



NOAA ARL Monthly Activity Report



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1. Highlight -- Awards. In a previous report, it was acknowledged that several ARL employees received NOAA awards (see <http://www.arl.noaa.gov/data/pubs/monthly/jul2000.pdf>). Not mentioned was the award of a bronze medal to the Washington Volcanic Ash Advisory Center (VAAC). The VAAC

received the NOAA Bronze Award for “customer service in the area of volcanic ash hazards to aviation.” The VAAC is composed of the NESDIS Satellite Analysis Branch, NWS NCEP Senior Duty Meteorologists, and OAR ARL. The key ARL people involved are Barbara Stunder and Nick Heffter.

2. *Highlight -- AIRMoN Station Closed.* Several changes have been made to the AIRMoN-wet deposition measurement program over the past few months. Measurements at the Oxford, Ohio station have been discontinued because of a lack of funding. A new site has been set up at Davis, WV (funded by Congressional earmark). Support of the Tampa Bay site is now being provided by the State of Florida. Finally, an additional site, funded by the Chesapeake Bay Program, is being planned for the Eastern Shore of Maryland. (richard.artz@noaa.gov)

Silver Spring

3. *National Atmospheric Deposition Program.* The fall Technical Meeting of the National Atmospheric Deposition Program was held in Saratoga Springs, New York from October 17-20. The focus of the meeting was on changes in air quality and deposition following the passage of the 1990 Clean Air Act Amendments, particularly as they related to the Adirondack Mountains and surrounding region. Two other sessions examined the role of atmospheric deposition on coastal eutrophication and various air toxics (principally mercury and dioxin) in the environment. Approximately 40 scientific papers and 35 posters were presented. Keynote speakers included Commissioner John Cahill, the head of the New York Department of Environmental Conservation, and Ms. Janet Joseph, Program Manager for Environmental Research for the New York State Energy Research and Development Authority. Fifteen presenters have indicated their desire to publish a special NADP volume in the peer-reviewed literature; discussions are underway with several journals at this time. The meeting was coordinated by Rick Artz, working closely with colleagues at Pennsylvania State University, the National Park Service, and EPA. (richard.artz@noaa.gov)

4. *The Atmospheric Transport and Deposition of Toxic Substances.* Work continued on modeling the atmospheric fate and transport of toxic pollutants, with emphasis on deposition to the Great Lakes. Extensive sensitivity analyses have been completed to demonstrate that the relative importance of different source regions and the relative importance of different source categories are not strongly influenced by significant changes in the modeling methodology. These results mean that the policy makers can use these and other related results with greater confidence. (mark.cohen@noaa.gov)

5. *Atmospheric Dioxin Transport to the Arctic.* Mark Cohen served on the Advisory Board for a CEC-sponsored year-long study of atmospheric dioxin transport to the Canadian arctic. The study was performed by scientists at Queens College, in New York City, using a dioxin modeling methodology developed by ARL. The study found that most of the dioxin depositing in the Canadian Arctic arose from sources emitting dioxin to the air in the United States. The final report was released at a press conference in New York City on October 3, 2000. Richard Artz and Mark Cohen of ARL participated in the press conference. An executive summary and the full report can be downloaded from the CEC website at:

http://www.cec.org/programs_projects/pollutants_health/develop_tools/dioxins/dioxexec.pdf
http://www.cec.org/programs_projects/pollutants_health/develop_tools/dioxins/dioxrep.pdf

The report generated a fair amount of media attention, including articles in the New York Times, Science Times, and the New Scientist. (mark.cohen@noaa.gov)

6. SPARC Temperature Trends Assessment Panel. Input on ARL's contributions to the SPARC Temperature Trends Assessment Panel were provided to the panel chair. The contributions include work by all members of the Climate Variability and Trends Group in the following areas: 1) stratospheric temperature monitoring; 2) north circumpolar vortex studies; 3) tropical tropopause climatology and variability. The panel will likely meet at the SPARC General Assembly in November. (dian.gaffen@noaa.gov)

7. CARDS -- Adjusting Radiosonde Temperature Data for Climate Monitoring. Dian Gaffen and Tom Peterson (NCDC) organized a workshop, held Oct. 11-12, 2000, at NOAA National Climatic Data Center, in Asheville, NC. Scientists representing six groups involved in identifying problems in, and adjusting, radiosonde temperature data participated, as did other experts in radiosonde observations and interpreting climate data records. The major activity was the examination and intercomparison of the different methods, applied to specific radiosonde station data time series. Advantages and disadvantages of each method were identified. A workshop report is currently in preparation for the *Bulletin of the AMS*. (dian.gaffen@noaa.gov)

8. CMDP CBRAMS Evaluation. Additional stations were analyzed for the Chesapeake Bay Coastal Marine Demonstration Project CBRAMS forecast runs during the Summer 1999 and Winter 2000. Error analysis was performed by forecast analysis and at additional sites over water, along the western and eastern shore of the Bay coastlines. Of particular value are the data collected at the NOAA AIRMoN dry deposition site (Wye, MD) on the Eastern Shore. The greatest improvements in using high resolution wind forecasts over Eta was most evident over water, in the narrower northern Bay where coastal features are complex, and in the afternoon when terrain induced forcings were greatest. (jeff.mcqueen@noaa.gov)

9. Seagrass Chesapeake Bay Wave Study Results Presented. The 4 km CBRAMS was coupled with the GLERL wave model run at 400 m horizontal resolution for the Seagrass Wave experiment (July 22-28, 1998). A cursory analysis shows some small differences in speeds and directions over water (1-2 m/s). A more thorough analysis was presented at the Mid Atlantic Bight Physical Oceanography and Meteorology Meeting (MABPOM) held at Silver Spring on October 26-27. (jeff.mcqueen@noaa.gov and lin@hpl.umd.edu)

10. High Ozone and Particulate Pollution Episodes for Vermont. A high resolution meteorological reanalysis was completed over the North East states for the Summer 1999 (June 1- August 31, 1999). Several cases required reruns with different physics parameterizations when numerical instability occurred.

The 3 km horizontal resolution finest analysis covers all of Vermont and New Hampshire and the Adirondack Mountains in NY. The 9 km reanalysis covers all the North East states except NE Maine. These reanalyses are currently being evaluated for use as an alternative for regulatory air quality assessments in complex terrain. The 9 and 3 km grids can be visualized and analyzed in READY from the Hysplit archive run menu or archived meteorology menus. Support is being given to the VT-DEC as they complete the evaluation of the high resolution local reanalyses using 20 sites over the 3 km domain and two abstracts based on the results were submitted to upcoming conferences. (jeff.mcqueen@noaa.gov, richard.artz@noaa.gov)

11. READY Quick Links. In a continuing series of additions to READY, we are pleased to announce a new section of the current meteorology page on READY called Quick Links. Currently two products are available: *Meteogram and Sounding*. These Quick Links allow users to produce default meteograms and vertical soundings for a location chosen by the user. In addition the interface makes it easier to look at meteograms and soundings from different forecast models without having to re-enter the station location and other parameters each time. Users that want to look at specific fields or levels can still use the original links for meteogram and sounding on the current meteorology page. (glenn.rolph@noaa.gov)

12. Emergency Response Toolbox. Work continues on adapting the emergency response “Toolbox”, installed by Jean-Philippe Gauthier from the Canadian Meteorological Center (CMC) in September, to run the HYSPLIT model and produce NOAA graphics. The CMC Toolbox is a Tcl/Tk and C++ interface to launch a dispersion model and then graphically manipulate the results into a final graphical format for distribution to users. CMC offered their interface to foster collaborative development between NOAA and CMC in regard to atmospheric emergency response. (glenn.rolph@noaa.gov)

13. Volcanic Ash News. At the request of the Washington and Anchorage VAACs, a GRIB-format concentration file was added to the VAFTAD model output. The NWS will be able to analyze the model output from this file using their NAWIPS workstations. No change was made to the model graphics output, which is disseminated over WAFS and made available on the Internet.

During September and October, VAFTAD output was issued by NCEP for the following volcanoes: Tungurahua, Ecuador (9 eruptions), and Popocatepetl, Mexico (6). NCEP also ran VAFTAD for an eruption of Copahue, Argentina, in support of the Buenos Aires Volcanic Ash Advisory Center. (barbara.stunder@noaa.gov)

Boulder

14. SURFRAD. From Oct. 6-12, Gary Hodges, Dennis Wellman, and John Augustine performed the instrument exchange and implemented several changes to the Fort Peck SURFRAD station. The instrument exchange occurred on Oct. 7. A small six ft. by 10 ft. climate-controlled trailer was hauled to Fort Peck on which to mount the Total Sky Imager (TSI), and house its computer as well as the site UPS. To do this, new electrical lines and a telephone line had to be run from the power pole to the trailer. A local company was hired to trench these lines in, connect the power, and help mount the trailer. The trailer was located about 45 ft. -southeast of the SURFRAD station, far enough away from the solar tracker to

preclude interference with the direct solar measurement. Now all SURFRAD stations have a TSI that reports one-minute fractional sky cover. Pictures of this new configuration at Fort Peck may be found at:

ftp://space.srrb.noaa.gov/pub/SURFRAD_Pics/FPK0010/.

The Fort Peck SURFRAD station has become a multi-agency (NOAA, USDA, NADP) cooperative site, with four monitoring activities now taking place there. Besides SURFRAD, the USDA has a UV monitoring site, ARL/ATDD has installed an atmospheric flux system, and the NADP moved their station, that used to be about 20 mi. to the north, to the SURFRAD location. Besides broadband and spectral UV monitoring, the USDA has an MFRSR that is useful for aerosol optical depth measurements, which they share with SURFRAD. (John Augustine, 303 497 6415)

15. Umkehr and SBUV2 Ozone Profiling. During October 10-12, Drs. Bhartia, Stolarski, McPeters, and Labow of NASA Goddard and Mike Newchurch of the University of Alabama at Huntsville, held a meeting with ARL and CMDL ozone research scientists to discuss combining the Umkehr and SBUV2 ozone profiling methods to improve the U.S. ozone profile data base. The goal was to prepare and analyze an improved ozone profile data base for the next international SPARC and UNEP ozone assessment which will be conducted in 2003. Another goal is to begin developing a methodology for detecting the ozone depletion turn around time which is expected to later follow the reduction of chlorofluorocarbon releases to the atmosphere. Improvements to the ozone profile retrieval algorithms for the SBUV and Umkehr methods, which are fundamentally related, were discussed as well as analyses for trends. Drs. Bhartia and Petropavlovskikh presented their ideas for future research at a CMDL seminar. SBUV ozone sensing instruments are routinely flown on NOAA's satellites, but NASA Goddard, through an MOU with NESDIS has the responsibility to provide and manage the ozone profile retrieval algorithms.

The algorithm research that is being conducted by Dr. Petropavlovskikh that was supported by the DOE ACP and the European REVUE (Greece, Italy, Spain, and France) projects has stimulated and renewed NASA's interest in making improvements to both the SBUV and Umkehr algorithms. The present algorithms are biased by the a priori information they contain and this can influence the nature of the profiles and trend analyses accordingly, but mostly in the layer below 20 km. The SBUV ozone profiler has occasionally suffered from instrumental instabilities and orbital drift. The inexpensive worldwide Dobson network for total ozone and Umkehr observations is seen by many persons to be vital for confirming the conclusions drawn from the use of satellite platform observations.

In perspective, this new cooperative activity is another demonstration of the need for ground-based measurements to confirm results obtained from satellite observations. NASA scientists will be seeking support for a joint program with NOAA. NOAA's participation is critical because of its scientific commitments to the ozone depletion problem. (John DeLuisi, 303 497 6824)

Research Triangle Park

16. NARSTO Ozone Assessment is Now Complete. The state-of-science assessment for tropospheric ozone conducted by NARSTO is now complete. The two components of the assessment include a set of

Critical Review papers covering the science that underpins the understanding of the tropospheric ozone issue, and an Assessment Report that relates current ozone science to outstanding issues of ozone air quality management in North America. The Critical Review papers were published in a special NARSTO issue of Atmospheric Environment in May 2000. They covered topics that include monitoring networks and trends, field studies and their findings, atmospheric chemistry and modeling, source emissions, and measurement technologies. The Assessment Report was published by NARSTO in October 2000. It indicates that the emissions controls established over the last thirty years in portions of North America are responsible for some downward ozone trends, especially in large urban areas, including Los Angeles, New York and Chicago. However, there is no single pattern for ozone trends. In some Canadian urban areas there have been upward trends; in Mexico City rising ozone concentrations in the 1980s seem to have leveled off. The report emphasizes that air quality today would be considerably worse if the emissions controls were not in place. In Los Angeles, for instance, there have been continued ozone reductions even in the presence of growing population and vehicle use. Among other things, the Assessment recommends that: (1) extensive monitoring be conducted in rural areas of North America to better understand the role of background conditions and how extensively ozone travels; (2) a real-time central archive of air quality data be established to facilitate a broader understanding of air quality; (3) the iterative use of emission-based air quality models and diagnostic analysis of air quality observations be used to guide air management strategies; and (4) the relationship between the scientific and policy communities be strengthened to continue the most cost-effective ozone abatement strategies. The full text of the Assessment Report can be found on the NARSTO website: www.cgenv.com/Narsto. (Ken Schere, 919 541 3795)

17. Human Exposure Modeling. Several projects are developing improved methods for modeling the source through the air pathway to human exposure in significant micro-environments of exposure. Special attention is being given to exposures within vehicles traveling along roadways and in neighborhoods near major roadways. The MicroFacCO mobile “real-time” mobile source emission model is being applied with roadway dispersion models and compared with CO air concentrations measured inside a vehicle and along the roadside along roadways in RTP, NC. Computation Fluid Dynamics modeling is being developed for use in developing improved simplified roadway air pollution models for modeling human exposure. The Meteorological Instrumentation Cluster of three trailers (MIC3) has become operational. Measurements from this system include portable mini-SODAR winds, SODAR winds, and three-level Tower winds and temperature/humidity. This system will be used to provide local meteorological characterization in support of human exposure field studies which will help in the development of improved human exposure related micro-environmental models. The nocturnal boundary layer and the morning transition period can be studied in detail. (Alan Huber, 919 541 1338)

18. Models-3/CMAQ Enhancements. A Stand-Alone Version of the Models-3/Community Multiscale Air Quality (CMAQ) modeling system has been released with numerous enhancements. It includes code needed to run CMAQ’s initial conditions preprocessor (ICON), CMAQ’s emissions interface preprocessor (ECIP), and CMAQ’s chemistry-transport (CTM) model on a parallel multi-processor platform such as the CRAY T3E. The CMAQ codes are now all Fortran 90 compliant, which are necessary for running applications on a parallel platform. The codes are also “single-source,” in the sense that the same codes can be compiled on any platform, eliminating the need to maintain separate codes for different platforms. Another major improvement is the addition of a new aerosol module, which

incorporates variable standard deviations into the modal approach and which uses a new aerosol surface area species. The release of this version of CMAQ represents the Division's continued effort to understand the science and regulatory impacts in multi-scale, multi-pollutant air quality modeling. (Jeff Young, 919 541 3929)

19. Examination of CMAQ in Regulatory Applications. As part of a multi-tiered effort designed to accelerate the usage of the Models-3/ Community Multiscale Air Quality (CMAQ) modeling system in the policymaking arena, applications of CMAQ over a series of domains and meteorological episodes were completed. Several base case simulations and sensitivity tests were completed for a 36/12 km domain covering the western United States. A limited model performance evaluation indicated that the model was performing as good as, or better than, existing modeling tools for this particular set of input data. Models-3/ CMAQ has also been applied over the eastern United States to estimate the impacts of the Federally required emissions control measures being implemented between 1996 and 2007, as well as to estimate the potential effects of additional emissions reductions beyond 2007. Significant reductions in ambient levels of fine particulate matter and ozone are expected. The results of these analyses will be used by the EPA promote the use of Models-3/CMAQ and to highlight the effectiveness of the control measures studied. (Pat Dolwick 919-541-5346)

20. Flux Measurement Errors. Flux measurements, employing the eddy correlation method, are used to determine CO₂ fluxes in global change studies, pollutant deposition for ecosystem exposure studies, and latent and sensible heat fluxes for weather systems modeling. Sampling errors in eddy correlation flux measurements arise from the small number of large eddies that dominate the flux during typical sampling periods. Several methods to estimate sampling or random errors in flux measurements have been published in the past. Compared to a more statistically rigorous method we developed which calculates the variance of a covariance when the two variables in the covariance are auto- and cross-correlated, the older methods' estimates were 20% to 25% too low. We applied the new approach to define the random error component of representative eddy correlation flux measurements of momentum, sensible and latent heat, CO₂, and O₃ from five field studies, three over agricultural crops (corn, soybean, and pasture) and two from towers over forests (deciduous and mixed). The mean normalized error for each type of flux measurement over the five studies ranged from 12% for sensible heat flux to 31% for ozone flux. There were not large nor significant differences between random errors for fluxes measured over crops versus those measured over forests. A paper on these results has been accepted for publication in the Journal of Geophysical Research. (Pete Finkelstein, 919 541 4553)

21. United States/Russia Working Group Meeting. The 22nd Meeting of Working Group 02.01-10 on Air Pollution Modeling, Instrumentation, and Measurement Methodology, was held at the Main Geophysical Observatory (MGO) in St. Petersburg, Russia, during November 6-10, 2000. Russian scientists presented information regarding the development of a new version of Russian regulatory dispersion model which will be introduced next year as a national guideline. They informed also about current works aimed to develop and generalize a hybrid methodology of computational monitoring which jointly uses the results of measurements and computations. A summary of Russian work in forecasting urban air pollution was outlined. (Frank Schiermeier, 919 541 4542)

Idaho Falls

22. VTMX-CBNP 2000. The VTMX-CBNP 2000 study field deployment was a resounding success. The study was even reported in the news papers and on the radio. An Associated Press reporter and photographer visited our field headquarters. News articles subsequently appeared in the *Deseret News*, a local Salt Lake City newspaper, and also made national news in *USA Today*. Some local Idaho newspapers attempted to grab readers attention with headlines that read “Gas attack tests on Salt Lake.” An example newspaper article is shown below. This notoriety probably heightened suspicions of the local police, who destroyed one of our bag samplers during the final test, thinking it was a bomb. Nevertheless, FRD’s contribution to the program went almost without a hitch.

Defense agency studying potential Olympic threat

By Paul Foy
Associated Press

SALT LAKE CITY — A U. S. defense agency is in Salt Lake City testing its ability to track the movement of deadly chemical or industrial gases — a potential threat being assessed by security planners for the 2002 Olympic Games.

The Defense Threat Reduction Agency is monitoring the flow of a harmless gas being released over the Salt Lake Valley this month for a weather study.

It is taking advantage of the Olympic-related study of tricky weather patterns in this mountain-rimmed city, where winter inversions can trap cold, stagnant air — or worse — near ground level. The weather study involving several other federal agencies also aims to improve snowfall forecasts for the Winter Games.

“We are piggybacking on their efforts,” Capt. Bob Bennett, a spokesman for the Defense Threat Reduction Agency, said Thursday. “It’s a story of more bang for the buck.”

The mission of the Defense Threat Reduction Agency is to detect and predict the spread of chemical and biological attacks and give American troops an early heads-up.

One phase of the weather study now under way involves the release of a nontoxic gas, sulfur hexafluoride, over the Salt Lake valley. The tracer gas is helping scientists measure swirling air motions.

The Defense Threat Reduction Agency is using its computers to track the heavy gas as it flows through Salt Lake City and penetrates buildings by way of ventilation ducts and open doors and windows. The results are expected to help the agency better predict the movements of the deadly gases under variable weather conditions.

“We’re fine-tuning our models and making them more accurate in an urban environment,” Captain Bennett said.

William Alder, the Salt Lake meteorologist in charge for the National Weather Service, said the October phase of the weather forecasting study is being conducted as a benchmark of tranquil weather between summer and winter.

Bennett emphasized that the Defense Threat Reduction Agency can put its technology to use for more than military objectives. It can measure diesel fumes and industrial emissions and warn of accidental releases of deadlier gases.

Associated Press news release appearing October 23, 2000.

During the month of October, six different nocturnal tests were conducted, using sulfur hexafluoride tracer with real-time and whole-air tracer sampling and analysis. These tests were conducted in downtown Salt Lake City and the surrounding urban area out to a distance of 6 km from the release site. Six mobile

analyzers were employed for the study, as were 130 whole air samplers with 12 sample containers each. We also supplied two sonic anemometers for measurement of the complex wind flow around the buildings at the release site. At times, nearly the entire FRD staff was in Salt Lake City. The “can do” attitude of the FRD staff ensured the success of this deployment, and the sponsors are requesting our participation in the next CBNP field study. (kirk.clawson@noaa.gov, and staff)

The 915-MHZ radar wind profiler and phased-array Doppler sodar was deployed on October 3 in an open parking lot site, southwest of downtown Salt Lake City. The radar was configured to acquire one-hour wind profiles in a dual mode. The first mode acquires high resolution (~60 m) wind profiles over a limited range (~ 2 to 3 km) while the second mode acquires low resolution (~100 m) wind profiles over a higher range (~ 4 to 5 km). The Doppler sodar was configured to acquire 15-min wind profiles from near the surface to about 300 m with a 20 m resolution. In addition, a 10-m tower was installed for the measurement of wind speed, wind direction, air temperature, and relative humidity. All of these instruments worked exceptionally well during VTMX-CBNP 2000. (jerry.crescenti@noaa.gov)

Instrument and computer upgrades were performed on the aircraft data system in preparation for VTMX 2000. The upgrades included modifications to the BAT-REM/computer interface to use commercially available PC boards for data collection from the remote AQ cards. Also, new Ashtech GPS sensors were fully integrated into the MFP system. These sensors replace the Novatel GPS cards and will provide higher accuracy in both GPS position and velocity, utilizing precision code in two frequencies. (jeff.french@noaa.gov, Ed Dumas)

23. *Refractive Turbulence Study.* The design and construction of the second generation of the FRD Fast, Ultra-Sensitive Temperature (FUST) probe has been completed. The new design eliminates the housing that acted as an expansion chamber to reduce the flow speed passing the sensor. Flight tests conducted earlier this year indicated that the housing did not enhance the measurement of temperature. The electronics in the new design remain essentially unchanged. They are contained within a 1 inch copper cylinder, 15 inches in length. The primary sensing element is a 1/1000 inch Cu-Co thermocouple with a reference junction tied to a micro-bead with relatively large thermal mass. The element is exposed to the free stream, roughly 6 inches in front of the electronics section of the probe. Flight tests are to be conducted in early November, with a second round of measurements to be made for RTS-2000 during November and December. We believe the upgrades to the probe will allow us to measure temperature with a resolution of 0.005 C with a response time of 0.01 s. Such high resolution and response is necessary for understanding turbulence spectra from the upper regions of the troposphere. (jeff.french@noaa.gov, Tim Crawford, Randy Johnson, Shane Beard)

24. *Cooperative Research with INEEL.* Fourteen new relative humidity sensors were added to the INEEL Mesoscale Meteorological Network this fall. All 33 towers in the network will now report 5-minute relative humidity averages along with their other measurements. (roger.carter@noaa.gov, Randy Johnson, Tom Strong)

25. *AMS Symposium on Meteorological Observations and Instrumentation.* Three meteorology students have been given grants of \$500 each to help defray travel costs to attend the Annual Meeting of

the American Meteorological Society (AMS) in Albuquerque, New Mexico from January 14-19, 2001. As the chair of the AMS Measurements Committee, Jerry Crescenti identified students who have written papers for the Eleventh Symposium on Meteorological Observations and Instrumentation (SMOI) that deal with instrument development or observation techniques. On behalf of the AMS, Crescenti was able to offer travel assistance. These students include:

© Jerald A. Brotzge, University of Oklahoma, for his papers entitled *closure of the surface energy budget at 10 OASIS super sites* and *the OASIS Project Network for monitoring the surface energy budget*;

© V. Sridhar, Oklahoma State University, for his paper entitled *estimating downwelling longwave radiation for input to a land surface model*;

© Robert C. Gilliam, North Carolina State University, for his paper entitled *qualitative observational analysis of the boundary layer structure using surface-based tower and remote sodar data*.

In addition, eighteen student travel grant applications were reviewed. These were submitted to the AMS by students wishing to attend the SMOI. Each student submitted a short essay as to why he/she should be given the expense-paid opportunity to attend the meeting. It was recommended that at least eight of the eighteen students be given travel assistance by the AMS to attend the SMOI.

SORD

26. Continuous Atmospheric Dispersion Display (CADD). An operational version of CADD has been completed and implemented, for use by SORD emergency response personnel, the Emergency Operations Centers (EOC)s, and NTS operations centers. Plume descriptions are based on real-time data from the ARL/NTS Mesonet (META). A background map is developed from high-resolution terrain data. P/Q values are computed for each depiction of the plume. Close-up plots are accessed by displaying the output on a four-panel map, and mouse-clicking on the panel of interest. (Walt Schalk, 702 295 1262)

27. Urban Climatic Change Project. Research continues on the impact of urban growth and expansion on boundary layer temperature. Las Vegas offers a good opportunity to explore the linkage. About 95% of the population within Clark County reside in the valley that includes Las Vegas. Even though there are separate cities within the valley, the valley is essentially one large metropolitan area with little or no open space between cities. Graphs showing the population increase and the association between average annual minimum temperature and population are shown below. (Doug Soule', 702 295 1266, and Darryl Randerson, 702 295 1231)

