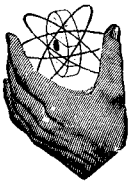
—Cover detail by Doug Anderson after H. Danska.

SR / Research

SCIENCE & HUMANITY



RESEARCH IN AMERICA

THE MAKING OF WEATHER

A LONG-RANGE weather forecast appeared in this space one year ago.

It anticipated the naming of a new chief of the U.S. Weather Bureau, it named the new chief as Dr. Robert M. White—then president of Traveler's Research Center, Inc., in Hartford, Connecticut—and it said that Dr. White would concern himself above all else with perfection of mathematical models of the air and water oceans which together breed earthly storms.

On the morning of the day the forecast reached homes of *SR* readers, the late President John F. Kennedy announced Dr. White's appointment. Work on the mathematical models of earth's atmosphere and hydrosphere has gone apace since then.

It is now time to extend the forecast, as follows:

On September 1, 1964, Dr. White will bring into the Weather Bureau, as its chief scientist, Dr. Verner E. Suomi, of the University of Wisconsin.

Perhaps from a Finnish ancestry, perhaps from a boyhood spent in Minnesota, perhaps from a mixture of the two, Dr. Suomi acquired a mind that flashes in spectacular streaks like the northern lights (see Personality Portrait LII, *SR*, July 2, 1960). During the academic year 1964-5, he will flit between the Great Lakes and Chesapeake Bay, alternately throwing darts of thought at his graduate students on the Wisconsin campus in Madison and at Weather Bureau researchers in Washington, D.C. Typically, he has no ready-made plan to propose to Dr. White; experiments will evolve as consultations proceed through the twelve months of Dr. Suomi's assignment as chief scientist. But the implications of at least two brilliant Suomi innovations of the past can hardly be escaped.

Both of these are related to the fact that rainfall—still the great uncertainty in weather prediction—is not (as most people think it is) a primary process of the laws of physics but only a by-product of heat rising with evaporation and falling with condensation of water vapor churned through a pipeless system of steam circulation by a solar furnace blazing 93,000,000 miles away.

Dr. Suomi has specialized in studying the atmosphere as a heat engine for the last decade, beginning with his Ph.D. thesis at the University of Chicago. Working in a cornfield, he transplanted two rows of cornstalks from their normal rooting in the soil to a pan of water. Most of the sun's heat that fell on the corn, he found, was used up in evaporating moisture from the soil rather than in raising the temperature of the soil.

Ever since then, he has looked at the whole planet as a scientifically sophisticated corn farmer might. Over and over again he has asked one question of the atmosphere: "What is your heat budget?"

Against the steady energy income from the sun, he has tried to balance the energy spent in extraterrestrial space by the earth.

Generations of his predecessors in meteorology had established the fact that clouds are formed of vapor evaporated by the sun's rays from surface waters of seas and lakes and from the gentle "sweat" of the green leaves of growing plants and trees. Hence, although the power that drives storms comes from the direct force of sunlight falling on the whole atmosphere, local weather changes depend on the differential spacing of that fragment of the light which earth reflects back into the air. And this reflected energy is transmitted almost exclusively in the invisible infrared end of the spectrum: the heat rays.

To calculate the atmospheric heat budget, then, Dr. Suomi had to measure infrared light rising from the earth. Earth satellites came into being just in time to carry the necessary instruments around the globe at a sufficiently long distance out in the atmosphere to allow meaningful readings.

The Weather Bureau's famous family of Tiros satellites is best known for its photographs of clouds and consequent advance warnings of approaching storms—hurricanes especially. But riding along with the peering cameras have been Dr. Suomi's infrared light sensors, and these robot "feelers" of heat sensation are discovering far more revealing elements of weather-making than can possibly be seen in the cloud pictures.

As was expected from earlier knowledge obtained in simpler ways, the radioed reports of the Tiros sensors say "cool" when the satellites pass over cloud-covered regions of earth. In other words, the infrared light is being trapped by the undersides of the clouds and held in the air below; those regions of earth are consequently warmer. The trapped heat expands the air underlying the clouds, creating pressure gradients which, in response to the constant turning of the planet, induce motion of the dynamic cells marked "high" and "low" on daily weathermaps.

What the infrared sensors were not expected to find—but what they did find—was that heat losses from the air into space around the eastern edges of cloud banks differ from the losses around the western edges of the clouds. The expected differentials either warm cool air or cool warm air. In the midst of them is this surprise exception where *warm air is warmed.* That is, the warm air on the leading eastern edges of cloud formations ("leading" because weather moves predominantly from west to east) cools less rapidly than does the cold air following the western edge of the cloud pattern.

Before this anomaly in the traditional picture of weather turned up, the main drive in all storms was assumed to be the temperature gradient between air heat-

ed by the direct light of the equatorial sun and air heated to a lesser extent by slanting sunlight north and south of the equator. And several years of infrared reports from the Tiros satellites confirm that the big powerhouse of the atmosphere indeed does run on a north-south axis. However, an east-west drive is now known to exist, too. It is so small that if it were found between cloud masses it would be dismissed as inconsequential; or, if its energy were moving in an opposite direction, it could be assumed to act to maintain the prevailing status of the atmosphere. Instead, it occurs at a point where the air cycle is already verging on instability and its energy is traveling in the direction normal to overturn of the air mass. Thus Dr. Suomi's experiments have raised a fundamental question: Does the east-west drive perhaps trigger the north-south drive into action?

If this spacebird's perspective on the atmosphere's workings were all that recommended Dr. Suomi to Dr. White as the Weather Bureau's chief scientist, it would be quite enough. But this is only one of the Wisconsin professor's credentials. Most compelling of them all is an uncanny ability to pick crucial fundamentals on which experiments will exert historical leverage. An example is the Suomi invention of a sonic whistle which could in time become a shepherd's pipe for men to use in whistling clouds away.

THE significance of this eerie device begins with the fact that water can contain more heat than can air. Hence the oceans of earth are the greatest reservoirs of latent energy for weather making. It is known that much of this energy is transferred to the air off the crests of breaking waves and by evaporation from quiet water. Microscopic particles of salt mist are snatched upward by the wind. In separating from the sea, the salt carries off an electric charge. The charged salt particles are the most efficient of all recognized nuclei for condensation of raindrops at high altitudes where the cooler air encourages formation of droplets into clouds.

Winds carry the particles from the sea for thousands of miles inland, where the play proceeds across the great stage of the earth like a magician's performance. A small cloud forms from the vapor droplets. The cloud rises like a frail fountain, and evaporates. One after another cloud takes shape and disappears. Finally (and there is yet no way to predict in which of many clouds this will happen) one cloud grows and rises until it holds enough billions of droplets to make millions of raindrops and loose a thunderstorm.

Where the land is flat for a sufficient distance, dynamic forces in some manner not yet understood generate tornadoes. Over the vast relative flatness of the sea, similar vortical motion makes hurricanes.

Covering, as they do, two-thirds to three-fourths of the earth's surface, the

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PERSONALITY PORTRAIT—XCVII

A SCIENTIST'S SCIENTIST

Dr. Robert M. White

INSOFAR as scientific research is the art of dealing imaginatively with the unexpected, Dr. Robert M. White, U. S. Weather Bureau chief since last October, must be ranked as a scientist's scientist.

As a boy in Boston, he enjoyed exploring the nearby water, woods and rocks. He expected to be a geologist. But when he needed a summer job between terms at Harvard, he found an unexpected chance to work at the university's Blue Hill observatory. There he was assigned to watch the weather.

Once out of Harvard, he expected to soldier in World War II, along with his fellow students. But when the Air Force called for officer candidates knowledgeable in the atmosphere's behavior, he again took the unexpected chance. Joining up as an Air Cadet in Meteorology, he landed first at Massachusetts Institute of Technology and later at the Air Force Cambridge Research Center, where for eight years he analyzed weather phenomena mathematically.

Neither he nor anyone else expected the destructive New England hurricanes of 1955-6. Nor was it foreseen that the Traveler's Insurance Company of Hartford, Connecticut, would undertake a long-range search for reliable means of predicting violent storms. But the unexpected happened once more. MIT Professor Thomas Malone moved to Traveler's as research director of the company, and a non-profit research center dealing with all the geophysical sciences was set up in Dr. Robert White's charge.

In the four years since then, Traveler's weather broadcasts over Hartford radio station WTIC have become famous throughout lower New England for the degree to which they share the forecaster's uncertainty with lay listeners.

Wind speeds and temperatures are fairly easy to predict in the present state of knowledge of the atmosphere. Forecasts of rainfall are considerably more tricky, so Drs. Malone and White encouraged the Traveler's weathermen to handle the problem statistically.

"The chances of rainfall through tonight are three in ten," a broadcast might say, "rising to five in ten by morning and to ten in ten by tomorrow night."

U. S. Weather Bureau forecasts in cities elsewhere in the country have adopted the probability statements since Dr. White moved to Washington last autumn. The philosophy behind the change is a most welcome and vigorous counter to widespread pseudo-scientific propaganda.

The starting point is that man is always at the mercy of his environment.

—U.S. Weather Bureau.

This is a way of denying the popular illusion that man has conquered nature. Man is a part of nature, and the best he can ever do is discover means of living in harmonious balance with the rest of nature.

Such being true, it is important for people to act intelligently in the face of a threatening environment. Where violent storms are involved, the difference between acting and not acting can be acute suffering or death.

People tend to respond to warnings if the warnings come from trustworthy sources. Trust is established by repetitive demonstration of dependability. Hence, by broadcasting forecasts which frankly state the forecaster's uncertainty, trust is built up against those times when it may save property and life.

As Dr. White propped his feet on a table in his office on M Street and talked simply about this fundamental question, I felt immensely relieved to have him