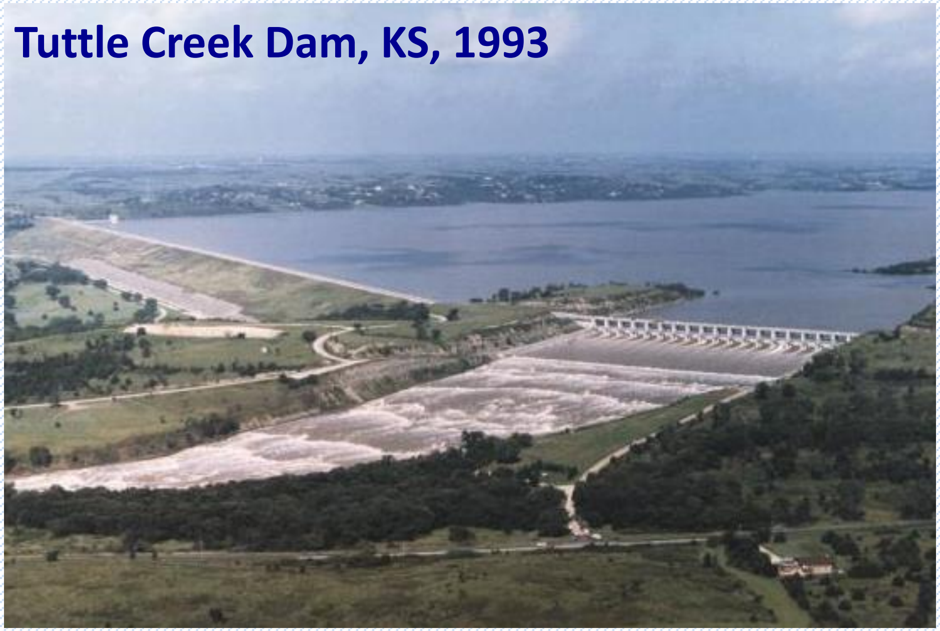
Climate Change: Impacts on Stormwater



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Kansas State University

Dialog on Sustainability

July 20, 2019

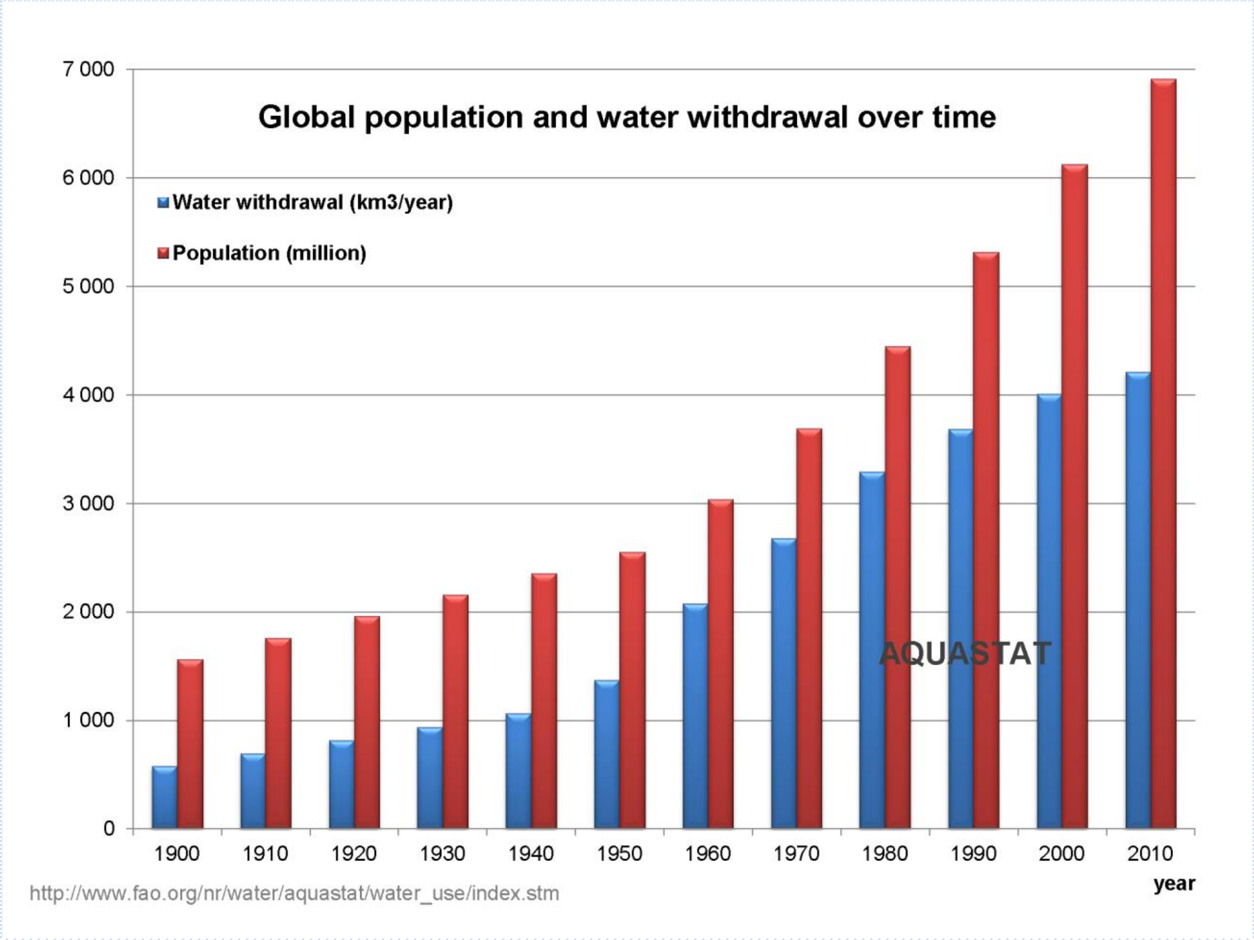
Outline for Today's Talk, Three Parts

1. **Background**

2. **Research**
   - Grand challenges, water
   - Precipitation patterns
   - Design storms
   - Flood frequency analysis
   - Antecedent soil moisture

3. **Concluding remarks**

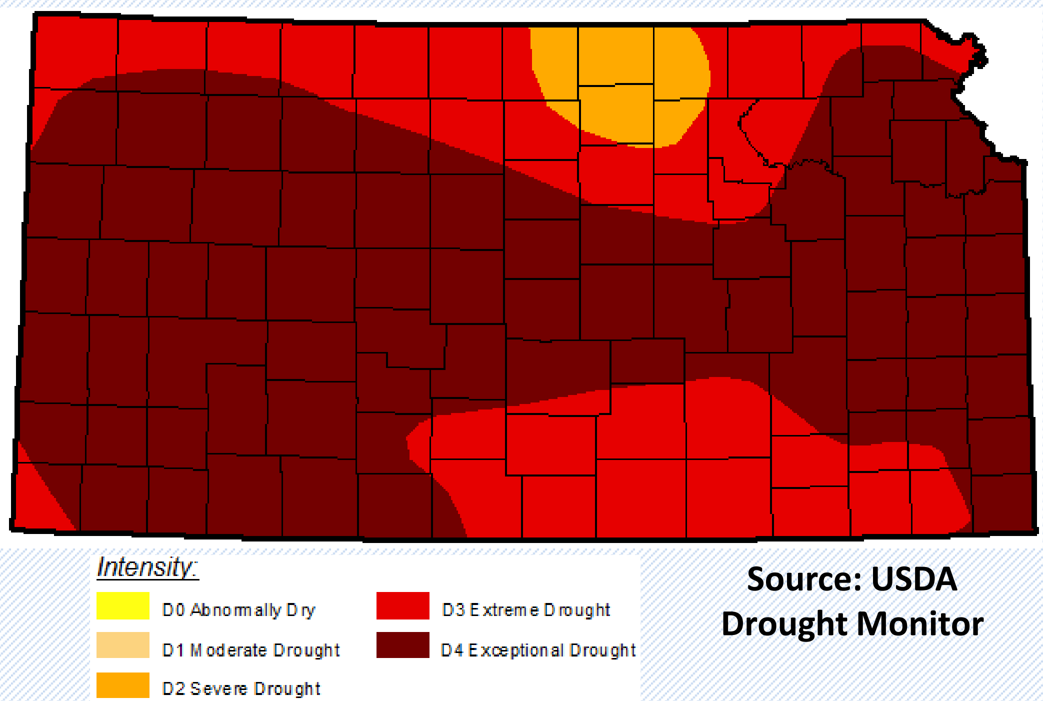
Global Water Withdrawal and Population



- World population increased 4.4 times
- Water withdrawal increased 7.3 times

Too Much Too Little

Kansas drought; August 21, 2012



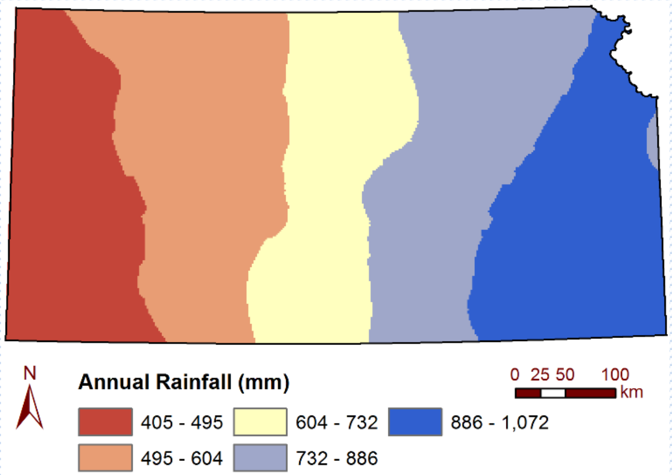
Source: USDA Drought Monitor

Kansas flood; May 4, 2015

Flash flooding 2.97" ***breaks the daily rainfall of 2.91" in 1908***

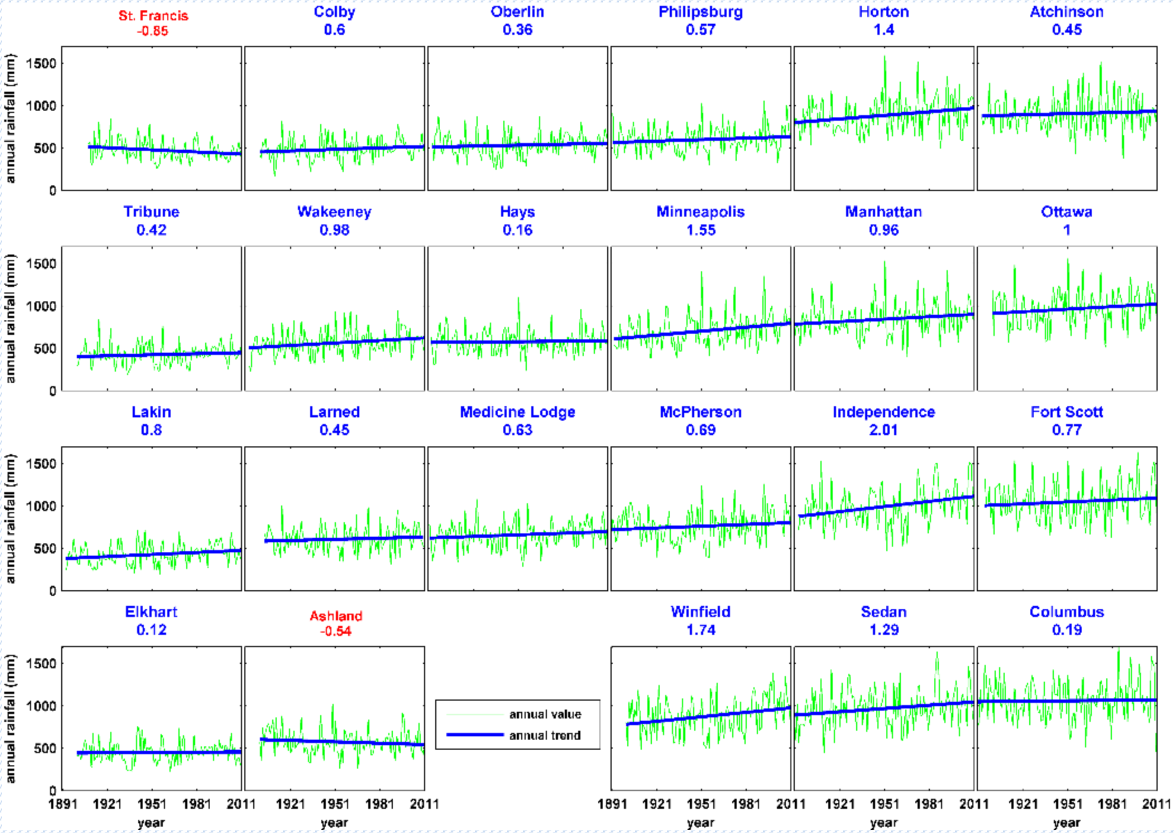
Manhattan, Kansas, USA

Spatiotemporal Precipitation Patterns- Mean values



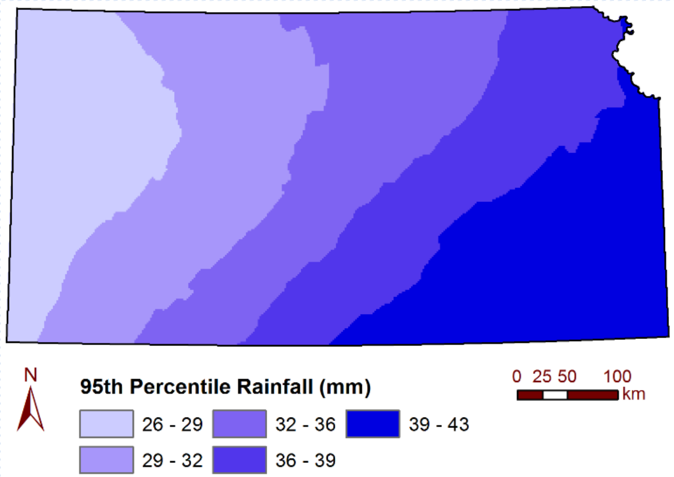
Total annual precipitation - Spatial

Total annual precipitation – Spatiotemporal



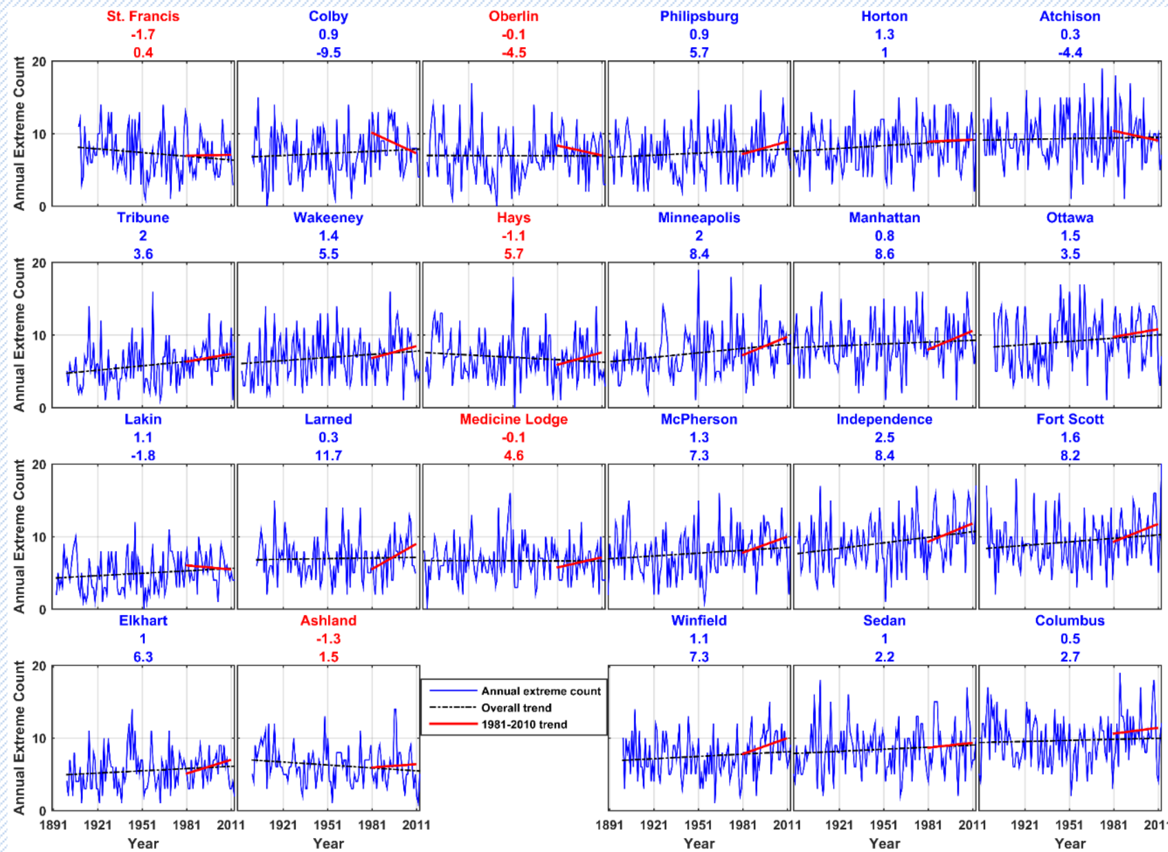
Rahmani et al. 2015

Spatiotemporal Precipitation Patterns- Extreme values



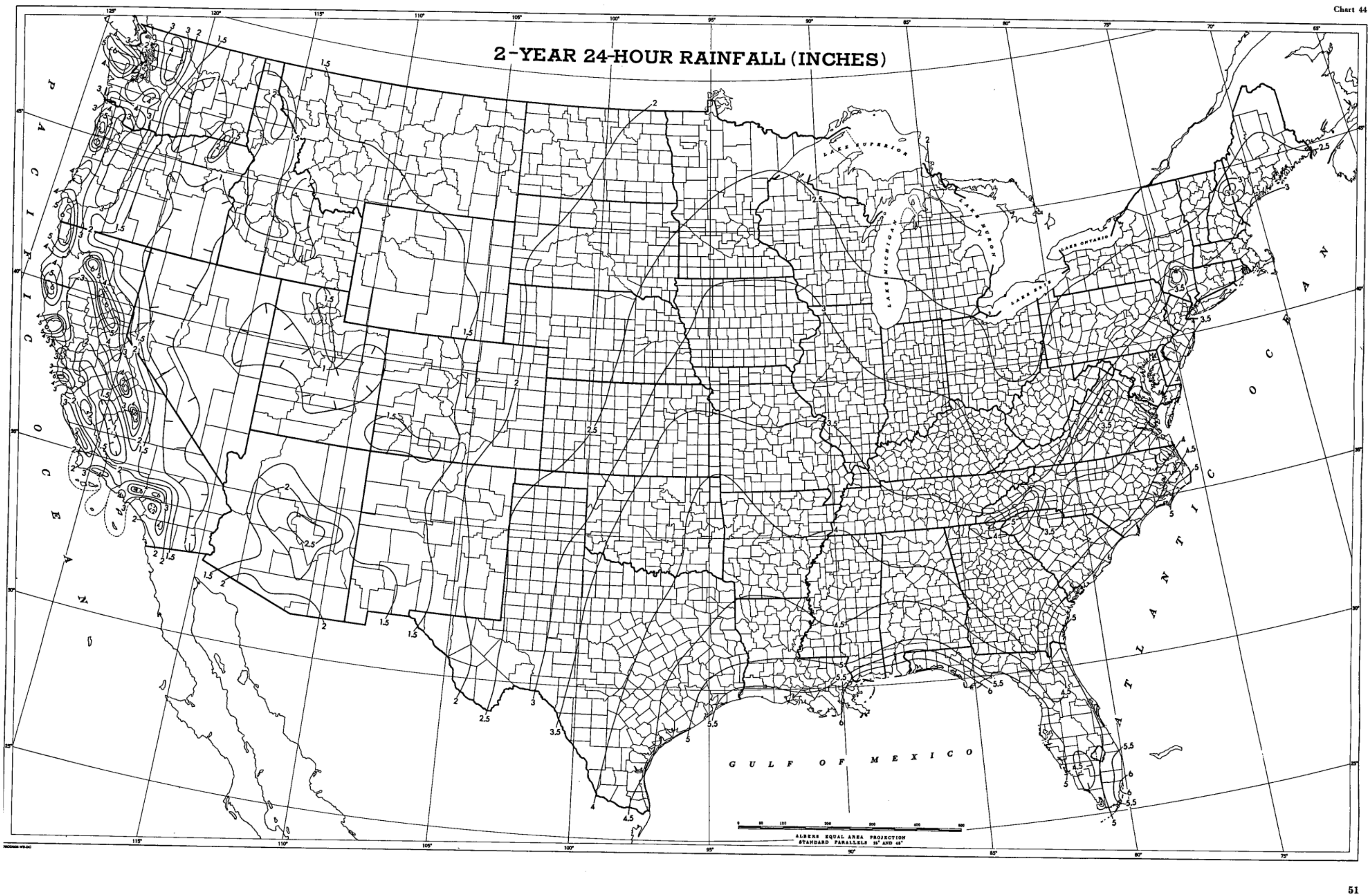
Extreme precipitation magnitude - Spatial

Extreme precipitation frequency – Spatiotemporal



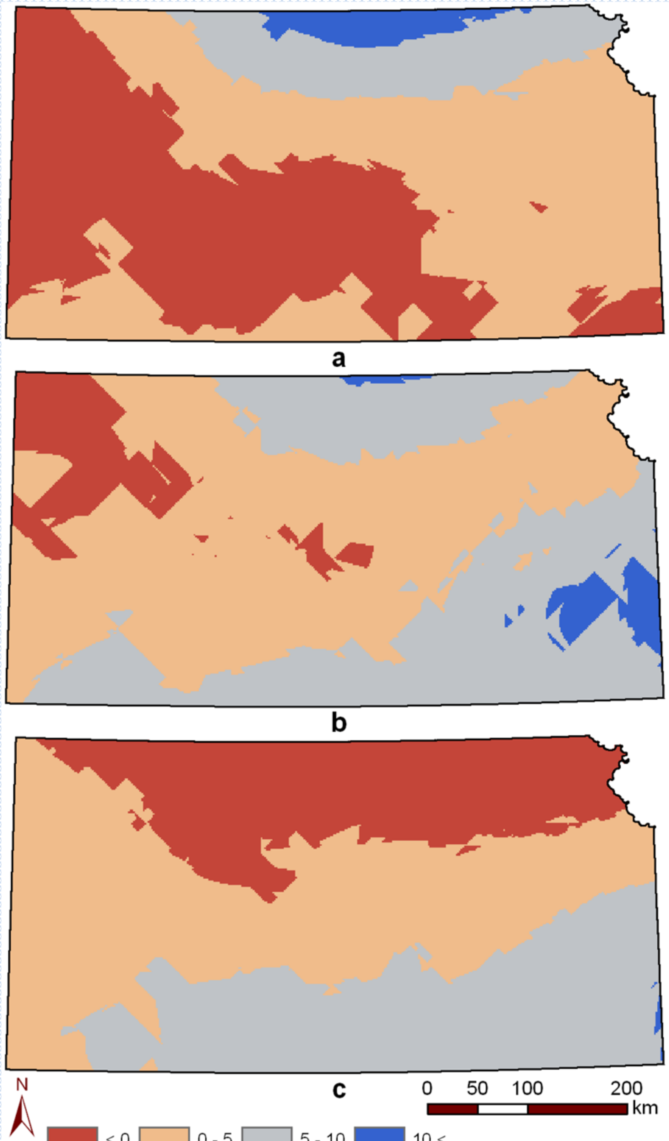
Rahmani et al. 2016

Design Storms



Rahmani et al. 2014

Precipitation shifts- 2-yr return period



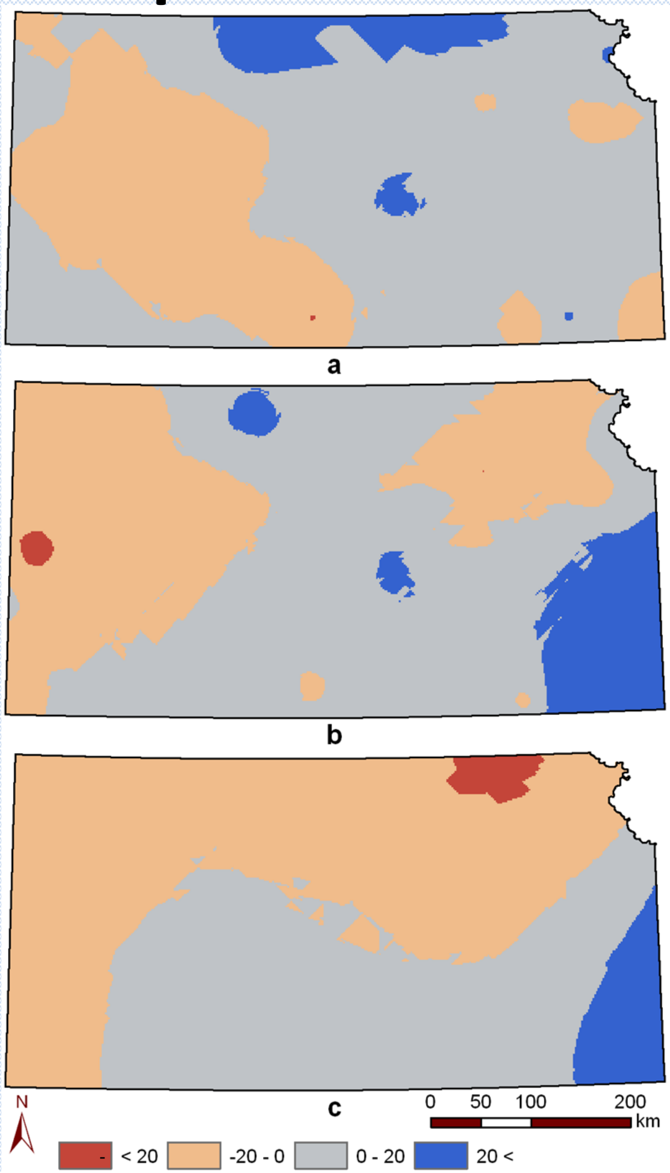
Periods	Increase in area
2 vs. 1	64%
3 vs. 1	90%
3 vs. 2	68%

1: 1920-1949
2: 1950-1979
3: 1980-2009

Precipitation difference for 2 year return period of a)1950-1979 vs. 1920-1949, b)1980-2009 vs. 1920-1949 duration, and c) 1980-2009 vs. 1950-1979.

Rahmani et al. 2014

Precipitation shifts-100-yr return period



Periods	Increase in area
2 vs. 1	69%
3 vs. 1	66%
3 vs. 2	42%

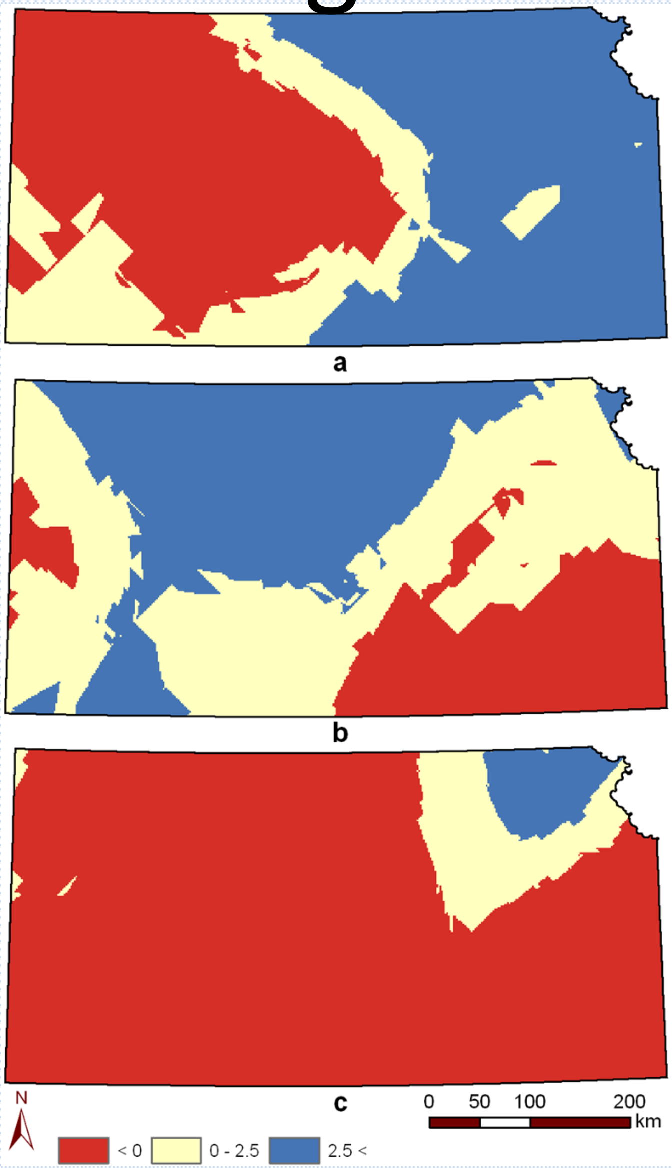
1: 1920-1949

2: 1950-1979

3: 1980-2009

Precipitation difference for 100 year return period of a)1950-1979 vs. 1920-1949, b)1980-2009 vs. 1920-1949 duration, and c) 1980-2009 vs. 1950-1979.

Design storms- 2-yr return period



Periods	Increase in area
1 vs. TP40	33%
2 vs. TP40	43%
3 vs. TP40	84%

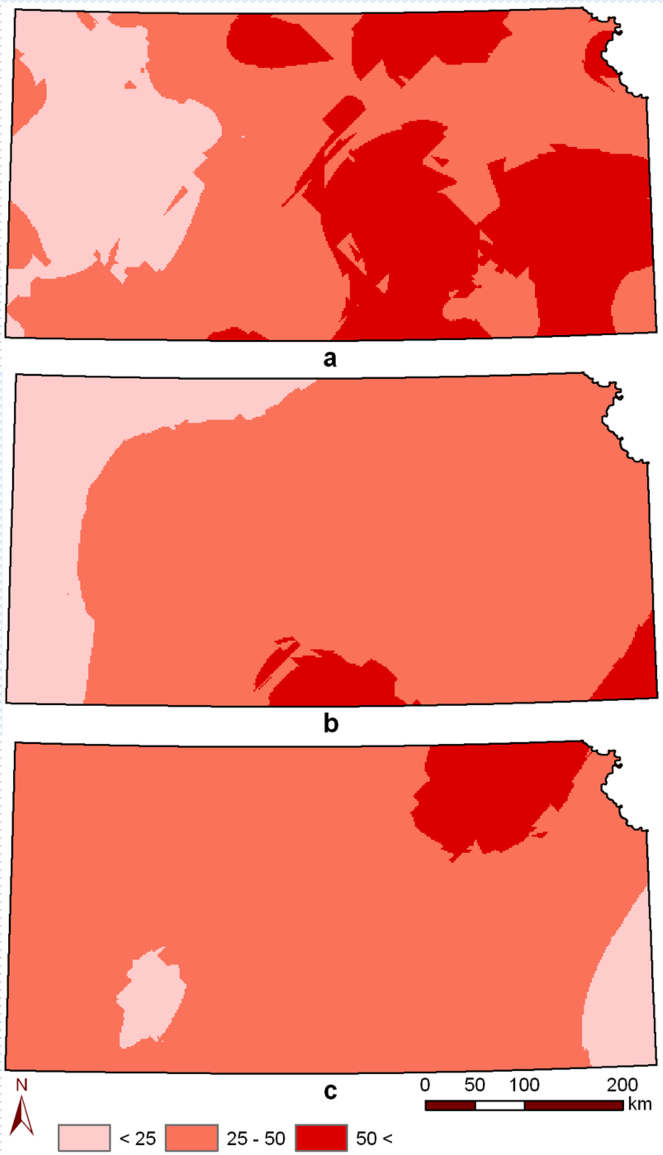
1: 1920-1949

2: 1950-1979

3: 1980-2009

Precipitation distribution shift (mm) of Hershfield [1961] vs. the period of a)1920–1949, b)1950–1979, and c)1980–2009 for 2-year return period

Design storms- 100-yr return period



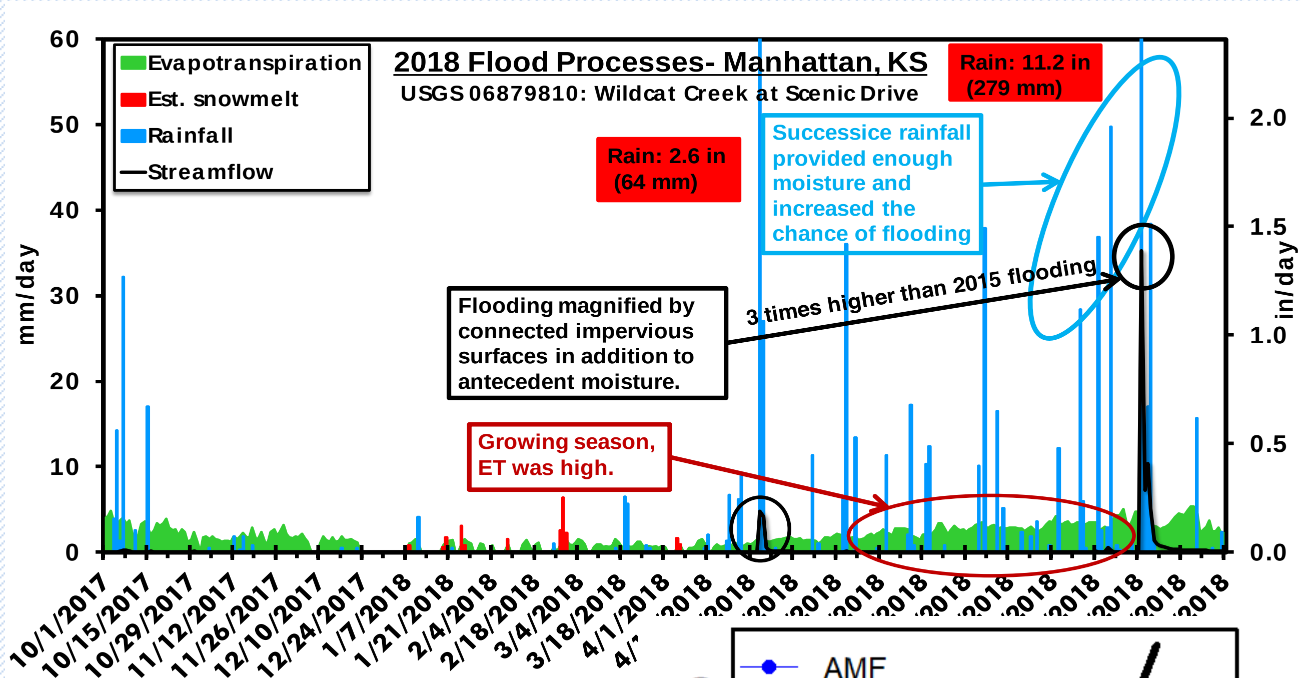
- 1920-1949: 28% of the state gained more than 50 mm of rainfall, 53% between 25 and 50 mm, and 19% less than 25 mm.
- The majority of the state was **over-predicted** by 25–50 mm during the second period (69%) and **third period (84%)**.

Precipitation distribution shift (mm) of Hershfield [1961] vs. the period of a)1920–1949, b)1950–1979, and c)1980–2009 for 100-year return period.

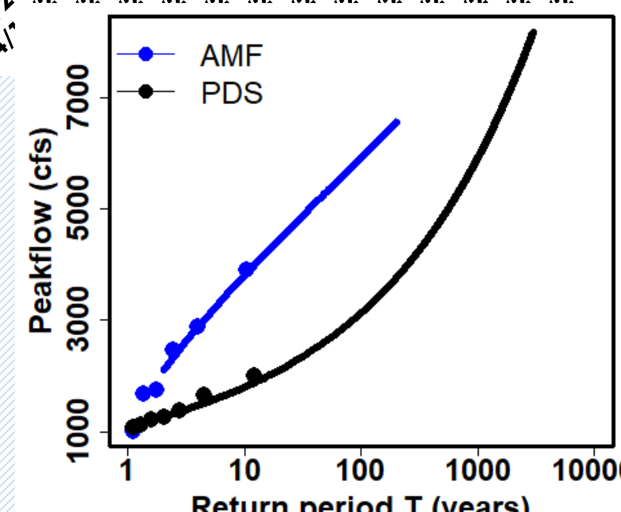
Improving Flood Estimates- 2018 Labor Day Flashflood

2018 Flash flooding 11.2” (284 mm) *breaks the daily rainfall of 2.97” in 2015, Manhattan, KS*

Flood generating mechanism

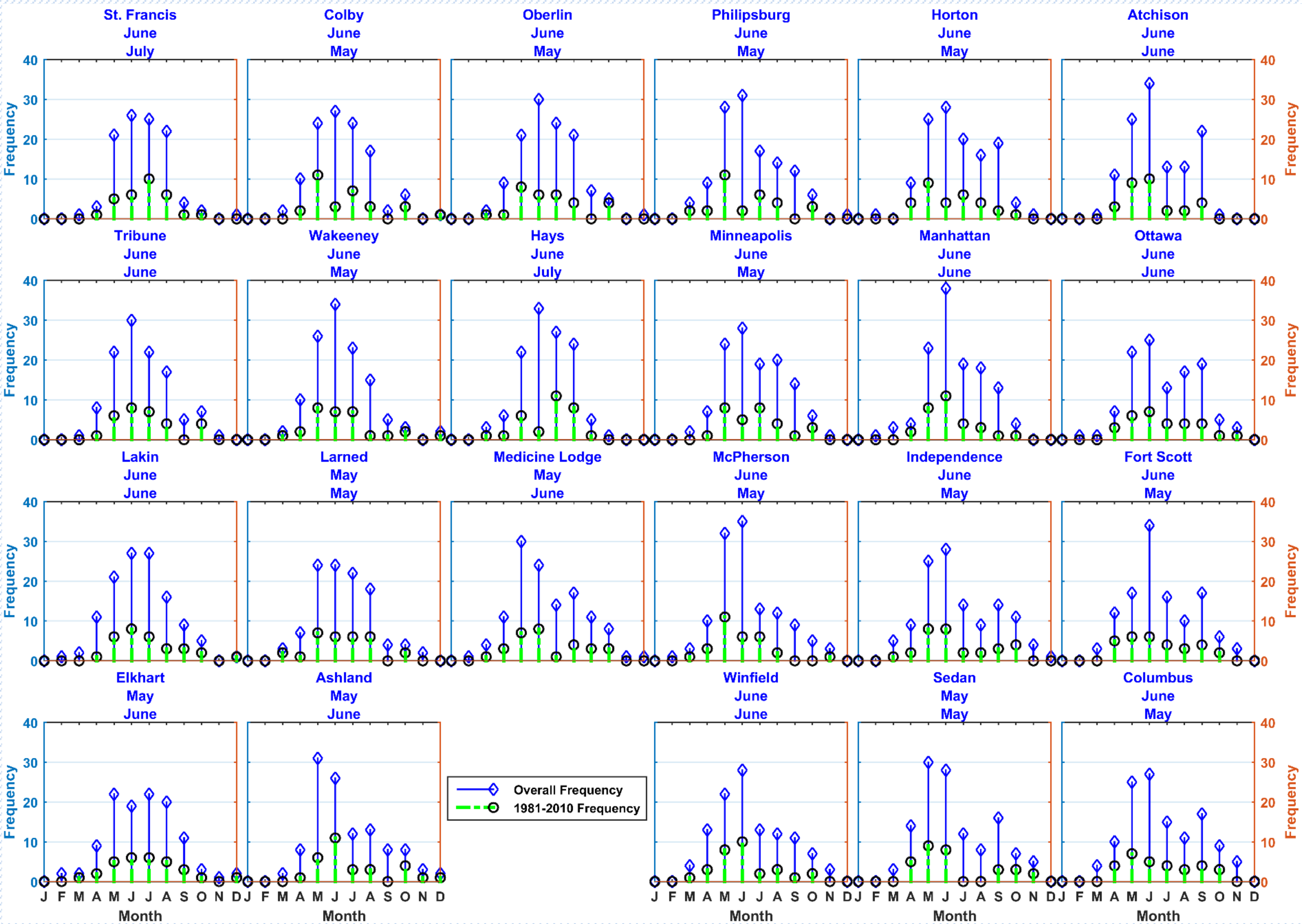


Flood frequency analysis



Rahmani and Berton 2018

Shifts in Seasonal Precipitation-
From June to May



Rahmani et al. 2016, 2018

Remote Sensing Soil Moisture-Flashflooding

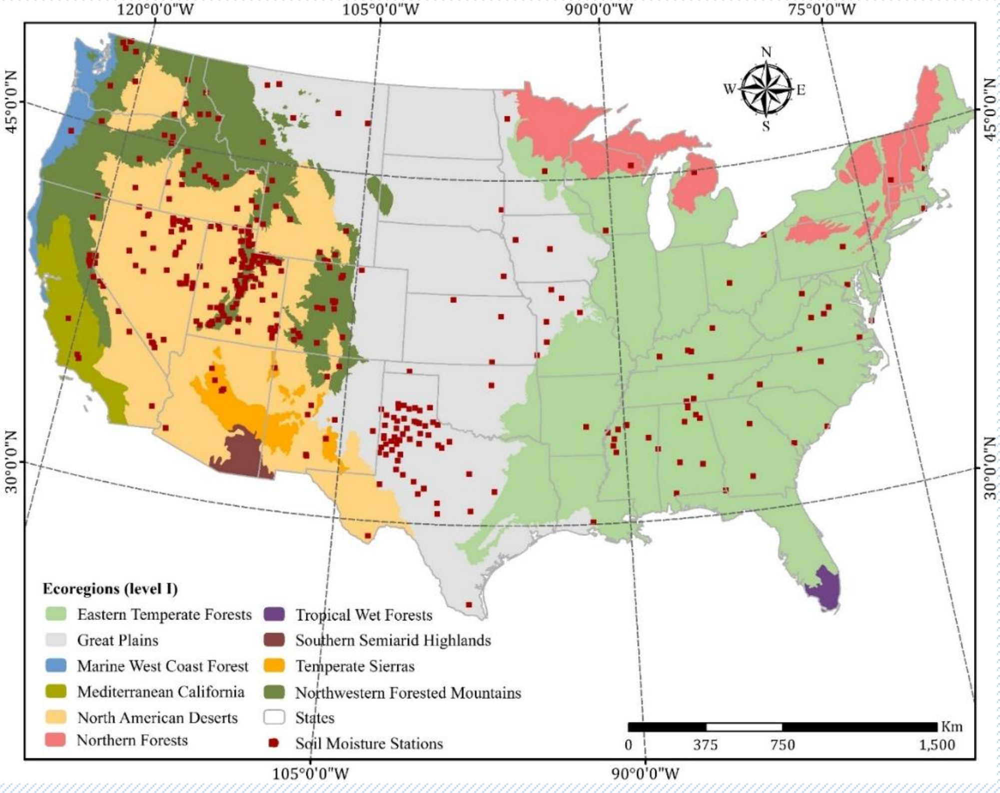
- **Using remote sensing soil moisture against in situ soil moisture**

- **NASA Soil Moisture Active Passive (SMAP) launched in 2015**

- **Large scale soil moisture information for flood and drought assessment and prediction**

- **Streamflow prediction**

- **Regional scale water management**



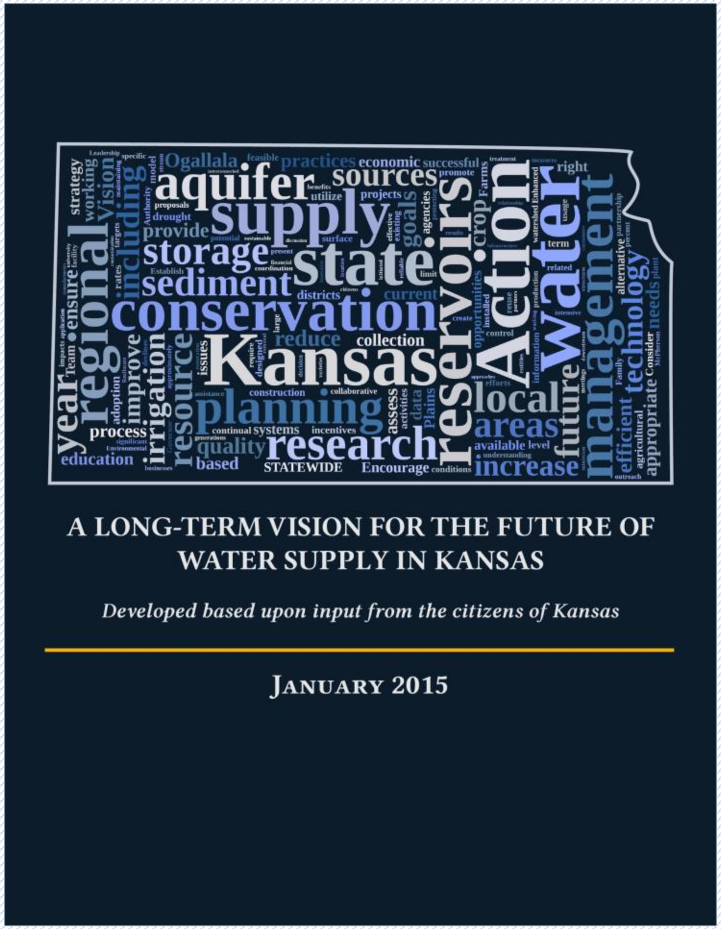
Tavakol et al. 2019

Concluding Remarks

- **Climate change: "Stationarity is Dead!"** (Milly et al. 2008)
  - Extreme precipitation: Rethinking of design storms
  - Precipitation distribution: Short-, mid-, and long-term decisions for sustainable water management
  - Trends: Policy makers and water managers

A Long-term Vision for the Future of Water in Kansas

- **Governor Support**
- **Focus: sustainable water supply**
  - Surface water and groundwater
  - Reduce vulnerability to extreme events; floods and drought
  - Develop and maintain water infrastructure
  - Sedimentation management
  - Provide reliable, sustainable water supply



Thank you!

Questions?

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- ***Dr. Larry Erickson***

- ***My students and colleagues***

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- **Rahmani, V., and J.A. Harrington, Jr. (2018), Assessment of Climate Change Precipitation Indices: a Case Study from the Central United States, International Journal of Climatology, 1-13, doi: 10.1002/joc.5858**
- **Tavakol, A*, and V Rahmani (2018), Changes of Heat Wave Duration in the Mississippi River Basin, American Society of Agricultural and Biological Engineers (ASABE) Annual International Meeting, Detroit, MI. July 30, 2018, doi: 10.13031/aim.201801071**
- **Rahmani, V., S.L. Hutchinson, J.A. Harrington, Jr., and J.M.S. Hutchinson (2016), Analysis of Frequency and Magnitude of Extreme Rainfall Events with Potential Impacts on Flooding; a Case Study from the Central United States, International Journal of Climatology, 36(10), 3578-3587, doi: 10.1002/joc.4577**
- **Rahmani, V., S.L. Hutchinson, J.A. Harrington, Jr., J.M.S. Hutchinson, and A. Anandhi (2015), Analysis of Temporal and Spatial Distribution and Change-points for Annual Precipitation in Kansas, USA, International Journal of Climatology, 35(13), 3879-3887, doi: 10.1002/joc.4252**
- **Rahmani, V., S.L. Hutchinson, J.M.S. Hutchinson, and A. Anandhi (2014), Extreme Daily Rainfall Event Distribution Patterns in Kansas, Journal of Hydrologic Engineering, 19(4), 707-716, doi: 10.1061/(ASCE)HE.1943-5584.0000839**
- **Tavakol, A.*, V. Rahmani, S. Quiring, S.V. Kumar (2019), Validation analysis of NASA SMAP L3 and L4 and SPoRT-LIS soil moisture data in the United States, Remote Sensing of Environment**

Other relevant publications on climate and hydrologic extremes

- ***Loeffler, K.M.*, V. Rahmani, J.H. Kastens, and D.G. Huggins (2018), Identifying Potential Wetland Development Areas Around Managed Reservoirs Using LiDAR, Journal of Applied Geography, 93, 16-24, doi: https://doi.org/10.1016/j.apgeog.2018.02.010***
- ***Rahmani, V., J.H. Kastens, F. deNoyelles, M.E. Jakubauskas, E.A. Martinko, D.G. Huggins, C. Gnau, P.M. Liechti, S.W. Campbell, R.A. Callihan, and A.J. Blackwood (2018), Examining Storage Capacity Loss and Sedimentation Rate of Large Reservoirs in the Central U.S. Great Plains, Water, 10(2), 190, doi:10.3390/w10020190***
- ***Berton, R.*, and V. Rahmani (2018), Potential Improvement in Flood Frequency Analysis in Nonstationary Conditions in the Conterminous United States, Water Resources Research, in review***
- ***Bandad, DA*, and V Rahmani (2018), Analysis of PDSI and Vegetation Condition Index (VCI) and their Links to Streamflow, American Society of Agricultural and Biological Engineers (ASABE) Annual International Meeting, Detroit, MI. August 1, 2018, doi: 10.13031/aim.201801344***
- ***Tavakol, A*, and V Rahmani (2018), Evaluation of NASA SMAP L4 Soil Moisture Data in Land Use Clusters using Ground-based Data, American Society of Agricultural and Biological Engineers (ASABE) Annual International Meeting, Detroit, MI. July 31, 2018, doi: 10.13031/aim.201801070***
- ***Ahiablame, L., A.Y. Sheshukov, V. Rahmani, and D. Moriasi (2017), Annual Baseflow Variations as Influenced by Climate Variability and Agricultural Land Use Change in the Missouri River Basin, Journal of Hydrology, 551, 188-202, doi: https://doi.org/10.1016/j.jhydrol.2017.05.055***
- ***Schroeder, A.J., J.J. Gourley, J.D. Hardy, J. Henderson, P. Parhi, V. Rahmani, K.A. Reed, R.S. Schumacher, B.K. Smith, and M.J. Taraldsen (2016), The Development of a Flash Flood Severity Index, Journal of Hydrology, 541(A), 523-532, doi: http://dx.doi.org/10.1016/j.jhydrol.2016.04.005***

Ideas for Collaboration?

- **Changes in Interconnected Climatic and Hydrologic Extremes**

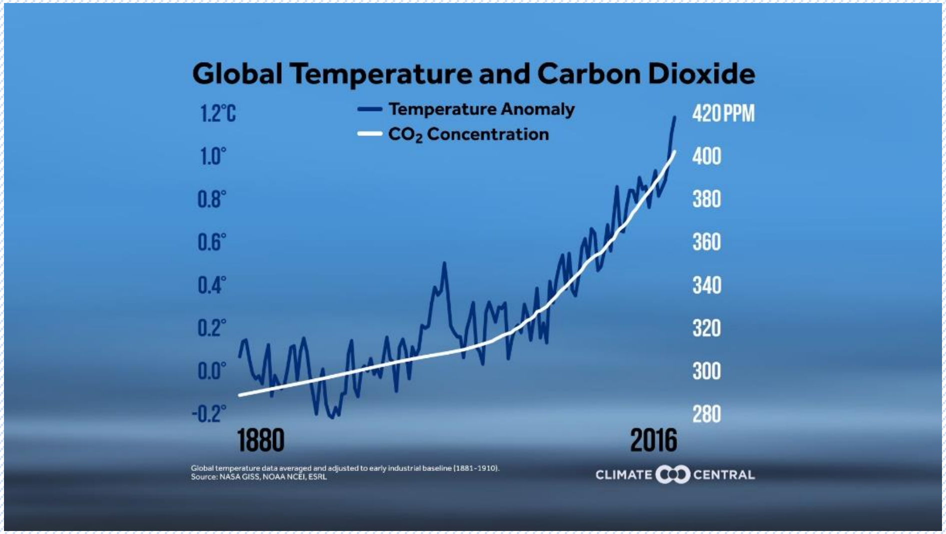
Precipitation changes ; Flooding/Flash Flooding ; Soil moisture ; Streamflow Prediction ; Sedimentation ; Wetlands ; Surface water/groundwater ; Drought ; Heatwaves ; Ecosystem health ; Plant/animal/human health ; Water quality

…?

Climate Change: Global Warming

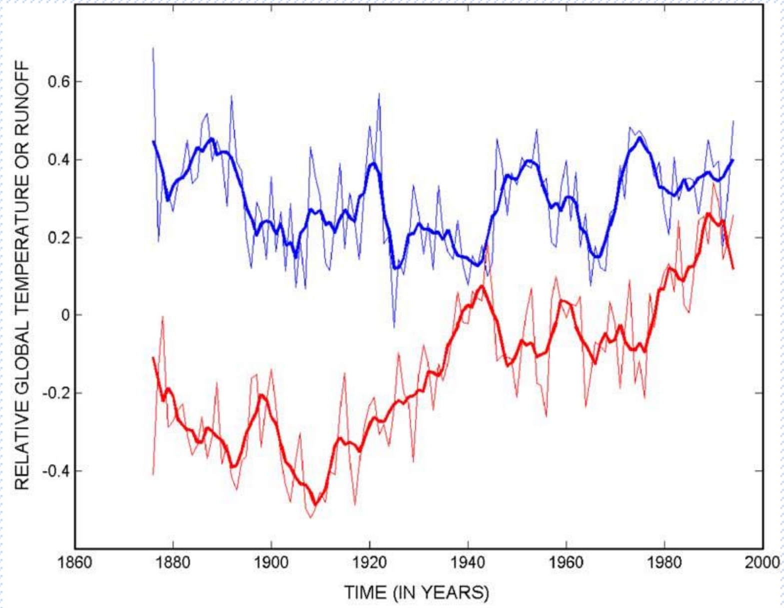
- **Temperature increase of 0.74 °C for 1906 to 2005 (IPCC 2007)**
  - **Steeper slope for the last 50 years**
  - **Greater rate of runoff for higher latitudes and wet tropical regions (Karl et al. 2009)**

Global Temperature and CO2 Concentration

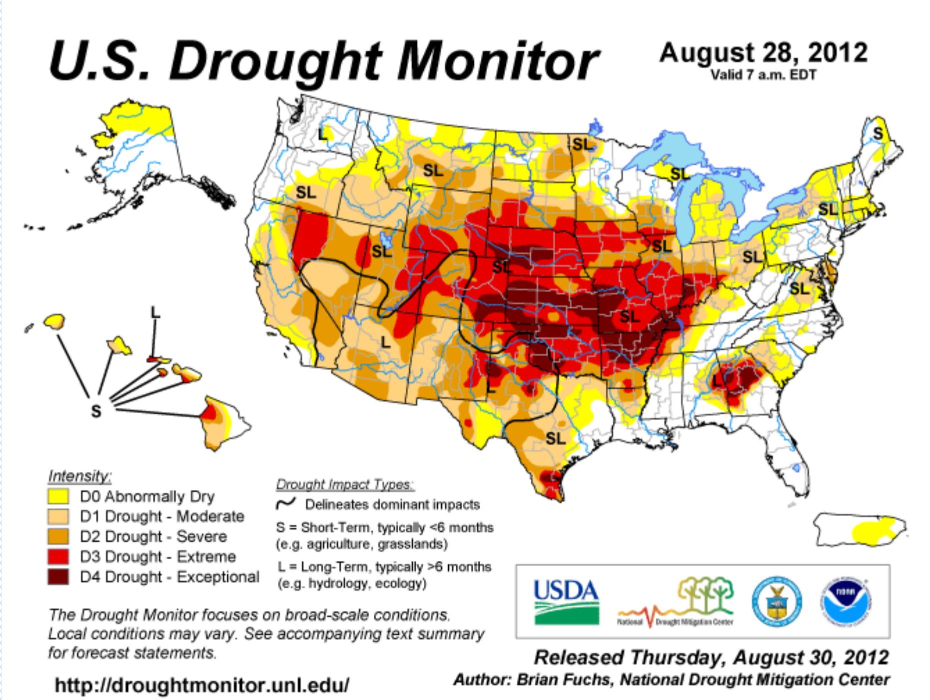


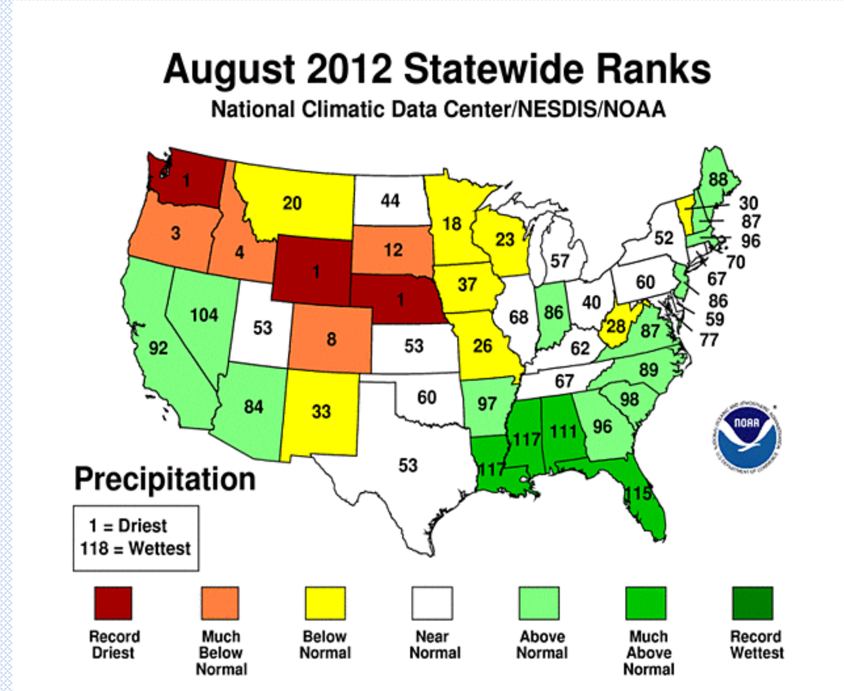
Climate Central 2017

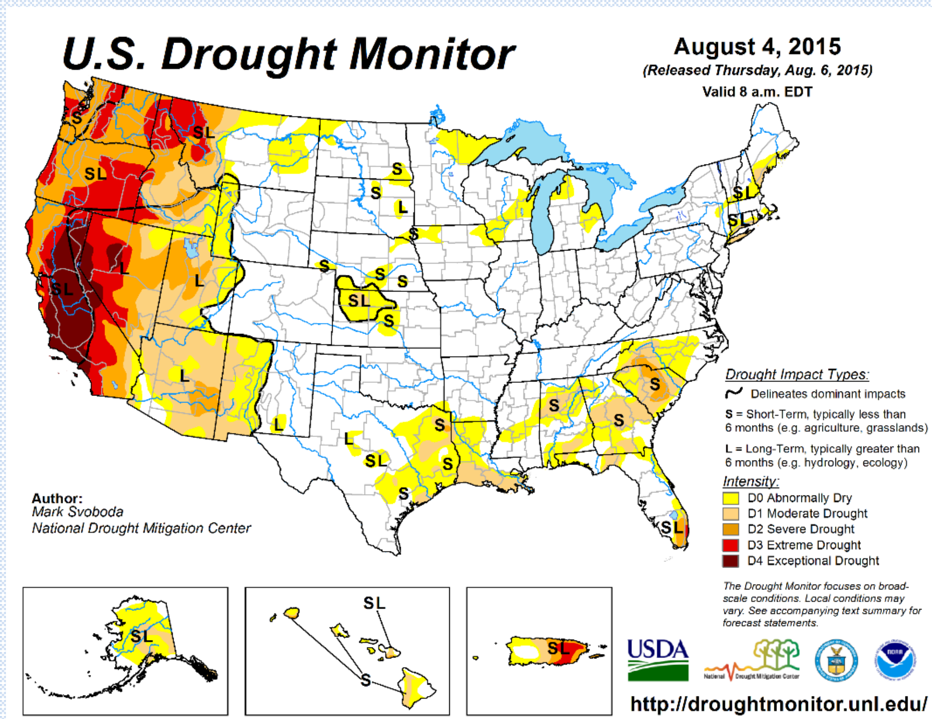
Global Runoff and Temperature



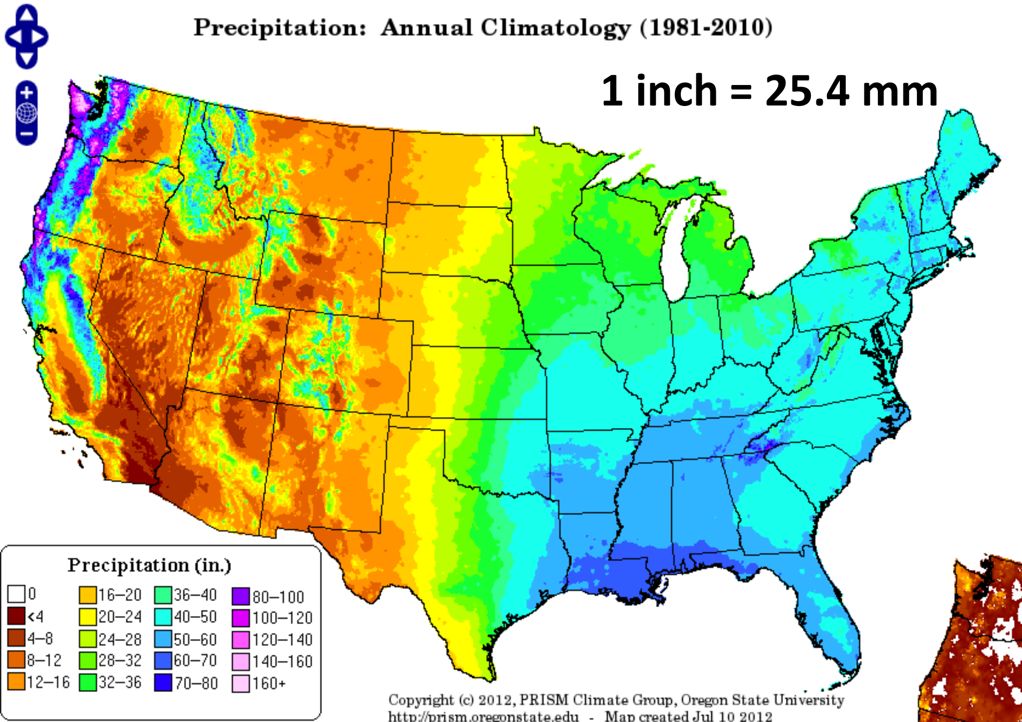
Karl et al. 2009


U.S. Drought Monitor
August 28, 2012
Valid 7 a.m. EDT
Intensity:
D0 Abnormally Dry
D1 Drought - Moderate
D2 Drought - Severe
D3 Drought - Extreme
D4 Drought - Exceptional
Drought Impact Types:
Delineates dominant impacts
S = Short-Term, typically <6 months (e.g. agriculture, grasslands)
L = Long-Term, typically >6 months (e.g. hydrology, ecology)
The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.
USDA
Released Thursday, August 30, 2012
Author: Brian Fuchs, National Drought Mitigation Center
http://droughtmonitor.unl.edu/


August 2012 Statewide Ranks
National Climatic Data Center/NESDIS/NOAA
Precipitation
1 = Driest
118 = Wettest
Record Driest
Much Below Normal
Below Normal
Near Normal
Above Normal
Much Above Normal
Record Wettest

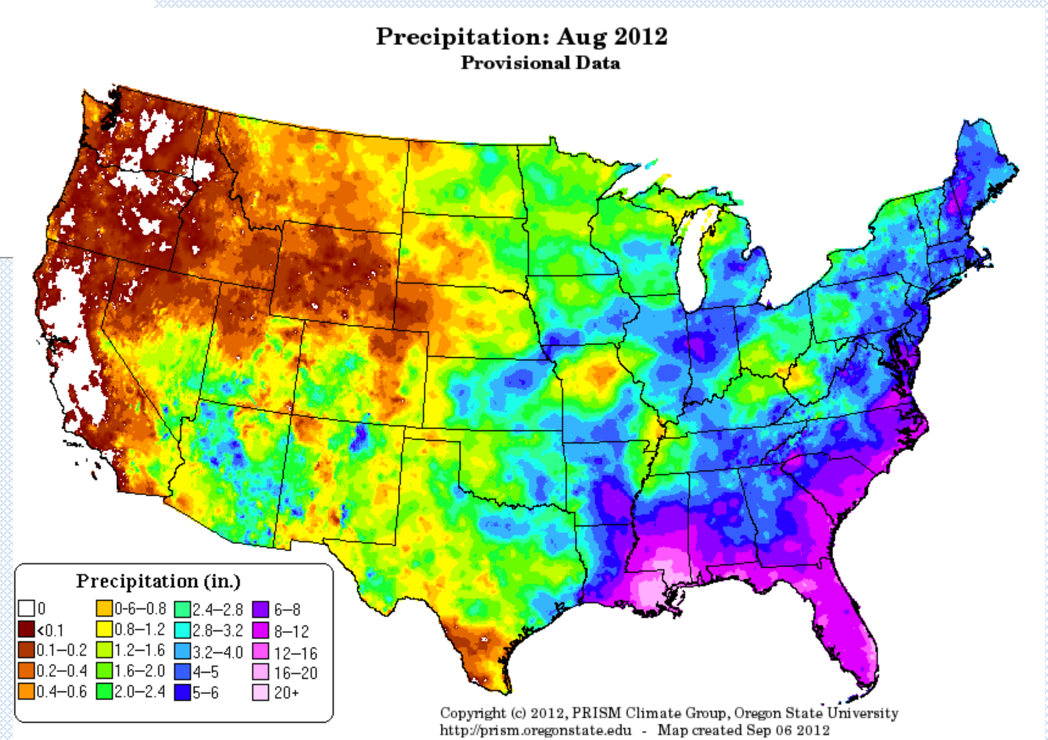

U.S. Drought Monitor
August 4, 2015
(Released Thursday, Aug. 6, 2015)
Valid 8 a.m. EDT
Drought Impact Types:
Delineates dominant impacts
S = Short-Term, typically less than 6 months (e.g. agriculture, grasslands)
L = Long-Term, typically greater than 6 months (e.g. hydrology, ecology)
Intensity:
D0 Abnormally Dry
D1 Moderate Drought
D2 Severe Drought
D3 Extreme Drought
D4 Exceptional Drought
The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.
Author:
Mark Svoboda
National Drought Mitigation Center
USDA
http://droughtmonitor.unl.edu/

Sustainable Water Resources Management in the USA and Kansas



1 inch = 25.4 mm

30-yr average: <u>Expected</u>

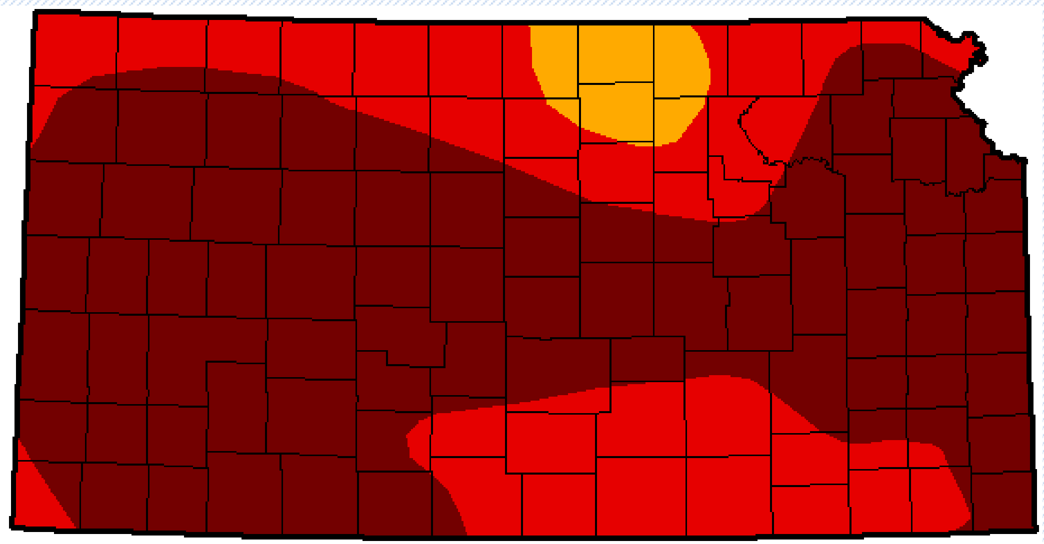


<u>Extreme</u> conditions

Water Resources Management

- **Access to reliable, sustainable clean water** **(NAE, 2014)**
  - **Extreme events:**
    - Flooding in eastern Kansas and drought in western Kansas

Kansas drought; August 21, 2012



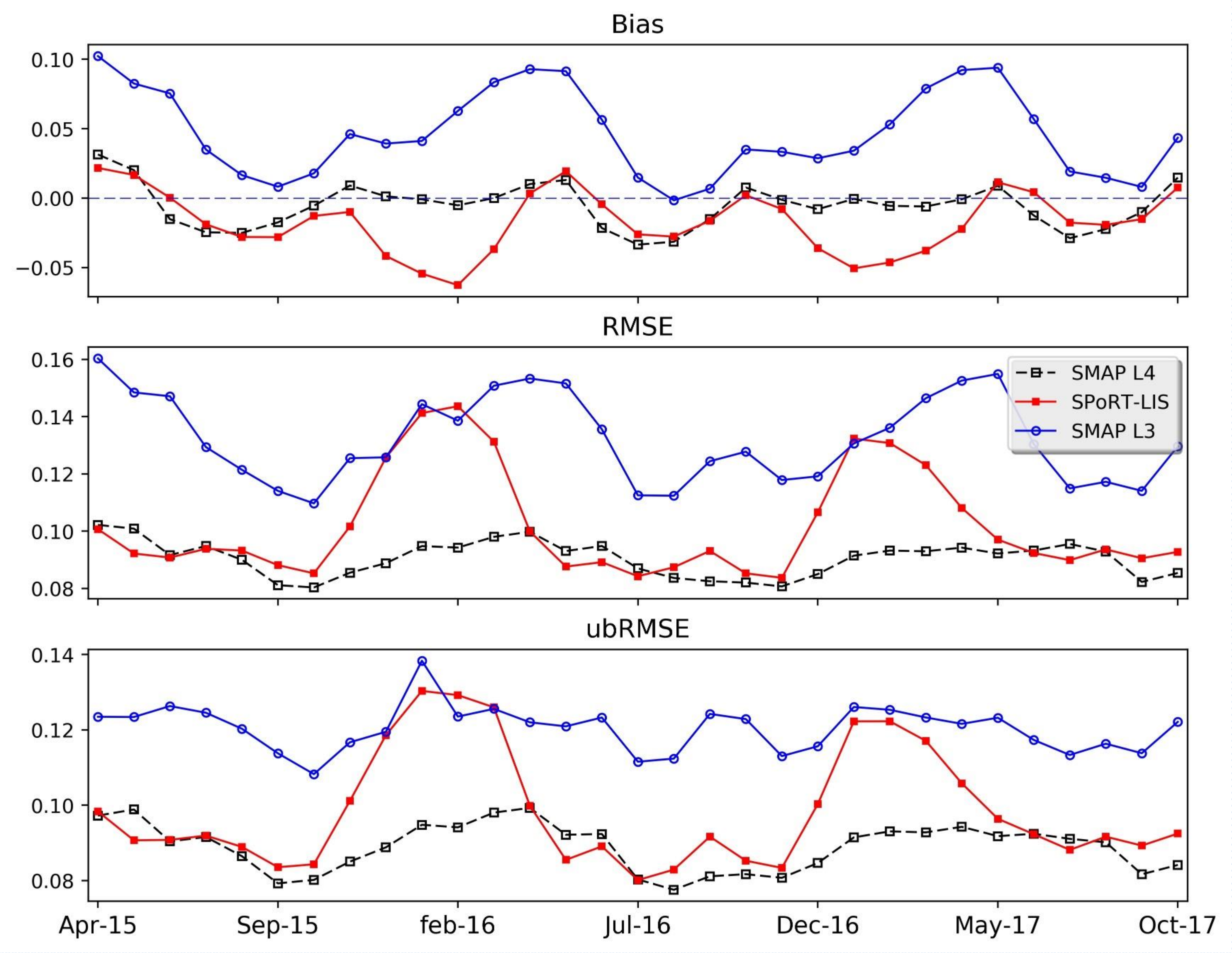
Source: USDA Drought Monitor

Kansas flood; May 4, 2015

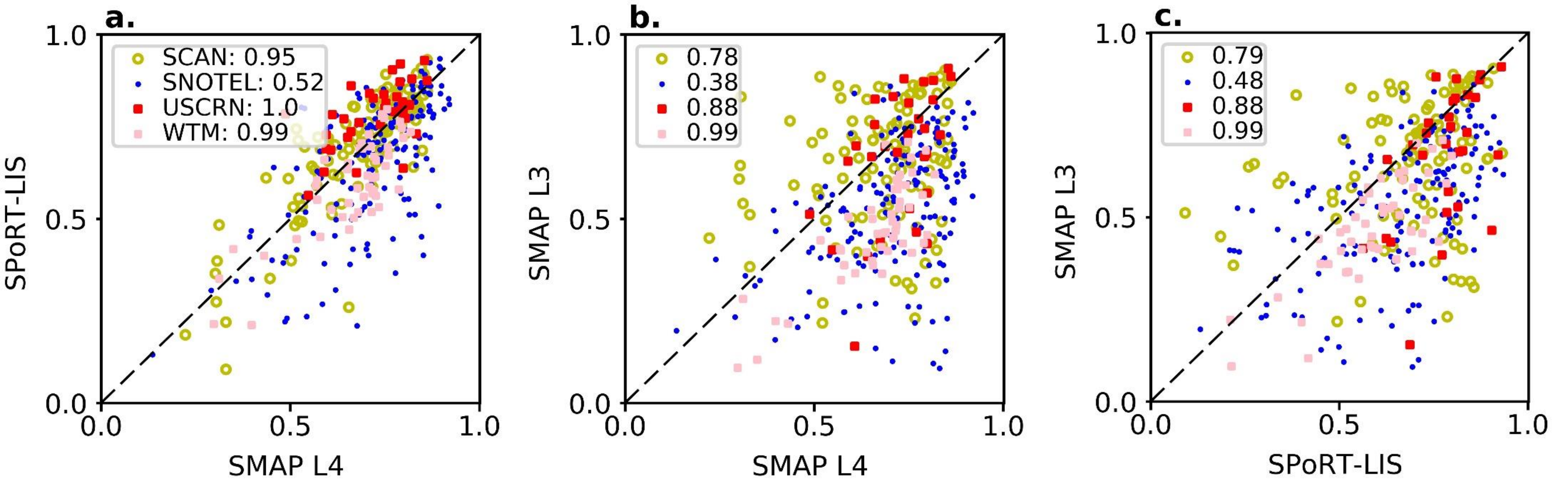
Flash flooding 2.97" ***breaks the daily rainfall of 2.91" in 1908***

Manhattan, KS

Evaluation of Remote Sensing Soil Moisture



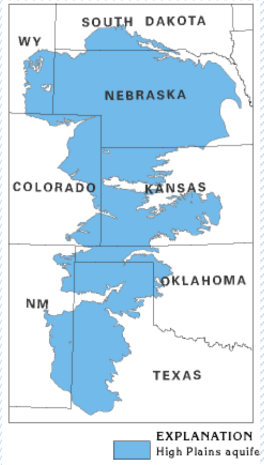
Correlation between Remote Sensing and In-situ Soil Moisture



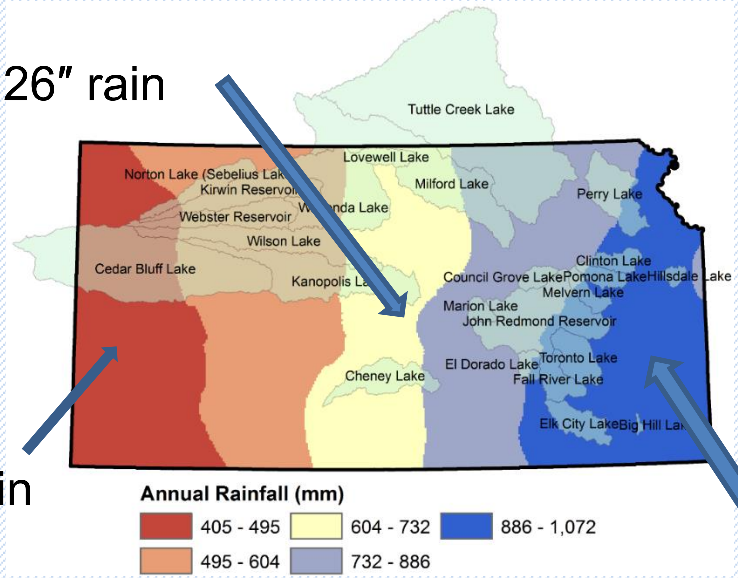
Tavakol et al. 2019

Groundwater Use for Agricultural Production- Dry Heatwaves

- High Plains Aquifer, Ogallala
- 85% of diverted water goes to irrigation

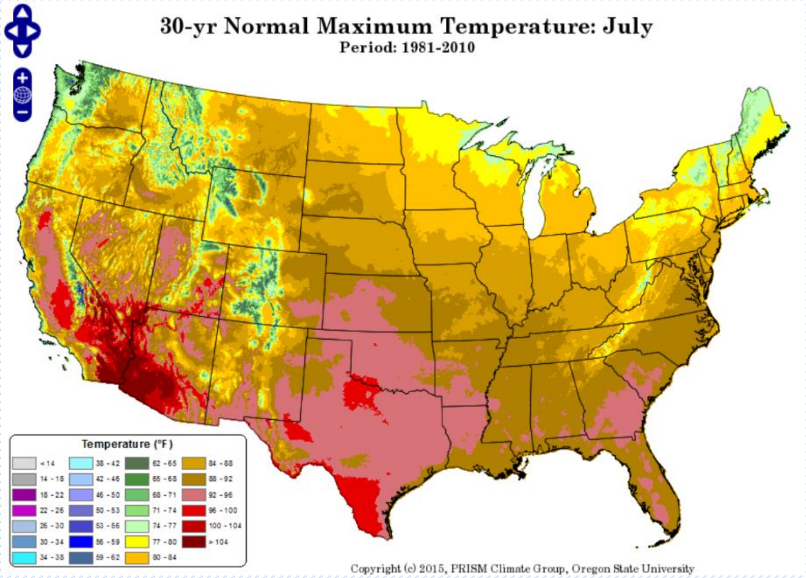


26″ rain



20″ rain

37″ rain



AMF and PDS flood quantiles using LP3 and GEV distributions