Researchers Uncover Extreme Lake in Antarctic Environment

Researchers drilling into Lake Vida, an antarctic “ice-block” lake, have found the lake isn’t really an ice block at all. In the 16 December issue of the Proceedings of the National Academy of Sciences, the National Science Foundation team reveals that antarctic Lake Vida may represent a previously unknown ecosystem, a frigid, “ice-sealed” lake that contains the thickest nonglacial lake ice cover on Earth and water 7 times saltier than seawater.

Because of the arid, chilled environment in which it resides, scientists believe the lake may be an important template for the search for evidence of ancient microbial life on Mars and other icy worlds. Researchers previously thought Vida was one of several antarctic lakes that are frozen to their beds year-round. However, using ground-penetrating radar, ice core analyses, and long-term temperature data, the researchers now show that Vida has a thick light-blocking ice cover, a vast amount of ancient organic material and sediment, and a cold, super-salty, liquid zone underlying the ice—an environment that remains liquid at temperatures below -10°C, well below the freezing point of pure water.

Peter Doran of the University of Illinois at Chicago conducted the research along with colleagues at the Desert Research Institute in Reno, Nevada; NASA’s Ames Research Center in Moffett Field, California; and Montana State University in Bozeman, Montana. The researchers extracted two ice cores from Lake Vida in the early antarctic spring (October) of 1996. With an electromechanical drill, team members spent two weeks at temperatures below -35°C drilling a 10-cm-diameter core through 16 m of ice cover. “It was some very cold drilling,” added Doran. “We were there for two weeks at temperatures approaching -40°C... camping.”

The core segments collected provided new insights to a previously undescribed antarctic ecosystem. From the cores, the scientists found a layered chemical and biological history preserved in the ice and revived viable microbes that are at least 2800 years old.

“The ice covers of these lakes represent an oasis for life in an environment previ-
Scientists are studying the possibility that the fall of the World Trade Center towers may cause a wider area of Lower Manhattan to be exposed to lightning strikes. Attention to this possibility increased after a man was struck and killed by a lightning bolt near the Chinatown area last summer. “My first thought was, that wouldn’t have happened if the World Trade Center were still there,” said Jack Buchsbaum, chief electrical engineer of the Port Authority of New York and New Jersey. The possibility of a building being struck by lightning increases with its height. Dave Rust, a NOAA scientist, noted that a 1400-ft building (the height of the north tower of the World Trade Center) in an area with moderate lightning frequency will be hit approximately 35 times a year. While it seems apparent that the removal of such a structure could lead to more strikes in a surrounding area, researchers say it may take 5 years of analyzing thunderstorm data and other information to establish conclusive results.

University. “These life forms may possess novel ice-active substances such as antifreezes and ice nucleation inhibitors that allow the organisms to survive the freeze-thaw cycles and come back to life when exposed to liquid water,” he said.

“Importantly, the cold temperatures preserve DNA extremely well, making them perfect ‘ice museums’ for the study of ancient DNA,” Priscu added. Research on the ancient DNA will provide an evolutionary and functional history of the microorganisms, he said, and he believes the findings might help scientists draw implications for the type of life that may exist in Lake Vostok, a huge lake which lies more than 4 km beneath the East Antarctic Ice Sheet.

Lake Vida, more than 5 km long, is one of the largest in the cold antarctic desert region known as the McMurdo Dry Valleys. The area receives less than 10 cm of snow per year and the average annual temperature hovers around −30°C.

Using data from the ice sensors and from an automatic meteorological station on the shore of the lake, the researchers created a thermodynamic model to understand the complex melting and freezing processes within Vida. The model provided a better understanding of the evolution of the ice cover and the underlying salt water. The freezing, growing ice cover concentrates the salt, thereby depressing the freezing point of the water and extending the viability of a lake ecosystem.

“Lake Vida provides insight into a novel terrestrial ecosystem,” said Doran. “What happened at Lake Vida may have been the fate of other antarctic lakes, during even colder times, and more tropical aquatic ecosystems during extreme global glaciations of the past, such as the ‘snowball Earth’ 550 million years ago.” The research was carried out as part of NSF’s McMurdo Long-Term Ecological Research project and was also funded in part by NASA’s Exobiology program.

Rainmaking with Seawater
Stephen Salter is looking to make seawater into rain. The Edinburgh University professor, who received a grant from the British government worth over £100,000, is designing a machine that could help produce rain in areas where it is needed.

The wind-powered machine is made of a hollow tub that stands upright on a platform at sea with its base just below water. Two hollow blades emerge from the sides of the tubes and as the wind spins these blades, they power the turbine, which sucks up seawater by centrifugal force. The seawater creates a fine spray that can gradually form into clouds.

“We are trying to break through the layer of rather stagnant, humid air that’s at the very, very bottom of the atmosphere, in contact with the sea surface, and lift large volumes of water through this and squirt them out from 10 m up in the air as a very fine spray, with a very big surface area,” Salter said. He says that ideally the machines would be positioned about 10–20 km off a mountainous coastline. There they could get an onshore wind to blow the moisture-filled air toward land, and the mountains could lift it farther up to form clouds.

His team is now using computers to track the movement of air in different parts of the world, working out where to test the rainmaker after it has been built. There are still technical problems to sort out, Salter said, including controlling the size of the water droplets and how to make sure that the salty residue falls back into the sea.

Climate Change May Stunt Plant Growth
Recent studies have suggested an increase of carbon dioxide in the
atmosphere will stimulate plants to grow more abundantly (see BAMS, 83, 1746–1747). However, new research in California has found that when other elements linked to climate change are added, carbon dioxide might do the opposite and act as a drag on growth.

In the new study, the results of which appear in a December issue of Science, researchers artificially applied the four major climate-change elements at levels they are expected to be at by the year 2150 if current use of fossil fuels remains unchanged. “Most studies in the past have just looked at a single element, such as an increase of CO₂ or warming temperatures,” said Rebecca Shaw, a Carnegie Institute of Washington researcher and first author of the study. “Our study looked at the effects of all the climate-change elements.” The elements are atmospheric carbon dioxide, expected to double in current density; temperature, expected to rise by a degree or more; nitrogen, deposited in the soil when it is washed from the atmosphere by rain; and precipitation, expected to increase by 50% in some areas.

Every combination of the added elements was applied many times over several years on plots of grassland near Stanford University in California. They found, as in previous studies, that if CO₂ levels alone were increased, plant production increased as well. However, when the other elements were involved, there was a reduction in growth. In plots where they added CO₂ and more water, there was an 8% decrease in production when compared to untreated grass, Shaw said. When enhanced temperature, nitrogen, and water were applied to a plot, the production soared by 84%, but when CO₂ was added to the mix, the production dropped by 40%. “This was unexpected,” Shaw said. “We think that by applying all four elements in combination in a realistic situation, some other nutrient becomes a limited factor to growth.”

Richard J. Norby, an environmental scientist at the Oak Ridge National Laboratory, was surprised by the results of the study. “We don’t really understand the responses of the plants,” he said. “I think this challenges some of our assumptions about global climate change. What happens when all these conditions change at the same time is much more difficult to interpret.”

STUDIES FIND AMPHIBIANS MAY NOT BE AFFECTED BY RADIATION

Scientists consider amphibians to be very helpful in the study of environmental issues because they breathe partially through their skin and are thus highly susceptible to changes in their habitat. Recent studies have focused on the increase in deformities and decrease in the overall population levels in amphibians. It has long been thought that these problems were caused by ultraviolet radiation, but two recent studies suggest they may be caused by various factors that are particular to specific species, and that amphibians may actually be protected from radiation by organic matter in the water.

Earlier studies found that ultraviolet-B (UV-B) radiation caused deformities and higher mortality rates in amphibian embryos. Many scientists felt these results indicated that the diminishing ozone layer was to blame for the decreasing population of adult amphibians.

But the new studies, which both appear in the November issue of Ecology, discovered that dissolved organic matter in the water provides protection from dangerous radiation. In fact, it is now theorized that the attention given to the effects of radiation may have distracted scientists from the real causes.

“All of the concentration on UV might have misdirected our conservation and research priorities,” said Wendy Palen, a doctoral student at the University of Washington and lead author on one of the studies. Palen’s group analyzed water samples taken from 136 amphibian habitats in Washington and Oregon. They found that 85% of these sites were protected from UV-B radiation by dissolved organic material that absorbs radiation as it penetrates the water. This organic matter is introduced into lakes and streams through rain and melting snow.

This study allows for expansion to a larger scale that is representative of conditions that can affect an entire population. This was not the case in earlier experiments, which were done on a small scale under controlled conditions. Palen said that this limitation prevented a complete understanding of the variety of environmental conditions that affect amphibians.
She noted that the causes of amphibian deformity and mortality might vary depending on geography. She pointed out that California’s endangered mountain yellow-legged frog was in a population decline due to the arrival of nonnative species of trout that feed on the frogs and their eggs.

A second study supported Palen’s findings by investigating the boreal chorus frog’s breeding at a Colorado pond. Here, researchers found breeding by the frogs depended on snow cover—the quicker the snow melted in the spring, the earlier the frogs bred. It was discovered that the earlier breeders were exposed to less radiation than those that bred later.

“The results of our study suggest that the timing of breeding must also be taken into account, and that the earlier breeding after dry winters may alleviate some of the UV-B exposure resulting from shallower water,” said Stephen Corn of the U.S. Geological Survey.

Researchers have also identified viral infections and fungus as two causes of amphibian population declines. Other theories suggest global change, chemical contamination, and the introduction of new predators as possible causes.

**California May Put Out Fireplaces**
The San Joaquin Valley in California is one of the smoggiest regions in the country. As a result, officials there are now looking to ban wood-burning fireplaces in homes. Proposed new laws for 2003 would require most masonry fireplaces in older homes to be disabled, changed to natural gas, or modified to include pollution controls. New homes would not be allowed to have fireplaces or stoves that burn wood. Additionally, many residents in the area would be restricted from lighting their fireplaces on particularly smoggy days.

“Local citizens are outraged by the proposals. “I have a problem with you telling me I can’t light my fireplace,” said Pat White, a Bakersfield resident, at a public hearing on the issue. “You’re telling me what I can and can’t do in my home. That’s not fair.”

There are approximately 500,000 homes in the region that have stoves or fireplaces that will be affected by the new rules, which are intended to limit the release of microscopic particles that can enter the lungs and cause headaches, asthma, and allergies. The valley has a poor history of regulating these particles. Past attempts to encourage a voluntary ban on fireplace use on bad air days were unsuccessful, according to Janis Parker of the San Joaquin Valley Air Pollution Control District, which is expected to approve the new proposal in the spring of 2003. If approved, regulatory officials would inform homeowners of days when the air is particularly unhealthy and fireplace use was forbidden. This could occur an estimated 5–20 days per winter. Violators of the ban could be forced to pay a fine.

But the cost of complying with the laws is also considerable. A new gas stove can cost $3000 uninstalled, while converting a brick fireplace to natural gas can be even more expensive. Pollution controls generally cost at least $2000. According to local stove salesperson Dawn Keeton, many residents in the valley prefer burning wood for heat because of its low cost.

“I know we are all attracted to the ambiance, but I believe for most of us, it’s a necessity,” Keeton said.

Exemptions from the ban would cover houses that have no other heat source than wood, those above 3000 feet, and those in areas inaccessible to natural gas and propane services.
High and low temperatures are featured prominently in virtually all media weather forecasts. These forecast elements are usually defined as the maximum and minimum temperatures, respectively, occurring in a 24-h period beginning at midnight on the specified day. At a midlatitude location such as Milwaukee, Wisconsin, daily high and low temperatures are generally expected to occur in the late afternoon and early morning, respectively. The highs typically lag a few hours behind the daily maximum in solar elevation, whereas the lows tend to occur around sunrise.

The expectation of afternoon highs and morning lows can create confusion in interpreting icon-based weather forecasts, which many consumers examine without considering additional explanatory information. Combining the usual definitions of “high” and “low,” stated above, with the expectation that the high occurs in the afternoon and the low occurs in the early morning, results in the following interpretation of the low temperature forecasts shown in Fig. 1: Tuesday’s low will occur late Monday night, Wednesday’s low will occur late Tuesday night, and so on.

This interpretation is problematic only if the forecaster (i.e., the media outlet) and the consumer have different working definitions of high and low. We contacted meteorological personnel at all major television and print media outlets in Milwaukee, and learned that two of the five media outlets indeed define the low as the “daily low,” the minimum temperature expected to occur in a 24-h period beginning at midnight. The other three, however, define the low as the “overnight low,” the minimum temperature expected to occur during the night. Thus, depending on the forecaster’s definition, the low temperature forecasts in Fig. 1 might refer to the minimum temperature expected to occur on the specified day, or alternatively to a temperature (and not necessarily the minimum temperature) expected to occur the following day. Because very little explanatory text typically appears on forecast icons, it is very easy for the consumer to interpret the low temperature forecast incorrectly.

In order to investigate the extent of this problem, we examined hourly surface temperatures measured...
in Milwaukee from January 2000 to December 2001. As shown in Fig. 2, minimum daily temperatures indeed tend to occur in the morning. However, during the two years analyzed, nearly 50% of the daily minimums occurred outside the range of 0300—1000 LT. Moreover, large frequencies of 17% and 7% are observed in the hours just before and after midnight, respectively. The 17% spike just before midnight corresponds to cold advection episodes in which the temperature consistently decreases throughout the day, reaching a minimum at midnight. A similar phenomenon attributable to warm advection episodes is responsible for the 7% frequency just after midnight. Turning to the maximum daily temperatures, Fig. 2 shows that 70% of the daily highs occurred in the afternoon or early evening, between 1200 and 1900. About 10% of the daily highs occurred in the hour after midnight, again corresponding to cold advection episodes.

In summary, we find that the correct interpretation of a low temperature forecast icon is dependent upon proper specification of what is being forecast: the daily minimum temperature or the overnight minimum temperature. In the event that the daily minimum temperature is expected to occur in the early morning (and our analysis suggests that in Milwaukee this occurs roughly 50% of the time), this distinction is unimportant. For the other 50% of the time, however, without a clear definition of terms the consumer might substantially misinterpret both the magnitude and the timing of the low temperature forecast. An analogous problem exists, although to a lesser extent, in interpreting high temperature forecast icons. Such misinterpretations decrease forecast value and create difficulties in verifying the forecasts. We recommend that media forecasters include the timing of high and low temperatures in their forecast icons.

Japanese Weather Education

AMS Atmospheric Education Resource Agent Bruce Smith, a science teacher in Appleton, Wisconsin, spent three weeks this past summer as a guest of the Japanese government studying Japanese schools and culture. He shared his experience with the Packerland chapter at their December meeting.

During the trip Smith gained insights into the dissemination of meteorological and natural hazard information and stumbled onto a weather enthusiast’s gem in the heart of bustling Tokyo. The opportunity was made possible through the Fulbright Memorial Fund (FMF). The Fulbright Memorial Fund was established in 1996 to commemorate the 50th anniversary of the Fulbright Program, a U.S. government project created in 1946 to foster international exchanges for university students, faculty, and teachers. The Japanese government established the FMF to continue the tradition of dialogue and exchange between the United States and Japan. Over 3500 American

An illustration from a Japanese high school science text.
educators have visited Japan as part of the FMF program. Smith was part of a group of 200 educators from all 50 states. Smith spent his visit in Bizen City, Okayama Prefecture, in the south central part of the main Japanese island of Honshu.

Since 1997, the Japanese educational system has been in the midst of major reforms. Smith visited schools in Bizen City with an eye toward science education and earth science education in particular. One impression he got during these visits was that meteorology education is taught in primary and secondary grades as part of the entire science curriculum. It is woven into chemistry, physics, and biology lessons. A weather lesson in a Japanese text will be very similar to one found in an American text, but may be preceded by a lesson on field geology and followed by cell biology.

This parallels the Japanese approach to other aspects of education and the environment. Surrounded by oceans and monsoonal circulations, the Japanese are deeply in tune with weather and change in everyday living. In Japan weather education is placed in a context of other natural hazards, such as earthquakes, volcanoes, tsunamis, and floods. Hazardous weather is not isolated but dealt with as part of the pantheon of other natural episodes that frequent Japan.

Smith found this difference in approach was made clear when he spotted a sign saying, “Meteorological Agency 300 m.” Not wanting to miss this opportunity, he eventually found a building sprouting a myriad of remote sensing devices on the roof and housing the Japanese Meteorological Agency (JMA). Even more exciting, this was also the site of the Japanese Meteorological Museum. Unfortunately, the museum was closed. Smith explained to local security personnel that he was a visiting American teacher and would not be able to return at another time. Despite the lack of a common language and with the assistance of Saito Mituyuki of the Public Relations Office of JMA, Smith was eventually allowed a personal tour of the museum.

The museum is housed in several rooms and contains an interesting array of historical and contemporary weather instruments, including World War II vintage radar, automated data collection systems, weather balloon sounding packages, and sonic sounders used to remotely measure and report snow depth. The museum is a real treat for a true weather enthusiast. In addition to the instruments, the museum had many posters and kiosks raising awareness about natural hazards—and not just weather hazards. The JMA is also charged with disseminating information about all natural hazards in the country. Devices recreate and measure earthquake shocks of varying intensities. Pamphlets on urban flooding and typhoons are available side by side with those dealing with volcanic hazards and earthquake evacuation plans. It was this seamless approach to hazards that extends to other aspects of the JMA, which is also the umbrella organization for gathering environmental information, making predictions and providing warnings, and for all natural hazards. The AMS Education Programs office fosters a similar approach in education through DataStreme, Water in the Earth System, and other ongoing efforts. It is an approach that serves the people of Japan well.

More information about the FMF program, including application information, can be obtained online at www.glocomnet.or.jp/fmf/index.html. The English Web site for the JMA is www.jma.go.jp/JMA_HP/jma/indexe.html. Also, you can contact Bruce Smith at bsmith733@new.rr.com about the FMF program or weather education in Japan. Smith has served in various capacities with the AMS Programs office.

—Scott Patrick
Packerland chapter
and Bruce Smith
THE HYDROLOGICAL RAMIFICATIONS OF FOREST FIRES
For the November SEACAMS (Southeast Arizona chapter) meeting, Mike Schaffner, a hydrologist from the NWS office in Tucson, discussed “Forest Fire and its Hydrologic Ramifications.” The talk covered last summer’s wildfires in Arizona, including the Bullock fire near Tucson that consumed 30,563 acres and the grand Rodeo-Chediski fire in northeastern Arizona that burned 469,000 acres.

Schaffner explained that the biggest hydrologic consequence of forest fires is hydrophobic soil. This results from the fire boiling off the resins and sap of trees and the resins/sap mixing with the ash under high temperatures. This mixture combines with the soils on the forest ground, creating an almost water-resistant cover, dramatically increasing the chances of a flood. The U.S. Forest Service has a burn severity index that is related to the amount of time water beads on the soil prior to any infiltration. High burn severity is defined as more than 20 s (some samples at the Bullock fire exceeded 18 min), moderate burn severity is less than 20 s, and low burn severity is close to normal.

According to Schaffner, the ash and sediment increased reservoir infilling, reduced the “life” of the reservoir, and clogged water intakes at reservoirs. Pools inhabited by fish were filled with mud. The fire retardant contains toxic proteins called polybrominated diphenyl ethers (PBDEs), which are fat-soluble and mimic hormones. This can enrich aquatic ecosystems with phosphates, and acute toxicity seems likely in early stages of certain fish species.

Schaffner said that after the fire the area was closely watched even though monsoon storms are typically small and less likely to produce flooding. Yet this winter the area will still need to be watched due to the rains and El Niño.

In conclusion, Schaffner demonstrated that fires can have a dramatic impact on both physical hydrology and water quality, and that the physical hydrologic impacts are expected to persist for a 3–5-year period. The NWS and other agencies will have to be vigilant to monitor the situation and alter their approach as conditions warrant.

—Lisa Reed
SEACAMS chapter

Drought Monitoring in North Carolina
Woody Yonts of the North Carolina Drought Monitoring Council spoke at the October meeting of the Central North Carolina chapter. The Drought Monitoring Council is made up of numerous state and federal agencies that assess and respond to drought conditions in the state, including the State Climate Office and the NWS. They maintain a Web site on drought issues (http://drought.ncwater.org) that includes a list of all local water restrictions within the state as well as a map showing current drought conditions across North Carolina. As the drought conditions worsened this summer, the council hosted a conference for the media and water systems managers and a separate conference for elected officials.

The council faces critical issues in efforts to reduce the impact of the drought, including illegal dams, water use conflicts, communities running out of water, and resistance to water-use restrictions. This year, 230 communities within the state had some measure of water-use restrictions. The restrictions increased cost of buying water, reduced revenues to local water utilities, and/or diminished water quality.

Regional field offices monitor public water systems and rank them according to their vulnerability to drought in a three-tier system. Tier 1 represents a crisis situation, with less than 100 days of water supply remaining. Tier 2 is used for communities that are not in a crisis yet, but could be within the next few months. Tier 3 indicates that a community is not invulnerable at this time. The governor created a water system protection team that meets with the tier 1 communities

ON THE WEB: WWW.WORLDWEATHER.ORG

The United Nations launched a new Web site, the World Weather Information Service, in December, aimed at making it simpler to check on weather forecasts worldwide. The site, online at www.worldweather.org, collects information from 69 national meteorological services to provide official forecasts for 680 cities. It will give two-day predictions and severe weather warnings, as well as monthly climatological information for various cities.

The site was developed by the United Nations in cooperation with the Hong Kong Observatory and the National Meteorological Service of Hong Kong. “International cooperation is the key for a truly global meteorological network at the service of the international community,” World Meteorological Organization Secretary-General G. P. Obasi said. The organizers hope the number of cities covered by the site will grow as the project expands.
to ensure they are doing everything possible to limit the economic and environmental impact of the drought in a timely manner.

The long-term drought is closely related to a lack of ground water. The absence of this ground water supply prevents recharging of streams. Streamflow levels statewide have been below normal for much of the past two years, with almost 30 stream-gauging stations in North Carolina setting new record low daily discharge levels in the 2002 water year.

Looking to the future, communities are continuing to monitor remaining water supplies, searching for additional supplies, and working to develop response plans for future shortages. The concept of regional water supply development and interconnection between water systems is being strongly encouraged to alleviate future supply problems.

—MICHAEL J. BRENNAN
Central North Carolina chapter

During 3–5 October 2002, approximately 110 people participated in a very successful Mid-Atlantic Winter Storms Regional Conference held in Silver Spring, Maryland. This event brought together operational and research meteorologists from the government, industry, academia, and media; students and teachers from local colleges, universities, and secondary schools; as well as regional transportation, emergency management, and safety experts. This is intended to be the first in a series of regional meetings focused on specific environmental issues important to unique regions around the United States.

The conference was an overwhelming success thanks to the active participation of a tremendous diversity of experts in every area of the production, dissemination, and receipt of winter storm products and services, including both the meteorological community and customers who use weather information.

Not only did we discuss current and projected capabilities in the science of forecasting winter storms, but we also talked about the process of forecasting. The critical communication of forecasts was part of this, and we spent several sessions discussing all aspects of this issue, from the producer, disseminator, and user perspectives. We tried to develop ways to improve communication and dissemination of winter weather information. The conference closed with important initiatives to promote outreach, both within our profession and in partnership with the education and public communities.

A unique aspect of this conference was a simulation of the forecast process. We examined two winter storms in detail: one storm that was forecast but didn’t occur in the Washington, D.C., metropolitan area, and one that occurred in spite of forecasts that it wouldn’t happen. Steve Tracton (NCEP) led a panel
discussion of these storms highlighting the forecast process as well as communication to users and connecting with their decision-making process. We emphasized analyses of forecasts with and without information on uncertainties. This proved to be a successful approach to discussing and critiquing the forecasting process. As a result, numerous discussions covered the data and tools used by forecasters; communication of forecasts by the NWS, media, and private vendors; and the use of weather information in decision making by users ranging from a person on the street to community leaders and emergency managers.

I think the broad participation and perspective of this conference was no accident. Like other operationally focused AMS conferences and symposia, we sought to have a balance of public, private, media, and academic participants. Several key issues were identified and resolved early on to make this happen.

At the beginning, we put together a diverse planning committee to include public/government (e.g., NWS, U.S. Air Force and Navy, FAA), private, media, research, and academic sectors, as well as several customer representatives, including emergency management and safety officials. Through numerous conference calls and one-on-one meetings, we hammered out the conference goals, built a consensus on where we are headed, and solidified support for our conference themes.

October/November time frame was ideal both for our theme and to minimize conflicts with other events. Finally, since we wanted to keep registration costs at or below $50 per day, our early registration fee for those who registered 30 days prior to the conference was $95 (that included two lunches, a dinner, and an ice breaker), with a lower $70 fee for students to encourage their attendance. A major lesson learned was the need have a viable strategy to garner the financial support necessary to keep expenses as low as possible. The conference would not have been as successful without the generous financial support provided by several corporate and agency sponsors, including SAIC, Mitretek Systems, Inc., QSS, Inc., and the National Weather Service.

The conference also owed success to the experience of the AMS staff, particularly Melissa Ficek, Yale Schiffman, and Claudia Gorski. The national AMS staff helped us establish an e-mail listserv to ensure that key committee members and panel chairs could
remain highly involved, published articles in BAMS and posted announcements on the AMS Web site, helped formulate plans to maximize publicity and visibility, administered the conference registration including setting up the online registration pages, and provided invaluable technical support.

AMS and NWA planning committee members collaborated on a preview article published by both organizations. This and other documents were published on the conference Web site, which was developed by Bryon Lawrence, the District of Columbia AMS chapter Webmaster. Since the chapter Web site (www.dc-ams.org) is owned, operated, and maintained by the chapter, it was extremely easy to keep it current and relevant.

Although local media, the AMS, and planning committee members helped us send out a blitz of publicity—including verbal announcements, news releases, and e-mail—attendance from the general public may have been negatively affected by the now infamous sniper shootings in the Washington, D.C., metropolitan area.

In the weeks after the conference, we mailed a CD with every presentation to every conference participant. We also transformed the conference Web site into a portal for feedback about the conference.

This conference was intended to stir a debate on the current state of winter storm forecasting, future outlook, necessary research, and product delivery. I think we were successful in doing that. I sincerely hope that other local chapters undertake similar gathering on topics relevant to their local regions. Through events like this, the partnerships between the AMS, the meteorological community, and the public will be strengthened, and our nation’s weather services will be better off.

—Ken Carey
D.C. chapter and Mitretek Systems, Inc.

A CONFERENCE OF OPPORTUNITIES
Students’ Perspective

Our group of 12 students from California University of Pennsylvania represented the Southwestern Pennsylvania chapter of the AMS at the Mid-Atlantic Winter Storms Conference. For most students, this conference was their first regional, professional conference. Attending a conference like this one was a great opportunity for any student. There was, in fact, a waiting list of students who wanted to attend. Logistics only allowed for a smaller number to attend.

In addition to simply absorbing the information at the presentations, the conference was an opportunity to meet professionals in the field, and to network with other meteorologists. Everyone was very polite and eager to talk to us.

“The Mid-Atlantic Winter Storms Conference was a great experience in that it allowed me to get in touch with possible job contacts and enabled me the opportunity to mingle with the meteorology community,” one student commented afterward. “Meeting several famous weather people was well worth the trip.”

We were also appreciated the chance to see research in progress or work utilizing cutting-edge model guidance. Students particularly noted presentations by Louis Uccellini and Paul Kocin. The atmospheric science community, as seen through the eyes of a student, is a tightly knit group of scientists; they enjoy both gaining new knowledge and sharing each
others’ company. Conferences in the atmospheric science community give students and professionals alike the opportunity to learn.

The conference itself was very informative—an occasion to hone winter forecasting skills. The students’ views on the problem of communicating forecasts to the public were similar to those of the many of the speakers. If we, as forecasters, cannot communicate forecast information in a timely and informative manner, who are we helping? One of our students, Chapter Vice President Richard Wirdzek, participated in one of the panel discussions with noted broadcast and operational meteorologists.

Our chapter is redeveloping, and this experience proved to be a great opportunity for us to grow as both an AMS chapter and an academic program. Upon returning from the conference, our chapter was energized. Information from the conference was a topic of discussion in both the synoptic meteorology course and the Seminar in Atmospheric Sciences. We also shared our experiences with one another in our forecast shifts in the California University Weather Center [Operational Laboratory]. Students participating in the National Forecasting Competition via Penn State were able to utilize forecasting techniques for cold-weather locations in the contest. Finally, our chapter was able to generate many new ideas for our own Regional Symposium occurring in the spring semester (4 April 2003).

On behalf of California University’s Meteorology Program, we wish to thank everyone at the conference, especially Major Ken Carey, who assisted in every manner possible. We greatly appreciate it.

—CHAD KAUFFMAN, LARRY SMITH, AND PATRICK TAYLOR

Winter Weather—Communication, Uncertainty, and Better Decision Making

By all objective scientific measures, weather forecasts on all timescales are becoming ever more accurate. The skill in forecasting winter storms has shown significant improvement in the last 50 years, but has that skill been translated into increased understanding and better decision making by the public and other users of winter weather forecasts?

More and more forecasts are being presented in graphic form. Local television, cable, newspapers, and the Internet offer a variety of forecasts for one city and each source of forecast information presents the forecast with different symbols. Together the symbols we use in the visual media to “show” the forecast constitute a visual language, and thus semiotics—a way of viewing the languagelike use of these symbols—particularly applies to these forecasts. But do users of this semiotic information know what graphic artists or we meteorologists mean by the symbols we use to describe the weather and weather forecast? Better communication of weather and forecast information is critical to better decision making, especially during winter weather situations. During the past two years we have conducted a number of online surveys to try to determine how to better communicate with the weather symbols we use. What we might see as a symbolic way to show heavy snow (Fig. 1), four flakes versus two flakes, was interpreted by almost 45% of the Washington area viewers who took the survey (about 2000 respondents) as indicating not heavier snow but a greater chance of snow. This result suggests that the use of a wide variety of symbols, from a variety of media and the NWS, can confuse the public. Shouldn’t we as forecasters and meteorologists better understand semiotics and communication theory before we create and expand to such widespread use a variety of symbolic forecasts? Should we try to agree on one symbol to indicate a forecast of rain, just as we all use the word “rain” (in English anyway) to indicate a forecast of that meteorological element?

Another important part of informed decision making, especially in winter weather situations, might be knowledge of how confident the forecaster is in their forecast. Among the questions we asked in the online survey in the Washington area was, “Would forecaster confidence in his forecast on a scale of 1 (no confidence) to 10 (highest confidence) be useful to you?” Almost 80% of the respondents felt such information would be slightly to very useful.
(there were five categories of “usefulness”), and 20% felt it would not be useful or might find it confusing. A way to indicate how confident the forecaster is in the forecast certainly seems to be an element that would help in user decision making and an element we have adopted in our weathercasts.

A forthcoming National Research Council report discusses the utility of a discussion of uncertainty in weather and climate forecasting. But how can we effectively communicate uncertainty when more and more the public and users are seeing forecasts presented as deterministic numerically and symbolically 7 days into the future . . . and farther. The uncertainty of the track of winter storms may be understandable to the public, which is now used to seeing hurricane forecast tracks shown as fans, or tracks of increasing uncertainty (Fig. 2). We have begun using such “fan tracks” with winter storms 1–2 days in advance of the expected event. Such visuals help the public and user understand the uncertainty of forecasting rain–snow boundaries and the amount of snow. The local NWS office in Philadelphia experimented with probability forecasts of snow amounts, which seemed to meet with user acceptance and was viewed as a useful product in helping decision making.

We all need to give more consideration to the symbols, words (printed and spoken), and use of uncertainty as a decision-making tool in our forecasts. Serving the public in the years ahead will not only be done through increasing skill, it will be done through increasing forecasting skill and increasing communication skill, including better communication of uncertainty.

—BOB RYAN
NBC4-TV, Washington, D.C.

**FIG. 2.** An example of a track “fan” forecast.

**CHILDREN AND FAMILIES APPLY LESSONS FROM RISK WATCH: NATURAL DISASTERS**

Children in preschool through grade 8 will soon be learning about severe winter storms and other natural disasters through the Risk Watch: Natural Disasters curriculum. The National Fire Protection Association (NFPA), with funding from the Home Safety Council and the Federal Emergency Management Agency (FEMA), developed materials that can be integrated into core subject curriculum. Classroom instruction, presentations from community experts, and take-home activities are structured to inform and prepare children and their families for dealing with disasters. Content includes what to do before, during, and after the event, whether at school or at home.

The first lesson, general preparedness, encourages discussion about types of disasters and the need to be prepared. It instructs family members to assemble a family disaster supply kit for their home and vehicle and encourages

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**CROCODILES AND Drought: Not a “G’Day (to) Mate”**

Australian crocodiles have hit a dry spell during the severe drought that continues to linger down under. Not only does a male crocodile’s sperm count fall during dry periods, but females tend to reabsorb their eggs as a survival mechanism if droughts became prolonged. John Lever, owner of the Koorana Crocodile Farm in the eastern state of Queensland, said in December that if the drought did not break soon, his production of 1600 baby crocodiles per year would be cut by half. “It’s pretty rough when your sex life is determined by the weather,” he said. Many parts of Australia had no significant rain during 2002, making it the fourth driest year since 1900.

Lever noted that thunder and lightning, something Australia has been lacking of late, is the ultimate aphrodisiac for crocodiles. There are artificial ways of stimulating crocodiles, such as helicopters flying overhead. Crocodiles seem to respond to this method, but as Lever points out, it’s a rather expensive way to go about getting crocodiles to mate, mate.
children to put together a “personal pack” of their favorite items for comfort in the event of an evacuation. All members of the family are asked to know out-of-area contact numbers so they may keep each other informed if separated during a disaster.

Subsequent lessons deal specifically with the natural disasters that affect the most people: earthquakes, floods, hurricanes, severe winter storms, tornadoes, and wildfires. For instance, after hearing the story, “The Big Flood,” by Wendy Pfeffer, teachers may ask young children to apply their understanding of floods and the correct actions to take when a flood warning is issued. They determine whether the responses of characters in a fictional story are safe or not. Middle-school students may be asked to consider the potential hazards and resources in their own community. They might hear from community experts, such as a civil engineer, a community planner, or meteorologist, about flood-prone areas, zoning, and interpretation of topographical maps. Students then consider safety when designing a model community plan.

Each type of disaster is accompanied by a Home–Community Bulletin. Specific information is provided for caregivers and other adults in the community regarding what to do before, during, and after the event. This will encourage these people to mitigate against the effects of natural disasters and to plan for safe shelter or evacuation if necessary.

Risk Watch: Natural Disasters adds to the Risk Watch: Injury Prevention curriculum developed in 1998 and now used by more than 75,000 classrooms in North America. Preparing students in an instructional setting, using age- and ability-appropriate methods, and allowing time to practice skills is shown to be effective in developing safe attitudes and behaviors. Although learning how to deal with disasters is a serious topic, it doesn’t have to be frightening. Children gain confidence when activities are presented in a positive way with assurance that the adults who care for them have a plan. Young children need to understand their role and what to expect when emergency plans are put into place.

We are grateful to those agencies and individuals who provided expert technical resource material and review of Risk Watch: Natural Disasters. NOAA/NWS, USGS, The American Red Cross, FEMA, USFA, The U.S. Forest Service, the Department of Natural Resources, and classroom teachers have all contributed valuable hours for the assurance of accuracy and consistency. Information about Risk Watch: Natural Disasters will be posted at www.riskwatch.org in early 2003 or you can contact the NFPA Public Education Division at 617-984-7269.

—PEG CARSON
NFPA Risk Watch field advisor

**AVOID NOWCAST SURPRISES!**

9 January 2001 is a day that few forecasters will forget in the Washington, D.C., area. As I prepared to leave for work at 5:30 A.M., I heard the slight pitter-patter of raindrops on my roof. Before getting in my car, I quickly went online to look at the conditions on Bob Ryan’s 4-WINDS WeatherNet (a mesonet) and saw temperatures hovering around 31°F, dewpoints in the low to mid-20s, and relative humidity rising sharply. As I drove toward the AWS office in Gaithersburg, Maryland, I heard a meteorologist give a live forecast at 5:45 A.M. The forecast: partly cloudy with a high of 45°F.

Within minutes, the radio station was inundated with calls from listeners saying the roads were a skating rink. The accident reports were too numerous to report and, unfortunately, two people died that morning. Events such as this can seriously tarnish the credibility of the entire meteorological community.

This situation was one of the worst of all cases—one where the nowcast is wrong as it is presented. All meteorologists can agree that they are business clients or the general public. Are weather forecasters using the best science, tech-

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**FIG. 1.** Defining the surprise factor: the timescales and rating factor are not absolute and are for illustrative purposes only.
nology, and information available to prevent forecast surprises?

While I am not a forecast meteorologist, I am CEO of a medium-sized weather company and regularly make business forecasts. The last thing I want to do is surprise my board of directors. With that in mind, I extended my business forecasting methodology to weather forecasting and defined a “surprise factor” (see Fig. 1).

As you can see in the figure, the “surprise factor” increases exponentially as we get nearer to the nowcast phase. Depending on the nature of the event, a forecaster has more leeway to hedge farther from the event. It is always better to under-promise and over-deliver. Obviously, the nature of the forecast and the composition of your constituency will determine the appropriate timescale and the nature of the hedge. My business forecasts need to be very accurate to 1 year and reasonably accurate out to 3–5 years.

As the forecasted event approaches, it is critical to use all available data to provide the most accurate nowcast. Constituents always seek more spatial and temporal accuracy. Too often, forecasters rely primarily on model output, which encourages a type of “forecast inertia.” In other words, though a careful review of all real-time data would show that the forecast should be changed, the forecasters don’t make the change. Available observations (from surface, upper air, radar, and satellite) can show very detailed local effects (see Fig. 2). Tools like the AWS mesonet in the Washington, D.C., area allow forecasters to monitor real-time local conditions and make more-effective nowcasts.

Therefore, a corollary to the surprise factor theory is that the most pertinent information should be reviewed and changes to the nowcast should be made if reality is different than model-based information. It is better to alert your constituents to a change in the forecast than to be wrong in a nowcast. At the end of the day, our credibility is the inverse of the surprise factor.

—Bob Marshall
Founder, President, and CEO
AWS Convergence Technologies, Inc.

**Probabilistic Quantitative Snowfall Forecasts**

The National Weather Service at Mount Holly, New Jersey, has begun to issue experimental probabilistic quantitative snowfall forecasts (PQSF) for potential winter storms in its forecast area.

We developed the PQSF in the fall of 2001 to address the uncertainty associated with snowfall amount forecasts. This uncertainty had been especially noticeable during the storm of 4–5 March 2001, which had been advertised by some as another “Storm of the Century” for the northeastern United States, but which ultimately produced only light snowfall over the major metropolitan areas. In that event, some people tended to focus on the “worst-case scenario.” We hope that a probabilistic forecast will help direct attention toward the most likely snow amounts, rather than the very highest possible totals.

The experimental PQSF forecasts are tables showing the probability that storm-total snowfall will exceed any one of seven thresholds, ranging from 2 to 24 inches. The seven probabilities are chosen from a table of precomputed values, according to the midrange of the amount of snow expected at a given location. The precomputed values were derived from a statistical analysis of observations and forecasts made during past winter storms. Forecasters are free to modify these values given their confidence in the storm track and intensity; however, they are discouraged from making anything beyond modest changes.

The winter of 2001/02 was unusually warm and dry in the mid-Atlantic region and offered very few opportunities for testing the new forecasts. On those occasions when PQSFs were issued, local emergency managers gave us some positive feedback. We plan to issue the PQSFs again this winter, with the hope of more opportunities to obtain feedback, verify the results, and refine the product accordingly.

—Alain Cope
National Weather Service
**PRODUCTS**

**COMBINED NAVIGATION—WEATHER DEVICE**
Storm Hawk™ integrates mobile navigation and weather forecasting for land and marine use and will be available in early March 2003. Developed by WeatherData, Inc., Storm Hawk is a portable, handheld system with weather-overlaid mapping based on Global Positioning Satellite (GPS) data. It is designed for recreational uses such as boating and driving as well as business use.

Using GPS technology and wireless or satellite communication, Storm Hawk provides weather information in real time through a personal digital assistant (PDA). It tracks your travel route and anticipates weather movement to warn of weather hazards. When updated weather is loaded onto the PDA, a detailed color map of your location appears, overlaid with weather radar, applicable weather advisories, and other information such as lightning and wind speed. Available with road maps and marine navigational charts, the Storm Hawk moving map display is always oriented to the user's location and direction of travel. By logging onto the Storm Hawk Web site (which is under construction at www.storm-hawk.com), you can receive a customized trip plan incorporating road closures and marine warnings. Storm Hawk provides updated directions and information to the PDA.

The complete system requires an iPAQ PDA from COMPAQ loaded with the Storm Hawk software, a GPS card, and a cellular or satellite phone. Storm Hawk download service is $9.95 per month. The entire system with cellular phone card will retail for about $1500; the satellite phone option will cost slightly more. For more information visit the WeatherData Web site at www.weatherdata.com.

**USB SERIAL ADAPTER**
The USB Serial Adapter allows most HOBO and StowAway data loggers to be easily connected with available USB ports on Windows PCs. The USB Serial Adapter features "plug and play" installation and draws its power from the USB connection, eliminating the need for a power adapter. The operating range is 0°-40°C (32°-104°F), and it weighs just 2 ounces. Priced at $59, the USB Serial Adapter began shipping in October 2002.

**AT THE ANNUAL MEETING**
The following papers are being presented at the 83rd AMS Annual Meeting, 9–13 February 2003, in Long Beach, California. Each paper's respective conference is noted immediately following it. For more information on the Annual Meeting, please visit the AMS Web site (www.ametsoc.org/ams).

**CONNECTING HYDROLOGIC BALANCE WITH CARBON SINK TRENDS**
The continental U.S. hydrologic cycle has changed significantly since 1900, including increases in precipitation, atmospheric humidity, and streamflows. As a consequence, plant growth, which is often limited by water, increased and absorbed greater amounts of atmospheric CO₂. Two-thirds of the increase in observed forest growth rates could be accounted for by observed climatic changes, including the confluence of earlier springs and wetter autumns leading to a lengthening of the vegetation carbon uptake period. However, regional differences in precipitation trends produced differing regional carbon sink responses.

Despite these trends, the changes in the hydrologic cycle are often overlooked in the recent debate over carbon sequestration in the United States. Our research suggests a link between changes in the hydrological cycle and the evidence collected (since the latter part of the twentieth century) of an increased U.S. carbon sink. Currently, between 15% and 30% of the nearly 1.5 billion tons of carbon dioxide that the United States coughs out into the atmosphere each year is being absorbed back into the land, and this sink appears to be draining more carbon as time goes by.

Researchers have proposed a number of theories as to why the land is pulling carbon dioxide (CO₂) from the air at greater rates. The most talked about theories revolve around an observed greening of North America. Viable causes for why plants have done so well include a revival of forests from agricultural and urban clear-cutting in the 1800s, greater concentrations of atmospheric CO₂ from fossil fuel burning, and warmer global temp-
peratures in the 1900s. But a new study points to another factor vital to plant growth that may be at the root of the matter—more water.

We estimated the continental U.S. carbon fluxes using a prognostic terrestrial ecosystem model, and the results show that increased growth by natural vegetation was associated with increased precipitation and humidity, especially during the 1950–93 period. CO$_2$ trends and warmer temperatures had a lesser effect. The strong coupling between carbon and hydrologic cycles implies that global carbon budget studies, currently dominated by temperature analyses, should consider changes in the hydrologic cycle.—RAMAKRISHNA R. NEMANI (UNIVERSITY OF MONTANA), MICHAEL A. WHITE, AND STEVEN RUNNING. “Changes in Hydrologic Balance Enhanced Terrestrial Carbon Sink in the U.S.” Observing and Understanding the Variability of Water and Weather and Climate.

**Low Level Jets and Urban Ozone Concentrations**
The reliable prediction of high ozone and particulate matter episodes in the mid-Atlantic and northeastern United States hinges upon our understanding of the complex local and regional circulations that can dramatically modify the properties of an otherwise benign quasi-stationary air mass. A convoluted coastline, coastal-to-Piedmont sloping terrain, and differences in radiative heating and cooling between land, ocean, and bays all serve to generate near-surface gradients that give rise to local and regional-scale (mesoscale) circulations within extensive hubs of urban and industrial source emissions. During the summers of 1999, 2001, and 2002, a team of investigators documented the influence of a wide array of recurring boundary layer phenomena on the meteorology and air chemistry at an urban site located 17 km NNE of Philadelphia, Pennsylvania. In particular, aspects of nocturnal low-level jets showed interesting relationships with episodes of high ozone and particulate concentrations.

Summertime nocturnal jets are relatively common in many preferred locations under quasi-stationary synoptic conditions. Of particular interest during the North American Research Strategy for Tropospheric Ozone—Northeast—Oxidant and Particle Study (NARSTO—NE—OPS) was the overnight transport of pollutants and precursors by LLJs that develop along the Northeast Corridor. A wind profiler/RASS, Raman lidar, and tethered sounding system provided high-resolution profiles of wind aloft, temperature, water vapor content, ozone, and aerosol concentrations. These concentrations were used to identify the LLJ and characterize its vertical structure and temporal evolution. The measurements revealed a conveyor of fast-moving air residing at the top of the nocturnal inversion within the residual boundary layer—a remnant of the previous daytime mixed layer.

**Northeast LLJs** are typically confined to a layer between 400 and 800 m above the surface, with wind speeds often in excess of 15 m s$^{-1}$. Analyses of several LLJ occurrences suggest that 30%–50% of the total ozone measured at a particular monitoring station may be transported in by an LLJ and mixed to the surface during the growth of the daytime mixed layer. Often the highest concentrations of ozone during a multiday episode are reported during the afternoon following a well-developed LLJ. In addition, rapid increases in ozone concentrations (~20–30 ppbv) observed in the early morning hours (0300–0500 LT) can be attributed to vertical transport of ozone during “bursting” episodes of dynamic instability in the shear layer between the surface and the layer of maximum wind speed.

The inertial oscillation, a distinctive characteristic of summertime LLJs, continually changes the upstream trajectories for air parcels arriving at the site (see Fig. 1). Organizing around sunset, the south-southwesterly LLJ transports elevated quantities of ozone, water vapor, and aerosols from the Baltimore–Washington urban plumes and helps sustain higher pollutant/particle concentrations and stronger wind speeds at the surface. As the nocturnal inversion
deepens and the friction layer essentially decouples from the flow aloft, however, the LLJ further accelerates while the wind field rotates to a more westerly direction, and the ozone, water vapor, and aerosol concentrations become more characteristic of the upstream (western) regions. During a developing ozone episode, Raman lidar measurements have identified significant quantities of ozone being transported eastward in drier layers embedded in the LLJ (see Fig. 2).

While the vertical structure of the LLJ has been observed in some detail, the horizontal extent and structure of northeastern LLJs are less certain. In addition, the interaction between the developing LLJ and the decaying ocean/bay breeze and other daytime circulations that form under similar synoptic conditions is complex and not well understood. Numerical models (e.g. Meso-Eta, MM5) are capable of resolving the general features of LLJs, yet many subgrid-scale phenomena important to air chemistry are still not adequately represented. Studies to date have focused primarily on the transport of ozone and particulates, whereas major questions remain regarding the types of precursors and the size distributions of aerosols advected along by the LLJ. Herein lies the impetus and opportunity for additional research.—RICHARD D. CLARK. “Low-Level Jets over the Mid-Atlantic Region during NE–OPS 1999–2002.” Fifth Conference on Atmospheric Chemistry: Gases, Aerosols, and Clouds.

**CROSS-TROPOPAUSE CONVECTIVE TRANSPORT OF WATER VAPOR**

The plumes above thunderstorms that are often observed in higher-resolution satellite images are successfully simulated by a convective cloud model. The analysis of model results indicates that the plumes form from water vapor that is injected into the stratosphere by the cloud-top gravity wave-breaking mechanism.

Nearly all previous studies of the transport of water vapor from the troposphere into the lower stratosphere focused on the isentropic diffusion. But recent observations of the plumes above some severe storms in midlatitudes point out the possibility of nonadiabatic cross-tropopause transport by the deep convective process.

We simulated this process using a 3D cloud dynamical model with explicit microphysics and use a few typical severe thunderstorms in the U.S. Midwest to illustrate this penetrating plume phenomenon. Analysis of the model results indicates that water vapor can be transported from the cloud into the stratosphere when the gravity waves caused by vigorous convection in the storm break. The breaking waves send water vapor through isentropic surfaces that are strongly distorted already by the updrafts. Once in the stratosphere, the water vapor moves largely along isentropic surfaces by upper-level winds and forms a structure resembling a chimney plume. Characteristics of the simulated plumes and those observed by satellites show good agreement, strongly supporting the proposed process.

This finding indicates that water vapor can be transported through the tropopause, which has often been considered impen-
etrate due to the strong stability of the overlying stratosphere. This could have important implications in global climate process and atmospheric chemistry. Water vapor is the most important greenhouse gas in the atmosphere and its radiative effect in the stratosphere is orders of magnitude higher than in the troposphere. In addition, water vapor in the stratosphere is the source for strong oxidants, such as OH and HOX radicals, which are related to ozone destruction. Recent observational studies indicate that the lower-stratospheric water vapor concentration increased by 1%–1.5% annually in the midlatitudes in the last 35 years. The mechanism proposed here may be a key process in the possible explanations for the observed trend.

If water vapor can penetrate tropopause by this mechanism, so can other chemical species, such as aerosol particles and CFCs, which are even less susceptible to the freeze-drying effect of the cold tropopausal temperatures. A preliminary simulation using the same model but for inert tracer transport by these storms shows that this is indeed the case.—PAO K. WANG. "Cross-Tropopause Convective Transport of Water Vapor: Model Study, Satellite Observation, and Implications." 14th Symposium on Global Change and Climate Variations.

**The Nano-Revolution in Observing**

Technological advancements in microelectromechanical systems (MEMS) have inspired a revolutionary observing system known as Global Environmental MEMS Sensors (GEMS). MEMS combine electrical functions with sensors and other mechanical devices embedded in semiconductor chips. GEMS would be an integrated system of MEMS-based probes that are mass produced at very low per unit cost in approximately 20 years. The probes would remain suspended in the atmosphere for hours to days and take measurements of pressure, temperature, humidity, and wind velocity as they are carried by atmospheric currents. In addition to gathering meteorological data, the probes could monitor the dispersion of particulates, pollutants, ozone, carbon dioxide, and chemical, biological, or nuclear contaminants. Once the probes settle out of the atmosphere, they could continue taking surface measurements from land or water.

GEMS will require integration of evolving technologies to make an observing system with scalability and applicability over a broad range of weather and climate phenomena. The system should expand our understanding of the earth system and greatly improve weather forecast accuracy and efficiency, helping weather-sensitive industries and mitigating against life-threatening weather.

The Phase I project, funded by the NASA Institute for Advanced Concepts (NIAC), focused on validating the viability of GEMS and determined the technologies that will enable future design and development of the system. For instance, probes may require various developments in biomimetics and nanotechnology, biodegradable materials, micro fuel cells and solar energy, free-space optics for communications, and autonomous self-healing networks (a form of artificial intelligence).

Assessing the optimum probe design and deployment strategy requires an interdisciplinary collaboration to examine complex trade-off issues such as the number of probes necessary for communication and networking, development and manufacturing costs, and the impact of probe observations on forecast accuracy. The framework for a simulation-design-test cycle was developed as a cost-effective and controlled way to explore the trade-offs. Depending on specific applications, the probes will be as small as 50–100 μm across and lightweight enough to pose virtually no danger to people or property. The size, mass, aspect ratio, component geometry, buoyancy control, and aerodynamic design will all determine how long probes remain airborne. Buoyancy control could be the most effective way to keep them suspended for extended periods of time.

The probes will communicate with other probes, remote receivers, and data collectors using radio and/or optical transmissions, forming a wireless mobile network (Fig. 1). A critical challenge for GEMS is to define a viable net-
working solution given available power and probe separation. In observing system simulation experiments, the assimilation of probe data substantially reduced errors and improved precipitation predictions in regional forecasts for a day with active convection over Florida. Excluding any of the GEMS variables substantially degraded the model’s forecast. For this case, the maximum data impact resulted when GEMS provided a full suite of temperature, moisture, pressure, and wind measurements.

For global coverage, as many as $10^{10}$ airborne probes may be necessary at any given time, assuming an average horizontal and vertical probe spacing of ~1 km from the surface up to about 20 km above ground level. With this many probes GEMS would generate $\sim 10^{12}$ observations per day, assuming measurements are taken once per hour. Observing systems expected in the next decade may collect data at a similar rate, necessitating significant advances in computing architecture, modeling and data assimilation, speed and bandwidth of communication systems, and data-management algorithms to support such systems.

Phase II of the GEMS project would involve detailed feasibility studies, including analyzing potential performance and cost benefits and developing a technology road map that will help NASA to integrate GEMS into future missions and/or programs.—JOHN MANOBIANCO (ENSCO Inc.), JONATHAN L. CASE, RANDOLPH J. EVANS, DAVID A. SHORT, AND KRISTOFER S. J. PISTER. “Global Environmental MEMS Sensors (GEMS): A Revolutionary Observing System for the 21st Century.” Seventh Symposium on IOS: The Water Cycle.
In April 1992, the U.S. House of Representatives Subcommittee on Investigations and Oversight of the Committee on Science, Space, and Technology held a hearing titled, “Projecting Science and Engineering Personnel Requirements for the 1990s: How Good are the Numbers?” chaired by Congressman Howard Wolpe. The hearing was described by a Washington Post report (Rensberger 1992) as follows:

“The familiar claim that the United States faces a major shortage of scientists and engineers—often cited by National Science Foundation officials when seeking budget increases—is false and was based on a seriously flawed NSF study,” seven scientists, engineers and government officials told a congressional subcommittee yesterday.

The hearings were acrimonious. Congressman Wolpe stated in the hearings that “one has a sense that the goal was to create the impression of a crisis to lend urgency to the effort to double the NSF’s budget.” Several days after the hearing, one witness, former NSF Director Eric Bloch, wrote to Congressman Wolpe: “Members of Congress, lawyers, and MBAs are not going to improve our competitive standing in the world. Scientists and engineers just might.” Commentator Daniel Greenberg viewed this remark as a “disdainful jibe . . . that would have been unthinkable if he were still director of the Foundation” (Greenberg 2002, 143).

Debate on this topic persists in the science and engineering community to this day (cf. Greenberg 2002). On the one hand, some scientists view criticism of supply projections as criticism of the practice of science itself, while on the other hand, some critics see calls for increasing the supply of scientists and engineers to reflect deeper issues in modern academia. Gover and Huray (1998, 11) provide a typical view of the latter perspective: “Research shows that today’s supply of Ph.D. candidates in science and engineering has less to do with the labor market for Ph.D.s than it has to do with the production needs of academia, for example, providing low-cost teaching and research assistants.” George Will (cited in Weinstein 1999) sees an institutional motive as well: "The [NSF] study in question argued that supplies of scientists and engineers would shortly decline in America and that this meant we had to increase production of people with these skills. This thesis was dubious at best, but, worse, the study made no estimates of job-market demands for scientists and engineers. Thus, the research completely forgot about whether these people were likely to find jobs."

Weinstein notes that while supply-side economics were politically in favor during the Reagan era, the approach was not a favorite among academics. He cites economist Paul Krugman, who makes an even stronger statement, "the supply-siders are cranks." Thus, the debate over NSF had a partisan element as well.

But politics aside, there were real issues about strategies of supply and demand in the analysis of the production of science Ph.D.s. Berliner and Biddle (1995) write:

"There is a crisis of overproduction of Ph.D.s and underconsumption of scholarship. To save money, schools rely increasingly on "gypsy scholars" drawn from the reserve army of unemployed Ph.D.s. They are hired on short-term contracts to teach but are not on the tenure track and denied health care and other benefits.

As these examples suggest, the subject is not only important, but also falls very close to the sensitivities of those who employ as well as those employed.

One of the primary criticisms of the study produced by NSF that ultimately led to the House hearings was that it focused on the "supply" of scientists with no consideration of the "demand" in the marketplace. Congressman Wolpe observed:

"The NSF study projected a shortfall of 675,000 scientists and engineers without considering the future demand for such individuals in the marketplace. It simply observed a decline in the number of 22-year-olds and projected this demographic trend would result in a huge shortfall. This could be termed the supply-side theory of the labor market analysis. But making labor market projections without considering the demand side of the equation doesn’t pass the laugh test with experts in our field."

(Weinstein 1999)

E. Weinstein is codirector of the Project on the Economics of Advanced Training (PEAT) in Science, Engineering and Related Disciplines of Harvard University and the National Bureau of Economic Research.

"See, e.g., the exchange of Bloch and Wolpe cited earlier."
The debate over the supply and demand of scientists in the 1990s had important implications for not only science policies, but also for immigration and labor policies (North 1995).

The debate over methodologies took on a new light when studies performed in the years following the Wolpe hearing indicated that there was in fact a glut of scientists and engineers. A highly respected 1995 study by Stanford’s W. Massey and RAND’s C. Goldman concluded that

Perhaps twenty-five percent of newly-minted doctorates end up unemployed. . . . The natural production rate of doctorates is driven by departmental needs [in universities] for research and teaching assistants, and departmental doctoral-student intake is limited by financial constraints rather than output market considerations. . . . Faculty tend to believe that more scientifically trained manpower is better than less, and that job opportunities will materialize somehow. . . . In any case, the department’s shortrun requirements for inexpensive research and teaching labor, and the desire of faculty to replicate their own skills, is of stronger relevance to admissions decisions than the more abstract and distant concept of labor market balance.

(Greenberg 2002, 145)

Others see fewer problems in an oversupply of scientific Ph.D.s in the job market. Weinstein notes “the question of whether the effects of a flooded market are good or bad for the nation is not at all clear and is frequently contested between even the most knowledgeable of analysts.”

What constructive guidance does the history of the debate over supply and demand of Ph.D.s provide to the atmospheric sciences community?

First and foremost, it suggests the importance of discussing supply and demand together. Any discussion of the “needs” for atmospheric sciences graduates, should also discuss the job market or societal needs for atmospheric sciences professionals. There are several professional societies who collect such information for their disciplines, among them the American Institute of Physics, the American Mathematical Society, and the American Chemical Society (see also the American Association for the Advancement of Science’s Next Wave); more information is available online at http://www.aip.org/statistics/trends/emptrends.htm, http://www.ams.org/employment/surveyreports.html, http://pubs.acs.org/cent coverstory/8031/8031salary.html, and http://nextwave.sciencemag.org, respectively. Based on the readily available examples of disciplines that do in various ways track demand, one recommendation for the atmospheric sciences community is that any effort to assess supply should be done in the context of also seeking to assess demand. Specifically, UCAR and the AMS should ensure that any future surveys that they undertake include characterization of demand, as well as supply (cf. Vali et al. 2002).

In 1997 Congressman George Brown diagnosed the implications of considering the production of Ph.D.s only in terms of supply:

The unthinking linkage of R&D to graduate education means that the number of Ph.D.s produced reflects the availability of academic R&D funding, rather than having a relationship to a set of national goals for science and engineering education. . . . The predictable result of this haphazard system is a series of surprises such as the current “overproduction” of science and engineering Ph.D.s. . . . Funding for federal R&D will not only not fix the problems in graduate education, but may make them worse. If true, the data indicates that broad science and engineering education reform is needed before we can discuss levels of funding.

(Brown 1997)

Following Congressman Brown’s suggestions, a more compelling focus than “shortfall” or “surplus” would be to first focus on the job market for atmospheric sciences graduates once they have left the university setting and then given an analysis of that market, to focus what sort of education and training might best serve the student and society broadly. During a 2000 workshop sponsored by the U.S. Weather Research Program (USWRP) on the research needs of the private sector, several participants noted that graduates in the atmospheric sciences are largely unprepared for private sector careers because they lack appropriate breadth in their education (USWRP 2001). A second recommendation is to recognize the importance for policy analyses in the atmospheric sciences to be grounded in the context of broader science and technology policy issues. Lack of awareness or acknowledgement of the earlier NSF-inspired debate on the supply of scientists could lead atmospheric scientists into a minefield of hot-button issues that have been considered in considerable depth in other parts of the science and engineering community.
Broader awareness of the degree to which such issues have been discussed, debated, and resolved outside of the atmospheric sciences would elevate both the quality of debate and corresponding policy recommendations. Debate of public- and private-sector roles and responsibilities is another area of discussion in the atmospheric sciences that suffers from an apparent lack of awareness of the broader science and technology policy context (cf. USWRP 2001).

The science and technology community generally experienced considerable loss of credibility in the early 1990s when a number of prominent figures claimed a looming shortage of scientists. Leaders in the atmospheric sciences are in a position to use experience to avoid such errors in future assessments of the labor market. In particular, considerable care must be taken in raising expectations of potential students and policymakers about the future prospects for employment.

REFERENCES


Meritorious Service Award for his work in the NWS, NOAA, and the WMO (where he served both as first director of the World Climate Programme and director of the World Weather Watch); the NOAA Administrator’s Award; and the USAF Legion of Merit for his service as vice commander of the AWS. Potter, who is a research professor emeritus in the University of Utah Meteorology Department, recently retired for the fourth time.

Vladimir A. Rakov has been elected an IEEE Fellow, effective 1 January 2003. Each year, following a rigorous evaluation procedure, the IEEE Fellow Committee recommends a select group of recipients for one of the institute’s most prestigious honors. Rakov, a professor in the Department of Electrical and Computer Engineering at the University of Florida, Gainesville, Florida, was honored for “contributions to the understanding of lightning discharge phenomena.”

Rakov received both his master’s and Ph.D. from Tomsk Polytechnic Institute in Russia. In 1977 he joined the institute as an assistant professor of electrical engineering. In 1988, Rakov took a 10-month sabbatical, funded by the U.S.–USSR Research Exchange Program, at the Department of Electrical Engineering, University of Florida, which led him to his current position of professor.

Along with IEEE and AMS, Rakov is a member of the American Geophysical Union, the Society of Automotive Engineers (SAE Aerospace), IEEE Power Engineering Society, and the IEEE EMC Society.

THE MAP ROOM

A Structured Process for Prediction of Convection Associated with Split Cold Fronts

By Steven E. Koch and Jamie D. Mitchem

A major severe weather event occurred 21–23 January 1999, resulting in 17 deaths, 150 injuries, and more than $1 billion in damage. This case far surpassed the records for the most tornadoes in any state on any day in January. An incredible 56 tornadoes were produced in Arkansas (the previous record for a single outbreak was 34). Millions of dollars of damage resulted from a severe squall line spawned by this storm system as it swept across the Southeast on 23 January. In addition, massive flooding aggravated by rapid snowmelt affected the Ohio Valley region as heavy rains fell over frozen soils for most of 22–23 January.

Weather Surveillance Radar–1988 Doppler (WSR-88D), Geostationary Operational Environmental Satellite (GOES) geostationary satellite, and Eta model analyses reveal that the vast majority of the severe weather occurred in conjunction with two split cold fronts and their merger in the midtroposphere (Fig. 1). A split cold front is characterized by cold, dry air aloft that advances ahead of the surface cold front by several hundred kilometers (Browning 1985). For this reason, variables such as wet-bulb potential temperature $\theta_w$ or equivalent potential temperature $\theta_e$ are often used to detect the presence of a split cold front. A cold front aloft (CFA) is quite similar to the split-front model, but according to Hobbs et al. (1990), a pressure trough (typically a dryline, or “dry trough”) replaces the surface cold front, giving rise to a warm occluded frontal structure. These nonclassical frontal systems are often prolific producers of heavy precipitation and severe thunderstorms, since they increase the potential instability and also provide for the lifting mechanism (the associated frontal circulation) to release this instability (Locatelli et al. 1995). The purpose of this brief article is to communicate the fact that the structure of split cold fronts can be diag-
nosed and predicted in real time by applying a systematic procedure that employs operationally available data, mesoscale numerical weather prediction (NWP) models, and special diagnostic tools, as follows:

1. Is there pronounced cold advection in the midtroposphere (~700 hPa) associated with a cloud band or rainband at least 200 km ahead of a surface trough or cold front? This feature is often most pronounced in the $\theta_w$ or $\theta_v$ field from a mesoscale model.

2. Is there a forecast band of strong upward motion associated with the cloud/rainband, and do vertical cross sections indicate that the upward motion band is one branch of a frontal transverse circulation in the midtroposphere?

3. Does GOES water vapor imagery show a pronounced dry wedge (slot) in association with strong isentropic descent diagnosed from mesoscale NWP model data?

4. Do WSR-88D radar velocity–azimuth display (VAD) winds show midlevel backing (indicative of geostrophic cold advection) above veering (warm advection)?

5. Does application of the thermal wind equation to retrieve geostrophic thermal advection from the VAD data (or wind profiler data) indicate pronounced cold advection in the 1.5–4.0-km layer? Such retrievals quantify the cold advection inferred from the often subtle backing wind patterns and make the advection patterns much more discernible to the forecaster.

This systematic procedure is demonstrated with the 21–23 January 1999 severe weather case. Surface frontal systems (Figs. 2b,d,f) included a stationary or warm front from Missouri eastward to Indiana, a dryline in eastern Texas and Oklahoma during the early part of this event, and two surface cold fronts in Texas. The location of these forecast frontal systems compared very well with what was observed (not shown). Comparison to the corresponding radar imagery shows that the strong convection was located several hundred kilometers ahead of the surface frontal systems throughout this event. Two split cold fronts are depicted in this figure (actually, the leading one was a CFA during the time that a dryline was present). The split-front analyses were obtained from a 32-km version of the Eta model forecast $\theta_w$ and wind fields at 700 hPa. The leading edge of the strong horizontal gradient of $\theta_w$ defines each split cold front, with the provision that lower values of $\theta_w$ were progressively advancing toward the ridge in $\theta_w$.

Potential instability was generated in a narrow region ahead of the dryline over Arkansas by 1800 UTC 21 January 1999 as the leading split cold front advected lower $\theta_w$ air over higher $\theta_w$ air near the sur-
FIG. 2. (a) Eta model 9-h forecast winds at 0000 UTC 22 Jan at 700 hPa (full barb, half barb, and flag = 5.0, 2.5, and 25 m s⁻¹, respectively) and wet-bulb potential temperature (1-K isotherm interval); (b) corresponding composite radar imagery. (c), (d) Same as (a), (b) except at 1200 UTC 22 Jan, and (e), (f) same as (a), (b) except at 0000 UTC 23 Jan. Forecast frontal features at 700 hPa, including split cold fronts, are shown using open pips. Surface fronts are denoted with conventional frontal symbols. Location of cross sections appearing in Figs. 3 and 4 is also depicted.
face, resulting in a sharp increase of convective available potential energy (CAPE). This is where and when intense convection, which produced numerous tornadoes as well as large hail and high winds, rapidly developed. The southern half of the first split cold front subsequently crept slowly eastward while the northern half advanced to the northeast. Meanwhile, a second surge of low $\theta_w$ air defining another split cold front advanced across Texas. This second split cold front began to merge with the first one by 1200 UTC 22 January (Fig. 2c), and as it did so, heavy precipitation leading to flash flooding developed.
along and northward of the merged frontal system (Figs. 2d,f).

A cross section of front-relative vertical circulation and relative humidity from Midland, Texas, to Macon, Georgia, shows two bands of strong rising motion had developed along the leading edge of each of the split cold fronts by 1200 UTC 22 January (Fig. 3b). A thermally direct frontal circulation was associated with active frontogenesis along each split cold front, with the rising branch of the circulation acting upon very moist, unstable air. These circulations combined into one large, deep region of upward motion 12 h later as the two split fronts merged (Fig. 3c). Relative humidity was maximized along or just ahead of the split cold fronts, followed by a surge of dry air. Isentropes sloped upward behind the analyzed split cold fronts (Fig. 4). Thus, the split cold fronts were not merely “humidity fronts,” but were actually the leading edge of colder air; nevertheless, the split fronts were most pronounced in fields of \(\theta_e\) or \(\theta_v\), as is usually the case.

Dry, stratospheric air descended to 700 hPa in association with a deep tropopause fold behind the second split cold front by 0000 UTC 23 January (Figs. 3c, 4c), accentuating the moisture contrast across the midtropospheric front. Isentropic analysis showed strong cross-isobar flow directed toward higher pressure in west Texas, indicating that rapid descent did indeed occur in association with the second split cold front. This developing “dry conveyor belt,” which is unmistakable in satellite water vapor imagery at 1200 UTC 23 January (Fig. 5a), propagated entirely around the upper-tropospheric trough to its eastern side and interacted with the intense squall line that formed over the Gulf states. The nature of this interaction consisted of the following enhancements to the severe convection environment: drying in the midtroposphere, a resultant increase in the potential instability aloft, and a doubling of the vertical wind shear magnitude in the 1000–500-hPa layer from that existing 30 h earlier. The resulting squall line displayed a characteristic leading convective line followed by a trailing stratiform precipitation region, as seen in the Fort Rucker, Alabama, radar display (Fig. 5b).
VAD winds from level-II WSR-88D radar data can be used effectively to detect the presence of split fronts. In each of several detailed case studies of split cold fronts performed by the lead author over the past few years, the dry air in the dry conveyor belt has not prevented determination of winds aloft using the VAD technique. Nevertheless, other sources of this information are available from the more sensitive wind profiler systems and GOES water vapor–derived winds in the midtroposphere. The VAD wind profile (VWP) product, which is a time–height display of the mean horizontal winds using the VAD technique, is well suited for detecting temporal changes in the vertical profile of winds. Geostrophic cold and warm advection can be inferred from the backing and veering of winds with height, but it is even better to compute the advection from the VWP layer mean winds and retrieved temperature gradients using the thermal wind equation. Analyses performed as the strong squall line impacted Fort Rucker (Fig. 6) clearly show the split cold front. The retrieved cold advection in the layer from 1.5 to 4.5 km, beginning shortly after 1000 UTC, occurred in direct association with a rear inflow jet behind the squall line (evident as a bull’s eye in the radial velocity isodop display, not shown). The extended region of most pronounced cold advection and the associated westerly momentum surge from the leading edge of the split cold front at 2.0 km at 1030 UTC to the 3.5-km level at 1300 UTC (a distance of ~150 km) suggests that the descending rear inflow jet was linked to the synoptic-scale cooling behind the nose of the split cold front.

In summary, the structure of split cold fronts can be understood in real time by synthesizing water vapor channel satellite imagery, isentropic and cross-sectional analysis of mesoscale model fields, and thermal retrievals and other products obtained from radar VWP data. Although thermal advections retrieved from the VWP wind data are not currently available in real time for operational use as a WSR-88D product field, they can be (and have been) computed offline in real time in a National Weather Service office with good results (e.g., Koch 2001). Increased use of Doppler radar retrievals in this manner would aid in forecasting the complex interactions between surface frontal features and fronts aloft leading to major outbreaks of severe weather seen in this case and others that have been documented in the literature.

**FOR FURTHER READING**

PAPERS OF NOTE

SYNOPTIC AND LOCAL FACTORS IN THE 1998 NORTHEAST ICE STORM

The ice storm of 5–9 January 1998 devastated regions of northern New York and New England, and southern regions of the provinces of Quebec, Ontario, and New Brunswick. This storm was unprecedented during the past two decades for this region, both in meteorological terms—it persisted for five days, and in Montreal, Quebec, for example, the 80–100 mm of freezing rain produced accreted radial ice loads—and in economic terms (approximately $4.4 billion damage). History shows, however, that the large-scale patterns associated with the 1998 storm were not unique, despite the lack of comparable freezing rain events in the record. This suggests that local details may have played a role in regulating the event.

With respect to persistence, the operational numerical model guidance was consistent in its depiction of the northward displacement with time of the freezing line from 5–10 January. The persistence of the surface-based cold air was tied to orographic channeling, in the absence of which, model sensitivity simulations suggest that little or no freezing precipitation would have occurred at some locations during the storm. The persistence of the cold air within the St. Lawrence and Ottawa River valleys also supplied a frontogenetical focus and modulated the intensity of the precipitation within the region. Model sensitivity estimates indicate that in the absence of the valleys, total freezing rain volumes would have been reduced by 12.1% and 16.5% in the first and second episodes of the storm, respectively. As a result, while operational forecasts of this event correctly identified the risk of freezing rain, the magnitude of the event was not anticipated.

Despite this finding, the intrinsic predictability of such events may be relatively high, because large-scale factors form an environment in which such cases frequently develop and the mesoscale focus is strongly linked to orographic forcing. Since the effectiveness of the orographic channeling is controlled by the synoptic-scale pressure field, however, an important sensitivity of this forecast is reflected in the position and magnitude of the cyclone–anticyclone couplet. Variations in this couplet would affect the component of the pressure gradient force along the valley and would have considerable impact on the persistence of the cold air, the associated frontogenetical zones, and the persistence, phase, and intensity of the resultant precipitation. Hence, any intrinsic predictability at the mesoscale can only be accessed through sufficient prediction at the larger scales. We will explore these issues in detail in a subsequent paper.—PAUL J. ROEBBER (UNIVERSITY OF WISCONSIN—MILWAUKEE) AND JOHN R. GYAKUM.

OROGRAPHIC INFLUENCES ON THE MESOSCALE STRUCTURE OF THE 1998 ICE STORM

ACCURACY OF RADIOMETER MEASUREMENTS OF HURRICANE SURFACE WINDS

Measurement of the hurricane surface wind field and, in particular, the estimation of wind maxima are important in both research and forecasting. One method of making such measurements is with NOAA Hurricane Research Division’s (HRD) Stepped-Frequency Microwave Radiometer (SFMR), which currently is flown aboard the NOAA WP-3D aircraft. Now, with the additional use of GPS dropsondes that complement this remote-sensing technique with in situ measurements, we are finally able to verify the accuracy of the SFMR measurements.

The first experimental SFMR surface wind measurements were...
made in Hurricane Allen in 1980 on board the NOAA WC-130 aircraft. Since that time the SFMR has undergone a number of design updates and has obtained winds on 95 flights in 30 tropical cyclones. For years, the only independent verification of SFMR wind data had been based on surface winds extrapolated from flight level. Collocated marine buoy wind measurements at hurricane force were extremely rare. The GPS sonde marked a vast improvement in the accuracy of wind measurements within the boundary layer. Since the use of the GPS dropwindsonde system in hurricanes was first initiated in 1997, routine collocated SFMR and GPS surface wind estimates have been made.

During the 1998, 1999, and 2001 hurricane seasons, a total of 249 paired samples were acquired and compared. The SFMR equivalent 1-min mean, 10-m level neutral stability winds were found to be biased high by 2.3 m s\(^{-1}\), relative to the 10-m GPS winds computed from an estimate of the mean boundary layer wind. Across the range of wind speeds from 10 to 60 m s\(^{-1}\), the rms error was 3.3 m s\(^{-1}\).

This research quantitatively demonstrates that winds estimated by the SFMR now represent an important operational tool for mapping the distribution of surface winds in hurricanes, and establishes an unprecedented independent validation of remotely sensed sea surface wind speeds from 10 to well in excess of 50 m s\(^{-1}\).

In addition to providing forecasters with a high-resolution distribution of surface wind data in hurricanes, the SFMR is showing promise as a research tool for studies of momentum exchange at the air–sea interface. The physical basis for the SFMR’s operation is the increased microwave emissivity of foam, whose coverage on the sea surface is assumed to increase monotonically with wind speed. In reality, however, foam coverage is a result of breaking surface waves, which is related not only to the wind energy input to the waves, but to the development of the waves themselves (the wave age). Results of this research show significant storm quadrant differences in SFMR winds relative to the GPS winds, which may indicate the possible effect of fetch length on wave development and subsequent breaking activity.—Eric W. Uhlhorn (University of Miami) and Peter G. Black. “Verification of Remotely Sensed Sea Surface Winds in Hurricanes,” in the January Journal of Atmospheric and Oceanic Technology.

**Better Tropical Storm Tracks from Models**

An enhanced objective method for detecting and tracking model tropical storms in atmospheric general circulation models (AGCMs) improves the tropical storm climatology and interannual variability. The method takes into account model biases and variability of storm statistics from one ocean basin to another, whereas previous detection/tracking algorithms monitored used global dynamical and thermodynamical thresholds determined from observed tropical storm climatologies.

Previous tracking algorithms connected nearby locations for which the model storm detection criteria were met for longer than some fixed time and produced tracks that were shorter than observed storm tracks. The new tracking algorithm extends these tracks forward and backward in time using relaxed threshold criteria, allowing the identification of model tropical storm formation and decay, as shown in the figure below.

Realistic tropical storm tracks are important for landfall studies, and the new tracking method may increase prospects of dynamical forecasting of seasonal hurricane activity. Routine seasonal forecasts of tropical storm frequency in different ocean basins are produced using statistical methods. The present study reinforces earlier results suggesting that dynamical

**Tracks of a storm in the (a) Atlantic and (b) western North Pacific using the new tracking (*) routine and the previous one (o).**
AGCMs and coupled hurricane activity using climate models is also a promising approach. Tropical cyclone–like structures are present in both AGCMs and coupled atmospheric–ocean models.

The new detection and tracking algorithms have been tested with several different AGCMs and are found to improve the climatology and interannual variability. The new algorithms are presently being used to identify model biases and to evaluate the skill of low-resolution AGCMs in forecasting seasonal tropical cyclone activity.—Suzana J. Camargo (International Research Institute for Climate Prediction) and Stephen E. Zebiak, “Improving the Detection and Tracking of Tropical Cyclones in Atmospheric General Circulation Models,” in the December Weather and Forecasting.

**Thundersnow climatology**

A climatology of snow events with thunder reveals that the central United States, the Intermountain West, and the Great Lakes are the preferred regions for “thundersnow” occurrence within the contiguous states. This is the first national climatology devoted solely to the occurrence of snow with thunder, and represents the first phase of a larger project to better forecast these kinds of storms.

We extracted reports featuring thunder with snow from 30 years of 3-hourly observations from the 48 contiguous United States. There were 229 individual reports comprising 191 thundersnow events.

Additional analysis of thundersnow events reveals a nationwide seasonal preference for occurrence in March, but no clear preference as to time of day. Most thundersnow events are typically reported at only one station, and only rarely in consecutive 3-hourly observations. These results reinforce the idea of thundersnow as a fairly brief, local event. In terms of intensity observed by the reporting station, the thundersnow events investigated in this study feature light snow about half of the time, with the remaining events split nearly evenly between moderate (25%) and heavy (23%) snowfall.

Most events (52%) form to the north of a midlatitude cyclonic storm system, while other event types include an orographic class, events that occur with a coastal cyclone, events associated with an Arctic front, lake-effect events, and those borne of upslope flow. A relative few snowstorms feature lightning and thunder, yet those that do, produce moderate to heavy snowfall about half of the time. At times, these snow events can also produce heavy accumulations in narrow bands, making forecasts of snow location as difficult as those of snowfall amount. Research is currently under way to better understand the environment that engenders thundersnow so that forecasts can improve.—Patrick S. Market (University of Missouri–Columbia), Chris E. Halcomb, and Rebecca L. Ebert, “A Climatology of Thundersnow Events over the Contiguous United States,” in the December Weather and Forecasting.

**Hydrologic Memory for ENSO signal**

The El Niño–Southern Oscillation (ENSO) affects the weather patterns across the globe. In North America it affects the precipitation...
and consequently all the terrestrial hydrologic processes. Runoff anomalies from the northern part of North America are most often negatively correlated with ENSO, and there are four distinct spatially coherent regions over the continent where the runoff anomalies are positively correlated. The terrestrial systems have a delayed response to the ENSO signal, as compared to the precipitation, and the delay may range from a month to a season or longer.

The shorter and longer delays are typically associated with rainfall-generated and snow accumulation and snowmelt processes, respectively. The influence of the ENSO signal on runoff is generally communicated through total soil moisture deficit, while near-surface soil moisture deficit is more coherent with the rainfall pattern. One hypothesis is that the relatively slower dynamics of terrestrial moisture storage serves as a memory in causing the delayed peak in runoff as compared to the precipitation. The soil moisture memory plays a very vital role in delaying the effects of the climate variability on the terrestrial hydrologic processes and in extending the influences of the El Niño or La Niña events on the terrestrial climate.

These results were obtained using a large area basin–scale (LABs) land surface model driven by the European Centre for Medium-Range Weather Forecasts reanalysis dataset for 1979–93. The entire continent was divided into 5020 basins for the simulation. Extreme runoff situations—including floods, of course—have many potential impacts, including ecological damage, so the analysis presented here enables us to localize the potential influences by ENSO. It may be possible to predict monthly, seasonal, or annual terrestrial climate for these areas based on the knowledge and capability of predicting ENSO.

—JI CHEN (UNIVERSITY OF ILLINOIS) AND PRAVEEN KUMAR. “Role of Terrestrial Hydrologic Memory in Modulating ENSO Impacts in North America,” in the 15 December Journal of Climate.

**Stratospheric Ozone Variation and Atmospheric Structure**

Interannual changes of dynamical structure and ozone in the stratosphere are shown to follow changes of the so-called residual mean circulation, the wave-driven meridional circulation of the stratosphere. The residual circulation regulates wintertime temperature and ozone. Changes of the momentum transmitted upward by planetary waves and of equatorial wind associated with the quasi-biennial oscillation represent anomalous forcing of the residual circulation. These anomalous forcings are shown to account for the major changes of dynamical

Anomalous wintertime tendency of Northern Hemisphere ozone (solid), as a function of year, compared against the tendency accounted for by anomalous forcing of the residual circulation and anomalous photochemical environment (dashed). Superimposed are years of unusually low spring ozone (solid circles).
structure and Northern Hemisphere ozone observed during the 1980s and 1990s.

Anomalous dynamical structure associated with those changes shares major features with the Arctic Oscillation. Both reflect a modulation of downwelling over the Arctic, with a commensurate change of the polar-night vortex. Anomalous downwelling over the Arctic is compensated at lower latitudes by anomalous upwelling. Operating coherently with these changes of stratospheric dynamical structure are changes of planetary wave structure in the troposphere. They are associated with an amplification of the ridge over the North Pacific and an expansion of the North Atlantic storm track.

Changes operating coherently with anomalous forcing of the residual circulation account for most of the interannual variance of Northern Hemisphere ozone during the 1980s and 1990s. What remains (about 20%) is largely accounted for by changes of photochemical environment, associated with volcanic aerosol and increasing halogens (see figure on previous page). During unusually cold winters, ozone decreases substantially below the climatological mean level. Yet it remains broadly consistent with the relationship established from the overall population of winters over the two decades.

Accounting for changes in ozone that are introduced through changes of the circulation will be essential to identify anthropogenic changes of ozone. —MURRY L. SALBY (UNIVERSITY OF COLORADO) AND PATRICK F. CALLAGHAN. “Interannual Changes of the Stratospheric Circulation: Relationship to Ozone and Tropospheric Structure,” in the 15 December Journal of Climate.

**INTERPRETING ETA MODEL SOUNDINGS**

Forecasters frequently examine numerical weather prediction model soundings as an important part of the forecast preparation process. In particular, forecast soundings from the National Centers for Environmental Prediction Eta Model are often used to evaluate the potential for convective activity. The Betts–Miller–Janjic (BMJ) convective parameterization used in the Eta Model introduces characteristic profiles of temperature and moisture. These structures are distinctive, and the trained eye can often readily recognize the “signature” of BMJ activity. Such recognition is important because these profiles often mask critical details of the vertical structure and affect the calculations of stability parameters that are often relied upon in predicting severe convection (convective inhibition, lapse rate, convective available potential energy, etc.).

As an example, consider the effect of BMJ shallow convection on a springtime forecast sounding (see figure). The distinctive “signature” of BMJ shallow convection can be seen in the 600–800-hPa layer. This can be characterized by linear decreases in temperature and moisture with decreasing pressure, often including an anomalous midtropospheric stable layer. The observed convective inhibition layer near 700 hPa was distorted by the scheme. Warming near the parameterized cloud base has apparently introduced an anomalous stable layer near 800 hPa, while cooling near cloud top induced an isothermal layer in the sounding near 600 hPa. The moisture profile was also altered. The scheme has dried the lower part of the cloud layer and moistened the middle and upper parts. The
ings. In addition, we provide several other “real-life” examples of forecast soundings affected by the BMJ convective parameterization in order to help forecasters recognize these characteristic profiles in their daily routine. —Michael E. Baldwin (CIMMS), John S. Kain, and Michael P. Kay. “Properties of the Convection Scheme in NCEP’s Eta Model that Affect Forecast Sounding Interpretation,” in the October Weather and Forecasting.

LIQUID WATER IN ARCTIC CLOUDS

Within a day or two brightness temperatures ($T_B$) in satellite microwave signatures over snow-covered sea ice in the Arctic region can vary by more than 30 K at 85 GHz. This variation can be seen in horizontal distributions of $T_B$s over a spatial scale of hundreds of kilometers, as well as in the $T_B$ time series observed at a single location. This warming frequently occurs in the Arctic Ocean, particularly over the regions where low-pressure systems often pass. The $T_B$ anomalies are significantly correlated with clouds and precipitation associated with low-pressure systems. This finding raises the possibility of using satellite microwave data to estimate cloud liquid water path and precipitation in the Arctic.

While the microwave $T_B$ warming is associated with cloudiness, the extra radiance that causes the warming comes from both the atmosphere and the surface. The atmospheric effect is due to cloud liquid water emission and the surface effect arises from the cloud-induced longwave heating to the snow/ice surface. Thereby cloud liquid water and surface temperature are the main contributors to the observed microwave $T_B$ warming. One interesting implication of the large $T_B$ warming is the indication that a significant amount of cloud liquid water exists in the polar clouds even during winter. A rough estimate suggests that the liquid water path of the clouds could reach 50 g m$^{-2}$ or higher at satellite pixel scale (~15 km) in some cases. Ground-based radiometer observation at SHEBA also indicates that the liquid water path can be as large as several hundred grams per square meter, which further emphasizes the importance of cloud liquid water in contributing to the microwave $T_B$ increases.

—Guosheng Liu (The Florida State University) and Judith A. Curry. “Observation and Interpretation of Microwave Cloud Signs over the Arctic Ocean during Winter,” in the January Journal of Applied Meteorology.
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