Proceedings

INTERNATIONAL WORKSHOP ON MESOSCALE RESEARCH AND TAMEX PROGRAM REVIEW

國際中尺度氣象研究與TAMEX計畫檢討與評估研討會

April 26-30, 1993
National Taiwan University, Taipei, Taiwan, ROC

Supported by

National Science Council
Ministry of Transportation and Communications
Ministry of Education

Sponsored by

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Department of Atmospheric Sciences, National Central University
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台大思亮館國際會議廳

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Preface

Flash floods are major meteorological disasters which occur in many parts of the world. These disasters are especially destructive in Taiwan. During late spring and early summer, mesoscale convective systems often develop and interact with the steep orography of Taiwan to produce heavy rainfall and flash flood. With the rapid economic development in last two decades, the heavy rainfall and flash floods in the Mei-Yu season have caused severe property damage. In view of this problem, the National Science Council of the Republic of China established a Multiple Hazards Mitigation Project in 1982. With the awareness that prediction of flash floods is greatly hampered by a lack of understanding of the mesoscale processes responsible for producing heavy rain, a mesoscale research program–the **T**aiwan **A**rea **M**esoscale **EX**periment (TAMEX) was initiated. The long term goal is to improve the prediction of heavy precipitation. The field phase of TAMEX extended from May 1 to June 29, 1987, and included thirteen Intensive Observing Periods and ten research aircraft missions.

The research based on data sets collected during TAMEX field phase has led to a better understanding of 1) the mesoscale circulation associated with the Mei-Yu front; 2) the evolution of the subtropical mesoscale convective system (MCS) and 3) the topographical effects and local circulation in and around Taiwan. To improve heavy rainfall prediction, the TAMEX research results were put into operational use during the Post-TAMEX Forecast Exercise in May and June 1992. Judging from the large volume of high-quality scientific publications on the TAMEX results and the progress in heavy rainfall forecasting skills at the Central Weather Bureau, there is no doubt that the TAMEX program has fulfilled its original objectives and represents one of the most successful international mesoscale research programs. The devotion, dedication and unselfish contributions of many scientists in Taiwan and the United States were crucial to the success of TAMEX.

At the conclusion of the first ten-year TAMEX program, it is essential that we critically review what we have accomplished, and carefully plan for the future. In this spirit, we invited prominent researchers in various areas of mesoscale meteorology to meet at the campus of the National Taiwan University in Taipei, Taiwan, the Republic of China on April 26-30, 1993, for an International Workshop on Mesoscale Meteorology and TAMEX Program Review. The first part of the program will provide a presentation of recent advances and critical research issues in mesoscale meteorology. The second part focuses on the review of the TAMEX Program and the suggestions for the future mesoscale research activities beyond the first phase of TAMEX. With this workshop we wish to promote continued international collaboration on mesoscale research programs such as TAMEX, which are not only of high scientific merit, but also of great practical importance.

George Chen Bill Kuo

George Tai-Jen Chen and Ying-Hwa Kuo
Program Co-chairs

Taipei
20–26 April, 1993

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MESOSCALE METEOROLOGY AND IMPROVED WEATHER FORECASTING

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An Extended Abstract

I. INTRODUCTION

The general public understands that meteorology and weather forecasting are very closely related; indeed, most lay people do not distinguish between them. However, it is also true that most would not understand the term "mesoscale meteorology" and would view regional climate and climate variability synonymously with "the weather". Within our own discipline, we tend to think of meteorology as a basic and applied science, with weather forecasting as a clear application of the science.

When one thinks of mesoscale meteorology, the terms "theoretical research", "numerical modeling", "physical process studies", and "basic understanding" come to mind. On the weather forecasting side, we think of persons who use numerical models as guidance but who rely extremely heavily on current observations, past empirical evidence, statistical evidence, local peculiarities, pattern recognition, and experience for their daily forecasts. I personally add to this a highly developed intuition and a sixth indescribable sense and talent that borders on the artistic, mixed with a good degree of metaphysical perception. Meteorological research is associated with carefully designed experiments, case studies, long periods of time for analysis of data, and publication of results. Weather forecasting consists of continual adjustment to constantly changing atmospheric conditions and the need to make rapid and, in some cases, split-second decisions.

Professionally, we distinguish between science and forecasting with a host of tailored journals. Within the American Meteorological Society, there are the Journal of Atmospheric Science, the Monthly Weather Review, the Journal of Applied Meteorology, and Weather and Forecasting, which clearly delineate the span of interests and activities within the field of meteorology.

From an abstract point of view, all of this makes perfectly good sense. Oftentimes, however, there is a lack of mutual respect and understanding between those involved in meteorological research and those tasked with the extraordinarily difficult job of forecasting the weather on a daily basis. Scientists may view forecasters as being non-scientific, non-analytical, and lacking in basic understanding of atmospheric processes. Weather forecasters may view researchers as detached, impractical, focusing on irrelevant details and/or unrealistic situations.

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There is a trend very much alive today in the United States to ask the question, "What has science done for us lately?" This is perhaps best articulated in the report released by Congressman George Brown (1992) to the Committee on Science, Space and Technology of the U.S. House of Representatives. In this report, Congressman Brown questions the traditional scientific paradigm, namely, that the best research is the research that is defined and undertaken by the most creative scientists, and that scientists should have unlimited freedom to pursue their inclinations. The hypothesis continues by assuming that basic understanding will be advanced at the greatest rate through this process and that ultimately benefits will trickle down in unknown ways to serve society.

The U.S. Congress and the public in the United States are now beginning to question this theory. The research enterprise in the U.S. continues to be at the pinnacle of basic science internationally. We excel in the numbers of papers published, numbers of patents issued, numbers of PhDs granted, and spend more money on research and development than any other country in the world. Yet, the benefits to society are perhaps not as evident as they once were. Despite our high technology and level of scientific advancement, the country has major problems in education, in its balance of trade, in health care, and in environmental quality. The public is asking; if our research enterprise is so great, why is the country facing all of these problems? The simple answer may be that we have been failing to structure our research agenda to address the right questions and solve the right problems. In other words, we might be focusing too much on doing problems right rather than doing the right problems. Congressman Brown is not excessively critical of the accomplishments of the scientific community, but is asking that it examine itself to ensure that its work is relevant to the needs of society.

II. RESEARCH AND APPLICATION: A MERGER

In the field of mesoscale meteorology, we are fortunate to have a very clearly identified application in mind, namely, weather forecasting. The challenge to the community is to develop its research agenda so as to maximize improvements in weather forecasting. Following are several themes that may help in achieving this goal.

A. Build on existing and forthcoming opportunities.

There are three areas of technological and scientific advancement that collectively provide one of the cornerstones for meteorological research in the future. These might effectively be considered as the tools with which improved understanding of mesoscale processes and better weather forecasting will be accomplished. These three tools, (1) dramatically improved observations, (2) improved high resolution models, and (3) advanced computers and communications, are central to the planning for the U.S. Weather Research Program in the United States (Subcommittee on Atmospheric Research, 1992) to the modernization of the United States Weather Service (National Research Council, 1991, 1992) and, indeed, to modernized weather services in countries throughout the world. Serafin (1991) describes how advanced weather observations, including research-quality Doppler radar networks, automated surface observations, new sounding systems, improved satellite observations, and other data sources, will provide a wealth of research quality data with unprecedented spatial and temporal resolution. Mesoscale and cloud models nested within global or national models and initialized by local observations, including water and precipitation fields, offer the opportunity for accurate high-resolution weather prediction on regional and local scales. Advanced computers, possibly with highly or massively parallel architectures, will allow for the economic and timely model runs that are necessary to make such numerical weather forecasts practical. And, national and global communications networks, using very wide band-width fiber optic cables, will allow for easy access to these data bases by weather forecasters and a host of other users of weather information, alike. Powerful workstations with specialized software will produce displays and analyses tailored for the user. Our research programs in the future will clearly be strongly influenced by the existence of these rapidly developing capabilities.

B. Examine the relevance of mesoscale research.

Any research endeavor might be improved if, as Anthes (1992) has suggested recently, each researcher would ask him or herself the question, "If my research is 100% successful, what difference will it make?" In the fields of mesoscale research and weather forecasting, these questions can be implicitly or explicitly addressed if the research involves collaboration between researchers and weather forecasters. The weather forecasters are the users of basic research and can best answer the question, "What difference will it make?" They can identify for researchers what their real needs are and will challenge researchers to produce results that can be tested in an operational environment. Moreover, the feedback from research on weather forecasting to basic science can be enormous. In my opinion, all mesoscale field research efforts should contain within them a forecasting component that can be quantitatively evaluated.

Conversely, weather forecasters should be involved in some research as part of their everyday activities. Within the modernized weather service in the United States, each Weather Forecasting Office (WFO) will have one person, the Science Operations Officer (SOO), who will be the primary liaison between the WFO and the research community. The SOO will be encouraged and expected to work with national laboratories and universities, to engage in mutually compatible research efforts for development of improved forecasting techniques. The Modernized Weather Service will also have several, geographically distributed, Experimental Forecast Facilities (EFF). The EFFs will be colocated with WFOs, to undertake more comprehensive technique development studies, than will be possible at all WFOs.

Interactions between researchers, students, and operational weather forecasters will be further enhanced by the colocation of several WFOs on university campuses. Access to the state-of-the-art equipment and daily forecast activities will be enormously beneficial to students, by allowing them to see how their formal education relates to the real atmosphere and its predictability. The weather forecasters, on the other hand, will be stimulated by the intellectual curiosity of the students and their professors, as well as by the formally rigorous approach that is found in the academic environment.

C. Focus on specific scientific and forecasting objectives.

Too frequently we hear of scientific objectives for research programs described in the following ways: Scale Interactions, Convective Storms, Mesoscale Convective Systems, the Mei-Yu Front, the Interactions of the Mei-Yu Front with Monsoon Flow, Squall Lines, Tornadoes, Heavy Rain, Hail, Air/Sea Interactions, and a host of others. Implicitly, when researchers set forth such objectives, what they mean is, "We want to study the area of scale interactions" or "We want to study mesoscale convective systems", or "We want to study the properties of the Mei-Yu Front". None of these objectives so stated contains any testable hypotheses. None of them describes what we want to learn or how we expect specific processes to behave or interact with others. Projects and programs of this nature are often referred to as fishing expeditions, namely, investigators fish for whatever happens to bite on the hook, and the fishing grounds are vast and unexplored. Oftentimes, such preliminary and basic studies are justified because insufficient knowledge exists to create plausible hypotheses or to test specific theories and ideas.

Mesoscale meteorology and weather forecasting are now sufficiently advanced that this is no longer the case. To extend the fishing analogy, it is time now to go fishing for trout, with dry flies, with barbless hooks, and to predict where the trout might lie and might be caught. I firmly believe that programs with specific, thoughtfully-prepared and clear objectives will produce the greatest benefit for both basic understanding and weather forecasting applications. To be sure, there will always be unexpected surprises to either deflate the egos of the researchers or to produce exciting new findings. The latter are added bonuses that will be warmly received by all involved in the projects.

D. Think globally.

1. *Work with people in other regions.* Mesoscale research, by its very nature, is regionally focused. This frequently leads to research activities by universities, individuals, and laboratories, that are aimed at phenomena that occur in the region in which those individuals work or those laboratories reside. Researchers at the University of Oklahoma will tend to study severe thunderstorms, squall lines, and tornadoes. On the east coast of the United States, the focus will be on cyclogenesis and large winter storms; in the northwestern United States on extratropical cyclones; in the southeast on hurricanes; in Taiwan, on the Mei-Yu Front, typhoons and orographic precipitation. While not universally true, mesoscale research has tended to be a regional or national, rather than a multinational endeavor.

Rapid progress can be made in the future if scientists throughout the world combine their resources, their knowledge, and their regional experiments, and collaborate with one another to understand how weather systems in their regions are similar to and differ from those in other regions of the world. Such a multinational and multiregional approach to mesoscale research should result in larger, critical masses of talent, addressing the most important and relevant problems in the field.

2. *Work with people in other disciplines.* A properly balanced mesoscale research agenda can be more effectively developed by speaking with people in a variety of other disciplines. These people can be thought of as users who are outside

of the weather forecasting community. The mesoscale community should reach out to atmospheric chemists, hydrologists, agronomists, energy researchers, and the aviation community, to ask about questions that these communities would like to have answered and then to determine how mesoscale research can answer these questions. The perspectives might be very different or the differences might be quite subtle, but nevertheless extraordinarily significant. Mesoscale researchers should view their research from these different perspectives, to sharpen their own visions of what is needed.

3. *Don't forget the connection to climate.* Mesoscale research has at least two principal applications. The first is weather forecasting and the second is the development of realistic, representative parameterizations for global climate models. Too frequently, these two applications are viewed as separate and distinct, with the mesoscale community being inclined toward the former. Yet, in reality, these applications are very similar. The ability to forecast the weather is a direct consequence of understanding how mesoscale systems dynamically and physically respond to the larger environment, and are influenced by local orography and other topographical features. From a climate perspective, the desired output from regional climate simulations is a statistical ensemble of these mesoscale events, in order to characterize the regional climate within a fixed and changing global climate environment. Developing better parameterizations for climate models requires better understanding of mesoscale processes but also requires that regular substantive and long-term interactions between the mesoscale and the climate communities be developed. If these interactions are established, the mesoscale research community will be able to point to a second principal collection of users, namely the economists, sociologists, ecologists, political scientists, and policymakers who must have accurate and reliable regional, climatic change assessments in order to make effective decisions.

III. A VISION FOR THE FUTURE

The mesoscale and weather forecasting research effort of the future should be aiming at a global weather data base; one that contains in it past, present, and future visualizations of the state of the atmosphere. Such a data base should be gridded and contain variables that are meaningful to a wide range of users, from researchers to forecasters to local emergency planners. Contributing to such a data base would be the global numerical weather prediction models, within which nested regional and local models would be embedded. Data would be assimilated from diverse and asynchronous sources, including both *in situ* and remote sensing systems. The data base itself, however, should in many cases be transparent as to the source of the data. For example, from a user's perspective, satellite radiances or radar reflectivity factors may not be of greatest importance; rather, it is the phenomenology -- precipitation rates, tornado locations, damaging winds and storm motion -- that is of most interest.

Such a data base, through advanced communications networks and interactive workstations, would be available to the entire community of users, including private industry, the general public, and educational institutions. Interpretative software and displays would be tailored for each specific use. Through advanced computing and communications networks, it may even be possible for non-specialists to create their own statistical mesoscale climatologies, utilizing state-of-the-art models, and advanced interpretative and analytical software.

This vision is realizable within a decade. All the components of such a system need not be simultaneously put into place. Much of the technology, modeling, and basic understanding are already available. All that is needed now is a commitment to the concept and agreement on how it can be implemented. If implemented, we should all be able to rest with a good conscience and be gratified that society has benefitted dramatically from the results of mesoscale research.

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