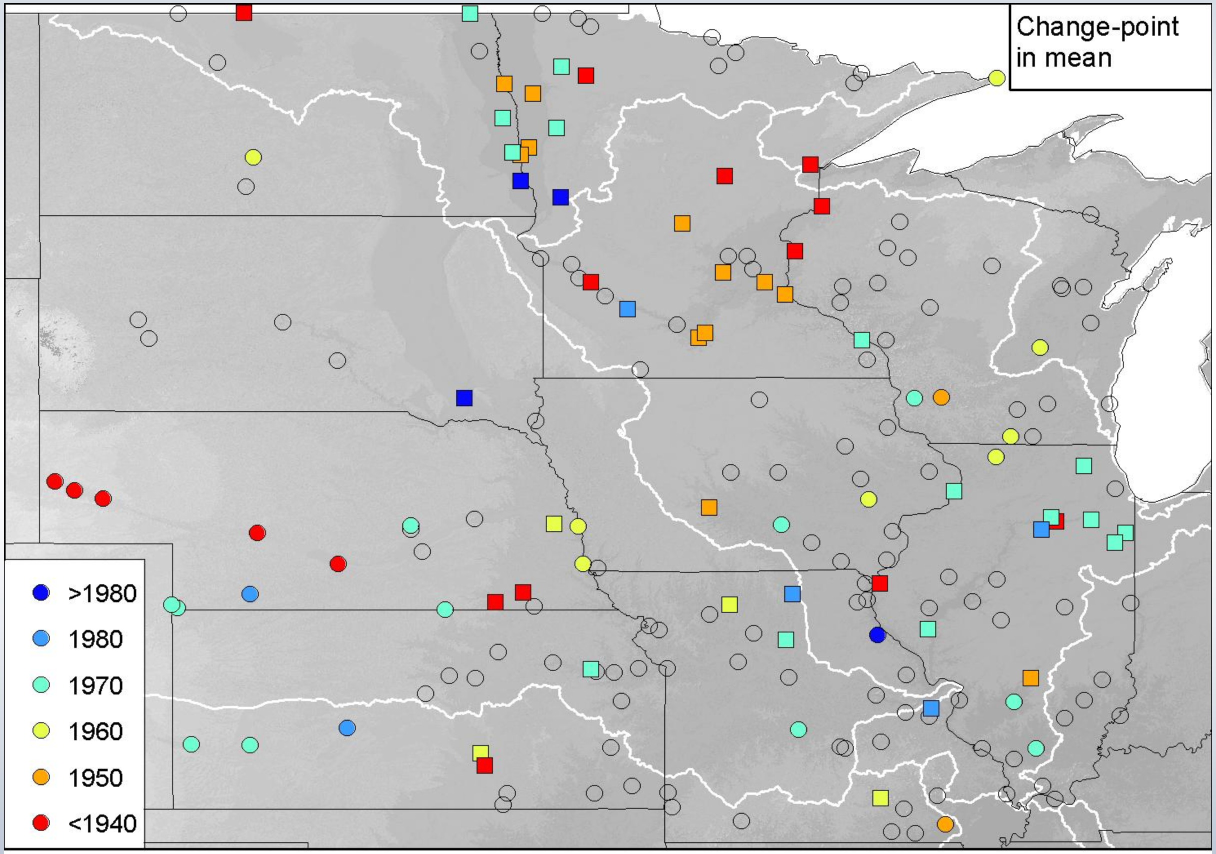
Stationarity: Eastern US





Villarini, G., and J.A. Smith, Flood peak distributions for the Eastern United States, *Water Resources Research*, doi:10.1029/2009WR008395, 46, W06504, 2010

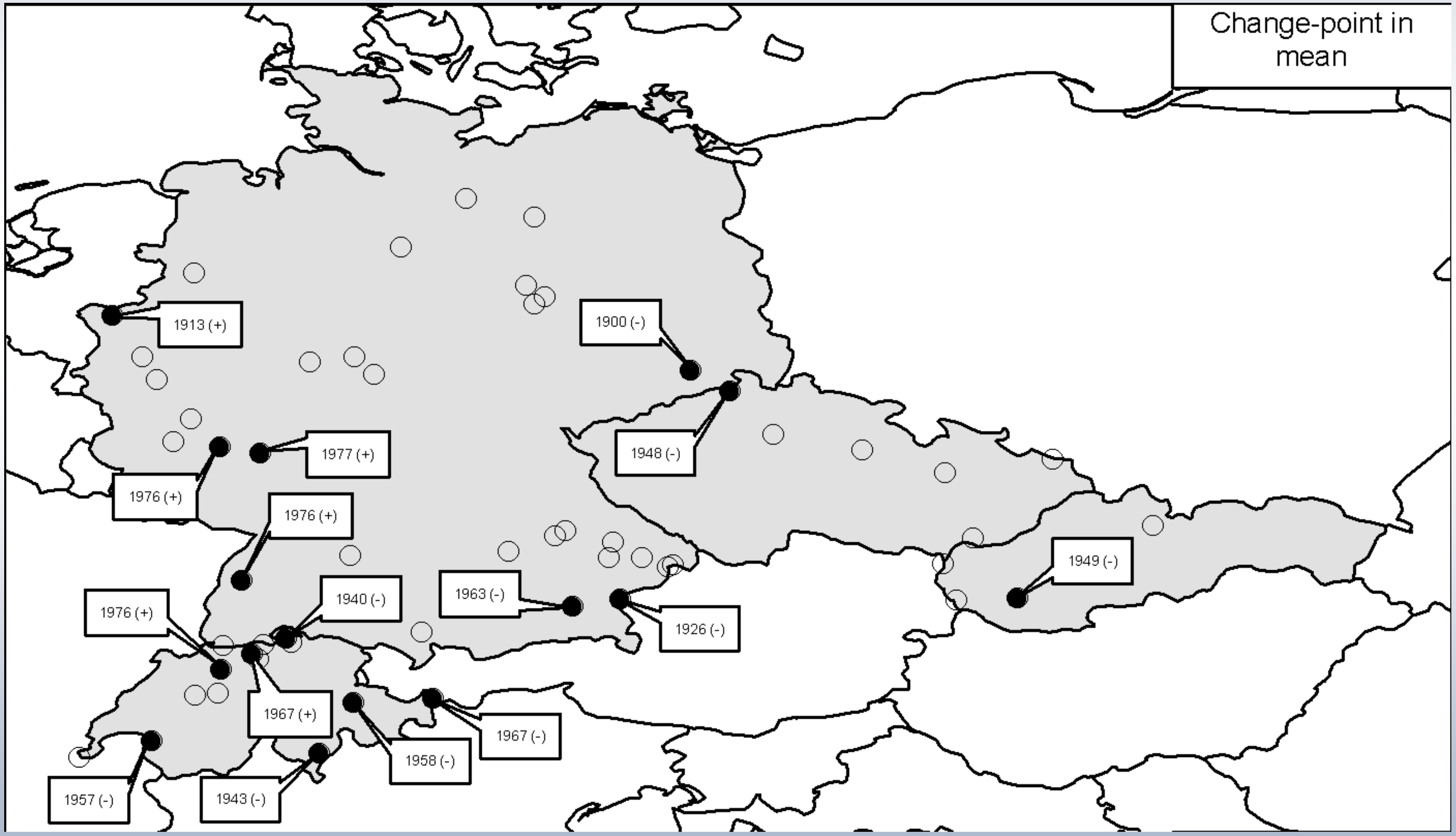
Stationarity: Central US



Villarini, G., J.A. Smith, M.L. Baeck, and W.F. Krajewski Examining flood frequency distributions in the Midwest U.S., *Journal of the American Water Resources Association*, 2010 (in press).

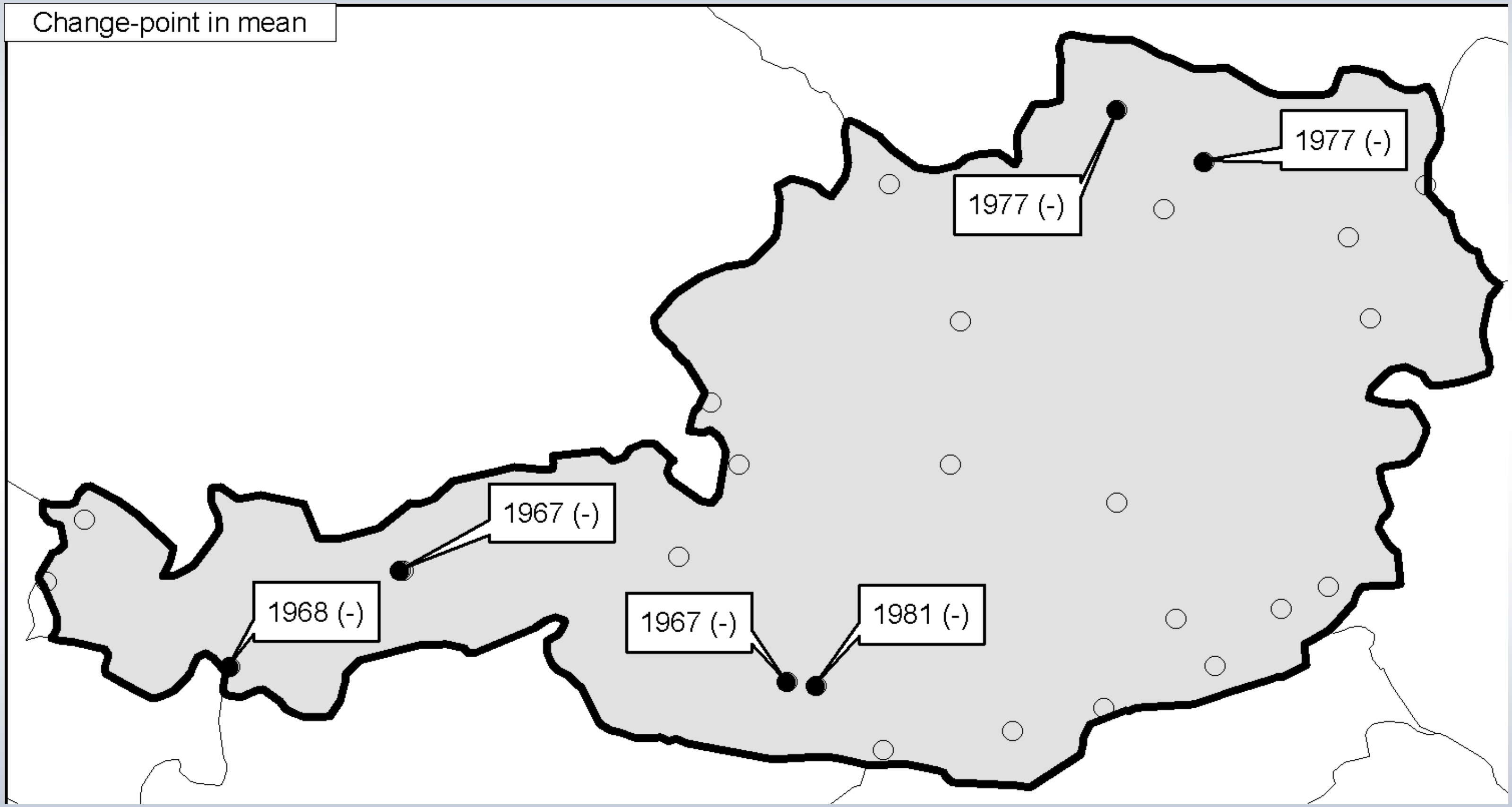
Stationarity: Central Europe

Most of the violations of the stationarity assumption are associated with construction of dams and river engineering (e.g., straightening, diversion, meander cut-off).



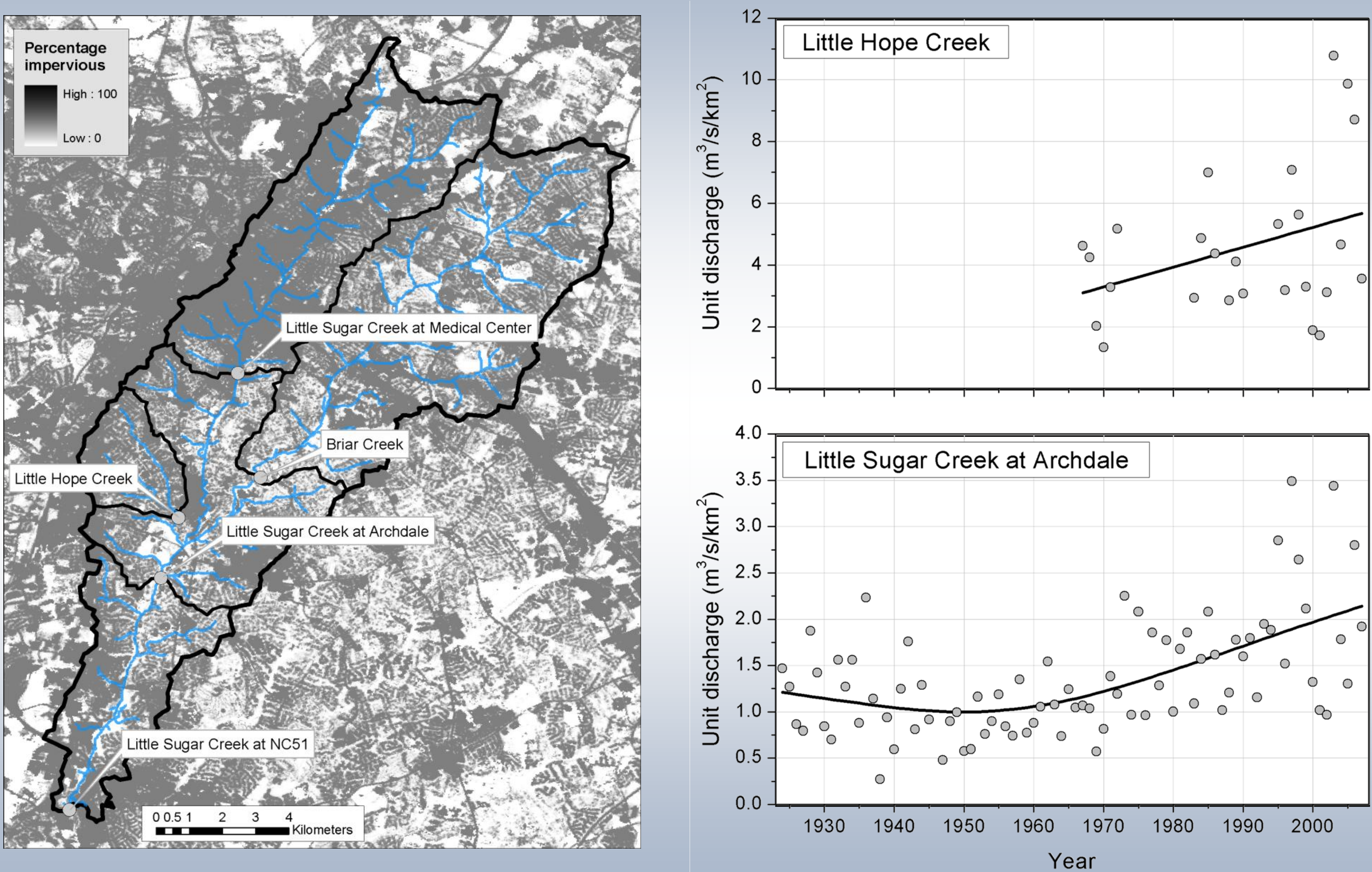
Villarini, G., J.A. Smith, F. Serinaldi, and A.A. Ntelekos, Analyses of seasonal and annual maximum daily discharge records for Central Europe, *Journal of Hydrology*, 2010 (submitted).

Stationarity: Austria



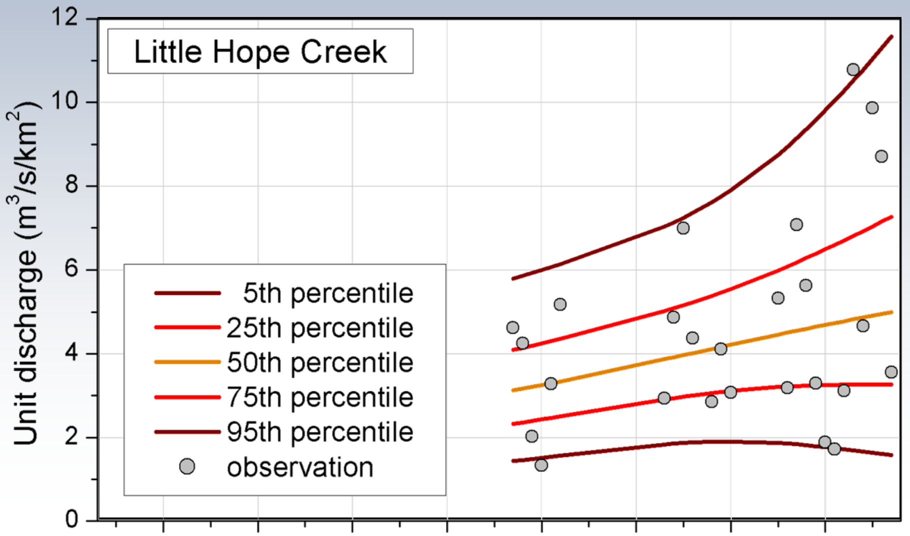
Villarini, G., J.A. Smith, F. Serinaldi, A.A. Ntelekos, and U. Schwarz, Analyses of extreme flooding in Austria over the period 1951-2006, *Journal of Hydrometeorology*, 2010 (near submission).

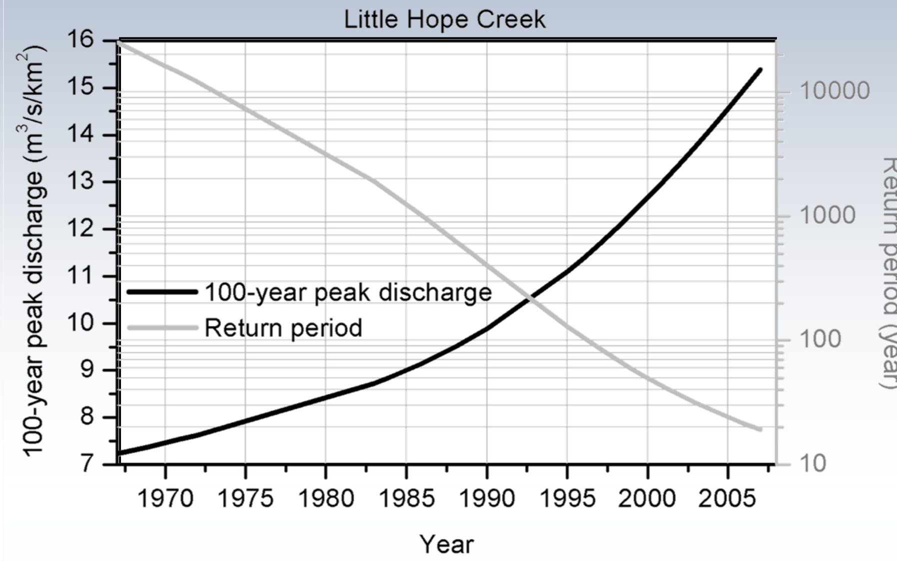
Flood Frequency – Charlotte NC

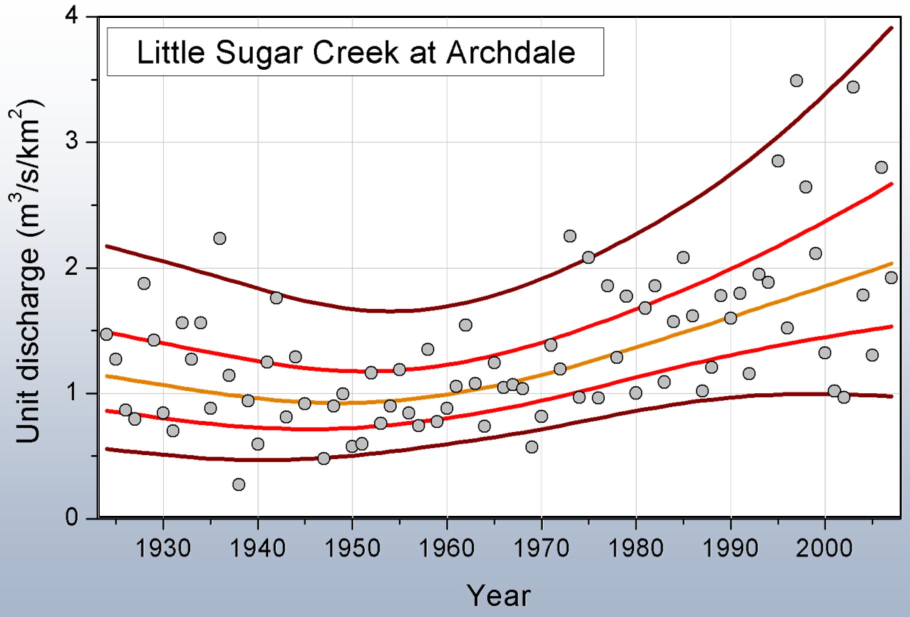


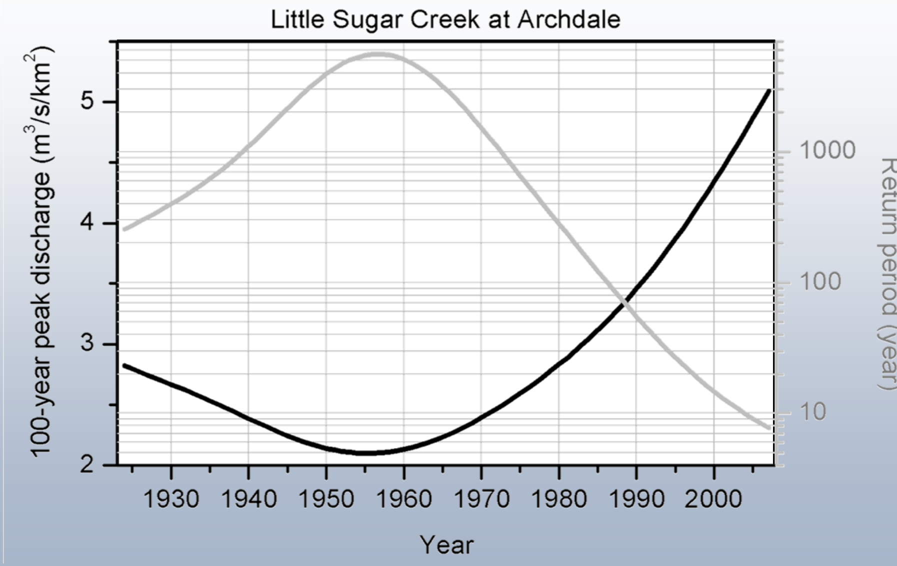
Villarini, G., J.A. Smith, F. Serinaldi, J. Bales, P.D. Bates, and W.F. Krajewski, Flood frequency analysis for nonstationary annual peak records in an urban drainage basin, *Advances in Water Resources*, 32(8), 1255-1266, 2009.

Nonstationary Modeling

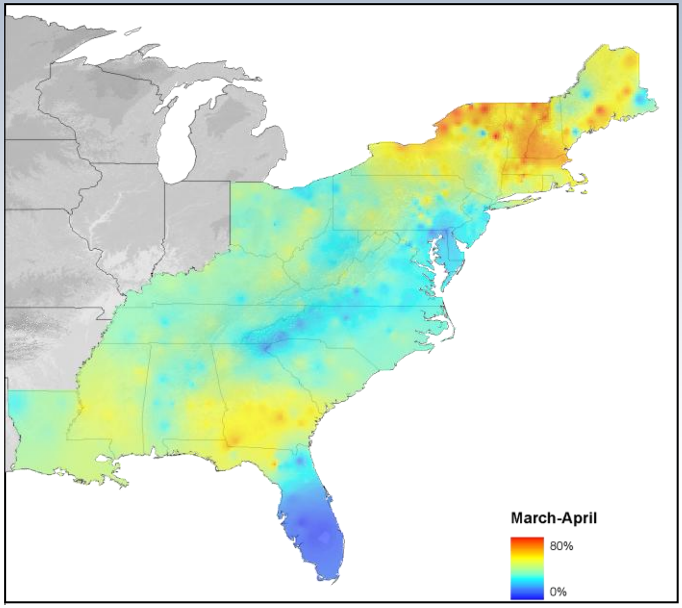


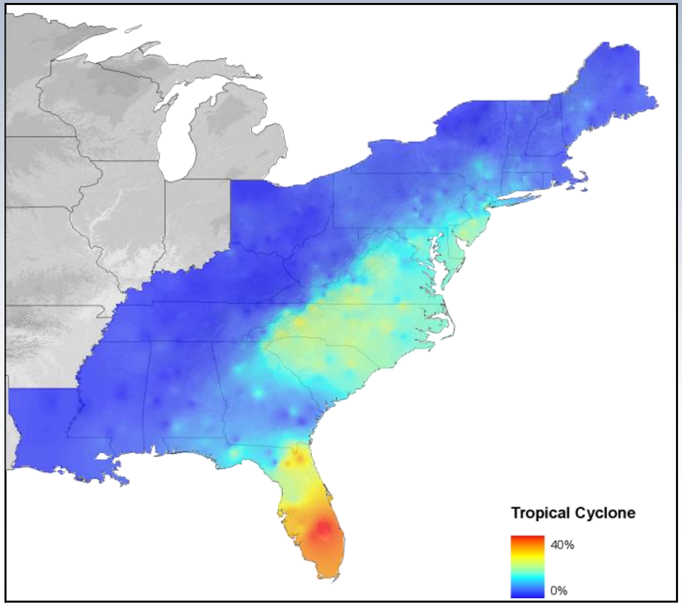


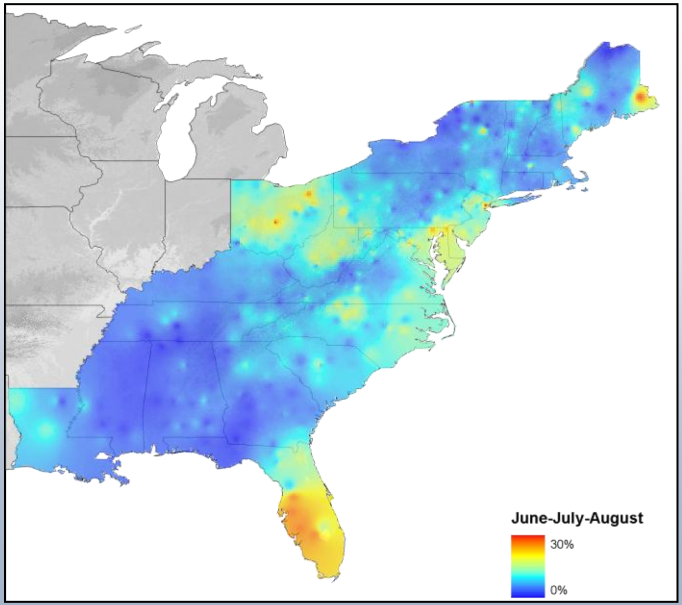




Mixture Distributions



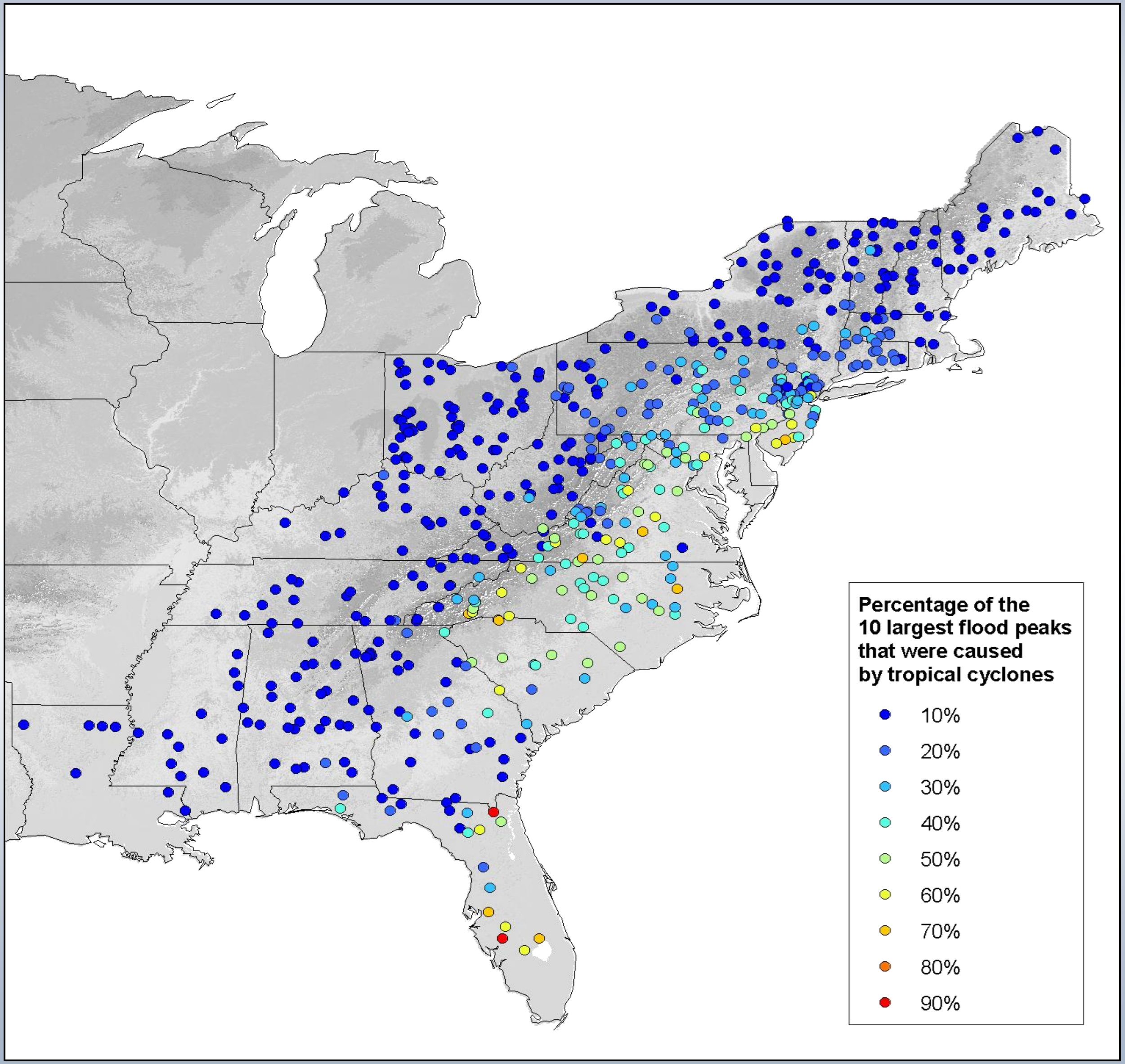




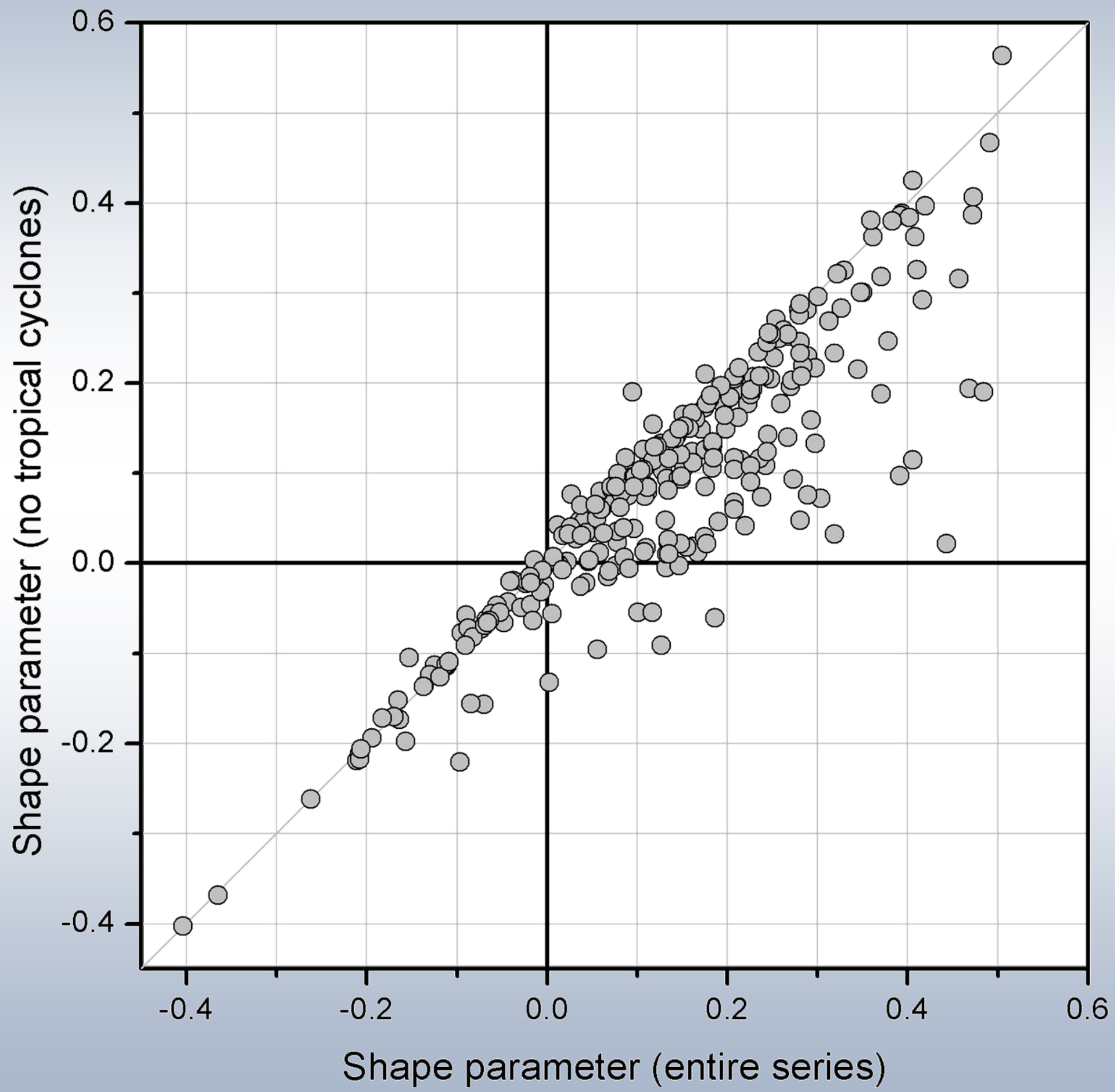
"Mixtures" and spatial heterogeneities of flood peak distributions

Villarini, G., and J.A. Smith, Flood peak distributions for the Eastern United States, *Water Resources Research*, doi:10.1029/2009WR008395, 46, W06504, 2010

Impact of Tropical Cyclones

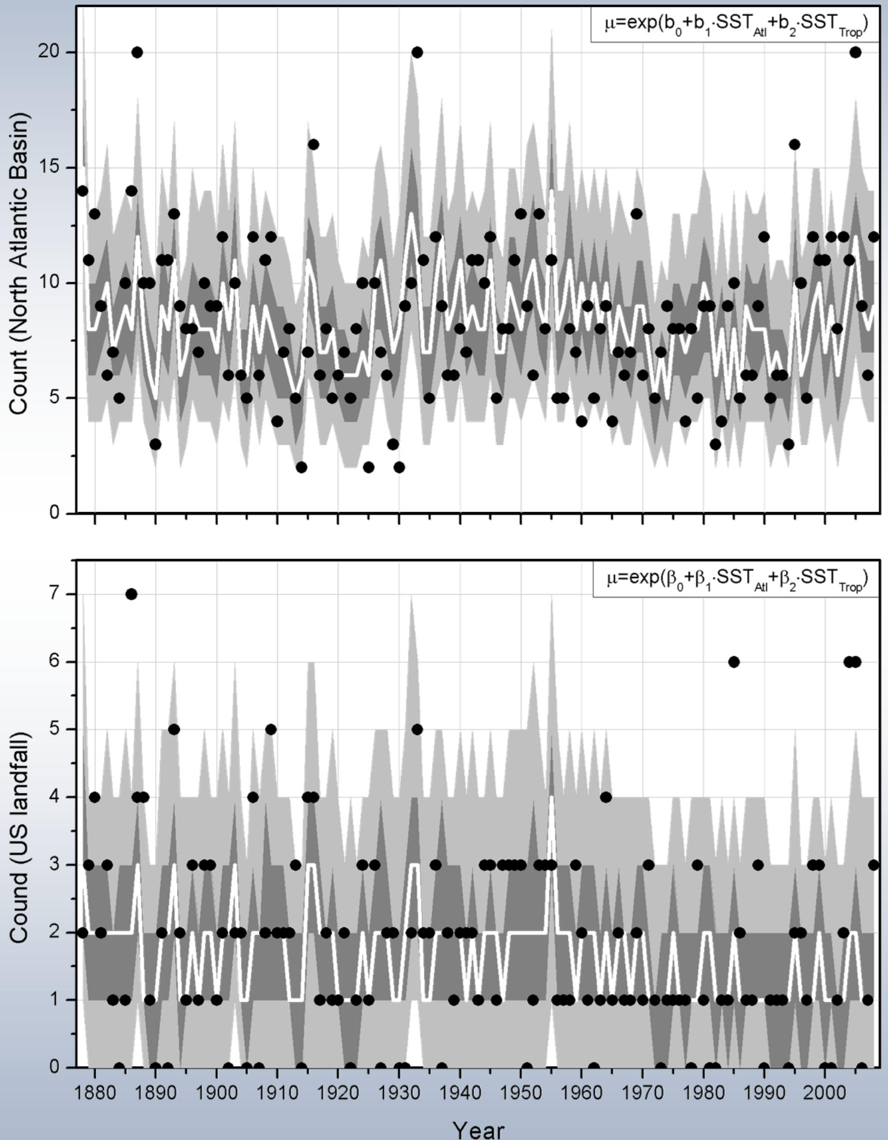


Upper Tail and Tropical Cyclones



The shape parameter of the GEV distribution is used to evaluate the impact of tropical cyclones on the upper tail of the flood peak distribution

Modeling of Tropical Storm Count

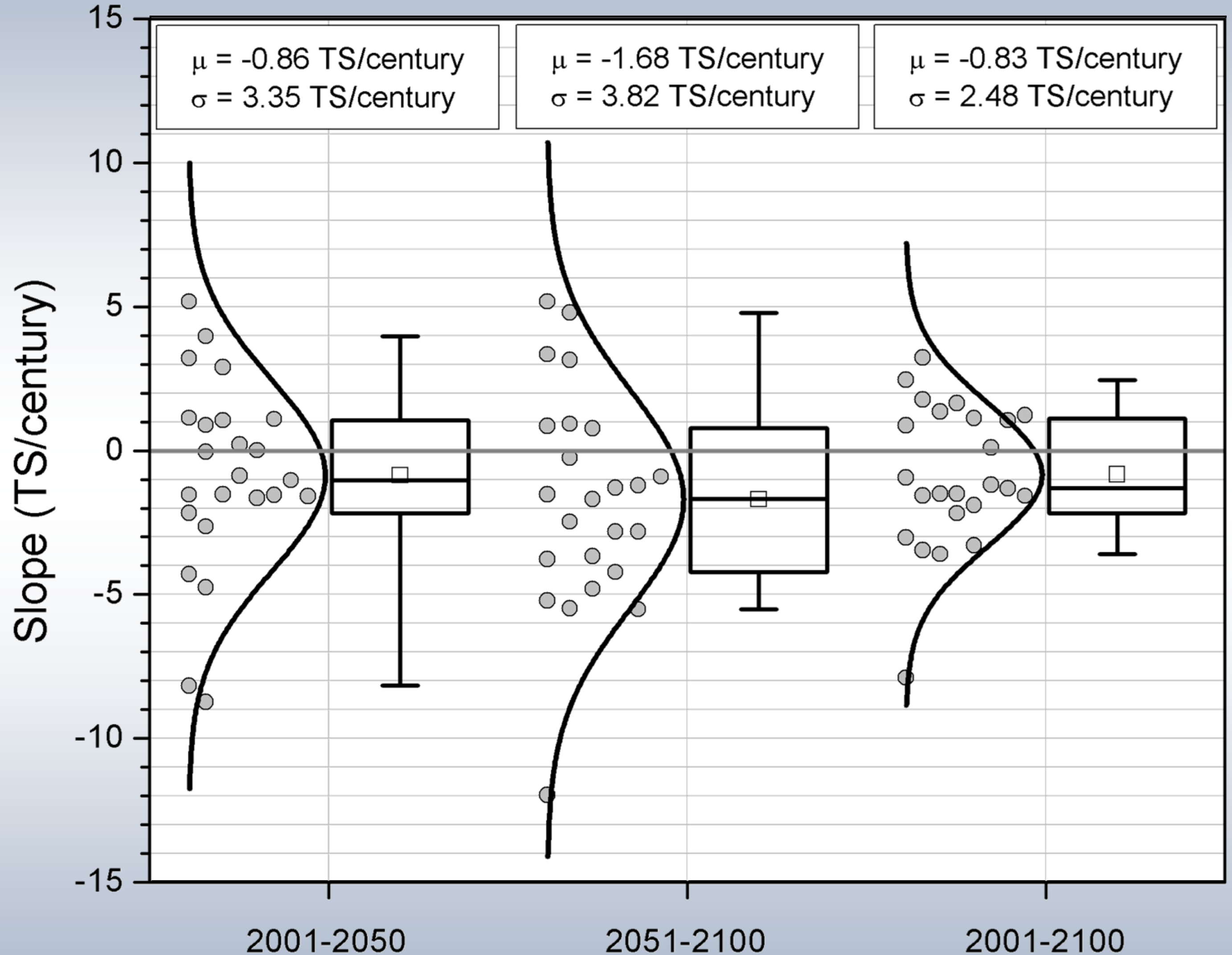


Statistical modeling of the tropical storm count for the North Atlantic basin using a Poisson regression model and the following covariates:

- Southern Oscillation Index
- North Atlantic Oscillation
- Tropical Atlantic SST
- Tropical mean SST

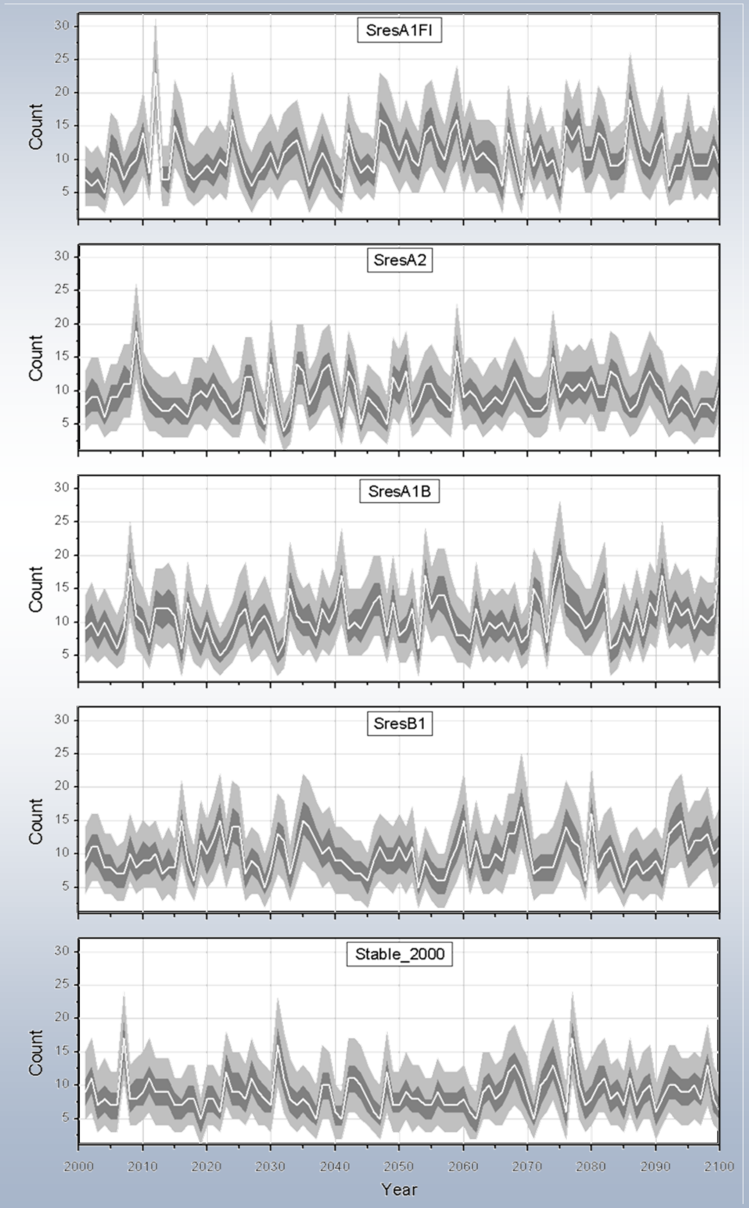
11. Villarini, G., G.A. Vecchi, and J.A. Smith, Modeling of the dependence of tropical storm counts in the North Atlantic Basin on climate indices, *Monthly Weather Review*, 138(7), 2681-2705, 2010.

North Atlantic TS Activity (SresA1B)



Villarini, G., G.A. Vecchi, T.R. Knutson, M. Zhao, and J.A. Smith, North Atlantic tropical storm frequency response to anthropogenic forcing: Projections and sources of uncertainty, *Journal of Climate*, 2010 (submitted)

North Atlantic TS Activity (5 scenarios)



Conclusions

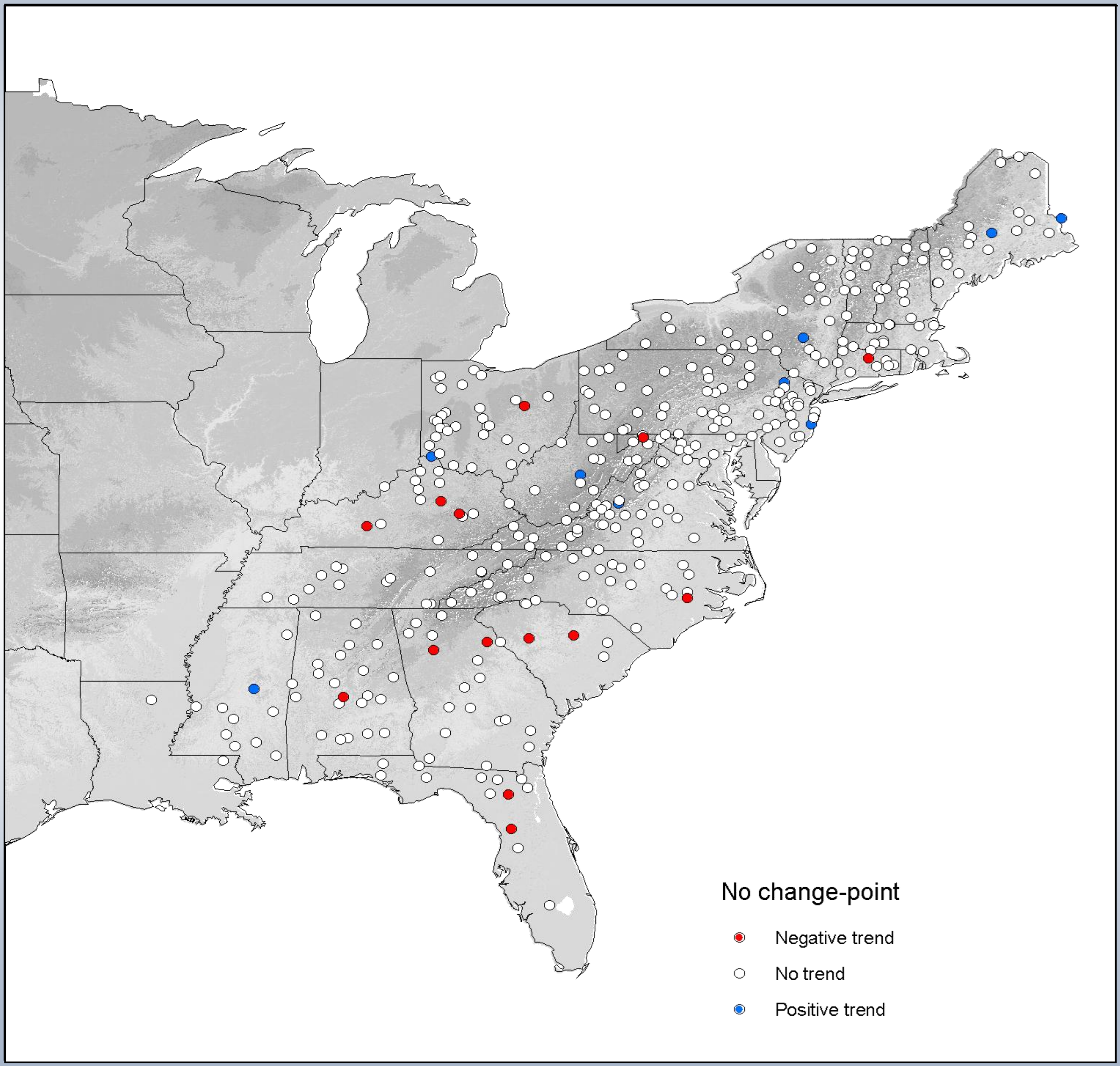
- **Change-points rather than monotonic trends are responsible for the violation of the stationarity assumption.**
- **Analyses of historical discharge records do not point at changes in the flood peak distribution due climate change.**
- **Non-stationary modeling of flood peaks in urban environment**
- **Under nonstationary conditions, alternative definitions of return period have to be sought.**
- **Spatial heterogeneity in "mixtures" of flood peaks.**
- **Tropical cyclones control extreme flooding in much of the eastern US. Analyses of tropical storm frequency in a warmer climate do not suggest a significant increase in tropical storms in the North Atlantic basin over the 21st century.**

Thank You!

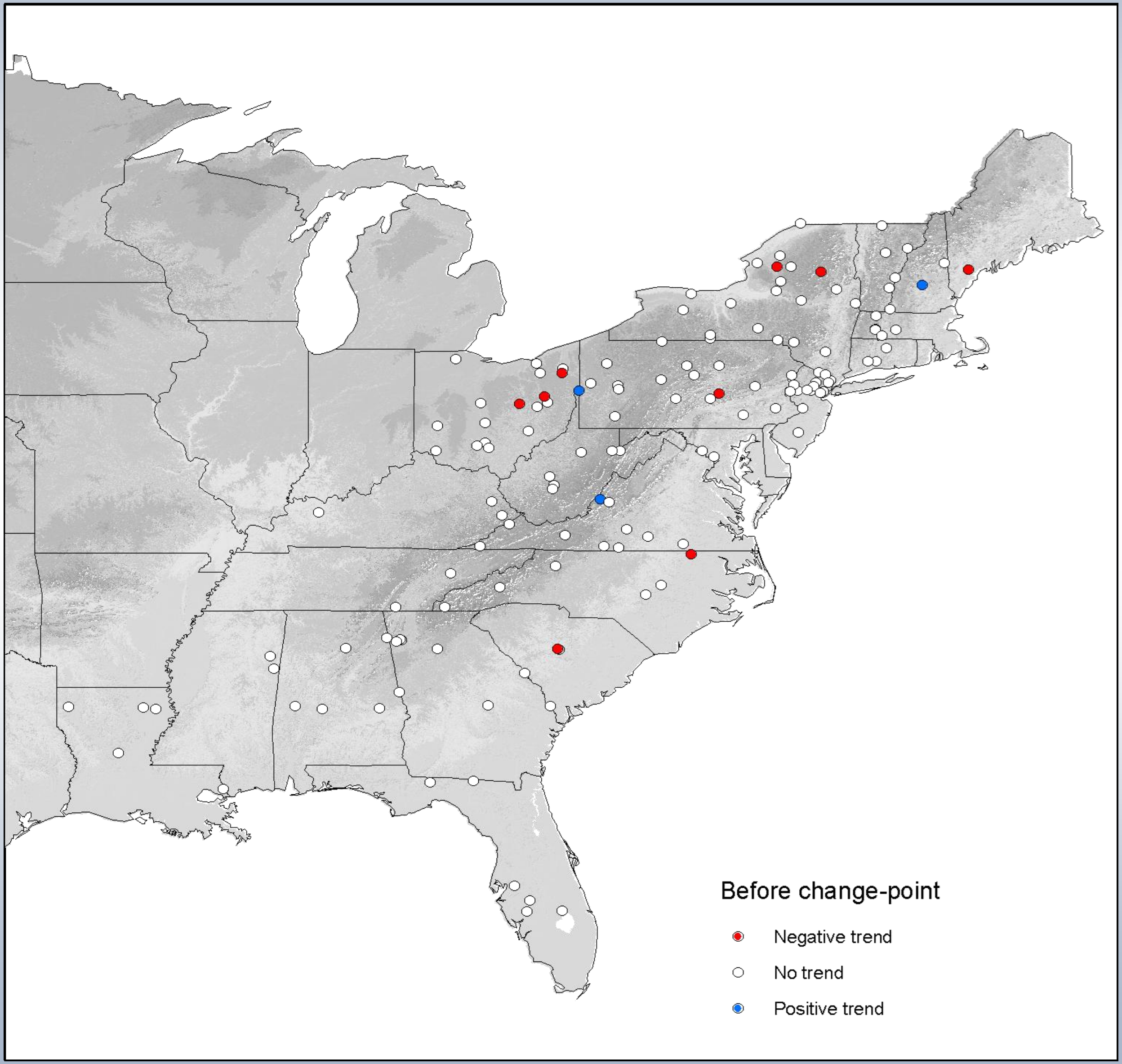
The End

Extra slides

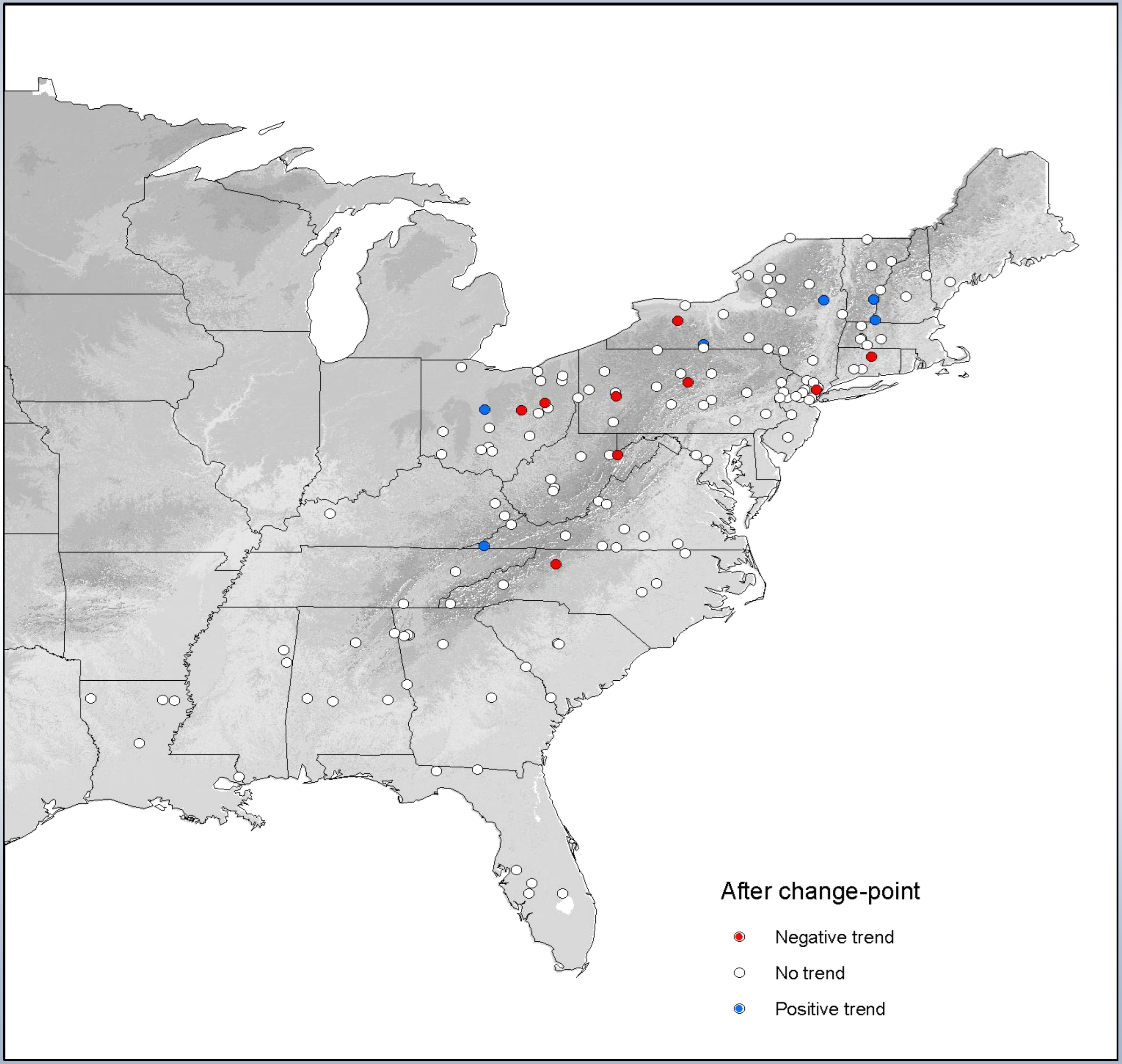
Trend Analyses: no change-point (Eastern US)



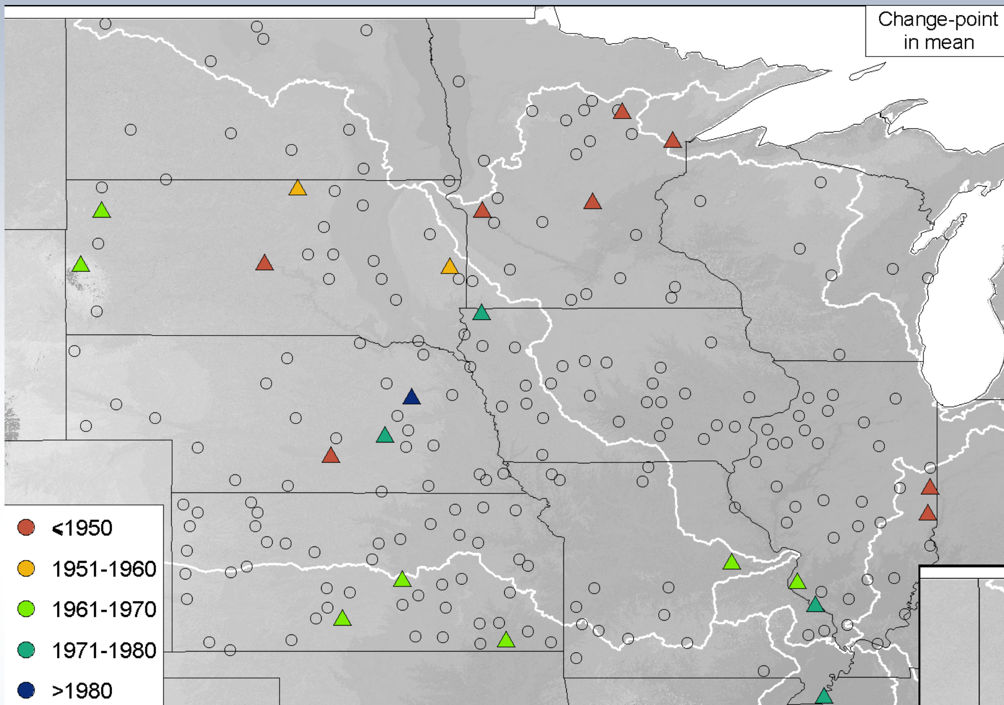
Trend Analyses: before cp (Eastern US)



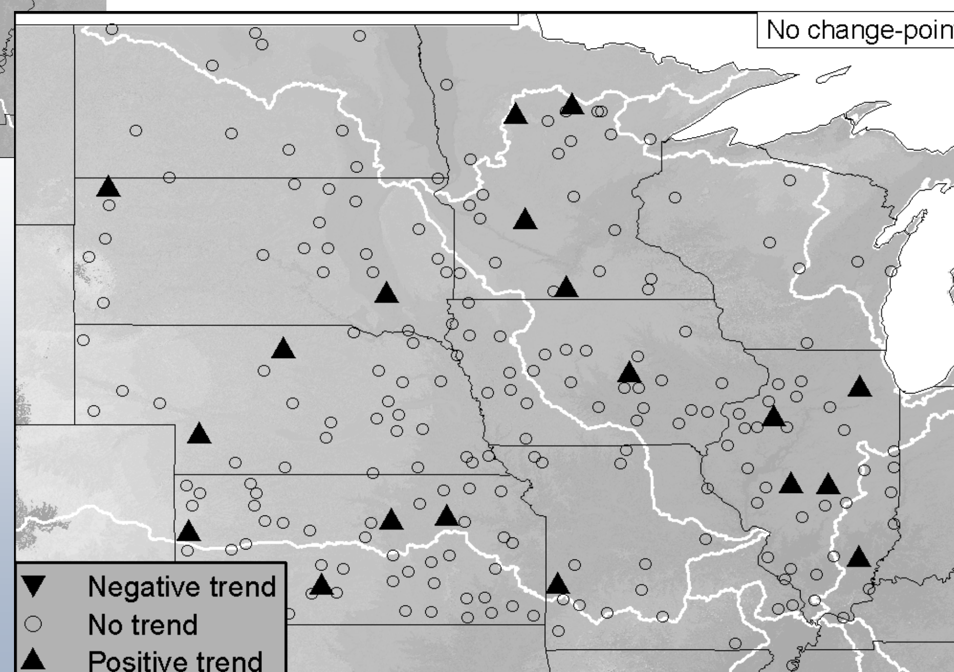
Trend Analyses: after cp (Eastern US)



Extreme Rainfall: Central US



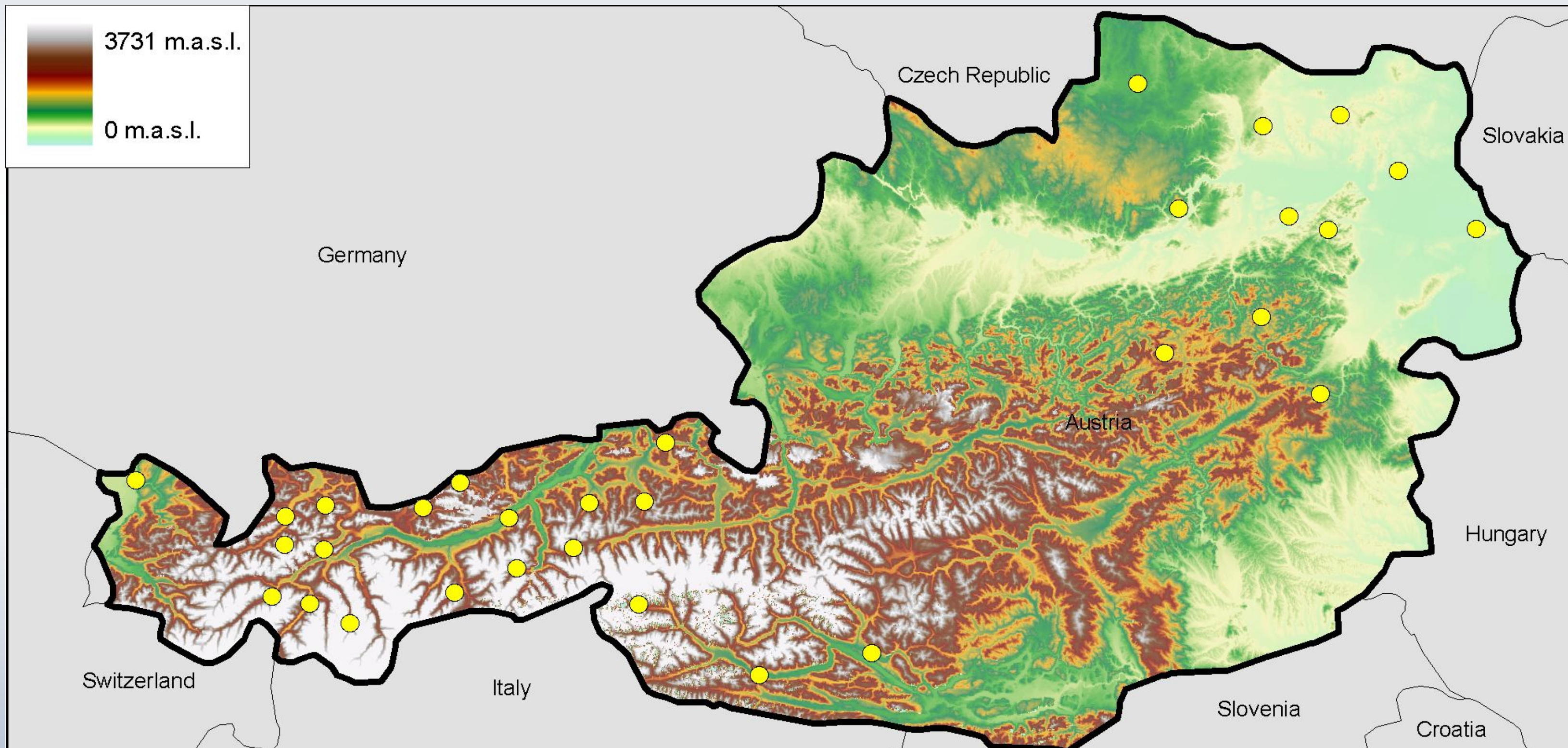
Analyses of 221 rain gages with at least 75 years of daily rainfall.



Villarini, G., J.A. Smith, M.L. Baeck, R. Vitolo, D.B. Stephenson, and W.F. Krajewski On the frequency of heavy rainfall for the Midwest of the United States, *Journal of Hydrology*, 2010 (submitted).

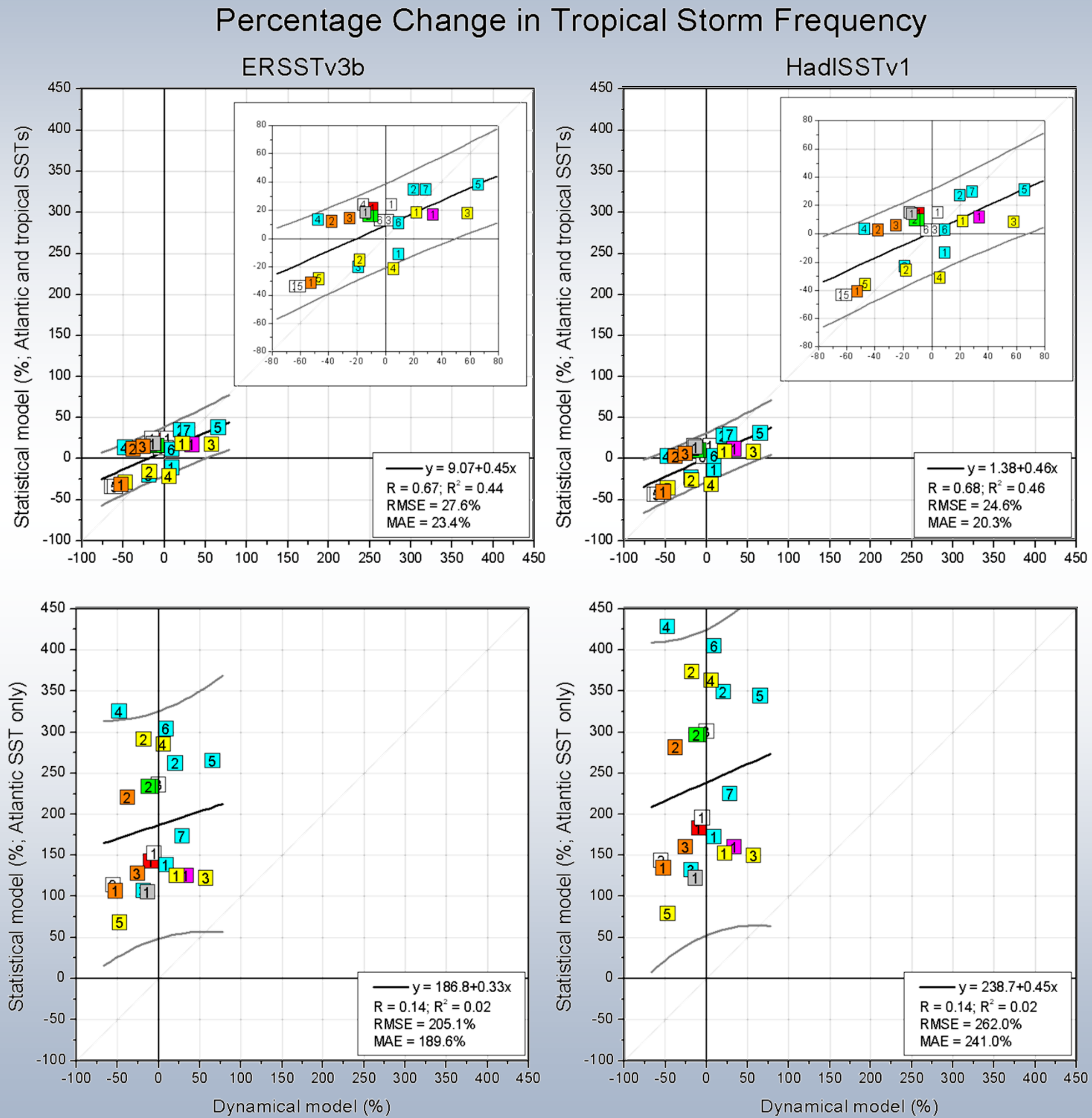
Extreme Rainfall: Austria

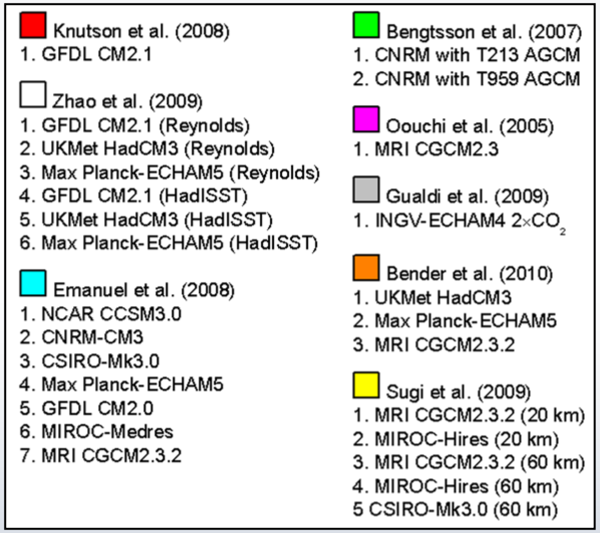
Analyses of 31 rain gages with at least 50 years of daily rainfall.



Villarini, G., J.A. Smith, A.A. Ntelekos, and U. Schwarz, Annual maximum and peaks-over-threshold analyses of daily rainfall accumulations for Austria, *Journal of Geophysical Research*, 2010 (submitted).

Tropical Storms: Climate Projections





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