Title
Faster than Wind: Predicting Duration and Onset of Rapid Intensification in Tropical Cyclones
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Project Objective
My objective is to better predict when tropical cyclones will start and their duration using historical data, satellite imagery, environmental conditions, and machine learning models. To predict the onset of the storm, I will use a hybrid model that gathers spatial data from satellite imagery and temporal data from environmental conditions to predict the onset of the storm. I will then predict the duration of Rapid Intensification using regression or classification algorithm. Lastly, I plan to refine the accuracy of my model using different kinds of algorithms that can also solve this problem.

Project Background and Significance
Rapid Intensification (RI) in a tropical cyclone is where there's a sudden increase in wind speed from a tropical cyclone within a short period of time. It is defined as storms increasing by 30 knots (35 mph) within 24 hours. A deadly example of this is when Hurricane Mitlon grew from 35mph, a tropical depression, to 160mph, a category 5, within 49 hours [3]. This is not an uncommon phenomenon as at least 31.2% of tropical cyclones undergo at least one RI [5].

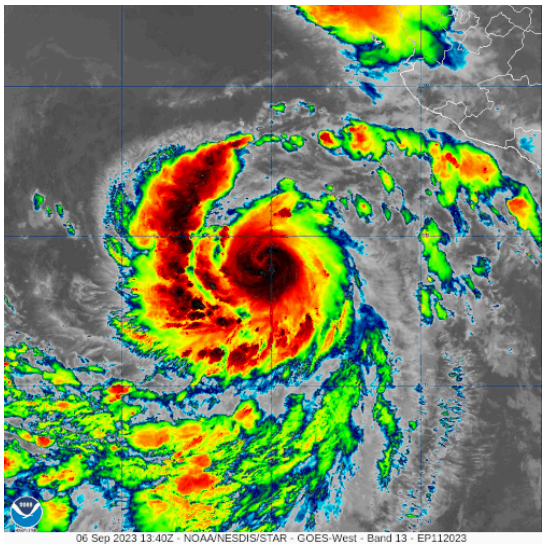
Previous research has been conducted on whether RI will happen with a 92.3% accuracy, however, no research has been made on figuring out the duration and when RI will happen [2]. With this crucial piece of information, people living in the tropical cyclone's (TC) trajectory can become more prepared. Emergency teams would have a better idea of how to defend civilians and reduce damage to the area. Furthermore, we can get a better understanding of TC, what causes them to undergo RI, and possible ways to mitigate this odd behavior.

My critical framework to approach this research is to use previous meteorological data in conjunction with multiple different machine learning models to produce the best results. This approach is inspired by research done a few months ago that can predict if RI will happen with a very low error rate also using a Machine Learning approach [2]. Research to predict other natural disasters like wildfires, floods, and volcanic eruptions also uses a Machine Learning approach.

To evaluate my predictions on my output variables for duration and onset, I would find how much time my predicted onset and duration time differ from the actual duration and onset of the RI. If the time is within some small delta value, for example, 1 minute, I would consider my model as predicting correctly. I would also use a multitude of performance metrics to evaluate how well my model performs. For example, getting metrics like accuracy, precision, recall, and F1 scores would allow me to see the performance of my model from different points of view. I will then continue to train my model until the best performance metrics are achieved.

Research Methods

My first step is to collect previous datasets on tropical cyclones. I plan to see datasets that other relevant research also relied on. I need to look for temporal data such as wind shear, sea surface temperature, relative humidity, and any other factors that can play a crucial role in RI [1]. Additionally, I need to look for satellite imagery as it would give me a lot more data visually about cloud formations, brightness temperatures, and information about the eyewall. All of these data points can play a huge role in predicting the onset and duration of the RI.



My second step is to perform data preprocessing. In this stage, I would fill in any missing data values with the most appropriate value. Then, I would also normalize my dataset so my model doesn't run into issues such as the vanishing or exploding gradient problem. I would also analyze my dataset to see if there are any significant correlations between certain variables

My third step would be to perform feature engineering. I can create more features given the features present. This can provide my model with additional information. I would also apply a dimension reduction algorithm such as PCA to remove any redundant variables while keeping the most important variables in my dataset.

My fourth step would be to create my models. To predict the onset of the RI, I plan to use a hybrid model that is efficient in taking in time-series data and one that is good at recognizing spatial patterns from satellite imagery. LSTMs and CNNs are perfect for this use case. To predict the duration of the RI, I can use a regression or classification algorithm. There are many different algorithms I can consider, but I will use Random Forests and XGBoost as they are efficient for tabular data.

My fifth step would be to train my model on the dataset. Additionally, I would provide different performance metrics such as accuracy, precision, recall, and F1-score.

Step 1 (collecting datasets): 2 weeks
Step 2 (data preprocessing): 3 weeks
Step 3 (feature engineering): 3 weeks
Step 4 (trying different models to produce the best results): 7 weeks
Step 5 (training the model): 1 week

Expected Outcome

I believe that since not much research has been conducted related to my work, it would gain a lot of interest and traction when my work is publicized. To do this, I plan to first create a scholarly journal article and submit it to meteorological-related societies such as the Artificial Intelligence for the Earth Systems (AIES) and Weather and Forecasting (WAF). Then, I would like to give talks to share my findings at large Computer Science-related clubs at UCF such as AI@UCF and Knight Hacks. Additionally, I would also like to present my findings at well-known AI/ML conferences such as the International Joint Conference on Artificial Intelligence (IJCAI) and the International Conference on Machine Learning (ICML). From these public appearances, I hope to meet other people in my field who can be potential collaborators in further advancing this research. I hope I can work with other companies such as Google DeepMind or Nasa. With the attention from publicizing my research, I hope I can also get more funding to continue further my research and produce better results.

From this project, we gain new knowledge in having better predictions of the onset and durations of RI in TC. I hope that we can have a better understanding behind the root cause of RI. This research can open up actionable steps people can take to reduce the chance of RI occurring. I hope that this research can be used by emergency teams and people to save lives and people's property.

Within the machine-learning community, I think this continues to show how important it is to use machine-learning techniques to solve problems. My techniques to solve my specific problem could potentially be applied to some problems in different fields.

For the UCF community, I hope I can get a chance to also work with other professors who are more experienced in this field to continue conducting this research. This can create a tighter and stronger research community within UCF. I also believe with the publication of my research, UCF would gain more reputation and prestige.

Literature Review

1. Bhatia, K., Baker, A., Yang, W., Vecchi, G., Knutson, T., Murakami, H., Kossin, J., Hodges, K., Dixon, K., Bronselaer, B., & Whitlock, C. (2022, November 4). A potential explanation for the global increase in tropical cyclone rapid intensification. Nature News. https://www.nature.com/articles/s41467-022-34321-6
2. C. Wang, N. Yang, & X. Li, Advancing forecasting capabilities: A contrastive learning model for forecasting tropical cyclone rapid intensification, Proc. Natl. Acad. Sci. U.S.A. 122 (4) e2415501122, https://doi.org/10.1073/pnas.2415501122 (2025).
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4. Kim, S.-H., Lee, W., Kang, H.-W., & Kang, S. K. (2023, December 29). Predicting rapid intensification of tropical cyclones in the western North Pacific: A machine learning and net energy gain rate approach. Frontiers.

https://www.frontiersin.org/journals/marine-science/articles/10.3389/fmars.2023.1296274/full
5. Yang, J., & Chen, M. (2019, September 30). Landfalls of tropical cyclones with rapid intensification in the western North Pacific. Natural Hazards and Earth System Sciences Discussions. https://nhess.copernicus.org/preprints/nhess-2019-279/

Preliminary Work and Experience

I have not accomplished any work for my project. However, I have taken an Artificial Intelligence class where I have implemented many of the algorithms mentioned above. I understand the theory and code behind the algorithms. I have been studying the field of AI ever since I took my AI class in Fall 2024. In my free time, I have also taken Andrew Ng's Coursera course on Artificial Intelligence which goes into Supervised and Unsupervised Learning. I have also watched lectures taught by Andrej Kaparthy, which solidified my core understanding of the theory behind AI/ML algorithms.

I have applied my knowledge from theory to code outside the classroom as well. I have worked on projects that use AI as a core feature. I have also participated in Kaggle competitions that require you to solve a data science problem using AI/ML techniques. In these competitions, I have had exposure to many different algorithms and the process of creating a good model.

IRB/IACUC Statement

My project does not require IRB or IACUC approval.

Budget

Computational resources for cloud computing: $100
Software tools (MATLAB): $100
Paid datasets: $200
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Total: $400