

How do large-scale climatic patterns influence lake sinkhole events?

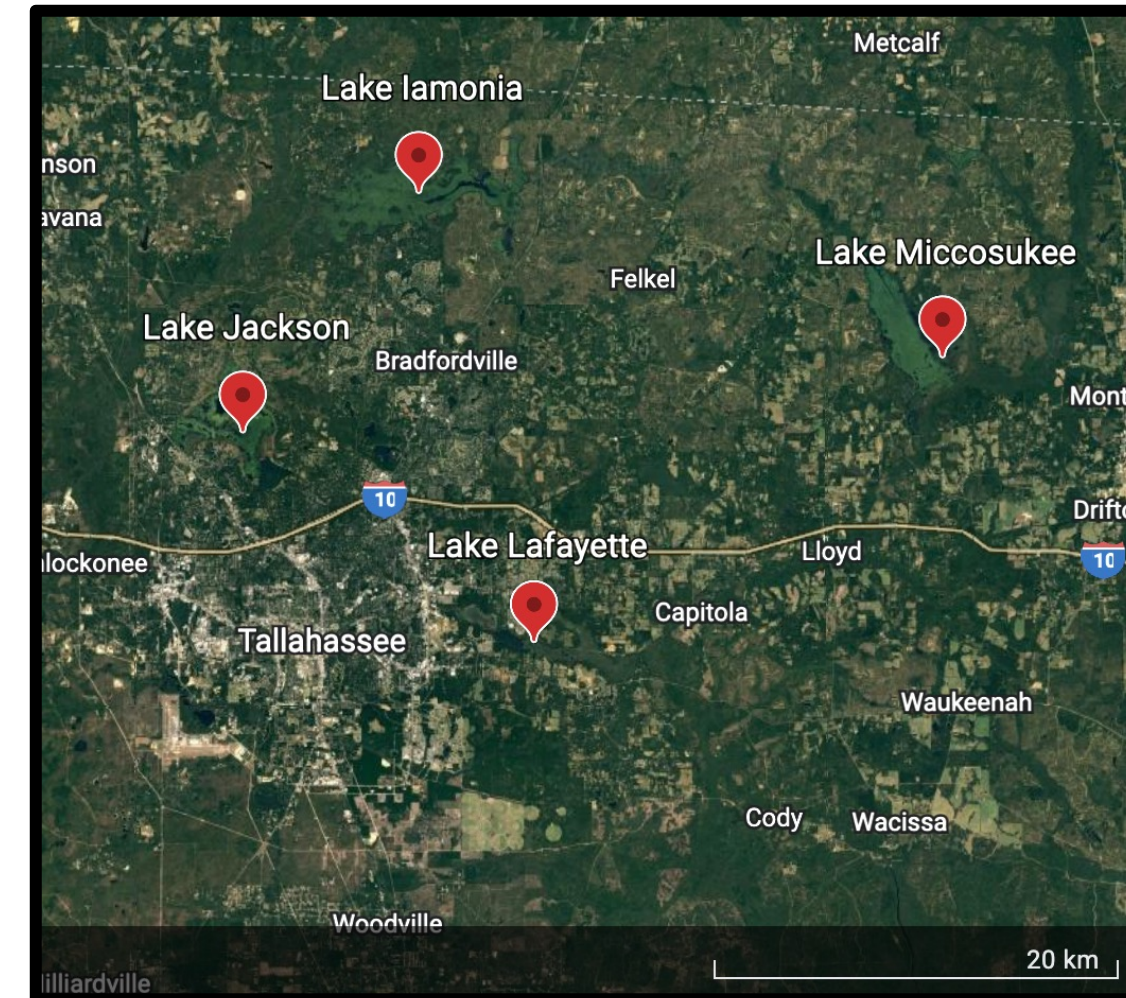
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Abstract

In Tallahassee and the surrounding region, lake “dry-down” events appear to be increasingly more common. These occur when a sinkhole opens beneath a body of water and drains it into the aquifer. In 2021, three of these events were reported: one occurring with Porter Sink opening twice under Lake Jackson in North Tallahassee, and another sinkhole forming beneath Gilbert Pond northeast of Tallahassee.



In the past, these have usually occurred every ten years or so, thus deeming three events in one year to be quite unusual. This apparent increase in frequency justifies further research into the cause of these events. In this project, we are investigating the correlation of large-scale climatic events (i.e., droughts and teleconnection cycles) on the opening of these sinkholes and their subsequent lake dry-down events. By comparing several monthly drought indexes as well as the monthly indexes for several teleconnection cycles on the months that sinkholes occurred, we hope to determine a correlation between the indexes and these events. In doing so, we may be more able to predict these occurrences using the current phase of a drought or teleconnection cycle.

Introduction

Tallahassee is a karst environment

- **Karst environment:** terrains with distinct geology and landforms consisting of caves, sinking streams, large spring, sinkholes, etc.

Sinkholes form when the water table sinks and forms an enclosed void space underneath the surface, which becomes unstable and collapses. When this occurs under a body of water, it causes a **dry-down event**, and drains the body of water

Any event that influences groundwater availability will likely influence sinkhole formation, such as teleconnection events or droughts

- **Teleconnection events:** a recurring large-scale atmospheric pressure and circulation pattern
- North Atlantic Oscillation (NAO) cycle, El Nino Southern Oscillation (ENSO) cycle, and Arctic Oscillation (AO) cycle

We will consider the indexes of these oscillation cycles and drought indexes to look for a correlation between these large-scale climatic factors and sinkhole events

Methods

Teleconnection Cycles considered

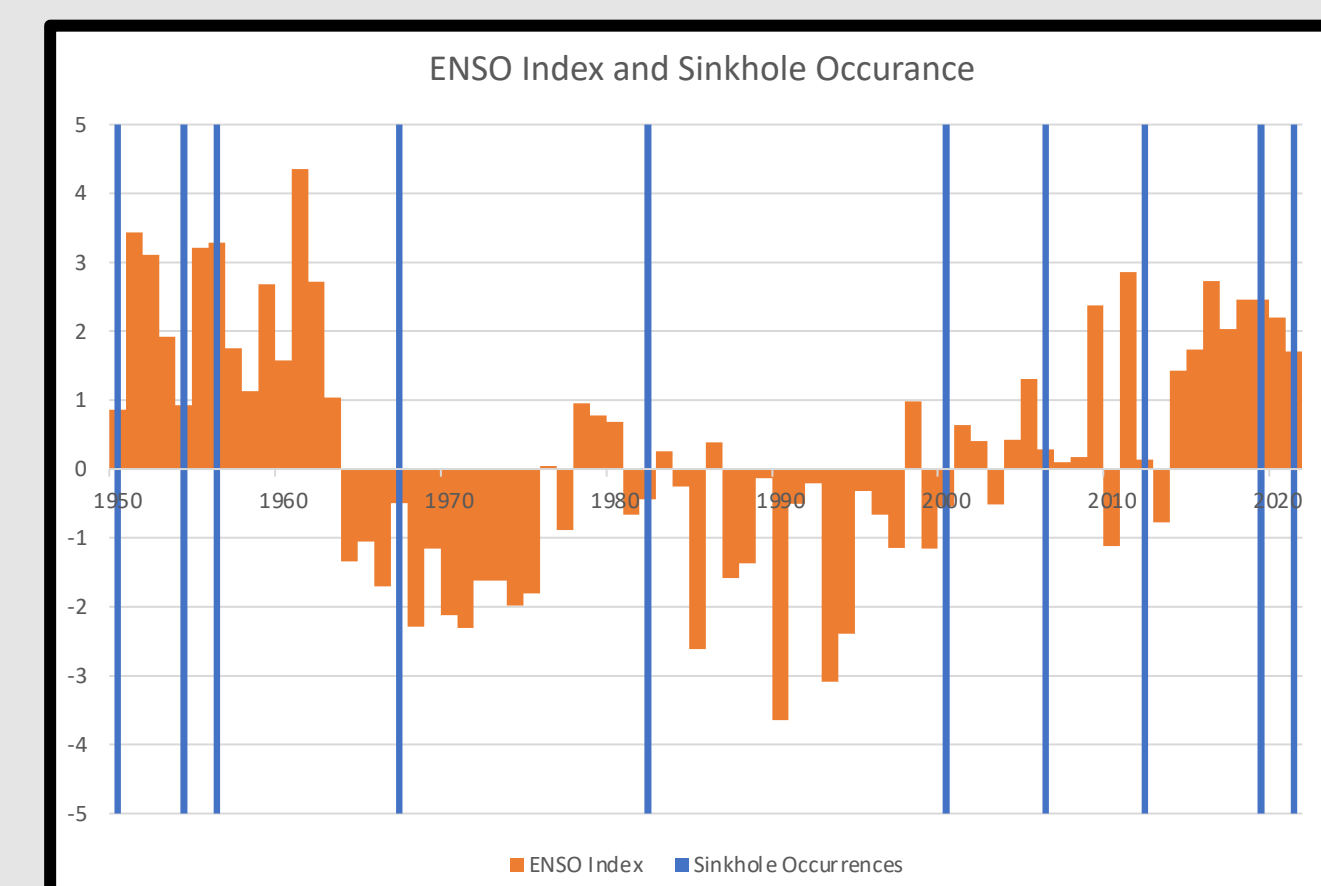
- NAO: has influence on air temperature, air pressure, and precipitation
- ENSO: has influence in air temperature, and precipitation
- AO: has influence on air temperature and air pressure

Drought indices considered

- Standard Precipitation Index (SPI): uses monthly sum values of precipitation from 1950 to 2021

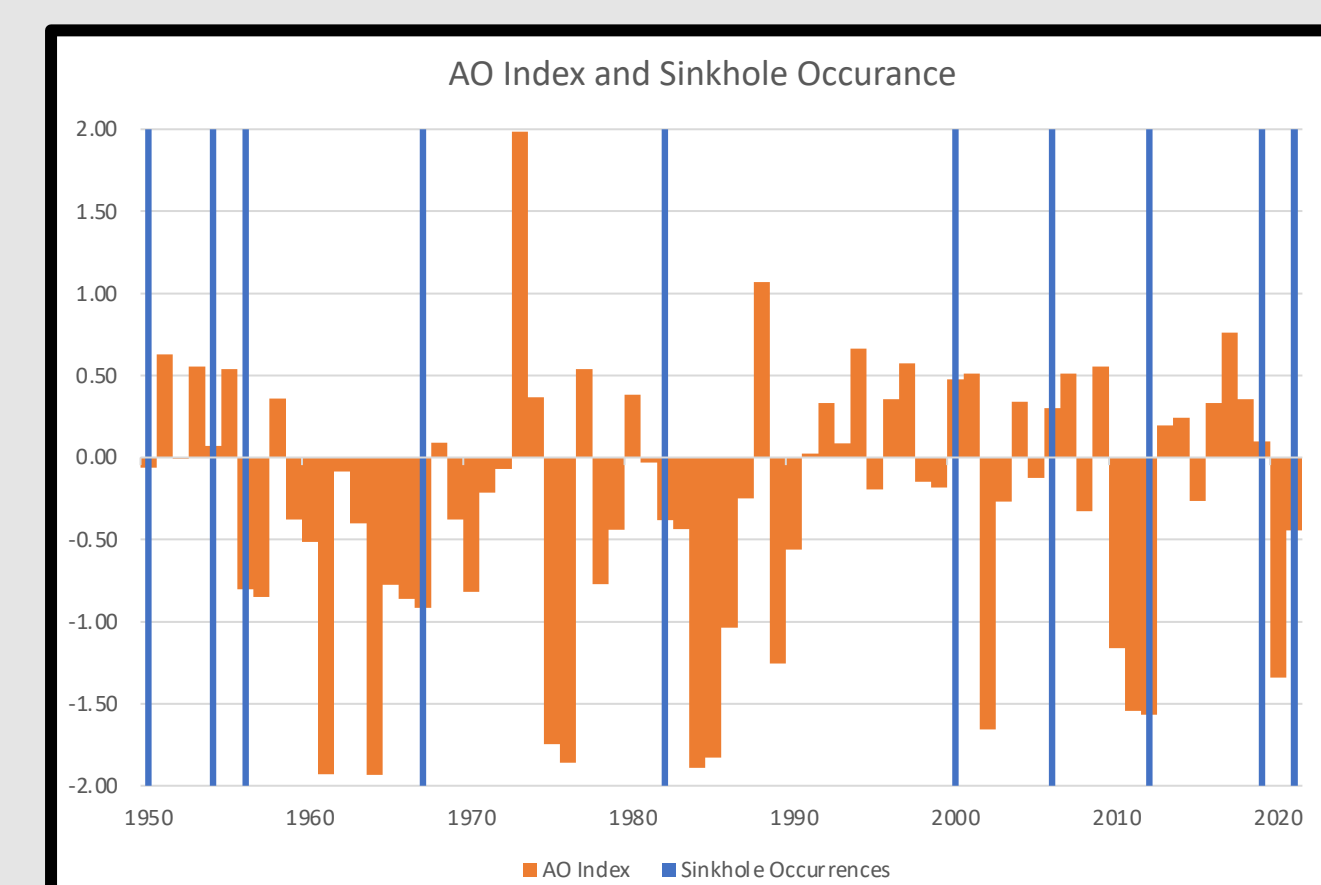
We found index values from all four of these variables for each month from 1950 to 2021 and compared those values to the months where sinkholes occurred.

Results



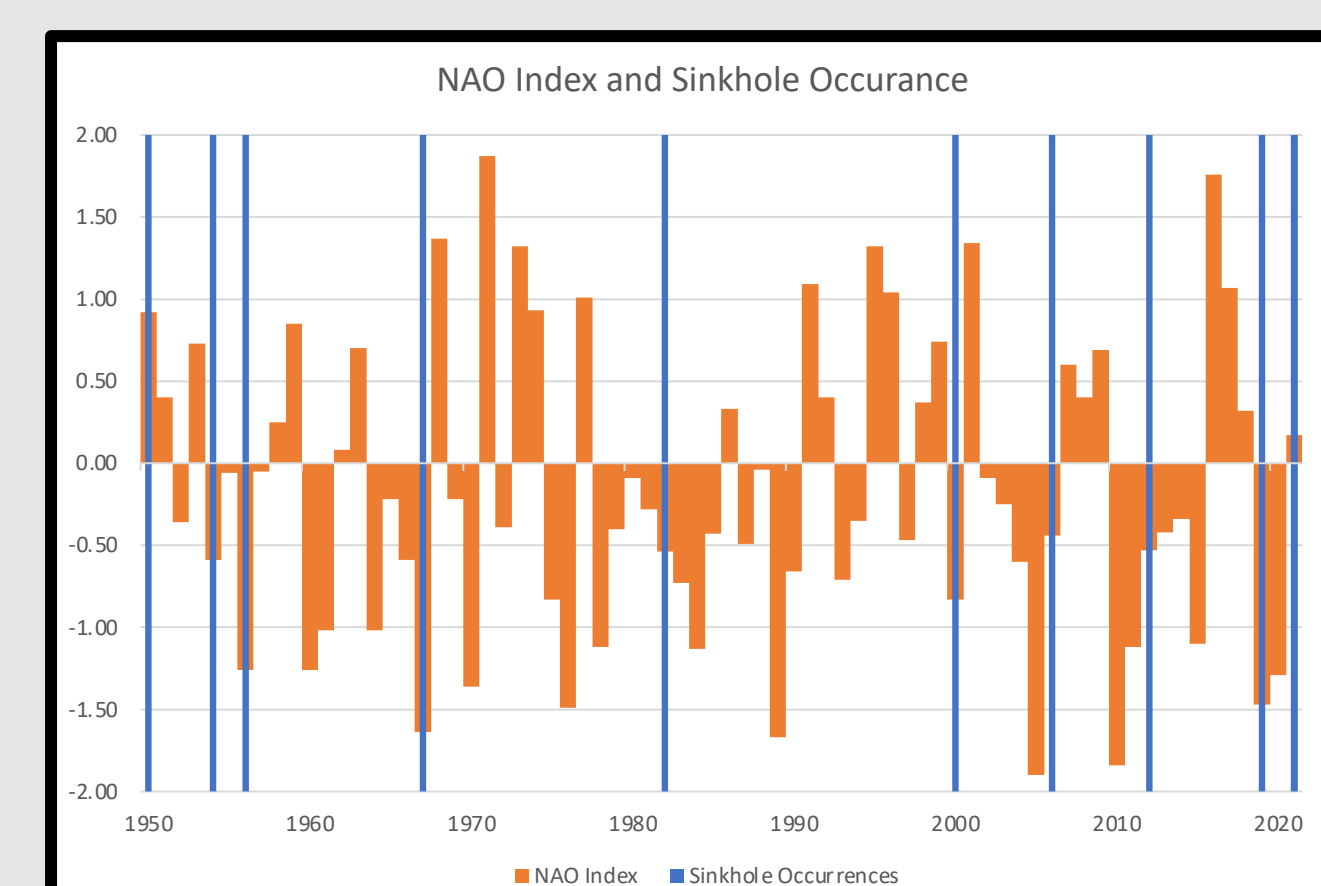
- Strongly positive ENSO index values = La Nina
- Strongly negative ENSO index values = El Nino

From this plot, it appears that lake sinkholes were more common during a **neutral phase** or in the **presence of a La Nina**. It should be noted that a sinkhole was never reported to have occurred when there was a strong El Nino present.



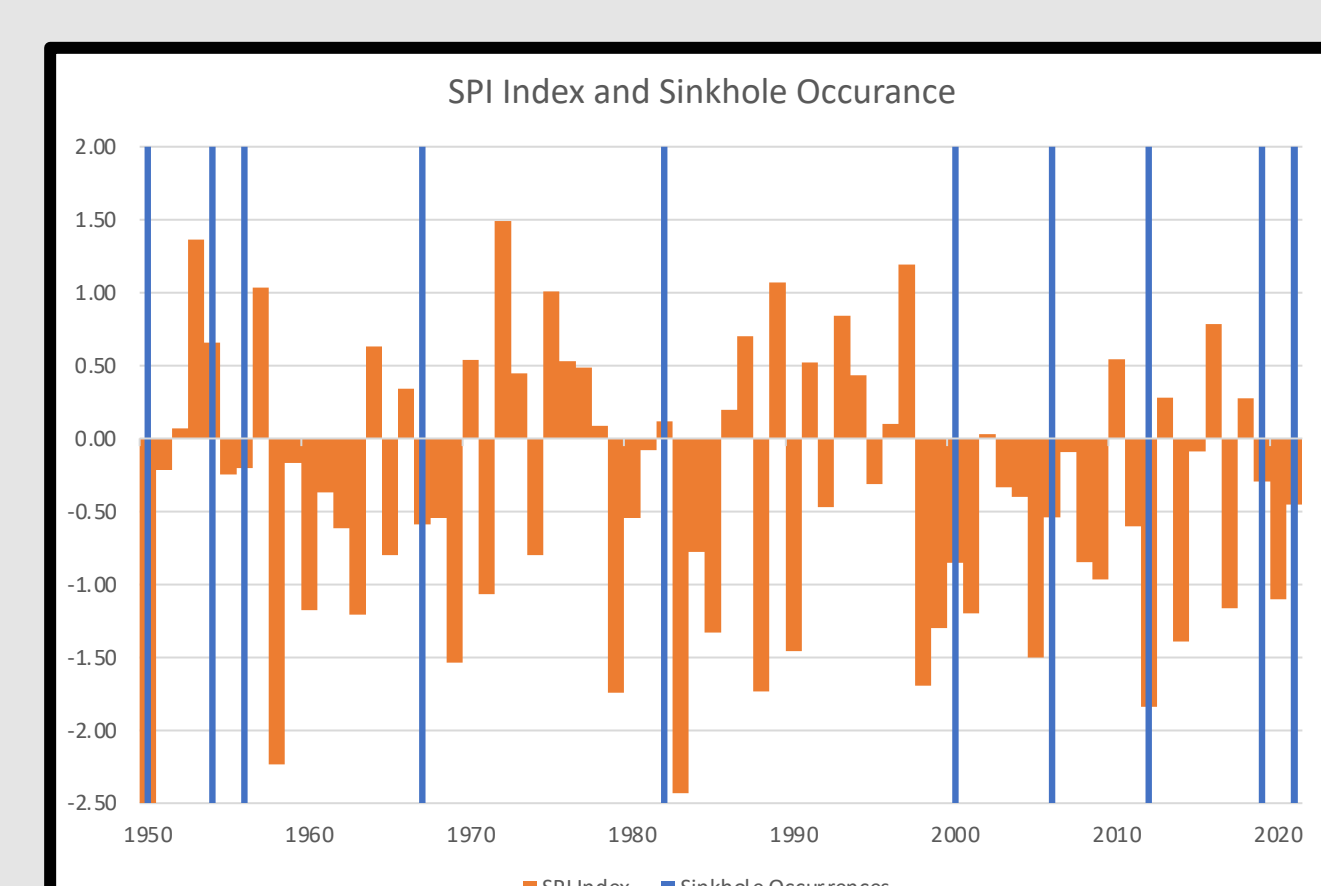
- Strongly positive AO index values = more frequent warm temperature extremes
- Strongly negative AO index values = stronger winter storms and colder-than-average temperatures

Lake sinkholes were much more common when the AO index value was **neutral** or **strongly negative**. Although, there have been some instances of sinkholes with a slightly positive AO value, such as the one in the year 2000.



- Strongly positive NAO index values = above normal temperatures and pressure, and decreased storminess
- Strongly negative NAO index values = below normal temperatures and more storm outbreaks

Most of the sinkhole occurrences seemed to coincide with **negative** index values. The only notable exception being the positive NAO value and sinkhole occurrence during the year 1950.



The SPI index uses monthly precipitation amounts to determine whether a wet (positive values) or dry (negative value) event is occurring. Based on this plot, most sinkhole occurred when the SPI value was strongly **negative** or **neutral**. However, there is a notable exception in 1954 where the SPI value was slightly positive.

Discussion

General correlation observed between index value and sinkhole occurrence between 1950 and 2021. The timing of sinkholes coincided with times of:

- Positive or neutral ENSO index values
- Negative or neutral AO, NAO, and SPI index values

Many of these neutral index values may provide further evidence for a correlation. Some of the sinkhole months where a neutral index value was reported, was preceded by strongly negative index values. Since sinkhole formation tends to lag lower amounts of precipitation, this lines up. A notable example of this occurs with the AO and NAO indexes in 2021, where a sinkhole formation occurs a little after a phase of strongly negative index values.

ENSO, AO, and NAO correlate these values with wetter conditions and/or colder-than-average temperatures. However, SPI correlates negative values with drought-like conditions. Which appears to be a contradiction. However, one would assume that a lack of precipitation is more likely to cause sinkholes, as correlated by the SPI, since sinkholes are generally caused by a lowered water table.

Further research should be done, possibly using different drought index values or different teleconnection indices, to determine if these results are conclusive.

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