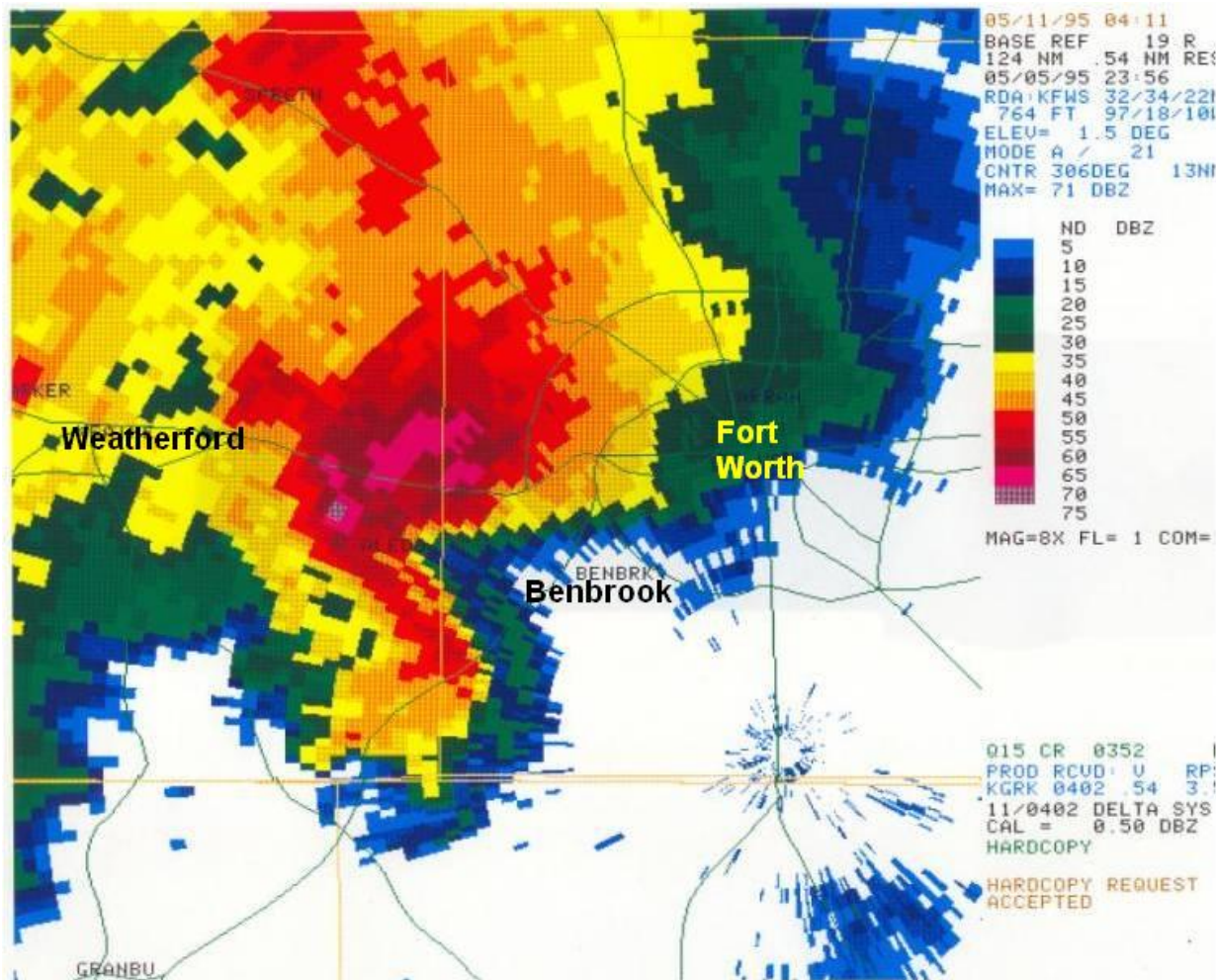


Predicting severe hail storms

March 23 2016, by Aaron Dubrow



Radar imagery from 6:56 p.m. shows a close-up of the Mayfest supercell centered west of Benbrook, Texas. The pink and darkest red colors represent radar indications of large hail with this storm. The storm impacted the Mayfest festival at 7:10 p.m. Credit: National Weather Service

When a hail storm moved through Fort Worth, Texas on May 5, 1995, it battered the highly populated area with hail up to 4 inches in diameter and struck a local outdoor festival known as the Fort Worth Mayfest.

The Mayfest storm was one of the costliest hailstorms in U.S history, causing more than \$2 billion in damage and injuring at least 100 people.

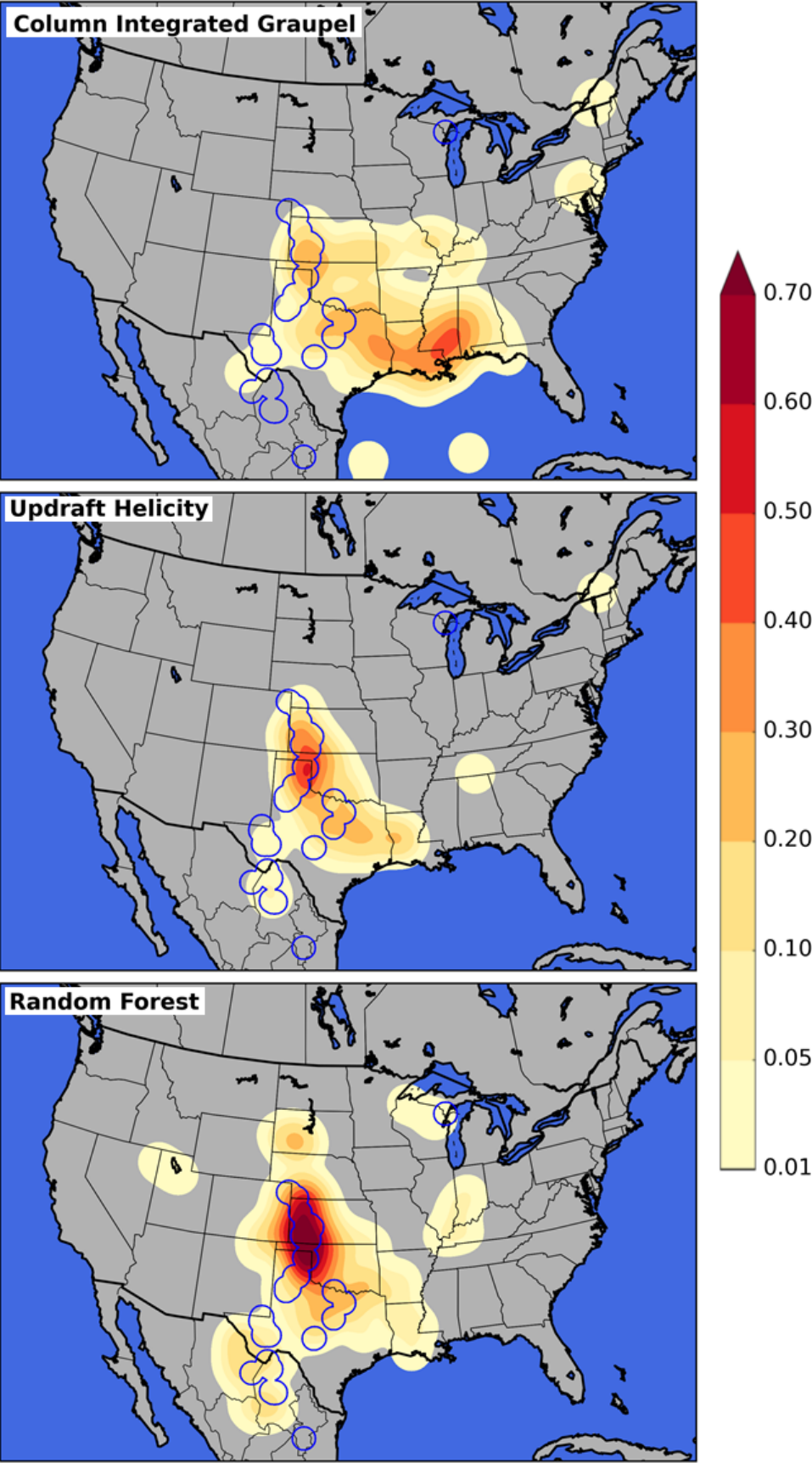
Scientists know that storms with a rotating updraft on their southwestern sides—which are particularly common in the spring on the U.S. southern plains—are associated with the biggest, most severe tornadoes and also produce a lot of large hail. However, clear ideas on how they form and how to predict these events in advance have proven elusive.

A team based at University of Oklahoma (OU) working on the Severe Hail Analysis, Representation and Prediction (SHARP) project works to solve that mystery, with support from the National Science Foundation (NSF).

Performing experimental weather forecasts using the Stampede supercomputer at the Texas Advanced Computing Center, researchers have gained a better understanding of the conditions that cause severe hail to form, and are producing predictions with far greater accuracy than those currently used operationally.

Improving model accuracy

24-Hour Neighborhood Probability 50 mm Hail May 27, 2015



An image from the work of Ph.D. student David Gagne using machine learning algorithms to predict hail a day in advance using the Storm Scale Ensemble Forecast (SSEF) that is run each year by CAPS as part of NOAA's Hazardous Weather Testbed. The top two panels show raw output of variables in the model associated with hail. The bottom panel shows results from the random forest machine learning algorithm, which is used to calibrate the raw model output and dramatically improve the forecast of hail. Credit: David Gagne, University of Oklahoma

To predict [hail storms](#), or weather in general, scientists have developed mathematically based physics models of the atmosphere and the complex processes within, and computer codes that represent these physical processes on a grid consisting of millions of points. Numerical models in the form of computer codes are integrated forward in time starting from the observed current conditions to determine how a weather system will evolve and whether a serious storm will form.

Because of the wide range of spatial and temporal scales that numerical weather predictions must cover and the fast turnaround required, they are almost always run on powerful supercomputers. The finer the resolution of the grid used to simulate the phenomena, the more accurate the forecast; but the more accurate the forecast, the more computation required.

The highest-resolution National Weather Service's official forecasts have grid spacing of one point for every three kilometers. The model the Oklahoma team is using in the SHARP project, on the other hand, uses one grid point for every 500 meters—six times more resolved in the horizontal directions.

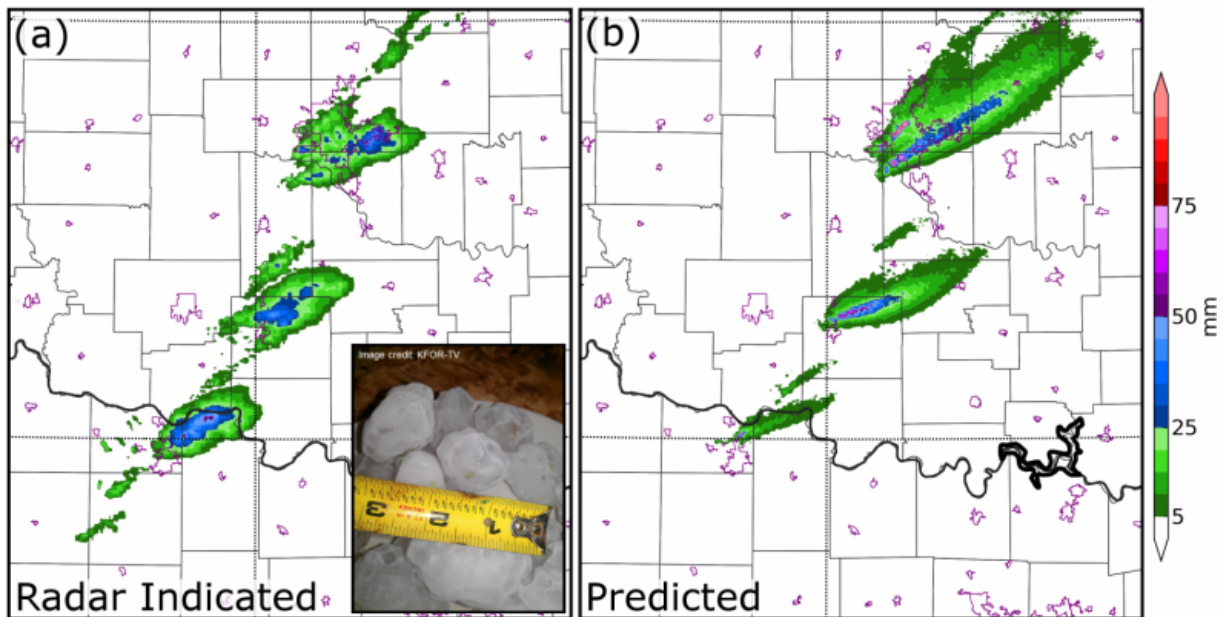
"This lets us simulate the storms with a lot higher accuracy," says Nathan Snook, an OU research scientist. "But the trade-off is, to do that, we need a lot of computing power—more than 100 times that of three-kilometer simulations. Which is why we need Stampede."

Stampede is currently one of the most powerful supercomputers in the U.S. for open science research and serves as an important part of NSF's portfolio of advanced cyberinfrastructure resources, enabling cutting-edge computational and data-intensive science and engineering research nationwide.

According to Snook, there's a major effort underway to move to a "warning on forecast" paradigm—that is, to use computer-model-based, short-term forecasts to predict what will happen over the next several hours and use those predictions to warn the public, as opposed to warning only when storms form and are observed.

"How do we get the models good enough that we can warn the public based on them?" Snook asks. "That's the ultimate goal of what we want to do—get to the point where we can make hail forecasts two hours in advance. 'A storm is likely to move into downtown Dallas, now is a good time to act.'"

With such a system in place, it might be possible to prevent injuries to vulnerable people, divert or move planes into hangars and protect cars and other property.



Radar-indicated swaths of hail from the May 20, 2013 Oklahoma-Moore tornado in the left panel, and, in the right panel, swaths of hail predicted by the ensemble computer forecasts. Credit: University of Oklahoma

Looking at past storms to predict future ones

To study the problem, the team first reviews the previous season's storms to identify the best cases to study. They then perform numerical experiments to see if their models can predict these storms better than the original forecasts using new, improved techniques. The idea is to ultimately transition the higher-resolution models they are testing into operation in the future.

Now in the third year of their hail forecasting project, the researchers are getting promising results. Studying the storms that produced the May 20, 2013 Oklahoma-Moore tornado that led to 24 deaths, destroyed 1,150 homes and resulted in an estimated \$2 billion in damage, they

developed zero to 90 minute hail forecasts that captured the storm's impact better than the National Weather Service forecasts produced at the time.

"The storms in the model move faster than the actual storms," Snook says. "But the model accurately predicted which three storms would produce strong hail and the path they would take."

The models required Stampede to solve multiple fluid dynamics equations at millions of grid points and also incorporate the physics of precipitation, turbulence, radiation from the sun and energy changes from the ground. Moreover, the researchers had to simulate the storm multiple times—as an ensemble—to estimate and reduce the uncertainty in the data and in the physics of the weather phenomena themselves.

"Performing all of these calculations on millions of points, multiple times every second, requires a massive amount of computing resources," Snook says.

The team used more than a million computing hours on Stampede for the experiments and additional time on the Darter system at the National Institute for Computational Science for more recent forecasts. The resources were provided through the NSF-supported Extreme Science and Engineering Discovery Environment (XSEDE) program, which acts as a single virtual system that scientists can use to interactively share computing resources, data and expertise.

The potential of hail prediction

Though the ultimate impacts of the numerical experiments will take some time to realize, its potential motivates Snook and the severe hail prediction team.

"This has the potential to change the way people look at severe weather predictions," Snook says. "Five or 10 years down the road, when we have a system that can tell you that there's a severe hail storm coming hours in advance, and to be able to trust that—it will change how we see severe weather. Instead of running for shelter, you'll know there's a storm coming and can schedule your afternoon."

Ming Xue, the leader of the project and director of the Center for Analysis and Prediction of Storms (CAPS) at OU, gave a similar assessment.

"Given the promise shown by the research and the ever increasing computing power, numerical prediction of hailstorms and warnings issued based on the model forecasts, with a couple of hours of lead time, may indeed be realized operationally in a not-too-distant future, and the forecasts will also be accompanied by information on how certain the forecasts are."

The team published its results in the proceedings of the 20th Conference on Integrated Observing and Assimilation Systems for Atmosphere, Oceans and Land Surface (IOAS-AOLS); they will also be published in an upcoming issue of the *American Meteorological Society* journal *Weather and Forecasting*.

"Severe hail events can have significant economic and safety impacts," says Nicholas F. Anderson, program officer in NSF's Division of Atmospheric and Geospace Sciences. "The work being done by SHARP project scientists is a step towards improving forecasts and providing better warnings for the public."

Provided by National Science Foundation

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