The extended forecasts section finds clues to what may happen in the future by checking current observations of the atmosphere, which can be made directly. They then apply physical and statistical methods to determine what will happen during a specified time interval in the future. The calculations are so complex, however, that they can be made only with the help of a fast electronic computer.

General Circulation

A different approach in learning about the weather is being taken by Dr. Joseph Smagorinsky, head of the General Circulation Research Laboratory, and his co-workers.

General circulation is the name given to the behavior of the atmosphere as averaged over a long period of time and large distances, often an entire hemisphere. Dr. Smagorinsky and his group try to understand atmospheric motions theoretically.

First they formulate a mathematical framework, or model, containing the very complex equations expressing the physical laws believed to govern weather changes. A computer is instructed to use this mathematical model to make a weather prediction based upon pressure, temperature and other weather factors at a large number of places. This is often for a very short time in the future, such as five minutes.

Then the results of the first prediction are used by the computer to make a second. The second is then used for a third, and so on, until a sufficient series of predictions has been made for final analysis.

Ultimately Dr. Smagorinsky expects the computer to simulate day-to-day weather changes at 10,000 points around the world and up to 20 miles above the surface. To model weather changes for a 24-hour period will require ten billion computations, and is possible now only because the International Business Machines' STRETCH computer is one of the fastest and most powerful yet built.

The same kind of approach Dr. Smagorinsky is using in his research is the basis for most of the weather maps issued routinely by the Weather Bureau in Washington for use by forecasters. The method is called numerical weather prediction. Numerically based forecasts using a relatively simple model of atmospheric motions have been made routinely by electronic computers for several years.

Some of the equations used at the National Meteorological Center for numerical prediction and at the General Circulation Research Laboratory have their origins with Isaac Newton, who formulated the fundamental laws of particle dynamics. Later theorists extended these laws to cover fluid motion and applied them to studies of the atmosphere.

At the beginning of the 20th century, V. Bjerknes of Norway foresaw the possibility of using laws of fluid motion for weather forecasting. In 1922, the English mathematician Lewis Fry Richardson suggested specific means for doing this. However, he estimated that 64,000 persons would be needed to analyze weather observations and prepare forecasts by this method, now called numerical weather prediction.

Since electronic computers did not exist at that time, Richardson's methods could not be used successfully.

In the following 25 years, more sophisticated theories were formulated by many scientists, particularly the late Dr. Carl-Gustaf Rossby, a noted Swedish-American who developed a formula for predicting the speed of westerly waves high in the atmosphere. Simply stated, the speed of a wave depends on the wind speed, the size of the wave and its latitude.

With the development of computers during World War II and the theory of westerly waves, numerical weather prediction became a practical possibility. The actual techniques were developed at the Institute for Advanced Study, Princeton, N. J., under the direction of the late Dr. John von Neumann and Dr. Jule Charney, now at Massachusetts Institute of Technology.

These techniques, developed for short-range weather prediction, soon showed their potential for being used to study longer periods of atmospheric motions. Also at the Institute, Dr. Norman A. Phillips undertook the first numerical study of the atmosphere's general circulation, using hydrodynamical equations to represent motions and an electronic computer.

In addition to the two-pronged Weather Bureau attack on the how and why of long-range weather behavior, meteorologists in other Government departments, many organizations and universities are tackling facets of the problem.

Included among the groups are the National Center for Atmospheric Research at Boulder, Colo., the National Aeronautics and Space Administration, the U. S. Air Force and Navy, Massachusetts Institute of Technology, the University of Chicago, New York University, the University of California at Los Angeles, Florida State University, Colorado State University and the University of Washington.

• Science News Letter, 83:10 January 5, 1963

AGRICULTURE

Frost Penetration Statisticians—Morticians

➤ THE WEATHERMAN now is working with the undertaker.

Figures on the amount of frost penetration throughout Wisconsin are now obtained from some 250 funeral directors and cemetery officials, in a joint project of the University of Wisconsin, the Weather Bureau and state agriculture officials.

Arthur Peterson, of the University's soils department, said this new method was much easier and made possible accurate reports from widely scattered points.

The previous system had been to drive a King soil tube into the ground with a hammer, a laborious and time-consuming process.

He pointed out that frost penetration data are important to a wide variety of persons, including farmers, contractors, conservationists, hydrologists, flood forecasters, insurance companies that have a frost protection rider, the highway departments, and army engineers—and of course gravediggers.

• Science News Letter, 83:11 January 5, 1963