Chemical and Biological Hazard Environmental Prediction

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NAVSEA WARFARE CENTERS DAHLGREN

Description of Effort

- **Improve the state-of-the-art of CB hazard prediction modeling beyond Gaussian puff by:**
  - **Developing a Lagrangian particle transport model for rapid analysis of atmospheric releases [MESO]**
  - **Developing CB libraries to support a computational fluid dynamics based model for high resolution analysis around buildings and ships [CBW-CFX]**
- **Address the physical and CB processes affecting CB agents released**
- **Transition physics into libraries that will be tested in CBW-CFX**
- **Provide MESO and the libraries for transition to the Joint Effects Model (JEM) and the Joint Operation Effects Federation (JOEF)**

Develop hazard prediction models and CB libraries for transition to JEM and JOEF.

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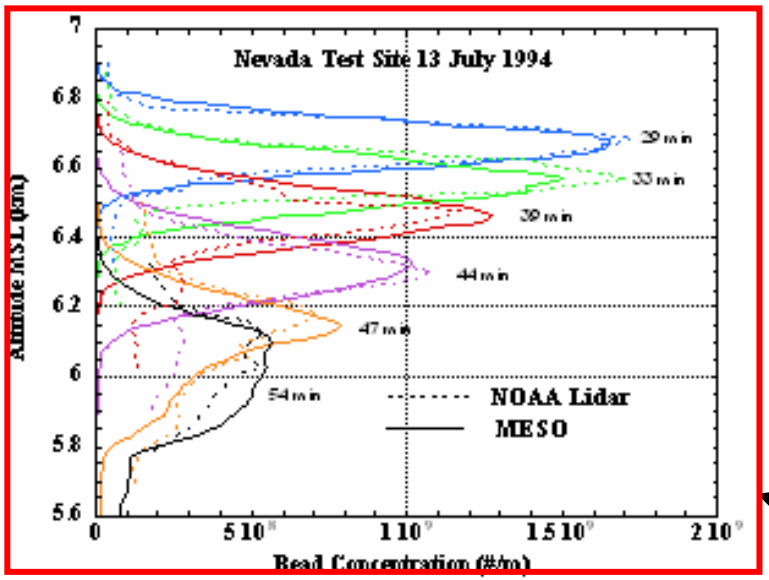
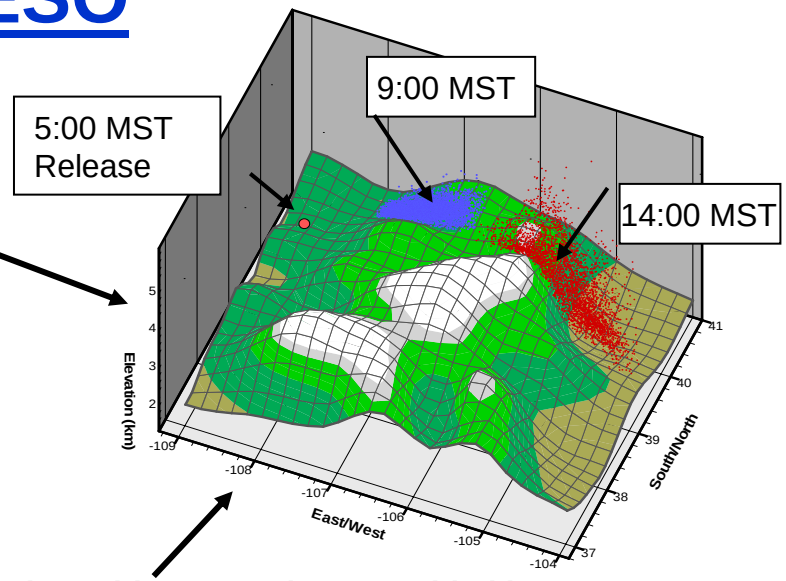
Background – MESO

MESO prediction showing transport of hazard across complex terrain



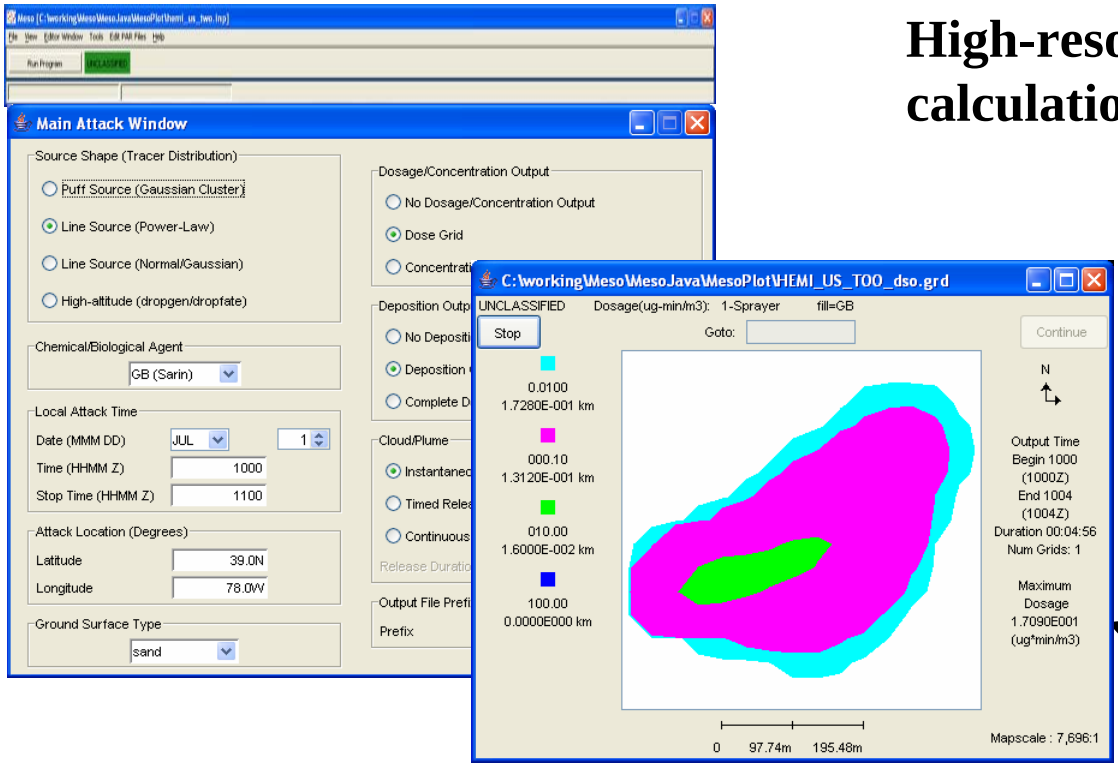


MESO Simulation With Meteorology provided by COAMPS (Coupled Ocean/Atmosphere Mesoscale Prediction System)

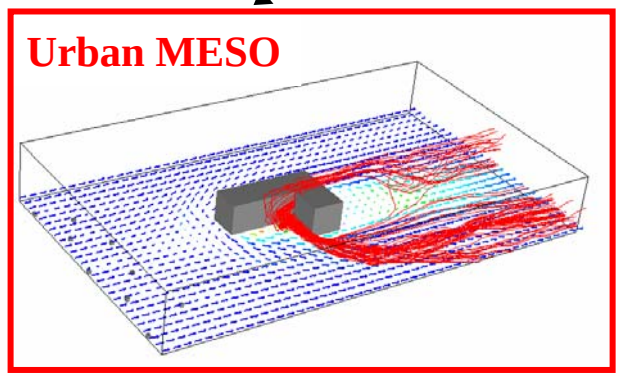
MESO validation using Crystal Mist data shows excellent performance at high elevations (up to 7 km)

MESO incorporates advanced meteorological and agent physics into a Lagrangian particle transport model to provide higher resolution simulations.

Background – MESO (cont.)



High-resolution dispersion calculation around buildings



More user-friendly interface

Past improvements to MESO (ease of use, improved atmospheric and CB physics, run-time enhancements, etc.) have been leveraged toward the urban environment.

MESO: FY05 Objectives

- **Verification**
  - **Complexity Analysis**
  - **Test of MESO GUI Inputs**
  - **Verification of Methodology in Code**
  - **Test of Subroutines**
- **Validation**
  - **Field Trial Comparisons**
- **Documentation**
  - **SDD**
  - **SUM**
  - **V&V Report**

MESO needs V&V and documentation to support transition to JEM.

MESO Verification of Code

- **Verification of Methodology in Code**
  - **Developers verification of code complete**
  - **Work resulted in corrections to: BndryLayerUpdate3D, ClearAirTurb, VertDiffus, and DepositionVelocity**
  - **NSWCDD reviewing and spot-checking equations**
- **Test of Subroutines**
  - **Exercise every function**
  - **Qualitatively check each version**
  - **Test design complete**

The MESO methodology was verified during the SDD development and is being independently checked. Test cases are being designed to exercise every function for initial check of new modifications.

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MESO Validation

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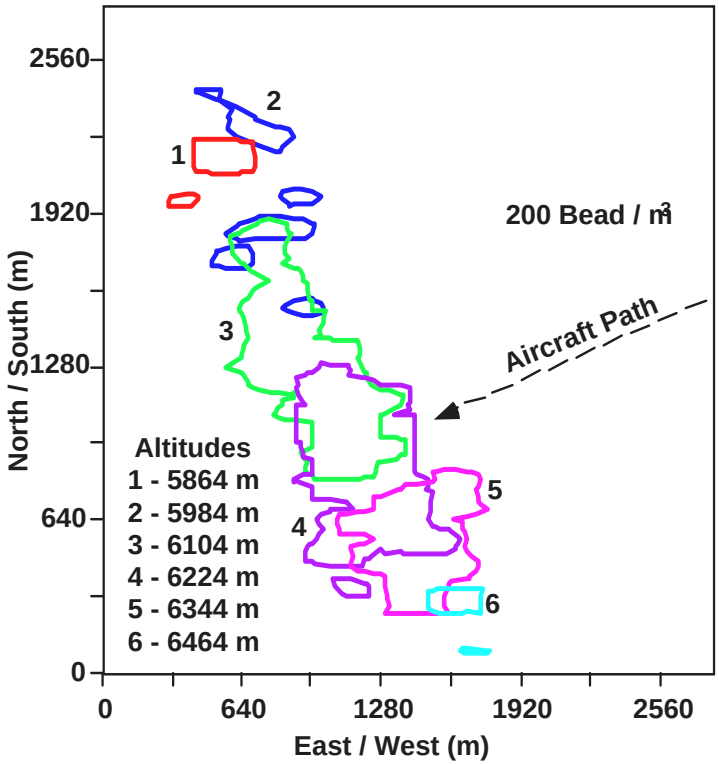
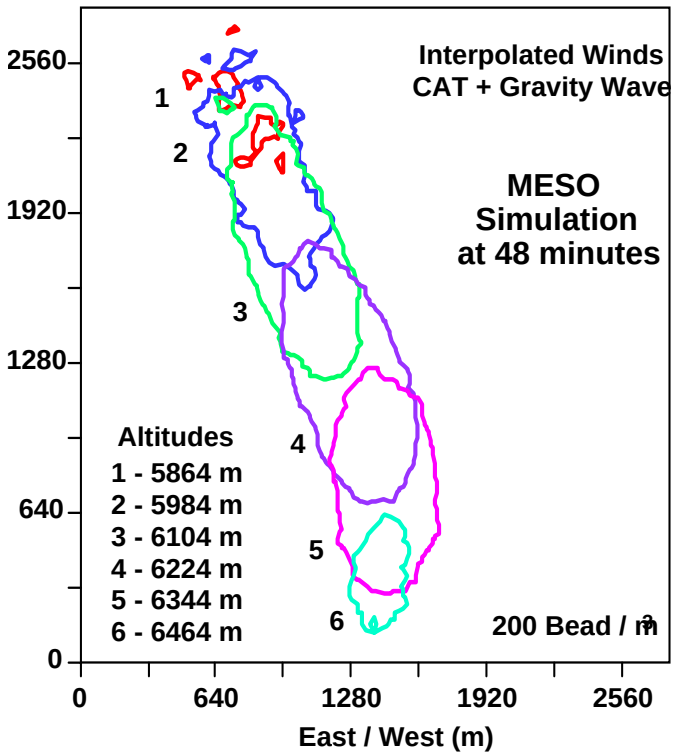


MESO Simulation



A subset of cases run during the VLSTRACK validation is being used to validate MESO in a three-way comparison.

MESO Documentation

- **Software User's Manual**
  - Needs minor updates for new version
  - In review
- **Software Design Description**
  - 900 page document
  - In review
- **Verification and Validation Report**
  - Forward sections complete
  - Field trial sections in progress

The V&V reports are awaiting completion of the V&V tasks.

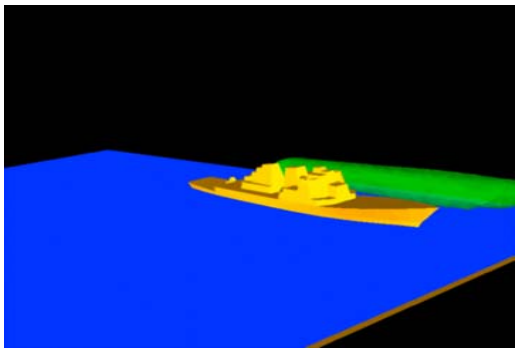
MESO Status

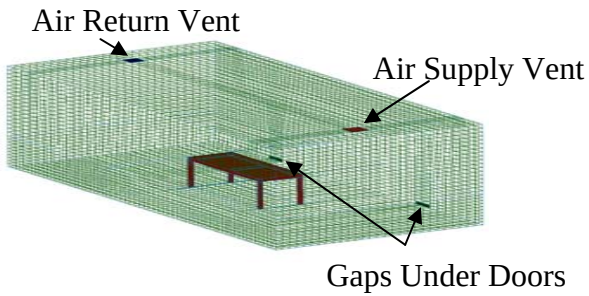
- **Verification**
  - Complexity Analysis — Complete
  - Test of MESO inputs — 90%
  - Verification of Methodology in Code — 85%
  - Test of Subroutines — 90%
- **Validation**
  - Field Trial Comparisons — 70%
- **Documentation**
  - SDD — In review
  - SUM — In review
  - V&V Report — 45%

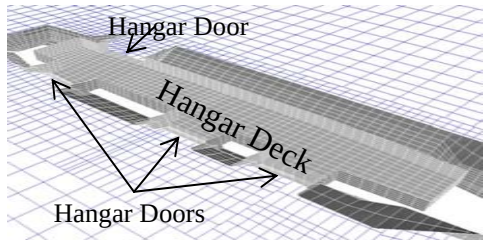
V&V progressing, but at a slower pace than expected.

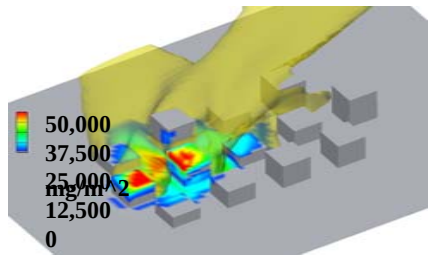
Background - CBW-CFX

- **An integrated system of COTS and Government Computational Fluid Dynamics (CFD) technology for CBW Hazard Prediction**









- **Models transport of vapor and particles entrained in the air flow**
- **Models droplet evaporation, surface deposition, and weathering effects**
- **Implement additional CBW physics via user-defined subroutines**

CBW-CFX provides high-fidelity CFD simulation over and through moving or stationary 3D structures such as ships and buildings.

Work Transition: CBW-CFX/CBWLIB

- **The Past:**
  - **Under CB.55, NSWCDD advanced the fidelity of hazard predictions through the development of CB capabilities within CBW-CFX**

- **Current and Future:**
  - **NSWCDD is now developing these capabilities to be useable as compiled generic library functions**
  - **Updated and extendable library framework**
  - **Easily interfaced and called from any general CFD code**
  - **Modularize legacy code with minimal rewriting**
  - **The libraries will be validated vs. experimental data (incl. field trials)**
  - **Dynamic library approach will enhance transition to JEM through dynamically linked library (.dll) or shared object library (.so)**

CB capabilities developed, tested, and embedded in existing codes are being converted to libraries that will be easier to transition to JEM.

CBWLIB: FY05 Objectives

- **Develop CB-hazard-specific physics models into generic, standalone library functions with clean interfaces for ease of reuse and incorporation into evolving CFD-based transport and dispersion simulation tools**
- **V&V of libraries to ensure proper functionality and accuracy**
- **Document libraries and their functions to ensure ease of use and integration with candidate simulation codes**
- **Execute configuration management practices to ensure reliability**

FY05 shifts toward library development to provide better mechanism for transition.

CBWLIB: Achievements

- Developed a systematic approach to library development
- Implemented a robust configuration management process
  - Stress tested with 5 developers simultaneously working on the same 1500 line module
- Systematic peer review of legacy source code
- Created documentation standard and documented the existing CBW-CFX code
- Ported legacy capabilities into CBWLIB

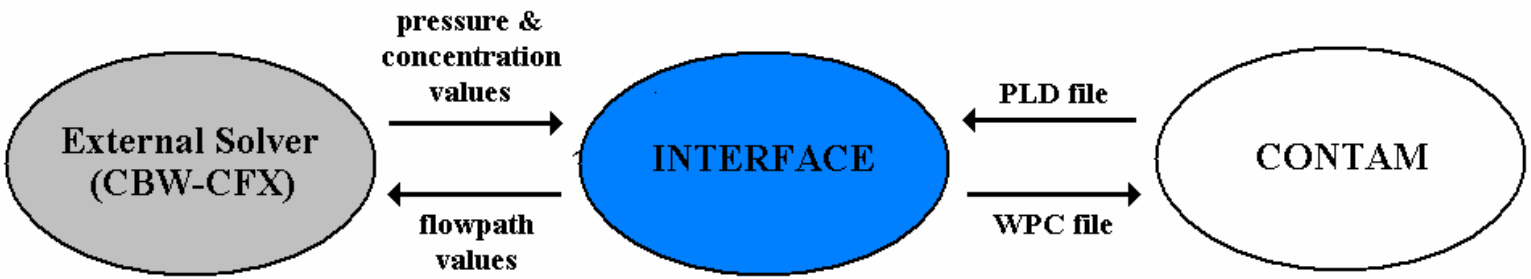
A systematic approach is being used to port legacy capabilities into CBWLIB.

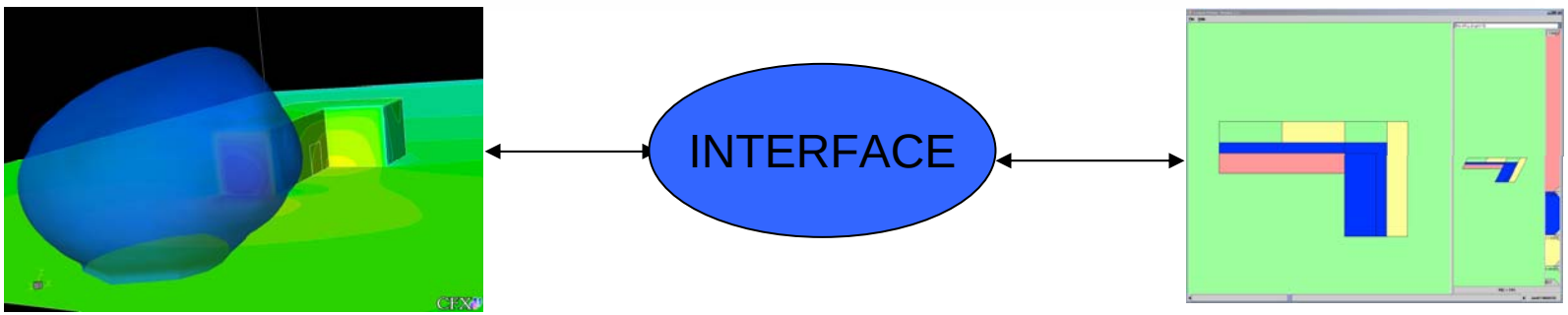
CBWLIB: Contributors

- Leverages multiple projects
  - DARPA Immune Building
  - JEM
  - Agent Fate
  - MESO
- International collaboration
  - Missile Intercept (NL)
  - Explicit Uncertainty (UK)

CBWLIB has contributors and users among many DoD projects and the CB community.

CONTAM Interface





A new technology developed within the CBWLIB framework and utilized by several outside projects.

FY06 Objectives

- **MESO Model Standardization Effort (atmospheric and urban versions)**
  - MESO Atmospheric and Urban Model Integration
  - MESO GUI and document standardization
- **CFD Library Development Effort**
  - CBWLIB Development
    - Continue CBW-CFX Methods Integration
    - Integrate JEM High Altitude Intercept Library
    - Integrate Relevant ADVEDS Modules
    - Integrate Surface Evaporation Functionality
  - CFD Model Comparison
  - Module Validation vs. Legacy Benchmark
    - CBW-CFX vs. CFX (with library) Verification
    - Sample FLUENT (with library) Runs vs. Benchmark
  - Library Documentation

FY06 plans are to merge and standardize the two MESO models and complete CFD Library development for transition to JEM.

Currently Two Slightly Different MESO Models

- **Atmospheric MESO - NSWCDD has been developing the MESO Lagrangian model for atmospheric releases**
- **Urban MESO - Urban capabilities were added to NSWCDD developed model through leveraging by other DoD organization**
- **FY06 will standardize the models**
  - **Common call**
  - **Code reuse**
  - **Documentation**
  - **GUI**

Work under CB55 was leveraged and configuration management is necessary to control the final product.

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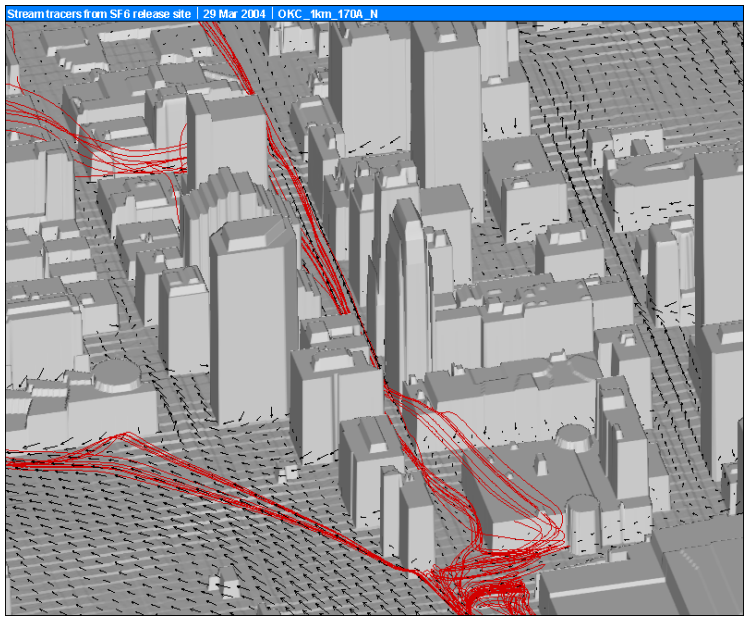
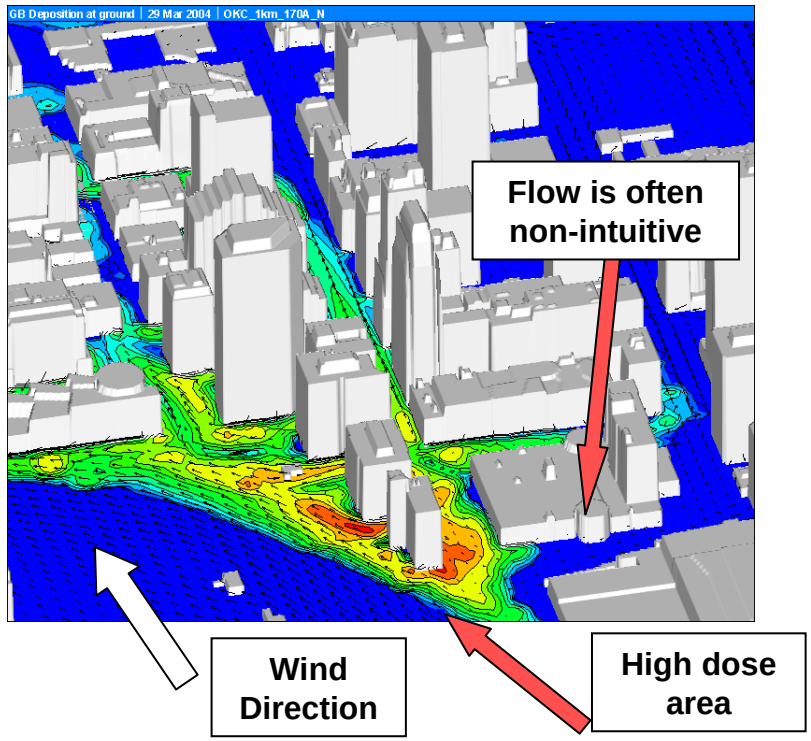
MESO/RUSTIC is a New Generation Model That Provides Accurate 3D Urban Hazard Definitions

Two Steps for Urban CBR Hazard Definition with MESO/RUSTIC

1. **Compute turbulent "wind flow" with RUSTIC for urban scenarios.**
2. **Use MESO to compute contaminant dispersion with flow and turbulence predicted by RUSTIC.**



Downtown Oklahoma City July 2003



Approved for Public Release, Distribution Unlimited, DARPA (MESO/RUSTIC Case 2585)

Results from the leveraged MESO effort in an urban environment.

Questions?

Summary

The models being developed address a variety of challenges:

- **Wide range of scales (meters to many kilometers)**
  - **MESO developed for large open areas and CFD codes for urban and ships**
- **Wide variety of interacting processes involved and variety of operational environments that must be addressed**
  - **Models that include full CB physics**
- **Interaction between models for various purposes, domains**
  - **Libraries that help interface VLSTRACK to CBW-CFX and CBW-CFX to CONTAM**
- **Supporting databases (e.g., buildings) and enabling technologies (e.g., weather)**
  - **urban-MESO grid generator; MESO interface to COAMPS meteorological data**
- **Computation time vs. resolution**
  - **Speed enhancements to MESO; use of CFD codes for sensor placement, studies, or validation of other models**
- **V&V - verification reviews, data collection, validation studies**
  - **V&V of MESO and CBWLIB**

The model development addresses many challenges while advancing the state-of-the-art.