

Climate Change Pulse: An Agentic RAG-Enhanced Framework for Interactive Sentiment Analysis and Global Disaster Data Visualization

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Abstract

Climate change is an urgent global issue, with natural disasters becoming more severe and frequent due to human activities. Understanding public sentiment around these events can inform climate awareness and policy. We developed ClimatePulse, a web-based tool that visualizes natural disasters alongside Twitter data to analyze how proximity and time influence climate-related sentiments. Using the Climate Change Twitter Dataset, we examined over 15 million tweets, mapping them with disaster data through an interactive UI. Challenges included missing geospatial data and sentiment classification limitations, addressed by refining data filters and leveraging embedded tweets. Our experiments tested how distance and time around disasters affect sentiment, revealing that proximity intensifies negative emotions, and climate change deniers exhibit surprisingly strong negative sentiments. Compared to prior methodologies focused on data collection or basic sentiment analysis, our approach emphasizes user interactivity and behavioral analysis. ClimatePulse offers a dynamic way to understand climate discourse, bridging data insights with public engagement.

Keywords: Natural Language Processing, Machine Learning, Sentiment, Disasters

1 Introduction

Climate change is one of the most prominent, terrible issues we are facing right now. Extreme heat and climate change induced natural disasters directly and indirectly impact people worldwide. Climate change from human activities causes disasters to be more intense and frequent. Hot seasons now keep breaking record temperature and worse heat waves, floods and droughts are normal in many countries. Ice sheets are melting, ocean levels are rising and warmer oceans create bigger hurricanes. Importantly, with the rising temperature, tipping points, changes in systems are passed which are irreversible. From The Climate Book by Greta Thunberg “IPCC estimates that global warming will reach 3.2°C by 2100”. When Hurricane Sandy hit New York, 8 billion dollars of damage from the storm surge were because of climate change. In 2003, a heatwave in Europe caused more than 70000 premature deaths, and climate change has doubled the chance of occurrence. If global warming is under 2°C over 50 years, it could prevent 4.5 million premature deaths in the U.S alone. Technology can give us information about peoples ideas—tools like data analysis can assess people’s perception of different issues. For climate change, how would being near a disaster impact a person’s emotions, or their sentiment? And how can we use data from social media platforms such as X, formerly known as Twitter? Answering these questions is key to better inform the general public to help drive change in policy-making in our society. Present examples in tweets show potential areas of interest that we aim to further explore. We aim to observe whether natural disasters amplified by climate change impact people’s sentiment. Compared to surveys that evaluate people’s stance and awareness on current issues, people tend to express themselves more intensely and personally. This advantage is because social media is a less formal environment. Additionally, social media has more younger users and can be more diverse than sample populations used in surveys. As seen from the Pew Research Center report in 2023, when observing user activity among various social platforms such as TikTok, Instagram, Snapchat, Youtube, and Facebook, “a third of teens use at least one of these five sites almost constantly.” This advantageous presentation of information is what allows us to extract more meaningful insights from the readily collected data.

2 Method Proposal

Climatepulse is a web tool that visualizes disasters onto a world map, overlaid by various different tweets. There is a scroll feature for the user to visualize which natural disasters occurred per year. Red dots on the map indicate a recorded disaster, and upon selection, tweets within a 1000 mile radius to the disaster will be displayed. The world map combines tools such as javascript and d3 from the following github repository. Our research aims to use the datasets to see if there are any connections between sentiment and disaster. Both the tweets and disaster data were pooled from the “Climate Change Twitter Dataset” research initiative by Dimitrios Effrosynidis et al. (2022). Over fifteen million data points spanning over thirteen years related to climate change were sourced from the social media platform, where data such as gender, stance, sentiment, and disaster type are included. The tweets are from different people and organizations but are all talking about climate change.

3 Challenges

One primary challenge is incorporating the dataset with the world map interface. For example, the world map has a dropdown menu showing the name of all the countries, however some countries have different naming in the datasets. This would have to be dealt with because it can cause issues in the pairing of those countries and the tweets in the area. Other data is also formatted so javascript code cannot work with it. The disaster data’s date records needed to be converted into standardized date-formatted to work with the code. Additionally creating the interface itself has its own challenges. Disasters are represented with some icons, and the map needs to be constantly updated to remove old icons and add new icons. Also, ever since Elon Musk acquired twitter, the data can’t be accessed directly. This means getting the contents of tweets by hydrating them is no longer viable.

Another challenge was ensuring twitter and disaster data was properly structured and accessible for analysis. A significant portion of data had incomplete properties, so they can’t be visualized. Missing latitude and longitude values means that tweets and disasters can’t be placed on the map. This means that in order to render the data, we would have to preprocess it by parsing dates, grouping records and filtering invalid entries. At the same time, if we filtered out invalid entries it excludes a substantial portion of the data which is misleading. So an approach to get usable data would also need methods to fill in errors in order to keep as much data as possible.

When deciding on the architecture of our LLM, we explored different methods, such as large-context windows and fine-tuned LLMs. We’ve opted for a RAG-based solution, instructing the model to act as a “data analyst” to interact with the dataset. Due to the complexity of the task, and the limitations of accessible data, training and fine-tuning a model seemed less promising compared to the RAG-based solution, where all we need to do is instruct the LLM to generate queries to index our data. We also considered the advantages and drawbacks between an in-memory pandas dataframe versus an out-of-memory SQLite database. Due to the limitations of available cloud-computing resources, and the performance differences for this specific task, designing an LLM to generate SQL queries made more sense for the task of retrieving data efficiently and accurately.

4 Method Analysis

3 The web application is a map visualization tool with a conversational chatbot. can change the year and observe differences in tweet sentiment and disaster severity across various countries. When the user clicks on a disaster, the system will collect from the tweets dataset and select those within a specific time and distance. For more clarification, the user can ask context-driven questions regarding the dataset. The data was grouped based on attributes as year and country, a map object was created to efficiently store tweets based on ID. The visualization update function incorporates the data to be displayed. We fill in missing data points from our dataset using the Google Maps API. Notably, we fill in the missing latitude and longitudinal coordinates by using the region / address a disaster has occurred—that way, we ensure that we can overlay every disaster into the visualization. We used a Google Maps API key to find

the locations based on the data and calculated the coordinates. We also worked more on the data, we removed tweets from the twitter data that didn't have coordinates. Due to the large sample size, and the lack of other geospatial information from the Twitter dataset, finding the location for these tweets was not possible. Pandas was used for extensive data visualization and analysis to better understand the underlying distributions and patterns in the data. For example, one visualization compared the mean sentiment of tweets and their aggressiveness with the worst disasters. The purpose of showing tweets when you click on a disaster is to see if there are changes in sentiment. Specifically, to see if being near a disaster around the time of it is related to sentiment on climate change.

4.1 Component A

3.1

4.2 This is an example for second level head—subsection head

3.1

4.2.1 This is an example for third level head—subsubsection head

3.1.1

Sample body text. Sample body text. Sample body text. Sample body text. Sample body text. Sample body text. Sample body text. Sample body text.

5 Equations

Equations in L^AT_EX can either be inline or on-a-line by itself (“display equations”). For inline equations use the `$...$` commands. E.g.: The equation $H\psi = E\psi$ is written via the command `$H \psi = E \psi$`.

For display equations (with auto generated equation numbers) one can use the `equation` or `align` environments:

$$\|\tilde{X}(k)\|^2 \leq \frac{\sum_{i=1}^p \|\tilde{Y}_i(k)\|^2 + \sum_{j=1}^q \|\tilde{Z}_j(k)\|^2}{p+q}. \quad (1)$$

where,

$$\begin{aligned} D_\mu &= \partial_\mu - ig \frac{\lambda^a}{2} A_\mu^a \\ F_{\mu\nu}^a &= \partial_\mu A_\nu^a - \partial_\nu A_\mu^a + gf^{abc} A_\mu^b A_\nu^c \end{aligned} \quad (2)$$

Notice the use of `\nonumber` in the `align` environment at the end of each line, except the last, so as not to produce equation numbers on lines where no equation numbers

are required. The `\label{}` command should only be used at the last line of an align environment where `\nonumber` is not used.

$$Y_{\infty} = \left(\frac{m}{\text{GeV}}\right)^{-3} \left[1 + \frac{3\ln(m/\text{GeV})}{15} + \frac{\ln(c_2/5)}{15}\right] \quad (3)$$

The class file also supports the use of `\mathbb{}`, `\mathscr{}` and `\mathcal{}` commands. As such `\mathbb{R}`, `\mathscr{R}` and `\mathcal{R}` produces \mathbb{R} , \mathscr{R} and \mathcal{R} respectively (refer Subsubsection ??).

6 Tables

Tables can be inserted via the normal table and tabular environment. To put footnotes inside tables you should use `\footnotetext[...]` tag. The footnote appears just below the table itself (refer Tables 1 and 2). For the corresponding footnotemark use `\footnotemark[...]`

Table 1 Caption text

Column 1	Column 2	Column 3	Column 4
row 1	data 1	data 2	data 3
row 2	data 4	data 5 ¹	data 6
row 3	data 7	data 8	data 9 ²

Source: This is an example of table footnote. This is an example of table footnote.

¹Example for a first table footnote. This is an example of table footnote.

²Example for a second table footnote. This is an example of table footnote.

The input format for the above table is as follows:

```
\begin{table}[<placement-specifier>]
\caption{<table-caption>}\label{<table-label>}%
\begin{tabular}{@{}l l l l@{}}
\toprule
Column 1 & Column 2 & Column 3 & Column 4\\
\midrule
row 1 & data 1 & data 2 & data 3 \\
row 2 & data 4 & data 5\footnotemark[1] & data 6 \\
row 3 & data 7 & data 8 & data 9\footnotemark[2]\\
\botrule
\end{tabular}
```

```

\footnotetext{Source: This is an example of table footnote.
This is an example of table footnote.}
\footnotetext[1]{Example for a first table footnote.
This is an example of table footnote.}
\footnotetext[2]{Example for a second table footnote.
This is an example of table footnote.}
\end{table}

```

Table 2 Example of a lengthy table which is set to full textwidth

Project	Element 1 ¹			Element 2 ²		
	Energy	σ_{calc}	σ_{expt}	Energy	σ_{calc}	σ_{expt}
Element 3	990 A	1168	1547 ± 12	780 A	1166	1239 ± 100
Element 4	500 A	961	922 ± 10	900 A	1268	1092 ± 40

Note: This is an example of table footnote. This is an example of table footnote this is an example of table footnote this is an example of table footnote this is an example of table footnote.

¹Example for a first table footnote.

²Example for a second table footnote.

In case of double column layout, tables which do not fit in single column width should be set to full text width. For this, you need to use `\begin{table*}` ... `\end{table*}` instead of `\begin{table}` ... `\end{table}` environment. Lengthy tables which do not fit in textwidth should be set as rotated table. For this, you need to use `\begin{sidewaystable}` ... `\end{sidewaystable}` instead of `\begin{table*}` ... `\end{table*}` environment. This environment puts tables rotated to single column width. For tables rotated to double column width, use `\begin{sidewaystable*}` ... `\end{sidewaystable*}`.

7 Figures

As per the L^AT_EX standards you need to use eps images for L^AT_EX compilation and pdf/jpg/png images for PDFL^AT_EX compilation. This is one of the major difference between L^AT_EX and PDFL^AT_EX. Each image should be from a single input .eps/vector image file. Avoid using subfigures. The command for inserting images for L^AT_EX and PDFL^AT_EX can be generalized. The package used to insert images in L^AT_EX/PDFL^AT_EX is the graphicx package. Figures can be inserted via the normal figure environment as shown in the below example:

```

\begin{figure}[<placement-specifier>]
\centering
\includegraphics{<eps-file>}

```

Table 3 Tables which are too long to fit, should be written using the “sidewaystable” environment as shown here

Projectile	Element 1 ¹			Element ²		
	Energy	σ_{calc}	σ_{expt}	Energy	σ_{calc}	σ_{expt}
Element 3	990 A	1168	1547 \pm 12	780 A	1166	1239 \pm 100
Element 4	500 A	961	922 \pm 10	900 A	1268	1092 \pm 40
Element 5	990 A	1168	1547 \pm 12	780 A	1166	1239 \pm 100
Element 6	500 A	961	922 \pm 10	900 A	1268	1092 \pm 40

Note: This is an example of table footnote this is an example of table footnote this is an example of table footnote
this is an example of table footnote.

¹ This is an example of table footnote.

```
\caption{<figure-caption>}\label{<figure-label>}
\end{figure}
```



Fig. 1 This is a widefig. This is an example of long caption this is an example of long caption this is an example of long caption this is an example of long caption

In case of double column layout, the above format puts figure captions/images to single column width. To get spanned images, we need to provide `\begin{figure*}` ... `\end{figure*}`.

For sample purpose, we have included the width of images in the optional argument of `\includegraphics` tag. Please ignore this.

8 Algorithms, Program codes and Listings

Packages `algorithm`, `algorithmicx` and `algpseudocode` are used for setting algorithms in \LaTeX using the format:

```
\begin{algorithm}
\caption{<alg-caption>}\label{<alg-label>}
\begin{algorithmic}[1]
. . .
\end{algorithmic}
\end{algorithm}
```

You may refer above listed package documentations for more details before setting `algorithm` environment. For program codes, the “verbatim” package is required and the command to be used is `\begin{verbatim}` ... `\end{verbatim}`.

Similarly, for listings, use the `listings` package. `\begin{lstlisting}` ... `\end{lstlisting}` is used to set environments similar to `verbatim` environment. Refer to the `lstlisting` package documentation for more details.

A fast exponentiation procedure:

```
begin
  for  $i := 1$  to 10 step 1 do
     $\text{expt}(2, i)$ ;
     $\text{newline}()$  od
where
```

Comments will be set flush to the right margin


```

proc expt( $x, n$ )  $\equiv$ 
   $z := 1$ ;
  do if  $n = 0$  then exit fi;
    do if odd( $n$ ) then exit fi;
      comment: This is a comment statement;
       $n := n/2$ ;  $x := x * x$  od;
    {  $n > 0$  };
     $n := n - 1$ ;  $z := z * x$  od;
  print( $z$ ).
end

```

Algorithm 1 Calculate $y = x^n$

Require: $n \geq 0 \vee x \neq 0$

Ensure: $y = x^n$

```

1:  $y \leftarrow 1$ 
2: if  $n < 0$  then
3:    $X \leftarrow 1/x$ 
4:    $N \leftarrow -n$ 
5: else
6:    $X \leftarrow x$ 
7:    $N \leftarrow n$ 
8: end if
9: while  $N \neq 0$  do
10:  if  $N$  is even then
11:     $X \leftarrow X \times X$ 
12:     $N \leftarrow N/2$ 
13:  else [ $N$  is odd]
14:     $y \leftarrow y \times X$ 
15:     $N \leftarrow N - 1$ 
16:  end if
17: end while

```

```

for  $i := \text{maxint}$  to 0 do
begin
  { do nothing }
end;
Write( 'Case-insensitive- ');
Write( 'Pascal-keywords.' );

```

9 Cross referencing

Environments such as figure, table, equation and align can have a label declared via the `\label{#label}` command. For figures and table environments use the `\label{}` command inside or just below the `\caption{}` command. You can then use the `\ref{#label}` command to cross-reference them. As an example, consider the label declared for Figure 1 which is `\label{fig1}`. To cross-reference it, use the command `\ref{fig1}`, for which it comes up as “Figure 1”.

To reference line numbers in an algorithm, consider the label declared for the line number 2 of Algorithm 1 is `\label{algn2}`. To cross-reference it, use the command `\ref{algn2}` for which it comes up as line 2 of Algorithm 1.

9.1 Details on reference citations

Standard L^AT_EX permits only numerical citations. To support both numerical and author-year citations this template uses `natbib` L^AT_EX package. For style guidance please refer to the template user manual.

Here is an example for `\cite{...}`: [?]. Another example for `\citep{...}`: [?]. For author-year citation mode, `\cite{...}` prints Jones et al. (1990) and `\citep{...}` prints (Jones et al., 1990).

All cited bib entries are printed at the end of this article: [?], [?], [?], [?], [?], [?], [?], [?], [?], [?] and [?].

10 Examples for theorem like environments

For theorem like environments, we require `amsthm` package. There are three types of predefined theorem styles exists—`thmstyleone`, `thmstyletwo` and `thmstylethree`

<code>thmstyleone</code>	Numbered, theorem head in bold font and theorem text in italic style
<code>thmstyletwo</code>	Numbered, theorem head in roman font and theorem text in italic style
<code>thmstylethree</code>	Numbered, theorem head in bold font and theorem text in roman style

For mathematics journals, theorem styles can be included as shown in the following examples:

Theorem 1 (Theorem subhead) *Example theorem text. Example theorem text. Example theorem text. Example theorem text. Example theorem text. Example theorem text. Example theorem text. Example theorem text. Example theorem text. Example theorem text.*

Sample body text. Sample body text. Sample body text. Sample body text. Sample body text. Sample body text. Sample body text. Sample body text.

Proposition 2 *Example proposition text. Example proposition text. Example proposition text. Example proposition text. Example proposition text. Example proposition text. Example proposition text. Example proposition text. Example proposition text.*

Sample body text. Sample body text. Sample body text. Sample body text. Sample body text. Sample body text. Sample body text. Sample body text.

Example 1 Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem.

Sample body text. Sample body text. Sample body text. Sample body text. Sample body text. Sample body text. Sample body text. Sample body text.

Remark 1 Phasellus adipiscing semper elit. Proin fermentum massa ac quam. Sed diam turpis, molestie vitae, placerat a, molestie nec, leo. Maecenas lacinia. Nam ipsum ligula, eleifend at, accumsan nec, suscipit a, ipsum. Morbi blandit ligula feugiat magna. Nunc eleifend consequat lorem.

Sample body text. Sample body text. Sample body text. Sample body text. Sample body text. Sample body text. Sample body text. Sample body text.

Definition 1 (Definition sub head) Example definition text. Example definition text. Example definition text. Example definition text. Example definition text. Example definition text. Example definition text.

Additionally a predefined “proof” environment is available: `\begin{proof} ... \end{proof}`. This prints a “Proof” head in italic font style and the “body text” in roman font style with an open square at the end of each proof environment.

Proof Example for proof text. Example for proof text. Example for proof text. Example for proof text. Example for proof text. Example for proof text. Example for proof text. Example for proof text. Example for proof text. Example for proof text. \square

Sample body text. Sample body text. Sample body text. Sample body text. Sample body text. Sample body text. Sample body text. Sample body text.

Proof of Theorem 1 Example for proof text. Example for proof text. Example for proof text. Example for proof text. Example for proof text. Example for proof text. Example for proof text. Example for proof text. Example for proof text. Example for proof text. \square

For a quote environment, use `\begin{quote} ... \end{quote}`

Quoted text example. Aliquam porttitor quam a lacus. Praesent vel arcu ut tortor cursus volutpat. In vitae pede quis diam bibendum placerat. Fusce elementum convallis neque. Sed dolor orci, scelerisque ac, dapibus nec, ultricies ut, mi. Duis nec dui quis leo sagittis commodo.

Sample body text. Sample body text. Sample body text. Sample body text. Sample body text (refer Figure 1). Sample body text. Sample body text. Sample body text (refer Table 3).

11 Methods

Topical subheadings are allowed. Authors must ensure that their Methods section includes adequate experimental and characterization data necessary for others in the field to reproduce their work. Authors are encouraged to include RIIIDs where appropriate.

Ethical approval declarations (only required where applicable) Any article reporting experiment/s carried out on (i) live vertebrate (or higher invertebrates), (ii) humans or (iii) human samples must include an unambiguous statement within the methods section that meets the following requirements:

1. Approval: a statement which confirms that all experimental protocols were approved by a named institutional and/or licensing committee. Please identify the approving body in the methods section
2. Accordance: a statement explicitly saying that the methods were carried out in accordance with the relevant guidelines and regulations
3. Informed consent (for experiments involving humans or human tissue samples): include a statement confirming that informed consent was obtained from all participants and/or their legal guardian/s

If your manuscript includes potentially identifying patient/participant information, or if it describes human transplantation research, or if it reports results of a clinical trial then additional information will be required. Please visit (<https://www.nature.com/nature-research/editorial-policies>) for Nature Portfolio journals, (<https://www.springer.com/gp/authors-editors/journal-author/journal-author-helpdesk/publishing-ethics/14214>) for Springer Nature journals, or (<https://www.biomedcentral.com/getpublished/editorial-policies#ethics+and+consent>) for BMC.

12 Discussion

Discussions should be brief and focused. In some disciplines use of Discussion or ‘Conclusion’ is interchangeable. It is not mandatory to use both. Some journals prefer a section ‘Results and Discussion’ followed by a section ‘Conclusion’. Please refer to Journal-level guidance for any specific requirements.

13 Conclusion

Conclusions may be used to restate your hypothesis or research question, restate your major findings, explain the relevance and the added value of your work, highlight any limitations of your study, describe future directions for research and recommendations.

In some disciplines use of Discussion or 'Conclusion' is interchangeable. It is not mandatory to use both. Please refer to Journal-level guidance for any specific requirements.

Supplementary information. If your article has accompanying supplementary file/s please state so here.

Authors reporting data from electrophoretic gels and blots should supply the full unprocessed scans for key as part of their Supplementary information. This may be requested by the editorial team/s if it is missing.

Please refer to Journal-level guidance for any specific requirements.

Acknowledgements. Acknowledgements are not compulsory. Where included they should be brief. Grant or contribution numbers may be acknowledged.

Please refer to Journal-level guidance for any specific requirements.

Declarations

Some journals require declarations to be submitted in a standardised format. Please check the Instructions for Authors of the journal to which you are submitting to see if you need to complete this section. If yes, your manuscript must contain the following sections under the heading 'Declarations':

- Funding
- Conflict of interest/Competing interests (check journal-specific guidelines for which heading to use)
- Ethics approval and consent to participate
- Consent for publication
- Data availability
- Materials availability
- Code availability
- Author contribution

If any of the sections are not relevant to your manuscript, please include the heading and write 'Not applicable' for that section.

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Scientific Reports: <https://www.nature.com/srep/journal-policies/editorial-policies>

BMC journals: <https://www.biomedcentral.com/getpublished/editorial-policies>

Appendix A Section title of first appendix

An appendix contains supplementary information that is not an essential part of the text itself but which may be helpful in providing a more comprehensive understanding of the research problem or it is information that is too cumbersome to be included in the body of the paper.