National Atmospheric Release Advisory Center (NARAC) ATD Modeling

17th Annual GMU Conference on Atmospheric Transport and Dispersion Modeling: Progress in Governmental ATD Modeling and Response Panel

June 25, 2013

Gayle Sugiyama, NARAC Program Leader

Lawrence Livermore National Laboratory

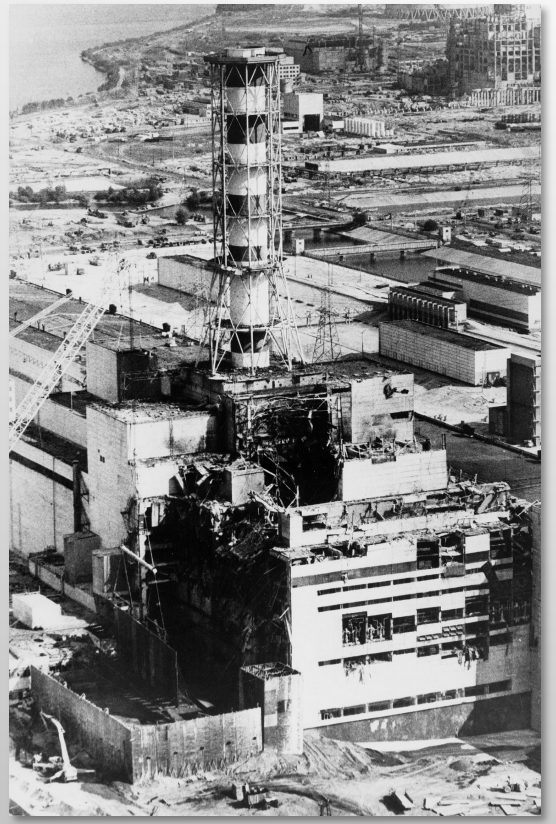
National Atmospheric Release Advisory Center

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-639634

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 responds to toxic industrial chemical spills, nuclear-power plant accidents, fires, chemical/biological agents, radiological dispersal devices (RDDs), nuclear detonations, and some natural airborne hazards.

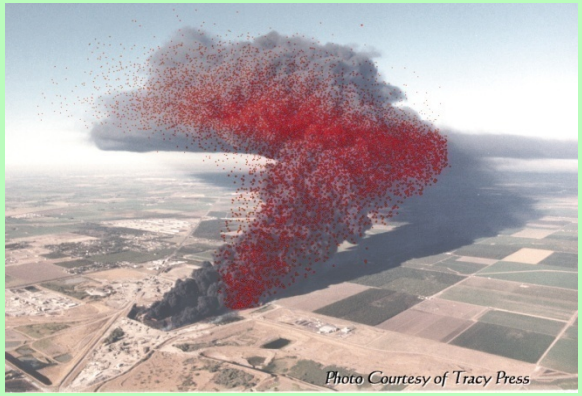
NARAC Provides Operational Services, Tools, and Expertise for Preparedness, Response, & Recovery

Event Information

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

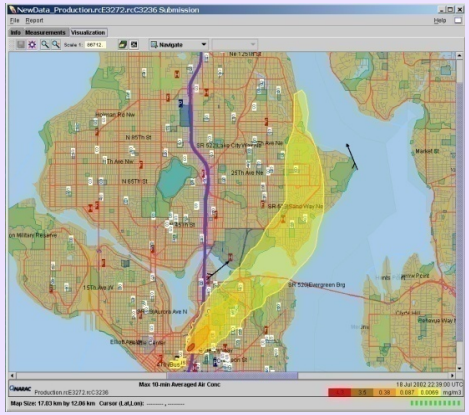
Operational Services and Expertise

- 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



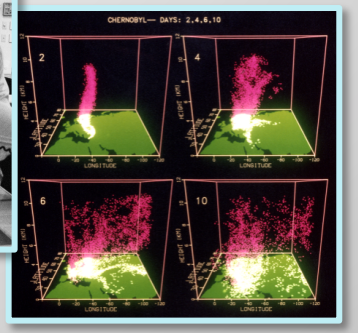
Actionable Information

- 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 Supports A Wide Range of DOE, DHS, DoD, NASA, and Other Missions

- 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
- NASA spacecraft launch support (coordinated via the DOE Office of Radioisotope Power Systems)
- DHS IMAAC – radiological/nuclear products under DOE auspices
- DOE Safety Toolbox codes for safety analysis and hazard assessments (HotSpot and EPIcode)
- Other DOE, DoD, DHS, and agency missions



NARAC predicted the spread of Chernobyl radioactivity over Europe and Asia

NARAC supports international cooperation under DOE/IAEA auspices

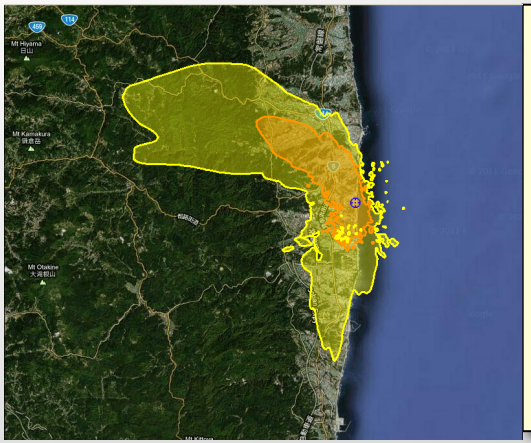
NARAC provides the Senior Science Advisor and support for NASA spacecraft launches

Model 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
- Experiences in real-world emergencies (e.g., Fukushima)
- Updated 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)
- Customer / user feedback and communications
- Interagency collaborations and partnerships

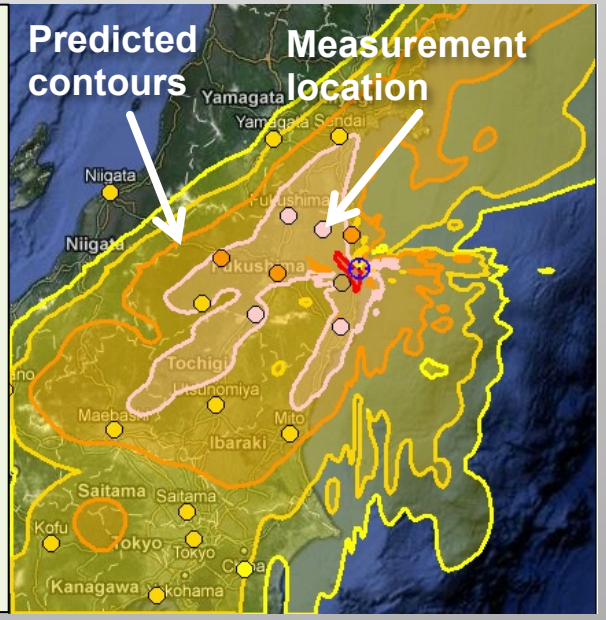
Model Development Priorities: Data-Model Fusion Capabilities

- Measurement-model integration
  - Numerical weather prediction data assimilation
  - Field-data acquisition including quality assurance
  - Software to rapidly process measurement data
  - Data-model comparison and analysis tools
  - Improved source estimation capabilities
- Uncertainty estimation
  - Ensembles (meteorological and dispersion)
  - Source estimation methods
  - Communicating uncertainty



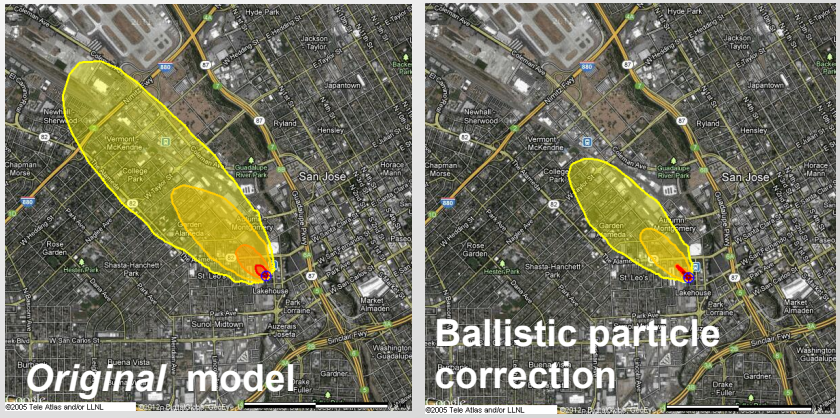
NARAC Fukushima predictions based on source estimation from measurement data

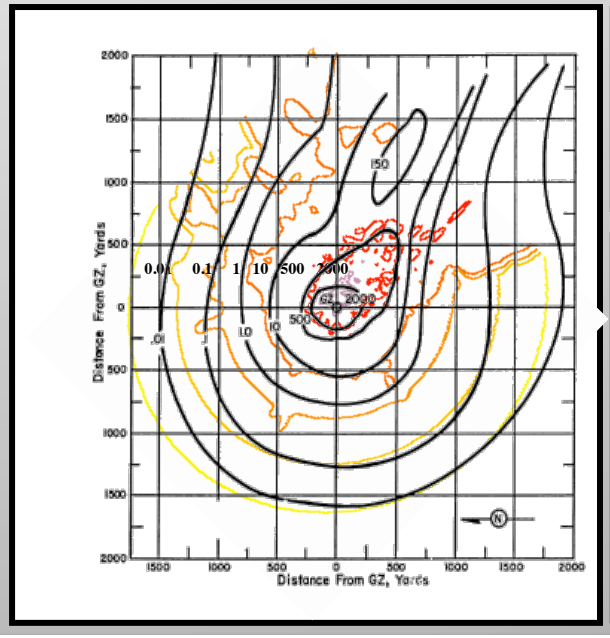
NARAC model predicted dose rate compared to MEXT data for March 15,1800 UTC. Colors code: 120μGy h^{-1} (red), 4μGy h^{-1} (pink), 0.4μGy h^{-1} (orange), 0.04μGy h^{-1} (light orange) and 0.004μGy h^{-1} (yellow).



Model Development Priorities: Improved Physics and Model Fidelity

- Source term physics
  - RDDs: ballistic particle corrections based on SNL experimental data, improved cloud rise height from Greenfield experiments)
  - Nuclear detonations: prompt effects, improved cloud rise, cloud geometry, and particle/activity-height distributions; new particle-cloud coupling methods; radionuclide inventories; and fallout fractionation (different particle size distributions for volatile and non-volatile)
  - Collaborative effort with NRC on improved nuclear power plant source terms and data exchange formats
- Numerical weather prediction modeling improvements (key to accurate modeling of Fukushima impacts)
  - Meteorological data assimilation
  - Precipitation
- Improved dry and wet deposition models
- Maxwell and Anspaugh resuspension model (2011)





LWAC/LODI prediction compared to NTS data

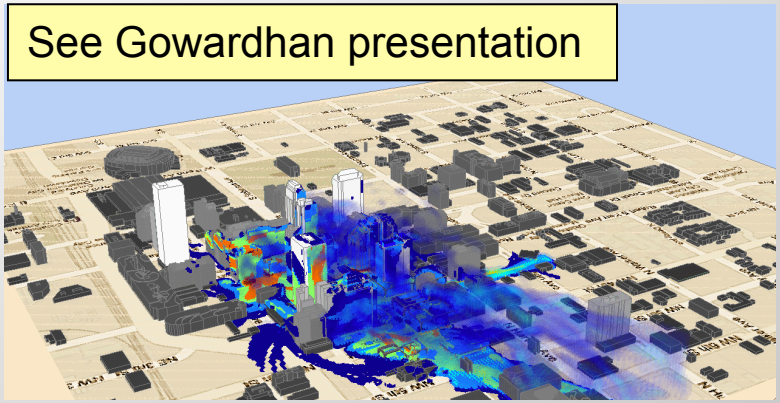
Total exposure rate compared to combined LWAC / LODI Fallout Results (R/hr):

- 0.01
- 0.1
- 1
- 10
- 500
- 2000

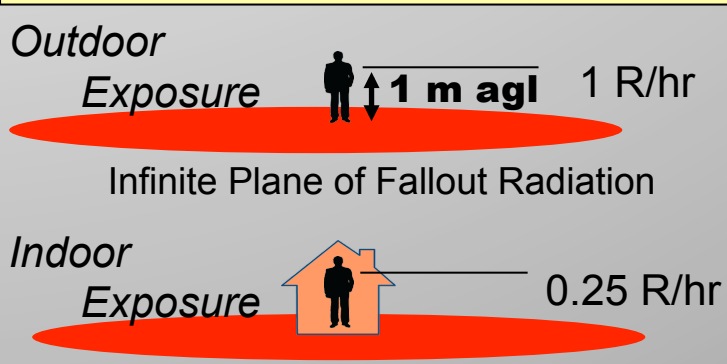
Model Development Priorities: Urban Modeling

- Urban building-resolving flow and dispersion
  - Efficient computational fluid dynamics code (AEOLUS) with RANS and LES modes
  - Rapid grid generation from building footprint data
  - Coupling to regional scale model
- Building sheltering to calculate indoor dose exposures and improve casualty estimates
  - Infiltration models and building leakiness databases (with LBNL)
  - LLNL *PFscreen* model provides estimates of building protection factors
  - LLNL *Regional Sheltering Analysis* tool estimates potential protection from gamma radiation for a variety of shelter strategies based on existing database of building properties (e.g., FEMA HAZUS data)
  - Indoor-outdoor coupled models

See Gowardhan presentation

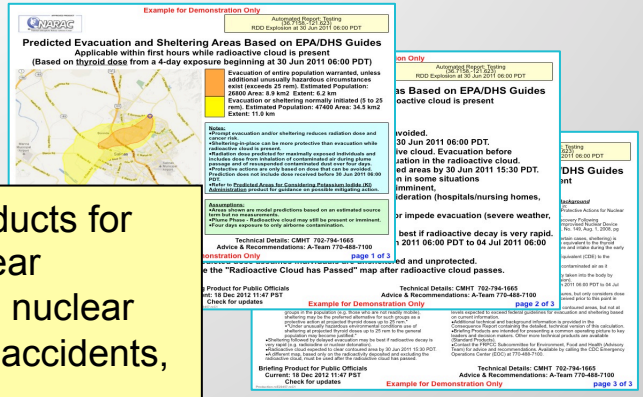


Building Protection Factor
= ratio of outdoor/indoor exposures
= 4



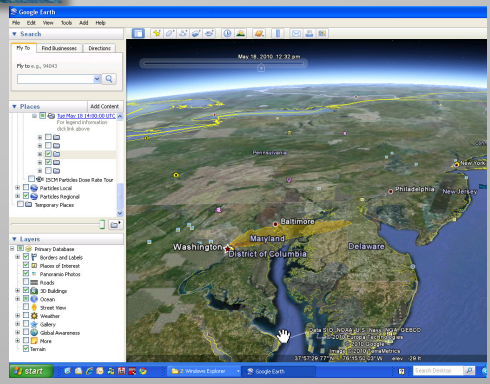
Model Development Priorities: Improved Products for Communication with Users

- Standard NARAC technical products developed with interagency input showing plume hazard areas, affected populations, health effects, protective action guide levels, and geographical information
- Consequence reports documenting results, inputs, assumptions, and plot interpretation
- NARAC Briefing Products intended for decision makers and emergency responders focused on actions that need to be considered
- Supplementary analyses (meteorological, deposition, field data, animations)
- NARAC map layers output in multiple formats (PDF, PowerPoint, HTML/XML, JPG/PNG, ESRI shapefiles, Google Earth KMZ)



Briefing products for RDDs, nuclear detonations, nuclear power plant accidents, CB releases

Animations and time series plots to display evolving impacts

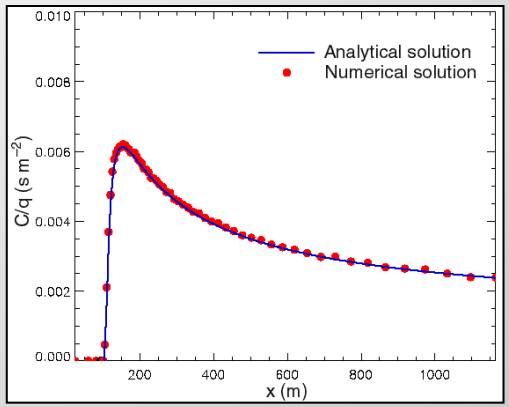


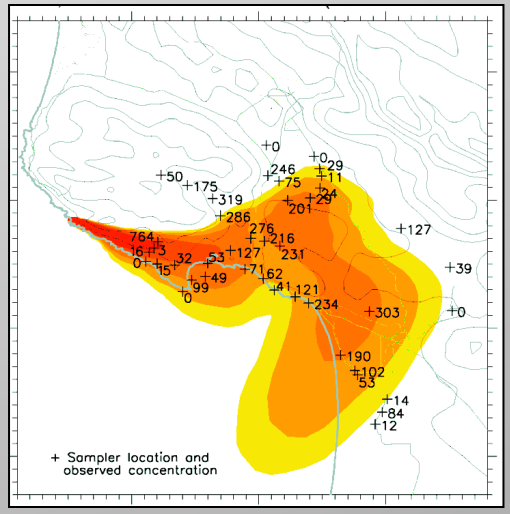
PDF, PowerPoint, HTML/XML, JPG/ PNG graphics,

ESRI Shape and Google Earth KMZ GIS files with plume areas

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

- Multiple validation components
  - Analytic comparisons against known results
  - Laboratory experiments validate model physics against experimental data
  - Field studies test models in real-world conditions (statistical and graphical metrics)
  - Operational testing evaluates 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)



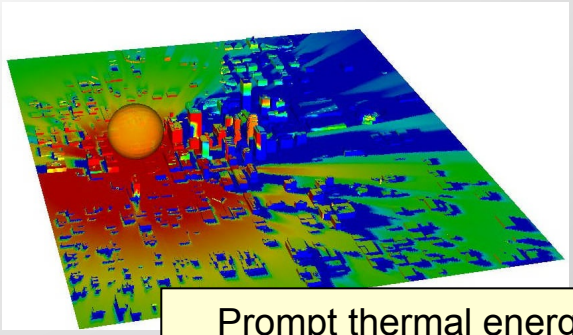


Data is Needed for Both Real-World Response and Testing of Models

- Environmental monitoring measurement data needs
  - Real-time standardized data collection methods
  - Standard formats and metadata for data exchange
  - Rapid quality assurance
- Additional experimental data needed for model development, testing and validation
  - Dispersion/deposition data for complex meteorology/terrain
  - Urban dispersion
  - Particulate releases
  - Buoyant sources
  - Nuclear fallout data (for conditions different from nuclear test sites)
  - Health effects and dose exposure models, including impacts of compounding injuries
  - Deposition, weathering, degradation, viability, and resuspension data and models
- Long-term open-access field experiment databases with quality-assured data and documentation

On-Going Challenges

- Other needed areas for ATD model improvements
  - CBRNE source terms
  - Effects of urban environments on RDD and nuclear detonations
  - Methods for estimating uncertainty and range of possible effects for different environmental and meteorological conditions
- Communicating with planners, decision makers, and emergency responders
  - Conveying technical information and how to use it (Briefing Products)
  - Uncertainty estimation and communication to inform planning guidance and response
- Development of multi-disciplinary staff in CBRNE dispersion and effects
- Cost-effective support for local, state, federal, and private sector (tools, training, events)
- Exercises/drills with sufficiently realistic complexity to train analysts



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

Example of fallout dose pattern for New York City from multiple weather conditions

National Atmospheric Release Advisory Center

NARAC

Web: narac.llnl.gov

Email: narac@llnl.gov

Contributors to material in this briefing: John Nasstrom, Brenda Pobanz, Shawn Larsen, Michael Dillon, Kevin Foster, Peter Goldstein, Akshay Gowardhan, and Matthew Simpson

Lawrence Livermore National Laboratory

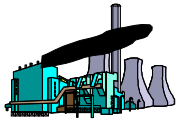
Backup / Supplemental Slides

NARAC Modeling System Integrates Multiple Models (Example for Radiological / Nuclear Incidents)

IND source models:
- LLNL *KDFOC*
- LLNL *LWAC*
- ORNL *ORIGEN*
- ORNL *DELFIC*

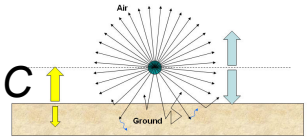
RDD Source models:
- SNL *Source Term Calculator*
- SNL *PUFF*

Nuclear power and fuel sources:
- NRC *RASCAL*

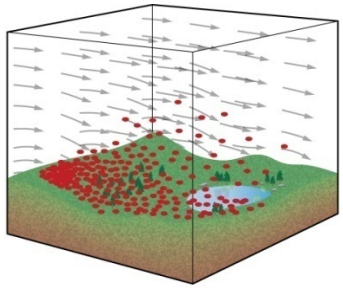


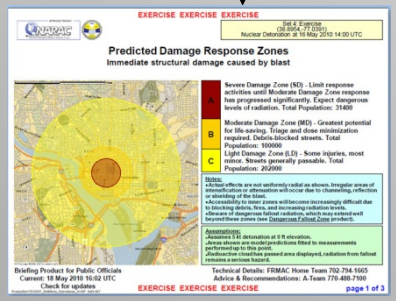
Fire source model:
- LLNL

IND and RDD Prompt effects models:
- SNL *Nuke*
- SNL *Blast*
- LLNL *LWAC*

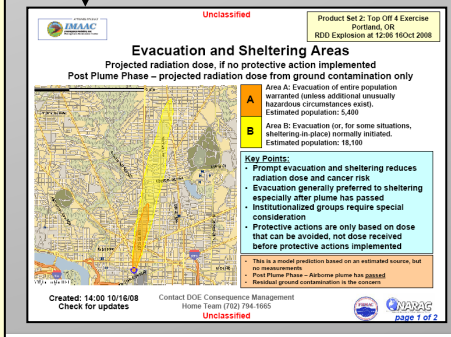


3-D Atmospheric Dispersion and Fallout models:
LLNL *ADAPT/LODI*





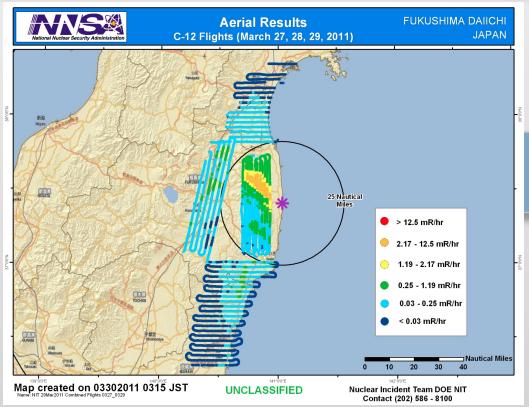
Products:
- Airborne and fallout contamination and dose predictions for worker and public protection
- Affected population and casualty estimates
- Building damage from blast overpressure
- Radiation, blast and thermal casualty estimates
- Neutron-activation ground shine dose



Refinement of Dispersion Model Simulations Is Made Based on Radiological Measurements

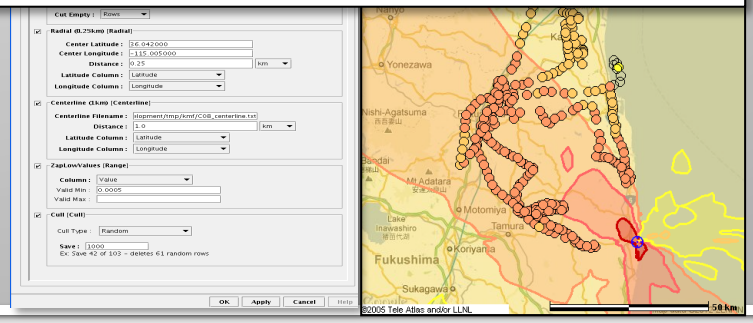
Initial Model Predictions Guide Measurement Surveys

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



Measurement Data transferred electronically to LLNL/NARAC

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



Updated predictions using measurement data