SATELLITES EMBARK ON COAST-MAPPING MISSION

The European Space Agency (ESA) has embarked on an ambitious new project to map coastlines from space. The CoastChart project, formally started in September, aims to produce by 2006 a specialized system that provides satellite-derived coastal data products suitable for operational use by hydrographic organizations.

Accurate up-to-date marine charts are essential for safe shipping navigation and for economic, environmental, and other management issues in the populous coastal zones. Ship- and air-based surveying campaigns by the various national hydrographic organizations provide maps of the sea as well as the littoral—the stretch of shore affected by the sea. However, the world has over 530,000 mi of total coastline, and coasts are always changing: sand and mud banks can shift hundreds of feet during a single year. Aerial surveying can cover hundreds of miles in a day, but is costly and can only be performed if weather conditions are right. Tropical and polar coasts may stay enshrouded in cloud and precipitation for weeks or months at a time.

Radar sensors such as the Advanced Synthetic Aperture Radar aboard ESA’s Envisat can measure surface roughness regardless of cloud cover as well as local darkness. CoastChart will involve synchronizing satellite sensors with the tides to accurately depict shoreline features.

“The textures of land and sea surfaces are quite different, so radar imagery shows coastlines very well in most cases,” says Professor Jean-Paul Rudant of the Université de Marne La Vallée in Paris, France, a pioneer of the use of radar imagery for coastal mapping and scientific advisor to the CoastChart project. “We began using

Acquired 24 Feb 2004 by Envisat’s Medium Resolution Imaging Spectrometer, the most striking feature in this image is the contrast between the desert areas of Senegal in the north to the vegetated coastal plains of Guinea-Bissau, The Gambia, and southern Senegal (shown in red on the image). The country of Guinea-Bissau also incorporates the Bijagos Archipelago. These islands lie off the coast opposite the River Ge'ba estuary. The Bijagos includes 15 large islands with numerous smaller ones. These are separated from the mainland and the capital Bissau, at the mouth of the river, by a 16-km channel. The green color of the sea around the islands is caused by sediment being swept out to sea from the river. To the north of the image in Senegal we can see clearly the “hook-shaped” Cape Verde peninsula. At the end of the peninsula is the country’s largest city and capital, Dakar.
VOTE OR STAY DRY?

Before the presidential election in November there was a lot of talk about the political influence of weather. But apparently its effect depends on where you live, as well as what kind of election is taking place. By examining temperature and precipitation records in Indiana and Kentucky for 20 primary and general elections between 1990 and 2000, the researchers found that Indiana voter turnout was more susceptible to weather than its neighboring state. “There was a statistically measurable influence of minimum temperatures on voter turnout,” says Greg Bierly, Indiana State geography professor. “The measurement was probably more significant for independent voters than it was for traditional Republican or Democratic voters.” Yet the 2004 election-day weather—with heavy rains in some places—did not seem to deter voters, who turned out in record numbers, and in some places waited in line for hours before voting.

raster data from Envisat’s predecessor satellites ERS back in the early 1990s to update maps of French Guiana. Coastal changes occur very rapidly but satellites make possible the easy updating of charts in a way that ships and aircraft cannot.”

The plan is to map 3700 mi of West African coastline covering 15 countries, extending from Senegal to the Republic of Congo. Paper and digital maps of the entire coastline will be delivered to a scale of 1:50,000, with 14 key sites, including harbors, maritime facilities, and river approaches, mapped at a very-high-resolution 1:15,000 scale.

“Participating in CoastChart is a means of testing how well Earth observation can meet our needs in delivering charting in this area,” says John Pepper of the United Kingdom Hydrographic Office. “By capturing coastal information, we will better be able to deliver solutions to users both on shore as well as at sea. For example, there is a growing interest in the detailed spatial mapping of coasts as a tool for environmental monitoring and managing marine resources, as shown by Europe fostering a major new strategy on integrated coastal zone management.”

The project is due to conclude in late 2006.

NEW SYSTEM ACCURATELY IDENTIFIES DRIZZLE

For the past two years, heavy freezing drizzle—appearing to be harmless light drizzle—cost airlines as much as $2 million in engine damage as jets waited for take-off in Denver, Colorado. A new system developed by Roy Rasmussen of the National Center for Atmospheric Research (NCAR) that accurately identifies the drizzle will be installed this winter in the Denver International Airport (DIA). Rasmussen hopes his research will enable airlines to revise pilot training and on-ground procedures to avoid future damage.

Rasmussen studied two cases of heavy freezing drizzle at DIA on 31 October 2002 and 31 October 2003. The two storms caused a total of $2.85 million in damage to 18 jet engines on United Airlines 737 aircraft. Trained meteorologists were on site throughout both events, but the freezing drizzle conditions were not accurately noted. In about half of all cases of freezing drizzle, the intensity is under-reported, according to Rasmussen.

Freezing rain falls past an idling jet engine, Rasmussen explains, but freezing drizzle falls at a much slower rate, so it gets sucked into the engine. The droplets freeze on contact, and the resulting ice builds up on the engine’s hub, or spinner. When the engine is revved up to takeoff speed, ice shards are thrown off the spinner into the rest of the engine.

In the two Denver storms, the major damage was to the delicate tips of the fan blades. If they’re damaged, Rasmussen says, the plane loses thrust, and hence lift, because the blades are not at the correct angle to produce the maximum thrust.

“Freezing drizzle is hard to see, and its intensity is hard to estimate visually,” says Rasmussen. “Often it goes undetected because the droplets are so small.” The typical droplet diameter is about half of a
millimeter, or half the thickness of a compact disc.

Rasmussen has worked with United Airlines to alert pilots of the hazard, and the airline has changed its procedures as a result of his research. Formerly, if an airport meteorologist observed heavy freezing drizzle, engines were revved close to flying speed (called an engine run-up) every 30 min to throw off ice.

"Now, if anyone says 'freezing drizzle,' they do engine run-ups every 10 minutes," says Rasmussen. "Airline people are sensitized to the possibility that freezing drizzle can cause engine damage."

The real-time freezing-drizzle detection system developed by Rasmussen and colleagues will be part of Weather Support for Decision Making (WSDM), a system now at DIA that offers minute-by-minute weather reports tailored to aviation users. WSDM data are displayed in a color-coded, user-friendly format that can be easily read by pilots and other nonmeteorologists. WSDM also provides data on snow and unfrozen rain.

**Strong Earth Tides Can Trigger Earthquakes**

For more than 100 years, scientists have wondered about the effects of the tides—the sloshing of waters caused by the gravitational pull of the Moon and Sun. Now University of California, Los Angeles, scientists show that earthquakes can be triggered by the Earth’s tides. Tides raise and lower stress on faults roughly twice a day.

"Large tides have a significant effect in triggering earthquakes," says Elizabeth Cochran, a UCLA graduate student in Earth and space sciences and lead author of the paper announcing these findings, in the November issue of Science. "The earthquakes would have happened anyway, but they can be pushed sooner or later by the stress fluctuations of the tides."

"Scientists have long suspected the tides played a role, but no one has been able to prove that for earthquakes worldwide until now," says John Vidale, a UCLA professor and interim director of the school’s Institute of Geophysics and Planetary Physics and co-author of the paper. "Earthquakes have shown such clear correlations in only a few special settings, such as just below the sea floor, or near volcanoes."

"There are many mysteries about how earthquakes occur, and this clears up one of them," Vidale says. "We find that it takes about the force arising from changing the sea level by a couple of meters of water to noticeably affect the rate of earthquakes. This is a concrete step in understanding what it takes to set off an earthquake."

Cochran, Vidale, and coauthor Sachiko Tanaka are the first researchers to factor in both the phase of the tides and the size of the tides, and are using calculations of the effects of the tides that are more accurate than were available just three years ago. Tanaka is a seismologist with Japan’s National Research Institute for Earth Science and Disaster Prevention.

Cochran and Vidale analyzed more than 2000 earthquakes worldwide, magnitude 5.5 and higher, that struck from 1977 to 2000. They studied earthquakes in

---

**ECHOES**

*El Niño is the main villain.*

—M. Rajeevan, director at the India Meteorological Department. Monsoon rains, necessary for the farm-dependent economy, were 13% below normal between 1 June and 15 September 2004, which Indian weather officials attributed to El Niño-like weather patterns.
“subduction zones,” where one tectonic plate dives under another, such as near the coasts of Alaska, Japan, New Zealand, and western South America. “These earthquakes show a correlation with tides because along continent edges ocean tides are strong,” Vidal says, “and the orientation of the fault plane is better known than for faults elsewhere.”

Cochran conducted a statistical analysis of the earthquakes and tidal stress data, using state-of-the-science tide calculations from Tanaka and the best global earthquake data, which came from Harvard seismologists. This research follows up on a 2002 study by Tanaka.

Cochran and Vidal found a strong correlation between when earthquakes strike and when tidal stress on fault planes is high, and the likelihood of these results occurring by chance is less than one in 10,000. They found that strong tides impose enough stress on shallow faults to trigger earthquakes.

Three-quarters of the earthquakes occurred when tides were very large—more than 2 m. In California and, in fact, most places in the world, the correlation between earthquakes and tides is considerably smaller, Vidal says.

In California, tides may vary the rate of earthquakes at most one or two percent; the overall effect of the tides is smaller, he says, because the faults studied are many miles inland from the coast and the tides are not particularly large.

**Universities Expand Degree Offerings**

In addition to a new climate program at Columbia University’s International Research Institute (see page 16), several other universities recently have added programs, some quite unusual, to meet growing needs in oceanography and meteorology.

The University of Rhode Island is expanding the possibilities for budding oceanographers with its new five-year graduate program in archaeological oceanography. Graduates will receive a master’s degree in history and a doctorate in oceanography, and the university is calling it the only program in the country that combines these two disciplines into one area of

---

*Geophysical Fluid Dynamics Fellowships at the Woods Hole Oceanographic Institution*

**2005 Program of Study in Geophysical Fluid Dynamic - June 20 to August 26, 2005**

Up to ten competitive fellowships are available to support graduate student participants in the ten-week 2005 Program in Geophysical Fluid Dynamics (GFD) at Woods Hole Oceanographic Institution (WHOI).

The aim of the program is to bring together graduate students and researchers from a variety of fields who share a common interest in the nonlinear dynamics of fluids.

The Program commences with two weeks of Principal Lectures on a particular theme. In 2005, this theme will be “Fast Times and Fine Scales”, and the lectures will be given by Joseph B. Keller (Stanford), George C. Papanicolaou (Stanford), and Eric Vanden-Eijnden (Courant Institute).

After the Principal Lectures, the Program continues with an intense schedule of seminars and discussions on both the topic of the summer and GFD in general.

For the graduate student fellows, the centerpiece of the program is a research project that each fellow pursues under the supervision of the staff. At the end of the program, each fellow presents a lecture and a written report for a proceedings volume. Successful applicants will receive stipends of $4,600 and an allowance for travel expenses within the United States.

The application deadline is February 15, 2005. Awards will be announced in April. Applications from women and members of underrepresented groups are particularly encouraged.

Further information and application forms may be obtained through the Academic Programs section of the WHOI web pages at http://gfd.whoi.edu/gfd_fellowship.html, or by writing directly to:

**The GFD Fellowship Committee**

Academic Programs Office, MS #31  
Woods Hole Oceanographic Institution  
266 Woods Hole Road  
Woods Hole, MA 02543-1541

Telephone: (508) 289-2219  
Fax: (508) 457-2188  
Email: gfd@whoi.edu  
Internet: http://www.whoi.edu/gfd

The GFD Program is funded by the National Science Foundation and the Office of Naval Research.

**Equal Employment Opportunity/Affirmative Action Organization**
COMING SOON: IN EARLY 2005!
“WeatherInfo”

The National Weather Station, a weather consulting and forecasting company in business since 1985, will launch our new weather data service; “WeatherInfo.” “WeatherInfo” is a service provided to the meteorologist and weather enthusiast. The service is provided to the user via internet delivery. Service includes current/observed data as well as model data including our own exclusive “in-house” model developed by our model expert called PCMM5. We will also have past data available for case studies/research/comparison.

DATA SERVICES INCLUDES:

**Model Data:**
- All NCEP models, European Suite and our exclusive PCMM5 model.
- All will have animation capabilities and specific location requests.
- The models will also be able to be displayed in text only format for specific locations such as 500 mb heights for Philadelphia for the next 10 days.
- Sounding generation capability.
- Customized model domain selection for real-time model (additional cost).
- Automated email of text forecast fields for specific longitudes/latitudes
- Hurricane applet with past/current hurricanes and NHC hurricane forecast models.
- Very functional, allows users to toggle on/off storms, models, etc.

**Current Observations:**
- Current surface observations in text format, image format or graphical table.
- Current radar with customized region selection (full looping capability)
- Current satellite with customized region selection (full looping capability)
- Current sea surface temperature plot
- Java applet allows user to toggle on/off current observations of wind, temperature, pressure, dew point, etc over a specific region. Much more functional than most other weather data services.

**Past Data:**
- Built up database of observations from ASOS/AWOS and other sites.
- Java applet for past data
- Past model data for case studies, research and comparison.

The service is offered in varied “tiers” of service with pricing based on the types of services required. Our service is the best on the web and our price is lower than our competitors!

1 week free trial available. Reserve your free demo now.

Price structure:
- Non profit/weather enthusiast hobbyist: $25 per month.
- Commercial Account: $75 per month. Up to 5 users.
- Deluxe Account: $195 per month, unlimited access/multiple user license.

For custom “area” models and more information on our exclusive PCMM5 model, call for details. Call now: 1-877-44-SNOWY… that is 1-877-447-6699 or 201-288-6890 or email us at storm1dv@verizon.net. Thank you!
study. The first five students in this program began their studies in the fall of 2004. “It’s a bringing together of two worlds that historically have not granted joint degrees,” notes program creator Robert Ballard. “They’re about as far apart as you can take two sciences and bring them into one.”

Besides the novelty of the program, it offers other unique opportunities. For one, students can work with the explorer who discovered the sunken Titanic in the North Atlantic Ocean—Ballard and his team did so in 1985. Also, Rhode Island voters recently approved the establishment of a $14 million Undersea Exploration Center that will be the headquarters of the new program. A main component of this facility will be the Inner Space Center, which will utilize satellite telecommunications technology to link to several exploration vessels around the world, providing students and instructors with live access to oceanographic expeditions.

“What Houston is to outer space, the Inner Space Center will be to undersea exploration,” Ballard says.

The University of North Carolina at Charlotte began a new bachelor’s degree program in meteorology in the fall of 2004. It will focus on three main disciplinary areas: air pollution, weather forecasting, and tropical meteorology. Coursework will include calculus, chemistry, oceanography, Earth science, physical geology, and physics. The school will graduate its first class of meteorology students in 2007.

“We’re really excited to offer this program,” says Brian Ether-}

EastFIRE Conference
May 11–13, 2005 at George Mason University, Fairfax, VA
http://eastfire.gmu.edu/workshop

The EastFIRE Conference brings together researchers, subject matter experts, technicians, vendors, and decision makers to share information on using remote sensing (RS), models and simulation, and decision support systems to better manage wildland fire in the Eastern United States. Planned publications from this conference include a peer reviewed book, a special journal edition and the proceedings.

The sessions planned for the conference are

* Fire occurrence, behavior and burned areas
* Climate variability and wildland fire
* RS and simulation models to assess social, cultural, and economics of Eastern wildland fire
* Fire and air quality in the East
* RS and modeling applications for fire, biodiversity, and species in the East
* RS and modeling applications for wildland fire in Eastern wildland urban interface
* Fire in Eastern states landscapes and watersheds
* RS and modeling applications for fire fuel treatments in the East
* Decision support systems for wildland fire management in the Eastern states

Join us to identify eastern states wildland fire challenges and opportunities.

Submit abstracts online by 31 January 2005 - Notification abstracts accepted: 14 February 2005
which in recent years has increased its recruitment of qualified meteorologists. The air force has allocated scholarship funding for potential students in the new program who meet qualification requirements.

Least traditional of all the new programs is the offering at Edith Cowan University in Australia: a course on surf science and technology—technically, the science of surfing. This unusual course educates students in both surfing (surfboard design and construction, surfing history) and the physical properties of the Earth that affect the surfer, including meteorology, waves and tides, and beach morphology. Approximately 60 students were enrolled in the course in the fall of 2004, on track for a bachelor of science degree.

"It's a broad degree, you can use it as a platform, go in whatever direction you want to take," says student Russell English.

HEAVENLY TINTS

Sliding through Earth's shadow, the Moon turned haunting shades of red and orange during the widely viewed total lunar eclipse of 27 October. The reddish hues are caused by sunlight scattered and refracted by the atmosphere into the Earth's otherwise dark central shadow region. Astronomer Fred Espenak (www.MrEclipse.com) recorded the images used in this composite photo. The image, viewed from right to left, shows the Moon at the beginning, middle, and end of totality, which lasted about 81 minutes.

PRODUCTS

PRESSURE TRANSDUCER

The Model 278 barometric pressure transducer by Setra Systems, Inc., was introduced at the AMS Annual Meeting in San Diego, California. The Model 278 transducer is used for the accurate measurement of barometric pressures and is ideal for the environmental extremes typically found in Automated Weather Systems (AWS) applications. It features a high-level output signal, has a fast, dynamic response, and proven stability and accuracy.

The Model 278 is designed with patented electronic circuitry and Setra's SETRACERAM variable-capacitance sensor, which is a symmetrical ceramic capsule that deforms proportionally to applied pressure. A standard element in many of Setra's higher accuracy transducers, the SETRACERAM sensor provides thermal expansion coefficient and low mechanical hysteresis, helping achieve long-term stability of 0.1 hPa full scale per year.

The rugged Model 278 is temperature-compensated for changes in temperature from −40° to +60°C with accuracies to within 0.3 hPa of the full-scale pressure range. The Model 278 is offered in three different absolute pressure ranges, and users can choose either a 2.5 or 5.0 V DC output with 9.5 to 28 V DC excitation. Energy efficient, the Model 278 consumes less than 3 mA of power during operation and wakes up in 1 s from sleep mode. Compact (3.6 in. × 2.4 in. × 1.0 in.), it fits push-on tubing and a power and data-logger connection.

For more information contact Setra Systems, Inc., 159 Swanson Road, Boxborough, MA 01719; 1-800-257-3872; fax: 978-264-0292; or e-mail: sales@setra.com. Visit Setra on the web at www.setra.com.
New Master’s Program at Columbia Fociues on Climate Impacts and Policy

A new interdisciplinary master’s program at Columbia University (CU) responds to the need for skilled professionals who can bring an understanding of climate science and forecasting techniques to policy implementation, especially in those parts of the world where people are most vulnerable to a varying or changing climate. The M.A. Program in Climate and Society welcomed its first class to CU’s New York City campus in September 2004.

Program Director Mark Cane, professor of Earth and climate sciences at CU, envisions the unique program as a vehicle for training a new generation of professionals who can interpret climate information for social and policy contexts. The program grows out of his observation that the key for policy makers is not only to learn how to apply the current scientific capacity for prediction, but also to establish the political will and institutional mechanisms to prevent disasters.

The specially tailored curriculum stands apart from more conventional master’s tracks by combining elements of established programs in Earth sciences, Earth engineering, international relations, politics, sociology, and economics. Core courses cover the dynamics of climate variability and climate change; regional impacts; quantitative methods for assessing social and natural phenomena; and an in-depth look at applied policy scenarios. During the summer, the final term of the 12-month program, an internship or research thesis is required.

Since 1993, the International Research Institute for Climate Prediction (IRI), which Cane helped to found, has offered short courses in topics related to climate variability and the use of climate information. These courses have been open only to students from developing countries. The new degree is an elaboration on these training workshops and on IRI’s unique mission to “enhance society’s ability to understand, anticipate, and manage the impacts of seasonal climate fluctuations, especially in developing countries.”

Several of the first students represent the IRI’s focus on capacity-building in the developing world. Diriba Korecha Dadi leads a weather forecast and early warning unit at the National Meteorological Services Agency in Ethiopia, a country vulnerable to malaria, drought, and soil degradation. He is part of a network of scientific professionals who advise governments on climate-related risks and mitigation strategies. After completing the M.A. Program in Climate and Society, he plans to focus on improving the network of meteorological information in Ethiopia, with an ultimate goal of contributing to Ethiopia’s long-term food security and self-sufficiency. A prestigious joint Japan/World Bank Graduate Scholarship covers Dadi’s travel, tuition, and living expenses to attend the institutional of his choice. The World Bank has provided these scholarships to students from developing countries since 1987.

Akong Charles Ndika is a journalist and activist with the nongovernmental organization Global Village Cameroon. A prolific writer on energy, sustainable development, and justice amid globalization, Ndika was drawn to the conjunction of economic development, awareness of fragile ecosystems, energy policy, and climate change policy addressed by the new Climate and Society degree. In a recent commentary on the Chad-Cameroon oil pipeline project, he observes, “Turning oil revenue into long-term benefits for the masses is the most contentious issue in resource-rich countries, particularly in Africa. Ultimately, this depends on the quality of public policy.”

Journals Online: Topping the Charts

Allen Press, which prints BAMS and hosts all AMS journals online (http://ams.allenpress.com), reports each month which articles receive the most “hits.” The following were the top five for October:

2. Understanding controls on historical river discharge in the world’s largest drainage basins. Earth Interactions, 8, 2.
With undergraduate degrees that range from economics to marine biology, U.S. students also express concerns about the environmental and socioeconomic impacts of climate change. Sibyl Nelson, a recent graduate of the University of Chicago, wrote her undergraduate research thesis on calculating black carbon emissions. Nelson is coming to the program "to concentrate on the effects of climate change, by learning how potential effects are predicted and by what means solutions could be implemented. As developing countries are projected to experience more dire impacts of climate change, I’d be interested in focusing on that part of the world."

Student research interests range from ENSO-related disaster mitigation to the diplomatic fine points of the Kyoto Protocol to the interaction of ocean and atmosphere in advancing forecast models. Students are especially looking forward to working with faculty and researchers at CU. New York City is home to a wealth of climate-related research and policy organizations—both IRI and the NASA Goddard Institute for Space Studies are affiliated with the Lamont-Doherty Earth Observatory and the Earth Institute at Columbia University. The presence of the United Nations and numerous policy organizations helped to draw quite a few students far from home.

The career trajectories for students who complete the program are likely to vary as widely as their own backgrounds. The program should impart an ability to understand, apply, and communicate climate information, which could be useful to policy advisers, public health officials, journalists, science teachers, water managers, tourism officials, risk analysts, and urban and regional planners. Midcareer students such as Diriba Korecha Dadi will return to their work with new insights. Some students might continue on toward a Ph.D. in a related field. Several students indicated they are treating this year as the first phase of a foray into Earth sciences, social sciences, or policy.

Undoubtedly, the first group of students will help to shape the program, as well as the significant set of climate and policy problems at hand.

—Abigail Schade, David Downie, and Mark Cane
M.A. Program in Climate and Society, Columbia University

### COIN-A-PHENOMENON #2: TERMS SIZZLE IN A HOT CONTEST

As the weather turns colder around the country, at the *Bulletin* we’re still thinking hot—at least in terminology. In the July issue we posted the “Heated Contest,” Coin-a-Phenomenon #2. The challenge: Come up with a term for a heat wave so severe, people will inevitably blame it on global warming. So bring out those fans you may have packed away for the winter and make yourself a nice tall glass of iced tea. We’re beginning to sweat just thinking about the results.

Let’s begin with the “therm” terms *Bulletin* readers sent in. There was *thermowave*, which Buzz Bernard felt captured the traditional heat wave notion and the connotation of something thermonuclear. There was also *thermeon* (“therm eon”), with the adjective form of *thermeonic*, from Bob Variz’s 13-year-old nieces Miranda and Alyssa Hanou of Pleasanton, California. Being twins they offered a twin term, *fryat*, which sounds positively sizzling in its adjective form, *fryatic*.

In the cross-breed category, one entry in particular conjured up the image of an actual dog: *copoodle*. Now there are, of course, the dog days of summer, but what Jerry Pell intended was a mix of “COP,” from the Conference of the Parties to the United Nations Framework Convention on Climate Change and “oodle,” being a reference to “googol,” which is a very large number (10 to the 100th power). Then there was *globalroast*, also from Bernard, which while we admit makes the mouth water, did not quite capture what we were aiming for. While we’re on the topic of cooking, it was inevitable that the old adage “out of the frying pan” would appear in some form. Nicholas Tito submitted *El Sarten*, which is Spanish for “the frying pan.” As he notes, “we have ‘El Niño’ and ‘La Niño,’ why can’t we have ‘El Sarten,’ the severe semiclimatic heat wave?”

In the “down under” category (and we don’t mean Australia), Kara Smith gave us just plain hell, which those in the midst of a heat wave would have to agree with. Ian Jollife, however, one-upped that with the term *HellNino*. However, since we at the *Bulletin* feel that El Niño gets enough blame globally for unusual weather patterns, the winner of Coin-a-Phenomenon #2 is Buzz Bernard’s *atmos-sear*. Blistering, searing, concise, you can feel the heat coming right off the word. Maybe Bernard can use his prize of the AMS *Glossary of Meteorology* to fan himself off.

While some of these terms had us chuckling, now we’re looking for some real laughs. For Coin-a-Phenomenon #3, instead of coining a term, send us your best (or worst) weather joke. We know they’re out there, we hear them all the time. What we’re looking for, along with humor, of course, is cleverness and originality. The one that gets the biggest laugh (or groan) will receive the Glossary (either the bound volume or on CD-ROM) or a book of equal or lesser value. Please send your entries to letterstotheaditor@ametsoc.org by 1 March 2005. The winners will appear in an upcoming issue of BAMS.
CLIMATE INDEX FOR WEST NILE VIRUS

The mosquito-borne West Nile Virus (WNV) has become a significant health threat in the United States. Very little has been known about the specific role that weather and climate play in transmission. We developed a simple climate model for the relative abundance of two mosquito species most commonly implicated in human infection in the central and northeastern United States. This model can explain more than 65% of the variance in the time of year when these mosquito species thrive.

The Culex species of mosquitoes appear to be the predominant vectors in the transmission cycle. The predominant WNV-positive species from field collections have been Cx. pipiens and Cx. restuans, especially in the central and northeastern parts of the United States. There is a well-documented seasonal shift in abundance from early-season dominance of Cx. restuans to late-season dominance of Cx. pipiens. The seasonal pattern of Cx. pipiens abundance precedes and parallels the temporal pattern of human cases, which primarily occur late in the season.

The basis for a climate index reflecting the risk of WNV transmission is a unique data set of mosquito population in east-central Illinois. This dataset consists of time series of the relative abundance of Culex restuans and Culex pipiens. Because data collection began in 1988, a wide range of climate conditions can be explored. The time of change (crossover) in relative abundance from Cx. restuans to Cx. pipiens varies greatly from year to year. Investigation of several thermal measures indicated that this variation could be related in large part to climate conditions with warmer temperatures correlated with later crossover dates. Models based on degree days (bases of 15°-20°C) and number of days that daily maximum temperature exceeded specified thresholds (27°-28°C) explained more than 65% of the variance.

The models developed here to estimate crossover date from climate data provide one component of an overall climate index for the risk of WNV transmission. Our long-term goal is to develop a complete climate index that would accurately reflect climate influences on the entire cycle of WNV, in order to be used in an overall risk model. A better understanding of the temporal variation in mosquito population dynamics will be important for developing vector and disease management programs.—KENNETH E. KUNKEL (ISWS) AND R. NOVAK. "Toward a Climate Index for West Nile Virus." 16th Conference on Biometeorology and Aerobiology.

FLIGHT ALTITUDES OF BIRDS

Daily and hourly variations in the flight altitudes of birds are related to a variety of factors, including weather. Previous studies have shown that the altitudes of soaring birds are strongly influenced by the convective boundary layer height and updraft strength. The flight altitudes of birds feeding on aerial arthropods may also be strongly influenced by weather, which affects the altitude distribution of their prey. We have conducted the first study to directly compare the influence of weather on the flight altitudes of birds using different flight strategies such as flapping flight or soaring and gliding flight.

Using the flycatcher radar with a fan beam antenna for selection and a pencil beam antenna for tracking of birds (Figs. 1 and 2), we were able to study and derive models of maximum flight altitude for a wide range of bird species, flight strategies and meteorological conditions. Results of our study are

---

**Fig. 1.** Flycatcher radar with fan beam antenna for echo selection and a pencil beam antenna for tracking of birds.
being applied to the development of a Dutch Bird Avoidance Model aimed at predicting the spatial and temporal distribution of birds in northwest Europe under changing environmental conditions. Several species were selected as representatives of different flight strategy groups including buzzards (Buteo buteo), a bird of prey using soaring flight; Eurasian swifts (Apus apus), flapping and gliding flight and obligatory aerial foragers; and black headed gulls (Larus ridibundus), an intermediate group using flapping or gliding flight. The relationship between maximum flight altitudes and meteorological variables from surface stations, radiosondes, numerical forecasts, and reanalysis gridded data were modeled using multiple linear regression.

Different combinations of weather variables explained 50%–90% of the variance in maximum flight altitudes. Factors that influenced flight altitudes of buzzards and swifts included temperature, relative humidity, cloud cover, boundary layer height, and lifted index. Flight altitudes of these birds increased with increasing thermal activity; however, the hourly dynamics differed per species. These birds were more strongly influenced by meteorological conditions than birds using powered flight during local movements. Black-headed gulls were influenced by meteorological conditions. During soaring and gliding flight weather had a much stronger influence on flight altitudes than during flapping flight.

Understanding the dynamics of the flight altitudes of birds above the landscape has important implications for several applied fields such as civil and military flight safety, bird conservation, risk assessment and mitigation particularly in relation to wind turbines, power lines and other tall features in the landscape. Models may be improved in the future by coupling them to numerical simulations of the convective boundary layer.—JUDY SHAMOUN-BARANES (UNIVERSITY OF AMSTERDAM), H. VAN GASTEREN, J. VAN BELLE, W. BOUTEN, AND L. BUURMA. “Influence of Meteorological Conditions on Flight Altitudes of Birds.” 16th Conference on Biometeorology and Aerobiology.

CORRECTIONS

In “Rotund Rain” (BAMS, October 2004, p. 1467), we incorrectly listed the institutional affiliation for Peter Hobbs. He works at the University of Washington. Hobbs also informed the Bulletin that the largest raindrops ever observed, reported in that article, will be included in the 2006 edition of The Guinness World Records.

In the news article, “Climate Record Extended by 300,000 Years,” that appeared in the November 2004 issue of BAMS (p. 1647), the location of the recently discovered ice core that extends the climate record was incorrectly identified. According to Stephen Hudson of the University of Washington, the core was made at Dome C (Concordia Station), Antarctica, approximately 500 km east-northeast of Vostok.
**IMPROVING COASTAL RAINFALL ALGORITHMS**

We used the abundance of radar data now available, particularly from the space-based Tropical Rainfall Measuring Mission (TRMM) Precipitation Radar (PR), to devise an improved method for identifying coastal rain using microwave data. Our results indicate that the method developed in this study increases the estimated rainfall in tropical coastal regions and gives better correspondence with radar compared to the previous algorithm version, which should result in improved coastal rainfall predictions.

This project involved updating the coastal rain identification procedure for satellite microwave rainfall algorithms used for official NASA products based on TRMM Microwave Imager (TMI) and Advanced Microwave Scanning Radiometer-EOS (AMSR-E) microwave data. Two major improvements are made. The first involves identifying conditions where non-zero rain rates should be estimated rather than leaving the areas with an 'ambiguous' classification. The second is a modification of the rain/no-rain classification procedure from a brightness temperature cutoff to a polarization-corrected temperature (PCT) criterion that is less sensitive to the surface conditions.

We were motivated by a deficiency over coastal areas in recent TMI and AMSR-E products. As the separate land and ocean components of microwave algorithms have improved over several years—a result of many ongoing research efforts (the current land algorithm is based on our recent work)—the coastal component has remained virtually the same. Meanwhile, the algorithm is applied to different microwave sensors than the Special Sensor Microwave/Imager (SSM/I) for which the original coastal method was developed over 10 years ago. As a result, the performance of the global algorithms is worse over the coast than over land and ocean.

This work was done specifically for TMI and AMSR-E. In particular, the modifications are made for the TRMM Version 6 product release and the third (1 Sept) release of AMSR-E products to the public, both in 2004. Further testing needs to be done to apply these changes to SSM/I. Additional future work on the coastal component of the TMI rainfall retrieval algorithm will deal with the use of the polarized corrected temperature (PCT) to estimate rainfall rates, as this study deals with rain identification only and uses existing methods for rainfall rate estimation. This work in microwave coastal rainfall estimation has practical importance in applications that affect people and property; for example, these coastal rainfall estimates are used directly in some prediction methods for land-falling rainfall from tropical cyclones. —JEFF McCOLLUM (UNIVERSITY OF MARYLAND) AND R. FERRARO. “Status of AMSR-E Land and Coastal Rainfall Algorithms.” 13th Conference on Satellite Meteorology and Oceanography.

**SUPERROBBING FOR ATMOSPHERIC MOTION VECTORS**

Atmospheric motion vectors (AMVs) from geostationary and polar-orbiting satellites have benefited almost every operational numerical weather prediction (NWP) center that assimilates them. It has been suspected, however, that spatially correlated error

---

**DRINK JUICE, HELP HURRICANE RECOVERY**

The next time you have a glass of orange juice, you’re not just helping yourself. According to television advertisements by the Florida Citrus Commission, “Every glass you drink is helping rebuild Florida.” The juice ads show the names and dates of the three hurricanes—Charley, Frances, and Jeanne—that hit the citrus-producing areas (Hurricane Ivan struck farther north and west). The hurricanes made this the smallest orange crop in 11 years—and the smallest grapefruit crop in more than 60 years—according to the U.S. Department of Agriculture.
Inherent in the derivation of the vectors limits their impact.

To alleviate this error, most centers thin AMVs, lowering the spatial resolution of the winds and the effect of the correlated error. Although thinning addresses the problem in a computationally inexpensive way, it throws out a high percentage of the winds. As an alternative, a superobbing scheme was tested at the (U.K.) Met Office. Superobbing involves averaging the difference between observations and their collocated backgrounds within a three-dimensional box and assimilating this superobservation in lieu of the component winds. This method reduces the data volume as thinning does, but the averaging process also reduces the random error within the AMVs.

To test the impact of superobbing, forecast impact experiments were run for 24 days in January and February 2004 in the Met Office’s global NWP system. In these experiments, the AMVs were superobbed in 2° × 2° × 100 hPa boxes. The observation error was reduced to account for the reduction in random error. These experiments were compared with a control run that was identical except the AMVs were thinned to the same resolution instead of being superobbed. Superobbing showed some skill in the Northern Hemisphere for medium range forecasts and generally showed neutral to slightly negative impact in the tropics and the Southern Hemisphere (see figure).

This work’s mixed results raise some important questions about AMVs. Is the reduced random error from superobbing sufficient to overcome a possible degradation in the analysis from superobbing. Is the quality control used for thinning the optimal quality control for superobbing as well? How well do NWP centers and data providers understand the errors in the winds? How well do AMVs capture the actual wind in high gradient regions where the data are most useful? Each of these questions is important and must be addressed in subsequent research.—Howard I. Berger (University of Wisconsin/CIMSS), M. Forsythe, J. Eyre, S. Healy, and C. Velden. “A Superobbing Scheme for Atmospheric Motion Vectors.” 13th Conference on Satellite Meteorology and Oceanography.

**Satellite-based Nowcasting of Convective Initiation**

Forecasts of convective initiation over the 0–1-h time period using operational GOES satellite data are expanding toward 1–2-h predictions of lightning. Now a method that addresses first lightning initiation is under development.

Few studies address the prediction of lightning initiation, flash rates, or scales. The relationships between total lightning, radar echoes, and satellite-observed clouds are poorly understood. It is known however that charge separation is related to freezing altitude and the depth of the cloud above that altitude. Updraft width and strength likewise affect the mass of suspended graupel and ice hydrometeors. Our project aims to develop and exploit relationships between
Nowcasting of convective initiation and lightning initiation can use a methodology incorporating (1a) visible imagery, (1b) cloud-motion tracking vectors, (1c) cloud-top cooling rates $\frac{\delta(10.7 \mu m)}{\delta t}$, and (1d) a convective initiation forecast made at 2045 UTC 6 July 2004, valid at ~2130 UTC. Panels (e and g, f and h) show thunderstorm development (>35 dBZ echoes) and lightning flash numbers between 2045 UTC and the 2132 UTC valid time.

Satellite-observed cumulus growth and known lightning behavior, with an understanding that cumulus—lightning relationships vary significantly across convective regimes (e.g., midlatitudes, tropics, and mountains).

Our nowcasting approach combines National Weather Service (NWS) WSR-88D radar, GOES 1-km visible and 4-8-km infrared data, and “total lightning” data (intra-cloud, cloud-to-cloud, cloud-to-ground) from the NASA Marshall Space Flight Center’s North Alabama Lightning Mapping Array (LMA). The LMA uses 10 ground detectors, operating at 1/80th-second frequencies, to provide extraordinary three-dimensional views of lightning. One unique aspect of this research entails monitoring the evolution of 1-km-resolution cumulus as they grow, glaciate, precipitate and produce lightning.

We use several aspects of the GOES data stream to form satellite infrared—LMA lightning relationships: cloud growth rates via trends in cloud-top temperatures, as well as inferences of glaciation using multiple satellite channels. Figure 1 demonstrates the algorithm’s capability for identifying rapidly developing cumulus clouds.

Using remote sensing to forecast lightning events prior to storm development has obvious benefits to many sectors of society. Farmers, pilots, utility workers, and outdoor enthusiasts stand to gain critical warnings of lightning as a result of this research. The plan is to operate a real-time convective initiation and lightning initiation and intensity nowcasting algorithm for the continental United States to support NWS and aviation weather forecasting.—JOHN R. MECIKALSKI (UNIVERSITY OF ALABAMA), S. J. PAECH, AND K. M. BEDKA. “Correlating Satellite Infrared Trends, Total Lightning Flash Rates, and Rainfall to Convective Initiation, Development, and Evolution.” 13th Conference on Satellite Meteorology and Oceanography.

AMSU-A Radiance Assimilation for U.S. Navy On 9 June 2004, the Naval Research Laboratory Atmospheric
FIG. 1. (left) Southern Hemisphere and (right) Northern Hemisphere 500-hPa height anomaly correlation vs. forecast hour for 16 July to 30 Sept 2003. The test run (AMSU-A) includes NAVDAS assimilation of AMSU-A radiances, while the control run assimilated NESDIS ATOVS retrievals with NAVDAS. 120-h forecasts were improved by 14 h in the Southern Hemisphere and 6 h in the Northern Hemisphere.

FIG. 2. Time series of Southern Hemisphere 500-hPa height anomaly correlation comparisons for the 96-h forecasts for 16 July to 30 Sept. AMSU-A assimilation is better than ATOVS retrieval assimilation at the 99.5% confidence level.

Variational Analysis System (NAVDAS) began operational assimilation of Advanced TIROS Operational Vertical Sounder (ATOVS) radiances for the Navy Operational Global Atmospheric Prediction System (NOGAPS). ATOVS consists of the Advanced Microwave Sounding Units (AMSU-A/B) and High-Resolution Infrared Sounder (HIRS/3). The assimilation of the satellite-based AMSU-A radiances, which replaced the assimilation of NESDIS ATOVS temperature retrievals, substantially improves the height, wind, and temperature forecasts for both hemispheres at all forecast lengths. Verification statistics indicate forecast improvements of 6–14 h (Fig. 1), with significantly fewer forecast “busts” (Fig. 2). Tropical cyclone track forecasts, critically important to the U.S. Navy, show error reductions up to 25 n mi (see Fig. 3).

Successful radiance assimilation requires careful channel selection and quality control. Channels that peak at altitudes above the model top, or with strong sensitivity to the land surface temperature or emissivity, are not assimilated. Channels with strong contributions from clouds and water vapor are used only for quality control. Over oceans, brightness temperatures affected by cloud liquid water (CLW), precipitation, mixed fields of view, or sea ice are rejected. Bias correction is essential, as the differences between the observed and forecast brightness temperatures are often larger than

Fig. 3. As in Fig. 1, but for the comparison of the mean tropical cyclone track error vs. forecast hour for the month of September 2003. Verification was against the Joint Typhoon Warning Center “best track” positions. The numbers below the forecast time are the total number of forecast tracks for the month used in the comparison. The results over all three basins (Western Pacific, Eastern Pacific, and Atlantic) are statistically significant at between 75% (2-day forecast) and 98% (3-day forecast) confidence levels.
Planned improvements include increased use of AMSU-A over land, and assimilation of HIRS/3 and AMSU-B. The successful assimilation of AMSU-A radiances has prepared the U.S. Navy to effectively utilize the vast amounts of future satellite data from future U.S. and European polar-orbiting satellites programs.—NANCY L. BAKER (NRL) AND W. F. CAMPBELL. “The Impact of AMSU-A Radiance Assimilation in the U.S. Navy’s Operational Global Atmospheric Prediction System (NOGAPS).” 13th Conference on Satellite Meteorology and Oceanography.

**Morning versus Evening Rainfall across the Globe**

Precipitation information is critical in understanding the hydrologic cycle on a global scale and in understanding the complex interactions among the small and large-scale components within the global hydrologic cycle. By using global satellite measurements, we are working toward an understanding of the effects of the El Niño/Southern Oscillation (ENSO) on the magnitude, distribution, and diurnal cycle of global and regional precipitation. Results so far graphically illustrate the tremendous variability of these precipitation characteristics across the planet.

We analyzed 16 yr of passive microwave observations from the Special Sensor Microwave Imager (SSM/I), an instrument aboard a succession of Department of Defense polar-orbiting satellites.

---

**Fig. 1.** Rain estimates for 1800 LT minus 0600 LT for the period July 1987 to Dec 2003.

**Fig. 2.** Rain estimates for Oct–Dec 1997 (El Niño) minus Oct–Dec 1988 (La Niña).
Rainfall estimates based on these data were stratified into 0600 and 1800 local time (LT) components. We suggest that the difference (1800 LT - 0600 LT) can be used as a proxy for the amplitude of the diurnal cycle.

In Fig. 1 we show an example of the diurnal amplitude of rainfall, globally from 60°N to 60°S. The differences between the afternoon maxima over land and the morning maxima offshore are striking, in particular over the islands that comprise the Maritime Continent. These results suggest intense land–sea circulations, as well as enhancement of precipitation due to elevated terrain. A preference for morning rainfall is noted over virtually all open-ocean areas. Prominent morning maxima are often found along concavities in the coastline, for example in the Gulf of Panama and the Gulf of Guinea (Africa), quite possibly two of the rainiest spots on the planet. Late afternoon maxima are the rule over land, with some notable exceptions: along the northern coast of Brazil, the diurnal effects of coastal squall lines are evident, as is the mountain–valley circulation associated with the Andes Mountains. A preference for morning rainfall over the U.S. Midwest is also noted.

To examine the rainfall differences between El Niño and La Niña, we choose Oct–Dec of 1988 (La Niña) and 1997 (El Niño), the two strongest events in the period of SSM/I data record. The difference between these two extremes is presented in Fig. 2. The main features of this analysis include the decrease (during El Niño) in precipitation over the Maritime Continent and the South Pacific Convergence Zone, as well as over Amazonia, equatorial Africa, and the midlatitude Pacific Ocean. Increased precipitation during El Niño is found over the Intertropical Convergence Zone, U.S. Southeast, Indian Ocean, and southern Brazil.

In future work we hope to examine the hypothesis that the amplitude of the diurnal cycle will be affected by ENSO variations, due to its unequal effect on land and ocean.—ANDREW J. NEGRE (NASA/GSFC LABORATORY FOR ATMOSPHERES) AND COAUTHORS. "A 16-Year Climatology of Global Rainfall from SSM/I Highlighting Morning Versus Evening Differences." 13th Conference on Satellite Meteorology and Oceanography.
ECHOES

"It seems like Mother Nature is throwing everything at us."

—MATT LEINERT, quarterback for the University of Southern California (USC) football team, after a victory in November over Oregon State at Corvallis, Oregon, in a fog that was so thick at times that it was difficult for players to see the ball in the air. The previous week, USC played through a hailstorm in a game against Washington State in Pullman, Washington. The conditions in the fog game created difficulty for the teams, the coaches, and the reporters covering the game. "Early in the game, I felt very uncomfortable about making the calls because I couldn't tell who they had in the game," said USC head coach Pete Carroll. Meanwhile, radio announcer Pete Arbogast was forced to descend from the press box and broadcast the game from the sideline.

A few predictions consider the immature stages of mosquitoes, while the population of the insects is significantly controlled by their development and survival in the aquatic stage. The temperature distribution of shallow waters is an important parameter determining the growth and development of mosquito larvae living in the surface layers. In particular, the daily variation in thermal distribution caused by solar radiation and turbulent heat exchange affects the growth rate of mosquito populations, such as the malarial Anopheles spp. However, information about these relationships in the population dynamics of mosquitoes is not available. By necessity, current epidemiological models use data on adult mosquitoes, but this rarely reflects on the dynamic processes of population regulation as determined by larval conditions.

We recently started a fundamental study of the effects of the physical environmental on aquatic stages of malarial mosquitoes. Our first experiments involved a small artificial body of water (1-m diameter, 0.4-m deep) at our meteorological observatory in Wageningen. In an example of our measurements (see figure, previous page), the daytime stable stratification can clearly be observed, which is mainly caused by the near-infrared absorption in a thin water layer at the water–air interface and the extinction of the visible light within the water body. During nighttime, however, a well-mixed layer develops starting at the water–air interface, which is mainly caused by radiative cooling and nighttime evaporation at the water surface.

Experiments were scheduled to start in November 2004 in the Tropics near the Kenyan Medical Research Institute in Kisumu during their spring season. Here, the temperature behavior in natural small water bodies formed by, for example, animal footprints and tire tracks, will be studied. It appears that the larval population develops especially well in these small and very muddy water bodies.


**DIURNAL CYCLE IN THE NORTH AMERICA MONSOON**

Variations of cloudiness and precipitation associated with the North American Monsoon System (NAMS) are dominated by the diurnal cycle. This finding comes from a comprehensive diagnostic

![Fig. 1. Time series of mean precipitation (mm day⁻¹) averaged over a spatial domain from 22°–32°N, 5° west and east of the Sierra Madre Occidental mountain range for a 6-month period from 1 May to 31 Oct 2003. The top panel shows the results for a sub-period of 6 days, while the bottom panel presents time series for the entire period.]
study of the temporal and spatial structure of NAMS clouds and precipitation over the summer of 2003.

We used the NOAA Climate Prediction Center morphing techniques (which essentially take satellite microwave data and move it using the IR information) and the three-dimensional precipitation data observed by the TRMM Precipitation Radar. The data were used to compute 3-hourly fields of cloud amounts and mean precipitation on a 0.25° lat/lon grid over a spatial domain of 22°–32°N; 120°–90°W for a 6-month period from May to October 2003. We composited time–longitude sections of mean cloudiness and precipitation relative to the crest of the Sierra Madre Occidental (the range extending southward from Arizona along the northwest coast of Mexico).

The phase of the diurnal cycle is relatively stable, while the magnitude presents changes on synoptic and intraseasonal time scales, suggesting connections between local convection and large-scale circulations (Fig. 1). Orography plays an important role in the formation and development of the NAMS cloud and precipitation systems: clouds and precipitation start from higher elevations in the morning and move toward the coast as they reach maximum in late afternoon (Fig. 2). As a result of the cloud system developments, the maximum of higher clouds is west of that of lower clouds. The position of deep convection and precipitation is about 50–100 km west of the Sierra Madre crest (Figs. 2 and 3).

Further work is underway to extend the examination to other years and to investigate the relationship between changes in diurnal cycle and large-scale circula-

![Fig. 2. East–west section of 3-hourly mean cloudiness (%) and precipitation (mm day⁻¹) averaged for a 6-month period from May–Oct 2003 over a spatial domain from 22° to 32°N relative to the crests of the Sierra Madre Occidental, together with the mean elevation (bottom).](image1)

![Fig. 3. For same domain as Fig. 2, height–longitude section of mean precipitation observed by TRMM precipitation radar.](image2)

MODELING BEETLE MOVEMENT BY WIND

The mountain pine beetle outbreak in the central interior of British Columbia is growing exponentially and has reached epidemic proportions, affecting 4.2 million hectares of forest and timber valued at $13 billion. This is enough lumber to construct 5.2 million homes, three times the annual number of U.S. housing starts. In British Columbia, mountain pine beetles emerge in vast numbers from the bark of host pine trees after they have reached biological maturity on days during July or August in which the air temperature is between 25° and 30°C. Upon emergence, the beetles seek new host pine trees to colonize and produce larvae, relying on massed attack to overwhelm tree resistance.

A successful attack leads to colonization and subsequent tree mortality. The northward range of the mountain pine beetle is limited by the annual –40° minimum temperature isotherm. Historically, the beetle’s range has been mainly limited to the west of the Canadian Rockies, however in 2002 new areas of infestation appeared to the east of the Rockies in northeast British Columbia, raising concern that the epidemic could spread to the Jack Pine forests of central Canada. The beetle’s short-range movements (within a few km) in the forest canopy, seemingly in search of hosts, have received considerable attention. Movements above the canopy (on the order of hundreds of km), in which the beetle is largely advected by the mean wind, have largely been ignored even though they are mostly recognized as important for rapidly spreading the infestation, especially during epidemics.

We therefore focused on the above-canopy transport of the mountain pine beetle by the wind. The Colorado State University Regional Atmospheric Modeling System (RAMS) is used to numerically simulate the atmosphere at 1-km horizontal and 25-m vertical resolution during periods of peak beetle emergence. We used the RAMS output to develop back trajectories from areas of known infestation east of the Rockies in 2002. The trajectories indicate that a mountain pine beetle flying at altitudes of around 1 km above ground had the potential to cross from the main infestation west of the Rockies to the new infestation east of the Rockies in 2002. The simulations give a better understanding of the between-stand movement of MPB, and can therefore give a more complete picture of the historical and future redistribution of the MPB population.—PETER L. JACKSON (UNIVER-
ECHOES

"You can think of the tax as a low-cost insurance policy that protects against climate change. The policy premiums could be used to develop alternative energy technologies."

—MICHAEL SCHLESINGER, professor of atmospheric sciences at the University of Illinois, Urbana-Champaign. He coauthored a paper that called for a rising tax on gasoline over the next 30 years that would allow for immediate mitigation of climate change, rather than the wait-and-see strategy suggested by many policy makers. The researchers suggest a tax starting at $10 per ton of carbon—equivalent to five cents per gallon of gasoline—and increasing to $33 per ton in 30 years.

now we have modeled UVB irradiance across a horizontal domain at the base of the crowns under the full range of cloud conditions from clear to overcast (CLR, FEW, SCT, BKN, OVC, as used in U.S. National Weather Service Automated Surface Observing System reports). We used a 3D-canopy-radiation-transfer model and assumed that urban tree cover could be represented by a regular array of spherical tree crowns with differences in the cover established by varying the radius of the tree crowns. The modeling showed decreased spatial mean erythemal irradiance (radiation weighted by the spectrum for sunburn effectiveness) at pedestrian height as tree cover increased, but the irradiance was similar for all cloud classes up to overcast (OVC; see figure). Using tree cover determined by a field survey in Baltimore, Maryland, we estimated that for people walking in high-building-density residential land-use class, where tree cover averages 20%, UVB exposures would be 27%–29% higher than in the low- to medium-density residential land use class, where tree cover is 32%. In the open away from trees, the erythemal irradiance exposure with 4 octas (SCT) or less of cloud cover is not remarkably different from that under clear skies, but exposure decreases significantly with broken cloud cover (BKN, 5 to 7 octas). In tree shade, the modeled irradiance under partly cloudy (FEW and SCT) conditions was as great as or greater than under clear skies.

Thus, urban planning and epidemiological studies could benefit from knowledge of tree influences on UVB radiation. Future work will be directed toward additional model verification by measurements below and above urban tree canopies and the inclusion of buildings in the modeling. Another need is to develop illustrations for public education of tree shade patterns using the 3D radiation transfer model.—GORDON M. HEISLER (USDA FOREST SERVICE), RICHARD H. GRANT, AND WEI GAO. "Impact of Sky Conditions on Erythemal UV-B Exposure under Tree Canopies." 16th Conference on Biometeorology and Aerobiology.

UV EXPOSURE IN THE SHADE

Overexposure of people to solar ultraviolet radiation (UVB) is a widely recognized health hazard. One way to avoid excess exposure to UVB is to seek shade during the high-radiation portions of the day. In some conditions, however, the UVB exposure in the shade can be quite high. In previous studies, for instance, we measured ultraviolet-B (UVB, 280–320 nm) radiation below individual or scattered tree canopies and found that with clear-sky conditions UVB irradiance in shade is as much as 60% of that in the open away from trees.
HURRICANE PREPAREDNESS AT WFO TALLAHASSEE

While the NWS Weather Forecast Office (WFO) at Tallahassee, Florida, stresses hurricane preparedness to its partners and customers, hurricane preparedness is also taken very seriously at the WFO itself. Paul Duval, meteorologist-in-charge at the Tallahassee WFO, spoke to the North Florida chapter on how the 2004 hurricane season provided the WFO with ample opportunity to test and improve its preparedness plans.

Duval said that during the hurricane season, the WFO staff monitors the Tropics for long-range threats. When a tropical cyclone develops anywhere in the Atlantic Basin, the WFO monitors and participates in routine National Hurricane Center (NHC) conference calls as appropriate, and provides current basic information on the tropical cyclone on its NOAA Weather Radio transmitters as well as the office telephone recording system. Office storm shutters are tested routinely.

When a possible tropical cyclone threat exists within 72 h anywhere within the WFO County Warning Area (CWA) of responsibility, supervisors and shift leaders begin planning for additional staffing. Duval noted that by this time, the WFO hydrometeorological technician staff (HMT) is usually taking additional upper-air observations every 6 h in support of NHC forecasts. Critical items such as backup generator fuel, upper-air supplies (instruments, balloons, parachutes, and helium), batteries, first-aid supplies, inflatable beds, and emergency water and food supplies for the staff are stockpiled at the office.

When a tropical storm or hurricane watch is issued for all or a portion of the WFO CWA, the WFO begins issuing a Hurricane Local Statement (HLS) within an hour of each NHC advisory, detailing the expected specific impacts of the storm on the CWA. Additional operational staff are added to accommodate the increased workload associated with answering the telephone and participating in routine conference calls with the State of Florida, the emergency management officials in the affected counties, and the River Forecast Center. In addition, an area outside the operations area is set aside for a “Tropical Information Center,” with a staff member whose job is to provide one-on-one briefings and information over the phone and in person to partners in emergency management and the media, as well as public customers. Amateur radio operators and SkyWarn spotters are alerted. Careful and thorough documentation of all actions begins. Staff members are notified of impending schedule changes and given an opportunity to make provisions for family members and protection of their property.

Duval said that when a tropical storm or hurricane warning is issued, the WFO shifts to emergency staffing, including 12-h shifts, continuous HMT coverage, and continuous multiple radar shift coverage as the outer rain bands begin to approach the CWA. The WFO amateur radio station WX4TAE is activated and staffed continuously by volunteers from the local amateur radio club. As the storm situation develops, the WSR-88D is placed in tropical weather conditions.

METHANE IN THE MUD

Many scientists keep a close eye on methane, a greenhouse gas that is involved in the production of ozone in the troposphere. Sources of methane include rice production, animal waste, wetlands, termites, and some industrial activity. But the amount of methane measured recently in the atmosphere has been greater than the amount known to come from recognized sources. This disparity may recently have been explained by scientists who studied mud volcanoes—mounds of mud and rock formed by methane emissions from the earth. Although these volcanoes have been studied for some time, the methane they release had never been measured until Giuseppe Etiope and colleagues at the National Institute of Geophysics and Volcanology in Rome looked at four mud volcanoes in the country of Azerbaijan, located between Russia and Iran on the Caspian Sea. They calculated a release of 1400 metric tons of methane per year from an area of volcanoes that covered about 3.5 mi². Etiope expanded that finding to estimate a release into the atmosphere of at least 6–10 million metric tons from mud volcanoes around the world. While these results are by no means conclusive, it is hoped that the research, which appeared in the June issue of Geology, will lead to a greater understanding of the impact of geologic sources of methane.
operating mode, and staffing expands to include a member of the maintenance staff and a member of the senior management staff at all times. The WFO senior hydrologist remains on station as much as possible during the event. It is not unusual for the tornado threat to develop first, as the outer rain bands begin moving onshore. Hurricane Ivan primarily posed a tornado threat in the Tallahassee CWA; 130 warnings were issued within about 18 h.

After the storm, the staff collects all relevant records, including surface observations and spotter and storm reports and prepares and transmits a final report to regional headquarters within five days of issuing the last HLS. The WFO management team and the Tropical Warning, Forecast, and Services Team conduct a thorough and critical review of the event.

—Robert Banks (North Florida Chapter) AND Paul Duval

Monitoring Snow Melt in the Arctic

In September, Mark Anderson, professor of meteorology at the University of Nebraska, Lincoln, spoke to the Omaha–Offutt chapter on "Monitoring Snow Melt in the Arctic." Reasons for studying annual snow and ice melt are that it marks the transition between cold and fairly warm weather during the summer; it reduces the albedo of the surface, which is not handled well by numerical forecast models; and it helps gauge the extent of global warming.

Over 25 years, Anderson's research has covered sea ice over the Arctic Ocean and surrounding bays, as well as the ice cap over Greenland. He mainly has used satellite data (NIMBUS prior to 1986 and DMSP SSM/I since 1986) to note that the warming of the atmosphere triggers snow and ice melt, which develops a positive feedback cycle: the snowmelt allows the Earth's surface to absorb more heat, which further warms the atmosphere, which melts more snow. Overall, the coverage and concentration of polar ice during the summer months has decreased through the years. Anderson also noted a trend during the melting process: surface albedo actually increases when melting first starts, then drops as the bare earth is exposed.

As part of his work, Anderson joined a team of researchers spending June–July 1993 on the ice...
cap in Greenland. For data collection, the researchers set up a weather station to relay observations and dug fox holes and additional cylindrical columns in the snow to take measurements of the "history" of the snow pack. Measurements included temperature, density, and O-18 isotope concentration of the snow and ice. Anderson said they discovered that while the ice cap on the edges of Greenland is melting more each summer, the cap in the center is actually getting thicker, as a result of more precipitation falling in recent years.

Anderson also described his research on sea ice, which has shown that the summer thickness and extent of polar sea ice have been decreasing, with a greater decrease in the thickness than in the extent, which has decreased only slightly, but not uniformly. The Beaufort Sea area has been melting earlier in recent springs, while the area north of Greenland has been melting slower and later. Last year was unusual, with the ice along the north coast of Asia melting very early and the ice in Hudson Bay melting very late. The delayed Hudson Bay melting was symptomatic of the unusually cool summer over most of eastern North America.

Anderson concluded his presentation by listing opportunities to use polar ice research data, such as studying atmospheric correlations (e.g., El Niño weather patterns and the Arctic Oscillation), and applications in numerical modeling and in biology (mainly whale migration patterns). In the future he also intends to address annual freeze patterns.

—John Roth
Omaha-Offutt chapter

PAPERS OF NOTE

INTERDECADAL SEA LEVEL FLUCTUATIONS AT HAWAII
Interdecadal sea level fluctuations at Hawaii are correlated with sea surface height (SSH) variations over a significant portion of the North Pacific (see figure) as a result of common forcing by large-scale, low-frequency atmospheric modulations. These atmospheric modulations, rather than oceanic Rossby wave propagation, are the main connection between Hawaii sea level and sea level at California, or Hawaii sea level and tropical variability such as El Niño–Southern Oscillation (ENSO).

Over the past century, tide gauges in Hawaii have recorded interdecadal sea level variations with 10–25-yr time scales and peak-to-trough changes of ~5 cm. The Hawaii record is similar to long sea level records at San Francisco and San Diego, California. Unlike the California records, however, it does not have a clear dependence on ENSO. We addressed the questions of what forces interdecadal Hawaii sea level and how it is related to other interdecadal variability.

The Hawaii sea level record was compared to other oceanic and atmospheric variables, including SSH from the Topex/Poseidon altimeter, dynamic height from the World Ocean Atlas and from the Hawaii Ocean Time-series, surface winds and pressure from the NCEP re-
analysis, scatterometer winds from the World Ocean Circulation Experiment (WOCE), the Southern Oscillation Index, and the Pacific North America index (PNA), which represents midlatitude atmospheric variability and its teleconnections to tropical ENSO variability. After finding correlations between interdecadal Hawaii sea level and SSH, dynamic height, local wind and pressure patterns, and the PNA, we attempted to reproduce the Hawaii sea level signal using a simple model forced by NCEP wind stress curl, and including mode-one Rossby wave propagation.

This model was not able to explain a significant portion of interdecadal Hawaii sea level variability. Forcing with WOCE wind stress data, however, showed some promise of better results, suggesting a return to the problem when there is a longer time series of accurate satellite-based wind stress available.—YVONNE L. FIRING (UNIVERSITY OF HAWAII AT MANOA), MARK A. MERRIFIELD, THOMAS A. SCHROEDER, AND BO QIU. "Interdecadal Sea Level Fluctuations at Hawaii," in the November Journal of Physical Oceanography.

**Kelvin–Helmholtz Instability**

Although previous studies associate large-amplitude shear instability with Kelvin–Helmholtz billow clouds along frontal zones, to our knowledge, until now, no large-amplitude Kelvin–Helmholtz billows have been documented inside a tropical convective anvil. They were documented with the University of Miami 95-GHz cloud radar over Miami on the evening of 21–22 July 2002.

The billows lasted more than 3 h, suggesting that internal anvil circulations helped continuously regenerate the instability, even more than an hour after the demise of all deep convection. At times, the shear layer was small enough to be contained within a single radar gate (30 m). In addition to the main shear axis along which the Kelvin–Helmholtz instability developed, several identifiable weaker shear layers existed in the anvil, evident in the Doppler spread, especially of the aged anvils. The analysis demonstrates that the frequent assumption of an anvil as a well-mixed layer is not always valid. Hence, models built on this assumption will need to be...

**QUESTIONING ASSUMPTIONS ABOUT ESTUARY BALANCE**
Analytic theories of estuarine circulation almost always assume a steady balance between salt flushed seaward by river flow and salt returned to the estuary by tidal and baroclinic circulations. Real estuaries, however, are often forced by environmental changes too rapid to be followed in near-equilibrium: large changes over a few days in river input, local wind stress, sea level, ocean water properties, and tidal range are all well documented. In a new study of Willapa Bay, Washington, these transients actually drown out the mean for much of the year, suggesting a general analytic approach that emphasizes, rather than averages away, such unsteadiness.

Willapa is the largest in a chain of small, relatively unstudied estuaries on the U.S. Pacific Northwest coast (the Columbia River being the dramatic exception) that have large tidal ranges (in Willapa, 50% of total volume is intertidal) and highly seasonal river input. In addition, wind shifts on the 2–10-day time scale of synoptic weather patterns force shifts between coastal upwelling and downwelling (and thus salinity changes of several ppt) in all seasons. The Columbia River plume, furthermore, episodically fills the nearshore waters of Washington during downwelling conditions. As a result of this complex forcing, over the course of one year Willapa occupies most of the possible states of a partially mixed estuary (see figure).

The relationship between these hydrographic variations and the underlying circulation—the overall estuary–ocean exchange rate—is not direct, however. By regressing the rate of change of estuarine salt storage to the axial salinity gradient, we calculated an effective horizontal diffusivity, parameterizing all up-estuary salt flux, as a function of river flow, and then compared this diffusivity to the value that would maintain a steady salt balance. For most of the year, there is a net loading of salt into the estuary; the compensating net loss comes during high-flow winter storms. This disequilibrium is made possible by the strength of lateral tidal stirring, which is independent of river flow and the salinity field. Thus, the variability of Willapa’s salinity and other properties turns out to be evidence of an exchange circulation not unexpectedly variable but unexpectedly constant across changing forcing.—N. S. BANAS (UNIVERSITY OF WASHINGTON), B. M. HICKEY, P. MaccREADY, AND J. A. NEWTON. "Dynamics of Willapa Bay, Washington: A Highly Unsteady, Partially Mixed Estuary," in the November Journal of Physical Oceanography.

**CYCLONES WITH MULTIPLE WARM FRONT–LIKE ZONES**
Forecasters at the Storm Prediction Center have long observed ex-
tropical cyclones over the central United States with two or more warm front–like baroclinic zones. These baroclinic zones can serve as a focal point for the development of severe convective storms, yet research on these baroclinic zones has not been performed. Our climatological study shows the frequency with which various mechanisms lead to these structures.

We examined 108 cyclones over two years (1982 and 1989) and found that 42% have multiple baroclinic zones. Ninety-four percent of all baroclinic zones were coincident with a significant dew-point temperature gradient, and 81% of all baroclinic zones possessed a wind shift of at least 20°, suggesting that these baroclinic zones were significant airmass and airstream boundaries.

Although cyclones with multiple baroclinic zones formed in a variety of ways, two synoptic patterns dominated. Thirty-eight percent of cyclones with multiple baroclinic zones formed as a cold or stationary front from a previous cyclonic system was drawn into the circulation of a cyclone center, forming the southern baroclinic zone. Twenty-two percent of cyclones with multiple baroclinic zones formed as a cold front to the north of the cyclone center was drawn into the circulation of the cyclone, forming the northern baroclinic zone. In cyclones with multiple baroclinic zones, 58% of the southern baroclinic zones were associated with reports of severe weather. Despite the increased potential for severe convective storms along these southern baroclinic zones, 51% were not identified on the surface analyses made at the National Meteorological Center (now the National Centers for Environmental Prediction).

**Fig. 1** (below). Schematic illustration of the attachment of the southern baroclinic zone.

**Fig. 2** (at right). Schematic illustration of the attachment of the northern baroclinic zone.
CAMELS ARE QUIETER, TOO

After examining global satellite images from the last 50 years, Andrew Goudie of the University of Oxford, England, has come to a conclusion: it’s dusty out there. Goudie’s research, presented in August at the International Geographic Congress in Glasgow, Scotland, shows that about 3 billion tons of dust is blowing through the sky each year. Of particular concern are dust storms that originate in the Sahara Desert in Africa. Goudie found that such storms now occur 10 times more frequently than they did 50 years ago. He attributes much of this increase to the replacement of camels with autos as the new method to cross the desert—what Goudie has coined “Toyota-isation” due to the many Toyota Land Cruisers that are used for this purpose. “If I had my way, I would ban them from driving off-road,” Goudie says. He explains that the activity of the autos takes away a layer of lichen or algae that normally covers the sand and prevents it from blowing away.

The results of this study yield two important implications. First, a single conceptual model of cyclone structure and evolution, like the Norwegian cyclone model, is inadequate to explain the observed variety of cyclones in the central United States. This evidence indicates forecasters and research scientists must be alert to the potential for weather systems that differ from previously published research. Second, the importance of performing manual analyses of the surface data in real time and recognizing these baroclinic zones cannot be overstated, given their association with severe convective storms.—NICHOLAS D. METZ (OKLAHOMA WEATHER CENTER RESEARCH EXPERIENCES FOR UNDERGRADUATES/VALPARAISO UNIVERSITY), DAVID M. SCHULTZ, AND ROBERT H. JOHNS. "Extratropical Cyclones with Multiple Warm Front–like Baroclinic Zones and Their Relationship to Severe Convective Storms," in the October Weather and Forecasting.

RADAR VORTEX DETECTION: SIGN OF TORNADOES?

Mesoscale vortices—vertically rotating columns of air that can extend to 10 km in diameter and over 10 km deep—are often associated with severe weather phenomena such as tornadoes (a smaller, but stronger vortex). However, in comparing approximately 100,000 radar-detected mesoscale vortices with ground truth tornado reports, we find that only a very small percentage (<5%) of all vortex detections are associated with the occurrence of a tornado. The results are very much dependent on how vortices are determined algorithmically: tornadic percentage increases to approximately 10% as the criteria for defining a vortex detection as a mesocyclone detection become more strict; however, many tornadic events are only associated with weaker detections, and are “missed” when the detection threshold is increased. Early mesocyclone research suggests that as many as 50% of radar-detected mesocyclones in supercell-type thunderstorms are tornadic. More recent research suggests this number ranges between 20% and 30%. Some research using much larger datasets even suggests that as few as 2% of all mesocyclone detections are tornadic.

This range of results may seem excessive, but must be taken in the light of significant changes over the years in the criteria for “detecting” a mesocyclone. The criteria for a mesocyclone detection were often set high so that vortices not associated with the primary mesocyclone did not contaminate the results. In constructing our dataset of mesocyclones, we used a radar algorithm that uses much lower threshold criteria and more robust diagnosis techniques to produce a detection. However, the mesocyclone detection algorithm (MDA) is designed to pick up vortices that are not necessarily associated with a classic tornado-producing mesocyclone. Thus, a detection dataset produced by the MDA will contain more than just “mesocyclone” detections.

This research involves two years worth of data from six Southern Plains radars. The primary goal is to better determine the relative proportion and characteristics of tornado-producing mesocyclones, and what are the best criteria to use when classifying vortex detections as mesocyclones. The large detection datasets used here may not be large enough to produce long-term statistics. As the mesocyclone dataset increased in size with the addition of the second year of data, the percentage of detections classified as tornadic decreased. This decrease may well continue for even larger datasets, resulting in the possibility that less than 2% of the mesocyclone detections produced by the MDA are tornadic using the lowest reasonable classification threshold. Using the highest, no more than 10% to 12% of...
detections are likely to be tornadoic. Repeating this work with a much larger dataset several years from now could provide very interesting results.—THOMAS A. JONES (UNIVERSITY OF OKLAHOMA/UNIVERSITY OF ALABAMA IN HUNTVILLE), KEVIN M. MCCRATH, AND JOHN T. SNOW. "Association between NSSL Mesocyclone Detection Algorithm-Detected Vortices and Tornadoes," in the October Weather and Forecasting.

ECOSYSTEMS SERVING AS A CLIMATE MEMORY MECHANISM
With a fully coupled atmosphere-biosphere model, we show that vegetation dynamics (i.e., the changes in vegetation cover over time, such as changes in forest and grass cover) may be capable of producing long-term variability in the climate system, particularly through the hydrologic cycle and precipitation. We find that dynamic interactions between the atmosphere and vegetation enhance precipitation variability on land at time scales from a decade to a century. These interactions introduce persistent precipitation anomalies in several ecological transition zones: between forest and grasslands in the North American Midwest, in southern Africa, and at the southern limit of the tropical forest in the Amazon basin; and between savanna and desert in the Sahel, Australia, and portions of the Arabian Peninsula (see figure).

Until now, interannual to interdecadal variability was mainly attributed to the interaction between atmospheric and oceanic processes, with the ocean acting as the “memory” of the climate system. Here, we show that terrestrial ecosystems, because they operate on time scales of years to centuries, can also provide a memory to the climate system, causing important variations of climate and ecological conditions on interannual to interdecadal time scales.

To show this, we performed two simulations of the global climate, with fixed climatological sea-surface temperatures: one including vegetation as a dynamic boundary condition and the other keeping vegetation cover fixed. The comparison of the simulated precipitation fields and their power spectra shows that vegetation dynamics enhances the long-term variability of the precipitation. Slow changes in the vegetation cover, resulting from a “red noise” integration of high-frequency atmospheric variability, are responsible for generating this long-term variability.

Decadal variability of precipitation has been documented in the Sahel and the U.S. Midwest. Observations and models suggest that vegetation dynamics play an important role in the Sahel, while the causes in the Midwest are still a matter of debate. Our results indicate that vegetation feedbacks might play a role.

We have only considered natural ecosystems in our study. To analyze how current terrestrial vegetation affects climate variability, we should include managed ecosystems as well as processes affecting the functioning of terrestrial ecosystems—like soil erosion or natural disturbances—that are not represented in this model.


Regions where precipitation anomalies persist for more than 1 yr (shown by the lagged autocorrelation coefficient of the yearly precipitation time series for the dynamic vegetation simulation with a 1-yr time lag).

GENESIS OF MESOSCALE CONVECTIVE SYSTEMS ABOVE UNEVEN SOIL MOISTURE CONDITIONS
Heterogeneities in vegetation type, soil type, or soil moisture can induce physiographically forced mesoscale circulations through sensible heat flux gradients at the surface. These mesoscale circulations can provide regions of convergence, triggering deep convection. Convection often organizes itself on the mesoscale, leading to convective systems (MCSs) hundreds of kilometers across, which produce a large part of the precipitation in the central United States in summer. Our studies show that the location of these systems may
be affected by soil moisture heterogeneity.

We examined the sensitivity of a simulation of the genesis of a mesoscale convective system to the initial soil moisture distribution. In the initialization of this cloud-resolving simulation, we used antecedent precipitation to make the soil moisture distribution heterogeneous. In the sensitivity experiments, we 1) removed the fine-scale features of the soil moisture distribution, 2) used homogeneous soil moisture initialization, and 3) displaced a soil moisture anomaly from its initial location.

Most of the experiments produced qualitatively similar results, producing a quasicircular cloud shield, indicating the importance of large-scale dynamics. However, the soil moisture distribution affected where convection was likely to occur. For the case examined, a wet soil moisture anomaly suppressed convection, but convection preferentially occurred on the periphery of the wet soil moisture anomalies due to the mesoscale circulations there. Sensitivity experiments also showed that soil moisture with grid spacing of 40 km may be adequate to initialize a cloud-resolving model for MCS simulations.

Because of the negative feedback between convection and soil moisture in this case, we surmise that the soil moisture gradient will be reduced with time for cases like the one in this study. Because the MCS case studied here was weakly forced by its large-scale environment, it would be of interest in future studies to test the effects of small-scale soil moisture anomalies on large-scale environments with differing strengths.—WILLIAM Y. Y. CHENG (COLORADO STATE UNIVERSITY) AND WILLIAM R. COTTON.

Results from a selected numerical experiment in the cloud-resolving grid: (a) anomalous vertical velocity at the lowest level above ground (in contour intervals of 2 cm s⁻¹) with orange (blue) representing upward (downward) motion and anomalous sea level pressure in shading (hPa), superposed with anomalous horizontal wind vector (m s⁻¹) due to heterogeneous soil moisture distribution during the pre-MCS genesis phase (at model hour 6). (b) Precipitation rate (mm h⁻¹) in shading superposed with contour of initial volumetric soil moisture at 50% saturation at model hour 9.75 during the MCS genesis phase.