Lake level trends in central Alberta

Cristina Buendia, PhD
North Saskatchewan Watershed Alliance
Flowing Waters, October 2017
Beaverhill lake....
Lac Ste Anne...
Lakes are important sources of water, but....

Socio-economic uses:
- Municipal water supply
- Irrigation/Industrial processes
- Recreation
- Strong spiritual and cultural value

Ecological functions

As the population grows, demand for freshwater will increase
Lakes are important sources of water, but....

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Critical in the semi-arid climate of the prairie region of Canada

- Undergoes significant variation in wet and dry conditions (i.e. PDO, ENSO)
- Future scenarios -> intensification and persistence of drought

Lakes are becoming more vulnerable to human and natural stressors
Fluctuations in Prairie lakes

Prairie lakes have varied markedly over decades:

- Following **climate variability**:
  - Changes in precipitation and evaporation
- Influenced by changes in **land use** and water management

**STUDIES EVALUATING LAKE LEVEL DECLINES**

**Van der Kaamp et al. (2008)**

*Changes in closed-basin lakes of the Prairies*

- **16 closed-basin lakes in the Prairies**
  - Most of the lakes show a long-term water level decline from ~ 1920 to the present.
  - Patterns hold from SC-EC Alberta to through C and SE Saskatchewan
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**Casey (2011)**
*Trends in Alberta lake levels*

- 37 lakes in AB
- 51% No trend
- 35% Declining
- 14% Increasing

- 37% No trend
- 2% Declining
- 0% Increasing
Main objectives

• Compile and summarize available and updated lake level data
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Challenge:

- Few lakes have sufficient long term and consistent data
- Many gaps, data is not consistent throughout the year
- Trend detection is largely influenced by the record length as well as the start and end points
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Trends between 1985 - 2016 (~ 30 y of lake level data)

- Maximize the number of studied lakes
- Avoid potential effects introduced by the wet 1970s
- Keep the period consistend amongst lake records

**Provide a regional overview of lake level trends, subject to the same climatic conditions, during the time when much of the development occurred**

**Focus on the broad spatial scale, not on individual lake balances!**
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Methods

1. Loss of lake surface area in the NSRB using satellite images
2. Statistical trend analyses on median annual lake levels
3. Annual Lake Level Index (ALI; Islam and Seneka, 2015)
Study of Global Surface Water and its long-term changes
by The European Commission’s Joint Research Center (JRC)

• Global data sets documenting changes in water surface between 1984 and 2015
• Produced from inventories, national descriptions, statistical extrapolation of regional data and satellite imagery.
• High resolution: 30x30m

Maps document different facets of water surface dynamics:

- **Surface Water Occurrence**
  - Frequency with which water was present on the surface from 1984 to 2015

- **Occurrence Change Intensity**
  - Information on where surface water occurrence increased, decreased or remained the same between two epochs: 1984-1999 and 2000-2015.
  - Direction and intensity of change are documented

- **Seasonality**
  - Information concerning the *intra-annual behaviour* of water surfaces.

- **Recurrence**
  - Information on the *inter-annual behaviour* of water surfaces (variability in the presence of water)

- **Transitions**
  - Information on the *change in seasonality* between the first and last year
    - Unchanging permanent water surfaces
    - New seasonal water surfaces
    - New water permanent surfaces
    - Lost seasonal water surfaces
    - Lost permanent water surfaces
    - Conversion of permanent into seasonal
    - Unchanging seasonal water surfaces
    - Conversion of seasonal into permanent
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Change in seasonality

Transitions...

Total lake Area = 2,278 km² (~ 2% of the NSRB)
Water transitions map - Lakes
(Beaverhill)
Water transitions map - Lakes
(Isle lake and lac Ste. Anne)
Transitions

Change in seasonality

- Change: 39% (889 Km²)
- No Change: 61% (1,390 Km²)
Change in seasonality

- Change towards the loss of lake area (both permanent and seasonal surface waters)

- Change
- No Change

- Lost permanent or seasonal: 8% of 1,390 km² = 111.2 km²
- New permanent or seasonal: 8% of 889 km² = 71.12 km²
- No change: 92% of 1,390 km² = 1,288.8 km²

- 61% of 1,390 km² = 839.9 km²
- 39% of 889 km² = 347.91 km²
94 lakes selected to evaluate temporal trends
• Records extent from at least from 1985 until the present
• Levels respond to natural fluctuations
• Not used as reservoirs or subject to major diversions
Temporal trends

THE DATABASE

94 lakes selected to evaluate temporal trends

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- Levels respond to natural fluctuations
- Not used as reservoirs or subject to major diversions

Lakes from the South Saskatchewan are highly regulated
Temporal trends

Mann Kendall trend test applied to median annual lake levels
Non-parametric test to detect monotonic trends in environmental data

Trends classified in 5 categories:

- Decreasing: Negative trend at the 95% CL
- Increasing: Positive trend at the 95% CL
- Likely decreasing: Negative trend at the 90% CL
- Likely increasing: Positive trend at the 90% CL
- No trend: No statistical trend
(2) Temporal trends

RESULTS

Overall decrease in lake levels across the province:

- **Decreasing**: 50%
- **No trend**: 32%
- **Likely Increasing**: 12%
- **Increasing**: 4%
- **Likely decreasing**: 2%
Some Examples...
Some Examples...

Antler Lake

738.476 → ~ 0.6m → 737.898
SOME EXAMPLES...

Lac Sante

Level (m GSC)

607.126

~ 4m

603.147

SOME EXAMPLES...

Lac Ste Anne

- Increasing
- Likely Increasing
- No trend
- Likely Decreasing
- Decreasing

Some examples...

722.888

Level (m GSC)


722.4 722.6 722.8 723.0 723.2

722.767
**ALI — Alberta Lake Level Index**

- Index developed by Islam and Seneka (2015)* - AEP –
- Compares water levels recorded throughout the year to historical patterns
- Resulting index for each year is ranked according to 5 categories:

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Lake Level Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MAN</strong>-</td>
<td>Much Above Normal</td>
<td>Lake Level &gt; 90&lt;sup&gt;th&lt;/sup&gt; perc.</td>
</tr>
<tr>
<td><strong>AN</strong>-</td>
<td>Above Normal</td>
<td>70&lt;sup&gt;th&lt;/sup&gt; perc. &lt; Lake level &lt; 90&lt;sup&gt;th&lt;/sup&gt; perc.</td>
</tr>
<tr>
<td><strong>N</strong>-</td>
<td>Normal</td>
<td>75&lt;sup&gt;th&lt;/sup&gt; perc. &lt; Lake Level &lt; 25&lt;sup&gt;th&lt;/sup&gt; perc.</td>
</tr>
<tr>
<td><strong>BN</strong>-</td>
<td>Below Normal</td>
<td>25&lt;sup&gt;th&lt;/sup&gt; perc. &lt; Lake Level &lt; 10&lt;sup&gt;th&lt;/sup&gt; perc.</td>
</tr>
<tr>
<td><strong>MBN</strong>-</td>
<td>Much Below Normal</td>
<td>Lake Level &lt; 10&lt;sup&gt;th&lt;/sup&gt; perc</td>
</tr>
</tbody>
</table>

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Percentage of lakes for each category (1985-2016)

- Not all lakes are included in every year (data constraints)
- 86 lakes/year on average
- Min: 48 lakes in 2010
PERCENTAGE OF LAKES FOR EACH CATEGORY (1985-2016)

1985
88% -> N - AB - MAN
12% -> BN - MBN

2016
45% -> N - AB - MAN
55% -> BN - MBN
PERCENTAGE OF LAKES FOR EACH CATEGORY (1985-2016)

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45% -> N - AB - MAN
55% -> BN - MBN
More questions…

- What are the main drivers of the decline?
- Is there any characteristic that makes a lake more vulnerable to climate/human effects?
More data...

- **Average annual change rate in lake level**
- **SLOPE OF DECLINE**

**Variations in Lake Level Decline**

- **Watershed**
  - Geology
  - Land Cover
  - Linear Developments

- **Hydrology**
  - Water Yields
  - Connectivity to stream network

- **Climate**
  - Precipitation
  - Temperature
  - Evapotranspiration

- **Lake Properties**
  - Lake morphology

**Graph**

Level (m GSC) vs. Time (1985-2000)
On going work... Some preliminary results.

PRINCIPAL COMPONENTS ANALYSIS (PCA)

- Emphasizes variation and brings out strong patterns in the dataset
- Finds correlations between the data and plots it in a 2D space
On going work... Some preliminary results..

PRINCIPAL COMPONENTS ANALYSIS (PCA)
On going work... Some preliminary results..

**PRINCIPAL COMPONENTS ANALYSIS**

![Diagram showing principal components analysis with categories SLOPES <0 and SLOPES >~0. The diagram includes points labeled with categories such as Prec, LL, PA, Ur, etc., and a box highlighting the Lisen category.](image-url)
On going work... Some preliminary results..

**PRINCIPAL COMPONENTS ANALYSIS (PCA)**

- Water Yield
- Precipitation
- Elevation
- % Forest

**Coarser geology:**
- Colluvial deposits
- Eolian deposits
- Fluvial deposits

**Finer geology:**
- Lacustrine deposits
- Glaciolacustrine deposits
- Stagnant ice moraine

**Lisens**
On going work... Some preliminary results..

PRINCIPAL COMPONENTS ANALYSIS (PCA)

Emphasize variation and bring out strong patterns in the dataset

Natural Regions
On going work... Some preliminary results...

**Lake Order** *(Riera et al., 2000)*

Type and strength of the connections between a lake and the surface drainage network

**Numbering System:**

<table>
<thead>
<tr>
<th>Lakes without permanent inlets/outlets</th>
<th>Lakes with inlets/outlets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seepage lakes</td>
<td>Drainage lakes</td>
</tr>
<tr>
<td>Negative lake order</td>
<td>Positive lake order</td>
</tr>
<tr>
<td>Closed lakes -&gt; more negative values</td>
<td>Order of the stream that drains the lake</td>
</tr>
</tbody>
</table>

*Riera et al., 2002. A geomorphic template for the analysis of lake districts applied to the Northern Highland Lake District. Freshwater Biology, 43.*
Lake level decline (slope)

Lake Order (Riera et al., 2000)*

 Larger lake orders show no/lower lake level declines (less negative/positive slopes)

On going work... Some preliminary results.
On going work... Some preliminary results..

Lake Order (Riera et al., 2000)*

Larger lake orders show lower declines (less negative/positive slopes)

Large order lakes
- Tend to be in closer contact with aquifers (Cheng and Anderson, 1994)
- Will have (in general) larger watershed-to-lake area ratios

Low order lakes
- Usually seepage lakes that receive most of the water from precipitation/surface runoff
- Hydrologic balance might be more dynamic across years -> Influenced by climate

On going work… Some preliminary results..

**SHAPE OF ALBERTA LAKES (Islam and Seneka, 2016)**

Evaluated volume to depth relationships of Alberta lakes and assigned an “idealized shape”

Relationship between Lake Volume/Surface Area and Depth

Lake morphometry influence lake functioning and processes such as mixing and evaporation

Islam and Seneka, 2016 (AEP)- *Development of generic shapes of Alberta lakes to support water policy development
Some observations…

Spatial scale

Watershed scale

Connectivity to stream network

Morphometry
Take home message...

- Different methods yield similar results
  - Regional lake level decline across the province

- Lake levels are naturally dynamic
  - Climate is an important signal in lake fluctuations
  - Others drivers that influence in lake dynamics

Understanding the dynamics of the lakes in the landscape is essential for developing an adaptive approach in lake management.
THANKS!

Comments
Questions
Ideas