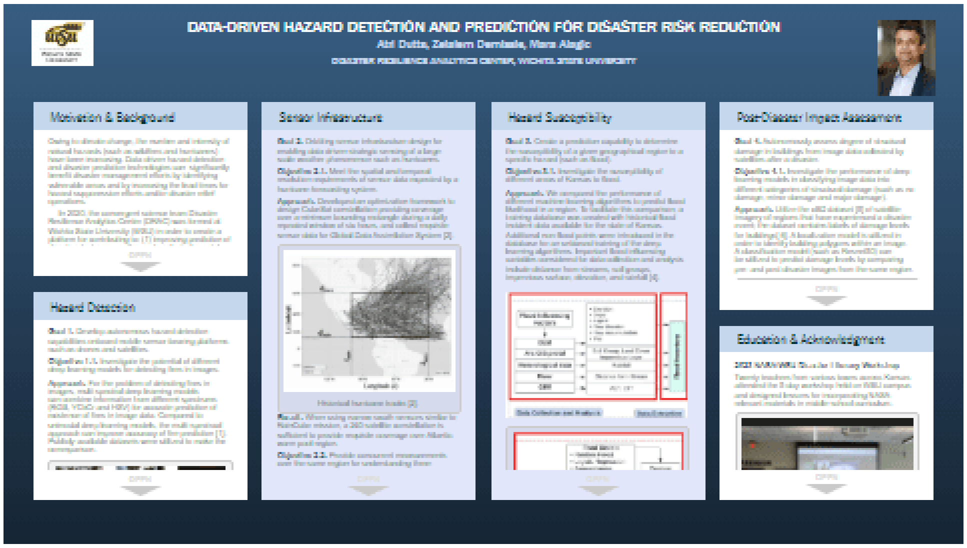
DATA-DRIVEN HAZARD DETECTION AND PREDICTION FOR DISASTER RISK REDUCTION



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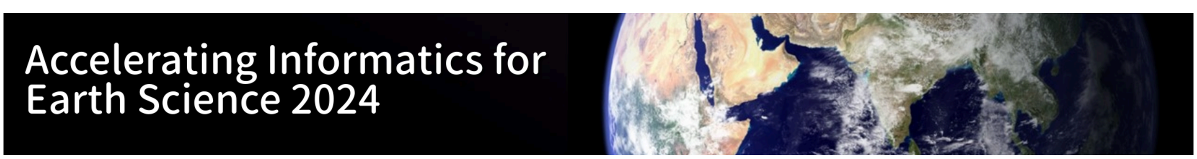
PRESENTED AT:



MOTIVATION & BACKGROUND

Owing to climate change, the number and intensity of natural hazards (such as wildfires and hurricanes) have been increasing. Data-driven hazard detection and disaster prediction technologies can significantly benefit disaster management efforts by identifying vulnerable areas and by increasing the lead times for hazard supporession efforts and/or disaster relief operations.

In 2020, the convergent science team Disaster Resilience Analytics Center (DRAC) was formed at Wichita State University (WSU) in order to create a platform for contributing to: (1) improving prediction of disasters (extreme weather and geological events), (2) understanding the resilience of communities to such disasters, (3) creating awareness in the communities of the Great Plains region regarding potential risks and mitigation strategies, through outreach and STEM education.

HAZARD DETECTION

Goal 1: Develop autonomous hazard detection capabilities onboard mobile sensor-bearing platforms such as drones and satellites.

Objective 1.1: Investigate the potential of different deep learning models for detecting fires in images.

Approach: For the problem of detecting fires in images, multi-spectral deep learning models can combine information from different spectrums (RGB, YCbCr and HSV) for accurate prediction of existence of fires in image data. Compared to unimodal deep learning models, the multi-spectraal approach can improve accuracy of fire prediction [1]. Publicly-available datasets were utilized to make the commparison.

Sample image types for wildfire occurrences [1].

Objective 1.2: Reduce the computational resource requirements of data-driven fire detection algorithms.

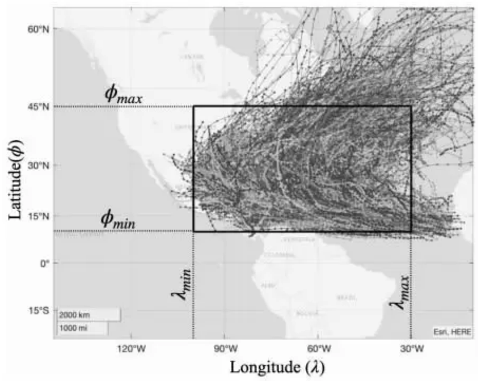
Approach: Develop lightweight models, which require relatively lower computational power, and investigate their potential for incoorporation within drones or satellites.

SENSOR INFRASTRUCTURE

Goal 2: Orbtiting sensor infrasturcture design for enabling data-driven strategic sensing of a large-scale weather phenomenon such as hurricanes.

Objective 2.1: Meet the spatial and temporal resolution requirements of sensor data expected by a hurricane-forecasting system.

Approach: Developed an optimization framework to design CubeSat constellation providing coverage over a minimum bounding rectangle during a daily repeated window of six hours, and collect requisite sensor data for Global Data Assimilation System [2].

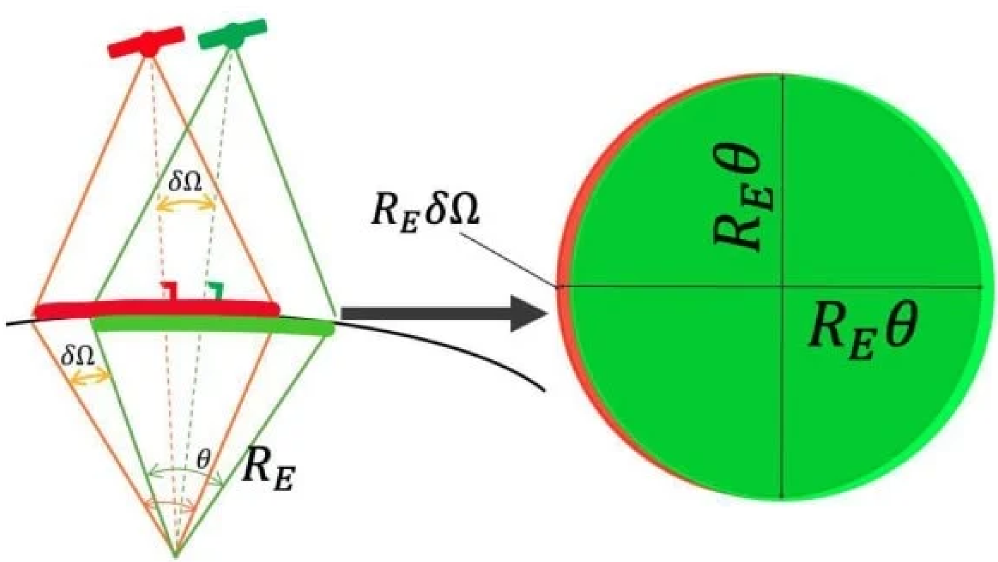


Historical hurricane tracks [2].

Result: When using narrow-swath sensors similar to RainCube mission, a 240 satellite constellation is sufficient to provide requisite coverage over Atlantic warm pool region.

Objective 2.2: Provide concurrent measurements over the same region for understanding three-dimensional structure of precipitation systems.

Approach: Design formation flying spacecraft with overlapping coverage between chief and deputy satellites containing different sensors onboard [3].



Overlapping coverage between satellites for concurrent measurement [3].

Result: Formation flying spacecraft utilizing miniaturized precipitation and synthetic aperture radars can potentially be used to provide measurements over a region of overlapping coverage; different formation architecture were considered to identify scenarios where the amount of propellant needed for formation-keeping is reasonable [3].

Objective 2.3: Create a framework for data-driven sensing of precipitation systems.

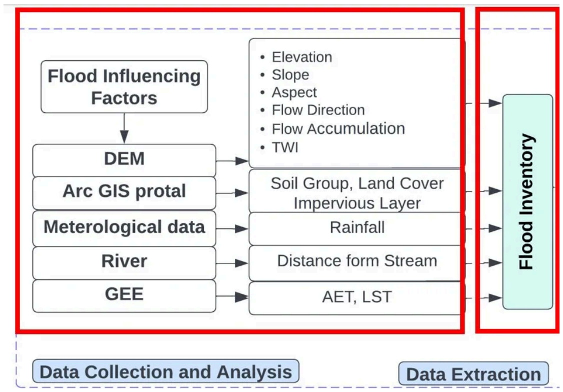
Approach: Consider an architecture when the satellite is aware of anticipated hurricane path from prior forecasts. Determine satellite maneuvering strategies for enhancing sensor data collection close to the eye of the storm.

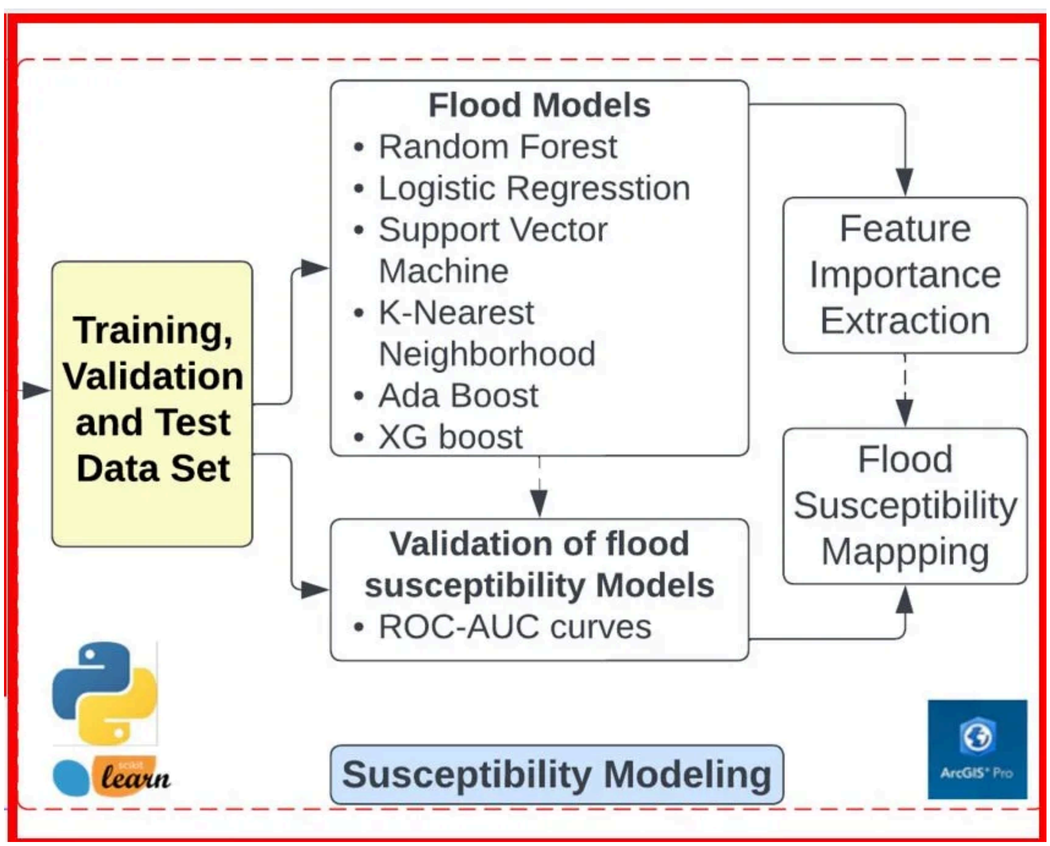
HAZARD SUSCEPTIBILITY

Goal 3: Create a prediction capability to determine the susceptibility of a given geographical region to a specific hazard (such as flood).

Objective 3.1: Investigate the susceptibility of different areas of Kansas to flood.

Approach: We compared the performance of different machine learning algorithms to predict flood likelihood in a region. To facilitate this comparison, a training database was created with historical flood incident data available for the state of Kansas. Additional non-flood points were introduced in the database for an unbiased training of the deep learning algorithms. Important flood influencing variables considered for data collection and analysis include distance from streams, soil groups, impervious surface, elevation, and rainfall [4].





Block diagram representation of methodology: flood inventory (right of top figure) is the basis for the data set (left of bottom figure) [4].

Results: Random forest (RF) and XGBoost Models outperformed others. Varied response per resolution (no clear pattern was observed) but finer resolution dataset is preferred.

Significant differences observed in highly vulnerable flood-prone areas for two separate scenarios highlight the importance of including non-flood control points in the modeling process. Stacking-based approach showed improved performance while using RF.

Flood susceptibility maps can serve as a foundation for developing strategies to minimize flood susceptibility and aid in the formulation of adaptation measures.

POST-DISASTER IMPACT ASSESSMENT

Goal 4: Autonomously assess degree of structural damage in buildings from image data collected by satellites after a disaster.

Objective 4.1: Investigate the performance of deep learning models in classifying image data into different categories of structural damage (such as no damage, minor damage and major damage).

Approach: Utilize the xBD dataset [5] of satellite imagery of regions that have experienced a disaster event; the dataset contains labels of damage levels for buildings[6]. A localization model is utilized in order to identify building polygons within an image. A classification model (such as Resnet50) can be utilized to predict damage levels by comparing pre- and post-disaster images from the same region.

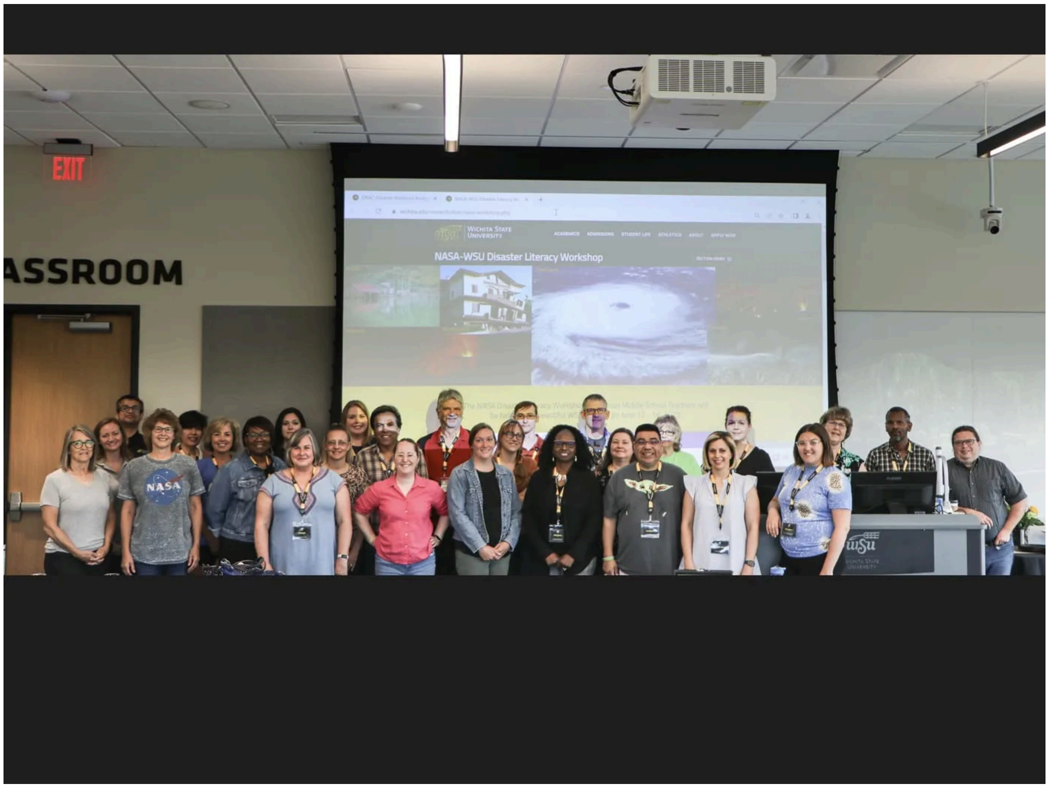
Prediction from pre- & post-disaster image [7].

Objective 4.2: Understand the impact of different geographical region on the prediction performance of different deep learning models.

EDUCATION & ACKNOWLEDGMENT

2023 NASA/WSU Disaster Literacy Workshop

Twenty teachers from various towns across Kansas attended the 5-day workshop held on WSU campus and designed lessons for incorporating NASA-relevant materials in middle school curriculum.



Attendees and organizers of the workshop [8].

YouTube channel

A platform to disseminate recorded technical talks and panel discussion [9]. .

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TRANSCRIPT

ABSTRACT

This poster presents some of the recent and ongoing research at Disaster Resilience Analytics Center at Wichita State University. The main goal of the center is to provide a transdisciplinary platform to improve disaster prediction, understand resilience of communities, and promote disaster literacy in Great Plains region of the United States. The poster provides an overview of our research with respect to four themes: fire hazard detection from images, design of orbiting sensor infrastructure to meet resolution needs of hurricane forecasting systems, understanding flood susceptibility of different parts of Kansas, and post-disaster damage assessment by comparing pre-disaster and post-disaster satellite images. .

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