AI for Earth Grantee Profile

Lower Atmospheric Research Group

Improving short-term forecasting with radar analysis

Summary

Weather forecasting is notoriously difficult. So many factors play into predicting what is going to happen in the earth's atmosphere. Jennifer Davison, President of the Lower Atmospheric Research Group, is taking advantage of existing Next-Generation Radar data (NEXRAD) measurements to map out the mean mesoscale, real-time vertical structure of moist, dry, and other significant layers to improve short term forecasting and our knowledge of the lower atmosphere.

Using data to improve short-term forecasting of the lower atmosphere

Scientists have been predicting weather formally since 1835, but even now, it is not fully understood. Scientists use radar and satellite technology along with an assortment of other instruments to try to assemble a complete picture of current weather conditions. Forecasters analyze that data along with output from various numerical, statistical, and conceptual models, and then apply their local experience to predict how conditions will change with time. Even with all this data available, forecasts are infamously inaccurate. The nature of the earth's atmosphere is chaotic, and the incomplete sampling of its physical properties means that the weather is even harder to predict over longer periods of time. Research scientist Dr. Jennifer Davison describes atmospheric science as an "interwoven process having so many moving parts that it's like

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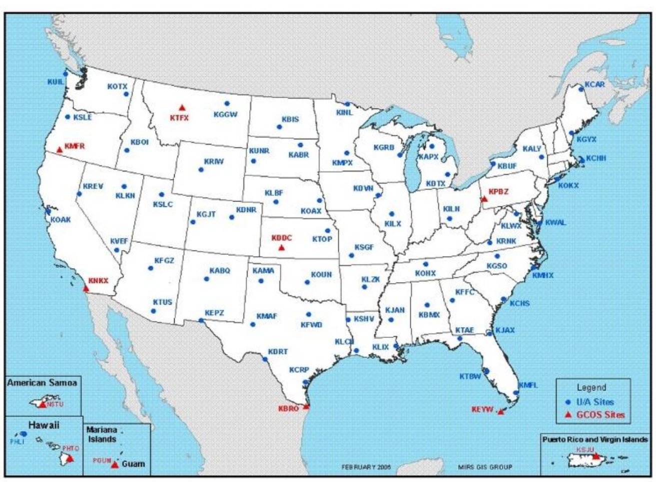
trying to braid with 100 threads in a complicated pattern. Switch any two unassuming threads, and a completely unexpected final outcome might result."

"There are amazing things [in atmospheric science] that are easy to wrap your head around, that are not well understood," says Dr. Davison. "Even the freezing process of ice and the point at which pure (or nearly pure) water actually freezes is not fully understood, which is mindboggling." Davison is the founder and president of the Lower Atmospheric Research Group (LARG), a small business dedicated to furthering data-driven science in atmospheric research. She founded LARG to follow through on her doctoral and post-doc research into the methodologies of weather prediction, in which she discovered a way to tackle an important discrepancy in current data collection practices.

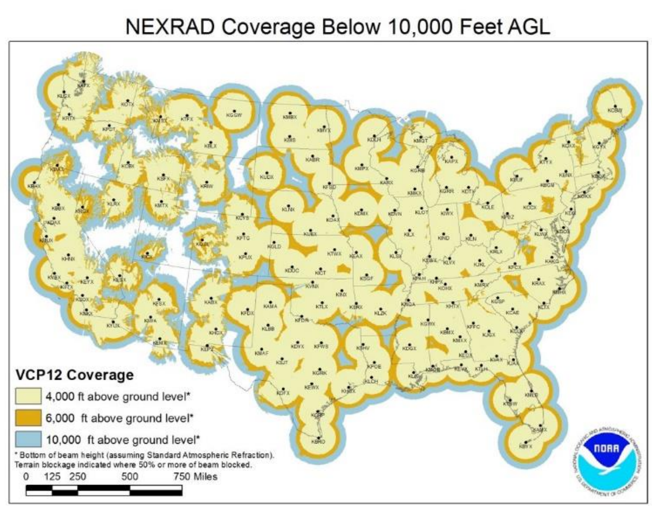
Using weather balloons and radar to forecast the weather

Weather balloons are the backbone of weather forecasting in the United States. These balloons carry instruments that collect data in a process called soundings, measuring the vertical structure of atmospheric parameters like temperature, pressure, relative humidity, and wind along their tiny, thread-like path. These values are put into a model along with other ancillary data and nudged using earlier forecasting data to create a "reanalysis" of what the current weather is. The challenge (beyond each sounding's limited sampling area) is that these soundings are only done twice a day, at zero and twelve UTC, and at large distances from one another. Some states don't even have weather balloon launches. This makes it difficult to get an accurate picture of what's happening in the atmosphere.

Despite the limitations, the reanalysis data are treated as a reliable average. Yet the soundings which serve as their basis aren't cross-checked against other data (such as radar) to see if their readings are representative or anomalous; it is assumed that the model nudging will "fix" any such issues. According to Davison, even at the



Weather balloon launch sites



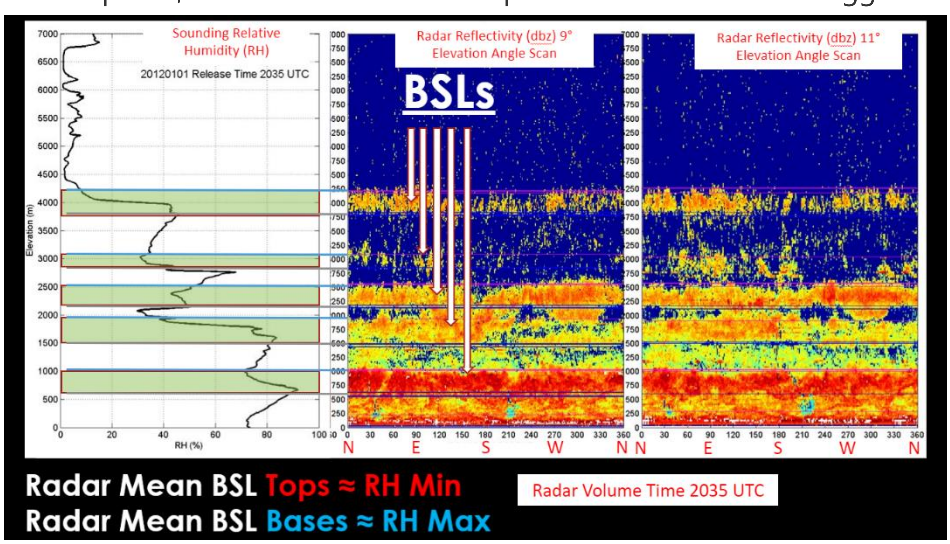
Radar coverage map

same location, launching a sounding 15 minutes earlier or 15 minutes later can give a reading of 400 meters altitude difference in the top of the mixed layer when conditions are changing rapidly—and that could completely change the accuracy of a local forecast. She says, "We can do fine scale really well, which is what the sounding does. We can do really big scale—like satellite data—but these data are so coarse that the vertical resolution is *maybe* 100 meters between data points over a horizontal grid of 500 meters between data points. Finding that middle ground, that's the mesoscale, to get the data that help tie everything together, has really been a problem area in the field." Using the radar data, Davison is able to find the local mean mesoscale structure in real time and by combining this information with soundings will ultimately work to improve short-term forecasting.

Enhanced Bragg scattering layer analysis

"Water vapor is the gasoline that drives storm systems. It's probably the least well-measured variable, and it's one of the most critical," says Davison. "Differences between dry and moist air can also be a driver of severe weather. Some of the nastiest storms form along dry lines—where you have very moist air on one side and very dry air on the other. So, it's not just that you need moisture but the gradients in moisture are also critical as well." Radar offer much more thorough and consistent coverage than soundings and are hampered mainly by intervening terrain. In addition to clouds, radar can detect the different layers of relative humidity (temperature and moisture) in the air and show how and where these layers are mixing in visually clear skies. This is because strong relative humidity gradients will cause index of refraction gradients large enough to return power to the radar in an effect called Bragg scattering. While moisture is a necessary ingredient for clouds, it is the differences in moisture and temperature between air layers and masses that drive air density currents and thus the development of storms, making this vital information for forecasting.

To find the mesoscale structure of the atmosphere, Davison identifies the tops and bottoms of the Bragg scattering layers (BSLs) through BSL analysis. In the adjacent example, the left graph shows a sample sounding. The middle and right graphs show the concurrent radar scans with the associated BSLs. "If this is relative humidity, it's technically both temperature and moisture, and it tells you how close you are to making a cloud," Davison says. "These really sparsely separated soundings that they only do twice a day, they're the



Sounding RH grounding compared to Bragg scattering layers showing similar tops and bases backbone of our weather analysis and prediction. But because radar has much better spatial coverage and is going on all the time, it can tell you how the atmosphere's structure changes between the soundings."

In her doctoral and post-doc work, Davison conducted cross-analysis of radar data against balloon soundings, and demonstrated that analysis of the radar data can show the structural evolution of the lower atmosphere over time and thus provide indications of storm triggers (which might necessitate sending up extra soundings to gather more detailed data). She developed an algorithm to run an Enhanced Bragg Scattering Layer (EBSL) analysis using both plan position indicator data as well as range-height indicator data that allow the scientists and meteorologists to find the altitudes of the tops and bottoms of the Bragg scattering layers. Using this data, for instance, Davison can detect not only the height of the (moist) boundary layer, which is a critical part of understanding weather, but also bores and elevated waves which can provide the lifting mechanisms to trigger sudden storm development.

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Although moisture is one of the most critical variables, it's one that scientists have a hard time getting a handle on. If forecasters could see the change in the Bragg pattern on a consistent basis, they would have earlier visual indicators of potential storm triggers, allowing them time to evaluate other environmental factors and decide if an additional sounding is warranted in assessing the severe weather threat. However, conventional practice doesn't include doing quantitative analyses of radar data for Bragg scattering; radar is typically used only to "see" clouds and precipitation or measure the wind profile.

Using data in the cloud to make research accessible to others

In 2019, Davison was looking for National Weather Service radar data when she came across Microsoft's AI for Earth technical resources. Davison applied for the AI for Earth grant to use the processing power of Microsoft Azure to make her research available to others. Additionally, the grant has given her opportunity to use data from NEXRAD, a network of 159 radar stations across the United States operated by the National Oceanic Atmospheric Administration (NOAA). The dataset is used for weather forecasting and climate science and can consume hundreds of terabytes—impractical to use on a local computer, but easy to access through the cloud on Azure. Davison has been using NEXRAD measurements to map out the mean mesoscale, real-time vertical structure of moist, dry, and other significant layers. "The data files are huge, so having my virtual machine very close to where the data is stored, that was a ton of time saved," Davison says. She says that it takes about 30 minutes to process data from a 24-hour period. Her hope is that in the future her analysis can be output with the National Weather Service data as another variable they produce in real time.

Currently, through her website, Davison runs the EBSL analysis of National Weather Center data and posts it for anyone to access. Users can choose a date, state, and radar station to see the EBSL plots. Her research is geared toward graduate students doing departmental weather briefings, researchers who are looking for data, even scientists and students from smaller universities who wouldn't otherwise have access. Davison says she is trying to get her research and data adopted through grassroots movements. She is hoping as scientists use the data, they will see the patterns in what she is showing and understand the value.

Davison would like to see her analysis integrated into NWS real-time data but for now, she makes her research available to anyone who is interested and will allow them to run an analysis for any state or radar station. In the future, she is looking for ways to automate the statistical estimates for her research, which for now she grabs all by hand. With the example of projects by other AI for Earth grantees, she believes AI could help identify the relevant data from the radar scan output. With an automated way to do this, a new set of metrics can be input into weather forecasting models.

About Jennifer Davison

Jennifer Davison is the president of the Lower Atmospheric Research Group (LARG) and currently resides in Melbourne, Florida. She has B.S. degrees in Physics and Mathematics and a Minor in German from the University of Kentucky and an M.S. and Ph.D. in Atmospheric Sciences from the University of Illinois, Urbana-Champaign. She completed her post-doctoral work with a National Science Foundation Atmospheric and Geospace Sciences Post-doctoral Research Fellowship at the University of Louisville, Dept. of Physics and Astronomy from 2013 to 2015. In 2016, Davison founded LARG, a small business dedicated to furthering data-driven science in atmospheric research. LARG is focused on re-examining existing datasets and instrumentation networks to glean new insight into weather systems and processes, in particular by utilizing S-band radar data. Davison is currently a member of the American Meteorological Society (AMS), the American Geophysical Union (AGU), and the Asia Oceania Geosciences Society (AOGS).

Resources

Websites

Lower Atmospheric Research Group (LARG) home site

Publications

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