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THE NATIONAL SEVERE STORMS LABORATORY: 40 YEARS YOUNG AND GOING STRONG

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1. INTRODUCTION

In 1964, a small group of researchers started a new organization that would forever change the severe storm scene in the United States and around the world. The U.S. Weather Bureau's National Severe Storms Project (NSSP) moved from Kansas City to Norman, Oklahoma and changed its name to the National Severe Storms Laboratory (NSSL). The mission of the laboratory is to increase scientific understanding of severe storms that leads to better forecasts and warnings of hazardous weather conditions.

During its first 25 years, NSSL continued NSSP's (and its predecessors') long-standing tradition of improving understanding of severe storms by conducting a data collection program each spring that included surface and upper air mesonetworks, research aircraft, and radars. Over the years, Doppler radars (including dual polarization), an instrumented TV transmitter tower, storm intercept teams, and storm electricity measurements were added. In recent years, spring programs have become more intermittent because of funding constraints, with many associated with national research programs (involving airborne Doppler radars) in the southern Plains. Since the early 1990s, various NSSL sensors have become mobile with the addition of mobile rawinsonde release vehicles, balloon-borne storm electricity sensors, mesonetwork instruments on the tops of cars, and Doppler radars mounted on trucks.

2. EARLY SUCCESS – IMPROVED AIRLINE SAFETY

Early NSSL research has had a positive impact on improved public safety. Aircraft studies of turbulence in severe thunderstorms, called Project Rough Rider, during the 1960s, 1970s, and early 1980s, involved aircraft flying into thunderstorms measuring the turbulence while the WSR-57 radar was monitoring the storms continuously and measuring the reflectivity. This research led to improved commercial airline safety guidelines in the vicinity of thunderstorms that are still in use today.

3. WEATHER RADAR RESEARCH AND DEVELOPMENT LEADING TO WSR-88D

The very foundation of today's National Severe Storms Laboratory lies in weather radar research and development that began before its formation in 1964. Part of NSSL's initial role was to maximize the use of the WSR-57 surveillance radar for the Weather Bureau. NSSL continues to push the weather research community to the edge through its research and development efforts such as Doppler radar, operational WSR-88D Doppler radar and now dual polarization and phased array radar.

In the late 1960s, NSSL obtained a surplus 10-cm Doppler radar that had been used by the U.S. Air Force. In the early 1970s, use of this radar led to an historical discovery. The Union City tornado of 24 May 1973 was a significant event in the history of weather research and warning. NSSL's storm intercept team was in the vicinity of the tornado and they were able to document the entire life cycle of the tornado on film. Researchers used the Norman Doppler radar to collect data within the tornadic storm. They found a definitive signature of the tornado in the Doppler velocity data. Their discovery of what is now known as the tornadic vortex signature had a major impact on the development of the national network of Doppler radars.

NSSL Doppler radar studies of thunderstorm mesocyclones and tornadoes during the 1970s, including the Joint Doppler Operational Project, proved Doppler radar could improve the nation's ability to warn for severe thunderstorms and tornadoes. This led to the decision in 1979 by the National Weather Service (NWS), U.S. Air Force's Air Weather Service, and Federal Aviation Administration (FAA) to include Doppler capability in their updated operational WSR-88D and Terminal Doppler Weather Radar (TDWR) net-

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works. The WSR-88D has helped forecasters significantly improve severe thunderstorm and tornado warnings, saving countless lives. In 1995 NSSL received a gold medal from the Department of Commerce for work leading up to, and its ongoing support of, the national WSR-88D deployment.

4. CONTINUING TO IMPROVE WSR-88D

Researchers have been working on an upgrade to current radar technology for about 20 years. Dual-polarization capability—where pulses are alternately polarized vertically and horizontally—was added to NSSL's second 10-cm Doppler radar (located at Cimarron Field 26 miles northwest of Norman) in time for the 1985 spring storm season. Dual-polarized radar has three primary benefits. First, it improves data quality, since nonmeteorological artifacts, such as birds and insects, can be removed. Second, it will help forecasters make more accurate flood forecasts, because it improves the user's capability to estimate how much rain is falling. Third, it allows forecasters to discriminate between rainfall, snowfall, hail and other types of precipitation particles.

Dual polarization, which has been tested on NSSL's new research and development WSR-88D (KOUN) and shared with the Norman NWS forecast office for several years, has proven useful for forecasters. Dual polarization technology is scheduled as an upgrade to the operational WSR-88Ds within the next five years.

Starting in the mid-1980s, NSSL researchers made automated Doppler radar data available to National Weather Service forecasters. Various algorithms were developed that detected and notified forecasters of hail, mesocyclones, tornado circulations, downbursts and gust fronts, and tracked the movement of storms. These algorithms were later combined with a display system and became known as the Warning Decision Support System (WDSS).

WDSS was primarily a single radar based system. To incorporate multiple radars into a regional mosaic with other data, a new system called WDSS-II was developed. NSSL researchers have integrated sources of information from other sensors, including satellite and lightning information and near-storm environment data from numerical models. All of these data streams have been combined in order to help forecasters make better and more effective and efficient warning decisions.

Additional highlights of NSSL's radar work include design and software development for WSR-88D's Open Radar Product Generator, the Open Principal User Processor, and the Open Radar Data Acquisition Unit. These open system approaches allow the WSR-88D system to be more easily modified and updated.

More recently, through a program called CRAFT—the Collaborative Radar Acquisition Field Test—researchers in Norman and elsewhere were able to prove that Internet access to high-resolution data from multiple radars is technically possible and economically viable. As a result, high-resolution radar data from the national network of WSR-88D radars is now available over the Internet in near real-time for use by government, university and private sectors.

5. MOBILE RESEARCH CAPABILITIES

For the past 20 years or so, NSSL has been involved in developing mobile facilities to take instruments to the storms rather than waiting for the storms to come to the instruments. Mobility has proven to be a key to NSSL's scientific success. The two greatest accomplishments in this area have been mobile mesonetworks that have allowed researchers to make measurements beneath storms as they move with the storms, and mobile ballooning that has allowed scientists to put instruments into the desired regions of storms.

The type of research that has gained the most attention has been the study of tornado development and evolution through a project called VORTEX—Verification of the Origins of Rotation in Tornadoes Experiment—that ran during the springs of 1994 and 1995. VORTEX utilized the mobile facilities to a great extent and with great success. The project deployed a team of investigators who operated a dozen mobile mesonet vehicles, two mobile laboratories, a mobile Doppler radar and two Doppler-equipped aircraft. VORTEX produced a number of high quality data sets of tornadic and nontornadic supercell thunderstorms that led to several important new findings.

In partnership with the University of Oklahoma, Texas A&M and Texas Tech, NSSL recently developed the Shared Mobile Atmospheric Research and Teaching Radar, or SMART-R, a mobile 5-cm Doppler radar. Two SMART-Rs have been used to study tornadoes, hurricanes and other phenomena across the country.

6. NUMERICAL MODELING

By the mid-1980s, NSSL had begun to develop an expertise in numerical modeling. Various techniques, including ensembles, are being investigated today to improve the numerical prediction of storm-scale, mesoscale, and synoptic-scale processes. NSSL researchers made a tactical decision 15–20 years ago that they wouldn't develop their own models—rather, they would use existing models and make them better.

NSSL uses numerical modeling in two ways. First, they use models to simulate the evolution of severe storms. They try to understand what is going on in terms of the physical processes within the storms. Second, they use numerical models to forecast the weather. NSSL researchers are now developing ensemble techniques to use with models. Ensembles are a collection of model results that were created by varying the model initial conditions and/or model parameters to produce a suite of forecasts and probabilities.

7. SUPPORTING THE STORM PREDICTION CENTER

In 1997, soon after the National Severe Storms Forecast Center in Kansas City changed its name to the Storm Prediction Center (SPC), it moved to Norman. This deliberate move to collocate research with operations has resulted in many opportunities for NSSL meteorologists to help SPC forecasters develop improved severe storm forecasting techniques, including the application of probabilistic forecasting techniques. Collaboration with the SPC has broadened the focus of NSSL researchers to include the study of hazardous winter weather and its effects on the population, as well as the study of processes that take place inside those storms.

8. IMPROVING PRECIPITATION ESTIMATES

NSSL has also addressed precipitation forecasting issues through hydrometeorological research since the mid-1990s. The work started with the Salt River Project, a power and water utility based in Phoenix, Arizona. The utility noticed that estimates of rain and snow were not very good for operational purposes in the cool season. It asked NSSL to take a more detailed look at the problem because accurate estimates of precipitation are important to utilities that use hydropower to generate electricity. NSSL researchers subsequently came up with a methodology to improve estimates of precipitation in Arizona over complex terrain. The concept was then turned into an algorithm that has world-wide applications.

The Lab's technique is different from traditional quantitative precipitation estimation (QPE) because of its multisensor approach that integrates sensors such as satellite data, rain gauges and model data, together with radar data, and combines them in a physically sound way. Improved estimates of precipitation are expected to help forecasters improve the timeliness of flash flood warnings.

Today NSSL is heading a project to seamlessly integrate all National Weather Service and Department of Defense WSR-88D radars across the U.S. into a single mosaic, thus providing the first high-resolution depiction of storms and quantitative precipitation estimation from coast to coast in real time.

9. INTERNATIONAL COLLABORATIONS

NSSL conducts collaborative research efforts with other countries. For example, there have been studies of the summer monsoon that brings most of the annual rainfall to the southwestern U.S. and northern Mexico. Forecast models do not handle precipitation estimation very well owing to the sparsity of surface and upper air observations over Latin America. For nearly a decade, an NSSL researcher has been influential in augmenting the observational network by obtaining rain gauges and recycled theodolites for tracking upper air balloons and by training local inhabitants how to use the instruments.

10. OUTREACH ACTIVITIES

Research at NSSL has impacted people beyond the weather research community—from emergency managers and storm spotters to the media and the general public. Much of the work at NSSL has been accomplished with the help of students, many of whom have gone on to very successful careers with leading meteorological organizations throughout the world. For the past several years, the Lab has cultivated future researchers through the Research Experiences for Undergraduates program, a National Science Foundation sponsored program that is run through the University of Oklahoma. Each summer, about 10 college students from across the country are paired with scientists throughout the Norman meteorological community, including NSSL, to work on a research-directed program. At the end of the 10 week program, the students each write a paper and give a presentation. The program gives them a chance to see most of the aspects of a research career.

Outreach efforts at NSSL also include a newsletter, work with a television program for middle school students called “Passport to Knowledge,” consulting on the movie “Twister,” posters about downbursts, lightning and tornadoes, interviews with local and national news media, interviews with production companies for programs that have aired on the Discovery Channel, National Geographic and The Weather Channel, as well as numerous open houses and tours for schools and special groups.

11. RADAR OF THE FUTURE

NSSL, with the help of its partners, the Navy, Federal Aviation Administration, the University of Oklahoma, the Oklahoma State Board of Regents, the National Weather Service, Lockheed Martin, and Basic Commerce and Industries, is now leading radar technology into the future with the National Weather Radar Testbed located in Norman. This phased array Doppler radar system is the first facility of its kind to be available on a full-time basis to the radar research community.

Phased array radar could be the next significant technological advancement to improve our nation’s weather services. This technology has a unique antenna that allows the collection of the same amount of information as conventional radar, but five to six times faster. Scientists will be able to adapt the radar scan to focus on the most important weather features and gather high temporal resolution storm information that will improve the understanding of storm evolution. Researchers and forecasters can then improve conceptual storm models and use the radar data to initialize and improve stormscale computer models. In addition, the FAA is supporting research to see if the radar can have a dual use—for both weather surveillance and aircraft tracking. It is expected to take 10 to 15 years to move the phased array radar from research and development to technology transfer and deployment.

12. SUMMARY

Established in 1964, NSSL leads the way in investigations of all aspects of severe and hazardous weather. NSSL is part of NOAA Research and is the only federally-supported laboratory focused on severe weather. NSSL’s scientists and staff continue to explore new ways to improve understanding of the causes of severe weather and ways to use weather information to assist National Weather Service forecasters, as well as its federal, university and private sector partners.

Through its various research activities during the past 40 years, NSSL has been instrumental in advancing the state of the art of severe storm detection, warning and prediction. Its accomplishments are long and varied, and the list of what it hopes to do is even longer. Overall, NSSL has significantly contributed to saving lives. NSSL’s greatest asset has always been its employees and its focused mission.

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