A GEOSPATIAL ANALYSIS OF THE SUNSPOTS EFFECT ON GROUNDATER LEVELS IN LONG ISLAND, NY DURING 2002-2021

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Abstract

An Island as a landmass surrounded by water may be considered a more representative location to explore a possible association between groundwater level fluctuations and extra-terrestrial influences such as solar activity or gravitational tides. This research investigates the influence of solar activity such as sunspots number variation and its absolute change to groundwater levels at all USGS monitoring stations in Long Island, NY, between 2002 and 2021. Numerical and geospatial analysis has revealed a weak correlation between the raw data due to a low signal-to-noise ratio, but after applying a methodology to remove short-term variations the long-term time series show very high correlations. Interestingly, in the long-term time scale, stations located far from the coastline and far from regions where manufacturing job rates are at their peak show very strong correlation. We interpret this correlation as an interesting approach to distinguish three different regions of Long Island, NY at which factors may weigh each one differently to the water cycle. Therefore, long-term evaluations should consider a similar methodology to evaluate water sustainability.

Introduction

Worldwide, investigation of flood events has shown mostly a connection to human intervention or climate change. However, there is limited research on extra-terrestrial or exogenic influence of the sun to groundwater. Furthermore, it is likely to neglect the isolation of the exogenic factor to any water cycle assessment or endogenic factors evaluation. While the hydrological cycle depends on inputs, storage, transfers, and outputs, it also depends on the location and surrounding drainage basins and human usage. These dependencies may not be well interpreted within an island if an exogenic effect introduces noise to seasonal variations on the water table. Water sustainability in islands may be a serious concern, especially when industrial or commercial usage changes over a short time, such as close to highly populated cities (e.g., New York). In other locations, sunspots number seem to affect the groundwater levels, such as in the Yellow River in China (Wang and Zhao, 2012; Li et al., 2017). Moreover, removing the sunspots number effect may facilitate a better understanding of another factor such as a human factor on the groundwater resources.

Methodology

R programming language helped perform numerical modeling and spatial analysis to process the data. Sunspots number data were downloaded from the website (http://sidc.oma.be/silso/INFO/_sndtotcsv.php) using the *fread(link)* command in R from the

data.table package (Dowle & Srinivasan, 2021). Groundwater data were downloaded from 61 USGS monitoring stations and Long Island, NY website links and cleaned after developing an R script. The Long Island Index provided Demographic maps (Long Island's Changing Demographics; http://historiccensus.longislandindexmaps.org/?latlng=40.867798%2C72.858149&z=10&variable=PctMnfg&year=2010) to investigate regions of interest with a Pearson correlation. Time series decomposition facilitated the understanding of the association of the variables. Separation of the different signals on the data minimized interferences between the components of the time series with a methodology previously described (Zurbenko, 1986; Zurbenko & Sowizral, 1999; Tsakiri et al., 2014, 2018). This research presents the long-term component that expresses the fluctuations of a time series longer than a given threshold. A low-pass filter called KZ (Kolmogorov-Zurbenko) removed short-term variations from the variables of sunspots number and groundwater level. The time series were transformed into stationary time series prior to analysis. The following equation (1) describes the KZ filter applied for three iterations with a 365-day window m (where m=2k+1) for each time series X_t.

$$Y_t = \frac{1}{m}\sum_{j=-k}^{k} X_{t+j}$$

equation (1)

Absolute changes of the sunspot numbers were calculated by subtracting the previous day's value. A statistical association was explored between the groundwater and the sunspots number at each of the 61 USGS stations in Long Island, NY. The results were projected on the map to analyze the data spatially.

Results

Investigation of the correlation between the raw data of groundwater levels and sunspot numbers for each of the 61 USGS monitoring station has shown a very weak relationship. The KZ filter has been applied to the time series data to remove the short-term variations. The KZ filter provides the long-term time series, and reveals very strong correlations. A strong negative correlation between the groundwater levels and sunspot numbers in the long-term variables shows an inverse relationship between the variables across most of the monitoring stations on Long Island, NY (Fig. 1), with some exceptions. The exceptional locations indicate an opposite sunspots number effect on the groundwater and coincide with locations where there is an increased rate of employed Long Island residents in manufacturing jobs over the period of 1970-2010 (Fig. 2).

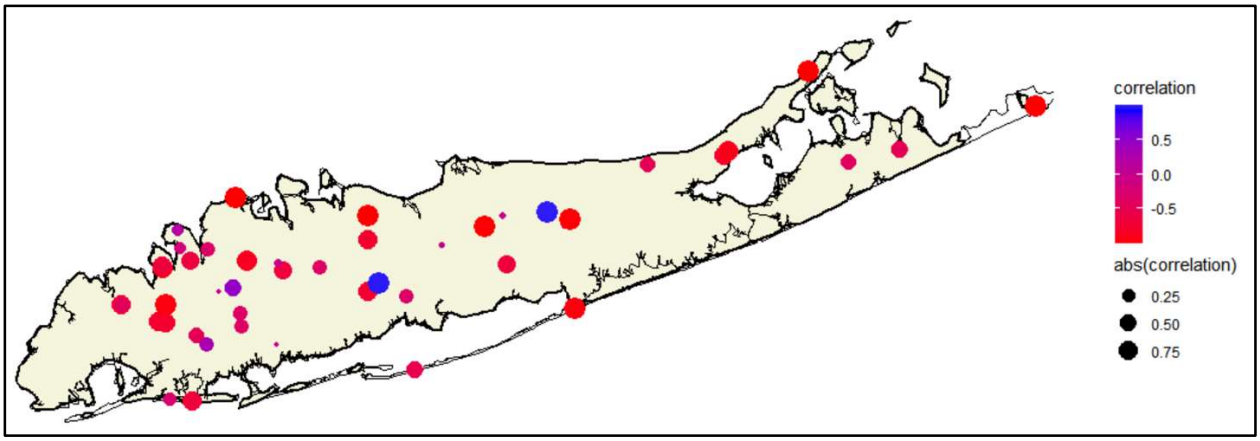

Figure 1: Long-term spatial representation of correlations between groundwater levels and sunspot numbers are projected at each USGS monitoring station in Long Island, New York for the duration of the last 20 years (2002-2021). A negative correlation is prominent by the red large solid circles across the island with exceptions at few locations with large blue solid circles.

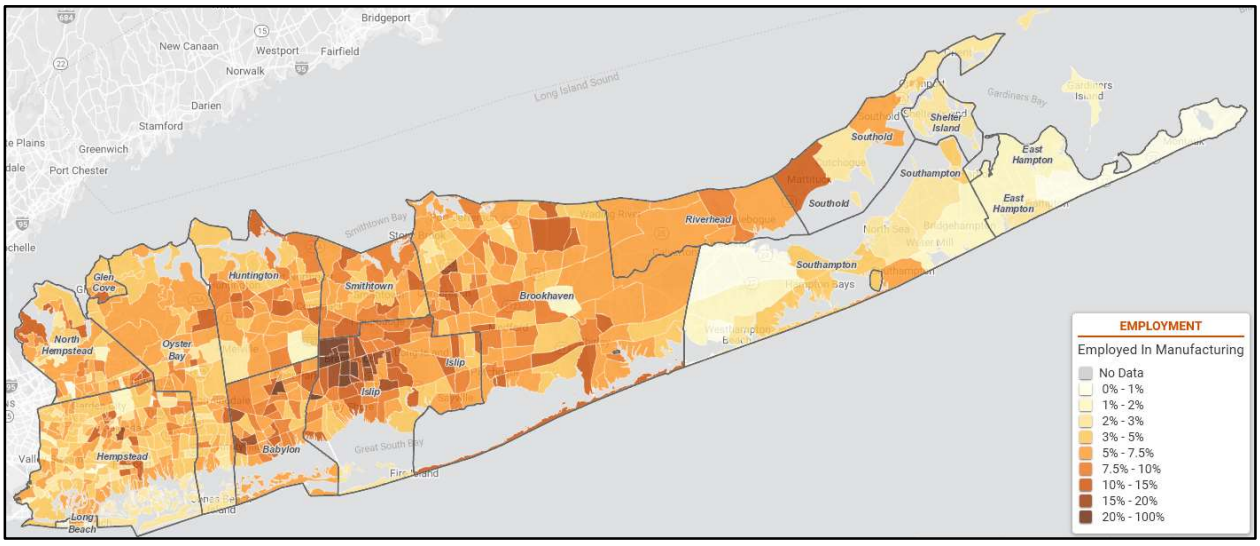

Figure 2: Long Island's demographic map showing employed Long Islanders in manufacturing jobs for the period of 1970-2010.

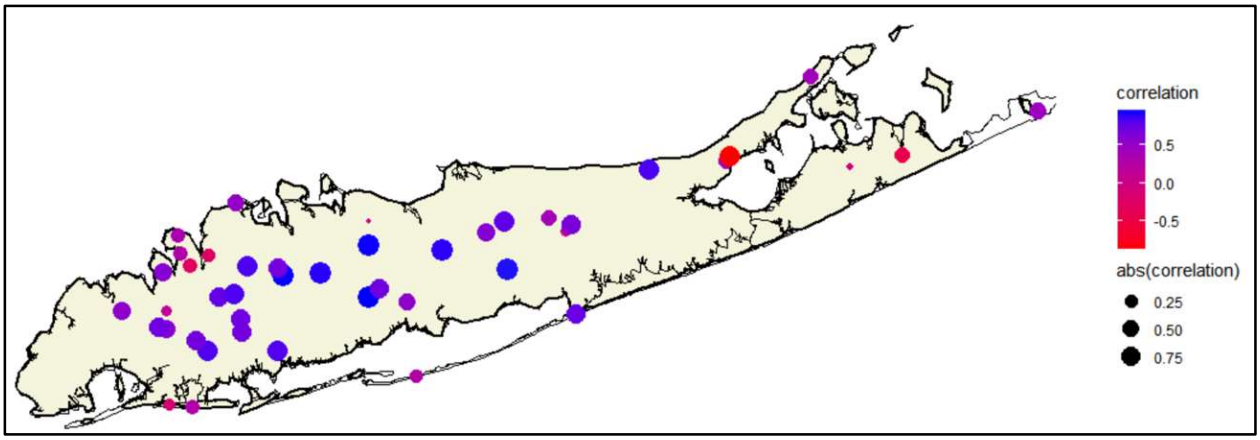

Figure 3: Long-term spatial representation of correlations between groundwater levels and sunspot numbers (absolute changes) are projected at each USGS monitoring station in Long Island, New York for the duration of the last 20 years (2002-2021). A positive correlation is prominent by the blue large solid circles across the island with exceptions at some locations with smaller red solid circles.

Absolute changes of the sunspots number seem to correlate positively with most of the stations providing groundwater levels time series, while there are some exceptional regions with moderate association and few with strong negative correlation (Fig. 3). The small cluster of strong positive correlations with changes in the sunspots number are prevailing located along the coastline of Long Island, NY.

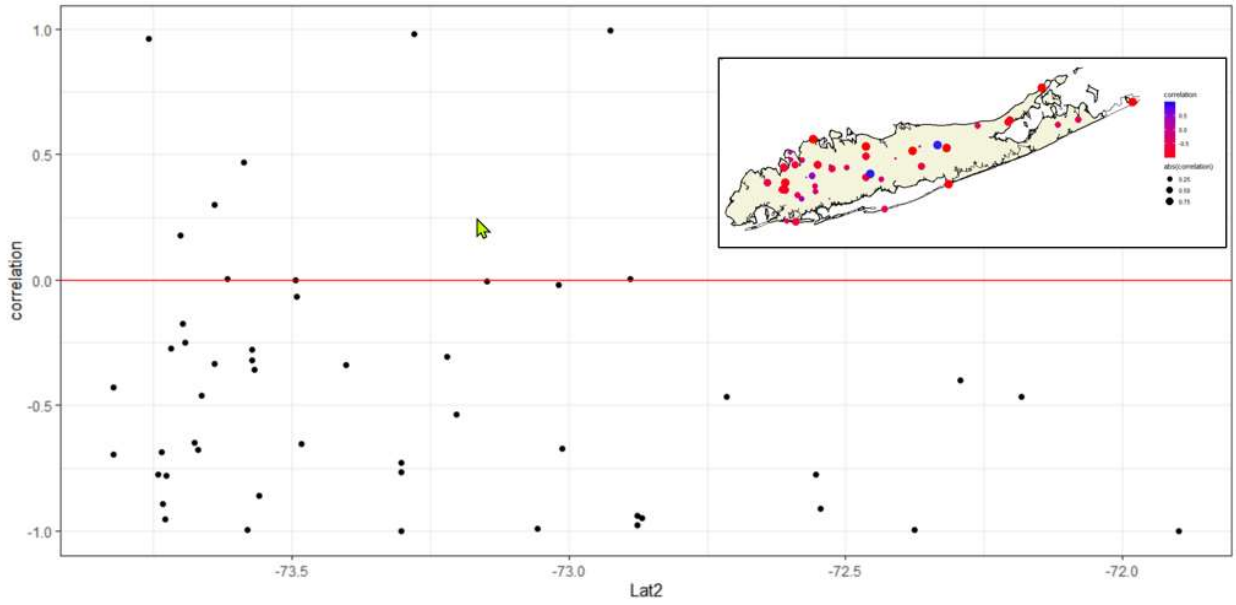

Figure 4: Latitudinal profile in the study area of the long-term negative correlation between sunspots numbers and groundwater from each USGS station located at Long Island, NY. X-axis is parallel to the direction from west (towards New York city; left side of graph) to the east (right side of graph).

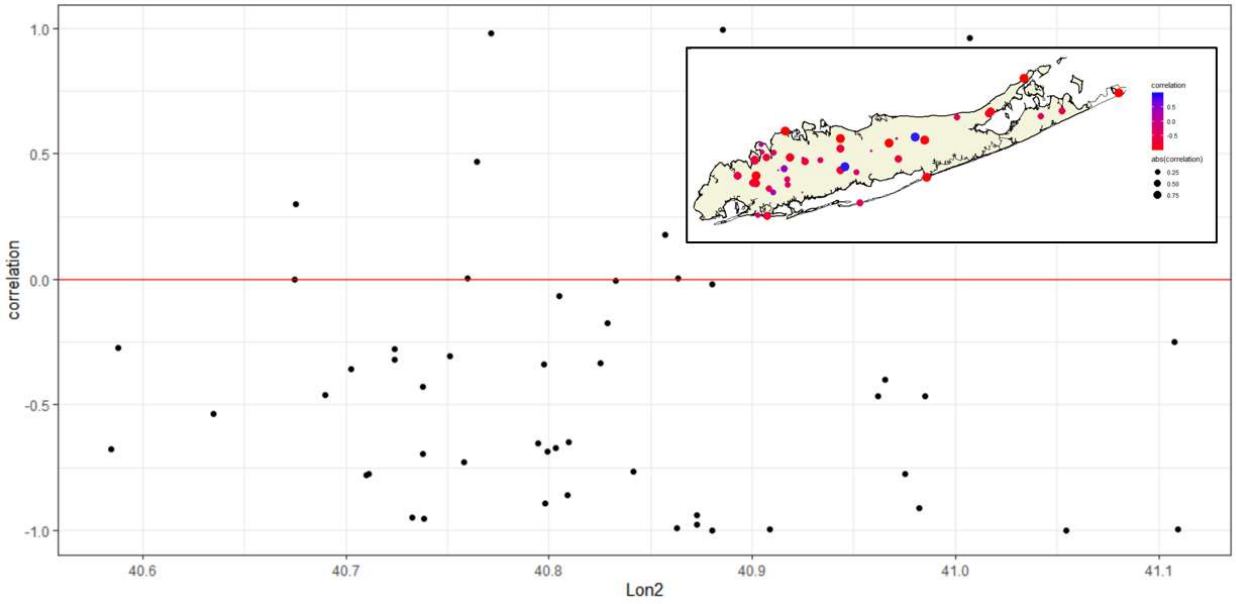

Figure 5: Longitudinal profile of the study area of the long-term negative correlation between sunspots numbers and groundwater from each USGS station located at Long Island, NY. X-axis is parallel to the direction from south (left side of graph) to the north (right side of graph).

Discussion

Long Island, NY, was selected as an appropriate location to investigate the relationship between groundwater levels fluctuations and solar activity. Long Island is a unique example of an island adjacent to a highly populated city such as New York City. New York City has an independent water network infrastructure from Long Island. However, many employees are commuters utilizing groundwater resources from the island. In addition, there are industrial operations in Long Island. A significant manufacturing job rate of increase is prominent in some areas of Long Island that coincide with the regions showing as outliers of the correlation between sunspot numbers and groundwater levels.

A human factor has always been significant to the water cycle. There is an evolving population distribution, land use, and industrial activity on various areas on Long Island over the last 50 years that has been noticed (Fig. 2). Those few exceptional opposite relationships occur where the human factor is more prominent such as regions with increasing manufacturing jobs (Fig. 2) over 1970-2010. In addition to those exceptional locations, coastline regions also show some exceptions with opposite or weaker relationships to the absolute changes of sunspots number. Consequently, we identify three different regions where various factors may weigh each region differently to the water cycle. Those factors identified by this geospatial statistical analysis include but are not limited to exogenic, endogenic, and human activity. This study suggests that a water sustainability assessment should consider all those factors, especially the exogenic factor that is often neglected. Long Island, NY, shows that water sustainability is a

significant concern. Therefore, long-term evaluations should consider a similar methodology to evaluate water sustainability.

Conclusions

The statistical analysis has effectively eliminated interferences that obscure the strong correlation between the sunspots number and groundwater levels fluctuations. The long-term association between the groundwater and the sunspots reveals a negative correlation between the variables. Sudden changes in the sunspots number positively correlate with the groundwater's long-term component of stations. This correlation is prominent to locations being far from the coastline of Long Island, NY, and far from regions influenced by industrial or related manufacturing operations. This correlation may imply that water cycle and water sustainability assessment should consider exogenic factors such as solar activity.

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