Ninth Meeting of the Heads and Chairs of Departments of Atmospheric Science: A Summary

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1. Introduction

The Ninth Meeting of the Heads and Chairs of Atmospheric Science Departments was held at the National Center for Atmospheric Research (NCAR) Foothills Laboratory on 13–14 October 1994. As is customary, the meeting was cosponsored by the American Meteorological Society (AMS) and the University Corporation for Atmospheric Research (UCAR). The program committee included representatives from UCAR and the AMS Board for Meteorological and Oceanographic Education in Universities (BMOEU). Over 40 universities were represented at the one and a half day meeting.

The meeting was opened by R. Anthes, president of UCAR, who welcomed the participants and offered a moment of silence for those university faculty and researchers who had died since the last biennial meeting. Anthes discussed briefly the changing climate for atmospheric science funding and noted the increased emphasis throughout the nation on education issues. J. Snow, AMS commissioner for education and human resources, welcomed the participants on behalf of the AMS.

2. Keynote speaker

S. Zevin, in her capacity as past chair of the AMS Board for Women and Minorities, presented the re-

sults of the AMS survey, highlighting those issues that are of particular interest to the university community. The results were presented in Zevin and Seitter (1994). After her presentation, she led a group discussion on various issues. Two issues were of particular concern and interest to the participants. The first was the lack of minorities in the society, reflecting low numbers in the field. The AMS survey results were quite discouraging in this area. Comparison with earlier surveys (Kellogg 1977; Stephens and Kazarosian 1992) suggests that the AMS minority population will not increase since there is no evidence of an increased student minority population.

The second issue was the continuing lack of salary parity between men and women. There is near parity early in their careers, but parity decreases with age. This was true even when the responses were stratified by years of experience and given the fact that part-time workers were removed from the sample. Many participants offered ideas as to why this has occurred and what can be done about it. All agreed that the AMS sample size is quite small, although this is also a symptom of the problem the field has—its need to attract more women and minorities into atmospheric science.

3. Discussion groups

The participants were divided into three discussion groups. The program committee selected three subjects for the meeting and authored papers that were mailed to every head and chair before the meeting. The subjects covered were parity in faculty salaries, graduate student recruitment, and graduate student requirements. After about 90 minutes of discussion, a rapporteur from each discussion group presented a summary of the discussions.

*Chair, AMS Board for Meteorological and Oceanographic Education in Universities (1994).

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a. Parity in faculty salaries

J. Winkler presented results from the discussion group on parity in faculty salaries. For analyses of the responses to the 1993 AMS membership survey, only full-time tenure-stream faculty with Ph.D. degrees were considered academic employees, in order to control for terminal degree and type of position. The salary and demographic characteristics of tenure-stream faculty were then compared to those of Ph.D.-level atmospheric scientists in nonacademic jobs. The analyses of the AMS survey indicated the following.

- Both the mean and median annual salary of women who are full professors fell below that of men who are full professors by more than \$18,000.
- A surprisingly small proportion of women faculty responding to the survey held the rank of associate professor.
- Women with Ph.D.s in atmospheric science appear to have fared better in nonuniversity positions in terms of salaries comparable to men at a similar rank; advancement from entry- to midlevel positions; and a lighter, although still substantial, workload that provides greater opportunity to balance career and family.

The small group discussion at the Heads and Chairs Meeting centered on four general issues that were thought to impact women in faculty in atmospheric science:

- 1) the small size of the pool of female Ph.D.'s in atmospheric science;
- 2) the impact of family constraints, particularly for women who are married to other atmospheric scientists;
- 3) salary structure (although several chairs noted that entry-level salaries for male and female faculty are now similar) and the theories that discrepancy at higher ranks may be an artifact of past salary practices or due to differences in productivity among individual faculty; and
- 4) the role of mentoring.

The discussion ended with a call for further information. Chairs were particularly interested in a more accurate measure of the size of the pool of women atmospheric scientists at different educational levels and professorial ranks, as well as the number of women progressing to each professorial rank, in order to better ascertain whether more women faculty

than male faculty drop out at each level. Several chairs suggested future monitoring of faculty salaries.

b. Graduate student recruitment

W. Beasley presented results from the discussion group on graduate student recruitment, which was chaired by P. Smith. The discussion group considered a number of issues, including the following.

- Are there enough graduate students in the atmospheric sciences? The discussion groups indicated that the number was about right.
- Are the graduate students of sufficiently high quality? On the average, the discussion groups felt that the quality of graduate student applicants was satisfactory.
- Are our admissions standards appropriate for contemporary needs? The discussion group felt that admission standards were appropriate.
- Are M.S. degrees without a thesis option desirable and would their availability improve graduate student recruiting? The discussion group felt that some programs should offer the nonthesis option but that it would not be healthy for the majority of the departments to do so.
- Should we recruit students more vigorously from other fields and from the professional world? The discussion group felt this would be desirable.
- Should B.S. degree recipients be encouraged to go to graduate school right away or work in the field first? The group could not reach a consensus on this question but did agree that it depends on the student.

c. Graduate student requirements

R. Stull presented the results of the discussion group on graduate student requirements. Some preliminary conclusions were the following.

- Roughly 50% of new students enter without a degree in meteorology.
- Research assistantships support roughly 90% of the graduate students, while only about 10% have teaching assistantships.
- About 60% of the M.S. students do not continue for a Ph.D.
- There is no standard entrance requirement for Ph.D. programs.
- While about 10%–20% of students fail the comprehensive and qualifying exams, only about 5% fail the preliminary and very few fail the final dissertation defense.

These preliminary responses come from 32 schools that offer both M.S. and Ph.D. programs in the atmospheric sciences. A more complete summary of these findings will appear in a future *Bulletin* article written by Stull and S. Businger.

4. Recommended B.S. program in meteorology

Smith presented the revised recommended bachelor's degree in atmospheric science or meteorology, as prepared by a subcommittee of the AMS Board of Meteorological and Oceanographic Education in Universities. The discussion period was lengthy, and there were many suggestions. The final result was that, with a few modifications, the report of the BMOEU subcommittee was endorsed. The actual recommended program has been published in the *Bulletin*, so it will not be repeated in this article (American Meteorological Society 1995).

5. Program reports

Directors of several programs of interest to the heads and chairs were invited to give brief updates on their activities. Two reports are summarized in this section.

a. The COMET program

T. Spangler, director of the Cooperative Program for Operational Meteorology, Education and Training (COMET), provided a look at the future of the COMET program. A number of activities will dominate the next 3–5 years. First, the library of computer learning modules on topics of mesoscale meteorology will be finished, and some revisions of previous modules will also be completed. Future modules will be available on compact disc, an option that will provide for much broader use in the university community. New distance learning techniques will also be introduced, potentially including videoconferencing, electronic performance support systems on the operational workstations in weather service offices, and the possible delivery of computer-based learning via the Internet.

The COMET Residence Program will continue offering some 32 weeks of courses per year. New courses include a one-week course for managers and a course for university faculty, which was held 31

May–10 June 1994. More course seats will be open to university faculty and the private sector during coming years.

The COMET Outreach Program, an initiative for providing funding for joint projects between universities and local National Weather Service (NWS) and Air Weather Service offices, is expected to expand. The program will also include funding for graduate student and postdoctoral fellowships beginning in the spring of 1995.

b. National Climatic Data Center

K. Hadeen gave an overview of the National Oceanic and Atmospheric Administration's (NOAA) National Climatic Data Center (NCDC) and explained its legal mandate as the official weather records center for the United States. As a steward for weather data, the NCDC acquires weather data (both in situ and remotely sensed data) from the national networks of NOAA, the Department of Defense, and other agencies and organizes and quality controls the data as needed. Hadeen stressed the importance of making the data available as economically and efficiently as possible and of preserving the data for retrospective analysis and use by the next generations of scientists. He also explained that the NCDC is "a national resource for climate information" because it provides data and information to every social and economic sector of the nation. The NCDC has increased its efforts to provide more data and information to academia and the research community, in addition to serving more than 100 000 other users each year.

The NCDC has programs to develop long-term regional and global "science-quality datasets" by working with the World Meteorological Organization Commission on Climatology and various science advisory teams. Most of these datasets date from the mid-1800s and have the attributes of being as complete as possible and carrying a high level of quality control with questionable data removed or flagged. The NCDC maintains an archive of gridded analyses from the National Centers for Environmental Prediction (formerly the National Meteorological Center) and model output from some of the global climate models, such as the Geophysical Fluid Dynamics Laboratory 500- and 1000-yr runs.

The NCDC distributes data and climate information over various media, including monthly and annual publications, compact discs, electronic bulletin boards, facsimiles, and the Internet. Hadeen distrib-

uted information on ways to access climate data and information over the various media and also over the World Wide Web home page for NCDC.

6. K–12 activities in universities

D. Smith of the U.S. Naval Academy presented a summary of K–12 activities at universities. He first discussed the history of pre-college activities in the atmospheric and oceanic sciences, which began with the establishment of an AMS education program. A brief history is summarized in Table 1.

After his discussion of the history, Smith summarized which features of precollege programs seem to work well. This list included the following examples.

- *Partnerships*—Collaborative efforts of professional societies, universities, government agencies, and private corporations in concert with precollege educators maximize the talent and resources of each.
- *Strong teacher involvement*—The role of pre-college teachers is the key to the success of a K–12 program. Because they are the critical element in the K–12 educational system, teachers should be provided with the tools they need (content, instructional materials, equipment, encouragement, sense of professionalism) and then allowed to do the rest.
- *Enhancement of content and leadership skills*—Many teachers lack appropriate background in some of the subjects they are required to teach. In addition, some require development of skills and encouragement to go beyond their classrooms to become role models for their colleagues and “agents of change” in their own educational structures.
- *Activity-based instructional materials*—Hands-on learning materials that focus on “doing science” are

- important for stimulating student enthusiasm.
- *Realistic role of technology*—Technological advances for the classroom mirror society at large; students need to prepare for their future roles in a technological society. However, the level of technology present in schools and the ability of teachers to appropriately incorporate it into the classroom is highly variable. It should be warned that technology can be seductive—it needs to be the medium, not the message, in a successful teaching–learning environment.
- *Sustained interaction between teachers and scientists*—A successful program does not stop at the end of an instructional workshop; it only begins. Continued communication (e.g., newsletters, facsimiles, e-mail, annual training sessions) between teachers and scientists cements the partnership by continuing the teaching–learning process.

TABLE 1. Historical perspective of precollege education programs in the atmospheric and oceanic sciences. Names in parentheses are directors of the respective educational programs.

1960	Establishment of the Education Program of the AMS, including formation of the Board for Meteorological Education in Schools
1970	Board for School and Popular Meteorological and Oceanographic Education
1975	Use of the Media for Meteorological Education (I. W. Geer)
1976	Speaker’s Bureau of the Miami, FL, local AMS Chapter (H. A. Friedman)
1979	Use of NOAA Weather Radio to Increase Weather Awareness (I. W. Geer)
1980	For Spacious Skies (J. Borden)
1982	District Eleven Weather Station Program (S. J. Richards)
1984	First International Conference on School and Popular Meteorological Education (Oxford, United Kingdom) Weather: Sensing, Analyzing and Forecasting (I. W. Geer and R. S. Weinbeck)
1985	KSAM (K–6 Science and Mathematics) (E. L. Kern and E. C. Stoevers) National Student Weather Experiment (H. M. Mogil and A. Livermore)
1987	Everyday Weather Project (I. W. Geer and R. S. Weinbeck) Atmospheric Science Education Program (G. H. Krockover, D. R. Smith, and J. T. Snow)
1988	West Chester University Satellites and Education Conference (N. McIntyre)
1989	Second International Conference on School and Popular Meteorological and Oceanographic Education (Crystal City, VA)
1990	AMS Council approves and funds K–12 educational initiatives
1991	NSF funding of Project ATMOSPHERE

TABLE 2. 1993 UCAR survey of member institutions summary sheet.

	No. included	Avg years since first degree	Actual				Annualized	
			Avg monthly salary	Std dev	Avg annual salary ^a	Std dev	Avg annual salary ^b	Std dev
Atmospheric								
Professor	256	29.3	\$7,597	1,970	\$80,074	20,946	\$89,877	23,283
Associate	108	19.3	\$5,230	1,102	\$56,189	13,070	\$61,716	13,213
Assistant	89	11.4	\$4,196	891	\$45,092	9,701	\$49,403	11,023
Research assoc.	108	12.3	\$3,158	930	\$36,867	12,376	\$37,845	11,059
Oceanic								
Professor	145	28.8	\$7,144	2,086	\$80,274	19,970	\$85,112	25,126
Associate	121	19.0	\$5,211	1,120	\$60,226	12,477	\$61,981	13,371
Assistant	61	12.7	\$3,940	458	\$45,974	5,883	\$46,822	5,601
Research assoc.	84	20.3	\$4,325	2,653	\$50,846	28,782	\$51,201	29,220

^aBased on actual number of months worked.^bBased on number of months permitted to work by institution.

7. Reports from funding agencies

Representatives from funding agencies provided an outlook on university funding from their agencies. Two reports are summarized in this section.

a. National Science Foundation

R. Greenfield, director of the Atmospheric Science Division (ATM), discussed funding from the National Science Foundation (NSF). Greenfield reviewed the requested budget and compared it with the appropriated budget. Questions were raised about strategic program labels used by the ATM, in particular the designation of significant parts of NCAR's base program as parts of the United States Weather Research Program (USWRP). Greenfield said that this was done throughout ATM, as a response to pressures on the NSF to show resource commitment to strategic research areas.

b. Office of Naval Research

S. Payne, acting superintendent for the Marine Meteorology Division of the Naval Research Laboratory, presented an overview of the Office of Naval Research (ONR). His presentation included a descrip-

tion of the programs and the structure of the ONR. In addition, he emphasized the ONR focus on vertical integration, which he described as the transition of research from sponsored universities into the navy's applied research activities and, eventually, into operations.

8. UCAR survey

M. Weaver, manager of human resources for UCAR, described the results of the UCAR annual survey of salaries in UCAR-member universities. The survey has been conducted annually since 1987 and has included 43 responses this year. This year (actually conducted in 1993 and based on 1992 salary data), the salaries were all annualized to the maximum number of months allowed by the institution rather than uniformly to 12 months. The results of the annual survey are presented in Table 2.

9. NWS modernization

S. Zevin, deputy director of the National Weather Service, presented the group with an update on the

NWS modernization. The deployment of the WSR-88D Doppler radars is going extremely well, and the new data are rapidly being integrated into operations. The Automated Surface Observation System program is also going well, although it is more controversial. It was emphasized that there will be a natural transition from dependence on observer data to that collected from instruments. Zevin was unable to answer questions about the Advanced Weather Interactive Processing System program but provided interesting insight into the NWS training program. The NWS is currently providing approximately 340 000 person hours of training per year, a number that is expected to decrease only modestly to 240 000 per year by the end of the century.

The audience was particularly interested in staffing plans and university support for the next several years. The support for university and NWS interactions is approximately \$8 million per year, not including the cost for 12 offices collocated with university atmospheric science departments, which may also represent \$8–10 million. Because of current limits on hiring, it appears that there will be few new meteorologists at the NWS for the next one to two years. Hiring after 1997 or 1998 is expected to average 100 meteorologists a year to replace those employees lost through attrition.

10. Workshop on mesoscale meteorology instruction

P. Smith reported on the Unidata/COMET Workshop on Mesoscale Meteorology Instruction held 13–17 June 1994 in Boulder, Colorado. The workshop focused on the teaching of mesoscale meteorology in the age of the modernized National Weather Service. The principal objective was to assess the need for changes in the university community if students are to learn mesoscale and synoptic-scale meteorology effectively. Leading scientists were invited to share their ideas for integrating new data, new mesoscale numerical models, and new conceptual models of the atmosphere into the classroom. The results of the workshop included a model mesoscale

meteorology course that faculty can use to design classes at their home institution. A more complete description of the workshop is presented in Ramamurthy et al. (1995).

11. Resolutions

The heads and chairs traditionally pass resolutions that express their views on various issues. During their ninth biennial meeting, the following resolutions were passed unanimously.

- 1) The Heads and Chairs of Atmospheric Science Departments commend the committee drafting the AMS statement “The Bachelor’s Degree in Atmospheric Science or Meteorology” for their efforts: P. J. Smith (chair), E. A. Pani, J. Zabrausky Jr., and S. Businger.
- 2) The Heads and Chairs of Atmospheric Science Departments endorse the proposed AMS statement “The Bachelor’s Degree in Atmospheric Science or Meteorology” and strongly recommend the approval of this statement by the AMS Council.

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meeting summary

Summary of the 14th Conference on Weather Analysis and Forecasting

Tim Crum* and Gary Carter⁺

1. Introduction

The 14th Conference on Weather Analysis and Forecasting was held in conjunction with the 75th Annual Meeting of the American Meteorological Society (AMS) in Dallas, Texas, on 16–20 January 1995. The primary emphasis of this conference was on the dramatic progress in operational weather analysis and forecasting during the past 75 years, with a view toward further advances during the next 25 years. Well-known and highly respected experts were invited to make the opening and closing presentations in sessions focused on the following themes: operational weather analysis and forecasting, methodology, products, and service; the impact of numerical weather prediction and data assimilation as related to operational weather analysis and forecasting; and the impact of sophisticated remote sensor technology on weather analysis and forecasting. The opening presentations reviewed the progress that our profession has made throughout the history of the AMS, while the invited closing presentations focused on the progress that is possible in these areas as the AMS moves toward its 100th anniversary.

The conference provided an opportunity for forecasters and applied researchers to present case studies and “lessons learned” using new technology, theories, and tools in analyzing and forecasting a wide range of weather phenomena. Sharing these case studies and insights was intended to facilitate the optimum

use of information from the new technology, scientific theory, and enhanced observational systems. The conference supported interaction with other disciplines to discuss issues that are of considerable concern to weather forecasters. The joint session with the Conference on Hydrology highlighted the role of weather analysis and forecasting in the prediction of significant hydrometeorological events, with an emphasis on the meteorological conditions that preceded and caused the disastrous flooding of 1993 in the central United States. The intent of the joint session with the 24th Conference on Broadcast Meteorology was to keep this important segment of the profession informed of new activities in weather analysis and forecasting and to illustrate how forecast offices are striving to get warning information into the hands of the media and public more quickly and accurately. The joint session with the Ninth Conference on Applied Climatology served as a forum for considering the value and utility of forecasts produced by operational meteorologists. A lively panel session with the heads of the major U.S. government meteorological centers (the National Centers for Environmental Prediction, Air Force Global Weather Central, and Naval Oceanographic Office) on civilian/military cooperation culminated the conference. The session provided a look back and a look ahead at how these important components of our nation’s weather services intend to produce better and more cost-effective products and services.

2. Session summaries

a. Operational analysis and forecasting:

Methodology, products, and service

(chairperson: G. Carter, NWS Eastern Region Headquarters, Bohemia, New York)

The conference began with the keynote presentation by L. Uccellini, who provided a fascinating re-

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view of the dramatic advances made in the operational prediction of rapid cyclogenesis during the past 40 years. He illustrated how the forecast process has evolved from one of observations and subjective, experience-based forecasting to a “forecaster–machine” mix that today makes use of the following: more extensive global observations, expanded model-based data assimilation systems, application of global and regional numerical models, extensive model output statistics and national guidance products, coordination and production of local forecasts, and outreach/coordination with a diverse “user community.” This review indicated that tremendous advances have been made in forecasting rapid cyclogenesis as measured by the increasing skill level, especially in the 1- to 4-day range, and the extension of “useful predictions” of major cyclone events out to 5 days in advance, even over data-void regions. The breakthrough in predicting rapid cyclogenesis is related to the introduction of model-based analysis and initialization schemes, the utilization of the full-resolution primitive-equation numerical models as a basis for weather forecasting, and the increasing skill and confidence of forecasters who work with the models and interpret nonlinear interactions that lead to specific severe weather events. An important result of these advancements is an increase in accuracy of the *watches and warnings* issued for winter storms with lead times now approaching 2 days!

Following the keynote address, P. Hobbs et al. presented an animated video depicting a new conceptual model for winter storms in the central United States. The model accounts for the role of the Rocky Mountains in the modification of cyclogenesis and the structure of cyclones in this region. R. Brintjes and G. Thompson discussed a case study of a freezing drizzle event over Colorado and Nebraska during the Winter Storms and Icing Program (WISP), which was characterized by a frontal surge with an upslope stratiform cloud developing behind it. This case was used to evaluate a new, four-class freezing drizzle diagnostic scheme, which is part of the icing algorithm developed by the Research Applications Program at the National Center for Atmospheric Research (NCAR). L. Bosart et al. reviewed the antecedent conditions associated with the 12–14 March 1993 “Storm of the Century” over eastern North America. This so-called superstorm was induced by the amalgamation of two potential vorticity anomalies over the southeastern United States and adjacent northern Gulf of Mexico. M. Dickinson et al. analyzed the performance of the National Oceanic and Atmospheric Administration/

National Weather Service (NOAA/NWS) and the National Centers for Environmental Prediction’s (NCEP, formerly known as the National Meteorological Center) dynamical model guidance during the 1993 Storm of the Century. The largest model forecast cyclone central pressure errors occurred during incipient cyclogenesis when convection was especially widespread and prominent near the cyclone center. These large forecast errors were in sharp contrast to the excellent model guidance during the latter stages of the storm life cycle.

b. Operational analysis and forecasting:

Methodology, products, and service—Focus on the future (chairperson: W. Junker, NCEP, Camp Springs, Maryland)

There were six presentations in this session, which focused on forecast techniques under research and development and case study results that may have operational application. P. Janish et al. discussed results of what has been learned from experiences at four experimental forecast facilities (EFFs). These EFFs were established to help create and enhance working relationships among forecasters, researchers, and university faculty and students in quasi-operational settings. The EFFs implement, test, and transfer applied research and new technology within the forecasting environment. C. Doswell et al. outlined the goals of the Verification of the Origins of Rotation in Tornadoes Experiment project and discussed some of the challenges that arose during the field project. Some phenomena (i.e., the complex structure and evolution of a dryline) were observed in great detail for the first time during the project. T. Dulong outlined the products and procedures used by forecasters at the Denver Weather Service Forecast Office (WSFO) for predicting heavy rainfall and severe weather events during the 1994 warm season. Forecasters used a functional prototype of the Advanced Weather Interactive Processing System (AWIPS) workstation as their primary source of data during the experiment. F. Glass et al. discussed findings from a study of eight cases of heavy convective rainfall during the warm season across the middle Mississippi Valley. Forecasters can use a conceptual model of atmospheric stability and the advection of temperature and moisture to predict the location of a heavy convective rainfall event. K. Liu et al. presented a case study of a frontal system that produced thunderstorms in Taiwan on 19 March 1994. Forecasters using the quasigeostrophic theory did a good job of describing the area of upward motion

along the front, with strong frontogenesis located over the Taiwan Strait. Conditional symmetric instability (CSI) was found along an area where one of the heavy rainbands was located. R. Livingston and J. Schaefer discussed the passage of a fast-moving cold front through the Wind Profiler Demonstration Network (WPDN). A strong case was made that synoptic-scale conceptual models of frontal circulations should be used judiciously in attempting to explain future weather.

M. Fritsch closed the session with a thought-provoking invited talk, which stimulated a great deal of discussion. He reviewed the anticipated changes that are, and will be, taking place in operational meteorology. He predicted that many forecast problems are likely to be solved as the resolution of dynamical models increases and as the physics in these models becomes more precise. Furthermore, the combination of more sophisticated models and better statistical output will make it difficult for forecasters to predict the weather better than the guidance. He argued that the rapid advances in numerical weather prediction, and in the dissemination of products via electronic communications, would eventually change the role of the forecaster. He also speculated that future forecasts would become so detailed that it would be impossible for forecasters to modify the guidance and then disseminate the information to the public. Hence, the role of the operational meteorologist might become similar to that of a commercial airline pilot, who makes use of extensive training and experience to carefully monitor a sophisticated array of electronic, computer-based equipment and controls, with manual intervention only when necessary.

*c. Operational analysis and forecasting:
Methodology, products, and service—Poster
session (chairperson: G. Byrd, Cooperative
Program for Operational Meteorology,
Education, and Training, Boulder, Colorado)*

Posters in this session presented several diagnostic studies and forecasting applications related to a variety of synoptic- and mesoscale disturbances. Three papers focused on the East Coast “Blizzard of 1993.” M. Jones et al. documented the explosive cyclogenesis associated with the event. As in past “bombs,” there was a strong baroclinic environment accompanied by substantial low-level convergence, upper-level divergence, low-level positive vorticity, upper-level positive vorticity advection, heat and moisture advection, and convection. In a companion

paper, C. Holiway and D. Smith discussed the role of a tropopause undulation in the intensification of a cyclone. A warm pool within a trough at 200–300 mb deepened and followed the track of the developing surface cyclone from the Gulf of Mexico up the eastern seaboard. W. Bracken et al. presented a study of synoptic- and mesoscale aspects of the Tehuantepecer (cold-air outbreaks characterized by strong, gusty, north winds that penetrate into the Gulf of Tehuantepec) associated with the early stages of the storm. Despite the mesoscale nature of the disturbance, the European Centre for Medium-Range Weather Forecasts (ECMWF) initialization showed some success at capturing the cold air surge.

Climatological studies of snowstorms were the topic of two papers. B. Lambert and R. Peterson developed a climatology of heavy snow events in west Texas and eastern New Mexico. Over 90% of the heavy snow events were associated with a split-flow pattern at 500 mb, and heaviest snowfalls (> 25 cm) almost always occurred when accompanied by a closed-contour 500-mb low. E. Tollerud and J. Mahoney composited meteorological fields to identify differences between Denver and Colorado Springs snowstorms. Analysis of precipitation patterns reveals that Denver snowstorms tend to have snowfall concentrated on the eastern Colorado High Plains, whereas Colorado Springs storms exhibit snowfall concentrated near and to the west of the Front Range.

Three papers discussed aspects of drylines in the Southern Plains. J. Waters and R. Peterson presented a synoptic climatology of the springtime dryline over the southern High Plains. Over three-quarters of April dryline occurrences were observed with a surface front or trough and southwesterly flow aloft, with even more prevalence of drylines accompanied by southwesterly flow aloft in May and June. H. Brooks et al. showed observations of the complex structure of an Oklahoma dryline on 14 April 1994. Although deep convection did not develop, a unique set of mesonet, special sounding, and the Weather Surveillance Radar-1988 Doppler (WSR-88D) data showed a convoluted structure with wavelike corrugations on scales of tens of kilometers, which persisted for several minutes. T. Clark and R. Peterson documented the evolution of the elevated mixed layer associated with the Lubbock tornado of 1970. Generally, the environmental profile agreed with the conceptual model, with a lid forming in response to advection of a deep mixed layer from Mexico over warm moist air from the Gulf of Mexico.

Forecast methodology was the topic of several papers. R. Leffler and W. McGovern presented a methodology that makes use of climatological cooperative observer data to produce daily maximum and minimum temperature adjustments to complement model output statistics (MOS) guidance for use in NWS zone forecasts. This technique has the potential to improve county-level temperature forecasts. F. Norte and M. Silvea showed a method for predicting the severity of the zonda wind of Argentina, a warm, dry downslope flow similar to the chinook wind in the United States. A stepwise discriminant analysis technique has been employed that predicts intensity up to 24 h in advance with a high degree of success. P. Kucera and W. Roberts discussed warm season product usage patterns from the Denver AWIPS-90 Risk Reduction and Requirements Evaluation and pre-AWIPS workstations at the WSFOs in Denver and Norman. Doppler radar products and vertical and plan views of profiler data were found to be widely used. High-resolution output from the Local Analysis and Prediction System (LAPS) and the Mesoscale Analysis and Prediction System (MAPS) were also used, and the Norman WSFO made extensive use of Oklahoma mesonet data. M. Mach examined multiple-county warnings issued by the Fort Worth WSFO and their impact on the false alarm rate (FAR). The FAR was reduced when multiple-county warnings were minimized in favor of warnings on an individual county basis and when ground truth and spotter information was incorporated into the decision-making process. P. Nurmi discussed operational real-time forecast verification and its impacts on forecast quality in Finland. The purpose of this verification is to provide more immediate feedback on operational forecasts and model output and improve the forecasts.

M. Bedrick and L. Bosart discussed the characteristics of midlevel cutoff vortices observed during STORM-FEST. Analyses of two case studies reveal that deformation plays a substantial role in vortex formation and that dissipation occurs when the vortices migrate over a region of unstable air near the surface. G. Dismukes and S. Colucci analyzed the severe ice storm that struck western and central New York on 3–4 March 1991. The heavy icing resulted from frozen precipitation falling into and melting in an advectively warmed layer prior to refreezing upon contact with the surface. S. Fano and R. Peterson developed an extensive climatology of cold frontal passages across the High Plains of Texas. During a 10-yr period, two-thirds of all cold frontal passages occurred between

1900 and 0600 LT, suggesting an important diurnal influence. G. Mathews and R. Peterson presented a study of the relationship between temperature and precipitation patterns and low-level isentropic surfaces over the United States during the month of April. This analysis revealed the important role that derived quantities such as vorticity played in determining pattern anomalies. P. Pauley et al. presented an analysis of the “I5” California dust storm of 1991, which caused a series of chain reaction collisions that resulted in 17 deaths. It appears that strong synoptic subsidence led to a downward transport of momentum along the eastern edge of an upper-level jet stream, resulting in the high winds and blowing dust that impacted the San Joaquin Valley. J. Wegiel and K. Kloessel examined the role of the Atlantic subtropical anticyclone in a rapid stratocumulus clearing episode that occurred during the Atlantic Stratocumulus Transition Experiment project. Subsidence associated with the anticyclone, combined with the advection of dry continental air, appeared to have combined to strengthen and lower the subtropical inversion that led to the dramatic clearing. J. Locatelli et al. studied the structure and evolution of a major winter cyclone over the central United States. This was accomplished using a series of three-dimensional visualizations that appear to be an excellent method by which to diagnose storm characteristics.

Two posters dealt with the application of conceptual models to operational forecast situations. P. Smith and D. Rolfson used a generalization of the Peterssen–Sutcliffe equation known as the Zwack–Okossi equation to diagnose development of 12 extratropical cyclones. The diagnosis showed the importance of upper-tropospheric/lower-stratospheric warm air advection and cyclonic vorticity advection in cyclone development. D. Schultz et al. examined the effect of large-scale flow on low-level frontal structure and its applications to conceptual models of cyclone evolution. Cases that conform to the Shapiro–Keyser conceptual model are associated with confluent flow in a jet entrance region, while cases conforming to the Norwegian cyclone model tend to be associated with diffluent flow in the exit region of a jet.

d. New products and services—Joint session with 24th Conference on Broadcast Meteorology (cochairs: J. D’Aleo, WSI Corporation, Billerica, Massachusetts, and D. Tyler, WITI-TV, Milwaukee, Wisconsin)

This session began with four presentations that outlined NWS efforts to improve severe weather

warning accuracy and dissemination. W. Alexander described plans to shift the severe local storm watch function from the NOAA/NWS National Severe Storms Forecast Center to WSFOs and to change the format of the watch area from a "box" to a county-based watch product. These changes will allow for greater space and time resolution of watch areas. The new NWS Storm Prediction Center will support WSFOs with graphical probabilistic guidance. P. Sirartka and T. Mefferd described the combined efforts of the NWS, College of DuPage, and DuPage County to develop the Multi-County Severe Weather Warning System. Its purpose was to first increase preparedness for the onset of severe weather and then implement a communications backbone to provide rapid information transfer between the NWS and the communities affected. M. Foster et al. described how the 25 April 1994 outbreak of tornadoes in the Dallas/Fort Worth area provided an opportunity to test operationally the WSFO staffing plans and the effectiveness of the three WSR-88Ds in the affected region. The WSR-88D products enabled early detection of the severe weather. R. Thompson et al. described the well-warned tornado outbreak of 16 November 1993 in the Houston area. As the storm evolved, the forecasters in Houston used the WSR-88D displays together with information from spotter networks to monitor the storms, provide nowcasts, and issue timely warnings.

The session closed with two presentations on research of weather phenomena of high interest to the public. R. Holle and A. Watson presented an analysis of two winter storm situations in which lightning was reported. In winter storms, echo tops may be a more reliable tool for finding thunderstorms than radar reflectivity values. The combination of lightning with echo tops appears to be useful for identifying winter weather hazards (e.g., ice potential) for downstream regions. K. Hubbard et al. explained how national Water Needs Forecasts are generated by the NOAA/NWS Regional Climate Centers to provide guidance for optimal use of water for irrigation of lawns and crops. The forecasts are generated with input from the NGM-based statistical guidance.

e. Impacts of numerical weather prediction and improved data assimilation, data processing, and communications on operational weather analysis and forecasting (chairperson: M. Ramamurthy, University of Illinois, Urbana, Illinois)

The session opened with an invited review talk by W. Bonner on the progress made in the field of nu-

merical weather prediction in the 1970s and 1980s. He particularly emphasized the positive nature of the extensive collaborations between operational NWP centers around the world in tackling important NWP scientific problems. He made specific mention of advances in the areas of objective analysis, model initialization, and four-dimensional data assimilation. He showed several examples of the steady increase in the skill of operational forecasts during the two decades on timescales ranging from 2 to 10 days and highlighted the remarkable advances in the speed and memory of computers that became available for operational prediction and research. However, he cautioned that there has been little improvement in the skill of precipitation forecasts.

The next five presentations dealt with the utility of numerical models to improve forecasts of various weather phenomena. T. Black and M. Baldwin described the winter forecast characteristics of the NCEP mesoscale eta model, a 29-km by 50-layer version of the operational eta model (80 km by 38 layer). The model forecasts of a typical East Coast cold air damming and freezing rain event from January 1994 show the benefit of higher model resolution in both the horizontal and in the vertical. E. Rogers et al. presented details of the Eta Data Assimilation System (EDAS) for the NCEP mesoscale eta model. Results of a case from February 1994 demonstrated that the new EDAS was able to resolve features that were either poorly recreated or absent in previous operational analyses. Y. Lin et al. studied the impact of satellite moisture observations on forecasts made by the eta model. The Special Sensor Microwave Imager (SSM/I) moisture information in the eta model's initial moisture analysis was combined with the first-guess moisture field provided by the global model. The SSM/I data made a small, but positive, impact on the initial analysis, as well as in the short-range forecast of precipitation. P. Dallavalle et al. described the statistical weather forecast systems based on the Aviation and Medium-Range Forecast (MRF) runs of the NCEP Global Spectral Model. In general, the operational forecasts produced by the MRF-based system are reliable and skillful throughout the 192-h forecast period. However, the level of skill varies depending on the season and location. J. Cortinas and C. Crisp examined the use of The Pennsylvania State University (PSU)/NCAR mesoscale model (MM4) in a short-lived freezing rain event that occurred on 10 January 1994. The increased resolution used in the MM4 forecasts enabled them to more accurately ana-

lyze small subtleties in the thermodynamic structure and temporal evolution of precipitation. The session concluded with a case study by T. Funk et al. of different forcing mechanisms responsible for the heavy snowstorm that occurred across northern Kentucky on 16–17 January 1994.

f. Impacts of numerical weather prediction and improved data assimilation, data processing, and communications on operational weather analysis and forecasting (chairperson: S. Colucci, Cornell University, Ithaca, New York)

Nineteen posters were presented in this session. Nine of these were concerned with aspects of weather analysis: in 4 of these, the authors used numerical model output to diagnose atmospheric phenomena. G. Byrd et al. described numerical experiments with the State University of New York College at Oswego model related to the impact of the Great Lakes on lake-effect snowfall. Removal of upstream lakes in the experiments produced an enhanced model response to cold air flow over downstream lakes. R. Igau and J. Nielsen-Gammon reported on the simulation of a Gulf Coast return flow event by the PSU/NCAR mesoscale model. Three distinct low-level jets were simulated by the model during the event. D. McCann used eta model analyses to calculate horizontal fields of equivalent potential vorticity. These fields can supplement vertical cross sections in the evaluation of CSI. G. Peng and C. Mooers applied the Advanced Regional Prediction System (ARPS) to the study of the south Florida sea breeze. The structure of the simulated sea breeze was found to be sensitive to the coastline configuration, the presence of Lake Okeechobee, and model resolution.

In three posters, authors used PC-GRIDDS to analyze events. A. Czarnetzki reported on a PC-GRIDDS analysis of a heavy snowfall event over Iowa. Much of the precipitation was convective in nature, possibly due to CSI. R. Kleyla presented PC-GRIDDS analyses of NGM output during a freezing rain event over Texas. The analyses revealed substantial isentropic uplift in the precipitation area. Finally, T. Shea and R. Przybylinski used PC-GRIDDS to analyze eta model output during a midwestern snowstorm. The analyses revealed that the circulations associated with interacting jet systems produced the heavy snow but limited its northern extent.

Ten posters in this session were directly concerned with weather prediction. M. Antolik evaluated the quantitative precipitation guidance from NGM-based

model output statistics. An improvement of this guidance over the raw NGM gridpoint precipitation forecasts was noted. In a related poster, J. Settlermaier discussed the conditional probability of frozen precipitation forecasts generated, in model output statistics fashion, from the NGM and MRF model. The forecasts are skillful relative to climatology but require careful interpretation by forecasters. E. Berry demonstrated the use of Hovmöller (longitude–time) diagrams in medium-range forecasting. Hovmöller diagrams of planetary-scale MRFs and analyzed 500-mb height eddies (departures from zonal averages) in selected latitude bands could assist medium-range forecasters. S. Beckman and K. Polston compared winds predicted by MAPS to those observed by profilers. General agreement was found, although winds speeds were underpredicted in low-level jet cases. W. Browning and M. Foster showed how NGM-gridded output could be used to predict regions of CSI. The method was applied to a case of a freezing rain storm over Texas. L. Loboeki and C. Peters evaluated eta model predictions of boundary-layer structure during a cold air outbreak/return flow event over the Gulf of Mexico. The model boundary layer was too dry, too cold, and too shallow relative to observations in this case. P. Janish et al. described an experiment in real-time prediction of severe thunderstorms using ARPS. The system was capable of predicting several types of severe storms with, in most cases, adequate lead time. A similar experiment was described by J. Scala et al., who applied the Goddard Cumulus Ensemble model to real-time prediction of thunderstorms over North Dakota. A favorable comparison between observed and model-predicted fields was reported in one thunderstorm case. M. Roch et al. described the implementation of a new variable resolution, nested model prediction system by the Canadian Meteorological Center. Tests of the system suggest that it could achieve results comparable to those of a single, high-resolution, but computationally more expensive, global mode. W. Wehry presented a nowcasting scheme used in Germany. The system uses fine-mesh model output as guidance, which is compared hourly to observations for forecast updates as necessary.

S. Nelson et al. demonstrated the Application Visualization System (AVS) for graphic interpretation of weather data. The system allows three- and four-dimensional visualizations of atmospheric phenomena. Finally, in the theme of weather analysis, A. Cristaldi and S. Colucci documented the mesoscale

and synoptic-scale structure of a rare late season severe weather event over the northeastern United States. Warm air advection was proposed to have contributed greatly to the destabilization of the environment and the resultant ascending motion.

g. Remote sensing impacts on operational analysis and forecasting (chairperson: T. Crum, WSR-88D Operational Support Facility, Norman, Oklahoma)

The invited presentation for this session by J. Purdom provided a number of examples of how data from satellites have had a major impact on operational weather forecasting. Today's polar-orbiting satellites provide routine sounding and imagery information ranging from tenths of microns to microwave wavelengths. Geostationary satellites have played a critical role in NWS operations by providing unique information on emerging storms and storm systems for two decades. Examples were used to show how the new *GOES-8* represents a major advancement in operational geostationary capability, allowing for a number of exciting imager products as well as independent operational soundings from geostationary orbit for the first time. System evolution, training, and integration with other new technologies were recognized as the major challenges for the next decade.

The next four presentations summarized work to incorporate Geostationary Operational Environmental Satellite (*GOES*) data into numerical models. C. Velden discussed algorithms used at the Cooperative Institute for Meteorological Satellite Studies to extract quantitative wind information from geostationary satellite water vapor data. Full-disk wind sets have been derived from two geostationary satellites and delivered to the NCEP and ECMWF for assimilation into research versions of their global assimilation systems. J. Smart and D. Birkenheuer presented an investigation of the quantitative use of *GOES-7* AWIPS-formatted satellite data (ASD) for objective analysis and NWP. The ASD data will be much improved with *GOES-8*, as both the visible and IR imagery will have much greater precision than the *GOES-7* data. R. Bankert and D. Aha summarized a portion of the Satellite Image Analysis System automated cloud pattern identification being developed at the Naval Research Laboratory. Pattern attributes (shape, size, textures, etc.) are computed and presented to the identifier. P. Hirschberg et al. reported the results of a climatological study that quantitatively evaluated the utility of the 54.96-GHz microwave sounding unit

(MSU) brightness temperature data in nowcasting and forecasting baroclinic waves. A statistical comparison of horizontal analyses and time series of MSU brightness temperatures to horizontal analyses, and time series of various conventionally derived fields, indicated that the MSU analysis can be used to reliably track baroclinic waves over conventional data-sparse regions such as the ocean basins.

The final two presentations dealt with the use of radar and lightning detection data to forecast tornadoes. M. Foster et al. reported on radar observations of a tornado that occurred on 19 February 1994 within 20 miles of the Dyess Air Force Base, Texas, WSR-88D system. While the supercell displayed some of the radar characteristics of a high-precipitation supercell, the storm top at no time exceeded about 9 km, and the storm diameter was on the order of 5 km. Successful detection of the evolution of a supercell in real time was possible because detailed observations of midlevel (3–4 km) storm-relative velocities and reflectivities revealed the rapid development of a bounded weak echo region and mesocyclone. W. Carle described a study of the cloud-to-ground (CG) flash-rate tendencies for total, positive, and negative lightning for 20 F3 and F4 cases. The average lag time between a peak in the 5-min CG flash rate and the tornado touchdown was approximately 6 min. No polarity reversals coincident with the tornado touchdown were observed.

h. Remote sensing impacts on operational analysis and forecasting—Focus on the future (chairperson: R. Bensinger, U.S. Air Force, Seoul, South Korea)

Six presentations in this session focused on how data from remote sensors are being applied to operational forecast and warning operations. L. Quetone and K. Huckabee presented a look at the severe weather warning process, especially as it relates to the addition of the WSR-88D in the modernized WSFO. The issues included event anticipation; quickly assimilating, digesting, and prioritizing information; spotter reports; product selection; feature recognition; warning generation; and nonmeteorological factors such as staff experience, equipment problems, and human factors. They also presented a warning methodology to help lead the forecaster to a logical warning decision and ways of preparing staff and resources for optimum performance during an event. J. Gyakum et al. looked at two significant weather events by using an instrumented research aircraft, a boundary-

layer wind profiler, a ground-based temperature sounder, and a laser ceilometer. They showed how the radio acoustic sounding system data can be used to add to the understanding of weather phenomena and detect low-level jet features that conventional rawinsondes do not always detect. R. Przybylinski et al. presented a look at a June 1993 case of a northeastward moving line of severe storms that passed over several remote sensing sites, including the WSR-88D and a wind profiler. The eta and NGM-gridded fields were used to assess the synoptic and mesoalpha vertical motion fields. Midaltitude convergence and vertically integrated liquid (VIL) values exhibited encouraging results as predictors.

E. Thaler examined snowbands in northeast Colorado. He used potential vorticity and quasigeostrophic arguments to show large-scale ascent over the area. MAPS, now the Rapid Update Cycle, did an excellent job of predicting the movement of areas of CSI up to 6 h in advance. Forecasters could predict CSI and banded precipitation structures several hours before their occurrence. P. Ruscher et al. used the Melbourne WSR-88D to look at an interaction between the East Coast sea-breeze front with a ring outflow boundary over east central Florida. Complementary data for the case included *GOES-7* visible satellite imagery and Kennedy Space Center (KSC) mesonet data with objectively analyzed convergence/divergence at 5-min intervals. S. Smith et al. looked at a variety of datasets to analyze tornadic storms that occurred during the 26 April 1991 Oklahoma–Kansas–Nebraska tornadic outbreak. They studied updraft intensity by looking at *GOES-7* infrared pixels colder than -40°C on the anvil. VIL was used as a measure of radar-based storm intensity. Finally, CG lightning activity and polarity were analyzed.

The invited speaker for this session, R. Carbone, presented a thoroughly entertaining and insightful look at the future of remote sensing. In an era apparently characterized by too much data, and sometimes confusion on how to apply the data, he discussed several near-term needs and opportunities in atmospheric observations as applied to weather analysis and forecasting. He defined the primary needs as filling the oceanic void, determining water vapor distribution, precipitation estimation, land surface fluxes, metropolitan-area airflow and precipitation, and cold cloud water. He presented the associated technological and technique development opportunities as adding bistatic Doppler and polarimetric evolutions of the WSR-88D system for urban-area airflow and nation-

wide quantitative precipitation estimation; adding constituent measuring and Doppler lidars for water vapor and ozone profiles and fluxes; using commercial and/or pilotless aircraft for adaptive sampling at the mesoscale and for mitigation of the oceanic void; close coupling of radar, surface, and profiler data with mesoscale models and their adjoints to provide very detailed short-term forecasts of convection; exploring the Global Positioning Systems to fill the water vapor estimation gap globally; and increasing operational use of highly mobile and adaptive sampling techniques as guided by models.

i. Remote sensing impacts on operational analysis and forecasting (chairperson: H. Brooks, National Severe Storms Laboratory, Norman, Oklahoma)

The session featured 22 posters, covering a wide range of sensors and weather phenomena. R. Clements and K. Kloesel investigated a central Texas flash flood event by using a variety of hydrological instruments, including lake level, stream flow, rain gauge observations, and radar. By combining these datasets, they were able to make the connection between the heavy precipitation and flooding events.

Five presentations focused on applications of the WSR-88D that make it a powerful tool in the operational warning and forecasting environment. T. Smith demonstrated three-dimensional visualization of radar data using AVS. He showed a microburst case in which the 3D technique made detection much easier. B. Choy and S. Spratt described the use of the WSR-88D in forecasting waterspouts. The WSR-88D has proven especially useful in detecting important boundaries and initial cell development, allowing for timely warnings. D. Young illustrated the detection of a ducted gravity wave by using the WSR-88D. The detection allowed for better short-term forecasts of significant weather associated with the passage of the wave. R. Turner discussed the advantages and disadvantages of using the WSR-88D mid- and high-level layer composite reflectivity maximum (LRM) products to investigate potentially severe thunderstorms. In a case presented, the LRM product increased the lead time for a severe thunderstorm when compared to the VIL graphic. J. Korotky et al. presented a case study of severe convective winds associated with Tropical Storm Alberto. The Doppler velocity data indicated isolated regions of strong winds descending toward the surface within rainbands, permitting severe thunderstorm warnings to be issued.

Extensive use of satellite-derived data was the focus of four posters. H. Guerrero and W. Wong gave examples of the use of water vapor imagery in thunderstorm forecasting. In conjunction with NWP model output, the satellite view allowed the forecasters the opportunity to monitor the temporal evolution of features such as jets that were significant in creating an environment favorable to severe convection. D. Casey et al. combined satellite observations with a simple numerical model for forecasting mesoscale convection. While the overall forecast and observed patterns looked similar and appeared to have qualitative value, pixel by pixel correlation explained only about 27% of the variance in the data. D. Prosis and A. Schwartz analyzed the Braer Supercyclone in the North Atlantic, a storm that deepened 73 mb in 24 h. Given the data sparsity over the oceans, the use of satellite-based analysis to estimate parameters of oceanic bombs is particularly important to maritime interests. G. Thompson et al. compared SSM/I-derived estimates of integrated water vapor with numerical model predictions of integrated liquid water during WISP-94. Preliminary results indicate that the inclusion of the satellite data can improve model forecasts by providing important information on moisture fields where surface-based observations are sparse.

Two other papers also focused on cases from WISP-94. B. Bernstein et al. carried out an investigation of a mixed winter precipitation and aircraft icing incident. By including Doppler radar, microwave radiometers, aircraft, rawinsonde, and surface mesonet observations in a detailed mesoscale analysis, they were able to deduce the changes in precipitation type associated with the interaction of the larger-scale system with the topography. J. Marwitz and T. Damiana coupled observations from the University of Wyoming King Air research aircraft with polarized Doppler radar data during a blizzard in Oklahoma in 1994. The aircraft carried out a Lagrangian airborne dynamics experiment to investigate secondary circulations in conjunction with the jet structure associated with the storm system.

Doppler radar wind profiles were the subject of three presentations. S. Beckman used the WPDN 404-MHz profilers, along with surface pressure changes, in a technique to forecast the development of low-level jets. Areas of $2 \text{ hPa } 3 \text{ h}^{-1}$ isallobaric pressure falls were found to be associated with the occurrence of these jets. P. Spencer and P. Janish demonstrated the operational utility of a triangle analysis package to analyze kinematic properties of the atmosphere from

WPDN data. Computed vertical velocity, divergence, and temperature advection time sections were shown to be useful in anticipating development of weather systems. In the third profiler paper, R. Schumann et al. used a 50-MHz profiler in support of launch operations at KSC. The improved detection of wind shifts by the profilers provides an increased ability to make critical decisions for launching weather-sensitive spacecraft.

Two posters described the lightning characteristics of thunderstorms. A. Perez et al. examined the CG lightning associated with 42 violent tornadoes over the last decade. Most of the storms had a peak CG rate prior to tornadogenesis, but signatures in the CG rate and polarity were not consistent across the sample. L. Maier et al. used a 3D lightning locator to look at the total lightning, including intracloud, in Florida thunderstorms. The use of such tools to understand microphysical and electrical structures of storms has promise for helping improve forecasting of electrical activity dangerous to aircraft and spacecraft launch interests.

Large-amplitude internal-gravity waves (IGWs) were studied in two presentations. L. Koppel et al. examined hourly surface observations over a 15-yr period at a number of stations across the United States. Eliminating those IGWs associated with convective activity, there is a late winter/early spring peak in occurrence, and a geographical peak in the south-central and mid-Atlantic states. In a companion poster, A. Seimon et al. examined one case of a very large amplitude (10–13 hPa) IGW from 1994 using a detailed mesoanalysis including wind profiler data and WSR-88D observations. The radar data provided great detail on the 3D structure of the wave and associated changes in surface weather.

Three posters focused on programs to assist forecasters in the analysis of disparate datasets through automation. J. Passner described a program to determine weather hazards (e.g., turbulence, clouds, poor visibility) from sounding data as part of the army's Integrated Meteorological System. This system is serving as a prototype for the prediction of weather phenomena on the battlefield, when communications may limit the amount of information available to the forecaster. P. Tag and J. Peak presented an example of a machine learning technology program applied to forecasting maritime fog. The program generated a series of several rules in the form of a decision tree to forecast clear, hazy, or foggy conditions. B. Rappolt and J. Henz showed their method for using mesonet sur-

face observations to modify rawinsonde observations. The soundings, which can be generated every 5 min, can then be used for forecasting sensible weather and its gradients across small regions.

j. Hydrometeorological forecasting and hydrological processes—Joint session with Conference on Hydrology (chairperson: S. Zevin, NWS Headquarters, Silver Spring, Maryland)

J. Henz led off the session with a presentation on refining regional quantitative precipitation forecasts into a local product by analysis of predicted (via skew-*T* analysis) thunderstorm updraft characteristics. A 2-yr study using 136 ALERT rain gauges revealed that the depth of the predicted updraft warmer than 0°C appeared to be directly related to both the amount of the observed rainfall and the observed surface to the 500-mb precipitable water index. R. Schofield et al. discussed how moisture advection, moisture convergence, and surges or areas of moisture are principal ingredients for heavy precipitation and flash floods. GOES water vapor imagery has been used to monitor surges of moisture or water vapor plumes from the Tropics, often collocated with unstable air. Extremely heavy precipitation can result if the plume interacts with a lifting mechanism. J. Moore et al. discussed how supercell thunderstorms are usually noted for their ability to generate large hail, strong winds, and/or tornadoes. However, during one of the many episodes of heavy rainfall that plagued the central Midwest during the summer of 1993, high precipitation (HP) supercells formed that were not only attended by severe weather but also heavy precipitation.

Studies of flooding causes and models concluded this joint session. N. Junker et al. discussed the recurrent mesoconvective activity that resulted in the “Great Midwest Flood” of 1993. The synoptic pattern associated with the flood was unusually persistent with a mean 500-mb ridge over the eastern United States, a trough over the western United States, and a ridge just off the west coast of North America. Most of the heavy precipitation events during the summer were associated with water vapor plumes and a strong northward transport of moisture. F. Quinn et al. described a study of the sensitivity of Great Lakes hydrology and water levels to basin meteorological conditions, basin runoff, and lake thermodynamics. They used the unique climatic conditions resulting in the 1993 Mississippi River flood as input and noted a major rise in lake levels, but not as large of a rise as on the Mississippi River. D. Schwartz summarized the

flood-prone Houston urban watershed (Greens Bayou and tributaries). Basin average rainfall, determined from river stage and rain gauges, were used as input into a hydrologic model. Calibration of the model was accomplished using three case studies representing different types of meteorological and hydrologic conditions.

k. Impacts of numerical weather prediction and improved data assimilation, data processing, and communications on operational weather analysis and forecasting—Focus on the future (chairperson: R. Hutcheon, NWS Alaskan Region, Anchorage, Alaska)

This session consisted of summaries of numerical modeling and data assimilation research aimed at improved operational forecasting. M. Xue et al. described a test of ARPS with real-time data in an operational setting. The version of ARPS used for this experiment included a newly developed surface physics package that predicted the land surface properties using surface energy equations and a soil mode. This paper concentrated on several cases of the 5-km resolution forecasts and presented the results and their utility, as well as the limitations. W. Lyons et al. described how terrain-induced thunderstorms are a major forecast problem at KSC. Lightning, strong winds, and precipitation associated with storms triggered by East and West Coast sea breezes, plus small cells generated by the local circulations formed by the islands on which the KSC is located, are a major cause of work stoppages and launch delays. L. Dunn and J. Horel presented preliminary results of a cooperative project between the University of Utah Meteorology Department and the Salt Lake City WSFO on the use of a mesoscale model for daily operations. The Utah Local Area Model uses a terrain-following coordinate system with 17 vertical levels and a horizontal grid spacing of roughly 25 km. C. Mass described how during the past two years the PSU/NCAR mesoscale model has been used to simulate and study important mesoscale features of the Pacific Northwest. This effort has three goals: to show the feasibility of high-resolution modeling in a coastal region of complex terrain, to provide a detailed model dataset for improving the understanding of mesoscale features of the region, and to determine the short-term predictability of the orographic features of the Northwest.

S. Tracton and E. Berry focused upon the practical aspects of ensemble prediction, particularly the display, use, and reliability of products derived from ensembles. These products include the ensemble

mean, dispersion fields, clustering of similar forecasts, simple probability estimates, envelope of potential storm tracks, measures of circulation regime, and the potential for major weather events. S. Colucci et al. presented an evaluation of NCEP's 6–10-day temperature and precipitation outlooks at 15 locations around the United States from December 1988 through December 1991. The outlooks, overall, were more accurate than persistence forecasts. However, there is considerable variability in accuracy from one outlook to the next. This suggests that the outlooks are sensitive to the numerical forecast model accuracy, which in turn may be sensitive to atmospheric conditions at the time of model initialization.

J. McGinley concluded this session with an invited presentation that considered the opportunities for high-resolution data analysis, prediction, and production dissemination within local weather offices. An unprecedented opportunity exists to provide operational forecasters with the type of products that have enough spatial variation to fully support the requirements of zone forecasts and warnings. Rapid gains in data, fusion and analysis software, mesobeta numerical weather models, high-speed computer workstations, and dissemination systems are creating an environment where these elements can be performed in local weather offices. He described the impact of high-resolution data sources, LAPS, the Regional Atmospheric Modeling System, workstations, and product dissemination.

l. The economic value of forecasts—Joint session with the Ninth Conference on Applied Climatology (chairperson: B. Brown, NCAR, Boulder, Colorado)

This session included five presentations, covering a range of topics and areas of application of weather forecasts from methodological issues to real-world evaluations of economic benefits. The first talk by A. Murphy concerned methods of assessing forecast value and the results of a few relevant studies, including an overall assessment by the U.K. Meteorological Office of the benefits of its meteorological services. He also discussed the complex relationship between forecast value and forecast quality, and showed some examples from specific case studies. J. Evans discussed issues related to measuring the economic value of aviation meteorological products. Economic benefits in the areas of safety and delay reduction were considered. Due to complex decision processes, numerous decision makers, and additional consider-

ations associated with the queuing of aircraft, measuring the benefits of improved meteorological information in reducing air traffic delays is not a straightforward task. The next presentation by R. Weiher concerned the economic value of weather forecasts for agriculture and NOAA's program for investigating the value of long-range forecasts. He also described the use of a combined decision-analytic/econometric model to determine the value of improved El Niño forecasts for growing corn in the southeastern United States.

D. Wilks described a cost-loss decision-making model used to evaluate the economic value associated with a forecast of forecast skill through ensemble forecasts. Results of the analysis indicated that for the most realistic combinations of the cost-loss ratio and forecast quality, the modeled ensemble forecasts had substantial economic benefits relative to the baseline forecasts. The final talk in the session by P. Roebber and L. Bosart concerned an assessment of the relative economic value of MOS and local forecasts for several specific cases. In some cases, the local forecasts had higher economic value even though they were only slightly more skillful than the MOS forecasts.

m. Special panel discussion on civilian-military cooperation in meteorology (chairperson:

R. McPherson, NCEP, Camp Springs, Maryland)

The conference concluded with a panel discussion that focused on civilian-military cooperation in meteorology and oceanography. Moderated by J. Wright, the panel consisted of D. Martin, F. Kniskern, R. Mairs, J. Dushan, R. Plante, and R. McPherson. The general theme of the discussion was that the various organizations constitute a valuable national resource that can be applied to many national objectives involving defense, protection of life and property, and enhancement of national economic efficiency. Each panel member offered a short statement describing the activities of the organization he represented, with particular emphasis on areas of cooperation between the civilian and military components.

The floor was then opened to questions from the audience, which numbered about 70. A vigorous discussion followed on questions that ranged from, Why don't all the processing centers use the same model?, to How will the processing centers be impacted by the 104th Congress of the United States? The discussion concluded with a brief statement by McPherson, which reaffirmed the commitment and resolve of the civilian and military leaders to work together and to

share resources wherever appropriate in order to improve meteorological analysis and forecasting procedures on the global to local scales.

3. Concluding remarks

The objectives of this conference were accomplished through a mix of oral and informative poster presentations. Except for the six invited presentations, the oral presentations were selected on the basis of submitted abstracts. For these presentations, the approach of two 15-min presentations followed by a 15-min question and answer period covering the preceding two oral presentations was tried. The comments we received on this approach were positive, and we urge other conference program committees to employ this approach as a way to provide sufficient time for questions and dialog between the presenters and the audience. The poster sessions were an integral part of this conference and they highlighted the major conference themes at the end of each of the first three days.

The Weather Analysis and Forecasting Conferences are now on an 18-month cycle. We believe that the large number of abstracts submitted, and the new issues and case studies presented at this conference, justify this frequency. The operational community needs to keep informed of the rapid progress being made as new sensors, numerical models, and data assimilation methods are deployed and made available to all forecasters within the public and private sectors.

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