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Uncertainties in the Projections of Future Heavy Rainfall: Climate Non-stationarity and Urban Flood Risk in Greater Chicago

Momcilo Markus and Gregory Byard

University of Illinois at Urbana-Champaign

Report in Final Internal Review (funded by NOAA-SARP)

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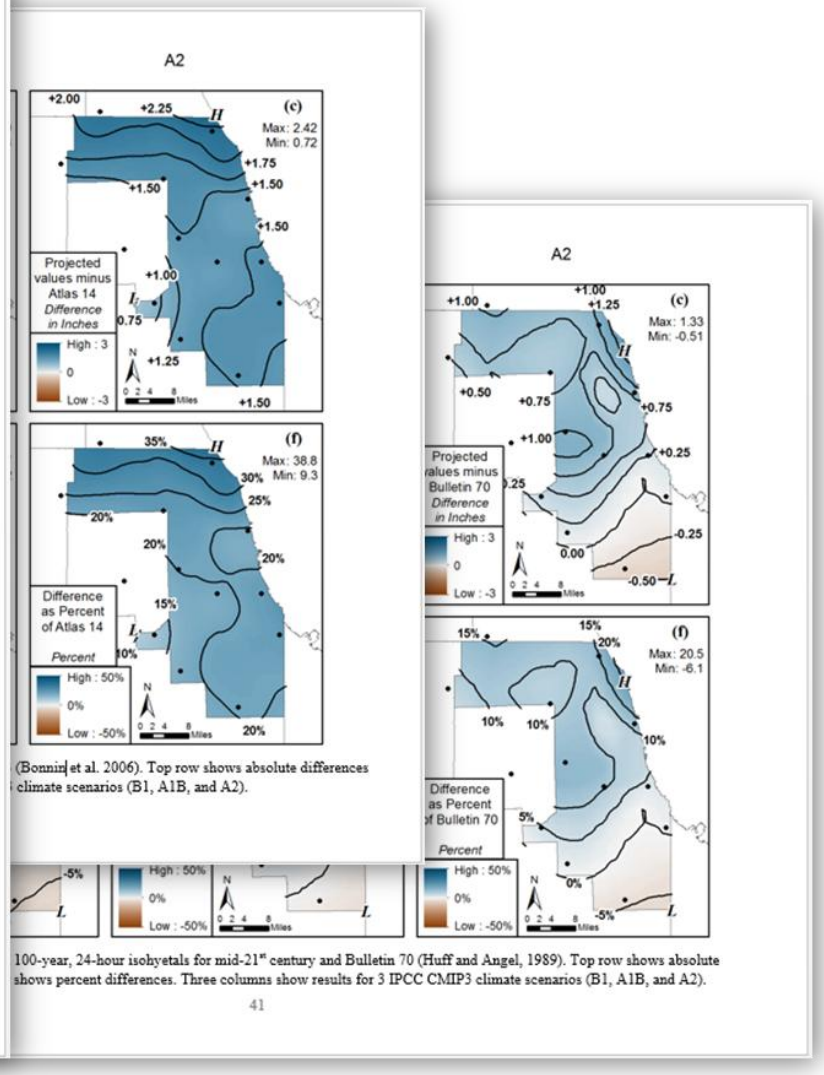
Contract Report 2016

Communication of Climate Change Data for Community Assessment of Impacts of Severe Storms on Urban and Stormwater Infrastructure and Flood Risk in Cook County, Illinois

Principal Investigators:
Momcilo Markus
Sally McConkey
James Angel
Gregory Byard
Chen Zhang
Zoe Zaloudek

ILLINOIS



(Bonnin et al. 2006). Top row shows absolute differences climate scenarios (B1, A1B, and A2).

100-year, 24-hour isohyetals for mid-21st century and Bulletin 70 (Huff and Angel, 1989). Top row shows absolute shows percent differences. Three columns show results for 3 IPCC CMIP3 climate scenarios (B1, A1B, and A2).

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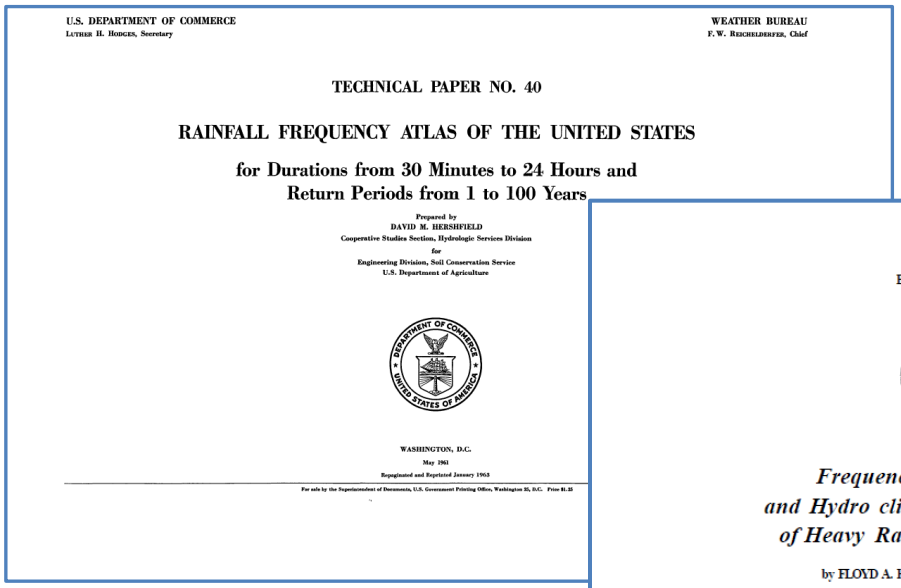
Rainfall frequency sources
TP-40, ISWS Bulletin 70/NOAA Atlas 14



U.S. DEPARTMENT OF COMMERCE
LUTHER H. HODGES, Secretary

WEATHER BUREAU
F. W. REICHELDERFER, Chief

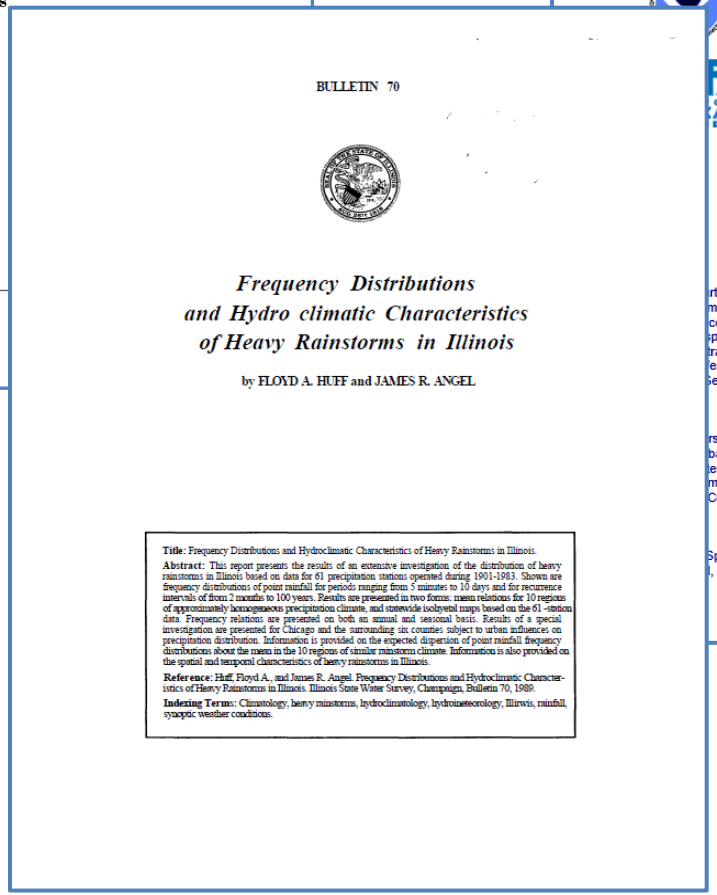
TECHNICAL PAPER NO. 40

RAINFALL FREQUENCY ATLAS OF THE UNITED STATES

for Durations from 30 Minutes to 24 Hours and
Return Periods from 1 to 100 Years

Prepared by
DAVID M. HERSHFIELD
Cooperative Studies Section, Hydrologic Services Division
for
Engineering Division, Soil Conservation Service
U.S. Department of Agriculture

WASHINGTON, D.C.
May 1961
Reprinted and Reprinted January 1963



BULLETIN 70

Frequency Distributions
and Hydro climatic Characteristics
of Heavy Rainstorms in Illinois

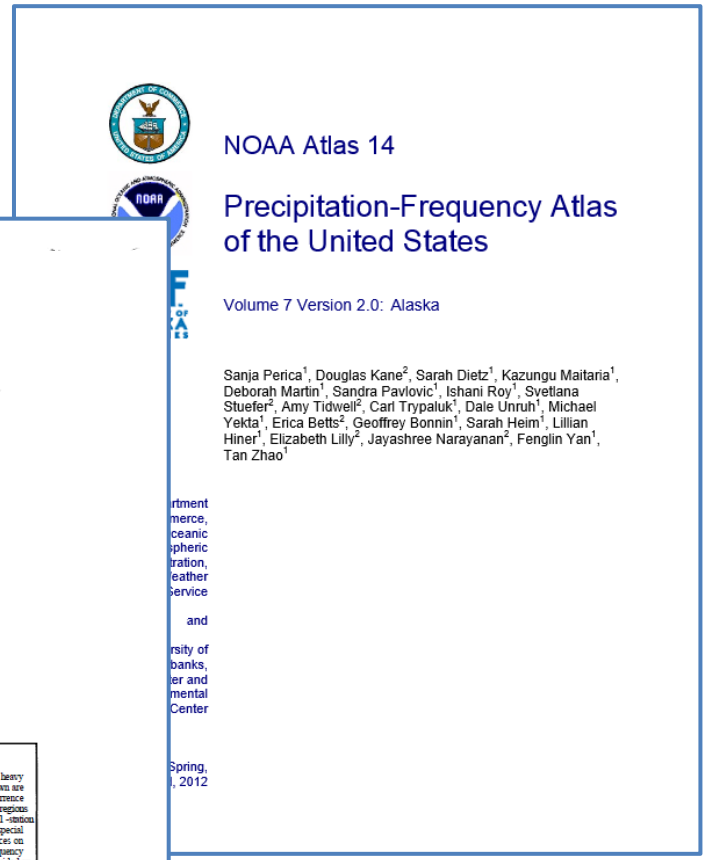
by FLOYD A. HUFF and JAMES R. ANGEL

Title: Frequency Distributions and Hydroclimatic Characteristics of Heavy Rainstorms in Illinois.

Abstract: This report presents the results of an extensive investigation of the distribution of heavy rainstorms in Illinois based on data for 61 precipitation stations operated during 1901-1983. Shown are frequency distributions of point rainfall for periods ranging from 5 minutes to 10 days and for recurrence intervals of from 2 months to 100 years. Results are presented in two forms: mean relations for 10 regions of approximately homogeneous precipitation climate, and statewide isohyetal maps based on the 61 -station data. Frequency relations are presented on both an annual and seasonal basis. Results of a special investigation are presented for Chicago and the surrounding six counties subject to urban influences on precipitation distribution. Information is provided on the expected dispersion of point rainfall frequency distributions about the mean in the 10 regions of similar rainstorm climate. Information is also provided on the spatial and temporal characteristics of heavy rainstorms in Illinois.

Reference: Huff, Floyd A., and James R. Angel. Frequency Distributions and Hydroclimatic Characteristics of Heavy Rainstorms in Illinois. Illinois State Water Survey, Champaign, Bulletin 70, 1989.

Indexing Terms: Climatology, heavy rainstorms, hydroclimatology, hydrometeorology, Illinois, rainfall, synoptic weather conditions.



NOAA Atlas 14

Precipitation-Frequency Atlas of the United States

Volume 7 Version 2.0: Alaska

Sanja Perica[1], Douglas Kane[2], Sarah Dietz[1], Kazungu Maitaria[1], Deborah Martin[1], Sandra Pavlovic[1], Ishani Roy[1], Svetlana Stuefer[2], Amy Tidwell[2], Carl Trypaluk[1], Dale Unruh[1], Michael Yekta[1], Erica Betts[2], Geoffrey Bonnin[1], Sarah Heim[1], Lillian Hiner[1], Elizabeth Lilly[2], Jayashree Narayanan[2], Fenglin Yan[1], Tan Zhao[1]

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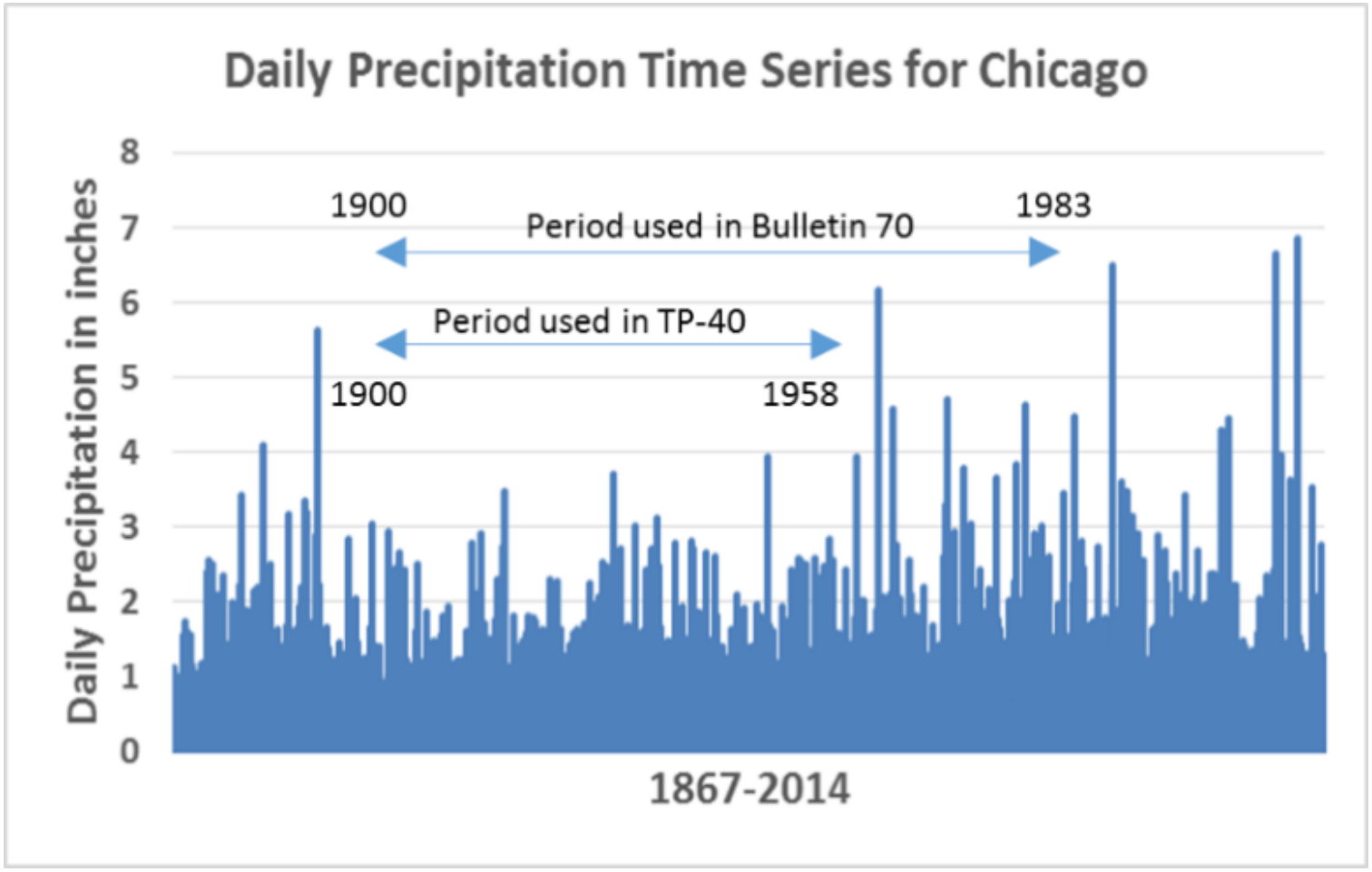
Daily Precipitation Time Series for Chicago
Daily Precipitation in inches
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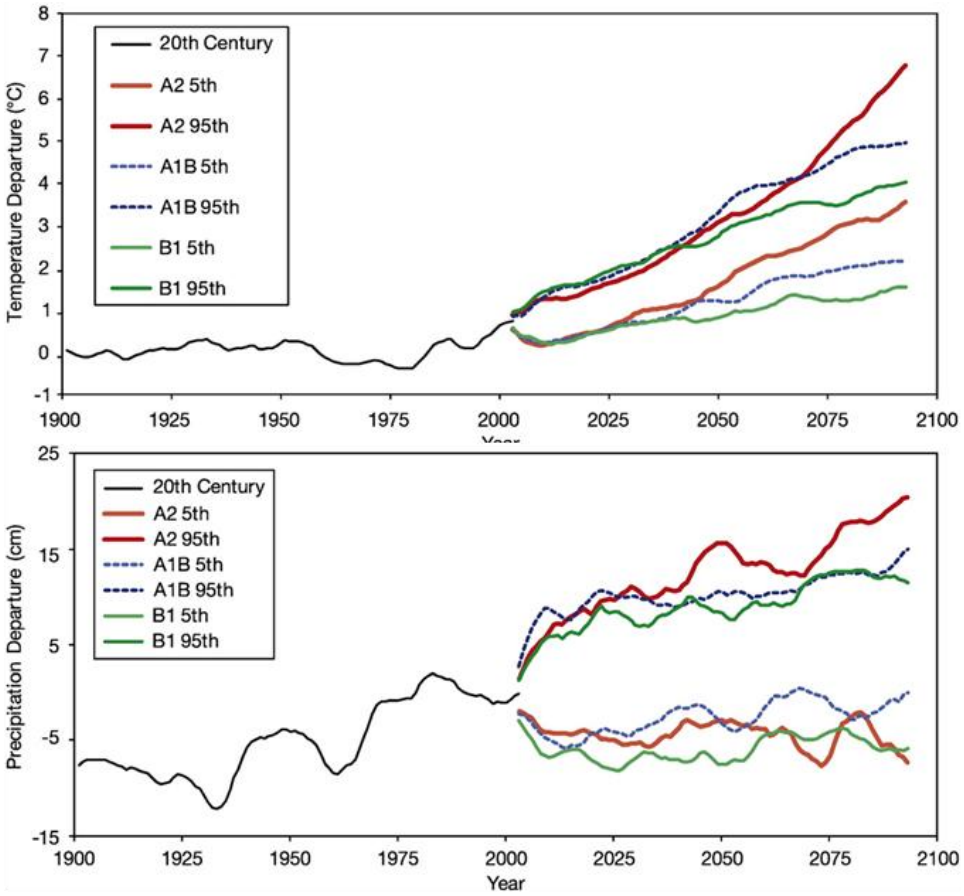
1
2
3
4
5
6
7
8
1900
1983
Period used in Bulletin 70
Period used in TP-40
1900
1958
1867-2014

Future trends in rainfall frequency

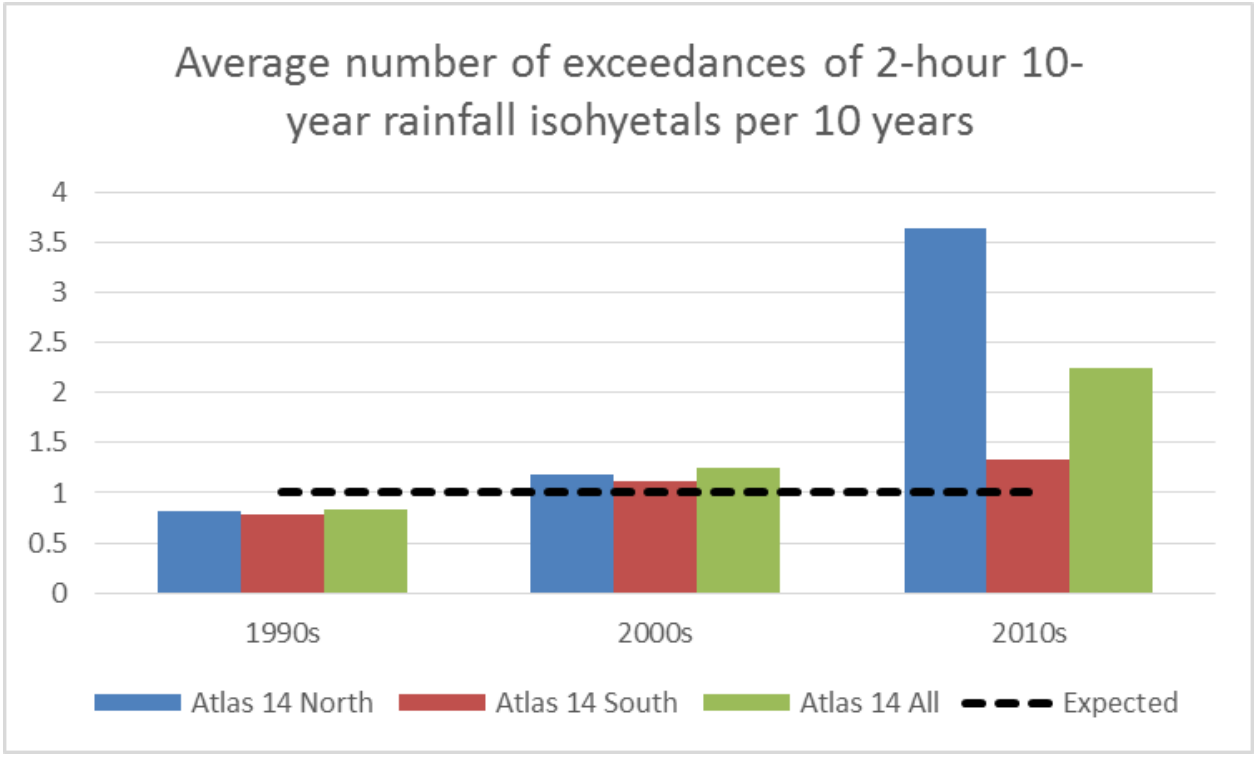
- Monitoring data and research indicate that the intensity and frequency of heavy rainstorm events in the Midwest and other parts of the U. S. have been increasing and are likely to continue to increase.
- However, it is not exactly known if it will actually happen, and if it does, to what degree.

Projected Climate Changes



J.R. Angel, K.E. Kunkel / Journal of Great Lakes Research 36 (2010) 51–58

Exceedances of NOAA Atlas 14

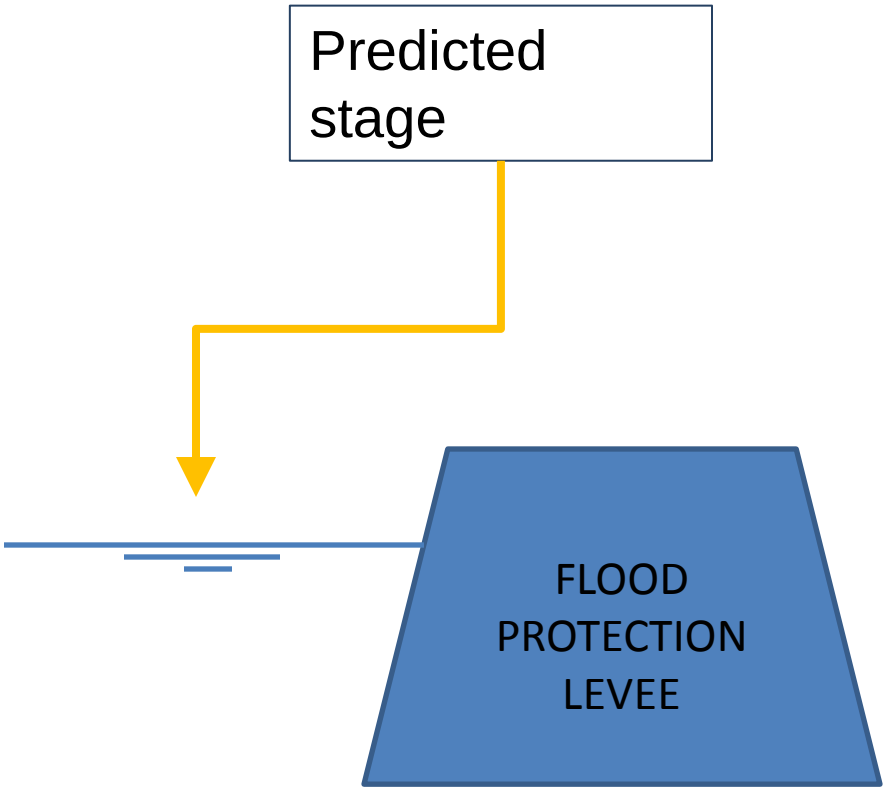


UNCERTAINTY

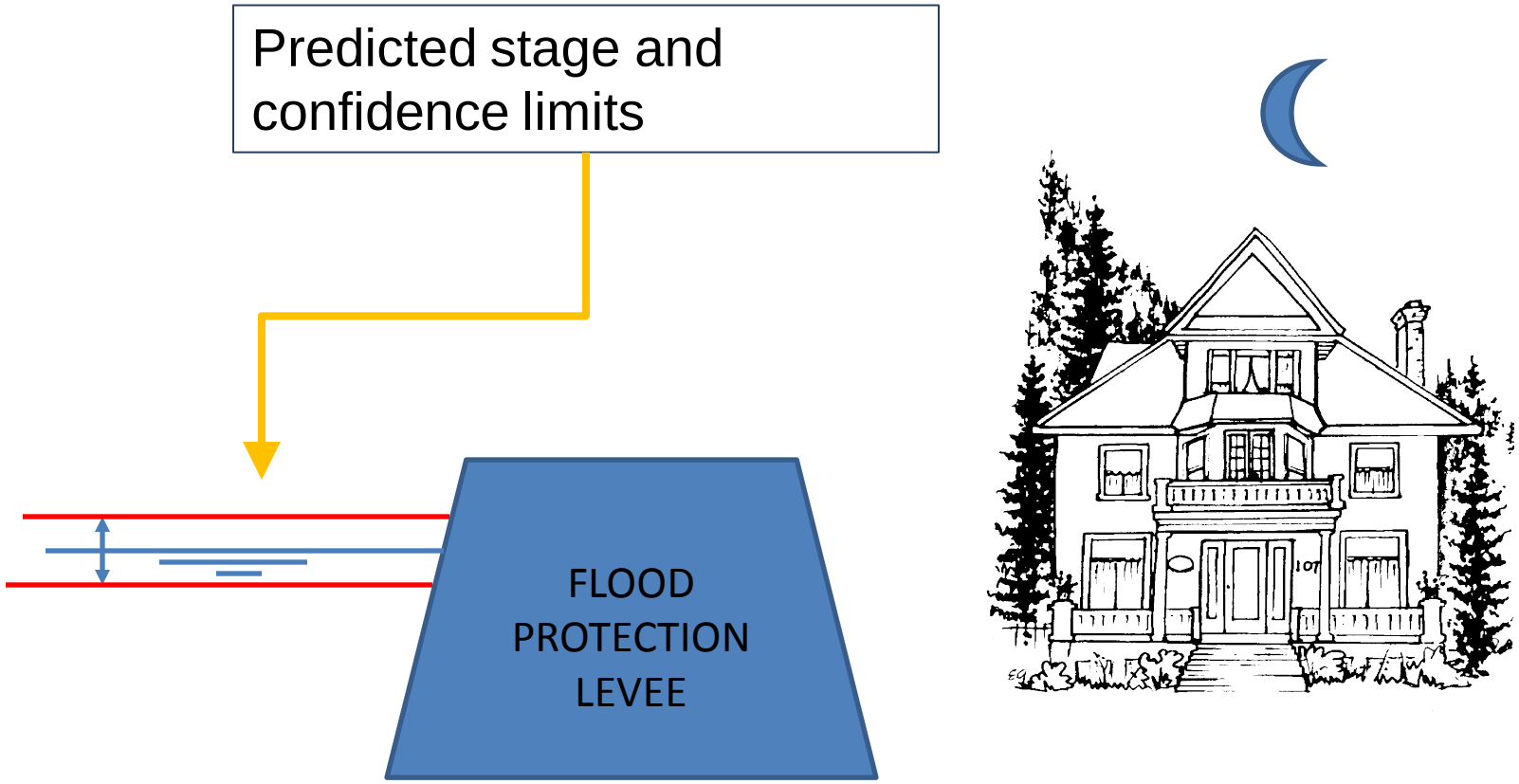
Modeling Uncertainties

- Data
  - Observation
  - Aggregation
  - Sampling Variability
- Model (physical, conceptual, mechanistic, statistical, empirical, data mining, soft computing)
  - Model Limitations
  - Calibration
  - Initial Conditions
- Future Climate

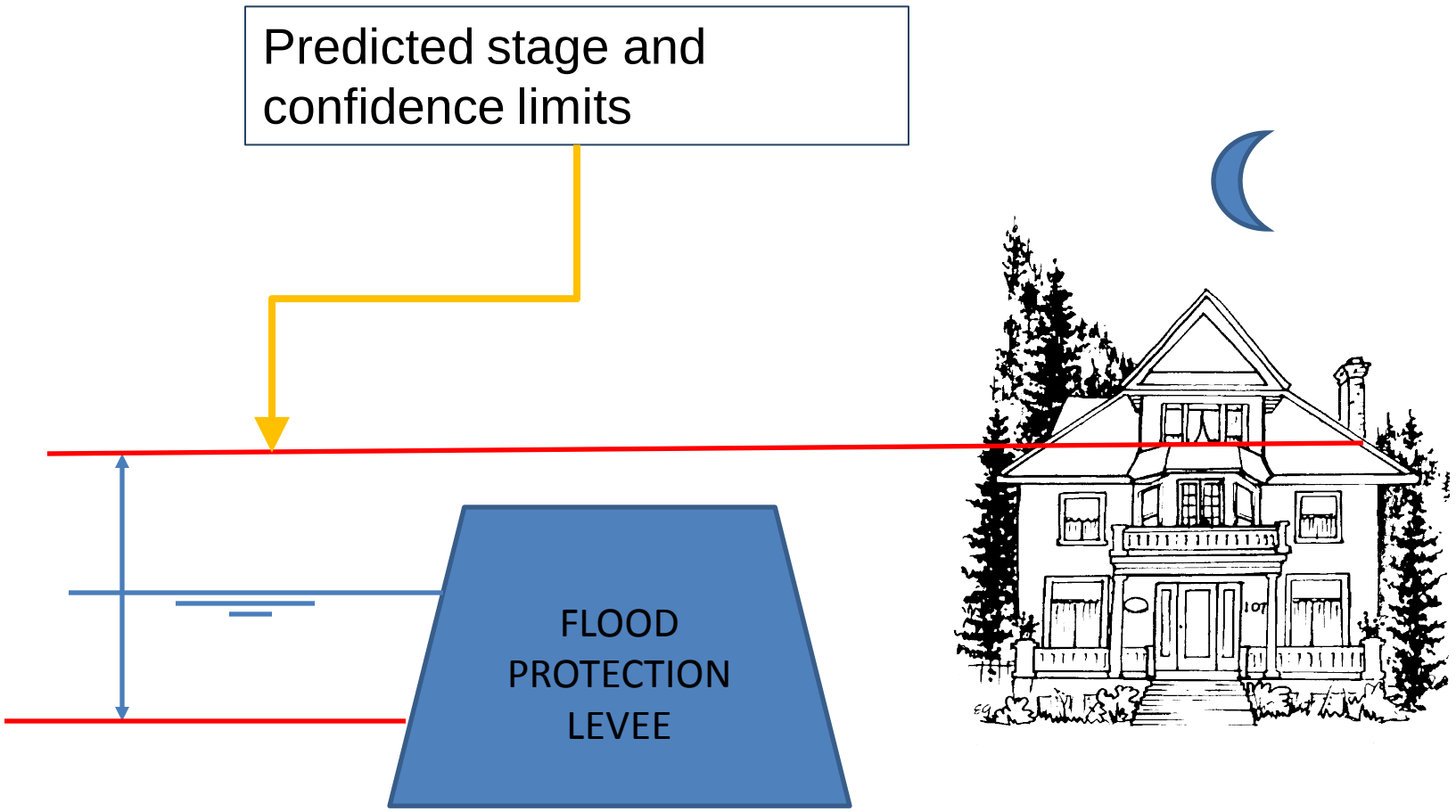
Predicted flood level



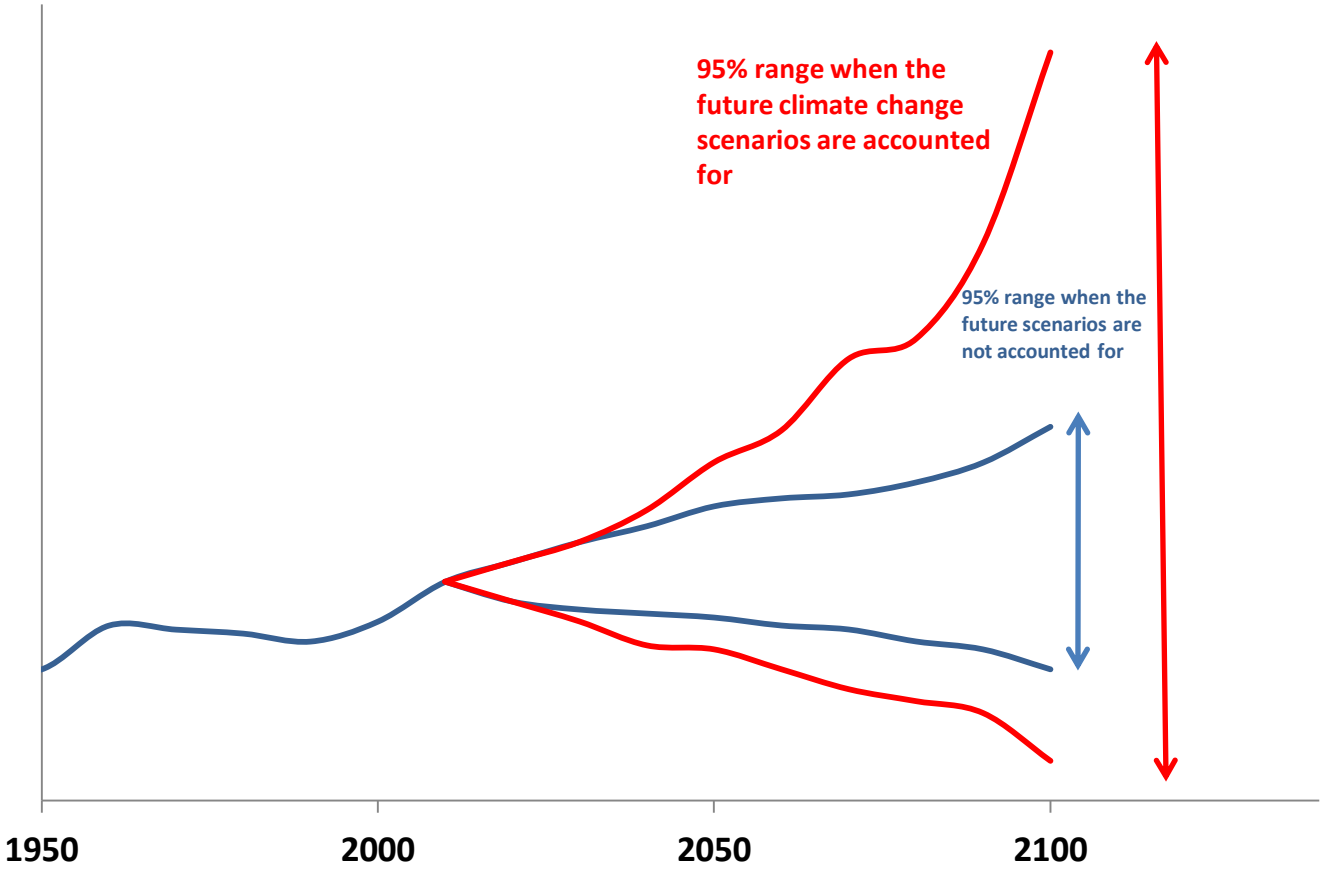
Predicted flood level



Predicted flood level



“… the future is not what it used to be” (Paul Valery)



Accounting for uncertainty

- A majority of climate models project future increases in heavy rainfall in the Chicago area, but some models for some climate scenarios project decreases.

Accounting for uncertainty

- This uncertainty is significant, and many of us tend to use it to simply ignore the projections of future precipitation. However, ignoring a potentially big change just because it is uncertain could be very costly.

Accounting for uncertainty

- Accounting for the uncertainty would give us a range of possible heavy rainfall events, along with their probabilities. This range could serve as a tool for urban managers to adopt somewhat more stringent urban drainage standards by applying suitable safety factors.

Climate change and floods – findings and adaptation strategies for flood protection in Baden-Wurttemberg, Germany

W. Hennegriff, Federal Institute for Environment, Measurements and Nature Protection Baden-Wurttemberg, Landesanstalt fur Umwelt, Messungen und Naturschutz Baden-Wurttemberg (LUBW), Griesbachstraße 1, D–76185 Karlsruhe (E-mail: Wolfgang.Hennegriff@lubw.bwl.de)

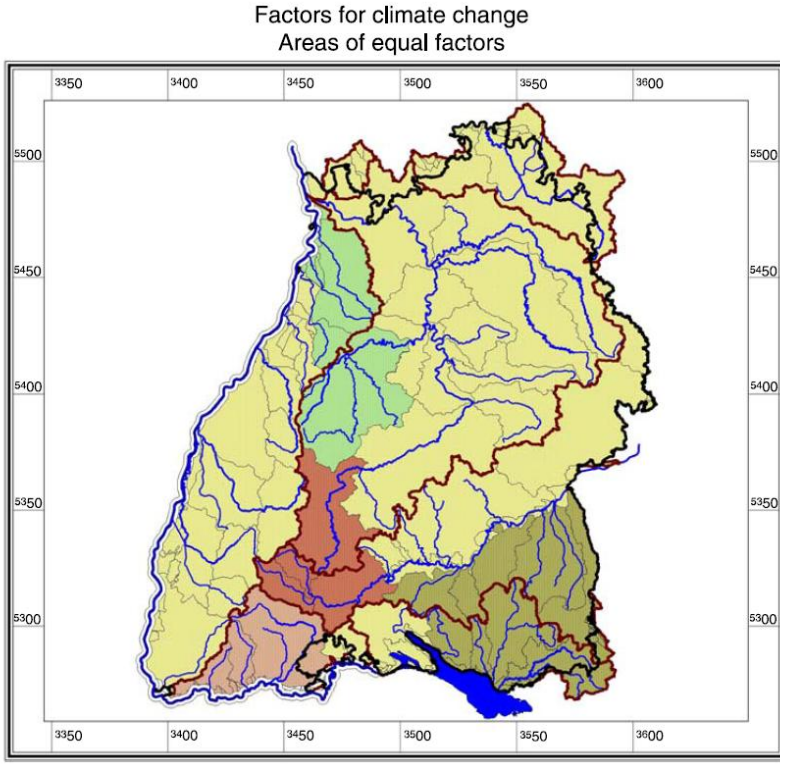


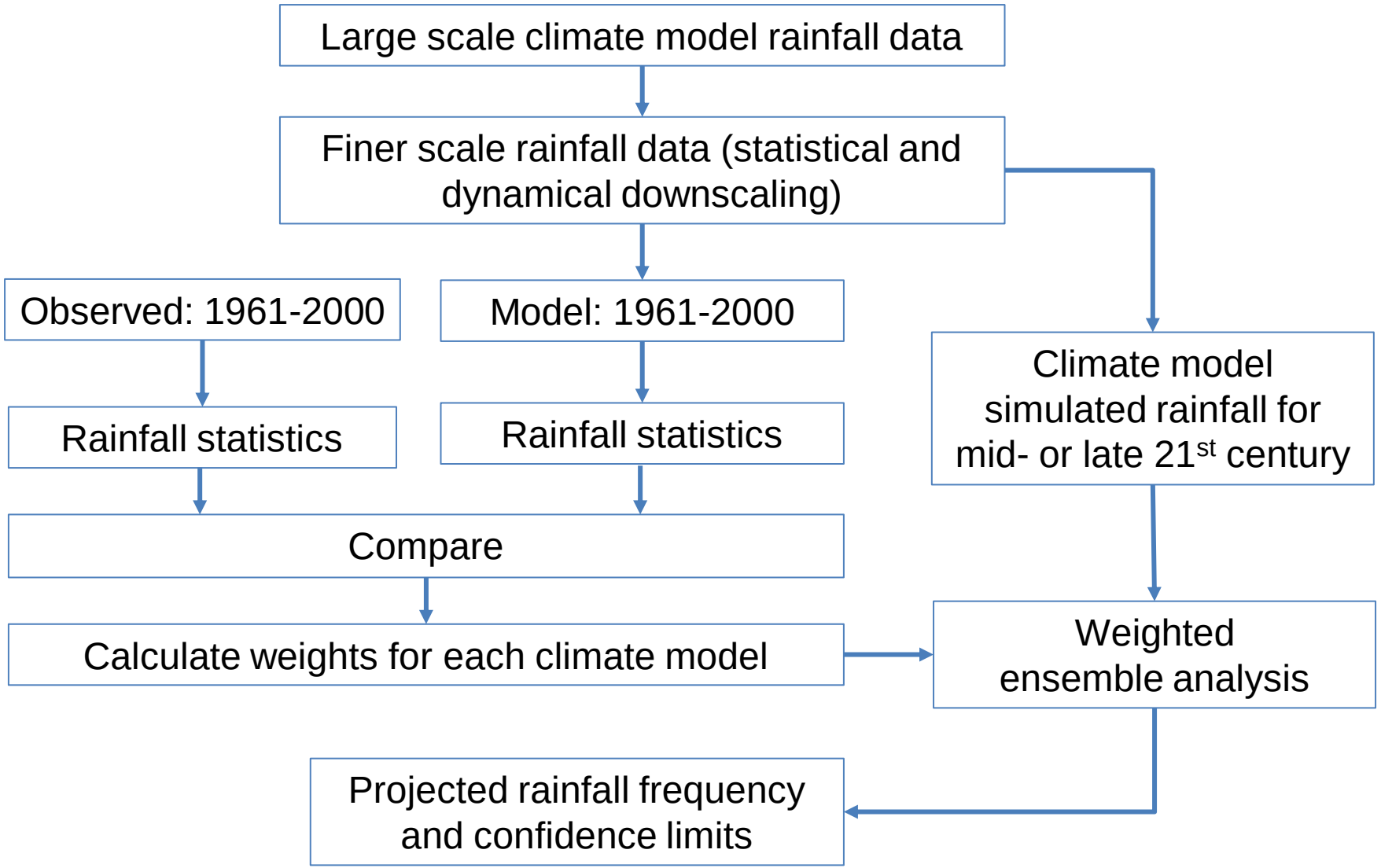
Figure 6 Areas in Baden-Württemberg with uniform climate change factors $f_{T,K}$

T [years]	Factors for climate change $f_{T,K}$				
	1	2	3	4	5
2	1.25	1.50	1.75	1.50	1.75
5	1.24	1.45	1.65	1.45	1.67
10	1.23	1.40	1.55	1.43	1.60
20	1.21	1.33	1.42	1.40	1.50
50	1.18	1.23	1.25	1.31	1.35
100	1.15	1.15	1.15	1.25	1.25
200	1.12	1.08	1.07	1.18	1.15
500	1.06	1.03	1.00	1.08	1.05
1000	1.00	1.00	1.00	1.00	1.00
Remark: Factor is equal 1.0 for annualities T>1000a					

Figure 7 Climate change factors $f_{T,K}$ to determine the design flood for the areas or river catchments in Baden-Württemberg

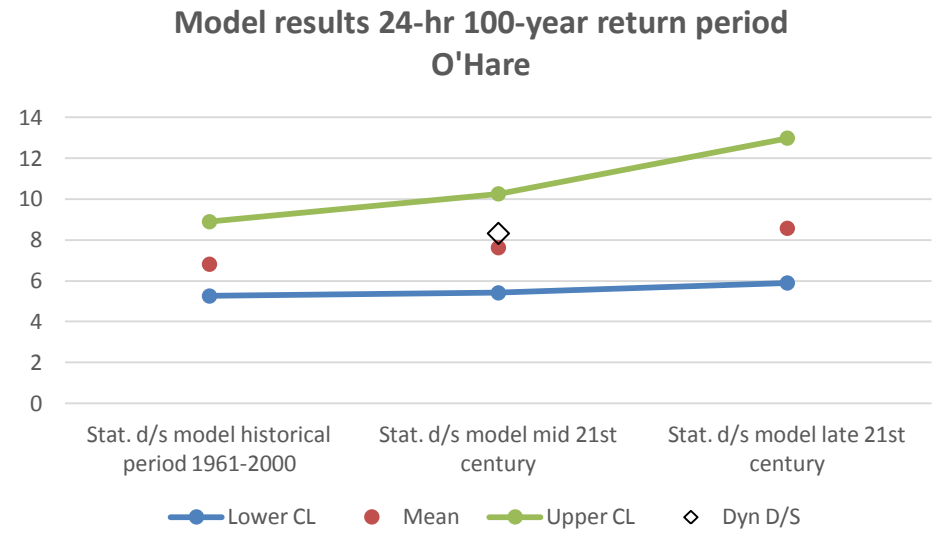
PROJECT SCHEMATIC

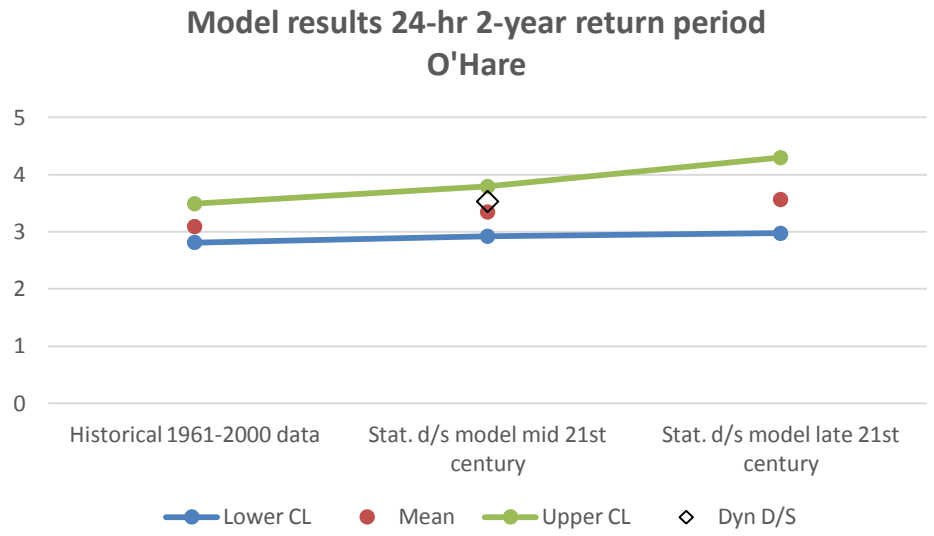
Weighted Ensemble Analysis for heavy rainfall

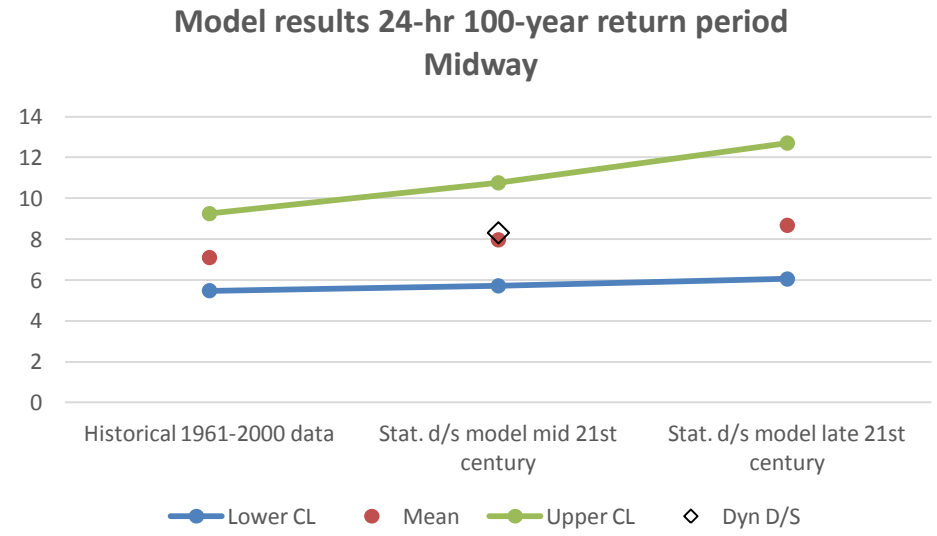


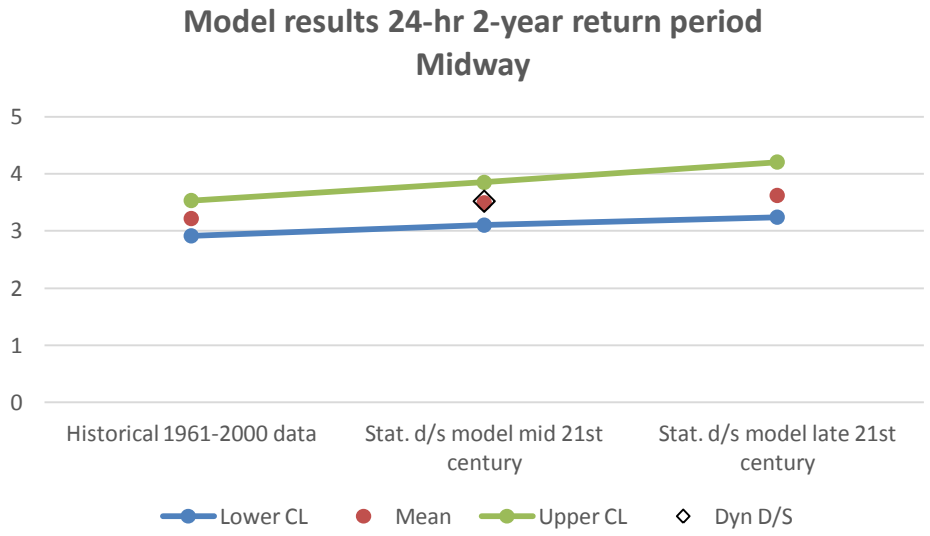
RESULTS

Results for O'Hare and Midway rain gages

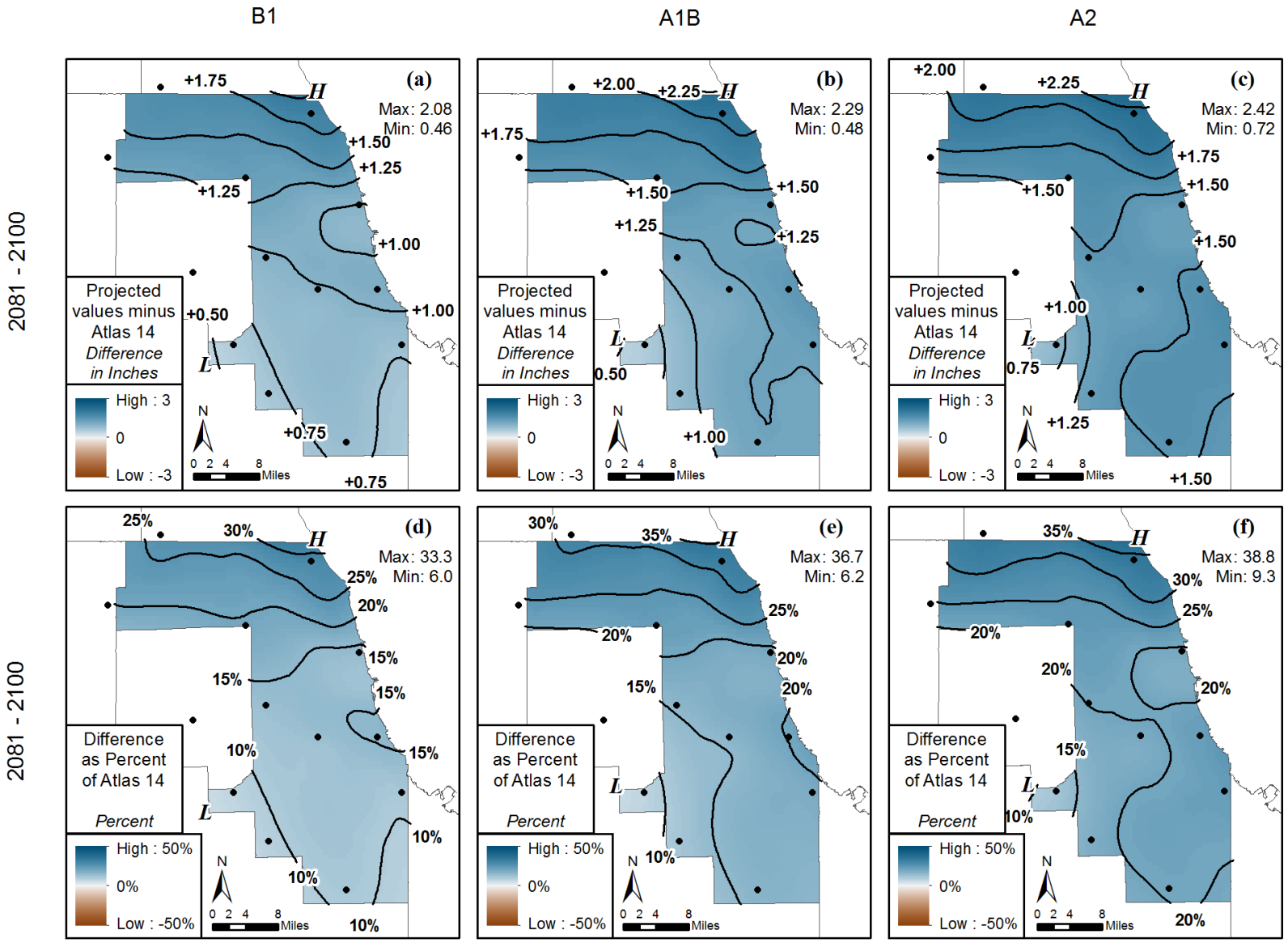






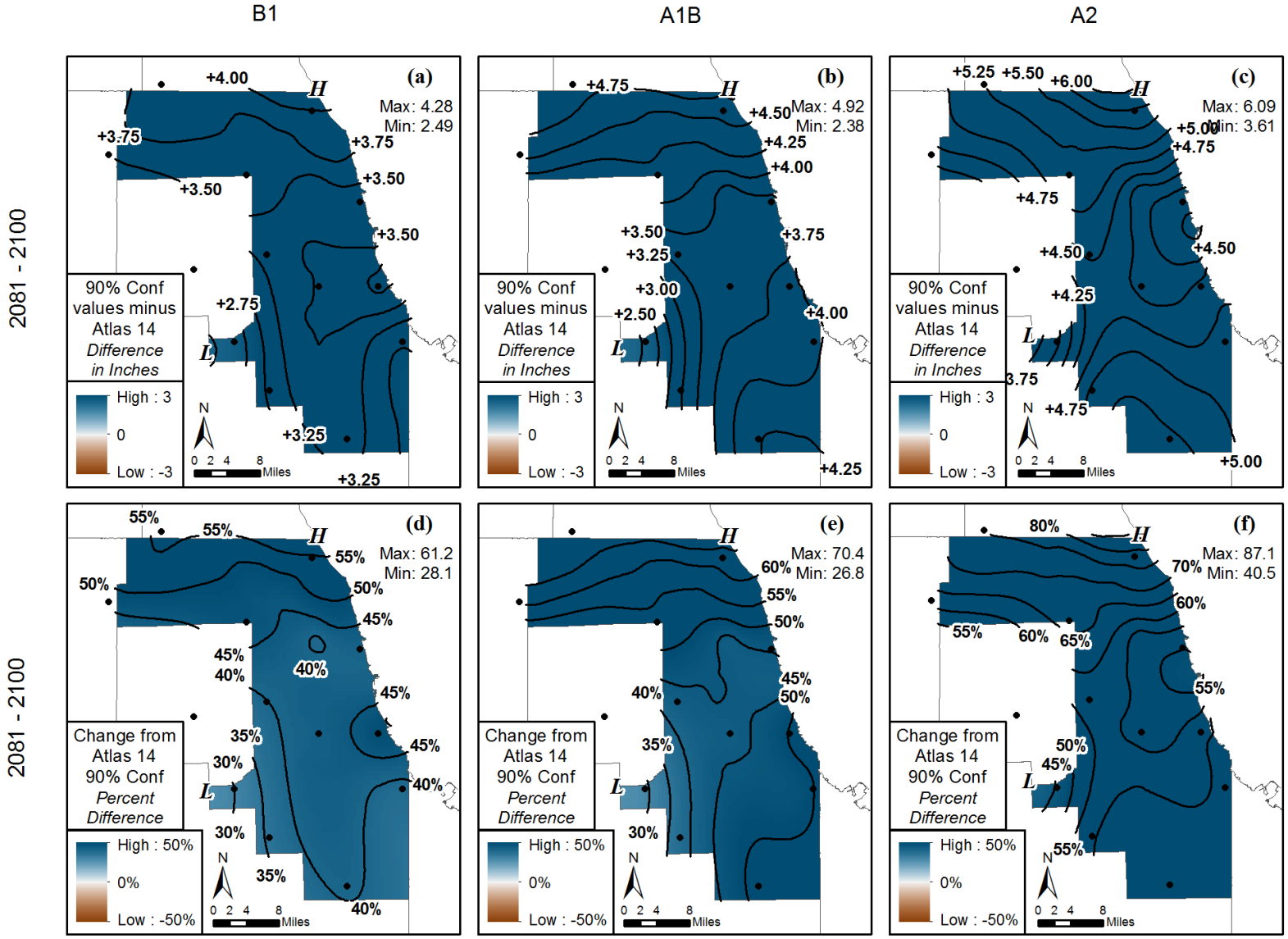


Differences between projected 100-year, 24-hour isohyetals for late-21st century and those based on NOAA Atlas 14



These results are not designed for operational use, nor do they replace the existing sources

Differences between projected for late 21st century and Atlas 14 upper 90% confidence limits for 100-year, 24-hour isohyetals



These results are not designed for operational use, nor do they replace the existing sources

Climatic Change (2016) 135:143–155
DOI 10.1007/s10584-015-1549-1

Assessing decision support systems and levels of confidence to narrow the climate information "usability gap"

Richard H. Moss[1]

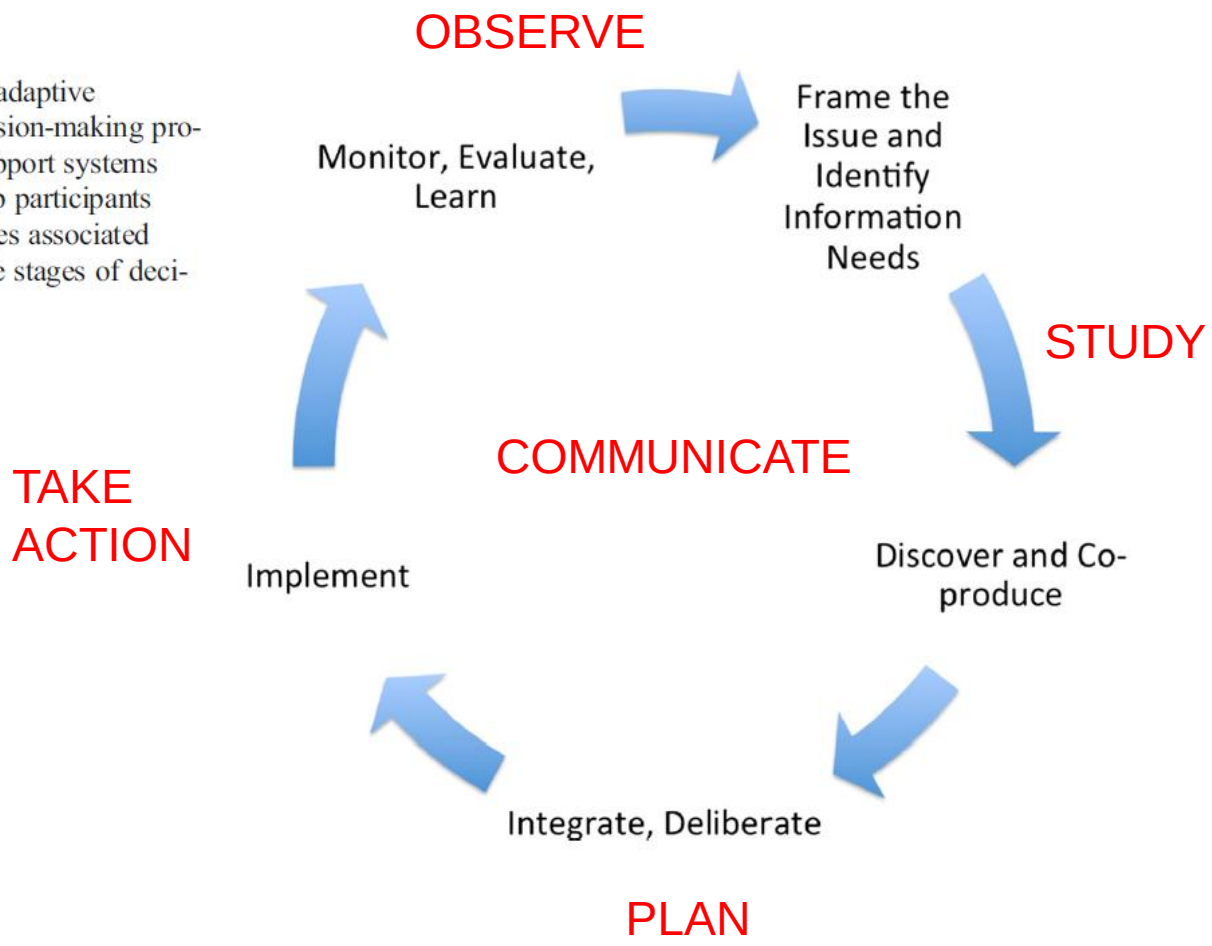


Fig. 1 Idealized adaptive management decision-making process. Decision-support systems and tools can help participants confront challenges associated with each of these stages of decision-making

Summary

Projections

- Heavy rainfall events are expected to increase
- Large confidence intervals

Future activities

- Continuing monitoring
- Research
- Model development, validation and testing

Expected outcomes

- Better understand and quantify the random nature of the projected rainfall
- Reduce the epistemic uncertainties

Questions?

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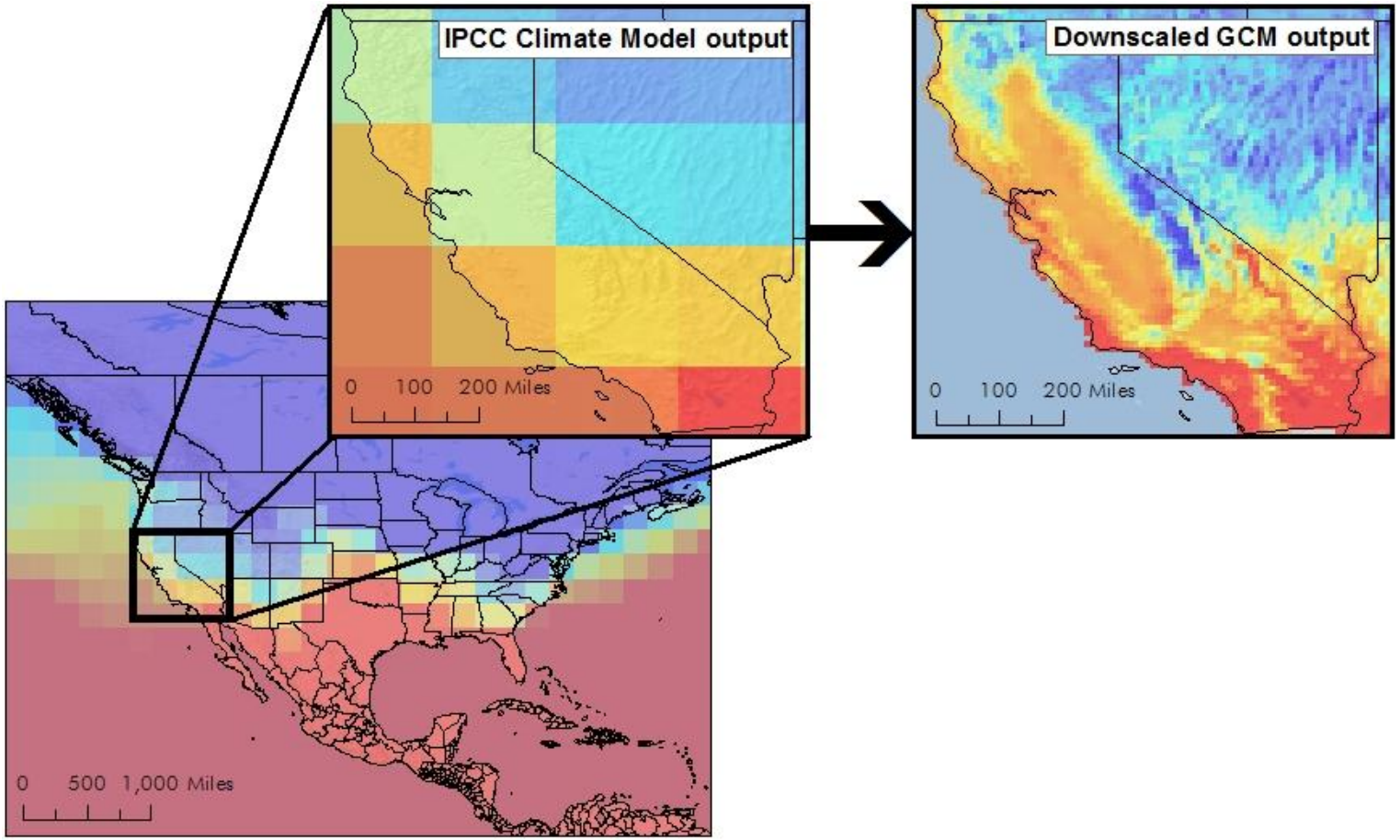
Downscaling – dynamical and statistical



Past Project: Single Model Projection for Chicago

- The regional climate model (RCM) used in this study is a climate extension of the fifth generation Pennsylvania State University-National Center for Atmospheric Research Mesoscale Model (MM5, Dudhia et al. 2005), referred to as CMM5. (Liang et al. 2004a, b, 2007; Zhu and Liang 2005, 2007)

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

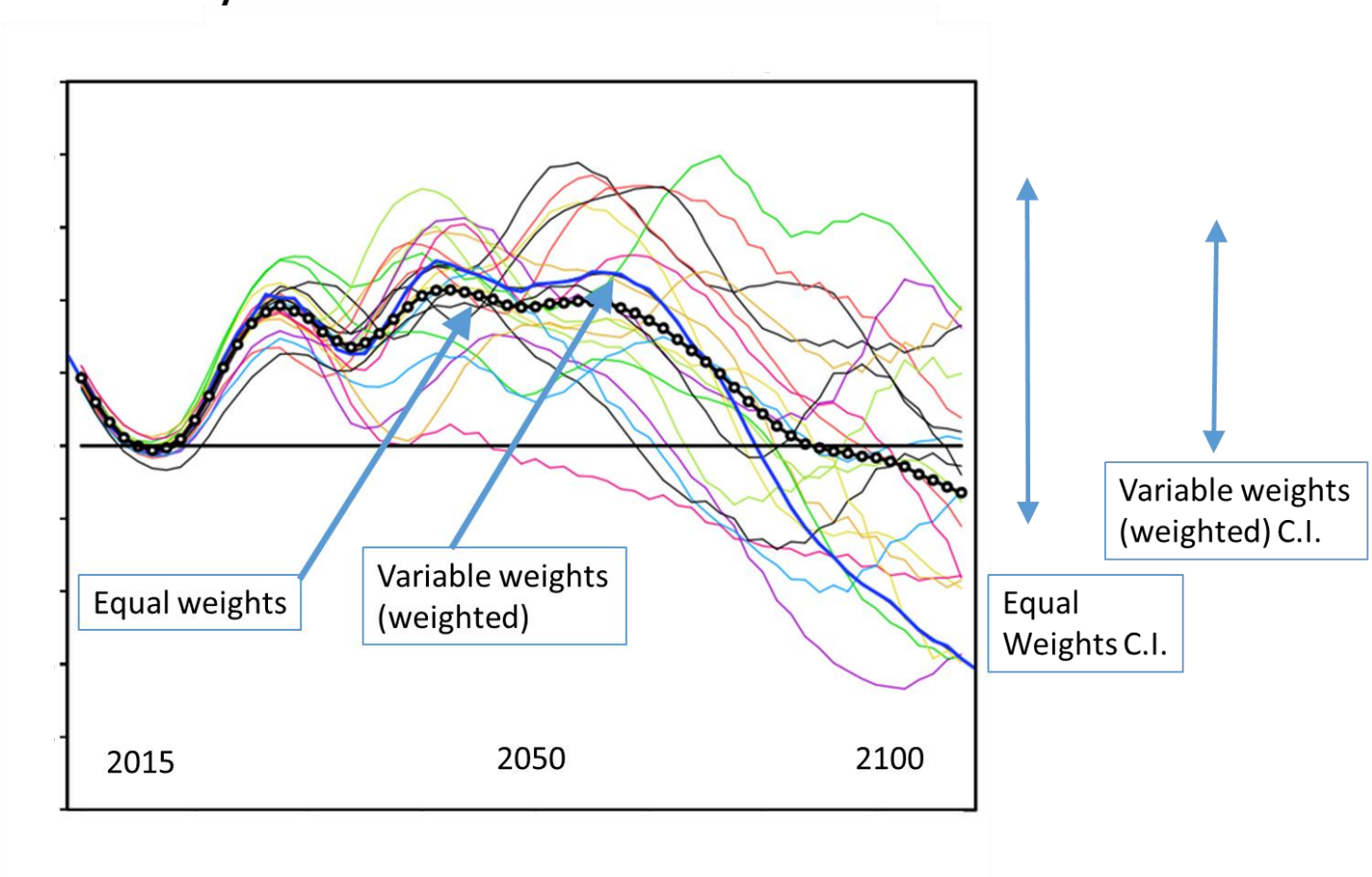
Diagnostic analysis of future climate scenarios applied to urban flooding in the Chicago metropolitan area

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.

Ensemble analysis



Change in Heavy Rainfall 2050 vs. 2000

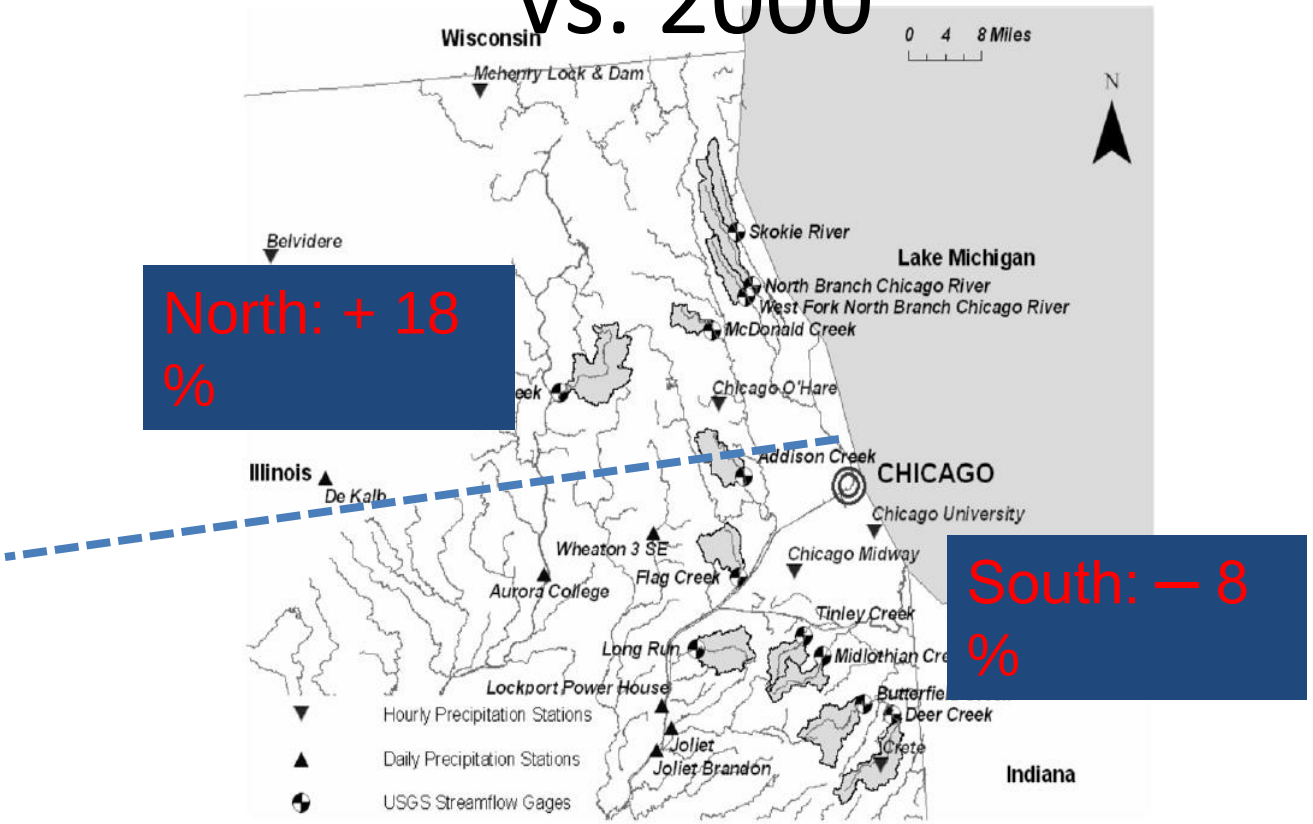
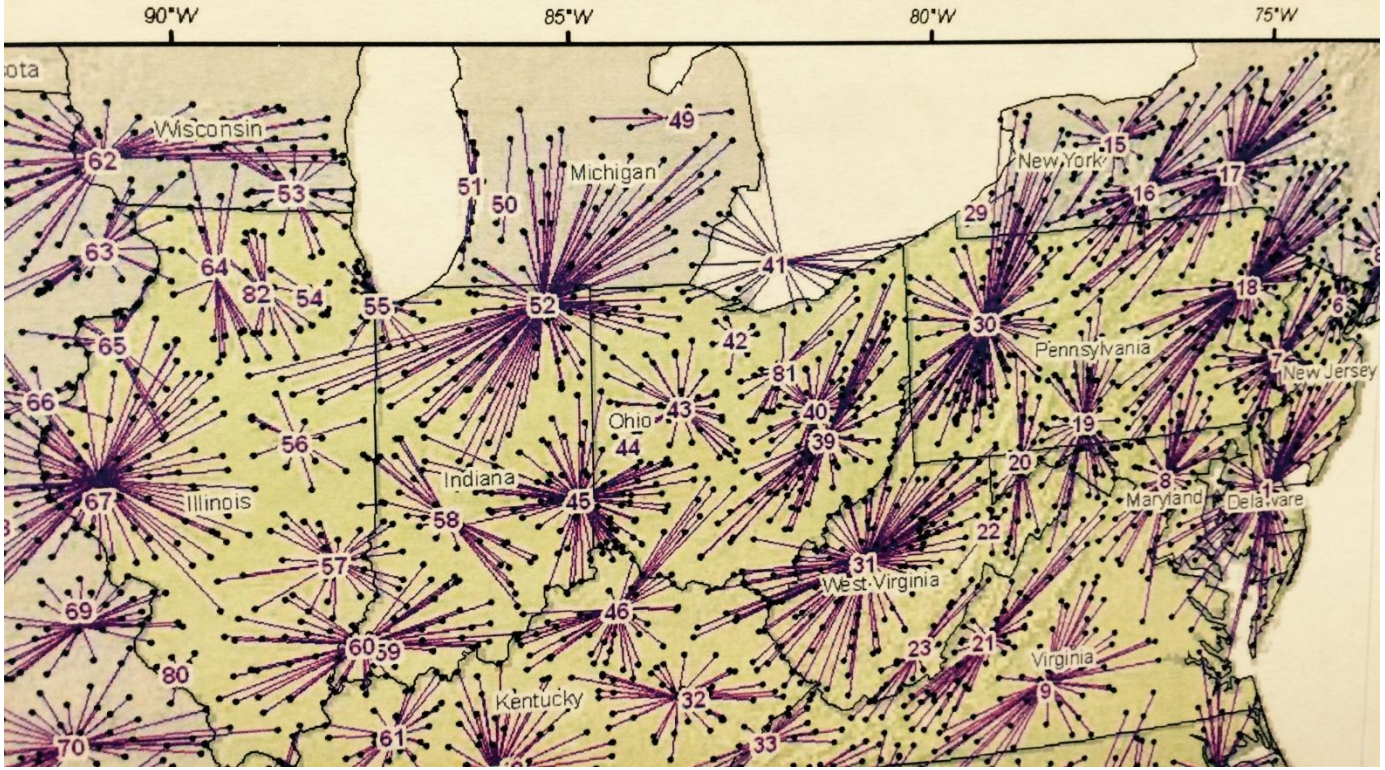
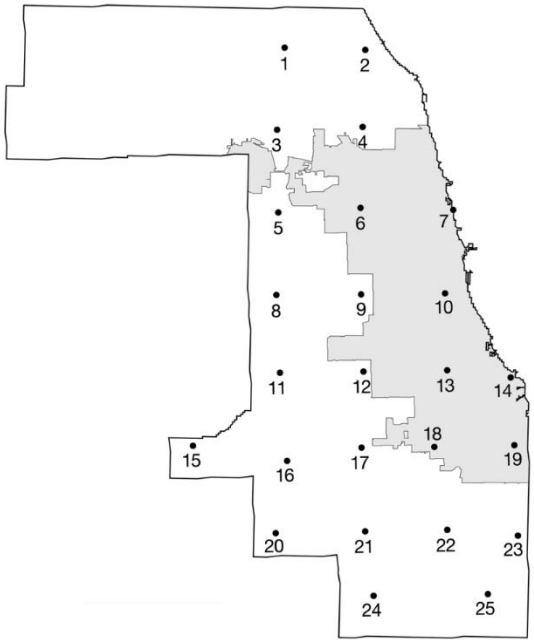


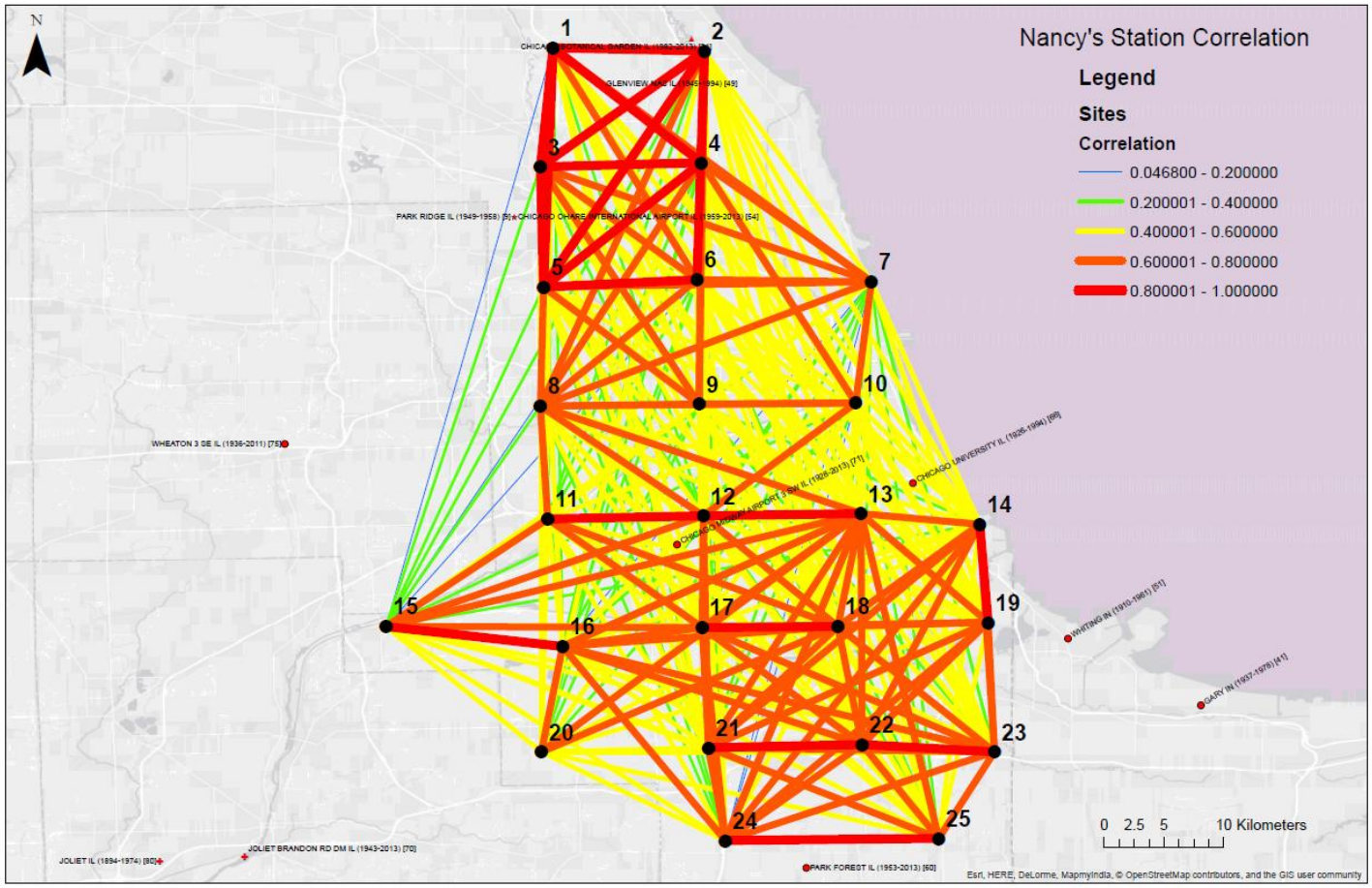
Figure 2 Location of watersheds and raingages.

Figure 4.4.1. Regional groupings for daily data used to prepare NOAA Atlas 14 Volume 2.



Cook County Precipitation Network




Nancy's Station Correlation
Legend
Sites
Correlation
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0.200001 - 0.400000
0.400001 - 0.600000
0.600001 - 0.800000
0.800001 - 1.000000
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PARK RIDGE IL (1949-1958) [5]
CHICAGO OHARE INTERNATIONAL AIRPORT IL (1959-2013) [54]
WHEATON 3 SE IL (1936-2011) [75]
CHICAGO UNIVERSITY IL (1926-1994) [69]
WHITING IN (1910-1961) [51]
GARY IN (1937-1978) [41]
JOLIET IL (1894-1974) [80]
JOLIET BRANDON RD DM IL (1943-2013) [70]
PARK FOREST IL (1963-2013) [60]
0 2.5 5 10 Kilometers
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