CDC's New Preparedness Modeling Initiative: Beyond (and Before) Crisis Response

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on Humanitarian Logistics

Overview of Presentation

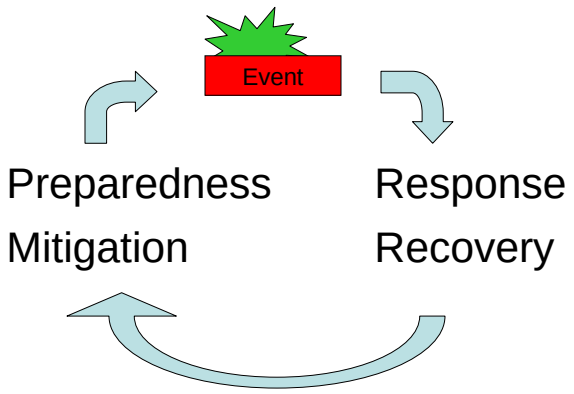
CDC Preparedness Modeling Initiative

- Background: What we mean by Preparedness Modeling?
- Spectrum of Preparedness Modeling
- Preparedness Modeling at CDC Today
- Building *Capability*
  - CDC Preparedness Modeling Unit
  - External modeling network
  - Scientific community and development

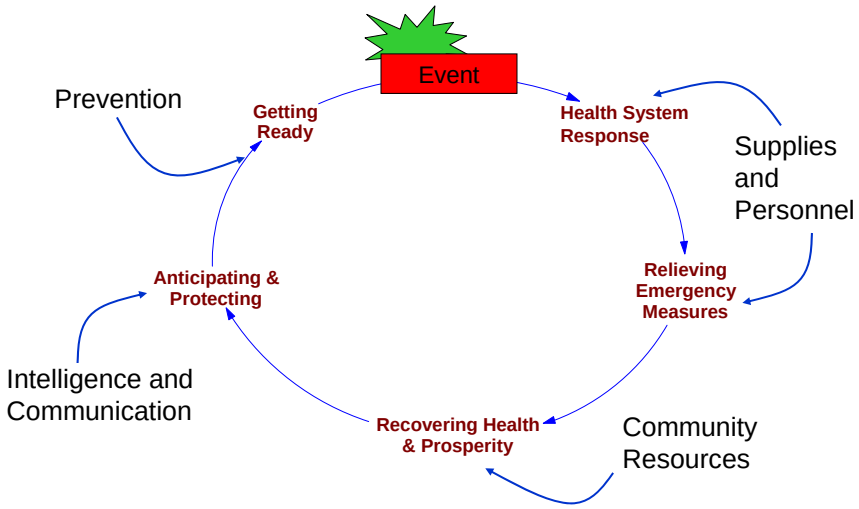
Modeling lessons I have learned…

- Every decision is based on a model
- Not every model is based on a decision
- Experts often think that modelers want to “take away” their ability to make decisions
- The process of modeling can help clarify, unify, and energize or…alienate users
- Goal: Represent what is going on in the “expert’s” head in order to…
  - Analyze
  - Optimize
  - Teach
  - Train

Classic Disaster Response Cycle



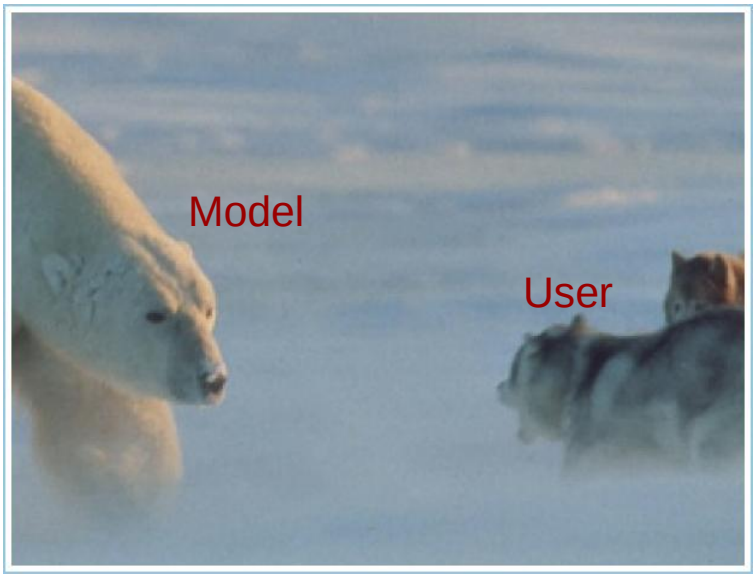
Broader View of Preparedness



Why Model Anything?

- A simplified or abstracted representation of the "real world" in order to:
  1. Characterize dynamically complex systems
  2. Quantify the impact of specific events or processes, and
  3. Anticipate likely outcomes of alternative policies
- Mathematical and simulation modeling has become a central element of planning in many arenas (logistics (obviously!), human resources, supply chain management), but…
- Not (as yet) in most of public health…

Can we break the paradigm…



Don't Just Change This…

1. Outreach to End-Users

The first step in model development does not involve a computer…

2. Collaborative Problem Definition

What do we need to know?

What do we need to report?

What can be modeled?

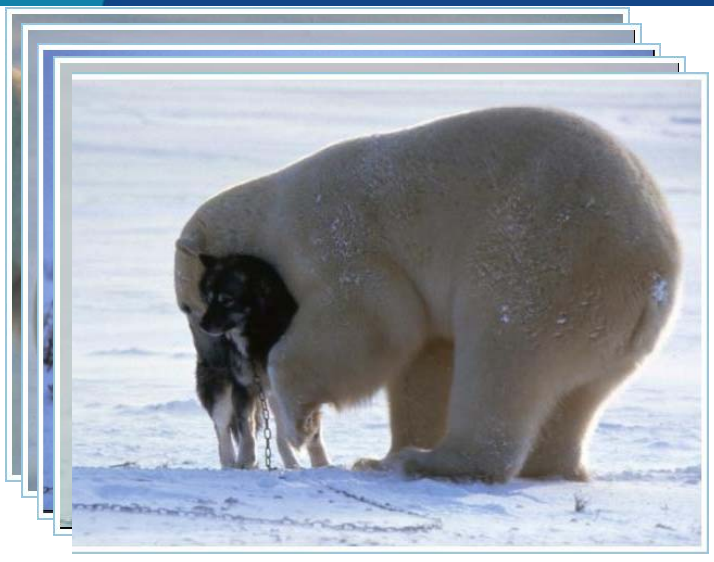
3. Appropriate Modeling Methods

Level of detail?

Speed?

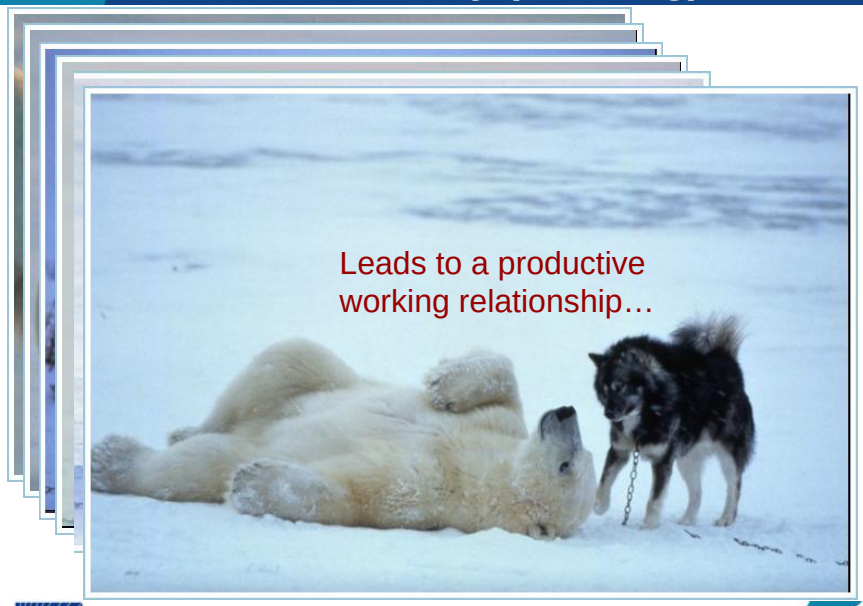
Interactive?

4. Feedback and Model Improvement



Self-Explanatory

5. Sustainability (Funding)



Modeling lets us…

- Gain insight into mechanisms influencing health, link individual scale 'clinical' knowledge with population-scale patterns.
- Focus thinking: model formulation forces clear statement of assumptions, hypotheses.
- Derive new insights and hypotheses from mathematical analysis or simulations.
- Establish relative importance of different processes and parameters, to focus research or management efforts.
- Explore policy options in systematic, quantitative manner

Note the absence of predicting future trends.

→ Accurate quantitative predictions are difficult and rare:

"Wall Street indices predicted nine out of the last five recessions!"

- Paul Samuelson, Nobel Laureate in Economics, 1966.

Managing Over-expectations…

- **Alan/Cleese:** …here's Jackie to tell you all how to rid the world of all known diseases.
- **Jackie/Idle:** Hello, Alan.
- **Alan:** Hello, Jackie.
- **Jackie:** Well, first of all become a doctor and discover a marvellous cure for something, and then, when the medical profession really starts to take notice of you, you can jolly well tell them what to do and make sure they get everything right so there'll never be any diseases ever again.
- **Alan**: Thanks, Jackie. Great idea.

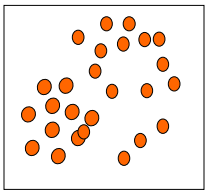
-- Monty Python's F.C., Episode 28

Variety of Modeling Approaches

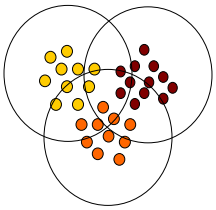
- Mathematical/compartmental models
  - Analytic (formula-based) representation of the world
    - Epidemiological models
    - Hospital models (tremendous data needs)
- State transition models
  - Non-analytic ("do-loop") representations of time-dependent events
    - Pre-hospital disease interventions
    -
- Discrete event simulation
  - Complex, time-dependent activities +/- emergent phenomena
    - Mass prophylaxis
    - Trauma response
- Linear and integer programming
  - Operations research: finding optimal solutions to complex problems
    - Patient allocation and ambulance routing after mass casualty events

Complex Modeling and Modeling Complexities

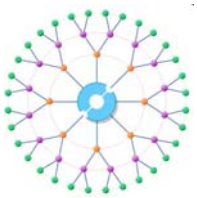
Homogeneous mixing



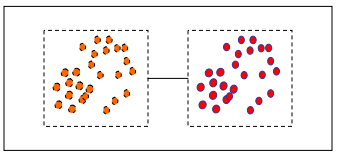
Age/social structure



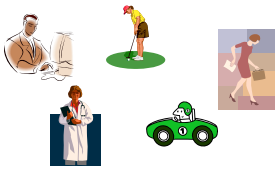
Network structure



Patch structure



Individual-based model



Making the Right Assumptions

Simplicity/Transparency vs. Complexity/Realism

- Structural decisions
  - Homogeneous vs heterogeneous population
  - Random mixing vs hierarchical associations
- Computational approach
  - Deterministic vs stochastic
  - Discrete vs continuous time

Possible Scope of Preparedness Modeling

Relevant Knowledge Domains	Selected Examples
Earth & Atmospheric Sciences	• **Hurricane path prediction**
Ecosystem Ecology	• **Vector biology**
Disease Dynamics	• **Drug resistance** • **Vaccine effectiveness**
Industrial Hygiene/Exposure Assessment	• **Chemical or radionuclide exposures**
Demography	• **Disparities in vulnerability** • **Emergency health services demand**
Social & Behavioral Sciences	• **Social communication response in a crisis** • **Support for long-term prevention policies**
Operations Research/Logistics	• **Stockpile distribution , supply chain mgmt.** • **Hospital surge capacity**
Many more…	• **Population movement** •**Transportation**

Why Model Crises?

- Low probability/high impact events lead to anecdotal lessons that may not be optimal policy solutions across the range of possible scenarios
- Explore "what if?" interventions in high-risk locales with minimal disruption of daily operations
  - Mass casualty events in crowded urban locales
  - Hospital emergency departments
- Low cost vs. live exercises
- Explore value of information
  - Absolute—"Do I need to know this?"
  - Marginal—"How much of this information do I need?"

State of the Science: Disaster Response Modeling 2008

Medline Search
2725 Citations

Supplemental Searches
(Manual searches of bibliographies, INFORMS Database, Experts' libraries, Google Scholar) 207 Citations

Title/Abstract Reviews
2932 Citations

Potentially Relevant Models
567 Citations

Excluded 447 Citations (Not a model, not a disaster, or not a health sector response)

Full Text Review
120 Citations

Models Included
68 Citations Describing 56 Models
Representing a variety of types of disasters, response decisions, model methodology, model quality, and reporting quality

Source: Brandeau M, McCoy J, Hupert N, Holty J-E, Bravata D. "Recommendations for Modeling Disaster Responses in Public Health and Medicine: A Literature Review and Position Paper of The Society for Medical Decision Making." Under public review by the Society

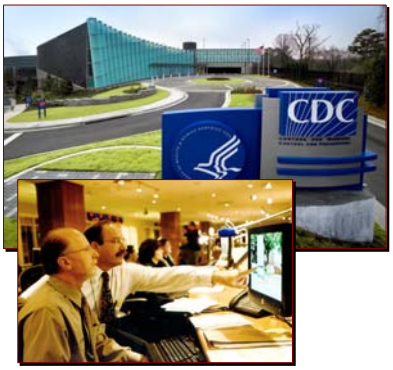
CDC Preparedness Modeling Initiative

Niche for CDC's Contributions

- Many Federal (and some state) agencies have a relatively long history of quantitative modeling for preparedness
- Within DHHS, several significant efforts are under way
  - ASPR/BARDA
  - NIH – MIDAS Network
  - AHRQ – Surge capacity in hospitals and healthcare systems
- Any CDC initiative in this area will acknowledge, respect, and build upon existing work

CDC Preparedness Modeling Initiative

CDC's Unique Attributes



- Potential to provide national focal point for medical/public health subject matter expertise in preparedness modeling
- Emphasis on combining science with practice
- Major responsibilities for responding to health emergencies, with related opportunities to enhance performance and fulfill stakeholder expectations
- A track record in creating and managing large-scale scientific and policy collaborations

Seminars and Workshops

- June 19, 2007 – "Introduction & Demonstration of the Tri-Lab Critical Infrastructure Protection Decision Support System", Dennis Powell, Gary Hirsch, Rene LeClaire, Michael Samsa, Sharon Deland, Matthew Berry, Jeanne Fair, Sandia, Los Alamos, and Argonne National Labs
- August 30, 2007 – "Heterogeneous Mixing in Epidemic Models", Fred Brauer, University of British Columbia
- August 30, 2007 – "Representing the Public Health Perspective in Interactive Simulations of Infectious Diseases", Matthew Samore, University of Utah
- October 2, 2007 - "Mass Casualty Trauma Modeling", Nathaniel Hupert, Weill Cornell Medical College
- March 6, 2008 - "Software and Tips to Consider When You Design Your Mass Influenza Vaccination Clinic", Michael Washington, Navy Medicine Support Command

Seminars and Workshops

- September 15, 2008 - "Developing a Modular Web-Based Preparedness Modeling Tool for Heat Waves", Patrick Phelan, Arizona State University
- October 23, 2008, “Modeling the evolutionary implications of influenza medication strategies,” Zhilan Feng, Purdue University
- Workshop "Modeling for Pandemic Influenza: Hospital and Community Preparedness for Pregnant Women and Infants" in partnership with programs in CDC's NCCDPHP and NCBDDD and several Atlanta hospitals (2007).
- Workshop "Modeling the Impact of Policy Options During Public Health Crises" in partnership with the Center for Discrete Mathematics and Theoretical Computer Science at Rutgers University (2008)

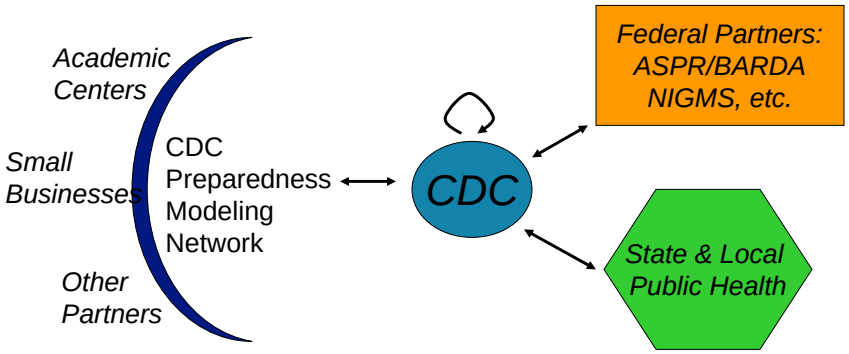
Projects – FY 2008

FY 08

- Adapting an SEIR model to evaluate interventions against a pandemic influenza outbreak in the US using ARENA (Bill Thompson, NCIRD)
- Estimation of economic capacity of large-scale vaccination clinics using Ex-Ante cost function (Mark Messonnier, NCIRD)
- Identifying geographical areas with high risk of refusing interventions for infectious agent related public health emergencies (Stacey Martin, NCIRD)
- Modeling to project city-specific health impacts of increases in the frequency, intensity, and length of heat waves (George Luber, NCEH)
- Predicting occurrence of plague epizootics and understanding how Y. pestis is transmitted during plague epizootics (Rebecca Eisen, NCZVED)
- The risk of yellow fever introduction into Puerto Rico (Michael Johansson, NCZVED and Nina Marano, NCPDCID)

CDC Preparedness Modeling Unit

Vision of Preparedness Modeling Network

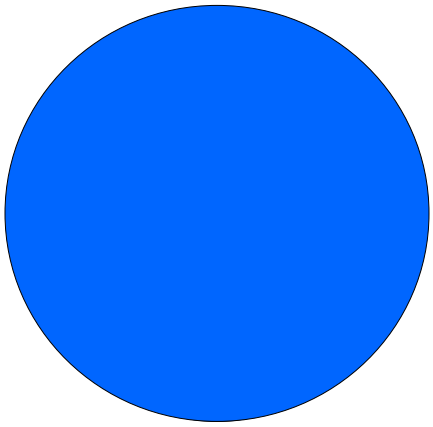


Challenges for Preparedness Modeling

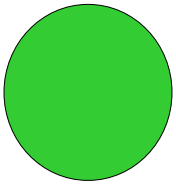
Workforce Development

- Training opportunities
  - Fellowship opportunities
  - Inter/Externships
- Curricular innovations
  - Schools of Public Health (e.g., PERRCs)
  - Engineering/Computer Science
- Professional development
- Who should funds this? CDC/NIH/NSF/DHS/…

Public Health Modeling Today



Modeling/Informatics for Industrial + Financial Organizations



Modeling/Informatics for Public Health Response Logistics

Specific Challenges for Health Models

Understanding health outcomes requires modeling of complex intersecting systems…

- Public Health + ….
  - Emergency Medical Services
  - Primary, Hospital-based, and Long Term Care
  - Housing, Access to food, Public safety, etc.
- Regional boundaries
- Competing or overlapping jurisdictions

CDC Preparedness Modeling Initiative

"Success" is…

- Foster development of problem-appropriate, data-centric modeling environments
- Raise the standards of evidence and depths of critical thinking for planning and response operations
- Improve representation of uncertainty in modeled processes and on model outcomes
- Make more transparent the values and trade-offs that shape public health preparedness decisions
- Develop sustainable supply chain of public health modeling expertise

Who we are…

- **National Center for Environmental Health/Agency for Toxic Substances and Disease Registry**
  - Howard Frumkin, MD, MPH, Director
  - Preparedness Modeling Initiative
    Led by Julie Fishman, MPH and Bobby Milstein, PhD, MPH
  - Preparedness Modeling Unit
    Nathaniel Hupert, MD, MPH, Director and Associate Professor of Public Health and Medicine, Weill Cornell Medical School, NYC

    Future staff: 5 FTEs representing public health, engineering, and computer science/programming
  - *Slides contributed by Wei Xiong, PhD, Weill Cornell Medical College; and David Fisman, MD, MPH, Research Institute of the Hospital for Sick Children (Ontario, Canada)*