Quantifying Flood Risk and Sensitivity to Climate Change in the Huron River Watershed Using SWAT

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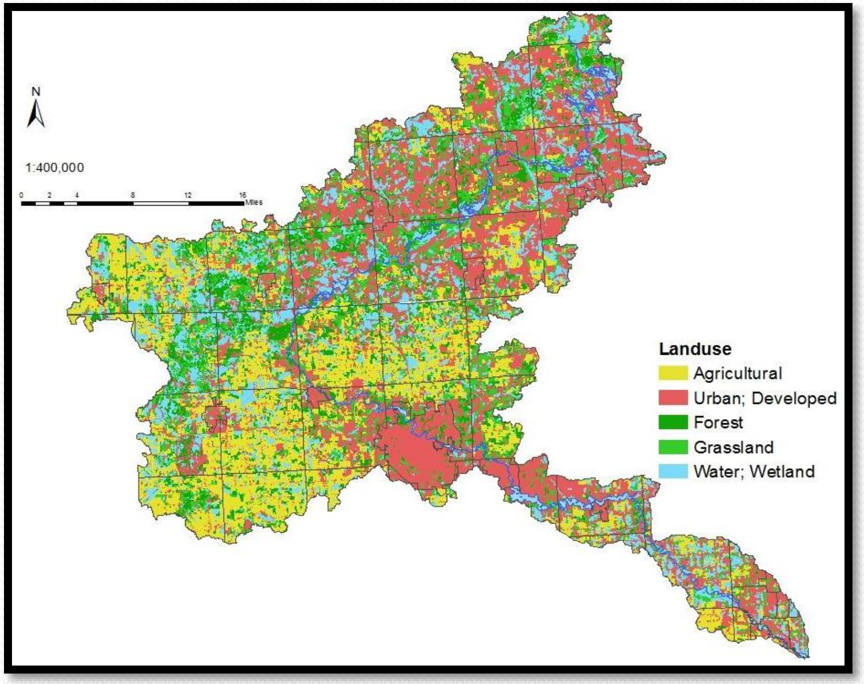
- Don Scavia
- Huron River Watershed Council
- Water Center, University of Michigan

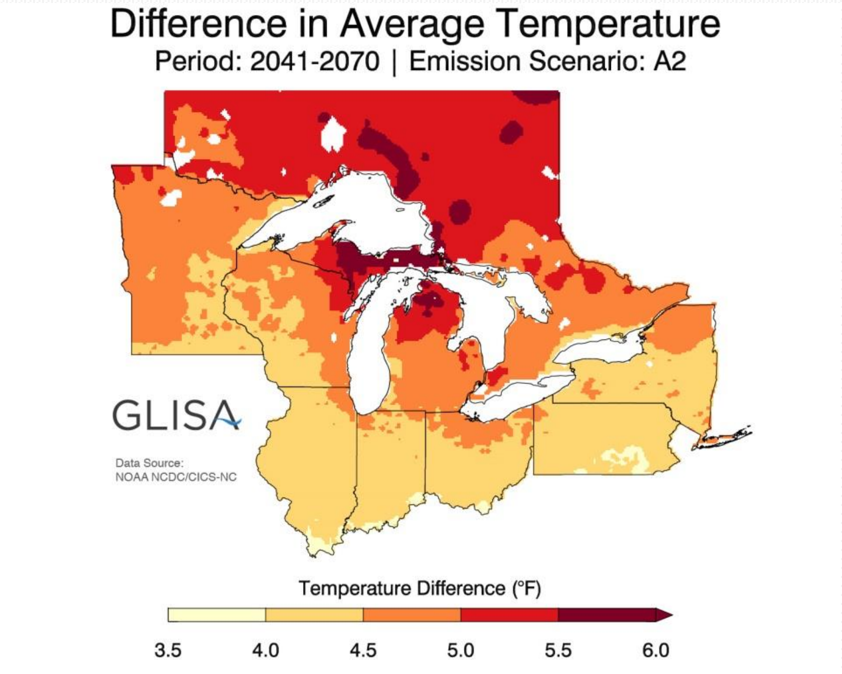
Overview

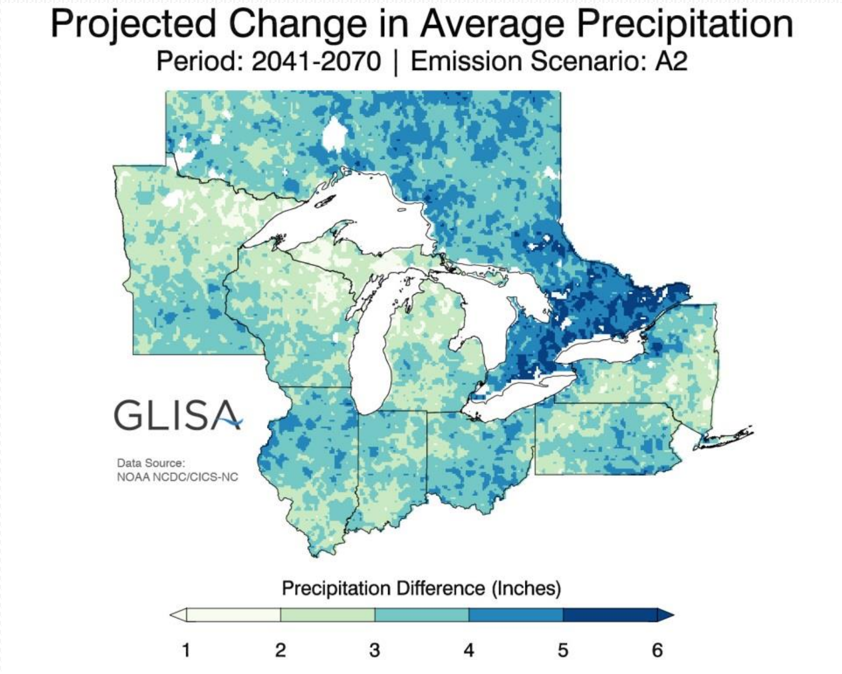
- Huron River Watershed Council
  - The needs for flood risk assessment of Huron River Watershed under climate change.



https://en.wikipedia.org/wiki/Huron_River_(Michigan)

Climate Change around the Great Lakes



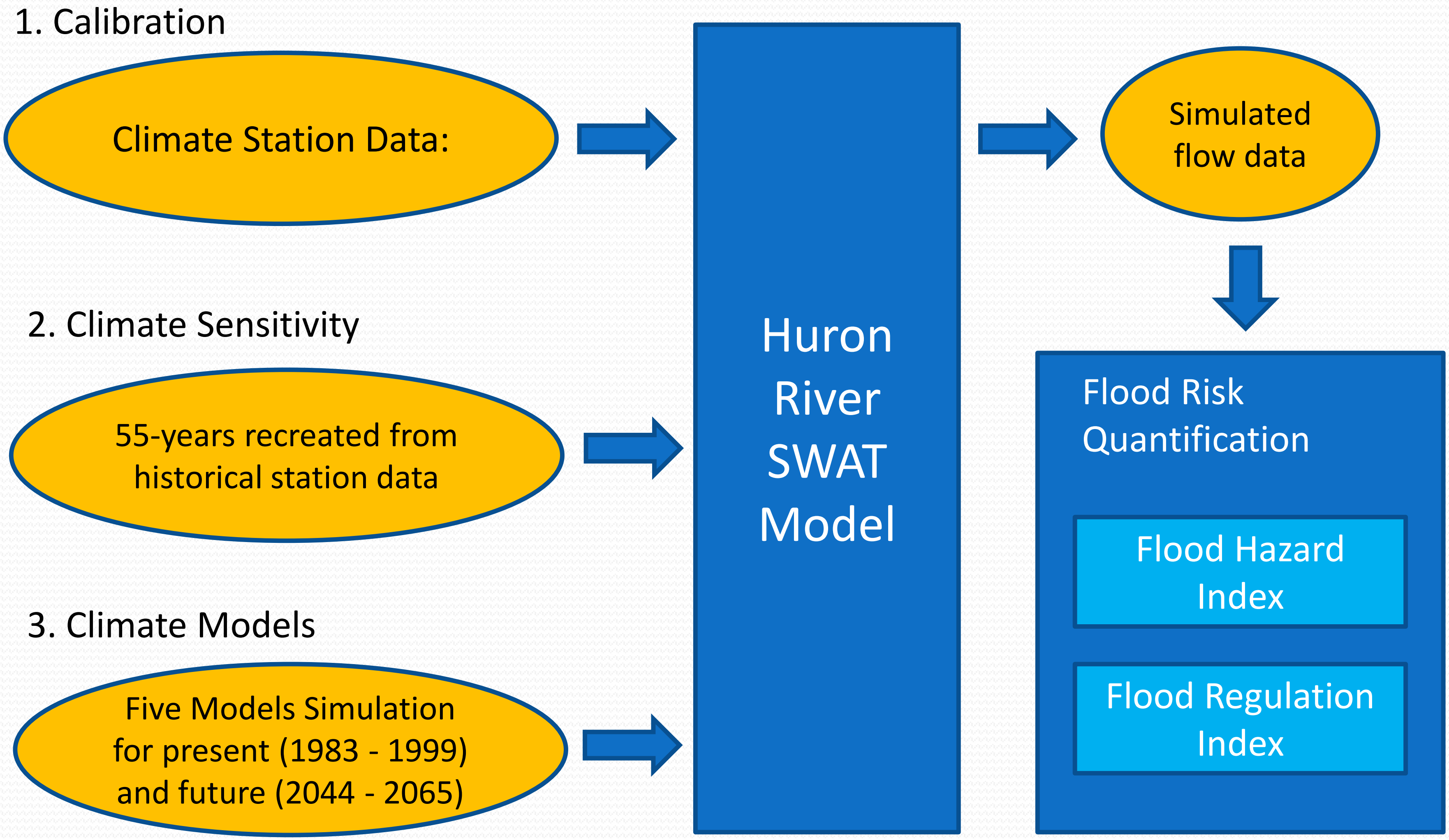


http://glisa.umich.edu/resources/great-lakes-regional-climate-change-maps

Research Needs

- Quantify the risk of flooding.
- Predict the impact from climate change on flooding.
  - Determine flooding “hot spots” and susceptibility to climate change.
  - Explore the use of climate models on flow prediction.

Research Method



Flood Hazard Index (FHI)

- The probability of daily stream flow above bankfull discharge (2-year return period) in a period of time.

$$FHI = P(Q > Q_{bankfull}) = \frac{\text{Days when } Q > Q_{bankfull}}{\text{Total number of days}}$$

Q: flow

$Q_{bankfull}$: bankfull flow

(Cheng, 2013)

Flood Regulation Index (FRI)

- Duration, magnitude, and number of flooding events.

$$FRI = \frac{1}{\exp[w1(DF/DF_{LT}) + w2(QF/QF_{LT}) + w3(FE/FE_{LT})]}$$

DF: Duration of flooding (days)

QF: Average magnitude of flooding (m3/s)

FE: Number of flood events per year

w1, w2, w3: User-defined weights

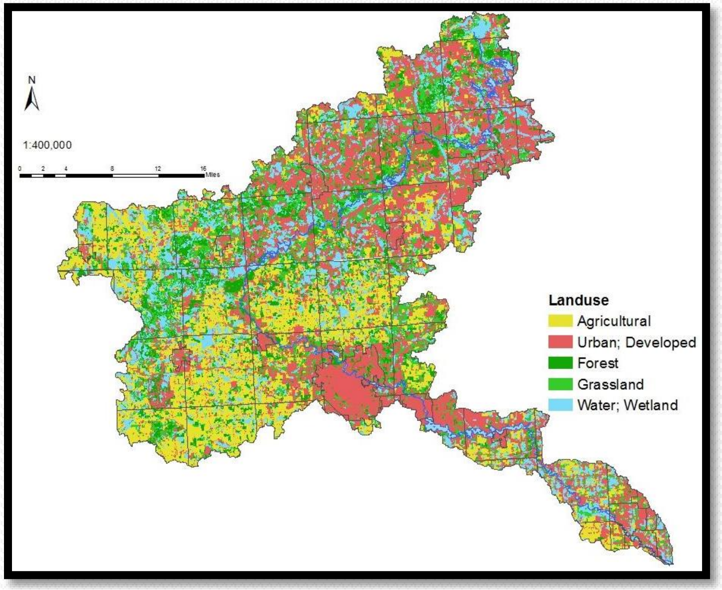
$w1 + w2 + w3 = 1$

(Logsdon and Chaubey, 2013)

1. SWAT Model Calibration

- 2006 NLCD land use classification
- Calibration period: 2001 to 2005
- Challenges:
  - About 30% of the land is in urban or developed land use.
  - More than 100 dams, about 5.7% of land use is water.
- Two sets of parameters for agriculture land and other land covers
  - SURLAG for agriculture: 1.5
  - SURLAG for other land cover: 0.08

		Subbasin 40	Subbasin 49
Daily	R^2	0.69	0.59
	NS	0.61	0.58
	PBIAS	9.5%	-8.2%
Monthly	R^2	0.77	0.65
	NS	0.73	0.64
	PBIAS	9.5%	-8.3%

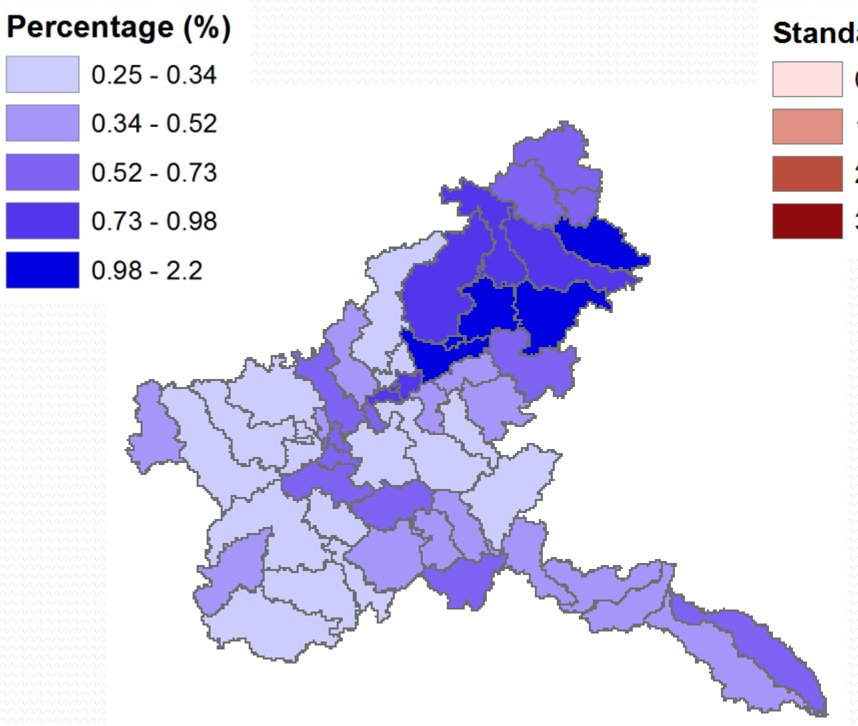


2. Climate Sensitivity Testing

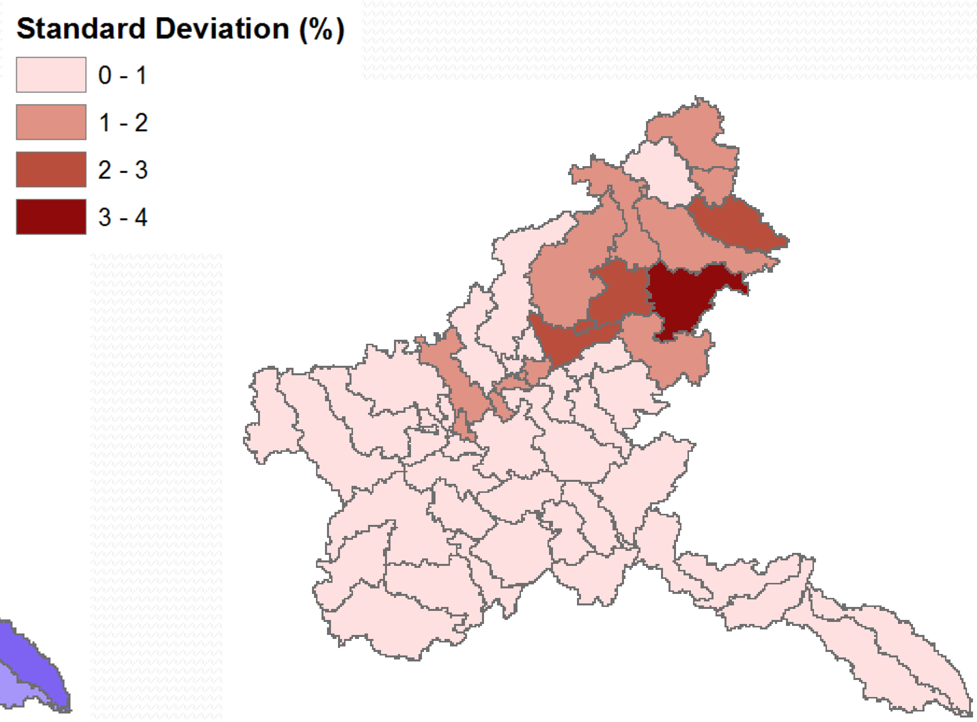
- Baseline Temperature and Precipitation Condition
- Increase Temperature by 1, 2, 3, 4, 5 °C
- Increase/Decrease Precipitation by 0%, 10%, 20%
- 30 scenarios
  - Generate simulated flow data
  - Calculate FHI and FRI to see which subbasin could have more changes when climate conditions change.

2. Climate Sensitivity: Flood Hazard Index

FHI Baseline

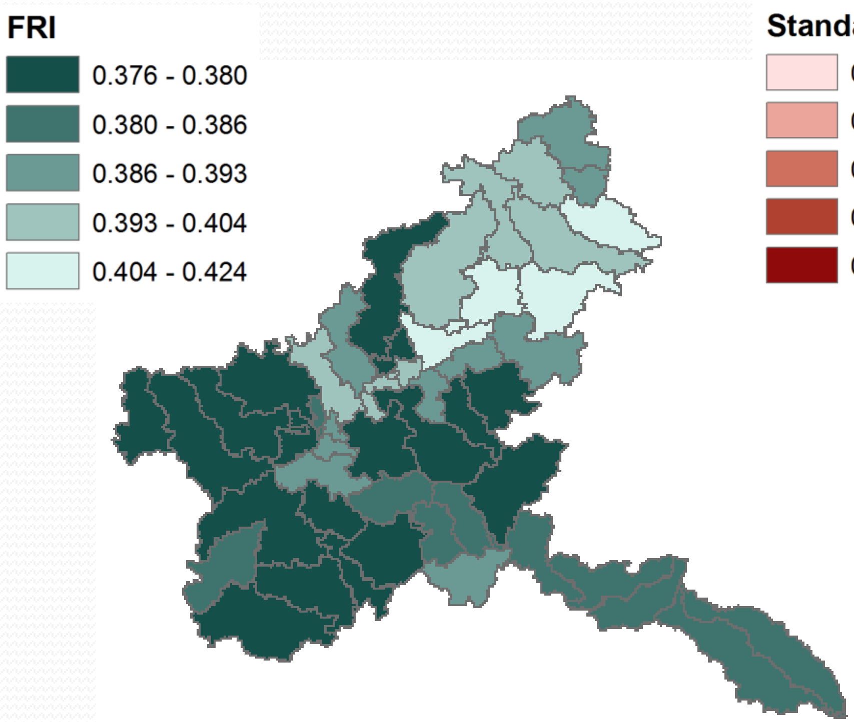


FHI Standard Deviation

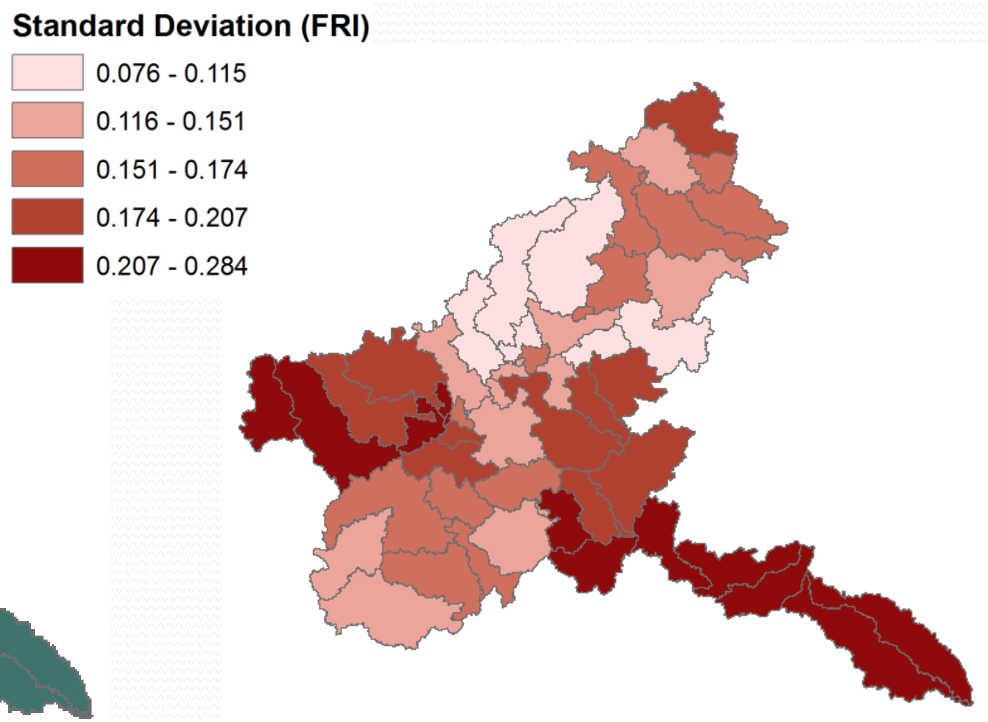


2. Climate Sensitivity: Flood Regulation Index

FRI Baseline



FRI Standard Deviation

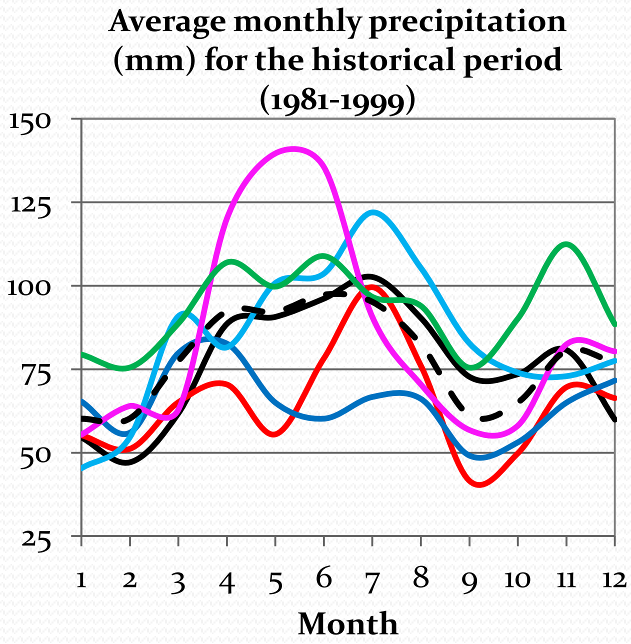


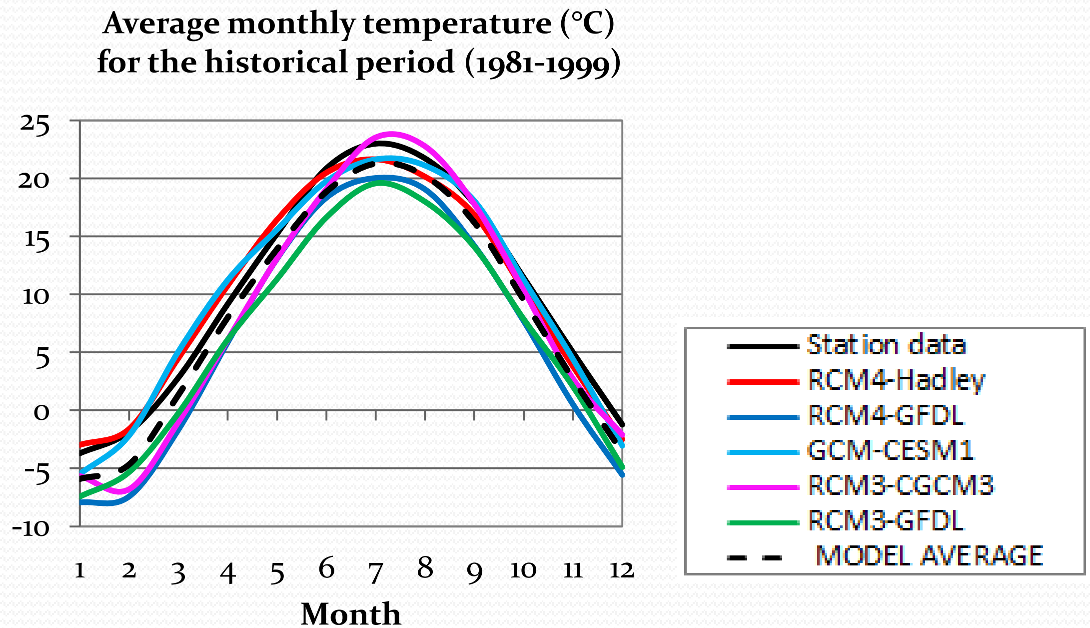
3. Climate Model Testing

Model	Type	CO2 Emission
GFDL	Regional dynamically downscaled models	RCP 8.5
HadGEM	Regional dynamically downscaled models	RCP 8.5
CRCM (CGCM3)	Regional climate models - NARCCAP	A2 emissions scenario
RCM3 (GFDL)	Regional climate models - NARCCAP	A2 emissions scenario
CESM1	Global climate model	RCP 8.5

3. Climate Models

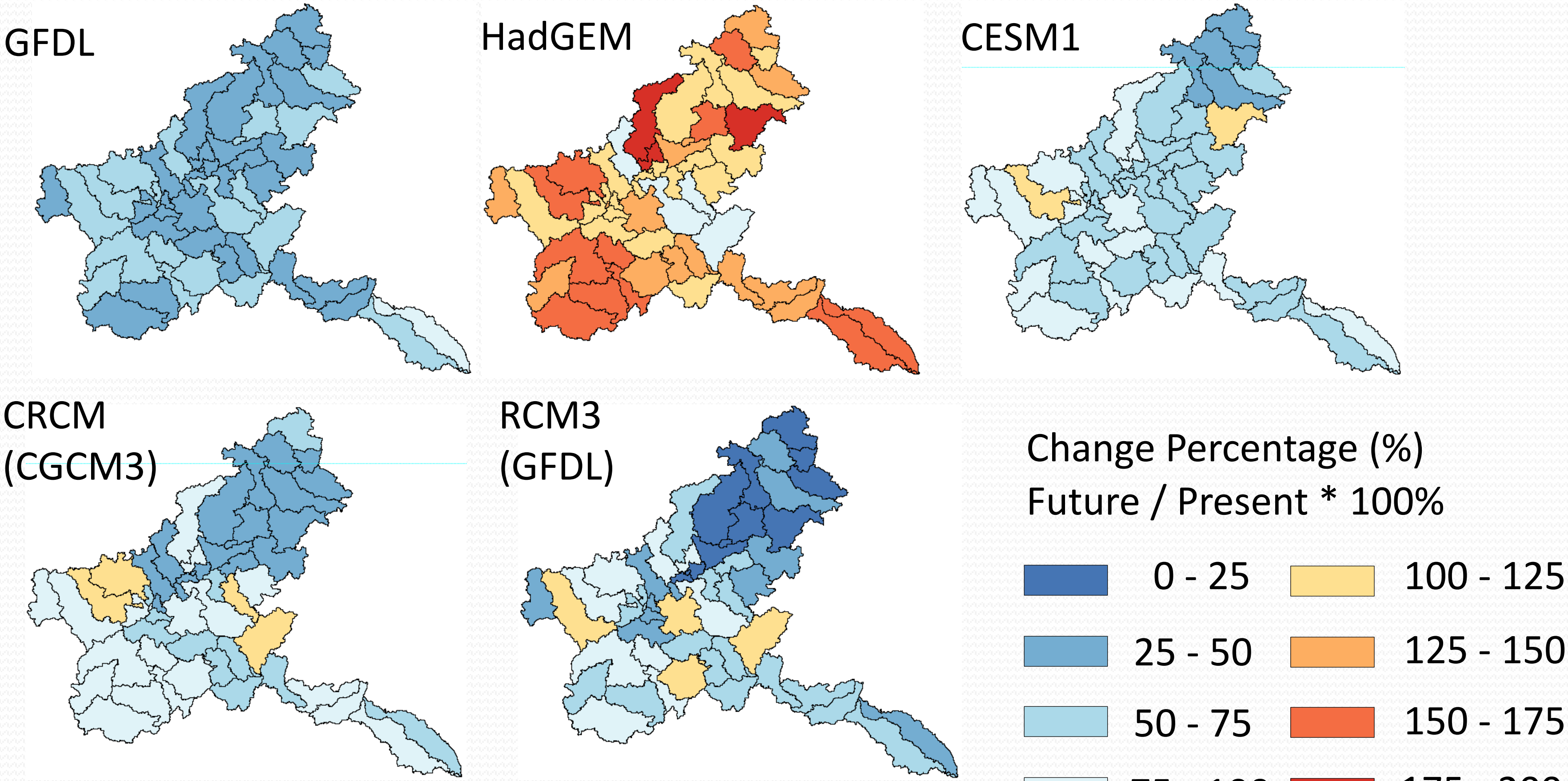
- Five Models Simulation for present (1983 - 1999) and future (2044 – 2065)
  - Generate simulated flow data for present and future
  - Calculate FHI and FRI and compare the values
  - Calculate the change percentage (future indices / present indices * 100%) for each climate model.



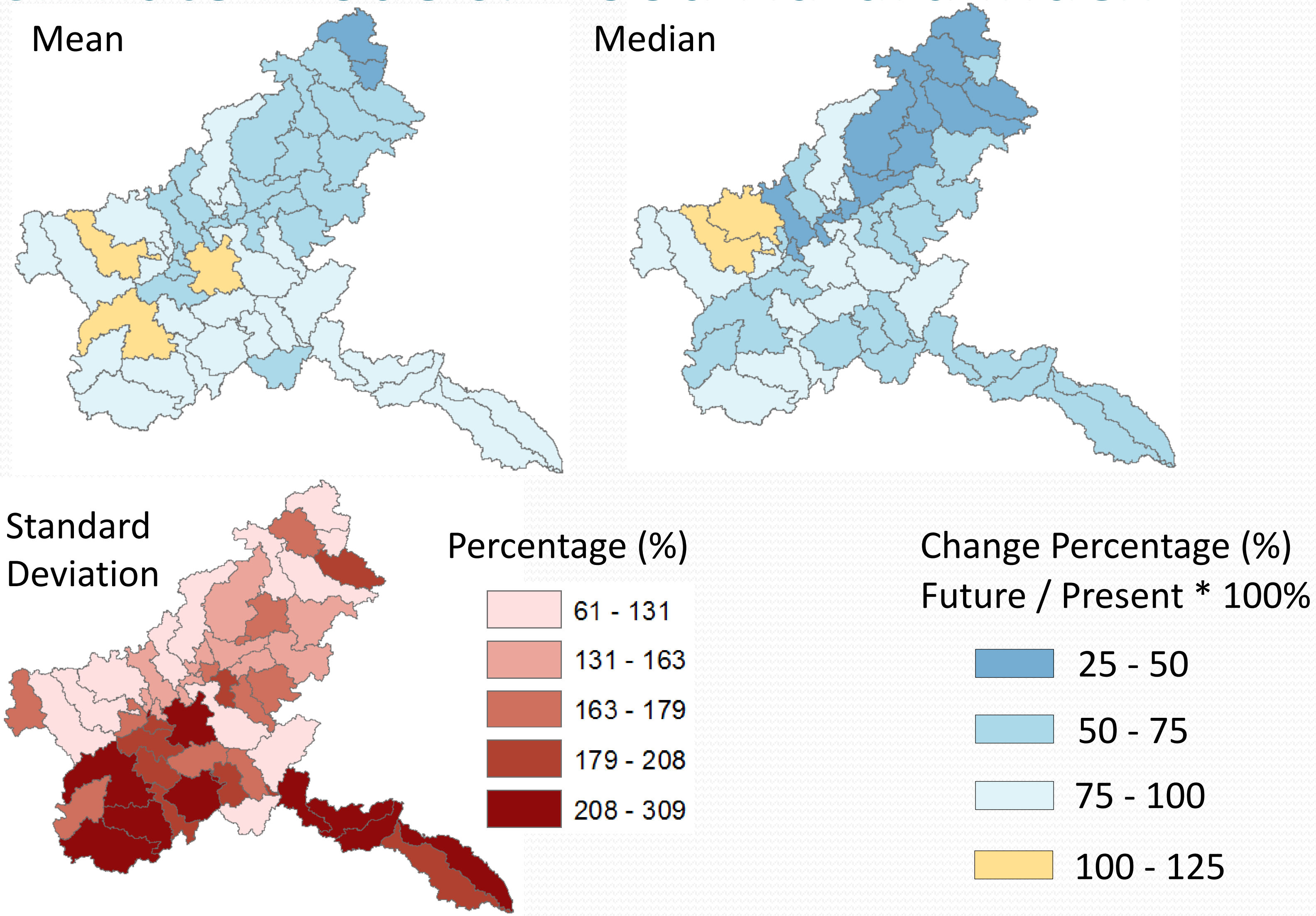


3. Climate Models: Flood Hazard Index

- Compare historical and future conditions under different climate models.
  - Determine the direction of change.



3. Climate Models: Flood Hazard Index



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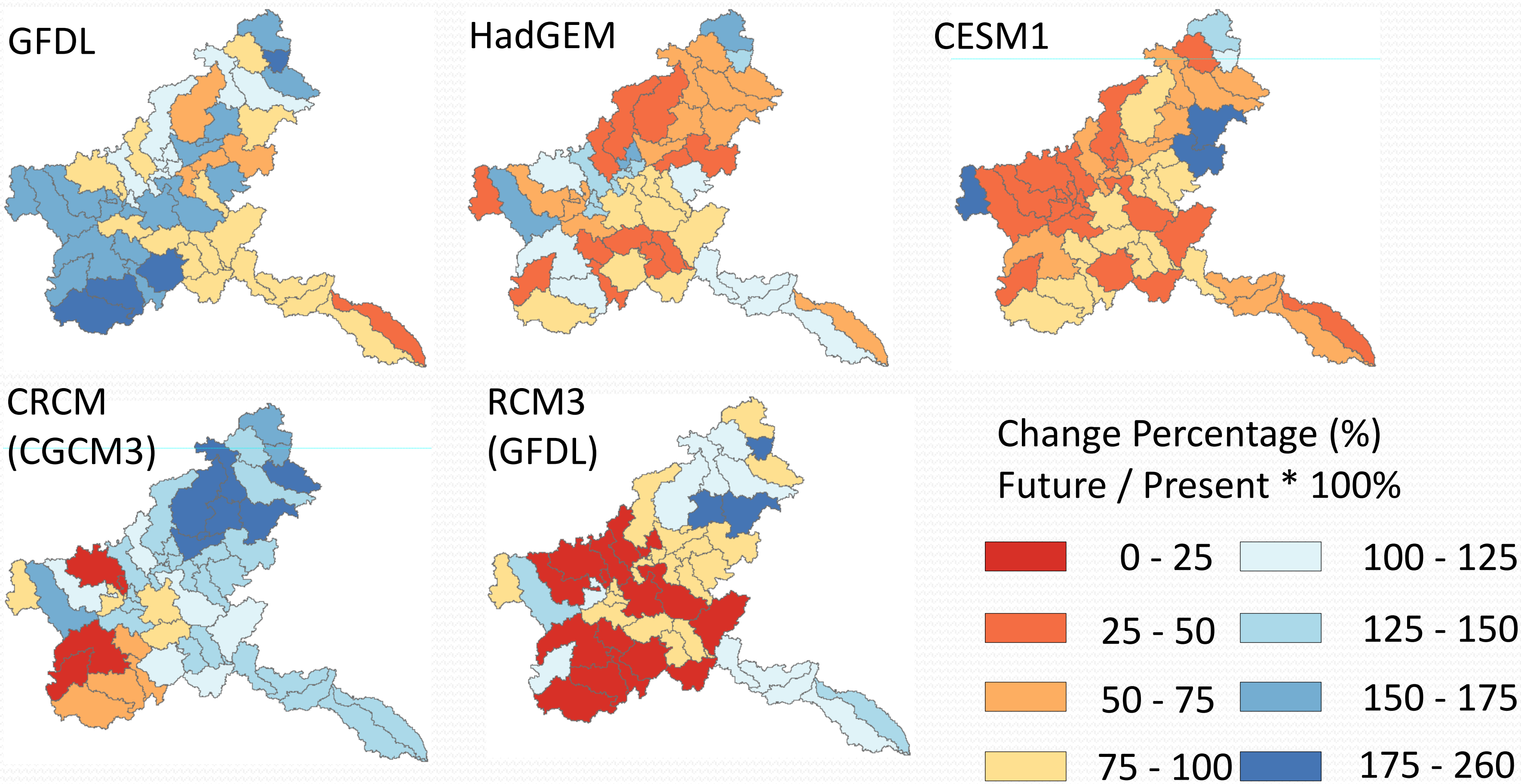
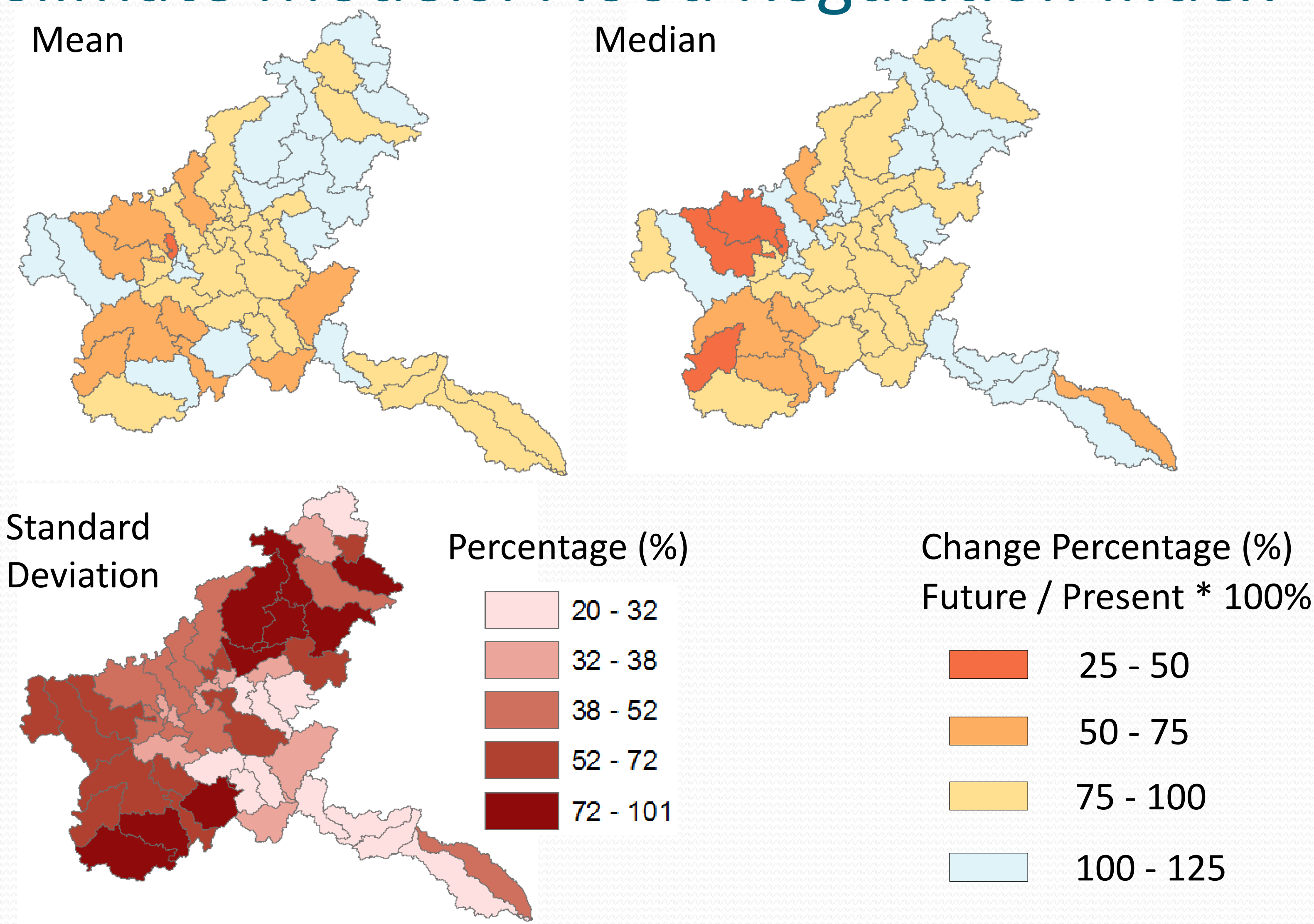


3. Climate Models: Flood Regulation Index



Key Findings

- Comparison of two flooding indices shows:
  - Considerably different hotspots depending on flooding index
- Climate sensitivity tests shows:
  - higher temperatures decrease level of flooding
  - greater precipitation increases level of flooding
  - changing temperature and precipitation results in different response of FHI and FRI
    - FHI: higher variation around upstream region
    - FRI: higher variation around downstream region
- Climate model tests show:
  - Both FHI and FRI identify sub-basins with potential flood increase in the future. The central part of Huron River Watershed could be a focus area.

References

- William Baule, Elizabeth Gibbons, Laura Briley, and Daniel Brown. Synthesis of the Third National Climate Assessment for the Great Lakes Region. 2014. GLISA.
- Chingwen Cheng. Social vulnerability, green infrastructure, urbanization and climate change-induced flooding: A risk assessment for the Charles River watershed, Massachusetts, USA. 2013. PhD – Dissertation. University of Massachusetts – Amherst.
- Rebecca Logsdon and Indrajeet Chaubey. A quantitative approach to evaluating ecosystem services. 2013. Ecological Modelling: pp. 57 – 65.

3. Climate Models

Estimated precipitation (mm) change in 2050 compared to historical models

Estimated temperature (°C) change in 2050 compared to historical models