Exploring how extreme weather events, natural disasters and climate change are reported in online news articles for countries with differing climate baselines

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Abstract

Online news article analysis has been a field of research that has been undergoing particular attention by the computer and data science disciplines. Research on extreme weather and natural disaster news coverage has been confined to new machine learning and natural language processing techniques to detect different categories, and events. This research has been lacking in analyzing the long term trends in online news articles as they relate to real world conditions. This study conducts a quantitative and qualitative analysis of news coverage about extreme weather events and natural disasters between two countries, Colombia and South Africa, with similar economic and development conditions but differing climate baselines. Overall this study finds that precipitation levels alone are not sufficient, and can be misleading, in identifying and understanding what and how extreme weather events and natural disasters occur. Instead a quantitative and qualitative analysis of the news coverage of such events provides a more nuanced and comprehensive timeline of these extreme weather events and natural disasters, for both high and low precipitation baseline climates.

Acknowledgements

Special thanks to my advisors Dr. Shelie Miller and Dr. Derek Van Berkel, without whom this work would not have been possible.

Introduction

Online news article analysis has been a field of research that has been undergoing particular attention by the computer and data science disciplines. Thus far research has been concentrated on developing different natural language processing (NLP) and machine learning methods to mine the content of news articles, classify articles and detect events (Kaur & Bajaj, 2016, Nugent et al., 2017). One such study focused on classifying news articles based on techniques such as keyword graphs, used previously with social networks, to identify and track stories and events in the news (Sayyadi et al., 2009). Another study developed more efficient and accurate event detection techniques based on "word embeddings" on top of term frequency-inverse document frequency (TF-IDF) and clustering methods (Hu et al., 2017). Other research in this field has been concentrated on analyzing real time social media coverage of climate hazards, for emergency preparedness and response systems (Wang et al., 2016) (Smith et al., 2017). These studies have been used to provide a real time assessment and evolution of natural disasters and extreme weather events. Climate change news analysis has been focused thus far on understanding the current landscape of climate change news coverage (Schafer & Painter, 2021), and exploring bias in reporting and polarization within news articles (Bolsen & Shapiro, 2018, Chinn et al., 2020).

Research in extreme weather and natural disaster news coverage has been confined to understanding how to detect different categories, and events, however has been lacking in analyzing the long term trends in online news articles as they relate to real world conditions. Additional research gaps exist when specifically trying to understand the relationship between climate change news coverage and news articles on extreme weather events, and natural disasters such as floods, storms and hurricanes.

This study analyzes what news coverage of natural disasters and extreme weather events can tell us about their effects and consequences and their relationship to climate change. In order to do this effectively we compare news coverage across two countries, Colombia and South Africa, specifically to contrast the differences in news coverage across environments with differing: baseline precipitation levels, frequency and severity of natural disasters (storms, floods, landslides), and climate change vulnerabilities. The goal of this study is to assess what news coverage can tell us about natural disasters and extreme weather events and to identify if it is reflective of real conditions. We will do this by assessing the following questions: (1) Does news about extreme weather events and natural disasters follow the same trends as real precipitation conditions? (2) What can news coverage on extreme weather and natural disasters tell us about heavy precipitation events? (3) How does climate change news relate to real precipitation conditions, and news articles about extreme weather events and natural disasters?

Systematic Comparison of Colombia and South Africa

Media and news coverage on climate change has been found to be a function of economic factors and the views of specific stakeholders such as political and advocacy groups (Brulle et al., 2012). Key national and international political events and conferences have been shown to fluctuate climate change news coverage and establish new baseline levels of news article frequencies (Holt & Barkemeyer, 2012, Stoddart et al., 2016). This study minimizes the effects of non-environmental

factors in news coverage by comparing two countries, Colombia and South Africa, that have similar socioeconomic and developmental statuses, and have similar international relationships. The main differences between Colombia and South Africa are focused around their: baseline precipitation levels, frequency and severity of natural disasters (storms, floods, landslides), and climate change vulnerabilities (The World Bank Group, 2021).

Economy

Colombia and South Africa are economically similar countries, with Gross National Incomes (GNI) per capita of $5,790 and $6,010, respectively, both are categorized as upper middle income. Both economies have similar sectoral compositions characterized by Services, Industry and Manufacturing (in decreasing order by percentage of GDP) with the Agricultural sector making up the smallest percentage of their GDPs (World Bank Data, 2020). While South Africa's trading partners are more evenly dispersed than Colombia's, with its top five trading partners representing 36.57% of its exports compared to Colombia's 57.24% (43.97% and 63.69% of their imports, respectively), both countries rely heavily on the US and China as trading partners (World Integrated Trade Solution, 2020).

Development

The UN defines Colombia and South Africa as "Developing Economies" (Economic Analysis and Policy Division - UN DESA EAPD, 2021), being further categorized in the high development category with Human Development Index (HDI) scores of 0.767 and 0.709, respectively. From 1990 to 2019 Colombia saw a 27.2% increase in its HDI score while South Africa saw an increase of 13.1%. Between the two, while only Colombia was found to have an above average HDI score for countries in the high development category, both countries were found to have above average HDI scores amongst countries within their respective regions: Latin America and the Caribbean and Sub-Saharan Africa (UNDP, 2020). Similar trends were found when breaking HDI by gender and inequity through the Gender Development Index (GDI) and Inequality-adjusted HDI.

Weather, Baseline Climate and Vulnerabilities

Colombia's country level average temperature, and average precipitation are 24.8 degrees celsius and 2,627.9 mm, respectively. However, there is great variability across the nation which can divided into three main categories/zones: high elevation cold zones (above 2000 m elevation, 15 degrees celsius average temperature), temperate zones (1000-2000 m elevation, 18 degrees celsius average temperature) and tropical zones (below 1000 m elevation, 25 degrees celsius average temperature). This climate variability is similarly reflected in Colombia's precipitation levels ranging from 6 mm to 7000 mm per year in the West Pacific and Andean regions to less than 500 mm per year in the north and south west regions (The World Bank Group, 2021).

Colombia's major climate vulnerabilities are caused by the El Niño and La Niña phenomena and have been exacerbated by climate change, both in terms of frequency and severity (Velasquez, 2016). El Niño causes droughts and increases the risk of underground fires (Field Museum, 2019) especially as it gets coupled with projected increases in temperature for the region. La Niña on the other hand

brings cooler weather and heavy rainfall, which is predicted to increase due to climate change (Karmalkar et al., 2012). These high precipitation events and climate change trends are predicted to cause further riverines floods, coastal floods and landslides classified at a high hazard level for the next 10 years (ThinkHazard!, 2020).

South Africa's country level average temperature and average precipitation are 18.3 degrees celsius and 456 mm, respectively (Department of Environmental Affairs, 2018). An estimated 50% of the country, majorly in the northwestern region, is classified as arid or semi-arid ("Review of Current and Planned Adaptation Action. South Africa," 2011), with the rest being classified as sub-humid and wet in the east. The South African landscape is characterized by its water scarcity as it has high levels of evaporation and near absence of surface water. Future rainfall trends and predictions suggest a decline in the number of rain days and an increase in intensity of rainfall events, divided by long dry spells in between (Perine & Keuck, 2018). These increasingly frequent high precipitation events will increase the risk of riverbank overflowing and flash floods (The World Bank Group, 2021).

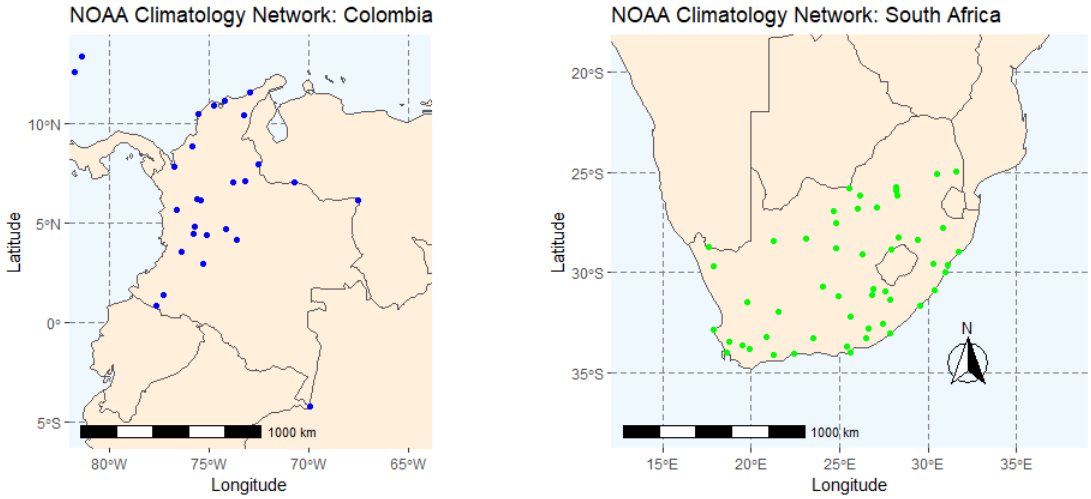
Colombia and South Africa are impacted by high precipitation and extreme weather events that are projected to increase in frequency and intensity, and will be exacerbated by climate change. While both countries have cyclical dryer and rainy seasons, historically, Colombia has higher and more sustained precipitation levels throughout the year. At the same time Colombia does suffer from droughts and desert like conditions. Colombia and South Africa's different climate conditions, frequency and severity of extreme weather events and natural disasters, provides an interesting lens by which to analyze how these environmental factors affect and highlight the relationship between real life conditions, and news coverage on climate change and extreme weather events.

Methods and Data

Weather Data

The Global Historical Climatology Network by NOAA (*NOAA Climate Data Online*, n.d.)was used to get daily precipitation data, reported in millimeters, for each country. It has over 100,000 weather stations across the world, with Colombia having 27 (Appendix Table 9), and South Africa having 52 weather stations (Appendix Table 10), shown in Figure 1. Monthly precipitation totals were calculated for each country by summing together all the precipitation measurements from all weather stations in each country by month.

Figure 1: Maps of Colombia and South Africa identifying where NOAA stations are located



News Data

The Global Database of Events, Language and Tone (GDELT, n.d.) project was created by Google to monitor different news media (broadcast, print and web) globally. It allows for a full search across news articles' main text allowing for keyword matches. The database allows customizable searches using news articles text based on exact keyword matches. For example a keyword search looking for exact matches to "rain" AND "weather" would be formatted as ""rain" "weather"", the same query that accepts partial and exact matches would be formatted as "rain weather". A keyword search that was looking for articles that included at least one of two terms would be formatted as "(rain OR weather)".

GDELT's dataset includes articles written in over 100 different languages. However, keyword searches can be conducted in English, as articles are translated using Google Translate. This was not an issue for South African news articles, however a vast majority of Colombian news articles were translated from Spanish to English. Google Translate was assessed to have over 90% accuracy in one study (Khoong et al., 2019) with errors occurring due to grammar issues, and 91% accuracy in another (Jackson et al., 2019). Since keywords were used instead of phrases to search through news articles the Google Translate function was sufficient for this study. GDELT will return daily counts for all articles matching keyword searches and counts of all "monitored", or collected, articles (for comparison and normalization) in the database on a given day. Additionally these searches return 75 of the most relevant news articles with their titles and links to their content. Some of these articles have "dead" links that point to error pages when their content is replaced as publishers either stopped hosting an article or replaced it. This was not an issue for our study as this represented a minority of news article results.

News (GDELT) Data Collection and Processing

A series of keyword searches were conducted on the GDELT database in order to understand news articles trends in both Colombia and South Africa from 01/01/2017 to 12/31/2020. The following keyword searches were conducted with either “Colombia” or “South Africa” as an exact match term at the beginning, depending on which country’s news was being analyzed: “(storm or storms)”, “(flood OR floods OR flooding OR floodings)”, “(hurricane OR hurricanes)”, “("climate change" OR "global warming")”. An example of a complete keyword search for Colombia would be “Colombia (storm OR storms)”. These keyword searches returned counts of all matching articles and “all monitored” articles in the GDELT database, at a daily resolution.

In order to ensure an appropriate comparison between the two countries, we normalized the news article counts by dividing the monthly counts for each keyword search by a series of different normalization factors. These normalizations were then inspected to test which would be most appropriate for our raw news article counts. The following normalization factors were used: total monitored counts across all of GDELT, all articles published by each country that spoke about each country (achieved by keyword searching “Colombia”, “South Africa”), and an estimate for all articles published on a given day by a given country (achieved by keyword searching for a series of stop words “(the OR is OR a OR and OR but)”). Time series were constructed for each country showing the monthly counts for news, and the normalized monthly news article counts, and total precipitation.

Normalized peak months were generously defined and identified as a period, of at least two months, of continuous increase followed by a subsequent period, of at least two month, of continuous decrease. Keyword searches were run on GDELT for all peak months and summaries were developed based on the titles and content of the 75 most relevant articles that were returned by the GDELT database.

To understand the general trends and differences between the news articles and real precipitation measurements for both countries, the total (or sum), mean and coefficient of variation (standard deviation / mean) were calculated for the precipitation time series and for each news query. The coefficient of variation, also known as the relative standard deviation, was specifically calculated because it highlights the relative variability around a mean or baseline. This allows us to compare variability amongst different groups, such as different news queries across different countries, that might have different baselines or magnitudes. For Colombia and South Africa the correlation of the news queries against their precipitations was calculated. To further explore if news articles were anticipatory or reactive to precipitation the news article time series were shifted forward and backward by one to three months and correlations for the shifted time series against the precipitation data were calculated.

Results

Table 1, confirms that Colombia and South Africa both have cyclical precipitation patterns, seen by their similar coefficients of variation, 0.48 and 0.52, respectively. Both countries have similar levels of variability relative to their mean or baseline precipitation. Table 1 further confirms that Colombia

has received greater total precipitation, 5900 mm versus 4254 mm, and has a higher mean or baseline level of precipitation, 120 mm versus 70 mm, from 2017 to 2020 than South Africa.

Table 1. Summary of precipitation statistics for Colombia and South Africa

	Colombia	**South Africa**
Total (mm)	5900.22	4254.53
Mean (mm)	120.41	70.91
Coefficient of Variation	0.48	0.52

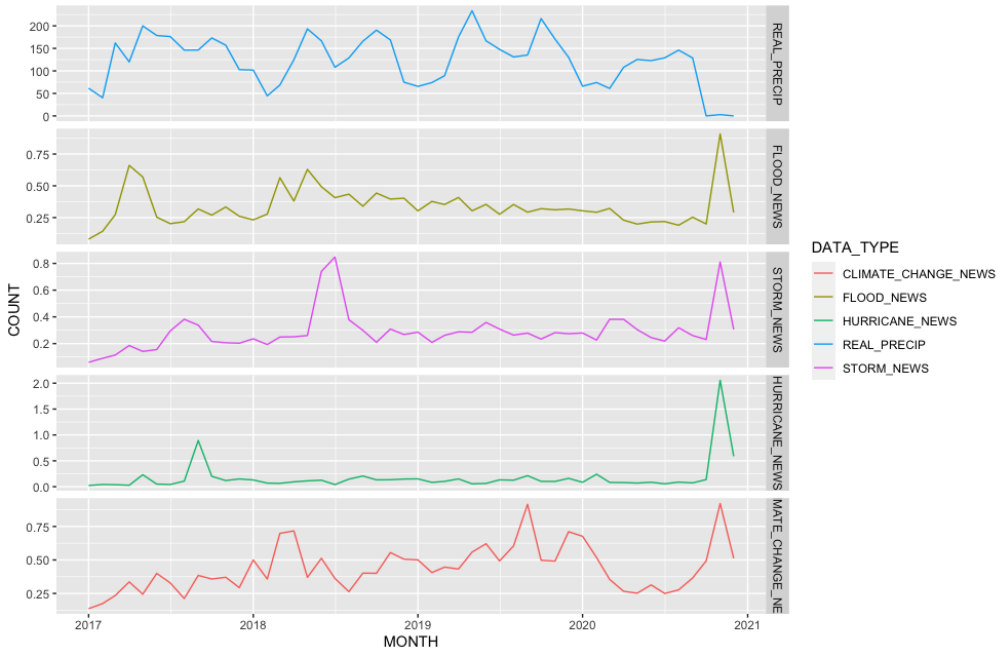
We find that climate change and storm news is reported similarly for both countries as their totals (as percentage of all news coming from each country), means (as percentage of all news coming from each country) and coefficients of variation are fairly similar to one another (Table 2). Flood news is shown to be reported differently because while both countries report about floods in the news at a relatively similar rate (similar totals and means), Colombia's news coverage on flooding is almost two times more variable, with a coefficient of variation of 0.710 versus 0.497, that South Africa's. News coverage about Hurricanes is shown to be most different between the two countries. Colombia reports more on hurricanes than South Africa. Hurricane news takes up three times more of Colombia's total and mean news coverage, 0.126% and 0.003%, than South Africa's total, 0.034% and mean, 0.001%. Further, Colombia's hurricane news coverage is almost twice as variable (coefficient of variation equal to 1.478), as South Africa's (coefficient of variation equal to 0.888).

Table 2. Summary of news article statistics for Colombia and South Africa

	Climate Change		**Flood News**		**Hurricane News**		**Storm News**	
	Colombia	**South Africa**	**Colombia**	**South Africa**	**Colombia**	**South Africa**	**Colombia**	**South Africa**
Mean (% of all articles)	0.007	0.007	0.006	0.004	0.003	0.001	0.005	0.006
Total (% of all articles)	0.342	0.441	0.285	0.259	0.126	0.034	0.225	0.387
Coefficient of Variation	0.409	0.328	0.710	0.497	1.478	0.888	0.550	0.472

The raw precipitation data and news article data normalized by all published articles for a given country are shown in Figures 2a and 2b. Graphs depicting the time series for each country under different normalization factors can be found in Appendix Figures 1 to 6, which show similar trends to Figures 2a and 2b, indicating that the type of normalization factor does not greatly impact results.

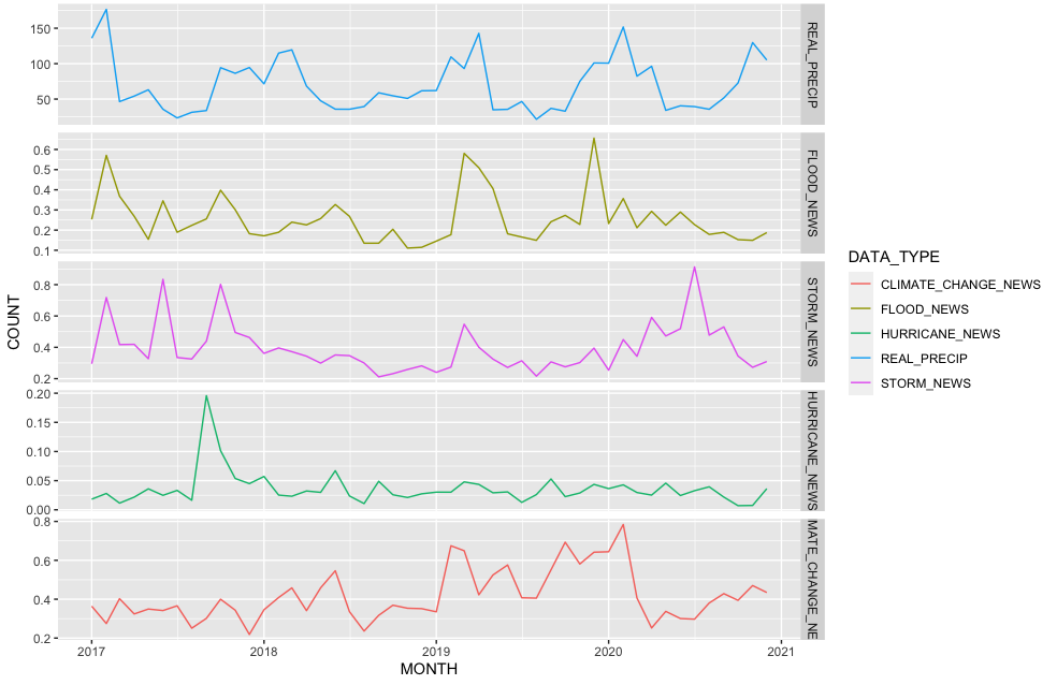
Figure 2a. Colombia Precipitation (mm) and News normalized (% of daily volume) against all articles published on a given day



There were significant peaks of online news in Colombia addressing floods, hurricanes and storms, in 2017, 2018 and 2020. Appendix tables 1 through 3 show monthly summaries of Colombian news articles for each of these GDELT news queries. In April 2017 a state of emergency was declared due to major floods and landslides that killed 314. In May 2017 news articles first warned about tropical storms having the potential to turn into hurricanes, and delivered warnings around landslides due to heavy rainfall. In March 2018 warnings about the rainy season and the potential for floods and landslides ensued. Later in May 2018 national level warnings were upgraded from yellow to red level threats as the Hidroituango Dam overflowed due to the high precipitation levels during this rainy season. Lastly in November we see a sharp spike in Figure 2a for all Colombian news. This was in large part due to Hurricane Iota, which started in Central America, impacting Colombia. Electrical and Tropical storms landed before Hurricane Iota flooding various regions, overall more than 60,000 families were affected by the storms and hurricane, due to heavy rainfall, rivers overflowing, floods, landslides and infrastructure damage.

Comparing the precipitation time series for Colombia and South Africa, in figures 2a and 2b, we can confirm that South Africa has more pronounced periods of low precipitation, as seen by its minimum levels being sustained for longer periods of time than Colombia's.

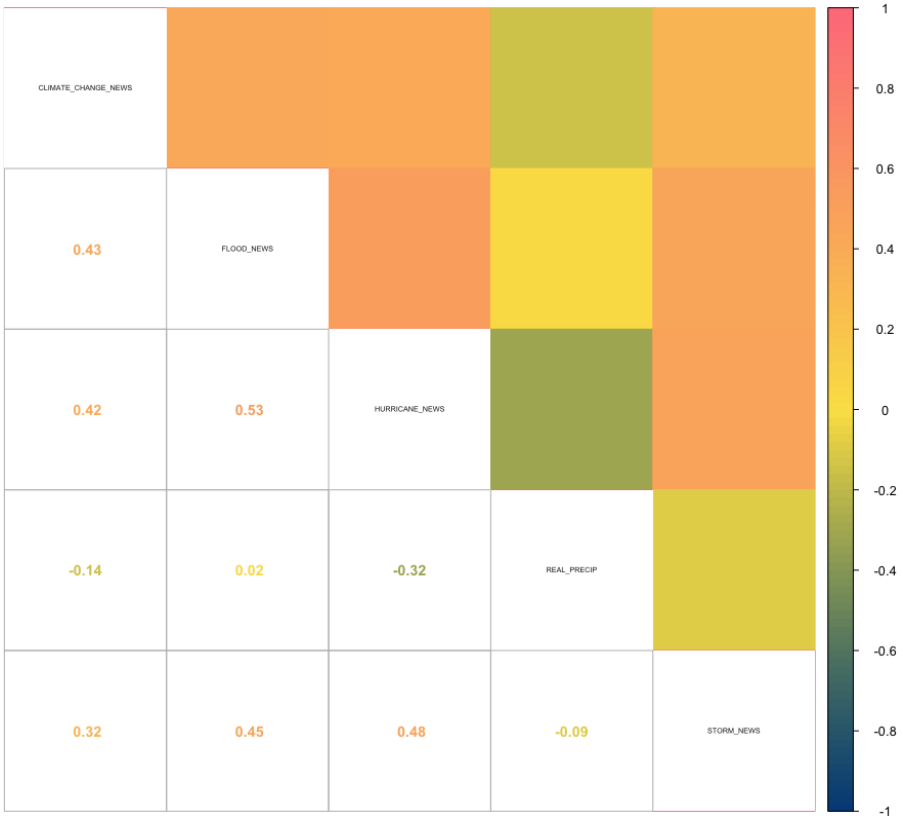
Figure 2b. South Africa Precipitation (mm) and News normalized (% daily volume) against all articles published on a given day



News coverage wise, Figure 2b shows major peaks in flood, hurricane and storm South African news articles, in 2017, 2019 with a spike in storm news articles in 2020. The 2020 spike in storm news coverage is mainly due to "storm" being used as metaphors describing the COVID-19 spread and infection rates for example: "COVID storms", "COVID takes South Africa by storm". The 2017 and 2019 news article peaks related to actual weather events. In February 2017 Tropical storm Dineo, subsequently downgraded to a depression, hit South Africa and flash flood warnings were issued and expected throughout the country. In June 2017 flash floods occurred, specifically affecting Cape Town, displacing thousands and causing travel delays, in what was described as " the worst storm in 30 years". Ending 2017 in October, warnings were issued around floods in preparation for thunderstorm season and critical infrastructure, such as hospitals, were damaged as a result of the extreme weather events. In March 2019, flood and storm news article peaks were caused by Cyclone Idai hitting South Africa after traveling through Mozambique and Malawi. Conversations around this news peak started with neighboring countries requesting aid for the cyclone from South Africa and continued on to different regions in South Africa, such as Gauteng, being affected by the cyclone themselves.

Figures 3a and 3b show correlation matrices highlighting the relationships between real precipitation levels and news article queries for Colombia and South Africa, respectively. Warmer colors, such as orange and red, denote strong positive correlations, pearson coefficients greater than 0.5, yellow to orange indicate weak positive correlations, pearson coefficients between 0 and 0.5, yellow to green indicate weak negative correlations, pearson coefficients between 0 and -0.5, and finally green to blue indicate strong negative correlations, with pearson coefficients greater than -0.5.

Figure 3a. Correlation matrix showing the relationships and correlations between Colombian precipitation data and news article data



There is no significant correlation between the real precipitation data and any of the news article counts in Colombia, with absolute values for pearson coefficients ranging from 0.02 to 0.14 (Figure 3a). Appendix Figures 7 through 12 explore these correlations against different time lags (1 to 3 months) and leads (1 to 3 months) and similarly show that no significant correlations were found between the news and precipitation levels. News articles neither show strong reactive nor anticipation of precipitation at a monthly level. However, there is a weak to strong positive correlation between floods, hurricane and storm news, ranging from 0.45 to 0.53. This means that Colombian news articles about floods, hurricanes and storms are being published roughly at the same time. We can see similar trends when looking at weak positive correlations, 0.32 to 0.43, for news between climate change and floods, hurricanes and storms.

Frome 2017 through 2020 Colombian news around climate change fluctuated from 0.14% and 0.92% of all articles published by Colombian news publishers. While some peaks matched up with key weather events and weak to strong positive correlations, 0.48 and 0.45, between climate change and flooding and hurricane news were found, conversations around climate change continued long after extreme weather events impacted Colombia. Climate change news articles switched from mentioning areas of high vulnerability to climate change when storms or hurricanes hit to talking about

environmental politics. These political topics included: Colombia's commitment and ratification of COP21, bilateral relationships with the UK, France and Austria, deforestation regulation around the Amazon, supreme court rulings around land rights, and investments in climate change adaptation.

Figure 3b. Correlation matrix showing the relationships and correlations between South African precipitation data and news article data

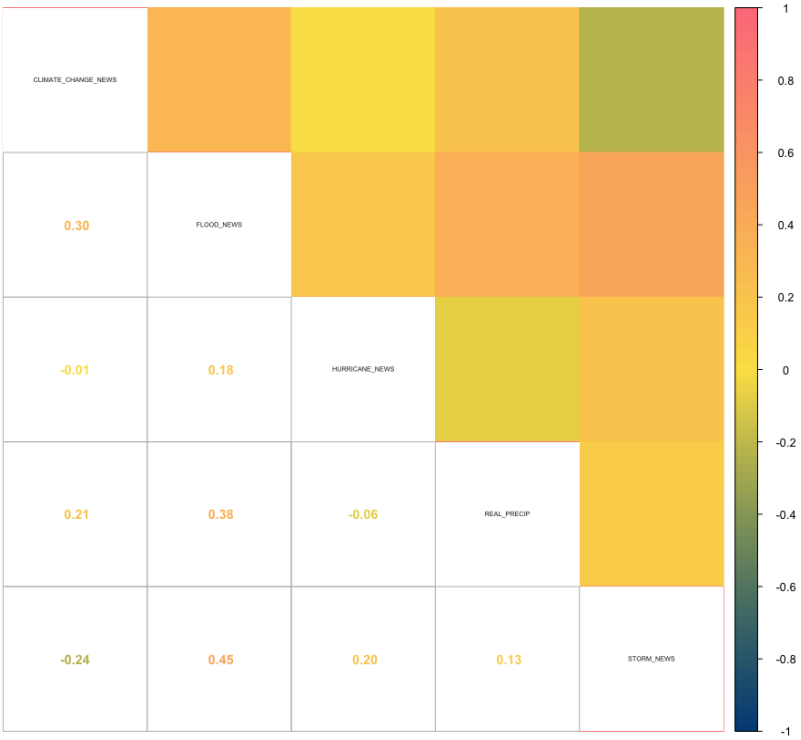


Figure 3b shows there are weak positive correlations, 0.38 and 0.45, between real precipitation and South African flooding news and between South African flooding and storming news, respectively. There were no differences in correlations when news articles were shifted forward and backward seen in Appendix Figures 13 through 18.

While there is not a strong correlation between South African climate change news and other news categories or precipitation data, Figure 3b, there is a continuous level of climate change conversation from 2017 through 2020, with a significant portion of these news articles being published in 2019, Figure 2b. Throughout 2019 the uptick in news articles around climate change was caused by discussion, criticism and introduction of a carbon tax. Outside of 2019 the majority of South African climate change news articles were centered around investments in climate change action projects, South Africa's energy system's transition to renewables, drought impacts on food security and economy, and a high court ruling against a power station, Appendix Table 8.

Discussion

The main goal of this study is to understand how news coverage on extreme weather events and climate change relate to real precipitation conditions and if news article trends are reflective of real life conditions.

Does news about extreme weather events and natural disasters follow the same trends as real precipitation conditions?

This study saw there were notable peaks in Colombian news coverage of extreme weather events and natural disasters (floods, hurricanes, storms) (Figure 2a). However, there was no real correlation between precipitation and reporting on extreme weather events in the form of flooding, storms, or hurricanes (Figure 3a). There were peaks in some news on extreme weather events and natural disasters that were not represented by fluctuations in precipitation levels (Figure 2a). This suggests that short term fluctuation in precipitation levels is not the only indicator in assessing whether natural disasters like flooding will occur. Flooding can occur as a result of long term exposure to heavy rainfall and the severity and lag time of the flood is subject to environmental factors such as soil infiltration, interception (anything that traps rainfall), and location especially whether it is up or downstream (Nelson & Tulane University, 2015). Therefore fluctuations in precipitation levels might not be the only factor in creating natural disaster like conditions, and alone are not a great indicator of the severity and impact of a weather event. As summarizing online news-peaks indicated that high impact or severe conditions developed by floods, landslides or even infrastructural damage such as dams overflowing received the most new coverage. The news summaries around Colombian extreme weather events and natural disasters, often mentioned the rainfall in the context of its impact such as infrastructural damage or casualties. Our findings show that high levels of precipitation by themselves were not necessarily cause for concern or public interest, even when warnings or states of emergency were issued. This suggests that unknown social factors are likely driving these discussions. An in-depth analysis of new coverage would be required to understand these factors.

On the other hand this study found a weak positive correlation, 0.38, between South African flooding news and real precipitation conditions suggesting that reporting on flooding follows real precipitation conditions as they happen. South Africa has a much lower precipitation mean than Colombia and is characterized by desert-like conditions throughout its landscape. Water scarcity and drought have become increasingly severe in South Africa, with the country receiving intermittent high precipitation events (The World Bank Group, 2021). South Africa has minimum precipitation levels that are sustained for longer compared to Colombia's. South Africa has been concentrating their climate related plans on drought related events as these affect their food security and overall well being (Department of Environmental Affairs, 2018). When high levels of precipitation do occur, they are more likely to be associated by extreme weather events such as storms, which is supported by the 0.45 correlation, found between South African flooding and storming news. Interestingly South African storm news was not found to be correlated with monthly precipitation levels. Further investigation is needed as to why this was the case potentially starting with different temporal

resolutions. It might be the case that storms did occur and high precipitation measurements could be detected at more refined temporal scales.

From 1990 through 2020 Colombia experienced 2 droughts, 50 major floods,7 severe storms, and 42 landslides. During the same time period South Africa experienced 11 droughts, 25 floods, 22 storms and 1 landslide (The World Bank Group, 2021). Based on the frequency of occurrences alone, Colombia is impacted by floods even when there are not severe storms. South Africa on the other hand seems to have floods as a consequence of the storms that impact it. This starts to explain why South African flooding and storming news had a weak correlation of 0.45, Figure 3b. Further, high South African precipitation levels might be caused by storms, suggesting they might be short term, but high impact events (floods). Contrastingly, Colombia would seem to have high precipitation levels irrespective of storms, signaling more long term conditions. This offers a potential explanation as to why correlations (Figure 3a and 3b) were found between South African news coverage of extreme weather events and natural disasters, and their precipitation levels, but not between Colombian news coverage and their precipitation levels. For South Africa we would be comparing short term high impact events in news to short term high impact events in the weather and environment. For Colombia, on the other hand, we would be comparing short term high impact events in the news to long term conditions in the weather and environment.

Previous research on news coverage related to real world conditions can be divided into two categories: studying long term equilibria and trends over decades (Holt & Barkemeyer, 2012) or studying how news coverage mimicked or predicted short term fluctuations (Soroka et al., 2015). News around extreme weather events (storms, hurricanes) or natural disasters (floods, landslides) are part of the later category. They revolve about short term but high impact events. However the base measurements for ground truthing such as precipitation levels can be misleading by themselves. Special attention needs to be made in assessing a country's climate and environment to understand what measurements and temporal resolutions should be used.

What can news coverage about extreme weather and natural disasters tell us about extreme weather events?

News around extreme weather events and natural disasters provides a necessary complement to precipitation levels in order to properly identify severity, public concern, key vulnerable locations and have an accurate account of all natural disasters.

Throughout this study there was a concentration of keyword searches around storms, hurricanes and floods. However,we found that flooding and landslides were a significant and frequent consequence of sustained high levels of precipitation in Colombia. Unpacking this further, firstly, landslides were not a natural disaster we were actively searching for, but instead was one we discovered as an impact of high precipitation levels by our qualitative news summaries. Secondly flooding, especially riverine flooding, and landslides were reported as a consequence of sustained high precipitation levels. Our precipitation data shows that Colombia has sustained high levels of precipitation. It is this prolonged exposure to high levels of precipitation that caused rivers to overflow into the environment and urban

areas, causing landslides or floods accordingly. Therefore news coverage can start to provide a more nuanced understanding of how and when short term high impact natural disasters are caused by long term climatic conditions. This starts to shed light on why flooding news was not correlated with precipitation measurements in Colombia. On the other hand, South African flooding news was correlated to actual precipitation measurements. After a review of South African news summaries, we discovered this was because they were mentioning the effects of "flash floods". Our qualitative analysis allowed us to uncover and differentiate between different versions of natural disasters, riverine floods versus "flash floods". Precipitation measurements alone might have only uncovered "flash floods" because of their more instantaneous nature.

Precipitation trends alone can be misleading based on a county's 'normal' or long term climatic conditions. In countries like South Africa they can help us identify weather events that were of most note and impact to the public. However, for countries like Colombia where high precipitation levels are more of a norm, trends based on precipitation do not provide accurate information on extreme weather events and natural disasters. This is why a qualitative approach like developing news summaries, is a valuable complement to correlation or quantitative based approaches. Through the news summaries, we were additionally able to identify regions and infrastructure (dams, hospitals, etc) in both countries that were reportedly most vulnerable to heavy precipitation. Additionally we were able to identify which events carried warnings ahead of time and the overall consequence of the events after they passed. Our qualitative analysis of news coverage allowed us to uncover and develop a timeline of short term extreme weather events and natural disasters that occured based on both short term fluctuations in precipitation levels, for South Africa and long term precipitation levels, for Colombia.

How does climate change news relate to real precipitation conditions, and news articles about extreme weather events and natural disasters?

Climate change news in Colombia and South Africa did not follow the same trends as extreme weather events and natural disasters, or real precipitation levels. News around climate change did spike with news coverage of extreme weather and natural disasters and some weak positive correlations were found in this study (Figure 3a). However, these news articles simply shed light on which and how regions in each country were most vulnerable to climate change, seen through the news summaries, Appendix tables 4 and 8. A minority of news articles related the frequency and severity of extreme weather events (storms, hurricanes) and their consequences (floods) to climate change directly. Our study supports that while climate change might be mentioned in conjunction with extreme weather events and natural disasters, these are not the main drivers. From a review of the climate change news peaks, most of the news coverage was dedicated to political actors, environmental policy and investments in mitigation and adaptation. Climate change has become a topic that relates to more than just actual climate and weather conditions, and it has been shown that news coverage around climate change news is better influenced and related to key political stakeholders and events (Brulle et al., 2012).

As with other studies this study found that news around climate change shifted and more closely followed different international events and topics such as conferences, international partnerships and key environmental legislations (Holt & Barkemeyer, 2012). Throughout this study we did find that climate change news often focused on investment into climate change adaptation plans and the environmental and financial cost of the consequences of climate change in both countries. Other studies have highlighted the efficacy of using news articles to find which environmental and conservation topics are most salient at the time, and the direction policy is taking (Killion et al., 2019) (Mele et al., 2019). This study identified a similar shift in climate change reporting, seen in figure 2b, where in 2019 South Africa showed sustained higher levels of climate change news coverage than any other year. This was due to the fact that a specific carbon tax policy was being debated and eventually implemented. Climate change news is better suited to find what events are becoming noteworthy for countries and how different governments are focusing their efforts on their adaptation and mitigation plans. Climate change reporting has become far more complex and interconnected to be simply reflective of shifts in the world's climate.

Conclusion

This study highlighted the value of conducting quantitative and qualitative analyses of news coverage on extreme weather events, natural disasters and climate change to develop a more comprehensive account of such events than can just be uncovered through precipitation measurements.

We can summarize our research goals in (1) trying to identify if news about extreme weather events and natural disasters follow the same trends as real precipitation conditions, (2) what news coverage on extreme weather and natural disasters tell us about extreme weather events and (3) how climate change news relates to real precipitation conditions, and news articles about extreme weather events and natural disasters. Regarding the first goal, we found that quantitative measurements like correlation tying news coverage to precipitation levels is misleading. Extreme weather events and natural disasters are short term and high impact.The accuracy of precipitation measurements in identifying extreme events and natural disasters is heavily dependent on what the baseline precipitation conditions are. Therefore ground truthing news coverage with precipitation levels alone is discouraged. Further news coverage of extreme weather events and natural disasters was able to provide a timeline of such events regardless of baseline precipitation conditions. Regarding the second goal, a qualitative analysis and summary of news 'peaks' was able to provide a more nuanced and comprehensive understanding of what and why natural disasters occured. These news summaries further provided context and could be used to understand the overall impact of extreme weather events and natural disasters on the environment, infrastructure and the population affected. Lastly, regarding the third goal this study, similarly to others, found that while climate change news coverage may identify vulnerable areas, it has extended beyond simply being reflective of actual fluctuations in climate conditions. Instead it is a highly connected topic that can be used to identify events around, climate change investment, planning, key stakeholders, events and legislation. Additionally, extreme weather events and climate conditions are no longer key influencers of climate change news coverage but instead political events and stakeholders are better indicators of climate change news reporting.

Overall we found that a quantitative and qualitative analysis of extreme weather and natural disaster

news coverage was a valid, and at times better, method in providing identification, impact and context of weather events and natural disasters for both Colombia and South Africa from 2017 through 2020, than precipitation measurements alone. Next steps should include confirmation that this kind of analysis works for other countries with similar climates, vulnerabilities and economic and political structures.

Future work in this area should look to include more meteorological measurements beyond precipitation levels, and their relationship with extreme weather events and natural disasters. This should be tested across countries of differing climate baselines. Contrastingly, it would be interesting to compare news coverage on climate change, weather events and natural disasters, between countries with similar climate conditions that suffer from the same climate vulnerabilities and weather hazards, but have different political and economic structures. If possible, studies that included longer time frames would benefit from analyzing how news coverage baselines and equilibria on extreme weather events fluctuate as new policies and investments get implemented.

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Appendix

Table 1: *A table showing news article summaries for Colombian news about floods*

April 2017	• Major floods in the south of Colombia, State of Emergency declared, landslides, death toll: 314, 120 families affected, schools closed
March 2018	• 7 billion pesos invested into Colombian Climate adaptation fund • Warnings around rainy season and flooding • Warnings around landslides
May 2018	• Warnings (Red, Yellow) strongest rains are still too come could make damn crisis even worse and delay recovery and maintenance • Channels to damn above average levels due to rain levels season • Hidroituango Dam Crisis • Thousands evacuated in preparation for river overflowing
November 2020	• Flooding across the nation: Magdalena, El Banco, Cauca, Cali, San Andres, Providencia • Heavy rains affect more than 60,000 families • La Niña phenomenon expected to extend until May 2021 • Rivers overflowing: La Cumbre, Valle del Cauca • Landslides in Medellin • Flooding in Choco region

Table 2: *A table showing news article summaries for Colombian news about storms*

April 2017	• Stronger storms to come • Storm causing floods • “Semana Santa” (week long religious

	celebration) will start with high probability of strong storms and rains
October 2017	• Tropical storm NATE warnings - indirect effects, strong winds and waves will affect coast, San Andres and Cartagena • Tropical storm will bring electric storms
July 2018	• Storm used mostly as a metaphor, ie political storm, football storm references
November 2020	• Electric Storm alerts in San Andres • Hurricane Iota affecting Magdalena and Cartagena • Potential formation of a cyclone, warnings • Four municipalities in Magdalena in state of emergency due to tropical storm

Table 3: *A table showing news article summaries for Colombian news about hurricanes*

May 2017	• Two tropical storms have potential to become hurricanes this year • Hurricane season will start in June • Agencies request contingency planes to be started for incoming hurricanes in Colombia • Warnings about landslides because of heavy rain • State of Emergency: Orange alert changed to Red Alert
September 2017	• Hurricane Maria increasing strength and threat level • Colombia sending planes to Puerto Rico to evacuate nationals • Colombian Caribbean coast braces for heavy rains by hurricane Maria • Hurricane Maria impact in Colombia imminent • Hurricane Maria causes heavy rain across

	Colombia
November 2020	● Hurricane Iota hits San Andres, Providencia, Santa Catalina (regions in Colombia) ● Hurricane Iota reaches category 4 (70 km per hour) in Providencia ● Hurricane Iota surpasses expectations that action plans have prepared for ● 98% of infrastructure in Providencia was damaged by Hurricane Iota

Table 4: *A table showing news article summaries for Colombian news about climate change*

April 2017	● 7.7 billion colombian pesos invested in climate change adaptation plans. ● BID (Banco Interamericano de Desarollo) increasing loans for projects aimed at climate change ● Discussion on climate change and disaster preparedness as a reaction to Mocoa disaster (254 casualties) - avalanches and rivers overflowing. ● Articles identifying municipalities that are vulnerable to a similar Mocoa disaster
June 2017	● Conversation about Colombia ratifying COP21 terms and agreement ● Bogota, San Andres and various cities in the Caribbean and Pacific identified as vulnerable to climate change ● Commentary on Trump leaving the Paris Agreement
September 2017	● Temperature in Colombia expected to be 2 degrees celsius higher by 2100 ● San Andres to be most affected city by climate change in Colombia ● Climate Change Documentary Festival - Cine Planet 2017 coverage
January 2018	● Austria and Colombia to work together on renewable energy ● Colombia reiterates commitment to Sustainable Development Goals ● MIT to work with Colombia in creating climate adaptation plans

	● Climate change and la Niña phenomenon linked to greater rainfalls
April 2018	● Colombia supreme court declares Amazonian territory and Rainforest has rights and orders stop of deforestation of the Amazonian Rainforest ● Mary Gomez Torres becomes the new director of the Colombian Sustainable Fund
June 2018	● Deforestation in the Amazon Rainforest has doubled over the last year ● New government showing new look at climate change and environmental issues ● Colombia Sierra Nevada to have no snow by 2030.
November 2018	● Climate change will cost Colombia $3.8 billion ● Religious leaders, indigenous populations, and afrocolombians unite to protest and fight against climate change ● Colombian mining sector to reduce 11.2 million tonnes of CO2 by 2030
June 2019	● Colombia and the UK form an alliance to fight climate change and commit $35 billion pesos and deforestation ● Colombia and France sign bilateral agreement to protect natural resources
September 2019	● President of Colombia Duque, speaks at the UN on Colombia's efforts to fight climate change
December 2019	● Colombia to join coalition with the UK, Norway and Germany to protect the country against deforestation, and will receive $366 million in aid for climate change mitigation ● COP25 - indigenous representative voice violations against their human rights in efforts for plans against climate change ● COP25 - Colombia to ask for strict rules against carbon emissions
November 2020	● Boris Johnson highlights Colombian carbon emission reduction (-51%) goals ● Shark fishing is banned in Colombia ● Conversations around how a Trump or Biden win in the US will affect climate

	change goals between the US and Colombia

Table 5: *A table showing news article summaries for South African news about floods*

February 2017	● Tropical storm Dineo hits South Africa ● Flash floods expected
June 2017	● Flash floods ● 8 killed, thousands displaced due to Cape Storm ● Cape town bracing for worst storm in 30 years ● Travel delays due to storm
October 2017	● Thunderstorm season approaching - Flood warnings in Johannesburg ● Hospitals damaged by heavy storms ● Durban floods
June 2018	● Widespread flooding in cape town due to severe rain
October 2018	● Gauteng heavy rain and thunder
March 2019	● Cyclone Idai hits South Africa, Mozambique, Malawi - kills 115 ● Articles about Mozambique and Malawi requesting aid from SA
December 2019	● Heavy rains wreak havoc on SA ● Warnings about hail and floods ● Mines shut down due to floods ● Gauteng major region mentioned

Table 6: *A table showing news article summaries for South African news about storms*

February 2017	● Cyclone Dineo warnings for South Africa ● Dineo downgraded to depression
June 2017	● Cape Town storm, 8 killed, thousands displaced ● Worst storm in 30 years
October 2017	● Johannesburg, Gauteng, Durban storms, damage costing in the millions

	• Insurance mentioned frequently
March 2019	• Tropical cyclone Idai • Countries asking SA for help - at first was going to miss SA • Gauteng affected by Idai
July 2020	• Talking about COVID ‘storm’
January 2021	• Tropical cyclone Eloise reaches SA • Threatens SA power supply • Upgraded to severe tropical storm

Table 7: *A table showing news article summaries for South African news about hurricanes*

September 2017	• Talking about external hurricanes (Harvey)

Table 8: *A table showing news article summaries for South African news about climate change*

March 2017	• Landmark climate change court case victory - High Court rules in favor of Earthlife Africa against Thabametsi power station
July 2017	• Expected cold front to hit South Africa • G20 summit in Hamburg receives mass South African support, President to lead high level delegation to summit
October 2017	• Nuclear power to define South African energy system in the future • Warnings about more frequent and greater severity weather events to hit South Africa
March 2018	• South Africa creating a new carbon tax - criticism around loss of jobs due to tax • Big energy users oppose new carbon tax • Growing water crisis in South Africa - Greenpeace demands further commitment to defend South African people’s right to water
June 2018	• 137 million rand invested in climate change projects in South Africa and new Climate Change Bill • Several cities in South Africa identified as most vulnerable to climate change • Cape Town will take 3 years to address

	drought impact and vulnerabilities
October 2018	● Development Bank Southern Africa (DBSA) develops Climate Finance Facility ● DBSA secure 55 million towards 2 billion Climate Finance Facility ● Opposition towards government coal plant plans ● South Africa struggles to transition to renewable energy
February 2019	● Carbon Tax Bill passed by National Assembly ● South Africa will need to produce 50% more food or will face hunger crisis ● Massive gas reserves found off the coast of South Africa ● Eskom power company closes down coal plants
June 2019	● Extinction Rebellion protests arrive in South Africa ● Criticism on carbon tax bill - taxpayers paying more for carbon bill and greener economy, carbon bill too low to curb carbon emissions
October 2019	● Climate change will impact biodiversity on many levels ● Drought issues driven by climate change, water shedding will hit South Africa ● Congressman Sisulu states there is a government plan being formulated to fight water crisis
February 2020	● Climate change threatens socio-economic development in South Africa
May 2020	● COVID 19 and climate change exacerbating water crisis ● Anglo American coal plants to exit South Africa ● Cape Town advocates for buying electricity from private producers
September 2020	● Food insecurity further highlighted through climate change ● South African President Ramaphosa, highlights renewable energy projects as path for future of power generation

	● Two utility scale solar power plants are operational in the Northern Cape of South Africa
November 2020	● Investment in green infrastructure needed to secure a sustainable South Africa ● Criticism of green investment - going green will cost jobs ● University of Pretoria joins NASA's efforts in understanding health effects of air pollution ● Ramaphosa congratulates Biden on win and has conversation about bilateral relationship

Figure 1. Colombia Precipitation and News as raw counts

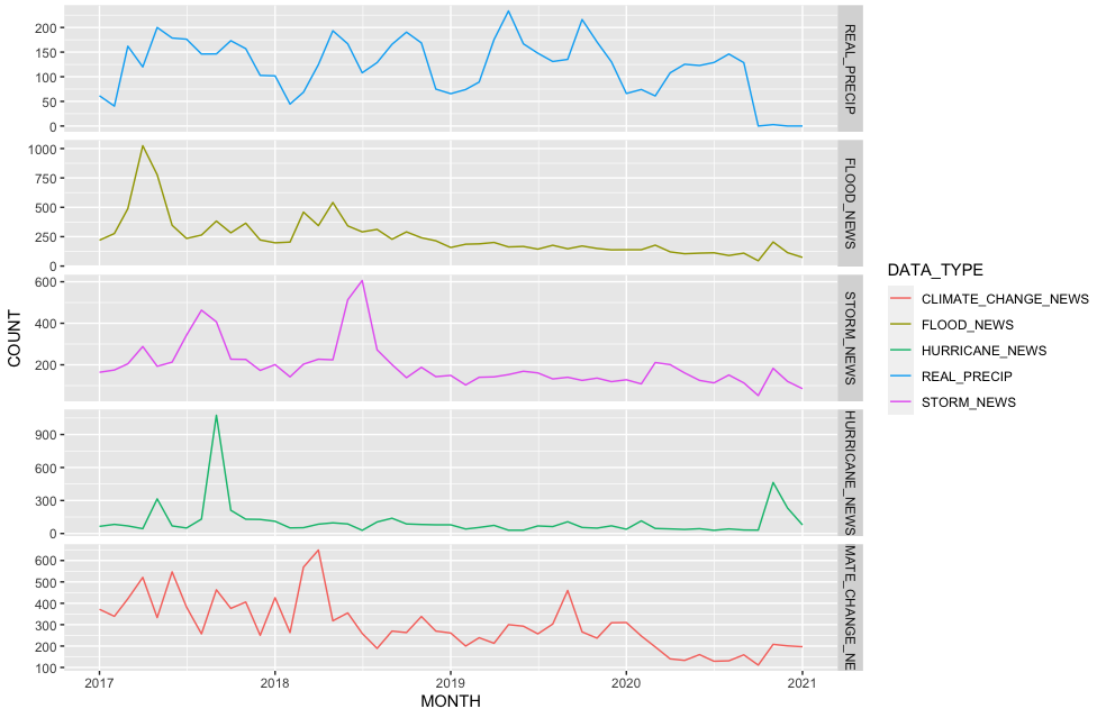

Figure 2. South Africa Precipitation and News as raw counts

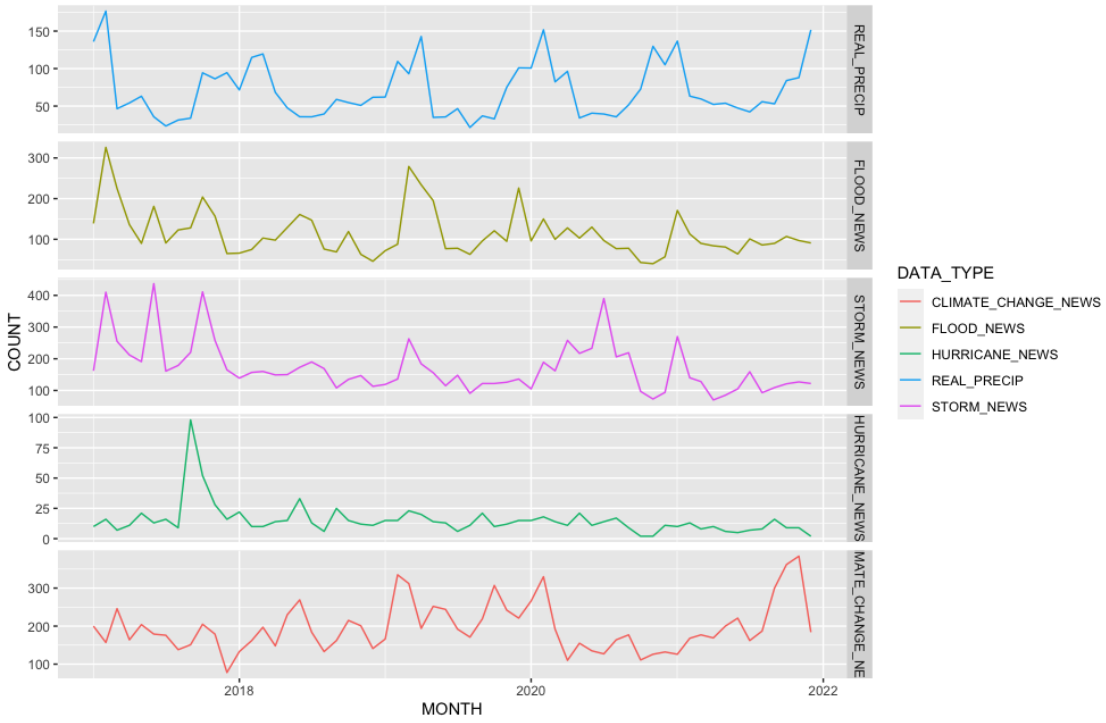

Figure 3. Colombia Precipitation and News normalized against all articles collected by GDELT on a given day

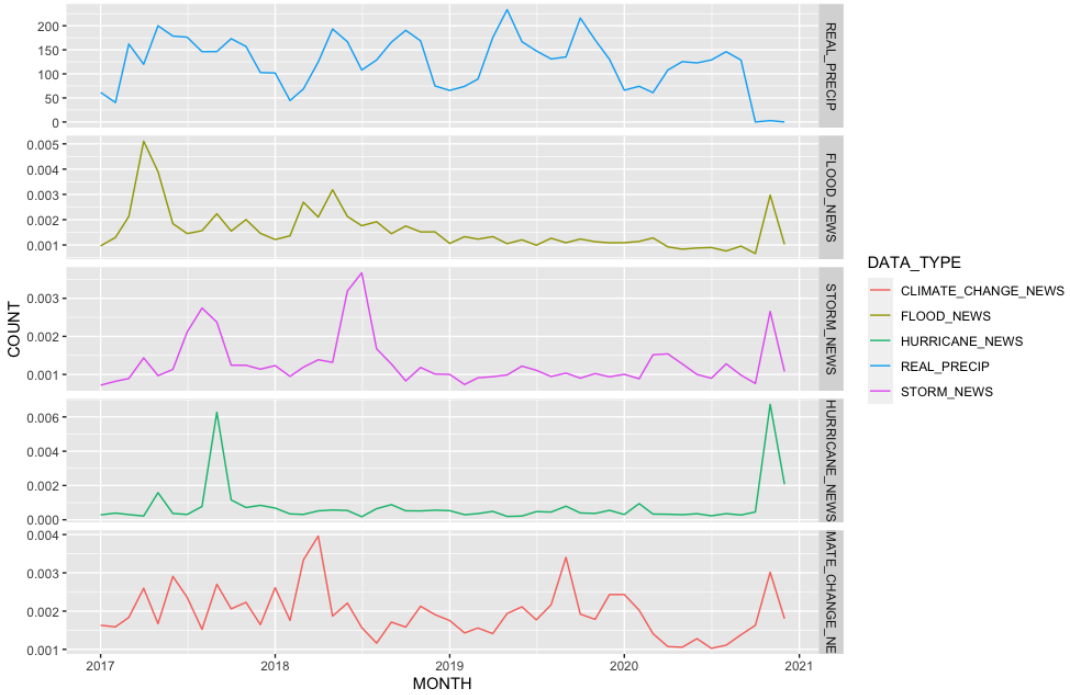

Figure 4. South Africa Precipitation and News normalized against all articles collected by GDELT on a given day

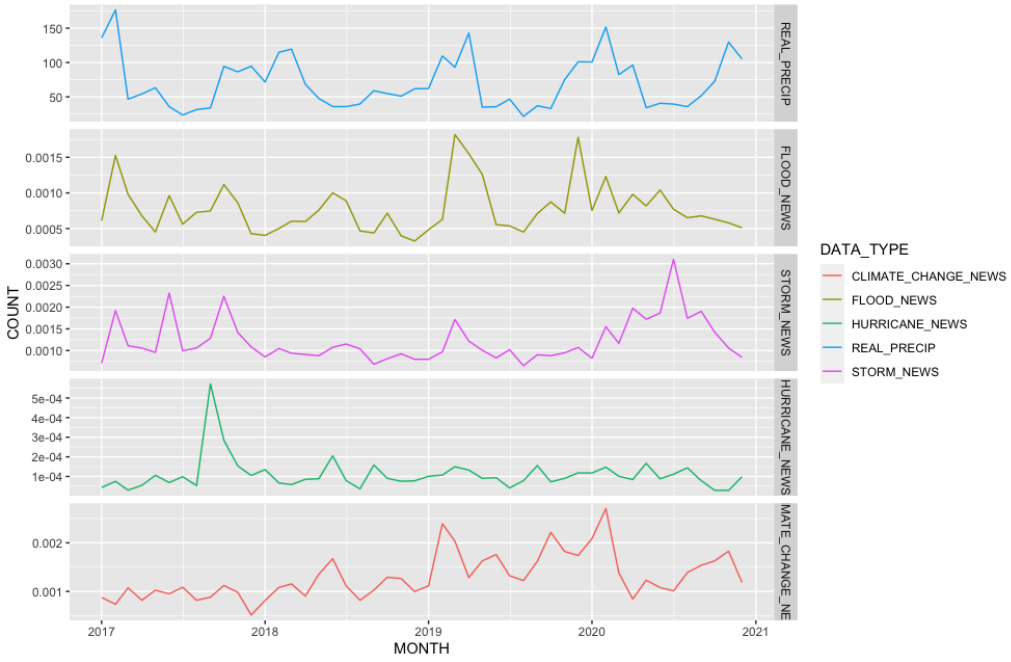

Figure 5. Colombia Precipitation and News normalized against all articles published by Colombia that are talking about Colombia

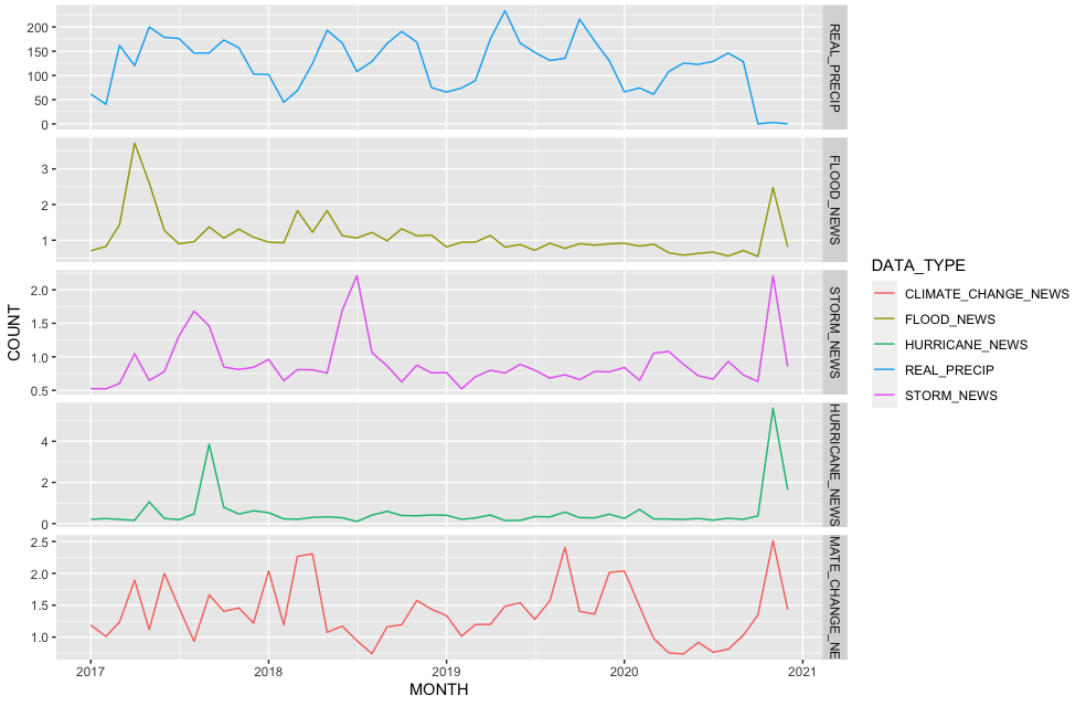

Figure 6. South Africa Precipitation and News normalized against all articles published by South Africa that are talking about South Africa

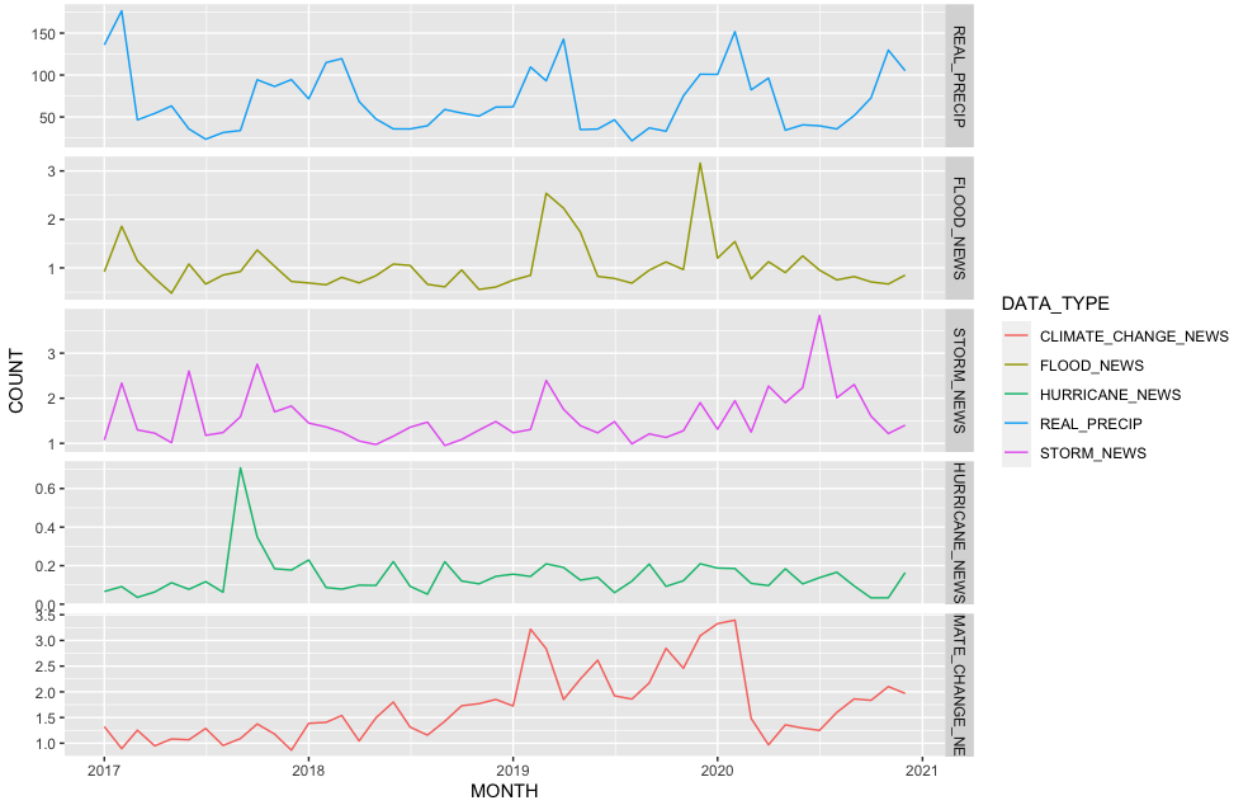

Figure 7. Correlation matrix showing the relationships and correlations between Colombian precipitation data and news article data (lagged by 1 month)

Figure 8. Correlation matrix showing the relationships and correlations between Colombian precipitation data and news article data (lagged by 2 months)

Figure 9. Correlation matrix showing the relationships and correlations between Colombian precipitation data and news article data (lagged by 3 months)

Figure 10. Correlation matrix showing the relationships and correlations between Colombian precipitation data and news article data (shifted forward by 1 month)

Figure 11. Correlation matrix showing the relationships and correlations between Colombian precipitation data and news article data (shifted forward by 2 months)

Figure 12. Correlation matrix showing the relationships and correlations between Colombian precipitation data and news article data (shifted forward by 3 months)

Figure 13. Correlation matrix showing the relationships and correlations between South African precipitation data and news article data (lagged by 1 month)

Figure 14. Correlation matrix showing the relationships and correlations between South African precipitation data and news article data (lagged by 2 months)

Figure 15. Correlation matrix showing the relationships and correlations between South African precipitation data and news article data (lagged by 3 months)

Figure 16. Correlation matrix showing the relationships and correlations between South African precipitation data and news article data (shifted forward by 1 month)

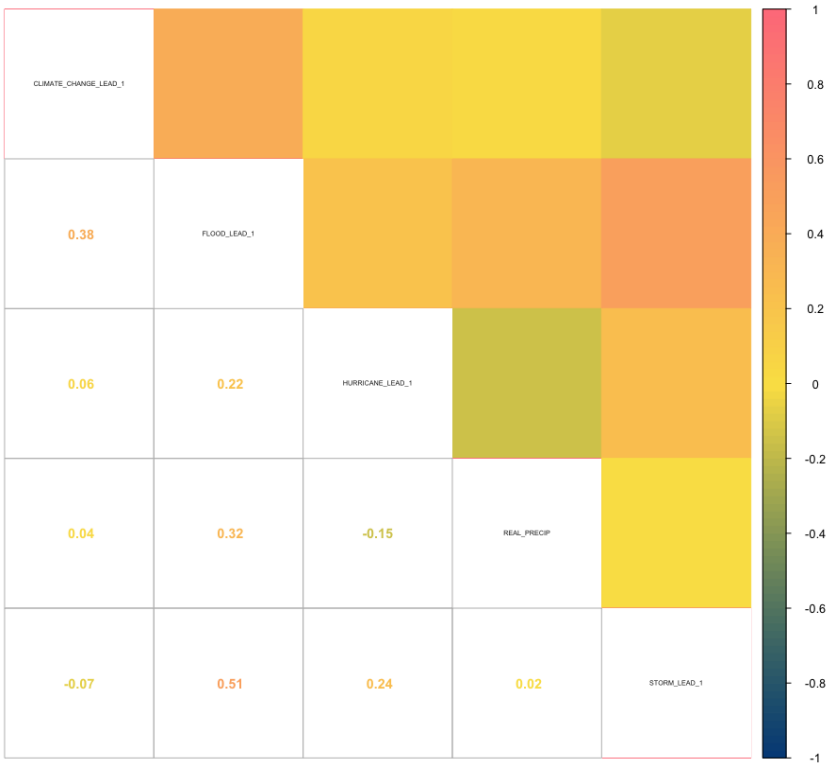

Figure 17. Correlation matrix showing the relationships and correlations between South African precipitation data and news article data (shifted forward by 2 months)

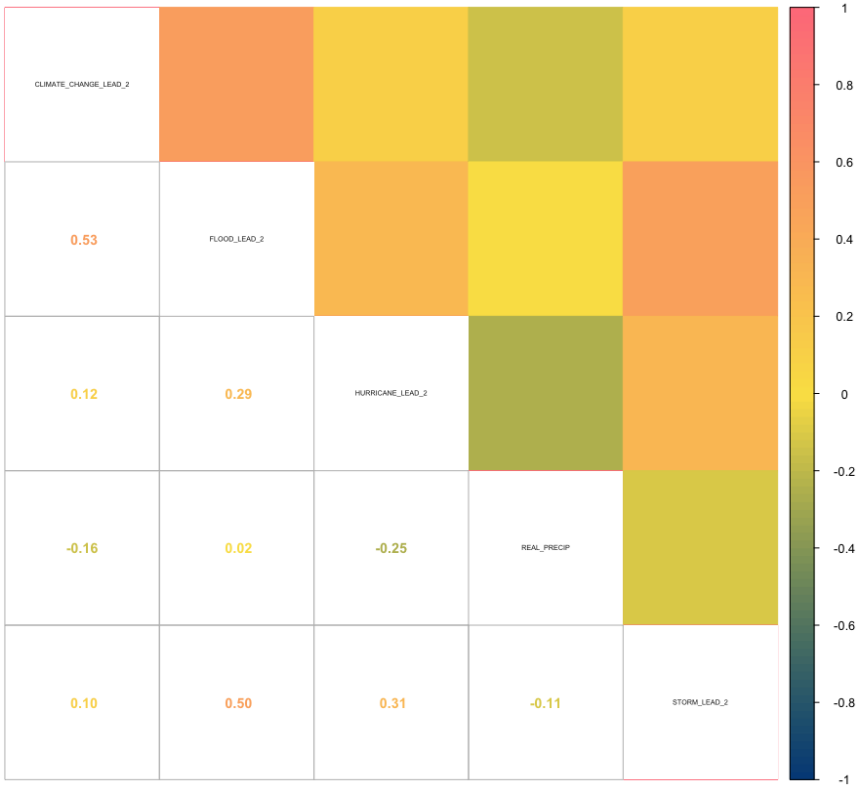

Figure 18. Correlation matrix showing the relationships and correlations between South African precipitation data and news article data (shifted forward by 3 months)

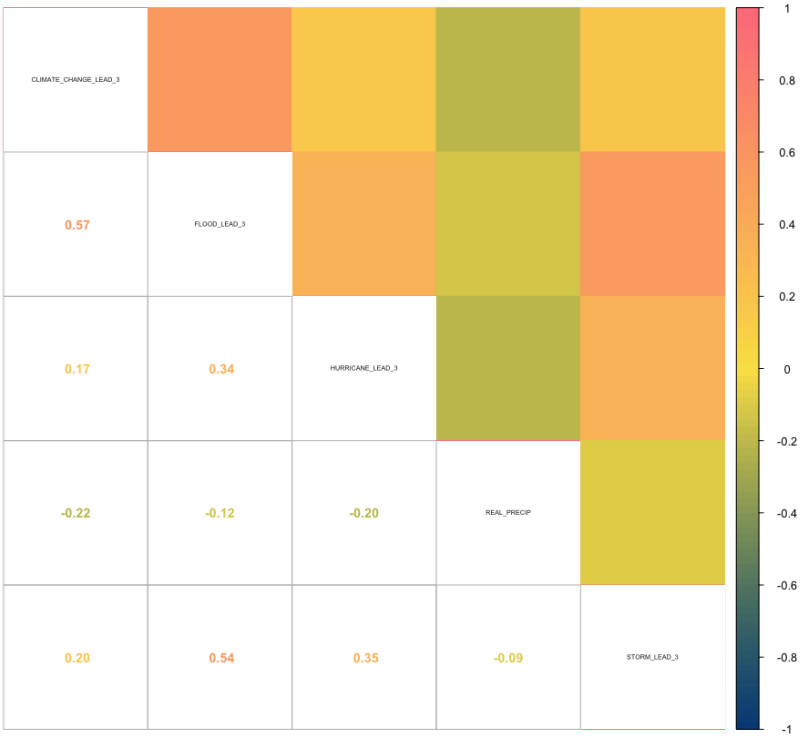

Table 9: A Table listing all NOAA weather stations, with their station number, name, latitude, longitude, and elevation, in Colombia

STATION	NAME	LATITUDE	LONGITUDE	ELEVATION
COM00080094	PALONEGRO, CO	7.127	-73.185	1187.8
COM00080370	SAN LUIS, CO	0.862	-77.672	2976.4
COM00080099	SANTIAGO PEREZ, CO	7.069	-70.737	128
COM00080110	OLAYA HERRERA, CO	6.22	-75.591	1505.7
COM00080097	CAMILO DAZA, CO	7.928	-72.512	334.1
COM00080036	ALFONSO LOPEZ PUMAREJO, CO	10.435	-73.25	147.2
COM00080234	VANGUARDIA, CO	4.168	-73.614	424.9
CO000080001	SAN ANDRES ISLA S, CO	12.583	-81.717	6
CO000080342	PASTO ANTONIO NARIN, CO	1.417	-77.267	1826
COM00080210	MATECANA, CO	4.813	-75.74	1346
COM00080035	ALMIRANTE PADILLA, CO	11.526	-72.926	13.1
COM00080112	JOSE MARIA CORDOVA, CO	6.165	-75.423	2142.1
COM00080211	EL EDEN, CO	4.453	-75.766	1216.2
COM00080398	ALFREDO VASQUEZ COBO, CO	-4.193	-69.943	84.4
COM00080315	BENITO SALAS, CO	2.95	-75.294	446.2

CO000080222	BOGOTA ELDORADO, CO	4.701	-74.15	2548
COM00080214	PERALES, CO	4.422	-75.133	949.1
VE000005484	PUERTO CARRENO A.GU, VE	6.167	-67.5	55
COM00080084	ANTONIO ROLDAN BETANCOURT, CO	7.812	-76.716	14
COM00080022	RAFAEL NUNEZ, CO	10.442	-75.513	1.2
COM00080063	LOS GARZONES, CO	8.824	-75.826	11
COM00080144	EL CARANO, CO	5.691	-76.641	62.2
COM00080002	EL EMBRUJO, CO	13.357	-81.358	3
COM00080028	ERNESTO CORTISSOZ, CO	10.89	-74.781	29.9
CO000080259	CALI ALFONSO BONILL, CO	3.55	-76.383	969
COM00080009	SIMON BOLIVAR, CO	11.12	-74.231	6.7
COM00080091	YARIGUIES, CO	7.024	-73.807	125.6

Table 10: A Table listing all NOAA weather stations, with their station number, name, latitude, longitude, and elevation, in South Africa

STATION	**NAME**	**LATITUDE**	**LONGITUDE**	**ELEVATION**
SF001447910	NOUPOORT, SF	-31.183	24.95	1496
SF000068296	SKUKUZA, SF	-24.983	31.6	271
SFM00068263	PRETORIA IRENE, SF	-25.917	28.217	1500
SFM00068262	PRETORIA MET, SF	-25.733	28.183	1322

SF000798110	DOHNE, SF	-32.517	27.467	900
SF003724960	VRYHEID, SF	-27.783	30.8	1163
SFM00068591	MARGATE, SF	-30.85	30.333	154
SFM00068592	KING SHAKA INTERNATIONAL AIRPORT, SF	-29.617	31.133	127
SF002613650	BLOEMFONTEIN AIRPOR, SF	-29.1	26.3	1354
SF002394820	CEDARA, SF	-29.533	30.283	1071
SF000347620	UITENHAGE, SF	-33.7	25.433	157
SFM00068538	DEAAR UA, SF	-30.667	24.017	1287
SF002146700	SPRINGBOK, SF	-29.667	17.9	1007
SF004322370	VRYBURG, SF	-26.95	24.633	1234
SFM00068816	CAPE TOWN INTERNATIONAL, SF	-33.965	18.602	46
SF000414170	MALMESBURY, SF	-33.467	18.717	102
SF000570480	GRAHAMSTOWN, SF	-33.283	26.5	642
SF001506200	ELLIOT, SF	-31.333	27.85	1463
SF003174470	UPINGTON AGR., SF	-28.45	21.25	794
SF005547860	LYDENBURG, SF	-25.1	30.467	1425
SFM00068461	BETHLEHEM, SF	-28.248	28.336	1695
SF001771780	BARKLY EAST, SF	-30.933	27.6	1819
SF000068858	EAST LONDON, SF	-33.033	27.833	125
SF002760720	VIOOLSDRIF, SF	-28.7	17.6	168
SFM00068588	DURBAN INTERNATIONAL, SF	-29.97	30.951	10.1
SF000508870	WILLOWMORE, SF	-33.283	23.5	842
SF000068994	MARION ISLAND, SF	-46.883	37.867	21
SF001485170	JAMESTOWN, SF	-31.117	26.8	1603
SF003044460	MTUNZINI, SF	-28.95	31.7	38
SF001290070	CAPE HERMES, SF	-31.633	29.55	47

SFM00068242	MAFIKENG, SF	-25.798	25.548	1274.4
SF004722810	LICHTENBURG, SF	-26.133	26.167	1487
SF000288380	GEORGE AIRPORT, SF	-34.017	22.383	190
SF000981900	CRADOCK, SF	-32.167	25.617	102
SF003336820	VAN REENEN, SF	-28.367	29.383	1680
SF002966820	FICKSBURG, SF	-28.817	27.9	1614
SF001344780	CALVINIA, SF	-31.467	19.767	975
SF000782270	FORT BEAUFORT, SF	-32.783	26.633	455
SF004371040	POTCHEFSTROOM, SF	-26.733	27.067	1351
SF000227590	WORCESTER, SF	-33.617	19.467	270
SF004348880	OTTOSDAL, SF	-26.817	26.017	1500
SF000104560	RIVERSDALE, SF	-34.083	21.25	116
SF000236780	ROBERTSON, SF	-33.8	19.9	204
SF003605120	TAUNG, SF	-27.55	24.767	1100
SF003211100	POSTMASBURG, SF	-28.333	23.067	1321
SF000456110	LAINGSBURG, SF	-33.2	20.867	656
SF001130250	FRASERBURG, SF	-31.917	21.517	1268
SF001753710	ALIWAL NORTH, SF	-30.8	26.883	1351
SFM00068368	JOHANNESBURG INTERNATIONAL, SF	-26.139	28.246	1694.1
SFM00068842	PORT ELIZABETH INTERNATIONAL, SF	-33.985	25.617	68.9
SF000068438	KIMBERLEY, SF	-28.8	24.767	1196
SF000068712	CAPE COLUMBINE, SF	-32.833	17.85	67