An Operational Perspective on Atmospheric Dispersion Modeling

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OFCM Session Panel

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Operational Systems Provide Timely Information to Protect the Public and the Environment Via End-to-End Capabilities

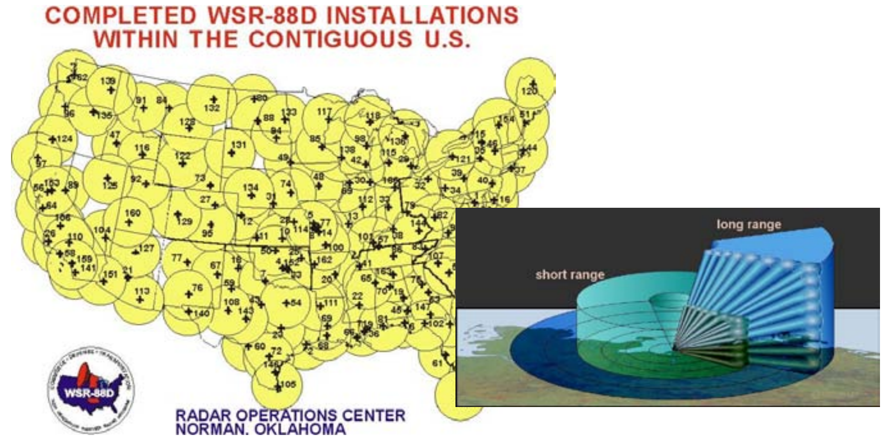


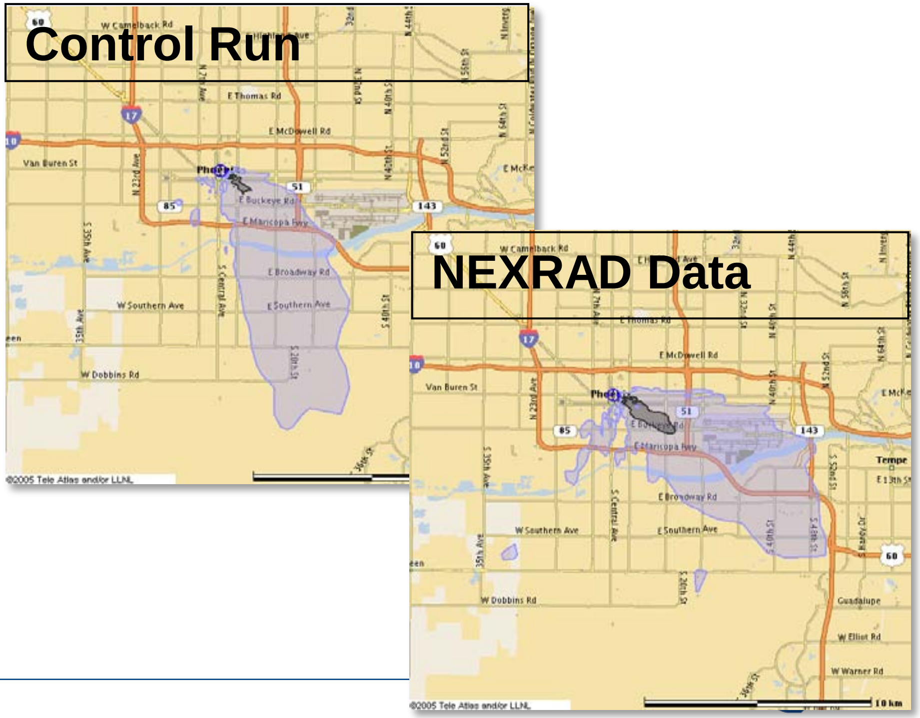



- Event information
  - Weather data
  - CBRN material and source terms
  - Geographic and population databases
  - Field data and observations
- Operational services
  - Suite of multi-scale tools
  - 24/7/365 reachback to experts
  - Product distribution
  - Interagency coordination
- Actionable information
  - Characterization of hazard areas
  - Affected populations, including casualty and fatality estimates
  - Health effect, protective action guide, worker protection levels
  - Sampling plan guidance

Higher-Resolution Data and Data Assimilation Methods are Key to Reducing Meteorological Uncertainty

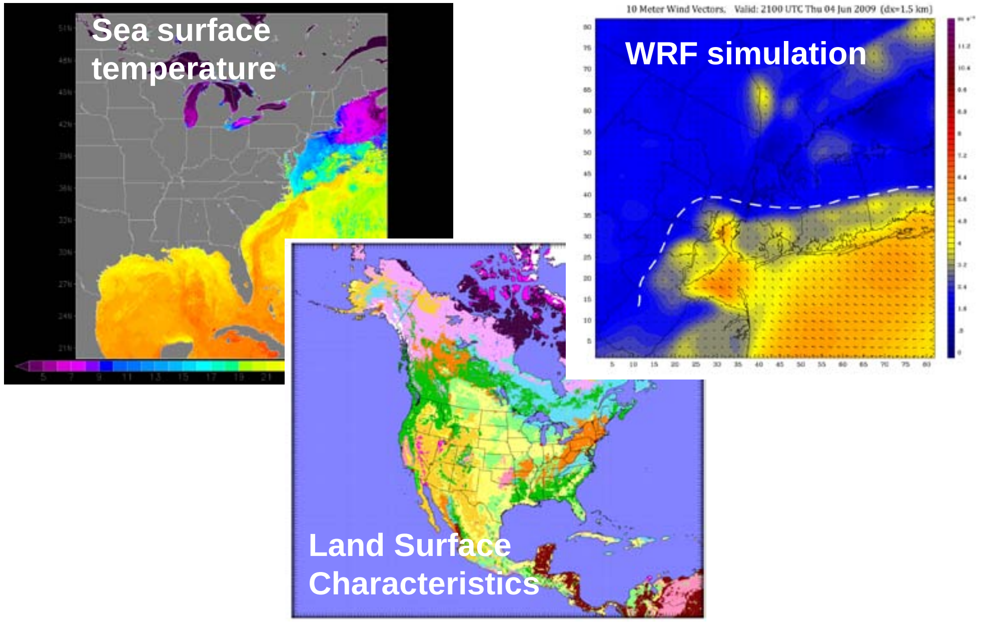
- Real-time collection and quality assurance of data from diverse observing networks (wind velocity, T, turbulence)
- Remote sensing system provide much higher resolution upper level wind observation
    - Example: NEXRAD hourly data, improved boundary layer resolution, volume coverage
    - Example: LIDAR
- Methods for using and assimilating diverse data (e.g., radar-derived winds, aircraft data, satellite)

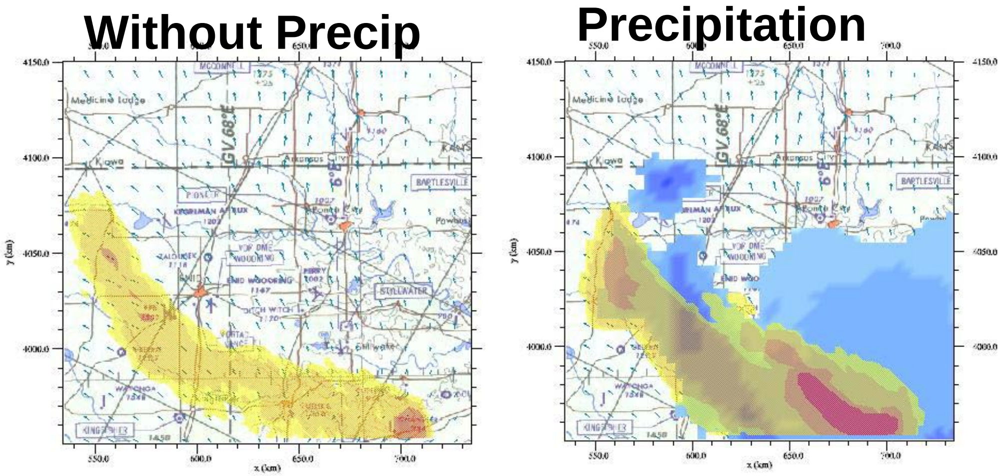




Higher-Resolution Data and New Data Assimilation Methods are Key to Reducing Uncertainty

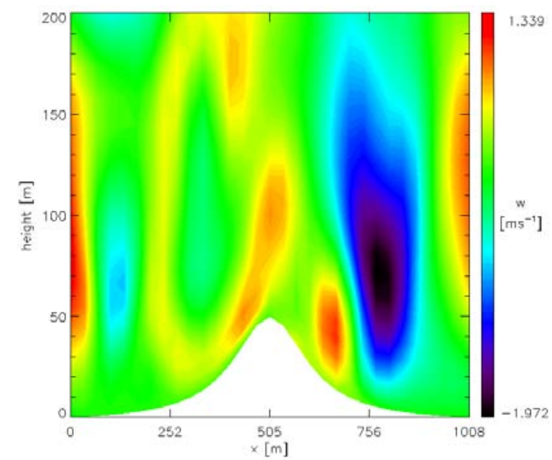
- Example: Satellite retrievals incorporated into NWP simulations provides seasonal and regional variation and improve simulations in heterogeneous environments (coastal, urban, complex terrain)
  - Surface roughness
  - Sea surface temperature
  - Land-surface characteristics
- Example: Rain rate and particle-size dependent precipitation scavenging
  - Radar precipitation data calibrated with rain gauge data

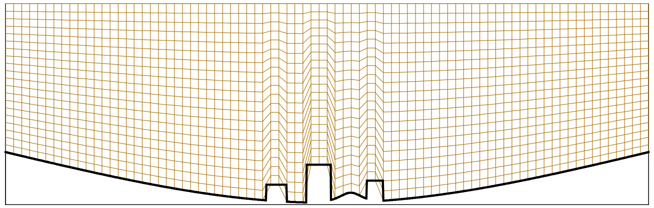


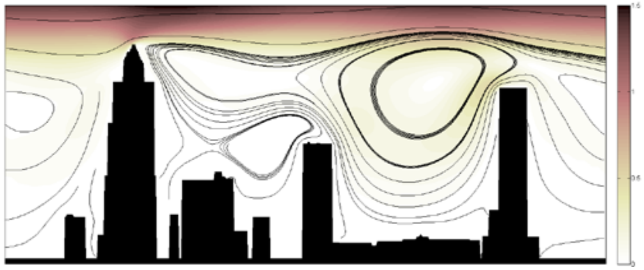


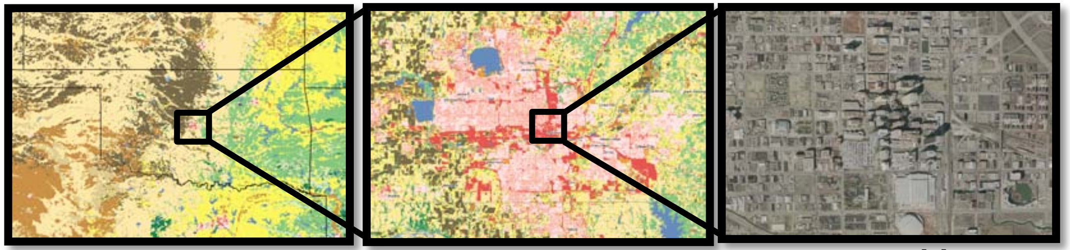
Methods are Needed that Integrate Physical Processes Across a Range of Scales (Micro-to-Mesoscale Gap)

- Development of advanced turbulence models for large-eddy simulations
- Example: Immersed boundary conditions to represent complex geometries on a structured grid
  - Standard NWP methods at mesoscale with terrain following coordinates
  - IBM on inner nest to explicitly resolve urban structures (boundary conditions) imposed inside computational domain
  - Nesting with up-and-down scale coupling









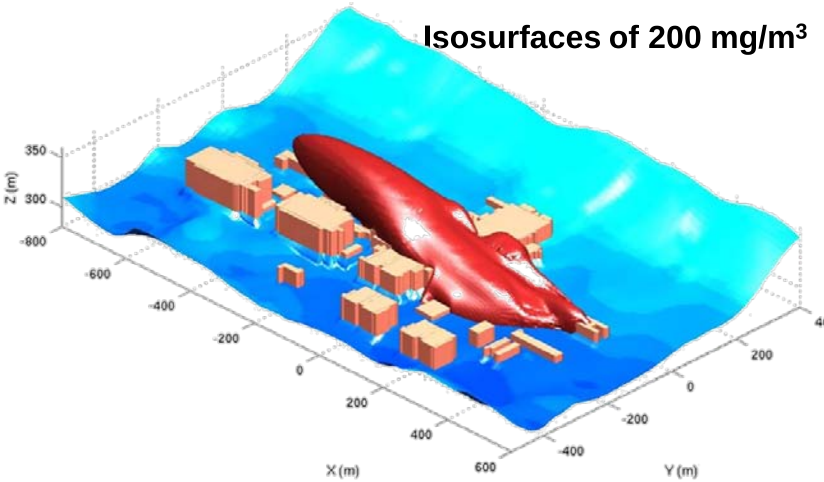
1 km grid

100 m grid

5 m grid

Release Source Term is Often the Greatest Unknown During a Real-World Response

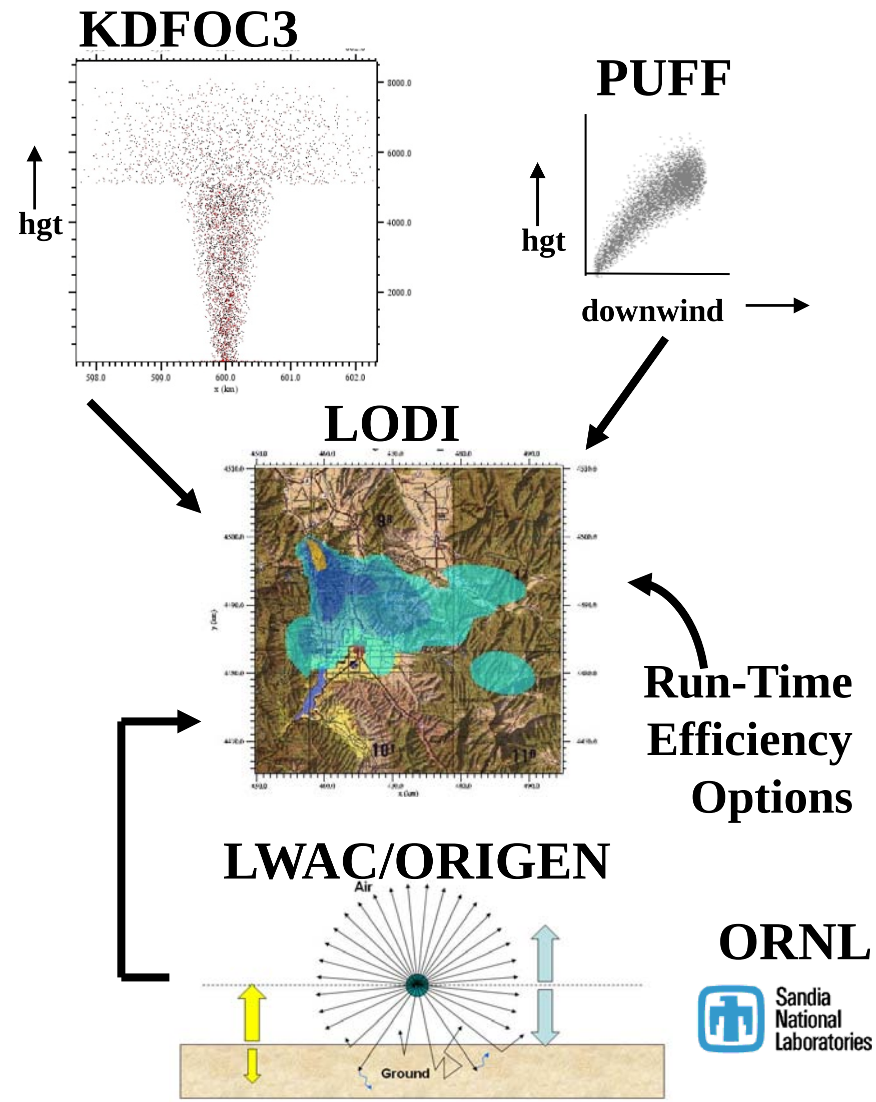
- Toxic industrial chemicals
  - Chemical mixtures and reactions
  - Multi-phase source terms
  - Dense gas effects in urban environments
  - Catastrophic releases
- Operational need: Reducing complex physics to key elements based on observables or derivable from field data
- RDD
  - Radiological mixtures
  - US/Canada/Israel cloud rise experiments
  - Deposition of ballistic-size explosively dispersed particles (SNL experiments)
  - Gap: urban effects on initial cloud rise



Example: Urban-scale dense gas release. Density reduces vertical mixing, increases lateral spreading and upwind spread, and induces downslope transport

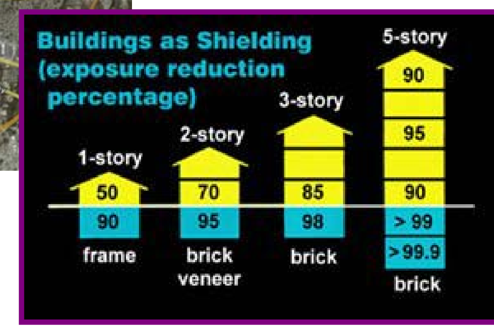
User Community is Asking Questions Requiring Higher Fidelity Integrated Models: IND Example

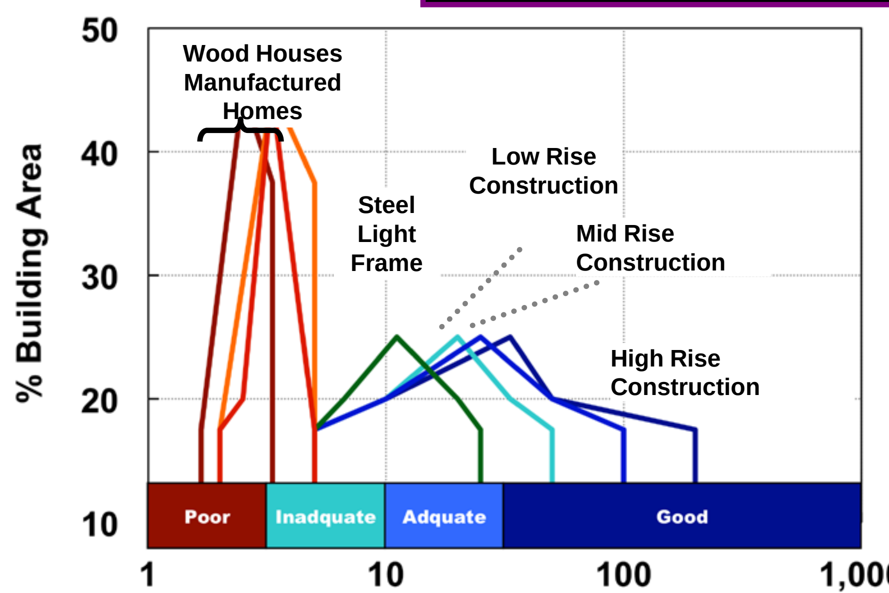
- LLNL/SNL model
  - Fission product inventory (ORNL ORIGEN)
  - Device and surface-dependent neutron-activation products plus ground-shine dose from undisturbed soil activation (LLNL LWAC)
  - Nuclear detonation source description (LLNL KDFOC)
  - Dynamic high-explosive cloud rise model (SNL PUFF)
- Improvised nuclear device (IND)
  - Fractionation
  - Gap: Impact of urban structures on nuclear detonation prompt effects and fallout
  - Gap: Activity size distribution resulting from different environments and emplacement (water, underground)
  - Gap: Validation data



Incorporation of Building Information Improves Estimates of Casualties and Protective Action Guidance for INDs

- Building shadowing calculations of nuclear detonation prompt effects (thermal radiation)
- Building damage by structural type and related injury estimates
- Improved injury estimates from broken glass
- Building protection factors / shielding reduces fallout radiation casualties
- Data gap: Improved database of building structure details and categories building on FEMA HAZUS data





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Health Effect and Detailed Population are Necessary for Realistic Casualty Projections

- CB health effects for civilian and special populations
  - Chemical toxic load models
  - Biological agent data (viability, dose-response, degradation)
  - Official federal Protective Action Guide and Worker Protection Levels for CB exposures
- Improved methods that account for compounding effects of combined injuries
  - INDs: radiation, thermal, blunt trauma, lacerations
- Continued development of higher resolution population data for improved casualty estimation
  - Demographic data
  - Indoor-outdoor fractions
  - Population movement
  - Building category occupancy data for shielding / sheltering effects

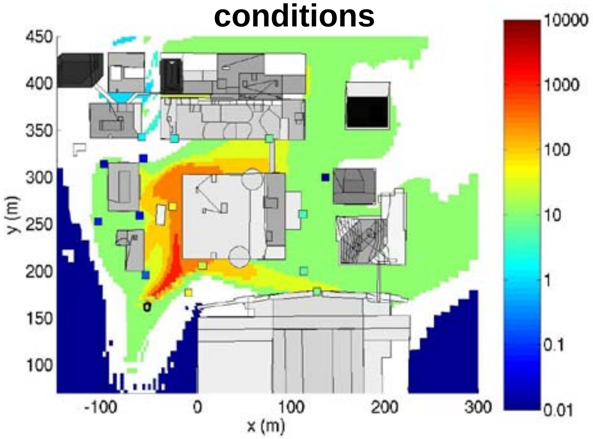
Degradation, Deposition, and Secondary Transport Information are Needed for Response and Recovery

- Chemical reactions and phases changes
  - Atmospheric chemistry
  - Gas-to-particle decay (nuclear power plants and reactors)
- Environmental effects
  - Deposition based on spatially varying land-use properties and building materials
  - Weathering (causes resuspension to decrease with time)
  - Mitigation measures
- Secondary transport (biological agents, radiological materials)
  - Wind-induced resuspension models
    - Time depending models perform better
    - Data sets typically provide long-time averages appropriate for months to years after deposition; wind tunnel show significant early resuspension
  - Mechanical abrasion (vehicle tracking, fomites)

Uncertainty Estimation Relies on a Wide Range of Methods and Sampling and Lacks Operational Robustness

- Meteorological ensembles
- Dispersion "ensembles" (range of key input parameters, Monte Carlo sampling)
- Event reconstruction tools (inversion, adjoints, statistical matching, Bayesian inferencing and stochastic methods) for rigorous treatment of a large number of correlated source and transport variables
- Operational response based on measurement data, expert judgment and statistical tools
- Gaps
  - End-to-end uncertainty estimation from source to effects
  - Data-driven operational approaches for optimizing building-scale models

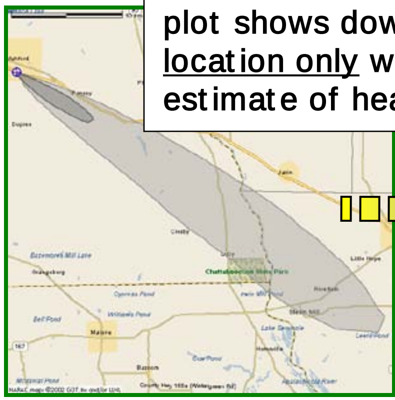
Average fallout dose pattern for a sampling of historical weather conditions



90% confidence plume derived from Bayesian inference and stochastic sampling

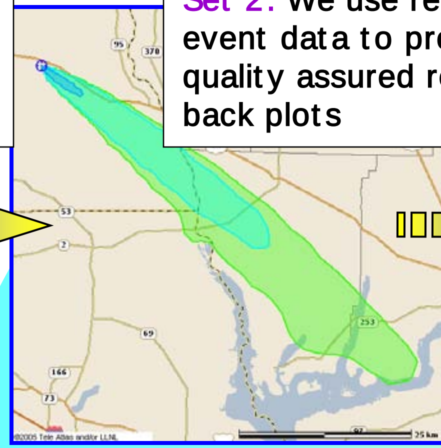
Standard Operational Procedures Couple Modeling and Monitoring in a Cyclical Process to Reduce Uncertainty

Set 1. An initial automated plot shows downwind location only with no estimate of health effects



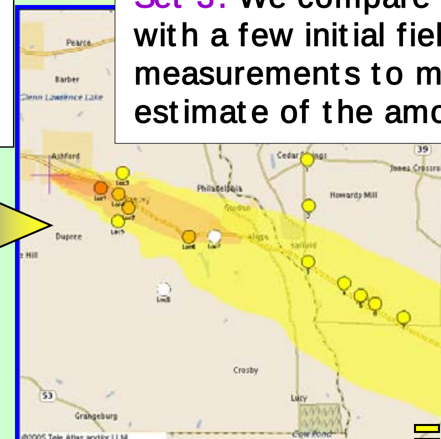
Automated Web-Initiated or via Emergency Call; Only know release time and location

Set 2. We use revised event data to produce quality assured reach-back plots



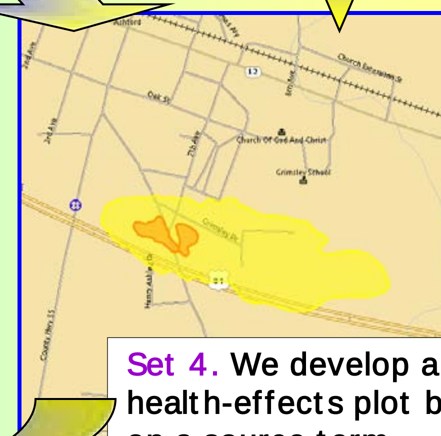
Example revised data: Updated source location, detailed weather

Set 3. We compare the model with a few initial field measurements to make an initial estimate of the amount released



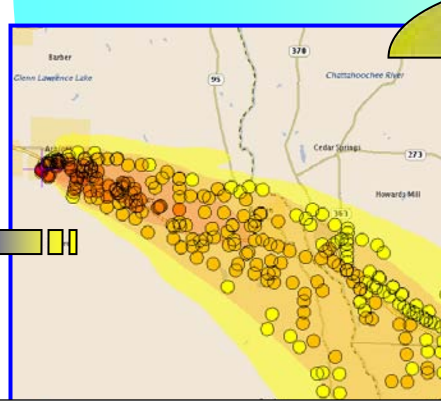
Source scaled to initial set of measurements

Set 4. We develop a health-effects plot based on a source term estimated from field measurements

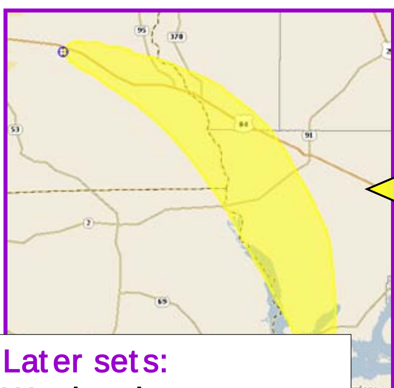


Cycle of new products based on updated sets of measurements

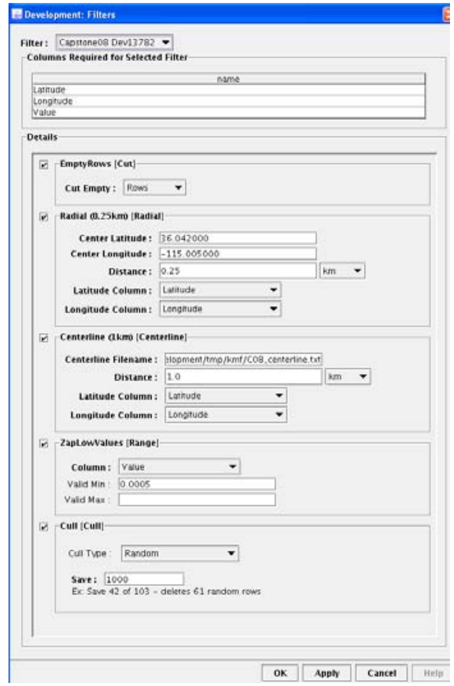
Set 5. We use more extensive sets of field measurements to improve the accuracy of the source term calculation

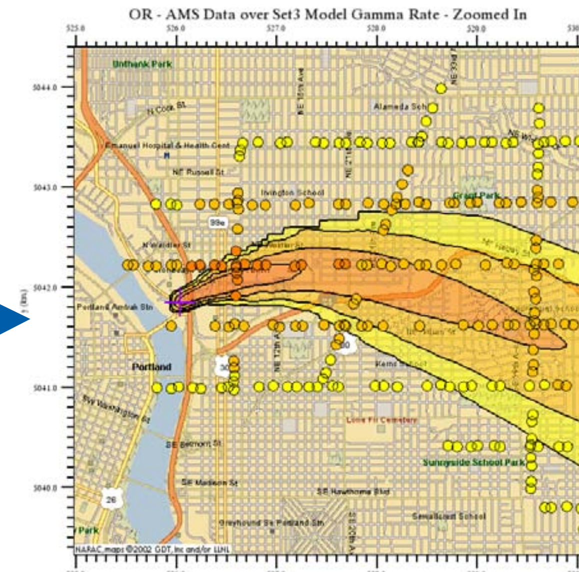


Later sets: We develop Relocation and Food-Ingestion plots



Real-Time Field Data Acquisition and Processing Reduce the Delivery Time for Data-Model Products





Electronic transfer of measurement data

• DOE RAMS, EPA Scribe, CST

• XML, Excel/CSV formats)

Analysis Software

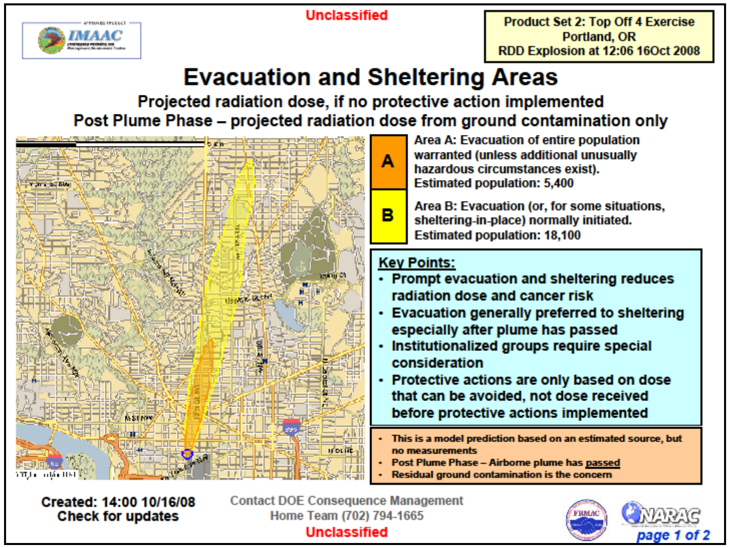
- Data filtering, selection and outlier elimination
- Graphical/statistical analysis of data-model agreement
- Determination of improved model inputs

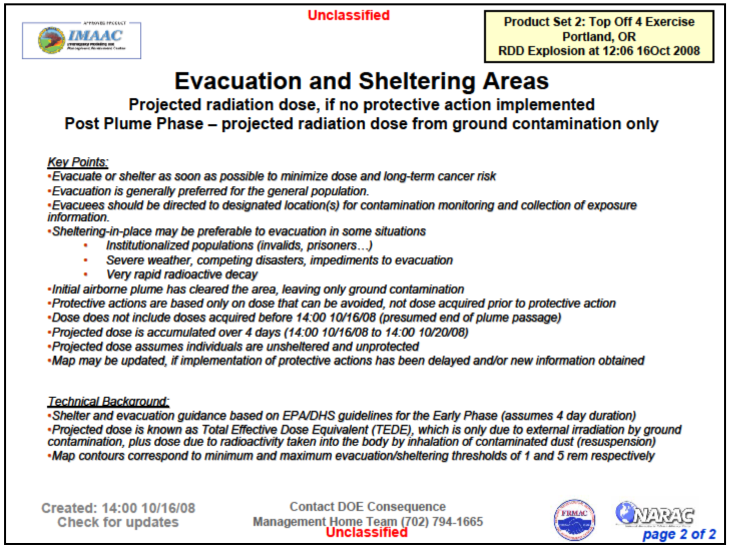
Filtered Data and Refined Model Predictions

Processing time to use large field measurement data sets to update model predictions has been reduced by a factor of ten (from over 1 hour to under 10 minutes)

Interagency Briefing Products Were Tailored to Convey Actionable Information to Decision Makers

- Goal: Develop hazard area graphics and non-technical language to assist SMES in briefing decision makers (Homeland Security Council tasking)
  - Three slide PowerPoint format
  - Focused on possible actions (evacuation/sheltering, relocation, worker protection)
  - Standard plot suites and levels based on interagency collaboration
- Briefing versions of standard IMAAC/NARAC RDD and IND model-data products (DOE)
- Draft chemical/biological briefing product templates proposed under development (DHS S&T)



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