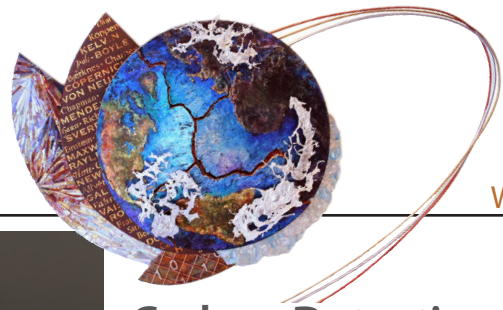


# ESRL Quarterly

News from NOAA's Earth System Research Laboratory



WINTER  
2008

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Warren Gretz/NREL

## Carbon Detectives

### Scientists track CO<sub>2</sub>'s increase

**Wanted:** The notorious greenhouse gas carbon dioxide, CO<sub>2</sub>, and a detailed investigation into its activities.

**Description:** Invisible.

**On CO<sub>2</sub>'s tail:** ESRL scientists, who are using instruments on tall towers, air flask analysis, and a data assimilation system called Carbon Tracker, to track and visualize the gas as it swirls around the globe.

Wouter Peters, working in the Carbon Cycle Greenhouse Gases group (CCGG, part of GMD), developed the initial version of CarbonTracker, first released in 2007, to better follow the origins and destinations of atmospheric carbon dioxide. CO<sub>2</sub> has been increasing steadily since the Industrial Revolution because of fossil fuel burning and other human activities.

see p.7

## Renewable Energy Collaboration Grows

### ESRL leads NOAA effort to support deployment of renewables

ESRL researchers have long worked to improve scientific understanding and prediction of weather, climate, and climate change. Now, scientists here are doing something to help *solve* the energy and climate crises, by using NOAA's extensive observation networks and modeling skills to support alternative energy production.

NOAA's observing networks and models were not developed for or intended to support the renewable industry, said Jim Wilczak (PSD). But energy companies have already begun using NOAA data to guide wind farm deployment, select solar sites, and predict daily energy demand—and the renewable energy community is asking NOAA to do more.

"NOAA needs to begin thinking of renewable energy as a primary issue, not secondary," said Wilczak. "We are making this an active collaboration."

To that end, Wilczak and Melinda Marquis (DO) are leading the agency into a formal relationship with the National Renewable Energy Laboratory (NREL) in Golden, 20 miles from ESRL in Boulder. This fall, ESRL Director Sandy MacDonald and NREL Director Dan Arvizu signed a letter of intent to work together on projects that "advance National interest."

Advancing science in support of the renewable energy industry addresses three linked goals, Marquis said: Meeting energy demand, supporting the economy with quality jobs, and reducing the emission of heat-trapping greenhouse gases.

A more detailed Memorandum of Understanding is in the works, Marquis said, and the list of possible collaborative topics is long, she said, given ESRL's "expertise in measurement systems, observational networks, and short- and long-term forecasts."

During the past few years, ESRL scientists have collaborated with NREL on smaller projects related to wind energy. Expanded work could include establishing wind-energy test beds to measure and improve the prediction of winds at the 20 m to 200 m height of wind turbines—a poorly instrumented region of the atmosphere. "There's costly imprecision in our models," said Bob Hawsey, Associate Director for Renewable Electricity and End Use Systems at NREL.

ESRL researchers could also continue working toward more precise, more high-resolution, and more quickly updated weather forecasts, which are key for predicting energy demand (heating or cooling) and supply

see p.6



Dave Metzke (WFO, Pueblo, CO), Steve Amburn, (WFO, Tulsa, OK), Matt Peroutka (NWS) and Tom LeFebvre (GSD) at ESRL workshop

## Probabilistic Forecasts

### ESRL quantifies uncertainty to improve weather products

Joe Concrete checks the forecast before heading out to pour a foundation—and sighs. There's a reminder that temperatures could drop mid-afternoon, and then the usual two numbers: high of 52°F, low of 31°F. Not enough. If water seeps into setting concrete and freezes, it expands, fracturing and weakening the material. What Joe really needs is the likelihood that temperatures will freeze before he finishes work.

see p.4



## Director's Corner

You can almost hear the hinges of history creaking as the nation and the world consider policy options to deal with greenhouse gases. In December, I attended a celebration of the completion of France's Presidency of the European Union at the French Embassy, and the discussions ranged from the recent European greenhouse emission agreements to what new directions the United States will take during the Obama administration. Many of the Europeans remarked on the strong climate orientation of the Obama cabinet and other senior nominations. The NOAA mission of understanding and predicting the oceans and atmosphere will play a central role in the U.S. response to the climate change issue. In this issue of ESRL Quarterly we describe a number of research and development activities that will help NOAA respond to these new priorities.

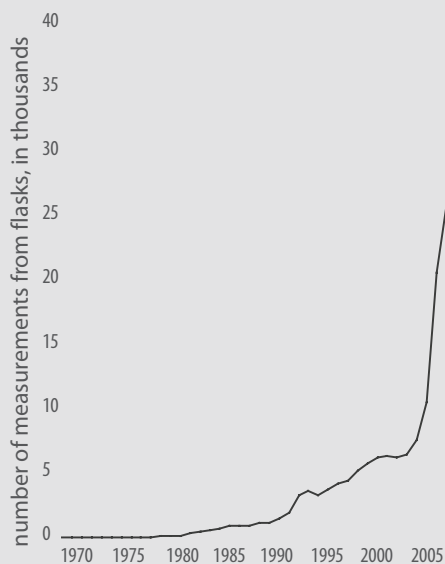
The cover article on renewable energy describes many areas of research that are important for the future of renewable energy. An important example is the design of the national energy grid. Two forms of renewable energy that are already economically viable for large-scale power generation are wind turbine farms and solar thermal plants (power plants that concentrate the sun's heat using mirrors). Each of these renewable energy sources has a limited geographic range in which it is most economical. In our competitive market-based system, this means that, for example, a large part of the wind energy generation will be located on the Great Plains from North Dakota to Texas, while solar thermal plants will thrive in the desert southwest. The design of a national renewable energy system should ideally have excellent low-cost power transmission across the country, combined with a national architecture of renewable power generation that takes advantage of the spatial variability of weather—to decrease the time variation of national renewable power availability. The collaboration between the National Renewable Energy Laboratory, NREL, and ESRL thus brings together two institutions with complementary areas of expertise, both of which are critical to design of the national renewable energy system.

The fact that ESRL and NREL are complementary in their disciplines is important, but there is another compelling reason for joint effort. ESRL, as part of NOAA, works closely with the National Weather Service (NWS) to assure that NOAA's operations will meet the requirements of the renewable energy era. NWS does not currently forecast the precise physical phenomena needed for renewable energy generation. Winds at the 100 meter level and direct and diffuse solar energy will be best predicted by implementing national observing and high-resolution operational modeling systems that meet those requirements. Fortunately, these needs are close to what the NWS needs to do to improve aviation weather, severe weather warnings, and other important national priorities. A couple of months ago, I had the opportunity to meet with NOAA OAR Assistant Administrator Rick Spinrad and NWS Assistant Administrator Jack Hayes to discuss how NOAA's research could expedite the improvements needed for the next generation of the NWS operational system. By working with ESRL, NREL assures that the operational prediction system is being developed with this important new requirement in mind. For ESRL, it is a good example of prioritizing endeavors that prepare NOAA for its future mission.

As NOAA studies the need for a National Climate Service (NCS), it is easy to see the relevance of ESRL's extensive work on carbon and the Arctic, both discussed in this issue, and both at the core of NOAA's future mission needs. The amazing decrease in Arctic Ocean summer ice in the last two years is the latest evidence that we need to understand the Arctic climate much better. In the case of carbon, the world is entering an era in which tracking carbon with observations and models is extremely important. Field campaigns like ARC-PAC, the circumpolar Arctic observatories, and the rapid increase of GMD's global flask measurement network all prepare NOAA for the coming enlargement of its mission.

—Alexander MacDonald

## By the Numbers Flask Samples



For 40 years, ESRL researchers have been measuring trace gases in air samples collected weekly in glass flasks from dozens of sites around the world. The result of this cooperative global effort is an invaluable long-term record of many critical gases, from those that contribute to climate change to those that deplete the ozone layer. Flask data document the rise in concentration of the greenhouse gas carbon dioxide, and the decline of ozone-depleters, which were phased out in accordance with an international treaty. In 1967, only carbon dioxide was measured. Today, ESRL GMD scientists measure more than 62 “species” from flasks, including, for example, the isotopic ratios of carbon dioxide, which can help researchers determine whether the gas came from land or sea sources.

Pat Lang (ESRL GMD) preparing flasks for sampling





Ru-Shan Gao/CSD

## China's Black Carbon

Joshua Schwarz (ESRL CSD) and Xiofeng Huang

In the autumn, plumes of air laden with black carbon and other particles sweep southwest out of China's industrial Pearl River Delta, formed from diesel combustion, biomass burning, and other activities in Guangzhou and Hong Kong. Two ESRL scientists traveled to a research station in rural South China this fall, to help scientific colleagues track black carbon and other pollutants downwind of the delta.

"We are particularly interested in black carbon, because it is a very potent warming agent," said Ru-Shan Gao (ESRL CSD).

Researchers have long understood that black carbon can damage lungs—that is one of the motivations for the regional Chinese air quality experiment in which Gao and Joshua Schwarz (ESRL CSD) participated. In recent years, it has also become clear that the particles contribute significantly to atmospheric warming, by absorbing sunlight rather than reflecting it as many other aerosols do.

Gao, Schwarz, and their colleagues are trying to better quantify black carbon abundance and its role in warming. Climate modelers are interested in using reliable black carbon data to improve model accuracy, Schwarz said.

The ESRL scientists were hosted by Professor Xiaofeng Huang of Peking University, a prin-

cipal investigator of the multiple-site, regional project 3C-STAR (Synthesized Prevention Techniques for Air Pollution Complex and Integrated Demonstration in Key City-Cluster Region). Sites included the megacity of Guangzhou, an area upwind, and the rural Jiangmen research station downwind. In Jiangmen, the ESRL scientists and Huang used a Single-Particle Soot Photometer (SP2) to measure the concentration and size distribution of black carbon particles in air.

"The SP2 can be tricky to optimize," Gao said. "To produce good data, it needs a lot of fine tuning." He and Schwarz, an SP2 expert, helped Huang better understand and use the instrument. In return, the ESRL researchers will be able to analyze black carbon data from a region unlike any in the United States.

"If I think about our highest measurement in urban Houston, well, this was about four times higher, and we were in a rural area, far downwind of sources," Schwarz said.

The early data look interesting, Schwarz said, and there was at least one completely unexpected event. About 3 a.m., black carbon levels tripled for an hour or so. The spikes likely came from illegal tire burning, done at night, possibly to recycle metals inside the tires.

## Quick Response Science

After wildfires scorched more than 150,000 acres of mountainous terrain near Big Sur, CA this past summer, U.S. Geological Survey scientists surveyed the damage and discovered a significant risk of devastating debris flows. Even a moderate rainstorm could quickly get soil, rock, and vegetation moving down dozens of drainage basins.

Weather forecasters already knew that operational radar coverage in the area was inadequate for detecting low-altitude rain clouds. Given the high risk—and a recent history of debris flows in fire-scorched areas of Southern California—the National Weather Service asked for ESRL's help.

It was late September when David Reynolds, the Meteorologist-In-Charge at the National Weather Service's San Francisco/Monterey Weather Forecast Office, made the request. By the end of October, Marty Ralph (ESRL PSD), Allen White (ESRL PSD), and colleagues had state-of-the-art weather probing instruments up and running at Point Sur, including an S-band precipitation profiling radar. The goal: Give weather forecasters the information they need to issue earlier warnings when rain threatens the burn area. Shallow rain clouds form when moist air off the Pacific Ocean flows up coastal mountain slopes. These clouds consistently elude the Weather Service's operational radar.

Nov. 1, a bank of these shallow clouds began to drop rain along the coast near Big Sur, invisible to the closest National Weather Service NEXRAD radar, in Monterey. The shallow rain echo was clearly observed by the new Point Sur S-band radar, which had been operating for just a couple of days.

"As soon as we hit the first hour of rain falling at a rate of 0.6 inches an hour, the debris was coming down the hill," exactly as the Geological Survey study predicted, Reynolds said. Rocks, mud, tree trunks, and branches roared down two drainages, he said. One of the flows filled a house with a couple feet of mud and continued on into the local Grange Hall, forcing election officials to find another polling site.

The S-band radar saw the rain as it was falling, precluding officials from issuing a warning, Reynolds said. But another tool at Point Sur—a suite of instruments developed by ESRL scientists combining measured winds aloft with integrated water vapor provided by a GPS receiver—should allow a short-term prediction of rainfall potential. That system is available now, White said.

"It might just give us the lead time we need for saving lives," Reynolds said.

## Reaching Out

Led by ESRL's Outreach Team, NOAA hosted more than 500 visitors this fall: 20 middle school teachers from around the country, 275 8<sup>th</sup> grade students from Boulder Valley School District, 100 2<sup>nd</sup> grade students from Mesa Elementary, more than 150 folks for "Bring Your Family to NOAA," and 40 Colorado teachers for a workshop on bringing NOAA science into classrooms. Visitors saw Science On a Sphere®; witnessed the workings of NOAA laboratories and centers; and learned about the scope of research here, from the poles to tropical oceans, on mountains, ships, and inside hurricanes. The Team also "took the NOAA show on the road" to local schools, science and education conventions, and career fairs.



...PROBABILISTIC, from p.1

He's not alone, said Paul Schultz, an ESRL meteorologist (GSD). Businesses and governments are making increasingly sophisticated weather-related decisions. A city might understand precisely the financial and safety risks involved when ice threatens roads and managers must determine if de-icing is necessary—but the weather variables often remain poorly defined.

“We need to start quantifying uncertainty,” said Schultz, who has spent the last year figuring out how to better incorporate probabilities into weather forecasts. This fall, Schultz and his colleagues brought five National Weather Service forecasters to ESRL. They tested several probabilistic forecasting concepts that could be included in the next generation of AWIPS, the workstation used in National Weather Service offices around the country. The ESRL workshop was part of a growing NOAA enterprise dedicated to improving the agency's communication of forecast uncertainty.

“Our users are demanding complete forecasts...and that includes uncertainty

information,” said Douglas Hilderbrand, NOAA Forecast Uncertainty Program Manager from NWS's Office of Science and Technology. “Probabilistic weather forecasts are extremely important for risk-based decision making. Customers not only want the most likely outcome, but quantification of the full range of possibilities.”

Being able to provide probabilities of certain types of weather occurring—the possible times when rain will start freezing, the possible locations of a squall line—into mathematical decision tools will help users, Hilderbrand said. “Better decisions can be made for many parts of our economy, from rerouting aircraft based on probabilistic convective forecasts that saves fuel, to more effective water resource management.”

Probabilistic forecasting requires ensembles of forecasts, which can be analyzed statistically. If a forecaster can access 10 sets of model output in the future, the mean might suggest a high of 52°F, which could be reported along with statistical uncertainty. Perhaps the ensembles suggest an 80 percent chance that the high will fall between 49° and 53° (at 10 and 90

percent likelihoods, respectively). Or, if 50° represents a critical threshold in a certain region, a forecaster could easily calculate the probability of exceeding it.

Two years ago, a National Research Council study concluded, “no forecast is complete without a description of its uncertainty.” The study charged NOAA with incorporating uncertainty information in predictions. AWIPS II, expected by 2010, will eventually include probabilistic tools created by GSD, Schultz said.

“We can do better,” Schultz said. “As a provider of this kind of information, I want to give as accurate and scientific information as possible. We know it will save everyone money.”

**NOAA's probabilistic forecasting efforts are guided by the NOAA/NWS Forecast Uncertainty Steering Team. ESRL members include Schultz, Tom Hamill (PSD) and Steve Koch (GSD Director). NOAA is working closely with private industry, too, through the American Meteorological Society's Ad-Hoc Committee on Uncertainty in Forecasts.**

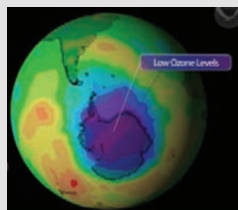
## Achievements, in brief

The following sections—News, Honored, and Published—highlight a few measures of ESRL's impact.

### News

#### Ozone Loss

In September, ESRL scientists reported that the ozone hole over Antarctica was fifth largest on record, since NOAA satellite records began in 1979. The ozone layer protects Earth's surface from damaging radiation, and ozone loss is caused primarily by human-produced chemicals, although the size of the hole fluctuates with temperature and sunlight. A ban on ozone-depleting substances has led to improvements, but colder-than-average temperatures in the Antarctic stratosphere may have pushed the ozone hole to develop more fully this year.



(CFCs). HCFCs are more ozone friendly than the CFCs they replace, but still destroy some stratospheric ozone. ESRL CSD scientist David Fahey also attended the Doha meeting, and participated in discussions of ozone, climate, and the warming avoided by the Montreal Protocol.

#### People

John Schneider, formerly Deputy Director of ESRL GSD) became the ESRL Deputy Director for Research. Robbie Hood (formerly NASA) was hired to lead NOAA's Unmanned Aircraft Systems (UAS) program, from ESRL.

#### Service

Northrup Grumman used data from ESRL's surface radiation network (SURFRAD) during research at the Nevada Test Site this fall. ESRL scientists created a web site to accommodate the company's need for data updates every 15 minutes, from a SURFRAD station at Desert Rock, Nevada. Northrup Grumman used the data to remove the atmospheric contribution from other signals.

#### VOCALS experiment

ESRL scientists participated in December's international VAMOS Ocean-Cloud-Atmosphere-Land Study, focused on a region of the Pacific Ocean where broad decks of stratocumulus clouds form. VOCALS is designed to improve understanding of the southeast Pacific coupled ocean-atmosphere-



land system. Chris Fairall (ESRL PSD) was aboard the Research Vessel *Ron Brown*, off Chile and Graham Feingold (ESRL CSD) was stationed at Iquique, Chile, for the aircraft part of the mission. ESRL tested a new radar system on the cruise; the radar took measurements of winds, turbulence, and aerosols, and was especially sensitive to drizzle and stratus-type clouds.

#### Honored

Chris Fairall (ESRL PSD) was awarded the American Meteorological Society's 2009 Sverdrup Gold Medal Award for outstanding contributions to the scientific knowledge of interactions between the oceans and the atmosphere....Susan Solomon (ESRL CSD) earned a Distinguished Presidential Rank Award, for outstanding leadership and service to the federal government....ESRL scientists co-authored six of the nine papers that earned OAR Outstanding Scientific Paper Awards this fall. Special recognition went to the IPCC's Climate Change 2007: The Physical Basis, co-chaired by Susan Solomon. Other winning papers were: Wouter Peters<sup>1</sup>, Andrew Jacobson<sup>1</sup>, Colm Sweeney<sup>1</sup>, Arlyn Andrews<sup>1</sup>, Thomas Conway<sup>1</sup>, Kenneth Masarie<sup>1</sup>, John Miller<sup>1</sup>, Lori Bruhwiler<sup>1</sup>, Gabrielle Petron<sup>1</sup>, Adam Hirsch<sup>1</sup>, Douglas Worthy, Guido van der Werf, James Randerson, Paul Wennberg, Maarten Krol, and Pieter Tans<sup>1</sup>, 2007, An atmospheric perspective on North American carbon dioxide exchange: CarbonTracker, PNAS, 104....Xuebin Zhang, Francis Zwiers, Gabriele Hegerl, Hugo Lambert, Nathan

Gillett, Susan Solomon<sup>2</sup>, Peter Stott, and Toru Nozawa, 2007, Detection of Human Influence on Twentieth-Century Precipitation Trends, *Nature*, 448.... Thomas Hamill<sup>3</sup>, Jeffrey Whitaker<sup>3</sup>, and Steven Mullen, 2007, REFORECASTS: An Important Dataset for Improving Weather Predictions, *BAMS*, 87.... Larry McMillin, Jiang Zhao, Rama Varma Raja, Seth Gutman<sup>4</sup> and James Yoe, 2007, Radiosonde humidity corrections and potential Atmospheric Infrared Sounder moisture accuracy, *J. Geophys. Res.*, 112.... Tracy Lorraine Smith<sup>4</sup>, Stanley Benjamin<sup>4</sup>, Seth Gutman<sup>4</sup>, and Susan Sahn<sup>4</sup>, 2007, Short-range forecast impact from assimilation of GPS-IPW observations into the Rapid Update Cycle, *Mon. Wea. Rev.* 135.... **Anatta** wrote one of NOAA's top five NOAA press releases from this fall, ranked by "hits" from the media.... **Steve Koch** (ESRL GSD Director) and **Carl Bullock** (ESRL GSD) became AMS fellows.... **Debra Wilson** (ESRL CSD) and **Sharon Berner** (OAR in Boulder) were given OAR's 2008 Research Employee of the Year Awards. ESRL's <sup>1</sup>GMD, <sup>2</sup>CSD, <sup>3</sup>PSD, <sup>4</sup>GSD.

### Published

More publications can be found on division web sites (<http://www.esrl.noaa.gov/gmd/publications/>, <http://www.esrl.noaa.gov/psd/pubs/2008/>, <http://www.esrl.noaa.gov/csd/pubs/>, and <http://www.fsl.noaa.gov/publications/> [GSD].)

Campbell, J.E., G.R. Carmichael, T. Chai, M. Mena-Carrasco, Y. Tang, D.R. Blake, N.J. Blake, S.A. Vay, G.J. Collatz, I. Baker, J. A. Berry, S.A. Montzka, C. Sweeney, J.L. Schnoor, and C.O. Stanier, 2008, Photosynthetic Control of Atmospheric Carbonyl Sulfide During the Growing Season, *Science*, 322. ESRL scientists and colleagues found that atmospheric gradients for COS during the growing season are controlled primarily by plants undergoing photosynthesis. The results provide additional evidence that COS may provide unique insights into the uptake of CO<sub>2</sub> by terrestrial vegetation.

Koch, S.E., C. Flamant, J.W. Wilson, B.M. Gentry, and B.D. Jamison, 2008, An atmospheric soliton observed with Doppler radar differential absorption lidar, and molecular Doppler lidar, *J. Atmos. Oceanic Tech.*, 25. This paper describes the use of remote sensing data to derive the detailed structure and dynamics of an atmospheric soliton during the International H2O Project (IHOP). Solitons can trigger new convection, and a goal of IHOP was to improve convective rainfall prediction.

Li, W., Y. Xie, Z. He, K. Liu, G. Han, J. Ma, and D. Li, 2008, Application of the Multigrid Method

to the China Seas' Temperature Forecast, *J. Atmos. Oceanic Tech.*, 25. This paper describes use of a new assimilation scheme to quickly minimize errors in the analysis of sea surface temperature and shipboard data. In a test of sea surface temperature forecasts, the new method was more accurate than the traditional one.

Lu, M.-L., G. Feingold, H.H. Jonsson, P.Y. Chuang, H. Gates, R.C. Flagan, and J.H. Seinfeld, 2008, Aerosol-cloud relationships in continental shallow cumulus, *J. Geophys. Res.*, 113. Using aircraft data from a climate and air quality study in the Houston region, these authors performed an extensive analysis of aerosol effects on cumulus clouds. They quantified the role that aerosols play in modifying cloud microphysical properties, and their radiative forcing of climate.

Mastepanov, M., C. Sigsgaard, E.J. Dlugokencky, S. Houweling, L. Ström, M.P. Tamstorf, and T.R. Christensen, Large tundra methane burst during onset of freezing, 2008, *Nature*, 456. The authors report bursts of methane released from permafrost during the onset of freezing.

Neff W., J. Perlwitz, and M. Hoerling, 2008, Observational evidence for asymmetric changes in tropospheric heights over Antarctica on decadal time scales, *Geophys. Res. Lett.*, 35(18). This new analysis of five decades of Antarctic sounding data shows that the Antarctic troposphere lying in the Western Hemisphere is responding to ozone depletion and climate change much differently than indicated from coastal observations in the Eastern Hemisphere.

Neiman, P.J., F.M. Ralph, G.A. Wick, Y.H. Kuo, T.K. Wee, Z.Z. Ma, G.H. Taylor, and M.D. Dettinger, 2008, Diagnosis of an Intense Atmospheric River Impacting the Pacific Northwest: Storm Summary and Offshore Vertical Structure Observed with COSMIC Satellite Retrievals, *Mon. Wea. Rev.*, 136 (11). The results show that the new COSMIC retrievals, which are global, provide high-resolution vertical-profile information beyond that found in the numerical model first-guess fields and can help monitor key lower-tropospheric mesoscale phenomena in data-sparse regions.

Shupe, M.D., J.S. Daniel, G. De Boer, E.W. Eloranta, P. Kollias, E. Luke, C.N. Long, D.D. Turner, and J. Verlinde, 2008, A focus on mixed-phase clouds: The status of ground-based observational methods, *Bull. Amer. Meteor. Soc.*, 87. This overview paper describes the status of our ability to use ground-based measurements to characterize clouds containing both liquid water and ice. Such "mixed-phase" clouds play a key role in Arctic and global climate.

Spackman, J.R., J.P. Schwarz, R.S. Gao, L.A. Watts, D.S. Thomson, D.W. Fahey, J.S. Holloway J.A. de Gouw, M. Trainer, and T.B. Ryerson, 2008, Empirical correlations between black carbon



Susan Solomon (ESRL CSD)



Chris Fairall (ESRL PSD)

aerosol and carbon monoxide in the lower and middle troposphere, *Geophys. Res. Lett.*, 35. This paper describes the observed black carbon ("soot") vertical profile in the lower and middle troposphere, which constrains aerosol models that estimate regional and global radiative forcing. The black carbon/carbon monoxide emission ratios, derived for an urban/industrial region and a biomass-burning plume, improve air quality models.

Stark, H., S.S. Brown, J.B. Burkholder, M. Aldener, V. Riffault, T. Gierczak, and A.R. Ravishankara, 2008, Overtone dissociation of peroxyacetic acid (HO<sub>2</sub>NO<sub>2</sub>): Absorption cross sections and photolysis products, *J. Phys. Chem. A*, 112(39). We used a sensitive laboratory laser-based technique to measure light absorption spectra of peroxyacetic acid, a gas important for atmospheric oxidation, which is formed under dark and cold conditions. Our new results indicate slightly increased oxidative capacity of the atmosphere.

Tollerud, E.I., F. Caracena, S.E. Koch, B.D. Jamison, R.M. Hardesty, B.J. McCarty, C. Kiemle, R.S. Collander, D.L. Bartels, S. Albers, B. Shaw, D.L. Birkenheuer, and W.A. Brewer, 2008, Mesoscale moisture transport by the low-level jet during the IHOP Field Experiment, *Mon. Wea. Rev.*, 136. This paper reports improved measurements (with lidar) of narrow "atmospheric rivers," which are associated with the low-level jet over the central Great Plains. The authors conclude that models such as WRF could be improved with better vertical resolution and initialization fields.

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A.R. Ravishankara (ESRL CSD Director, third from right) at the Meeting of the Parties to the U.N. Montreal Protocol in Doha, Qatar

# Storm Chasing by Balloon

## Flotillas target data-poor areas to improve hurricane forecasts

As Hurricane Paloma churned through the Caribbean Sea south of Cuba in November, four teams of NOAA-trained students and scientists got ready. In a carefully choreographed experiment, the teams released 57 superpressure balloons, from Florida, Mississippi, Barbados, and Puerto Rico.

The mylar balloons, 3 to 5 feet in diameter and pyramid-shaped, carried Global Positioning Systems and transmitters—and the high expectations of NOAA and Department of Homeland Security (DHS) researchers.

“The purpose was to test the concept that long drift balloons could be used to report back data in real time from data-poor regions,” said ESRL Director Sandy MacDonald, who began laying plans for WISDOM (Weather In-Situ Deployment Optimization Method) in late 2007.

With the 2008 hurricane season already underway, DHS funded a pilot project. Justyna Nicinska, WISDOM project manager at NOAA Headquarters, and Russ Chadwick (ESRL GSD) quickly worked with Near Space Corporation and Engenium Technologies Corporation to design the balloons/payload system and train meteorology students to release the devices.

In an October test run, students and staff released 19 balloons, which ESRL tracked in the atmosphere for up to two weeks. As Hurricane Paloma took shape in early November, the teams launched and tracked a flotilla of 57 more.

“We learned this is a viable method to obtain data,” Nicinska said in late November, as hurricane season wound down.

The superpressure balloons are not aimed at a hurricane itself, Nicinska said. Rather, they’re targeted at atmospheric regions that a storm may pass through, where winds, temperature, and humidity can steer, strengthen, or weaken the hurricane. Today, scientists have only limited data on the atmosphere over oceans, Nicinska said, and sending a couple hundred or more instrument-bearing balloons into flight in advance of a threatening hurricane should, in theory, give researchers better information to forecast the storm’s behavior.

This year’s balloons carried only GPS units, but the WISDOM team hopes also to measure temperature and relative humidity in the future, and to send out many more balloons. Eventually, WISDOM data will be incorporated into forecasts of hurricane track and intensity, Chadwick said, but it will be several years until researchers understand the value of the new measurements.

“The key to making something work is to get data where there isn’t any,” Chadwick said. “WISDOM can do that, and therefore it *should* help.”

### WISDOM Season One Stats:

**140:** Number of superpressure balloons and GPS units built for WISDOM, including 10 prototypes

**78:** Number of balloons launched

**2 to 15:** Number of days individual balloons remained aloft

**20 to 25:** People trained to release balloons, from students at the University of Miami, Mississippi State University, the Caribbean Institute of Meteorology and Hydrology, to NOAA staff in Puerto Rico.

# Climate Change and Colorado’s Water

Colorado water resource managers should prepare for warmer temperatures and earlier runoff in most of the state’s river basins, according to an assessment of climate change by CIRES, NOAA ESRL, and Colorado State University researchers. The team analyzed the possible effects of climate change on Colorado’s water resources—for state water providers, the Colorado Water Conservation Board, and the Governor. The scientists did not detect consistent trends in state precipitation in the past 30 years, but temperatures here rose by 2°F during that period of time, and peak streamflow from snowmelt shifted earlier by about two weeks. Changes in the nature of Colorado’s water resources are expected to occur regardless of future precipitation changes. Earlier melt, increased evaporation, and drier soils will reduce runoff for most of the state’s river basins, with a 6 to 20 percent decline in Colorado River streamflows by the middle of this century, the report concluded.

<http://cwcb.state.co.us/Home/ClimateChange/ClimateChangeCOReport.htm>

Joe Barsugli (ESRL PSD) at the October Governor’s Conference on Managing Drought and Climate Risk



...RENEWABLES, from p.1

(clouds and wind speeds matter if wind or solar energy is in the mix.)

ESRL also maintains a sparse surface radiation network, eight sites in the United States that provide ground truth for error-prone satellite solar measurements, Marquis said. NREL and others could benefit quickly if NOAA revived eight additional sites that are currently instrumented but not operated.

To encourage collaboration and foster information exchange, ESRL and NREL launched a joint seminar series this fall. NREL engineer Chuck Kutscher presented the inaugural lecture to a standing-room-only crowd of about 150 at ESRL.

“Governor Ritter has made it clear that Colorado’s new energy economy revolves around renewable energy,” Kutscher said after his lecture. “We have here in our state all

September WISDOM training in Miami, FL



“CarbonTracker is a new way to model the sources and sinks of carbon dioxide in a way that maintains consistency with observations of CO<sub>2</sub> in the atmosphere,” said Pieter Tans, CCGG leader. “CO<sub>2</sub> is the main human-controlled driver of climate change, and it is going to be even more important in the future,” Tans said. Eventually, carbon regulations may require governments or industries to account for greenhouse gas emissions—some municipalities are already trying to do so.

This fall, GMD scientists, in collaboration with many others, updated CarbonTracker with quality controlled carbon dioxide data gathered last year from more sites around the world, and with improved models. Data are available free online in several formats, but among the most popular are short movies that animate the invisible gas. In the Northern Hemisphere’s summer, purples and blues, indicating lowered CO<sub>2</sub>, swirl across North America, as growing forests and other ecosystems pull CO<sub>2</sub> out of the atmosphere and into plant tissue. In spring, fall, and winter, reds and yellows highlight CO<sub>2</sub> emissions from cars, cities, power plants, and natural cycles.

“Because it is invisible and non-toxic, CO<sub>2</sub> is just not very real to many people. That may contribute to skepticism,” Tans said. “So there is value in simply visualizing these swirls.”

Eventually, the ESRL team and colleagues hope to make the system precise enough to inventory CO<sub>2</sub> sources and sinks by sector and by region, accounting for power plants, cars, growing forests, regional drought, and more. “For that, we really need much higher resolution observations, and higher-resolution transport models,” Tans said.

NOAA’s relatively sparse network of observations picked up a clear atmospheric signature

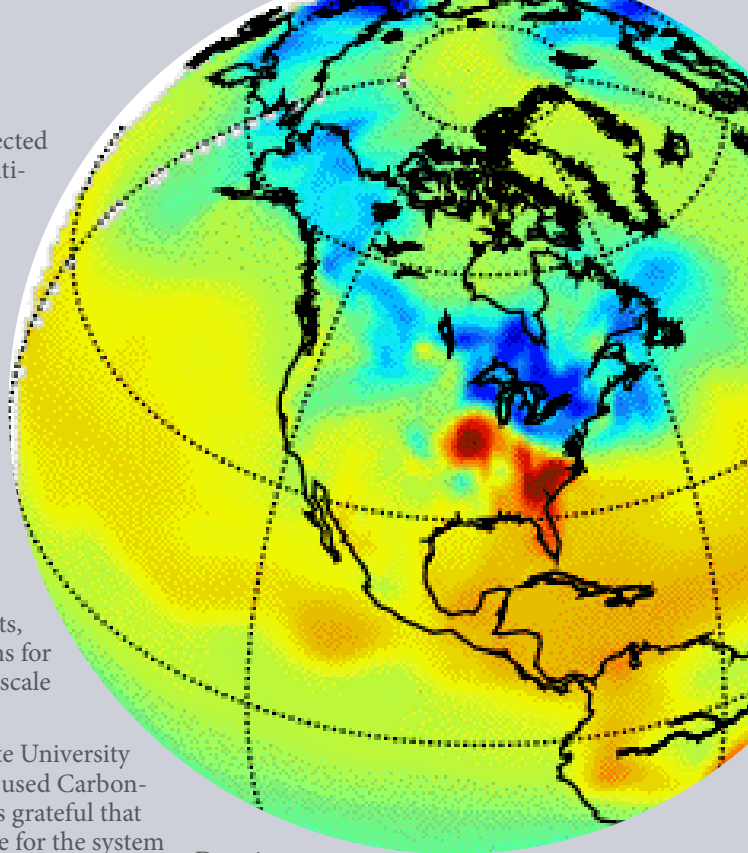
of the 2002 drought, which affected the entire North American continent, but it could not catch the drought in the U.S. Southeast this summer.

Every month, more than 200 people download some kind of data from the CarbonTracker site, said Ken Masarie (ESRL GMD), and at least 10 researchers per month are downloading the actual CarbonTracker source code. “They’re using CarbonTracker results to compare with other reanalysis products and with detailed, regional measurements, and to provide initial conditions for their high-resolution, regional scale models,” Masarie said.

Scott Denning, a Colorado State University atmospheric scientist, said he’s used CarbonTracker in his own work, and is grateful that ESRL has made the source code for the system free and easy to access.

“As scientists, we get credit with our community by publishing results, and so normally, when people do analysis like this, they might publish a few plots and several pages of information,” Denning said. “This is amazing in that this is completely open. You can actually re-create the whole thing.”

Denning said he’s shown CarbonTracker movies to students, and also to his 73-year-old mother. “My mom is never going to read the *Journal of Geophysical Research*, or learn about inverse modeling, but she can watch the movie and say, ‘Wow! So why is it green over there?’”



Denning said CarbonTracker is part of a growing community of scientists around the world trying to piece together the planet’s precise carbon budget. A new NASA satellite, scheduled for launch next year, will help clarify carbon sources and sinks. Sinks are critical, Denning said. “Half the world’s fossil fuel emissions are being vacuumed up by poorly understood processes. We need programs like CarbonTracker to help us understand how it works so we’ll be able to predict how it might change in the future.”

[www.esrl.noaa.gov/gmd/ccgg/carbontracker/](http://www.esrl.noaa.gov/gmd/ccgg/carbontracker/)  
YouTube: search “carbontracker”

these experts on climate change, water issues, and renewable energy...It’s time for us not to be working as independent groups, but to collaborate with an overall vision to solving these issues. We’re all in this together.”

Marquis and Stan Benjamin (ESRL GSD) spoke at NREL in November. Benjamin and others in his group have created some of ESRL’s highest-resolution weather prediction models, and are continually improving them. “Precise weather forecasts of solar and wind are going to allow you folks to make precise forecasts of transmission and storage needs,” Benjamin said.

Lucy Pao, a professor specializing in control systems at the University of Colorado at Boulder, applauded ESRL’s growing work in renewable energy forecasting. “I’m very interested in tying together atmospheric science and engineering, to enable better systems, from turbines to wind farms,” said Pao.

In Pao’s research on control of wind turbines, she is particularly interested in wind forecasts and measurements that are more comprehensive and updated more quickly than is currently possible. The engineer has played a leading role in the Colorado Renewable Energy Collaboratory’s Center for Research and Education in Wind (CREW), involving CU-Boulder, NREL, Colorado State University, the Colorado School of Mines, as well as NCAR and NOAA.

Other NOAA laboratories, from the Atlantic Oceanographic Meteorological Laboratory to the Pacific Marine Environmental Laboratory, have data and research expertise relevant to wave energy, ocean currents, and other forms of renewable energy, Wilczak said. “Our vision is for all of NOAA to be involved.”

[www.esrl.noaa.gov/research/events/seas/](http://www.esrl.noaa.gov/research/events/seas/)

Chuck Kutscher (NREL)



# Arctic Skies

## ESRL scientists help build global Arctic science network

Climate observatories at Barrow, Alaska and Summit, Greenland both lie between 71° and 73° North, a few hundred miles above the Arctic Circle—but the sites are hardly similar otherwise.

At NOAA's Barrow Observatory in Alaska, 36 feet above sea level, winds sweep across the tundra from the ocean, just 2 miles away. Summit Observatory in Greenland—run by the National Science Foundation and a Danish commission—sits in the middle of a massive ice sheet at more than 10,000 feet altitude, far from the sea.

Climate change processes in the vast Arctic cannot be understood with data collected from just weather stations, said ESRL's Taneil Uttal (ESRL PSD). So a few years ago, she began using the organizational mechanisms provided by the International Polar Year committee to contact colleagues around the world and coordinate activities at the few observatory sites in the Arctic. The result is the International Arctic Systems for Observing the Atmosphere (IASOA), which now includes 10 observatories, from Barrow and Summit to Tiksi, Russia and Abisko, Sweden. NOAA helps with instruments, staff, or budget contributions at all sites.



"We are filling data gaps," said Uttal, who is the network's "Activity Leader."

In much of the Arctic, temperatures are rising far faster than models predicted, and ice and perma-

frost are thawing. "We need better science on the Arctic atmosphere and how it interacts with the ocean and cryosphere to understand the 'Why' behind rising temperatures and other trends," Uttal said. "What's the role of greenhouse gases? Aerosol loads? Cloud properties?"

During December's American Geophysical Union meeting, about two dozen scientists from around the world presented talks and posters based on measurements from IASOA observatories. The AGU sessions—a first for IASOA—exemplified the data-sharing and collaborations that are the network's hallmarks, said Lisa Darby, ESRL PSD and IASOA program manager.

One key question for many Arctic scientists is whether or when the region's warming permafrost will increase releases of the greenhouse gas methane, contributing to a feedback cycle of further warming and melt. The IASOA observatories will eventually be able to help scientists detect and understand major changes in methane flux, said ESRL researcher Ed Dlugokencky (GMD).

John Calder, director of NOAA's Arctic Research Office, which funds IASOA, said the global network is designed to let scientists study Arctic changes in greater detail—a necessity for improving climate models and predictions.

"Barrow Observatory is very nice, but it's not answering every question we need answered," Calder said. Temperatures at Tiksi are rising more quickly than anywhere else, for example. "We want to get in there and understand why," Calder said. "We need ESRL because within NOAA, ESRL is the center of our atmospheric expertise. We need the intelligent leadership there, to understand what the data mean."

Each IASOA site supports a suite of sophisticated instruments, from some that measure ozone to others that track surface radiation or

Taneil Uttal  
(ESRL  
PSD)



cloud physics.

In some cases, NOAA has helped other countries obtain, install, or operate instruments, Uttal said—ESRL recently sent a cloud radar system to Finland, for example. In the past, such exchanges were often difficult and unpredictable, especially when political relationships between two countries were tense. Today, Uttal works openly with international colleagues, guided by intergovernmental agreements on scientific cooperation.

In Tiksi, Russia, the latest site in the IASOA network, ESRL teams are partnering with Russian colleagues to upgrade a dated but venerable research station, with funding from the National Science Foundation, NOAA, the Russian Federal Service for Hydrometeorology and Environmental Monitoring, and the government of Yakutia, in the Sakha Republic of the Russian Federation. With NSF funding, NOAA technical guidance, and Russian construction teams, two new research buildings are now taking shape at Tiksi. Instruments from U.S. agencies and universities are expected to be installed beginning in the spring of 2009.

[www.iasoa.org](http://www.iasoa.org)

## Earth System Research Laboratory

325 Broadway  
Boulder, CO 80305

<http://www.esrl.noaa.gov/>

**ESRL Quarterly editor:** Katy Human

**Photographer/Photo Editor:** Will von Dauster

**Contributors:** Anatta, Debra Dailey-Fisher, Barb DeLuisi, Christine Ennis, Carol Knight, Annie Reiser

**Contact:** [katy.g.human@noaa.gov](mailto:katy.g.human@noaa.gov)

[www.esrl.noaa.gov/news/quarterly](http://www.esrl.noaa.gov/news/quarterly)

## ESRL Leadership

**Alexander MacDonald**

Director

**John Schneider**

Deputy Director, Research

**Donald Mock**

Deputy Director, Administration

**A. Ravishankara**

Chemical Sciences Division Director

**James Butler**

Global Monitoring Division Director

**Steven Koch**

Global Systems Division Director

**William Neff**

Physical Sciences Division Director

## Acronyms

**ESRL:** Earth System Research Laboratory

**CCGG:** Carbon Cycle and Greenhouse Gases group of GMD

**CIRES:** Cooperative Institute for Research in Environmental Sciences

**CSD:** ESRL Chemical Sciences Division

**DO:** ESRL Director's Office

**GMD:** ESRL Global Monitoring Division

**GSD:** ESRL Global Systems Division

**NREL:** National Renewable Energy Laboratory

**NWS:** National Weather Service

**PSD:** ESRL Physical Sciences Division

**WFO:** Weather Forecast Office

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.

