Interview

OPERATIONAL DOPPLER RADAR - IS IT WORTH IT?

Article and Interviews
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Future weather radar historians will note that 1979 was the year Doppler radar became a household word. Government officials are ballyhooing Doppler's superior storm detection capabilities, television weather reporters are crusading for a Doppler in every hamlet and the National Enquirer seems to rank Doppler's prognostic abilities only slightly inferior to Jean Dixon's.

Even Al Pearson appealed on the "Today" show for fifty cents from every man, woman and child in America to finance a network of Doppler radars around the country.

Conventional 10 cm weather radars in use today cost around $450,000. This includes the radar, antenna, protective dome and installation. The optimum 10 cm Doppler radar has a projected price tag of $1,000,000.

Is the improved tornado detection capability of Doppler radar worth the extra $550,000? How much better is Doppler than conventional radar in warning for tornadoes? What are the limitations of Doppler radar? How difficult is it to operate a Doppler radar and how long does it take to train an operator?

I had a chance to interview a cross section of the nation's leading experts on Doppler radar at the October 1979 Severe Storms Conference in Kansas City. This paper presents their paraphrased responses and attempts to bring Doppler radar objectively into focus for the operational weather community.

Digest: Do you favor replacing the National Weather Service's network of WSR-57 radars with Doppler radars?

Fujita: Yes. I advocate replacing them slowly with Doppler as they wear out. The WSR-57 radars are getting old and the next generation radar should be Doppler.

Digest: Do you feel that Doppler radar can identify 100 percent of all tornadoes?

Fujita: No. I worry about the public's misunderstanding Doppler's tornado detection capability. We need more cases in our data base. It is like the initial chest X-ray that detected a cancer. The first scientific papers overestimated the X-ray as a tool in cancer detection. The implication was that it would detect all cancers. We just can't promise the public that Doppler will identify all tornadoes. Doppler does identify mesocyclones (areas of storm rotation) and tornadic vortex signatures. The degree of severity of a tornado is connected with the identification of a mesocyclone, however not all mesocyclones produce tornadoes. It is sometimes like beating the bushes with a very large stick and flushing a small snake.

DR. T. THEODORE FUJITA

"SOMETIMES DOPPLER RADAR IS LIKE BEATING THE BUSHES WITH A VERY LARGE STICK AND FLUSHING A VERY SMALL SNAKE."

Digest: What are some of the advantages and disadvantages of Doppler radar?

Fujita: A major advantage of Doppler over conventional radar is its ability to measure particle velocity towards or away from the radar. Sometimes this information is ambiguously presented due to the problem of range folding.

Digest: Range folding?

Fujita: The maximum unambiguous range at which velocity measurements can be made is a function of the wavelength of the radar and the number of pulses per second transmitted by the radar. In general, higher Doppler velocities can be measured only by increasing the number of pulses, and this decreases the maximum unambiguous range. The result is something like a double exposure. Also, we can't detect mesocyclone signatures all the way to the ground at greater ranges. These storms are below the radar horizon.

Digest: Doppler research has shown a significant increase in the lead time of storm detection by radar and the occurrence of severe weather.

Fujita: Yes, however you can attempt to have too much lead time. It is a tradeoff between the accuracy of the warning and the length of the warning lead time.

Digest: Have we collected enough statistical evidence to adequately define Doppler's capabilities and limitations?

Fujita: No. We need to collect more data on Doppler's operational use. Perhaps the National Weather Association could assist in this. Also, we have a tendency to publish our successes and not publish our failures. We need to publish our failures more.

Digest: What are your future research plans?

Fujita: I plan to learn more about and work with Doppler radar at the University of Chicago and the National Severe Storms Laboratory (NSSL). For example, I advocate the use of fast scan Doppler radar to detect low level wind shear around airports. I have taken over 30,000 pictures in the last several years during aircraft reconnaissance flights of severe convective storms and I worry about the safety of my friends and professional colleagues encountering downbursts while landing at airports.

Digest: How much better is Doppler radar over conventional radar in tornado detection?

Burgess: The Joint-Doppler radar experiment comparing 10 cm Doppler and conventional radar data using radars located around the Oklahoma City area has shown only a slight, 5-10 percent, tornado detection advantage over conventional radar, but the storm warning lead time for Doppler is 20 minutes compared with 2 minutes for conventional radar. The 20 minutes lead time is based on mesocyclone and TVS identification.

DONALD BURGESS

"THE IDEAL WARNING SYSTEM OF THE 80'S WOULD INCLUDE DOPPLER RADAR, TRAINED SPOTTERS, INSTANT MASS MEDIA COMMUNICATION AND A PUBLIC EDUCATION PROGRAM."

Digest: TVS?

Burgess: A region of high wind shear (direction change) within tornadic thunderstorms, called a tornadic vortex signature. Unlike the hook echo of conventional radar, the TVS is a radar signature of the tornado itself. This allows us greater resolution in geographically locating a tornado on radar. The false alarm rate for tornado warnings issued on the basis of Doppler imagery is about 40 percent lower than conventional radar. Half of the spotter reports from the field verified, while only 30 percent of conventional radar detected hook echoes verified. Still, the current conventional radar system is quite good.

Digest: Rumors surfaced that Doppler radar was unsuccessful in detecting the tornado that struck Wichita Falls, Texas in April of 1979.

Burgess: The Wichita Falls tornado occurred during a planned time when the 10 cm Doppler radar was running a raingauge experiment for Project Severe Environmental Storms and

Mesoscale Experiment (SESAME) 1979. We were not conducting an operational test for tornado detection. As a result of this test mode, the selected pulses per second resulted in range folding on our 10 cm Doppler radar, but a mesocyclone was detected at Seymour Texas (about 93 km, 50 nmi, southwest of Wichita Falls). Our 5 cm Doppler had the problem that another storm around Lawton, Oklahoma attenuated the Wichita Falls returned echo so severely that it disappeared from the radar scope. This is a problem common to any 5 cm radar whether it is Doppler or conventional radar.

Digest: Is Doppler radar worth the projected $1,000,000 per 10 cm radar price tag?

Burgess: I don't know. The proper government agency needs to study this problem. We average about 100 tornado deaths per year in this country compared to 40,000 plus for automobile accidents. Doppler radar is not a panacea for all our tornado warning problems; however the Joint-Doppler experiment over the past several years has shown that the 15 percent of tornadoes not detected by Doppler were relatively weak. I am concerned about Doppler's operational storm detection capabilities not being oversold or undersold. For example, promises were made about weather satellites that could not be kept and in my opinion, John Coleman of the "Good Morning America" show has oversold Doppler's capabilities. However, we can make a significant improvement in tornado warnings during the 1980's by combining Doppler radar with trained spotters, instant mass media communications and a public education program.

Digest: What are your future research objectives?

Burgess: We need to expand our studies of Doppler's operational capabilities and also investigate wind and hail storms, turbulence and general storm structure. We need a network of reporting stations like the SESAME project and several Doppler radars. A measure of our critical success is only as good as our data base.

Digest: What has been your most rewarding research experience to date?

Burgess: The opportunity to participate in the expansion of Doppler knowledge and the team effort of my colleagues at NSSL.

Digest: Do you advocate replacing conventional radars with Doppler?

Donaldson: Yes. Don't wait for the WSR-57's to wear out. Put Dopplers in tornado-prone locations and areas subject to hurricanes as soon as possible. Doppler radars will reduce loss of life and limb, and also diminish anxiety.

Digest: Anxiety?

Donaldson: The greater precision of warnings in both lead time and geographic location will make the warnings more meaningful and reduce the public's anxiety over false alarms. There will be fewer false alarms with Doppler.

Digest: What are some of the other advantages of Doppler radar?

Donaldson: The Oklahoma Joint-Doppler experiment had an average tornado warning lead time of over 20 minutes. Some tornado producing supercells have been identified as troublemakers an hour before tornado touchdown. The stronger maxi-tornadoes are easier to identify with Doppler than with conventional radar, say to a range of 200 km (108 nmi). Within that range, Doppler radar detection of the maxi-tornado is close to 100 percent. On the color display of velocity, it is somewhat like seeing a dragon breathing a lot of fire.

Digest: What are some of the limitations of Doppler radar?

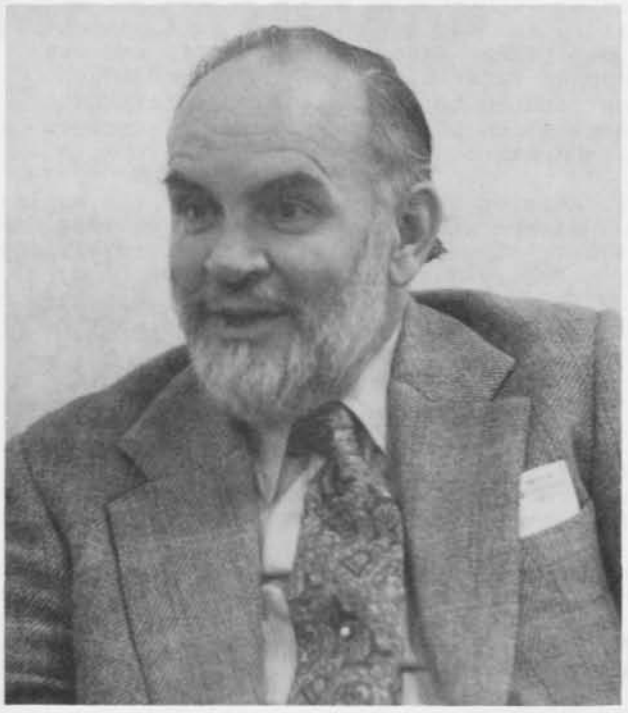
Donaldson: We don't know if a Doppler-detected mesocyclone will produce tornadoes or not. About half of them do. Although a tornado has a much better chance of appearing with a TVS than with a mesocyclone, TVS statistics are not as reliable because far fewer TVS's have been identified. This is a problem which will be cured as more Doppler observations accumulate. Another limitation is the small size of the TVS, so it is rarely detected beyond a range of 100 km (54 nmi). Finally, range folding and velocity folding also create difficulties, with the velocity folding problem being the more serious of the two. Still, mesocyclones and TVS's can be detected despite the folding problems.

Digest: What wavelength do you recommend for an operational Doppler radar?

Donaldson: The optimum Doppler radar for severe storm warning has a wavelength of 10 cm. Cheaper Doppler radars with shorter wavelengths of 5 cm can be built, but they suffer from double and even triple range and velocity folding. Add to this the signal attenuation problems inherent to 5-cm radars and you end up with a radar that is much less effective in detecting storms. In fact, I advocate 10-cm radars for use by everybody, including television stations.

Digest: What is the cost of a Doppler radar?

Donaldson: The projected cost is around one million dollars. This is an estimated cost though, because 10 cm Doppler radars are not yet in production. However, you can't put a cost on human life.



RALPH DONALDSON, JR.

"DON'T WAIT FOR THE WSR-57'S TO WEAR OUT."

Digest: How long does it take to train someone in the fundamentals Doppler radar interpretation?

Donaldson: The interpretation of a Doppler velocity field is very difficult. Nevertheless experience with the Joint-Doppler experiment has shown us that people with backgrounds in conventional radar can be trained in the basics of Doppler interpretation in about one month.

Digest: Are you concerned that the Doppler signature of a severe storm might be different depending on the part of the country it is being reported in?

Donaldson: No.

Digest: Do you consider Doppler radar ready to be used operationally?

Donaldson: Yes. The basic Doppler research has been done and it is now operational. Additional research will refine existing knowledge. The Critical Success Index for storm detection with Doppler radar is much better than with conventional radar, but these numbers are likely to lower under operational pressure.

Digest: What is the Critical Success Index?

ROBERT GREBE DR. EDWIN KESSLER

"DOPPLER RADAR CAN DO EVERYTHING CONVENTIONAL RADAR CAN DO --- PLUS MORE."

Donaldson: The Critical Success Index is used in radar to weight the ability to detect a storm against the number of false alarms that result in using a particular storm signature as the basis for issuing a warning. You are penalized for false alarms. A recent two-year study done by NSSL established Critical Success Indices of 56 percent and 30 percent for Doppler radar detection and conventional radar detection, respectively, of tornadoes in the Oklahoma City area.

Digest: Do you advocate replacing conventional radars with Doppler?

Kessler: Yes. Doppler radars should replace our conventional radars, which are wearing out. Doppler provides improved detection capability over conventional radar and remarkably greater lead time for severe storm warning. Doppler radar can do everything conventional radar can do plus more. Thus, Doppler radar can detect mesocyclones from their velocity distribution and Doppler radar provides a potential for frequent determination of horizontal winds in clear air as well as in precipitation.

Digest: How about the increased cost?

Kessler: Doppler will add less than 40 percent to the cost of a non-Doppler system. This includes means for acquiring, processing, and displaying radar data as required nowadays. The Doppler includes more than a radar for the $550K differential -- it includes a data processing system which the present radar system should have had long ago! We should not bar from our future

weather services the obvious benefits of improved weather diagnosis and storm warnings. On the other hand, I advocate that Doppler radars replace elements of the present system on a selective basis, and until they are replaced, the radars we already have should be used with modern data processing equipment in order to realize more of their potential contribution.

ABOUT THE INTERVIEWEES:

Dr. Fujita is Professor of Meteorology at the University of Chicago and has been working with Doppler radar since the early 1970's.

Donald Burgess is a research meteorologist with the National Severe Storms Laboratory and has been working with Doppler radar since 1970. Mr. Burgess contributed to the discovery and documentation of the tornadic vortex signature.

Ralph Donaldson, Jr. is a research meteorologist with the Air Force Geophysics Laboratory and has been working with conventional radar since World War II, and with Doppler radar since 1965. Mr. Donaldson contributed to the initial Doppler radar observation of a mesocyclone in a severe thunderstorm.

Dr. Kessler has been Director of the National Severe Storms Laboratory since 1964. In 1973, NSSL was first with real time displays of velocity contours derived from Doppler radar data. Dr. Kessler began researching the application of radar data to weather forecasting in 1954.

ABOUT THE INTERVIEWER:

Robert Grebe is Senior Instructor of Radar Meteorology at the National Weather Service Training Center.

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