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WATER SURVEY
PRAIRIE RESEARCH INSTITUTE

Uncertainties in the Projections of Future Heavy Rainfall: Urban Flood Risk in Chicago

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Contract Report 2016-05

Communicating the Impacts of Potential Future Climate Change on the Expected Frequency of Extreme Rainfall Events in Cook County, Illinois

Momcilo Markus, James Angel, Gregory Byard,
Chen Zhang, Zoe Zaloudek, Sally McConkey

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Prairie Research Institute
University of Illinois at Urbana-Champaign

Champaign, Illinois

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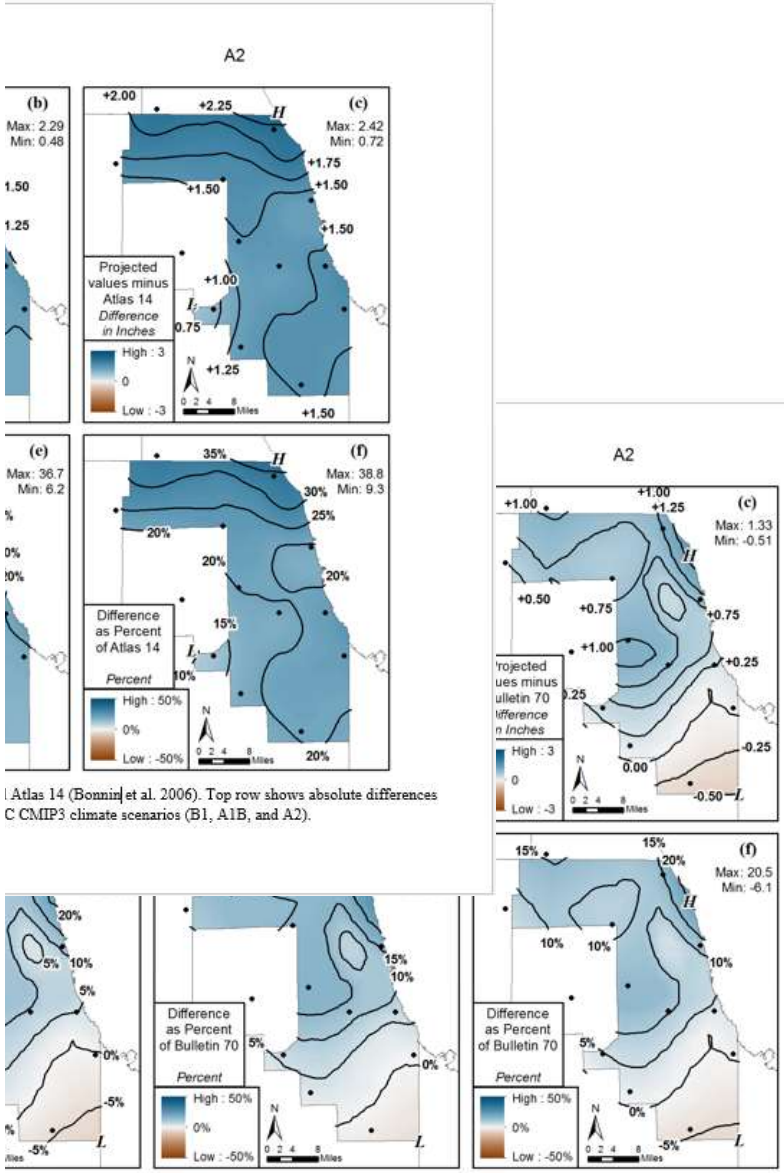

Atlas 14 (Bonnin et al. 2006). Top row shows absolute differences
C CMIP3 climate scenarios (B1, A1B, and A2).

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

Stationarity of hydroclimatic data

- Hydro-climatologists have used long-term rainfall and streamflow records to estimate the probability of extreme events (e.g., the 100 year storm) occurring in the future, assuming that future variability will be like past variability.
- This assumption is sometimes called "stationarity."
- In the light of climate change, that assumption now appears to be problematic. Addressing this problem is an area of active research.

CLIMATE CHANGE

Stationarity Is Dead: Whither Water Management?

Climate change undermines a basic assumption that historically has facilitated management of water supplies, demands, and risks.

P. C. D. Milly,[1]* Julio Betancourt,[2] Malin Falkenmark,[3] Robert M. Hirsch,[4] Zbigniew W. Kundzewicz,[5] Dennis P. Lettenmaier,[6] Ronald J. Stouffer[7]

Systems for management of water throughout the developed world have been designed and operated under the assumption of stationarity. Stationarity—the idea that natural systems fluctuate within an unchanging envelope of variability—is a foundational concept that permeates training and practice in water-resource engineering. It implies that any variable (e.g., annual streamflow or annual flood peak) has a time-invariant (or 1-year–periodic) probability density function (pdf), whose properties can be estimated from the instrument record. Under sta-

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STATIONARITY: WANTED DEAD OR ALIVE?[1]

Harry F. Lins and Timothy A. Cohn[2]

ABSTRACT: Aligning engineering practice with natural process behavior would appear, on its face, to be a prudent and reasonable course of action. However, if we do not understand the long-term characteristics of hydroclimatic processes, how does one find the prudent and reasonable course needed for water management? We consider this question in light of three aspects of existing and unresolved issues affecting hydroclimatic variability and statistical inference: Hurst-Kolmogorov phenomena; the complications long-term persistence introduces with respect to statistical understanding; and the dependence of process understanding on arbitrary sampling choices. These problems are not easily addressed. In such circumstances, humility may be more important than physics; a simple model with well-understood flaws may be preferable to a sophisticated model whose correspondence to reality is uncertain.

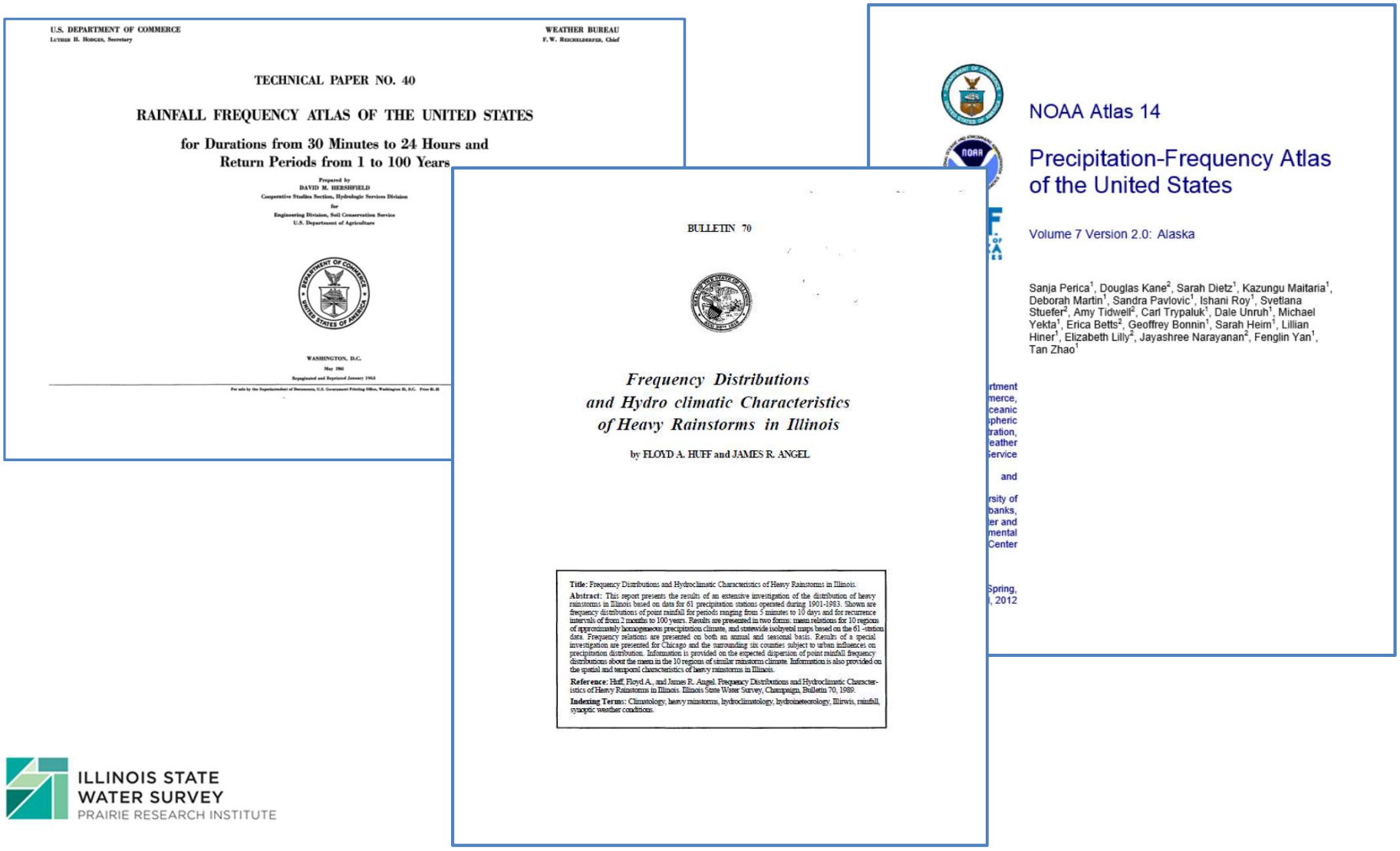
(KEY TERMS: stationarity; nonstationarity; long-term persistence; Hurst-Kolmogorov phenomenon; trend testing; hypothesis testing.)

Lins, Harry F. and Timothy A. Cohn, 2011. Stationarity: Wanted Dead or Alive? *Journal of the American Water Resources Association* (JAWRA) 47(3):475-480. DOI: 10.1111/j.1752-1688.2011.00542.x

Observed or Projected Rainfall?

	Is the time period used for design appropriate for the structure?	Uncertainty (accuracy)
Observed Rainfall	Using past observed data to design future structures	Low uncertainty (high accuracy)
Projected Rainfall	Using future projected data to design future structures	High uncertainty (low accuracy)

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 1901-1963. 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 isolyetal 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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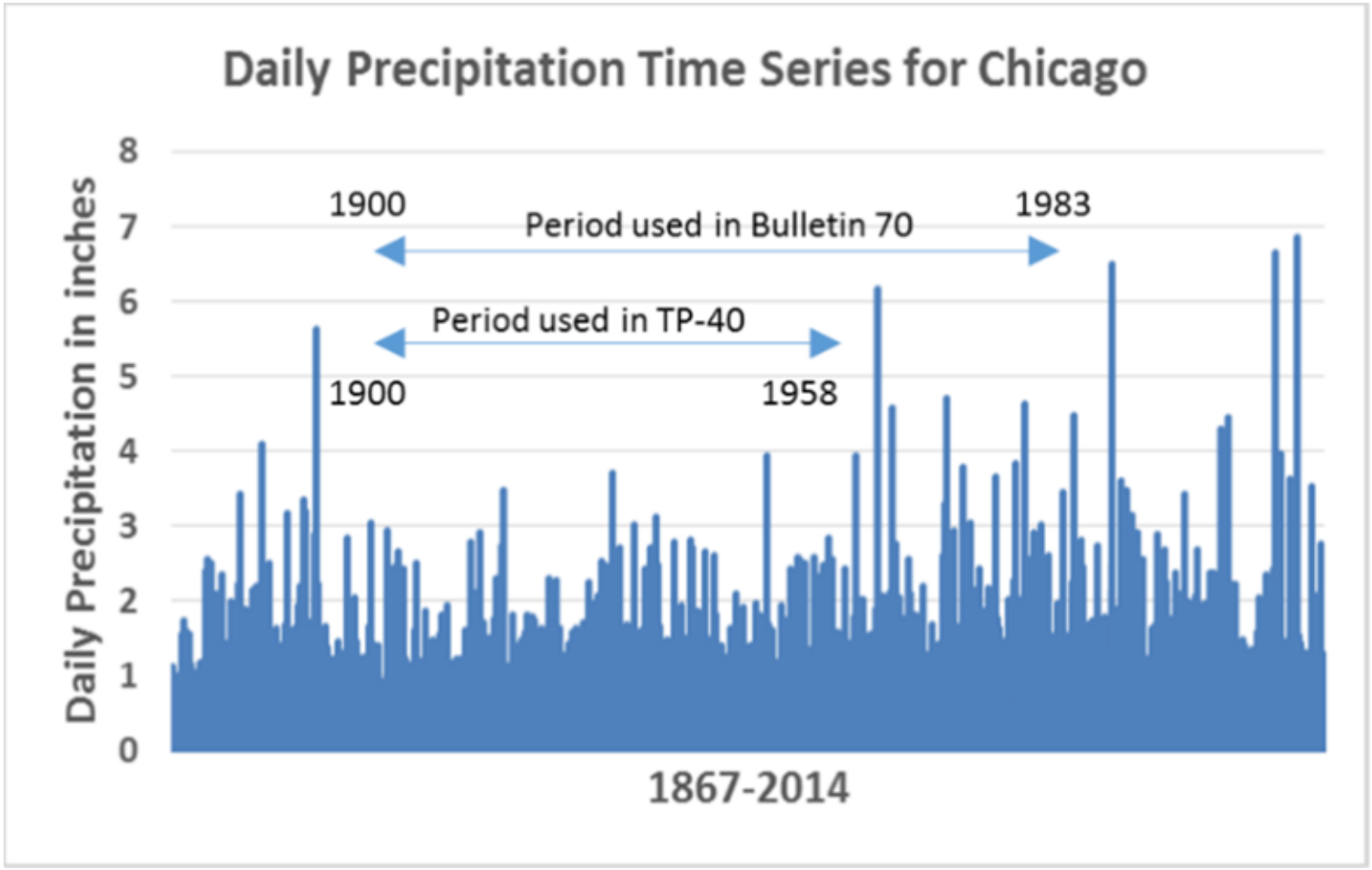
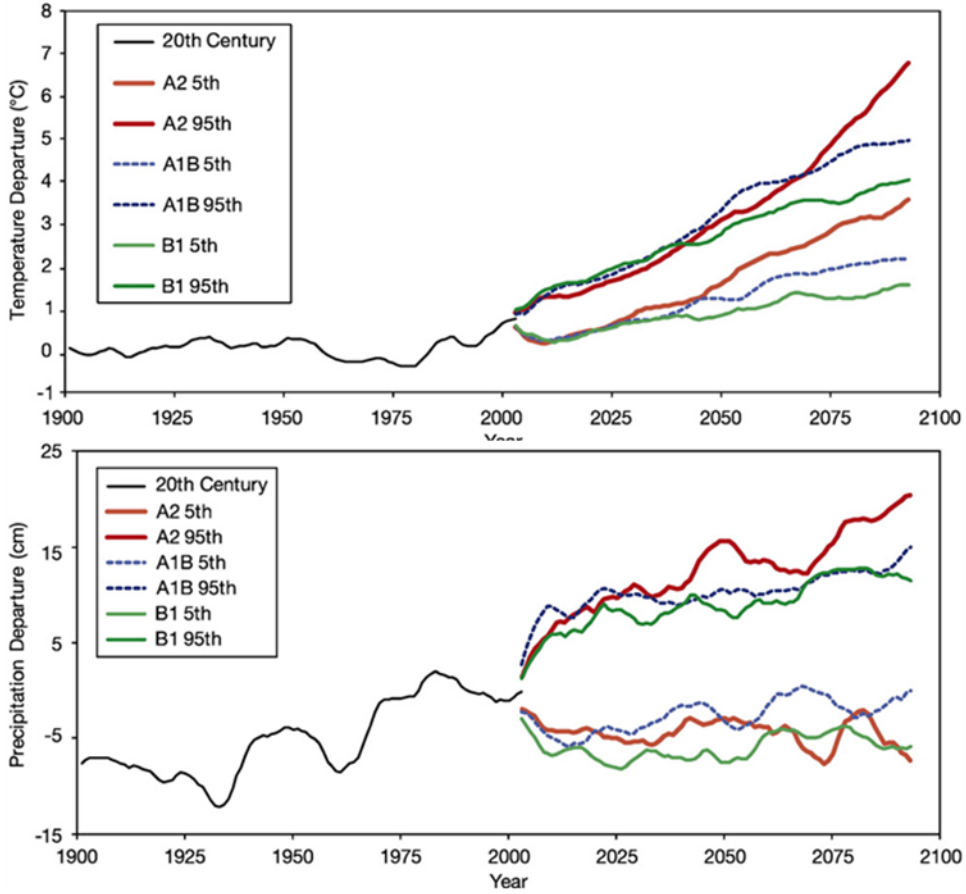

Daily Precipitation Time Series for Chicago
Daily Precipitation in inches
8
7
6
5
4
3
2
1
0
1900
1983
Period used in Bulletin 70
Period used in TP-40
1900
1958
1867-2014

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

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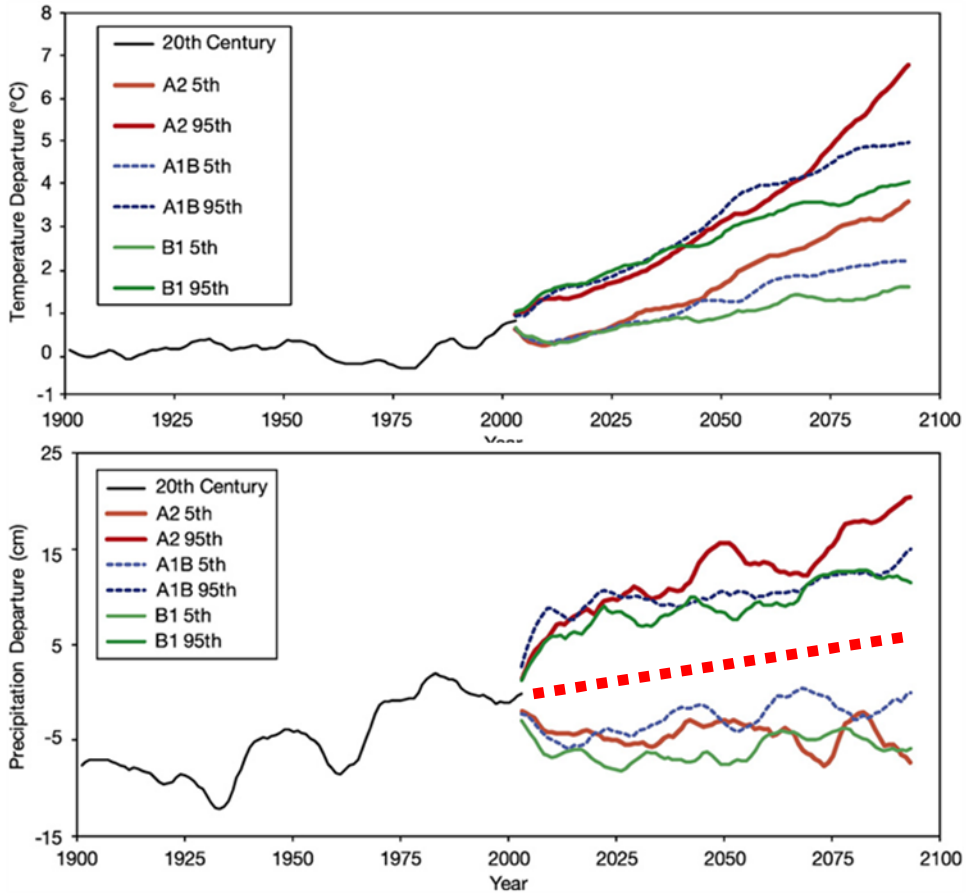
Projected Climate Changes



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

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UNCERTAINTY

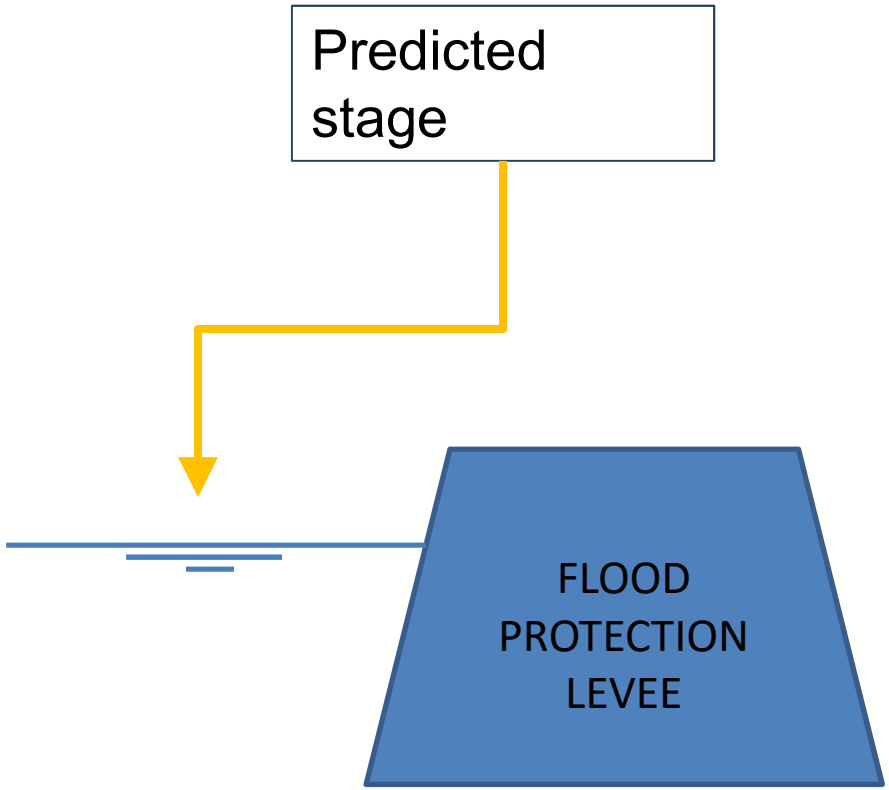
Modeling Uncertainties

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

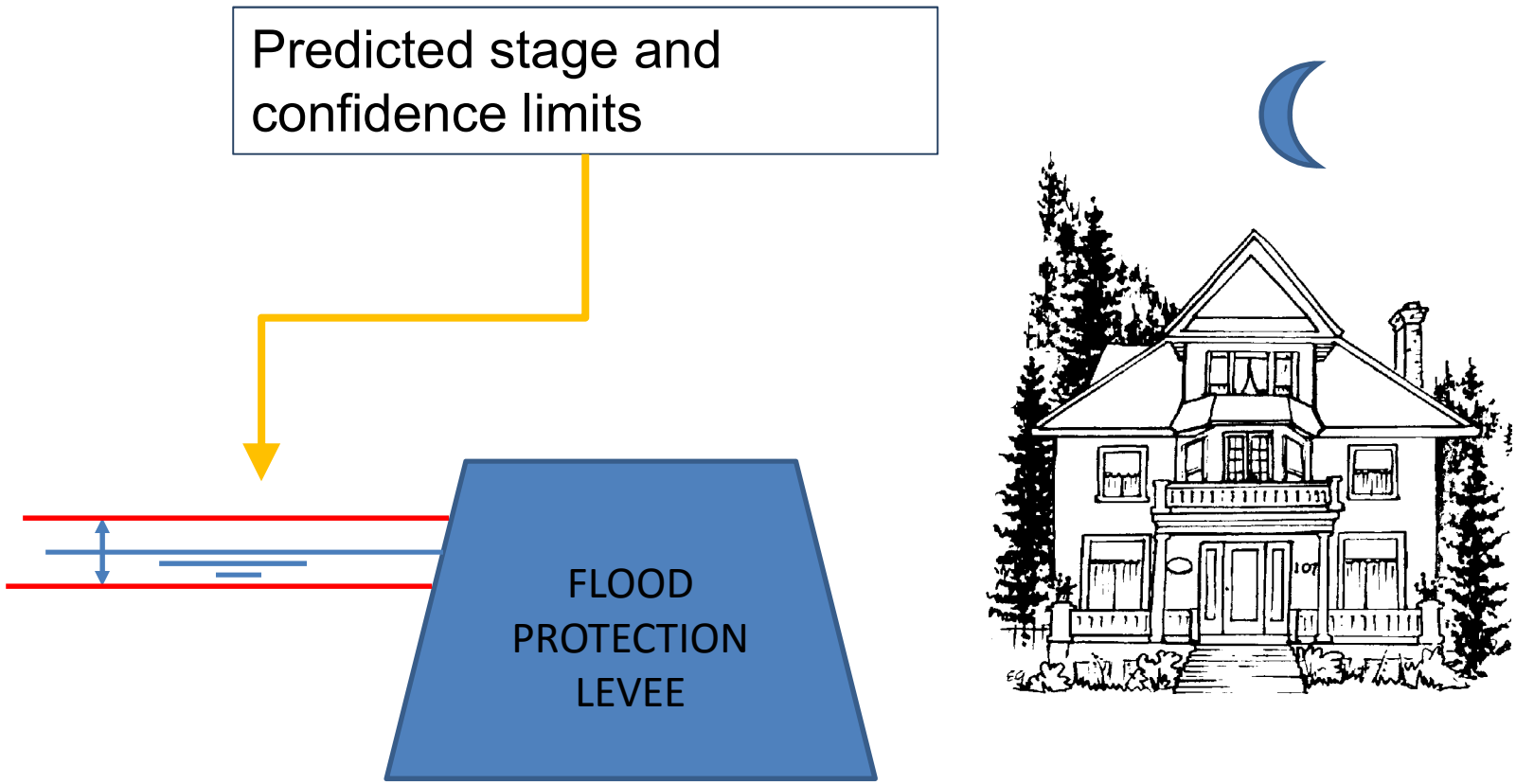
Uncertainty is expressed through confidence interval/limits

- Large interval = high uncertainty = low accuracy
- Small interval = low uncertainty = high accuracy

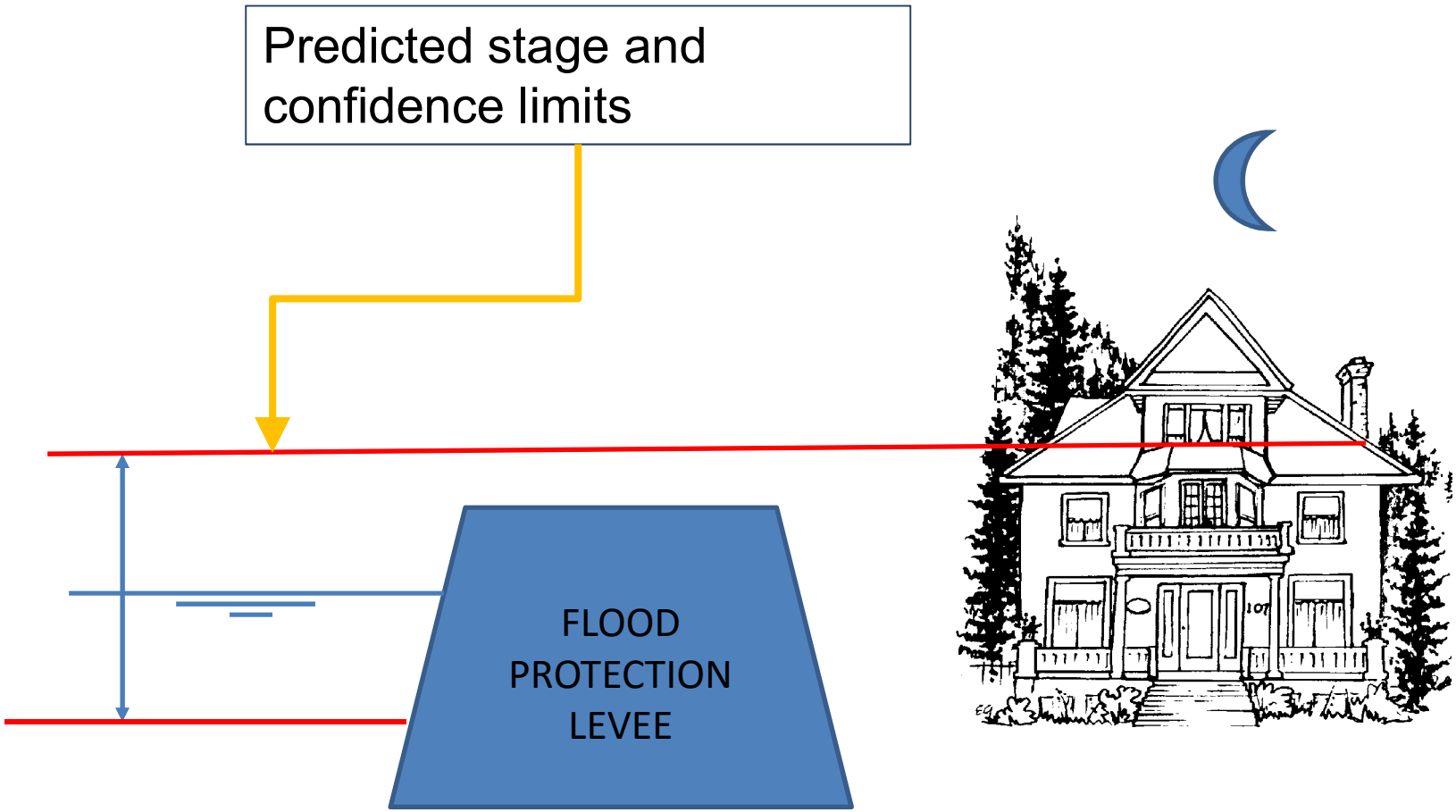
Predicted flood level



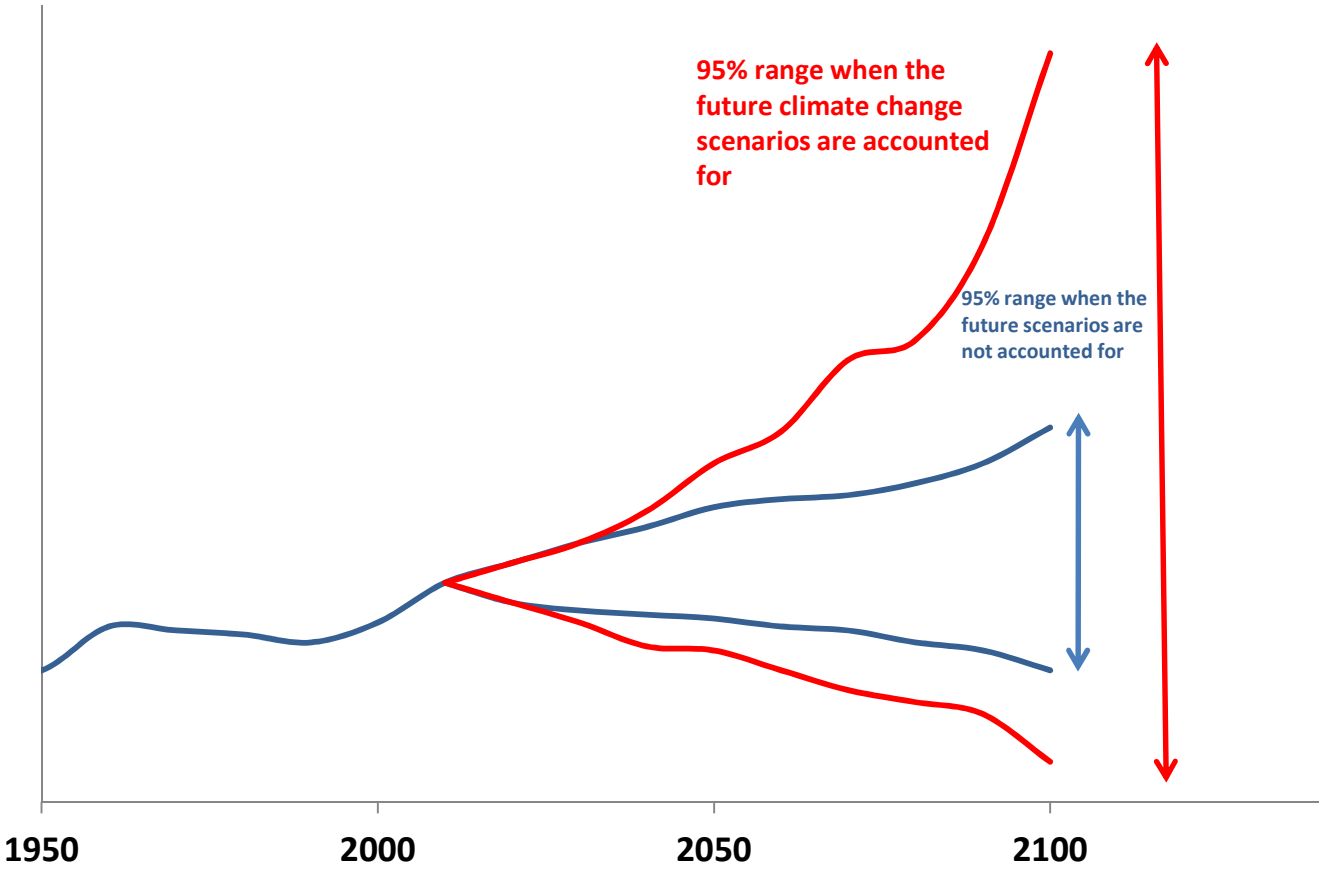
Predicted flood level



Predicted flood level



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



Accounting for uncertainty

- The uncertainty in projected heavy rainfall is significant, and many of us tend to use it to simply ignore these projections. However, ignoring a potentially big change just because it is uncertain could be very costly.

RISK=PROBABILITY × IMPACT

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)

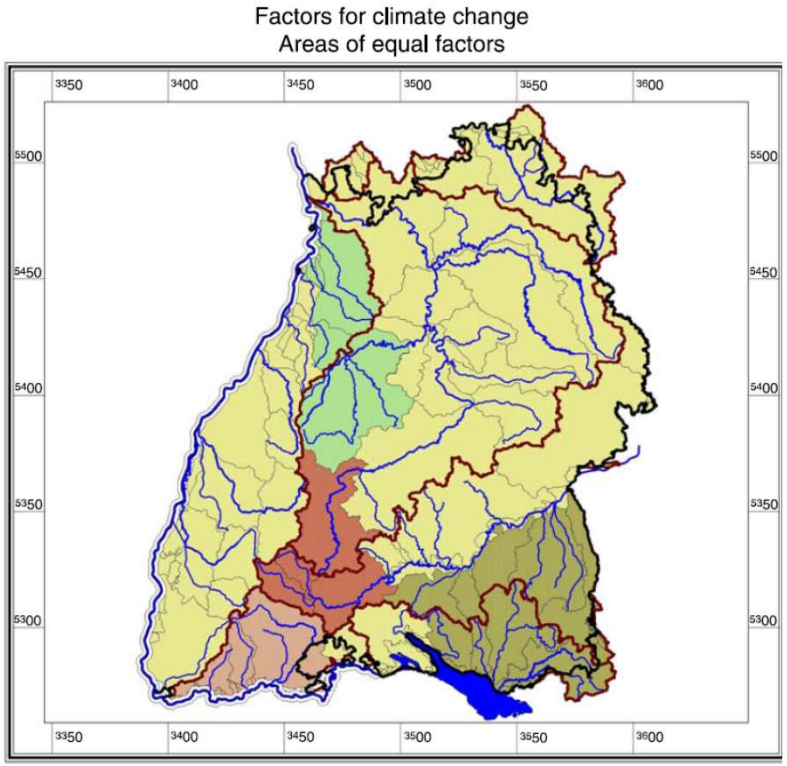


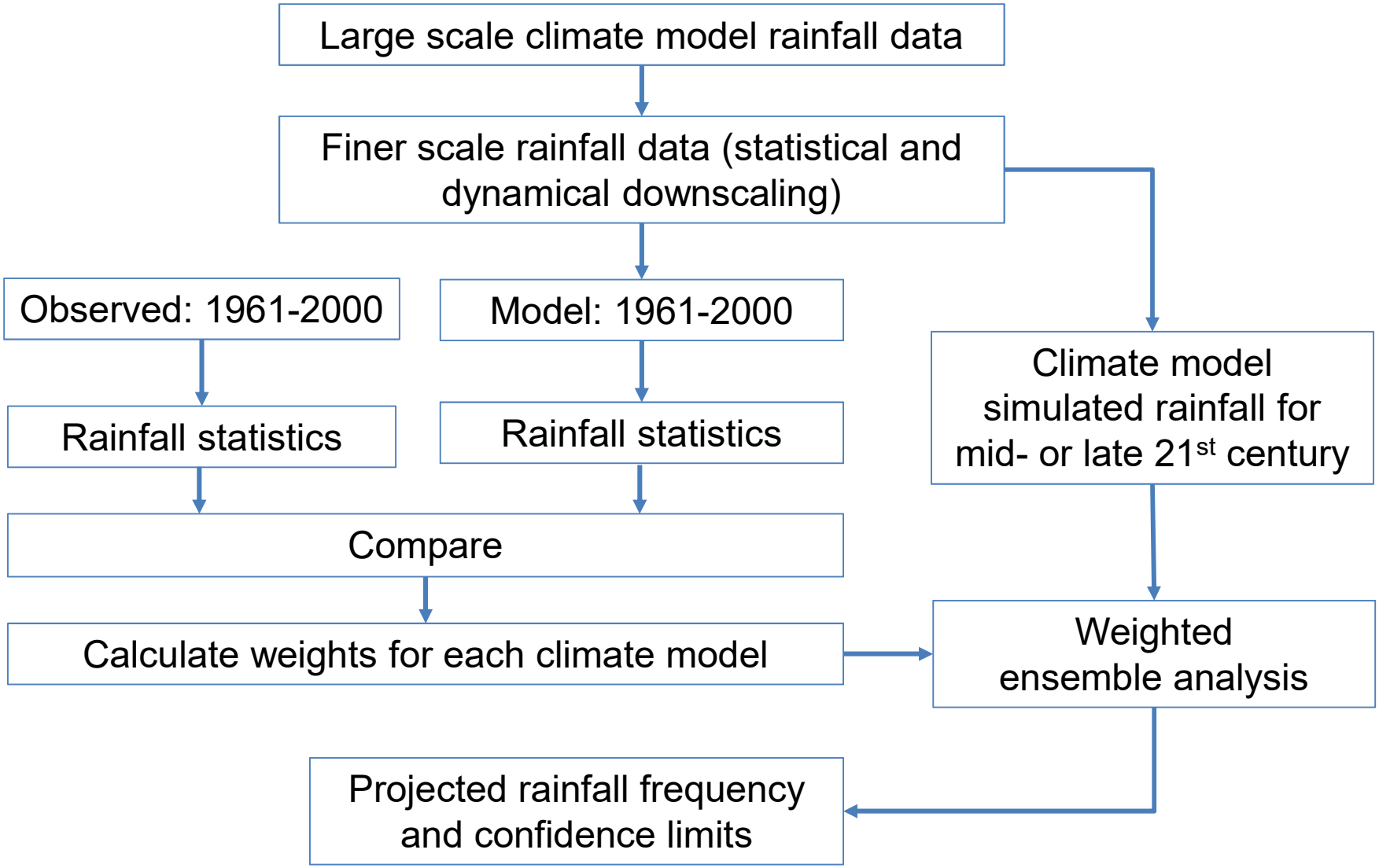
Figure 6 Areas in Baden-Württemberg with uniform climate change factors $f_{T,K}$

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					

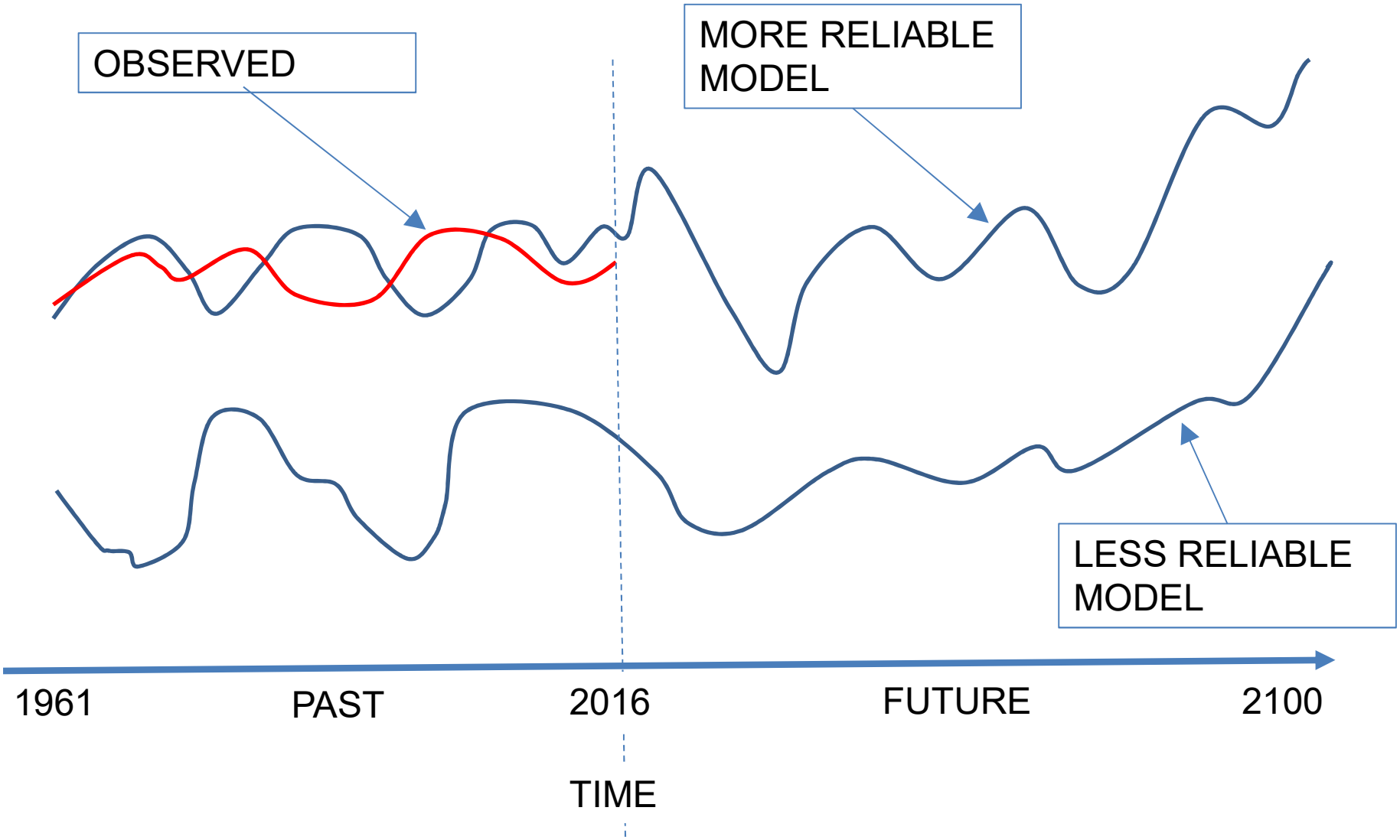
Figure 7 Climate change factors $f_{T,K}$ to determine the design flood for the areas or river catchments in Baden-Württemberg

PROJECT SCHEMATIC

Weighted Ensemble Analysis for heavy rainfall

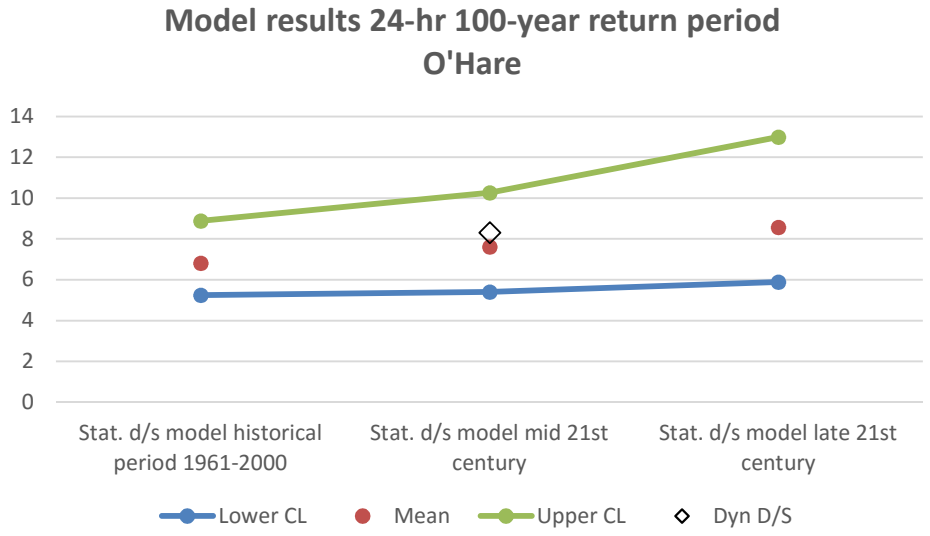


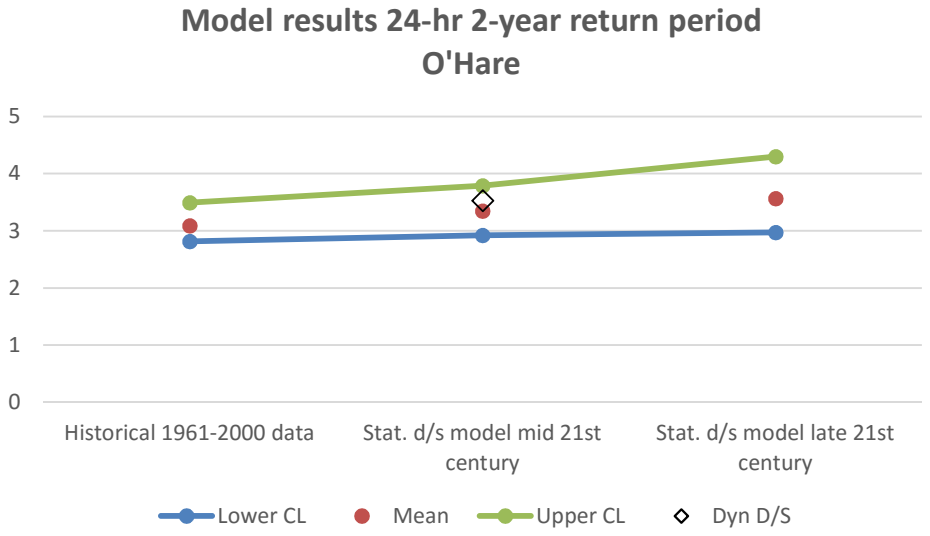
A schematic of climate model evaluation

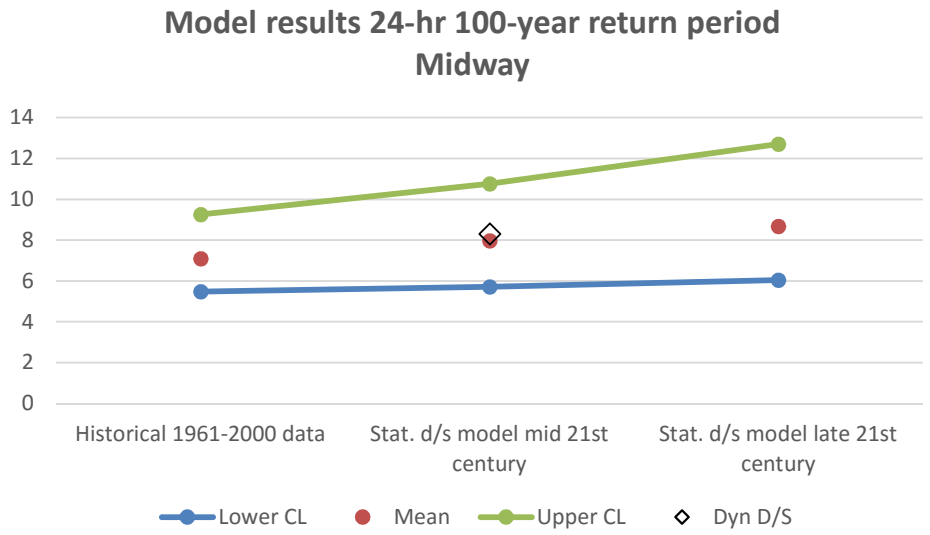


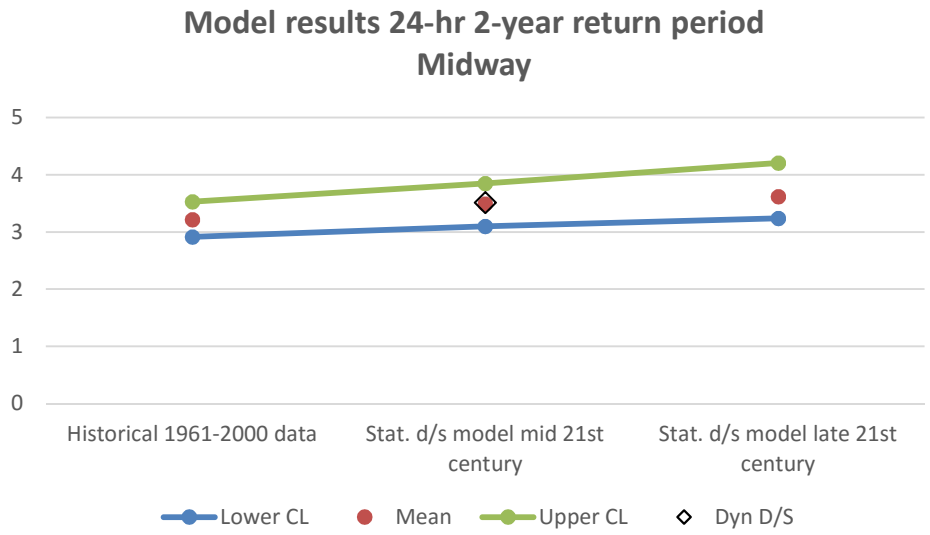
RESULTS

Results for O'Hare and Midway rain gages

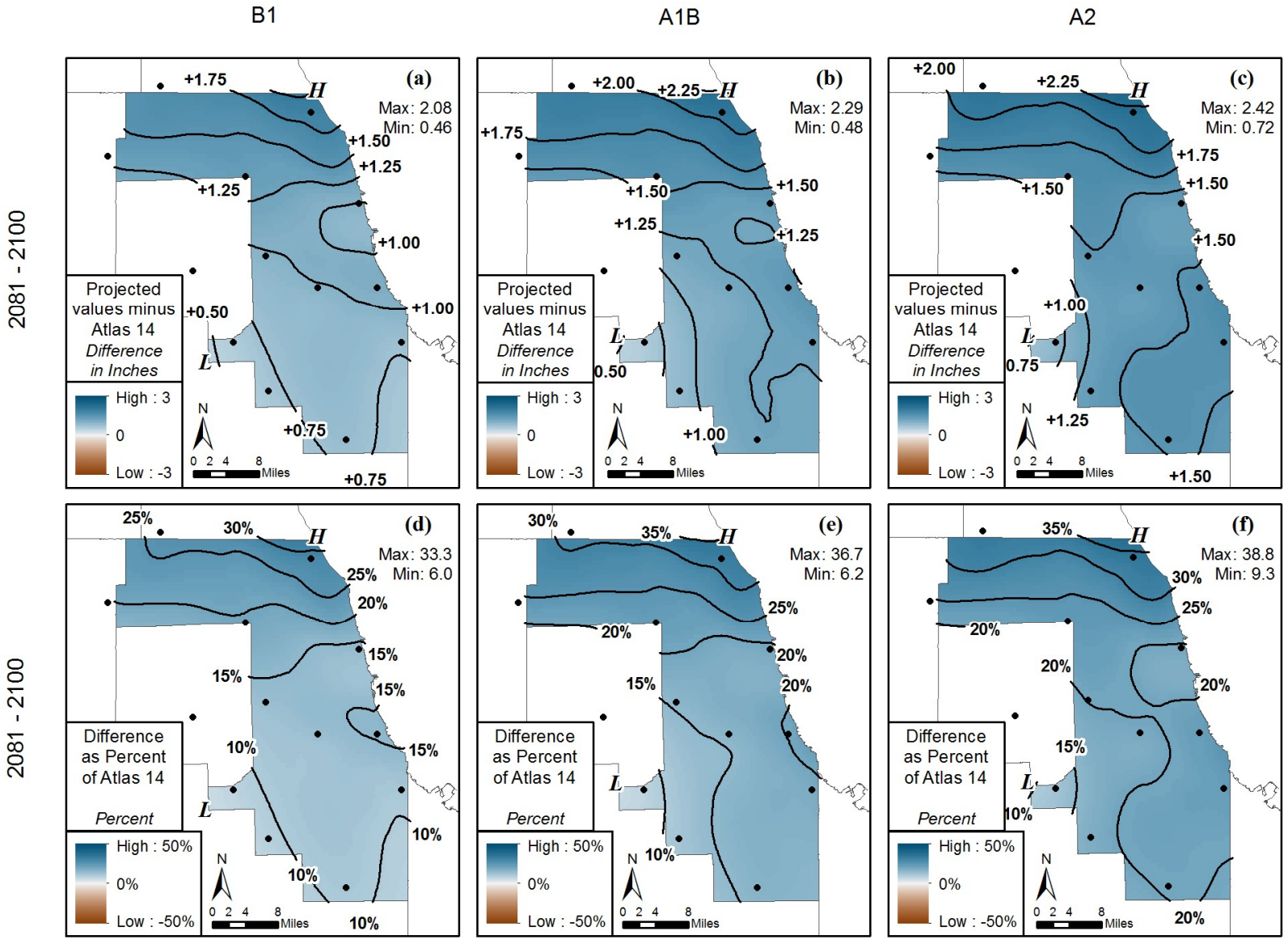






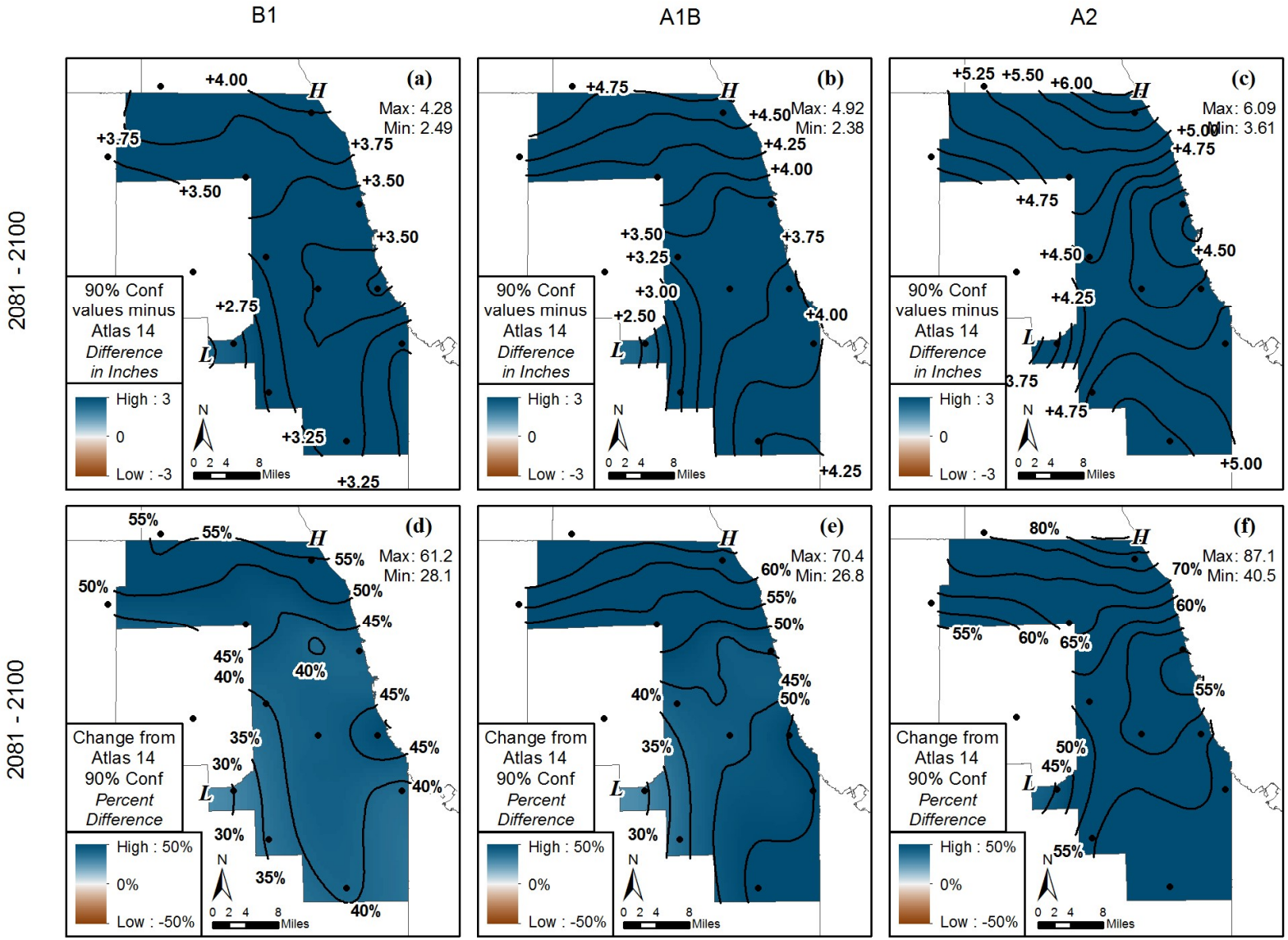


Differences between projected 100-year, 24-hour isohyetals for late-21st century and those based on NOAA Atlas 14



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

Summary

- Heavy rainfall events are expected to increase
- Confidence intervals will become larger
- To increase our confidence in projected rainfall statistics:
  Continue monitoring, research, and model development, validation and testing to better understand and quantify the random nature of the projected rainfall.

Questions?

Exceedances of NOAA Atlas 14