METEOROLOGY

Into the eye of a storm

Two new techniques give unprecedented views of storms, turbulence

ESSA

Mobile Doppler-radar units probe the core of an approaching thunderstorm.

by Kendrick Frazier

Meteorologists, it has been said, too often are forced to combine inadequate observations with unsupportable assumptions. This is perhaps most true of research into severe storms, but it can apply to other atmospheric events as well.

A basic problem is the difficulty, if not the impossibility, of observing a meteorological phenomenon with the detail necessary to understand its essential processes. Research aircraft, for example, are generally not sent into thunderstorms because of fears that they would be damaged by hailstones or torn apart by the shearing action of adjacent updrafts and downdrafts.

To draw more information from the atmosphere and the hearts of storms, meteorologists are turning to a host of electronic aids. Laser beams, microwaves and sound, radio and infrared waves all are being used to probe the atmosphere.

Two recent developments drawing the attention of atmospheric scientists make use of an electronic tool that meteorologists have had available for some time—radar. Both new applications represent significant advances in data-gathering capability beyond previous radar meteorology techniques. Both have come to fruition within the past year.

One is a multistation Doppler-radar system developed by Dr. Roger Lhermitte, a physicist at the Environmental Science Services Administration laboratories in Boulder, Colo. It provides the first direct, three-dimensional view of the insides of a thunderstorm or other turbulent weather disturbance. "For the first time in meteorological research," says Dr. Lhermitte, "we will be able to study updrafts, downdrafts, convergence, divergence and vortices in a developing storm by actually observing them."

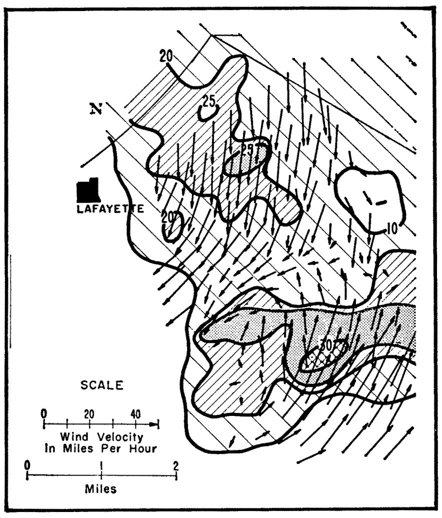
The other is an ultrahigh-resolution radar. Developed by Dr. J. H. Richter of the Naval Electronics Laboratory Center in San Diego, it opens a wide range of until-now invisible atmospheric phenomena to finely detailed examination. "The use of this technique," says Dr. David Atlas of the University of Chicago's Laboratory for Atmospheric Probing, "promises advances in meteorological knowledge comparable to those in medicine resulting from X-ray fluoroscopy."

Dr. Lhermitte's multiple Doppler technique has been 10 years from conception to use in the field. Development had to await the availability of advanced computers capable of handling large amounts of data in a short time.

Conventional radars can locate a storm, determine its general movements and map out its general areas of precipitation.

Doppler radars, which have been used in meteorological research for about a decade, can do one important additional task—measure the radial velocities of windblown precipitation particles. The technique makes use of the well-known Doppler effect, in which the observed frequency of waves emitted or reflected from an object varies with its velocity relative to the observer. But a single Doppler radar is unable to determine the true speed and direction of the particles because most of them are moving diagonally across the radar beam.

Dr. Lhermitte's system makes use of an array of strategically placed portable Doppler radars and a high-speed digital computer. With two or three radar units, the particle movements can be monitored from several directions simultaneously. Each Doppler simultaneously observes a series of 24 points along the length of its radar beam. This allows Dr. Lhermitte to receive velocity data for 24 points from front to rear of a storm. Every two seconds the antenna automatically shifts to a new direction and observes another 24 points. A complete scan of the storm is completed in a few minutes.

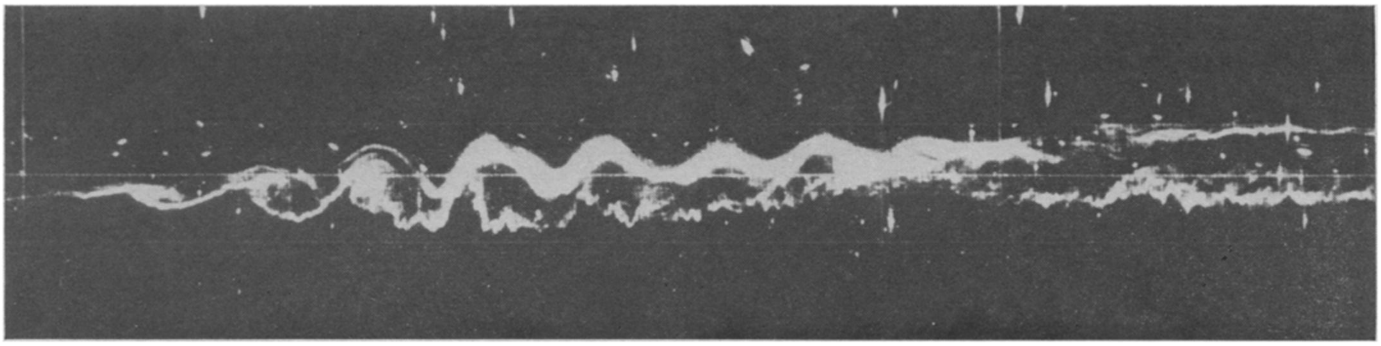


ESSA

Winds inside a storm near Boulder.

With these data and the means to process them rapidly, the way is open to observe in three dimensions the birth, development, internal wind field, hailstorm growth and death of convective thunderstorms.

The field test that proved the feasibility of the technique was carried out late last summer outside of Boulder. Two radar vans set up 11 miles apart probed the turbulent interior of a thunderstorm 40 miles to the northwest. Later analysis of the data resulted in maps of wind speeds and direction at



Univ. of Chicago

Unstable, amplifying and breaking waves on the radar screen indicate the presence of clear air turbulence.

dozens of selected points and several levels within the thunderhead.

Dr. Lhermitte and his colleagues believe the system makes it practical to study the entire volume of a storm by observation.

"It would be almost impossible to derive such data by any other technique," says Dr. C. Gordon Little of ESSA's Boulder laboratories. "You would have to have 20 aircraft flying through the storm to obtain comparable data."

Since last summer's tests, the group has been working to improve the scanning and computer techniques. Dr. Lhermitte says he thinks field studies this summer near Boulder may provide enough data to permit the first conclusions about the development, nature and life of convective thunderstorms.

In the present arrangement, the data are recorded on magnetic tape and later analyzed back in the laboratory at Boulder. It is not a satisfactory system. "The problem of processing the Doppler-radar information is quite a difficult one and still hasn't been solved," says Dr. Lhermitte.

"One of our goals is to design a very fast computer for installation directly in the portable radar units," he says. "We are developing the computer ourselves and hope to have it ready in the next year or so. Then we will be able to show Doppler velocities in three-dimensional displays in real time. This is something that is badly needed if we are to observe the wind field within a developing storm."

The ultrahigh-resolution radar developed at San Diego—unlike the Doppler-radar units that study the interior of visible, severe storms—probes the fine structure of invisible layers of turbulence.

The principles of the technique, called FM-CW (for frequency-modulated, continuous-wave) radar, have been known since pre-World War II days. But it was only last year that the full capabilities of such a system for meteorology were developed in a radar designed and built by Dr. Juergen Richter at the Naval Electronics Laboratory Center. The system provides a resolution of about one meter, compared to the 100 meters previously possible.

"The curtain has been raised on a whole view of atmospheric activity that we never had before," says Dr. Atlas. "As you can tell, I am very excited." He, Dr. Richter and Dr. E. C. Gossard have performed joint studies with the radar since its development.

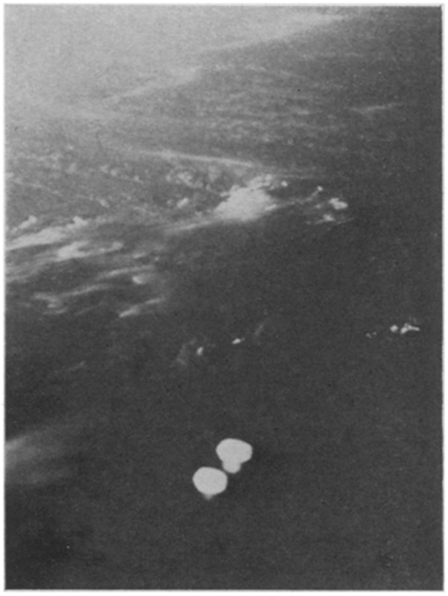
Already it is clear as a result of the studies that the atmosphere contains organized structures on a much finer scale than previously perceived. Significant atmospheric inversions may occur with vertical dimensions of a meter or less.

The radar has revealed, for example, the finely detailed structure of inversion layers. "The inversion is generally not the static sort of surface which our textbooks have led us to believe," says Dr. Atlas. "Even when high-resolution meteorological measurements indicate what appears to be a stationary surface, the radar will frequently show small-amplitude wave activity, breaking and microscale turbulence."

He points to what he calls a remarkable set of observations of wave and turbulence activity recorded over San Diego on July 19, 1969, with a resolution of two meters. Initially a single echo layer was seen. The layer remained flat for 20 minutes. Then appeared the formation of a series of amplifying and breaking waves, like the surf at the beach. Most of the waves broke backward, opposite to the direction of propagation. This was due, in effect, to friction against the air medium in which they were traveling.

These amplifying unstable waves, says Dr. Atlas, are clearly what are called Kelvin-Helmholtz waves. They occur when the wind shear across a stable layer is sufficient to shear off the crests relative to the troughs. Virtually all theories on the origin in nonmountainous regions of that invisible enemy of airline pilots, clear air turbulence (SN: 1/31, p. 134), call upon the occurrence of unstable K-H waves.

"I am confident that what we are seeing here," says Dr. Atlas, "is the birth and life of CAT, not very strong CAT, but CAT nevertheless." The observations show that clear air turbulence is clearly transitory in both time and space, and its intensity can vary sharply in only a few tens of meters vertically.



NICAP

UFO's: A meteorological explanation.

Practical CAT detection by this method awaits attainable increase in sensitivity and portability. But the University of Chicago scientist recommends that immediate application to monitoring of the depth of the mixing layer for air pollution should be considered.

The observations have dispelled doubt about the existence of intense microscale turbulence in submeter scales, he believes. But how this kind of turbulence is started in layers that are stable remains a mystery.

Finally, Dr. Atlas believes the findings may help clear up many instances of unidentified flying objects: "It seems entirely possible," he speculates, "that both radar and optical UFO phenomena may now be explained in terms of reflection, refraction and scattering from such strata. At the very least this possibility needs to be examined critically." □