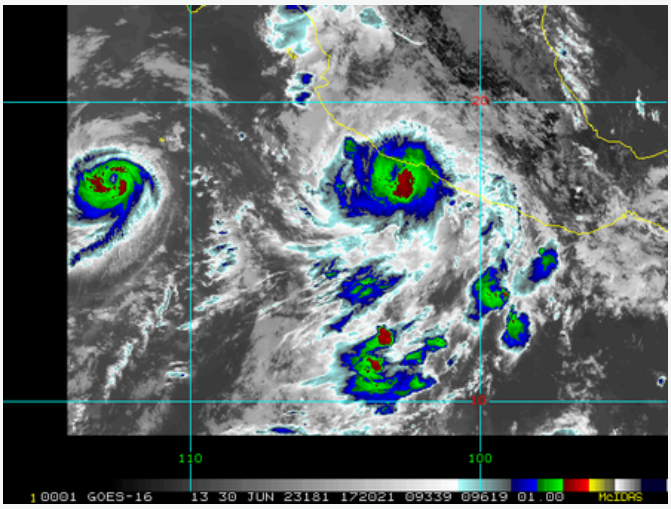
The vision of AI2ES is to create trustworthy Artificial Intelligence (AI) methods for diverse environmental science (ES) users that will revolutionize our understanding and prediction of high-impact atmospheric and ocean science phenomena and create new educational pathways to develop a more diverse AI and environmental science workforce.

AI2ES News

Edited by Raven Reese, Jayne-Marie Linguist,
Dr. Amy McGovern, and Jennifer Warrillow

June 2023 Edition



Infared Imagery from Tropical Storm BEATRIZ (CIRA TC Realtime, 6/30/2023)

Tropical Cyclones

This month, the AI2ES newsletter focuses on the Tropical Cyclone (TC) team at the Cooperative Institute for Research in the Atmosphere (CIRA) and their work with satellite imagery to predict the occurrence of TC weather events across the globe. Thank you, Dr. Kate Musgrave and Dr. Marie McGraw at CIRA, Jay Rothenberger of University of Oklahoma, and Dr. Eric Grimit at Vaisala for their contributions to this month's edition of the newsletter!

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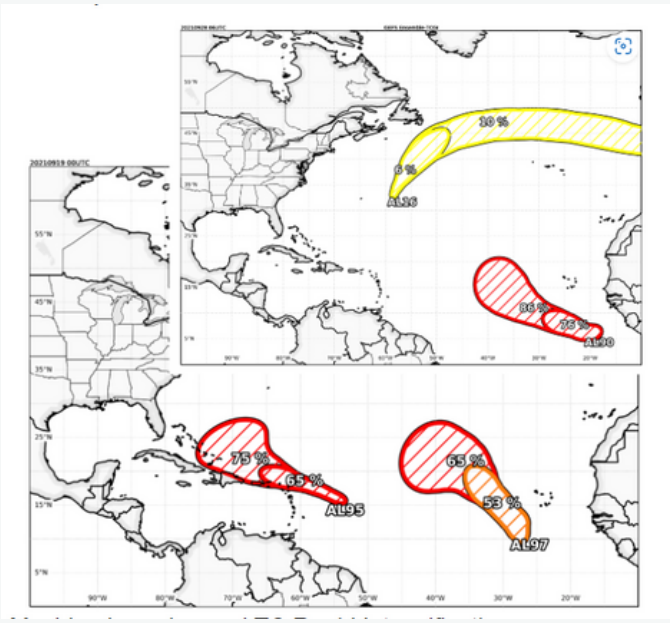
Why Tropical Cyclones?

The Tropical Cyclones Prediction Project , which was started by a former CIRA employee who now works at the National Oceanic and Atmospheric Administration (NOAA), uses satellite imagery to collect data and tropical cyclone (TC) images, creates AI models, and predicts TC events. The AI components of this project are now part of AI2ES.

"We were excited to partner with AI2ES to explore [this research] further," said Dr. Kate Musgrave. "A good combo of subject matter expertise and machine-learning expertise" were two facets of the project that drew her in, she said. When asked why she is interested in researching TCs, Dr. Musgrave stated, "I think in weather almost everybody has a story of 'Oh I remember when this event happened' and so for me, that was Hurricane Elena off the coast of Florida... that was the source of my interest and I didn't realize that was a career until halfway through college."

Dr. Marie McGraw's research interest in TCs began shortly after completing her PhD. "I've been in tropical cyclones for two years, which for tropical cyclones is still pretty new because a lot of people stick with that topic for their entire career," she explained. Dr. McGraw received her PhD at Colorado State University and returned there shortly after as a research scientist. She wanted to work further with AI2ES and already worked with Dr. Musgrave before when asked to join the project.

Integrating advanced AI techniques into the tropical cyclone project has allowed Drs. Musgrave and McGraw to "explore the things that are not being explored by our sensor models." The project previously used regression model AI, but the team met with limitations in "expressing meaning in non-linear circumstances outside the model limits," explained Dr. Musgrave. Dr. McGraw added that the simulated satellite imagery has filled in gaps in their data, "We have better data than we've ever had before...[and] using AI to address these problems provides better prediction accuracy unmeasurable by simple satellite and geospatial data receptors."



Example of the Ensemble Global TC Genesis Index, an example of combined ML techniques and ensemble model output to improve cyclogenesis predictions (CIRA, 09/19/2021)

Satellite Imagery

A large component of the Tropical Cyclone Prediction Project is the CIRA team's use of satellite imagery to gather weather data from across the globe. Dr. Musgrave explained that their process in extracting so much data from several sources starts with NOAA's polar-orbiting satellites. The importance of this satellite lies in its ability to see beneath the cloud tops and reveal the internal structure of the storm in terms of rainfall and ice. However, the satellite only produces a limited amount of images due to the fact that the orbiter takes "more than half a day or even a day in passing" between captures of relevant data. "We have limited observation types and availability," she explained, which creates gaps in the data that researchers then try to fill with AI imagery. Dr. Musgrave's team started with a random forest approach to try to generate the microwave imagery from the geospatial satellites based on the imagery collected. This is not the only issue in using polar orbiters, as the team must also match up what overpasses the polar-orbiters make with the plethora of ground data outside of the satellite imagery. "We pull buoy data, sea-surface temperature data, model data, precipitation, aircraft reconnaissance data, drone data, we use everything!" stated Dr. Musgrave. This task of matching ground data to satellite imagery (much of which is already limited in frequency) is difficult but integral to building a reliable prediction model for TCs. Dr. Musgrave's team consists of "over a dozen people working on different aspects of the tropical cyclones project," such as data archiving, image capturing, and model construction. Once the imagery data was expanded by the output of their random forest model, the team constructed a convolutional neural network (CNN) model to begin the larger process of predicting TC events.

Rapid Intensification and XAI

Dr. Marie McGraw, Research Scientist at CIRA and alumna of CSU, focuses on predicting rapid intensification during TC events and using ML for the team's prediction model. Rapid intensification (RI) is one of the more difficult components to predict within a TC event, as this has even less observable data. TCs rarely accelerate past 30 kts within 24 hours, so data captured by satellite imagery is minimal. For Dr. McGraw's work, RI is "like a rare event in a rare event, so trusting underlying data is difficult because you don't have that many samples." This led her to work with the random forest models developed for TC visualization to increase the available RI data.

With several smaller research projects, such as Dr. McGraw's work with RI, feeding into the ultimate goal of predicting TC events, the incorporation of explainable AI into CIRA's model development process is essential to producing cohesive, trustworthy, and functional results. Dr. Musgrave explained that the complication of their project in "using AI models with input of AI imagery" requires multiple points of XAI evaluation. For example, in developing the CNN model for TC prediction, Dr. Musgrave realized that "while the CNN gives us our lowest errors, it also blurred results a bit." However, "the little bit of blurring on the CNN is actually a much better resolution than most polar orbiters" can provide in real time, she said. Using XAI to evaluate model output and the feasibility of resulting data allows CIRA researchers to communicate where the model is performing well and where there's higher levels of uncertainty in geospatial conditions with forecasters using their prediction tools. This implementation of XAI allows Drs. Musgrave and (continued on page 4)

(XAI, page 3 continued) McGraw to warn the forecasters of what errors may happen. If the model fails, or if they don't know in advance that it can fail, they will not use it again, so XAI methods are essential to creating trustworthy and applicable predictions.

Application

This hurricane season, the tropical cyclone predictions team will be demonstrating their AI models and research for forecasters. The feedback received from these forecasters will then be evaluated and used to make modifications and improve the models. Dr. Marie McGraw touched on the importance of these AI models on TC event predictions, noting that "[The project has] really emphasized the fact that AI can be really helpful and improve our ability to detect patterns in data and to extract information from a lot of data in a short amount of time." As the AI models improve at predicting TC events, Dr. McGraw emphasized how important the human element is to this project and AI in general. "You need both AI scientists and domain scientists. Having AI scientists look in a book without talking to a domain expert, you're very limited in what you can do. Having both involved from start to finish is very important." Dr. Musgrave added, "It's critical to know what you're looking at because if you don't know, then you don't know where things have gone wrong." Dr. Musgrave also explained that since joining AI2ES, she has seen interest among TC researchers in using AI, particularly with XAI and trustworthy AI, to communicate more efficiently between forecasters and TC researchers at CIRA. "If it was just a black box with no explanation, there would be no trust, and it wouldn't get used."

The products created by the project team are available publicly, but are intended for a target audience of expert users such as forecasters and emergency management. Dr McGraw described the broader impacts of the models, saying, "Our models can be useful for educating the future scientific community on both earth sciences and AI." Additionally, the team is developing "workbooks to teach people how to read these data sets and apply them," Dr. Musgrave explained. Currently, the AI models are not yet operational, but the CIRA team is opening this model for forecaster evaluation this summer.

Dr. Kate Musgrave
Research Scientist
CIRA - CSU

Dr. Marie McGraw
Research Scientist
CIRA - CSU

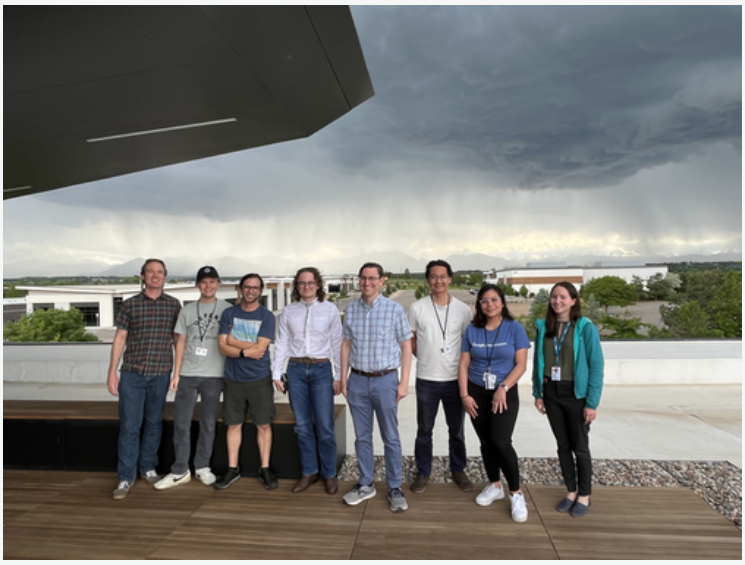
Student Spotlight

As an NSF Institute, AI2ES is privy to several industry partner collaborative opportunities that are not usually accessible to emerging researchers. For this month's Student Spotlight, Jay Rothenberger, Graduate Researcher with OU's AI2ES, discussed his most recent internship with industry partner Vaisala. Jay normally operates under his advisor Dr. Dimitrios Diochnos as part of the Robust AI research group, focusing on trustworthy ML mechanics for AI models. Recently, Jay has been working on explainability, submitting papers to the upcoming Neural Information Processing Systems (NeurIPS) conference and working more in depth with XAI applied to the environmental sciences. When Vaisala offered an internship through OU in the same field of research, Jay leaped on the opportunity. Dr. Eric Grimit, Head of Science at Vaisala's North American X-Weather team, described the business as "a global leader in weather, environmental, and industrial measurement – with quality, sustainability, and science-based innovations at its core." After joining the AI2ES industry advisory board in 2021, Dr. Grimit discovered that "at least three of the use-inspired research objectives" outlined by AI2ES "overlap significantly with current business areas where Vaisala is already providing actionable industry solutions." In many ways, collaboration between AI2ES and Vaisala benefits both their industry goals and OU's academic research. This partnership opened doors for AI2ES members at Vaisala, said Dr. Grimit, "in a multi-faceted way: as a consultant on the industry advisory board, as a data provider, and as a host for student internship." In Jay's case, Vaisala's internship appealed to him "because of (Vaisala's) connection to weather and climate, and their commitment to creating instruments that allow us to make observations that will lead to a better world." This ethos of a company that is dedicated to mitigating some of the effects of climate change resonated with Jay, so he took the trip to Colorado for the summer and began working on their larger AI explainability project.

Jay Rothenberger
Graduate Researcher
OSU AI2ES

At Vaisala, Jay is working with Dr. Grimit's X-Weather team for his internship. "They're more or less trying to predict severe weather events and severe weather conditions and measure things like lightning and hail," he said. Jay's internship will last 12 weeks and he will spend one week attending the International Conference on Machine Learning next month. Jay explained that the X-Weather team "[has] a very nice lightning detection network in the U.S. and globally. They use that kind of data to warn air traffic about dangerous lighting conditions and they also help insurance companies identify locations where hail has caused damage and things like that." (continued on page 6)

(Spotlight, continued from page 5) When asked about his experience so far during his internship, Jay stated, “I think a big part of my experience is interacting with domain scientists. I was in Colorado last week visiting and I’ll be there a week again in early August and it’s been really great sitting down with them because they have a lot to say. They really are very passionate about the weather and what they do.” Collaborating with these domain scientists and participating in convergent science has been impactful on Jay’s work and outlook on his research. Jay mentioned that he was drawn to working with Vaisala because the employees “work there because they believe in the mission and they enjoy the work they do.” Jay also reminisced about some of the meetings he’s attended at Vaisala. “ I’ve had meeting scheduled for one hour or 30 minutes last three hours because it's been so fascinating to sit down and talk with the lightning scientists about the physics of the scenarios, and they've been really interest in machine learning and how it works the limitations of explainability methods, working with me to mitigate some of the downsides of those approaches with their domain knowledge.” The impacts of Jay’s internship with Vaisala perfectly demonstrate the importance of multidisciplinary collaboration and convergent science, a principle central to the AI2ES program.



Jay Rothenberger (fourth from left) and other internship participants in the midst of a real-time weather event, Louisville, CO, June 2023

NSF Annual Report

The annual report for AI2ES was recently completed and submitted to the National Science Foundation. Those who are interested in receiving a redacted copy of the report may email Dr. Amy McGovern at amcgovern@ou.edu. Thank you very much to Dr. McGovern and Ms. Susan Dubbs for their hard work in writing this annual report!

Are you interning or travelling for AI2ES-related research this summer? Let us know ho it's going! Post pictures, new experiences, and other resources in the Slack #newsletter channel for a chance to appear in next month's edition of the AI2ES Newsletter!

Q&A

Are you using custom loss functions while training AI models? How are they impacting your training process?

Submit answers, resources, and questions for next month in the AI2ES Slack #general channel!