

Research Products & Services

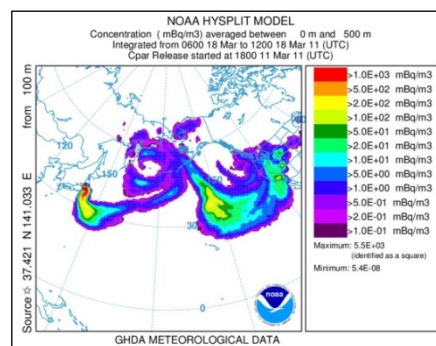
ARL has several research products and services that have been developed and/or continue to be enhanced for a variety of users. More information about ARL's products and services is available upon request.

Models

Atmospheric Dispersion and Boundary Layer

HYSPLIT-Dispersion Modeling System

The ARL HYSPLIT model is a complete system for computing simple air parcel trajectories, as well as complex transport, dispersion, chemical transformation, and deposition simulations. HYSPLIT continues to be one of the most extensively used atmospheric transport and dispersion models in the atmospheric sciences community. One of the most common applications is a back trajectory analysis to determine the origin of air masses and establish source-receptor relationships. HYSPLIT has also been used in a variety of simulations describing the atmospheric transport, dispersion, and deposition of pollutants and hazardous materials. Some examples of the applications include tracking and forecasting the release of radioactive material, wildfire smoke, windblown dust, pollutants from various stationary and mobile emission sources (such as mercury), allergens and volcanic ash.

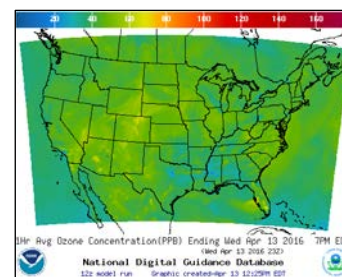


The model calculation method is a hybrid between the Lagrangian approach, using a moving frame of reference for the advection and diffusion calculations as the trajectories or air parcels move from their initial location, and the Eulerian methodology, which uses a fixed three-dimensional grid as a frame of reference to compute pollutant air concentrations (The model name, no longer meant as an acronym, originally reflected this hybrid computational approach). For more than thirty years, HYSPLIT has evolved from estimating simplified single trajectories based on radiosonde observations to a system accounting for multiple interacting pollutants transported, dispersed, and deposited over local to global scales. Examples of HYSPLIT improvements/upgrades are listed below. For more information on HYSPLIT, please see: Stein et. al, 2015: NOAA's HYSPLIT atmospheric transport and dispersion modeling system. [doi:10.1175/BAMS-D-14-00110.1](https://doi.org/10.1175/BAMS-D-14-00110.1)

Atmospheric Chemistry

National Air Quality Forecasting Capability (NAQFC)

A national air quality forecasting capability for ground-level ozone (O_3) and fine particulate matter ($PM_{2.5}$) was contemplated by the U.S. Congress in 2002. As a result of the *H.R. Energy Policy Act of 2002 (Senate Amendment) S. 517, SAI383, Forecast and Warning*, NOAA was mandated to provide this forecasting service. The resulting National Air Quality Forecasting Capability (NAQFC) is an integrated system linking the National Weather Service (NWS) numerical weather prediction (NWP)



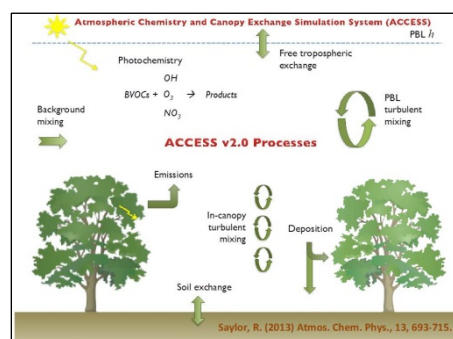
model to the NOAA-EPA developed Community Multiscale Air Quality (CMAQ) model. For the past fourteen years, ARL has led the research, configuration and testing of the NAQFC. An operational air quality forecasting capability for ground-level O₃ was established in 2007.

Since 2010, ARL has performed several upgrades to the NAQFC; many of which were instigated by ARL's research to improve model forecasting or to expand into additional regions of the United States. A few upgrades were imposed by upstream processes, such as changes to the North American Model. In early 2016, using model upgrades provided by ARL, the National Centers for Environmental Prediction (NCEP), the group responsible for operating the NAQFC modeling system, began providing air quality forecasts for PM_{2.5} across the U.S.

For more information, see: http://www.nws.noaa.gov/ost/air_quality/

Atmospheric Chemistry and Canopy Exchange Simulation System (ACCESS)

The Atmospheric Chemistry and Canopy Exchange Simulation System (ACCESS) is a general column modeling system that can be used to simulate one-dimensional atmospheric chemistry, vertical turbulent transport and surface-atmosphere exchange processes from the ground to a specified model top height. The ACCESS modeling system has been designed by ARL to provide a more physically, chemically and biologically consistent and robust representation of important processes affecting the exchange of trace chemical species between the Earth's surface and the lower atmosphere than can be included in large-scale, 3-dimensional air quality models. This is a long-term research product designed to provide improvement to the NAQFC.



Inputs to ACCESS include:

- meteorological variables, such as temperature, pressure, humidity, mean horizontal wind speed, vertical turbulent flux data, canopy attenuation of actinic radiative flux and photosynthetic photon flux density;
- forest canopy morphology (including the vertical profile of leaf area density, biogenic volatile organic carbon emission factors, and soil emission factors), and
- background trace species concentrations (including species mixed from the remote background and concentrations of species above the Planetary Boundary Layer).

Meteorological variables for a simulation can be provided from observed data, from a vertically resolved land surface model or can be generated from user defined parameterizations. Outputs from ACCESS include vertical profiles of concentrations, fluxes, and process budgets for all simulated trace species, as well as calculated emissions rates, resistances and deposition velocities.

In conjunction with observations from intensive field measurement campaigns, ACCESS is being used to help answer many important questions concerning the simulation of surface-atmosphere exchange. For example:

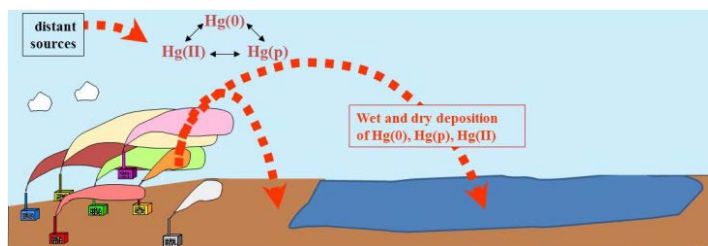
What are the magnitudes, variations and controlling processes for biosphere-atmosphere fluxes of atmospheric trace species relevant to air quality, weather and climate? How well are we able to model these fluxes in large-scale simulations?

What are the chemical and physical processes that control the oxidation of biogenic VOCs and what are the implications for the formation of ozone, reactive nitrogen and aerosol precursors?

Details of the major components of the simulation system can be found in Saylor (2013) [doi:10.5194/acp-13-693-2013](https://doi.org/10.5194/acp-13-693-2013).

HYSPLIT-Mercury

ARL has created a special version of the HYSPLIT model (HYSPLIT-Hg) to simulate the atmospheric fate and transport of mercury. HYSPLIT-Hg starts with a mercury emissions inventory; then utilizes meteorological data assembled by NOAA and others to estimate the atmospheric dispersion of mercury from each source. Chemical reactions in the air; the partitioning of mercury into gaseous, aerosol, and droplet phases; and wet and dry deposition are then simulated by the model. Numerous pre- and post-processing programs have also been developed for use with the HYSPLIT-Hg model. A key feature of the HYSPLIT-Hg modeling system is that it can estimate the overall atmospheric concentrations and deposition arising from emissions of mercury to the air and at the same time keep track of the individual contributions of each source to the overall totals. A powerful and relatively unique feature of the model is that it can be run in a *Lagrangian* (“plume”) mode, an *Eulerian* (“gridded”) mode, or an integrated *combination* of the two, in which emitted mercury is first considered in a plume and then transferred to a global grid for simulation of more distant fate/transport. This capability allows the model to simulate source/receptor relationships at length scales ranging all the way from “local” to “global”. This is important as mercury emissions can have ecosystem deposition impacts over an unusually large range of distances from the source.



ARL evaluates the model's performance by comparing its predictions against ambient air measurements collected by ARL and other scientists. To date, model results are encouragingly consistent with observations. However, important research continues to be needed to evaluate, refine, update and extend the modeling system. This will allow a better estimation of the relative contribution of different source types and source regions to deposition to sensitive key ecosystems.

Since 2011, ARL's HYSPLIT-Hg modeling has been a key aspect of the NOAA-EPA Great Lakes Restoration Initiative (GLRI). The goal of this multi-year modeling project, funded through an Interagency Agreement between NOAA and the EPA, is to estimate the amounts and source-attribution for atmospheric mercury deposition to the Great Lakes. For more information about ARL's Mercury Modeling, please see: http://www.arl.noaa.gov/Mercury_modeling.php

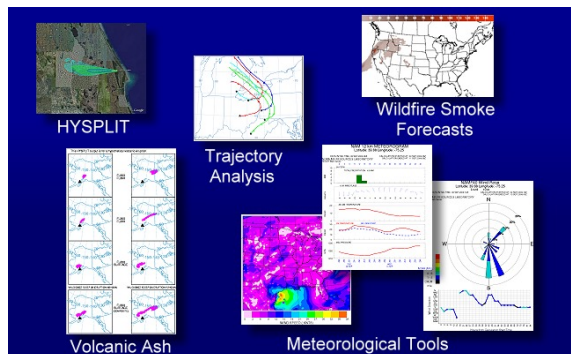
Web-Based Services

Atmospheric Dispersion and Boundary Layer

Real-time Environmental Applications and Display sYstem

The Real-time Environmental Applications and Display sYstem (READY) is a web-based system, developed by ARL in 1997 for accessing and displaying meteorological data and running trajectory and dispersion model products on ARL's web server. READY brings together the HYSPLIT dispersion model, meteorological display products, and textual forecast products generated over many years at ARL into a form that is easy to use by anyone, but with the atmospheric scientist as the primary user. Within the last 5 years an emphasis has been placed on improving the user interface for HYSPLIT and enhancing the results with interactive maps.

READY has been maintained and routinely updated by ARL for 20 years and presently has over 3,600 unique users from Governments (Federal, State, and Foreign, 1293), Universities (1809), Commercial entities (273), Military (64), Non Profits (84), and Private Pilots (77). In a typical month, between 60,000 and 80,000 HYSPLIT simulations are run through READY by these users for locations all over the world. In 2014, over one million HYSPLIT simulations were performed through READY alone. Based on comments and questions received by ARL, user applications include air quality forecasting and analysis, emergency response, wildfire smoke forecasting, hot air ballooning, hang-gliding/soaring, and even insect and plant spore transport. For more information, see: <https://ready.arl.noaa.gov/index.php>



Information and Services

ARL has been providing climatological, dispersion and mesoscale meteorological advice and expertise to the Department of Energy (DOE), Idaho National Laboratory (INL), and its predecessors for over 60 years. NOAA's relationship with DOE is formalized with Memoranda of Agreement that establish the NOAA/INL Meteorological Research Partnership. Through MOAs, ARL scientists serve on a number of guidance committees and panels. The scientists also continue to provide guidance on meteorological issues, including local climatology, weather, and dispersion.

ARL has been providing research, information, services, and expertise in meteorology since 1956 for the DOE Nevada National Security Site (NNSS). The relationship is formalized in an Interagency Agreement between NOAA and DOE, allowing scientists to collect and analyze data to support the safety and security of people and property, climate studies, air quality studies, complex wind flow studies, and emergency response plume dispersion. In addition, a mobile upper air data capability is used to collect data on and off the NNSS for the support of national security experiments.

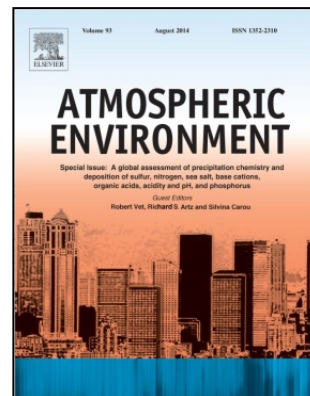
Assessments

Atmospheric Chemistry

WMO Global Assessment

ARL was a lead author of a global assessment of precipitation chemistry and deposition of major ions: sulfur, nitrogen, sea salt, base cations, organic acids, acidity and pH, and phosphorus. The global assessment was conducted under the auspices of the World Meteorological Organization's Global Atmosphere Watch. The assessment includes a global data set of quality assured wet deposition monitoring data for 2000–2002 and 2005–2007 and global wet deposition maps of major ions combining measurement and modeling results.

The assessment has had over 50 citations since it was published in *Atmospheric Environment* in August, 2014. For more information, see: Vet et. al., (2014) [doi:10.1016/j.atmosenv.2013.10.060](https://doi.org/10.1016/j.atmosenv.2013.10.060)



Great Lakes Restoration Initiative

ARL's HYSPLIT-Hg modeling system has been used to assess the source-attribution for atmospheric mercury deposition to the Great Lakes under the auspices of the Great Lake Restoration Initiative (GLRI). The overall goal of these assessments is to estimate the amount of atmospheric mercury deposited to the Great Lakes and the amounts coming from different source regions and source types. This information is useful to stakeholders in prioritizing local, regional, national, and international actions to reduce mercury loadings to the Great Lakes. Annual assessment projects have been funded through the GLRI during each year from FY-2010 through FY-2015. Work is ongoing on the assessments commissioned with FY14 and FY15 GLRI funds. Final Reports for the FY10, FY11, FY12, and FY13-funded assessments have been completed:

- Cohen, M., R. Draxler, R. Artz (2011). *Modeling Atmospheric Mercury Deposition to the Great Lakes*. Final Report for work conducted with FY2010 funding from the Great Lakes Restoration Initiative. NOAA Air Resources Laboratory, Silver Spring, MD. 160 pages. Available at: http://www.arl.noaa.gov/documents/reports/GLRI_FY2010_Atmospheric_Mercury_Final_Report_2011_Dec_16.pdf
- Cohen, M., R. Draxler, R. Artz (2013). *Modeling Atmospheric Mercury Deposition to the Great Lakes: Examination of the Influence of Variations in Model Inputs, Parameters, and Algorithms on Model Results*. Final Report for work conducted with FY2011 funding from the Great Lakes Restoration Initiative. NOAA Air Resources Laboratory, College Park, MD. 157 pages. Available at: http://www.arl.noaa.gov/documents/reports/GLRI_FY2011_Atmospheric_Mercury_Final_Report_2013_June_30.pdf
- Cohen, M., R. Draxler, R. Artz (2014). *Modeling Atmospheric Mercury Deposition to the Great Lakes: Projected Consequences of Alternative Future Emissions Scenarios*. Final Report for work

conducted with FY2012 funding from the Great Lakes Restoration Initiative. NOAA Air Resources Laboratory, College Park, MD. 193 pages. Available at:

http://www.arl.noaa.gov/documents/reports/GLRI_FY2012_Atmos_Mercury_09_Oct_2014.pdf

- Cohen, M. (2016). *Modeling Atmospheric Mercury Deposition to the Great Lakes: Updated Analysis*. Final Report for work conducted with FY2013 funding from the Great Lakes Restoration Initiative. NOAA Air Resources Laboratory, College Park, MD. 81 pages. Available at: http://www.arl.noaa.gov/documents/reports/GLRI_FY2013_Atmos_Mercury_Final_Report.pdf

Climate Observations

IPCC Report

ARL has actively contributed as authors and reviewers to regional, national and international scientific assessments. ARL served as contributing author to the Intergovernmental Panel on Climate Change's Fifth Assessment Report (AR5), providing a section on changes in the width of the tropical belt. National and international climate scientists and decision-makers use this information to understand trends and the need for mitigating and adapting to climate change.

Datasets

Atmospheric Dispersion and Boundary Layer Characterization

DCNet

DCNet is a part of the ARL dispersion research program, based in the National Capitol Region. This urban network was proposed in 2003 in response to a NOAA inquiry concerning meteorological aspects of the events of September 11th. The questions asked were “how many?” and “where to install?” urban meteorological monitoring stations in order to provide first responders with accurate, timely, and appropriate transport and dispersion information.

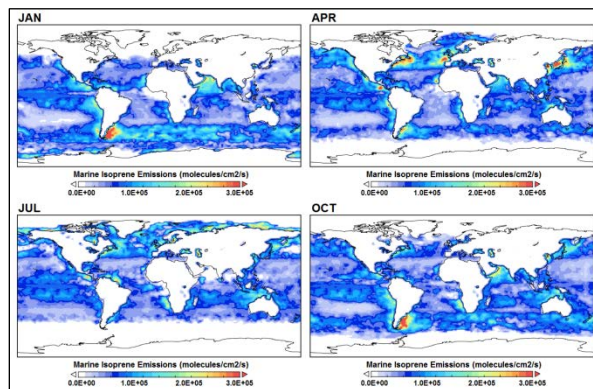
For DCNet, meteorological measurements of temperature, wind speed and direction, as well as measurements of atmospheric turbulence, are used to address the difficulties associated with the use of routine weather observations and atmospheric turbulence within the complexity of an urban environment to protect the public. Through September 2015, observations were continuously transmitted to NOAA's MADIS (Meteorological Assimilation Data Ingest System), a meteorological observational database and data delivery system that provides observations that cover the globe. Data are presently archived at ARL's Atmospheric Turbulence and Diffusion Division. The DCNet data are used primarily by the Pentagon, DC Metro, the Naval Research Laboratory, and the Department of Homeland Security, who access the current observations from a public ftp site: <ftp://ftp.atdd.noaa.gov/pub/dcnet/>. Copies of the raw data files are available upon request.



Atmospheric Chemistry & Deposition

Marine Isoprene Emissions

ARL collaborated with the NOAA/National Environmental Satellite Data and Information Service's Center for Satellite Applications and Research (STAR) to develop a near real-time satellite-based marine isoprene emissions product. The NAQFC relies on forecasts of emissions and weather to predict surface levels of air pollutants, including ozone and fine particulate matter. Isoprene, emitted by trees, grass and phytoplankton, is a reactive biogenic hydrocarbon that is important for the formation of tropospheric ozone and secondary organic aerosols. ARL teamed with the STAR Ocean Color Team and George Mason University to combine the ocean color retrievals from the Visible Infrared Imaging Radiometer Suite (VIIRS) aboard the NOAA Suomi-NPP satellite and meteorological data from the NWS to derive a marine isoprene emissions product.



A beta version of the new product was introduced to the air quality community at the 7th International Workshop on Air Quality Forecasting Research held in College Park, MD from September 1-3, 2015. A dedicated town hall meeting was held at the Earth System Science Interdisciplinary Center of the University of Maryland to introduce the product, to provide technical details, and to collect user feedback to address community needs and guide future development. The many users of this product include the NOAA NAQFC, NOAA's Geophysical Fluid Dynamics Laboratory, US EPA, and the Texas Commission of Environmental Quality.

Atmospheric Integrated Research Monitoring

ARL provides support to national and international networks that measure the most abundant trace chemicals (referred to as "major ions") commonly found in precipitation. These substances include several sulfur- and nitrogen-containing compounds, as well as chemicals found in soil and seawater. The primary products of these networks are high quality data sets of chemical fluxes made available on publicly accessible web sites and other venues as appropriate. ARL's Atmospheric Integrated Research Monitoring (AIRMoN) network is a daily (event-based) collection of precipitation chemistry data at six locations in the U.S.



The AIRMoN datasets are provided to the National Atmospheric Deposition Program (NADP), a partnership program with twelve other federal agencies and numerous states and universities, and posted to: <http://nadp.sws.uiuc.edu/data/AIRMoN/>. The data sets inform evaluation and development of policies, plans, and models. Some stations in the network date back to 1976.

Monitoring of Atmospheric Mercury Species

ARL operates three of the founding sites in the Atmospheric Mercury Network (AMNet) administered by the NADP. The network was established for the purpose of measuring atmospheric mercury species (gaseous elemental, gaseous oxidized, and particulate-bound mercury) using automated, continuous measurement systems. The instrumentation is operated across the network in accordance with standard operating protocols and the raw data from each site are reduced with a common algorithm, ensuring uniformity of reporting. The long-term data records collected at each site offer high-quality measurement data to estimate dry and total deposition of atmospheric mercury; detect trends in atmospheric concentrations in response to mandated and market-driven emissions reductions; and evaluate models of atmospheric fate and transport of mercury. In addition, the sites serve as important test bed facilities that can promote collaborative measurements (e.g., mercury in litterfall, mercury isotope studies, passive sampler deployment), measurement method comparisons and evaluations, and focused Quality Assurance/Quality Control investigations. The data sets are uploaded to and made available by the NADP (as password protected data).

<http://nadp.sws.uiuc.edu/amn/data.aspx>

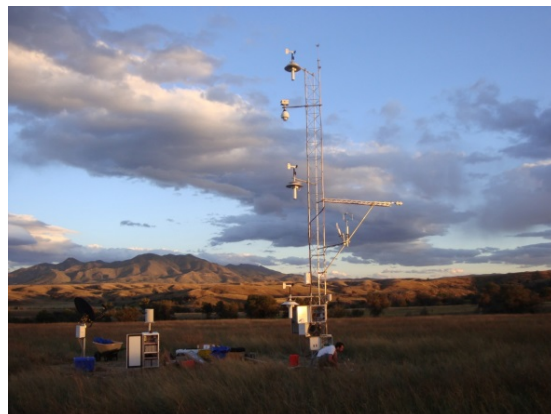


Climate Observations & Analyses

Surface Energy Budget

ARL provides comprehensive datasets of energy and carbon fluxes from sites in Arizona, Illinois, South Dakota, and Tennessee to both national and international networks (e.g., Ameriflux, Fluxnet, and the Global Energy and Water cycle Experiment (GEWEX)). A fifth site in Montana was removed in 2015. These data are also used by the NOAA National Centers for Environmental Prediction (NCEP) land-surface modeling team to evaluate, test and improve the land surface schemes currently part of the NOAA suite of models. For more information about Ameriflux, see:

<http://ameriflux.lbl.gov/about/about-ameriflux/>



For more information about Fluxnet, see: <http://fluxnet.ornl.gov/>

For more information about GEWEX, see: <http://www.gewex.com/>

Hardware

Atmospheric Dispersion and Boundary Layer

Best Aircraft Turbulence (BAT) probe

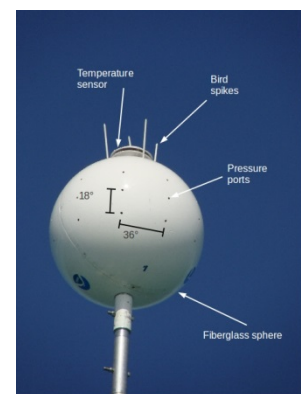
The Best Aircraft Turbulence (BAT) probe was developed in the early 1990s by ARL in collaboration with the Airborne Research Australia to measure meteorologically-relevant turbulent three-dimensional wind vectors, air temperature, and air pressure from a moving platform. Over the years it has been flown on a dozen research aircraft around the world, including the U.S., Australia, Italy, Argentina, The Netherlands, Sweden, and Scotland. The BAT probe recently formed a fundamental part of a new airborne instrument system, Flux of Carbon from an Airborne Laboratory (FOCAL), developed in collaboration with Harvard University and Aurora Flight Sciences. In 2013, FOCAL was used to measure fluxes of carbon dioxide and methane, two important greenhouse gases, over the permafrost region of Alaska.



For more information, see the NOAA/ARL Technical Memorandum entitled “Airborne measurements of CO₂ and CH₄ fluxes over the Alaskan North Slope using the Flux Observations of Carbon from an Airborne Laboratory (FOCAL) system” at: <http://www.arl.noaa.gov/documents/reports/ARL%20TM-267.pdf>

Extreme Turbulence (ET) probe

ARL developed the Extreme Turbulence (ET) probe in the early 2000s based on the same technology used in aircraft gust probes, such as ARL’s Best Aircraft Turbulence probe. The ET probe is an innovative wind sensor specifically designed to work on a stationary tower or a buoy in hurricane conditions. It uses a 43 cm diameter fiberglass sphere with three horizontal rows of pressure ports. Each port is connected to pressure sensors mounted on circuit boards inside the sphere. The size of the ports and the orientation of the internal tubing are designed to minimize the effects of rain and spray. A fast-response temperature sensor is located in a housing unit on top of the sphere. The probe measures all three vector components of the wind at 50 Hz, providing turbulence statistics and estimates of vertical surface fluxes in addition to mean winds.



The latest development work on the ET probes took place in 2011, when a probe was deployed through the hurricane season on a navigational light in the Florida Keys. The primary goal of that deployment was to test upgrades to the instrument that would allow it to operate for extended periods in a harsh maritime environment and still provide useful turbulence and flux data under severe meteorological conditions. Despite inquiries concerning applications of the probes during hurricanes and other forms of severe weather, this program presently remains on hold due to budget limitations.

Small Unmanned Aircraft System (sUAS)

ARL has developed an airborne measurement platform for measuring the dynamics of land-atmosphere interactions in the lower boundary layer, using a DJI S-1000 small Unmanned Aircraft System (sUAS). The sUAS is capable of lifting approximately ten pounds of payload to an altitude of up to 1000 feet above ground level. The payload includes a small downward looking infrared camera, a visible camera, and a radiosonde package to measure air temperature and relative humidity. Measurements of this type promise to capture the dynamics of the developing boundary layer and link these observed changes to the heat and water fluxes measured at the land surface.



This emerging technology provides NOAA with a new observing platform that will provide critical missing data between land-based measurements and satellite remote sensing measurements. By using the sUAS, observations can be obtained both vertically and horizontally to get an accurate picture of the scale and extent of the temperature and moisture fields. The diurnal development of the vertical temperature and humidity profiles in the atmospheric boundary layer are linked to the aggregated sensible and latent heat fluxes at the land surface and help provide a better understanding of convective initiation. With the ability to profile temperature and relative humidity in the lower boundary layer and map the thermal land surface temperature fields at the same time, the sUAS provides an inexpensive platform capable of capturing the dynamics of a developing boundary layer and linking that development to observed changes to the heat and water fluxes at the land surface. The sUAS was first used in the ARL Convective Initiation study (2015) and is being used in the NOAA VORTEX-SE study (2016).