Himashield 2025

Team Name - Glofsense

Problem Statement Title - Early warning detection system for

Glacial Lake Outburst Floods (GLOFs)

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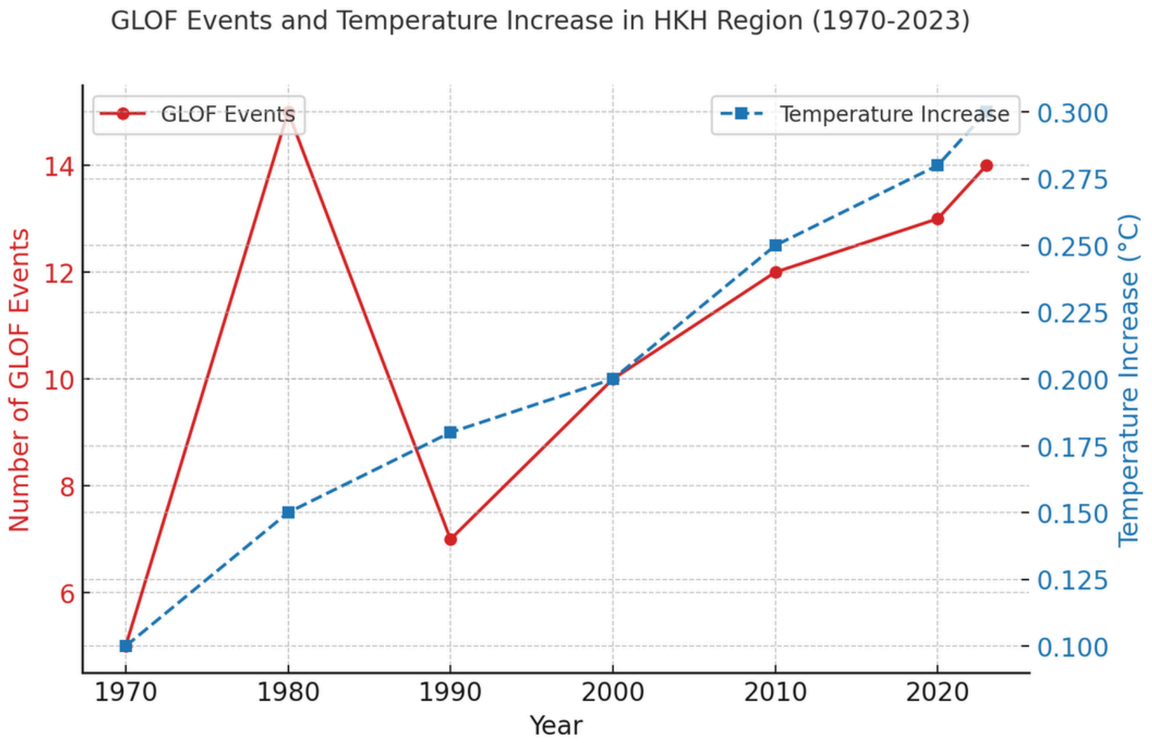
Problem

- Between 1970 and 2023, India experienced around **55 GLOFs**, with the **2013 Kedarnath disaster** causing **~6,000 deaths** and the **2023 South Lhonak Lake GLOF** killing at least **46 people** and destroying the Teesta III Hydropower Plant.

- Over **2 million people** in India are at risk, with **188 critical glacial lakes** identified, mainly in Jammu & Kashmir and Sikkim.

- Around 54% of GLOFs are triggered by **avalanches, landslides, or rockfalls**, while 18% result from **extreme rainfall**.

- Climate change, with a **0.2°C per decade warming rate**, is accelerating glacial melt and increasing GLOF risks.



Past GLOF Occurence in HKH region

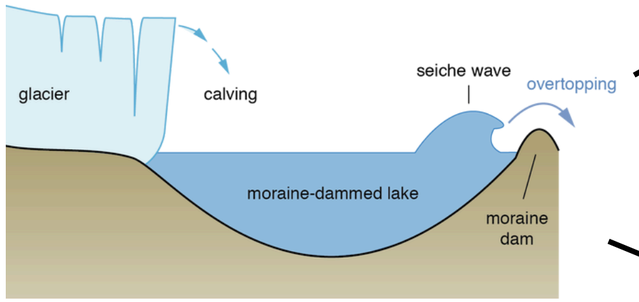
1. https://www.downtoearth.org.in/natural-disasters/what-190-years-of-glacial-lake-outburst-flood-data-tells-us-about-the-hindu-kush-himalayas-93412

2. https://www.unoosa.org/documents/pdf/psa/activities/2024/UN-CostaRica/T5/01-Shrestha.pdf

Idea

- Our Idea is make a web interface (**glofsense.com**) for early prediction of GLOFs in **Hindukush and Sikkim region**. **(188 lakes)**
- We use a integrated approach of **Sensor deployment in lake (Float) and attachment to shores** and **Prediction of outburst based using Sentinel 1 GRD Db Gamma images (around 600)**.
- For sensor based detection, we developed a **floating device (Water temperature, Gyro, GPS, Air Temperature, Humidity)** and **shore attachment (vibration, Humidity)** and data can be transferred through LORA (For now - **INSAT preferred**) with hybrid battery.
- The ML model trains by time-series data of lake images from 1970 - 2023 by **LSTM** to predict the increase in area and perimeter. We achieved an **96% accuracy**.
- Upon increase in threshold, the data will be transmitted to nearest control center and buzzer to alert residents.

Real time workflow (overview):



lake with high risk of GLOF

Device To float on lake & attached to shore

Data transmission on Increase of threshold values

send alert to nearest control centre

Alerts residents to migrate

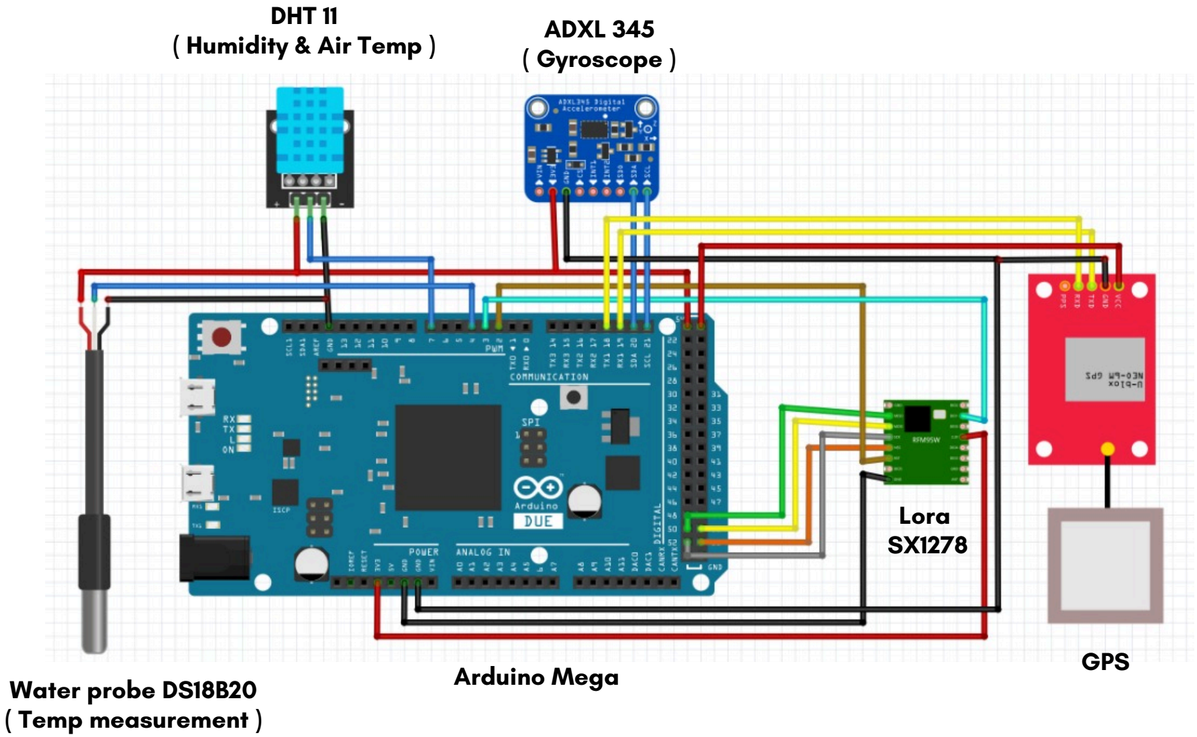
Sentinel 1 images of the same lake

ensembled CNN model to predict increase in size

Alert messages to our website and NDAP

Sensor based prediction

Circuit Architecture (Floating device) :

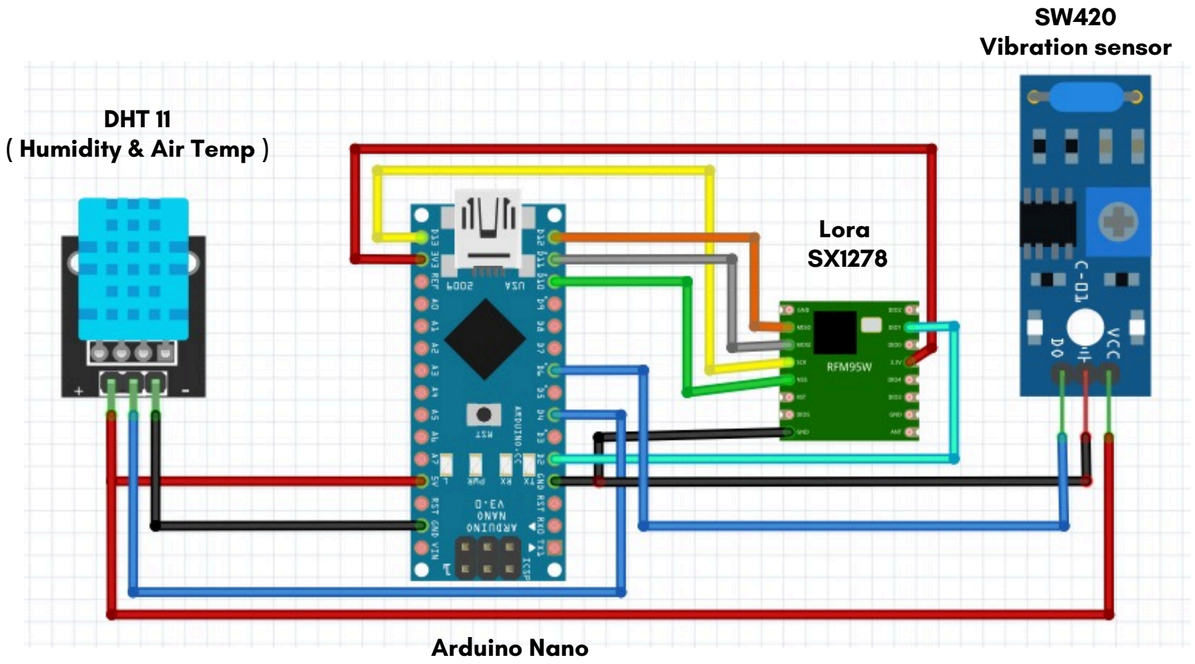


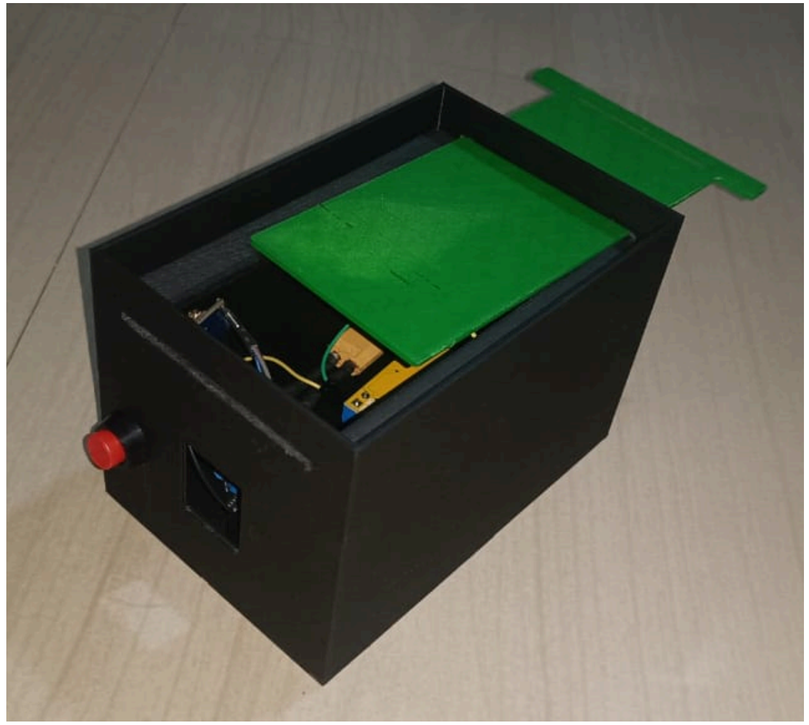
Floating Device for Glacial lakes with alert system

- The device will transmit sensor data to an **LORA receiver**, that will transmit the **final packets to Firebase**
- The Device can **withstand Temperatures upto (-45 C)** and **Ice formation due to it's build.**
- Installation of these devices can be done through **drones** to remote lakes and the whole setup weighs around **2.5kg.**

Sensor based prediction

Circuit Architecture (shore attachment) :





- This device will be **attached to steady shores to transmit vibrational data**, which is the major cause of GLOFs
- It weighs around **150g** and vibrational sensor will be embedded to the steady shore. It transmits the data to the same **LORA reciever.**

Shore Attachment Device for Glacial lakes focused on vibrations.

Sensor based prediction

Predictive Analytical model:

Data collection From sensors

Altitude (m)	Humidity (%)	Latitude	Longitude	Temp (°C)	Water Temp (°C)	X-Axis (°)	Y-Axis (°)	Z-Axis (°)	Humidity (%)	Temp (°C)	Vibration (Hz)	**GLOF_ risk**
0.00	43.00	0.000000	0.000000	32.00	31.75	-0.08	1.22	8.75	28.10	31.20	290.00	**High**

Feature selection and preprocessing

```
features = {
    "Vibration": 3.0,
    "Temperature": 2.5,
    "Altitude": 2.5,
    "Water Temperature": 2.0,
    "Humidity": 1.5,
    "Tilt (X, Y, Z)": 1.0
}
```

XG_boost model

$$\hat{y}_i = \sum_{m=1}^{M} \gamma_m T_m(x_i) = \sum_{m=1}^{M} \gamma_m \sum_{j=1}^{L_m} w_{mj} 1(x_i \in R_{mj})$$

```
num_round = 100
model = xgb.train(params, dtrain, num_round)
```

Evaluation for prediction

```
Accuracy: 99.40%
Confusion Matrix:
 [[204   0   0]
 [  0 196   0]
 [  0   3  97]]
Classification Report:
              precision    recall  f1-score   support

         Low       1.00      1.00      1.00       204
      Medium       0.98      1.00      0.99       196
        High       1.00      0.97      0.98       100

    accuracy                           0.99       500
   macro avg       0.99      0.99      0.99       500
weighted avg       0.99      0.99      0.99       500

F1 Score: 0.99
Precision: 0.99
Recall: 0.99
AUC (Area Under Curve): 1.00
```

Sensor based prediction

Deployment : (South Lhonak lake - LANDSAT image)

- **Floating device**
- **Shore Attachment**
- **LORA reciever at the top**
- **camera**

the sensor feeds along with the model prediction will be send to nearest disaster management centre.

Alert buzzers can be added to important areas of possible GLOF villages.

The prediction will provide enough time of **3 - 5 days** for evacuation or further measures.

Alerts to Pakyong centre in the case of South Lhonak lake

buzzer alert system to provide alarms in villages.

SAR Based Prediction (Satellite)

Sentinel 1 GRD Db Gamma IW_VV (20 mm) Image of South Lhonak lake (On 25.02.2025)

Data collection Sentinel Hub API on real time updated to the model's data

Preprocessed image with water on the mid (black) surrounded by Terrain on white boundary

Preprocessing through Gaussian blur and Otsu's Thresholding for SAR images.

```
1. Model Performance Metrics
--------------------------
Mean Squared Error: 0.013063
Root Mean Squared Error: 0.114292
R⍰ Score: 0.749375
Mean Absolute Percentage Error: 21.37%

2. Classification Performance
---------------------------
Accuracy: 0.9621052631578947
Precision: 1.0000
Recall: 0.8333
F1 Score: 0.9091

3. Future Predictions
------------------
Date: 2025-03-07
  - Area: 176141.47 pixels
  - Perimeter: 9431.13 pixels
  - Area/Perimeter Ratio: 18.0532
  - GLOF Risk Level: 0.3542
```

Model with 96% accuracy on predicting GLOF based on area and perimeter increase

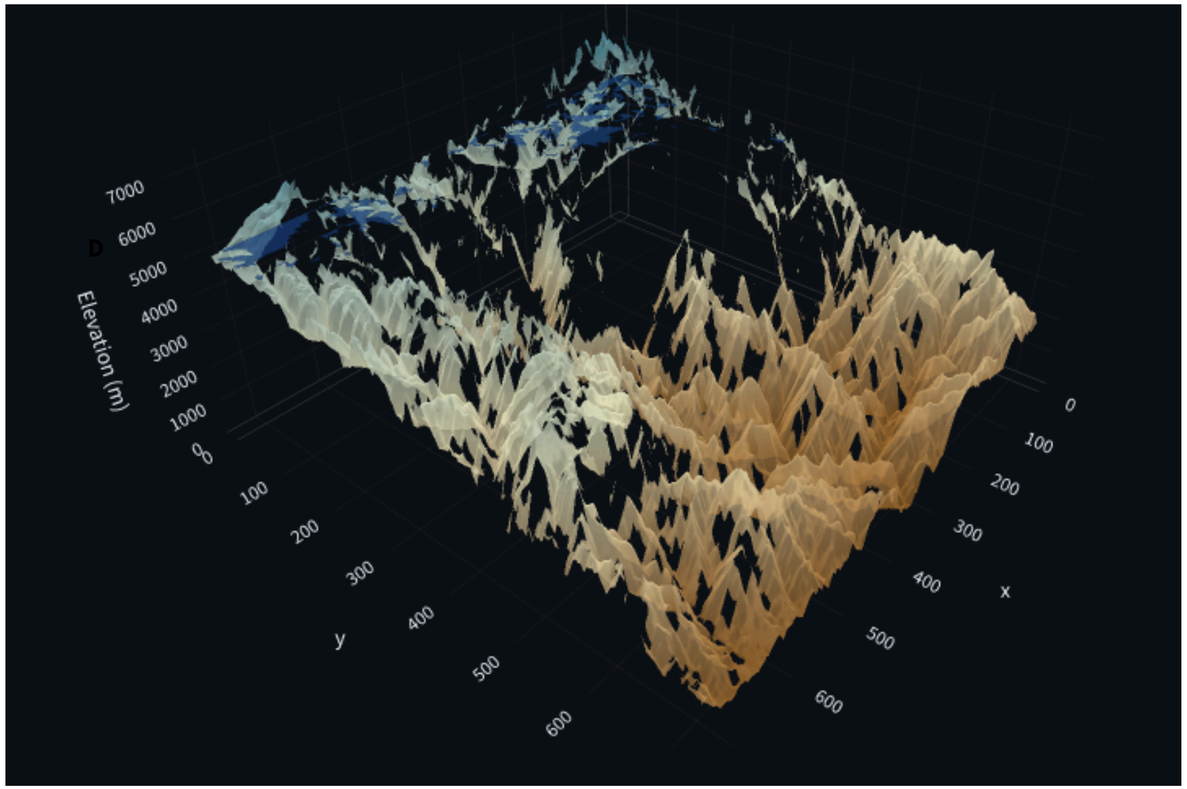
A two-layered LSTM network is used for Model training with 100 Epochs of 600 images.

Water Flow Visualizer

Often times, the parent lake is from another country (Pakishan & China) and Flow of water is harder to detect.

We made an tool to visualize the waterflow from top to the roots, when a DEM is given is an input.

- The DEM is **uploaded, downsampled, and smoothed, with a water threshold** set based on elevation.
- A **3D plot is initialized using Plotly**, displaying the terrain and water layer.
- Water spreads using **binary dilation, constrained by elevation, with flow speed** controlling the expansion rate per frame.
- Metrics like **coverage, volume, depth, and velocity** are calculated and displayed in real time as the simulation progresses.



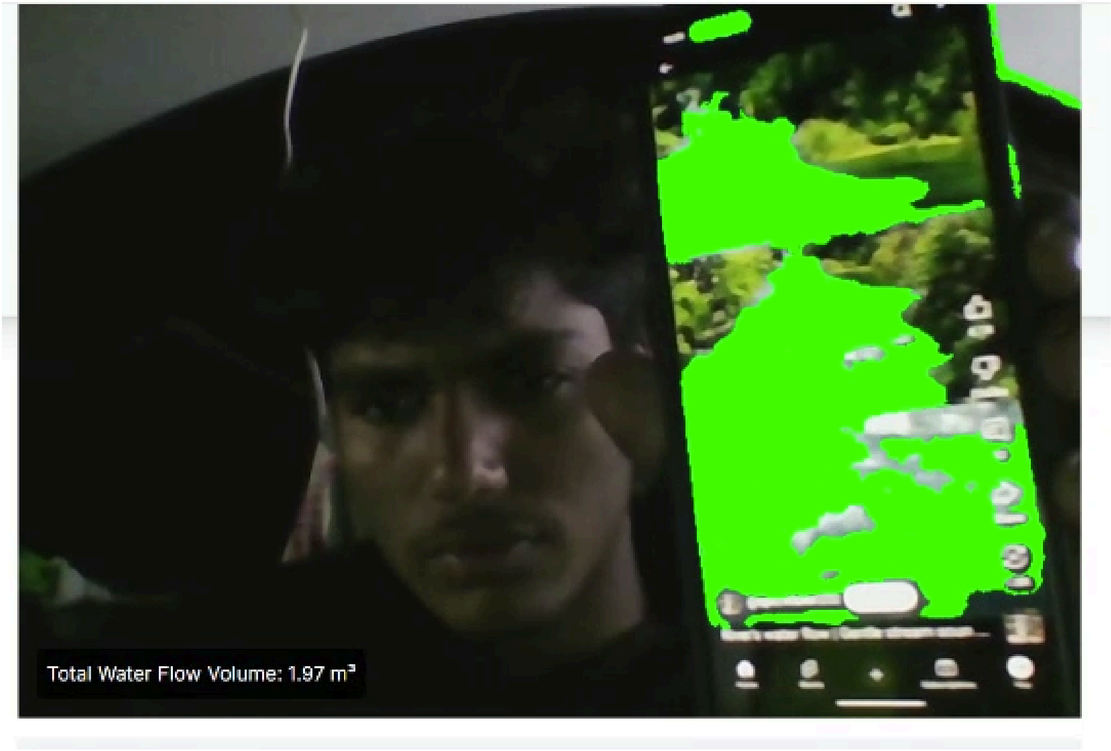
Water Flow of a DEM in Karakoram range

Camera motion detector

Current methods involve motion detection of a water through manual labour,

We made a tool which detects abrupt motion in lake through an camera and alerts based on flow volume.

- The camera interface processes video from a **webcam, IP camera, or uploaded file** for real-time glacial lake detection.
- It captures frames, converts them to a canvas, and analyzes water pixels based on **HSV color ranges.**
- The processed image highlights **detected water areas, calculates volume**, and updates the display.
- Users can configure **calibration settings and start/stop detection**. Errors are handled, and results are shown as an overlay on the video feed.



Flow prediction sample using MP4

Feasibility (cost analysis)

Hardware components :

Component	Explanation
MS5803-14BA	Water level sensor
DHT11	Temperature sensor
YFS201	Water flow sensor
ADXL345	Tilt/Inclinometer sensor
BME280	Pressure/Humidity sensor
NEO-6M GPS	Location tracking
LoRa SX1276	Long-range communication
ESP32	Main microcontroller
Solar Panel	Power supply
Li-ion Battery	Power storage

Software components :

Component	Explanation
Python	Programming language
LSTM	Machine learning model
Onrender	Web server for UI
Sentinel Hub	Image dataset (600 images)

Cost :

The cost of a one particular setup comes out be **16000** and one time installation cost will be **4000**.

For a lake, we need **20000 INR**

To monitor all **critical lakes in India (189)** - we need **38 lakhs.**

References & demo

Github - https://github.com/Ni8crawler18/glofsense

Website - https://glofsense.com

Youtube - https://youtu.be/aGuI9aw29T4

Papers

1. https://www.unisdr.org/files/14048_ICIMODGLOF.pdf
   Formation of Glacial Lakes in the Hindu Kush-Himalayas and GLOF Risk Assessment.

2. https://link.springer.com/article/10.1007/s12665-021-09740-1
   Prevalent risk of glacial lake outburst flood hazard in the Hindu Kush-Karakoram-Himalaya region of Pakistan.

3. https://www.tandfonline.com/doi/full/10.1080/19475705.2011.615344
   Glacial lake outburst flood hazards in Hindukush, Karakoram and Himalayan Ranges.

4. https://www.researchgate.net/publication/358958944
   Glacial Lake Outburst Flood (GLOF) Triggering Factors at Hindu Kush-Himalaya, Mt. Everest Region, Nepal.

Thank you

Will do a demo now.

Floating Device deployment in the college.