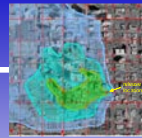
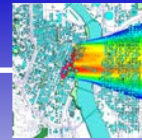
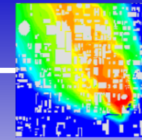
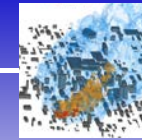





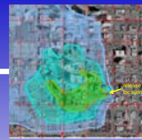
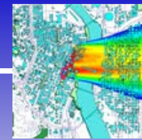
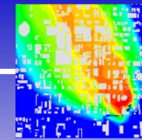
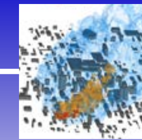
Tracking and Predicting the Atmospheric Dispersion of Hazardous Material Releases: Implications for Homeland Security

A report produced by the National Academies'
Board on Atmospheric Sciences and Climate

Briefing by
Dr. John Wyngaard, Pennsylvania State University
General William Odom, (Ret.), Hudson Institute

THE NATIONAL ACADEMIES
Advisers to the Nation on Science, Engineering, and Medicine

June 19, 2003

Committee Members

Robert Serafin (Chair), National Center for Atmospheric Research

Eric Barron, Pennsylvania State University, College of Earth and Mineral Sciences

Howard Bluestein, University of Oklahoma, Department of Meteorology

Steve Clifford, University of Colorado–CIRES

Lewis Duncan, Dartmouth College, School of Engineering

Margaret LeMone, National Center for Atmospheric Research, Mesoscale and Microscale Meteorology Division

David Neff, Colorado State University, Department of Civil Engineering

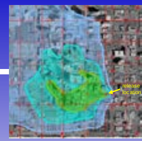
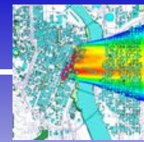
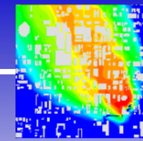
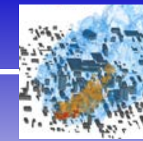
William Odom, Hudson Institute, National Security Studies and Yale University

Gene Pfeffer, Orbital Sciences Corporation

Karl Turekian, Yale University, Department of Geophysics

Tom Warner, University of Colorado, Program in Atmospheric and Oceanic Sciences

John Wyngaard, Pennsylvania State University, Department of Meteorology

Study Overview

Study Task

The National Academies' Board on Atmospheric Sciences and Climate will organize a workshop to:

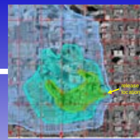
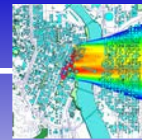
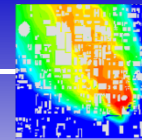
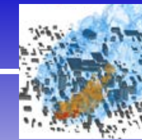
- Review the current suite of models used in characterizing atmospheric dispersion, and examine how they are applied operationally for emergency response efforts;
- Examine the observational data needed to initialize, test, and use these models effectively; and
- Assess research and development needed to enhance models' effectiveness and operational use.

Study Origin

Initiated internally by the National Academies' Board on Atmospheric Sciences and Climate. Supported by BASC core funds and National Academies' endowment funds.

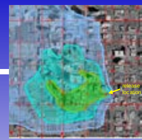
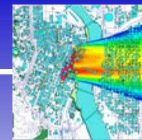
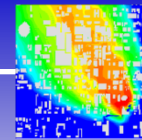
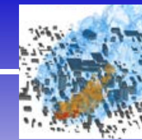
Timeline

Planning meeting: May, 2002; Washington, DC
Workshop: July, 2002; Woods Hole, MA
Report released: June 2003

Workshop and Meeting Participants

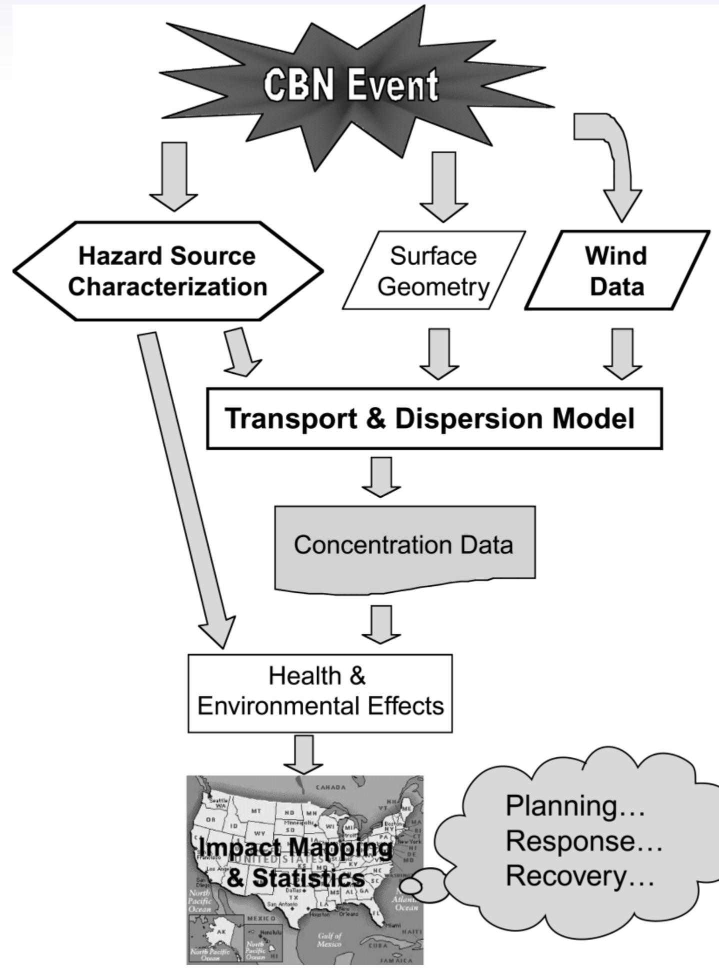
David Bacon, SAIC
Martin Bagley, DTRA
Brian Beitler, DTRA
Warren Bowen, TSWG
Yu-Han Chen, MIT
Walter Dabberdt, Vaisala Inc.
Paula Davidson, NOAA/NWS
Frances Edwards-Winslow, San Jose Emergency Preparedness Office
James Ellis, LLNL–NARAC
Steve Hanna, GMU
Michael Hardesty, NOAA/ETL
Charles Hess, FEMA
Paul Hirschberg, NOAA/NWS
Kathy Houshmand, DOD
Alan Huber, EPA / NOAA
Vladimir Kogan, Battelle (DOD)
Michael Lowder, FEMA
Donald Lucas, MIT
Bob Lyons, U.S. Army Soldier and Biological Chemical Command
Steve McGrail, Massachusetts Emergency Management Agency
Duncan McGill, DTRA
Mark Miller, NOAA
Debbie Payton, NOAA
Lew Podolske, White House OHS
Jennifer Reichert, DOE
David Roberts, Mitretek
David Rogers, NOAA/OAR
Jack Settelmaier, NOAA/NWS
John Sorensen, ORNL
Gerald Streit, LANL
Gayle Sugiyama, LLNL –NARAC
Don Wernly, NOAA/NWS
Sam Williamson, OFCM

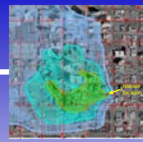
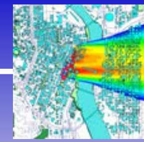
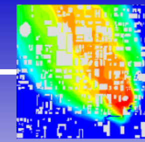
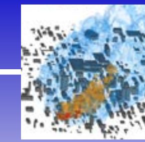
   

Dispersion Modeling Overview

Meeting the challenge of tracking and predicting the dispersion of hazardous (chemical/biological/ nuclear) agents requires three interconnected elements:

- Atmospheric dispersion models that predict the path and spread of hazardous agents
- Observations of the plume and local topography and meteorology
- Effective communication and coordination among the relevant atmospheric science and emergency response communities



Using Dispersion Modeling in 3 Phases

Preparedness

- intelligence and threat assessment; training and planning; prevention and protection

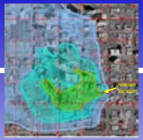
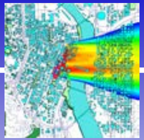
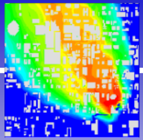
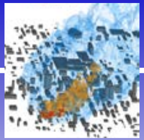
Response

- immediate first response (0-2 hours)
- early response (generally 2-12 hours)
- sustained response support (generally greater than 12 hours)

Recovery and Analysis

- monitoring environmental contamination; restoration and decontamination; reconstruction of exposure patterns

Different observational/modeling capabilities are required for each of these phases.

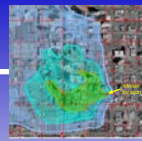
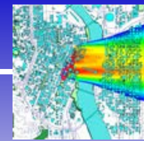
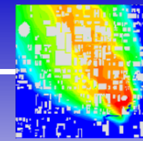
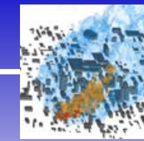
   

Meeting User Needs

Emergency responders face a confusing array of seemingly competitive models, and often do not have a clear understanding of where to turn for immediate assistance. → *Recommendation:* Establish a single federal point of contact to connect emergency responders to dispersion modeling centers for immediate assistance nationwide

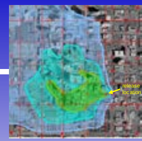
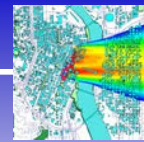
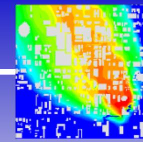
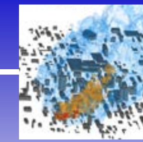
Emergency responders need to better understand strengths and weaknesses of dispersion modeling tools. Atmospheric scientists need to better understand how dispersion forecasts are used in emergency response. → *Recommendation:* Regularly conduct tabletop event simulation exercises with emergency responders and atmospheric modelers & observers

Emergency managers need a realistic understanding of the uncertainties in a dispersion model prediction → *Recommendation:* Models should quantify both the average downwind concentration and expected event-to-event variability for a given release

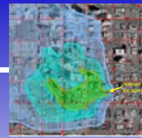
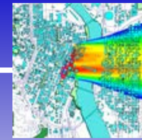
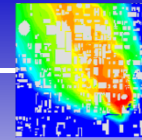
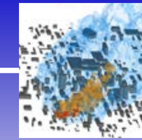
Observations: Needs and Capabilities

- Plume location and composition
  - direct observations, C/B/N sensors, symptom identification
- Local wind fields
  - multi-use observational networks (including Doppler radars)
  - 900 MHz BL radar wind profilers (augmented with sodars or RASS)
  - optical crosswind sensors and webcams (for winds in urban canyons)
  - mobile sensors (scanning lidars or radars, UAV platforms)
- Depth and intensity of turbulent layers (especially their diurnal variations)
  - radar wind profilers, RASS, lidar
- Potential areas of agent degradation and deposition
  - cloudiness, precipitation, humidity fields

Observations: Recommendations

1. Conduct **comprehensive survey** of capabilities and limitations of existing **observational networks.**
2. Explore **supplementing Doppler radar network** with sub-networks of short-range, short-wavelength radars
   - to estimate BL winds, monitor precipitation, track plumes.
3. Integrate **wind and temperature profilers** into fixed-observational networks.
4. Continue developing airborne and surface **mobile observational platforms**
   - to characterize wind, temp., and turbulence in areas where fixed platforms cannot be deployed easily, and
   - to ensure rapid deployment for timely use.

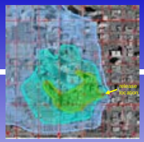
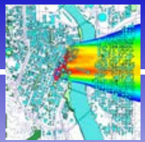
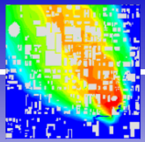
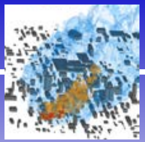
   

Observations: Recommendations (cont.)

5. Characterize **local wind flow** patterns (over full diurnal cycle) in selected areas,
    - to help optimize design of observational system and educate local forecasters.
6. Conduct **field programs** to test and improve dispersion and mesoscale models,
    - capitalizing on related field studies in wx forecasting, BL turbulence, etc.

To help justify and assuage costs:

- **prioritize** by identifying areas of greatest need
- utilize instrumentation for **other purposes**, such as air pollution, agriculture, severe-storm forecasting, etc.

Categories of Dispersion Models

Coordinate system

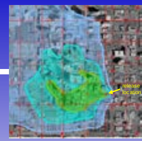
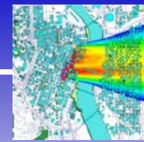
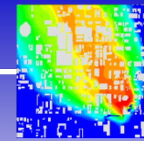
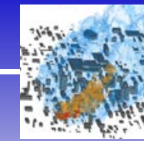
- Eulerian or Lagrangian

Wind field

- Single mean wind vector at one height
- Time-varying winds measured at several points in the domain
- 3-dimensional grid of winds calculated by a meteorological model

Type of Averaging

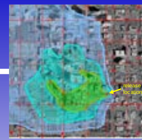
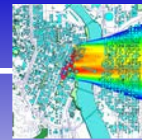
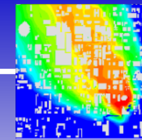
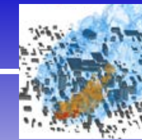
- Ensemble: model predicts the average of many episodes (realizations)
- Spatial: model predicts a coarse-grained version of one realization, highlighting turbulent character of solution fields

Modeling Systems Discussed in the Report

(This is NOT a comprehensive list or an endorsement of the 'best' systems)

Sponsoring Org.	Model Acronyms
DTRA/DOD	HPAC/SCIPUFF
LLNL/DOE	NARAC/ADAPT-LODI NARAC/FEM3MP
LANL/DOE	QWIC HIGRAD
NOAA/EPA	CAMEO/ALOHA
EPA	CALPUFF Fluent
SAIC	OMEGA
UK DSTL	UDM

Modeling to Assist Emergency Response

Preparedness phase

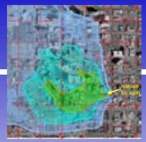
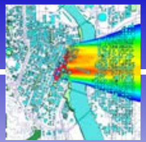
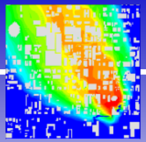
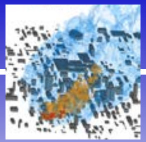
- Site-specific meteorological data coupled with probability-based dispersion model predictions and/or wind-tunnel simulations
- Site-specific 3D databases of urban buildings and topography

Response phase

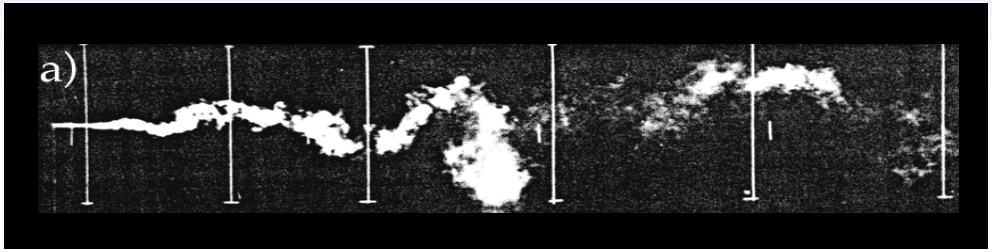
- Rapidly assimilate local wind and contaminant data, then initialize source characteristics
- Short-execution-time dispersion models are essential!

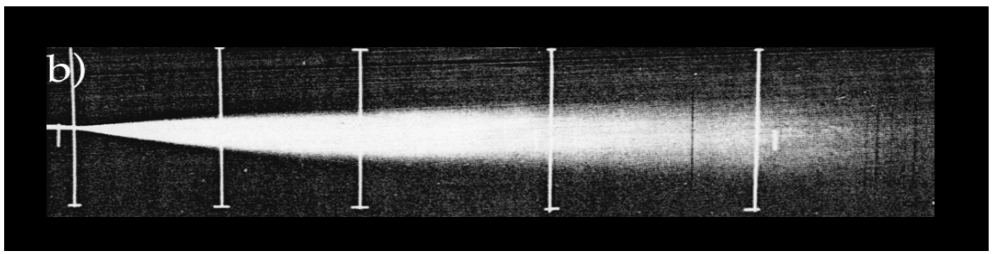
Recovery and Analysis

- Slower models that incorporate all available data to reconstruct plume's space/time distribution

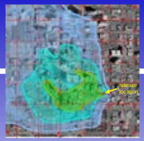
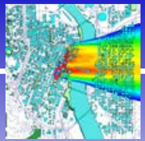
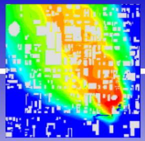
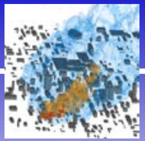





Model Output

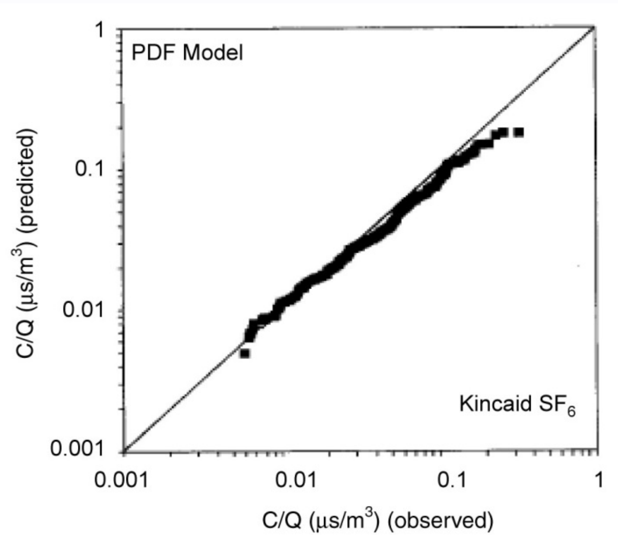


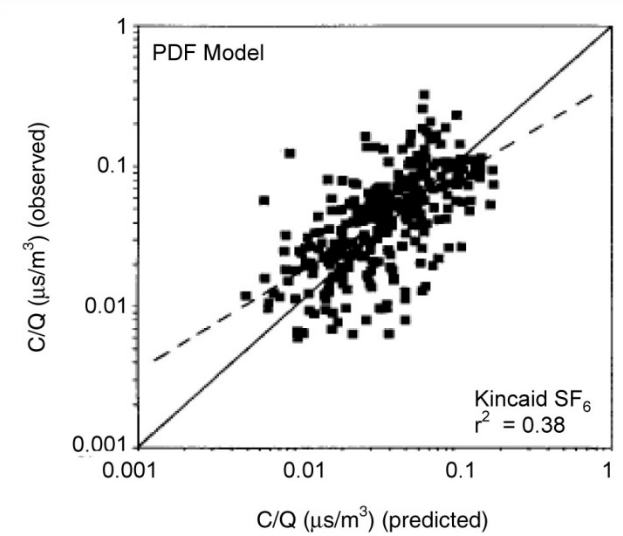


- Neither an individual realization nor an ensemble average is sufficient for assessing dispersion. Predictions of both the ensemble average and the realization-to-realization variability are needed.
- Ideally, a dispersion model would provide a 3-D contour map of the hazard zone and estimate the concentration (or dosage) PDF throughout the plume's domain.

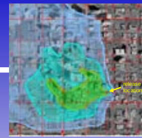
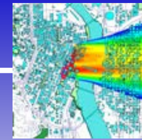
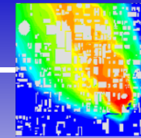
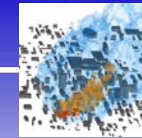
Model Evaluation





Unpaired (quantile-quantile) comparisons of observations vs. predictions can be misleading.

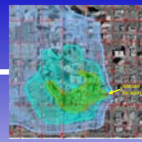
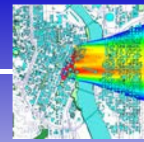
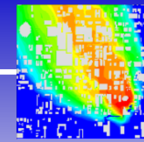
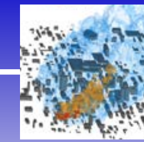
Observations that are paired in space and time give a more realistic picture of a model's performance.

Models: Recommendations

A carefully crafted management strategy, with a strong center of coordination and clear lines of responsibility, is essential to ensure further progress. A **nationally coordinated effort** is needed to support and evaluate current models, and oversee future R&D, with focus on:

1. exploring **new modeling constructs** for operational, urban use (e.g., short execution time, adaptive grids);
2. developing **ensemble dispersion forecasts** on the urban scale **that quantify confidence levels;**
3. **assimilating meteorological and C/B/N sensor data** into models;
4. **conducting urban-field programs and wind-tunnel simulations** to test, evaluate, and improve models (proper experimental design is essential);

Models: Recommendations (cont.)

5. researching effects of **urban surfaces** on **urban meteorology**;
6. building/maintaining 3D databases of **urban building and topography;**
7. establishing an operational dispersion tracking and forecasting system in a large urban area (preferably in various types of urban areas), as a test bed for understanding capabilities and limitations.

This coordinated effort should make use of the considerable expertise that resides in universities, NWS forecast offices, the private sector, and federal agencies.