An Operational Perspective on Atmospheric Dispersion Modeling

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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

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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
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

Isosurfaces of 200 mg/m³
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
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.

Example revised data: Updated source location, detailed weather.

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

Source scaled to initial set of measurements.

Cycle of new products based on updated sets of measurements.

Later sets: We develop Relocation and Food-Ingestion plots.

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

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

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