International Conference: "Global and Regional Climate Changes" Kyiv, Ukraine 16-19 Nov, 2010

Practical Decisionmaking for Climate Adaptation in the Water Sector: the Great Lakes

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(ЗЕНОН СТАХІВ)

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and

Institute for Water Resources

U.S. Army Corps of Engineers

US NAS – UkrNAS
Workshop Overview
Water Sector Adaptation to Climate Change
(Washington, DC Dec 2-3, 2009)

Ukrainian NAS Delegation at the UN

Ukrainian UN Ambassador
Dr. Yuriy Sergeyiev

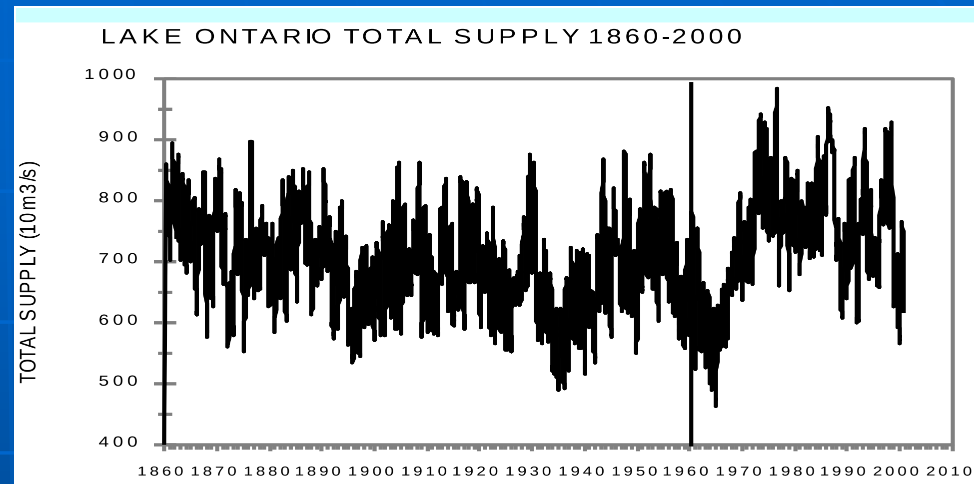
UN Workshop on Climate Change in Ukraine

- The Workshop had four main themes, and a half-day was devoted to each:
- Topic 1 - **Climate Change and Flooding**
- Topic Two – **Watersheds and Reservoir Systems Management**
- Topic Three - **Black Sea Climate Impacts**
- Topic Four: **Ground Water Mgmt**

Great Lakes Regulation

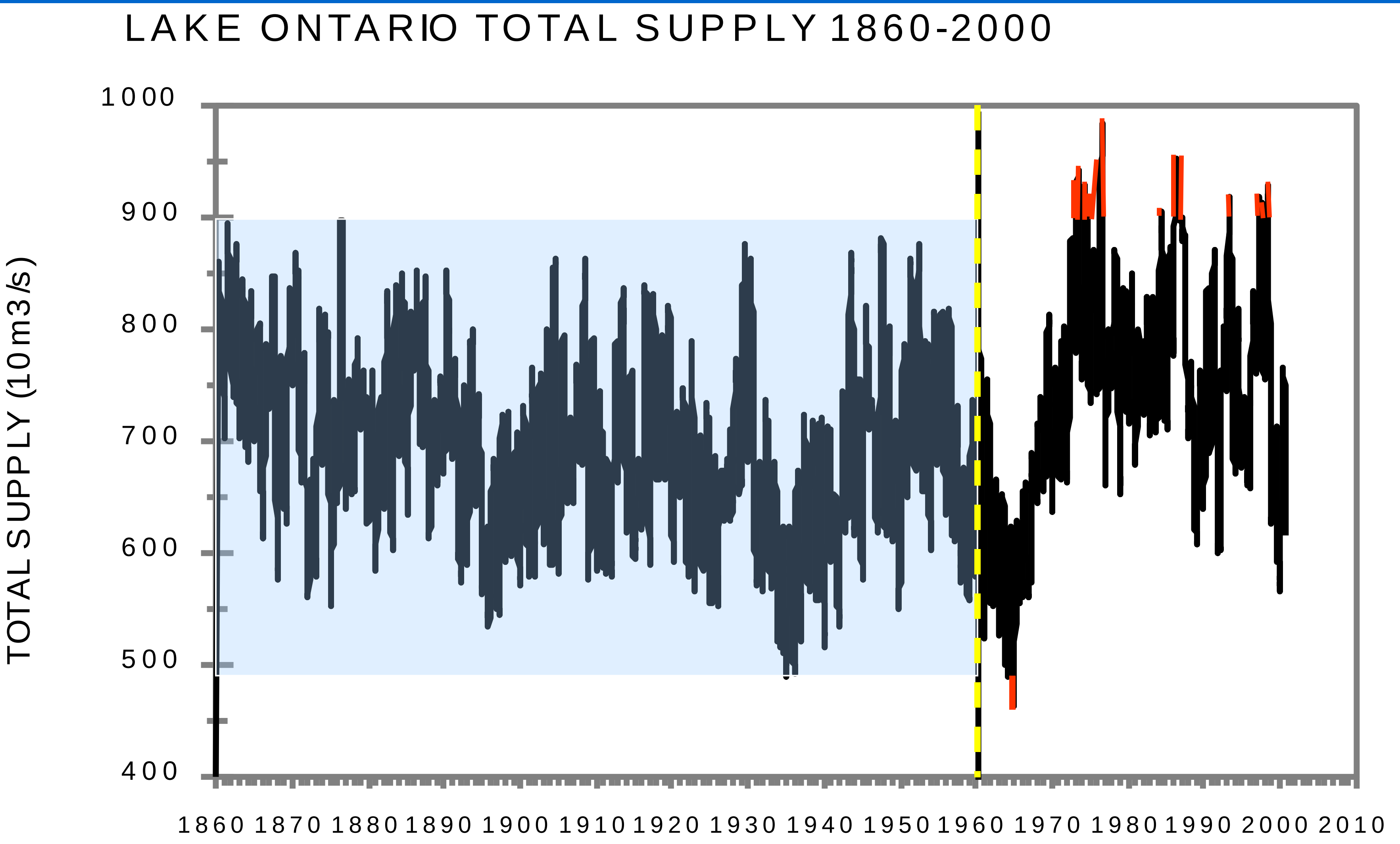
Changing Great Lakes Water Levels

- **Water Level Shifts**
  - **Highs - 70s-90's**
  - **Lows - 60's, 1998-2001**



- **Impacts**
  - **High Levels**
    - **Erosion – Flooding**

    - Low Levels
    - **Hydropower - Navigation - Recreational Boating - Environment**
- **Actions - Review of IJC Orders**
  - **$20 M St. Lawrence-Ontario Study (completed)**
  - **$20 M Upper Lakes Study (2006-2011)**
- **Unknown - Climate Change**

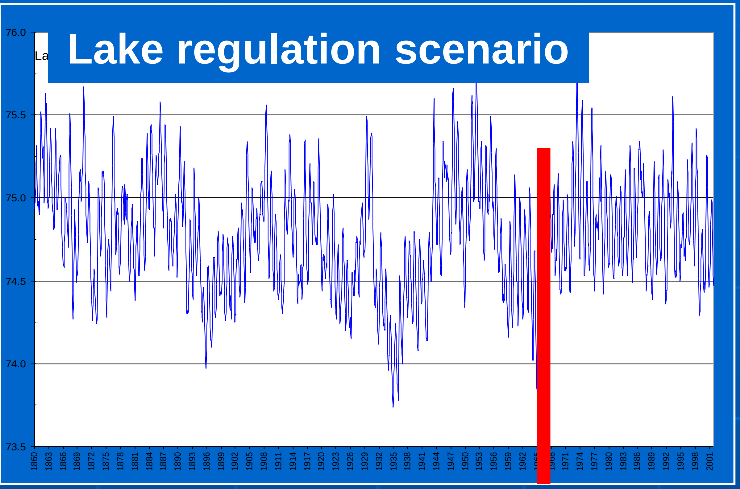


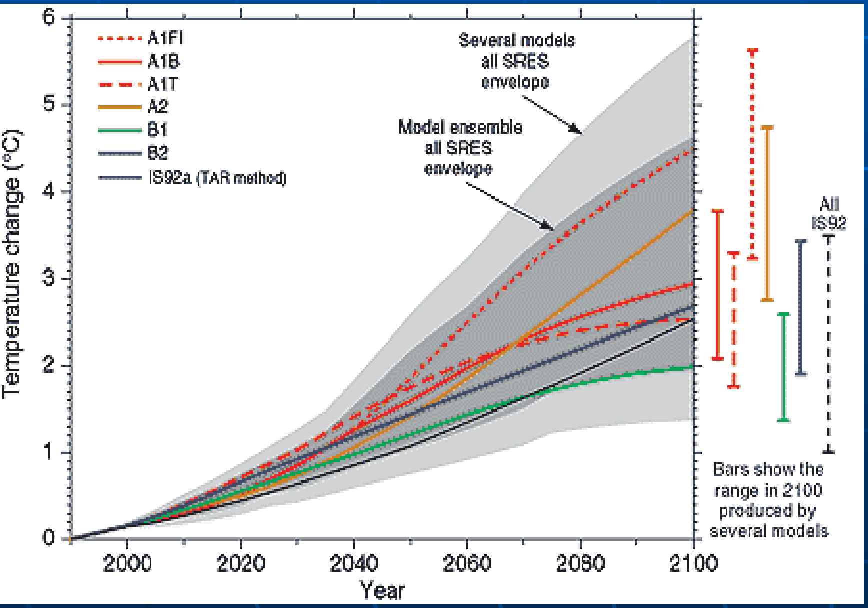
(Current Plan 1958D was not designed to handle the extreme low water of the 1960s or the high water of the 70s, 80s and 90s)

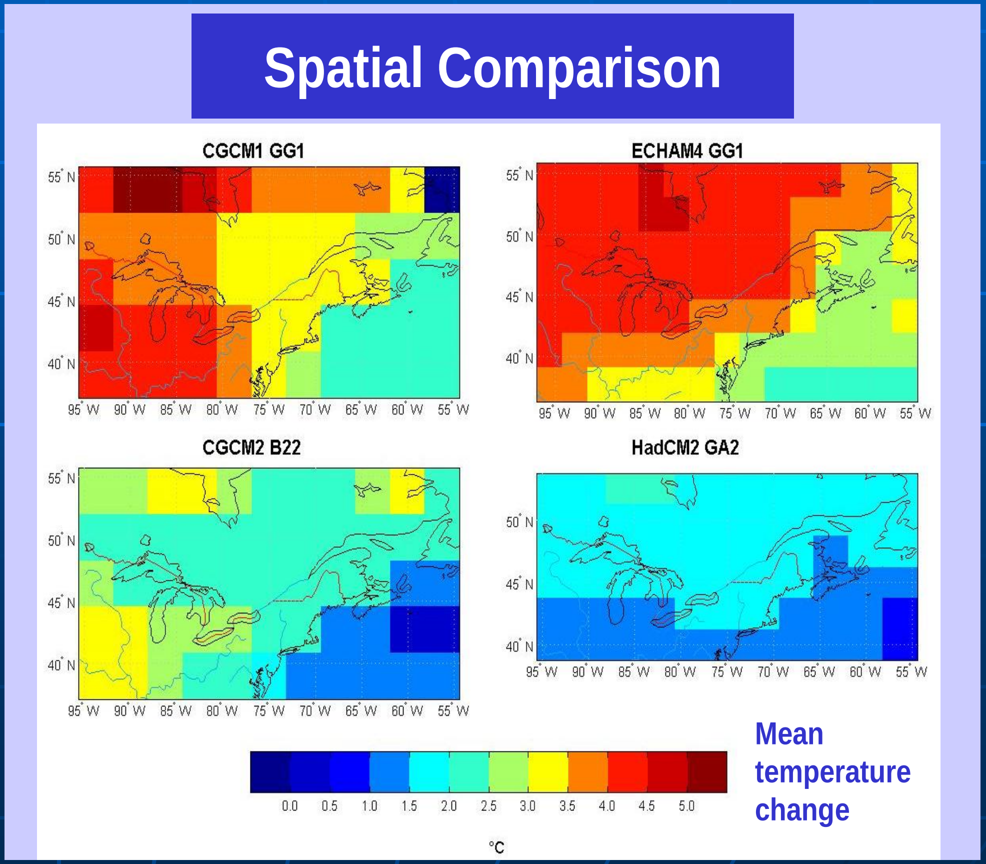
LOSLR Study Board Guidelines

- Contribute to **Ecological Integrity**
- **Maximize economic and ecological net benefits**
- No **disproportionate loss to any sector (Equity)**
- Flexible in recognition of **unusual or unexpected** conditions
- Adaptable to **climate change** and **climate variability (**AM Plan for key uncertainties)
- **Adapt** to future advances in knowledge, science and technology (Adaptive Management Plan)
- Decision-making will be **transparent and representative**

Hydrologic Scenarios Including Climate Change

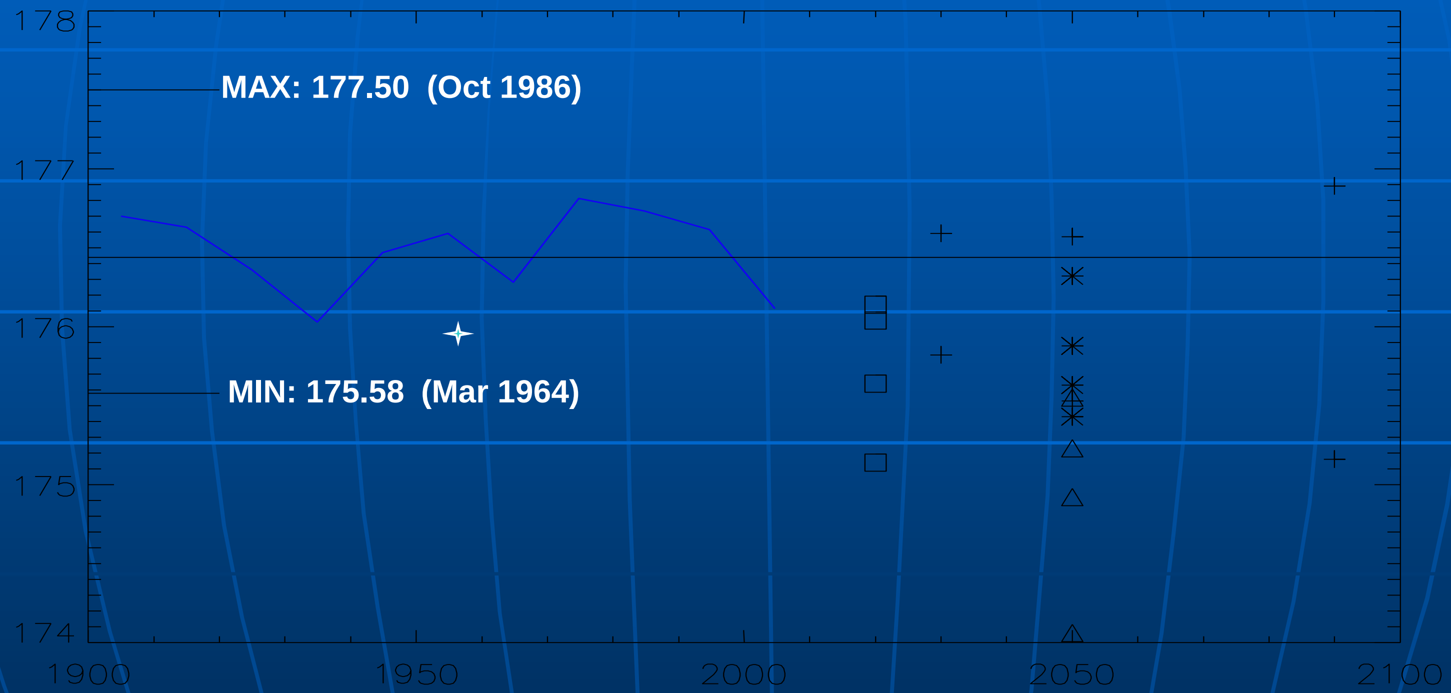






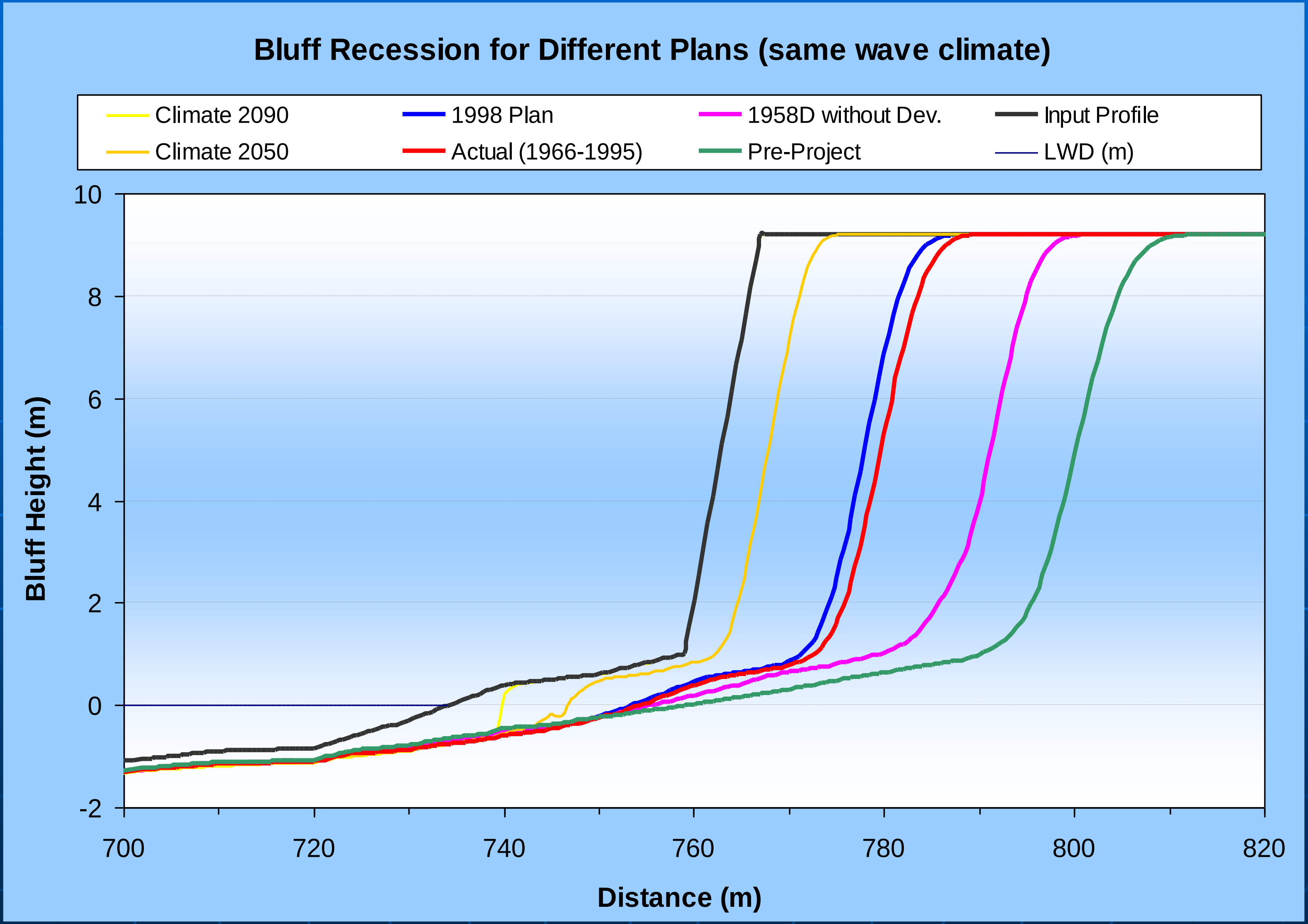
Climate Prediction – LOSL Study, 2000

Michigan – Huron Lake Levels: Decadal Mean



Performance Indicators

- Over 500 ***initial*** PI's & hydrologic & hydraulic criteria covering ecosystem, navigation, erosion, flooding, M&I water, hydropower, recreational boating
- Winnowed to 81 PI's, incl 32 Ecol PI's for evaluation/decisionmaking


Bluff Recession for Different Plans (same wave climate)
Climate 2090
1998 Plan
1958D without Dev.
Input Profile
Climate 2050
Actual (1966-1995)
Pre-Project
LWD (m)
Bluff Height (m)
10
8
6
4
2
0
-2
700
720
740
760
780
800
820
Distance (m)

IJC International Lake Ontario – St. Lawrence River Study (1999-2005)

Candidate Plans:
- A: Balanced Economics
- B: Balanced Environmental
- D: Blended Benefits

Natural Flow Plan
- E: Natural Flow

Interest Specific:
- Ontario Riparian Plan
- Recreational Boating Plan

Reference Plans:
- Plan 1998
- Plan 1958DD
- Plan 1958D

Net Economic/Ecologic Benefits of Alternative Plans

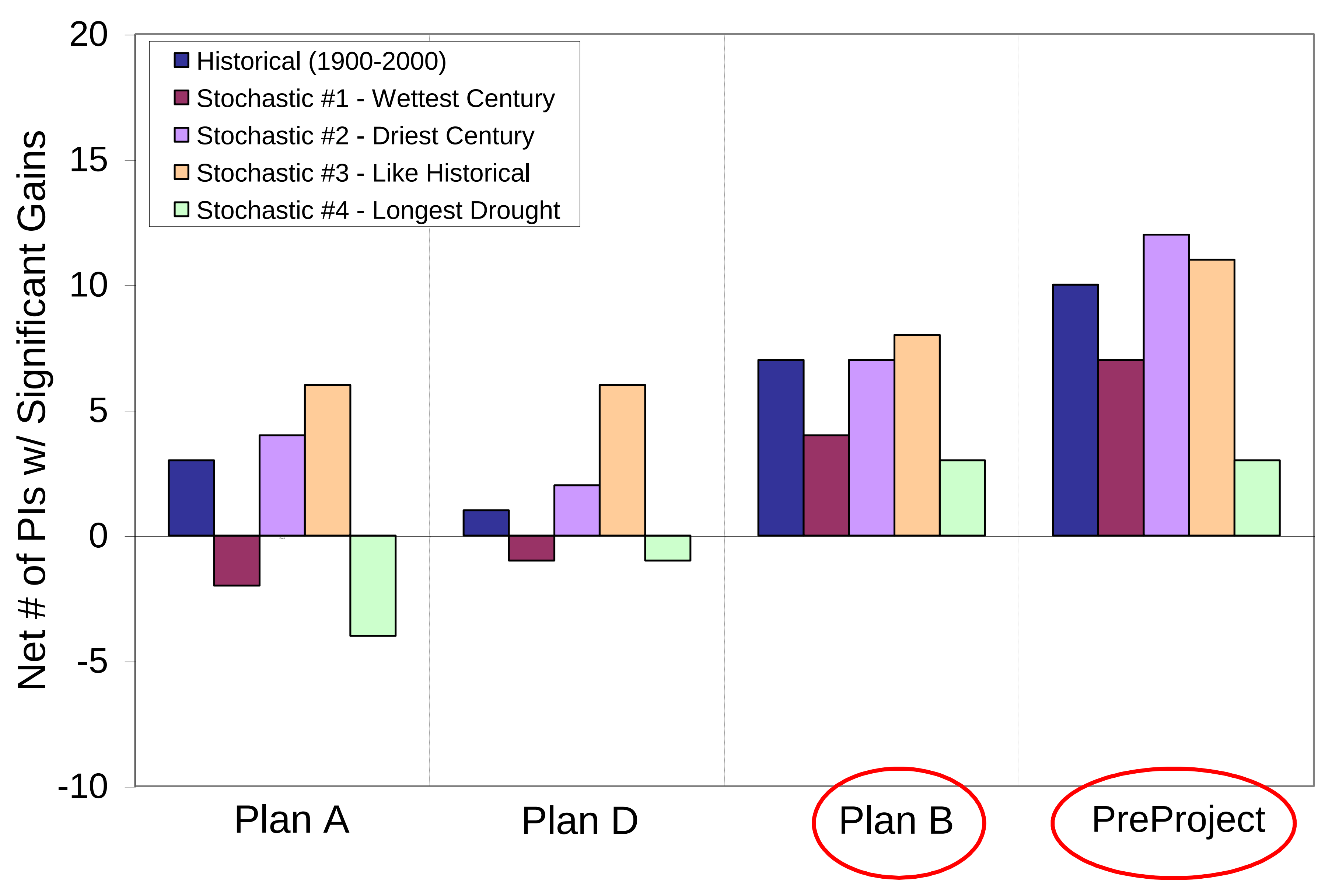
Avg. annual net benefits ($US million)	**Plan 58DD**	**Plan A**	**Plan B**	**Plan D**	**Plan E**
Net Benefits	**0.00**	**7.52**	**6.48**	**6.52**	**-12.30**
Shoreline Damages	0.00	**-0.62**	**-1.11**	**0.32**	**-25.96**
Navigation	0.00	0.41	2.20	2.31	4.13
Recreation Boating	0.00	4.23	-0.58	2.04	**-4.64**
Hydroelectric	0.00	3.50	5.97	1.82	14.16
Municipal Water	0.00	0.00	0.00	0.00	0.00
Environmental Index	**1.00**	**1.06**	**1.35**	**1.10**	**4.04**
Wetlands Index	**1.00**	**1.02**	**1.44**	**1.17**	**1.56**

GCM Scenarios: Economic Robustness of Plans
IJC Lake Ontario-St. Lawrence Regulation
w.r.t Climate Change Scenarios

Avg. ann. net benefits ($US million)	**Plan 1958DD**	**Plan A**	**Plan B**	**Plan D**	**Plan E**
		***Econ* Efficiency**	***Environ* Quality**	***Combo* Benefits**	***Natural* Flows**
Plan 1958DD (current plan)	**0**	**7.52**	**6.48**	**6.52**	**-12.30**
C1- Hot/Dry	**-115.65**	**34.89**	**-1.42**	**20.09**	**-4.91**
C2 - Warm/Dry	**-49.52**	**9.85**	**4.89**	**5.25**	**-34.03**
C3 - Hot/Wet	**-81.69**	**21.53**	**2.61**	**17.77**	**-2.46**
C4 - Warm/Wet	**13.98**	**8.33**	**11.78**	**9.65**	**-21.38**

Ecological Robustness/Resiliency- **Stochastic Scenarios**

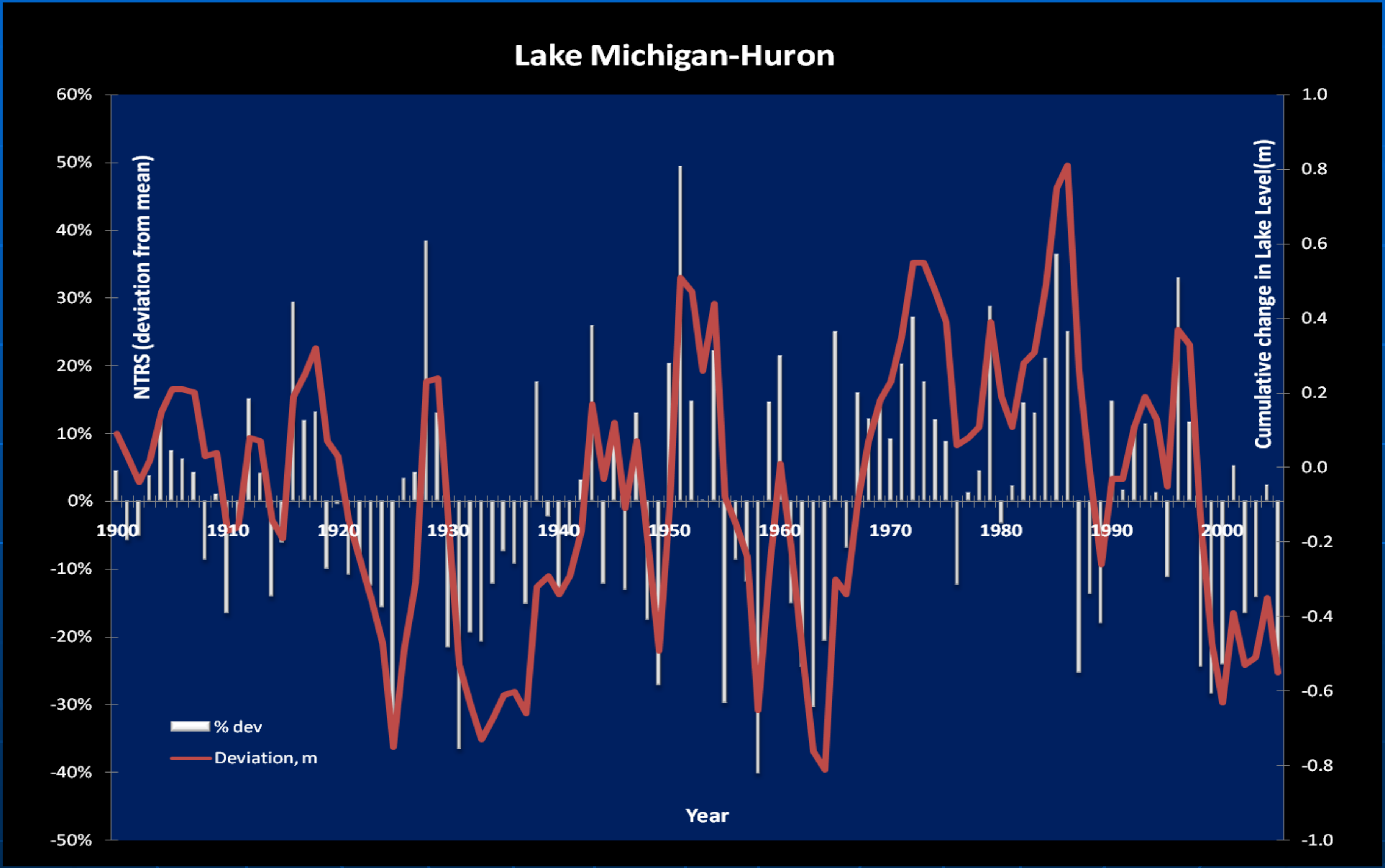
(# Ecological Performance Indicators's (of 32) with gains or losses)



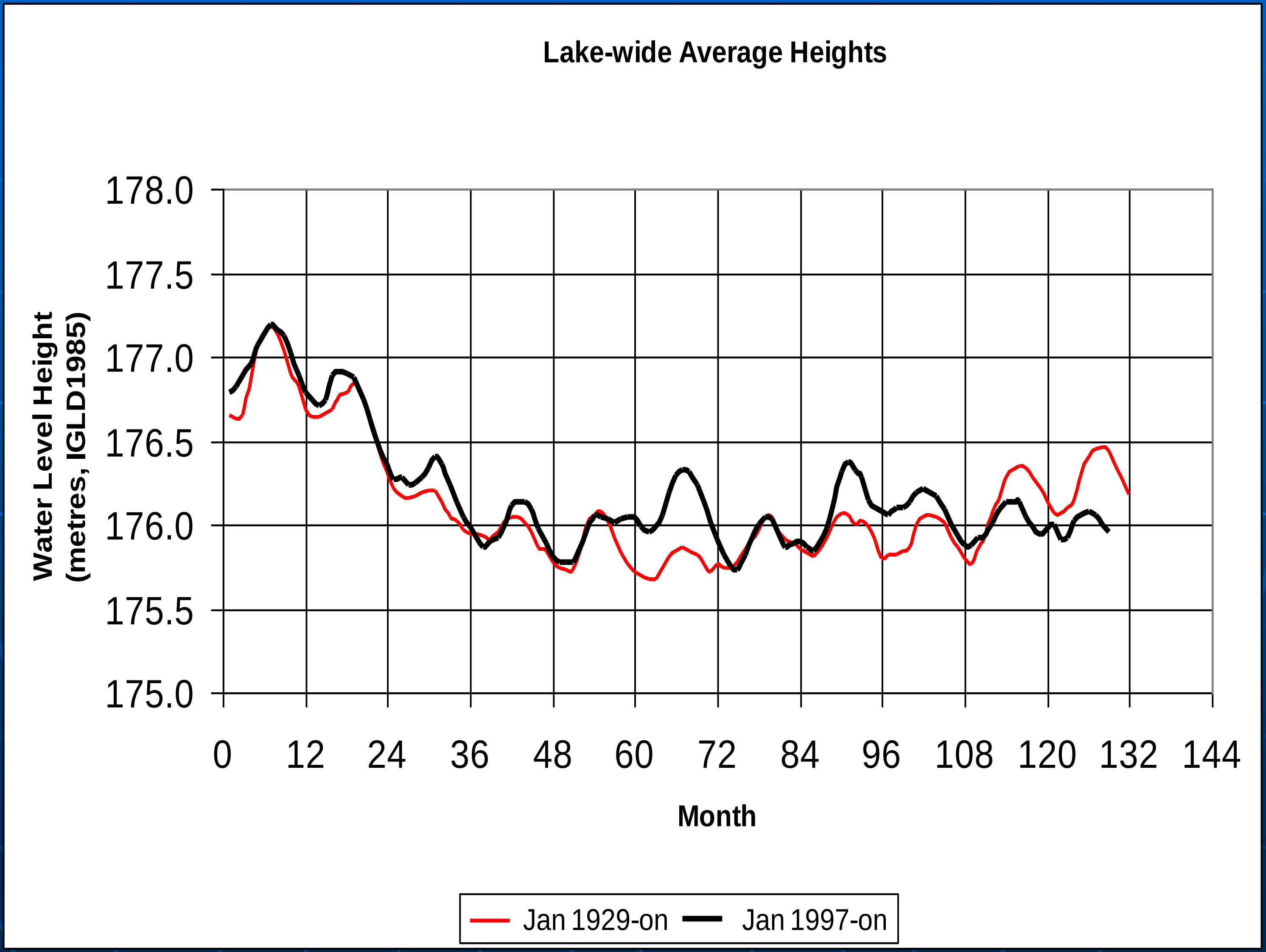
Presentation Outline

St. Marys River at Sault Ste. Marie

Water Supply Deficit & Lake Levels



Current LMH levels compared to 'Dust Bowl' Drought

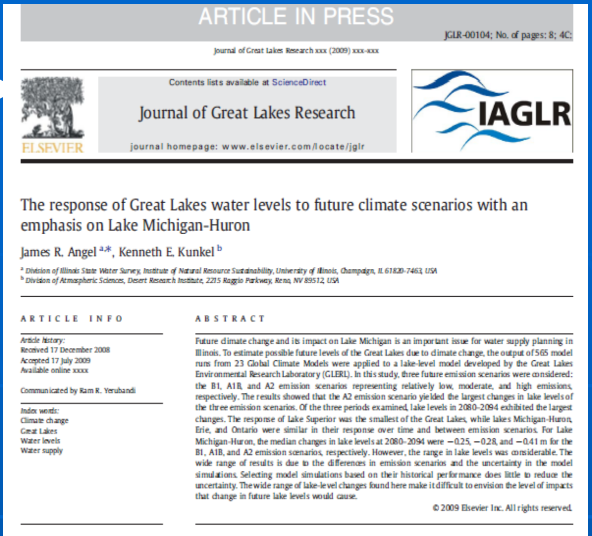


METHODOLOGY

1. **Analyze/refine GCM based results of Angel and Kunkel**
    - 23 GCMs (565 runs) → large scatter in results
    - rational basis of selection to reduce uncertainty?
2. **Analyze existing CRCM projections for Great Lakes**
    - based on 4 GCMs

      ECHAM5 (A2), **CGCM3.1** (A2)
      ARPEGE-Uniforme (A1B – not in IPCC-AR4)
      CCSM (maybe)
3. **Downscale CRCM runs with new version of model**
    - finer (20km) resolution
    - new land surface scheme

Angel and Kunkel, 2010 (in press)


ARTICLE IN PRESS

JGLR-00104; No. of pages: 8; 4C:
Journal of Great Lakes Research xxx (2009) xxx–xxx
Contents lists available at ScienceDirect
Journal of Great Lakes Research
journal homepage: www.elsevier.com/locate/jglr

The response of Great Lakes water levels to future climate scenarios with an emphasis on Lake Michigan-Huron

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ARTICLE INFO

Article history:
Received 17 December 2008
Accepted 17 July 2009
Available online xxxx

Communicated by Ram R. Yerubandi

Index words:
Climate change
Great Lakes
Water levels
Water supply

ABSTRACT

Future climate change and its impact on Lake Michigan is an important issue for water supply planning in Illinois. To estimate possible future levels of the Great Lakes due to climate change, the output of 565 model runs from 23 Global Climate Models were applied to a lake-level model developed by the Great Lakes Environmental Research Laboratory (GLERL). In this study, three future emission scenarios were considered: the B1, A1B, and A2 emission scenarios representing relatively low, moderate, and high emissions, respectively. The results showed that the A2 emission scenario yielded the largest changes in lake levels of the three emission scenarios. Of the three periods examined, lake levels in 2080–2094 exhibited the largest changes. The response of Lake Superior was the smallest of the Great Lakes, while lakes Michigan-Huron, Erie, and Ontario were similar in their response over time and between emission scenarios. For Lake Michigan-Huron, the median changes in lake levels at 2080–2094 were −0.25, −0.28, and −0.41 m for the B1, A1B, and A2 emission scenarios, respectively. However, the range in lake levels was considerable. The wide range of results is due to the differences in emission scenarios and the uncertainty in the model simulations. Selecting model simulations based on their historical performance does little to reduce the uncertainty. The wide range of lake-level changes found here make it difficult to envision the level of impacts that change in future lake levels would cause.

IPCC Fourth Assessment Report Models

	Model ID, Vintage	Resolution
1	BCC-CM1, 2005	T63 (1.9° X 1.9°) L16
2	BCCR-BCM2.0, 2005	T63 (1.9° X 1.9°) L31
3	CCSM3, 2005	T85 (1.4° X 1.4°) L26
4	CGCM3.1(T47), 2005	T47 (2.8° X 2.8°) L31
5	CGCM3.1(T63), 2005	T63 (1.9° X 1.9°) L31
6	CNRM-CM3, 2004	T63 (1.9° X 1.9°) L45
7	CSIRO-MK3.0, 2001	T63 (1.9° X 1.9°) L18
8	ECHAM5/MPI-OM, 2005	T63 (1.9° X 1.9°) L31
9	ECHO-G, 1999	T30 (3.9° X 3.9°) L19
10	FGOALS-g1.0, 2004	T42 (2.8° X 2.8°) L26
11	GFDL-CM2.0, 2005	2.0° X 2.5° L24
12	GFDL-CM2.1, 2005	2.0° X 2.5° L24
13	GISS-AOM, 2004	3.0° X 4.0° L12
14	GISS-EH, 2004	4.0° X 5.0° L20
15	GISS-ER, 2004	4.0° X 5.0° L20
16	INM-CM3.0, 2004	4.0° X 5.0° L21
17	IPSL-CM4, 2005	2.5° X 3.75° L19
18	MICRO3.2(hires), 2004	T106 (1.1° X 1.1°) L56
19	MICRO3.2(medres), 2004	T42 (2.8° X 2.8°) L20
20	MRI-CGCM2.3.2,	T42 (2.8° X 2.8°) L30

- 565 simulations
- 3 emission scenarios (B1,A1B,A2)

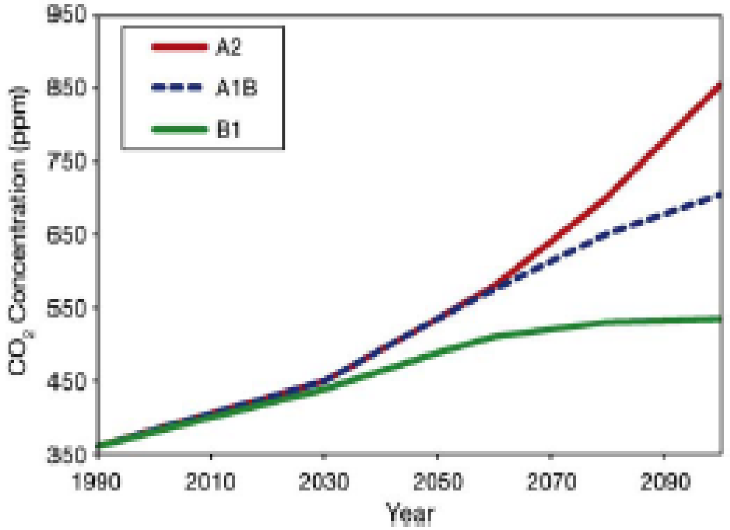
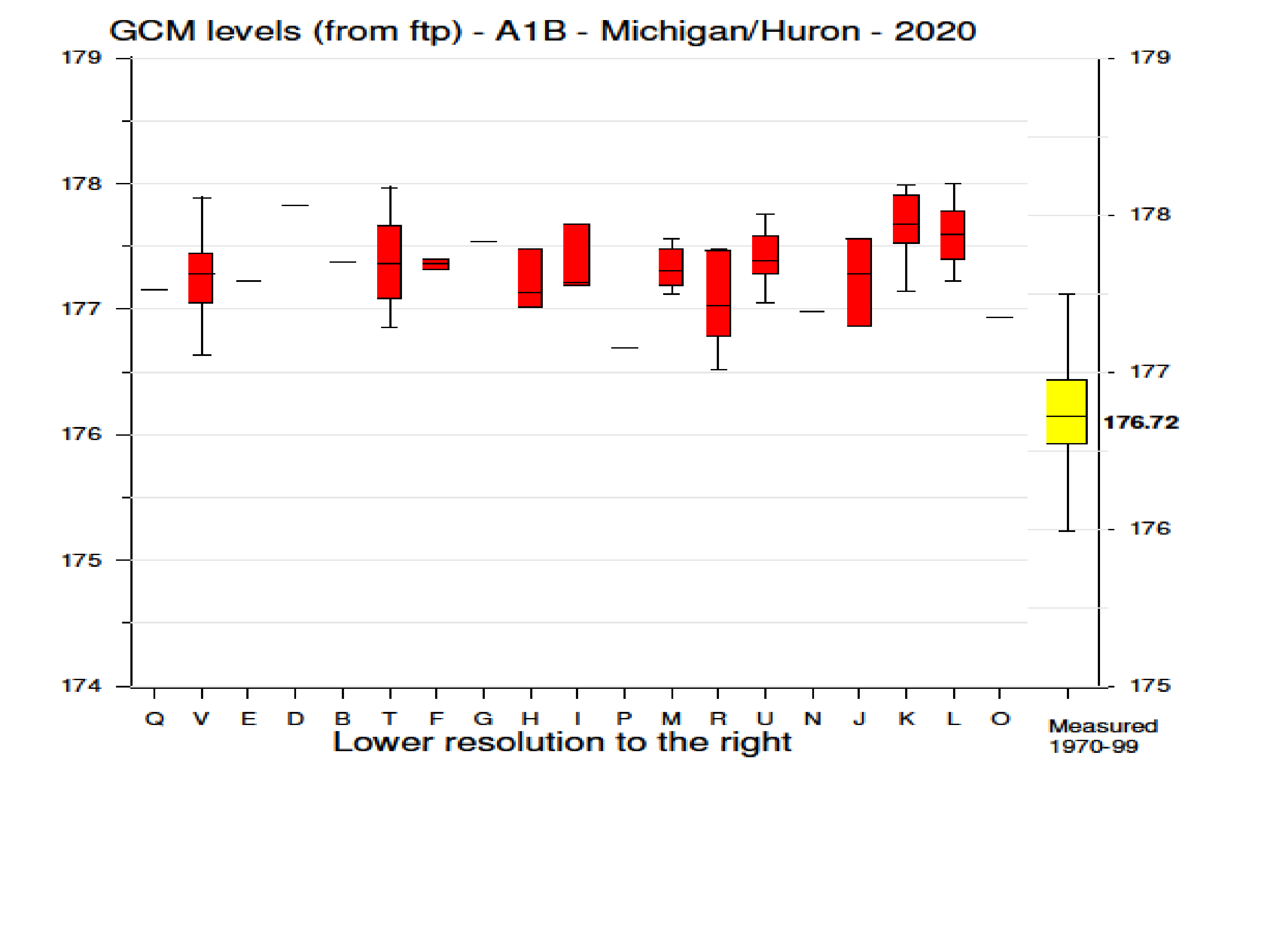
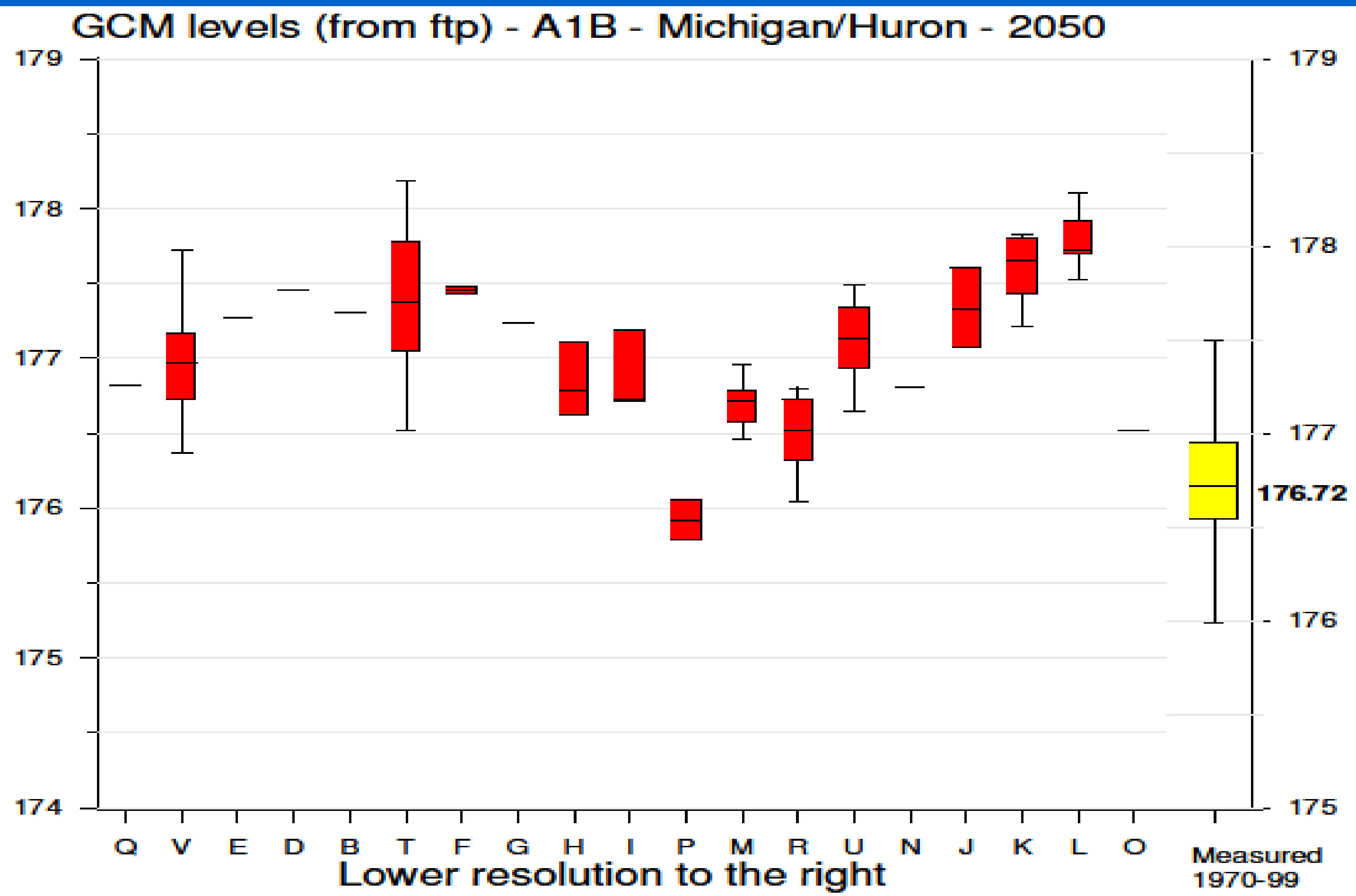


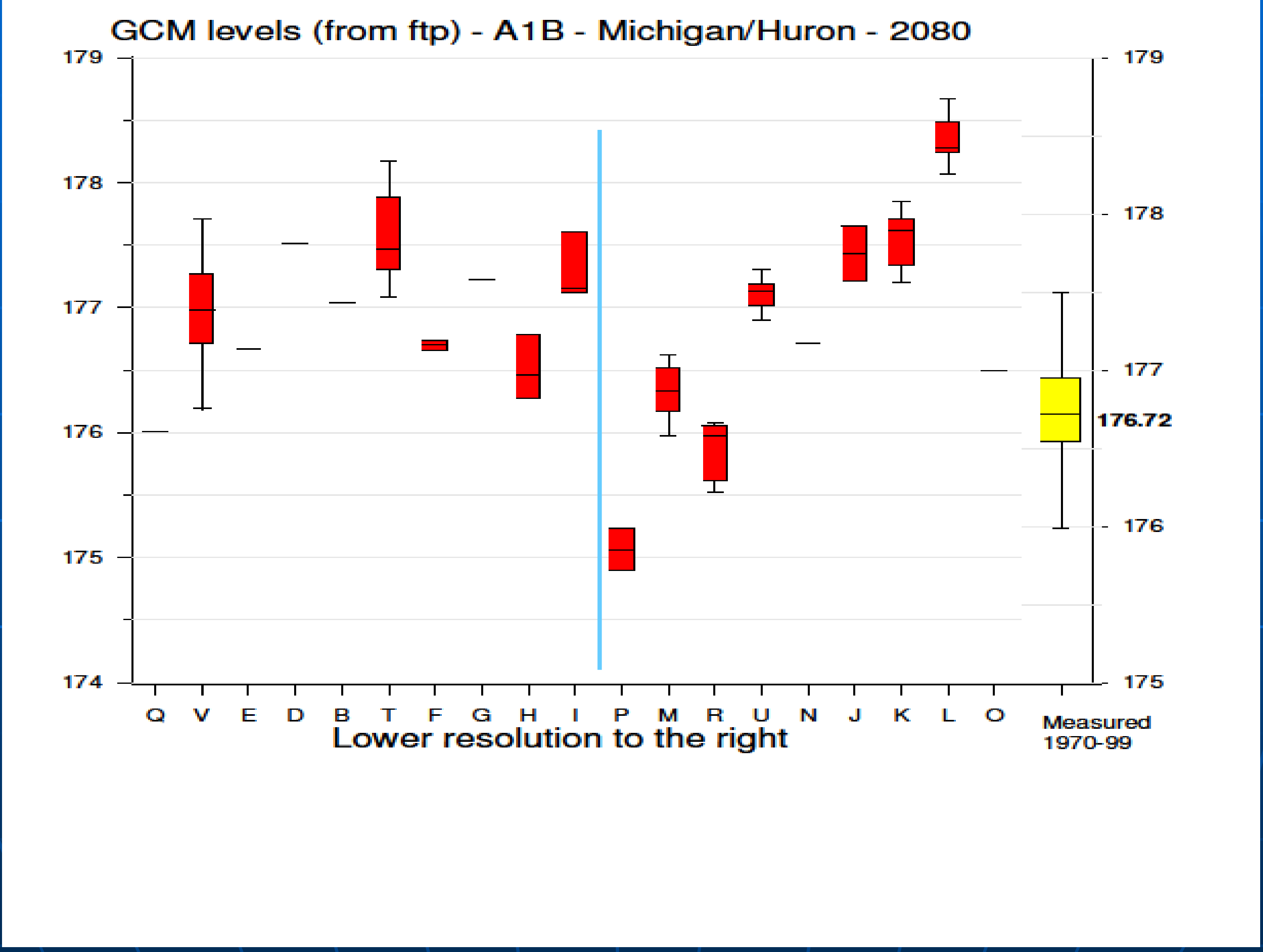
Fig. 2. Time series of CO_2 concentration for 1990-2100 for the three CO_2 emission scenarios used in this study. The emission scenarios are as follows: A2 = moderately high, A1B = intermediate, and B1 = low.



GCM levels (from ftp) - A1B - Michigan/Huron - 2020
179
178
177
176
175
174
179
178
177
176.72
176
175
Q V E D B T F G H I P M R U N J K L O
Measured 1970-99
Lower resolution to the right

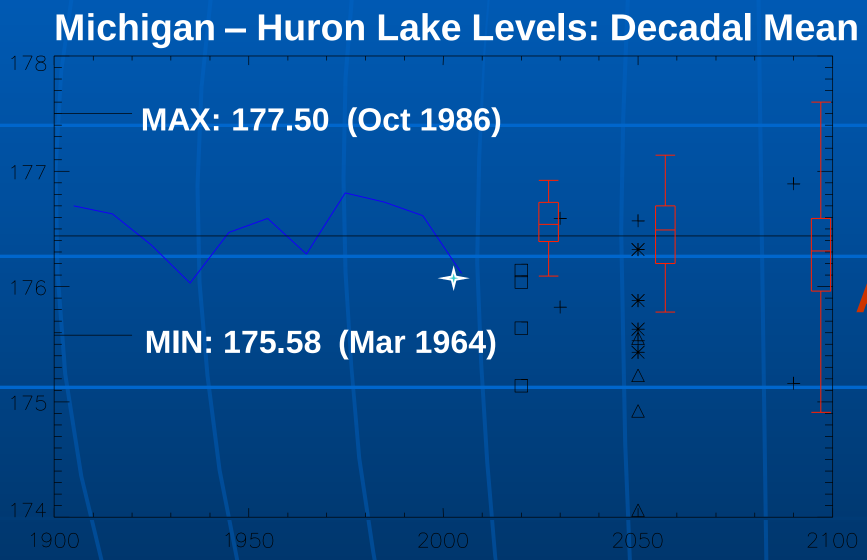


GCM levels (from ftp) - A1B - Michigan/Huron - 2050
179
178
177
176
175
174
Q V E D B T F G H I P M R U N J K L O
Measured 1970-99
176.72
Lower resolution to the right



GCM levels (from ftp) - A1B - Michigan/Huron - 2080
179
178
177
176
175
174
Q V E D B T F G H I P M R U N J K L O
Measured
1970-99
Lower resolution to the right
176.72

Climate Prediction



<u>Angel and Kunkel, JGLR *in press*</u>

23 GCMs (IPCC AR4 – 2007)
3 scenarios (B1, A1B, A2)
565 simulations

A2 results (160 simulations)

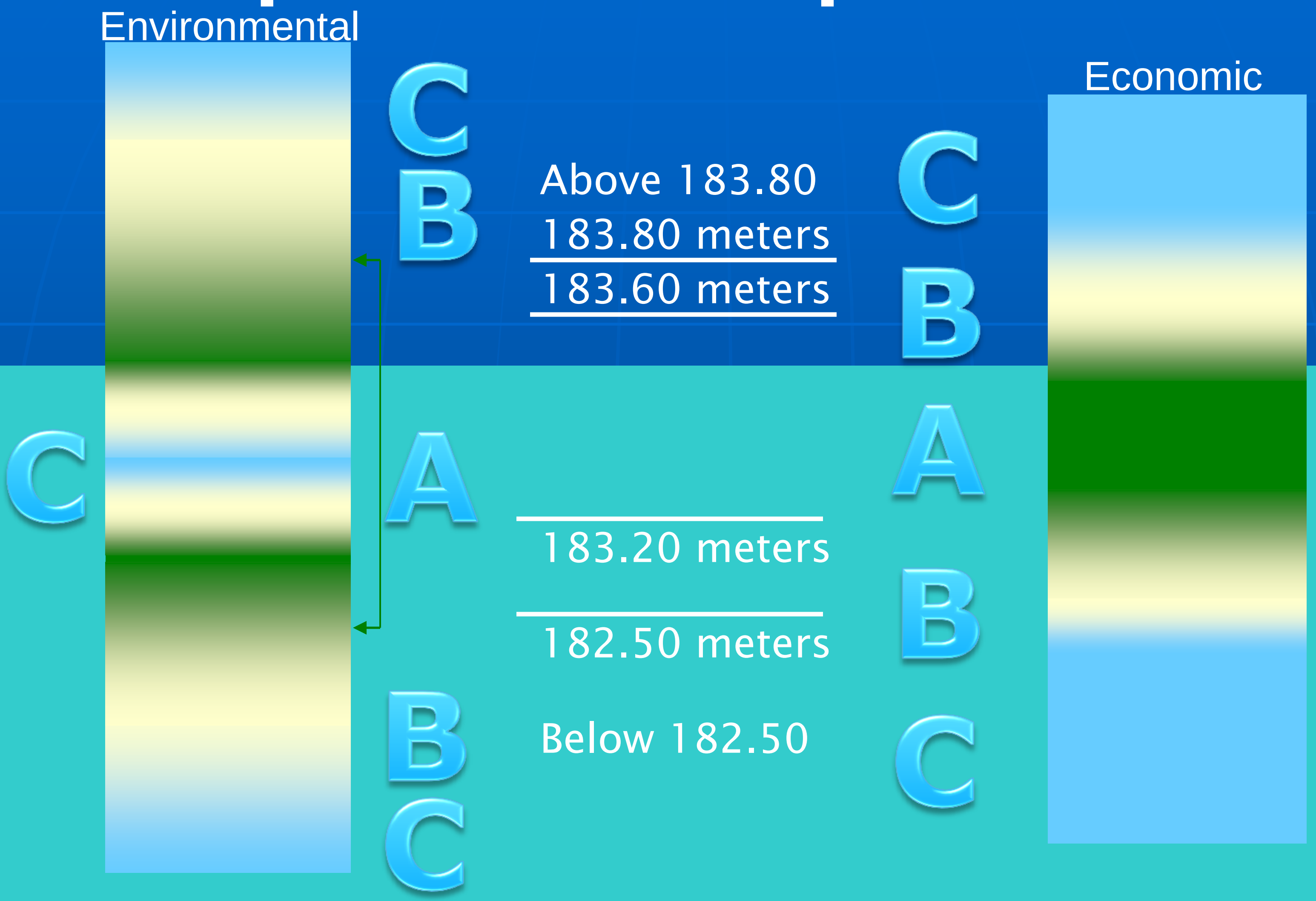
Understanding vulnerabilities

Establish Coping Zones:

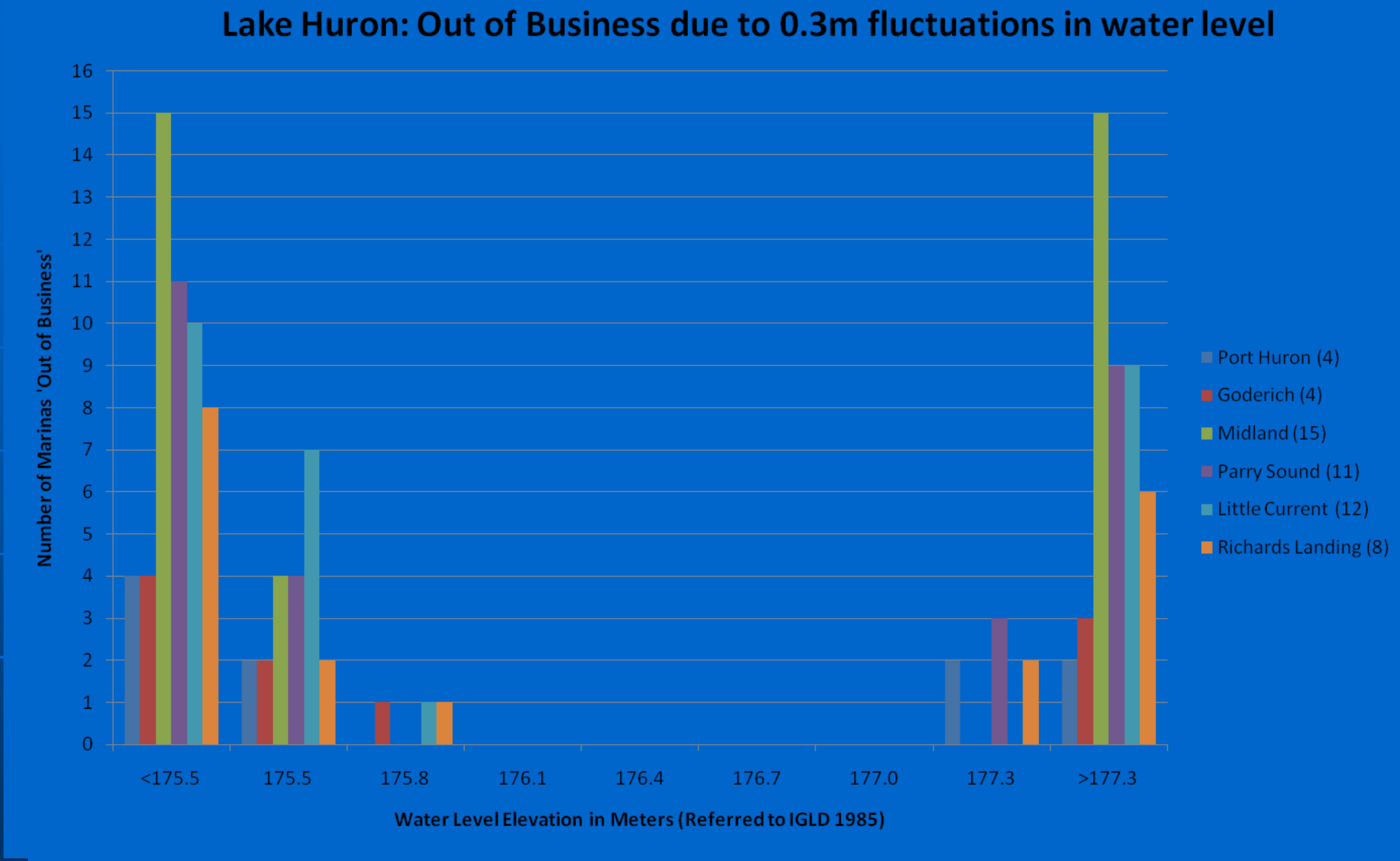
- **A Zone:** acceptable – within expectations
- **B Zone:** non-trivial costs (or environmental impact), interests will persevere
- **C Zone:** significant costs, interest cannot survive (bankruptcies) or serious degradation of ecosystem function

- Zones include levels/flows, range, duration, frequency, seasonality, rate of change
- Will vary by location - focus on key vulnerabilities

Example - Lake Superior Zones



Recreational Boating



- On Lake Huron, at least half of the marinas in the Little Current, Port Huron, and Goderich AOS would go out of business if the water level were to drop by three feet (0.9m) from the average elevation for May through August, 2009 (176.4m).

IUGLS Strategy