Meteorological Instruction and Research at the University of Oklahoma

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In the fall of 1960, the University of Oklahoma initiated a program in meteorology within the School of Engineering Physics. The undergraduate program of instruction is based on general chemistry, general physics, and mathematics through calculus. Presently the undergraduate has a choice of three Bachelor of Science curricula, all of which satisfy requirements for graduate study and also for professional employment in meteorology. One is the engineering meteorology option, an option in Engineering Physics, in which the student completes the engineering core curriculum, the meteorology requirements, and also advanced courses in physics and mathematics. There are two science options, one in physics and one in mathematics, and in these the emphasis — besides meteorology — is in the respective basic science. Justification for these various programs lies in the needs for physical science and engineering in the scientific and technological advancements of meteorology, advancements which have already been vast since World War II, and which were accelerated by advent of the space age.

The graduate program extends through both M.S. and Ph.D. The master's program is convenient for both meteorology and non-meteorology graduates. It was devised with purposeful intent of attracting promising graduates of the physical sciences or engineering, who may have had no previous contact with meteorology, to enter graduate studies in meteorology; for those graduates of other curricula the equivalent of one semester of prerequisites in meteorology is required. On the other hand, those students who majored in meteorology as undergraduates are required to complete a graduate minor in a related physical science or engineering field. The emphasis is on breadth of knowledge in the basic and applied fields which bear on modern-day meteorology.

Our Ph.D. students majoring in meteorology follow the Ph.D. in Engineering Sciences program. It requires broadening in the basic sciences, and it also allows the flexibility to include graduate courses in other technical areas useful for present and future developments in the science, e.g., nuclear engineering, sanitation, computer science, statistics, hydrology, and so on.

The present student body of meteorology majors consists of three in the Ph.D. program, six in the master's program, and about 45 in special graduate and the various undergraduate programs, excluding freshmen. About 30 new major students are expected to enter the next semester, thus increasing enrollment by about 50 per cent. We have accommodated all of our qualified students who desired them with assistantships, mostly in the large meteorological research program which has developed. Undergraduate students may spend the summer months employed in the student-trainee programs of the U.S. Weather Bureau.

The research program in meteorology at the University of Oklahoma has shown a rapid development in the two years. This is due in part to the natural laboratory which nature has endowed central Oklahoma in the form of intense convection and severe weather in the springtime, and in part also to the ever-increasing national emphasis on the understanding of earth's atmosphere, for the atmosphere is critical in the national defense effort, the space effort, and the almost limitless number of human activities.

The National Severe Storms Project of the U.S. Weather Bureau has been operating an extensive program of severe storms investigations in central Oklahoma each spring, employing several instrumented aircraft, weather radars, atmospheric soundings, and a dense network of surface recording stations. The aircraft operate from Will Rogers Airport and Tinker Air Force Base. The NSSP Weather Radar Laboratory is now being established permanently at the University of Oklahoma; it includes several powerful, long-range radars of different characteristics, and will be the most complete weather radar installation in the world. Figure 1 gives an exterior view of part of that facility in construction, which is located adjacent to the university meteorological laboratory. The surface network is in a grid covering south central Oklahoma; at each station continuous automatic records of wind, temperature, humidity, and rainfall are made. Other national agencies operate regular and experimental detection equipment during springtime investigations. These facilities and data are available for use in the university program.

Now, we briefly summarize some of the meteorological research programs of the University of Oklahoma.

Upper Atmospheric Circulations. The region of the atmosphere extending roughly from 10 to 50 km altitude is known as the stratosphere; the next layer above, from 50 to 90 km, is the mesosphere, and above that is the ionosphere. The stratosphere is, generally speaking, the "reservoir" of

Figure 1. Radar installations of the Weather Radar Laboratory, U.S. Weather Bureau, on the North Campus of the University of Oklahoma, in process of construction. The tower on the right supports the antenna of the WSR-57 system, and the vacant tower next to it will support the CPS-9 radar antenna.

radioactive particles from atomic and nuclear explosions. It is also the region of concentrated ozone, which has a vital role in regulating life on earth, and it plays a part in the weather observed near the ground. There is thus concern for circulations and physical transformations within this region. The density variations of the mesosphere and ionosphere have become of concern in the missile and space ages, largely in the problem of atmospheric re-entry, besides their long-known effects on sound and radio propagation. There are two current research programs on analysis of the upper atmosphere, one emphasizing stratospheric circulations, the other having the objective of formulating models of atmospheric density up to 200 km altitude with the three space dimensions and time as variants.

Laboratory Vortex Investigations. Miniature "tornadoes" 10 inches long and 2 inches in diameter are created in the Vortex Laboratory for the purpose of studying their pressure and velocity structure, and to determine the conditions that cause them to form, grow, or dissipate. Unusual displays of lightning are often observed inside tornado funnels. For many years meteorologists have wondered whether the tornado causes the electrical phenomena, or conversely, or whether their association might be just a coincidence. By using a high-voltage power supply to simulate the electric field of a thunderstorm, one can produce a continuous electrical discharge inside the miniature laboratory tornado. This electrical display seems to resemble the one that sometimes occurs in real tornadoes. With special instruments, the effect of the tornado on the electrical discharge is measured, and *vice versa.* It is found that under certain conditions the center of a tornado can serve as a preferred path for lightning. The laboratory experiments indicate that the heat given off by the lightning will slow down a strong tornado, but will keep a weak tornado going after it might otherwise have decayed. Later experiments are designed to seek methods of controlling the tornado, and to test out methods for tracking the "electrical" tornado by using the radio waves emanating from the electrical discharge in its center.

Mesoscale Phenomena. A broad research program in our laboratory is concerned with the investigation of mesoscale atmospheric phenomena, which are associated with systems of thunderstorms and tornadoes. "Mesoscale" implies "medium scale", i.e., of the order of ten to a few hundred miles in horizontal dimension, and mesometeorology is the study of those mesoscale atmospheric phenomena. Ordinary weather charts, shown on television or in newspapers, reveal only the broad or "macroscale" circulation pattern. In general, the rainy and stormy weather is associated with low pressure and fronts in the broad circulation, but important detail is lacking. In recent years, due to developments in meteorological observations by aircraft, radars and satellites, we have been able to find those details in the mesoscale disturbances and also certain of their relations to the macroscale systems. It became evident that so-called "bad weather" is not distributed uniformly in the area of low pressure. In particular, severe storms relate directly to the mesoscale disturbances which form, develop, and decay within a few hours in some limited areas of low pressure systems.

Figure 2 is an example showing the distribution of one-hour rainfall amounts (for the hour ending at the time indicated). Shading gives the gradation of rainfall intensities. Note that the rainfall areas are in the form of many cells. Some lighter shaded areas are simply the results of movements of heavy rainfall areas since the figure gives time-integrated amounts. Notice further that they are some distance from the low pressure center and the fronts, and located in the southeastern sector of the low. The rainfall areas were moving to northeast, and as a whole they were approximately along a line, i.e., a squall line.

Radar and satellite photographs show some detail of the above cellular distribution at any instant. Figure 3 is a composite photograph taken by radars located in Oklahoma and neighboring states. Radar echoes from rainfall are shown in the figures by white spots, which are distributed in the southeastern area of the low as an irregular group of many cells.

Similar nature is found in hurricanes. Figure 4 is a composite radar photograph of Hurricane Audrey on the Louisiana coast on 27 June 1957. Indeed, the hurricane was not covered by uniform heavy rainfall but was composed of many individual cells which were arranged in rather parallel spiral bands, and one of them was very much like the line in the previous figure.

With weather satellites photographing clouds from 300 to 400 miles aloft by means of telephoto and wide angle cameras, we were given for

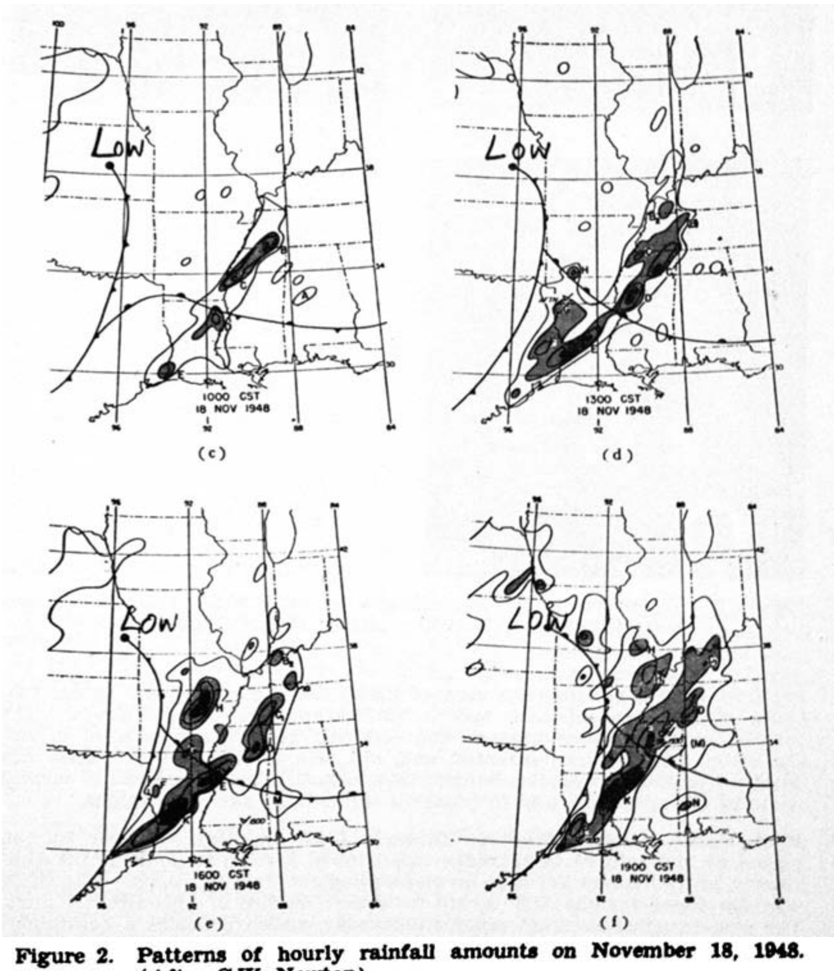

Figure 2. Patterns of hourly rainfall amounts on November 18, 1948. (After C.W. Newton).

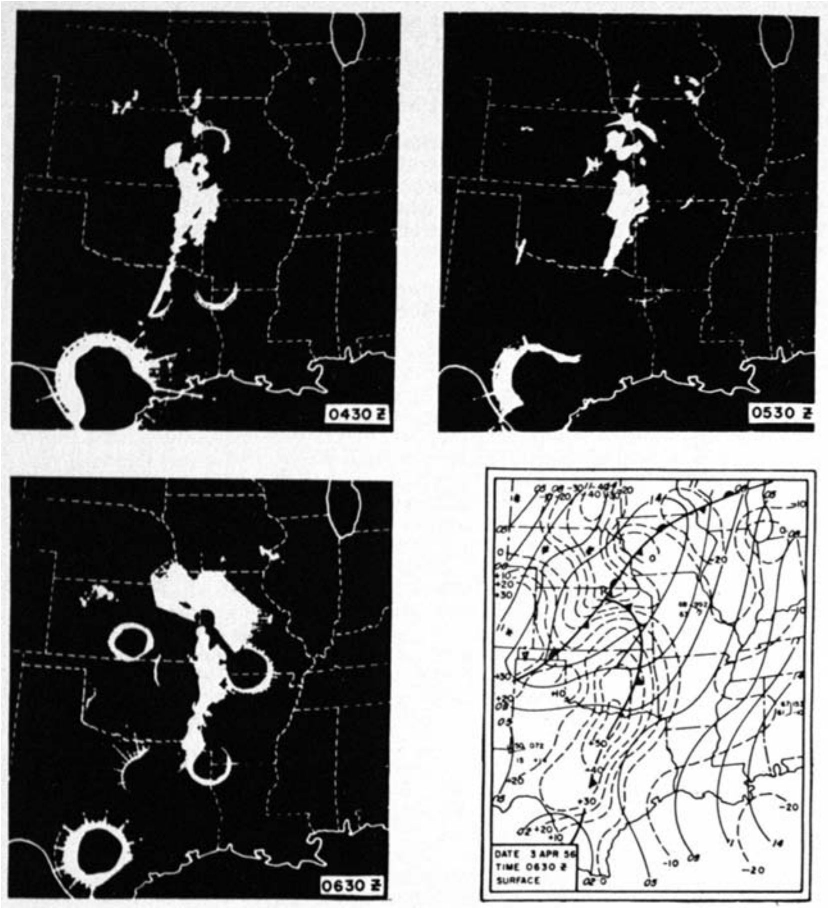

Figure 3. Composite radar photographs at 0430, 0530, and 0630 Greenwich time, April 3, 1956. (After M.G.H. Ligda).

the first time a satisfactory view of cloud patterns. Figure 5 shows two types of weather satellite; one is TIROS and the other Nimbus. The former one was space-oriented and followed generally equatorial orbits; the latter will be earth-oriented and will follow polar orbits. They are designed to photograph clouds and make radiation measurements in several parts of the spectrum, and to transmit the data to surface stations.

M-33 Radar Weather Studies. In early 1962, the U.S. Weather Bureau placed an unmodified M-33 radar fire control system on loan to the University of Oklahoma for use in meteorological investigations. The M-33 was developed for the U.S. Army to direct the fire of anti-aircraft guns. The system consists of an acquisition radar, which provides a continuous sweep of the surrounding area and gives a visual presentation by means of a PPI scope; a tracking radar, which automatically tracks a designated target; a computer, which receives the target-position information from

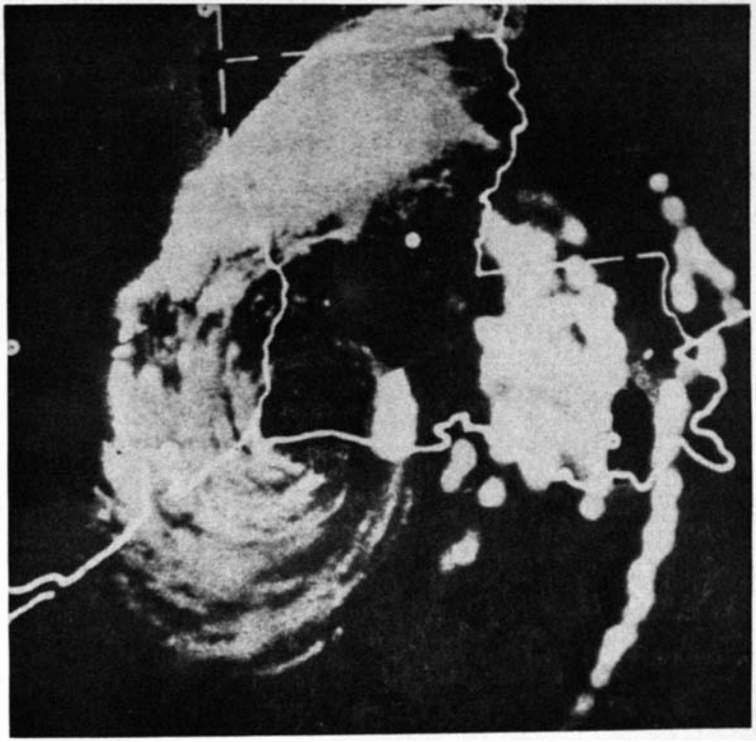

Figure 4. Composite radar photograph of Hurricane Audrey when centered over southwestern Louisiana. (After M.G.H. Ligda).

the tracking radar and converts it into rectangular coordinate positions; and a plotter which then plots the track of the moving target.

The M-33 system is readily adaptable to meteorological investigations by tracking serially-released balloons to which radar reflectors have been attached, and plotting the trajectory of the balloons in a convenient form for readout of wind speed and direction and balloon ascent rate. This is being used mainly in investigations of energy and mass inflow into thunderstorms, the major controls on storm behavior. Related phenomena are also being studied. Some of these are the nocturnal wind maximum commonly known as the low-level jet, wind systems in the vicinities of cold fronts, atmospheric diffusion, and convective processes and related vertical motion.

The principal value of the M-33 radar is its ability to make wind soundings at frequent intervals in studying small scale circulations of the atmosphere, such as jet streams, thunderstorms, squall lines, *etc.* Such information, combined with that gathered by the elaborate radar, network, and aircraft facilities of the National Severe Storms Project, will give us the insight into those systems which we have long wanted.

Radioactive Fallout Study. The stratosphere is the reservoir of radioactive materials from past atomic tests. Location of concentrated fallout

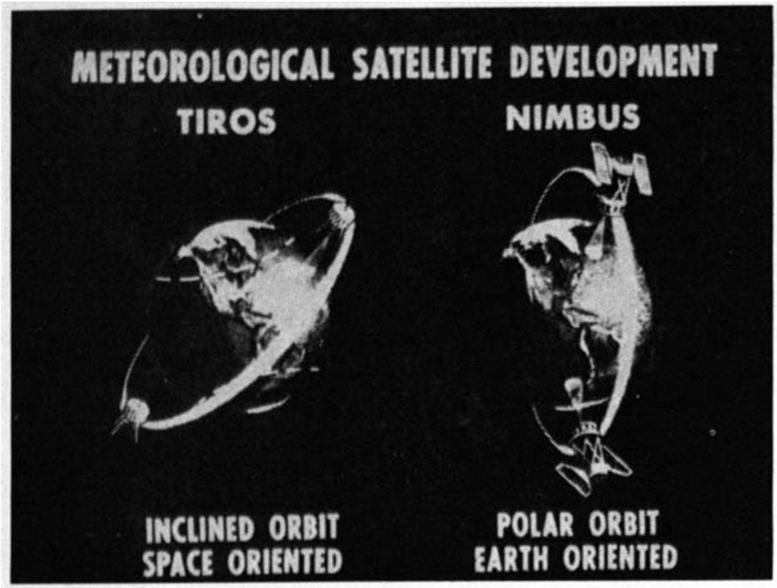

Figure 5. Certain orbital characteristics of meteorological satellites.

from the reservoir is an important question. Some intense Oklahoma thunderstorms penetrate into the stratosphere, carrying the materials down with rain and hail. With a network for rainfall collection at the ground, the use of radar for four-dimensional location of the storm, and radiochemical analysis of the precipitation, there are means for studying the fallout mechanism and the radioactive content of the lower stratosphere, and fallout can serve as a new tool for measuring convection. Such a program is planned to begin in the near future under sponsorship of the U.S. Atomic Energy Commission.

The above presents a sketch of the meteorological activities at the University of Oklahoma, which are really just the initial phase of a developing program. The needs of state and nation in the atmospheric aspects of environmental science are continually increasing, in regard to both manpower and technology. The developments at Oklahoma are intended to meet some of those needs.