Trends in heavy precipitation/flooding in Chicago

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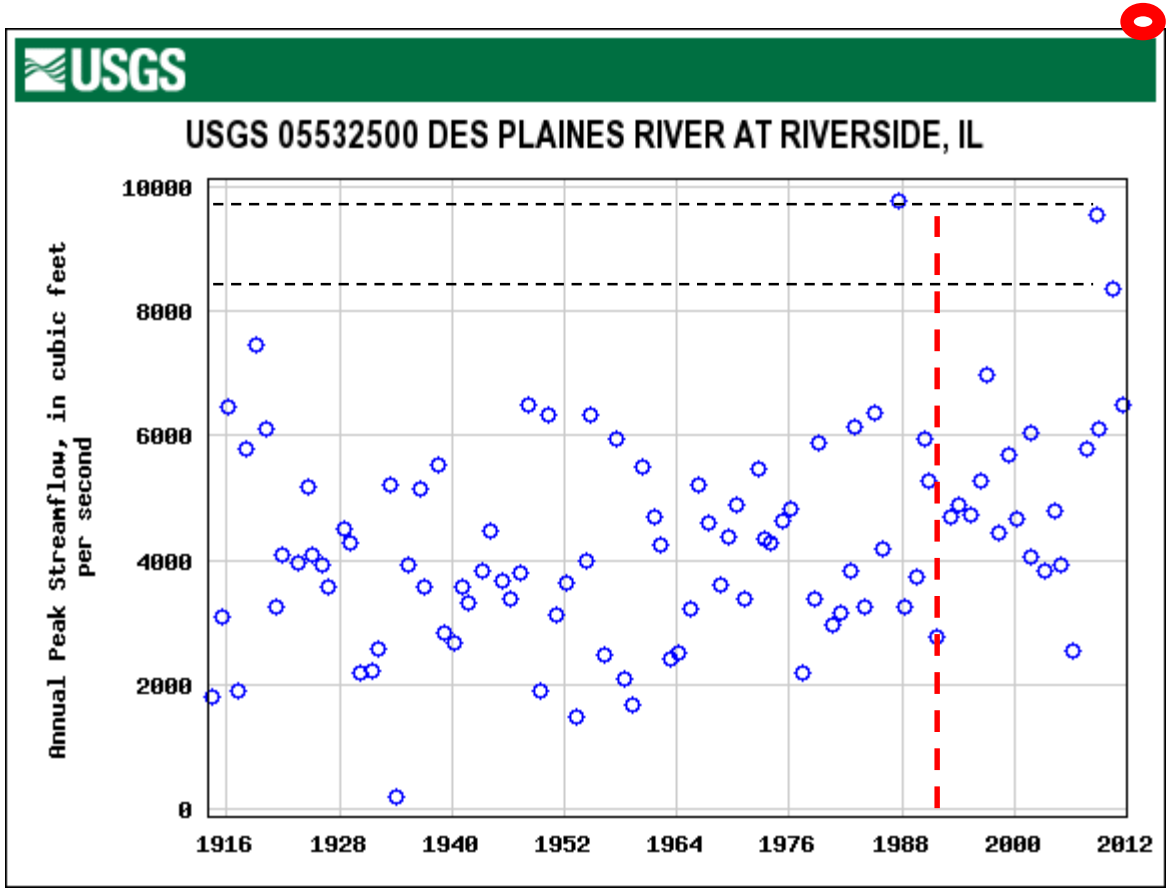
Outline

- Past trends in heavy rainfall and flooding
- Future trends (climate models) (statistical downscaling and regional climate modeling)
- North-south separation in Chicago
- Some notes on uncertainty
- Adequacy of the standard methods

Flood peaks and precipitation trends in the Chicago area

Des Plaines River April 18, 2013

Des Plaines River at Riverside



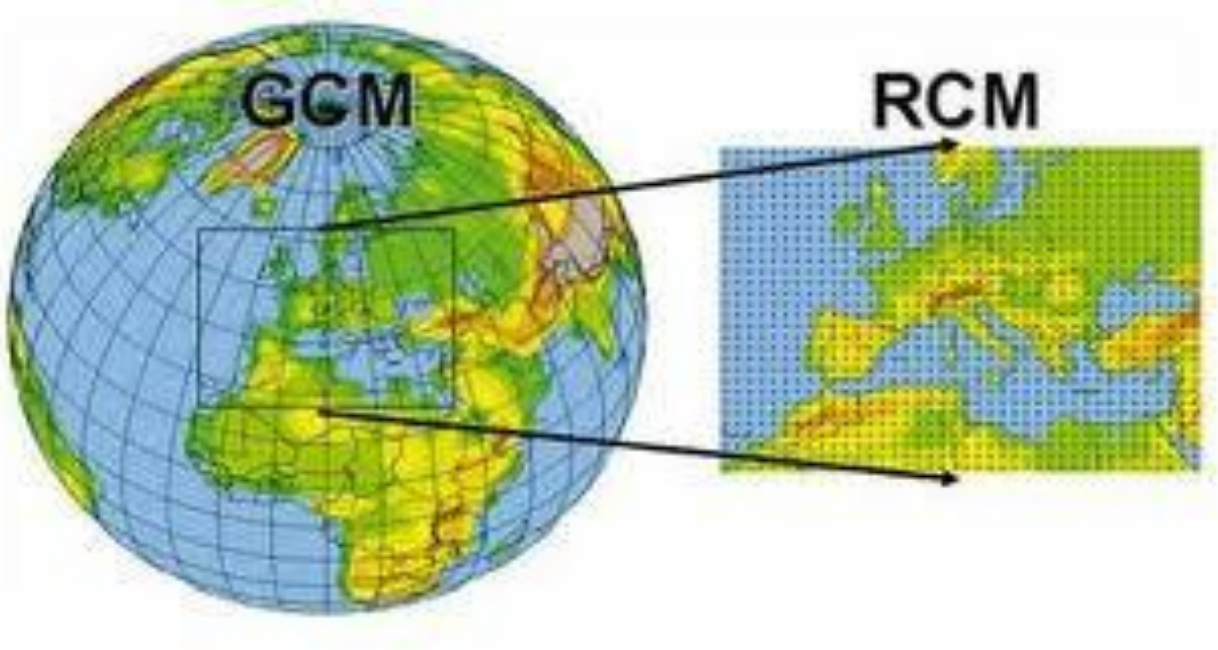
April 2013

500-yr

100-yr

Future flood risk

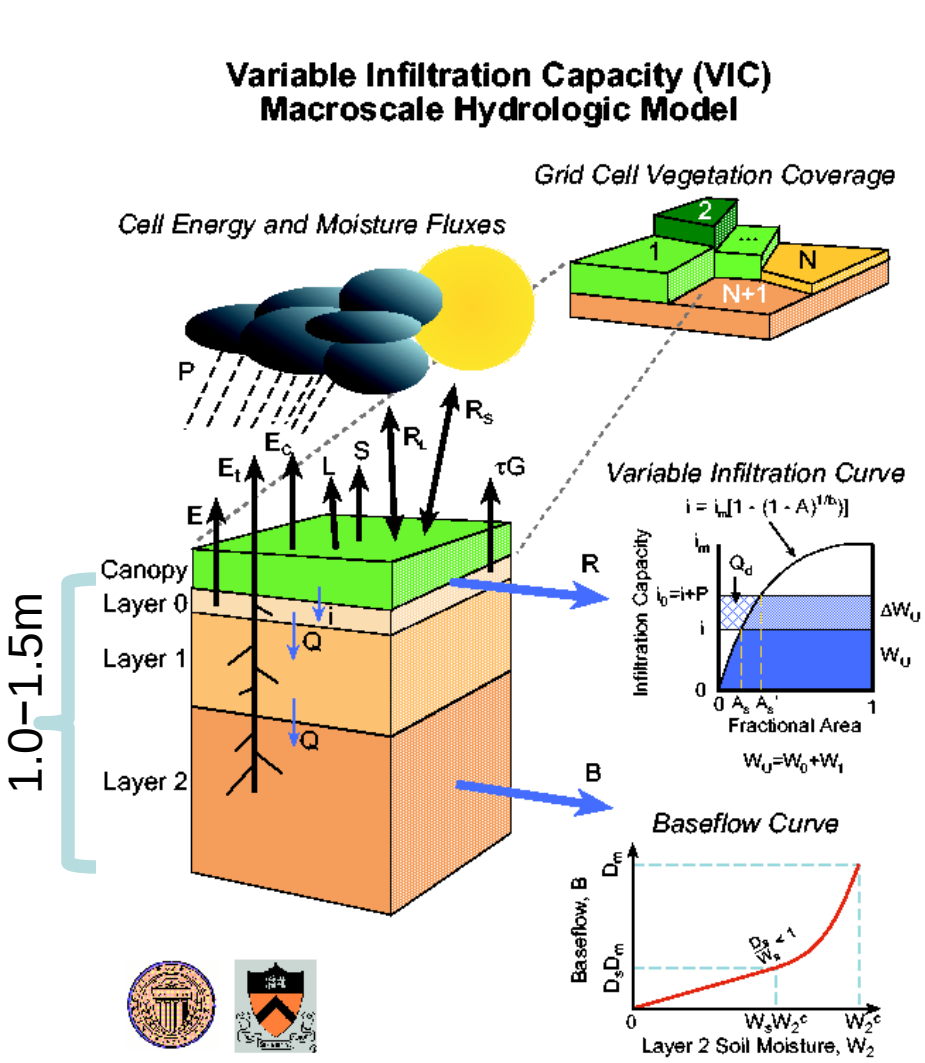
- Calculations are based on future climate projections of climatic data generated by GCM's and downscaled to watershed scale using statistical (or dynamical RCM) downscaling methods.

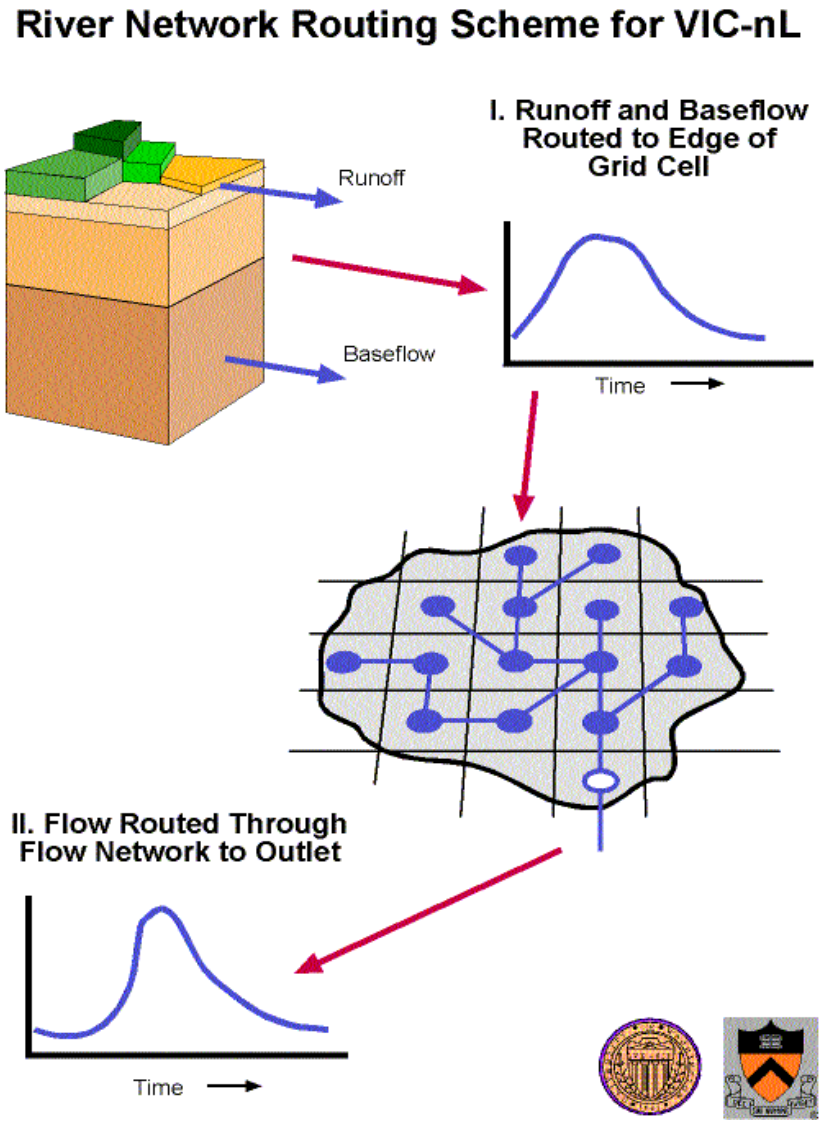


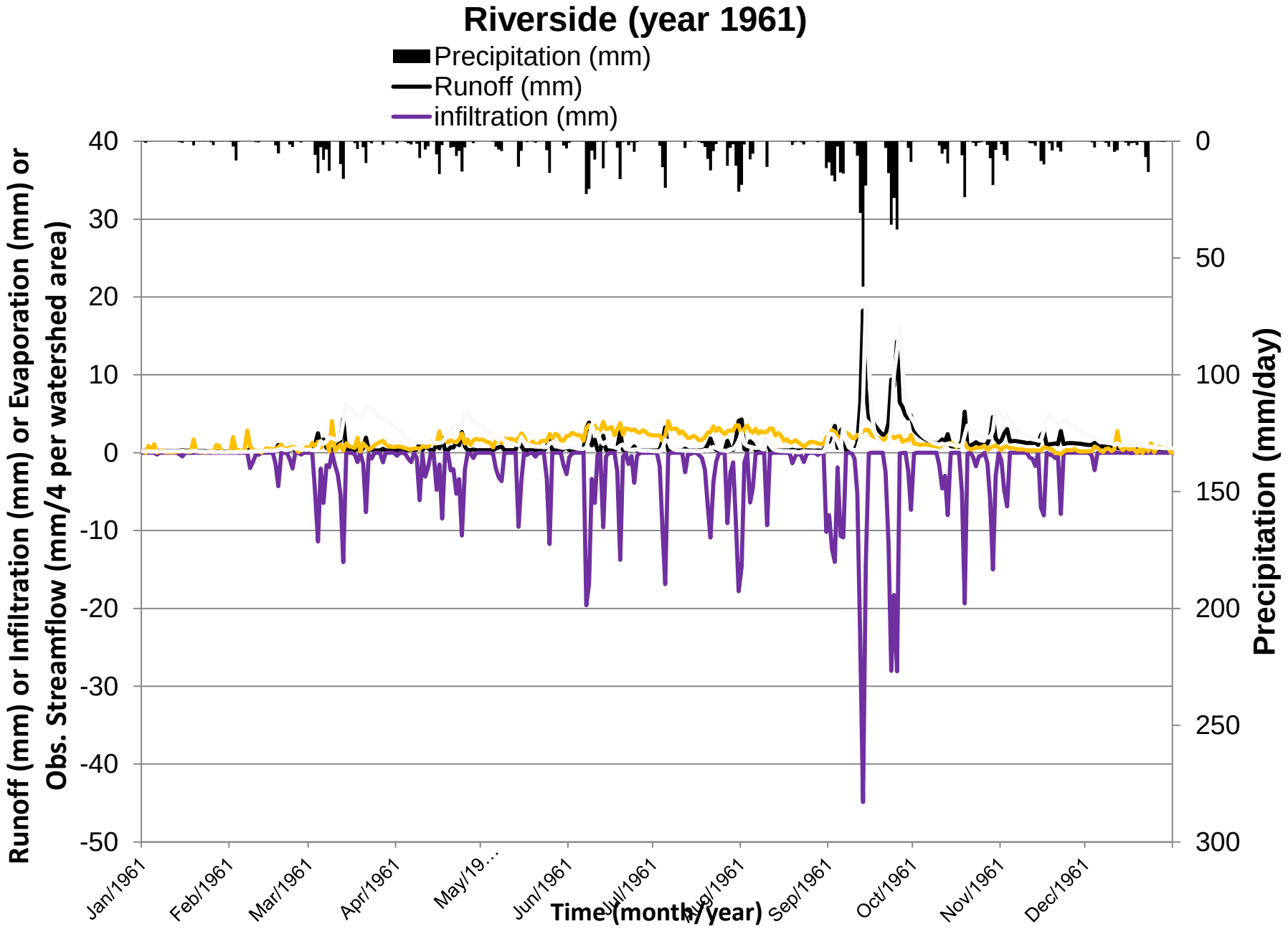
Climate downscaling

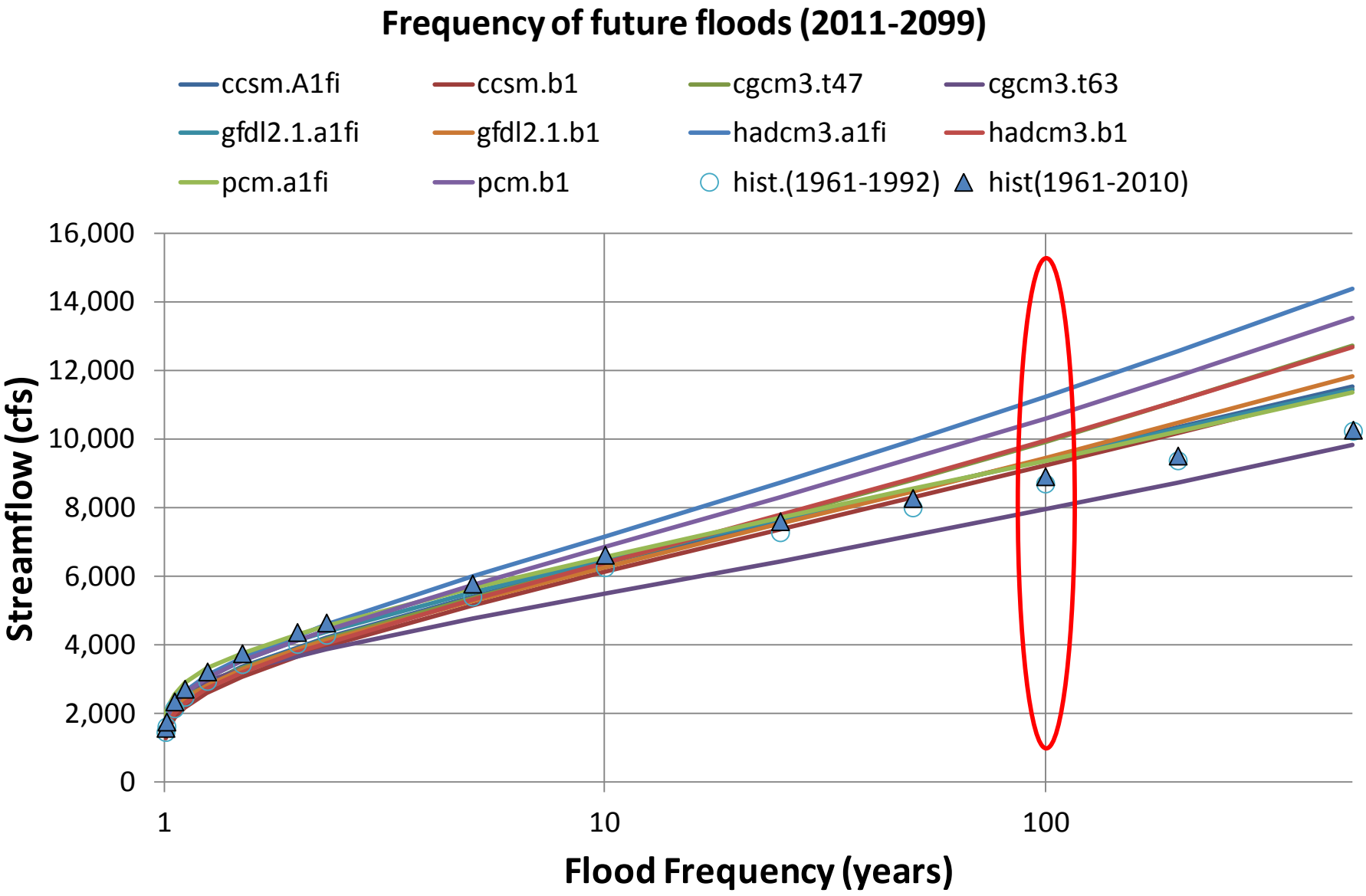
- These future climatic data (precipitation and temperature) are used as inputs to hydrologic models to simulate hypothetical future flood flows.
- Then, the flows are analyzed statistically to produce 2- to 100-year events.

Variable Infiltration Capacity (VIC) Model





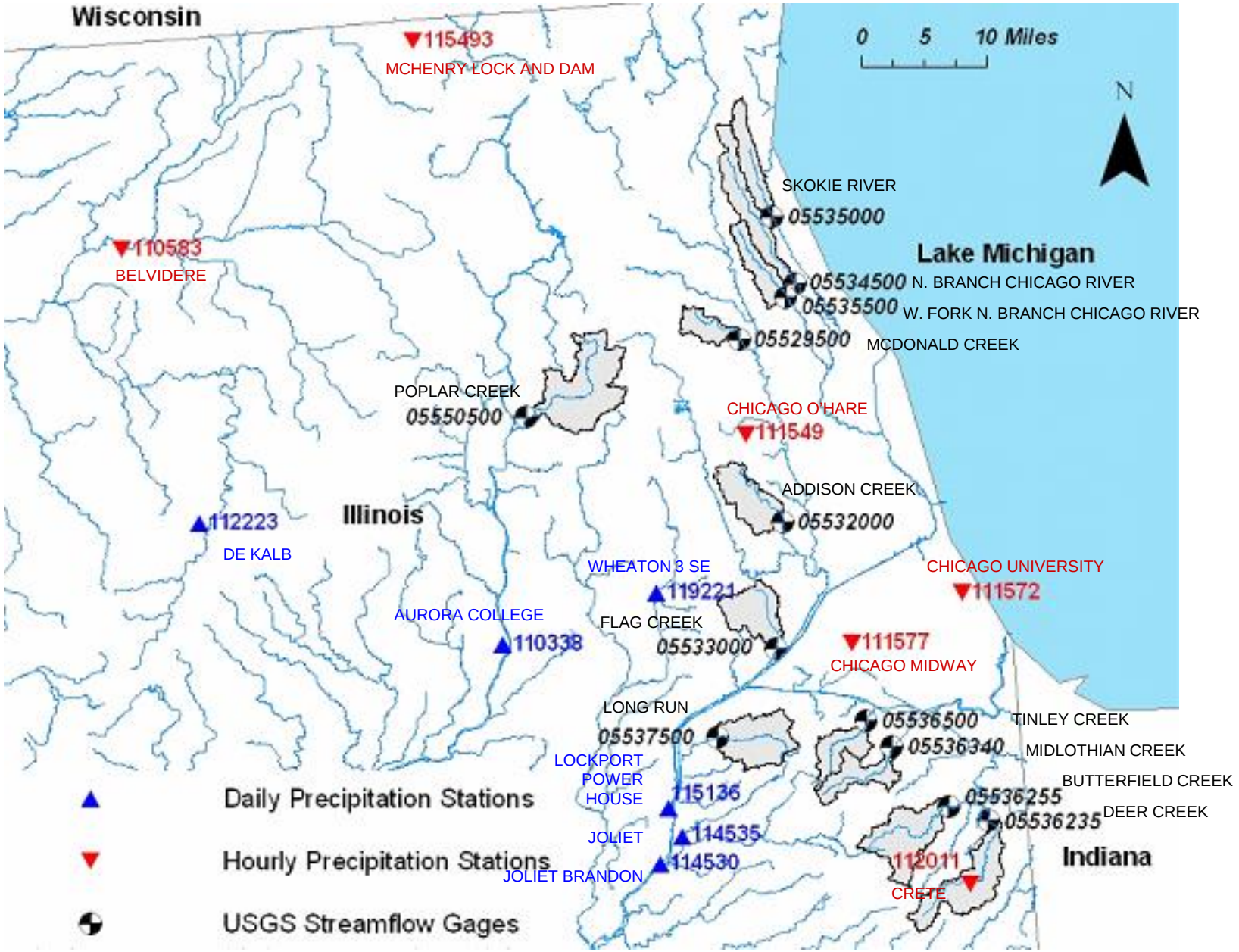

Riverside (year 1961)
Precipitation (mm)
Runoff (mm)
infiltration (mm)
Runoff (mm) or Infiltration (mm) or Evaporation (mm) or Obs. Streamflow (mm/4 per watershed area)
Precipitation (mm/day)
Time (month/year)
40
30
20
10
0
-10
-20
-30
-40
-50
0
50
100
150
200
250
300
Jan/1961
Feb/1961
Mar/1961
Apr/1961
May/19…
Jun/1961
Jul/1961
Aug/1961
Sep/1961
Oct/1961
Nov/1961
Dec/1961


Frequency of future floods (2011-2099)
ccsm.A1fi
ccsm.b1
cgcm3.t47
cgcm3.t63
gfdl2.1.a1fi
gfdl2.1.b1
hadcm3.a1fi
hadcm3.b1
pcm.a1fi
pcm.b1
hist.(1961-1992)
hist(1961-2010)
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Streamflow (cfs)
1
10
100
Flood Frequency (years)

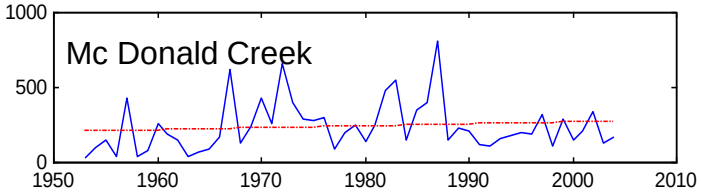
Des Plaines River at Riverside

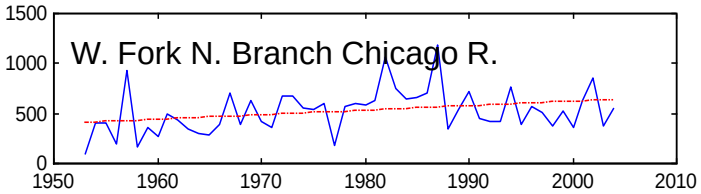
- The VIC model suggests that the 100-year flood peak for 2100 will be approximately 15% higher than the present estimate.
- The land use was kept unchanged to isolate the effects of future projected precipitation. Future urbanization could cause additional increase in flooding.

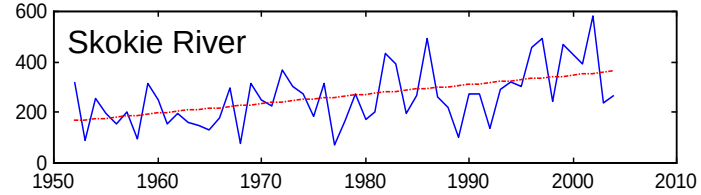
Example: Twelve urban watersheds in Chicago

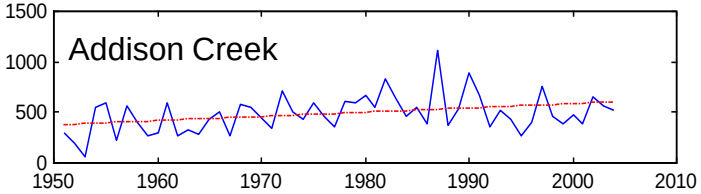


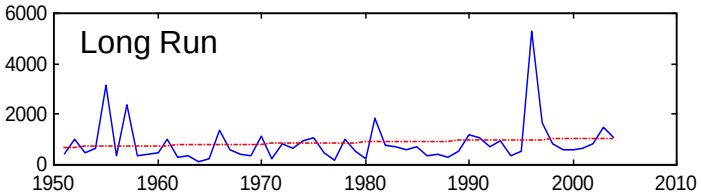
Maximum Annual Flood Peaks (cfs)

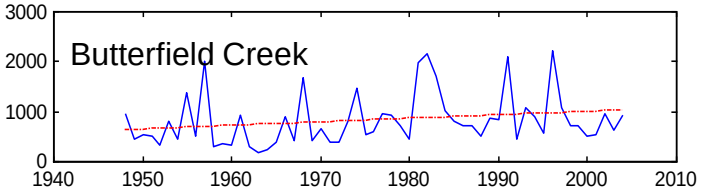


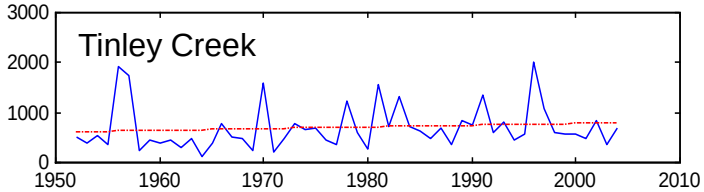


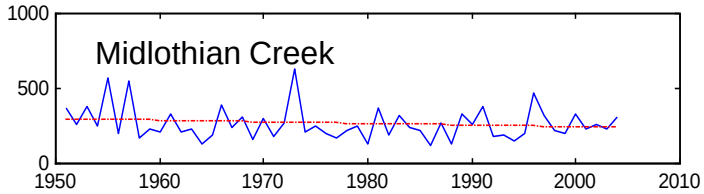


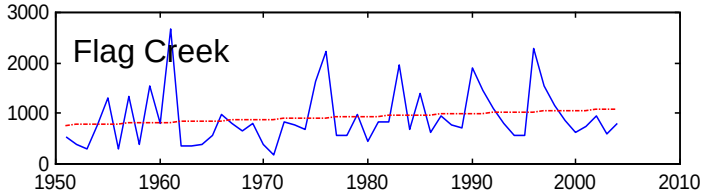


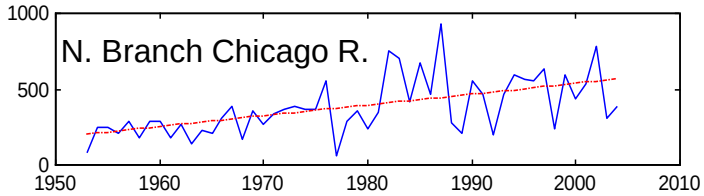


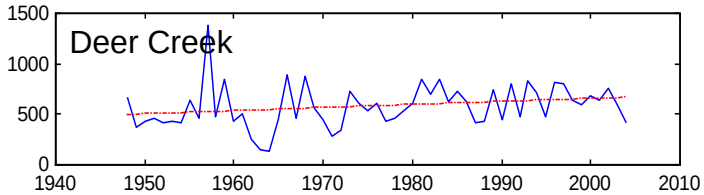


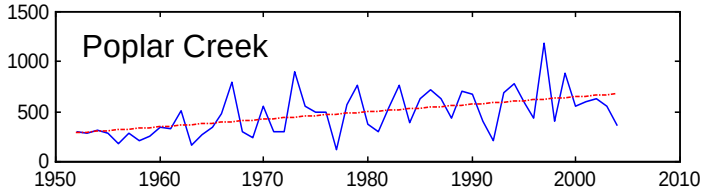












Statistical Significance of Trends

(Shaded areas indicate statistically significant trends)

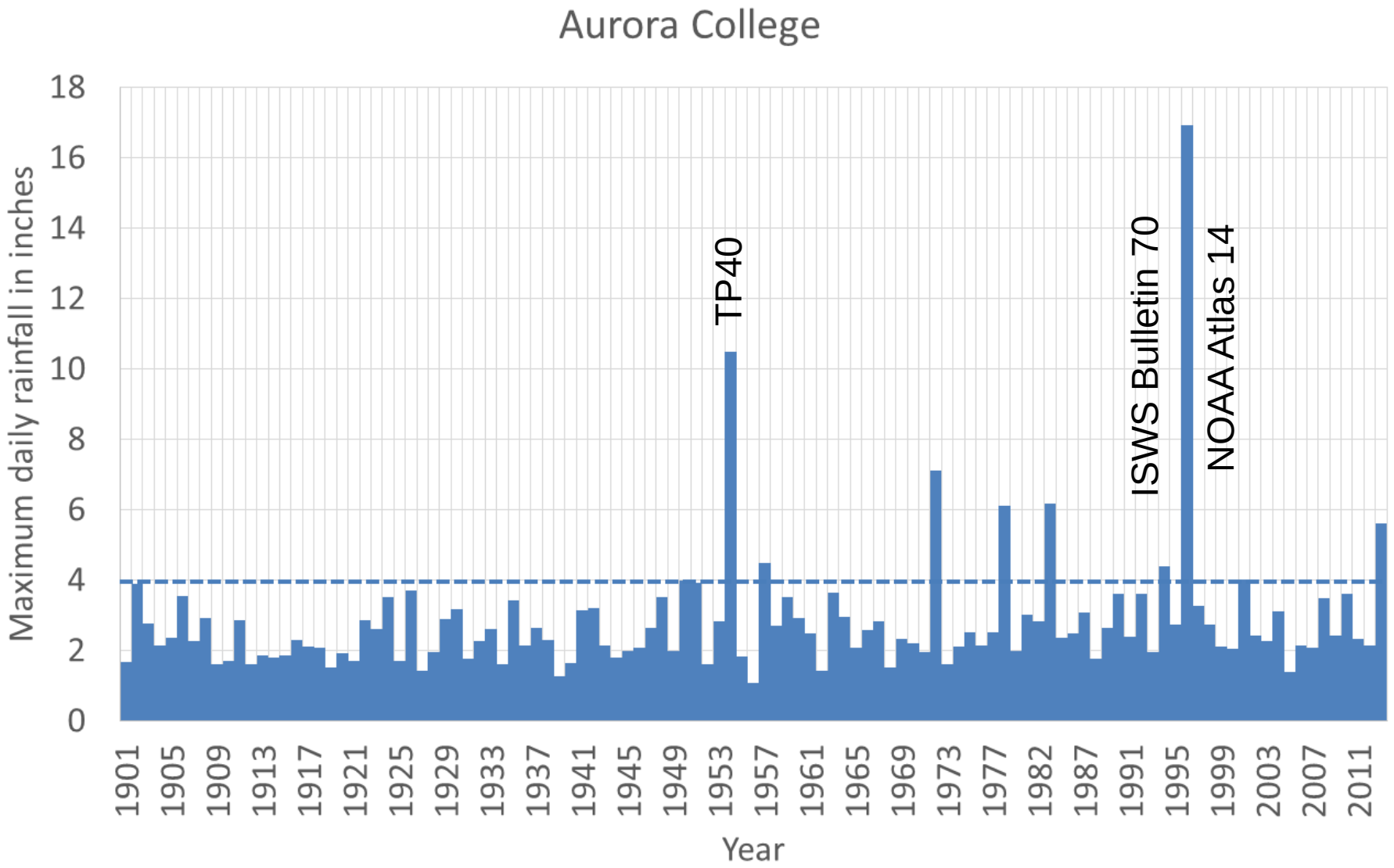
USGS Station	Stream Name	Kendal τ	Confidence Level				
			80%	90%	95%	98%	99%
5529500	McDonald Creek	0.1373					
5536500	Tinley Creek	0.1792					
5535500	West Fork North Branch Chicago River	0.2300					
5536340	Midlothian Creek	-0.0552					
5535000	Skokie River	0.3215					
5533000	Flag Creek	0.1880					
5532000	Addison Creek	0.2313					
5534500	North Branch Chicago River	0.4351					
5537500	Long Run	0.1565					
5536235	Deer Creek	0.2218					
5536255	Butterfield Creek	0.1736					
5550500	Poplar Creek	0.3839					

Annual Flood Peaks Have Been Increasing

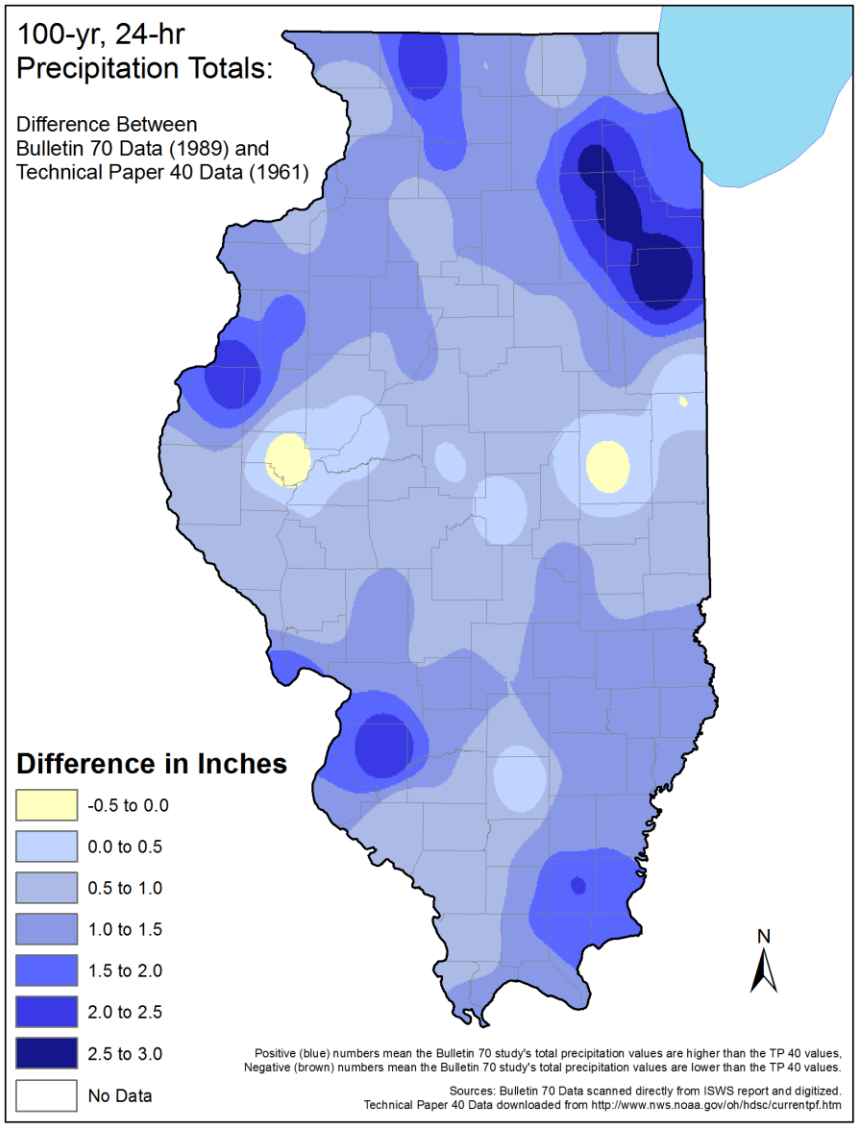
Why?

1. Extreme Precipitation

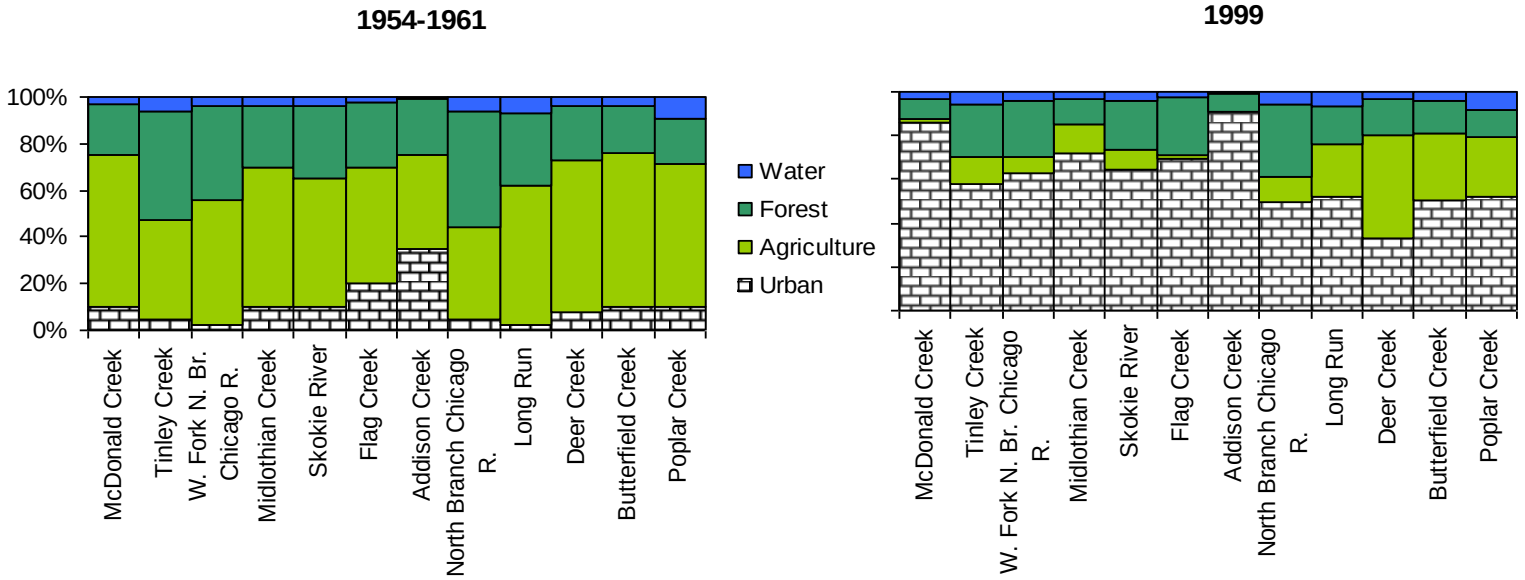
(none of the 11 largest values at Aurora College were observed prior to 1950)

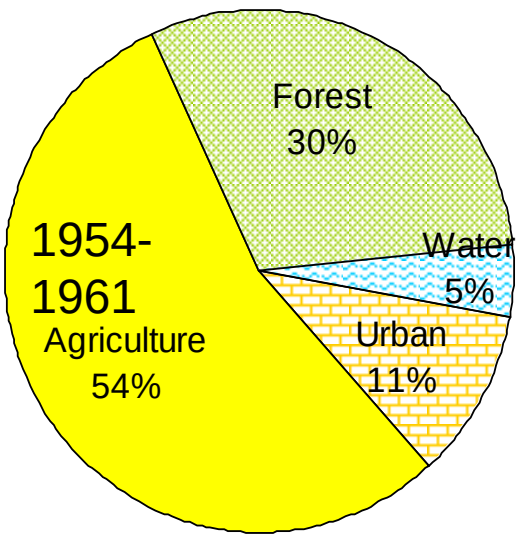


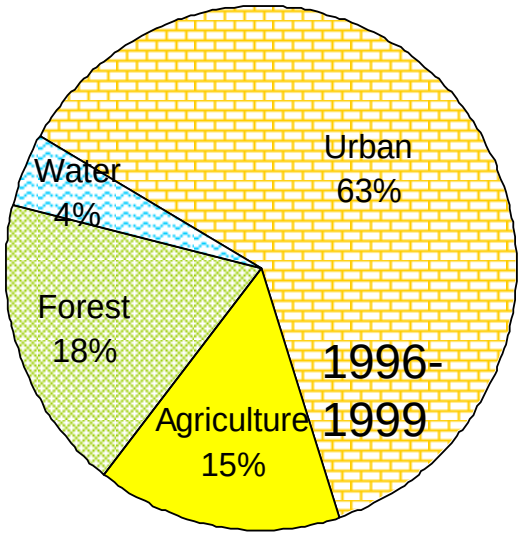
Difference between TP-40 and Bulletin 70



2. Significant urbanization in the 12 watersheds







North-south separation

- Three independent studies indicated that a north-south separation in the Chicago area exists:
  - Research paper on future climate in Chicago by Markus et al (2012) in Climatic Change
  - Analysis of data observed at Cook County Precipitation Network
  - NOAA Atlas 14 region definition

Climatic Change (2012) 111:879–902
DOI 10.1007/s10584-011-0172-z

Diagnostic analysis of future climate scenarios applied to urban flooding in the Chicago metropolitan area

Momcilo Markus · Donald J. Wuebbles · Xin-Zhong Liang · Katharine Hayhoe · David A. R. Kristovich

9 North-Southeast separation

In order to provide a possible physical explanation for differences in response to different climate scenarios between the north and southeast, one must consider the possibility that the differences are either portions of larger-scale synoptic patterns (e.g., the north being representative or a large region of increases) or due to local interactions between the circulations generated by Lake Michigan, the urban area of Chicago, and inland areas. Given the large differences in responses over such a short distance, it seems unlikely to be reflective of synoptic patterns in precipitation fields.

Change in Heavy Rainfall 2050 vs. 2000

(from: Markus et al, 2012, Climatic Change)

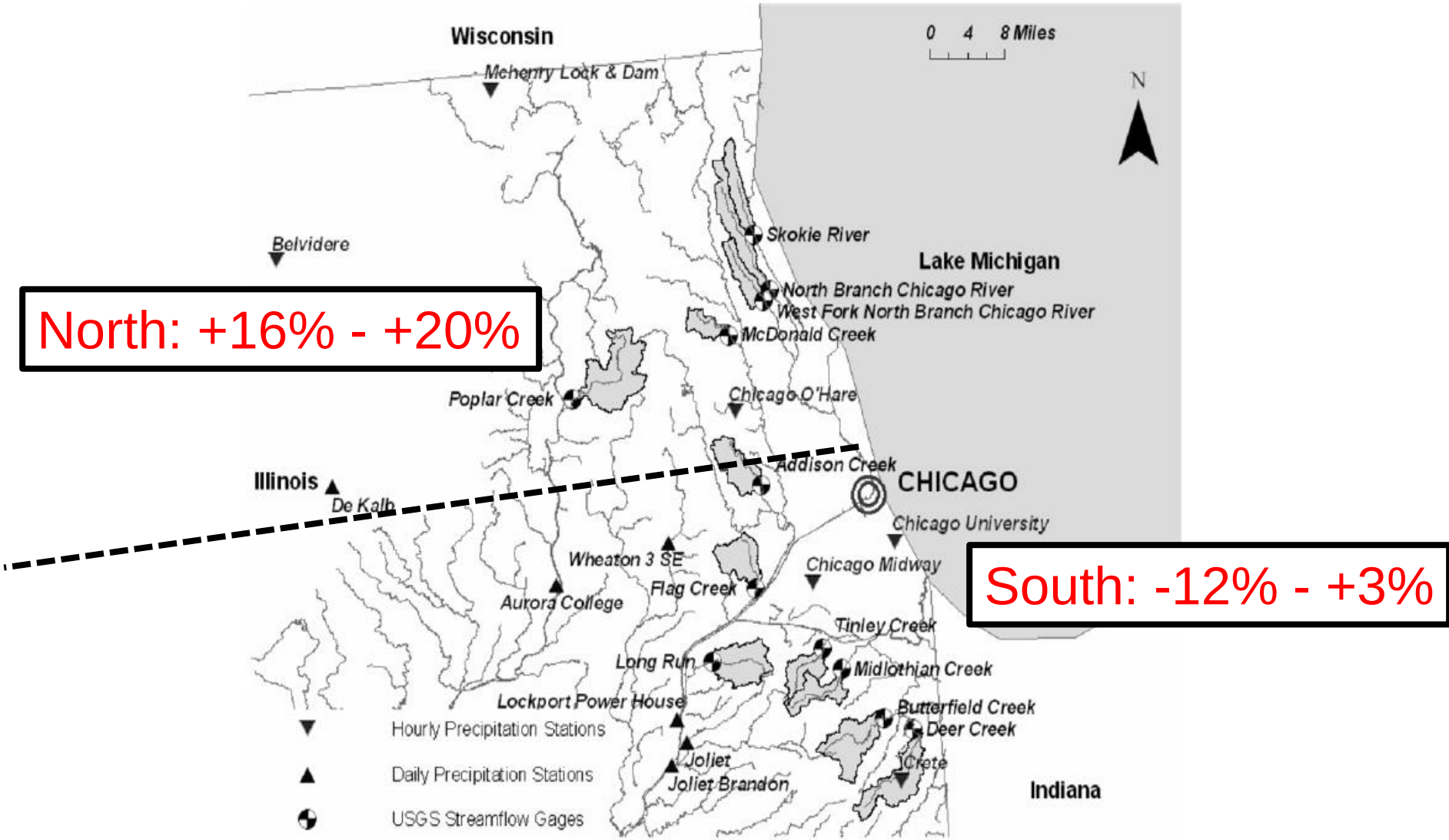
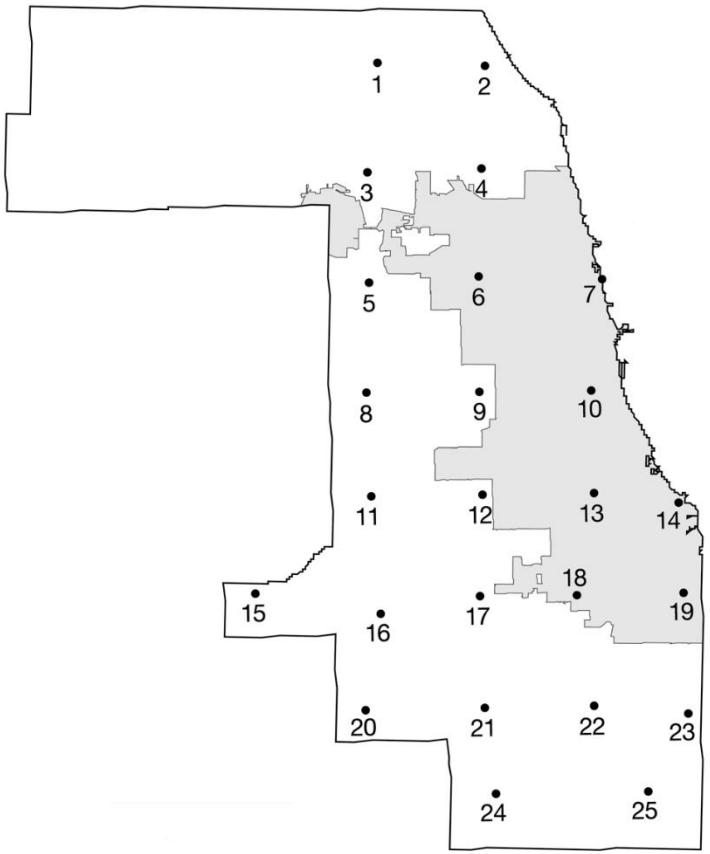


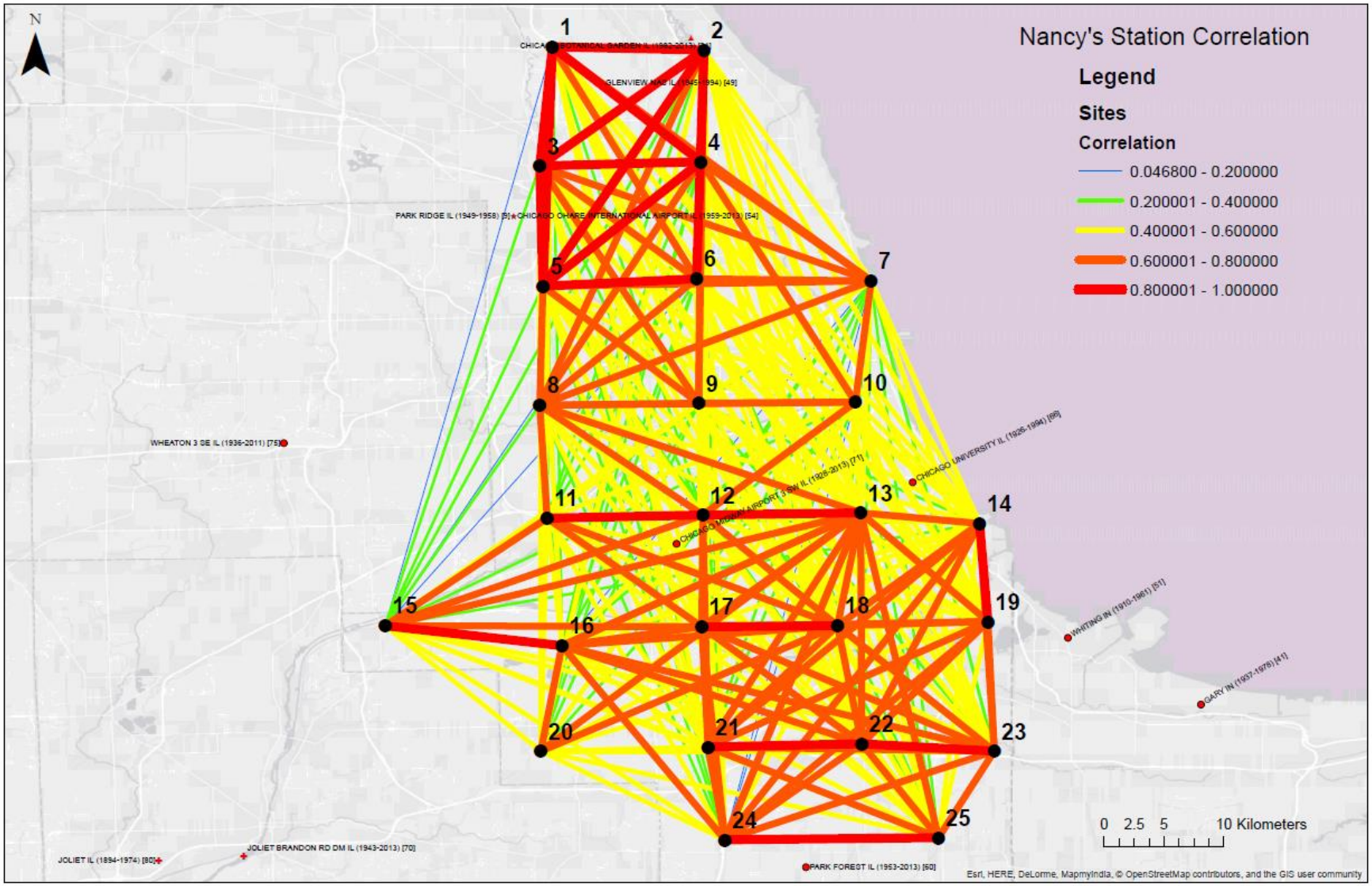
Figure 2 Location of watersheds and raingages.

Cook County Precipitation Network (CCPN)



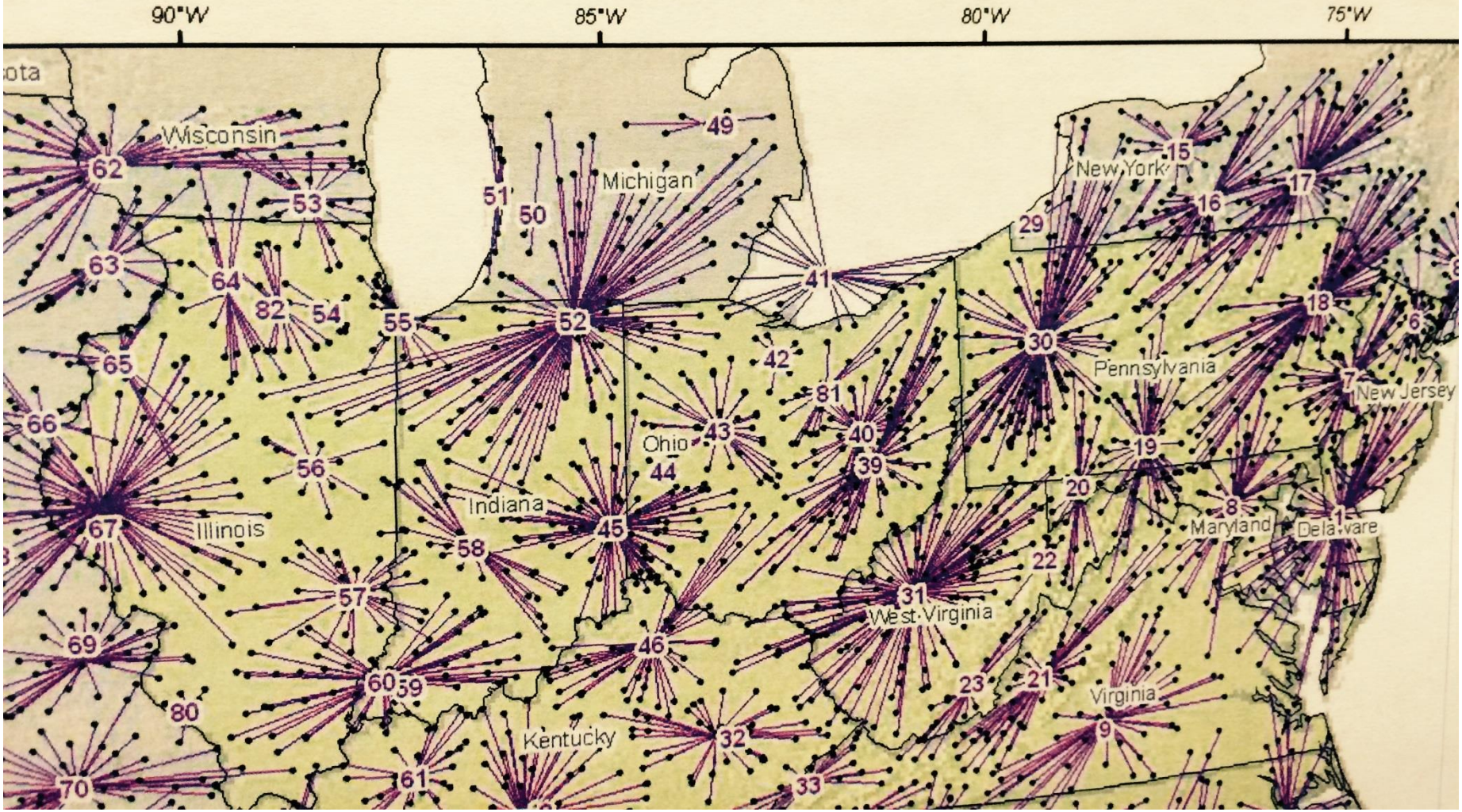
Spatial Correlations for CCPN

showing the north-south separation



NOAA Atlas 14 regions

showing the north-south separation in Chicago



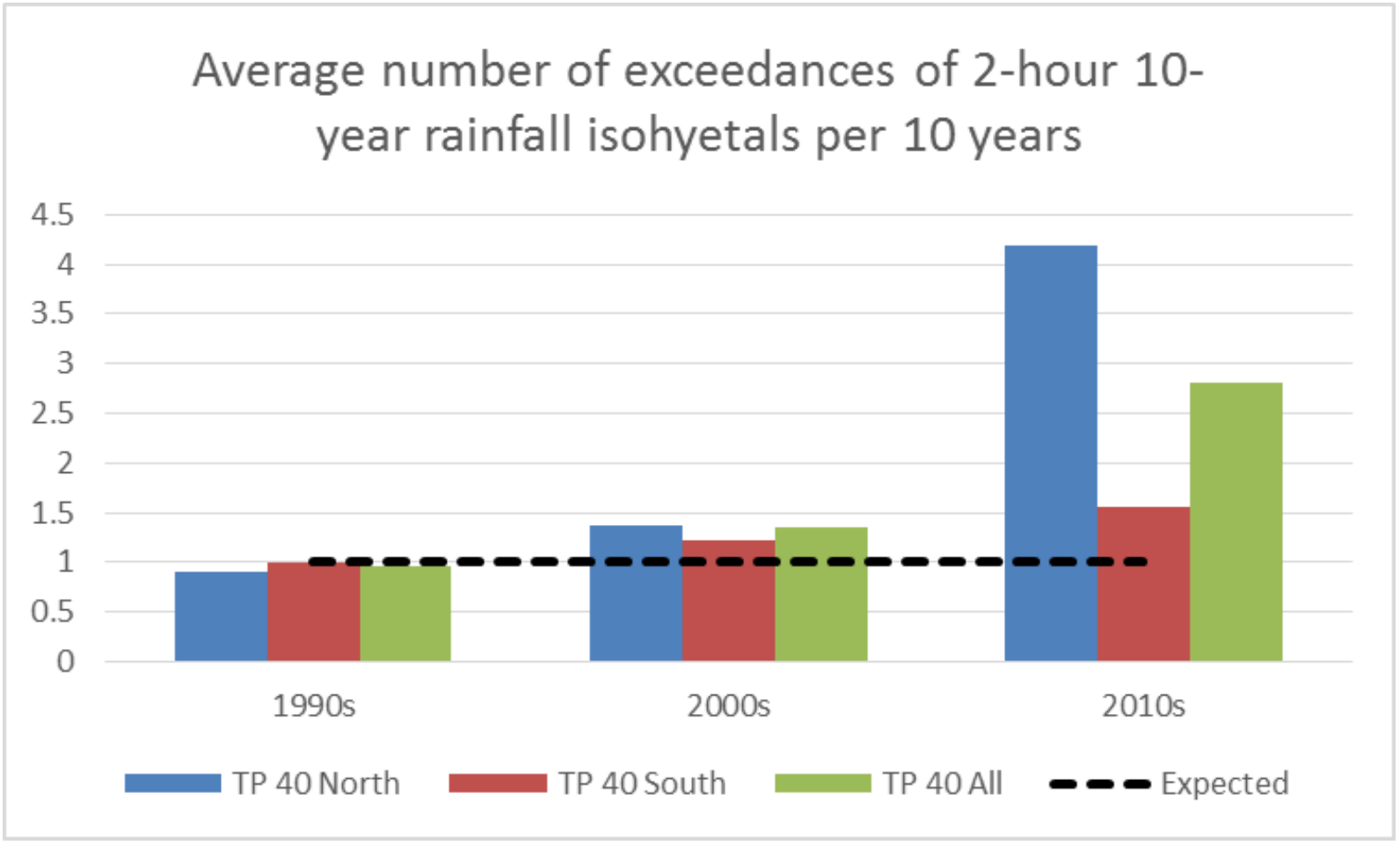
The importance of the north-south separation

Exceedances of TP-40 and Atlas 14

for the entire Cook County

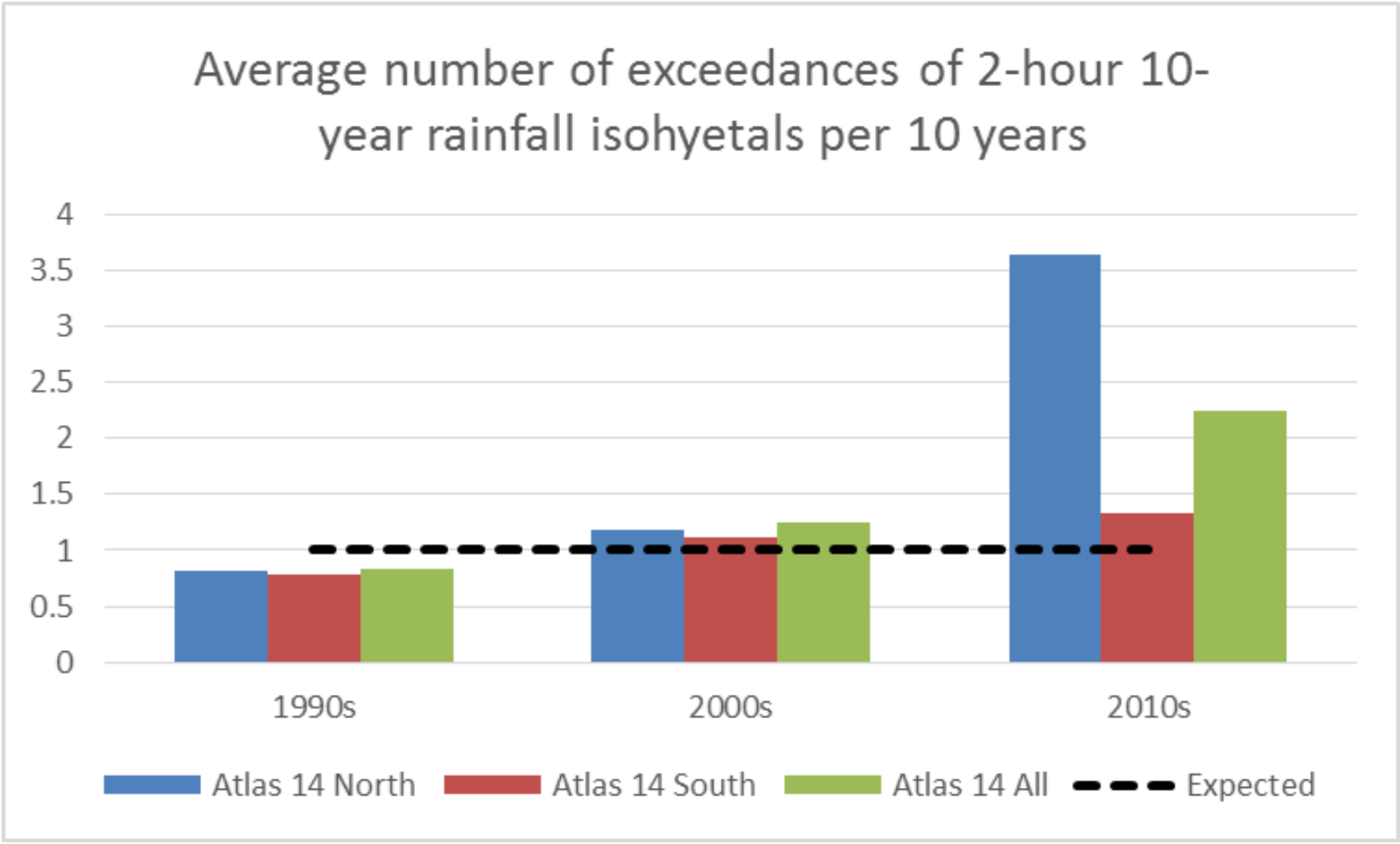
Exceedances of TP-40

for north and south



Exceedances of NOAA Atlas 14

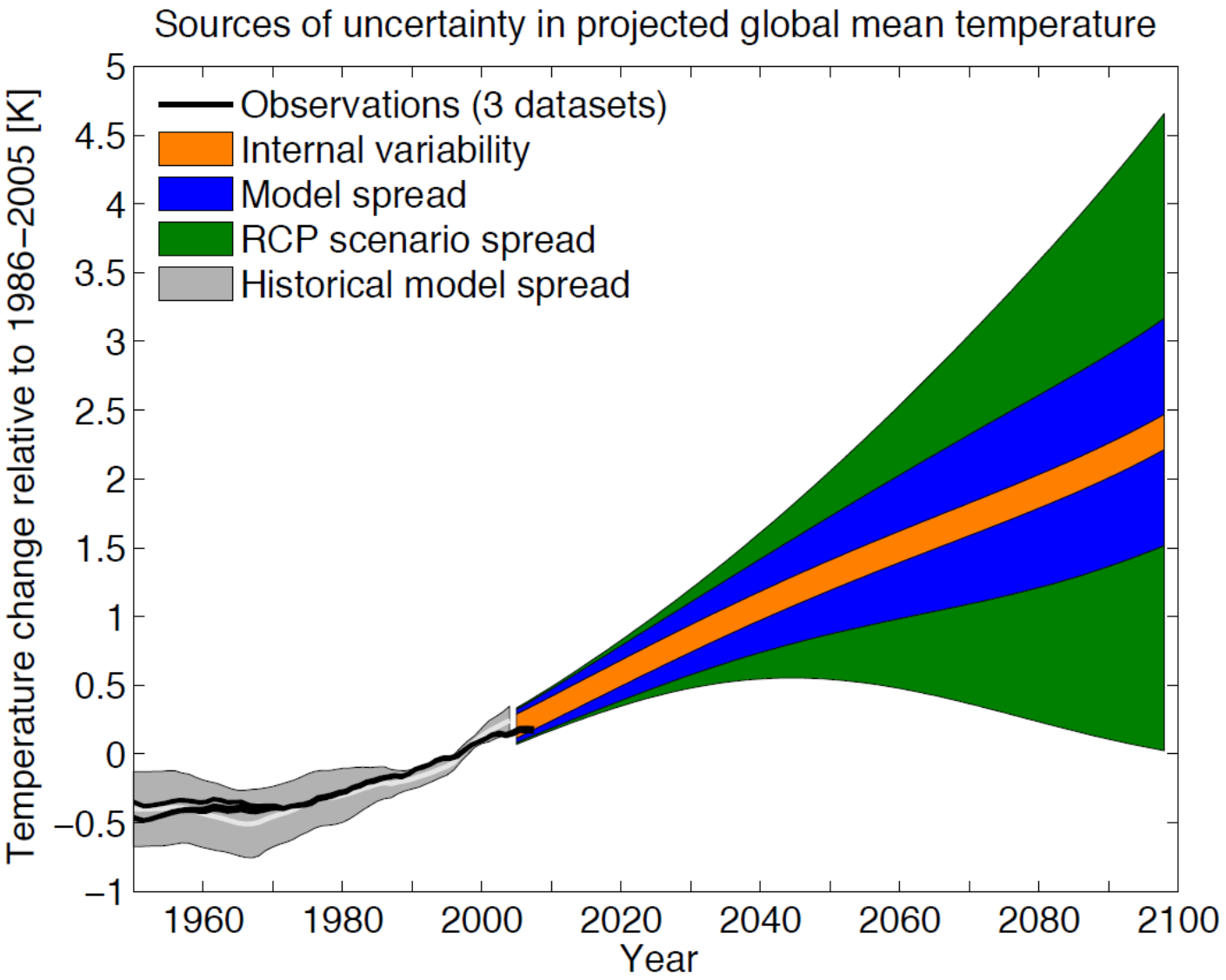
for north and south



Uncertainties

- Data observations
- Data aggregation
- Data downscaling
- Model structure
- Model calibration
- Initial conditions
- Future climate – the largest source of uncertainty
- Other

Future projected temperature and precipitation are uncertain



Predicted flood level

(confidence limits missing)

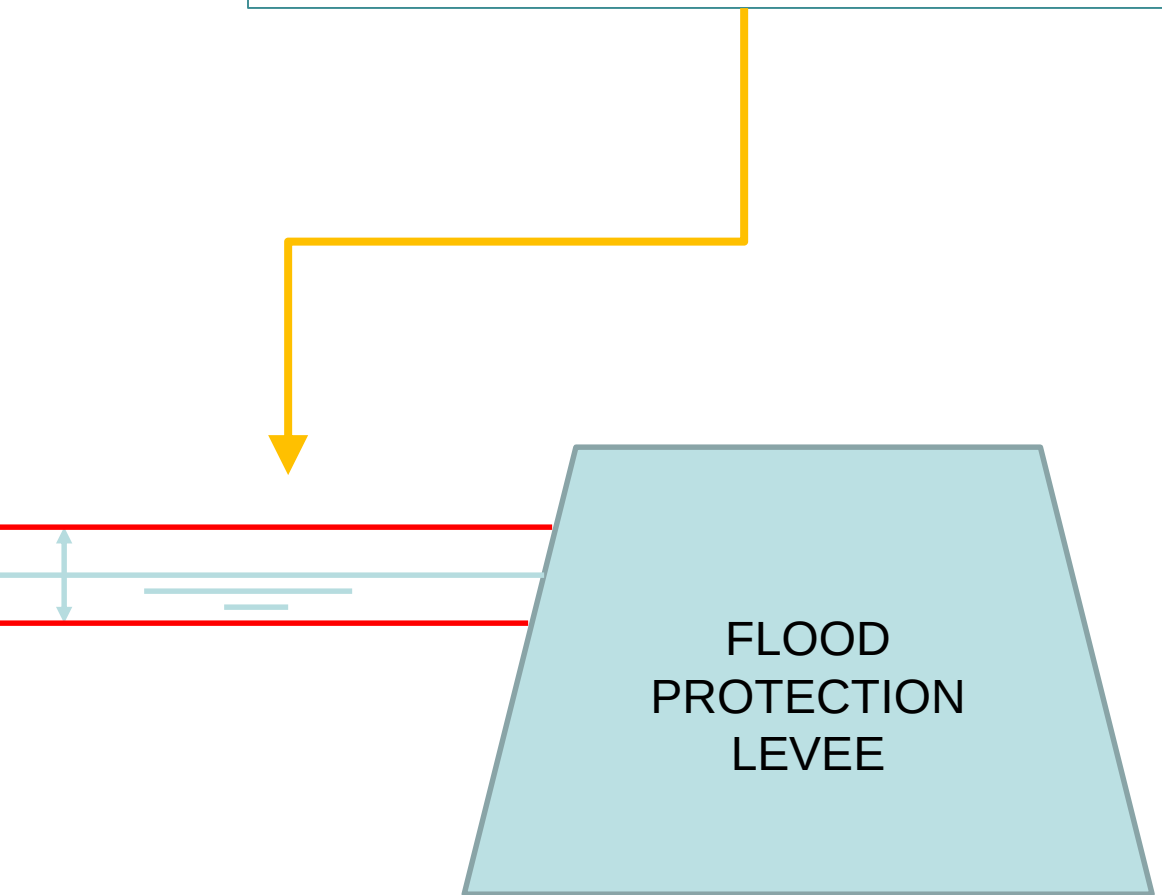
Predicted river stage

FLOOD
PROTECTION
LEVEE

Predicted flood level

(smaller confidence interval)

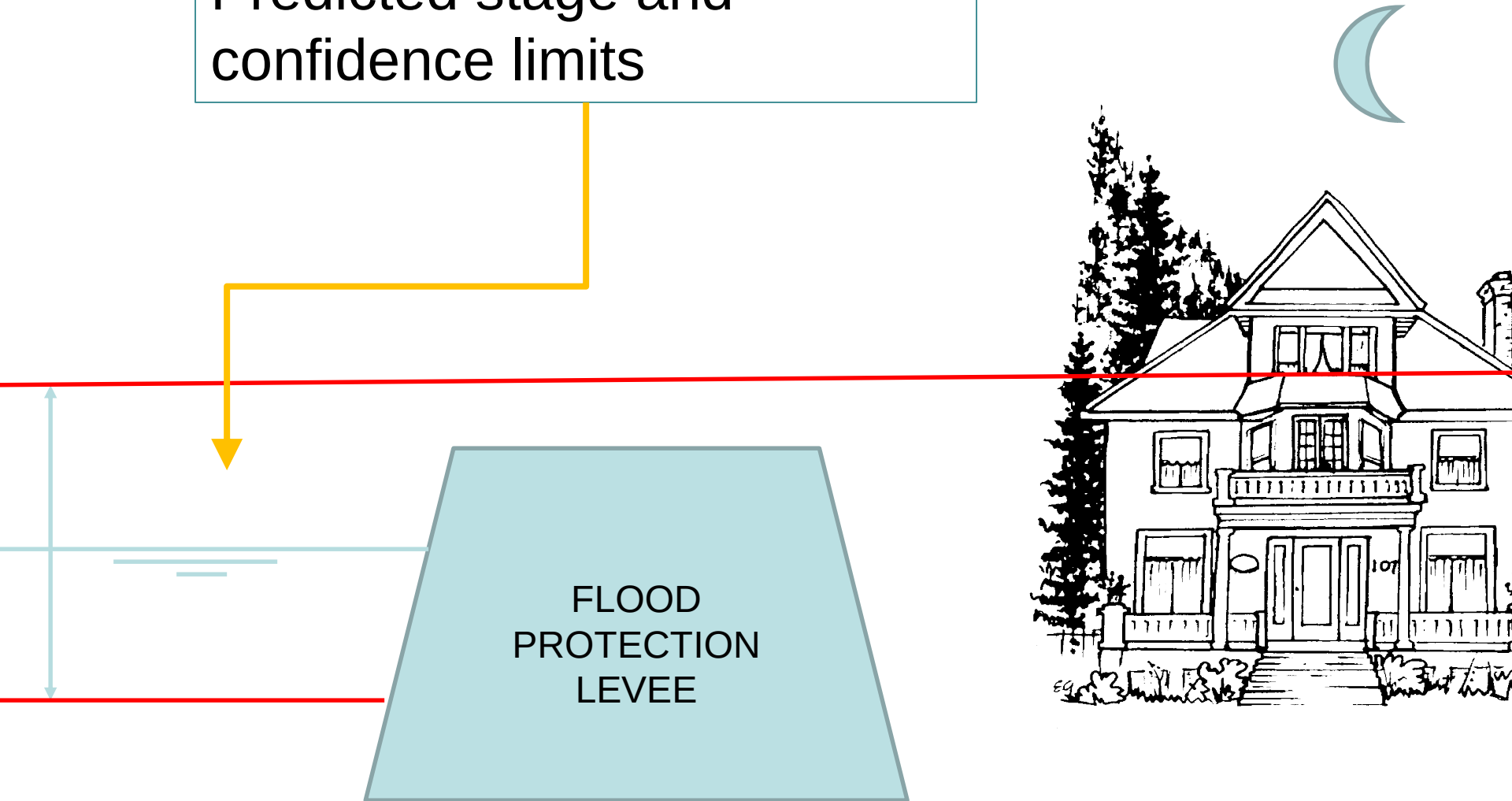
Predicted stage and confidence limits



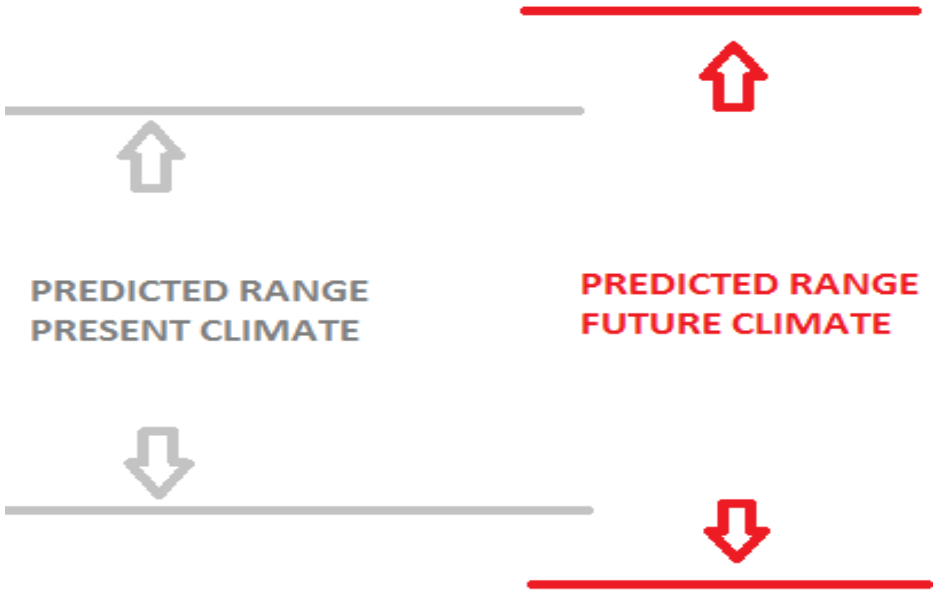
Predicted flood level

(larger confidence interval)

Predicted stage and confidence limits

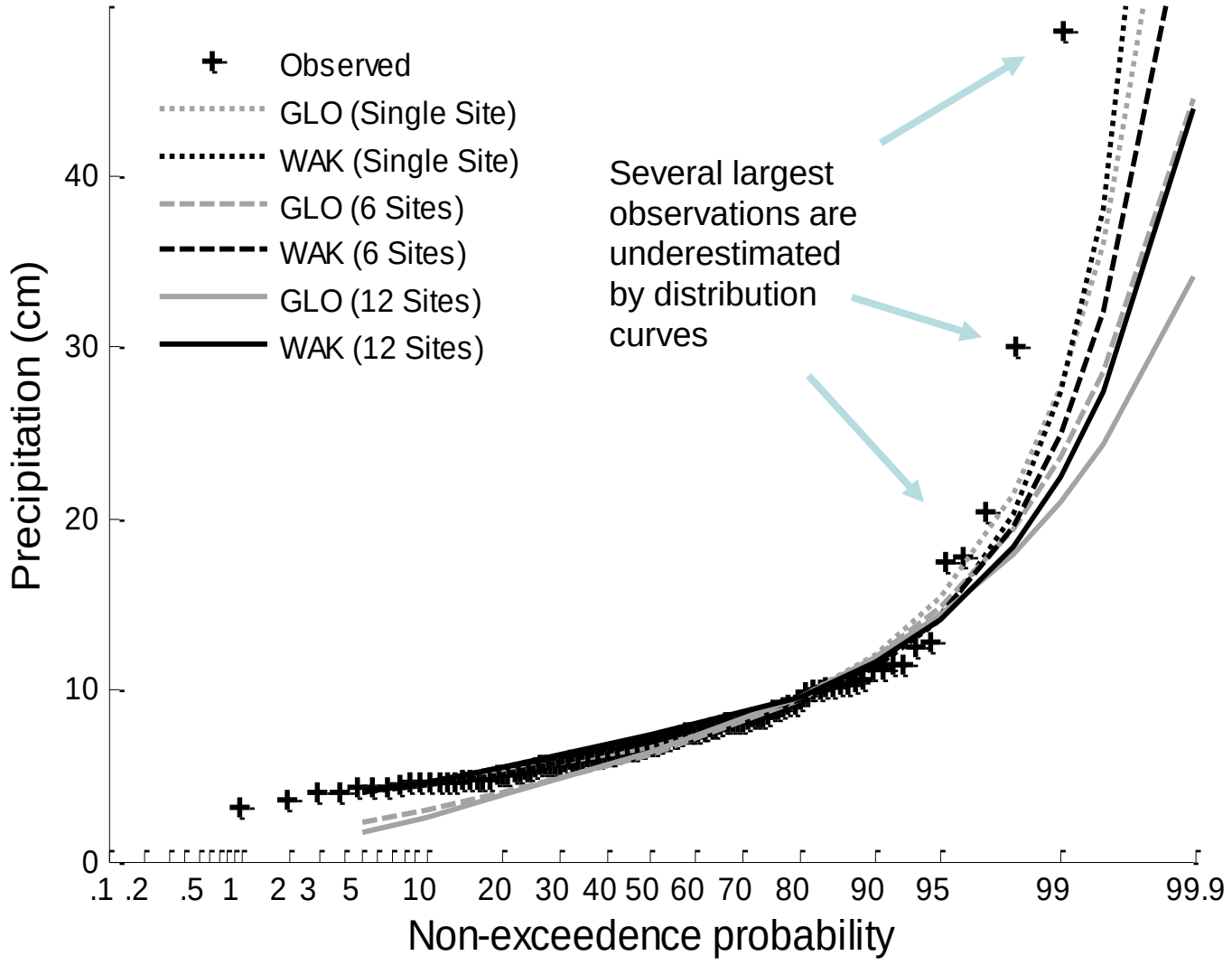


Uncertainty of future climates

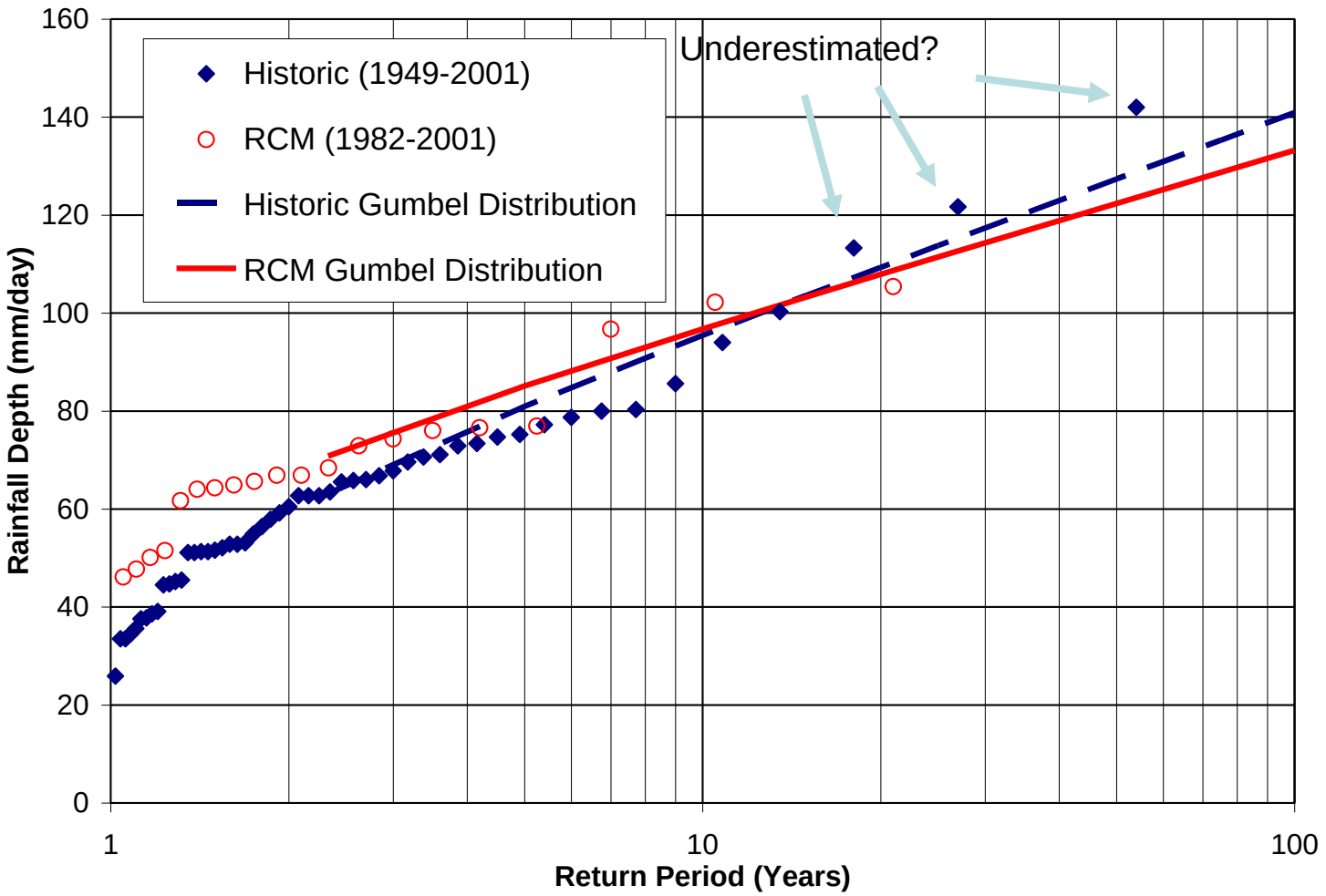


The standard methodology for rainfall frequency estimation may not be adequate

24-Hour Precipitation Annual Maximum Frequency Analysis Results for Aurora, IL.

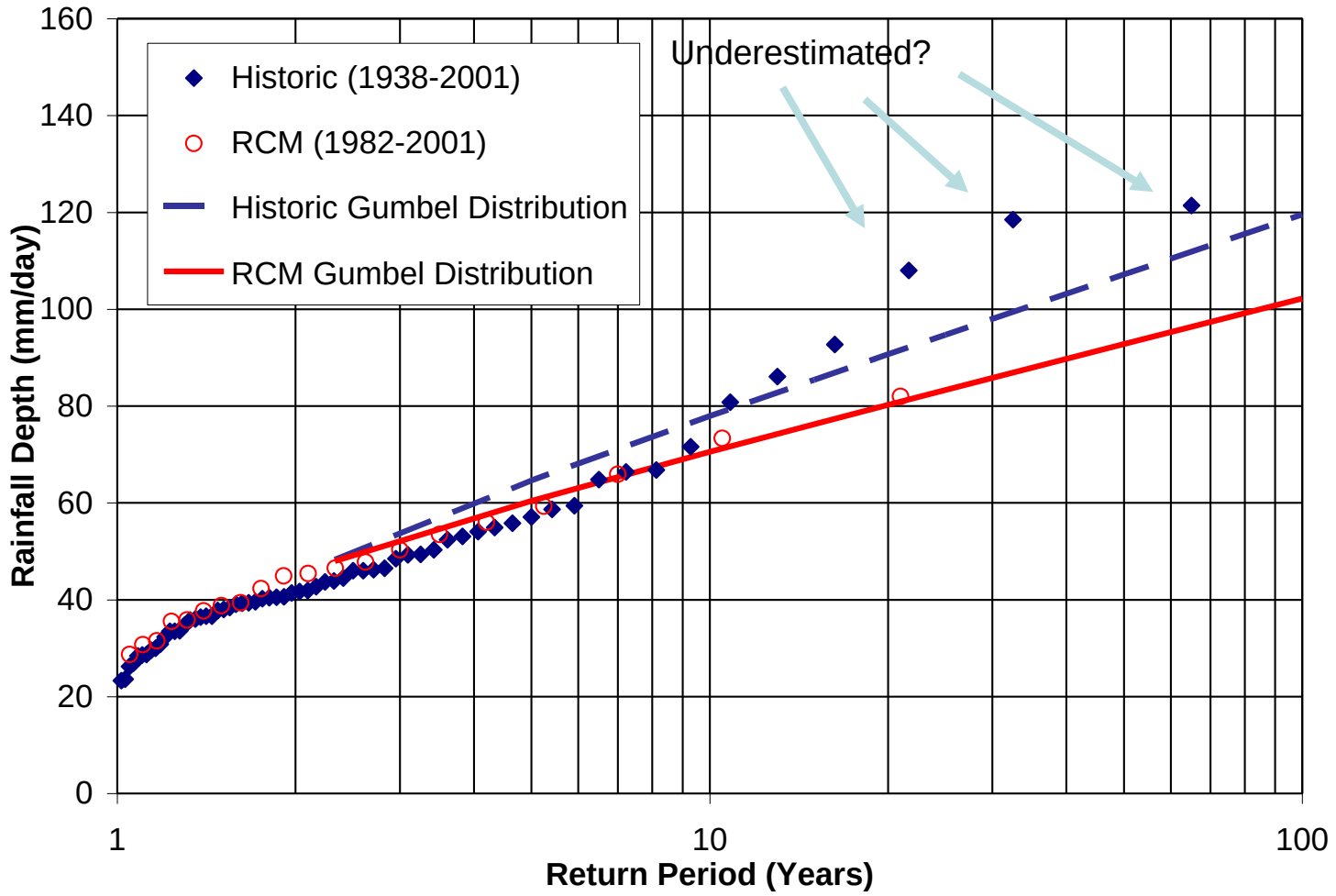


Comparison of 24-Hour Precipitation Annual Maximum Frequency Analysis Results for St. Louis, MO.



Guo, Y, and Senior, M.J., 2006, Climate Model Simulation of Point Rainfall Frequency Characteristics, J. of Hydrologic Eng., 11(6):547-554

Comparison of 24-Hour Precipitation Annual Maximum Frequency Analysis Results for Toronto, ON.



Guo, Y, and Senior, M.J., 2006, Climate Model Simulation of Point Rainfall Frequency Characteristics, J. of Hydrologic Eng., 11(6):547-554

The importance of accurate determination of design rainfall and design floods

- Practically all urban drainage structures are designed to fail from time to time, which minimizes their overall costs.
- Underestimating or overestimating the magnitude of design rainfall and design floods will result in higher costs.
- It is important to have accurate estimates of rainfall and flood magnitudes for different return periods.

Key Points

- Past data show increasing trends in intensity and frequency of heavy rainfall events in the Chicago area. Application of older design standards such as TP40 (1961) resulted in an undersized storm drainage infrastructure.
- Although these trends are observed in the entire Chicago area, they are more pronounced in the northern suburbs.
- Although climate projections are very uncertain, this uncertainty needs to be accounted for, rather than ignored.

Questions?

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