# ESRL Quarterly

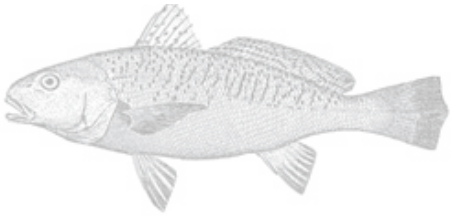
News from NOAA's Earth System Research Laboratory

Summer 2010

U.S. Coast Guard

## Inside





# Target: Gulf Spill

## Instrumented aircraft heads to Gulf, to help assess air quality

On April 20, a now all-too-well known deepwater oil rig exploded in the Gulf of Mexico, killing 11 people on board and igniting a fireball visible for miles.

ESRL's Tom Ryerson (Chemical Sciences Division) was among several NOAA scientists scheduled to fly a research airplane from Florida to Colorado three days later, and he and his colleagues figured they might shift the flight slightly to sample the plume from the burning rig on the way. The airplane was already extensively outfitted for a major air quality and climate mission over California, with instruments that would be ideal for understanding some of the air quality implications of the disaster.

"We would have done it, but the rig sank the day before we flew," Ryerson said, "we thought the sinking, which extinguished the rig fire, would be the end of it." He and his colleagues left the Gulf tragedy behind and concentrated on CalNex (a study focused on the nexus of air quality and climate in California). It would be a week before the first eye-opening estimates of 5,000 barrels of spilled oil daily were available—now up to 35,000-60,000 barrels daily, of which about 24,000 barrels are being

*see page 5*

# Pseudo Storms, Key Decisions

## OSSEs mimic reality to help NOAA prioritize resources

It's notoriously difficult to know when a hurricane is about to spin up into a monster, or when a storm will settle down a notch, sparing a coastal city of major damage. To predict those shifts in intensity and other changes, weather researchers and forecasters need better observations of hurricanes and storm environments.

But what's the most effective way to gather those observations? Launch a new billion-dollar satellite? Buy a few multi-million-dollar unmanned aircraft systems, UAS, to gather observations? Or send instruments out over the ocean on relatively inexpensive balloons?

To help NOAA make such decisions, Yuanfu Xie, Nikki Privé and their colleagues are creating Observing System Simulations Experiments or OSSEs—worlds of make-believe observations and simulated weather. OSSEs are designed to help researchers plan future observing systems, and how to best use the data from those systems.

"This is what you do when you want to know how much impact a new observing system

*see page 4*

# Croaker Climate

## The fish's future is bright, collaborative study suggests

Jonathan Hare of NOAA's Northeast Fisheries Science Center in Narragansett, R.I. wanted to know how climate change information could be used to help plan for the future of our fisheries. "Most current management plans do not include the effect of climate change on specific fish populations, some of which will increase and others decrease as a result," said Hare.

Hare knew that the Atlantic croaker would be an excellent species of fish for such a study since its survival is directly related to temperature changes. Millions of pounds of this mild-flavored fish are caught in the United States every year. In the winter, croakers travel to shallow bay areas along the U.S. northeast coast and lay eggs. Once hatched, the young fish have a better chance of making it to adulthood when winters are warm. To figure out how climate change might affect croakers, Hare needed the right kind of climate information.

So Hare gave ESRL's Mike Alexander (Physical Sciences Division, PSD), a call. The two had previously served together on a scientific committee, and Hare knew Alexander worked

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# Director's Corner

Like everyone, the story that has galvanized my attention during the last couple of months is the oil spill. If one could have imagined something that tested NOAA from one end of the organization to the other, its doubtful if we could have come up with anything as compelling and comprehensive as the disaster in the Gulf of Mexico. NOAA has mission responsibility for prediction of the oceans and atmosphere, and for stewardship of our coasts and our fisheries. NOAA's Office of Restoration and Response, in fact, was set up to deal with events such as the oil spill, based on the hard experience of previous situations, such as the breakup of the Exxon Valdez in Prince William Sound. The National Weather Service is, as I write this, tracking a potential tropical storm that could enter the Gulf of Mexico in the next couple of days, and National Marine Fisheries staff are dealing with a host of issues including the moratorium on fishing in the affected areas.

Leading NOAA is one of the world's preeminent scientists. Dr. Jane Lubchenco is a leader in the understanding of ocean life, which happens to be the primary issue we face with the Deepwater Horizon spill. I had the privilege of attending a symposium put together by NOAA to bring together scientists from academia and industry, and to ask them for their help on how to deal with the spill. It was held in Baton Rouge, LA on June 2 and 3, and a highlight was the presentation by Dr. Lubchenco of the challenges we face, and the efforts that are underway to observe and deal with the situation. The thing that was impressive to me was talking to the various scientists—I met people who had investigated previous spills such as the Ixtoc (a Mexican spill similar to Deepwater Horizon), Exxon Valdez, and numerous others. There were experts on every facet of the fate of oil and how it will affect our ocean life and beaches. The next day I rode with Dr. Lubchenco in the NOAA P3 to look at the Deepwater Horizon site and the Gulf Coast. I took the picture below of a ship plowing through deep oil near the well site.

I am particularly proud of the role that ESRL has played in responding to this national emergency. A.R. Ravishankara (Director of the Chemical Sciences Division) and the team working on CalNex volunteered to suspend their work and fly missions over the Gulf to determine the effects of the disaster on air quality, as described on the front page of this ESRL Quarterly. NOAA's Office of Oceanic and Atmospheric Research (OAR) has been using its people and research infrastructure repeatedly to provide capabilities required by the disaster. NOAA's Atlantic Oceanographic and Meteorologial Laboratory has supplied expertise on ocean modeling, OAR people and our affiliates have participated in cruises to observe the northern Gulf, and NOAA Sea Grant has made a big effort to work with the local communities who have been so hard hit by the impact on their environment and livelihoods. As the hurricane season approaches, the outstanding work of the ESRL scientists, notably those involved with the ensemble Kalman filter developed in our Physical Sciences Division, and the FIM (Flow-following, finite-volume Icosahedral Model) developed in the Global Systems Division, will make the forecasts needed for hurricane preparedness significantly better. Not only are these predictions showing new skill, they are being run on the newly upgraded supercomputer in this building, highlighting the role of our IT professionals who have made these model runs feasible.

As difficult as this oil spill is, it brings to the forefront the necessity of dealing with the nation's energy future. I was privileged to testify before the House Science Committee last week, building on the excellent efforts of Melinda Marquis and other ESRL people who have been pushing the importance of NOAA's contribution to Renewable Energy. Thus NOAA is not only the "go-to" agency to deal with the oil spill, it is also working on the ultimate solutions that the nation will need to avoid similar environmental problems.

*—Alexander MacDonald*

*A ship travels through oil in the Gulf of Mexico, leaving a temporary trail of clear water behind.*

# It's a bird, it's a man...it's SuperPlane

## Spring mission demonstrates Global Hawk's chemistry prowess; next up: Gulf hurricanes

This spring, NASA and NOAA outfitted an unmanned military airplane with atmospheric instruments and sent it on a spectacular series of flights to study the atmosphere over the Pacific Ocean. Now, scientists are aiming the research plane at hurricane formation and intensification in the Gulf of Mexico. Because the aircraft can soar for 30 hours per flight, researchers will get an unprecedented look at hurricanes as they develop and evolve.

"These long-endurance aircraft demonstrations represent a historic achievement for the Earth science community," said Robbie Hood, NOAA Unmanned Aircraft Systems, UAS, program. "We now have a new observing tool that will allow us to closely study varying land, ocean, or atmospheric conditions in a single flight from the North Pole to the Equator or to stay and observe a rapidly changing event like a hurricane for more than a day."

The Pacific. The Global Hawk Pacific mission (GloPac) represented the first science mission for the 116-foot wingspan unmanned aircraft, which NASA acquired from the U.S. Air Force two years ago. The drone, which can soar up to 65,000 feet and for 10,000 miles, is piloted remotely from NASA's Dryden Flight Research Center in California.

During GloPac flights, ESRL scientists and their colleagues anxiously watched computer screens in Dryden mission control. They cheered as data streamed in from instruments designed to measure greenhouse gases, ozone-depleting chemicals, and aerosols.

Within a few weeks and after three long science flights up to 28 hours, scientists checked off all key science goals, according to ESRL's David Fahey (Chemical Sciences Division), co-mission scientist on GloPac mission. They demonstrated the capability of the Global Hawk to routinely access chemical and dynamical events in different atmospheric regions from 85°N in the Arctic to 12°N in the near tropics. Highlights included sampling the chemistry and structure of a fragment of polar air, which swirled down into the northern Pacific from the Arctic; catching the edge of a dust plume sweeping across the Pacific; and atmospheric sampling coordinated with a NASA satellite passing overhead.

The GloPac team also gathered stunning photographs—shot from the UAS—of Arctic sea ice, suggesting that the aircraft could be used to survey ice extent and thickness.

"Part of this was luck," Fahey said, "but luck favors the prepared."

The Atlantic. GRIP is next, the NASA Genesis and Rapid Intensification Processes experiment, which will begin targeting hurricanes in late August for six weeks.

For GRIP, the Global Hawk will carry a new suite of instruments, more appropriate for hurricane research—100 dropsondes for measuring temperature, pressure, humidity and winds from high altitude to the surface; a lightning detector; a wind and rain profiler; and a radiometer.

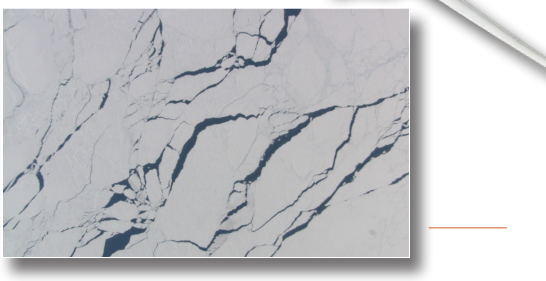
ESRL's Gary Wick (Physical Sciences Division) is principal investigator for the dropsondes, and he expects to be busy well before August, testing out the new instruments and their deployment system, recently designed and built at the National Center for Atmospheric Research.

NOAA already releases dropsondes into hurricanes from manned research and operational airplanes, Wick said, to better understand the wind and thermal structure of the storms and their environment – key information for better storm intensity and track predictions.

But the range of those piloted airplanes is limited, usually to fewer than nine hours, Wick said. Those airplanes typically drop up to 30 sondes, while the Global Hawk may be able to remain in hurricane regions for up to 20 hours at a time, releasing more than 90. On a map, conventional dropsonde locations look "like a few drops," Wick said; Global Hawk's releases look like "a pincushion."

It's not yet clear if the Global Hawk will be able to fly safely above hurricanes, Wick said. But even if the craft can only soar in close, the aircraft should be able to probe storm structure from several angles, characterize the environment in front of the storm, and track its evolution. "That's what's new here," Wick said. "The fact that we will be able to follow the evolution of a storm."

"It's kind of an exciting time in hurricane research," said Michael Black, with NOAA's Atlantic Oceaographic and Meteorological Laboratory, who is working closely with Wick and other colleagues this summer. "A platform like this Global Hawk… could be really tremendous for us."





# By the Numbers

## Federal Virtual World Participants

**1,600** **people** participated in this year's Federal Consortium for Virtual Worlds, in May in Washington, D.C. This number of virtual enthusiasts has grown steadily from five founding members in 2007. ESRL's Eric Hackathorn (Global Systems Division and also NOAA's virtual worlds program manager) is an ambassador for developing virtual worlds for the federal government, and renowned as one of the first to establish a science presence in Second Life. Hackathorn went on to lead a multi-organizational effort to develop the expanding virtual continent SciLands, also within Second Life. In addition to NOAA, NASA, the National Institutes of Health, the Department of Energy, and others have created islands in this virtual archipelago; all neighbors with a focus on science education. "By being in close virtual proximity to one another, conversations take place and ideas take form that would have never have occurred in the real world Hackathorn said.

More: http://www.scilands.org/

*A virtual conference.*

# ...OSSE, from page 1

could have on numerical weather prediction—you set up an OSSE," Privé said. "We are supporting NOAA's UAS program (Unmanned Aircraft Systems) and others, to determine the best potential use."

Privé, Xie, Scott Mackaro, and other ESRL Global Systems Division scientists are working with colleagues at the National Centers for Environmental Prediction, NOAA's Atlantic Oceanographic and Meteorological Laboratory , AOML, NASA, and the European Center for Medium-Range Weather Forecasts to finish building two OSSEs this year: A global one, focused on improving hurricane track forecasts, and a finer-resolution regional OSSE, targeting hurricane intensity.

In the case of the global system, the interagency research team has already created a "nature run," which represents global weather and atmospheric conditions for the entire year of 2006, at a resolution of about 40 km. The run includes 10 hurricanes and typhoons that formed between June and August, three of them near the United States.

It was tricky enough to create a complete and accurate representation of Earth's weather for an entire year, but next came the task of creating synthetic observations from existing meteorology networks and proposed new ones. Creating observations is an exacting science, said GSD's Steve Weygandt, who has worked on OSSEs for about a decade now. The simulated observations cannot be perfect—they need to be riddled with the same kinds of errors and missing data points that plague reality.

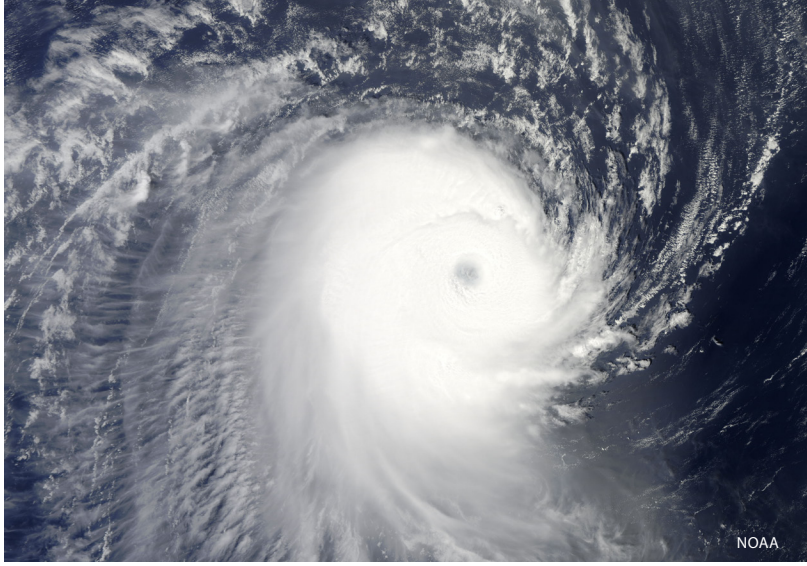
"Everything is in specifying the errors," Weygandt said. "If synthetic observations from proposed new systems are too perfect, it's very easy to get an overly optimistic result about the effect of a proposed observing system."

Synthetic observations for the global OSSE will be complete this summer, Xie and Privé said, and then can be used to run weather prediction experiments toward the end of the summer. How skillfully does the model predict weather, given conventional observations? Does skill improve if measurements from a new observing system—say a system of UAS with dropsondes—are assimilated?

"We can do this because we know the truth," Xie said. "We know what (weather) actually happens."

"You can even use the models to tell you about where to collect observations," Weygandt said. For example, which improves forecasts more significantly: Observations from near the center of a hurricane, or around the edges of it?

"Some really Interesting questions emerge about reality," Privé said. In the global model nature run, one of the three hurricanes that swing near the United States passes directly over Cuba. Would a system of UAS airplanes—similar to military drones—be allowed to conduct atmospheric surveillance over that country?




*Hurricane Ike in 2008.*

Xie and his colleagues will ask researchers at AOML for guidance about which UAS to "fly" in the simulation, along what routes, and carrying what payloads. "Then we can ask, could we do a better job if we took a different route?" Xie said.

The regional OSSE is also nearly ready for experiments, Privé said, and although it is at significantly finer resolution than the global one, it has not yet been calibrated. The resolution of about 4 km, however, will allow researchers to investigate hurricane intensity changes (hurricane intensity forecasts have not improved in 20 years; hurricane track forecasts have improved 50 percent in that time). That OSSE will focus on three days in the development of a single storm: 2008's Hurricane Ike.

**"Many of us who have worked on OSSEs believe they should be used to help NOAA make wise decisions about major observing system investments.**

—Steven Koch, Global Systems Division Director

Privé said she and her colleagues will be cautious when interpreting the results of the two OSSEs. "Both of these are really case studies," she said. Results may speak to potential forecast improvement in the specific forecast models used: GFS/GSI in the case of the global OSSE; and HWRF/GSI in the case of the regional one.

Even given those limits, OSSEs represent the best way to evaluate expensive systems, without actually deploying them, Privé and Weygandt said.

"What else could we do? Fly a new satellite for two months and study the global impact of the observations on forecast skill and other statistics? What if it doesn't help?" Privé asked.

Xie and Weygandt estimated that OSSEs—which can cost $1 million, given the many agencies, computing power, and people involved—cost a small fraction of a new observation system, whether a satellite or UAS-based observation network.

***Observing Systems.*** *A GOES satellite at launch, a Global Hawk unmanned aircraft, two "hurricane hunter" airplanes. ESRL scientists are creating models to help NOAA understand the potential value of future observations for improving hurricane forecasts.*

# ...Gulf spill, from page 1

recovered.

The ESRL-led team got its chance in early June. NOAA redirected the WP-3D airplane from California back to the Gulf of Mexico, to help in a multi-agency effort to understand the environmental effects of the now disastrous BP Deepwater Horizon Oil Spill. The spill itself and controlled burns of spilled oil and natural gas could affect air quality, with implications for the health and safety of response workers and others.

The WP-3D—filled with customized, real-time chemistry instruments and air sample flasks—flew for a total of about 14 hours directly over the spill site, downwind, and in "clean air" parts of the Gulf, currently unaffected by the spill, Ryerson said. During two flights June 8 and 10, the aircraft flew mostly between altitudes of 600 to 2,000 feet, to sample the marine boundary layer, which was expected to trap most pollutants. At its lowest, the airplane was just 200 feet above the water.

"The only way we could have responded so quickly is that CalNex was happening, so we already had everything tested, installed, and ready to go," Ryerson said. "We were lucky to already have had the aircraft instrumented for an air quality study. Even if we had plenty of time to figure out a specific payload for this sort of incident, we probably wouldn't have changed much."

In California, the airplane was one of several platforms involved in CalNex, which has been in planning for more than four years and included researchers from all ESRL divisions, several other NOAA laboratories and centers, the state of California, and academic and international collaborators.

ESRL's custom instruments onboard included those to assess the concentrations of volatile organic compounds (some of which are damaging to human health), aerosols, ozone (a lung-damaging pollutant at Earth's surface), and particulate matter including soot, as well as the transport and evolution of plumes of polluted air.


*Oil slick seen from a window of the NOAA WP-3D research airplane, which flew over the Gulf spill to collect air quality data.*

In the Gulf, the U.S. Environmental Protection Agency, EPA, has been conducting extensive air quality monitoring throughout the oil spill response effort. EPA, NOAA, and the Occupational Safety and Health Administration, OSHA, worked collaboratively to take advantage of NOAA's specialized instruments.

"Ensuring the health and safety of Gulf Coast families is a priority for NOAA," Jane Lubchenco, under secretary of commerce for oceans and atmosphere and NOAA administrator, said in a statement. "We want to make certain that the air is safe for coastal residents as well as workers on the water. We are pleased to partner with EPA in this effort and to provide state-of-the-science air quality instruments in our flying laboratory aboard the P-3 aircraft."

"We have a lot of data to get through and we're still trying to understand everything we saw," Ryerson said. An initial assessment suggested that most pollutants were trapped within a well-mixed boundary layer, and data from the WP-3D were consistent with measurements taken by EPA and OSHA, and independent measurements from a ship in the region. More detailed information will be available in coming weeks.

# Balloon Science

## ESRL celebrates 30 years of water vapor data

A six-foot diameter weather balloon soared into low clouds over Boulder, CO, April 21, its historic payload dangling from a string below. For 30 years now, NOAA researchers have sent balloon-borne instruments nearly 100,000 feet into the air twice a month, to collect data about the atmosphere, from the ground up to the darkness of near space. Among the measurements the balloon would take on its journey was water vapor concentration, which is critical for understanding climate change.

A few dozen scientists, journalists, and members of the general public watched the NOAA-instrumented balloon disappear into the clouds, during a celebration of the unique, 30-year "Boulder Record" of water vapor measurements.

"Today, we sing a little bit about something that often goes unsung: long-term monitoring," said Jim Butler, Director of the NOAA Earth System Research Laboratory's (ESRL) Global Monitoring Division (GMD). Butler and several colleagues recognized the scientific foresight of ESRL's Sam Oltmans, who began the water vapor measurements in 1980. Scientists are increasingly interested to know if the amount and distribution of water vapor in the upper atmosphere are changing, said Dale Hurst, who runs the Boulder water vapor program today. Water vapor is a greenhouse gas that plays critical roles in climate change.

When Oltmans began the measurement program, the balloons had to be even bigger to carry water vapor instruments, called frost-point hygrometers, that weighed three times as much as today's miniaturized versions. Over the years, Oltmans and his colleagues have worked to ensure that the water vapor data are precise, accurate, and comparable with those from previous years. Along the way, these data have helped solve some significant scientific disputes about the amounts of water vapor in various parts of the atmosphere, Oltmans said, and they've uncovered patterns that remain puzzling today.

ESRL's Susan Solomon, who helped lead the Intergovernmental Panel on Climate Change effort that earned the 2007 Nobel Peace Prize, spoke at the ceremony. She thanked Oltmans and his colleagues for their dedication, and described how she used the Boulder water vapor record—and satellite data—in a recent paper linking changes in upper atmospheric water vapor levels to temperatures here at Earth's surface.

"You can be assured that the world scientific community recognizes the incredible value of this dataset," Solomon said.

*Sam Oltmans (GMD) holds an historic computer print-out of data from a balloon-borne water vapor instrument called a frost-point hygrometer.*

NOAA

## ... Fish, from page 1

with climate data.

"I was excited about the prospect of collaborating," said Alexander, a climate scientist who has always been interested in marine biology. He had already done research on how climate variability may impact amphibians and stellar sea lions, for example. He worked with Hare to determine what data would be best for this study and where to get it.

Because ocean temperatures in near-shore bays and estuaries generally track the overlying air temperature, the latter could be used as input to the croaker model. Alexander and Jamie Scott (PSD and CIRES), extracted air temperatures along the U.S. East Coast spanning 1870-2001 from 14 General Circulation Models (GCMs) that were used in the Intergovernmental Panel on Climate Change Fourth Assessment Report. Also used from this widely established and freely available dataset were three different $CO_2$ scenarios that estimate greenhouse gas and air temperature changes from the present out to the year 2100. Alexander also helped explain the climate models, how to use the data, and checked the consistency of the information both in nature and within the model.

Hare and his colleagues at NFSC then fed the climate data into a fish population model that combined temperature and fishing rates; two key factors that affect fish mortality. This new fish-climate model is one of the first to look at the relationship between temperature change and its impact on a specific fish population.

The results looked pretty positive for the Atlantic croaker: If global temperatures continue to increase as predicted, more croakers will make it to adulthood and, therefore, the population will grow. Climate change may also widen the geographic range of croakers. Currently the Chesapeake Bay houses the highest density of croakers. Over time their range could expand into an area around New York.

The team of scientists published their work in the March 2010 issue of *Ecology Applications*.

Alexander cautioned that the results are specific to the Atlantic croaker: "While climate change may increase the population and range of croakers, it is likely to adversely affect other fish such as cod," he said. Because climate change information has not traditionally been included in fisheries planning, this model could be a breakthrough in performing stock assessments and planning for sustainable fisheries.

Hare concluded: "Our results demonstrate that climate effects on fisheries must be identified, understood, and incorporated into the scientific advice provided to managers if sustainable exploitation is to be achieved and maintained in a changing climate."

Current GCMs can only provide forecasts out to 50-100 years, a bit far in the future for most fisheries planning, said Hare. Shorter-term forecasts ranging between 5-50 years may soon become available for incorporation into fisheries models, to make even better informed decisions.

*—Barb DeLuisi*

# Ozone Symposium

Twenty-five years ago in May, scientists with the British Antarctic Survey reported that the springtime stratospheric ozone layer over the Antarctic was thinning dramatically. In the years since then, ESRL scientists have been extensively involved in understanding the reasons for that decline, tracking levels of the chemicals that deplete stratospheric ozone, and calculating the effectiveness of international policies to allow ozone layer recovery.

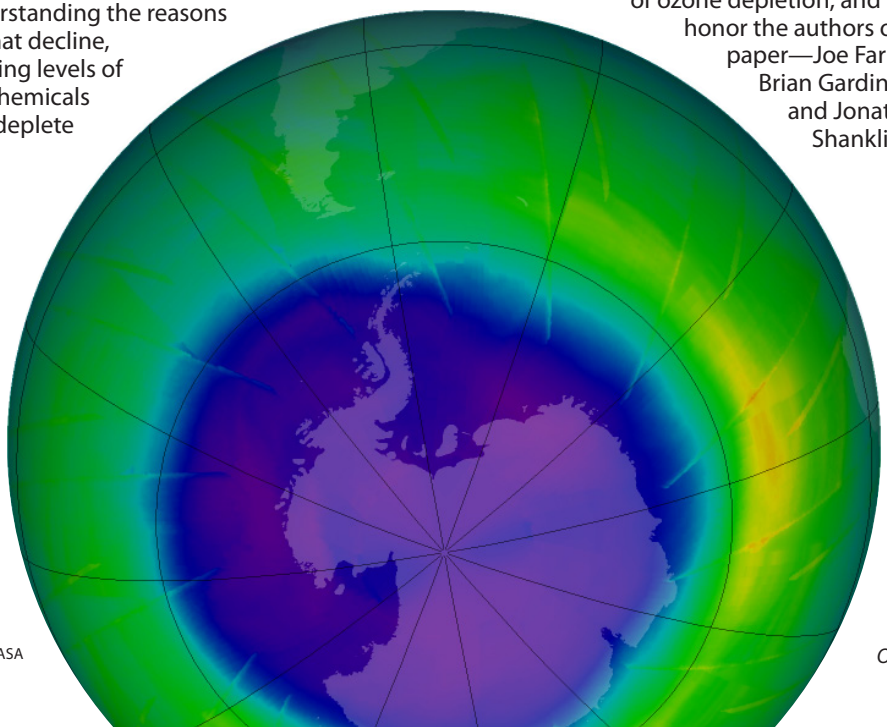
Three of those ESRL researchers traveled to the University of Cambridge this spring, to celebrate the 25th anniversary of the publication describing the discovery of ozone depletion, and to honor the authors of that paper—Joe Farman, Brian Gardiner, and Jonathan Shanklin.

Susan Solomon (Chemical Sciences Division, CSD) spoke about past and future ozone depletion. David Fahey (CSD) described how an international treaty to regulate ozone-depleting chemicals has also benefitted climate. A.R. Ravishankara (CSD Director) attended the symposium; he was at nearby Oxford University, serving as the distinguished Hinshelwood Lecturer.

## Quadrennial Assessment

ESRL scientists from the Global Monitoring and Chemical Sciences divisions are helping to co-author the *2010 Scientific Assessment of Ozone Depletion*, conducted under the auspices of the World Meteorological Organization and the United Nations Environment Programme. The last assessment came out in 2006; the executive summary of the 2010 assessment will be released in July.

A.R. Ravishankara is co-chair of the 2010 assessment, and coordinating lead authors include John Daniel (CSD), Steve Montzka (GMD), and David Fahey (CSD). Christine Ennis (CSD) is coordinating editor, and other ESRL staff are serving as lead authors, coauthors, reviewers, and in other roles.



NASA

*Ozone minimum over Antarctica in September 2009.*

# Matt Shupe

## In search of clouds over Greenland

Christopher Cox, University of Idaho

At 10,000 feet high in the middle of the Greenland Ice Sheet, ESRL's Matthew Shupe and colleagues spent part of May and June installing a powerful suite of climate and weather instruments to better understand how clouds contribute to rapid warming and melting in the region.

The work required the help of skilled carpenters, careful insulation of the instruments, and sleeping in tents in subzero temperatures. Some days, the air sparkled with "diamond dust" ice crystals, swept around by the wind. Others, fog swept through, leaving a rime of feather-like ice crystals on exposed surfaces.

Shupe (also with CIRES) blogged about his work in Summit at http://cires.colorado.edu/blogs/shupe/. He wrote about the challenges of installing instruments, living in a tent city, and doing yoga in Carhartt pants.

Scientifically, Shupe is working with David Turner (University of Wisconsin) and Von Walden (University of Idaho) to study clouds, precipitation, and atmospheric structure, all of which are poorly understood over the Greenland Ice Sheet. Clouds can have profound effects on climate and climate change by altering the radiative balance in the atmosphere and at the surface, and through their roles in converting water between vapor, liquid, and ice phases. An improved understanding of cloud structure and processes is vital to understanding climate change.

The researchers installed many new instruments at Summit: a cloud radar, two microwave radiometers, a ceilometer, an Atmospheric Emitted Radiance Interferometer, an X-band precipitation sensor, a sodar, a cloud and aerosol polarization and backscatter lidar, and a micropulse lidar. The researchers also initiated a program to launch radiosondes twice daily, to measure the atmospheric structure above the station. The full suite of instruments will be operated for at least the next four years.

Shupe's work is funded by a five-year National Science Foundation, NSF, grant, and the Summit project is part of the Arctic Observing Network, an NSF effort to expand understanding of Arctic climate change. Additional support for the project is coming from the NOAA Earth System Research Laboratory, the Department of Energy, and Environment Canada.

The project is called ICECAPS: Integrated Characterization of Energy, Clouds, Atmospheric state, and Precipitation at Summit.

More: http://cires.colorado.edu/blogs/shupe/

# America's Climate Choices

## A.R. Ravishankara, Susan Solomon co-author National Research Council reports

Credible, strong science shows that human-caused climate change is occurring, and poses serious risk for human and natural systems, according to *Advancing the Science of Climate Change*, one of three reports issued by the National Research Council, NRC, in May.

The NRC will release two more reports later this year, for the five-part study known as *America's Climate Choices*, requested by Congress. ESRL's Susan Solomon (Chemical Sciences Division, CSD) is co-authoring the overarching study, which aims to provide "a scientific framework for shaping the policy choices underlying the nation's efforts to confront climate change."

ESRL's A.R. Ravishankara (CSD Director) was one of 21 authors of the new *Advancing the Science* report. That report outlines what is known about climate change, from steady increases in Earth's average surface temperature during the past century, to the predominant cause of those changes—"human activities that release carbon dioxide and other heat-trapping greenhouse gases into the atmosphere."

It also calls for significant changes to the way climate change research is organized, including an expanded integrative and interdisciplinary approach to studying climate change issues, combining physical, social, biological, health, and engineering sciences.

*Advancing the Science* recommends that a single federal entity or program coordinate a national climate research effort, and urges the nation to deploy a more comprehensive climate observing system. CIRES scientist Waleed Abdalati was also a report co-author, and Pamela Matson of Stanford University served as chair.


*Susan Solomon speaks during an America's Climate Choices Summit in 2009.*

More: http://americasclimatechoices.org/

# Art of the Inlet

## Precision engineering and innovation for airborne science

It's tricky to study the atmosphere from a research airplane speeding faster than 325 feet per second through thin air. Researchers rely on "inlets" to draw samples into custom instruments onboard—and designing those inlets can take exquisite attention to detail.

"Some of them are dead simple, but some are full-on instruments in their own right," said ESRL's Tom Ryerson (Chemical Sciences Division, CSD).

It's not just a matter of avoiding jet exhaust: If an inlet isn't designed correctly, particles could shoot by the opening, evading observation by instruments onboard. Gases might chemically react with the lining of an inlet tube, or temporarily absorb enough to mess up measurements.

As NOAA's WP-3D research airplane—studded with inlets—headed out for the CalNex mission in California this spring, it stopped for a few days at the Rocky Mountain Region Airport in Broomfield, CO. ESRL researchers installed and tested equipment on a practice flight before the mission, a major study of the nexus of air quality and climate change in California. Ryerson, Carsten Warneke (CSD and CIRES), and Chuck Brock (CSD) also showed curious colleagues around the airplane, explaining the science and art of airplane-based sampling.

Morgan Heim, CIRES

### The Experiment

"This is an experiment," Ryerson said, pointing to an oddly angled inlet on the right side of the WP-3D. Researchers have struggled for years to obtain accurate measurements of nitrogen oxide compounds as a group, Ryerson said.

"You want to measure them all in the gas phase, but you also want to exclude the aerosols, some of which have nitrogen components. That's very hard to do."

His inlet uses a ring-shaped point-of-entry to smooth the airflow, and also angles the main tube, which is roughly parallel to the aircraft body, to make that smoothed airflow race even faster. The idea is to trick lightweight aerosols into speeding past the gas intake, in the center of that tube, so that only true gases are sucked in.

The angle of Ryerson's inlet can be adjusted mid-flight, and he based his design, in part, on the pattern of sticky oil residue on a research airplane (similar to the WP-3D) that flew through the Kuwaiti oil fires in the early 1990s. When that plane landed, the oil smudges quickly dripped off—but the photograph someone took as the airplane landed traced the pattern of airflow over the airplanes' body—key information for Ryerson's instrument. His experimental inlet is flying for the first time during CalNex.

### The Workhorse

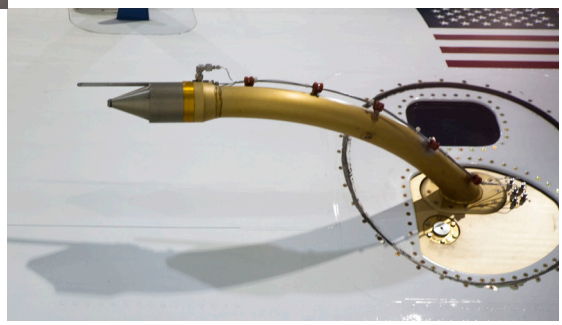
Stainless steel tubes three-eights of an inch in diameter collect air samples for many instruments on board—those measuring carbon monoxide, for example (that gas can be used to calculate the age of an airmass or to help trace its source) and carbon dioxide (a key greenhouse gas). Ryerson puts both CO and $CO_2$ in the "non-sticky" gas category. "You could sample those through old socks and still get a good measurement," he joked.

For some instruments, steel inlets must be lined with Teflon—necessary if you're sampling ozone, for example. "Steel eats ozone," Ryerson said. Other Teflon inlets are heated so that water can't condense inside and "blur" the measurements of "stickier" gases such as sulfur dioxide, nitric acid, and ammonia.

# CalNex Completed

## Mission probes nexus of air quality and climate change in California

The CalNex mission, led by ESRL's Chemical Sciences Division, CSD, began winding down June, after three months of work to assess air quality and climate in California. Hundreds of researchers from across ESRL and NOAA, NASA, the state of California, academia, and international institutions took to the land, sea, and air to measure and track greenhouse gases and air pollutants. The scale of the mission was unprecedented for an atmospheric research project in California. CalNex involved four instrumented aircraft; the research vessel *Atlantis*; and two ground sites in Pasadena and Bakersfield. CalNex also included six-day-



### The LTI, low-turbulence inlet

"There are only a handful of these in the world," Chuck Brock said, pointing to an arrow-shaped inlet emerging from the left side of the WP-3D. Brock is in charge of a suite of instruments on the WP-3D designed to study many aspects of particles (aerosol) in the atmosphere: their mass, size distribution, light-absorption and extinction behavior, and whether they can take up water and help form clouds. These measurements are critical for understanding how particulate pollutants are transported and transformed in the atmosphere, and how they affect climate directly (by absorbing or scattering light) and indirectly (via clouds).

*see page 9*


*Haze hangs over Los Angeles during CalNex.*

a-week ozonesonde releases from six sites across California, and atmospheric data from more than a dozen radar wind profilers, two tall towers, and more than 100 state air quality sites.

The mission was a great success, said David Parrish (CSD). A quick look at the data shows that the scientists were able to capture simultaneous measurements of air quality and greenhouse gases emitted from California's agricultural region—including during agricultural burning events. Nighttime chemistry measurements should let scientists significantly improve understanding of air quality in the Los Angeles region, Parrish said, and CalNex captured detailed information on the transport of some pollutants, particularly ozone, into, within, and out of California.

***Above**: Smog in the Los Angeles Basin, photographed from NOAA's P3-WD research airplane, during the CalNex mission on air quality and climate change in California.*
***Far left**: The experimental inlet and two conventional workhorse inlets.*
***Left**: The low-turbulence inlet.*

*...low-turbulence inlet, from 8*

Brock's inlet needed to slow the airflow from about 100 m/s down to 10 m/s, without creating turbulence. Turbulence allows larger aerosol particles, with greater inertia, to spin off into walls, changing the composition of samples that pass through to the instruments. So the low-turbulence inlet has porous walls that remove air from the turbulent edges of the tube, allowing a central, laminar core of air to flow into instruments. Only about 35 percent of the air mass pulled into the tip of the inlet makes it to the instruments inside the plane.

# Indigenous Knowledge and Science

## Inuit forecasters with generations of environmental knowledge help scientists understand Arctic weather

An Inuk living in the Canadian Arctic looks to the sky and can tell by the way the wind scatters a cloud whether a storm is coming or if it's safe to go on a hunt. Thousands of miles away in a Boulder laboratory, scientists collect data and use computer models to predict weather. They are two practices serving the same purpose, living in separate worlds.

But in the past 20 years, something's run amok with Inuit forecasting. Old weather signals don't mean what they used to. The cloud that scatters could signal a storm that comes in an hour, instead of a day. And now a melding of indigenous environmental knowledge with modern science is helping researchers learn something new about what's happening to the Arctic climate.

Researchers had heard reports of unpredictable weather coming in from Arctic communities. But their stories didn't seem to match up with the numbers. By scientific measurement, weather around the world appeared to be growing more persistent with less variation. The disparity left scientists—including ESRL's Betsy Weatherhead (Global Systems Division and CIRES), who has long been interested in the issue—scratching their heads.

She contacted Shari Gearheard, a scientist with CIRES' National Snow and Ice Data Center, who lives in Clyde River, Nunavut, Canada, an Inuit community on eastern Baffin Island. For the past 10 years, Gearheard has been working with Inuit hunters and elders to document their knowledge of the environment and environmental change. Gearheard meticulously collects the stories told to her by the Inuit and makes systematic records of indigenous environmental knowledge. Through this, patterns begin to emerge, leading Weatherhead and colleague Roger Barry, a CIRES Fellow, to focus their analysis on patterns of weather "persistence" in the springtime.

Statistical analysis of day-to-day temperatures at Baker Lake, Nunavut, showed that in May to June, the persistence of temperature has recently declined, matching Inuit reports of greater unpredictability for that season.

The scientific story matched what people were witnessing on the ground. Weather along the Arctic latitudes was behaving more unpredictably than in other parts of the world. "That's an incredibly important parameter to care about, incredibly important," said Weatherhead. "The way I try to describe it to some people, if we get an inch of rain out at my house in the month of July, I don't need to turn on the sprinklers. But if we get an inch of rain on July 1, and no rain after that, my lawn is dead."

"Ecosystems have evolved under a certain type of pattern. So if that is changing, that could be just as important as a small increase in temperature or some of the other changes we're talking about," Weatherhead continued.

The study helps refine and test climate models, while also providing these models with a new category of information to consider. And Gearheard's work with the Inuit is demonstrating the value of indigenous environmental knowledge to modern climate science.

"When we first started talking about this, indigenous knowledge didn't have the place it does now in research," Gearheard added. "It's growing. People are becoming more familiar with it, more respectful of it."

*—Morgan Heim, CIRES*

More, including a podcast interview with the paper authors: http://cires.colorado.edu/news/press/2010/gearheardInuit.html

# Achievement

**More news, publications, and honors from NOAA's Earth System Research Laboratory**

## SOS® update

ESRL unveiled a new traveling Science On a Sphere® (SOS) exhibit on Ocean Discovery Day (May 1) at NOAA's Flower Garden Banks National Marine Sanctuary in Galveston, TX. SOS, an educational tool developed at ESRL, now wows audiences at more than 50 science museums and other institutions around the world. The sphere is a six-foot-diameter sphere-and-projection system, used to illustrate Earth System science, from hurricane development to climate change.

Projectors supporting the old traveling sphere were eight years old and the computers were five, said Beth Russell (Global Systems Division and CIRES). Moreover, the new traveling exhibit takes one day to setup—the old one took two-and-a-half days.

Also, SOS is showing in the MeteoWorld Pavilion at the World Expo, which is running from May to October in Shanghai, China.

## Sea ice forecasts

NOAA is making plans to forecast Arctic sea ice extent on several time scales, ranging from one day out to a decade or more in the future. The forecasts could be critical for local Arctic communities, the shipping industry, and marine mammal stewardship, said ESRL's Janet Intrieri (Director's Office).

She and John Calder (NOAA's Arctic Research Office) hosted a multi-agency workshop at ESRL in May, to begin developing plans for the sea ice forecasts. The work will involve close collaborations with other agencies, from the U.S. Coast Guard and Navy to international research and meteorology institutions.

Near-term forecasts, on the order of a few days, would likely focus on sea ice along the northern coast of Alaska: extent, concentration, thickness, and timing of ice formation and melt. Long-term forecasts would rely on understanding about natural and greenhouse-gas driven changes in the Arctic climate, ensemble forecasts, and estimates of snow cover (to support marine mammal stewardship).

## Testbeds workshop

In May, ESRL hosted the second annual NOAA Testbed Workshop, sponsored by the NOAA U.S. Weather Research Program's Executive Committee, and chaired by Marty Ralph (Physical Sciences Division). About 80 people participated from across NOAA, the National Center for Atmospheric Research, and NASA. Testbeds link weather research and operational forecasting through the development, demonstration, and evaluation of new technologies and predictive models—making researchers more aware of critical forecast challenges, and forecasters more aware of advances in science and technology.

Testbeds represented were: the Joint Hurricane Testbed, Hydrometeorology Testbed, Hazardous Weather Testbed, Developmental Testbed Center, Climate Testbed, Societal Impacts Program, and the Short-term Prediction Research and Transition Center. The Testbed workshop let participants from diverse sectors share experiences and lessons learned. Those gathered at this year's workshop agreed that testbed research should be important in NOAA's out-year planning process, especially research related to observing system and other potential major infrastructure investments.

## Australian honor shared

Greg Ayers, Director of Meteorology at the Australian Bureau of Meteorology (BoM), thanked NOAA this spring for support in implementing the Graphical Forecast Editor (GFE) and the associated digital database at Australia's Victoria Regional Office in Melbourne.

The GFE allows forecasters to prepare a gridded database of weather forecast elements. Those gridded elements, including temperature, clouds, winds, and precipitation, form the basis for many forecast products. Since 2006, the Global Systems Division's GFE team has worked to tailor this suite of graphical editing tools to BoM's needs.

The BoM was presented the 2009 annual Innovation Award for the agency's implementation of the GFE under the banner of the Australian Government Leadership Network. The BoM was given the top award for "vastly improved level of service that the Bureau can provide, especially to remote regional areas that have previously received only basic service."

BoM is in the process of extending the implementation to all parts of Australia during the next four years under the title of the Next Generation Forecast and Warning System.

# Published

ESRL's peer-reviewed publications are available in a searchable database:

**http://www.esrl.noaa.gov/search/pubs/**

Divisions also have Publication pages:

**GMD:** www.esrl.noaa.gov/gmd/publications/
**PSD:** www.esrl.noaa.gov/psd/pubs/
**CSD:** www.esrl.noaa.gov/csd/pubs/
**GSD:** www.esrl.noaa.gov/gsd/publications/

*Science On a Sphere® in the MeteoWorld Pavilion at the World Expo in Shanghai, China.*

## Flight guidance

Migrating birds could put the most state-of-the art GPS to shame with their arsenal of built in navigation sensors. These frequent flyers use tools such as Earth's magnetic field, the sun's orientation, visual cues, and weather to navigate migration routes sometimes spanning thousands of miles and multiple continents. Now a new study in progress looks at the possibility that waterfalls might also help birds stay on track. Waterfalls send out distinct sound signatures, so ESRL's Alfred Bedard (Physical Sciences Division and CIRES), is comparing the soundscape of Niagara Falls with the hearing power of pigeons and migration patterns of birds traveling along the Atlantic Flyway. If Bedard's suspicions prove correct, this would be the first evidence that birds use waterfalls as navigation beacons while migrating.

## Dry times ahead

Brad Udall of the NOAA/CIRES Western Water Assessment co-authored a perspective piece in *Science* at the end of June, calling for a "no-regrets" approach to planning for climate change in the U.S. West. The region is already experiencing higher temperatures, declining late-season snowpack, north-shifting winter storm tracks, and more frequent large wildfires, Udall and colleague Jonathan Overpeck of CLIMAS (the Climate Assessment of the Southwest), point out. They wrote that it is "both reassuring and troubling" that climate models project trends very similar to those observed. Udall and Overpeck call for smarter water use and an economy-boosting focus on harnessing the West's potential for solar, wind, and geothermal energy.

More: http://www.sciencemag.org

*Tom Karl (third from right, blue shirt) speaks with other participants during a break in the Global Monitoring Annual Conference. Karl gave a keynote speech at the May conference—an annual event hosted by ESRL that draws researchers from around the world. More: http://www.esrl.noaa.gov/gmd/annualconference/*

# Honors

**Susan Solomon** (Chemical Sciences Division, CSD) was one of two NOAA scientists named Service to America Medal finalists. Solomon was selected for nearly three decades of influential scientific research with NOAA, including identifying the cause of the ozone hole and service as co-chair of Working Group I of the Intergovernmental Panel on Climate Change. Also a finalist is Joe Schaefer, retired Director of NOAA's Storm Prediction Center. Winners will be announced in September.

**Curtis Alexander**, **Ming Hu**, and **Tatiana Smirnova** (Global Systems Division) were awarded a CIRES Bronze Medal in April for their roles in developing the first National Centers for Environmental Prediction operational radar reflectivity assimilation technique and improving convective storm forecasting.

**Steve Peckham** (GSD) received a CIRES Service Award for helping to develop and provide support to the complex modeling system, WRF-Chem (Weather Research and Forecasting-Chemistry). WRF-Chem allows research relevant to many current environmental challenges, including air quality and global climate change.

**Solomon** received an honorary Ph.D. from the Université Pierre et Marie Curie, the largest science and medical institution in France.

**Solomon** was also named as one of the 125 "Women who Changed our World," by *Good Housekeeping* magazine. She was lauded alongside Rachel Carson, Jane Goodall, Barbara Walters, and Madeline Albright. http://www.goodhousekeeping.com/family/real/women-who-changed-our-world

**Valery Zavorotny** (Physical Sciences Division) was selected as a 2009 Top Reviewer for IEEE *Transactions on Geoscience and Remote Sensing.*

**Laurel Watts** (CSD) is a finalist for graphical system design achievement award from National Instruments, for her design of the system that controls a new ozone instrument flown on this spring's GloPac mission over the Pacific Ocean. Award recipients will be announced in August.

*CIRES Director Koni Steffen presents Steve Peckham with the CIRES Service Award.*

# FIM Chem-Ash

## ESRL model forecasts volcanic ash cloud in real time

Henrik Thorburn

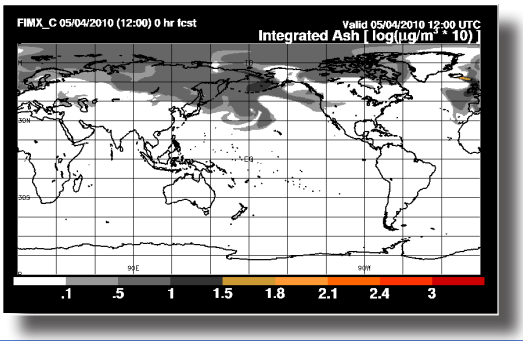
In April and May, European authorities canceled more than 100,000 flights affecting 10 million passengers and costing the aviation industry billions in lost business due to the eruption of Icelandic volcano Eyjafjallajökull. NOAA established a volcanic ash forecast response effort aimed at improving international guidance. ESRL responded with a new forecasting model, the FIM-CHEM-Ash, that began producing experimental real-time volcanic ash forecasts in May. This is the first time that a global model has been run with in-line chemistry; with 17 aerosol and gas-phase tracer concentrations and four size bins of volcanic ash.

The model currently includes eruption data from Eyjafjallajökull and has cycled 14 aerosol concentration and three gas-phase prognostic variables since April 14, the start of the Icelandic volcano's explosive eruption. Using the Global Forecast System for atmospheric initial conditions, the FIM-CHEM-Ash is run at 30-km resolution and maintains the aerosol/ash cycling with new five-day forecasts run on a daily basis. The inline treatment of chemistry and ash (interaction with other meteorological variables) within FIM-Chem-Ash will very likely provide a considerable improvement over current abilities to predict ash dispersion with regards to both accuracy and timeliness.

These new runs, though still under development and not considered official guidance, are an example of NOAA's effort to help the international VAAC community as it continues to deal with new waves of dense volcanic ash in European airspaces and for future volcanic eruptions worldwide. There are nine VAACs: http://www.ssd.noaa.gov/VAAC/vaac.html strategically located that were created when the International Civil Aviation Organization and other Aviation concerns recognized the need to keep aviators informed of volcanic hazards.

More: http://fim.noaa.gov/

*—Annie Reiser*





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**www.esrl.noaa.gov/news/quarterly**




At NOAA's Earth System Research Laboratory, we observe, understand, and predict the Earth system through research that advances NOAA's environmental information and services, from minutes to millennia on global to local scales. ESRL's partners are the Cooperative Institute for Research in Environmental Sciences at the University of Colorado at Boulder, and the Cooperative Institute for Research in the Atmosphere at Colorado State University in Fort Collins.

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