Integration of Earth observation and *in situ* data for analyzing lake level change in Minnesota (1990-2016)

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Introduction

➢ Lake ecosystems are crucial resources for aquatic wildlife and human being.
➢ Global climate change has begun to affect lake ecosystems.
➢ Understanding how climate change affects lakes is essential for managing water resource and the associated ecosystem services
➢ Few studies examined the relationship between lake level variations and climatic variables.
➢ Spatial and temporal similarity of lakes in Minnesota still unclear. Thus, it is questionable whether the lakes in Minnesota have spatial-temporal heterogeneity.

Study Area

➢ Minnesota is located in the northern regions of the United States.
➢ The region possesses numerous lakes and 11842 lakes over 10 acres.
➢ Lowest temperature usually in February, whereas the highest in July.
➢ The climate over the state is different featured by spatial heterogeneity. Thus, lakes in the different regions show distinctive responses to the climate.

Lakes in Minnesota
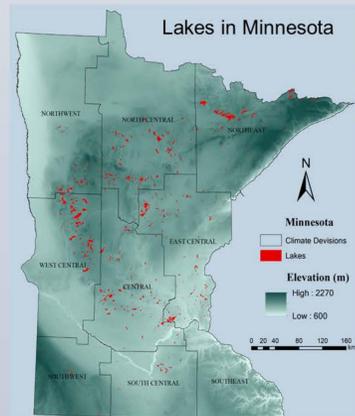
Data

Lake Area Data
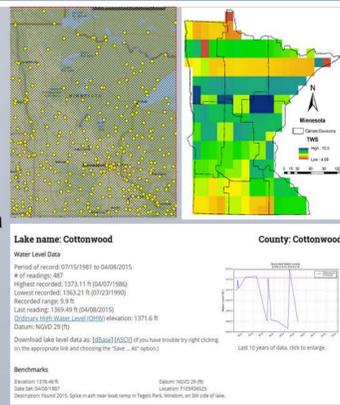Extracted from water frequency map

Lake Level Data
Daily reading on lake gauge

Meteorological Data
Monthly weather station data

Water Storage Data
GRACE mission were launched in March 2002 under the NASA earth system science pathfinder program

Methods

Cluster Analysis – k-means
➢ Lake level changing for the cases assigned to the same cluster tend to be more similar than those in different clusters.

Mann-Kendall Test
➢ Detecting the monotonic trends in time series hydro-climatic data.
➢ Kendall rank correlation coefficient is used to evaluate the relationship between two measure quantities.

Linear Regression
➢ Fitting a linear simple regression equation.
➢ Testing the statistical significance of the regression equation by the t-test
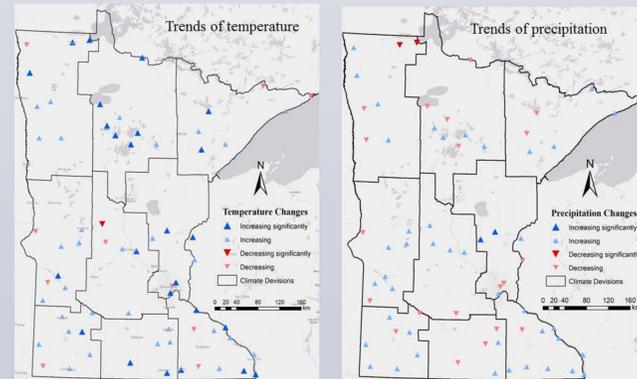
Datasets processing
➢ Meteorological data were collected from meteorological stations in Minnesota and calculated as monthly and yearly data.
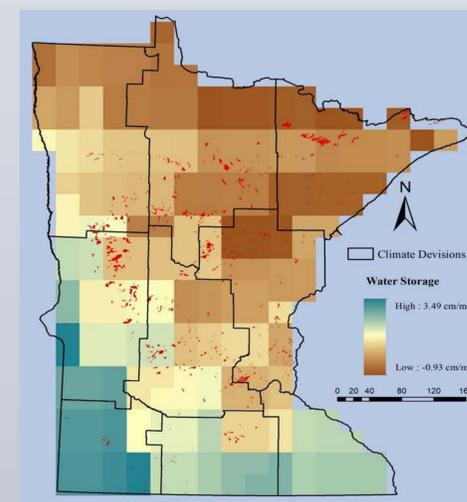➢ The lake area data were derived from water frequency map by using 1% as a threshold.
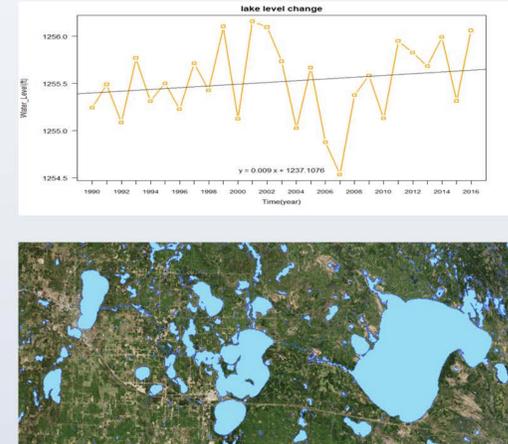
Results

1. Trends of climate change
➢ Temperature increased in most areas of Minnesota and some gauge stations showed significant increasing trend.
➢ Most of the south area experienced decreased precipitation.

3. Cluster analysis on water level change
➢ 233 examined lakes are divided into three clusters.
➢ Each lake level variation was calculate by averaging the water level variations for all lakes in the same cluster.
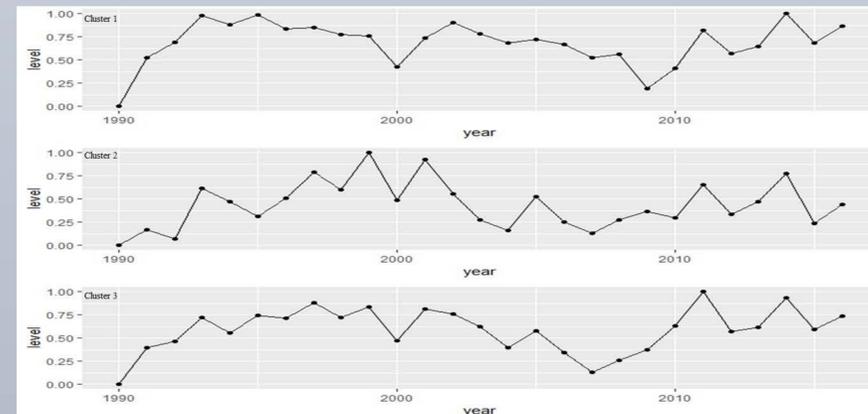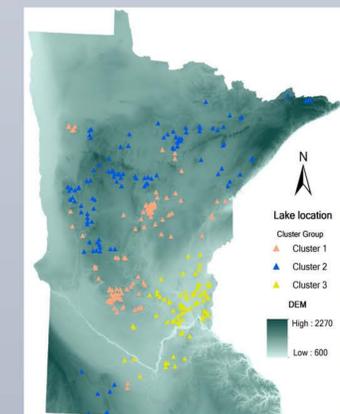

2. Water storage changes and lake-level variations
➢ Time-series of GRACE-observed mean water storage in 2009 over different cluster of lakes. The northeastern area experienced the decreased water storage.
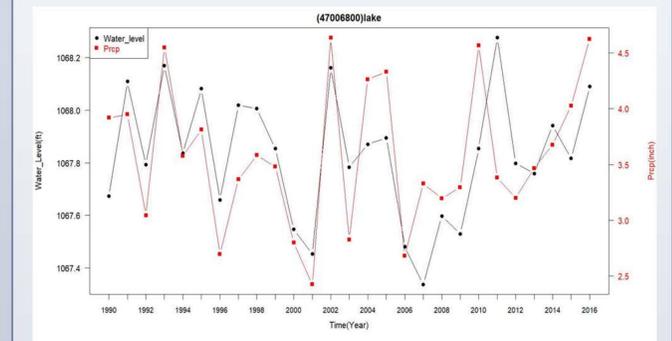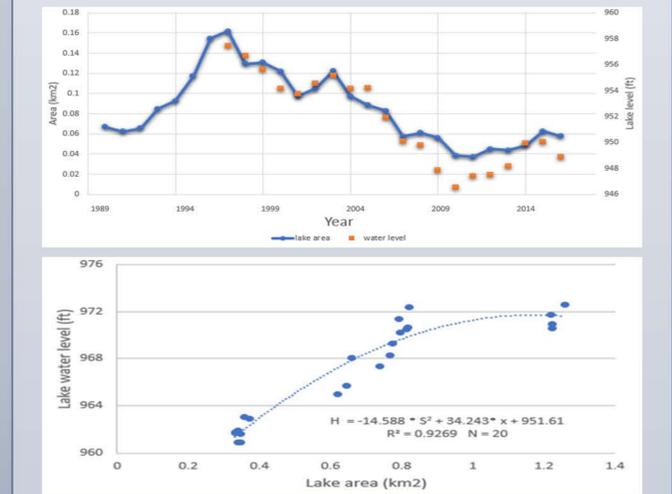

4. Relationship between lake level and precipitation
➢ Some lakes are sensitive to fluctuations in rainfall amounts.

5. Relationship between lake level and lake area
➢ The relationship between water level and lake area of Plaisted lake from 1990 to 2016.
➢ Correlation analysis of 20 data point pairs on lake level and lake area.

$H = -14.588 * S^2 + 34.243 * x + 951.61$
$R^2 = 0.9269$ N = 20

Conclusion

➢ Cluster analysis method based on lake level variation and the lake level changes are affected by geographic factors as well as geological materials. Thus not all lakes within one group are spatially clustering, with some lakes scattering-distributed.
➢ The abrupt lake-level changes were associated with change in climate conditions, especially under the high precipitation and low temperature.
➢ Considering the more climatic variables, for example evaporation, soil moisture, and glacier melting, and anthropogenic factors.

Reference

Zou, Z., Xiao, X., Dong, J., Qin, Y., Doughty, R. B., Menarguez, M. A., ... & Wang, J. (2018). Divergent trends of open-surface water body area in the contiguous United States from 1984 to 2016. *Proceedings of the National Academy of Sciences*, 201719275.

Save, H., Bettadpur, S., & Tapley, B. D. (2016). High-resolution CSR GRACE RL05 mascons. *Journal of Geophysical Research: Solid Earth*, 121(10), 7547-7569.