NOAA Air Resources Laboratory
Quarterly Activity Report

(October – December 2007)

Contents

1. Highlight - ARL Employees Receive NOAA Awards.

2007 Gold and Silver Medal. Congratulations to Dr. Dian Seidel and Dr. Randy Johnson for receiving the 2007 Department of Commerce Gold and Silver Medal Awards, respectively.

The Gold Medal was awarded to Dr. Seidel, along with other OAR and NESDIS colleagues, in the Scientific/Engineering Achievement category for improving the understanding of climate by showing that global average atmospheric warming is similar to surface warming. The Gold Medal is the highest honorary award granted by the Secretary of Commerce and is defined as distinguished performance characterized by extraordinary, notable, or prestigious contributions that impact the mission of the Department and/or one or more operating units, which reflects favorably on the Department.

The Silver Medal was awarded to Dr. Randy Johnson in the Scientific/Engineering Achievement category for successful development of an autonomous balloon instrument platform that has advanced our understanding of atmospheric behavior. The Silver Medal is the second highest honorary award granted by the Secretary of Commerce and is defined as exceptional performance characterized by noteworthy or superlative contributions, which have a direct and lasting impact within the Department.

2007 Bronze Medal and Distinguished Career Awards. Congratulations to ARL's Field Research Division (director, Kirk Clawson) for receiving the Bronze Medal "For preeminent research on atmospheric observation technologies addressing issues of important national significance." The Bronze Medal is the highest honor award that can be granted by the Under Secretary of Commerce for Oceans and Atmosphere.

Congratulations also to Ray Hosker (former director, ARL's Atmospheric Turbulence and Diffusion Division) for receiving the Distinguished Career Award "For leadership in research on the surface boundary layer, air-surface exchange, atmospheric turbulence and diffusion, and chemical deposition" during his 35 years of Federal service. The Distinguished Career Award is designed to recognize long-term achievement in advancing the goals and mission of NOAA.

StormReady Supporter Award. In April of this year, the Field Research Division (FRD) became the first NOAA entity to become a StormReady Supporter. StormReady is an education program designed by NOAA's National Weather Service (NWS) to establish severe weather safety plans and actively promote weather awareness. An award ceremony to honor this accomplishment was held on October 30, at the FRD office. Vernon Preston, Warning Communication Meteorologist with the NWS in Pocatello, presented a recognition plaque and a special StormReady sign to FRD in recognition of this honor. In addition, FRD Director Kirk Clawson received a StormReady Certificate of Achievement "for improving the timeliness and effectiveness of hazardous weather warnings for the public through a diligent and proactive approach of increased communication and preparedness." Several representatives from partner organizations attended the ceremony. A news release was prepared for the event and is available at http://www.noaa.inel.gov/PR-2007-10-25-PIH01.pdf

2. Highlight - The 50th Anniversary Celebration of the Mauna Loa Observatory. John Miller, a former Mauna Loa Observatory (MLO) director, represented ARL at a celebration of MLO's 50th anniversary on the Big Island of Hawaii. The Observatory was a part of ARL's Geophysical Monitoring for Climate Change (GMCC) program formed in the early 1970s. (GMCC became the principal component of the Climate Monitoring and Diagnostic Laboratory [now the Global Monitoring Division] when it was formed in 1990.) On November 26-27, Dr. Miller attended

several celebratory events in Hilo which included present and former staff members. On November 28-31, a symposium and celebration of the "50th Anniversary of the Global Carbon Dioxide Record" Symposium and Celebration took place on the Kona side of the island. This conference keyed in on all aspects of the CO_2 measurements and their implications for global warming. A broad range of talks were given that included not only the record itself but reports from coal company representatives, energy experts and regulatory personnel. All the talks are available on the conference web site http://www.co2conference.org/. As a contribution to this celebration, a retrospective video of Dr. Miller's time as director was produced by NOAA's Climate Program Office. It should be noted that a history of Mauna Loa is presently being completed by Forrest Mims entitled "Fifty Years of Monitoring a Changing Atmosphere: The Story of Hawaii's Mauna Loa Observatory" and will be available some time in 2008. john.miller@noaa.gov

3. ***Highlight - Tropical Widening Research.*** Two research papers (citations below) were published documenting the widening of the tropical belt over the last few decades. The *JGR* paper focused on use of tropopause observations, by radiosondes and in reanalyses, as a means to delineate the tropical belt and showed that the width of the belt has increased by several degrees latitude since 1979, with comparable trends over a longer period with sparser observational records. The *Nature Geoscience* paper, which appeared in the inaugural issue of the new journal, presented a review of recent observational studies, all indicating a widening tropical belt, and model simulations suggesting the tropics would widen at a much smaller rate as a result of anthropogenic climate change. Both the journal and NOAA Public Affairs issued press releases on this paper, which received considerable media attention both in the U.S. and abroad. dian.seidel@noaa.gov

Seidel, D.J., Q, Fu, W.J. Randel and T.J. Reichler, **Widening of the tropical belt in a changing climate.** *Nature Geoscience*, doi:10.1038/ngeo.2007.38 (published online: 2 December 2007) Reprint

Seidel, D.J., and W.J. Randel, 2007: **Recent widening of the tropical belt: Evidence from tropopause observations.** *J. Geophys. Res.*, 112, D20113, doi:10.1029/2007JD008861. Reprint

4. ***Highlight - Visit to National Center for Environmental Prediction.*** Jonathon Pleim was invited to visit the Environmental Modeling Center (EMC) at the National Center for Environmental Prediction (NCEP) in Camp Springs, MD on December 7, 2007. Dr. Pleim gave a seminar entitled, "A New Combined Local and Non-Local Boundary Layer Model: ACM2". Dr. Pleim spent the rest of the daylong visit conferring with the air quality forecast team, then with Zavisa Janjic, and with the physics group. The visit was instigated by recent discussions within the EMC regarding the choice of PBL model in future unified mesoscale and global modeling systems. The debate has focused on the choice between planetary boundary layer (PBL) models with non-local components, such as the MRF scheme that is used in the Global Forecast System (GFS), and TKE based models, such as the Mellor-Yamada-Janjic (MYJ) model that is currently used in the North American Mesoscale (NAM) model. Since both PBL models have their plusses and minuses and each has its advocates, the EMC modelers are considering some sort of hybrid that includes elements of both. Thus, there is much interest in ACM2 among the physics modelers at EMC since it is a combined local and non-local closure scheme. An advantage of the ACM2 over the MRF model is that it is consistently applicable to air quality and meteorology. Thus, given the emphasis at NCEP on using consistent modeling techniques for meteorology and air quality as well as for mesoscale and global

systems, the ACM2 would seem to be an interesting alternative for PBL modeling in the NCEP models. While models with non-local components seem to better represent the convective boundary layer, stable boundary layers may be better represented by TKE schemes, such as the MYJ model. Therefore, collaborative efforts to create a hybrid of MYJ and ACM2 were also discussed. jonathon.pleim@noaa.gov

Air Resources Laboratory Headquarters (ARL HQ) Silver Spring, Maryland

5. Mercury Modeling and Data Analysis. Development and testing work has continued on the HYSPLIT (HYbrid Single-Particle Lagrangian Integrated Trajectory)-Hg mercury model. During this period, a new, full, working version of the model was finished, based on the latest version of the HYSPLIT model. Extensive testing and sensitivity analyses were conducted to examine the ability of the model to simulate global mercury fate and transport. A significant challenge was encountered regarding the proliferation of puffs due to splitting during global simulations. For regional simulations this is not generally a problem, as puffs leave the model domain and are no longer tracked. However, for global simulations, puffs never leave the domain. Each puff that is released grows and splits numerous times during the simulation. Unless unusually strong splitting inhibitions and/or unusually liberal merging procedures are invoked, it is found that computational resources required become impractically large. However, when such splitting inhibitions / merging facilitations are applied, inaccuracies are introduced into the simulation. Hundreds of tests were performed to attempt to characterize the sensitivity of the global HYSPLIT-Hg simulation to parameters affecting these issues. Preliminary results suggest that a satisfactory puff-only approach may not exist for HYSPLIT-Hg. A hybrid approach may be required, in which puffs are eventually transferred to and simulated on an Eulerian grid system. The goal is to preserve simulation accuracy at local, regional, continental and global length scales with acceptable computer resource requirements. mark.cohen@noaa.gov (with Roland Draxler).

A paper has been accepted for publication regarding the integration of mercury model outputs with measurements. In this paper, sediment data and atmospheric models were used to estimate regional and global components of mercury deposition in the Bay of Fundy region of Canada. mark.cohen@noaa.gov

Sunderland, E.M., M.D. Cohen, N.E. Selin, and G.L. Chmura. **Reconciling Models and Measurements to Assess Trends in Atmospheric Mercury Deposition**. *Environmental Pollution*. Accepted for Publication.

A paper has been accepted for publication regarding trends in mercury wet deposition, using data from the Mercury Deposition Network. mark.cohen@noaa.gov

Butler, T.J., M.D. Cohen, F.M. Vermeylen, G.E. Likens, D. Schmeltz, and R.S. Artz. **Regional precipitation mercury trends in the eastern USA, 1998-2005: Declines in the Northeast and Midwest, no trend in the Southeast**. *Atmospheric Environment.* Accepted for Publication.

6. Intergovernmental Panel on Climate Change – Fourth Assessment Report (IPCC FAR). Dian Seidel served as a member of the U.S. Government review panel for the IPCC FAR Synthesis Report and as a member of the U.S. delegation to the IPCC's 27th Session (held November 12-17, 2007, in Valencia, Spain), at which the Synthesis Report was negotiated and adopted. dian.seidel@noaa.gov

7. Upper Air Temperatures for 2007. The Radiosonde Atmospheric Temperature Products for Assessing Climate (RATPAC) radiosonde dataset will again be included in the National Climatic Data Center's annual state of the climate report published in the Bulletin of the American Meteorological Society later this spring. While the global mean surface temperature was the second warmest since the beginning of RATPAC in 1958, the year (December 2006 through November 2007) was only the fourth warmest in the troposphere. In the Northern Hemisphere, the troposphere was the second warmest in the record, behind only the 1998 ENSO (El Niño/Southern Oscillation) year. In the Northern Hemisphere extratropics, the surface was the warmest ever, slightly warmer than the previous record year of 2005, and the troposphere was the third warmest in the record. In the stratosphere, 2007 was second only to last year in cold both globally and in the deep tropics. melissa.free@noaa.gov

8. Comparison of Modeled and Observed Upper-air Temperature Trends. A paper submitted to the *Journal of Climate* in October by John Lanzante (NOAA GFDL) and Melissa Free shows the similarities and differences between trends in two radiosonde datasets and those in six coupled climate models driven by estimated forcings for 1958-1999. The adjustments that have been made to the radiosonde data have generally improved agreement between the models and observations, but the models still have larger positive trends in the troposphere and smaller negative trends in the stratosphere than the observations in most cases. melissa.free@noaa.gov

9. Outreach. Dian Seidel gave a lecture on climate change at the Osher Lifelong Learning Institute at the Univ. of Maryland, as part of a course that John Miller is running. She was also interviewed for a film on global climate change, part of a series entitled "Environmental Science for Students" in production by JMW Productions. dian.seidel@noaa.gov

Atmospheric Turbulence & Diffusion Division (ATDD), Oak Ridge, Tennessee

10. Air Quality. Atmospheric mercury's processes in arctic Greenland and urban Texas can be compared through results from two studies in 2007. Reactive Gaseous Mercury peaks in both places after mean solar zenith. The photochemical connection in Greenland is through bromine, while in Texas (Houston) it is through ozone and OH^-. Gaseous Elemental Mercury in Greenland also peaks in daylight, but in Texas the peak is just before dawn. steve.brooks@noaa.gov

Atmospheric measurements of ammonia, nitric acid, sulfates, and sulfur dioxide made over maize in North Carolina by ATDD sampled atmospheric behavior of agriculturally applied fertilizer (NH_3). New understanding will help maximize ammonia's effectiveness as a fertilizer and minimize its effectiveness as an airborne nuisance. latoya.myles@noaa.gov

11. Climate. ATDD deployed instruments to measure air-canopy-surface exchange of heat, moisture, and net radiation during the summer experiment of the Cloud and Land-Surface Interaction Campaign (CLASIC) in Oklahoma. Surface moisture and heat influence convective clouds, which

in turn influence the surface through rainfall. Understanding this relation will improve forecasts of severe local storms and rain distribution on the Great Plains. tim.wilson@noaa.gov

Publication: "An aircraft-based data analysis method for discerning individual fluxes in a heterogeneous agricultural landscape," S. Kirby, R. Dobosy, D. Williamson, and E. Dumas to appear in Agricultural and Forest Meteorology. ron.dobosy@noaa.gov

Activity on the U.S. Climate Reference Network (USCRN) during autumn 2007 included three new installations, annual maintenance visits to 22 sites and unscheduled maintenance visits to four sites. Measurement of soil moisture and soil temperature at USCRN sites is in development, intended to expand NOAA's monitoring of drought conditions. mark.e.hall@noaa.gov

An Extreme Turbulence (ET) probe is being readied for long-term deployment at Key West Florida this summer. This probe was developed by Air Resources Laboratory for use where high wind, rain, and spray interfere with sonic anemometer operation (Eckman *et al.*, 2007: *Journal of Atmospheric and Oceanic Technology* 24, 994-1007). will.pendergrass@noaa.gov

12. Dispersion. A daily mesoscale forecasting capability for East Tennessee is being readied. It uses the Weather Research and Forecasting model at 3 km grid spacing initialized and bounded by the Rapid Update Cycle System and incorporating local mesonet observations. ron.dobosy@noaa.gov

Atmospheric Sciences Modeling Division (ASMD), Research Triangle Park, North Carolina

13. Evaluation of the University of California Davis Aerosol Module Coupled to the Community Multi-scale Air Quality Model (CMAQ-UCD). A sectional aerosol model that dynamically simulates gas to particle conversion has recently been coupled to the Community Multiscale Air Quality (CMAQ) model; the CMAQ-UCD model has been applied to simulate air quality in Tampa, Florida, during May 2002. Sea salt emissions are parameterized as a function of wind speed and relative humidity. The model has been evaluated against size-segregated and chemically speciated aerosol measurements made at three Tampa-area sites. Modeled total aerosol sulfate and ammonium concentrations and size distributions are in good agreement with measurements. Nitrate is correctly predicted to be predominantly in coarse particles (larger than 1-micron diameter); however, nitrate concentrations are biased low by a factor of two. The model accurately simulates the extent of aerosol chloride depletion due to displacement by nitrate as a function of particle size. A manuscript describing this work has been accepted for publication in *Atmospheric Environment*. chris.nolte@noaa.gov

14. A Comparison of the Community Multiscale Air Quality (CMAQ) Model HONO Predictions with Observations from the Northeast Oxidant and Particle Study. An article titled "A comparison of CMAQ HONO predictions with observations from the Northeast Oxidant and Particle Study" has been accepted for publication by the *Atmospheric Environment*. The article compares predictions of nitrous acid from the Community Multiscale Air Quality modeling system with the measurements from the 2001 Northeast Oxidant and Particle Study. Four different sources of nitrous acid were considered in the study: gas-phase reactions, direct emissions, a heterogeneous reaction, and a surface photolysis reaction. When only gas-phase reactions were considered in the model, the

diurnally-averaged Mean Bias, the Normalized Mean Bias, the Root Mean Square Error, and the Normalized Mean Error of the model were -1.01 ppbv, -98%, 1.05 ppbv, and 98%, respectively. However, the diurnally-averaged Mean Bias, Normalized Mean Bias, the Root Mean Square Error, and the Normalized Mean Error of the model improved to -0.42 ppbv, -41%, 0.45 ppbv, and 41%, respectively, when all sources were considered. Model results suggest that the heterogeneous reaction and the surface photolysis reaction are the most important sources of nitrous acid in the atmosphere accounting for about 86% of the predicted nitrous acid. Emissions and the gas-phase reactions were relatively minor sources and accounted for only 14% of the predicted nitrous acid. Model predictions suggest that the heterogeneous reaction is the most significant source of nitrous acid at night while the surface photolysis reaction is the most significant source during the day. The addition of these sources increased the diurnally-averaged hydroxyl radicals and ozone by 10% and 1.4 ppbv, respectively. sarwar.golam@epa.gov

15. Coarse Aerosol Modeling in the CMAQ Model. Condensation and evaporation of coarse aerosol components is known to significantly influence aerosol size-composition distributions. However, the CMAQ model currently assumes that coarse particles are inert. Work is ongoing to relax this assumption by calculating mass transfer of semi-volatile components between the gas-phase and coarse particles in CMAQ. As a first step toward this goal, a mass transfer scheme has been implemented in an aerosol box model based on CMAQ routines. Since the equations governing mass transfer are numerically stiff, two primary assumptions are used in the mass transfer method: (1) components of fine particles are in equilibrium with the gas phase (i.e., the hybrid approach), and (2) the flux of H^+ for a given time step is $\leq$ 10% of the H^+ concentration. Box-model results agree reasonably well with sectional (MADM) and modal (MAM) benchmark codes for an on-shore flow scenario in the L.A. area. This agreement suggests that the scheme was implemented correctly and that it adequately captures the dynamics of coarse particles (e.g., chloride replacement in sea salt). The next step of this project is to incorporate the new aerosol routines into CMAQ and evaluate CMAQ predictions with field measurements. kelly.james@epa.gov, prakash.bhave@noaa.gov

16. Structural Changes in the CMAQ Model. Work continues to put biogenic emissions, point source plume rise, and the deposition velocity calculation directly into the CMAQ model. This will allow a better time-resolved representation of these processes, enabling feedbacks to allow bi-directional deposition simulation. Additionally, the size of the emissions input files is significantly reduced at the expense of calculating plume rise in CMAQ. The biogenics emissions and deposition components have been successfully tested. However, the plume rise development was limited in that it had been developed for the inclusion on only one source sector. The continuing development on this component to incorporate the ability to read in multiple sector file groups, e.g. EGU and non-EGU, Canadian and Mexican, etc. sources is near completion. It will also be capable of computing and merging in the plume rise for wild land and other fire emissions sources. jeffrey.young@noaa.gov

17. AGU Special Session. Staff collaborating with Michael Kleeman (University of California at Davis) chaired a special session at the 2007 Fall Meeting of the American Geophysical Union in San Francisco, CA. The session was on monitoring and modeling of the trace elements in particulate matter. Presentations addressed topics such as problems in using observations in toxics metals from U.S. monitoring networks, source attribution of lead concentrations in particulate matter over North

America, analytical methods for monitoring, and comparison of emission profiles for gasoline and diesel vehicles. hutzell.bill@epa.gov

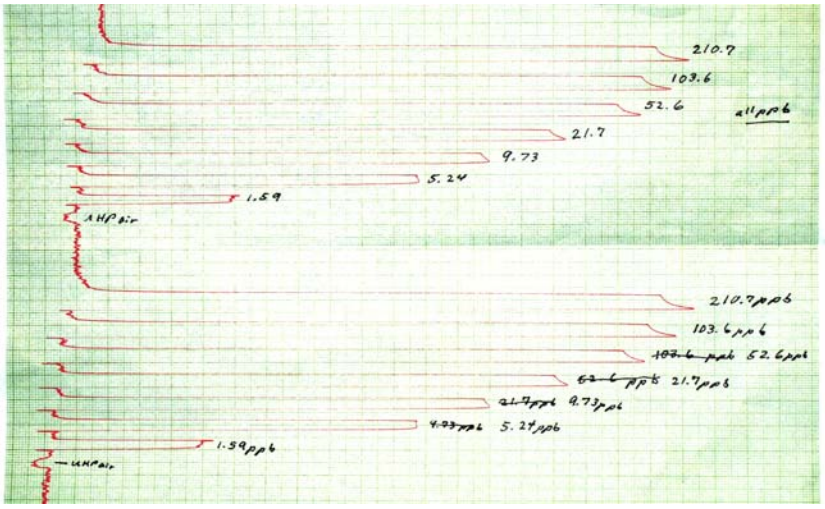
Field Research Division (FRD), Idaho Falls, Idaho

18. Perfluorocarbon Tracer (PFT) Analysis Development. Final testing of the PFT analysis method has been concluded and the method is at a stage where it is ready for actual deployment and experimental work. A final report summarizing the method, procedures, protocols, and cautionary notes has been prepared for internal use.

The report lists the PFTs tested by the method (PDCB, PMCH, m-PDCH) and details about the equipment used, detection limits, the operational settings on the gas chromatograph (GC), flow rates, peak integration parameters, and the like. The report also focused on sampling and analytical artifacts that will require the use of quality control procedures and protocols to achieve quality PFT data sets. Most of these artifacts arise from the "stickiness" of the PFT; that is, their tendency to adhere to surfaces. dennis.finn@noaa.gov and Roger Carter

19. Fast Response Analyzer Data System Upgrade. A new data system is being developed for the existing fast response tracer analyzers to replace the aging systems currently in use. The new system uses an embedded microcontroller to operate the system and collect the data. Data will be stored on a compact flash card as it is collected. We are currently developing the software for the system and simultaneously building a prototype circuit board and enclosure to test the system before printed circuit boards are designed and manufactured. roger.carter@noaa.gov and Randy Johnson

20. Low Cost Tracer Detector. The goal of the low cost tracer detector development is to create a tracer analyzer that will be: 1) significantly less expensive than existing fast response analyzers; 2) not require compressed gases; and 3) not require a dedicated operator. This quarter, the optimization of the prototype low cost tracer detector was completed and it was tested with the reactor/dryer from an existing continuous analyzer. The results were very promising showing a detection range of approximately 200 ppt to 50,000 ppt for SF_6 and a reasonable response time (see figure). Further experimentation has shown that the detector is very sensitive to the humidity of the sample stream so that drying of the sample gas will be essential. It is apparent that an oxygen/water removal system similar to the existing fast response analyzers will be needed with this detector and several options are under consideration. Although there are obstacles to overcome, the project looks promising. roger.carter@noaa.gov, Shane Beard, and Randy Johnson



21. Las Vegas Roadway Toxics Tracer Study. The planning for the Las Vegas Roadway Toxics Tracer Study has begun. Several conference calls have been held with our ARL colleagues at the Atmospheric Sciences Modeling Division at Research Triangle Park, NC. The current draft plan calls for the release of SF_6 from a 150m line during 6 intensive sampling periods in October 2008. The study will utilize 50 stationary bag samplers and 1-2 real-time SF_6 analyzers, and several 3-d sonic anemometers. Several details remain to be worked out, including funding and a site visit. kirk.clawson@noaa.gov

22. Mesoscale Modeling. As an outreach activity, FRD is assisting with the meteorological research being conducted by a graduate student at the University of Wyoming. The student plans to write a Ph.D. thesis on the topographically forced convergence-zone events that sometimes create enhanced snowfall in the Idaho Eastern Snake River Plain, including the Idaho National Laboratory (INL). FRD is performing a test simulation of one such event that occurred in November 2005, using the Weather Research and Forecasting (WRF) model configuration that is already in use for INL activities. The simulation has turned out to be more difficult than expected because the archived model outputs available for initializing WRF for a 2005 case are not as complete as the model outputs used to produce the current real-time WRF forecasts. richard.eckman@noaa.gov

23. Transport and Dispersion Modeling. Although radiological releases are the primary concern for dispersion modeling at INL, there has been increased emphasis on various types of chemical hazards that exist at the site. The hazard zones for chemical releases typically extend fairly short distances downwind, so complex dispersion models such as the NOAA HYSPLIT model tend to be overkill. FRD is therefore adding the NOAA ALOHA (Areal Location of Hazardous Atmospheres) model as one of its standard EOC support models for INL releases. ALOHA is well tailored to the shorter range chemical releases, and it has a built-in database of common chemicals. ALOHA will not replace MDIFF as the dispersion model for radioactive releases.

FRD continues to work toward a transition to the NOAA HYSPLIT model as its primary tool for INL dispersion applications. A major issue for FRD is to ensure that HYSPLIT can fully take advantage of the INL Mesonet observations in generating its wind fields. The standard version of the model is set up to use winds from NOAA forecast models, so it has no capability to ingest Mesonet winds to create a wind field. There does not appear to be a simple off-the-shelf solution to the data ingestion issue in HYSPLIT, so FRD may need to develop this capability in collaboration with other NOAA groups that are using HYSPLIT. We could use a simple interpolation scheme as does the current MDIFF model, but this has its own problems. Interpolation methods do not directly account for various physical constraints to the wind flow, including the effect of topography. Also, interpolation is better suited to generating a 2D wind field at a single height than to generating the 3D wind field required by HYSPLIT. richard.eckman@noaa.gov

24. Outreach. FRD is involved in an "Ask a Scientist" program in which local school students submit scientific questions that are answered by local scientists. The questions and answers are published in the Idaho Falls newspaper. FRD recently received two meteorological questions; one about the weight of clouds and why clouds don't fall to the ground, and the other question about altitude and air temperatures. One answer appeared in the newspaper in October and the other answer will appear in January 2008. richard.eckman@noaa.gov and Kirk Clawson

Special Operations and Research Division (SORD), Las Vegas, Nevada

25. Consequence Assessment. Began and continued training of the Department of Energy, National Nuclear Security Administration (NNSA), National Security Technologies, LLC, consequence assessment procedures and methods for the Nevada Site Office (NSO) and Nevada Test Site (NTS). The weekly (at a minimum) training included event classification, protective action recommendations, dispersion model runs, and product development for health physicists, industrial hygienists incident commanders, and emergency managers. walter.w.schalk@noaa.gov

26. Test-Readiness/Sub-Critical Tests. A meeting was held with the NNSA/NSO Meteorology Program Manager and his contractor to do a final review of the Under Ground Testing Tabletop Exercise. The fallout pattern, the sequence of events, and exercise "injects" were discussed. walter.w.schalk@noaa.gov

27. WRF Mesoscale Model. The WRF runs now include the 3D variational data assimilation system (WRFVAR) which assimilates MADIS (Meteorological Assimilation Data Ingest System) data. The WRF forecast system begins with a cold start at 00 UTC every Sunday and then cycles every 6 hours using the previous 6-hour forecast for initial conditions. MEDA stations with valid pressure data are now assimilated by WRFVAR. Work is being done to the model handling of the morning temperature low-level inversion. kip.smith@noaa.gov