METEOROLOGY AT WISCONSIN

A PLAN FOR THE FUTURE

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Preamble. The Department of Meteorology at The University of Wisconsin was born in 1948. In this document we shall try to project the possibilities and potentialities ahead to 1970. This means a forecast of more than half the lifetime of the department—an ambitious project even for meteorologists. However, in the present-day rapid development of the atmospheric sciences the department **must** look ahead. Meteorology is on the move, we must decide how to move with it.

This document is the result of teamwork. Beginning in May 1962 the academic staff of the department has spent many hours of deliberation in a number of special conferences devoted to the discussion of the future development of meteorology at The University of Wisconsin.

This team effort has resulted in the formulation of "Meteorology at Wisconsin, a Plan for the Future."

Madison, June 1963

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300–106

Foreword

The history of most scientific disciplines shows repeated alternations between periods of relatively slow development and times of great and sudden bursts of activity and progress. It is almost as if there must first be a season of nearly imperceptible growth preceding the sudden blossoming and proliferation of new knowledge. The atmospheric sciences are no exception to this rule—and all indications are that during recent decades we have again entered into a new meteorological spring, with new discoveries to be made every day. It appears that the current rate of development of knowledge of the atmosphere, at least in some areas, even exceeds the increasing pace of the general trend now apparent throughout the physical sciences. Meteorologists are, in fact, utilizing the ever-increasing volume of new discoveries in other fields to quicken the pace of advance within the atmospheric sciences.

As a result of the major advances in basic knowledge of weather and climate, the atmospheric sciences have become an increasingly effective tool for achieving improved living conditions over most of the area of the globe. Faster and more accurate weather forecasts and storm warnings are monthly saving untold numbers of lives and averting million-dollar property losses. Food production has been increased through improved knowledge of proper crop selection for various agricultural regions. Better homes and other structures have resulted from proper recognition of the need for designs suited to atmospheric factors. Small-scale weather modification has proved successful for protecting certain crops growing in marginal climatic areas from occasionally severe conditions. It is difficult to designate any particular phase of modern atmospheric science as being of greater importance than another. All have direct bearing upon human health, safety, and upon agriculture, industry, and transportation, whether they concern the surface-air boundary or the heights where satellites encounter only the most rarified outer fringe of the earth's gaseous envelope.

Perhaps the most important development of the past few decades, however, has been the slow but steady evolution of the atmospheric sciences from an empirical—even intuitive—pursuit into an analytic discipline employing the most rigorous methods. These decades have brought the development of a science from the weather lore of the past, a transition from meteorology to meteoronomy, to use an analogy provided by the related science of astronomy, which developed originally from the ancient empirical "science" of astrology. This transition, to be sure, began many years ago; only in recent years, however, has it become possible to bridge the gap between empirical weather forecasting (an art in which intuition has played no small part in the past) and the physical science of meteoronomy, which until recently concerned itself nearly exclusively with idealized models bearing only a superficial resemblance to the real atmosphere. It now seems reasonable to attribute the rapid strides in modern atmospheric science to this development; the next few years hold every promise of becoming even more productive of important knowledge and there is every possibility that soon we will be able to understand in some detail the physical mechanisms involved in the atmospheric events that we witness each day and that bear so importantly upon our health, industry, and welfare. Once understood, the knowledge can be applied to advantage in all of these areas of human endeavor. There are few things in nature that have as profound an influence upon human development and well-being as the air—in which we live, and upon which we depend, throughout all our lives.

The National Need

Many new problems have been encountered with the increasing recognition of the importance of the science of meteorology and the special national efforts invoked to insure its rapid development. In 1961 there existed a total meteorological faculty in the United States of 229 persons, and a total research force of 1,100 scientists. A recent report of the Committee on Atmospheric Sciences (National Academy of Sciences—National Research Council, Publication No. 946, 1962; commonly referred to as the "Petterssen Report") calls for a research force of 3,000 publishing scientists by 1970. This will require an average graduate student enrollment over the next eight years of at least three times the present number and a doctorate production averaging at least four times the present rate. It is apparent that the necessary scientific manpower is not available to staff a significant number of new graduate departments in time to meet this increasing demand. The burden must fall on the existing departments.

An enormous research program must be mounted during the same time that we increase our capacity to train doctoral candidates. Moreover, we must retain unusual flexibility. We must be prepared to move quickly into new areas of investigation as they are opened; and we must expect new revolutionizing concepts to appear, many of which will require major shifts in our way of looking at our scientific subject matter.

The outline for future development in meteorology has been aptly summarized by the Petterssen Report referred to above, prepared by the Committee on Atmospheric Sciences, which states in part:

"Scientific and technological developments over the past few years, and a growing appreciation for the importance of our atmospheric environment, have focused national attention on the need for a greatly expanded program of research on the atmospheric sciences. It has become evident also that the atmosphere is an international resource of fundamental importance for human activities and that many of the problems in atmospheric research can best be solved through international collaboration.

"This then, is an appropriate time for the United States to make a concerted effort to observe and understand the atmospheric processes, to place weather forecasting on a firmer scientific basis, and to explore the possibilities of modifying man's environment on a large scale. To mount such an effort, however, substantial augmentation of scientific manpower will be required. This, in turn, makes it imperative that university education at the graduate level be strengthened and expanded."

The University of Wisconsin's teaching and research program in meteorology has been—and will continue to be—part and parcel of the rapid national development of the atmospheric sciences. The department was founded in 1948, with one assistant professor and no students; and has grown until it now enrolls more than 10 percent of all meteorology graduate students in the United States. It seems apparent that this department will play a major role in the future development of meteorology, in meeting the expanding research demands of the next few decades and in helping to alleviate the critical meteorological manpower shortage. Its research program has grown to international importance in several branches of meteorology—and in the most exciting area of the present research effort, satellite meteorology, it provides leadership to which the entire world has turned.

The Wisconsin Potential

The Interdepartmental Committee on Atmospheric Sciences, of the Federal Government, has pointed out in reference to the Petterssen Report that:

". . . the report demonstrates that the atmospheric sciences are an area of scientific promise . . . for these sciences are endowed with an extraordinarily rich variety of important and unanswered questions."

To assess the role of The University of Wisconsin in the tremendous potentiality for development and expansion which now exists, we should review its past performance, present situation, and its future prospects—in teaching, in research, and in service.

The Teaching Program

There have been two major periods in the history of the Meteorology Department at The University of Wisconsin.

1. An initial period characterized by slight growth and small numbers, during which undergraduate majors often outnumbered graduate students.

2. A period of rapid transition, beginning about 1958, in which the department grew to major size and the graduate student enrollment far overshadowed the undergraduate.

We shall consider first the graduate teaching program, since the department is, at present, in fact, primarily engaged in a graduate program.

The rapid growth of graduate enrollment is shown graphically in Figure 1. The break between the first period of slight growth and the period of expansion coincides with the International Geophysical Year and the Sputnik Era. There undoubtedly exists a relation between these events, but other factors must be involved as well, for Wisconsin's growth has been greater than that of any other meteorology department in the United States. The spectacular satellite research program directed by Professor V. E. Suomi must also be responsible in part, but it is of some significance that students unaware of this program or interested in other aspects of meteorology represent the bulk of the new students.

Availability of research funds to provide financial support for graduate students is also shown in Figure 1, but even with unlimited funds the graduate group would not have grown without powerful factors initiating interest on the part of potential graduate students. Certainly an important factor has been the growth of the total faculty of the department above the "critical mass" required for academic vigor, breadth, and balance. Those members of the meteorology faculty who have witnessed this growth clearly recognize a change in the tempo and nature of the staff activity beginning about 1958 and the growth appears distinctly related to increasing possibilities for productive intellectual and scholarly interaction which have existed since that time.

The growth of the graduate student group to a size which is probably the largest in the nation (if military groups are excluded) has not been due to the general growth of The University of Wisconsin's graduate enrollment, but rather exceeds the general growth curve and proportionately has been much faster.

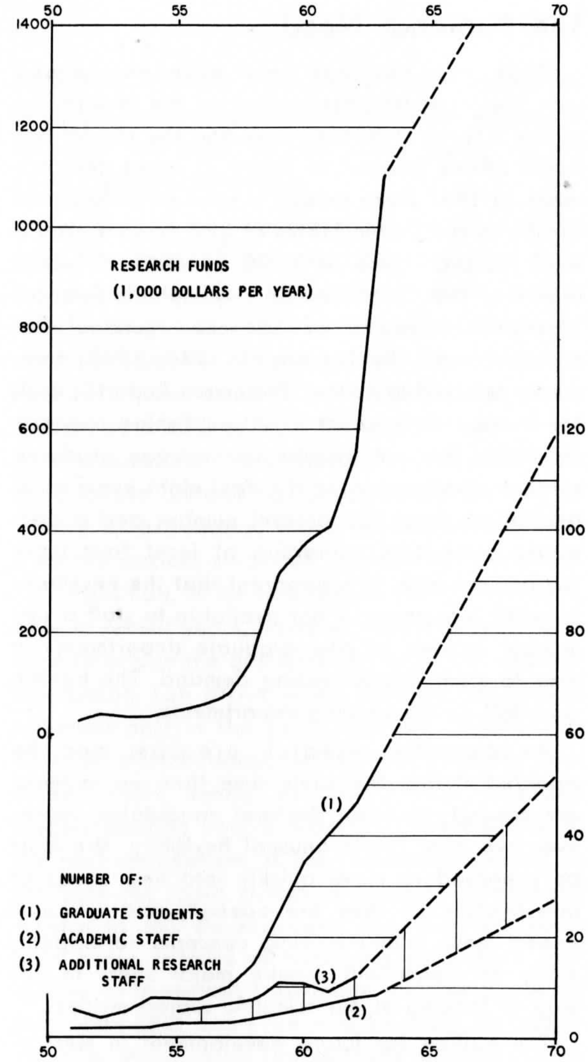

FIG. 1

Year Ending	Graduate Enrollment U.W.—Madison—L. & S.	% of Total Enrollment in Meteorology
1952	1655	0.5
1953	1469	0.3
1954	1359	0.4
1955	1296	0.6
1956	1360	0.6
1957	1512	0.5
1958	1640	0.6
1959	1839	0.8
1960	2080	1.2
1961	2336	1.5
1962	2616	1.7
1963	2953	1.8

At this point it seems pertinent to inquire into the prior training and subsequent employment of our students and to make comparisons between the patterns typical of years past and those of the present. The Petterssen Report emphasizes that meteorology is a subject for "students who have acquired a solid foundation in the primary sciences." The following table compares the background of previous graduate students with those currently enrolled in this respect.

Average Credits—Undergraduate Preparation of Graduate Students at the U.W. Meteor. Dept.

	Previous	Present
Mathematics	24.2	23.3
Physics	14.3	16.1
Other science and engineering	15.3	34.6

Thus, the present-day students (1962) have about the same mathematical and physical background as past students in the sample studied (25 percent of all our students), but they have far more experience in other sciences **not** including meteorology. Perhaps more revealing is the undergraduate major of the graduate students.

Undergraduate Major of Graduate Students at the U.W. Meteor. Dept.

Major Field	Previous	Present
Mathematics	0%	15%
Physics	8%	23%
Meteorology	24%	23%
Engineering	11%	9%
Biology	3%	6%
Other or not known	54%	24%

We believe that these tables show that a significant improvement in the background of the average graduate student has taken place; present indications are that the trend will continue.

After receiving graduate degrees in meteorology at Wisconsin, about half of the students have accepted positions of an operational nature, such as forecasting for the U.S. Weather Bureau or the Armed Forces. The remaining half went into research and teaching; and of this half, about two-thirds accepted academic positions.

Finally, the typical candidate for the master's degree in meteorology at Wisconsin has taken, as a graduate program, the following:

Courses to remove deficiencies	6.2 credits
Supplementary physics	0.6 credits
Supplementary mathematics	5.5 credits
Meteorology	
Regular courses	15.4 credits
Research courses	7.2 credits
	34.9 credits

Although at the present it is not possible to determine what courses our current master's candidates will take before completing their work, it appears that they are less reluctant to borrow from other fields.

In looking to the future, what might be the size and nature of the graduate student group in meteorology by 1970? Assuming that predictions of future enrollments based on extrapolations of the present graduate enrollment at The University of Wisconsin are correct and that the proportion of students enrolled in meteorology remains at the present level, there then will be about 120 graduate students in meteorology. If the proportion continues to rise at its past rate, the number may reach 170 in 1970. The present graduate enrollment is about 10 percent of the national total and the goal set by the Petterssen Report for 1970 is about 1,500. Our projected figure of 120–170 indicates that The University of Wisconsin will continue to play a significant role in the production of manpower in the atmospheric sciences.

What will be the quality of the product? Two facts may be cited to indicate the present situation:

1. As mentioned above, about one-third of our graduates with advanced degrees have gone into academic positions.

2. Of the 10 national meteorology fellowships awarded by the Sloan Foundation in 1961, three came to Wisconsin.

In general, the quality of the students will depend on the quality of the staff under whom they study, and the dynamic quality of the research program in which they participate. Let us examine, then, the research and staff potential of the department.

Fig. 2. V. Suomi (L.), designer of a radiation experiment carried in the satellite "Explorer VII"; and H. LaGow (R.), NASA project engineer, inspect the final installation prior to launch into orbit, at Atlantic Missile Range, Cape Canaveral, Florida, October 1959.

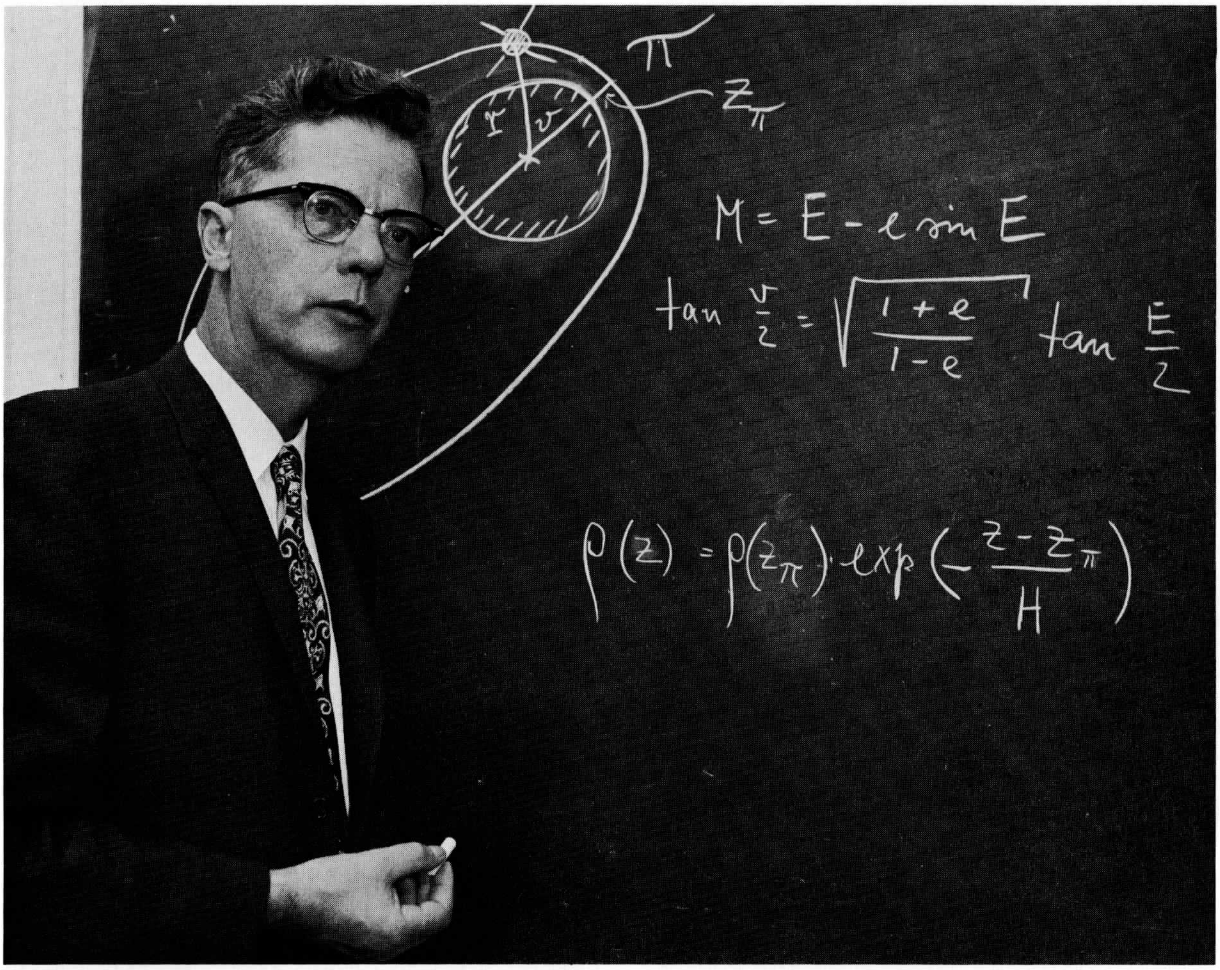

Fig. 3. E. Wahl lecturing a graduate course on "Satellite Meteorology" as a visiting professor during the fall semester of 1962.

The Research Program

The various research programs of the department fall into categories, each of which is characterized by one or more unique features.

The Satellite Program—The first meteorological satellite experiment ever launched was conceived and built by a group under the leadership of Professor Suomi. Several other experiments suggested by Professor Suomi have since been put into orbit. All of these experiments were concerned with the radiation balance of the earth. Two other experiments have been proposed, one dealing with the world-wide distribution of thunderstorms and one using a refined method of high altitude density measurement. **No other meteorology department has any experiments in orbit at the time of this writing.**

The Radiometersonde Program—Meteorologists have understood for many years that radiation processes are the driving source of atmospheric changes. The most effective instrument for measuring the distribution of radiant energy in the atmosphere, the "economical net radiometer" was devised by Professor Suomi. The U.S. Weather Bureau makes routine daily measurements with this device at stations in Antarctica, the Caribbean, and the United States and turns the data over to Wisconsin scientists for analysis. **The De-**

Fig. 4. R. E. Bryson and Project Associate C. B. Stearns checking equipment at the instrument tower in Lake Mendota off Second Point.

partment thus has the only radiation sounding network in this hemisphere.

Atmospheric Energetics Program—Since the differential heating and cooling of the atmosphere by radiation processes are the basic cause of atmospheric motion, a program of atmospheric energetics is closely tied to the satellite and radiometersonde programs. This research, under the direction of Professors Suomi, Horn, and Schwerdtfeger, seeks a better understanding of the energy conversion processes of the atmosphere. In particular the production of available potential energy and its conversion into kinetic energy are being considered. A study of the atmospheric circulation in the southern hemisphere is included in this program.

The Micrometeorology Program—A roster of the few leading scientists engaged in micrometeorology research would probably be headed by Professor H. H. Lettau. Under his leadership, an unusual program of research has developed, a study oriented toward "climatonomy" or an elucidation of the laws of air-surface interaction in combination with the free-air variables. This approach may very well yield methods capable of achieving precise formulation of the climate of an area in terms of the pertinent external parameters. While most research in micrometeorology has been focused on the distribution of climatic variables along a fixed vertical, the Wisconsin program has advanced to a consideration of horizontal variations and has mounted **the only air-borne micrometeorology research program in existence.** The major objective of the program is a parameterization of the process of boundary transfer of mass, momentum, and energy, to provide the basis for a realistic consideration of diabatic effects and energy dissipation in numerical models of the atmosphere. An active research program under Professor Deland deals with the study of atmospheric turbulence over a city.

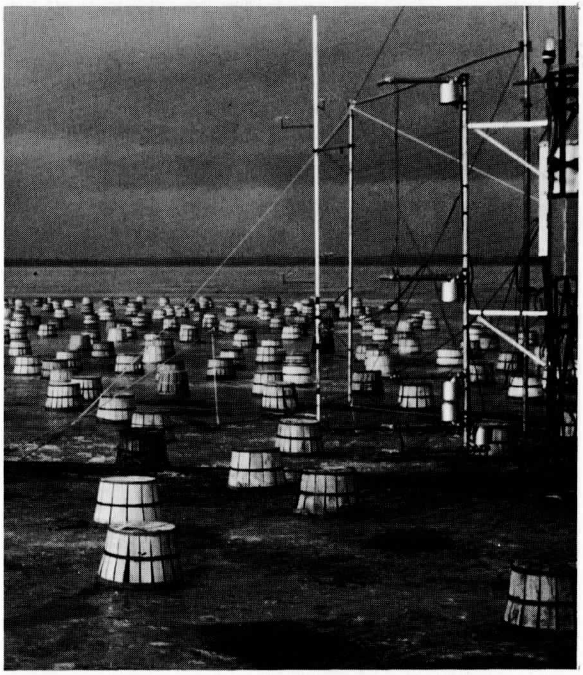

Fig. 5. Bushel basket array on the ice of Lake Mendota to study the effect of controlled roughness modification on micrometerological wind profile structure.

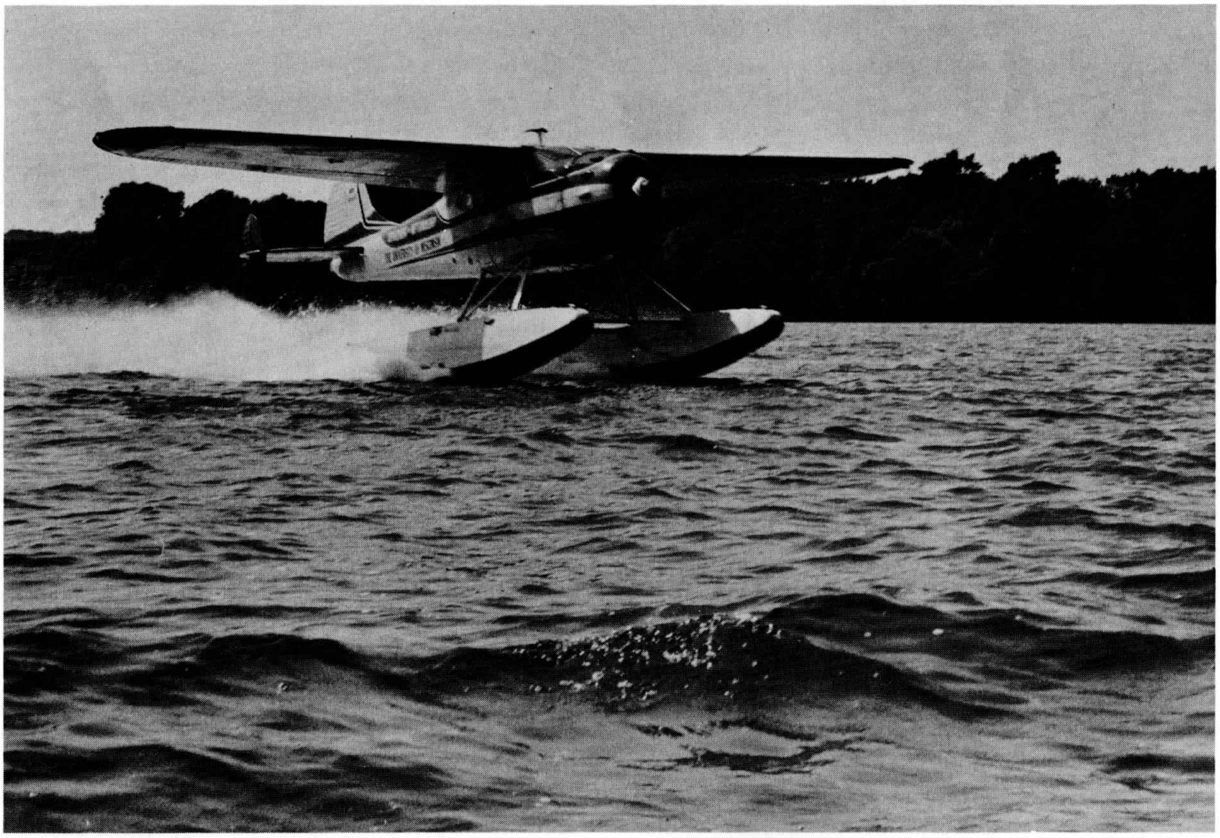

Fig. 6. Departmental research aircraft (Cessna 195) used for aerial sensing of surface parameters and for limnology-climatology reconnaissance on Wisconsin lakes and in the Canadian sub-arctic.

The Climatology Program—Over the past 20 years, climatology has changed from a cataloging of the mean atmospheric conditions in an area to a branch of dynamic meteorology utilizing rigorous mathematical tools and physical concepts to characterize the general circulation of the atmosphere and its variations. One particularly well-developed aspect of this field at Wisconsin concerns the changes in atmospheric circulation patterns as they vary seasonally and from year-to-year. Another concerns the exploration of circulation patterns in relation to terrain features. A strong research team under the leadership of Professor R. A. Bryson is engaged in what is probably the most extensive research program in climatology at any university. New concepts have been brought to bear on the problem of determining climatic conditions in regions where only sparse data are now available. **Only at Wisconsin is "field climatology" being actively developed.**

The Physical Limnology Program—Research on the mechanics of lakes has a long history in The University of Wisconsin Meteorology Department and represents another strongly interdisciplinary enterprise. Professors Ragotzkie and Bryson have been most prominent in this research and they direct programs which have uncovered a number of previously unknown physical phenomena in lakes. So active has this program been that about **90 percent of all lake currents measured in the United States have been measured by members of the Wisconsin department and more than a third of the papers on physical limnology in the Journal of Limnology and Oceanography come from Wisconsin.**

The Aeronomy Program—This research is presently in its beginning phase, and is concerned with theoretical and experimental investigation of magneto-hydrodynamic waves in the upper at-

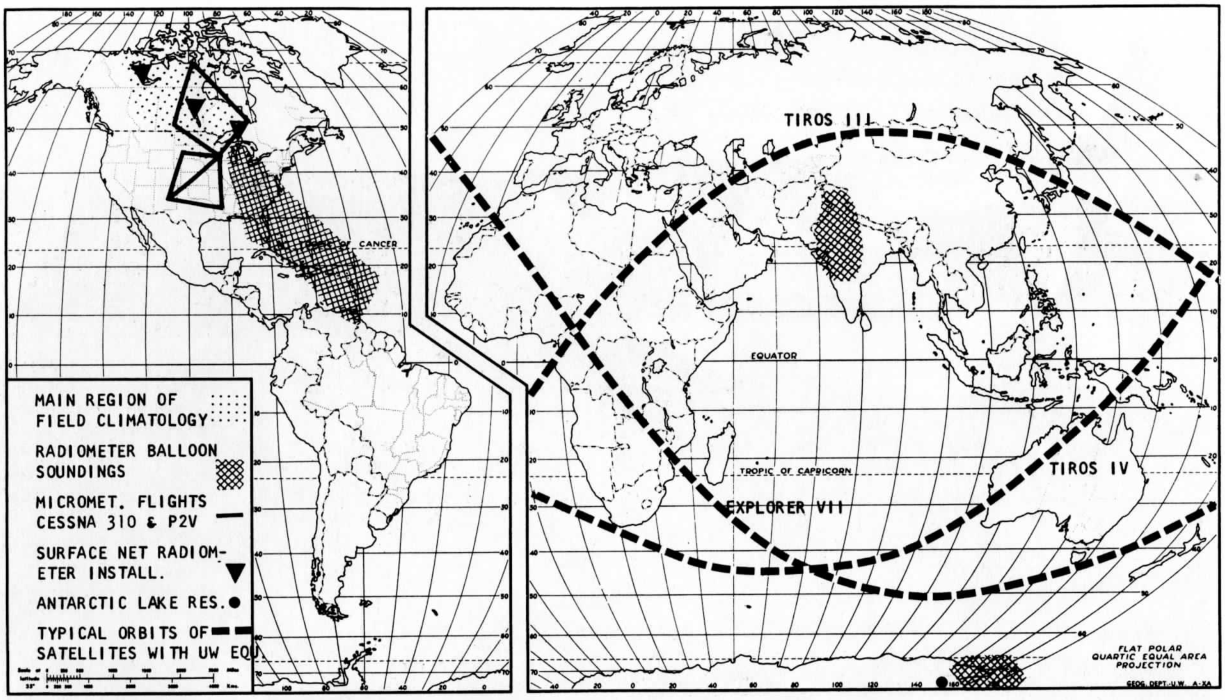

Fig. 7. Observational programs of the U.W. Meteorology Department.

mosphere and the nature of the magnetopause. In connection with this investigation, Professor Rossby is studying very low frequency radio emissions from the exosphere and atmospheric whistlers generated by lightning discharges. The former provide information concerning the incidence of solar plasmas in the earth's upper atmosphere. Whistlers are, in effect, probes of the medium through which the magneto-hydrodynamic waves generated by the solar plasma are propagated.

Other research in the department is concerned with biometeorology, agricultural meteorology, engineering applications of meteorology, the circulation of the air in the southern hemisphere, and relations of micrometeorology to radio transmission. Two general features of the research carried on by the department stand out with great clarity: it is truly interdisciplinary and it is geographically far-flung. The following list will give some idea of the interlocking of programs within the department and with other departments.

1. The Satellite Program—cooperative research by Professors Suomi, Horn, and Schwerdtfeger with the Department of Electrical Engineering and closely allied with the Department of Astronomy.

2. The Climatology Program—cooperative work by Professors Bryson, Ragotzkie, Lettau, and Horn; and the Departments of Geology, Soils, Anthropology, Geography, Botany, and Electrical Engineering.

3. The Micrometeorology Program—cooperative work by Professors Lettau and Deland and the Departments of Soils and Civil Engineering.

4. The Physical Limnology Program—cooperative research by Professors Ragotzkie, Bryson, and Lettau; and the Departments of Civil Engineering, Zoology, Geology, Sanitary Engineering, and Botany.

A University of Wisconsin motto is "the boundaries of the campus are the boundaries of the state." It is just as true that the boundaries of the Meteorology Department are the boundaries of the world, for its field program extends from the South Pole to the Arctic, from beneath the surface of the earth to the edge of interplanetary space (Figure 7).

The origins of present research are to be found almost entirely within the research history of the department. For example, the first research project in 1948 was a micrometeorological study of the heat budget on the University Marsh Farm. To obtain the radiation term in the heat budget, Professor Suomi devised a radiometer, which he later adapted to the radiometersonde, extending the same concepts to the radiation satellite and the heat budget of the earth. Increasing interest in this micrometeorological project provided the impetus for expansion which ultimately brought Professor Lettau to Wisconsin to exploit other aspects of the problem. It also strongly affected the lake research started in 1949, leading to consideration of the heat budget of Lake Mendota, the subarctic lakes, and subpolar climatology in general. In turn, studies of forest history in the sub-arctic, related to the lake work, stimulated a longstanding interest in climatic change, which is in turn an integral part of the present climatology program. This work also brought Professor Ragotzkie to the department.

Similar histories apply to other phases of the Wisconsin Meteorology Department's broad research program. It is to be expected that the future research program of the department will have its origins in the present program. How we visualize its development will be outlined in detail in later paragraphs on the goals of the department.

The research program of the department is an active one, growing and problem-generated, operating on the frontiers of knowledge rather than for the purpose of filling in bypassed details. The program is recognized, at least in major part, throughout the world. Though not an ideal measure, at least one yardstick of national recognition is the federal support of our research program shown in Figure 1. It seems reasonable to conclude that Wisconsin has a potential for greatness in the atmospheric sciences.

The Service Program

During the first phase of the history of the department, say prior to 1957, non-majors made up the bulk of the students in meteorology courses. For some time the largest course was oceanography, with mostly geology students enrolled. Civil engineers, geographers, agriculturists, botanists, zoologists—all interested in ecology of man, animal, wild plant, or crop—were to be found in our courses. At the graduate level, the doctoral minors often exceeded the departmental majors. One important aspect of this situation was that it stimulated the staff into active participation in a variety of research programs associated with other departments at The University of Wisconsin.

This close relation with other sciences has continued to play an important role in the activities of the department and extends to the faculty as well. There are, of nine professors on the staff, two with joint appointments in agriculture, two with Integrated Liberal Studies appointments, and one under a joint appointment with civil engineering. One professor with a joint zoology-meteorology degree is closely allied with hydrobiological work and the new limnology-oceanography graduate program.

An important segment of staff time is consultation with other departments whose personnel are engaged in research and teaching that involves meteorological considerations. Perhaps the most important staff role as expert and consultant is to be found at the national level. Within the last two years alone, faculty of the department has served on the following national boards, panels, and committees:

- NAS-NRC Committee on Interdisciplinary Problems
- NAS-NRC Ad Hoc Committee on Paleoclimatology, Chairman
- AMS Committee on Paleoclimatology, Chairman
- AGU Committee on Paleoclimatology, Chairman
- NAS-NRC Committee on Geography Advisory to ONR, Chairman
- Univ. Corp. for Atm. Res., Board of Trustees Exec. Comm.
- NCAR Balloon Panel, Chairman
- NSF Panel on Atmospheric Sciences, Chairman
- AMS Committee on Bioclimatology
- U.S. Army Quartermaster, R & D Consultant
- President's Science Advisory Committee, Panel on Atm. Sci.
- Jour. of Appl. Meteor. Assoc. Editor
- AMS Committee on Satellites
- AMS Committee on Educational Films
- USWB Consultant
- AMS Macelwane Award Selection Committee
- AMS Nominating Committee
- NAS-NRC Committee on Meteor. Aspects of Atomic Radiation
- AGU Committee on Atmospheric Diffusion and Pollution
- Advisory Panel to Space Science Board
- AGU Committee on Rockets and Satellites

Assoc. Program Director, Atmospheric Sci., NSF
Honorary Vice Pres., International Quaternary Association
AMS Committee on International Cooperative Prog. in Atm. Sci.

Summary

The Department of Meteorology has clearly come of age. In the past five years, it has changed from a small department to a major force in the atmospheric sciences in production of scientists, in research programs, and in a staff whose abilities may be brought to bear on significant atmospheric problems.

The present impetus of the departmental program, focused as it is on problems which lie at the frontier of meteorological knowledge, is such that its general nature may be forecast to the end of the decade simply because the long-range programs currently under way cannot reach full fruition sooner. It is the purpose of this document to explore the goals of the program and plan action which will contribute most efficiently to reaching those goals which might reflect credit on the University and the science.

Goals for 1970

Our concern with the atmospheric sciences is a concern with the environment of man.

The atmosphere in which man lives is a vast, stormy sea of air, bombarded by radiation from the sun and from space, interacting with earth and water over which it moves. Indeed, it interacts directly with man himself.

Concern with the influence of solar radiation upon the atmosphere led to the development of our radiometersonde and satellite programs and of our **Facility for Aerospace Research.** Concern with storms and turbulent motions in the sea of air has led to our research in synoptic and dynamic meteorology and the **Laboratory for Atmospheric Diagnostics.** Concern for the interaction of the two seas—air and water—has produced our program of physical limnology and oceanography and the **Hydrospace Research Laboratory.** Concern with the interaction of man, the air, and the earth (including human use) lies behind our programs in micrometeorology, bioclimatology, and field climatology—in short, the group of programs organized as our **Climatic Research.** These are the four foci about which we are to build our program for 1970.

We believe a major strength of the department has been its interdisciplinary character and it is clear that these four foci demand interdisciplinary staffing. It is also clear that the traditional organization of scientific departments along lines of narrow specialization cannot apply. Thus, for example, theoretical meteorology with its numerical models provides a test tube wherein hypothesis may be tested against observational fact, regardless of the source of the hypothesis or empirical data.

During the period of departmental growth, it was necessary to develop breadth both to give the student an adequate exposure to the various aspects of the field and to provide the necessary variety of scientific capabilities. With certain qualifications, it would appear that further growth should concentrate on the development of strength in depth.

The Research Program for 1970

Two problems of the atmospheric sciences stand out for the 1970's. One is manpower, the second is to advance our mathematical understanding of the atmosphere. A sound graduate training program at a university is likely to help solve both needs. We believe that the previous section of this document entitled "The Teaching Program" shows that while the number of students in atmospheric sciences at The University of Wisconsin is on the increase, their talent and background training have improved as well. We expect this trend to continue.

The various fields of meteorological research which have come to be emphasized in the Wisconsin program and the organization which has grown as a result point clearly to the research structure which can be anticipated during the 1970's. Our goals for the various programs can be visualized, in part, in terms of the facilities they would utilize, primarily:

1. Facility for Aerospace Research. New opportunities exist for observing the atmosphere on a global basis. While there is always a danger of overemphasizing hardware and gadgetry, the shoe now is definitely on the other foot. At present only a small number of meteorologists and

atmospheric scientists are in a position to exploit the new possibilities. One has to know the language of the new technology in order to converse usefully with those who create it. Clearly, a gap exists which must be closed by the development of "creative gadgeteering." An example of this is the search for sensors suitable for small-rocket probing of the atmospheric region between 50 and 100 km altitude on a synoptic basis. In a paper entitled "Observing the Atmosphere—A Challenge" published in Vol. 50 of the Proceedings of the IRE, Professor V. E. Suomi has broadly outlined the challenge, in the language of the engineers and not the meteorologists.

Our department has already benefited from the cooperation of the College of Engineering in the Meteorological Earth Satellite Program which involved the Vanguard launch attempt, and the orbiting satellites Explorer VII, and TIROS III, IV, V, and VII. A location of the new meteorology building near the engineering campus and the University computer facility should foster even more this cooperation in research.

In more detail, the Facility for Aerospace Research would include the research programs in experimental physical meteorology, the satellite program, aeronomic research, the radiation program, and ozone studies. These are essentially the programs presently under the leadership of Professor Suomi plus the engineering aspects of these studies. At least four subsidiary programs are envisioned:

a. Design, fabrication, and calibration of devices for meteorological measurement such as those carried on satellites; and the integration of these with other payloads on the aerospace vehicle. This, of necessity, involved close coordination with the U.S. Weather Bureau, National Aeronautical and Space Administration, and the Armed Forces.

b. Utilization, evaluation, and investigation of the physical measurements as they become available, on a broad basis. Development of data handling techniques, computerization, and guidance of potential users.

c. A strengthened program of air-borne radiometry, in conjunction with studies of the general circulation of the atmosphere, to fill the gap between the data available to ground observation stations and that obtained with satellites. This program also should include the theoretical program utilizing mathematical models and the applications of numerical methods; it would be advantageous to have the theoretical program allied to the extensive synoptic network providing direct access to information on energy sources and distribution.

d. A theoretical group concerned with energy processes in the upper atmosphere; linked closely with the experimental work, this program would lead inevitably to new insights and to the initiation of experiments designed to verify hypotheses and open new avenues of atmospheric exploration.

2. Hydrospace Research Laboratory. The department has been engaged in research in physical limnology since 1949 and has made significant contributions to the lake research program for which the University is famous. With the present upsurge of interest in oceanography and the new program of graduate education in this area, it is logical that this should be one research focus of the department.

We do not wish, however, to be just another group doing the same things in the area of air-sea interaction. There are many groups now planning cruises and shipboard research programs. There are several groups planning or operating micrometeorological towers over water surfaces such as the one we have used for four years. We propose a bold leap forward into a new kind of limnology and oceanography based on the airplane as a vehicle and utilizing remote sensors involving infrared, microwave, radar, and similar techniques. This would put an oceanographic expedition at sea from the Midwest faster than a ship from New York could be out of Long Island Sound. Utilizing a heavy amphibian aircraft, the Great Lakes of the United States and Canada could be explored very rapidly, with landings on the water to make soundings, obtain samples, and the like.

A program of air-borne limnology and oceanography must be based on close interdisciplinary cooperation between physicists, chemists, meteorologists, engineers, and oceanographers for the utmost of sophistication is required of the equipment and the experimental design.

Our goals in hydrospace research include the development within the decade, of an interdisciplinary capability for air-borne physical limnology and oceanography. The field tools of the physical limnologist-oceanographer must be developed well beyond the current state of the art and a system must be designed which is capable of airborne operation and compatible with modern computer data processing techniques now available. The Wisconsin program has made a modest start in this field through utilization of light aircraft, and the goal is to increase the scale of the effort and be operational by 1970.

3. Climatic Research. Climatology is concerned with the atmospheric events giving each region its character and individuality. It is concerned both with theoretical aspects of atmospheric behavior and with actual measurement and study of the weather and climatic elements characteristic of the various regions of the world. Climatology is not merely statistical meteorology nor meteorological statistics, but rather utilizes distinctive techniques to answer the many puzzling questions still existing concerning the nature of the world's atmospheric environment. It is unique in the breadth of viewpoint and number of other scientific fields that must be called into use to investigate these problems.

In recent decades, the research in climatology has not kept up with the quickening pace in the other branches of meteorology. This is not to say that there has been little good work in climatology, but the field is underdeveloped in terms of its importance, undermanned in its teaching programs, and underestimated in terms of its potential value to mankind. The development of a modern, effective research network has progressed faster in some of the other fields of meteorological research than it has in climatology. The Committee of Atmospheric Sciences of the National Academy of Science—National Research Council recently recommended the establishment of a climatic research center at a university where there are strong programs in meteorology, oceanography, geology, and other related subjects.

For more than a decade such programs have been in existence at The University of Wisconsin. Our past research programs have included upper-air climatology, bioclimatology, microclimatology, and climatonomy. During most of the history of the department, the microclimatic aspect of micrometeorology has received considerable emphasis, and pioneering research on the heat, momentum, and moisture fluxes at the earth's surface has provided insights critical to an understanding of the regional distribution of climates. A large continuing program in this field directly involved the study of fluxes over water, a knowledge of which is important in obtaining an understanding of the effects of lakes and oceans on world climate. Airborne radiation surveys are providing a comparable fund of information on the climatic effects of various land surface types. It can safely be stated that The University of Wisconsin is among the world leaders in microclimatology.

A large grant from the National Science Foundation in 1962 has greatly strengthened this program. We propose to continue the development of broadly interdisciplinary research in climatology at Wisconsin. In particular, we intend to develop the following areas:

a. A global study of modern climates in three dimensions, with special attention to the climate of oceanic, polar, and desert areas.

b. A study in depth of past climates, as far back as evidence will permit us to go, to be carried out with the broadest of interdisciplinary teams.

c. An elucidation of the laws which govern the relation between the fundamental variables of terrain, solar radiation, and atmosphere. This study is conducted in part by means of mathematical models, an aspect with important implications in atmospheric diagnostics; and the field data are to be obtained by air-borne instrumentation in an extension of our present air operations.

d. An expansion of the program of agricultural and environmental climatology. An appraisal of world needs in meteorology would show clearly that the most important realm is related to food and water supplies. If we are to serve mankind, we must develop vigorous programs in this field.

e. Development of a program in bioclimatology and its engineering applications. The viewpoint of our climatological program has been ecological. We propose to extend and strengthen this ecological approach and emphasize direct considerations of man's interaction with his environment. This involves close ties with sanitary engineering for the study of air pollution, with civil engineering for the study of water supplies, with planning groups for the study of city climates, with medicine for the study of health-climate relations, and with architecture for application of environment climatology to building design.

4. Laboratory for Atmospheric Diagnostics. The basic simple models of weather distribution about pressure maxima and minima were suggested more than 100 years ago and had attained a considerable degree of refinement by about 50 years ago. They are employed today with only slight modification from the original ideas and at best demonstrate only a limited degree of success. On the other hand, the modern mathematical models of the atmosphere which are used in daily forecasting are equally limited. Their numerical integrations are only indirectly related to actual weather patterns. Most of the mathematical models assume that energy sources and energy dissipation are unimportant—in other words, that the atmosphere is a closed system or that the atmospheric "engine" is coasting.

The Laboratory for Atmospheric Diagnostics is needed to improve the apparently weakest area in our previous atmospheric science program at The University of Wisconsin. However, we have already established a solid basis. On the one hand we have collected and analyzed radiation data on a global and regional scale with satellite and ballon radiometer/sondes and continue to improve our picture of the energy input and losses at the outer fringes of the atmosphere. On the other hand, we have worked intensively on the parameterization of regional and global friction processes and energy transfer at the lower boundary, thus improving our understanding of the world-wide energy dissipation in the atmosphere. The real atmosphere is an open system, not a closed system governed by conservative principles. Yet, we are not in a position to study the implications in a suitable mathematical model of the atmosphere. We have the experiment, but no test tube. While previously we have made extensive use of the computer for data processing, atmospheric energy spectrum analysis, and climatology, we have not done what is needed in modeling the atmosphere numerically. To improve this situation we need both space **and** additional staff. We will not need a large computer facility under present planning, but a smaller "satellite" computer connected to the large facility of the University's Numerical Analysis Department by cable. The required input and output devices peculiar to the atmospheric problem will be housed in the Meteorology Department. Thus, as the University improves its general computer capability over the years, we will be linked automatically with the new benefits.

There is a need here for the welding of theory and observation and for the introduction of energy concepts into the analytical system. This is the field of atmospheric diagnostics—a study of the role of energy supply and dissipation in the driving of the atmosphere, the path of energy through the system, the role of the latent heat of condensation, the relation of these processes to the distribution of clouds, precipitation, heat, cold, storms, and the numerous effects that form the ever-changing environment of man.

In the past, theory of the atmospheric circulation was largely the realm of the "dynamic meteorologist," whereas concern with the distribution of actual weather was left to the "synoptic meteorologist" who in turn was often regarded as an inferior sort of quasi-scientist. We propose a research program wherein the dynamic and synoptic aspects are combined with the new capability of world-wide weather and radiation surveillance by satellite. This program would require a large computer in which automated output of the sensing systems is coupled directly with a numerical model whose parameters may be varied to match observed weather and calculated weather. Once again a mathematical model becomes a "test tube" for conducting atmospheric experiments.

The Academic Program for 1970

The Atmospheric Sciences, although old—dating back to the times of Herodotus and Aristotle—are now in a period of dynamic growth. Decade by decade and year by year important new concepts are introduced and new tools and techniques developed. Standard courses of yesterday will be obsolete tomorrow. It is not possible, then, to specify the courses that will be offered in 1970. It is possible, however, to lay down broad principles to be followed in the development of the academic program and its actual execution.

First, excellence must not be sacrificed for expediency. This high principle finds application in many small day-by-day decisions. Who teaches the beginning courses? We believe that young professors and new instructors should not teach the beginning courses—these should be taught by the most experienced senior men. The younger men are usually quite capable of teaching advanced courses and in the process develop the experience and techniques that are more vital in the instruction of beginners. Since the senior men are often in demand for committee service and administration, the expedient solution often is to assign introductory courses to instructors. However, excellence demands the use of the senior professors.

Similarly, though it is easy to continue offering a particular course year after year, excellence demands frequent and ruthless reappraisal of each course and its content. It is the intent of the department to overhaul its curriculum continuously to meet the needs of the students and the times.

Second, the department, including its research program, exists for the students. It is not an organization for the sake of research nor a club of professors. It exists for education of the students through discourse, dialogue, and the intellectual encounters of cooperative research. This principle has several corollaries at the graduate level:

1. Students must be participants in all the research programs, not as hired help, but as working scientists expected to question, to innovate, to suggest, to write, and to struggle with the essentials of each problem.

2. It follows that assistantships must not be just 20 hours a week of employment, with the students' research done "on the side." Each student must be totally immersed in his studies in depth.

3. Individual problems, or flashes of insight, cannot be scheduled. Thus, students must have access to the staff as freely as possible to capitalize on the inspiration of the moment.

Third, the staff of the department is unanimously agreed that the atmospheric sciences at Wisconsin shall be concerned with the welfare of man, through our study of his environment. While ~~recognizing~~ emphasizing the necessity of a ~~broad~~ theoretical background and developing it as strongly as possible, it is the intention of the department to ~~continue its past orientation towards~~ include experimental and applied aspects of the field as well

In 1970, then, we will not see a fixed curriculum of studies for all graduate students. As long as possible, we will counsel and work with students as individuals, to develop each to his maximum potential of creativity in the atmospheric sciences. But since each student is an individual, living in and contributing to the society of which he is a part, we shall strive to provide each with the broadest base of understanding consistent with the special research requirements of graduate study.

What of the undergraduate program? It has been said often in the past decade that the atmospheric sciences present a field of study for mature students who are thoroughly grounded in the basic sciences. This is certainly true. It has also been said that maximum efforts must be exerted to recruit top students to the field, for the vast opportunities there cannot be fully exploited by the small number currently in the field. Two facts are pertinent here: (1) recruitment of excellent students who are already committed to other fields is very difficult and (2) academic achievement is strongly enhanced by early identification of the student with his chosen field of study.

The facts and needs can be reconciled with an undergraduate program of studies. A freshman course provides an introduction to the field, and also a sense of identity for these students who enter the university with a career in atmospheric sciences in mind. There is a growing number of these students, for whom a major in meteorology appears desirable. Many would be lost to the field if they were turned away and advised to major in some other field. Such a course also serves as a recruiting ground for those still uncommitted. Once a student identifies himself with the atmospheric sciences, he may be sent to the basic sciences for background as intensive as those acquired by majors in the other fields, while taking a minimum of course work in atmospheric science. Thus, he acquires the sound background without losing his sense of identity as one preparing for an atmospheric science career. At the same time, his identification with the field enhances his academic achievement.

The best of these undergraduate majors are ideal candidates for further graduate work. Those who do not continue provide some of the large numbers of intermediate level practitioners needed by the atmospheric sciences at the service level. For these individuals, we envision sufficient operational courses as to guarantee useful employment, courses centered about an outline utilizing the latest available material relating Tiros photos, infrared, and other satellite data to the day-to-day problems of forecasting and climate analysis.

In 1970, then, there should be an undergraduate program leading to a baccalaureate in the atmospheric sciences, with a limited number of courses in atmospheric sciences as such, and a large number of basic science background courses consistent with broad cultural development of the individual.

Since man lives in the atmosphere and is subject to its vicissitudes, we will continue to offer an elective cultural survey of the atmosphere and its behavior.

Throughout the academic program we propose to maintain and develop excellence of the program **and** of the individual, not only as a scholar, but as a duty-conscious member of a research team upon whose shoulders rests the best hope for a fuller life for much of our nation and the world.

Implementing the Plan

In the preceding sections of this report, the past development of the department, its present status, and the planned extension of its trends into the coming decade have been detailed. Clearly more is needed for the realization of these plans than just a statement of them, no matter how strongly this statement is supported by the staff of the department. Specific fiscal and physical supports also are needed.

In terms of the period for completion of a new facility, the 1970's are not a long time away. Changing directions within the atmospheric sciences, however, make it difficult for us to state what our precise needs for physical support will be for that date. However, when we look at what must be the **necessary** growth of meteorology and the upper air sciences, we can formulate in some detail the most probable course of departmental change, and what we should set as our own targets in implementing the plan.

To the extent that we seek public support for our work, we feel we are obligated to turn our attention to solution of public problems, and we have set our goals accordingly. It is with this in mind that we say that our goals are, simply, to educate a cadre of personnel capable of probing the atmosphere, and, to whatever extent within our reach, to seek by departmental research to spotlight a path toward solutions of problems within it.

We note that in a university, these two major goals are not simply compatible; they can hardly be separated, even if we should wish to try. Locating promising students may not be easy, yet the growing challenges within our field are daily bringing new talent into the field, and we need physical space to provide them with opportunities for distinction. The calibre of our present graduates, we feel, is adequate comment on our present recruiting and pedagogy; and appraisal of future quality must hinge on the fiscal and logistics support of our proposed programs.

Future atmospheric research, it seems clear, must seek (1) to observe the atmosphere better, (2) to understand more fully what is observed, and on an ever increasing scale, and (3) to harness and control the atmosphere—in gross and micro scale—for the general benefit of mankind.

Better observations will certainly mean more complex hardware, and more sophisticated gadgets, also more space to utilize them and train students to master them. Yet, we would emphasize that we do not visualize ourselves as gadgeteers—though our students may be seen with many of the same texts on electronic circuit design, heat transfer, optics, or physical instrumentation as are common in engineering or physics classrooms. Rather, we believe our role must be to keep our students well informed as to the technological problems within our field; and, so far as possible, try to prepare each to help plan further developments in observational techniques or data handling. But our main stream is first of all, meteorology; if our students have creative abilities in hardware design or utilization, we will seek to prepare each to exploit them. But we shall be content, if, in the main, we prepare students capable of research analysis of meteorological problems, plus a speaking knowledge of technology sufficient for him to convey his hardware needs to men whose career it is to design and build gadgets.

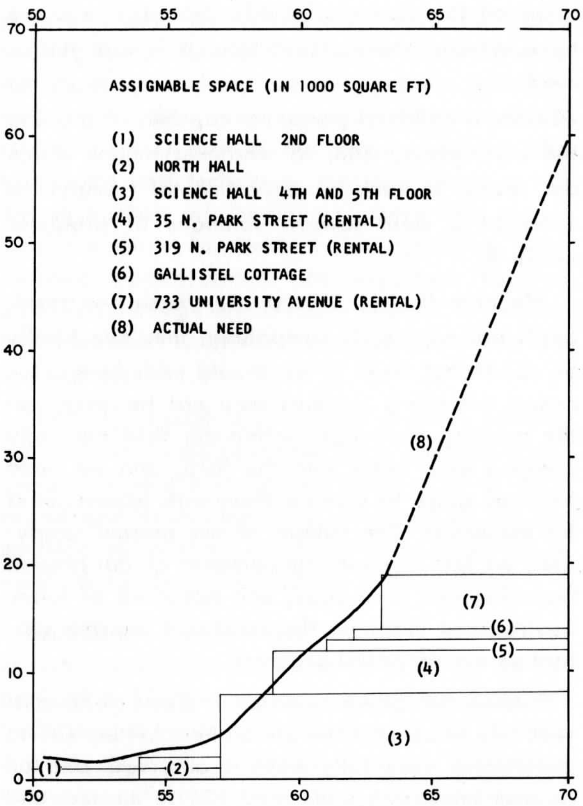

Fig. 8. History of areal expansion of the U.W. Department of Meteorology and projection of actual need into the future.

We must emphasize, further, that in seeking more space to train a graduate student in the firm grasp of electronics, computer techniques, and the principles of other specialized fields with applications to the atmospheric sciences, we emphatically do not envision a little university within this department. We may, as already has been done, seek to work with other departments in tailoring their courses to the needs of our own (and other liberal arts) students, but each department, we believe, best teaches its specialties.

It is with an eye to this future meteorologist that we have stressed that the proposed building will stand in close proximity to research structures slated for geophysics, engineering, and numerical analysis—and to a nearby student union structure where, we can safely predict, students from all these allied fields will rub shoulders.

We can already point to some steps along this road toward interdepartmental cooperation for tackling extraordinarily complex problems of theory and technology. This department has, since the advent of its satellite-borne radiation measurements, been allocated space within the Electrical Engineering Building, quarters shared jointly with E.E. staff and graduate personnel working on problems having similarities of approach and technology. The result, we believe, has been mutually profitable, but at the moment, due to our lack of space and equipment, the benefits have largely flowed in a single direction. We sometimes fear our welcome may one day wear thin, if some prospect for a change is not scheduled.

Among the graver threats to the meteorologist's reaching an understanding of the weather processes are (1) that in the years ahead, he may be simply too swamped with data to make heads or tails of it, theoretically; and (2) that he may, as so often has been the history of the past, find himself tailoring the suit of his data-handling and research programs to match the cut of already-available data and equipment. Thus, while we expect to utilize increasingly two-dimensional photos of the Tiros type for forecasting and theoretical study, we believe thought must be given, constantly, to what other types and formats of data might more quickly lead to our long-term goals. This again needs space for experimenting.

Space

The history of areal expansion of the Department of Meteorology is illustrated in Figure 8. This graph must be compared with the curves on Figure 1 which show the rate of increase in graduate student enrollment, staff size, and research budget.

When the department was established in 1948, one of two small rooms on the second floor of Science Hall housed the entire staff—two professors—the other room served as a small research laboratory and shop. In the first few months, the addition of a part-time student secretary and one graduate assistant began the history of overcrowding that has characterized the department since then. The addition of one small office in North Hall a few years later was more than matched by the addition of new research assistants and a full-time secretary. This situation changed very little until 1958 when about 8,000 square feet on the fourth and fifth floors of Science Hall was substituted for the space on the second floor and in North Hall. An explosive increase in graduate enrollment, research activity, and staff size saturated this space in less than one year, and necessitated the utilization of a rented warehouse on 35 North Park Street, which is shared with astronomy. Other rental space, formerly residential and commercial, at 319 North Park Street and 733 University Avenue was needed in 1961 and 1963, the latter to house personnel and equipment for climatic research. An unfinished and ramshackle summer cottage, made available in 1962, is located on the west side of the campus near Second Point on the shore of Lake Mendota; it houses the equipment and the workshop used for the micrometeorological program. Relatively small rooms (fewer than a few 100 square feet total) have also been made available in the Electrical Engineering Building (bench space for satellite data evaluation), and one office by the Zoology Department in its new Limnology Laboratory for hydrospace research.

The most pressing need of the department at present and in the future is space. The greatest obstacle to the realization of our plans is lack of space. If the full potential of the department in teaching, research, and service is to be achieved, this problem must be solved in a more permanent and less scattered manner than in the past. Figure 8 illustrates that nearly all the time the actual space available lagged behind space needed. In other words, the department was continuously working in an overcrowded condition.

Assuming that the estimates of graduate enrollment in 1970 are approximately correct, an estimate of needed staff may be made by either analyzing the equivalent contact hours that must be provided or by comparison with other science departments of the expected size. From these figures on students and staff, space requirements may be estimated either by applying standard space/person ratios or by detailed analysis of individual room assignments.

Allowing for classrooms and lecture hall space primarily devoted to undergraduate instruction, either method of space estimation yields a requirement of about 60,000 assignable square feet. This is not an estimate that would yield spacious quarters, for if slightly more than the projected number of people are involved in the department, the space/person would not be greatly different than at present—and the present crowding is intolerable.

Research and teaching in the theoretical aspects of the atmospheric sciences do not require large areas/man or specialized facilities other than the availability of large computers, but the departmental emphasis on experimental and applied research involves a requirement for specialized laboratories of many kinds.

Staff

One of the discernible trends in the nature of our graduate enrollment is its changing composition in terms of terminal degree sought. Many more are now candidates for the doctorate. With no increase in enrollment, this would mean a greatly increased academic load for the staff in terms of more, small but highly technical seminars, and thesis advising. If we assume that in 1970 one-third of the graduate students are candidates for the doctorate and two-thirds seek the master's degree and further assume that the Ph.D. takes 4.5 years and the M.S. 2, we can arrive at an estimate of the thesis-advising load. Each year there will be about 55 per cent of the students working on either M.S. or Ph.D. theses. Allowing three courses/semester for M.S. candidates and two for Ph.D. candidates, about 56 contact hours of upper-level courses will be required each semester for about 100 graduate students or about 70 contact hours for all students. If each thesis requires half an hour a week from the professor, 120 graduate students plus perhaps 30 undergraduate majors would require a full-time academic staff of about 17 professors. Judging by the present division of research support and state support, this implies a total academic staff of 25 to 30. This is about 2½ times the present staff for a graduate enrollment of about 2½ times the present.

More important than the number of professors is their distribution by specialization. In previous sections of this report, the research program for 1970 was detailed; and, since the research program must be integrated with the instructional program, the staff structure may be visualized in the same terms. The division of research into four major foci determines the breadth of competence required.

Aerospace. The program in experimental physical meteorology led by Professor Suomi is an outstanding one, but rests almost entirely on this one man. For continuity of the program and to cover its various phases adequately, additional talent in instrumentation and data processing techniques are needed.

Hydrospace. The new interdisciplinary program in oceanography at Wisconsin relies on the work of Professor Ragotzkie for physical oceanography. Another senior professor in dynamic oceanography along with the existing departmental competence in air-sea interface problems would make this a strong program indeed.

Climatology. An extensive research program under the direction of Professors Bryson and Lettau exists, with strong ties to several other departments. Within this program there is a great variety of technique, topic, viewpoint, and application, which should be matched with a variety of academic talents. Particularly needed competences are in statistical climatology and atmospheric chemistry.

Atmospheric Diagnostics. The work of Professors Deland, Horn, and Schwerdtfeger in this area should be supplemented by competence in numerical methods to bring the staff to proper breadth.

With the staff additions mentioned in the paragraphs above, we would achieve correct breadth of competence. Strength in depth requires that more junior positions be established in these same general areas. There must, of course, be room for the generalist or scholar whose view is broader than described by any one program. Nor is the orientation of the department toward four foci equivalent to sub-departmentalization, for our tradition is to study that which we find most challenging, regardless of the realm of atmospheric science within which it lies.

The history of the department demonstrates strong interdepartmental ties, cemented by joint appointments with civil engineering, soils, and Integrated Liberal Studies. It is our intention to continue to draw heavily on competence in related disciplines, both as it appears in the training of new staff, and through joint appointments.

Support Personnel

With a research budget of over a million dollars a year, nearly 50 graduate students and more than a dozen academic and research staff members, the present secretariat of three secretaries, an accountant, and five student typists is inadequate. Clearly a program of at least double the present size demands an addition of at least one secretarial position/year for the next five years.

Even more pressing is the need for technicians. The amount of specialized equipment and expensive gear used in the department has grown to a point where lack of technicians to maintain it is uneconomical. Many man-hours are lost because some item which we have is not in usable condition and must be duplicated. Minimum needs within the next year are one additional computer programmer, two electronic technicians, and one machinist. By 1970, these numbers should be at least tripled.

While it is certain that such personnel will be added only as our research and teaching workload warrants, we feel it is best to project work space for them at this time, due to the long lag-time in constructing additional quarters.

Research Training

The Department of Meteorology offers graduate work leading to the master's and Ph.D. degrees. The master's degree is awarded upon the successful completion of a comprehensive examination and the preparation of a thesis involving research. A student is admitted to candidacy for the Ph.D. degree upon passing a preliminary examination and is granted the degree only after the completion of a thesis demonstrating a high degree of research competency. For details on graduate student enrollment, undergraduate preparation, and graduate course programs, reference is made to the section entitled "The Teaching Program," in which the continuous trend towards improvement of the quality of graduate research training at The University of Wisconsin Meteorology Department is evidenced.

During the past five years, the department has awarded nine Ph.D. and 36 master's degrees. Of the 50 graduate students currently enrolled in the department, 26 are candidates for the Ph.D. degree. As previously noted, we estimate our graduate enrollment to reach at least 120 students by 1970. It is likely that at least one-half of these will be Ph.D. candidates. Along with the intensification of research programs, we look for a marked increase in the quantity and quality of scientists who do postdoctoral research in the department. Thus, it appears certain that The University of Wisconsin will continue to play a major role in the research training of atmospheric scientists.

To maintain this role in research training, it is essential that the department's need for physical space be met. We have a strong research program, an expanding staff and a continuously increasing graduate student enrollment; however, our need for physical space is acute. At present, the department's research facilities are spread over six locations. This means that many of our students are forced to do their research in inadequate, temporary facilities located considerable distances from their major professors' offices, from storage space for tools and equipment, and from the reference library. As our enrollment grows, the fragmentation of the department cannot but increase. It has already reached the point where the advantages gained from the bringing together of a vigorous faculty and student body are being seriously diluted. Without a solution to this problem within the next two years, the research program of the department will be stifled. The problem is indeed imperative!

Conclusion

In proposing construction of a building on the campus of The University of Wisconsin to house the research and training facilities of the Department of Meteorology, the departmental staff takes cognizance of the economic and social impact expected within the next decades, and of advances within the atmospheric sciences. Thus, we do not say that additional office, classroom, and bench spaces are needed simply because the nation's population increase will, in all likelihood, burgeon the number of students beyond that which we can handle in our present or available quarters.

Rather, we concur with those in the field of the atmospheric sciences who emphasize that the increasing world population and income are heralding a new era; that just as population pressures necessitate solutions to long-ignored problems, so such breakthroughs as satellite measurements and the steadily accelerating research in all branches of science and technology spell out clearly that the coming decades will be periods of critical decisions, for meteorology and world history alike. Thus, we can look ahead and envision that such questions as the effects on climate of removal of the Arctic sea ice, of cloud seeding on a hurricane or monsoon scale, or of diversion of ocean currents, will almost without doubt be investigated, and perhaps be acted upon, before the turn of the century. It is, we feel, paramount that this nation recruit, motivate, and train sufficient personnel capable of taking a leading role in such research well in time to insure that our long-term national interests are not jeopardized by unilateral action.

Our logic, in urging financial support for facilities enabling this department to expand its research and educational roles in the years ahead, is twofold:

1. We believe our current and projected research programs fully warrant the necessary support, as has been documented in detail in the preceding pages.

2. The history of the growth of this department from its inception in 1948 suggests that the burden of training an increased roster of highly skilled research personnel in the decade just ahead must be borne by departments already existing and already capable of mounting major investigative efforts. The unavoidable long period of departmental maturation, we believe, dictates this conclusion beyond question.

Finally, we suggest that at present, as well as in the future, our ability to prepare our students for a creative career in research, our opportunity to make the most effective use of our necessarily limited laboratory equipment, and the climate for the optimum interplay between staff members through the mutual sharing of ideas and solutions to common problems, all suffer gravely through the existing spatial fragmentation of the department.