NOAA Air Resources Laboratory
Quarterly Activity Report
FY2015 Quarter 4
(July - September, 2015)

Contents

DISPERSION AND BOUNDARY LAYER

1. HYSPLIT Integration into the DELFIC Nuclear Fallout Model

Glenn Rolph attended a meeting where discussions and plans were made for the Oak Ridge National Laboratory (ORNL) to integrate the HYSPLIT atmospheric transport model into the DELFIC (Defense Land Fallout Interpretative Code) model and Fallout Planning Tool. DELFIC is an advanced tool to characterize the cloud dynamics and fallout of nuclear material from a nuclear explosion. The particles created by DELFIC will be transported and deposited by HYSPLIT in this application and the results displayed in the DELFIC Fallout Planning Tool. ARL will be providing HYSPLIT model support to the effort. glenn.rolph@noaa.gov

2. 2015 International MACCS User's Group Meeting

Glenn Rolph and Ariel Stein participated in the 2015 International MACCS User's Group meeting at the U.S. Nuclear Regulatory Commission (NRC) September 21 and 22. The MELCOR Accident Consequence Code System (MACCS), developed at Sandia National Laboratories for the NRC, is a fully integrated, engineering-level computer code developed to analyze the off-site consequences of an accidental atmospheric release of radioactive material. Domestic and international users attended the 2nd annual meeting and presented results of studies conducted using MACCS for consequence analysis. At the request of NRC, Glenn Rolph made a presentation on the World Meteorological Organization's effort to evaluate dispersion modeling results of the Fukushima nuclear accident. An effort is currently underway by the Sandia National Laboratories to incorporate the HYSPLIT dispersion model into the MACCS software to improve the dispersion calculations with ARL providing HYSPLIT support under a recently approved Memorandum of Understanding between ARL and the NRC. glenn.rolph@noaa.gov

3. Convective Initiation Project

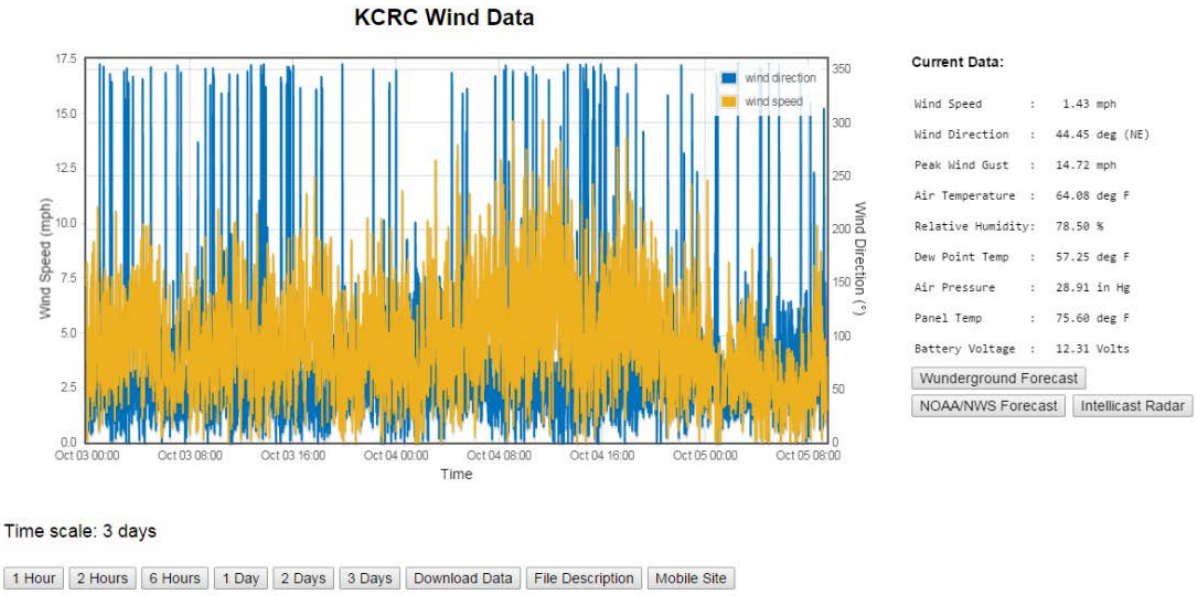
A field campaign near Huntsville, AL, was performed to better understand locally-forced convective initiation. Two eddy covariance systems, a microwave temperature/relative humidity profiler, a scanning wind Lidar profiler, and sensors used to monitor the state of the surface layer and the soil were deployed in July. A science workshop was then held in September at the Atmospheric Turbulence and Diffusion Division (ATDD) allowing participants in the 2014-2015 convective initiation project to present results and discuss future work. tilden.meyers@noaa.gov, J. Kochendorfer

A meteorological tower was installed at Knox County Radio Control (KCRC) Society's model flying field in anticipation of performing comparisons with instruments installed on the DJI S-1000 small unmanned aircraft systems (sUAS). The tower is 5 meters tall and contains a MetOne aspirated radiation shield that houses one Thermometrics platinum resistance thermometer (PRT) and a Vaisala HUMICAP HMP110 temperature and relative humidity sensor. Also installed on the tower are a RM Young wind monitor and a Vaisala

PTB101B pressure sensor. Data are recorded every 10 seconds using a Campbell Scientific CR3000 data logger and are transferred to ATDD every five minutes using a Verizon cellular modem.

Data recording began on July 28, 2015. There were some issues in the first few days with maintaining continuous A/C power to the tower, but after installing a separate A/C power line from the breaker box those issues have been solved. ed.dumas@noaa.gov, C. Brown

The KCRC Society's meteorological tower has been used to measure the performance of an International Meteorological Systems iMet-XQ temperature and relative humidity sensor in both aspirated and non-aspirated environments. The iMet-XQ sensor will be used to measure temperature and relative humidity from the sUAS. Two comparison tests lasting approximately six hours each were performed in September, 2015. Data from the aspirated test are shown below. Both the iMet-XQ temperature and relative humidity were filtered to match the frequency response of the Thermometrics platinum resistance thermometer (PRT) and the Vaisala relative humidity sensor. Data were also corrected using a linear calibration correction and R^2 values calculated for each device.



The comparison data show good performance of both the temperature and relative humidity sensors in an aspirated environment, much like the environment that the sensor will be exposed to while installed on the DJI S-1000 sUAS. ed.dumas@noaa.gov and C.B. Baker

ATDD and the Field Research Division (FRD) have been working jointly on modeling aspects of the Convective Initiation project. Through the summer, Michael Buban at ATDD has been running a series of Large Eddy Simulations (LES) on NOAA high-performance computers to investigate how horizontal variations in surface heat fluxes affect convective initiation. The fluxes are varied in either horizontal bands or

checkerboard patterns with different length scales. The simulations used nearly all of ARL's computing allocations through August but have been ramping down since then. An abstract describing the simulations entitled "The Simulated Effect of Surface Flux Heterogeneity on Convection Initiation in the Southeast US" has been accepted for presentation at the 2016 American Meteorological Society annual meeting. richard.eckman@noaa.gov, Michael Buban, and Tilden Meyers

4. Project Sagebrush

The comprehensive data report for Phase 1 of Project Sagebrush (PSB1) was published in July, 2015 (Project Sagebrush Phase 1, NOAA Technical Memorandum OAR ARL-268). It provides a detailed description covering all aspects of experimental design, instrumentation, measurements, quality control procedures, and the final database for the project.

FRD is presently in the process of developing manuscripts to be submitted to peer reviewed journals. Issues to be explored include:

- Revisiting the values of the horizontal plume spread parameters σ_θ and σ_y
- Investigating the magnitude and variation in the standard deviation of horizontal wind direction σ_θ
- Empirical alternative means for estimation of the horizontal plume spread parameter σ_y based on results from Project Sagebrush Phase One

Much of the present work focuses on differences found between the Sagebrush data set and historical data. Key findings will be presented following journal acceptance.

Intensive planning for the next phase of the Project Sagebrush field study will begin early in the first quarter of FY2016.

Bruce Hicks continued to work on his analysis aimed at the parameterization of nighttime turbulence in the stable boundary layer. He reports achieving some insights when utilizing data from the Grid 3 area in combination with data from other sites. FRD continues to provide him with updated data sets from the Grid 3 tall tower. He recently requested some customized datasets for his analysis and work on preparing those datasets is in progress. dennis.finn@noaa.gov, Rick Eckman

5. Birch Creek Valley Wind Flow Study

The U.S. Forest Service Fire Sciences Laboratory (FSL) has provided FRD with their final database of field measurements from the Birch Creek Valley Wind Flow Study in 2013. The data have been integrated with data collected by FRD and Washington State University. Part of that work includes creating a customized meteorological visualization package. A prototype of this package has been developed and should be completed early in the first quarter of FY2016. Preliminary analysis indicates strong evidence for a gap flow regime in the Birch Creek Valley. It is expected that the new visualization package will greatly enhance the ability to use the FSL data to identify the gap flow dynamics.

6. Wind Forecast Improvement Project (WFIP2)
In late September, FRD deployed instruments at three WFIP2 locations in Oregon. The equipment includes a 915 MHz radar wind profiler, three minisodars, two surface-flux systems, and some additional surface observation systems. Most of the equipment was installed without incident. One exception was the radar profiler deployed at the Boardman airport, which was planned to be operated with a Radio Acoustic Sounding System (RASS) provided by the Earth System Research Laboratory (ESRL). The combined profiler-RASS system can provide observations of both wind and temperature profiles. However, there have been difficulties in getting the profiler and RASS to interact properly. ESRL is looking for a solution to the problem. Data from the FRD deployment sites are being sent back to the office using cell-phone connections. kirk.clawson@noaa.gov

Matthew Brewer started a postdoctoral position at FRD in late August after completing his Ph.D. at the University of Washington. His position supports the WFIP2 and is administered through ARL's contract with Earth Resources Technology. Most of Matt's background has been in atmospheric modeling using the Weather Research & Forecasting (WRF) model and related modeling systems. Matt will be working with the WFIP2 Model Development team as well as be involved with the field deployment team. kirk.clawson@noaa.gov and Rick Eckman

OAR's FY 2016 plan for renewable energy research is undergoing revisions, and two tasks have been added for FRD's planned work. One task is for the field operation of the deployed equipment described above, which will extend through the entire year. The second task involves using the WFIP2 observations to evaluate NOAA forecast models, with an emphasis on forecasts of air-surface exchange and boundary layer development. richard.eckman@noaa.gov, Kirk Clawson, and Matt Brewer

7. HYRad
The complete HYRad 2.0 has been formally released. As reported last quarter, the new user interface provides for creating multiple simultaneous source releases and the use of proxy isotopes to reduce model runtimes. The latest upgrades feature the use of compressed xml output files that encapsulate the model run status, summary, pdf, and plume outputs. This enables the visualization of plume animations and gives the user access to complete information used to configure the model run. The ability to smooth the plume output was also added to the interface. At the request of INL EOC hazardous assessment personnel, enhanced T-Roads (minor INL site roads) and facility locations, in addition to other minor changes, were also added to the interface.
brad.reese@noaa.gov, and Dennis Finn

8. Consequence Assessment for the Nevada National Security Site
James Wood and Rick Lantrip participated in an emergency response Functional Exercise as the Consequence Assessment Team (CAT) for the NNSA Nevada Field Office. The exercise was conducted on the Nevada National Security Site (NNSS). In this exercise, they provided exercise specific weather data and weather forecasts, and generated dispersion products based on the worst case event scenario information

provided for the event. The event was a gas tank truck spill which forced the evacuation of the Emergency Operations Center at the Site and caused a relocation event and a COOP implementation. These events were conducted with the DOE/NNSA/NFO Emergency Response Organization. Walt Schalk was the CAT facilitator for the exercise. kip.smith@noaa.gov, Rick Lantrip, James Wood, and Walt Schalk

9. SORD Mesonet Upgrade

The SORD Mesonet Upgrade installation is on-going. Approximately 95% of the towers have been installed. The final sensor, 3D sonic anemometer, has been delivered. Some boxes were damaged during shipping, so the sensors were inspected and tested. Two were sent back to the vendor for replacement. The communications portion of the new system is currently being tested. Final tower/sensor configurations and data logger programming are in process. Sensor installations began and are on-going. SORD's goal is to have the new sensors operating in Q1 of FY16 for testing and comparison. walter.w.schalk@noaa.gov , Kip Smith, James Wood, Phil Abbott, Rick Lantrip, and Bobby Gates.

10. Support to DOE/NNSA NNSS Projects and Experiments

SORD's participation in the Shock Physics Experiment (SPE) series continues as Kip Smith and Walt Schalk participated in a kick-off meeting. General results from the previous experiment (4 Prime) were presented. In addition, goals, time lines, contacts, and changes were presented for the next experiment.

James Wood and Walt Schalk worked on a proof of concept field test of a tethered balloon elevated platform that will hopefully be used during the next SPE. There is a desire to measure the infrasound signal from an elevated location. We are working with Los Alamos National Lab in tethering a weather balloon to lift an instrument package about 50 meters above the ground. The initial proof of concept was successful. Several areas of improvement were identified and are being addressed. walter.w.schalk@noaa.gov, Kip Smith, James Wood.

AIR QUALITY

11. International Workshop on Air Quality Forecasting Research

ARL hosted the 7th International Workshop on Air Quality Forecasting Research (IWAQFR) in College Park, Maryland from September 1-3. Over 100 scientists participated, with 20 international participants from South America, Australia and Canada, Asia, and Europe. The conference opened with a statement from ARL Director Steven Fine welcoming the group and reinforcing the purpose of the program to meet the scientific and technical challenges associated with air quality science to protect the citizens in this country and globally. Presentations (many provided by ARL scientists) and discussions held throughout the conference emphasized the need to acquire temporally- and spatially- relevant satellite-based data; to develop high resolution

models and ensemble modeling systems; and to address current limitations in atmospheric aerosol science. There were seven oral sessions, one poster session and a town hall reception announcing the official release of a prototype marine isoprene emissions product developed by ARL and NESDIS/STAR and based on a Joint Polar Satellite Systems ocean-color product. The seven sessions were: (1) *Operational Air Quality Forecasting: Progress and Challenges*, (2) *Emissions Forecasting*, (3) *Data Assimilation*, (4) *Evaluation and Post-Processing*, (5) *Evaluation and Post-Processing*, (6) *Evaluation and Post-Processing*, and (7) *Forecasting and Communicating Impacts*. pius.lee@noaa.gov.

IWAQFR presentations (oral and poster) have been posted on the website. A special journal issue is planned for the Journal of the Air and Waste Management Association for late in 2016. richard.artz@noaa.gov

12. Mercury Measurement Workshop at NCWCP

Winston Luke organized, hosted, and led a workshop at the NOAA Center for Weather and Climate Prediction (NCWCP) designed to assess and summarize the current state of the art for mercury measurements across national and global monitoring networks. The workshop was held September 22-24 and drew 25 attendees (both remote and in person at NCWCP) including scientists from Canada, France, and Norway. In recent years the weight of evidence suggests that currently used techniques to measure gaseous oxidized mercury (GOM), the most important atmospheric mercury species from an ecosystem perspective, can suffer from severe biases and artifacts under certain conditions. Workshop attendees engaged in extensive discussions about the current understanding of mercury measurement science, and shared best practices for network monitoring operations. Workshop proceedings will be promulgated to all invitees to the workshop and will be summarized at the National Atmospheric Deposition Program's Network Operations Subcommittee meeting held during the 9th International Conference on Acid Deposition in Rochester, NY October 19-22, 2015. winston.luke@noaa.gov

13. Development of a Gaseous Oxidized Mercury Calibration Source

Although gaseous oxidized mercury (GOM) is the most critically important form of atmospheric mercury, owing to its water solubility, rapid removal from the atmosphere, and ready bioavailability in aquatic ecosystems, our ability to reliably measure GOM is compromised by biases and inaccuracies in commonly deployed measurement methodologies. In addition, the development of a reliable, robust, and precise calibration source of GOM species has proved challenging and elusive. Paul Kelley and Winston Luke designed, built, and deployed a GOM calibration source at the Beltsville, MD AMNet site for evaluation. The calibration source is based on the permeation of GOM compounds from Teflon® vessels at constant temperature, and is housed in a compact, weather-tight enclosure for deployment in a monitoring environment. Laboratory and field tests of the source will continue through FY2016. winston.luke@noaa.gov and Paul Kelley

14. Atmospheric Mercury Modeling with HYSPLIT-Hg

Analyses continued with the HYPLIT-Hg module. Simulations were carried out with model spin-up periods of 3, 4, and 5 years. Earlier simulations had used a 2-year spin-up period before the simulation of the analysis year (e.g., 2005). Modeled concentrations and deposition in the analysis year generally increased slightly with increased spin-up time: typical increases were ~3%, ~4%, and ~4.2%, respectively, for 3, 4, and 5-year spin-ups, compared to the 2-year spin up baseline. This was an expected result as the model was allowed to "fill up" more completely before the analysis year was simulated. A complete set of simulations and analysis was carried out with the new extended spin-up configuration, and new source-receptor and model evaluation results were generated. These new results will be used in a forthcoming publication. To aid in current and future post-processing model evaluation analysis, measurement and model results were converted to the HYSPLIT DATEM format. The DATEM format is a specific, common format for which post-processing analysis programs have been created within the HYSPLIT modeling suite. Special programs were created to create and process these DATEM format files in the context of the HYSPLIT-Hg model. Finally, simulations were carried out for 2011, using a 5-year model spin-up, with updated emissions inventory and meteorological data. mark.cohen@noaa.gov

15. Fireworks and Fine Particulate Matter

During the July 4 holiday week, there was substantial press coverage of the paper on "Effects of Independence Day Fireworks on Atmospheric Concentrations of Fine Particulate Matter in the United States" by Dian Seidel and Abigail Birnbaum, which appeared in late June online in *Atmospheric Environment* and in print form in the August issue. The paper reports results from a national, multi-year analysis of air quality monitoring data and shows statistically significant increases in concentrations of atmospheric particulate matter. Concentrations of fine particulate ($PM_{2.5}$) are elevated on July 4 evening and July 5 morning. On national average, holiday 24-hr $PM_{2.5}$ levels are elevated by 5 µg/m3 (42%). Stories appeared in Time magazine, USA Today, and many other newspapers across the country; online publications, including Slate and Bloomberg News, and radio news programs. Since it appeared, this paper has been and continues to be (as of October 2015) the first or second most downloaded *Atmospheric Environment* article. dian.seidel@noaa.gov

16. Ammonia Studies

Data analysis and discussion of results from the Illinois ammonia study is ongoing. Simone Klemenz completed ion chromatography analysis of filter samples for particulate ammonium. Those data were shared with partners at the University of Illinois at Urbana-Champaign, who are incorporating them into models. Mark Heuer completed several laboratory tests with the cavity ring-down spectrometer to investigate response times with various sample delivery configurations. Latoya.myles@noaa.gov, M. Heuer, and S. Klemenz

CLIMATE

17. Cloud Cover

Melissa Free and colleagues finished working on a paper titled "Comparison between total cloud cover in four reanalysis products and cloud measured by visual observations at U.S. weather stations." The paper compares U.S. weather station data to cloud cover from reanalyses produced by NCEP, NASA, the European Center for Medium-range Weather Forecasting, and the Japan Meteorological Agency. While the reanalyses generally show much lower cloud amount than the visual weather station data, they largely succeed in simulating the main aspects of interannual variability in cloudiness in the contiguous U.S. Trends in the reanalysis datasets for the U.S. mean for 1979-2009 range from -0.38 %/decade to -1.8%/decade, compared to -0.50 %/decade for the station data. The paper was submitted to the Journal of Climate. melissa.free@noaa.gov

18. Changing Width of Earth's Tropical Belt

Dian Seidel, along with three other colleagues from NOAA's Earth System Research Lab and the Cooperative Institute for Research in Environmental Sciences, convened an AGU Chapman Conference on the Width of the Tropics: Climate Variations and Their Impacts. The conference, held July 27-31 in Santa Fe, NM, brought together scientists from a wide range of backgrounds to explore the state of the science regarding tropical widening. New perspectives on this intriguing problem became apparent during the meeting, resulting in consensus among participants on the need to better understand several key topics, including a) the relationships among various ways of defining and measuring the edge of the tropics; b) the connections between tropical atmospheric circulation patterns and both tropical oceanic circulations and mid-latitude atmospheric dynamics; and c) the regional manifestations of changes in tropical width, as more informative than the latitude-average approaches employed to date. Plans are being made to address these topics. dian.seidel@noaa.gov

19. Analysis of Soil Moisture Satellite Data

Comparison analysis of the soil moisture satellite data from the European Space Agency and NOAA/NESDIS was performed. The satellite observed data were also cross-validated with model simulated soil moisture data and in-situ observed station data from NASA DAAC and NCEP/EMC. Preliminary results revealed great differences among the different data sources, particularly on a climate scale. ARL will continue to collaborate with NESDIS scientists to understand and reach consensus of those differences from a climate perspective. julian.wang@noaa.gov

20. FOCAL – Alaska Study

ATDD continued its analysis of the data collected during the Flux Observations of Carbon from an Airborne Laboratory (FOCAL) – Alaska study. The study involved, for perhaps the first time, the capability of measuring not only methane, water vapor, and carbon dioxide at a fast enough rate for eddy-covariance flux calculations, but also their isotopologues with carbon-13 and deuterium, all from a relatively unobtrusive light-twin airplane. Flights were conducted over the North Slope of Alaska in August 2013.

Samples were collected approximately 10 meters above ground in order to capture the effect of surface heterogeneity on the concentrations and fluxes of these gases. The results for methane flux are complex and analysis is ongoing. Conclusions so far are:

- Methane flux varied in absolute value by a factor up to 25 with clear sunny days having the strongest upward flux.
- Though all days analyzed had net upward methane flux, downward flux was quite common, especially on cooler days.
- The strongest mean upward flux, about 175 kg / (km^2 d), was found on August 13, a day with a well-developed mixed layer 160 m deep.

A proposal was submitted to the National Science Foundation for continued funding of the FOCAL study. The proposal includes engineering development flights near Wallops Island, Virginia, in the summer of 2015, followed by deployment to the North Slope of Alaska in the summers of 2016 and 2017. A new component was added to the proposal to include use of the Weather Research Forecast with Stochastic Time-Inverted Lagrangian Transport (WRF-STILT) model to extend the high resolution spatial methane and carbon dioxide flux data from the Centaur aircraft to larger regional scales. ed.dumas@noaa.gov, R.J. Dobosy and C.B. Baker

21. World Meteorological Organization -SPICE

The World Meteorological Organization- Solid Precipitation InterComparison Experiment (WMO-SPICE) measurements ceased. The field portion of this international study to assess biases and uncertainties in snow measurements is complete, and preliminary results have been made available to contributors for analysis of different scientific topics, assessment of gauges under test, and publication of journal articles. The final report is due in the fall of 2016. john.kochendorfer@noaa.gov

22. Climate Reference Network (CRN)

In July, August, and September the National Centers for Environmental Information (NCEI) retrieved 51 data files from USCRN sites through the server ftp.atdd.noaa.gov. Data are passed to NCEI by this path when retrieved episodically by ATDD from individual site visits to fill data gaps. Instrument characteristics for each site are maintained in the Integrated Station Information System database on NCEI's server, along with a record of events which affect data quality. New events are identified from ATDD's field crews and archived data. lynne.satterfield@noaa.gov

The CRN staff spent 213 days on travel status. Two sites were installed in Alaska. The CRN staff made 50 annual maintenance visits and four unscheduled maintenance visits. mark.e.hall@noaa.gov

23. NOAA/INL Mesonet

Rick Eckman attended a meeting of the Carbon Free Power Project (CFPP) in Idaho and gave a brief presentation on FRD's permanent tower network and other measurement capabilities. CFPP is an effort by Utah Associated Municipal Power Systems, NuScale, and Energy Northwest to install modular nuclear reactors at the Idaho National Laboratory (INL) Site. They are proposing to install 12 of NuScale's

small modular reactors to generate about 570 MW of power. It is not clear whether the Department of Energy will ultimately allow CFPP to move ahead with their plans. If it does proceed, FRD may become involved to the extent that the division already has existing meteorological observations near the proposed construction sites. richard.eckman@noaa.gov

A Campbell Scientific CR6 datalogger is being tested as a potential replacement for the aging CR23X dataloggers currently used in the NOAA/INL Mesonet. It was operated for several weeks on a test weather station installed just outside the FRD office and appeared to operate without any problems. As soon as the WFIP2 deployment is completed and personnel are once again available, the datalogger will be installed at one of the NOAA/INL mesonet stations to test its RF communication abilities within the NOAA/INL Mesonet. We have also received three Esteem radio modems that will be tested as potential replacements for the radio communication system currently used in the mesonet. roger.carter@noaa.gov and Shane.Beard

ARL 4th Quarter Publications

Krishnan, P., **J. Kochnendorfer**, E. Dumas, P. Guillevic, **C. B. Baker**, **T. Meyers**, and B. Martos (2015). Comparison of in-situ, aircraft, and satellite land surface temperature measurements over a NOAA Climate Reference Network site. Remote Sensing of Environment 165: 249-264. doi:10.1016/j.rse.2015.05.011

Colli, Matteo, Roy Rasmussen, Julie M. Thériault, Luca G. Lanza, **C. Bruce Baker**, and **John Kochendorfer** (2015). An Improved Trajectory Model to Evaluate the Collection Performance of Snow Gauges. Journal of Applied Meteorology and Climatology 54(8): 1826-1836. doi: 10.1175/JAMC-D-15-0035.1

Seidel, D. J. and A. N. Birnbaum (2015). Effects of Independence Day fireworks on atmospheric concentrations of fine particulate matter in the United States. Atmospheric Environment 115: 192-198. doi:10.1016/j.atmosenv.2015.05.065

Wang,S., Pan,M., Mu, Q., Shi,X., Mao,J., Brümmer,C., Jassal,R.S., Krishnan,P., Li, J., and T.A. Black (2015). Comparing evapotranspiration from eddy covariance measurements, water budgets, remote sensing, and land surface models over Canada, J. .Journal of Hydrometeorology , 16, 1540–1560, doi:10.1175/JHM-D-14-0189.1

Kim, H. C., **P. Lee**, F. Ngan, Y. Tang, H.L. Yoo, and L. Pan (2015). Evaluation of modeled surface ozone biases as a function of cloud cover fraction, Geoscientfic Model Development. 8, 2959-2965. doi:10.5194/gmd-8-2959-2015

Outreach

Each year the Appalachian Regional Commission and Oak Ridge Associated Universities (ORAU) sponsor a summer science camp in Oak Ridge, Tennessee for

middle-school students from Mississippi to New York. An important component of the program is wind-generated electricity. A highlight of the activity was a visit to ATDD's wind tunnel to test the model wind generators the students built using a small commercial generator hub and blades of their own design and construction (see photos below). The test in the wind tunnel's outflow often results in flying blades; therefore, an instructor inside a protective cage holds the model during the test while the student records the voltage drop across a 1000-ohm load resistor for each wind-speed setting. Knowing the voltage and resistance, the students can compute the generated power in watts. There is usually a clear range of power generated among the different designs, and some designs perform better at low wind speed and some at high speed. ATDD staff explained that the preferred design in real life depends on the expected ambient wind. ron.dobosy@noaa.gov, R. White, D. Senn