Final Project Submission – Faisal Adams

Analysis of Drought and Fire occurrences for the US West Coast

Background

For years, the Western United States have had issues meeting their water demands for their ever-growing population, agricultural needs and industries. This increased demand has been met by reduced supply, especially in California where droughts are persistent. Similarly, there have been increased incidences of fires that have devastated the entire West Coast. These fires lead to loss of lives and cause billions of dollars in damage while the smoke produced causes atmospheric pollution even in areas not in the path of the fires. recently as 2020. Among other factors, the availability of water to combat these fires, as well as in the surrounding soil may play a major role in the occurrence and persistence of these fires.

This report details an attempt to determine if any direct correlation exists between the two variables for the 3 states bordering the western Contiguous United States – Washington, Oregon and California.

Methods

Dataset

Fire incidence data was obtained from the Terra and Aqua Moderate Resolution Imaging Spectrometer (MODIS) fire products. This data is collected by satellites at 1-km pixel resolutions while the time and date of the fire incidence is also recorded. Data from 2005 to 2020 was obtained, iteratively, for each year. Relevant variables for this dataset were time, coordinates and brightness of the fire event.

Groundwater storage (GWS) was used as a drought indicator. The data for this was obtained from the Gravity Recovery and Climate Experiment (GRACE) Data Assimilation (DA) for Drought Monitor (DM), which provides groundwater data based on sophisticated models involving GRACE satellite data for the contiguous United States. The data has a spatial resolution of 0.125 ° x 0.125 ° and a temporal resolution of 7 days. The data was extracted using the Pydap module on OPeNDAP servers, and relevant variables such as coordinates, groundwater storage percentile, and time were stored in dictionaries.

Analyses

In both cases, polygons for each state, as well as a combined polygon representing the entire West Coast, were used to generate masks for coordinate values that fell within state boundaries. This refined dataset was added to a new dictionary, and the subsequent data saved to a file using the Pickle module. This action was performed for both datasets to reduce program run times and costs.

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Groundwater storage data was further processed by calculating the mean weekly GWS value for the study area and plotting it as a function of time to determine the presence of temporal dependencies. Spatial and temporal trends for the first 4 principal values were returned and observed.

In the case of the fire dataset, the percent change in fire occurrences since 2005 was obtained, and the results for that data were fit to regression models.

Finally, a count was performed of pixels possessing GWS values less than 95% at the end of 2015 and 2020. A KMeans cluster analysis was performed for fires in 2015 and 2020 using the pixel numbers to constrain the number of individual clusters.

All programming and analysis were performed on Python using JupyterLab.

Results and Discussion

In Figure 1 below, sample plots of the location and intensities of fire can be observed.

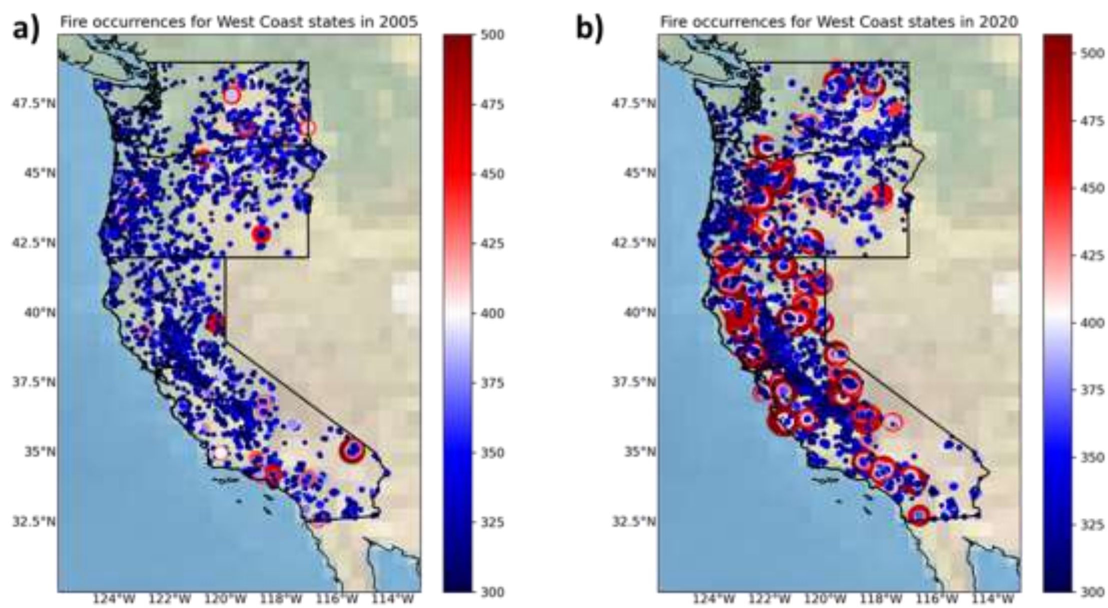

Figure 1. Total number of recorded fires for 2005 (a) and 2020 (b).

The size of the circles in Figure 1 correspond to the brightness of the fire as recorded in the MODIS dataset, and the red circles to aid in visual identification. By visual observation, there appears to be a stark difference between the number and intensity of fires occurring in 2005 (Figure 1a) compared to occurrences in 2020 (Figure 2b). This result is corroborated by the data in Figure 2 that shows a plot of the total annual fire incidence as a function of time.

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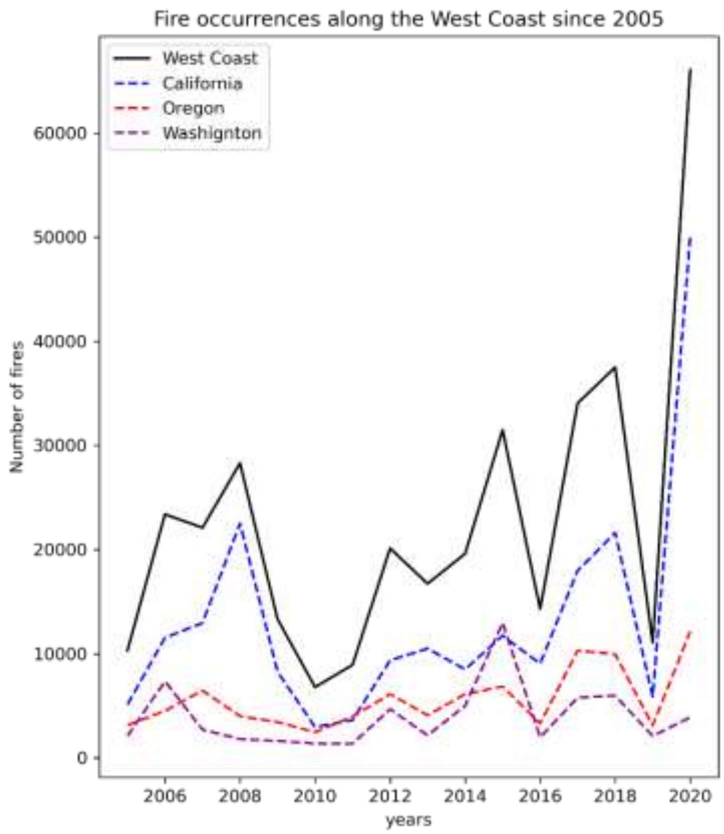

Figure 2. Total annual incidence of fires for the West Coast

Although there is no observed constant increase in the number of fires (Figure 2), there are highs that seem to supersede the values for previous years. This inference is confirmed in Figure 3 that looks at the percentage increase in fire occurrences.

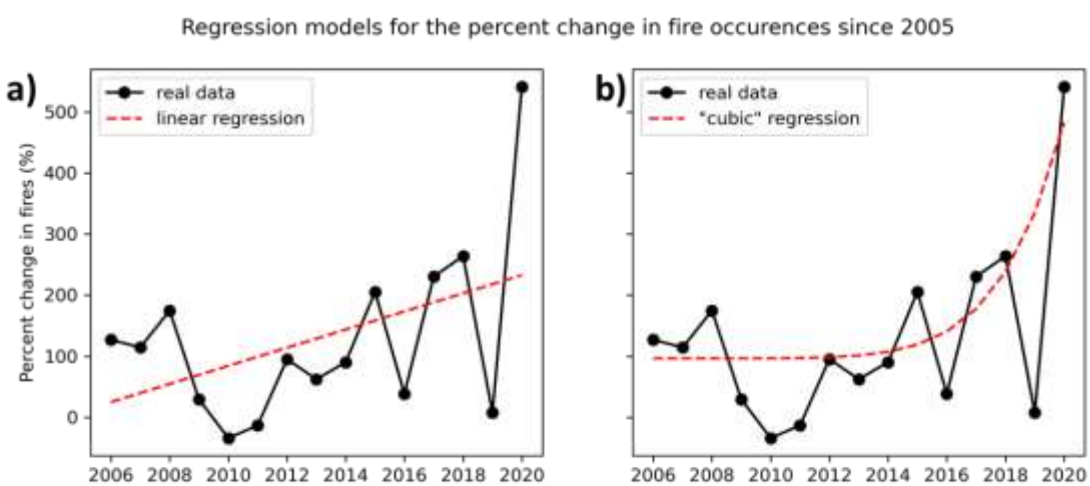

Figure 3. Percentage change in the number of fires for the entire West Coast since 2020 with (a) a linear regressing and (b) a polynomial regression.

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There is a marginal increase in fires by ≈20% in 2006 with higher values in 2008, 2015, 2017 and 2018 and periods of relatively lower occurrence from 2009 to 2014 (Figure 3). All these values are dwarfed, however, by a markedly sharp increase by over 500% in 2020. The linear regression model could not capture this exponential increase as well as the polynomial model could, although no predictions were made based on these fits. The reason being that any model here would imply that time is the factor controlling the rate of fires.

Groundwater storage data does not show a similar increase or decrease with time under various analyses, and an example plot is show in Figure 4 below.

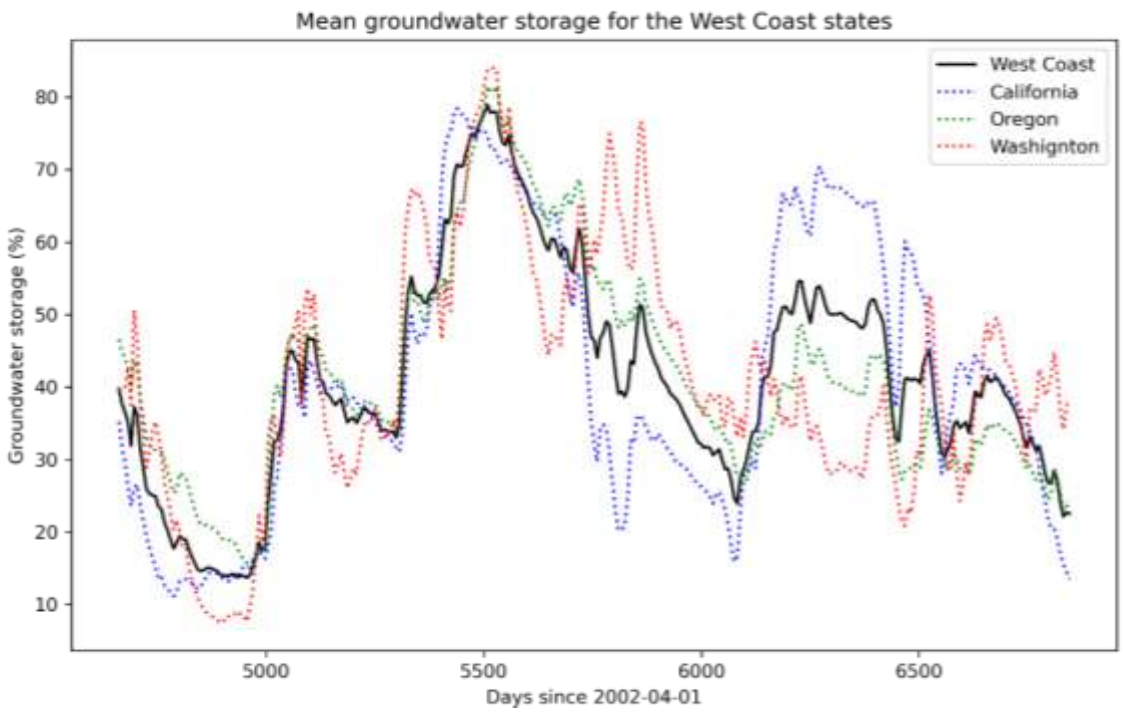

Figure 4. Weekly variation in groundwater storage for the entire West Coast from 2015 to 2020.

Spatial and temporal trends of the SVD showing the first four singular values are shown in Figure 5 below. There is no obvious uniform spatial trend of GWS for the entire West Coast although some localized variations are observed.

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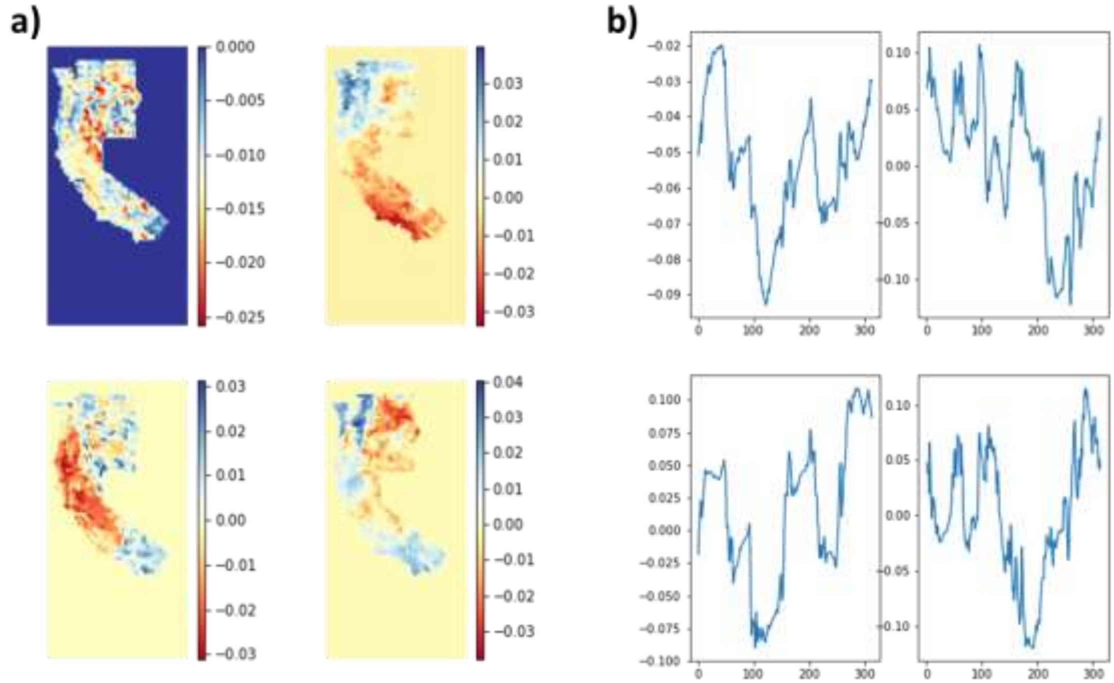

Figure 5.

Further analysis of the SVD data shows that it takes at least 100 singular values, out of 313, to recreate 90% of the data. By the 7th singular value, the temporal variation appears to exhibit a sinusoidal variation.

The spatial variation of the fires with respect to groundwater levels is explored in Figure 6 below.

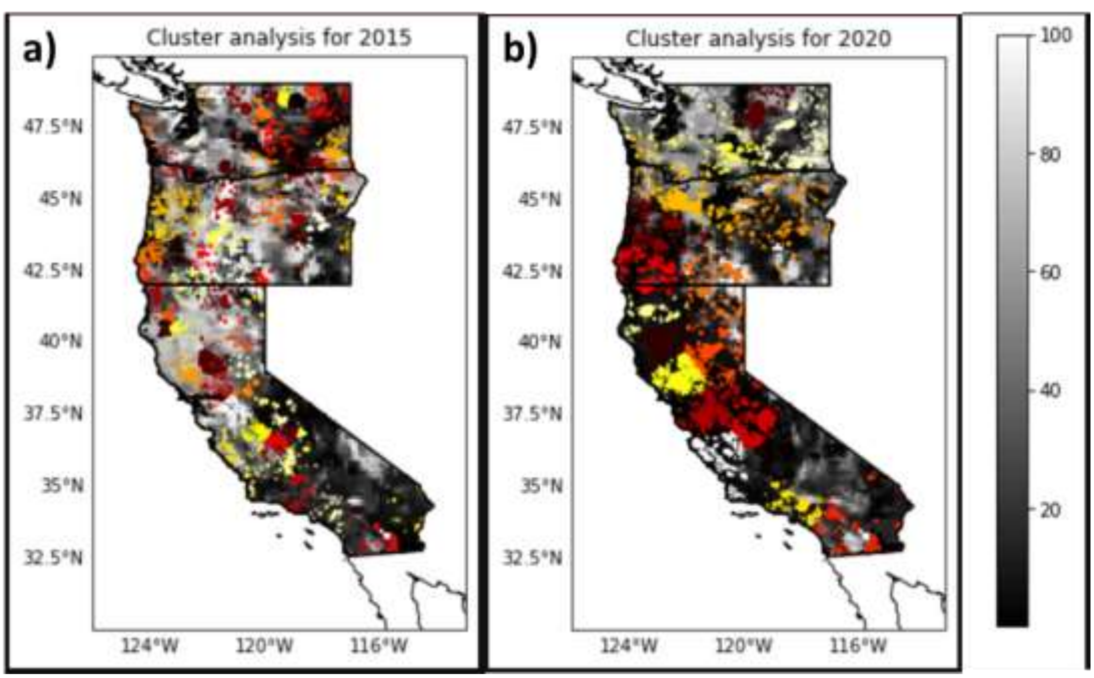

Figure 6. An overlay of cluster analysis and groundwater storage percentile for the West Coast in (a) 2015 and (b) 2020.

In 2015, there are relatively smaller clusters compared to 2020 (Figure 6). These clusters are smaller in size and seem to overlay smaller areas of low GWS values. Conversely, there are larger clusters in the image for 2020, and these clusters stretch along areas that also have larger sections of reduced GWS values. These results may imply a spatial correlation rather than a temporal or quantity correlation.

Conclusion

The prevalence of droughts and fires of the West Coast of the United States may indicate some relationship between the two disastrous events.

Although increased incidence of low GWS values seem to coincide with increased fire occurrences, the results of this report can only confirm that a spatial correlation seems to exist, with larger drought areas responsible for larger fire clusters. In other words, the extent of the drought seems to play a larger role than the intensity of the drought.

Understandably, only extremely arid areas with no vegetation (southeastern California for example) had prevalent low GWS values but no corresponding fire incidences.