

**NIEHS TALK: THRUST AREAS: HIGHLIGHTS  
-AND A RECOMMENDATION-**

**Setting the Stage**

Emergent Geospatial Geotemporal Hotspot Analysis System

Cartoon: Space Age Data, Stone Age Analysis

(Hotspot: Outbreak, Elevated Rate Cluster, Critical Area)

**Thrust Areas and Highlights**

- Poverty, Ethnicity, Environment and Health
- Agent Orange Dioxin, Environment and Health
- Biosurveillance for Biosecurity and Biodefense
- Disease Hotspot Detection, Prioritization and Evaluation
- Emergent Hotspot Analysis Software System

**Thrust 1: Environmental Justice**

Persistent Poverty and Environmental Justice:

Appalachian Region, Mississippi Delta, ...Nation as a Whole

Aggregation Level: Tract, County

Poverty Rate; Pollution Proximity/Vulnerability

1.1 Poverty Hotspots, Pollution Hotspots  
Co-location of Hotspots  
Intra-Hotspot Association of Rates of Poverty and Pollution  
Appropriateness of Aggregation Level  
Filtering of Correlates: Looking for Unique Local Lurking Factors  
Pre-epidemiologic Investigations

1.2 Persistent Poverty and Persistent Hotspots  
Typology of Persistent Space- Time Hotspots for Metro Areas  
Time-wise Sections of Persistent Hotspots as Trajectory  
Persistent (Memphis, TN), Concentrated (Camden, NJ),  
Growing (Detroit, MI), Shifting (Oakland, CA), ...  
Census Tract Population and Economic Attributes to Further Characterize These  
Metropolitan Areas.  
Poverty Rate, Residential Segregation, Health Outcomes

**Thrust 2: Agent Orange Dioxin, Vietnam**

Human Health

Deforestation, Ecosystem Health

Downloadable Multiscale Advanced Raster Map Analysis System

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**Thrust 3: Syndromic Surveillance**

Subway System Surveillance  
Drinking Water Distribution System Surveillance  
West Nile Virus Surveillance  
Hospital Admissions Surveillance

...

**Thrust 4: Disease Mapping and Evaluation**

Chronic Disease Mapping and Evaluation  
Breast Cancer Mortality, Prostate Cancer Incidence and Staging  
Water-borne (Cholera) and Vector-borne (Malaria, West Nile Virus), ...  
Urban Heat Island, Traffic Flow, Childhood Asthma  
Infectious Diseases: Creutzfeldt-Jacob Disease, West Nile Virus  
Acute Respiratory Disease in Cattle Herds  
Downloadable SaTScan Software System

**Thrust 5: Geoinformatic Biosurveillance Initiative**

Geoinformatic Hotspot Detection and Evaluation  
Synoptic and Network-Based Hotspot Detection,  
Prioritization, and Early Warning  
Concepts, Methods, Tools, Softwares  
Downloadable User-friendly Software System

**Recommendation:**

Research, Education, and Outreach Initiative  
National Center  
Concepts, methods, tools, applications, validations, prototype softwares  
Priority activities and regional projects  
Downloadable Geoinformatic Hotspot Detection and Evaluation Software System

## NOTES

### **Thrust 1: Environmental Justice**

**NAS/NRC Report on Environmental Justice (1999) p. 34, National Academy Press.**

Is environmental degradation worse in poor and minority communities? Do these communities suffer more adverse health effects as a result?

Research is needed to improve the capacity of epidemiologic studies **to detect adverse health impacts** in small populations and **to evaluate clusters** of effects observed in populations.

Appendix A discusses these and other related issues in greater depth.

Appendix A: **Using Disease-Cluster** and Small-Area Analyses to **Study Environmental Justice**:

Pre-epidemiology and Its Appropriate Uses: ... Hotspot Detection and Evaluation

#### **Persistent Poverty in Appalachia and the Delta**

- Examine issues of persistent poverty and the environment, health, and economics for individuals, children, and families
- Characterize the meaning and measurement of persistent poverty and its spatiotemporal distribution, causes, consequences, and responses at appropriate aggregation level/spatial scale.
- Environmental burden and health-related concerns
- Spatial makeup of poverty neither just urban-rural nor north-south. Self-perpetuating and intergenerational poverty. Primary causes become derivative causes. Poverty persistence and its trajectories.

More spatiotemporal complexity than the initial individual factor-based spatiotemporal condition. Links between longterm economic distress, environmental vulnerability, poverty persistence, and health-related concerns. **Co-location research hampered by the lack of methods and tools of investigation. Geoinformatic analysis and persistent hotspot analysis emergent methodology and technology.**

Amy Glasmeier, Bernard Goldstein, Kenneth Olden, G. P. Patil, Lance Waller, Daniel Wartenberg ...

## **Thrust 2: Agent Orange Dioxin**

### **Joint Vietnam-United States MOU, March 2002**

Critical research needs, highest priority areas

- Research on existing populations with high exposures to dioxin relative to populations with low exposures (e.g. people living near **hotspots**)
- Dioxin contaminants of Agent Orange have **persisted** in the environment in Vietnam for over thirty years. In addition to a better understanding of outcomes of exposure, an improved understanding of residue levels and rates of migration of dioxin and other chemicals in the environment is needed...(**Persistent hotspots trajectories**)...
- ‘**Hotspots**’ containing high levels of dioxin in soil have been identified and others are presumed to exist, but **have yet to be located**.
- Ecological and restoration research on a degraded upland forest and research on the identification, characterization, and remediation of **hotspots**.

### **Health Workshop**

- Criteria for site selection for population studies—While there is a clear interest in hotspots (i.e. highly contaminated areas), they should not be the only sites of interest. (**Ranking and prioritization of hotspots, cold spots, and midlevel spots.**)
- Health effect **surveillance systems**, which allow **GIS** and **spatial disease monitoring, modeling, and tracking ... (Geoinformatic biosurveillance, persistent hotspot trajectories)**

### **Environment Workshop**

- Analytical research, including research into **detection and assessment of ‘hotspots,’** areas of high contamination
- Degraded upland forest. Ecosystem impact from deforestation rather than residual chemical contamination. Impacts of defoliation... (**Hyperspectral change detection and accuracy assessment, emergent multiscale advanced raster map analysis system**).

### **Ecosystem Impact Assessment**

Hyperspectral change detection and accuracy assessment, emergent multiscale advanced raster map analysis system to help with the following:

- What message does a remote sensing-derived land cover land use map have about the large landscape it represents? And at what scale and at what level of detail?
- Does the spatial pattern of the map reveal any societal, ecological, environmental condition of the landscape? And therefore can it be an indicator of change?
- How do you automate the assessment of the spatial structure and behavior of change to discover critical areas, hotspots, and their corridors?
- Is the map accurate? How accurate is it? How do you assess the accuracy of the map? Of the change map over time for change detection?
- What are the implications of the kind and amount of change and accuracy on what matters, whether human health, climate change, carbon emission, water resources, urban

sprawl, biodiversity, indicator species, or early warning, or others. And with what confidence, even with a single map/change-map?

**Prioritization and Ranking of Study Areas Based on Multiple Considerations, Multiple Indicators, Multiple Criteria**

Prioritization and ranking can be accomplished without having to integrate/composite/crunch multiple considerations into an index. This is now possible using procedures based on Hasse diagrams and partial order sets.

Ann Sassaman, Chris Portier, Sheila Newton, William Suk, William Farland, G. P. Patil, Robert Brooks, Wayne Myers, Jeff Niemann, Gary Petersen, Denice Wardrop

### **Thrust 3: Syndromic Surveillance**

#### **National Syndromic Surveillance Conference, September 2002**

Recent **bioterrorism** events have highlighted the need for improved public health surveillance systems **to detect outbreaks**. Systems utilizing real-time electronic surveillance of non-specific disease indicators (syndromic surveillance) may provide **early warning of large outbreaks**, whether intentional or naturally occurring.

- Syndromic surveillance systems
- Outbreak detection methods
- Traditional surveillance data: Work or school absenteeism, emergency department visits, outpatient visits, pharmaceutical sales, ambulance dispatches, ...
- Non-traditional surveillance data: Grocery store sales, video camera monitoring, web searches, veterinary surveillance, ...
- Detection of temporal-spatial clusters in the context of spatially-resolved syndromic data sources

Richard Heffernan, Martin Kulldorff, G. P. Patil, Daniel Sosin, ....

#### **Hotspot Detection and Early Warning for Synoptic and Network-Based Syndromic Surveillance**

**(1) a new version of the spatial scan statistic that allows for detection of clusters of arbitrary shapes; (2) a space-time version for the early detection of outbreaks; (3) generalization of the method for detection and evaluation of hotspots on networks, such as subway systems, water distribution systems, and river systems; (4) assignment of a hotspot rating to each network node using hotspot confidence regions on the network.**

**Watersheds and river systems provide relevant contexts for syndromic surveillance of both human health and ecosystem health.** At the watershed level, synoptic scan statistic techniques can be utilized effectively. The hierarchical nature of watershed delineations allows one to assess the effect of aggregation on hotspot determination. **Hotspots within hotspots can be explored with multi-scale scanning.**

Treatment of a stream and river system as a formal network serves to reframe the hydrologically-based surveillance information into a network topology. **Scanning protocols for networks constitute a subject of substantial research opportunity in hotspot detection.** Strategies for linking potential explanatory variables to critical subnetworks (hotspots) await exploration for purposes of etiological analysis.

G. P. Patil, David Brown, Richard Heffernan, Martin Kulldorff, Charles Taillie, ...

#### **Thrust 4: Disease Mapping and Evaluation**

##### **Elevated Rate Cluster Detection and Assessment**

In geographic disease surveillance, an important problem lies in the identification and/or evaluation of areas with exceptionally high or low prevalence, incidence, or mortality. **The spatial scan statistic has become a popular method for the detection and evaluation of disease clusters**, and is now used by many health departments and academic epidemiologists, both nationally and internationally.

In terms of its mathematical definition, the spatial scan statistic is defined in broad terms in order to accommodate clusters of different shapes and forms. In practice, it is typically the circular spatial scan statistic that is used, due to the circle's natural compactness, available software (SatScan), and computational efficiency. The circular scan statistic works well, even when the true cluster is not a circle, as long as it is reasonably compact. **If the true cluster is very irregular, however, such as along a long winding river, or along a narrow urban corridor, a circular scan statistic has low power.**

Martin Kulldorff, G. P. Patil, Linda Pickle, Chris Portier, Ed Sondik, ....

#### **Thrust 5: Geographic Biosurveillance Initiative**

##### **Hotspot Detection, Delineation, and Prioritization for Geographic Surveillance and Early Warning System**

**Following issues and approaches emerge:** (i) versions of the spatial scan statistic designed for the detection of clusters of irregular shapes. Specifically: an elliptic spatial scan statistic, a tree-structured spatial scan statistic, and a simulated annealing based spatial scan statistic; (ii) space-time versions for the early detection of disease outbreaks; (iii) detection and evaluation of clusters on predefined networks, such as subway systems and water distribution systems; (iv) comparative studies involving statistical power, geometric accuracy in cluster estimation, and computing time, and (v) real data findings, as a bridge to discovery, knowledge, and response.

G. P. Patil, Richard Heffernan, Martin Kulldorff, Linda Pickle, Chris Portier, Charles Taillie, ...

## **References for Geoinformatic Biosurveillance, Syndromic Surveillance, and Multiscale Advanced Raster Map Analysis System**

The following concept papers and proof-of-concept papers given with their websites will be used to illustrate the methods and tools proposed for geoinformatic biosurveillance and syndromic surveillance, accomplishing cross-disciplinary cross-fertilization between geospatial ecosystem health and geospatial public health for hotspot detection and early warning.

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Website: <http://www.stat.psu.edu/~gpp/PDFfiles/TR2002-0501.pdf>
2. Myers WL, Kurihara K, Patil GP, Vraney R (2002). Finding upper level sets in cellular surface data using echelons and SaTScan. Proof-of-Concept Paper 2. Invited paper, 2002 Joint Statistical Meetings, New York.  
Website: <http://www.stat.psu.edu/~gpp/PDFfiles/TR2002-0801.pdf>
3. Patil GP, Kulldorff M, Heffernan RT, and Taillie C (2002). Spatial scan statistics for irregularly shaped clusters and early warning system. Concept Paper 8, Penn State Center for Statistical Ecology and Environmental Statistics. 34 pp.  
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5. Patil GP, Myers WL, Taillie C, and Wardrop DH (2002). Network-based analysis of biological integrity in freshwater systems. Concept Paper 11, Penn State Center for Statistical Ecology and Environmental Statistics. 22 pp.  
Website: <http://www.stat.psu.edu/~gpp/PDFfiles/Prospectus-11.pdf>
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8. Patil, GP, Balbus, J., Biging, G., JaJa, J., Myers, WL, and Taillie, C. (2002). Multiscale advanced raster map analysis system: Definition, design and development. *Environment and Ecological Statistics* (to appear).  
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9. Patil, G. P. (2002). Multiscale advanced raster map analysis for sustainable environment and development.

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10. Patil, G. P. (2002). Background Biographics-1.

Website: <http://www.stat.psu.edu/~gpp/PDFfiles/Patil-3-page%20bio.pdf>

11. Patil, G. P. (2002). Background Biographics-2

Website: <http://www.stat.psu.edu/~gpp/PDFfiles/GP%20NSF%20Bio.pdf>

**Surveillance, Pre-Epidemiology, and Biosurveillance  
For Monitoring, Assessment, and Management**

- Surveillance methodologies and hotspot detection need a statistical shot in the arm in geotemporal and geospatial epidemiology, even while current SaTScan provides a somewhat sophisticated approach with high statistical power of detecting the most likely compact and regular cluster within a spatial data set. If the true cluster is very irregular, however, such as along a long winding river, or along a narrow urban corridor, the current circular scan statistic has low power of detection.
- Geographical surveillance for hotspot detection and prioritization has been an extremely important area of investigation both in geospatial ecosystem health and in geospatial public health. A timely cross-disciplinary cross-fertilization will help accomplish an effective and efficient geographical surveillance for arbitrary shape hotspot detection, prioritization, and early warning for monitoring, etiological analysis, and management at multiple scales and aggregation levels in space, in time, and in space-time.
- What we need is a downloadable geoinformatic hotspot detection and evaluation software system based on sound concepts, methods, tools, and computer programs.