NEXRAD PEERS INTO

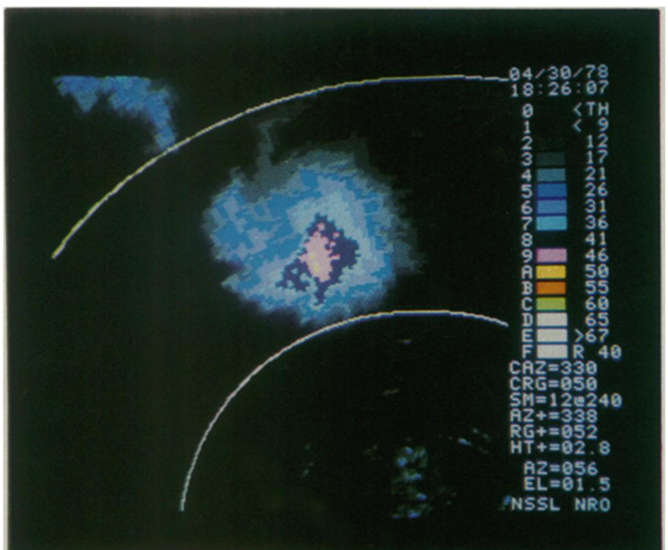
A new generation of severe-storm-monitoring Doppler weather radars is planned for the 1980s

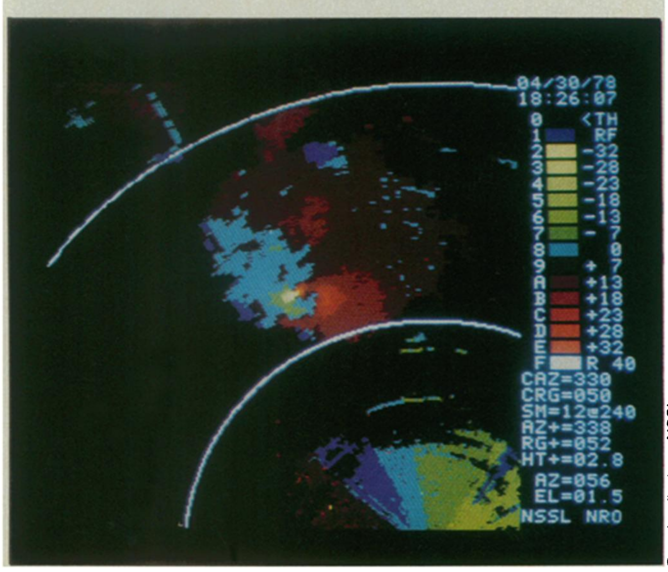
BY KENDRICK FRAZIER

Spring may symbolize the renewal of life, but it also brings harbingers of death. Severe thunderstorms and tornadoes swirl out across the land, leaving in their wake a trail of tragedy wherever their paths intersect centers of population. Last year's major killers were the series of giant tornadoes that struck Wichita Falls and Vernon, Tex., and Lawton, Okla., on April 10. Fifty-six persons were killed, many while trying to flee in their cars.

The 1980 tornado season started with a rush in April. On April 7 and 8 an explosively developing storm system spawned at least 40 tornadoes from southern Texas to Wisconsin, leaving four persons dead and about 100 injured. Sixteen more tornadoes broke out over Arkansas, Louisiana, Texas, Oklahoma, and Tennessee on April 10 and 11. Mid May brought another outbreak. Fourteen tornadoes struck Missouri, Pennsylvania and four other states on May 12. On May 13, tornadoes struck downtown Kalamazoo. At least seven persons were left dead, and the destruction continues this month.

Research meteorologists and government agencies, following years of tests, are now making plans to institute a whole new severe-weather-warning capability that they are convinced will provide earlier and more accurate warnings of tornadoes and other severe storms. The program is called NEXRAD, for next generation weather radar. It would replace the nation's present aging network of weather





Doppler displays: NSSL

Doppler radar will do more than brighten up your local TV weather forecasts. Display at left indicates reflectivity of April 1978 tornado that struck Piedmont, Okla. Display at lower left indicates velocity of same tornado, and one on facing page reveals gust front of a thunderstorm that occurred near Oklahoma City. With such information provided in a multicolor format, meteorologists hope to be able to provide timely and accurate severe-weather warnings. Tornado pictured above hit down near Seymour, Tex., early this spring.

radars with new Doppler radars, which can detect the velocities of rain and ice particles within a storm and display on color-coded video screens the patterns of wind motion that herald a tornado. The same capabilities can also better distinguish between severe and nonsevere thunderstorms and help detect outrushing gust fronts and wind shears so destructive to property and so dangerous to landing airliners. They also can undoubtedly be useful in better monitoring hurricanes and severe winter storms, although those possibilities have yet to be studied in detail.

Doppler radar as a research tool in studying processes inside storms has been around for some years. What is new is the confirmation in a multi-agency research program that Doppler is indeed superior to the present system in providing both far longer tornado warning lead times and much reduced false alarm rates. Armed with the conviction that Doppler can help reduce tornado casualties and otherwise upgrade warning services, severe-storm meteorologists are pressing for its general introduction into the national meteorological network starting in the mid-1980s. But it will be expensive—$1 million to $1.5 million for each unit—and with the current economic climate it's hard to forecast whether the outlook for the Doppler network is cloudy or sunny.

"We in the scientific community and the agencies are convinced that Doppler is a better radar," says Donald W. Burgess of the National Severe Storms Laboratory in Oklahoma. "The question is can our country afford to put in 150 of them at $1 million each . . . ?"

Ken Wilk, chief of technology and operations at NSSL, says the NEXRAD concept

STORMS OF FUTURE

Gene Moore

does seem to be popular with lawmakers, especially those from states frequently afflicted by severe-storm tragedies. "It has a lot of congressional support," he says, "probably more than any recent project I've seen." Nevertheless, he says, "I'm not sure what will happen."

Wilk is the laboratory's liaison with the new three-agency NEXRAD Joint Systems Program Office (JSPO) set up in Washington. Its goal is to further develop meteorological techniques for the system in university and government laboratories; to develop, design, test and evaluate the system over the next five years with the help of industry; and to arrange for the actual procurement and installation of the equipment.

Wilk says if all goes well, "The plan would put the first systems on line for 1985, with completion of the transfer to Doppler by 1988." Of the many hurdles to be cleared before operational Doppler can become a reality, the next is a detailed review of the concept by the three major agencies involved (Commerce, Defense and Transportation), now nearing completion. It will have to document and certify for the Office of Management and Budget that NEXRAD is required to meet the major needs of the agencies. Arthur L. Hansen, director of the JSPO office, at the National Weather Service headquarters in Silver Spring, Md., says he hopes that agency approval will be forthcoming by mid-June.

All these steps are necessary before Congress can approve any special funding for NEXRAD. Right now NEXRAD planning is being supported by the reprograming of funds within the three agencies. Hansen says it will probably be around 1985 before the first funds for procurement of hardware have to be requested of Congress.

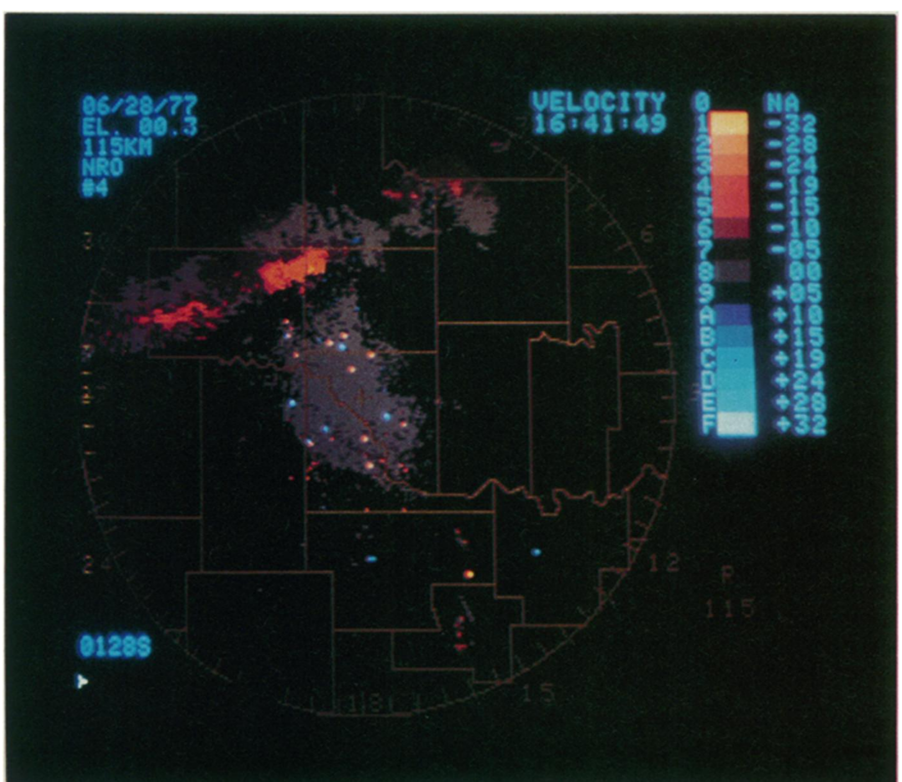
What exactly is Doppler radar? Its proposed operational use has been compared in significance to the first introduction of conventional weather radar after World War II. The technique makes use of the Doppler effect to calculate the velocities away from and toward the radar beam of precipitation particles within a storm. Conventional radar measures only degree of reflectivity. Its accuracy and reliability in diagnosing damaging winds and tornadoes is limited. "Hook echoes" and other signs of a tornado are often seen on conventional radar only after the tornado is already doing damage.

Doppler radar, in contrast, can detect the swirling motion of the parent mesocyclone, the intense rotating wind system in the lower part of a thunderstorm that produces tornadoes. Sometimes it can even see the signature of the even smaller and more intense tornadoes themselves.

One hundred meters southwest of the National Severe Storms Laboratory's modern two-story building on the north outskirts of Norman, Okla., is the freshly painted white dome of the 30-foot-diameter antenna of the laboratory's Doppler radar. It was with this instrument that the research program conducted from 1977 to 1979 proved the operational capability of Doppler.

In the darkened control room beneath the antenna, a series of video consoles are set up. One provides displays of reflectivity, the intensity coded into up to 15 different colors. This is essentially identical to the output of the conventional color radar now seen on many commercial television weather forecasts. To the right is a color display of the velocity data. This is the key Doppler display. The mix of colors is arbitrary. Different operators have their own preferences. But increasing degrees of red usually will indicate increasing velocities away from the radar, and increasing degrees of green or blue indicate increasing velocities toward the radar. The signature of a tornado is close proximity of two bright contrasting colors, a sign the radar is seeing the right and left sides of a rapidly swirling mass of air. The operator can select a suspect storm and "zoom in" on it for a closer look. To the right of the velocity display is another in color showing degrees of turbulence within the storm.

To the left of these three color consoles is a black and white unit displaying a field of arrows. This is another type of visual Doppler readout. The length of the arrows indicates the degree of reflectivity, the width of the arrowheads the degree of turbulence, and the orientation of arrows the velocities within the storm. Right-facing arrows indicate zero velocities, with clockwise rotation indicating velocities toward the observer, counterclockwise rotation velocities away—"like a speedometer," notes Burgess. Although the arrows aren't vectors, the visual effect is much the



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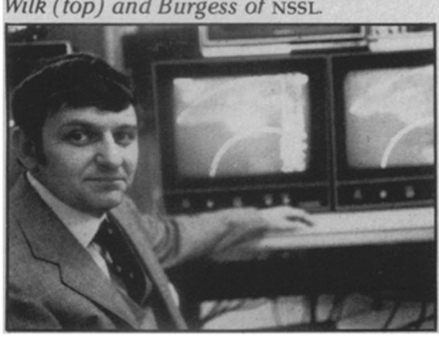
same. Where there are rapid swirling wind systems, the arrows in the field tend to wind up tightly into a spiral.

Still another color display became available during the second and third years of the Joint Doppler Operational Project. It uses a minicomputer to automatically plot each storm cell track on a map display and forecast their future positions. This display was developed by the Air Force Geophysical Laboratory, which participated in the project along with National Severe Storms Laboratory, the National Weather Service, the Air Force Air Weather Service, and the Federal Aviation Administration.

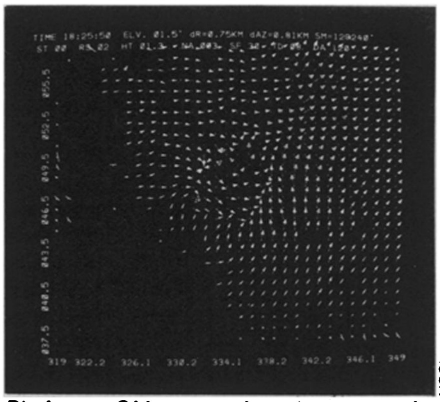
The best close-in Doppler view of a strong tornado came late in the afternoon of April 30, 1978, when four tornadoes raked across the suburb of Piedmont, on the northwest outskirts of Oklahoma City. Burgess, who was lead research meteorologist for the Doppler project, remembers the day well. One reason is that the Piedmont storms were only one of four violent storm systems around the state, and the Doppler group was trying to monitor them all. Another is that at that time his home was still in the northern Oklahoma City suburbs, and he spent some antsy moments worrying whether the tornadoes would veer toward his neighborhood. They didn't. But one of the Piedmont tornadoes was a big one, a maxi-tornado of F4 intensity on a scale of 5, meaning its damage could be described as "devastating." Its damage path was more than a mile wide and nearly six miles long. Although 15 homes in Piedmont and 10 rural homes were destroyed and damage amounted to $7 million, no one was killed or injured.

On the Doppler screens at Norman, 60 kilometers to the southsoutheast, strong

Wilk (top) and Burgess of NSSL.



Photos: K. Frazier



NSSL

Piedmont, Okla., tornado as it was seen by Doppler multimoment arrow display.

cyclonic shear was detected early. A tornado advisory based on a mesocyclone containing a tornado vortex signature was issued at 5:42 p.m. As a result a National Weather Service warning went out at 5:50 p.m. The maxi-tornado touched down at 6:20 p.m., a full 30 minutes after the warning went out. It remained on the ground for 15 minutes during which time it showed clearly on the Doppler velocity display as a close juxtaposition of the colors green and red. The multimoment arrow display showed a tightly wound circulation.

The long lead time afforded by the Doppler monitoring turned out to be typical of all the storms monitored during the Doppler project's two main years. Statistical records showed Doppler out-performing the conventional warning system (consisting of the Oklahoma City Weather Service radar plus reports from spotters and the public) in several important respects.

The probability of detecting a tornado was about the same: 0.64 for conventional, 0.69 for Doppler. But Doppler's false alarm rate (0.25) was far lower than the conventional method's (0.63), an important consideration in severe storm forecasting and warning. Doppler's critical success index (C.S.I.) was almost twice as high as the conventional system's, 0.56 to 0.30.

But where the Doppler really excelled was in the lead time between warning issued and the tornado striking. With Doppler, the average lead time was 21.0 minutes. With the conventional, it was 1.8 minutes. This reflects the fact that many tornado warnings now result from actual visible sightings, and those seldom are made much before the tornado hits. The Doppler system detects the conditions up inside the storm that lead to a tornado.

Those additional 19 minutes of precious lead time are what give the proponents of Doppler their strong conviction that a nationwide NEXRAD system using Doppler radars is very much in the public interest.

Doppler has other advantages as well. It offers a higher probability of detecting severe thunderstorms. Its narrow beamwidth can distinguish between severe and non-severe thunderstorms at long range (230 to 350 kilometers) and between tornadic and non-tornadic storms at closer ranges (less than 230 km). It can more precisely locate severe storm and tornado signatures. This will allow warnings to be more specifically directed to much smaller areas than they now are. And it should make for safer commercial aircraft flights in thunderstorm areas by identifying in-storm turbulence, wind shear, medium-scale air vortices and gust fronts. (Gust front detection by Doppler is being studied again this spring in Oklahoma.)

All these were findings of the JDOP, whose participants agreed that "the next generation meteorological radar should have Doppler capability."

The issue is not academic. The problem is that the present WSR-57 radars used in the national meteorological network are rapidly wearing out. Their designs go back to 1957, and some of the actual units are 20 years old. "They are three generations behind the time," says Burgess. "They are tube-type, not solid state, and they are old. It is an aged system."

In Washington, Hansen agrees. The new capability demonstrated by the Doppler is only one of the motivations for NEXRAD. The other is "the aging weather radars in the National Weather Service and FAA." Something, he says, does have to be done.

In testimony March 5 to the House Science and Technology Committee, Administrator Richard A. Frank of the National Oceanic and Atmospheric Administration (parent agency of the Severe Storms Lab and the National Weather Service) estimated that a full system of 128 NEXRAD sites in the 48 contiguous states and 33 additional sites overseas would cost $270 million. There is a possibility of reducing that figure somewhat by substituting non-Doppler radar in some non-severe-storm areas, but that would raise the political problem of some regions getting less than top-of-the-line forecasting potential. Besides, only now are studies turning to the apparent usefulness of Doppler in such areas. One has found it able to detect strong wind shifts in California's Sacramento Valley.

One thing that has been decided is that to save on expense, the National Weather Service, the Air Weather Service, and the FAA can all make do with one Doppler radar in each forecasting area (rather than their now independent ones), and all tie into it with their own computers and display systems. Television stations could presumably do the same thing.

NEXRAD has many uncertainties before it. One is the administration's recent 10 percent budget cutback. There's a lot of nervous joking about that. ("Maybe we ought to cut tornadoes by 10 percent," says one severe-storms forecaster.)

But the program has broad support in the meteorological community. And the potential has been proved. All in all, the chances are good that you'll be receiving improved forecasts and warnings of tornadoes and severe weather, courtesy of Doppler radar, sometime in the 1980s. □