National Atmospheric Release Advisory Center (NARAC) Overview

January 27, 2015

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Lawrence Livermore National Laboratory

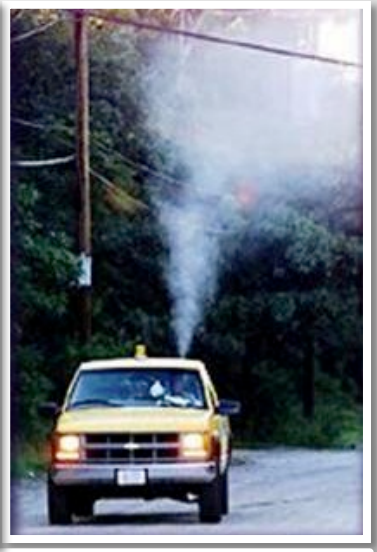
National Atmospheric Release Advisory Center

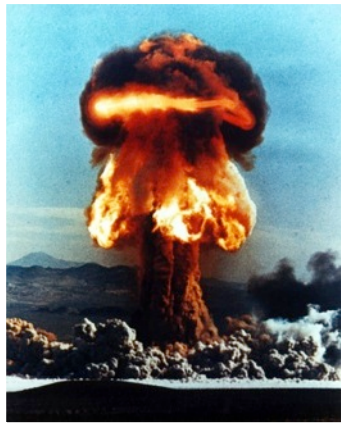
NARAC

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC. The Department of Homeland Security sponsored part of the production of this material.

LLNL-PRES-609358-Rev1

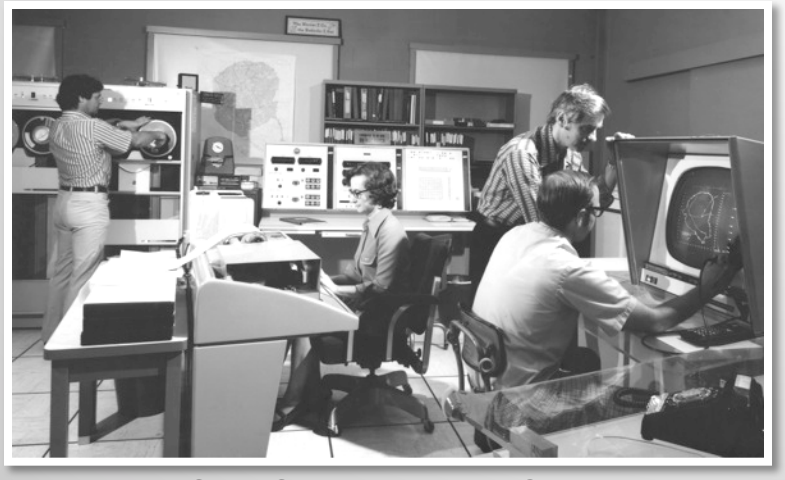
NARAC Provides Critical Information to Protect the Public and the Environment





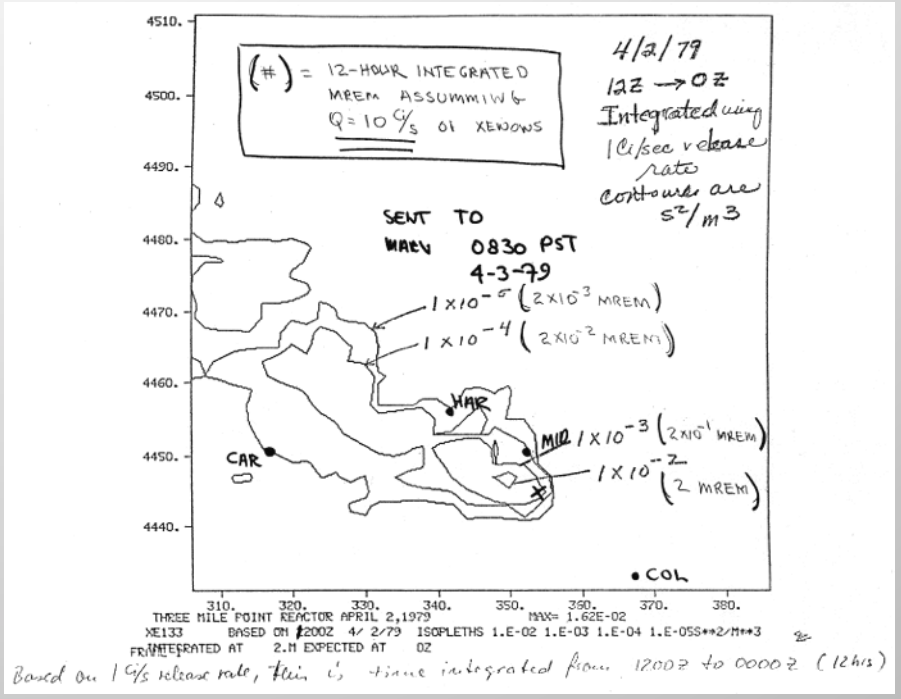
Hazardous airborne releases are a rapid and effective means to impact large populations. NARAC has capabilities to respond to toxic industrial chemical spills, nuclear-power plant accidents, fires, radiological dispersal devices (RDDs), nuclear detonations, chemical/biological agents, and some natural airborne hazards.

LLNL Operational Center Was Founded During Three Mile Island (Dept. of Energy / Nuclear Regulatory Commission)



Original DOE Operations Center at LLNL

Three Mile Island Nuclear Power Plant and DOE Aerial Measuring System (AMS)



NARAC prediction of downwind dose from a potential release from the Three Mile Island nuclear power plant

NARAC Has a Multi-Decade Operational Record of Timely and Accurate Hazard Atmospheric Release Assessments

1973 DOE R&D Program

1979 ARAC Operational Center established

Generation-2 system (nuclear/ radiological)

Naval Nuclear Propulsion Program

DOE site support for toxic industrial chemicals

DOE CBNP program

1996 DOE NARAC facility dedicated

Generation-3 system (CBRN)

2002-2005 Local Integration of NARAC with Cities

2004 IMAAC established

2007 IXP Web

2008 CMweb

2010-2014 DOE Safety Software codes (HotSpot and EPIcode)

2012 NARAC compute cluster

1980

1979 Three Mile Island reactor leak

1980 Titan Missile explosion AK

1980 China atmospheric nuclear tests

1985

1983 Russian Cosmos satellite re-entry

1986 Chernobyl reactor accident

1988 Henderson NV rocket fuel plant explosion

1991 Mt. Pinatubo eruption, Philippines

1990

1991 Kuwaiti oil field fires

1993 TOMSK-7 waste-tank explosion, USSR

1993 Richmond, CA oleum tank car release

1995

1997 Cassini satellite launch

1998 Tracy tire dump fire

1999 Tokaimura criticality accident

2000

2001 Post-September 11 threat scenarios

2003 Staten Island oil barge fire

2003-2004 New Years Orange Alert

2004 Conyers, GA chemical fire

2005

2006 NASA Pluto New Horizons launch

2007 Top Officials 4 (TOPOFF4) exercise

2009 Inaugural events

2010

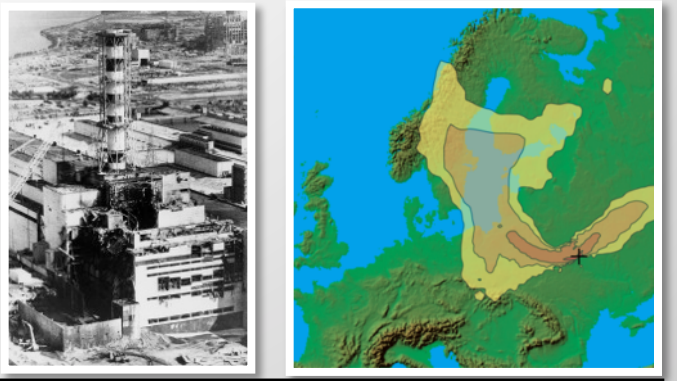
2010 National Level Exercise (NLE) 2010

2011 Fukushima Nuclear Power Plant accident

2011 Mars Science Laboratory launch

2015

2014 Waste Isolation Pilot Plant accident



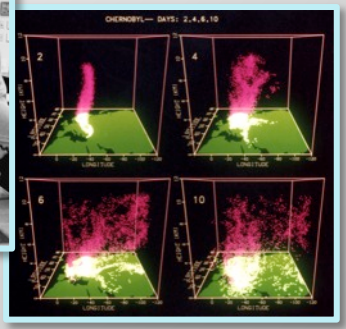
Chernobyl reactor building after explosion (Ukraine, 1986) and LLNL plume prediction

Photo of smoke from tire dump fire (Tracy, California, 1998) with plume prediction in red

NARAC prediction of possible protective action areas around Fukushima Nuclear Power Station (2011)

NARAC Serves as the Department of Energy's (DOE) Plume Modeling Center and Supports Other Agencies

- DOE/NNSA Emergency Operations
  - Office of Emergency Response
  - Office of Emergency Management
  - National Technical Nuclear Forensics
  - Office of International Emergency Management and Cooperation
- DOE / DoD Naval Nuclear Propulsion Program
- DoD Special Weapons Facilities
- NASA (spacecraft launch support coordinated via the DOE Office of Radioisotope Power Systems)
- DHS Interagency Modeling and Atmospheric Assessment Center (IMAAC) – NARAC is the primary provider of radiological/nuclear products to the IMAAC
- DHS/FEMA response planning and Nuclear Incident Response Team support
- DHS/HHS threat assessments, preparedness planning
- DOE site safety analysis / hazard assessment models



NARAC predicted the spread of Chernobyl radioactivity over Europe and Asia

NARAC supports international cooperation under DOE/IAEA auspices

NARAC provides the Senior Science Advisor and support for NASA spacecraft launches

NARAC Provides Operational Services, Tools, and Expertise for Preparedness, Response, & Recovery

Event Information

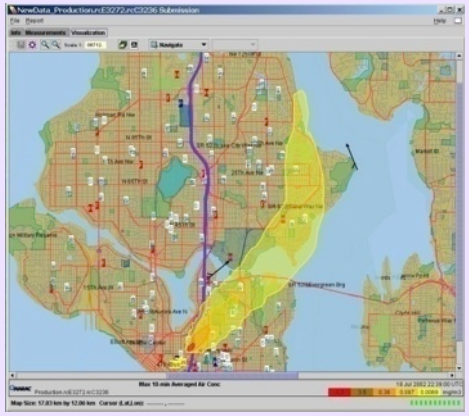
- Weather data
- Nuclear, radiological, chemical, and biological source information
- Terrain, land use, and population databases
- Measurement data and observations

Operational Services and Expertise

- Suite of stand-alone to advanced WMD modeling tools (multi-scale models)
- 24/7/365 expert scientific staff (< 5 min. reach-back)
- Detailed analysis, expert interpretation, quality assurance, and training
- Event reconstruction

Actionable Information

- Hazard areas and affected populations
- Health effect, public protective action, and worker protection levels based on federal guidelines
- Casualty, fatality, and damage estimates
- Planning and consequence assessments



NARAC Products Are Distributed to Federal, State, and Local Agencies Involved in a Response


Unclassified

Product Set 2: Top Off 4 Exercise
Portland, OR
RDD Explosion at 12:06 16Oct 2008

Evacuation and Sheltering Areas

Projected radiation dose, if no protective action implemented
Post Plume Phase – projected radiation dose from ground contamination only

A — Area A: Evacuation of entire population warranted (unless additional unusually hazardous circumstances exist). Estimated population: 5,400

B — Area B: Evacuation (or, for some situations, sheltering-in-place) normally initiated. Estimated population: 18,100

Key Points:
- Prompt evacuation and sheltering reduces radiation dose and cancer risk
- Evacuation generally preferred to sheltering especially after plume has passed
- Institutionalized groups require special consideration
- Protective actions are only based on dose that can be avoided, not dose received before protective actions implemented

- This is a model prediction based on an estimated source, but no measurements
- Post Plume Phase – Airborne plume has passed
- Residual ground contamination is the concern

Created: 14:00 10/16/08
Check for updates

Contact DOE Consequence Management Home Team (702) 794-1665

Unclassified

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Unclassified

Product Set 2: Top Off 4 Exercise
Portland, OR
RDD Explosion at 12:06 16Oct 2008

Evacuation and Sheltering Areas

Projected radiation dose, if no protective action implemented
Post Plume Phase – projected radiation dose from ground contamination only

Key Points:
- Evacuate or shelter as soon as possible to minimize dose and long-term cancer risk
- Evacuation is generally preferred for the general population.
- Evacuees should be directed to designated location(s) for contamination monitoring and collection of exposure information.
- Sheltering-in-place may be preferable to evacuation in some situations
  - Institutionalized populations (invalids, prisoners…)
  - Severe weather, competing disasters, impediments to evacuation
  - Very rapid radioactive decay
- Initial airborne plume has cleared the area, leaving only ground contamination
- Protective actions are based only on dose that can be avoided, not dose acquired prior to protective action
- Dose does not include doses acquired before 14:00 10/16/08 (presumed end of plume passage)
- Projected dose is accumulated over 4 days (14:00 10/16/08 to 14:00 10/20/08)
- Projected dose assumes individuals are unsheltered and unprotected
- Map may be updated, if implementation of protective actions has been delayed and/or new information obtained

Technical Background:
- Shelter and evacuation guidance based on EPA/DHS guidelines for the Early Phase (assumes 4 day duration)
- Projected dose is known as Total Effective Dose Equivalent (TEDE), which is only due to external irradiation by ground contamination, plus dose due to radioactivity taken into the body by inhalation of contaminated dust (resuspension)
- Map contours correspond to minimum and maximum evacuation/sheltering thresholds of 1 and 5 rem respectively

Created: 14:00 10/16/08
Check for updates

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Unclassified

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NARAC supports over 300 collaborating local, state, and federal agencies and 2500 on-line users. NARAC staff provide expertise for over 100 exercises and real-world events annually.

Web-based Software Tools Provide Easy Access and Distribution of Predictions and Analyses

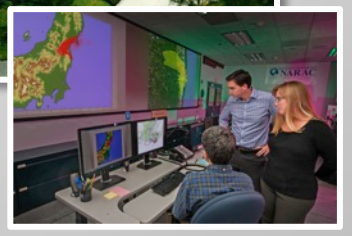
Federal/State/Local Operations Center

Information distribution & decision making

Local, Regional, State Responders

Internet, dial-up, satellite or wireless communication

NARAC



CMweb
NARAC Web

- Emergency Response Guides
- Fast-running local models (HotSpot)
- Access to advanced NARAC models

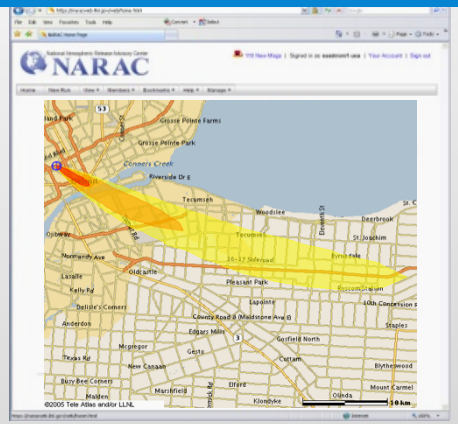
- Scientific support and analyses
- Advanced modeling tools

Collaborating City, County, State & Federal Agencies

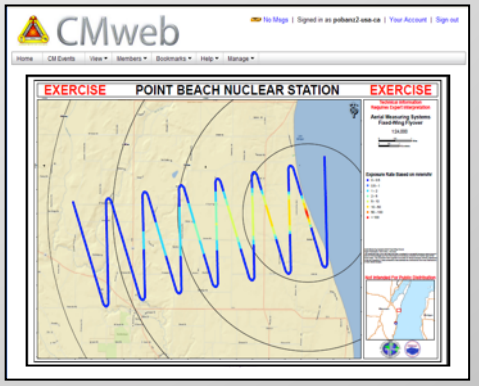
Web Software Tools Provide Remote Users with Quick Access to NARAC Predictions

- Authorized *Web* users can
  - Run 3-D plume models with real-time weather data
  - Share predictions and data with other users or groups of users
- *CMweb* serves as the unified DOE NA-42 Web site for distribution of Federal Radiological Monitoring Assessment Center (FRMAC) consequence management and NARAC data and model products
- *IXP* Web supports the International Atomic Energy Agency (IAEA) and member states under DOE NA-46 auspices
- NARAC products produced for the Interagency Modeling and Atmospheric Assessment Center (IMAAC) are also distributed via the DHS-hosted Homeland Security Information Network (HSIN)

https://naracweb.llnl.gov



cmweb.llnl.gov



https://ixp.llnl.gov

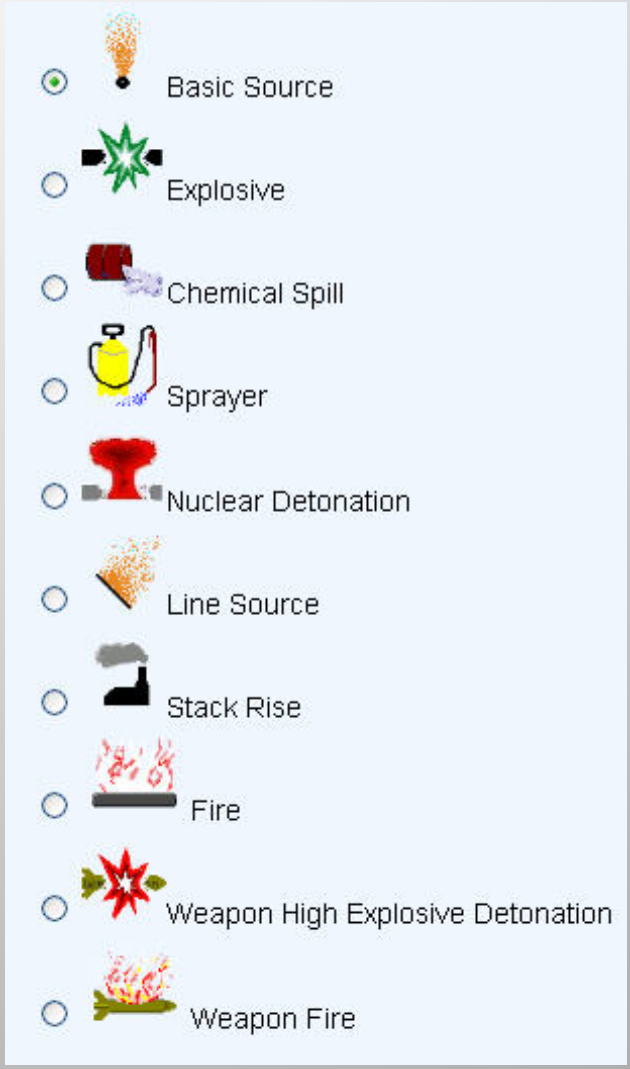
HSIN

NARAC Products Provide Actionable Information to Inform Emergency Response Decisions

- Safe approach routes
- Incident command post or resource siting
- Deployment of field monitoring teams (sampling plan guidance)
- Evacuation, sheltering-in-place, and relocation decisions
- Need for personal protective equipment (PPE)
- Potential impacts on, and contamination of, critical infrastructure
- Potential number of casualties requiring hospital or medical treatment
- Determination of areas where agricultural crops may be contaminated (human food and animal feed)

Key Information is Used to Drive NARAC Plume Modeling Analyses

- When requesting NARAC assistance, provide as much information as possible but do *not* delay contacting the center to collect additional information
- Essential information (initial product):
  - Location of release (e.g., latitude/longitude, street address)
  - Time of release
- Other key information for effects predictions:
  - Type of material (e.g., radiological isotope, biological agent, bio-toxin, toxic industrial chemical, chemical agent,)
  - Type of release (e.g. explosion, fire, spill)
  - Amount released or at risk (e.g., 90 ton rail car, 1000 Curies, 2 lbs)
  - Observations related to the initial plume (e.g., height of plume, size of crater)



Additional Information Can be Valuable During a NARAC Response

- Local meteorological observations
- Field measurement data
  - Type of measurement or instrument
  - Location
  - Time of measurement
  - Measures value, units, threshold, sensitivity
- List of agencies involved in response for NARAC product distribution

Federal

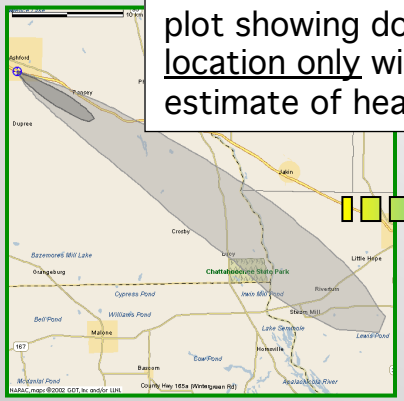
State / Tribal / Regional

Local

Local responders

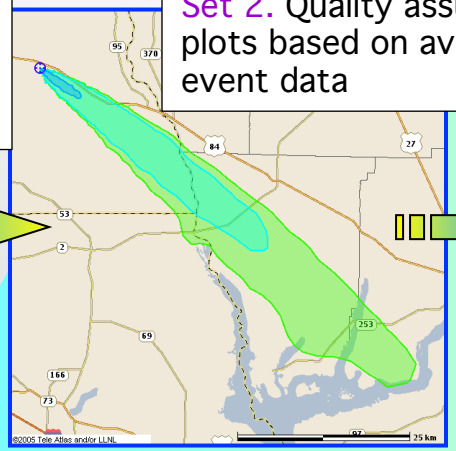
NARAC Model Results Are Continually Refined with Field Data Until the Impacts Are Characterized

Set 1. Initial automated plot showing downwind location only with no estimate of health effects



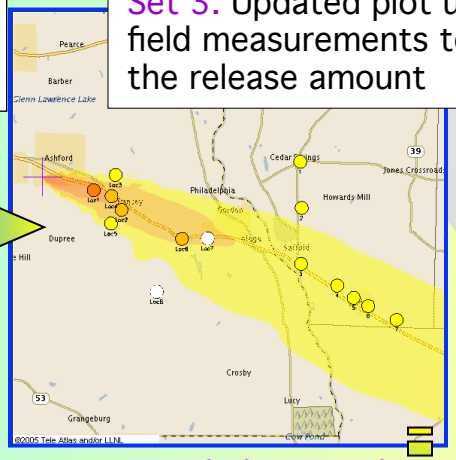
Response initiated via automated Web request or Emergency Call (only release time and location are known)

Set 2. Quality assured plots based on available event data

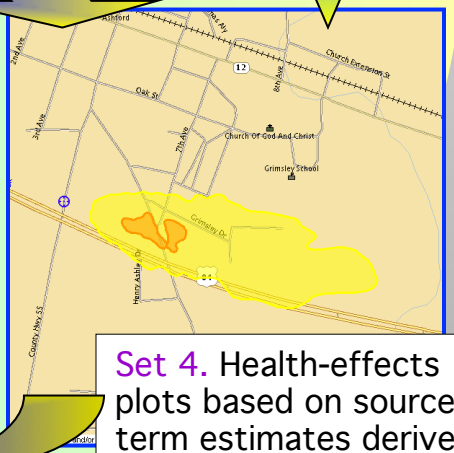


Plot based on identification of material, updated source location, detailed weather

Set 3. Updated plot using initial field measurements to estimate the release amount

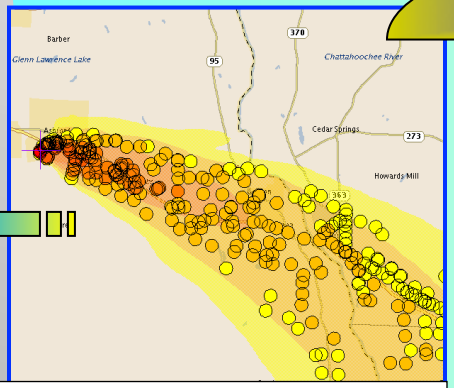


Source scaled to initial set of measurements



Set 4. Health-effects plots based on source term estimates derived from field measurements

Iterative updates of products based on field data and other observations



Set 5. Refined model results with improved accuracy and source term estimates from more extensive sets of field measurements

Later product sets. Relocation and food-Ingestion plots

NARAC Products

Lawrence Livermore National Laboratory

National Atmospheric Release Advisory Center

NARAC

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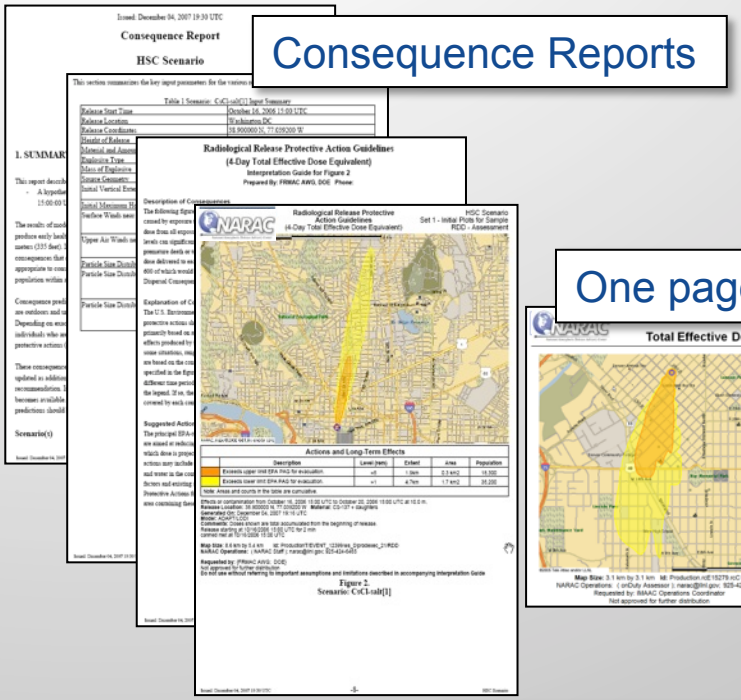
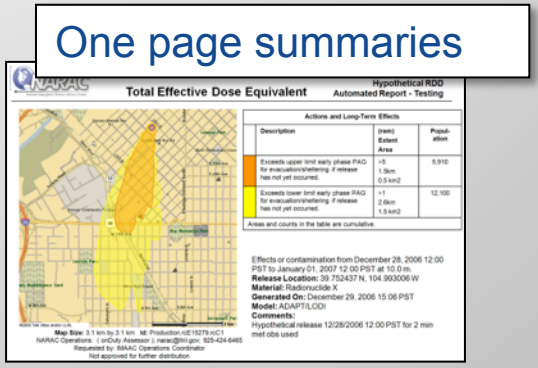
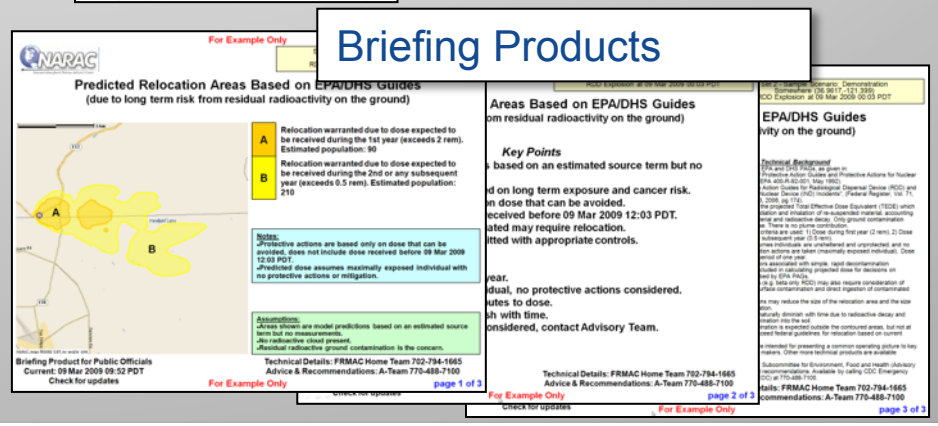
LLNL-PRES-609358-Rev1

NARAC Products Inform Evacuation, Sheltering, Relocation, Worker Protection, and Sampling Plan Decisions

- Standard plot sets
  - Plume hazard areas
  - Affected population numbers
  - Expected health effects
  - Protective action guide levels
  - Geographical information
- One-page map summary plots
- Multi-page consequence reports
  - Expanded descriptions
  - Input data and assumptions
  - Interpretation guides
- Briefing Products
  - Focus on actions and decisions that need to be considered
  - RDD, IND, nuclear power plants, chemicals, and biological agents
  - Developed with interagency consensus







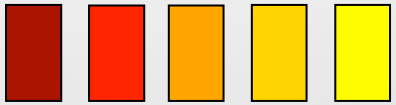
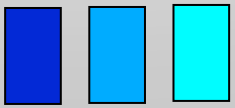
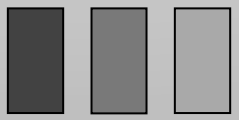
NARAC Provides Standard Plots Derived From Interagency Input and Consensus

- Plot standards are developed with user input and agency consensus
  - Standard plot format and color schemes
  - Standard plot types and contamination/dose levels of concern
  - Maps showing areas reaching health effect levels, and protective action guides from DHS/EPA, if available
  - Consequence reports documentation of model inputs and assumptions and interpretational guidance
- Default plot sets are produced automatically when a model request is made
  - Web users may directly initiate a modeling request
  - NARAC Operations can produce and share results with designated users
- NARAC Operations provides reach-back support to:
  - Develop additional event-specific plots
  - Refine predictions based on field data and event information
  - Provide subject matter expertise on plots and analyses

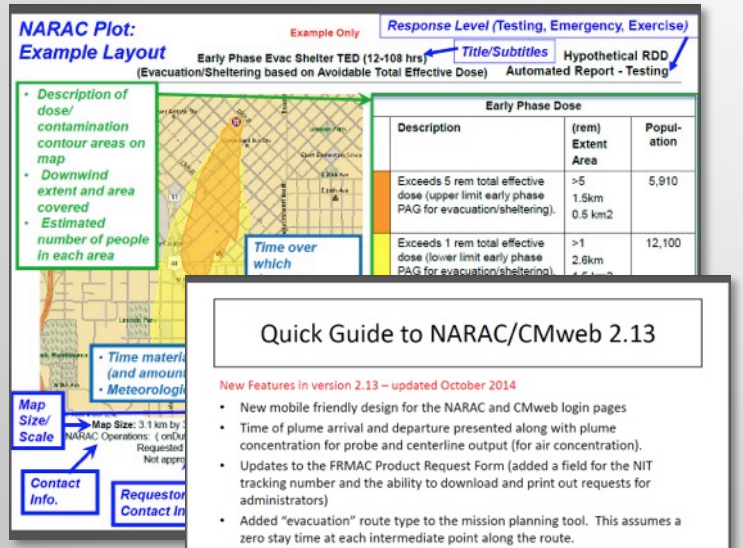
A Standard Default Plot Set is Provided For Each Type of Release (Developed with Interagency Input)

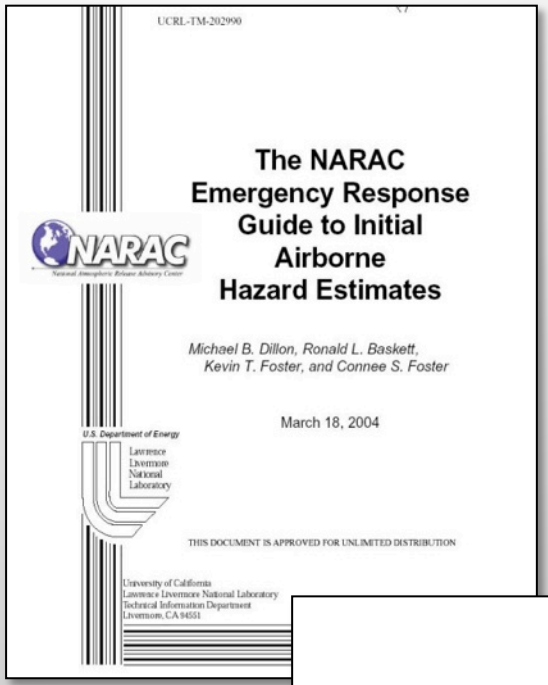
Release Type	*Default Plot Type*
Unknown source material	Hourly average air concentration Deposition if particulate is used
Industrial chemical	"Peak" average air concentration, deposition
Chemical agent	"Peak" average air concentration, deposition
Biological agent	Time-integrated air concentration, deposition
Explosive	Health effects from blast overpressure
Radiological	Dose, dose rate, deposition
Nuclear	Prompt effects, dose, dose rate

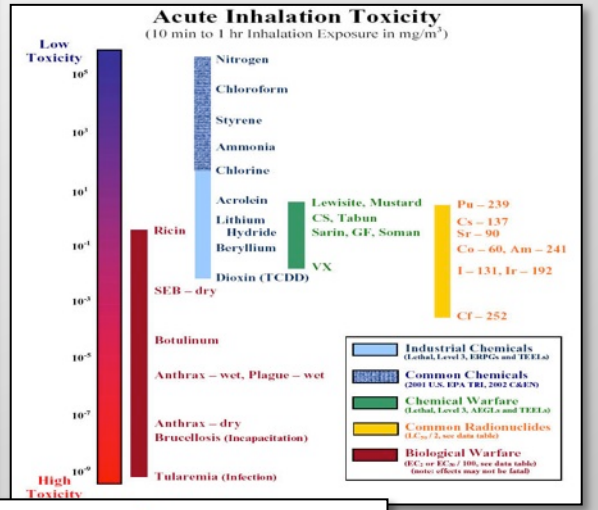
Standard Product Contour Level and Color Schemes are Used for Ease of Interpretation

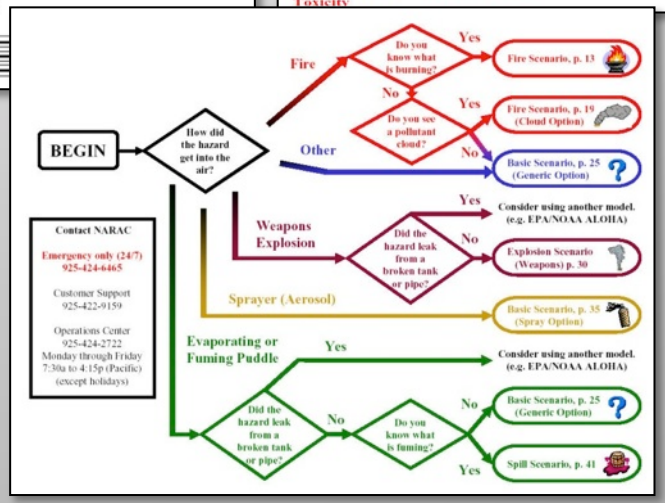
Model Contour Levels	Have levels been reached?	Contour Colors	Description Wording
Acute/Chronic exposure/dose or protective action guideline levels exist in the NARAC database (release amount assumed to be known)	Yes		Consistent with EPA, NRC, FDA or other guidance
	No		Values below health effect or PAG levels Possible contaminated areas Confirm with monitoring surveys
Customer specified levels	Yes		Customer specified levels
	No		Values below customer specified levels
No levels exist in NARAC database (or no release amount known)			No guidelines specified Possible contaminated areas

Extensive User Documentation Includes User Guides and Web-Based Training









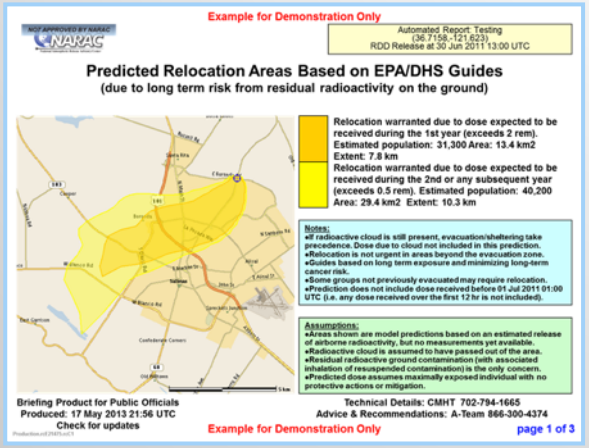
- Technical manuals
- Web-based training
- Step-by-step guide to software use
- Guide books for determining model inputs from known information

Interagency Briefing Products Communicate Key Information to Decision Makers and Responders

- DOE / DHS tasking by Homeland Security Council to produce hazard area graphics targeted at officials, decision makers, and public affairs officers
  - Present information on effects in plain, non-technical language
  - Explain actions that need to be considered and why (e.g., sheltering, evacuation, relocation, worker protection, agricultural embargoes)
  - List assumptions and limitations
- Based on existing pertinent agency-published documents for guidance
- Developed with extensive interagency input with on-going updates based on interagency feedback and recommendations
- Designed for Subject Matter Experts to use in briefing officials and responders (not intended for direct briefing of the general public)

The development of Briefing Products has been sponsored by DOE/NNSA and DHS, and involved a collaboration of LLNL, RSL, Sandia, EPA, DHS, NRC, and HHS/CDC.

Briefing Products Use a Standard Three Slide Format With Information Determined Via Interagency Consensus


Example for Demonstration Only

NARAC

Automated Report: Testing (36.7158,-121.623) RDD Release at 30 Jun 2011 13:00 UTC

Predicted Relocation Areas Based on EPA/DHS Guides
(due to long term risk from residual radioactivity on the ground)

Relocation warranted due to dose expected to be received during the 1st year (exceeds 2 rem). Estimated population: 31,300 Area: 13.4 km2 Extent: 7.8 km

Relocation warranted due to dose expected to be received during the 2nd or any subsequent year (exceeds 0.5 rem). Estimated population: 40,200 Area: 29.4 km2 Extent: 10.3 km

Notes:
- If radioactive cloud is still present, evacuation/sheltering take precedence. Dose due to cloud not included in this prediction.
- Relocation is not urgent in areas beyond the evacuation zone.
- Guides based on long term exposure and minimizing long-term cancer risk.
- Some groups not previously evacuated may require relocation.
- Prediction does not include dose received before 01 Jul 2011 01:00 UTC (i.e. any dose received over the first 12 hr is not included).

Assumptions:
- Areas shown are model predictions based on an estimated release of airborne radioactivity, but no measurements yet available.
- Radioactive cloud is assumed to have passed out of the area.
- Residual radioactive ground contamination (with associated inhalation of resuspended contamination) is the only concern.
- Predicted dose assumes maximally exposed individual with no protective actions or mitigation.

Briefing Product for Public Officials
Produced: 17 May 2013 21:56 UTC
Check for updates

Technical Details: CMHT 702-794-1665
Advice & Recommendations: A-Team 866-300-4374

Example for Demonstration Only

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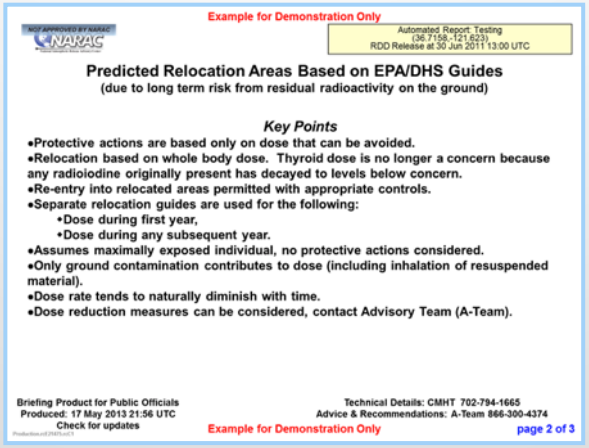
Example for Demonstration Only

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Automated Report: Testing (36.7158,-121.623) RDD Release at 30 Jun 2011 13:00 UTC

Predicted Relocation Areas Based on EPA/DHS Guides
(due to long term risk from residual radioactivity on the ground)

Key Points

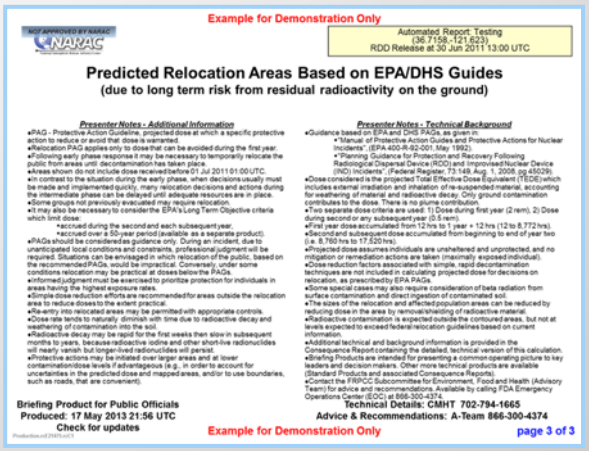
- Protective actions are based only on dose that can be avoided.
- Relocation based on whole body dose. Thyroid dose is no longer a concern because any radioiodine originally present has decayed to levels below concern.
- Re-entry into relocated areas permitted with appropriate controls.
- Separate relocation guides are used for the following:
  - Dose during first year,
  - Dose during any subsequent year.
- Assumes maximally exposed individual, no protective actions considered.
- Only ground contamination contributes to dose (including inhalation of resuspended material).
- Dose rate tends to naturally diminish with time.
- Dose reduction measures can be considered, contact Advisory Team (A-Team).

Briefing Product for Public Officials
Produced: 17 May 2013 21:56 UTC
Check for updates

Technical Details: CMHT 702-794-1665
Advice & Recommendations: A-Team 866-300-4374

Example for Demonstration Only

page 2 of 3


Example for Demonstration Only

NARAC

Automated Report: Testing (36.7158,-121.623) RDD Release at 30 Jun 2011 13:00 UTC

Predicted Relocation Areas Based on EPA/DHS Guides
(due to long term risk from residual radioactivity on the ground)

Presenter Notes - Additional Information

- PAG - Protective Action Guideline, projected dose at which a specific protective action to reduce or avoid that dose is warranted.
- Relocation PAG applies only to dose that can be avoided during the first year.
- Following early phase response it may be necessary to temporarily relocate the public from areas until decontamination has taken place.
- Areas shown do not include dose received before 01 Jul 2011 01:00 UTC.
- In contrast to the situation during the early phase, when decisions usually must be made and implemented quickly, many relocation decisions and actions during the intermediate phase can be delayed until adequate resources are in place.
- Some groups not previously evacuated may require relocation.
- It may also be necessary to consider the EPA's Long Term Objective criteria which limit dose:
  - accrued during the second and each subsequent year.
  - accrued over a 50-year period (available as a separate product).
- PAGs should be considered as guidance only. During an incident, due to unanticipated local conditions and constraints, professional judgment will be required. Situations can be envisaged in which relocation of the public, based on the recommended PAGs, would be impractical. Conversely, under some conditions relocation may be practical at doses below the PAGs.
- Informed judgment must be exercised to prioritize protection for individuals in areas having the highest exposure rates.
- Simple dose reduction efforts are recommended for areas outside the relocation area to reduce doses to the extent practical.
- Re-entry into relocated areas may be permitted with appropriate controls.
- Dose rate tends to naturally diminish with time due to radioactive decay and weathering of contamination into the soil.
- Radioactive decay may be rapid for the first weeks then slow in subsequent months to years, because radioactive iodine and other short-live radionuclides will nearly vanish but longer-lived radionuclides will persist.
- Protective actions may be initiated over larger areas and at lower contamination/dose levels if advantageous (e.g., in order to account for uncertainties in the predicted dose and mapped areas, and/or to use boundaries, such as roads, that are convenient).

Presenter Notes - Technical Background

- Guidance based on EPA and DHS PAGs, as given in:
  - "Manual of Protective Action Guides and Protective Actions for Nuclear Incidents", (EPA 400-R-92-001, May 1992).
  - "Planning Guidance for Protection and Recovery Following Radiological Dispersal Device (RDD) and Improvised Nuclear Device (IND) Incidents", (Federal Register, 73:149, Aug. 1, 2008, pg 45029).
- Dose considered is the projected Total Effective Dose Equivalent (TEDE) which includes external irradiation and inhalation of re-suspended material, accounting for weathering of material and radioactive decay. Only ground contamination contributes to the dose. There is no plume contribution.
- Two separate dose criteria are used: 1) Dose during first year (2 rem), 2) Dose during second or any subsequent year (0.5 rem).
- First year dose accumulated from 12 hrs to 1 year + 12 hrs (12 to 8,772 hrs).
- Second and subsequent dose accumulated from beginning to end of year two (i.e. 8,760 hrs to 17,520 hrs).
- Projected dose assumes individuals are unsheltered and unprotected, and no mitigation or remediation actions are taken (maximally exposed individual).
- Dose reduction factors associated with simple, rapid decontamination techniques are not included in calculating projected dose for decisions on relocation, as prescribed by EPA PAGs.
- Some special cases may also require consideration of beta radiation from surface contamination and direct ingestion of contaminated soil.
- The sizes of the relocation and affected population areas can be reduced by reducing dose in the area by removal/shielding of radioactive material.
- Radioactive contamination is expected outside the contoured areas, but not at levels expected to exceed federal relocation guidelines based on current information.
- Additional technical and background information is provided in the Consequence Report containing the detailed, technical version of this calculation.
- Briefing Products are intended for presenting a common operating picture to key leaders and decision makers. Other more technical products are available (Standard Products and associated Consequence Reports).
- Contact the FRPCC Subcommittee for Environment, Food and Health (Advisory Team) for advice and recommendations. Available by calling FDA Emergency Operations Center (EOC) at 866-300-4374.

Briefing Product for Public Officials
Produced: 17 May 2013 21:56 UTC
Check for updates

Technical Details: CMHT 702-794-1665
Advice & Recommendations: A-Team 866-300-4374

Example for Demonstration Only

page 3 of 3

Slide 1. Plot

- Map of the areas of concern
- Plot legend (associated with actionable guidance)
- Important notes, assumptions, and limitations

Slide 2. Key Points

- Expanded list of information concerning relevant actions for consideration (evacuation, sheltering, relocation, worker protection)
- Key point highlights to present

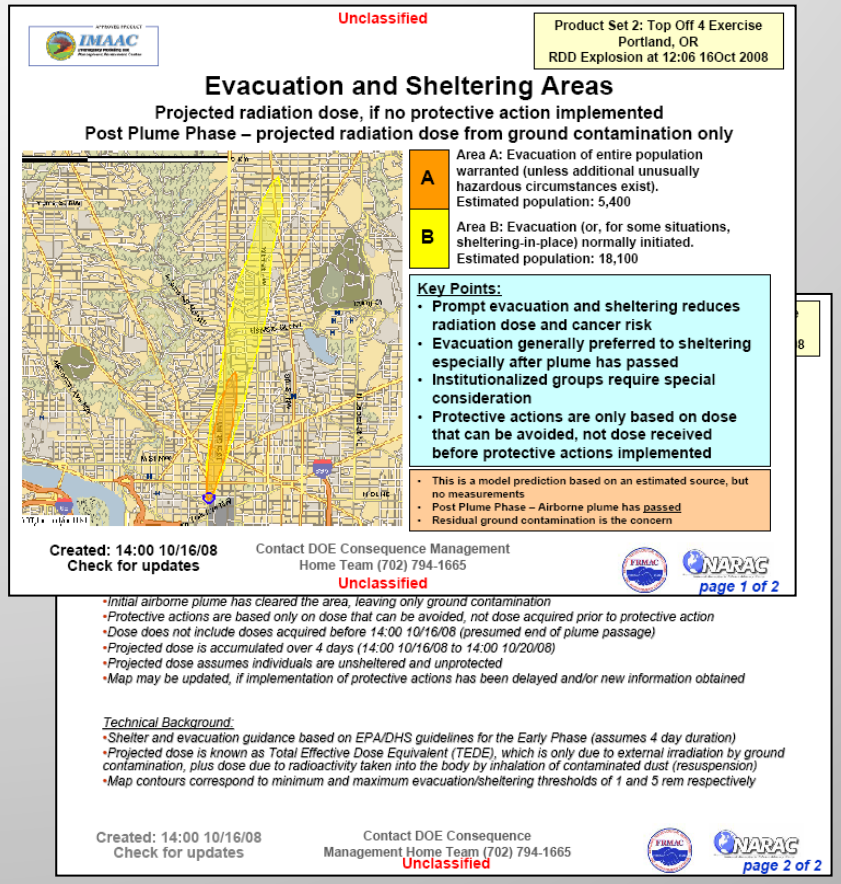
Slide 3. Presenter Notes

- Background and technical information
- Intended for use by the presenter (not for display)

All slides include product titles and sub-titles, short scenario description, product creation date/time, and contact phone numbers for technical details and advice (e.g., NARAC/IMAAC, CMHT/FRMAC or Federal Advisory Team for Environment, Food and Health for radiological advice, EPA for chemical advice)

NARAC Software Allows Users to Automatically Generate Briefing Products

- Briefing Products are available for multiple release types
  - Nuclear detonations (e.g., Improvised Nuclear Devices [INDs])
  - Radiological Dispersion Devices (RDDs)
  - Nuclear Power Plant (NPP) accidents
  - Toxic industrial materials/chemicals and chemical agents
  - Biological agents
- Briefing Products available in two formats
  - PowerPoint
  - PDF
- LLNL NARAC software quickly and automatically produces briefing products
- Products are available for upload/distribution on CMweb/NARAC Web, HSIN, ECN or email

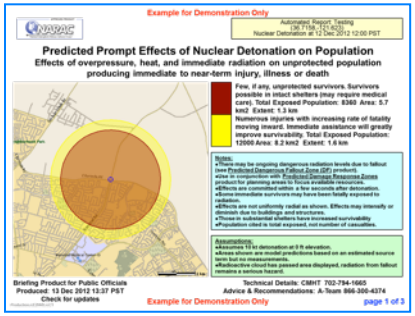
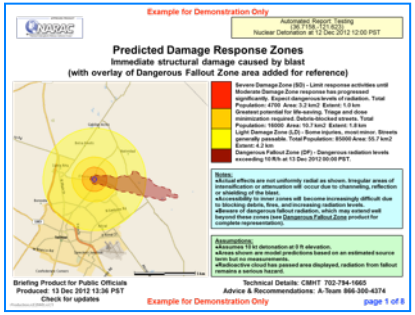


Comparison of Technical and Briefing Products

Characteristic	**Technical Products**	**Briefing Products**
User and purpose	For use by subject matter experts to support the decision-making process	To assist subject matter experts in the communication of consequences and guidance to decision-making officials
Language	Technical terminology	Plain language
Content	Complex: Includes data used to develop products such as source term, meteorology, measurements	Streamlined: Includes only essential details and focuses on explaining results
Protective action criteria and guidelines	Use established agency guidelines for standard default products, but may include additional information specified by subject matter experts for a special purpose	Use established agency guidelines to focus user's attention on potential actions for consideration
Training needed to use products	Requires a technical background and training before using	Each product includes two pages of key notes and background information, but training on product interpretation is recommended

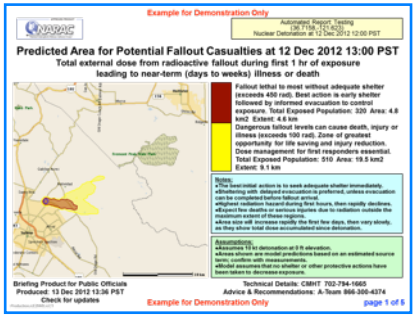
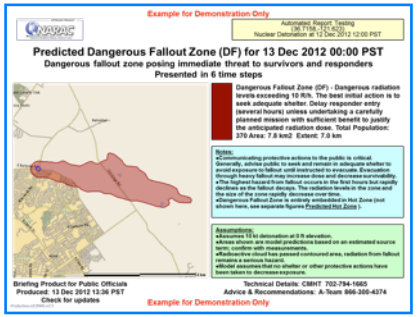
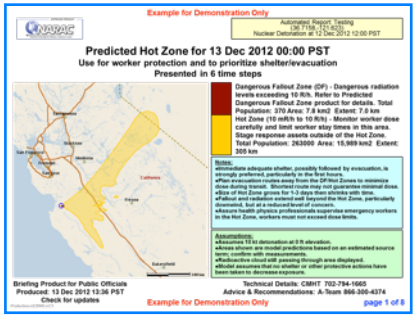
Note: Neither type of product is intended for distribution or presentation to the general public

Nuclear Detonation Briefing Products – Prompt Effects: Summary

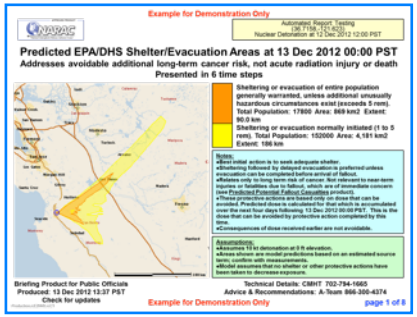
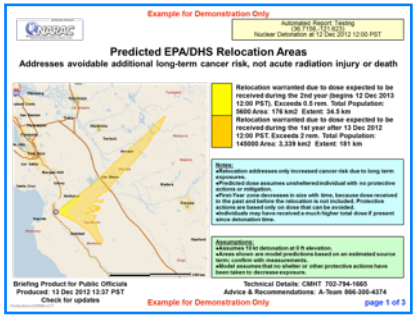
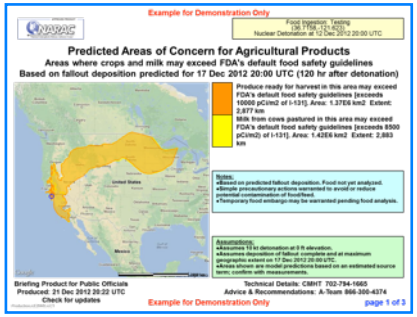
Time Phase	Product	Sample	Purpose
Early (minutes)	Predicted Prompt Effects on Population		• Estimate areas with immediate near-term injury, illness or death • Prioritize rescue
	Predicted Damage Response Zones		• Estimate immediate structural damage and related consequences • Inform search & rescue • Time-varying dangerous fallout zone included

Nuclear Detonation Briefing Products – Fallout: Summary (1)

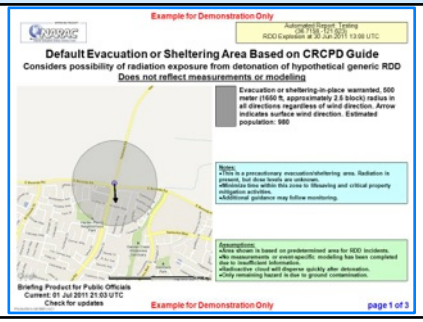
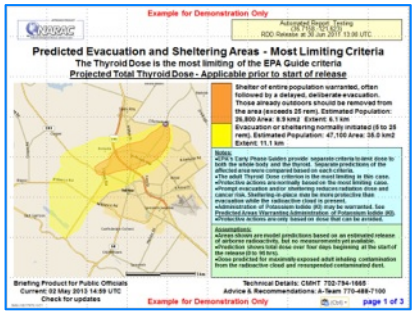
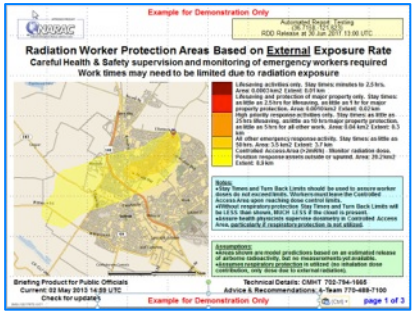
Multiple Times Shown Due to Rapid Fallout Decay

Time Phase	Product	Sample	Purpose
Early (minutes)	Predicted Area for Potential Fallout Casualties		• Estimate total fallout casualties/ injuries • Estimate external groundshine dose from radioactive fallout during first hours to days of exposure leading to near-term (days to weeks) health effects • Presented for multiple times
	Predicted Dangerous Fallout Zone		• Estimate high dose fallout zone posing immediate fatality threat to survivors and responders • >10 R/h • Presented for multiple times
	Predicted Hot Zone /Worker Protection Areas		• Use for worker protection and stay time guidance • Determine access control area • > 10 mR/hr • Presented for multiple times

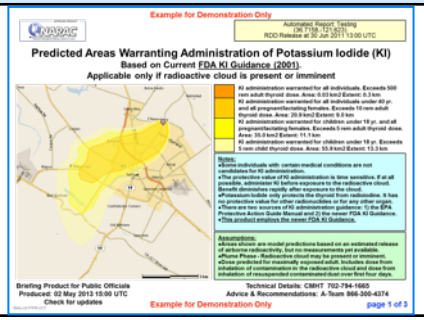
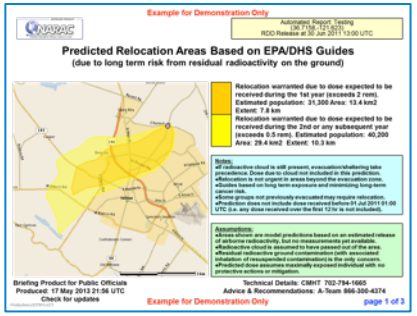
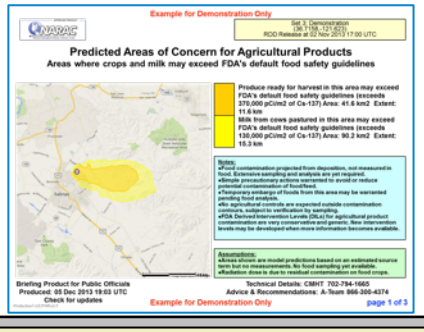
Nuclear Detonation Briefing Products – Fallout: Summary (2) Multiple Times Shown Due to Rapid Fallout Decay

Time Phase	Product	Sample	Purpose
Early (hours to days)	Predicted EPA/ DHS Sheltering/ Evacuation Areas		• Guide sheltering and evacuation decisions • Assess avoidable additional long-term cancer risk, not acute radiation injury or death (1-5 Rem and >5 Rem in 4 days) • Presented for multiple times
Intermediate (days to months)	Predicted EPA/ DHS Relocation Areas		• Guide population relocation decisions • Assess avoidable additional long-term cancer risk, not acute radiation injury or death (2 Rem in first year and 0.5 Rem in subsequent or later year)
Late Phases (days to years)	Predicted Areas of Concern for Agricultural Products		• Guide crop sampling • Guide crop/food control decisions • Predict areas where crops and milk may exceed FDA's food safety guidelines based on fallout

RDD Briefing Products: Summary (1)

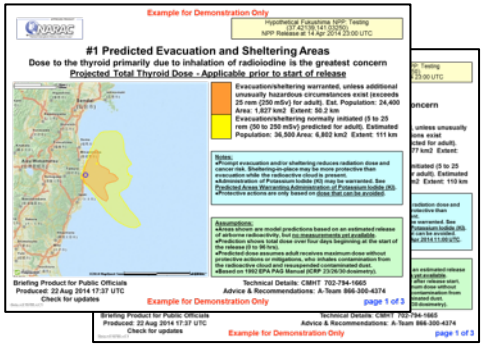
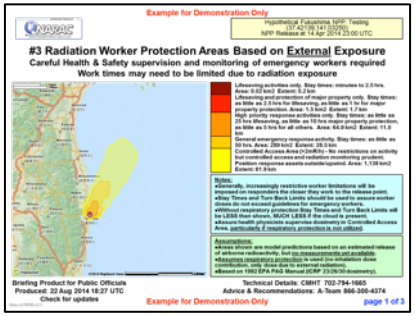
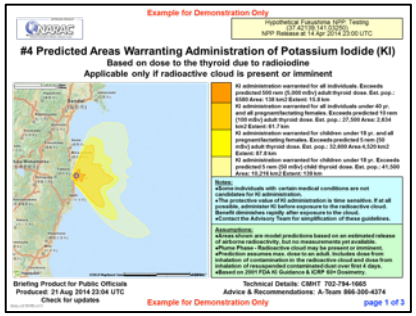
Time Phase	Product	Sample	Purpose
Early (minutes)	Default Evacuation or Sheltering Area		• Guide precautionary sheltering and evacuation decision • Guide access control and monitoring
Early (hours to days)	Predicted EPA/DHS Sheltering/ Evacuation Areas (TED or Thyroid CDE)		• Update guide for sheltering and evacuation decisions • Assess avoidable additional long-term cancer risk • Uses most-limiting 4-day dose (Whole-body Total Effective Dose [TED] of 5 Rem and1-5 Rem or Adult Thyroid Committed Dose Equivalent [CDE] of > 25 Rem and 5-25 Rem)
	Predicted Worker Protection Areas		• Use for worker protection and stay time guidance • Determine access control area

RDD Briefing Products: Summary (2)

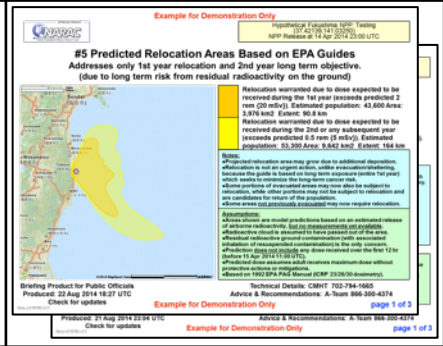
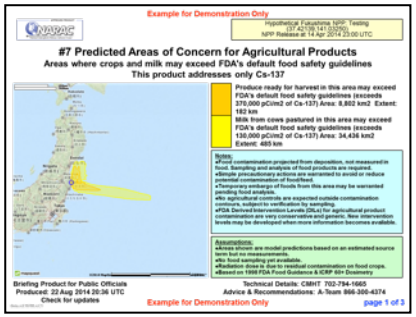
Time Phase	Product	Sample	Purpose
Early (hours to days)	Predicted Potassium Iodide Administration Areas		• Guidance for potassium iodide administration to reduce thyroid dose and long-term cancer risk from inhaled radioactive iodine • Based on FDA 2001 (age-dependent dose levels) publications
Intermediate (days to months) and Late Phases (months to years)	Predicted EPA/ DHS Relocation Areas		• Guide population relocation decisions • Assess avoidable additional long-term cancer risk, not acute radiation injury or death (2 Rem in first year and 0.5 Rem in second or later year)
	Predicted Areas of Concern for Agricultural Products		• Guide crop sampling • Guide crop/food control decisions • Predict areas where crops and milk may exceed FDA's food safety guidelines based on ground contamination

Note: ICRP60 dose conversion factors are used for radiological dispersal device products

NPP Briefing Products: Summary (1)

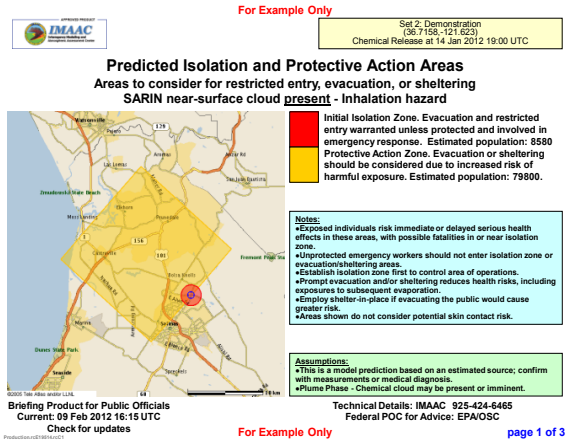
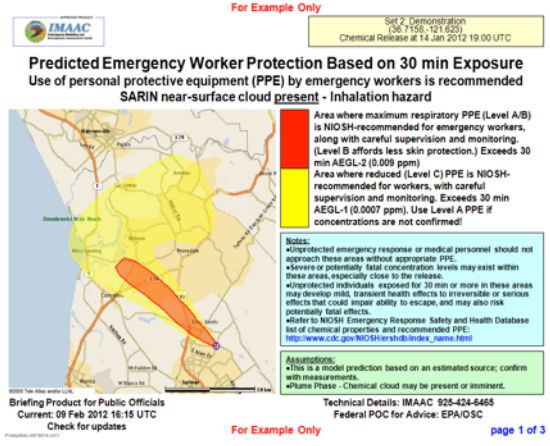
Time Phase	Product	Sample	Purpose
Early (hours to days)	Predicted EPA/ DHS Sheltering/ Evacuation Areas (TED or Thyroid CDE)		• Guide for sheltering and evacuation decisions based on most-limiting organ dose criteria • Assess avoidable additional long-term cancer risk (4-day Total Effective Dose Equivalent: 1-5 Rem and >5 Rem levels; or Adult Thyroid Committed Dose Equivalent: >25 Rem and 5-25 Rem levels)
	Predicted Worker Protection Areas		• Use for worker protection and stay time guidance • Determine access control area
	Predicted Potassium Iodide Administration Areas		• Guidance for potassium iodide administration to reduce thyroid dose and long-term cancer risk from inhaled radioactive iodine • Customer-specific guidance based on FDA 2001 (age-dependent dose levels) publications

NPP Briefing Products: Summary (2)

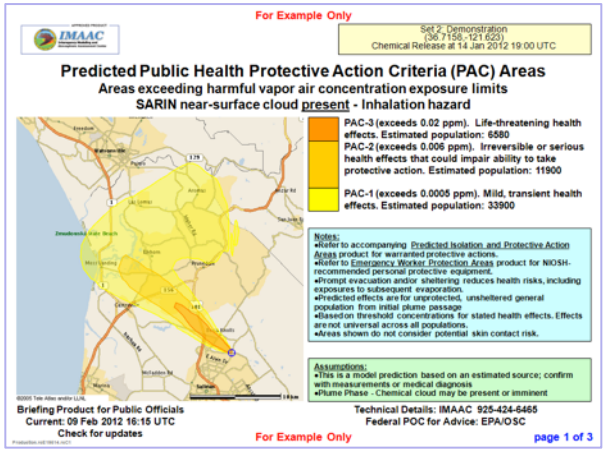
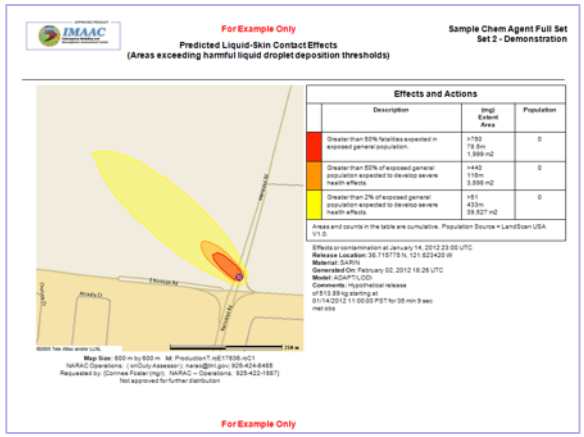
Time Phase	Product	Sample	Purpose
Intermediate (days to months) and Late Phases (months to years)	Predicted EPA/ DHS Relocation Areas		• Guide population relocation decisions • Assess avoidable additional long-term cancer risk (2 rem in first year, 0.5 rem in subsequent or later year and 5 rem over 50 years)
	Predicted Areas of Concern for Agricultural Products		• Guide for areas to sample crops • Guide crop/food control decisions • Predict areas where crops and milk may exceed FDA's food safety guidelines based on ground contamination

Note: ICRP26/30 dose conversion factors are currently used for nuclear reactor release products, apart from the FDA 2001 potassium iodide administration product which is based on ICRP 60

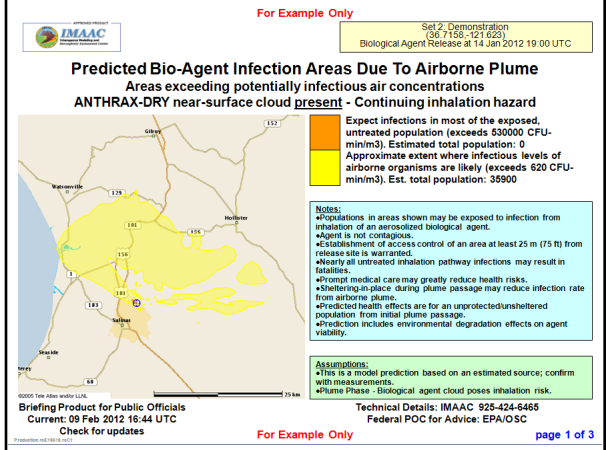
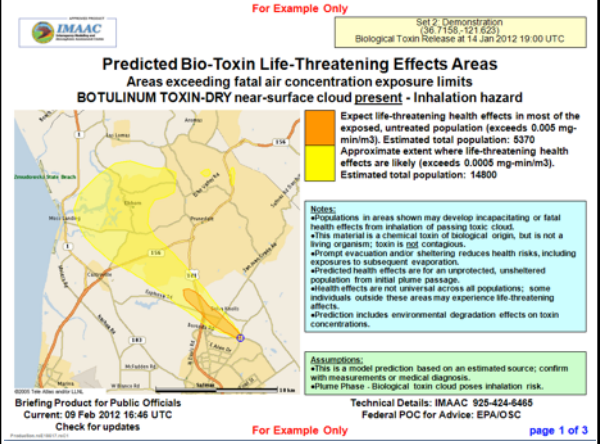
Chemical Briefing Products: Summary (1)

Chemical Product	Sample	Purpose	Uses
Predicted Isolation and Protective Action Areas		Guidance for decisions on actions to be taken to reduce potential health effects from inhalation for exposed population (sheltering or evacuation)	• Estimate locations at which access control areas should be considered • Inform response operations of potential geographic extent of response
Predicted Public Health Protective Action Criteria (PAC) Areas		Show potential health effects to the exposed general population from inhalation of the chemical	• Inform and prioritize emergency response operations

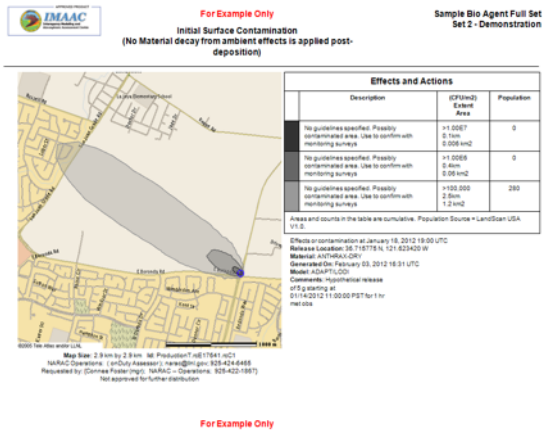
Chemical Briefing Products: Summary (2)

Chemical Product	Sample	Purpose	Uses
Predicted Emergency Worker Protection Based on *XX* min Exposure		Guidance for the use of personal protective equipment (PPE) by workers entering areas of concern	• Estimate areas where different PPE levels should be considered for rescue workers, <u>once concentrations have been confirmed</u> • Estimate PPE requirements for emergency response
Predicted Liquid-Skin Contact Effects (<u>Technical Product Only</u>)		Show potential health effects to the exposed general population from absorption of the liquid chemical through the skin	• Inform and prioritize emergency response operations based on additional potential skin contact hazard posed by chemical weapons agents

Biological Briefing Products: Summary (1)

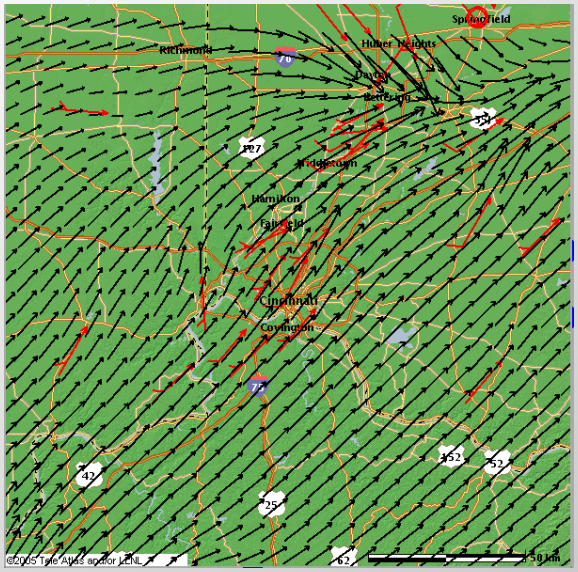
Biological Product	Sample	Purpose	Uses
Predicted Bio-Agent Infection Areas Due to Airborne Plume		Show potential infection areas and related health effects to the exposed general population from inhalation of the biological agent	• Inform and prioritize emergency response operations • Inform planning of treatment and longer-term care needed by infected population
Predicted Bio-Toxin Life-Threatening Effects Areas		Show areas with potentially life-threatening concentrations and related health effects to the general population from inhalation of the toxin	• Inform and prioritize emergency response operations • Inform planning of treatment and care needed for affected population

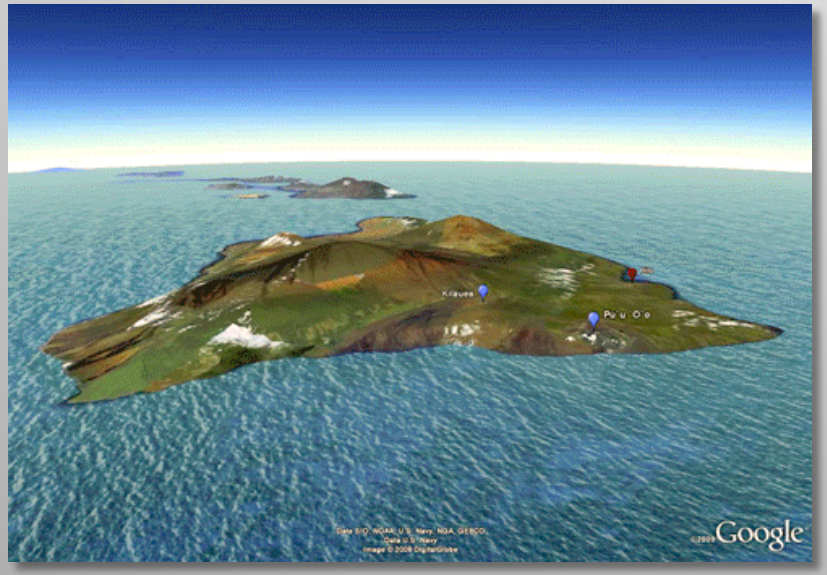
Biological Briefing Products: Summary (2)

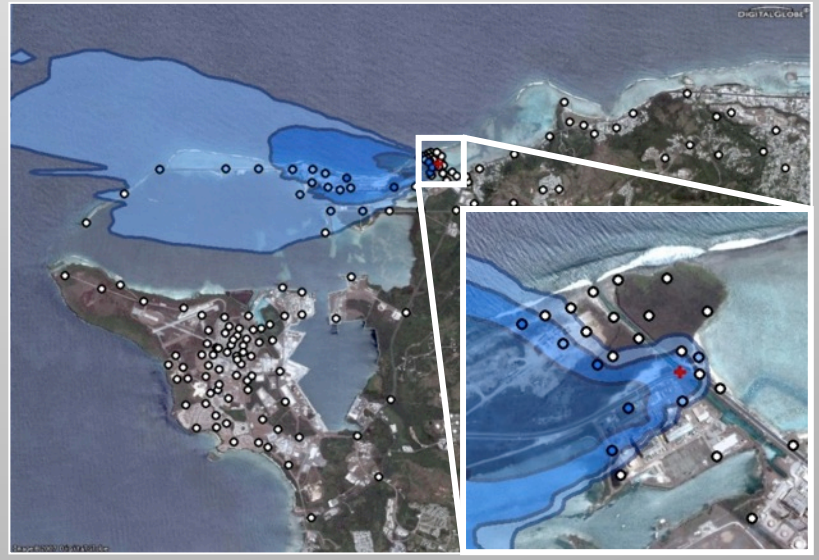
Biological Product	Sample	Purpose	Uses
Predicted Initial Surface Contamination (Technical Product Only)		Show areas of higher deposition concentrations of agent	• Inform emergency response operations and decontamination efforts • Compare predicted contaminated areas with instrument detection or analysis thresholds (if available) to build confidence in predictions for unmonitored areas • Conduct model-data comparison for source term reconstruction

Auxiliary Analyses Are Provided For Situational Awareness

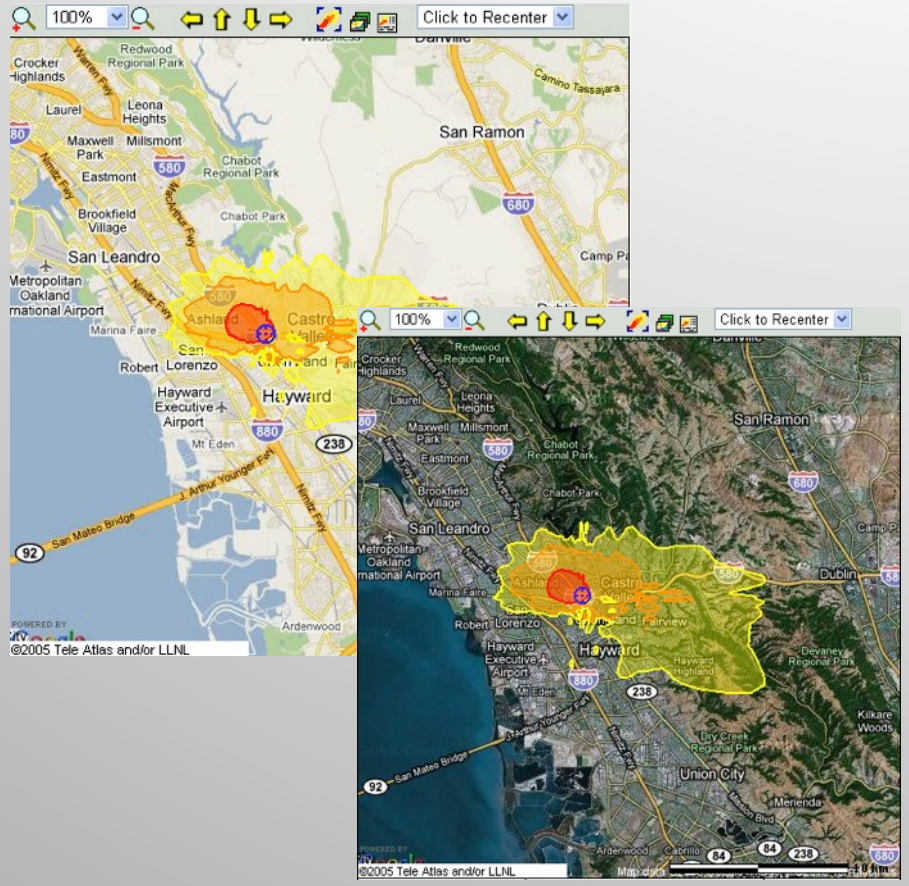
- Wind observations and fields
- Numerical weather prediction forecasts
- Field measurement data
- Deposition
- Time series, particle, or plume animations



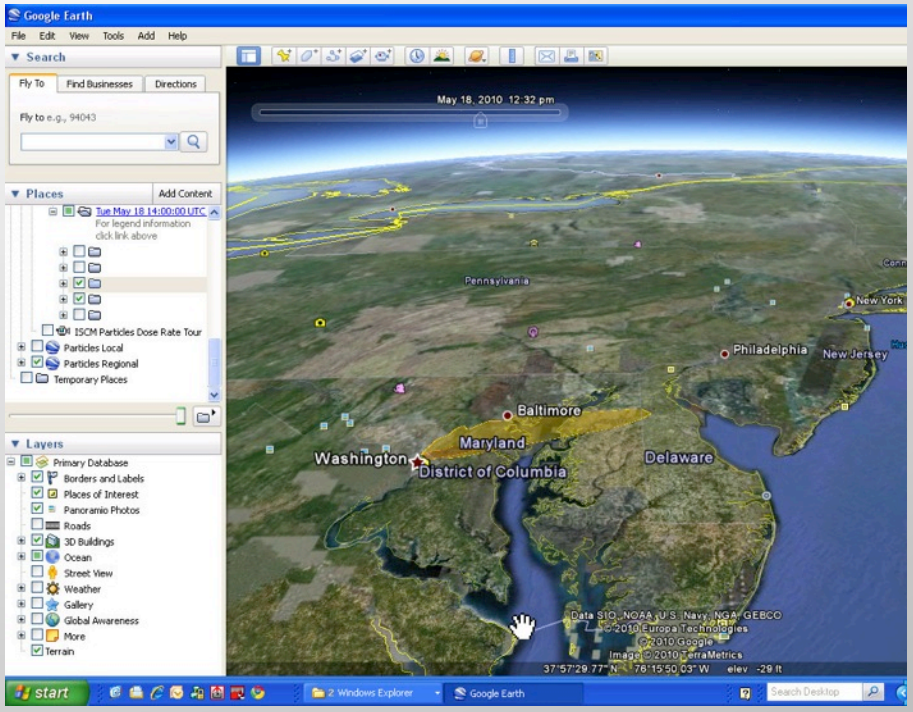




Products and Map Layers are Provided in Multiple Formats (PDF, ESRI, Google)



Worldwide Google Street and satellite displays



Export plumes to *Google Earth* (FEMA)

Available on NARAC/CM Web

PDF, PowerPoint, HTML/XML, JPG/PNG graphics,

ESRI Shape and Google Earth KMZ GIS files with plume areas

Response to Real World Events

Examples

Lawrence Livermore National Laboratory

National Atmospheric Release Advisory Center

NARAC

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC. The Department of Homeland Security sponsored part of the production of this material.

LLNL-PRES-609358-Rev1

NARAC Responds to Real-World Emergencies

April 19-20. 2004
Queen City Barrel
warehouse fire, Cincinnati

May 25-26,2004
chemical warehouse fire
in Conyers, GA

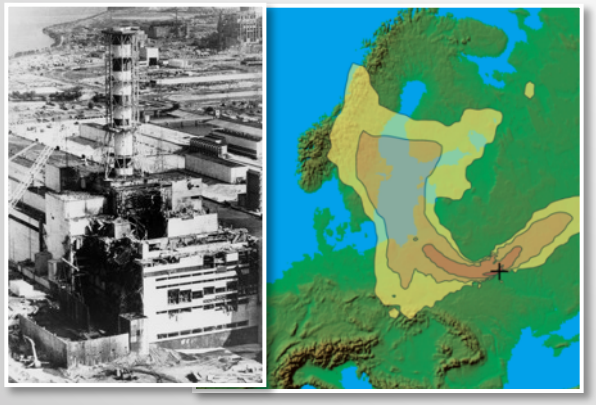
July 28, 2005 solvent
plant industrial fire in
Ft. Worth, TX

Jan 16, 2007 train
derailment fire in
Sheperdsville, KY

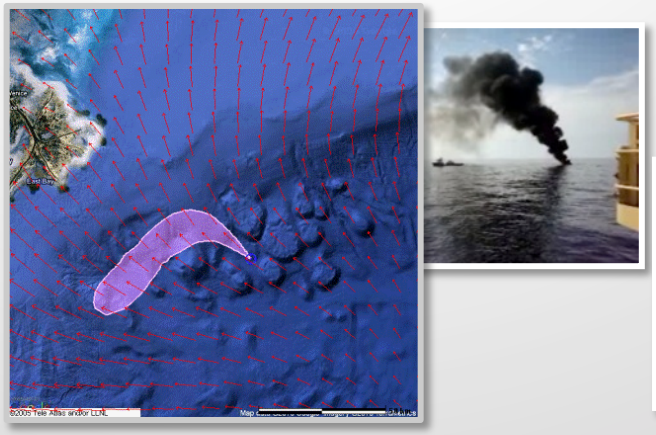
July 17, 2007
Barton solvents fire
in Valley Center, KS

April 7-10, 2008 Kilauea,
Hawaii sulfur dioxide
releases

NARAC Responds to Real-World Emergencies

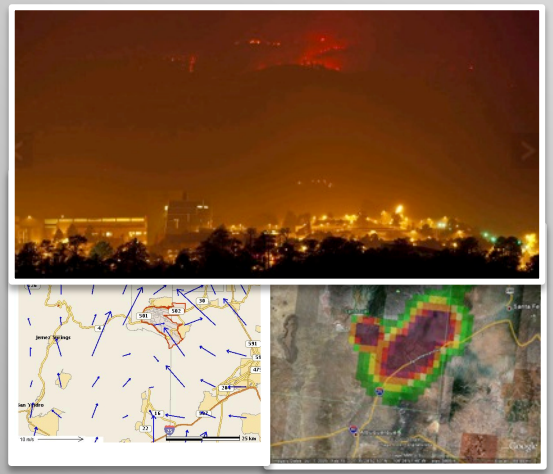


April 26, 1986
Chernobyl nuclear power plant accident



May-June, 2010 in-situ burns
Deepwater Horizon, Gulf of Mexico

March 11 – May 28, 2011
Fukushima Dai-ichi Nuclear Power Plant accident



June 26 - July 1, 2011
Las Conchas Wildfire, NM

November 26, 2011
Mars Science Laboratory
Launch, Cape Kennedy, FL

February 14-20, 2014
Waste Isolation Pilot Plant
radioactivity venting

NARAC Worked with DOE/NNSA to Produce Estimates of On and Off-Site Impacts of WIPP Release

- Underground release of Plutonium and Amerecium isotopes from New Mexico Waste Isolation Pilot Plant (WIPP), New Mexico
  - Stack and environmental air monitoring system detected release starting on February 14, 2014
  - WIPP workers exposed to radiation during initial release
  - NARAC/CMHT activated by DOE the following week to perform analyses of release
- NARAC plume model simulations used to estimate on and off-site dose and contamination levels
  - Detailed 15-minute average meteorological data provided by the site
  - Source terms developed by WIPP from stack emission data
- Initial analysis indicated that public protection guide levels would not be reached outside the site
- Re-analysis using latest data on emission rates (and air sampler) data from WIPP to be completed in 2015
- NARAC / CMHT products cited in DOE WIPP information provided to the public about the event

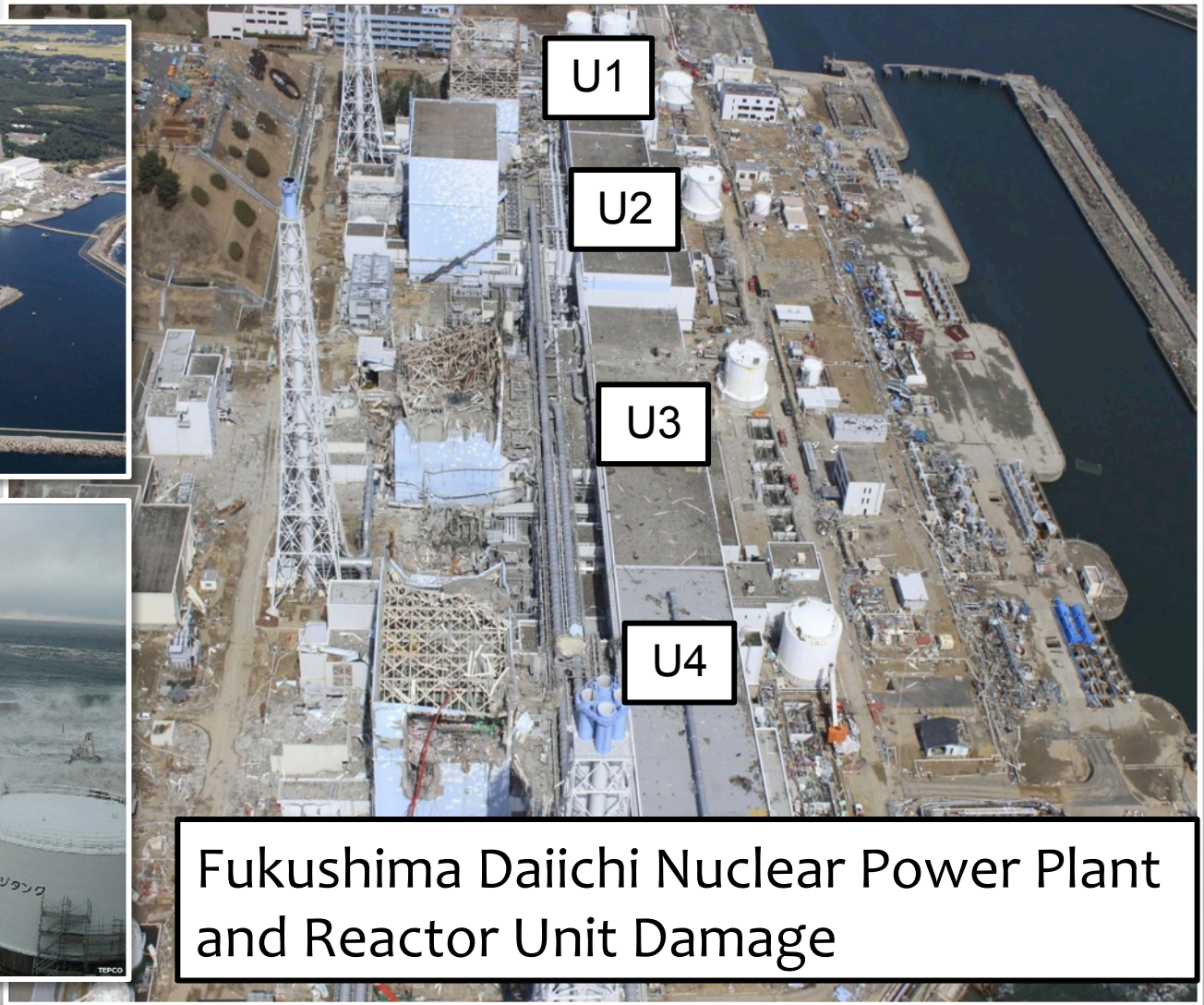
Fukushima Nuclear Power Plant Accident

March 11 – May 28, 2011

National Atmospheric Release Advisory Center

NARAC

Fukushima Daiichi Units 1-4 Were Damaged by the Tsunami Following the Tohuku Earthquake

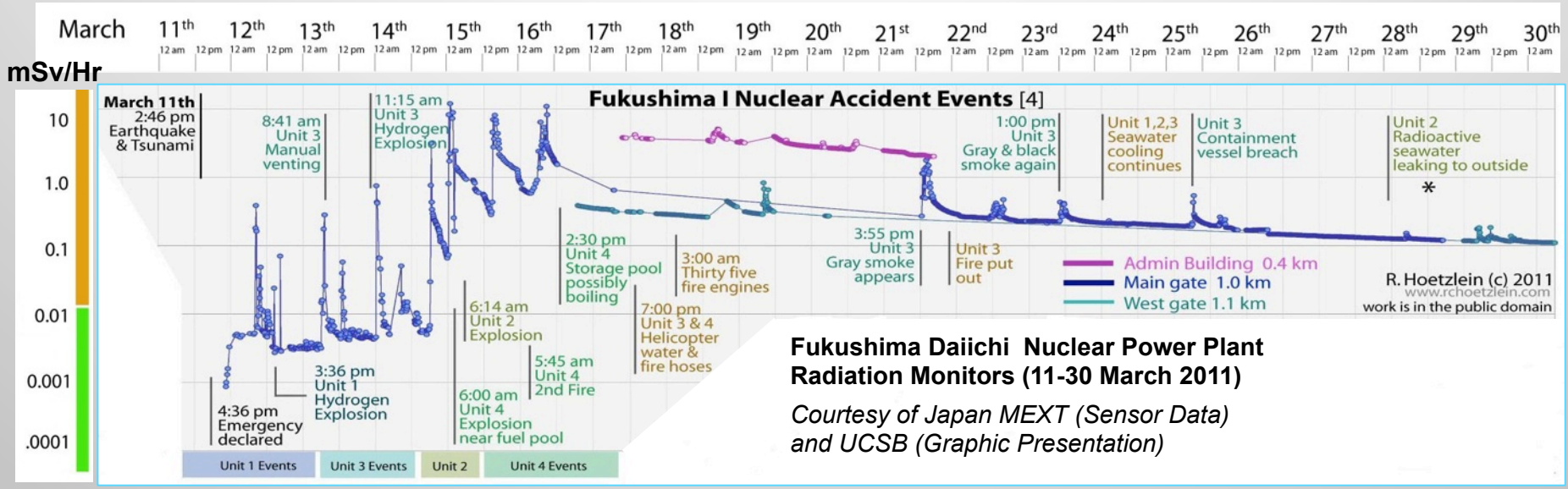


Fukushima Daiichi Nuclear Power Plant and Reactor Unit Damage

DOE/NNSA Activated Personnel to Respond to the Fukushima Dai-ichi Accident

- DOE/NNSA mission: Assess the consequences of releases from the Fukushima Dai-ichi Nuclear Power Plant
- DOE/NNSA deployed personnel and home teams
  - Predictive modeling
  - Air/ground monitoring and sample collection
  - Laboratory sample analysis
  - Dose assessment
  - Data interpretation

Time Progression of Fukushima Daiichi Accident and DOE/NNSA Response



Fukushima Daiichi Nuclear Power Plant Radiation Monitors (11-30 March 2011)

Courtesy of Japan MEXT (Sensor Data) and UCSB (Graphic Presentation)

March / April / May / June / July

Reactor release, transport, deposition, resuspension (ongoing)

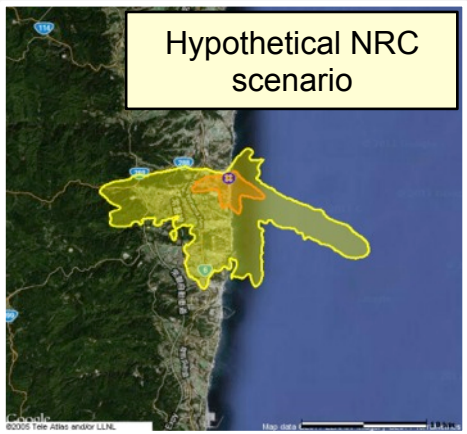
DOE Home Team Ops (Plume Modeling, Rad Assays, Dose)

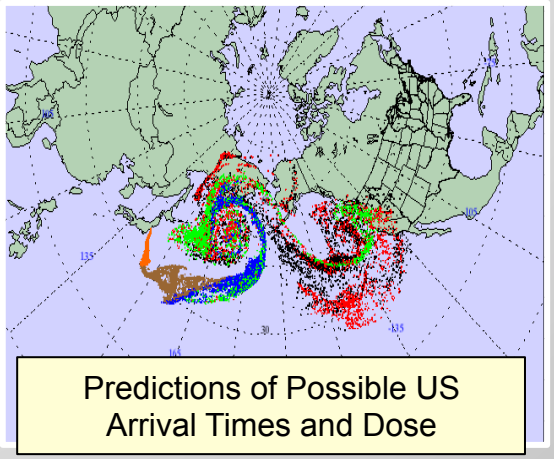
DOE Field Ops (Air, Ground)

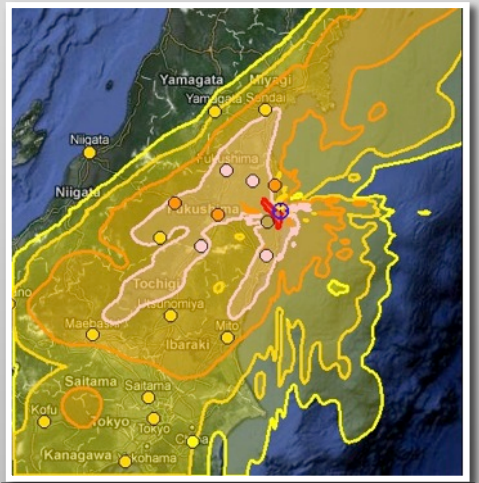
DOE After Action

NARAC Supported A Variety of Requests During the Fukushima Response (March 11-May 28, 2011)

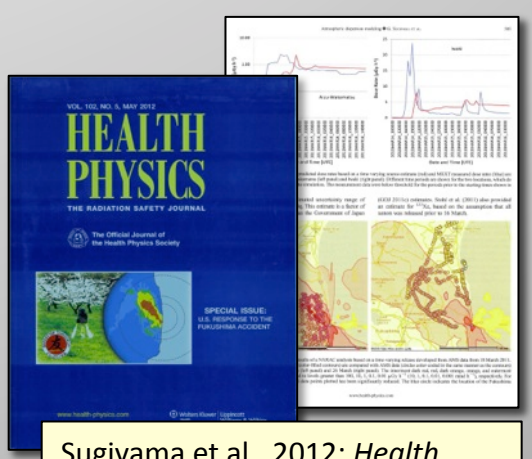
- Daily weather forecasts to support mission planning and situational awareness
- Estimates of possible dose in Japan based on hypothetical U.S. Nuclear Regulatory Commission radionuclide release scenarios to support protective action planning for U.S. citizens in Japan
- Predictions of possible arrival times and dose levels at U.S. locations
- Source term estimation and plume model refinement based on field data




Predictions of Possible US Arrival Times and Dose



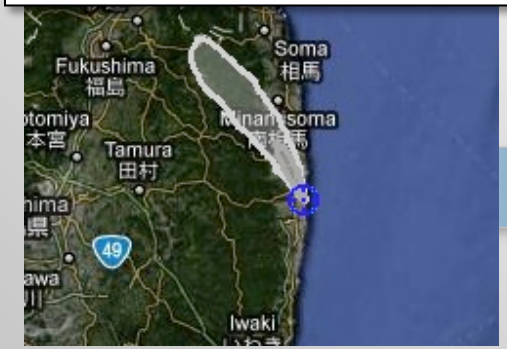
Source estimation and model refinement



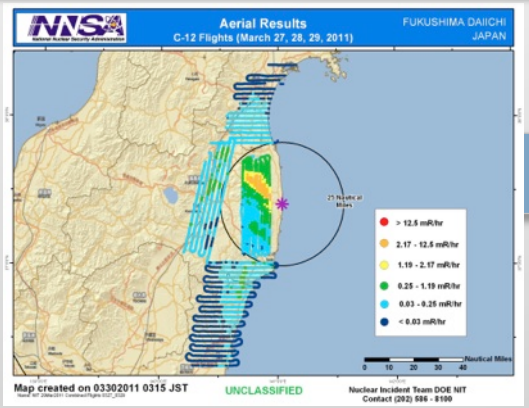
Sugiyama et al., 2012: *Health Physics*, 102, p 493–508

Source Terms Estimation and Refinement of Dispersion Simulations Were Based on Radiological Measurements

Initial Model Predictions Guide Measurement Surveys

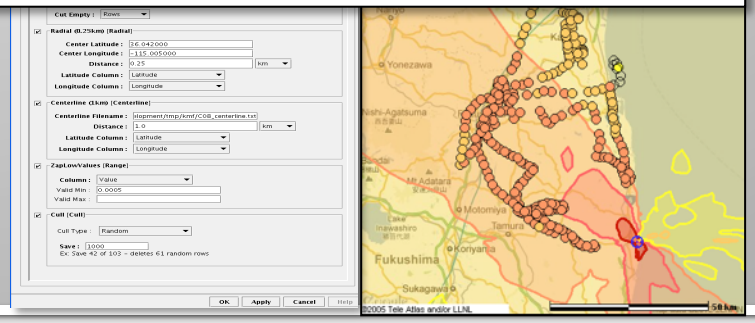


Measurement surveys and sensor data, e.g., DOE AMS, DOE, DoD, Japanese field data

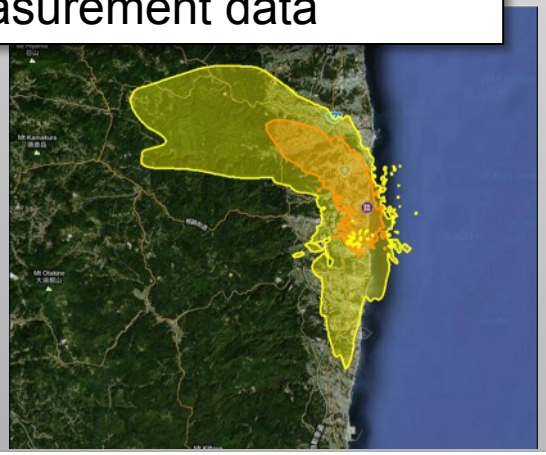


Measurement Data transferred electronically to LLNL/NARAC

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

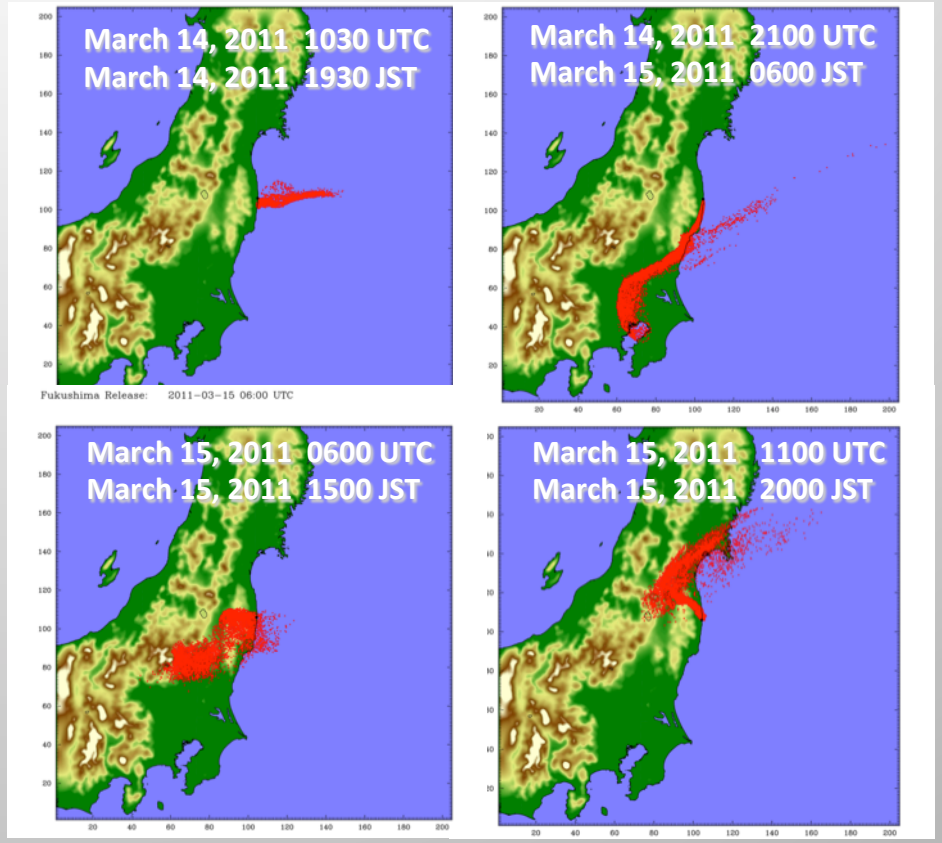


Updated predictions using measurement data



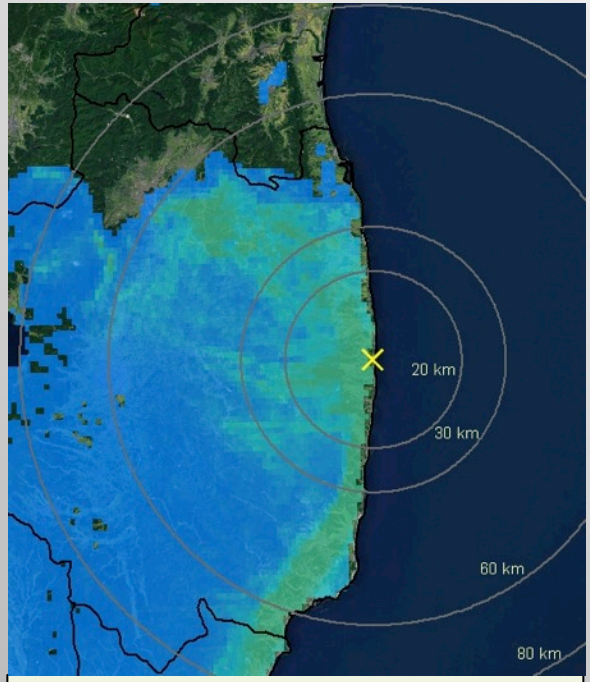
Rapidly Changing Meteorological Conditions Presented a Significant Modeling Challenge

- Winds primarily off-shore until March 14 – March 16 when wind direction rotated clockwise apart from a brief period on March 12
- Winds remained primarily off-shore until March 21
- Initial NARAC forecasts captured overall pattern of winds and occurrence of precipitation
- Subsequent higher resolution (3-km) Weather Research and Forecasting Four-Dimensional Data Assimilation (WRF FDDA) simulations provided increased accuracy in modeling the timing of the wind shifts and precipitation patterns

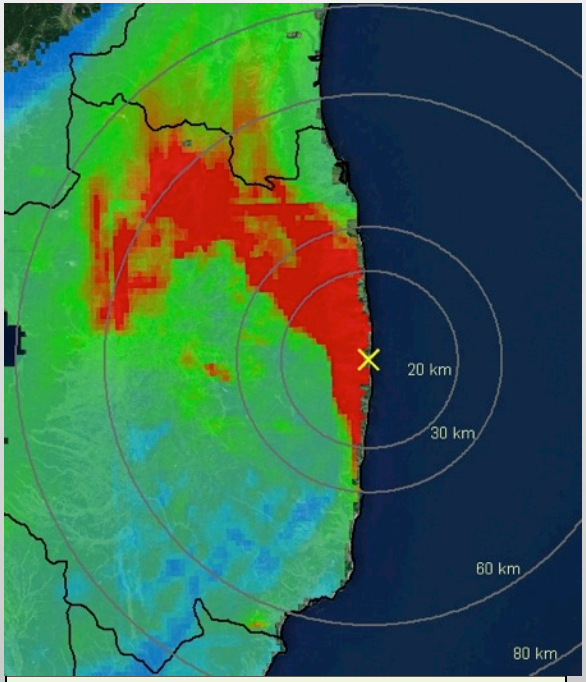


Particle animation for hypothetical constant release rate from March 14 00 UTC - March 16 00 UTC

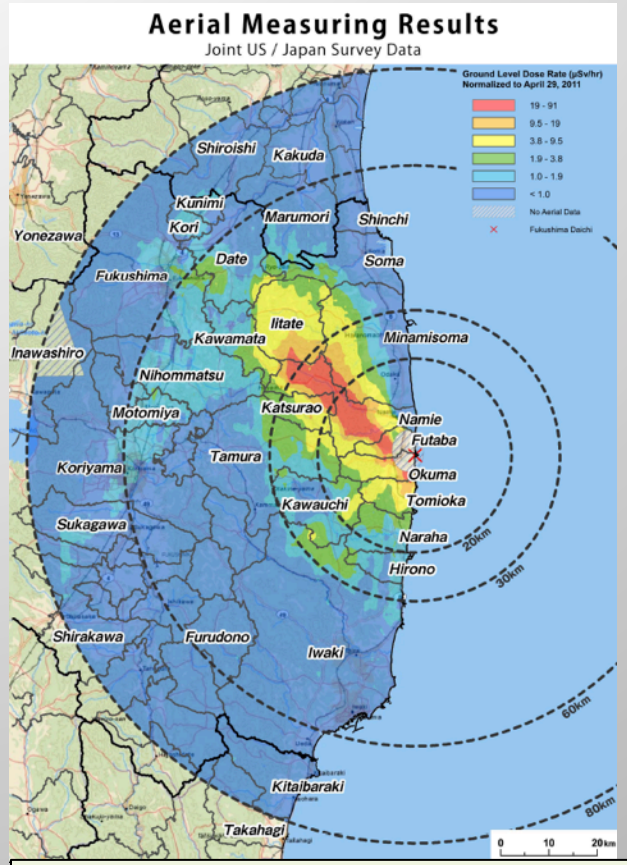
Precipitation Scavenging Was Key to Realistic Predictions of Ground Deposition



Predicted relative ground deposition pattern with dry deposition, but no precipitation scavenging



Predicted relative ground deposition pattern with precipitation scavenging (spatially and temporally-varying)



Measured AMS groundshine dose rate pattern

NARAC Conducted a Range of Source Reconstruction Analyses During the Response

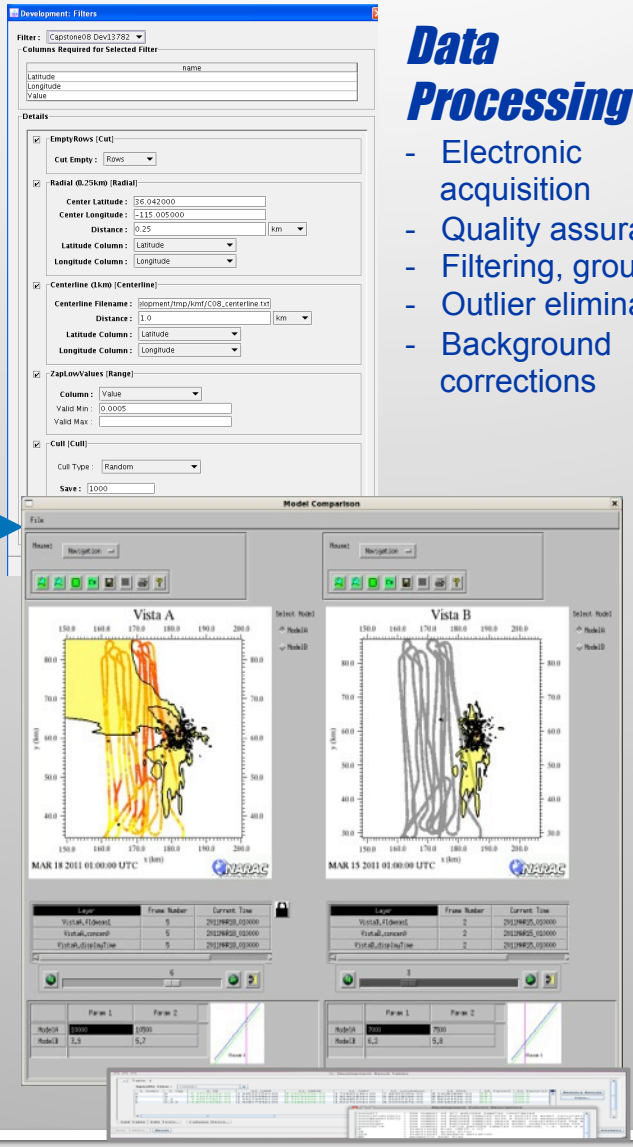
- Time-varying releases from multiple sources treated as one combined source
- Simulation of key radionuclide contributors to dose using ratios from lab analysis: ^{133}Xe:^{131}I: ^{132}I: ^{132}Te:^{137}Cs:^{134}Cs
  - 100:20:20:20:1:1
  - 100:10:10:10:1:1
- Meteorological analyses developed from:
  - Local meteorological data
  - Numerical weather prediction and WRF FDDA simulations at 1, 3, 5, and 15-km resolutions
- Optimization of overall fit of model results and data paired in space and time using statistical measures (e.g., percentage of values with factor R, bias, etc.)

NARAC Source Term Estimation and Model Refinement Were Performed Using Data Processing and Analysis Tools

Monitoring / Field Data

- Multi-agency data / databases
- Electronic data acquisition (standardized and custom formats)

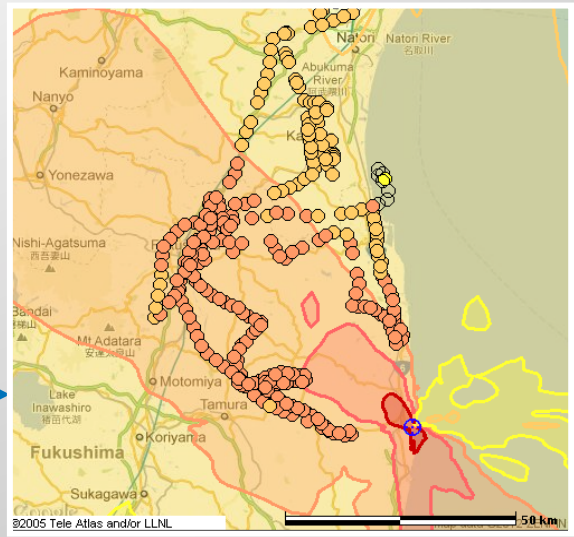
Aerial Measurement - Gamma Spectroscopy
In situ field assays – Gamma Spec, Alpha/Beta Survey, Dose Rate
Air Filters (paper, charcoal) – Gamma Spec, Alpha/Beta Counters, Lab Analysis
Soil and Soil Cores – Gamma Spec, Lab Chemistry



Data Processing

- Electronic acquisition
- Quality assurance
- Filtering, grouping
- Outlier elimination
- Background corrections

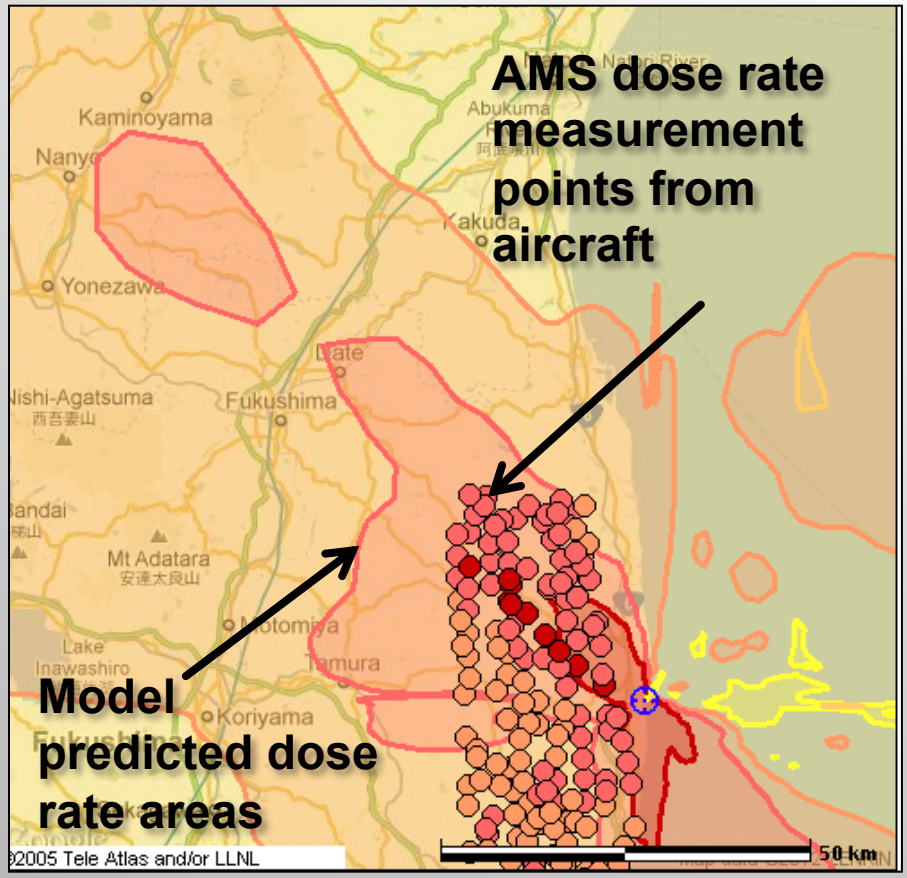
Data-Model Comparisons Refined Model Predictions



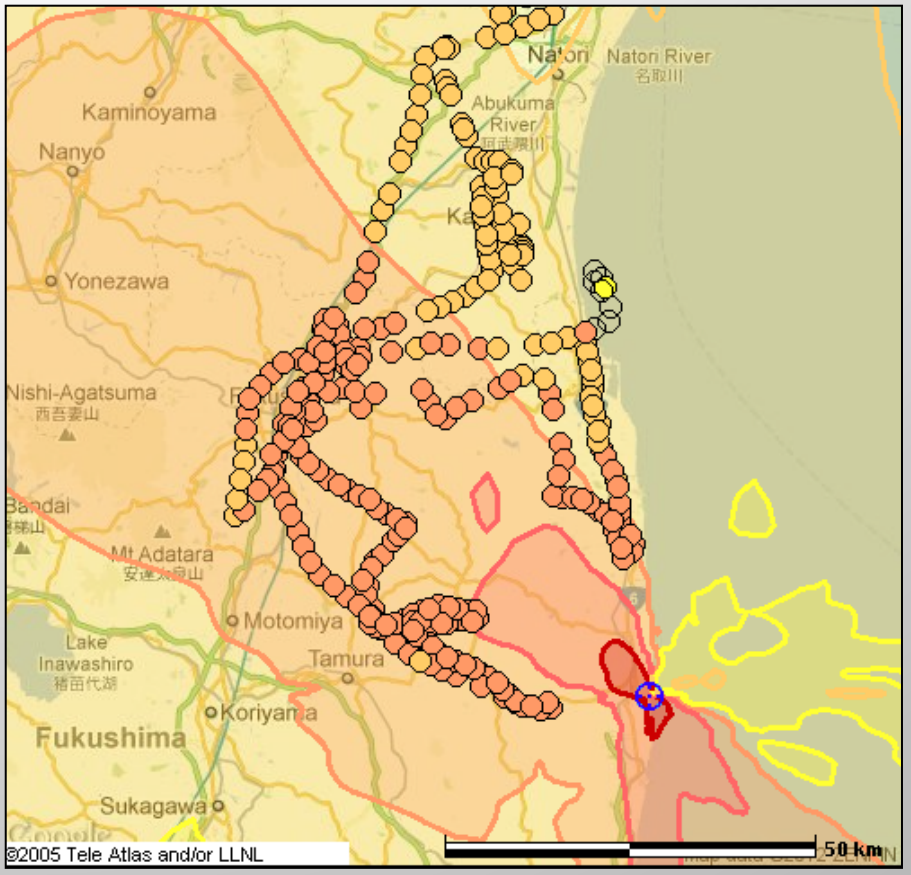
Graphical/Statistical Data-Model Comparison Tools

- Data-model comparisons paired in space time
- Statistical metrics (e.g. bias, [geometric] variance, standard deviation, root mean & normalized mean square area, factor of R)
- Measurement and model map displays
- Graphical model-data displays
- Source strength scaling based on average measured/computed ratio

NARAC ADAPT/LODI Simulations Compared to U.S. DOE Aerial Measuring System (AMS) Data



NARAC modeled dose rate levels overlaid with March 18 AMS data. Meteorology based on Japanese weather observations

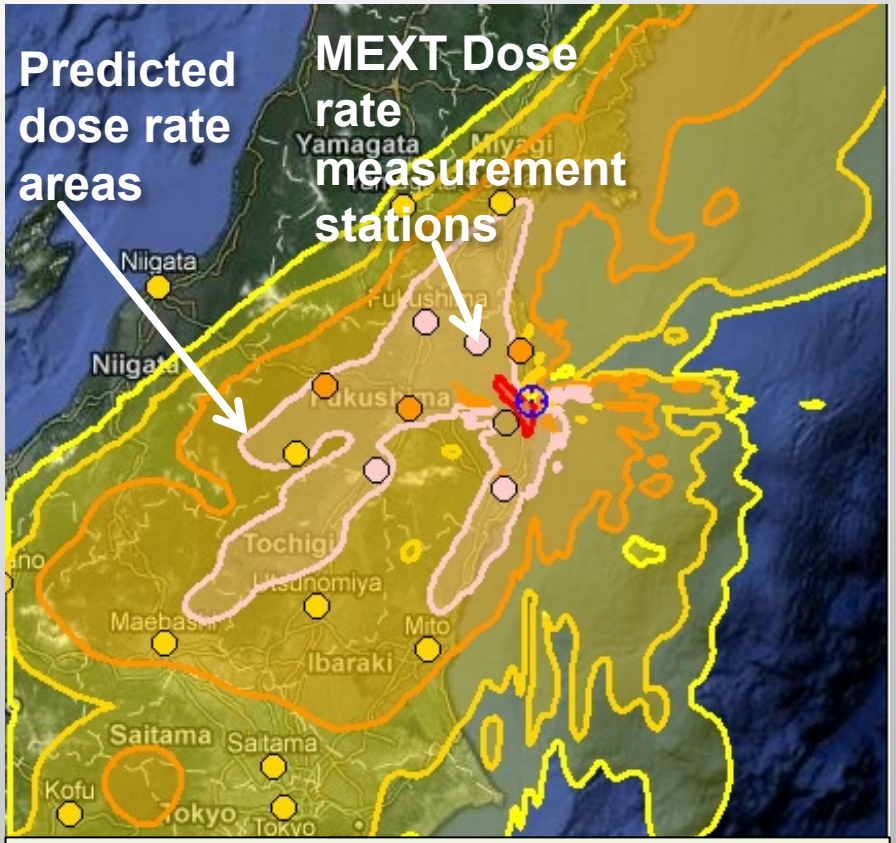


NARAC modeled dose rate levels overlaid with March 26 AMS data (data not used in source estimation process).

Dose rate levels greater than 100, 10, 1, 0.1, 0.01 μGy h^{-1} (10, 1, 0.1, 0.01, 0.001 mrad h^{-1}) are shown as dark red, red, dark orange, orange, and yellow contours respectively

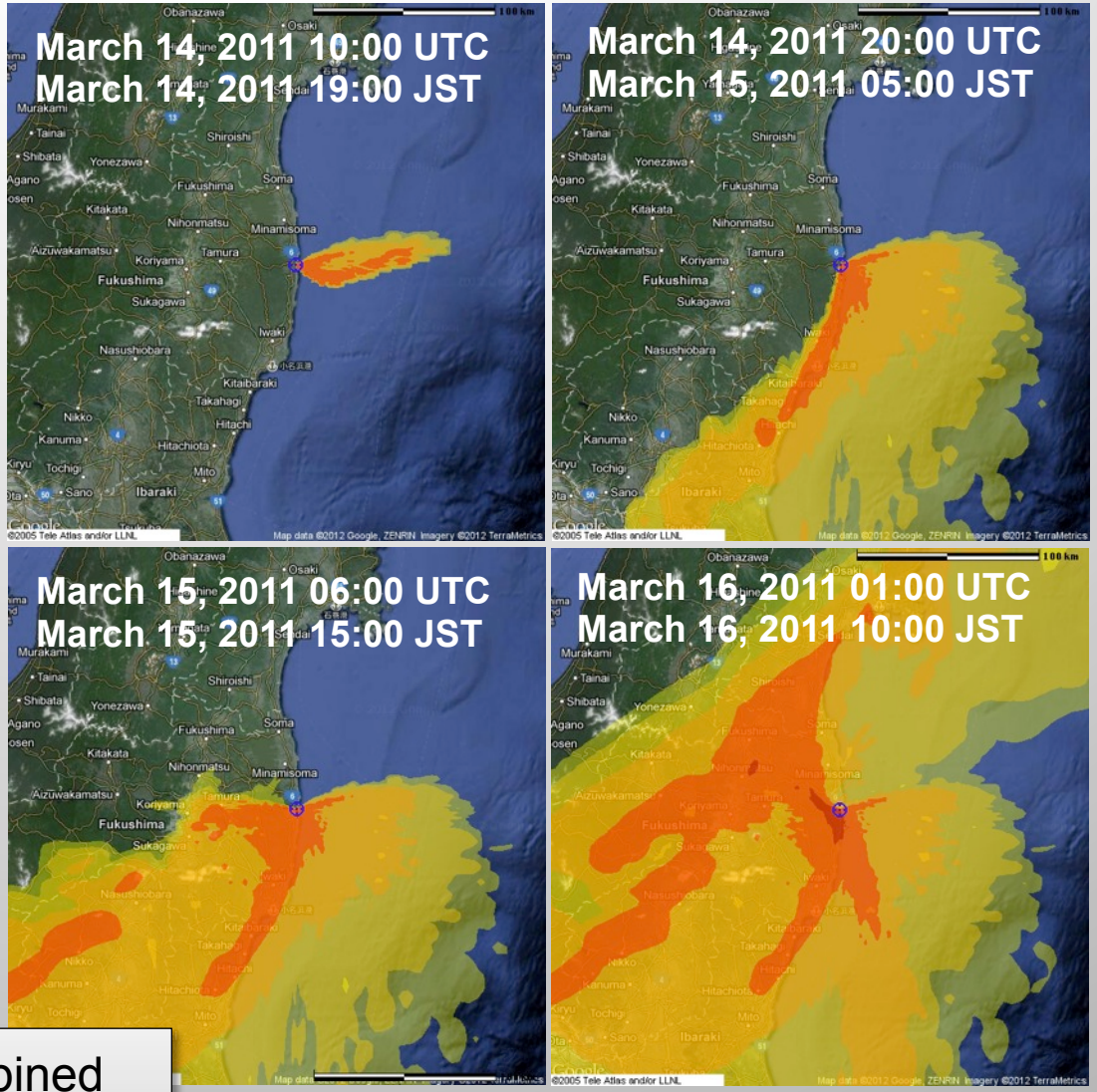
NARAC ADAPT/LODI Source Reconstruction Based on MEXT Dose Rate Data for March 14-16

- NARAC "baseline" simulation
  - 3-km WRF FDDA model meteorology
  - Uniform release rate
  - Cs-134, Cs-137, I-131, I-132, Te-132, Xe-133 in relative activity ratios of 1:1:20:20:20:100
- Good agreement with AMS data collected on March 18 (not shown), that was *not* used in this source estimation analysis
- "Baseline" release estimate for March 14-16 release period
  - Cs-137 3.7×10^{15} Bq (1×10^{5} Ci)
  - I-131 7.4×10^{16} Bq (2×10^{6} Ci)



NARAC model predicted dose rate contours compared to MEXT data for March 15,1800 UTC. Contours and data circles color coded to show levels: 120μGy h^{-1} (red), 4μGy h^{-1} (pink), 0.4μGy h^{-1} (orange), 0.04μGy h^{-1} (light orange) and 0.004μGy h^{-1} (yellow).

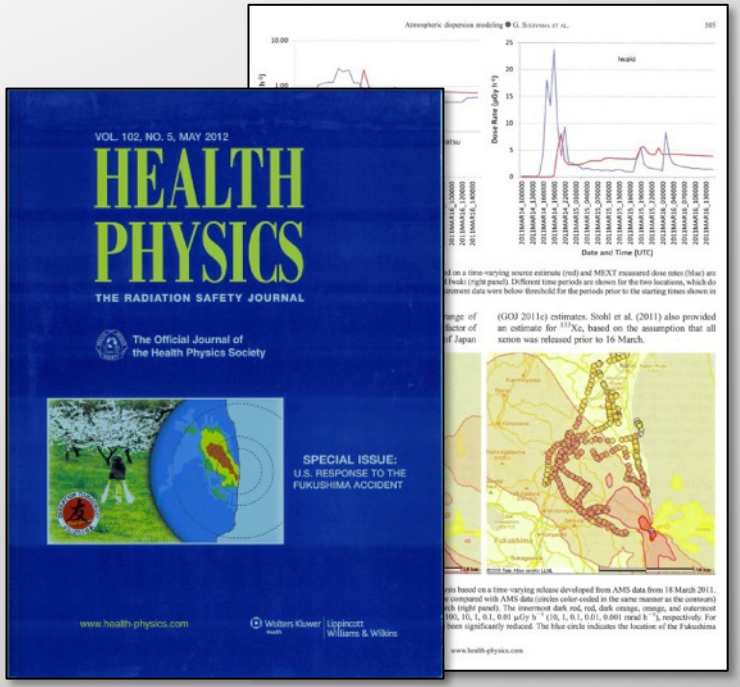
NARAC Simulations of Total External Dose Rate Show Combined Effects of Airborne and Ground Contamination



NARAC animation of combined predicted ground shine and air immersion dose rate

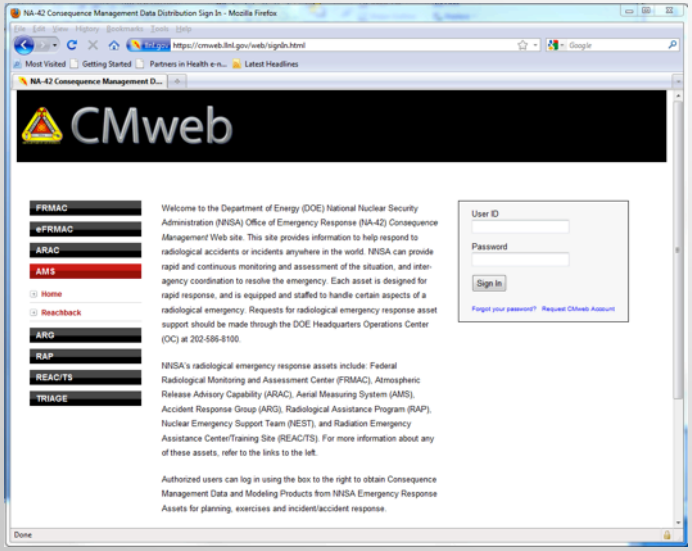
NARAC Estimates of Radioactivity Release Quantities Are Consistent with Other Published Estimates

- NARAC estimates of release quantities varied within a factor of approximately three from the “baseline” case for the same radionuclide mix
- NARAC radioactivity release estimates consistent with other published estimates
  - Chino et al. 2011; GOJ 2011a, 2011b, and 2011c; Stohl et al. 2011
  - Release estimates use different source reconstruction methodologies, meteorological models, types of radiological data, and reactor condition assumptions.
  - NARAC and other cited estimates agree within a factor of approximately six
- Source estimates for off-shore-wind times are significantly more speculative due to limited regional radiological monitoring data (only long-range data available)



Sugiyama, G; Nasstrom, J; Pobanz, B; Foster, K; Simpson, M; Vogt, P; Aluzzi, F; Homann, S (2012) Atmospheric Dispersion Modeling: Challenges of the Fukushima Daiichi Response, *Health Physics*, 102, p 493–508.

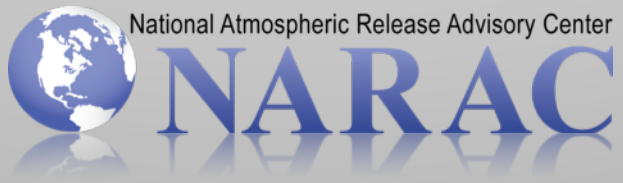
NARAC and Other LLNL Staff Invested More than 5000 Person-Hours During the Fukushima Response



- NARAC-hosted CMweb system provided 24/7 access to information throughout the response
  - Used to store and share information with DOE and the supported interagency community
  - Model predictions (300+ analyses and 115 shared products)
  - Radiological measurement data
  - Mapped data products
  - Reports
  - Status logs

DOE/NNSA Principal Deputy Administrator Neile Miller (in yellow) with the NARAC team during the Fukushima response

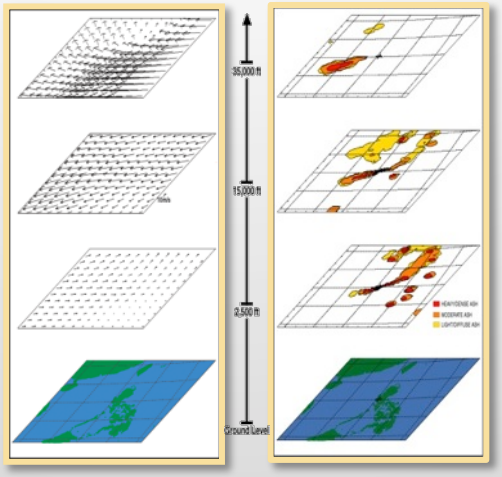
Natural Hazards



NARAC Responds to Volcanic Eruptions In Special Circumstances

Mt. Pinatubo (June 1991)

- 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

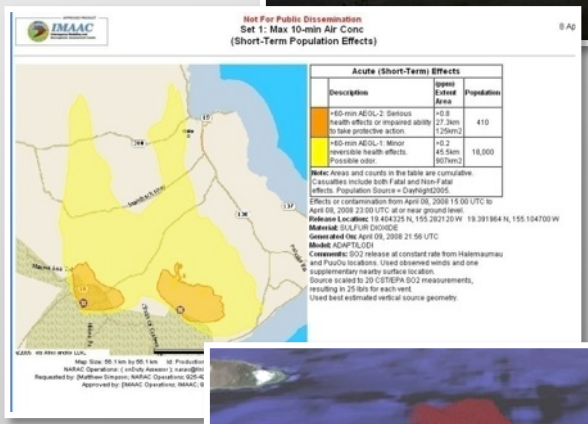


Eyjafjallajökull Volcano eruption, Iceland (April, 2010)

- NARAC provided simulations to the Iceland Civil Defence Authorities and Meteorological Office under DOE/IXP auspices
- Example: 144-hour forecast of evolving local, near ground-level airborne and deposited ash concentrations using information provided by Icelandic government agencies on measured ash particle sizes

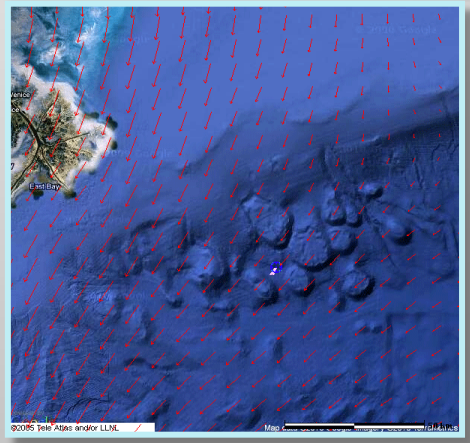
NARAC Responded to the Kilauea HI Volcanic Eruption (April 7-11, 2008) Under IMAAC Auspices

- EPA On-Scene Coordinator requested IMAAC activation due to potential health impacts from SO_2 (sulfur dioxide) releases from two volcanic vents, Hawaii
- Coordinated with DHS, EPA, DTRA, NOAA, Civil Support Teams (CST), National Park Service, USGS and State/County of Hawaii
- Initial calculation based on USGS estimate of release amount and wind forecast from the Honolulu Weather Forecast Office
- Additional analyses based on local observations and high-resolution weather forecasts
- Preliminary measurement-model analyses based on CST field data
- 24-hr high-resolution forecasting of winds and plumes
- Utilization of both standard NARAC operational tools and new simulation capabilities

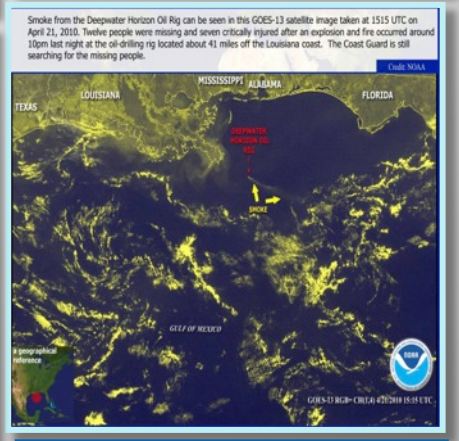


NARAC/IMAAC Provided Plume Simulations for the Deepwater Horizon Oil Spill, Gulf of Mexico

- LLNL simulated the original fire on the Deepwater Horizon oil platform on April 22, 2010 at the request of the Department of Homeland Security
- LLNL produced 24-hour forecasts of the potential smoke concentrations from planned oil slick burns in April 27 – May 18 , 2010
  - Simulations requested by the federal Scientific Support Coordinator for the Deepwater Horizon incident
  - Results provided to the National Oceanic and Atmospheric Administration and the Environmental Protection Agency.
  - Analysis indicated that air quality impacts from the small *in-situ* burns would not affect operations farther than a few km downwind



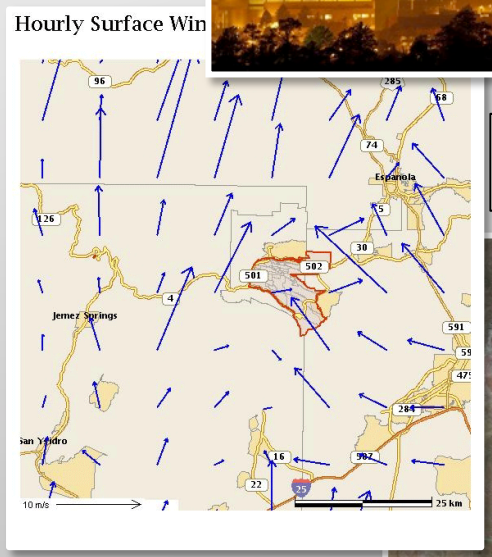
NARAC animation of potential particulate concentrations from controlled burns



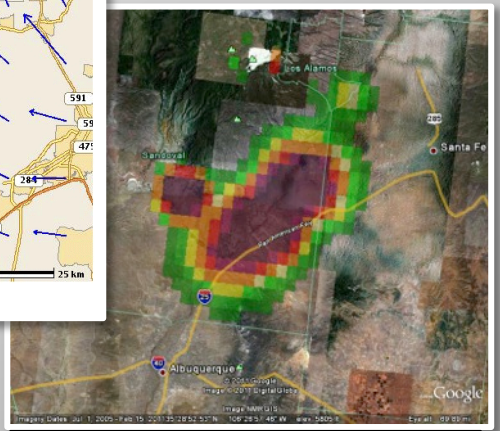
Satellite picture of smoke plume from oil platform fire 2010 April 21

NARAC Was Activated by DOE for the Las Conchas Wildfire (June 26 - July 1, 2011)

- NARAC activated by DOE on June 26 due to the proximity of the wildfire to Los Alamos National Laboratory (LANL)
- Provided twice-daily high-resolution regional wind forecasts to LANL, DOE, EPA, and US Fire Service (USFS)
- Collaborated with LANL Emergency Operations to ensure that radiological source terms would be available if fire affected key LANL areas (no simulations were needed)
- Provided NARAC 3-km weather forecasts to USFS for use on an experimental basis
  - Used to issue a smoke visibility warning Verified by USFS on July 1
- Worked with DOE NA-42 to coordinate the shipment of 9 portable real-time radiological monitors with satellite data feed to NARAC from the NASA Kennedy Space Center (monitors not deployed as danger to LANL facilities passed)



NARAC wind forecast for June 29-30



USFS visibility warning for July 1 based on NARAC 3-km forecast verified by USFS

Queen City Barrel Chemical Warehouse Fire

Local Integration of NARAC with Cities (LINC)

National Atmospheric Release Advisory Center

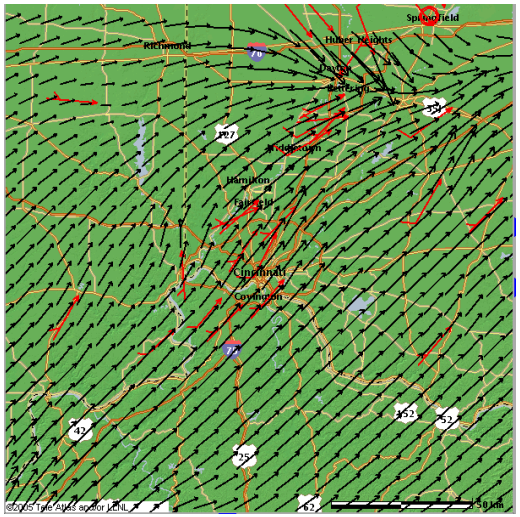
NARAC

NARAC Responded to the Queen City Barrel Chemical Warehouse Fire in Support of the City of Cincinnati

- 7:25pm EDT. Massive fire begins at chemical storage facility (50000 drums)
- Cincinnati Fire, Health, and Environmental Departments immediately concerned about potential health effects from unknown chemicals in the smoke
- 7:45pm EDT. Cincinnati activates and requests LLNL assistance
- 7:54 pm EDT. NARAC distributes initial predictions via Web
- 8:00pm EDT. Cincinnati uses initial predictions to guide approach routes, air sampling, and shelter-in-place recommendations

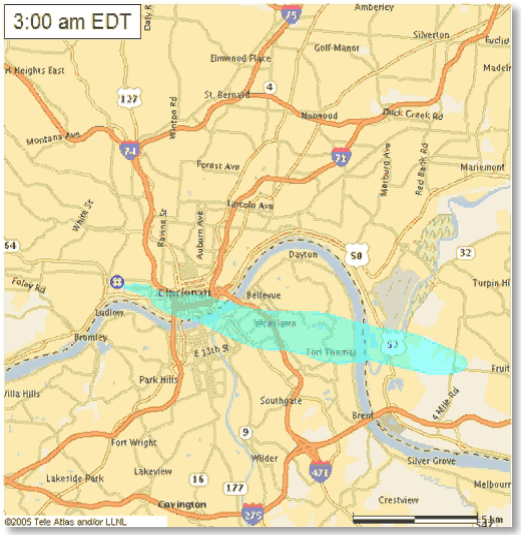
Queen City Barrel chemical warehouse fire
Evening Local News
August 19, 2004

NARAC Worked with Cincinnati Responders to Develop Accurate Impact Predictions



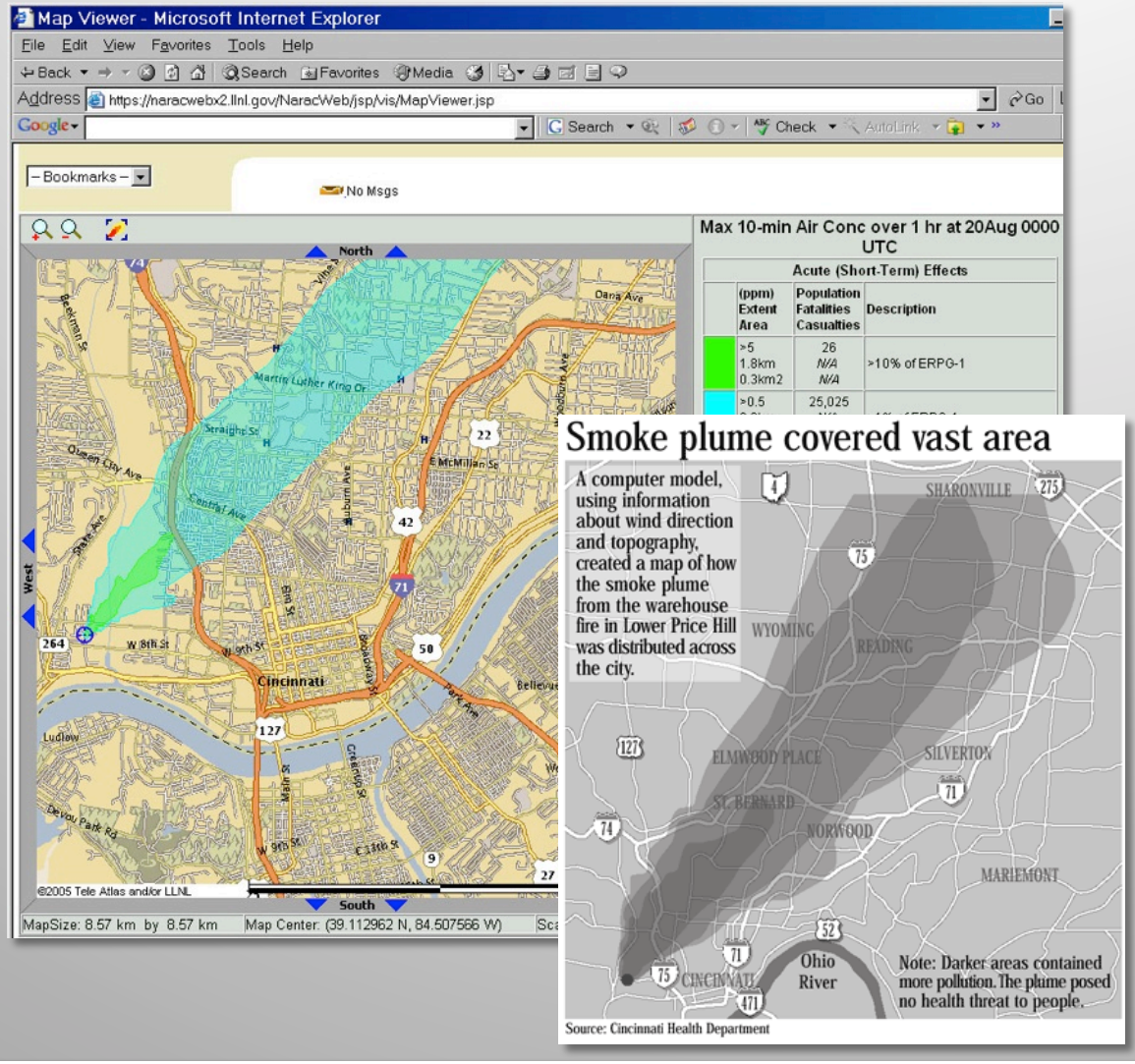
Surface observations (red arrows) and model wind pattern (black vectors) at time near the beginning of the fire

Winds shifts due to passage of a front, caused plume to change direction (initial northeast heading veering later to the southeast)



- Analysis of local and regional weather observations
- Selection of NOAA National Weather Service ETA model as the best forecast data
- Changing weather conditions communicated to Cincinnati, Ohio, and EPA incident command and responders

NARAC Worked with Cincinnati Responders to Develop Accurate Impact Predictions



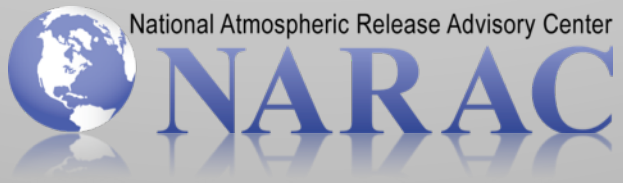
8:00pm – 12:00am

- Analysis of chemical inventory to estimate emission rate
- Maps of acute health impacts
- Updated plume maps based on air sampling, photographs, eye witness accounts

9:00am (next day)

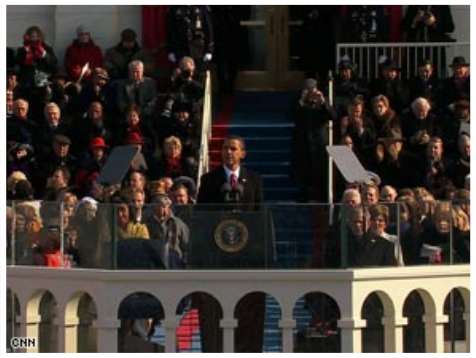
- Cincinnati releases plots based on AC analyses and briefs plots on TV

Event Support



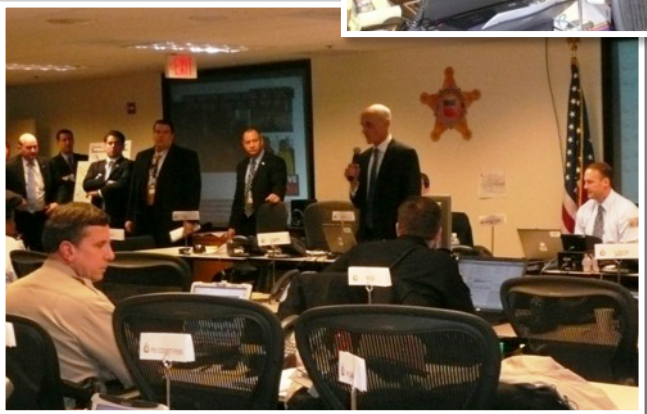
NARAC Supported the 2009 Inaugural Events Under IMAAC Auspices (January 17-20, 2009)

- NARAC/IMAAC engaged in three months of pre-event coordination in preparation for the Inauguration
- LLNL deployed an NARAC/IMAAC liaison to the US Secret Service-led Multi-Agency Communications Center (MACC)
- NARAC/IMAAC established excellent working relationships with federal, state, and local agencies
- NARAC/IMAAC Operations at LLNL stood up for extended hours and participated in plume modeling exercises
- DHS IMAAC Director expressed his appreciation and thanked NARAC/IMAAC Operations for its outstanding support
- DHS Secretary Chertoff thanked the MACC for the highest level of preparedness for any NSSE on his watch



Inauguration of President Obama January 20, 2009

NARAC staff member deployed to IMAAC Desk in MAAC (right) with DOE Senior Energy Official (left) and NOAA liaison (center)



DHS Secretary Chertoff thanks MACC participants

NARAC Supported the Mars Science Laboratory Mission Launch (November 26, 2011)

- DOE, NASA, EPA, and FEMA emergency response managers assembled at the Kennedy Space Center's (KSC) Radiological Control Center to be ready to respond in the unlikely event of an accident involving the Pu-238 radioisotope thermal generator (RTG)
- LLNL provided the DOE Senior Science Advisor (SSA) and NARAC modeling support for the Mars Science Laboratory launch,
- NASA deployed 30 Environmental Continuous Air Monitors (ECAMs) which transmitted real-time respirable alpha radiation data from KSC and the surrounding communities under the guidance of SSA Steve Homann
- NARAC's home team provided timely credible worst case analyses of potential accident scenarios
- Over 70 local, state, and federal emergency responders and decision makers accessed NARAC products via a user-friendly and robust Web site

DOE Senior Science Advisor Steve Homann (LLNL) explains ECAMs at press briefing

NASA and deployed LLNL staff (NARAC liaison Ron Baskett and DOE SSA Steve Homann) review a NARAC plot at the KSC Radiological Control Center

MSL launch at 10:02 am EST on November 26, 2011

Exercise Support

Examples

Lawrence Livermore National Laboratory

National Atmospheric Release Advisory Center

NARAC

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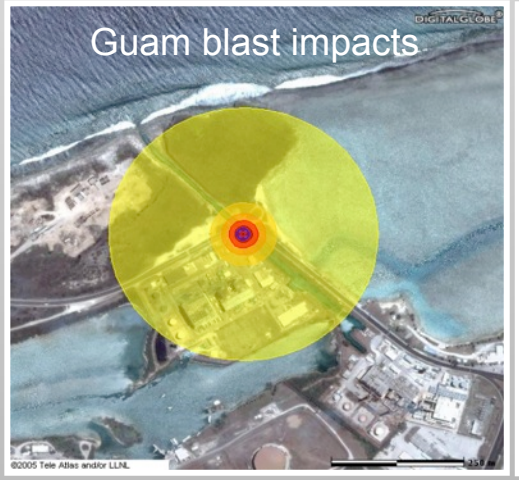
NARAC/IMAAC Supported the Top Officials 4 (TOPOFF4) Counterterrorism Exercise (October 15-19, 2007)

- Largest exercise to date involving over 15000 participants
- Tested response to three radiological dispersal device attacks (Guam, Oregon, Arizona)
- LLNL staff served as exercise planners and controllers
- NARAC/IMAAC provided 24x7 support 2007 October 15-19
  - Worked collaboratively with operations centers, field teams, and technical experts
  - Predicted blast and radiation impacts
  - Correctly estimated source and explosive quantity from limited initial field data
  - Distributed plots to a wide range of federal, state, and local agencies



NARAC Supported the DOE-Led Empire 09 Full Scale Exercise (June 2-5, 2009)

- DOE-led Tier II National Level Exercise
- 550 participants from 30 federal, New York State and local agencies in Albany NY
- NARAC planner / controller / observer deployed to Albany NY
- Excellent performance from NARAC staff, who generated eight major sets of analyses/ predictions in a timely manner
- Successful first exercise application of new LLNL CMweb portal to distribute all NA-42 consequence management products
- First use of new RDD Briefing Products (developed pursuant to a Homeland Security Council tasker)
- New NA-42 TI-developed software used to streamline electronic processing of eFRMAC field data and speed up NARAC response time
- Generation of special products to address scientific issues arising from overlapping cesium and americium RDD plumes

NARAC Operations LLNL

Aerial Measuring System helicopter

FRMAC Operations, Albany NY

LLNL Emergency Response Support Includes Monitoring (ECAMs) and Lab Analysis Capabilities

- Nuclear Weapons Accident Exercise in Colorado (NUWAIX14)
  - NARAC produced the official IMAAC atmospheric plume model prediction used by multiple agencies
  - LLNL supported the first deployment of a Environmental Continuous Air Monitor (ECAM) for a DOE emergency response exercise
- Deployment of ECAM on DOE Forrestal Building
- FRMAC Capstone "Tracer" Exercise at Nevada National Security Site (formerly NTS)
  - Deployment by 4 LLNL personnel, including Fly-Away Lab (FAL) manager and deputy manager
  - Processed actual radiological contamination (Tc-99m) samples for the 1st time using FAL equipment
  - NARAC modeling support

NARAC plume model prediction of potential contamination for NUWAIX14 exercise

Steve Homann (LLNL) deploying ECAM during NUWAIX14 Exercise

Fly-Away Lab (FAL) sample analysis equipment

NARAC Web Demo

Lawrence Livermore National Laboratory

National Atmospheric Release Advisory Center

NARAC

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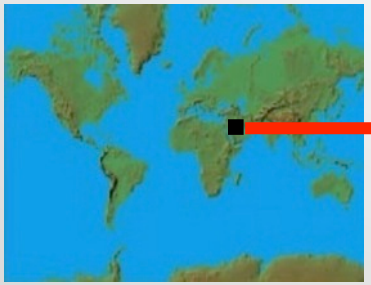
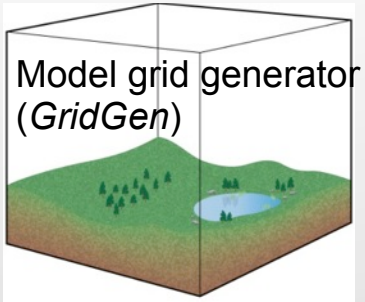
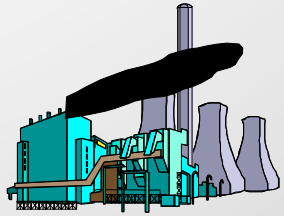
NARAC Central Modeling System Provides Automated 3-D Worldwide Plume Model Predictions

Geographical, Terrain Elevation, Population Databases



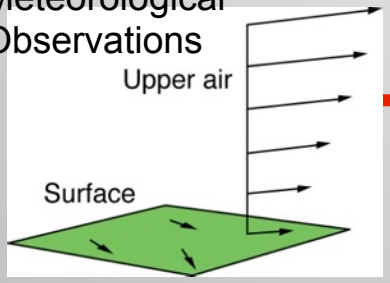
Model grid generator (*GridGen*)



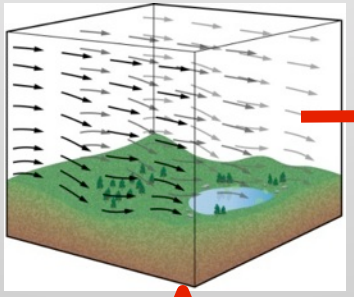


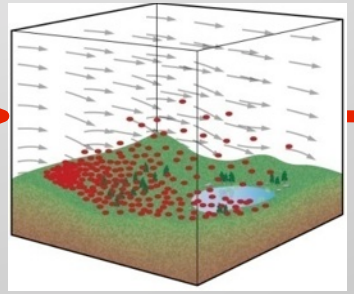
Source characteristics

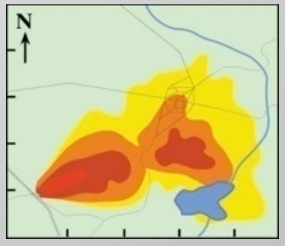
Meteorological Observations



Data assimilation model (*ADAPT*)



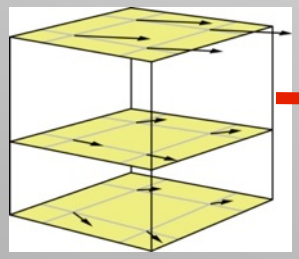




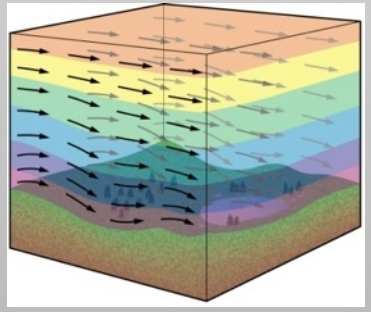
Lagrangian Operational Dispersion Integrator (*LODI*)

Air and ground contamination, Dose, Protective Action Guides, acute health effects

Large-scale forecast models (Navy, NOAA)



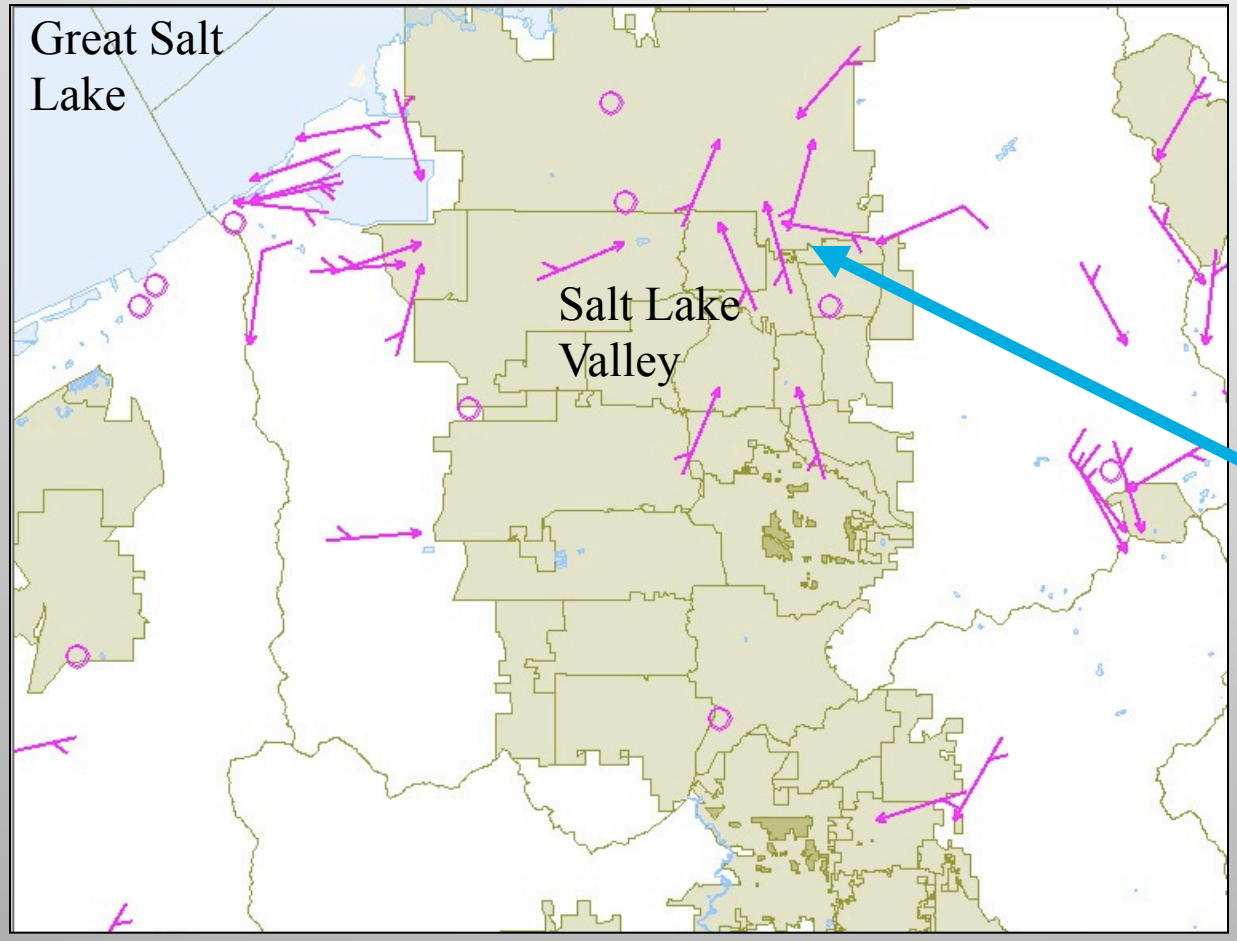
Regional Forecast Model (*WRF, COAMPS, RUC*)



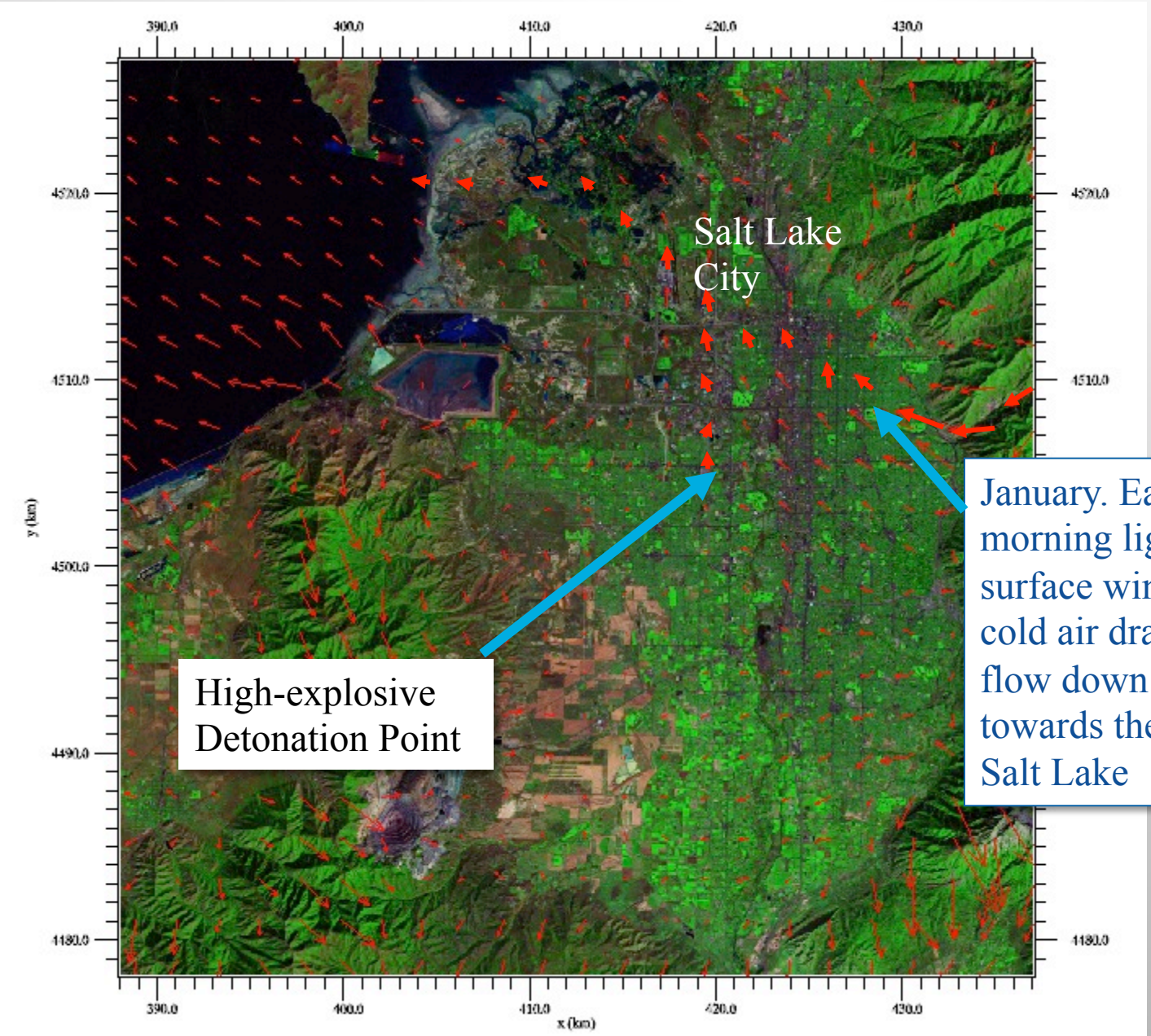
Automated initial products are available in 5 to 10 minutes. Quality-assured refined products based on field data are available in 10 – 60 minutes, depending on the quantity and quality of the data.

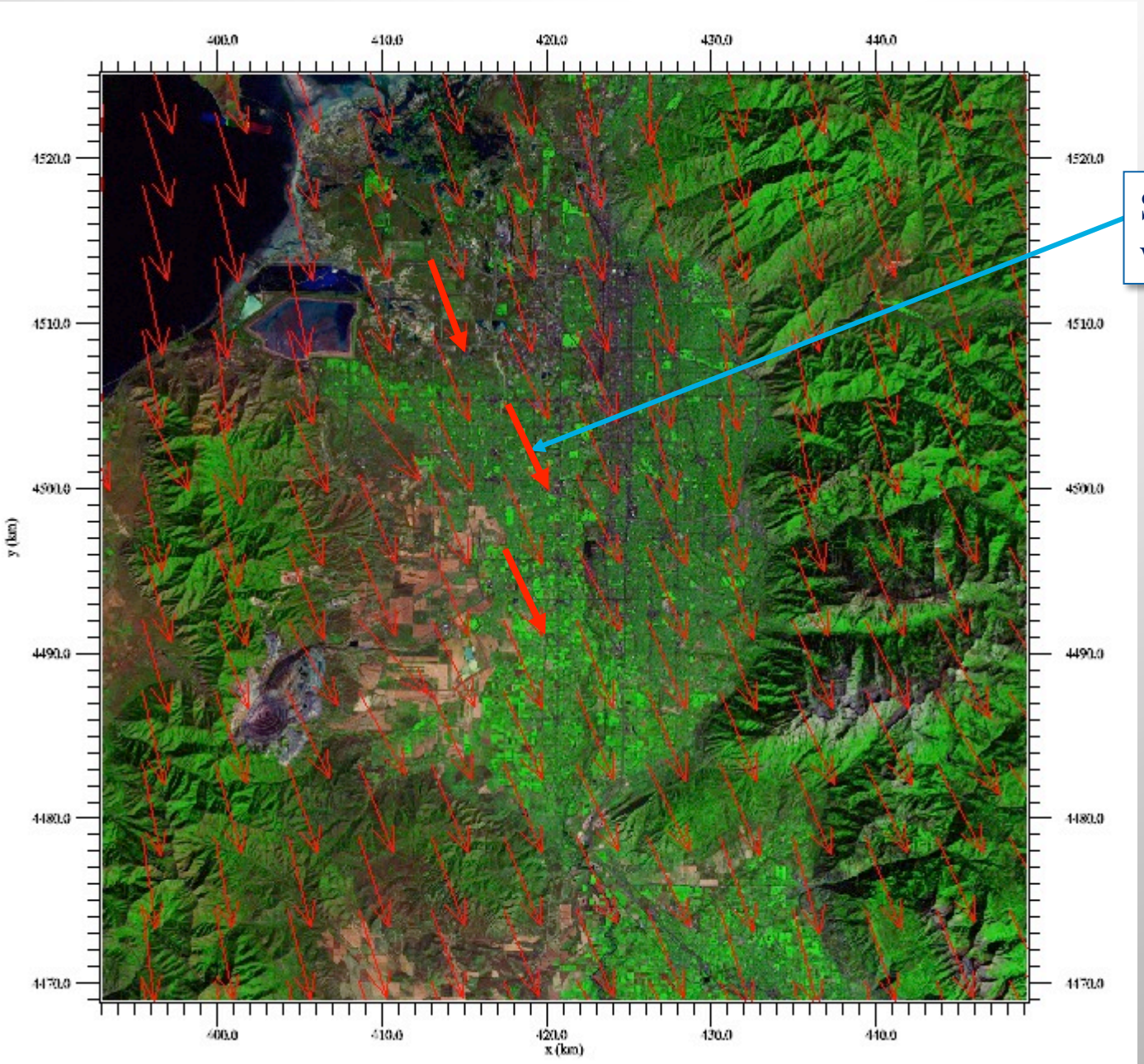
Winter Case Study: Hypothetical RDD in Salt Lake City

Mesonet Surface Wind Observations

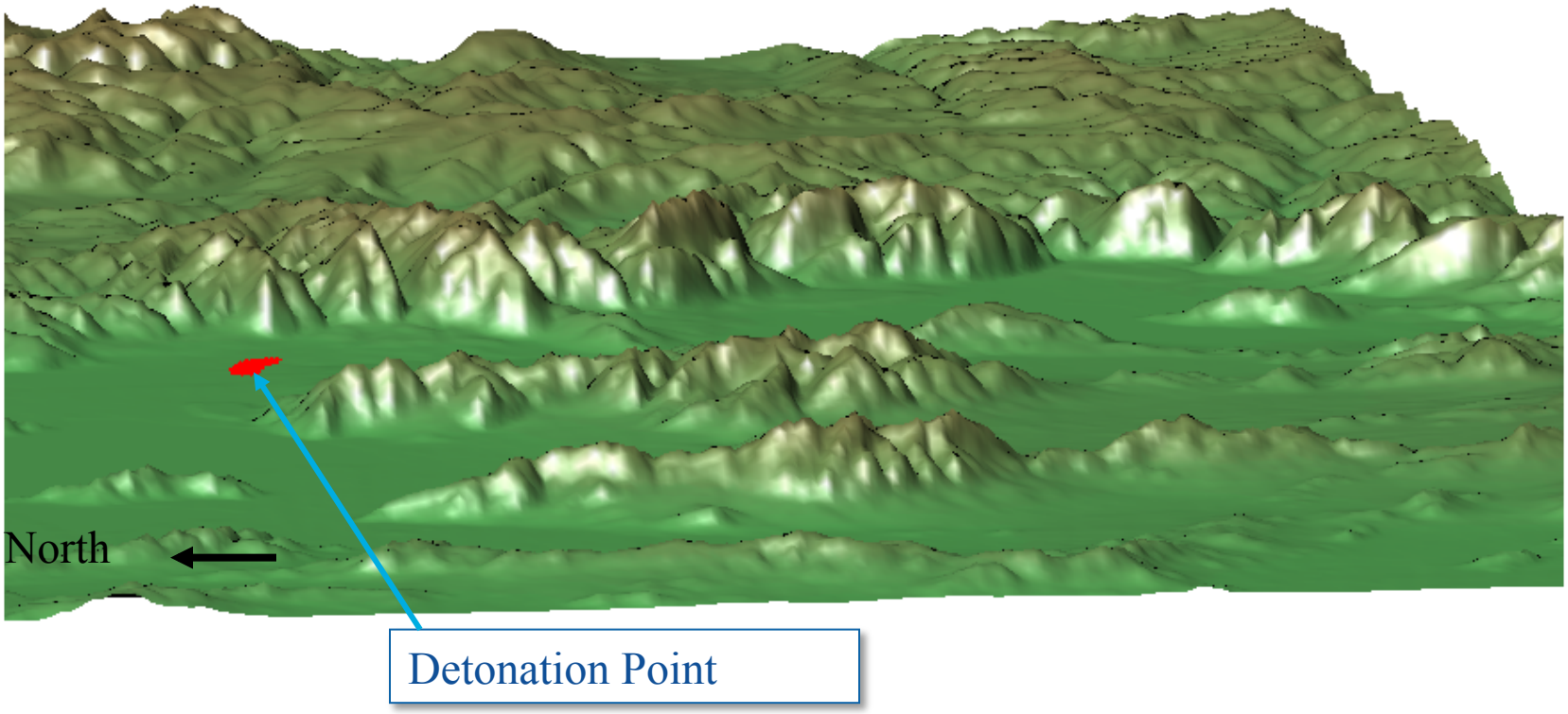


January. Early morning light near-surface winds show cold air drainage flow down slopes & towards the Great Salt Lake


390.0
400.0
410.0
420.0
430.0
4520.0
4510.0
4500.0
4490.0
4480.0
y (km)
x (km)
Salt Lake City
High-explosive Detonation Point
January. Early morning light near-surface winds show cold air drainage flow down slopes & towards the Great Salt Lake

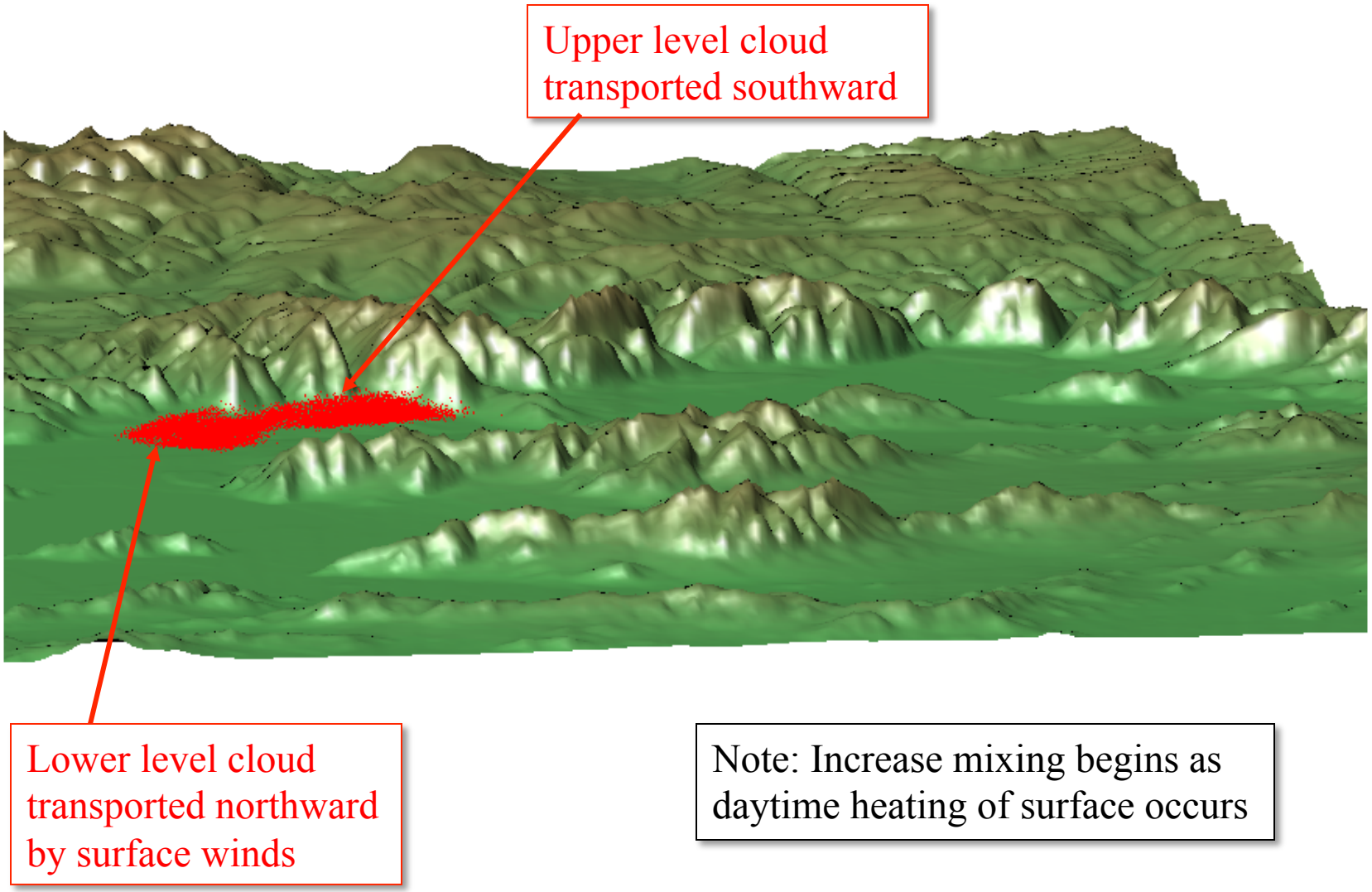


Stronger upper-level winds from the north

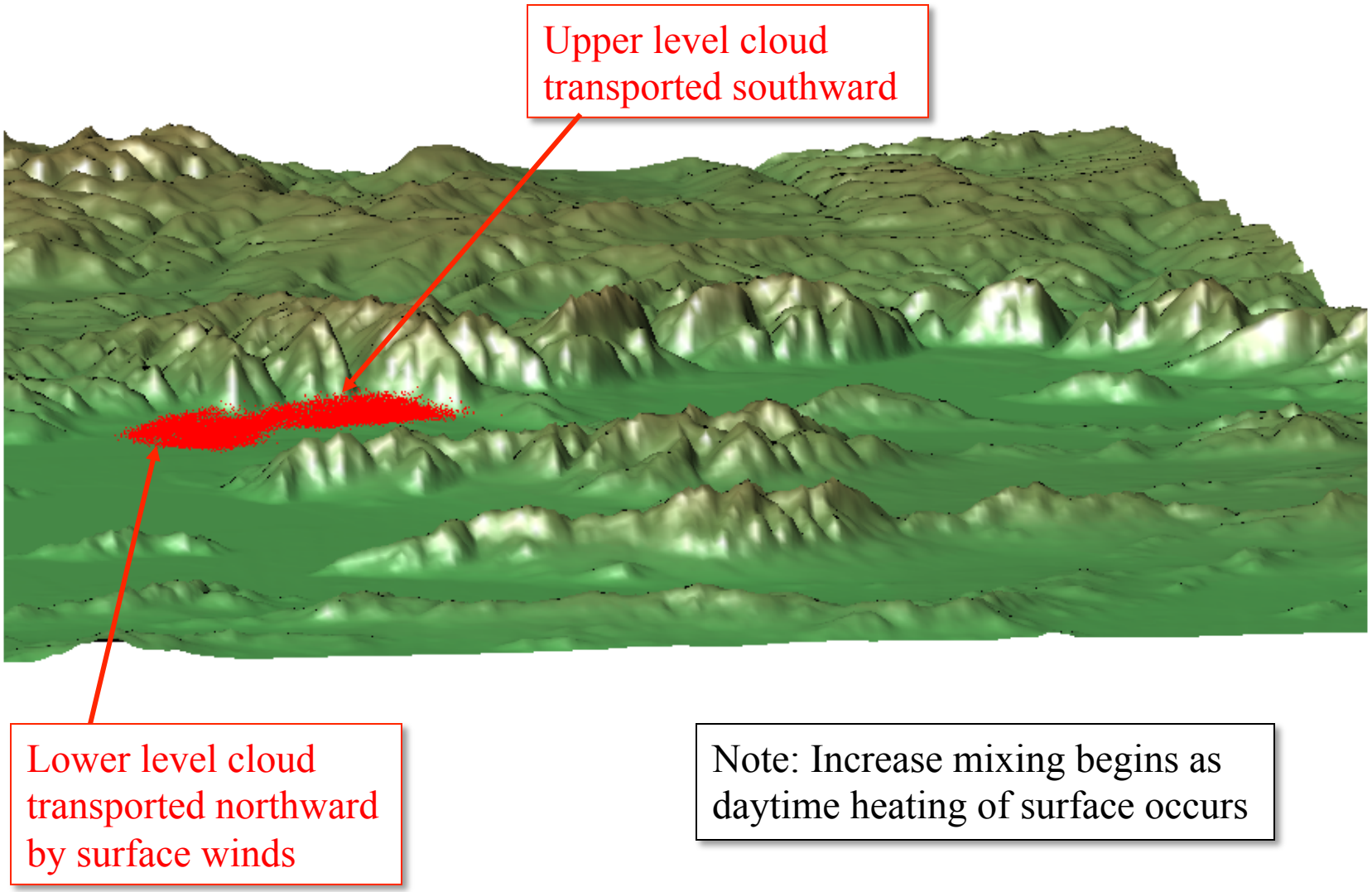


Red particles show LLNL NARAC ADAPT/LODI dispersion simulation using SNL ERAD explosive source characteristics (particle size distribution and spatial distribution of mass from surface to several hundred meters above ground) .

Simulation begins at 05:00 MST and ends at 11:00 MST



Note: Increase mixing begins as daytime heating of surface occurs



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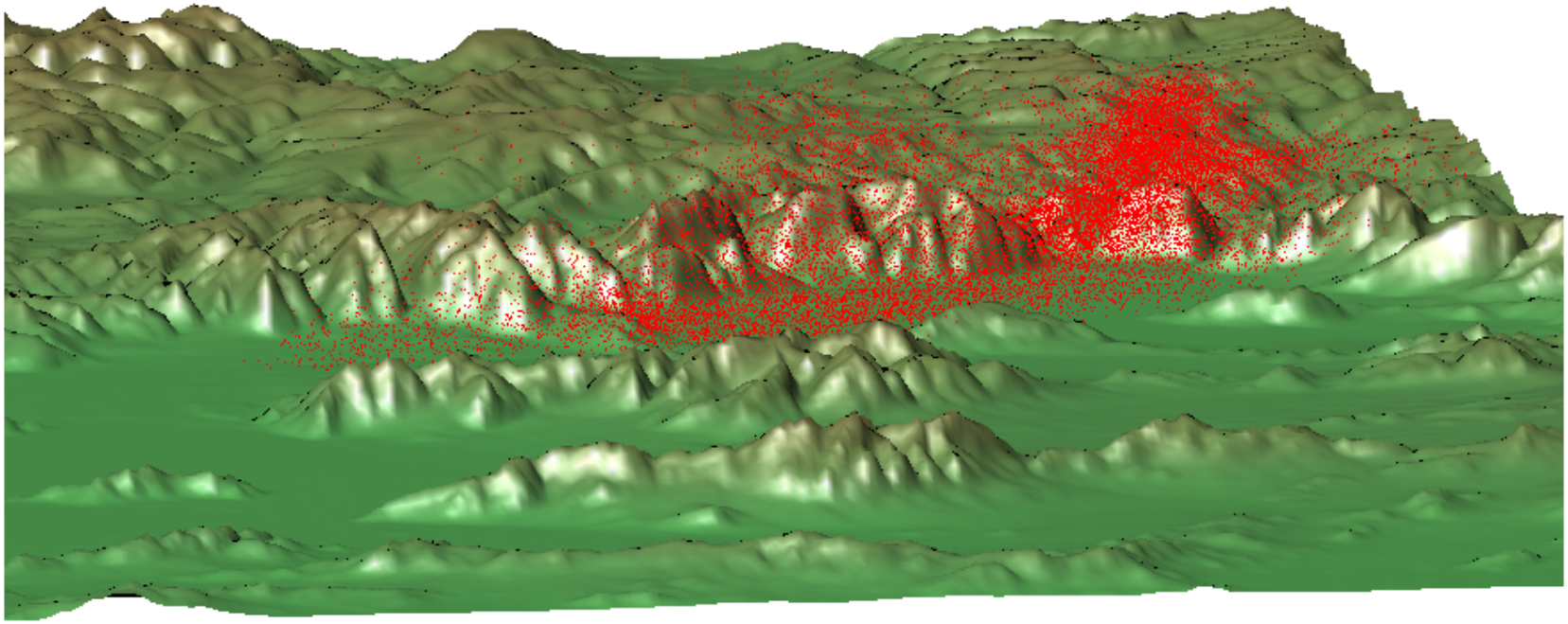
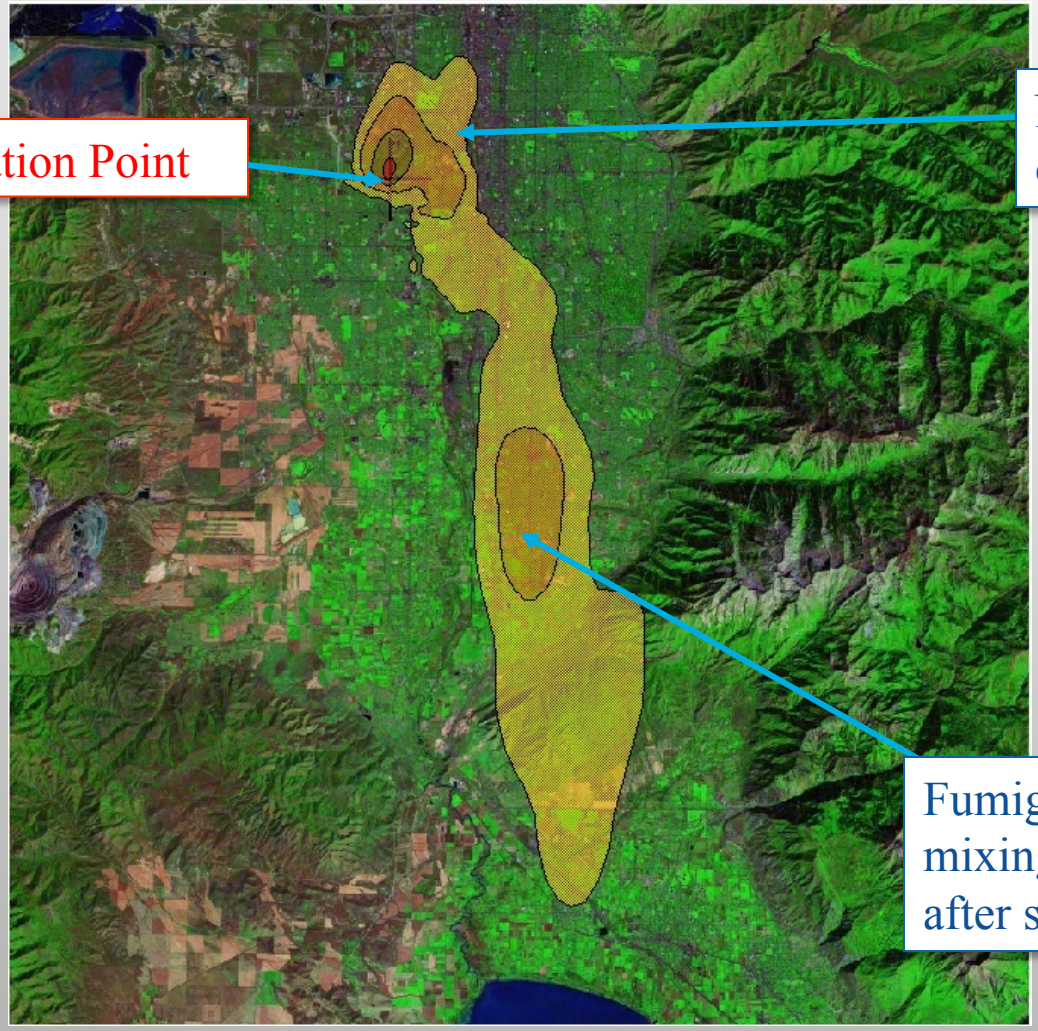


Winter Case Study: Hypothetical RDD Ground-Level Time-integrated Dose



Animation of NARAC/IMAAC Model Simulation of Airborne Nuclear Debris Cloud and Fallout Contamination Footprint

FEMA IND Response Strategy Planning Guidance

Lawrence Livermore National Laboratory

National Atmospheric Release Advisory Center

NARAC

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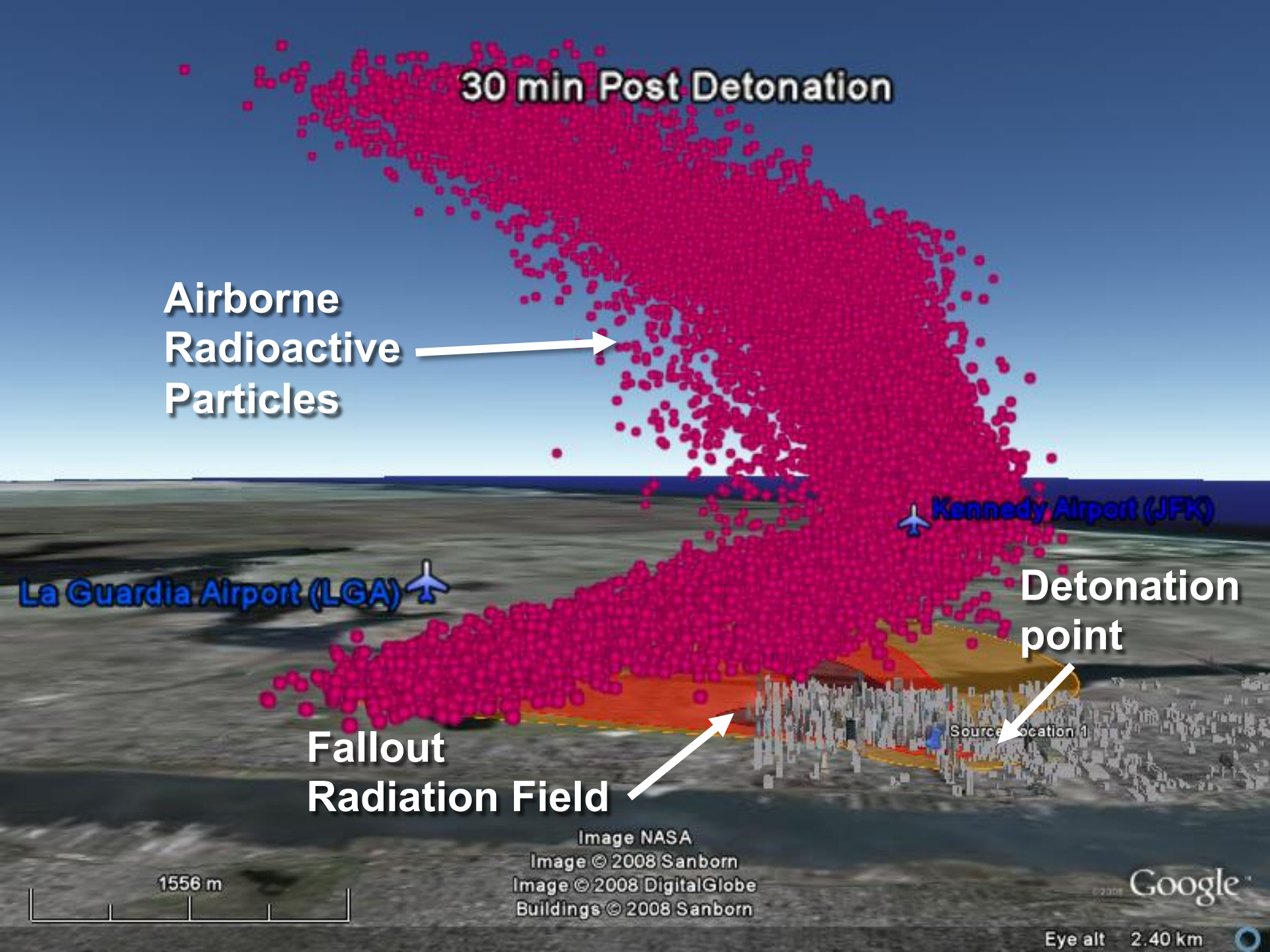
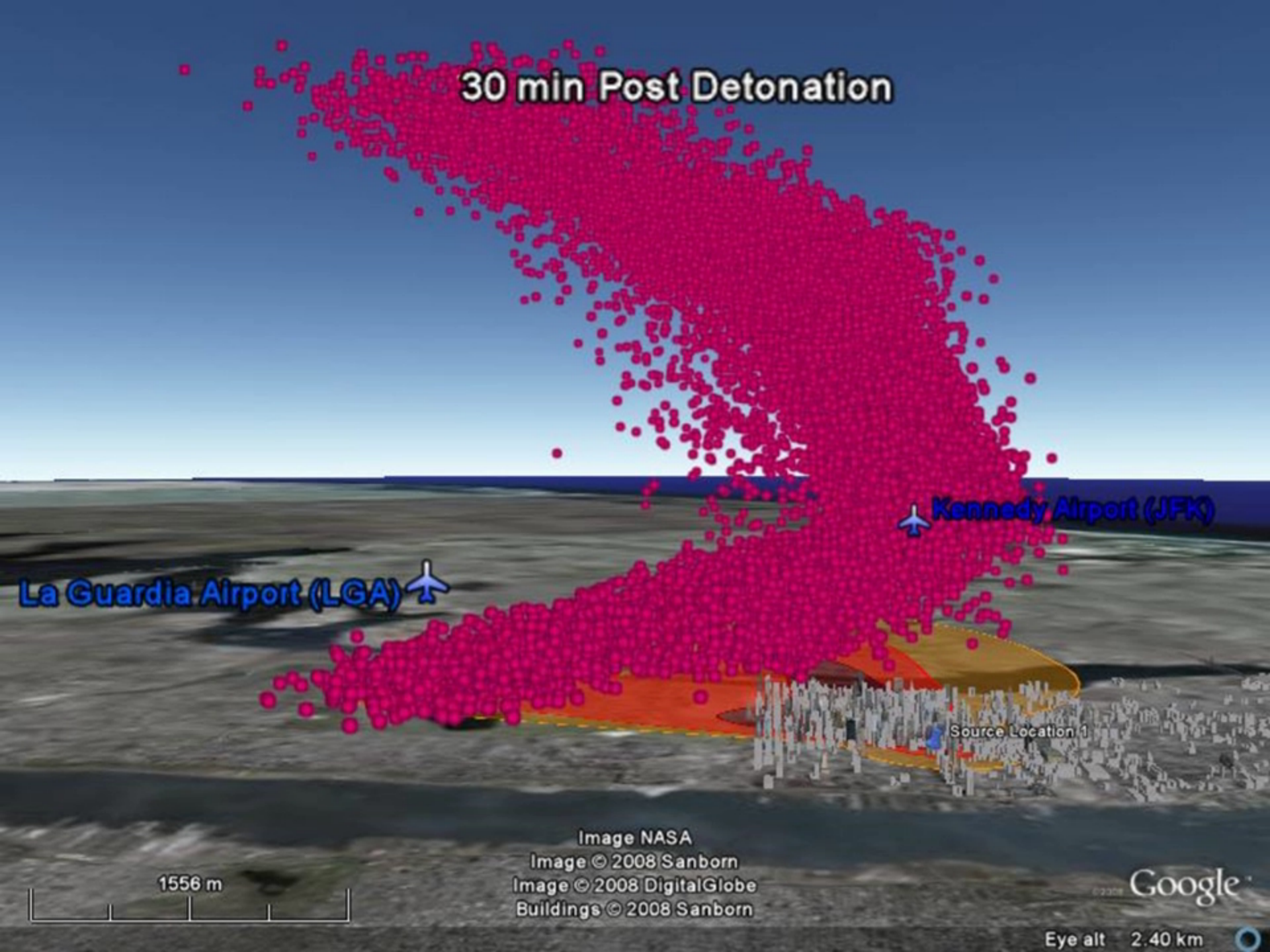

30 min Post Detonation
Airborne Radioactive Particles
Kennedy Airport (JFK)
La Guardia Airport (LGA)
Detonation point
Fallout Radiation Field
Source Location 1
Image NASA
Image © 2008 Sanborn
Image © 2008 DigitalGlobe
Buildings © 2008 Sanborn
1556 m
Google
Eye alt 2.40 km


30 min Post Detonation
Kennedy Airport (JFK)
La Guardia Airport (LGA)
Source Location 1
Image NASA
Image © 2008 Sanborn
Image © 2008 DigitalGlobe
Buildings © 2008 Sanborn
1556 m
Google
Eye alt 2.40 km

NARAC Modeling System

Lawrence Livermore National Laboratory

National Atmospheric Release Advisory Center

NARAC

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Component-based NARAC Computer Systems at LLNL Support In-house and External Users

LLNL Computer Systems

Central System: Automated model set-up and execution software

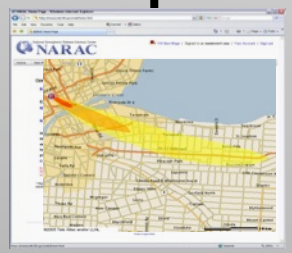
- Weather Data & Forecasts
- Geographic/Terrain Data
- CBRN Material Property Data
- Dose/Risk Factor Data
- Measurement Data
- Source models
- 3-D Meteorological, Dispersion and Fallout Models
- Prompt Effects Models
- Data-driven modeling tools
- Mapping and product generation software
- Population, casualty and fatality estimation

Remote Access Computer System

User interfaces and Analysis Tools for LLNL scientists

Internet/Intranet

Standalone models and mapping



External User Tools

CM/NARAC/IXP Web

- Over 400 software applications
- 50 databases
- 3 million lines of computer code
- 28 servers
- 8 data storage systems

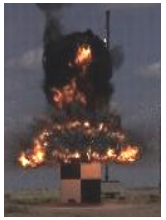
Suite of NARAC Models Are Used to Model Impacts (Operational Radiological/Nuclear Example)

Nuclear Detonation source models:

- LLNL *KDFOC*
- LLNL *LWAC*
- ORNL *ORIGEN*
- ORNL *DELFIC*

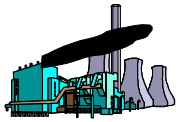
RDD Source models:

- SNL *Source Term Calculator*
- SNL *PUFF*
- SNL *ScatterMe*



Nuclear power and fuel sources:

- NRC *RASCAL*

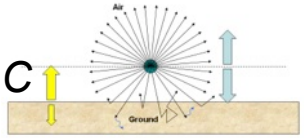


Fire source model:

- LLNL

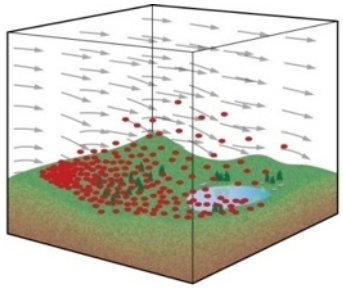
NucDet (IND) and RDD Prompt effects models:

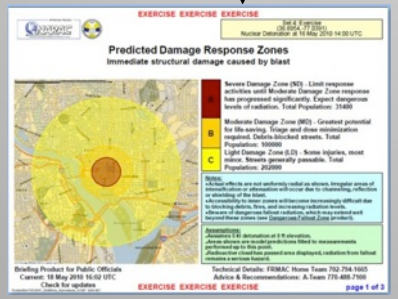
- SNL *Nuke*
- SNL *Blast*
- LLNL *LWAC*



3-D Atmospheric Dispersion and Fallout models:

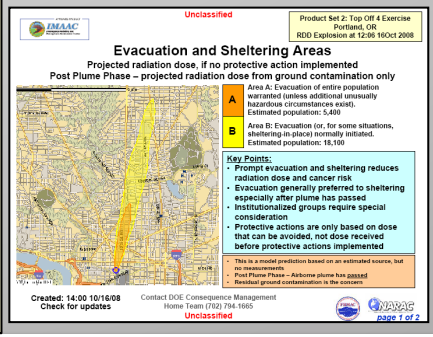
LLNL *ADAPT/LODI*



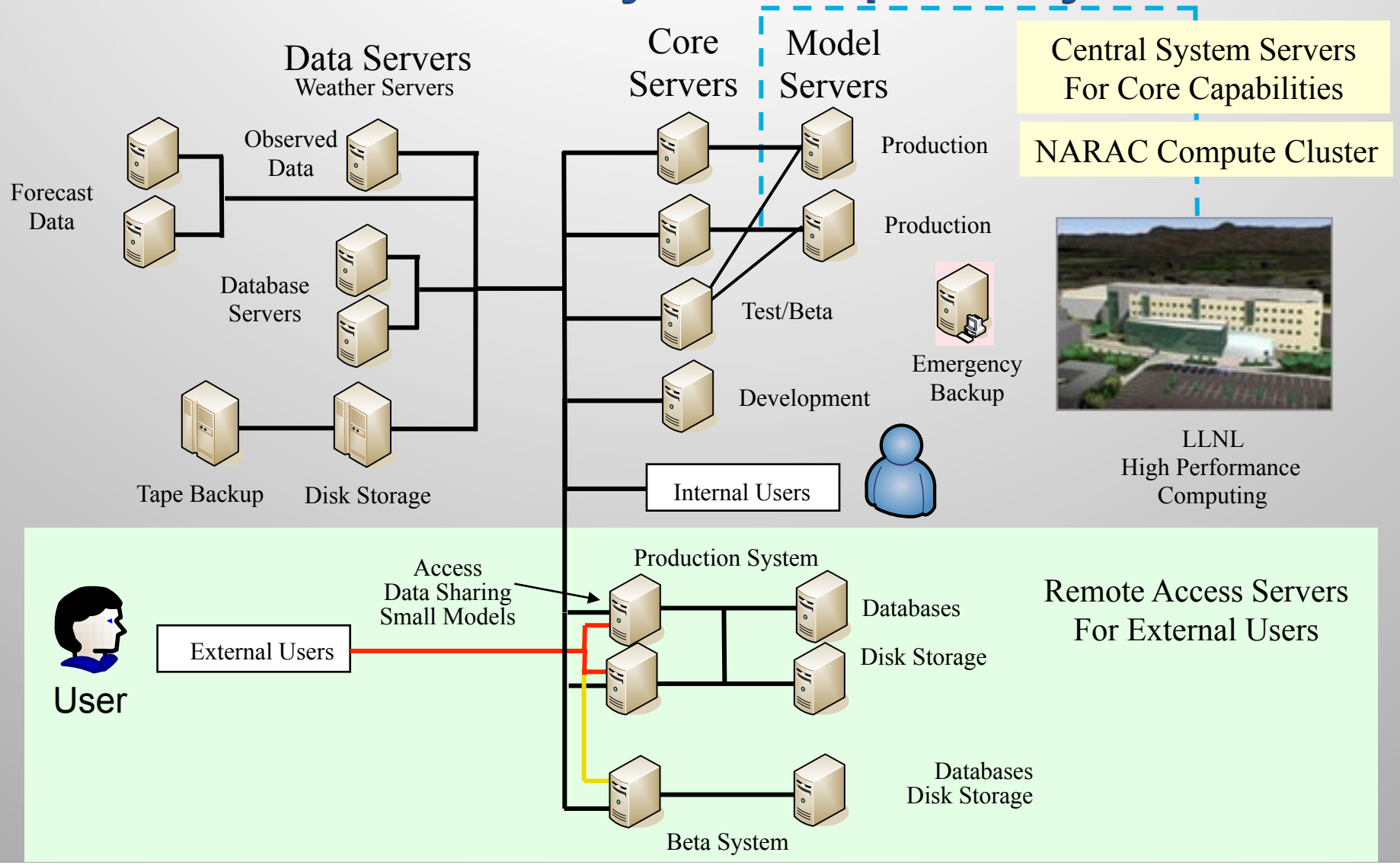


Products:

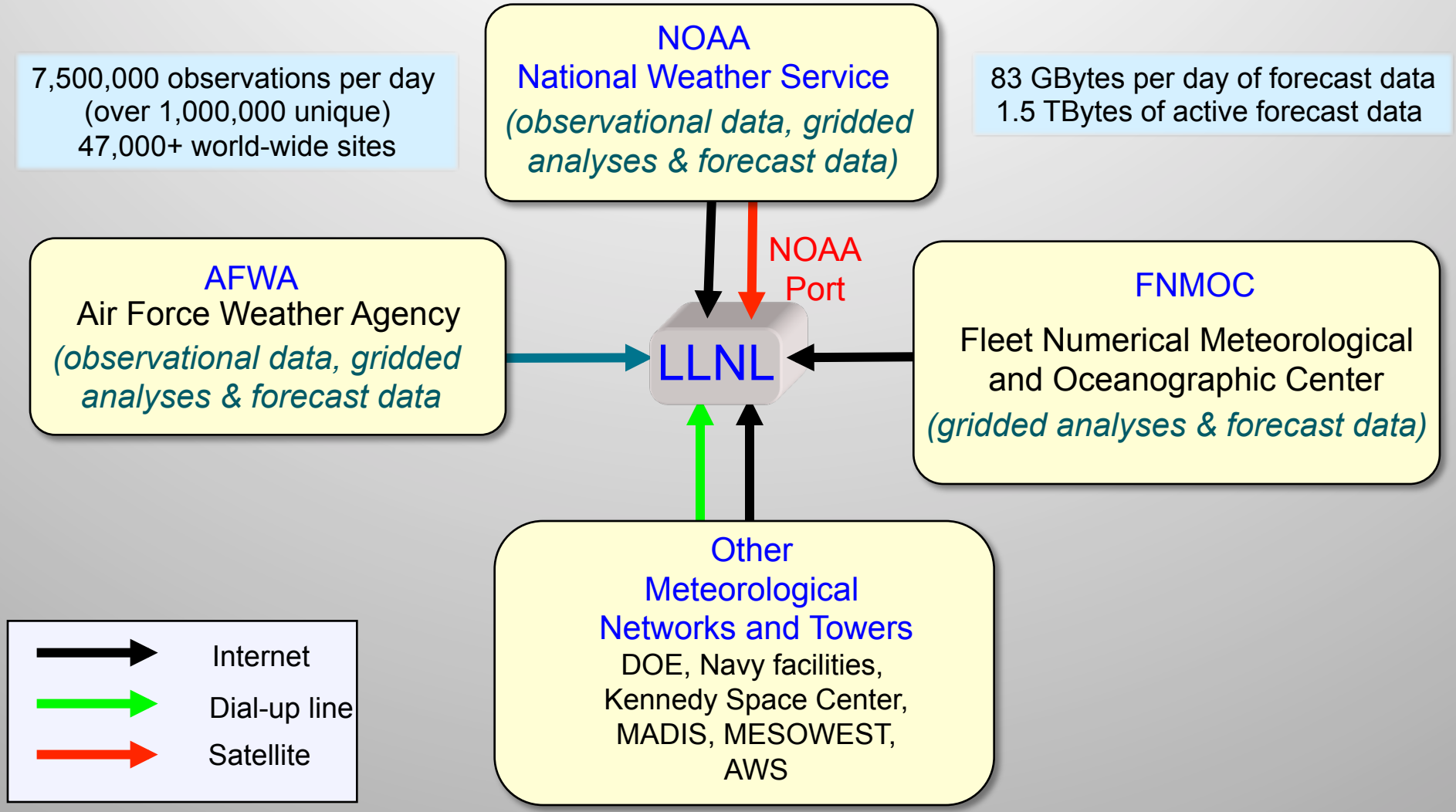
- Airborne and ground contamination for public exposures (evacuation / sheltering, relocation)
- Affected population and casualty estimates
- Worker protection (stay times)
- Building damage from blast overpressure
- Radiation, blast and thermal casualty estimates
- Neutron-activation ground shine dose



Modular, Redundant, Fault-Tolerant Servers Ensure 24/7 Reliability of Computer Systems



Multiple Weather Services and Networks Provide Automated Meteorological Data

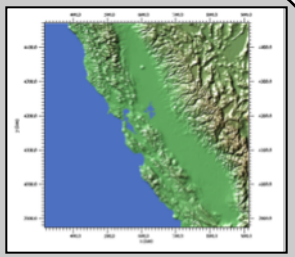


Multiple Meteorological Data Feeds Are Used to Ensure Availability of Weather Model Results

Forecast Model Results from External Sources		
Agency	**Model**	**Resolution/Coverage**
Air Force Weather Agency (AFWA)	WRF	45 and 15 km resolution, special regional forecasts
Fleet Numerical Meteorology and Oceanography Center (FNMOC)	NOGAPS	0.5° (~50 km) resolution, global, 3 hr intervals to 72 hrs from 0000 and 1200 UTC daily
National Weather Service (NWS)	WRF	12 km resolution, North America Model (NAM)
	GFS (AVN)	0.5° (~50 km) resolution, global, 3 hr intervals to 180 hr from four initialization times per day
	RUC	13 km resolution, US, 1 hr intervals to 9 hrs from hourly initialization times
NARAC In-House Capabilities	WRF	Variable resolution (US, world-wide capabilities)

World-Wide Geospatial Databases Provide Input Data to Model Calculations and Assessment Products

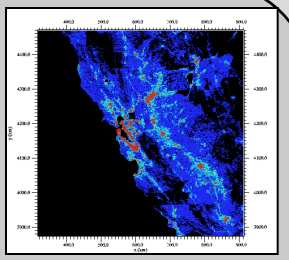
Terrain Elevation **is used in 3-D airflow and dispersion models**



Global coverage
- NGDC ETOPO2 3km
- USGS GTOPO30 1km
- NGA DTED 1km, 100m, 30m
- NASA ASTER 30m

U.S. coverage
- USGS DEM 30m, 10m

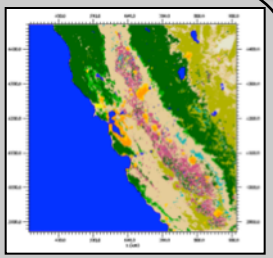
Population **is used to estimate the number of impacted people and casualties**



Global coverage
- ORNL 1km LandScan

U.S. coverage
- Census Bureau
- LANL day/night
- ORNL LandScanUSA day/night

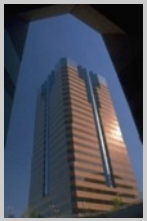
Land Characteristics **are used to model their effects on wind and turbulence**



Global coverage
- ORNL 1km GLCC

U.S. coverage
- USGS 200m LULC
- USGS 30m NLCD

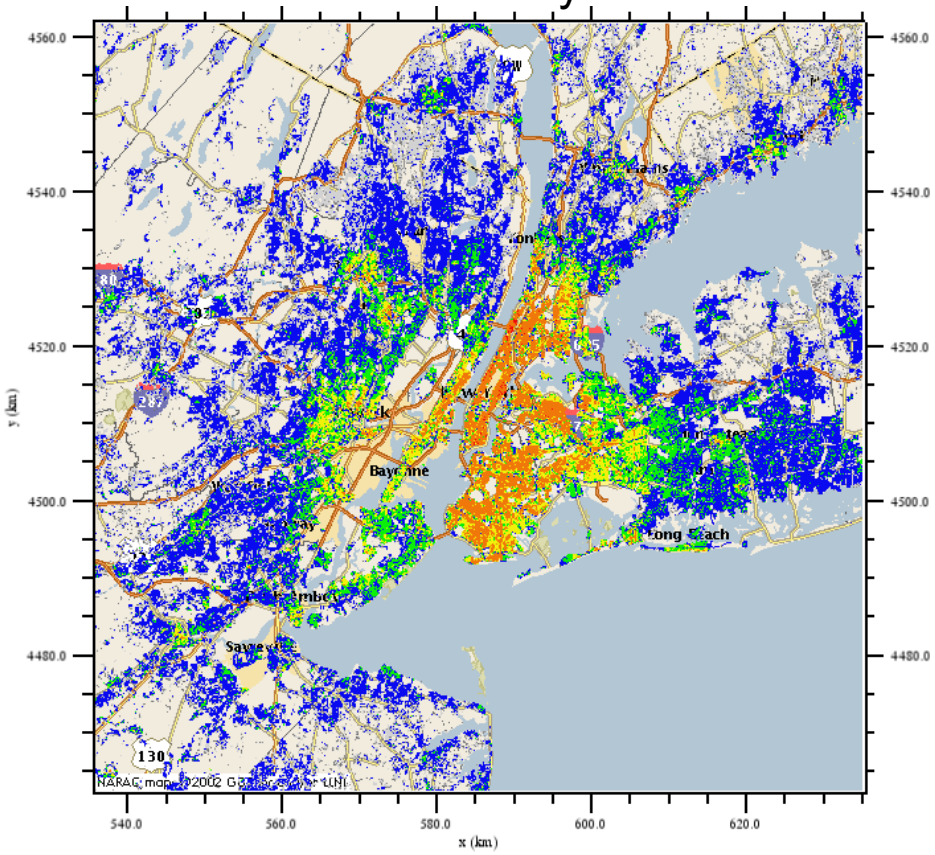
Building Data **is used to estimate sheltering, wind, and turbulence effects**



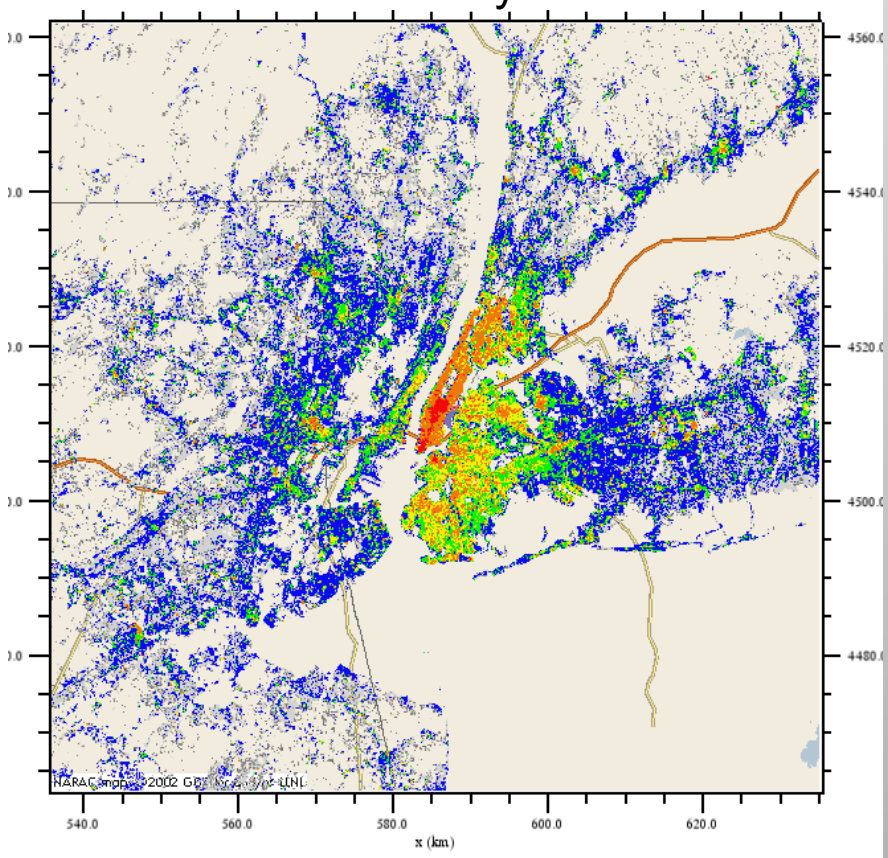
U.S. coverage
- NGA 133-city 3-D LIDAR data
- DHS HAZUS
- LBNL US building infiltration database
- City Assessor Property Data
- Census Summary data by tract

High-Resolution Day-Night Population Databases are Used in Model Calculations

Nighttime Population Density
New York City Area



Daytime Population Density
New York City Area



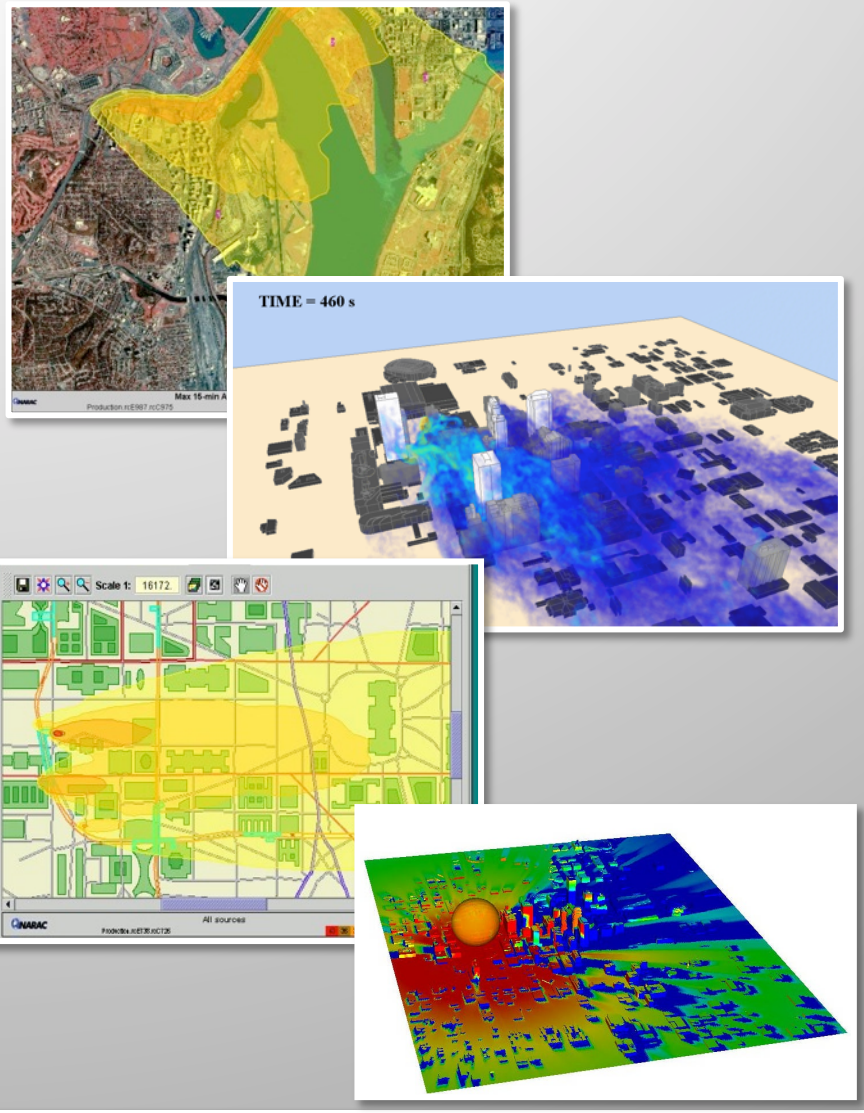
Oak Ridge National Laboratory (ORNL) LandScan USA day-night population data obtained from HSIP GOLD dataset

Multiple Source Term Models are Included in the NARAC System

- RDD source characteristics: airborne fractions, particle-size distribution (SNL *Source Term Calculator*)
- Nuclear detonation (LLNL KDFOC3, LWAC)
- CBRN material properties (DIPPR, ORNL, DoD)
- Chemical and biological weapon sources/sprayers (SNL Source Term and Dose Response Assessment Tool)
- Classified weapons data (DoD, DOE)
- Toxic industrial chemicals (leaks, spills, tanks) (NOAA/EPA)
- Buoyant & momentum plume rise from fires or stack emission (LLNL *LODI* model)
- Nuclear power plant release characteristics (NRC *RASCAL* model)
- Nuclear detonation fission products, soil activation products and particle size distributions (LLNL *LWAC*, ORNL *ORIGEN,* DOD *DELFIC,* LLNL *GEODYN,* Classified codes and data)

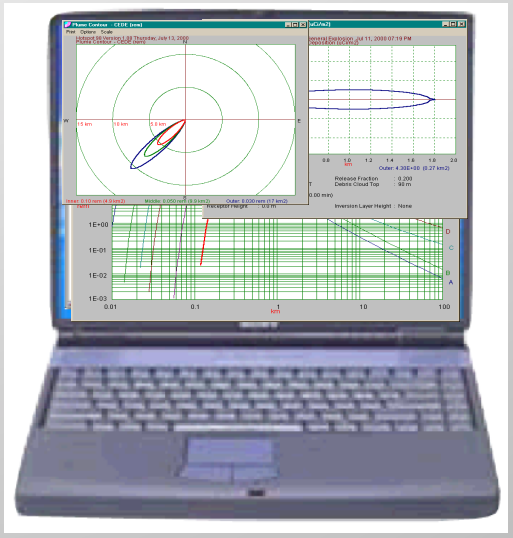
NARAC Utilizes a Suite of LLNL and Collaborating Agency Atmospheric and Plume Models

- Weather forecast models (NOAA, Air Force and Navy global and regional models, LLNL in-house version of WRF)
- LLNL regional modeling suite (ADAPT/ LODI)
- LLNL fallout model (KDFOC)
- Radiological plume models (DOE HOTSPOT)
- Explosive prompt blast effects prediction (SNL *BLAST*)
- Nuclear detonation prompt blast, thermal and radiation effects (SNL *NUKE*)
- Hazmat / toxic industrial chemical models (e.g., NOAA/EPA ALOHA / CAMEO, EPICode)
- LLNL urban building-scale models
- Urban prompt effects models (LLNL *Cityray,* ARA *NucFast)* under evaluation (FEMA)
- NOAA HYSPLIT
- DoD Joint Effects Model / HPAC
- Subway (ANL) and indoor (LBNL/NIST)

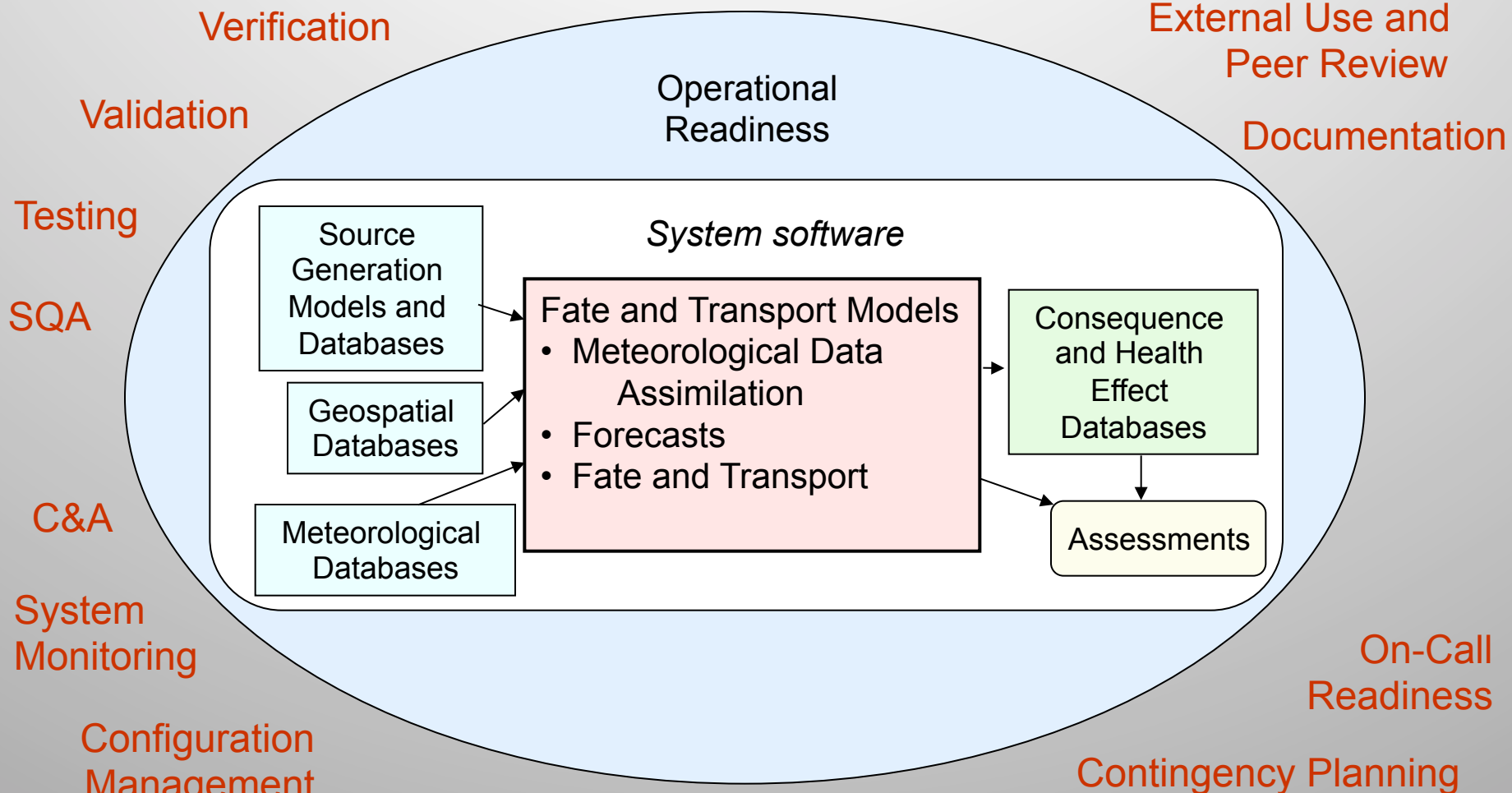


NARAC Maintains and Develops the DOE Site Safety Software Codes HotSpot and EPIcode

- Provide emergency response personnel and planners with a fast, field-portable set of software tools for evaluating incidents involving radioactive materials
- Approved for use in DOE Safety Analysis and Emergency Planning Hazard Assessments as part of DOE *Safety Software Central Registry* Toolbox
- Latest version of the radiological/nuclear HotSpot software package formally accepted for use in 2010
  - New 95th percentile dose based on site meteorology
  - Improved source terms and dose conversion factors
  - Support for plume mapping in Google Earth
- EPIcode toxic industrial chemical model now maintained by LLNL
  - New LLNL-supported version will be made available to DOE sites in 2015
  - Gas, vapor, aerosol chemical release modeling for industrial and transportation accidents



A Comprehensive Approach to Quality Assurance and Operational Readiness Ensures Reliability and Accuracy

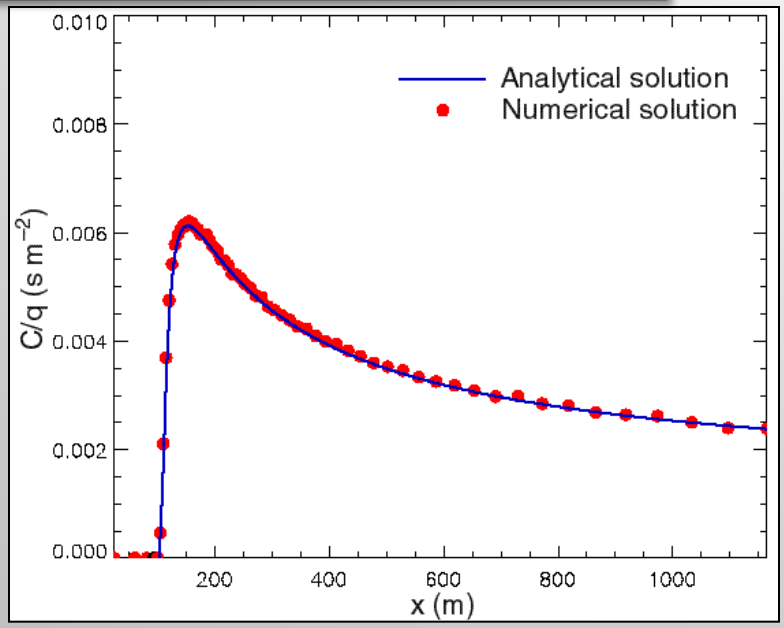


Model Validation is an On-Going Process Involving Multiple Components and Real-World Events

- Multiple validation components
  - Analytic comparisons against known results
  - Laboratory experiments to test model physics against experimental data
  - Field studies to evaluate models in real-world conditions (statistical and graphical metrics)
  - Operational testing to validate the usability, efficiency, consistency and robustness of models for operational conditions
- Transferability to operations
  - DOE / LLNL software quality assurance (SQA) standards
  - Extensive testing by in-house analysts and external beta users
- Accreditation
  - NARAC: DOE SCAPA Consequence Assessment Modeling Toolbox for DOE sites (certifies compliance with SCAPA SQA guidance for non-safety applications)
  - HotSpot and EPIcode: DOE Safety Software Central Registry toolbox code (meets DOE Office of Health, Safety, and Security (HSS) Safety SQA criteria)

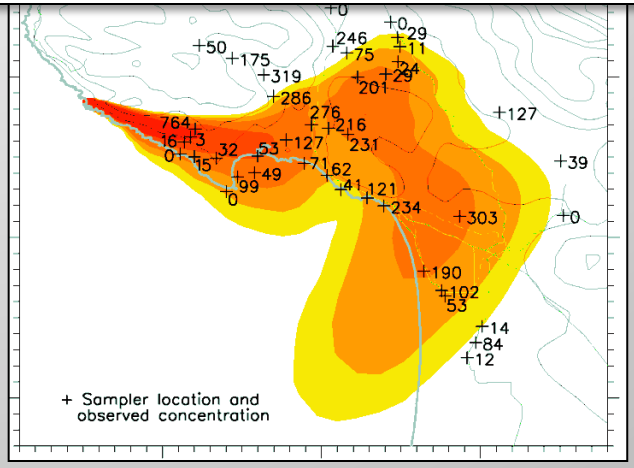
NARAC Models and Capabilities are Extensively Tested and Evaluated

- Analytic solutions test models versus known, exact results



- Field experiments test models in real-world cases

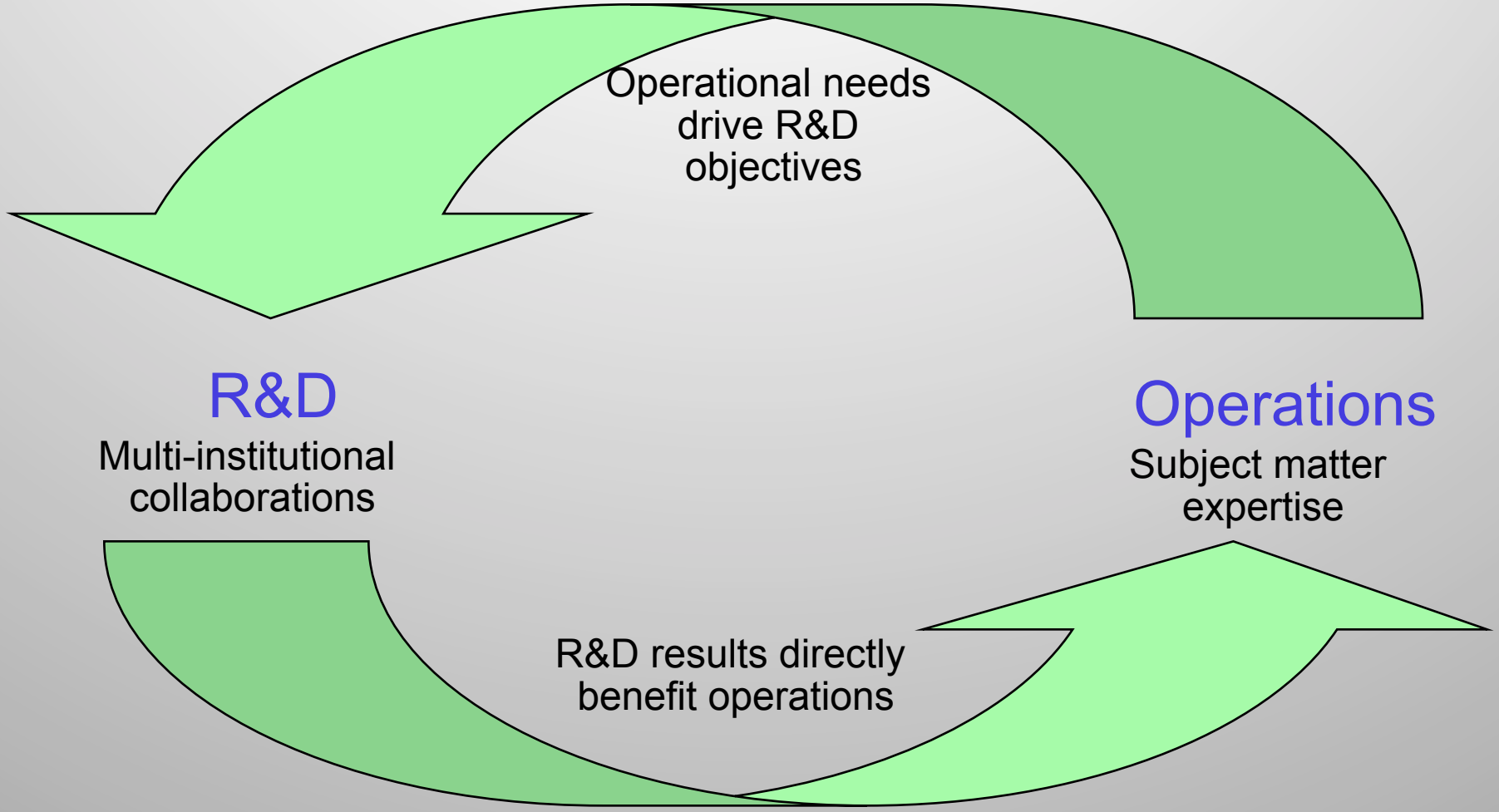
Examples: Roller Coaster, Project Prairie Grass, Savannah River Musicale Atmospheric Tracer Studies, Diablo Canyon Tracer Study, ETEX, Urban 2000, Joint Urban 2003, UDP



- Operational testing evaluates the usability, efficiency, consistency and robustness of models for operational conditions

Examples: Chernobyl, Kuwait oil fires, tire fires, industrial accidents, Algeciras Spain Cesium release, Tokaimura criticality accident, Cerro Grande (Los Alamos) fire, Fukushima Dai-ichi, WIPP

LLNL's State-of-the-Science System Benefits from a Tight Coupling of R&D and Operations



NARAC Model/Tool Development Drivers

- Mission areas requirements (e.g., emergency response, hazard assessment, consequence analysis, FRMAC and other interagency needs, nuclear forensics)
- Lessons learned from exercises (consequence management, emergency response
- Customer / user feedback and communications
- Experiences in real-world emergencies (e.g., Fukushima Daiichi nuclear power plant accidents)
- Externally driven updates to databases and data feeds (geographical, hazardous material, meteorological, CBRN field data, health effects / dose response)
- S&T developments (internal model development, integration of externally-developed capabilities)
- Interagency collaborations and partnerships

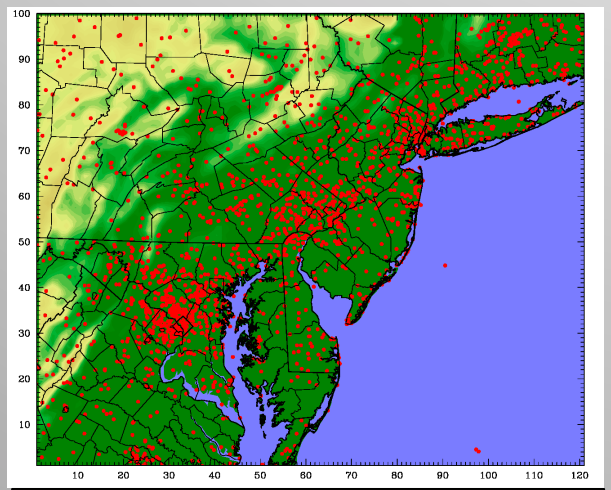
Meteorological and Dispersion Physical Process Models

National Atmospheric Release Advisory Center

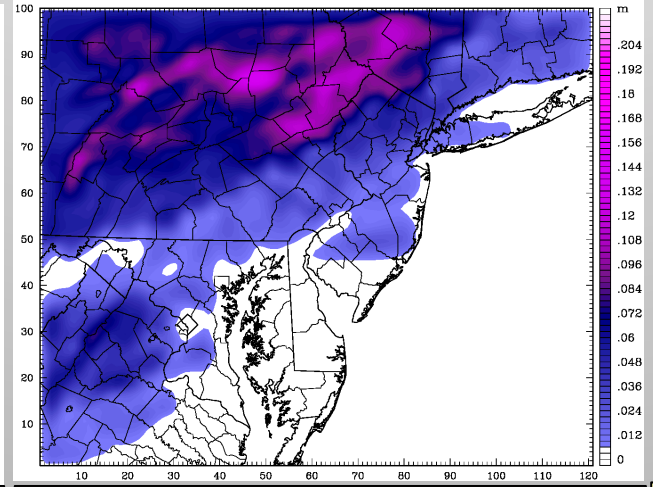
NARAC

High-Resolution Numerical Weather Prediction (NWP) Modeling and Data Assimilation Enhance Model Fidelity

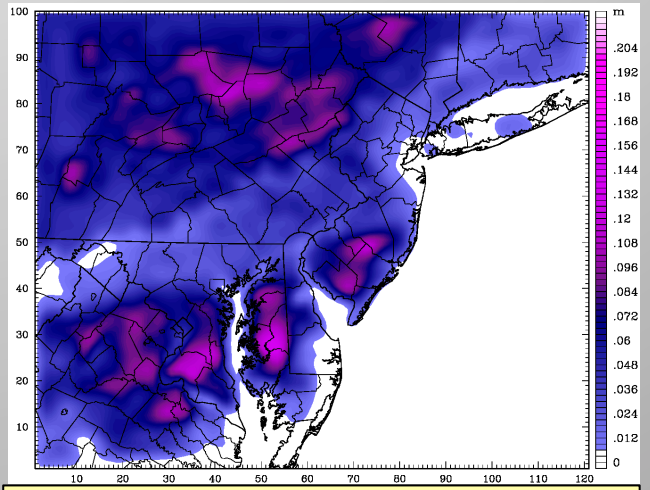
- Weather Research and Forecast (WRF) used to provide high-resolution meteorology
  - Solves atmospheric equations of momentum, heat, and moisture
  - Provides efficient model nesting capability
  - Provides additional meteorological fields (e.g. precipitation)
- 4-dimensional data assimilation (4DDA) found to improve the accuracy of WRF simulations when a sufficient density of observations is available
  - Analysis nudging on outer domains
  - Observational nudging capability on inner domain
  - Sensitivity of results to user specification of observation radius of influence (smaller radii typically improve results in complex terrain)



Surface weather stations used in 4DDA study



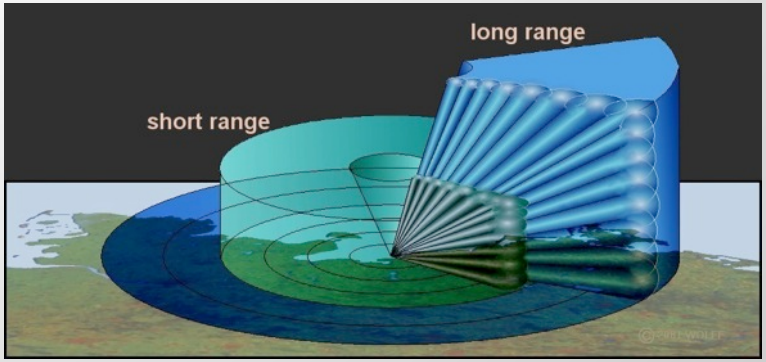
WRF predicted 2013 Dec 09 12:00 UTC snow depth w/o observational nudging

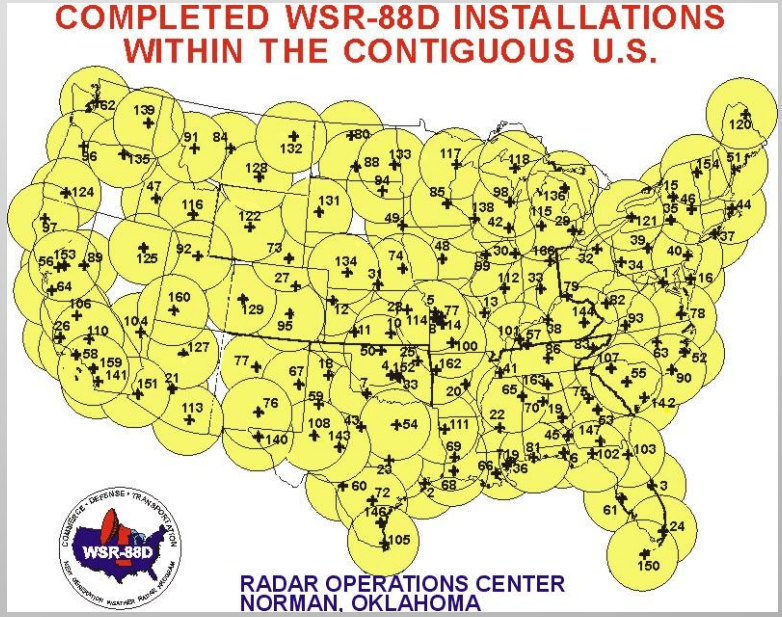


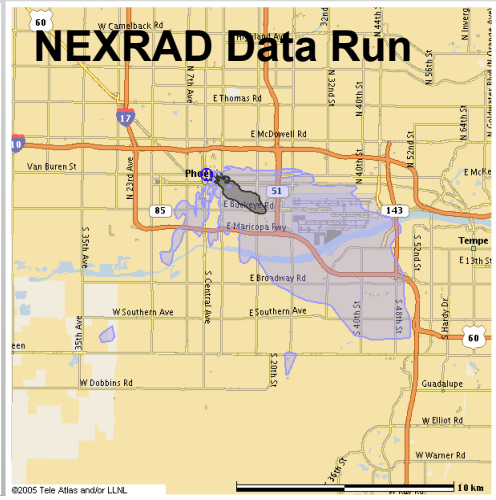
WRF simulation with observational nudging improves predicted snow depth

DHS S&T Project Evaluated the Impact of NEXRAD Radar Derived Winds for Dispersion Applications

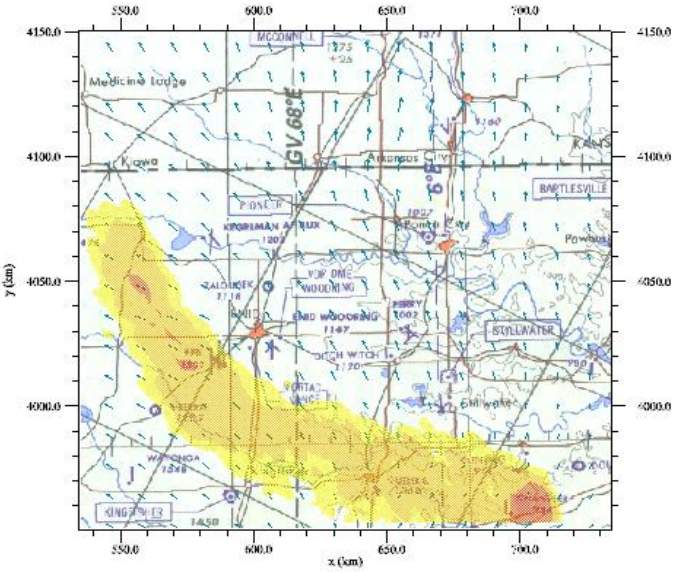
- Radar potentially provides higher resolution upper air data by measuring the altitude, range, speed of moving objects
- PNNL developed-algorithm used to convert raw data to gridded profiles
- Quantified availability of NEXRAD data
- Quantified NEXRAD data availability
- Conducted statistical analysis of impact of NEXRAD-derived into diagnostic
- Evaluated impact of NEXRAD-data assimilation into weather prediction model



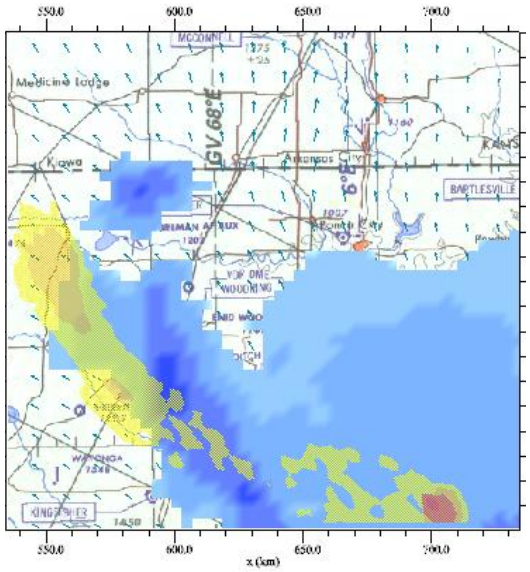




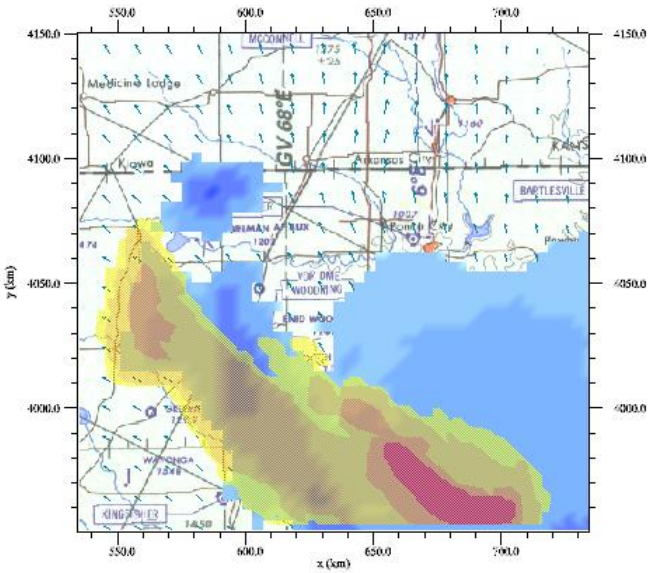
NARAC Incorporates a Rain-Rate and Particle-Size Dependent Precipitation Scavenging Algorithm



Air concentrations when precipitation is not included



Air concentrations when precipitation (blue) is included

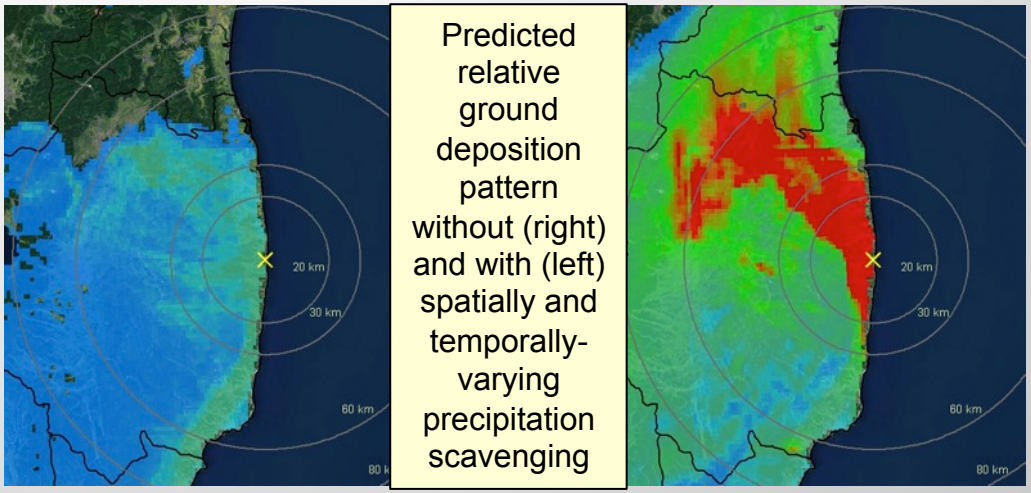


Wet deposition hot spots (red) produced by precipitation (blue)

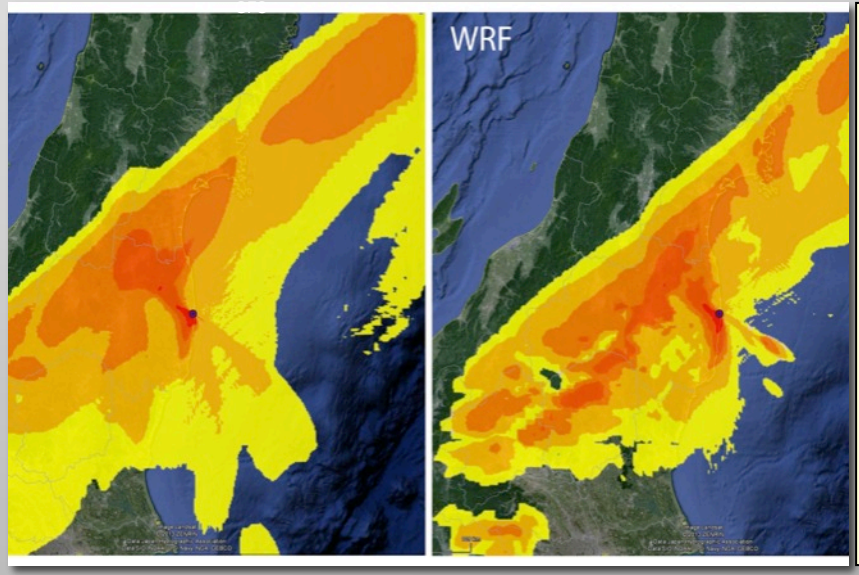
LODI dispersion model simulation for July 18, 1997 using observed winds and NEXRAD weather radar precipitation data for a continuous source release near ground in lower right corner of grid

NARAC is Implementing Improvements to Physics Process Models (Example: Deposition Velocity)

- Particle dry deposition: Petroff & Zhang (2010)
  - Parameterizes effects of vegetation canopies
  - Applicable/validated against widest range of land-use types
- Gas dry deposition: Wesley (1998 & 2002) surface canopy resistance model
- Particle-size and precipitation-rate dependent wet deposition with separate treatment of in-cloud and below-cloud processes
  - In-cloud scavenging: Hertal et al. (1995) and Stohl et al. (2010)
  - Below-cloud scavenging: Slinn (1984) and Loosmore & Cederwall (2005)
  - Height of cloud base and top: Seiber & Arnold (2013)



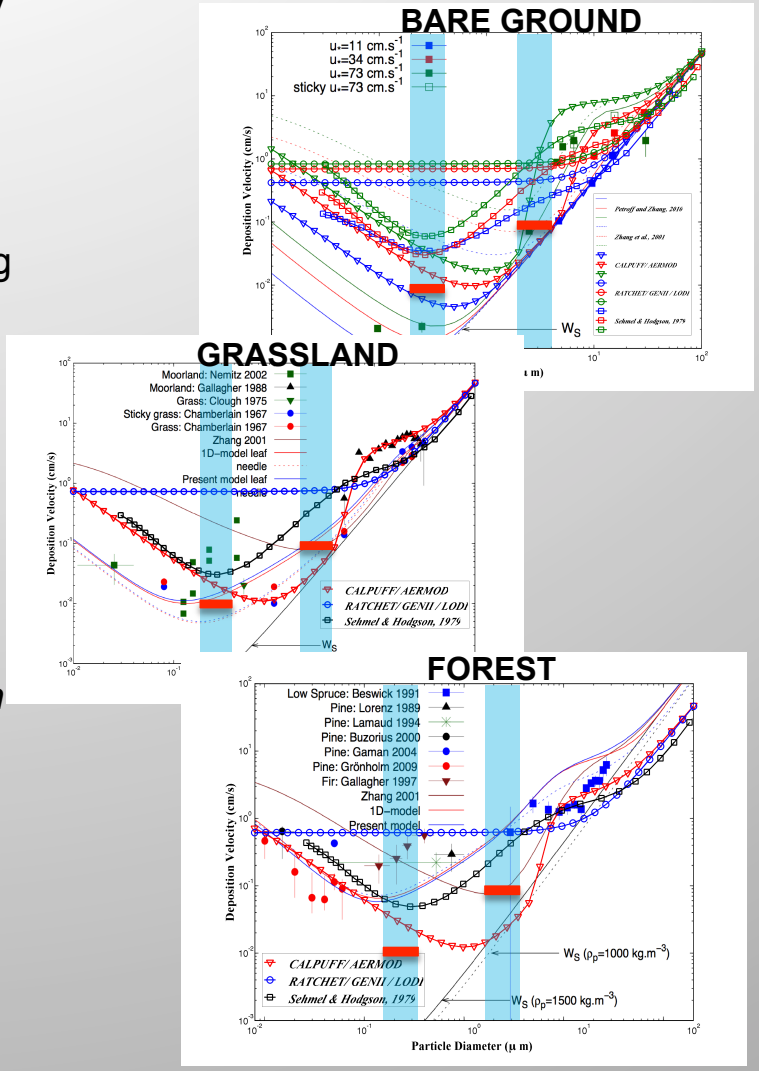
Predicted relative ground deposition pattern without (right) and with (left) spatially and temporally-varying precipitation scavenging



Comparison of Japan wet deposition pattern from lower resolution GFS/LODI (left) and higher resolution WRF/LODI (right) simulation

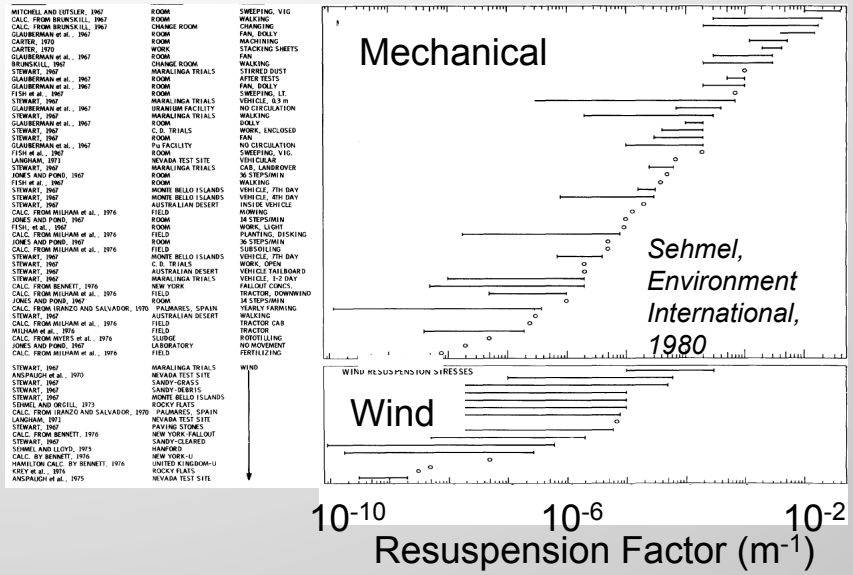
NARAC Investigated Deposition Velocity and 95th Percentile Methods at the Request of the DOE Chief of Nuclear Safety

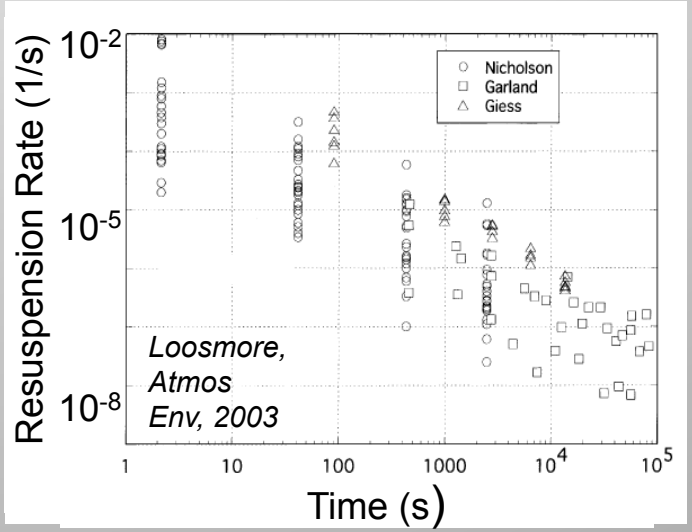
- Driven by concerns raised by the Defense Nuclear Facility Safety Board (DNFSB) in 2010 about the deposition velocity values used in site safety analyses
- Petroff and Zhang (2010) model identified as best current state-of-the-science deposition model
- Comparison with experimental data and Petroff and Zhang (2010) model showed that HSS recommended default values (red bars) are conservative for most scenarios apart from cases involving bare ground
- Software developed to calculate 95th percentile air concentrations that combines hourly meteorology with wind-sector dependent deposition velocities, land-use categories, and site-boundary distances to avoid hyper-conservatism
- Final Report released and distributed by CNS: *Deposition Velocity Methods for DOE Site Safety Analyses* (LLNL-TR-654366)
- Results briefed to Accident Analysis Working Group and DOE Energy Facility Contractors Group Safety Analysis Workshop (2014 October 11-16)
- DOE CNS stated that the LLNL effort is an important contribution to addressing the DNFSB concerns



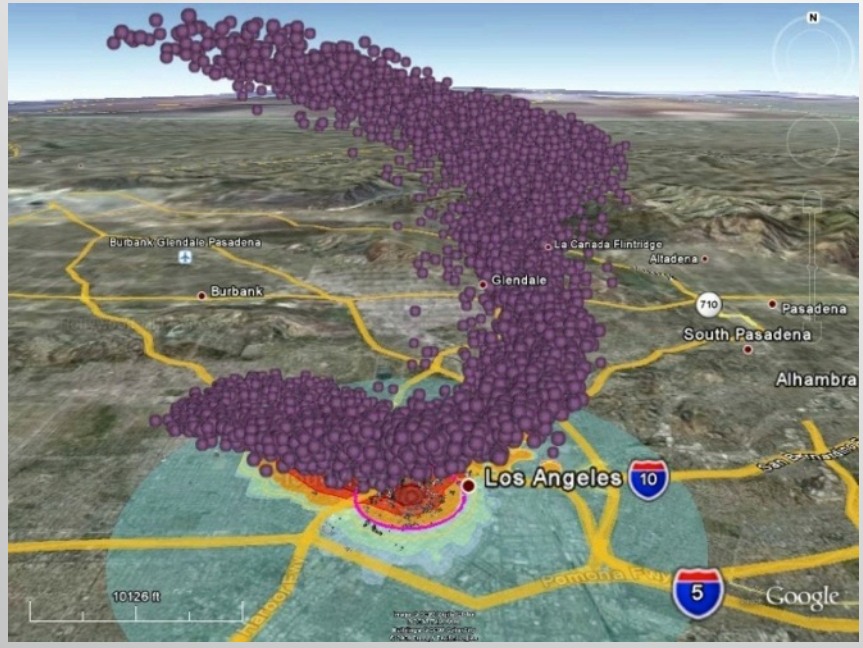
Resuspension Modeled Via Either Resuspension Factors or Resuspension Rates

- Resuspension factors depend on wind, surface conditions and mechanical disturbances
- Weathering causes resuspension rates to decrease with time as aerosols become bound in the environment (and migrate into soil, vegetation)
- Easily resuspended aerosols are lost early with 50-75%of first-year resuspension occuring the first day
- Models that account for time dependence of resuspension rate perform better
- Updated resuspension model based on Maxwell and Anspaugh (2011)





LLNL Models Are Provide Analyses of Prevailing Winds and Variability of Dispersion Calculations



Simulation of nuclear debris particles, prompt damage (circles), and two-lobed fallout pattern several minutes after a hypothetical nuclear explosion in Los Angeles (FEMA IND response planning)

Example of fallout dose pattern for New York City under multiple weather conditions (Homeland Security Presidential Directive 18 assessments)

Source Term Models

National Atmospheric Release Advisory Center

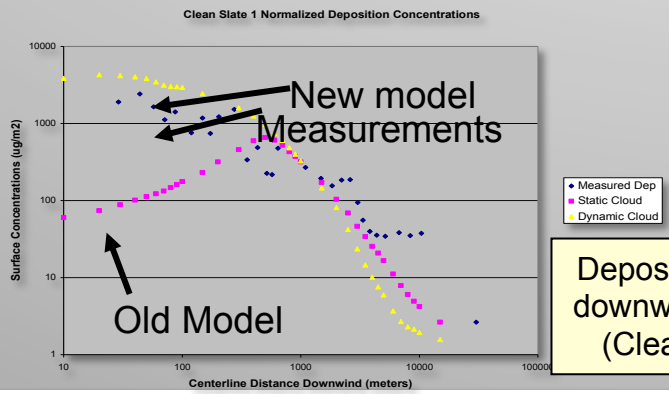
NARAC

LLNL/NARAC is Improving the Fidelity of RDD Models Based on Experimental Studies

- NARAC models have incorporated results from SNL experiments
  - Ballistic particles (>100 um) ejected from the thermally buoyant cloud faster than previously assumed
  - Increases near-source ground contamination, but reduces downwind ground concentrations
- Experimental results from on-going Green Field (GF) experiments are being used to:
  - Improve predicted cloud-top heights for lower high explosive amounts
  - Investigate new particle-cloud coupling methods
  - Test RDD modeling
- Improved activity/particle size and height distributions for different surfaces (on-going)

Sandia National Laboratories

LODI predicted ground-shine dose without (left) and with (right) ballistic particle correction for a source with 30% 0.1-100 μm and 70%100-1000 μm particles. Ballistic particle correction increases near-source concentrations but reduces downwind contamination levels.

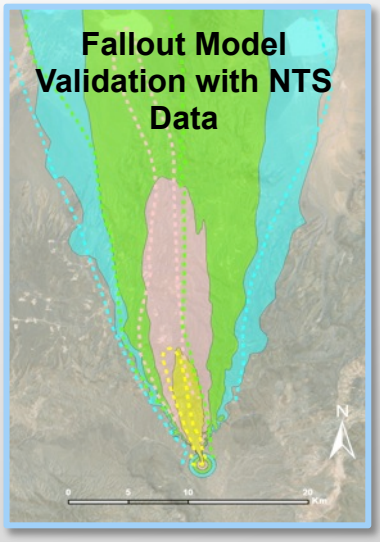


Deposition versus downwind distance (Clean Slate 1)

RDD Models: Stephanie Neuscamman and Kevin Foster (ret.)
RDD Expt: Fred Harper and Marv Larsen (SNL)

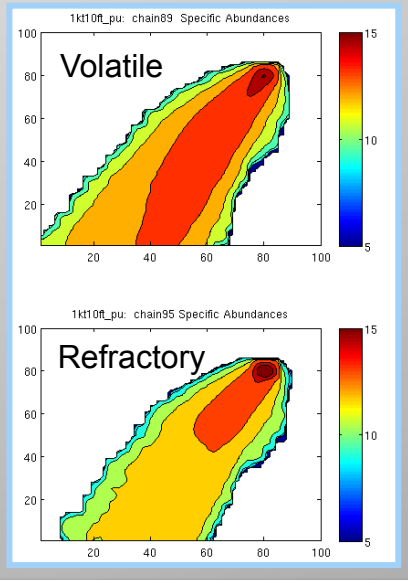
Higher Fidelity Nuclear Detonation / Fallout Models Are Used for Response and Forensics Applications

- Coupled suite of LLNL, Sandia Nat. Lab. (SNL) and Oak Ridge Nat. Lab. (ORNL) computer models
  - Radionuclide inventories (ORNL/ORIGEN fission products) and neutron activation products (LLNL/LWAC)
  - Dynamic cloud rise (ORNL/DELFICST and SNL/ERAD) and geometry
  - Particle/activity-height distributions and cloud geometry (LLNL/KDFOC, ORNL/DELFICST)
  - Fallout fractionation (different particle/activity size distributions for volatile and non-volatile nuclides)
- New products for nuclear forensics applications (for fallout sample collection guidance)
  - Total fallout debris mass
  - Equivalent fissions
  - Specific abundance
  - Fractionation ratios
  - Nuclide or mass chain total deposition
- Future model development
  - Non-desert environments (urban, water)
  - First principles cloud rise, particle formation, and cloud-coupling methods



LLNL-ORNL LODI-LWAC-DELFICST code predicted groundshine dose rate (colored areas) overlaid with contours of measured dose rate (dashed lines) NTS Operation Sunbeam/ Johnnie Boy Test

Different downwind distributions of volatile and non-volatile radionuclides due to fractionation



NucDet Models: John Nasstrom, Peter Goldstein, Brenda Pobanz, Nathan Wimer, Kevin Foster (ret.)

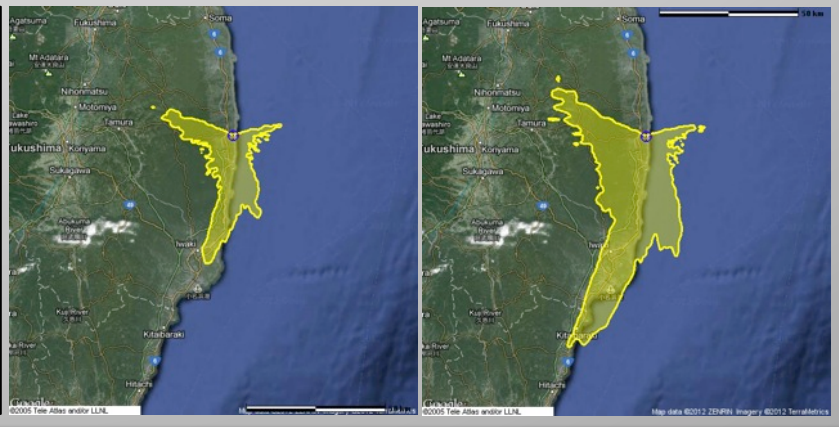
NARAC Has Implemented Enhanced Source Term Exchange Formats and Nuclear Power Plant Scenarios

- Collaborative effort with US Nuclear Regulatory Commission (NRC) for nuclear power plant accidents
  - Expanded electronic files to share/import complex nuclear power plant release information into NARAC model simulations
  - Default set of nuclear reactor release scenarios
  - Exploratory efforts to determine whether/how SNL's MELCOR severe accident analysis code could be effectively coupled to atmospheric dispersion models

Real World	Ci
Chernobyl	2.1E+08
Fukushima	1.2E+07
Three Mile Island	2.5E+06
Tomsk Reprocessing Plant	
Windscale Fire	
RASCAL Workbook	
Assessing a PWR Core Damage Accident	
Loss Of Coolant Accident (pg 14, 200)	
Long Term Station Blackout Source Term (pg 84, 205)	
Release Pathway Reduction Mechanisms (pg 95, 207)	
1 -Sprays and Fans off, Ice bed exhausted, 4 inch hole, pressure 15 lbs/in2	
2 - Sprays and Fans off, Ice bed exhausted, 4 inch hole, pressure 5 lbs/in2	
3 - Sprays and Fans off, Ice bed exhausted, 2 inch hole, pressure 5 lbs/in2	
4 - Sprays and Fans off, Ice bed NOT exhausted, 2 inch hole, pressure 5 lbs/in2	
5 - Sprays Off and Fans On, Ice bed NOT exhausted, 2 inch hole, pressure 5 lbs/in2	
6 - Sprays and Fans On, Ice bed NOT exhausted, 2 inch hole, pressure 5 lbs/in2	
Containment Bypass (pg 101, 210)	
Steam Generator Tube Rupture with Coolant Release (pg 104, 211)	
Containment Holdup (pg 106, 212)	
Specified Core Damage Point (pg 108, 215)	
Spent Fuel Assembly Damaged Underwater (pg 160, 219)	
Spent Fuel Pool Drained (pg 162, 221)	
Spent Fuel Dry Cask Rupture (pg 166, 222)	

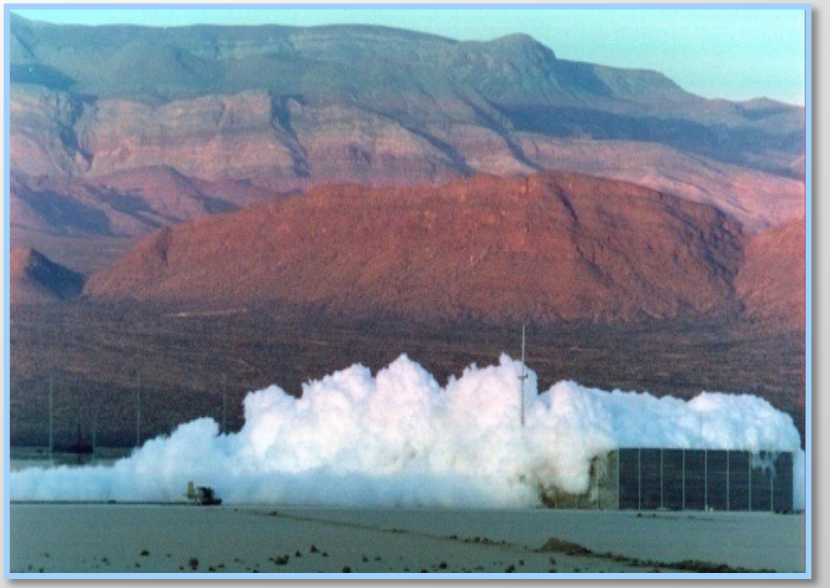
PWR/BWR Examples	
PWR	
Station Blackout, Containment Leakage	1.6E+05
Station Blackout, Steam Generator Tube Rupture	7.2E+08
Station Blackout, Containment Bypass	3.0E+08
Loss of Coolant Accident, Containment Bypass	4.0E+07
Loss of Coolant Accident, Containment Leakage	1.0E+05
Loss of Coolant Accident, Steam Generator Tube Rupture	6.1E+08
Coolant Release, Steam Generator Tub Rupture	2.4E+02
Coolant Release, Containment Bypass	5.0E-01
BWR	
Station Blackout, Containment Bypass, Release from Reactor building	4.9E+08
Station Blackout, Containment Bypass, Release via Standby Gas Treatment System	3.5E+08
Station Blackout, Dry Well, Release from Reactor building	5.2E+05
Station Blackout, Dry Well, Release via Standby Gas Treatment System	3.1E+05
Station Blackout, Suppression Pool, Release from Reactor building	3.1E+05
Station Blackout Suppression Pool, Release via Standby Gas Treatment System	3.1E+05
Coolant Release, Containment Bypass, Release from Reactor building	2.4E+00
Coolant Release, Containment Bypass, Release via Standby Gas Treatment System	2.0E-02
Loss of Coolant Accident, Containment Bypass, Release from Reactor building	1.7E+08
Loss of Coolant Accident, Containment Bypass, Release via Standby Gas Treatment System	6.6E+07
Loss of Coolant Accident, Dry Well, Release from Reactor building	4.4E+05
Loss of Coolant Accident, Dry Well, Release via Standby Gas Treatment System	3.6E+05
Loss of Coolant Accident, Suppression Pool, Release from Reactor building	3.6E+05
Loss of Coolant Accident, Suppression Pool, Release via Standby Gas Treatment System	3.6E+05

Different iodine gas partitioning:
- (Left) 100% respirable particles
- (Right) 25% particles in respirable size range, 45% organically-bound gas, and 30% inorganic gas



LLNL Has a Multi-Decade Record of Dense Gas Experiments and Modeling

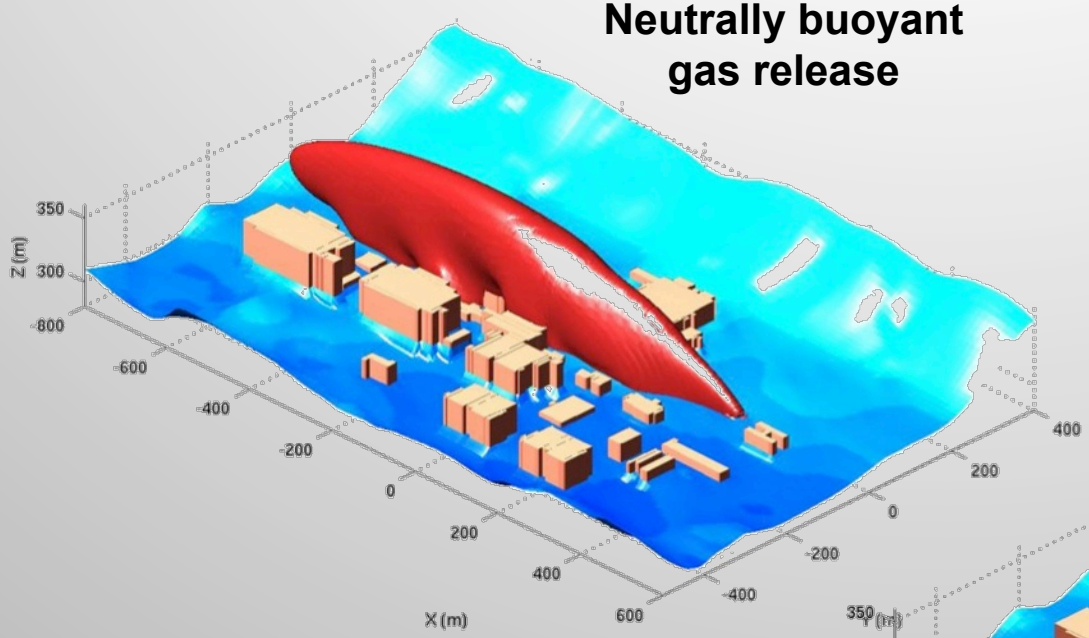
- Releases of large quantities of cold or pressurized toxic industrial chemicals may result in a denser-than-air gas
  - Dense gases remain close to the ground, flow down terrain slopes
  - Plumes may spread upwind of the source location
- LLNL played a lead role in the study of releases of liquefied natural gas and conducted field experiments at the Nevada Spill Test facility in the 1980s
- 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 the present, LLNL developed advanced models have been developed and used to simulate dense-gas dispersion in the presence of buildings and/or complex terrain



Aeolus LES dense gas simulation

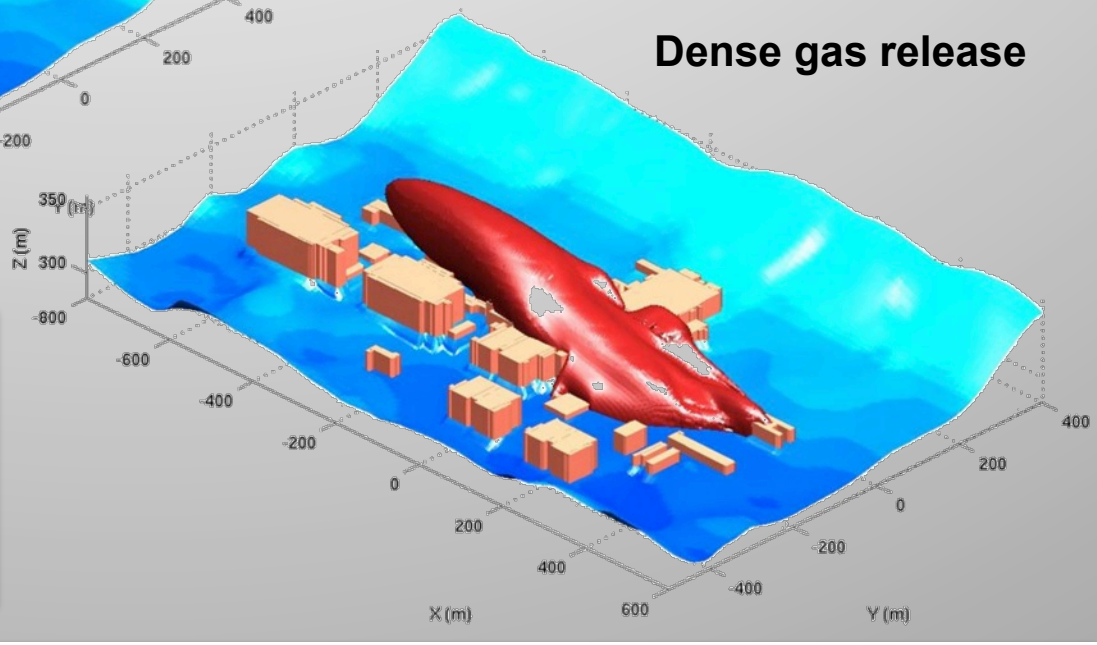
CFD Models Provide More Realistic Predictions for Toxic Industrial Chemicals in Urban Areas

Neutrally buoyant gas release



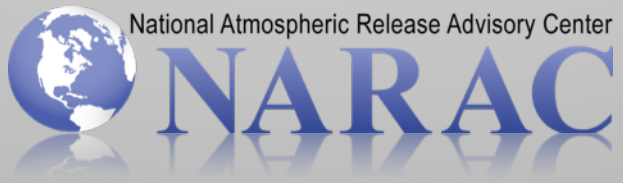
Isosurfaces of 200 mg/m^3 (10 minutes after release

Dense gas release



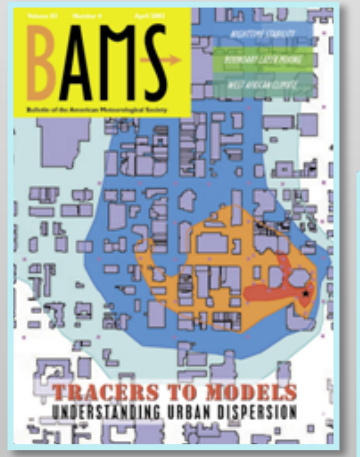
Buildings increase vertical mixing. Gas density suppresses vertical mixing, while increasing lateral spreading near the source and upwind dispersion.

Urban Models



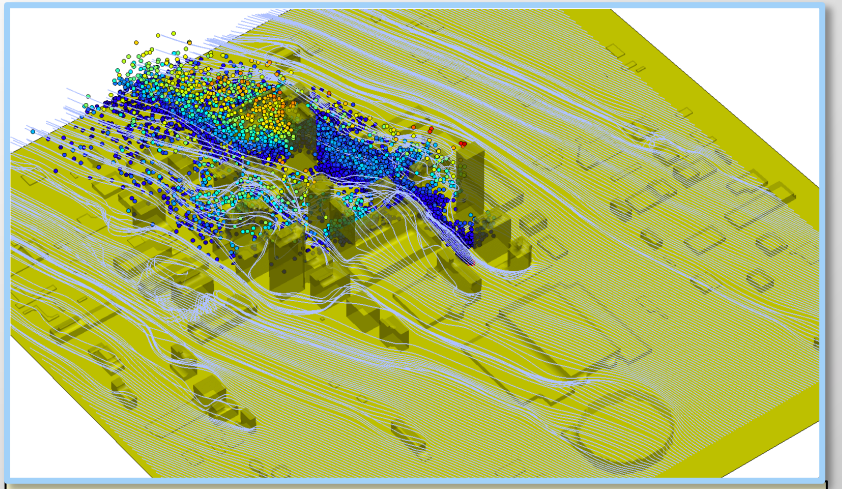
Urban Field Studies Have Resulted in New Physics Understanding and Improved Urban Models

- LLNL has been a major participant in ground-breaking U.S. 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 international agencies collaborated on these experiments

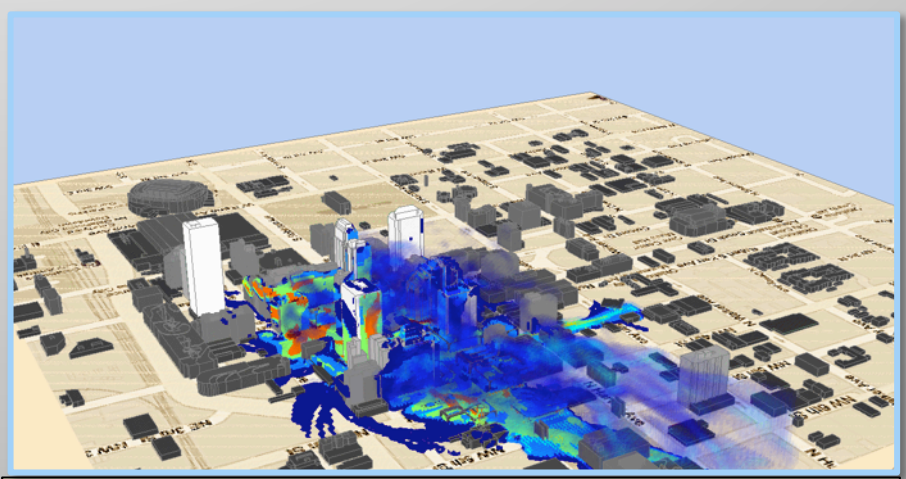


NARAC is Developing a New CFD Capability For Urban and Complex Terrain Environments

- New building-resolving computational fluid dynamics model *Aeolus*
  - Based on first principles physics
  - Particulate, neutrally buoyant and dense gas releases; Static and moving sources
  - Prediction of important flow features (e.g., channeling, reversed flow, end vortex, divergence)
  - Lagrangian dispersion code
- Rapid automated model grid generation based on NGA/USGS building data
- Fast-running Reynolds Averaged Navier-Stokes model (RANS) steady state solution
- High-fidelity time-dependent Large Eddy Simulation (LES) solution
- Excellent performance for 12 different trials during Joint Urban 2003 field campaign
- Computational performance suitable for operational applications

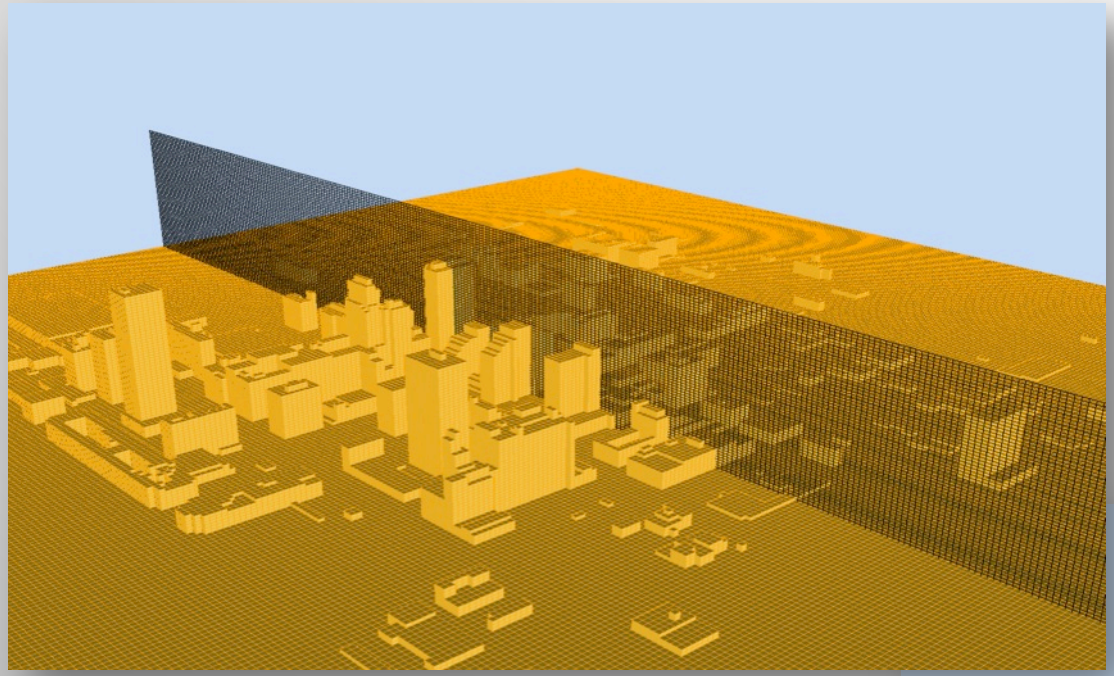


RANS simulation

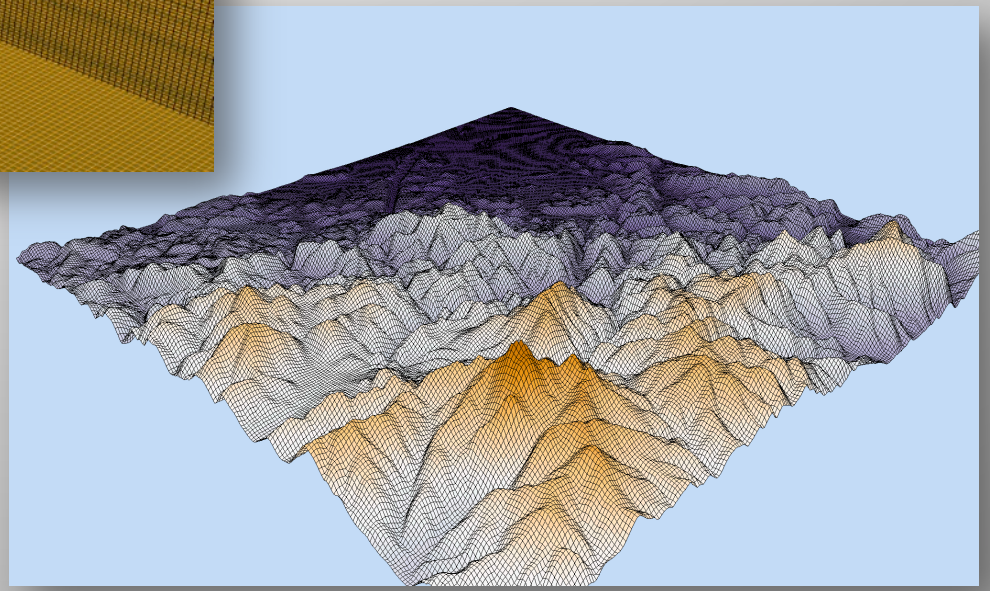


LES simulation including building deposition

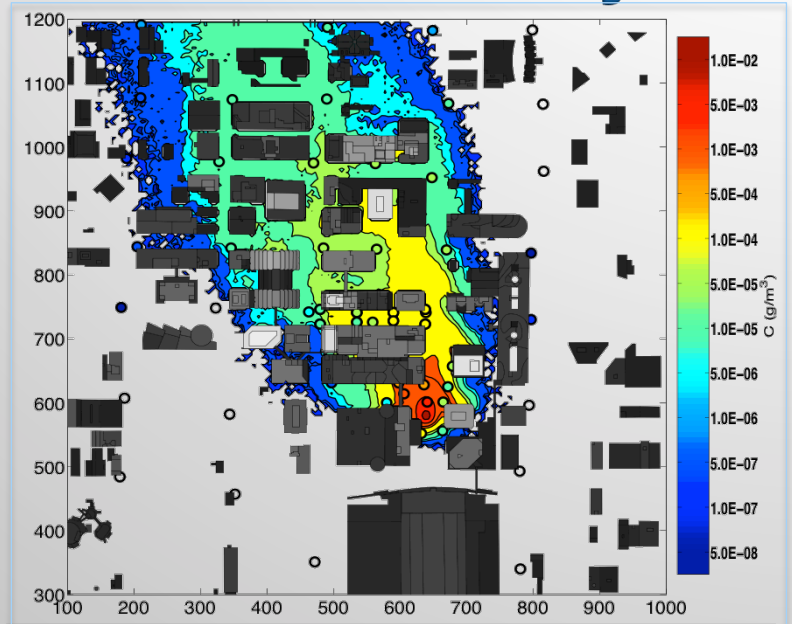
Aeolus Grid Generation is Rapid and Fully Automated



- Stair-stepped grid (3D matrix of 1s and 0s)
- Same grid used for flow and dispersion

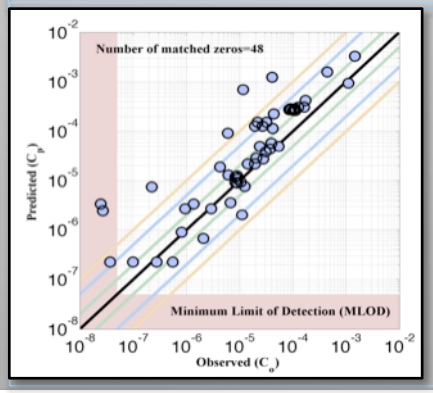


Aeolus Has Been Extensively Validated Against Urban Field Study Data Sets

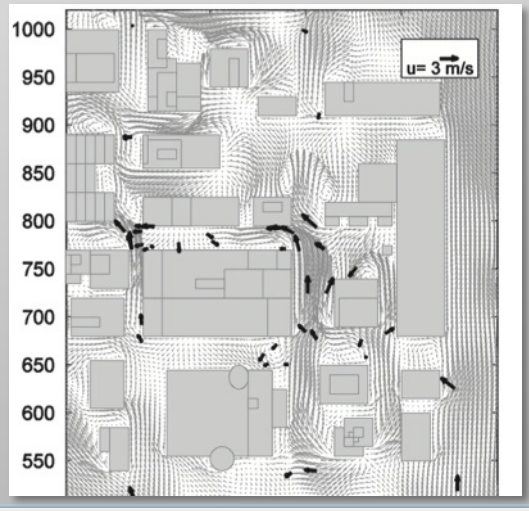


Contours of 30 minute averaged concentration overlaid with 30 min averaged field concentration data (color coded circle): horizontal slice (*x*-*y* plane) at 2 m AGL.

- Model was validated using data from 12 different trials during Joint Urban 2003 field campaign
- Concentrations predicted by the model were found to be in good agreement with the field data (~50% were predicted within a factor of 2, ~70% within a factor of 5 and ~80% within a factor of 10)
- Performance on quad-core laptop
  - RANS model took ~200 sec for each of these cases (4.5 million grid points)
  - Lagrangian dispersion model took ~80 sec (using 0.5 million particles)



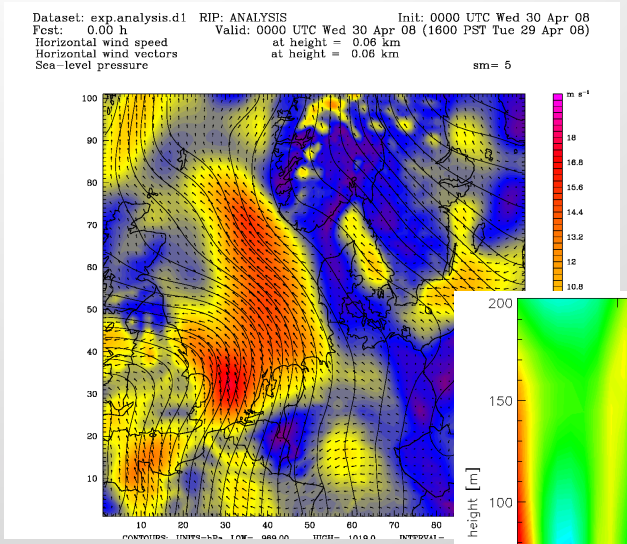
Scatter plot of predicted and observed 30 minute averaged concentration (g/m^3) paired in space and time on a horizontal slice (*xy* plane) at 2 m above ground level



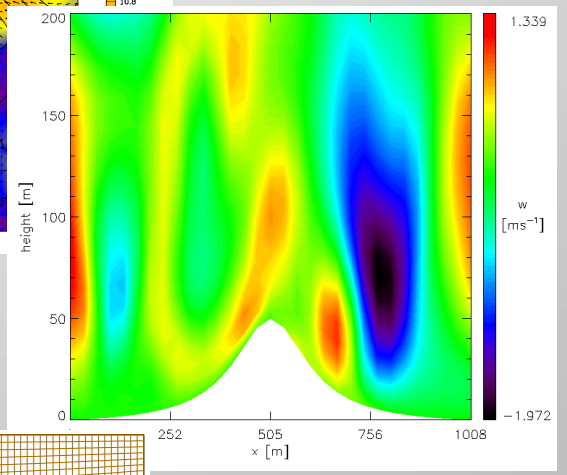
Aeolus predicts Important urban flow features including channeling, reversed flow, vortices, divergence etc.

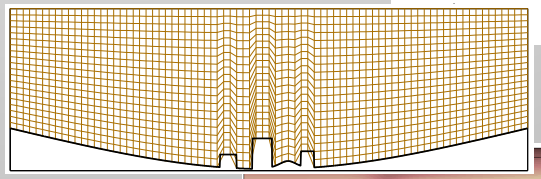
LLNL Research is Advancing Regional Numerical Weather Prediction Models to Resolve Buildings

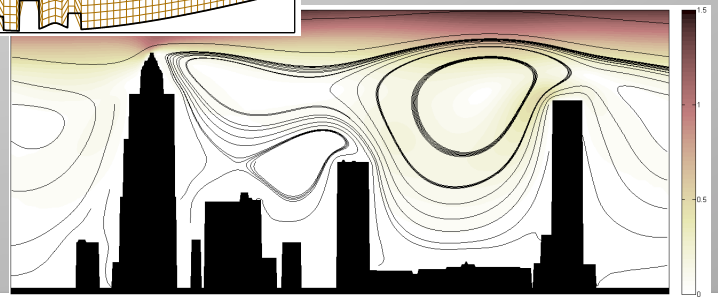
- Immersed Boundary methods (IBM) represents complex geometries on a structured grid by imposing boundary conditions inside of the computational domain
- IBM allows model coupling of physical processes across a range of scales
- IBM can be used on the inner nest to explicitly resolve complex and urban terrain
- Advanced turbulence models developed for large-eddy simulations are required
- Developed and implemented into WRF numerical weather prediction models (LLNL, UC Berkeley, NCAR)



LLNL LDRD: Lundquist, Chow, and Lundquist



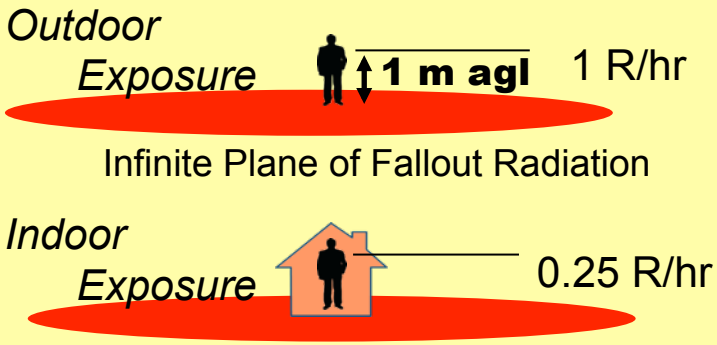


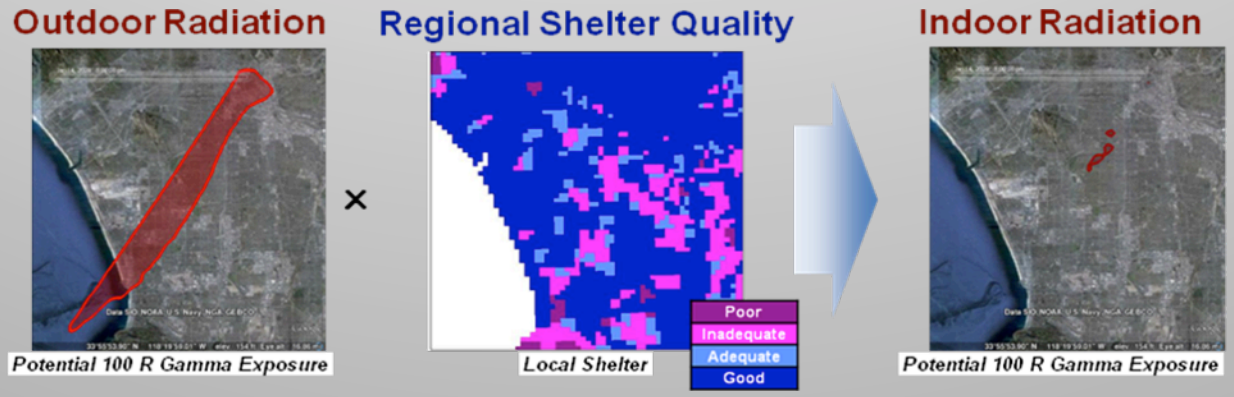


Building Shielding Calculations Improve Estimates of Casualties from Fallout

- Modeling of effects of building sheltering/ shielding to calculate indoor dose exposures and improve casualty estimates
- LLNL *PFscreen* model provides estimates of building protection factors
- LLNL *Regional Sheltering Analysis* tool estimates potential protection against gamma radiation for a variety of shelter strategies based on existing database of building properties (e.g., U.S. FEMA HAZUS data)
- Infiltration models and building leakiness databases

Building Protection Factor =
ratio of outdoor/indoor exposures = 4

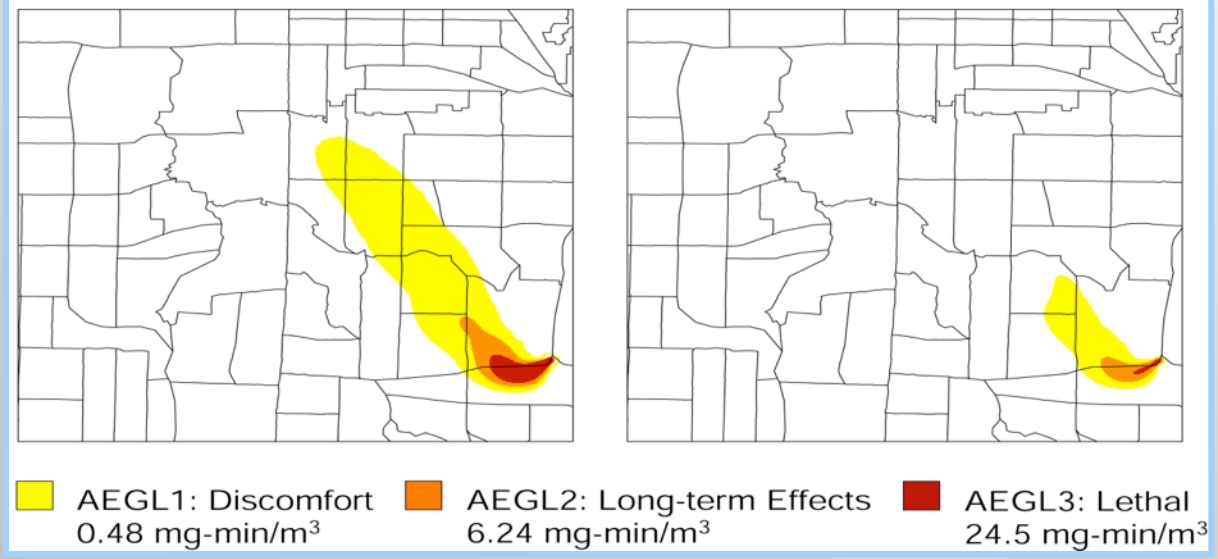


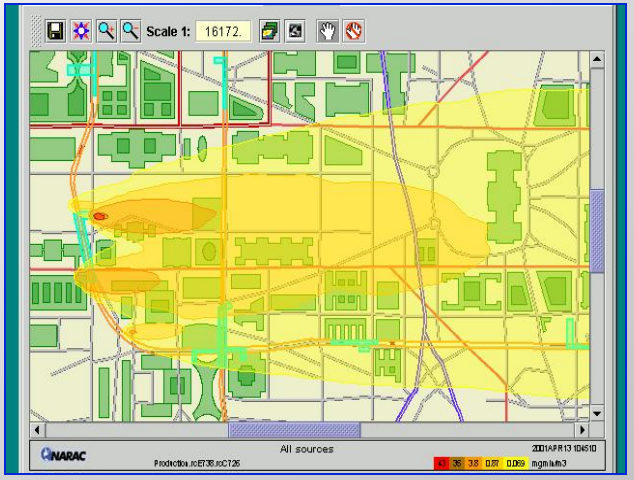


PFScreen: Steve Homann
RSA: Michael Dillon

LLNL/NARAC is Collaboratively Developing Methods to Calculate Indoor Exposures Based on Coupled Models

Outdoor Plume Air Concentration	Corresponding Indoor Air Concentration





Building infiltration models and Census data on residences used to develop statistical relationships and derive a U.S.-wide geospatial leakiness database to infer indoor exposures from outdoor plumes (LBNL collaboration)

Prototype capability estimates outdoor impacts from a subway release (coupled ANL-LLNL model)

Model-Data Analysis Capabilities

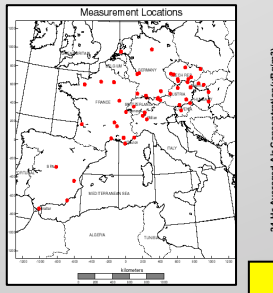
National Atmospheric Release Advisory Center
NARAC

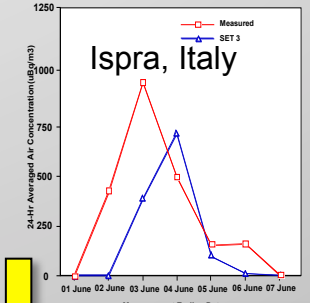
A Variety of Source Estimation Methods Are Used to Refine Plume Modeling Based on Field Data

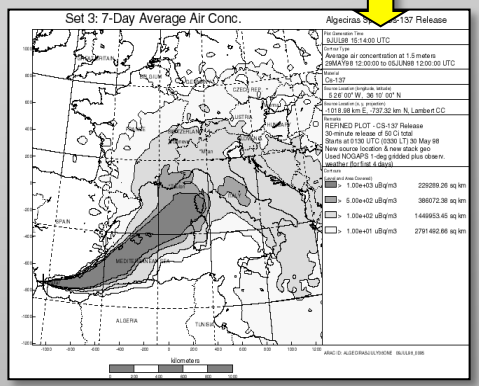
- Backward trajectory methods (accounting for null data)
- Minimization of cost functional
- Source-receptor optimization starting with *a priori* estimate ("predictor-corrector")

- Bayesian inferencing and stochastic sampling
  - Statistically-rigorous technique
  - Backwards analyses to determine probabilistic distribution of unknown source characteristics
  - Optimal forward predictions for consequence assessment
  - Dynamic reduction in uncertainty as additional data become available
  - Complex sources (e.g., multiple, moving)

NARAC chemical odor source location analysis based on backward trajectories



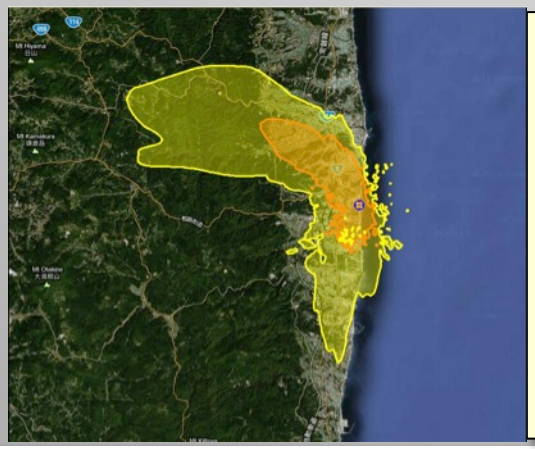




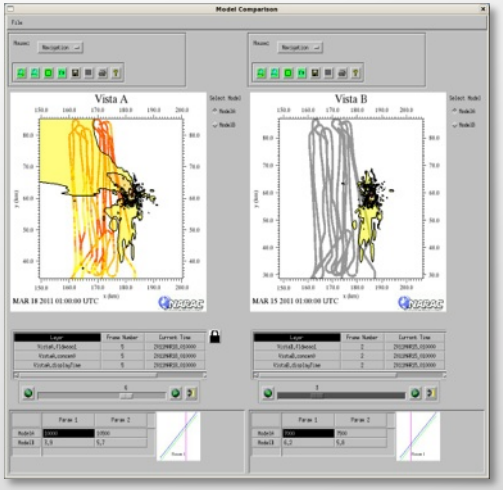
NARAC operational analysis reconstruction of probable source area and emission rate for Algeciras steel mill Cs-137 release

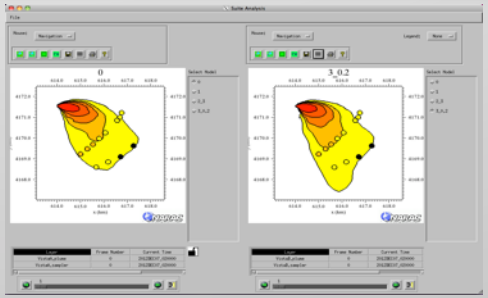
Automated Field Measurement and Model Comparison Tools Reduce Delivery Time for NARAC Data-Model Products

- Measurement-model integration
  - Field-data acquisition including quality assurance
  - Software to rapidly process measurement data
  - Automated sampling of range of potential scenarios consistent with all available information
  - Improved data-model statistical/ graphical comparison and analysis tools to support expert source estimation analyses
  - Source-term estimation



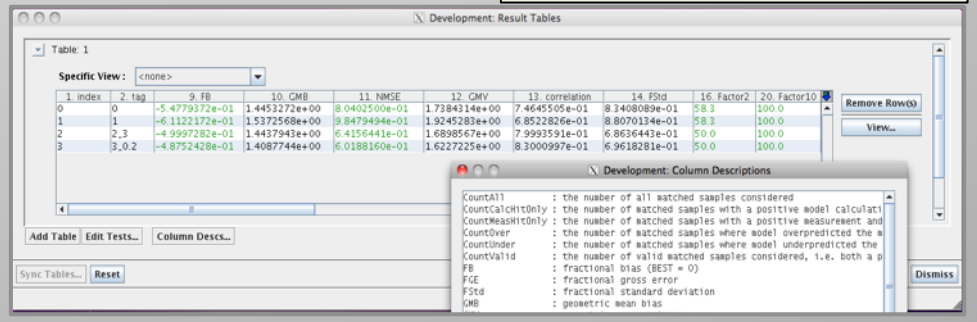
NARAC Fukushima predictions based on source estimation from measurement data



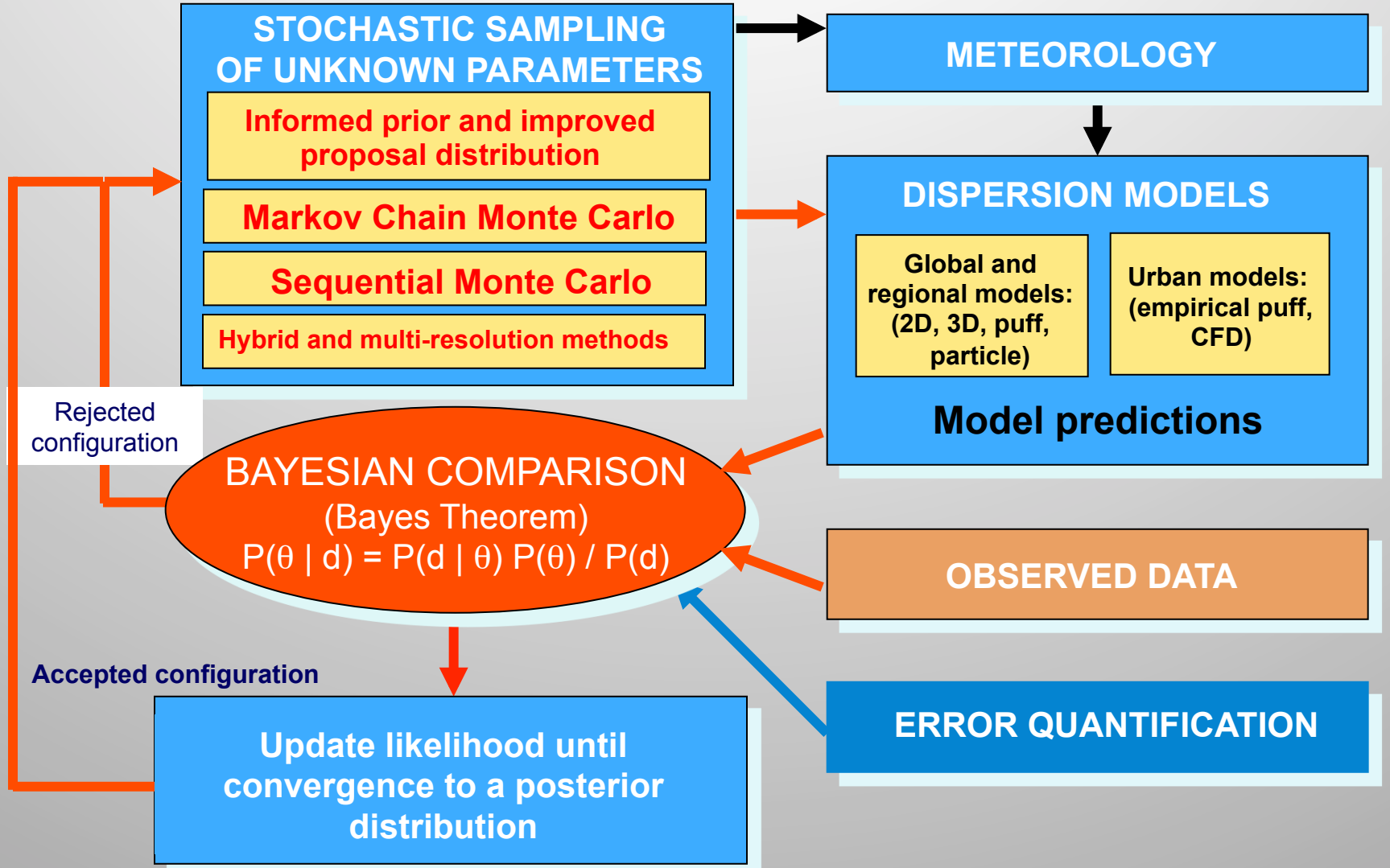


Model-data analysis tools

- Automated generation of a suite of model simulations sampling input parameter space
- Data-model comparisons paired in space time
- Statistics: fractional bias, root mean & normalized mean square error, standard deviation, geometric mean variance, factor of R, etc.
- Graphical model-data comparisons



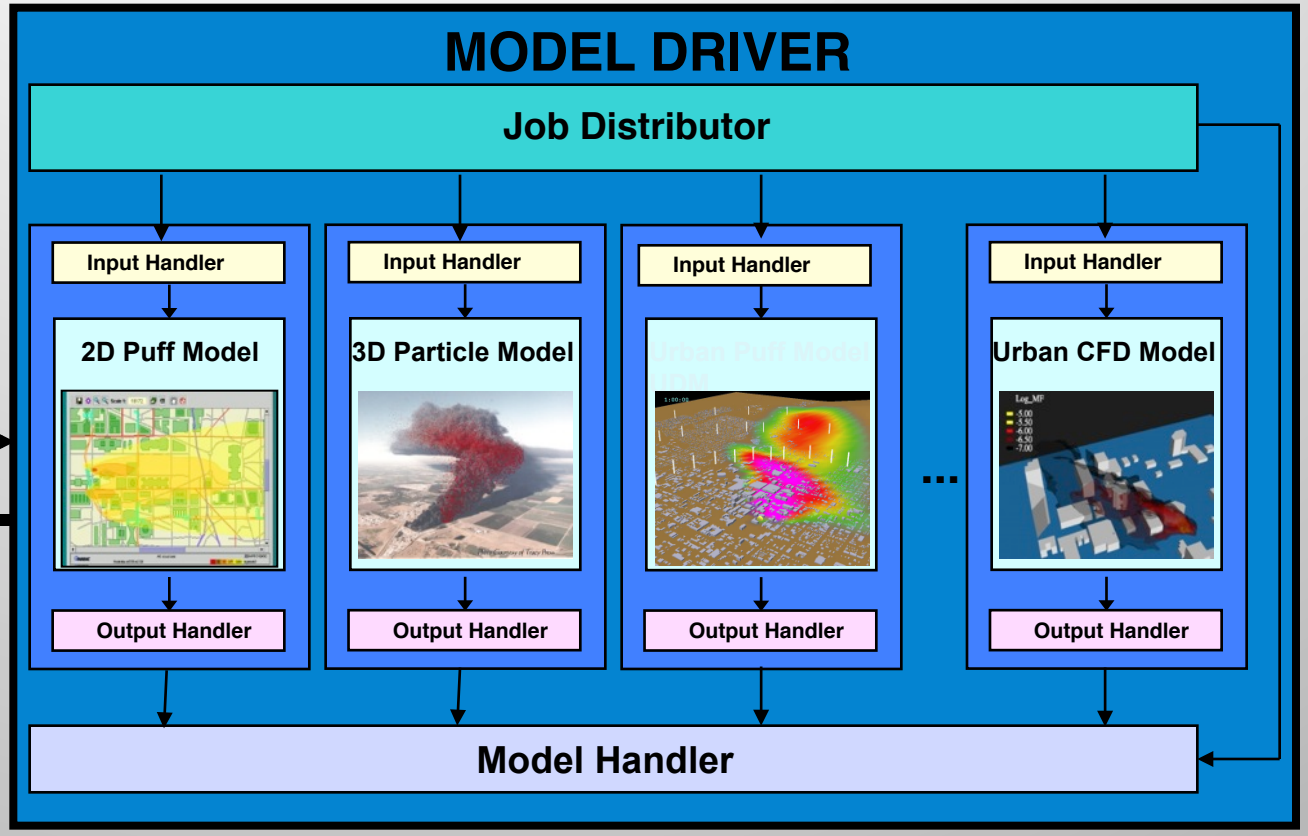
Event Reconstruction Uses Data-Driven Simulation to Answer Critical Questions About Release Events



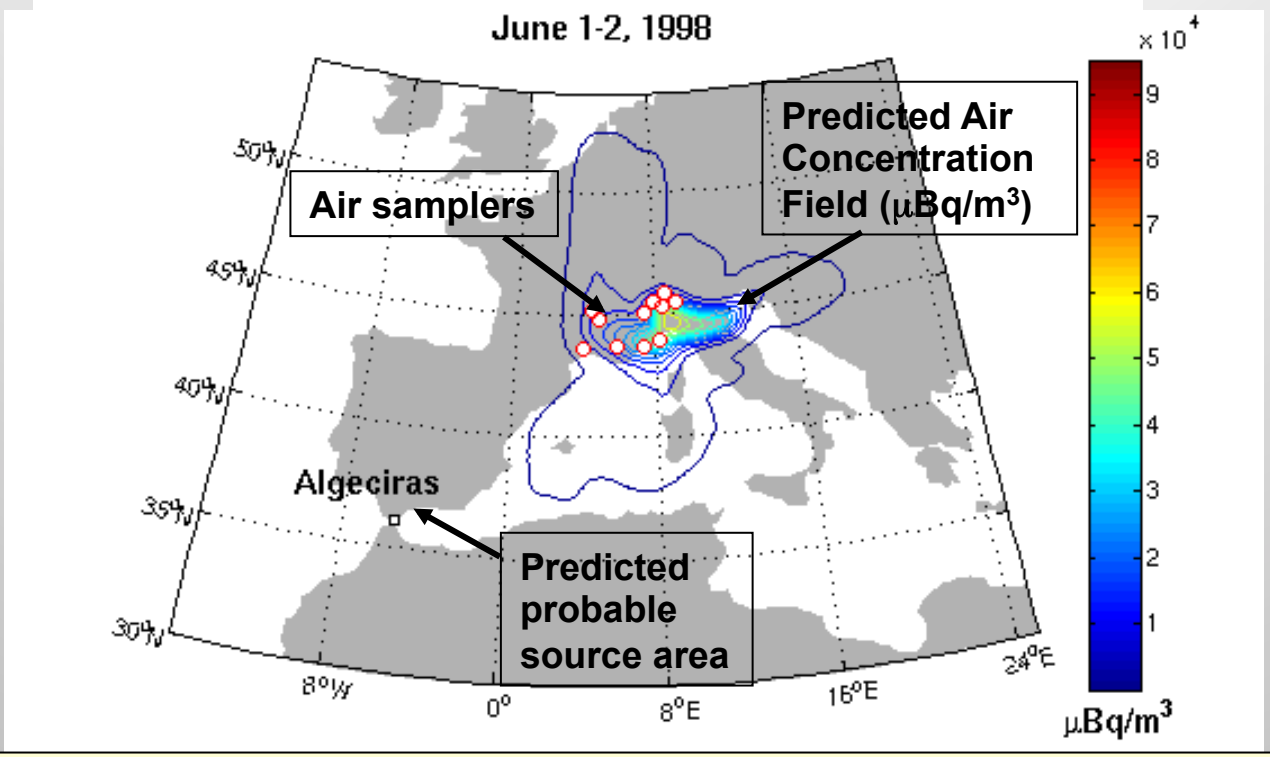
Computational Framework Supports Multiple Atmospheric Models and Stochastic Algorithms

Stochastic Sampling of Unknown Parameters

Bayesian Comparison of Predictions and Measurements



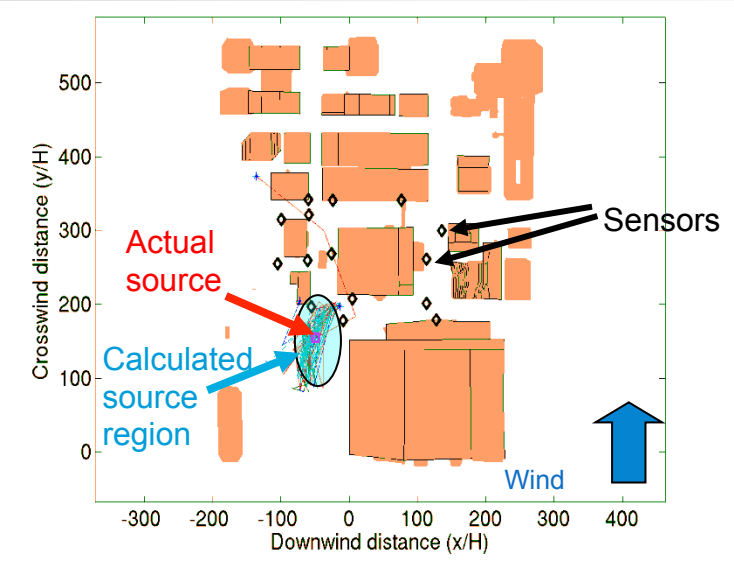
NARAC Source Location / Reconstruction For the Algecieras Cesium-137 Detection in Europe (1998)

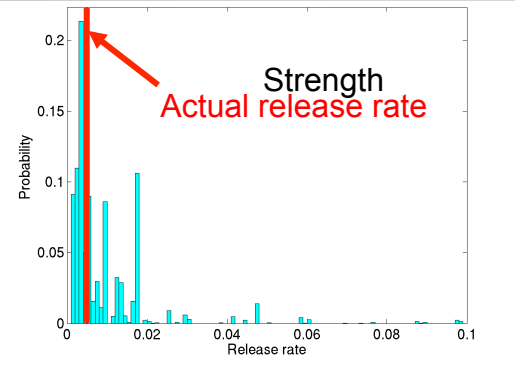


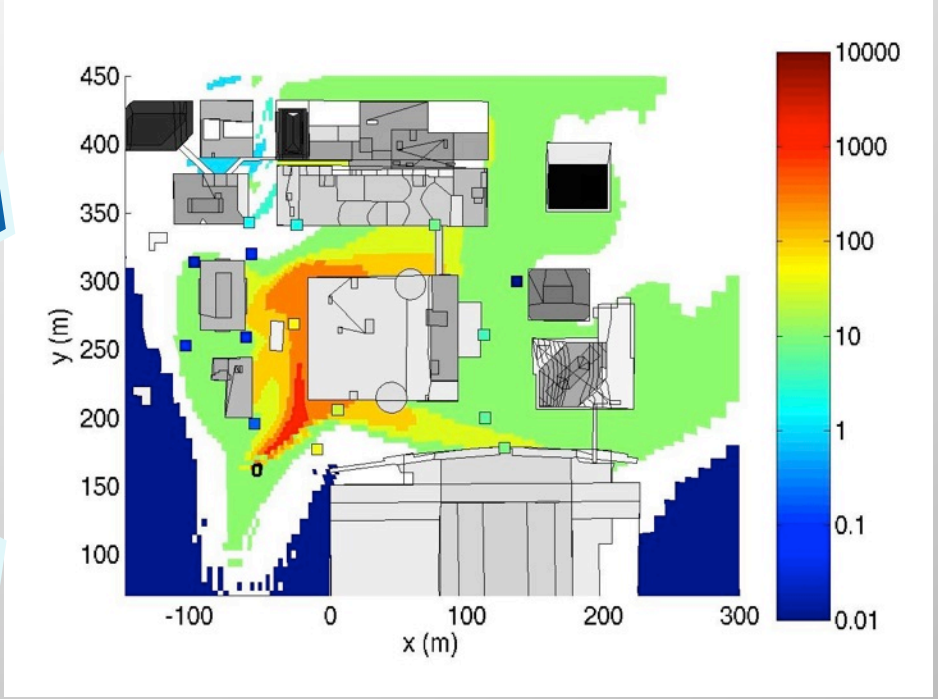
Air concentration (color contours) of plume on the 1st day of detection (June1-2, 1998), was reconstructed using known winds and sensor measurements (at locations shown by red circles) by the event reconstruction tool

- NARAC used operational analysis tools soon after the release was detected to determine the probable source area and emission in southern Spain
- NARAC tested Bayesian inferencing and stochastic sampling methodology using a small subset of the available data to determine the likely source area, emission amount and air concentration fields

Event Reconstruction Produces Composite Plume with Uncertainty Estimate Based on Field Data







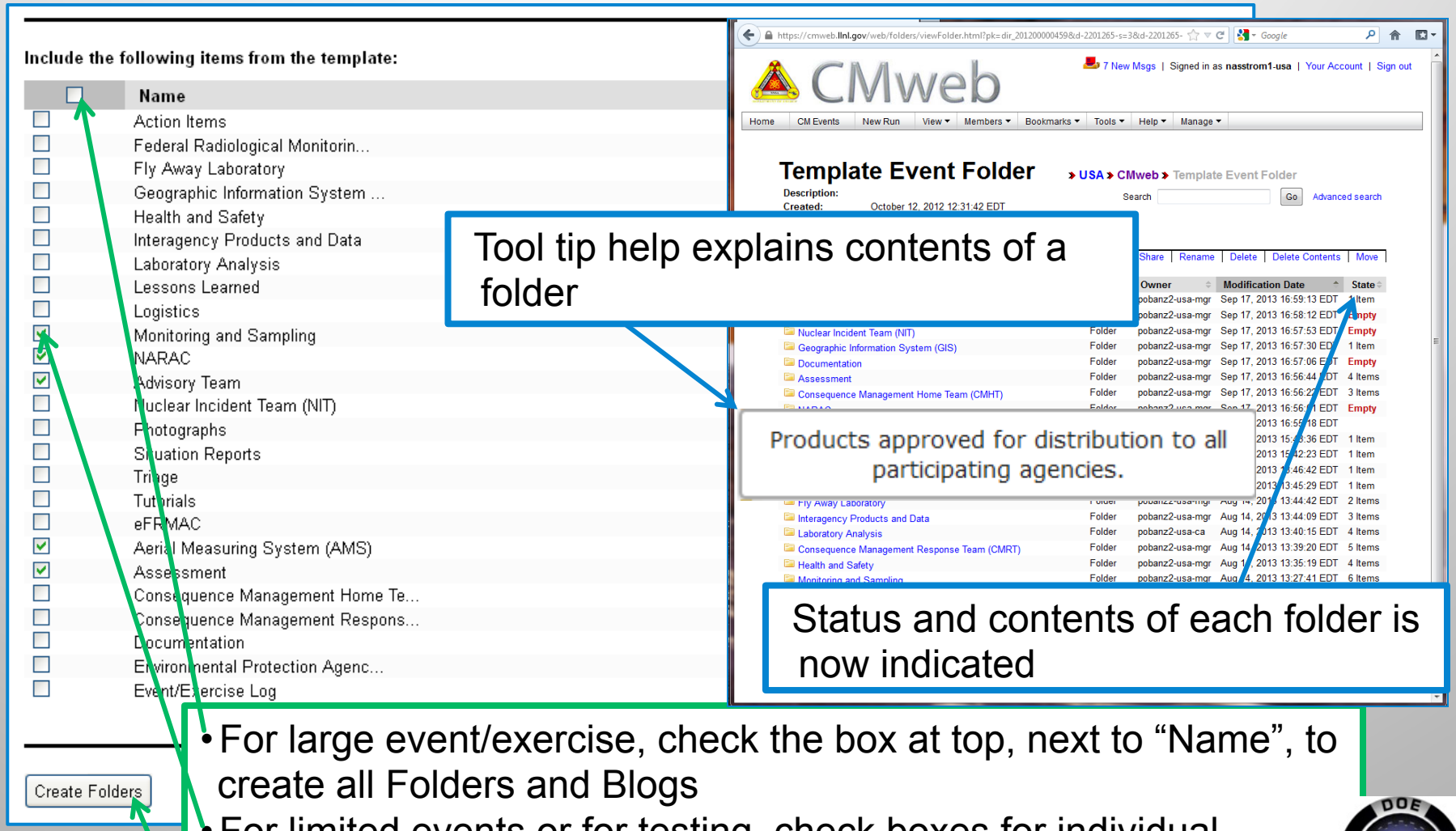
90% confidence plume

Event reconstruction based on Bayesian inference and stochastic sampling estimates source location to within a half block and release rate (left figures) for the JU2003 Oklahoma City release. The 90% confidence level composite plume contours are compared to field data (colored squares) in the figure at right.

Field and Home Team Support Tools (Examples)

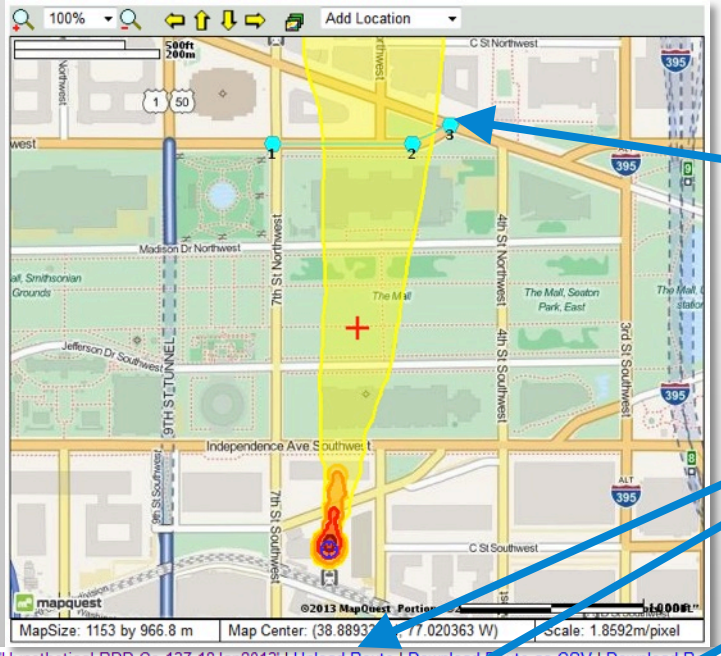
National Atmospheric Release Advisory Center
NARAC

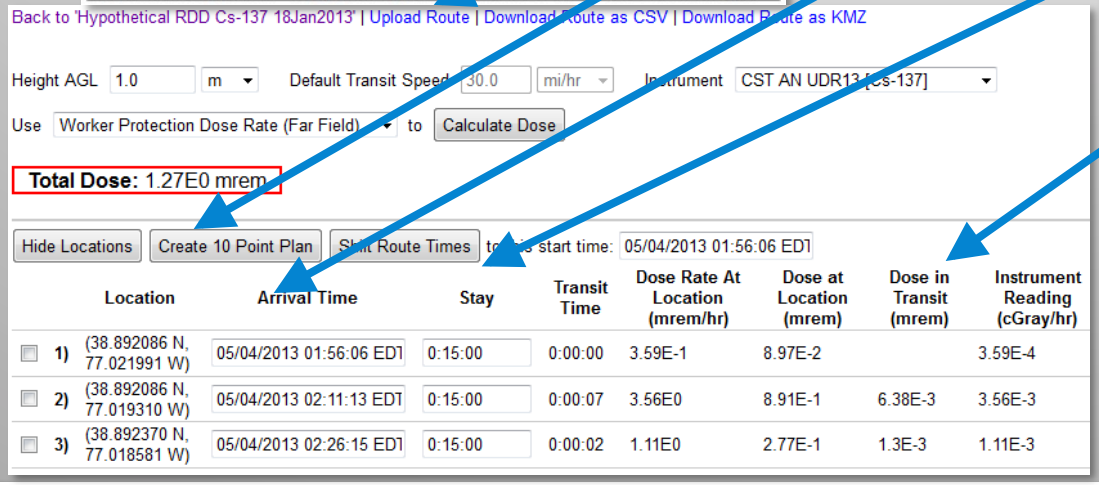
New CMweb Event Creation Wizard Facilitates Information Sharing and Organization During Events



- For large event/exercise, check the box at top, next to “Name”, to create all Folders and Blogs
- For limited events or for testing, check boxes for individual Folders/Blogs you would like to include (to avoid time consuming effort to delete unneeded folders)
- Then, click “Create Folders”

Tools Are Provided to Support Field Teams: Example Web-based Mission Planning Tool





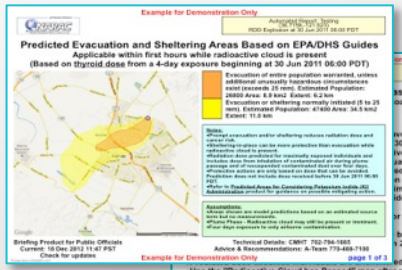
	Location	Arrival Time	Stay	Transit Time	Dose Rate At Location (mrem/hr)	Dose at Location (mrem)	Dose in Transit (mrem)	Instrument Reading (cGray/hr)
1)	(38.892086 N, 77.021991 W)	05/04/2013 01:56:06 EDT	0:15:00	0:00:00	3.59E-1	8.97E-2		3.59E-4
2)	(38.892086 N, 77.019310 W)	05/04/2013 02:11:13 EDT	0:15:00	0:00:07	3.56E0	8.91E-1	6.38E-3	3.56E-3
3)	(38.892370 N, 77.018581 W)	05/04/2013 02:26:15 EDT	0:15:00	0:00:02	1.11E0	2.77E-1	1.3E-3	1.11E-3

Estimate potential dose bases on route and stay times

- Select route by clicking on monitoring route points
- Upload monitoring route or use DOE “10 Point Plan”
- Edit arrival times and stay times
- Shift route times to account for time variation of groundshine dose
- Display calculated dose rate, dose, instrument readings
- Extensions: aerial monitoring and evacuation planning

Products for Communication with Users Are Developed with Interagency Input

- Standard suites of CBRN technical products showing plume hazard areas, affected populations, health effects, protective action guide levels, and geographical information
- Consequence reports documenting results, inputs, assumptions, and plot interpretation
- Interagency-developed Briefing Products for decision makers and emergency responders focused on actions that need to be considered to protect the public and the environment
  - Evacuation / shelter-in-place, relocation, worker protection, agricultural embargo
  - Operational products: radiological dispersal devices, nuclear detonations, nuclear power plant accidents
  - Draft versions: toxic industrial chemicals, chemical/biological agents
- Supplementary analyses (meteorology, deposition, field data, animations)
- Product output in multiple formats for integration into user's GIS systems

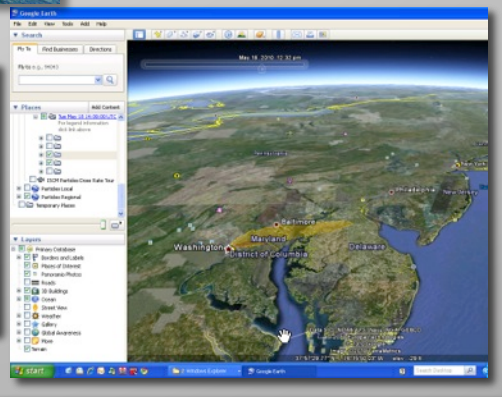


Briefing products for radiological dispersal devices, nuclear detonations, nuclear power plant accidents, CB releases

Animations and time series plots to display evolving impacts

PDF, PowerPoint, HTML/XML, JPG/PNG graphics

ESRI Shape and Google Earth KMZ GIS files with plume areas



Briefing Products: Kevin Foster (ret.), Kristen Yu (LLNL), Harvey Clark (RSL)

NARAC Hardware and Software Upgrades Have Significantly Reduced Response Times

- DOE-funded compute cluster integrated into NARAC operational system
- Software performance enhancements
  - Core physics model run times reduced from 2 hours to 5 min for complex problems
  - Model output pre- and post-processing times reduced from 1+ hour to 10 min for large problems
  - Improved simulation restart capability
  - On-going performance optimization of meteorological data processing software and other subsystems

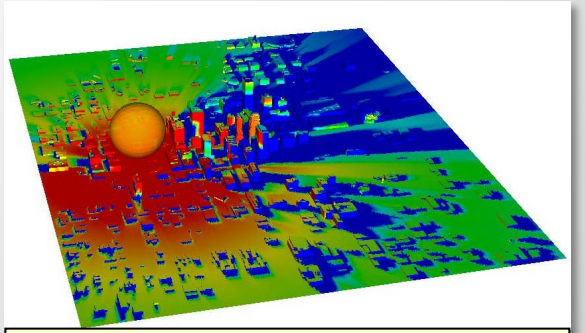
Configuration

- 336 processor cores (3.46 GHz Intel 5690 chipset)
- 1344 GB total memory (4 GB/ processing core)
- High-speed communications network/switch (40 Gbit QDR)
- Linux-based system

Software upgrades and cluster utilization have reduced computational times for complex long-duration simulations involving multiple radionuclides by a factor of 25

Atmospheric Dispersion Modeling Challenges

- Meteorological and dispersion model improvements
  - CBRNE source models
  - Meteorological processes: precipitation, turbulence, vertical mixing, land-sea breezes
  - Physical processes models: deposition, phase/chemical changes, resuspension
  - Effects of urban and other (e.g., over-water) environments
  - Additional field study data for models validation
- Data assimilation and source estimation
  - Use of non-traditional (e.g. remote sensing) data and/or information sources
  - Rigorous quantitative tools and methods for source/event reconstruction and data fusion
- Methods for estimating uncertainty for different environmental / meteorological conditions
  - Ensembles (meteorological and dispersion)
  - Quantitative rigorous uncertainty estimation (source term, meteorology, dispersion processes)
- Data for real-world response and model testing
  - Standardized data (instrumentation, data exchange formats, metadata, quality assurance)
  - Open-access field experiment databases with quality-assured data and documentation
- Communicating technical information and uncertainties to planners, decision makers, and emergency responders



Prompt thermal energy from a nuclear explosion in an urban environments (courtesy of Ross Marrs, LLNL)

National Atmospheric Release Advisory Center

NARAC

Web: narac.llnl.gov
Email: narac@llnl.gov

Lawrence Livermore National Laboratory

Substitute Slides

(not to be included in posted version of slides, but released for use in tour/briefings)

Lawrence Livermore National Laboratory

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This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC. The Department of Homeland Security sponsored part of the production of this material.

LLNL-PRES-609358-Rev1

NARAC Supports Federal Agencies for a Wide Range National & International Missions

- **DOE/NNSA Emergency Operations (NA-40)**
  - Office of Emergency Response (NA-42) – Nuclear search, stabilization, render safe, consequence management
  - Office of Emergency Management (NA-41) – DOE site CBRN emergency planning and safety analyses
  - National Technical Nuclear Forensics (NA-45) – Nuclear forensic sample collection/analysis
  - Office of International Emergency Management and Cooperation (NA-46) – Global dose assessments center for nuclear emergencies
- **DOE NA-30 / DoD Naval Nuclear Propulsion Program (NNPP) and DoD Special Weapons Facilities** – Site emergency preparedness and response
- **NASA via the DOE Office of Radioisotope Power Systems** – Nuclear-powered spacecraft launch accident emergency preparedness and response
- **DHS/FEMA** - National response planning, IMAAC federal plume modeling coordination (through DOE), Nuclear Incident Response Team support
- **DHS & HHS** – National-level hazardous material threat assessments

NARAC services, tools and products predict airborne hazards to (1) make emergency plans, (2) plan crisis response operations, and (3) assess consequences to guide response and recovery decisions

International Users Access NARAC Predictions Using the *International eXchange Program* (IXP)

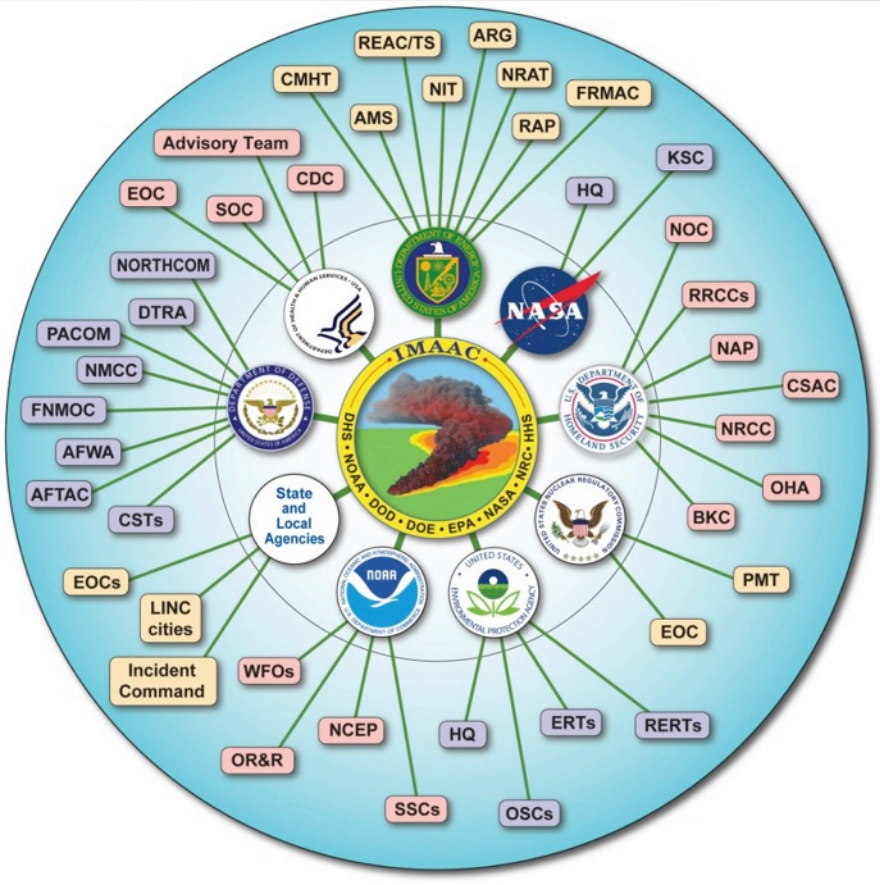
- *International eXchange Program* (IXP) is a Web-based system that allows authorized users around the world to:
  - Run radiological atmospheric dispersion and dose calculations on a *NARAC* computer system for their country only
  - Receive dispersion and dose calculations done by experts at NARAC and other Global Dose Assessment Centers (*GDACs*) in Japan (JAEA) and Russia (FEERC)
- The IXP web site https://ixp.llnl.gov/ provides secure and password-controlled access for users approved by DOE/NNSA and their country's competent authority
- The IXP is used by approximately 40 countries and 3 international organizations including the International Atomic Energy Agency (IAEA), European Commission Joint Research Centre, Nuclear Energy Agency, Org. for Economic Cooperation and Development)

NARAC Provides Radiological Assistance to the International Community Under DOE Auspices

- NARAC supports the International Atomic Energy Agency (IAEA) and its member states
  - Provides the International eXchange Program (IXP) system for sharing information and performing radiological release simulations
  - Conducts outreach and training activities for the DOE Office of International Emergency Management and Cooperation (OIEMC) Program
  - Provides subject matter expertise in atmospheric transport and dispersion
- IAEA Atomic Energy Agency Atoms for Peace support: *"The Incident and Emergency Centre is pleased to welcome the participation of the International Exchange Program, National Atmospheric Release Advisory Center 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." (2011)*

IMAAC Coordinates Federal Dispersion Modeling Under the National Response Framework

- IMAAC created by the Homeland Security Council in 2004
  - Led by DHS, which provides the IMAAC Director
  - Partnership between eight federal agencies
  - 2010 MOU recognizes NARAC as the "operations hub of the IMAAC" (five-year renewal)
- National deployment plan
  - Federal operations centers
  - Federal agency regional assets (e.g., EPA OSCs, NOAA SSCs)
  - Special events
  - National Exercise Program



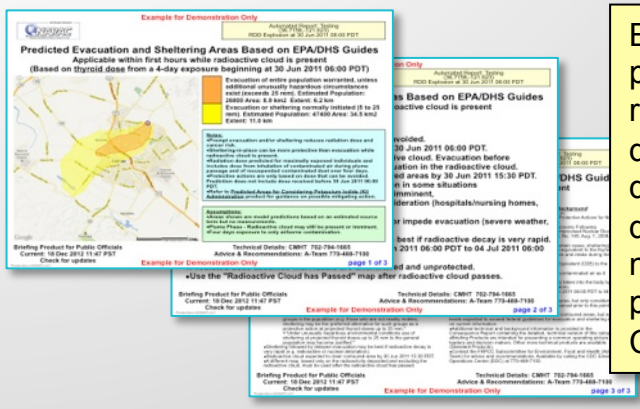
The IMAAC "provides a single point for the coordination and dissemination of Federal dispersion modeling and hazard prediction products that represent the Federal position" during actual or potential incidents - *National Response Framework, 2009*

NARAC Supports a Wide Range Emergency Preparedness and Response Activities

- **Planning and preparedness** predictions of population impacted by rad/nuc/chem/bio releases to help provide:
  - Guidance on emergency response, sheltering/evacuation (e.g., DHS/FEMA nuclear and chemical response guides)
  - Planning for medical countermeasures (e.g., DHS/HHS Material Threat Assessments for biological agent attacks)
- **Training** federal experts and emergency response teams in atmospheric hazards and modeling tools
- **Routine technical and scientific support** from NARAC help desk
- **Exercises and drills** with local, regional, national and international emergency response organizations, including U.S. Principal Level Exercises and National Level Exercises
- **Event** preparedness support for National Security Special Events
- **Emergency** support from 24x7 on-duty or on-call expert scientific staff
- **Post-event** analyses and event reconstruction (e.g., estimation of release amounts and reconstruction of dose)

Products for Communication with Users Are Developed with Interagency Input

- Standard suites of CBRN technical products that show plume hazard areas, affected populations, health effects, protective action guide levels, and geographical information
- Consequence reports documenting results, inputs, assumptions, and plot interpretation
- Interagency-developed Briefing Products for decision makers and emergency responders focused on actions that need to be considered to protect the public and the environment
  - Evacuation / shelter-in-place, relocation, worker protection, agricultural embargo
  - Operational products: radiological dispersal devices, nuclear detonations, nuclear power plant accidents
  - Draft versions: toxic industrial chemicals, chemical/biological agents
- Supplementary analyses (meteorology, deposition, field data, animations)
- Product output in multiple formats for integration into user's GIS systems

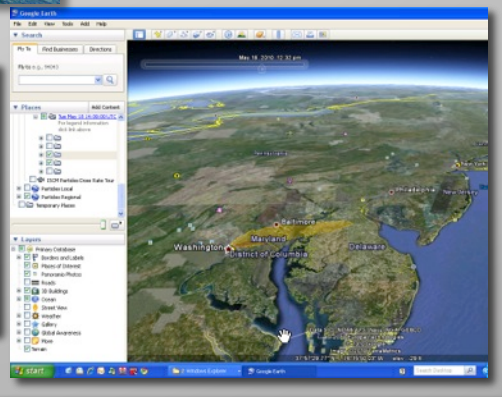


Briefing products for radiological dispersal devices, nuclear detonations, nuclear power plant accidents, CB releases

Animations and time series plots to display evolving impacts

PDF, PowerPoint, HTML/XML, JPG/PNG graphics

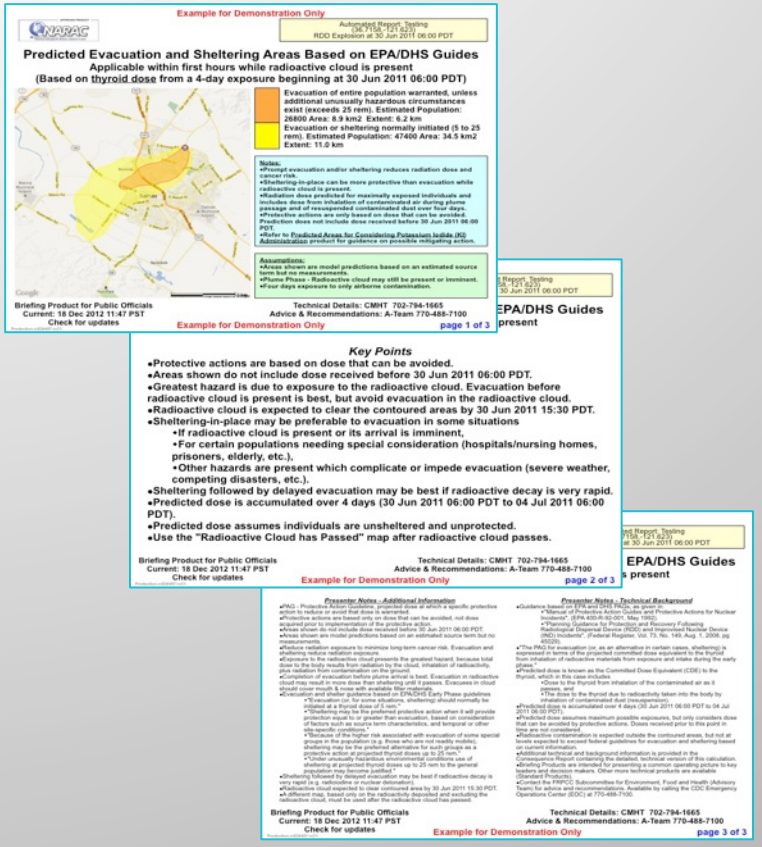
ESRI Shape and Google Earth KMZ GIS files with plume areas



Briefing Products: Kevin Foster (ret.), Kristen Yu (LLNL), Harvey Clark (RSL)

Improving Communication of Technical Information to Decision Makers and Responders is a Key Ongoing Effort

- U.S. DOE is leading the development of radiological/nuclear "Briefing Products"
  - Goal: improve the communication of technical information to planners, decision makers, and emergency responders
  - Focus on actions and decisions that need to be considered (evacuation/ sheltering, relocation, worker protection, agricultural embargoes)
  - Based on existing pertinent agency-published documents for guidance
  - Developed with extensive interagency input
- Designed for Subject Matter Experts briefing of officials and responders (not intended for the general public)



Briefing Products available for nuclear power plant accidents, radiological dispersal devices, nuclear detonations, and chemical/biological releases

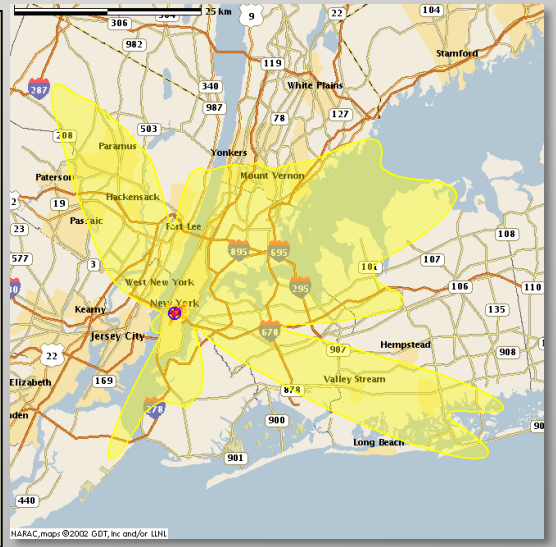
Standard and Customized Products are Used in Risk Assessments, Emergency Preparedness and Planning

Examples:

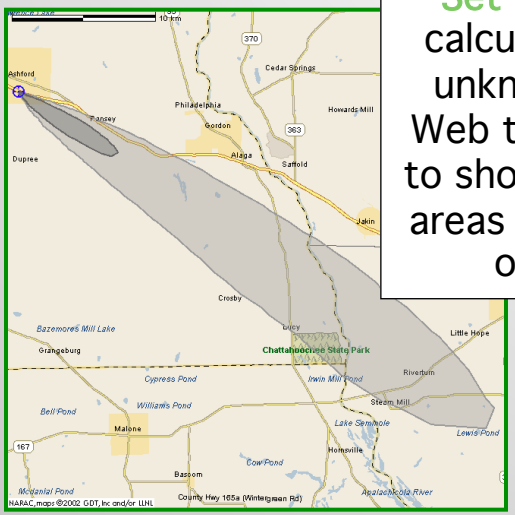
- Homeland Security Presidential Directive 18 assessments (improvised nuclear devices)
- FEMA Key Planning Factor Guidance (CBRN)
- DHS S&T threat assessments
  - Biological MTAs (BKC)
  - Chemical PTAs (CSAC)
- Consequence Assessment Initiative (CAI)
  - Nuclear fallout
  - Building protection factor / shelter data base

Prompt damage (circles), and two-lobed fallout pattern for hypothetical nuclear explosion in Los Angeles (FEMA IND response planning)

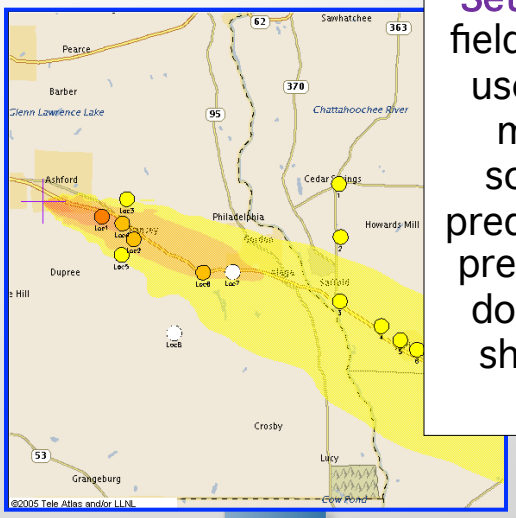
Example of fallout dose pattern for New York City under multiple weather conditions (Homeland Security Presidential Directive 18 assessments)



NARAC Standard Operational Procedures Couple Modeling and Monitoring in a Cyclical Process

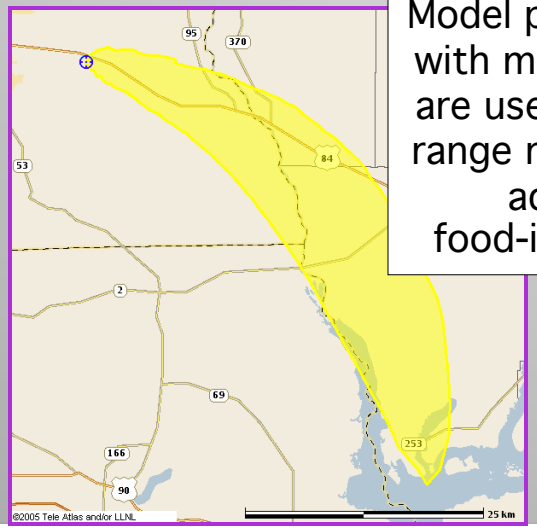


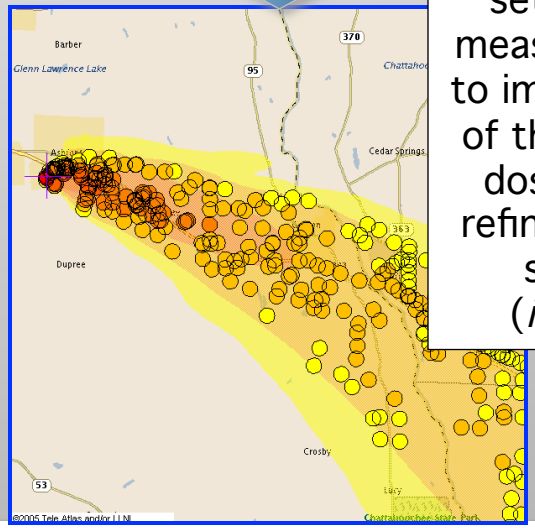
Set 1. Initial automated calculation can be run for unknown material (using Web tools or NARAC staff) to show downwind affected areas (no estimate of dose or health effects)



Set 2. Initially available field measurements are used to refine NARAC model inputs (e.g., source amount) and predictions to produce a preliminary estimate of dose for evacuation / sheltering protective action guides

Later Sets: Model predictions combined with measurement surveys are used to develop longer range relocation protective action guide and food-ingestion dose plots

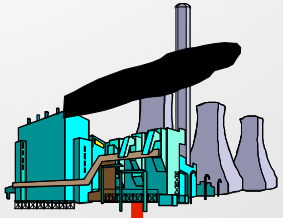




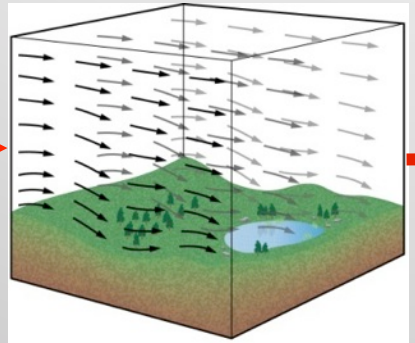
Set 3+. More extensive sets of FRMAC/AMS measurements are used to improve the accuracy of the source term and dose predictions for refining evacuation and sheltering guides (*iterative process*)

NARAC Computer Modeling System Provides Real-time Automated 3-D Worldwide Plume Model Predictions

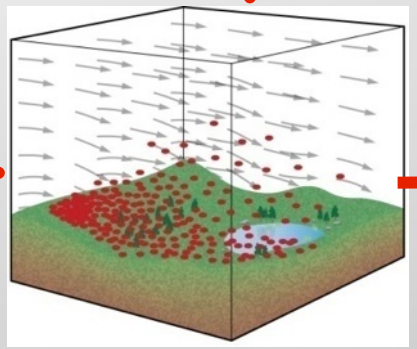
Hazardous material source characteristics



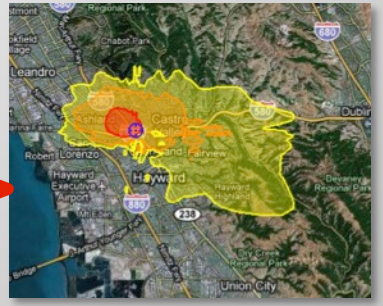
Global meteorological, geographical, terrain elevation, population databases



3-D meteorological and geographical data assimilation and forecast models



Atmospheric dispersion and ground deposition models

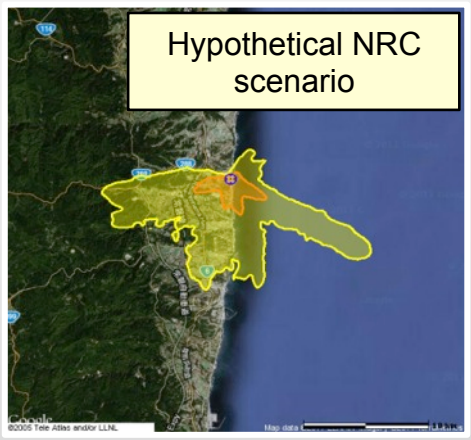


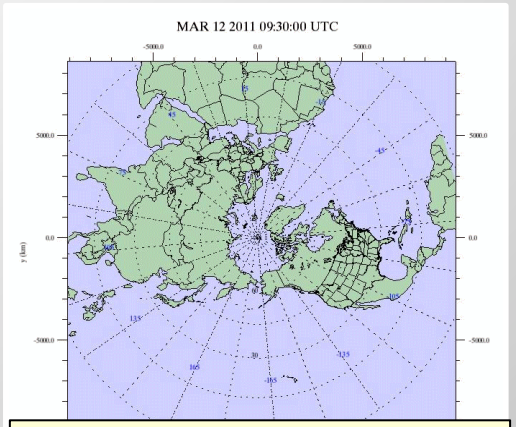
- Air and ground contamination, dose, Protective Action Guides, chronic & acute health effects
- Blast effects
- Population & casualty/fatality estimates

Worldwide predictions: Automated initial products are available in 15 minutes. Quality-assured refined products based on field data are available in 30 – 60 minutes, depending on the quantity and quality of the data.

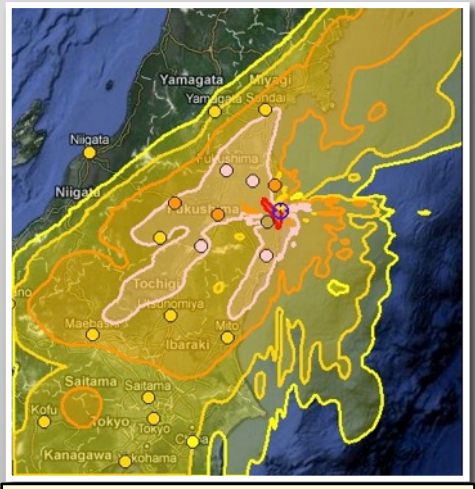
NARAC Supported A Variety of Requests During the Fukushima Response (March 11-May 28, 2011)

- Daily weather forecasts to support mission planning and situational awareness
- 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 arrival times and dose levels at U.S. locations
- Source term estimation and plume model refinement based on field data

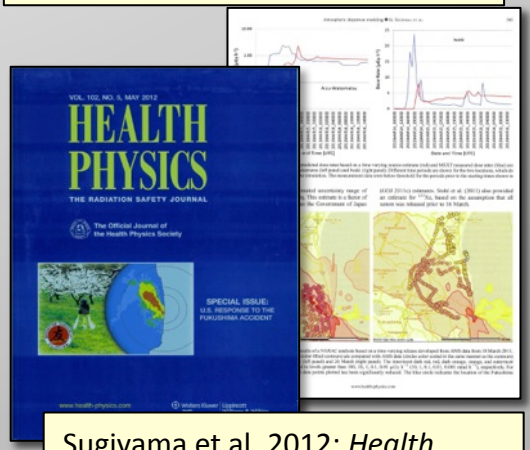




Predictions of Possible US Arrival Times and Dose

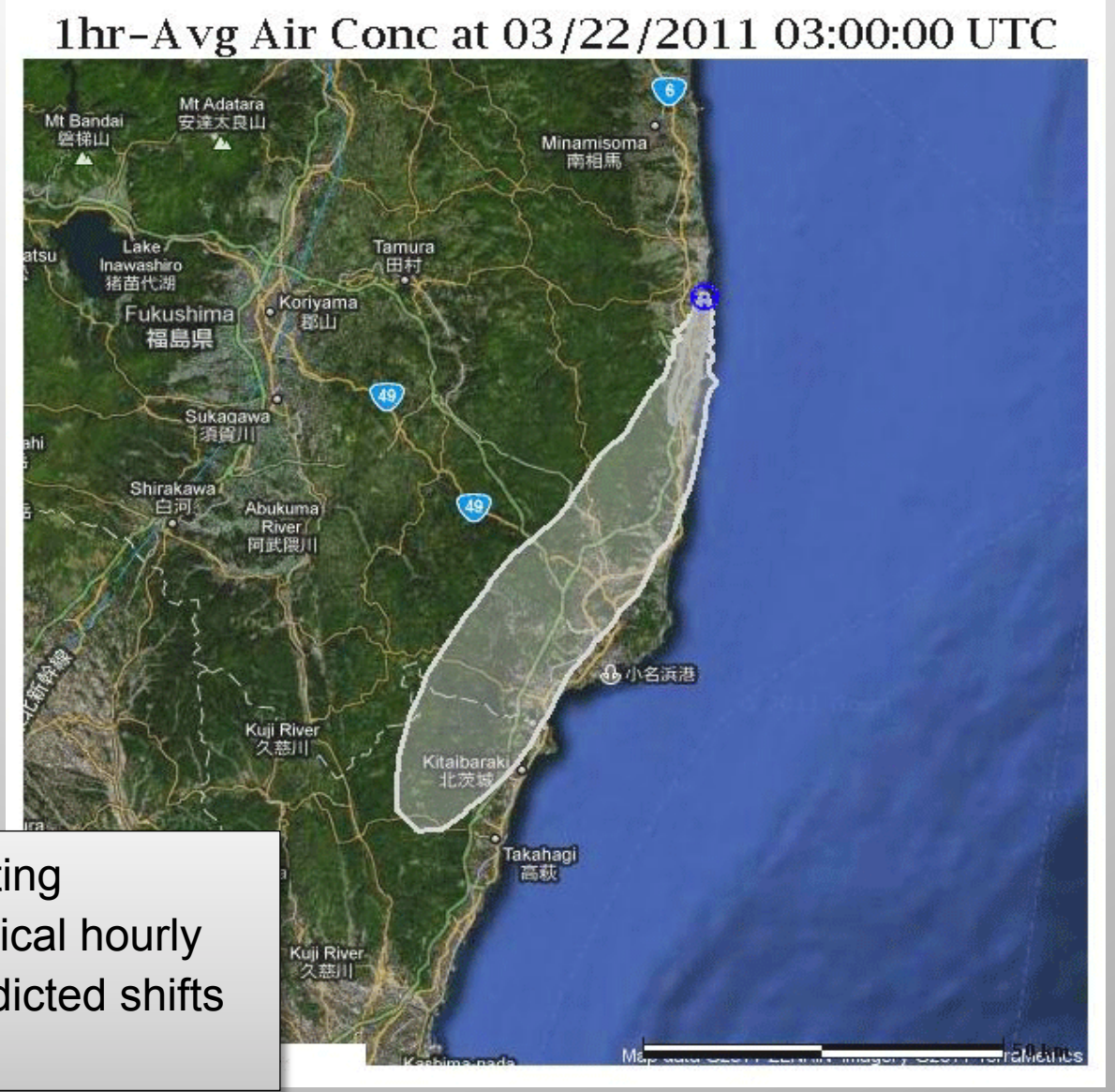


Source estimation and model refinement



Sugiyama et al.,2012: *Health Physics*, 102, p 493–508

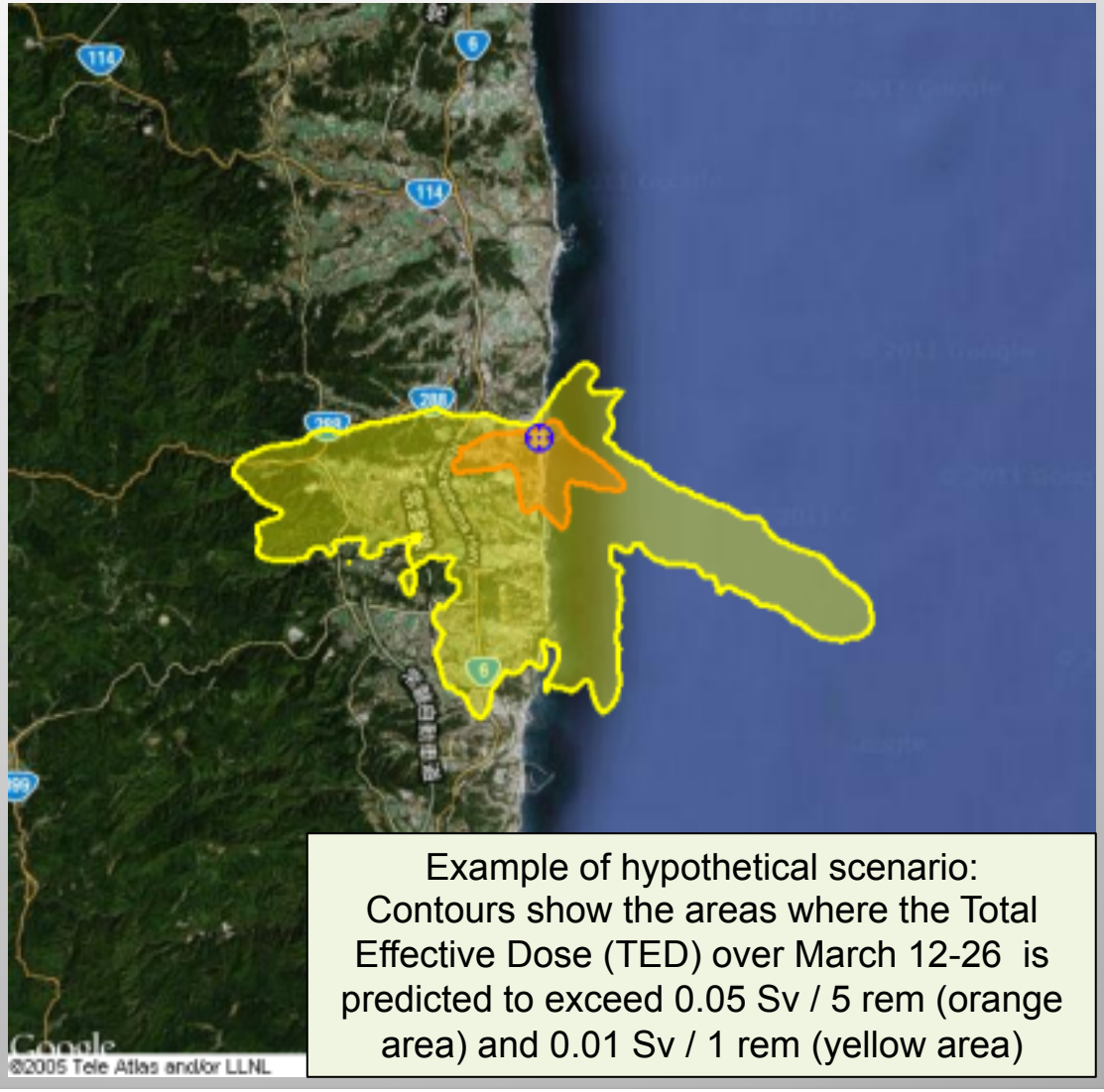
NARAC Provided Regular Forecasts to Support Mission Planning and Model Analysis



Daily weather forecasting visualized as hypothetical hourly plume to illustrate predicted shifts in wind direction

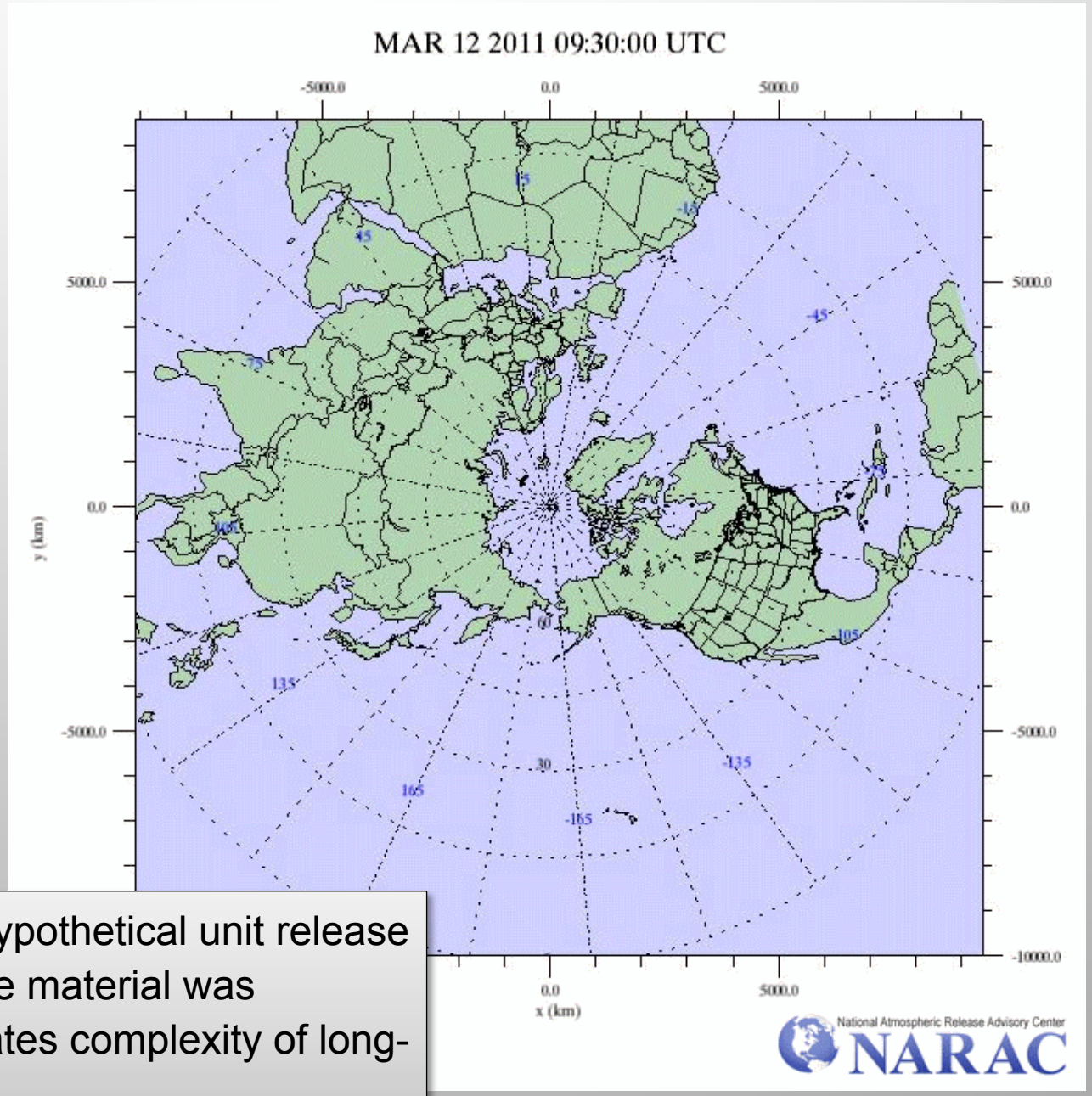
DOE/NARAC Worked Closely with the U.S. NRC to Estimate Impacts for a Wide Range of Hypothetical Scenarios

- Predictions of arrival times and protective action areas for
  - Sheltering / evacuation
  - Relocation
  - Iodine administration
  - Worker protection to inform emergency planning
- Used to inform U.S. recommendations regarding actions needed to protect US citizens in Japan



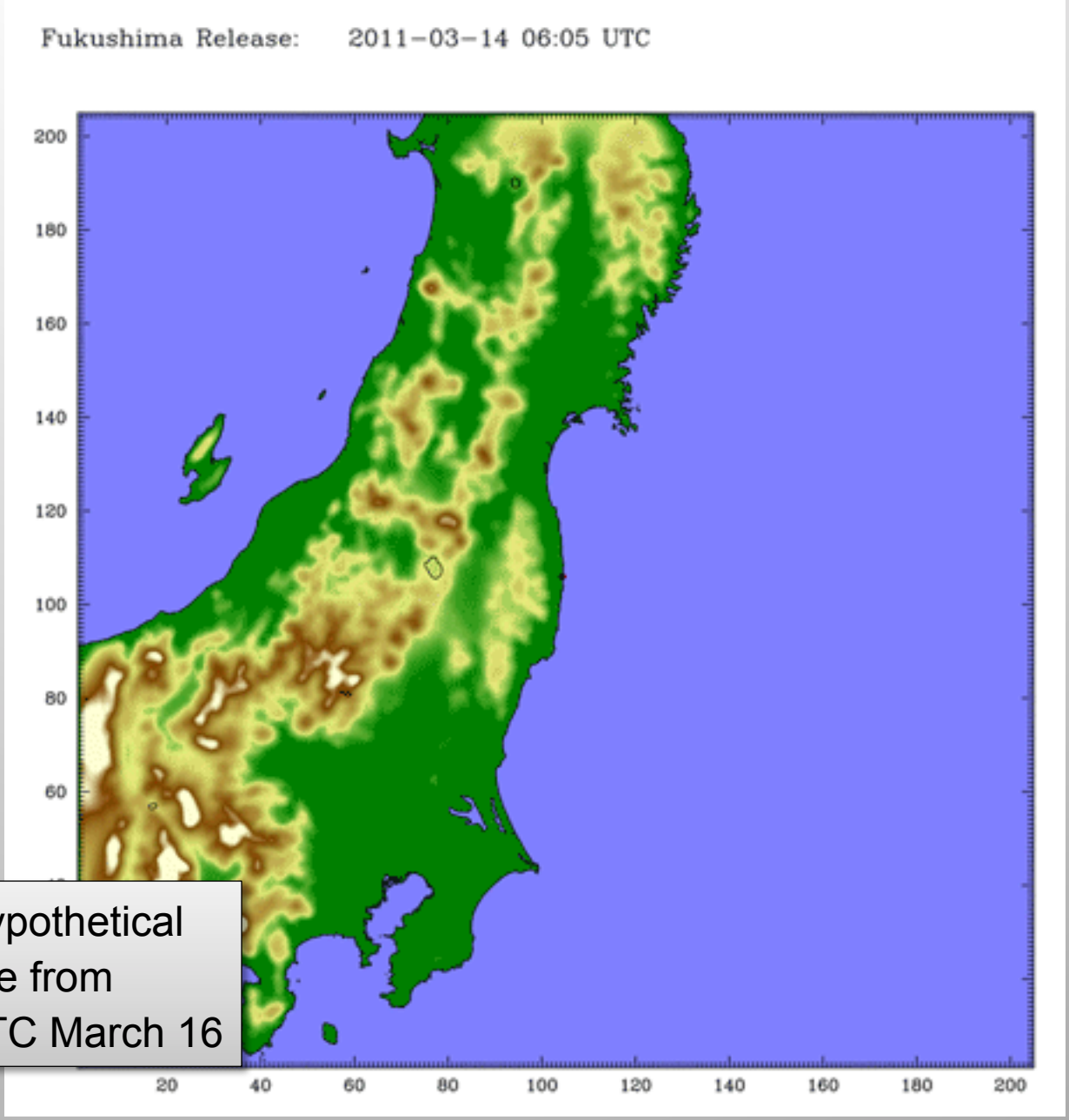
Example of hypothetical scenario: Contours show the areas where the Total Effective Dose (TED) over March 12-26 is predicted to exceed 0.05 Sv / 5 rem (orange area) and 0.01 Sv / 1 rem (yellow area)

DOE/NARAC Provided Predictions of Possible Arrival Times and Dose in U.S. Territories



Particle animation of hypothetical unit release shows when and where material was transported and illustrates complexity of long-range dispersion

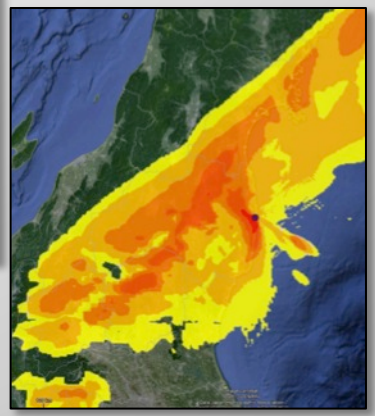
Rapidly Changing Meteorological Conditions in Japan Presented a Significant Modeling Challenge

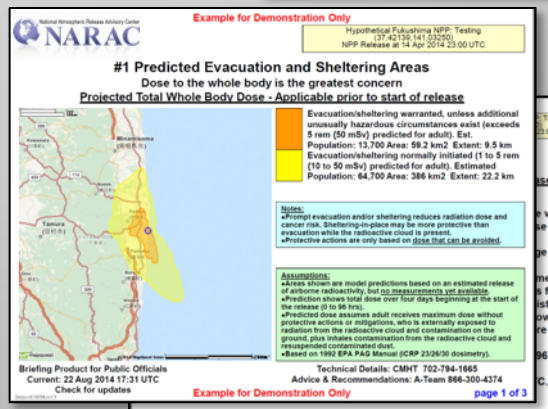


Particle animation for hypothetical constant release rate from 00 UTC March 14 – 00 UTC March 16

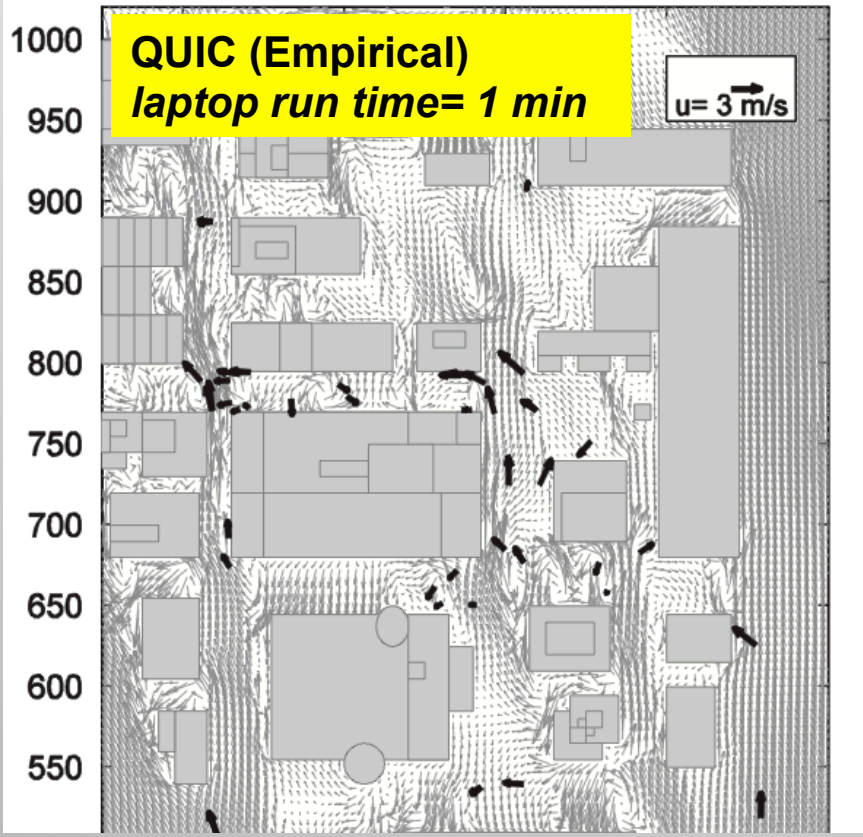
NARAC Enhancements Are Being Made to Improve Response to Future Incidents

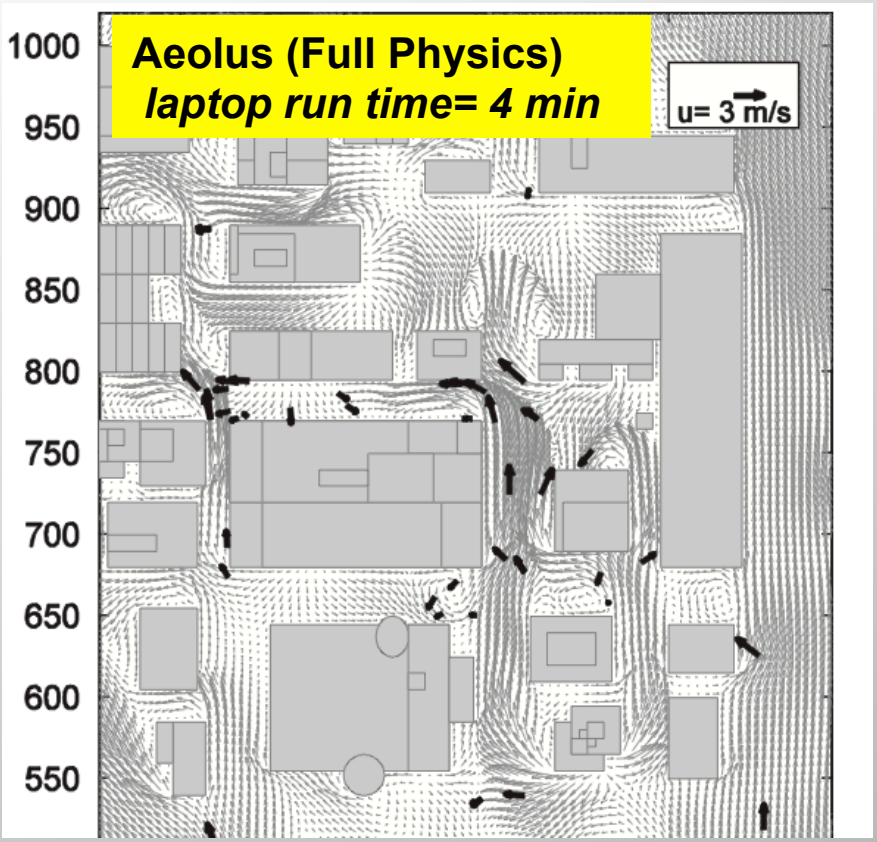
- **Significantly reduced time for complex NARAC atmospheric dispersion simulations**, using new dedicated 336-processor compute cluster and optimized software. (Run times reduced by factor of 10-100, e.g., from 2 hours to 5 min)
- **Development of higher-resolution modeling of dry deposition and precipitation / wet deposition**, which was key to prediction of ground contamination levels in Japan
- **Expanded electronic files to import complex nuclear power plant release information** from US Nuclear Regulatory Commission (NRC) in to NARAC model simulations, and created a default set of release scenarios
- **New decision-maker briefing versions of NARAC products** for nuclear power plant accident scenarios for more effective communication of information on actions that are warranted to protect workers and the public (e.g., evacuation, sheltering, relocation) in collaboration with DHS/FEMA and other US government agencies





Aeolus Exhibits Better Performance Than Empirical Models in Complex Urban Environments



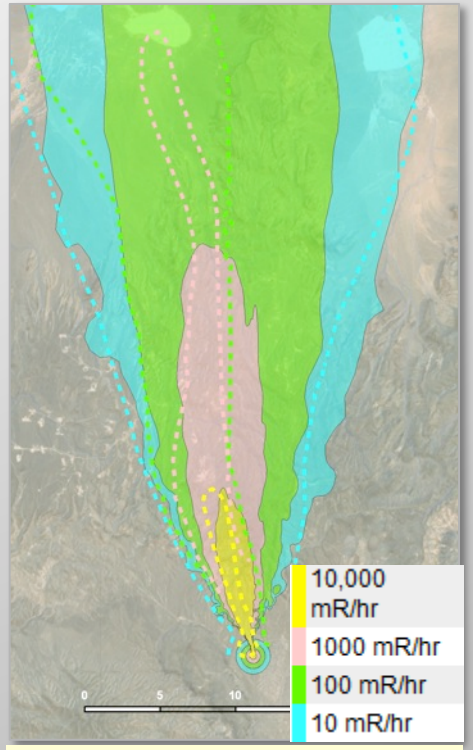


Aeolus (right panel) captures more of than important flow features (channeling, reversed flow, end vortex, divergence) than empirical urban models (left panel). Bold vectors show measured 30-minute averaged winds.

NARAC Has Enhanced Fallout Modeling In Support of National Technical Nuclear Forensics (NTNF) Program

- Three best-in-class operational coupled nuclear fallout models:
  - LLNL *LWAC* radionuclide inventories (using ORNL *ORIGEN* fission product code)
  - ORNL *DELFICST* fallout cloud rise and particle formation model
  - LLNL/NARAC *LODI* 3-D complex terrain dispersion and deposition model
- NTNF exercise planning and execution
  - NARAC predicted fallout dose, ground deposition and relative proportions of refractory and volatile radionuclides to guide field sample collection
  - Simulated fallout data for sample collection exercise ground truth, with real-time simulated measurement readings for field team using NARAC *HotSpot* software and GPS devices
  - Data products developed by DOE field teams and Aerial Measuring System (AMS) and distributed via NARAC-hosted *CMweb*

Fallout Model Validation with NTS Data



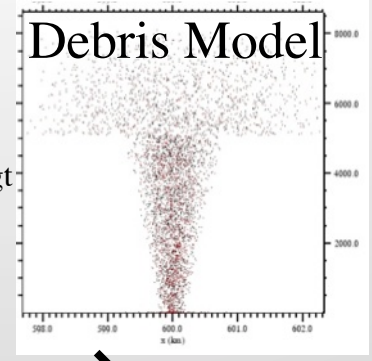
LLNL-ORNL LODI-LWAC-DELFICST code predicted groundshine dose rate (colored areas) overlaid with contours of measured dose rate (dashed lines) NTS Operation Sunbeam/ Johnnie Boy Test

NucDet Models: John Nasstrom, Peter Goldstein, Brenda Pobanz, Nathan Wimer, Kevin Foster (ret.)

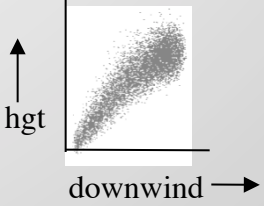
LLNL-SNL Explosive Dispersal Model Improves Predictions of Ground-level Contamination

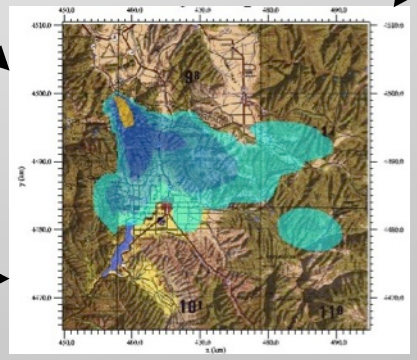
- KDFOC3 nuclear detonation source description extended and used in LODI particle dispersion model
- Neutron-activation products from LWAC code
- Fission product inventory from ORNL ORIGEN code
- Sandia PUFF dynamic high-explosive cloud rise model

KDFOC3 Nuclear Debris Model



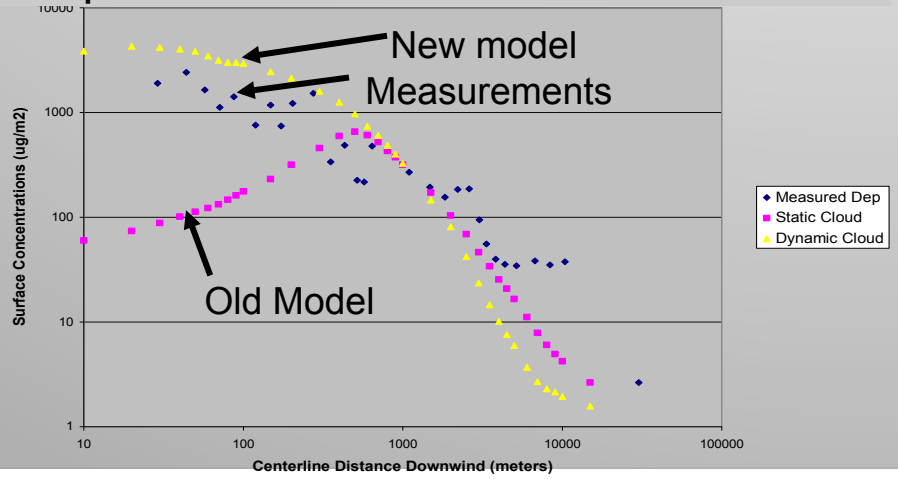
PUFF Cloud Rise Model



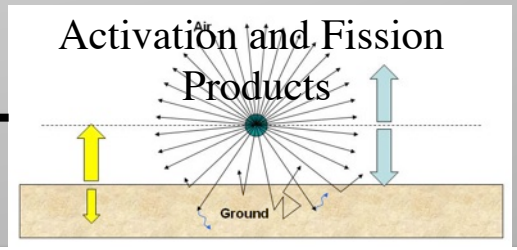


LODI Transport and Dispersion Model

Deposition versus Downwind Distance



LWAC/ORIGEN Activation and Fission Products



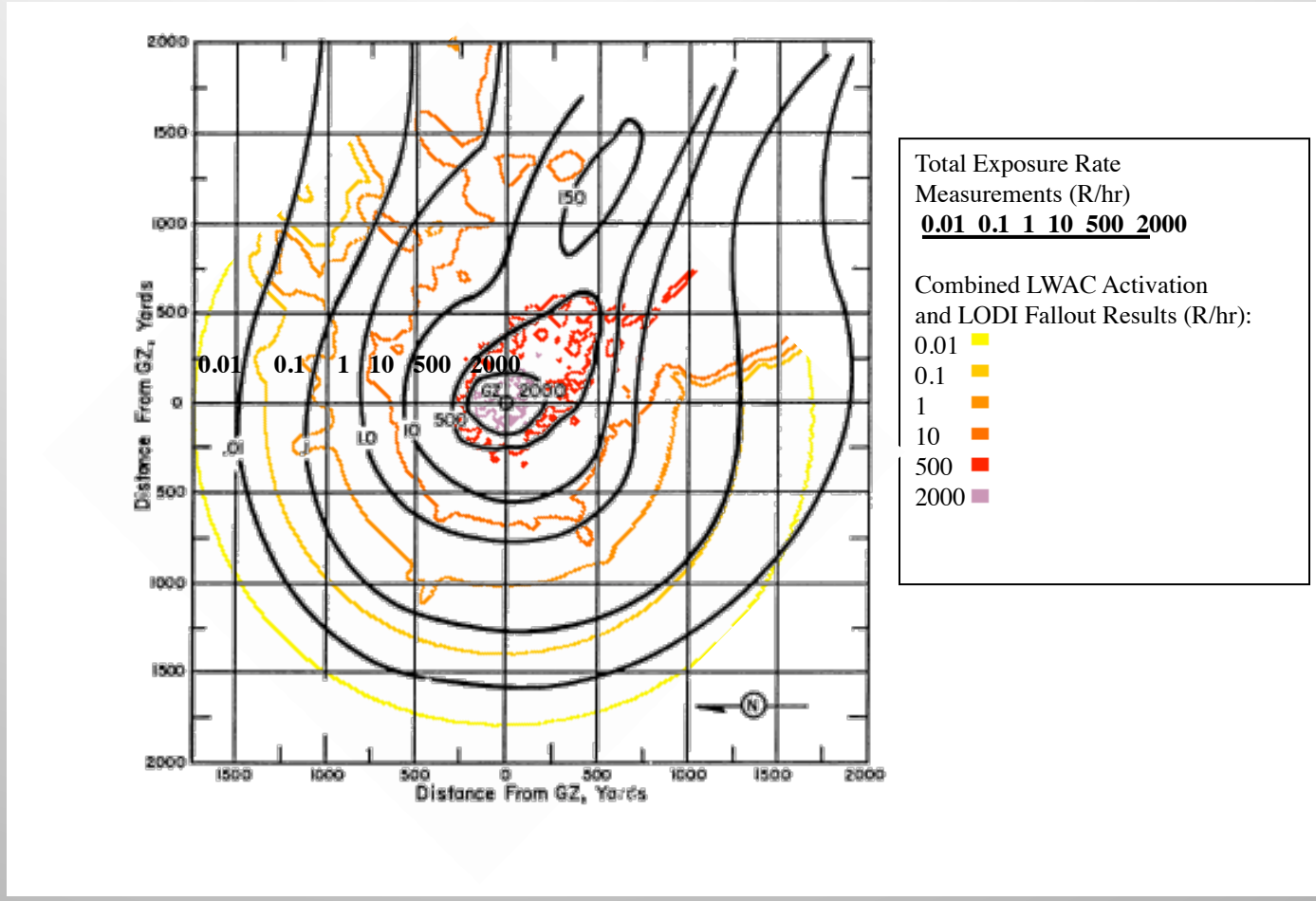
Sandia National Laboratories

OAK RIDGE National Laboratory

Kevin Foster (ret.), Ted Harvey
LWAC: Greg Spriggs

NARAC LODI/LWAC Model Predictions Have Been Validated Using Data from the Nevada Test Site

Comparison between measured total exposure rate contours (black lines) and predicted combined LWAC activation and LODI fallout exposure rates (colored lines)

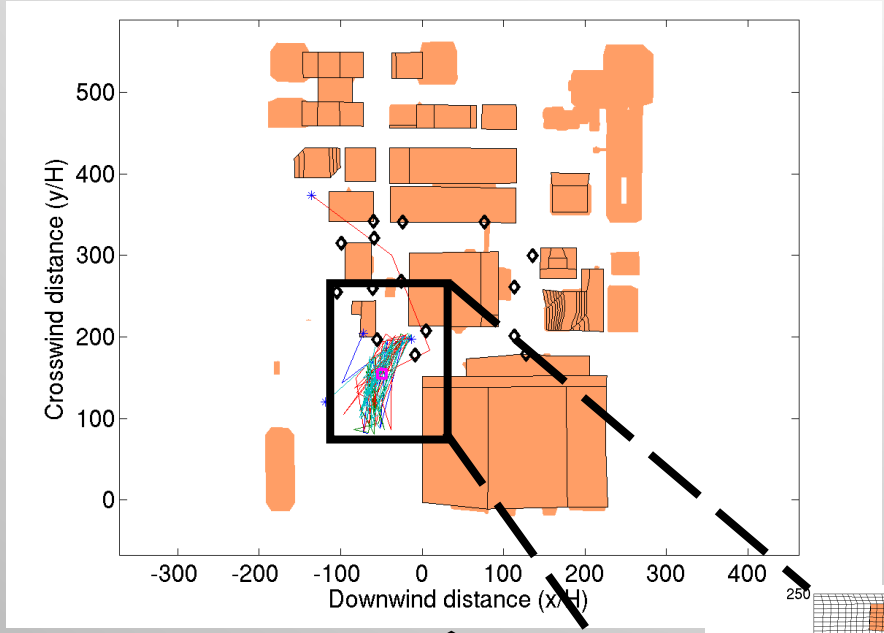


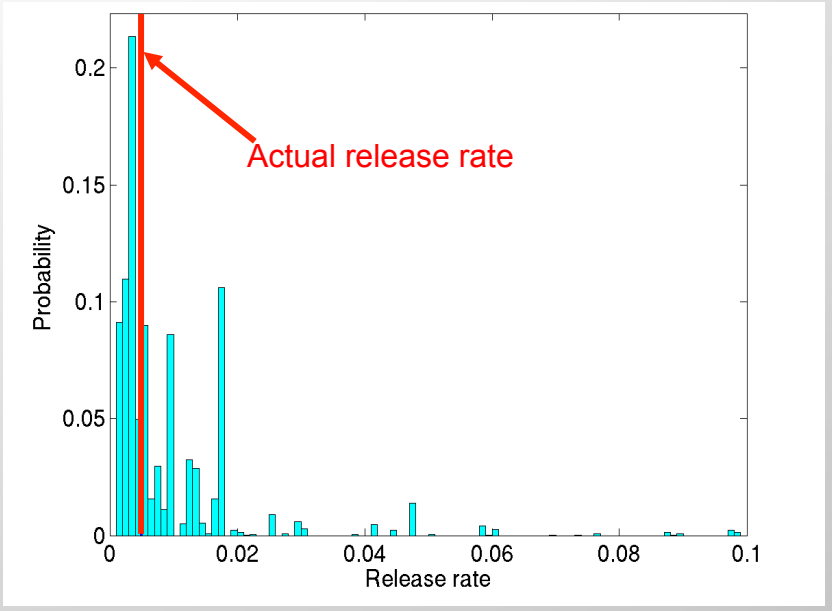
Calculated contours were rotated 45 degrees clockwise to make comparison to measured inner contour areas more straight-forward.

Urban Models Provide Additional Information for Protecting Health and Safety

Event Reconstruction For Urban-Scale Release Using Data from Joint Urban Tracer 2003 Field Experiment

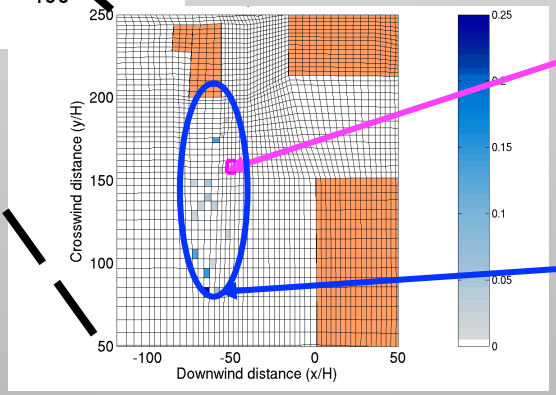
Markov chain sampling





Inflow wind

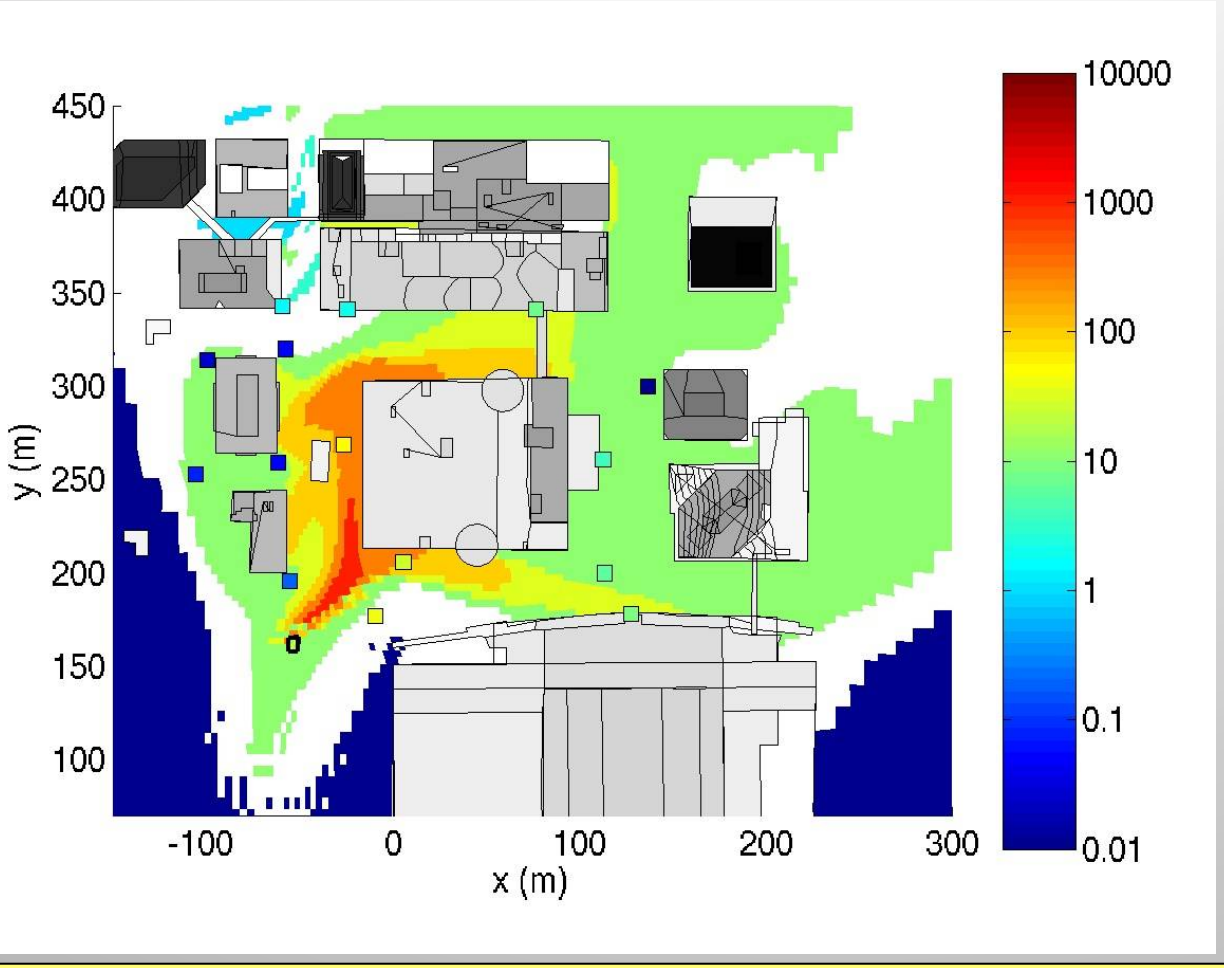
Sensors (◊)



Actual source location

Source location determined to <½ block area

Event Reconstruction Composite Plume Provides Confidence Levels (Quantitative Uncertainty Estimates)

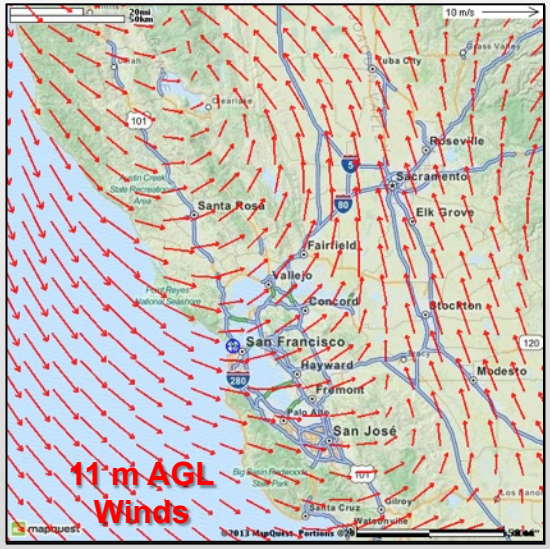


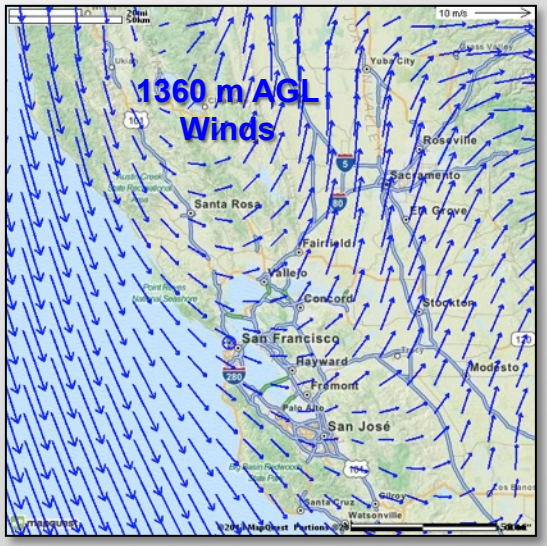
- JU2003 Oklahoma City release
- Contours show 90% confidence limits for given air concentration level compared to data (colored squares)
- Dark blue region envelopes composite plume (< 0.01 ppb)
- White indicates areas where 90% confidence limit cannot be determined (depends on chosen threshold of 0.01 ppb)

Event reconstruction based on Bayesian inference and stochastic sampling estimates source location to within a half block and release rate (left figures) for the JU2003 Oklahoma City release.

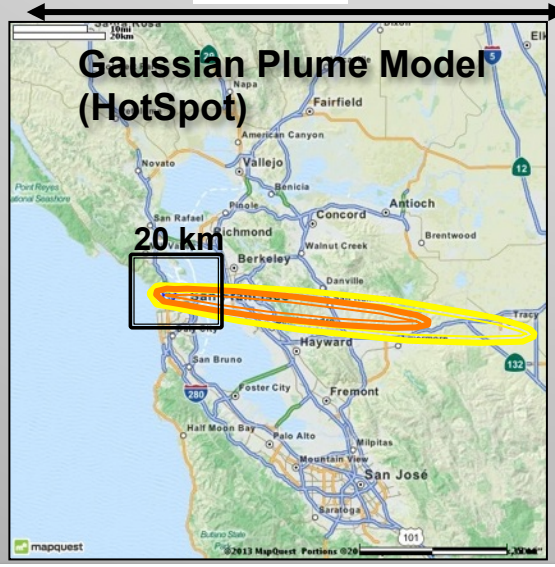
Model Comparison for Hypothetical Explosion Dispersing Radioactive Material to Heights of 2000 m

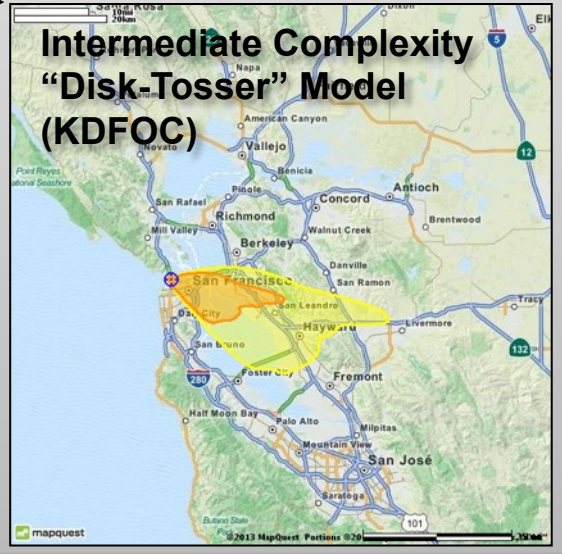
Input Weather Data

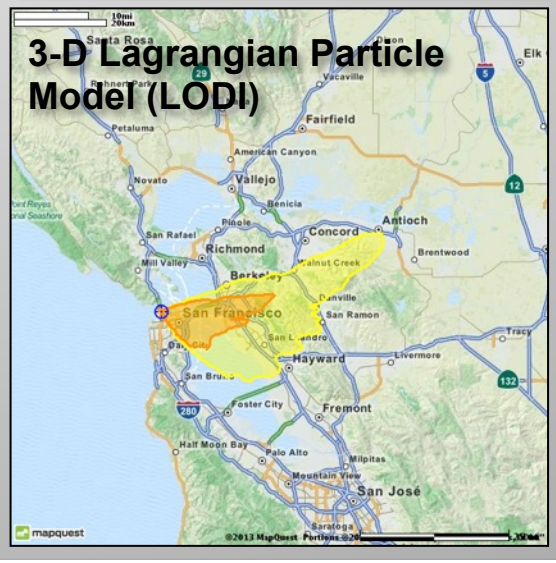




Plume Fallout Pattern







NARAC Web Demo

Lawrence Livermore National Laboratory

National Atmospheric Release Advisory Center

NARAC

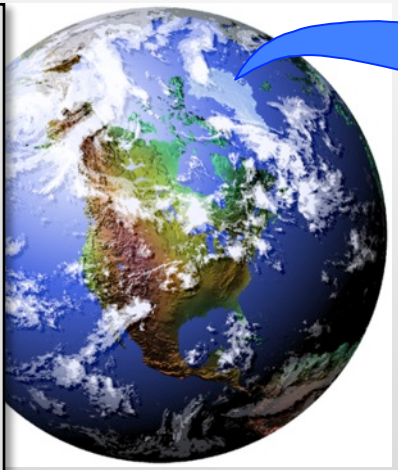
This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC. The Department of Homeland Security sponsored part of the production of this material.

LLNL-PRES-609358-Rev1

NARAC Provides Tools and Services to Predict and Map the Spread of Hazardous Material in the Atmosphere

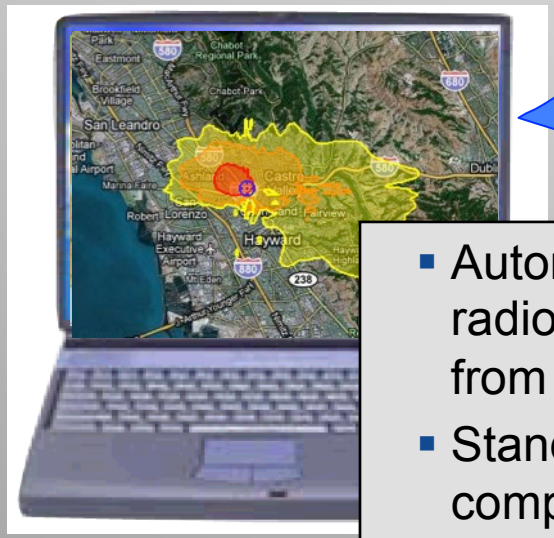
Access to world-wide weather data and geographical information:

- Observed & forecast weather data
- Terrain & land surface
- Maps
- Population



National Atmospheric Release Advisory Center (NARAC):

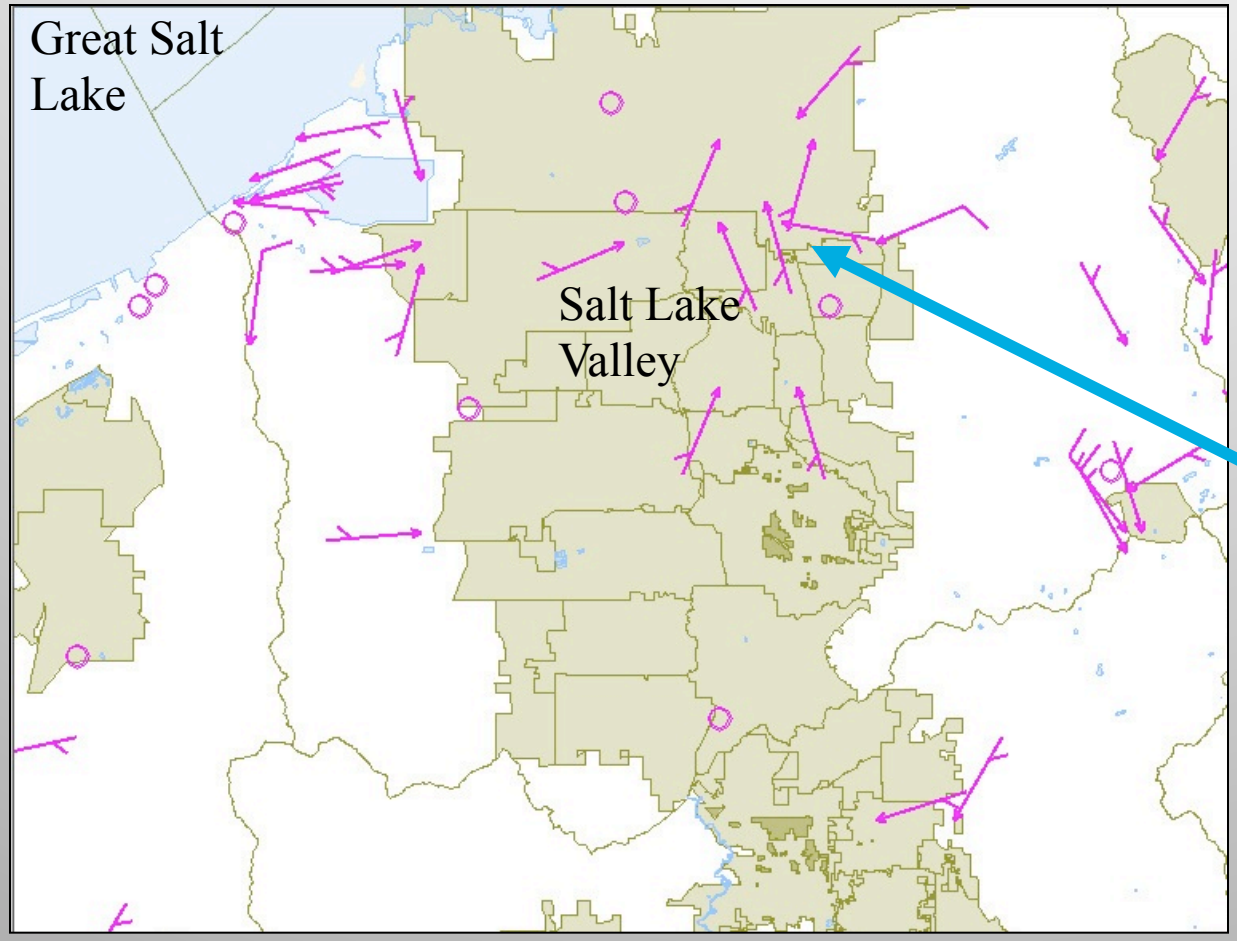
- Computer systems for real-time 3-D plume simulations
- Un-interruptible, backup power
- 24x7 scientific analysis & technical support



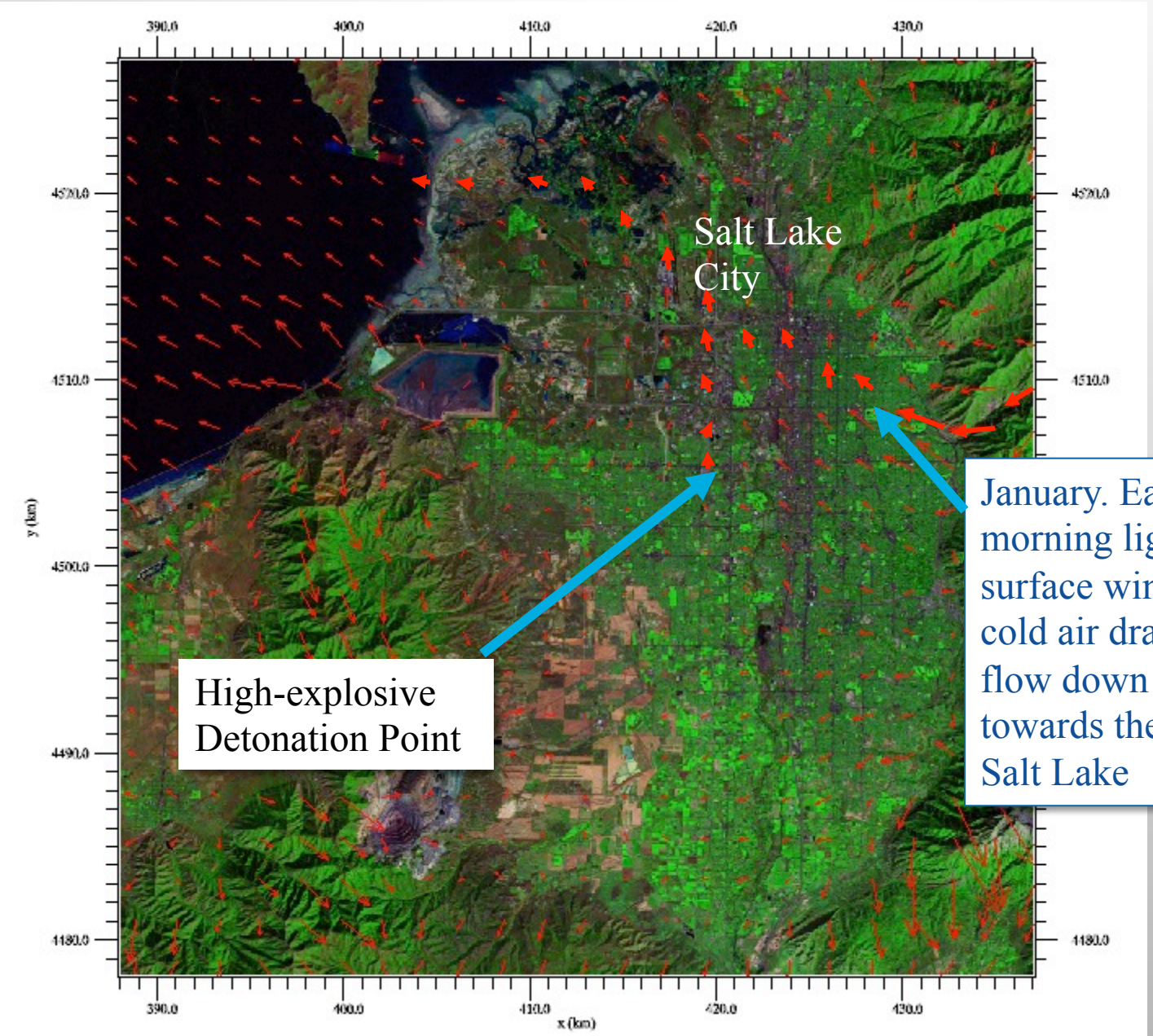
- Automated real-time 3-D plume model predictions for nuclear, radiological, chemical or biological releases available in minutes from national center using Internet/Web tools
- Standalone simple plume modeling tools for end-user's computer require no connection to LLNL

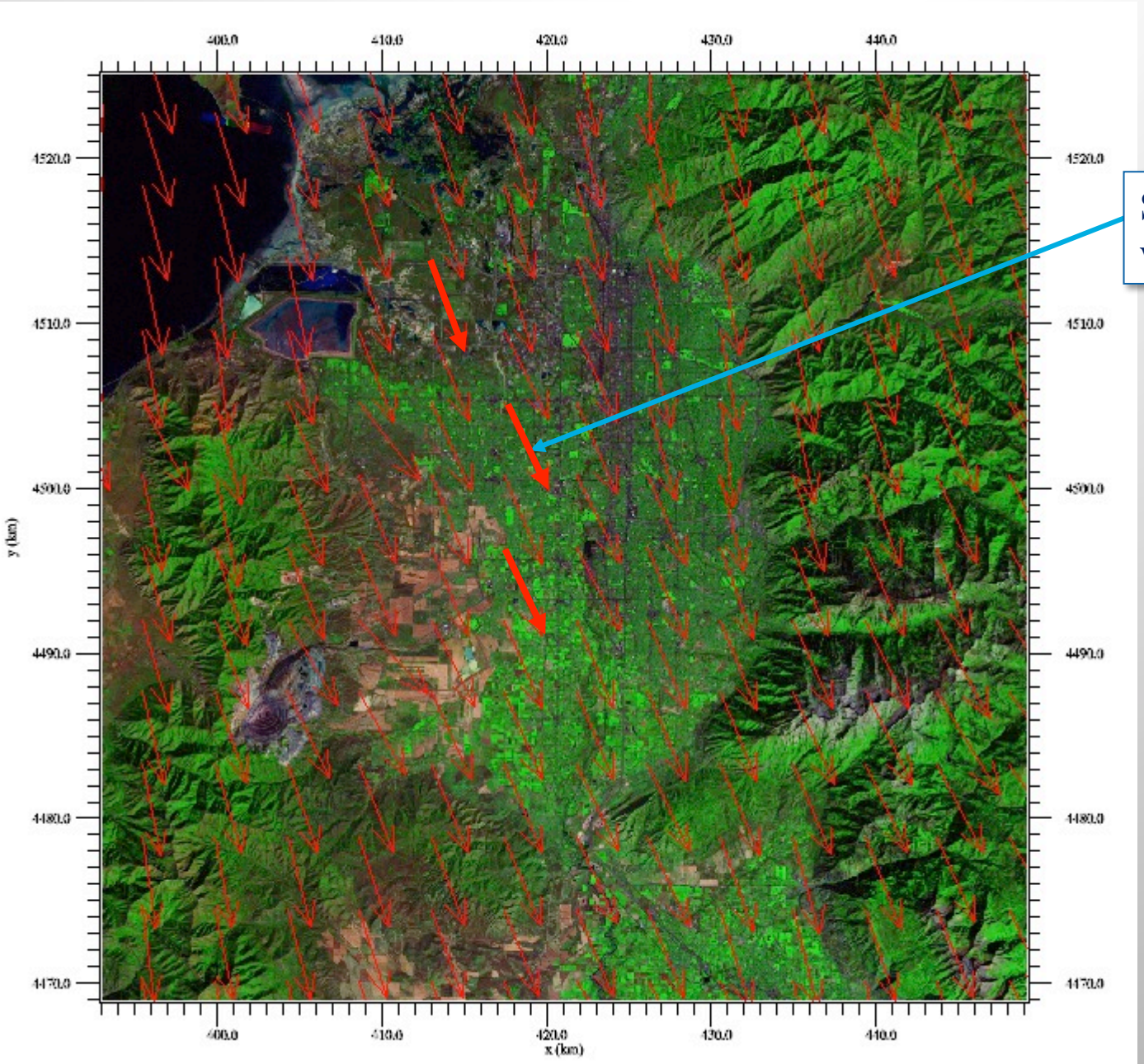
Winter Case Study: Hypothetical RDD in Salt Lake City

Mesonet Surface Wind Observations

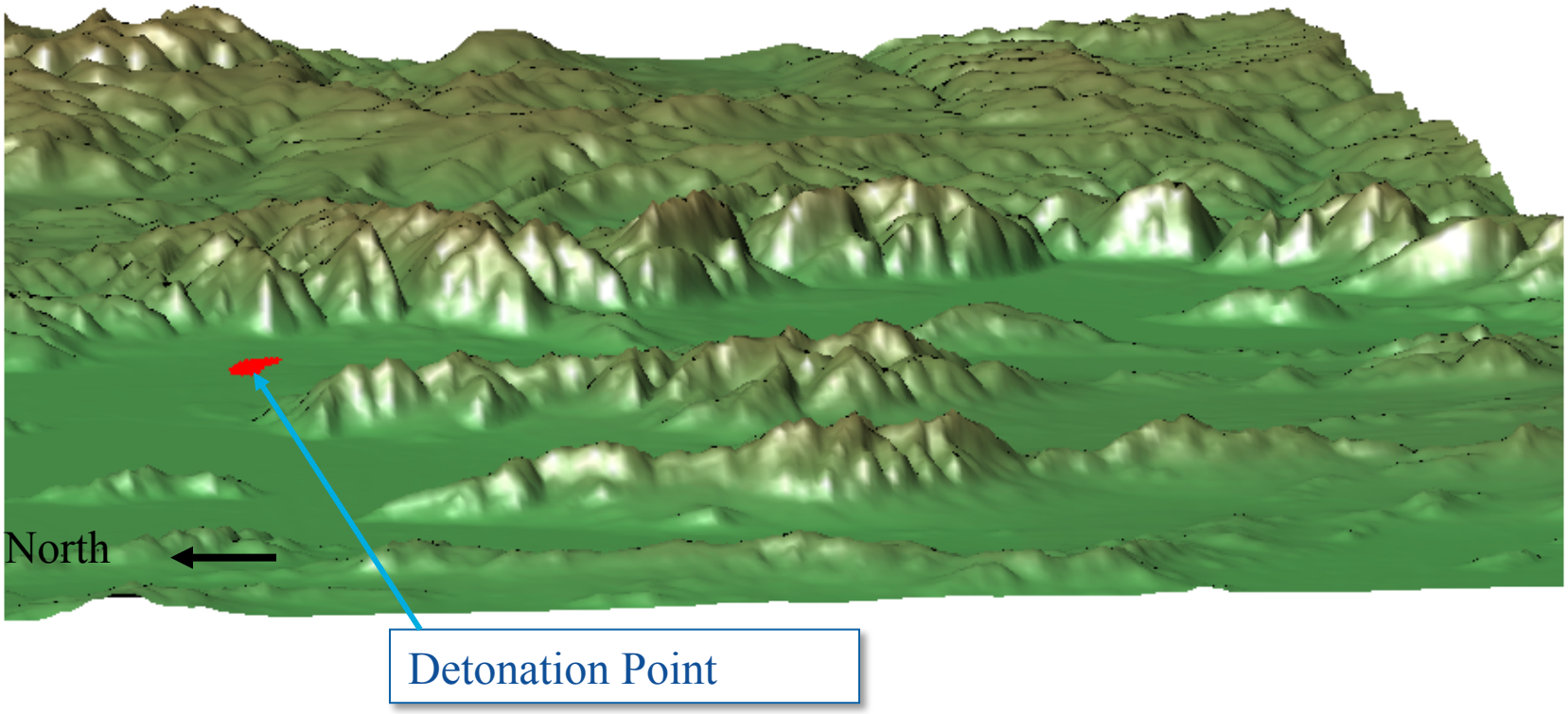


January. Early morning light near-surface winds show cold air drainage flow down slopes & towards the Great Salt Lake


390.0
400.0
410.0
420.0
430.0
4520.0
4510.0
4500.0
4490.0
4480.0
y (km)
x (km)
Salt Lake City
High-explosive Detonation Point
January. Early morning light near-surface winds show cold air drainage flow down slopes & towards the Great Salt Lake

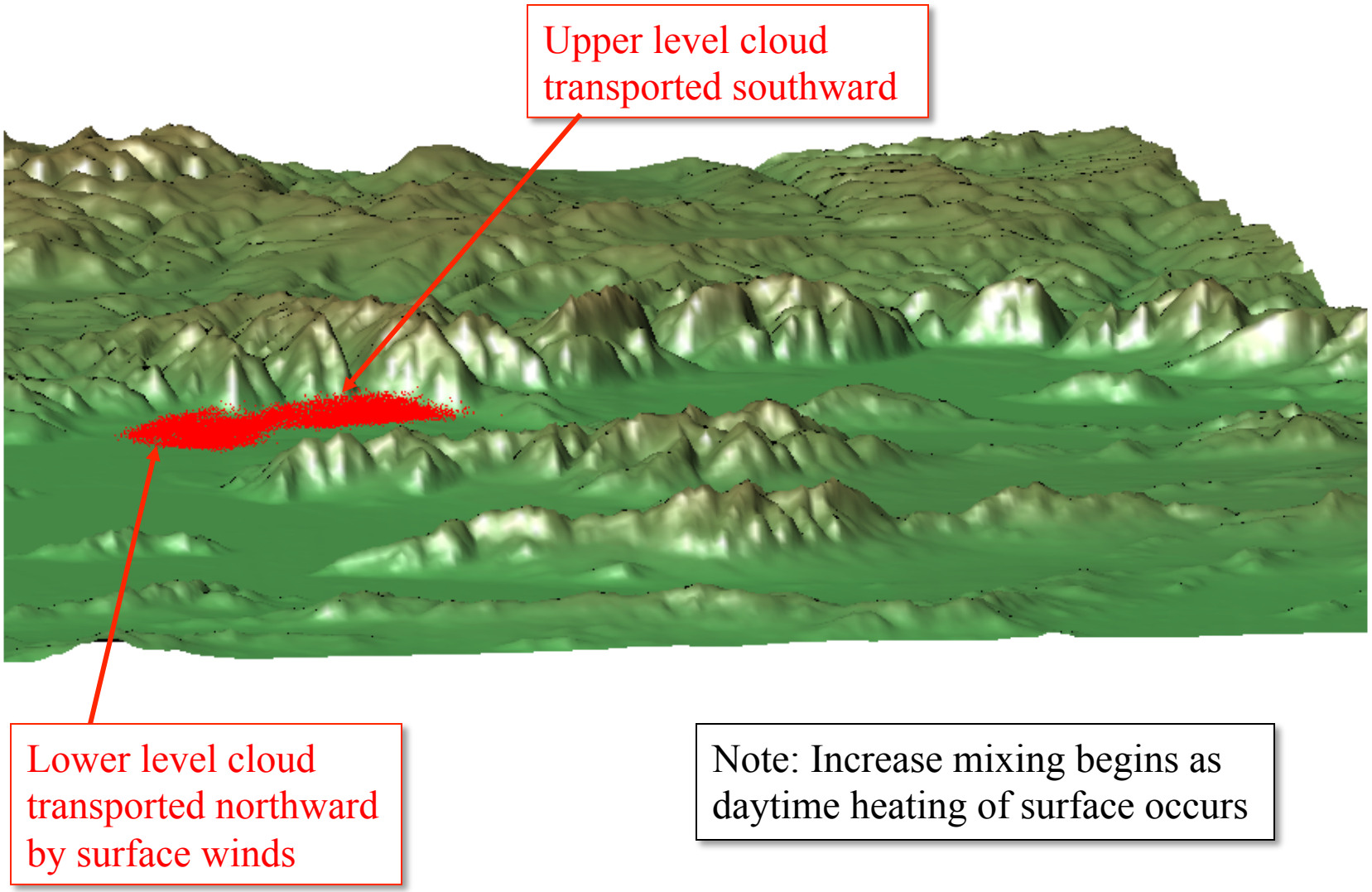


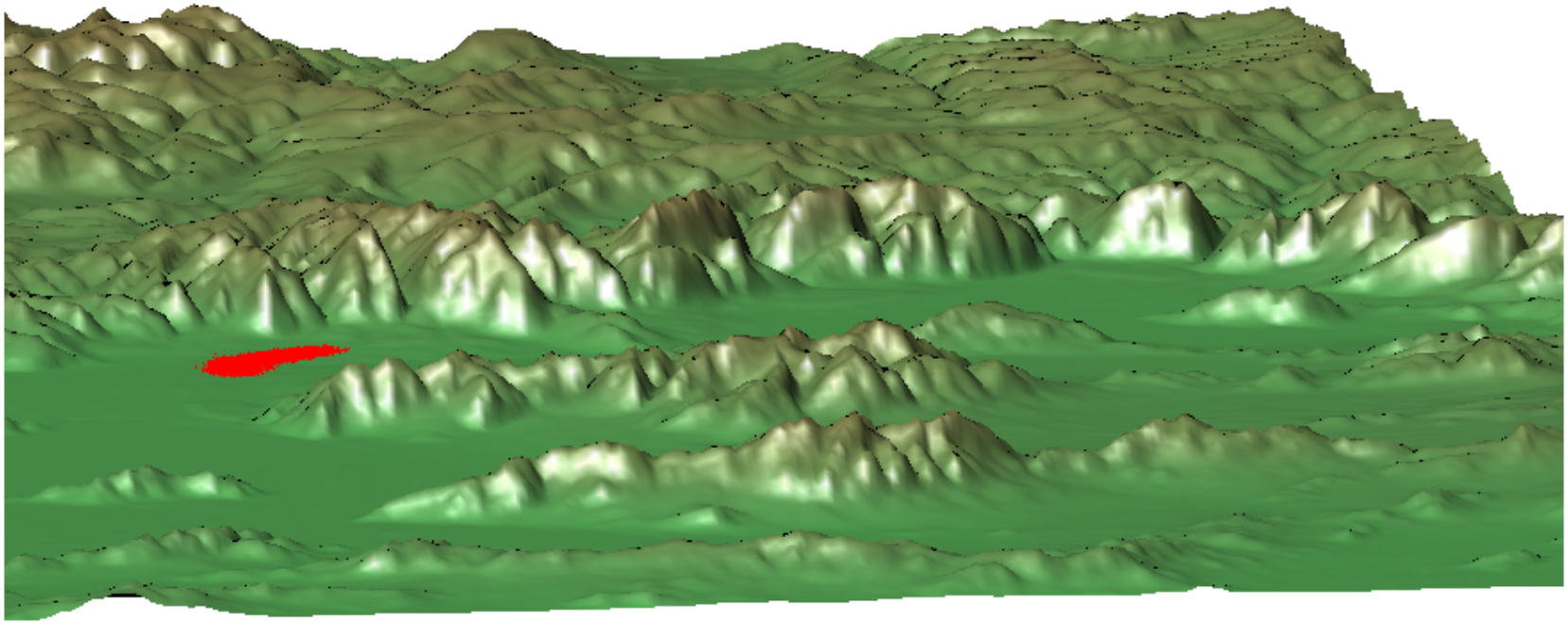
Stronger upper-level winds from the north

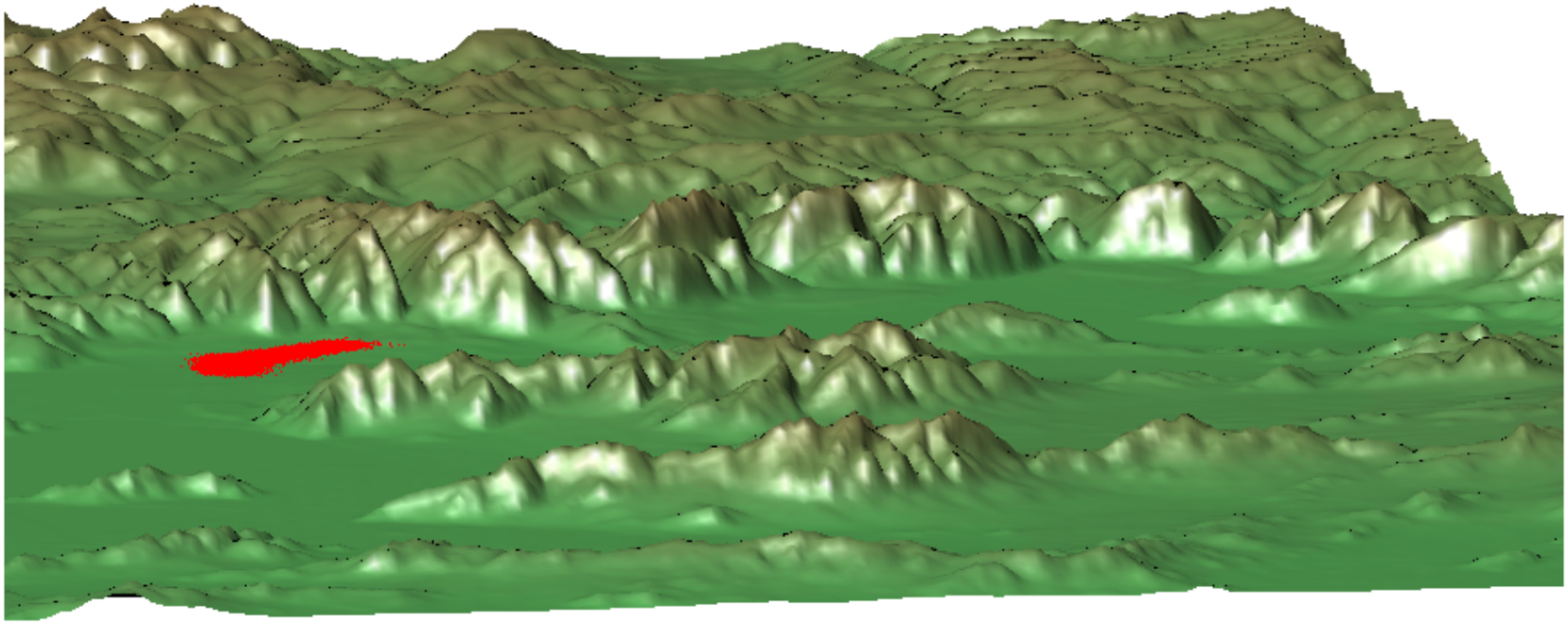


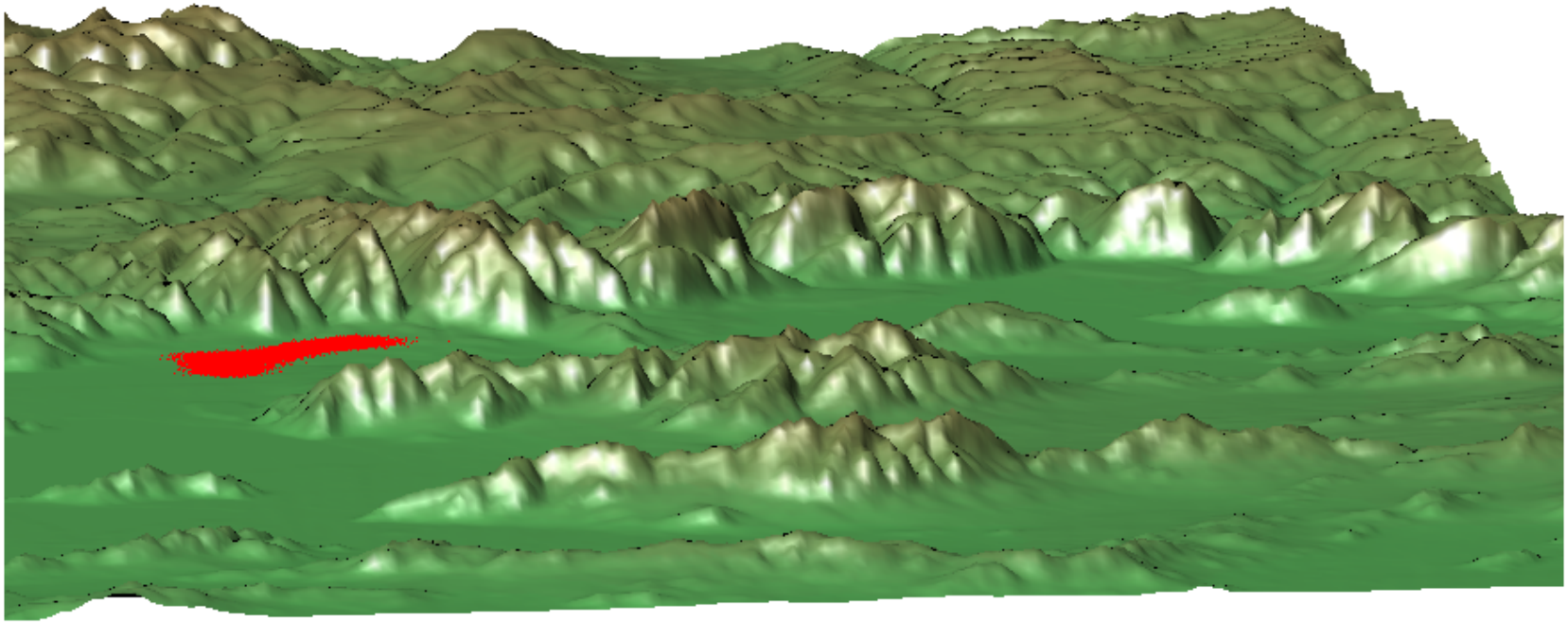
Red particles show LLNL NARAC ADAPT/LODI dispersion simulation using SNL ERAD explosive source characteristics (particle size distribution and spatial distribution of mass from surface to several hundred meters above ground) .

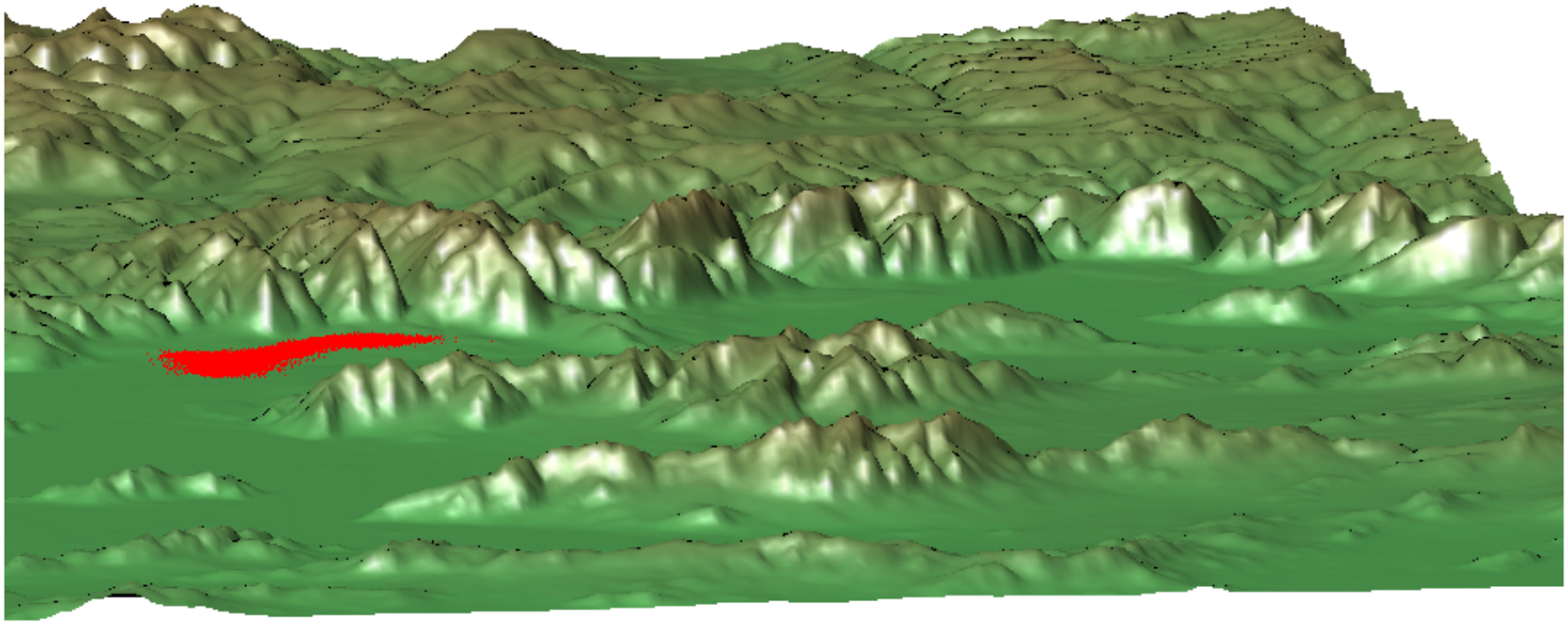
Simulation begins at 05:00 MST and ends at 11:00 MST

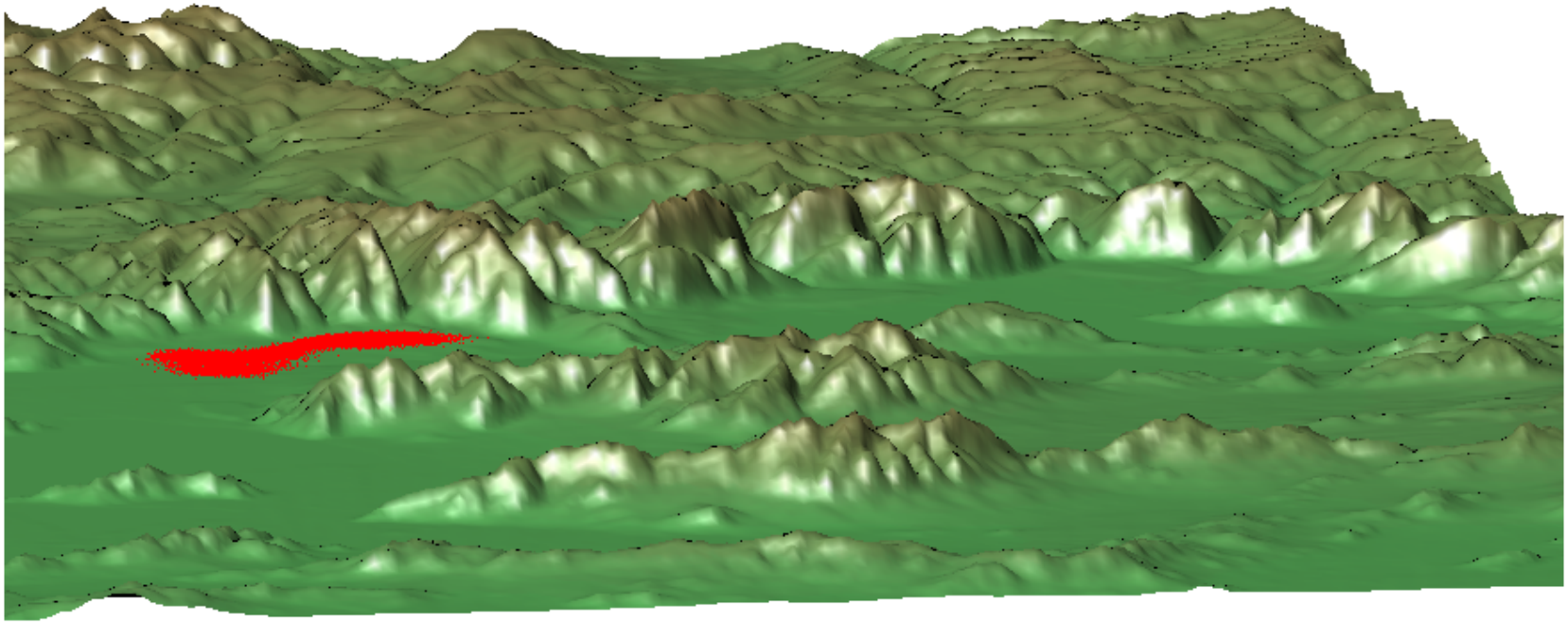

Upper level cloud transported southward
Lower level cloud transported northward by surface winds
Note: Increase mixing begins as daytime heating of surface occurs

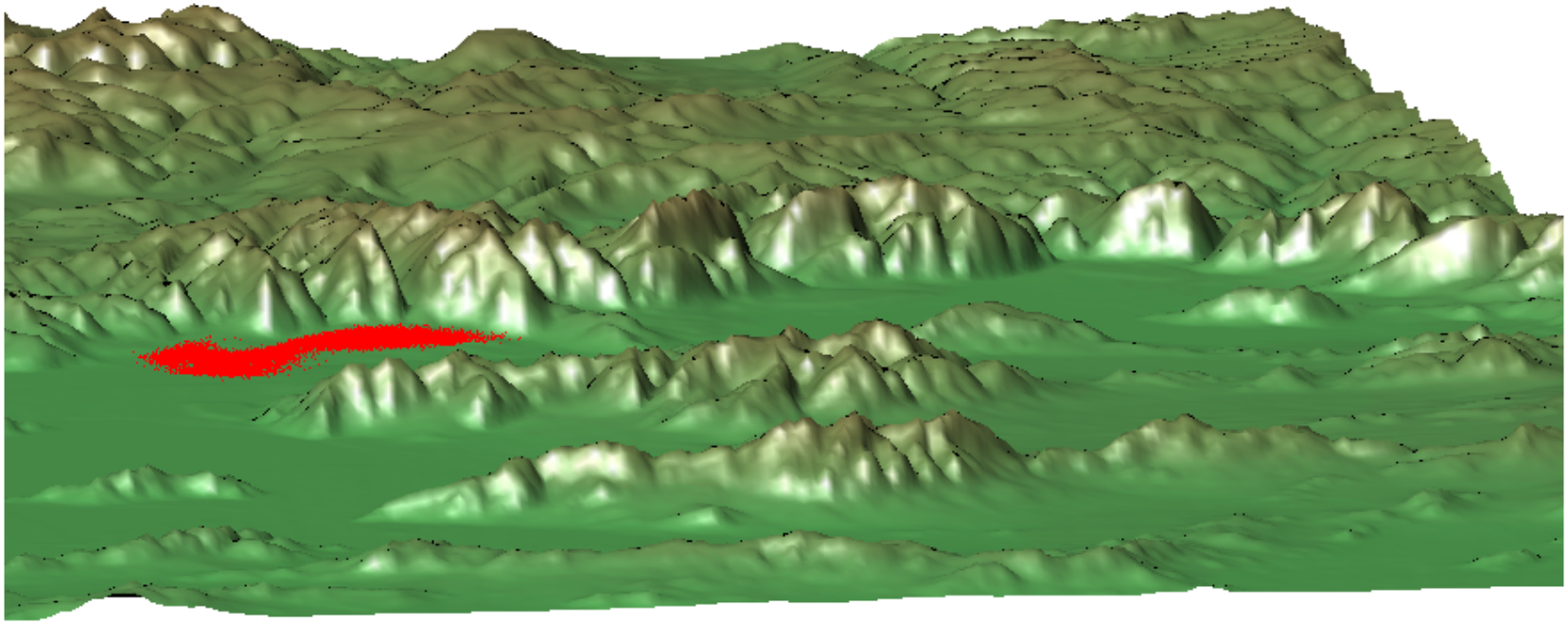


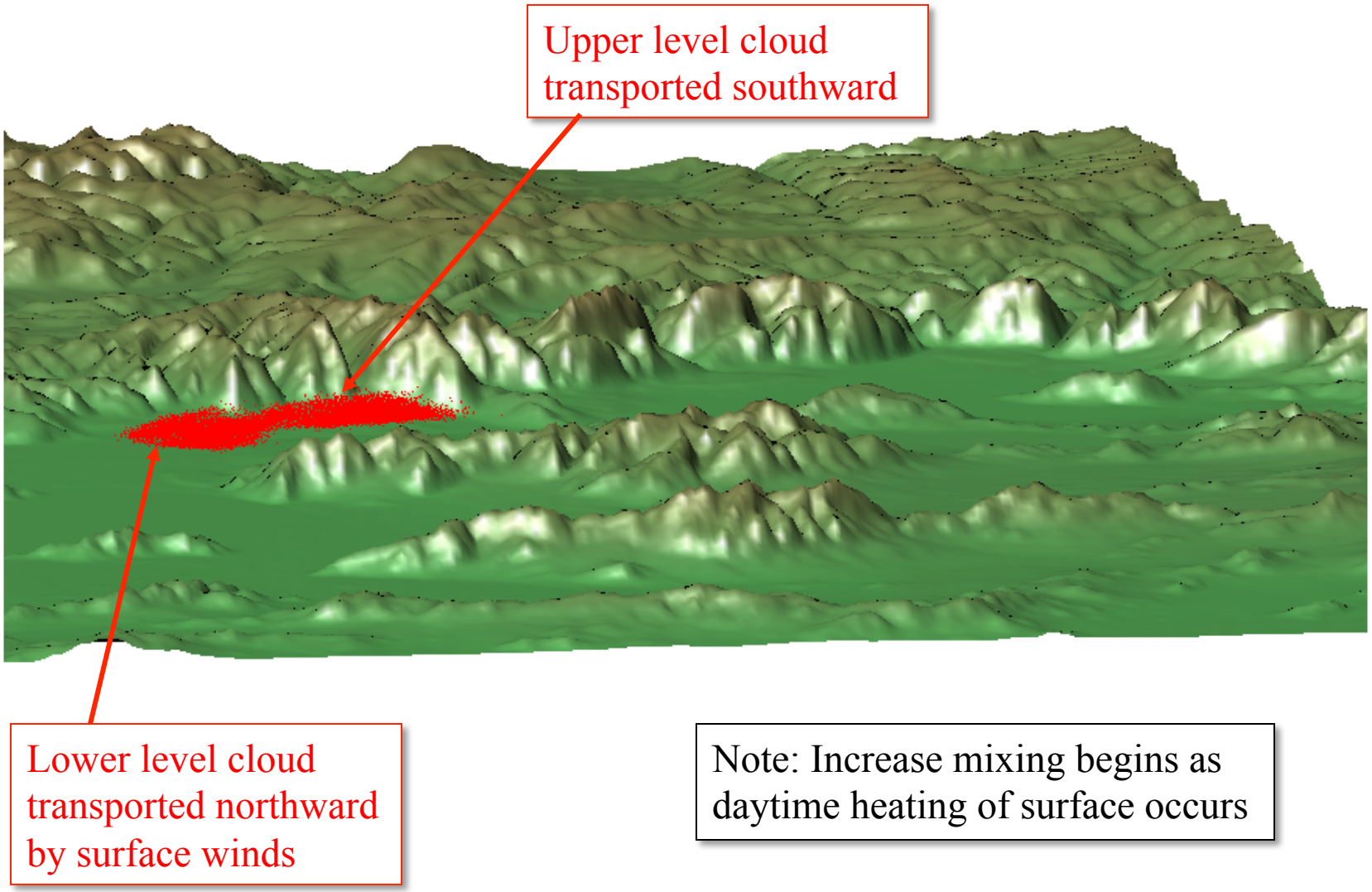








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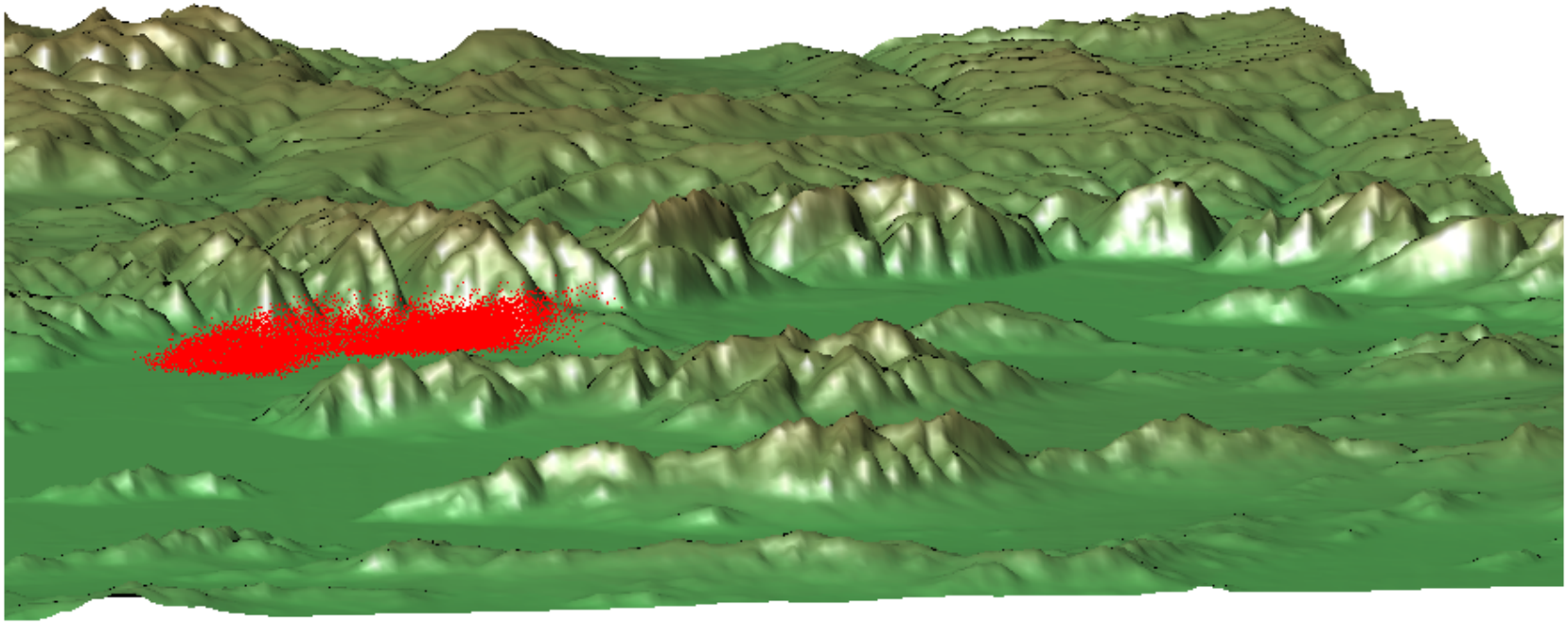

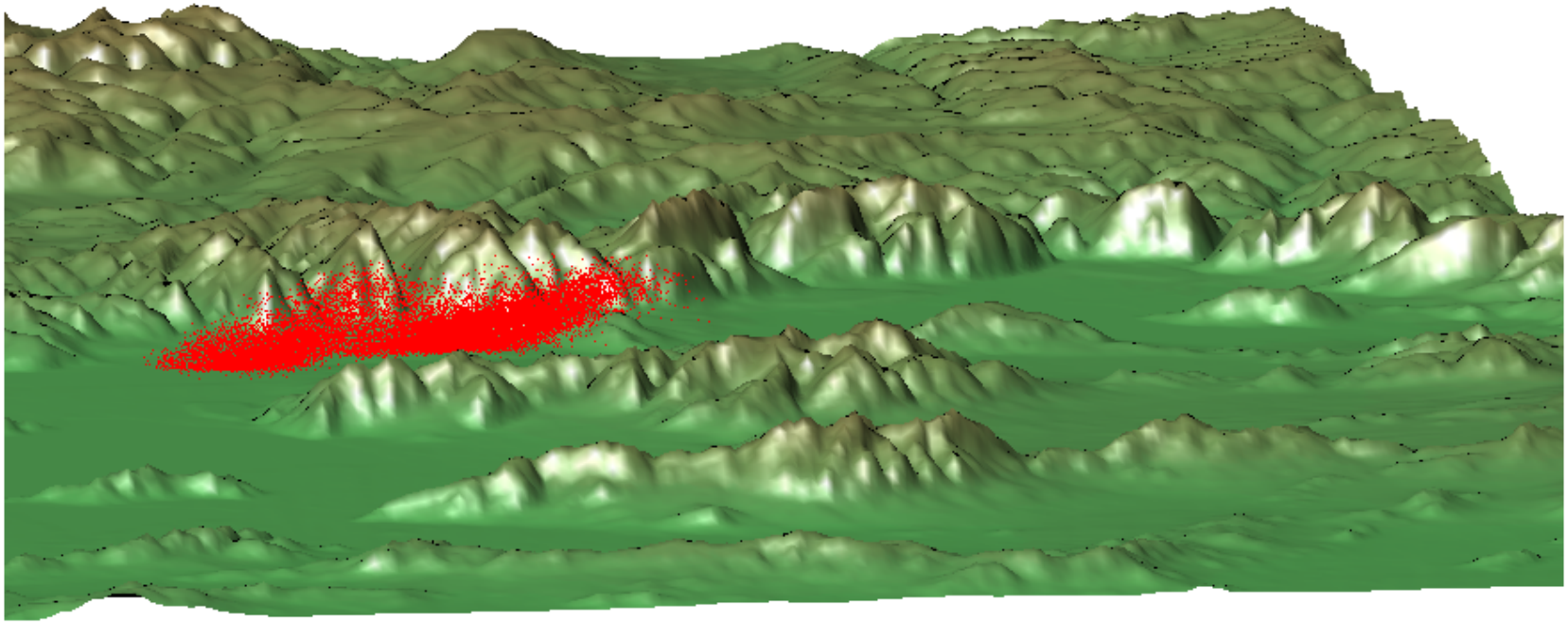

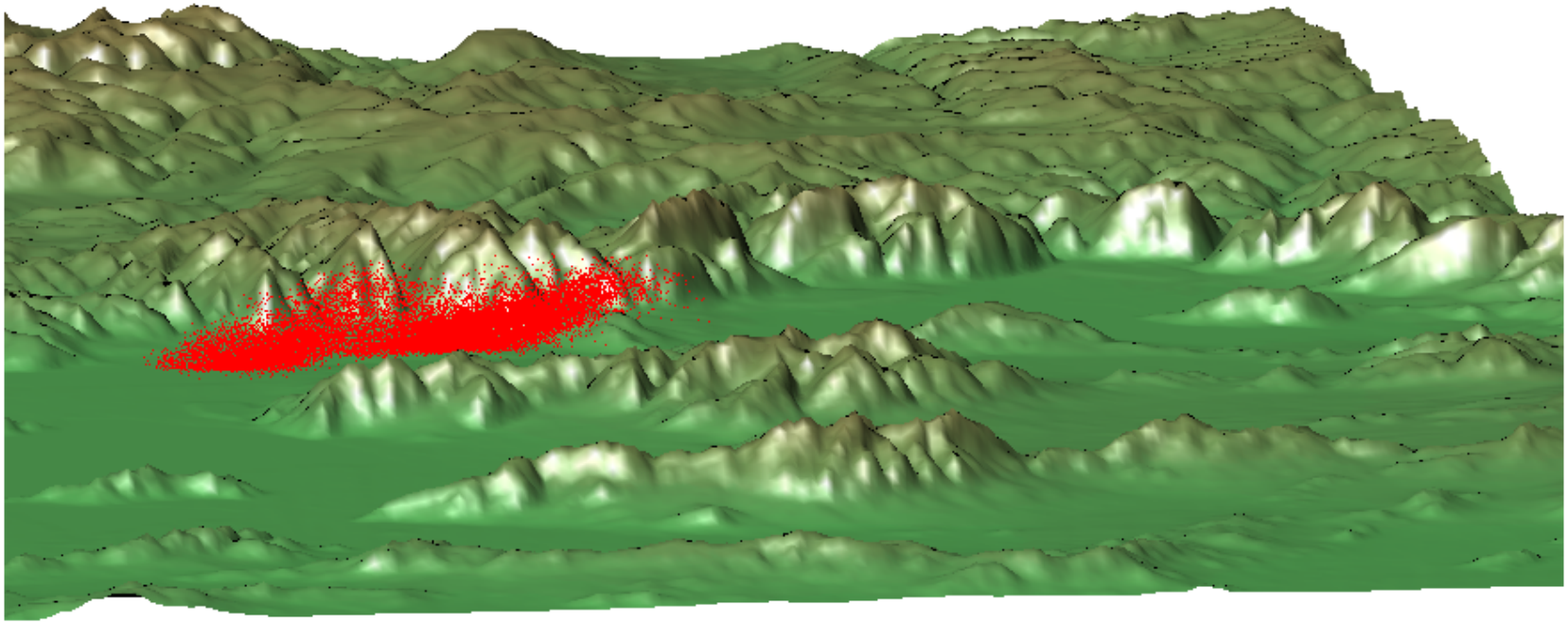

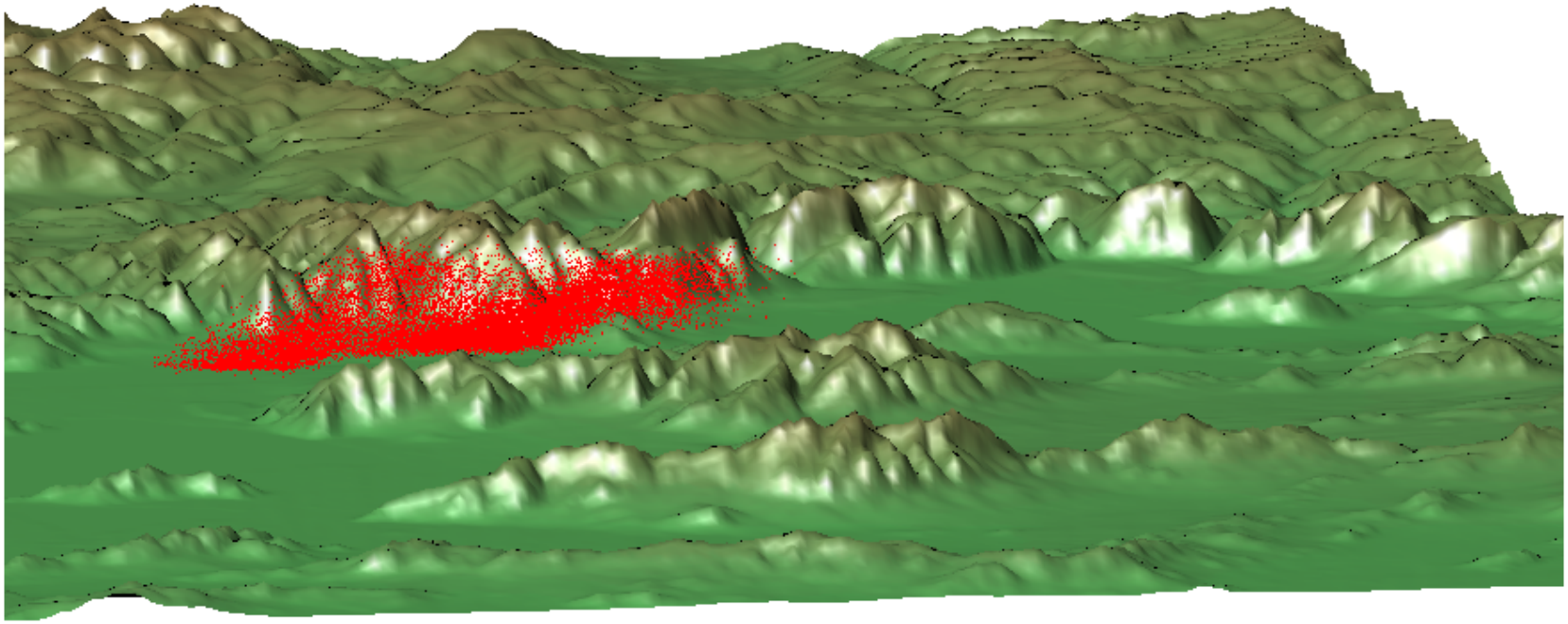

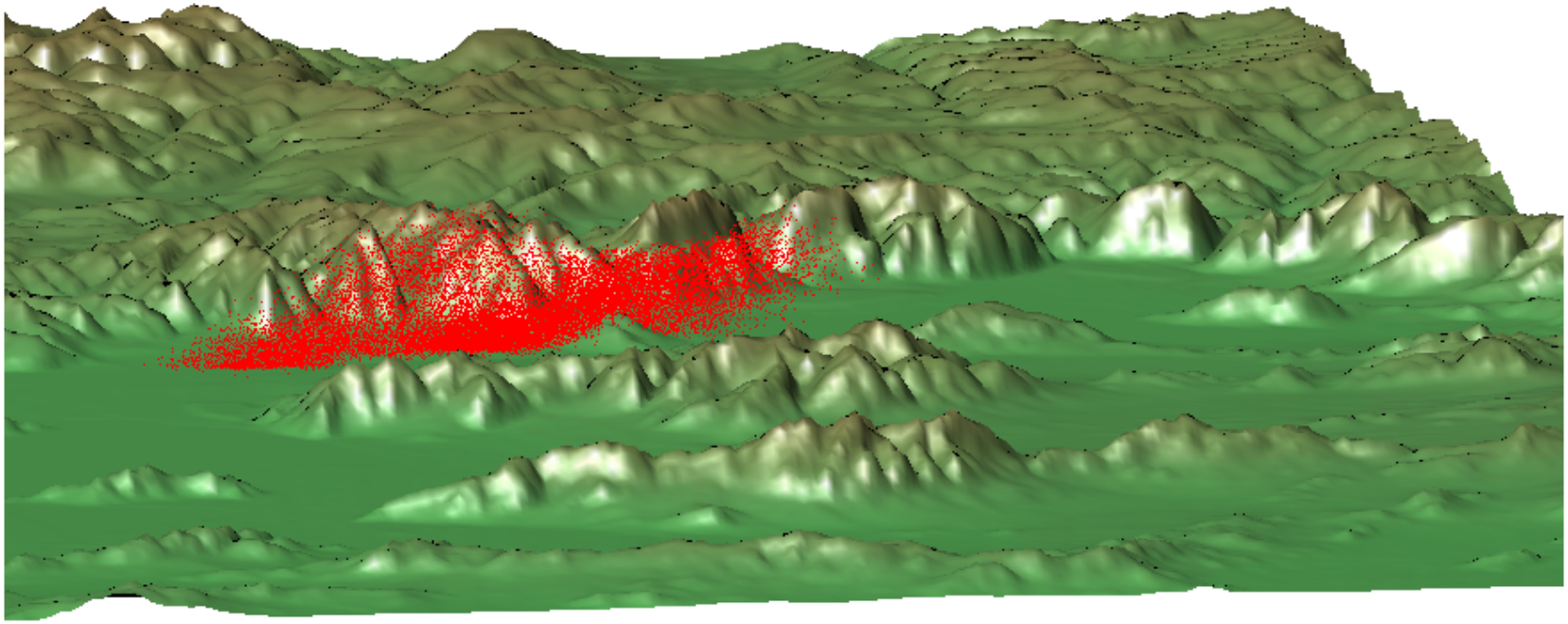

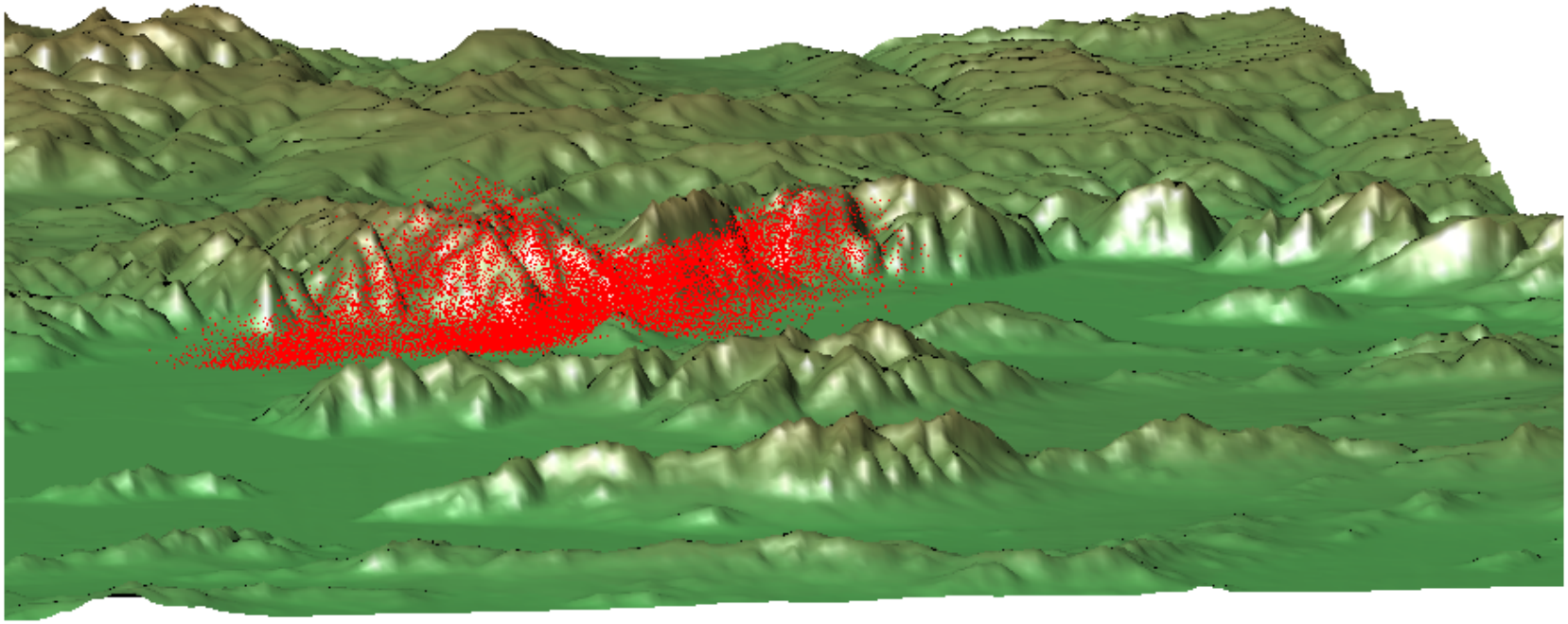

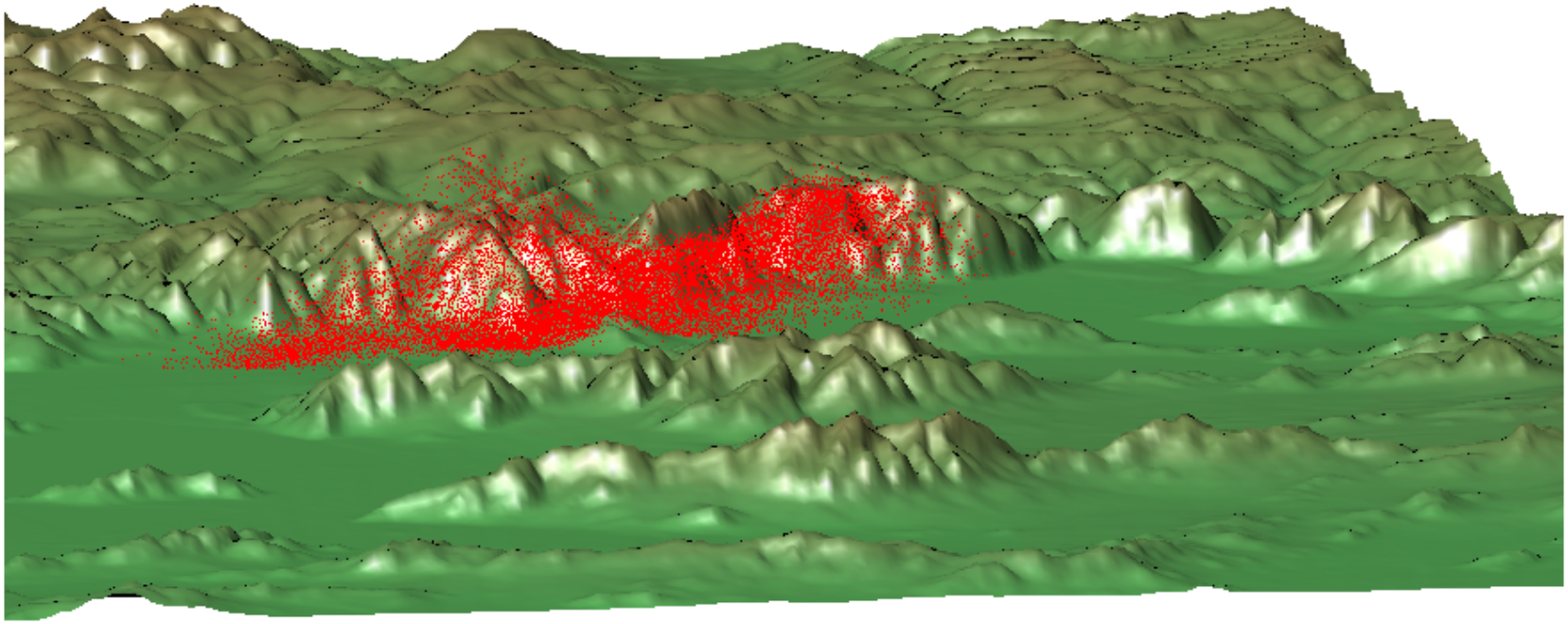

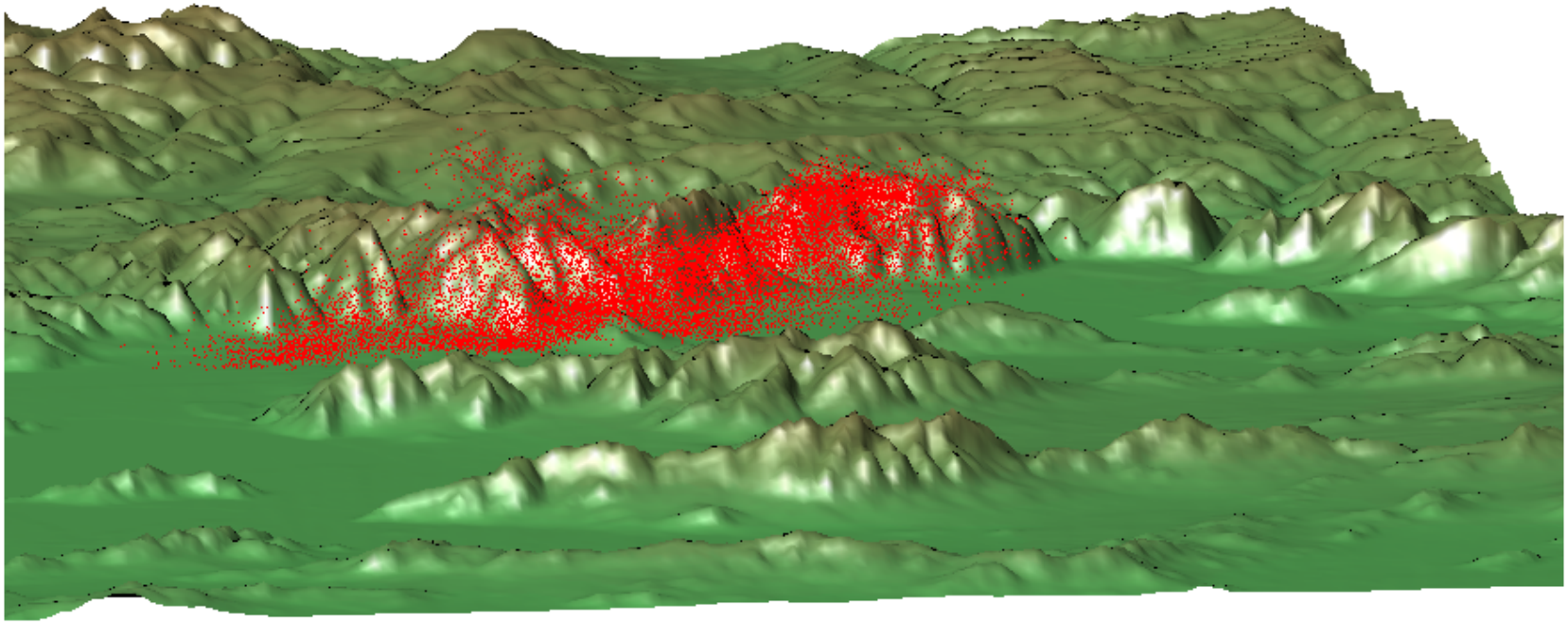

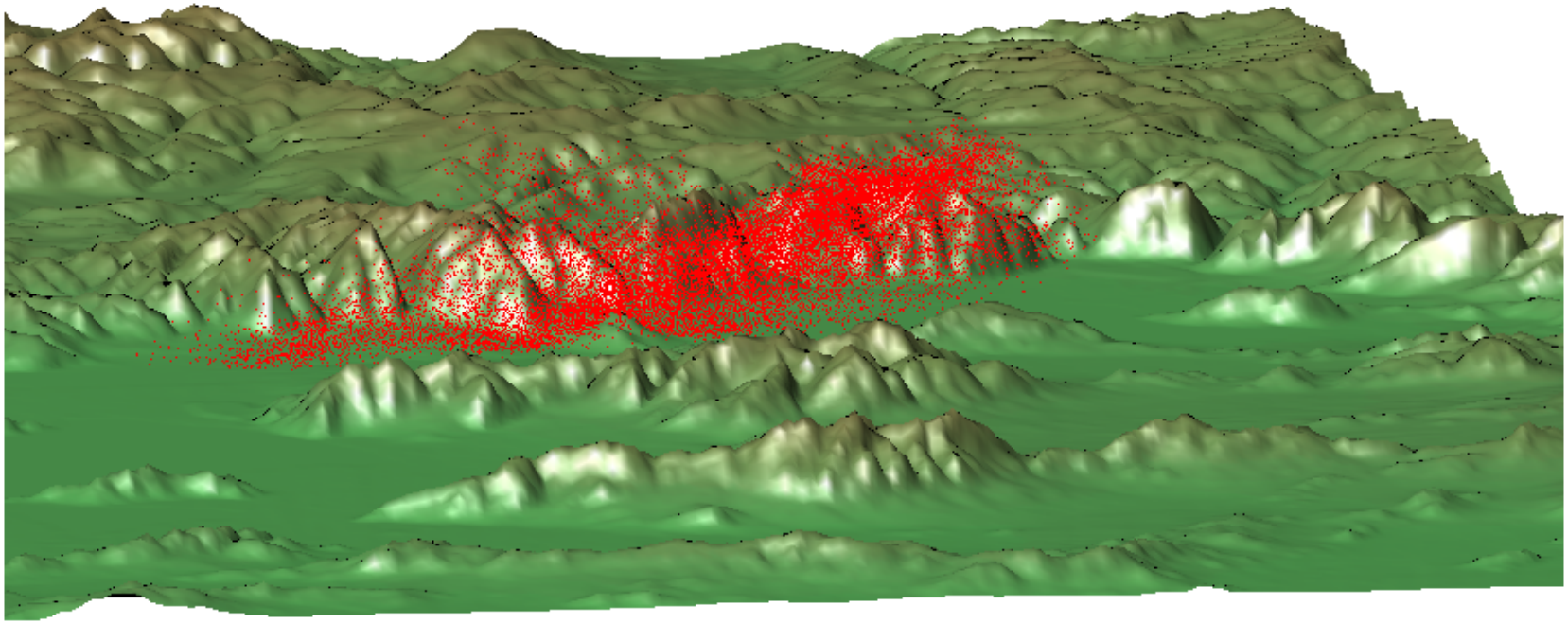

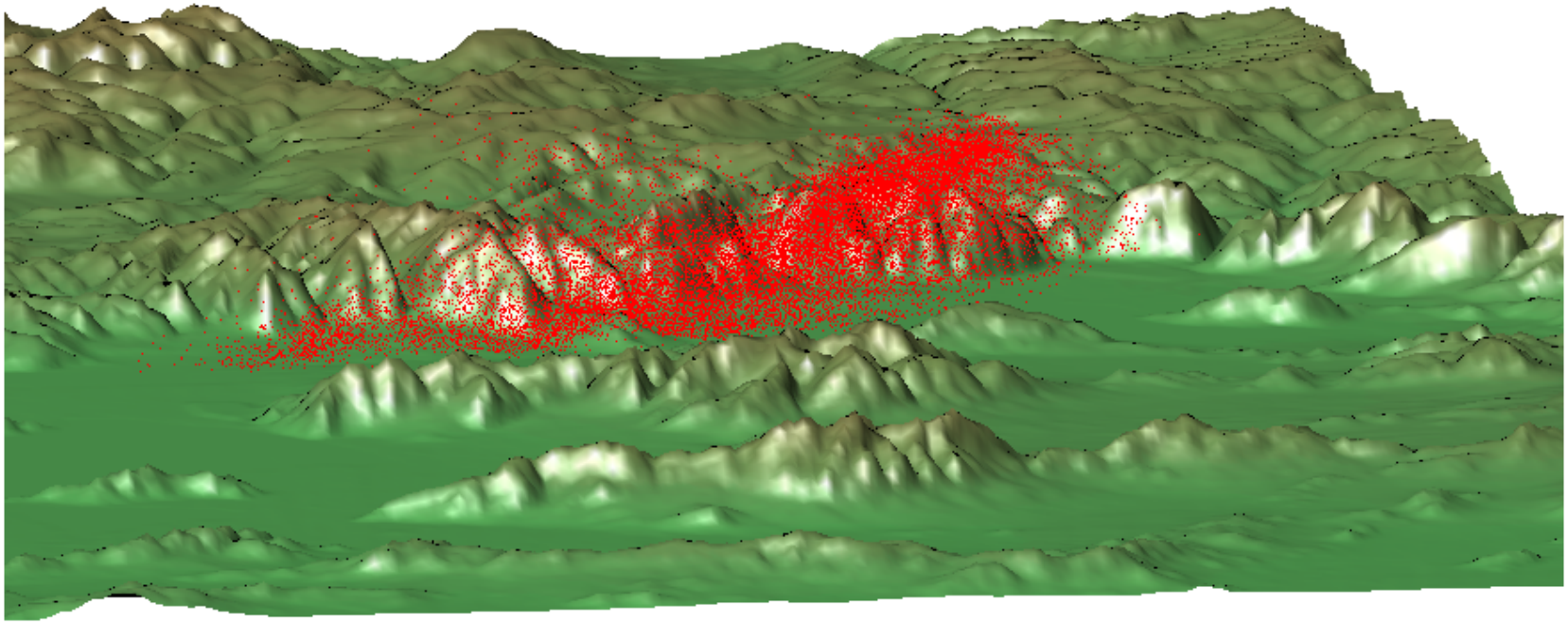

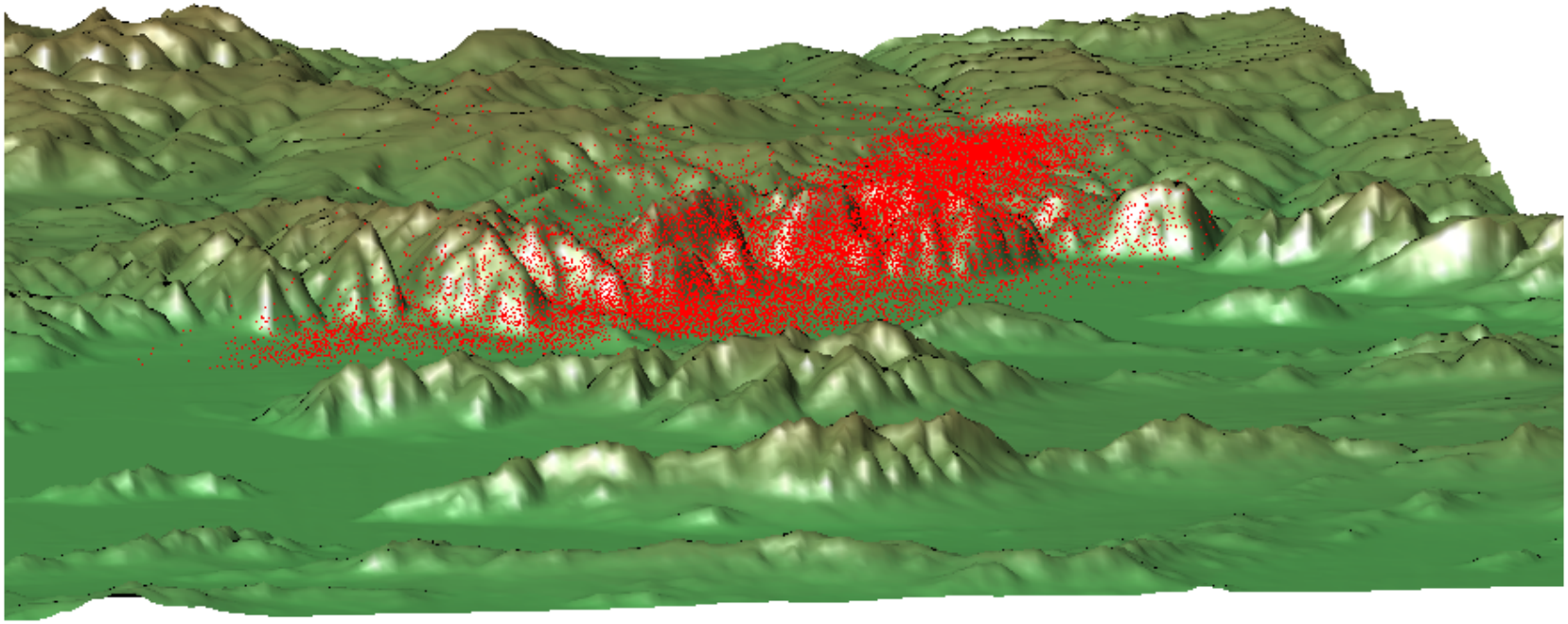

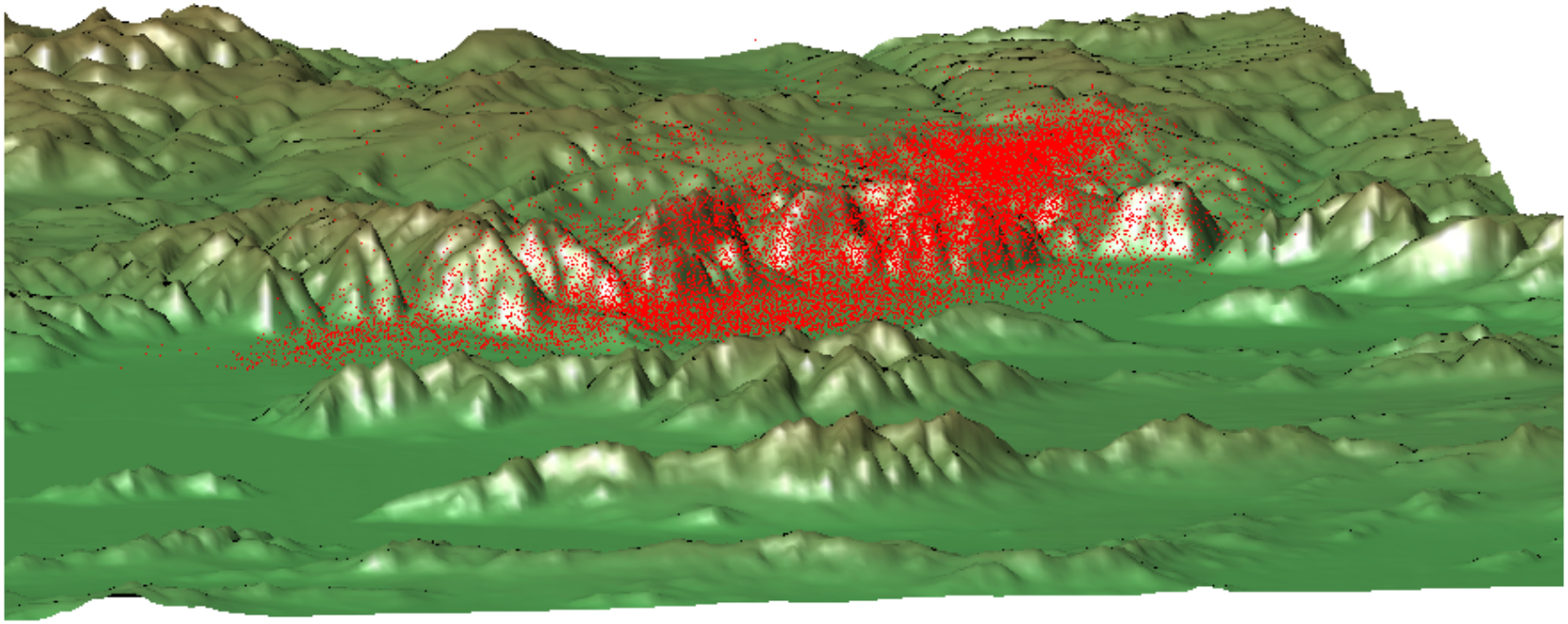

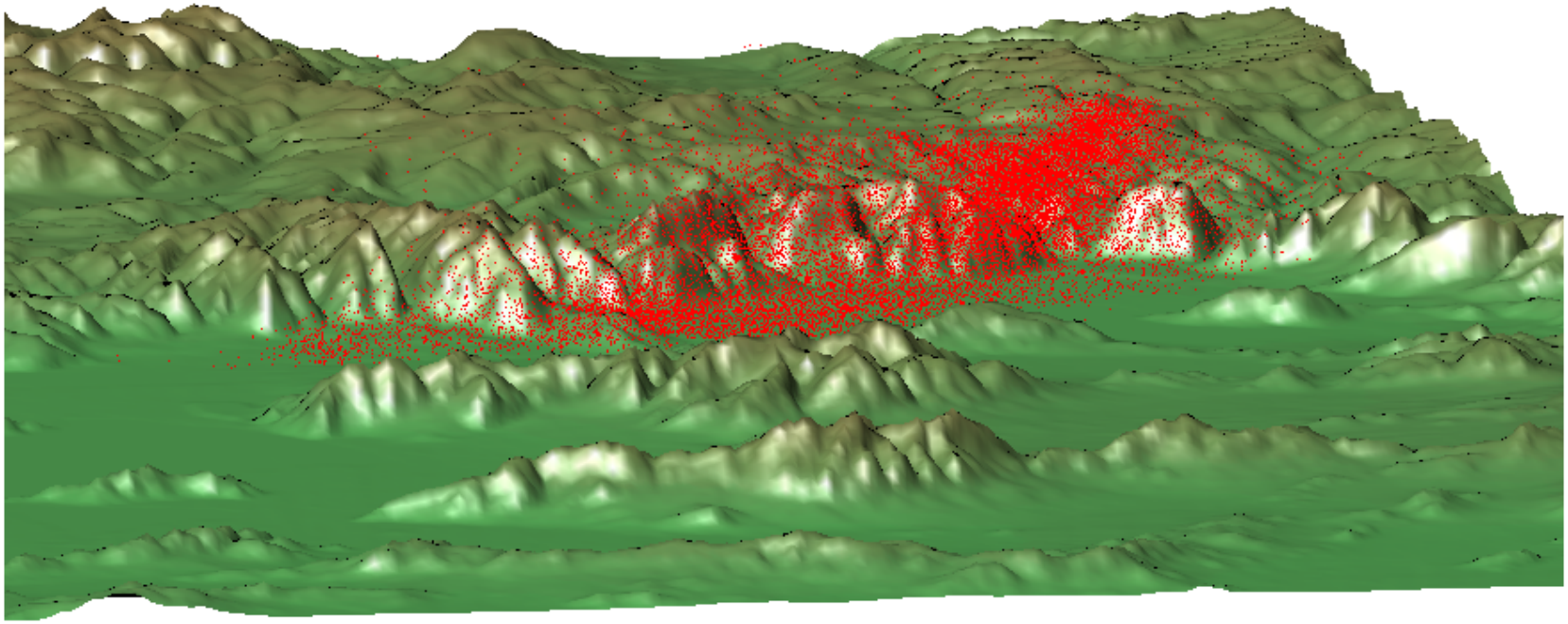

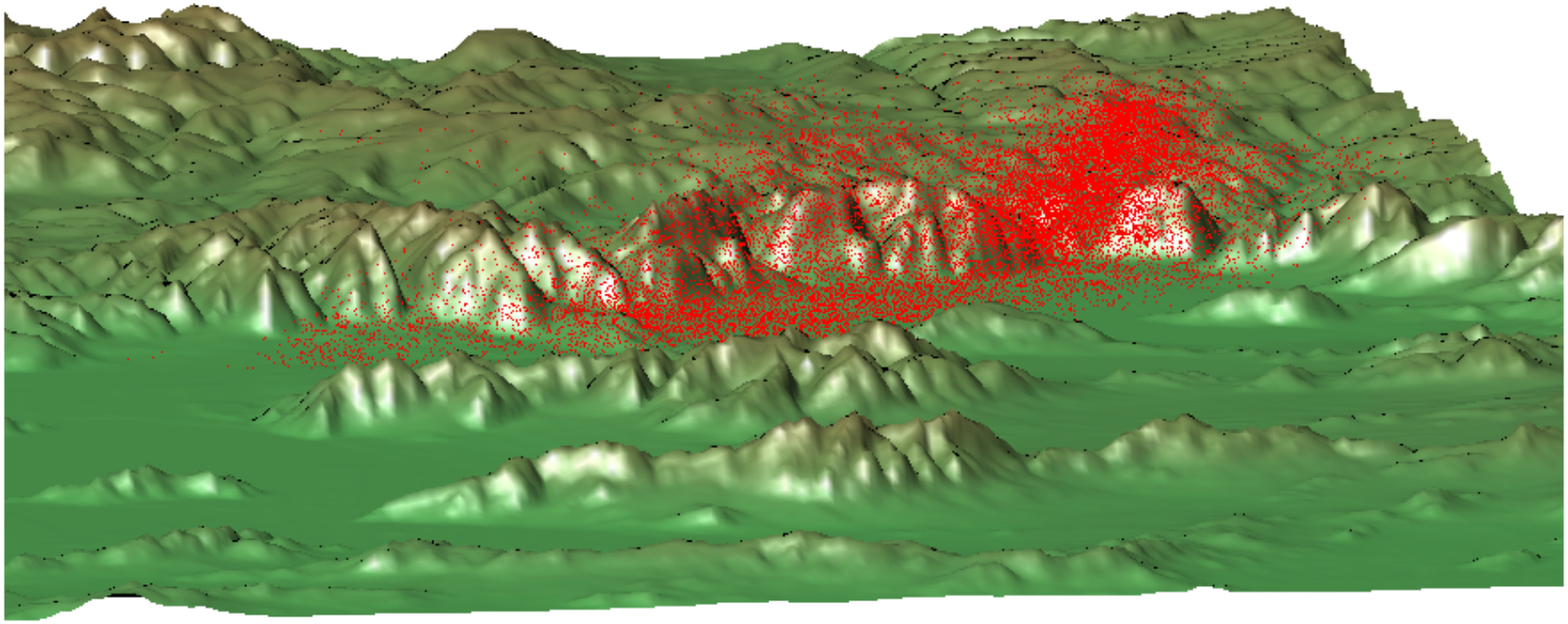

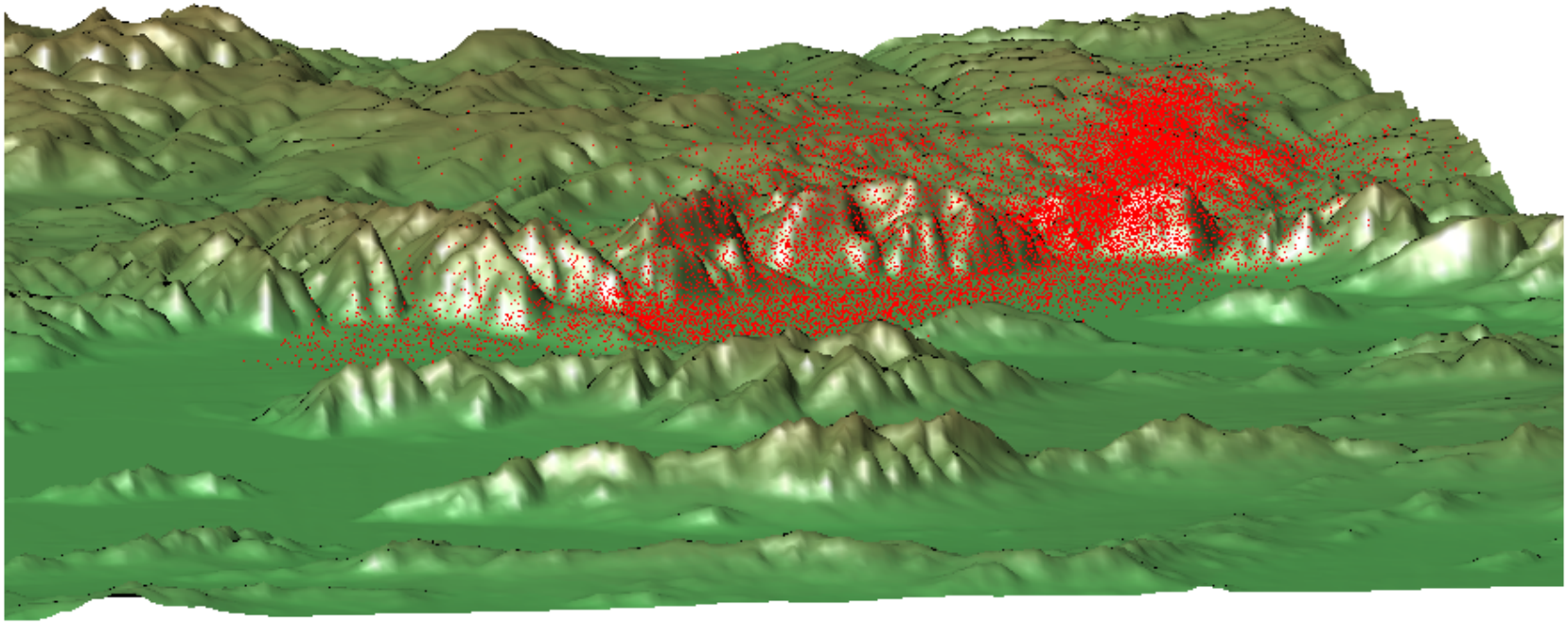

Winter Case Study: Hypothetical RDD Ground-Level Time-integrated Dose