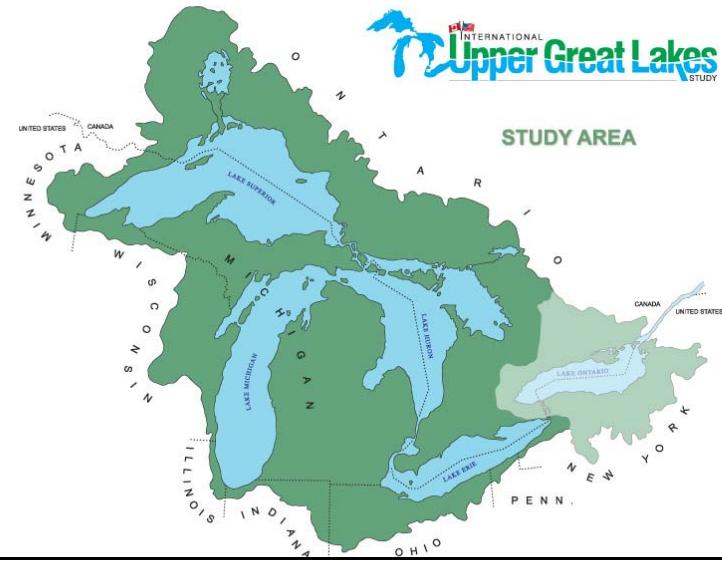
Evaluation of Lake Superior Regulation Plans Using Robustness and Climate Informed Risk

Paul Moody
3 Feb 2012

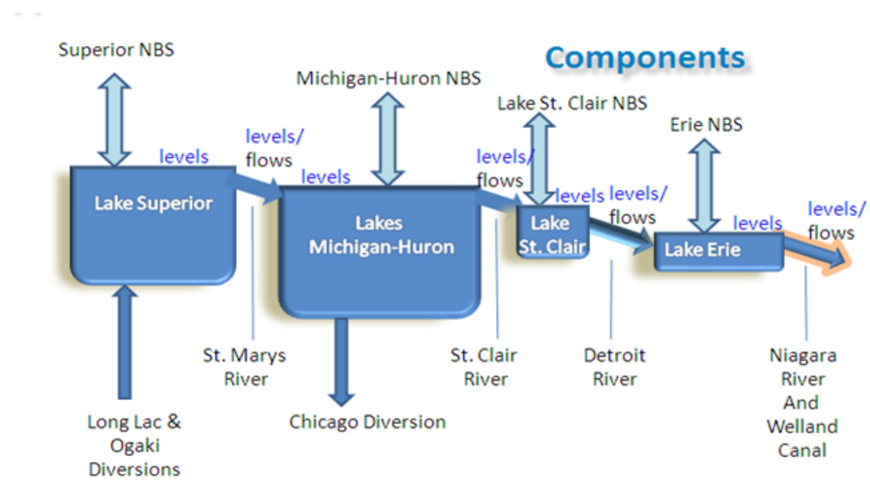
Agenda

- **Overview and Background**
- Decision Scaling Process
- Climate Response Function
- Application and Evaluation
- Ongoing and Future Work

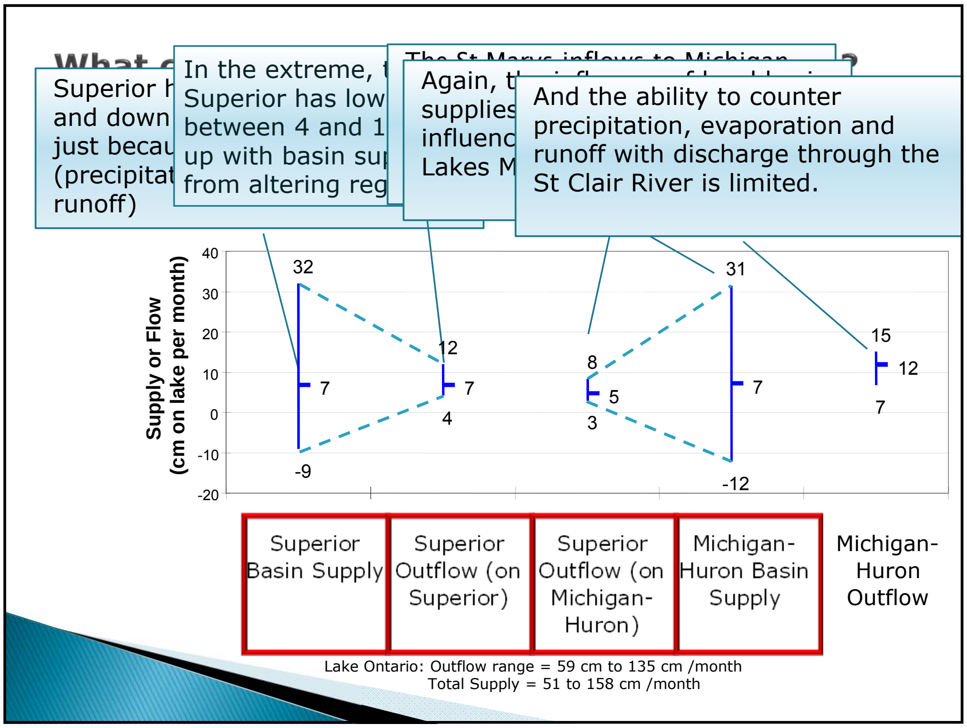
International Upper Great Lakes Study Overview



Upper Great Lake System Model



International Upper Great Lakes Study



A Brief History

- 1887 – Lake Superior outflow no longer "natural"
- 1909 – Boundary Waters Treaty, establishes International Joint Commission (IJC)
- 1914 – Orders of Approval
- 1979 – Supplementary Orders of Approval
- 1990 – Regulation Plan 1977A adopted
- 2003 – Lake Ontario – St Lawrence River Study
- 2007 – Start of IUGLS

Research Questions

- How vulnerable are the Great Lakes to climate change?
- Under what climate conditions will we see adverse results?
- What is the likelihood of these conditions?
- What regulation actions can we take to mitigate residual risk?
- Which decisions do our findings influence? (i.e. resource commitment)

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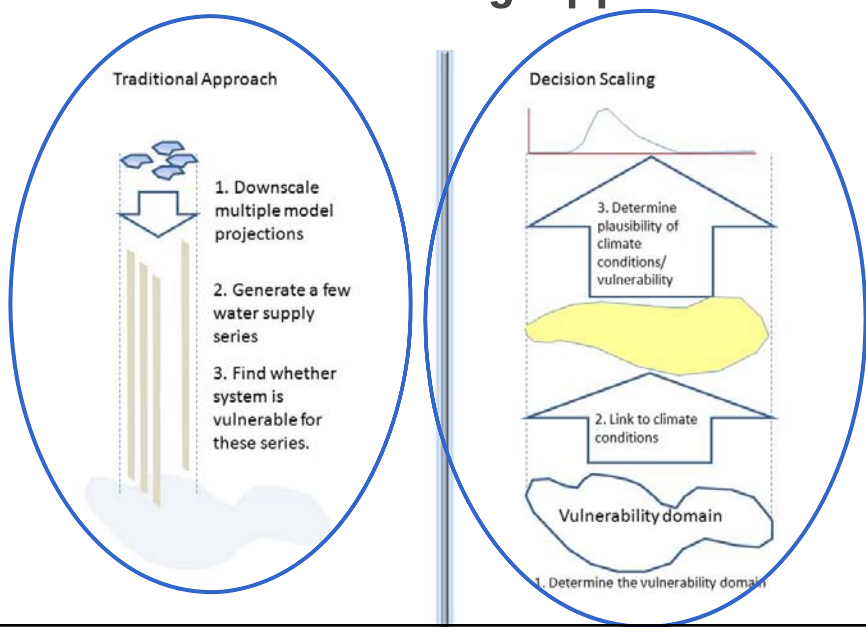
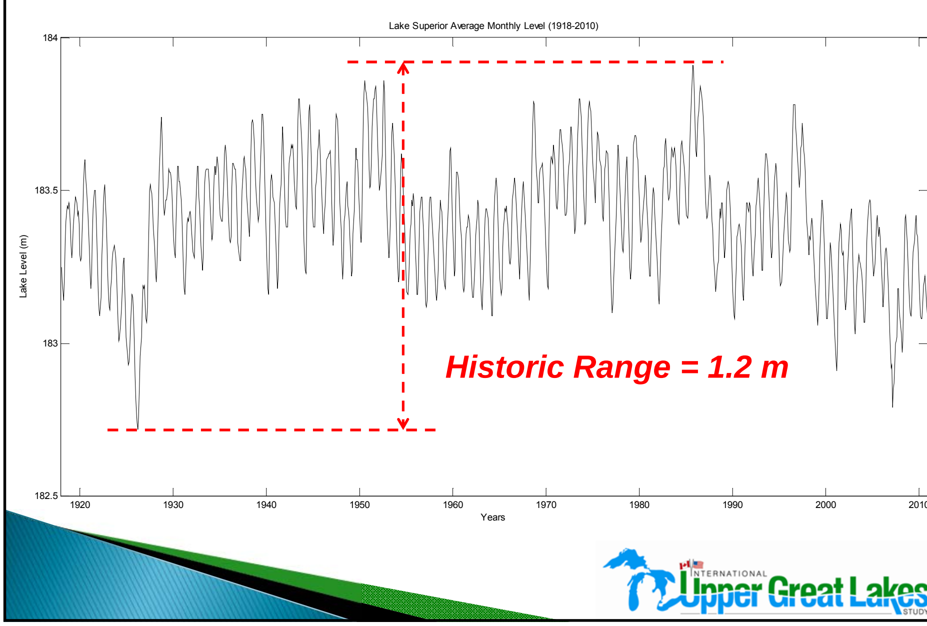
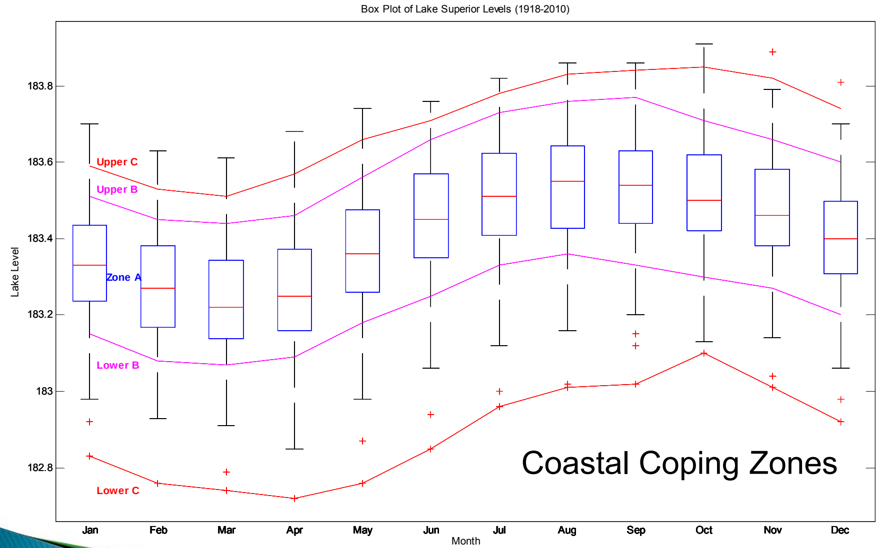
Decision Scaling Approach



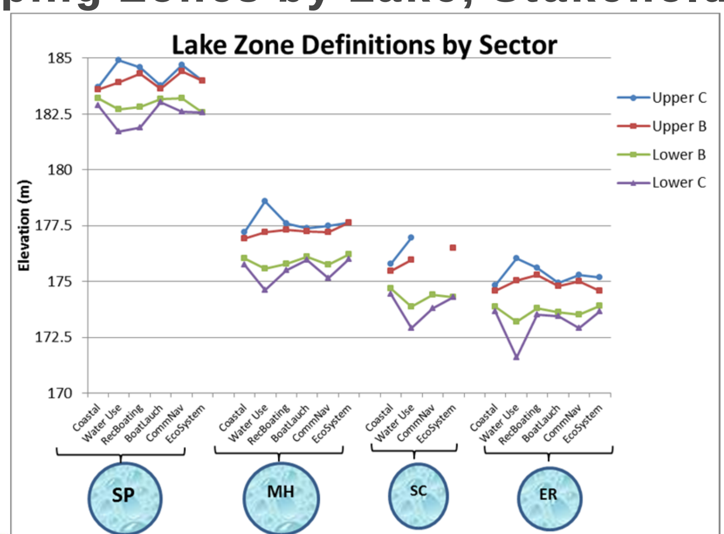
Hazard Identification – Levels



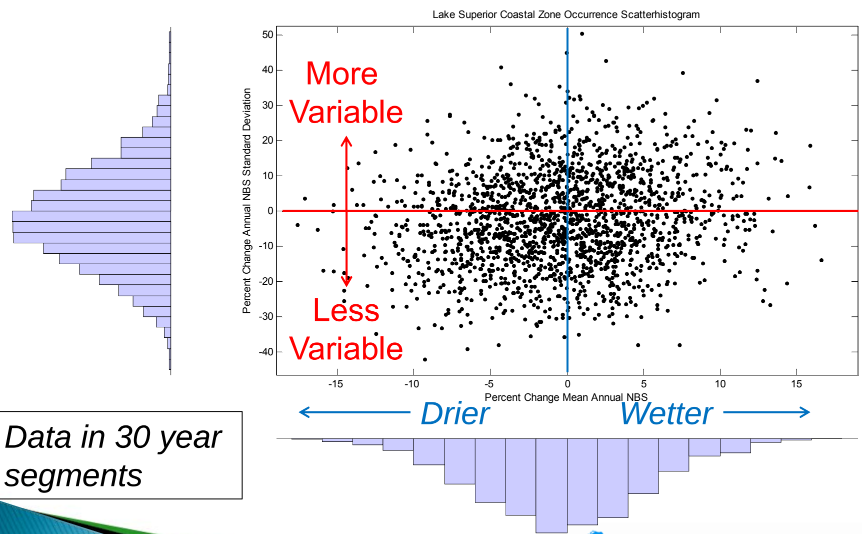
Monthly Water Levels



Hazard Identification – Coping Zones by Lake, Stakeholder

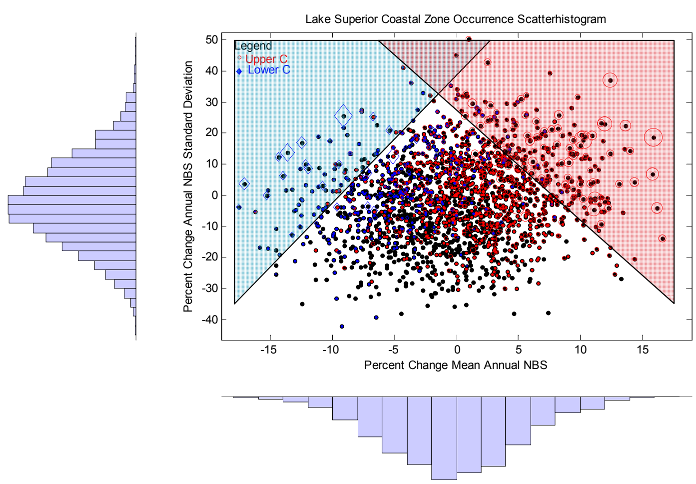


Data Mining From 50k year Stochastic Record



Data in 30 year segments

Data Mining From 50k year Stochastic Record



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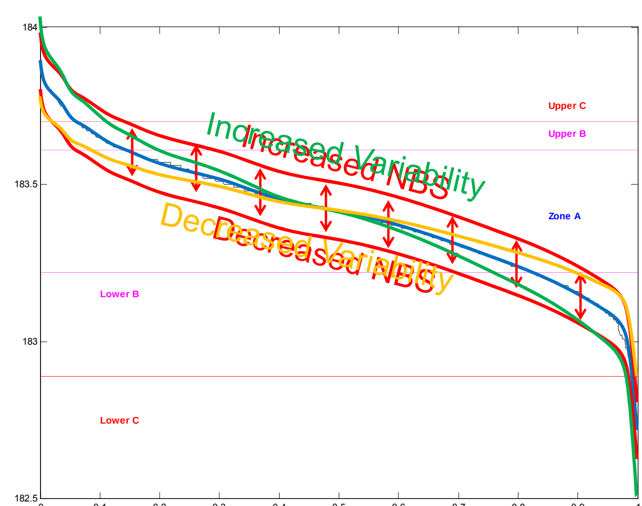
Climate Effects on Level Exceedance



Statistical Function Form

- Generalized Linear Function with:
  - Linear combination of inputs
    - $\boldsymbol{X} \cdot \boldsymbol{\beta} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3$
  - Inverse logit transformation
    - $\pi_i = ilogit(\boldsymbol{X} \cdot \boldsymbol{\beta})$
    - $ilogit(\alpha) = \frac{1}{1+\exp(-\alpha)}$
  - Binomial stochastic component
    - $P(Y_i = y) = \binom{n}{y} \pi_i^y (1 - \pi_i)^{(n-y)}$

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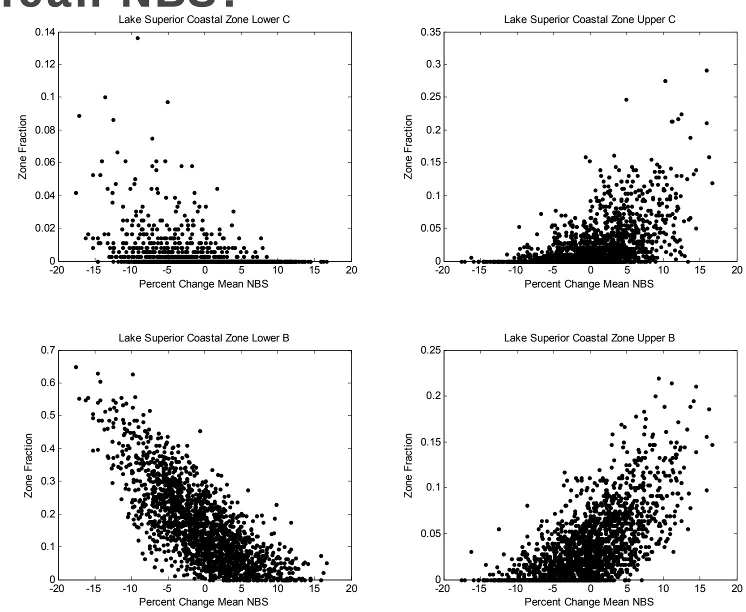
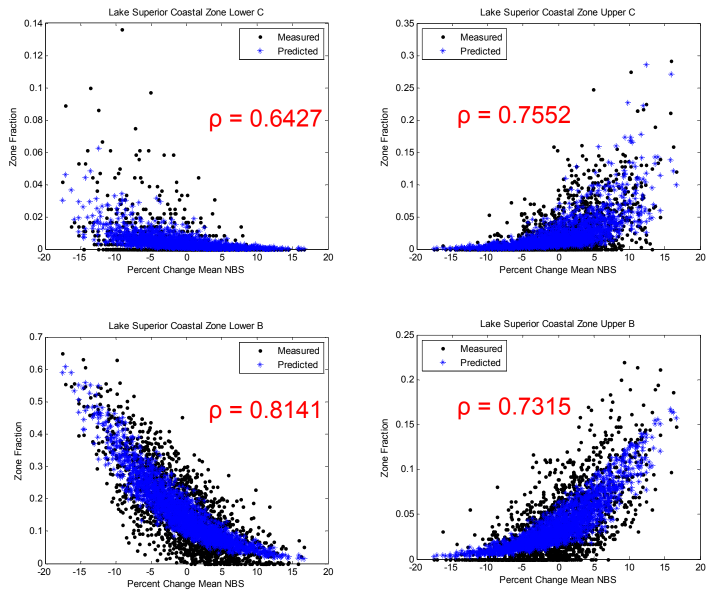
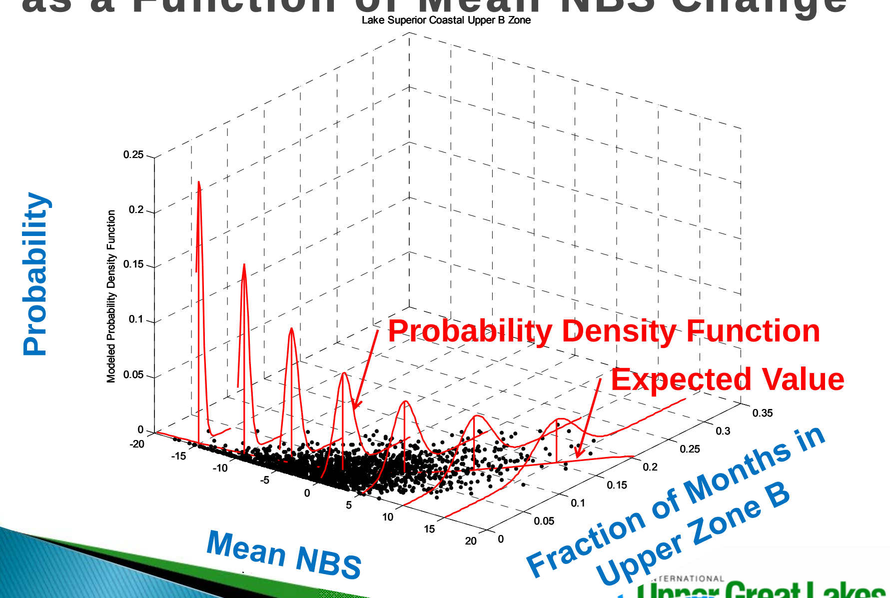
How do coping zones vary with mean NBS?



How well does the 3 parameter model fit?



Predicted Coping Zone Occurrence as a Function of Mean NBS Change



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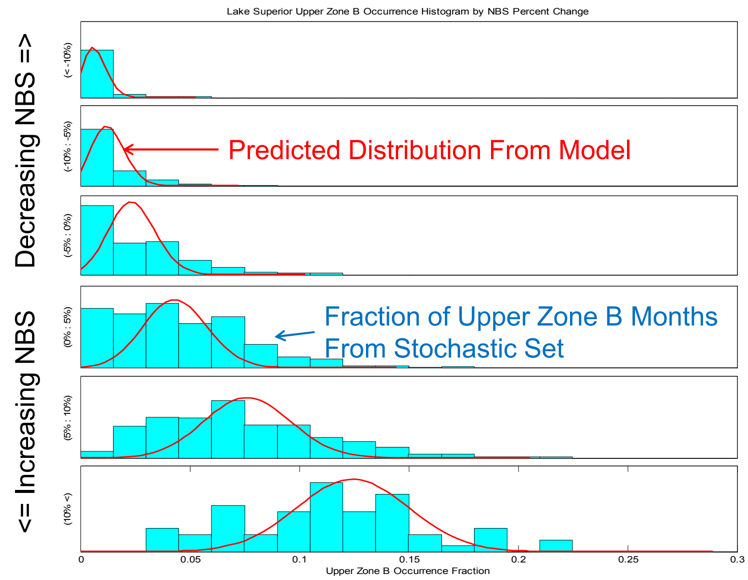

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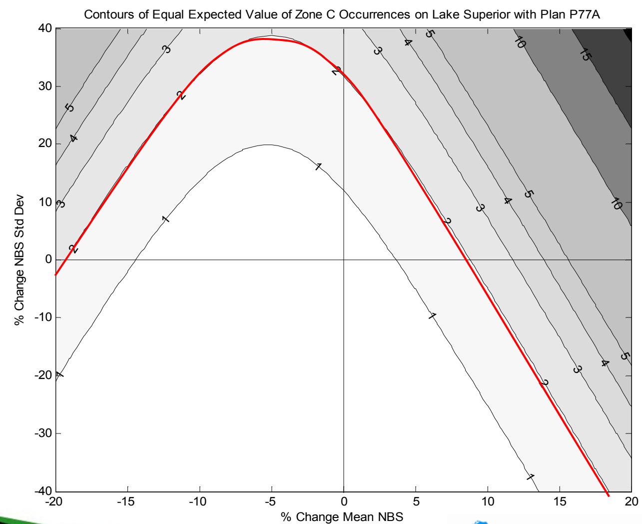
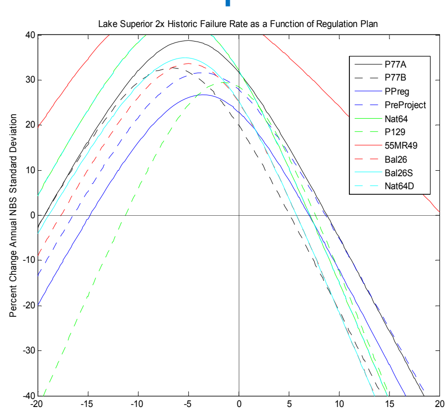
Expected Zone C Occurrence for Plan 1977A on Lake Superior

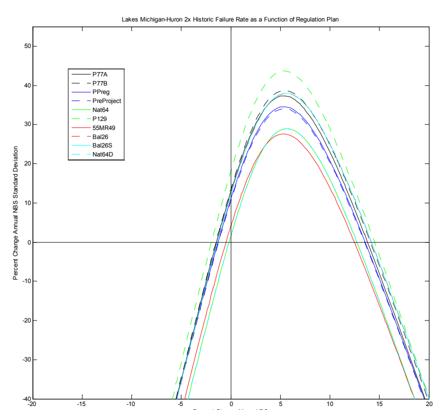


Regulation Plan Comparison

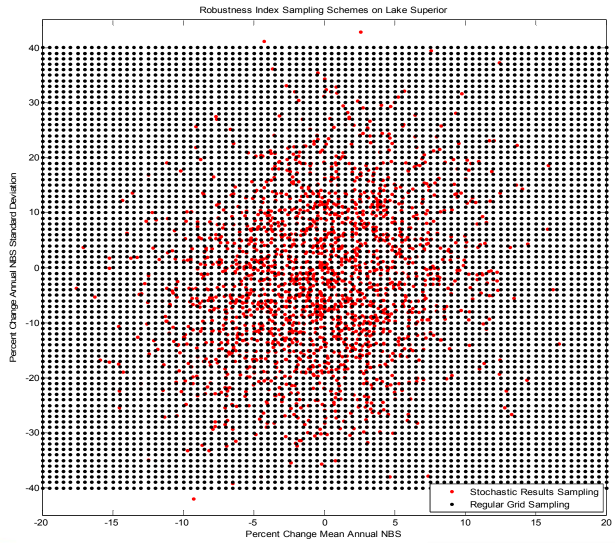
Superior



Michigan-Huron



Robustness Analysis



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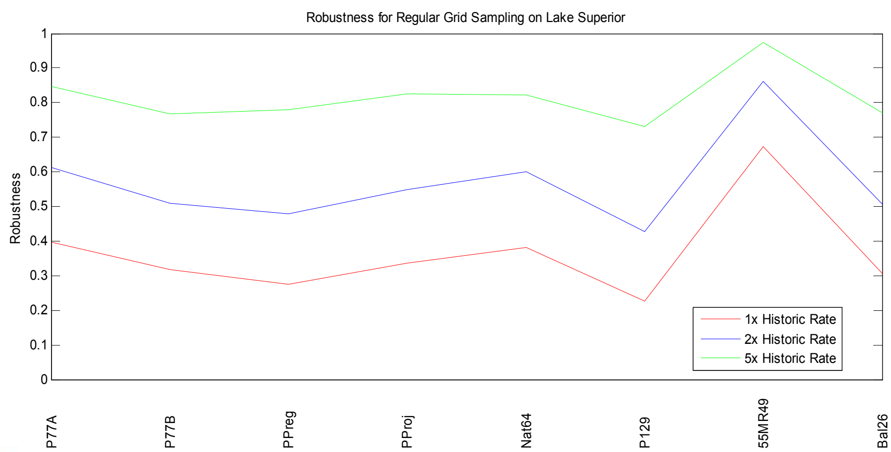

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Robustness and Climate Informed Risk (Reliability)

- Robustness is adequate performance over a wide range of inputs
- Reliability related to expected value of impact
  - $E(I) = \iiint_{climate} P(X_1, X_2, X_3) \cdot I(X_1, X_2, X_3)\, dx_1 dx_2 dx_3$
- Impact is a function of climate, regulation plan
- Probability is function of climate information
  - Historic data
  - Stochastic data
  - Paleo estimates
  - GCM projections

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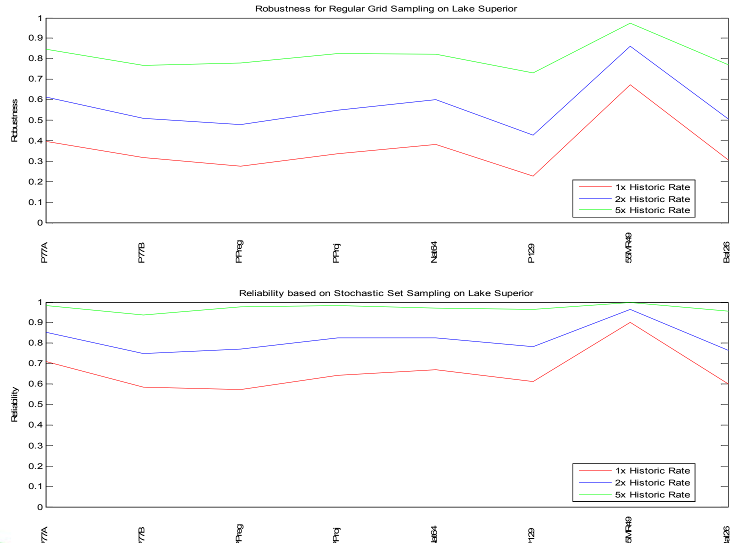
Robustness and Reliability



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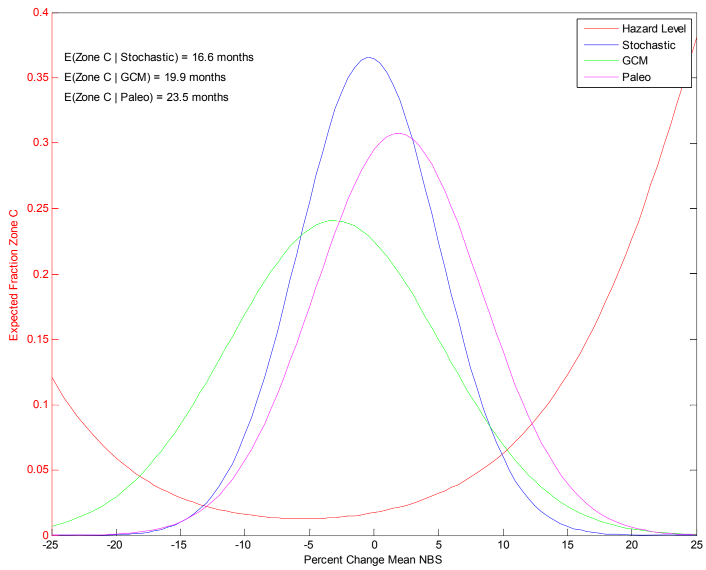
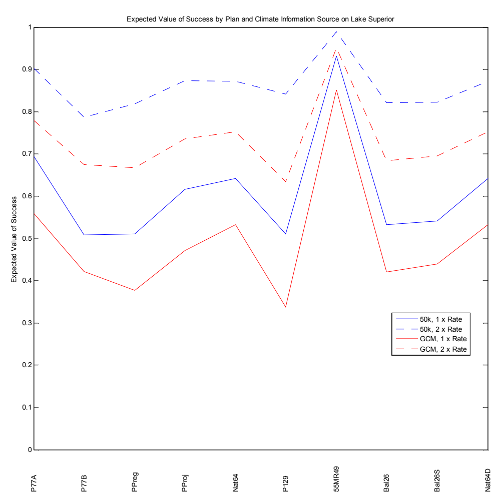
Why Probability Matters



How does climate information source affect reliability?



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Risk Evaluation Matrix

Focus of adaptive management will be on the things we are most concerned about and least prepared for.

Impacts, current policies					
Zone C (Outside the Max/Min range of last 90yrs)	Low	Moderate	Moderate	High	Extreme
Zone B (Outside the Max/Min range of 95-5% Exceedence)	Negligible	Moderate	Moderate	Moderate	High
Zone A	Negligible	Negligible	Slight	Slight	Slight
	0–1%	1–5%	5–15%	15–50%	50–100%

Not very plausible — Plausibility — ***Very plausible***

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Future Work

- Refine climate probabilities and risk estimates
- Apply Bayesian Analysis to climate variable probability distribution estimates
- Consider regulation plans with seasonal forecasting, adaptive management
- Develop decision points to drive changes in management plans
- Apply framework to other basins

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Acknowledgements

- Dr. Casey Brown, Jesus Morales, Ke Li
- IUGLS, USACE, USGS, Environment Canada

US Army Corps of Engineers

U.S.ARMY

USGS science for a changing world

Environment Canada

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QUESTIONS?

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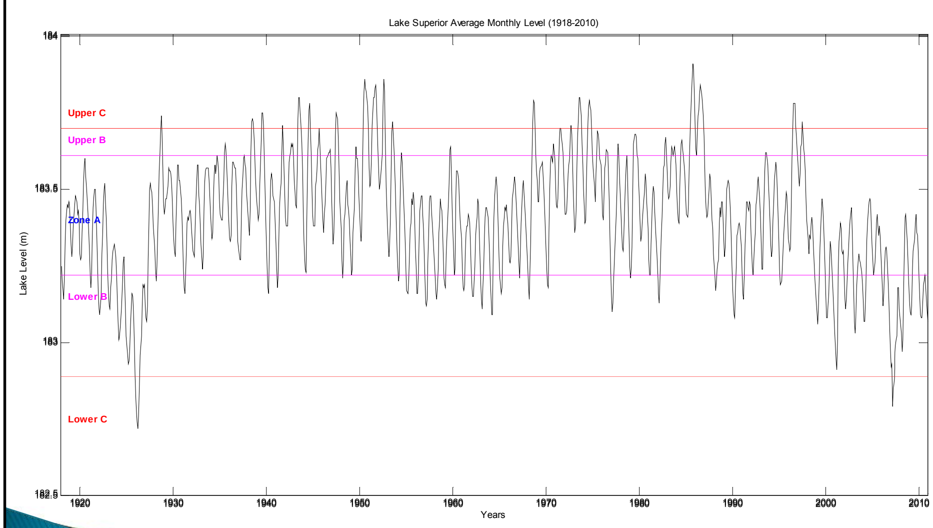

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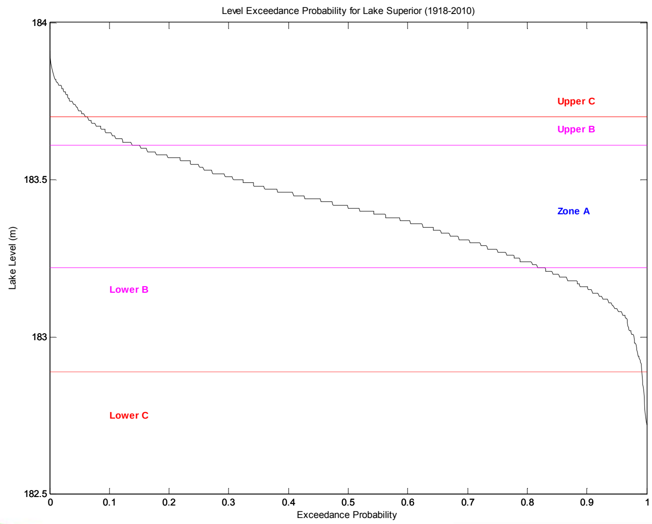

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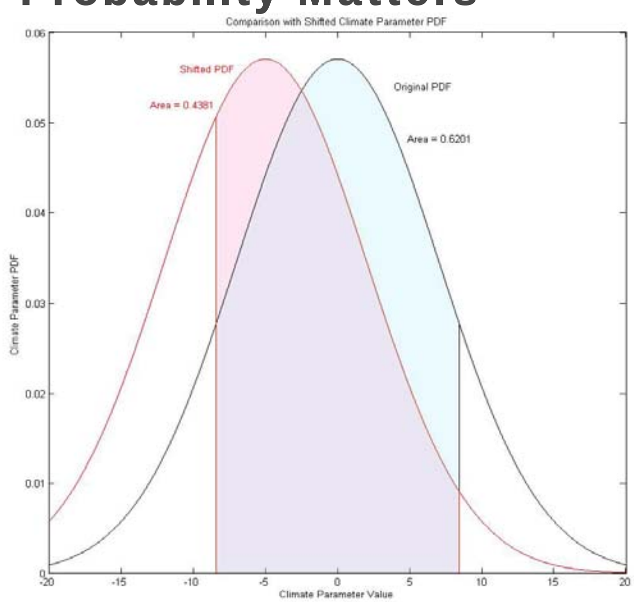

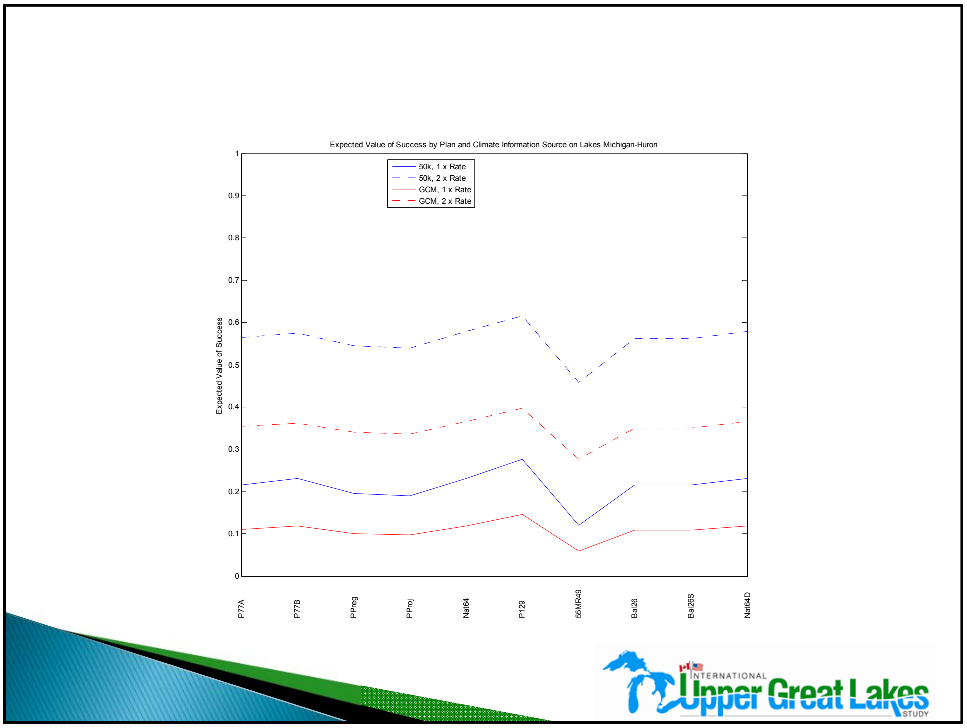
Expected Value of Success by Plan and Climate Information Source on Lakes Michigan-Huron
50k, 1 x Rate
50k, 2 x Rate
GCM, 1 x Rate
GCM, 2 x Rate
Expected Value of Success
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
P77A
P77B
PPreg
PProj
Nat64
P129
55MR49
Bal26
Bal26S
Nat64D
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