National Atmospheric Release Advisory Center

NARAC

Lawrence Livermore National Laboratory

World-Wide Emergency Response

NARAC Mission

NARAC subject matter experts and advanced modeling system can be used to map the spread of nuclear, radiological, chemical, or biological material accidentally or intentionally released into the atmosphere.

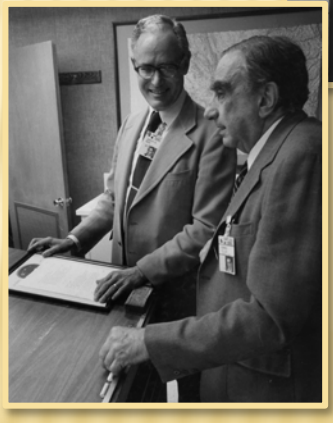
NARAC provides actionable information to protect lives and mitigate consequences during hazardous atmospheric releases.

NARAC's 24/7 reachback center supports federal, regional, state, and local agencies and is integrated into the national preparedness and response strategy.

NARAC Beginnings

In 1973, the Department of Energy (DOE) posed a question to Lawrence Livermore National Laboratory (LLNL) atmospheric research scientists:

Can an integrated computer-based system be built that uses models and weather data to estimate radiation exposure during a nuclear emergency anywhere in the U.S.?



Five years later, Livermore scientists had combined meteorological and dispersion models with computer technology to create a prototype emergency response system. On March 28, 1979, DOE called on LLNL to respond to the Three Mile Island accident. The center became operational on April 1, 1979.

Operation Morning Light, Canada

For several months, an LLNL team followed the steady decline of the orbit of a Russian Cosmos satellite powered by a nuclear reactor and calculated possible contamination footprints in case of re-entry. On January 16, 1978, the satellite crashed in a remote area of northern Canada. Over the next several weeks, U.S. aerial and ground survey crews assisted the Canadian clean-up effort (Operation Morning Light).

Russian Cosmos 954 satellite re-entry

1978

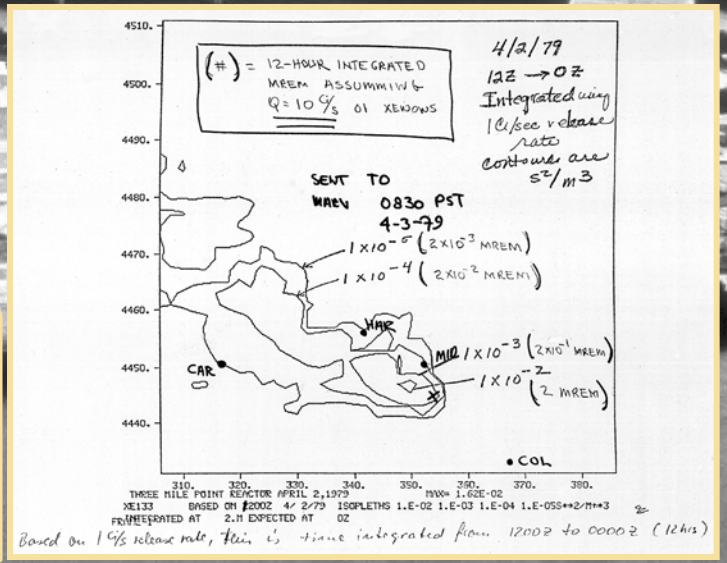
Chinese Nuclear Weapons Tests, Lop Nur

LLNL scientists estimated the path of nuclear debris from the last set of Chinese atmospheric nuclear-weapons tests in the remote Lop Nur region.

Three Mile Island Reactor Accident, PA

1979

The accident at Three Mile Island was the most serious nuclear-power accident in the U.S. to date.

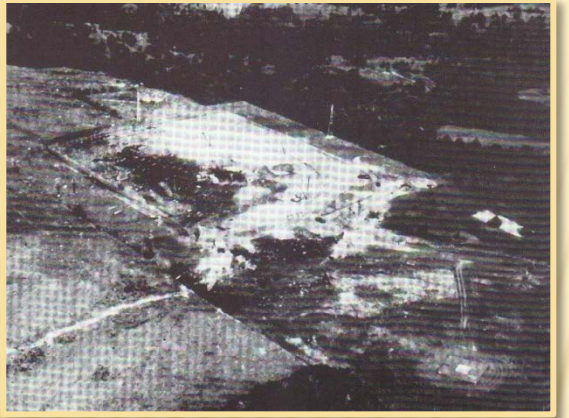


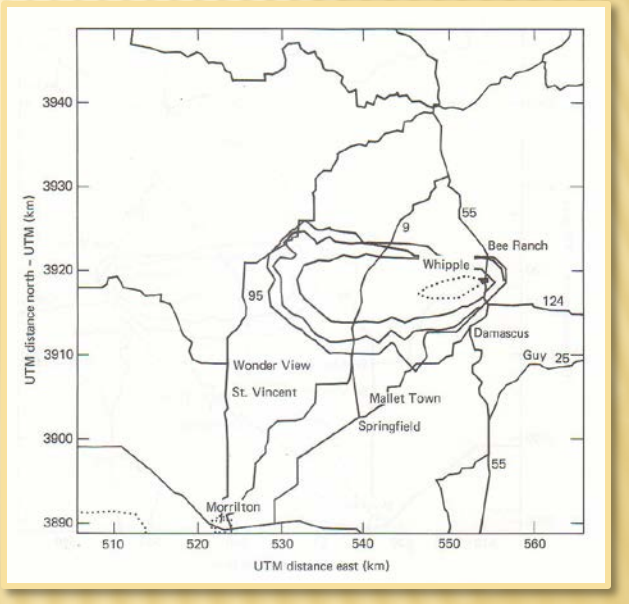
NARAC maps were used to guide Department of Energy and state measurement teams in determining the impacts of the radioactive material released. This event was the center's first major real-time response.

Plot faxed to NARAC Director, Dr. Marv Dickerson, deployed in Pennsylvania

Titan II Missile Accident, Damascus, AR

1980





A mechanic dropped a 2-foot-long wrench onto a Titan II missile in a silo, igniting the hydrazine tank and blowing the warhead half a kilometer away. NARAC developed estimates of the hazard from the hydrazine release and “what-if” radiological dispersal calculations in case the weapon was involved in an explosion. Fortunately, the warhead remained intact.

Russian Cosmos Satellite Re-entry

1983

Russia Denies Satellite Flying Out of Control

26 San Francisco Ch

U.S. Nuclear Search Team Put on Alert

New York

Soviet officials denied yesterday that their nuclear-powered reconnaissance satellite was out of control and in danger of crashing to earth, but American officials said "our information is different" and placed a nuclear emergency search team on standby alert.

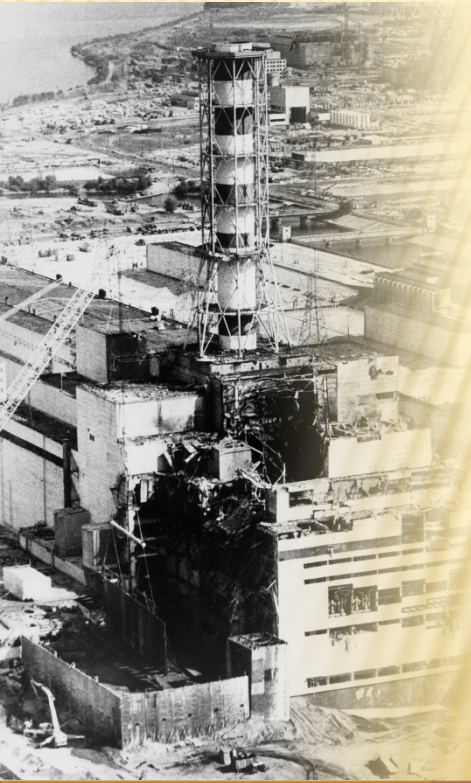
The North American Aerospace Defense Command (NORAD), which monitors all orbital traffic, reported that the satellite, Cosmos 1402, continued to behave erratically and to lose altitude. It is now about 150 miles above earth and, at its current rate of descent, could plunge into the atmo

The malfunctioning nuclear-powered satellite is similar to this model of the Soviet C

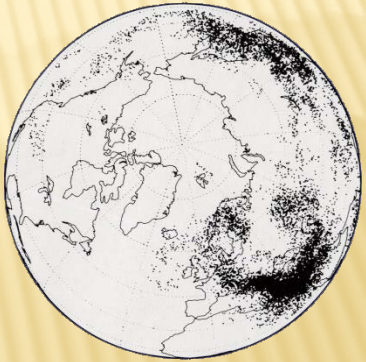
NARAC provided predictions of the dispersal of material from the uncontrolled re-entry of a Russian nuclear-powered satellite. Satellite debris landed in the Indian Ocean. NARAC has responded to several incidents involving chemical and radiological risks from satellite re-entries.

Chernobyl Reactor Accident, USSR

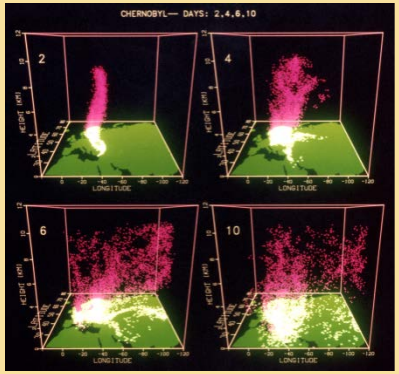
1986



A partial core meltdown at the Chernobyl nuclear power plant in the Soviet Union resulted in an explosion that blew the 2000-ton lid off the reactor core. Millions of curies of iodine and cesium were released. Over the next 16 days, NARAC estimated the activity released, modeled the transport and deposition of the radioactive materials, and calculated the dose to people in Europe and throughout the world.

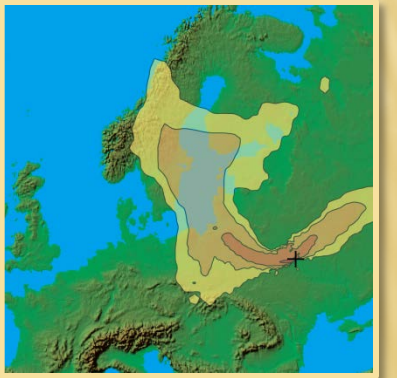


Cloud arrives over west coast of U.S. on Day 10



Extent of cloud over Europe and Asia

Press release by Dr. Marv Dickerson



Dose received after four days

Rocket Fuel Plant Accident, Henderson, NV

1988

Nevada explosions injure 250

One dead; poison cloud near Vegas

By Tim Dahlberg
Associated Press writer

HENDERSON, Nev. — A series of thunderous explosions destroyed a space shuttle fuel plant and a candy factory Wednesday, generating a 5-square-mile toxic cloud, killing one person and injuring more than 250, authorities said.

"It flipped cars over, knocked pedestrians to the ground and windows in the whole town shattered," said Susan Russo, 37, of Henderson, who was outdoors when the first explosions occurred shortly before noon.

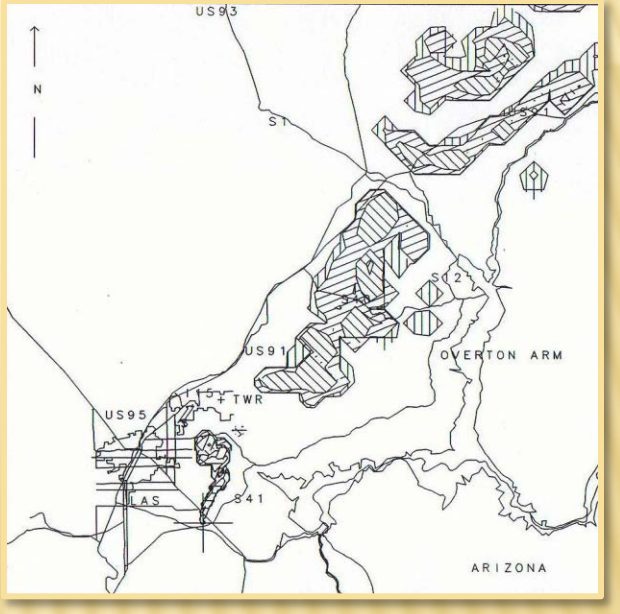
Flames and orange smoke rose into the sky, and buildings shook 10 miles away in Las Vegas after the explosions at the Pacific Engineering & Production Co. in the southern Nevada community of Henderson.

Fire Chief Roy Parrish said a body was found about 25 feet from the entrance to the fuel plant, but all 12 buildings leveled or severely damaged by the blasts had been

SMOKE RISES from fires at a rocket fuel plant in Henderson, Nev., Wednesday. Wing of photo plane is in foreground. Associated Press

People and cars hurled about

ORE. IDAHO NEVADA UTAH



NARAC provided emergency managers with estimates of the regional extent of the toxic smoke cloud resulting from an explosion and fire at the Space Shuttle solid rocket booster plant in Henderson, NV.

Railcar Spill, Sacramento River, CA

1991

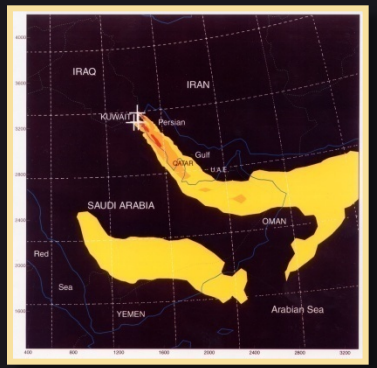
A derailed train spilled 19,000 gallons of soil fumigant near Dunsmuir, CA. The spill entered the Sacramento River and produced toxic gases as it flowed downstream. NARAC provided a forecast to the California Office of Emergency Services indicating that an evacuation of the Lake Shasta area would not be necessary. This forecast was later verified by measurements.

Oil Field Fires, Kuwait

1991

For six months after the first Gulf War, NARAC delivered twice-daily ground-level smoke concentration forecasts to 17 agencies and countries in the Persian Gulf region to help assess air quality conditions. This was one of NARAC's first responses utilizing regional forecast models outside the U.S.

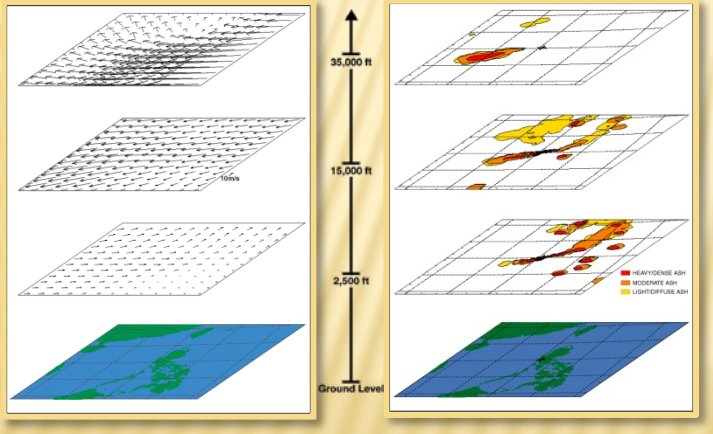
NARAC-model particles representing soot from the oil fires

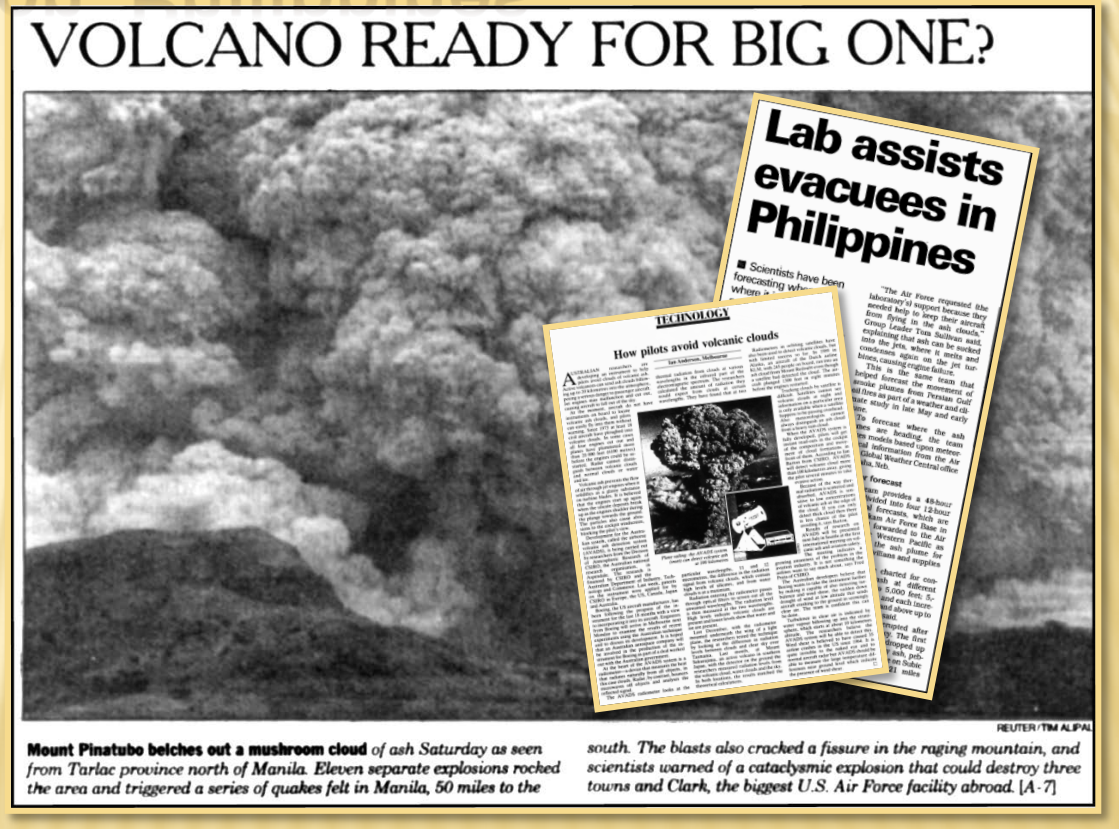


NARAC plot of ground-level smoke density

Mt. Pinatubo Eruption, Philippines

During multiple volcanic eruptions of Mt. Pinatubo, ash clouds reached heights of 90,000 feet. NARAC provided forecasts to assist in determining safe flight routes for the U.S. Air Force evacuation of 20,000 U.S. military and citizens.

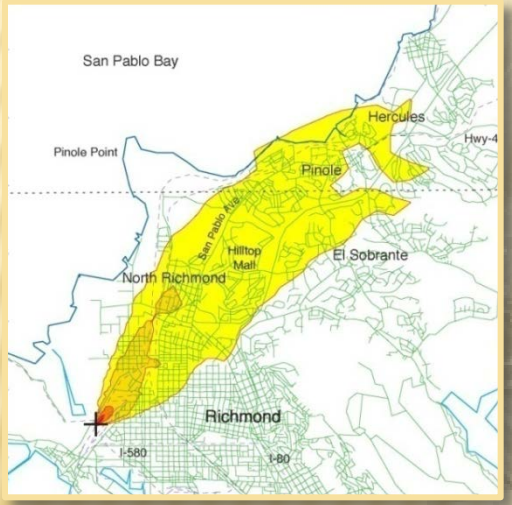




Sulfuric-Acid Railcar Accident, Richmond, CA

1993

NARAC delivered accurate predictions of the inhalation hazard to local and state agencies, based on real-time local meteorology and the estimated quantity of material released.



Workers overheated a railroad car when attempting to transfer liquid oleum (saturated sulfuric acid). The safety valve blew, releasing eight tons of sulfuric acid to the air.

Railcar Accident, Cajon Pass, CA

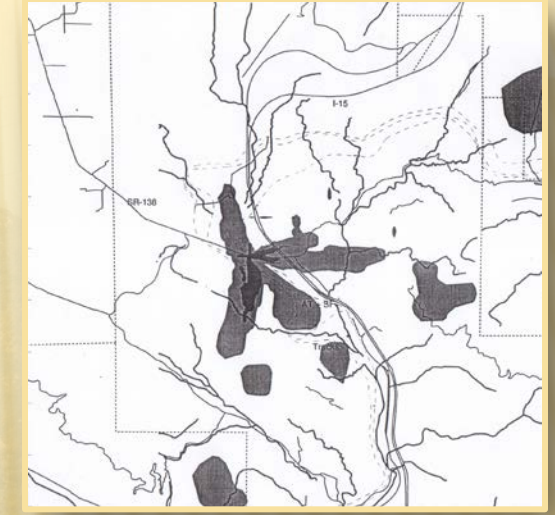
1996


Tragedy on the rails

Firefighters work at the scene of a train derailment and resulting chemical blaze in the Cajon Pass, 60 miles east of Los Angeles.

ASSOCIATED PRESS

On February 1, 1996, several tank cars of a derailed train in Cajon Pass, CA began leaking hazardous chemicals.



NARAC delivered a 30-hour forecast of the expected impacted areas to California Office of Emergency Services field teams, greatly assisting emergency planning.

NARAC Dedication, Livermore, CA

1996

The National Atmospheric Release Advisory Center (NARAC) was dedicated in 1996. A new, specially designed facility was built to house the NARAC operations center, computer room, backup power systems, training rooms, staff, and program offices.

Cassini Launch, Kennedy Space Center, FL

1997

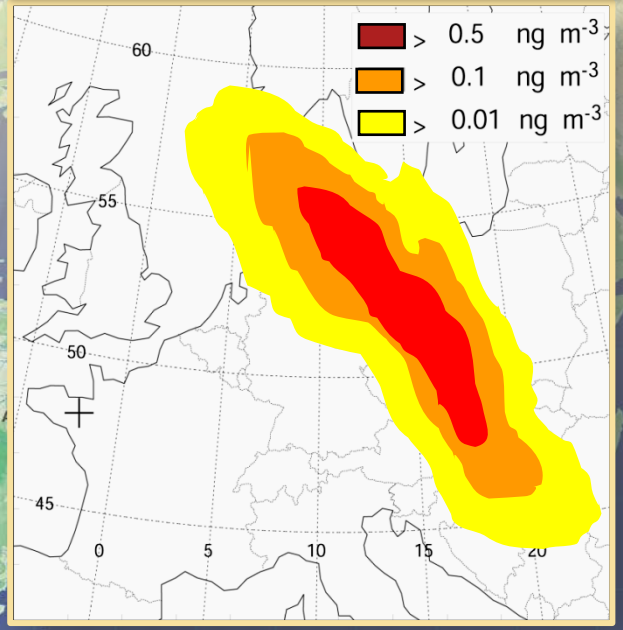
Electrical power for the Cassini spacecraft was supplied by three Radioisotope Thermoelectric Generators (RTGs). NASA requires NARAC to be stood up for any launch involving RTGs. LLNL staff deploy to Florida and the center is on alert in case of an accident.

European Tracer Experiment (ETEX)

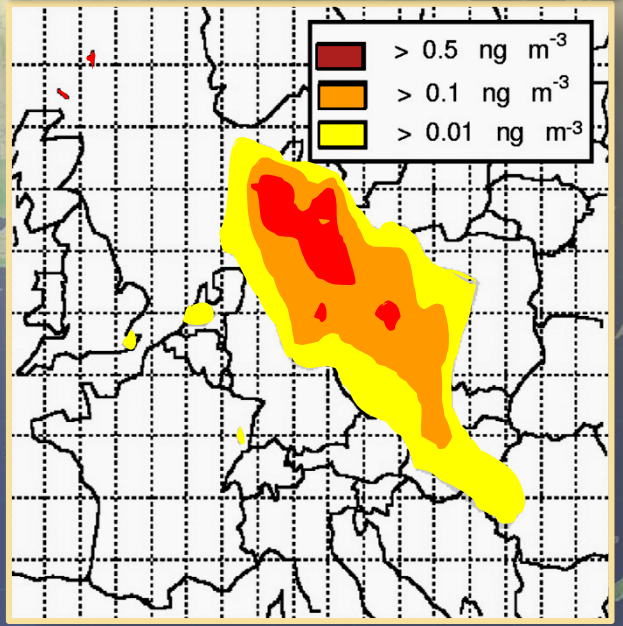
1997

NARAC participated in an international blind test of the ability of models to simulate dispersion on a continental scale, motivated by the Chernobyl accident. Experimentally measured air concentrations produced by a controlled atmospheric release of an inert gas in Europe were used to assess model performance. NARAC was one of the top performing models.

NARAC Simulation



Observed



Tire Dump Fire, Tracy, CA

1998

A large tire dump south of Tracy, CA caught fire late on the afternoon of Friday, August 7. The LLNL Fire Chief called NARAC for assistance. NARAC forecasted the density of ground-level smoke over the weekend for use in local decisions regarding protection of the public. The center regularly responds to requests for assistance from the State of California and local communities.

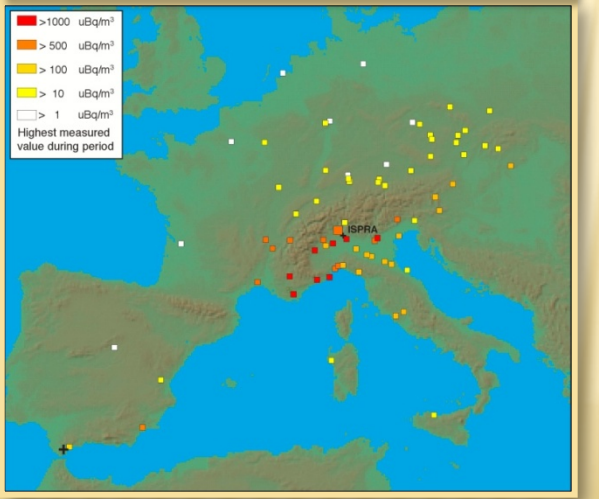
Photograph of smoke plume with NARAC-simulated particle positions in red

1998

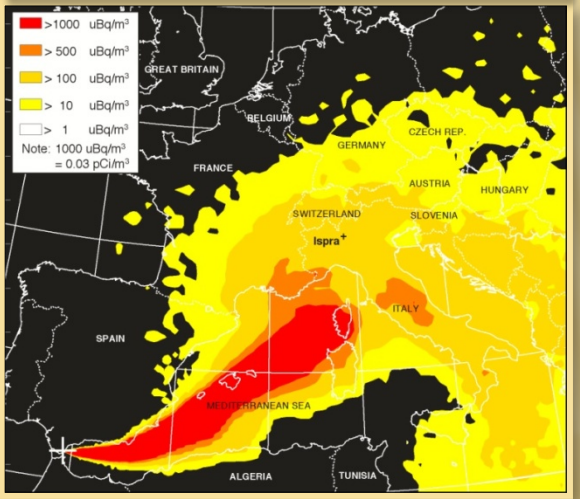
Cesium Release, Algeciras, Spain

In June 1998, radiological monitoring stations in Europe detected small amounts of cesium in the atmosphere. NARAC staff analyzed these measurements to reconstruct the event and develop model predictions consistent with the data. NARAC's estimate of the source location and time and the quantity of cesium released were later verified when Spanish authorities determined that a medical radiotherapy source had been accidentally melted in a scrap steel mill near Gibraltar on May 30, 1998.

Detection of Cesium



Modeled Cesium-137



Criticality Accident, Tokaimura, Japan

1999

Workers at a nuclear fuel-processing plant in Tokaimura, Japan, were adding enriched uranium to a precipitation tank when they saw a blue flash, indicating the initiation of a nuclear chain reaction. NARAC modeled the radioactivity released into the atmosphere from this criticality accident and advised that the radiological hazard did not extend beyond the facility boundaries.

2000

TOPOFF 1 Exercise, CO, NH, and NCR

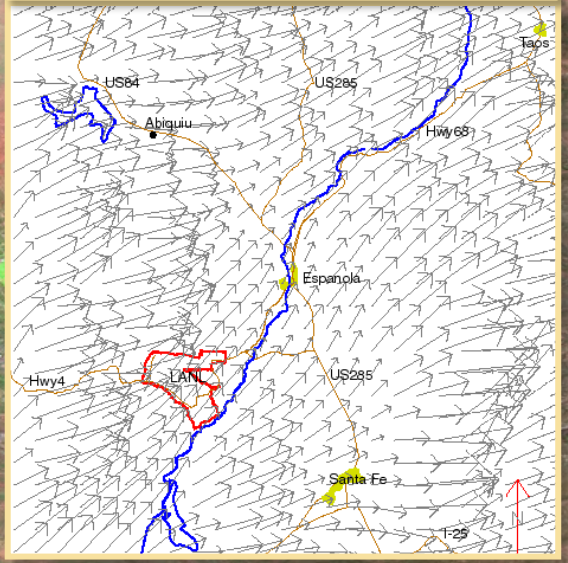
The four Congressionally mandated Top Officials (TOPOFF) counterterrorism exercises have been the largest exercises conducted in the U.S., involving local and state emergency responders and decision makers, federal agencies, and the White House. For TOPOFF 1, NARAC produced real-time plots for three scenarios: a bioterrorism attack in Denver, Colorado; a chemical agent release in Portsmouth, New Hampshire; and a radiological dispersal device in the National Capitol Region (NCR).

2000

Cerro Grande Fire, Los Alamos, NM

High winds turned a controlled burn into a disastrous forest fire that caused an estimated $1 billion of damage and destroyed hundreds of homes and buildings. NARAC developed wind forecasts and estimates of potential radiological hazards when the fire swept through parts of Los Alamos National Laboratory. Fortunately, there were no radiological releases.

Wind Field at noon MDT, May 10, 2000

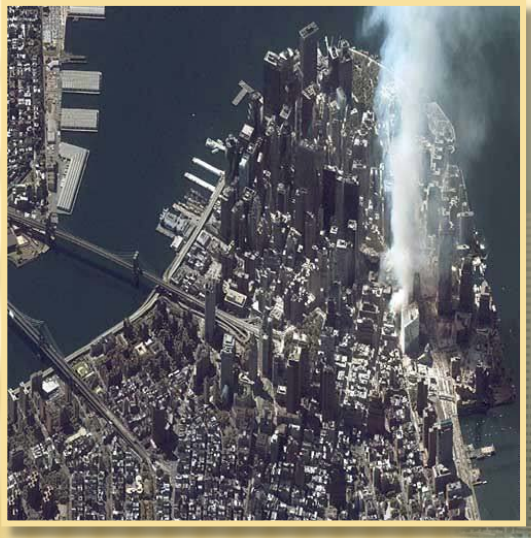


Local Integration of NARAC with Cities (LINC)

The LINC pilot program demonstrated the value of NARAC's advanced operational modeling capabilities to local, regional, and state agencies. NARAC worked closely with five cities—Seattle, New York City, Cincinnati, Fort Worth, and Albuquerque—and their regional partners to develop technologies, interagency procedures, and training to support first responders and emergency operations center staff.

Post 9/11 Threat Assessments

Although NARAC did not model the World Trade Center attack, the center provided assessments for a wide range of terrorist threats over the next several months.



2002 Winter Olympics, Salt Lake City, UT

2002

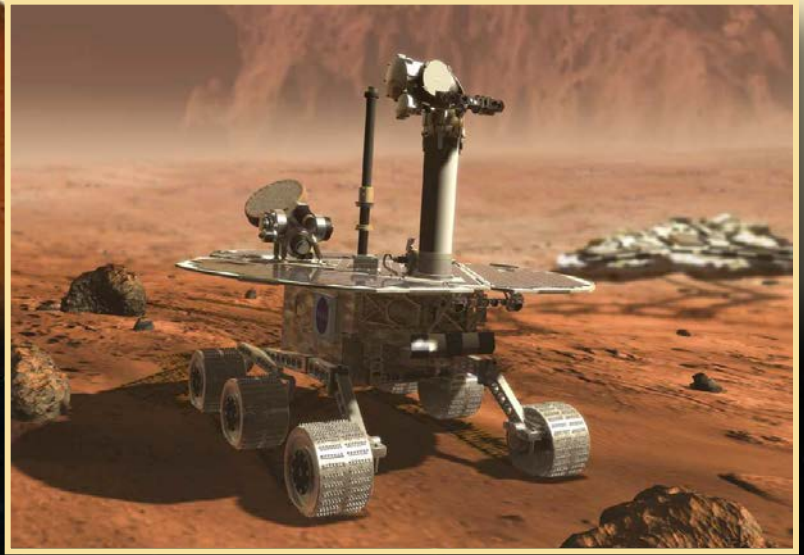
NARAC supported the 2002 Winter Olympics as part of DOE's radiological emergency preparedness efforts. NARAC developed access to a high-density regional meteorological observation network in the Salt Lake City area. LLNL staff deployed to the Unified Command Center in Salt Lake City and participated in interagency readiness exercises.

Barge Fire, Staten Island, NY

A gasoline tanker-barge exploded and caught fire near the southern end of Staten Island. The plume was visible throughout the New York City area, resulting in numerous 911 calls concerned about another terrorist attack. At New York City's request, NARAC modeled ground-level smoke concentrations, which were used to guide monitoring teams and to inform decisions on how to protect the public.

2003

NASA Mars Explorer Rover Launches, FL



NARAC deployed personnel to Kennedy Space Center, FL and provided daily forecasts of worst-case accident scenarios for the launches of NASA's two Mars Explorer Rover spacecraft.

2003

TOPOFF 2 Exercise, Seattle, WA

TOPOFF 2 was the first national-scale exercise led by the new Department of Homeland Security. NARAC had an unprecedented role in the “dirty bomb” scenario in Seattle, supporting DOE’s nuclear incident response teams, the Federal Radiological Monitoring and Assessment Center (FRMAC), and first responders under the LINC Program. NARAC used its new Web portal to distribute plume products.

The Local Integration of NARAC with Cities (LINC) program successfully demonstrated the value of NARAC services for state and local agencies. Seattle was one of the five LINC pilot cities.

2004

Establishment of the IMAAC

The DHS-led Interagency Modeling and Atmospheric Assessment Center (IMAAC) was created at the direction of the Homeland Security Council in April, 2004. The IMAAC's role is to serve as “the single point for the coordination and dissemination of federal dispersion modeling and hazard prediction products that represent the Federal position" during incidents requiring federal coordination.

The IMAAC is supported by eight federal agencies: DHS, DOE, DOD, EPA, HHS NASA, NOAA, NRC.

NARAC is the primary provider of radiological/nuclear plume modeling for the IMAAC.

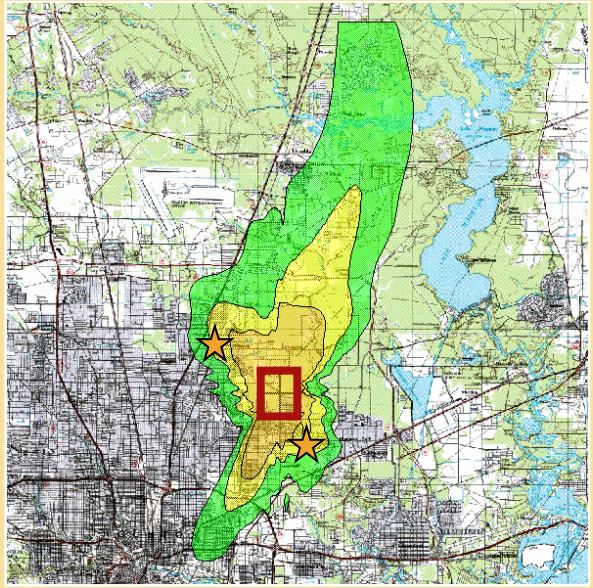
IMAAC
Interagency Modeling and Atmospheric Assessment Center

2004

Chemical Facility Fire, Conyers, GA

Only days after the Department of Homeland Security stood up the new Interagency Modeling and Atmospheric Assessment Center (IMAAC) at LLNL, a major fire broke out at a chemical facility in Conyers, GA. Approximately 250,000 lbs of chlorine compounds burned over a two-day period. IMAAC worked closely with the DHS, DOE, EPA, NOAA, State of Georgia, and other agencies to develop data-informed model predictions that were used to assess the public health risk, guide monitoring teams, and inform sheltering recommendations.

Biological Agent Detection



☆ Hypothetical detection of bacteria

Potential area of bacterial release that would have caused a hit at the two detectors

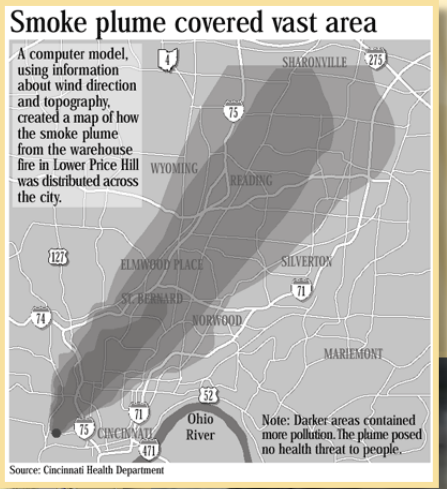
IMAAC/NARAC analyzed wind patterns and possible source locations following several detections of biological agents by monitoring systems deployed in U.S. cities. All airborne agents were found to originate from natural environmental sources.

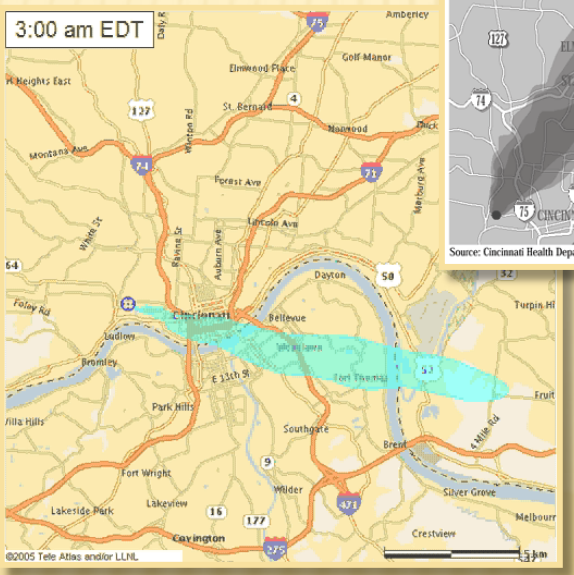
Chemical Warehouse Fire, Cincinnati, OH

2004

One of the largest fires in Ohio's history broke out at a storage facility in Cincinnati containing more than 50,000 drums of chemicals.

Concerned about potential health effects, the Cincinnati Fire, Health, and Environmental Departments used IMAAC predictions to guide approach routes, plan air sampling, and develop shelter-in-place recommendations. IMAAC staff worked with the city to analyze the chemical hazard and provided forecasts of changing wind and plume directions.





Democratic National Convention, Boston, MA

2004

IMAAC deployed a staff scientist to Boston to provide plume modeling expertise in support of the Multi-Agency Coordination Center.

Chlorine Railcar Accident, Graniteville, SC

2005

On January 6, 2005, at approximately 2:40 AM, two freight trains collided in the town of Graniteville, SC, resulting in the rupture of multiple railcars transporting liquefied chlorine. Approximately 60 tons of chlorine discharged, resulting in nine deaths, 500 injuries, and evacuation of more than 5,000 residents for up to nine days. IMAAC supported EPA-led monitoring teams during the week-long clean-up operations following the accident.

2005

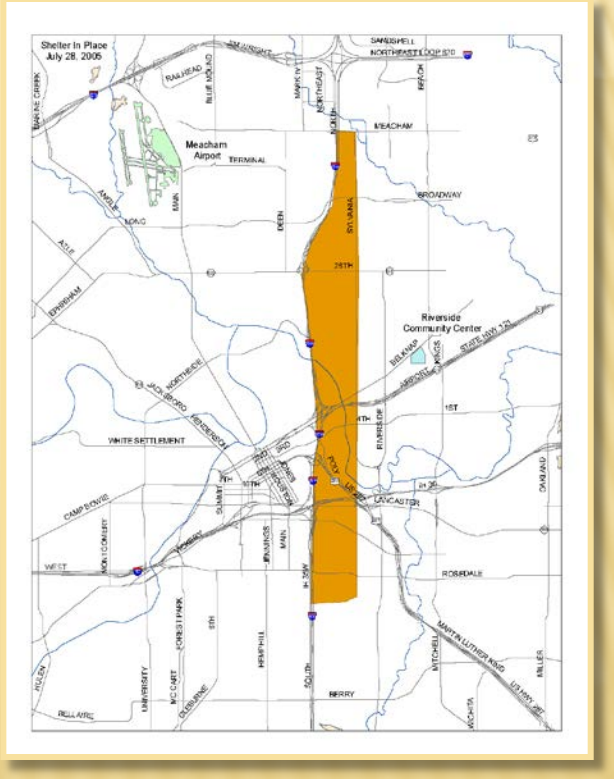
TOPOFF 3 Exercise, New London, CT

IMAAC provided accurate and timely predictions for TOPOFF 3, one of the nation's most realistic and complex counter-terrorism exercises. The exercise kicked off with a simulated truck bomb in New London, CT. IMAAC rapidly determined that the bomb could not have been the source of a blister-agent attack and that the agent had been delivered from a small plane. More extensive data later in the exercise confirmed the accuracy of this analysis. IMAAC predictions were used to make key decisions at the local, state, and federal levels, including the White House.

2005

Solvent Plant Fire, Fort Worth, TX

Fire and explosions occurred at a chemical plant in Fort Worth, TX. IMAAC used chemical-inventory information to estimate release rates. The City of Fort Worth developed a shelter-in-place map for the public based on IMAAC predictions.



2005

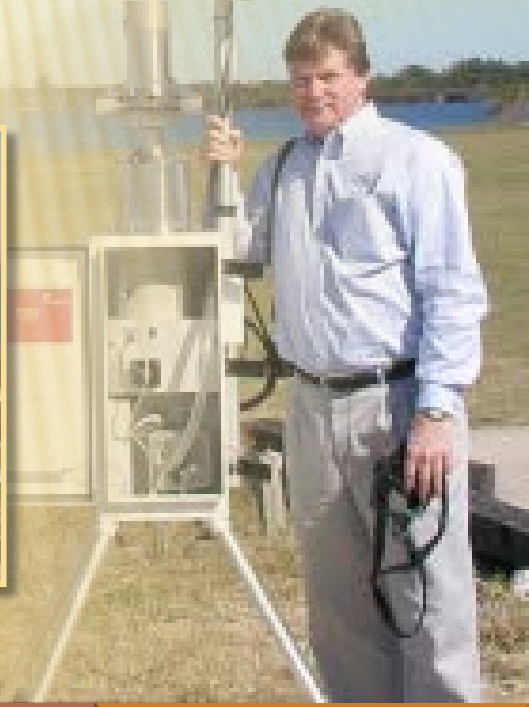
Hurricane Katrina, New Orleans, LA

In the wake of Hurricane Katrina, IMAAC provided airborne hazard predictions for several chemical facilities at risk and for major industrial fires. IMAAC worked closely with the NOAA Hazardous Materials and Response Division in Seattle and its deployed personnel in Louisiana. In the months that followed, IMAAC also assisted EPA's scheduling of debris burns by making 24-hour forecasts of the resulting plume footprint.

Pluto New Horizons Spacecraft Launch, FL

2006

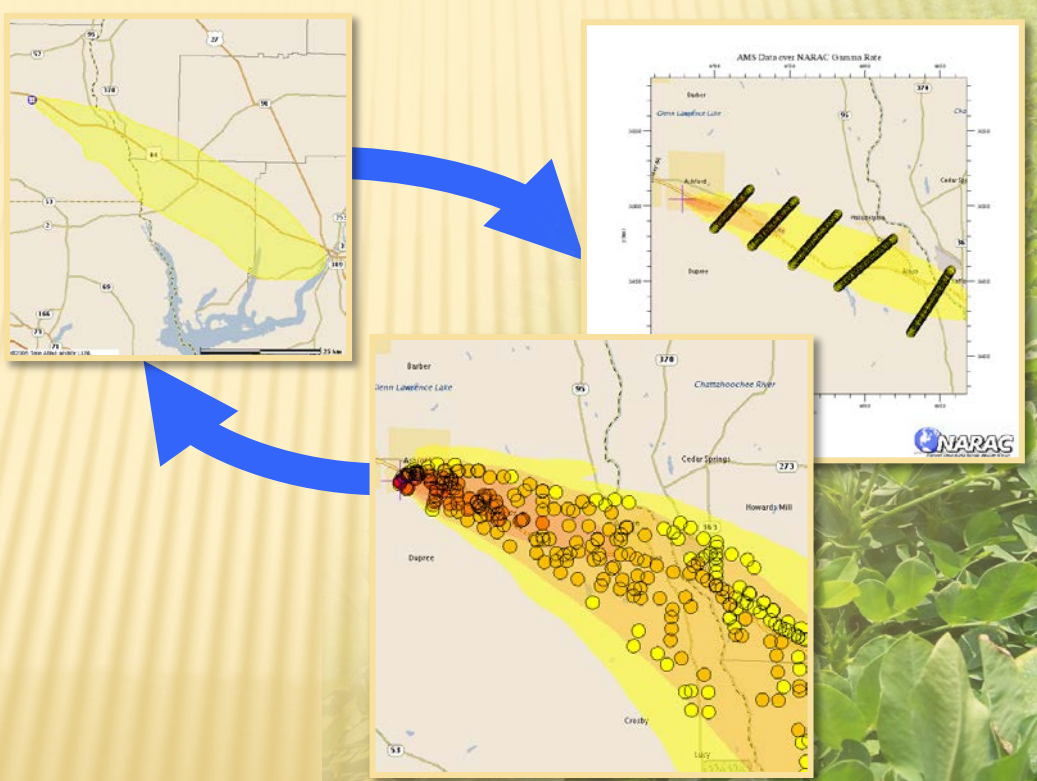
LLNL deployed automated radiological measurement stations as a new element of DOE/NASA's support for launches of spacecraft powered by radioisotope thermoelectric generators. These measurement stations provide near-real-time data feeds, significantly reducing the time required for NARAC to obtain data to refine model calculations.



Southern Crossing Exercise, Dothan, AL

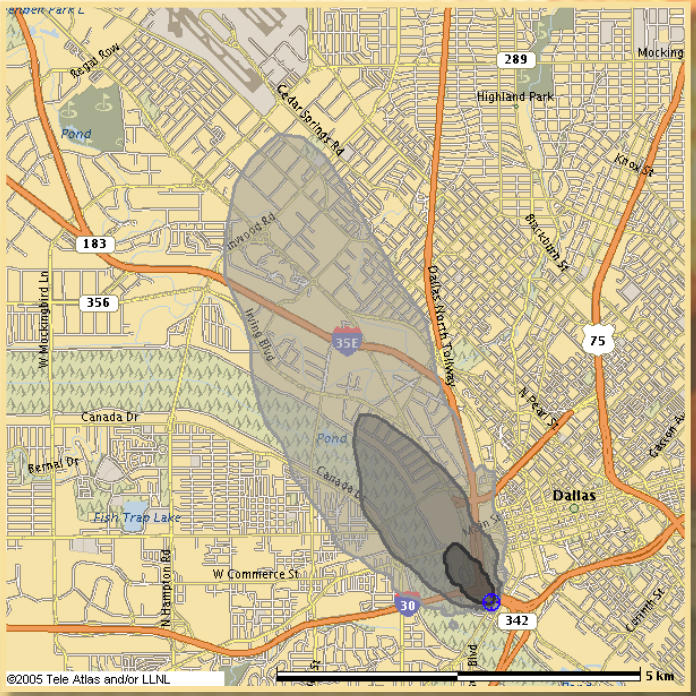
2006

During the Department of Energy (DOE)-led Southern Crossing exercise, NARAC worked closely with the DOE, the Federal Radiological Monitoring and Assessment Center (FRMAC), and state teams to develop realistic assessments of the consequences from a hypothetical dirty bomb. Based on measurements from field and aircraft surveys, NARAC and FRMAC estimated the amount of radioactive material in the bomb and projected doses to help guide public decisions on relocation and determine the extent of contaminated crops.



Welding Facility Fire, Dallas, TX

IMAAC estimated the downwind footprint from explosions and fire at a welding facility south of Dallas, TX.



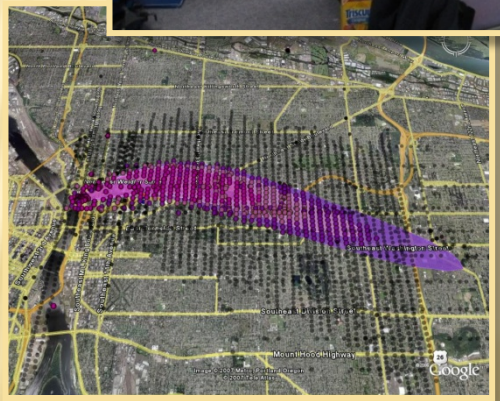
2007

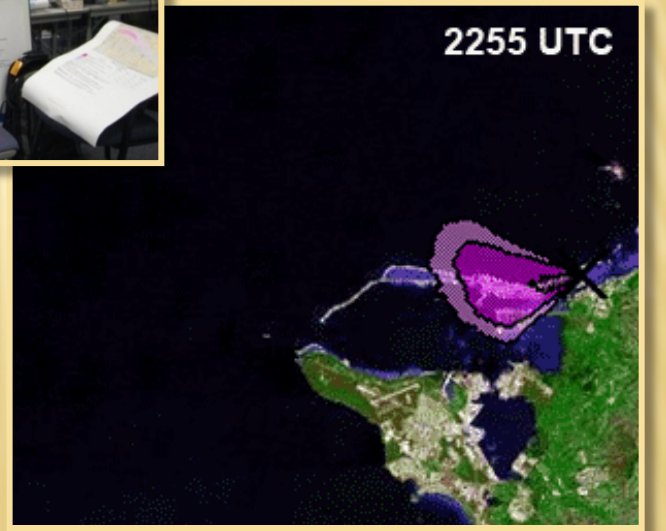
Solvents Tank Fire, Valley Center, KS

IMAAC provided a 12-hour plume forecast for the massive Barton Solvents tank fire in Valley Center, KS. Plume forecasts were used to inform evacuation decisions.

TOPOFF 4 Exercise, OR, AZ, and Guam

TOPOFF 4 challenged IMAAC/NARAC to respond to three near-simultaneous radiological dispersal devices in Portland, Oregon; Phoenix, Arizona, and Guam. The center worked collaboratively with multiple agencies, operations centers, field teams, and technical experts to predict blast and radiation impacts and correctly estimate the quantity of source material and explosives. IMAAC was cited in the After Action Report for its success in coordinating federal plume modeling and effectively distributing model products.





Kilauea Volcano Eruption, HI

2008

IMAAC predicted the health threat due to unusually large ventings of sulfur dioxide from the Kilauea crater in Volcanoes National Park, Hawaii. IMAAC used high-resolution forecasts and worked with the DHS, EPA, DTRA, NOAA, Civil Support Teams (CSTs), the National Park Service, USGS, and the State/County of Hawaii. The National Park Service closed the park, and the County of Hawaii evacuated the town of Volcano for several days.

ConvEx-3 International Exercise, Mexico

2008

The International Atomic Energy Agency (IAEA) holds the Convention Exercise-3 every 3–5 years. NARAC supported the 2008 exercise under the auspices of the Department of Energy. Mexico used LLNL's IXP Web system to send radiological event notification to the U.S. and to share source-term and weather data with NARAC. LLNL provided predictions of the potential radiological contamination and health effects from the hypothetical nuclear power plant venting scenario.

Laguna Verde Nuclear Power Plant, Veracruz, Mexico

Presidential Inauguration, Washington, DC

2009

IMAAC supports all National Security Special Events. For the 2009 Inaugural events in Washington, DC, IMAAC coordinated plume-modeling support with local, state, and federal agencies, developing detailed interagency response procedures. An IMAAC liaison deployed to the U.S. Secret Service-led Multi-Agency Communication Center.

Empire 09 Exercise, Albany, NY

NARAC participated in the DOE-led Empire 09 exercise, which involved 550 participants from 30 federal, state, and local agencies. The challenging exercise scenario involved two dirty bombs using different radiological materials. The new LLNL CMweb was used to distribute NARAC and FRMAC plots. New IMAAC/NARAC Radiological Dispersal Device Briefing Products were produced for presentations to decision makers.

Eyjafjallajökull Volcano Eruption, Iceland

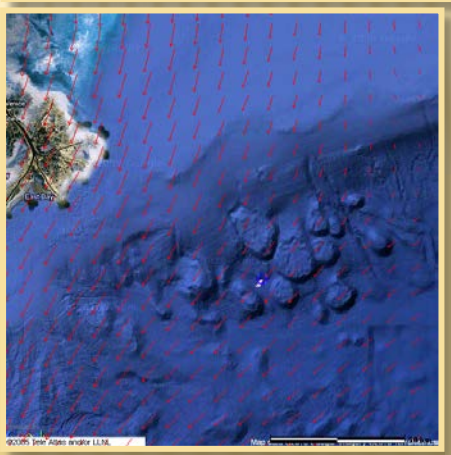
2010

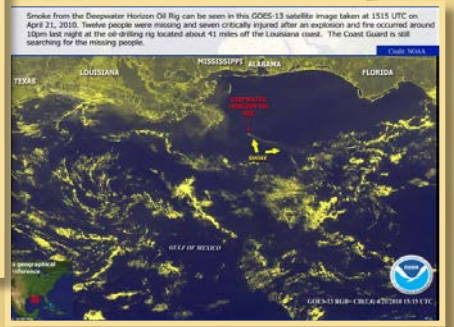
NARAC conducted demonstration predictions of the dispersion of volcanic ash from the Eyjafjallajökull volcano that erupted in April, 2010. These simulations were provided to the Iceland Civil Defence Authorities and Meteorological Office under the auspices of the Department of Energy. The simulations included a 144-hour forecast of the evolving spatial patterns of local, near-ground-level airborne and deposited ash concentrations using information provided by Icelandic government agencies on measured ash particle sizes. The model products from both runs were transmitted to Iceland using the International Exchange Program (IXP) system.

Deepwater Horizon Oil Spill, Gulf of Mexico

2010

At the request of the federal Scientific Support Coordinator for the Deepwater Horizon incident, IMAAC Operations at LLNL produced 24-hour forecasts of the potential smoke concentrations from planned oil slick burns in April-May, 2010. These simulations were provided to the National Oceanic and Atmospheric Administration and the Environmental Protection Agency. This analysis predicted that air quality impacts from the small *in-situ* burns would not affect operations farther than a few km downwind. IMAAC also provided a simulation of the original fire on the Deepwater Horizon oil platform on April 22, 2010 at the request of the Department of Homeland Security.



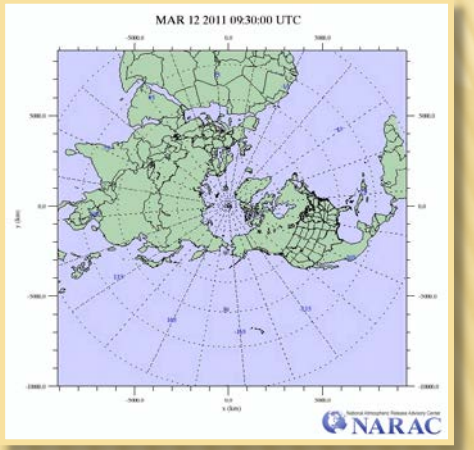


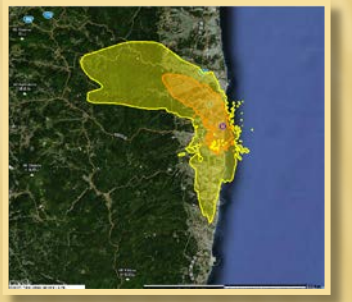
2011

Fukushima Nuclear Power Plant Accident, Japan

NARAC was activated on March 11, 2011 following the devastating earthquake and tsunami that damaged the Fukushima Dai-ichi Nuclear Power Plant. NARAC operated on a 24/7 base for almost 4 weeks and remained on alert through the end of May providing:

- Daily weather forecasts and atmospheric transport predictions to inform planning for field monitoring operations
- Estimates of possible dose in Japan based on hypothetical U.S. Nuclear Regulatory Commission radionuclide release scenarios to support protective action planning for U.S. citizens in Japan
- Predictions of possible plume arrival times and possible dose levels at locations in the U.S.
- Source estimation and plume model refinement based on atmospheric dispersion modeling and available monitoring data

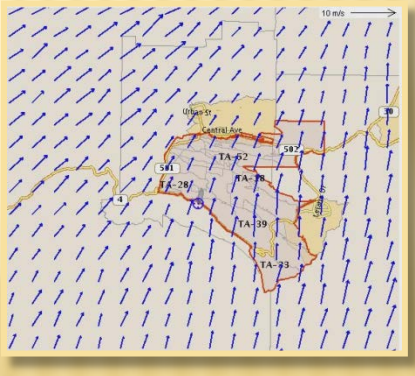


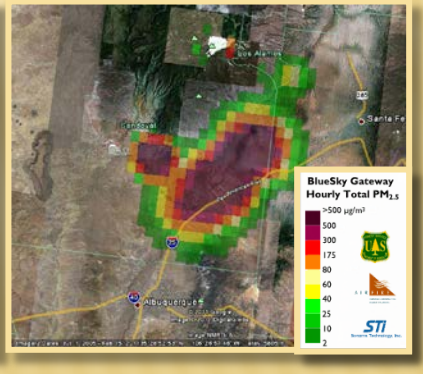


2011

Los Conchas Wildfire, New Mexico

NARAC was activated on June 26, 2011 by the Department of Energy (DOE) to respond to the Los Conchas wildfire in New Mexico which potentially threatened Los Alamos National Laboratory (LANL). NARAC provided twice-daily high-resolution regional wind forecasts to LANL, DOE, the Environmental Protection Agency and the U.S. Fire Service. The weather forecasts were used on an experimental basis to generate a smoke visibility warning for the Fire Service. NARAC also prepared radiological source terms and worked with DOE to coordinate the shipment of portable real-time radiological monitors with NARAC satellite data feeds in case the fire reached Los Alamos (fortunately neither were needed as the fire did not penetrate LANL).





2011

Mars Science Laboratory Spacecraft Launch, FL

National Aeronautics and Space Administration (NASA) and other federal emergency response managers assembled at the Kennedy Space Center to be ready to respond in the unlikely event of a launch accident involving the Mars Science Laboratory Pu-238 radioisotope thermal generator. A LLNL staff member served as the DOE Senior Science Advisor for the launch. Under his guidance, NASA deployed 30 Environmental Continuous Air Monitors which transmitted real-time alpha-radiation data from KSC and the surrounding communities. NARAC's operations center provided worst case analyses of potential accident scenarios to over 70 local, state, and federal emergency responders and decision makers. The successful launch occurred on November 26, 2011 at 10:02am EST.

International Atomic Energy Agency Support

Under the auspices of the Department of Energy Office of International Emergency Management and Cooperation, NARAC supports the International Atomic Energy Agency (IAEA) and its member states by providing the International eXchange Program (IXP) system for sharing information and performing radiological release simulations. In 2011, the IAEA Atomic Energy Agency Atoms for Peace recognized NARAC's contributions with a citation stating: "The Incident and Emergency Centre is pleased to welcome the participation of the International Exchange Program, National Atmospheric Release Advisory Center [LLNL/DOE] in the Response Assistance Network (RANET), thereby helping to strengthen the global system for the provision of international assistance in a nuclear or radiological emergency."

2012

NARAC Dedicated Compute Cluster

NARAC acquired a 336-processor computer cluster to improve computational performance for complex, long running simulations, such as those needed during the response to the Fukushima Dai-ichi Nuclear Power Plant accident. The system was successfully installed in under a week with stand-alone benchmark timing tests indicating excellent overall performance. The cluster then was interfaced with the NARAC modeling system and modifications were made to key models and software to enhance performance on cluster architecture. The run-time required for simulations of complex, long-duration problems are reduced by a factor of 25 due to software optimizations and cluster utilization.

Waste Isolation Pilot Plant

NARAC was activated by DOE on February 14-20 in response to a small release of transuranic radioactive material at the Waste Isolation Pilot Plant (WIPP) in New Mexico. Airborne radioactive material was detected by the plant's stack exhaust and environmental air monitoring systems. NARAC plume model simulations based on detailed on-site meteorological data and WIPP-developed airborne radioactivity release estimates were used to estimate on and off-site dose and contamination levels. NARAC predictions were used as part of DOE WIPP information provided to the public about the consequences of this event.

National Atmospheric Release Advisory Center

NARAC

Lawrence Livermore National Laboratory

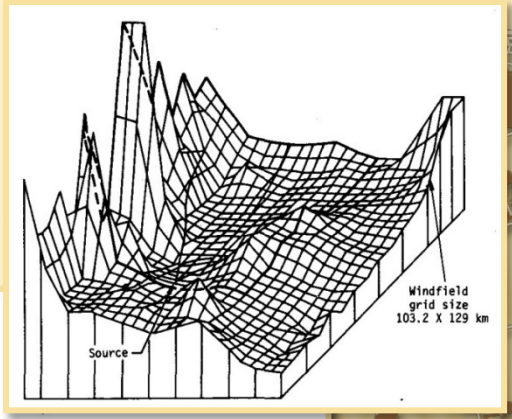
Research and Development

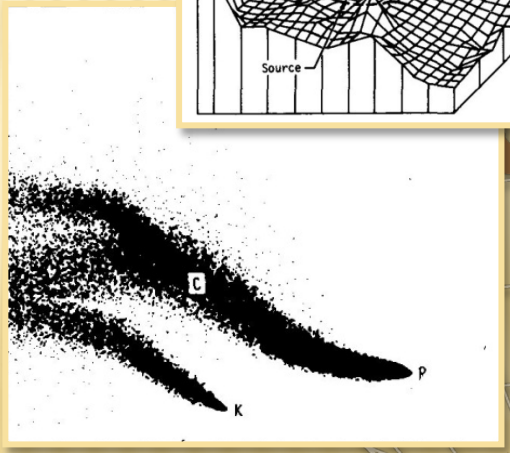
LLNL Regional and Global Models

In the 1970s, LLNL developed state-of-the-science regional and global atmospheric-transport and fallout models, including:

- 2BPUFF, a global atmospheric-transport model
- KDFOC, a nuclear fallout model
- LIRAQ, a regional air-quality model

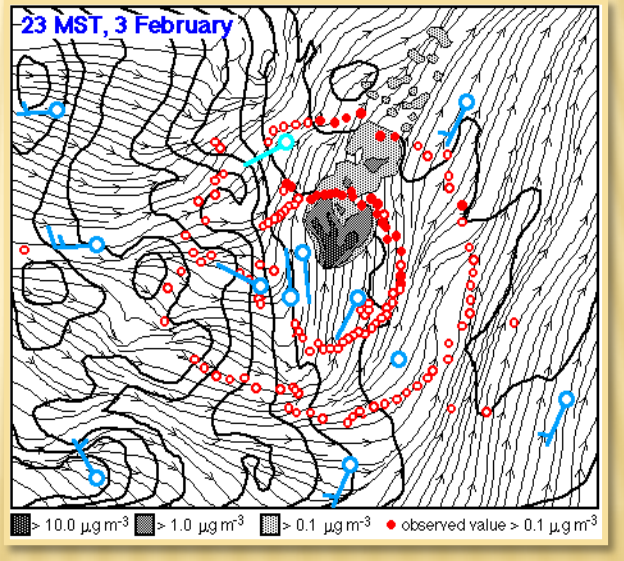
LLNL conducted leading-edge research on modeling of wind flow and dispersion in complex terrain. ARAC's TOPOG, MEDIC/MATHEW (mass-consistent wind field), and ADPIC (particle-in-cell dispersion) computer codes became the first 3-D complex-terrain models developed to run in near-real-time as part of an emergency response system.





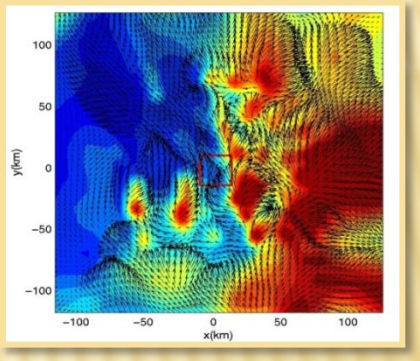
ASCOT Field Studies

LLNL played a lead role in the Atmospheric Studies in Complex Terrain (ASCOT) field experiments (1980–1991) that studied flow and dispersion in complex terrain. This research led to advances in the models used by the first-generation NARAC system.



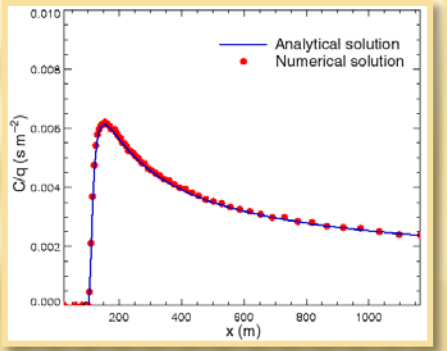
NARAC Operational Models

In the 1990s, LLNL developed a new generation of meteorological and dispersion models (GridGen, ADAPT/LODI), using continuous terrain, variable-resolution grids, meteorological data from high-resolution observational networks, new data-assimilation methods, and Monte Carlo diffusion methods. NARAC also integrated an in-house version of the U.S. Navy's COAMPS weather prediction model.

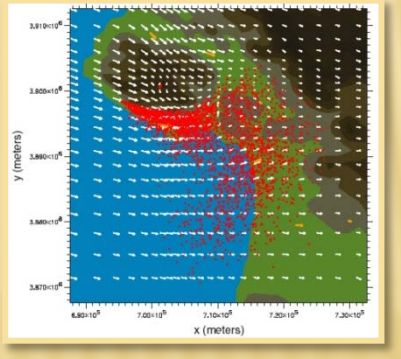


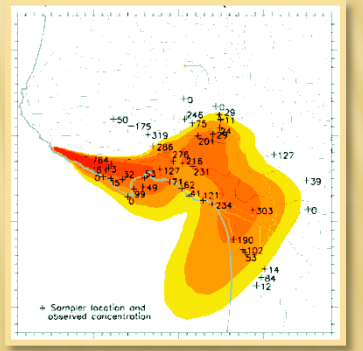
COAMPS Simulation of Salt Lake City Basin

NARAC conducted extensive model-evaluation tests of its new models using analytic mathematical solutions and field experiment data.



Analytical Test





Model Evaluation at PG&E Diablo Canyon

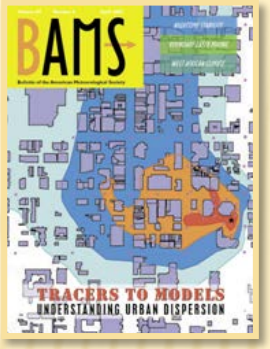
Urban Field Studies

LLNL was a key participant in three ground-breaking urban field studies:

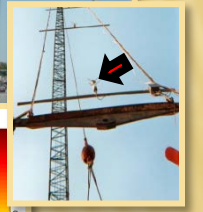
- Urban 2000 in Salt Lake City
- Joint Urban 2003 in Oklahoma City
- Urban Dispersion Program in Manhattan, New York City in 2005

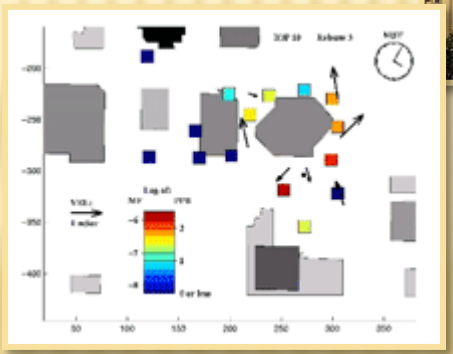
DOE, DHS, DOD, NOAA, other federal agencies, commercial companies, and the UK collaborated on these experiments.

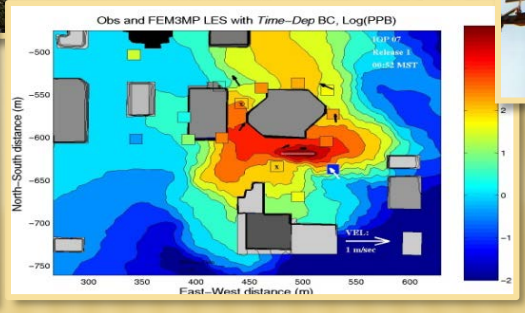
The studies resulted in new physics understanding and improvements in computational models for complex urban flow and transport.



Instruments on crane measure turbulence well above the ground



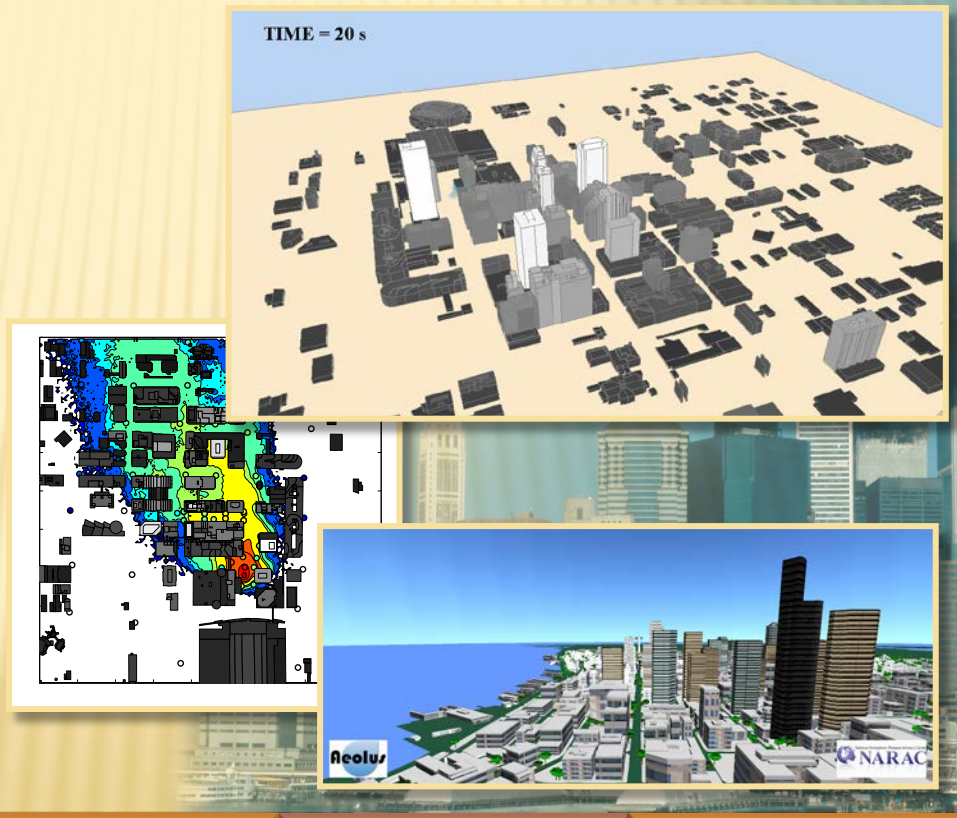




CFD Building-Resolving Models

Full-physics, high-resolution, computational fluid dynamics (CFD) models simulate flow and dispersion around buildings, facility complexes, and urban areas. These models are used to develop emergency response plans and provide guidance for special events, facilities, and cities.

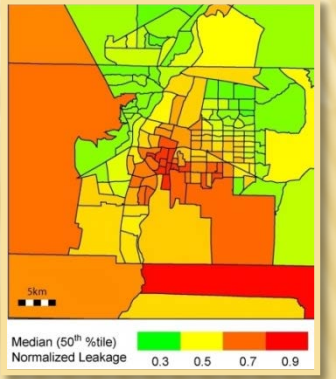
LLNL's most recent CFD model, *Aeolus,* model can be run in either an operational Reynolds Averaged Navier Stokes (RANS) mode requiring only minutes or in a high fidelity mode using a Large Eddy Simulation (LES) algorithm. The model has been validated against field data such as the Joint Urban 2003 tracer experiment.

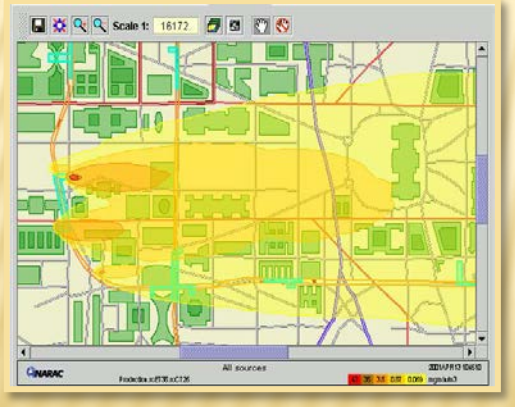


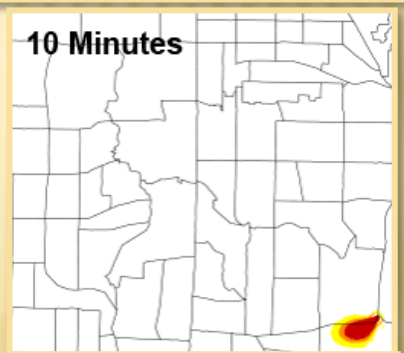
Indoor-Outdoor Coupled Models

LLNL and LBNL have developed a U.S.-wide geospatial building-leakiness database and methods for calculating indoor exposures from outdoor plumes.

LLNL has collaborated with ANL to create prototype coupled models for calculating outdoor impacts from a subway release.







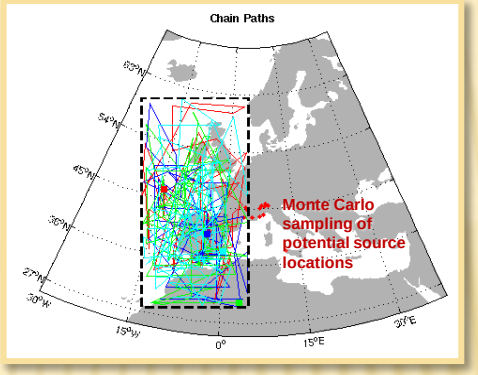
Outdoor Air Concentration

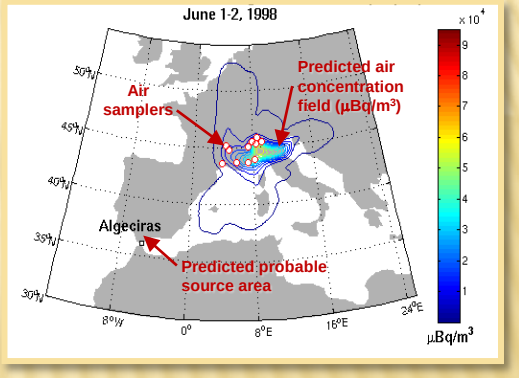
Indoor Air Concentration

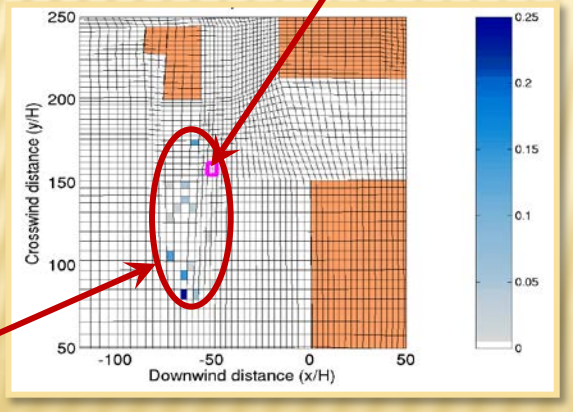
Event Reconstruction

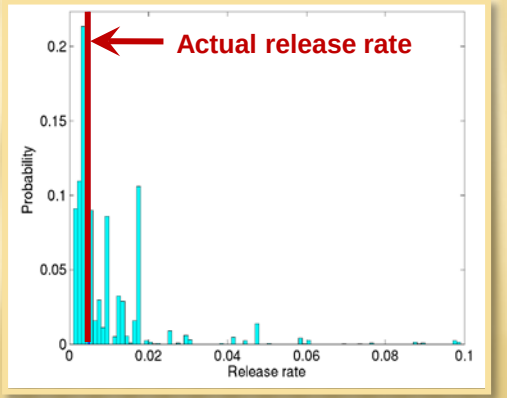
LLNL researchers have developed advanced statistical sampling and computational methods for identifying unknown source locations, times, and emission rates.

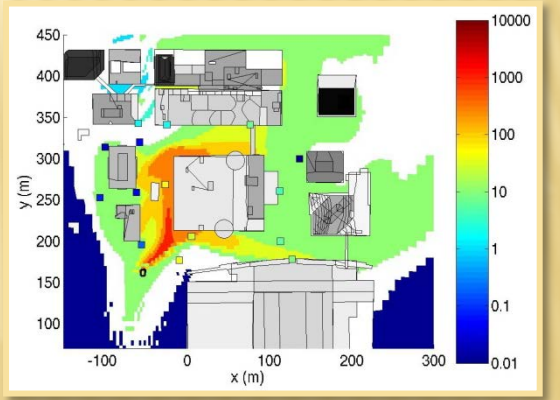
These methods have been successfully tested using data from urban, regional, and continental-scale gas releases.







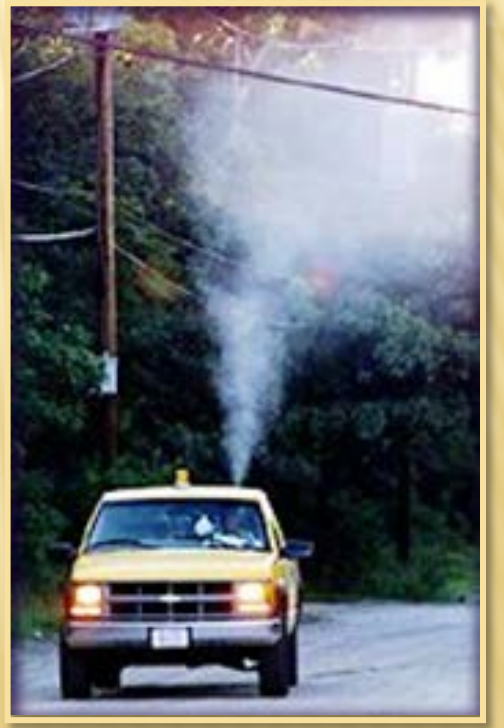




Panels show calculation of source rate, location, and resulting plume from sensor data

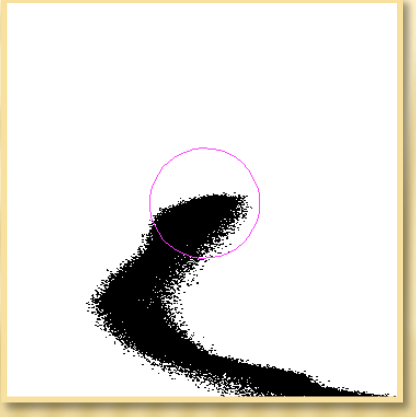
Chemical and Biological Agent Modeling

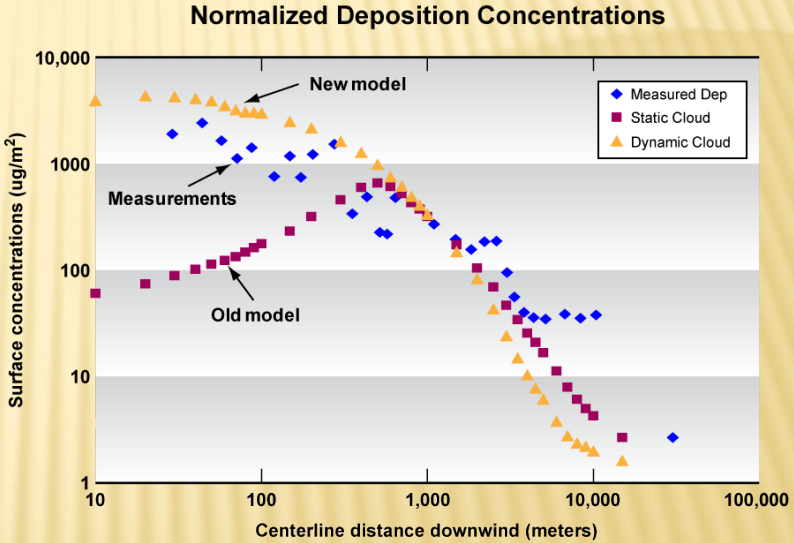
NARAC began development of chemical capabilities in the 1980s. An extensive set of toxic industrial chemical models and databases were added over the next decade. NARAC regularly incorporates new material-property databases and release models for chemical and biological agent dispersal (sprayers, moving vehicles, etc.) , as well as dose- and health-effect information in order to better estimate the potential impacts of terrorist attacks.



Explosive Dispersal and Fallout Models

LLNL, in collaboration with SNL, developed a new model of atmospheric dispersion and fallout from conventional and nuclear explosions. This model, based on the NARAC LODI code, is capable of tracking multiple individual isotopes over a wide range of particle sizes and downwind distances.



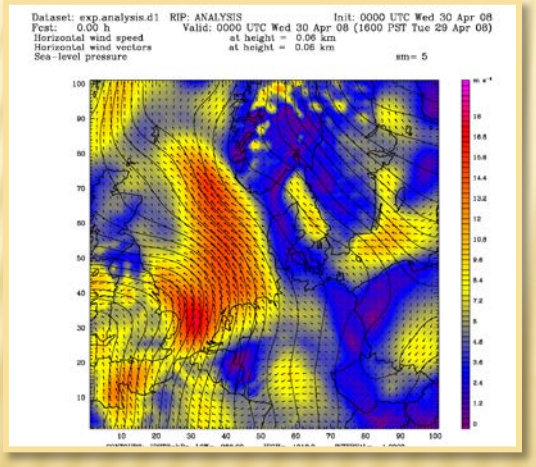


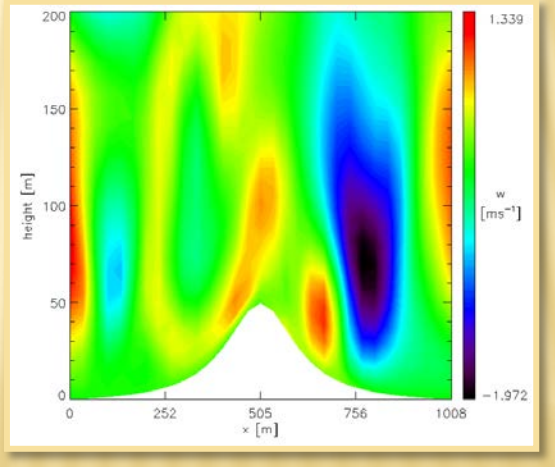
Predicted and Measured Ground Deposition versus Downwind Distance

Weather Research and Forecasting Model

The Weather Research and Forecasting (WRF) model is a scientific community model being developed as a collaborative effort among many agencies. WRF is the primary numerical weather prediction model used in NARAC operations.

Advanced turbulence models and an immersed-boundary method were developed by LLNL in collaboration with UC Berkeley and implemented in collaboration with NCAR.



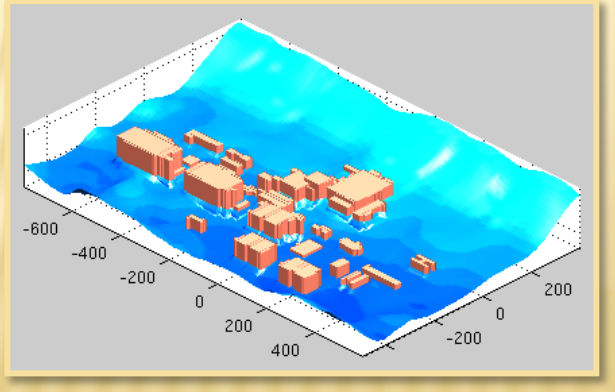


Dense Gas Experiments and Models

In the 1980s, LLNL played a lead role in the study of releases of liquefied natural gas and conducted field experiments at the Nevada Spill Test facility.

LLNL models for dispersion of denser-than-air gases (FEM and SLAB) derived from those studies are still being used to predict the impact of toxic chemical releases to the atmosphere.

From 2006 to 2009, LLNL developed an advanced model that simulates dense-gas dispersion in the presence of buildings and complex terrain.



Releases of large quantities of cold or pressurized toxic industrial chemicals may result in a dense gas. Dense gases remain close to the ground, flow down terrain slopes, and can spread upwind of the source location.

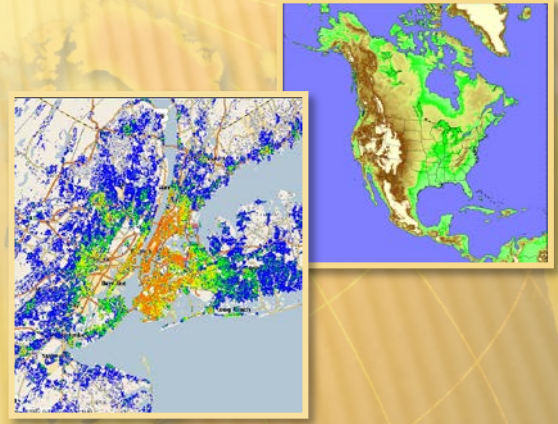
Global Geographic Databases

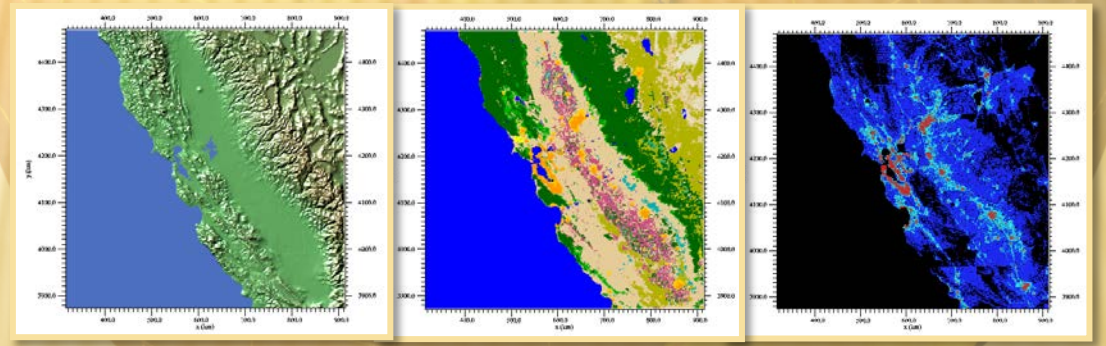
After the Chernobyl accident, NARAC developed global geographical databases (terrain elevation, maps) to more quickly respond to accidents anywhere in the world.

Databases of rural and urban land-use characteristics were added to model their effects on wind and turbulence.

NARAC incorporated global population data, including a high-resolution ORNL database of time-varying U.S. population density, to estimate the number of people potentially affected by hazardous releases.

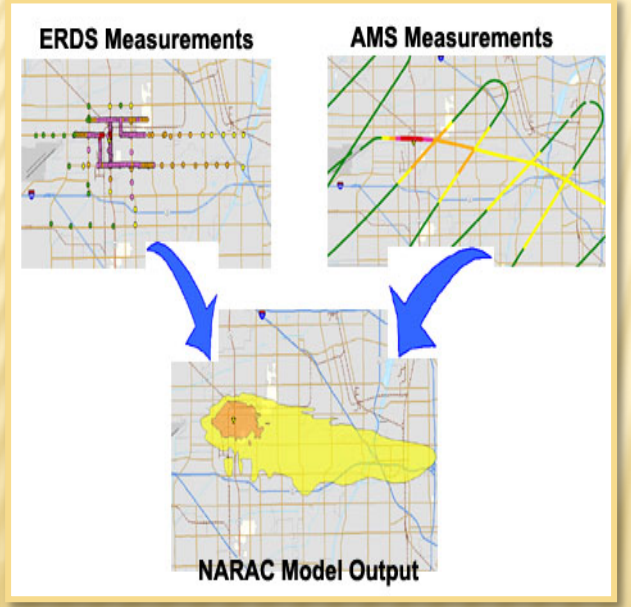
NARAC is integrating of NGA/USGS building data and FEMA/HAZUS information on types of structures.

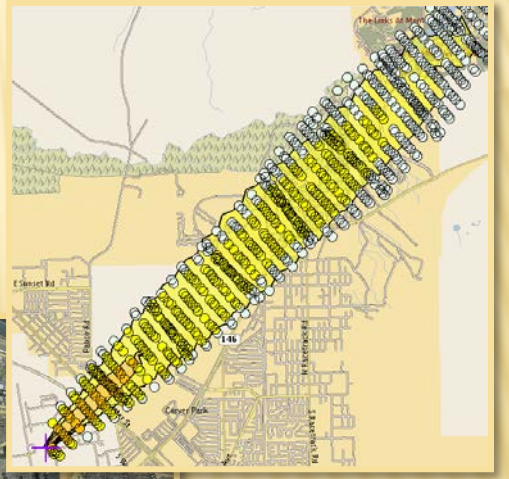


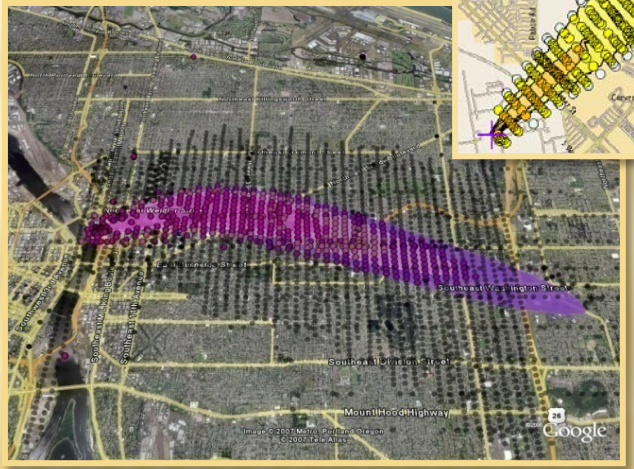


Field Measurement Data Tools

In collaboration with DOE and other agencies, LLNL is developing electronic data-exchange formats and software to rapidly process and analyze measurement data for updating plume-model predictions.





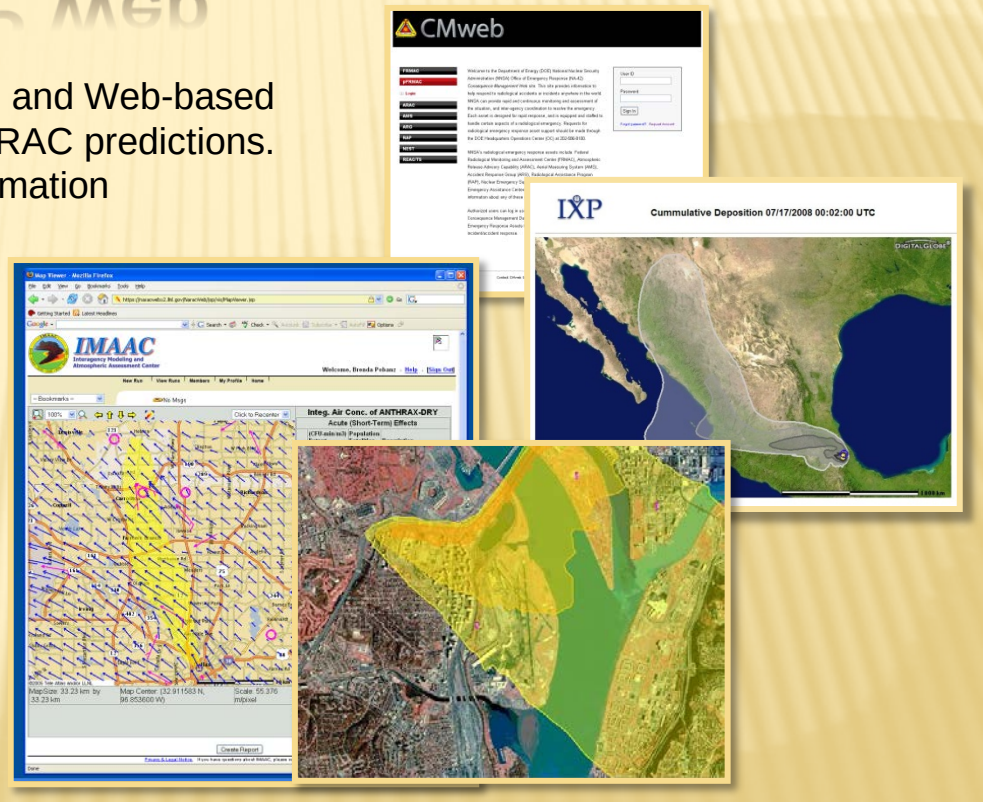


NARAC/IMAAC/CM/IXP Web

NARAC has developed and deployed Java (iClient) and Web-based tools that allow users to access, run, and share NARAC predictions. Plumes are displayed along with geographical information (street maps, aerial imagery, and population data).

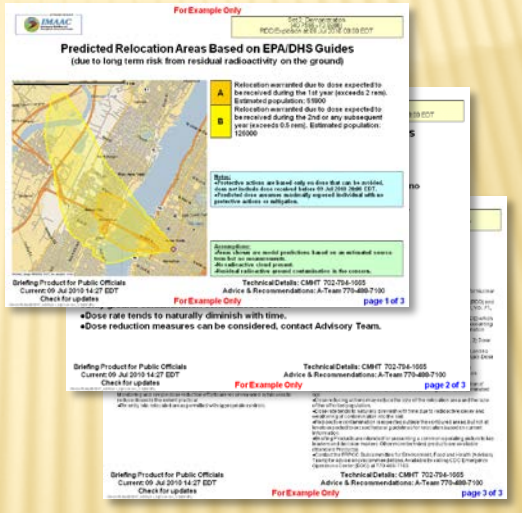
Separate Web portals have been provided for the DOE Office of Emergency Response (CMweb), IMAAC (IMAAC Web) and other NARAC (NARAC Web) users.

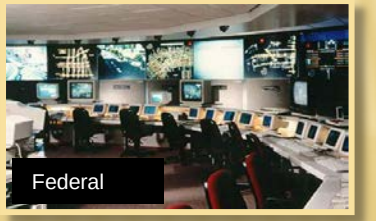
In 2007, LLNL developed a separate International eXchange Program (IXP) Web site that allows the International Atomic Energy Agency (IAEA) and other international partners to run NARAC models and share plume-model results under DOE auspices.



Communication of Plume Hazard Information

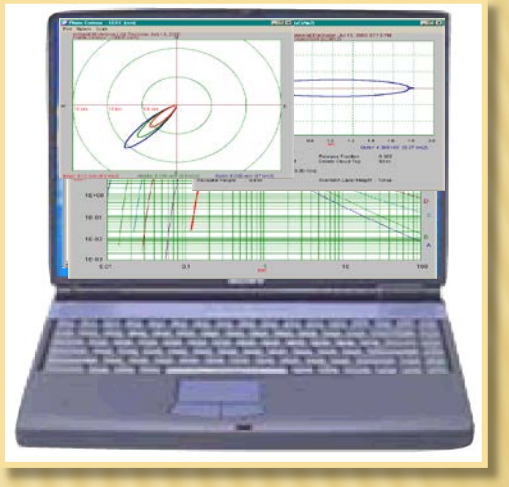
The National/Homeland Security Council tasked the Departments of Energy and Homeland Security to develop versions of NARAC/IMAAC atmospheric plume hazard products for use in briefing senior decision makers, emergency operations centers, and first responders. Initial versions of these “Briefing Products” are available for Radiological Dispersal Device (RDD), Improvised Nuclear Devices (IND), Nuclear Power Plant Accidents (NPP), and Chemical and Biological (CB) releases. The reception of the new “Briefing Products” has been overwhelmingly positive, with the products praised as a major advance in effectively communicating hazard areas in easily understood terms and providing important information on the actions decision makers need to consider.





DOE Safety Software Codes

HotSpot and *EPIcode* are PC-based plume modeling tools developed and maintained by NARAC that provide options to display air and ground contamination and dose, including mapping in Google Earth. Both codes are widely used at DOE/NNSA sites for Safety Analysis, Environmental Planning Hazard Assessments, and initial emergency response consequence assessments.



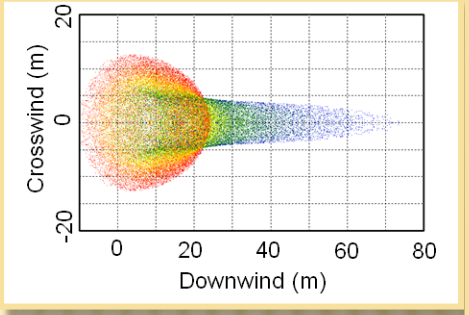
HotSpot is a software package that provides emergency response personnel and planners with a fast, field-portable set of software tools for evaluating incidents involving radioactive material. In 2010, HotSpot software package was accepted into the Department of Energy's (DOE) *Safety Software Central Registry* Toolbox for use in DOE Safety Analysis and Emergency Planning Hazard Assessments. HotSpot includes an option for calculating the 95th percentile dose based on site meteorological data.

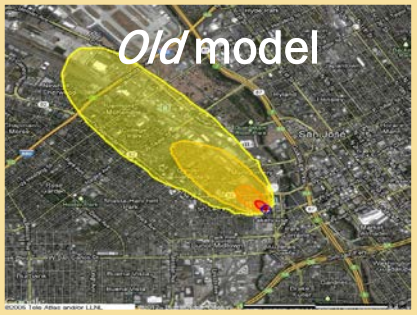
EPIcode is a DOE Toolbox that provides rapid modeling of downwind concentrations of chemicals (gas, vapor, or aerosol) released during industrial and transportation accidents.

Radiological Dispersal Device Improvements

R&D

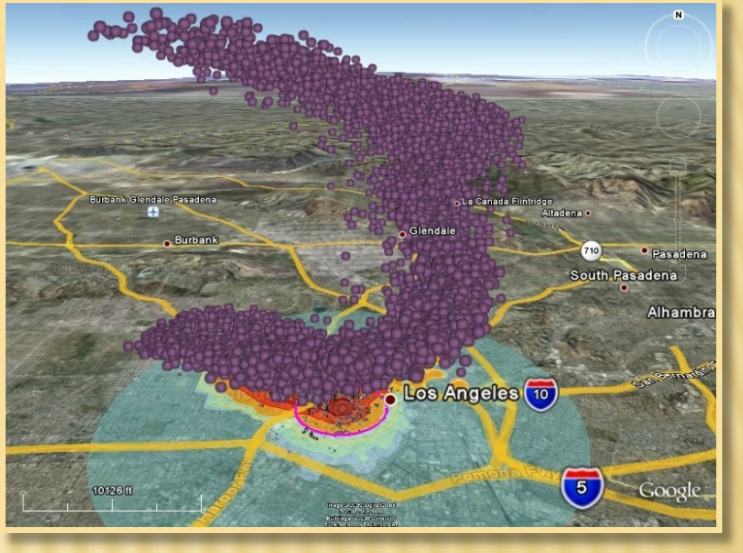
Experiments conducted by Sandia National Laboratories have shown that ballistic particles (>100 μm diameter) from a Radiation Dispersal Device (RDD) are ejected and leave the influence of the thermally buoyant cloud faster than previously assumed. This increases local ground contamination, but reduces downwind ground concentrations. NARAC's plume models were modified to include the latest experimental results on the explosive dispersal of material. NARAC also has implemented improved algorithms for estimating explosive cloud rise heights based on data from the on-going Greenfield experiments in Israel.





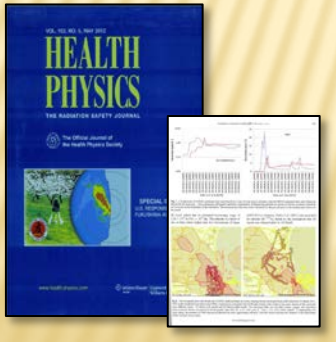
Nuclear Detonation Modeling

NARAC has developed high-resolution atmospheric dispersion and fallout simulation capabilities for nuclear detonations. Recent upgrades have improved the physics and fidelity of operational models by including algorithms that simulate complete radionuclide inventories, neutron activation, activity size distributions, initial time-dependent cloud rise, and fallout fractionation. A coupled suite of LLNL and Oak Ridge National Laboratory (ORNL) computer models produce realistic fallout simulations to support exercises and emergency response activities.

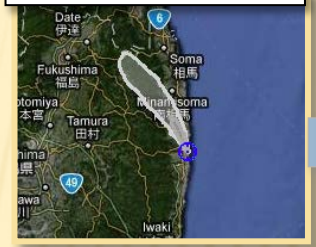


NARAC Source Estimation & Model Refinement

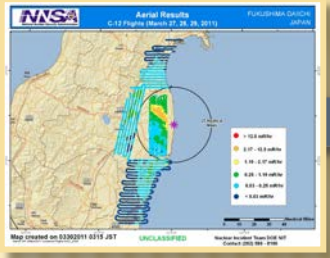
NARAC analysts regularly use field measurement data and other information to develop estimates of the amount of material released and develop refined estimates of the impacts of the impacts of the hazardous materials. This type of analysis was used in Fukushima to refine estimates of potential dose exposures and contamination levels.



Initial Model Predictions Guide Measurement Surveys

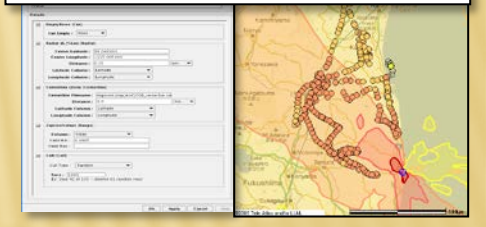


Measurement surveys and sensor data, e.g., DOE AMS, DOE, DoD, and Japan field data



Measurement Data transferred electronically to LLNL/NARAC

Software used to help select, filter and statistically compare measurements and predictions



Updated predictions using refined source estimates based on measurement data

Lawrence Livermore National Laboratory

National Atmospheric Release Advisory Center
NARAC

World-Wide Emergency Response

NARAC Mission

1970s

NARAC Beginnings

Operation Morning Light, Canada

Chinese Nuclear Weapons Tests, Lop Nur

Three Mile Island Reactor Accident, PA

1980s

Titan II Missile Accident, Damascus, AR

Russian Cosmos Satellite Re-entry

Chernobyl Reactor Accident, USSR

Rocket Fuel Plant Accident, Henderson, NV

1990s

Railcar Spill, Sacramento River, CA

Oil Field Fires, Kuwait

Mt. Pinatubo Eruption, Philippines

Sulfuric-Acid Railcar Accident, Richmond, CA

Railcar Accident, Cajon Pass, CA

NARAC Dedication, Livermore, CA

Cassini Launch, Kennedy Space Center, FL

European Tracer Experiment (ETEX)

Tire Dump Fire, Tracy, CA

Cesium Release, Algeciras, Spain

Criticality Accident, Tokaimura, Japan

2000s

TOPOFF 1 Exercise, CO, NH & NCR

Cerro Grande Fire, Los Alamos, NM

Local Integration of NARAC with Cities (LINC)

Post 9/11 Threat Assessments

2002 Winter Olympics, Salt Lake City, UT

Barge Fire, Staten Island, NY

NASA Mars Explorer Rover Launches, FL

TOPOFF 2 Exercise, Seattle, WA

Establishment of the IMAAC

Chemical Facility Fire, Conyers, GA

Biological Agent Detection

Chemical Warehouse Fire, Cincinnati, OH

Democratic National Convention, Boston, MA

Chlorine Railcar Accident, Graniteville, SC

TOPOFF 3 Exercise, New London, CT

Solvent Plant Fire, Fort Worth, TX

Hurricane Katrina, New Orleans, LA

Pluto New Horizons Spacecraft Launch, FL

Southern Crossing Exercise, Dothan, AL

Welding Facility Fire, Dallas, TX

Solvents Tank Fire, Valley Center, KS

TOPOFF 4 Exercise, OR, AZ & Guam

Kilauea Volcano, HI

ConvEx-3 International Exercise, Mexico

Presidential Inauguration, Washington, DC

Empire 09 Exercise, Albany, NY

2010s

Eyjafjallajökull Volcano Eruption, Iceland

Deepwater Horizon Oil Spill, Gulf of Mexico

Fukushima Nuclear Power Plant Accident, Japan

Los Conchas Wildfire, New Mexico

Mars Science Laboratory Spacecraft Launch, FL

International Atomic Energy Agency Support

NARAC Dedicated Compute Cluster

Waste Isolation Pilot Plant

R&D

LLNL Regional and Global Models

ASCOT Field Studies

New Operational Models

Urban Field Studies

CFD Building-Resolving Models

Indoor-Outdoor Coupled Models

Event Reconstruction

Chemical and Biological Agent Modeling

Explosive Dispersal and Fallout Models

Weather Research and Forecasting Model

Dense Gas Experiments and Models

Global Geographic Databases

Field Measurement Data Tools

NARAC/IMAAC/CM/IXP Web

Communication of Plume Hazard Information

DOE Safety Software Codes

Radiological Dispersal Device Improvements

Nuclear Detonation Modeling

NARAC Source Estimation & Model Refinement

Acknowledgments

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory in part under Contract W-7405-Eng-48 and in part under Contract DE-AC52-07NA27344.

The Department of Homeland Security sponsored part of the production of this material under the Department of Energy contract DE-AC52-07NA27344 for the management and operation of Lawrence Livermore National Laboratory.

Primary Authors: Gayle Sugiyama and John Nasstrom
Design by Kirk Hadley and Kwei-Yu Chu

LLNL-VIDEO-412279-Rev. 3
April 25, 2014