AI for Climate Change - Final Report

Team Name: Glacier Guardian

1. Introduction

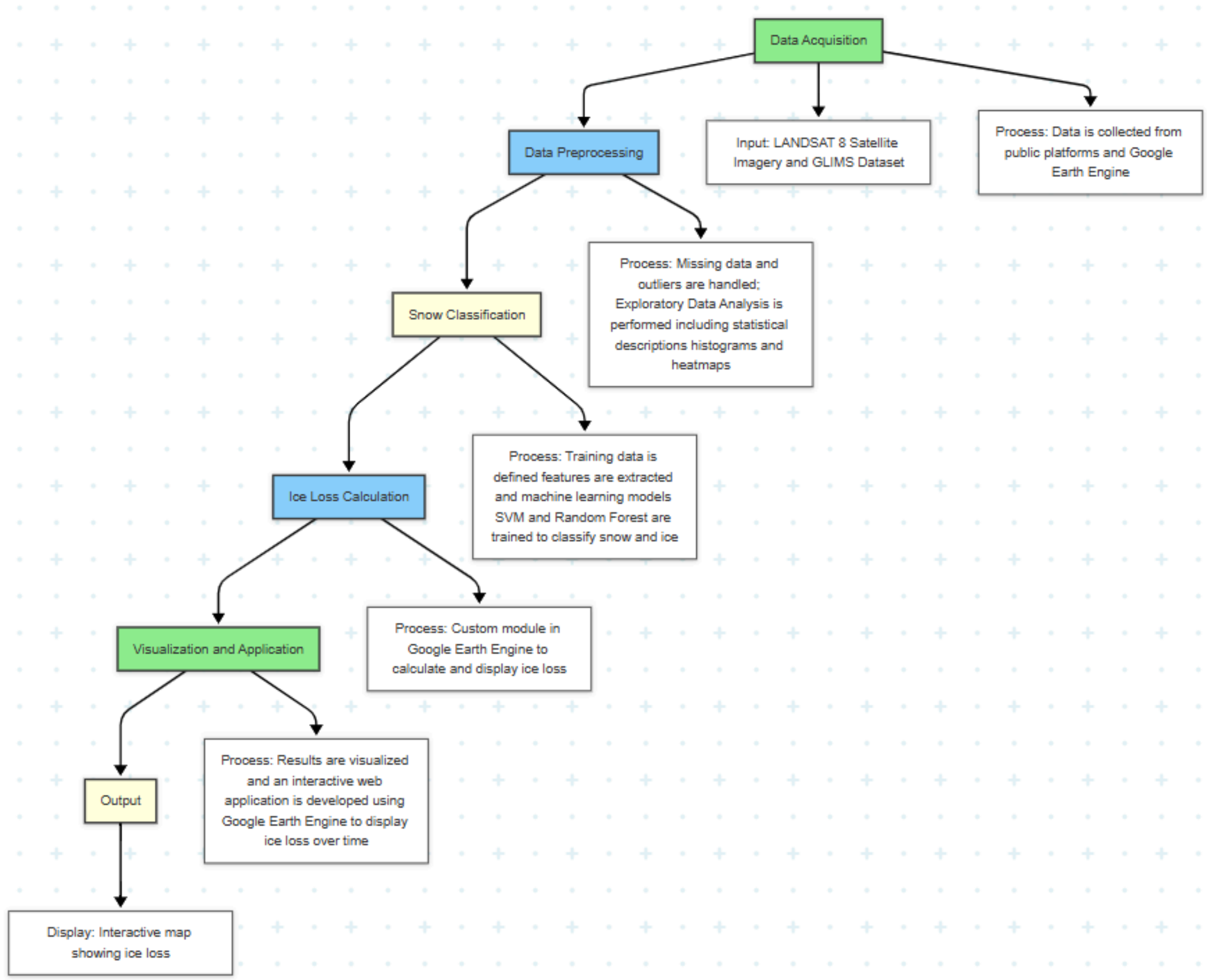
· Contextualizing the theme of the project

The Earth's climate is changing at an unprecedented rate, leading to significant impacts on various ecosystems. One of the most visible and critical indicators of this change is the melting of ice masses, including glaciers and ice sheets. Glaciers are particularly important as they serve as major freshwater reservoirs, and their melting contributes to sea-level rise, affecting coastal communities and ecosystems worldwide. Monitoring and predicting glacier changes is crucial for understanding the rate of climate change and its potential consequences. This project focuses on leveraging Artificial Intelligence (AI) to address the challenges associated with monitoring and predicting the effects of climate change on ice melting.

· Highlighting the advantage of using AI in solving the project problem

Traditional methods of monitoring glacier changes, such as field measurements and manual analysis of satellite imagery, are often time-consuming, labor-intensive, and limited in spatial and temporal coverage. AI, particularly machine learning, offers powerful tools to overcome these limitations. AI algorithms can automatically process large volumes of satellite data, extract relevant features, and detect subtle changes that may be difficult for humans to identify. By learning from historical data, AI models can also predict future trends, providing valuable insights for policymakers and stakeholders. In this project, AI is used to:

- **Automate the analysis of satellite imagery:** Machine learning algorithms can be trained to classify snow and ice cover, identify melt patterns, and quantify ice loss from satellite images.
- **Improve accuracy and efficiency:** AI models can achieve higher accuracy and efficiency compared to traditional methods, enabling more reliable and timely monitoring of glacier changes.
- **Enable large-scale analysis:** AI can process vast amounts of data from various sources, allowing for comprehensive monitoring of glacier changes at regional and global scales.
- **Predict future trends:** Machine learning models can be used to identify trends and predict future ice loss, providing critical information for climate change adaptation and mitigation efforts.



2. Existing methods for solving the problem

This project builds upon previous research in the field of AI for climate change, particularly in the analysis of satellite imagery for monitoring ice and snow. Two relevant articles are:

· **Article 1: Predicting Ice Flow using Machine Learning**

- **Data Used:** LANDSAT 8 satellite images.
- **Algorithm Used:** Stochastic Video Generation with Prior for Prediction, employing Convolutional LSTM for temporal modeling and a Deep Convolutional GAN for image prediction.
- **Results Obtained:** The model accurately reproduced ice flow patterns, improved correlation between subscenes, and enhanced the ability to track small textures. Challenges included noisy signals from high-pass filtering and the impact of cloud cover.

· **Article 2: Machine Learning for Sea Ice Monitoring From Satellites**

- **Data Used:** Sentinel-1 SAR data.
- **Algorithm Used:** Active Learning with Support Vector Machine (SVM), Variational Autoencoder (VAE), and k-Nearest Neighbors (k-NN).
- **Results Obtained:** The models achieved high classification performance, with k-NN reaching 89% accuracy and SVM reaching 88% accuracy. The study also quantified changes in ice cover and detected seasonal ice transitions.

3. Methods and Experimental Results

This project employs machine learning techniques to classify snow cover and analyze glacier changes using satellite imagery.

· **Data and Methodology**

- **Data Sets Used:**
    - **LANDSAT 8 satellite images:** Multi-spectral images with 7 bands (0.43m to 2.29m, covering visible, near-infrared, and shortwave light). The spatial resolution of the LANDSAT 8 images is 30 meters.
    - **GLIMS_Full_Dataset.csv:** Contains information about glacier topography, including location, size, and descriptive parameters.
- Experimental Methodology:
  The experiments were designed to answer the following questions:
    1. How accurately can machine learning models classify snow cover using LANDSAT 8 satellite imagery?
    2. Which machine learning algorithm (SVM or Random Forest) performs better for this classification task?
    3. How can the results of the classification be visualized and used to monitor ice loss over time?

  The methodology involved these steps:
    1. **Data Acquisition and Preparation**:
        - LANDSAT 8 images were acquired using Google Earth Engine (GEE).
        - Training data was defined by merging "snow" and "no_snow" data.
        - Exploratory Data Analysis was conducted on the GLIMS dataset.
    2. **Model Training**:
        - SVM and Random Forest classifiers were trained using the prepared training data.
        - For the SVM classifier, the following spectral bands from the LANDSAT 8 images were used as input properties: 'Blue', 'Green', 'Red', 'NIR', 'SWIR1', 'SWIR2', and 'NSI'.

        - The Random Forest classifier is an ensemble algorithm that combines multiple decision trees, reducing the risk of overfitting and improving the model's accuracy and generalization.
3. **Model Evaluation**:
    - The performance of both classifiers was evaluated using confusion matrices and accuracy metrics.
4. **Application Development**:
    - A Google Earth Engine (GEE) application was developed and deployed.
    - The application allows users to select a year and view (NSI, RGB, Ice Loss).
    - A custom GEE module (`melting_heatmap`) was used to calculate and display ice loss.
5. **Visualization and Analysis**:
    - The application was used to display classified images and ice loss.

· **Results Obtained**

The key results obtained from the experiments are:

- **SVM Classifier Performance:** The SVM classifier achieved an accuracy of 0.766.
- **Random Forest Classifier Performance:** The Random Forest classifier significantly improved the accuracy to 0.979.

· **Statistical/descriptive analysis of the results obtained**

The Random Forest classifier significantly outperformed the SVM classifier in this task. The confusion matrix for the Random Forest classifier shows that it correctly classified most of the data points, with very few misclassifications. This demonstrates the effectiveness of the Random Forest approach for classifying snow cover in LANDSAT 8 imagery. The improvement in accuracy from 0.766 (SVM) to 0.979 (Random Forest) shows a substantial increase in the reliability of the classification.

4. Conclusions and possible improvements

This project demonstrated the potential of AI for monitoring and predicting the effects of climate change on ice melting. The Random Forest classifier proved to be highly effective in classifying snow cover from LANDSAT 8 satellite imagery, achieving an accuracy of 0.979. The Google Earth Engine application provides a user-friendly interface for visualizing ice loss over time.

Possible improvements and future work include:

- **Incorporate additional data sources:** Integrating data from other satellite sensors (e.g., Sentinel) and ground-based measurements could improve the accuracy and robustness of the models.

- **Explore advanced AI techniques:** Investigating more advanced deep learning techniques, such as convolutional neural networks (CNNs) and recurrent neural networks (RNNs), could potentially improve the classification and prediction performance.
- **Improve the GEE application:** Enhancing the GEE application with additional features, such as time-series analysis tools and the ability to download data, could make it more useful for researchers and policymakers.
- **Expand the scope:** Applying the methodology to other regions and different types of ice masses (e.g., ice sheets, sea ice) could provide a more comprehensive understanding of the impact of climate change on ice melting.

5. References

- Article 1: Predicting Ice Flow using Machine Learning
- Article 2: Machine Learning for Sea Ice Monitoring From Satellites

6. Appendices

- GEE Application Link: https://ee-icemonitor.projects.earthengine.app/view/glacier-guardian